Environmental indicators for buildings

A search for common language. Ph.D. thesis

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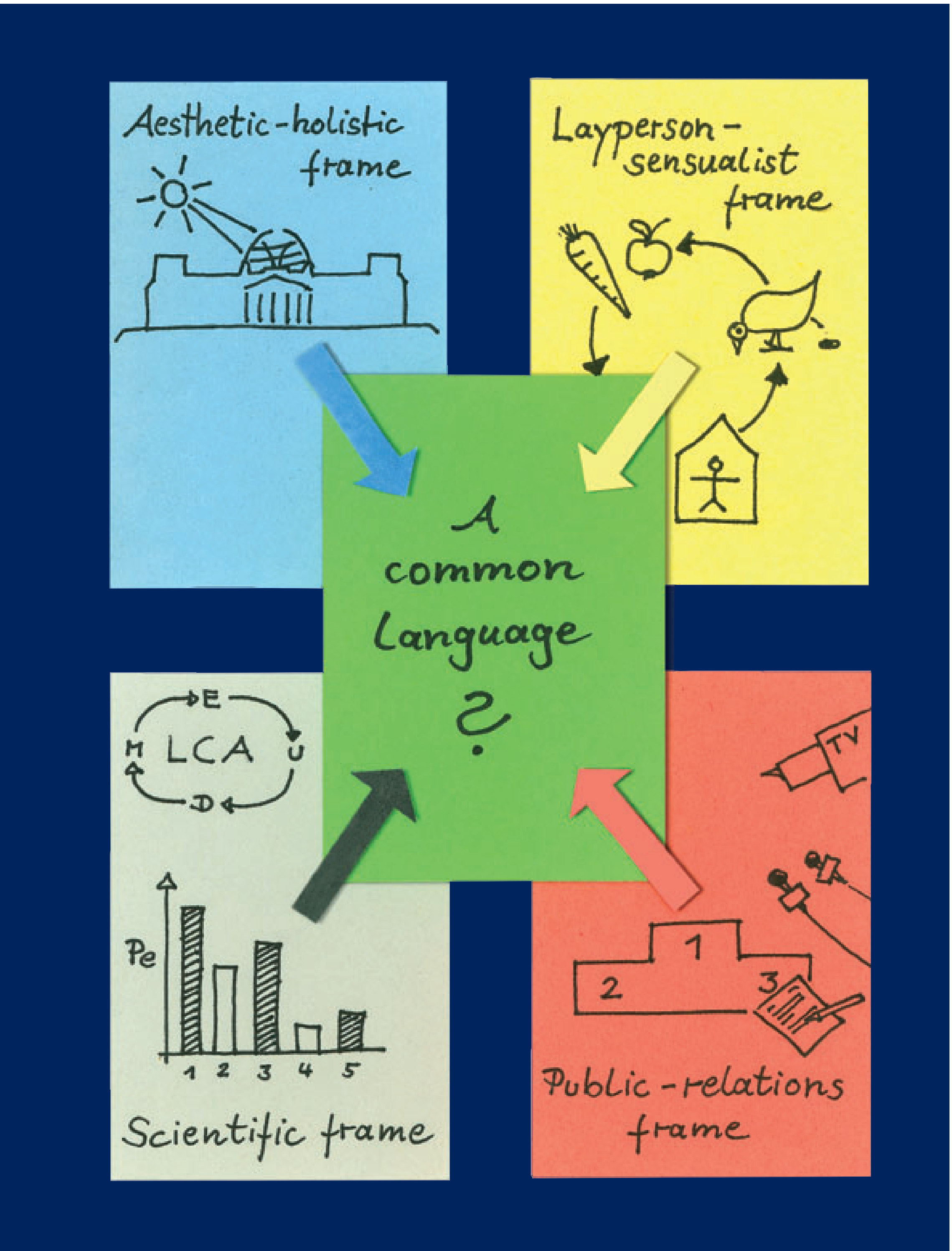
Statens Byggeforskningsinstitut
Danish Building and Urban Research



Environmental indicators for buildings

A search for a common language

Ph.D. thesis

Sven Dammann

By og Byg
Danish Building and Urban Research 2004

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Contents

Detailed Table of Contents

Preface

Whenever we shop, the products we consider buying are labelled with the price we have to pay if we want to purchase them – an important parameter in our decisions as purchasers.

The increasing awareness of environmental limits and backlashes from human activities also in the building sector have fostered the wish to define 'the ecological price' of a building as a help for environmentally conscious decision-making. This study, the Ph.D thesis of Sven Dammann, looks across and beyond the many different existing approaches to environmental indicators for buildings. It acknowledges that among the relevant actors in the building sector, the scientific perspective is only one among others. Typical for socially accountable and reflexive knowledge production this study combines natural-scientific knowledge with social-scientific knowledge, obtained in a close co-operation with actors in the building sector in Denmark.

This research project was financed by the Danish Research Agency and agreed upon in 2000 between the Technical University of Denmark (DTU) and the Danish Building and Urban Research Institute (DBUR). Sven Dammann commenced his studies in December 2000 and has defended his thesis in a public hearing and evaluation in August 2004.

Danish Building and Urban Research
Department of Energy and Environment
August 2004

Søren Aggerholm
Head of Department

Author's preface

I have to confess: I was brainwashed already as a teenager. Ever since my socialisation within the environmental youth movement in Germany being concerned about the environmental implications of what I come across in my life and world has been just as natural for me as being concerned about one's partner's toes when dancing tango.

It has not escaped my attention, however, that this not the rule. At my local bakery, I am still the only customer who reuses the bags – also in my architectural education green building had its niches, but it was not an integral part of the general agenda.

While compiling a survey on national urban research programmes for the European Commission I spotted the position for a PhD in environmental indicators for buildings at the Danish Building and Urban Research Institute and applied immediately. The prospect of investigating in close co-operation with practitioners, how the consideration of environmental aspects in the building sector could be facilitated and promoted by means of indicators was intriguing. It also appealed to me that in this project I could make use of previous experiences with qualitative research interviews and the conceptualisation and facilitation of actor-workshops. Furthermore, the pluralist, actor-oriented perspective, pursued in this study from the very start and embedded in its social-constructivist approach, met my personal commitment to the concept of non-violence and my interest in languages and communication. The theory of the social construction of technology and theories of non-violent conflict resolution have several elements in common:

Both acknowledge that different actors in parallel hold different relevant views on an object of dispute. Both concepts strive to make these views and the needs and motivations behind them explicit to the analyst and to the actors. And both hold the tenet that durable consensus is obtained by mutual understanding, by negotiation and by creating new solutions and not by use of power.

Research is always a voyage into unknown territory. I am grateful for the support and good company I experienced in the course of this voyage:
I thank my two supervisors Klaus Hansen, senior researcher at the Department for Energy and Environment of the Danish Building and Urban Research institute, who had successfully applied for the financing of this project at the Danish Research Agency, and Morten Elle, Associate Professor PhD at the section for Sustainable Urban Management, Department of Civil Engineering of the Technical University of Denmark (DTU). Right from the start with my application to the submission of my dissertation, both gave me relentless professional and moral support and made any efforts to smoothen my way: Whether it be overcoming administrative hurdles prior to my enrolment as a foreigner at the university or facilitating my networking with actors in the building sector and in the research environment. Our regular project meetings were reliable stepping stones on the way to the submission as well as a great experience of exciting scientific debates and joyful teamwork.

I also thank my friend and colleague Ole Michael Jensen, senior researcher PhD at DBUR for his manifold support: As an 'additional supervisor', as guide to the wider philosophical aspects of the study, as a 'pit stop' for mental refuelling and for fast-fixing of all sorts of transmission-problems (between engineering sciences and social sciences, between material and analysis, between analysis and conclusions, between brain and text, …) and, together with his family, as a local host for a late-working PhD-student from far-away Copenhagen.

During my research period in the Netherlands at the interdisciplinary research project ‘The Ecological City’ and the Faculty of Architecture’s section for Environment and Design of the Technical University of Delft the attentive hospitality and committed professional support of Dr. Sybrand Tjallingii and Prof. Kees Duijvestein and of my other Dutch colleagues made me quickly feel at home and greatly facilitated my access to ongoing developments in the Netherlands.

This project reached into several fields of research of my colleagues at DBUR and at the DTU. Thanks to them for their accessibility and willingness to share their expertise, which was a great help for me. Special thanks to Lars Gunnarsen, senior researcher PhD at DBUR, for his counselling on indoor climate and to Ebbe Holleris-Petersen, senior researcher PhD at DBUR, for patiently answering all my questions about life cycle assessment. A special thank also to Lilian Nielsen, head of DBUR’s library, for her great services and to Solveig Nissen, DBUR’s English correspondent, for acquainting me with the special features of English scientific writing.

This project wouldn’t have been possible without the practitioners in the building sector, who sacrificed a considerable part of their working hours to answer my interview questions and to participate in my workshops. Many thanks to them for permitting me to view the research subject from many different angles.

Writing this thesis in English was yet another fascinating dive into a foreign language. I am especially grateful to my translator-friend Mary McGovern, who so many times not only helped me find my way through prepositions, connotations, particles and conventions in her mother tongue, but who also lifted my spirits with good advice on writing techniques (‘*If you can’t get ahead – get a pillow!*’).

In the last phase of the project my friend Rosie Hyde, sustainable building researcher PhD at the Canadian consultancy Keen Engineering, made the proof-reading of the dissertation’s major part an inspiring transatlantic dialogue and cheered me up on the final meters to the submission.
Thanks also to my other proof-readers Gorm Gunnarsen, lector Ph.D at the University of Copenhagen, Katrine Hahn, research fellow at the Royal Veterinary and Agricultural University and Liliya Eskesen.

Apart from these people, who directly supported my study, I am grateful for those who were with me during these three years abroad: My parents, my friends Justus, Elke, Leo, Jennie, Kati, Antje and my housemates from Group 12, Cluster Red of the Association ‘Centraal Woonen, Delft’ in the Kraanvogelstraat.

Finally I thank Prof. emeritus Dr. Heinar Henckel, from the Institute for Regional Architecture and Settlement Planning, University of Hannover, for kicking off my travel into the world of research, Marlies Weise, for her valuable teaching in qualitative social research methods, and my grandparents, who have always supported my projects, be they building model-ships or writing a PhD-thesis.

Your tango-partner lets you know right on the spot when you step on her toe. May this thesis enable us to become better dancing partners to the sensitive lady upon whom we all depend.

Sven Dammann
Hørsholm, March 2004

Abstract

Background and objective

Building activities account for a considerable part of society's overall environmental impact. Broadly acknowledged environmental indicators for buildings (EIFOB) are to serve as a means of making the environmental impact of buildings visible to all relevant actors and to facilitate their consideration in the relevant decision-making situations. The objective of this study was to explore

1 if (and to which extent) consensus on environmental indicators for buildings as 'a common language for green building' can be reached among the core actors *local building authorities, professional clients, client consultants, project designers, administrators of buildings and developers of environmental indicators for buildings*; and
2 what environmental indicators for buildings that are acceptable as 'a common language for green building' for the relevant actor groups could look like.

The study focussed on buildings for housing, schools, day-care-institutions and office buildings in Denmark and the three decision-making situations *siting, project design and renovation*.

Research design

To answer the research questions, the investigation employed the theory of the social construction of technology (SCOT) *in a prospective way* and carried out research tasks in two spheres of scientific reasoning: the environmental scientific sphere and the social scientific sphere.

In the environmental scientific sphere the main environmental effects of buildings were studied and existing indicator approaches were analysed, distinguishing between the three indicator-principles *life cycle assessment (LCA), checklist indicators and input-output indicators*.

In the social scientific sphere the three decision-making situations *siting, project design and renovation* were analysed with regard to their environmental relevance, data availability and decision-makers and the actors' views on EIFOB and their demands to EIFOB were investigated in qualitative research interviews and actor-workshops.

Results: Indicators in a social constructivist perspective - four technological frames

The findings from the qualitative actor-investigation resulted in a description of educational backgrounds and power structures that influence the actors' acceptance of EIFOB and in the definition of *four technological frames* (TFs), that is four different views on EIFOB. Each technological frame comprises actors that share the same view on EIFOB. Their views differ from the views of the actors in the other technological frames:

– the public-relations-frame (PRF), mainly comprising of professional clients and administrators of buildings

– the scientific-frame (SF), mainly comprising of scientific indicator developers and consultants with an engineering background
– the aesthetic-holistic frame (AHF), mainly comprising of architects
– the layperson-sensualist frame (LSF), mainly comprising of non-professional private clients and users of buildings.

The public-relations frame
The main of the actors in the public-relations frame goal is to obtain a favourable public image. EIFOB are mainly seen as means of documenting and communicating one's environmental responsibility to the target groups (employees, customers, …), a means for quality assurance and risk-management preventing environmental accidents and scandals, and as a means of keeping consumption-related life cycle costs low. With regard to the environmental contents of the indicators, the public relations frame focuses on indoor climate and (costly) consumptions in the use phase, while aspects that might question one's lifestyle (for example transport in the use phase) are avoided. Key demands to EIFOB are that they shall be communicable to the target groups, operational (that is, cost-efficient and based on easily available data) and trustworthy.

The scientific-frame
The main goals of the actors in the scientific frame are to sell natural-scientific and technical expertise, to evaluate buildings scientifically and precisely and to ensure that efforts made really lead to environmental improvements. Quantitative, scientific EIFOB are seen as the only reliable navigation tool to environmentally advantageous decisions. With regard to the environmental contents of the indicators the scientific frame focuses on regional and global environmental aspects ('there and later') (such as global climate change, ozone depletion & photochemical ozone formation, toxicity …), waste & resource consumption and indoor climate. Not yet operational but considered relevant are land use, including biodiversity and impacts on local ground water formation. Key demands to EIFOB are that they shall be scientifically justifiable, precise & quantitative and cover the entire life cycle of a building.

The aesthetic-holistic frame
The main goals of the actors in the aesthetic-holistic frame are to defend their position as competent generalists, to avoid design restrictions, to avoid additional loads of boring, badly paid work and generally the acceptance of the aesthetic-holistic paradigm (in opposition to the rationalist paradigm). Some actors in this frame questioned the meaningfulness of EIFOB as indicators were seen as a threefold threat: a threat to the architects' competence and power to define 'ecological building', a threat to design freedom and as a potential additional workload outside their field of competence. This being said, preference is given to qualitative checklist-indicators based on concrete measures and principles, indicators that give unambiguous and simple answers to concrete design questions occurring in the daily work of the actors in the aesthetic-holistic frame. With regard to the environmental contents of the indicators it is characteristic of this frame that it doesn't operate with clearly defined notions (environment is mixed with general functional and aesthetical aspects) and that this was presented as the capacity to see things 'holistically' (in opposition to the 'unduly fragmented' view attributed to engineers). Apart from this, attention is paid to 'local' environmental aspects here and now (indoor climate & health, aesthetical quality, psychological environment, …) and global warming and resource consumption are generally accepted as relevant. Key demands to EIFOB are that they are easy to use and don't require much work of the kind, the AHF-actors usually do not like, that they don't restrict creativity and design freedom, are within the AHF-actors' field of competence and are preferably qualitative, not quantitative.

The layperson-sensualist frame

The main goals of the actors in the layperson-sensualist frame are (in ecological settlement projects) to create an identity and a social coherence among the residents of a settlement by giving the settlement a 'sustainable' or 'ecological' identity and the acceptance of the sensualist frame with its focus the on physical perceptibility of the effects of one's environmental efforts and behaviour (as opposed to the rationalist scientific frame). The concept of quantitative explicit EIFOB is unfamiliar and usually no relevant category as the LSF-actors are used to operate with implicit qualitative indicators, which serve as a 'brand' or 'lifestyle label' for one's settlement or building. Actors in the layperson-sensualist frame have an ambivalent view on quantitative, explicit EIFOB: On the one hand they are seen as a tool useful for consulting experts but incomprehensible for laypersons, on the other hand they seen as irritating and not always trustworthy as they question one's 'pet' solutions and one's judgements. The focus is on local environmental issues ('here and now'), that is on concrete measures and principles that are perceivable, have a symbolic significance and appeal to visions of an ecological home and lifestyle, on indoor climate and local circulation systems (for example for organic waste). Key demands to EIFOB are that they are easily understandable, preferably qualitative, not quantitative, trustworthy and address environmental concerns close to the actors' life world and decision-making.

Lines of conflict and areas of consensus

The discussion of the demands of these four technological frames revealed the following lines of conflict:

- Transparent, well-documented and consistent (public-relations frame, scientific frame) versus vague ad hoc indicators (aesthetic-holistic frame)
- Simple and easily understandable (public-relations frame, layperson-sensualist frame, aesthetic-holistic frame) versus scientifically justifiable and sufficiently detailed to reflect the complexity of the subject (scientific frame)
- Checklist-indicators (aesthetic-holistic frame, layperson-sensualist frame) versus life cycle assessment (scientific frame)
- Based on units familiar to the public (public-relations frame, layperson sensualist frame) versus using units familiar to scientists (scientific frame)

Further points of disagreement are the questions if aesthetics should be part of the environmental scope and if the system borders of EIFOB should include transport induced in the building's use phase. Consensus was observed about the general environmental scope of EIFOB. However, it became also clear that this consensus is rather weak, that actors have different environmental priorities and talk about environmental issues in 'different languages'. With regard to the relations between the technological frames the comparison of the four technological frames' demands to EIFOB showed that

- the scientific frame and the public-relations frame have a rather close relation,
- the public-relations frame and the layperson-sensualist frame have a close relation,
- the layperson-sensualist frame and the aesthetic-holistic frame have a close but weak relation,
- the aesthetic-holistic frame and the public-relations frame have a close but weak relation,
- the scientific frame and the aesthetic-holistic frame are rather far from each other and also
- the scientific frame and the layperson-sensualist frame are far from each other.

These findings resulted in a ‘map of the socio-technological landscape around EIFOB’. Additionally, the actor investigation revealed an increase of social knowledge among actors in the SF and an increase of environmental knowledge among actors in the PRF, AHF and LSF as two ongoing developments.

Conclusions

In light of these results, the answer to the first research question was that a closure of the EIFOB-debate on the basis of an all-actors consensus within the near future is very unlikely. Instead the technological frames can either remain separated, making temporary partial agreements on EIFOB, or three of the four technological frames can reach lasting agreements on EIFOB, possibly with the remaining ‘outsider’ slowly ‘joining in’. These options were elucidated and exemplified with possible indicators for the environmental aspects ‘energy’ and ‘indoor air quality’ in the three scenarios

– ‘Postmodern Relations’, in which the present situation with a multitude of indicators systems used in parallel with each other continues and the ‘multi-lingual actor’ helps to mitigate some of the problems deriving from the absence of ‘a common language’
– ‘Science goes public’, in which the scientific frame, the public-relations frame and the layperson-sensualist frame agree upon indicators based on life cycle assessment with a broad environmental scope and wide system borders that meet the public-relations frame and the layperson-sensualist frame demand for simplicity by offering three levels of aggregation, and
– ‘Keep it simple’, in which the public-relations frame, the layperson-sensualist frame and the aesthetic-holistic frame agree on simple, concrete measures-based checklist-indicators with only two levels of aggregation and narrow system borders.

The thesis concludes with a summary, a reflection on the implications of the three scenarios and perspectives with regard to a continuation of this project in the real arena, an elaboration of the prospective use of SCOT and fields for further indicator research and development.

Introduction

Background

At the 1992 United Nations Conference on Environment and Development in Rio de Janeiro the contract parties commonly acknowledged the concept of sustainable development as a response to the environmental, social and economical challenges the world is facing today. This approach of tackling economic, social and environmental issues in an integrated approach and anchoring their consideration institutionally[1] was concretised in the 'Agenda 21' – the action programme of the United Nations for the twenty-first century.

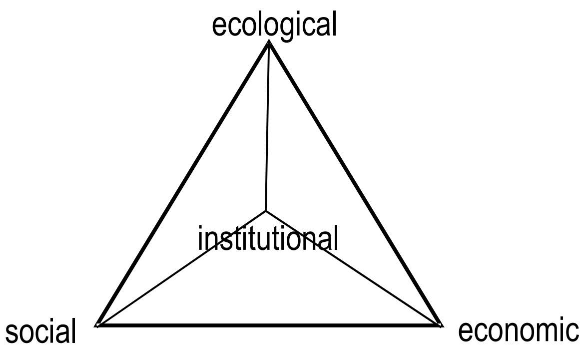

Figure 1: The four dimensions of sustainability

This document asks the contract parties (that is, the national states) to adopt a national strategy for sustainable development. Under the headline *'Improving planning and management systems'* it says:

> *'To support a more integrated approach to decision-making, the data systems and analytical methods used to support such decision-making processes may need to be improved. Governments, in collaboration, where appropriate, with national and international organizations, should review the status of the planning and management system and, where necessary, modify and strengthen procedures so as to facilitate the integrated consideration of social, economic and environmental issues.'* (UN, 1992)

Responding to this request the Danish government in 2001[2] issued the *'Danish Government Strategy for sustainable development - Development with care - a common responsibility'* (The Danish Government, 2001), which acknowledges that

> *'Buildings and infrastructure in cities constitute a considerable part of society's economic and cultural capital and play a central role in the overall resource consumption and environmental impact. Energy consumption for building activities and for operation of buildings accounts*

[1] In legislation and decision-making procedures

[2] In the Danish Planning Act the principle of sustainable development has been enshrined since 1999: *'§ 1 (Purpose) This Act shall ensure that the overall planning synthesizes the interests of society with respect to land use and contributes to protecting the country's nature and environment, so that sustainable development of society with respect for people's living conditions and for the conservation of wildlife and vegetation is secured.*
This Act especially aims towards: […] preventing pollution of air, water and soil and noise nuisance; […]' (Ministry of Environment and Energy Denmark 1999)

for half of Denmark's energy consumption, while material consumption for building activities and infrastructure constitute the main part of the consumption of Danish raw materials. It is therefore an essential challenge to make the resource consumption and environmental impact of a building's entire life cycle visible and to reduce it.' (The Danish Government, 2001) [author's translation]

In parallel with this governmental policy in fall 2000 the 'Byggepanel' (in English: 'Building panel') was established on initiative of the Danish Ministry for the Environment, representing key decision-makers from the entire construction sector, that is clients, project designers, constructional enterprises, manufacturers, consultants, researchers, authorities and users. Its task is to draw up an *'Action plan for sustainable development in the building sector'*. As part of this action plan environmental indicators for buildings shall be developed

'in connection with and based on […]

- *The national strategy for sustainable development […] and its demand for development of indicators […] and with the perspective, that environmental indicators in the long view can be used in […] building-related legislation.*
- *The international and European […] proposals for environmental indicators and […] standards […], e.g. […] ISO 14020 (on environmental declaration and environmental declaration of products), ISO 14020 (on life cycle assessment) […] and […] EU's drafts on integrated product policy.*
- *The development of guidelines in environmental management in project design with preparatory work for environmental declaration of building materials [and] environmental assessment and classification of buildings[3] […] as well as green accounting systems for housing blocks and districts. (Byggepanel, 2001) [author's translation]*

The numerous initiatives and approaches mentioned here and the other existing ones that are not cited differ in their environmental scope, in the addressed decision-making situations and the target groups and in their way to measure, to aggregate and to express environmental impacts. The areas of their useful application are therefore limited. A 'common language for green building' that is understood across the different actor groups and decision-making situations does not exist.

Accordingly the Byggepanel points out as central demands to environmental indicators for buildings that the indicators

'shall to the fullest possible extent

- *be practically employable in the relevant decision-making situations*
- *be able to indicate all relevant environmental impacts*
- *comprise the important contributions of buildings in their entire life cycle*
- *be comprehensible to relevant target groups*
- *be commonly accepted […].' (Byggepanel, 2001) [author's translation]*

[3] For more details on some of the mentioned initiatives see the following chapters, especially 'Indicator systems'

This list of demands implies that the actor groups represented in this panel assume

that consensus on environmental indicators for buildings (EIFOB) as a 'common language for green building' can be reached among the relevant actor groups within the near future if the indicators meet the demands of the relevant actor groups and if a consensus-finding process is initiated and facilitated.

It also expresses the recognition that environmental scientific justifiability of the indicators is a necessary but not a sufficient characteristic for indicators that are to help promoting environmental sustainability in the building sector. To assure that the indicators are broadly used in practice they also have to meet demands in the social realm – a recognition that also was repeatedly pointed out as a field for necessary future research in presentations at the Sustainable Building Conference 2002 in Oslo. As the programme director of the US-based Green Building Rating System LEED[4], Nigel Howard[5], put it in his opening speech after he had raised the question, why the various existing indicators systems are used so little:

'There is always a buyer and a seller. If we want to our indicators to be used we have to ask ourselves three questions:
1. For whom is the assessment?
2. Why does it matter to them?
3. How simple shall the indicators be?
These questions are the key to powerful indicators!'

The research project documented in this thesis was carried out to fill this knowledge gap by studying and treating demands to environmental indicators for buildings in the environmental scientific sphere *and* in the social scientific sphere in a symmetrical, coherent way. To permit the effective communication of environmental issues *throughout a building's entire life cycle* special attention was paid to the communication *across* actor groups and *across* decision-making situations.

Objective and scope of the study

The objective of this study was to explore

– if (and to what extent) consensus on environmental indicators for buildings as 'a common language for green building' can be reached among the core actors local building authorities, professional clients, client consultants, project designers, administrators of buildings and developers of environmental indicators for buildings; and
– what environmental indicators for buildings that are acceptable as 'a common language for green building' for the relevant actor groups could look like.

To reach this objective the study investigates

– the environmental effects of buildings from a life cycle perspective
– the major decision-making situations in a building's life cycle: what is the environmental relevance of the decisions taken, who are the relevant actors and which environmentally relevant data are available?
– existing indicator systems: Which indicators and indicator systems are already in use, what is their scope with regard to environmental issues, decision-making situations and target groups?

[4] ('Leadership in Energy and Environmental Design')
[5] Howard had formerly worked on the development of the British indicator system BREEAM (see the chapter 'Indicator systems' and the appendix) and was thus also speaking with a European perspective.

– the relevant actor groups' view of EIFOB: What do the different actors think of the existing indicators? What are their demands to EIFOB? What are reasons and motivations for their view on EIFOB?
– the implications of the different actors' views on EIFOB for the search for 'indicators as a common language for green building': Where are areas of consent and lines of conflict between the different actor groups? How are the perspectives for the establishment of commonly accepted indicators? And finally
– How could concrete examples of commonly or broadly accepted indicators look like?

Demarcations of the study

To assure the feasibility of the study within the given frame, a number of rough demarcations have been set from the very beginning, some of which were defined more precisely in the course of the investigation:

Geographical scope:
The geographical scope of this study is Denmark: most of the interviews were carried out in Denmark with actors who work in the country and special attention was paid to the existing Danish indicator systems and the actors' perception of these. Nevertheless the validity of the results presented in this thesis is not necessarily confined to Denmark as the study is also based on material gathered in a four-month research period in the Netherlands and on the study of relevant literature from various countries. In spite of some specifically national features (for example in the building legislation) Danish developments in the building sector are related to European and international developments and several of the indicator systems used in Denmark have been developed with inspiration from other countries by people who are working in an international research context.

Buildings:
The study principally addresses buildings for housing, schools, day-care institutions and office buildings, as these are similar in terms in terms of functional demands and relevant environmental aspects. Buildings for special purposes like industrial production, sport activities, medical treatment etc. were *not* within the scope of this study. The study focuses on *single buildings* and not on settlements. To what extent the buildings are seen in the context of the existing infrastructure varies from actor group to actor group and is described in the chapter 'Indicators in a social constructivist perspective'. The environmental scientific perspective, however, which is taken in the chapters 'Environmental effects of buildings' and 'Decision-making situations', clearly pictures a building in the contexts of the settlement and the existing infrastructure.

Decision-making situations:
The three decision-making situations (in the following also abbreviated with 'DMS') addressed are

1 the siting of the building,
2 the project design and
3 the renovation of the building.

The concentration on these three principal decision-making situations (in contrast to a focus on DMS at a more detailed level, like for example 'inception', 'pre-project', 'tender procedure', 'defects period' etc.) permitted to stay focused on patterns of general significance and to maintain a broad scope with regard to the indicators' possible application.[6] It also made possible the

[6] An more detailed investigation of the application of EIFOB in specific decision-making situations would certainly be a useful continuation of this study in future projects.

use of a broad range of material and statements of the actors interviewed in the course of this study, who usually dealt with different DMS in parallel and who neither in the interviews nor in the workshops requested a more specific distinction between DMS.

The decision-making situations ‘execution of the project’ and ‘dismantling of the building’ are not within the scope of this study. In the execution of the project it is more *the building process* than *the building itself* which is decisive. Accordingly a number of environmental parameters (for example vibrations, noise and pollution caused by construction machines) are relevant, that are quite different from the relevant environmental parameters in the other decision-making situations.

The environmental relevance of the dismantling of the building has to be *anticipated* in the other decision-making situations (for example by choosing recyclable or biodegradable building materials). When it comes to the dismantling, however, the building’s environmental characteristics are *not changed anymore*. Instead, society has to bear the consequences of the decisions taken earlier in the building’s life cycle.[7]

The *use phase of a building* is not within the scope of this study. Undoubtedly this phase is of great environmental relevance: It is a well-known fact that the behaviour of the building’s users[8] has at least as much influence on the environmental performance of the building – especially with regard to consumption of energy and water - as the building’s technical characteristics.[9] In this study, however, the use phase is not considered, because

– this study deals exclusively with the description of the environmental characteristics and performance *of buildings* and *not* of the users of buildings and
– the use phase is not a decision-making situation in which technical changes in the buildings substance are planned and carried out.

However, *technical and organisational characteristics of buildings and of their infrastructure context* that influence the environmental behaviour of the building’s users (for example, easily perceptible consumption displays, technical solutions that foster environmentally favourable ventilation habits, consumption management schemes …) are principally considered in this study.

Indicator systems:
The indicators and indicator systems investigated in the course of the study were environmental indicators in the building sector

– in use in Denmark
– in use in the Netherlands and
– the British ‘Building Research Establishment Environment Assessment Method’ (‘BREEAM’) and the international ‘Green Building Tool’ (‘GBTool’) as two further relatively well established approaches.

In accordance with the overall objective of this study the purpose of the investigation of current indicator systems as documented in the chapter ‘Indicator systems’ and in the appendix was to obtain an overview over the principal indicator approaches and their use-context rather than to gain detailed in-depth knowledge of the latest developments. Accordingly it was not within

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7 Of course one can argue that *how* the building materials are treated during and after the dismantling still are environmentally relevant decisions that cannot be anticipated with absolute certainty in the earlier decision-making situations. Here this study follows the reasoning that this is not a characteristic of the building (which should be expressed in environmental indicators for *buildings*), but of the dismantling process. The environmental indicators for building, however, should of course operate with the anticipation of *realistic* dismantling scenarios.

8 Also the purchasing of electrical devices such as refrigerators is considered part of the user behaviour in this study.

9 See e.g. (Gram-Hansen, 2003)

the scope of this investigation either to carry out case studies with the application of existing indicators.

Environmental issues:
The impacts of environmental factors on the degradation of building elements (for example disintegration of roof coverings caused by acid rain) were not within the scope of this study. Besides this no further demarcation with regard to other environmental issues considered was defined beforehand. Instead, it was part of the investigation to study, which environmental issues are considered relevant by the different actor groups.
As the study focuses on indicators as a means of describing the *environmental* effects of buildings, *economic* implications of environmental measures or possible linkages between environmental indicators and economic aspects are not within the scope of this investigation.

Actors:
This study focused first and foremost on the following professional actors in the building sector[10], who directly take environmentally relevant decisions:

– Local building authorities, represented by the municipality officers in charge of planning, building and environment
– Professional clients[11]
– Project designers
– Client consultants
– Administrators, that is those, who manage or deal with the operation, maintenance and renovation of existing buildings at higher levels, for example in the administration of co-operative housing societies or the building departments of municipalities and
– Developers of environmental indicators for buildings / building researchers.

Private, non-professional actors, especially clients and users of buildings, were not in the centre of this investigation. However, in the course of the project it became clear that they are an important point of reference for the professional actors. Therefore their perspective was considered on the basis of the statements of the professional actors, relevant literature and a supplementary interview with a non-professional private actor.

In order to assure a common minimum basis the investigation exclusively considered actors who are already working with environmental issues in the building sector. This permitted the study to focus on the research objective and to avoid debates on whether or not to consider environmental aspects in the building sector *in general*.

The study's subject: What is an 'indicator'?

Research can be understood as an iterative intellectual journey between the two poles of the abstract and the concrete. As the starting point of this journey in this section I elucidate the subject of this study – 'environmental indicators for buildings' – in an abstract way. What is an 'indicator'? What is an 'environmental indicator for buildings'? What does the notion 'environment' mean in this context and which understanding of 'the environment' do we imply if we use 'environmental indicators'? If 'environmental indicators for

[10] For a detailed list of the interviewed see the section 'qualitative interviews' in the chapter 'Research design'. The section 'Actors: their roles and educational backgrounds' in the chapter 'Indicators in a social constructivist perspective' describes the actors in the light of the findings from the interview.
[11] A distinction between different kinds of clients (e.g. between municipalities as clients or private clients or 'developer clients', 'domicile clients' and 'investor/landlord client') was not considered relevant for this study.

buildings' are to tell us something relevant about the reality 'environment' and the reality 'building' – how do indicators thus relate to reality and what do we mean when we use the notion 'reality'?

The Oxford Compendium points out the following meanings of the notion 'indicator':

> *indicator // n.*
> *1 a person or thing that indicates esp. performance, change, etc.*
> *2 a device indicating the condition of a machine etc.*
> *3 a recording instrument attached to an apparatus etc.*
> *4 Brit. a board in a railway station etc. giving current information.*
> *5 a device (esp. a flashing light) on a vehicle to show that it is about to change direction.*
> *6 Chem. a substance which changes to a characteristic colour in the presence of a particular concentration of an ion, so indicating e.g. acidity.*
> *7 Physics & Med. a radioactive tracer.*
> *8 Biol. a species or group which acts as a sign of particular environmental conditions. (Oxford Compendium, 2000)*

Indicators are used in many different disciplines and spheres of life to provide relevant information in an easily comprehensible way about (often complex) systems that do not readily reveal this information to the human actor and the limited perceptual capacities with which nature has equipped him. Often indicators use *quantification* to make phenomena accessible that may well be perceptible in a qualitative way but that are difficult to manage without a way of accessing them through numeric figures. Commonly known examples of indicators from different spheres of life are for example

– in education: examination marks for the learning performance of pupils and students
– in the economic sphere: for example the prices of goods, the gross domestic product, percentage of economic growth, unemployment rates
– in medicine: for example the body temperature, the weight/height ratio.

By making things measurable it becomes possible to monitor changes and to judge the severity of a problem and the effectiveness of the measures taken to solve it. This normative power indicators gain from the fact that they usually refer to a *reference-value* that is commonly considered 'good' or 'normal'. The quantitative element of the indicator is the measured deviation from this benchmark. The measured value can deviate from the benchmark either in space – if compared with a reference value measured at the same time at a different place (for example if the Gross Domestic Products and unemployment rates from different countries are compared as indicators for the state of national economies) - or in time – if compared with a reference value measured the same place at a different point in time (for example the development of the GDP and the unemployment rate in one country through time).

The temperature as an indicator for the health of the human body can serve as another illustration for what an indicator is: the average temperature of 37^{o}C serves as the reference value. Significant deviations from this average are considered to indicate a disease. A deviation is not a disease in itself as it may be the result of varying physiological processes. A complete understanding of each and every single link of the underlying causal chains is not even a precondition for the use of indicators: neither does one have to be able to name the physiological causes for the fever in order to speak of increased temperature of the body in a meaningful way, nor does the scientific debate on the processes and effects of global climate change have to have reached a consensus before the amount of CO_2-emissions can be used as an indicator in environmental policy.

Indicators thus draw a simplified picture of reality that helps our limited capacity to perceive and deal with primary data from the *world as it is*. They aggregate a confusingly large number of data in a few figures or enable us to perceive a process in a quantitative way, thus enabling or promoting the communication of the indicated phenomenon. Accordingly

> *'simplification, quantification and communication'*

can be named as the three main functions of indicators (Adriaanse, 1993).

After this clarification of the *general* concept of indicators the following section elucidates the specific application of this concept to the environmental effects of buildings.

What are 'environmental indicator for buildings (EIFOB)'?

In the first of 'The Ten Books on Architecture' the ancient Roman architect and engineer Vitruvius (ca. 25 bc) states that

> *'Architecture depends on fitness (ordinatio), and arrangement (dispositio) […]; it also depends on proportion, uniformity, consistency, and economy […]. (Vitruvius, 1826)*

a citation which today often is referred to as

> *'the Vitruvian triad of commodity, firmness and delight' (Architect's Council of Europe et al., 2001)*

or the evident necessity to balance *construction, function and aesthetic*[12] in order to achieve a 'good' building, all this, of course, within the building project's economic frames.

As mentioned in the section 'Background' (and elucidated in more detail in the chapters 'Environmental effects of buildings') the significant contribution of the building sector to society's total environmental impact requires consideration of yet another parameter in a building process if sustainable development is to be achieved: the building's environmental effects.

The basic idea of environmental indicators for buildings (in the following also abbreviated as 'EIFOB') is that they are to allow the consideration of a building's environmental effects at equal terms with the parameters construction, function, aesthetic and economy. As money and economic accounting as established indicator systems for economic management facilitate the consideration of a building's economic implications environmental indicators for buildings shall facilitate the consideration of a building's environmental effects. The *'Vitruvian triad of construction, function and aesthetic'*, which has always been seen in an economic perspective, too[13], shall be turned into a *'building pentad'* with 'environment' as the fifth corner, so to speak:

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[12] Any translation of ancient texts into a modern language of course has to face the problem of changed frames of reference, especially when translating dense texts and key notions. Vitruvius himself explains the notions he uses by referring to Greek terminology and by describing each notion in detail in separate paragraphs.

[13] Especially in the context of facility management attempts are made to combine the consideration of economic and environmental aspects (especially consumptions in the building's use phase) in integrated life cycle cost assessments. CHECK: the Darmstadt-conference proceedings.

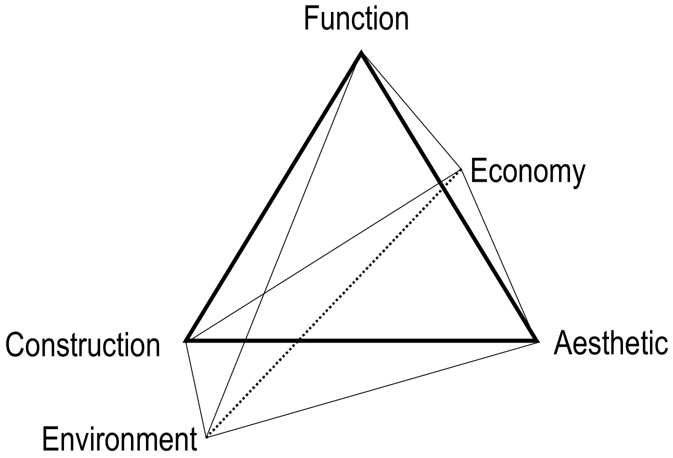

Figure 2: The addition of the corners ‘economy’ and ‘environment’ turn the *‘Vitruvian triad of construction, function and aesthetic’* into a *‘building-pentad’*

This study focuses on the aspect of ‘environment’, reasoning that for this aspect an established indicator system that could match the monetisation of the aspect ‘economy’ does not yet exist.

Considering its literal meaning, the term *‘environmental indicators for buildings’* can principally be understood as describing relations between a building and the environment in two different ways or ‘directions’:

1. *From the environment to the building*,
   that is as indicators that describe the effects of the environment in which a building is located (and of the indoor environment created by the building itself) on the functioning of the building and the human user.

2. *From the building to the environment,*
   that is as *‘indicators for the environmental friendliness of buildings’*, which describe the effects a building (and the human activity it houses) imposes on the surrounding (global and local) environment.

   (A combination of these two views is a third perspective.)

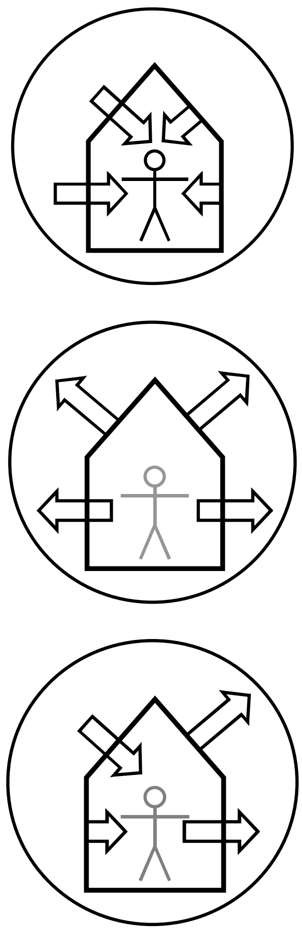

Figure 3: Two principal understandings of ‘environmental indicators for buildings’ and a combination of them.

These two perspectives can be related to two different, principal positions in the environmental debate:

The *anthropocentric viewpoint*, which regards the satisfaction of human needs as the centre and normative reference value of environmental politics, corresponds very much to Perspective 1.

The *ecocentric viewpoint*, which attributes an intrinsic value to other specimen or nature as a whole independent of their significance for humans[14] is more closely related to Perspective 2.[15]

The very notion of 'environment', and its equivalents in other European languages, also sheds light on the existence of different views on 'the environment':

Literally the English word 'environment' means 'the surrounding', which corresponds to the German equivalent 'Umwelt', literally meaning 'the surrounding world'. The Danish word for 'environment' on the other hand – 'miljø'- has the literal meaning 'centre', 'point in the middle'[16]. When compared with related notions 'eco-system' and 'nature' it becomes clear, that the notions 'environment', 'Umwelt' and 'miljø' only take different viewpoints within the same paradigm: all three postulate in a geometrical metaphor a *separation between a centre and its surroundings* – the words 'environment' and 'Umwelt' looking from the centre outwards and the word 'miljø' looking from the surroundings towards the centre, so to speak. This paradigm corresponds to the definition of 'environment' as

> *'the aggregate of all the external conditions and influences affecting the life and development of an organism' (Webster's New Collegiate Dictionary, cited from (International Encyclopedia of the Social Science, 1972)*

- a definition which implies that every kind of organism has its specific environment, as different organisms are affected by different conditions in the surrounding world –

> *'From a fly's point of view the environment is in perfect shape when the cat has vomited under the couch.'*[17]

The anthropocentric viewpoint thus is only *one* of many possible perspectives. However, also an anthropocentric perspective can include a concern for the well-being of non-human creatures, if they are seen as important elements in an ecological system of which human beings are a part. The increasing concern for the protection of biodiversity illustrates this point.[18]

In contrast to the term 'environment', the term 'ecosystem' steps outside the centre-periphery dichotomy. Instead it draws attention to the interdependence of the various elements of the system. Also the word 'nature', which to a certain extent is used as a synonym for 'environment', does not imply a separation between a subject and its surroundings.

It is a precondition for the functioning of EIFOB that the social groups, for which the indicators are designed, believe that the indicators are meaningful in the sense that the (numeric) values of the indicators make meaningful statements about a building's impact on the environment. This implies a series of problems:

As mentioned above it is a characteristic of indicators that the understanding of every single link in the underlying causal chains is not a precondition for the use of indicators. But the recognition that there is *some kind of* causal link between a construction-related activity and a change in the environment is a genuinely different one than a recognition of the kind '*quantity X of substance Y leads to effect Z in intensity Q'*. The case of CO_2 may again

[14] This ethical position in the ecological debate is also known as "deep ecology" (compare (Naess, 1993)).

[15] However, a concern for the environment as in perspective 2 can also ultimately also have an anthropocentric origin, when it is driven by the realisation that the stability of the ecosystem bearing the human race is it stake.

[16] *'miljø, (from French milieu 'the middle, centre point', from lat. medicus locus 'place in the middle')' (Den Store Danske Encyclopædi, 1999), in Danish* [author's translation]

[17] Dr. Herbert Glasauer, Kassel University, in a lecture at the Federal German Environmental Youth Conference in Neu Brandenburg 95.

[18] Compare the paragraph on biodiversity in the chapter 'Environmental effects of buildings'.

serve as a example: That the emission of CO_2 due to anthropogenic activities *has* an impact on the climate is today agreed upon by a majority in the scientific world. But the underlying processes are far too complex to allow a precise quantitative forecast. The *quantitative* reduction-targets laid down in the Kyoto-Protocol originate in the political need to operationalise the qualitative scientific statements. Another area of uncertainty is the use of chemicals and its significance for indoor climate, since of all the chemical substances that are used in construction only a small part has been investigated with regard to toxicity so far[19]. Thus a contradiction inherent in the design of indicators, is that they make quantitative statements on the environmental impacts of buildings though broad gaps in the knowledge of the underlying processes have to be bridged by estimation and speculation. These uncertainties may not matter so much if EIFOB are to describe single buildings in relation to others and to facilitate a comparison of different buildings, as the statement *'building A causes twice as much CO_2-emission than building B'* remains correct disregarding the effect of their emissions. But if EIFOB are used to define absolute environmental standards, for example in legal regulations or certifications ('normative indicators'), the implied statement 'this is an environmentally sound building' may very well be questioned in face of the knowledge gaps in environmental sciences. Thus in spite of a quantitative appearance EIFOB are essentially not a precise quantitative description of the impacts of buildings on the human environment but a tool to handle risks and to manage uncertainties[20] in accordance with the precautionary principle[21].

Why are environmental indicators on the agenda today?

For more than a decade environmental indicators have been on the political agenda at the global, the European and the national level. In the 1990s the OECD developed the 'driving forces, pressure, state, response' (DPSR)-approach for environmental indicators, which now serves the organisation as

> *'the backbone of the analysis of environmental changes, and of possible policy responses to address the environmental problems [and to tackle the] 'disruption of the environmental systems that support human life.' (OECD, 2001)*

The European Commission in its 'Sixth environmental action programme of the European Community' demands that progress in environmental policy

> *'should be measured through indicators and benchmarking' (European Commission, 2001).*

What has long been practised in the field of economics - to monitor and communicate the development by means of aggregated indicators like Gross

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[19] Prof. Finn Bro-Rasmussen, DTU, in his lecture at the conference "High Tech & Low Tech – mod en bæredygtig arkitektur" ["High Tech & Low Tech – towards a sustainable architecture", in Danish], in Middelfart 23.04.01.

[20] This thought is elaborated in more details in the next section 'Why environmental indicators for buildings?'.

[21] *'Precautionary principle: (1) Principle adopted by the UN Conference on the Environment and Development (1992) that in order to protect the environment, a precautionary approach should be widely applied, meaning that where there are threats of serious or irreversible damage to the environment, lack of full scientific certainty should not be used as a reason for postponing cost-effective measures to prevent environmental degradation. (2) The precautionary principle permits a lower level of proof of harm to be used in policy-making whenever the consequences of waiting for higher levels of proof may be very costly and/or irreversible.'*

Definition sources:

1) ETC/CDS. General Environmental Multilingual Thesaurus (GEMET 2000);
2) EEA. 1999. Environment in the European Union at the turn of the century. Page 278. Environmental assessment report No 2 (http://glossary.eea.eu.int/EEAGlossary)

Domestic Product (GDP), Net National Income, industrial production, unemployment rates and the balance of the current account, to mention a only a few – is now aimed at in the field of environment, too. (Alfsen et al., 1993)[22]

From having started as the concern of grass roots pressure groups, environmental issues have finally reached highest policy levels and operationally are dealt with in a similar way as economics. In contrast to economics, which affect the well-being of people rather directly and in an immediately perceptible way, there are some perceptual hindrances for environmental changes:

- the spatial distance between cause and effect
- the distance between cause and effect in time[23]
- the slowness of the environmental changes
- the lack of organs for the perception of environmental changes (for example for radioactivity or for toxicity)
- the wrong risk-estimations of environmental dangers[24] (Schahn et al., 1993)

Environmental indicators tackle these hindrances as they make environmental effects explicit by means of calculated figures. Sector- and product-related indicators like EIFOB trace environmental damages all the way back to their origin in, say, the choice of an energy-consuming construction material or a resource wasting building design.

The distances between cause and effect hides the causal links and seduces to ignore individual responsibility as it may be impossible to allocate environmental damages to individual causes. Effects are seldom *directly* perceivable as results of individual behaviour. In the cases of the environmental catastrophes of Chernobyl or Bhopal (Beck, 1986), the sources of the contamination were quite obviously specific industrial plants that ran out of control. The causal chains in these cases consisted of comparatively few links. In many other cases (such as global climate change, acid rain, creeping contamination through the food chain) the problematic environmental effects are in the first place perceivable in a more *anonymised* way, as the democratic sum-up of our collective misbehaviour so to speak[25]. Indicators can be seen as a means of bridging this gap between causes and effects by

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[22] Harste points out that the promise of stability is inherent in the political institution 'state' (as indicated by the very word 'state', also meaning 'present situation', compare also French 'état', which has the same double meaning), a promise which also is an intrinsic feature in the idea of 'sustainability' ('to sustain' meaning to support, to bear the weight of, esp. for a long period, to maintain or to keep (Oxford Compendium, 2000) and that ecological systems are gaining significance in the constitution of the European state-system:

'*From 1400 t0 1800 the European state-system was dominated by military systems; from 1800 to the present day by economic systems. Without the dominance of these systems disappearing, we can expect that in the future ecological systems will gradually enter the scene with a parallel significance*.' (Harste, 2000) [author's translation]

[23] With regard to time bindings and time-horizons in different subsystems of society (religious belief, the family- and love-system, the art-system, the political system, the legal system, the economic system,…) Harste writes:

'The social subsystems only seldom seem to have time bindings that […] have an impact on the functioning of society in favour of very long time horizons, that is in favour of sustainability in the long term. Time bindings of the same type as the earlier problems of sea-powers to provide supply with oak-wood are almost only to be found in the privatized and moralized consideration of future generations in the family system.'(Harste, 2000)

[24] Meaning that the environmental consequences of anthropogenic activities are often misjudged. But even, if sufficient awareness of the potential impacts on the environment exists, the estimated probability of the impacts occurrence can lead to wrong conclusions: Linstone points out that, for example, in the case of the Exxon-Valdez oil spill at the coast of Alaska the Exxon Corporation was prepared to cope with oil spills in the range of 1000 to 2000 barrels, which according to a consultant study were 'most likely' to occur while a catastrophic spill of more than 200.000 barrels (the Exxon-Valdez size) would only occur once in 241 years and was therefore regarded as negligible.

'*In cases of low likelihood events where the consequences of their occurrence is catastrophic, probabilities do not offer a basis for planning.'(Linstone et al., 1994)*

[25] Beck places the question of the distribution of risks in society in the centre of his reflection on the 'reflexive modernity'. (Beck, 1986)

pointing out (=‘indicating’) the environmental effects right where they originate in human activities. And they *individualise* the responsibility for environmental damages by providing quantitative figures for *how much* a specific building (existing or in planning) damages the environment.

Although humans have a long tradition in giving shape to their environment and have themselves *‘become a new geological force’*, (International Encyclopedia of the Social Science, 1972) (almost all of the European landscape is human-altered), anthropogenic influence on the environment has reached dimensions hitherto unknown: It is no longer *local* environmental damages that need to be dealt with, it is the possible impact of anthropogenic activities on the *global* environment that has become the object of environmental policy. The philosopher and anthropologist Bruno Latour calls this ‘*an experiment of- and with all of us’*:

> *‘The walls of the laboratory today include the entire planet. […] If global warming originates in human impacts or not can only be found out by embarking on the attempt to stop our harmful emissions. […] No protocol is written on these experiments that are performed with us, by us, for us. Nobody is explicitly charged with the responsibility to supervise them.’ (Latour, 2001) [author’s translation]*

Were indicators traditionally a means for scientists to trace the progress of their laboratory experiments - the environmental indicators today can be seen as an attempt to monitor how the development of the global experiment we - willingly or not – have become a part of.

On the changed role of science …

> *‘What is the difference between this collective experiment and what we usually call ‘a political situation’?’*

asks Latour and answers

> *‘There is none. […] The sharp distinction between scientific laboratories, which experiment indoors with theories and phenomena, and a political situation outdoors, in which non-experts deal with values, opinions and passions is vanishing in front of our eyes.’*

And so is the distinction between laypersons and scientists:

> *‘If a decisive part of scientific activity consists of the formulation of the problems that shall be solved, then it is obvious that scientists no longer remain among themselves. Those who should doubt this only need to ask ecological activists which kind of energy-research laboratory scientists should carry out.’ (Latour, 2001) [author’s translation]*

The science-society-relationship is not a one-way-street anymore. According to Ulrich Beck it is due to the fact that the major environmental problems we are facing today originate in science and technology that science had to give up its claims to infallibility and the rationality-monopoly. Today sciences

> *‘are targeted not only as a source of solutions to problems, but also as a cause of problems. […] Two constellations can be differentiated in the relationship of scientific practice and the public sphere:* primary *and* reflexive *scientization. At first, science is applied to a ‘given’ world of nature, people and society. In the reflexive phase, the sciences are confronted with their own products, defects, and secondary problems, that is to say, they encounter a* second creation in civilization*. The development logic of the first phase relies on a* truncated *scientization, in which the claims of scientific rationality to knowledge and enlightenment are still spared from the application of scientific scepticism to themselves. The second phase is based on a* complete *scientization, which also extends scientific scepticism to the inherent foundations*

and external consequences of science itself. In that way both its claim to truth *and* its claim to enlightenment *are* demystified.' *(Beck, 1986)*

At the same time the tacit knowledge of practitioners (Schön, 1983) and the expertise on local environments of local citizens has gained the reputation of being at least as valuable as scientific knowledge and is therefore considered an essential source of information in for example urban planning processes. (Hoffmann et al., 1999) 'Soft' research methods like qualitative research interviewing or the performance of scenario workshops have been developed to make this information accessible for scientists. The sustainability indicators for the community of Seattle are an example for indicators that

> *'are the result of a five-year effort of […] a volunteer network and civic forum' and were 'selected and researched by over 250 citizen volunteers' (Atkisson, 1995)*

Gibbons *et al.* point out that we here witness a new kind of knowledge production for which they have introduced the term 'Mode 2 knowledge production' (in contrast to the traditional 'Mode 1[26] knowledge production'):

> *'In Mode 1 problems are set and solved in a context governed by, largely academic, interests of a specific community. By contrast, Mode 2 knowledge is carried out in a context of application. Mode 1 is disciplinary while Mode 2 is transdisciplinary. Mode 1 is characterised by homogeneity, Mode 2 by heterogeneity. Organisationally, Mode 1 is hierarchical and tends to preserve its form while Mode 2 is more heterarchical and transient. Each employs a different type of quality control. In comparison with Mode 1, Mode 2 is more socially accountable and reflexive. It includes a wider, more temporary and heterogeneous set of practitioners, collaborating on a problem defined in a specific and localised context. […] In Mode 2 […] knowledge is always produced under an aspect of continuous negotiation and it will not be produced unless and until the interests of the various actors are included. […] Knowledge production in Mode 2 is the outcome of a process in which supply and demand factors can be said to operate […]. (Gibbons et al., 1994)*

Both the objective and the research design[27] of this study on EIFOB with their strong consideration of the different actor groups' demands and the active involvement of different stakeholders make this research project an example of Mode 2 knowledge production.

…and the implications on decision making

The transition from what Beck calls the 'primary modernity' to the 'reflexive modernity' can also be traced in changing approaches of decision making. The typical approach of the 'primary scientization', with the science's claim of the monopoly of rationality still being valid, can be described as the *'linear rational comprehensive planning model'*. This 'scientific' approach is characterised by a systematic consideration of different means (alternatives) to achieve the defined goals and has proved to be very successful to solve tasks of a mainly technical orientation such as the American moon flight. But according to Leleur societal problems genuinely differ from technical problems and demand an new kind of decision-making. To distinguish between these different approaches Morin operates with a so-called 'simplicity paradigm' versus the 'complexity paradigm'. The two paradigms are character-

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[26] *'Our view is that while Mode 2 may not be replacing Mode 1, Mode 2 is different from Mode 1 – in nearly every respect.' (Gibbons et al., 1994)*

[27] As described in the next chapter

ised in the following table[28] by a list of concepts that collectively describe the type of thinking associated with each paradigm:

Table 1: Simplicity and Complexity paradigms (Morin, 1986)

Simplicity paradigm	Complexity paradigm
Universality	Multiplicity
Determinism	Organisation
Dependence	Autonomy
Necessity	Possibility
Lawfulness	Self-organisation
Prediction	Surprise
Separation	Wholeness
Identity	Individuality
The general	The particular
Objects	Subjects
Elements	Interactions
Matter	Life
Quantity	Quality
Linear causality	Multi-causality
The automaton	Time
Objectivity	Culture

New kinds of 'soft' system techniques and planning methods were developed within the complexity paradigm, focusing more on communication, consensus building, interdisciplinarity and public involvement. (Leleur, 2000).[29]

The role of pure 'hard' science in decision making has diminished. It is no longer the experts that reach a consensus on the best way to go before action puts scientific knowledge into practice without adding to it - on the contrary: according to Latour the increasing number of public scientific controversies reveals that science cannot free us from the need to take risks as it is not able to provide us with the absolute knowledge that would be necessary to take decisions without risks. (Latour, 2001).

On the role of indicators in environmental decision making

The transformation of our society into a sustainable one is certainly of a complex nature according to Morin's model. And so is the attempt to integrate the demands of environmental sustainability into the performance of different sectors, like for example the construction sector.

But to which paradigm are environmental indicators to be sorted? The very idea of operationalising complex problems by quantifying them in the form of indicators traditionally derives from thinking in the simplicity-paradigm. Nevertheless I do not see EIFOB only in the simplicity-half of Morin's table. For two reasons:

1 The environmental- and sustainability-indicator debate does not take its point of departure in the simplicity paradigm and it does not follow the technocratic approach of applying the linear rational comprehensive planning model to complex societal problems. On the contrary: it is the merit of the sustainability debate that it has identified environmental problems as *complex* ones that can only be tackled successfully if seen in close connection with economic and social development. Indicators

[28] Taken from (Leleur, 1999)

[29] See also the remark about 'mode 2 knowledge production' (Gibbons et al., 1994) at the beginning of the next chapter ('Research design')

then, so to speak, attempt to build a bridge back to the simplicity paradigm by expressing the complex problem 'global environmental change' in a way that can be operated with in contexts where decisions are usually taken within the simplicity paradigm (legal regulations, statistics, choices between alternative constructions methods and designs,…). At the same time indicators can serve as a bridge in the opposite direction as scientific data aggregated to a commonly understandable set of simple indicators facilitates the communication of scientific questions outside the scientific world and can foster the participation of laypersons in the environmental debate.

2 The perception of environmental policy as a complex societal problem is mirrored both in the *design* and in the *designing* of environmental indicators:
in the *design* in the sense that the normative statements ('How do we rank the different environmental impacts and effects? Is, for example, climate change more important than depletion of scarce resources?') are explicitly integrated as a crucial element in many indicator systems: The Dutch Eco-indicator 99 for instance uses a three-stage method in which the final weighting of the data is performed in the *valuesphere* after the pressures on the environment had been monitored in the *technosphere* and their effects modelled in the *ecosphere*. (Goedkoop et al*.,* 2000)
In the *designing* to the extent that 'soft' characteristics like 'user-friendliness' and implementation aspects are considered along with purely environmental scientific questions already in the development of many indicators, for example by the discussion of indicator drafts in interdisciplinary advisory boards.

In this sense the research design (as described in the next chapter) of this project on EIFOB with its equal emphasis on the environmental scientific sphere and the social scientific sphere bears typical characteristics of the role of science in the reflexive modernity.

Research design

The previous chapter described the objective of the study – the questions that this study endeavours to answer. This chapter explains, how these questions were investigated. It begins with an explanation of the study's basic theoretical approach - social constructivism – and its position in the philosophy of science. Then the theory applied in this study is presented: The social construction of technology (SCOT), a concept, which needs to be understood in order to comprehend the research design.

Constructivism and Social constructivism in the theory of science

'How do we know what we believe we know?' is the subtitle of a book on constructivism (Watzlawick et al., 1984). This title directs our attention towards a core question of the philosophy of science: *'What is reality and what can we know about reality?'* Some philosophical schools claim that we can gain pure and objective knowledge of reality, either directly by observation and experience of the world (positivism, realism, empiricism) or by reasoning (rationalism). This position seems to be in *natural* accordance with our immediate experience, that our senses tell us the truth about the world, about the colour of things, their position, their structure. A chair looks like a chair, feels like a chair and functions like a chair - it seems very real.

Other philosophical schools question this direct link between reality and knowledge. Kant stated that it is impossible to obtain knowledge about the-world-as-it-is (*'die Welt an sich'*), as perception is only possible if it matches existing *categories* in the human mind (Osborne, 1992). An object can only be perceived as a chair if the observer already has the concept of a chair in mind. A people without that kind of furniture would probably perceive the same chair as some kind of strange construction, an object of art or merely as a source of firewood.

The late Wittgenstein pointed out, that the significance of language is exclusively determined by the situation in which the language is used. [*found in (Wenneberg, 2000)*]. His key notions *'Sprachspiel' ('language game')* and *'Lebensform' ('life form')* imply that as in a game so in life there are certain rules to be obeyed, if language is to function. And as there are different games with different rules there are different life forms (situational contexts) in which the same sentence or word may have different significations (Brier, 2000).

It is in this line of thought that social constructivism[30] arouse in opposition to the traditional empiricist epistemology. The central thought of social constructivism is that in contradiction to our immediate impression vast areas of our life world are not shaped by nature in the only possible, 'natural' way, but have been created and formed by society, or, in other words, are *socially*

[30] While *social* constructivism investigates phenomena in the light of their social embedding, usually taking various actors into consideration, the notion *constructivism* was originally coined by Kant to describe the viewpoint, that mathematical cognition is genuinely synthetic because it is based upon *constructed* mathematical elements. This thought has been developed further in the 20th century by Dutch intuitionists and mathematical philosophers of the Erlanger-school (Politikens filosfi leksikon, 1988). Watzlawick et al. employ the notion *constructivism* mainly to describe psychological phenomena on the individual level, e.g. where test persons in psychological experiments become convinced of the existence of causal links between events, the experimenter knows only have an arbitrary temporal connection (Watzlawick et al., 1984).

constructed. This may seem comparatively easy to see for example for the use of paper money: nobody would question that the value of the bills[31] does not derive from some intrinsic value[32] of the material they are made of, but must commonly be attributed to them by the people who trade with it. Also language is a rather convincing example, because it obviously differs from country to country. But the idea of social construction becomes more thrilling if other, less obvious areas are concerned, as for instance our understanding of technological artefacts, social interaction or body language.

Wenneberg (Wenneberg*,* 2000) points out that according to the different fields of application *four* forms of social constructivism (SC) can be distinguished in the theory of science, each showing a higher degree of radicalism than the preceding one[33]:

1. Social constructivism as a critical perspective (SC 1):
   The somewhat diffuse attitude not to take 'the natural' for granted. For example do various anthropological studies imply that certain patterns of behaviour that we consider 'natural' and determined by our body (for example to shed tears when feeling sorrow) actually are subject to cultural habits. Things don't have to be the way we are used to, they could potentially also be different.

2. Social constructivism as a sociological theory (SC 2):
   The critical perspective applied specifically to social institutions like for instance money, traffic rules or work contracts. Here the social constructivist perspective is used to investigate the origin and the nature of these institutions. By reconstructing their creation by society they appear less monolithic and more subjected to change.

3. Social constructivism as an epistemological theory (SC 3):
   If SC 2 is applied to the social institution called 'knowledge' it becomes an epistemological theory, if applied to scientific cognition a theory of science.
   As we shall see later, SC in society and technology studies (STS) was also triggered by the increasing environmental and political risks arising from technology. From here to an critical investigation of knowledge itself as the basis of risk-definitions is only a minor step, but due to the increasing importance of knowledge, at the same time an important one.
   'As the risk society develops, so does the antagonism between those afflicted *by risks, and those who* profit *from them. The social and economic importance of* knowledge *grows similarly, and with it the power over the media to structure knowledge (science and research) and disseminate it (mass media). The risk society is in this sense also the* science, media and information *society. Thus new antagonisms open up between those who produce risk definitions and those who* consume *them.' (Beck, 1986)*

4. Social constructivism as an ontological position (SC 4):
   If also the *physical reality* is seen as socially constructed, SC becomes an ontological position. Wenneberg illustrates this in the first place somewhat striking opinion with an metaphor and an historical example: The *cookie-roller metaphor* compares the physical world with a flat cookie-dough on a baking tin: Before the cookie-roller has rolled over it there are no cookies, only the unstructured plane of the dough. It is only after the treatment with the cookie-roller that the dough is divided and the cookies appear. Accordingly the physical world only begins to exist when our look and our consciousness wander over it and start to structure it by giving things names.

[31] Of course the same argument can also be applied to the value of golden coins or to gold itself. However, the example 'paper bills' is probably more accessible for 'the newcomers' to social constructivism, as the contrast between the cheap material 'paper' and the value of paper money is so striking.
[32] Which, the social constructivist would claim, does not exist!
[33] According to Wenneberg these can be seen as an 'intellectual slide': starting with the comparatively evident and 'innocent' assumptions of SC 1 one automatically comes to conclude the ideas of SC 2 and SC 3 and surprisingly ends up with the radical ideas of SC 4.

The discovery of America by Columbus serves as an historical example: According to SC 4 it does not make more sense to say ‘America was there even before it was discovered by Columbus’ as it does make sense to say ‘Feminism existed before it was brought into life by the feminist movement.’ Instead, the new continent ‘America’ only slowly came into existence in a long process of recognition, which only began with the voyages of Columbus – for whom ‘America’ still did not exist yet either, since he believed he had sailed to India.

Roots of social constructivism in the theory of science

After the main ideas of SC have been explained in the previous paragraph, now SC’s roots in the theory of science debate are scrutinised, focussing on those authors that have inspired the theory employed in this study, the theory of the social construction of technology (SCOT).

Epistemology, the theory of knowledge, has been a subject of philosophical reasoning since the Greeks. But it was only in the beginning of the 20th century, when the sociology of knowledge was developed by Scheler and Mannheim, that knowledge and science became the object of sociological studies. The beginning of the sociology of knowledge, however, was strongly inspired by the ideas of Karl Marx. He had made his point that *‘Das Sein bestimmt das Bewusstsein.’ (‘The being determines the consciousness.’*), emphasising that human thinking is strongly influenced by the social situation[34].

According to their different focuses - a) on knowledge in general and b) on scientific knowledge - one distinguishes between the *sociology of knowledge* and the *sociology of scientific knowledge*. The latter is closely linked to the names Robert K. Merton (born 1910), Thomas Kuhn, the authors of *the strong programme* (Bloor, Barnes et al.) and of *The Empirical Programme of Relativism (EPOR)* (Collins).

The modern *sociology of knowledge* on the other hand owes most to Peter L. Berger and Thomas Luckmann, who in 1966 published their chief work *‘The Social Construction of Reality: A Treatise in the Sociology of Knowledge’*. Their theory, which explicitly applies to everyday common sense knowledge as well as to scientific knowledge, is based on the three positions that

1. Society is a human product.
2. Society is an objective reality.
3. The human being is a social product.

The society-constituting process described by this somewhat iterative or self-referring series of theses gains its dynamic from the inclination of the human being to develop habits in order to avoid *‘cognitive dissonance’* – the uncomfortable uncertainty we feel in unfamiliar situations where we don’t know what to do.

Thomas Kuhn’s famous study *‘The Structure of Scientific Revolutions’* (1962) destroyed the picture of the continuous ‘cumulative’ science that gathers more and more knowledge thus providing us with a more and more realistic picture of reality. Instead Kuhn pinpoints the revolutionary changes that happened in scientific understanding, for example in the transition from Newton’s to Bohr’s and Einstein’s physics, a phenomenon for which he introduces the notions *‘change of paradigms’* between *‘normal science’* via *‘revolutionary phases’* to a new phase of *‘normal science’*. His special contribution to social constructivism is that he undertakes to trace the changes of paradigms back to their origins *both* in the scientific sphere *and* in the social sphere, where for example norms, *‘tacit knowledge’* as well as the socialisation, age and reputation of the involved scientists play a decisive role. Kuhn

[34] In this paragraph I take advantage of (Wenneberg, 2000) who illustrates Karl Marx’ significance for the sociology of science with yet another of Marx’ famous quotations: “The thoughts of the ruling class are the ruling thoughts.”

concludes that extrascientific parameters do not only determine what is chosen as an object of scientific research, but even the contents of what is presented as scientific knowledge (compare (Wenneberg, 2000)).

'The strong programme'

Kuhn's work inspired a group of younger sociologists (David Bloor, Barry Barnes, Steven Shapin et al.) that around 1975 developed *'the strong programme*', which again was an important source of inspiration for the theory of the social construction of technology (SCOT).
The strong programme can be characterised by the following key-notions ((Nørgaard, 1996), referring to (Andersen, 1994)):

- Relativism
- Impartiality (in relation to 'true' and 'false')
- Symmetry
- Reflexivity[35]
- Historical-empirical approach
- Natural science as the object of study

Impartiality means, that

> *'regardless of whether the sociologist evaluates a belief as true or false, as rational or irrational, s/he must search for the causes of its credibility in a symmetrical way.' (Nørgaard, 1996).*

'Symmetry' meaning that both types of beliefs are explained *in the same way*, that is in reference to social factors (Wenneberg, 2000).

> *'All knowledge and all claims to knowledge are to be treated as socially constructed, meaning all explanations of the genesis, acceptance and rejection of claims to knowledge are to be sought in the social world as opposed to the natural world. The two requirements of symmetry and impartiality, formulated by Bloor in 1976, stand firm in constructivist science and technology studies today.' (Nørgaard, 1996)*

The empirical programme of relativism

The empirical programme of relativism (EPOR) was mainly developed by the Britons Collins, Pinch and Travis in the prolonging of the strong programme, aiming to approve the strong programme's tenets by operationalising it for the performance of empirical studies. Bijker, who was strongly influenced by the EPOR in the development of SCOT, describes as the programme's main characteristics *'the focus on the empirical study of contemporary scientific developments and the study, in particular, of scientific controversies.' (Bijker et al., 1989)*

In its explanatory apparatus EPOR distinguishes three stages:

1. Display of *interpretative flexibility* of scientific findings:
   'in other words, it is shown that scientific findings are open to more than one interpretation. This shifts the focus for the explanation of scientific developments from the natural world to the social world.' (Bijker et al., 1989)
2. Termination of scientific controversies ('closure'):
   Here the social mechanisms that terminate the scientific controversies and form a consensus as to what is to be considered 'truth' are described.
3. A third stage, *'which has not yet been carried out through in any study of contemporary science, is to relate such 'closure mechanisms' to the wider social-cultural milieu.' (Bijker et al., 1989)*

As SCOT takes EPOR as its point of departure, these stages are also to be found in Bijker's SCOT theory.

[35] "Reflexivity implies that […] the patterns of explanation used to explain the content of other sciences must also be applicable to sociology itself." (Nørgaard, 1996)

Other roots
As other roots of the social constructivist approach to *science* (on which the social constructivist approach to *technology* is based) can be named

- *Ethnomethodology*, developed by Harold Garfinkel: its object of study is the subconscious everyday knowledge embodied in the implicit rules in societies. Ethnomethodological research endeavours to elicit these rules for example by on-site observations especially in situations where these rules are violated and thus become visible in the irritated reactions of the persons present. (Alvesson et al., 2000). Similar to ethnological studies, ethnomethodology favours an *extreme empiricism*. In making precise and detailed descriptions of every-day situations a key research approac, ethnomethodology shares the social constructivists' reluctance to reductionistic and generalising approaches. (Wenneberg, 2000)
- Postmodernism: Also postmodernist and deconstructivist ideas (Derrida, Foucault et al.) that particularly flourished in the 1970s and 1980s with their belief in the local instead of in the (abandoned) ideal and the universal have inspired and supported social constructivism.

Thus social constructivism could draw from different sources and can be seen as the product of a longer historical movement that scrutinised the social character of knowledge.

Technology in the light of social constructivism

Social constructivism versus technological determinism

One important application of SC 1 are society and technology studies (STS) which in the 1970s began to investigate the relation between technology and society in a new way. At first glance it may seem trivial to apply SC to technology, which by definition[36] is a human-made artefact. But here social constructivists challenged the hitherto prevailing view of deterministic technology development. This view, held by Louis Mumford and Jacques Ellul, stood in the positivistic/empirical tradition of science and can be characterised by the following central ideas (compare (Nørgaard, 1996)):

- society and technology are different spheres, clearly separated from one another
- technical change happens autonomously within the technological sphere (by scientific and technological progress) without influence from the social sphere
- technology influences society and determines the direction of societal development, but the relation is not reciprocal

Nørgaard points out that these deterministic perspectives that flourished in the 1960s gave rise to several practical problems such as blind faith in technology, the 'technological fix'[37] and social engineering[38] (Nørgaard, 1996).

This deterministic perspective on technology that was challenged when in the aftermath of the student movement of the sixties young scientists started to also critically inquire the supposed blessings of technology.

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[36] A closer definition of "technology" will be given in the paragraph on the social construction of technology (SCOT).

[37] *'The 'technological fix' is based on the belief that technology can solve all problems, including social ones. A technological solution often exempts society from finding more time-consuming political and social solutions.'* (Nørgaard, 1996) based on (Nørgaard et al., 1994).

[38] *''Social engineering' is a mechanism which is used to control and/or avoid reluctant and sceptical attitudes to the introduction and dissemination of technology. Social engineering is used when a technological solution is given a priori. The idea is that the individual person/society has to adjust to technology. The time interval between dissemination of technology and the acceptance and adaptation to it is called 'cultural lag''* (Ogburn, 1964)" (Nørgaard, 1996)

Wiebe Bijker, one of the fathers of the social construction of technology (SCOT), writes:

> *'Like many Dutch engineering students in the 1970s, I was drawn to the science-technology-society (STS) movement, whose goal was to enrich the curricula of both universities and secondary schools by offering new ways to explore issues such as the risks of nuclear energy, the proliferation of nuclear arms and other new weapons systems, and environmental degradation.' (Bijker, 1995) p. 3*

It is the distinct critical power social constructivism gains from the fact that it does not take anything as given which made the theory attractive for the young scientists.

Three constructivist perspectives on technology

Three main constructivist perspectives on technology can be distinguished39:

- the actor network theory (Latour, Callon, Law),
- the systems approach (Hughes) and
- the social construction of technology (Pinch, Bijker).

In the first following, the first two are described only sketchily while the third - as the theory applied in this study - is described in detail.40

The actor network theory sees the emergence of technology as taking place in a seamless web ('network') of science, technology and society. Its special characteristic, which distinguishes its sharply form SCOT, is its understanding of the notion 'actor', which includes humans as well as non human elements. Bruno Latour explains this in his famous 'hotel key study', where he points out that the large cumbersome weight attached to the room keys much more efficiently forces the customers to return the keys at the reception than an sign with an imperative statement. The weight is a 'key-actor' in this socio-technical-network, so to speak. (Latour in (Law, 1991)). Not untypical for French writing in the social sciences, the actor network theory is exemplified with various illustrative cases. It is, however, operationally not well developed as it lacks a clear structuring and a concise generalised description of its methodological approach. This gave it little attraction as a theoretical background for this PhD project, in which a clear distinction between actors and the technological artefact41 'EIFOB' is maintained.

The systems approach was developed by the American Thomas Hughes in connection with studies of Edison's role in the electrification in the USA. As its name suggests, it focuses on the development of big technological systems which Hughes describes with an evolutionary line of thought: Often starting with an innovative invention the systems grow in competition with other systems, reach a phase of consolidation where they gain what Hughes calls 'momentum':

> *'They have a mass of technical and organisational compounds; they possess direction, or goals; and they display a rate of growth suggesting velocity.' (Hughes in (Bijker et al., 1987)).*

As an underlying theory for my project the systems approach's focus on big technological systems did not seem appropriate.

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[39] These are documented in the anthologies "The Social Construction of Technological Systems" (Bijker et al., 1987) and "Shaping Technology / Building Society" (Bijker et al., 1992).

[40] Of course, far more could be written about these three perspectives, but as the focus of this study are different perspectives on EIFOB and not different social-constructivist perspectives only an appropriate share of the project's time resources were allocated to this subject in order to concentrate on the key tasks.

[41] In this thesis I spell 'artefact' with an 'e' as in British English. As the main source on SCOT, Wiebe Bijker's 'Of Bicycles, Bakelites and Bulbs' (Bijker, 1995) is published in the USA it spells 'artifact' with and 'i' in accordance with North American English, which I cite unaltered, of course.

The social construction of technology (SCOT) has been developed by Pinch and Bijker (Bijker et al., 1989) and later been conceptually refined in the direction of structural theory by Bijker (Bijker, 1995) for the investigation of comparatively well defined, concrete artefacts rather that phenomena on a big scale, which suits well for a project on a set of concise indictors for the support of specific decisions in a specific sector. SCOT also provides a well-described apparatus for the collection and analysis of data in an empirical research approach. In the following the SCOT-theory is described in detail.

The social construction of technology (SCOT)

'Technology' in the sense of SCOT

In the book *'The Social Construction of Technological Systems - New Directions in the Sociology and History of Technology'* (Bijker et al., 1987), of which Bijker was one of the editors, he outlines his understanding of the notion 'technology', also applied in SCOT:

> *'Three layers of meaning of the word 'technology' can be distinguished (MacKencie and Wajcman 1985).*
>
> *First, there is the level of* physical objects *or* artifacts*, for example, bicycles, lamps, and Bakelite.*
>
> *Second, 'technology' may refer to* activities *or* processes*, such as steel making or moulding.*
>
> *Third, 'technology' can refer to what people* know *as well as what they do; an example is the 'know-how' that goes into designing a bicycle or operating an ultrasound device in the obstetrics clinic.*
>
> *In practice technologies [often] cover all three aspects, and often it is not sensible to separate them further. Also, instead of trying to distinguish technology from science (or indeed from any other activity) in general terms, it seems preferable to work from a set of empirical cases that seem intuitively paradigmatic.' (Bijker et al., 1987)*

The three steps of a SCOT-analysis[42]

A basic tenet of SCOT is to

> *'take the 'working' of an artifact as* explanandum[43]*, rather than* explanans[44]*; the useful functioning of a machine is the result of socio-technical development, not its cause.' (Bijker, 1995)*

To explain the 'working' of an artefact the SCOT approach follows the three-steps analysis of EPOR, specified to address technological development by the concepts listed in the following table[45]:

Table 2: Steps and related concepts of the SCOT approach (by (Haugbølle Hansen, 1997) according to (Bijker, 1993))

Stepsin the SCOT analysis	Related concepts
1. Sociological deconstruction	Relevant social groups (RSG) Interpretative flexibility
2. Social construction	Closure, Obduracy & Stabilization
3. The explanatory scheme	Technological frame (TF) Sociotechnical ensemble (STE)

[42] The explanation of SCOT's essential parts in this paragraph bases mainly on (Bijker, 1995) as a primary source and on (Hansen, 1997) and (Nørgaard, 1996) as secondary sources.

[43] (Latin:) Something, that is to be explained (= should be the object of an explanation).

[44] (Latin:) Something, that is explaining (= is part of an explanation).

[45] From (Nørgaard, 1996).

Relevant social groups and interpretative flexibility

The first step is called *sociological deconstruction*, because here the artefact in question is, so to speak, *deconstructed* into different incongruent artefacts. The researcher shows that what *technically* appears to be *one* artefact *sociologically* incorporates more than one artefact according to the different perceptions, the artefact's different *relevant social groups (RSGs)* have of it. Bijker explains that the phrase *relevant social group*

> *'is used to denote institutions and organisations (such as the military or some specific industrial company), as well as organized groups of individuals. The key requirement is that all members of a certain social group share the same set of meanings, attached to a specific artifact. In deciding which social groups are relevant, we must first ask whether the artifact has any meaning at all for the members of the social group under investigation.' (Bijker, 1995)*

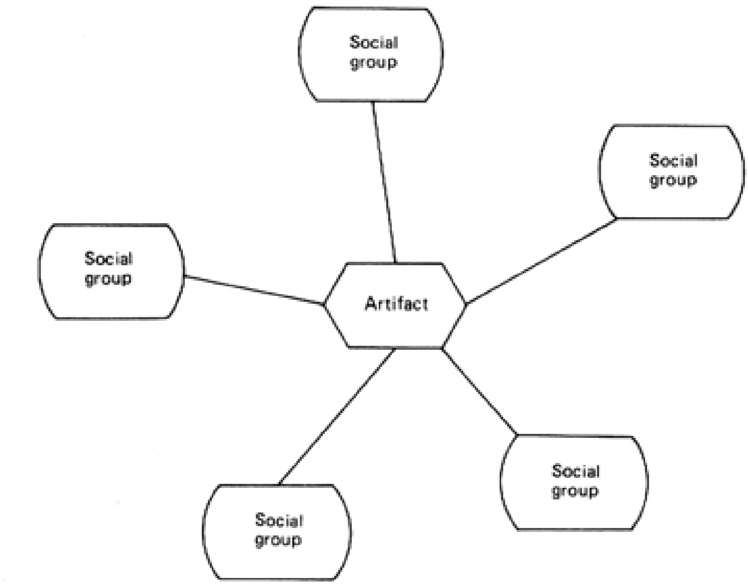

Figure 4: *'Related to the artifact, the relevant social groups are identified'* (Bijker, 1995)

To identify relevant social groups Bijker proposes to follow two rules:

> *''Roll a snowball' and 'follow the actors.' […] Typically one starts by interviewing a limited number of actors (identified by reading the relevant literature) and asks them at the end of each interview, who else should be interviewed to get a complete picture. In doing this with each interviewee, the number of new actors at first increases rapidly like a snowball, but after some time no new names will be mentioned – you have the complete set of actors involved in the controversy. […] By using the snowball technique, a first list of relevant social groups can be made. Using this as a starting point, the researcher can then 'follow the actors' to learn about the relevant social groups in more detail. […] Because these social groups are relevant for the actors themselves, they typically have described and delineated the groups adequately.' (Bijker, 1995) p. 30*

The concept of RSG is also important for the study of problems connected with the artefact. Here Bijker states that

> *'A problem is defined as such only when there is a social group for which it constitutes a 'problem'.' (Bijker, 1995) p. 30*

Bijker exemplifies SCOT with the development of the bicycle in the early days of cycling:

Figure 5: A *'young men of means and nerve'* riding his high wheeled bicycle (from (Bijker, 1995))

In the case of the high wheeled bicycle, relevant social groups were, among others, *the users*, whom Bijker describes as *'young men of means and nerve'* who saw cycling primarily as an athletic pastime (Bijker, 1995), and *the non-users* of the bike, who could not afford one, were physically not able to mount one or as pedestrians were simply afraid of being ran down.

Here it already becomes clear that the RSG concept is closely linked with the concept of *interpretative flexibility*, meaning that the artefact can be interpreted in different ways by different groups: in the case of the high wheeled bicycle, the artefact

> *is deconstructed into two different artifacts. Each of these artifacts, the 'Unsafe', and the 'Macho', are described as constituted by a relevant social group, and this description also includes a specification of what counts as 'working' for that machine for that group. In this way, the 'working' and 'nonworking' of an artifact are now being treated as explanandum, rather than used as explanans for the development of technical artifacts. The 'working' and 'nonworking' of an artifact are socially constructed assessments, rather than intrinsic properties of the artifact. (Bijker, 1995), p. 75*

The last thought can be seen as the very centre of SCOT. It becomes also clear why the *symmetry principle* is so important: If the 'working' of an artefact is primarily socially constructed, the researcher must be impartial with respect to opposing views of different RSGs in order to avoid promoting just one RSG's view as 'the right one'.

Closure and stabilisation

After having carried out the sociological deconstruction of the artefact, in the next step its social construction is investigated, which

> *'is the outcome of two combined processes, closure and stabilization. […] Stabilization can most easily be introduced by analysing the intragroup development of artifacts, while closure is primarily relevant to an intergroup analysis.' (Bijker, 1995), p. 85*

Closure means that the interpretative flexibility of an artefact diminishes as consensus among the different RSGs about the dominant meaning of the artefact emerges – only one interpretation is accepted by all. In the case of the bicycle, closure occurred when the constructions similar to the one shown below had become the dominant ones.

Figure 6: A 'safety bicycle' of 1886, near the closure of the social construction of 'the bicycle'[46]

Bijker stresses the often far-reaching consequences of closure:

> *'It restructures the participants' world […] History is rewritten after such a closure, and it is difficult to recapture the factual flexibility as it existed prior to the ending of the controversy.' (Bijker, 1995), p. 85*

I can illustrate this for the artefact 'bicycle' with an own experience: at the Architectural School in Århus (Denmark) I attended a lecture for architectural students on the construction of bicycles, held by a former Danish professional competition cyclist who was now running a bike shop. He lifted a conventional bicycle frame up and presented it with the words

> *'This is the ultimate bicycle frame; it has proved successful and there is no better way to construct bicycles.'*

His comment remained uncontradicted by my fellow students, who were all riding bikes of the kind he was showing, while I was perplexed about this ignorance, since I myself ride a recumbent, which in my opinion performs much better than the ordinary bike in terms of comfort and definitely in terms of aerodynamics, because its rider has a much smaller front area due to his recumbent position.

Figure 7: a contemporary recumbent bicycle[47]

Even though a great variety of recumbents are built today by professionals and private persons in many different countries, users of this kind of bicycle regularly meet amazed onlookers who demand explanations for the use of such a *'strange vehicle'*.

This example illustrates how difficult it can be to re-establish a interpretative flexibility around and artefact, once closure has been reached. It also exemplifies the phenomenon, which Bijker calls *'Obduracy'*:

'Obduracy' in Bijker's sense means the degree to which an artefact's meaning for its different relevant social groups has 'hardened', much as the building material concrete, when still liquid and 'soft', can be poured and

[46] From (Bijker, 1995)

[47] Source: http://www.hpv-ev.de/hpv/recumbent/geometry/swb/index.htm

adopts the form of its surroundings. Once it has hardened, the surrounding takes its shape for granted and adapts to it.

> *'High obduracy is manifested in (the existence of) an exemplary artifact, whose significance is not negotiable, low obduracy is manifested by a 'take it or leave it' attitude of the relevant social groups with regard to the artefact […]. (Bijker 1995)*

'Stabilization' signifies a similar process *within* a RSG: Its view of the artefact is not rapidly changing anymore but becomes stable, a phenomenon that can be traced by using the method of rhetorical analysis developed by Latour and Woolgar (1979) for science studies:

> *Thus the statements: 'The experimenters claim to show the existence of X,' 'The experiments show the existence of X' and 'X exists' exhibit progressively […] greater degrees of stabilization of X.' (Bijker 1995)*

As stabilisation describes the *intragroup* development of artefacts the degree of stabilisation will be different in different RSGs.

Technological frame and sociotechnical ensemble as anaytical units

It is striking that in neither the primary literature nor the secondary literature is a precise definition of 'technological frame' (TF) and 'sociotechnical ensemble' to be found. However, the concept become clear when Bijker's lengthy explanations are combined with the examples of the application of the concept in his case studies.

An entry point to the understanding of the concept 'technological frame' may be the visualisation Bijker provides in his book:

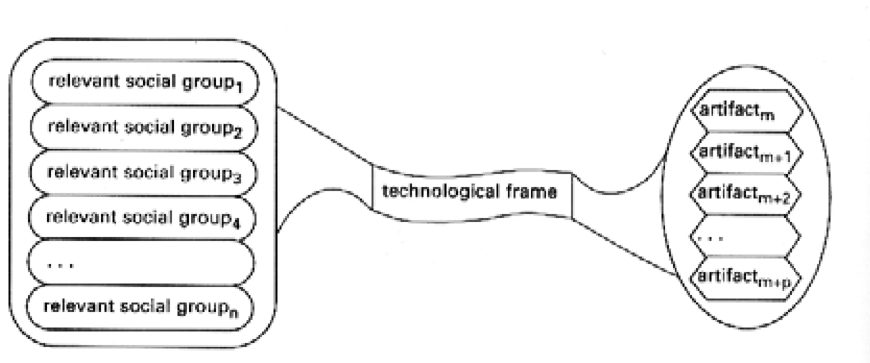

Figure 8: *'The concept of 'technological frame' as a hinge between social-interactionist and semiotic views of technical development.'* From (Bijker, 1995)

Here it becomes clear that the TF is what links the RSGs to the artefact. This hinge between RSGs and artefacts works in two directions: the social-interactionist view regards what the RSGs do to or with the artefact, the semiotic view regards what the artefact signifies for the RSGs. The TF comprises both perspectives. Misleading in this visualisation is that it displays only *one* technological frame but several RSGs and several corresponding socially constructed artefacts. Bijker's explanations as well as his case studies, however, clearly show that *each relevant social group has its own technological frame*. *Sharing one common technological frame actually is a characteristic that constitutes a relevant social group.*

After step one (the sociological deconstruction) and step two (the social construction) have provided a methodological apparatus to get hold of A) the artefact and B) the humans relating to it, what had been missing was an element that allows to capture what links A with B. To provide this element, Bijker introduces the concept TF and describes, what constitutes the TF, like this:

'A technological frame structures the interactions among the actors of a relevant social group. […] A technological frame is built up when interaction 'around' an artifact begins. […]
A technological frame comprises all elements that influence the interactions within relevant social groups and lead to the attribution of meanings to technical artifacts – and thus to constituting technology. […] These elements include: goals, key problems, problem-solving strategies (heuristics), requirements to be met by problem solutions, current theories, tacit knowledge, testing procedures, and design methods and criteria. The analogy with Kuhn's 'paradigm,' […] is obvious […].
Within a technological frame not everything is possible anymore (the structure and tradition aspect), but the remaining possibilities are relatively clear and readily available to all members of the relevant social group […].'(Bijker, 1995)

Though here Bijker mentions the TF concept mainly in connection with *intragroup* relations, his case studies reveal that he also applies it to analyse *intergroup* interactions.

An important notion in connection with dynamic aspects within and between TFs is *'inclusion'*. Single actors (and RSGs as a whole) can have different degrees of inclusion with regard to a specific TF. A high degree of inclusion means that the views, techniques and other elements that constitute the TF are very firmly anchored in the actor or the RSG. Actors with a high inclusion know the technology in question very well and can easily fix it or develop improvements *within* the TF. On the other hand, they are very unlikely to question the technology *profoundly* and to find genuinely new solutions *outside* the TF. In many cases it has been the privilege of actors with a low degree of inclusion in a TF (for example engineers who have just graduated or people with a professional background not directly related to the TF) to develop and introduce technological innovations.[48] A well-known example in the field of architecture is the famous 'Crystal Palace' (a milestone in architectural history and the breakthrough of glass architecture), which was not designed by an architect or an engineer but by the gardener Joseph Paxton (1801-1865), who could draw upon his experiences with green houses.

Most actors are involved in a single TF, but some participate in more than one TF, often having a boundary position between two relevant social groups.

Prolonging the symmetry principle and the idea of the seamless web SCOT aims to outlaw both technical reductionism (in which society is explained as an outgrowth of technical development) and social reductionism (in which the technical is explained as a by-product of the social. To overcome this dichotomy Bijker introduces the notion *'sociotechnical ensemble'*.

'Instead of technical artifacts, our unit of analysis is now the 'sociotechnical ensemble.' Each time 'machine' or 'artifact' is written as shorthand for 'sociotechnical ensemble,' we should, in principle, be able to sketch the (socially) constructed character of that machine. Each time 'social institution' is written as shorthand for 'sociotechnical ensemble', we should be able to spell out the technical relations that go into stabilizing that institution.' (Bijker, 1995)

Configuration models

Basing on the concept described above, Bijker distinguishes different general alternative *configurations* of technological frames in the description of socio-technological ensembles, each configuration inducing typical stabilisation and closure mechanisms:

[48] The parallel to Kuhn's concept of 'normal science' and 'revolutionary phases' is obvious.

– No clearly dominant TF guides the interaction.
  Characteristics:
  several different inventions exist in parallel,
  radical TFs,
  unlimited number of problem-solving approaches,
  stabilisation typically through RSG attempts to enrol other RSGs to support their TF
  One way of enrolling other RSGs is by *redefining problems* according to the newly enrolled RSG's expectations.

– One dominant TF guides the interactions.
  Characteristics:
  most common configuration,
  resembling a kind of 'normal sociotechnology' parallel to Kuhn's 'normal science'

– *More than one TF guide the interactions.*
  Characteristics:
  controversial and hectic closure process,
  Rhetoric frequently constitutes the closure mechanism[49]

SCOT and power

'Power' is not a central concept in the SCOT theory, even though Bijker acknowledges that technological artefacts often develop in the midst of power games. However, he dismisses the necessity of integrating a general theory of power into SCOT and states

> *'I would indeed rather argue for abstaining from its usage completely. At best the term 'power' can be a practical shorthand for more detailed and rich descriptions of situations, outcomes, relations etc. […], [a shorthand] indicating some important questions that can be raised in relation to the social shaping of technology and the technical shaping of society.' (Bijker, 1995)*

Taking Gidden's definition of power as

> *'the transformative capacity to harness the agency of others to comply with one's ends.' (Giddens, 1979)*

as his starting point Bijker sees power primarily as a relational, interactionist concept. He distinguishes between 'semiotic power' and 'micropolitics of power':

> *'[Semiotic power] is the apparent order of taken-for-granted categories of existence, as they are fixed and represented in technological frames. This semiotic power forms the structural side of [Bijker's] power coin.*
> *'The micropolitics of power describes the other side - how a variety of practices transforms and structures the actions of actors, thereby constituting a particular form of power. In Foucault's (1975) study of the development of discipline, this micropolitics of power results in producing obedient human bodies; in my framework the focus will be on producing technological frames.' (Bijker, 1995)*

[49]Luxenburger's and Asmussen (Luxenburger et al., 2001) point out that in this configuration closure can also be obtained by an *intentionally tailored interpretative flexibility*. Their SCOT analysis by of the newly build bicycle lane at Gammel Kongevej, one of Copenhagen's major streets, is provides a good example of this phenomenon: '*The raised edge [of the pave stones used as demarcation, author's note] between cycle and traffic lanes illustrates the third kind of closure, which does not unify the interpretations of the actors: by introducing a raised edge, cycle lanes could be interpreted as both lanes **and** paths.' (Luxenburger et al., 2001)*

Critique of SCOT

Critical comments on SCOT partly address social constructivist approaches in general as well as specific features of Bijker's theory.

A prominent point raised against social constructivism is that it lacks reflexive attention: As Woolgar (Woolgar, 1991) points out, social constructivist studies of knowledge or of technological artefacts imply that accounts quite different from the selected (dominant present) ones are possible and that these 'it-could-be-otherwise' accounts are alternative accounts of the 'same' reality. The 'difference' in accounts is 'explained' by juxtaposing a description of antecedent circumstances (such as social and cognitive interests or activities of certain key social groups) to underline that the selected accounts are the result of the specific configuration of these circumstances. If the circumstances were others, social constructivism suggests, the accounts would also be different.

> *'Notably, the sociologist's own account of these antecedent circumstances is not – in the course of explanation – subjected to […][a social constructivist analysis]; attention is not drawn to the fact that it is possible in principle to supplant the sociologist's own 'explanatory' account with another. […]'*

While he sends the objects of his studies sliding down the social-constructivist-epistemology slope into constructivist relativism the social constructivist researcher himself stands aside – standing firmly in his unaccounted-for-realism-spike shoes, so to speak.

> *'We thus see that the programmatic relativism gives way to realism in practice.' (Woolgar, 1991),*

Woolgar makes his point.

Two main points of critique specifically addressing SCOT are

– that the theory is ignorant with regard to power and related structural influences at the macro-level (Fuglsang, 1994), (Klein et al., 2002), et al.) and
– that its identification of relevant social groups is prone to incompleteness.

With regard to the first point Klein and Kleinman point out that

> *'Throughout Bijker's text ['Of Bicycles, Bakelites, and Bulbs – towards a Theory of Sociotechnical Change' (Bijker, 1995)], power is either ignored or deployed in an ad hoc fashion. […] Towards the end of his book, Bijker does introduce a casting of power linked to his notion of technological frame. Ultimately, however, this conceptualization comes too late and is overly vague.*
> *[Instead], Bijker's diagram of the relationship between social groups and an artifact [Figure 4] suggests groups are equally situated in terms of their capacity to shape artifacts.' (Klein et al., 2002)*

In most cases, power is likely to be unequally distributed among the different groups. And also *within* a relevant social group an elite's opinion can come to dominate the whole group.

If unequal distribution of power among or within the relevant social groups can have a decisive effect on the closure of an artefact's social construction, then an analysis of power should be included in the explanatory scheme, Klein and Kleinman state. Also the fact that

> *'In SCOT attention is mainly devoted to the relations between the actor groups that define technology at the micro-level rather than the functional and institutional aspects of technology or structural influences.' (Fuglsang, 1994)*

has been criticised for suggesting a wrong picture of the relevant social groups' actual space of manoeuvre.

Concerning the identification of relevant social groups in SCOT the methods 'roll a snowball' and 'follow the actors'[50] advocated by Bijker (according to which the researcher asks the actors to identify the other relevant social groups) contain the problem that some relevant social groups may be excluded from participation and their (significant) absence may go unnoticed.

> *'Simply because a multitude of individuals share a set of meanings does not ensure that they will organise themselves into a group to participate in a design process. This absence might have a great influence on the final artifact.' (Klein et al., 2002)*

Reasons for the application of SCOT in this study

According to the definition of 'technology' employed by Bijker, technology comprises the three layers

1 physical objects (for example bicycles)
2 activities and processes (for example steel making or moulding)
3 what people know and what they do (for example know-how used in designing bicycles or in operating medical equipment) (Bijker et al., 1987).[51]

As knowledge on environmentally sound building, operationalised in a form especially suitable for the support of environmentally relevant decisions, environmental indicators for buildings are a technological artefact of layer 3[52] and as such within the scope of SCOT.

I employed the SCOT-theory as the theoretical background for this study for the following scientific, pragmatic and personal reasons:

The proximity of this study (on the creation of environmental indicators for buildings as 'a common language for green building' in an actor- and consensus oriented process) to social constructivist theories is obvious.

SCOT has been developed for the investigation of comparatively well defined, concrete artefacts rather that of phenomena on a big scale. Thus SCOT is well suited to a project on a set of concise indictors for the support of specific decision-making situations in a specific sector.

SCOT provides a well-described apparatus for the collection and analysis of data in an empirical research approach. It supplies a nomenclature for phenomena and elements relevant to this study[53].

The application of SCOT has proven useful in previous research projects, among them some that are closely related to the field of this study ((Haugbølle Hansen, 97 A.D.), (Luxenburger et al., 2001)) and to the institutes this investigation was attached to. This brought about the a valuable resource of easily accessible advice and know-how.

Last, but not least, the pluralist perspective embodied in SCOT and from the beginning also in the outline of this project appealed to my personal commitment to non-violence and my interest in languages and communication. SCOT and theories of non-violent conflict resolution (for example (Rosenberg, 1999), (Wohland, 1997)) have several elements in common: Both acknowledge that different relevant views on an object of dispute are held by different actors in parallel. Both strive to make these views and the needs and motivations behind these views explicit to the analyst and to the

[50] For a detailed description see the section 'The three steps of a SCOT analysis'

[51] See the full definition cited from (Bijker et al., 1987) in the beginning of the above section 'Technology in the sense of SCOT'.

[52] *'In practice […] technologies [often] cover all three aspects, and often it is not sensible to separate them further. Also, instead of trying to distinguish technology from science (or indeed from any other activity) in general terms, it seems preferable to work from a set of empirical cases that seem intuitively paradigmatic.' (Bijker et al., 1987)*

[53] The application of the /SCOT-nomenclature to my project is described in detail in one of the following paragraphs.

actors. And both hold the tenet that durable closure is obtained by negotiation and reshaping the solution rather than by using power.

The application of SCOT to this study on EIFOB is described in the following section.

EIFOB as a socially constructed artefact according to SCOT

The application of SCOT and its concepts permit to interpret and to structure the elements of this study as follows:

The socially constructed artefact in this case are the sought-after 'EIFOB as a common language for green building'.

SCOT's demand to make the *sociotechnical ensemble the unit of analysis* corresponds to the study's scope comprising both an investigation of the artefact 'environmental indicators' (that is, already existing ones as well as the ones that are to be developed) *and* of the *social* environment in which the indicators are to be used.

SCOT's central tenet, that

> *'the 'working' of an artifact [is to be taken] as explanandum, rather than explanans; the useful functioning of a machine is the result of sociotechnical development, not its cause.' (Bijker, 1995)*

corresponds to the study's presupposition that EIFOB that are broadly accepted and used in practice need to be developed according to the users' needs and in a close dialogue with the different user groups.

The *relevant social groups* are the groups of the actors in the scope of this study, which share a view of EIFOB. Though an actor-scope of this study had been pre-defined from the very beginning, SCOT's 'follow the actors' concept in the course of the investigation led to the decision to also include private, non-professional actors (users of buildings).

The *technological frames* are the different views of EIFOB held by the different actor groups, comprising the actors' different goals, knowledge, perceived problems and favoured solution approaches. They illustrate the *interpretative flexibility* of the artefact 'EIFOB'.

The already existing indicator systems thus are seen as the different solution approaches, which form part of the distinct technological frames. Mapping the different actor groups' views of EIFOB corresponds to the *sociological deconstruction* of the artefact.

A characteristic feature of this study is its *reflexivity on the level of the definition of relevant social groups and technological frames*[54]: The study was carried out and supervised by actors that adhere to one specific technological frame (the scientific frame[55]), a frame which at the same time was an object of study. On the one hand, this gave easy access to information about this technological frame; on the other hand this required additional attention in order to refrain from implicit judgements out of the scientific frame's perspective. Nevertheless, making this potential pitfall explicit proved helpful.

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[54] This meets Woolgar's critique of lacking reflexivity in social constructivist studies (Woolgar, 1991) only partly, as he request a reflexivity at the analysis level (the definition of research scopes, relevant social groups, technological frames, …) while I am reflexive *within* my analyst categories and my definitions of relevant social groups and technological frames.
My response to Woolgar's critique is twofold:
As a pragmatic response I have to admit that it my reflective capacities in this study were exhausted with the handling of one level of reflexivity. A research and development project on how to improve the quality of social constructivist technology studies by systematically maintaining reflexivity would certainly be an honourable undertaking but would exceed the frame of this research project.
As an epistemological response the argument Woolgar employs against social constructivism can as well be turned against his critique: If a reflexive evaluation of a social constructivist study was written – how about the reflexivity of the reflexive evaluation? How many levels of reflexivity make 'good research' and how shall this be judged?

[55] For a detailed description see the chapter 'Indicators in a social constructivist perspective'.

After step 1 of the SCOT analysis, the social deconstruction (see Table 2), the application of SCOT to this study deviates in an important respect from other applications:

Prospective use of SCOT

In contrast to other SCOT-studies, which analyse the social construction of an already existing artefact in retrospect (as does Bijker in his case studies 'of bicycles, bakelites and bulbs' (Bijker*,* 1995), this study uses SCOT *in a prospective way*: it takes its point of departure in the 'childhood' of the artefact 'EIFOB as a common language for green building', studying the chances to foster its development towards an 'adult stage', that is a closure (and ultimately an established employment in decision making)[56].

Thus the *social construction* of the artefact 'EIFOB' could not be mapped on the basis of already existing data in the same way as the relevant social groups and the technological frames. This problem was tackled in three ways:

- A *social laboratory*[57] with representatives of the different relevant social groups was established, in which the debates that are likely to take place in a real arena were anticipated and documented.
- Tendencies and developments that could be traced hitherto were carefully taken as indices for possible future developments.
- Comparisons with the situation in the Netherlands served as additional indices for potential scenarios.

Obviously the uncertainties inherent in a prospective study do not permit to declare its results as '*closure'* on equal terms with 'closure' in retrospective studies. This study therefore concludes with three *scenarios*, in which, based on the findings from the sociological deconstruction of EIFOB, different probable solutions are exemplified and discussed.

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[56] This prospective use of SCOT also justifies to operate with an actor-scope defined beforehand instead of identifying the relevant actors according to SCOT's 'roll a snowball' and 'follow the actors', as the artefact EIFOB *by definition* is to be socially constructed and used by specific actors.

[57] For a detailed description see the section 'Methods'.

Table 3: Correspondence of characteristic features of the study with the concepts of SCOT

characteristic features of this study	corresponding concepts of SCOT
EIFOB as an object of dispute among the different actor groups	the socially constructed artefact
the study's scope, comprising both the environmental scientific and the social-scientific sphere	the sociotechnical ensemble as the unit of analysis
the study's presupposition: EIFOB that are broadly accepted and used in practice need to be developed according to the users' needs and in a close dialogue with the different user groups.	SCOT's central idea: '*The conceptual framework should take the 'working' of an artifact as explanandum, rather than explanans; the useful functioning of a machine is the result of socio-technical development, not its cause.' (Bijker, 1995)*
the different actor- and user groups with different views of EIFOB	the relevant social groups
the different views of EIFOB, comprising different goals, knowledge, perceived problems, favoured solution approaches, …	different technological frames
the different existing indicator systems	different solution approaches as part of different technological frames
the different understandings of what EIFOB are / should be	interpretative flexibility
the analysis of the different actor groups' views of EIFOB	the sociological deconstruction of the artefact
The prospective part of the study: The efforts to get closer towards a consensus about EIFOB (in the social laboratory)	the social construction of the artefact
consensus on certain indicators or a whole set of indicators, described in three scenarios	(partial) closure

How the elements mentioned above are woven together to form the texture of the study is described in the following section.

Research tasks and methods

It is characteristic of this study that it enters into two spheres of scientific reasoning: the environmental scientific sphere and the social scientific sphere. Of course in the analysis of the relevant social groups SCOT's *symmetry principle* is applied. A study on *environmental* indicators for buildings, however, has to also elucidate the *environmental* side of the coin. In this study this is done *from the environmental scientific perspective*, well aware of the fact that in the social constructivist approach this perspective is only *one* specific perspective held by a specific relevant social groups among other perspectives held by other groups. The reason for doing so is simply that the environmental scientific perspective could be predicted to offer most knowledge about 'the environment' and this in a structured way. Thus it could serve as a point of reference for the environmental foci of the other relevant social groups, whose view at 'the environment' could be anticipated to be less elaborated in terms of detailed, structured and documented environmental knowledge.[58]

[58] In his case studies Bijker (Bijker, 1995) also uses the knowledge from his engineering education and from scientific literature for his detailed descriptions of technical developments of the studied artefacts (e.g. constructional innovations in bicycle building).

The following figure gives an overview of the project's research design, research tasks and the methods to complete these tasks, which are explained more closely in the following text.

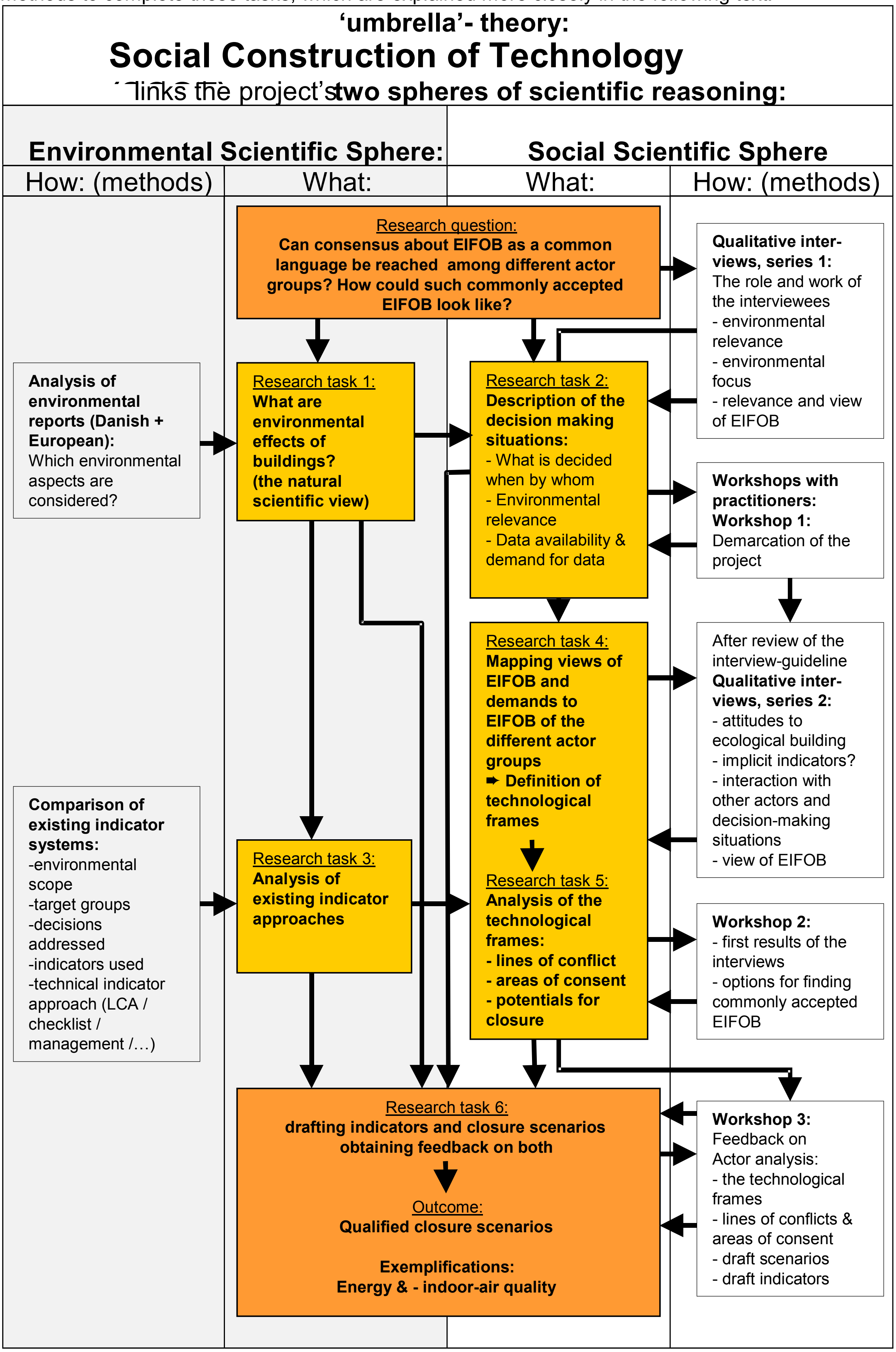

Figure 9: The project's research design.
The dark grey boxes in the centre contain the research tasks and their outcome. The boxes at the right and at the left contain the methods, how these tasks are addressed and how the relevant information is obtained. The arrows signify *'provides input to'*.

To answer the research question the following research tasks were addressed in the following order:

Research task 1 was to describe the environmental effects of buildings from the environmental scientific point of view.
The purpose was

- to elucidate the environmental significance of the subject and
- to establish a point of reference for the environmental foci of the different actor groups.

The method used was a literature survey (environmental reports and other publications).

Research task 2 was to describe the decision-making situations in the scope of the study (siting, project design and renovation) with regard to the questions

- What is decided by whom?
- What is the environmental relevance of this?
- Which data is necessary and which data is available?

The purpose of this task was to elucidate the envisaged use-context of EIFOB and to provide a basic structure for the other research tasks by establishing a consistent nomenclature for *where* in a building's life cycle we are, which is a prerequisite for a transparent discourse about EIFOB.
This was obtained by carrying out the first series of interviews[59], by analysing these and by using the input from the first actor workshop and from research task 1.

The first series of interviews with representatives of the different actor groups aimed at obtaining a general knowledge of the research subject and addressed

- the role and work of the interviewee,
- the environmental relevance and environmental focus of his or her work and
- the interviewees view of EIFOB.[60]

The input from the first series of interviews and the first actor workshop permitted the sharpening of the focus of the study's further research tasks:
With regard to the study's demarcations it was decided to exclude the construction phase with its distinct environmental implications (such as vibrations, noise caused by machinery, effects on working environment) as a decision-making situation from the study's scope and to concentrate on the decision-making situations siting, project design and renovation.

The experiences from the first interviews and the first workshop also permitted to be more precise and concrete in the second series of interviews and the following workshops.[61]

Research task 3 was to analyse existing indicator approaches.
The purpose of this analysis was to provide the knowledge base for

- the understanding of the different indicator approaches,
- the understanding of EIFOB-related conflicts between actors in the different technological frames and
- the development of closure scenarios and their excemplifications.

This was achieved by comparing existing indicator systems with regard to

59 A detailed description of this method is given further below.
60 The interview guideline of the first series of interviews is in the appendix.
61 For details see the section on the qualitative interviews and the workshops further below.

– environmental scope
– target groups
– decision-making situation addressed
– indicators used and
– indicator principle employed (LCA, checklists, input-output indicators,…).

Research task 4 was to map the different actor groups' views of EIFOB and demands to EIFOB. This was one of the study's key elements and had the purpose of

– identifying and defining the technological frames[62]
– preparing the ground for research task 5

This was done by analysing the interviews from the first and the second series of interviews as well as the results of the second actor workshop[63].

The second series of interviews focused on

– attitudes to ecological building
– the possible use of implicit indicators[64]
– interactions with other actors and between different decision-making situations
– the views of concrete indicator examples.[65]

In the second actor workshop, the first results from the interview analysis were presented to receive feedback from the actors. Furthermore the participants sketched and discussed closure options and possible indicators.[66]

Research task 5 was to analyse the technological frames with regard to areas of consensus and lines of conflict.
The purpose of this was

– to map the social environment in which EIFOB as a common language would have to exist and
– to evaluate the potential for closure.

While in research task 4 the positions of the different actor groups with regard to EIFOB were mapped, here the different actor groups' positions with regard to each other were described.
This was done by comparing the actors' demands to EIFOB and by obtaining feedback on the analysis in the third actor workshops.

In the first part of the third actor workshop[67] the results of research tasks 4 and 5 were presented and discussed to obtain feedback and input for research task 6.

Research task 6 was to draft indicators and closure scenarios and to obtain feedback on these.
The purpose of this was

– to return to the initial research question and
– to provoke concise statements from the actors.

The draft scenarios and draft indicators were therefore presented in the third workshop and the participants' feedback was documented.

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[62] The notion 'technological frame' is explained in the previous chapter on the social construction of technology.
[63] A detailed description of this method is given further below. The workshop programme is in the appendix.
[64] That is definitions of 'an ecological building' that do not have the form of quantitative indicators (for a more detailed explanation see the chapter 'Indicator systems').
[65] The interview guideline of the second series of interviews is in the appendix.
[66] The workshop programme is in the appendix.
[67] The workshop programme is in the appendix.

Based on the feedback obtained in the third workshop, the closure scenarios, draft indicator (exemplified with the environmental issues 'energy' and 'indoor air quality') and the conclusions were then elaborated as the final outcome of the study to answer the initial research question.

Among the methods employed to solve the research tasks, two deserve a closer description (see the following sections): The qualitative interviews and the workshops as the 'social laboratory'.

Qualitative research interviews

The analyses of *quantitative* research can principally only yield knowledge about phenomena that were already part of the model of reality, which formed the basis of the research (Flick, 1998).
In *qualitative* research, on the other hand,

> *'Research objects are not divided into different variables but are studied in their complexity and entirety in their everyday context. Accordingly the field of study [of qualitative research] is not the artificial situation in the laboratory, but the acting and interacting of the subjects in everyday life.' (Flick, 1998) [author's translation]*

This study of the social construction of EIFOB as a common language for green building had to employ *qualitative* research methods to solve the research tasks in the social scientific sphere.

Qualitative research interviews (and among them the semistructured life world interviews carried out in this study) are an established method of qualitative research

> *'to obtain descriptions of the lived world of the interviewees with respect to interpretations of the meaning of the described phenomena.' (Kvale, 1996)*

They are characterised by the following points:

> *'**Life world**: the topic of qualitative interviews is the everyday lived world of the interviewee and his or her relation to it.*
>
> ***Meaning**: The interview seeks to interpret the meaning of central themes in the life world of the subject. The interviewer registers and interprets the meaning of what is said as well as how it is said.*
>
> ***Qualitative**: the interview seeks qualitative knowledge expressed in normal language, it does not aim at quantification.*
>
> ***Descriptive**: The interview attempts to obtain open nuanced descriptions of different aspects of the subjects' life worlds.*
>
> ***Specificity**: Descriptions of specific situations and action sequences are elicited, not general opinions.*
>
> ***Deliberate Naïveté**: The interviewer exhibits an openness to new and unexpected phenomena, rather than having ready-made categories and schemes of interpretation.*
>
> ***Focused**: The interview is focused on particular themes; it is neither strictly structured with standardised questions, nor entirely "non-directive".*
>
> ***Ambiguity**: Interviewee statements can sometimes be ambiguous, reflecting contradictions in the world the subject lives in.*
>
> ***Change**: The process of being interviewed may produce new insights and awareness, and the subject may in the course of the interview come to change his or her descriptions and meanings about a theme.*

***Sensitivity**: Different interviewers can produce different statements on the same themes, depending on their sensitivity to and knowledge of the interview topic.*

***Interpersonal Situation**: The knowledge obtained is produced through the interpersonal interaction in the interview.*

***Positive Experience**: A well carried out research interview can be a rare and enriching experience for the interviewee, who may obtain new insights into his or her life situation.' (Kvale, 1996)*

According to (Kvale, 1996) a qualitative interview investigation comprises seven stages: Thematizing, designing, interviewing, transcribing, analysing, verification and finally reporting.

Thematizing

Here the *why* and *what* of the interview are clarified. In this study the principal purpose of the interviews as a means to map the different actor groups' view of EIFOB (research task 4) and (to a minor extent) to investigate the decision-making situations (research task 2) had already been identified as research task in previous projects. In accordance with this principal purpose the first series of interviews was carried out in the start phase of the investigation to obtain a general picture of the 'actor landscape' and of the present state of EIFOB, that is, to find out, which role EIFOB play in the actors' daily work and to what extent the concept of EIFOB was familiar to them. The purpose of the second series of interviews, which took place in the middle of the project's duration of three years, was to complete the general picture obtained in the first series of interviews with details on the new points of interest that had emerged so far. These were

– attitudes to ecological building,
– the possible use of implicit indicators[68],
– interactions with other actors and between different decision-making situations and
– the views of concrete indicator examples.

Furthermore, interviewees of the second series were chosen in such a way as to 'reinforce' the empirical basis of the study: representatives from housing co-operatives were included to elucidate the points mentioned by the representative from the national umbrella organisation of housing co-operatives and an interview with a layperson private resident-client was carried out to obtain first-hand information on this actor-group's perspective.

Designing

The interviews were conducted with the help of interview guidelines, containing the subjects and questions that should be addressed. It was, however, a characteristic of the interviews that the guideline questions were generally rather open and that the interviewees were given ample space to direct the attention towards aspects of concern to them.
The interview guideline of the first series of interviews addressed the following questions:

About the interviewee:

– information about the interviewee and her/his institution: educational background, professional experience, function

[68] That is definitions of 'an ecological building' that do not have the form of quantitative indicators (for a more detailed explanation see the chapter 'Indicator systems').

About the interviewee's contact with environmental issues

- in which context the interviewee deals with environmental aspects of buildings
- which environmental aspects s/he considers

About the interviewees use of indicators:

- in which situations s/he would could use quantifications of buildings' environmental aspects
- in which life-cycle phase s/he makes environmentally relevant decisions
- barriers for consideration of environmental aspects
- the interviewees use of existing indicator systems and experiences with this
- barriers for the use of EIFOB

About the interviewee's role in the social construction of EIFOB

- involvement in relevant panels or workgroups
- desired status of EIFOB (legal demands, voluntary commitment,…)
- on the history of EIFOB (key events, key documents, key actors in the past years and at present)
- expectations and perceived need for future development

About further co-operation in the course of the study

- the interviewees willingness to participate in the workshops/social laboratory
- could he/she point out further relevant material, web sides or events?

The interview guideline of the second series of interviews addressed the following additional questions:

About the interviewee's motivations

- the interviewee's motivation to consider environmental effects of buildings
- conflicts and consistencies between private and professional attitudes.
- possible use of implicit indicators
- developments in the interviewee's view of 'green building'

About communication and co-operation with other actors and decision-making situations

- perception of other actors (Who thinks differently? Who pushes? Who objects? Why do they do so?)
- Experiences with the communication of environmental demands across decision-making situations

About EIFOB

- How does the interviewee today make environmental choices?
- How detailed should the environmental information be?
- How should indicators be expressed / visualised?
- What are other demands to EIFOB?
- How would the different actors relate to the implementation of a set of EIFOB?

In the sometimes very specific expert interviews with developers of environmental indicators the interview guideline was adapted freely. Irrelevant guideline questions were left out, while other questions were added.

The body of interviewees was chosen according to the following considerations:

– The interviewees should explicitly deal with environmental aspects of building in their professional roles[69]
– The body of interviewees should include representatives of all the actor groups that were in the scope of the study.
– It should cover all three decision-making situations
– It should include actors that take decisions at different levels (concerning the design of local plans and settlements as well as the design of single buildings, but also actors dealing with the building-related environmental policy of entire enterprises).
– The body of interviewees should cover actors dealing with office-buildings as well as with buildings for housing and day-care institutions.
– There should be an overlap between the fields of work of the individual interviewees in order to have at least two interviews from each actor role, revealing potential intra-group conflicts or confirming shared views.

The experiences from previous research projects carried out at the Danish Building and Urban Research Institute and at the Section for Sustainable Urban Management of the Technical University of Denmark permitted the easy identification and approaching of interview partners that matched these criteria.

As the first series of interviews was carried out to get acquainted with the research object and to prepare the ground for a refinement of the further investigation the interviews of the first series also covered some actors at the periphery of the field of study.

The interviewees are listed in the following tables:

[69] The only exception was the president of the resident organisation an ecological settlement, who was a layperson and worked voluntarily. See also the section 'Demarcations of the study' in the chapter 'Introduction'.

Table 4: The interviewees from the first series of interviews:

interviewee & institution	educational background and field of work	decision-making situations & life cycle phases addressed
a researcher at the Danish Forest and Landscape Research Institute	civil engineer (planning), PhD on local plans development of urban environment indicators	designing the local plan siting
An engineer of a Danish consulting engineering company	civil engineer (chemistry) development of EIFOB	all, but especially the use phase
The president of the environmental committee of the Danish Association of Clients (also environmental director of Post Denmark)	civil engineer (mathematical operational analyses work experience: strategy development, implementation of environmental management system	all environmental aspects of the enterprise, all life cycle phase, but mainly the use phase & renovation
an officer in the Danish Energy Authority	civil engineer & master of public administration, energy consumption of buildings (households and public buildings) & energy saving policy	project design, use phase, renovation
a research consultant of a non-profit urban renewal consultency	architect; development of a management 'toolbox' for environmentally sound renovation	renovation
the head of the section 'innovation and technological management' of an international construction company	constructional engineer; environmental management; implementation of an environmental management system in the company	project design construction phase
the head of the department for planning and environment of a Danish town	civil engineer; all tasks related to building and environment	siting, design of municipality plan and local plan, project design, construction phase, use, renovation
an officer at the department for school-buildings and day-care institutions of a big Danish city	civil engineer (production planning and project management); economical management, environmental guidelines, working environment	siting, project design, renovation
an officer of the department for environmental planning and surveillance of a big Danish city and the surrounding county	architect, additional course in 'environmental design'; environmental impact assessment of building and construction projects, transport, soil contamination , local plans	siting, designing of local plans
the officer for 'environment and technology' of the National Association of Co-operative Housing Societies'	building constructor[70]; consulting for courses for resident-representatives and employees, development of 'green diploma' for co-operative housing societies, member of 'centre for legal metrology[71]	mainly renovation and facility management
a researcher at a Danish building research institute's department for urban research	geodesist, PhD in urban planning, doctorate in philosophy; development of' Green Accounting for Residential Areas', research on consumptions in the use phase of buildings	renovation, facility management
a researcher at a Danish building research institute's department for energy and indoor climate	civil engineer, PhD on life cycle assessment (LCA) of buildings;development of LCA-tools, research on environmental profiles of buildings and building materials	all life cycle phases, however, mainly project design
a researcher at a Danish building research institute's department for energy and indoor climate	civil engineer (construction); research on environmental indicators for buildings	All life cycle phases
a self-employed architectural consultant	architect; consulting on environmental management in project design, development of EIFOB, research projects	project design, renovation

[70] A technical education below university level.
[71] 'Metrology' is the scientific study of measurement. The centre deals among other things with the measurement of energy and water-consumptions in use phase of a building.

In the second series of interviews the following persons were interviewed:

Table 5: The interviewees from the second series of interviews:

interviewee & institution	educational background and field of work	decision-making situations & life cycle phases addressed
group interview with officers of a Danish co-operative housing society: 1. the architect in-chief 2. a project designer 3. the energy officer	1. architect; 2. architect, 3. civil engineer; maintenance and building of the co-operative housing society's building stock	mainly renovation, but also project design, siting and facility management
the director of a Danish co-operative housing society	graduated in political science; general management of the co-operative housing society	all, but from an economical perspective without knowledge of technical details
double-interview: 1. the project leader for infrastructure development of a developer firm funded by a big Danish city 2. a self-employed consultant (to the developer firm)	1. civil engineer 2. architect; 1. infrastructure planning for a new urban district 2. ecological renovations, public-relations work for ecological building	design of local plans, siting, pre-projects, project design, renovation
double-interview : 1. the head of a co-operative housing society's development department 2. the head of the society's construction department	1. building constructor (a non-university technical education) 2. building constructor; 1. providing environmental information to residents 1. & 2. formulate environmental demands to external consultants	(siting), project design, facility management, renovation
the president of the residents' association of an ecological settlement	administrative education (layperson in the building sector); decision-making within the resident organisation and with the municipality	initiating the settlement project, design of the local plan, siting, project design
an architect at a medium-size architectural office	architect; project design, renovation	project design, renovation
the environmental manager of a big international construction company	environmental planning; implementation of environmental management system (internally and externally)	project design, facility management
double interview: 1. the head of the planning department of 2. the environmental officer	1. draughtsman, administrative education, urban planner; 2. mechanical engineer, master of environmental management 1. urban planning 2.. environmental administration: green accounting for housing districts,	design of municipality plan and of local plan, siting, project design, facility management
the environmental manager of a big Danish engineering consultancy,	chemical engineer, management courses; editor of the 'handbook for environmental management in project design', environmental aspects of building materials	project design, facility management, building materials in a life cycle perspective
the head of the group for environmental management in project design, of a big Danish engineering consultancy	architect (physical planning of working environment); environmental management in project design	project design
an engineer of the building-department of a Danish town	civil engineer; carrying out building projects for the municipality	project design, facility management, (sometimes also urban planning)
a researcher at a Dutch environmental research institute	architect & urban planner; development of EIFOB, LCA-tools and sustainability indicators for buildings and districts	all life cycle phases
a researcher at a Dutch technical university	geology, environmental studies; life cycle assessments of the built environment, environmental decision-making in urban planning (development of a computer-tool for sustainable urban planning)	urban planning, siting

Apart from the persons listed above a number of short-interviews was carried out (and recorded) with the participants of a course on ‘environmental management in project design’ held by the Federation of Danish Architects as a supplementary training mainly for architects.

Furthermore several interviews with researchers working in the field of this study in Denmark and in the Netherlands were carried out, which strictly seen were not semi-structured qualitative interviews as described above, but usually addressed specific questions related to the interviewees’ research. These conversations were documented by taking notes during the conversation and through the scientific papers provided by the interviewed researchers.

Interviewing

The interviews in Denmark were carried out in Danish, the ones in the Netherlands in English. All interviews were recorded with the permission of the interviewees. Before each interview the interviewees’ demands to confidentiality, anonymity and approval of citations were clarified and agreed upon. An interview lasted usually between 1 hour and 1.5 hours. The group interviews occurred when some interviewees, after having received the interview-request, decided that they wanted to be interviewed together with specific colleagues, whom they considered relevant for the subject, as well.

Transcribing and analysing

Of the 27 interviews 10 (from the first series) were transcribed in full length by the author of this study. Of the other interviews ‘fresh impressions’ notes were taken immediately after the interview and more detailed notes when the interview recordings were listened to. Important passages were transcribed in full and the citations used in this report were translated into English by the author.

For the interview analysis an analysis-scheme[72] was used, which comprised the following categories relevant for the identification of the technological frames and the answering of the research questions:

Table 6: categories for the identification of the technological frames and the answering of the research questions

Categories	**Sub-themes**
General characteristics:	Institution, function of interviewee
Power structure	Sources of power, dependencies
Decision making situations	Environmental aspects considered relevant by the actors
The technological frame	General mindset & current developments Values / attitudes Key problems / conflicts Prevailing problem-solving strategies Available environmental expertise Currently used tools & methods for decision making Implications for the interaction with other relevant social groups Implications for the design of EIFOB Implicit indicators
Demands to EIFOB	Environmental aspects considered relevant Motivations for the demands Preferred type of indicator & mode of display
On the actors’ relation to other actors	Statements about clients, building authorities, engineering consultants, architects, administrators, users, researchers

[72] The analysis-scheme is in the appendix.

The interviews were then reread or reheard and interview statements were assorted to the categories.

Then the analysis schemes were read synoptically in order to trace general patterns.

Verification

The interview statements and the analysis of the interviews as a whole were verified in different ways:

Already during the interviews, statements that were unexpected or unclear were verified by 'mirroring', that is by condensing and interpreting the statements and then requesting the interview subject to confirm or to correct. The analysis of the interviews as a whole the was verified by triangulation[73], that is by relating statements on the same issue from different interviewees to one another, and by obtaining feedback on the analysis in the actor-workshops.

Actor workshops as the 'social laboratory'

Three actor-workshops were held in the course of the study. They had two main functions:

- To provide feedback on the SCOT-analysis and on the draft indicators (and thus serve as a verification instance) and
- to serve as a 'social laboratory'.

In the social sciences a 'social laboratory' means a social body of specific composition in a specific setting, in which social processes can be observed (as in a laboratory) that permit the drawing of conclusions for other social bodies.[74]

In this study the workshops with representatives of the different relevant social groups constituted the social laboratory, in which the debates around EIFOB that are likely to take place in a real arena were anticipated and documented.

To have a cross-section of the study's actor scope and at the same time establish a group that would become familiar with the subject throughout the project in general all interviewees were invited to the workshops.[75] In average the workshops had about 10 participants each (not including the facilitator and the two rapporteurs), which represented a broad range of actors and roles. Each workshop lasted four hours. To make efficient use of this relatively short time[76] and to focus the work, preparatory materials were distributed beforehand and the workshops were planned and facilitated by the author according to the 'Metaplan' method[77]. This method for the facilitation of group work uses among other techniques the change between plenary sessions and work in parallel in small sub-groups, the collection of the participants' contributions on paper cards and the constant visualisation of the debate on posters. Together with protocols written by rapporteurs in each subgroup these paper-cards and posters served as the workshop documentation.

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[73] 'To triangulate': measure and map (an area) by the use of triangles with a known base length and base angles. In a transferred meaning, this method used in land surveying, is here used in *mapping* the social landscape of EIFOB.

[74] Social laboratories can, for example, be isolated, comparatively homogeneous and stable societies in which impacts can be observed more easily due to the absence of continuous dynamic societal changes. An example could be the impact, the left behind wooden packaging of Roald Amundsen's north-west passage expedition had on the Inuit population of northern Canada, for whom the wooden boxes constituted a strong sudden increase of a scarce resource.

[75] In practice, however, some 'deviations' occurred as some interviewees sent a colleague to substitute them, while others participated without having been interviewed, because they were involved in closely related projects.

[76] As all participants joined the workshops during their usual working hours without reimbursement a longer duration was not considered feasible.

[77] Described e.g. in (Lipp et al., 2002) or at www.metaplan.de

The workshops were held in Danish, introductory presentations and lectures about the SCOT-analysis and the draft indicators were held in Danish and in English.

To maintain the contact with the interviewees and the members of the social laboratory throughout the project, protocols and state-of-the-project reports (for example with a summary on the research carried out in the Netherlands)[78] were send by e-mail to all interviewees in the periods between the workshops.

Reflections on the methods

The chosen methods proofed appropriate to the solution of the research tasks and yielded useful results, as the respective chapters of this study document. Especially the combination of qualitative research interviews with workshops gave the study a more solid empirical base than the choice of just one of the methods would have done and provided valuable material for the study's prospective part.

With the experiences from this study in retrospect some reflective comments can be made on the interviews and on the actor-workshops:

To carry out the relatively big number of interviews was very time-consuming, as each interview needed to be arranged, carried out at the interviewee's office and analysed afterwards. Some interviews did not yield significantly new results. This was, however, hardly foreseeable beforehand. Nevertheless, these interviews confirmed points already made by other interviewees. Efficiency-increasing modifications of the interview technique were the short interviews with the participants of the Federation of Danish Architects' course on 'environmental management in project design', which permitted the quick recording of several architects' opinions about the indicators approaches presented by the course's lecturers, and a telephone interview with the president of a residents' association.

Concerning the actor-workshops, their duration of four hours for each workshop led to very dense workshop programmes. At the beginning of each workshop the contents of the research carried out in the months prior to the workshops had to be presented in a concentrated and understandable way to the workshop participants to establish a common ground for the following group work. As the workshop participants represented a broad range of actors, who apart from the differences in the contents of their everyday work also differed in their familiarity with abstract debates, a workshop duration of only four hours was rather at the lower limit.[79] However, the efficiency of the workshops increased in the course of the project, as familiarity with the subject and with the other actors grew on the participants' side as well as on the side of the workshop hosts. The actor-workshops fulfilled their function as a social laboratory, in which debates around EIFOB between representatives of the different actor groups could be observed as an anticipation of negotiations in a real arena. Within the limited available time, however, these debates could not develop all the way to a closure of the kind, that might be reached after years of negotiation in a real arena. Even though not necessary for this project, a continuation of the work with the social laboratory with a bigger time budget appears promising.

[78] (Dammann, 2003)

[79] But, as mentioned before, it would have been difficult to let the interviewees dedicate even more of their working hours to the project.

Environmental effects of buildings

This chapter gives an overview of the main environmental effects of buildings seen mainly from the environmental scientific perspective of the life cycle assessment tradition[80]. This will provide the environmental knowledge necessary to understand the different indicator systems and the conflicts between the different technological frames described later in this study.
To put the environmental effects of buildings into a broader context light is shed briefly on the general societal environmental focus as expressed in key Danish and European environmental reports and documents.[81]

Introductory remarks

It is evident that a study on EIFOB has to describe the important environmental effects of buildings in order to create a basis for the understanding of EIFOB in their different forms.

A description of 'the important environmental effects of buildings' in a study with a social constructivist approach has to be transparent with regard to the questions

– '"Important" *for whom*?' and
– '"Important" why?'.

A description of 'the environmental aspects considered important by the different relevant social groups' in a real symmetrical way would require an analysis of the relevant social groups – an analysis, which is provided in some of the following chapters of this study. There are, however, two excuses for ignoring the symmetry principle at this point:

– For the first, writing this chapter mainly from the perspective of the scientific frame provides a solid frame of reference, which should permit the understanding also of the other technological frames' environmental foci, as the actors in the scientific frame can be expected to be those who reign over most environmental knowledge.
– Secondly the very starting point of this study was to investigate how *environmental knowledge* could be *better* integrated into the decision making in the course of the building process by means of EIFOB. This knowledge should also (at least partly) be displayed in this study.

What is considered a 'relevant environmental problem' in the scientific part of society is not constant, but subject to changes, too, of course. New environ-

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[80] Of course there are also different views on building and the environment in the scientific world. There is e.g. the tradition that focuses on the spatial dimension, local environmental impacts such as impact on local habitats and soil contamination. Environmental impact assessment is very much a method familiar to this tradition. The tradition which I mainly refer to in this study comes from the environmental evaluation of products rather than of locations, with life cycle assessment as a key method. In the Netherlands, however, both traditions seem to move towards each other, as the latter broadens its scope from building products over buildings to districts. (Kortman et al., 2001)

[81] The documents mainly referred to here are
'The State of the Environment in Denmark, 2001' (Bach et al., 2001),
the corresponding environmental report of the Danish Ministry of the Environment from 2002 (Grønnegaard et al., 2002),
the Environmental assessment reports 'Environmental Signals 2001' (European Environment Agency, 2001) and
'Environmental Signals 2002'(European Environment Agency, 2002) of the European Environment Agency.

mental problems may occur or be detected, while others may be regarded as solved or just are accepted.[82] Environmental reports, issued by public environmental agencies to provide information for policy makers and the broader public, reflect the prominent current environmental concerns from a scientific perspective.[83]

The description of current environmental problems in this chapter is mainly based on

– the Danish National Environmental Research Institute's expert report 'The State of the Environment in Denmark 2001'[84], (Bach et al., 2002) and
– the European Environment Agency's Environmental assessment reports No 8 'Environmental signals 2001' (European Environment Agency, 2001) and No 9 'Environmental signals 2002' (European Environment Agency, 2002)

supplemented by other environmental scientific literature ((Botkin et al., 2003), (The Encycopedia of the Environment, 1994)…). The chosen reports represent the national Danish perspective as well as the broader European perspective and their reflections of environmental issues.

As the objective of this chapter is, to give an *overview* of the main environmental effects of buildings, the descriptions of the different environmental issues point out core problems and key aspects but for the sake of conciseness and feasibility they refrain from entering into a presentation of details of the vast research fields behind each issue.

Before the environmental effects of buildings are described, however, some general features of the environmental scientific perspective have to be explained.

Causal networks in the environment

A key task of environmental science is to investigate and describe the causal relations between human activities, environmental effects and their consequences. Only when these are sufficiently clear can remedial action be taken[85]. These causal links are seldom unambiguous causal chains but usually 'causal networks', because single causes usually have multiple effects, as the next two figures illustrate:

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[82] At present, for example, a societal debate is gaining momentum whether electromagnetic waves from antennas for mobile phone networks constitute a health threat and shall be regarded as an environmental problem. Another relatively recent issue is hormone-like substances in water and drinking water. Around 1800, the fact that Denmark was coming close to complete deforestation was considered a serious problem: unregulated woodland grazing, firewood cutting, and timber harvest caused an unsustainable depletion of a key resource that is only renewable on a long term. The problem was addressed by protecting the woodlands from grazing animals in combination with massive plantings. After the loss of the Danish fleet to the English Navy in 1807, especially oak trees for shipbuilding became a scarce source. However, the shift from wood to metal as the main shipbuilding material, made these worries obsolete in the late 19th century. (Fritzbøger, 1994)

[83] Of course there are also controversies concerning the relative importance of different environmental issues *within* the scientific world. To discuss these, however, would exceed the frame of this study.

[84] While the 2001 report is 370 pages thick the 2002 report (Grønnegaard et al., 2002) comprised only 44 pages, reflecting that the liberal-conservative government, which governs Denmark since 2002, pays much less attention to environmental issues. Therefore I mainly refer to the older, but much more substantial 2001 report and only occasionally refer to the 2002 one.

[85] According to the *precautionary principle*, however, as e.g. laid down in the Treaty on the European Union, action shall be taken to prevent environmental problems even if there is no scientific proof yet but a reasonable probability for the occurrence of environmental problems: In the case of global climate change e.g., it has not been possible yet, to *proof* that greenhouse gas emissions are the main cause for global warming, as the climate is influenced by multiple natural and anthropogenic factors and changes only over long time horizons. Nevertheless it has been decided to reduce greenhouse gas emissions as the *risk* seems to big to remain inactive until probability has been replaced by proof (among others in the form of a documented increased occurrence of extreme weather conditions).

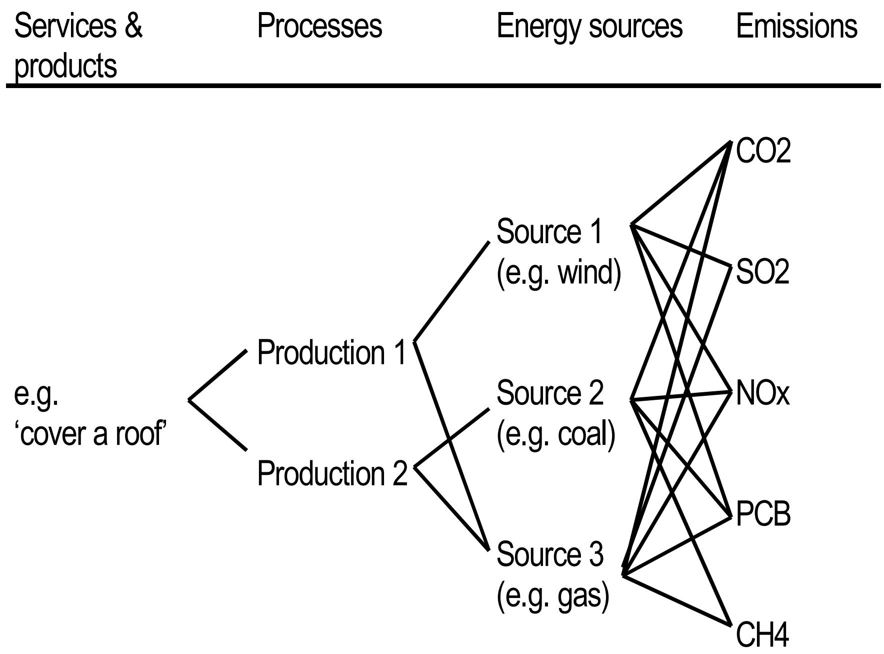

Figure 10: Part of the net of causal relations: the products consumed (for example roof tiles) to provide a service ('to cover a roof') cause multiple emissions[86], depending on the sources of the energy used in their production. This scheme can be thought to continue in the following figure →

Figure 10 illustrates how material consumptions as well as energy consumptions cause multiple emissions.[87] The quantity and the kind of emissions vary, however, depending on the source of the material and the source of energy. The emissions cause environmental impacts (such as global warming, ozone depletion, etc.) which bring about consequences such as the loss of human lives, the loss of ecosystems or the loss of cultural values (Figure 11).

[86] No guarantee for correctness in all details.
[87] The fact that different actors focus on different levels in the net of causal relations is elaborated in the chapter 'Indicators in a social constructivist perspective'.

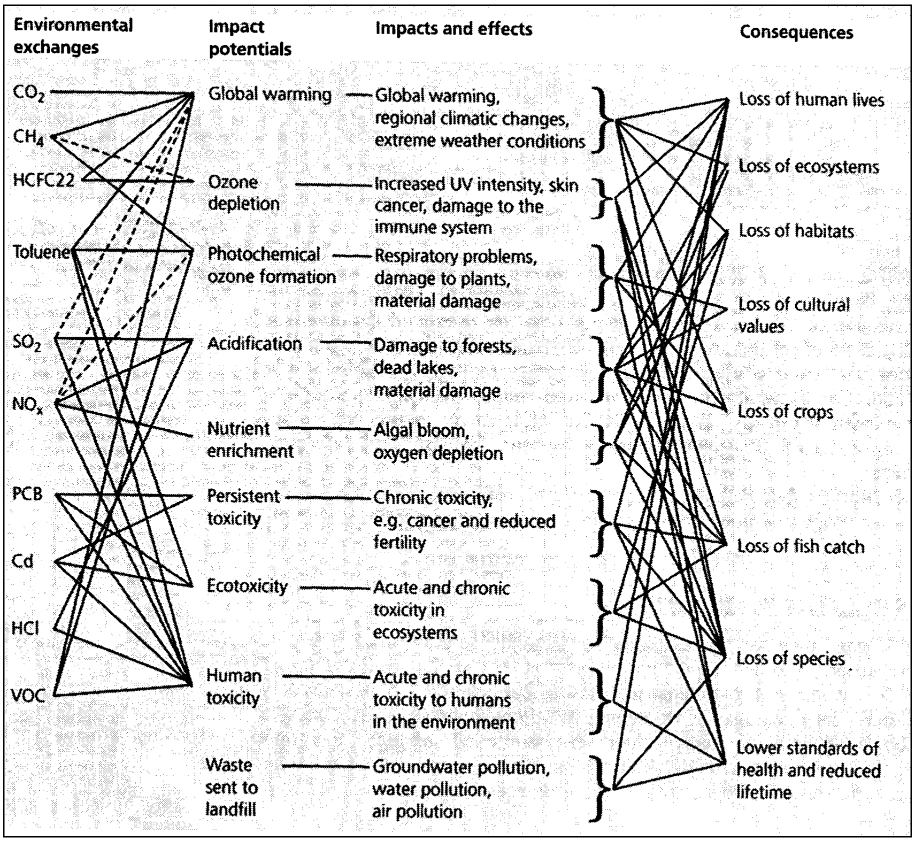

Figure 11: *'Interrelationships between emissions, environmental impact potentials and the various impacts and their consequences',* source: (Wentzel et al., 1997)

The goal of the scientific approach is to draw an environmental profile of a building as close to a building's real environmental effects as possible and during its entire life span, including the production of the building materials prior to the building's erection and the disposal of these materials after the building's dismantling. Two things are therefore characteristic for the scientific approach:

1 The focus on emissions and environmental impacts and
2 A life cycle perspective.

In the following, both are explained in more detail.

Focus on emissions and environmental impacts

From the scientific point of view it is not justifiable without further scrutiny to use a mere measurement of consumptions (for example of electricity consumption in the use phase) as an environmental indicator for buildings in general without further specification. Instead, the origins of the consumed resources and the emissions related to the production processes need to be taken into account, if the indicators are to express an environmental profile of a building that is close to its real environmental effects.[88] The emissions caused by the production of energy and materials are also just one element in the continuing causal network, as Figure 10 and Figure 11 show.

What ultimately triggers human efforts for environmental improvement are the *consequences* of human activities. It is, however, not possible to predict the actual effects and consequences of the environmental exchanges in a building's life cycle in an unambiguous, quantitative way. For this reason in life cycle assessment the categories of environmental impact are defined on

[88] Figure 6 'Overview of the phases in the life cycle of building materials and of important processes' further below illustrates that electricity consumption is only one of many elements in the life cycle of a building and that its sole measurement does not allow to state, which inputs and outputs it causes.

the basis of emissions and impact potentials (and usually[89] not on the basis of consequences).

The environmental impact categories according to the Danish life cycle assessment method 'Environmental design of industrial products' (abbreviated 'EDIP')[90], which also form part of the environmental systematisation and scope of this study (see Table 7), are

- global warming
- stratospheric ozone depletion
- photochemical ozone formation
- acidification
- nutrient enrichment
- toxicity

Additional categories are the generation of different kinds of waste (bulk waste, hazardous waste, slag & ashes) and the depletion of scarce resources.

Environmental systematisation of the study

As elucidated above, in a life cycle perspective it is not possible to allocate the *environmental impact categories* in an unambiguous way to *environmental issues* such as 'energy consumption', 'material consumption' or 'water'. Life cycle assessments focus therefore on environmental impact categories, to avoid the imprecision that goes along with operating on the level of *environmental issues*. In the general societal debate, however, attention is paid to the broader environmental issues rather than to environmental impact categories, because environmental issues like energy or water are familiar categories from our everyday life world and as such also better communicable to a broader audience.

In this study, *environmental issues* and *environmental impact categories* are related to each other by assigning the environmental impact categories in a pragmatic way unambiguously to environmental issues (see Table 7) to provide a structure that makes the complexity of the subject manageable. A similar structuring has also been employed in other studies (for example explicitly in (Dinesen et al., 2001) and (Byggepanel, 2001) or implicitly in (European Environment Agency, 2002)). Table 7 at the same time gives an overview of the environmental scope of the study.

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[89] The Dutch 'Eco-indicator 99' is one exception (Goedkoop et al., 2000).

[90] *'The method has been developed over a period of four years under the Danish EDIP programme […] by a team representing the Technical University of Denmark, five Danish industrial companies, the Confederation of Danish Industries and the Danish Environment Protection Agency. […] International developments in the field of life cycle assessment have been followed closely and have also been incorporated in the methodology.'* (Wentzel et al., 1997) EDIP also forms the basis for the 'Building environment assessment tool' BEAT. → see the chapter on indicator systems

Table 7: The environmental systematisation and environmental scope of this study[91]

	Environmental issue	Sub-themes
1	Energy + emissions to air[92]	contributions to global warming
		acidification
		nutrient enrichment
		photochemical ozone formation
		stratospheric ozone depletion
		consumption of fuel resources
2	Material consumption + waste	depletion of scarce resouces
		bulk waste
		hazardous waste
		radioactive waste
		slag & ashes
3	Water + wastewater	use of scarce water resources
4	Hazardous substances	
5	Local environment	Land use
		Local habitats / Biodiversity
		Ground water formation
6	Indoor climate	Thermal climate
		Indoor air quality
		Light
		Sound

The life cycle perspective in environmental management

Society's environmental focus has been shifting: from an 'end of pipe' policy, in the 1970s, focussing on the control and reduction of emissions of industry, automobiles and buildings, towards a consideration also of a product's or a building's environmental impact throughout its entire life cycle, including measures to *prevent* environmental problems and to use generally cleaner technologies.

The figure below from the book 'Environmental Assessment of Products' (Wentzel et al., 1997) illustrates the focus of traditional environmental policy *for industrial products*, where

> *'Efforts have mainly been concentrated on emissions from material production, [from] product manufacturing and disposal.' (Wentzel et al., 1997)*

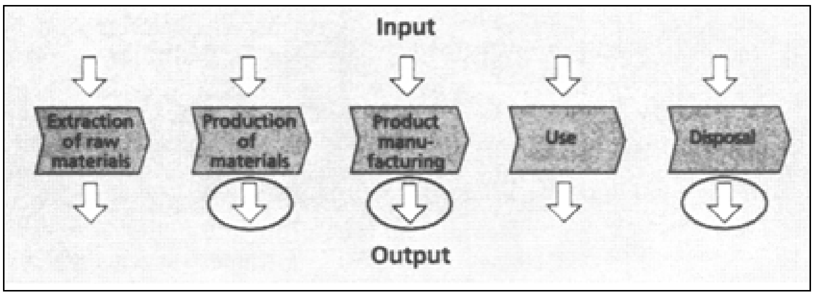

Figure 12: *'Environmental focus in the industrialised world: Efforts have mainly been concentrated on emissions from material production, [from] product manufacturing and disposal.'* (Wentzel et al., 1997)

[91] As mentioned in the introduction, 'working environment' is not within the scope of this study.

[92] Of course not all environmental effects of energy consumption are caused by emissions; 'landscape alterations' e.g. can be an effect of the methods of mining fossil fuels. These effects, however, are mentioned under the other respective environmental issues (e.g. 'land use').

In this area significant improvements have been reached. As an example

> *'Virtually all pollution parameter in industrial waste water emissions have been reduced by 80-90% for Denmark as a whole [from 1980 to 1990].' (Wentzel et al., 1997)*

At the same time the material standard of living has risen, neutralising and outweighing many environmental improvements by an increased consumption of resources.

In the building and housing sector the energy crisis of the 1970s set off efforts to reduce energy consumption, focusing primarily on the consumption in the building's use phase. In Denmark some improvements with regard to the energy consumptions *per household* have been achieved:

> *'Energy consumption for heating per m^2 has […] decreased by 24% from 1980 to 1999. […] Electricity consumption [per household] is stable in spite of the increasing number of appliances in the households, because the appliances' energy efficiency has been improved. (Bach et al., 2001)*

These improvements, however, are neutralised by the increasing number of households (in Denmark: 7.5 % from 1990 to 2000 (Grønnegaard et al., 2002), in Europe 19% from 1980 to 1995 (European Environment Agency, 2001)) and the continuing trend towards smaller households in Denmark as well as in the whole of Europe.

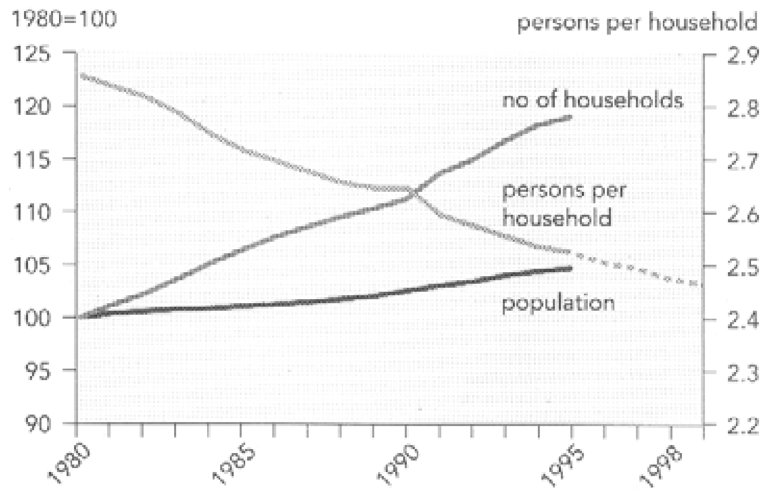

Figure 13: *'Development in the number of households and population and the average size of households in the European Environment Agency ['EEA'] area*
☹ From 1980 to 1995 the population in the EEA area increased by 5 per cent while the number of households increased by 19 per cent; the average household size consequently decreased. Small households consume more per capita than large ones.' (European Environment Agency, 2001):

Thus the European Environment Agency concludes in its 2002 'Environmental assessment report'

> *'The household sector remains one of the largest users of energy. Consumption by the sector in the EU increased during the 1990s by 10%, with energy used for space heating falling slightly and electricity consumption rising by about 22%. The overall increase was due to the increase in number of households, with consumption per household remaining nearly constant.' (European Environment Agency, 2002)*

This phenomenon of continuing increases in total consumption, that subsequently lead to continuing increases in pressures on the environment in spite of efficiency improvements at the level of single processes has led to the recognition that environmental policy has to broaden its scope so that attention is paid to the total impact from the entire product system. In this broader view, resource streams and emissions that occur during a product's entire life cycle are taken into consideration, as well as the important role played by consumer choices and behaviour in determining which products are sold on the market and how they are used.

> *'To a large extent, future environmental management will therefore occur at the interface between company and customer, as illustrated in [the below] Figure.' (Wentzel et al., 1997)*

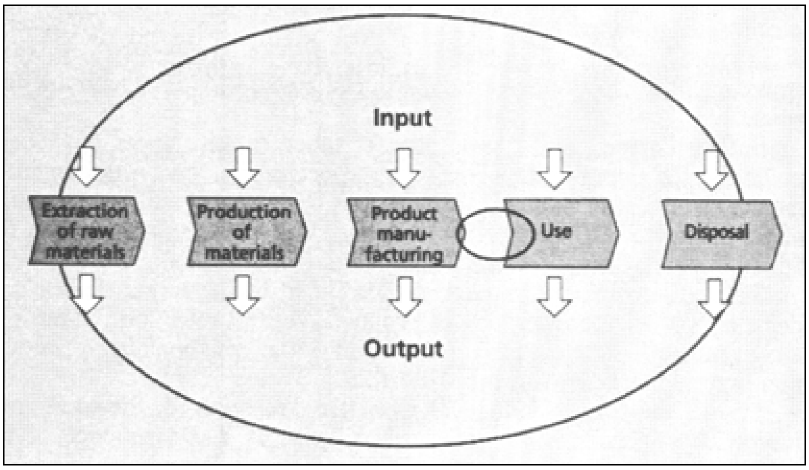

Figure 14: *'Future environmental focus in the industrialised world'* (Wentzel et al., 1997)

This broader optic also applies to the building and housing sector, where environmental declarations of building products and environmental profiles of buildings and building projects based on life cycle assessments are meant to foster conscious environmental choices among clients and their consultants.

Current environmental problems and the life cycle of a building

The figure below relates environmental issues from Table 7 to the technical system formed by a building, its demand for supply and its waste generation to illustrate the environmentally relevant inputs and outputs occurring during its life as considered in a life cycle assessment of a building.

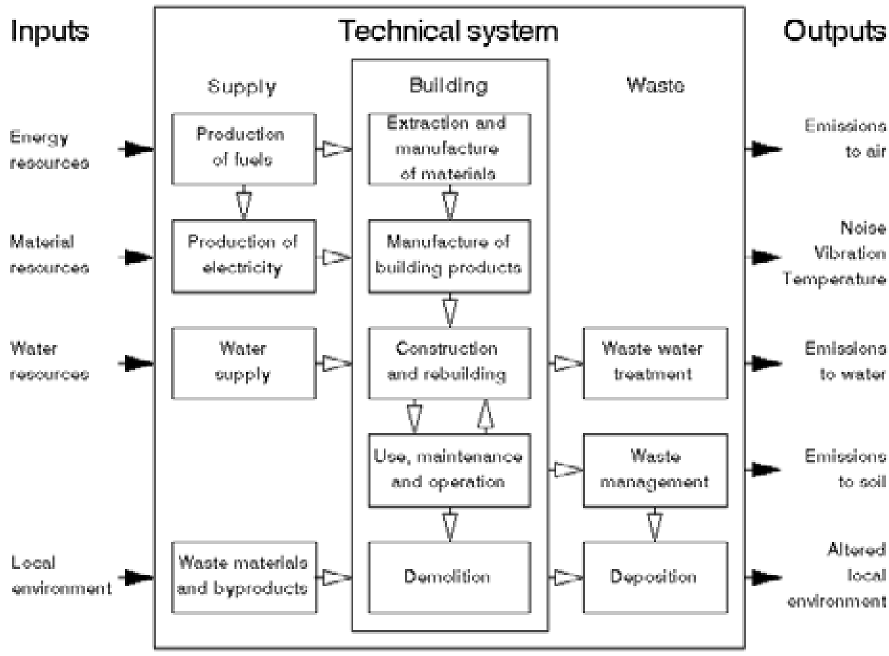

Figure 15: *'Overview of the phases in the life cycle of building materials and of important processes connected with especially energy supply and disposal of constructional waste. The most important types of environmental impacts (input and output) are shown.' (The board of environmental management in project design, 1998)* [author's translation]

The environmental issues 'hazardous substances' and 'indoor climate' are not explicitly named in this scheme but are thought to be comprised in the outputs 'Emissions to air', 'Noise' and 'Temperature', which include outputs to the external environment as well as to the indoor-environment. (The indoor climate aspect 'light' can be thought as yet another output of the technical system.)

The following description of current environmental problems and buildings' contributions follows the structure of general environmental scope as illustrated in Table 7 while employing the life cycle perspective as visualised in Figure 15.

The following sections first give a *general* explanation of the environmental problems before light is shed on *how buildings relate to the problem*. (At which points in a building's life cycle which environmental aspects are especially relevant is described in the next chapter, 'Decision-making situations'.)

Energy and emissions to air

Energy consumption is the cause of several environmental problems. Type and intensity of the problems depend on how the energy is produced. In general, *fossil, nuclear* and *renewable* energy sources are distinguished.

Environmental effects of fossil fuel consumption

Fossil fuels (crude oil, coal and natural gas) in 1999 accounted for 79% of the EU's total energy consumption (European Environment Agency, 2002). The combustion of fossil fuels emits CO_2, the most important greenhouse gas, and sulphur dioxide (SO_2) and nitrogen oxides (NO_x), which cause acidification. Nitrogen oxides, entering the nitrogen cycle through emission to air, in combination with other chemical compounds also contribute to nutrient enrichment in waters.

Natural gas, however, has a significantly lower carbon and sulphur content than crude oil and coal. Per energy unit it emits 40% less CO_2 than coal (Bach et al., 2002). Substituting oil and coal with natural gas therefore reduces the emission of CO_2 and SO_2.

In Denmark

> ***'SO_2-emissions declined considerably throughout the 1980s and 1990s owing to the use of fuels with a lower sulphur content and increasing use of flue gas desulphurization installations [at power stations and combined heat and power stations]. SO_2 emissions declined by 27% from 1998 to 1999 due to less use of coal and more use of natural gas and renewable energy.' (Bach et al., 2002)***

Several combustion products of fossil fuel are also precursors[93] for the photochemical formation of ground level ozone. High concentrations of ozone at ground level can occur especially in the summer in cities with heavy traffic and can have adverse health effects after a few days of exposure, in particular inflammatory responses and reduction in lung function.

Apart from the impact on climate change and acidification the consumption of fossil fuel resources by the industrialised world in the current quantities is also in conflict with the principle that limited resources should be shared among present and future generations in a just way – a key thought of the sustainability principle.

Nuclear energy

Energy production in nuclear power plants does not emit any gases (apart from those emitted due to the extraction and transport of uranium) and accordingly contributes little to acidification and global warming. The main envi-

[93] *'A substance from which another is formed by decay or chemical reaction etc.'* (Oxford Compendium, 2000)

ronmentally problems with using nuclear energy lie in the production of radioactive waste and the land use for uranium mining (see also the sections on waste and land use below). Especially the public concern about problems linked to radioactive waste and the risk that radioactive substances are emitted by accident or as a consequence of terrorist attacks

> *'[…] has led to plans to phase out nuclear power in Belgium, Germany and Sweden, with other countries either declaring or considering moratoria on the building of new power plants. At present only in Finland are there discussions on building a nuclear plant in the near future. (European Environment Agency, 2001)*

Denmark has never produced nuclear energy. It has, however, established one nuclear reactor for research purposes.

Different efficiencies

Big central electric power plants have a low energy efficiency due to losses in the transmission from the plant to the remote users. Another problem is that excess heat needs to be removed.

One way to address these problems is combined heat and power (CHP) production:

> *'Due to the utilisation of heat from electricity generation and the avoidance of transmission losses because electricity is generated on site, CHP typically achieves a 35 per cent reduction in primary energy usage compared with power stations and heat only boilers.' (http://www.chpa.co.uk/aboutchp.htm)*

In 1998 Denmark had the highest share of CHP in national gross electricity production among EU member states (Denmark 63%, EU average: 11%) (European Environment Agency, 2002). Central plants with large district heating systems prevail in Denmark. Improving energy efficiency in general is seen as one solution to climate change and security of supply and at EU level has led to the 'Directive 2002/91/EC on the energy performance of buildings' (European Parliament and the Council, 2002)[94].

Renewable energy

Another way to address the problems linked to the use of fossil fuels and nuclear energy is the use of renewable sources of energy, comprising solar energy, wind energy, geothermal energy, hydro energy, and energy from biomass. Renewable sources of energy in 1999 contributed 5.9%[95] to the EU's total energy consumption. The EU wants to increase the share of renewable energy. It agreed to an EU overall indicative target of 22.1% of gross electricity consumption from renewable sources by 2010 (in 1999: 14%) and issued the 'Directive 2001/77/EC on the promotion of electricity from renewable sources'.

Once in use, energy from renewable sources performs better environmentally than energy from non-renewable sources, because it has no emissions (energy from burning of biomass is considered neutral with regard to emissions, because in principle it releases only those substances into the biosphere, which have been incorporated into the biomass during their production). But of course also for renewable sources of energy an ecological price in terms of land use, material consumption, waste etc. has to be paid (see the respective sections for details).

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[94] For details see the section 'The Danish planning and building legislation and ongoing European developments' in the appendix

[95] *'Renewable electricity was dominated by large hydro-power (74% in 1999), followed by small hydro (11%) and biomass/waste (10%). Large hydro is an established technology, but its capacity is not expected to increase substantially because of concerns about its impact on the environment. Growth in renewable electricity will therefore have to come from other renewable sources such as wind energy, solar power, biomass and small hydro.' (European Environment Agency, 2002)*

Energy from waste incineration

The annual environmental report of the European Environment Agency 'Environmental signals 2002' (European Environment Agency, 2002) also counts waste incineration as a renewable source of energy, reasoning that

– once waste has been produced, it needs to either be recycled, disposed of or incinerated, the latter replacing fossil fuels in energy production and diminishing the use for landfills.
– if the environmental burdens caused by the production of the product which later becomes waste is entirely allocated *to the production* the energy gained by the product's incineration is 'environmentally for free', because it does not account for new environmental burdens.

I think this viewpoint is problematic, because only *part* of the incinerated waste actually stems from *renewable* sources (biomass including paper and wood). A big share (in Denmark in 1999 ca. 40%) (Bach et al., 2001) consists of non-renewable resources (mainly plastic). Surely, waste incineration may make the best of a bad situation, using the energy embodied in the already existing waste. Nevertheless, a reduction of our waste production and of our energy consumption would be an even better solution. Accordingly I don't include energy from waste incineration when I use the notion 'renewable energy'.

Stratospheric ozone depletion

An environmental problem that is not related to energy consumption but to emissions to air is stratospheric ozone depletion. Ozone in the stratosphere (about 20 km above ground) is important mainly because it absorbs harmful ultraviolet radiation emitted by the sun. The biological effects of this radiation include skin cancer, eye cataracts and disruption of the immune system in humans and reduction of growth rates in plants. The ozone in this stratospheric ozone layer is depleted by very small amounts of several pollutants, the most important of which is chlorine.

> *The chlorine that destroys ozone is carried to the upper level of the atmosphere in industrial compounds, principally in the chlorofluorocarbon (CFC) gases invented in 1928 for use in refrigerators. (The Encycopedia of the Environment, 1994)*

Relation to buildings

> *'Energy consumption for building-related services account for approximately one third of total EU energy consumption.' (European Union, 2002)*
> *'The residential and tertiary sector, the major part of which is buildings, […] is expanding, a trend which is bound to increase its energy consumption and hence also its carbon dioxide emission.' (European Parliament and the Council, 2002)*

On the other hand, the potential for energy savings in the building sector is also huge, especially with regard to energy consumption for heating and electricity in the use phase, as new so-called zero-emission buildings demonstrate.[96]

Besides the energy consumption in the use phase, the energy embodied in the building material is another significant part of buildings' total energy consumption. The production of some building materials, for example of aluminium, but also of other metals, is very energy-consuming.[97]

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[96] Visionaries state that in future buildings will even become net *producers of energy*.

[97] The energy consumption for the production of aluminium (from ore) is 200-250 MJ/kg (for aluminium from aluminium scrap, however, only 10-20 MJ/kg), for steel (from ore) 10-20 MJ/kg and for bricks 2-4 MJ/kg (Holleris Petersen et al., 2001).

The lower a building’s energy consumption in the use phase, the more important the embodied energy becomes for the building’s total energy performance, as the following LCA of a Danish design illustrates:

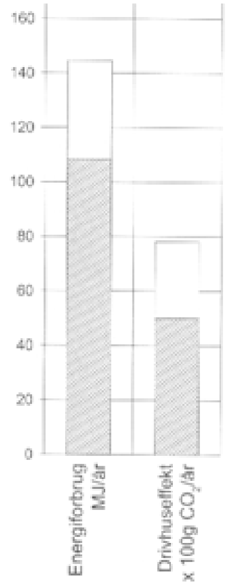

Figure 16: ‘Økohus 99’, 3x Nielsen, Kolding, and the building’s energy consumption (left bar, in MJ/year) and contribution to the greenhouse effect (right bar, in 100g CO2/year) for heating (grey, bottom) and for the production of its construction material (white), both per m^2 storey area.
‘The materials [here especially the big glass areas and aluminium window frames, author’s note] *are responsible for 36% of the total CO2-emission and 25% of the total energy consumption.*[98]*’ (Marsh et al., 2000)*

As explained in the previous section, it is, of course, *the origin of the consumed energy* that is crucial for the building’s environmental profile.

Indirectly the *siting* of a building influences the consumption of energy by the transport behaviour of the building’s users. Different modes of transport (walking, bicycles, cars, various kinds of public transport) differ significantly in their energy consumption. Which modes of transport the building’s users chose to get to the places of their activities (working, shopping, education, leisure activities,…) depends very much on the building’s distance to these facilities and on the availability of different modes of transport at the building’s location. In this respect urban areas perform much better than rural areas:

> *‘[Transport related] energy consumption and CO_2 emissions are 50% greater per person for rural inhabitants than for inhabitants of Copenhagen and the major provincial towns.’ (Bach et al., 2002)*

With regard to stratospheric ozone depletion, chlorofluorocarbon (CFC) gases had been used in systems for cooling, for foaming in insulation materials and in fire-extinguishing appliances. Emission of CFC and other ozone depleting substances can occur both during manufacture of the products and during their use and disposal. However, in accordance with the Montreal Protocol, which requires the signatory countries to phase out these substances, in Denmark

> *‘Over the past 15 years, use of the most potent ozone-depleting substances (CFCs, tetrachloroethane, 1,1,1-trichloro-ethane, halons and methyl bromide) has been almost completely phased out […]. Internationally, the phase-out has been successful too. The HCFCs, which are much less harmful to the ozone layer, have not yet been completely phased out in Denmark or internationally.’ (Bach et al., 2002)*

The contribution of buildings to stratospheric ozone depletion thus is not very significant anymore.

[98] The figures are calculated with the LCA-tool ‘BEAT’ for a 60-year life span of the building.

Material consumption + waste[99]

Material consumption

An indicator for the resource productivity of the EU's economy is the total material requirement (TMR)[100]. Since 1980, the TMR for the EU economy has remained around 51 to 52 tonnes per capita per year. The fact that these figures have remained relatively constant in spite of a growth of the EU gross domestic product of more than 50% in the same period indicates a beginning decoupling of economic growth from material flows (European Environment Agency, 2002), which is environmentally favourable. Nevertheless material flows on such a scale continue to be environmentally problematic. Some materials, like for example crude oil (as the raw material for plastic) and the metals copper and zinc have a limited supply horizon. The more they are used, the less there is left for following generations and future employments. The sources that remain are usually more difficult and expensive to exploit and their exploitation may conflict more sharply with the conservation of the natural and cultural heritage.[101] Also resources that principally are renewable (for example wood and wood-products) can become scarce if exploited at an unsustainable rate.[102] Apart from the supply aspect, consumption of material also has serious implications for land use and energy consumption, as explained in the respective sections.

Waste

In general

> *'The generation of waste represents a loss of materials and energy. Excessive quantities of waste result from inefficient production processes, low durability of goods and unsustainable consumption patterns.' (European Environment Agency, 2002)*

Accordingly the reduction of waste generation is a declared objective of European environmental policy as for example laid down in the Sixth Environmental Action Programme of the European Union.
This tenet permits the ranking of the different options of handling the materials after they have fulfilled their function and the waste occurring during the production of the materials. The common options are

- reuse
- recycling
- incineration and
- disposal in landfills.

Reuse, that is, a use of the abandoned material in a new function without major reshaping or processing (for example the reuse of old tires as fenders

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[99] Definition of 'waste': *'Materials that are not prime products (that is, products produced for the market) for which the generator has no further use in terms of his/her own purposes of production, transformation or consumption, and of which he/she wants to dispose. Wastes may be generated during the extraction of raw materials, the processing of raw materials into intermediate and final products, the consumption of final products, and other human activities. Residuals recycled or reused at the place of generation are excluded.',* Definition source United Nations. Glossary of environment statistics. http://esa.un.org/unsd/envmnt/default.asp

[100] *'The total material requirement (TMR) indicator comprises the cumulative volume of primary materials (excluding water and air) extracted from nature for the economic activities of a country […] with all resource flows aggregated in tonnes. […] From a systems perspective, any flows of material into the economy will lead to output flows sooner or later, many of them at other locations and with a changed composition. Thus, TMR indicates the total volume of material throughput of the economy, that is, the total amount of products, waste and emissions.' (European Environment Agency, 2002)*

[101] As e.g. in Germany, where open cast brown coal mining led to the destruction of several villages.

[102] In principle, crude oil and coal, too, are renewable resources, as they consist of plant matter. The time necessary for their formation, however, exceeds the normal human time horizon.

for ships or the reuse of an old church as a museum and cultural venue[103]) is in general environmentally most favourable, because the reuse of old material diminishes the need for new products and little or no energy is consumed for processing the old material.

Recycling means the abandoned material is processed in some way and brought into a new form to serve its new function, thus reducing the need for new material, too. Well-known examples are bottles from recycled glass and paper sheets from recycled paper, but also steel that is collected, melted and formed anew. This processing, however, usually causes energy-related emissions.[104]

Incineration is the burning of waste. If the gained heat is used for electricity production and heating, the waste can substitute for non-renewable fuels (as is the case in Denmark). However, air-polluting gases and ashes remain that contain toxic heavy metals and need to be disposed of. Incineration is also the dominating source of dioxin emission to air in Denmark. (Environment Protection Agency*,* 2003)

Disposal of waste in landfills is the environmentally least favourable solution: The German term for 'waste' is 'Wertstoff', meaning 'valuable matter'. It expresses the thought that the considerable resources (energy, time, work, money,…) that have been employed to produce the material make it a valuable resource that should not be take out of use and be disposed of. Disposed of material usually needs to be substituted by newly produced material, which causes the environmental pressures mentioned above. Furthermore

> *'[…] disposal of waste causes a number of environmental pressures, such as use of land for landfills; leaching of nutrients, heavy metals and other toxic compounds from landfills; low biodegradation of wastes; emission of greenhouse gases from landfills […].(European Environment Agency, 2002)*

Besides different ways of waste disposal, different kinds of waste can be distinguished according to the type of landfilling or dumping:

> *'Bulk waste, i.e. household waste, construction waste and similar waste is brought to a (controlled) municipal landfill. The waste is distinguished by not containing environmentally hazardous substances.*
>
> *Hazardous waste, i.e. waste brought to special treatment facilities for hazardous waste and thereafter dumped. The waste is characterised by containing environmentally hazardous substances which can be released to the environment after dumping.*
>
> *Radioactive waste, i.e. waste of low radiation intensity from nuclear power plants brought to special storage sites for radioactive waste.*
>
> *Slag and ashes from incineration at coal-fired power plants and waste incineration plants brought to special dumps for incineration slag and ashes.' (Wentzel et al., 1997)*

Hazardous waste forms only a small fraction of total waste generated in Europe. The largest quantities of it are generated by manufacturing industries and extraction activities (European Environment Agency*,* 2002).

In metal manufacturing, for example, paint wastes containing heavy metals, strong acids and bases, cyanide wastes and sludge containing heavy metals are generated (The Encycopedia of the Environment*,* 1994).

Radioactive waste is generated in nuclear power plants. Its radiation causes cancer and lasts for several thousand years. Plutonium, one com-

[103] As is the case in Amsterdam. In the Dutch city of Maastricht a church now serves as a bicycle storage for commuters.

[104] The composting of organic waste for fertilisation, however, is an emission-neutral process like the ones typical for most bio systems.

pound of radioactive waste, is also extremely toxic. To prevent radioactive waste from causing damage it needs to be isolated from the biosphere for several millennia, a problem as yet unsolved. Radioactive substances from nuclear waste are also a concern because they could be emitted by accident or as a consequence of terrorist attacks.

Relation to buildings

The building sector consumes 30% of all the raw material produced in Denmark.[105] (Bach et al*.,* 2002)

> *'Raw materials consumption for new buildings generally amounts to 1.1 tonnes per m², of which 70% is accounted for by concrete, mortar, gypsum, etc, 15% by sand, gravel and stone aggregates, and 9% by bricks, tiles, clinker. […] These solid raw materials derive from the upper parts of the subsoil and are excavated from depths down to 30–40 metres. ' (Bach et al., 2002)*

In Denmark the raw material extraction from the seabed has been increasing, in 1999 comprising about one fourth of the country's total extraction of sand, gravel and stones. Extraction from seabed (and from land) is regulated by the Raw Material Act. The act has for example restricted the extraction of boulders from the seabed, a practice which had previously threatened the existence of a special maritime habitat. (Bach et al*.,* 2002) Even though there is a general understanding that there is abundant sand, gravel, stone, clay, limestone and chalk, and that shortages will not arise within the near future,

> *'numerous local shortages of these raw materials already exist, especially shortages of raw materials of high quality. Exhaustion of local resources increases the need for transport of raw materials.' (Bach et al., 2002)*

The building and construction[106] sector in Denmark also accounts for a considerable proportion of the total wood consumption, the biggest part of which consists of Nordic softwood. The environmental impact of wood consumption depends very much on whether the wood is produced in sustainable forestry, as for example certified by the 'Forest Stewardship Council' (FSC) or by exploiting natural forests in an unsustainable manner.

Wood used in buildings can be seen as a CO2-sink, as it removes from the atmosphere, for the lifetime of the wooden construction element, the carbon, bound into the wood in photosynthesis.

Furthermore

> *'The building and construction sector uses considerable amounts of metals, especially copper, zinc and aluminium. […] Copper and zinc are relatively scarce resources. Mining and manufacturing of the metals from ore usually generate large amounts of waste and consume considerable energy.' (Bach et al., 2002)*

However, in 2001 in Denmark around 90% of the waste produced by the building and construction sector was recycled, not least due to the fact that recycled waste is exempted from waste levy. (ibidem)

Besides the waste directly caused by the building materials, there is, of course, the waste produced by the residents and users in the building's use phase. [107]

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[105] Another 60% are consumed by the construction sector. Thus, the building and construction sector combined consume 90% of the raw material produced in Denmark. (Bach et al*.,* 2002)

[106] 'Construction' meaning infrastructure constructions such as bridges, motorways, energy networks in contrast to buildings for e.g. housing or work.

[107] I will touch the question, if household waste should at all be considered in environmental indicators for buildings in more detail in the chapters on decision-making situations and on the technological frames. An argument *against* regarding household waste in EIFOB is that the production of household

'Generation of municipality waste[108] in EU countries continues to increase and averaged 540 kg per capita in 1999. […] Biodegradable waste counts for approximately two thirds of total municipality waste quantities.' (European Environment Agency, 2002)

Buildings also contribute to the generation of hazardous waste occurring in the production of building materials (especially of metals) and energy for the buildings operation or construction.

Water and wastewater[109]

In general, Denmark and Europe have sufficient fresh water resources. However, the fresh water supply is threatened by excessive water withdrawal in relation to the available fresh water resources and by discharge of pollutants, including nutrients and hazardous substances. Nutrient overloading (mainly in the form of high levels of nitrogen and phosphorus originating from agriculture), is one of the main problems affecting the Danish aquatic environment, including inland waters as well as marine waters. Excessive nutrient loading both diminishes the quality of the drinking water resource and destroys habitat conditions for plants and animals. Drinking water with a high nitrate content is harmful to health. In Denmark over the period 1987-1999, around 600 water supply wells have been closed down due to anthropogenic contamination with nitrate and other hazardous substances (Bach et al., 2002).

'Algalgreen lakes, turbid and unclear water and dead [sea-bottom] invertebrates in marine waters are other examples of the consequences of excessive nutrient loading.' (Bach et al., 2002)

A sustainable exploitation of the groundwater withdraws no more groundwater than is formed. Groundwater abstraction is presently sustainable in the most of Denmark. In the eastern part of Zealand and in some other closely populated areas, though, less new groundwater is formed than is abstracted. After periods of dry years, some watercourses can consequently dry out temporarily due to excessive abstraction.

'If the future drinking water supply is to be safeguarded, we must prevent further contamination and economize on the remaining pure groundwater.' (Bach et al., 2002)

With significant regional differences, the same problems obtain for Europe as a whole, too. Significant progress has been made reducing discharges from point sources such as urban wastewater treatments plants and industries (in Denmark discharges of organic matter from these sources have decreased by approximately 74% between 1989 and 1999 (Bach et al., 2002)), but discharges from diffuse sources, of which agriculture is the most important, remain a problem (European Environment Agency, 2001).

Relation to buildings

Buildings relate to the problems described above mainly in two ways:

- Their technical appliances can influence the consumption of water in households and institutions[110] and

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waste is far stronger influenced by the behaviour of the users of the building and by packaging practices of the retail industry than by the building. An argument *for* the inclusion of household waste is that in different decision-making situations in the building's life cycle decisions are taken that *are* relevant for the generation of household waste: e.g. in the siting of the building the choice of the site's waste infrastructure, or in the project design phase the planning of built facilities for waste separation, composting or reuse (e.g. a 'swap-shop' for used cloths and other things).

[108] Definition of 'municipality waste': *'Waste from households, as well as other waste which, because of its nature or composition, is similar to waste from household.'*, EEA glossary, definition source: Directive 1999/31/EC of 26 April 1999 on the landfill of waste.

[109] Source: (Luising, 2002) + interview with the author.

– the applied wastewater treatment influences the discharge of nutrients into the aquatic system.

Households account for about 10% of total water consumption in the whole of the EU; in urban areas and areas with poor water resources the figure may be significantly higher.

> *'Average consumption for all household purposes in the European Economic Area is about 150 litres per capita [per day]. […] About one third of this is for personal hygiene, one third for washing clothes and dishwashing, 25 to 30% for flushing toilets and only about 5% for drinking and cooking.' (European Environment Agency, 2001):*

That fact, that merely 5% of the water consumption (for drinking and cooking) actually requires drinking water quality, while in most cases drinking water is also used for washing cloth and even toilet flushing, sheds light on the considerable potential to increase the efficiency of household water use, for example by using rainwater instead of drinking water for washing and toilet flushing and by installing other water saving appliances. In Denmark

> *'Since 1989, household consumption of water has fallen by 30% because of […] the use of water-saving plumbing such as low-flush toilets, and increased collection of rainwater.' (Bach et al., 2002)*

Water-saving installations also include appliances that have proven to have an impact on the *user behaviour* (Jensen, 2003), such as visible displays of consumption, possibly in comparison with average consumption and best-practice consumption.

The applied wastewater treatment system is relevant with regard to the discharge of nutrients into the aquatic system and a number of other environmental aspects. In Denmark today the majority of properties are now connected to the sewer system and to treatment plants. In most cases the sewer carries both wastewater and stormwater. Wastewaters of different qualities and from different sources, for example from toilets and washing machines, are usually mixed together in the sewer. The wastewater treatment plants remove the majority of the oxygen-consuming organic matter as well as phosphorus and nitrogen. Also a large fraction of the heavy metals and other hazardous substances is completely or partially degraded or retained in the sewage sludge. The waste sludge is treated[111] and burned, the remaining ash is disposed of. Though these centralised large-scale wastewater treatment systems have solved some environmental problems, they have also brought about specific new ones:

The current central system requires a huge infrastructure (the sewers and the treatment plants), which cause material-related environmental burdens.

Also the processing of the wastewater causes environmental burdens such as energy consumption for the processing and related emission of CO_2 and nitrogen-compounds to air (the burning of the moist sludge is very energy-consuming). Land is used for disposal of the ash from the sludge burning.

Another problem is, that the current system extracts nutrients from natural cycles: The larger part of the valuable nutrients contained in the faeces and the urine[112] is burned or disposed of and only very little of it returns to nutrient cycles. At the same time, huge amounts of nutrients in the form of animal fodder for meat production and artificial fertiliser for crop production are im-

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[110] Of course the consumption behaviour of the building's users is a significant, if not the most important factor in this context. However, as explained in the chapter 'Introduction', this study focuses on environmentally relevant *building characteristic*, including those that can *influence user behaviour*, while user behaviour itself is not within the scope of this study.

[111] The digestion of the sludge produces methanol. This gas only covers 10-14% of the energy consumed in the wastewater treatment plant.

[112] Urine contains 80-90% of the nutrients of human faeces and urine together.

ported into Europe. This causes again among others transport- and production-related environmental burdens. The production of meat and dairy products leads to a surplus of animal faeces and urine, which can cause eutrophication, climate change and nitrification. All together, this creates an unfavourable environment for the reuse of nutrients from human faeces: as long as a surplus of nutrients in Europe causes environmental problems it appears pointless to make even more nutrients available by introducing human faeces into a nutrient cycle. However, nutrient circulation systems could help to avoid the problems mentioned above.

An issues that has entered the environmental debate only recently are persistent substances (for example from medicine) in the wastewater. [113] The behaviour of persistent substances in different wastewater treatment systems, however, is still unclear and subject of ongoing research (de Mes et al., 2002).

Hazardous substances

Many of the diseases and disorders in the human population as well as in ecosystems in general that are attributed to the 'environment' are caused by toxic chemical compounds. The environment (air, water, solid waste, etc.) provides the pathways from the source of these chemicals to the affected organisms. Even though

> *'Essentially all compounds can be toxic […] at some dose or with some use[114].' (The Encyclopedia of the Environment, 1994),*

the notion 'hazardous substances' usually means chemicals that are known to lead to especially serious disorders even in small concentrations. These substances are used in the first place, because some of their characteristics are desired (phtalates, for example, allow to keep plastics elastic and soft, pesticides kill undesired pests, lead is relatively persistent and easy to form, …). But the 'life' of these substances does not end here: they make their way into the biosphere as they corrode or decay, as they off-gase or as they are incinerated after their use – and often it is here that they have revealed their undesired characteristics, leading to serious diseases among humans as well as in the flora and fauna. PVC, a commonly used plastic in building, is an example of such problems occurring in the disposal phase of a product:

> *When PVC came into focus in Denmark at the end of the 1980s, it was primarily because chlorine is released from PVC upon combustion. As a consequence, hydrochloric acid is formed in the atmosphere, thereby entailing the potential danger of acid precipitation. Lime is added during flue gas abatement, thereby generating a waste product that contains heavy metals and hence has to be deposited as hazardous waste. Incineration of 1 kg PVC generates between 1 and 2 kg of waste residue. (Bach et al., 2002)*

A problem with the evaluation of a compound's hazardousness is that many substances have a low acute toxicity but may be toxic in the long term. The pesticide DDT, for example, efficiently killed mosquitoes (as was intended) while having a low acute toxicity for humans and animals. Only in the long-term, however, it was discovered that DDT, which is insoluble in water but highly soluble in fat, accumulated at the end of the food chain, where it

[113] Numerous medicines contain persistent substances that pass unaltered trough the human digestive system and the wastewater treatment. So finally these substances enter into the water circulation, still maintaining their power to interfere with the metabolism of higher organisms. An example of such a substance is the hormone oestrogen. As a main component of the broadly used contraceptive pill it enters into the water cycle in significant quantities and has led to the occurrence of ovules in male fishes. (de Mes et al., 2002)

[114] *'Oxygen is necessary for life and is safe, indeed essential at around 20% in inspired air, but at higher concentrations can damage lungs and in newborns, damage vision.' (The Encyclopedia of the Environment, 1994)*

caused egg-shell thinning in condors and also had toxic effects in humans, including breast cancer in woman. Thus, chemicals can have acute effects (for example immediate headache or allergic reactions) or delayed effects such as lung cancer as a consequence of exposure to asbestos several decades ago.

Apart from substances that are known as hazardous, hundreds of thousands of chemicals are in use without knowledge about their long effects.

Relation to buildings

In Denmark (and probably also in Europe as a whole) the building and construction sector is one of the sectors that uses the greatest number of different chemical products – just over 6,000 different products out of approximately 40,000 registered products.

> *In 1999, the [Danish] State Building Research Institute carried out a study of problematic substances in building materials (table 8). The main materials containing problematic substances were impregnated wood, paint, adhesives and sealants. In 1996, around 90,000 tonnes of paint were used, of which half contained organic solvents. In addition, just over 50,000 tonnes of adhesive, filler and sealant were used. There are also reasons for concern about the large amounts of chemical substances present in the existing buildings and structures, and which eventually end up as waste. (Bach et al., 2002)*

Table 8: Overview of hazardous substances in building materials that have or could in future have effects on human health and the environment (Krogh, 1999)

Type of substance	Substance/substance group	Building materials
Metals	Arsenic	Impregnated timber
	Lead and lead compounds	Flashing, cables, PVC
	Cadmium	Pigments, solder
	Chromium compounds	Impregnated timber
	Tin compounds	Vacuum-impregnated timber
	Nickel	Locks
	Copper compounds	Impregnated timber
Persistent substances	Polychlorinated biphenyls	Sealants
	Phthalates	Sealants, plastic
Solvents		Paint, impregnation oils
Biocides	Fungicides	Sealants, paints
	Preservatives	Sealants, paints
Monomers	Isocyanates	Foam sealants
	Epoxy compounds	Epoxy adhesives
	Phenol	Two-component adhesives
	Formaldehyde	Two-component adhesives

Though it is possible to reduce the environmental impacts by reducing consumption or improving the production and use of these materials, the report 'The State of the Environment in Denmark, 2001' (Bach et al., 2002) concludes that

> *'In the long term […] the greatest improvements are obtained by completely replacing these materials with other environment-friendly alternatives.'*

The current development, however, does not unambiguously point into this direction:

> *Since the 1950s, the consumption of various types of plastic in the building and construction sector has grown markedly, for instance within the electrical and sanitation areas and in connection with doors, windows, profiles, etc. The use of plastic has also introduced a large*

number of new substances that are potentially harmful to health and the environment. PVC and PE are the most commonly used types of plastic for building. Around 35,000 tonnes of hard PVC (1995 figure) are consumed annually in building materials, of which about 25,000 tonnes are used for various types of pipe (for example drain pipes, electrical pipes, guttering), 5,000 tonnes for window frames and just over 2,000 tonnes each for roofing and flooring. PVC is a hard material. Plasticizers are therefore added to it to make PVC plastic pliable and flexible. In some cases, PVC plastic contains as much as 60% plasticizer. The most commonly used plasticizers are the phthalates. Phthalates are generally considered to be undesirable due to their effects on health and the environment. Some phthalates have been shown to interfere with fecundity in experimental animals and to cause hormonal disturbances. Stabilizers and pigments containing heavy metals have also been added. (Bach et al., 2002)

Another issue of concern is wood preservation. The softwoods pine and spruce as the types of wood used in the greatest amounts for building in Denmark have only a limited natural durability when permanently exposed to humidity. Therefore much of the wood used is treated with chemical wood preservatives, either through industrial wood impregnation (vacuum or pressure impregnation) or by surface coating. Pressure-impregnated wood is mainly used in construction exposed to biodegradation, for example carports, fences, wall facing, etc.

It is estimated that about 3 million tonnes of impregnated wood have accumulated in Denmark over the past 50 years due to the use of such wood. Many of the impregnation agents developed contain active substances that are harmful to health or the environment. Examples are the chemical substances that contain the metals chromium, copper, tin or the formerly (in Denmark) approved arsenic oxides. Some of the tar products used in the past (creosote, etc.) also contain many substances harmful to health or the environment. Consumption of wood preservatives containing arsenic and chromium has declined markedly over the past 10–15 years due to a total ban on the use of arsenic, including arsenic-treated wood, and a ban on the impregnation of wood with chromium based agents in Denmark. However, much of the hazardous substance and heavy metal content is still present in the wood when it ends up as waste for incineration or land-fill. Moreover, although now banned, arsenic and creosote may be present in old impregnated wood. Following incineration or landfill, the hazardous substances in the wood can enter the environment. (Bach et al., 2002)

Local environment

Another important environmental issue is the question of land use and impacts on habitats and soil functions, among them groundwater formation. As Europe is the third most densely populated area of the world's major regions its land is intensely used.

'Major ongoing pressures include urban sprawl and the expansion of transport infrastructure to accommodate rising levels of traffic. These have resulted in the sealing of soil surfaces, the fragmentation of habitats and the loss or disturbance of natural areas.' (European Environment Agency, 2002)

In the past 20 years urban populations in Europe have increased at twice the overall rate of growth (40% rather than 20%). Migration from rural to urban areas, abandonment of developed land within many cities as a result of industrial decline and increase in space use per capita has led to increased urban expansion.

'In Germany, for example, total land take for built-up areas, including transport infrastructure, increased from 350 m^2 per person in 1950 to 508 m^2 per person in 1999 and the average area for living increased from 15 m^2 per person in 1950 to 38 m^2 per person in 1995. ' (Dorsch et al., 2000). […]The pattern of low-density expansion of large urban areas into surrounding agricultural and natural areas is defined as urban sprawl, and is illustrated below [by the development around Copenhagen].' (European Environment Agency, 2002).

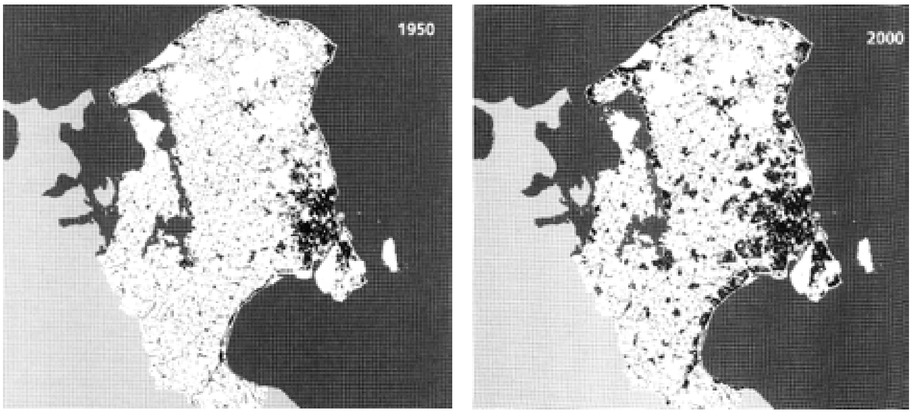

Figure 17: Development of the built-up areas (marked black) in the Copenhagen region from 1950 to 2000 (found in (Bach et al., 2002))

In Denmark as a whole the urban area has grown by 300 to 400% over the past 50 years.

'Although the percentage of the country accounted for by the urban zone is still modest (6%), there are considerable regional differences at county level in the relative distribution between urban and rural zones. In Greater Copenhagen, for example, the urban zone accounts for 23% of the total area. The corresponding figure for Copenhagen County is 46%.' (Bach et al., 2002)

One effect of urban sprawl is the rapid increase in soil that is being sealed. In Germany, for example, every year 235 000 000 m^2, an area half as big as the Bodensee, the country's biggest lake, is sealed. A total of 12% of the country's surface is covered with waterproof material (Vorholz, 2002). Sealed soil loses vital ecological functions: Precipitation cannot infiltrate and contribute to ground water formation. Sealed surfaces usually absorb more solar heat, which contributes to undue warming, while green areas cool through evaporation. And sealed soil is dead soil in the sense that it expels most flora and fauna and thus reduces local biodiversity.[115] Biodiversity can also be affected by the increased need for transport infrastructure that goes along with urban sprawl, as

'The construction of transport infrastructure can lead to the fragmentation of natural or semi-natural areas, which can reduce the resilience of biotopes and their capacity to host wild species. This, in turn, can disrupt the movement of species (for example through the elimination of 'wildlife corridors' and reduce the capacity of the habitat to maintain viable resident species populations.' (European Environment Agency, 2002)

[115] The fact habitat destruction threatens many species with extinction has raised awareness of the value of biodiversity. As Botkin and Keller (Botkin et al., 2003) point out, the wish to protect biodiversity can originate from various kinds of values with regard to living organisms: *'Ethical: The fact that they are alive; aesthetic: their beauty and the rewards humans derive from their beauty; economic: the direct and indirect ways in which they benefit humans; ecological: their contributions to the health of the ecosystem; intellectual: their contributions to knowledge; emotive: the sense of awe and wonder they inspire in humans; religious: having been created by a supernatural being or force; recreational: sport, tourism, and other recreations'*

Relation to buildings
Buildings can contribute to the environmental pressures described above in different ways and to varying degrees. The siting of a building can (in the context of the settlement layout) influences how much land is used for access roads and transportation systems in general. Here the way in which transport facilities like access roads, parking lots etc. are constructed makes a difference: While some materials (like asphalt or large concrete slabs) seal soils almost completely, others (like gravel or different kinds of paving) are water permeable. A newly erected building's impact due to soil sealing also depends on characteristics of the building site: if a building is built on solid rock or on the foundations of an antecedent building its environmental impact due to surface sealing may be close to zero; if it is built upon a valuable habitat or an ecologically relevant geological formation it may have a significant negative impact. Apart from its siting, the design of a building also influences its effects on the local environment: Densely built buildings with multiple storeys use less land than detached houses, and a building's design features (such as greened roofs and facades or other biotopes created by the building) can compensate for some of its negative impacts on the environment.

Besides the land use directly caused by buildings and the related transport infrastructure there are also corresponding effects due to a building's consumption of energy and materials:

The extraction of fossil fuels and the mining of uranium for nuclear power also bring about land use of different scales. In Germany, for example, open cast brown coal mining led to the destruction of several villages. Also renewable energy sources have impacts on the local environment:

> *'Windmills can, besides negative effects on the landscape, cause noise problems.[116] With regard to biomass it is discussed, if the soil's quality as a medium of cultivation deteriorates, when the straw is removed from the field for use as bio-fuel instead of letting it decompose on the spot. Hereby the carbon content in the soil is reduced.' (Bach et al., 2002) [author's translation]*

Similar to energy consumption a building's material consumption can cause negative land-use changes, for example due to ore mining or gravel mining, which can destroy local habitats. However, also new ones, for example quarry lakes, may come into existence.

Indoor climate

Introductory remark
'Indoor climate' as an environmental issue differs from the other environmental issues. The environmental issues mentioned so far have to do with the functioning of the ecosystems surrounding us. The concern for indoor climate on the other hand originates directly from an anthropocentric viewpoint. It is mainly about human health in the artificial environment inside buildings. 'Health' is here understood in the broad definition of the World Health Organisation, which includes human comfort and well-being.[117]

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[116] In Denmark promotion of renewable energy became a governmental policy in 1991 and the wind generator industry grew by some 40% each year from 1995 to 2000. In 2000, wind power generated ca. 13% of the electricity consumed. (European Environment Agency, 2001)

[117] This broad definition reflects that many indoor climate parameters can be sources of serious discomfort and annoyance without actually causing illness.
It is admittedly a simplification to mention only 'health' as the purpose of indoor climate. Nilsson e.g. identifies as the main purposes of indoor climate
– human comfort
– human health
– productivity

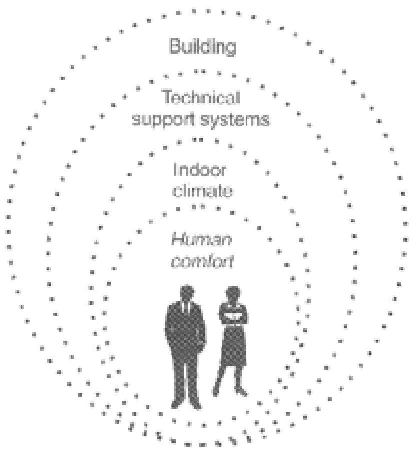

Figure 18: Human comfort as the focal point of the indoor climate of a building and its technical support systems (Nilsson, 2003)

It is the very meaning of a building to *create* an indoor climate. Accordingly it is debatable, whether 'indoor climate' should be included at all in *environmental* indicators, since assuring a good indoor climate should be an integral part of *any* building process and not a subject of environmental policy[118] (I describe different actor-views on this matter in more detail in the sections on the technological frames of the chapter 'Indicators in a social constructivist perspective'). In accordance with the social constructivist approach of this study, however, tribute is paid to the fact that indoor climate *is* considered a very important environmental issue by many actors. Therefore the subject is described in the following from a scientific perspective.

As for the external environment (compare Figure 10 and Figure 11) also for indoor climate causal networks of constructional choices, and consequences at several levels can be identified:

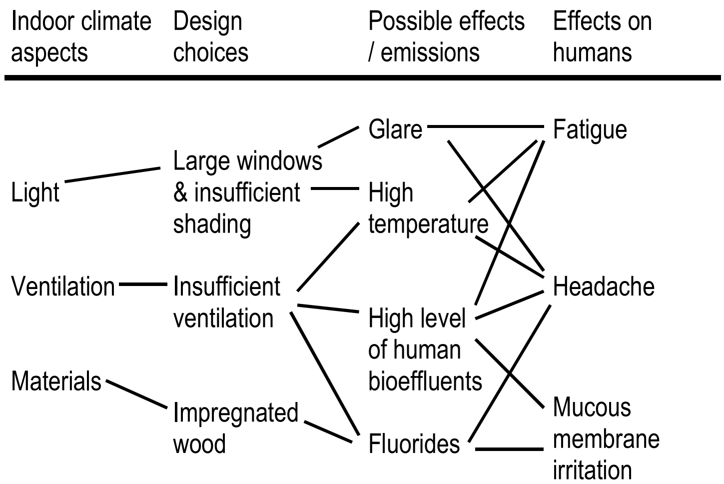

Figure 19: Examples of causal relations of indoor climate aspects (based on (Valbjørn et al., 1990)[119 120]

– products and processes requiring specialised indoor environments (e.g. surgery, keeping food and beverages fresh or producing microelectronic components). (Nilsson, 2003)

As this study does not deals with industrial buildings the last point is not relevant here.

[118] Neither the environmental assessment report of the European Environment Agency (European Environment Agency, 2002) nor the report by the Danish National Environmental Research Institute 'The State of the Environment in Denmark 2001' (Bach et al., 2002) explicitly address indoor climate. This underlines that its authors did not consider 'indoor climate' a subject of general environmental policy.

[119] *'mucous membrane: an epithelial tissue lining many body cavities and tubular organs and secreting mucus.'* (Oxford Compendium, Ninth edition).

In the scientific literature referred to in this section, indoor climate aspects are measured mainly

- at the level of human symptoms,
  where complaints are registered (and statistically evaluated, as complaints can principally also be caused by factors not related to the building) and
- at the level of technical measurements,
  where concentrations of gases, particles, substances are registered as well as the parameters of temperature, moisture, air change rate, noise, but also occurrence of mould and house dust mites.

Aspects of indoor climate

Indoor climate is multifarious. The following scheme gives an overview of the primary physical[121] indoor climate parameters:

Table 9: *'the primary physical climate parameters'* according to (Nilsson, 2003) and (Laustsen et al., 2000)

aspect	**parameters**
Thermal climate	Air temperature Relative humidity Temperature of surrounding surfaces Air movement
Indoor air quality	Content of pollutants (for example particles, chemicals) Smell
Light	Illumination Contrasts Glare Composition of the light View Daylight
Sound	Sound level Noise Reverberation time

In what follows, these four parameters are explained in more detail. At the end of each section the main characteristics influencing the different indoor climate parameters are described.

Thermal climate

A main characteristic of a building is that it provides an air temperature, which meets human requirements better than the outside weather. *Which* air temperature is perceived as comfortable depends on factors like the kind of activity and the resulting metabolic rate of the human body, the clothing and personal habits.

> *'Since humans are warm-blooded, they have a very powerful temperature regulation system. The human body will strive hard to maintain a temperature of 37°C in the core of the body, and it has several mechanisms to do so.'* (Gunnarsen, 2003)

[120] Human symptoms of indoor climate problems, of course, can lead to lower work efficiency, discontent with the workplace and absence due to illness. This corresponds with the fact that indoor climate is considered an important environmental issue by several actor groups, as I document in detail in the chapter on the technological frames.

[121] Besides the *physical*, there are also psychological parameters influencing the perceived indoor climate and human comfort, like e.g. aesthetical aspects or content with work and colleagues. (Valbjørn et al. 1990) However, as mentioned in the introduction, these are not within the scope of this study.

The indoor air temperature should be favourable to the body's efforts. For office and housing buildings in Denmark this means the air temperature should preferably not be lower than 20°C in winter and not above 26°C in the summer. These margins, however, require appropriate clothing. (International Organisation for Standardisation, 1984)

Air temperature is an important, but not the only crucial factor for thermal comfort; the relative humidity of ambient air determines, how effectively the human body can use evaporation of sweat for cooling. High air humidity prevents the sweat from evaporating.

> *'As may be seen, this is not very important at low activity levels and temperatures, where active secretion of sweat is limited. For sweating persons exercising heavily and/or at high temperatures, the impact of the partial pressure of water in the surrounding air becomes increasingly critical.'* (Gunnarsen, 2003)

The temperatures of surrounding surfaces can cause problems, when they differ too much. Temperature sensors near the surface of the skin are spread all over the body. They can sense, if parts of the body are exposed to heat radiation from a hot surface or if a cold window increases the heat loss by radiation from the body, both of which are unpleasant thermal sensations.

Air movement also influences thermal comfort. Strong air movement increases cooling by convection and by evaporation of sweat. In hot surroundings this may be a desired effect, for example provoked by the use of fans. If it occurs unintentionally, air drafts are a common cause of local thermal discomfort.[122]

Relevant building characteristics

Relevant building characteristics for achieving a comfortable air temperature are

– the building's heat insulation,
– the building's air tightness,
– a heating system with sufficient heating power,
– the possibility to regulate the set points of the heating system, preferably individually,
– other heat sources: direct sunlight through the windows, the lighting system,
– provisions to avoid overheating by direct sunlight and from other heat sources (excess heat from machines, lighting, humans): shading devices, ventilation, air conditioning, and
– the building's capacity to store heat in heavy building elements.

The relative humidity in a building is influenced by

– the strength of the indoor sources of moisture (for example cooking, showering, humans),
– the building's capacity to remove moisture from indoor sources: draining of kitchen and bathroom, ventilation to remove humid air (for example from humans, cooking, cloth drying),
– the building's capacity to keep outside moisture away from the inside, that is, the performance of the building's water barriers (roof, walls, foundation) and draining systems,
– the capacity of building materials to take up moisture, and
– the heating system, warming the indoor air, thus increasing the air's capacity to take up moisture from building materials and other sources.

[122] There are indications *'that dissatisfaction due to draft is not only caused by local cooling but also by fluctuating air velocities resulting in ever changing thermal sensations.'* (Gunnarsen, 2003)

The temperature of surrounding surfaces depends on

– the generation of heat,
– the heat insulation of the building elements,
– the distribution of heat sources in the building and
– the building elements' capacity to store and conduct heat of the building materials and building elements.

Air movement is influenced by

– the air tightness of the building,
– the location, performance and regulation of the ventilation system and
– temperature differences in the building, thus of the location, performance and regulation of heat sources and of the temperatures of surrounding surfaces. In particular, vertical cold surfaces such as windows may create a down draft due to buoyancy differences between warm and cool air.

Indoor air quality

> *'The concept of indoor air quality is used as a general denomination for the cleanliness of indoor air.'* (Nilsson, 2003)

Indoor air can be polluted by a wide variety of pollutants from different sources, with different potential effects on comfort and health. Table 10 gives some examples of pollutants and potential effects:

Table 10: Examples of common indoor air pollutants, sources and potential effects (Sources: (Valbjørn et al., 1990), (Nilsson, 2003)

pollutant	**source among others**	**potential effect**
phthalates	plasticizer	mucous membrane irritation
fluorides	impregnated wood	mucous membrane irritation headache
human bio-effluents (for example sweat, methane, acetone)	people	fatigue headache
carbon monoxide[123]	tobacco smoke unexpected combustion exhaust gas from automobiles	fatigue headache
ozone	copying machines outdoor air	mucous membrane irritation
radon	soil and rock building materials	cancer
organic biological dust (for example allergens)	pets house dust mites (residence) mould	asthma, allergy fatigue, eczema reduced lung function

> *'The severity of a pollutant in terms of its effect […] depends on the concentration and the time interval during which the exposure takes place.'* (Nilsson, 2003)

As with other indoor climate aspects also with regard to indoor air quality there are large differences between the sensitivity of individuals.

[123] Carbon *dioxide* normally (that is in the concentrations normally occurring) not a problematic pollutant in itself, but commonly used as an indicator for the concentration of human bio-effluents, which are the cause of fatigue and headache. (Source: interview with Lars Gunnarsen, senior researcher at DBUR)

Relevant building characteristics
Relevant factors for the cleanliness of indoor air are on the one hand the sources of pollution, and on the other hand the ventilation rate which can dilute polluted air with fresh clean air[124].

As shown in the above table, indoor air pollutants can originate from outdoor sources and from indoor sources. The existence of outdoor sources of pollution (for example traffic, agriculture, industry, radon or dust from polluted soil) depends on *where* the building is located and how well its construction and technical equipment protect the indoor air from these pollutants.

Another important source of pollution are building materials containing problematic substances. Pollutants from building materials get into indoor air through offgasing or through physical impact (for example rubbing off and air movement carrying fibres and particles into the air). Accordingly their impact on indoor air quality also depends on *how* they are integrated into the construction and how easily pollutants emitted from them come in contact with indoor air. Even if a building material is not a source of pollution itself, its physical characteristics can have an impact on indoor air quality:

– how well a surface can be cleaned
– if a material attracts dust because it is electrically charged
– how favourable a living environment it is for house dust mites
– how well it tightens the building against intrusion of pollutants from the outside (for example radon from the ground or chemicals from neighbouring laundries diffusing through foundations and walls)

The occurrence of organic pollutants like metabolic products of house dust mites and mould strongly depends on the humidity in the building, on which the respective parameters mentioned above in the subsection on 'thermal climate' have an impact. (Laustsen et al., 2000)

Light
Another important factor influencing human comfort in an indoor environment is light[125]. Apart from factors on the side of the human perceiver of light (such as mood or vision), generally accepted aspects of the quality of the light environment are, according to (Nilsson, 2003)

– how the overall magnitude of the illumination (abbreviated 'E'), corresponds to the needs of the human users. The need for light can of course vary in accordance with the human activities: sleeping, different kinds of work or social activities each demand specific light conditions for human comfort. The overall illumination depends of course on the available light sources. The 'amount of light' emitted by these light sources is called 'Luminous flux'[126], the magnitude of emitted light reaching the viewer is called 'Luminance'[127].
– contrast, that is the differences in luminance between objects within a field of vision. Luminance contrasts need to be kept low enough to avoid → glare.
– glare, that is, the
  'discomfort due to a reduced ability to see details or objects, caused by an unsuitable distribution or range of luminance, or extreme contrasts'
  (Dubois, 2001)

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124 Dilution, however, is not a sustainable solution as the sources of pollution still remain in place and the pollutants may cause harm in the outdoor environment, too. A sustainable solution would be to remove the sources of pollution.
125 In the context of this study 'light' means the visible electromagnetic radiation when it is perceived by the eye and interpreted by the brain.
126 Luminous flux is the energy of light emitted by a light source per unit time; the SI (The international system of units of measurement (from French 'Système International')) unit is lumen, abbreviated 'lm'.
127 Measured in the unit *candela per m2 (cd/m2)*

– the composition of the light, comprising the colour rendering and the colour of the light. The colour rendering, that is how the different colours of the spectrum are represented in the light, is important, because it determines our perception of the colour of objects. Many activities, for example in hospitals, museums or the graphic industry require colours to be perceived 'correctly', while in other places, for example in theatres or discotheques, 'unrealistic' colour effects are desired.
  The 'colour of the light' determines if we perceive light as 'cold' (for example daylight at noon, light from halogen lamps) or 'warm' (for example candlelight) and has a psychological impact. 'Warm' light is more in the reddish part of the spectrum, 'cold' light more in the bluish part.
– flickering (for example of damaged fluorescent tubes), which is a widespread source of annoyance.
– the view. Most people prefer work places close to a window and with a view out, while rooms without view can be perceived as uncomfortably enclosed.
– daylight is important in terms of light quality because it is essential for human comfort to be able to perceive the daily rhythm of shift between night and day. The changing composition of daylight in the course of a day reflects this daily rhythm. Daylight also has an excellent colour rendering, permitting to see the 'natural' colours of things. Finally, daylight from windows is diffuse light, which also is a favourable characteristic for most activities. A good light environment should therefore contain a certain amount of daylight[128]. The share of daylight is expressed in the 'daylight factor', defined as the ratio of the illuminance (at a point on a given plane) due to the light received directly or indirectly from the sky (the contribution of direct sunlight is excluded) (Dubois, 2001).

Relevant building characteristics

Relevant building characteristics for the light environment in a building are

– placement, quantity and quality of the artificial light sources
– placement, quantity and quality (for example glass colour) of windows, daylight distribution devices (such as reflectors) and shading devices
– the possibility to regulate the light conditions, preferably individually.
– the building's orientation with regard to the sun
– the building's location, determining the availability of daylight at this location, which is influenced by, among others, geographical latitude, vegetation, neighbouring buildings and topography.

Sound

A core characteristic of any good indoor sound environment is the absence of noise (defined as unwanted sound). What is perceived as noise, however, is very subjective;

> *'A given sound may be perceived as pleasant by some people, while others perceive it as noise. Music is an example of this.´ (Nilsson, 2003)'*

> *Disturbance due to sound is not necessarily associated with high sound levels.' (Nilsson, 2003)'*

The dripping of a tap is an example of a sound that can be very disturbing, though it is not very loud.
Noise in buildings originate from different sources, such as

[128] The daily shift in the composition of light occurring in daylight can also be produced with artificial light sources. The fact that the Danish Building Code contains requirements for daylight factors in buildings thus originates not only from the wish to assure comfortable light conditions but also from the wish to limit energy consumption for lighting.

– noise from outdoor sources (such as traffic), penetrating the building envelope
– noise transmitted from one part of the building to another, for example music, walking, etc.
– noise from building services such as fans, radiator valves, etc. (Nilsson, 2003)'

Noise can be transmitted to the receiver directly through air. It can also be reflected, for example at walls or ceilings, or be transported through the building structure in form of vibrations. These vibrations may again generate airborne sound, but they can also be perceived as vibrations and be a source of disturbance themselves.

What may be considered 'a good sound environment' depends on the function of the building: a meeting room, for instance, should allow all participants to hear each other without problems, while a lecture hall should primarily allow the audience to hear the voice of the lecturer. Besides the absence of noise and the provision of adequate sound levels the *reverberation time*[129] is a key parameter for the sound quality of a room.

> *'The reverberation time is determined as the time required for the sound pressure to fall to 1/1000 of the initial sound pressure. This corresponds to a decrease of the sound pressure level by 60 dB.' (Nilsson, 2003)*

Simply said, the reverberation time is an indicator for how fast the power of the sound waves is reduced in a room. If the reverberation time is very long, sound waves can be reflected again and again, reaching the receiver several times - a phenomenon know as 'echo', which can occur in large rooms with very hard wall surfaces. Long reverberation times are usually wanted in rooms for lectures or concerts (such as cathedrals, concert halls or lecture halls). A room with soft surfaces, on the other hand, 'swallows' the sounds and is suitable for, for example, meeting rooms, where several people or groups talk in parallel.

Relevant building characteristics

Relevant building characteristics influencing the indoor sound environment are

– the building's siting with regard to external sources of noise (for example traffic, industry)
– the building's insulation against noise from external sources
– the acoustic characteristics of the indoor building materials and the composition of building elements (for example sound insulation between rooms, sound absorbing characteristics of surfaces)
– the geometry of the building's rooms and the placement of acoustic elements (such as sound absorbers or sound reflectors)
– the position of internal sources of noise in the building with regard to different functions of the building (for example separation of noisy and quiet kinds of work, social activities and resting).

Concluding remarks

The above description of environmental effects of buildings showed that buildings contribute to a broad spectrum of environmental effects. From the environmental scientific point of view it is therefore not justifiable to use a single aspect, for example 'energy consumption' as a representative indica-

[129] *'The reverberation time is determined as the time required for the sound pressure to fall to 1/1000 of the initial sound pressure. This corresponds to a decrease of the sound pressure level by 60 dB.'* (Nilsson, 2003)

tor for a building's total environmental performance. Instead, seen from the scientific perspective, environmental indicators for buildings should cover all the environmental issues listed in Table 7, that is

- Energy and related emissions,
- Material consumption and waste,
- Water and wastewater,
- Hazardous substances, and
- Local environment.

The inclusion of 'indoor climate' is controversial but within the scope of several scientific studies on environmental indicators for buildings.

Decision-making situations

Environmental indicators for buildings shall foster the consideration of environmental aspects in the decision making in the course of a building's life cycle. This chapter describes the three decision-making situations (DMS) addressed in this study,

1. the siting of the building
2. the building design
3. the use and renovation of the building,

It answers the questions relevant for the design of EIFOB with regard to decisions:

– *Which environmentally relevant decisions are taken?*
– *What is the environmental relevance of this?*
– *Which data are available in the DMS to support environmentally conscious decisions?*

and decision-makers:

– *Who decides what?*

The description of the decision-making situations provides a basic structure for the other research tasks by establishing a consistent nomenclature for where in a building's life cycle we are, thus facilitating a transparent discourse on EIFOB.

Introductory remark
As mentioned in the chapter 'Research design' the demarcations of the study with regard to the decision-making situations were defined progressively in the course of the project. A precise definition and in-depth description of the decision-making situations was not the focus of this study. Instead, it was characteristic of the qualitative interviews' guidelines that they provided only a rough pre-definition of decision-making situations and gave the actors the opportunity to choose the focus of their statements themselves (within the overall limits of the subject). Accordingly, the nomenclature used in this chapter may have some softer edges than would be the case in a study that had focused more on DMS. As this does not affect the validity of the outcomes of this investigation, I consider this imprecision justifiable.[130]

The structure and the contents presented in this chapter are the result of own reflections and the study of relevant literature on the one hand *and* of the actor statements on the other hand:

Of the questions addressed in the following sections the answers to

– *'Which environmentally relevant decisions are taken?'*
– *'What is the environmental relevance of this?'*
– *'Which data are available in the DMS to support environmentally conscious decisions?'*

are written mainly on the basis of literature studies and own reflections from an environmental scientific perspective. The description of the environmental

[130] Apart from the order 'siting – project design – renovation' followed in this chapter the order of the decision-making can of course be different in specific projects (for example with the project already designed when the location is chosen). Here, however, I found it most useful to develop this chapter around the usual sequence of decisions.

relevance of the decisions taken follows the same order of environmental issues as employed in the chapter ‘Environmental effects of buildings’.

The question

– *‘Who decides what?’*

is answered on the basis of own reflections *and* interview results, describing *general patterns* (concrete cases may deviate considerably from these descriptions - for example with urban planners from local building authorities being deeply involved not only in the siting, but also in the project design as the ‘next’ decision-making situation’).

General reflections

It facilitates the understanding of the following sections to keep some general reflections in mind:

‘The building’ as the focal unit

The indicators in the scope of this study shall in the first place serve to describe *buildings* and their environmental characteristics. This implies a certain perspective on the decision-making situations: a perspective with the *building* as the focal point. To illustrate this: an urban planner focuses on the development of the municipality plan and the local plan – plans, which of course have very important environmental implication for the building that is or will be located in the plan’s area. Thus, the urban planner may be interested in having environmental indicators for municipality plans and local plans. The environmental aspects that would be comprised in these indicators are certainly also relevant for buildings. A study on environmental indicators *for buildings*, however, has to keep focused on *the building* as the central unit. So, seen from a ‘building-centric perspective’ the first decision-making situation in the life of a building is not ‘the development of the municipality plan‘ or ‘the development of the local plan’ but *‘the siting of the building’*, the decision, *where* the building (to be built or to be altered to serve its purpose) shall be located. It are, however, the *infrastructure parameters* of the chosen location that influence the building’s environmental profile in this phase – that is: parameters that are decided upon in the development of the municipality plan and local plan. Both spheres of decision-making are closely related, but for the sake of clarity they are distinguished in this study.

The Danish building legislation

As the descriptions of the decision-making situations further below show, the building legislation is not only an important element in the broader decision making environment of the planning process in general but also touches the decision-making situations in the scope of this study at some points in spite of the fact that a ‘building-centric’ viewpoint has been taken as described above. Therefore the main elements of the Danish building legislation as well as ongoing European developments relevant for the subject of this study are summed up in the appendix and are referred to in the following text.

Data availability

Indicators can only be as reliable as the data they base upon. Which indicators can be used in which decision-making situation also depends on which data are available in different stages of a building’s life cycle. Figure 20 gives an overview of the available data in the three DMS. It shows that

– the amount of available data increases from the siting to the renovation,
– in the siting *specific data* is available only about the building site. The (not yet designed) *building* can only be described on the basis of statistical average data.

– in the course of a building's life cycle more and more *specific data* about the building in question becomes available.

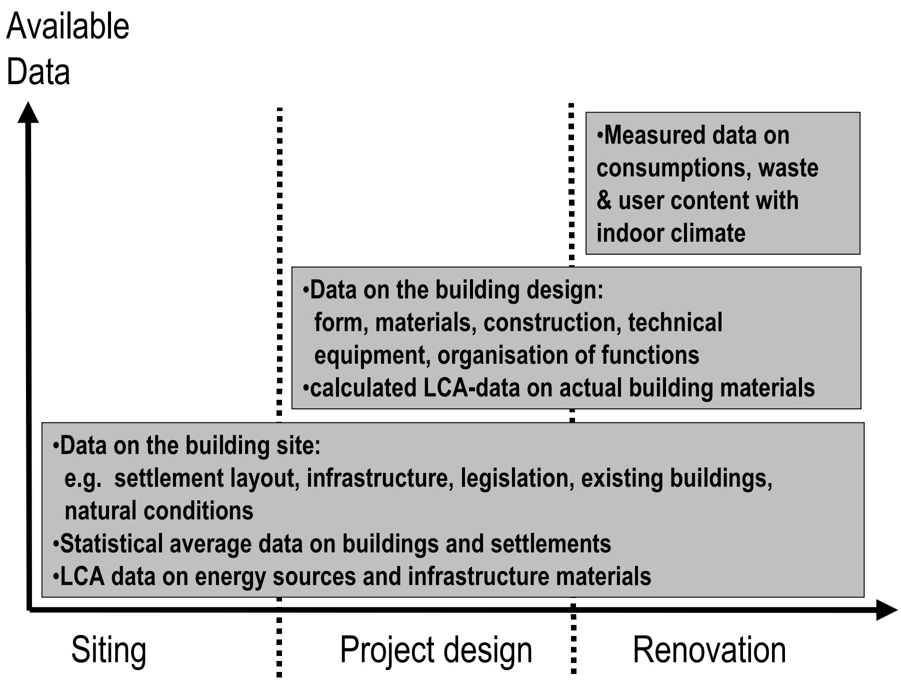

Figure 20: The amount of available data increases in the course of a building's life cycle

Siting of the building

Where a building is situated affects its environmental performance in many ways. A building, equipped with cutting edge environmental technology but placed at an unfavourable location, can, for example due to implied commuter transportation or habitat destruction, cause more severe environmental damages than an average building built in a environmentally favourable place. Regardless whether the building is already in existence or in the stage of planning it is therefore desirable that EIFOB take the building's siting into account.

As mentioned in the introduction of this chapter I mainly take a 'building-centred' viewpoint in the description of the DMS. However, as several of the interviewees' statements concerned the DMS 'planning of settlements' I also touch this DMS at some points.

The following description of the DMS 'siting of the building', however, mainly refers to the scenario of a client who wants to build a new building[131] and has to chose a location *in Denmark*[132].

Environmentally relevant decisions

Given the scenario of a client wanting to build a new building the environmentally relevant decision taken is

[131] This is certainly only *one* of many possible scenarios at the beginning of a building process (other scenarios are e.g. a client considering whether to erect a new building, to renew or to alter an existing one or to choose a solution combining both options. To investigate all these scenarios would exceed the boundaries of this study. The three 'elementary' DMS 'siting', 'project design' and 'use and renovation' described in this chapter, however, should principally allow the reader to extract information that is also valid for other constellations of DMS. Thus the scenario of a buyer-client searching to buy and possibly renovate an existing building can be interpreted as a combination of the two 'elementary' DMS 'siting' and 'renovation'. And a combined alteration and renovation of a building can be interpreted as a combination of the DMS 'project design' and 'renovation' and so on.

[132] As mentioned in the chapter 'Introduction', the geographical scope of this study is Denmark. If the choice was between locations in different countries the environmental implications of (among other things) local climate conditions would have to be considered.

'Where to place the building and how to place it on the site?'

The environmental implications of this decision depend on the characteristics of the chosen building site. Here *natural* and *human-made* site characteristics can be distinguished:

First, there are *natural characteristics of the site*, such as the latitude, topography, trees, habitats, wind conditions, geological composition of the ground etc.. All these have implications on one or several environmental issues (the topography and trees, for example, on the potential for use of solar energy, the wind conditions on heat losses due to convection and geological composition of the ground on the use of building materials, the occurrence of radon and other pollutants and the potential for use of geothermal heat). Some of these natural characteristics are definitely impossible to alter (the latitude), some can only be altered to a small extent and with great efforts (for example the topography or the geological composition of the ground) and others are relatively easy to alter (for example the vegetation).

Secondly there are *human-made characteristics of the site*. These can be of a *primarily physical nature*, as is the case with neighbouring buildings, existing technical infrastructure for water, transport (for example roads and railways) and energy supply (for example a district heating network) or of a *primarily organisational nature*, as is the case with the legal system applying to the site (for example the local plan and its contents), the way public transport is organised (frequencies, fares) and the waste treatment system applied to the site.

Which of the site characteristics are fixed beforehand and which still need to be decided upon or are open to alteration differs from case to case. In general, however, physical site characteristics are more long-lived and more difficult to alter than organisational characteristics.

The following table gives an overview of the environmentally most relevant aspects in the DMS 'siting of the building' (the explanatory concretizations in this and the subsequent tables are *examples* and not meant as a complete list):

Table 11: the environmental relevance of the DMS 'siting of the building'

Environ-mental issue	Aspects	Explanatory concretization (examples)
Energy & related emissions	Which energy sources?	Different energy sources (for example district heating, decentralised power plants using different kinds of fuels) have different environmental implications. Several site characteristics (for example shade of buildings / trees / terrain, or the local plan prescribing a certain positioning of the buildings) play a role for the potential for use of solar and thermal energy on the site.
	Energy embodied in material for the building's infrastructure supply	For example access roads, energy supply infrastructure, wastewater system. Possible constellations are: infrastructure is already in place infrastructure needs to be built from scratch different combinations of these
	Layout of the settlement	The layout of the settlement influences the buildings' heat demand. Relevant factors are density (detached houses / terrace houses /multi-storey blocks) common facilities, e.g. laundries, party rooms, kitchens[133]
	Energy management	The energy management system of the location can influences the energy demand in the use phase. Example: consumption displays for the settlement[134]
	Induced transport (to work and to other facilities)	Different transport modes (cars, public transport, bicycles, walking, …) differ significantly in energy consumption. The settlement layout can foster and hinder certain modes of transport (e.g. by good facilities for cyclists, pedestrians and public transport and unfavourable facilities for cars)

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[133] Common facilities, e.g. laundries, are relevant for the consumption of energy embodied in the material for the facilities and for the consumption of energy for their operation; the technical equipment of a laundry can more easily be maintained and upgraded than a multitude of single washing machines in private households.

[134] To raise awareness on energy consumption (Jensen, 2003) and to avoid peak consumptions (can be relevant for small decentralised combined heat and power plants).

Table 11: the environmental relevance of the DMS 'siting of the building' continued

Environ-mental issue	**Aspects**	**Explanatory concretization (examples)**
Material consumption & waste:	Which waste processing system (for household waste) is in place on the side?	reuse recycling incineration disposal in landfills different combinations of these
	Layout of the settlement	common facilities, e.g. laundries, party rooms, kitchens[135] facilities for reuse and recycling exist in the settlement (e.g. a 'swap shop' for clothes, a waste separations station, composting facilities)
	Material consumption for supply infrastructure for the building (e.g. access roads, energy supply infrastructure etc.)	Possible constellations are: infrastructure already in place infrastructure needs to be built from scratch different combinations of these
Water + wastewater	Consumption of drinking water	separation of different categories of water water saving facilities (e.g. vacuum/composting toilets, use of rainwater)
	Treatment of wastewater	regaining of valuable nutrients (e.g. urine separation, decentralised sanitation systems (e.g. a reed bed system) centralised sanitation systems
Hazardous substances		hazardous substances in materials for infrastructure (e.g. PVC-tubes)
Local environment:	Land use Local habitats Ground water formation	creating new habitats destructing habitats surface sealing facilities to foster infiltration
Indoor climate:	Thermal climate	daylight conditions at the site (possibilities for use of solar energy for warming, local outdoor temperature wind conditions at the site (wind removes heat from the building) vegetation (trees cool outdoor air)
	Indoor air quality	outdoor sources of pollution (e.g. traffic, industry, agriculture, radon)
	Light	daylight conditions at the site (shadows from trees/buildings, topography, orientation towards the sun)
	Sound	sources of outdoor noise (e.g. traffic, industry)

[135] Common facilities, e.g. laundries, can reduce the consumption of material as they can provide the same *service* ('washing the clothes') as individual solutions ('each household has its own washing machine) with the use of less material for machinery, as the washing machines in the common laundry are used much more intensely (and usually also built more robustly to stand intense use).

Data availability

As indicated in Figure 20, the data available in the DMS siting principally are

- statistical average data on buildings and settlements,
- LCA data on energy sources and infrastructure materials and
- data on the building site, such as on the settlement layout, the existing infrastructure, legislation, existing buildings, natural conditions.

While the first two kinds of data can principally be made very easily accessible in the form of databases, it may require an extra effort (for example in the form of measurements or plan analysis) to obtain specific data on the building site.

Concerning the different environmental issues, qualitative data on energy (such as 'Which source of energy?') and quantitative data on energy is comparatively easily available. To calculate the energy embodied in infrastructure material on the basis of material quantities extracted from plans and maps and LCA-databases is more demanding. Also for settlement layout, possible energy management systems and induced transport qualitative data is at easier to obtain than quantitative data. However, computer tools can significantly facilitate the calculation of site-specific quantitative figures or offer qualified statistical approximations.[136]

For water and wastewater data is comparatively easily available.

For material consumption and waste as well as well as for hazardous substances LCA-databases exist, but are used primarily by a limited number of experts. To define site-specific quantities of construction materials is time-consuming.

Data for the assessment of the local-environment parameters land use, local habitats and ground water formation has already been made available as part of the legally obligatory environmental assessments prior to the issuing of the local plan.

Qualitative data on the site's characteristics relevant for indoor climate can be collected rather easily while *quantitative* data usually requires costly measurements.

Who decides what

The prominent actors in this decision-making situation are the local building authorities, the clients and the client consultants. Supported by the advice of consultants (consulting engineers and architects) it is the client who chooses the location for his or her building *among the available building sites*. Which sites actually *are* available and with which infrastructural characteristics is to a large extent determined by the local building authorities who have issued the municipality plan and the local plan prior to the clients' decision where to built.[137] The current Danish building legislation[138] does not permit making explicit environmental demands in local plans[139]. However, the local plan can contain numerous detailed legally binding demands with regard to the shape, the siting and the function of buildings, which indirectly also have an

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[136] The Dutch tool 'VPL' (in English 'Local Transport Performance') (van Hal et al., 2001) is a good example for tool that facilitates among other things the calculation of induced transport in early phases of urban planning (a closer description is given in (Dammann, 2003)).

[137] In practice, it may occur that local plans are changed according to client demands in order to attract investors. This problematic devaluation of local plans, however, is no issue here.

[138] For details see the sections 'The Danish building legislation' and 'Ongoing European developments' in the appendix

[139] At the conference 'Byøkologi i Lokalplanlægningen' ['Urban Ecology in Local planning', in Danish] held by the Danish Centre for Urban Ecology in May 2001 in Vejle, representatives from local authorities disputed lively with the speaker from the Planning department of the Ministry for Environment, requesting a reform of the Planning Act that gives local authorities the right to make environmental demands in the local plan, e.g. demand energy performance standards that go beyond the ones in the national building code.. The municipality of Stenløse even went so far to integrate environmental demands into a local plan without being entitled to do so by the National Planning Act (Mørck, 2001). In the end it had to give in to the national legislation.

environmental significance. When local authorities act as *sellers* of land the can make almost any environmental demand, due to the legal tool of *easements*[140]*.* The same applies to local authorities in the role of clients or when they give subsidies for social housing and urban renewal.

Summarising note

A building's siting has far reaching implications for the building's environmental performance, as it sets several definite margins for decision-making in later life-cycle stages. From the scientific point of view the system borders of environmental indicators for buildings should therefore reflect the environmentally relevant parameters of this decision-making situation.

Project design

After it has been decided in the siting, *where* the building shall be situated, in the project design the question *how* the building shall be designed and built is elaborated.

Environmentally relevant decisions

The environmentally relevant decisions in the project design are

– the design: the size and form of the building, the precise grouping of the buildings and the size, form, function and order of the rooms,
– the construction: which materials to chose, which dimensions, how to join them with one another,
– the matter-flow and the energy-flow technology: which technologies to use for the flows of materials and energy through the building in its use phase that provide the services requested by the buildings user[141]: water & wastewater, electricity, energy for heating, food + organic waste, other materials (for example paper & plastic) + bulk waste.

[140] In Danish 'servitutter', compare (Tophøj, 2001)
[141] To varying degrees some of these parameters may already be determined by the choice of the building's location, for example in the area of a local plan which prescribes the use of the municipality's wastewater treatment system.

The table below gives an overview of the environmentally most relevant aspects in the DMS 'project design':

Table 12: the environmental relevance of the DMS 'project design'

Environmental issue	Aspects	Explanatory concretization (examples)
Energy + related emissions	Factors influencing the building's energy consumption in the use phase	the detailed layout of the settlement (volume-surface ratio): detached houses / terrace houses / multi-storey blocks of different kinds construction of the building elements: air tightness, k-value shaping of the technical building equipment: lighting, ventilation, heating positioning of consumption displays (affects user behaviour) the zoning of the building (the rooms' positions in relation to each other)
	Energy consumption for production of the building materials ('embodied energy')	choice of construction choice of construction materials (e.g. new / reused / recycled, different amounts of embodied energy) choice of construction materials origin
Material consumption & waste:	Choice of construction and construction materials for the building	materials with different environmental profiles, e.g. new / reused / recycled material use of scarce or renewable resources local material or material from abroad composite 'sandwich' materials vs. separable components construction: different kinds of joints (screwed, nailed, glued) with different consequences for reuse / recycling
	Measures influencing waste generation and separation in the use phase	waste separation facilities in the building (e.g. ample space for different containers)
Water + wastewater	Impact on groundwater formation Consumption of drinking water	separation of different categories of water water saving facilities and installations (e.g. vacuum/composting toilets, use of rainwater)
	Production of wastewater	installations for storm water and waste water (separated or joint)
Hazardous substances		choice of building materials choice of construction (how tightly the hazardous substances are fixed in the construction)

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Table 13: the environmental relevance of the DMS 'project design' continued

Environ-mental issue	Aspects	Explanatory concretization (examples)
Local envi-ronment:	Land use Local habitats Ground water formation	creation of new habitats (e.g. on / under the roof, …) destruction of habitats surface sealing (actual area covered by the building and building-related facilities such as terraces and paths
Indoor climate:	Thermal climate	choice of materials (heat storage, temperature of surrounding surfaces) choice of construction choice of technical systems (ventilation, heating, cooling) heat from sunlight and shading devices choice of design (where are which materials and technical installations)
	Indoor air quality	choice of materials (offgasing, dust, house dust mites, fibres) choice of construction ('Can sources of pollution reach the indoor air?') choice of technical systems (ventilation, heating, cooling) design (location of sources of pollution and the ventilation system)
	Light	orientation of the building and of the rooms in the building design of artificial lighting daylight design (windows, shading, reflectors) colour and structure of indoor surfaces
	Sound	choice and positioning of materials choice of construction

It needs to be noted that many of the explanatory concretizations cannot be seen isolated and as relevant for only one environmental issue. Instead, they have implications for other environmental issues and other concrete design parameters. The use of thermal ventilation, for example, is relevant for energy and related emissions as well as for indoor climate and has consequences for the entire building design.

Data availability

In the project design the building is described in a very detailed way. Concrete data is now available, especially on which kind of materials is to be used and in which quantities and how the materials form the construction of the building. This data on the building design, including the specification of the positioning and orientation of the building and of the façade design as laid down in the technical drawings, allows to calculate the building's heat demand. The heat demand calculation can also consider the impact of solar energy and wind. On the basis of the material volumes extracted from the plans – the materials' environmental impact potentials assessed in a LCA, including hazardous substances and use of scarce resources. While a heat demand calculation is obligatory in the Danish building legislation[142] a LCA of the building project is additional work and still the exception. The specifi-

[142] For details see the sections 'The Danish building legislation' and 'Ongoing European developments' in the appendix

cation of the applied water installations permits to improve the quality of the water-consumption estimates on the basis of easily available product data.

Uncertainties remain in the field of the actual future performance of the building, as all the data on the consumptions in the use phase and on the durability of the building's components and the building itself can only be estimated on the basis of measurements from buildings already existing. Here the question of the transferability of data arises.

The anticipation of consumptions (of water, energy and materials) also raises the question, whether the best potential performance (occurring in the case of ideal user behaviour) or the worst potential performance (on the basis of worst-case user behaviour) or the average of the two should be used.

The project plans also provide qualitative data relevant for local environmental aspects as they indicate possible appliances in the building design respecting or fostering local biodiversity. Also with regard to indoor climate qualitative data on the employed technical installations and building materials are easily available. A scientific assessment of these data, however, requires additional work, though computer tools[143]can facilitate this.

Who decides what

The prominent actors in this decision-making situation are the project designers, the clients and the client consultants. The project designers (architects, often supported by engineers for specific (technical) aspects of the project design) develop a building design according to the client's wishes and the legal and the natural characteristics of the building site. In bigger projects the client is usually supported by client consultants, who advocate the client's demands in the negotiations with the project designers. The local building authorities have to assure the compliance of the project design with legal demands of the building legislation in general and of the relevant local plan. Thus several actors are involved in the decision-making. Nevertheless architects as the overall designers of the project play a key role, because the building's future environmental performance depends very much on their capacity to transform various abstract and often interdependent environmental demands into a concrete building.

Summarising note

In the project design the step from the abstract to the concrete is taken. 'Environmental indicators cannot built houses' and the environmental potentials of a location do not guarantee an adequate performance of a building. The project design can be seen as the narrow passage through which intention and potential have to be carried to become built reality. As the overall project designers architects have a major impact on how much of the environmental potential is carried through.

Renovation of the building

Once the building has been erected its use phase begins, understood as the time from its erection until its dismantling. In this phase changes in the building's substance occur in the course of renovations. 'Renovation' here means the process, in which the building or parts of it are made more fit for their purpose by repairing, rebuilding, adding, removing and replacing building elements and technical installations. In contrast to 'maintenance', which keeps the status quo, renovation usually signifies a more profound effort to increase the building's functional and aesthetical value by carrying out major changes, typically in a concerted action with a budget that exceeds mere maintenance costs. The significance of the notion 'renovation' ranges from projects, which are almost newly built buildings, reusing only a small fraction

[143] Such as the DBUR-developed programme 'BSim' (Wittchen et al., 2002)

of old building substance, to projects, which only comprise minor changes of the building.[144] A building renovation can be part of an urban renewal[145], comprising also changes of site characteristics, for example the conditions for different modes of transport or the energy supply of the block or the district. In this section on 'renovation', however, urban renewal is not regarded.[146] The environmental impacts imposed by the consumptions in the use phase depend to a great extent on the behaviour of the building's users as the significant variations of the consumptions in equal flats or houses measured in respective research projects prove (Jensen*,* 2003). However, as this study aims to describe the environmental performance of *buildings* and not of their residents, the following reflections maintain the focus on the *characteristics of the building* that have the potential of influencing the environmental performance in this phase. *Organisational measures*, such as the monitoring and comparative displaying of household consumptions, have proven to influence the users environmental behaviour (Jensen*,* 2003), but they are no *building characteristic*. Accordingly the implementation of organisational measures is not within the scope of the decision-making situation described in this section. Instead, the focus is on the *changes in the building's substance* (which does, for example, include the installation of new, more visible consumption meters). This being said, it has to be mentioned, that the monitoring and communicating of consumptions in the building's use phase, for example with the Green Accounting system of course plays an important role as the basis for the decision making in a renovation process.

As the below description shows, the DMS 'renovation' in many ways resembles the DMS 'project design'. The main difference between the two is that in a renovation many building characteristics remain (typically most of the construction) and only selected parameters are changed while in the project design the range of choices in is far broader. Nevertheless, the alterations carried out in a renovation can decisively change a building's environmental performance: new energy efficient installations in connection with a tightening and improved insulation can reduce a building's heat demand by more than a half. Considering that in 1999 only 8.1%[147] of the Danish building stock was built after 1990 while 41.4 % was built before 1960 (Danmarks Statistik*,* 1999) and that the energy consumption for heating of residential buildings has decresed from 760 MJ/m^2 for buildings built between 1940 and 1960 to 290 MJ/m^2 for buildings built between 1980 and 1995 (Hansen et al.*,* 2002) the societal significance of energetic renovation becomes clear.

Environmentally relevant decisions

The principal decision in the renovation is which alterations shall be carried out in the existing building. In concrete this affects the same aspects as in the DMS 'project design' even though the range of the decisions is smaller in the renovation, where only parts of the building are subject to change (compared with the project design where the building is planned from scratch):

– The design: the size, form, function and order of the rooms
– the construction: which materials to chose, which dimensions, how to join them with one another
– the matter-flow and the energy-flow technology: which appliances and which technologies to use for the flows of materials and energy through

[144] This is a somewhat rough definition of the notion 'renovation'. Especially when extraordinary cultural value is attributed to a building (e.g. to a historical building) different attitudes and objectives of the building alterations can be distinguished, for example 'restoration', 'renovation', 'conservation', or 'refurbishment'. To enter into this debate would, however, go far beyond the demarcations of this study.
[145] *'Urban renewal [is] the commonest designation for the renewal for towns and cities. Used in some contexts to describe renewal in general, in other contexts specifically about publicly founded renewal.]* (Danish Ministry for Housing and Urban Affairs 2001)
[146] Aspects related to urban renewal are dealt with in the section 'siting of the building'.
[147] Measured in m^2 storey area

the building that provide the services requested by the buildings user: water & wastewater, electricity, energy for heating, food + organic waste, other materials (for example paper & plastic) + bulk waste.

The table below gives an overview of the environmentally most relevant aspects in the DMS 'renovation':

Table 14: the environmental relevance of the DMS 'renovation'

Environmental issue	**Aspects**	**Explanatory concretization (examples)**
Energy + related emissions	Factors influencing the building's energy consumption in the use phase	construction of the building elements: air tightness, k-value shaping of the technical building equipment: lighting, ventilation, heating positioning of consumption displays (affects user behaviour) the zoning of the building (the rooms' position with regard to each other)
	Energy consumption for production of the building materials ('embodied energy')	choice of construction choice of construction materials (e.g. new / reused / recycled, different amounts of embodied energy) choice of construction materials origin
Material consumption & waste:	Choice of construction and construction materials for the building	materials with different environmental profiles, e.g. new / reused / recycled material use of scarce or renewable resources local material or material from abroad composite 'sandwich' materials vs. separable components construction: different kinds of joints (screwed, nailed, glued) with different consequences for reuse / recycling
	Measures influencing waste generation and separation in the use phase	waste separation facilities in the building (e.g. ample space for different containers)

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Table 15: the environmental relevance of the DMS 'renovation' continued

Environ-mental issue	Aspects	Explanatory concretization (examples)
Water + wastewater	Impact on groundwater formation Consumption of drinking water	separation of different categories of water water saving facilities and installations (e.g. vacuum/composting toilets, use of rainwater)
	Production of wastewater	installations for storm water and waste water (separated or joint)
Hazardous substances		choice of building materials choice of construction (how tightly the hazardous substances are fixed in the construction)
Local environment:	Land use Local habitats Ground water formation	creation of new habitats (e.g. on / under the roof, …) destruction of habitats surface sealing (actual area covered by the building and building-related facilities such as terraces and paths
Indoor climate:	Thermal climate	choice of materials (heat storage, temperature of surrounding surfaces) choice of construction choice of technical systems (ventilation, heating, cooling) heat from sunlight and shading devices choice of design (where are which materials and technical installations)
	Indoor air quality	choice of materials (offgasing, dust, house dust mites, fibres) choice of construction ('Can sources of pollution reach the indoor air?') choice of technical systems (ventilation, heating, cooling) design (location of sources of pollution and the ventilation system)
	Light	orientation of the rooms in the building design of artificial lighting daylight design (windows, shading, reflectors) colour and structure of indoor surfaces
	Sound	choice and positioning of materials choice of construction

Data availability

In the renovation even more data is available than in the project design: Especially the consumptions of electricity, energy for heating and water that are measured for billing by the energy providers and water supply services are readily available data for each household and each building. These measured consumptions allow comparisons with average data, with neighbouring flats (in the case of apartment buildings) and with the calculated values from the heat demand calculation in the project design. (After adjustment for deviations due to user behaviour) these comparisons permit to identify improvement potentials for the measures carried out in the renovation. In Denmark this is institutionalised in the 'Energy labelling of houses and owner-occupied flats'[148], which by law prescribes an assessment with regard to consumption of energy and water (including the identification of improvement measures and a cost-benefit-calculation) for small properties (< 1.500 m^2) when they are sold and for large buildings (>1.500 m^2) once a year. These assessments have a broader scope than the obligatory heat demand calculations carried out in the project design as they also consider energy for lighting, unutilised heat losses in heating- and domestic hot water pipes plus unutilised heat losses in containers and valves. (Danish Energy Agency, 1999)

Apart from these readily available data, additional measurements can be carried out, for example a blow-door test for air-tightness or measurements of various other indoor-environmental parameters. These measurements, however, are costly. Also a life cycle assessment of the materials that are to be used in the renovation is additional work and still the exception. The energy consumption *after* the renovation can be calculated in a head demand calculation. However, there is no legal obligation to do so. For anticipations in general the same uncertainties apply as described in the DMS 'project design'.

Who decides what

The prominent actors in this decision-making situation are the clients, the administrators and the project designers. The clients as those who own the building and pay for the renovation decide about the budget and the contents of the renovation. Depending on the form of ownership of the building the clients may at the same time be the administrators and users of the building (as resident clients, for example in private properties or housing co-operatives). In contrast to the private sector, where the building owners have the decisive say, in Danish social housing associations the elected resident representatives also participate in the decision-making with the status of clients.

In bigger properties clients usually commission administrators with the administration of the building. Prior to a renovation, these administrators point out needs for renovation and pre-investigate possible solutions. Project designers (architects and consulting engineers) then elaborate solutions according to the client wishes.

Summarising note

Though the decisions taken in renovation are not quite as far reaching as in the project design their overall significance is immense, because a renovation can radically change a building's consumptions in the following use phase and its indoor climate parameters. It can create commodities equal to a new building while reusing a big share of the building material of the existing building, which is favourable for the material-related part of a LCA. If a renovation yields environmental improvements depends very much on the identification of environmental hot spots and on the contents of the renovation. Here the project designers and their capacities again play a key role in reflecting important environmental aspects in their plans. The clients, on the other hand have a great influence by deciding, what to use the budget for – for attractive indoor-architecture and additional measures that increase consumptions (air conditioning, bath tubs, more space per person, …) or for measures that reduce consumptions (better insulation, air tightening, an energy efficient ventilation system,…).

[148] For details see the sections 'The Danish building legislation' and 'Ongoing European developments' in the appendix

Concluding remarks

All together the investigation of the three decision-making situations

- siting of the building
- project design and
- renovation

illustrated that all three are environmentally relevant but differ with regard to the environmental 'hot spots' and the actors, who play a prominent role:

In the siting the local building authorities and the clients determine the infrastructural embedding of the building (including decisive parameters for induced transport) and the framework for the project design (with regard to height, land use, orientation, etc.).

In the project design architects (as the overall project designers) and clients are the main actors. They make the step of responding to the *potentials* of the location with a concrete project, determining the material consumption, the use of hazardous substances and the potential performance in the use phase, especially with regard to consumptions and indoor climate.

In the renovation the clients (as the owners of the building), the administrators and the project designers determine the focal points of the renovation. Their decisions are crucial for the building's future performance with regard to consumptions in the use phase, indoor climate, material consumption and waste generation and with regard to the possible use of hazardous substances.

Consultants are principally involved in all three decision-making situations, consulting clients and other actors.

Data availability increases from the siting to the renovation as more building-specific data become available in addition to statistical average data. However, many environmentally relevant data are only available after additional efforts.

The fact that all three decision-making situations are environmentally relevant confirms that EIFOB should cover all these three decision-making situations. This chapter also elucidated that decision-making on specific environmental issues does not take place within only one decision-making situation but often is inseparably linked with decisions taken in other DMS (both previous and following ones). Though the constellations of decision-makers are different in each DMS there are overlaps and continuities (clients[149], for example, are involved in all three decision-making situations). This confirms that indicators have to be consistent *across* the different decision making situations and agreed upon by the different actors involved if they shall permit an effective communication of environmental aspects throughout the investigated part of a building's life cycle. Non-coherent, individual indicators for each DMS require translation between different DMS and 'multilingualism' of actors involved in more than one DMS.

[149] As mentioned in the chapter 'Introduction' a distinction between different kinds of clients (e.g. between municipalities as clients or private clients or 'developer clients', 'domicile clients' and 'investor/landlord client') was not considered relevant for this study.

Indicator-systems

This chapter describes the main characteristics of current environmental indicators for buildings. Based on a comparative analysis of current indicator systems[150] (a literature survey supplemented with some interviews with indicator developers) from Denmark as well as from other countries the chapter distinguishes the indicator systems by

- *indicator principle employed (e.g. LCA, checklists, management indicators,…)*
- *environmental scope*
- *indicators used*
- *target groups and*
- *decision-making situation addressed.*

This provides one part of the knowledge foundation for the understanding of the different indicator approaches, for the understanding of EIFOB-related conflicts between actors in the different technological frames and for the development of closure scenarios and their exemplifications.

Introductory remark

The indicators and indicator systems investigated in the course of the study were environmental indicators in the building sector

- in use in Denmark[151]: Building Environment Assessment Tool (BEAT) (Holleris Petersen*,* 2001), (Dinesen et al.*,* 1999), Environmental Assessment and Classification of Buildings (Dinesen et al.*,* 1999), Green Accounting (Jensen*,* 1998) (Jensen*,* 1999), Energy labelling of houses and owner-occupied flats (Danish Energy Agency*,* 1999) (Danish Energy Agency*,* 1999), Environmental Product Declarations for Building Products (Hansen*,* 2002),
- in use in the Netherlands[152]: Local Transport Performance (van Hal et al.*,* 2001) and the National Packages Sustainable Building (Dutch Ministry for Housing*,* 2002) (van Bueren et al.*,* 2000)
- the British 'Building Research Establishment Environment Assessment Method' ('BREEAM') (Building Research Establishment Ltd.*,* 2001) (BRE Center for Sustainable Construction*,* 2002) (BRE Center for Sustainable Construction*,* 2002) and
- the international 'Green Building Tool' ('GBTool') (Green Building Challenge*,* 2002) (Boonstra*,* 2001).

The Danish systems, BREEAM and GBTool were analysed in detailed analysis schemes (the analysis is documented in the appendix of this study) in an early phase of this investigation. The insights obtained here rendered possible a more selective analysis of the Dutch systems in a later phase of the study, elucidating only those parameters that contributed *new* relevant elements.

The following sections do not describe the individual indicator systems but abstract general patterns. These are exemplified by referring to a selection

[150] For the detailed analysis see the 'Survey on environmental indicators in the construction sector' in the appendix
[151] Danish environmental indicators in the building sector are described in (Dammann et al.*,* 2002).
[152] An overview of Dutch indicator approaches is given in (Dammann*,* 2003).

of the analysed systems (a summarising overview of which is given in Table 22 further below). In accordance with the overall objective of this study the purpose of the investigation of current indicator systems was to obtain an overview over the principal indicator approaches and their use-context rather than obtaining detailed in-depth knowledge of the latest developments.

Indicator principles

The indicator systems in the scope of this study can be distinguished into three different indicator-principles:

- life cycle assessment (LCA)
- checklist indicators and
- input-output indicators

The characteristics of these principles are explained in the following.

Life cycle assessment

Life cycle assessment[153] (LCA)[154] is a method of assessing a product environmentally, that is,

> *'to define and quantify the service provided by the product, to identify and to quantify the environmental exchanges caused by the way in which the service is provided, and to ascribe these exchanges and their potential [environmental] impacts to the service.' (Wentzel et al., 1997)p. 26*

'Service' here means the function of the product, the purpose for which it is produced. The service of a bearing construction material, for example, would be to bear a quantified load for a certain period of time. LCA provides the possibility to identify environmental hotspots of a single product and to evaluate alternative products with regard to their environmental performance. To define the object of the evaluation and to assure comparability of the different ways of providing a service, the service must be defined and precisely quantified. This happens in the definition of the *functional unit* of a product. A functional unit for drink containers, for example, could be *'Serve as drink container for 200 cc of hot beverages three times a day for one year.'* Part of the definition of a product's functional unit is the description of the properties of the product considered necessary and desirable (EDIP uses the terms *obligatory properties* and *positioning properties*).

Buildings obviously are very complex 'products' that are expected to meet functional, aesthetical, economical and environmental demands. In architectural competitions the competition programme can be seen as providing the (more or less precise) description of the functional units that the competition projects have to relate to. In the evaluation of existing buildings comparability can be achieved by calculating environmental effects *per* m^2 or *per*

[153] 'The generally recognised term for environmental assessment of products is *Life Cycle Assessment* or *LCA* in abbreviation. LCA is sometimes also read as life cycle *analysis*, but life cycle analysis is not a particularly good designation since an LCA always contains an element of *assessment*, namely the consideration and weighting of different resource and environmental problems required to make a decision. The word "analysis" therefore signals too much objectivity.' (Wentzel et al., 1997)

[154] This presentation of LCA is mainly based on the Danish LCA approach EDIP ('Environmental Design of Industrial Products'), developed at the Technical University of Denmark's Department of Manufacturing Engineering and Management and described in (Wentzel et al., 1997). This Danish method, however, shares its core principles with LCA-systems in other countries as it accords with the international standards set by the International Standard Organisation (ISO) and the Society of Environmental Toxicology and Chemistry (SETAC).

person. (In this case the functional unit would be ‘providing one m^2 of housing space for one year’ or ‘provide housing for one person for one year’).[155]

As already mentioned in the chapter ‘Environmental effects of buildings’ it is the very idea of LCA that it considers the environmental impacts of a product throughout its entire life cycle - from the extraction of raw materials, the production of material, the product manufacturing and its use to its disposal (which transfers the product back to the natural world or into a new product – therefore the term ‘life cycle assessment’) (Figure 21).

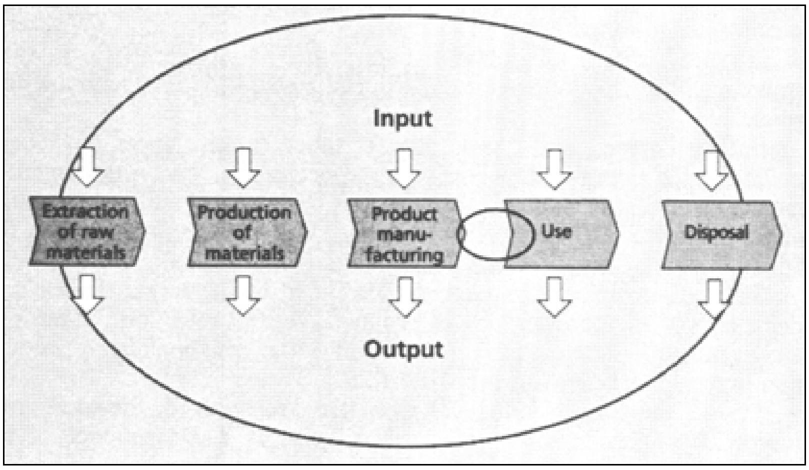

Figure 21: The *‘Future environmental focus in the industrialised world’* shifts from processes to products. The big oval indicates the scope of an LCA, the small one the decisive role of the consumer / client who, thanks to reliable environmental information, should be able to select environmentally friendly products, thus directly influencing the production. (Wentzel et al., 1997)

Departing from the definition of the functional unit and of the goal and scope (geographical scope, system borders,…) of the assessment in the *Inventory* the life-cycle data on the product or the building are collected and supplied with data from existing databases and then sorted in a computation model. In the next step, the *impact assessment*, impact potentials are calculated. These can be *normalised* to elucidate the relative magnitude of the different impact potentials by expressing the impact potentials in the unit *person equivalents per reference year and reference area*. Finally, a *weighting* can be carried out (by use of weighting factors) if different ‘degrees of severity’ of environmental impacts shall be considered in the LCA’s outcome.

The Building Environment Assessment Tool (BEAT) (Holleris Petersen, 2001) is the Danish application of the life cycle assessment principle to buildings. Figure 21 shows an example of an LCA output (a BEAT-assessment of a terrace house - only the normalised and weighted impact potentials are shown, resource consumptions and waste are displayed analogously).

[155] The definition of the functional unit thus determines the perspective of the assessment; if environmental effects are calculated *per m^2* a large villa built according to state-of-the-art ‘green building’ may perform better than an average smaller building with several housing units, while calculated *per person* the latter probably outranks the first due to its fare higher density of residents.

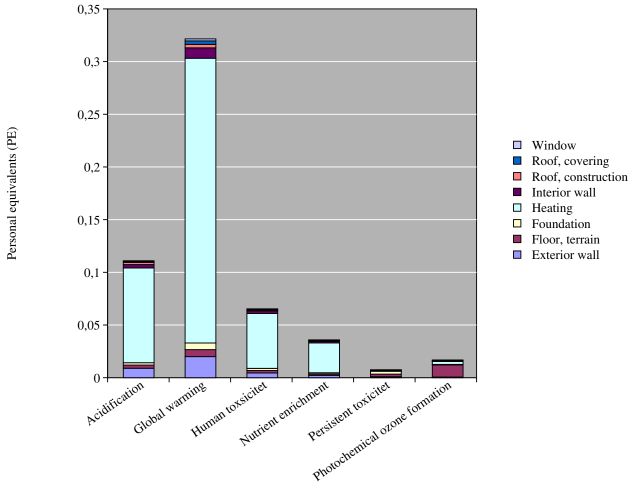

Figure 22: An example of an LCA output (a BEAT-assessment of a terrace house - only the normalised and weighted impact potentials are shown, resource consumptions and waste are displayed analogously)

Other countries have their own systems[156], which follow basically the same principles.

Checklist indicators

In contrast to LCA-based indicators, which calculate the environmental impact potential of buildings in a life-cycle perspective, checklist indicators register if *concrete measures*, that is materials, construction principles, technologies and management practices considered environmentally sound (for example wood, thermal ventilation, photovoltaics, training on energy-saving techniques) are applied to the building or not. The principle structure of checklist indicators is illustrated in the following table:

concrete measures & principles for example[157]	**checklist: measure applied / not applied**
Energy: sub metering for energy uses provided, for lighting, small power and others[158]	√ (x points)
Materials: no asbestos	√ (y points)
…	√ (x points)
	Indicator: registers number of applied measures (weighting of the measures is possible)

Figure 23: Structure of checklist indicators

Simple checklist-indicators make statements of the kind

X is good
Not having X is worse than having X.
Y is good.
X+Y is better than X.

156 E.g. 'Greencalc' and 'Ecoquantum' in the Netherlands, 'Envest' in the United Kingdom, 'LEGOE' and 'GaBi' in Germany (an overview of different national LCA-systems and other indicators systems in the building sector can be found at http://crisp.cstb.fr).
157 From the British 'Building Research Establishment Environment Assessment Method' ('BREEAM') (Building Research Establishment Ltd., 2001)
158 E.g. for major fans, computer room, catering facilities, humidification plant

These contrast the more complex, not always unambiguous to interpret outcomes of a LCA, which are statements of the kind

X is good if A.
X is not relevant if B.
X is bad if C.
Y is good if A.
Y is not relevant if B.
X_A+Y_A is better than X_A+Y_B.

The concrete measures registered in checklist indicators can address a wide range of environmental aspects and are usually assorted to a number of issues (for example[159] Energy, Materials, Transport, Water, Land use, Ecology, Pollution, Management, Health & Wellbeing). The registered concrete measures can also include *management indictors*, that is applied measures in the *social sphere*, for example

'Energy monitoring and targeting carried out […]

'Policy in place to encourage the use of public transport and discourage the use of the private car for both commuting and business' (Building Research Establishment Ltd., 2001).

Checklist systems can use other indicator systems (LCA and input-output indicators[160]) as sub-systems. BREEAM, for example, does both:

'Material: At least 80% of major building element components evaluated with the ENVEST [life cycle assessment] software achieve an 'A' rating' […]

Energy: Expected Total Net CO_2 emissions (in kg $CO_2/(m^2$ x year) [below certain benchmark values] (Building Research Establishment Ltd., 2001)

Examples for checklist systems are BREEAM, the Danish 'Environmental Assessment and Classification of Buildings' (Dinesen et al., 1999), (which uses checklists to cover the environmental issues 'Water and wastewater', 'Hazardous substances', 'Local environment' and 'Indoor climate') and the Dutch 'National Packages Sustainable Building' (Dutch Ministry for Housing, 2002).

Input-output indicators

A third type of indictors are input-output indicators. Input-output indicators describe flows (of energy, matter and water) through a building in the building's use phase by measuring (and calculating) the flows that enter the building (input) and the flows that exit the building (output) (Figure 24).

[159] From the British 'Building Research Establishment Environment Assessment Method' ('BREEAM') (Building Research Establishment Ltd., 2001)
[160] Described in the following section

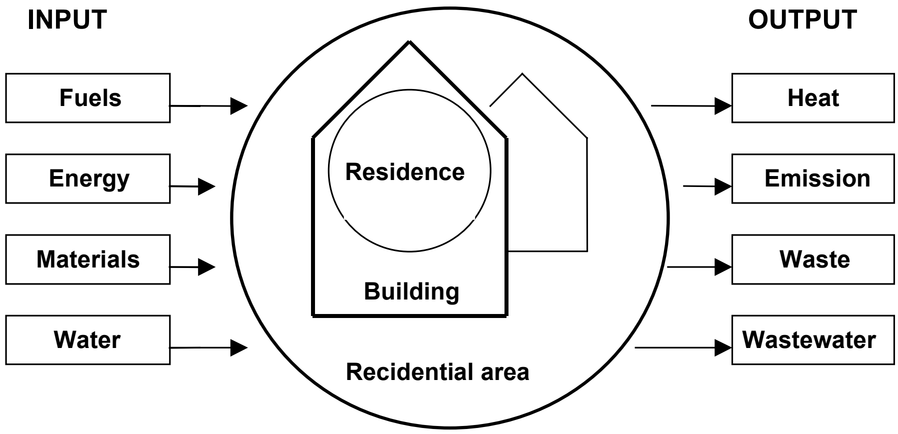

Figure 24: *'Principle figure showing how matter and energy flow through a [building] or a residential area.'* (Jensen, 1999)

Whether a flow is measured at the input side or at the output side, will depend on pragmatic reasons. In some cases it is easier to 'take the pulse' of a flow at the input side, for example in the case of energy, were consumptions are measured as part of the energy billing, while emissions (CO_2, NO_x, SO_2, …) are easier to *calculate* on the basis of the input[161] than to measure. In other cases it is easier to measure on the output side: The material flow during the use phase of a building, for example, is measured regularly in connection with the billing for waste disposal and is thus an indicator that already exists, is rather familiar and, accordingly, easier to communicate. Apart from this somewhat pragmatic choice of indicators, the input-output concept draws attention to the fact that

> *'[…] environmental figures, in the form of materials and energy, cannot leave a system (output), unless materials and energy have already been brought into the system (input). Nothing is lost in the process. […] Our statement of accounts reflects how a residence or residential area forms part of local and global material and energy flows.'(Jensen, 1999)*

In the form of 'Green accounting' (Jensen, 1999) input-output indicators are an established system for environmental monitoring in the *use phase* of a building. Even though the use phase is not within the scope of this study, input-output indicators are relevant, because the flows monitored by them constitute a major contribution to the environmental impact of a building throughout its life cycle. These flows have to be anticipated and reckoned with (for example in energy demand calculations) in the siting and the project design as well as in the renovation.

A special application of the input-output approach (in combination with a modelling tool) for the consideration of transport implied by building developments in the DMS siting is the Dutch system 'Local Transport Performance' (LPT). LTP follows a three steps procedure:

1 The determination of the ambitions and objectives of the building development
2 The drawing up of the urban design or (preferably) several design alternatives)
3 The calculation and assessment of the designs

LTP supports this procedure with the calculation tool 'LTP-KISS' (van Hal et al., 2001). On the basis of general statistical data and site specific data the tool calculates a broad range of output figures, among them the shares of

[161] Green Accounting reflects the fact that different sources of energy cause different emissions in its calculations. (Jensen, 1999)

the different transport modes ('modal split') and transport-related emissions (Figure 25).

Inputs into the calculation tool LTP-KISS:				
inhabitant data	dwelling data	road data	district data	general data
e.g. – number of households – size of households – % employed – bike- and car ownership	e.g. – number of dwellings – type of dwelling – existence of a bike shelter	e.g. – type of road (housing +/ business) – 30 km zone – orientation of front doors towards bicycle lanes	e.g. – public transport situation (distances to stops) – distances to work, shops and education	e.g. – average density (addresses per hectare) – % green area – access to facilities
Outputs of the calculation tool LTP-KISS: (usually PER HOUSEHOLD)				
– shares of transports means: – car – public transport – bicycle – walking	– distances: – share of each transport mean in km	– energy: – MJ for car – MJ for public transport – car emissions $CO_2 + NO_x$	quantitative comparison of the different design alternatives	

Figure 25: Input and output of the Dutch 'Local Transport Performance'-tool (van Hal et al., 2001)

Due to the fact that the tool automatically calculates with average data from its database when site-specific data are not yet available, the tool can be used already in an early phase, when an urban design is still sketchy.
It allows for the comparison of design alternatives and reveals the kind of mobility and emissions resulting from each variant.

How the indicator principles relate to the life cycle of a building

In the chapter 'Environmental effects of buildings' the life cycle of a building was presented in a schematic way in Figure 15. The figure below illustrates how the three indicator systems 'life cycle assessment', 'checklists' and 'input-output' relate to a building's life cycle as it was shown in Figure 15:

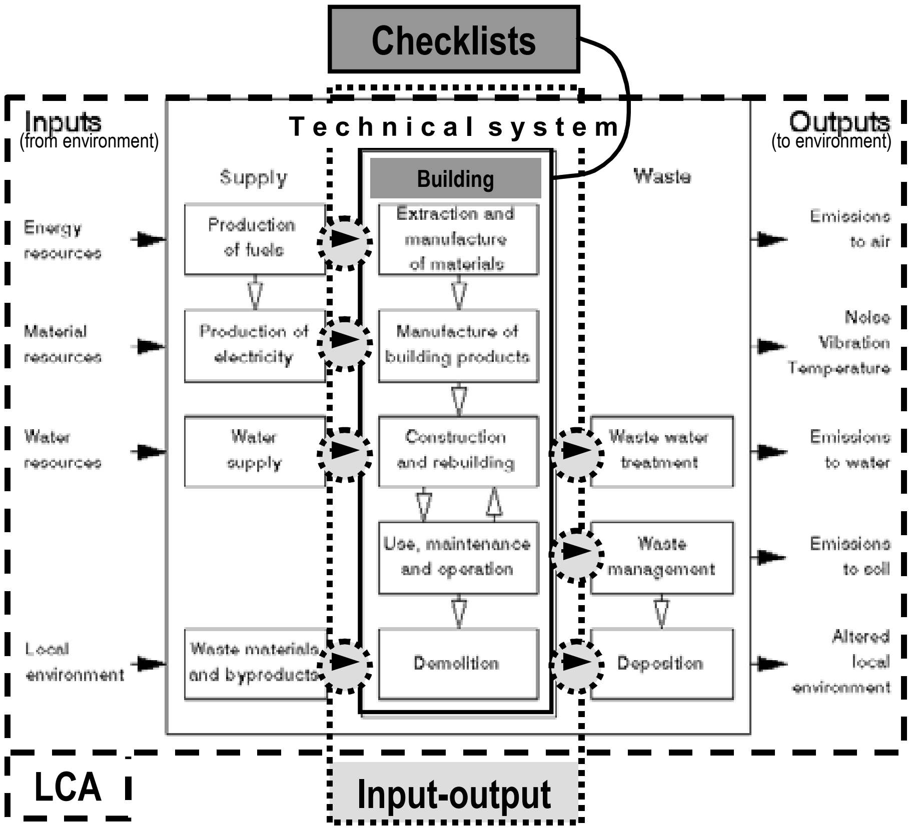

Figure 26: Relation of the three indicator principles 'life cycle assessment', 'checklists' and 'input-output' to a building's life cycle (compare Figure 15 in the chapter 'Environmental effects of buildings')

Life cycle assessment principally considers the entire life cycle and all included elements, that is the exchanges between the environment and the technical system as well as the flows within the technical system in all phases of a building's life cycle.[162]

Input-output[163] indicators focus on the flows that enter the Building from the supply side and leave the building on the waste side. Principally they can cover all phases of a building's life cycle from the extraction and manufacture of materials to the demolition. In practice, however, they focus on those flows that are easy to measure. The Danish 'Green Accounting' system covers only the flows that occur during the use and operation of a building. With its calculation of the emissions to air caused by energy consumption it leaves the 'core-concept' of input-output indicators and takes in an element (the *calculation* of environmental exchanges[164]) of the LCA-principle.

Checklist indicators, registering the application of concrete measures, focus mainly on the building itself. Some checklist-measures, however, may also reach into the neighbouring spheres (for example with management indicators or the BREEAM checklist indicator *'significant use of crushed aggregate or masonry in the building structure'*, which addresses the reuse of waste materials).

A historical perspective

Seen in a historical perspective the concept of life cycle assessment was developed in the late 60s but first in the 80s gained ground in connection with the increasing environmental awareness and the wish to carry out holistic evaluations of products and processes (Holleris Petersen, 1997). Early

[162] In practice, however, 'local environment' is not considered in the Danish tool BEAT as problems to operationalise this issue have not yet been solved. Research is, however, research is being carried out on this matter (for example in the Netherlands).

[163] The scheme distinguishes between *inputs and outputs from and to the environment* and *inputs and outputs within the technical system*. Crude-oil extraction, for example, is part of the first, while consumption of (processed) fuel for heating is part of the second.

[164] Compare Figure 27

LCA focused on the comparison of comparatively simple products (for example alternative kinds of milk packaging). The fact that the way, an LCA should be carried out, what it should include and how the final weighting should be performed, had not been standardised yet let in several cases to contradicting results: some LCAs pointed out cardboard packaging as the least environmentally problematic solution, others glass bottles and yet others plastic bottles (Guinée*,* 1995). As a response to this a standardisation of the LCA-approach has taken place since 1990 under the leadership of the Society of Environmental Toxicology and Chemistry (SETAC). In the late 1990s LCA-tools were developed specifically for the building sector. They have, however, not been very broadly used yet. The Dutch LCA-tool 'Eco-Quantum', for example, has so far been applied to no more than approximately 40 buildings, which corresponds approximately to the extent of the application of the Danish LCA-tool 'BEAT'.[165] In the last four years, however, some pilot-projects on the use of LCA-tools in the planning practice of municipalities have been carried out.

Checklist-indicator systems appeared in the early 90s in Denmark and in the Netherlands for use at municipality level. Due to their simplicity they were soon more in use than LCA-based indicators. According to estimates today in Denmark between 10 and 20 of the biggest municipalities employ a checklist-indicator system.[166] In the Netherlands the Dutch Association of Contractors in the Building Production (NVOB) in the mid 90s took the initiative for the development of a national standard to harmonise the multitude of different environmental checklists on municipality level. The following consensus talks among the building contractors and other stakeholders were led by the Organisation for Building Research (SBR) (The Ministry of Housing, Spatial Planning and the Environment (VROM) participated as only one stakeholder among others (van Bueren et al*.,* 2000).

The result was a collection of concrete measures gathered in the four checklists 'National Packages Sustainable Building' (Dutch Ministry for Housing*,* 2002)). The National Packages are not part of the legislation but the Ministry supports their application in communications and uses them to formulate environmental standards as a precondition for receiving public funding. The application of a certain amount of Package-measures has also been taken as the basis for a national sustainability certificate. Most of the Dutch municipalities use them today in agreements with contractors, though in varying degrees. According to estimations the National Packages are presently applied in 75% of all new building projects. Also in the United Kingdom the checklist system BREEAM is more widely used than the British LCA-system.

The input-output indicator system 'Green Accounting' came into use in Denmark in the mid-90s[167] and is today used by most Danish housing associations and approximately 25% of all municipalities (for their own buildings).

Indicators

The different indicator principles bring about different indicators and units. They also make different use of the option to aggregate indicators.

In principal, indicators differ in *where* in the causal network between building activities and the inflicted environmental damages they take the environmental pulse[168]: The 'indicator-stairway' in Figure 27 shows the range of

[165] Source: interviews with the developers of the tools.

[166] For examples see (Mørck, 2001), (Københavns Kommune ved Bygge- og Teknikforvaltningen, 2001)

[167] They were partly inspired by monitoring systems for the planned economies. (Source: interview with the developer of the 'Green Accounting for residential areas')

[168] This question was elaborated in the introduction of the chapter 'Environmental effects of buildings'.

options in relation to the three indicator principles, sorted according to 'distance to damage'. What ultimately triggers the concern for environmental issues is the damage (for example on human health, habitats, crops …). It is, however, in most cases very difficult (if not impossible) to allocate the inflicted damages unambiguously to individual sources (compare Figure 11 *'Interrelationships between emissions, environmental impact potentials and the various impacts and their consequences'* in the chapter 'Environmental effects of buildings'). Therefore the different indicator-principles use indicators at different 'distances-to-damage' levels.[169]

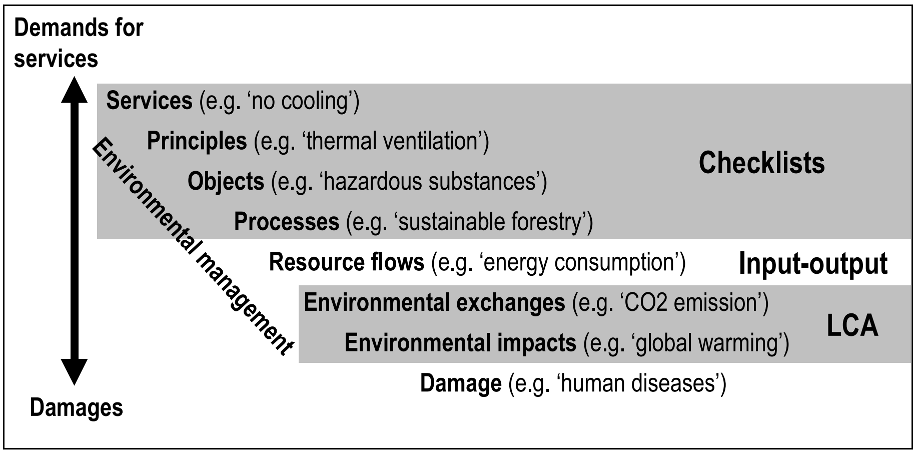

Figure 27: The range of options for taking the environmental pulse by means of indicators

Checklist indicators are at the upper end of the 'indicator-stairway' shown in Figure 27. They register the application of services (e.g. 'cooling in place/not in place'[170]) and principles (for example 'thermal ventilation/mechanical ventilation/…'), the use of objects and substances or the application of processes (for example of 'sustainable forestry'[171]). Input-output indicators in the middle of the 'stairway' measure the flow of resources (for example of energy consumption). LCA-based indicators calculate environmental exchanges (for example emission of CO_2 and other gases) and potential environmental impacts (such as global warming, acidification, …). Management indicators used in checklists (for example the BREAAM management indicator *'existence of a company environmental policy[172]'* (Building Research Establishment Ltd., 2001)) do not quite fit into the stairway-scheme as they may address environmental issues at all levels. Checklist-indicators are simpler than input-output indicators and LCA-based indicators in the sense that registering if a building has cooling or not is easier than calculating impact potentials.

[169] The 'stairway' in Figure 27 is to be read as a row of consequences: If a service (e.g. 'cooling') is demanded, different principals (e.g. 'thermal ventilation with ground-channels', 'evaporation', 'electric air conditioning'…) can be chosen to provide this service. Each principal requires the use of specific objects (e.g. certain substances and materials), which are produced in specific processes (e.g. wood in sustainable forestry) and cause specific flows of resources (energy, water …). These flows cause environmental exchanges (e.g. emission of various gases), which have effects in the environmental (e.g. 'global warming, acidification …) and can ultimately lead to damages, such as human diseases or loss of habitats.

[170] A principal demand of the last Danish Building Code (exemptions needed to be applied for). Today *'cooling may only be installed, when it yields satisfying indoor-climate conditions in an energy-economically reasonable way.'* (Danish Ministry for Housing and Urban Affairs, 1995)

[171] As, for example, certified by the 'Forest Stuardship Council'

[172] Addressing among others Health, Energy, Transport, Water, an action plan, annual (public) reviews,…

The following table gives and overview of indicators used in the indictors systems that were analysed in this study:

Table 16: Overview of indicators (and units) used in the different indictors systems

Indicator principle	Indicator level	Indicators and units[173] (examples)	used in
Checklists	environmental management	existence of a company environment policy	BREEAM
	services	good access to public transport within 500m and at least a 15 min / 30 min[174] frequency to a local urban centre public transport connections are good and car parking in the area is restricted by at least 20% from the standard Unit: no unit, but quantification with point scores possible	BREEAM
	principles	ventilation is easy to regulate possibility for forced ventilation windows that can be opened Units: no units, quantification with point scores possible	EACB[175] BREEAM
	objects	use of water-saving appliances water meters installed to all building supplies no halon-based fire-fighting systems installed Units: no units, quantification with point scores possible	EACB BREEAM
	processes	timber for key building elements comes from sustainably managed forests client commitment prior to hand over to ensure efficient operation of the building Units: no units, quantification with point scores possible	BREEAM
Input-output	resource flows	amounts of raw materials consumed (in tons) energy consumed in MJ	BEAT Green Account-ing EACB BREEAM
LCA	environmental exchanges	emission of CO_2, CO, N_2O, methane (CH_4), … Unit: tons	BEAT Green Account-ing LTP[176]
	environmental impacts	contribution to global warming in tons CO_2-equivalents/(m^2 x year) acidification nutrient enrichment … Unit after normalisation and weighting: Person Equivalents per reference year and reference area (mPE_{WDK95})	BEAT

[173] Many indicators can be expressed *in total*, *per m²*, *per person* and/or *per year*, depending on the objective and the context of the assessment. The basic indicator, however, remains the same. The implications of the calculation *per m²* versus calculation *per year* have already been discussed in the section on 'Life cycle assessment' further above.

[174] Different point scores are given for the different frequencies.

[175] = 'Environmental Assessment and Classification of Buildings'

[176] = 'Local Transport Performance'

Aggregation

A special feature of several indicators systems is the operation with *different levels of aggregation*. Aggregation of indicators means that several indicators together form the data-input of one indicator at a higher level of aggregation (Figure 28), a process in which precision is lost and simplicity is gained. The result may even be a single indicator, characterising a whole building.

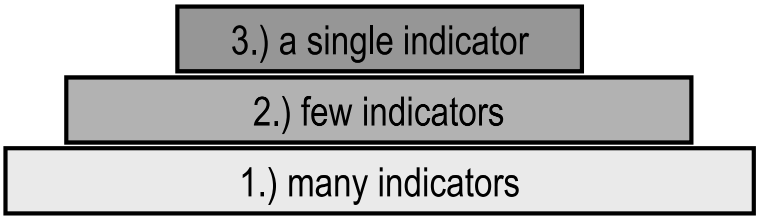

Figure 28: The principle of aggregation

Aggregation shall condense a large amount of information (which is at times confusing and difficult to relate to) into aggregated indicators that, in some situations and for some actors, are easier to interpret and to operate with. If indicators at aggregated levels shall be meaningful they have to make summarising statements about the overall performance of the indicators at the lower level. This ‘summarising’ of the lower indicator level can follow different principles:

- Simple addition, implying that all indicators at the lower level are equally important
- Addition with weighting, where weighting factors attributed to indicators express different degrees of significance.
- Representation, that is to let a single indicator from the lower level ‘represent all his colleagues’, so to speak.[177]

These principles can of course be combined within one indicator system.

[177] This can, or course, be seen as the special variation of the ‘addition with weighting’-approach, where the weighting factor ‘1’ is attributed to only one indicator while all other indicators at the same level are given the weighting factor ‘0’.

The modes of aggregation follow the logic of the indicator-principle:

Checklist-systems aggregate indicators addressing specific environmental themes to a limited number of indicators for broader environmental issues. The British 'Building Research Establishment Environment Assessment Method' ('BREEAM') (Building Research Establishment Ltd., 2001) for example operates with indicators at three levels of aggregation:

Table 17: Three levels of aggregation in a checklist-system (example: BREEAM)

1. level (concrete measures)	2. level	3. level
client commitment prior to handing over to ensure efficient operation of the building allocation of personnel for system management …	Management	Rating: 1 Excellent 2 Very Good 3 Good 4 Pass each corresponding to certain point-score benchmarks
cooling towers accessible for cleaning natural cross-ventilation possible percentage of daylit floor …	Health & Wellbeing	
expected Total Net CO2 emissions (in kg CO2/(m^2 x year) energy policy established …	Energy	
Public transport connections are good and car parking in the area is restricted by at least 20% from the standard provision of cycling facilities[178] for 10% staff …	Transport	
water meter installed to all building supplies leak detection system installed water consumption monitoring carried out …	Water	
no asbestos timber for key building elements comes from sustainably managed forces …	Materials	
sites has been previously built upon or used for industrial purposes in the last 50 years …	Land use	
build on land defined as having a low ecological value …	Ecology	
maintenance policy covering boiler/burner systems in place no halon-based fire-fighting systems installed …	Pollution	

The first level comprises the concrete measures. These are assorted to the nine indicators at level 2, which each cover a different environmental issue. Checklist-indicators aggregate by ranking and benchmarking, often in combination with a weighting of indicators. BREEAM, for example, attributes point scores to each level 1 indicator, which are summed up to allow a final ranking according to minimum-point scores attributed to the level 3 indicators.[179]

[178] Sheds, showers and changing facilities

[179] To explain all details of the different variations of checklist aggregation methods would exceed the focus of this study. Concrete, detailed examples of aggregations are described in the chapter 'Exemplifications 'Energy & Indoor air quality': Three scenarios'.

LCA-systems work with two main levels of aggregation:

Table 18: The two main levels of aggregation of an LCA-system (from the example 'BEAT')

1. level (environmental exchanges)	2. level (impact categories)
Unit: usually in tons, gas in Nm^3	Unit: After normalisation and weighting: Person Equivalents per reference year(1995) and reference area (Denmark / World) (mPE_{WDK95}) Before normalisation and weighting: - see in the respective cells -
Emissions to air: carbon dioxide (CO2), carbon monoxide (CO), N2O methane (CH4), …	contribution to global warming Unit: CO2-equivalents
Emissions to air: Sulphur dioxide (SO2), Ammonia (NH3), Hydrogen chloride (HCl, Nitrogen oxides (NOx), …	acidification Unit: SO2-equivalents
Emissions to air[180]: Nitrogen oxides (NOx), N2O, Ammonia (NH3),…	nutrient enrichment
Emissions to air (mostly transport-related): Carbon monoxide (CO), Volatile organic compounds ('VOC'); power plant, VOC; car (diesel), Methane (CH4), Formaldehyde,…	photochemical ozone formation
Emissions to air: Nickel (Ni), Lead (Pb), N2O, Quicksilver (Hg) Nitrogen oxides (N0x),…	human toxicity
mostly emissions to air: Arsenic (As), Lead (Pb), Cadmium (Cd), Zinc (Zn), Quicksilver (Hg), …	persistent toxicity
Unspecified hazardous waste, unspecified hazardous waste containing heavy metals, unspecified chemical waste,…	hazardous waste
Crude oil, natural gas, coal, brown coal, …	consumption of fuel-resources
Aluminium, iron, copper, manganese, nickel, zinc,…	consumption of metal-resources
slag & fly-ash (mainly from the power plant)	slag & ash
bricks, mortar, ….	bulk waste

At level 1 the calculated environmental exchanges, for example emissions to air and consumptions of resources. At level 2 these are aggregated to a limited number of environmental impact potentials. For emissions aggregation from level 1 to level 2 is carried out by multiplication with *equivalency factor*s (which can also be seen as a kind of weighting factors) and addition.

> *'The equivalency factor expresses the substance's strength measured relative to a reference substance […]. For global warming the reference substance is carbon dioxide , CO_2, and the impact factors thus express the substances' potential impacts as grams of CO_2 equivalent per gram of substance. When methane has an impact factor of 25, it means that emission of 1 g of methane contributes as much to global warming as the emission of 25 g CO_2.' (Wentzel et al., 1997)*

[180] Emissions to water can principally also contribute to nutrient enrichment but according to the author of BEAT occur very rarely in the construction sector.

After being multiplied by the respective equivalency factors, groups of the environmental exchanges calculated at level 1 thus can be summed to form the impact potentials at level 2.[181]

In the Danish LCA-system EDIP the level 1 resource consumptions are weighted according to their supply horizons and then appear individually as assessment parameters without further aggregation. (Wentzel et al., 1997). BEAT, on the other hand, simply sums the different level 1 resource consumptions after weighting and normalising to a single level 2 indicator.

Normalisation and weighting, are not necessarily elements of an *aggregation*. They are, however, usual steps in a LCA, which would also automatically be included in any indicator system that uses LCA-indicators as a subsystem (for example the checklist-systems BREEAM or Environmental Assessment and Classification of Buildings) and aggregates the LCA-level 2 indicators further to a single level 3 indicator. Therefore normalisation and weighting are briefly described in this section on aggregation.

> *'On normalisation, the magnitudes of the potential impacts and the resource consumptions are expressed in a unit which is simple to understand, namely fractions of the annual impact from an average person [that is in "Person Equivalents per reference year(1995) and reference area (Denmark / World) (mPE_{WDK95})]".' (Wentzel et al., 1997)*

As the next step the normalised impact categories are multiplied with weighting factors[182] to express the severity of the impact categories relative to one another. Normalisation and weighting facilitate the comparison of the different impact categories and make it easier to identify environmental hotspots.

The input-output system 'Green Accounting' operates with only 5 indicators (see Table 22) and does not aggregate. In principal, an aggregation of input-output indicators according to the methods described above would, of course, be possible.

[181] In the Danish LCA-system EDIP *'[…]Resource consumptions appear individually as assessment parameters […] and not further aggregation or conversion to "potentials" is made, as is done in the conversion of emissions to potential environmental impacts'.* (Wentzel et al., 1997) In a BEAT-based study (Marsh et al., 2000), however, the level 1 resource consumptions and waste volumes were simply summed (with an equivalency factor 1, so to speak).

[182] *'In determination of weighting factors for the individual impact categories, the EDIP method is based on the existing Danish political targets for reduction of various categories of environmental impacts.'* (Wentzel et al., 1997)

Environmental scopes

The analysed indicators systems also differ in their environmental scope:

Table 19: Overview of the environmental scope of the different indicator systems

Environmental issue	**Indicator system**				
	BEAT	Environmental Assessment and Classification of Buildings	Green Accounting	BREEAM	Local Transport Performance ('LTP')
Energy & emissions to air	**X**	**X**	**X**	**X**	**X**[183]
Material consumption & waste	**X**	**X**	**X**[184]	**X**	
Water and wastewater		**X**	**X**	**X**	
Hazardous substances	**X**	**X**		**X**	
Local environment		**X**	**(X)**[185]	**X**	
Indoor climate		**X**		**X**	

All systems consider energy and emissions to air (LTP, though, only with regard to induced transport), while the other environmental issues (material consumption and waste, water and wastewater, hazardous substances, local environment and indoor climate) are only considered by some of the systems. Only two systems (Environmental Assessment and Classification of Buildings and BREEAM) cover all environmental issues. A look at the sub-themes[186] of the environmental issues would reveal further discrepancies between the different indicator systems' environmental scopes.

[183] Considering exclusively induced transport.

[184] Green Accounting considers exclusively household waste generated in the use phase of the building and not waste due to building materials (which the other systems (mainly) focus on).

[185] Green Accounting has additional modules for 'transport' and 'green areas'. The transport module calculates the transport-related CO_2-emissions per person based on the amount of kilometres travelled with the different transport modes per year. The module for 'green areas' describes the biological value of a property by assorting 'bio-factors' to the different kinds of surfaces surrounding a building. (http://www.by-og-byg.dk/udgivelser/pc-programmer/groent_regnskab_for_boliger/index.htm) In practice, however, these are not broadly used.

[186] **CHECK**: create cross-reference!! See table 'The environmental systematisation and environmental scope of this study' in the chapter 'Environmental effects of buildings'

Decision-making situations

The following table gives an overview of the decision-making situations addressed by the different indicator systems:

Table 20: The decision-making situations addressed by the different indicator systems

Decision-making situation	**Indicator system**				
	BEAT	Environmental Assessment and Classification of Buildings	Green Accounting	BREEAM	Local Transport Performance ('LTP')
Siting				**(X)**	**X**
Project design	**X**	**X**	**(X)**	**X**	
Renovation	**X**	**X**	**(X)**	**X**	

Most indicator systems address the decision-making situations project design and renovation and leave out the siting. Only Local Transport Performance is designed for the consideration of induced transport already in the siting. The BREEAM indictors for transport, land use and ecology[187], however, can principally also be used in the DMS 'siting'. None of the investigated indicator systems offers a coverage of the siting with elaborated indicators for a broad range of environmental issues.
Green Accounting focuses on flows in the *use phase*. Its indicators can, nevertheless, principally also be used to define performance targets in the project design and in the renovation (which then can be controlled by monitoring in the uses phase).

Data foundation

The analysed indicator systems also differ with regard to their data foundations.

LCA-systems are based on material volumes extracted from the project plans, -LCA-data on these materials (usually supplied by databases attached to the LCA-tool) and an anticipatory calculation of the building's energy consumption in the use phase (for example with the IT-tool for the calculation of a building's thermal requirement and energy frame 'Bv98' (Aggerholm et al., 1998)).

Input-output indicator systems are based on measurements of the flows in the building's use phase. In case of the prospective use of input-output indicators the flows can also be calculated or estimated on the basis of statistical data.

Checklist-systems are based on qualitative or quantitative evaluations of concrete measures.

[187] For details see the analysis of BREEAM in the appendix

Target groups

The different indicator systems also address different target groups:

Table 21: Overview of the target groups addressed by the different indicator systems

Target groups	Indicator system				
	BEAT	Environ-mental Assessment and Classification of Buildings	Green Accounting	BREEAM	Local Transport Performance ('LTP')
Local building authorities			**X**		**X**
Professional clients			**X**	**X**	
Project designers	**X**	**X**	**X**	**X**	**X**
Consultants	**X**	**X**	**X**	**X**	**X**
Administrators			**X**	**X**	
Private clients		**X**	**X**	**X**	
Building researchers	**X**		**X**		

Only one indicator system (Green Accounting) addresses all the actors in the scope of this study, while the other systems each have different actor scopes. Only two systems (BEAT and Green Accounting) address the target group 'building researchers'. Also the target group 'local building authorities' is addressed by merely two indicator systems (Green Accounting and Local Transport Performance) whereas the target groups 'project designers' and 'consultants' are addressed by all five indicator systems.

Table 22[188]: Overview of selected examples of current indicator systems in the building sector (continues on the next page)

Indicator system	Indicator principle	Indicators, units used & levels of aggregation	Environmental scope	Decision-making situations	Data foundation	Target groups
Building Environment Assessment Tool ('BEAT')	Life cycle assessment ('LCA')	Person Equivalents per reference year and reference area (mPE_{WDK95}) effects (e.g. 'contribution to global warming in tons CO2-equivalents') amounts of raw materials/emissions	Energy & emissions to air Material consumption & waste Hazardous substances	Project design Renovation	LCA-databases & material volumes extracted from the project plans	Project designers Consultants Building researchers
Environmental Assessment and Classification of Buildings	LCA & checklist	Four levels of aggregation: 4th level: classes A(most environmentally friendly) B (quite good) C (only slightly above standard) 3rd level: PE/(m^2 x year) (Person Equivalents per square metre per year) for the different environmental issues) and a corresponding number of POINTS 2nd level: PE/(m^2 x year) for the different BEAT-impact categories 1st level: measurements & calculations (e.g. of volumes of materials, indoor climate parameters) in the respective units, points for application of checklist-measures	Energy & emissions to air Water & wastewater Material consumption & waste Hazardous substances Local environment Indoor climate	Project design Renovation	LCA-databases & material volumes extracted from the project plans (uses 'BEAT' as a subsystem) use of 'Indoor climate label for construction materials' as a subsystem checklists (qualitative evaluations of concrete measures), especially for indoor climate	Professional clients Consultants Project designers Private clients
Green Accounting	Measured consumptions (input-output) in the use phase	CO2-emission (for both Heating and Electricity) in t CO2-emission / (person x year) Heat consumption in MWh/(100m2 x year) or MWh/(person x year) Electricity consumption in kWh/(person x year) Water consumption in m3 / (person x year) Waste generation (in the use phase) in kg / (person x year)	Energy & emissions to air Water & wastewater Material consumption & waste	Project design Renovation	Measured consumptions (from the billing of the providers) Scientific data on different energy sources (CO_2-emissions and energy efficiency)	Local building authorities Professional clients Consultants Project designers Administrators Users of buildings Building researchers

[188] In the description of the indicator systems this table displays only those aspects that are within the scope of this study. Aspects covered by the indicator systems that go beyond the scope (for example 'transport security' as an aspect covered by the system 'Local Transport Performance') of this study are not displayed.

Building Research Establishment Environmental Assessment Method ('BREEAM')	Checklist	Three levels of aggregation: 3rd level: Rating 1 Excellent, 2 Very Good, 3 Good, 4 Pass each corresponding to certain point-score benchmarks 2nd level: point scores for – Management – Heath & Wellbeing – Energy – Transport – Water – Materials – Land use – Ecology – Pollution 1st level: checklist: application of concrete measures as sub-indicators for each level 2 indicator (corresponding to certain numbers of points)	– Energy & emissions to air – Material consumption & waste – Water and wastewater – Hazardous substances – Local environment – Indoor climate	– Project design – Renovation	LCA-databases & material volumes extracted from the project plans (uses the LCA-tool 'ENVEST' as a subsystem) checklists (simple qualitative measures)	Professional clients Project designers Consultants Administrators Private clients
Local Transport Performance ('LTP')	Input-output	– shares of transport modes – energy consumptions per transport mode – car emissions (in Kt CO_2 and Kt NO_x per year for the whole district)	– Energy & emissions to air[189]	– Siting	National statistical data & site-specific data on inhabitants, dwellings, roads and facilities in the district	– Local building authorities – Consultants – Project designers

[189] Considering exclusively induced transport.

Concluding remark

The above mapping of existing indicator systems (which is condensed in the above Table (Table 22) showed that indicators differ significantly with regard to several respects.
They employ three different indicator principles:

– life cycle assessment (LCA),
– checklists indicators and
– input-output indicators,

which each 'take the environmental pulse' at other points in a building's life cycle, using different indicators and units. The indicator systems also have different scopes with regard to the environmental issues covered (where 'indoor climate' has least coverage while 'energy and related emissions' are covered by all systems) and the addressed decision-making situations (where the siting has least coverage). With regard to their target groups only one indicator system addresses all actors while the other systems focus on selected actor groups.

The studied indicator systems overlap with regard to their scopes. As some use different indicator principles for identical matters without harmonisation, this co-existence can cause contradictions and hinder unambiguous communication. The two checklist systems, however, integrate LCA-systems as sub-systems in their coverage of building materials, thus partly mediating the differences between the checklist approach and the LCA-approach.

On the one hand these findings underline the study's initial statement that a set of indicators, that can serve as 'a common language for green building' for a broad range of actors and decision-making situations does not yet exist. On the other hand they show that a variety of 'local dialects for green building' is spoken, which constitute a rich source of inspiration for the development of EIFOB with a broader scope.

This chapter attempted to give a factual description of the indicator systems. No statements on strengths and weaknesses of the systems were made because the views of the different actor groups on the indicator systems and their demands and appraisal of the existing approaches are analysed in the next chapter.[190]

[190] The Strengths-and-Weaknesses notes in the indicator-analysis documented in the appendix bases on a first (in this early phase somewhat intuitive) perception of different actor views.

Indicators in a social constructivist perspective

This chapter is one of the core chapters of this study. It presents the SCOT[191]-analysis EIFOB in its socio-technological ensemble. This analysis forms the basis for the closure scenarios proposed in the chapter 'Exemplifications 'Energy' and 'Indoor air quality': Three scenarios'.

The chapter follows a two-step approach: first it elucidates three[192] parameters relevant for the understanding of the actors' positions with regard to EIFOB: their roles[193], their educational background and the power structures affecting them.

Then it identifies and describes four technological frames as a means to understanding the interpretative flexibility of the artefact EIFOB and explains how – from the perspective of each TF – 'good indicators' should look.

Actors: Their roles and their educational backgrounds

The actors' roles in the building process

As mentioned in the chapter 'Introduction' the actors in the scope of this study were

- local building authorities represented by the municipal officers in charge of planning, building and environment
- professional clients[194]
- project designers
- client consultants
- administrators
- developers of environmental indicators for buildings / building researchers and (though rather indirectly)
- private, non-professional actors (especially clients and users of buildings).

Local building authorities

The municipalities as the local building authorities determine in the local plan where and what may be built[195]. They also control the compliance of the project designs with the local plan and give clients building permits.

Professional clients

Clients play a key role in the building process: without a client, no building is erected. As those who finance the building they formally have the final say in most respects (within the limits of building legislation): where to build, what to build and how to build. In practice clients usually rely very much on the advice of their project designers and consultants.

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[191] The concept of the social construction of technology (SCOT) is explained in the chapter 'Research design' (see especially the section 'EIFOB as a socially constructed artefact according to SCOT').

[192] A third parameter, the actors' decision-making scopes, has already been described in the chapter 'Decision-making situations'.

[193] The actors' roles already been touched in the sections 'Who decides what' of the chapter 'Decision-making situations'.

[194] A distinction between different kinds of clients (e.g. between municipalities as clients or private clients or 'developer clients', 'domicile clients' and 'investor/landlord client') was not considered relevant for this study.

[195] See also the section on the Danish planning and building legislation

Project designers
Clients usually employ external project designers (architects and engineers) to design the project according to their outlines. Some institutions, for example bigger municipalities, may have their own project design departments that carry out the project design themselves. Project designers also develop plans for renovations and modifications of existing buildings. While the clients *formally* have the final say in the project design, *in practice* the *project designers* usually take most of the basic design decisions.

Client consultants
In the communication with the project designers clients usually rely on the expertise of consultants. These help the clients to provide the project designers with a precise description of the building task and to evaluate different design alternatives. Client consultants may again be in-house experts or external ones from a consultancy firm.

Administrators
Administrators[196] manage or deal with the operation, maintenance and renovation of existing buildings on superior levels, for example in the administration of co-operative housing societies or the building departments of municipalities. A characteristic feature of the work of administrators is their intense communication with users and residents of buildings.

Indicator developers
Developers of environmental indicators are located at different positions with regard to the other actors. Some work as environmental officers in major enterprises or in municipalities on the development and implementation of environmental management and monitoring schemes, both for internal and external use. Others sell their expertise as employees in private consultancy firms to customers of various kinds. A third group works in research institutions.

Most indicator developers focus on selected decision making situations (for example only the siting *or* the project design *or* the operation) or on selected actors. Others (like the initiators of this study) aim to address many decision-making situations and actors. In any case indicator developers are not directly ‘in the ring’ with the other actors but stand a step aside to *abstract* from the ongoing building activities and find ways to describe them in *general terms*.

Private, non-professional actors (clients and users of buildings)
Private, non-professional actors are users of buildings[197], that is people who use buildings for work or education as well as for housing. Ultimately, buildings are built with regard to them. Their behaviour influences the building’s performance in the use phase (Gram-Hansen, 2003). Users of buildings are recipients of the work of project planners and administrators but also of indicator developers. Depending on the power constellations (which are described further below) they also play a role in setting the agenda for the other actors. As clients, they principally play the same role as professional clients while lacking a professional background in the field of building.

These actors differ in many respects, for example with regard to experience and knowledge, values and attitudes – parameters that are analysed in detail in the section on the different technological frames. The educational background, however, appeared to have a significant impact on the actors’ views on environmental indicators. Therefore dominant features of the educational backgrounds of the actors are described in the following.

[196] Also called ‘facility managers’
[197] As mentioned in the chapter ‘Introduction’, the study principally addresses buildings for housing, schools, day-care institutions and office buildings.

Educational backgrounds

Architectural education

Actors with an architectural education were working mainly as project designers, a minor part also as client consultants, indicator developers, experts in local authorities and trainers in environmentally sound project design for architects and other project designers.

Especially in Denmark the architectural training is considered to be an artistic one, the school of architecture in Copenhagen forming part of the Royal Art Academy. Here, as well as at the country's other school of architecture in Århus, students have to pass an *artistic* exam prior to enrolment. Compared with the architectural education in, for example, Germany technical aspects of building like statics, construction, constructional physics and technical building equipment form only a marginal part of the teaching schedule. This focus on aesthetics and design as the free expression of the individual architect's creative power corresponds to the classical image of a successful architect as one who becomes known for charismatic designs and his own unmistakable architectural 'handwriting'. As the architectural researcher Claus Bech-Danielsen[198] put it in an interview:

> *'Usually it is the building that BREAKS the rules that is the most beautiful one. In contrast to engineers, who are educated more to work according to rules and natural laws, architects are trained rather to transgress them.'*

Though several attempts have been made to create systematic approaches to the design process (for example by Christopher Alexander in his 'Pattern Language' (Alexander et al*.,* 1977)), architectural teaching still largely remains a process characterised by

- the use of spontaneously drawn sketches instead of precisely formulated rules (Schön*,* 1983)
- individual counselling and between teacher and student in a 'master and pupil' relation
- an absence of clear-cut criteria for the evaluation of projects and a coherent terminology.

Courses on environmentally sound building are at present not a mandatory element of architectural education. At times students can choose them voluntarily. Consequently the majority of graduated architectural students does not have any professional knowledge about environmentally sound building.

Among practising architects, however, a group has made its environmental expertise part of its professional profile. Danish architects have formed the 'Association for Environmentally Correct Architecture' ('SELMA') to foster capacity building among themselves, the National Architects Association offers courses on environmental management in project design and environmentally sound building and some of my interview partners were architects specialised in training their colleagues in this field. Several interviewees with an architectural education have used post-graduate qualifications and work experience in other areas to leave the core field of architecture. They worked in consultancies or public agencies. These developments respond to the increasing demand in the market for environmental expertise.

Nevertheless, the education remains focused on aesthetics and creativity, which contrasts with the numerous restrictions architects as project designers have to face in practice:

- The clients have quite precise demands with regard to the function and the budgetary frame, and usually a somewhat diffuse wish about the architectonic expression of the building

[198] At the Danish Building and Urban Research institute

– The building legislation (building code and local plan) contains many precise demands concerning the construction, urban planning and the design.

In addition to that, the core labour market for architects has been characterised in Denmark in recent years by fierce competition. Unemployment rates among architects are very high[199] and the professional perspectives for recent graduates are rather gloomy.

Engineering education

Actors with an engineering education work principally in all phases of a building's life cycle and also hold a strong position in the field of ecological building: engineers work as environmental experts and decision makers dealing with environmentally relevant decisions in municipalities, construction enterprises, consultancies and research institutions.

Engineering education is characterised by reductionist thinking, quantifying approaches and a natural-scientific worldview. The engineering curricula ,however, also mirror our society's 'reflexive scientisation' (Beck*,* 1986), in which the science-society relationship is not a one-way street anymore, and science is confronted with its own products, defects and secondary problems[200]. Accordingly several of my interview partners with an engineering education had also studied subjects that reach into the social sphere such as environmental management, production planning and product management, besides having had an environmental focus in their education. Engineers have a stronger position than architects in the Danish labour market, their unemployment rate being below the national average and far below that of architects.[201]

Dichotomies between architectural and engineering education

The following table sums up major dichotomies between architectural and engineering education:

Table 23: Major dichotomies between architectural and engineering education

architectural education	versus	engineering education
holistic		reductionistic
concrete		abstract
creativity		natural laws
belief		measurement
art		technology
ideas and principles		control of each case
Plato		Aristotle

Other educations

Other educational backgrounds among the actors were non-university construction-related technical educations. The above-described engineering paradigm applies also to them. In comparison with the university educations, however, they are more practice-oriented and less academic. Among my interview partners actors with this education worked as administrators and clients consultants.

The decision-makers in the management of enterprises as clients usually held a degree in economics. A characteristic feature of their education rele-

[199] In December 2002 the unemployment rate among architects was 10.2 % (source: the Union of Salaried Architects', www.arch.dk). This can be compared with the average unemployment rate for Denmark, which was 5.2% in 2002 (6.1% in 2003)(source: Statistics Denmark, www.dst.dk), and for engineers 3.1 % (5.7% in December 2003)(source: the unemployment insurance for engineers IAK, www.iak.dk).

[200] As elaborated in the section 'On the changed role of science' in the Introduction of this report.

[201] See the previous footnote for details

vant for their view on EIFOB is the fact that economists constantly work with quantitative economic figures that indicate the financial performance of enterprises, products, markets or national economies. Thus economists are very familiar with the use of quantitative indicators. They are, however, laypersons with regard to construction technology. Accordingly they share with other lay decision-makers a preference for simple EIFOB that do not require construction-related expert knowledge.

Private non-professional clients had various educational backgrounds. Their occupation with building matters was usually triggered by the wish for a *home* that meets their needs and wishes.

Power structures

The actor interviews also revealed that specific actor groups feel obliged to or dependent upon other actor groups and that this affects their willingness to accept and use indicators suggested by the actor group in the stronger position. Thus, obligations and dependencies between actor groups are likely to have an impact on the content and status of the indicators in the envisaged closure process. They are therefore described in this section, also paying attention to SCOT's concept of power as described in the section 'SCOT and power' of the chapter 'Research design'.

Architects versus Engineers – the continuous struggle for the semiotic power to define 'the environmentally sound building'

As EIFOB naturally embody a definition of 'the environmentally sound building', the power to determine the shape of EIFOB is genuinely connected with the power to define 'the environmentally sound building'. For architects and engineers, being the two main professions in the scope of this study, the question of the shaping of EIFOB is a very sensitive one, because it affects the demarcations of the fields of competence of these professions in the building process and in the last instance also their respective shares of the market for consultancy services. Architects fear that *quantitative* indicators based on LCA-tools developed by engineers would strengthen the position of engineers, while checklist-indicators based on *principles and concrete measures* would be within the field of competence of architects, thus supporting *their* position. This strife for the power to define 'ecological building' between these two professions has an antecedent in Denmark as Haugbølle-Hansen (Haugbølle Hansen*,* 1997) describes in his study about the social construction of the 'Guidelines for Environmental Management in Project Design' (The board of environmental management in project design*,* 1998):

This 'Handbook for environmentally correct project design' (this being the literal translation of its title into Danish), developed under the leadership of the Danish Association of Consulting Engineers ('F.R.I.'), has gained the status of an environmental standard; clients use it to make environmental demands to project designers, and the latter can bill it as an additional consultancy service. Even though the Danish Council of Practising Architects ('PAR') was formally involved in the development of the Guidelines[202], the self-employed architectural consultant confirmed in an interview that

[202] In his study about the social construction of the 'Guidelines for Environmental Management in Project Design' Haugbølle Hansen underlines that the representative of Danish Association of Consulting Engineers *'tried to resolve the potential conflict [between architects and engineers] by directly involving the architects in the development work in order to avoid environmentally sound project design being perceived as an engineers' strategy to conquer a bigger share of the control over the construction process and a bigger share of the available fees. This was exactly what the Danish Council of Practising Architects feared. […]Only few architectural offices, however, showed an interest in environment and ecology. […]. The architects lack of motivation to participate in the development project was in striking*

'The "Guidelines" are very engineer-minded indeed, with all their tables and long explanations.'

To facilitate the access of architects to the 'Guidelines', his architectural office and consultancy is considering developing a digital, visualised version designed to more fully meet the needs of this profession.

With regard to micropolitical power it is important to have the decision making process[203] in mind. In the course of a typical building process it is usually *the architects* who take most of the basic decisions about form, size, construction, siting, orientation and organisation of the building in an early phase of the planning process – decisions that irreversibly set the frame for the building's environmental performance. Architects themselves, however, often do not acknowledge this factual micropolitical power, and point out the many design restrictions they perceive in their work. An architect participating in a course on environmental management in project design held by the Federation of Danish Architects completely denied that architects could make a difference and implied that environmentally sound building necessarily increases the costs of the project:

'The only way you can change something is through legislation and taxation. In any given situation the client will choose the cheapest solution. He will not say 'I will increase my investment by 25 or 30% to improve the environment in the long run." Instead of building short and fast. […] The decisive parameter of the choice is the economic one. The client always chooses the consultant with the cheapest offer, and a consultant who recommends costly solutions leads to an increase of the project costs. Therefore he'll choose cheap materials and the consultant who offers the cheapest solution. […] I doubt that I [as the architect] am going to have a decisive influence on the shaping of the project.'[204]

Clients: the power of purchasers and taxpayers

As the ones on the demand end of the building sector, clients are generally in a powerful position. They can decide what they want to buy and what not. The remark of the head of the department for urban planning and environment of a Danish town illustrates this power of the purchasers:

'[After we have trained our own staff in environmental management in project design] we invite the town's construction enterprises and consultants and architects to a conference and tell them that we now have taken the decision to apply environmental management in project design to all our building projects – "And if you want to work with us, you have to play according to these rules. Otherwise you are not attractive projects partners for us anymore." And it usually has an effect when such a big client announces that. We informed, for instance, the local printing houses that in the future we would only do business with those, who use paper with an environmental label and who are environmentally certified. First that laughed at us. But as anticipated – Bingo! – one year later all of them were certified! We imagine a similar process here with the local consultants. Politically we are not at all obliged to use the local consultants, but it clearly facilitates the dialogue if the person lives just around the corner and by the way carried

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contrast with the strong interest among consulting engineer enterprises, which had quickly spotted a new consulting market.' (Haugbølle Hansen, 1997), p. 133+134.

[203] As described in more detail in the chapter 'Decision-making situations'

[204] A possible explanation for this view could be that architectural education focuses on the building design as the free artistic expression of the individual architect. When confronted with the restricting parameters in real projects the remaining space for creative expression may seem small to the architect, compared with what he *would* have liked to build. It is, however, beyond the scope of this study to seek documentation for this.

out another project for us in 1962 or knows our district heating system or something like that. Therefore we have a "big consumption" of local consultants. And they want to be part of the game.'

Private clients also have a strong staning with regard to municipalities as the local building authorities. Municipalities generally try to attract new investors and taxpayers. Because they didn't want to repel potential clients they were cautious to raise environmental standards solely on the basis of their legislative power. Instead they made extensive use of 'soft' forms for implementing building-related environmental demands such as voluntary agreements, image campaigns or ecological strategies developed together with future residents in a participatory planning process. The ongoing development of Denmark's first high-rise office building district in the south of a big Danish City is a strong example of this policy. For the understanding of the citation it needs to be explained that the City founded a private developer firm to carry out the development of the district on behalf of the city.[205] The project leader of the infrastructure development and the external consultant for environmental construction said:

'[As the owner of the ground] we could have made massive legally binding environmental demands [by means of easements][206] […] – but we didn't want to do that! Because if we make these demands there would be many who would say "Under these conditions we won't move to [the new district]. We will just move to another location. [ ]" So this is not a possibility for us as we must get the ground sold so that we get money for the [already built] subway. We have therefore said "We hope that we can get the people to do it voluntarily." […] Besides, even though we are a private company, we are closely connected with the political and public system. If [the city-founded developer firm] raises demands that do not have political support and that furthermore have the effect that we do not get the ground sold and thus cannot finance the public investments, the management of [the city-founded developer firm] would not remain in office very long.'

they did not, however, mourn about the restricted use of legal measures but expressed their appreciation about a new way to influence decision-making:

'Actually, I think that this approach gives the most results. I can observe in the years I have been working here that things are moving. They are moving because we get closer and closer to those who really make the decisions and who are really going to build. Previously we stood outside and tried to shout at them but we never sat right in front of them. But that's what we do now. And we are actually listened to, we are taken seriously when we come to talk about these things. And now they have started to say "Ok, that sounds sensible. So let's see, how we can do it." And I think this is incredibly important and I believe that this VOLUNTARY effort reaches much further [than legislative dictates]. Once they have been convinced they actually WANT to do it! And among politicians there clearly is enough support to grant an exemption from the building legislation [if clients want to realise special environmental measures]. If the building legislation is in the way the attitude clearly is "If [a client] wants to [make an environmental effort] he shall be given the right to do so!" because [the city] wants environmentally sound buildings.'

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[205] An important reason for the choice of this solution was that the financial scale of the development, including the construction of a subway line, would have been difficult to handle within the city budget and that the private developer firm could more easily acquire bank loans to finance the project.
[206] The notion 'easement' is explained in introduction of the chapter on 'Decision-making situations'.

As an example they named that the demand to use district heating was waived for a client who wanted to install an more energy efficient heating system with waste heat recovery instead.

Users and residents: the power of the people

An influential factor with regard to the environmental efforts of the different actors was public opinion. The reputation with regard to one's environmental policy among citizens, residents and employees was by all actors considered a force to be reckoned with. Municipalities and politicians have to have a 'green' reputation if they want to seen as responsible stakeholders that care about the citizens and local liveability. As the head of the department for urban planning and environment of a Danish town put it:

> *'When I was employed [as an environmental expert] in 1996 it was because the town had a bad reputation with regard to environment. And it wanted to have a good one. […] And as you know, there are many good stories in the environment – and politicians are strongly dependent on good stories, disregarding their personal attitude towards environmental issues.*

Municipalities as clients and administrators were naturally also held responsible by the public and the electorate for their building activities because they are spending tax revenue on public buildings. These buildings (schools, daycare institutions, libraries etc.) are in general to be used by the citizens, for whom, for example, bad indoor climate conditions can be a concrete health threat. Several scandals about mould in school buildings have raised public awareness on this issue and have made it a very sensitive subject for municipalities. A similar dependency on the public opinion and the reputation among employees and customers applies to other professional clients in the public as well as in the private sector, as the environmental officer of a major Scandinavian construction enterprise explained:

> *'The Danish Confederation of Trade Unions, for example, is building new headquarters in Copenhagen; they have a policy that their building shall be environmentally correct and environmentally certified because they want to use the building to show they are acting in a responsible way themselves. It is of course important for big enterprises and big organisations [such as trade unions] to be seen as environmentally conscious. An organisation has to be aware of its societal responsibility in all respects. It would lose its credibility if it were seen as an organisation that is concerned only about higher salaries while at the same time running energy-wasting office buildings. […]*
> *Big enterprises and big organisations are forced to have these considerations. One cannot be a workplace for several thousand people if one does not act in an ethically responsible way. [The problem for our company] would be that young, talented employees would not want to work in an enterprise that neglects its responsibility for its staff and for society.'*

This point is confirmed by the statements in the Danish Post's general information leaflet about the companies environmental policy (Post Danmark, 2001):

> *'Post Danmark does not deal with environmental issues because we are urged to – we do it, because we want to.*[207] *[…] Environmental considerations in the form of green accounting and life cycle assessments have become simply something that people ask for.*
> *Environmental considerations and client-orientation form a higher*

[207] This phrase indirectly states that pressure from outside *can be* a factor that influences a company's environmental policy.

synthesis. Post Danmark wishes to live up to the expectations of society and our clients. We do this by taking responsibility for the environmental impacts imposed by our services.'

In the case of co-operative housing societies it is their democratic structure based on self-administration of the residents that imposes an a priori democratic control on the administrators, the officer for 'environment and technology' of the National Association of Co-operative Housing Societies[208] pointed out. He explained that his organisation therefore favours a *voluntary* participation in the association's 'Diploma for Green Housing Organisations':

'It would be very wrong for an institution like ours to try to force things. That is not even possible, because the executive committees [of our membership societies] ARE independent, one-hundred-per-cent independent! So we cannot… the ministry for housing can maybe make a law… but we cannot force people.'

One could expect that, in spite this democratic structure, professionals within the housing societies would have a strong position due to their expertise and easier access to information. The remarks of the head of the energy department of a big co-operative housing society and its supreme architect revealed, however, that this was not their main perception:

'We may not forget who comprise the building: they are comprise people who have almost a veto right with regard to how the building shall be. And these persons are chosen because they have their constituency in the residents' democracy. They were NOT chosen on the grounds of any professional knowledge in the field whatsoever. And this means – to say it in a less polite way – if one of those who sit in the building committee, … if his auntie has a plastic window that leaks and whose hinge has broken, the building won't get plastic windows, even if they are good and tight and easy to clean and to maintain.'

Consultants and indicator developers: scientific objectivity or delivery on demand?

Indicator developers and consultants depend to different degrees on those who finance their work.

The environmental manager of a big construction company, developing schemes for internal environmental monitoring and management and for the definition of environmental ambitions in the companies building projects, explained how this dependency can influence one's work:

'I wouldn't like to sit as the environmental manager in a company were the job is only about fooling the authorities… but one can be forced to do this. You know, I was the environmental consultant for this kind of enterprise…"If we do it like this and answer that letter [from the municipality] like that then it'll take another half a year before the letter has gone through the system and been treated in the technical committee and the executive committee for housing affairs and has then been sent back to the officer in charge and then they'll ask us this and so we'll answer that…", right – you can play a waiting game for several YEARS like that. […] The environmental authorities have a strategy to classify enterprises into "proactive" and "reactive" ones. And those who display a commitment to do something the authorities treat nicely and those who do not answer the letter – it is them whom the authorities put under pressure. And this you can consciously chose to use if you

[208] 'Boligselskabernes Landsforening' ['National Association of Co-operative [209] The SCOT-theory and its central notions are explained in more detail in the section 'The social construction of technology' of the chapter 'Research design'.

are employed as a consultant. […] All environmental managers know these kinds of tricks.'

He also explained how the environmental commitment of his company is used to create a positive image in the material the company uses to presents itself to customers or potential employees.

The same dependency from financial sources principally also applies to indicator developers, though to different degrees. Consultants developing indicators for a specific customer in the frame of a short-term contract are more inclined to let customer demands rather then environmental scientific considerations guide their work, while scientists working on the basis on long-term public research funding have more freedom to strive for scientific objectivity. They too, however, have to comply in their project outlines with the research programmes funded within the framework of the national research policy. The far-reaching reforms of the Danish research policy that came along with the change from a centre-left to a liberal-conservative government in 2001 clearly revealed that this is not a factor of constant magnitude.

Technological frames

Introductory remark

As explained in the chapter 'Research design', those actors that share the same view of the artefact in question – here 'environmental indicators for buildings' – according to the SCOT-theory constitute a *relevant social group (RSG)*[209]. Their shared view in the SCOT terminology is called *technological frame (TF)*.

> *'A technological frame comprises all elements that influence the interactions within relevant social groups and lead to the attribution of meanings to technical artifacts – and thus to constituting technology. […] These elements include: goals, key problems, problem-solving strategies (heuristics), requirements to be met by problem solutions, current theories, tacit knowledge, testing procedures, and design methods and criteria. […] Within a technological frame not everything is possible anymore (the structure and tradition aspect), but the remaining possibilities are relatively clear and readily available to all members of the relevant social group […].' (Bijker, 1995)*

An analysis of the interviews from the first and the second series of interviews[210], as well as the results of the second actor workshop, identified four technological frames, which are described in the following sections. This mapping of the technological frames addresses the points

– goals and view on EIFOB
– actors composing the frame
– the position of environment among other interests of the TF's actors[211]
– key problems (from the actors' points of view with regard to EIFOB and their use)
– environmental aspects considered relevant
– problem-solving strategies
– indicator systems already in use
– tacit knowledge[212]
– testing procedures
– design methods and
– the RSG's demands to EIFOB.

Any map is a simplification; to be legible it has to leave out details. This 'map' of the 'social landscape' around EIFOB has been selective too with regard to the details displayed and has to emphasise the characteristic features, landmarks and borders in accordance with the scale and size of the map and the area to be covered. The reader, who may be very familiar with a specific part of the area mapped in the following sections and who may wish for a smaller scale, so as to distinguish further details, is kindly asked to consider this.

The public-relations frame'

Goals and view on EIFOB

The main goal of actors within the public relations frame is to obtain and to maintain a favourable public image as being environmentally and societally conscious.

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[210] See the 'Scheme for the interview analysis' in the appendix

[211] A detailed investigation of the actors' other interests was not within the scope of this study. The statements displayed here are based on general observations, the statements that were made by different actors on this subject and common sense.

[212] Not all of these points appeared relevant for the description of all technological frames. Especially the categories 'tacit knowledge', 'testing procedures' and 'design methods' are left out in the description of some TFs.

In the public-relations frame EIFOB are seen as a means of documenting for employees and customers that one's enterprise or other institution is run in a socially responsible way and takes good care of its personnel. One's environmental efforts should be made visible and communicable in a trustworthy and broadly understandable way.

As part of a quality-assurance scheme or risk-management scheme reliable EIFOB, especially those on Indoor climate and toxicity, are also seen as a means of preventing major environmental accidents and scandals, which can be very costly and severely damage one's image[213].
Consumption-related indicators are also seen as a means to keep life cycle costs low.

Actors in the public-relations frame

The main actors in the public-relations frame are big professional clients (such as international construction companies, the Danish Post or Radio Danmark)[214], administrators of buildings, municipalities as clients and also local politicians. These actors on the one hand use EIFOB-based information in their decision making, on the other hand they 'broadcast' it to their target groups.

On the position of environment among other interests of the TF's actors

For the actors within the public-relations frame, environment is *one subject among others*. Clients' main concerns are

– costs, meaning in the first place construction costs. Often there is less concern for life cycle costs.
– constructional quality
– functionality
– aesthetics and image.

There are no unequivocal relations between these concerns and environmental aspects of the kind *'the consideration of X automatically has positive environmental effects'.* There are, however, relations of the kind *'the consideration of X raises questions of major environmental relevance'*, which thus are a point of departure for the investigation of possible synergetic effects.

Environmental aspects can especially be linked with the concern for life cycle costs: especially energy-saving devices usually cause additional expenses in the construction phase and have a longer amortisation period. In general, the thinking in long terms and larger contexts is a crucial element of economical *and* ecological sustainability.

Constructional quality generally increases a building's life span. This is environmentally positive for the LCA of the building material. Whether it is also positive for the building as a whole depends very much on the consumptions in the building's operation phase.

Functionality can have negative environmental implications as a demand for more facilities (for example air conditioning, elevators, space, daylight ...) also has its ecological price.

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[213] Examples are the asbestos contamination of the European Commission's main building (the 'Berlayment-building') in the heart of Brussels or the 1997 environmental scandal in a the Hallandsås tunnel-project in Sweden carried out by the Scandinavian construction enterprise Skanska, where toxic acrylamid from leak sealings contaminated ground water and poisoned nearby residents and cattle.

[214] Three groups of actors can be distinguished:

1. Developer clients (e.g. the Nordic Construction Company (NCC)): they build and sell.
2. Investor or landlord clients (e.g. member-owned co-operative housing associations): they build, rent out and administer for and in co-operation with their member residents.
3. Resident-clients (e.g. the Danish broadcasting company Danmarks Radio (DR)): they built for their own use.

It has not been part of this study to investigate the specific views of these three types of client in detail. It depends on the specific project, to what extent the environmental concerns of the building's users or the company's other target groups are taken into consideration by the actors in the PR-frame.

Key problems

The absence of a generally accepted set of EIFOB makes it more difficult to communicate one's environmental efforts effectively and convincingly. Instead the complexity of the subject and the diversity of indicators cause disorientation.

The idea of green building is often linked with a fear of additional expenses and grassroots-style buildings, which conflicts with the wish to be cost-efficient and representable.

Environmental aspects considered relevant

It forms part of the strive for credibility of the pr-frame to promote the impression that one's environmental efforts actually derive from an a priori concern about the environment. Representatives will therefore seldom admit their 'indirect' concern but rather make statements like the following:[215]

> *'Post Danmark does not deal with environmental issues, because we are urged to – we do so, because we want to.'*[216] *(Post Danmark, 2001):*

A general characteristic of this frame's view on environmental aspects is a somewhat indirect approach which can be sketched like this:
'Environmentally relevant is what our target groups consider environmentally relevant and what our consultants – whose expertise is to underline our credibility - consider relevant.'

Accordingly both professional clients, such as municipalities that build schools and institutions for their citizens and enterprises that erect or have erected new office buildings not surprisingly share and anticipate the future residents' and users' concern for indoor climate. They know that negligence in this field would result in conflicts with the buildings' occupants.

As the head of a municipal department for planning and environment put it

> *'It is funny – people pay much more attention to environmental issues, if it concerns their children – it has to be organic milk and such things in the day-care institutions, right, and at home, they don't bother to buy it. […] And when some of the employees [of the kindergarten] complain about headache there is very quickly the suspicion that there is mould in the building.'*

The fact that professional clients, be they municipalities or enterprises, usually relied upon external environmental consulting or professional in-house expertise to determine their environmental policy brings their efforts in this field more in line with state-of-the-art practice characterised by a balanced consideration of a broad range of environmental aspects[217]. A clear interest of companies, however, is the reduction of operation costs through low consumption of energy for heating, lighting and ventilation.

While enterprises use environmental standards in their buildings to promote a positive reputation, they avoid any formal proximity to grassroots architecture in their buildings. The self-employed environmental consultant to the developer firm founded by the municipality for Denmark's first high-rise district in the southern outskirts of a big Danish City said:

> *'The majority of the enterprises wants to build environmentally correctly but it must not look like that. They don't want to have a different life*

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[215] I am aware that his statement is epistemologically problematic and that I am partly leaving aside the symmetry principle by applying yet another layer of interpretation to actor statements. Nevertheless I consider this justifiable, since my stance is confirmed by statements from interviewees and from written material as well as by my overall perception of the public-relations frame.

[216] This phrase indirectly confirms that pressure from outside *can be* a factor that influences a company's environmental policy.

[217] For details see the chapter 'Indicator systems' and the section 'The scientific frame'

style. You know, we started this [development of the new district] with an "ecological VIP[218]-tour" to Berlin, were we chartered a jet plane that we filled with bosses from economy, municipalities, ministries and so on and showed them some of these [newly built ecological] buildings there. And afterwards several of the participants came to me and said "When we entered the Daimler-Chrysler-building at the Potsdamer Platz" (which has a very elegant atrium) "it was really an eye-opener: Aha! We don't have to have straw-bale houses – it can be damn elegant and damn high and look damn expensive and everything!" And I think this excursion moved something for some because it gave them different pictures on the retina.'

Principally EIFOB shall *not* suggest that one's *lifestyle* is wrong but rather positively underline one's efforts, that is focus on environmental improvements *within* one's current lifestyle and set of values. The publications of the city-founded developer firm reveal that this tension between this a positive environmental image on the one hand and the wish to continue 'business as usual' on the other hand lead to obvious contradictions:

In its 'Environmental vision for Ørestad' (the new district) (Ørestad Development Corporation, 2000) the developer firm names as a vision for infrastructure that

'The individual transport is subdued and the public transport is fostered.'

Within one year it had to chance its transport policy to comply with client demands and advertises in its general 2001-leaflet 'Ørestad – Expanding Copenhagen City' (Ørestad Development Corporation, 2001) that

'Getting to, from and around [the new district] by car will be easy. As will be parking. Ample parking facilities are being established throughout [the district] to service the individual districts, mainly in the form of public car parks.'

and – underneath a photo of a newly built street and car park –

'[The new district] has ample room and facilities to facilitate private transport.'

Problem-solving strategies:

Problem-solving strategies employed by the actors in the public-relations frame are

- to rely upon experts to obtain credibility and professionalism:
  All actors in this RSG employed professional environmental consultants.
- to use existing and accepted indicator systems:
  The municipality of a Danish town annually publishes its green accouns based on the Danish system 'Green accounting for residential areas'.[219] Also the 'Green Diploma' of the National Association of Co-operative Housing Societies[220] incorporates the Green Accounting system.
- to proactively develop and promote one's own EIFOB systems:
  A multinational construction company has developed its own 'Environmental profile' for buildings
  'as a support tool in the dialogue with clients, project designers and others.', said the company's environmental officer in an e-mail.
  The National Association of Co-operative Housing Societies has developed the 'Green Diploma' as a

[218] Abbreviation for 'very important person(s)'
[219] For a detailed description see the chapter 'Indicator systems'
[220] 'Boligselskabernes Landsforening'[221] corresponding to a block or settlement unit

'certification system, in which housing organisations and housing departments[221] can get their efforts for an environmentally sustainable development evaluated and made visible. […] Thus they obtain the possibility to make themselves publicly known for their environmental profile while at the same time enforcing their identity internally.' (Boligselskabernes Landsforening et al., 2001)

– to create publicity around one's environmental efforts.

The RSG's demands to EIFOB

The demands of the actors in the public-relations frame with regard to EIFOB are the following:

The indicators shall express one's environmental efforts in such a way that they are *communicable to the target groups* (employees / the public / the customers / the electorate / residents and their representatives). They shall also support layperson decision-making.

In more concrete terms this means that the indicators shall

– be simple and not many
– preferably be based on already familiar units (for example monetary units, kWh, kg, litres)
– be aggregatable to a single qualitative indicator (for example "red, yellow, green" or ☺, 😐, ☹ or A, B, C, D)
– preferably be linked with the economic implications of environmental measures (economic benefits, profitable investments)

An internal report of a multinational construction company on the development of corporate environmental indices from October 2001 confirms these points:

'In order to successfully communicate the environmental indicators, both externally and internally, they have to be easily understandable and easy to relate to. Therefore we suggest indicators based on well known units such as , for example, kWh, tons and kroner[222]. Indicators that express the amount of emitted CO2 are admittedly closer to the problem but are difficult to relate to. Also the connection to the economic advantages becomes more clear with well-known units.' (NCC, 2001)

Furthermore the indicators shall convincingly display one's environmental efforts. Accordingly actors in the PRF are inclined to avoid indicators that shed light on their environmental shortcomings when they use EIFOB in public relations, as the ambivalence with regard to in inclusion of transport induced in the use phase illustrates.

Apart from that EIFOB shall

– be well-documented
– be trustworthy and
– operational, that is cost-efficient and based on easily available data.

Table 24 gives an overview of the public-relations frame.

[222] The chief monetary unit of Denmark

Table 24: Overview of the public-relations frame

Overview of the public-relations frame	
Actors	professional clients, administrators
Main goal	to obtain a favourable public image
View of EIFOB	a means of documenting, visualising and communicating one's environmental responsibility to the target groups (employees, customers, …) a means for quality assurance and risk-management to prevent environmental accidents and scandals a means of keeping consumption-related life cycle costs down
Position of environment among other interests	environment is *one* subject among others (costs, constructional quality, functionality, aesthetics and image) indirect concern for environment (to live up to the expectations of the target groups)
Key problems	absence of generally accepted, broadly communicable EIFOB
Environmental focus	indoor climate (costly) consumptions in the use phase *not* lifestyle-related aspects (such as transport) – in public relations inclination to avoid EIFOB that shed light on one's environmental shortcomings
Problem-solving strategies	rely on experts use existing and accepted indicator systems create and promote one's own EIFOB create publicity
Indicators already in use	Green Accounting 'Environmental profile for buildings', developed by the construction company NCC for internal use only partly in use / still under development: the National Association of Co-operative Housing Societies' 'Green Diploma'
Demands to EIFOB	communicable to the target groups simple, not many, based on familiar units (e.g. monetary units, kWh, kg, litres) aggregatable to a single qualitative indicator well-documented trustworthy operational (cost-efficient & based on easily available data) linked to economic implications

The scientific frame

Goals and view on EIFOB

The main goals of the actors in the scientific frame are:

– to sell (their) natural-scientific and technical expertise to a broad range of potential indicator users
– to be able to scientifically evaluate concrete measures and design principles with respect to their environmental performance and to know precisely, what is good and what is bad
– to provide scientific knowledge for decision makers
– to ensure that efforts made actually lead to environmental improvements.

Quantitative, scientific EIFOB are seen as the only reliable navigation tool to take environmentally correct decisions and as a product essential for society, which the market has not properly adopted yet.

Actors in the scientific frame

Typical actors in the scientific frame are

– researchers as indicator developers, for example at the Danish Building and Urban Research Institute (DBUR)
– consultants with an engineering background.

A special position is held by the self-employed architectural consultant, who belongs to two technological frames: to the scientific frame and to the aesthetic-holistic frame[223]. His architectural education confirms his ties to the aesthetic-holistic frame while he has acquired knowledge of the scientific frame in courses and through carrying out research projects in close cooperation with scientists. He has a long history of work in the field of environmentally sound construction and clearly sees the advantages of the scientific approach and the use of LCA-tools. The architect was involved in several projects concerning the development of EIFOB in collaboration with the scientists of the DBUR. He also works as a consultant for architectural offices in environmental management in project design. His efforts to bridge the gap between the scientific frame and the aesthetic-holistic frame, among others, by creating LCA-based design tools according to the needs of architects, place him in a special position with regard to both technological frames.

On the position of environment among other interests of the TF's actors

For environmental specialists and researchers as indicator developers, environment is the main concern, of course.

Consulting engineers naturally follow the priorities of their employing clients. Due to their educational background they have, however, a tendency to pay attention primarily to constructional quality and functionality rather than to aesthetic and economy.

As already described in the section on 'power structures, obligations and dependencies', the consultants' client orientation implies that a demand on the client's side can foster environmental awareness and competence among the consultants. On the other hand it can also lead to scientifically doubtful solutions, as the example of the Dutch 'National Packages Sustainable building' (Dutch Ministry for Housing, 2002) illustrates. Dutch scientists criticise the fact that these checklist indicator systems had merely declared the lowest common denominator as 'sustainable', that the cookbook character of the Packages did not foster a more profound learning process on the actors' side and that the integrated display of additional investment costs ignores long term economic gains due to for example energy-saving measures. (van Bueren et al., 2000) After I had described the 'National Packages'

[223] Described in the next section

in an article (Dammann, 2003) several Danish consultants expressed their interest for the packages in spite of the fact that I had described them as scientifically unjustifiable.

Key problems
The problems with EIFOB expressed by the representatives of this TF can be divided into two groups:

1. problems with regard to other TFs
2. problems within the TF with regard to LCA[224] as the favoured technological approach

With regard to other TFs the main problem is the limited application of the scientific TF's solutions by practitioners.

Here it is necessary to distinguish between different actors within the scientific TF:

Researchers working with the development of LCA-tools and indicator sets are interested in a dispersing their results broadly to create a surrounding that puts their knowledge to use and demands further research in their field. Even though as researchers they are often more concerned about the scientific correctness of their models than about their user friendliness, it is in their interest to create tools and methods that practitioners are likely to adopt.

Consulting engineers are in a slightly different situation: they may even appreciate the fact that many architects consider nowadays LCA-tools too complicated, as this secures the consulting engineers' position on the market for consulting.

One of the problems within the TF with regard to LCA as the favoured technological approach are the sources of uncertainties contained in the LCA method. A researcher and developer of an LCA-tool for buildings at a Danish building research institute explained:

> *'There are several sources of uncertainty in an LCA-tool [for buildings]: First the allocation[225] of environmental effects: here there is no such a thing as "right" or "wrong". There are just different decisions leading to different results.*
> *The second source of uncertainty is the natural variation occurring in some products: the content of heavy metals in coal , for example, varies greatly from one spot to another.*
> *But the biggest problem is, that in the planning phase you usually don't know were exactly your building products come from. And the energy consumption between different brick producers, for example, can vary with a factor 2 to 3.*
> *A solution for tackling these uncertainties could be to calculate different scenarios, but this not very realistic as it would mean a lot of additional work.'*

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[224] The LCA-approach is described in the chapter 'Indicator systems'.

[225] Allocation contains uncertainties in two respects:
1. The allocation of environmental effects in the co-production of two products.
2. The allocation of environmental effects of materials that are recycled. Concrete example: the aluminium industry demands that LCAs of newly produced aluminium should reflect the fact that approx. 80% of the material can be expected to be recycled while scientists argue that LCAs should consider only the 35% share of recycled material contained in aluminium produced *today*. These two different allocations lead to very different environmental profiles. (Source: interview with Ebbe Holleris Petersen)

Another problem is to get reliable data for the life cycle assessments:

– in the planning phase data is lacking on the amount of transport that can be expected to occur in the building's use phase
– there are not records on how much material is used for technical installations in buildings
– the availability of data on the chemicals contained in construction materials has improved but data on the *emission* of chemicals from construction materials is still missing
– data may quickly become out of date due to changes in the manufacturing of the products

Further problems are

– to integrate *local* environmental aspects such as habitat destruction, effects on the local groundwater, noise and
– to agree upon the system borders of the assessment: if the building forms the system borders and the siting of the building is not considered, the transport behaviour of its users as a major source of environmental pressures in the operation phase, for example, is not mirrored by the indicators. If the siting, access to different means of transport and transport behaviour are considered, new questions arise, for example whether or not to regard holiday flights along with daily commutation.

It also proves difficult to integrate indoor climate. The researcher and developer of an LCA-tool for buildings explained in an interview, that

> *'there is no scientific method yet to express indoor climate parameters numerically so that they could be summed up in a [LCA-)calculation tool.'*

Finally there is the problem how to *weight* different environmental aspects, that is which concrete measure to choose when one of two alternative solutions performs better with regard to *one* parameter (for example 'consumption of scarce resources') but *worse with regard to another* (for example 'ecotoxicity').

Environmental aspects considered relevant

Generally speaking the scientific frame focuses in a *broad time- and spatial-horizon* on environmental aspects *'there and later'* in contrast to the focus of other actors on environmental aspects *'here and now'*.

Thus the primary concerns are *regional and global environmental aspects* in a broader time horizon. Local aspects and indoor climate only come in the second row. Indoor climate has been integrated into the scientific frame's indicator sets not because it has been considered an a priori element of the environmental profile of a building but as a tribute to needs of the other RSGs, hoping this may boost the implementation of the indicators suggested by the scientific frame. The statement of the LCA-tool developer confirmed this:

> *'There is a debate whether it makes sense at all to consider indoor climate as an ENVIRONMENTAL aspect of buildings as the very meaning of a building is to CREATE an indoor climate.'*

On the question, if he considered it desirable that indoor climate was integrated into his tool he responded

> *"Well, good question…. I should say "Yes". Why? Because some wish that it was integrated and then it is better to have it integrated and to have the possibility to leave it out if one wants to instead of NOT having it integrated and then maybe missing it…'*

In line with the global scientific community most LCA-based EIFOB figure the following environmental impact categories and resource consumptions:

– global warming
– ozone depletion
– photochemical ozone formation
– acidification
– nutrient enrichment
– persistent toxicity
– human- and ecotoxicity
– waste
– non-renewable resources
– renewable resources

In its indoor climate module the Danish 'Environmental Assessment and Classification of Buildings' developed at the Danish Building and Urban Research institute considers the parameters:

– air quality
– thermal indoor climate
– light
– noise

Not yet operational, but considered relevant is

– land use, including biodiversity and impact on local ground water formation

In Denmark as well as in the Netherlands there is a general tendency to broaden the scope of indicators by integrating more and more environmental aspects.(Dammann*,* 2003)

Problem-solving strategies

Problem-solving strategies with regard to the indicator approach are

– to *quantify* environmental aspects in order to achieve precision and comparability
– to follow the established process of scientific knowledge production of measurement, documentation, expert-conferences, peer-review of publications, etc.
– to adapt the life cycle assessment approach established for industrial products to building materials and buildings
– to develop computer tools with integrated databases to facilitate life cycle assessments
– to create databases with product data
– to integrate existing scientific knowledge from other fields into their indicator set: for example to refer to the health authority's register of hazardous substances

Problem-solving strategies with regard to other TFs are

– to involve indicator users in the development of EIFOB, for example in advisory panels or as project partners
– to design the indicators according to the needs of the actors, both with regard to the contents of indicators (for example by integrating indoor climate) and their shape (for example by offering a high level of aggregation)
– to develop indicators in iterative loops of
  development of draft indicators → test implementation → stakeholder feedback → reshaping of the indicators → test implementation → etc.

– to strive to obtain 'obduracy'[226] of their indicator-approach by institutionalising it, for example by prescribing LCAs in the building code[227], by using LCAs in the evaluation of architectural competitions or by creating national LCA-databases.

Indicators systems already in use

In Denmark and in other countries various indicator systems have already been developed by actors in the scientific frame. The Danish ones are

– Green Accounting[228]
– Energy labelling of houses and owner-occupied flats[229]
– Environmental assessment and classification of buildings[230]
– the LCA-tool 'BEAT' ('Building Environment Assessment Tool')[231]

In the Netherlands two LCA-tools for Buildings exist in parallel: Eco-Quantum and GreenCalc. (Dammann, 2003). Also other countries (Germany, United Kingdom,…) have 'their' LCA-tools for the building sector.

The RSG's demands to EIFOB

Generally speaking the scientific frame favours quantitative indicators, based on measurements and calculations. Demands to EIFOB are that they are

– scientifically justifiable, that is in accordance with international state-of-the-art research
– precise
– transparent and well-documented (with regard to how the results are calculated and uncertainties are treated)
– consistent (different users should obtain consistent results)
– covering the entire life cycle of a building.

Tacit knowledge[232]

In their work indicator developers and consultants get in touch with many different actors in the building sector, who are all potential users of their indicators systems. This gives them an extensive tacit knowledge the concerns and ways of thinking of the other actors.
Involvement of stakeholders in workshops, other meetings and interviews is another area of tacit knowledge.

Testing procedures

Concerning the testing of LCA-tools the researcher and developer of an LCA-tool for buildings at a Danish building research institute explained that

> *'It is impossible to test [our LCA-tool] in the meaning of approving anticipating calculations [of our LCA-tool] with measurements in reality. Environmental impact potential cannot be measured. But we tested [our LCA-tool] by gaining feedback from different users and discus-*

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[226] 'Obduracy' in the sense of Bijker meaning the degree to which an artefact's meaning for its relevant social groups has 'hardened': concrete, when still liquid and 'soft', can be poured and adopts the form of its surroundings. Once it has hardened the surrounding'a take its shape for granted and adapt to it.

[227] This is presently discussed in the Netherlands, where a regulation for an LCA-based material related environmental profile ('mmg') is drafted at present. See also (Dammann, 2003)
[228] For a detailed description see chapter 'Indicator systems'
[229] Ibid.
[230] Ibid.
[231] Ibid.
[232] 'Tacit knowledge' means knowledge or skills that its possessor is unaware of. He takes it for granted and would have difficulties making this knowledge explicit when ask by an outsider, what he is doing and why he does what he does. To explain the notion 'tacit knowledge' Bijker gives this example: *'It is unlikely that a modern bicyclist would be able to describe so adequately what exactly she is doing when keeping her balance. Her craft of riding a bicycle is almost completely "tacit knowledge".' (Bijker, 1995), p. 39*

sions of, for example, unexpected calculation results. […] The heat-loss calculation on the other hand can be checked by measurement in the existing building, and [our LCA-tool] uses the heat-loss calculation method.'

Design methods

Principal methods for the design of indicators are a systematic approach, documentation and peer-review.

Table 25 gives an overview of the scientific frame.

Table 25: Overview of the scientific frame

Overview of the scientific frame	
Actors	scientific indicator developers, consultants with an engineering background
Main goals	to sell natural-scientific and technical expertise to evaluate buildings *scientifically* and precisely to provide scientific knowledge for decision makers to ensure that efforts made actually lead to environmental improvements
View of EIFOB	quantitative, scientific EIFOB as the only reliable navigation tool to environmentally advantageous decisions (which still needs to be adopted by the market)
Position of environm. among other interests	environmental specialists & researchers: environment main concern consulting engineers: follow the priorities of employing clients
Key problems	*with regard to other TFs*: the limited application of the scientific TF's solutions by practitioners the opposition among architects and private laypersons *with regard to LCA as the favoured technological approach:* sources of uncertainties (allocation, natural variations, anticipation) to get reliable data to integrate *local* aspects (like habitat destruction, local groundwater, noise …) to agree upon the system borders of the assessment to integrate indoor climate how to weight different impact categories
Environmental focus	regional and global environmental aspects *'there and later'* global warming ozone depletion photochemical ozone formation acidification nutrient enrichment persistent toxicity human- and ecotoxicity waste & resource consumption: non-renewable resources renewable resources Indoor climate: air quality, thermal indoor climate, light, noise Not yet operational, but considered relevant: land use, including biodiversity and impact on local ground water formation
Problem-solving strategies	1. with regard to the indicator approach to quantify in order to achieve precision and comparability to follow the established process of scientific knowledge production to adapt life cycle assessment to building materials and buildings to develop computer tools to facilitate assessments to create databases with building product data 2. with regard to other TFs: to involve indicator users in the development of EIFOB to design EIFOB according to actor needs to actively promote LCAs in various ways
Indicator systems already in use	Green Accounting Energy labelling of houses and owner-occupied flats LCA-tools (in Denmark usually 'BEAT' ('Building Environment Assessment Tool') Environmental assessment and classification of buildings
Demands to EIFOB	scientifically justifiable precise & quantitative (to achieve comparability) transparent and well-documented consistent (different users should obtain consistent results) covering the entire life cycle of a building

The aesthetic-holistic frame

Goals and view on EIFOB

The main goals of the actors in the aesthetic-holistic frame are

- to secure space for autonomous creativity and innovative design and to avoid any further design restrictions
- to defend their position as competent generalists in the building sector
- to achieve acceptance of the aesthetic-holistic frame (in opposition to the rationalist scientific frame): that the aesthetic is a necessary element of the environment
- to avoid additional loads of boring, badly paid work
- to have their design priorities confirmed

Several members of this RSG question the meaningfulness of EIFOB. The general attitude to environmental indicators is somewhat defensive and sceptical, as EIFOB are seen as a potential threat in three respects:

1 a threat to the RSG's competence and power to define 'ecological building'
2 a threat to design freedom
3 a potential additional workload outside the RSG's field of competence.

With regard to the first two aspects an architect at a medium-size architectural office spoke against the concept of a consensus on the definition of 'the ecological building':

> *'The fact that different actors HAVE different ideas of an ecological building creates the dynamic that is necessary for the development in the sector.'*

This being said, preference is given to *qualitative* checklist-indicators based on concrete measures and principles – indicators that give unambiguous and simple answers to concrete *design* questions occurring in the TF's actors' daily work of project design.

Actors in the aesthetic-holistic frame

The aesthetic-holistic frame is mainly composed of architects.

One interviewee, the municipality officer of a big Danish city, responsible for the determination of general and environmental guidelines for the construction of schools and day care institutions, is a member of the aesthetic-holistic frame *and* of the scientific frame. In spite of his background in engineering he held in many respects a position in favour of the aesthetic-holistic TF (and partly also of the layperson-sensualist frame) which fits well with his further role as a non-professional organic farmer.

On the position of environment among other interests of the TF's actors

Architects often stated environmental aspects were an integrated part of their *'holistic'* approach[233] to project design:

> *'The environmental should be an inseparable part of the aesthetical. To stay in a beautiful room is also part of a good indoor climate. […] The holistic view is important.'*

an architect at a medium-size architectural office made his point.

> *'It is crucial [for the environmental performance of a building], that it is beautiful architecture. If that's the case, then the building lasts long. If one cannot stand to look at it, it won't last long, because people tear ugly things down,'*

an architect of a Danish co-operative housing society confirmed.

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233 The architects' understanding of this notion is described in more detail in the paragraph 'environmental aspects considered relevant' further below.

These statements, however, clearly underline the architects' primary focus on aesthetic design aspects. In most cases environment is dealt with in a reactive way to meet client demands.

Other concerns are aspects of functionality, especially the more obvious ones such as space for the user activities and accessibility, while the more technical functions such as ventilation, heating and lighting are usually not among the architects' primary concerns.

Nevertheless, as mentioned in the section 'Architectural education', there is a minor group among practising architects which has made environmental expertise a part or the core of its professional profile.

Key problems

A key problem of this RSG is the conflict '*LCA versus concrete measure based indicators'* which has different aspects:

One aspect is the closeness to decisions:

Architects have to make many concrete decisions[234] about, for example, choices of materials, constructions and technical systems, and would prefer indicators that make clear and simple statements of the type *'A is better than B'* on these choices. Simple qualitative indicators of this kind, however, are accused of being misleading and scientifically not justifiable from the scientific TF.[235] This causes confusion. The chief architect of a major housing association, said:

> *'Many good things were dismissed, because we haven't had reliable indicators. "Is this good at all…?" - "Wood is good." … but there are also some who say that that's not the case all the same. And like this there is always someone with a pet idea and finally one gets a bit confused. There is nobody who made a handbook where we can look up "It is good to use this, in terms of life cycle or environment."'*

Other aspects are *the workload and familiarity with approaches and tools*: The application of LCA-based indicators is cumbersome, as it requires a lot of work to insert the (often not readily available) data into the calculation programmes. The architect, mentioned before as belonging to the scientific frame, explained:

> *'[The LCA-tools] should be more visual ['if they should be more user friendly for architects'] You have to put a terrible amount of data into the programme as it is today, if you want to have a picture of an entire house – which is not an especially funny work either. And then you are still lacking some parts of "just this specific façade construction which I have here…and I can't find them anywhere. And if you start to experiment a bit, for example with unfired clay bricks, you have to spend time ringing to manufacturers to find the data which have big uncertainties and have you thought of including everything into your calculation, transport and all…?'*

The chief architect of a major housing association confirmed his statement, pointing out the economic aspects:

> *'We don't have time for that. If life cycle assessments and results of the different materials are not already available so that one immediately can compare them with one another we don't have the possibility to carry out the calculations ourselves. And we cannot assign a technician to it either. This would cost a fortune. […] We cannot carry out basic research just because we are building a house!'*

Another dilemma concerns *design freedom*:

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[234] See the chapter 'Decision-making situations' for details

[235] Which promotes statements more of the kind '*If C, than A is better than B, but if D, than E is the best.'*

Life cycle assessments may be cumbersome to carry out, but they do not encroach on design freedom as they leave it up to the architects *how* they achieve the quantitative goals. Environmental demands based on concrete measures and principles on the other hand are easier to evaluate and to handle, but leave less space for creativity and innovation. The officer responsible for environmental guidelines for the construction of schools and day care institutions in Copenhagen City's administration, pointed out this potential pitfall of indicators based on concrete measures:

> *'It would be nice, if there was an indicator which would not lead to a distortion of HOW one allocates the efforts, because, there are some things which are easier to measure than other things. […] One could risk ending up with projects that are optimised with regard to the indicators and not with regard to the objective. I know that , for example, in yachting – a totally different field – in the way handicaps are calculated in big races, there are a lot of funny factors such as the proportion between the surface of the sail and the boat's and the mast's length and the breadth and I don't know what, which enter into some complicated formulas and which are absolutely decisive factors for how modern sailing boats are designed. And which once in a while result in some boats, which are neither beautiful nor especially functional - but they win.*
> *And this trap we don't want to get caught in.'*

Not many architects, however, were aware of the fact that LCA-based indicators offer more freedom for creativity than indicators based on concrete measures. The majority seemed to favour the latter notwithstanding the constrains it presents.

Furthermore, an unfamiliarity and scepticism with regard to natural-scientific thinking creates a distance to environmental scientific approaches, the use of quantifying computer tools and their output figures, be they numerical or in the form of diagrams.

> *'A building is more than numbers,'*

as one architect expressed his scepticism with regard to scientific reductionist approaches.

Environmental aspects considered relevant

With regard to the question, what environmental aspects are considered relevant, three things are characteristic for the aesthetic-holistic frame:

1 There is a certain reluctance and incapability to give clear answers to the question. Environmental aspects are often mixed with general functional and aesthetical aspects.
2 This lack of clarity is not presented as a deficit but as the capacity to see at things 'holistically', in opposition to an unduly fragmented view that was attributed to engineers.
3 Among the environmental aspects considered relevant there is a bias towards the 'local', that is towards aspects, that are of concern for the residents or users *here and now* (like indoor climate and health, aesthetical quality, psychological environment).

These points are illustrated by the following observations:
As part of a *seminar on environmentally sound project design* held by the national Danish architect's association, an architect lectured about his project of an building renovation. After his presentation I asked him what he considered the main *environmental* improvements achieved in this project, as to me this information had not clearly emerged from his lecture.

> *'The working conditions for the employees, especially the creation of spaces of high aesthetical quality and the improved lighting.'*

was his answer – working environment and indoor-climate aspects, that I consider core elements of good architecture *in general*, but which do not ad an additional *environmental* dimension to the project. This, however, did *not* provoke any further critical questions or remarks, neither by the other course participants nor by the two architects leading the seminar.

In an interview with the same architect he later elaborated his point:

> *'The environmental should be an inseparable part of the aesthetical. To stay in a beautiful room is also part of a good indoor climate. I think that environment, health and economy form an inseparable unit. […] It is the HOLISTIC approach we consider important.'*

This emphasis on the 'holistic' was mentioned by several architects in several interviews. It reflects the fact that architects in their design work constantly have to make decisions that balance different and often contradicting parameters such as functionality, aesthetic, technical and economical feasibility; environmental soundness is yet another one to add to the list.

This 'holistic thinking' is a dominant feature already of architectural education and stands in clear contrast to the reductionist methods that characterise engineering and natural science education. This contrast was expressed in a sometimes provocative way by several of the interviewed architects:

> *'In the technical part, which is more the domain of the engineer, it is much easier to compare, for example, two mixer taps and see which one is the best. There is very often an unambiguous answer',* one architect said.

Another confirmed

> *''The holistic view is important. If environmentally sound buildings are so ugly that people cannot stand to look at them they won't hold very long. […] Environmental profiles of building materials can give a wrong picture, because they require that the material is used in a certain way. I think one of most important criteria for whether a building is environmentally correct or not is the capacity of the planner to develop a somewhat reasonable judgement about how things develop in the future. I think these things are far more significant than using the right joint filler.'*

However, *none* of the architects stated that energy and resource consumption in general as well as global warming were *not* important environmental issues. One architect declared that water consumption was not relevant while urban sprawl and land use were likely to become priority issues in the future.

The officer responsible for school buildings and day-care institutions in the City of Copenhagen's administration for education and youth, said his institution focused on

– indoor climate[236] and

> – *'energy consumption, especially consumption of electricity because schools and day-care institutions use a lot of electricity-consuming systems such as ventilation and lighting. And the amount is increasing due to the new building code. Schools form a very big fraction of Copenhagen municipalities building stock and electricity consumption in schools is a crucial factor for the municipality's total environmental impact. We don't pay nearly as much attention to heat consumption due to excess heat from the district heating system in the Copenhagen area. And we mean that the key to a reduc-*

[236] In a workshop he stated he considered *'psychological indoor climate'* important, too.

tion of the total energy consumption in the Copenhagen area is not heat consumption; it is electricity consumption. […]

- *a long life span in a material-resource-economy perspective, […] including flexibility of the design, which allows use [of the building] for something new after a couple of years without having to carry out heavy modifications.' […]*
- *finally there is a last thing, we have paid attention to in many places […], which is that the buildings' functionality and form shall support pedagogical initiatives dealing with environmental improvements. […] This can be in many different ways […], for example by creating nature-and-technology-gardens in schools or we experimented with measurements at solar panels and we have one school with a windmill and such things, which are solely pedagogically motivated. And – if we look at our administration as a whole: the biggest environmental impact of our administration – that's not at all through the buildings we build or the operation of our buildings but through the youngsters which are thought in the schools in Copenhagen. That how I see it. Like that we actually have a contact area with all the families with children in Copenhagen municipality. And that's a great many children, which go through our schools. […] Does this influence our building policy? Not so much. But we think of it!!'*

Problem-solving strategies

Problem-solving strategies among the actors in the aesthetic-holistic frame were

- to question the very concept of indicators:
  The self-employed consultant to the city-founded developer firm declared

  'I am not sure if I would use indicators. I would like that they were available somewhere in the internet, so I can download them if I should need them. But I won't make it a part of my general way of working as something I constantly use; because I am afraid, that if one has to … it somehow has to do with that if you look at the world in such small fractions – then you can happen to forget the whole. And I believe that what I am good at - that's holistic entities!'

- to copy or to seek inspiration from built examples presented as environmentally friendly in architectural journals or on excursions
- to operate with implicit qualitative indicators[237]
- to use mainly qualitative checklist indicators, such as the Dutch 'National Packages' or BREEAM
- to use the application of the 'Guidelines for environmental management in project design' (The board of environmental management in project design, 1998) as a qualitative indicator
- to get acquainted with tools and methods for environmental evaluations, for example in courses such as the one carried out by the Federation of Danish Architects in November and December 2001. In the course, however, so many different tools and methods were presented in short lectures without in-depth training that a participant commented

  'The problem defining the notion "environment" is really obvious in this course. They shoot with a shotgun[238] at an entire field. We are absolutely at beginner level here.'

[237] I use the definition of Bell and Morse, who distinguish two mindsets in the debate about sustainability indicators: one favouring indicators that are *'quantitative and explicit (clearly stated and with a defined methodology)'* and the other favouring indicators that are *'qualitative and implicit ("understood" to apply in vaguer terms, with no defined methodology)'* (Bell et al., 2001).

– attempts to adjust existing LCA-tools to the needs of architects: The architect, mentioned as belonging to the scientific frames RSG, explained:

'We may use [the Danish LCA-tool] BEAT more, especially if it becomes a bit more user friendly and visual. We are investigating if it is possible to create a purely physical model in which we have predefined for example an office building with three storeys, ten meters wide, to which all data has already been put in, and then you can use it and make it a bit wider or longer or change the window situation or rotate the house on the ground. And then you can go and play with some parameters of the house and you can see, how this affects the whole of the house.'[239]

Indicator systems already in use

Indicators systems already in use are thus

– implicit qualitative indicators such as 'use of natural ventilation', use of materials considered environmentally friendly, 'active or passive use of solar energy', …[240]
– mainly qualitative indicators, for example the Dutch 'National Packages Sustainable Construction'
– the quantitative indicators prescribed by the building code: the resulting figures (in kWh/m^2 per year or MJ/m^2 per year) of heat demand calculations and heat loss calculations
– the application of the 'Guidelines for environmental management in project design' as a qualitative indicator
– LCA-tools - to a limited extent and often reluctantly - (in Denmark BEAT, in the Netherlands EcoQuantum and GreenCalc)

The RSG's demands to EIFOB

The aesthetic holistic frame's RSG demands EIFOB that

– directly support the decisions to be taken by the actors, ergo indicators on the level of concrete measures and principles
– are easy to use and don't require much work of a kind the actors usually don't like.[241]
– don't restrict creativity and design freedom
– are within their field of competence
– are preferably qualitative, not quantitative.

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[238] A gun for bird and rabbit hunt, which shoots plenty of small projectiles to increase the probability of a hit.

[239] The comment of the developer of the Danish Building-LCA-tool on this idea was:
'What [he] wants basically is a 3-D [LCA-tool] and we will probably make this. Then you can have some reference buildings with all the data already put in and then you can easily modify these standard buildings and see how the environmental profile changes accordingly. That can be a very useful device for the early pre-design phase. However, the problem with this idea is, that architects may not be aware of the fact that these are only very rough approximations. If only they see a number then architects tend to believe that's a truth… If they give the building to the stress analyst to calculate the dimensioning of the structure everybody considers it evident that he as to have the detailed plan to carry out his calculations. But they still believe that one can make an environmental profile without detailed information. But that's just not possible!'

[240] The publication 'De Store Bygningers Økologi' ['The ecology of the big buildings', in Danish] (Lading et al., 2001), intended as a source of environmental inspiration for potential investors for the new urban district in the outskirts of a big Danish city, presents a number of big newly built or renovated buildings such as the German Parliament or the DEBIS (the Daimler-Chrysler Service company) building in the heart of Berlin as state of the art in environmental building. The publication is a good example of the use of implicit qualitative indicators as it describes the buildings almost exclusively in a qualitative way with phrases such as *'Double facades can be found at many new buildings abroad – a typical sign of environmental awareness.'*

[241] This is an important point: the work of putting numerical data into an LCA-tool may be attractive for engineers who fancy numerical computer programmes but unappealing to architects. This even more, if they feel the work is financially not rewarding.

Tacit knowledge

Tacit knowledge held by members of this RSG comprises especially experiences from previous projects about how certain materials and technical solutions perform in practice and how users react to certain design measures.

Testing procedures

'Testing' in the scientific sense is not a predominant concept in this RSG. Instead the tacit knowledge obtained through observation of existing buildings plays an important role.

However, the traditional design methods of model building and drawing of perspectives as well as the combined use of ground plans, elevations and sections can also be seen as a way of testing the design with regard to, for example, composition, functionality and correspondence with the conditions of the building site. If such drawings are, for example, combined with sun angles they can obtain explicit environmental relevance.

Especially innovative new or charismatic buildings are prototypes where new constructive and technical solutions may be applied. Building components and materials have always undergone testing as part of their market approval prior to their integration in a building. Here the architects rely on the data available in literature and product descriptions. For control of the structural performance of the design architects usually use the services of external engineers. Though simulation programmes for other aspects such heating / cooling and ventilation exist[242] they are seldom applied by architects. As a consequence avoidable problems with overheating caused by glass facades without sufficient shading or ventilation devices still occur in newly built buildings.

In some projects the potential of simulation tools has been put to good use, usually as part of a collaboration between architects and engineers in an integrated planning approach from the very beginning of the planning process on.

Table 26 gives an overview of the aesthetic-holistic frame.

[242] For example the Danish tool 'Bsim2002' (Wittchen et al., 2002)

Table 26: Overview of the aesthetic-holistic frame

Overview of the aesthetic-holistic frame	
Actors	architects, one engineer (at the same time member of the SF and organic farmer)
Goals	to secure space for creativity and innovative design / to avoid design restrictions to defend their position as competent generalists acceptance of the aesthetic-holistic paradigm (in opposition to the rationalist paradigm) to avoid additional loads of boring, badly paid work to have their design priorities confirmed
View of EIFOB	Some questioned the meaningfulness of EIFOB. Indicators were seen as a threefold threat: 1. a threat to the architects' competence and power to define 'ecological building' 2. a threat to design freedom 3. a potential additional workload outside the RSG's field of competence.
Position of environment among other interests	primary focus is on aesthetic design aspects + the spatial dimensions of functionality environment is seen as a part of the aesthetical
Key problems	LCA-based indicators are not close to decisions that architects have to take application of LCA-based EIFOB too cumbersome checklist-indicators encroach on design freedom general unfamiliarity and scepticism with regard to natural-scientific thinking ('*A building is more than numbers!*')
Environmental focus	Three characteristic points: 1. No clearly defined notions. Environment mixed with general functional and aesthetical aspects 2. this was presented as the capacity to see things *'holistically'*, in opposition to the 'unduly fragmented' view attributed to engineers 3. focus on 'local' environmental aspects *here and now* (indoor climate & health, aesthetical quality, psychological environment, …) general acceptance, that global warming and resource consumption are relevant
Problem-solving strategies	to question the very concept of indicators to copy or to seek inspiration from built examples with a green reputation to operate with implicit qualitative indicators to us qualitative checklist indicators to use the 'Guidelines for environmental management in project design' as a qualitative indicator to get acquainted with methods for environmental evaluations attempts to adjust existing LCA-tools to the needs of architects
Indicator systems already in use	implicit qualitative indicators (e.g. 'active or passive use of solar energy') mainly qualitative indicators: in the Netherlands: the 'National Packages Sustainable Construction' the quantitative indicators prescribed by the building code: the resulting figures (in kWh/m2 per year or MJ/m2 per year) of heat demand calculations and heat loss calculations the application of the 'Guidelines for environmental management in project design' as a qualitative indicator LCA-tools - to a limited extent and often reluctantly - (in Denmark BEAT, in the Netherlands EcoQuantum and GreenCalc)
Demands to EIFOB	shall support the decisions to be taken by the actors, ergo indicators on the level of concrete measures and principles are easy to use and don't require much work of the kind, the actors usually do not like don't restrict creativity and design freedom are within their field of competence are preferably qualitative, not quantitative

The layperson-sensualist frame

Introductory remark

As mentioned in the chapter 'Introduction', private, non-professional actors, especially clients and users of buildings, were not in the centre of this investigation. However, in the course of the project it became clear that they are important points of reference for the professional actors. Therefore their perspective was considered on the basis of the statements of the professional actors, relevant literature and a supplementary interview with a non-professional private actor (the president of the residents' association of an ecological settlement).

In general, this study focused on actors *who are already working with environmental issues* in the building sector. In the group of private, non-professional actors the members with an explicit environmental bias were mainly clients and residents of ecological settlements, for whom environmental issues were connected with lifestyle aspects. Of course this environmental avant-garde is not representative for all private, non-professional actors, as its environmental ambitions exceed the average. Nevertheless, several statements by the professional interviewees, who also referred to their experiences with 'average' non-professional actors, suggested that the environmental avant-garde, apart from its special environmental bias, shared the more general, EIFOB-relevant characteristics (for example the demand for simplicity) with 'average' non-professional private actors. Figuratively, the group of non-professional private actors may be pictured as a pyramid with a broad common basis for all members and a top composed of an environmental avant-garde. In accordance with the focus of this study on actors that are explicitly working with environmental issues, the ambitious ecologists at the top of the pyramid are given prominence in the following description of the laypersons' technological frame. In spite of the fact that their technological frame is generally characterised by a sensualist paradigm (see Table 27), a rational element, especially with regard to aspects beyond sensual perceptibility (such as hazardous substances or certain indoor-climate parameters), constitutes a potential affinity to scientific approaches.

Apart from this, however, the layperson-sensualist frame contrasts with scientific-rationalist approaches. The following table gives an overview of the characteristic features of the frame's underlying paradigm:

Table 27: characteristic features of the sensualist paradigm

	the sensualist paradigm[243]
point of departure:	immediate experiences and felt needs in the local environment
values:	alternative values - ecology is a question an alternative lifestyle, closely linked with social issues
legitimisation:	intuition and felt needs
environmental focus:	life style, environmental behaviour and social aspects, closed matter circles in the local environment, technical measures of symbolic significance

[243] Compare (Bech-Danielsen, 1998), whose characterisation of the ecological grass root movement in several respects corresponds to my description of the layperson-sensualist frame.

Goals and view on EIFOB

The main goals of the actors in the layperson-sensualist frame (LSF) are

- (in the case of co-operative housing projects / ecological settlements): to create an identity and a social coherence among the residents of a settlement by giving the settlement a 'sustainable' or 'ecological' identity (qualitative EIFOB as a *'brand'* or a *'lifestyle-label'*)
- the acceptance of the sensualist paradigm (in opposition to the rationalist paradigm)
- recognition of one's own critical view with regard to mainstream society and technology
- recognition of one's own judgement (sometimes even in opposition to expert-evaluations). This goal is based on the view that most of the current environmental problems actually *originate* in the scientific-rationalist paradigm[244] and accompanied by doubts that the cure can be achieved without a paradigm-change.
- perceptibility of one's environmental efforts and behaviour. The sensible dimension of the measures taken is considered important.

Apart from this rather critical view on scientific indicators, quantitative scientific EIFOB are appreciated by some actors in the layperson-sensualist frame as a means of handling indoor-climate aspects that are not sensually perceptible.

The actors in the layperson-sensualist frame are used to operate with *implicit qualitative indicators*[245]. The concept of *quantitative explicit EIFOB* is unfamiliar to them and usually not relevant category.

The perception of EIFOB rooted in the scientific rational paradigm is ambivalent: some perceive these indicators as irritating and not always trustworthy if they put question marks behind the environmental relevance of one's pet solution (for example a composting toilet, 'biological' materials such as wood or clay)[246]. Others see them as a tool for experts that is too complicated to be understood by laypersons, but that nevertheless helps consulting experts to find the path to the ecological level of ambition pursued by the layperson actors.

The president of the residents' association of an ecological settlement in a Danish town explained:

> *'One can say that in our project we [the residents] haven't been through the process yet, where we have to prioritise. That's the process, which is probably coming in the course of this year. So as a matter of fact I still haven't precisely thought about what kind of demands and what shall enter into the prioritising. The municipality made the demand that the design proposals [submitted by the architects in the competition] shall be evaluated with a system called "BEAT 2000" – I don't know this system. I just said "Yes, that's fine, that's ok!" But we [-the residents-] frankly speaking haven't done that much thinking yet with regard to which criteria shall form the basis for the prioritising that has to be carried out.'*

Actors within the layperson-sensualist frame

Actors in this frame are non-professional private clients and residents who either got together to create a settlement according to their visions or who wish to initiate alterations in their already existing co-operative housing unit. The levels of ecological ambition and the common vision of the groups of clients naturally varies from project to project.

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244 Compare Beck's notion 'reflexive scientization' (Beck, 1986), as described in the paragraph 'On the changed role of science' of the report's introduction.

245 (Bell et al., 2001)

246 In the project's third workshop a public sector participant confirmed *'Many residents are sceptic of experts and only appreciate their statements if they support the residents' favoured solutions.'*

The president of the residents' association of an ecological settlement explained:

> *'Our entire concept has been to try to build an ecological co-operative housing project as a suburb-settlement and not out in the countryside. Do you know [the other well-known ecological settlement in this region]? It lies out in the countryside. But our area lies in the middle of a suburb. So the way we want to live is on the premises of suburb. We don't expect to have our own agriculture and to grow our own fruits and vegetables.'*

However, despite these differences there are some common features, which are sketched in this section.

On the position of environment among other interests of the TF's actors

The main interest of the actors in this TF is to achieve a high quality of housing within the limits of their economic resources. Especially in projects planned with resident participation from the very beginning, the *social* dimension of quality of life has a prominent position, mirrored by common facilities (such rooms for common eating and cooking, common workshops and gardens) as well as by a certain homogeneity of the residents. Here a settlement's environmental profile has an important role as a bearer of common values and activities:

The president of the residents' association of an ecological settlement explained:

> *'I grew up in a housing co-operative – this meant that I wanted to create a housing co-operative myself.*
> *The co-operative housing association where I live at present started by the municipality building it. But the people, who have moved in, do not have anything special in common.*
> *But now we are creating an association where the building is initiated from the bottom – by the residents themselves. And the residents are more prepared that there are some environmental measures. And also maybe that it can be a bit more cumbersome than a normal settlement in some respects. In this way it is natural to say, if there is a housing co-operative it is a better housing form in which to reach agreements about some environmental measures than a block of flats where the residents have not known each other beforehand. […] Here [in our settlement] we announced from the beginning that it is an ecological or sustainable settlement we want to build – so the people that want to move in know this in advance and will hopefully be positive. Otherwise they have simply chosen the wrong place to move to.'*

The concern for ecology derives in the first place from the interest in the quality of one's immediate surroundings *('here and now')*, of which certain *perceivable* environmental features are seen as being an important element of. Concern for global environmental aspects *('there and later')* come only in the second place. Most residents are surprised when they learn in the course of the planning process that prioritising according to their focus on the environment *here and now* on the basis of their intuitive judgements and prioritising according to more global environment aspects *(there and later)* on the basis of rational scientific evaluations can reveal contradictions and conflicts. In this case the global environment is usually the loser when the limited financial resources require the abandonment of some objectives:

> *'[The ecological settlement] Munksøgård, [initiated by a group of ecologically minded private persons] did not reach all the objectives set in the beginning of the project. It has, for example, not achieved a significant reduction of the heating energy consumption, which amounts to 90% of the building code's demands – this is the usual standard for*

new housing buildings in Denmark and clearly exceeded by both Swedish standard houses and many buildings in Germany. […] In the final prioritising the need for social community and the demand for self-administration and an integrated agricultural production proved to be stronger than the demand for low resource consumption.' (Foldager, 2002)

Often, however, the wish for an ecological life-style and the wish for economic savings are allies in the attempt to keep consumption in the building's use phase low.

Key problems

Key problems of this RSG with regard to EIFOB are

- limited environmental knowledge, which makes it difficult for the laypersons to follow the conclusions of environmental experts and to interpret complex quantitative indicators
- the limited time resources to get involved in the subject
- the focus on specific technical 'pet' solutions disregarding the actual underlying *needs* of the residents and the specific conditions of the site[247]. Seen from the expert's perspective, these are not necessarily the building's environmental hotspots.

The environmental officer of a the municipality of a Danish town told:

'Some of the citizens wanted composting toilets. […] But if these shall be emptied by the municipality then there are also certain working-environment demands. And is a composting toilet the right thing here in the centre of a town? Here we have separated sewerage systems for storm water and wastewater. So maybe it is better to use the existing system here and use composting toilets in places were there is now sewage system. So we [the municipality] rather wanted to do something more on the energy side. […] But there are also splits in the citizens organisation: Some want the composting toilets and some think "That's disgusting" and some focus very much on water and some very much on energy and some very much on waste – according to the different persons' personal interests.'

- to identify the environmental hotspots
- and prioritise ecological measures in connection with economy and other parameters (such as user needs and wishes)

The president of the residents' association of an ecological settlement explained:

'We haven't really though very much about the question yet, which criteria shall form the basis for the prioritising we have to do…. The most significant criterion is – evidently – the economics. It has to be economically realisable. And basically we haven't come any further than that yet…'

Environmental aspects considered relevant

Actors in the layperson-sensualist frame, non-professional clients usually focus on concrete measures and technical solutions (for example clay walls, ecological gardens, solar panels, urine selection tanks) rather than on scientific environmental categories. In general they favoured those environmental measures that are directly perceivable, have a symbolic significance and appeal to the individual client's visions of an ecological home and lifestyle.

[247] This point has been elaborated by Hoffmann et. al. in the paper 'Assessing the sustainability of small wastewater systems – a context-oriented planning approach' (Hoffmann et al., 2000).

A resident of an ecological settlement explained

> *'For me it is important to live in a wooden house with walls of unfired clay and wooden constructions – materials that are easy to build with and consume less resources in production, transport and erection. This fits with my view that these are incredibly smart homes. But it is also much a part of the experience to live in a wooden house with unfired clay bricks.' (Foldager, 2002)*

Another aspect high on the agenda is indoor climate. The president of the residents' association an the ecological settlement told:

> *'One of the things I am looking forward to is to get a really good indoor climate in the apartment. One could say, this is very egoistic: it is only about me and my family.'*

He expressed, however, also a concern for broader environmental problems:

> *'It is just very important that we understand that the world is based on a CIRCULATION of substances. There is no such a thing as "to throw away". There is no "away" anywhere. It is important that we get a thinking in life cycles into our world. We in the West have become so good at hiding our waste away – we don't notice our own shit, to say it frankly.'*

The emphasis on matter-circulation as an ecological core principal is typical for private clients with environmental ambitions above average. Many of them vigorously demand local circulation solutions for organic waste and human faeces such as composting toilets, a separation of urine for use as fertiliser in the local vegetable garden, composting of organic waste or use of green waste for chicken feed.

Another characteristic of non-professional private clients is their focus on the *local* environment. The technical solutions favoured by them often have effects directly perceivable on the local level (for example use of organic waste as fertiliser for local food production).

Problem-solving strategies

Problem-solving strategies in the layperson-sensualist frame are

- to operate with implicit qualitative Indicators
- to copy solutions with a positive environmental reputation
- to hold fast in one's priorities despite contradicting scientific indicators
- to rely on external expertise
- to demand simple, preferably qualitative indicators
- to learn to understand more complex indicators.

A strategy followed by administrators to address actors in the layperson-sensualist frame is to boil down *quantitative* indicators to a simple *qualitative* indicator which is easily communicable to the public:

The municipality of a Danish town informs residents about their consumption of electricity, water and district heat, calculates comparative (average and best practice) figures and informs every household in a letter that *'You are a red/yellow/green consumer'*. The municipality's environmental officer described his positive experiences with this practice in an interview:

> *'And so there were some who called and said "We have lived here for thirty years and we think we are really environmentally conscious. And now you write that we are RED consumers. Why that?" And then you can have a dialogue and a discussion with them and explain "Well, it is so and so and so – therefore I say you are red. Then they can consider their choices, if they want to go on with having this consumption or life-style.'*

Indicator systems already in use
Of course residents and users are at the receiving end of the indicators addressed to them by those in charge of administrating the buildings (→ see the section on *'the public relations frame'*).
Indicators familiar to this RSG are

- implicit qualitative indicators
- costs expressed in money
- the basic measurements of consumption (kWh electricity, litres of water, kWh consumed for heating, kg of waste) as stated on the bills of the providers in connection with the costs
- the closely related indicators used in 'green accounting'[248]
- simple aggregated indicators (a overall character between 'A – M') as part of the Danish 'Energy labelling'-scheme for houses and owner-occupied flats[249]
- in the one Danish town the distinction between *'green, yellow and red consumers'*[250].

The RSG's demands to EIFOB
According to the actors in the layperson-sensualist frame EIFOB shall

- be easy to understand
- shall preferably be qualitative, not quantitative
- trustworthy
- be on the level of concrete measures or even above (aggregated to a single qualitative indicator)
- support the process of prioritising different measures and principles in the planning phase
- address environmental concerns close to the RSG's life world.

Tacit knowledge
Private laypersons usually have a fragmented, non-scientific knowledge about ecological construction deriving from examples seen or heard of in the media or their social surrounding. They tend to transfer this knowledge to their own building project without analysing the implications of the respective contexts[251].

Response to critical remarks in the third workshop

When the description of this frame was presented in the third actor-workshop to the participants some expressed the critique that

> *'Not all residents have so much straw in their wooden boots.'*
>
> *'Many residents want to have a good environment without solutions that are too radical.'*
>
> *'Also many normal residents are interested in environment.'*

This raised the question, if the definition of one 'layperson-sensualist frame' (together with the other three TFs) was sufficient, or if a second frame, for example a 'layperson rationalist frame' should be defined to get hold of more moderate layperson users and residents.

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[248] For details see chapter 'Indicator systems'
[249] For details see the appendix
[250] For details see the section on 'The public relations frame'
[251] As mentioned earlier in a citation a composting toilet may be an appropriate solution in a location where a sewage system does not exist and the composted faeces can be used as fertiliser on the spot while it may be less advantageous in an urban context with a separated sewerage system already in place.

My response to this critique is that

– it is important to keep in mind that *only actors with an explicit commitment to an environmentally friendly building and housing* were in the scope of this study. This signifies that ‘average’ layperson users and residents without any special awareness of environmental issues were not considered. And I maintain that among the committed ones, sensual perceptibility of green building is a dominant feature.
  This also implies that there is of course a large group of layperson users and residents, which is neither especially concerned about environmental issues nor about environmental indicators. This group forms the biggest target group of the public relations frame.
– for resident-users the building forms their home. ‘Home’ is by definition a sensed and not a cognitive category. And so are the environmental components of it.

Finally it is noteworthy that several other workshop participants expressed support for my description of the layperson sensualist frame.

> *‘I clearly recognise this frame – it is very much characterised by nature vision.’*

stated the head of a housing co-operative’s development department, with ‘environment’ as main responsibility.

Table 28 shows an overview of the layperson-sensualist frame.

Table 28: Overview of the layperson-sensualist frame

Overview of the layperson-sensualist frame	
Actors	non-professional private clients and users of buildings
Goals	to create an identity and a social coherence among the residents of a settlement by giving the settlement a 'sustainable' or 'ecological' identity (qualitative EIFOB as a 'brand' or a 'lifestyle-label') acceptance of the sensualist frame (in opposition to the rationalist scientific frame) recognition of one's own critical view with of mainstream society and technology recognition of one's own judgement (in opposition to expert-evaluations) physical perceptibility of the effects of one's environmental efforts and behaviour
View of EIFOB	used to operate with implicit qualitative indicators (implicit) qualitative indicators as a 'brand' or 'lifestyle label' for the settlement concept of quantitative explicit EIFOB is unfamiliar & usually no relevant category an ambivalent view: 1) EIBOB as a tool useful for consulting experts, incomprehensible for laypersons 2.) EIFOB are irritating and not always trustworthy as they question one's pet solutions and one's judgements
Position of environment among other interests	primary interests are high quality of housing & the social dimension environmental concern derives from interest in the quality of one's immediate surroundings ('here and now'), sometimes on the expenses of global environmental aspects
Key problems	limited environmental knowledge: difficulties to follow the conclusions of environmental experts & to interpret complex quantitative indicators limited time resources to get involved in the subject focus on specific technical 'pet' solutions disregarding the actual underlying needs of the residents and the specific conditions of the site to identify the environmental hotspots and prioritise ecological measures in connection with economy and other parameters (such as user needs and wishes)
Environmental focus	concrete measures and principles measures that are perceivable, have a symbolic significance & appeal to visions of an ecological home and lifestyle indoor climate circulation systems the local environment
Problem solving strategies	to operate with implicit qualitative Indicators to copy solutions with a positive environmental reputation to hold fast in one's priorities despite contradicting scientific indicators to rely on external expertise to demand simple, preferably qualitative indicators to learn to understand more complex indicators an administrator strategy to address the layperson-sensualist frame: to boil down quantitative indicators to a simple qualitative indicator which is easily communicable to the public
Indicator systems already in use	implicit qualitative indicators costs expressed in money the basic measurements of consumption (kWh electricity, litres of water, kWh consumed for heating, kg of waste) as stated on the bills of the providers in connection with the costs the closely related indicators used in 'green accounting' simple aggregated indicators: an overall character between 'A – M' (as part of the Danish 'Energy labelling'-scheme for houses and owner-occupied flats) distinction between 'green, yellow and red consumers'
Demands to EIFOB	easily understandable preferably qualitative, not quantitative trustworthy on the level of concrete measures or even above (aggregated to a single qualitative indicator) support the process of prioritising measures and principles in the planning phase address environmental concerns close to the RSG's life world

Concluding remarks

After the mapping of environmental effects of buildings, decision-making situations and existing indicator systems *from an environmental scientific point of view* the study has left the specific viewpoint and in this chapter looked at EIFOB in a broader, social constructivist perspective, in which EIFOB were seen as a socially constructed artefact in a socio-technological ensemble.

The first part, a description of the actors' roles, educational backgrounds and the power structures between them showed that their educational backgrounds have a strong influence on the different actors' appreciation of different indicator approaches:

An engineering or a technical education usually gives actors proximity to quantitative indicators based on measurements and calculations. It also makes it easier for them to understand the displaying of indicator values in diagrams and unfamiliar units.

An architectural education usually goes along with a focus on implicit qualitative indicators and a generally sceptical view on explicit quantitative indicators.

Actors with a degree in economics (typically actors in the management of private enterprises or co-operative housing societies, acting as professional clients) are familiar with the concept of quantitative indicators but as laypersons with regard to the technical aspects of building prefer simple and easily understandable indicators.

Layperson users of buildings (for example residents) often relate mainly emotionally and with sensual perception to the building, using implicit qualitative indicators. Scientific, quantitative indicators other than input-output indicators measuring consumptions in the use phase are unfamiliar to them.

Concerning the influence of power structures and economic dependencies it became clear that for architects and engineers the EIFOB debate is connected with the struggle for the semiotic power to define 'the environmentally sound building' and claims to shares in the marked for green building. In this struggle engineers have been proactive and are now ahead of architects. Clients can promote the use of EIFOB of their choice among actors that economically depend on them, for example architects, even though these may be reluctant to use indicators. Also consultants and indicator developers are influenced by economic dependencies and in their work react to the demands of those who finance their work.

With regard to the actors' *professional roles and occupations* the description of the four TFs revealed that these, too (apart from the actors educational background and the power structures), influence the actors' view on EIFOB:

In general actors (disregarding their own educational background) have a tendency to adopt their clientele's demands to indicators:

Actors with a technical education, which work in co-operative housing societies, private enterprises or municipalities, demand indicators that are communicable to their layperson target group and relate to the environmental focal points of these groups (residents, pupils, customers,…).

The self-employed architectural consultant, who belongs to the SF (being involved in several research projects with indicator developers at the Danish Building and Urban Research institute) *and* to the AHF (due to his architectural education) acknowledges the engineering- and environmental scientific indicator approaches and at the same time tries to 'translate' these into a language understandable to architects.

These findings led to the following core conclusion:

The shape of EIFOB is only *one factor among others* that influences the different actors' views on EIFOB. Other important factors are
– the actors educational background,
– power structures and economic dependencies and
– present roles and occupations.
This renders unlikely the perspective that a consensus about EIFOB can by reached if only EIFOB are given 'the right' shape and points towards looking for solutions also in the social sphere.

The SCOT-analysis of the actors' views on environmental indicators for buildings revealed four different technological frames (TFs):

– The public-relations frame (PRF),
– the scientific frame (SF),
– the aesthetic-holistic frame (AHF) and
– the layperson-sensualist frame (LSF).

Each frame comprises typical actors, goals, views on EIFOB, environmental foci and demands to EIFOB. The lines of conflict and areas of consensus emerging from the different TFs' demands to EIFOB are the subject of the following chapter.

Discussion

The chapter 'Technological frames' contained a 'mapping' of the different actors' views on EIFOB – four technological frames (TFs) and corresponding relevant social groups (RSGs) have been distinguished. This chapter contains a closer look at the different RSGs' demands to EIFOB in order to identify areas of consensus, lines of conflict and possibilities[252] *to resolve these conflicts. It also describes ongoing developments in the actors' view on EIFOB. This leads to reflections on the relation between the four technological frames, which form the basis for three scenarios for a future development of EIFOB as presented in the subsequent chapter.*

Actor demands to EIFOB

In the previous chapter, the views of the different actors on EIFOB were mapped, including their *demands* to EIFOB. The detailed description of the technological frames permitted the picturing of these demands, directly addressing the technological artefact 'environmental indicators for buildings', in the wider context of the other parameters that form the actors' view. This knowledge about the 'foundations'[253] of the demands also permitted an evaluation of their *significance* for the relevant social groups. Table 29 and Table 32 display the demands of the actors in the four technological frames in a synoptic way and indicate their significance for the relevant social groups from 'very high priority' over 'neutral' to 'strongly opposed'. It needs to be noted that this ranking, (used as a device to include different degrees of importance, attributed by the RSGs to the demands, into the synopsis) cannot compete in precision with a ranking based on a *quantitative* actor-investigation as it originates from a *qualitative evaluation* of the interviews. It was, however, presented in the third actors workshop, submitted to the participants' feedback and adjusted according to their comments.

Two kinds of demands are distinguished:
Demands to structure and system borders of EIFOB (Table 29) and
Demands to the environmental focus of EIFOB (Table 32).

[252] In the technical sphere as well as in the social sphere.
[253] A concept also used in theories on conflicts and conflict resolution (compare for example (Patfoort, 2002) or (Rosenberg, 1999), who uses the terms 'needs' and 'emotions' for Patfoort's 'foundations')

Demands to structure and system borders of EIFOB

The below table gives an overview of the demands[254] of the four relevant social groups to the structure and system borders of EIFOB and indicates areas of conflict:

Table 29: Synopsis of the four relevant social groups' demands to the structure and system borders of Environmental Indicators for Buildings

+ + + = 'very high priority' — = 'critical'
+ + = 'considered very important' — — = 'opposed'
+ = 'considered relevant' — — — = 'strongly opposed'
0 = 'neutral, neither in favour nor opposed, not an especially relevant category'
conflicting demands are marked grey

	demand to EIFOB	PRF	SF	AHF	LSF
1	simple & easily understandable	+ + +	(—)	+ +	+ + +
2	based on familiar units	+ + +	—	+	+ + +
3	aggregatable to a single qualitative indicator	+ +	0	0	+ + +
4	operational (cost-efficient + data easily available)	+ + +	+	+ + +	+ + +
5	supports the decisions taken by the actor	+	+	+ + +	+ +
6	are on the level of concrete measures[255] & principles	0	— —	+ + +	+ +
7	don't restrict design freedom	0	0	+ + +	+ +
8	trustworthy	+ + +	+ +	0	+
9	scientifically justifiable	+	+ + +	0	+
10	precise & quantitative	+	+ + +	— — —	—
11	transparent, well-documented & consistent	+ + +	+ + +	— —	+
	system borders:				
12	consider the entire life cycle of a building[256]	+	+ + +	0	+
13	include induced transport in the use phase	(+ / —)	+ +	0	—

[254] Apart from the demands listed in Table 29 the actors in the PRF expressed the wish that EIFOB are linked to economic implications. As mentioned in the Introduction, linkages between the environmenal sphere and the economic sphere (visualised in Figure 2 (in the Introduction) by the dashed line) exceed the demarcations of this study. However, this demand is taken up as a field for further research in the perspectives at the end of this thesis.

[255] In Danish 'virkemidler'

[256] That is the material-phase (production and supply of the construction materials), the design phase, the use phase and the dismantling (compare descriptions of the LCA-approach in the chapters 'Environmental effects of Building' and 'Indicator systems').

The above demand-synopsis reveals several lines of conflicts and areas of consensus. The conflicts are shown in the table below (the corresponding demands in Table 29 are referred to with the numbers in brackets):

Table 30: The conflicts contained in the Table 29-demands

1	Simple & easily understandable (1)	versus	scientifically justifiable (9) and sufficiently detailed to reflect the complexity of the subject (10, 12, 13)
2	Based on units familiar to the public (2)	versus	using units familiar to scientists (as an element of the LCA-approach) (implicitly contained in 9, 12)
3	qualitative checklist-indicators based on concrete measures and principles (6)	versus	quantitative LCA-based indicators (10, 12)
4	transparent, well-documented, consistent EIFOB (11)	versus	vague ad hoc indicators(7)
5	inclusion of transport induced in the building's use phase into the scope of EIFOB (SF 13)	versus	not regarding it. (the ambivalent (PRF) and negative (LSF) scores of 13)

Apart from these conflicts, which are discussed in detail in the sections following this overview of the actor demands, Table 29 reveals the following areas of consensus[257]:

Table 31: The areas of consensus contained in the Table 29-demands[258]

1	be operational, that is cost-efficient and based on easily available data (4)
2	support the decisions taken by the actor (5)
3	trustworthy (8)
4	scientifically justifiable (9)
5	consider the entire life cycle of a building (12)

These areas of consensus are discussed in the section 'Areas of consensus' further below.

[257] By 'consensus' I do not mean that all actors necessarily share the same degree of concern for the issue in question or the same degree of appreciation for a specific solution. Instead I follow a consensus-concept as applied in consensus decision-making for example by groups dedicated to non-violent decision-making and non-violent action:
They distinguish five levels of consensus in decision making (compare (Wohland, 1997)): '
1 I am in favour of the decision.
2 I don't agree completely but can accept the decision even though.
3 I stand aside: I have objections but don't want to hinder the supporters in proceeding.
4 I veto: I have profound objections and want the decision to be re-negotiated.
5 *I leave the group: I don't see a common basis with the other parties. Therefore I leave.'*
A consensus is reached if at least one party votes level 1 and no party vetoes.
Accordingly an 'area of consensus' also comprises demands that are 'not relevant ('0') to some actors, corresponding to consensus level 3. A level 1 consensus, however, has a higher quality than a level 3 consensus, of course.
[258] Corresponding demands in Table 29 are referred to with the numbers in brackets.

Demands to the environmental focus of EIFOB

The below table gives an overview of the demands of the actors in the four technological frames with regard to the environmental focus of EIFOB:

Table 32: Synopsis of the four technological frames' demands to the environmental scope of Environmental Indicators for Buildings

+ + + = 'very high priority' — = 'critical'

+ + = 'considered very important' — — = 'opposed'

+ = 'considered relevant' — — — = 'strongly opposed'

0 = 'neutral, neither in favour nor opposed, not an especially relevant category'

conflicting demands are marked grey

	environmental focus:	Publ.Rel.F.	Scient. F.	Aesth.Hol.F.	Layp.Sens.F
1	**local environmental aspects:**	+ +	+	+	+ + +
2	indoor climate	+ + +	+	+	+ + +
3	local biodiversity	0	+ +	0	+
4	aesthetics	0	— —	+ + +	+
5	**regional and global environmental aspects**	+ +	+ + +	+	+
6	electricity consumption	+ + +	+ +	+	+ +
7	energy consumption for heating	+ + +	+ +	+ +	+ +
8	drinking water consumption	+	+	0	+ +
9	global warming	+ +	+ +	+	+
10	ozone depletion	0	+ +	0	0
11	photochemical ozone formation	0	+ +	0	0
12	acidification	0	+ +	0	0
13	nutrient enrichment	0	+ +	0	0
14	persistent toxicity	0	+ +	0	0
15	human- and ecotoxicity	(+ + +)	+ +	(+)	(+ + +)[259]
16	regional and global biodiversity	0	+ +	0	0
17	land use	0	+ +	+	0
18	local ground water formation	0	+ +	0	+
19	**waste & resource consumption:**	+	+ +	+	+ + +
20	non-renewable resource	+ +	+ +	+	+
22	renewable resources	+	+ +	+	+ +
23	local circulation systems	+	+	+	+ +

With regard to the different technological frames' environmental foci the above synopsis shows[260]:

- There is a certain consensus about the environmental aspects which are considered relevant (1-3, 5-23).
- However, actors have *different environmental priorities*: Experts also consider global environmental aspects and aspects that are mainly perceivable in long-term monitoring with scientific methods (such as ozone depletion (10) or persistent toxicity (14)) while laypersons pay more attention to those aspects that are perceivable locally and in short time intervals (for example indoor climate (2) or waste in connection with local circulation systems (23))

[259] The scientific term 'human toxicity' is not part of the vocabulary of the actors in the LSF. Instead, in the interviews they spoke about their big concern about *'a good and healthy indoor climate'*, which of course implicitly includes aspects of toxicity. This difference in vocabulary from the SF principally also applies to the PRF (which also puts indoor-climate high on the agenda) and the AHF.

[260] The corresponding demands in Table 29 are referred to with the numbers in brackets.

– The actors in the different TFs use *different 'languages'* when they talk about environmental aspects: The Scientific Frame[261] talks about *environmental impact potentials* (9–16) (*and* about 'resource consumptions' with a broader scope, including the extraction of resources from the environmental system[262]), the other frames more about *consumptions* in the building's use phase (the technical systems – compare Figure 15 (chapter 'Environmental effects of buildings') and Figure 26 (chapter 'Indicator systems'))(6, 7).
– There is a conflict between the Scientific Frame and the Aesthetic Holistic Frame whether environment should be considered together with aesthetics (4).
– 'Noise' was not explicitly mentioned in the interviews.

In the following sections, the lines of conflict and areas of consensus pointed out above as well as possible solutions to the conflicts are discussed in details.

Lines of conflict

A closer look at the actors' demands discloses conflicting demands *within* technological frames as well as *between* technological frames.

Conflicting demands *within* a technological frame

Table 33 shows the main examples of conflicting demands *within* TFs.

Table 33: the main examples of conflicting demands *within* the technological frames[263]

TF	demand	conflicting demand	conflict
AHF	on level of concrete measures and principles (checklist-indicators) (6 Table 1)	don't restrict design freedom (7 Table 1)	Checklist-indicators 'measure' the application of a row of *pre-defined* concrete measures. To achieve a good evaluation a number of these measures *needs* to be applied. LCA-based EIFOB leave it open, *how* the targets are reached.
LSF	on level of concrete measures and principles (checklist-indicators) (6 Table 1)	scientifically justifiable (9 Table 1)	Concrete measures perform differently in different use contexts and are not unambiguously 'good' or 'better'. The complexity of this problem cannot be reflected in checklist indicators.
PRF LSF	simple & easily understandable (1 Table 1)	scientifically justifiable trustworthy (8, 9 Table 1)	The environment' *is* a complex system. Scientifically justifiable, trustworthy indicators need to reflect this complexity. Simplification is only possible at the expense of precision.
PRF	based on familiar units (2 Table 1)	scientifically justifiable (9 Table 1)	scientifically justifiable indicators need to be close to the environmental systems (impacts, emissions) whereas familiar units are close to human systems (economy, measured consumptions)

In most cases, however, the actors are apparently not aware of the self-contradictory character of some of their demands as this requires a certain insight into the problematic of the different EIFOB-approaches. To reveal these conflicts is already an act of knowledge-increase, which can clarify the actors' expectations to EIFOB.

261 Here (and in the following) I use a technological frame as the subject of the sentence, replacing the precise term 'the actors in the technological frame X' with 'the technological frame' for better readability.
262 Compare the section on life cycle assessment in the chapter 'Indicator systems'
263 The corresponding demands in Table 29 are referred to with the numbers in brackets.

The fact that no corresponding internal conflict can be pointed out for the SF coincides with the fact that the actors in the SF in a somewhat single-minded way pay most attention to scientific justifiability.

Conflicts between technological frames

As mentioned above (in Table 30) the synopsis of the demands to structure and system borders of EIFOB in Table 29 revealed five lines of conflict *between* technological frames:

1	transparent, well-documented, consistent EIFOB (PRF, SF, 11)	versus	vague ad hoc indicators(AHF, LSF, 7)
2	Simple & easily understand-able (PRF, LSF, AHF, 1)	versus	scientifically justifiable (9) and sufficiently detailed to reflect the complexity of the subject (SF, 10, 12, 13)
3	Based on units familiar to the public (PRF, LSF, 2)	versus	using units familiar to scientists (as an element of the LCA-approach) (SF, implicitly contained in 9, 12)
4	qualitative checklist-indicators based on concrete measures and principles (AHF, LSF, 6)	versus	quantitative LCA-based indicators (SF, 10, 12)
5	inclusion of transport induced in the building's use phase into the scope of EIFOB (SF 13)	versus	not regarding it. (the ambivalent (PRF) and nega-tive (LSF), 13)

Though some of the conflicts 2,3 and 4 are closely related, are their foundations not identical, as the following sections elucidate.

In addition to these five conflicts the synopsis of the TFs' demands with regard to the environmental scope of EIFOB (Table 32) indicated a sixth conflict

6	environment should be con-sidered together with aesthetics (AHF 4).	versus	aesthetics should not be considered together with environment (SF 4)

These six conflicts are discussed in the following sections.

Transparent, well-documented and consistent versus vague ad hoc indicators

The PRF, the SF and (though to a smaller extent) the LSF demand indicators that are transparent, well-documented and consistent (Table 29, 11) while the AHF generally sees this concept with some scepticism, fearing that it restricts design freedom and moves the power to define 'the ecological building' away from the AHF to the SF[264]. Rejecting well-documented and consistent indicators, actors in the AHF emphasised specific characteristics of individual building projects in an unsystematic manner[265]. Some members of the AHF perceived this as an asset:

> *'The fact that different actors HAVE different ideas of an ecological building creates the dynamic that is necessary for the development in the sector.' (an architect in a medium-size architectural office).*

However, there were also members of the AHF, who perceived the absence of a systematic approach as a drawback:

[264] Compare the section 'Power structures' of the chapter 'Indicators in a social constructivist perspective'.
[265] Compare the description of the AHF in the chapter 'Indicators in a social constructivist perspective'.

'The problem to define the notion "environment" is really obvious in this course. They shoot with a shotgun[266] at an entire field. We are absolutely at beginner level here.' (the participant at a course on 'Environmental management in project design' held out by the Federation of Danish Architects)

Implications for the development of EIFOB: possible solutions to the conflict
It is difficult to imagine that the general scepticism with regard to EIFOB among actors in the AHF can be overcome with solutions in the technical sphere. Generally, EIFOB that meet the needs of AHF-actors (see Table 29) are more likely to be accepted than indicators that do not.

With regard to solutions in the social sphere the analysis of the power structures in the previous chapter suggested that economic dependencies can make actors in the AHF give in to demands of the PRF and the LSF. Also competencies obtained in the professional education could increase the understanding and appreciation of transparent, well-documented EIFOB.

Simplification versus complexity
The PRF, AHF and LSF agree that EIFOB should preferably be *'simple and easily understandable'*. This is obviously most important to laypersons, who have no environmental expertise and little resources to enlarge their environmental knowledge. Also the actors of the PRF strongly support this demand in order to achieve communicability to their layperson target groups. For architects as professionals in the building sector, simplicity is a bit less important, as they do have a general, though not scientific knowledge. For them, the simplicity demand is closely linked with the need that EIFOB shall closely relate to the decisions they have to take.

In contrast, the SF's first priority is to mirror the complex and manifold interrelations between a building and the environment in a scientifically justifiable way. To them simplicity is desirable but it may not encroach on correct modelling.

Different environmental languages

The simplicity – complexity conflict is also closely linked with the question of the environmental foci of the different RSGs. In this respect Table 32 shows that most of the impact categories used in the SF (for example 'ozone depletion', 'photochemical ozone formation', 'nutrient enrichment') are not relevant categories for the other three RSGs. This is partly due to the fact that the SF uses a professional terminology unfamiliar to the other RSGs: *'human toxicity'* for example is not part of the vocabulary of the other three RSGs. Instead, in the interviews they spoke about *'a good and healthy indoor climate'*, which of course implicitly includes aspects of toxicity. These different vocabularies go along with different degrees of environmental knowledge: laypersons use more general, broad and imprecise notions while environmental experts operate with more clearly defined notions. Experts also consider environmental aspects which are mainly perceivable in long-term monitoring with scientific methods (such as ozone depletion or loss of biodiversity) while laypersons pay more attention to those aspects which are perceivable locally and in short time intervals[267].

The interviews clearly showed that most of the non-members of the SF had difficulties understanding the output categories of the Danish LCA-tool 'BEAT' and their bar-diagram visualisations. 'Global warming' has a special position as it is closely linked with 'energy consumption', a category, whose economic and environmental dimensions have long been operationalised by

[266] A gun for bird and rabbit hunt, which shoots plenty of small projectiles to increase the probability of a hit.
[267] Accordingly, the mere visualisation of consumptions can lead to more environmentally conscious behaviour and consequently to lower consumptions (Jensen, 2003).

energy billing and energy performance demands in building codes. Moreover, compared with the other impact categories, 'global warming' is relatively high on the political agenda and a comparatively known environmental issue.

Implications for the development of EIFOB: possible solutions to the conflict
the question that arises is 'What are the implications of this for EIFOB as 'a common language for green building?' In accordance with the concept of the 'the socio-technological ensemble as the unit of analysis'[268] the following sections discuss not only possible solutions in the technical sphere but also in the social sphere.

A) Solution approaches in the technical sphere
A technical solution to the simplicity-complexity conflict could be to operate with different levels of 'aggregation' as a means of simplification, for example:

1 The lowest level: the LCA-impact categories
2 The next level: a simplification of the LCA-impact categories, preferably using simple or already familiar units and notions.
3 The highest level: an aggregation to a single qualitative indicator

Seen from the SF's perspective simplification and aggregation require a weighting of the different impact categories[269]: 'How much significance shall be allocated to each impact category in an aggregated indicator? Shall global warming count just as much as human toxicity? Or more? Or less?' This leads to solution approaches in the social sphere:

B) Solution approaches in the social sphere:
If the approach of different levels of simplification is to be pursued a consensus among the indicator users on the weighting of the various impact categories would be a prerequisite in order to achieve comparability between different buildings.

A principally different approach would be to improve the understanding of LCA-based indicators by increasing the environmental knowledge among the non-members of the SF.

Statement on the feasibility and utility of the solution approaches
An approach with three levels of aggregation should definitely be pursued as it would meet an important demand by both the LSF and the PRF. The loss of scientific precision that goes along with simplification can counterbalanced by the awareness raising effect of indicators understood by a broad range of actors. The experience from a Danish municipality with the *'You are a green / yellow / red energy consumer'*-indicators shows that receiving an unexpected evaluation on a very simplified and very communicable level can arouse a layperson's curiosity and interest in entering into a more detailed analysis of his/her case together with an expert. The expert then has the opportunity to refer to and explain some of the more complicated indicators on the next level and suggest measures for environmental improvement.

This example also shows that easy access to expert knowledge, explanation and expert advice are necessary if the potential of simple, aggregated indicators to influence environmental knowledge and environmental behaviour is to be fully exploited.

Establishing a consensus of the weighting of different environmental aspects can be difficult, as different actors in the PRF may have a strong interest in implementing a weighting that results in an overall evaluation favour-

[268] Compare the section 'The social construction of technology' in the chapter 'Research design'.
[269] Compare the section on 'aggregation' of the chapter 'Indicator systems'.

able *to them* but which may conflict with the judgements of the SF[270]. A weighting decided upon by the legislator on the basis of expert advice seems the more appropriate solution, since the very objective of EIFOB is the protection of the environment as a common good.

Familiar units versus scientific units

The PRF's and the LSF's demand that EIFOB shall be simple and easily understandable is closely linked with their request for the use of familiar units. The AHF principally supports this demand.

The head of the department for planning and environment of a Danish town, himself belonging to the scientific frame, illustrated the significance of the choice of units for the communication between technological frames with an example:

> *'We constantly have to pay attention not to sound to too expert-like. How many times have I explained what CO2 is… ! When I explain how much traffic we have here in our municipality – it is all right to mention how many kilometres we have driven, I can also say that each day 32.000 litres of gasoline are used on all of our roads. People understand that. But if I say "So-and-so many tons CO2" – that is totally abstract. But they understand the idea of 32.000 litres of gasoline – "Wow, that really is a lot…!"'*

'Familiar units' are units, which are means of quantification well known from other contexts and whose use in everyday decision making is well established.

One of the most familiar units are monetary units. Monetary units have the advantage that they are directly associated with value.

Other familiar units are litres (for example of consumed water or oil), kilograms (for example of produced waste) and m^2 (for example of housing area). Also kWh, though already quite abstract, can still be considered a familiar unit, as people know it from their bills for electricity and heating.

The compound units l/(person x year) and kWh/(person x year) enter the next level of complexity but still seem rather communicable, especially when verbalised, for example, as *'Per year each person in your household consumes X times as much electricity as a the average resident in this apartment block.'*

The units l/(m^2 x year) and kWh/(m^2 x year) yet a bit more abstract.

The units common in LCAs before weighting (for example 'kg CO2-equivalents', 'kg SO2-equivalents') and after weighting ('Person Equivalents per reference year and reference area') are unfamiliar units outside the scientific frame.

Implications for the development of EIFOB: possible solutions to the conflict

A) Solution approaches in the technical sphere

A technical solution of the conflict 'familiar units versus scientific units' could be to provide a translation of the units used in the scientific frame into units familiar to the actors in the other frames, for example by monetising.

Two attempts to monetise environmental indicators can be distinguished: Monetizing the environmental damages caused by an activity or product; by estimating the costs of either the repair of the damages or the avoidance of the damages.

Monetizing the willingness to pay for environmental measures: The Dutch checklist-system 'National Packages Sustainable Building' (Dutch Ministry for Housing, 2002) allocates a price to each checklist-item (an environmental measure) and operates with benchmarks of investments in environmental measures. (Dammann, 2003)

[270] As it is the case in Denmark in negotiations with manufacturers of construction materials about an environmental declaration of their products. CHECK: ask Klaus for more details!

B) Solution approaches in the social sphere
A solution in the social sphere would be to make the actors outside the SF familiar with the units used in the SF, in the course of a societal learning process connected to the introduction of a new technology (the technology 'life cycle assessment'). The unit 'kWh' illustrates how the adaptation of new technologies (steam engines and electricity) has led to the introduction of a new unit, which today is considered familiar.

Statement on the feasibility and benefit[271] of the solution approaches

I would suggest a twofold approach:

On the one hand the use of familiar units should be pursued as it is an important element of indicators that are simple and easily understandable. The translation of LCA output units into such familiar units (for example monetary units), however, may be the source of further uncertainties and a loss of precision (apart from the danger of psychologically moving attention from the original subject (environment) to the subject usually described by the unit: economy). Therefore 'appetised' indicators using familiar units should refer to the indicators used in the scientific community.

On the other hand the understanding of the units close to the environmental aspects expressed by the indicators of the scientific frame should be promoted. Especially for professional decision-makers this should form part of a learning process about the environmental implications of building.

Checklist indicators versus indicators based on life cycle assessments

A major conflict between the scientific frame on the one side and the aesthetic-holistic frame and the layperson-sensualist frame on the other side is the conflict 'checklist indicators versus life cycle assessments'

Seen from the AHF's perspective the conflict is closely related to the demands that EIFOB shall

– support the decisions taken by the actor (Table 29, 5)
– be operational, that is: cost-efficient & based on easily available data (Table 29, 4)

The first demand means that architects wish indicators that make simple and unambiguous statements on the decisions they take in the design phase with regard to materials, design and technical equipment. The second demand signifies that these evaluations shall not be cumbersome but easy to carry out. Checklist indicators are appealing to the AHF because respond to both these demands. Furthermore, they are completely within architects' field of competence and do not require any further qualifications. For the same reason checklist indicators are also attractive to the LSF.

Scientists, on the other hand, criticise that the cookbook-character of checklist-indicators does not foster an in-depth environmental learning process and that the lack of life-cycle considerations can lead to environmentally wrong conclusions (van Bueren et al., 2000). They emphasise that it is impossible to evaluate a concrete measure isolated from the context of its application: Active use of solar energy may be environmentally positive in many places, while the use of geothermal energy may be the solution with the environmentally most favourable solution in Iceland.

But the attitude of architects towards checklist indicators is not unambiguous either: their stance, that things need to be evaluated in the context of their application and that a holistic view needs to be applied, in fact is *more* in line with life-cycle-assessment-based indicators, which *by definition*[272] apply a

[271] In accordance with the objective of this study the final criteria for the evaluation of the different solutions has to be environmental benefit which EIFOB influence indirectly through their effects on environmental awareness, environmental knowledge and environmental communication. (compare the 'Influence scheme for environmental conscious behaviour' of Fietkau and Kessel in (Schahn et al., 1993))
[272] Compare the concept of the 'functional unit' explained in the chapter 'Indicator systems'.

contextual perspective, than with checklist indicators, which *do not* consider the context. Checklist indicators also interfere more than LCA-based indicators with the demand of the AHF that indicators shall not restrict design freedom (Table 29, 7): while checklist-indicators (within a certain number of alternatives) prescribe *how* to build environmentally friendly, LCA-based indicators leave it up to the project designers *how* to reach the environmental performance targets.

Finally, it needs to be considered that LCA-based indicators in the building sector as the slightly younger technology also meet the inertia of explicit and implicit checklist indicators as the more widespread and more established technology.[273]

Implications for the development of EIFOB: possible solutions to the conflict
A) Solution approaches in the technical sphere:
Checklist-indicators are based on statements of the kind

X is good[274].
Y is good.
(X+Y) is better than X.

These kind of unambiguous and simple statements are attractive to non-SF actors with little or no environmental expertise. However, environmental scientifically they are often not correct. When X and Y are assessed in an LCA the resulting statements are of the kind

X is q times better than X_R[275] *if A.*
X is not relevant if B.
X is y times worse than X_R *if C.*
Y is z times better than Y_R *if A.*
Y is not relevant if B.
(X_A+Y_A) *are q times better than* (X_A+Y_B) *and z times better than* (X_R+Y_R)

These statements are not as easy to understand and not general but specific.

What options are there to tackle the checklist-versus-LCA conflict?

LCAs and checklist indicators are only compatible in theory: theoretically a checklist, listing all the measures which are used in today's building, could be refined in such a way that it would contain all the details that are part of a LCA in checklist form, thus describing the context of the concrete measure as precisely as in a LCA. In practice this would make the use of checklist indicators as cumbersome as the use of LCAs and there would be no point in preferring checklist indicators anymore.

273 Compare the section 'A historical dimension' of the chapter 'Indicator systems'.
274 'Good' here meaning 'environmentally more favourable than the standard solution / a defined reference.'.
275 The reference

Therefore in practice there are only three options to overcome the checklist-versus-LCA conflict to obtain indicators as *'a common language'*:

Table 34: The three optional outcomes of the LCA-versus-checklists conflict with regard to indicators as *'a common language'*.

	Status of LCA	**status of concrete measure checklists**	**Strengths ('+') & weaknesses ('-')**
Option 1	Common indicators are mainly[276] LCA-based	concrete measures only occur in handbooks, guidelines and design tools, preferably supplemented with LCA-information	+: high scientific quality, learning opportunities –: cumbersome handling
Option 2	LCA serves as a tool for monitoring and research and design advice in special cases.	Common indicators are mainly concrete-measure based, preferably integrating some LCA-information	+: easy handling -: environmentally misleading
Option 3	There is no single set of common indicators, LCA-based indicators and concrete-measure based indicators exist side by side.		+ : many actor demands are met -: no *'common language', contradictions can occur*

In **option 1** common indicators are mainly LCA-based, notwithstanding the fact that they can have several levels of aggregation. To support architects in the project design phase, when the detailed data necessary for an LCA is not available yet, LCAs of existing buildings and the concrete measures applied in them can serve as qualitative guidelines, pointing out conclusions and probable environmental hotspots. These can be presented in the form of books[277] or in the form of computer programmes as design support tools.
The use of LCA-tools and their indicators can also be promoted by creating LCA-tools that are more user-friendly for architects,

– providing more comprehensive databases to minimise the work of gathering data
– giving LCA-tools a visual dimension closer to the architects design work / linking LCA-tools to the programmes for computer aided architectural design

The main advantage of option 1 is the high scientific quality of the assessments, which offers good opportunities for environmental learning.
The main disadvantage is the cumbersome handling of the huge amount of data necessary for an LCA.

[276] As mentioned earlier, the LCA-approach does not cover indoor climate and is also weak in the field of chemicals – two fields, in which other, also qualitative indicators, are applied.
[277] (Marsh et al., 2000) is one example for such a book.

In **option 2** common indicators are mainly based on checklists. The concrete measures and principles listed in the checklists can be linked with certain conditions based on results of LCAs in order to increase the environmental scientific quality of the checklist indicators. The figure below sketches a possible structure of such an indicator system:

concrete measures & principles for example:	**LCA-module:** **'is positive *if*'/ 'is negative *if*'** LCAs of the concrete measures & principles with background information and statements on the relevance of their use context[278] for example:	**Evaluation of environmental effects of chosen solution in the actual context with weighting of relevance for total environmental performance**
use of active solar energy	consideration of energy infrastructure in the settlement	
	LCA of the solar panels	
	consequences with regard to material use, volume-surface ratio + heat loss, ….	
toilet- and washroom floor cover	LCA of different kinds of tiles and other solutions in different use contexts	solution 1
		solution 2
		solution 3
…	…	…
		Indicator: sums up numerical values

Figure 29: Possible structure of checklist indicators containing some information from LCAs.

LCA serves for monitoring, research and design advice but does not form the basis for common indicators.

Main advantages of this option are the simplicity of the system, which makes them easy to understand and makes it easy to evaluate a building with the system. The main disadvantage is the limited environmental scientific quality.

In **option 3** two indicator systems exist in parallel. They may even use the same indicators on higher levels of aggregation, but the qualities of their assessments differ; the more precise assessment with LCA-indicators cannot be compared with an assessment with checklist indicators. In this situation with a 'first class assessment' and a 'second class assessment' a *'common language for green building'* does not exist.

The main advantage of this option is that many actor demands are met. The main disadvantage is that the absence of *'a common language for green building'* impedes reaching high environmental building standards.

B) Solution approaches in the social sphere

Architects usually focus on the *disadvantage* of LCA-based indicators of being cumbersome to use and on the *advantage* of checklist-indicators of being user friendly. They are much less aware of the *advantage* of LCA-based indicators of complying with the important demand of design freedom and the *disadvantage* of checklist indicators of interfering with design freedom. Enlightenment in this respect could change the view of architects on the two indicator approaches.

Architects could also learn to use the existing LCA-tools. Making the use of LCA-tools a part of the architectural education (along with the use of other tools for computer aided architectural design) would probably change the

[278] The 'use context' forms part of the concept of the 'functional unit' in an LCA.

AHF's view on LCA-based indicators as they then would fall within the field of the professional competence of architects.

As a third possibility architects could commission external experts to carry out LCAs for them. This organisational separation of environmental expertise from the actual designing of the project is likely to render a real *integration* of environmental aspects into the project design more difficult.

If option 3 was pursued, a threshold could be defined on the basis of the economic or spatial scale or the environmental relevance of buildings as a border between the two indicator systems: the simpler, cheaper checklist system could then only be applied to buildings up to a certain size, while for bigger projects only the LCA-based indicators would be valid.

Among the actors in the scientific frame especially indicators-developers and developers of LCA-tools could enter into a more intense dialogue with actors in the AHF, increasing their understanding of the AHF's needs and investigating ways to consider these in their indicators and tool and co-operation with architects.

Statement on the feasibility and benefit of the solution approaches

Experiences from the Netherlands with the 'National Packages' and Danish reactions to this approach suggest that option 2 would be the easiest to implement. At the same time, it is probably the option which yields the least environmental benefit. In this option the used indicators do not allow a quantification of the environmental benefit on the level of environmental effects, which makes any evaluation of the indicators impact rather vague.[279]

Option 1 would provide the best conditions for documented environmental benefits and in-depth learning among the actors. At the same time, it is probably the one that is most difficult to implement.

Option 3 has an intermediate position and corresponds to the present situation in the Netherlands, where the checklist-system 'National Packages Sustainable Building' and the two LCA-based systems 'GreenCalc' and 'Ecoquantum' exist side by side. My evaluation of the Dutch situation is that in the long term the technologically and scientifically more advanced LCA-based indicator systems will become the prevailing ones, as their user-friendliness and application increase steadily (Dammann*,* 2003).

In Denmark several checklist-indicator systems exist at the municipal level[280] but there is no national checklist systems, while one LCA-system[281] and one checklist-system with LCA as a subsystem[282] have been developed and have been employed several times. Instead of using resources to develop and implement an indicator set based an outdated approach (the checklist approach) it seems more recommendable to focus efforts on the promotion of a state-of-the-art technology (LCA-based indicators). In the exemplification of the draft indicators I propose on the basis of my actors analysis I therefore chose to follow option 1.

Concerning the use of indicators by the different actors it is important that architects consider the indicators already in the early phases of the project design, where the project can still easily be altered according to environmental evaluations. Timely environmental information in form of indicators are of course more easly available to architects if they carry out the assessments themselves instead of commissioning them to external experts. If the

[279] One could argue that *broad* use of a simple checklist system might, in total, be environmentally more beneficial then *limited* use of an LCA-based system perceived as elitist. To respond to this argument is beyond the scope of this study as there are many factors (utility of the system, economic incentives, legislation, public opinion, definition of benchmarks, …) that determine, to what extent an indicator system is used and what environmental benefit is yields.

[280] For example (Mørck*,* 2001) and (Københavns Kommune ved Bygge- og Teknikforvaltningen*,* 2001)

[281] BEAT

[282] 'Environmental assessment and classification of buildings' (see chapter 'Indicator systems') – for more details see the appendix and the chapter 'Indicator systems'

latter is the case, early co-operation between different actors, for example in form of 'partnering'[283], can, however, help to secure environmental quality.

Inclusion of transport induced in the building's use phase?
With regard to the system borders of EIFOB there is the conflict, whether transport induced in the use phase shall be included or not (Table 29, 13). The first position is held by the SF, reasoning that commuter transport, induced due to a building's unfavourable siting, can spoil environmental ambitions of the building's design.[284] The LSF tends to not wanting to consider transport *as an environmental category.* Of course, good public transport connections are appreciated, but as the LSF focuses on sensually perceivable environmental aspects in the immediate surroundings it may well pay attention to car-free zones in the settlement-layout, but not to regional and global environmental effects of individual transport.

The PRF is ambivalent: If the consideration of transport can be expected to be received positively by the target groups and promote a positive image of oneself, it shall be included, if not, not.[285]

Implications for the development of EIFOB: possible solutions to the conflict
A possible reaction to this conflict is to restrict the system borders of EIFOB to the areas that all TFs can agree upon, thus to exclude transport induced in the use phase. From the scientific point of view this is, of course, problematic and would conflict with the demand for scientific justifiability. A compromise could be to operate with two variations of EIFOB; one *including induced transport* and *one without*. This compromise would also meet the ambivalence of the PRF. This would, however, constitute an element of ambiguity, thus conflicting with the very concept of EIFOB as a common language.

Ultimately this conflict touches the question, how much 'environmental truth' actors in the PRF and in the LSF want to be confronted with. If the 'mirror' EIFOB shall be flattering or true also depends on the beauty of its users.

Aesthetics as part of the environmental scope?
A conflict with regard to the environmental scope of the indicators is the conflict between the AHF (and to a smaller extent the LSF) and the SF concerning aesthetics as part of the environmental scope. Actors in the AHF emphasise that[286]

1. environment should be an inseparable part of the aesthetical,
2. the aesthetical is an indoor-climate parameter
3. a high aesthetical quality of a building prolongs its life span, which is environmentally advantageous.

Actors in the SF hold against that

– the aesthetical has always been a core element of architecture (in contrast to environmental aspects) and does not need additional emphasis by means of indicators
– the aesthetical as a purely subjective and anthropocentric aspect is outside the ecological paradigm

[283] Documented in (Bang et al., 2002) as a means to secure constructional quality, budgetary targets and delivery on schedule. An ongoing study at DBUR on the building of the new headquarter of the National Organisation of Trade Unions ('LO') underlines that partnering serves as well as a means to secure environmental quality.
[284] For the SF's reasoning see also the chapter 'Environmental effects of buildings'
[285] Compare the citations in the description of the PRF in the chapter 'Indicators in a social constructivist perspective'.
[286] Compare the citations in the description of the AHF in the chapter 'Indicators in a social constructivist perspective'.

– argument 3 in this simple form is not correct. To find out, if a longer life span improves or worsens a building's environmental performance depends on the environmental impacts of its use-phase and requires closer scrutiny.[287]

The AHF's stance, that the aesthetical should be considered as an environmental issue, is accompanied by its general scepticism with regard to quantitative, explicit EIFOB

'A building is more than numbers.'

as one architect put it. This scepticism naturally also applies to a possible quantification of the aesthetical qualities of a building, the central field of competence of architects. Thus, it is likely that the AHFs emphasis on aesthetics as an *environmental* focal point is to be understood in the following way:

'Environment should be an inseparable part of the aesthetical…AND THEREFORE environment should be dealt with in the same way as the aesthetical: that is, in a QUALITATIVE way and by architects (for example individually by each project designer or in peer-review procedures as established for the evaluation of architectural competitions)'

rather than as an argument for making the aesthetical part of a fixed set of EIFOB. (Here the SF shares the AHF's doubts about a quantification of aesthetical qualities.)

In accordance with this interpretation I conclude that the conflict around the question 'Shall aesthetics be part of the environmental scope of EIFOB' will only disappear with a general 'yes' of the AHF to EIFOB.

[287] It may, for example, be an environmentally recommendable decision to dismantle an old building with an energy-consumption in the use phase far above average immediately and replace it with a new, resource-efficient building, instead of prolonging the old building's high consumption.

Areas of consensus with regard to the structure and system borders of EIFOB

Apart from the conflicts described above, the synopsis of demands to the structure and system borders of EIFOB in Table 29 also revealed consensus[288] about the demands five demands:

Table 35: Areas of consensus about demands to the structure and system borders of EIFOB (extract from Table 29)

+ + + = 'very high priority' — = 'critical'

+ + = 'considered very important' — — = 'opposed'

+ = 'considered relevant' — — — = 'strongly opposed'

0 = 'neutral, neither in favour nor opposed, not an especially relevant category'

	demand to EIFOB	PRF	SF	AHF	LSF
4	operational (cost-efficient + data easily available)	+ + +	+	+ + +	+ + +
5	supports the decisions taken by the actor	+	+	+ + +	+ +
8	trustworthy	+ + +	+ +	0	+
9	scientifically justifiable	+	+ + +	0	+
	system borders:				
12	consider the entire life cycle of a building[289]	+	+ + +	0	+

As mentioned above[290], by 'consensus' I do not mean that all actors necessarily share the same degree of concern for the issue in question or the same degree of appreciation for a specific solution but that there is support from a majority of the of the TFs and no opposition.

The ranking in Table 29/Table 35 reveals that the support of the different demands varies from TF to TF. The problem with these 'weak' consensus is, that the different demands are not isolated from one another but conditionally interlinked and that 'the weakest link' among the four TFs may withdraw its support if a demand interferes with another demand of higher priority to the TF. Therefore it is important to evaluate the contextual significance of the areas of consensus amongst the TFs' general goals.

The demand that *'EIFOB shall be operational, that is cost-efficient and based on easily available data'* (4) ,for example, is strongly supported by the PRF, the AHF and the LSF, but only weakly by the SF, whose first priority is to mirror the complex and manifold interrelations between a building and the environment in a scientifically justifiable way. To the SF, operationality is desirable but it may not encroach on correct modelling. Apart from that, the members of the SF certainly have higher standards with regard to the efforts

288 By 'consensus' I do not mean, that all actors necessarily share the same degree of concern for the issue in question or the same degree of appreciation for a specific solution. Instead I follow a consensus-concept as applied in consensus decision-making for example by groups dedicated to non-violent decision-making and non-violent action:
They distinguish five levels of consensus in decision making (compare (Wohland, 1997)): '
6 *I am in favour of the decision.*
7 *I don't agree completely but can accept the decision even though.*
8 *I stand aside: I have objections but don't want to hinder the supporters in proceeding.*
9 *I veto: I have profound objections and want the decision to be re-negotiated.*
10 *I leave the group: I don't see a common basis with the other parties. Therefore I leave.'*
A consensus is reached if at least one party votes level 1 and no party vetoes.
Accordingly an 'area of consensus' also comprises demands that are 'not relevant ('0') to some actors, corresponding to consensus level 3. A level 1 consensus, however, has a higher quality than a level 3 consensus, of course.

289 That is the material-phase (production and supply of the construction materials), the design phase, the use phase and the dismantling (compare descriptions of the LCA-approach in the chapters 'Environmental effects of Building' and 'Indicator systems').

290 See the respective footnote at the beginning of this chapter

they found acceptable in the acquisition of data and the use of an evaluation tool than the other TFs.

The demand that *'EIFOB shall support the decisions taken by the actor'* is strongly brought forward by the AHF and the LSF, while it seems less relevant for the PRF and the SF. In their analysis of the learning processes in the transdisciplinary research project 'The Ecological City' at the Technical University of Delft, which involved disciplines such as architecture, urban and regional planning, civil engineering and policy science, Müller, Tjallingii and Canters (Müller et al., 2002) elucidate how the different disciplines make different contributions to joint problem solving of a complex societal problem such as sustainable urban development and suggest cyclic models for this phenomenon:

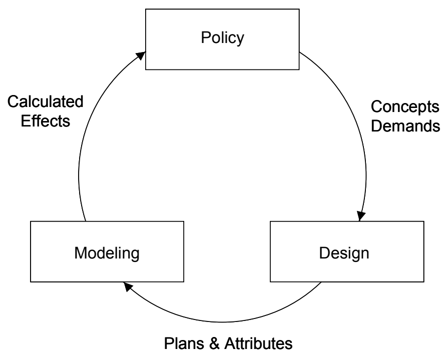

Figure 30: *'Functional link of design, modelling and policy-making:*

The design uses policy concepts and demands as input and generates alternative plans supplied with attributes, which is the input for the models. The models are used to calculate effects of different design scenario, which are interpreted by policy-makers, who might refine their concepts etc.' (Müller et al., 2002)

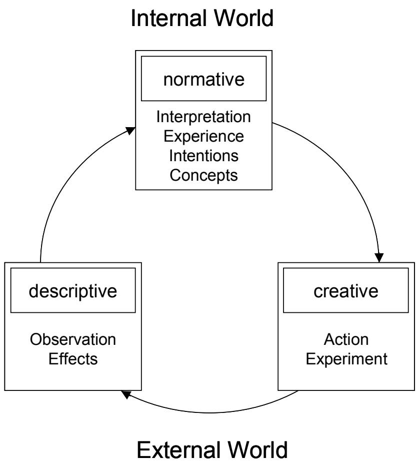

Figure 31: *'Generic learning cycle:*

Learning processes follow a sequence of normative, creative and descriptive steps. The creative step is a translation from the internal world of thoughts and feelings to the external world of forms; the descriptive step is a translation from the external world to the internal world; the normative step is a translation from experience to a formulation of new concepts. (Müller et al., 2002)

These models make clear that the creative design activities, which mainly are in the sphere of actors in the AHF, are at a different part of the circle than the descriptive modelling activities, which are more the domain of actors in the SF. As the a design process requires to make numerous concrete design-decisions, AHF-actors wish for EIFOB as a *design-tool* that directly supports these decisions, while the decision-support aspect is less important to actors within the SF, who see EIFOB in the first place as a *tool for modelling, monitoring and evaluating*. Also actors in the LSF (and clients in general) demand EIFOB-support of design-decisions when they have to approve or disapprove design-proposals.[291]

EIFOB that shall serve as 'a common language for green building' should preferably accommodate both functions: design-support and monitoring.

[291] The upper part of the model circles relates primarily to policy-makers, a group who does not fall within the scope of this study. However, local building authorities and clients also act in the normative sphere when they make demands for building projects, but I do not think a clear relation between the models' normative policy-part and one particular technological frame can be identified.
Müller, Tjallingii and Canter, however, point out that the 'generic learning cycle' also appears *within* design, modelling and policy-making (a recognition, which led them to their model of the 'transdisciplinary learning cycle'). (Müller et al., 2002)

The demands that *EIFOB shall be trustworthy* and *scientifically justifiable* are closely related but not identical: For the PRF, trustworthiness is a core 'ingredient' of EIFOB which carries a positive public image. Scientific justifiability is a useful means of obtaining trustworthiness, but not a end in itself (as the PRF's ambiguity with regard to the consideration of induced transport illustrates). For the SF scientific justifiability is elementary. The LSF is likely to follow the PRF, sharing with the AHF the paradigm of belief (in opposition to the SF's measurement-paradigm)[292]. The AHF's indifference to the demand also reflects its general scepticism with regard to the concept of EIFOB.

This suggests that the SF depends on the PRF as an ally if it wants its demand of scientific justifiability to be reckoned with in an agreement about common EIFOB.

The demand that *EIFOB shall consider the entire life cycle of a building* for the SF is an essential element of scientific justifiability. For the PRF and the LSF it is relevant in a more indirect way as it may contribute to trustworthiness (PRF) and knowledge-based decision-making (PRF, LSF). However, if the conclusions of a life cycle assessment conflict with their 'pet' solutions, actors in the LSF may quickly withdraw their support of the SF on this point.[293]

Consensus with regard to the environmental scope of EIFOB

The synopsis in Table 32 showed the different TF's technological frames' environmental 'languages' (which were discussed in the section on 'simplification versus complexity' further above) and different environmental priorities:

- There is a certain consensus about environmental aspects considered relevant; apart from the conflict about the consideration of aesthetics, which has been discussed further above, no TF questions the general relevance of any of the listed environmental aspects. Especially the consumptions of energy for heating and electricity and the (partly related) resource consumption are considered important in all TFs.
- However, actors have *different environmental priorities*: Experts also consider global environmental aspects and aspects that are mainly perceivable in long-term monitoring with scientific methods (such as ozone depletion or persistent toxicity) while laypersons pay more attention to those aspects that are directly perceivable locally and in short time intervals (for example indoor climate or waste in connection with local circulation systems).

With regard to the shaping of EIFOB as a common language the simple and obvious conclusion of this is that the indicators should cover all the environmental aspects considered relevant by any of the actors and that attention has to be paid to the use of the 'environmental languages' rather than to the environmental scope.

In the cases of local biodiversity and land use, however, the 'weak' consensus could possibly turn into a conflict when the consideration of these environmental aspects could undermine the ranking of building projects striving for a green image.[294]

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292 Compare the section 'Dichotomies between architectural and engineering education' in the chapter 'Indicators in a social constructivist perspective'.

293 Compare the citations in the description of the LSF in the chapter 'Indicators in a social constructivist perspective.

294 Analogous to the conflict around induced transport discussed further above.

Relations and dynamics between the technological frames

The above sections described the lines of conflict and areas of consensus between the four technological frames. This section uses the above description to map the relations and dynamics between the technological frames: Which frames are close to each other, which are distant, which move towards each other and which are divided by a growing distance? The answers to these questions result in a 'map of the socio-technological landscape around EIFOB'.

Relations between the technological frames

Table 36 gives an overview of the conflicts dividing TFs and the areas of consensus that unite TFs. The comparison of the different TFs' demands makes it possible to determine the degree of proximity between the TFs. It shows that

- the **SF** and the **PRF** have a rather **close relation**[295] with a clear overlap of interests: Both want well-documented, consistent and thus trustworthy indicators. For the PRF, scientific justifiability grants trustworthiness.
- Also the **PRF** and the **LSF** have a **close relation**: Both want simple indicators and share the focus on indoor climate and consumptions in the use phase.
- The **LSF** and the **AHF** have a **close, but weak relation**: Both are ambivalent with regard to the concept of scientific EIFOB and have an affinity for indicators based on concrete measures. On the other hand they are separated by the conflict 'alternative life style versus trendy architecture' and the AHF's stronger opposition to documented EIFOB.
- Also the **AHF** and the **PRF** have a **close but weak relation**: Both want simple, operational EIFOB and are concerned about a positive image. On the other hand the conflicts 'documented & scientific versus qualitative & sceptic' separate them.
- The **SF** and the **AHF** are rather **far from each other**, separated by the AHF's general scepticism with regard to EIFOB and the core-conflict 'checklist-indicators (based on concrete measures and principles) versus life cycle assessment (LCA)'.
- Also the **SF** and the **LSF** are **far from each other**, as the LSF's focus on local environmental issues and perceptible concrete measures conflicts with the SF's concept of scientific, quantitative LCA-approach.

[295] The different shades of grey refer to those in Table 36, indicating different degrees of proximity.

Table 36: Synopsis 'Relation between the different technological frames'. Degrees of proximity:

medium (close but weak)	close	distant

	AHF	PRF	SF
LSF	<u>**proximity AHF-LSF:**</u> **medium (close but weak)** <u>**areas of consensus:**</u> little environmental knowledge, ergo **demands to EIFOB:** concrete measure level simple, operational don't restrict design freedom **environmental focus:** sensually perceivable aspects <u>**lines of conflict:**</u> **demands to EIFOB** general scepticism of indicators (AHF) versus well-documented (LSF) **environmental focus:** trendy architecture (AHF) versus symbols of alternative lifestyle (LSF)	<u>**proximity PRF-LSF:**</u> **close** <u>**areas of consensus:**</u> **demands to EIFOB:** simple & easily understandable (not many, based on familiar units) operational (cost-efficient + data easily available) **environmental focus:** indoor climate energy consumption in use phase <u>**lines of conflict:**</u> **demands to EIFOB:** concrete measures (LSF) versus LCA-based (PRF) **environmental focus:** sensually perceivability (LSF) versus scientific categories (PRF) symbols of alternative lifestyle (LSF) versus 'invisible ecology' in trendy architecture (PRF)	<u>**proximity SF-LSF:**</u> **distant** <u>**lines of conflict:**</u> environmental expertise (SF) versus little environmental knowledge (LSF) **demands to EIFOB:** quantitative & scientific (SF) versus qualitative, on level of concrete measures (LSF) 'scientifically justifiable' (SF) versus simple (LSF) sensual perceivability (LSF) versus scientific categories (SF) <u>**areas of consensus:**</u> scientific & well-documented (SF) + indoor climate and health (LSF)
SF	<u>**proximity AHF-SF:**</u> **distant** <u>**lines of conflict:**</u> generally sceptic of EIFOB (AHF) versus EIFOB as only reliable tool for green building (SF) little environmental knowledge (AHF) versus environmental expertise (SF) **demands to EIFOB:** qualitative, on level of concrete measures (AHF) versus quantitative & scientific (SF) simple (AHF) versus 'scientifically justifiable' (SF) **environmental focus:** aesthetics (AHF) versus 'aesthetics no relevant EIFOB-category' (SF) little concern for regional and global environmental issues (AHF) versus much concern for regional and global environmental issues (SF) <u>**areas of consensus:**</u> **demands to EIFOB:** LCA-based (SF) + shall not restrict design freedom (AHF)	<u>**proximity PRF-SF:**</u> **close** <u>**areas of consensus:**</u> **demands to EIFOB:** trustworthy / transparent, well-documented scientifically justifiable precise and quantitative **environmental focus:** regional and global <u>**lines of conflict:**</u> LCA output categories (SF) versus familiar units (PRF) scientifically justifiable (SF) versus simplicity (PRF)	
PRF	<u>**proximity AHF-PRF:**</u> **medium (close but weak)** <u>**lines of conflict:**</u> generally sceptic of EIFOB (AHF) versus well-documented, scientific, and trustworthy (PRF) **demands to EIFOB:** qualitative, on level of concrete measures (AHF) versus quantitative & scientific (PRF) **environmental focus:** little concern for regional and global environmental issues (AHF) versus 'global issues part of societal responsibility (PRF) <u>**areas of consensus:**</u> image (smart architecture) is important **demands to EIFOB:** simple operational		

The common and conflicting demands and the resulting degrees of proximity between the four TFs can be summed up in a 'map of the socio-technological landscape around EIFOB' (Figure 32):

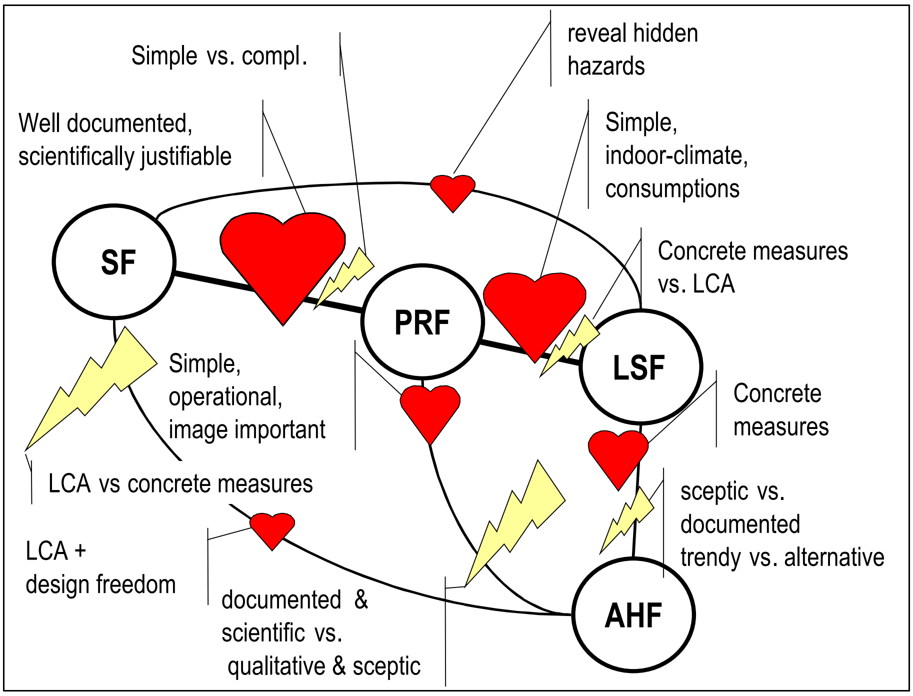

Figure 32: Map of the 'socio-technological landscape around EIFOB - relations between the different technological frames – conflicts and areas of consensus
Explanation:
The circles represent the four Technological Frames.
Their constellation represents distance and closeness, the lines connecting them represent strong or weak bonds.
Hearts (and the attached callouts) show common interests between the Technological Frames, the lightning bolts show conflicting interests.
The bigger the heart / lighting bolt, the more important the common interest / conflict.

Ongoing developments

In addition to the status quo, which is captured in the above map, the qualitative investigation of the actors' views on EIFOB indicated two ongoing developments concerning changes in the constellation of the four TFs:

Architects go scientific?

When the head of a municipal department for planning and environment was interviewed in the winter of 2001, he expressed his discontent with the environmental competence of architects and engineering consultants bidding for planning tasks for the municipality. Nevertheless, he also emphasised a development towards more competence both on the side of the caller for tenders and on the side of the bidders:

> *'In the case of this building on the other side of the street we don't make specific environmental demands. But we ask for an account of which materials they intend to use because we want to have healthy and good materials in the building. Thus we play the ball over to them, so to speak, and say that this forms part of the evaluation of the bids we get. So that we get THEM to be active and to explain "We have thought of THIS." […] So, the only demand we make is that they must account for the materials from an environmental perspective and must account for the resource consumption in the use phase. We do not want that they make anything which requires extreme ventilation or a big electricity consumption or such things. They must also account for their thoughts about the use phase of the building.*

'And I would not say that we have thrillingly good experiences with this, because they are not very competent. It is the best architects and the best engineering-enterprises that participate in the competitions, but I actually don't think they are doing a good job. And this is a problem for us, I think. But they are getting better – you see, when we tried this first time about four and a half years ago we asked nearly in the same way, and at that time they very much tricked us and said "We will do the best!" without specifying it much. They wrote a bit about the good and healthy materials and brick walls and blah-blah – but they didn't really get into it. They have got better at it now, this is also, because we ask for more and more. We rely upon our own capability to formulate demands (which we stick to in an evaluation) and we rely upon the knowledge of the tenders.'

In the third actor workshop, held in September 2003, the same person (the head of a municipal department for planning and environment) stated that

'[…] Today […] architects belong more to the scientific frame.'

Two other workshop-participants, the architect, mentioned before as also belonging to the scientific frame, and the officer responsible for the construction of schools and day care institutions in the administration of a big Danish city supported his position, stating that

'Many architects are also interested in the "systematic approach" to environment." (the officer)

and that

'Architects work scientifically, TOO, but from a holistic perspective.'
(the above mentioned architect)

The researcher at a Danish building research institute's department for energy and indoor climate disagreed:

'I don't agree that many architects have entered the scientific frame; recently I was involved in the environmental evaluation of the projects submitted to two architectural competitions. Only architectural offices with a good reputation for environmentally sound building had been invited to participate. And yet the results regarding the choice of building elements and materials were not very convincing. I don't think, any of the participants has used [the LCA-tool] BEAT or a similar tool for real in the design process, even though it was clearly stated in one of the competitions, that BEAT would be used to evaluate the project proposals.'

Seen also in the context of the observations as described in the section 'The aesthetic holistic frame' the above statements indicate three things:

1 There are different understandings of what is to be called 'scientific': Actors who are firmly located in the scientific frame (such as the above quoted researchers at DBUR) have higher and more precise standards for the attribution of the label 'scientific'.
2 There is a movement among actors in the aesthetic holistic frame towards the scientific frame.
Keeping the constellation of the four TFs as presented in the above figure 'Relations between the different technological frames' in mind it is, however, likely that this movement mainly is a movement towards the public relations frame, caused by the 'economic gravitational force' which

binds AHF to the PRF[296]. Nevertheless, an original movement towards the scientific frame may form a minor part of it.

3 The normative power of practice can overrule the environmental scientific rationale: Even though environmental knowledge is generally increasing among all actors and an actor may express himself/herself in favour of a scientifically correct approach, in practice his/her attitude may be compromised by applicability aspects[297].

Scientists go public

> *'The communication and propagation of the result [of an LCA] has become an important objective, too.'*

stated the environmental manager of a big international construction company in the third workshop, touching another general tendency: the raising awareness among actors in the scientific frame about the needs of actors in other frames.

This awareness is manifested in different ways:

In the **acquisition of tacit knowledge**, obtained by indicator developers and other actors in the scientific frame while thy employ their indicator systems in practice.

In **reflexive research projects**: As opposed to a tradition of technological determinism reflexive research projects (like this study[298]) attempt to establish a perspective through which they see the actors within the scientific frame in a symmetrical way as one group among others.

In the **shape of indicator systems:** Tacit or explicit knowledge about users and target groups of scientific EIFOB influence their shape in different respects, such as the design of their corresponding computer tools, visualisations and structure of their output, etc. One such reflection of the non-natural-scientific sphere on a profound level is the *weighting* of the environmental effects incorporated in LCA-systems:

> *'In Life Cycle Impact Assessment we have to deal with three fields of scientific knowledge and reasoning. We refer to these fields as "spheres":*
> *- Technosphere, the description of the life cycle, the emissions from processes […]*
> *- Ecosphere, the modelling of changes (damages) that are inflicted on the "environment"*
> *- Valuesphere: the modelling of the perceived severity of such changes (damages), as well as the management of modelling choices that are made in Techno- and Ecosphere.*
> *The first two spheres can be considered to be in the technical and natural science paradigms, the third sphere is clearly in the social sci-*

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[296] Compare also the statement of the head of the department for urban planning and environment of a Danish town on the promotion of the 'guidelines for environmental management in project design' as cited in the section 'Power structures':
'[…] we invite the town's construction enterprises and consultants and architects to a conference and tell them that we now have taken the decision [to apply environmental management in project design to all our building projects – "And if you want to work with us, you have to play according to these rules. Otherwise you are not attractive projects partners for us anymore." And it uses to have an effect when such a big client announces that; […] they want to be part of the game.'

[297] Here again, the reaction I received on my article about EIFOB-systems in the Netherlands (Dammann, 2003) can serve as an illustration: Even though in this article argues for environmental scientific reasons clearly in favour of LCA-based indicators and against the Dutch checklist-indicator system, the architectural and engineering consultants who contacted me after having read the article were exclusively interested in obtaining a copy of the checklist-indicator system, because they found its simplicity and operationality appealing and marketable.

[298] As already mentioned in the chapter 'Introduction', the elements reflexivity, social accountability, and the transdisciplinary, non-hierarchical and symmetrical approach with strong stakeholder involvement make this study an example of mode 2 knowledge generation (Gibbons et al., 1994).

ence world, as natural science cannot deal with a term like "seriousness".' (Goedkoop et al., 2000)

A twofold knowledge increase among actors

The developments described above are accordingy accompanied by a twofold knowledge increase:

1 Increasing social knowledge among actors in the scientific frame: in the course of the employment of their indicator systems in practice indicator developers and other actors in the scientific frame gather knowledge on the reception of different indicators among other relevant social groups. This knowledge may be tacit or (as in this study) explicit.
2 Increasing environmental knowledge: among all actors environmental knowledge is increasing rather than decreasing in the course of their occupation with environmental issues and the general public debate on current environmental problems.

These two developments were visualised by a participant in the third workshop (the researcher at a Danish building research institute's department for energy and indoor climate) in the scheme show below:

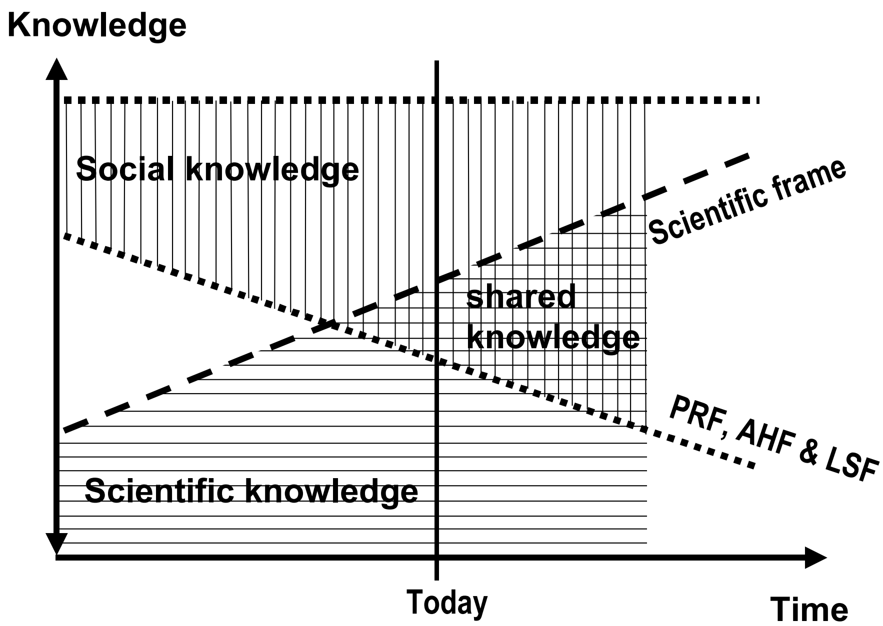

Figure 33: increase of social and scientific knowledge among the technological frames

The hatched areas and sloping lines illustrate the increasing scientific knowledge among the actors in the PRF, the AHF and the LSF and the increasing social knowledge among the actors in the SF. The situation at the 'today-axis' suggests that there already is a small overlap-area where all frames share some social and environmental-scientific knowledge. The most of the social and scientific knowledge still remain 'unshared' but the area of shared knowledge continues to increase.[299] The underlying thought is, of course, that within the area of shared knowledge communication of environmental issues among different social groups is significantly easier than outside this area.

Concluding remarks

The objective of this study, as defined in the Introduction, was to explore

[299] Of course, also the environmental scientific knowledge increases continuously. This, however is not the subject of Figure 33.

1 if (and to what extent) consensus on environmental indicators for buildings as ‘a common language for green building’ can be reached in the near future among the core actors *local building authorities, professional clients, client consultants, project designers, administrators of buildings and developers of environmental indicators for buildings* and
2 what environmental indicators for buildings that are acceptable as ‘a common language for green building’ for the relevant actor groups could look like.

The results of the SCOT-analysis, discussed in this chapter, permit to answer the first question and provide a foundation for a response to the second question.

With regard to the first question the results show that *it is not possible to create a set of EIFOB that meets the demands of all actors*. This means that a closure of the indicator debate on the basis of an all-actors consensus (illustrated in Figure 34) within the near future is very unlikely, as the actors in the four TFs are divided by rather strong conflicts while the areas of consensus that unite all four TFs are rather weak.

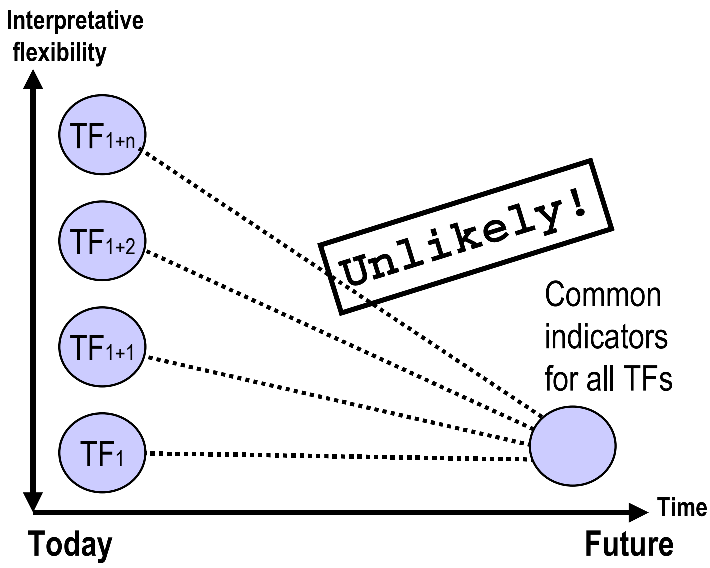

Figure 34: It is unlikely that the different technological frames converge on common indicators in the near future.

However, the results also show proximity between *some* TFs and increasing areas of shared knowledge.

Two things can happen:
The relevant social groups and their technological frames remain separated. Instead of EIFOB as a common language for all four TFs, actors in different TFs in changing constellations make temporary partial agreements. (Figure 35 - The red dots symbolise the temporary partial agreements.)

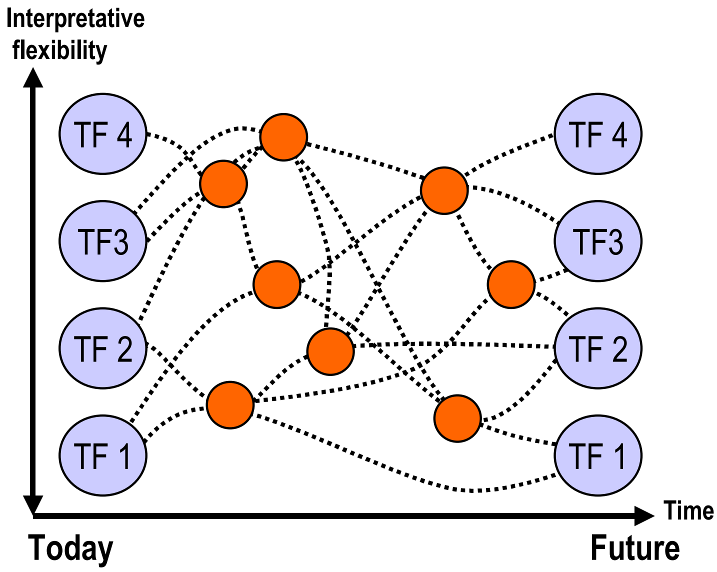

Figure 35: The four technological frames remain separated but reach different temporary partial closures for specific situations (the red dots). The indicator landscape is confusing.

Not all relevant social groups, but some reach a lasting agreement on EI-FOB. The 'outsider' group converges slowly towards the others (Figure 36):

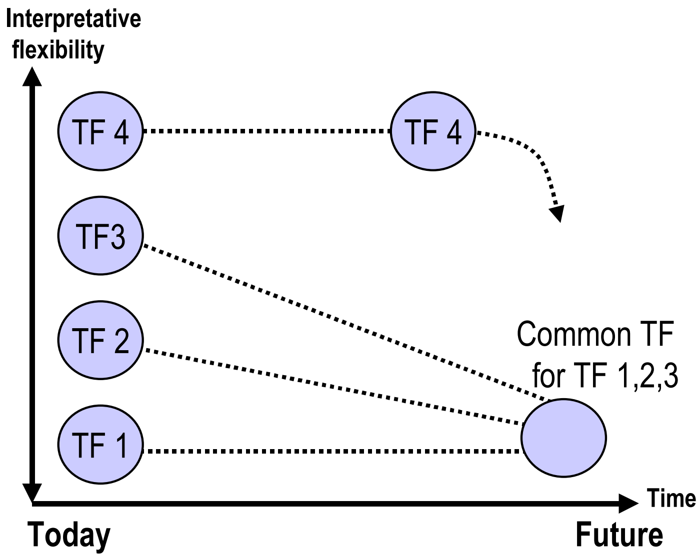

Figure 36: Scenario 1: Three of the four technological frames converge by agreeing on common indicators, the fourth frame's dependencies force it to move towards the others.

The increase of social and environmental knowledge among actors in different TFs can principally be in favour of the first option (facilitating the parallel use of 'local languages' among selected actors instead of 'a common language' shared by all actors) as well as of the second (smoothening the way towards a general consensus).

Based on these considerations and the results of the SCOT-analysis three scenarios[300] emerge as probable, which are presented in detail in the following chapter, the *prospective* part of this study.

[300] The 'scenarios' in this study correspond to the concept of 'configuration models' in SCOT, as described in the section 'The social construction of technology' in the chapter 'Research design'.

Exemplifications ‘Energy’ and ‘Indoor air quality’: Three scenarios

Introductory remark

The SCOT-analysis of EIFOB showed that within the near future contradicting actor demands make a closure of the indicator debate on the basis of an all-actors consensus very unlikely. (Figure 37)

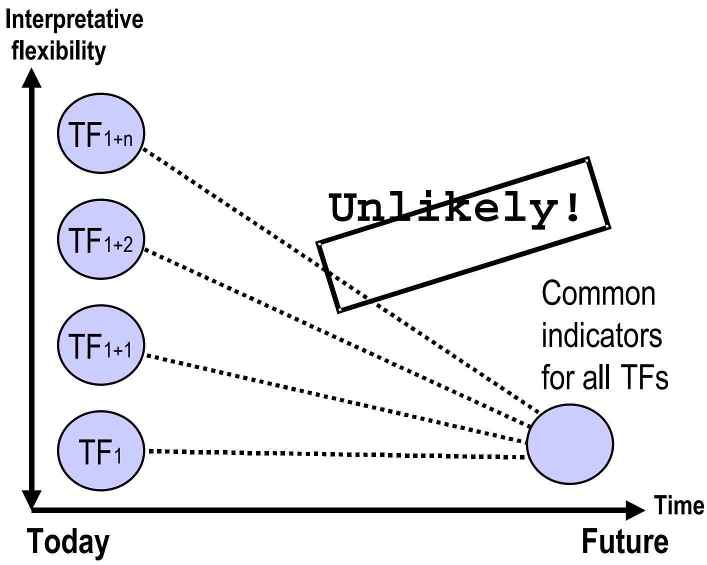

Figure 37: It is unlikely that the different technological frames converge on common indicators in the near future.

‘If indicators that meet the demands of all relevant social groups and therefore are accepted by them all cannot be created – what CAN be achieved?’ is the question that arises.

As documented in the previous chapters, the actors’ acceptance of different indicators is influenced by several parameters, the *design of the indicators* being only *one parameter among others*:

– economic dependencies
– education and capacity building
– public opinion and general societal developments

can also influence the development of EIFOB in their socio-technological environment.

As it is impossible to predict the development of all these parameters. Therefore it is also impossible to predict how a set of EIFOB, for example suggested as ‘the next-to-the-best indicators set’ (that is the set of indicators that would satisfy not *all*, but *most* actor demands), would be received by the relevant social groups.

The ‘map of the socio-technological landscape’ around EIFOB, in which indicators as ‘a common language for green building’ are to be located, does not show *one* clear way to ‘the great unifying set of EIFOB’. It *does* show, however, the present positions of the different actors, which obstacles separate them and which paths could bring them together.

Two things can happen now:

1. Nothing. Despite temporary partial agreements the relevant social groups and their technological frames remain separated. (Figure 38, left)
2. Not *all*, but *some* of the relevant social groups reach a lasting agreement on EIFOB. (Figure 38, right)

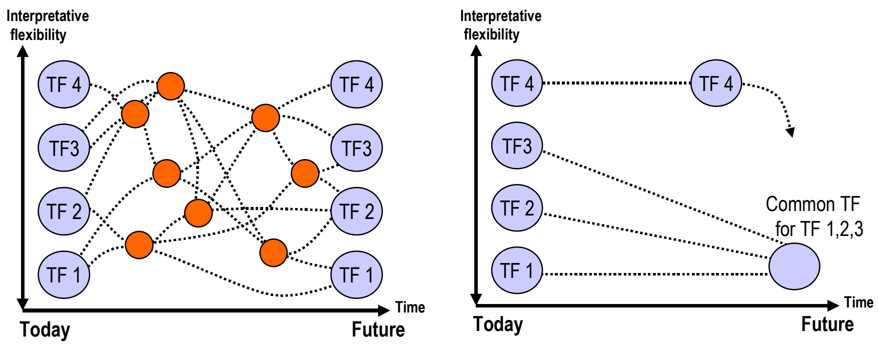

Figure 38: Two options for the future development:
1.The technological frames remain separated despite temporary partial agreements (here symbolised by the red dots). (left)
2. Not *all*, but *some* of the relevant social groups reach a lasting agreement on EIFOB. (right)

This chapter investigates these two options more closely. It does so by describing three scenarios:

– One scenario, 'scenario 0: Postmodern Relations', for option 1 and
– two scenarios, 'scenario 1: Science goes public' and 'scenario 2: Keep it simple' for option 2.

The description of these scenarios on the one hand contain reflections on the general societal constellations and actor motivations that would favour the development towards the different scenarios. On the other hand they contain examples of indicators that correspond to the scenarios.

These indicator examples do not cover the entire range of environmental issues, as this would neither have contributed to the clarity of the scenarios nor would it have been feasible in the frame of this project. Instead, the indicators are exemplified with the two environmental issues

– Energy and
– Indoor air quality,

because

– the actor investigation carried out in the course of this project clearly showed that these are issues the majority of the actors consider relevant,
– these two issues permit the reflection of the two different perspectives on environmental effects of buildings as revealed in the actor investigation: the eco-centric, global perspective, seeing *the building in the environment* and focussing on building's effects on the surrounding environment, and the local, anthropocentric perspective, focussing on *the environment in the building* and its effect on the human user.

Corresponding to the predictive nature of the scenarios in the description of the indicators examples I focused on giving them clear contours rather than elaborating all details. The scenarios and the indicators suggested in them are meant as inspirations and illustrations of possible future developments and in no way as final solutions.[301]

[301] To endeavour to present 'the author's solutions' in a social constructivist study like this would be self-contradicting.

Scenario 0: ‘Postmodern Relations’

General description

Scenario 0 ‘Postmodern Relations’ is the continuation of the status quo as described in detail in the previous chapters. It is called ‘scenario 0’ because the status quo is of course the ‘point of reference’ for statements about the future development of EIFOB. At the same time it suggests that in this scenario the increase of closure of the indicators debate is ‘zero’ – a ‘dynamic stagnation’, in which various actors reach various temporary partial closures for specific decision-making situations but profoundly remain separated in the four technological frames. The indicator landscape is confusingly multifarious (Figure 39).

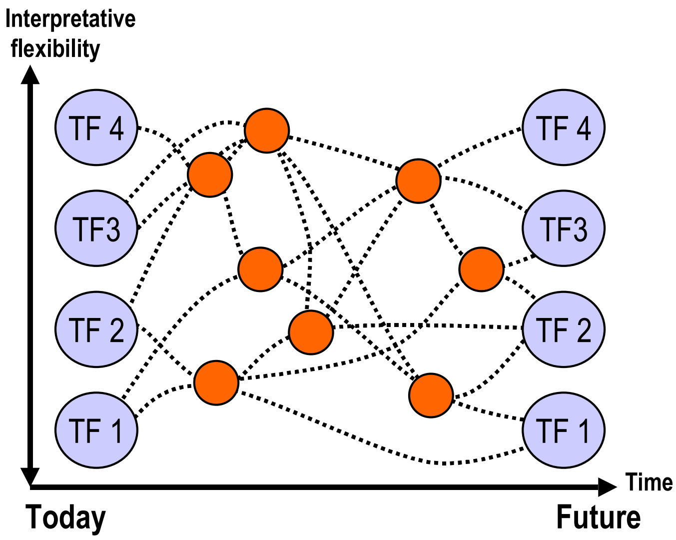

Figure 39: Scenario 0: the four technological frames remain separated but reach different temporary partial closures for specific situations (the red dots). The indicator landscape is confusing.

The scenario’s title ‘Postmodern Relations’ refers to key features of the current situation, using the picture of postmodern human couple relations as a metaphor. The figure below, already used in the section ‘Relations and dynamics between the different TFs’ to give an overall picture of the current situation, is here displayed again to illustrate the scenario ‘Postmodern Relations’:

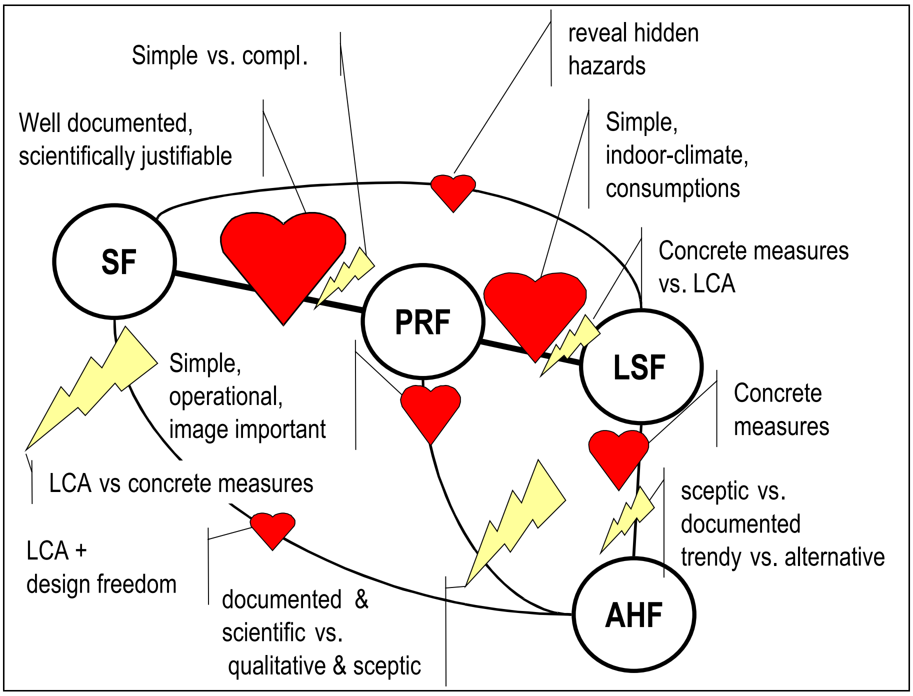

Figure 40: Illustration of scenario 0 'Postmodern Relations': the current relations among the different technological frames, including conflicts and areas of consent, continue. Instead of a closure by consensus temporary, individual agreements are made.
Explanation:
The circles represent the four Technological Frames. Their constellation represents distance and closeness, the lines connecting them represent strong or weak bonds. Hearts (and the attached callouts) show common interests between the Technological Frames, the lightning bolts show conflicting interests. The bigger the heart / lighting bolt, the more important the common interest / conflict.

Characteristic of this scenario is that the idea of a set of coherent EIFOB, covering the entire life cycle and addressing the majority of actors involved has been abandoned. Instead, the recognition that buildings *are* being built, and that whoever wants to make environmental efforts in his building activities finds ways to do so, is taken as the token of the fact that satisfying ways to communicate and consider the environmental dimension in a building process exist and do not require harmonisation. Actors in the different TFs make individual, temporary agreements on indicators for specific projects with actors in other TFs, with whom they see possibilities for fruitful cooperation.

In a 'dynamic stagnation' also in this scenario the different TFs refine their individual approaches to EIFOB, of course, and react to impulses they altogether are exposed to, such as the implementation of the EU-directive on the energy performance of buildings into national law by 2006[302]. A closure of the EIFOB debate on a broad basis, however, is not in sight.

The scenario and the actors

As scenario 0 is a continuation of the status quo a more detailed description of this scenario would only be a repetition of the analysis presented in the previous chapters.

It is evident that in scenario 0 the 'multilingual actor', that is the actor, who '*speaks the languages of different TFs'*, so to speak, plays an important role. By being able to 'interpret' and 'translate' from one 'indicator language' to another he creates parts of the coherence that a common set of EIFOB would have created. Among the actors interviewed in this study, the head of a municipal department for planning and environment and the officer responsible for environmental guidelines for the construction of schools and day-care institutions in the administration of a big Danish City, mentioned in

[302] For details see the section 'The Danish planning and building legislation and ongoing European developments' in the appendix

the descriptions of the SF and the AHF (in the chapter 'Indicators in a social constructivist perspective') as belonging to *two* technological frames, were examples of such 'multilingual actors'.

Actor motivations that could stabilise the current situation into a scenario 0 could be perceived advantages of an interpretative flexibility of EIFOB:

– Without commonly accepted indicators each TF can maintain the claim 'to have the right approach' for itself and its clientele.
– Indicators that *are not commonly used* may even be seen as a better way to underline the protagonist character and special level of environmental commitment of a project.
– The lack of a common set of EIFOB may leave loop-holes for ecological downsides in green marketing of building projects.

The societal constellation

At the societal level a governmental policy with little concern for environment could foster this scenario, reducing funding for research and development in the field of EIFOB and removing legislative driving forces and fiscal incentives for environmental efforts in the building sector, which indicators could have helped to operationalise. The example of attempts to create a norm for a material-related environmental profile (Nederlands Normalisatie-institut, 2000) and to integrate it into the building code in the Netherlands illustrates how such a development can lose momentum when governmental support is withdrawn and things are left to the private sector. (Nederlands Normalisatie-institut, 2002)

Another factor in favour of this scenario would be a perceived stabilisation or improvement of the state of the environment. In the same way, as the energy crisis in the 1970s greatly promoted the concern for energy efficiency in the building sector, a societal perception that there are no imminent environmental threats could diminish the concern for environmental effects of building activities. The significant change in Danish environmental policy between the social-democrat led government and the liberal led government after the Danish 2001 elections and the designation of Bjørn Lomborg, author of the fiercely debated book 'The true state of the world', in which he claims

> *'We actually leave the earth as a better place to live than it was when we received it. Enjoy this!' (Lomborg, 1998)*

as director of the newly founded 'Environmental Assessment Institute'[303] can be seen as the expression of such a perception, that environmental problems are less urgent than hitherto thought.

Exemplification:

The indicators used in this scenario are principally the same as documented in the previous chapters of this thesis.

Discussion of the scenario

In this scenario the problems linked to the absence of a commonly accepted set of EIFOB, which formed the point of departure of this study and which are described in the chapter 'Introduction', remain unsolved. A multitude of different and often contradicting interpretations of 'green building' is not likely to lead from the current 'Babylonian' confusion to a situation in which a coherent language for green building fosters concerted efforts and innovation in environmentally sound building. Single environmentally ambitious projects my be carried out, but the perception of these is likely to be more strongly characterised by individual PR-efforts than by a transparent environmental

[303] Whose purpose it is *'to get most environment for the money'* (source: www.imv.dk , 'The institute', 'Objectives')

assessment with broadly known and accepted indicators. This will also make it more difficult to provide environmental assessments of building stocks on a larger societal scale, for example on '*the material-related emissions and in-door climate quality of all flats built in Denmark since 2003'*.
Finally a disadvantage is that the lack of common EIFOB does not induce a concerted learning process among the actors in the building sector. The remark of the architect-participant in the course 'environmental planning in project design' by the Federation of Danish Architects on the confusing amount of different approaches is likely to remain as true as it was:

> *'The problem to define the notion "environment" is really obvious in this course. They shoot with a shotgun[304] at an entire field. We are absolutely at beginner level here.'*

Scenario 1: 'Science goes public'

General description

The general setting of this scenario is that three of the four technological frames converge by agreeing on common indicators, while the fourth frame's dependencies force it to move towards the other three. (Figure 41)

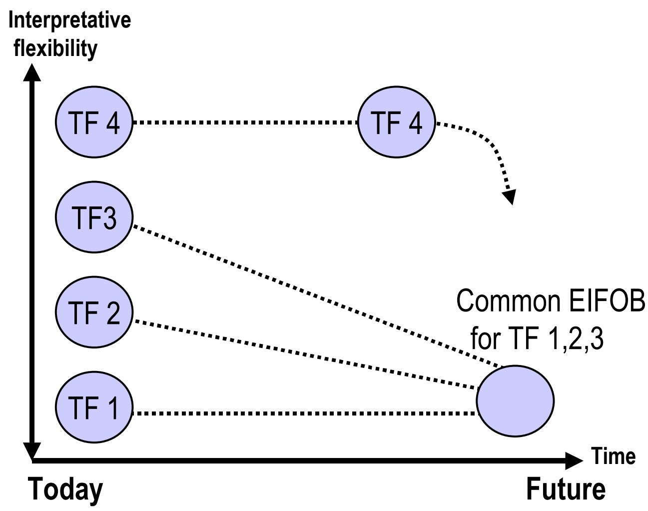

Figure 41: Scenario 1: Three of the four technological frames converge by agreeing on common indicators, the fourth frame's dependencies force it to move towards the others.

As Figure 42 suggests, in this scenario the scientific frame, the public relations frame and the fraction of the layperson-sensualist frame, that has an affinity to rationalist approaches, establish a stable unit around their common interests. These are first and foremost

– the demand for well-documented, scientifically justifiable indicators,

which binds the SF and the PRF as the main protagonists - hence the scenario's title 'science goes public' - in this scenario together. Their collaboration is mainly driven by the SF's wish to sell its scientific expertise and the PRF's wish for *a positive, trustworthy public image and their aim to avoid in-door-climate problems.*
With regard to the PRF's inclination to avoid EIFOB that shed light on one's environmental shortcomings the PRF has realised that the wish for a positive, trustworthy public image can only be obtained if indicators do not leave space for manipulation.

[304] A gun for bird and rabbit hunt, which shoots plenty of small projectiles to increase the probability of a hit.

Together the SF and the PRF develop and promote a set of EIFOB that overcomes the dichotomy of 'scientifically justifiability' versus 'simplicity' by offering different levels of simplicity, into which the basic scientific indicators are aggregated in a consistent and transparent manner. This simplification makes it easy to promote the indicators among those actors in the LSF, who are principally open to guidance from the scientific-rationalist paradigm but want to be free from having to deal with the complexity of the SF's approach. The development of the scientific paradigm to the predominant approach may well divide the actors in the layperson sensualist frames, repelling the 'lifestyle ecologists' who insist on employing certain concrete measures as icons of their alternative values. The lifestyle ecologists may reject the conclusions of the SF's approach as they adhere to a principally different, sensualist epistemology.

Also the bond between the LSF and the SF is strengthened. The actors in the LSF are increasingly concerned about indoor climate and become more and more aware of the value of scientific knowledge especially in this field where hazards such as toxic substances or radiation are not detectable with human senses without support by scientific methods. Layperson actors also valued scientific knowledge about sources of pollution and remedial or preventive action.

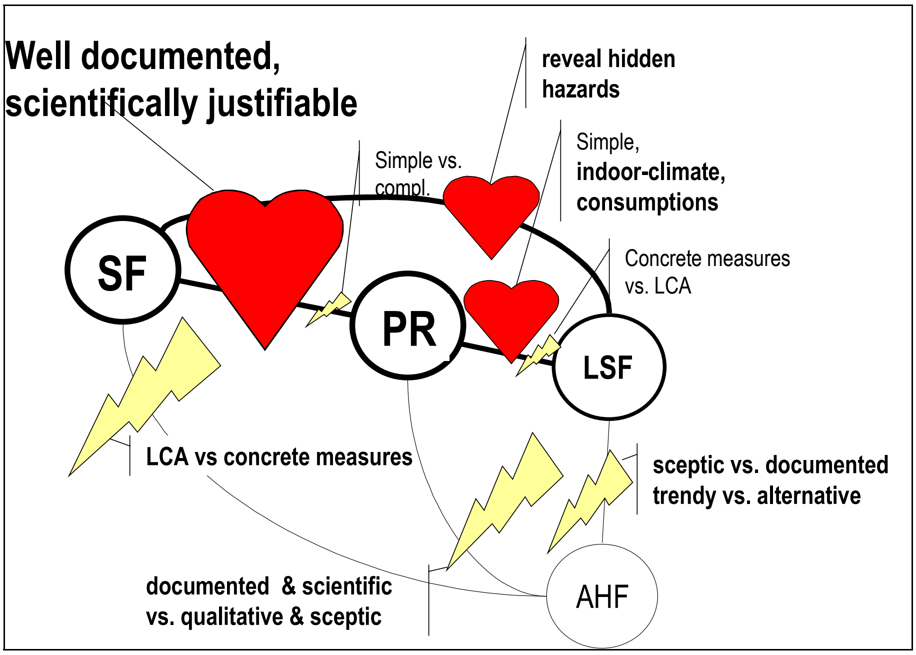

Figure 42: Illustration of scenario 1 'Science goes public': The scientific frame and the public relations frame establish a tight unit around their common interest in well-documented, scientifically justifiable indicators. Actors in the layperson sensualist frame join. The aesthetic-holistic frame is marginalised.

As the SF, the PRF and the LSF form unite around EIFOB in the scientific paradigm the aesthetic-holistic frame is marginalised. The scepticism and opposition of the actors in the AHF becomes the dominant feature in their conflictual relation with the other TFs. As the AHF is economically dependent on the actors in the PRF and the LSF it successively acknowledges the predominance of the indicators agreed upon by the 'three unionist frames' and also begins to work with these indicators.

The societal constellation:

At the societal level the 'science goes public' scenario could be fostered by several factors:

A new government could endeavour to re-establish Denmark's role as an environmental avant-garde, seeing high environmental standards as a motor of innovation and growth[305] rather than as an obstacle. Legislative and fiscal frames could actively promote higher environmental performance of the building sector, thus creating a need to operationalise environmental considerations by means of commonly accepted EIFOB.

Similar incentives could also originate from European legislation, for example with a 'Directive on the material-related environmental performance of buildings'.

A development towards the 'science goes public'-scenario could also be driven by a changed environmental situation: as the oil-crisis of the 1970s triggered the concern for energy consumption, drastic environmental threats like extreme weather conditions causing economic and health damage could urge environmental policy to the top of the political agenda. Specifically in the building sector new knowledge about indoor-climate-related health threats could kick off new efforts, because unhealthy indoor climate usually concerns a large fraction of the population in a very direct way. The 'science goes public' scenario could also begin with a voluntary agreement between major players in the building sector, motivating other actors to successively join in.

It is important to mention that this scenario also assumes a process of capacity building among the actors, which enables more and more actors in the other frames to understand and work with the indicators used in the scientific frame.

Exemplifications

To illustrate, what EIFOB in the 'science goes public' scenario could look like, the indicators that correspond to this scenario are exemplified with the environmental issues 'energy' and 'indoor air quality'.

The guiding demands to EIFOB in this scenario can be divided into two kinds:
The first is that the indicators be

- scientifically justifiable
- trustworthy
- transparent, well-documented and consistent.

The second is that the indicators be

- simple and
- easily understandable (and thus communicable to the target groups of the public relations frame).

To meet the first group of demands the indicators are based on the concept of life cycle assessment as the principal approach of the scientific frame and on the scientific concepts used in indoor climate research. To exclude the occurrence of 'green buildings in the middle of nowhere' whose environmental burden caused by commuting transport by far exceeds the environmental savings of the building and of 'green palaces' with an excellent environmental performance *per m²* but horrendous *per person* values, 'induced transport' is included in the energy indicators and the figures are generally[306] expressed '*per person'*. To obtain consistency, the same or closely related indicators are used in all three decision-making situations.

To meet the second group of demands the 'primary indicators' used in the scientific frame can be aggregated to simpler indicators, operating with three levels of aggregation:

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[305] The Danish 'windmill-experience' illustrates this: In Denmark promotion of renewable energy became a governmental policy in 1991 and the wind generator industry grew by some 40% each year from 1995 to 2000 (European Environment Agency, 2001), giving the country an international leadership position in this relatively young economic sector.

[306] In cases, where figures 'per m²' or total figures are more useful these are employed.

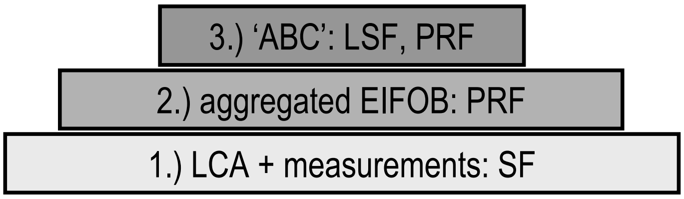

Figure 43: Three levels of aggregation

At the first level - the 'scientific level' – the various indicators of the SF as described in the following text are used. These are aggregated to a limited number of simpler level 2 indicators[307] for the actors in the PRF (Actors in the AHF successively also begin to use the level 2 indicators). For this aggregation a *weighting* of the level 1 indicators is carried out, which permits the indicator system to reflect different 'degrees of severity' of the various environmental aspects, based on scientific knowledge.

Indicators at level 2	**Ranking**	**Quantification**
Energy & related emissions	A / B / C	3 / 2 / 1
Indoor climate[308]	A / B / C	3 / 2 / 1

Table 37: The level-2 indicators

The ranking system employed here is a simple ABC ranking combined with a simple point-score system. This scoring system is also used for the aggregation from level 2 to level 3. The 'A,B,C'-indicator scores signify:

Indicator score	Points	Description
A	3	very much above standard ('very good')
B	2	significantly above standard ('good')
C	1	slightly above usual standard

Table 38: General significance of the A/B/C-indicator-scores

The quantification of the A,B,C indicator scores with the corresponding point scores from 3 to 1 allows the aggregation of the different indicators by means of relatively simple calculations, thus responding to the demand for simplicity of the PRF and the LSF. The fact that the highest point score ('3') corresponds to the best environmental performance ('A') (and not vice versa) relates the system to other broadly known scoring systems (for example marks in schools and universities, goals or points in sports, the point scores in the European song contest and the stars for hotel and restaurant rating).[309] This makes it easy for layperson target groups to relate to the indicator scores.

ABC are only *positive* scores, because the public-relations frame is mainly interested in positive indicators that can *'name and fame'* and not in negative indicators that 'shame and blame'. For some decision-making situations and some environmental aspects, however, (for example indoor

307 The level-2 indicators cover the whole range of environmental issues as described in the chapter 'Environmental effects of buildings'. This exemplification, however, only comprises the indicators for energy and related emissions and Indoor air quality.

308 At level 2 the indicators for 'indoor air quality' together with the other indoor climate indicators (covering sound, thermal climate and light) are aggregated to the single indicator 'indoor climate'.

309 This 'the higher the number, the better'-logic is also inherent in our growth-oriented economy and in our monetary system, where a thing that cost e.g. 10 Euro is considered ten times more valuable than a thing that costs 1 Euro. An argument for using the opposite 'the lower the number the better' logic is that it corresponds to the 'less is better' principle contained in many environmental considerations: less resources consumption, fewer emissions, fewer sick-building symptoms …., which has its popular counterpart in the '1./2./3. place' ranking known from the world of sports.
This 'restraint perspective', however, does not go along well with the PRF's demand for 'popular' indicators. Besides, other environmental issues like e.g. 'number of habitats and species', 'share of renewable energy' or 'share of public transport' correspond to the 'the more the better' logic.

air quality in the DMS 'renovation') negative indicators are more useful.[310] In these situations additional 'negative' indicator scores can be used:

Indicator score	Points	Description
0	0	usual (reference) standard ('neutral')
😐	-1	slightly below standard ('problematic')
☹	-2	environmentally especially problematic ('bad')

Table 39: The additional negative indicator-scores

The level-2 indicators from Table 37 are aggregated to the level 3 ranking of buildings as

A buildings
B buildings
C buildings
according to the table below:[311]

Ranking	Definition
A building	arithmetic average of all level 2 indicators ≥ 2,5 points *and* no score below 2
B building	arithmetic average of all level 2 indicators ≥ 1,5 points *and* no score below 1
C building	arithmetic average of all level 2 indicators ≥ 0,5 points *and* maximal two scores ≤ 1

Table 40: Aggregation of the level 2 indicators to the level 3 A/B/C-ranking

This simple building classification responds to the demand of the actors in the layperson-sensualist frame for very simple indicators.[312] ABC-classifications are familiar to Danish layperson actors from the Danish 'Energy labelling of houses and owner-occupied flats'.[313]

To operate with the three levels of aggregation as described above is a way to reach closure by combining two closure mechanisms:

– On the one hand interpretative flexibility is diminished by agreeing on *scientific justifiability* and *communicability* as core characteristics of the indicators.
– On the other hand, the simplicity-versus-complexity conflict is resolved by *intentionally maintaining a certain degree of interpretative flexibility*: With the three levels of aggregation and clearly defined transitions between the three levels the indicators are *simple and complex at the same time*, depending on which level of aggregation one looks at.[314]

[310] See Table 53 – it is easier to measure the occurrence of symptoms than the absence of symptoms in a differentiated way.

[311] To aggregate the level 2 indicators to a single level 1 indicator two different principles of aggregation can be used:
The first is, to *weight* the different environmental issues with weighting factors, calculate the sum of all indicators to one overall score to which then benchmark values can be attributed that correspond to the A/B/C-building ranking.
The second is to define an A/B/C-building as 'all level 2 indicators have (at least) an A/B/C-score', that is *all* level 2 indicators have to reach or exceed a certain benchmark.
The method applied in this scenario is a combination of both methods with the stress on the second approach. This pays tribute to the fact that from an environmental scientific point of view a weighing is not possible, as unambiguous data on the 'severity' (that is the final effects) of the different environmental impacts is not available.

[312] It does, however, *not* meet their demands for sensually perceptible indicators.

[313] Find a closer description in the Chapter 'Indicator systems' an in the appendix.

[314] This closure mechanism has previously been described by Luxenburger and Asmussen in their SCOT analysis by of the newly build bicycle lane at one of Copenhagen's major streets: '*The raised edge [of the pave stones used as demarcation, author's note] between bicycle lanes and motor lanes illustrates the third kind of closure, which does not unify the interpretations of the actors: by introducing a raised edge, cycle lanes could be interpreted as both lanes AND paths.' (Luxenburger, Jan; Asmussen, Rune, 01)* (see also the section 'Technology in the light of social constructivism')

In the following concrete indicators for the environmental issues ‘energy’ and ‘indoor air quality’ are suggested for the three decision-making situations (DMS) ‘siting’, ‘project design’ and ‘renovation’. Each decision-making situation begins with a description of the indicators at the first level (the ‘SF-level’) for energy and indoor air quality before suggesting a way to aggregate the SF-indicators to the levels 2 and 3.

Exemplification ‘energy’

In the scenario ‘science goes public’ the environmental issue ‘energy’ is understood as all forms of energy consumption that occur in a life cycle perspective of a building with the system borders including induced transport and energy embodied in the share of the infrastructure allocated to the building. Of the LCA impact categories only

– contribution to global warming
– acidification
– nutrient enrichment
– photochemical ozone formation
– consumption of fuel resources[315]

are attributed to the environmental issue ‘energy’, that is those impact categories to which our current form of energy consumption makes major contributions and which therefore can be communicated as related to energy consumption also to a broader public.

Siting of the building

The energy indicators to be used in this DMS cover the five aspects[316]

1 Energy sources
2 Energy embodied in material for infrastructure
3 Energy embodied in building materials
4 Induced transport
5 Energy management

1. Energy sources:

The indicators are based on life cycle assessments of the different sources of energy that can be employed in the location in question, calculating the environmental impact potentials for emissions to air and the consumption of fuel resources for these in the usual units of the Danish LCA-system ‘EDIP’ (Wentzel et al., 1997), also employed in the LCA-tool ‘BEAT 2000’.

Indicator	Unit before normalisation	Unit after normalisation
contribution to global warming	kg CO2-equivalents	PE_{WDK95}[317]
acidification	kg SO2-equivalents	PE_{WDK95}
nutrient enrichment	kg NO3-equivalents	PE_{WDK95}
photochemical ozone formation[318]	kg C2H4-equivalents	PE_{WDK95}
consumption of fuel resources	PE (‘Person-Equivalents’)[319]	PE_{WDK95}

Table 41: LCA-indicators for the assessment of different energy sources (all units ‘per person per year’)

[315] And *not* the other impact categories (material consumption & waste, toxicity,…) – the contributions of ‘energy’ to them appears in the respective issues in the same way as the energy embodied in materials appears here under the environmental issue ‘energy’ and not under ‘material consumption & waste’.
[316] The settlement layout certainly also has an impact on the energy performance of a building. In this scenario, however, the relevant settlement layout parameters such as density or provision of common facilities (bicycle repair workshops, laundries,…) are thought to be implicitly included in the other indicators (e.g. ‘density’ in the anticipated energy consumption in the use phase). Nevertheless, in practice additional checklist indicators may turn out to be useful.
[317] Person Equivalents per reference year (1995) per reference area (Denmark / World)
[318] ‘Stratospheric ozone depletion’ principally is an impact category in the BEAT-system, too. In practice, however, there are almost no contributions to this impact category from buildings.
[319] After normalisation and weighting the consumptions of fuel resources (coal, natural gas, crude oil) are added to one figure.

For this assessment, the energy consumption for heating and electricity of the future building can be predicted on the basis of statistical data on similar buildings. The energy consumption can be calculated per year or as a total figure for the building's expected life span (common figure for calculations: 60 years = two generations), depending on the precise purpose of the calculation: if, for example, a change in the energy source is expected at a certain point in the future, the building's life span is relevant, if not, not.

Indicator	Unit
the building's anticipated energy consumption for heating and electricity (based on statistical data on similar buildings)	kWh/(m^2 x year) or kWh/$m^2_{\text{entire life span}}$

Table 42: The building's anticipated energy consumption as an additional level 1 indicator

2. Energy embodied in material for infrastructure

To reflect the energy embodied in the material for the building's infrastructure supply, the consumption of material for the share of the infrastructure (access roads, energy infrastructure, connections to wastewater treatments system, …) allocated[320] to the building is calculated. Then an LCA on this material consumption is carried out to calculate the emissions to air and consumption of fuel resources (as in the above table 'LCA-indicators for the assessment of different energy sources'). These are added to the level 1 indicator values of the point 'Energy sources'.

3. Energy embodied in the building materials

As explained in the chapter 'Environmental effects of buildings' the energy consumption for the production and transport of the building materials constitutes a significant share of a building's total energy consumption.

Even though decisions on the choice of constructions and building materials have not been taken yet in the DMS 'siting' the energy embodied in the building materials is calculated on the basis of statistical data on similar buildings. This makes possible the comparison of the relative significance of the different energy-issues and the identification of possible environmental hot spots already in this early planning phase.

Also these statistical average values are added to the values of the points 'Energy sources' and 'Energy embodied in material for infrastructure' (see Figure 44 further below).

4. Induced transport

In recognition of the fact that almost half of the energy consumption of an average Danish household is caused by transport and that depending on the siting of a settlement the implied average daily car transport of the residents can vary by a factor of 4 (Hartoft-Nielsen, 2001) the importance of this aspect is also reflected by indicators. These are inspired by the Dutch system 'Local Transport Performance' (LTP) (van Hal et al., 2001)[321].

On the basis of general statistical data and site specific data and an IT-tool (a Danish version of the Dutch tool 'LTP-KISS' (van Hal et al., 2001)) permits the generation of figures on the specific transport performance of the building at the specific location.

Input data are among others:

[320] A precise solution of this allocation problem is beyond the scope of this study. However, *principles* for the allocation are that infrastructure is seen as a technical system that continuously needs to be renewed with new materials in spite of the fact that some infrastructure elements may have a very long life span. Therefore there is no distinction between existing infrastructure and newly built infrastructure. Disregarding, whether a building is located in a new settlement or at an inner city location within existing infrastructure a share of the infrastructure is allocated to the building.

[321] See also the more detailed description in the chapter 'Indicator systems'

inhabitant data	dwelling data	road data	district data	general data
e.g.	e.g.	e.g.	e.g.	e.g.
number of house-holds size of households % employed bike- and car own-ership	number of dwellings type of dwelling existence of a bike shelter	type of road (hous-ing +/ business) 30 km zone orientation of front doors towards bicy-cle lanes	public transport situation (distances to stops) distances to work, shops and educa-tion	average density (addresses per hectare) % green area access to facilities

Table 43: Input data of the IT-tool 'Local Transport Performance'

Missing site specific and building specific data is automatically substituted by statistical average data.
Output data are:

modal shares:	energy:	distances:
car	MJ for car	share of each transport mode in km
public transport	MJ for public transport	
bicycle		
walking		

Table 44: Output data of the IT-tool 'Local Transport Performance'

For the energy consumptions of the different transport modes the emissions to air and the consumption of fuel resources are calculated and expressed in the LCA-indicators for the assessment of different energy sources (see Table 41). Thus the figures from 'energy sources' and 'induced transport' can be added to a single figure.

LTP has mainly been designed for the comparison of transport impacts of alternatives urban designs. It is therefore suitable to be applied to groups of buildings but principally also to single buildings. However, the application to single buildings may require some modifications.

5. Energy management

The existence of an energy management system at the building's location is likely to cause lower consumptions in the building's use phase due to energy-conscious user behaviour. Based on empirical research, quantitative relations are established between the energy management system in place and the energy consumption in the buildings' use phase. These are of the kind

> *'The energy management system X brings about a factor Y reduction of energy consumption in a settlement of type Z.'*,

'Z' comprising socio-economic parameters of the buildings' users that have an impact on their energy consumption. Based on such a quantitative relation the figure for the building's anticipated energy consumption (see Table 42) is multiplied by the factor 'Y'.[322]

Synopsis

The quantitative indicators described above are added and displayed together in a bar diagram:

[322] If such a quantitative relation cannot be or has not been established the existence of an energy management system at the location can be expressed by a qualitative indicators *'Energy management system in place'*, possibly refined with a checklist of sub-indictors like e.g. *'Consumption displays in place', 'Consultation on energy saving techniques is given', …* - Compare (BRE Centre for Sustainable Construction, 2001). For quantification the 3, 2, 1, -2 point scores are attributed to benchmarks for the 'number of sub-indicator measures applied'.

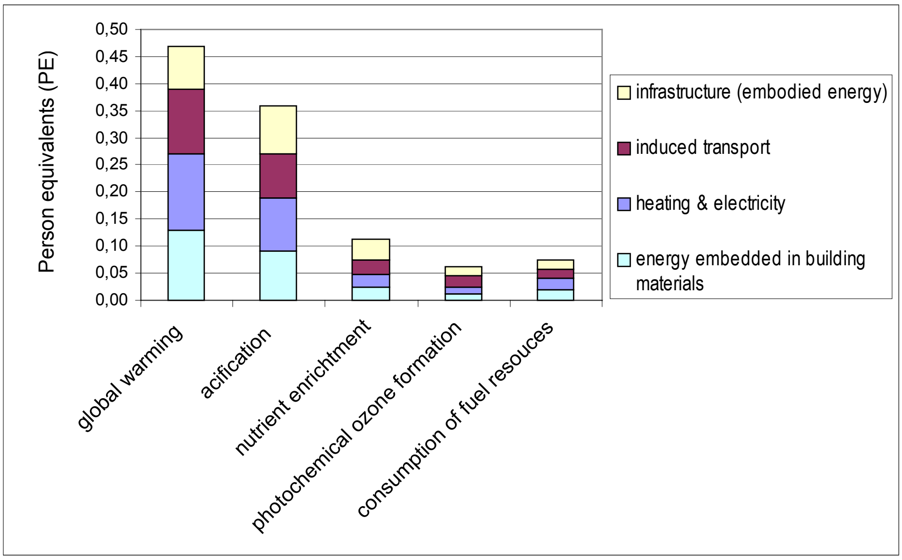

Figure 44: Synopsis of the contributions of infrastructure, induced transport, heating & electricity to the LCA energy indicators (fictive values, generally all 'per person per year')

Aggregation to level 2

These five indicators are aggregated to the single level 2 indicator *'Energy & related emissions'* in two steps: First the values of the five impact categories are multiplied with the weighting factors of the Danish LCA system 'EDIP' (Wentzel et al. 1997) and summed up to one resulting figure.

Then this value is ranked with the ABC-scores on the basis of three benchmark values:

		Benchmarks e.g.	
Indicator	**A (=3 points)**	**B (=2 points)**	**C (=1 point)**
Energy & related emissions	≤ 0.25 PE	≤ 0.30 PE	≤ 0.35 PE

Table 45: A/B/C/3/2/1 ranking of the level 2 indicator 'energy & related emissions'

Project design

Energy:

The indicators for the environmental issue 'energy and related emissions' in the DMS 'project design' reflect three aspects of energy consumption:

– Energy sources[323]
– Energy consumption in the building's use phase and
– Energy embodied in the building materials[324]

The indicators employed to describe these aspects are the same as in the DMS 'siting'. The major difference between the two DMS regarding the use of EIFOB is that there are more data available in the project design than in the siting. As a consequence, statistical average data on the building's anticipated energy consumption for heating and electricity and on the energy embodied in the building materials used in the DMS 'siting' can now be replaced with building-specific data. These data are calculated on the basis of the energy-relevant parameters of the actual project design (for example the insulation-values of the construction elements, design and orientation of the façades, the technical equipment, …) and the chosen building materials. IT-tools (such as the DBUR-developed programme 'BSim' (Wittchen et al. 2002) and the LCA-tool 'BEAT' facilitate this work.

[323] Even though the number of energy sources among which to chose may be smaller compared with the DMS 'siting' (as e.g. natural gas or district heating may not be available at the chose location) there are still different alternatives in the DMS 'project design for the energy sources for heating (e.g. oil, wood, solar heat) and electricity (different electricity providers on the liberalised market).

For the building's anticipated energy consumption for heating and electricity the result is the same indicator as in Table 42, only based on *building specific data* instead of on statistical average data:

Indicator	Unit
the building's anticipated energy consumption for heating and electricity (based on energy demand calculations for the specific building)	kWh/(person x year) or kWh/person$_{\text{entire life span}}$

Table 46: The building's calculated energy consumption

For the calculation of energy embodied in the building materials the amounts of the different building materials are extracted from the project's construction drawings (or estimated, if the project is still in an early stage) and their emissions to air and consumptions of fuel resources are calculated in a LCA, again using the same indicators as in Table 41:

Indicator	Unit before normalisation	Unit after normalisation
contribution to global warming	kg CO2-equivalents	PE_{WDK95}[325]
acidification	kg SO2-equivalents	PE_{WDK95}
nutrient enrichment	kg NO3-equivalents	PE_{WDK95}
photochemical ozone formation[326]	kg C2H4-equivalents	PE_{WDK95}
consumption of fuel resources	PE ('Person-Equivalents')[327]	PE_{WDK95}

Table 47: LCA-indicators for the assessment of the energy embodied in the building materials (generally all units 'per person per year')

These building-specific values then replace the statistical average values from the siting in the synopsis already familiar from the DMS siting:

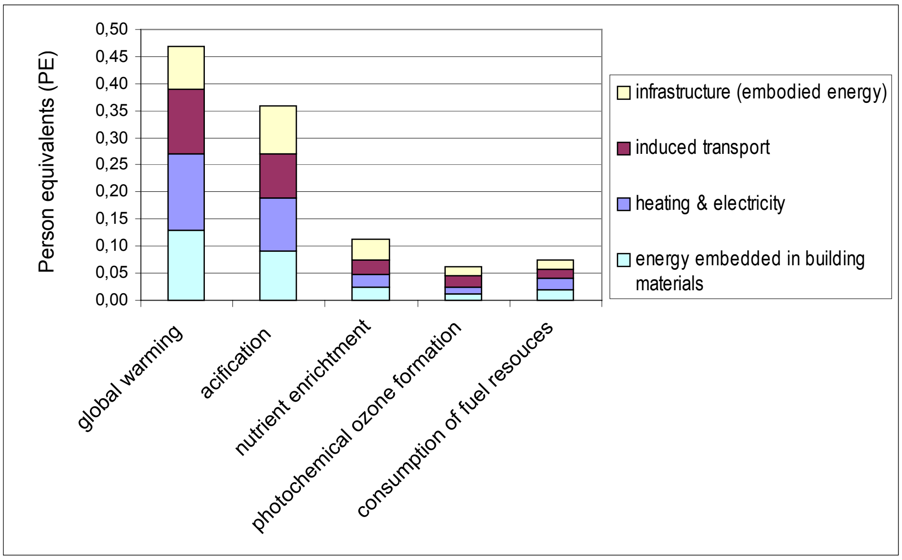

Figure 45: Synopsis of the contributions of infrastructure, induced transport, heating & electricity and the energy embodied in the building materials to the LCA energy indicators (fictitous values, generally all 'per person per year')

The aggregation to single level 2 indicator *'Energy & related emissions'* is carried out in the same way as in the DMS 'siting'.

325 Person Equivalents per reference year (1995) per reference area (Denmark / World)

326 'Stratospheric ozone depletion' principally is an impact category in the BEAT-system, too. In practice, however, there are almost no contributions to this impact category from buildings.

327 After normalisation and weighting the consumptions of fuel resources (coal, natural gas, crude oil) are added to one figure.

Renovation

Energy:

Also in the DMS 'renovation' the same indicators as in the siting and the project design are used. Characteristic of this DMS is that *measured data* on the actual consumption of heat and electricity is available in connection with billing. Data on the induced transport is not readily available but can in principal be obtained, for example by means of questionnaire inquiries.

Exemplification 'Indoor air quality'

Siting

The level 1 indicator in the DMS 'siting' reflect the potential impact of outdoor sources of indoor air pollution at the locations in question. They are based on measurements of pollutant concentrations and defined benchmark levels:

Pollutant	**Source**	**Concentration in % of benchmark level**[328]	**Potential effect**	**Possible remedy** **- difficult** **- medium** **- easy to achieve**
airborne particles	traffic	150	lung cancer cardiovascular diseases	mechanical ventilation + filters for air intake - difficult
organic gases and vapours	agriculture	70	odour annoyance	mechanical ventilation + filters for air intake - difficult
heavy metals	polluted soil	200	cancer	soil exchange - medium
tetrachlorethene	neighbouring dry-cleaning plant	50	cancer	sealing of walls shared with the dry-cleaning plant, mechanical ventilation + filters for air intake - medium
…	…	…	…	…

Table 48: Indicators for outdoor sources of indoor air pollutants in the DMS 'siting' (not conclusive)

Aggregation to level 2

The measurements in Table 41 are aggregated to *one* indicator (as a sub-indicator[329] for the level 2 indicator *'indoor climate'*) in two steps:

First a 'severity score' from 3 to 1 (with 3 indicating a 'high degree of severity' and 1 indicating a 'low degree of severity' based on an evaluation of the parameters

– concentration of the pollutants
– number of people exposed
– duration of exposure
– potential effect and
– possible remedy

[328] The values of course have to be averages over longer periods of time to eliminate deviations due to changing weather conditions. To describe such a method in detail is, however, beyond the scope of this study.

[329] Along with the other sub indicators of the level 2 indicator *'indoor climate'*: *'thermal climate', 'light'* and *'sound'* (compare chapter 'Environmental effects of buildings').

is used to convert the above measurements into a form suitable for aggregation:

Pollutant	(Source)	Severity score (1-3)
airborne particles	traffic	3
organic gases and vapours	agriculture	1
heavy metals	polluted soil	2
tetrachlorethene	neighbouring dry-cleaning plant	1
…	…	…
	Total:	**7**

Table 49: Indicators for outdoor sources of indoor air pollutants in the DMS 'siting' (not conclusive) with 'Severity score' and ABC-classification

Next the single level 1 indoor air quality indicator is formed according to the table below:[330]

Indoor air quality	Definition
A (= 3 points)	sum≤ 2 *and* no score above 1
B (= 2 points)	sum≤ 4 *and* no score above 1
C (= 1 point)	sum≤ 6 *and* no score above 1

Table 50: Aggregation of the scientific measurements to a single indicator

The single level 2 indicator 'indoor climate' is obtained by iterating this process with the four level 1 indoor-climate indicators on

– thermal climate
– indoor air quality
– light and
– sound.

Project design

The decisions relevant for the indoor air quality of the building in the DMS 'project design' are the

– choice of materials (affecting the occurrence of volatile organic compound[331] emission, dust, house dust mites, fibres)
– choice of construction ('Can sources of pollution reach the indoor air?')
– choice of technical systems (ventilation, heating, cooling)
– design (location of sources of pollution and the ventilation system).

In this scenario the indicators from the indicator system 'Environmental assessment and classification of buildings' (Dinesen et al. 2001)[332] are used, which cover the above mentioned aspects. It employs the 'Indoor climate declaration of building materials' (Nielsen et al., 1993) as an indicator subsystem.

[330] Alternatively the Table 49 indicators could be aggregated analogously to the weighting approach used for the energy indicators: first a 'damage potential' could be calculated for each Table 49 indicator, than the numerical damage-potential values for each indicator could be added to *a single* figure, which then could be ABC-ranked by the use of benchmark values. This approach allows a more targeted weighting than the simpler 'severity scores' and the following aggregation according to Table 50.

[331] Abbreviated 'VOC' – the substances emitted from offgazing materials

[332] For a more detailed description see the chapter on 'Indicator systems'

Indoor air quality						
Indicator	Objective	Concretization	Reference building	Class C	Class B	Class A
Protection from outdoor pollution	To protect indoor air from outdoor pollution	measures to protect indoor air from the outdoor sources of pollution (see Table 49) are taken to the following extent:	meeting legal requirements	all measures taken to counteract sources of pollution with severity-score 3 1 points	all measures taken to counteract sources of pollution with severity-scores 3 & 2 2 points	built at location without outdoor pollution or all measures taken to counteract sources of pollution with severity-scores 3, 2 & 1 3 points
Offgasing	Reduction of emissions of VOC from building materials to indoor air	building materials with indoor climate label (or corresponding documentation) shall be used for indoor surfaces to the following extent:	meeting legal requirements	at least floor covering 1 points	all surfaces without consideration of time value[333] 2 points	all surfaces with lowest possible time value 3 points
Dust	Reduction of dust through choice of building materials, cleaning and maintenance	smooth, non-dirt hiding, easy-to-clean, non-toxic building materials, easily accessible surfaces	meeting legal requirements	easy-to-clean materials 1 point	easy-to-clean materials, few inaccessible surfaces 2 points	easy-to-clean, durable building materials that don't wear off, no inaccessible surfaces, no hazardous substances in covered building materials[334] 3 points
Ventilation	Ventilation shall be able to assure a good indoor air quality	easy to regulate, possibility for forced ventilation, windows that can be opened	meeting legal requirements	windows that can be opened 1 point	windows that can be opened, ventilation can be regulated 2 points	easy to regulate, possibility for forced ventilation, windows that can be opened 3 points
Moisture protection	Avoidance of moisture in construction, especially at inaccessible spots	constructions that can be inspected, no easily degradable materials in wet rooms, no hidden water pipe installations, pitched roofs with drainage and blanket course[335]	meeting legal requirements	constructions that can be inspected in the roof, wet rooms without easy degradable materials in walls and floor 1 point	constructions that can be inspected in the roof, wet rooms without easy degradable materials in walls and floor, no hidden pipe installations 2 points	constructions that can be inspected in the roof, wet rooms without organic materials in walls and floor, no hidden pipe installations, pitched roofs with drainage and blanket course 3 points
			Sum:	5 points	10 points	15 points
			overall level 1 indicator 'indoor air quality':	C: < 10 points	B: < 15 points	A: 15 points

Table 51: The indicators for indoor air quality. Based on (Dinesen et al. 2001)

333 The 'time value' is part of the 'Indoor climate declaration of building materials' and expresses how long it takes until the offgazing of the material in question has reached an *'acceptable indoor-climate relevant level'* (Nielsen et al., 1993)

334 e.g. fly ash containing heavy metals as additive to concrete (which can for instance be released when holes are drilled into walls).

335 A sealing layer to prevent capillary action

Aggregation to level 2

The single level 2 indicator ‘indoor climate’ is again obtained by using the A/B/C(3/2/1) rating system for the four level 1 indoor-climate indicators:

Level 1 indicator	Ranking
Thermal climate	e.g. A (= 3 points)
Indoor air quality	e.g. B (= 2 points)
Light	e.g. A (= 3 points)
Sound	e.g. C (= 1 point)
Sum	9 points

Table 52: The A/B/C(3/2/1) ranking of the four level 1 indoor climate indicators

Then the aggregation is again carried out according to Table 50.

Renovation

In contrast to the siting and the project design in the renovation phase, data is available on the actual performance of the building with regard to indoor air quality: on the one hand technical measurements can be carried out, on the other hand the users of the buildings can be interviewed to assess the occurrence of symptoms related to indoor air quality. These two sources of data form the basis for additional indicators that express the actual and the perceived indoor air quality of the building.

Perceived indoor air quality:

To assess the perceived indoor air quality the building’s users are asked whether they have been bothered by the factors

– stuffy ‘bad’ air
– dry air
– unpleasant odour
– dust and dirt

‘often’, ‘sometimes’ or ‘never’ during the last three month
and whether they have had the symptoms of

– fatigue
– headache
– eczema
– asthma
– irritated, stuffy or runny nose
– hoarse, dry throat
– cough
– Other: ……….

‘often’, ‘sometimes’ or ‘never’ during the last three month and do believe that they occurred due to the building’s indoor climate.[336]

Based on the responses the percentages of users with complaints are calculated[337].

[336] Based on the ‘Employee Questionnaire’ from (Valbjørn et al., 1990).

[337] Valbjørn et al. point out that *‘in every large group of people somebody is likely to be suffering from one of [the mentioned] symptoms’* and that *‘in practice it cannot be expected that less than 10-15% will complain of being bothered often (more than once a week).’* (Valbjørn et al., 1990).

Table 53: Indicators for perceived indoor air quality and perceived symptoms

	Complaints (in % of users)	ABC0☹☹-Quantification
Perceived indoor air quality:		Definition of four benchmark percentages, e.g. < 10%: A / 3 points[338] < 15%: 0 / 0 points > 30%: ☹ / -1 points > 50%: ☹ / -2 points
stuffy bad air		
dry air		
unpleasant odour		
dust and dirt		
Perceived symptoms:		
fatigue		
headache		
eczema		
asthma		
irritated, stuffy or runny nose		
hoarse, dry throat		
cough		
other: ……….		

To make these indicators compatible for aggregation four benchmark percentages are defined for each symptom. These benchmark-percentages can also 'contain' a ranking according to the severity of the symptoms: the more serious the symptom, the lower the benchmark percentage. These four benchmark-percentages correspond to A0☹☹/3,0,-1,-2 scores. The scores 'B' and 'C' do not exist in this category, reasoning that indoor air quality can either be very good (='A'), normal (='0': minor, but tolerable annoyances) or unsatisfying in different degrees (='☹☹') but not 'a little bit good' (='B' or 'C'). The different indicators in Table 53 are aggregated to a single indoor-air quality indicator according to the table below:

Table 54: Aggregation of the indicators for perceived indoor air quality and perceived symptoms to a single indicator for indoor-air quality.

Ranking	Definition
A / 3 points	arithmetic average of all indicators ≥ 1,5 *and* no score < 0
0 / 0 points	arithmetic average of all indicators ≥ 0 and < 1,5 *and* no score < 0
☹ / -1 points	arithmetic average of all indicators ≥ - 0,5 and < 0 *and* maximal 2 scores ≤ -1
☹ / -2 points	arithmetic average of all indicators ≥ - 1 and < -0,5 *and* maximal 2 scores < 0

These indicators in Table 53 indicate indoor air quality problems. To detect the causes of the perceived discomfort and to decide on remedial actions, however, in many cases the indicators may need to be supported with technical measurements. Technical measurements also permit the identification of pollution, which cannot directly be perceived with human senses such as the radioactive gas radon or ultra-fine particles, which may lead to symptoms only after long-term exposure.

[338] See the above footnote

Table 55: Scientific measurements of indoor air quality parameters

Indicators and measurements	Unit	ABC0☹☹-Quantification
air change rate	number/hour or l/sm[2]	Definition of four benchmark values for each measurement, corresponding to the A0☹☹/3,0,-1,-2 scores
CO_2 concentration (as an indicator gas for the concentration of human bio effluents)	parts per million (ppm)	
radon concentration	becquerel/m^3_{air}[339]	
concentrations of other problematic gases	parts per million (ppm)	
concentration of various problematic chemicals	µg/m^3_{air}	
concentration of ultra-fine & fine particles	number/cm^3_{air}	
concentration of coarse particles	mg/m^3_{air}	
odour annoyance	odour units (ou)	

The different measurements and indicators in Table 55 are aggregated to a single indoor air quality indicator analogously to the system sketched in Table 54. The results are two ranked indicators:

Table 56: Ranking of the indicators 'perceived indoor air quality' and 'measured indoor air quality'

Indicator	Ranking[340]
Perceived indoor air quality	B (2 points)
Measured indoor air quality	C (1 point)
Arithmetic average	1,5

As a rule, in this scenario indoor air quality is always assessed *both* with user questionnaires *and* with measurements. Measurements are necessary to detect pollution that is not sensually perceptible and questioning the users is necessary to trace pollution occurring irregularly or symptoms occurring due to specific combinations of indoor air pollution, for example with other indoor climate parameters.
Then both the 'indicator for perceived indoor air quality and perceived symptoms' and the 'indicators and measurements' are aggregated to a single indoor air quality indicator according to the table below:

Table 57: Aggregation of the indicators for perceived indoor air quality and perceived symptoms to a single indicator

Ranking	Definition
A / 3 points	arithmetic average of both indicators ≥ 2,5
0 / 0 points	arithmetic average of both indicators ≥ 0 and < 2.5 and no score < - 1
☹ / -1 points	arithmetic average of both indicators ≥ - 0,5 and < 0 and no score < - 1
☹ / -2 points	arithmetic average of both indicators ≥ - 1

After this ABC-ranking the level 1 indicators in Table 56 can be aggregated to the single indicator level 1 indicator 'indoor air quality' according to Table 58:

Table 58: aggregation to level 1 indicator 'indoor air quality' for the DMS 'project design'

Rank	Definition
A	all indoor air quality indicators have an A-score
B	all indoor air quality indicators have at least a B-score
C	all indoor air quality indicators have at least a C-score

[339] all air-volume units imply 25°C and atmospheric pressure
[340] Random scores

Discussion of the scenario

The fact that the indicators used in this scenario are based on state-of-the-art environmental science and indoor climate research ensures the quality of the indicators as what they originally were meant to be:

a reliable means of communicating the state of the complex system 'environment' in a simplified way.

Their three levels of aggregation permit a closure while maintaining a certain degree of interpretative flexibility. This has ambiguous implications.

On the one hand it can be the starting point of a continued learning process among all actors analogous to the one described in the layperson sensualist frame, where residents searched a more detailed explanation for their unexpected 'red/yellow/green-consumer' ranking, thus starting to learn about the lower levels of aggregation.

On the other hand, however, it means that there are three 'subgroups', each using mainly the indicators at the level of 'its' aggregation.

Reverting to the metaphor of *'EIFOB as a common language for green building'* used in the introduction of this study the first option would be a real development towards a 'common language' while the second option corresponds to a situation with greatly differing degrees of 'literacy' with regard to the indicator system as an entity: One party only utters the three sounds

'A', 'B' 'C'

the second party mumbles the six phrases

'Energy & related emissions
Water & wastewater
Material consumption & waste
Toxicity & hazardous substances
Local environment
Indoor climate'

and only the third party is capable of forming complete sentences in the language, so to speak – this is not a situation where all communicate easily in one shared language.

Nevertheless, compared to scenario 0, where there are no coherent linguistic elements shared by all four TFs, the situation in scenario 1 is a clear improvement. It does not allow all actors to communicate at the scientific level, but it does permit a functioning communication even though, which is comparable to a family on vacation in Italy ordering dishes in a restaurant:

The little child may say the single word 'Hunger!' to the childminding parent, who then addresses the other, Italian-speaking parent with 'The child is hungry, we should order some pasta with a lot of sauce!', whereupon the latter says to the waiter *'Prendo gli spaghetti napoli per il bimbo. Ci metti molto sugo, per piacere?'*[341]

The uneven distribution of environmental knowledge goes along with different 'degrees of indicator-literacy'. To allow a fruitful communication across the different technological frames (and the corresponding levels of aggregation) it is *not* necessary that the actors with less environmental knowledge speak the language of the actors with more knowledge but it is necessary that the actors with more knowledge are able to speak the language of the actors with less environmental knowledge. Thus, the 'common language' does not comprise all three levels of aggregation, but only the level understood *all* (including the group with the least environmental knowledge), that is level 3. The figure below illustrates this:

[341] *'I take the spaghetti napoli for the boy – with a lot of sauce, please!'*

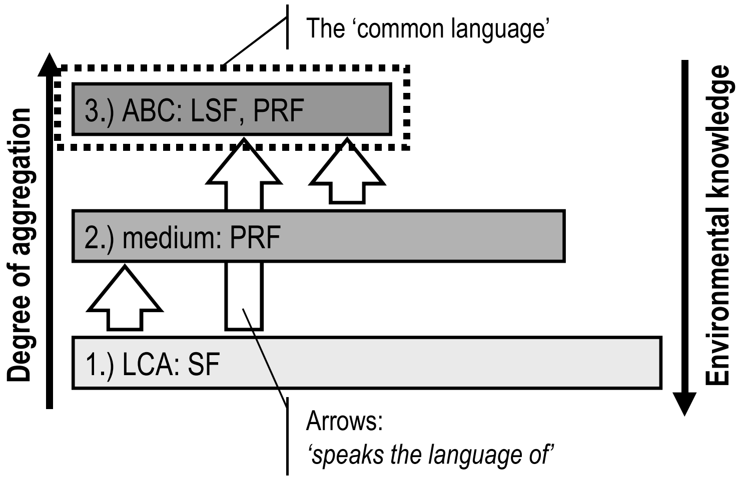

Figure 46: Levels of aggregation, environmental knowledge, and the 'common language' (the block arrows mean 'speaks the language of'

As *'indicators don't built houses'* the decisions taken on the basis of the indicators remains decisive. Much depends on to what extent the actors in the aesthetic-holistic frame, among them the majority of architects as core actors in the project design, accept and use the indicators, even though they are not mainly designed according to their demands. Here the 'translation' of the indicators into concrete means, for example in books displaying built examples[342], emphasis on the design freedom granted by LCA-based indicators and professional training may help to also integrate the aesthetic-holistic frame.

Scenario 2: 'Keep it simple'

General description

Also in the scenario 'Keep it simple' three of the four technological frames converge by agreeing on common indicators while the fourth reluctantly follows the 'economic gravitational force' exerted by the other three. However, compared to scenario 1 in this scenario the common EIFOB are 'located' at a different place in the socio-technological ensemble and the supporters and opponents of the EIFOB are other ones than in scenario 1 (Figure 47).

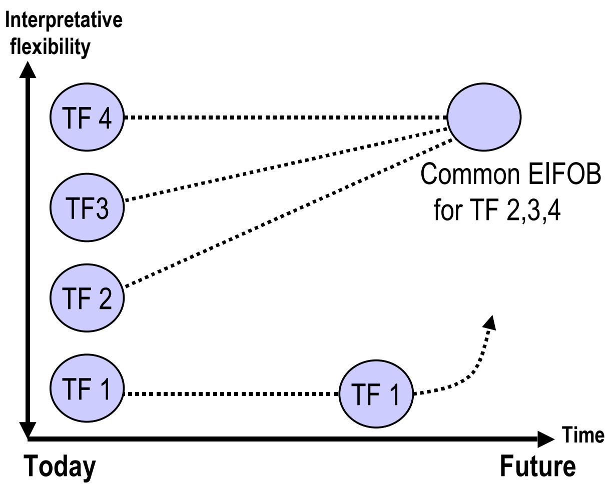

Figure 47: of the four technological frames three different ones than in scenario 1 converge by agreeing on common indicators, the fourth frame's dependencies force it to move towards the others.

[342] Such as (Marsh et al., 2000)

As Figure 48 illustrates, in the scenario ‘Keep it simple’ the key actors who reach an agreement on a common set of indicators are the actors in the public-relations frame, the layperson-sensualist frame and the aesthetic-holistic frame. Their indicators meet their common demand for indicators that are

– simple, easily understandable and communicable
– based on concrete measures
– operational (based on readily available data and easy to use) and

their inclination to avoid EIFOB that shed light on their environmental short-comings - accordingly the environmental scope of the indicators is narrower than in scenario 2: Induced transport is ignored, as none of the relevant social groups dominating in this scenario wanted the indicators to reflect this issue. Indicators are generally calculated *‘per m²’* as this draws a more positive picture of spacious offices and apartments than calculation *per person*.

The scientific frame is marginalised. The PRF, LSF and AHF actors reject the concept of life cycle assessment as too difficult to understand and to communicate and too cumbersome to use. They emphasise unsolved problems in the LCA-approach such as allocation questions, lack of data, and difficulties in handling indoor climate and siting aspects and have concluded that the SF’s approach may be suitable for research and scientific advice to selected projects with big budgets but is unsuitable for broadly used environmental indicators for buildings.

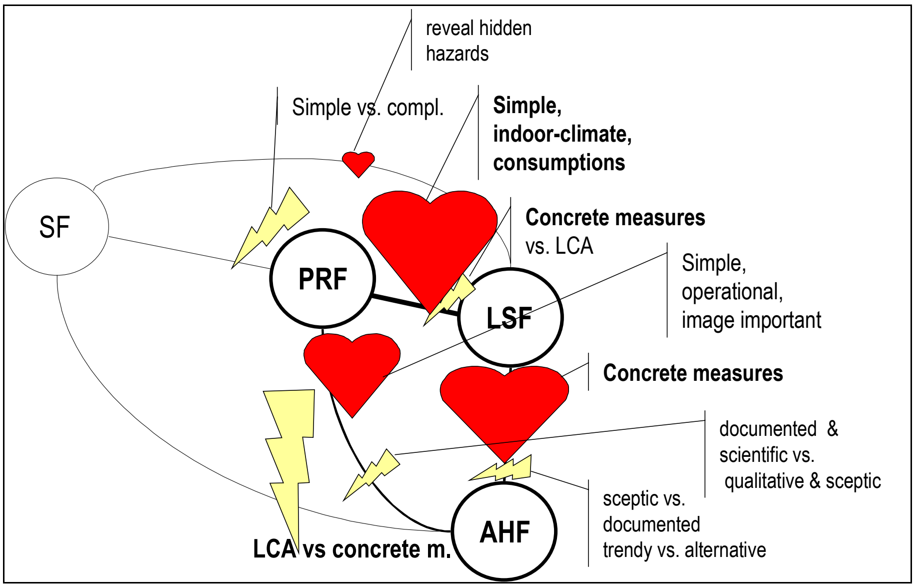

Figure 48: Illustration of scenario 2 ‘Keep it simple’: The public relations frame, the layperson sensualist frame and the aesthetic-holistic frame agree upon checklist indicators based on concrete measures that are very simple, operational and easily to communicate. The scientific frame is marginalised.

The agreement on common indicators by the other TFs has split the scientific frame: scientists of course oppose this kind of closure and criticise the indicators promoted by the other three TFs as misleading. They use their methods to point out the weaknesses of the ‘keep it simple indicators’. In an attempt to ‘prevent the worst’, experts in the SF try to add at least *some* scientific advice to this approach favoured by the other TFs. Many consulting engineers, however, have simply followed their clients’ demands and have quickly started to use the indicators in their work. Those architects who feel restricted in their design freedom by the concrete measure-based indicators, are campaigning for regular revision of the indicators’ content of concrete measures rather than for a shift towards an LCA-based system. Most architects support this concrete measure-based system because it lies within their field of competence.

The societal constellation:

A possible societal constellation fostering a ‘Keep it simple’ scenario can be parallel to the process that has led to the ‘National Packages Sustainable Building’[343] in the Netherlands:

There the umbrella organisation of contractors in the building sector took the initiative for the development of a national standard to harmonise the multitude of different environmental checklists at the municipality level. The result is a national checklist-indicator system. Though it is to be used voluntarily it has achieved further obduracy[344] by the fact that the Dutch Ministry for Housing supports its application in communications and uses it to formulate environmental standards as a precondition to receive public funding. The application of a certain number of checklist measures has also been taken as the basis for a national sustainability certificate. Most of the Dutch municipalities use them today in agreements with contractors, though in varying degrees. According to estimations the National Packages are presently applied in 75% of all new building projects. (van Bueren et al. 2000) (Dutch Ministry for Housing 2002)

Exemplifications

The ‘Keep it simple’ scenario also operates with indicators at three levels of aggregation. The most detailed of them, however, are not indicators in the scientific frame but mainly simple checklist indicators. Accordingly they are seen as a sub-level (‘level 1.1’) of the level 1 indicators, which address mainly the professionals in the aesthetic-holistic frame and the public relations frame, that is architects, professional clients and client consultants:

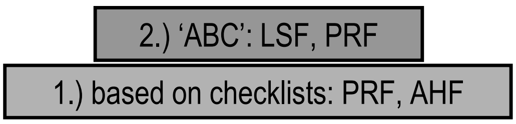

Figure 49: Two principal levels

Also in this scenario consistency is obtained by using the same or closely related indicators in all three decision-making situations.

The level 1.1 indicators are:

Table 59: The detailed indicators at level 1.1.

	Indicators at level 1.1	Ranking	Quantification
Energy	Renewable energy share	A / B / C	3 / 2 / 1
Energy	The building’s energy demand	A / B / C	3 / 2 / 1
Energy	Energy embodied in building materials	A / B / C	3 / 2 / 1
	…[345]		
Indoor climate:	indoor air quality	A / B / C	3 / 2 / 1
Indoor climate:	outdoor impact on indoor air quality[346] / site’s indoor air quality disposition	A / B / C / ☹	3 / 2 / 1 / -2
Indoor climate:	….[347]	A / B / C	3 / 2 / 1

[343] For a more detailed description see the chapter on ‘Indicator systems’

[344] For an explanation see the section on ‘The social construction of technology’ in the chapter ‘Research design’

[345] The level 1.1 indicators covering the other environmental issues (water & wastewater, material consumption + waste, etc.) are not mentioned in this exemplification.

[346] In the DMS ‘project design’ the aggregated indicator ‘outdoor impact’ is used (which comprises the two indicators ‘sites’s indoor air quality disposition’ and ‘protection from outdoor sources of pollution’, in the DMS ‘siting’ only the indicator ‘site’s indoor air quality disposition’ is used.

[347] ‘Indoor climate’ of course comprises more subjects (thermal climate, light, sound) to be covered by other indicators. These are, however, not within the scope of this exemplification.

As in scenario 1 the indicator scores ‘A,B,C’ generally signify:

Table 60: General significance of the A/B/C-indicator-scores

Indicator score	Points	Description
A	3	very much above standard (‘very good’)
B	2	significantly above standard (‘good’)
C	1	slightly above usual standard

The level 1.1 indicators in Table 59 are aggregated[348] to the level 1 indicators ‘Energy’ and ‘Indoor climate’[349]:

Table 61: The level 1 indicators

Indicators at level 1	**Ranking**	**Quantification**
Energy	A / B / C	3 / 2 / 1
Indoor climate	A / B / C	3 / 2 / 1

The level 1 indicators are aggregated to the next (and final) level (level 2) according to the table below:

Table 62: aggregation of the level 1 indicators to the single level 1 indicator

Rank	**Definition**
A	all level 1 indicators have an A-score
B	all level 1 indicators have at least a B-score
C	all level 1 indicators have at least a C-score

Level 2 comprises one single aggregated A/B/C indicator and addresses mainly the non-professional actors such as layperson clients, the broader public, professional decision-makers without a building-related education (politicians, management) and users of buildings.

Also in this scenario the different levels of aggregation are a way to reach closure by combining the two closure mechanisms

– diminishing interpretative flexibility by agreeing on constituting characteristics of the indicators (here: ‘simplicity & communicability’ and ‘based on ‘concrete measures’) and
– *intentionally maintaining a certain degree of interpretative flexibility*: the two levels of aggregation permit the interpretation of the indicators as ‘checklist-indicators based on concrete measures’ and as a ‘simple eco-labels that are easily communicable to laypersons’ at the same time, depending on which level of aggregation one looks at.[350]

Compared to the three-level system suggested in scenario 1, however, the interpretative margins of the indicators in this scenario are narrower than in scenario 1.

[348] The mode of aggregation is explained in details in further down in the text.
[349] The level 1 indicators cover the whole range of environmental issues as described in the chapter ‘Environmental effects of buildings’. This exemplification, however, only comprises the indicators for energy and indoor air quality.
[350] This closure mechanism has previously been described by Luxenburger and Asmussen in their SCOT analysis by of the newly build bicycle lane at one of Copenhagen’s major streets: ‘*The raised edge [of the pave stones used as demarcation, author’s note] between bicycle lanes and motor lanes illustrates the third kind of closure, which does not unify the interpretations of the actors: by introducing a raised edge, cycle lanes could be interpreted as both lanes* ***and*** *paths.’ (Luxenburger, Jan; Asmussen, Rune, 01)* (see also the section ‘Technology in the light of social constructivism’)

Exemplification 'energy'

Siting of the building

The energy indicators to be used in this DMS only cover the aspect 'Energy sources'. The aspects

– Energy embodied in material for infrastructure
– Induced transport and
– Energy management

are neglected.[351]

<u>Energy sources</u>

The indicators distinguish between

– non-renewable energy, comprising all fossil fuels
– renewable energy, comprising solar energy, wind energy, geothermal energy, hydro energy, and energy from biomass. Energy from waste incineration is only considered as 50% renewable, because it is also fuelled with non-renewable resources.

The main energy-indicator for the building's siting phase at the first level of aggregation is the share of renewable energy of the building's energy supply:

Table 63: level 1.1 indicator 'Percentage of renewable energy'

Indicator
% of renewable energy of the building's energy supply

To make it compatible with the A/B/C-indicator system it is combined with benchmark-values and a point-evaluation system:

Table 64: Transformation of the level 1.1 indicator 'renewable energy share' into an A/B/C-indicator

Indicator: 'A/B/C'	A	B	C
Renewable energy share	≥90%	≥50%	≥25%
Points	3	2	1

Project design

<u>Energy:</u>

In the DMS 'project design' the indicators reflect two aspect two aspects of energy consumption:

1. Energy consumption in the use phase
2. Energy consumption for production and transport of the building materials

<u>1. Energy consumption in the use phase</u>

At the first level of aggregation the main energy indicator is the building's anticipated energy consumption in the use phase, based on the calculations that need to be carried out in any case to document that the building meets the energy requirements of the Building code[352]:

351 The aspect 'settlement layout' is again implicitly contained in the aspect 'induced transport'.

352 For details see the section 'The Danish building legislation' in the chapter 'Decision-making situations'.

Table 65: Indicator 'The building's anticipated energy consumption'

Indicator	Unit
the building's anticipated energy consumption for heating and electricity[353] (based on energy demand calculations for the specific building)	kWh/(m^2 x year) or kWh/$m^2_{\text{entire life span}}$

To reach the second level of aggregation this indicator is combined with benchmark-values and a point-evaluation system. For different building categories (schools, office buildings, different kinds of residential houses) reference buildings may be defined:

Table 66: Aggregation of the level 1 indicator 'Anticipated energy consumption for heating and electricty' to the level 2 indicator 'A/B/C'

Indicator: 'A/B/C'	**Reference building**	**A**	**B**	**C**
Anticipated energy consumption for heating and electricity[354]	just meets the Building code demands	≤ 50% of legal demands	≤ 65% of legal demands	≤ 80% of legal demand
Points		3	2	1

Of course, the indicator 'percentage of renewable energy of the building's energy supply' as introduced in the section on the siting of the building is also valid in DMS 'project design'.

<u>2. Energy consumption for production and transport of the building materials</u>
The energy embodied in the building materials is reflected by

– an A/B/C/☹[355]-ranking of building materials according to a rough estimate of energy needed for production (along with other simple, mainly qualitative criteria, such as *natural material, from certified organic production, recyclable / reusable,….'*.
– The indicator 'Percentage of A-rated building materials in major building element components', which uses the A/B/C/☹-ranking of building materials as a subsystem.

The A/B/C/☹-ranking list of common building materials is structured by building elements. A brief explanation gives the reasons for the ranking of each material.

[353] By including the energy consumption for electricity I anticipate the revision of Danish Building code by 2006 according to the EU Directive 2002/91 (for details see the section 'Ongoing European developments' in the chapter 'Decision-making situations')
[354] By including the energy consumption for electricity I anticipate the revision of Danish Building code by 2006 according to the EU Directive 2002/91 (for details see the section 'Ongoing European developments' in the chapter 'Decision-making situations')
[355] '☹' indicates an unfavourable profile.

Table 67: A/B/C/☹-ranking of building materials as a subsystem for the embedded-energy (non-conclusive list)

building element	material	rank	explanation
facades & bearing structure	Scandinavian wood	A	explains the reasons for the material's ranking
	unfired clay	A	
	wood from overseas	B	
	concrete with at least X% content recycled material	C	
	brick	C	
	….		
windows	Scandinavian wood	A	
	wood from overseas	B	
	recycled aluminium	C	
	PVC	C	
	new aluminium	☹	
	…		
roof	…		
floors			
….			
	….		

The indicator 'Percentage of A-rated building materials in major building element components' uses the A/B/C/☹-ranking of building materials as a subsystem:

Table 68: Indicator 'building materials', including criteria 'embodied energy'

Indicator: 'A/B/C'	A	B	C
Percentage of A-rated building materials in major building element components	≥90% of the major building element components have an 'A' rating[356]	≥60% of the major building element components have an 'A' rating	≥30% of the major building element components have an 'A' rating
Points	3	2	1

All the three level 1.1 indicators

- 'renewable energy share',
- 'The building's anticipated energy consumption' and
- 'building materials'

are aggregated in a single energy indicator in the same way as in Table 69:

Table 69: aggregation to level 1 indicator 'energy' for the DMS 'project design'

Rank	Definition
A	all three indicators have an A-score
B	all three indicators have at least a B-score
C	all three indicators have at least a C-score

Exemplification 'Indoor air quality'

Siting

In the DMS 'siting' outdoor sources of indoor air pollution are reflected by a series of simple indicators:

[356] Inspired by the BREEAM indicators (see chapter 'Indicator systems')

Table 70: simple indicators for outdoor sources of indoor air pollution (not a conclusive list)

source of fresh air / source of pollution	**A (3 points)**	**B (2 points)**	**C (1 point)**	**☹ (- 2 points)**
sea shore	≤ 100m away	≤ 300m away	≤ 500m away	
forest / big park	≤ 100m away	≤ 300m away	≤ 500m away	
main road with four or more lanes	≥ 500m away	≥ 300m away	≥ 100m away	≤ 50m away
main road with two lanes	≥ 100m away	≥ 60m away	≥ 30m away	≤ 10m away
dry-cleaning plant				≤ 20m away
source of odour annoyance (e.g. waste water treatment plant, pig farm,…)	≥ 2500m away	≥ 2000m away	≥ 1500m away	≤ 1000m away
radon: % of the municipality's detached houses having an indoor radon concentration over 200 Bq/m^2 [357]	≤ 0.3%	≤ 1%	≤ 3%	≥ 4%
…	…	…	…	…

These indicators can be aggregated on the basis of the arithmetic average[358] of the point scores achieved in Table 70 (where for each 'A' achieved three points are given, for each 'B' two, for each 'C' one, for each '☹' minus 2 and so on):

Table 71: aggregation to the indicator 'site's indoor air quality disposition'

	A (3 points)	**B (2 points)**	**C (1 point)**	**☹ (- 2 points)**
arithmetic average of the point scores achieved in Table 70	≥ 2,3	≥ 1,3	≥ 1,3	≤ 0

Thus, the location's disposition with regard to the indoor air quality of the building to be sited there can be expressed at level 2 with the general ABC☹-scores:

Table 72: The general ABC☹-scores expressing the location's indoor air quality disposition

Indoor air quality disposition of the location		
Indicator score	Points	Description
A	3	very much above standard ('very good')
B	2	significantly above standard ('good')
C	1	slightly above usual standard
☹	-2	environmentally especially problematic ('bad')

Project design

To describe the indoor-air quality of buildings' in the DMS 'project design' simple checklist indicators are used. These indicators are based on lists of

[357] Data easily available on maps.

[358] = the added values of all the scores achieved divided by the number of scores

'good' materials and 'good' measures. Measures and materials on these lists are ranked according to the A/B/C-system (corresponding to 3 to 1 points).

Table 73: Indicators for indoor-air quality

Indicator	Yes[359]	Concrete measure	Points	Sum[360]
Protection from outdoor pollution	✔	Removal of contaminated soil	3	
	✔	Filtering of outdoor air intake	3	
	✔	sealing of walls to neighbouring dry-cleaning plant	3	
		windows facing towards sources of pollution ≤ 40m away cannot be opened without key	2	
		…	2	
		….	1	
Offgazing	✔	all surfaces covered with one of these materials[361]: linoleum, tiles, wood, …	3	3
		floor covered with one of these materials[362]: linoleum, ceramic tiles, wood, …	2	
			1	
Dust	✔	all surfaces covered with one of these materials[363]: linoleum, tiles, wood, …	3	6
		floor covered with one of these materials[364]: linoleum, tiles, wood, …	2	
	✔	no inaccessible surfaces	3	
		few inaccessible surfaces	2	
Ventilation	✔	natural cross ventilation possible	3	9
	✔	windows can be opened	3	
		forced mechanical ventilation possible	3	
	✔	special provisions in place to remove pollution from indoor sources (e.g. extractor fans over hot plates in kitchens/ printers & copy machines)	3	
Moisture protection	✔	pitched roofs with drainage and blanket course	3	9
		no hidden pipe installations	3	
	✔	wet rooms without organic materials in walls and floor	3	
	✔	roof construction can be inspected	3	

[359] Checks, if the measure is applied. If it is, its ranking points are counted in the 'sum' column.
[360] For the indicator 'protection from outdoor pollution' the sum is irrelevant: (see Table 74)
[361] Supplemented with a list of materials with indoor climate label (or corresponding documentation)
[362] Supplemented with a list of materials with indoor climate label (or corresponding documentation)
[363] Supplemented with a list of easy-to-clean materials
[364] Supplemented with a list of easy-to-clean materials

The indicator 'protection from outdoor sources of pollution' of course needs to be seen in connection with the indicator 'site's indoor air quality disposition'. Therefore both are aggregated to the single indicator 'outdoor impact' according to the table below:

Table 74: aggregation of the indicators 'site's indoor air quality disposition' and 'protection from outdoor sources of pollution' into the indicator 'outdoor impact'

ranking	Definition
A (= 3 points)	'site's indoor air quality disposition' = 'A', no protective measures necessary or 'site's indoor air quality disposition' = 'B' and all relevant protective 3-point, 2-point and 1-point measures taken
B (= 2 points)	'site's indoor air quality disposition' = 'B', and all relevant 3-point and 2-point protective measures taken
C (= 1 point)	'site's indoor air quality disposition' = 'B' and all relevant 3-point protective measures taken
☹ (= -2 points)	'site's indoor air quality disposition' ≤ B and not all relevant 3-point protective measures taken

All Table 73 indicators for indoor air quality are ranked according to the table below:

Table 75: ranking of the indoor air quality indicators

Indicator	**A (= 3 points)**	**B (=2 points)**	**C (=1 point)**
Outdoor impact		- according to Table 74 -	
Offgazing	sum=3	sum=2	sum=1
Dust	sum=6	sum=5	sum=4
Ventilation	sum=12	sum=9	sum=6
Moisture protection	sum=12	sum=9	sum=6

After this ABC-ranking the level 1.1 indicators in Table 75 can be aggregated to the single indicator 'indoor air quality' analogue to Table 69:

Table 76: aggregation to level 1.1 indicator 'indoor air quality' for the DMS 'project design'

Rank	**Definition**
A	all four indoor air quality indicators *and* the indicator 'outdoor impact' have an A-score
B	all four indoor air quality indicators *and* the indicator 'outdoor impact' have at least a B-score
C	all four indoor air quality indicators *and* the indicator 'outdoor impact' have at least a C-score

Renovation

Like the scenario 'Science goes public' in the DMS 'renovation' this scenario, too, takes advantage of the fact that in the renovation phase, data on the building's actual indoor-air performance is available. The indicators used in addition to the indicators from the other decision-making situations, however, only use questionnaire-investigations with users of the buildings' as a source of information and not technical measurements.

<u>Perceived indoor air quality:</u>

To assess the perceived indoor air quality the building's users are asked (as in the scenario 'Science goes public') whether they have been bothered by the factors

– stuffy 'bad' air
– dry air
– unpleasant odour
– dust and dirt

‘often’, ‘sometimes’ or ‘never’ during the last three month and whether they have had the symptoms

- fatigue
- headache
- eczema
- asthma
- irritated, stuffy or runny nose
- hoarse, dry throat
- cough
- Other: ……….

‘often’, ‘sometimes’ or ‘never’ during the last three month and do believe that is due to the building’s indoor climate.[365]

Based on the responses the percentages of users with complaints are calculated[366] and quantified according to the ABC☹ ranking

Table 77: Indicators for perceived indoor air quality and perceived symptoms

	Complaints (in % of users)	A0☹-Quantification
Perceived indoor air quality:		Definition of four benchmark percentages, e.g. < 10%: A / 3 points[367] < 15%: 0 / 0 points > 50%: ☹ / -2 points
stuffy bad air		
dry air		
unpleasant odour		
dust and dirt		
Perceived symptoms:		
fatigue		
headache		
eczema		
asthma		
irritated, stuffy or runny nose		
hoarse, dry throat		
cough		
other: ……….		

These indicators indicate the existence or absence of indoor air quality problems.

To make these indicators compatible for aggregation, four benchmarks percentages are defined for each symptom. These benchmark-percentages can also ‘contain’ a ranking according to the severity of the symptoms: the more serious the symptom, the lower the benchmark percentage. These four benchmark-percentages correspond to A0☹/3,0,-2 scores. The scores ‘B’ and ‘C’ do not exist in this category, reasoning that indoor air quality can either be very good (=’A’), normal (=’0’: minor, but tolerable annoyances) or unsatisfying in different degrees (=’☹’) but not ‘a little bit good’ (=’B’ or ‘C’).

[365] Based on the ‘Employee Questionnaire’ from (Valbjørn et al., 1990).
[366] Valbjørn et al. point out that *‘in every large group of people somebody is likely to be suffering from one of [the mentioned] symptoms’* and that *‘in practice it cannot be expected that less than 10-15% will complain of being bothered often (more than once a week).’* (Valbjørn et al., 1990)
[367] See the above footnote

The different indicators in Table 77 are aggregated to a single indoor-air quality indicator according to the table below:

Table 78: Aggregation of the indicators for perceived indoor air quality and perceived symptoms to a single level 1.1. indicator 'perceived indoor air quality'

Ranking	Definition
A / 3 points	arithmetic average of all indicators ≥ 1,5 *and* no score < 0
0 / 0 points	arithmetic average of all indicators ≥ 0 and < 1,5 *and* no score < 0
☹ / -2 points	arithmetic average of all indicators ≥ - 1 and < -0,5 *and* maximal 2 scores < 0

This level 1.1 indicator 'perceived indoor air quality' supplements the indicator 'indoor air quality' from the DMS 'project design' (see Table 73). The human perception is seen as a holistic indicator, which even can point out indoor air problems that may have escaped the attention of the checklist-evaluation according to Table 73. When decisions about concrete measures are taken in the renovation phase, however, the decision-making situation 'renovation' resembles in many respects the DMS 'project design' and the checklist indicators in Table 73 are employed accordingly.

Both indicators are integrated into the A/B/C-aggregation system analogously to Table 76.

Also in this scenario, supplementary technical measurements of the indoor air quality are used to detect causes of perceived discomfort, to decide on remedial actions and to identify pollution which cannot directly be perceived with human senses. These measurements are, however, not an element of the indicator set.

Discussion of the scenario

The main differences between the indicators suggested in the scenario 'science goes public' and the scenario 'keep it simple' are that the latter

- make no use of LCA
- do not aggregate by weighting but treat all indicators equally in the benchmark aggregation
- have a narrower environmental scope: the aspects 'energy embodied in materials for infrastructure', 'induced transport' and 'energy management' are neglected
- calculate indicators *per* m^2 instead of *per person*
- do not base their indicators for indoor air quality on technical measurements.

These characteristics have different implications:

The unambiguous recommendation of building materials as 'good' in checklists assigns a large share of responsibility to those who issue these lists. If they take their task seriously they will soon be confronted with cases in which environmental gains in one respect have to be 'paid for' with environmental disadvantages in another respect, making unambiguous recommendations very difficult, especially when scientific expertise is not to be relied upon. This weak point of scenario 2 could be an entry point for actors from the scientific frame, who could provide life cycle assessments as a basis for the ABC☹-ranking of the building materials.[368] But even if this was the case, the complexity of the system 'environment' would still be *'hidden from the indicator users behind the checklist-curtain'*, so to speak. The explanations contained in the checklists offer a bit more insight. But nevertheless this indicator system is more likely to promote and consolidate 'rough' environmental knowledge of the *'X is good, Y is bad'* kind than to foster an in-depth learning process about environmental interdependencies among the non-SF actors.

[368] BREEAM uses this solution (with LCA as a subsystem).

The absence of a weighting system makes it difficult to identify a project's environmental hot spots and provokes an even distribution of effort rather than a concentration on key areas. The calculation *per* m^2 can 'greenwash' high levels of consumption *per person*.

The narrow environmental scope bears the danger of giving green labels to projects that, seen in a broader context, do more harm than good. The exclusion of the environmental aspect of 'induced transport' results in decisions that are blind to a major source of pollution and resource consumption.

If environmental indicators for buildings are to picture a building's environmental performance then the scenario 2 indicators can be said to show a somewhat unfocused picture with a low resolution. For 'newcomers' this may be satisfying and better than the fragmented ad-hoc descriptions they may have been used to, but to those familiar with the state of the art it clearly is far from what is possible.

Considering the obduracy a closure obtains once a closure solution is well established the weaknesses of the 'keep it simple'-indicators can be an environmentally problematic legacy, establishing 'indicators' that in extreme cases may indicate *'a giant leap forward for global environment!'* when seen from the moon the project may at best be *'one small step for indoor climate'*.

For the actors left outside in the scientific frame the scenario leaves a possibility 'to sneak in through the backdoor':

Firstly a scientific review of the checklists could increase the environmental scientific justifiability of the measures recommended and the ranking of the measures. Secondly the simplifying ABC-ranking could be replaced by a weighting system that reflects the environmental significance of the different alternatives more precisely.

Finally the environmental aspect 'induced transport' could be included in a 'keep it simple' version, using the level 1.1 indicators suggested in the table below:

Table 79: Indicators for induced transport[369]

	Points	Definition
A	3	good access to public transport within 500 m and at least a 30 min frequency to a local urban centre + settlement layout (car parking not directly at the building, car-free zones, bicycle shelters) favouring the use of environmentally friendly transport (walking, cycling, public transport)
B	2	urban conurbation location with typical public transport connections
C	1	small town location with typical public transport connections
☹	-2	rural location with typical public transport connections

The three scenarios,

– scenario 0 'Postmodern Relations',
– scenarios 1 'Science goes public' and
– scenario 2 'Keep it simple'

sketch three possible future developments of environmental indicators for buildings. The following chapter summarises the findings of this study, draws conclusions with regard to the research questions and puts the scenarios into the context of these conclusions.

[369] Inspired by the BREEAM indicators (see chapter 'Indicator systems')

Summary and conclusions

Now it is time to return to the research questions posed in the introduction. The objective of this study was to explore

- *if (and to what extent) consensus on environmental indicators for buildings as 'a common language for green building' can be reached in the near future among the core actors local building authorities, professional clients, client consultants, project designers, administrators of buildings and developers of environmental indicators for buildings and*
- *what environmental indicators for buildings that are acceptable as 'a common language for green building' for the relevant actor groups could look like.*

To answer these questions, the results from the separate research tasks are recapitulated. Core results and core conclusions drawn from the results are displayed in separate tables for better readability.

Results from the research task in the environmental scientific sphere

The separate research tasks that have been investigated in the different chapters of this thesis to answer the overall research questions revealed the following results:

Environmental effects of buildings and environmental relevance of the decision-making situations

The investigation of the *environmental effects of buildings* and of the three *decision-making situation*s,[370] based on a literature survey and the qualitative interviews with the representatives of the different actor groups, showed that buildings contribute to a broad spectrum of environmental effects. From the environmental scientific point of view it is therefore not justifiable to use, for example, 'energy consumption' as a representative indicator for a building's total environmental performance. All phases of a building's life cycle are environmentally relevant. Indicators should therefore cover all life cycle phases of a building.

The description of the three *decision-making situations* in the scope of this study[371]

- siting of the building
- project design and
- renovation

illustrated that all three are environmentally relevant but differ with regard to the environmental 'hot spots' and the actors, who play a prominent role:

In the siting the local building authorities and the clients determine the infrastructural embedding of the building (including decisive parameters for induced transport) and the framework for the project design (with regard to height, land use, orientation, etc.).

In the project design architects (as the overall project designers) and clients are the main actors. They make the step of responding to the *potentials*

[370] For details see the respective chapters (*'environmental effects of buildings'* and *'decision-making situation*s*'*)

[371] On the demarcations of the study see the chapter 'Introduction'

of the location with a concrete project, determining the material consumption, the use of hazardous substances and the potential performance in the use phase, especially with regard to consumptions and indoor climate.

In the renovation the clients (as the owners of the building), the administrators and the project designers determine the focal points of the renovation. Their decisions are crucial for the building's future performance with regard to consumptions in the use phase, indoor climate, material consumption and waste generation and with regard to the possible use of hazardous substances.

Consultants are principally involved in all three decision-making situations, consulting clients and other actors.

Data availability increases from the siting to the renovation as more building-specific data become available in addition to statistical average data. However, many environmentally relevant data are only available after additional efforts.

The fact that all three are decision-making situations are environmentally relevant but differ with regard to the environmental 'hot spots' and the actors, who play a prominent role confirms that indicators have to be consistent across the different decision-making situations and agreed upon by the different actors involved if they shall permit an effective communication of environmental aspects throughout the investigated part of a building's life cycle.

Parallel existence of different indicator approaches

The mapping of existing indicator systems, based mainly on literature studies, supplemented with some interviews with indicator developers, showed that indicators differ significantly with regard to several respects.
They employ three different indicator principles:

- life cycle assessment (LCA),
- checklists indicators and
- input-output indicators,

which each 'take the environmental pulse' at other points in a building's life cycle, using different indicators and units. The indicator systems also have different scopes with regard to the covered environmental issues (were 'indoor climate' has least coverage while 'energy and related emissions' are covered by all systems) and the addressed decision-making situations (where the siting has least coverage). With regard to their target groups only one indicator system addresses all actors while the other systems focus on selected actor groups.

The studied indicator systems overlap with regard to their scopes. As some use different indicator principles for identical matters without harmonisation this co-existences can cause contradictions and hinder unambiguous communication. The two checklist systems, however, integrate LCA-systems as sub-systems in their coverage of building materials, thus partly mediating the differences between the checklist approach and the LCA-approach.

On the one hand these findings underlined the study's initial statement that a set of indicators, which can serve as 'a common language for green building' for a broad range of actors and decision-making situations, does not yet exist. On the other hand they showed that a variety of 'local dialects for green building' are spoken, which constitute a rich source of inspiration for the development of EIFOB with a broader scope.

EIFOB in a social constructivist perspective

After this mapping of environmental effects of buildings, decision-making situations and existing indicator systems *from an environmental scientific point of view* the study left this specific viewpoint and looked at EIFOB in a broader, social constructivist perspective, in which EIFOB were seen as a socially constructed artefacts in a socio-technological ensemble.[372]

The chapter *'Indicators in a social constructivist perspective'* displayed the observations from the investigation of the actor's views on environmental indicators for buildings. This investigation consisted of qualitative, pre-structured interviews supported by literature studies, and facilitated workshops, in which representatives of the different actor groups gave feedback on my analysis and discussion of the interview results. The analysis was carried out according to Wiebe Bijker's theory of the social construction of technology (SCOT) (Bijker, 1995).[373] The chapter contained two parts:

– A description of the actors' roles, educational backgrounds and the power structures among them, and
– a description of four technological frames.

Relevance of the actors' educational backgrounds, present roles & occupations and power structures

The description of the actors' roles and educational backgrounds showed that

– the actors' educational backgrounds and present professional roles and
– power structures and economic dependencies

have a strong influence on the different actors' appreciation of different indicator approaches:

An engineering or a technical education usually gives actors proximity to quantitative indicators based on measurements and calculations. It also makes it easier for them to understand indicator values displayed in diagrams and unfamiliar units.

An architectural education usually goes along with a focus on implicit qualitative indicators and a generally sceptical view on explicit quantitative indicators.

Actors with a degree in economics (typically actors in the management of private enterprises or co-operative housing societies, acting as professional clients) are familiar with the concept of quantitative indicators, but (as laypersons with regard to the *technical* aspects of building) prefer simple and easily understandable indicators.

Layperson users of buildings (for example residents) often relate mainly emotionally and with sensual perception to the building, using implicit qualitative indicators. Scientific, quantitative indicators other than input-output-indicators measuring consumptions in the use phase are unfamiliar to them.

Concerning the influence of power structures and economic dependencies it became clear that for architects and engineers the EIFOB debate is connected with the struggle for the semiotic power to define 'the environmentally sound building' and claims to shares in the marked for green building. In this struggle engineers have been proactive and are now ahead of architects. Clients can promote the use of EIFOB of their choice among actors that economically depend on them (for example architects) even though these are reluctant to use indicators. Also consultants and indicator developers are influenced by economic dependencies and in their work react to the demands of those who finance their work.

These findings led to the following core conclusion:

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[372] See a detailed explanation of the concept 'socio-technological ensemble' in the section 'The social construction of technology (SCOT)' of the chapter 'Research design'

[373] A detailed explanation of the SCOT-theory can be found ibid.

The shape of EIFOB is only *one factor among others* that influences the different actors' views on EIFOB. Other important factors are

the actors' educational background and

power structures and economic dependencies

(A third relevant factor are *present roles and occupations*, as the description of the four technological frames revealed (see the paragraph further below).

This renders unlikely the perspective that a consensus about EIFOB can by reached if only EIFOB are given 'the right' shape and points towards looking for solutions also in the social sphere.

Four technological frames

The SCOT-analysis of the actors' views on environmental indicators for buildings revealed four different technological frames (TFs)[374]:

– The public-relations frame (PRF),
– the scientific frame (SF),
– the aesthetic-holistic frame (AHF) and
– the layperson-sensualist frame (LSF).

Each frame comprises typical actors, goals, views on EIFOB, environmental foci and demands to EIFOB:

[374] See a detailed explanation of the concept 'technological frame' ibid.

Table 80: Overview over the public-relations frame (PRF) and the scientific frame (SF)

	Overview over the public-relations frame (PRF)	**Overview over the scientific frame (SF)**
Typical actors	professional clients, administrators	scientific indicator developers, consultants with an engineering background
Main goal	to obtain a favourable public image	to sell natural-scientific and technical expertise to evaluate buildings *scientifically* and precisely to provide scientific knowledge for decision makers to ensure that efforts made actually lead to environmental improvements
View of EIFOB	a means of documenting and communicating one's environmental responsibility to the target groups (employees, customers, …) a means for quality assurance and risk-management to prevent environmental accidents and scandals a means of keeping consumption-related life-cycle costs down	quantitative, scientific EIFOB as the only reliable navigation tool to environmentally advantageous decisions (which yet needs to be adopted by the market)
Environmental focus	indoor climate (costly) consumptions in the use phase *not* lifestyle-related aspects (such as transport) – in public relations inclination to avoid EIFOB that shed light on one's environmental shortcomings	regional and global environmental aspects (*'there and later'*), e.g., global climate change ozone depletion & photochemical ozone formation toxicity but also waste & resource consumption Indoor climate: air quality, thermal indoor climate, light, noise Not yet operational, but considered relevant: land use, including biodiversity and impact on local ground water formation
Demands to EIFOB	communicable to the target groups simple, not many, based on familiar units (e.g. monetary units, kWh, kg, litres) aggregatable to a single qualitative indicator well-documented trustworthy operational (cost-efficient & based on easily available data) linked to economic implications	scientifically justifiable precise & quantitative (to achieve comparability) transparent and well-documented consistent (different users should obtain consistent results) cover the entire life cycle of a building

Table 81: Overview over the aesthetic-holistic frame (AHF) and the layperson-sensualist frame (LSF

	Overview over the aesthetic-holistic frame (AHF)	**Overview over the layperson-sensualist frame (LSF)**
Typical actors	architects	non-professional private clients and users of buildings
Main goal	to secure space for creativity and innovative design / to avoid design restrictions to defend their position as competent generalists acceptance of the aesthetic-holistic paradigm (in opposition to the rationalist paradigm) to avoid additional loads of boring, badly paid work to have their design priorities confirmed	(in ecological settlement projects:) to create an identity and a social coherence among the residents of a settlement by giving the settlement a 'sustainable' or 'ecological' identity (qualitative EIFOB as a 'brand' or a 'lifestyle-label') acceptance of the sensualist frame (in opposition to the rationalist scientific frame) recognition of one's own critical view with of mainstream society and technology recognition of one's own judgement (in opposition to expert-evaluations) physical perceptibility of the effects of one's environmental efforts and behaviour
View of EIFOB	Some questioned the meaningfulness of EIFOB. Indicators were seen as a threefold threat: 1. a threat to the architects' competence and power to define 'ecological building' 2. a threat to design freedom 3. a potential additional workload outside the RSG's field of competence.	used to operate with implicit qualitative indicators (implicit) qualitative indicators as a 'brand' or 'lifestyle label' for the settlement the concept of quantitative explicit EIFOB is unfamiliar & usually no relevant category an ambivalent view: 1) EIBOB as a tool useful for consulting experts, incomprehensible for laypersons 2.) EIFOB are irritating and not always trustworthy as they question one's pet solutions and one's judgements
Environmental focus	Three characteristic points: 1. No clearly defined notions. Environment mixed with general functional and aesthetical aspects 2. this was presented as the capacity to see things *'holistically'*, in opposition to the 'unduly fragmented' view attributed to engineers 3. focus on 'local' environmental aspects *here and now* (indoor climate & health, aesthetical quality, psychological environment, …) general acceptance, that global warming and resource consumption are relevant	local environmental issues (*'here and now'*): concrete measures and principles that are perceivable, have a symbolic significance & appeal to visions of an ecological home and lifestyle indoor climate circulation systems (e.g. for organic waste)
Demands to EIFOB	shall support the decisions to be taken by the actors, ergo indicators on the level of concrete measures and principles are easy to use and don't require much work of the kind, the actors usually do not like don't restrict creativity and design freedom are within their field of competence are preferably qualitative, not quantitative	easily understandable preferably qualitative, not quantitative trustworthy on the level of concrete measures or even above (aggregated to a single qualitative indicator) support the process of prioritising measures and principles in the planning phase address environmental concerns close to the actors' life world

With regard to the actors' *professional roles and occupations* the identification of the four technological frames revealed that these, too (apart from the actors educational background and the power structures), influence the actors' view on EIFOB:

In general actors (disregarding their own educational background) had a tendency to adopt their clientele's demands to indicators:

Actors with a technical education, who work in co-operative housing societies, private enterprises or municipalities, demand indicators that are communicable to their layperson target group and relate to the environmental focal points of these groups (residents, pupils, customers,…).

A consultant for architectural offices, having an architectural education and being involved in several research projects with indicator developers at the Danish Building and Urban Research Institute, acknowledges the engineering- and environmental scientific indicator approaches and at the same time tries to 'translate' these into a language understandable to architects.

The lines of conflict and areas of consensus emerging from the different technological frames' demands to EIFOB were the subject of the chapter 'Discussion':

Lines of conflict and areas of consensus

The different frame-specific demands to EIFOB create specific lines of conflict and areas of consensus between the technological frames, which were analysed and described in the chapter *'Discussion'*.
The *conflict lines* were

transparent, well-documented, consistent EIFOB (PRF, SF)	versus	vague ad hoc indicators (AHF, LSF)
Simple & easily understandable (PRF, LSF, AHF)	versus	scientifically justifiable and sufficiently detailed to reflect the complexity of the subject (SF)
qualitative checklist-indicators based on concrete measures and principles (AHF, LSF)	versus	quantitative LCA-based indicators (SF)
Based on units familiar to the public (PRF, LSF)	versus	using units familiar to scientists (as an element of the LCA-approach) (SF)
inclusion of transport induced in the building's use phase into the scope of EIFOB (SF)	versus	not regarding it. (the ambivalent (PRF) and negative LSF)
environment should be considered together with aesthet-ics (AHF)	versus	aesthetics should not be considered together with environment (SF)

In general, the concept of transparent, well-documented, consistent EIFOB, supported by the SF and the PRF, is seen with some scepticism by actors in the AHF who worry that EIFOB could restrict design freedom and their power to define 'the ecological building'.

The 'simplicity versus complexity' conflict originates from the fact that the PRF, AHF and LSF share the demand for EIFOB that are simple, easy to use and easy to understand while the SF's first priority is that EIFOB mirror the complex and manifold interrelations between a building and the environment in a scientifically justifiable way. Along with this conflict goes the fact that the actors in the SF talk about environmental effects in specific scientific terms (like, for example, 'human toxicity' and 'persistent toxicity', 'nutrient enrichment', 'photochemical ozone formation') that are unfamiliar to most other actors. These use more general terms like 'good indoor climate' or 'environmentally correct building'.

Closely related with the simplicity versus complexity conflict is the conflict of *'checklist indicators versus life cycle assessments'*: Checklist indicators (based mainly on concrete measures and principles) appeal to the AHF and the LSF because they are directly address the decisions taken by the actors in these frames and because they are in their sphere of competence and thus easy to understand and to use.

From the SF's point of view checklist indicators are too imprecise and lead often to wrong conclusions because they don't consider the use context of a concrete measure in the way LCA-based indicators do. The PRF is ambivalent: Checklist indicators are appealing because they are easily communicable to the target groups and very operational, but lack the trustworthiness of LCA-based indicators. As LCA-based EIFOB are younger than checklist indicators they are also confronted with the a business-as-usual inertia.

Seen from the PRF and the LSF the use of LCA-based indicators also brings about the problem of indicator-units ('Person Equivalents') that are unfamiliar to the public and thus more difficult to understand and to communicate than familiar units.

With regard to the environmental scopes of the different technological frames there are two conflicts:

- *Transport in the use phase* is considered relevant by the SF[375]. The PRF considers it only when it is expected to be received positively by the target groups. The LSF see it as out of the scope of EIFOB, while the AHF is indifferent.
- *Aesthetics* is considered a relevant *environmental* aspect in the context of EIFOB only by the AHF, while the SF sees it as out of the scope of EIFOB.[376]

To evaluate the severity of these conflicts the chances to resolve them were investigated. A core conclusion was the following:

The key conflict *'checklist indicators (based on concrete measures and principles) versus life cycle assessment'* is of such a character that it cannot be resolved with a technical solution but only with solutions in the social sphere. This makes it unlikely to reach a consensus on EIFOB in the *near future*.

Possible solutions in the social sphere could be

- to raise awareness among actors in the AHF about the design freedom granted by LCA-based indicators
- to facilitate the use of LCA-based indicators for actors in the AHF by training, more user-friendly tools and better data availability.
- to promote the use of LCA-based indicator for actors in the AHF, for example with economical incentives or legal demands.
- to let experts carry out the assessments with LCA-based indicators for the actors in the AHF.

A second core conclusion concerned the related conflict of 'simplicity versus complexity':

[375] As pointed out in the chapters 'Environmental effects of buildings' and 'Discussion', from the SF's perspective this is a question of defining system borders.

[376] The PRF and the LSF didn't express prominent positions in this respect, the LSF, however, tending towards the AHF's position.

The related conflict of 'simplicity versus complexity' can partly be resolved by operating with different levels of aggregation in an indicator system, with each level addressing different actors. For example

an 'ABC'-ranking of the building as the highest level of aggregation for actors in the LSF and the PRF,

a limited number of aggregated indicators at the second level of aggregation (for example 'indoor climate', 'induced transport'[377], 'contribution to climate change', 'resource consumption', ….) for actors in the PRF and the AHF and

scientific indicators (such as the LCA-impact categories, measured indoor climate parameters, calculated figures on the induced transport,…) at the lowest level of aggregation for actors in the SF.

The analysis of the actors' demands to EIFOB also revealed *only one area of consensus* that included all four technological frames: All four technological frames agree on the general relevance of most environmental aspects. However it also revealed the following core result:

In spite of the consensus among all four technological frames about the general relevance of most environmental aspects the technological frames have clearly distinct environmental foci. These different environmental foci need to be considered in the attempts to shape and establish indicators as 'a common language for green building'.

The SF focuses more on regional and global environmental aspects (like, for example, global climate change, acidification, depletion of scarce resources…) and is less concerned about indoor climate. For the PRF and the LSF 'indoor climate' and consumption in the use phase are priority issues, as they generally are more attentive towards environmental issues with direct, local significance for health and operation costs. Waste and local circulation systems are also high on the agenda of actors in the LSF.

This led to the following core conclusion:

With regard to the environmental scope, addressing the environmental issues

indoor climate

local and global biodiversity

consumption of electricity, water and energy for heating in the use phase

global warming

air pollution (photochemical ozone formation, acidification)

ground and water pollution

land use

local ground water formation

waste and resource consumption

is likely to be accepted by the actors in all technological frames.

To expand the system borders to include 'transport induced in the building's use phase' would probably meet with some resistance from actors in the PRF and the LSF.

The inclusion of the environmental issue 'Indoor climate' is crucial to gain the support of actors in the PRF and the LSF, because this issue is extremely important to them.

Apart from this overall consensus of all four TFs there are several areas of consensus between *some* of the TFs.[378] The comparison of the different

[377] Meaning transport (of the building's users) induced in the building's use phase

[378] For a detailed overview over the different TF's demands to EIFOB see the section 'Actor demands to EIFOB' in the chapter 'Discussion'

TFs' demands permitted the determination of the degree of proximity between the TFs and showed that

- the SF and the PRF have a rather close relation with a clear overlap of interests: Both want well-documented, consistent and thus trustworthy indicators. For the PRF, scientific justifiability grants trustworthiness.
- Also the PRF and the LSF have a close relation: Both want simple indicators and share the focus on indoor climate and consumptions in the use phase.
- The LSF and the AHF have a close, but weak relation: Both are ambivalent with regard to the concept of scientific EIFOB and have an affinity for indicators based on concrete measures. On the other hand they are separated by the conflict of 'alternative lifestyle versus trendy architecture' and the AHF's stronger opposition to documented EIFOB.
- Also the PRF and the AHF have a close but weak relation: Both want simple, operational EIFOB and are concerned about a positive image. On the other hand the conflicts of 'documented & scientific versus qualitative & sceptic' separate them.
- The SF and the AHF are rather far from each other, separated by the AHF's general scepticism with regard to EIFOB and the core-conflict 'checklist-indicators (based on concrete measures and principles) versus life cycle assessment (LCA)'.
- Also the SF and the LSF are far from each other, as the LSF's focus on local environmental issues and perceptible concrete measures conflicts with the SF's concept of scientific, quantitative LCA-approach.

The common and conflicting demands and the resulting relations between the four TFs were summed up in the following figure, which is a 'map of the social landscape around EIFOB', so to speak:

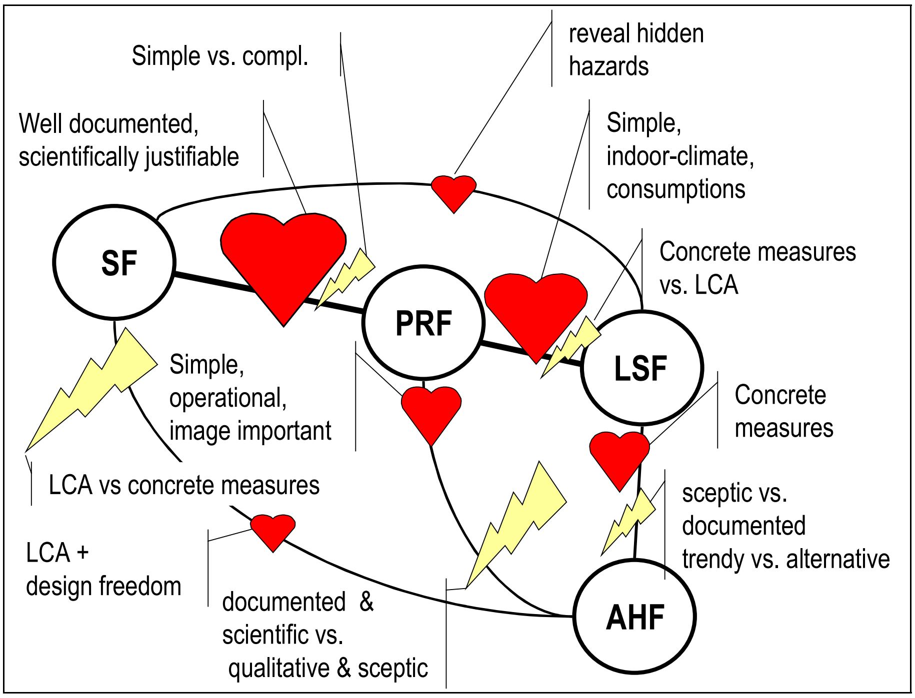


Figure 50: Relations between the different technological frames – conflicts and areas of consensus
Explanation:
The circles represent the four Technological Frames. Their constellation represents distance and closeness, the lines connecting them represent strong or weak bonds. Hearts (and the attached callouts) show common interests between the Technological Frames, the lightning bolts show conflicting interests. The bigger the heart / lighting bolt, the more important the common interest / conflict.

Finally the qualitative investigation of the actors' views on EIFOB indicated *two ongoing developments* concerning changes in the constellation of the four TFs:

– Actors in the aesthetic-holistic frame (especially architects), probably driven by the economic 'gravitational force' exerted by the PRF, take small steps towards the public relations frame. By doing so they move at the same time towards the scientific frame, for example by accepting the relevance of the SF's and the PRF's demand for well-documented, scientifically justifiable indicators.
– Actors in the scientific frame become increasingly aware of the needs of actors in the other frames and try to consider these in their indicator approaches.

Both developments a accompanied by a general, twofold knowledge increase:

– An increase of social knowledge among actors in the scientific frame and
– an increase of environmental scientific knowledge among actors in the PRF, the AHF and the LSF.

Within the area of shared knowledge communication of environmental issues among different actor groups is easier than outside this area.

Conclusion with regard to the central research question

The above results lead to the following core conclusion with regard to the central research question

if (and to what extent) consensus on environmental indicators for buildings as 'a common language for green building' can be reached in the near future among the core actors local building authorities, professional clients, client consultants, project designers, administrators of buildings and developers of environmental indicators for buildings:

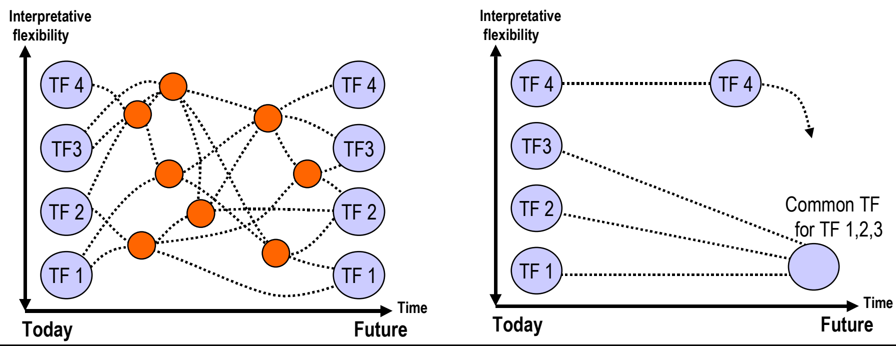
Several strong conflicts separate the different TFs, while the areas of consensus that unite *all four TFs* are rather weak.

It is not possible to create a set of EIFOB that meets the demands of all actors.
This means that the EIFOB-debate can not be solved by consensus among all four TFs in the near future.

Instead, two things can happen:

1. The relevant social groups and their technological frames remain separated. Instead of EIFOB as a common language for all four TFs, actors in different TFs in changing constellations make temporary partial agreements. (The left of the two figures below - the red dots symbolise the temporary partial agreements.)

2. Not all relevant social groups, but some reach a lasting agreement on EIFOB. The 'outsider' moves slowly towards the others. (the right of the two figures below.)[379]



[379] The increase of social and environmental knowledge among actors in different TFs can principally favour the first option (facilitating the parallel use of 'local languages' among selected actors instead of 'a common language' shared by all actors) as well as the second (smoothening the way towards a general consensus).

Three scenarios for future development

Applying the SCOT-theory in an innovative way *prospectively* these two possibilities for a future development were elaborated and exemplified with the environmental issues of 'energy' and 'indoor air quality' in the section *'Exemplifications "Energy" & "Indoor air quality": Three scenarios'* to answer the second of the two central research questions,

what environmental indicators for buildings that are acceptable as 'a common language for green building' for the relevant actor groups could look like.

The core ideas of the three scenarios, that is

– the respective constellations of the technological frames and
– key characteristics of the respective indicator approaches

had been presented in the last workshop to members of the different actor groups, which confirmed the scenarios as realistic possibilities.

Scenario 0 'Postmodern Relations' basically is a continuation of the present situation. The technological frames remain separated, no commonly accepted indicators that could serve as 'a common language for green building' exist. Instead, in a state of 'dynamic stagnation', actors in different TFs in changing constellations make temporary partial agreements. 'Local languages' and 'multilingual actors' emerge.

Scenario 1 'Science goes public' assumes the emergence of closure among the SF, the PRF and increasingly also the LSF on the basis of well-documented, scientifically justifiable indicators, which serve as a reliable means of communicating the state of the complex system 'environment' in a simplified way.
Three levels of aggregation –

– LCA impact categories mainly for the SF
– a limited number of intermediate indicators mainly for the PRF and
– an ABC-ranking mainly for the LSF –

are obtained by weighting and offer different degrees of simplicity in order to meet the diverging needs of the three TFs. This maintains a certain degree of interpretative flexibility and has ambiguous implications: On the one the hand it can be the starting point for a continued environmental learning process in which actors successively learn more about the lower levels of aggregation. On the other hand it means that actors in the different TFs, each using mainly 'their' level of aggregation, have greatly differing degrees of 'literacy' with regard to the indicator system as an entity. This conflicts with the idea of 'EIFOB as a *common* language'. *'Indicators don't built houses.'* – as the actors in the aesthetic-holistic frame (first and foremost architects) still remain key decision-makers much depends on how the conclusions from indicator assessments are communicated to them, for example by means of books with built examples and understandable explanations.

In scenario 2 'Keep it simple' the scientific frame is marginalised, while the PRF, the AHF and the LSF reach an agreement on EIFOB that

– are simple, easily understandable and communicable
– are checklist indicators based on concrete measures
– are operational (based on readily available data and easy to use) and

do not shed light on environmental shortcomings – accordingly the indicators do not cover induced transport and are generally calculated 'per m^{2}' instead of 'per person'. They are aggregated to a ABC-ranking without a weighting system, which makes it difficult to identify a project's environmental hot spots. The focus on concrete measures without consideration of their use context is not likely to foster an in-depth learning process about environmental interdependencies among non-SF-actors.

These scenarios are suggestions for future developments, based upon the investigation documented in this thesis. The uncertainty, which naturally adheres to the scenarios, makes it impossible to once more draw conclusions (‘meta-conclusions’, so to speak - from them). Instead, I conclude the summarising of results and conclusions with the following reflection on the three scenarios (which does not conceal my own adherence to the scientific frame):

> These three scenarios,
>
> scenario 0 ‘Postmodern Relations’,
>
> scenarios 1 ‘Science goes public’ and
>
> scenario 2 ‘Keep it simple’
>
> sketch three possible future developments of environmental indicators for buildings. To elucidate the overall significance of the different scenarios, an allegory from the world of navigation may be helpful:
>
> The societal challenge to steer society from the present stage of unsustainable pressure on the carrying capacity of ecological systems to a sustainable situation can be compared with having to sail a big ship through a narrow passage with banks and reefs towards safe waters. To master such a task without losses, navigation instruments – indicators – are required to determine the ship’s present position and which course to steer. If we were passengers on board, how would we prefer the navigation to be handled?:
>
> By a whole bunch of navigators, sailors and skippers, each with his favourite chart and individual way to measure depth and headway, shouting contradicting orders to the mate at the steering wheel (scenario 0)?
>
> By a team of jovial seamen without in-depth navigation training but with a weakness for easy-to read charts in bright colours, who unisonously pass somewhat vague directions to the persons in charge of steering while the only person with a precise chart stands unheard aside (scenario 2)?
>
> Or by some well-trained navigators with state-of-the-art equipment and precise charts, on whose calculations the other crewmembers base their manoeuvres (scenario 1)?
>
> The high ‘indicator-diversity’ in the first option may have been valuable in the early days of EIFOB when different approaches were to be created, tested and compared with one another. But it cannot give orientation for society as a whole. Though the second option certainly appears better than the first, it is clear that the third option would be the choice of most passengers if they were asked in such a simplified way.
>
> In practice, however, much would already be achieved if all actors – and not only those interested in navigation beforehand – agreed that space for manoeuvring is diminishing and that a sincere debate is necessary on how we want to navigate.

Perspectives

Continuation in the real arena

This thesis has underlined that environmental indicators for buildings as ‘a common language for green building’ cannot be created in a research institute but have to be negotiated, created and implemented in the life world in which they are to be used. The workshops of this project as a ‘social laboratory’ gave a picture of the debates that are likely to take place among core actors in the building sector if attempts to install commonly accepted EIFOB in practice were made. As a next step this debate should be carried from the social laboratory into the real arena, where it needs to be set up with a sufficient time budget and authorised representatives of the different actor groups. The results presented in this thesis provide enough knowledge to serve as a starting point for such a process, as they clarify positions, options and their consequences.

The thesis made also clear that a well-functioning common language for green building requires shared environmental knowledge. Especially striking the unfamiliarity of most architects with a systematic consideration of environmental aspects supported by indicators. The integration of environmental scientific aspects into architectural education would be a significant step towards the integration of this decisive actor group into an agreement about scientifically justifiable indicators.

Fields for further indicator research and development

Besides such a continuation of this study in the practical realm, several fields for further research and development can be pointed out. They concern the general challenges to

– widen the indicators' scope,
– harmonise and integrate,
– increase user-friendliness and
– improve the environmental scientific content of the indicators.

The *indicators' scope should be widened* to include more types of buildings and to cover not only single buildings but also ensembles of buildings at different scales (blocks, districts, cities,…), including infrastructure and other new aspects relevant at these superior levels, to support decisions concerning these. It needs to be investigated to what extent environmental indicators for *buildings* can be used for larger built units and to what extent they need to be *harmonised* with independent indicators for districts or cities. *Harmonisation* should also be striven for with regard to different tools and databases (for example LCA tools for building products and for buildings or tools originating form different countries) and different applications of environmental evaluations (for example demands in architectural competitions, in the building code, in local plans or for building product labels) to assure consistency and compatibility.

The geographical scope of this study was Denmark. The political aim to further promote European integration in the building sector as well as in environmental policy brings about the need for EIFOB at the European level. Here comparative studies on the actor-indicator-environment relations in different European countries would provide a knowledge base for the development of European EIFOB. Relevant research issues in this context are

– different educational systems and their impact on the actor's views on EIFOB,
– different regional environmental conditions and their consideration in harmonised indicators and
– different points of departure due to indicator systems already in use.

EIFOB should also be *integrated with indicators for other fields* (for example the two other sustainability aspects 'economy' and 'social sustainability') into a set of sustainability indicators.

Especially actors in the public relations frame and in the layperson-sensualist frame expressed concern for the economic implications of environmentally relevant decisions. Here it would be important to investigate if and to what extent economics can be linked with or integrated into EIFOB within and beyond the usual focus of facility management[380] on costs related to consumptions in the use phase but considering also external environmental costs in a life-cycle perspective. Stakeholders in the financial sector (for example in credit banks, assurances or public funding institutions) as the ones that finance building activities should be integrated into the investigation as a relevant actor group.

User-friendliness of EIFOB should be improved, for example

[380] For the state of developments in this field see for example (Graubner et al., 2003)

– by facilitating access to environmental data and to consulting on the use of the indicators and
– by improving supporting IT tools and literature according to user demands.

Research on the transmission of environmental information at the 'synapse' between actors in the scientific frame and in the aesthetic-holistic frame appears to be especially rewarding for overcoming a key conflict line between core actors.

To *improve the environmental scientific content of the indicators* further efforts are necessary to collect data on buildings and building products (for example with regard to chemicals or data for LCAs), to solve allocation problems and to study how further environmental aspects like, for example, land use and related effects (habitat destruction, local ground water formation, noise, …) can be integrated into EIFOB.

Elaboration of the prospective use of SCOT

With regard to the research methods applied in this study the use of the theory of the social construction of technology *in a prospective way* deserves further scrutinization other fields of technological development. It would be especially interesting to use the scenarios based on the SCOT-analysis as the point of departure of a negotiation panel in the real arena, to monitor the subsequent debates and finally to compare the scenarios in a follow-up study with the actual result of the negotiations.

Concluding remark

'Good' indicators do not guarantee environmentally sound buildings – the decisions taken on the basis of the indicators are what counts. But 'good' indicators allow a concise debate and permit to take 'good' decisions.

I hope this study contributes to the development of 'good' indicators and that decision-makers make good use of them. The environmental problems that triggered the request for environmental indicators at the 1992 World summit in Rio have not become less urgent since.

Appendix

The Danish planning and building legislation and ongoing European developments

Seen from the 'building-centric' viewpoint as described in the chapter 'Decision-making situations', the building legislation is not directly relevant to the research question. As it, nevertheless, is an important element in the broader decision making environment in the planning process a brief introduction to the Danish building legislation is given here.
The building legislation is one potential application for EIFOB. Already today it contains some quantified demands of environmental relevance.

The Danish building legislation

The Danish law addresses building and its environmental aspects in different parts of the legislation:

– The Planning act forms the framework legislation for land use planning. In the Danish planning system with strongly decentralised responsibilities it determines the scope and the proceeding of spatial planning at different levels (for details see the below sub-section 'The Planning act').
– The Building Law is the framework law for building activities. Its §1 says

  'The purpose of this law is […]
  to promote measures, which can counteract unnecessary energy consumption in buildings,
  to promote measures, which can counteract unnecessary raw material consumption in buildings.' (Danish Ministry for Housing and Urban Affairs, 1998)[381]

  and its §5 says

  'The Minister for Housing and Urban affairs issues a building code with rules about […] the conditions that are addressed by this law.'[382]

– The Building code[383] contains the technical demands to buildings. Here energy consumption is the environmental issue that is paid most attention to[384]. Contradicting the Building Law the Building code *does not* address 'unnecessary raw material consumption' at all.
  The Building code does not have a hierarchical structure but is binding for

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381 This and the following citations from Danish laws have been translated into English by the author.

382 It is noteworthy that the Building Law does not contain any reference to 'environmental protection' in general.

383 To be precise there are TWO Building codes: The 'Building code' and the 'Building code for small houses', the latter being valid for
'- houses with ONE apartment for residence all the year round, either as detached houses or as partially attached single-family houses (double houses, row houses, chain houses or the like)
- summerhouses, allotment-garden houses and camping huts. […]' (Danish Ministry for Housing and Urban Affairs, 1998)

384 The Danish government intends to tighten up the demands of the Building code on buildings' energy performance:
'In the light of the fact that today it is possible to reduce the energy consumption considerably below the level fixed in the current Building code from 1995/98 the government intends to tighten up the energy provisions in the Building codes […]. The new energy provisions shall enter into force latest by January 1 2005. Point of departure is a tightening up of the energy demands by 25-30%, but the actual demands will be fixed on the basis of an evaluation of the technological possibilities […].' (Danish Energy Agency, 2003)

the whole Denmark, however, only for newly built buildings and renovations.

– The 'Law on the promotion of the reduction of energy consumption' (Danish Ministry for Environment, 1996)

  'shall promote energy saving among consumers in accordance with environmental and national economic considerations with the intention to contribute to the reaching of Denmark's international environmental obligations.
  The Law shall […] especially
  - assure the prioritising of energy saving activities and […]
  - assure an effective and user friendly counselling on energy saving for the consumers.
  §2 The law applies to the increase of the efficiency and the reduction of energy consumption in […] buildings, including systems for the buildings' supply with energy, and to information for consumers on energy conscious behaviour.'

  The mandate given in this law has led to the 'executive order 789' on the Danish 'Energy labelling of Houses and owner-occupied flats' (Danish Ministry for Economy and Labour, 2002)[385].

– Indoor climate issues are addressed in different laws and executive orders: The Building code says in its chapter 4 ('The fitting out of buildings')

  'Buildings shall be designed and fitted out in a way which provides satisfying conditions with regard to health for all […] and cleaning […].'

  Chapter 11 of the Building code is entirely dedicated to indoor climate. It demands
  specific air change rates,
  for living rooms windows that can be opened
  and measures to prevent health threats due to off-gazing, micro fibres from construction materials, radon and other gases.

  Furthermore the 'Law about working environment' (Danish Ministry for Labour, 1999) (a framework law like the Building law) in its chapter 6 'The fitting out of the workplace' says

  'The workplace shall be fitted out in such a way that is completely in good condition with regard to health and safety. […]
  The minister of labour can determine rules […], among others on the work room, for example its height, […] floors, walls, ceilings, lighting, temperature, air change and noise.

  Chapter 8 'Substances and materials' gives the minister the mandate to issue executive orders concerning the use, testing, labelling, production and prohibition of hazardous substances and materials.
  Based on this mandate various executive orders have been issued.

Apart from that, the Danish Environmental Protection Agency (EPA) has issued a 'List of effects', listing the dangerous effects[386] of about 20.000 chemical substances, and a 'List of undesirable substances' (LOUS).

'Substances, which are listed on the Effect list and which are used in amounts over 100 t per year are comprised on the "List of undesirable substances". Apart from that, it contains a series of substances, which the Environmental Protection Agency either evaluates as especially

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[385] As mentioned in the chapter 'Indicator systems' and described in detail further below in the appendix.

[386] *'Substances are included in the list […] if they are mutagenic, carcinogenic, dermatologically allergenic, have acute oral toxicity or are dangerous to the aquatic environment. Substances are included in the list if they have one or more of these effects.'* (Danish Environmental Protection Agency, 2000)

> *problematic or whose use Denmark through international conventions is obliged to reduce. The list contains in total 68 substances or groups of substances […]' (Danish Environmental Protection Agency, 2000)*

Both lists are *advisory* lists.

> *'The fact that a substance is included on the LOUS does not signify that the Danish EPA has decided to recommend prohibition of that substance. Regulations on total or partial prohibition are considered to be just one of many means of reducing the environmental loading caused by substances that have undesirable effects. […]*
> *Thus, the LOUS should be considered as a signal to, and a guideline for, the manufacturers, product developers, purchasers and other players concerned with chemicals, the use of which should either be restricted or stopped in the long term. This could be achieved by the companies involved which, based on the information of the LOUS, take the initiative to substitute the problematical substances themselves.' (Danish Environmental Protection Agency, 2000)*

The Planning Act

Vertically the Danish planning system is divided into national, regional and local levels, each of the lower levels having to comply with the planning decisions at higher levels. Horizontally it divides the country into three zones: urban, recreational and rural.

> *'In the urban and recreational zones, development is allowed in accordance with the current planning regulations. In rural zones, covering about 90% of the country, developments or any changes of land use for other purposes than agriculture and forestry are prohibited, or subject to special permission […]. The change of rural areas into an urban zone requires provision of a legally binding local plan […].' (Enemark, 2002)*

As all of the plans at the different levels deal with the question 'Where to build?' they all have environmental implications. The regional plans at county level, for example

> *'must contain guidelines for the designation of urban areas, the location of large public institutions, large shopping areas and major traffic and infrastructure facilities, the location of major projects and enterprises having special environmental requirements and, finally, guidelines for both rural land use and recreational and environmental protection.' (Enemark, 2002)*

At this level the Danish Environmental Impact Assessment is integrated in the planning process.
At the municipality level the Danish Planning Act is comprised of plans on two scales:

> *'A municipality plan determines the overall goals for the development of a municipality for a period of 12 years. The main themes are land use, transport, retail trade and other urban functions, recreational areas and the protection of land and natural resources. […] The municipality plan is not directly binding for the actions of property owners but can be made binding by preparing local plans.' (Ministry of Environment and Energy Denmark, 1999).*

In this plan the municipalities shall document the strategies for the development of their community. The municipality plan, a written document illustrated with a map in a scale between 1:10.000 and 1:50.000, is meant to address the policies for the spatial development of the different sectors.[387]

The local plan regulates use and development of each individual property and is legally binding for each individual person and property owner. It is drawn on a scale between 1:500 and 1:5000.

'A local plan may contain provisions on:

1) transferring areas covered by the plan to an urban zone or a summer cottage area;

2) the use of the area, including reserving specific areas for public use;

3) the size and extent of properties;

4) roads and paths and other matters related to traffic, including the rights of access to traffic areas and with the intent of separating different kinds of traffic;

5) the location of tracks, pipes and transmission lines, including electric power lines;

6) the location of buildings on lots, including the ground level at which a building shall be constructed;

7) the extent and design of buildings, including provisions that regulate the density of residential housing;

8) the use of individual buildings;

9) the design, use and maintenance of undeveloped areas, including provisions that regulate the ground, fences, conservation of plants and other matters pertaining to plants, and the lighting of roads and other traffic areas;

10) preserving landscape features in connection with development of an area allocated to urban or summer cottage development;

11) the production of or connection with common facilities located within or without the area covered by the plan as a condition for starting to use new buildings;

12) providing noise-abatement measures such as plantings, sound baffles, walls or similar construction as a condition for starting to use new buildings or changing the use of an undeveloped area;

13) establishing landowners' associations for new areas with detached houses, industrial or commercial areas or areas for leisure houses, including compulsory membership and the right and obligation of the association to take responsibility for establishing, operating and maintaining common areas and facilities;

14) preserving existing buildings, so that buildings may only be demolished, converted or otherwise altered with the permission of the municipal council;

[387] In the first workshop of this study a participant from the academic sector stated that in practice this strategic dimension of the municipality plan was often neglected or of poor quality, many municipalities all too willingly adjusting the plan in a short sighted manner to meet investor demands or sudden trends.

15) keeping an area free from new construction if buildings may be exposed to collapse, flood or other damage that may endanger users' life, health or property;

16) cessation of the validity of expressly mentioned negative easements if the continued validity of the easement will contradict the purpose of the local plan, and if the easement shall not lapse as a result of §18;

17) combining flats in existing residential housing;

18) insulating existing residential housing against noise; and

19) banning major construction projects in existing buildings, so that such projects may only be carried out with the permission of the municipal council or if they are required by a public authority in accordance with legislation.' (Ministry of Environment and Energy Denmark, 1999)

In practice this means that the local plan does not allow to make explicit environmental demands[388]. However, it can contain numerous detailed legally binding demands with regard to the shape, the siting and the function of buildings, which indirectly also have an environmental significance.

When local authorities act as *sellers* of land they can make almost any environmental demand due to the legal tool of *easements*.[389] The same applies to local authorities in the role of clients or when they give subsidies for social housing and urban renewal.

Ongoing (European) developments

The Directive 2002/91/EC on the energy performance of buildings

In December 2002 the European Parliament and the Council of Ministers passed the 'Directive 2002/91/EC on the energy performance of buildings', which has to be transferred into national law and implemented by January 2006.

The objectives of the directive are

- to enable the EU to meet its Kyoto protocol greenhouse gas reduction obligations
- to improve the EU's security of energy supply.

'One possible solution to both the above problems is to reduce energy consumption by improving energy efficiency.' (European Union, 2002)

To achieve these objectives the directive

- sets out a general framework for the calculation of the energy performance of buildings,
- establishes minimum requirements for the energy performance for new buildings and for major renovations,
- makes energy certification of buildings mandatory,

[388] At the conference 'Byøkologi i Lokalplanlægningen' ['Urban Ecology in Local planning', in Danish] held by the Danish Centre for Urban Ecology in May 2001 in Vejle, representatives from local authorities argued lively with the speaker from the Planning department of the Ministry for Environment. They requested a reform of the Planning Act that gives local authorities the right to make environmental demands in the local plan, e.g. demand energy performance standards that go beyond the ones in the national building code. One municipality even went as far as integrating environmental demands into a local plan without being entitled to do so by the National Planning Act (Mørck, 2001). In the end it had to give in to the national legislation.

[389] In Danish 'servitutter', compare (Tophøj, 2001)

– demands regular inspections of heating systems and air-conditioning systems

An important innovation for the Danish legislation[390] is the broadening of scope of the energy calculation *'from a building's net energy demand to its gross energy demand'*, as a researcher at the DBUR put it.

The present Danish energy regulations are mainly based on *heat demand calculations*. The EC directive instead requires an *energy* demand calculation with a much broader scope, which environmental scientifically is much more justifiable. Its *'General framework for the calculation of energy performance of buildings (Article 3)'* says:

> *'1.The methodology of calculation of energy performances of buildings shall include at least the following aspects:*
>
> *(a) thermal characteristics of the building (shell and internal partitions, etc.).These characteristics may also include air-tightness;*
>
> *(b) heating installation and hot water supply, including their insulation characteristics;*
>
> *(c) air-conditioning installation;*
>
> *(d) ventilation;*
>
> *(e) built-in lighting installation (mainly the non-residential sector);*
>
> *(f) position and orientation of buildings, including outdoor climate;*
>
> *(g) passive solar systems and solar protection;*
>
> *(h) natural ventilation;*
>
> *(i) indoor climatic conditions, including the designed indoor climate.*
>
> *2.The positive influence of the following aspects shall, where relevant in this calculation, be taken into account:*
>
> *(a) active solar systems and other heating and electricity systems based on renewable energy sources;*
>
> *(b) electricity produced by CHP;*
>
> *(c) district or block heating and cooling systems;*
>
> *(d) natural lighting.*
> *(European Parliament and the Council, 2002)*

The Directive 2001/42/EC on the assessment of the effects of certain plans and programmes on the environment

In June 2001 the European Parliament and the Council of Ministers passed the 'Directive 2001/42/EC on the assessment of the effects of certain plans and programmes on the environment' (='Strategic Environmental Assessment, 'SEA'), which has to be implemented in the member states before July 2004.

This directive supplements the environmental impact assessment (EIA) 'Directive 85/337/EEC on the assessment of the effects of certain public and private projects on the environment'. While EIA addresses individual *projects* ,such as a motorway, an airport or a factory, Strategic Environmental Assessment addresses *plans, programmes and policies*.[391]

[390] For a comparison of different EU-member states' current legislation with the new directive see (Beerepoot, 2002)

[391] *'Environmental assessment is a procedure that ensures that the environmental implications of decisions are taken into account before the decisions are made.' (European Commission, 2003)*

'There will thus among other things be introduced rules for a strategic environmental assessment of regional plans, municipality plans and local plans.' (Spatial Planning Department, 2003)

'The purpose of the SEA-Directive is to ensure that environmental consequences of certain plans and programmes are identified and assessed during their preparation and before their adoption.' (European Commission 2003)

To achieve this objective the directive prescribes among other things the following elements:

Assessment at an early stage:

– *'The environmental assessment […] is carried out during the preparation of a plan or programme and before its adoption or submission to the legislative procedure.' (European Parliament and the Council, 2001)*

Environmental report:

– *'[…] an environmental report shall be prepared in which the likely significant effects on the environment of implementing the plan or programme, and reasonable alternatives […] are identified, described and evaluated.' (ibidem)*

Consultation:

– *'The draft plan or programme and the environmental report […] shall be made available to the authorities […] and the public. [Both] shall be given an early and effective opportunity […] to express their opinion. ' (ibidem)*

Information on the decision:

– *'[…] when a plan is adopted […] 'the authorities [and] the public […] are informed […][with] a statement summarising how environmental considerations have been integrated into the plan or programme and how the environmental report […], the opinions […] and the results of the consultations […] have been taken into account […].' (ibidem)*

Monitoring:

'Member states shall monitor the significant environmental effects of the implementation of plans and programmes in order, inter alia, to identify at an early stage unforeseen adverse effects, and to be able to undertake appropriate remedial action.' (ibidem)

Non-energy-related environmental performance requirements and an EU eco-label for construction materials

The communication 'Towards a thematic strategy on the urban environment' (European Commission, 2004) states that the

'The [European] Commission will […] propose further non-energy-related environmental performance requirements to complement Directive 2002/91 on the energy performance of buildings, taking into account the methodology of this Directive. […]

The Commission will develop the environmental labelling of construction materials (EPDs and/or EU eco-label), and will propose an EU eco-label and/or a harmonised EPD for buildings and/or building services.' (European Commission, 2004)'

Survey on environmental indicators in the building sector

This survey presents environmental indicators in the building sector in a schematic form. The presentations of the Danish indicators systems have already been published in a *Survey on Danish Environmental indicators in the building sector* for the European Network Project 'CRISP' (Dammann et al., 2002).

BEAT
('Building Environment Assessment Tool')

General characteristics

Name: BEAT ('Building Environmental Assessment Tool') **Origin (country, developers, year):** Denmark, Ebbe Holleris Petersen, Danish Building and Urban Research (DBUR), 2001 (second edition) **Contact:** Ebbe Holleris Petersen, eep@by-og-byg.dk / www.by-og-byg.dk **Web site:** http://www.by-og-byg.dk/udgivelser/pc-programmer/beat2001/generelt.htm **Sources:** (*Holleris Petersen, Ebbe, 97*), (*Holleris Petersen, Ebbe; Dinesen, Jørn et al., 01*)			
Form of presentation:	Book	IT-tool	Other
		X	

Status		**State of development**	
Legal obligation		Implemented / in use	x
Voluntary	**X**	Test-implemented	**X**
Certificate		Draft	
Scientific descriptive	**X**		
Other			
Evaluation			
Strengths: precise, voluminous database, database can be accomplished if necessary, good visualisations in bar-charts			
Weaknesses: **1.) scope** Water consumption is not addressed in general, since water is not considered a scarce resource. However, water could easily be integrated as scarce resource into the database. **2.) use** Quite labour intensive. Specific data not yet in the database are sometimes difficult to provide.			

Scope

BEAT is an LCA-based IT-inventory tool and database for the environmental assessment of building products, building elements and buildings. The database currently contains data for most conventional primary building products used in the Danish building industry (cement, concrete, gypsum-boards etc.), as well as a large number of commonly used building elements. In addition to these it also contains a number of energy sources and means of transport. It calculates the environmental impacts caused by the construction materials, considering the materials' entire life cycle in an LCA-approach, and the expected energy consumption in the building's operation phase.

User groups[392]**:**		**Decision making situations**[393]**:**	
internat. Organisations		Legislation	
Government		District plan and municipality demands	
Municipality		Architectural & engineering. design activities	**X**
The public		Production of building materials & -elements	x
Scientists	x	Construction	**X**
Suppliers[394]	x	Buying and selling	
Construction enterprises	**X**	Renovation	**X**
Consultants	**X**	Operation[395] and maintenance	
Building owners		Use (residents' + user activities)	
Facility managers		Others:	
Residents and users			
Others:			

Scale:	**Life cycle phases:**			
	Siting	Production / Construction	Use / operation396	Demolition / waste management
Building elements / construction materials		X	**X**	**X**
Buildings		**X**	**X**	**X**
Groups of buildings		x	x	x
Infrastructure	x[397]			

392 '**X**' in bold indicates the focus points of the indictor-system, normal 'x' indicates peripheral points.
393 *'Decision* making situations' means those situations, in which environmentally relevant *decisions are taken*, NOT the situations, when the consequences of the decisions taken in earlier phases of the building's life cycle occur.
394 Meaning suppliers of construction materials and –elements in the construction- and renovation phase as well as suppliers of electricity, water, and heating in the use / operation phase.
395 This means all what is independent of the users' and residents' individual activities.
396 The consumption of energy for ventilation and heating is calculated separately, painting and building elements that need to be replaced are fully considered, energy consumption due to individual applications (lamps, electric machines,..) are ignored.
397 BEAT considers different ways of energy supply (e.g. renewable energy, coal power plants,…)

Environmental aspects		sphere of quantification				
		Driving forces[398] & Societal response[399]	Application of principles[400] / specific measures[401]	Resource – consumption[402] / measurement / pressures on the Environment[403]	Environmental effects[404], [405] Environmental damages[406]	Others:
Energy + related emissions	**X**			x	**X**	
Water + wastewater						
Material consumption + waste	**X**			x	**X**	
Toxicity & hazard. substances	**X**			x	**X**	
Indoor climate						
Working environment						
Local environment[407]						
Others:						

[398] E.g. growth of the human population.
[399] E.g. implementation of an eco-taxation, environmental management,…
[400] E.g. thermal ventilation
[401] E.g. the existence of energy saving bulbs, shared washing facilities, water saving installations,… .
[402] These can either be measured (like the electricity and water consumption in the operation phase) or calculated, like the amount of raw oil consumed for transport in the production of a certain product or material.
[403] E.g. amount of emitted CO_2
[404] E.g. acid rain. acidification, nutrient enrichment, ecotoxicity, human toxicity, persistent toxicity, stratospheric ozone depletion, photochemical ozone depletion, global warming, hazardous waste, slag and ashes & bulk waste.
[405] BEAT calculates acidification, nutrient enrichment, ecotoxicity, human toxicity, persistent toxicity, stratospheric ozone depletion, photochemical ozone depletion, global warming, hazardous waste, slag and ashes & bulk waste.
[406] E.g. diminution or extinction of certain species.
[407] E.g. land use, destruction of habitats, air quality, noise,…

Indicators

Underlying indicator principle (LCA, DPSIR, input-output, checklist, other)	LCA
BEAT can present the results of its calculations both as amounts of raw materials/emissions, as effects (for example CO2-equivalents for global warming and SO2-equivalents for acidification – here the emissions of various substances contributing to the environmental effect (for example to global warming) are converted by multiplication with an equivalency factor to, for example, CO2-equivalents and thus made comparable with one another) and as normalised and weighted environmental profiles (using the Danish EDIP-method – 'Environmental Design of Industrial Products', (Wentzel et al. 1997))	
The indicators used	
Highest level of aggregation	next level of aggregation
Unit: After normalisation and weighting: Person Equivalents per reference year(1995) and reference area (Denmark / World) (mPE_{WDK95}) Before normalisation and weighting: - see in the respective cells -	Unit: usually in tons, gas in Nm^3
contribution to global warming Unit: CO2-equivalents	Emissions to air: carbon dioxide (CO2) carbon monoxide (CO), N2O metane (CH4), …
acidification Unit: SO2-equivalents	Emissions to air: Sulphur dioxide (SO2) Ammonia (NH3) Hydrogen chloride (HCl, Nitrogen oxides (NOx), …
nutrient enrichment	Emissions to air[408]: Nitrogen oxides (NOx) N2O Ammonia (NH3),…
photochemical ozone formation	Emissions to air (mostly transport-related): Carbon monoxide (CO) Volatile organic compounds ('VOC'), power plant VOC, car (diesel) Metane (CH4) Formaldehyde,…
human toxicity	Emissions to air: Nickel (Ni) Lead (Pb) N2O Quicksilver (Hg) Nitrogen oxides (N0x),…
persistent toxicity	mostly emissions to air: Arsenic (As) Lead (Pb) Cadmium (Cd) Zinc (Zn) Quicksilver (Hg), …

[408] Emissions to water can principally also contribute to nutrient enrichment but according to the author of BEAT occur very rarely in the construction sector.

consumption of fuel-resources	Crude oil, natural gas, coal, brown coal, …
consumption of metal-resources	Aluminium, iron, copper, manganese, nickel, zinc,…
hazardous waste	Unspecified hazardous waste, unspecified hazardous waste containing heavy metals, unspecified chemical waste,…
slag & ash	slag & fly-ash (mainly from the power plant)
bulk waste	bricks, mortar, unspecified, hazardous waste (glasswool), ….

Energy labelling of houses and owner-occupied flats

General characteristics

Name: Energimærkning af huse og ejerlejligheder ['Energy labelling of houses and owner-occupied flats', in Danish] **Origin (country, developers, year):** Denmark, Ministry for Environment, The Danish Energy Agency, , 1997 **Contact:** Ole Michael Jensen, omj@by-og-byg.dk / www.by-og-byg.dk **Web site:** http://www.emsekretariat.dk/, http://www.ens.dk/uk/index.asp **Sources:** (*Danish Energy Agency, Ministry for Environment, 99*),			
Form of presentation:	Book	IT-tool	Other
	X	**X**	**X** through professional energy consultants

Status		**State of development**	
Legal obligation	**X**	Implemented / in use	**X**
Voluntary		Test-implemented	
Certificate		Draft	
Scientific descriptive			
Other			

Evaluation

Strengths:

1.) scope

2.) use

Based on easily accessible data, very user friendly, comprehensible and action oriented due to:

- quantification in units per property
- quantification in money
- combination with proposals for measures for improvement and a cost benefit analysis
- extreme simplification (the A to M-ranking)

linkage with the selling of the property, a situation, where the new residents consider in which improvements to invest

Weaknesses:

1.) scope

2.) use

Scope

Rating system that describes a property's characteristics related to energy- and water consumption, independent of the residents actual consumption. Along with the certification concrete improvement measures are proposed and a cost-benefit-calculation is carried out. Legally prescribed (for small properties when they are sold, for large buildings once a year). Scope: consumption of electricity, heating, water. Two different systems: for small properties: calculations scheme, for large buildings: measurement

User groups:		**Decision making situations:**	
internat. Organisations		Legislation	
Government		District plan	
Municipality		Architectural & engineering. design activities	**X**
The public		Production of building materials & -elements	
Scientists		Construction	
Suppliers		Buying and selling	**X**
Construction enterprises		Renovation	**X**
Consultants	**X**	Operation and maintenance	**X**
Building owners	**X**	Use (residents' + user activities)	
Facility managers	**X**	Others:	
Residents and users	**X**		
Others:			

Scale:	**Life cycle phases:**			
	Siting	Production / Construction	Use / operation	Demolition / waste management
Building elements / construction materials				
Buildings			X	
Groups of buildings				
Infrastructure				

Environmental aspects		sphere of quantification				
		Driving forces & Societal response	Application of principles / specific measures	Resource – consumption / measurement / pressures on the Environment	Environmental effects, Environmental damages	Others: Cost-benefit calculation
Energy + related emissions	**X**			**X**		
Water + wastewater	**X**			**X**		
Material consumption + waste						
Indoor climate						
Toxicity & hazard. substances						
Working environment						
Local environment[409]						
Others:						**X**

Indicators

Underlying indicator principle (LCA, DPSIR, input-output, other)		input-output
The used indicators		**unit of quantification**
Two different systems:		
For small properties	For large properties	
highest level of aggregation: a letter: A: low environm. impact B: medium C: high + Emission of CO_2/year	highest level of aggregation: a letter between A and M, with A being the best (= low consumption	Tons CO_2 per year / property
next level: Annual consumption of Oil / gas for heating Water Electricity		Heating: litres of fuel / (property x year), calculated expenses: Danish Crowns Water: m^3 / (property x year), calculated expenses: Danish Crowns Electricity : kWh / (property x year), calculated expenses: Danish Crowns

[409] E.g. land use, destruction of habitats, interference with infrastructure systems,…

Green accounting

General characteristics

Name: Green Accounting for Residential Areas **Origin (country, developers, year):** Denmark, Ole Michael Jensen, Danish Building and Urban Research Institute ('By og Byg'), 1998 **Contact:** Ole Michael Jensen, omj@by-og-byg.dk / www.by-og-byg.dk **Web site:** http://www.by-og-byg.dk/udgivelser/pc-programmer/groent_regnskab/index.htm **Sources:** (*Jensen, 98*), (*Jensen, 99*)			
Form of presentation:	Book	IT-tool	Other
		X	

Status		State of development	
Legal obligation		Implemented / in use	X
Voluntary	X	Test-implemented	
Certificate		Draft	
Scientific descriptive	X		
Other			
Evaluation			
Strengths: Based on easily accessible data, widely in use, comparatively simple comprehensible method, comparison of the green accounts from different years clearly reveal, if improvements have been achieved and can serve as an incentive for action.			
Weaknesses: **1.) scope** Restricted to resident behaviour-related consumption, does not take transport into account **2.) use**			

Scope

Focuses on the resource- and energy consumption in the operation phase. Monitoring of behaviour-related consumption.			
User groups:		**Decision making situations**[410]**:**	
International. Organisations		Legislation	
Government		District plan	
Municipality	X	Architectural & engineering. design activities	X
Main contractors		Construction	
Construction enterprises		Production of construction materials	
Suppliers		Operation	X
Buyers of property		Renovation	X
Facility managers	X		
Residents and users	X		
The public	X		
Consultants	X		
Scientists	X		
Others:			

[410] '*Decision* making situations' means those situations, in which environmentally relevant *decisions are taken*, NOT the situations, when the consequences of the decisions taken in earlier phases of the building's life cycle occur.

Scale:	**Life cycle phases:**			
	Siting	Production / Construction	Use / operation[411]	Demolition / waste management
Building elements / construction materials				
Buildings			**X**	
Groups of buildings			**X**	
Infrastructure			x[412]	

Environmental aspects		**sphere of quantification**				
		Driving forces & Societal response	Application of principles / specific measures	Resource – consumption / measurement / pressures on the Environment	Environmental effects, Environmental damages	Others:
Energy + related emissions	**X**			**X**		
Water + wastewater	**X**			**X**		
Material consumption + waste	**X**			**X**		
Indoor climate						
Toxicity & hazard. substances						
Working environment						
Local environment	(X)[413]			(X)		(X)
Others:						

Indicators

Underlying indicator principle (LCA, DPSIR, input-output, other)	input-output
The used indicators	**unit of quantification**
CO_2-emission (for both Heating and Electricity)	t CO_2-emission / (person x year)
Heat consumption	MWh/(100m^2 x year) or MWh/(person x year)
Electricity consumption	kWh/(person x year)
Water consumption	m^3 / (person x year)
Waste	kg / (person x year)

[411] The consumption of energy for ventilation and heating is calculated separately, painting and building elements that need to be replaced are fully considered, energy consumption due to individual applications (lamps, electric machines,..) are ignored.

[412] Green Accounting considers different sources of energy (e.g. renewable energy, coal power plants,…)

[413] Green Accounting has additional modules for 'transport' and 'green areas'. The transport module calculates the transport-related CO_2-emissions per person based on the amount of kilometres travelled with the different transport modes per year. The module for 'green areas' describes the biological value of a property by assorting 'bio-factors' to the different kinds of surfaces surrounding a building. In practice, however, these are not broadly used.

Environmental Product Declarations for building products

General characteristics

Name: Environmental Product Declarations for building products (EPDB) **Origin (country, developers, year):** Denmark, Danish Building and Urban Research (DBUR), Danish Technological Institute, 2002 (under development) **Contact:** Klaus Hansen, klh@by-og-byg.dk , www.by-og-byg.dk **Web site:** **Sources:** (*Hansen, 02*)			
Form of presentation:	Book	IT-tool	Other
	X		

Status		State of development	
Legal obligation		Implemented / in use	
Voluntary	X	Test-implemented	
Certificate	X	Draft	X
Scientific descriptive			
Other			
Evaluation			
Strengths: Good visualisation of the environmental impacts in bar charts Environmental impacts are clearly allocated to the phases 'material', 'production', 'use' and 'disposal', which makes it easy to identify improvement potentials. Concept contains a lot of thoughts on the implementation.			
Weaknesses: **scope** **2.) use** Some producers complain about the difficulty to collect the necessary data on their products.			
Comments / implications for my project:			

Scope

EPDB can be characterised as a concise LCA for each specific building product accompanied by an environmental 'user guideline'. It shall fulfil ISO type III requirements and therefore includes an assessment based on the LCA methodology (read 'BEAT') and a third party control. The declaration for each specific product is a document of two pages, containing – the product's contents – an environmental profile (in the form of bar charts) – a short description of processes, which contribute considerably to the environmental impact – a 'user guideline', pointing out processes for which the environmental impact to a high degree depends on the context in which the product is used.			
User groups:		**Decision making situations:**	
internat. Organisations		Legislation	
Government		District plan and municipality demands	
Municipality		Architectural & engineering. design activities	**X**
The public		Production of building materials & -elements	**X**
Scientists		Construction	**X**
Suppliers	**X**	Buying and selling	**X**
Construction enterprises	**X**	Renovation	**X**
Consultants	**X**	Operation and maintenance	
Building owners	**X**	Use (residents' + user activities)	
Facility managers		Others:	
Residents and users			
Others:			

Scale:	**Life cycle phases:**			
	Siting	Production / Construction	Use / operation	Demolition / waste management
Building elements / construction materials	**x**[414]	**X**	**X**	**X**
Buildings				
Groups of buildings				
Infrastructure				

[414] The LCAs consider transport and different forms of energy supply (renewable, fossil-fuel based,…)

Environmental aspects		sphere of quantification				
		Driving forces & Societal response	Application of principles / specific measures	Resource – consumption / measurement / pressures on the Environment	Environmental effects· Environmental damages	Others:
Energy + related emissions						
Water + wastewater						
Material consumption + waste						
Toxicity & hazard. substances	**X**					
Indoor climate						
Working environment						
Local environment						
Others:						

Indicators

Underlying indicator principle (LCA, DPSIR, input-output, checklist, other)	LCA (based on BEAT)
The indicators used	
(the same as in BEAT[415] + calorific value) Contribution to Global warming Acidification Energy consumption Calorific value Material consumption Nutrient enrichment Photochemical ozone formation Toxicity Volume waste Hazardous waste	Unit: After normalisation and weighting: Person Equivalents per reference year(1995) and reference area (Denmark / World) (mPE_{WDK95})
In the bar chart the different overall values of the bars indicating the values of the different indicators are subdivided, indicating the shares of the different phases 'material', 'manufacturing', 'use' and 'disposal'.	

[415] For a more detailed description see the 'indicator' paragraph of the BEAT presentation

Environmental assessment and classification of buildings

General characteristics

Name: Miljødeklarering og –klassificering af bygninger ['Environmental assessment and classification of buildings', in Danish]			
Origin (country, developers, year): Denmark, Danish Building and Urban Research Institute, consultancy enterprise 'RAMBØLL', architectural office 'arne hansen miljø og arkitektur', 2001			
Contact: Jørn Dinesen, jod@by-og-byg.dk / www.by-og-byg.dk			
Web site:			
Sources: (*Dinesen, Hansen, et al., 01*)			
Form of presentation:	Book	IT-tool	Other
		X	

Status		State of development	
Legal obligation		Implemented / in use	
Voluntary	**X**	Test-implemented	
Certificate		Draft	**X**
Scientific descriptive			
Other			

Evaluation

Strengths:

scope

Broad scope.

2.) use

Well balanced between the environmental scientific demand of broad coverage and precise display of the relevant environmental aspects and the user demand of simplicity.

Smart aggregation system (through expression in points)

Takes the residents' / users' interests in indoor climate into account by addressing it rather thoroughly.

the building's environmental profile can be displayed in a very comprehensible radar chart

the high level of aggregation facilitates the system's common use as a labelling / declaration system

Weaknesses:

1.) scope

Does not take the placement of the building into account.

2.) use

Lacks experiences from test-implementation.

Scope

(The quantification on all the environmental aspects in scope is based on BEAT, except for indoor climate) In comparison with a 'normal' reference building and along with a visualisation of their environmental impacts are buildings placed in class C, B, or A. *'The purpose of the method is to motivate buildings owners to choose alternative solutions with low environmental impacts by pointing out relevant environmental objectives and provide a documentation of their fulfilment. Furthermore, the method could be used as a basis for a voluntary arrangement of environmental declaration in co-operation with the buildings sector." (Dinesen, Hansen, et al., 01)*

User groups:		**Decision making situations:**	
International. Organisations		Legislation	
Government		District plan	
Municipality		Architectural & engineering design activities	**X**
Main contractors	**X**	Construction	
Construction enterprises		Production of construction materials	
Suppliers		Operation	
Buyers of property	**X**	Renovation	**X**
Facility managers			
Residents and users			
The public			
Consultants	**X**		
Scientists			
Others:			

Scale:	**Life cycle phases:**			
	Siting	Production / Construction	Use / operation	Demolition / waste management
Building elements / construction materials		X	X[416]	
Buildings		X	X[417]	X
Groups of buildings				
Infrastructure	x[418]			

[416] In the same way as BEAT the 'Environmental assessment and classification of buildings' considers the durability of the building, building elements and construction products in its LCA-based assessment.
[417] It also considers the consumptions that can be attributed to the buildings technical standards (installations, insulation, …). It does not measure the actual consumptions as caused by the individual users / inhabitants.
[418] The building's distance to public transport facilities is considered as well as different sources of energy supply (e.g. renewable / non-renewable energy – compare BEAT 2002, which the 'Environmental assessment and classification of buildings' is based upon).

Environmental aspects		sphere of quantification				
		Driving forces & Societal response	Application of principles / specific measures	Resource – consumption / measurement / pressures on the Environment	Environmental effects· Environmental damages	Others:
Energy + related emissions	**X**			**X**		
Water + wastewater	**X**			**X**		
Material consumption + waste	**X**			**X**		
Indoor climate	**X**		**X**			
Toxicity & hazard. substances	**X**		**X**			
Working environment						
Local environment	**X**		**X**			
Others: 'Own choice'[419]	**X**					

Indicators

Underlying indicator principle (LCA, DPSIR, input-output, checklist, other)	LCA, checklist
The indicators used	
Additional explanation In order to reach a high level of aggregation (7 Indicators and finally only one of the characters A, B or C) this assessment system is composed of indicators, some of which are composed of sub-indicators so that the system in some respects operates with indicators on four different levels. From level to level information is aggregated by using a point-system, that expresses the buildings environmental performance in certain respects in 'points', which then are summed up to reach the next level of aggregation. Example: gas emission, dust, ventilation and moisture protection (level 4) together form the indicator 'air quality' (level 3), which, together with energy consumption, material consumption, impact on the climate, air quality and "other indicators" forms the level 2. The last level aggregates these to one of the classes A, B or C.	
Four levels of aggregation, each with its indicators: 4. level.(the highest) Unit: points (the fewer the better) Three classes, all referring to a reference building, which is defined by corresponding precisely to the demands of the current building regulations: Class A (most environmentally friendly, cutting edge technology) Class B (quite good) Class C (just slightly above standard)	

[419] *'Finally there has been included an indicator "own choice", which is open for new indicators, that are considered important." (Dinesen, Hansen, et al., 01)*

3.level	2. level	level
Unit: Except for ‘Indoor climate’ the indicators at the 3. level and at the 2. level are based on calculations with the IT-tools BEAT 2001 and Bv98[420]: PE/(m^2 x year) (Person Equivalents per square metre per year) and a corresponding number of POINTS		Unit: for not quantifiable indicators (especially the indoor-climate -related ones): points given for the application of certain measures (for example water saving installations)or the reaching of certain benchmarks (for example maximum indoor temperatures)
Energy consumption		
Material consumption		
Waste	Volume waste Slag and ashes Hazardous waste	
Contribution to global climate change	Global warming Ozone depletion	
Contribution to air pollution	Acidification Photochemical ozone formation	
Indoor climate	Air quality	Offgasing Dust Ventilation Moisture resistance
	Thermal climate	Low temperature High temperature Draught Heat radiation to cold surfaces Individual climate control
	Daylight, view, artificial light	Daylight conditions View Solar shading Artificial lighting
	Noise and acoustics	Transmitted noise from outside Transmitted noise from other rooms Noise from installations Reverberation time
Other indicators	Hazardous substances Water consumption Operation of the building Siting of the building (transport) Own choice	

420 An IT-tool for the calculation of a building’s thermal requirement and energy frame (*Aggerholm; Grau, 98*).

BREEAM
('Building Research Establishment Environmental Assessment Method')

General characteristics

<table>
<tr><td colspan="4">Name: BREEAM ('Building Research Establishment Environmental Assessment Method')
Origin (country, developers, year): United Kingdom, Building Research Establishment (BRE), R), 2001 (second edition, scheme first launched in 1990)
Contact: BRE Centre for Sustainable Construction. Tel: (01923) 664462,
fax (01923) 664103, email: breeam@bre.co.uk
Web site: http://www.bre.co.uk/sustainable/envest.html
Sources: (BRE Centre for Sustainable Construction, 2001)</td></tr>
<tr><td rowspan="2">Form of presentation:</td><td>Book</td><td>IT-tool</td><td>Other</td></tr>
<tr><td></td><td></td><td>'a network of licensed operating agents and assessors' (BRE Centre for Sustainable Construction, 2002)</td></tr>
</table>

<table>
<tr><th colspan="2">Status</th><th colspan="2">State of development</th></tr>
<tr><td>Legal obligation</td><td></td><td>Implemented / in use</td><td>X</td></tr>
<tr><td>Voluntary</td><td>X</td><td>Test-implemented</td><td></td></tr>
<tr><td>Certificate</td><td>X</td><td>Draft</td><td></td></tr>
<tr><td>Scientific descriptive</td><td></td><td></td><td></td></tr>
<tr><td>Other</td><td></td><td colspan="2"></td></tr>
<tr><td colspan="4">Evaluation</td></tr>
<tr><td colspan="4">Strengths:
1.) scope
Quite broad scope. Mainly very simple, comprehensible indicators based on easily accessible data.
2.) use
The subsequent citations seem to indicate, that BREEAM is very well established:
"[…] with a network of licensed operating agents and assessors BREEAM is a world-leading product that is continuing to gain widespread adoption and recognition.' (BRE Centre for Sustainable Construction, 2002)

'It has proved very popular with around 400 buildings assessed so far, about 25-30% of all new office floor space developed in this period. It also forms part of the standard design specifications for major property owners, occupiers and managers, such as National Westminster, Barclays plc, BBC and Government departmental estate managers.' (BRE Centre for Sustainable Construction, 2002)

'BREEAM has become international. Schemes have been launched in Canada (1996) and Norway (1995) based on BREEAM. Hong Kong is close to launching an adaptation of the UK method and other countries such as New Zealand, Australia, Sweden and South Africa are discussing developing versions of BREEAM for their particular climate, social and market conditions, and national priorities.' (BRE Centre for Sustainable Construction, 2002)</td></tr>
<tr><td colspan="4">Weaknesses:
1.) scope
2.) use
Formulations like 'The points should be awarded where it is felt the design will meet the compliance criteria.' sound rather vague and may indicate a certain lack of precision of this system.</td></tr>
<tr><td colspan="4">Comments / implications for my project:
The management indicators are interesting: Here not the environmental pressures themselves are measured but the commitment 'to do something about it', the intentions, the clients have with regard to the buildings environmental performance. It is not entirely clear to me yet, whether this is meant to building or the client. I is questionable, how reliably these management indicators correspond with the actual performance of the building.
Simple and smart system to evaluate the expected transport-related CO_2 emission.
The system makes use of an LCA based assessment software for construction materials (ENVEST) as a subsystem by defining a benchmark ('at least 80% of the external wall / windows / […] specifications achieve an "A" rating.').</td></tr>
</table>

Scope

The authors describe BREEAM as 'a means of *reviewing and improving* the environmental performance of buildings.' Especially in its strong integration of management indicators, which to a large extent describe the company that runs the building[421] rather than the system itself, BREEAM's character as a management support-tool becomes obvious.

The system has different applications, each with modified evaluations-schemes:

Design stage new build and refurbishment schemes

Existing buildings that are occupied and are being assessed as part of an environmental management review

Existing buildings which are vacant or where a review or the fabric and services only is required

User groups:		**Decision making situations:**	
internat. Organisations		Legislation	
Government		District plan and municipality demands	
Municipality		Architectural & engineering. design activities	X
The public		Production of building materials & -elements	
Scientists		Construction	
Suppliers		Buying and selling	
Construction enterprises		Renovation	X
Consultants	X	Operation and maintenance	X
Building owners	X	Use (residents' + user activities)	
Facility managers	X	Others:	
Residents and users			
Others:			

Scale:	**Life cycle phases:**			
	Siting	Production / Construction	Use / operation	Demolition / waste management
Building elements / construction materials		X	X	X
Buildings	X[422]	X	X	X
Groups of buildings				
Infrastructure			X[423]	

[421] In the case of 'BREEAM for Offices'

[422] Transport related CO_2-emissions, also considering commuting traffic in the buildings use phase.

[423] The Transport indicator classifies different degrees of access to public transport.

Environmental aspects		sphere of quantification				
		Driving forces & Societal response	Application of principles / specific measures	Resource – consumption / measurement / pressures on the Environment	Environmental effects· Environmental damages	Others: 1) Management-indicators[424], 2) reference to well established external sub-systems[425]
Energy + climate relevant emissions	**X**			**X**		**X(1)**
Water + wastewater	**X** [426]		**X**			**X(1)**
Material consumption + waste	**X**		**X**	**X**[427]		**X(1)**
Toxicity & hazard. substances						
Indoor climate	**X**		**X**			
Working environment			**X**			
Local environment	**X** [428]		**X**			**X(2)**
Others: 'good neighbourli-ness' during construction	**X**					**X**

[424] Points are granted for the application of certain management measures, e.g. appointment of personnel for complex systems management (ventilation, heating, …), a guideline for building users, benefits from flexible working hours, incentives to use public transport, teleworking, …
[425] E.g. '*land defined as contaminated'* by the authorities
[426] *'Water shortages during dry summers, caused by low annual rainfall and high demand, have highlighted the growing need to conserve water. Coverage of this issue has been increased in BREEAM so that a full range of water conservation options are recognised and rewarded.'* (BRE Center for Sustainable Construction, 2002)
[427] Among others 'reuse of certain percentages of the material of previous buildings on the site'
[428] Biodiversity, *'ecological value'*,

Indicators[429]

Underlying indicator principle (LCA, DPSIR, input-output, checklist, other)	Checklist
BREEAM (BRE Environmental Assessment Method) assesses buildings against a range of environmental issues and awards credits where the building achieves a benchmark performance for each issue. The building is rated Excellent, Very Good, Good or Pass depending on the total score gained.	
The indicators used	
Highest level of aggregation	
Rating: Excellent Very Good Good Pass each corresponding to certain point-score benchmarks	
Next level of aggregation: Unit: points	sub-indicators[430] Unit: an indicator demand met corresponds to a certain number of points
Management	client commitment prior to hand over to ensure efficient operation of the building allocation of personnel for system management provision of a simple guide for the 'non-technical' building manager firm commitment to achieve certification firm commitment for environmental management during construction existence of a company environmental policy431 …
Health & Wellbeing	cooling towers accessible for cleaning natural cross ventilation possible percentage of daylit floor glare prevention zoning to provide separate control of lighting and temperature view out internal noise level maintenance schedule for heating, lighting, ventilation, hot water system established smoking ban recording of occupant feedback and comparison with historical data improvement targets in place …

429 The information displayed stems from the *'BREEAM For Offices – Assessment prediction checklist'* which is '*a simplified version of the full method'* (BRE Centre for Sustainable Construction, 2002) and may therefor differ from the one of the full method. It was, however, this assessment prediction checklist, that was send to me by the BREEAM-office on my request for material on BREEAM, its scope and its method of data aggregation.

430 In the checklist-layout the sub indicators are classed with the three indicator-classes 'building performance', design & procurement', 'management & operation'.

431 Addressing among others Health, Energy, Transport, Water, an action plan, annual (public) reviews,…

Energy	expected Total Net CO_2 emissions (in kg CO_2/(m^2 x year) sub metering for energy uses provided, for lighting, small power and others432 energy policy established training on energy saving techniques is given to building managers energy monitoring and targeting carried out …
Transport	'Total Net CO_2 emissions arising from transport too and from the building will be predicted based on location. Credits given are based on the scale below: Rural location with typical public transport connections (TPTC) Edge of town location with TPTC Small town location with TPTC Town / small city location with TPTC Urban conurbation location with TPTC National transport node location with TPTC Public transport connection are good and car parking in the area is restricted by at least 20% from the standard provision of cycling facilities433 for 10% staff Good access to public transport within 500m and at least a 15 min / 30 min434 frequency to a local urban centre Policy in place to encourage the use of public transport and discourage the use of the private car for both commuting and business
Water	predicted water consumption (in m3/(person x year) water meter installed to all building supplies leak detection system installed water consumption monitoring carried out …
Materials	no asbestos at least 80% of major building element components evaluated with the EN-VEST software435 achieve an 'A' rating the design reuses more than 50% of existing building facades by area the design allows reuse of at least 80% of the existing major structure by building volume timber for key building elements comes from sustainably managed forces significant use of crushed aggregate or masonry in the building structure corporate policy for collection and recycling of office consumables436 in place information on the presence of hazardous materials is available for staff and contractors
Land use	sites has been previously built upon or used for industrial purposes in the last 50 years build on land defined as 'contaminated' and adequate steps have been taken to contain or clean the site prior to construction

[432] E.g. for major fans, computer room, catering facilities, humidification plant
[433] Sheds, showers and changing facilities
[434] Different point-scores are given for the different frequencies.
[435] An LCA-based IT-tool for the environmental assessment of construction materials
[436] *'should cover at least paper, printer cartridges, toner cartridges and plastics'*

Ecology	build on land defined as having a low ecological value change in ecological value of the site (different degrees: minor and negative, neutral, minor and positive, positive, significant and positive) seeking and action on advice from Wildlife Trusts or a member of the Institute of Environmental Management and assessment contract ensures maintenance and protection of all trees over 100mm trunk diameter, hedges, ponds, streams etc during clearing and construction works …
Pollution	refrigerant[437] type has a ozone depleting potential of zero or no refrigerants refrigerant leak detection system in place burners in boilers are below NOx emission benchmarks[438] oil separators/filtration is present thermal insulants free of ozone depleting substances[439] maintenance policy covering boiler/burner systems in place no Halon based fire fighting systems installed …

[437] the substance used for cooling
[438] specified in 'mg/kWh delivered heating energy'
[439] in manufacture as well as in composition

GBTool

General characteristics

Name: GBTool (Green Building Tool) **Origin (country, developers, year):** Developed in the context of the 'Green Building Challenge '98', (GBC '98), a Canada initiated international project with partners from 14 countries. **Contact:** Nils Larsson, Executive Director, International Initiative for a Sustainable Built Environment (iiSBE), larsson@greenbuilding.ca, 130 Lewis Street, Ottawa, K2P 0S7, Canada, Tel: 613 769-1242, Fax: 613 232-7018 **Web site:** http://iisbe.org **Sources:** (Cole et al., 2002)[440]			
Form of presentation:	Book	IT-tool	Other
		X	

Status		**State of development**	
Legal obligation		Implemented / in use	
Voluntary	**X**	Test-implemented	**X**
Certificate		Draft	**X**
Scientific descriptive	**X**		
Other			

Evaluation

Strengths:

1.) scope

GBTool has a very broad scope, including even less 'famous' environmental aspects like acoustics, electro-magnetic pollution, light conditions, and at the same time a high degree of aggregation.

2.) use

The comprehensiveness and scientific sophistication of GBTool makes it a not especially user-friendly tool.

Weaknesses:

1.) scope

2.) use

It needs to be emphasised that GBTool is a draft-tool for scientists and not a tool ready to be used by end-users. Thus favours sophistication and scientific correctness before simplicity and end-user friendliness. Accordingly a number of values necessary for the calculation must, for example, be supported by computer simulation or prediction tools.

Some of the indicators are not operational yet: Commuting Transportation, L9.3 impact of construction process or landscaping erosion within or adjacent to site, L8 hazardous wastes resulting from renovation or demolition wastes, L5 emissions with eutrophication potential from building operations, R2.3 Change in agricultural value of site, R2.4. Change in recreational value of the site, …

Comments / implications / inspiration for my project:

Especially the service quality indicators are interesting. They undertake the difficult task to capture characteristics of the building design, that directly do not have an environmental impact, but indirectly can have an immense environmental effect, for example when the needs to be adapted to new functions. The question is, if flexibility is the decisive factors that determines a buildings life span. Economic, aesthetical and other social factors may be even more important.

The ranking from –2 ('level of performance below the acceptable level in the region') over 3 ('Best Practice') to 5 (the best technically achievable, without considerations of costs') is a dynamic benchmarking system where the data of the assessed buildings can be used to constantly adjust and refine the benchmark values. This process requires some kind of institution, where the assessment data are collected, compared and the benchmarks defined. This institution's authority needs to be accepted by the indicator users.

[440] If not indicated otherwise *all* citations in this text are from this source.

Scope

'The GBTool software has been developed as part of the international Green Building Challenge (GBC) process.' '*GBC set out to design a system that would allow regional variation and issues, while sharing terminology and structure.*' It is was initiated in 1998 by the Canadian government body 'Natural Resources Canada' with the overall goal *'to inform the international community of researchers, designers and builders about advances in green building performance and to test and demonstrate a comprehensive building performance assessment tool. Specific objectives include: […]* *To establish international benchmarks for building performance while respecting regional and technical diversity;* *To showcase "best-practice" examples of green buildings around the world;* *To* document the successful elements of individual green buildings' (Cole et al., 1998) These goals are also mirrored in the actual design of GBTool, which is adaptable to regional differences (for example with regard to the scarcity of water or other resources). GBTool is not intended directly for application by end users but to researchers who then are expected to modify it for the regional use. (Green Building Challenge 2002)

User groups:		**Decision making situations:**	
internat. Organisations		Legislation	
Government		District plan and municipality demands	
Municipality		Architectural & engineering. design activities	X
The public		Production of building materials & -elements	
Scientists	X	Construction	
Suppliers		Buying and selling	
Construction enterprises		Renovation	X
Consultants	X	Operation and maintenance	X
Building owners		Use (residents' + user activities)	
Facility managers		Others:	
Residents and users			
Others:			

Scale:	**Life cycle phases:**			
	Siting	Production / Construction	Use / operation	Demolition / waste management
Building elements / construction materials		X		
Buildings		X	X	
Groups of buildings				
Infrastructure				

		sphere of quantification				
		Driving forces & Societal response	Application of principles / specific measures	Resource – consumption / measurement / pressures on the Environment	Environmental effects· Environmental damages	Others: 1) Management-indicators[441], 2) reference to well established external sub-systems[442]
Energy + climate relevant emissions	**X**			**X**		**X1**
Water + wastewater	**X**			**X**		**X1**
Material consumption + waste	**X**			**X**		**X**[443]
Toxicity & hazard. substances						
Indoor environment[444]	**X**		**X**	**X**		
Working environment						
Local environment	**X**		**X**	**X**		
Others: Service quality[445]	**X**		**X**	X		

Indicators[446]

Underlying indicator principle (LCA, DPSIR, input-output, checklist, other)	LCA, checklist, input-output
GBC *'is structured hierarchically in four levels, with the higher levels logically derived from the weighted aggregation of the lower ones'* (Cole et al., 2002) Performance Issues Performance Categories Performance Criteria Performance Sub-criteria	
The indicators used	
The GBTool-indicators are not shown here for the sake of brevity as their display would extend over several pages. The indicators can be found at http://iisbe.org	

[441] Points are granted for the application of certain management measures, e.g. appointment of personnel for complex systems management (ventilation, heating, …), a guideline for building users, benefits from flexible working hours, incentives to use public transport, teleworking, …

[442] E.g. '*land defined as contaminated'* by the authorities

[443] 'R5.3 Use of wood products that are certified or classified'

[444] Including noise and acoustics.

[445] Details: see list of indicators below

[446] The information displayed stems from the *'BREEAM For Offices – Assessment prediction checklist'* which is '*a simplified version of the full method'* (BRE Centre for Sustainable Construction, 2002) and may therefor differ from the one of the full method. It was, however, this assessment prediction checklist, that was send to me by the BREEAM-office on my request for material on BREEAM, its scope and its method of data aggregation.

Interview guidelines and workshop programmes[447]

The interviews using the follwing guidelines were carried out in Danish with guidelines in Danish. The texts below are translations of the Danish guidelines into English.

Interview guideline for first series of interviews

1. Introducing myself:

– referring to my letter
– that I have only recently begun work on the project
– this is the first series of interviews, the aim of which is to gain a picture of the situation

2. Possible questions from the interviewed?

3. The setting of the interview:

– time limits?
– recording?

4. The interview

Interview Guideline
1 Information on the interviewee
General field of work:
Date: Place:
Name: Institution:

Position: Educational background:
Co-ordinates / card:

2 The persons appreciation / perception of environmental indicators for buildings:
2.1 Does the person deal with indicators as a
□ **U**ser □ **D**eveloper □ **O**ther
2.2 relevance of □ indicator system / □ environmental aspects in the persons field of work and decision-making:

2.3 **U**: Where in the planning process / life cycle of the building do they start to consider environmental aspects?

2.4 **U**: Has any indicator system been used? □ yes □ no

2.5 **U**: Which? (Green accounting, LCA, Checklists...)

U: How was that appreciated?

2.6 What are the main obstacles for
1. environmentally friendly choices in the life cycle of a building

2. the implementation of an indicators system?

3 Role of the person / organisation in the social construction of EIFOB:
3.1 **D**: participation in any relevant work group / panel:

3.2 **D**: Aim of EIFOB-related activity (legal status, voluntary self-obligation / avoidance of any such…?):

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[447] Supplement to the section 'Research tasks and methods' of the chapter 'Research design'.

3.3 the social construction of EIFOB (Environmental Indicators for Buildings):
3.3.1 How did EIFOB get started?

3.3.2 What were key events / documents?

3.3.3 What groups / persons does the person identify as relevant actors / social groups?

3.4 Where does the person see the main need for further development of EIFOB?

4 Future co-operation:
4.1 Would the person be willing to become part of the "social laboratory"?

4.2 What other persons / actors would the person regard as part of a relevant social group and therefor recommend for participation in the "social laboratory?

5 Remarks, further hints, other aspects:

6 Any relevant printed material / websites / events?

Interview guideline for second series of interviews

Introduction
1. Presentation of myself:

- Refer to my letter
- I am in the middle of my project
- This is the second series of interviews. Aim: to get a picture of the situation and the actor-landscape
- Any questions from the interviewee?

2. Frame of the interview:

- Time limitations?
- Audio recording?
- Confidentiality

<u>The interview</u>
Note: Questions from the first series of interviews should of course only be asked, if the interviewee hasn't already answered them.

1. On the interviewee's roles
1.1 What institutions do you work for?
1.2 What is your function here?
1.3 What is your professional background?

Present my scheme to explain my focus on three roles, thus clarifying with the interviewee, which decision-making situation his answers refer to:

Actors	**Decision-making situations**		
	siting / design of local plan	project design	administration, operation, renovation
Municipalities	**X**	**X**	**X**
Architects and other consultants	**X**	**X**	

1.3 In which context do you deal with environmental aspects of building activities?

1.4 Are you, for example, a member of a panel dealing with environmentally sound building or development of environmental indicators?

2 About the interviewee's attitude with regard to environmentally sound building
This is the central part of the interview – ask supplementary questions to get to the bottom.

2.1 Why is it, according to you, important to build in an environmentally sound way?
Have there been special occasions, which led to your dealing with environmental issues?
(How important are environmental aspects for you in relation to other parameters such as economy, aesthetics, health?)

2.2 What is your idea of an 'environmentally sound building'?
Has your idea changed over time?
Which environmental problems do you consider essential?

2.3 How do your attitudes and ideas as a private person go along with the positions you represent at work?

3 Interaction with other actors and decision-making situations
One of my tasks is to describe how the different actors 'get along with each other' / co-operate with regard to environmentally sound building and development of environmental indicators. Therefore I would like to ask you some questions concerning this issue:

3.1 Do you believe that other actors (clients, municipalities, architects, engineers, politicians…) have the same idea about what an 'environmentally sound building' is? Where would the differences lie?

3.2 Who, according to you, does most to promote environmental efforts in building?
Why do they do it?

3.3 Who is most obstructive ost?
Why?
(See also question 5.7 on the actors' view on indicators)

3.4 If we look once more on the scheme with the different decision-making situations: What are your experiences with the communication and consideration of environmental demands at the border-crossings between the decision-making situations?

4 About indicators
As explained, my project is about measuring the 'environmental friendliness' of a building and preferably expressing it in a quantitative way in order to be able to, for example, compare to buildings and tell, which one is more environmentally friendly and why.
We call these descriptive figures that express how environmentally friendly a building is, 'environmental indicators for buildings', and I would like to ask you some questions about them:

4.1 If you shall choose between different solutions (for example between a wooden construction or a steel construction or between thermal ventilation and mechanical ventilation – how do you find out, which one is the environmentally sound solution?

4.2 How detailed should information be for you to use it to support the environmentally relevant decisions that you take?

4.3 Do you use any indicator-system that describes a building or some aspects of building in a quantitative way or could you imagine using such a system?
What would you use it for? / If not – why not?

4.4 What are your experiences with the system you mentioned?
(critique, wishes, suggestions for improvements…)

4.5 What, according to you, hinders that indicators are used more?

4.6 Here I have two examples of indicator systems:

1.) Environmental Declaration and Classification of Buildings (show the radar chart and the ABC scheme)
2.) BEAT (show the visualisation[448] from the book 'arkitektur og miljø'[449]
What do you think of them?

---

[448] Similar to CHECK
[449] In English 'Architecture and Environment', (Marsh et al., 2000)

4.7 Could the shown indicator systems be useful for your work, too?
If yes: Why?
If no: What should be changed so that they could be of use for you?

4.8 If you think about the future: How, do you think, the future is going to look for environmental indicators for buildings? Where do you see the greatest need for further development?

4.9 Do you have a guess, how the different actors would react to the implementation of a set of environmental indicators for buildings?

5 Closure
5.1 Do you have any material or websites or events that you think might be interesting for my project?

5.2 Future co-operation: One idea of my project is that an advisory panel consisting of the relevant actors shall be established for test implementation and feedback. We call that 'social laboratory'. Could you imagine taking part in the social laboratory?

5.3 Mention workshop,
Wednesday, 28 August 2002, 8.30 a.m. – 12.30 p.m.

6 Debriefing:

– Switch off the recording device
– Give brief feedback about what I have learned in the interview – possibly hear the interviewee's comments on this.
– 'I don't have any more questions. Do you have any questions left?' – Informal talk

Form for the interview analysis[450]

Municip. **Client** **Consultant** **Admin.**

General characteristics

Relevant social group representatives interviewed		
Institution	**Function of interviewee**	**Name**
Role in the construction sector + power to influence the building's environmental performance		
Formal decision maker		
Actual decision maker		

Power structure:			
Sources of power	**Significance[451]**	**Dependencies**	**Significance**
General remarks			

Decision-making situations

Contents +	**Environmental aspects considered by the actor**

450 The form was used for inserting handwritten notes based on the transcriptions of the interview or directly on the audio-recordings. into it. The original scheme has ample space for notes, here the size of the table cells has been reduced for ease of reading.

451 Ranked from 1 ('of minor significance') to 3 ('very significant')

The technological frame (TF)

General mindset + current developments
Values / attitudes
Key problems / conflicts[452]
Prevailing problem-solving strategies
Degree of available environmental expertise / staff allocated to subject (+ their educational background)
Tacit knowledge
Currently used tools & methods for decision-making
Implications of the TF for the interaction with other Relevant social groups
Implications for the design of EIFOB

[452] Including conflicts between position-related attitudes and personal attitudes/values

Demands to EIFOB

Environmental aspects considered…	
a) especially relevant	**Explanation**

b) generally relevant	**Explanation**
Preferred type of indicator / mode of display	
e.g. concrete measures ('virkemidler') / emissions / cost-benefit-figures,…	

On the actors' relation to other actors

municipalities	clients	consultants	administrators

Implicit Indicators

Implicit Indicator	Environmental aspect	Remarks

Programme for the first workshop

'Workshop talk about environmental indicators for buildings and groups of buildings', Tuesday, 14 August 2001 at the Danish Building and Urban Research Institute

Time	Duration (in min)	What
14.00-14.05	5	Arrival
14.05-14.10	5	Welcome Supervisor DBUR: The objective of the project
14.10-14.15	5	Supervisor DTU: 'Why the subject has to be addressed in a social-scientific way, too
14.15- 14.25	10	Input 1 (Sven): 'The actors and decision-making situations'
14.25-14.40	15	Participants discuss the input contents Supervisors facilitate Sven participates and takes notes
14.40-14.50	10	Input 2 (Sven): 'Which environmental aspects should be considered'?
14.50-15.05	15	Participants discuss the input contents Supervisors facilitate Sven participates and takes notes
15.05-15.15	10	Input 3: 'What is an indicator? What are environmental indicators for buildings? Demands to EIFOB / criteria'
15.15-15.30	15	Participants discuss the input contents Supervisors facilitate Sven participates and takes notes
15.30-15.40	10	Input 4 (Sven): 'How shall the project be continued?'
15.40-15.55	15	Participants discuss the input contents Supervisors facilitate Sven participates and takes notes - End -

Programme for the second workshop

Programme for the second workshop about environmental indicators for buildings and groups of buildings', Wednesday, 28 August 2002, 8.30 a.m. – 12.30 p.m. at DBUR[453]

Some of the presentations will be given in English, the discussions will be in Danish.

Objective of the workshop:

- to share information about the status of EIFOB among the different actors
- to develop ideas for the creation of a coherent set of EIFOB that can be used by all the relevant actors and in all the relevant decision-making situations.
- to get closer to a consensus on EIFOB

General structure of the workshop:

1.) input from Sven, to create a common basis for the work
2.) parallel group work in three small subgroups, each facilitated by Klaus Hansen (DBUR), Morten Elle (DTU) or Sven Dammann (DBUR) (who are also rapporteurs for the groups), aim: to reach consensus – in the subgroup, the participants document the results of their work on a poster.
3.) each group presents its results in plenum, discussion in plenum, attempt to create a consensus in the whole group

The timetable in detail:

Time	what	who and how
15 min 8.30 – 8.45	Breadrolls, tea & coffee	
15 min 8.45-9.00	Welcome Round: the participants introduce themselves presentation of the programme Questions, remarks?	Sven "What you do, in which context you deal with EIFOB." Morten and Klaus at the end. Sven
30 min 9.00 –9.30	Introductory lecture: 'Building houses – constructing indicators – the social construction of environmental indicators for buildings - results of the interviews' objective: To provide a common basis for the work in the small groups	Sven sketching + overheads
10 min 9.30 – 9.40	Round with feedback + questions on the presentation The actual discussions shall take place in the small subgroups.	Sven
10 min 9.40 – 9.50	Short introductions to the three parallel working groups, explaining the objective + the tasks the role of KMS	Sven overheads: the tasks of the group work creating groups, preferably heterogeneous ones
10 min 9.50 – 10.00	Break	

[453] The detailed script as displayed below was for internal use, a less detailed version was distributed to the participants together with the invitation.

70 min 10.00-11.10	Parallel work in three groups, all working on the same tasks, but on different decision-making situations / actors: commenting sections of my scheme "overview 'actors, decision-making situations, considered environmental aspects & indicators'" discussing how to meet the actor-demands sketch a solution for EIFOB, especially for the integration of different sub-indicators into ONE coherent system. make a poster with your comments and the results of your work.	Klaus, Morten and Sven as table hosts and rapporteurs, all the others as participants Material: paper for posters, markers, tape, cards
10 min 11.10 – 11.20	Break	
3 x 10 = 30 min 11.20 – 11.50	Presentation of the session results	the participants themselves
30 min 11.50 – 12.20	Discussion of the session results	Klaus is facilitator, Sven supports him in equal distribution of talking time, Morten is rapporteur
10 min 12.20 – 12. 30	Round: What I learned, what I take home with me, what was important to me. What I liked, what I think could be improved	
12.30	Common Lunch: hosted by DBUR	

Programme for the third workshop on environmental indicators for buildings

Some of the presentations will be given in English, the discussions will be in Danish.

General structure of the workshop:
Part A: feedback on actor analysis, demands, conflicts and consent
(the shorter part, no group work)

Part B: scenarios, exemplifications, conclusions for EIFOB
(The longer part, with group work)
TWO groups:
Criteria for group formation:
heterogeneous (in order to have inter-TF-conflicts *within* each group) + different horizons → *we* (Klaus Hansen (DBUR), Morten Elle (DTU), Sven Damman (DBUR)) should also participate…!)

The timetable in detail:

Time	what	who and how
5 min 9.00 – 9.05	Welcome presentation of the programme	Klaus, Morten, Sven
Part A: feedback on actor analysis, demands, conflicts and consent		
30 min presentation + 25 min feedback = 55 9.05. - 10.00	Introductory lecture + feedback in the course of the lecture the four TFs demands to EIFOB relations between the TFs (conflicts + consent)	Sven **Card-request!**[454] say that there will also be space for in-depth debates in the sub-group sessions of Part B!
Part B: scenarios, exemplifications, conclusions for EIFOB		
20 min 10.00 – 10.20	Introductory presentation: scenarios exemplifications	Sven
10 min 10.20 – 10.30	Short introductions to the three parallel working groups, explaining the objective + the tasks the role of KMS	Sven overheads: the tasks of the groups work creating groups, preferably heterogeneous ones
45 min 10.30 – 11.15	Parallel work in three groups, all working on the same tasks, comment on my presentation and on the material I have mailed on Monday make a poster with your comments and the results of your work.	Klaus, Morten and Sven as table hosts and rapporteurs, all the others as participants Material: paper for posters, markers, tape, cards
15 min 11.15 – 11.30	Here would be time for a short break	
2 x 15 = 30 min 11.30 – 12.00	Presentation of the session results	the participants themselves
30 min 12.00 – 12.30	Discussion of the session results	Klaus is facilitator, Sven supports him in equal distribution of talking time, Morten is rapporteur
12.30	Common Lunch: hosted by DBUR	

[454] A core element of the Metaplan facilitation-method (Lipp et al., 2002): The collection of the participants' contributions on paper cards, which are read aloud and displayed and clustered on posters for visualisation and documentation.

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Danish abstract / Sammenfatning på dansk

Baggrund og formål

Byggeriet bidrager væsentligt til samfundets samlede miljøbelastning. Der er derfor behov for alment accepterede miljøindikatorer for bygninger (”EIFOB” for ”environmental indicators for buildings”), som skal synliggøre bygningers miljømæssige effekter for alle byggeriets parter og derved gøre det nemmere at tage miljøhensyn i de relevante beslutningssituationer.

Formålet med forskningsprojektet var at undersøge:

1. Om, og hvorvidt, der kan opnås konsensus om miljøindikatorer for bygninger – dvs. et fælles sprog for grønt byggeri - blandt de centrale aktører *lokale byggemyndigheder, professionelle bygherrer, bygherrerådgivere, projekterende, administratorer af bygninger og udviklere af miljøindikatorer for bygninger*
2. Hvordan fælles miljøindikatorer for bygninger kan se ud

Undersøgelsen fokuserede på bygninger til boligformål, skoler, daginstitutioner og kontorbygninger i Danmark og de tre beslutningssituationer *lokalisering, projektering* og *renovering*.

Forskningsmetode

For at besvare spørgsmålene er teorien om den sociale konstruktion af teknologi (SCOT) benyttet *på en prospektiv måde*, ligesom projektet generelt har omfattet indsatser indenfor såvel den miljøvidenskabelige sfære som den socialvidenskabelige sfære.

I den miljøvidenskabelige sfære er de væsentlige miljøeffekter af bygninger blevet belyst og eksisterende indikatorsystemer analyseret. Der blev skelnet mellem de tre indikator-principper *livscyklusvurdering (LCA), tjekliste-indikatorer* og *input-output indikatorer.*

I den socialvidenskabelige sfære blev de tre beslutningssituationer *lokalisering, projektering* og *renovering* analyseret med hensyn til deres miljømæssige betydning, datatilgængelighed og relevante beslutningstagere. Desuden blev aktørernes syn på EIFOB samt deres krav til EIFOB undersøgt i kvalitative forskningsinterviews og aktør-workshops .

Resultater: Indikatorer i et socialkonstruktivistisk perspektiv – fire teknologiske rammer

Den kvalitative aktør-undersøgelse blev anvendt til at beskrive de uddannelsesmæssige bagrunde og magtstrukturer, som har en væsentlig indflydelse på aktørernes accept af EIFOB. Desuden blev undersøgelsen anvendt til at definere fire *teknologiske rammer* (på engelsk ”technological frames”), det vil sige fire forskellige opfattelser af EIFOB:

– den PR-orienterede ramme (på engelsk ’public-relations frame’), som hovedsageligt omfatter professionelle byggeherrer og administratorer af bygninger

– den videnskabelige ramme (på engelsk 'scientific frame'), som hovedsageligt omfatter videnskabelige indikator-udviklere og konsulenter med en ingeniøruddannelse
– den æstetisk-holistiske ramme (på engelsk 'aesthetic-holistic frame'), som hovedsageligt omfatter arkitekter
– den sanselige lægmands ramme (på engelsk 'layperson-sensualist frame'), som hovedsageligt omfatter ikke-professionelle byggeherre og brugere af bygninger.

Den PR-orienterede ramme

Hovedmålet for aktørerne i den PR-orienterede ramme er at opnå et positivt image i offentligheden. EIFOB betragtes hovedsageligt som et middel til at dokumentere og kommunikere miljømæssig ansvarlighed over for målgrupperne (de ansatte, kunderne m.fl.) samt et middel til kvalitetssikring, risikomanagement og til at holde forbrugsrelaterede omkostninger nede.

Med hensyn til det miljømæssige indhold af indikatorerne fokuserer aktørerne i denne ramme på indeklima og dyre forbrug i driftsfasen, medens aspekter som kunne sætte spørgsmålstegn ved ens livsstil (for eksempel transport i driftsfasen) undgås. Centrale krav til EIFOB er, at indikatorerne skal kunne tilegnes af målgrupperne, skal være praktisk anvendelige og tillidsvækkende.

Den videnskabelige ramme

Hovedmålet for aktørerne i den videnskabelige ramme er at afsætte naturvidenskabelig og teknisk ekspertise, at vurdere bygninger videnskabeligt og præcist samt at sørge for at iværksatte tiltag, der virkelig fører til miljømæssige forbedringer. Kvantitative, videnskabelige miljøindikatorer for bygninger anses som det eneste pålidelige navigationsværktøj til miljørigtige beslutninger.

Med hensyn til det miljømæssige indhold af indikatorerne fokuserer denne ramme på regionale og globale miljøaspekter (ikke "her og nu" men "der og senere"), fx globale klimaforandringer, ozonnedbryding og fotokemisk ozondannelse, toksicitet mv., samt på affald & ressourceforbrug og indeklima. Men også arealforbrug inklusive biodiversitet og indvirkninger på den lokale dannelse af grundvand anses for relevant.

Centrale krav til EIFOB er, at de skal være videnskabeligt forsvarlige samt præcise og kvantitative, og at hele bygningens livsforløb skal iagttages.

Den æstetisk-holistiske ramme

Den æstetisk-holistiske rammes medlemmer har som hovedmål at forsvare deres position som kompetente generalister, at afværge formgivningsrestriktioner, at afværge kedeligt, dårligt betalt ekstraarbejde, og overordnet at det æstetisk-holistiske paradigme bliver accepteret (i opposition til det rationalistiske paradigme).

Nogle rammens aktører sætter generelt spørgsmålstegn ved meningen med EIFOB, som bliver anset som en trussel i tre henseender: En trussel mod arkitekternes kompetence og magt til at definere "økologisk byggeri", en trussel mod formgivningsfriheden og som en potentiel merarbejde udenfor deres kompetenceområde.

Når dette er sagt, foretrækker rammens medlemmer kvalitative tjeklisteindikatorer, som baserer sig på konkrete tiltag og principper; indikatorer som giver entydige og enkle svar på de konkrete formgivningsspørgsmål, som dukker op i denne ramme aktørers daglige arbejde.

Med hensyn til den miljømæssige indhold af indikatorerne er det karakteristisk for den æstetisk-holistiske ramme at den ikke opererer med klart definerede miljøbegreber (miljø ses i nøje sammenhæng med generelle funktionelle og æstetiske aspekter), og at dette opfattes som evnen til at se ting på en holistisk måde – i modsætning til den "urimeligt fragmenterede" tilgang som tilskrives ingeniørerne. Bortset fra dette iagttages "lokale" miljøaspekter her og nu (indeklima og sundhed, æstetisk kvalitet, psykologisk indeklima mv.); men også drivhuseffekt og ressourceforbrug accepteres generelt som relevant at iagttage.

Centrale krav til EIFOB er, at de skal være let anvendelige og ikke må kræve meget arbejde af den slags, som aktørerne i denne ramme normalt ikke kan lide, at de ikke må indskrænke kreativiteten og formgivningsfriheden, at de skal være indenfor denne aktørgruppens kompetenceområde og at de fortrinsvis skal være kvalitative, ikke kvantitative.

Den sanselige lægmandsgruppe

Hovedmålene for aktørerne i den sanselige lægmandsgruppe (i økologiske bebyggelses projekter) er at skabe identitet og social samhørighed blandt beboerne ved at give bebyggelsen en "bæredygtig" eller "økologisk" identitet. Denne rammehar sit fokus på den fysiske mærkbarhed af effekter af miljøindsatsen og miljøadfærden (i modsætning til den rationalistiske videnskabelige ramme). Konceptet med kvantitative eksplicitte EIFOB er fremmed og normalt ikke en relevant kategori, eftersom denne rammes aktører er vant til at operere med implicitte kvalitative indikatorer, som tjener som en "brand" eller "livsstil-label" for ens bygning eller bebyggelse.

Aktørerne i den sanselige lægmandsramme har et ambivalent syn på kvantitative, eksplicitte EIFOB: På den ene side anses EIFOB som et værktøj, der er nyttigt for rådgivende eksperter men uforståeligt for lægmænd. På den anden side anses EIFOB som irriterende og ikke altid troværdige, fordi de sætter spørgsmålstegn ved ens yndlingsløsninger og ens egne vurderinger. Opmærksomheden rettes mod lokale miljøtemaer ("her og nu"), dvs. mod konkrete tiltag og principper, som er synlige/mærkbare, har en symbolsk betydning og taler til drømmen om et økologisk hjem og en økologisk livsstil, samt mod indeklima og lokale genbrugssystemer (for eksempel for organisk affald).

Centrale krav til EIFOB er, at de er nemme at forstå, fortrinsvis kvalitative, ikke kvantitativ, troværdige og at de tager fat i miljøemner som direkte vedkommer aktørernes livsverden og beslutningstagning.

Konfliktlinier og konsensusområder

Diskussionen af de fire teknologiske rammers krav afslører følgende konfliktlinier:

- Transparent, veldokumenterede og konsistente (den PR-orienterede og den videnskabelige ramme) kontra vage ad-hoc indikatorer (den æstetisk-holistiske ramme)
- Enkle og nemme at forstå (den PR-orienterede, den æstetisk-holistiske og den sanselige lægmandsramme) kontra videnskabeligt forsvarlige og tilstrækkeligt detaljerede til at afspejle emnets kompleksitet (den videnskabelige ramme)
- Tjekliste-indikatorer (den æstetisk-holistiske og den sanselige lægmand ramme) kontra livscyklusvurdering (den videnskabelige ramme)
- Baseret på alment kendte enheder (den PR-orienterede og den sanselige lægmandsramme) kontra brug af enheder som videnskabsfolk er fortrolige med (den videnskabelige ramme)

Herudover er der uenighed om æstetik skulle være inkluderet i det miljømæssige indhold af indikatorerne, og om systemgrænserne for EIFOB skal omfatte den transport, der induceres i bygningens brugsfase.

Men der er konsensus med hensyn til det generelle miljømæssige indhold af EIFOB. Dog blev det også klart, at denne konsensus er temmelig svag, at aktører har forskellige miljømæssige prioriteter og taler om miljøemner i "forskellige sprog". Med hensyn til relationerne mellem de teknologiske rammer viser sammenligningen at:

- den videnskabelige og den PR-orienterede ramme har en temmelig tæt relation,
- den PR-orienterede og den sanselige lægmands ramme har en tæt relation
- den æstetisk-holistiske og den PR-orienterede ramme har en tæt men svag relation
- den videnskabelige og den æstetisk-holistiske ramme er temmelig fjernt fra hinanden og også
- den videnskabelige og den sanselige lægmands ramme er fjernt fra hinanden.

Disse resultater blev anvendt til så at sige at tegne et kort over det socioteknologiske landskab omkring EIFOB. Derudover viste aktørundersøgelsen en forøgelse af den sociale viden blandt aktører i den videnskabelige ramme og en forøgelse af den miljøfaglige viden hos aktørerne i den PR-orienterede, den æstetisk-holistiske og den sanselige lægmands ramme som to igangværende udviklinger.

Konklusion

I lyset af undersøgelsens resultater er svaret på det første spørgsmål vedrørende muligheden for at opnå konsensus om miljøindikatorer for bygninger, at det er usandsynligt, at man i den nærmeste fremtid kan lukke EIFOB-debatten på grundlag af en omfattende konsensus blandt de involverede aktører.

I stedet kan de fire teknologiske rammer enten forblive separerede og arbejde med midlertidige, partielle overenskomster om EIFOB, eller tre af de fire teknologiske rammer kan opnå vedvarende overenskomster om EIFOB, som den isolerede "outsider" eventuelt tilslutter sig på et tidspunkt.

Disse to muligheder er i forskningsprojektet blevet belyst og eksemplificeret med mulige indikatorer for miljøaspekterne "energi" og "indeluftkvalitet" i de tre scenarier:

- 'Postmodern Relations', i hvilket den nuværende situation med en mangfoldighed af indikatorsystemer, som bliver brugt parallelt, fortsætter og den "flersprogede aktør" mindsker nogle af de problemer, der opstå som følge af det manglende "fællessprog"
- 'Science goes public', i hvilket den videnskabelige, den PR-orienterede og den sanselige lægmands ramme bliver enige om indikatorer, som baserer sig på livscyklusvurdering, et bredt miljømæssigt indhold og vide systemgrænser, som imødekommer den PR-orienterede og den sanselige lægmands rammens krav om enkelhed ved at tilbyde tre forskellige aggregeringsniveauer
- 'Keep it simple', i hvilket den PR-orienterede, den æstetisk-holistiske og den sanselige lægmands ramme bliver enige om enkle tjekliste-indikatorer, som baserer sig på konkrete tiltag, med kun to aggregeringsniveauer og snævre systemgrænser.

Afhandlingen afsluttes med en sammenfatning, en refleksion over implikationerne af de tre scenarier og perspektiver med hensyn til en fortsættelse af dette projekt på den virkelige arena, en udarbejdelse af den prospektive brug af SCOT og områder for yderligere indikatorforskning og udvikling.

Whenever we shop, the products we consider buying are labelled with the economical price we have to pay if we want to purchase them – an important parameter in our decisions as purchasers.
The increasing awareness for environmental limits and backlashes of human activities also in the building sector have fostered the wish to define 'the ecological price' of a building as a help for environmental conscious decision-making.
In a social constructivist approach this Ph.D. thesis looks across and beyond the manifold existing approaches for environmental indicators for buildings. It acknowledges that among the relevant actors in the building sector the scientific view is only one perspective among others.
This study combines natural-scientific knowledge with social-scientific knowledge, obtained in a close co-operation with actors in the building sector in Denmark and a research period in the Netherlands. It identifies lines of conflict and areas of consent between the relevant actors and elaborates scenarios for a possible closure of ongoing debate about environmental indicators for buildings.

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