

Strategy for Climate Change Adaptation

Rasmussen, Torben Valdbjørn

Published in:
CIB Proceedings

Publication date:
2014

Document Version
Publisher's PDF, also known as Version of record

[Link to publication from Aalborg University](#)

Citation for published version (APA):
Rasmussen, T. V. (2014). Strategy for Climate Change Adaptation. *CIB Proceedings*.

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal -

Take down policy

If you believe that this document breaches copyright please contact us at vbn@aub.aau.dk providing details, and we will remove access to the work immediately and investigate your claim.



Strategy for Climate Change Adaptation

Rasmussen, Torben Valdbjørn

Danish Building Research Institute, SBI, Aalborg University, Copenhagen, Denmark

Abstract: *It has been a world priority for more than a decade to reduce greenhouse gas emissions within the frame of the Kyoto Protocol. However, since the Kyoto Protocol it has proved difficult to reach an international consensus at the Conference of the Parties on the continuation of a global agreement. This absence of an agreement calls for adaptation to climate change. Emphasis should be put on buildings, as they play a vital economic and social role in society and are vulnerable to climate change. Therefore, the building stock deserves its own policy and implementation plans as well as tools that enable adequate and cost-efficient adaptation to climate change. This paper explains the need for climate change adaptation of the building stock and suggests a pattern for a strategic approach to how to reach the climate change adaptation needed. The suggested and presented need of a strategic approach is based on three main initiatives consisting of the need to examine the potential impacts of climate change on the building stock, the need to assess and develop a roadmap of current and future adaptation measures that can withstand the effects of climate change, and the need to engage relevant stakeholders in the private and public sectors. Furthermore, the paper describes some issues that must be addressed in case a strategic approach is not developed, as the building sector is continuously investing in measures to adapt to climate change as impacts emerge.*

Keywords: *Adaptation, Buildings, Climate change, Planning, Strategy*

Introduction

Climate change and measures to mitigate its effects have been a world priority for more than a decade. They have been implemented partly by trying to reduce greenhouse gas emissions on an international level and partly through individual national initiatives. On a world priority scale, efforts to mitigate climate change impacts have focused on reducing greenhouse gas emissions within the frame of the Kyoto Protocol, [1]. The Kyoto Protocol came into force on 16 February, 2005. Industrialised countries signatory to the Protocol were obliged to limit their emissions of greenhouse gases between 2008 and 2012. However, reaching a new global international agreement like the Kyoto Protocol, taking over from 2013 and on, has failed.

The effort of elaborating a new climate policy agreement failed at the Conference of the Parties, COP meetings held in 2009 in Copenhagen (COP15), in 2010 in Mexico City (COP16), in 2011 in Durban (COP17) and in 2012 in Doha (COP18). The intention was to continue to follow the Kyoto Protocol by introducing new obligations to limit emissions of greenhouse gases after 2012. At COP18 it was stated that from 2013 only the European Union, EU Member States, Australia, Switzerland and eight other industrialised countries will continue the Kyoto Protocol to 2020 including new Kyoto obligations to limit emissions of greenhouse gases, [2]. In total, these countries are responsible for 15% of all emissions of greenhouse gases. Against all odds, the global emission of greenhouse gases rose by 2.6% in 2012, reaching a level higher than 50% above the level measured in 1990, [3]. However, at COP17 the parties agreed on the development of a global, climate agreement that must



include all the countries with the largest emissions of greenhouse gases. The global climate agreement needs to be agreed on in 2015 and come into force in 2020. At COP 15, a Green Fund was agreed and at COP17 the fund was designed, with the purpose of aiding underdeveloped countries in meeting the challenges of climate change. The EU countries agreed independently on their own climate visions, [4]. The ambition was global and aimed to limit global warming to a maximum of 2°C. In this vision, industrial countries need to reduce their emissions of greenhouse gases by a total of 80-95% by 2050 compared with 1990 emissions.

The lack of global agreement on reducing global warming demands a strategic approach to climate change adaptation that complies with the climate change impact. As buildings play a vital economic and social role in society and are vulnerable to climate change emphasis should be put on buildings. The building stock represents 60-70%, [5] of the economic capital stock. Substantial losses of building stock or loss of productivity will have important implications for the economy at large. For instance, the Danish building stock has a replacement value of approximately €1,600 to €1,850 billion, [6], excluding infrastructure such as roads, rails, bridges, embankments, harbours and sewers. The value was determined in 2010 for the whole country based on the built-up area, [7] with a mean value of 2,400 €/m², equalling the value of €325 thousand for each inhabitant. This is equivalent to approximately €216,000 billion for all EU Member States. Climate change has already been observed in Europe, [8] and is expected to continue noticeably during this century. Even if – somewhat surprisingly – the implementation of increasingly radical emission reduction measures would gain truly global momentum within the next 10 years, and lead to radical greenhouse gas emission reductions in the next decades, global warming and climate change will continue for many decades, if not the entire century. Consequently, the need to develop a strategic approach to climate change adaptation of existing buildings becomes urgent not only in the EU Member States but in all regions of the world.

The paper suggests and outlines actions needed for developing a broad strategic approach for existing buildings to withstand climate change. As effects of climate change are a serious challenge for the design and upgrading of buildings, adaptation must include key requirements dictated by the effects of climate change, which for the time being are uncertain and evaluated differently.

Climate Impacts

The adaptation needed in the built environment is closely related to the projected climate impacts. Available emission scenarios A2 and B2, [9, 10], as well as the EU2C, [4] were used as a basis for the strategy for adapting to a changing climate, as they are considered the most likely by the EU Member States. Global surface warming presented in the Intergovernmental Panel on Climate Change, IPCC 4th Assessment report, [9] is shown in Figure 1. Scenario A2 assumes a world with little global economic integration and slow development and distribution of effective technological solutions that can reduce the emissions of greenhouse gases. Furthermore, it is assumed that population growth will continue to be high, [9]. Like

Scenario A2, Scenario B2 assumes a world with little global economic integration and a slow development and distribution of effective technological solutions that can reduce the emissions of greenhouse gases. Scenario B2 considers a situation with more reduced emissions of greenhouse gases than Scenario A2 as a result of moderate population growth and more environmentally conscious consumers, [9]. Scenario EU2C is the scenario that the EU Member States follow as their climate vision, [4]. The ambition aimed to limit global warming to a maximum of 2°C. This scenario assumes a world-wide implementation of a large reduction of the emissions of greenhouse gases. Consequently, it is stated that global warming will be limited to a maximum of 2°C, [9].

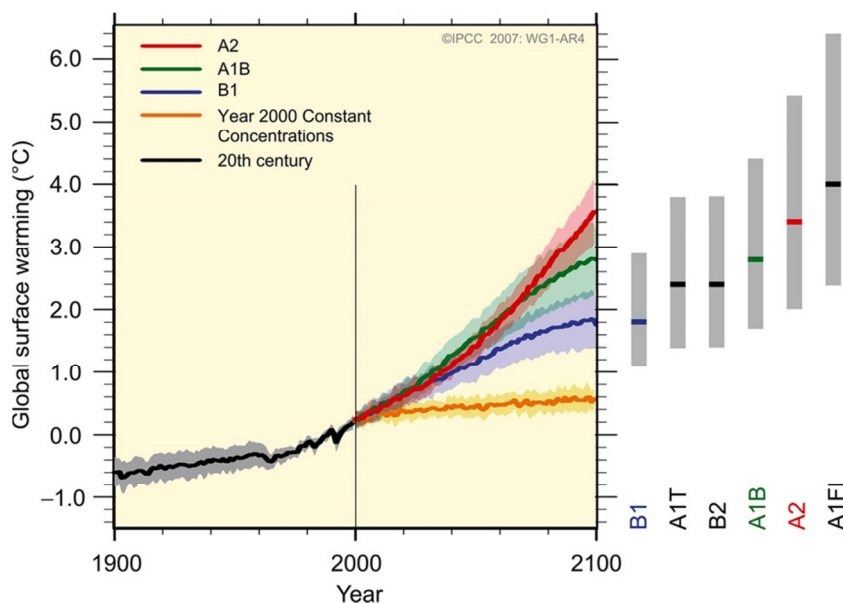


Figure 1. Multi-model averages and assessed ranges for surface warming, figure SPM.5 in the IPCC 4th assessment report. Solid lines are multi-model global averages of surface warming (relative to 1980 and 1999) for Scenarios A2, A1B and B1, shown as a continuation of the 20th century simulations. Shading denotes the ± 1 standard deviation range of individual model annual averages. The orange line shows the experiment where concentrations were held constant at year 2000 values. The grey bars at right indicate the best estimate (solid line within each bar) and the likely range assessed for the 6 SRES marker scenarios. The assessment of the best estimate and likely ranges in the grey bars includes the AOGCMs in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints, IPCC 4th Assessment report.

Most important effects of climate change

For the building stock in the EU region the five most important effects of climate change are:

- a. More frequent and heavier rain fall that can cause for instance water damage to buildings, technical equipment and technical plants along with the need for accumulation of rainwater and controlled draining of water
- b. More extreme temperatures and heat waves of long duration that will create an indoor environment that can pose a health risk for inhabitants with a weak constitution and create an unacceptable indoor environment for others. More hours of sun create the opportunity to produce energy

- c. Warmer and more humid winters that stimulate mould growth and increase the activities of house-dust mites, which can result in inconvenience and induce allergic reactions among inhabitants
- d. More frequent and heavier storms that can result in serious damage to buildings
- e. Extreme snowfall, which can lead to damaged buildings and to collapse of buildings.

Apart from the five most important effects of climate change, single events like a heavy windstorm, extreme snowfall and heavier rain fall seem to be more frequent.

Heavy windstorm

A heavy windstorm passed over the southern half of Denmark on the 3 December 1999 and caused significant damage to a large number of buildings, see figure 2. The storm is regarded as the worst one for the past 100 years. The mean wind speed slightly exceeded the characteristic value of the design loads given in the load and safety code, [11]. This value was expected to be exceeded only once every 50 years on average.



Figure 2. Damage to a building after the heavy windstorm passed over the southern half of Denmark on 3 December 1999.



Figure 3. Damage to a sports arena after the roof collapsed, caused by heavy snow loads in 2007.



Figure 4. Flooding after a heavy rainfall in 2009 in the northern part of Zealand.

Extreme snowfall

In winter 2007 in Denmark, unusually strong winds packed falling snow so hard in snowdrifts that the roof of 12 large buildings collapsed, see figure 3. Snowdrifts were packed to exceed the weight of 400 kg/m^3 and combined with a change in weather and rain it was expected that the weight at exposed locations increased to a tonne per m^2 . The combination of the high mean wind speed and loads from local snowdrifts on the roof might have slightly exceeded the characteristic value in the design loads given in the load and safety code, [11]. On average, these combinations of load values are not expected at the design stage of these buildings.

Heavier rain fall

Heavy rain fall has passed over Denmark in recent years, see figure 4. Such a heavy rain fall passed over Denmark on 2 July 2011 and is regarded as one of the heaviest ever measured in Denmark. Within a few hours, 150 mm rain fell which is twice the normal amount of rain falling in the whole month of July. Furthermore, 50 mm fell within 30 minutes and the highest intensity was measured at more than 3 millimetres per minute over a period of 10 minutes.

Model for a strategic approach to climate change adaptation

A model for a strategic approach to climate change adaptation of buildings requires actions that besides project management and project communication and dissemination include three main initiatives consisting of the need to examine the potential impacts of climate change on the building stock, to assess and develop a roadmap of current and future adaptation measures that can withstand the effects of climate change, and to engage relevant stakeholders in the private and public sectors.

Examining potential impacts of climate change on the building stock

The main objective of an examination is to provide background knowledge on climate change by developing assessment methodologies to delineate and evaluate the likely impacts of future climate change on the building stock. Long-term climate change as well as single extreme weather events associated with climate change will increase destruction of buildings and need to be evaluated according to lifetime issues.

Building typology must be exhaustively listed and used to implement a set of scenarios on the possible evolution of the building stock. Specification and analysis of climate change relevant for the building stock in the specific geographical region must be performed as well as determination of uncertainties in climate change. Finally, the collected extensive knowledge can be used to bring together information including building typology, climate impact for building stock scenarios and uncertainty factors, of both natural (e.g. climate variability) and human origin (e.g. impacts on the vulnerability thresholds of an ageing population inhabiting the building stock), in order to develop a standard methodology to assess the vulnerability of the building stock.

Building typology should include descriptions of buildings according to age, size and other parameters relevant to climate change, such as location in or close to areas exposed to weather



events, for instance coastlines, rivers, mountain areas, storm tracks, and vegetation in arid areas.

Assessing and developing a roadmap of adaptation measures

An exhaustive list should be established that comprises current and future adaptation measures to climate change for buildings, based on the results of the assessment carried out during the examination for potential impacts of climate change on the building stock. Such measures can be used to develop a comprehensive assessment framework of adaptation measures, including their economic, social, environmental, operational and technical impacts. It can also be used as a key input to a decision-making tool that needs to be provided to stimulate actions among stakeholders in the private and public sectors.

Feasible adaptation measures should be exhaustively listed and supported by technical assessments including their effectiveness, their feasibility, their conditions for optimal use and their applicability in different geographic locations. Furthermore, it is important to include cost-benefit analyses to balance the overall strengths and weaknesses of each of the feasible adaptation measures, as well as related macro-economic impact assessments. If any, such validations need to include support policies at government and local levels to motivate to the adaptation to climate change.

Engage relevant stakeholders in the private and public sectors

It is hugely important to engage decision-makers in the building stock issue, thereby providing a visual decision-support tool with user-friendly access that clearly depict the economic impacts of adaptation measures to climate change for the building sector and their uncertainties. Such a tool needs an optimisation algorithm in order to be able to suggest an optimal solution for a variety of climate scenarios attached to feasible single or interconnected adaptation measures for a particular building identified by its building typology. To engage end-users, the tool needs to provide a set of optimised scenarios that take into account the technologies to be installed and their responsiveness over the buildings' life. Such a simulation environment should also calculate the capital cost versus the operational cost taking into account the various adaptation measures in each optimal scenario. It should also provide decision support from a return-on-investment perspective regarding environmental impact, energy savings and contribution to smart cities or other benefits. End-users, recognised as policy-makers, decision-makers from private companies, urban planners as well as the academic community and the general public, should be helped to explore possibilities and be assisted in the optimal set of decisions when adapting to climate change.

Discussion

Buildings play a vital economic and social role in most industrialised countries. In all EU Member States, it is estimated that buildings have a replacement value of approx. €216,000 billion. The consequences that climate impacts may have on the existing built environment are not known, as climate impacts and hence the vulnerability of the existing building stock has yet to be investigated. This leaves society with major challenges that, if not addressed and



taken into account, will grow far more serious as climate change progresses. The need for a strategic approach becomes even more urgent now that the effort of elaborating a global agreement on climate policy and reducing greenhouse gases failed at the COP meeting in Doha, 2012. Until a strategic approach to climate change adaptation has been launched, initiatives to challenge the climate impacts will be ad-hoc and stand-alone initiatives.

Many resources have been spent on defining data relevant for the building sector regarding the impact of climate change, and ever more data are needed as assumptions change over time. Assumptions are closely related to the successful mitigation of climate impacts. The impact of climate change on the built environment is unknown and there are inevitably degrees of uncertainty associated with individual parameters such as temperature, precipitation, wind speed, relative humidity, solar radiation or soil moisture. In addition to the scenarios describing projected climate impacts, most countries have already witnessed extreme single events. Single events have been more intense than predicted. Data clearly show a rise in precipitation in the period from 1874 to 2010, [12].

Observations from the last 100 years show changes in the geographic pattern of precipitation globally. The connection between a warmer climate and heavier rainfall is confirmed by several studies. Some studies even estimate that the change in the total amount, seasonal variations and the intensity of rainfall estimated by the IPCC, [13] is underestimated both for the tropics and for Europe, [14, 15].

Without a strategic approach, building owners have at present no knowledge of which climate impacts would be necessary to address and which scenarios are the most likely to occur. Existing buildings and buildings constructed today should be able to withstand climate impacts at best until 2100, as the main structures of buildings are expected to last for at least 100 years. The challenge of contemporary building requirements is that they should take account of climate impacts for a period corresponding to the service life of the individual building components. Climate impacts therefore pose a serious problem in relation to the design and upgrading of buildings. Climate change scenarios foresee an increased maximum wind load. A heavier wind load calls for stronger constructions. Compared with the safety margin of load-bearing structures in buildings, a 20% increase in the wind load is not critical. However, the heavy storm that hit Denmark in 1999 reached the limit of today's design wind standard and cost insurance companies sums that equal about 10% of the yearly investment in buildings in Denmark, [16]. In addition, it was found that the strengths of the damaged buildings was about half of what is required according to the Danish Building Regulations, [17]. Therefore, a 20% increase of the wind load is supposed to result in a situation for which adaptation measures must be developed, both for existing buildings and for buildings that are to be designed for climate impacts. Such adaptation measures are expensive, but far less expensive than rebuilding damaged buildings after a storm worse than the storm in Denmark in 1999.



Climate change scenarios also foresees more frequent and heavier rain fall in Denmark. Depending on where the rain falls, the damage is more or less costly. The damages paid by the insurance companies resulting from heavy rain falls in the period from 1 June to 15 September in the years 2006 to 2011 reached €1 billion. However, the heavy rain fall that hit Copenhagen on 2 July 2011 was far the most costly with damages amounting to €658 million.

Another important climate impact is the possible threat posed by a more humid and warmer climate. This would challenge the building design that provides humans with thermal comfort, good indoor air quality, and durable constructions. Such challenges are unlikely to be met at moderate maintenance costs.

Circumstances demand a continued need for a strategic approach to impacts of climate change and optimised adaptation measures for buildings that also need to be implemented in building requirements generally.

Conclusion and Further Research

The absence of a global agreement on the reduction of the emissions of greenhouse gases makes it difficult to expect anything but a global economically regulated use of available fossil fuels such as oil, coal and gas. Due to the shortage of available fossil fuels together with an increasing demand and higher production costs, the same economic conditions will drive policy for energy consumption and the development of new and other energy-supply sources. However, the economically regulated use of fossil fuels and hence the emissions of greenhouse gases will lead to climate impacts that are very difficult to forecast and will pose threats as well as opportunities for the design of buildings. Therefore, it is unknown whether or not existing buildings and buildings constructed today will be able to withstand the effects of climate change in 2100 as the main structures of buildings are expected to last for at least 100 years.

As climate change progresses, its effects will change requirements to buildings. However, as the impact of climate change is unknown, it is very difficult to forecast the necessary building requirements. This will leave investments, necessary for the preservation of the value of the building stock to become ad-hoc and stand-alone investments as future climate impacts emerge. Thus the opportunity is lost to upgrade a building to meet key climate impacts as part of the maintenance, which increases the costs of necessary measures. Therefore, the uncertainty of the scenarios leaves major challenges that, if not addressed and taken into account at the building design stage will grow far more serious as climate change progresses.

A continuous strategic approach to climate change and adaptation grows ever more urgent as to ensure that the vital economic and social role of buildings in society is kept. Until a strategic approach is launched, initiatives to challenge climate impacts will leave end-users as policy-makers, decision-makers from private companies, urban planners as well as public and private building owners left at a crossroads without knowledge of what climate impacts to address and what scenarios are most likely to occur. A strategic approach needs to be

developed to help explore possibilities and to assist in the optimal set of decisions when adapting to climate change.

Circumstances related to national and international policy, economics, energy consumption, emissions of greenhouse gases and the development of new energy-supply sources demand a continued strategic approach to climate impacts and adaptation for existing buildings as well as to building requirements. Further detailed descriptions of the ideas given in this article are found in the proposal Strategic approach to climate change adaptation in the building sector, connected with the ENV.2013.6.1-6 Economics of Adaptation of Climate Change – FP7-ENV-2013 programme, on which this article is based.

Acknowledgement

The work on which this paper is based was supported by the Danish Building Research Institute, SBI, Department of Construction and Health at Aalborg University and the ENV.2013.6.1-6 Economics of Adaptation of Climate Change – FP7-ENV-2013. The proposal Strategic approach to climate change adaptation in the building sector is abbreviated to Climatebuild.

References

- [1] UN (United Nations) (1998), 'Kyoto protocol to the United Nations framework convention on climate change', United Nations headquarters (official headquarters of the United Nations), Turtle Bay neighborhood of Manhattan, First Avenue, East 42nd Street, East 48th Street, East River, New York, United States, (Document available at: <http://unfccc.int/resource/docs/convkp/kpeng.pdf>).
- [2] Doha – news (2012), <http://www.cop18.qa/news/singlestory.aspx?id=297> , http://unfccc.int/meetings/doha_nov_2012/meeting/6815.php#decisions. Doha – news, Doha.
- [3] Børsen (2012), 9. december, http://borsen.dk/nyheder/politik/artikel/1/247580/cop18_kyotoaftalen_er_forlaenget_til_2020.html, Børsen, Copenhagen, Denmark.
- [4] CEU (2009), 'Presidency conclusions', 15265/1/09 REV1 CONCL 3, Council of the European Union (CEU), Brussels, Belgium.
- [5] Inferred from European Central Bank (2011), data and corroborated by Finnish statistics.
- [6] Valdbjørn Rasmussen, T. & de Place Hansen E. J. (2011), 'Climate Change – Mitigating Effects vs. Adapting to Climate Change', World sustainable building conference Proceedings– SB11, 18-21 October 2011, Helsinki.
- [7] Statistics Denmark (Danmarks Statistik) (2010), 'Statistikbank', Danmarks Statistik, Sejrøgade 11, Copenhagen, Denmark.
- [8] European Environmental Agency EEA (2012), 'Climate Change, Impacts and Vulnerability in Europe 2012 – an indicator based report', EEA Report 12/2012, Copenhagen.
- [9] Nakicenovic, N., Alcamo, J., Davis, G., de Vries, B., Fenhann, J., Gaffin, S., Gregory, K., Grübler, A., Jung, T. Y., Kram, T., la Rovere, E. L., Michaelis, L., Mori, S., Morita,

- T., Pepper, W., Pitcher, H., Price, L., Raihi, K., Roehrl, A., Rogner, H-H., Sankovski, A., Schlesinger, M., Shukla, P., Smith, S., Swart, R., van Rooijen, S., Victor, N. & Dadi Z. (2000), 'IPCC Special Report on Emissions Scenarios', Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 599 p.
- [10] DMI (2005), 'Prediction of Regional Scenarios and Uncertainties for Defining European Climate Change Risks and Effects', (PRUDENCE), Final Report 2005, Danish Meteorological Institute (Danmarks Meteorologiske Institut), Lyngbyvej 100, Copenhagen, Denmark.
- [11] Danish Standard (1998), 'Norm for last på konstruktioner', (4. udg.), (DS 410:1998), Dansk Standard, København.
- [12] Drews, M., Boberg, F., Cappelen, J., Christensen, O.B., Christensen, J.H, Lundholm, S.C. & Olesen, M. (2011), 'Fremtidige nedbørsændringer i Danmark - Fremtidige nedbørsændringer i Danmark', Digital ISBN: 978-87-7478-599-6, ISSN: 1399-1957 Versionsdato: 01.09.2011, Danish Meteorological Institute (Danmarks Meteorologiske Institut), Lyngbyvej 100, Copenhagen, Denmark.
- [13] Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K. B., Tignor, M. & Miller, H. L. (Eds.) (2007), IPCC: Climate Change 2007: 'The Physical Science Basis', Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, University Press, Cambridge, United Kingdom and New York, NY, USA, p. 996.
- [14] Allan, R.P. & Soden, B.J. (2008), 'Atmospheric warming and the amplification of precipitation extremes', Science, 321(5895), pp. 1481-1484.
- [15] Lenderink, G. & van Meijgaard, E. (2008), 'Increase in hourly precipitation extremes beyond expectations from temperature changes', Nature Geoscience, 1, 511–514.
- [16] Nielsen, J. (2006), 'On the design of buildings in relation to climate change', World Conference on Accelerating Excellence in the Built Environment, 2-4 October, Birmingham, UK.
- [17] Munch-Andersen, J. & Buhelt, M. (2000). 'Stormskader på bygninger', By og Byg Resultater 001, Danish Building and Urban Research, (Statens Byggeforskningsinstitut), Dr. Neergaards Vej 15, Hørsholm, Denmark.