THE HOUSING COMPLEX AS A FIELD FOR SUSTAINABLE ARCHITECTURAL DESIGN

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A housing complex, consisting of several homes build together as a single development, has great potential for sustainable architectural design. Due to its size, the housing complex may constitute its own microclimate and topography, which can benefit climate mitigation and climate adaptation crucial to environmental sustainability. With its level of scale mid between the home and the city, it connects the private and the public, which is crucial to social sustainability. The fact that it is a single development means that you can design for all this in one take if you are able to combine closely the physical, social and aesthetic aspects of architecture in an integrated design. A holistic view on construction and economy may offer long-term savings addressing also economical sustainability. It spite of such broad potential, housing complex design rarely recognizes as a mean of sustainability. This paper intends to shed some light on the sustainable architectural potentials including aspects as urban density, microclimate, outdoor stay, private and public zones, exergy conditions and passive solar.

Keywords: Housing complex, architecture, environmental and social sustainability, integrated design.

Introduction

A housing complex, consisting of several homes build together as a single development, has great potential for sustainable architectural design. Due to its size, the housing complex may constitute its own microclimate and topography, which can benefit climate mitigation and climate adaptation crucial to environmental sustainability. With its level of scale mid between the home and the city, it connects the private and the public, which is crucial to social sustainability. The fact that it is a single development means that you can design for all this in one take if you are able to combine closely the physical, social and aesthetic aspects of architecture. A holistic view on construction and economy may offer long-term savings addressing also economical sustainability. It spite of such broad potential, housing complex design is rarely recognized as a mean of sustainability. This paper intends to shed some light on the potentials.

Scope, methods and limitations

This paper aims to encircle the major aspects of sustainable architectural design of housing complexes based on literature studies and empirical research. Addressing such very broad subjects is critical from a research point of view as there is an evident risk of being superficial. On the other hand, a broad approach is necessary if to highlight the multi-disciplinary character of architectural sustainable practice and the urge for transdisciplinary cooperation in the design process. The paper only deal with the design of new housing complexes, not the refurbishment of existing housing complexes, though existing housing may have huge potentials for sustainable improvement. Neither does the paper deal with different sustainable certification tools such as DGNB, BREEAM or HQE, though they may well apply as check lists during architectural design. Engineering solutions are mentioned only if they carry architectural consequences.

Basic terms

Housing and housing design involves a multitude of stakeholders from the fields of politics, finances, sociology, occupancy, city planning, architecture and engineering. Each field tend to have a mindset and vocabulary of its own, and certain phrases may have different connotations depending on the professional and national context, so firstly the basic terms of 'housing complex', 'sustainable' and 'architectural' needs clarification.

A *housing complex* is in this paper defined as 'a group of homes and other buildings built together as a single development'[1]. The definition does not exclude a minor percentage of non-residential functions. In UK, USA and other countries 'housing' has strong connotations of being 'social housing' or 'public housing' for low-income households, often deprived of much architectural ambition, just providing roof over the head and some practical amenities. In other societies such as Vienna or the Scandinavian countries, housing - be it 'social' or not - has through the twentieth century up to present day been a highly esteemed architectural task. In this article, the central point is not ownership or social class but rather 'complex', the fact that housing units are designed and fit together in a complex way.

While urban housing historically works as the more anonymous parts of the urban tissue providing the background for urban plazas and outstanding buildings such as churches or town halls, housing complexes has in later years in some cases taken on more iconic outlooks with forms that may resemble i.e. a whale[2] or a mountain[3]. This indicate a broad potential for architectural form. Central in the perspective of sustainable architecture is that housing complexes often constitute single developments that are so huge that one can design for and establish specific microclimates and social communities.

The UN World Commission on Environment and Development in 1987 defined *sustainable* development as a 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'[4] and identified three major aspects, namely environmental, social and economic sustainability. The definition is very broad and difficult to operate from, causing Herman Daly to settle three operational principles for *environmental sustainability*: Sustainable use of renewable resources means that the pace should not be faster than the rate at which they regenerate. Sustainable use of non-renewable resources means that the pace should not be faster than the rate at which their renewable substitutes can be put in place. Sustainable rate of emission for pollution and wastes means that it should not be faster than the pace at which natural systems can absorb them, recycle them, or render them harmless.[5]

Applying the three principles to housing, especially the two last are causing major concerns. Renewable resources mainly in the form of wood goes into construction of buildings. European forests have increased in area by 17 million hectares between 1990 and 2015 thus regenerating at a satisfying pace. Tropical wood constitutes a minor part of building finishes and is often harvested without regeneration unless FSC-certified, but in general the first principle concerning non-renewable resources is relatively easy to meet. *Non-renewable resources* covers all minerals and thereby the majority of contemporary building materials including concrete, brick stones and metals. There are short supply horizons for a number of metals, but locally also large-quantity materials like sand and clay are increasingly hard to get, extraction causing major impact on environment and landscape. Fossil fuels are limited non-renewable resources used in all phases of a buildings lifetime from extraction of raw materials through building use to demolition. The consumption of fossil fuels causes greenhouse effect, which is an enormous *pollution* problem threatening eco-systems and human civilization with global average temperatures expected to rise three to four degrees in the twenty first century[6]. *Climate mitigation* has been on the sustainable as well as the architectural agenda since the mid-nineties, while *climate adaptation* of buildings is still a relatively new concern.

Housing complexes represent large investments by i.e. private developers or housing organizations and the financial set-up lies beyond the scope of building design. However, the balance between construction economy and in-use economy does not, as the appliance of in-adequate constructions and non-durable materials may cause huge maintenance costs and as the cost of i.e. extra insulation may heavily reduce heating costs. In the perspective of *economic sustainability* of housing complexes, total economy encompassing construction as well as operational and maintenance costs is a central approach - and a possible design driver.

Social sustainability has been defined as 'a process for creating sustainable successful places that promote wellbeing, by understanding what people need from the places they live and work. Social sustainability combines design of the physical realm with design of the social world – infrastructure to support social and cultural life, social amenities, systems for citizen engagement, and space for people and places to evolve.'[7] Although this definition aims for larger entities such as cities or neighborhoods, they are relevant also on the smaller scale of the housing complex, where the private sphere connects to the social sphere dependent on the architectural design.

Roman Architect Vitruvius claimed that *architecture* must encompass the three principles of strength (or durability), utility and beauty[8], and his writings gained new authority through the renaissance while master builders still attended all aspects of house building. Centuries later, the Parisian Académie des Beaux-Arts opened in 1648 placing architectural education with the fine arts; the École Polytechnique followed in 1794 paving the path for an educational split between the aesthetic and technical aspects of building design and a split between architects and engineers that is now a common reality across Europe[9]. For the same reason, architecture may reckon as a matter of function and style, leaving technical matters on the side. Yet, architecture is an essentially contested concept[10]. More than anything else, the urge for environmental sustainability has in recent decades helped reinstall technical matters as a basic and unavoidable design driver thus favoring a broader Vitruvian understanding of architecture. Social sustainability is an up-coming term in the field of architecture, and may naturally deepen the perspective of utility encompassing the socio-functional aspects of design and use of buildings.

The universal and the local

This paper points to general potentials of sustainable housing complex design. Yet, general or universal principles should adjust to local conditions. It is one of the failures of modern architecture that the Corbusian white cubic forms of the 1920ies were reckoned as universal; later named the International Style, and after second world war - in a more brute and greyish version - spread to most of Europe and to other continents often regardless of local climate, resources or culture. In the case of sustainable housing complexes, these should not only relate to climate and culture, but to the specific city and the urban fabric, they become part of in both physical and social ways. This is particularly true when it comes to the edges of the site, where the complex ground meets the surrounding city. In her famous 1961 book, Jane Jacobs identifies three qualities needed to provide safety on sidewalks: 'First, there must be a clear demarcation between what is public space and what is private space. Public and private spaces cannot ooze into each other as they do typically in suburban settings or in projects. Second, there must be eyes upon the street, eyes belonging to those we might call the natural proprietors of the street. […] [The buildings] cannot turn their backs or blank sides on it and leave it blind. And third, the sidewalk must have users on it fairly continuously, […]'. Though Jacobs specifically addresses greater American cities, the quote emphasizes the obligation of any housing complex to take social responsibility not only internally but also in the way, it architecturally addresses the urban surroundings.

The complex may be neighbor to a green park or to water, which calls for different types of edges. The surrounding city may be tall or low; may have flat or gabled roofs and may appear as made of concrete, brick or wood. In all cases, the housing complex must relate to the context, not necessarily by copying the forms and textures of the surroundings, but by entering an architectural dialogue. General principles should adapt to specific contexts. Both the global and the local environment should inform the sustainable building design.

Urban density

Architectural building practice aiming for sustainability sometimes focus exclusively on the building scale overlooking the disadvantages of the motorized traffic that every human settlement generates. A Danish citizen will in average use twice as much energy for private transportation compared to the primary energy used for heating and power consumption in a modern well-insulated townhouse for three people[11]. In the context of settlement-generated traffic, the urban density, indicating the number of people living in an urban area, is a central notion. Urban density is often measured by plot ratio or floor area ratio, FAR defined as the total floor area divided by the area of the lot on which the buildings stand. Some countries refer to residential density defined by number of housing units per hectare. Both measurements are imprecise in telling the exact density of people per area.

Kenworthy and Newman studied major cities all around the world and found a strong correlation between gasoline consumption per capita and urban density[12]. If the population decreases to less than 30 people per hectare, the private car use and gasoline consumption starts to increase dramatically. Taking 40 dwellers as a minimum each occupying 60 m2 will result in a plot ratio of 48% if housing covers half of the total urban area. This could resemble row houses or three story apartment buildings in an open plan layout[13]. A comparison of gasoline consumption in 22 Nordic cities[14] confirms the correlation between urban density and the use of private vehicles, and British research[15] suggests Victorian row houses as representative of the low end of desired urban density, while still having private gardens.

Next to the aspect of private vehicles, other infrastructural matters such as collective transport systems, district heating and power supply talks in favor of dense cities, so does the desire not to include even more agricultural or natural land for the purpose of building cities.

There is also an upper limit to sustainable urban density in a strictly environmental perspective. This is closely linked to the concept of exergy defined as the energy that is available, in the context of housing complexes in the form of wind and sun useful for the purpose of natural ventilation, heating, passive solar and active solar systems. Considering building energy use, more compact housing complex and building forms will increase the volume/surface ratio thus decreasing the need for heating, but compact city building might also block the access of sun especially during wintertime. The relation between urban density and solar radiation and its impact on domestic heating demand for London climatic conditions and constructions indicates a turning point for plot ratios at around 250 %, over which heating demands will increase[16]. Other research show, that for plot ratios between 125 and 500 %, a doubling of the density increases the energy use in the order of 25%[17]. A general study including the perspectives of fuel for vehicles, building energy use and urban greenery suggest plot ratios between 50 and 150 %[18].

Beside the latitude of the city, the environmentally sound urban density relies on local climate. New research must map the possible influence of climate change while taking point of departure in those 'nearly zero-energy' residential buildings that are a goal in current EU- legislation.

Microclimate

Housing complex design represents the opportunity to create a local environment and microclimate geared for pleasant indoor and outdoor stay. This is increasingly important in the light of future climate change encompassing higher average temperatures and more extreme weather phenomena including heavy cloudbursts. Dense cities may experience urban heat island effects due to the city's stone surfaces heated by the sun during summer. Urban greenery may reduce this effect due to shading and evaporation. Comparison between residential areas with 50-52 % green space and 12-15 % green space shows summer temperatures 6 to 7 degrees higher in the less green residential areas[19] [20]. This can dramatically increase the need for artificial cooling, wherefore sustainable cities and their housing complexes in most climates much incorporate vegetation to mitigate and adapt to climate change. Urban vegetation is also important in the perspective of cloudbursts that may flood streets and cellars, having overloaded the drainage systems. Urban greenery in the form of green roofs, green facades and green areas may, along with semi-permeable surfaces withhold precipitation thus decreasing the run-off to drainage systems. Basins or ponds may as well help to withhold water, ideally having also other purposes such as playgrounds or as part of small biotopes to increase the nature quality of the housing complex. Keeping rainwater above ground as an architectural element may increase the awareness of water use and circulation among residents as is the conscious intention in several new housing developments[21].

In colder climates and during wintertime access of sun is crucial to outdoor stay, wherefore the sustainable housing complex must be designed ideally not to cast shadows upon private balconies and terraces or on common outdoor space. This is of course more difficult to obtain the higher the urban density is and puts an upper limit to the density dependent on the exact latitude. To avoid shadows in the winter deciduous trees are preferred to coniferous trees in dense settlements. The roof scape of the housing complex may provide common outdoor space with full access of sun. In this case, one must also consider the question of wind and lee. In windblown regions, having lee may be as important as access of sun in order to obtain a thermal comfortable outdoor stay. Open high-rise buildings may cause wind turbulence and wind speeds three times as high as the current average wind speed, while dense low-rise building may hold a 'carpet-effect', causing the wind to pass over the settlement rather diving into it[22]. In order to calm down wind it must be filtered rather than blocked. Solid walls may cause turbulence while trees, hedges or semipermeable walls will break the wind. In some cases, wind may have positive effects: Cooling outdoor spaces in hot climates, enabling natural ventilation of houses and line drying clothes.

A recent study on architecture and climate change identifies three main strategies for architectural adaptation to climate change: A defensive strategy, fortifying the architecture against the climate. Passive house-design may fall in this category. A reactive strategy, where the house responds to changes in climate. Active house-design may fall in this category. An embedded strategy, where the house 'embed itself with the local landscape and ecology' and is 'intrinsically linked to site, ecology and microclimate'[23]. Bioclimatic design falls into this category.

Building volume and form

The housing complex, with its many housing units build together, represents as a starting point a much more sustainable way of building than the detached house as the surface per volume and therefore the heat loss per unit is much lower in the complex. Depending on the level of insulation, the apartment may have a heat consumption less than half of the detached house[24]. This does not mean that extremely voluminous buildings are an optimal solution. As the building depth exceeds ten meter it will be increasingly hard to obtain good daylight conditions in the central part of a one-story apartment and it will be increasingly hard to obtain effective cross ventilation. The result may be decreased health and well-being, increased power consumption for light and mechanical ventilation, or both. Very tall buildings cast long shadows on their surroundings and if the buildings raise beyond four floors, it is difficult to maintain social contact between residents on the upper floors and people at ground level, i.e. between parents and their kids playing outside[25]. From a heat loss perspective, the marginal effect of going from four to five stories is much lower than going from one to two.

As a starting point, compact buildings and plain facades have less surface and heat loss than facades that break in and out, but this does not mean that the architecture has to have a plain or boxlike expression. Only the heated part of buildings needs to be relatively compact, and variation can be obtained by designing external staircases, access balconies, weather porches, balconies, small green houses, espaliers and climbing plants supplies by bicycle sheds and trees at ground level.

A thorough Danish study on sustainable city building with high urban densities between 200 and 550 % compared different housing types such as slabs, urban villas, urban blocks, grouped high-rise etc. No housing type in particular disqualified, but the more closed building types provided the most comfortable wind conditions at ground level. For all types, the study stressed the importance of slim buildings volumes in order to obtain good daylight conditions in the apartments. Concerning social life, in the cases of very high urban density open space and common areas at ground level have to be supplied by common areas on different floors above ground[26].

Life between buildings

Space for outdoor stay next to occupant's homes holds several sustainable perspectives. Firstly it furthers health and well-being having access to daylight and fresh air, the vision of greenery and the sound of birds singing. Secondly, there is a strong environmental argument: A reason, why children families choose to settle in detached houses in green suburbia of low urban density, is the garden and the obvious potentials for outdoor stay. If the sustainable city of semi-high urban density shall attract not only low-income groups but also those, who can afford detached houses it must offer private or semi-private outdoor space of higher volume and standards than French or other micro balconies. Thirdly, space for outdoor stay may further social contact between residents. Indoor and outdoor space in the city is often by psychologists, sociologists and architects characterized according to the level of privacy, differing at least between private and public space, sometimes with semi-positions in between the two. There is, however, no established definition, and the use of the terms vary a lot. For the purpose of architectural design of sustainable housing complexes, I suggest the following:

The streets of the city, where everyone can walk, are termed public space. The inner courtyards of housing complexes mostly used by the residents are termed semi-public space. So are roof gardens, access balconies etcetera shared by many local residents. Front gardens, terraces and balconies belonging to one housing unit are termed semi-private. The apartments are private space.

This is not a bulletproof definition. Housing complexes may not have inner courtyards but rather open, park-like surroundings that floats into the public sphere, and there are other cases where clear distinctions are not possible. Despite such ambiguity, the main argument is that semi-private and semi-public space is crucial in order to establish social contact. You can live anonymously in a city with only private apartments and public streets, but a balcony or front garden allows you to interact with by-passers, and semi-public space offers opportunity for common, but internal activity[27].

This section lends its headline from the book Life between buildings, originally published in Danish in 1971 by architect Jan Gehl[28]. His office has now developed twelve urban quality criteria that is also very relevant in the case of housing complexes and their open space. The three basic criteria is about protection: Protection against traffic and accidents, protection against harm by others and protection against unpleasant sensory experience. Without protection, people will avoid spending time in this such space. For a place to be inviting, it must offer comfort defined by six options: Options for mobility, options to stand and linger, for sitting, for seeing, for talking and listening and finally options for play, exercise, and activities. In order to be a great space offering enjoyment it is about scale (Is the public space and the building that surrounds it at a human scale?), opportunities to enjoy the positive aspects of climate, and experience of aesthetic qualities and positive sensory experiences[29].

All of these criteria are relevant to housing complex space at ground level and most of them are relevant to space at the top of or at the facades of buildings. Considering social contact from apartments to common areas at ground level, this works easily from the ground and first floor, and is possible from the second and third floor where talking, yelling and gestures among people at ground level is still perceived. Above the fourth floor, details cannot be perceived, and people at ground level can hardly be recognized or contacted[30]. This puts a natural limit to the height of housing complexes of an intimate and social character.

Construction and materials

The use of materials for residential building has several sustainable implications such as the availability or scarcity of materials, the environmental impact of producing materials, the impact of the materials on the consumption of energy for building operation, and the impact of the materials on resident's health, well-being and safety. As mentioned in the section Basic terms, most of the materials used for house building such as concrete, brick stones and metals are non-renewable materials, in many cases with short supply horizons meaning we will run dry soon. This puts pressure on developing methods for the reuse of constructions and materials based on LCA, Life Cycle Analyzes, and the term 'Circular Economy' has entered the building agenda along with long known themes like low energy building. Circular economy operates with central terms like upcycling and down cycling depending on the qualitative level of reuse: For instance brick stones, that are crushed and used for road fill, are down-cycled. Re-use on a similar qualitative level as the original is seldom possible, as very few building components are designed for disassembly. Therefor they break down to some degree even during careful demolition or they are contaminated with remnants of chemical glue or foam. Brick stones used to connect with lime mortar allowing relatively easy re-use. Since the 1960'ies, cement mortar is used now preventing disassembly brick by brick. This has caused architects to design and plan for cutting out meter-long pieces of wall that are then re-used with pieces of other walls in other colors in a collage-like architecture[31]. Such architecture indicates a new sustainable aesthetics. Sustainable architecture will in general have to design for disassembly and alternatives to chemical glue and foam; an aesthetic that deals with the joint.

Besides scarcity of materials, the energy embedded in production, transport, construction and demolition of materials has a high environmental impact. In the case of Danish residential buildings built according to the 2015 standard allowing app. 40 kWh/m2/year (excluding electrical appliances), the embedded energy and related carbon dioxide emission is higher than the energy used for building operation during the buildings entire lifetime[32]. If to include also LCA-calculations in future building standards, methodology, reliable material data, expected lifetime of buildings and calculation tools need to be developed and settled.

Wood has become increasingly interesting as a sustainable construction material as it is a renewable resource considered as nearly carbon-neutral. It consumes carbon dioxide during growth that are then stored in materials and buildings during use and re-use until released only when burned or otherwise degraded after demolition. The use of non-renewable energy is much lower in wooden building construction than in heavy constructions. Along with traditional post and beam structures also so-called solid wood-constructions and CLT, cross-laminated timber constructions has developed in recent years. Wooden construction techniques is now applied in European high-rise buildings over ten floors[33]. In a local city perspective, it is an advantage that wooden buildings constructs much faster needing less truck traffic and causing less construction noise compared to heavy building techniques.

The biggest problem concerning high or semi-high residential wooden buildings seems to be fire safety, extremely important in buildings where people are sleeping. Some projects has wooden constructions covered with slow-burning gypsum boards blocking the visual experience of wood, in other projects sprinklers secures safety. The fire regulations differ extremely across Europe indicating a strong need for engineering and architectural development as well as trust-worthy tests of modern wooden multi-story construction.

Concerning external cladding a certain group of building components are of special interest, namely solar cells, which are often the best or the only way to implement active energy supply in dense urban contexts. In order to reach zero energy standard by local means, the use of solar cells in adequate number and orientation and a housing complex design that allows the sun to reach the cells are therefore crucial. Solar cells principally comes in three versions being mono-crystalline, poly-crystalline and thin film cells, each of these in different color and detailing. Solar cell-panels usually had the character of add-ons to existing buildings and most often as visually disturbing elements. From an architectural point of view, they should rather replace other materials finishing the building envelope. If solar cells replace other claddings, the environmental impact and the construction economy related to building materials diminishes compared to add-on panels. Solar cells now come as roofing, as façade cladding and as railings on balconies in bright or more discrete colors. Their glassy surfaces must be treated or oriented in order to avoid glare.

Diversity of space

In a sustainable perspective, living units should fit their users in order to provide sufficient and useful space for living. A large percentage of new living units are designed for nuclear families, but the size of nuclear families change over time, and divorces and new family constellations with shared children may cause days with many children and other days with no children at all in the same housing unit. In order to accommodate change over time, the single housing unit must have a general usefulness, meaning that the individual rooms can change function from year to year or even from day to day. It might also be flexible in the sense that walls can be add or taken down in order to provide more or fewer rooms[34]. On a more advanced level, extra rooms can be add to the single apartment. A Danish dense/low development operates with a singular room between two apartments, that can belong to one or the other apartment due to the current size of the families. In some cases these rooms has their own entrance and bathrooms to fit teenagers on their way to an independent life, while still eating with the family[35]. A sustainable multi-story housing complex may hold such additional rooms for a variety of purposes, avoiding upsizing each apartment for maximum pressure.

In most cases, families will end up having only one, elderly member. This person may well stay in the family size apartment, especially if all other apartments in the well-known neighborhood are family-sized. Socially this may cause loneliness. Environmentally seen, the energy costs of heating and ventilating redundant space may be unnecessary high.

Currently, many alternative ways of living are emerging, compared to the traditional nuclear family. In forty percent of all Danish living units only one person are living, thus reflecting the individuality of modern times[36]. At the very same time, different sorts of co-living see the light of day, maybe as a response to fragmented modern life: Families living together, younger singles living together, elderly living together. Recently a housing complex, ‘house of generations’ are being built in Aarhus, with the outspoken intention to gather all generations from nurseries to elderly and handicapped under the same roof[37].

In order to respond to contemporary needs in a flexible way, the sustainable housing complex must hold a diversity of homes and space in order to provide social inclusiveness concerning both age, lifestyle and income and to ensure that people can upsize and downsize their use of space according to current needs. There must also be common rooms for people to meet for common activities and strengthen relations between residents.

Living

On a basic, physical level, the task of a housing unit is to provide a comfortable indoor environment for its occupants and to facilitate cooking, dining, toilet use, bathing and sleeping. Such functions depends on historical and cultural context: It is not until the twentieth century that toilet and bath, originally situated in cellars and courtyards, became self-evident elements in apartments for low-income groups. In many cases also washing and drying clothes is now part of basic apartment functions.

Since the oil crisis of the nineteen seventies, there has been increased focus on reducing energy consumption for space heating and in 2002 EU settled a directive on the energy performance of buildings where in principal all building energy uses must be included and calculated as primary energy[38]. Later directives states the ambition to reach a level of 'nearly energy neutral buildings' and that national legislation must back up such ambitions[39]. In reality, the legislations differ widely across Europe.

In Denmark, during the last 50 years the calculated primary energy consumption for heating, ventilation and cooling in new buildings has been reduced from around 350 kWh/m2year (1961), over 180 (1979), 110 (1995), 80 (2006) to less than 40 kWh/m2/year from 2015[40]. The early and most comprehensive reductions has been achieved through increased insulation of the building envelope which, along with compact building forms, is the most important and basic approach to reduced heating. Later on, around the millennium there has been strong architectural focus on passive solar achieved through large glazed areas facing southerly directions, and an engineering focus on mechanical ventilation with heat recovery. However, as houses has become extremely well-insulated, the risk of overheating due to passive solar has increased wherefore shading is now considered equally important; and though heat recovery is important during wintertime, there is now an increased awareness of the qualities of natural ventilation during summer. In both cases, the local microclimate will play an important role. Plans for new standard legislation to reduce the calculated energy consumption for heating, ventilation and cooling to 20 kWh/m2/year has now been cancelled as the costs of such marginal savings seems too high.

Rather, other environmental issues call for increased awareness. As already mentioned, the environmental impact from constructions and materials plays an important role. Secondly, the energy consumption for electrical appliances used in the home may very well exceed the consumption for building operation, wherefore user habits are of high importance. This is also the case looking at heating and cooling. Several international surveys shows that the actual, measured energy consumption is larger than the calculated consumption especially in new buildings. There is a 'performance gap'. A reason for this may be the occupant's preferences and behavior; sustainable buildings does not necessarily support sustainable behavior[41]. 30 - 60 % of the advantages of good building energy standards may be transferred to better comfort rather than lower energy consumption[42]. A Dutch survey show that while the actual energy consumption in A-marked (high energy-standard) buildings is 30 % higher than expected, in G-marked (bad energy-standard) houses the actual energy consumption are only half the calculated[43].

The housing unit is not only a physical entity where people can be expected to act in rational ways. It is a home, where people unfold their lives not necessarily having sustainability being their first thought or intention. If to optimize for sustainability, architecture and technical equipment must facilitate sustainable behavior[44]. This can be done be installing the most energy efficient appliances and by installing displays that tell of current energy and water consumption in the apartment in general and for special purposes, thus visualizing otherwise hidden consumptions. Visible rainwater collection on roof or ground level can the same way expose water supply.

Architecturally there may be a larder connected with the kitchen allowing for cold storage thus reducing the need for large refrigerators, room for sorting garbage, or an outdoor natural drying cabinet connected with bathroom or scullery in order to supersede the very energy consuming tumble dryer. In general, shared activities and functions may have less environmental impact than individual activities, wherefore the housing complex has certain potentials compared to the individual house, apartment and household: A common deep freezer room is less energy consuming than a high number of individual deep freezers. Cooking and dining together takes less energy and cause less food waste. A common, covered space for drying clothes reduces the need for tumble dryers. A common workshop allows for repair of different items otherwise thrown out. A common area for sorting waste allows for many fractions and better reuse. All such activities allows for people to meet intendedly or unintendedly, eventually experiencing small talk on practical issues develop into deeper conversations or even friendship. In the end such space may further not only environmental, but also economic and social sustainability.

Conclusion

The design of sustainable architecture depends on transdisciplinary knowledge and understanding, as it relies on research from a wide variety of professional disciplines covering traffic and town planning, climate, greenery and landscape architecture, sociology and psychology, building architecture and building engineering encompassing statics and constructions as well as energy and indoor climate. Both global and local context is crucial to the design; the global physical context being abstract depending on scientific information; the local physical context to some degree experienced and sensed. The social and cultural programming relies on analytical knowledge as well as first-hand experience.

The scale of the housing complex is particular interesting and demanding as a design task as it connects the technical infrastructure and the social and cultural profile of the city with the home, life and possibilities of individual human beings and families while setting the frame for life between buildings and relations between residents.

Architectural design of housing complexes has huge and broad potential to further sustainability both in terms of environmental, social and economic sustainability depending on, if considerations on all such aspects are allowed to influence the design. This challenges current building practice: If the architect designs a housing complex only or mostly considering aesthetic and social aspects, and the engineer joins late in the process only to add technical features to a fixed design, a lot of potential will be lost. On the other hand, the engineer must be able and willing to take part in the design process. It is the same case, if social concern and organization goes into considerations late in the process when the overall design is already in place. Techniques, social and aesthetic concerns must be involved early on. Sustainable architecture is not about preconceived style or aesthetics, but about sensing and understanding the natural, climatic, physical, social and aesthetic context and designing according to this in an integrated way.

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