Origin and Development of Environmental Design

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ABSTRACT **Buildings are characterised as some of the greatest consumers and pollutants of the planet. However, the genesis of environmental design, in the context of its modern meaning, as shown in this paper, is not so much based on initial requests to reduce the negative pressure on the environment, but more on the tendency to ensure the continuity of the supply of resources. Only when awareness of the state of environment and the negative anthropogenic contribution matured enough in the second half of the 20th century, the idea of environmental design started to grow and become more complex. Eventually, environmental design became a framework comprising various strategies and measures that aim to reduce the negative ecological impact of buildings by aligning conventional design requirements with their environmental significance. By connecting resource efficiency with the reduction of environmental impact of buildings, this paper reviews current trends and challenges in the utilisation of energy, materials, water, and land, and reflects the scenarios of possible resource-efficient futures in which wider social and economic schemes could become increasingly relevant for the successful outcomes of environmental design.**

KEYWORDS buildings; environmental impact; life cycle; resource efficiency

1 Introduction

Throughout history, mankind has learned to cultivate and exploit the broad variety of resources in the Earth's systems, in order to secure the species' survival and wellbeing. Along with industrialisation came the intensification of human interference, and the increase in the consumption of resources, causing changes with unpredictable and irreversible ecological effects. While massive impacts on nature took place during the last two hundred years, the social awareness of such impacts developed only in the second half of the last century, when politically and socially motivated environmentalism became a new focus.

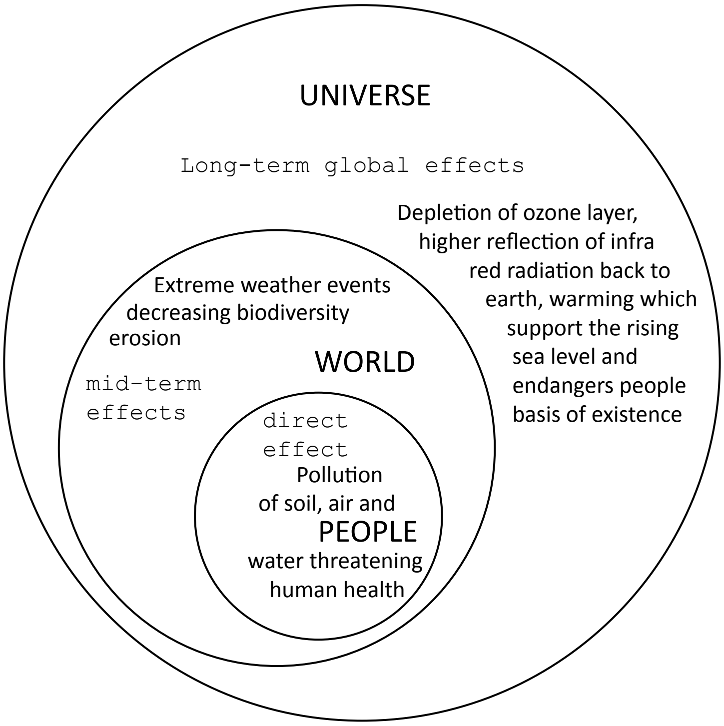

FIG. 1.1 Three levels of ecological impact *(Hildebrand, 2014)*

Anthropogenic interaction with nature provides a living basis for society. Therefore, the impact of humans on the environment is not necessarily problematic. The level of harm, on the other hand, is determined by the type, extent, and consequences of the interference that is either planned (e.g., energy generation, raw materials extraction, land conversion, etc.) or accidental (e.g., Chernobyl and Fukushima nuclear disasters).

Tracing the ecological effects may be a difficult task due to the complex interaction of natural cycles with mankind. While some human actions result in immediate repercussions on nature, other effects cannot be easily linked to their cause. Therefore, the impact on nature can be categorised as direct, medium, or long term global effects. Gradation helps to define the interventions that should be carried out at the level of their cause, having regarded that the improvement can be made only when the interrelation between the cause and the effect has been proven. For example, levelling aims to distinguish between the urban heat island and the stable temperature increase due to global warming, in the case when both phenomena occur at the location of a building. There are building measures at hand to actively reduce heat islands, whereas designers can only react to global warming and generally try to reduce CO_2 emissions with a long-term prospect.

Pollution occurring at a defined spatial level, causing in-situ consequences with immediate effects, is a manifestation of a direct ecological impact. The leakage of toxic substances into water, air, or soil during the production stage of building materials is an example of such a level of ecological impact.

Medium-term ecological effects produce consequences that mark a broader range of changes across time and place. A triggering event firstly changes natural conditions, thus harming human life. Such an example is deforestation, which leads to soil erosion, further worsening of air quality, changes in weather conditions, and other influences. The consequences for human life might not be immediate and directly detectable at the site of the event, but they can be related to certain man-made impacts.

Long-term effects include consequences that occur after a certain time delay and affect the entire globe. Man-made emissions that cause a chain of events (from pollution to global warming, to rising sea levels, to flood occurrence in coastal areas, etc.) can be identified within this category of ecological effects.

This differentiation between levels of ecological impact builds understanding about their intricacies, and paves the way for them to be addressed. The distances in time and place from the generation of a negative effect to its manifestation account for the main factors that influence the type and scope of reaction that is required. While direct harmful consequences require immediate reactions, larger distances in time and space require more profound knowledge, increased responsibility, and a global approach. The time of occurrence also influences the regulatory process; the earlier a harmful consequence is manifested, the earlier a regulation is established to prevent its repetition.

The awareness of the implications of human actions is essential to adequately address environmental pollution and degradation. The type and scope of actions aimed to reduce the negative environmental effects are field-specific. In building design, knowledge of the environmental dimension is fundamental in being able to define technical, social, or economic measures. In that regard, this paper unfolds the platform of facts necessary for the understanding of the progressive anthropogenic impact on the environment, explains the genesis and development of environmental design in wider social conditions, and considers in detail the segments that are most well developed currently. The paper further reveals the main challenges in contemporary building design with respect to the use of natural resources: water, land, energy, and materials, and simultaneously reflects upon possible scenarios for a resource-efficient future.

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2 Anthropogenic Impact on the Environment Through History

Ecological systems on Earth encompass living entities and their non-living environments. They function in complex cycles that have undergone tremendous changes over the last million years, together with the shifts in environmental conditions and living matter. Since the beginning of life on Earth, mainland has become water, continents have changed their position and size, temperatures have varied from cold to hot extremes, and living species have disappeared or emerged. All of these changes were accompanied by slow and stable cosmic processes and conditions, and their manifestation and responses (self-regulation) on Earth, because of which the cycles of the past may be considered as consistent. The evidence of such consistent cycles can be found in records of ice cores, boreholes, plants, etc. Nevertheless, the cycles on Earth in the past could also have been interrupted by surprise events such as volcano activation, which often instigated massive changes in ecosystem conditions.

Over the last 12,000 years, a human-friendly climate on Earth has developed. This period began after the last glacial epoch and is called the Holocene or Interglacial period. In this phase, only minor climate shifts, such as temperature variations and less intensive cold periods, e.g., during the 16th and the 17th century (Feulner, 2011), could be experienced.

Tangible traces of the development of civilisations and societies allow for the reconstruction of past systems of human functioning, the ways of using available resources and the impact on nature. Through the centuries, humans and their activities affected natural environments primarily though the transformation of land cover, and when transportation methods became better developed, the exploitation of surface resources (e.g., the wood) increased disproportionately (Hornborg, McNeill, & Martinez-Alier, 2007). New inventions and technological developments, from the 19th century and beyond, intensified extraction and utilisation of natural resources and became the impetus for a new generation of changes made to the Earth's systems, which today are known as anthropogenic impacts on the environment.

From the beginning of industrialisation period, the consumption of resources has been increasing continuously. Consequently, the environmental impact at all levels was growing and the rate of changes in the environment was accelerating. The economic boom of the 1950s offered a whole variety of products that used electrical energy to a broad portion of society. Along with the rising standards of living and comfort requirements, energy consumption increased enormously. The zest in the construction industry led to the massive production of different types of building materials whose ecological performance over the life cycle phases is now questioned. Continuous growth in the consumption of natural resources - non-renewable energy, fresh water, land and raw materials - has been followed by the intensification of the environmental pollution of water, air, and soil with huge amounts of

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generated waste and emissions. At this time, the relationship between humans and other parts of nature has already been largely broken, as a result of modern lifestyles. In parallel, the global population marked a trend of increase. New artefacts in the built environment and its expansion into the natural environment became new sources of environmental pollution and degradation. Concurrently, the number and intensity of 'surprises', i.e. extreme weather events grew with the increase of global temperature.

To secure continuous functioning of the Earth's systems, it is necessary to address both current patterns in resource consumption, and the future demands. At the same time, it is necessary to deal with the consequences of past anthropogenic actions, such as climate change.

3 Environmentalism and Sustainability

The awareness of connections between people and other living beings, natural resources and the environmental issues represents the core of environmentalism (Armiero & Sedrez, 2014, p.1). As a cultural phenomenon, environmentalism relates to the active involvement of individuals, groups, and organisations, motivated towards the preservation of the planet's diverse systems and values.

Apart from the events and ideas that shaped Western environmentalism, from the 13th century onwards, and the warnings of the 19th century scientists with regard to the threats to nature (Grove, 1992), a collective reaction to the state of the environment was strengthened only during the second half of the 20th century. In Europe, social and political awareness of environmental consequences developed during the 1960s, in left-oriented groups that aimed to draw attention to nature and its proclaimed value, whereas the book *Silent Spring* (Carson, 2002) was deemed to be a trailblazer for environmentalism in the US. On the 22nd of April 1970, Earth Day was celebrated first time. In 1972, the organisation Greenpeace was established, and the Club of Rome published *The Limits to Growth*, drawing a dramatic picture of the near future (Meadows, Meadows, Randers, & Behrens III, 1972). Although the predictions (e.g., shortage of the oil by 1990) were proven to be rather unrealistic, the report's translation into 30 languages demonstrated an international interest for environmental issues.

With the Brundtland Report (Brundtland, 1987), the consequences of mankind's relationship to nature became a worldwide concern, and the use of the term *sustainability* was revived, marking a shift from the original meaning in the context of forestry, where this term was introduced in the 18th century by Hans Carlowitz (1713) to describe the dimension of wood harvest; the amount of wood withdrawn from the forest should not exceed the amount growing back. In the years following the publishing of the *Our Common Future* (Brundtland, 1987), the terms environmentalism, ecology, and sustainability were often used interchangeably, until their notions later became better distinguished. To bring sustainability and environmentalism into context, O'Riordan (1991, p. 7) defined the 'new environmentalism' that aims to "devise a series of strategies that enables people to see how their interests, as well as those of the earth as a whole, are served by reforms that enshrine the triad of sustainability, ecologically appropriate development at the local level, and the provision of basic needs and political rights". In contemporary terms, the word *sustainability* is used in different contexts and scales of society, and its notion is therefore complex. To understand the significance of sustainability nowadays, it is necessary to elaborate upon both the general and field-specific frames of reference to which this term relates.

In general, the verb 'to sustain', according to the Oxford Dictionary, refers, inter alia, to the "cause to continue for an extended period or without interruption" (Simpson & Weiner, 2010). Sustainability therefore represents a prerequisite for the continual progress of global society. Because of the complexity of sustainable direction of human development, sustainability nowadays encompasses aspects of ecology, economy, and social considerations, as well as their interlinkages through culture. In building design, sustainability most commonly relates to the environmental dimension, although the inclusion of other aspects of sustainability is necessary too.

4 Environmentalism in Building Sector

The building sector is responsible for the consumption of about 50% of resources on a global level, as well as the production of about 60% of global waste, and 40% of greenhouse gases (Hegger, Fuchs, Stark, & Zeumer, 2008). Although the environmental impact of buildings increased steadily from the beginning of the period of industrialisation, awareness started to grow only from the second half of the 20th century, when the recognition of environmental risks resulted in different actions that are nowadays considered as retarders of negative trends on Earth (Fig. 4.1).

In general, modern architecture did not operate within natural limitations, state of environment, or ecological consequences of expressed creativity. Instead of ecological issues, priority was assigned to mass production and the opportunities created by it, especially in the early phases of the Modern Movement from the 1920s to the 1950s (Fig 4.2).

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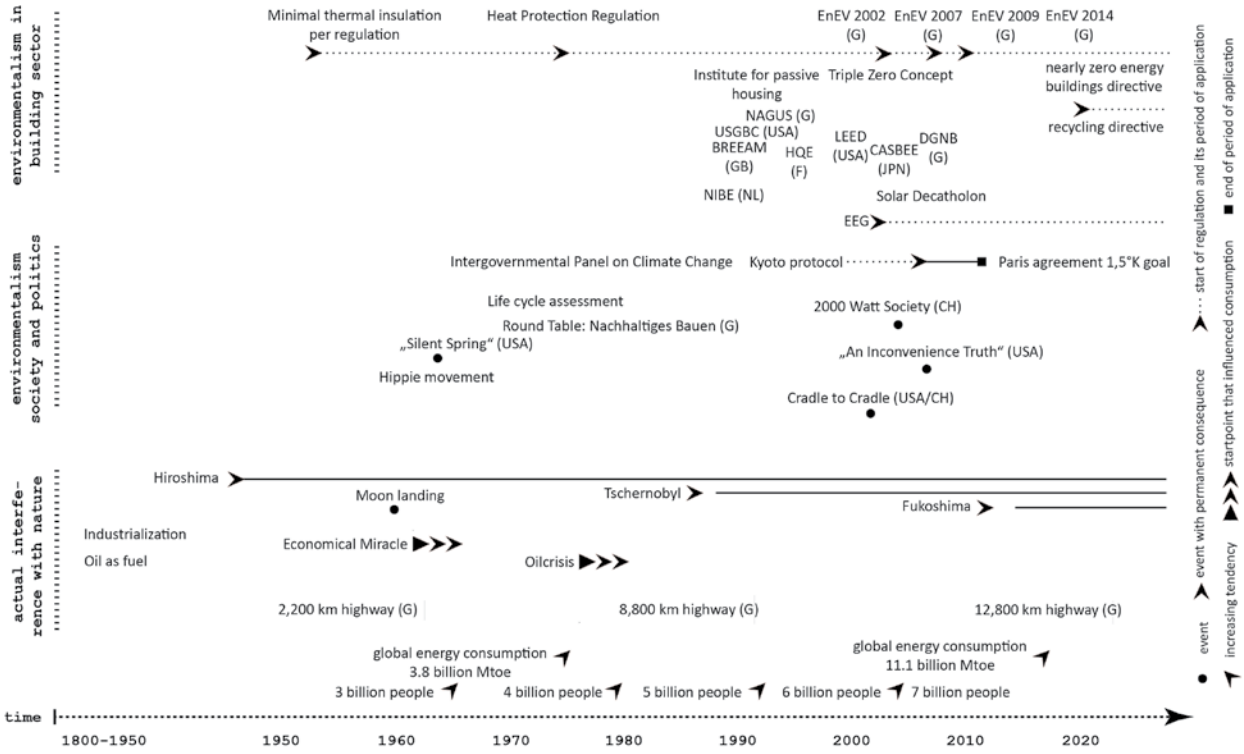


FIG. 4.1 Environmentally significant trends and events, and the responses to them *(Hildebrand, 2014)*

FIG. 4.2 Bauhaus Dessau, Walter Gropius, 1925-26. *(Image by Marcel Bilow)*

The modern movement set a new architectural trend with transparency and uninsulated large glass facades but often caused high energy consumption and discomfort. Environmental issues were not on the agenda in such times.

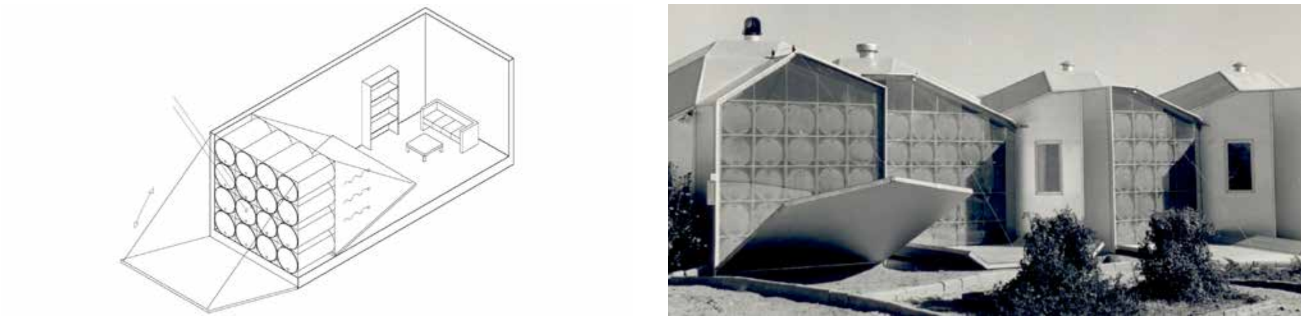
From today's perspective, nevertheless, some developmental trends that influenced the shaping of modern buildings, such as the blossoming of prefabrication, could fit well into the environmental design postulates. To that end, it can be added that some notable modern architects gave an unintended contribution to the development of environmental design. Among them stand Le Corbusier, who included roof gardens and free designing of the ground plan in his five points of architecture; Frank Lloyd Right and Alvar Aalto, who offered modern interpretations of organic architecture; or Oscar Niemeyer, who integrated solar control measures into architectural configuration (Fig. 4.3).

FIG. 4.3 Banco Mineiro de Produção, Belo Horizonte, Oscar Niemeyer, 1953. *(Image by the author)*

High sun radiation in Brazil caused high cooling loads and discomfort in modern style buildings. Niemeyer integrated environmental strategies in his architecture by installing fixed louvres on those facades that are oriented towards the sun.

The enthusiasm for bio-climatic design during the 1960s was articulated in the work of Hassan Fathy, who explored vernacular design principles, or Buckminster Fuller, who relied on the ability of technology to provide a dynamic architectural response to varying external conditions, etc. With the energy crisis of the 1970s, energy consumption in buildings became a relevant political, research, and design topic. Consciousness of resource dependence has raised the interests for energy performance of buildings and possibilities for the generation of useful forms of energy from renewable sources. Some energy-efficient solutions, like active solar systems and energy controls, and passive design strategies were offered (e.g., Steve Baer's inventions, Fig. 4.4), and the number of publications about energy conservation, and technological and design reactions started to increase. During the same decade, material recycling opportunities began to be researched in the US.

The Postmodern Movement transformed the architectural expression and (re)introduced a variety of previous forms. The context of place again became relevant in design, as opposed to preceding International Style, and this further influenced the change in perception of relationship between architectural artefacts and the environment. During the 1980s, the measures aimed to decrease the amount of operational energy in buildings expanded notably. At the same time, research on the ecological impact of building materials (primarily in the field of toxic emissions) was initiated, together with possibilities to reduce the value of their embodied energy. At the end of this decade, the significance of water conservation measures was revealed. In the last decade of the 20th century and the first decade of the 21st century, comprehensive environmental design principles for various building typologies were established, and terms like 'green architecture', 'sustainable architecture', 'eco-friendly architecture', 'eco-tech architecture' (although viewed as an architectural direction, rather than the quality of buildings), 'environmentally conscious design', etc. became extensively used. In parallel, different international methods and building certificates have been developed to measure the level of achieved environmental quality.



A *B*

FIG. 4.4 A+B: Detached House, Corrales, New Mexico, Steve Baer, 1973. *(Image A by the author, image B by Steve Baer, Zomeworks)*

An early low-tech approach towards sustainable architecture. During the day, the desert sun heats up water barrels. At night, when it is cold, energy is released to heat the interior. The energy flow is controlled by operable insulated doors on both sides of the façade.

Next to the improvement of the physical quality of buildings, efforts today also aim at improving the energy performance of existing buildings by optimising the design process (e.g., Konstantinou & Knaack, 2013). Other attempts aim to create new business models, for example leasing concepts, in order to align incentives of demand side (investors and users) and supply side (industry and designers). The traditional building world rewards an approach of minimal initial investment to meet the minimal legal requirements. The idea is to shift towards an attitude that rather rewards an optimal environmental performance over the whole life cycle of buildings including the end of life scenarios (e.g. Azcarate-Aguerre et al., 2017) (Fig. 4.5). The difficulty lies, amongst other things, in the long product life span of buildings in comparison to other product service models such as the leasing of cars or printers.

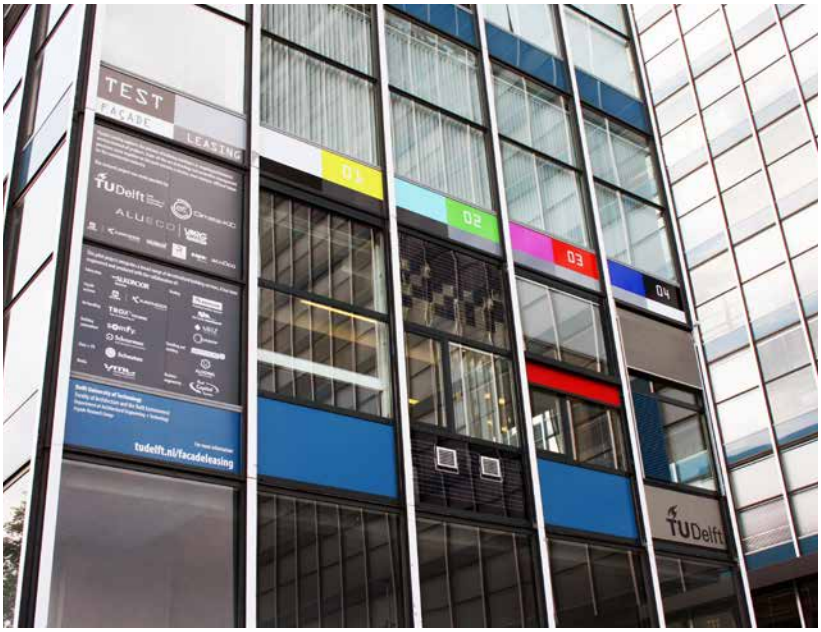


FIG. 4.5 Façade leasing at Delft Technical University. *(Image by Marcel Bilow)*

Testing the value of different façade configurations of the predicted whole life cycle for the refurbishment of a high-rise building on the university campus. The aim is to find new business models for optimal energy performance and CO_2 reduction.

Although the characteristics of spatial context largely inform environmental design strategies, for which reason this approach is accentuated as being place-specific, the consumption of operational energy and the ecological impact of building materials today account for the main universal fields of activity in the framework of environmental building design.

4.1 Energy

Energy in buildings is used for heating, ventilation, cooling, lighting, water heating, etc., i.e. for the operation of different electrical systems and individual appliances, equipment, and machines. The amount of operational energy used in a building for the aforementioned purposes depends on its position, typology, and physical and spatial characteristics, used electrical systems, climatic conditions, occupant's behaviour, etc. Heat losses from ventilation and transmission through the building fabric, together with the gains from the sun and indoor equipment and other heat sources result in energy demand for heating and cooling (McMullan, 2002). Fabric heat losses or transmission heat losses refer to the energy that flows through the building envelope. They are directly dependent on the thermal transmittance of materials and temperature differences between inside and outside, which are expressed by the thermal resistance coefficient U-values. On the other hand, ventilation heat losses depend on the permeability of façade, the size and quality of openings, the nature of mechanical ventilation systems, etc. The location of a building, its orientation, and façade design also define solar heat gains. More generally, location plays the dominant role in defining the type of sources used for building operation and optimising supply and demand.

More than 50% of energy consumed in residential buildings in the European Union is used for space heating (Itard & Meijer, 2008), reaching up to 70% depending on climate variations (BPIE, 2011). Although heating demand was the most significant operational energy issue in the past decades, other forms of energy consumption, such as water heating, cooling, and electrical lighting are also important to address.

Since the 1970s, there has been a tendency to reduce the total amount of operational energy. Accordingly, the terms like 'energy-efficient', 'low-energy', or 'zero-net energy' buildings have emerged. Following the oil embargo in the winter of 1973/1974, a series of energy-related standards were introduced internationally to limit the level of dependence by limiting consumption, such as the German thermal insulation ordinance *Wärmeschutzverordnung* (Heat Conservation Regulation) from 1976, which focused on building envelope and the reduction of its transmission heat losses. Over time, national standards and regulations in European countries became higher and more comprehensive, both regarding energy consumption and comfort provision. Several nationally applicable European building codes were additionally developed to regulate the passive features of a building envelope and to define active energy methods of building operation. The standards aiming to reduce operational energy in buildings have developed into a broad catalogue over the last decade. The adoption of the *Directive 2010/31/EU on the Energy Performance of Buildings* (European Parliament and the Council of the European Union, 2010) marked a significant legal step towards the reduction of operational energy in newly constructed buildings, as well as in buildings undergoing major renovation, and the evidence of the level of operational energy utilisation became supported through labelling.

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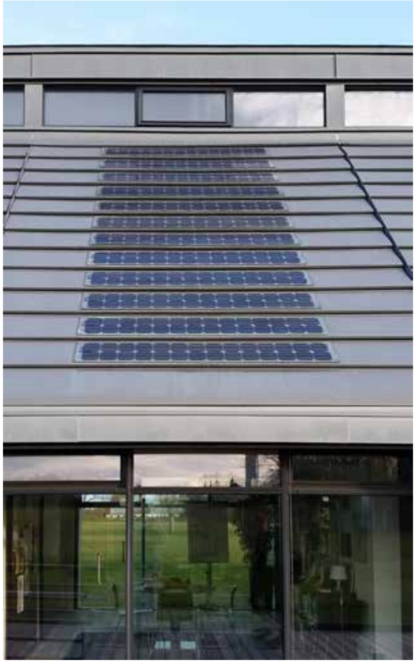

FIG. 4.6 Building Integrated Photovoltaics (BIPV) or other means of energy generation is needed to create buildings that are almost energy neutral Balancing energy demand and generation is difficult because it depends on buildings and installations but also on the type of use, comfort demand, and user behaviour. The architectural integration of components is a future challenge for designers. *(Image by the author)*

A

B

FIG. 4.7 A+B: Manitoba Hydro, Kuwabara Payne McKenna Blumberg Architects and Transsolar KlimaEngineering, Winnipeg, 2009. *(Images by the author)*

The harsh climate (extreme cold in winter and heat in summer) demands special measures. The building relies on natural energy resources such as geothermal energy and sunlight, which makes it one of the most efficient buildings in Canada. In contrast to most buildings in the region, which are fully climatised, it is 100% naturally ventilated. In combination with the atrium, a solar chimney is used, driving the ventilation system and preheating or precooling air before it enters the offices.

According to this document, from 2020 onwards, it will be mandatory to provide the energy label for tenants and purchasers of buildings. Additionally, public buildings larger than 500 sqm must put the energy label on display. The Directive 2010/31/EU also prescribes that all newly constructed buildings in the EU must be 'nearly zero energy' buildings by the 31st December 2020 (public buildings by the 31st December 2018). This means that more than just the active and passive capacities will have to be exploited to achieve the functional and physical qualities that are required for the current level of comfort while maintaining nearly zero energy consumption to operate the building. The Directive leaves it up to individual EU countries to define national ways for achieving standards and adapting to different climatic conditions, i.e. to set national minimum energy performance requirements.

The reduction of the operational energy of buildings is tightly connected to the consideration of the source of the energy used. In actuality, the source of energy represents a key factor in influencing the ecological impact caused by operational energy utilisation. An energy carrier is subject to treatment before it becomes useful energy, delivered in the form of heat or electricity. The efficiency of each source depends on the effort required for its transformation into a form of energy that is useful for building operations. Where less energy is needed to convert the source into useful energy, that source is considered to be more efficient overall. Besides the efficiency of resources needed to deliver heat or electrical energy to the buildings, the evaluation of their ecological performance in relation to the generation of emissions is equally significant. Therefore, the main classification of energy sources, as renewable and non-renewable, reflects not only their availability over time, i.e. the renewal potential, but also the ecological impact created in different phases of energy flow (from extraction to end-use in buildings). To that end, and not only for the end-use in buildings, some energy sources, such as coal, are being gradually excluded from future energy supply strategies.

By summing up the needs to regulate energy consumption, emission generation, and related climate change mitigation, the European Commission has developed the *Europe 2020 Strategy for Smart, Sustainable and Inclusive Growth,* which targets bringing CO_2 emissions 20% lower than the 1990 level, to reach at least 20% of energy coming from renewable sources and to achieve a 20% increase in energy efficiency (European Commission, 2010). More recently, new targets and policy objectives have been set for 2030, dictating that a 40% cut in greenhouse gas emissions compared to 1990 levels should be achieved, together with at least a 27% share of renewable energy consumption, i.e. at least 27% of energy savings compared with the business-as-usual scenario (European Commission, n.d.).

4.2 Materials

The continuous implementation and upgrade of energy-related regulations, on the one hand, and the development of new technologies and energy systems, as well as the increased use of renewable energy sources on the other, have expanded the basic focus of environmental design towards the comprehensive consideration of the environmental performance of materials. The achievement of material resource efficiency complements the achievement of sustainable development goals (e.g., United Nations, 2015), and relates not only to the reduced use of materials, but also to a range of their characteristics, such as origin, availability, production inputs (e.g., water, energy and raw materials) and outputs (like emissions and waste), possibilities for reuse, and recycling, etc.

The study of the environmental performance of materials is based on the analysis of a series of processes and steps that together constitute a life cycle. Potentially, a material makes a negative environmental impact in every phase of its life cycle, from the acquisition of raw materials, through manufacture, transportation, construction (installation), and actual use and maintenance, to the end of life – deconstruction or demolition, waste processing, and recycling. To determine the environmental impact of a material (or a component) closely, the information regarding the different life cycle phases are needed (European Committee for Standardisation, 2011).

Life Cycle Assessment (LCA) today represents a standard method for the evaluation of the ecological impact of building materials. The Integrated Product Policy, introduced in 1998, accounts for one of the first instruments that emphasised the relevance of ecologically friendly materials and the significance of life cycle assessment (Ernst & Young, 2000). In subsequent years, the results obtained from the LCA studies of different materials resulted in increased awareness about ecological impact and correspondingly in formation of different databases and software tools that sort the results according to the type of impact, allow for comparability, and facilitate design decision-making.

The energy used to produce and eventually dismantle the materials and components stored in a building can be calculated, but is neither measurable nor visible. Because of these properties, it was named *grey* or *embodie*d energy. The amount of embodied energy in a building (per gross floor area unit) depends on the type of used materials and construction system (e.g., Hildebrand, 2014). A number of strategies can be implemented to decrease the embodied energy and hence the ecological impact of materials: selection of materials with a closed cycle (reused and recycled materials); inclusion of deconstruction in scenarios by the type of connections; reduction of material amounts in building construction; utilisation of renewable materials; application of durable materials; etc.

5 Current Challenges in Environmental Design and Development Prospects

Even though the environmental impact of buildings can never be completely removed, by continually developing the principles of environmental design, the negative effects can be addressed more successfully. To that end, and having regarded that the environmental impact of buildings primarily represents the consequence of utilisation of natural resources (energy, materials, water, and land), the achievement and advancement of resource efficiency stand out as leading objectives of contemporary environmental design. Differently from the previously discussed aspects of materials and energy, the use of water and land in the activities connected with buildings has been given less attention to date.

5.1 Water Efficiency

The use of any quantity of fresh water in buildings, for any purpose, results in its pollution. Consumption of fresh water also means pressuring the water resources that, in the light of growing population and climate change, form a huge social and ecological problem. Finally, the use of water in buildings is often connected with the use of energy needed for its heating. Only during the last decade, these water-related building issues have been recognised as a challenge on the level of the European Union (e.g., Commission of the European Communities, 2007; BIO Intelligence Service, 2012). Besides that, water efficiency in buildings has been considered to date at the levels of (most often voluntary) building assessment systems, individual, local or, more rarely, national initiatives and measures, and published recommendations.

Proposed measures for achieving water efficiency in buildings encompass the reduction of the fresh water utilisation, introduction of alternative water resources, closing water loops, and purification of wastewater in situ. To achieve these currently ambitious goals and to overcome existing barriers, a set of actions that supplement the design are necessary, from policy establishment (e.g. regarding water metering), to economic measures and changes of occupants' behaviour.

5.2 Land Efficiency

While land use in the built environment has been comprehensively addressed at urban and neighbourhood scales, its consideration, in cases in which action boundaries actually overlap with the lot boundaries, is noticeably more modest, mainly limited to the building assessment systems (e.g., Comprehensive Assessment System for Built Environment Efficiency (CASBEE)). Ecological effects of site preparation, construction, and subsequent land use for the physical base of a completed building and the activities of its users, point to a necessity for appropriate land use management at the level of a lot. Even though the challenge is highlighted in densely built areas, the significance of micro-scale is, with regard to climate change, general, having regarded that the land and the elements on its surface could mitigate the effects of both stable temperature increase and extreme weather events.

Land should be understood as a base resource that allows for the implementation of measures to regulate the parameters of the outdoor air. As such, the treatment of lot surface and cover can be connected with the measures to reduce operational energy demands. At the same time, land is an indispensable agent that brings nature close to the borders of materialised environment, impacts the wellbeing of building occupants, and, ultimately, provides ecosystem services.

To secure stable ecological functioning of the land and to achieve land efficiency, building design should primarily be concerned with the reduction of land use, the reduction of soil pollution, and the disturbance of its structure and content. Therefore, land-efficient design strategies range from the definition of the building form, to the compensation of the occupied portion of land through the interventions on a building (e.g. Fig. 5.1), to the reduction of the surface of materialised (sealed) areas, to the selection of materials and construction systems and methods, to the consideration of natural and built morphologies in immediate surroundings (for example, to enlarge the unfragmented area of free land), etc. (e.g., Kosanović & Fikfak, 2016). Only when these aspects are successfully articulated in design, a building lot (and potentially a building itself) may become a pedestal for unfolding the advanced principles of regenerative design. For this to happen, an interdisciplinary approach to the design, multi-stakeholder support, and the revision of economy-driven actions at the policy level are necessary (e.g., regarding the economic vs. ecological value of construction land).

The consideration of land use in the activities connected with individual buildings, nevertheless, does not end at site boundaries (e.g., Allacker, de Souza, & Sala, 2014). Clearly, if environmental design aims to lessen

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environmental harm, with regard to all types of natural resources and in all phases of a building life cycle, then the scope of current LCA studies needs to be widened.

FIG. 5.1 Bosco Verticale, Boeri Studio, Milan, 2014. *(Image by the author)*

The vertical forest aims to bring nature back into the city. By creating a green zone around the building, the architects want to foster biodiversity and filter fine particles.

5.3 Energy Futures and Human Needs

Negative energy-related issues in the global system represent challenges to overall sustainable development and as such extend far beyond the boundaries of individual buildings. Therefore, the use of energy is primarily a capital socio-economic subject that, according to the current trends, obviously must continue to look for solutions to reduce differences, alleviate energy poverty, and mitigate negative environmental effects. This also means that the base from which current energy challenges should be addressed, and a sustainable energy future planned, differs between countries and regions, even where the common policy platforms have been developed and agreed (e.g., Attia et al., 2017).

In the future, the use of energy in buildings will, according to the current indications, be increasingly impacted by the regulation of relations between different stakeholders and at different key points of energy chain, from generation, to distribution, to end consumption (Bulut, Odlare, Stigson, Wallin, & Vassileva, 2015). While the advancement (or even only the achievement) of energy efficiency of buildings accounts for the already established environmental priority, further technological development and the definition of suitable multi-actor business models are important next steps towards success in reducing non-renewable and increasing renewable energy use in buildings. On the other hand, if future development will enable proportional relations between the available renewable energy and the needs (i.e. the consumption), the understanding of energy demands and limitations that currently represent the key postulate of efficiency might be significantly changed.

It is certain that there exists a time span over which it will be necessary to carry out a comprehensive transformation of some existing social and economic schemes.

Besides demands, some current discussions on sustainable energy futures imply a shift in understanding the comfort. Regardless of the speculations on whether comfort conditions and their definitions will change over time or not, it is unquestionable that the energy performance of buildings will continue to persist as an indication of activity patterns. Even now, the estimation of energy-related behaviour of building users is an intricate task with often inaccurate results (e.g., Delzendeh, Wu, Lee, & Zhou, 2017), for which reason building professionals must, besides the initial settings adjusted to efficiency goals (preferably above the level of prescribed minimum), also consider the ways in which occupants interact with the buildings. Offering different possibilities to the occupants will increase the chances for an adequate response to individual requirements and to changes that may occur with time.

Predicting the occupants' behaviour in the future characterised by climate change manifestations (like temperature changes) seems even more complex. For a climate-resilient energy future, it is necessary to balance users' needs, functional requirements, and design with the range of climate change-related situations that might occur during the service life of a building.

5.4 Models of Material Efficiency

The environmental impact of buildings is based on flows and stocks of matter and energy. Accordingly, a comprehensive approach to the reduction of any negative environmental impact of materials needs to frame both matter and energy. The traditional linearity of the design, construction, and use processes, i.e. of the life cycle, has been identified as a principal constraint. In essence, the linearity of a material life cycle means that transformed natural resources are used only once from cradle to grave, for which reason the balance between what has been taken from nature, what has been used, and what has been returned to nature, left as waste or forwarded to other man-made processes is largely disturbed. In a linear process, input resources, product, and its output form, display significant disproportions in terms of amounts, quality, and related environmental impacts.

Closing the life cycle has been proposed as a method for reducing the environmental impact of materials with main purpose to reduce the demand for new material resources as well as the impact occurring in different life cycle phases. To support the conceptualisation of a closed life cycle approach, several different terms such as *re-use* and *recycling* have been introduced, while the *biological decomposition* remained as the only positive side of linearity.

However, the success in taking measures to increase material efficiency cannot solely be attributed to designers' decisions and precedent analyses, because of the complexity of subject and the variety of actors that participate in the process. Therefore, the achievement of efficiency of material utilisation is a matter of establishing an acceptable, integrated economic-environmental-social model.

In the Cradle-to-Cradle approach, possible end-of-life scenarios have been introduced into two different entities – technosphere and biosphere (Braungart & McDonough, 2002). Like the Cradle-to-Cradle approach, other approaches dealing with the ecology of materials are integrated with industrial and economic models, e.g., industrial ecology (Frosch & Gallopoulos, 1989), green economy, performance economy (Stahel, 2008), blue economy (Pauli, 2015), and circular economy (Pearce & Turner, 1990; Webster, 2017) that synthetise all previously mentioned concepts according to the '6R' methodology (reduce, reuse, recycle, recover, redesign, and remanufacture (Jawahir & Bradley, 2016)), and currently represents the most relevant conceptual framework for sustainable production and utilisation.

Based on the idea to minimise resource input, waste, emissions, and energy leakage by slowing, closing, and narrowing material and energy loops (Geissdoerfer, Savaget, Bocken, & Hultink, 2017), a circular economy model is also known as circularity. In general, circularity concepts provide a spirited incentive in an ongoing debate about comfortable living standards in planetary boundaries. In a short time, interest in studying circularity has increased significantly, which, from one perspective, raised the relevance of the subject and, from another, generated a multitude of definitions, interpretations, and recommendations on the basis of which the lack of coherence in the accurate description of circularity can be noticed (Kirchherr, Reike, & Hekkert, 2017).

FIG. 5.2 ABNAMRO Pavillion, Amsterdam, de Architekten Cie, 2017
(Image by Ossip van Duivenbode, 2017)

The building attempts to be as 'circular' as possible. A large proportion of the used materials are biological (wooden primary structure); components can be reused wherever possible and wall finishing are simple to replace or can even be left away.

The implementation of circular economy schemes is influenced by actors who drive the transition (Lazarevic & Valve, 2017); economic implications of supply chains (Nasir, Genovese, Acquaye, Koh, & Yamoah, 2017); barriers to the application of the '6R' principles, particularly regarding closing the material loops; delivery of new options to the customers (Ritzén & Sandström, 2017), such as using or renting instead of owning; etc. Materials and components based on the principles of circularity shift standard design and construction methods. Having regarded the novelty of the approach, additional research and testing in terms of the performance of offered solutions during the exploitation phase are certain, just like systemic re-formulations of the overall building systems. By including different stakeholders into the estimation of circularity prospects and desired implications, it becomes obvious that there is a necessity to bring the design of new concepts closer to the legal regulations, and that the environmental impact will be sufficiently balanced only when both reliability and acceptance of the concept are achieved. Nevertheless, to unite circularity with business and growth means to join together often conflicting environmental and economic interests and to redefine existing production-consumption relations, for which reasons the contribution of a circular economy to sustainable development seems to be promising.

6 Conclusions

Environmental design must be understood as a continuous developmental process (rather than the desired state of a building) that evolves together with new scientific findings, new technological advancements, new users' demands, and wider environmental, social, and economic conditions. The main existing constraint in environmental design, as argued by GhaffarianHoseini et al. (2013), is the lack of national and international policies, in spite of their proven contribution to the mitigation of negative environmental impact. Although the efforts to frame environmental issues are clear, the absence of a standardised basis reflects negatively on the potential of environmental design to act as an agent that is able to anticipate future challenges such as resource scarcities, and to address uncertainties like climate change. Instead of applying a systemic approach that optimises the use of all types of natural resources, the dominant current concerns of environmental design are energy and materials.

Besides the integration of different measures of environmental design into a holistic framework, the integration of environmental design into wider sustainability frameworks is necessary, where the increased relevance of social issues could in turn result in the improved environmental performance of buildings. In that way, the user factor that has been identified as the key maintainer of the environmental quality of design would be more successfully addressed. It also means that the principles of environmental design may be more comprehensively applied only when suitable wider social and economic conditions are established.

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