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Educating architects - an optimistic vision for building sustainability evaluation

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ABSTRACT: Is it still possible to keep global warming below 2°C? Is climate change an inevitable disaster, already causing extreme heat and flooding coastal cities? With regards to this, the authors dislike the atmosphere of *Götterdämmerung*, especially in education. The fact is, along with industrialisation and economic growth, CO_2 emissions have increased significantly. However, economic growth and the reduction of CO_2 emissions are possible at the same time: through an increase in renewable energy. At present, there is enough knowledge and technology available to reverse climate change. Renewable energy is the fastest growing energy source worldwide. In urban planning and architecture, there are many good examples of resource and energy-saving projects. There is a need for more such efforts. Everyone must act now: through a success-orientated approach and best practice. The authors of this article believe that an optimistic approach is a necessity in education. Science and technology are good sources of optimism. Social systems inculcate and propagate information, regardless of its veracity. This is not the role of education.

INTRODUCTION

Carbon dioxide (CO_2) is one of the greenhouse gases considered to be the main cause of climate change. The increasing levels of CO_2 in the Earth's atmosphere are linked to economic growth and are caused by industrial activities that have ignored the environment; CO_2 levels have increased since the First Industrial Revolution. Since the start of the Second Industrial Revolution around 1860, the concentration of CO_2 in the Earth's atmosphere has grown exponentially [1]. The central aim for this century of the Paris Agreement (2015) was to keep the rise in global temperatures below 2°C above pre-industrial levels, and to pursue efforts to limit the temperature increase to 1.5°C.

To fight climate change, CO_2 emissions must be reduced. However, the emissions gap (the difference between *where we are likely to be* and *where we need to be*) has increased significantly. Global CO_2 emissions increased in 2017 and reached a record high. To change the direction of climate change, global greenhouse gas emissions in 2030 need to be significantly lower than in 2017. Technically, it is still possible to bridge the gap and achieve the temperature goals of the Paris Agreement, but it requires action from every country [2].

When applying an optimistic approach, a problem has to be viewed holistically. On the one hand, humanity today faces environmental problems. On the other hand, industrialisation, economic growth and the use of fossil fuels have dramatically improved human well-being. Statistically, people live longer and healthier lives than ever before [3]. With an optimistic approach, problems are handled as challenges. There is now enough knowledge and technology to reverse climate change. In architectural education, current problems should be presented to students as problems to be solved rather than as approaching apocalypses. *A problem-solving process, which is centered [on] concrete needs, creativity and innovation seems well tailored, as an approach, to solving the many environmental problems of current times* [4].

Younger people, especially students, should be motivated to opt for a more sustainable and greener future. *Architecture reflects the contemporary needs of society which, experience shows, constantly changes. No matter whether buildings, designs or visions are considered, they need to address up-to-date problems. Architectural education should provide tools for identifying and analysing such issues and encourage students' designs* [5].

Architecture students should promote building sustainability in their future profession. *Sustainable design, which once seemed to be a novelty and a thing of the future, is now a commonplace for students and future architects and must be so* [6].

In this article, an optimistic approach for architectural students' educations is discussed, regarding a sustainable future vision. The authors have the ambition to transfer this approach to lifelong learning.

FACT-BASED OPTIMISTIC APPROACHES

While there are alarming scenarios for climate change, there are approaches that consider the problem from another point of view. Hans Rosling, Ola Rosling and Anna Rosling Rönnlund, authors of the book *Factfulness*, offer a radical new explanation as to why global trends happen. These authors aim to change the way people look at things and information - not through a dramatic attention filter, which easily leads to a stressful, overly dramatic impression of the world, but through facts. Critical thinking is required to maintain a fact-based worldview. *When we worry about everything all the time instead of embracing a worldview based on facts, we can lose our ability to focus on the things that threaten us most* [7]. The authors claim that, according to statistics and data, the world is improving.

Steven Pinker in his book, *Enlightenment now: the Case for Reason, Science, Humanism, and Progress*, shows that health, prosperity, safety, peace and happiness have been rising worldwide. *If you think the world is coming to an end, think again: people are living longer, healthier, freer, and happier lives, and while our problems are formidable, the solutions lie in the Enlightenment ideal of using reason and science* [3]. Pinker supports all his statements with quantitative data. He shows concern about climate change, but does not see it as a problem that cannot be solved. He claims that all problems, if studied long and hard enough, can be understood and, at some point, solved. Scientific progress is essential for attaining knowledge that will enable humans to find the cleanest and most efficient use of energy [8].

Sustainability nowadays is a general mainstream issue, but too many academic colleagues are frightening students about the future. They predict the end of civilisation and mankind. The point of view of the authors is different, i.e. that a sustainable future is in the hands of society. The human race just needs to use what is available at the tips of their fingers. The best way to achieve this, is through education in appropriate ways of thinking and acting. Examples concerning technological progress are considered in this article in support of the above argument. Appropriate educational approaches are suggested.

OPERATIONAL CARBON VERSUS EMBODIED CARBON

> *I've been polluting the planet for years. I'm not an oil exec - I'm an architect. And no amount of data or complex modelling will rectify the building industry's staggering impact on the environment. Design culture itself needs to change* [9].

The role of an architect and engineer and their everyday design decisions are crucial for climate change. Together, building and construction are responsible for 39% of global carbon emissions [10]. There are two types of carbon emission caused by buildings: operational carbon (the energy used to operate a building) and embodied carbon (the materials and construction processes used throughout the entire building's life cycle) [9]. Operational carbon accounts for 28%, while the remaining 11% is estimated to be from embodied carbon emissions - see Figure 1 [10].

The most discussed topic to reduce energy, costs and emissions from a building, is energy efficiency during the operation of a building. However, activities, such as mining, processing, transportation, industrial operations and the combination of chemical products all result in the release of greenhouse gases. The global construction industry is booming right now, and because of population growth, new construction is expected to double the world's building stock by 2060. It is estimated that more than half of total carbon emissions from global construction between 2020 and 2050 will be due to embodied carbon [11]. Therefore, one of the biggest concerns of architects should be the reduction of embodied carbon emissions. This is a standard part of teaching.

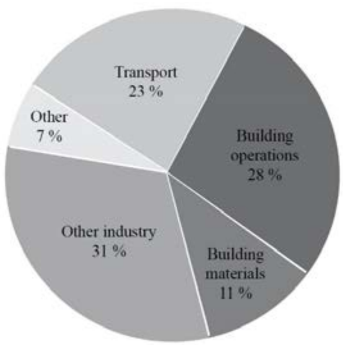

Figure 1: Global share of emissions by buildings and construction (2018) [10].

Every material has a different environmental impact, depending on its extraction, manufacturing, construction, maintenance and disposal. For example, reinforced concrete is a material with extremely high embodied carbon, mostly caused by cement. The production of cement is a complex and energy-intensive process. Because of the high temperatures required during processing (around 1,450°C), fossil fuels have to be burned to reach this temperature. However, other commonly used construction materials are also high in carbon and are energy intensive, such as iron, steel, aluminum and glass, as well as ceramics, brick and plastic, since the minerals in them must be extracted and treated in an energy-intensive process. Local conditions have to be considered as well - a sustainable material in one place may have a high energy load in another due to local availability and the type of transport involved [12]. Using local materials is a subject of studio teaching, often understood as an alternative to using industrial building products.

EVALUATION: CARBON-BASED BUILDING SUSTAINABILITY

The assessment of the sustainability and creation of materials has undergone both philosophical and physical development. Originally, the focus mainly was on operational energy and its reduction through energy-saving concepts (thermal insulation, efficient HVAC systems). Gradually, the carbon footprints of buildings were taken into account. Carbon footprint appears to be the optimal method of environmental impact assessment: both embodied and operational carbon must be considered. In architecture, there are methods to evaluate the environmental impact of a building, from the extraction of materials and the manufacturing of products to the end of their life, as well as disposal. Life-cycle assessment (LCA) is a standardised method, which is already well known, but still not frequently applied in architecture design teaching and practice.

> *Low-carbon architecture is ethical architecture. (...) The goal is not to transform architectural design into an act of analysis. The real work now is to figure out how to make carbon assessments part of ethical and inspired design practice. (...) The vision of a radically decarbonised building sector is possible, but only if we all work as if our future depends on it* [9].

To reduce the carbon footprint that comes from building, a balance between embodied and operational carbon must be found. By adding thermal insulation to reduce heat energy (linked with reduced operational carbon emissions), the embodied carbon emissions related to the thermal insulation increase. Depending on the kind and amount of material and heating requirements, it is important to find the optimum ratio. A similar principle can be applied to operational and embodied energy, as shown in Figure 2. Initially, in this example, the thicker the insulation, the more the total primary energy requirement of the house decreases. However, from a certain insulation thickness, a further increase then causes an increase in the total primary energy requirement [13].

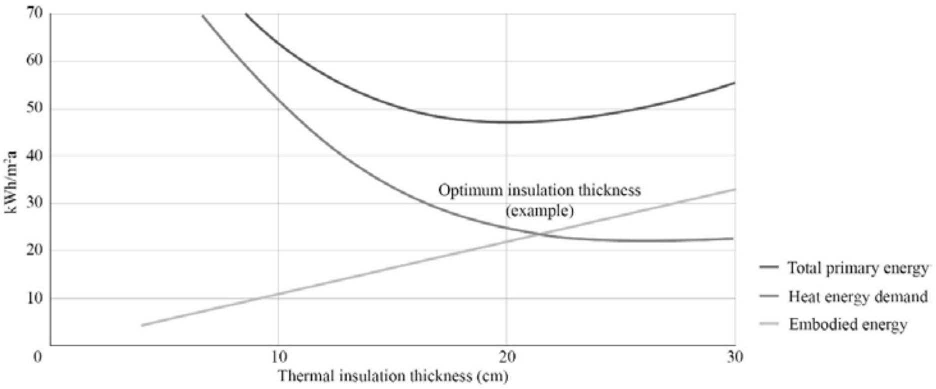

Figure 2: Example: life-cycle analysis of a building according to embodied, heat and total primary energy.

The overall amount of 39% of carbon footprint caused by buildings will need to be reviewed. There are several options to reduce the environmental impact of buildings; for example, by reducing comfort and area demand per capita; by reducing energy consumption through insulation in the building's envelope; by using highly efficient HVAC systems; by extending the building's life time (less resources, more use) or by increasing the share of low carbon technology in the energy mix. In the future, an increase in the share of renewable energy in the overall energy mix should be expected.

The positive effects of a CO_2 neutral energy sector are that a building's embodied carbon can be saved - when there are enough renewable energy sources to cover the energy demand during the building's operation, and that the resources used to insulate the building can be reduced. In a sustainable building assessment, calculating the carbon footprint will gradually replace the energy efficiency evaluation of the building. The amount of operational energy saved through thermal insulation must then show a higher carbon footprint than the applied insulating material.

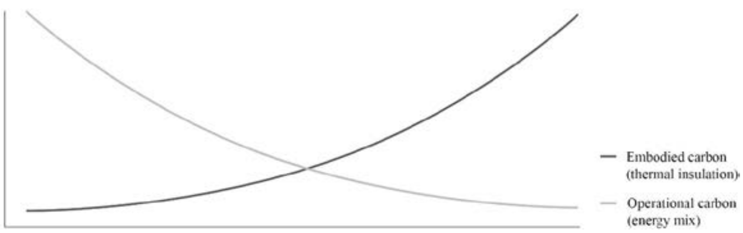

Figure 3: Both the embodied and operational carbon footprint related to the life cycle of a building.

A vision of energy with a carbon footprint close to zero will change the definition of effectiveness. In seminars, students have to evaluate their building designs according to the above-mentioned methodology. Considering the higher amount of green energy in energy mixes in public networks, students should rethink the building's needed thermal insulation. Figure 3 shows an example where the higher the share of renewables in heat energy consumption, the lower the effectiveness of the building's envelope thermal insulation. However, this approach is not popular among green fundamentalists.

OPTIMISTIC VISION: NET ZERO OPERATIONAL AND EMBODIED CARBON BY 2050

In the report, Bringing embodied Carbon Upfront: coordinated Action for the Building and Construction Sector to tackle embodied Carbon, the World Green Building Council set goals for the whole lifecycle of all buildings and infrastructure to be net zero carbon by 2050. Reversing climate change is possible only through decarbonising the whole lifecycle of buildings. *By 2030, all new buildings, infrastructure and renovations will have at least 40% less embodied carbon with significant upfront carbon reduction, and all new buildings must be net zero operational carbon. By 2050, new buildings, infrastructure and renovations will have net zero embodied carbon, and all buildings, including existing buildings, must be net zero operational carbon* [11].

According to the report, the goals can be achieved only through the co-ordinated action of businesses, government and civil society. There are already many examples of leadership: developers and construction companies, designers, financial institutions, city networks and governments, as well as industry representatives (concrete, steel, timber) and many more. Among the best is in Oslo, Norway, which has a commitment to fossil-free construction sites; and Vancouver, Canada, which has a goal of a 40% reduction of embodied carbon in new buildings by 2030.

The development and construction group Skanska enables projects to be evaluated by lifecycle analysis, and Heidelberg Cement has committed to developing carbon neutral products by 2050. The report contains an urgent call to others from the field of building and construction to work together to fully decarbonise buildings and infrastructure by 2050 [11]. In design studio teaching is the *carbon assessment* of building materials a crucial issue? A new, low-carbon paradigm for architecture should be an educational issue.

OPTIMISTIC VISION: 100 PERCENT GLOBAL RENEWABLE ENERGY BY 2050

Economic growth and a reduction in carbon emissions are possible at the same time - through an increase of the renewable energy share in energy consumption. This means a drastic reduction in the use of fossil fuels (oil, gas, coal), in parallel with the development of renewables and other low-carbon energy sources. It is necessary in education to focus on facts about positive developments in energy sectors around the world. Students have a tendency to perceive the present situation as mostly negative. Therefore, positive trends from the past 10 to 20 years should be relayed to students. As Rosling stated, several situations are not good, but they are getting better [7].

In 2017, renewable energy accounted for an estimated 18.1% of total energy consumption, with 10.6% supplied by modern renewables. Renewable energy has established itself on a global scale - its share in global energy consumption has increased significantly in a growing number of countries worldwide in recent years. Today, the largest proportion of avoided emissions are generated by regenerative electricity. Furthermore, consumption of biofuels has increased in transport, while far less growth has occurred in the heating and cooling sector. Modern renewables include hydropower, wind power, solar energy (photovoltaics, solar thermal heating and cooling), bioenergy, geothermal power and heat [14].

In Europe, the share of renewable energy in total energy consumption increased between 2004 and 2018, from 8.5% to 18.9%, following the legally binding targets for 2020, according to Directive 2009/28/EC from the EU on the promotion of the use of energy from renewable sources. Wind power is the largest source for renewable electricity generation in the EU, but solar power and solid biofuels (including renewable wastes) have also grown significantly [15]. For example, in Germany about 203 million tons of CO_2 emissions were avoided in 2019, based on data from the development of renewable energies [16]. In 2019, the EU presented the *European Green Deal*, with the goal to make Europe the first climate-neutral continent by 2050 [17].

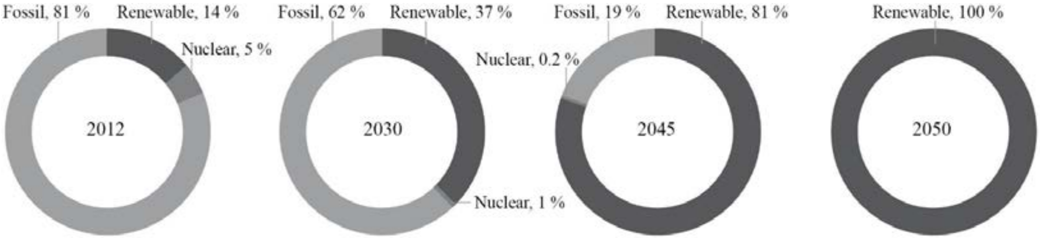

Figure 4: Greenpeace Energy [R]evolution scenario 2015.

More scientists, engineers and activists are actively promoting a 100% renewable energy vision. According to studies, existing technologies make it possible to have fully sustainable energy by 2050. There are countries that already obtain almost 100% of their electricity from renewables, with the goal of a carbon-neutral energy system in the next few years. Examples are Iceland, Paraguay, Costa Rica, Norway, Austria, Brazil, Denmark and New Zealand. The main renewables in these countries are hydropower, wind, geothermal and solar [18]. Depicted in Figure 4 is a Greenpeace scenario for the phase-out of coal, oil, gas and nuclear energy, as fast as technically and economically possible, by expanding the renewable energy share to 42% in 2030, 72% in 2040 and 100% in 2050 [19].

OPTIMISTIC VISION: DECENTRALISATION AND SMART INFRASTRUCTURE

Decentralisation and citizen-based renewable projects are important means by which to reach 100% renewables in Europe. Conventional energy comes from a few large, centralised monopolies. However, it makes more sense to generate energy at or near the point of its consumption and renewable energy sources are ideal for a decentralised energy policy. *The two countries in Europe that have installed the most renewable energy since 2009 are Denmark and Germany. These are also the countries with the highest citizen participation in this energy transition. In Germany, many different ownership models exist, and only 5% of the installed renewable energy capacity is owned by large, traditional energy utilities. In Denmark, wind projects are given permits only if the developers are at least 20% owned by local communities* [20].

Citizens play a key role as part of the renewable energy system in Europe's energy transition. In addition, they profit from decentralised systems and participation models through ownership or attractive job opportunities. Citizen-based activism is highly popular among younger generations, so it is also a useful teaching tool. *A 2016 report by CE Delft, a research organisation, estimated that 264 million energy citizens could generate 45% of the EU's electricity needs by 2050. The same report also shows the potential of different types of energy citizens: in 2050, collective projects and cooperatives could contribute 37% of the electricity produced by energy citizens* [20]. Other projections suggest that *energy citizens* could produce twice as much power in 2050 as nuclear power stations produce now. Decentralised energy production is becoming more important: architects have to integrate energy generators into buildings and their façades, create energy-efficient building clusters and reach a symbiosis with a building neighbourhood. It is an inevitable part of architectural and urban design teaching.

As the availability of renewable energy from natural resources varies during day/night and seasonally, there is a need to develop new, smart infrastructure and storage. A smart grid as a network of integrated micro grids is a key element, and with the help of digital technologies, a highly efficient energy system is possible. Some examples are: implemented demand management (in relation to peak times and variable energy supply); smart appliances that run at optimal times; smart storage (energy generated in off-peak times is stored for later use); or smart e-car charging [21]. Digitalisation, intelligent technologies, smart buildings and cities bring unlimited energy-saving possibilities and belong to key elements in decarbonising buildings, communities and cities.

OPTIMISTIC VISION: INNOVATION AND PRACTICE

Innovation and practice are the best means for fighting climate change. Research in photovoltaics and other renewable energy technologies has resulted in a continuous increase in their efficiency. Costs of photovoltaics and solar thermal panels are lower than ever before and affordable for almost everyone. Furthermore, simple household power storage, such as powerwall batteries, are available to buy. Innovation projects, such as transparent solar cells, automated concentrated solar plants, CO_2 capture, storage technology and much more are paving the way for decarbonisation of energy and the building industry. In addition, there are concepts being developed with the goal of making carbon-intensive materials, such as concrete, more sustainable. Some examples are material reduction technologies through the use of voided building methods, sustainable cement manufacturing strategies and innovations, such as living or carbon concrete. There are projects all over the world showing that decarbonisation in construction is possible and affordable.

A demonstration project shown in Figure 5 to Figure 8 is from the Energy Positive School Rostock, IGEL (Initiative for Global Environmental Leadership) Institute. The building not only generates more energy from renewable sources than it consumes, but also saves embodied carbon emissions through construction from local, natural materials and use of voided methods for concrete ceilings [22]. Designed with the direct participation of teachers, it represents a best practice example for students.

Figure 5 to Figure 8: Energy Positive School Rostock (original photos - M. Wollensak, L. Oberfrancová).

DISCUSSION AND CONCLUSIONS

The authors introduced in this article a small part of the positive developments and best examples in the decarbonisation of the building industry. Living in an era of smart technologies and innovations means there are now many more concepts and projects around the world by which to reverse the negative impact that humans have had on the environment. Decarbonisation is not the only issue. A circular economy, sustainable water and waste management, health and well-being also belong to the main goals of sustainable development.

Many problems still exist, but with today's technology and innovations, solutions can be found for most of them. There are successful initiatives, projects and actions that are finding solutions for issues, such as plastic waste in oceans, extinction of the animal species, water and air pollution, deforestation, and many more. The hope is that younger generations will grasp innovation and the need to be positively motivated. For this reason, the teaching of sustainable architecture, based on facts and science, should help students perceive the problems holistically, and inspire them to contribute, through their future professional activities, to a healthy and sustainable environment.

Technological progress and current knowledge make possible the introduction of an optimistic approach in architecture education. Teachers will have to deal with a new educational approach, since long-held truths in textbooks are no longer enough. Today, on-line information based on current trends is accessible to everyone and students have to be motivated to find and use them.

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