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Sustainable Architecture—What's Next?

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Abstract: DefinitionSustainable architecture encompasses more than energy efficiency, zero carbon dioxide (CO_2) emission or renewable energy use in the built environment. It also needs to alleviate overall impacts on the natural environment or ecosystem that surrounds it. It may be argued that primitive vernacular architecture (architecture without architects) built and operated using local techniques and resources alone can be considered to be sustainable. Yet later, after the 1992 Rio Conference and its declarations, more specific definitions emerged putting weight on the rational use of land area, materials and energy, preferably local, as well as area efficient planning, economy and recyclability. The advantage of this is to reduce the ecological footprint of buildings and the climate gas emissions from a sector that represents 35–50 percent of global climate gas emissions, depending on how one counts. This paper clarifies concepts, questions cemented truths and points a way forward by asking; what's next?

Keywords: sustainable; architecture; Zero Energy Mass Custom Homes (ZEMCH); energy; efficiency; forecasting; ethics; climate change; log burning

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1. Background

A few months ago, the author of this article had the pleasure to be part of a zoom-union, a 50 years celebration with classmates from first year at the School of Architecture, University of Manchester, England in 1970. The group was supposed to meet in that great city, but the reunion was cancelled, like so many other trips during 2020, due to the Covid-19 pandemic. The way all had adapted digitally since the lockdown started mid-March was impressive. Everybody has been intensively digitalized and the impact of that change was remarkable since it happened in a very short period of time and its long-term positive effects are not yet clear. This paper will not only deal with shaping the notion of sustainable architecture but also speculate how today's COVID-19 pandemic could change the way we think and act from viewpoints of the author's learning experiences as a professor, teacher, researcher, and an architect over the last 50 years. The intention is to communicate and share them in a structured way, as eleven thoughts.

2. Climate Change

The consensus among the majority of the climate change experts in the UN's Intergovernmental Panel on Climate Change (IPCC) is that the climate is changed and it is manmade. While we continue to do our utmost as professionals and private citizens to avoid further climate change, EU has set the goal of reducing CO_2 emissions by minimum 55% by 2030 and China claims it will be climate neutral by 2060. The question is now how much the climate will change, in spite of these new goals, and how much will we have to adapt to the new situation or climate to deal with it [1].

According to one of the lead authors of IPCC's report now working on the next report not yet published, global average temperatures can rise as much as somewhere between 3.2 and 3.6 degrees C by 2100 compared to pre-industrial time, the period 1850–1880 [2]. We have already passed 1.25 degrees C. Several sources have earlier forecasted temperature rise by between 2- and 6-degrees C. Thus, 3.6 degrees C is hence moderate [3]. But what does it mean for buildings and cities, is it a lot or not?

The answer is simple; it is a lot.

If we look at Europe, the continent is basically split into roughly three climate zones: the northern (Stockholm), the middle (Zurich) and the southern (Milan). The annual average temperature between the northern and the middle is 2.4 degrees C and the same is the case between the middle and the southern, 2.4 degrees C. In other words, the design manuals for buildings in Stockholm in 2100 will have to show designs capable of managing the temperatures 3.6 degrees higher than now, like in climates in the regions halfway between Zurich and Milan [4] (pp. 95–101). That is hot and needs a total rethink.

In addition, and complicating the matter further, the "heat island effect" will mean that temperatures in cities will occasionally be much higher than the above. The above were averages only, but in cities, due to heat escaping from buildings, sheltered spaces, sunlight reflection from neighboring buildings "heat island effects" can mean temperatures 5–12 degrees above averages. Heat is going to become a huge challenge and the need for cooling through natural ventilation and/or air conditioning will increase dramatically. We, therefore, need a total rethink of how we design highly insulated buildings. We need to rethink all we have known until now and go back to the drawing board. That is the scale of the challenge.

3. Sustainable Architecture

Defining sustainability is almost impossible due to all the preconceptions connected to the word. It must be one of the most extensively used word of our time trying to describe something but not succeeding. Before the word was introduced words like ecology or environmental were often used and. Rachel Carson's *Silent Spring* in 1962 was a wake-up call about the use of pesticides and the damage to the ecological balance in nature, to the environment [5]. She wrote about the loss of insects leading to the possible extinction of birds, hence the title, no birds—no bird song—just silence. In Alvin Toffler's book *Future Shock*, ten years later in 1971, scientific trajectories were sketched. In the last chapter, number 20, Toffler writes about the strategy of social futurism, the death of technology and the humanization of the planner [6]. It is a signal of what is later to come. In architecture a "going back to nature" school emerged. Some architects designed buildings with turf on the roof, built from logs or local brick. Not much different from the vernacular architecture in earlier periods, yet the new awakening was coupled with modest attempts at using technology. Solar thermal systems for domestic hot water heating emerged, either home built or by local plumbers. They were very simple systems and many of them clogged up due to high levels of chalk in the local water. Some remote housing schemes using primitive windmills to pump water or try to produce some electricity emerged. Others used large log fires to produce direct heat and to heat water for storage. Finally, small solar Photovoltaic (PV) units delivering some electricity became available after the spacecraft industry had developed them for use to power communication links, satellites and space rockets. The advanced PV technology with no moving parts rubbed off into the building industry. Some of the early architectural experiments even used a combination of all of the above technologies. With all this gear inside, on or around the house it looked more like an engineer's dreamy Christmas tree than architecture.

However, and luckily, more and more architects engaged to make solar and other technologies as integrated parts of buildings. The early examples from 1988, as in the Chanelle house Figure 1, was one attempt at creating acceptable solar architecture and at the same time integrate as many technologies as possible.

(**a**) (**b**)

Figure 1. (**a**) The Chanelle house, Stavanger, Norway was one of the first modern energy autonomous buildings in Europe trying to integrate renewables like solar PV, solar thermal, windmill and battery and thermal storage in a more architecturally acceptable way through building integration. The house designed by the author was an attempt at showing alternatives to the messy roofscape developing throughout Europe at the time, due to lack of engagement among architects, as this picture from the Eastern Europe apartment block and the Greek house show the roof chaos is total (**b**). All photos: the author.

From this period, the UN's work with the Commission on Environment and Development led by the Norwegian Prime Minister Gro Harlem Brundtland, hence the report's nickname "the Brundtland Commission Report" began to have an impact [7]. This was partly because it actually tried to define the concept sustainability. However, it struggled to define it because the report wanted to show some hope and combat critics that had argued the report will end with a lot of words trying to stop a natural technological development and global growth. After two world wars, people wanted growth and prosperity and not more obstacles. Hence, the concept of sustainable growth was coined, and it still stands as a viable surviving concept, mainly because it is round and not very concrete. It has been applied to all kinds of situations and professions. In architecture, the concept of sustainable architecture became dominating for a long time. The other slogan that came out of the report was our common future. This too lives on.

The Brundtland Commission documented that the world in many ways was on the way towards ecological disaster. We, especially us in the Western world, were not living sustainable lifestyles. Here the definitions emerged, and they basically stated that we need to make sure that whatever we do does not make life harder for coming generations. We must treat the natural environment as if we just borrowed it, to pass it on to the next generations. This, almost religious statement, is not sensational but very simple and self-explanatory in its general simplicity; sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own need.

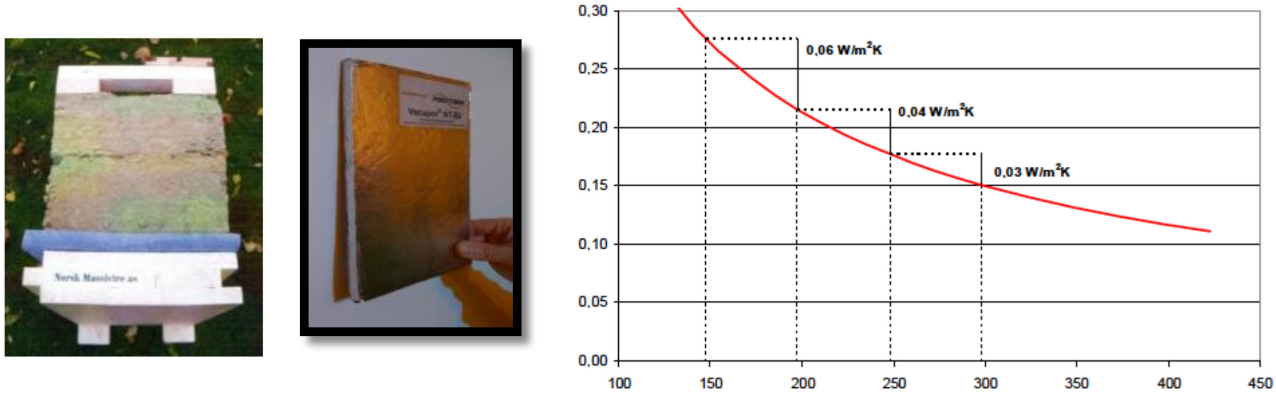
If there is anything people in the Western world have actually done during the last couple of generations, it is to do the contrary of what the Brundtland Commission preached. Furthermore, when you get down to the nitty-gritty of life and have to make actual decisions as an architect, for example, how do you do it in a sustainable way? While the Commission argued for the generational perspective in general terms it was very clear, especially in debates after the launch, that the use of solar energy is the only way to avoid the dangerous use of nuclear energy in the future. The commission also made it clear that buildings account for a huge proportion of energy use globally. Later, we have come to realize that buildings as a rule of thumb represent approximately 40% of global energy use and the figure for buildings' part of climate gas emissions including production and transport of building materials, represent between 40 and 50% of global annual emissions.

Then in 1992 followed the UN Rio Conference. The first of a range of international conferences on sustainability, although climate had become the overarching theme by now. Avoiding climate change was the main objective. Still, and mysteriously, at Rio it was not planned to deal with energy as a separate issue. Instead it was hidden in between all kinds of other headlines like agriculture, transportation and housing. It was dealt with as a minor issue. Through the work of Eurosolar, World Council Renewable Energy (WCRE), International Solar Energy Society (ISES) and World Watch Institute, through a process initiated by this author and German Hermann Scheer of WCRE, the issue of energy was lifted higher up on the agenda and today is one of the top priorities, along with energy efficiency and behavior change [8].

Further into the 1990s it appeared that to get the mixed solution to work in a built context you needed to be an engineer in order to live in the houses, but slowly but surely the simpler solutions won. At their base was always energy efficiency in order to reduce the need for energy. By doing that, the energy supply system could be smaller and cheaper to buy as well as better integrated. The emergence of zero energy buildings and later mass production removed the problems related to self-build mistakes and improved quality control. The concept of zero energy mass custom homes (ZEMCH) was born and its organization developed over time. Two events were crucial to this development; first the ZEMCH technical tour in 2006, later called ZEMCH Mission to Japan and in 2010 the establishment of the ZEMCH Network. Secondly, the international ZEMCH conference in Glasgow in 2012, which spiraled work in its intended direction, hence contributing further to the development of the fields of zero energy mass construction housing [9] (pp. 83–95). In order to see such changes some kind of forecasting skills are useful.

3.1. Insulation

The need for thick insulation will disappear with the kind of climate change indicated above. New insulation methods like the ones used in refrigerators and caravans that are more compact than glass wool and rockwool based ones, will probably be taking bigger market shares. Thus, making housing construction slimmer and cheaper. Designing buildings with in total 35–50 cm thick walls can become useless as overheating the inside of the building will become a problem, instead, 10 cm wall thicknesses could do the job most of the days over a year, even in the colder climates of the world. We already know the efficiency of increasing the thickness of wall- and roof insulation is minor over a certain insulation thickness, as shown in Figure 2. Increasing the insulation thickness from 10 to 15 cm increases the insulation value (U-value) by 0.06 W/m^2K. Increasing insulation thickness from 25 to 30 cm increases the U-value with only half, 0.03 W/m^2K. This is illustrated with the curve getting flatter and flatter as the insulation thickness increases. Increase from 45 to 50 cm insulation hence only increases the U-value by less than 0.015 W/m^2K.



(**a**) (**b**) (**c**)

Figure 2. Housing using 35–50 cm thick walls, whereof most is insulation is very material-, transport- and workmanship demanding (**a**). The search has started for slimmer insulation methods inspired by the caravan and refrigeration industry, fridges that people use in kitchens is one example (**b**). The science of insulation thicknesses and insulation efficiency is clear. As illustrated for a Norwegian climate, the improvement of insulation is smaller and smaller the thicker the wall is (**c**). The *X*-axis shows insulation thickness in cm (rockwool or glass wool). The *Y*-axis shows u-value. All photos and illustrations: the author.

This was tried out in the Kolnes house in Randaberg, Norway where a 10-kW solar façade made the house net energy autonomous over the year by grid connection producing between 6500 and 9000 kWh a year. See Figure 3 The house's annual energy need is 6000 kWh. The cost of the solar modules, inverter and mounting is reduced by the saving in cladding materials that it is replacing. If that cladding was planned to be of an expensive type like marble or stone sheets, bricks, high quality metals or expensive timbers, the solar PV cladding would be cheaper than that. The cost of the solar system module part, normally at least 60 percent of the total solar system cost, is hence paid back instantly. The house is area efficient, a compact house of only 60 m^2 total floor area. In addition to the annual surplus production of solar electricity from the south east and south west facades, the designer has questioned the following:

Is the use of extremely thick insulated walls, nowadays ending up with up to 50 cm overall to design Net Zero Energy Buildings (NZEBs) in the Norwegian climate, wasteful? Instead, a refrigerator-type insulation was tried, leading to total wall thickness of 15 cm only. This led to savings in materials needed, their transport and workmanship hours as well as floor area. The area saving, footprint on site, was as high as 23% for a 60 m^2 house with 30 m^2 on two floors, if the difference between 50 cm and 15 cm walls are used as a basis for the calculation—Figure 3c.

Is the use of centralized balanced ventilation and heat recovery being essential in order to achieve NZEB standard in a cold climate like the Norwegian one? Ducting for transporting air to and from a central heat recovery unit is demanding necessary floor height and vertical ducts adding to material use and costs. Instead, a point-based, local heat recovery/fresh air unit is used, one for each room. It is a small 20 cm diameter duct like a prefabricated unit. There is one per room inserted through the external wall. The length of ducts saved is for this compact house hence 60 running duct meters and a room of 3 m^2 that a central air handling unit would have needed—see Figure 3b.

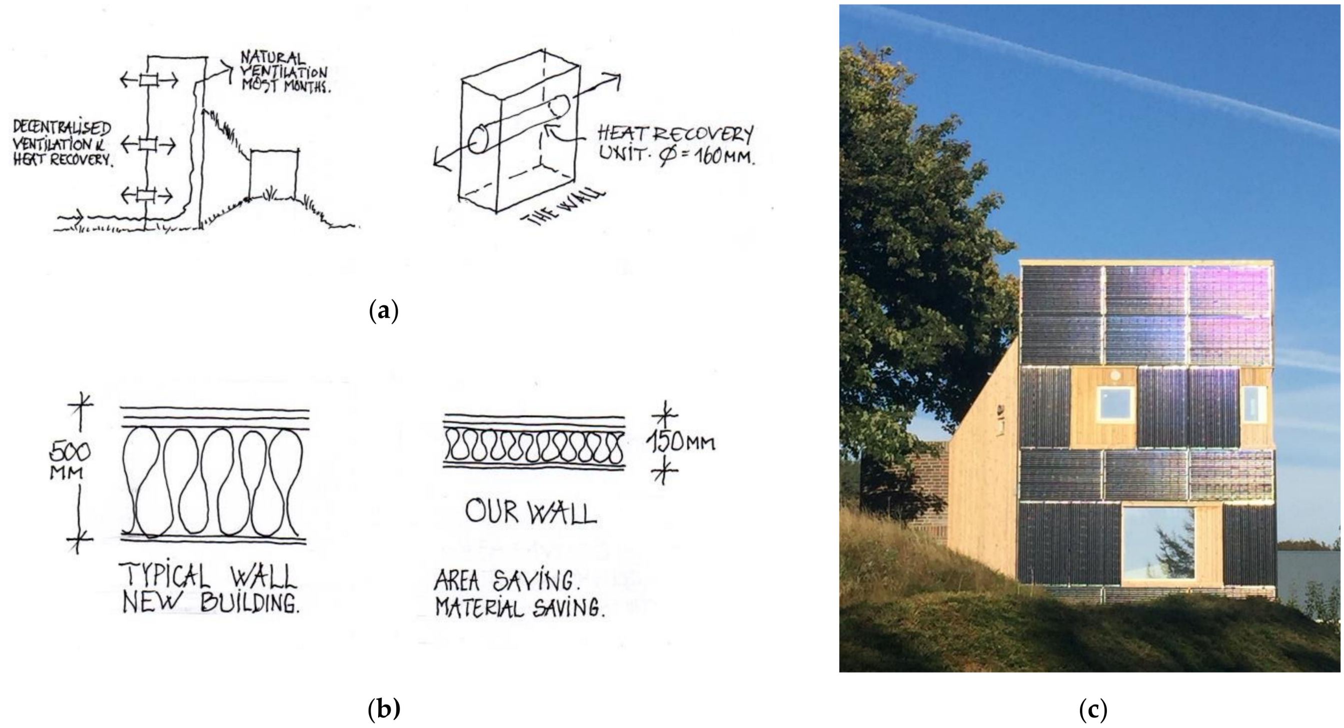


Figure 3. Kolnes compact house, Randaberg, Norway: 60 m^2 total floor area (**a**,**c**). New refrigerator insulation materials for envelope applied. Instead of the typical 50 cm total wall thickness in new NZEBs in Norway, the total wall thickness here was 15 cm, leading to huge material and area savings (**b**). Instead of a centralized ventilation and heat recovery system, demanding floor height and ducts a point fresh air and heat recovery system was used in each room. This saved 60 running meters of ventilation distribution ducts and a 3 m^2 room that a centralized system would have needed (**c**). All drawings and photos: the author, which is also the architect.

The massive use of insulation as one way of reducing heating need often seems like a one eyed and very short-sighted strategy because it is designed to reduce building envelope heat losses to almost zero during the coldest periods when outdoor temperatures are minus 1 to minus 10 degrees C. In many climates this happens very rarely. An alternative strategy would be to design the envelope's thickness based on the annual average temperatures. In the Norwegian cold climate example above this means that a traditionally insulated wall could be 20 cm instead of 50 cm total wall thickness and heating systems would still easily cope. As Figure 2c shows, the U-value gain from increasing insulation to extreme levels is marginal and probably not economical, to the house buyer and society at large, all factors considered. Considering that the global climate is getting warmer and warmer and extreme weather more likely, rather than designing a house as a heavily insulated thermos, as if the outdoor temperature was minus 10 C all year round, it could be designed for a mild climate and with a small emergency room for the few extreme winter days. Such a room would have to be located near kitchen and bathroom and facilitate both living room and bedroom possibilities in one room. However, this is only to be used for a short time and under extreme weather conditions. Rethinking such possibilities would lead to a more radical approach among house designers and more rational use of materials than the laidback approach we mostly see today.

There is also bound to be a rethink of the value of the extreme insulation achieved for windows and glass doors. The drive towards making better insulated glass have been very successful, but the downside is rarely informed about. In cold climates when the nights are below zero, the sky is cloud free and the humidity in the air is high, combined with no wind, a layer of frost appears on the outside of the glass making it impossible to see through it. It is the dew or condensation that forms a layer on the external side of the glass. It occurs because there is hardly any leakage of heat from the inside of the building through the glass, hence no melting occurs. Many new flat owners wake up on their first frost morning during autumn or winter in their newly acquired, often expensive top flat, only to realize they will not be able to enjoy the view on days like that. This phenomenon is well known among manufacturers and contractors, but not always communicated clearly to the buyers of apartments.

This should also send a signal to planners, including designers of ZEMCH. We must pose the following question: Is this high-quality insulation really worth it when the cost is high cost windows and occasional lost view to the outside? Are there other solutions? Other solutions could be to go for a less insulating window quality and instead allow some more use of energy. If the energy supplied is renewable, the sustainable considerations are covered. If the energy in addition is provided on site and is cheap the total cost for housing and its running costs will decrease or at least stay stable and with less challenges for the views.

Could we instead develop windows with multiple functions, not only as an insulator and an area for view and daylight but also to actually produce energy—passive solar and electricity, PV as shown in Figure 4b?

(**a**) (**b**)

Figure 4. After a night of minus 3 degrees C humidity in the outdoor air has frozen to ice on the outside of the windows making them look like frosty glass (**a**). This occurs at regular intervals during the winter when high air humidity is combined with frosty nights and clear sky. The problem is that this frosty glass was not ordered and people that are unaware of this gets shocked when their often expensive views are completely eliminated during most of the following day. The photo is of a brand-new housing development at Ledaal Park, Eiganes, Stavanger, Norway—opened 2020. Windows can also have a double function both being transparent and producing solar electricity PV as shown in this Sanyo product from 1989 (**b**). All photos: the author.

The great concern to insulate buildings better in spite of climate change's consequence, raised temperatures, is the often lack of concern with indoor temperature increase. There are growing g concerns that in the future buildings will no more just be protected from cold environment but avoiding and controlling solar heat gains during the warm season. This challenge will then have to be addressed for example through screens or inner thermal mass.

3.2. Solar Energy

The use of solar energy for all kinds of purposes has expanded fast over the last ten years. Prices of solar PV electricity today are below 1/100th of the level 30 years ago and they keep falling [10]. Solar thermal for buildings is also taking a big share of the market, basically for domestic hot water. The square meter of roof, wall or garden becomes valuable and can be put to use for solar equipment. While in northern Europe, it is possible to get

120 kWh per m^2 of useful electricity out of a PV module per year, the similar figures for evacuated glass tube solar heating system is 500 kWh. Flat plate collectors are slightly below around 300–400 kWh. When using solar in relation to a building, it is crucial that the modules are well integrated and replace other cladding materials in order to save on costs, thus making solar more rational and viable [11] pp. 46–58. The use of passive solar as heat through windows and greenhouses is another way of making use of the sun's energy. However, since this is not a technology, a sellable product, but rather depends on the knowledge of the planner, it is frequently forgotten. However, passive solar is still applicable and the oldest of all solar techniques. Cave dwellers used it and when the forests around Rome were chopped down for log burning purposes, they had to import wood from Caucasus. It became complicated and costly. Emperor Justinian who was ruling from 527 to 565 hence introduced a law ensuring houses' right to sunshine through windows. This was possibly the world's first passive solar law. It was written into the Justinian's Codex [11] (pp. 170–171).

When in the 80s architects tried to design energy autonomous solar housing, they often ended up with very complex combinations of systems combining several energy sources as in the Chanelle case, Figure 1a—as opposed to in the Kolnes case, Figure 3 where only one energy source, solar PV, is used. Nowadays and in the future, it does seem that simpler systems will win. Solar PV is hence a gift because the electricity it can produce can be used as that, as electricity, or it can be used to power a heating system. The challenge is of course energy storage and the solution is a choice between either running two-way on a city- or rural central grid system (grid-connected), a local neighborhood grid system (positive energy district grid—PED) or an in-house electric storage normally battery based, like in the Madla-Revheim case, Figure 5, a new part of town to be housing 10,000 people.

In the latter case and also possibly in the PED case, the huge increase in the number of electric vehicles will allow the sharing of battery capacity between houses and vehicles, as the drawing in Figure 5 shows. Electric vehicles and bikes are often charged at home, but also at work and at public charging points. The vehicles hence often return home with quite full batteries that can be tapped by the household and filled again by the house's solar PV system when there is surplus. In this way, in the future ZEMCH, the battery capacity particularly of electric vehicles has to be considered when designing a total energy balance system. The electric storage buffer will hence be larger than that of the house itself. A more holistic approach-thinking is in demand to respond to the new possibilities offered by a co-operation between buildings and all kinds of vehicles.

In this context, one must follow the development of batteries and push for more ecological or sustainable solutions as regards the exploration of the raw materials used in batteries, the handling of them to protect the workers, the effective use of materials and finally a complete recycling of materials. New materials for battery production will be invented and we already see great developments in this field. In the future, cheaper and more ecological and sustainable batteries are bound to emerge. This will propel the electrification of the vehicle fleet and simultaneously possibly the use of batteries—in houses and vehicles—as electric buffers for individual ZEMCH, groups of housing or whole districts. That option is at least now in sight.

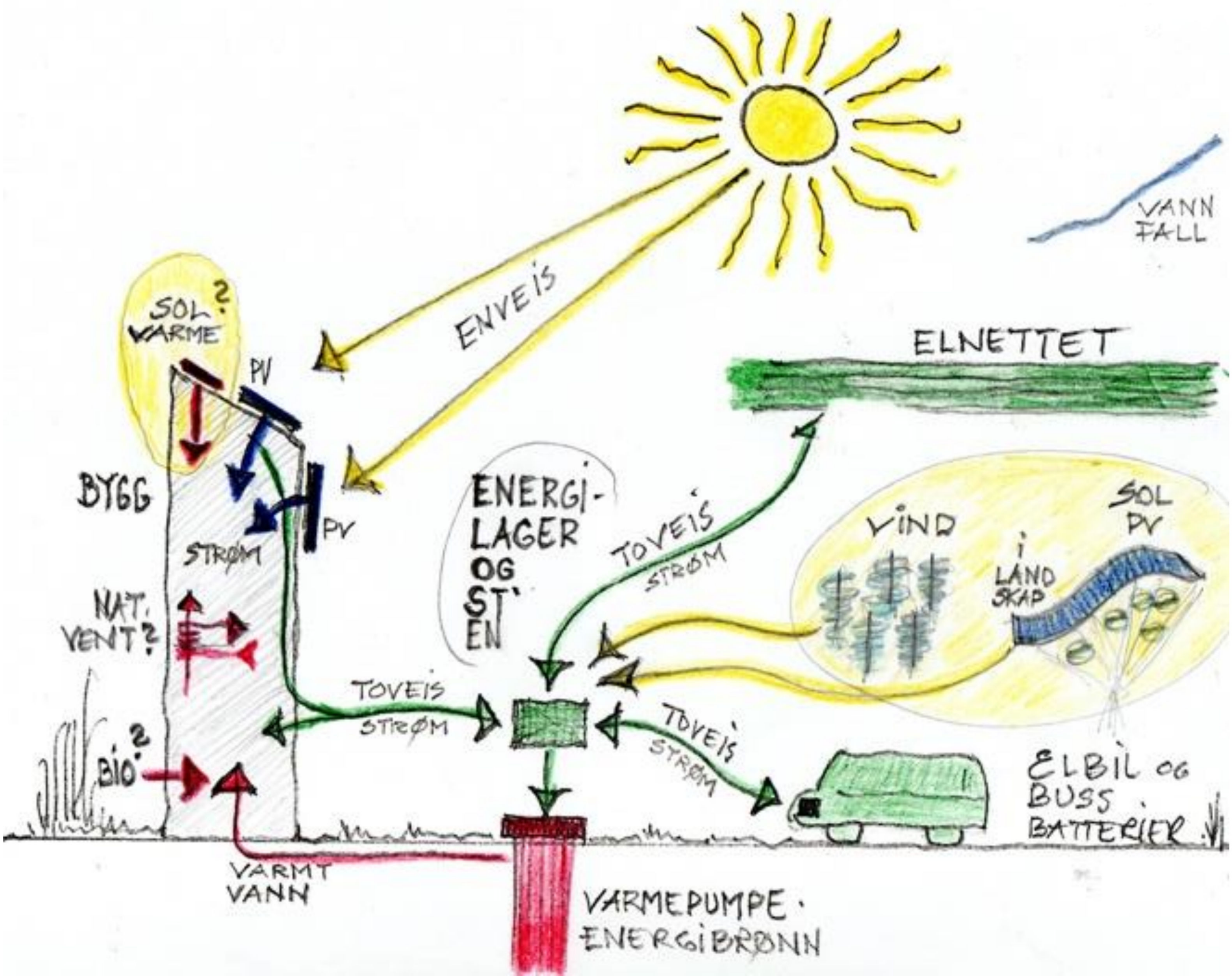
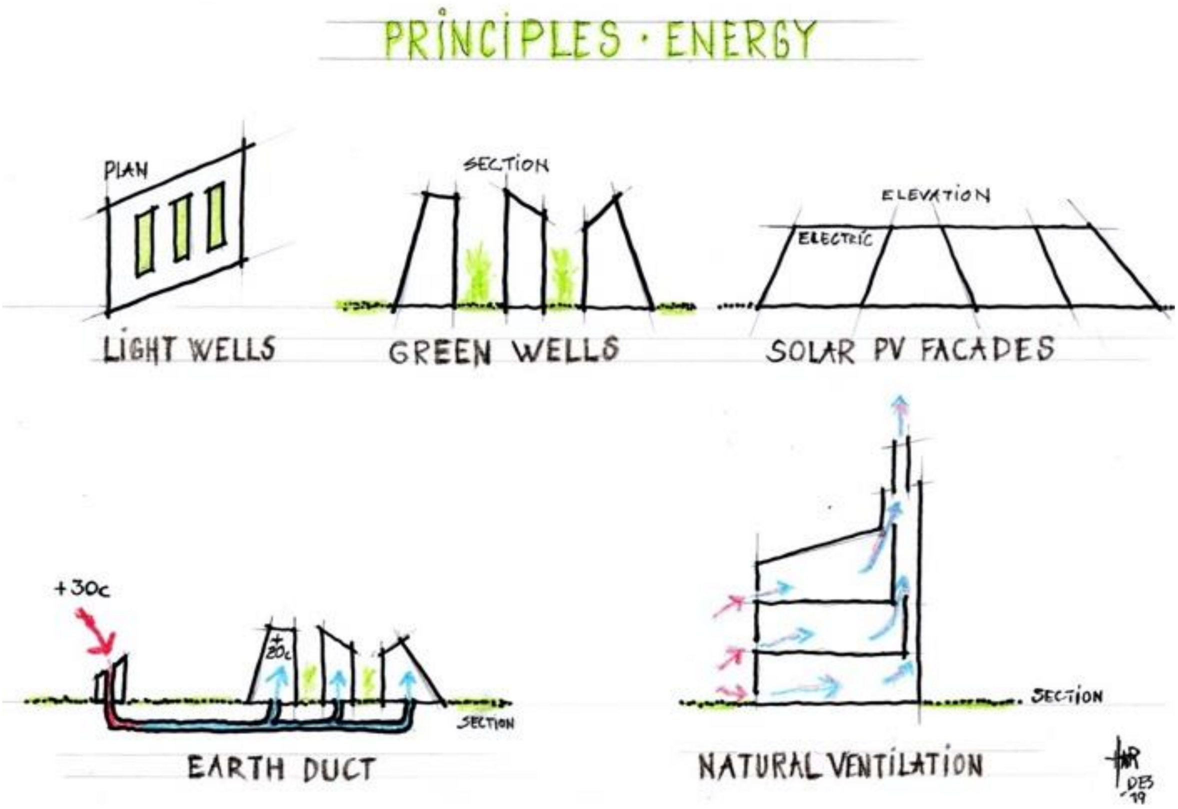


Figure 5. Madla-Revheim, Stavanger, Norway. Energy autonomous new part of town for 10.000 people, where a combination of renewable energy like solar PV, solar thermal on buildings and in the landscape is combined with wind power. This again is connected to running a geothermal heat pump and a stationary central battery bank storage as well as grid-connection when necessary. The transportation sector is linked through this and vehicle batteries provide a united and huge battery bank in addition to the stationary battery bank. The illustration is from the concept design energy system at the Municipality of Stavanger Quality Program for the Madla-Revheim development, designed and drawn by: the author.

It is crucial that solar when applied, is applied with a rational intention behind it. The simple idea that cannot be repeated too often is that the first design step should be to design a building as energy efficient as possible—but without overdoing it, as discussed in the contexts above on insulation values of walls, roofs and windows. It is possible to design a perfectly well-operating building without going to extremes. However, in any climate, we must respond to the local climate. Principles applied in Norway may not be applicable in Sri Lanka or Cyprus. As an example, below is a case of a university building in Cyprus, Figure 6. This building is set in an extremely hot dry climate where earth ducts for cooling the natural ventilation driven air solution was found to be the best option to reduce the enormous cooling need of the building. It was also necessary to first reduce the energy need in order to reduce the size (area demand), capacity and cost of the facade integrated solar PV system intended to run the building. In this kind of setting as much as 80% of the total energy need of the building would typically represents the cooling and ventilation need. Natural ventilation is generally an underrated possibility in our time. Although it can be used both to ventilate and cool buildings in efficient and inexpensive ways if done well. Our knowledge in this age-old method of cooling must be upgraded and literature can help us as the techniques are well-documented [12].



(**a**)

(**b**)

Figure 6. Design principles for the International University of Cyprus' Engineering building inaugurated 2019 (**a**). Energy system overall principles (**b**). The author. Natural ventilation design: Max Fordham, London, UK. Architect: Saffet Kaya Ltd. Drawing and photo: the author.

3.3. Burning Logs

The concept of universal design includes considerations to ensure that people with any kind of physical handicap can function as well as possible in society. As a result, planners and architects have become used to dealing with appropriate door widths, low thresholds and ramps to allow people in wheelchairs and blind people to function well in society. However, we have not been so engaged perhaps in ensuring everybody's rights to a clean environment, free from pollution of waters and what connects us all—air. Air pollution is becoming a rising problem in many parts of the world and a lot of it arises from transportation related emissions but also a lot from log fires. The burning of logs in homes has in some areas of the world, at times, created unhealthy air quality. There are two issues here: one is the general international theoretical agreement that wood is climate neutral because trees, while they grow, store CO_2. In an international agreed climate gas accounting system wood, both as building material and for burning to generate heating in homes, is met with positivity. However, the other issue is the consideration of particle emission. Particle matter, PM 2.5 are tiny particles emerging from the burning of wood. Their size allows them to go straight from the lung to the blood vessels and create bad damage. In Norway alone, it is calculated that 1700 people die an early death every year as a result of PM 2.5 from log burning—not from traffic [13]. To give a scale to this, less than 100 people die in traffic accidents in Norway every year. Contrary to earlier beliefs, the health damage to people from log burning is not only caused through outdoor inhaling from chimneys, but also in the indoor rooms. Opening and closing log burner doors to light fires and put logs into a burning fire releases damaging gases into the rooms [14]—so does an open fireplace. The new research shows that both the current log burning technology but also the way we use it is faulty and a health hazard. Research shows that in winter log burning is far more polluting as regards particle (PM 2.5) than traffic fumes. In London half of the PM 2.5 stems from log burning—not traffic [15].

From this follows a need for us all to re-question the whole issue of the applicability of wood in a sustainability context. Two questions arise: One is related to the international agreed assumption that wood is climate neutral. It is of course correct that wood has stored a lot of CO_2 over its lifetime before it is chopped. This is the reason why it is seen as climate neutral. It has done a job in the past and it is valued. However, when trees are chopped for building or firewood purposes an open land area emerges. The catching of CO_2 by trees on that land hence stops. When new trees are planted, it may, depending on tree type, take 30–60 years before trees get old enough to really catch CO_2 in a big way. As the CO_2 catching ability by trees are very small in the younger years and in elder age than in mid-life, chopping should not happen in mid-life as the main catching of CO_2 happens when threes have developed a considerable leaf area. That happens in a tree's mid-life. The lost CO_2 catching time, the negative part of the calculation, while waiting decades for the new, planted trees to develop is not included in the usual CO_2 calculation. Only the positive part, the past catching is calculated [16,17]. This biased calculation leads to a general misconception that the use of timber for construction and burning to generate heat purposes is sustainable, while it is probably not. The debate about these different views have been ongoing among highly qualified people in for example agriculture and many strong opponents to the current CO_2 calculation method are people in the academic and forestry fields. Strange as it seems this discussion has not siphoned into the field of architecture.

Why is this relevant in relation to ZEMCH? It is relevant because in a proper sustainability-based CO_2 counting system timber will probably not keep its remarkably protected position as a do-gooder forever. Its position and the logic behind it are being questioned and it is always wise to be prepared for changes in the CO_2 accounting system before they actually appear.

Having mentioned this, it is of course important to underline the actual qualities of timber. It is beautiful, it can regulate humidity levels in indoor rooms through "breathing", it created a comfortable acoustic environment, it smells good and it is a renewable material.

Sometimes it is even local, although a lot of the timber industry is not at all local and leads to transport over huge distances. All these will be enough good arguments for the use of timber as a construction material, but we cannot ignore its downsides as mentioned above and in addition add the bulkiness of timber constructions and complicated logistics compared to several other materials. Keeping our eyes open for new materials and new applications of old ones is part of the complicated decision puzzle planners and architects will have to engage in in order to ensure sustainable design and construction.

Timber, like any other material will have to undergo LCA analysis or other evaluations in order to uncover too long travel distances for the timber leading to emissions from lorries, calculating refinement processes and their emissions as well as and waste and recyclability possibilities. This applies to individual types of materials as well as ZEMCHs at large.

Finally, it is crucial to understand that in modern, heavily insulated homes, log burning becomes a challenge in that it will occasionally overheat spaces.

4. Ethics

Many architects throughout history have had a tendency to want to serve the rich and mighty, since they were the ones that had the resources to build buildings, and through this they became rich and famous when designing palaces for real kings and queens as well as monetary “kings”. Simultaneously, the ancient history of architecture is full of examples of architecture without architects. Modernism, in an attempt at both searching for new expressions and create mass production to provide shelter for the many at a reasonable cost, often stumbled into terribly deep traps. The product they came up with often did not last due to poor workmanship, poor detailing and the use of low-cost materials that hampered durability. Demolishing was sometimes the only way to fix the problem and hence buildings’ lives became short. Such an approach, scrapping young buildings, is of course not sustainable and we must look for better solutions with higher quality and—if necessary—more compact and area efficient solutions to create more lasting products.

The ethical responsibilities of architects are supposedly to not different from those of doctors or dentists, tailors and chefs. The questions each one could pose is—who do I want to serve? It is always a dilemma as an architect to make up one’s mind as to whether the designing of houses with five bathrooms per family is meaningful when the need for mass produced social housing is so great in most societies. Shifting the priorities away from the mansion sector onto the low-cost sector is a challenge both in terms of fees and prestige, but it is for any profession and ethical issue too. Interesting places like Timbuktu in Mali, Western Africa where the characteristic mud architecture has inspired so many through the beauty of the buildings and the use of local materials. This author had the pleasure to design such buildings in Mali and adding some minor technological gadgets making it possible to light them and run an evaporative cooling device helped by a PV run fan, Figure 7. The function of these were to deliver some electricity miles from any grid by using small solar modules and a battery to provide light. The concept of architecture without architects emerged in in 1974 through the book of Bernard Rudofsky and the great exhibition based on his book “Architecture without Architects”, showing at the Design Centre Gallery in The Mall in London the same year [18].

(**a**) (**b**)

Figure 7. (**a**) The book by Rudofsky and other books about the hand-made architecture of Mali has been inspiring many generations of architects. (**b**) The author's solar run and naturally ventilated office and housing building for the Strømme Foundation in Bafoulabe, Mali in 1985 made of local sun-dried mud and covered ion hand-clad mud uses some simple solar PV and thermal technologies to evaporate cool the building. All photos: the author.

The exploration of aged architecture makes a great impression and it inspires most people. Many ask; what can I learn from this? Richard Sennet's great book "Building and Dwelling. Ethics for the City", resounds many architects' own experience where he writes; "As a young urbanist, I was persuaded to the ethics of modern making by reading a book by Bernard Rudofsky" ... "who documented how the materials, shapes and siting of the built environment have arisen from the practices of everyday life" ... "Rudofsky argued that the making of places had no need of self-conscious artiness" [19] (p. 13).

Coupling this with the work of Hassan Fathy as explained in his book "Architecture for the Poor", there is a good mix of choices eliminated as to who one wants to serve [9]. Fathy's local materials and local production, mass customized as it was at the time, constructed with local builders, self-builders and helpers coupled with his ideas of creating cool indoor spaces through using mass and natural ventilation. This cheap way of temperature- and comfort-control was unbeatable when he added to his mud brick designs using water-filled clay jars in the windowsills and patio fountains removing heat from the air through evaporative cooling.

When this author later got the opportunity to work for Save the Children in Colombo, Sri Lanka to develop all kinds of solar energy-based solutions, they were mostly built from local materials. They were solar stills to produce clean drinkable water from salt or saline water as shown in Figure 8a, cooking by solar heat, drying vegetables and fish to reduce rotting and waste. Later, when designing Sri Lankas's first, and largest, solar electric grid-connected and naturally ventilated building for Worldview Global Media/Young Asia Television (WGM/YATV) in Battaramulla near Colombo and testing out the electric three-wheeler solar taxi in the same city as shown in Figure 3b,c, a combination of solutions were applied. All this happened in the 1990s. It included a steep learning curve on issues like deep poverty, need, compact living and scarcity of materials. It can teach us a lot about the human condition and how different life is in a developed and a developing country. It can teach us a lot about energy, people and the sky above—about the enormous potential for introducing the use of decentralized solar energy in a big way. It is low cost, simple and mostly repairable on the spot. It also teaches us a lesson about lack of repeatability. In many countries like Sri Lanka mass production has not been natural. Instead, hand-made products were dominating. It was only when international construction industries entered the Sri Lankan market through international collaboration that some kind of mass production was introduced. The point is this: if we are going to encourage mass production for houses, other buildings or vehicles we first have to build something in those countries to really understand what the level of workmanship for production and repair is. When we understand that we can start introducing more relevant mass production by preferably using the local work force as a base. It is useless if new industries get entirely based on the flying in of too much expensive foreign staff without interest or knowledge of the local challenge ahead. Development is a slow process and it can only take place and have a chance of succeeding if the conditions on the ground are understood.

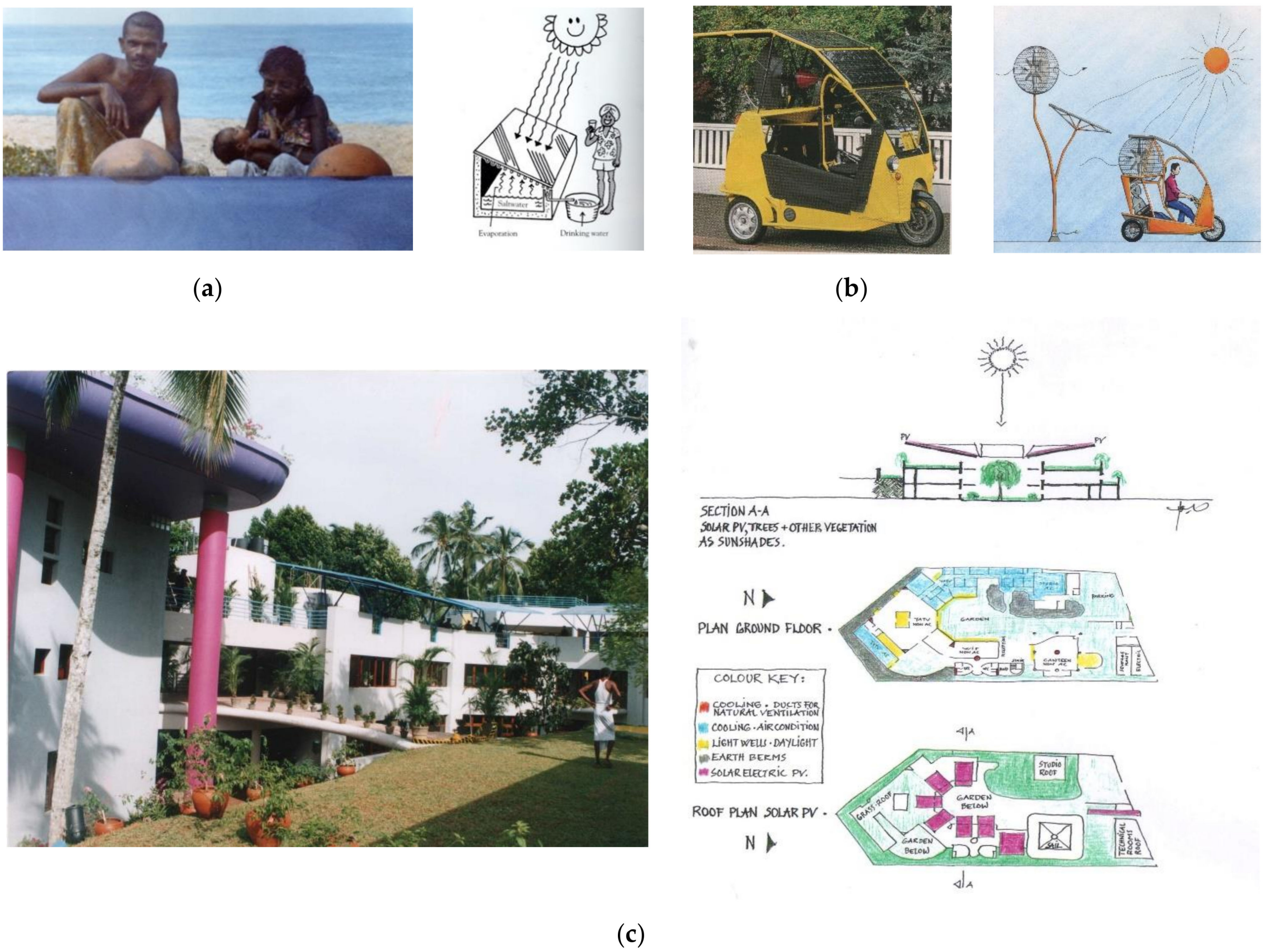


Figure 8. Through working with crucial challenges in developing countries one can learn a lot that can be applied in the developed world, like simplicity, lowering costs and repairability on the spot: simple still to produce drinking water from salt water through evaporation and condensation (**a**), solar run and naturally ventilated World Global Media (WGM)/Young Asia Television (YATV) headquarters (**c**), solar electric three wheeler taxi for cities prototype test. (**b**). All tests performed in and around Colombo, Sri Lanka. The solar electric vehicle design and drawing: the author and Peter Opsvik AS. All other designs and photos: the author.

However, from hot tropical and humid Colombo to cold mountainous Katmandu, Nepal the story is different. People are freezing in the mountain landscapes with its sunny days and extremely cold nights. However, every day, the sun rises and shines bright and warm. The solar potential is gigantic, yet people are chopping down the woods to get firewood for their meals and for heating their crowded, densely populated locally built stone and clay houses. Many knowledgeable scientists and practitioners have observed this and wanted to shout from frustration when seeing our fellow nationals doing development aid but ignoring the huge potential of developing the use of solar energy into a solution and instead, and with huge aid budgets pushing fossil fuels like diesel and gas as the, normally imported, solution or huge centralized hydropower dam projects. Which energy sources are pushed in which country and by whom, is an ethical issue often based on strong economic interests and pure greed?

In the book, Philosophy and Architecture, Christian Illies and Nicholas Ray show many examples of ethical borderlines [10]. Examples of people, both architects and planners that have played a supportive role within regimes that has a long record of human rights violation, are referred to and the overarching theme is that there will always be people that don't see the ethical issues at hand or refuse to see them. The authors refer to philosophical thinkers that have suggested that architects and other professionals should refuse to associate themselves with commissions that obviously end up on the wrong side of the ethical borderlines. Those are similar ideas of double roles and dichotomies that this author developed in the book Corruption the Nobel way [20].

4.1. Being Brave

All planners, architects, suppliers and developers have access to research results. They should be accepted and result in action accordingly. Braveness and long-term goals are crucial to create faith in mankind's own ability to see what is coming. By conscientiously following our internal ethical guidelines and listening to our internal ethical alarm bells, we can better develop our ability to forecast, to see what will be in demand in the future and what will not. When confronted with scary reports on the future, our attitudes and priorities sometimes change. While writing this, an alarming message occurred through The Guardian of dramatic change in our climate; the world is at its hottest in 12,000 years [21]. That kind of research makes a big impact and should accelerate the shift for a more ecological future. This applies to our sustainable future as well as practical responses to it—like being in involved in developing ZEMCHs. There are many kinds of possible futures. It is our hard task to choose which future we believe most in and act to embrace that one according to our holistic conviction after having studied all the parameters involved and trying to look at them without being biased. We must believe in the future—a future we choose to believe in—and be brave.

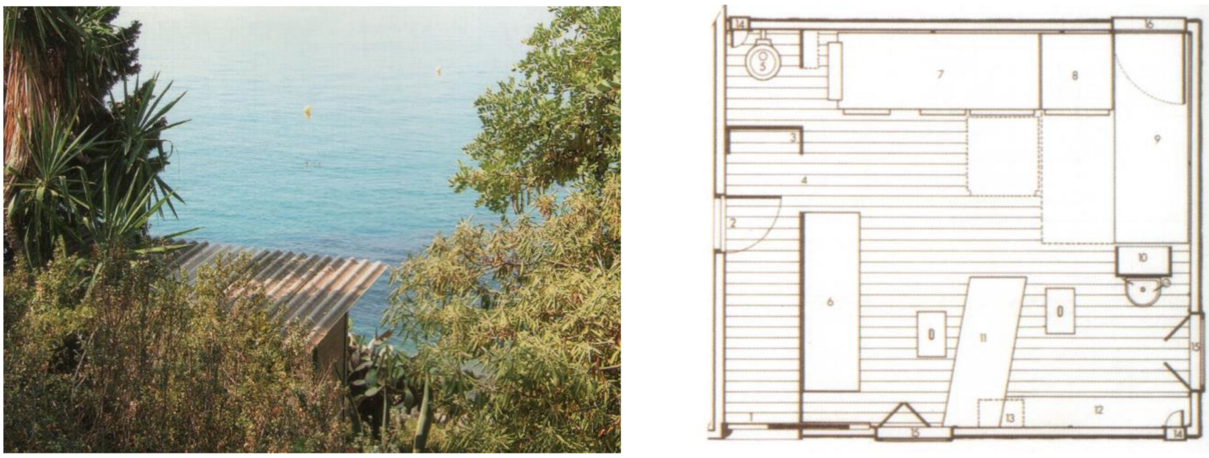
4.2. Being Humble

It seems everybody is fighting a hard battle, so we should be kind to each other. However, let us not be fooled. There are tough robust people out there and people do not always mean well. There are selfish bullies too and some people steel from need or greed. We should stop them by sticking our necks out and blow the whistle. However, most of the time and above, we should be humble. Many great thinkers were brought up in humble, tiny houses of mediocre quality. It is not the size of the house that decided which thoughts are being thought in there. It is the capacity of the mind, the brain, to fly, that makes the difference.

The philosopher Ludwig Wittgenstein inherited one of the largest fortunes in Europe from his father who was a rich steel magnate in Vienna, Austria. LW gave it all away in order to become a philosopher and he built his modest little 60 m^2 timber house on a mountain shelf in Skjolden, Norway in 1915. It was completed while he spent time as a volunteer in the Second World War on the European continent. In his house, he collected water from the lake 30 m below and he heated his house with logs chopped from the nearby forest as shown in Figure 9a. His 1.5 m^2 unheated toilet shed was 15 m from the house and he had to empty the bucket and bury the content every spring. Candles lit the house after dark. There was, of course—no electricity [22]. However, Wittgenstein was knowledgeable, and he used local craftsmen with local knowledge to help him. In order to become one of the world's leading philosophers ever, he studied many subjects. First, he spent a few years doing engineering at a university in Berlin, then he moved to University of Manchester and spent four year studying aeronautics. He was flying kites there and even patented a fuel injection system for helicopter wings. From there, he moved to University of Cambridge to study philosophy and he spent the rest of his life as a philosophy teacher at the university there, when he was not in Norway and on travels elsewhere [23].

What can we learn from this? That housing size does not matter, really, and that multidisciplinary knowledge is useful? Probably, and there are other examples, like the example of Le Corbusier, the architect. When he built his summer house in the South of France at Cap Martin, it was a 16 m^2 house for him and his wife; 8 m^2 per person. They called it Le Cabanon. He had been inspired by his trips with ocean liners and planes across the Atlantic and learnt how compact the accommodation had become. In his own Cabanon, he applied the same principles, almost like designing a compact cabin for a brain and a pencil only [24]. As shown in Figure 9b, although it did not have a full-size overdone kitchen because there was a restaurant next door where they had all their meals, the compactness is striking and impressive. Perhaps we can learn from it that bare essentials are enough for many, most of the time. At least it was enough for these two giants, Wittgenstein and Corbusier. They were certainly showing their humble side in the way they selected their accommodation.

(**a**)



(**b**)

Figure 9. Ludwig Wittgenstein's 60 m^2 remotely located cottage outside the village Skjolden, near the end of Norway's longest fjord Sognefjorden and by a lake higher up. Note the string on the drawing by which a bucket was lowered to get drinking water from the lake (**a**). Le Corbusier's 16 m^2 Le Cabanon, Cap Martin, France (**b**). Photos and drawings: the author.

This leads to the big question: are there still things to learn for us from other industries than the housing industry. Can we draw experience and learning from the compact caravan or even vehicle industry, in the way they mass produce and make the solutions compact? The caravan sector is certainly a field to be studied, both from the perspective of insulation, compact living—kitchen, bath, living- and sleeping quarters. Although it is not applicable to all, that is not the point, it could be applicable to many and it could provide many more with reasonable, although humble, low-cost and mass-produced solutions on a global scale as shown in Figure 10.

(**a**) (**b**) (**c**)

Figure 10. There are useful zero energy mass custom homes (ZEMCH) lessons to be learnt from other industries, like cruises where thousands of passengers are transported in relatively compact living quarters, although the rest of the floating hotels are full of huge shared spaces (**a**). Compact living as a camper can end in many physical expressions (**b**,**c**). All photos from Stavanger city: the author.

If the concept of ZEMCH is going to develop in a big way, we need to look at it from all angles and try out many more solutions than the on-site, part on site, part factory mass production now going on. We must look for even more ingenious solutions, and perhaps we have to go back 70 years, when Europe was rebuilding after the Second World War and mass production became necessary in order to house the homeless. At that time, housing was produces in huge numbers—and fast. The result was often mediocre quality. In an earlier ZEMCH conference paper from 2012 this author covered that side of the issue [9] (pp. 83–95).

5. Forecasting

Most of us are poor forecasters and we fail to accept this fact. Most of us are too entangled in our own ideas and preconceived positions in the art of debate, so that we cement our attitudes rather than stay open to learn about new positions and possibilities. This hampers our personal development and developments at large—privately, in the family, socially and at work. That is a great loss. Super-forecasting or the art of prediction has been extensively dealt with by Wharton professor Philip Tetlock and journalist Dan Gardener through the release of their book Superforecasting: The Art and Science of Predictions [25]. They argued that everything we do involves some kind of forecasting about how the future will unfold. In a twenty-year study they registered actual predictions and tested them against what actually happened twenty years later. They found that the actual experts were only slightly better than the average person doing guesswork. They also found that some of the most visible experts used as commentators by the media were lousy at predicting the future. Contrary to our general belief in experts, the study uncovered that the absolutely best predictors were quite ordinary people, from former ballroom dancers to retired computer programmers. They had an extraordinary ability to predict the future twenty years ahead with an accuracy of 60 percent greater than the average. Tetlock's study found that independence seemed to be the most valuable quality at being a great predictor and that the ability can be trained and improved. The main point was that most people are not independent. Our predictions tend to lean towards what we have sympathy for, general interest in or vested interest in. When we find ourselves in double roles, we tend to be lousy forecasters. We hence need to distance ourselves from our interests and sympathies and look cooler at the questions ahead in order to improve our prediction abilities.

What Tetlock's study showed us was really that when we listen to other people's predictions, we need to question why they lean the way they do. When an employee in an oil company forecasts the oil age to be lasting hundreds of years, we should treat that prediction with caution and ask about vested interests as well as concrete, factual arguments, why oil will be dominating that long. Similarly, when a solar expert forecasts the solar age, ask for data and concrete arguments, not wishful thinking, and when a designer of zero energy housing argues that this is the future, ask for data as to why. Is it the future because it is a wish or are there logical explanations? If so, which?

These are the test questions that help us understand better, both our fellow men and women, but also our future. We can only predict the future if we can argue for why a certain direction in the future will "win" or dominate. We must have some basic logical data at hand, only then can we begin from there to use our imagination and use our gut feeling, our experience and only if we manage to stay independent can we pose reliable predictions. If not, we are just chatters, like so many of the commentators: big talkers, lousy predictors, useless forecasters, and time wasters.

We don't want to be like that, so from here on we must ask some hard questions and if necessary, turn everything upside down in order to possibly arriving at some new "truths". As a vehicle, as theme, we can use ZEMCH and try to forecast the future of ZEMCH and how it should develop in order to endure.

Covid

The Covid-19 pandemic has changed a lot. It is a disastrous experience for most people although some are hit harder than others. If only we could learn enough from it to justify the damage and loss of life, it would be easier to accept that nature from time to time hits at us in this way. Throughout history, pandemics have occurred from time to time and they will occur again in the future. This author has (during the pandemic) slightly changed some of the courses taught at the university to study the actual learning outcome of the pandemic so far. By doing that, students have been able to concentrate on events actually ongoing and discuss them in light of sustainability related issues and draw learning from the pandemic so far. One must of course be cautious of such an approach, since we have not yet seen the end of the pandemic, as this is written. Surprises may yet occur, but the following have been experienced and noted:

Traffic naturally decreased during the pandemic because people stayed at home. As a result, CO_2 emissions fell. The world appeared more sustainable and less polluting, however:

In many parts of the world, people fired more with logs while working from home during daytime and the particle pollution (PM 2.5), due to increased use of log fires compensated for the air pollution gains from less traffic. The air was in many places almost as polluted as before the pandemic [16].

Due to the increased cleanliness caused by hand-washing and social distancing, the occurrence of other respiratory diseases, like flu and colds, fell during the pandemic. In most countries large numbers of people die every winter from flu and the number varies from year to year depending on how tough the virus is. In Norway, a country of 5.4 million people an average of 900 people dies, every winter, because of flu. In a particularly hard winter four years ago, 1.600 people dies. The variation over the last decades has been between 200 and 1.600. As a comparison, 550 people have dies from the Covid-19 pandemic so far in Norway from mid-March to end December 2020. During all of 2020, 94 people lost their life in traffic accidents. That is the scale of the log fire problem on human health. It is important to add that the Norwegian society have been practically closed down for months to keep the pandemic death toll down so the cost to society has been extremely high as it caused unemployment, loneliness and mental challenges for many.

From these examples we can at least draw two conclusions and learning experiences:

We can make life better for many, if we increase the level of hygiene in the future.

We can reduce congestion, climate gas emissions and air pollution if those that are able to work from home, does that say one day a week or more. Or we can reduce morning and afternoon congestion by working from home an hour or two in the morning before travelling. In this way, the number of job travels are reduced or shifted timewise and hence pollution is reduced. The world becomes more sustainable through such examples of behavior change. Such measures are also so much easier to implement than establishing huge monitors for toll road payments and road prizing. Behavior change does not need any new infrastructure that needs excavation by air polluting heavy machinery, production and transport of toll road equipment. All it takes to change behavior is knowledge, motivation and the right attitude.

The pandemic has also reminded of us the health side of our lives and could lead to an upgrade of issues like healthy buildings and environments. Planners will possibly find new challenges to be addresses like congestion in lifts and shared ventilation systems circulating air in buildings. The issue of more decentralized air supply and removal as well as issues related to recirculation of air will have to be addressed. Air filters will have to have a better quality and a better servicing routine to make sure they are changed regularly so that quality and efficiency is not compromised. High efficiency particulate air (HEPA) filters will have to be explored and applied. All this will lead to a new way of thinking about how human beings share spaces and share air. The pandemic might already have changed our way of thinking in so many ways. Many of the changes are wise, ecological and long-term winners.

6. The Next Step and Conclusions

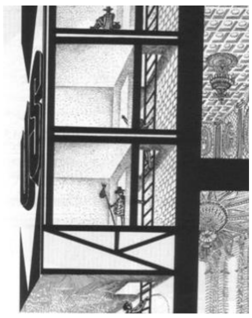
There will always be a next step, but the biggest mistake we can make is to ignore facts. When something is not working, we must step back, have a look at it again and either fix it or scrap it and start again. Not accepting being on the wrong track can lead to big damage. Progress is only progress if we accept that we sometimes do mistakes. Learning from mistakes is crucial. The process of innovation is sometimes cruel when having to kill a good idea—a "darling". However, this is a necessary process in order to proceed with some kind of chance of success.

The above also applies to sustainability and ZEMCH. It is crucial that we constantly keep a critical eye on the development of new knowledge, preferably research-based knowledge, and make sure it is addressed and somehow included in the way we deal with innovation in everyday life. This is as crucial as it is to define where one builds and why. The world has many climatic zones—some are cold, and some are hot, there are many different cultures as well as many different economic levels. The range is so wide it makes it almost impossible to write or talk about housing people without defining exactly the context and the human condition on the ground. If the concept of ZEMCH is going to succeed even more, it needs to go through this motion too; clearly define the context as challenges differ in London, Calcutta and Stockholm [26].

What's next then? The simple answer is we have no idea that can be clearly cut in stone apart from this: The best forecasters and the ones we normally listen to, see on screens or read about are lousy forecasters. As shown in the chapter on forecasting they fail to deliver exact forecasters that are useful. Many "ordinary" people though do, basically because many of them are more unbiased. They do not have so many positions, earlier own forecasts or vested interests to defend. The late Beatle John Lennon, in his song and for his son "Beautiful Boy" wrote: "Life is what happens to you when you're busy making other plans" [27]. Lennon, while making plans, was shot dead. Humankind, while making plans were suddenly faced with a pandemic that has changed a lot of routines and of our thinking about the future. Seemingly impossible ideas become realistic and former realistic ideas impossible. Our main goal and the main message and conclusion from this contribution is hence that the best we can do is to stay open and receptive to new ideas, always, and hence expose ourselves to the difficulty of an insecurity as regards future vision. Although we have ideas, we must realize that we have no exact idea of what the future holds. However, what we at least can do is to try to stay on top of the flow of new information, stay updated, build on new research and always question cemented truths.

In conclusion, the ZEMCH issue could be turned on its head and we could look at it from the perspective of a homeless person. How, if it is a wish that is, can a homeless person find better shelter and how can we that work on ZEMCHs help? That is a challenge possibly more complicated and meaningful than many tasks we are posed with. As Victor Papanek argued in his book "Design for the Real World", we must make sure we use our capabilities and competencies to the best of mankind and design useful stuff [28]. As the illustrations in Figure 11 below indicate, life on the street is rough. Some have chosen it, most have not. Can we, through very small measures be of assistance and apply our imagination as the examples below show? Can huge advertising structures in cities house homeless in the space between a building and the front board? The space is available, the construction up. It takes minor readjustment to ensure proper ladder access and separate spaces. There could even be a legal requirement in cities, the "Thick-Ad Law", using thick advertising boards as shelter. It is a wild idea from the 1987 UN Shelter for the Homeless international competition. That year UN set the goal of abolishing homelessness by 2000. A useless, beautiful dream that is not anywhere near coming through. However, we must keep trying, like UN does [29,30].

(**a**)



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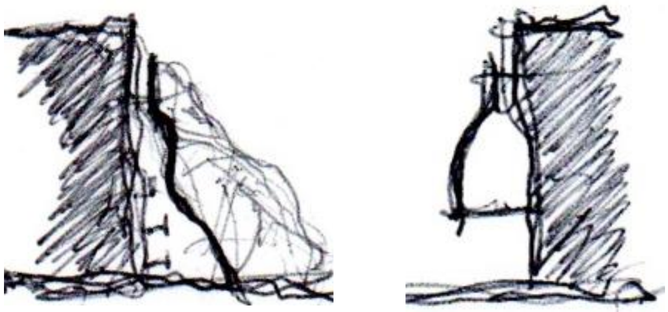

(**c**)

Figure 11. Targeting the client. Who are ZEMCHs for? Homeless asleep on a frosty London February morning in 2018 (**a**). Can we use the spaces "in between" for safe shelters (**b**)? Can huge advertising structures in cities house homeless in the space between a building and the front board. The space is available, the construction up. It takes minor readjustment to ensure proper ladder access and separate spaces. It is a wild idea from the 1987 UN Shelter for the Homeless international competition (**c**). All photos and illustrations: the author.

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