imagine 05

ENERGY

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imagine 05 – ENERGY

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imagine 05

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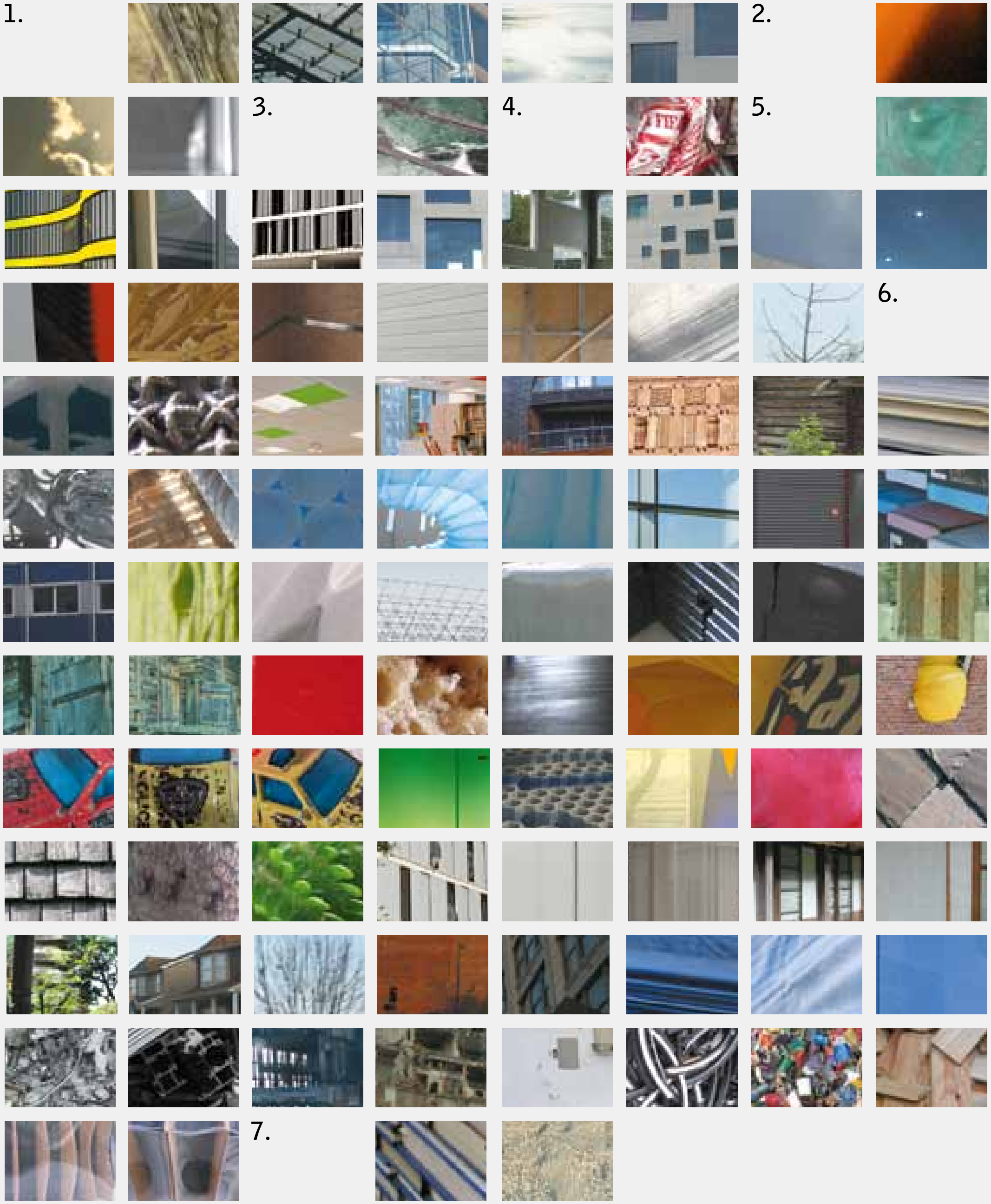
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CONTENTS

1. INTRODUCTION

WHY ENERGY?

The last two centuries has seen our energy consumption surge exponentially, leading to many questions about the sustainability of our cities, lifestyles and world. In Europe and North America, the building sector is responsible for almost 50% of all domestic CO_2 emissions and energy use. Seen as a key leverage point for reducing our ecological impact, the European Union now requires that all buildings built after 2020 achieve net zero energy, while the entire building sector must reduce carbon emissions by 90% by 2050. Unfortunately, we have designed only a handful of buildings that achieve carbon neutrality, especially in a dense urban context. Thankfully, architecture is constantly evolving. The study of building design, function, budget, structure and performance are among many of the key elements needed to create a high performing building. In recent years, construction technologies and climate engineering have added new possibilities and areas of study to further improve the built environment. Yet there is a need to go deeper, to think further on the future of building design. Two main forces compel us to do so. First, the necessity and the political will to reduce energy expenditures; second, the ability to calculate not only operational energy but also the embodied energy in its production and deconstruction.

The need for political will power can be seen through the evolution of our energy portfolios on both scale and diversity. We've moved continuously over the last 200 years from renewable sources like wood to non-renewable resources like oil. Around the year 1800, wood provided almost 100% of the energy resources, while in 1900 around 80% of the need for energy was met with coal, and by 1970 there was a more diversified energy mix of 40% oil, 30% gas, 20% coal, and 10% other resources, which remains basically unchanged to this day. Looking back over more than 200 years we see that there have been several major shifts[1]. A closer look at the time between 1800 and 1940 reveals that despite the onset of industrialization, the use of energy increased comparatively slowly. It was only in the middle of the 20th century that the demand for energy surged, from then on doubling every ten years up until the oil crisis in the 1970s. Since then the increase of demand has risen more slowly than before, however it maintained the general surge[1]. With this trend of increasing energy consumption and the knowledge that the resources needed to meet this demand are running low, the political direction in Europe is clear: energy use must be limited even if that means certain challenges. ROADMAP 2050 is one example of this development as it outlines a scenario in which Europe would limit

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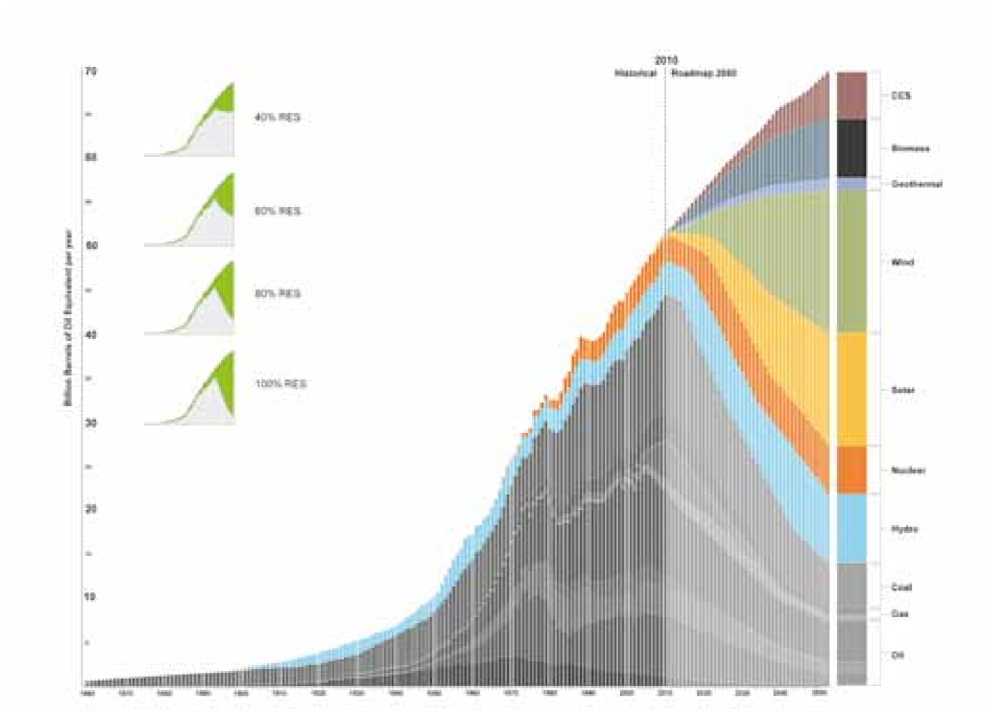

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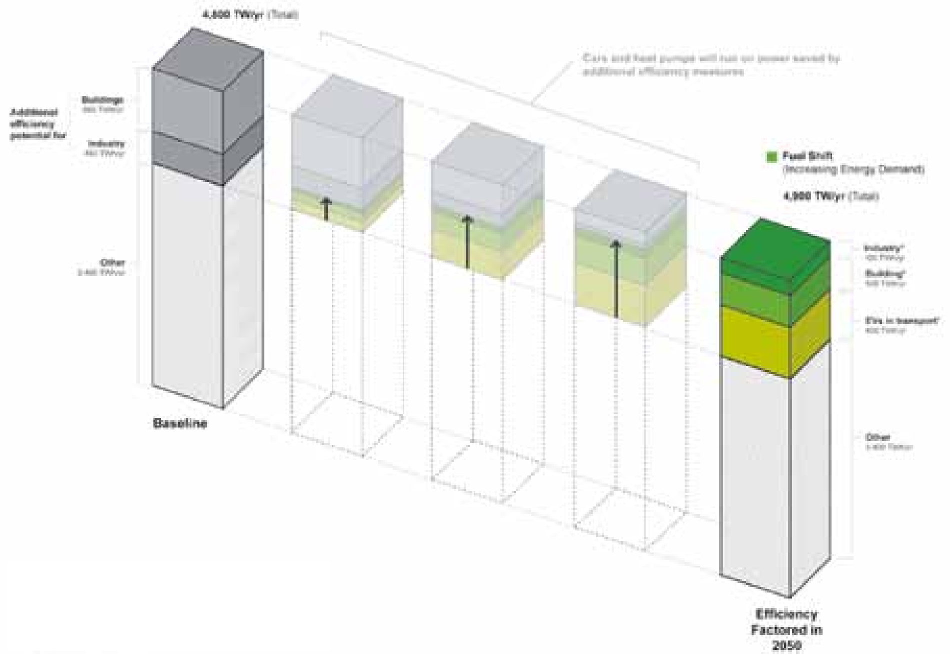

1 Energy supply in historical development and assumption for the future, related to a new approach to energy supply
2 Energy efficiency and fuel shift balance demand with a focus on buildings, to reduce the energy consumption by approximately 50%

its growing need for energy while making the production of energy more environmentally friendly.

The second force is our improved ability to assess the energy embodied and used in building and modifying a structure. Due to the strong development in the field of climate engineering we are now able to track energy better than ever before. This has led to most new construction in developed countries having reduced operational energy consumption. The main factors in this reduction are improvements in heat recovery ventilation, improved technologies in areas like lighting and energy production (such as combined heat and power plants), as well as passive means like improved insulation. All these measures result in a positive outcome: the operational energy is lowered. Climate Engineering has naturally claimed a highly relevant place in the planning and design of architecture.

It is because of these new technologies and knowledge that we can now show that the amount of energy used in a building over the course of 30 years is similar to the amount needed to produce all the materials and construct the building[2]. These new skills allow us to improve the overall energy efficiency by not only controlling the operational energy but also the energy production costs of the building. By gaining insight into how we can control our energy consumption on multiple levels it is clear that to meet the reduced energy consumption policies in Europe, to almost 10% of their 1990s levels, it is essential to design buildings not only for their operational efficiency but also for their embodied energy.

The first law of thermodynamics says that energy cannot be created or destroyed, but only transformed into other forms of energy[3]. In the context of architecture that means that we have to use the energy, more specifically the solar radiation that the earth receives or has received. In Central Europe there is an average of 1000 kWh/m^2 yr of irradiation on a horizontal surface[4]. We rely not only on the current radiation of the sun, but also on the energy stored in coal, oil, gas, biomass/wood and geothermal energy. For each of these, the key factor is the length of their renewal cycle. This is several million years for coal, oil and gas, or only years or decades for biomass/wood.

These thoughts are not new. However they find new importance when considering the future of energy supply and performance regulation. Prof. Dr. Dirk Althaus is just one example of a man who, during his time as researcher at the University of Hamburg, pioneered his interpretation of the “Ex-und-Hop Architektur” (temporary throw-away architecture), whose design focuses on limited energy input because of a limited lifespan. He also shows Frei Otto’s architecture in the context of energy life cycle assessment, providing new perspectives on lightweight architecture[5].

By extending Althaus' work the idea of sustainability is reached as well as various scenarios around the overall building economy. The German economist Johann Heinrich von Thünen developed models proposing the pursuit of overall sustainability and economic independence of cities by layering agricultural land around each city, basing his model on the sun as the primary source of energy. This model may lack transferability to mega cities or less comfortable climates than that of Central Europe, but its principles and approach are valid and worth learning from.

We are now able to deal with a building based on its operational and embodied energy. If we consider how long we want to use the building we are able to define how much energy we should invest, knowing that the energy used for raising a building and that used for operating it are simply different forms of energy. In fact we are turning time into a key variable in the equation for embodied energy building design. That means that a short life span would require the use of preferably little energy for a building, even if its operational energy was not fully optimized. Conversely it is sensible to invest more energy into a building if we know that it will have a longer lifespan and that it pays off to minimize its operational energy. The question then becomes: How can we incorporate lifespan, operational and embodied energy, material choices and construction methods into the building design process?

If we look at a brick wall as an example, we see that its thermal transmission coefficient equals 2.0 W/m^{2}K. If you add 10 cm of polystyrene insulation with plaster, you reach a much lower coefficient of 0.2 W/m^{2}K. If we change the polystyrene to 20 cm, the number is only 0.11 W/m^{2}K. That leads us to the question: Is the investment of material and, with it, its embodied energy, worth a further reduction? The energy expended for the additional 10 cm insulation to reach 20 cm of polystyrene is about 73.3 kWh/m^2 while the heat transmission savings are about 7.56kWh/yr per m^2. This suggests that the additional energy costs would be recouped in approximately ten years, a clearly good investment for a house. However if we increased the insulation from 20 cm to 30 cm, this additional 73.3kWh/m^2 of embodied energy provides a coefficient of 0.072 W/m^{2}K which only leads to a saving of 3.2kWh/yr per m^2. This would suggest a 23 year energy payback period which is a potentially less sensible investment. This is a fairly large simplification; things become more complex when we start thinking about comparing glass facades with a timber framed house with windows or other more complex constructions. Furthermore, what if that house is only going to be used for a short time? Hasn't IKEA taught us to get rid of quality furniture and to replace it with short lived but fashionable pieces? How fast do functional changes and refurbishment become necessary as our lifestyles and even country demographics shift so quickly? If building 'fashion' and style demands such quick changes, what then is the right balance between operational energy and embodied energy in design?

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3 Olympic Stadium Munich
4 City Gates of Düsseldorf
5 Eilean Donan Castle – Loch Long / Scotland
6 Design School Essen

Recognizing the need to find a balance, future buildings will need to be designed in a new way. We should design them not only for their initial purpose, but also for reusability and future flexibility. There will have to be a distinction between mono-functional buildings and flexible construction for maximum lifespan.

Right now, choices with regard to materials and construction method are based on economics and aesthetics only. Including the factor of embodied energy into the design of a building adds another layer to the decision making process. In order for this factor to be considered, it needs to be simple and easy to incorporate in the early iterative design phases so as not to overwhelm or slow down this creative process.

This book introduces PAT – the Performance Assessment Tool, which assesses and presents the amount of energy needed to create a building, both embodied and operational energy. The tool's purpose is to present the data in a manner that is easy to process so that it can be utilized in the early stages of the design process. The level of detailed and exact information is determined by the user and often avoided so that it does not overwhelm an already complex drafting phase.
Recognizing the plethora of factors essential in building design beyond energy, such as design, technical aspects and subsequent changes, the tool has focused on maximizing usefulness as opposed to precision. A certain level of imprecision is deemed acceptable in the initial design phase as driving elements will be identifiable. Otherwise, PAT could not be used due to its complexity and would not be incorporated in the early stages of the drafting process at all. After presenting the tool, its use is demonstrated using the example of already established buildings and ones currently being designed, which all have different purposes as well as differently constructed façades. This section of the book serves as an indicator for decisive factors for the assessment through PAT, as well as the effects of certain construction principles. At the core of the book lies Imagine, a chapter which presents realistic and unrealistic visions, concrete suggestions as well as possible solutions that may not yet be feasible but possible with the right technology. This chapter is intended to inspire, generate ideas and make them available for designers and developers.

One doesn't need to look far to find examples of buildings that have multiple functions over their lifetime. One prominent example would be those of Olympic Villages, whose intended use is only four weeks, after which they are often turned into condominiums or other housing. Using the tool, one might come up with creative solutions that would allow the energy focus to be not only on their final use as condominiums but also on their four weeks as an Olympic Village. For example, a design could be imagined where much of the building is deconstructed, repurposed, or completely changed by using the appropriate materials and design. If the building lifespan and deconstruction are not considered, then it is not unusual to see buildings like those from the Chicago Columbian Expo that are mostly torn down despite being designed for hundreds of years. No matter what decision is made for material use, it is clear that the lifespan must become a variable in the design process of new buildings. Our belief is that through sharing this tool, architects, engineers and designers can start designing buildings that minimize overall energy consumption and not just operational energy consumption. It is through this that we can begin to address the challenges and opportunities in the future of architecture and design.

LITERATURE

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2. COMFORT AND OPERATIONAL ENERGY

COMFORT AND OPERATIONAL ENERGY

Different types of buildings, such as residential buildings and office buildings have different requirements for comfort. The most important factors are temperature, hygiene, acoustics and visual comfort. These parameters all need to be considered during the design or development phase of a building and need to be balanced and communicated with all/everybody involved in the (building) design process. Isolating certain aspects and not considering them in balance with the other factors may affect other requirements of the building.

A comfortable space will be defined subjectively and slightly differently by each user. Thus, comfort cannot be measured with objective methods representing all users. However, suggestions can be made regarding air movement, temperature, the intensity of light and the humidity in the air, even though each user will perceive these differently and may feel more or less comfortable in the environment.

Most countries provide minimum comfort requirements for spaces like workplaces or residential spaces. However, very often these only secure the major factors. Requirements for the space should be determined with all parties involved. We will now take a closer look at the major factors for achieving high occupant comfort in a building.

THERMAL REQUIREMENTS – HEAT AND COOLING

The human body does not only transfer heat to air through convection, i.e. transmission of energy through molecules in fluids, but it also heats its environment through radiation. Both heat transfer through convection and through radiation have to be considered when dealing with thermal comfort in a building. Because of these, temperature is described as “felt temperature” and “operative temperature”. This value, also known as “space temperature”, approximates the mean of the room air temperature and mean radiant temperature of the surrounding surfaces; this illustrates the impact the surrounding surfaces have on thermal comfort.

Most countries have regulations for the temperature requirements of certain rooms or buildings. As a basic principle, the temperature should always be determined in relation to the outside temperature. A difference of 5 to 6 K (temperature differences are measured in Kelvin. 1K = 1°C) between inside and outside temperature has proven to be a realistic starting point, while an operative temperature of more than 26°C is to be avoided.

Studies have shown that users display a greater acceptance of the room temperature if it can be individually controlled, e.g. through the opening of a window or through a thermostat in an office. Users are less content when the temperature is controlled centrally and thus not under their control.

Figure 1 shows a comparison of the different comfort zones. With the help of the Psychrometric Chart international norms can be compared according to their maximum values. Figure 1 shows the American ASHRAE 55 – 2004 standard for cooling in the summer and heating in the winter in the case of mechanical ventilation. In the same way the broadened spectrum of natural ventilation by the ASHRAE code for natural ventilation is displayed. It can clearly be seen that there are no minimum or maximum values for humidity since it

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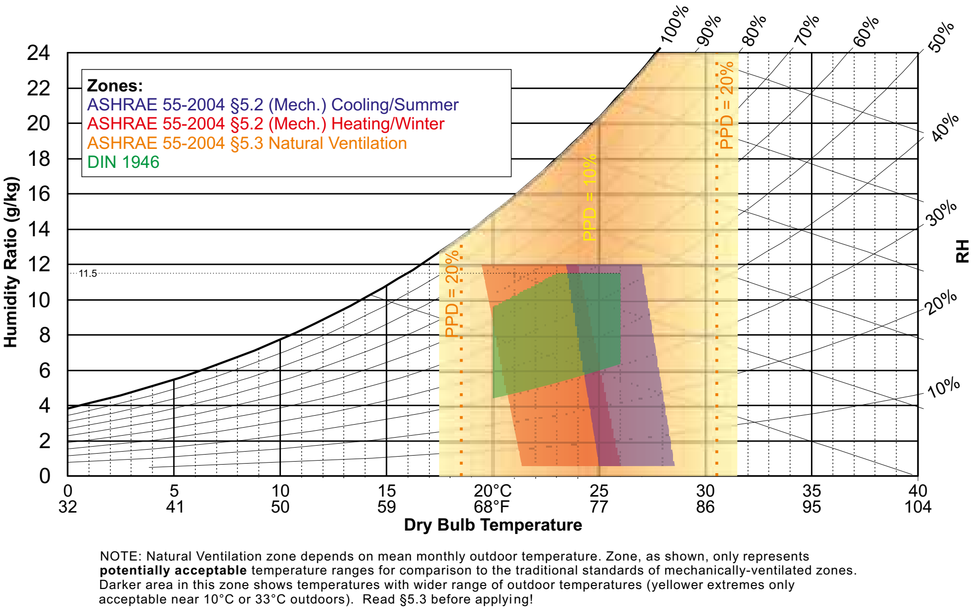

1 Comparison of different international comfort zones/transsolar
2 Horizontal sun redirecting elements allow the gain of natural light
3 Vertical sun redirecting elements

cannot be regulated through natural ventilation. The fourth comfort zone is the one provided through the German DIN 1946 standard.

Depending on the requirements of the individual countries and the use of mechanical or natural ventilation, different comfort zones and models can be chosen to determine comfort and the limit values.

VISUAL REQUIREMENTS – LIGHT

Visual requirements are intended to make the people in a room feel comfortable. As discussed/debated with thermal comfort, this perception is highly subjective and can vary strongly between users. Generally, rooms should be designed in a way that helps the human eye to grasp its environment quickly, giving it a sense of the room. Means of orientation, as well as lighting and low contrasts promote the perception of the room and add to visual comfort. Colors, too, add to the effect a room has on a user.

Another factor, which is often underrated in visual comfort, is natural lighting. If natural light is available, it is advisable to make use of it. The human metabolism needs sunlight. To protect against overheating of the rooms and glare at the workspace, protection from the sun has to be installed. Another disadvantage this poses is the potential for stark contrasts between light and dark due to shading. This demands a compromise. In many cases the light supply through artificial light is too high; the required 500 lux, which is generally seen as an international standard, is frequently perceived as too high. A solution for workplace or home can be stationary spotlights that replace universal room lighting. In this way, stationary lights can be used to improve the time spent in a room.

A good solution to gain more natural light is for instance the use of sun redirecting devices as seen in figures 2 and 3.

HYGIENE REQUIREMENTS – AIR

A study by the BMFT (German Federal Ministry of Education and Research) conducted in 1998 comparing air-conditioned with naturally ventilated rooms revealed that the workers in air-conditioned rooms felt uncomfortable more often than those in naturally ventilated rooms. “This idea provides the foundation of the ASHRAE standard for thermal comfort in naturally-ventilated spaces. As seen earlier, the comfort standard for a naturally-ventilated space is broader than that for a mechanically-conditioned one. This is due to two main factors. First, human thermal comfort can be defined relative to outdoor temperatures. In the winter, for example,

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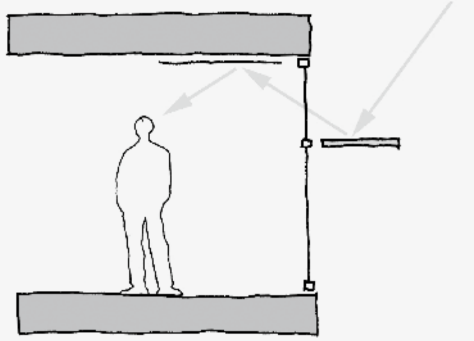

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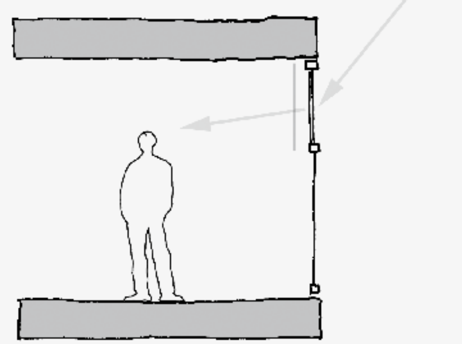

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4 If the weather changes the interior climate must be stable
5 Glare problems

people expect cooler temperatures inside than they do in summer. A naturally-ventilated space is directly relatable to outside conditions. Second, naturally-ventilated spaces are almost always controllable (to some degree) by the occupants. Giving occupants control over their airflow and temperature vastly improves their perceived thermal comfort – even if the occupant never exercises their control."

Air quality is a crucial factor for hygienic comfort. The two main aspects that influence it are the quality of the air when it enters the system (i.e. the outside air) and contamination from within the building. This contamination can be dust, CO_2, odours, viruses, bacteria and others.

To ensure hygienic comfort, ventilation has to be guaranteed. This phenomenon is known to some of us: entering a vacation rental that has been vacant for a while causes us to aerate the place because of the musty smell and muggy air.

ACOUSTIC REQUIREMENTS – NOISE

Acoustic comfort in spaces is mostly determined by the transmission of sounds from outside the building, inside the building or one's own noise production or the room's echo.

Street and construction noise are the biggest source of noise from outside of the building. Inside, the users themselves can cause acoustic discomfort by talking on the phone, walking or through music. There is a distinction between airborne noise that travels from the source through the air into the room, and structure-borne noise which spreads through the building elements, like footfall sound spreads through walking on hard floors with heels.

Noise can also come from technical equipment or electric lines and spread through the building, thus reducing acoustic comfort.

If we look at the requirements of individual building components, there can be contradictions. Acoustically, for example, it may be sensible to suspend a ceiling. Covering the concrete may, however, result in a restricted thermal capacity, thus limiting the cooling effect that the concrete can provide during summer. If the suspension is indispensable, and the room's acoustics can be manipulated through room dividers or sound absorbing furniture, a different way of cooling the building has to be considered. Consequently, these factors all need to be considered simultaneously and balanced when planning a building.

If the external noise poses high demands on the sound insulation of the façade and natural ventilation is also to be integrated, both functions cannot be maintained with a simple facade, while the windows are open. As an alternative, other means of ventilation will have to be considered or the façade has to be changed in a way that allows for sound insulation while providing natural ventilation.

OPERATIONAL ENERGY

To achieve a certain level of comfort in a building, the building's construction and its services have to be balanced depending on climate. If we look at Berlin as an example, we see that during the winter, outdoor temperatures drop much lower than the desired room temperature. Heating is unavoidable. However, the quality of the building has great impact on the amount of energy needed. The better the building's insulation, the lower the need for heating.

During the summer outside temperatures can go beyond the desired room temperature. This can be alleviated actively with the use of air-conditioning. Still, the thermal mass of the building can be utilized even to a higher extent by using thermally activated building systems (TABS). Sunlight protection can help to reduce elevated inside temperatures.

Depending on the local climate, the demand for operational energy has to be assessed in detail. If the outside climate is very close to the desired inside climate, there is less need for temperature regulation, thus reducing the capacity for active systems. Passive measures alone, like natural ventilation, thermal weight and efficient sunlight protection can suffice to provide a pleasant indoor climate.

Nevertheless, if the difference between indoor and outdoor temperature is greater, active measures are required, thus making services like air-conditioning and heating inevitable. The demand for operational energy increases in these climates. However, passive measures like proper insulation and sunlight protection can reduce these expenditures. In figure 4 a comparison is made to indicate the average operational energy use in eight different cities covering different climate zones. You will easily notice that the operation of a building is "strongly" dependent on its climatic surroundings.

Figure 1 also reveals the relation of passive and active measures. If a room is mechanically ventilated, e.g. according to DIN 1946, the comfort zone is very small and building services are constantly intervening to heat/cool the building in an effort to maintain the room's comfort. If ASHRAE 55-2004 regarding natural ventilation is applied, however, the comfort zone is much wider. The user is content despite potential temperature fluctuation and demands less of the room. Thus, building services are used less, lowering the operational energy.

To maintain natural ventilation efficiently, the façade must support this function. The same is true for the operational energy that is needed for artificial light. If the building provides enough sunlight through bigger windows and façade surfaces, the work spaces can be aligned to reduce electrical lighting demand.

It must be noted, when only focusing on the factor of natural light, a transparent building might be created which then heats up too much in the summer and requires heating in the winter.

User comfort must be maintained throughout the year with regards to the climate. Regardless of the climate, passive measures to reduce operational energy should always be considered.

Much like a sailboat, planners should design a building so that it utilizes weather and climate. A motor should only be an aid and not the ultimate solution since it requires energy input. This can be achieved if everybody involved in the design process works together from the beginning to find a concept that fits into its environment.

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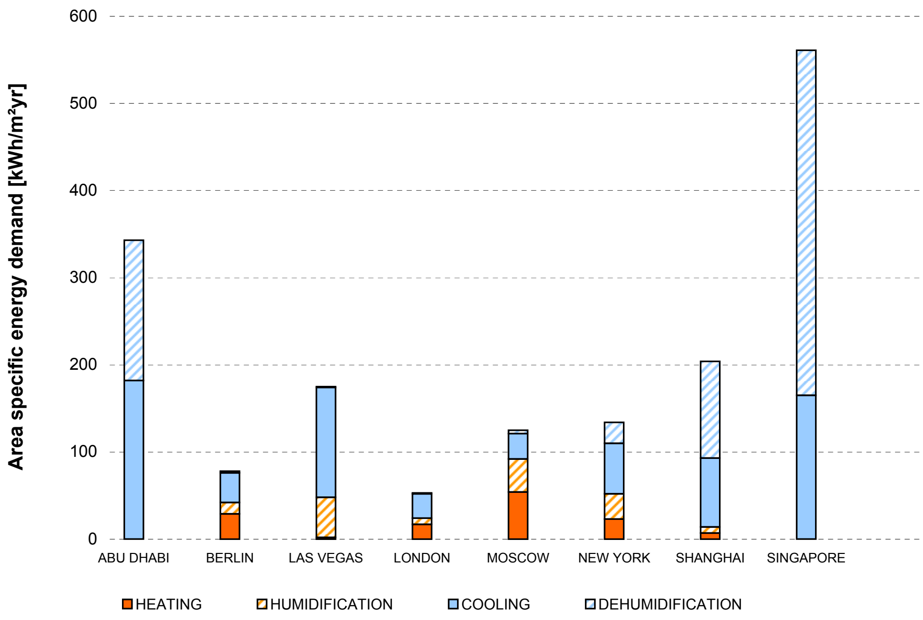


4 Energy demands in comparison

3. ECOLOGICAL ANALYSIS OF MATERIAL AND CONSTRUCTION

ECOLOGICAL ANALYSIS OF MATERIAL AND CONSTRUCTION

ASPECTS OF ENERGY IN A BUILDING

This chapter focuses on the ecological aspects of sustainable design. Different materials and types of construction will be evaluated according to their effect on the environment. Through the holistic approach to life cycle assessment, the quality of different products can be compared and analyzed.

The energy assessment of a building depends on several factors, such as the amount of external surface area, positioning, use, its access to energy supply systems as well as its façade. There are three different categories of energy relating to the efficiency of a building:

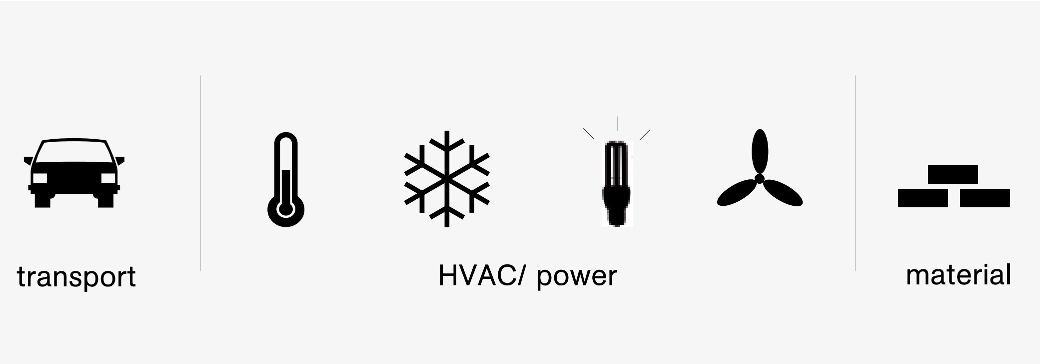
1. Transportation energy: Especially in urban design transportation energy is a very influential parameter which is determined by the density of the building's site.
2. Operational energy: the amount of energy needed to operate a building and provide electricity. It tends to be the highest share in the overall energy (especially in office buildings).
3. Embodied Energy: the amount of energy needed to "construct" a building and dispose of it after its use, which can account for 50% of the overall energy usage of a building, if its operational energy is low.

While the operational energy has become an increasingly important parameter in designing a building, the energy bound in the material has yet to be integrated in the design process. The necessary data providing life cycle information for building materials are increasingly available but interpreting them remains difficult so that only specialized planners are able to implement them.

The intention of this chapter is to alleviate this drawback. By evaluating existing life cycle assessment data usability for architects is improved. Life cycle assessment data from Type III Umweltdeklaration according to DIN EN ISO 14025 provided by the German Federal Ministry of Transport, Building and Urban Development will put it in context.

LIFE CYCLE ASSESSMENT

Environmental impact is caused by the extraction of resources and by emissions. The term Embodied Energy was coined by Spreng in 1989 and defines the amount of



energy necessary for the production, maintenance and disposal of a material. This assessment is based on the methods of Life Cycle Assessment (LCA), which is explained in DIN EN ISO 14040 cf. The different tools to assess a material's life cycle differ greatly in depth and breadth and therefore can only be compared to a certain extent. There is not one universal tool that is applied throughout.

Assessment of a material's energy performance holistically has been prompted by building certification systems, such as the German DGNB and the British version BREEM. LEED, the American green building certificate, does to some extent include the holistic energy assessment of materials.

Although these tools are progressive and valuable for the energy assessment of buildings, they do not support the design process as they are made to assess already existing, finished buildings. However, the effects of certain construction patterns and choices of material are essential to the result of a holistic energy assessment and should therefore be considered early on.

The assessment of a building's energy is a standardized process. However, it is applied in different ways such as different grading scales, so that the results of such an assessment have to be reviewed carefully. The Round Table for Sustainable Building (Germany, Runder Tisch Nachhaltiges Bauen) established seven categories of which only two are used commonly. Those are Non-renewable Primary Energy (PEnr) and Global Warming Potential (GWP). The other five factors (Renewable Primary Energy, Ozone Depletion Factor, Acidification Factor, Eutrophication Factor, Tropospheric Ozone) require expert knowledge and, therefore are not applied as much. The analysis of primary energy allows for a comparison with operational energy. Some of the assessment programs use this opportunity and present a cumulative term in the form of a ranking, e.g. A+. Unfortunately, doing so limits the transparency and the comparability of different tools and studies regarding the topic. Critics further claim that that very ranking cannot be taken as authoritative as there has not been enough research on the individual factors. This account, therefore, focuses only on PEnr and Global Warming Potential.

COMPARISON OF MATERIALS

A building's ecologic assessment links a building's weight with the LCA of its materials. The results will be presented based on either volume or weight. The building materials are divided into the following sub-categories: 01 Mineral Building Materials, 02 Wood Products, 03 Metals, 04 Synthetic Materials and 05 Insulation Materials. These categories are based on their resource material, except for Insulation Materials, which can be made from synthetic materials as well as mineral material. Insulation Materials are dealt with separately because of their high relevance.

The analysis of the material uses different sources, such as the database Ökobau.dat, which was developed by PE International and transferred to the German Federal Ministry of Transport, Building and Urban Development (BMVBS), EPDs from different suppliers, the assessment of the Swiss Society of Engineers and Architects (SIA) as well as online resources.

The overall comparison reveals that the amount of embodied energy ranges from 0 to 210 MJ/kg. Comparing the data in relation to volume there is a range from 0 to 900.000 MJ/cbm. Both in the weight classification and in the volume classification mineral and wood products score the lowest. Mineral ones span from

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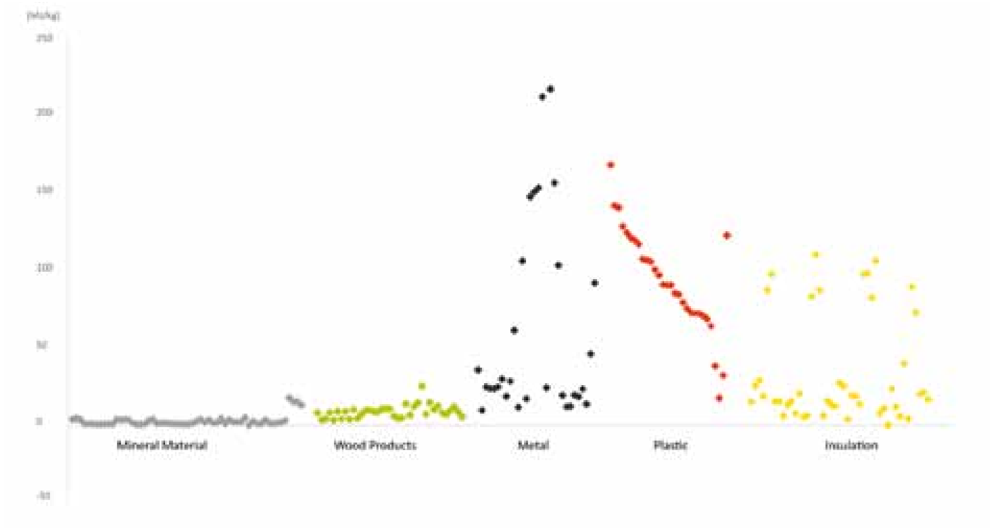

1 Material comparison

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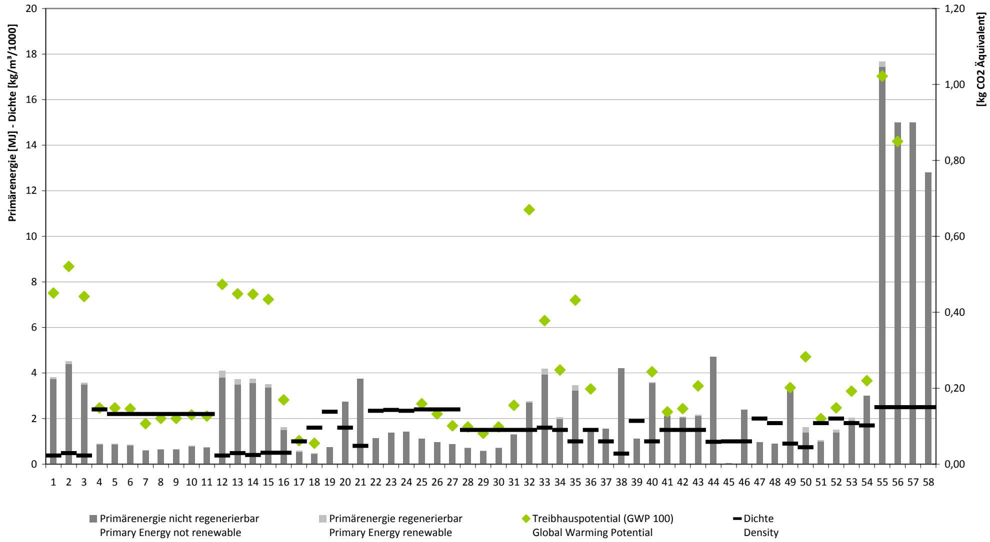

1 Aerated concrete P2 04 without reinforcement
2 Aerated concrete P4 05 with reinforcement
3 Aerated concrete P4 05 without reinforcement
4 Concrete
5 Prefab concrete slab 20 cm
6 Prefab concrete slab 40 cm
7 Prefab concrete stair
8 Prefab concrete wall (12 cm)
9 Prefab concrete wall (40 cm)
10 Prefab concrete tube with reinforcement
11 Prefab concrete tube without reinforcement
12 Aerated concrete P2 (H+H Celcon)
13 Aerated concrete P4 (H+H Celcon)
14 Aerated concrete PPW 2 (Xella)
15 Aerated concrete PPW 4 (Xella)
16 Light concrete exterior wall (average for associations)
17 Light concrete interior wall (average for associations)
18 Light concrete separation wall
(average for associations)
19 Concrete
20 Light concrete
(in-situ concrete with aerated concrete)
21 Light concrete
22 Reinforced concrete (0.8% steel)
23 Reinforced concrete (1.5% steel)
24 Prefab concrete (0.8% steel)
25 Concrete (in-situ floor slabs, structure)
26 Concrete (in-situ floor slabs) with 25% PFA RC40
27 Concrete (in-situ floor slabs) with 50% GGBS RC40
28 Mortar (Baumit)
29 Mortar (Ökobau.dat)
30 Mortar (Schwenk)
31 Cement screed
32 Cement (Ökobau.dat)
33 Basecoat mortar (Schwenk)
34 Special mortar Baumit
35 Light mortar (Schwenk)
36 Finishing coat (Baumit)
37 Gypsum coat
38 Light coat
39 Cement coat
40 Gypsum
41 Gypsum coat
42 Gypsum lime coat
43 Gypsum lime interior coat
44 Gypsum plaster board
45 Gypsum stone
46 Brick
47 Lime stone
48 Concrete stone
49 Clinker
50 ThermoPlan and ThermoBlock brick
(average for associations)
51 Limestone (Xella)
52 Limestone lintel (Xella)
53 Limestone Silka Therm Kimm (Xella)
54 Bricks (common)
55 Window glass
56 Window glass
57 Float glass
59 Cast glass

2 Mineral Building Materials

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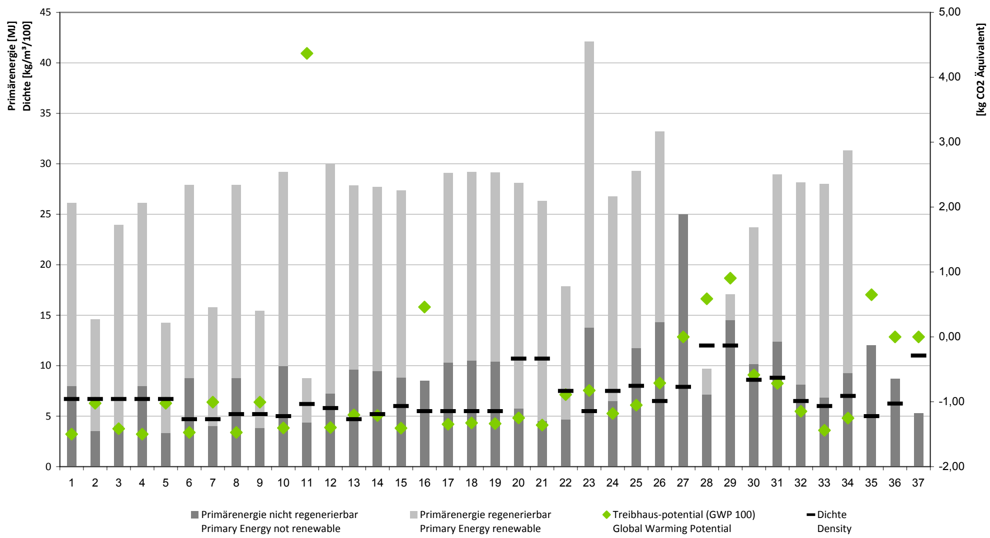

1 Sawn beech (12% humidity/10.7% water content)
2 Sawn beech (65% humidity/40% water content)
3 Sawn douglas spruce (12% humidity/10.7% water content)
4 Sawn oak tree (12% humidity/10.7% water content)
5 Sawn oak tree (65% humidity/40% water content)
6 Sawn spruce wood (12% humidity/10.7% water content)
7 Sawn spruce wood (65% humidity/40% water content)
8 Sawn mandible (12% humidity/10.7% water content)
9 Sawn mandible (65% humidity/40% water content)
10 Sawn larch tree (12% humidity/10.7% water content)
11 Teak wood
12 Sawn cedar wood (12% humidity/10.7% water content)
13 Construction wood spruce
14 Construction wood mandible
15 Construction wood (15% humidity/13% water content)
16 Timber (general)
17 Laminated beam pine wood (12% humidity)
18 Laminated pine wood (12% humidity)
19 Laminated timber board (12% humidity)
20 Three layer laminated wood
21 Five layer laminated wood
22 Plywood board
23 laminated veneer lumber
24 Oriented straw board
25 High density fibreboard
26 Medium density fibreboard
26 MDF medium density fibreboard
28 Wood cement board
29 Wood cement board (coated)
30 Medium density fibreboard MDF (EGGER)
31 High density fibreboard HDF (EGGER)
32 EUROSPAN-board
33 Oriented straw board (EGGER)
34 Pfleiderer Living Board
35 Glue laminated timber
36 Plywood board 8% UF
37 Plywood board (64% cement)

3 Wood products

0.5 to 5 MJ/kg with the exception of glass (12 to 18 MJ/kg). Wood products have only a slightly higher range of 5 to 15 MJ/kg. Metals vary more greatly with aluminum having the highest ratio of 155MJ/kg. Synthetic materials, too, have a strongly varying ratio ranging from 30 to 160 MJ/kg. In the insulation category there is a clear distinction depending on the resource; mineral based materials range from 0 to 40 MJ/kg, whereas synthetic materials range from 70 to 100 MJ/kg.

Mineral materials

Up to 85% of a building created with solid construction can account for mineral building materials (GFÖB). Materials can be concrete, cellular concrete, sand lime bricks, clay bricks, plaster, glass and mineral wool. Mineral materials have a long life cycle and are generally long-lasting. Only surfaces like plaster and paint have to be renewed regularly. These materials' bonding is usually permanent and irreversible, which limits its flexibility and recyclability. In addition, options for prefabrication are limited.

If a building is demolished, it is destroyed entirely. Metals are sorted out and then the rubble is separated and either added to new building material or used in road construction.

Compared to synthetic materials, mineral materials contain little primary energy. Their ratios range from 1 to 5 MJ/kg, except for glass (12 to 18 MJ/kg) due to the high temperature needed to process it. The lowest ratios are found for concrete (1 to 2 MJ/kg), as well as light-weight concrete, ready-mixed concrete and cast-in-place concrete. Cellular concrete has a slightly higher ratio (3 to 4.5 MJ/kg), followed by plaster and floor paving (1 to 4 MJ/kg). Brickwork lies between 1 and 5 MJ/kg, while sand lime brick (1 to 2 MJ/kg) performs significantly better than clay brick (3 to 3.6 MJ/kg).

The primary energy contained in concrete is determined by the amount of reinforcement it receives. Even if recycled concrete is added to the mix, it only affects the energy input marginally as the reconditioning of the used concrete requires more energy input. Even though using recycled concrete is not energy efficient if it has to be brought from more than 100 km away, using it should still be considered if the energy input for fresh concrete is about the same, so that resources can be conserved.

Assessing mineral building materials clearly reveals their low and therefore attractive ratios. Nevertheless, in this case it is crucial to factor in that one kilogram of concrete or mortar can bear relatively little function and thus, is usually employed in bigger amounts.

Wood

Wood is the least problematic building material. Once used it can be down-cycled or burnt, and it achieves outstanding energy ratings because of its ability to bind CO_2. Depending on the subsequent processing of the wood, both GWP and Primary Energy can be rated almost neutral if the End of Life is incorporated into the assessment. Wood materials are an outstanding example of how crucial it is to look at the entire life of a material. Only looking at the production phase results in a positive factor for Primary Energy. In addition, the GWP is below zero since CO_2 is embodied in the material. Incorporating the end of life into the assessment, though, changes the rating. Burning the wood generates more energy than was needed for extraction, which lowers the value of PEnr. Nevertheless, burning the wood also releases the CO_2 it previously embodied, thus increasing the overall factor for GWP.

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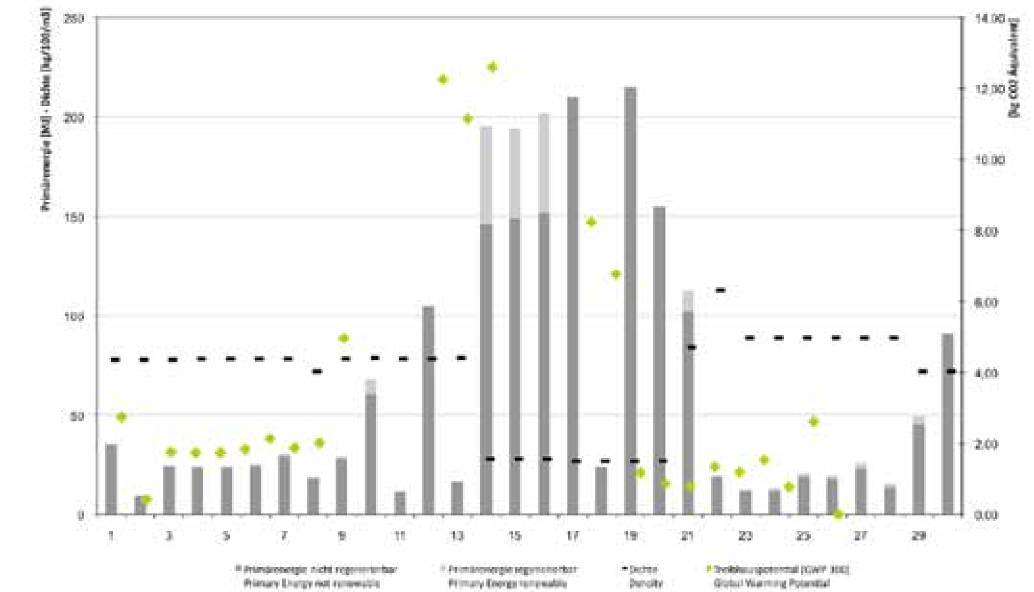

1 Steel (virgin)
2 Steel (recycled)
3 Steel (typical virgin/recycled)
4 Steel hot rolled profile (I/U/T/H/L)
5 Steel hot rolled sheets (2 – 20mm)
6 Steel thin sheet (0,3 – 3,0mm)
7 Steel thin sheets (20µm zinc-coated)
8 Gray iron
9 Wrought-iron steel
10 Stainless steel
11 Reinforcement steel (CH)
12 High-alloyed thin sheet < 3 mm, 100% recycling share
13 Thin sheet < 3 mm
14 Aluminium sheet
15 Aluminium casting
16 Aluminium extrusions profile
17 Aluminium profile, 0% recycling share
18 Aluminium 100% recycling share
19 Aluminium membrane
20 Aluminium (general & incl. 33% recycled)
21 Brass profile
22 Lead sheet
23 Copper sheet
24 Copper reel-Classic (TECU)
25 Copper oxide (TECU)
26 Patina (TECU)
27 Gold (TECU)
28 Bronze (TECU)
29 Titanium zinc sheet
30 Zinc

4 Metals

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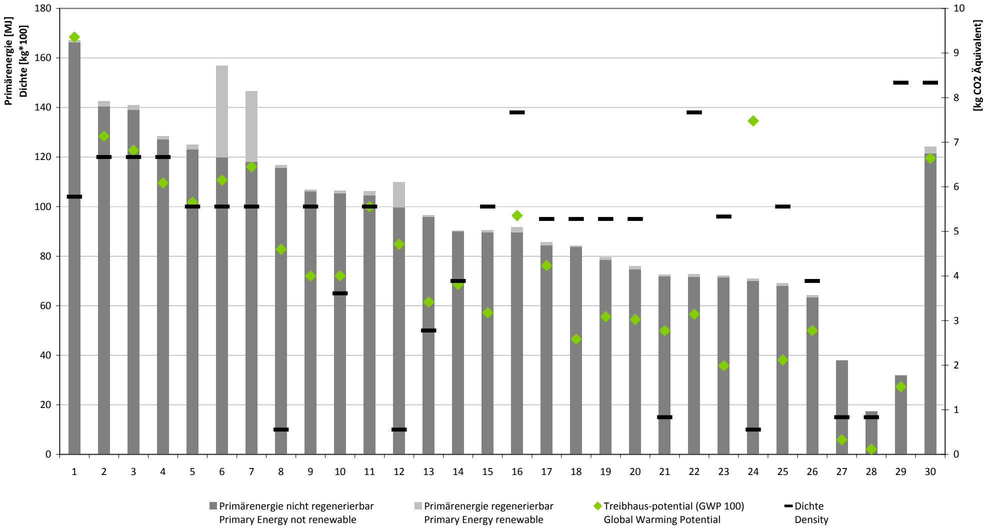

1 Membrane PA
2 Transparent board PC
3 Transparent board PMMA
4 Transparent board PMMA
5 Vapour retarder PET
6 Silicone sealing compound
7 Silicone profile
8 EPDM extrusion profile
9 Elastic roof cover
10 Synthetic rubber
11 PUR on PET-fleece)
12 PUR sealing compound
13 Styrol-butadiene-rubber (SBR)
14 Acrylnitril-butadiene-styrol-granulate
15 Foil (EVA)
16 PVC membrane
17 Fibre reinforced membrane PE
18 Sealing PE with PP-fibres
19 Membrane roof
20 Membrane green roof
21 Acrylic sealing compound
22 Transparent board PVC
23 Membrane (PE HD)
24 Glass fibre fleece
25 Vapour barrier
26 PVC sealing compound
27 Bitumen glue
28 Bitumen emulsion
29 Urea formaldehyde resin foam
30 Melamine resin foam

5 Synthetic Materials

The primary energy ratio of wood products is about 3.5 MJ/kg (birch lumber) and 14.5 MJ/kg for a cement-bonded wood fiber board. The average ratio of wood materials is 10 MJ/kg. Since wood is a renewable resource, its Primary Energy Renewable Factor is extremely high. Its absorption of CO_2 during growth is credited against its GWP, which results in wood having a negative GWP for its production phase. The ratio for plywood is higher than that of lumber due to the difference in production expenditures. The gluing of plywood increases the primary energy contained.

As wood grows back in relatively short cycles, the impact on nature is more easily remedied. Wood is easily harvested and processed. Wooden materials are very efficient; they are very stable despite their low weight. Steel, for example, is only ten times harder, but 20 times heavier. Additionally, wood does not cause any waste problems since it can be reused, processed or used as an energy carrier. When using wood as a building material, local resources should be preferred over imported resources to keep the impact of transport as small as possible. Should tropical wood be required because of its unique qualities, a certified product, as provided through the Forest Steward Council, should be guaranteed.

As a result of an overall assessment of embodied energy the use of wood is being recommended. Nevertheless, it is crucial to think in a sustainable way and review functional and economic interests. Wood is a renewable resource, but it should be used sparingly. It does improve the overall assessment, but using wood as a building material hinders it from absorbing CO_2 in the future.

Metal materials

Metals belong to the hardest products in the building industry. Steel and iron have a very high density and are shapeable, which makes them indispensable for the stability of bigger buildings and in the construction of facades. The long lifespan of metals is another great advantage as they can be reused countless times. To shape and process the metal it needs to be melted down under very high temperatures, which results in very high energy expenditures of up to 210 MJ/kg. Aluminum has the highest ratio of PEnr with 145 to 210 MJ/kg, which depends on the share of recycled material and can be brought down to 24 MJ/kg. The recyclability of the metal affects the ratio positively. Nevertheless, at this point the acquisition of recycled aluminum is very limited because it has been in use only since the 1970s. The same is true for steel, which has a ratio of 23 to 35 MJ/kg for new material, but only 10 MJ/kg for recycled steel.

Synthetic materials

Synthetic materials are poor performers when it comes to ecological design. Their limited recyclability and the high energy expenditures needed for their production cause designers to be cautious with these materials. Nonetheless, their flexibility in color, shape and function make it a very attractive material. Even very thin synthetic membranes can span great distances and bear comparatively heavy loads, which makes them very attractive for temporary constructions. When assessing synthetic materials a distinction has to be made between thermoplastic and duroplast. While duroplast is more durable, thermoplastic can be heated and mixed with other materials or separated from them. Duroplasts, on the other hand, can only be repurposed with a lot of energy input.

In most cases these products will get burned. Thermoplastics can be recycled much more easily. The two when mixed bring about a degradation of the material. Hence, when designing with these materials, it is important to keep them separated to ensure a proper recycling process.

Synthetic materials range from 60 to 150 MJ/kg with more transparent materials ranging at the higher end of the spectrum, which makes them the material with the second highest energy demand after metals. Incorporating the end of life into the holistic energy assessment can have positive effects on synthetic materials if they are kept pure. Burning them can add to its performance. Nevertheless, emissions should be investigated.

Insulation

If a material's thermal transmission is less than 0.1 W/(mK), it is counted among the insulation materials. Rock and glass wool, as well as expanded polystyrene are the most common insulation materials. Glass and rock wool belong to the group of mineral wool, which requires 5 to 30 MJ/kg, giving it a low environmental impact. Polystyrene is a synthetic material and requires 70 to 110 MJ/kg. Natural fiber insulation materials account for very little energy (cellulose and cork are both below 5 MJ/kg). Loose-fill insulation has an even lower rating of 0.03 to 1 MJ/kg.

Another factor is the choice between mineral materials and oil-based materials. The latter have a higher PEnr, e.g. EPS and XPS in comparison to mineral wool. On the other hand, mineral materials have a longer lifespan, thus reducing the need for replacement.

PARAMETERS DETERMINED BY THE CONSTRUCTION

Functional unit

Comparing materials based on their weight or volume is the first step to a fair assessment and comparison of building materials. To find the right material for every building however, materials need to be compared in terms of the functions they fulfill. Here, a desirable ratio is not calculated based on weight, but on function. The assessment then relates function with environmental impact.
The thermal transmission coefficient, for example, can serve as a way to compare different insulation materials. When looking for a coefficent of 0.2 W/mK, mineral wool of 17.5 cm thickness achieves the best result. Even though other materials could be less material intensive (EPS: 12 cm), the amount of embodied (gray) energy is still lower. When considering not only gray energy but also the material's lifespan, the distinction becomes even clearer. While fulfilling all the same functions, mineral wool clearly proves to be a better ecological choice.

Comparing materials based on their functions is a very promising tool. While this may be true of simple examples such as insulation and load transfer, other functions are more difficult to define and separate. When assessing façades, ceilings or walls, functions will overlap so that an assessment based on function is challenging.

Three phases in the life of a building

A holistic energy assessment contrasts input and output in three phases: the production phase, use phase and end of life. The production phase is the construction of the building; the use phase comprises all operational energy and all measures necessary to maintain the building, such as replacements of building parts (especially surfaces), their

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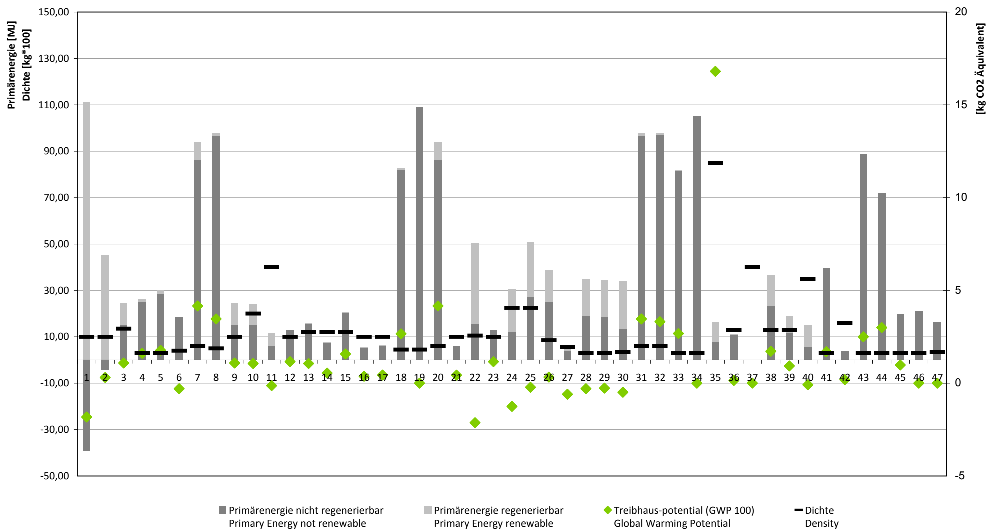
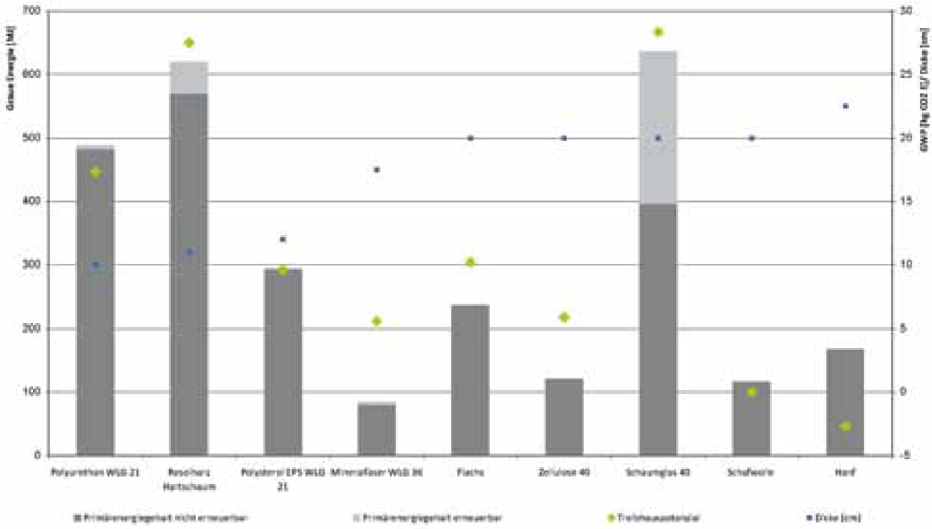


1 Wood fibre board DHF
2 Wood fibre board (self supporting) DFF
3 Foam glass insulation W+F
4 Rock wool insulation
5 Glass fibre insulation
6 Hemp insulation
7 Polyurethane hard foam
8 Polyurethane foam
9 Foamglas W+F
10 Perinsul SL
11 Heraklith BM
12 Resin bound mineral wool
13 Mineral wool (ground insulation)
14 Mineral wool (façade cladding)
15 Mineral wool (flat roof insulation)
16 Mineral wool (interior insulation)
17 Mineral wool (Roof insulation)
18 XPS Extruded polystyrene foam
19 XPS polystyrene extruded
20 Polyurethane hard foam
21 Perlite
22 Expanded cork
23 Rockwool
24 Wood fibre board
25 Wood fibre insulation
26 Cellulose board
27 Cellulose fibre
29 Hemp fibre fleece
30 Cotton fibre
31 Plastic foam
32 Rubber foam
33 EPS
34 EPS
35 Calcium silicon insulation board
36 Aerated concrete insulation panel
37 Thermal insulation composite system synthetic render
38 Foam glass Perinsul
39 Foam glass W + S
40 Wood wool board
41 Flax insulation
42 Cork insulation
43 Polystyrene insulation
44 Polyurethane insulation
45 Wood wool board insulation
46 Wool (recycled) insulation
47 Sheep wool

6 Insulation material

7



1 Polyurethane WLG 20
2 Resole resin foam
3 Polystyrene EPS WLG 20
4 Mineral wool WLG 35
5 Flax
6 Cellulose
7 Foam glass
8 Sheep’s wool
9 Hemp

7 Comparison of insulation material

maintenance and care. End of life describes the time when the building loses its function. Reusing, recycling or burning the materials affects the overall assessment differently, which makes it crucial either to only look at the production phase or to make sure end of life data is available.

Reference value

Another important parameter is the context and reference unit of comparison. While kilogram is the most common unit, cubic meter can also be found. When evaluating the amounts of embodied energy or GWP, they are assessed against the energy absorption area. The outer surface area is commonly presented in square meters and is equally assessed against the net floor area. As a result, buildings of different sizes, uses and volumes can be compared. The more information combined in one ratio, the more difficult it is to retrace the individual factors. To ease comparability even further, it is recommended to assess the ecology factors per energy absorption area and year, thus making an evaluation of the operational energy relatively easy.

Duration

Over a lifespan of 30 years operational energy and embodied energy roughly equal each other. If longer or shorter, the proportions change together with their relevance. Embodied Energy becomes more relevant when the life is intended to be shorter, while a building's operational energy gets relatively high when it is used for a very long time.

Building owners in Switzerland generally assume 30 years as the lifespan of a building. The rationale for this is that sustainability, i.e. minimal environmental impact for future generations, is achieved over the time of one generation. In Germany opinions on the lifespan of a residential building range from 50 to 100 years.

EMBODIED ENERGY IN BUILDINGS

The amount of embodied energy in a building is influenced by different parameters, which will be introduced briefly below.

Material

Wooden products receive the best energy ratings in comparison to metals or synthetic materials. The label "renewable", however, does not mean that the supplies of wood are infinite. Using metals increases the amount of energy embodied in a building. Yet, these ratings have to be seen in relation to the functionality of a building element. "High Tech Façades", for example, have to justify the higher input of energy with higher quality (comfort) and reduced operational energy.

Construction

Since most ratios in the holistic energy assessment are based on weight, heavy construction receives high ratings. In solid construction 1.5 to 2 t/m^3 are being used whereas lightweight construction is able to stay at $< 1t$. This striking difference results in a difference of about 20% in embodied energy. When comparing constructions, it is important to highlight the implications for the operational energy: lightweight construction has a higher need for heating and cooling because of the lack of thermal mass. In addition, there might arise the need for sound insulation. If the building elements of a solid construction are pre-fabricated, this will affect the assessment positively; in general, prefabricated materials are to be preferred over on-site constructions.

Opaque surfaces tend to contain less primary energy than transparent ones. Window areas with aluminum frames also receive a higher rating because of the metal frames, whereas wooden and plastic frames are rated considerably lower.

Volume and shape

The proportion between the outside surface area of a building to its volume (A/V) impacts the overall rating of a building. Not only heat/cooling loss are influenced by this ratio, but also the material expenditures. A low A/V ratio optimizes the use of material. Furthermore, daylight and solar surplus can be incorporated, as well as the use of electricity. Generally, a complex shape has to be justified through an increase in visual, thermal or acoustic comfort and aesthetic appeal.

Flexibility

Designing buildings suitable for various purposes improves flexibility. A building intended for a limited time should be built with materials of limited lifespan. Ideally, possible future uses should be incorporated into the design of the building to guarantee the development of a resource-friendly concept.

Lifespan

If the time assigned for a building's use equals its life, the building's potential has been used in the best possible way. Ideally, that time frame should also be the lifespan of the supporting structure. If a construction or its structure loses its function, reuse should be checked as a first response. That way, resources can be protected and repurposing can be avoided. When a material has to be recycled, additional energy is necessary to make it useable as material again. This energy investment must not be out of proportion; if the same amount of energy is needed to create the material anew, the recycled material is to be preferred. If recycling is not an option, the material needs to be dismantled and separated. This option should ideally be included into the design process of a building. Separating materials into layers of durability is an option worth considering. Short-lived elements would have to be easily accessible and replaceable. Reversible connections would allow for a flexible replacement and could save materials and cost.

Potential for optimization

The majority of the amount of embodied energy is found in the structure. The more structure that is necessary, the higher the building's rating. Basement floors additionally add to the rating. The support structure and the façade both account for about a third of the overall structure. While the potential for change in the structure is relatively small, the façade is able to assume all kinds of materials, shapes and functions. This reveals the tremendous potential for optimization through the adaptation of the façade. It is the crucial factor and linchpin of the entire holistic energy assessment.

CONCLUSION

The holistic energy assessment is a powerful tool to the ecology of a building when applied during the beginning phase of the design. Embodied Energy is one factor in ecological design and its strength lies in the direct comparison of different options for one functional context. To utilize the energy assessment to its full potential, the purpose of the object of assessment needs to be clearly defined so that the best solution for that purpose can be found.

Choice of material, construction type, shape and volume and lifespan are the factors that impact the holistic energy assessment of a building. When looking at the potential for optimization, façades prove to be the most influential factor

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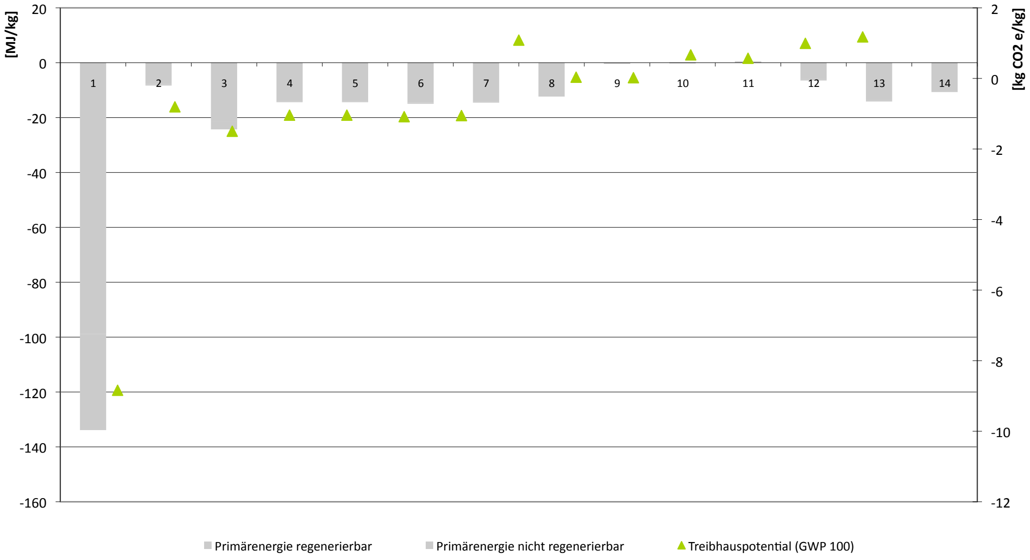

1 Recycling potential aluminium sheet
2 Recycling potential steel sheet
3 Recycling potential copper sheet
4 Recycling potential steel sheet hot rolled
5 Recycling potential steel profile warm milled
6 Recycling potential thin steel sheet galvanized
7 Recycling potential thin steel sheet
8 Combustion carpet in waste incineration plant
9 Processing construction waste
10 Building rubble processing plant
11 Landfill
12 Combustion of waste in incineration plant
13 Wood untreated incineration plant
14 Chipboard in incineration plant

8 End of life

for the result of an energy assessment making it the linchpin of energy performance. It is receiving increasing attention since it accounts for a major share of the energy input in a building, ranging anywhere from 500 MJ/m (wood studding) to 4,000 MJ/m (automated double skin façade). With the rising demand for building certificates façade designers will have to justify their choices more and more. Apart from thermal transmittance, the amount of embodied energy should serve as an important parameter for the evaluation of a façade. Furthermore, its intended lifespan and function should be critical: short-lived, temporary buildings will be made with light façades, whose nature would require earlier replacement of individual components, whereas buildings with a longer intended lifespan would be made with massive construction, or, when designed in a skeletal manner, they would stand out through the possibility of replacement of individual building components, efficiency and flexibility in their function. It will be important to further develop scenarios for the different variants.

The relevance of an ecological assessment that incorporates all forms of energy involved in the life cycle of a building becomes even more obvious when looking at the impact and difference it can make since the building industry accounts for a tremendous amount of energy. Incorporating the building materials into the energy assessment completes the picture and provides more accurate guidance. The goal of optimizing the building industry's energy use is herein addressed more clearly. In reverse, this means that a high investment of energy has to be justified through high quality. Here, efficiency is the balance between quality and invested energy.

The graphs are also available at www.imagineblog.tumblr.com

4. THE PERFORMANCE ASSESSMENT TOOL

THE PERFORMANCE ASSESSMENT TOOL – PAT

When looking at operational and embodied energy in a building, we have to find a way to express the relation between the two parameters. Since both are energy – albeit in different forms – they will be put in relation to each other and presented according to the assumed lifespan to illustrate their interdependence as well as the relevance of the building's weight. This is done by assigning time as the factor of the x-axis. The y-axis shows the absolute embodied energy for year one, broken up into envelope, structure, interior and building services. The negative area of the y-axis shows the operational energy in absolute terms.

With progress in time the yearly operational energy remains the same, while the embodied energy is being divided by the number of years, thus lowering the mean with every year. The depiction shows increments of five years, providing a perspective on the absolute embodied energy (z-axis).

The basis for this representation is formed by the projects specified in this book. Their ratings of embodied energy were established based on their weight, construction parts, components and their respective energy indices and then fed into the "Lixel" database, which was established for just that purpose. To illustrate the use of the PAT tool, general experience-based assumptions were used for the base chart: a building's life span of 30 years, a proportion of embodied to operational energy of 90% to 10% as well as the interrelation between the factors façade, structure, interior and building services.

Due to these assumptions, the tool operates with a certain vagueness. This, however, is essential to the tool's readability and its easy and quick applicability, which underlines the tool's purpose of being more of a qualitative advisor than a quantitative one. For this reason, the individual lifespan of the façade, structure, interior and building services are not dealt with in depth. Furthermore, the building's purpose, its technical engineering and operating mode, which all require substantial analysis, will not be dealt with in detail to serve the clarity of the tool.

The PAT does however compete with the various international tools for the sustainability assessment of buildings. While those tools advertise their holistic approach, PAT is able to focus on individual building parameters and actively impact the design process, making it indispensable in the early design phases. Here, its vagueness serves as a way to make qualitative statements that are based on quantitative facts.

When replacing the average assumed lifespan of 30 years with a life cycle of 50 years, the embodied energy in proportion to the operational energy is reduced to a very small share. Thus, it can be inferred that buildings that are intended for a longer lifespan should be carefully designed in a way that will be more costly up front but will allow for a low operational energy in the long run. Despite their potentially higher energy requirements in production, higher quality details, durable materials or more complex assembly requirements would pay off if they could reduce the operational energy long-term. An additional factor should be the building's flexibility in changing its

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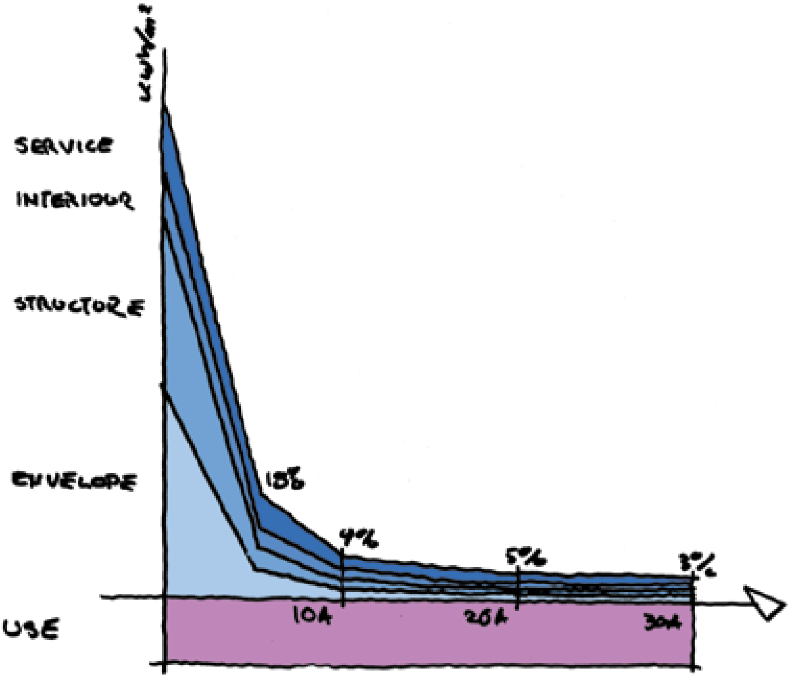

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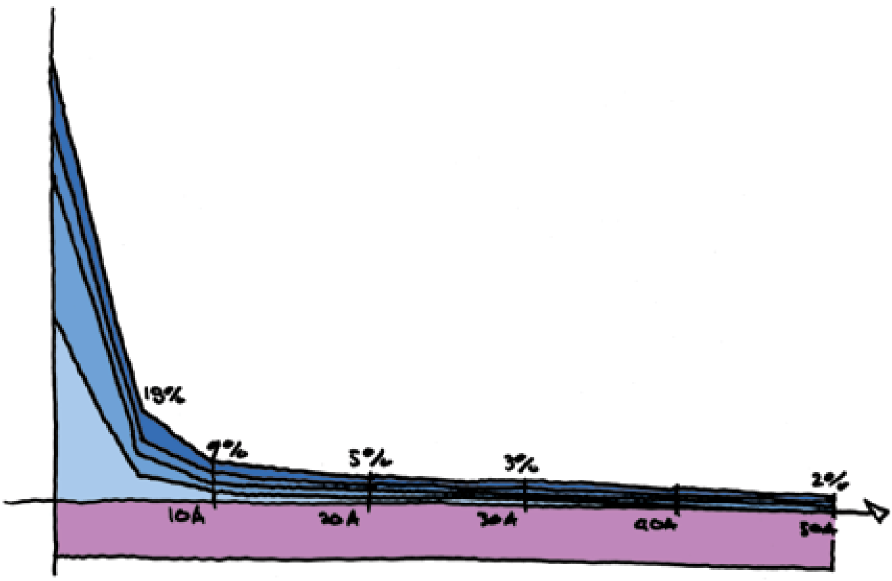

1 PAT principles
2 Extended durability

function. Ideally, a change in purpose should be possible with little additional energy input. At the same time, buildings/ building parts designed for a shorter lifespan allow more generalization in itemization and other parameters, which, in turn, can lead to more innovation in the architecture.
When looking at refurbishment, the embodied energy of the existing building is to be taken as the basis for the analysis into which the additional input is added. The embodied energy that is added through new materials and new construction then has to be spread over the lifetime of the newly refurbished building. Since most cases of refurbishment use the existing structure, and since the amount of newly invested materials is limited, the introduced embodied energy tends to be lower too. This causes a reduction in the operational energy as an improvement of the efficiency of the building.

When considering a major refurbishment where major building parts are replaced or when the function of the building is being changed altogether, the pattern of analysis can be applied so that the base embodied energy of the existing building remains as the embodied energy of the new building. The energy embodied in the new materials and construction is then added. Since less energy is expended in comparison to a new building, a holistic energy assessment displays those savings, thus rating the building with an overall energy advantage.

Looking at demolition and rebuilding against the backdrop of embodied energy, the existing material can no longer be accounted for the material used in the new building since it is destroyed in the demolition. New embodied energy then has to be brought in and set into relation to the operational energy. Since the existing building was destroyed, and with it its embodied energy (of 5% in this example), that embodied energy can be added to the new building's expenditure. As a result, this building can be seen as performing worse than a new building for which no existing building was demolished. However, most new buildings operate with considerably less energy so that its overall performance is positive when considered over a long life cycle. Furthermore, this approach to a building's assessment does not include functional and technical aspects, which are an important factor in the decision for or against complete demolition. If, for example, the ceiling height or capacity of the structure does not serve the purpose anymore, the embodied energy can only be a secondary factor in the decision about the demolition. Retrospectively it is however possible to look at the building and consider how different, possibly energetically more expansive decisions in the design of the original building would have affected the current repurposing.

Part of the examination of embodied energy is, apart from the actual energy for the production and transport of materials, the possibility of giving materials another "life" by assigning it a subsequent use. There are options of direct reuse of the materials, reconditioning and recycling, down-cycling, and occasionally even up-cycling. This potential can be assessed from an energy point of view. Different ratings are given to the material depending on its recycling potential and its ability to be returned to its original quality. In light of this, minimizing the different kinds of material used in construction is preferred. In addition, decomposable construction and design for deconstruction are forms of design/ construction that should be considered. Temporary buildings, such as exhibition

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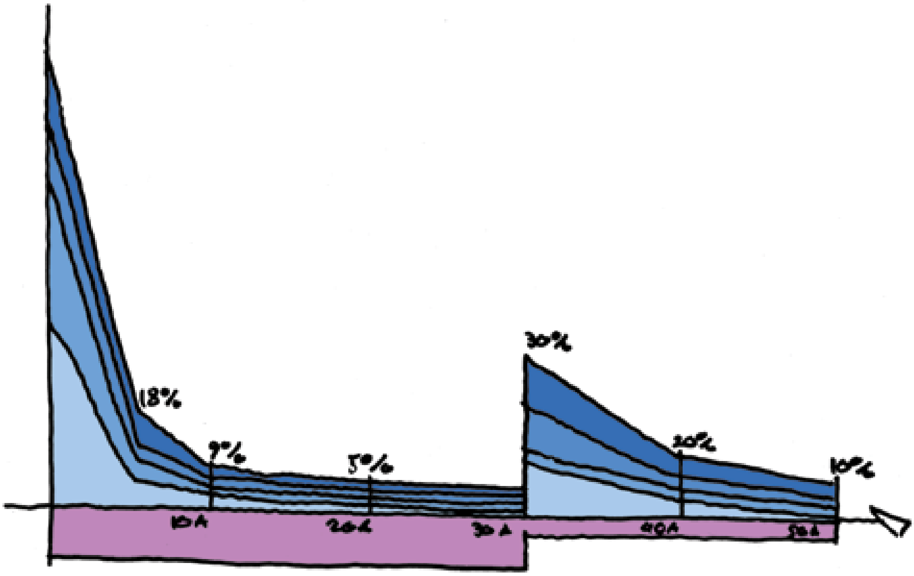

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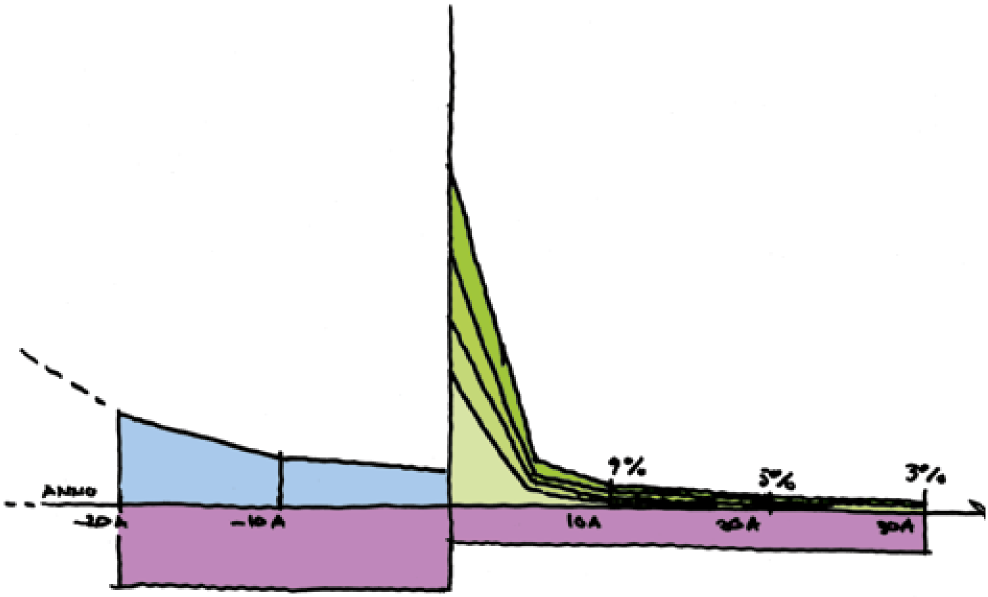

3 Refurbishment
4 Reuse

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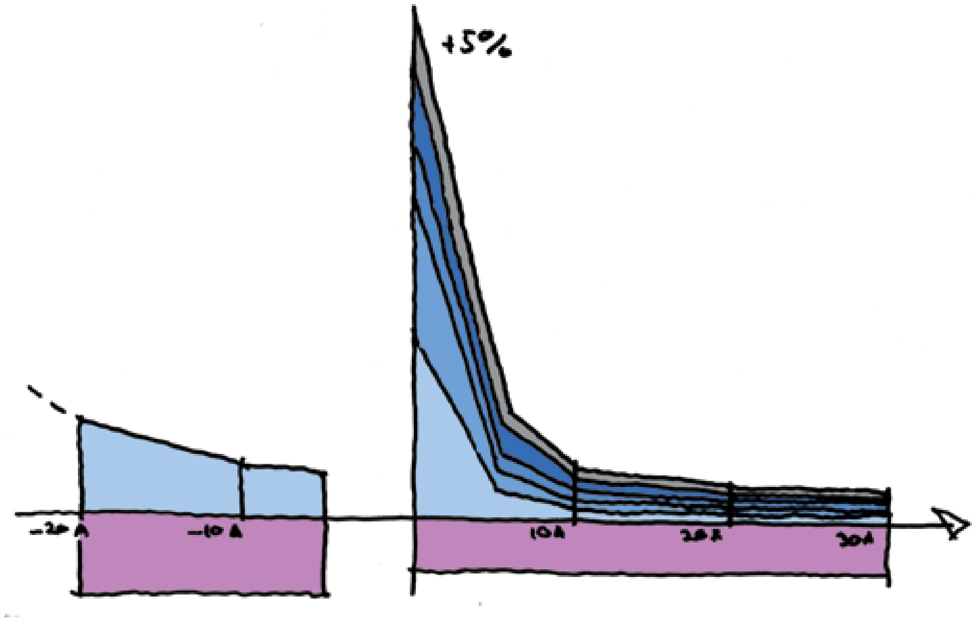

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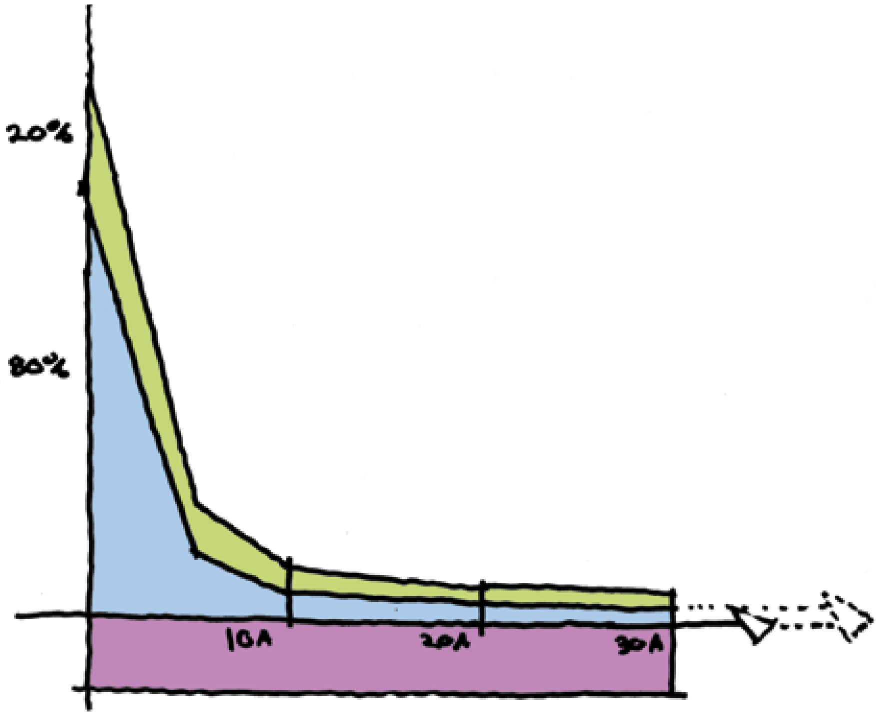


5 Rebuild
6 Recycling potential

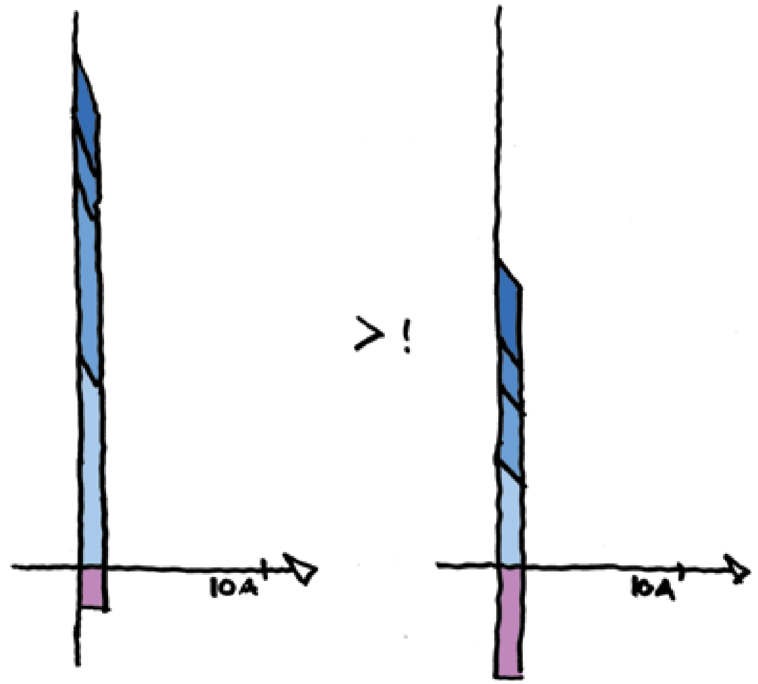
buildings, call for the evaluation of overall input of energy. Heavy buildings, i.e. buildings of weight or expansive constructions that require intensive energy input, receive an unfavorable rating despite their potentially low operational energy. This can be explained by the limited use among which the energy is apportioned. Hence, it is more reasonable to opt for simpler buildings, which will have a less favorable operational energy, but require less embodied energy. Furthermore, the recyclability of the materials should be considered when choosing buildings in this category.

If we engage with the concept of the representation of a building as energy, models can be formulated that propose reuse not of the building but of the energy. The simplest way in which this is possible is thermal reuse: burning it. Other methods of energy conservation in building materials are also conceivable. A timber house could serve as energy carrier for a limited amount of time until it was ready to be burnt, if possible entirely. But other, even more superior energy in the form of material is conceivable, as showcased in Chapter 5. Figure 8 explains how the end of life of the building compensates for part of the operational energy through thermal reuse. A crucial factor for this procedure is the purity of the recycled material since it is essential for the reutilization of its energy.

Taking this concept even further, buildings could come to be seen as energy funds whose functional uses would be subordinate to the use of the building's embodied energy as a commercial investment. Depending on market value and demand, the conventional uses of the building would have to be put in subjection to freeing up the embodied energy of the building. Understandably, these projects would be highly influenced by the functional and technical parameters involved in the building's service as a harvestable energy source with grand-scale influences on the overall design of the building. Figure 9 demonstrates an attempt to win back the needed lifespan energy of the building by reclaiming its embodied energy.

A less extreme and currently more feasible approach is the attempt to create a building that generates energy. This happens when the building has generated the same amount of energy that is embodied in its materials and components. If the building works efficiently or if its lifespan is long enough, it can generate additional energy. Figure 10 shows estimates based on the projects presented in Chapter 5. They are general indicators on how to approach the topic and show the possibility of discussing different scenarios during the drafting process. While not predicting exact energy amounts or evaluating a building's energy performance, PAT serves as a tool that has the ability to make the design process easier and more intelligible.

7



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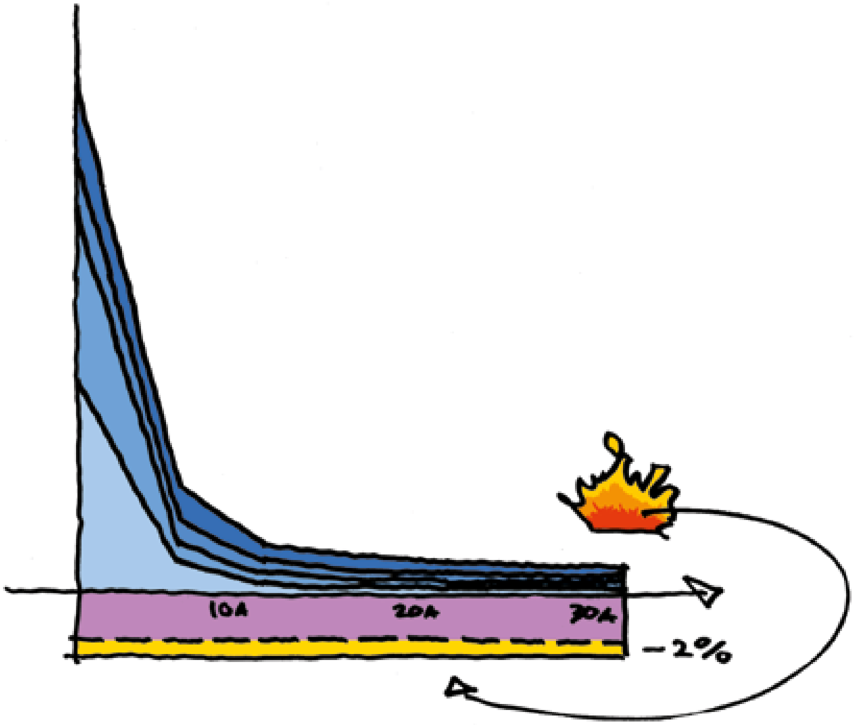
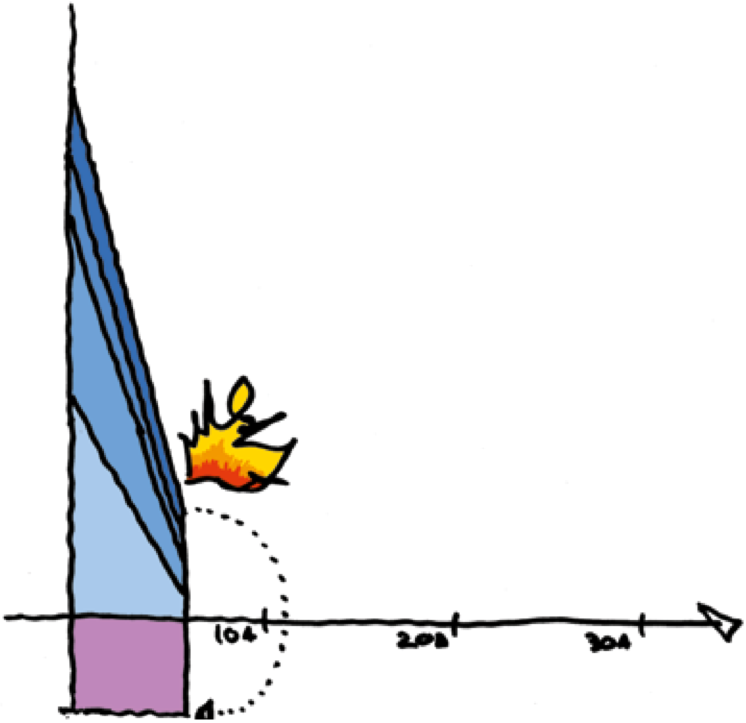


7 Short Term Use
8 I am Energy

9



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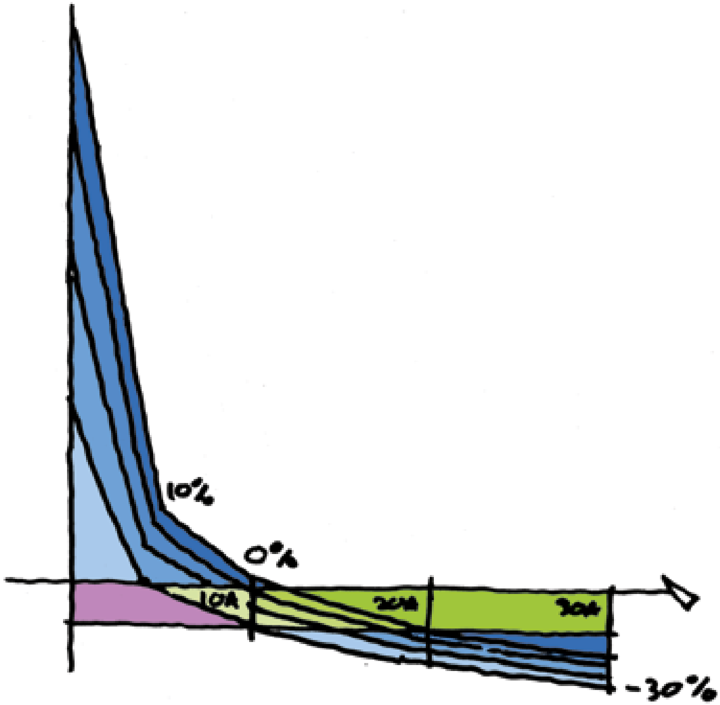


9 I am Energy as an energy fund
10 Energy-generating Building

5. CASES / EXAMPLES

5.0. INTRODUCTION

The following chapter introduces PAT and its application in analyzing different types of buildings and contrasting them. The purpose of this chapter is to present the interrelation of design and construction choices and the implications for structure, envelope and interior. Different projects will be presented and discussed according to the challenges they pose for the architect.

5.1. PROJECT – OFFICE BUILDING

PROJECT PARTNER

Student course "Sustainable Construction" at the Detmolder Schule für Architektur und Innenarchitektur

CHARACTERISTICS

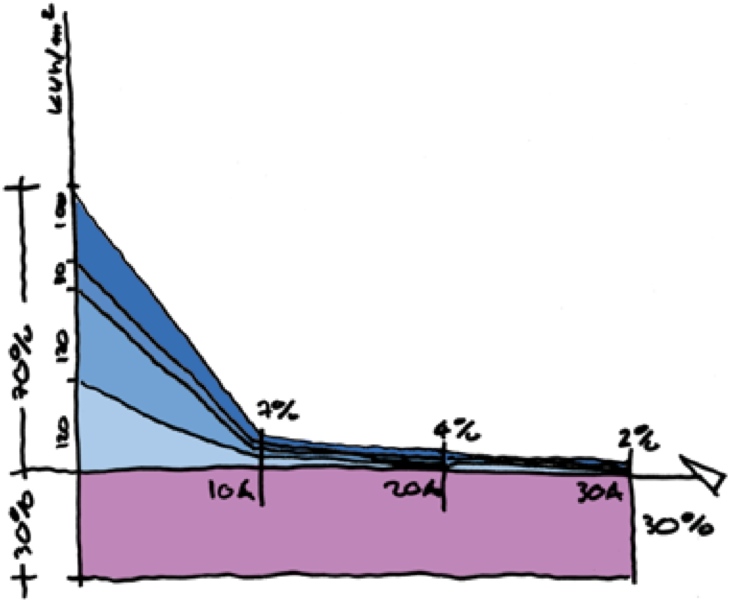
Office building, 12,000 m²

Students of the Sustainable Construction undergrad class at the Detmolder Schule für Architektur und Innenarchitektur were given the task to design an office building of 12,000 m² GFA. The problem requirements were the building's function, its square footage and a limit of medium height. Underground parking and urban development were not to be considered. Apart from the classic tasks of drafting and constructing, the students were required to determine the amount of embodied energy by evaluating material effort in relation to choices in construction. As this was the focus of the task, the designs display a variety of results, spanning from ideally low to high values. The determining factor in the students' assessment was their integration of the factors and their understanding of the impact of their planning decisions.

The comparison of the building illustrates that solid construction pieces affect the building's assessment greatly. The structure especially adds to the environmental burden. While steel and concrete support structures achieve about the same value, a wooden structure performs better. In addition to the support structure, the façade is another determining factor. The concrete building (fig. 1) uses a wooden façade to improve its assessment. The steel building uses a shift of proportion in the relation between structure and façade as its façade is partly load-bearing (fig. 2). Figure 3 shows how a building with a cement-bonded wood fiber composite construction and a wooden façade accounts for less energy in erection and demolition, but requires more energy input for its conditioning because of the lightness of the façade and its resulting low mass capable of heat storage.

1 Office building concrete
2 Office building steel

1



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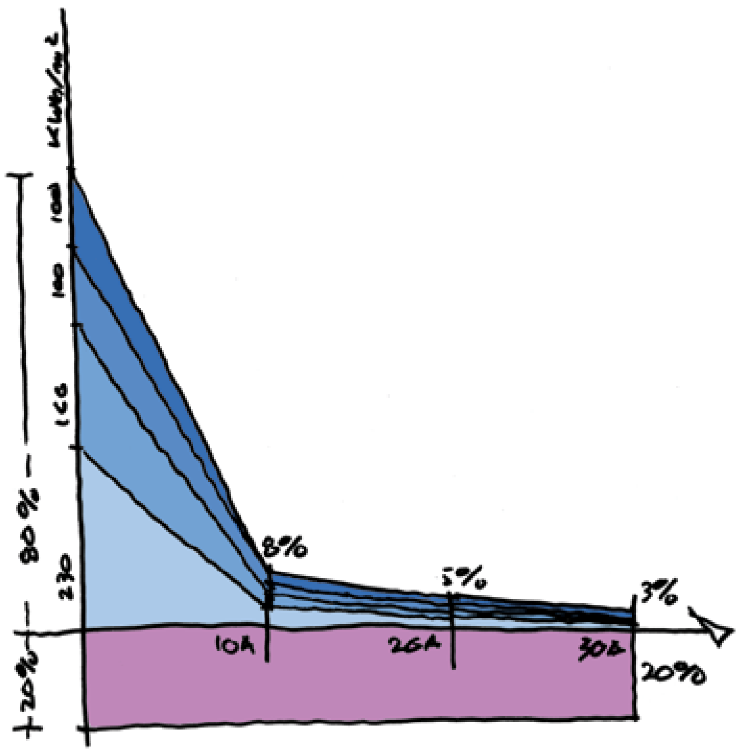

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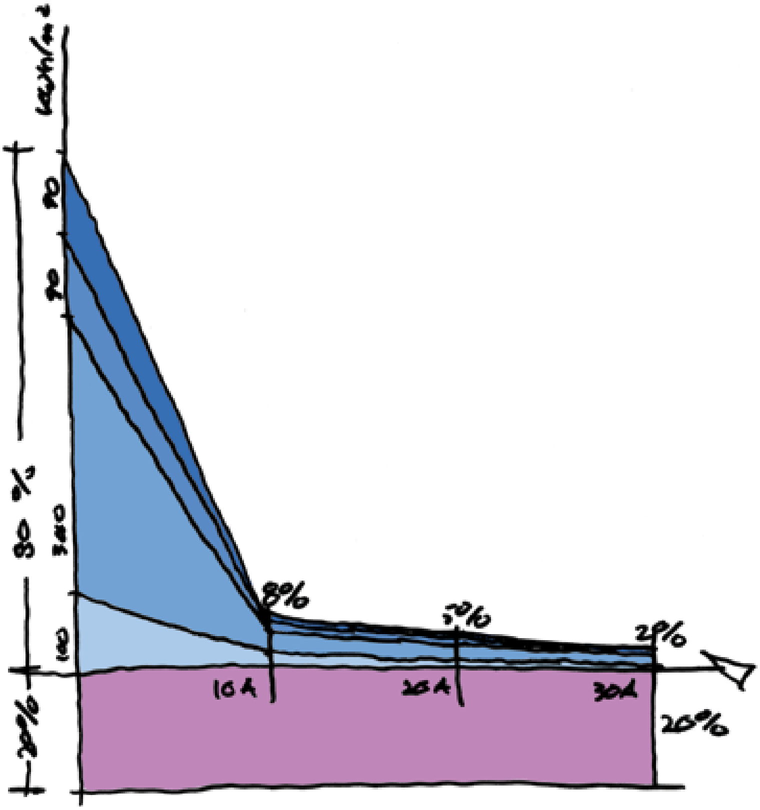
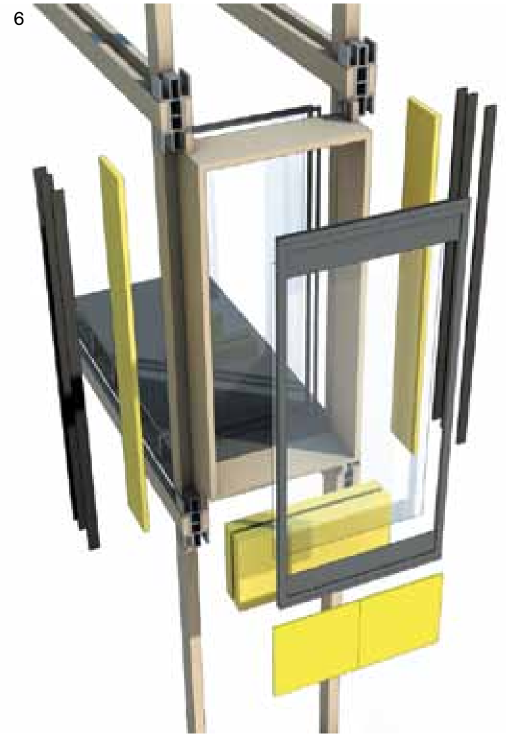


3 Office building wood

5


6


7


5 View from the plaza
6 Exploded view of façade components
7 Façade view

5.2. PROJECT – ORGANISATION MONDIALE DE LA PROPRIÉTÉ INTELLECTUELLE OMPI

PROJECT PARTNERS
Architects Behnisch Architects
Climate Engineering Transsolar
Structural Engineering Schlaich Bergermann + P.

CHARACTERISTICS
Conference, temporary use, comparison between concrete and wood structure

In 2008, Behnisch Architects designed a conference building for the World Intellectual Property Organization. The conference center is only used temporarily. A heavy concrete structure would take a long time and a lot of energy for conditioning in advance of an event. This, in return, increases the costs and the energy input itself. A lighter construction would result in lower expenditures in operational energy plus less embodied energy. As a reaction to this challenge the design team developed a solution that modifies light-weight constructing in a way that maximizes the use of wood in parts of the support structure as well as in the façade. To assess the overall performance the amount of embodied energy was modelled. The comparison between the two buildings (figs. 3 and 4) reveals that the wood version has the potential to perform much better.

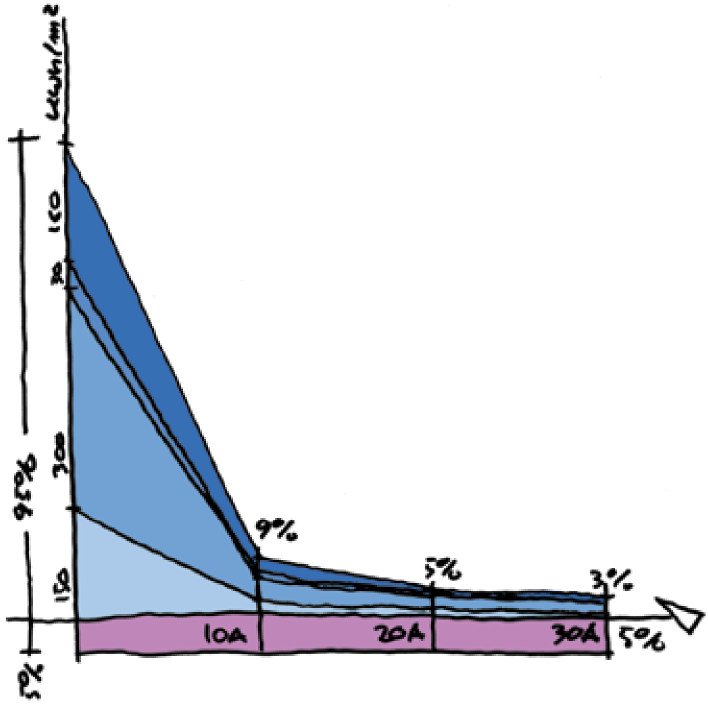
Project images courtesy of Behnisch Architects Stuttgart

1 Presentation model
2 Exterior perspective
3 Chart of massive mineral façade
4 Chart of wooden façade

1

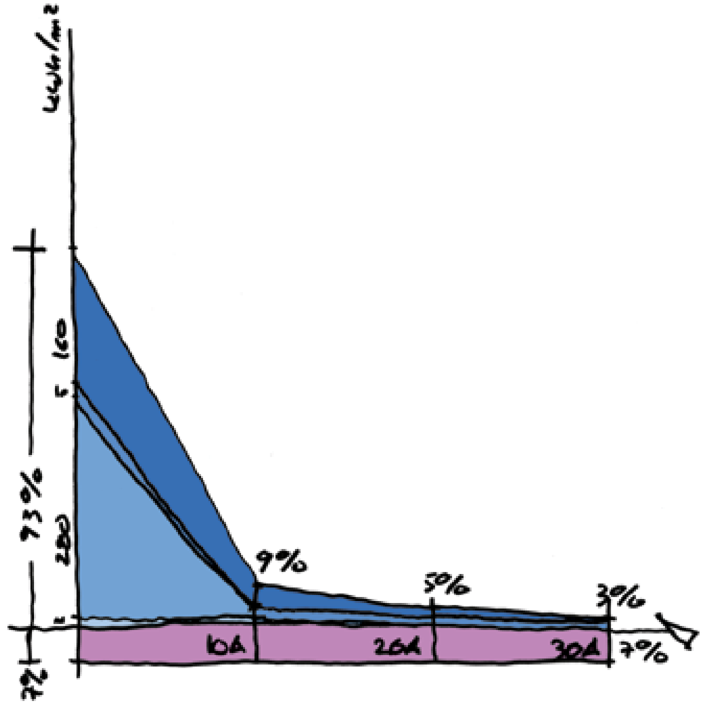

2


3



kWh/m2
160
90
300
150
95%
5%
9%
5%
3%
10A
20A
30A
5%

4



kWh/m2
160
280
73%
7%
9%
5%
3%
10A
20A
30A
7%

5.3. PROJECT – ZOLLVEREIN SCHOOL ESSEN

PROJECT PARTNERS

Frau Kazuyo Sejima + Herr Ryue Nishizawa
Architekturbüro SANAA, Tokyo
Dipl.-Ing. Heinrich Böll Architekt BDA, DWB
Transsolar

CHARACTERISTICS

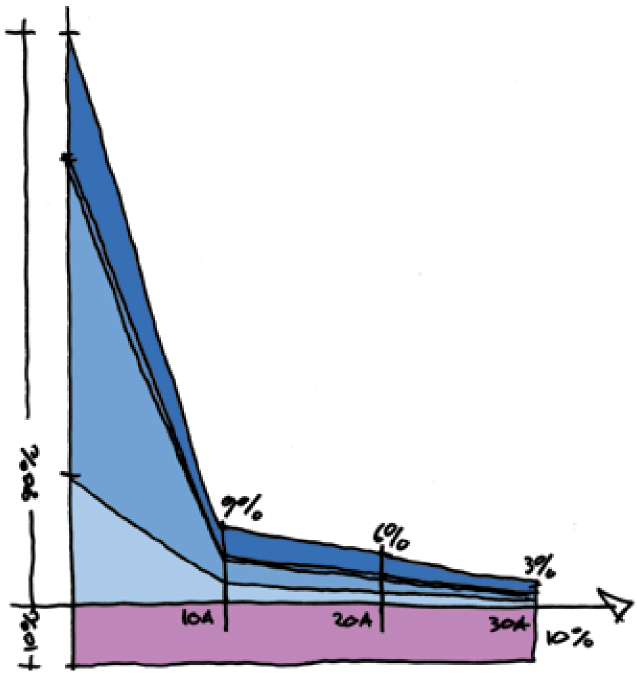
Concrete, renewable energy

The Design School is a cube of exposed concrete whose impression of massiveness is broken up by the random figuration of windows of varying sizes. These square openings are different on every side of the building and do not reveal the building’s internal structure. The openings are continued throughout the roof, where three big cubes are cut into the outside layer of the roof creating an interesting space.
The façade consists completely of concrete and has inlaid loops of heating tubes. The building sits on a deep foundation and uses warm pit water that is pumped through the piles into the tube to heat the outside walls, thus functioning as insulation. By controlling the temperature through the façade, loss of heating through the outside walls is avoided and the temperature on the inside of the building is maintained.
The amounts of embodied energy, both operational as well as embodied, are relatively high. Since ceilings, façade and foundation are all made of concrete, the building is comparatively heavy.
The amount of energy necessary for running the building is equally high due to the façade’s conditioning. However, it should be noted that here renewable primary energy is used.

1 Design School Essen
2 Chart of Design School Essen

1

2



5.4. PROJECT – LOW ENERGY STANDARD BUILDING

CHARACTERISTICS

Residential building, low operation energy

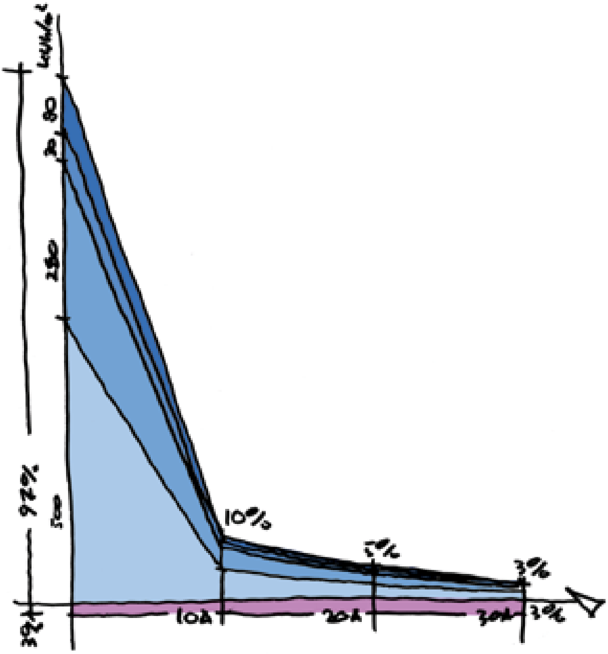
Springing from the correlation between operational energy and operating expenses and an increasing awareness of the depletion of fossil resources, the last 30 years have been characterized by efforts to reduce the amount of energy needed to heat/cool a building.
Various standards were developed and adopted by lawmakers. Apart from the efforts to increase the efficiency of technical equipment in building services the focus of improvement has been on passive measures, such as orientation, compactness of the building and the development of the façade. A good proportion between the outside surface and the volume positively affects both embodied energy and operational energy.
The fewer cantilevers, overhangs and recesses, the more compact the building and the better the result. Additionally, this reduces heat loss.

Passive measures in the low energy building are intended to retain operational energy in the building as long as possible. Hence, the façade is relatively material intensive (fig. 2) and heavy construction parts and (mostly synthetic) insulation create a major impact.
Lowering the operational energy shifts the focus to the potential of lowering the embodied energy. Hence, evaluating both energy parameters is crucial for the assessment of low energy buildings.

1 Façade detail
2 Chart of building with low operation energy/low energy standard

1

2



5.5. PROJECT – COMPARISON OF A LIGHTWEIGHT CONSTRUCTION IN ORIENTED STRUCTURAL STRAW BOARD AND A TRADITIONAL CHINESE BRICK HOUSE

PROJECT PARTNERS

Panel Board Holding
Delft University of Technology

CHARACTERISTICS

Oriented Structured Straw Board, lightweight construction

At the request of the producer of Oriented Structural Straw Board (OSSB), Panel Board, a comparative study of the traditional Chinese construction versus the lightweight construction of OSSB was conducted by the Delft University of Technology. The reference construction typically consists of concrete ceilings and brick walling. The lightweight construction uses steel frames and OSSB with mineral insulation. Figures 3 and 4 differ in the amount of energy needed for the construction and demolition of the building. The solid construction parts have a high energy rating; they do however achieve a more positive rating through the incorporation of the end of life as the wood releases energy when being burned. The lightweight construction requires more operational energy, which increases the overall energy assessment rating.

1 Material sample
2 Building details
3 Chart of standard building heavy construction
4 Chart of OSSB building lightweight construction

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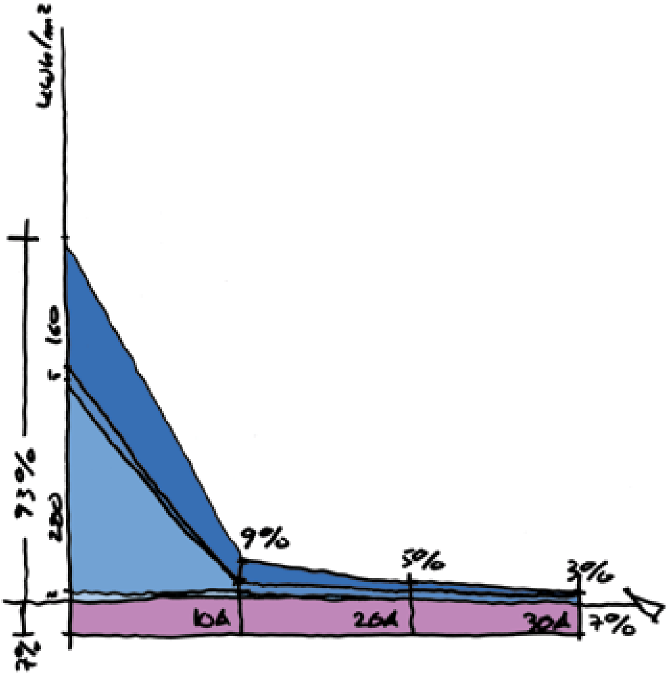

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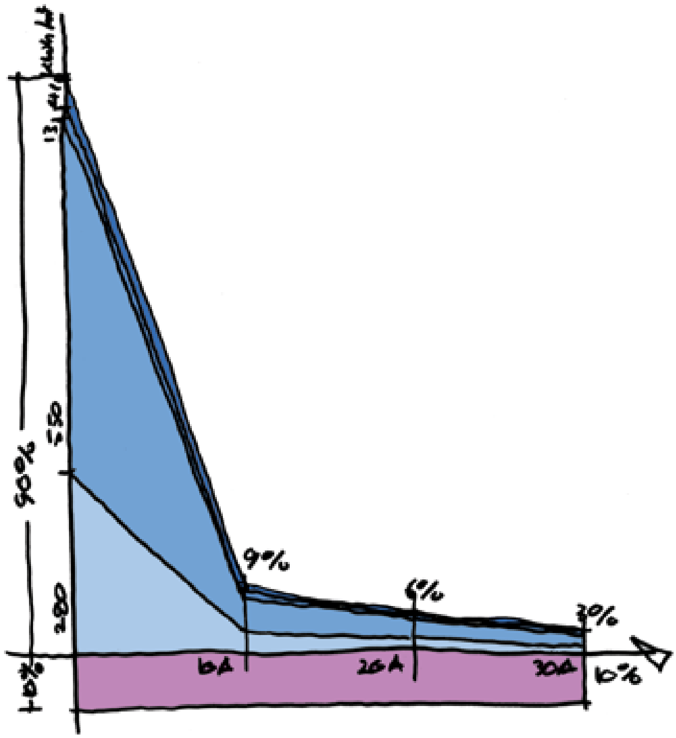

5.6. PROJECT – EVALUATION OF FAÇADES

While the relation between operational and embodied energy is crucial in the assessment of a building, when focusing on just the façade, other questions call for our attention. Figure 1 shows four different façade systems: a brick wall, a double skin façade, a post-and-beam construction and a wood façade.
A purely ecological comparison presents the wood façade as the most reasonable solution. For a fair comparison, however, the façades would all have to fulfill the same functions. But since they all have different qualities and since those are not measurable (e.g. aesthetics), a merely qualitative ranking is essential. The provided information, then, will need to be examined further.
A solid construction starts off with high energy ratings but gets by with few replacements. A wooden façade consumes less energy during production and demolition, but is limited to a lifespan of about 30 years. The double skin facade is more versatile than the post-and-beam construction.
It depends on the requirements of the building as to which façade is the best solution. As with all decisions made during the drafting process, the quality and function need to be determined first, and the ecologically reasonable solution will be found based on those decisions.

1 Düsseldorf Stadttor
2 Detail of a wooden shingle façade
3 Umwelt Bundesamt Dessau
4 Bauhaus Dessau
5 Chart showing comparison between façades

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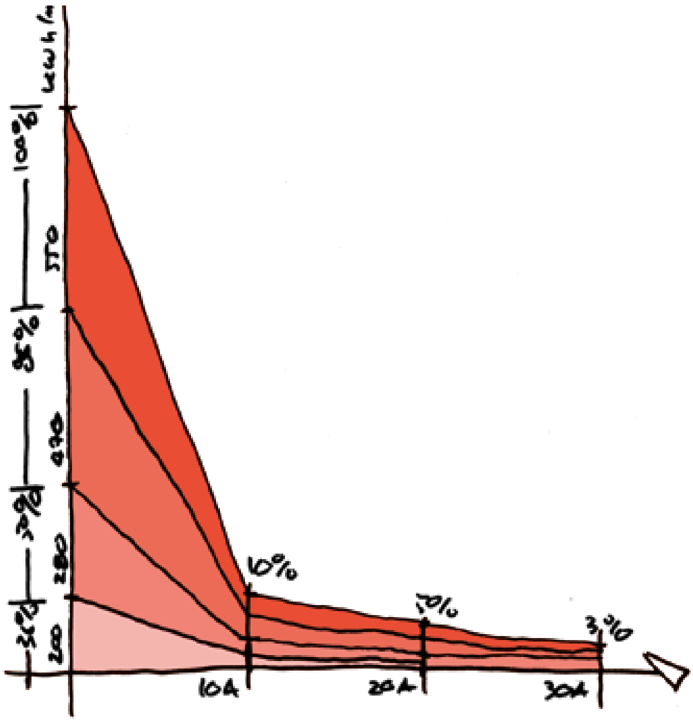


ACTIVE INSULATION
AIR ARCHITECTURE
BALLOON INSULATION
BOOK WALL
CO_2 CONTAINER STRUCTURE
CONTOURLESS CRAFTING
DEFLATABLE BUS STOP
DISTRIBUTED ENERGY GRID
ECO MINI BAR
ELECTRO CHROMIC SHADING
ENERGY GUIDE APP
ENERGY IS MONEY
FEM DRIVEN STRUCTURES
FOLDED CARDBOARD HOUSE
GLASS HOUSE OFFICE
GRAVITY-FASTENED STRUCTURES
GROWING BUILDINGS
HAY FAMILY HOUSE
HEAT BALLOONS
HOUSE OF FUEL
I AM ENERGY
KRYMMEL – HAGELSLAG SEASONAL INSULATION
LAVA-LAMP 2.0
LEGO 2.0
LOW ENERGY REFURBISHMENT
MATCHBOX FAÇADE
MIRRORING PV-CELLS
MOVING COMFORT ZONE
MUSH-ROOM
PIG SKIN GREENHOUSE
SMART PAINT
SOLAR KINETIC BIMETAL FAÇADE
SQUOOSH FAÇADE
SUPER LIGHT APPROACH
THE BRICK THING
THE HOME OF THE FREE
THE STRAW HOUSE
TSUNAMI ENERGY
ULTRA LIGHT STRUCTURE
URBAN MINING
WASTE BARREL
WRAP IT 2 PROTECT IT
YOGHURT CUP HOTEL

6. IDEAS AND PRINCIPLES

It's all about energy, as the title suggests. All the principles published in this volume follow this common thread.

- Principles based on ideas to save energy, be it by intelligently applying new technologies or new materials.
- Principles based on ideas to transfer existing technologies, which – in a different context – offer new functionalities.
- And yet other principles focusing on reducing the amount of embodied energy as early as during production, or on reusing materials in a different shape or form.

A few ideas were made by the Dessau Institute of Architecture (DIA) within the course "CAD Logic Presentation" of Prof. Daniel Dendra.

Another set was made during the OpenJapan 72hr Worksprint which was held in world spread events to support the Japan tsunami victims. For more info about this event have a look on: http://openjapan.opensimsim.net

So, get inspired!

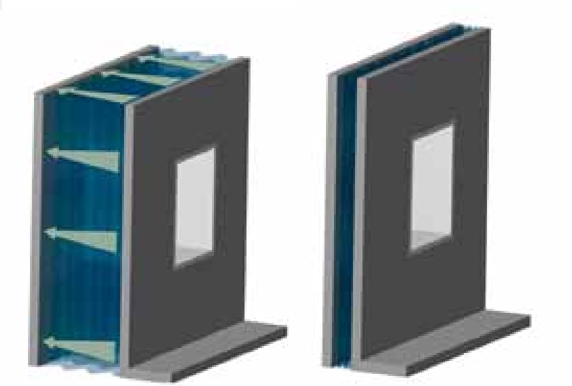
ACTIVE INSULATION

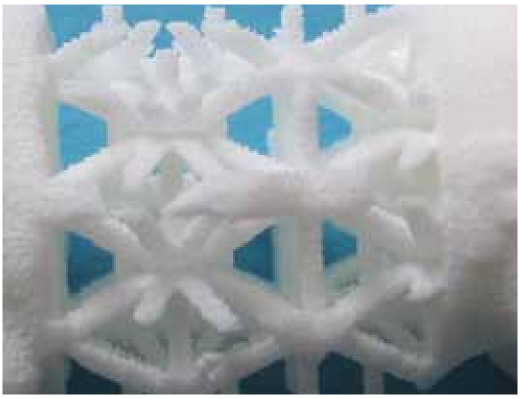
27-06-2008

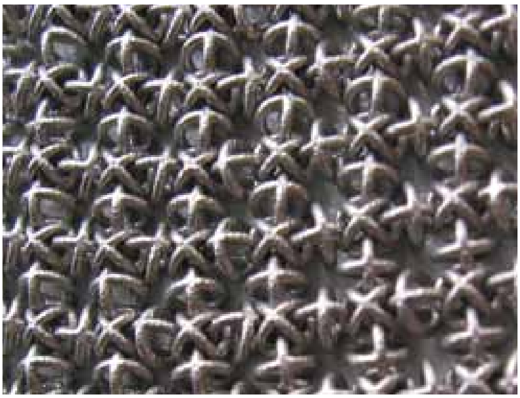
IMAGINED BY Ulrich Knaack, Holger Strauss

KEYWORDS layered construction, insulation, adaptable, envelope, unknown material

Why can't our houses have the insulation they need, when they need it? Like birds that fluff up their feathers to add air for warmth, building structures could extend in wintertime to achieve better insulation. Printed micro-structures could provide this possibility.







Dedicated to Yves Klein

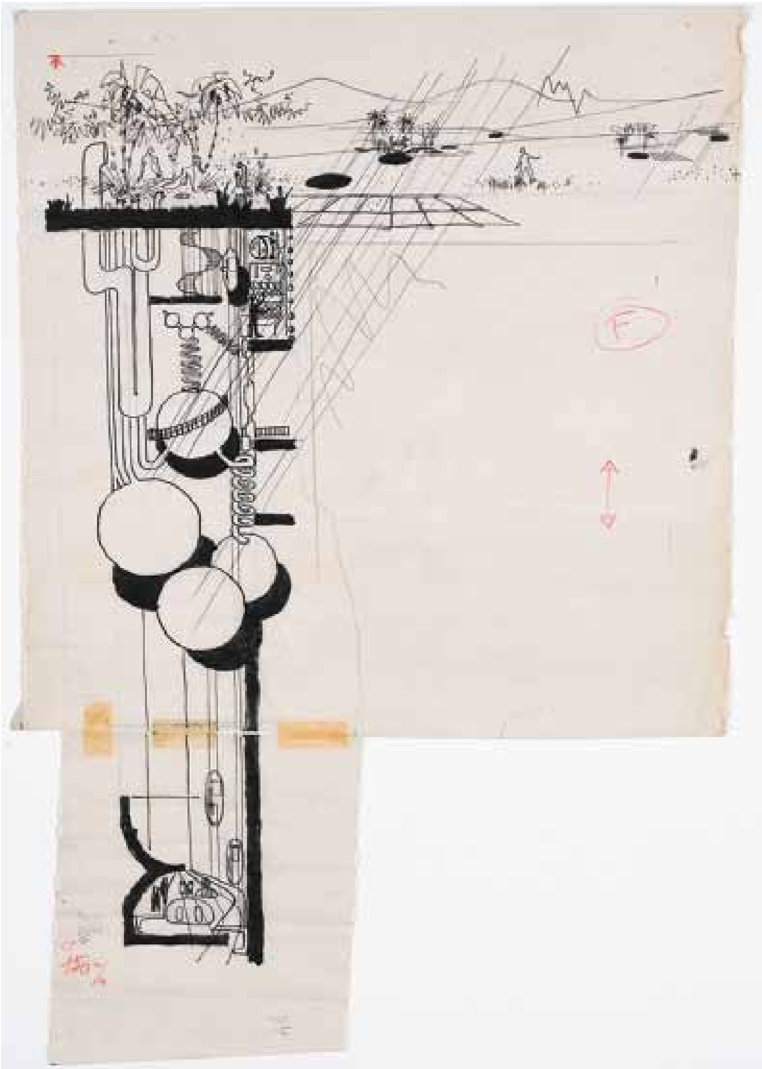
AIR ARCHITECTURE

1951

IMAGINED BY Yves Klein

"My walls of fire and my walls of water, with the roofs of air, materials for a new architecture. With these three classical elements, fire, air, and water, the city of tomorrow will be constructed; it will at last be flexible, spiritual, and immaterial."
— Yves Klein, excerpt from "The Evolution of Art Toward the Immaterial," lecture at the Sorbonne

Picture courtesy of Yves Klein Archives / from the catalogue : «Antagonismes 2 L'objet», Musée des Art Décoratifs, Paris, France, March 1962



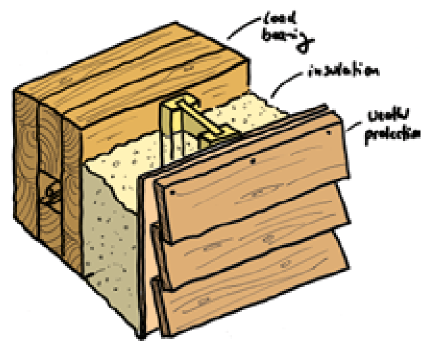
ALL WOOD WALL

09-06-2010

IMAGINED BY Marcel Bilow, Ulrich Knaack

KEYWORDS mono-material, wall, wood, timber construction, stored energy

The idea is not new, but using wood will definitely reduce the carbon footprint. If we try to build our currently layered wall constructions, the goal should be to use only wood or timber materials. Even the insulation should be made out of wood chips or similar products that might be created out of waste materials from the wood industry.
To overcome a mixture of materials the vapor-tight barriers should be also eliminated. Thus, the plastic films we are using now would have to be avoided and solutions like high pressure wood products, which fulfill the same purpose, would have to be found. Using this kind of construction we would have to accept that the wood on the outside will become gray and old. A finishing touch with paint or other chemicals could not be the solution.



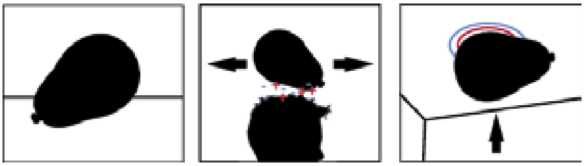
BALLOON INSULATION

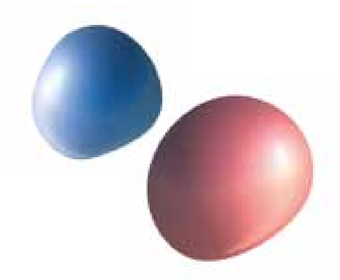
09-06-2010

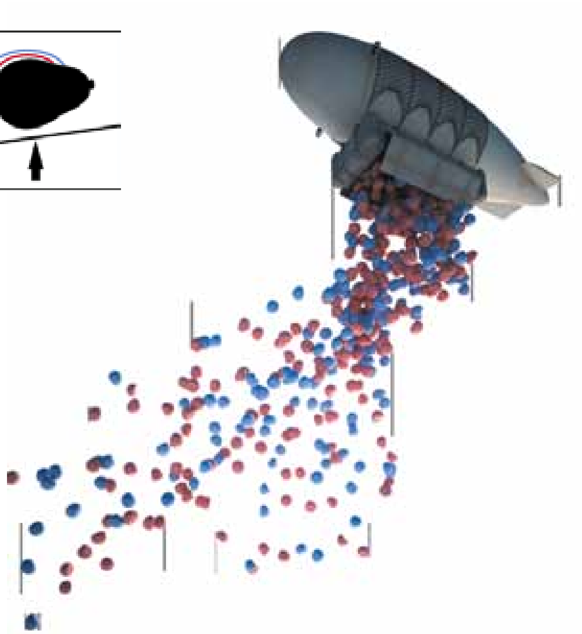
IMAGINED BY Workshop “I am Energy”, Royal Danish Academy of Fine Arts – School of Architecture, TU Delft – Faculty of Architecture – Façade Research Group, renderings by Jens Böke

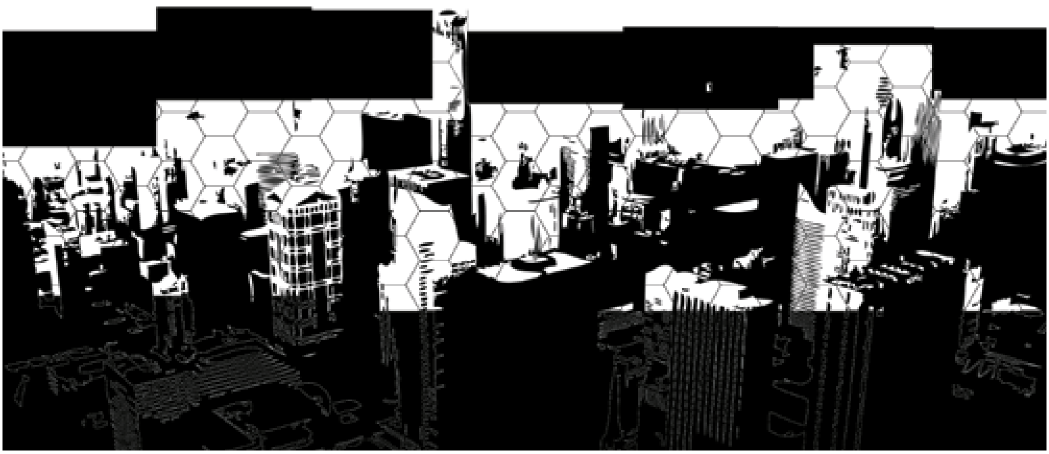
KEYWORDS pneumatic, electrostatic, flying architecture, adaptivity

This concept uses balloons to provide an insulation volume. The level of insulation can be controlled by electrostatic charge: switched on, the balloons are attracted by the building parts and rise from a storage. To improve adaptivity the storages could be supported with balloons from zeppelin suppliers.





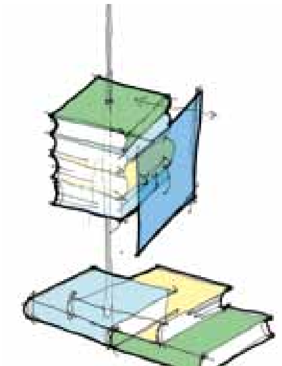


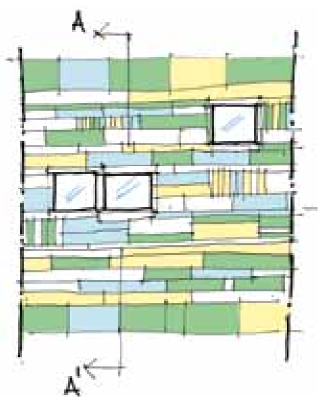


BOOK WALL
09-06-2010

IMAGINED BY Workshop “I am Energy”, Royal Danish Academy of Fine Arts – School of Architecture, TU Delft – Faculty of Architecture – Façade Research Group
KEYWORDS recycling, reuse, embodied energy, books
BRAINSTORMING START cardboard, tower

In the digital age we have to reconsider the use of books (that is, belletristic publications and not books important for society and science) and how this material could be reused. In the workshop the idea to reuse books to build massive constructions like brickwork buildings came up.
Related to the heavy construction and the direct load flow within the structure even high buildings seems to be possible – especially if we consider the limited fire risk by using stacked paper.
To fulfill the performance aspects of a façade, the massive wall can be treated in two ways: A – adding a cavity with a rain resistant surface or B – a chalk paint, which would need to be renewed every year.
The biggest advantage of this construction, apart from giving the used books a second life, is that there is a potential of finalizing the use of the books by burning them as an End-of-Life.





CO_2 CONTAINER STRUCTURE

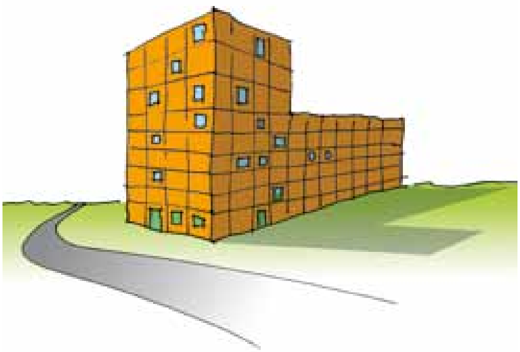
24-03-2011

IMAGINED BY Till Klein, Marcel Bilow, Linda Hildebrand, Ulrich Knaack
KEYWORDS CO_2, waste storage, reuse

Let's think about the potential of storing CO_2 – no, we are not trying to hide the CO_2 in old mines – We are trying to create an environment that lets us see what we produce. Our challenge is to come up with storage that is aesthetically pleasing and that can be used for additional purposes: the CO_2 container structure!

The idea is to use CO_2 for filling containers and use this as in an air-supported structure (pneus) as a structural component of buildings – like PET bottles, which become stiff when filled with water or air and then closed, so that the structure can be used as a compression unit.

To be developed:
- Technology for collection and storage of the CO_2
- Construction technology for stacking containers
- Security aspects of damage protection
- Potentials for the end-of-life scenario

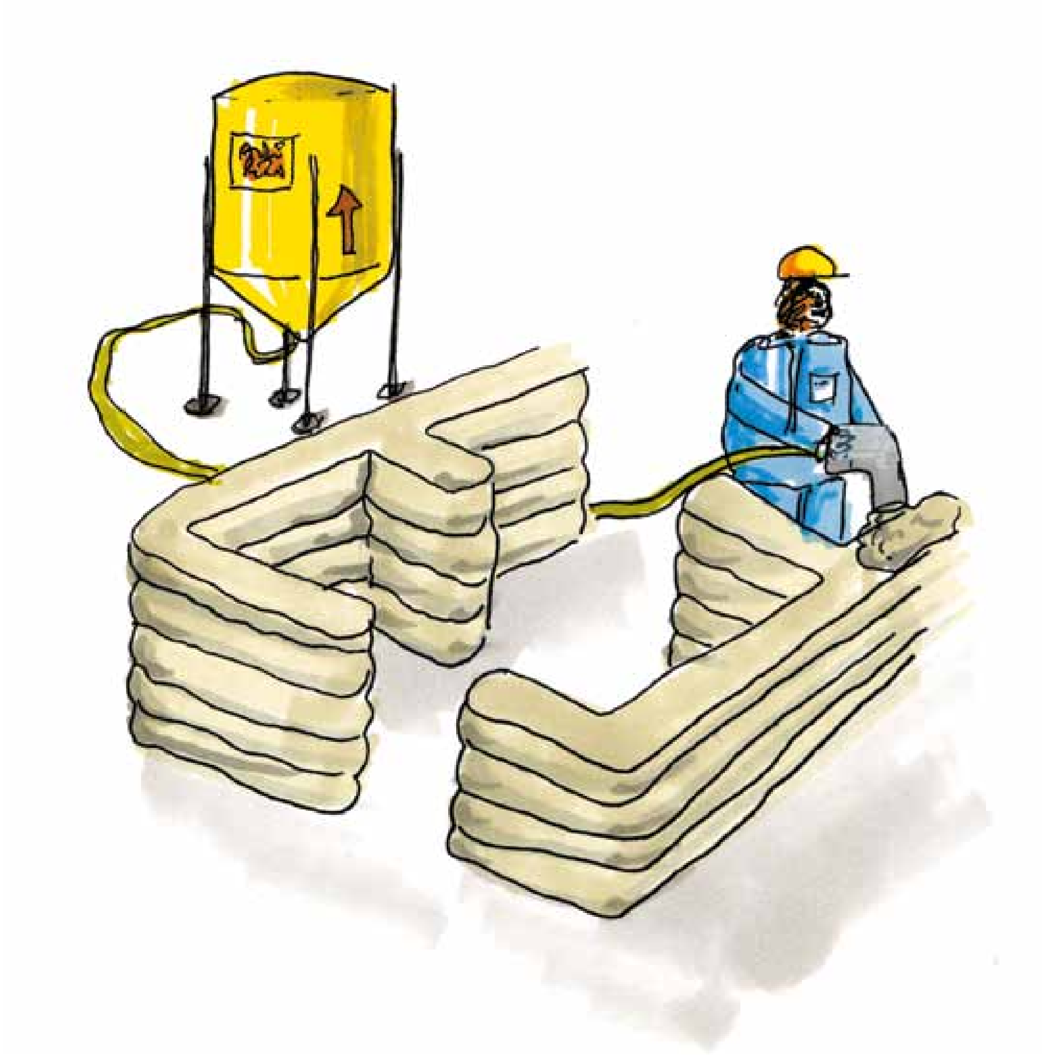


CONTOURLESS CRAFTING

25-05-2009

IMAGINED BY Marcel Bilow
KEYWORDS mono material, load-bearing, liquid, system building, unknown material

If you use a material that hardens fast enough when it is ejected out of a spray nozzle, you can build any kind of shape or geometry with total freedom. Openings have to be made by applying frames or windows directly into the structure. The material has to be fast hardening, and of course have the possibility of bearing loads, as well as being air and water tight. An insulation feature could be added by using a material that creates a foamy structure inside during the hardening process. The perfect match would be a material that is mostly made out of recycled material.

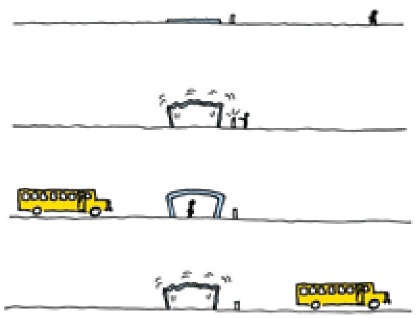


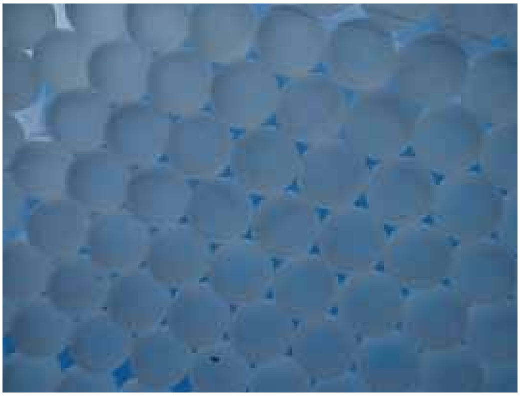
DEFLATABLE BUS STOP

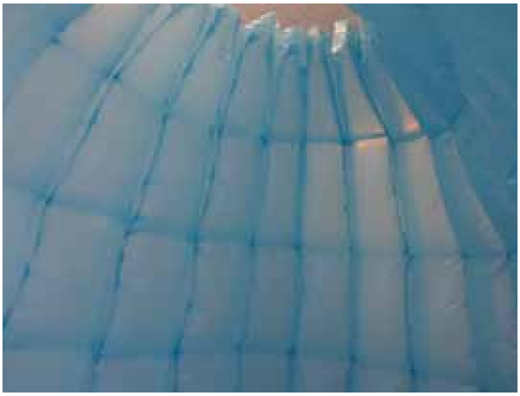
09-06-2010

IMAGINED BY Workshop “I am Energy”, Royal Danish Academy of Fine Arts – School of Architecture, TU Delft – Faculty of Architecture – Façade Research Group
KEYWORDS pneumatic, vacuum, flying architecture, short term use, public architecture
BRAINSTORMING START inflatable, bus stop

The idea of deflatable structures leads to the principle of “flying architecture” – objects which are efficient to their maximum because they are only erected in a situation where their use is required. The result is a suggested bus stop which inflates only on demand.





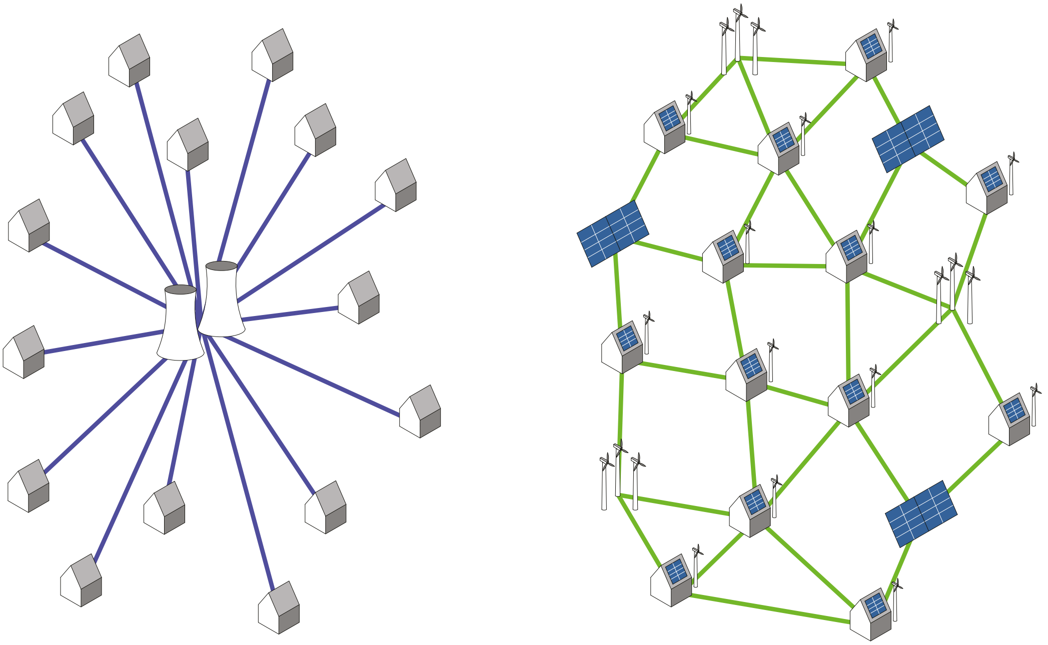


DISTRIBUTED ENERGY GRID

06-10-2011

IMAGINED BY OpenJapan 72hr Worksprint
KEYWORDS energy, distribution, collective, decentralized, disaster

The traditional method of energy distribution through a centralized system often fails when a natural disaster occurs, leading to massive blackouts. To help cities manage energy after a disaster and to prevent further blackouts, energy systems need to move towards a decentralized distributed grid. This grid allows for individuals to distribute renewable energy and decreases the risk of massive blackouts from natural disasters or peak energy usage.



ECO MINI BAR

04-08-2010

IMAGINED BY Boris Petrov and Prof. Daniel Dendra / DIA
KEYWORDS adiabatic cooling, cooling, energy, sustainability

How can we provide a low energy fridge for hotels? The main idea of this fridge is evaporation. It contains two shells (one placed inside of the other). Between the shells is an absorbent layer that can absorb water, and in the external shell there are holes for evaporation. When the absorbent layer is soaked with water, the evaporation begins and cools down the internal shell.

When the system is integrated in a hotel room's façade in the winter, this fridge works without water, getting its cold from the outside, so the absorbent layer works like insulation. During the summer time the fridge uses grey water from the bathroom to cool. A small fan can even increase the cooling power with energy created by a PV cell on the outside of the hotel room.

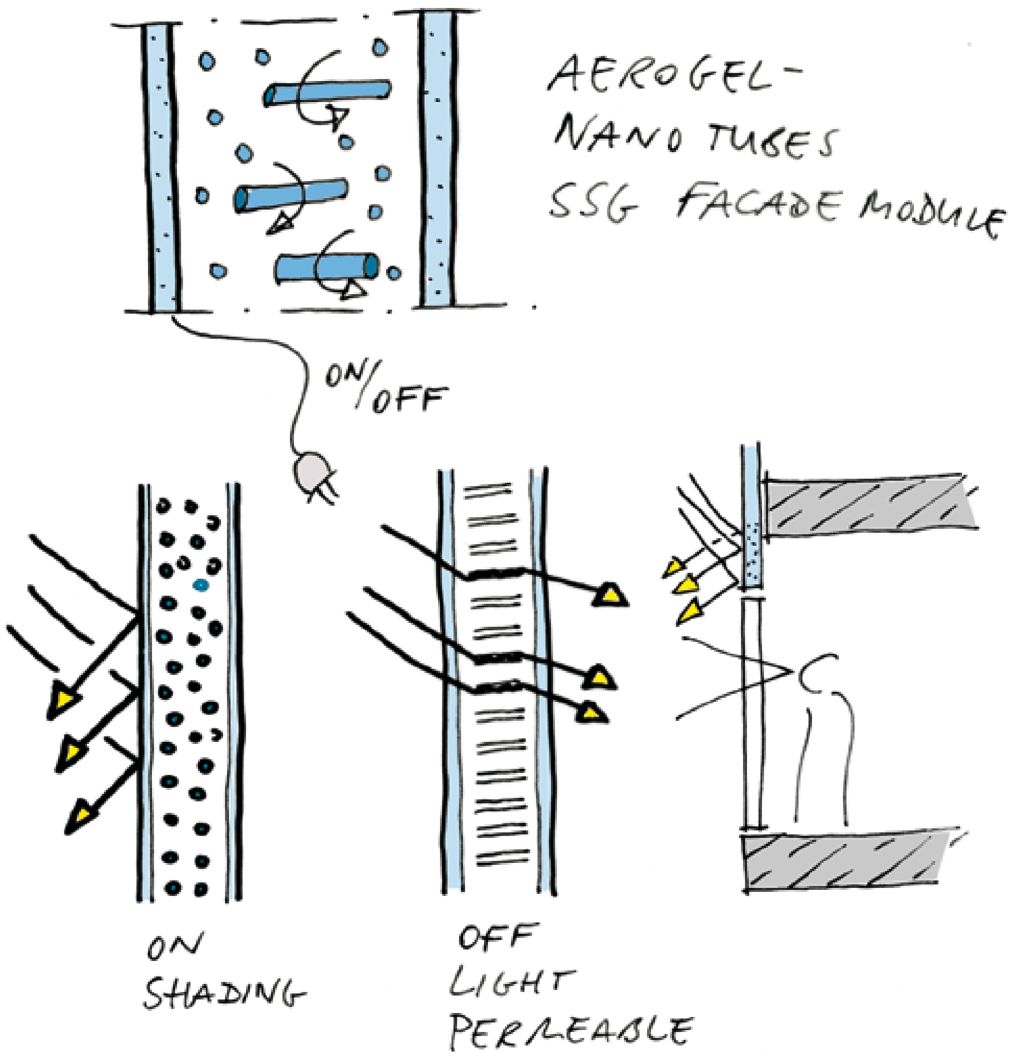
ELECTRO CHROMIC SHADING

18-06-2009

IMAGINED BY Holger Strauss

KEYWORDS self-organizing, sun shading, adaptable, façade, dynamic material

As a module of SSG façades (Structural Sealant Glazing), this feature offers the possibility to direct micro carbon nano tubes inside the cavity of a glass pane. By simply turning the panes on and off, the interior is either shaded or not. If used across the entire height of the glazing it could provide transparent or opaque glass panes.



ENERGY GUIDE APP

15-01-2011

IMAGINED BY Marcel Bilow
KEYWORDS energy, user guide, façade, App, knowledge system

There are always two principles to teach people: reward and punishment.
We have to pay for our energy consumption. When you pay the heating bill at the end of the year, you realize that you wasted too much energy and your behavior may change, but for how long? Imagine a tool in your hands using augmented reality that combines tips on energy saving and how to interact with your building. It is much more fun to use your smartphone and gain knowledge on how to save energy and explore your surroundings. And of course this is just one example of how we can use this technology.

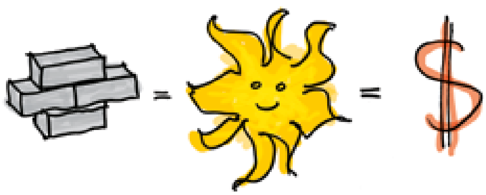
ENERGY IS MONEY
17-02-2010

IMAGINED BY Marcel Bilow, Ulrich Knaack
KEYWORDS energy, leasing, bank account, temporary use, architecture

Energy can be seen as a value. Each material contains energy – so it is directly related to a value.

Usually we erect a building and have to pay for the materials we use. A payback at the end is very little if some parts can be recycled. What if we think about a system in which we only lease or rent the materials or even the whole structure for a fixed time period and then the building will be given back to the producer, because he will need the materials and their embodied energy.

Each structure should be designed for disassembly. Then it will be much easier to take the things apart at the end of the leasing contract.



FEM DRIVEN STRUCTURES

29-08-2007

IMAGINED BY Ulrich Knaack, Marcel Bilow, elaborated by Heiko Oexle
KEYWORDS self organizing, load-bearing, strength, structure, unknown material

This principle is based on the fact that generative production procedures can now generate anything from complicated geometries to insoluble constructions.

According to the principles of bionic bone structures, material is only placed where forces act on the structure. So if we can use Finite Element Analysis to detect the regions where the forces interact, we can design lightweight structures. Material with zero line-forces can be minimized or cut out entirely.

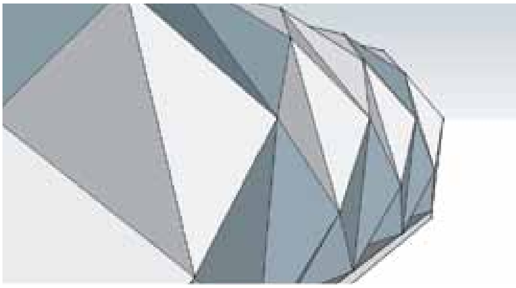
With Rapid Manufacturing technologies we might be able to create load-bearing structures with fewer materials such as steel or aluminum to create effective and lightweight facade structures.

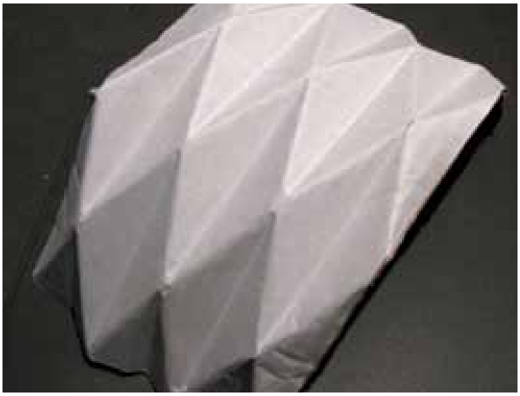
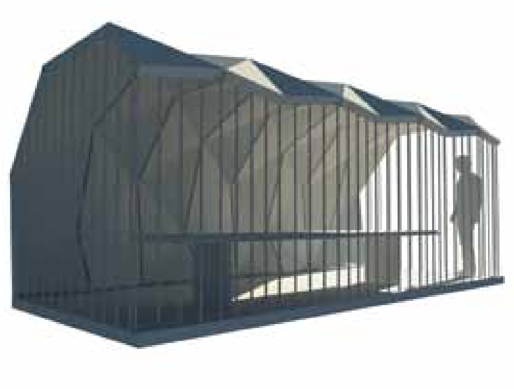
FOLDED CARDBOARD HOUSE

12-12-2010

IMAGINED BY Ulrich Knaack
KEYWORDS cardboard, folded structure, bio-sandwich, short term use

Cardboard is produced in flat sheets in dimensions of 3 x 6 meters. By cutting and folding the cardboard it can be used as a 3-dimensional structure. To improve the structure the connection at the folded joints has to be closed. Besides this the materials need to be covered for weather protection.
The chosen solution is a 55% bio based resin, which is used with bamboo fibers as a stress surface on the inside and outside of the cardboard. The result is a sandwich construction, which is lightweight and can be burnt after use.

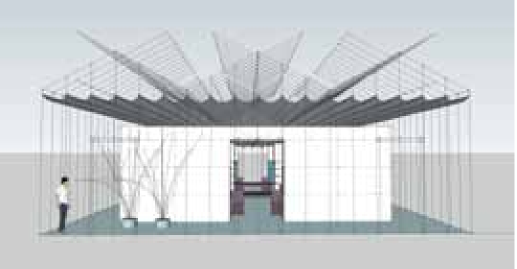


GLASS HOUSE OFFICE
10-08-2010

IMAGINED BY Ulrich Knaack
KEYWORDS simple structure, simple deconstruction, flying architecture, short term use, climate control

This concept delivers the potential to build an office in a glass house.
Glass houses are simple and efficient structures which offer rain protection and solar gain in spring and fall. To control the temperature in the summer in addition to ventilation via the roof, the proposal contains water tanks made out of standard PRT water bottles, which can be cooled during night time by cross ventilation and would act as a cold buffer in the daytime. For the winter period the glass house does need to be improved by additional insulation, which is provided in the design via 0.5 x 0.5 x 1 m polystyrol blocks, stacked like brickwork and oversailing the workplaces with a bracing system.

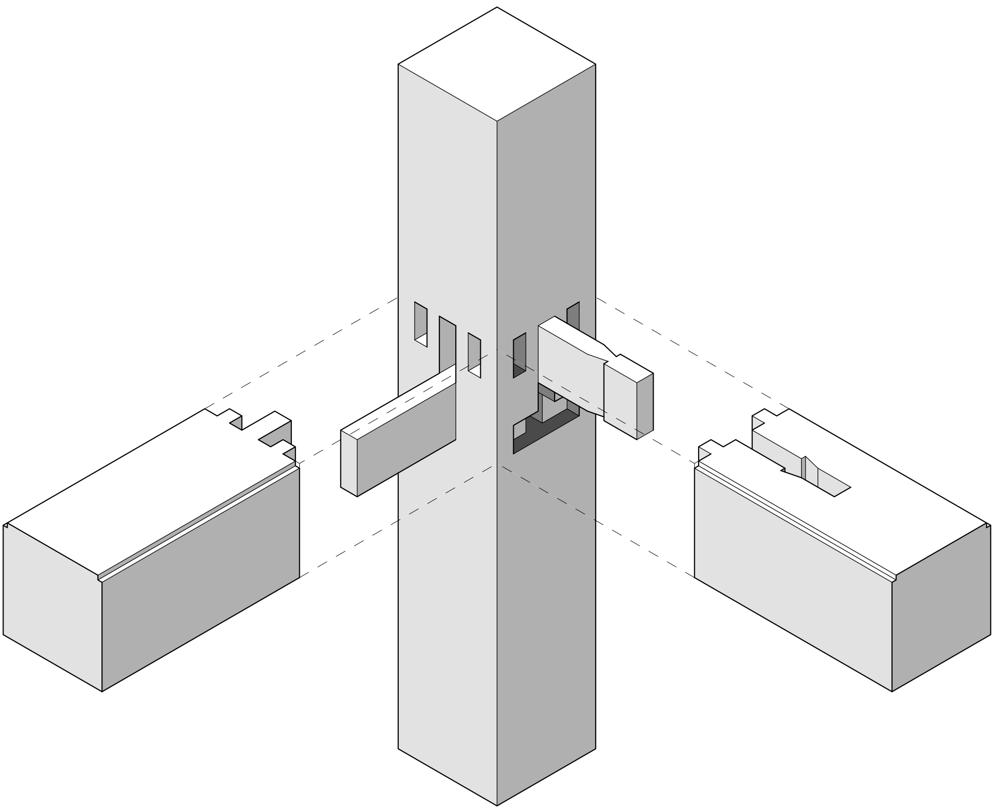



GRAVITY-FASTENED STRUCTURES

08-09-2011

IMAGINED BY Kyle Rogler
KEYWORDS recyclability, structure, façade, embodied energy, prefabrication, Japanese temples

Inspired by the wood structural system used in Japanese temples, a system of gravity-fastened prefabricated parts would increase the potential of recycling and reuse of building structures. By minimizing the amount of welding, gluing, and drilling, a building made from the principle of using gravity to support the structure would be easier to assemble, disassemble, and reuse to lengthen the life of its embodied energy. The system could use these prefabricated parts to help make structures potentially earthquake-proof as well as providing a quick means of post-disaster housing.

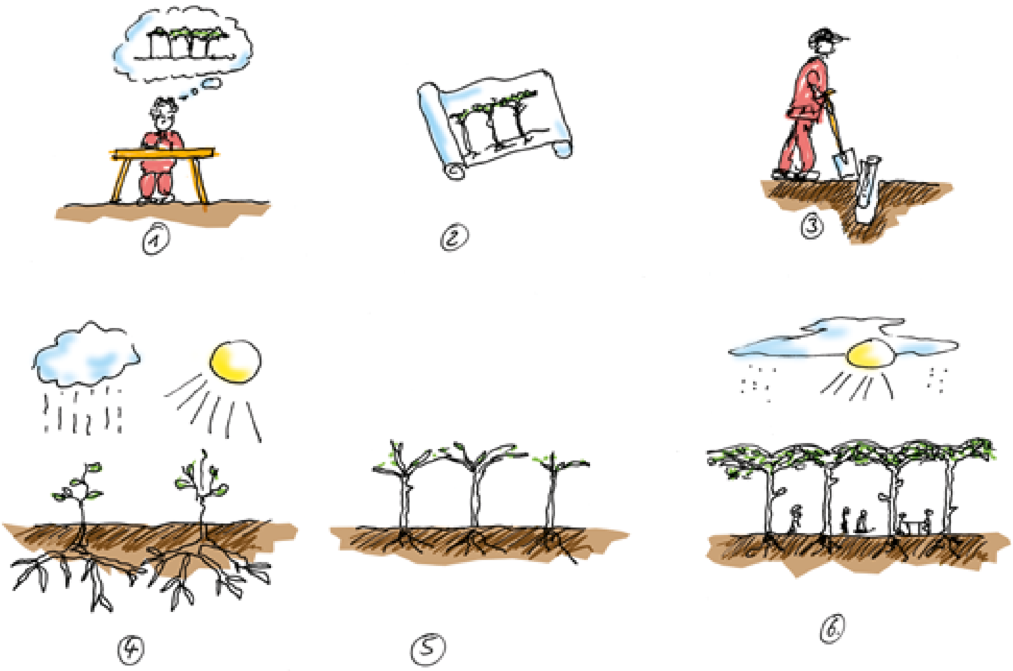


GROWING BUILDINGS

02-05-2007

IMAGINED BY Hans Knaack
KEYWORDS self growing, structure, plants, seeds, architecture

"That's much too complicated…with all the building constructions…" Hans Knaack complained. "If we have to use as much wood as possible to reduce our carbon footprint as you explained, why not train the plants and trees themselves to do the job for us? Imagine a method where we can draw a structure on a piece of paper (or something similar) and then put it into a hole in the ground and let nature do its thing … you only have to wait and maybe protect the young plants while growing and then we have the building! No nails or bolts needed. Don't ask me how we teach the seeds to assume that shape, that's up to you…!"



HAY FAMILY HOUSE

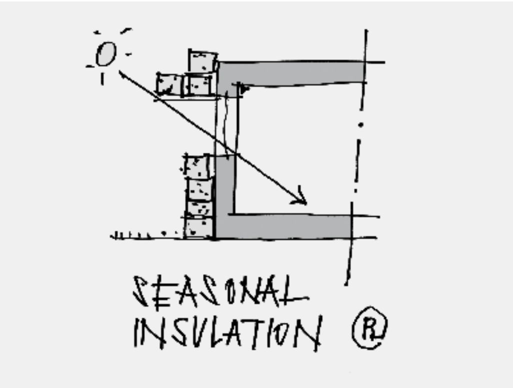
09-06-2010

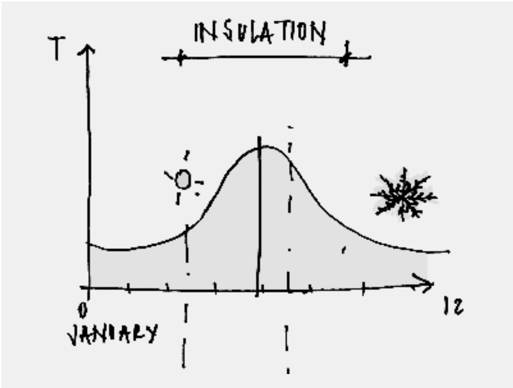
IMAGINED BY Workshop "I am Energy", Royal Danish Academy of Fine Arts – School of Architecture, TU Delft – Faculty of Architecture – Façade Research Group
KEYWORDS biomaterials, energy storage, temporary use, housing, modular construction
BRAINSTORMING START Hay, family house

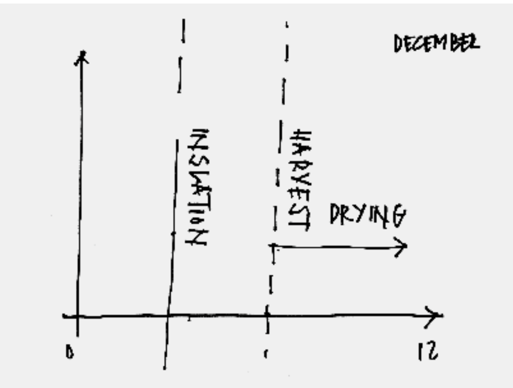
Hay as a biomaterial guarantees a renewable resource production. After its use for the building, it serves as a source of energy, if stored and maintained well.

The family house requires a limited height of one or two levels and provides the potential of personal involvement of the users during the design and construction phase. Thus, experimental buildings are possible.

The "Hay-One-Family-House" was created to use the potential of a biomaterial with limited embodied energy that has the potential of thermal protection and the option to be burnt when the building is not needed any more.





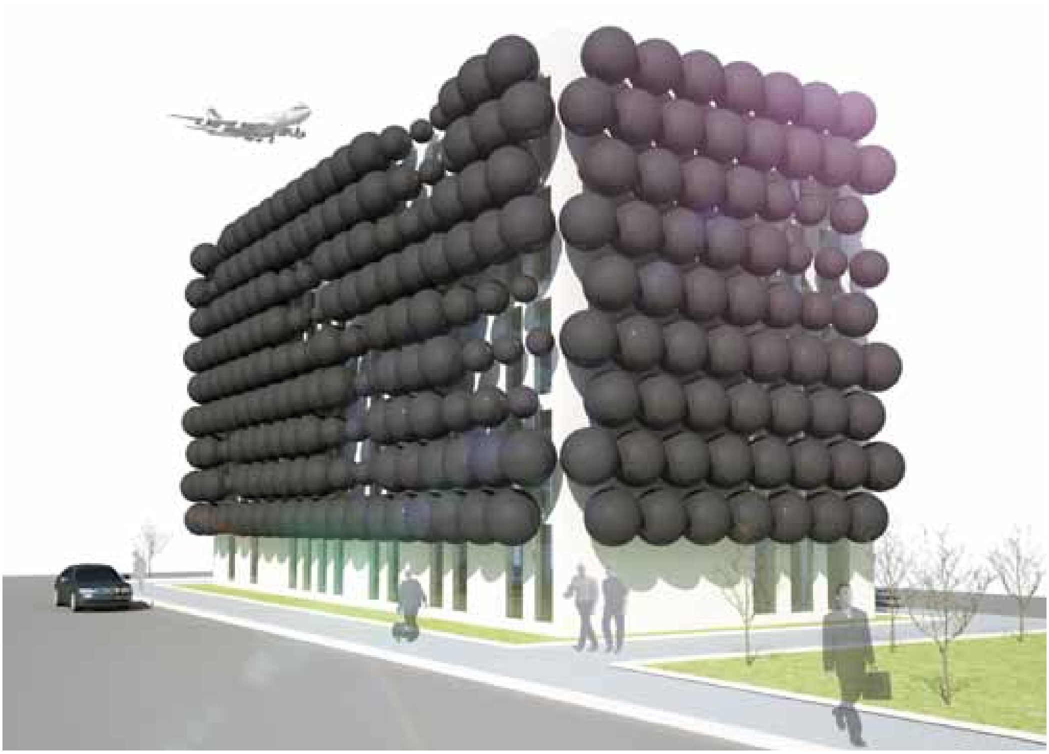


HEAT BALLOONS

05-09-2010

IMAGINED BY Maksym Iurovnikov and Prof. Daniel Dendra / DIA
KEYWORDS energy, sunshading, façade, energy harvesting

This concept is based on the principle of heat absorbing balloons. Imagine a layer of black balloons covering the whole surface of a building's façade that is able to harvest the sun's energy. The balloons can be filled with water or air to be used for the rooms next to the façade. By regulating the size of the balloons by their filling amount you are also able to control the amount of solar energy that penetrates the façade area.

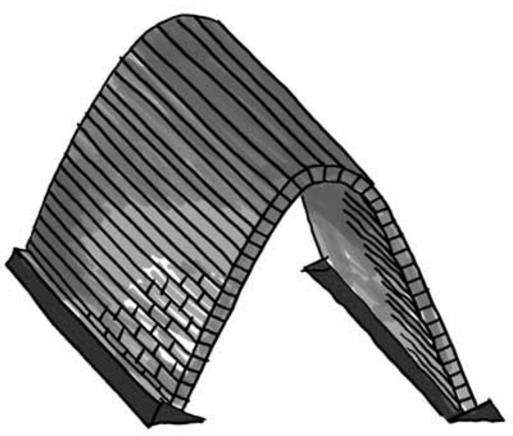


HOUSE OF FUEL

05-03-2011

IMAGINED BY Ulrich Knaack, Linda Hildebrand, Marcel Bilow
KEYWORDS fuel, building material, energy, reusable, structure

Each material already contains an amount of energy. We are able to use a bit of it at the end of life from the building when we burn it. So what about the concept of constructing our buildings directly out of burning material or even out of solid fuel like coal, briquette or brown coal? Then the purpose of the material – to create energy while burning – is briefly delayed while using it for a building structure. To realize this approach we have to try to use the materials as raw as possible so please no adding glue or mortar!



I AM ENERGY

12-02-2010

IMAGINED BY Ulrich Knaack, Marcel Bilow, Linda Hildebrand
KEYWORDS energy, sustainable buildings, architecture, buildings, structure

Wood is the only material that incorporates CO_2 during its growing process. By burning it at the end of its life we are able to gain energy. By calculating in this manner we have a neutral result.

So each building made out of wood can say to itself: I am Energy!

KRYMMEL – HAGELSLAG SEASONAL INSULATION

09-06-2010

IMAGINED BY Workshop “I am Energy”, Royal Danish Academy of Fine Arts – School of Architecture, TU Delft – Faculty of Architecture – Façade Research Group
KEYWORDS particles, insulation, temporary, energy saving, enclosure
BRAINSTORMING START Krymmel, insulation

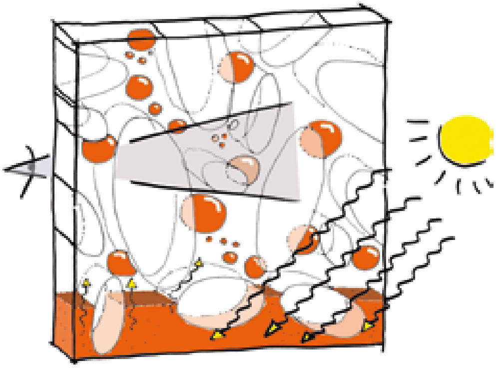
Imagine an insulation that works like a topping on muffins. In the wintertime a seasonal insulation will stick to the building’s envelope using an electrostatic surface that will hold the insulation particles.
Companies may provide this insulation on call and the material would be dropped over the building by a blimp or a spraygun.
After the wintertime the material could be taken away and recycled or reused in the next season.

LAVA-LAMP 2.0

18-06-2009

IMAGINED BY Holger Strauss, elaborated by Daniel Schröder
KEYWORDS system, energy generating, liquid, façade, dynamic material

The principle of the lava lamp can be transferred to façade systems. The energy storage potential of the wax could be used to collect warmth from sunlight that is later transmitted into the building. Another benefit is that the façade is adaptive, since it could change its appearance depending on the climatic conditions.

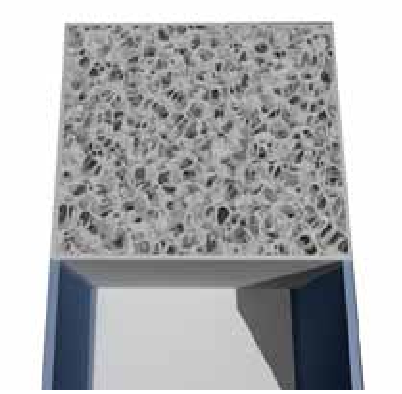


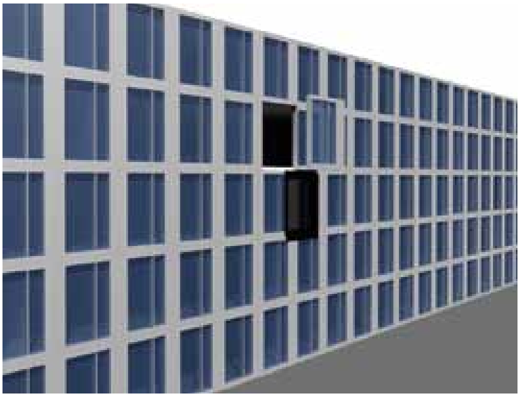
LEGO 2.0

03-02-2009

IMAGINED BY Daniel Wiegard, Holger Strauss, Ulrich Knaack
KEYWORDS prefabricated, building process, easy to assemble, façade, unknown material

Façade elements are pre-produced and mounted on site. This advanced module has an integrated connecting system – the Lego 2.0. With this system each individual element can be locked/unlocked in the façade. Single units can be taken out for maintenance or replacement.
Advanced window elements consist of printed lightweight structures for insulation and optimized weight.





LOW ENERGY REFURBISHMENT

08-03-2011

IMAGINED BY Ulrich Knaack, Marcel Bilow
KEYWORDS refurbishment, low energy, short usage, time, material

Do we have to invest a huge amount of energy to do a refurbishment? It all depends on the time period. Imagine a temporary solution for just a few months using less material and maybe more energy to operate. Using this principle we can think of solutions that wrap around an old industrial space to use it for some weeks and create a comfortable space, or even inflate a membrane that covers all leaks of that space into the room to create a new temporary space.

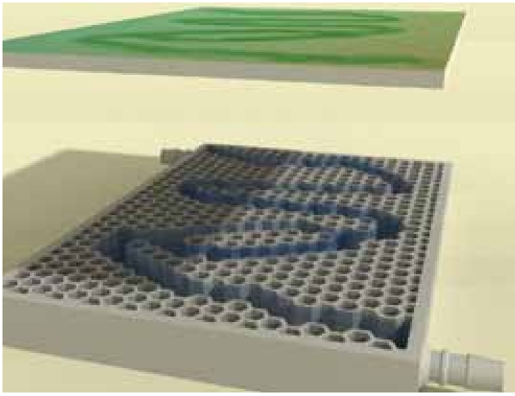



MATCHBOX FAÇADE

09-05-2009

IMAGINED BY Jörg Drügemöller, Carsten Wieth
KEYWORDS self-organizing, interactive, liquid, façade, dynamic material

Added value by using thermochromatic color and paint to achieve a changeable appearance of the façade. Integrated water drains could add to this phenomenon. The idea could be used to create façade panels with extra features.

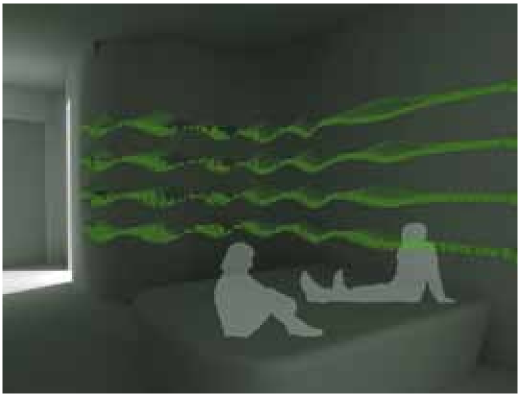


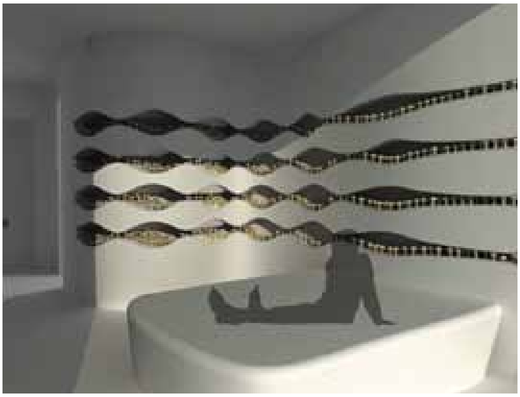
MUSH-ROOM

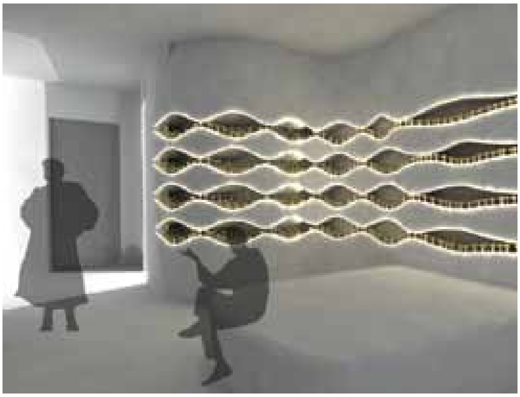
04-08-2010

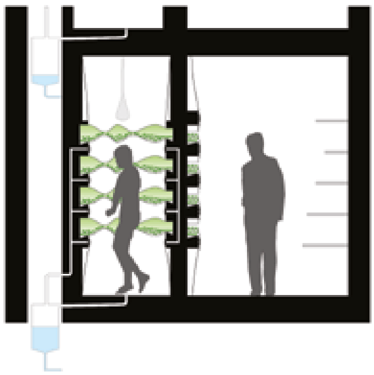
IMAGINED BY Güley Alagöz and Prof. Daniel Dendra / DIA
KEYWORDS organic, living organism, life cycle, interior

This concept tries to harvest the often used shower actions in a hotel room. The wasted water contains a lot of nutritions that can be used to feed a mushroom culture inside the hotel room. Using a special Japanese mushroom species (Mycena lux-coeli) that glows in the dark it will create a very special atmosphere in the hotel room during the night.









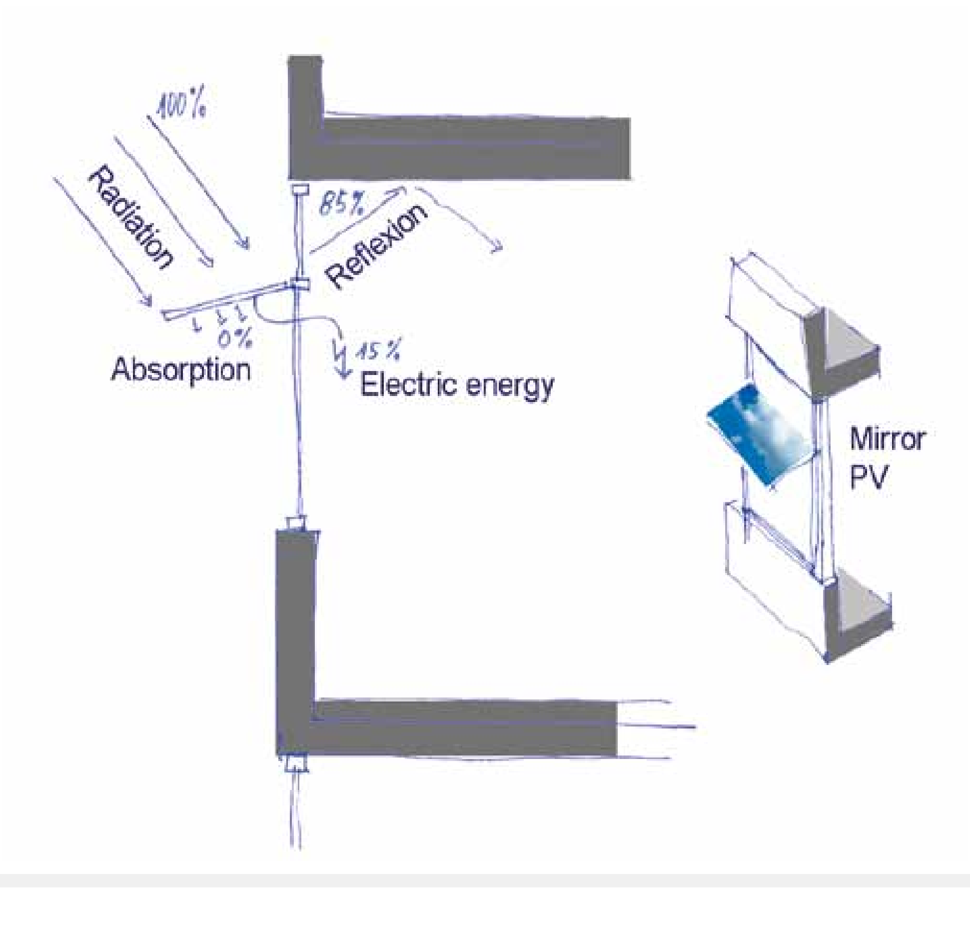
MIRRORING PV-CELLS

05-01-2009

IMAGINED BY Thiemo Ebbert
KEYWORDS system, energy generating, PV, light-transporting, sun-shading, façade, glass, 0 –10 years

Highly reflective solar cells are mounted perpendicular to the façade. The cells provide several advantages: Sun-shading for the window below, a light shelf function to reflect additional daylight into the room, and generation of electricity. So far, the system is well known.

Innovative Thin-Film PV cells provide a very high grade of reflexion comparable to a mirror. Thus the light-shelf effect is improved. And, the more light that is reflected, the less that is absorbed in the cell. The cell itself does not heat up as much as a conventional one. Hence it provides a higher efficiency.



MOVING COMFORT ZONE

08-03-2011

IMAGINED BY Marcel Bilow
KEYWORDS adaptive, comfort zone, smart material, heating, mechanical service

Normally we heat or cool the whole room in which we are, often even the rooms we might use. What if we are able to create surfaces that are able to heat or cool down very quickly and will also recognize your presence? If that's achievable, we are able to create a surface maybe on the roof of our buildings that will follow us and provide a pleasant comfort wherever we are. The energy should be transferred via radiation and should be as fast as light to be able to follow our path through the room. This way, the overall energy consumption will be much lower than it is normally.

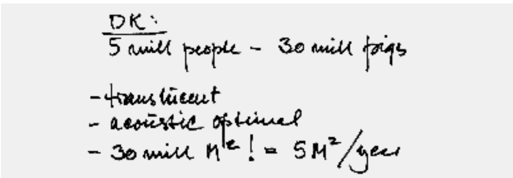
PIG SKIN GREENHOUSE

09-06-2010

IMAGINED BY Workshop “I am Energy”, Royal Danish Academy of Fine Arts – School of Architecture, TU Delft – Faculty of Architecture – Façade Research Group
KEYWORDS pigs, renewable materials, biomaterials, greenhouses, meat, transparency
BRAINSTORMING START pig’s skin, greenhouse

Denmark has about 5 million people – and about 30 million pigs. If we consider that we have to kill the pigs to use the meat, we can also think about using the skin as construction material. But what to do with its limited shape?

Aside from this there is a need for 30 million cubic meters of greenhouses for plant production. Combining these two facts, the following suggestion occurs: By developing a peeling technology, the skin could be reshaped via air pressure and molded into a mini greenhouse of approximately 1 cubic meter.



SMART PAINT

09-06-2010

IMAGINED BY Marcel Bilow
KEYWORDS smart materials, air quality, comfort, CO_2 measurement, education

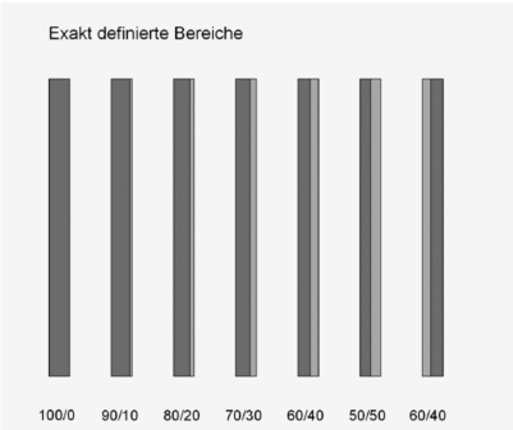
You can feel if it's too hot or too cold. But we don't have a sense for a high concentration of CO_2. Wouldn't it be nice to be notified through a smart paint that changes its color when the air quality drops? Then we are able to control our natural ventilation and save energy for the operation of the building just by looking around and acting accordingly.
A familiar warning color like red would tell you that the air quality is bad. Open the window! And when it turns green you can close it again. Of course we are able to measure it with sensors and can hook up our motorized windows to a control circuit, but acting is much more refreshing than sitting in a closed box and hoping everything will be regulated for you…

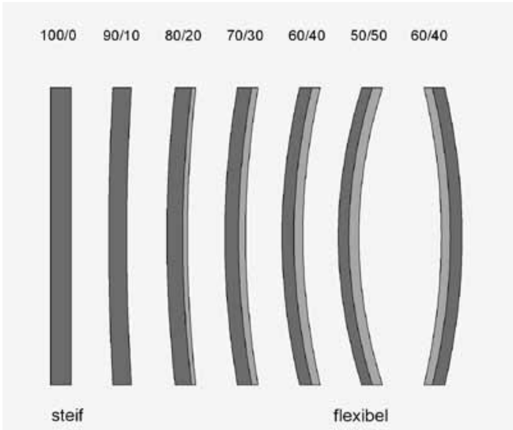
SOLAR KINETIC BIMETAL FAÇADE

27-06-2008

IMAGINED BY Holger Strauss
KEYWORDS bionic, interactive, adaptable, envelope, Functionally Graded Material

By using FGM's made from two metals, we can produce parts that deform at precisely predictable rates. An accurately calculated mixture of two different metals is implemented into one single part using CAD. Temperature changes the behavior of the bimetal parts, thus making the façade change accordingly. There is a broad range of possible designs: inspired by shingles, slate cladding, fish scales and much more, smaller or bigger parts of the façade could be heat-adaptive. Application in the façade could be used for shading, ventilation or as visors.



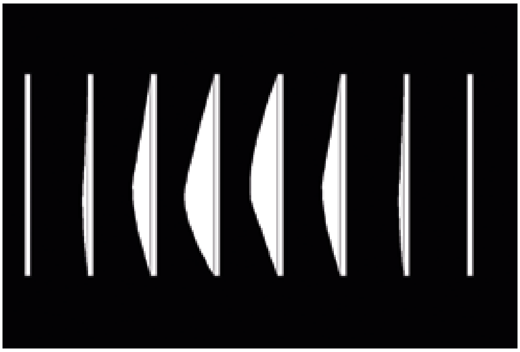


SQUOOSH FAÇADE

03-02-2009

IMAGINED BY Phillip Bödekker
KEYWORDS mono-material, shape-shifting, façade, adaptable, structure, material

A special high-performance acrylic is printed onto standard glass-pane sizes. The material is able to become flexible – thixotropic – when load is being applied. Thus, the spaces of windows and glazing now offer the possibility to sit and relax. After use the pane slowly moves back to the initial position. By using this principle the material can be reused several times rather than being wasted after its original use. In this case it makes sense to use a material that will create a bigger footprint in the first place.



SUPER LIGHT APPROACH
03-05-2010

IMAGINED BY Marcel Bilow, Ulrich Knaack
KEYWORDS energy, lightweight structures, personal comfort zone

By building our spaces with the least amount of materials we are able to reduce the amount of embodied energy. To create a comfortable space we can learn from Japanese architecture which is built out of paper walls and creates a small space as a comfort zone – which is normally a massive table with a stove underneath it to provide a cozy warm place to rest and sit.

THE BRICK THING

11-04-2011

IMAGINED BY Ulrich Knaack
KEYWORDS urban mining, reuse, bricks

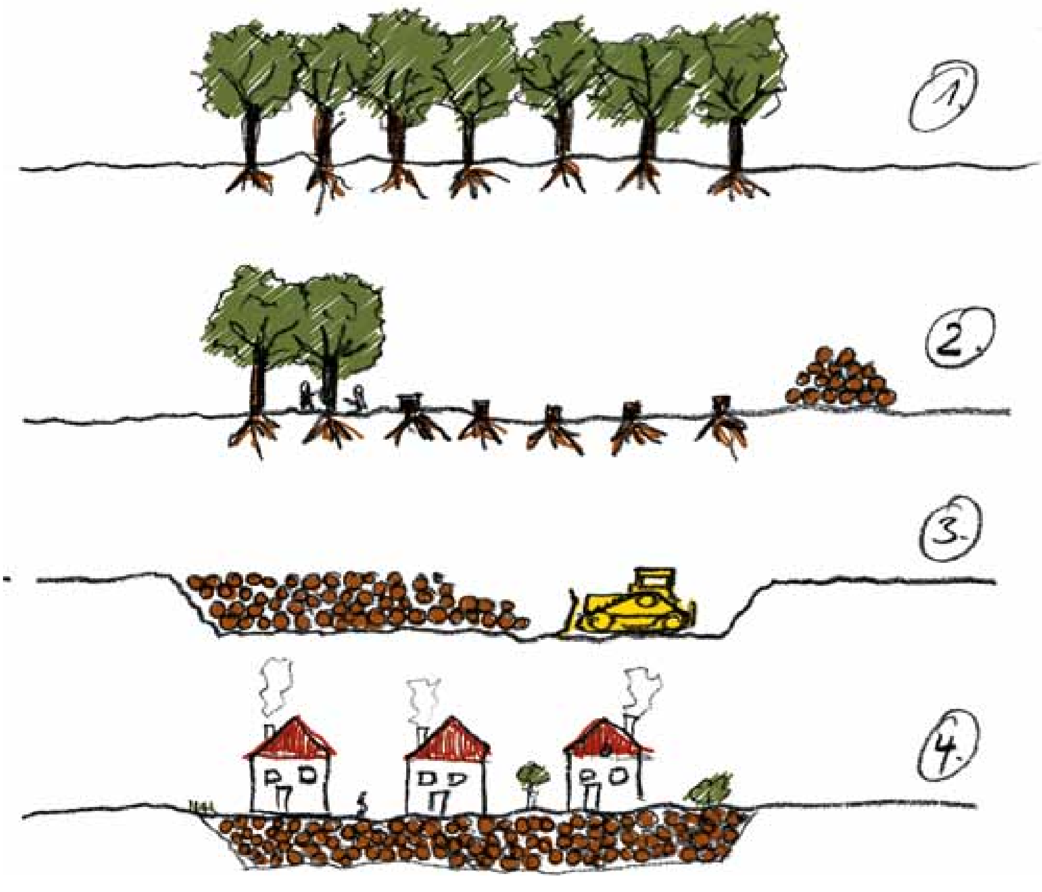
Today friends from Washington University told us the story of the companies who are tearing down old und unused buildings from St. Louis and selling the used bricks to Florida, where they are used to build new buildings.
Well, this is real urban mining. Actually it is also quite a fair way of dealing with embodied energy – instead of downcycling or not using the material, it is reused and given a second life.
When we consider this as a strategy of dealing with the migration of people from one urban area to another, it would also be a fair way of taking material with them – almost like cradle to cradle – wouldn't it?

THE HOME OF THE FREE

27-07-2010

IMAGINED BY Marcel Bilow
KEYWORDS energy, zero carbon, wood

A provocative approach, but correct according to the theory: If we clear part of a forest, then use that wood as a foundation, anything could be built on top of it since the overall energy rating will always be positive due to the incorporation of the wood.



THE STRAW HOUSE

09-06-2010

IMAGINED BY Workshop “I am Energy”, Royal Danish Academy of Fine Arts – School of Architecture, TU Delft – Faculty of Architecture - Façade Research Group
KEYWORDS self growing material, biomaterial, renewable construction, self active architecture
BRAINSTORMING START coat, layering

The straw house consists of a timber skeleton structure which is closed and covered with straw. For renewing purposes the straw is replaced from inside and on the roof and is established as a social event within the family. This will develop a tradition of replacement once a year – presumably in September, following this process:

Wall:

A – cut straw in September

B – Stitch straw to mattress

C – Place it inside

D – Pull off the 10 year old outer layer

E – Replace the straw mattress from inside and push package forward.

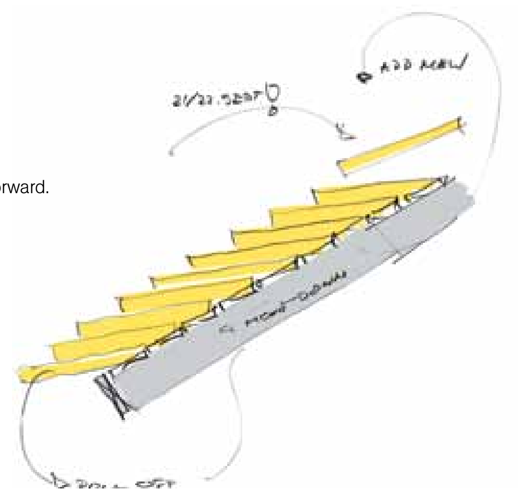
Roof:

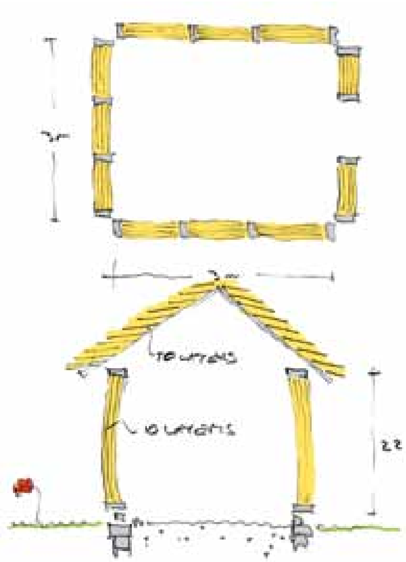
A – cut straw in September

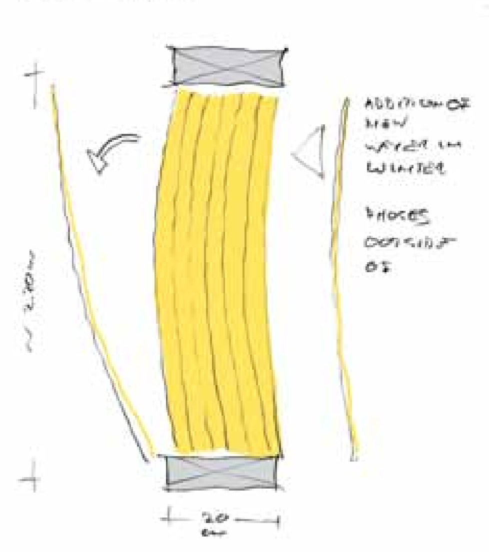
B – Stitch straw to roof shingles

C – move roof package towards edge

D – place roof shingles at top





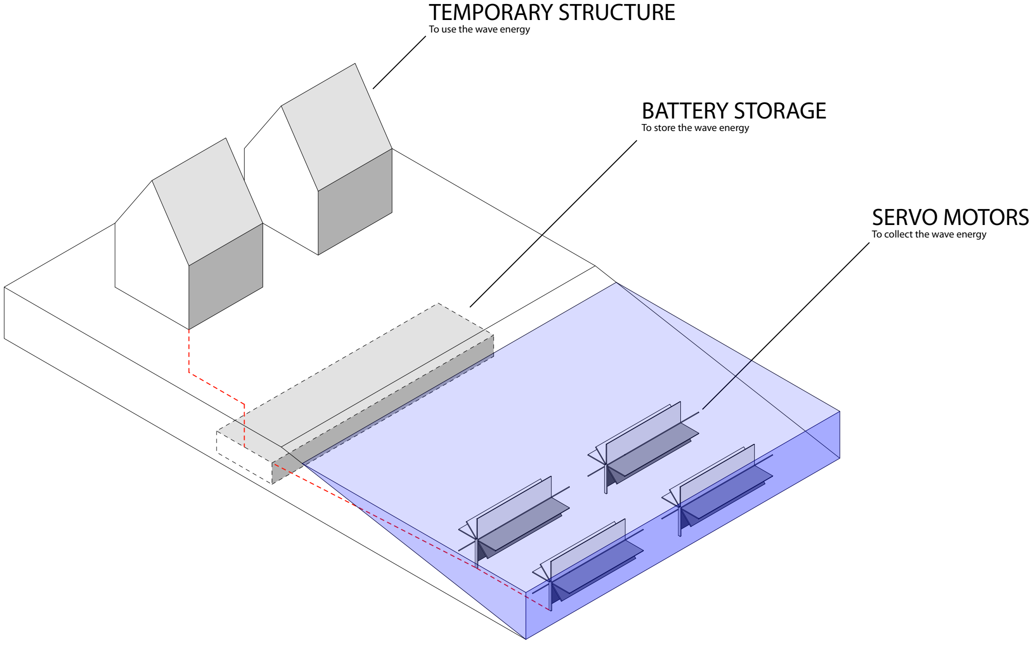


TSUNAMI ENERGY

11-06-2011

IMAGINED BY OpenJapan 72hr Worksprint
ILLUSTRATED BY Kyle Rogler, OpenSimSim
KEYWORDS energy, tsunami, energy storage, disaster

Energy is one of the greatest resources needed following a disaster. This idea looks at harvesting the energy from the natural disaster (i.e. Tsunami) and converting it into stored energy which can be tapped into by the survivors for communication, motors, heating, and cooling. The energy would be captured by having an array of servo motors that would feed into a battery storage unit that could be later used by survivors and temporary structures.



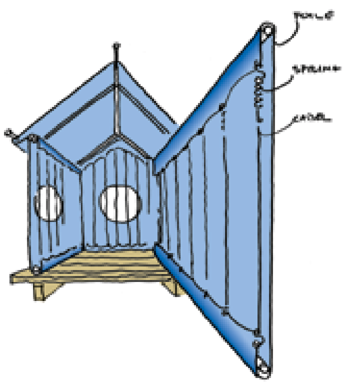
ULTRA LIGHT STRUCTURE

17-02-2010

IMAGINED BY Ulrich Knaack
KEYWORDS temporary use, architecture, light weight, structure

If we try to reduce the amount of embodied energy within our structures, there is also the question of time: For how long do we need the building? If we build for just a temporary purpose, like an exhibition or a fair, we should build as light as possible to reduce the embodied energy in the building materials. We might use a little bit more energy to operate the building and to create a comfortable space, but in relation to its purpose it is right.

So think about a structure made only out of film, foil or textile.



URBAN MINING

24-08-2010

IMAGINED BY Linda Hildebrand, Ulrich Knaack
KEYWORDS energy, mining, recycling, raw materials, material

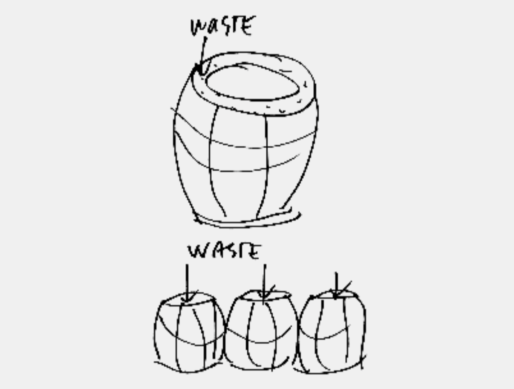
We still have mental pictures if we talk about the “Trümmerfrauen” (women of the rubble) who cleared and sorted the bricks of the bombed cities after World War II. In our future this kind of urban mining, i.e. using old materials because of their energetic and recycling value, may well become a totally new business. What is regarded as waste nowadays may become valuable to those who are willing to invest the labor to gain it.

WASTE BARREL

09-06-2010

IMAGINED BY Workshop “I am Energy”, Royal Danish Academy of Fine Arts – School of Architecture, TU Delft – Faculty of Architecture - Façade Research Group
KEYWORDS reuse, waste, new function, modular construction
BRAINSTORMING START waste, barrel

The positive thing about waste is that it can be a valuable material, if you can find a new purpose for it: by creating barrels for transportation out of waste, this idea would offer potential for reuse. The problem to be solved is that of “which waste”…

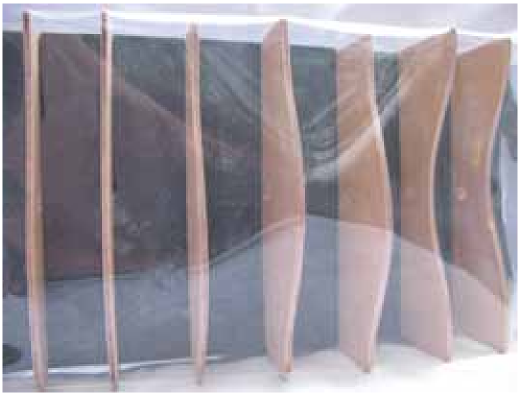


WRAP IT 2 PROTECT IT

03-05-2008

IMAGINED BY Marcel Bilow
KEYWORDS pneumatic, vacuum, protection, short term use, material mix

Many constructions can be made out of wooden materials. When exposed to the elements you normally have to protect the construction against the weather. Normally, a paint or layer of lacquer is applied to protect the wood. If we wrapped a layer of film or foil around the structure using vacuum to keep it in place we would be able to avoid any kind of glue or other additives to protect the wood structures. After the use of these structures, all elements could easily be dismantled or disassembled and separated. By doing so the amount of waste would be reduced and all materials could be used further or recycled the best way.

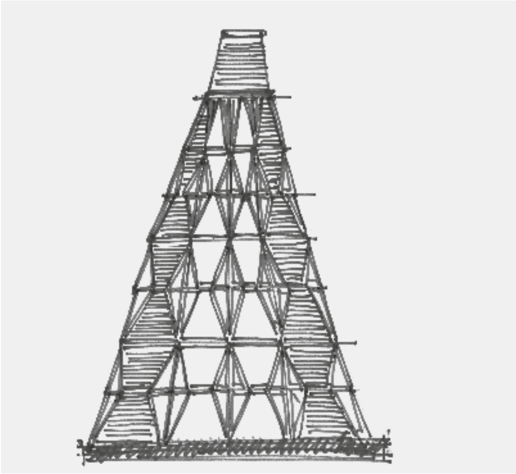


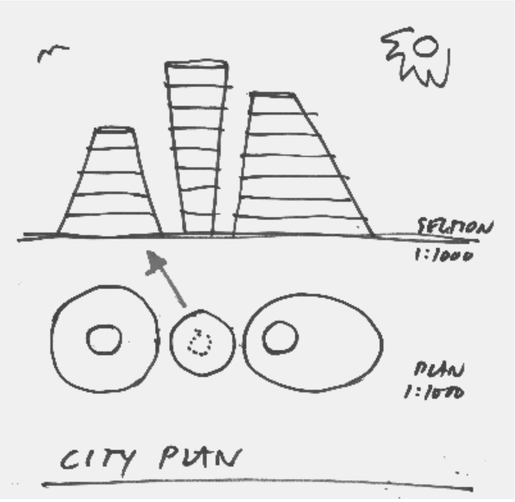

YOGHURT CUP HOTEL
09-06-2010

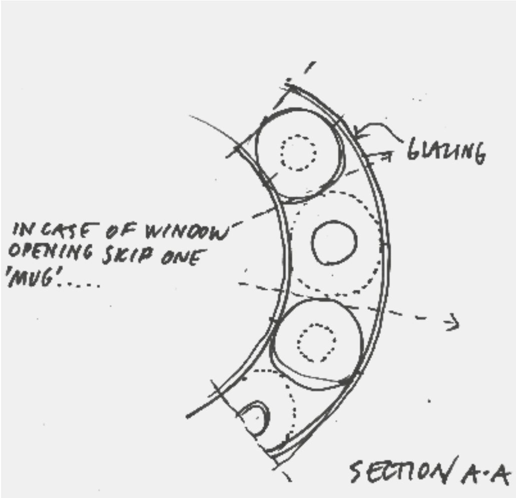
IMAGINED BY Workshop “I am Energy”, Royal Danish Academy of Fine Arts – School of Architecture, TU Delft – Faculty of Architecture – Façade Research Group
KEYWORDS recycling, bioplastic, hotel
BRAINSTORMING START yoghurt cup, hotel

Developed out of the idea of stacking used yogurt cups, this hotel can be developed in relation to the urban situation with truncated cones to provide natural light and shading.

The construction is developed out of the geometry of the cups and will be covered with curved glass sheets. In the case of windows cups can be left out.
The issues of floor slabs and vertical transport are not developed yet and still have to be solved.







7. PERSPECTIVE

IMPLICATIONS

If we continue using our resources in the same wasteful manner, using the majority of the energy available to us for transport and another major share for the building industry, we will soon face increasing energy prices and a shortage in supplies. The impact on nature, societies and culture from this will likely shape our future behavior. Thus, while striving to maintain existing standards we have to start conserving energy and reducing our footprint. But is that sufficient or hopeful? The real question should be: How can we improve the quality of our lives while reducing our impact on the environment? This provides a promising starting point for boosting innovation around energy efficient and reusable buildings.

We have started the conversation of how we are faced with the challenge of incorporating the embodied energy as a factor into the development of the building. Although the tools to do this are becoming more available and comprehensive and the policy requirements are starting to be developed, this does not by its nature trigger a new wave of innovation. On the contrary, it makes the development process more complicated; building design becomes more expensive and more difficult. But like any new design aspect, it cannot just be tagged on to the end of the design process as an item to check off. If it is to be effective, this new level of complexity must be incorporated as early as possible into the design process.

Though high levels of precision are possible in embodied energy tools to complete post-design evaluations, few applications are available for early development and design. As we add more complexity to the design process, including new assessments it becomes harder to quickly iterate and incorporate creative ideas. On top of that, there is little to no experience to draw from. Given the added complexity, lack of experience and poor tools for design, the hope for innovation seems slim. Then we end up not trying and instead relying on tried and true strategies; developing instead new strategies in an evolution of small steps. Taking a linear approach to changing our design practices won’t lead to the fundamental innovations that are needed to create change in this field.

However, if we approach the issue from a different perspective and consider the embodied energy of a single family passive house with a life cycle of 40 years in relation to its operational energy we see that both are about the same. Thus, the embodied energy becomes crucial when trying to lower energy expenditures and it is necessary to consider a holistic approach. If we try to look at the individual factors that reduce energy or help us use them more efficiently, this opens new paths and room for innovation (i.e. invention and market placement). Here is where the interesting challenge begins! If we put more value on the embodied energy of materials into the decision making process then we will tip the balance from labour efficiency to material efficiency.

However, the challenge doesn't only exist in the new building market. In fact, only 3% of buildings are built new every year, so the existing building stock will need to play a significant role in reaching the EU's goal of 90% carbon emissions reduction by 2050. The question then becomes, when is it worthwhile to renovate and when is rebuilding important. In the car sector, we might be able to improve the efficiency of a Hummer, but the reality is it will never become a smart car. Similarly, some existing buildings are unlikely to ever become efficient, such as museums, labs, etc. This means that the remaining existing stock will need to become essentially carbon neutral either by renovation or by being deconstructed and rebuilt from scratch. Deciding between renovation and reconstruction involves using PAT to determine the time needed for the energy savings from a renovated building to surpass those of a new much more efficient building. In some cases, like the Hummer, the amount of time may be very short, suggesting the need for a new building, while in other cases, renovation may be a better option for the expected lifetime of the building.

We can predict a trend comparable to the initial years of energy efficiency due to the oil crisis. As a commodity becomes scarce there is a demand for new solutions to meet existing needs. Concurrently a shift in paradigms must take place that joins the absolute priority of investment cost with life cycle assessment. Energy investment planning or energy real estate management will evolve and guide us through the question of how, how long and what we design and build. Despite this change one thing will remain constant: Money will drive us, and it will be through higher energy costs. No doubt, competition will accelerate the process; initially as friendly ambition, but more importantly as a marketing tool. Rankings for the "greenness" of a building are becoming a requirement to compete in the real estate market.

The real potential of the issue is actually the necessity for innovation; innovation of building methods, like masonry whose approaches have not changed in centuries or even millennia. We will be forced to change those methods and define:

- How long we want to use a building
- What we intend to do with it after its use
- Which materials are available to us and which of those are suitable
- And how much energy is reasonable to use for the erection of the building.

This will require some kind of material mapping or energy mapping. This is where the new horizons of techniques will be found.

One more topic needs to be discussed in this context: Which materials are actually efficient and sensible? The answer to this question will depend on the evaluation method, place and purpose. Nonetheless, two general assumptions or myths need to be discussed.

The first myth to deal with is that of wood: “The more the better!” While this may be true, it can also cause doubtful developments as mentioned in Chapter 6. Wood is good because it grows naturally, needs little energy for processing and even binds CO_2. So let’s build log cabins! Another approach would be to use trees as a form of carbon storage in a construction; logs could be stacked in the basement to act as carbon sinks for the construction to compensate for other energy intensive aspects or poor overall quality. As wood is a carbon and energy negative when used for embodied carbon or energy calculation, the math works. Fortunately, energy balance isn’t the only factor in the equation. With economics still driving material efficiency it is unlikely that this would occur. Other extreme ideas in Chapter 6 go even further, suggesting the use of energy carriers like wood as an interim material that would later be used in energy recovery.

The reason these approaches are questionable is that even though wood improves the amount of embodied energy in an individual building, looking at a wider context shows that this resource is also needed to meet other needs and if this was not possible, other resources would have to replace it.

The second myth is from the opposite extreme: “Aluminum is bad, because it has such a high embodied energy.” This is true: Aluminum is one of the most energy intensive materials to produce. However, two things should be considered here. First, the weight of the material to be used is decisive for the construction, as well as its use and performance. For example, a façade made of aluminum may not seem to be a good energy choice while a limestone façade seems better. However the aluminum is much thinner than the limestone and as a result makes a purely weight based comparison not useful. As a quick analysis shows, the difference between 6 cm of limestone façade (81MJ/m^2) and the equivalent 1mm of aluminum (112MJ/m^2) is about 38%. So although higher the aluminum has a long expected lifetime, offers better performance and can be reused and recycled. Depending on the situation this might make sense to use despite a slightly higher initial energy investment, though not near the order of magnitude difference that would have been assumed if it had been compared to limestone kg to kg. Thus aluminum cannot be immediately rejected on an energy basis.

Second, the material's performance determines its function for the construction. A thin layer of aluminum on the surface area of a construction will retain its function of water tightness without requiring any maintenance from a technical point of view. The same function, fulfilled by wood, would require continuous maintenance and protection of the material to preserve it. After its use the wood could be used in a similar fashion – however within the limits of its measurements, which can be regarded as a kind of down-cycling – or it could be used for thermal energy. While, aluminum can be recycled in remaining quantities, making it a distinguished material for repeated life cycles. So in specific uses aluminum could be the ideal product that provides better performance, reusability, and a lower long term energy cost. Unfortunately right now, these materials aren't sufficiently reused or recovered and despite the respective industries' capacity to do so.

Both myths are examples that show different extremes and highlight how we can push these ideas further. What if we only built with "future energy carriers", such as wood or plastic? Their subsequent use would be predetermined. We would only have to ensure deconstruction and possibly a monomaterial building approach. The ideas in Chapter 6 show different approaches with oil, wood and coal. Here, too, wood excels despite its relatively low efficiency because it provides a direct transfer from wood to house to burning material and it does not affect resources that needed millions of years to form.

We can conclude that the prerequisites and the materials of the individual building need to complement each other: lifespan, function and materials have to create a sensible overall concept. Apart from the energy aspect and the challenge for smarter construction, this makes the topic aesthetically influential: Buildings should be attractive or especially normal. Attractive here means that they have a deep architectural quality and are loved enough to be used for a long time. This allows them to be designed for both operational and embodied energy. An alternative approach could be followed such that broad functionality is guaranteed and little energy input would be needed to change the building's purpose. "Normal" buildings in this case are ones that are universal and versatile. They must also be efficient from an operational energy perspective, and ideally are attractive as well.

It becomes clear that apart from the complete package with the evaluation of the embodied energy and the incorporation of the performance of the building, the choices made about the use of the building, its duration and changes in function are important. Short term use, short material cycles and energy transfer will influence the concept and design just as well as the desire for long term use. Through this process of considering different materials, whether renewable, reusable or other, and new techniques the door is being opened to an enhanced sense of aesthetics. As a society, we must face the challenges ahead of us. We need to harness innovation and think of design and buildings differently. By understanding the embodied energy in our materials and using time as a variable we open up a whole new world of possibilities for smarter more sustainable construction. We remain convinced that if we are to drive change towards lower energy use, it cannot be through sacrifice but through the creation of a better living environment. We must create places that people want to live in; places that have used innovation not only to lower energy consumption but to increase our quality of life.

APPENDIX

CVs

ULRICH KNAACK (*1964) was trained as an architect at the RWTH Aachen, where he subsequently obtained his PhD in the field of structural use of glass. In subsequent years, he worked as an architect and general planner with RKW Architektur und Städtebau, Düsseldorf, winning several national and international competitions. His projects include high-rise buildings and stadiums. Today, he is Professor for Design and Building Technology at the Delft University of Technology, Netherlands, where he established the Façade Research Group and is also responsible for the Industrial Building Education research unit. He has organized interdisciplinary design workshops such as the Highrise XXL. Knaack is also Professor for Design and Construction at the Detmolder Schule für Architektur und Innenarchitektur, Germany, and author of several well-known reference books.

TILLMANN KLEIN (*1967) studied architecture at the RWTH Aachen, completing his studies in 1994. He subsequently worked in several architectural offices; from 1996 onward he was employed by Gödde Architekten, focusing on the construction of metal and glass façades and glass roofs. At the same time, he attended the Kunstakademie in Düsseldorf, Klasse Baukunst, completing the studies in 2000 with the title “Meisterschüler”. In 1999, he was co-founder of the architectural office rheinflügel baukunst with a focus on art-related projects. His practical work includes the design of a mobile museum for the Kunsthaus Zug, Switzerland, the design and construction of the façades for the ComIn Business Centre, Essen, project management for the construction of the Alanus Kunsthochschule, Bonn, and project management for the extension of the University of Applied Sciences, Detmold. In 2005, he taught building construction at the Alanus Kunsthochschule, Bonn-Alfter. The same year, he was awarded the art prize of Nordrhein-Westphalen for young artists. Since September 2005 he has led the Façade Research Group at the TU Delft, Faculty of Architecture.

MARCEL BILOW (*1976) studied architecture at the University of Applied Science in Detmold, completing his studies with honors in 2004. During this time, he also worked in several architectural offices, focusing on competitions and later on façade planning. Simultaneously, he and Fabian Rabsch founded the “raum204” architectural office. After graduating, he worked as a lecturer and became leader of research and development at the Chair for Design and Constructions at the FH Lippe & Höxter in Detmold under the supervision of Prof. Dr Ulrich Knaack. Since 2005, he has been a member of the Façade Research Group at the TU Delft, Faculty of Architecture.

LINDA HILDEBRAND (*1983) completed the study of Architecture at the Detmolder Schule für Architektur und Innenarchitektur in 2008. Graduating in green certificates in the building industry she started her career with applying the German DGNB certificate in the pilot phase. The same year she started her PhD research at the TU Delft analyzing the relevance of embodied energy for the building sector as well as teaching Sustainable Construction in Detmold. She is part of Delft’s Façade Research Group and was involved in several publications such as the Imagine book series and different research projects.

THOMAS AUER (*1965) Trained as a Process Engineer at the Technical University in Stuttgart, Thomas is a partner and managing director of Transsolar GmbH, a German engineering firm specialized in energy efficient building design and environmental quality with offices in Stuttgart, Munich and New York.
Thomas collaborated with world famous architecture firms on numerous international design projects and competitions. A specialist in the fields of integrated building systems and energy efficiency in buildings, Thomas has developed energy and building services concepts for projects around the world noted for their innovative design and energy performance – as an integral part of signature architecture. Among his projects in Germany are the Hochtief Prisma naturally-ventilated atrium building in Frankfurt, the new spa in Bad Aibling, and the KfW Westarkade in Frankfurt. The office tower for Manitoba Hydro in downtown Winnipeg, Canada is considered one of the most energy efficient high rise buildings in North America.
Outside of Transsolar, Thomas is teaching at Yale University and was a visiting professor at the ESA in Paris and other universities. He speaks frequently at conferences and symposia. In 2010 Thomas received the Treehugger “best of green” award as “best engineer”.

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Climate design and climate engineering are nowadays standard in the design process. The more successful we are in this, the less energy we need to run the building during its useful life and we can focus instead on an additional aspect: the embodied energy – the energy we need for the material production and construction process. Interestingly, the reduction in energy used in a climate-efficient building during its lifetime is equal to the energy consumption necessary to produce and install the building. This aspect triggers us to reconsider the design potentials of focusing on less energy in the construction. Which materials make sense energy-wise? Do we need to build with simple materials for 500 years or should we go high-tech and design the complete life cycle for a perfect reuse with maximum recyclable materials? Or should we build out of materials that can be used as energy after being a building? This publication focuses on the embodied energy aspects of building materials, their life cycle and their potentials for reuse as energy or in construction, and presents some far-reaching design ideas.