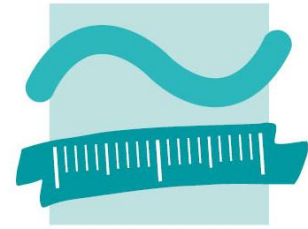


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**IDEAS FOR
SUSTAINABLE
CITIES OF THE
FUTURE**

**BUILDINGS OF THE FUTURE AS A
SOLUTION FOR SUSTAINABLE
EVOLUTION OF CITIES**



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Introduction

Ever since humans have begun to settle, first settlements, villages and then small cities slowly started to form. The growth of cities stagnated and cities looked manageable until the era of industrialization was ushered with the Industrial Revolution, a period from 1750 to 1850¹. This period led to more jobs in the cities, which led to wealthier cities, which led to bigger cities and so on.

"Until the Second World War, urbanization primarily was a phenomenon of developed countries", says Prof. Frauke Kraas from the Geographical Institute of the University of Cologne. "But afterwards, rapid urban growth started in the developing countries due to high population growth, intensive industrialization, increase of attractions in the cities and rural exodus," adds the expert on cities and mega-city research.² Mega-Cities started to shape and since 2007 more than half of the world population lives in cities which leads to major problems. Cities which have become so complex consume a lot of energy and produce even more waste. In 2011, the world had 20 Megacities³ per definition, which would be a city with a population of over 10 million. Together with unique problems like traffic and transportation, which megacities have to deal with because of their vast dimension, there are common problems which every city has to face, like energy and water supply, environmental or healthcare issues. To secure a healthy future for those who live in cities and reduce the impact of cities on the worldwide environment we need to aim for sustainable cities in the future. But what exactly does sustainability mean? In Wikipedia, Sustainability is defined as: "the capacity to endure", and "...the responsible management of resource use"⁴. For a city to become sustainable, it has to manage the usage of its resources in a responsible way. There are many different approaches to reach this goal as there are different resources in cities that can be monitored. In this case, I have chosen the following approach to present to you to save and reorganize the way energy is used in buildings and transportation. I want to present to you: Buildings of the future as a solution for sustainable evolution of cities.

¹ en.wikipedia.org – Industrial Revolution

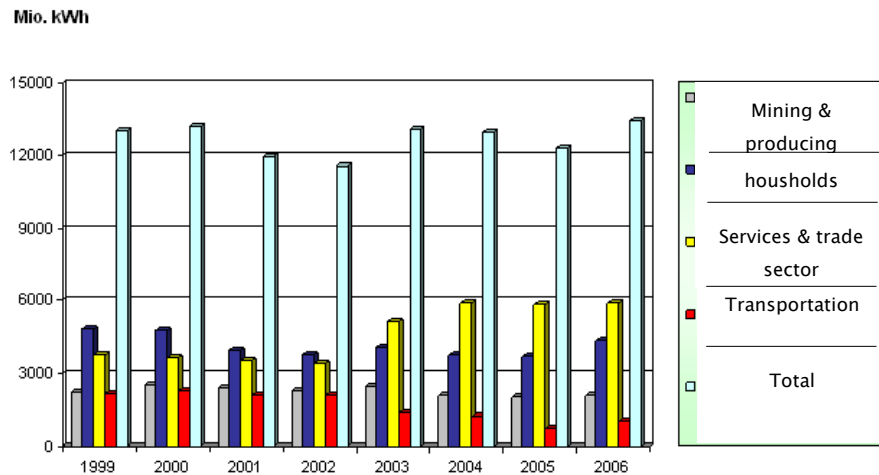
² Scinexx – Die urbane Wende 2007...

³ en.wikipedia.org – Megacity

⁴ en.wikipedia.org – Sustainability

Facts about energy consumption in Cities

Modern cities are not always modern. Old buildings and traditional districts surround us even in capital cities. Buildings, independent of size or height are the components of cities which use most of the energy in the private sector. The second most energy consuming sphere in the private sector is transportation.



Picture 1 Energy consumption of Berlin divided in different sectors

Picture 1 shows some numbers of energy usage in Berlin. It is obvious, that the total of energy use in Berlin lies in between about 1.2 and 1.4 billion kWh per year during the years of 1999 up till 2006. While the energy consumption in transportation went down due to technological improvements, modernization and higher prices for transportation and therefore more careful use, there were practically no improvements in the building sector for private living space. The energy consumption remained nearly the same. In order to reduce the overall consumption significantly, we need to rethink the way of how living works in cities. Here is a short example of how much energy is used:

A standard house makes use of between 70 and 100 kWh/m² a year to keep it warm. Apartments which have not yet been refurbished even consume between 150 and 250 kWh / m² a year. In this way about 40%⁵ of the total energy of Europe is consumed by private buildings for heating and to power multimedia devices. In order to become sustainable, we have to redefine our way of living, reinvent our buildings and rethink the structure of modern cities.

⁵ Hitec - Episode "Häuser von Morgen"

Plus Energy Houses

In contrast to regular houses, plus energy houses produce more energy than they consume. An excess of energy can be introduced into the regular power supply system. This requires a method called Smart Metering to enable the monitoring of energy consumption or even production for large energy companies in order to adapt to the consumers behavior. The surplus of energy can also be stored or used to power EVs (electrical powered vehicles). The two main difficulties of the usage of plus energy houses are:

- How do you build a house that produces more energy than its habitants consume?
- How do you connect these houses together to build a smart grid which distributes the energy in an intelligent way?

Different approaches to optimize the energy consumption of buildings and ideas of how to generate energy from homes are presented at the “Solar Decathlon Europe” in Madrid. The Team of the FH Rosenheim from Germany, which won second place at the Solar Decathlon in Madrid in 2010, published their ideas during that event. Their concept used following ideas:

Energy and Design

The team has mounted solar panels on the roof of their concept building. The idea was not only to stack solar panels on top of a building but to integrate them into the building facade. “If solar panels adopt tasks of the actual facade they have to be considered differently”, says Willy Ernst, one of the judges at the solar decathlon 2010. They do not only count as energy-producing devices but begin, by being part of the facade, to



Picture 2 – German "Efficiency House Plus" in Berlin

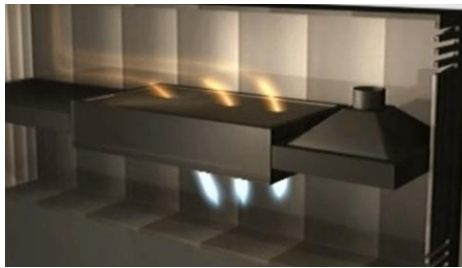
represent general design elements of buildings, and take over basic tasks of the outer skin of a house like weather protection. The team from FH Rosenheim even used solar panels to cool their concept building by sprinkling water on their panels at night. The night sky absorbs energy and therefore cools the water on the solar panels. The cooler water then is collected again and can be used to cool the building during the day without using much energy.⁶ Some ideas were adapted by the German “Efficiency House Plus” presented in December 2011 in Berlin. The black coating you can see in picture 2 consists of solar panels. Crystalline Solar

⁶ Hitec- Episode “Häuser von Morgen”

Panels mounted on the side of houses produce about 30 to 40 % less energy than those which are placed on top; nevertheless there are existing solutions like thin film solar cells, which can be produced cheaper and have a higher efficiency when it comes to transform ambient light. Also thin film solar cells have the advantage of being able to replace existing coating materials in order to protect the house from wind, water and other weather influences.⁷ They do not have to be as brittle as common crystalline solar cells which makes them predestined for this task.

Airtight construction

The natural behavior of gases and liquids is to reach a homogenous balance of concentration and temperature. If cold air, which has a high density, meets with warm air which has a low



Picture 3 – Cooling through PCM Plates

density, they try to align their temperature. This mechanism explains how most of the energy we use to heat up our homes, is wasted even if the house has already been refurbished or has a new coating. As long as air is able to flow freely, it can exchange with fresh

air from the outside. In this case, the outside temperature is heated or cooled as long as the air inside the building is exchanged with fresh air from the outside for example through door slots or other air gaps. The team of FH Rosenheim uses an airtight construction in their house to save energy. By directing the outside air through so-called PCM (Phase Change Materials) batteries, the air cools down and the warmth is stored within the PCM plates (as shown in picture 3). The cold air can be used to regulate the building's temperature. This method guarantees an exchange of air with the outside without wasting energy. Phase change materials aren't new. You might already have recognized their application in heating pads to carry a warming pad with you. But what exactly are PCM?



Picture 4 – A sodium acetate heating

- Basically PCM are substances with a high heat of fusion⁸
- When heat is applied to these materials, they begin to fuse
- For example when using a sodium heating pad, this process is reversible. When the sodium acetate recrystallizes, it generates heat.

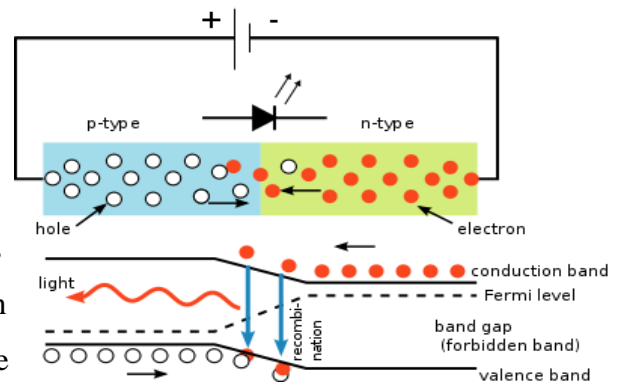
⁷ Willy Ernst during Hitec "Häuser der Zukunft"

⁸ en.wikipedia.org – Phase Change Materials

As tried by the FH Rosenheim team, a lot of energy can be saved by using this precept and applying it for regulating the temperature of homes.

Future Lighting

Most of the participating teams at the solar decathlon make use of modern light technology. The most popular one is the LED (light emitting diode) technology. LEDs are much more efficient than regular light bulbs due to their way of functioning. LEDs generate more light at equal performance compared to other lighting appliances. Light emitting Diodes are semiconductors as are normal diodes. The main difference is that as soon as enough voltage is applied between the two layers consisting of different materials, the LED begins to light up. Although less heat is generated through this process, a single LED is not made for a high power purposes. An LED lamp comprises a whole grid of LEDs to reach the desired brightness.



Picture 5 – schematic of how LEDs work

Because LEDs are so-called SSL (solid state lighting) devices they only produce light of a specific wavelength which is proportional to the width of the band gap between conduction band (where the electrons are moved) and the valence band (where so-called holes travel which can be seen as space-holder for electrons). Electrons are attracted to fall into holes. This process is called recombination. In order to recombine, electrons have to surmount the band gap. By falling “down” into the holes as shown in picture 5, energy is set free in the form of light. To generate more electrons on the one hand and holes on the other hand, energy is needed. This particular amount of energy is the rated power of the LED. The efficiency of a lamp is stated in lm / W which means that a certain brightness is measured in a specified area (lm) whereas the lamp transforms a measurable amount of electrical energy (W).

	LED	Fluorescent bulbs	Incandescent bulbs
Efficiency	≈80 lm/W	>80 lm/W	<15 lm/W
Lifespan	>20.000 h	<10.000 h	1000 h ⁹
costs	≈0,06 \$/lm	≈0.002 \$/lm	≈0.0005 \$/lm

Table 1 - Comparison between lamps

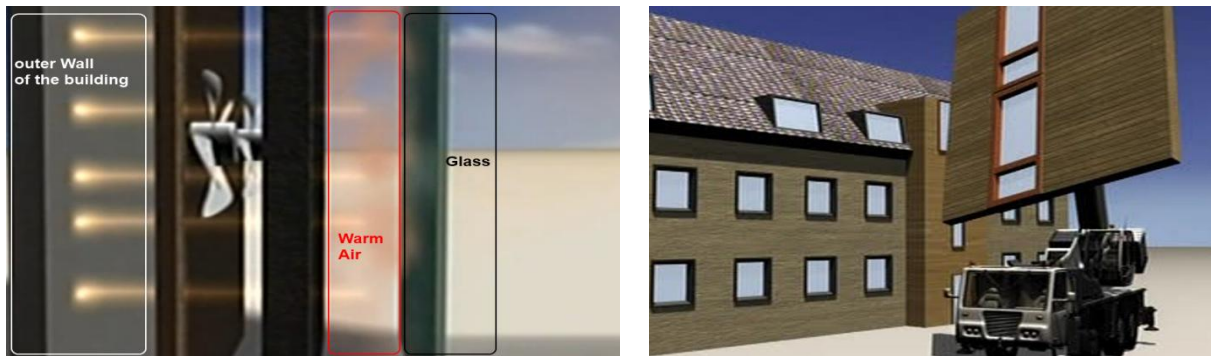
⁹ The lifespan of an incandescent bulb highly depends on its operating temperature. 1000h are meant for an operating temperature of 3400 K which is specified as a studio lamp – <http://de.wikipedia.org/wiki/Gl%C3%BChlampe#Lebensdauer>

The table 1 shows, that LEDs are not the most efficient way to light up a building but they might be the most sustainable one. Contrary to fluorescent bulbs, LEDs do not contain toxic materials. Moreover, they last longer and are smaller, which makes it easier to use them as a design element for interior design of homes. A main advantage of LEDs as a source of illumination is that they emit directional light while fluorescent bulbs radiate flare, a factor which must not always be used.¹⁰ To simulate sunlight or reach a certain color temperature, LED lamps have to consist of a mixture of different LEDs or LEDs with different color capabilities because of their SSL characteristics. With this mixture of colors it is possible to adjust different sorts of white light with desired CCT (correlated color temperature). Another form of sustainable lighting not yet explored as the LED is the OLED whereas the O stands for organic. OLEDs function the same way LEDs do, but because they are organic, there are even more possibilities of application. OLEDs, for example, can be printed upon surfaces. Connected to a voltage source, they begin to illuminate so that no additional wires or circuits are needed. Because of their way of functioning, they are most likely to be very efficient but they do not yet surpass the efficiency of the LEDs. Currently their lifespan seems to be shorter than the lifespan of LEDs.

¹⁰ Gemeinderat-online

Methods of Refurbishing

According to an Article of Hitec (topic: “Häuser von Morgen”): “Ninety percent of the energy demand of buildings is caused by buildings that were built before 2000.” Not all houses can be rebuilt with sustainable technology and proper insulation so that there has to be a different solution to compensate the missing insulation of old buildings. In fact there are different solutions which can dramatically reduce the loss of energy of those buildings.



Picture 6 – solar activated facade (left) and pullover shell for buildings (right)

Arthur Schankula, a German architect, who has specialized in refurbishing of old buildings, has developed a method to create a shell for buildings which makes them more energy efficient. This allows a renovation while the building is still inhabited. Because the shell is produced somewhere else, the time of renovation of the building itself is minimized. "Houses of the 30's or 70's have a heat demand of about 200 kilowatt hours per square meter per year. After the installation of the insulation, it sinks to about a third or fifth, depending on the standard of insulation", says Mr. Schankula. To guarantee a perfect fit of the shell, the building's surface is first scanned with lasers. A high precision 3D model is generated from this data, which results in the actual shell. In the end, this shell is just stripped over the building like a pullover.

However, not only the insulation can be integrated to this pullover for buildings. Arthur Schankula has set himself the goal to make his shell for buildings even more efficient. He wants to integrate methods and functions for energy saving like his so-called solar activated facade. This consists of an extra layer in the shell in which air can flow around the building. Transparent areas out of glass let the sun heat the air, which can be redirected through suction created through a ventilation system so that even cold regions can be heated without extra costs.

Recompression of Cities

Recompression of cities is an idea Hans Drexler presented in the TV Show Hitec¹¹. He thinks that it is essential to concentrate buildings in the core of the cities to minimize energy usage of transportation. Commutation traffic which causes rush hours not only consumes energy but it also increases the air pollution. A simple way to avoid this big traffic is to keep the people near their work, mostly in the core of cities. Nowadays, there is not enough space for living left so that the rental costs are quite expensive. "I believe that in the next few years, the mobility will become even more expensive. This will cause inner city regions to become economically attractive and therefore there will be more possibilities for extensional constructions.", says Hans Drexler to Hitec. The extensional constructions in cities he mentions are buildings or places to which extensional buildings could be added. In his interview he also calls them "mini apartments".



Picture 7 – space for extensional construction



Picture 8 – conceptual mini apartment on the space of picture 7

¹¹ Hitec – Episode "Häuser von Morgen"

Conclusion

The presented ideas are relatively new but I am sure that they will slowly change the surface of cities. Future renovations and refurbishments of old buildings will contain insulations which will increase their energy efficiency. The easier the application of insulation becomes, the cheaper it will be and the more people will be attracted to refurbish their homes. Also the LED already is replacing conventional methods of lighting which will also have a big impact on the energy usage in the public sector like factories, illumination of streets and cities, shopping windows and so on. New houses which were built after the year 2000 already have sustainable ideas and energy saving architectures implemented. As soon as the technical improvements of plus energy houses become affordable, a new challenge awaits us - smart grids. But already today “plus energy houses” prove that a sustainable future is not only possible but in our reach. Disadvantages like the lack of efficiency of LEDs and solar panels are steadily compensated and sustainable technologies improved.

This lets me be very confident about the idea of living in a sustainable city of the future during my lifespan.

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