Section 1

Electricity Infrastructure

VIEWS ON ELECTRICITY

In this section we look at Electricity, a specific type of energy carrier, and ask the following questions, as they all have impact on architecture, urban design, and territorial planning:

- **Where is electricity being used?**
- **How is electricity transmitted and distributed?**
- **How is electricity produced?**
- **How is electricity stored?**

We focus on this view, as it enables the integration of electricity into the design process.

Electricity plays a special role among the most important energy carriers, such as crude oil, petroleum, natural gas, coal, district heat, wood, waste, gasoline for transportation, and the emerging range of alternative energies such as sun, biogas or biofuels.

Electricity

Electricity – The effects of which were known for millennia, its engineering ticking off much later - has developed into one of the planet‘s most versatile and important sources in facilitating and simplifying daily life. Its uses are endless, and we cannot imagine a day without it. It supports communication around the globe, mobility from electric vehicles to traffic lights, air travel from lighting to controlling and enabling the mechanical systems, moving people in elevators more than 800 m tall in a few seconds, transporting humans on people movers in extensive airports, cooling down our office spaces, melting gold, steel and aluminium. It literally surrounds us in our habitat. Imagine approaching a modern residential building: a sensor (uses electricity) detects you and turns on the light (uses electricity), you ring the bell (uses electricity), the door opens (uses electricity), you take the lift (uses electricity), and before you enter the door of the apartment, you may have used half a kilowatt hour already. Inside the apartment the situation continues with the use of lighting (uses electricity), air conditioning (uses electricity), heating (uses electricity), the refrigerator (uses electricity), taking a shower (uses electricity), listening to music (uses electricity), using the gym (uses electricity), or the swimming pool (uses electricity). The list of electricity uses (obvious or less obvious) is endless, and it is one of the main reasons why the per capita use of energy, and of electricity in particular, is growing continuously - in Switzerland, for example, it raised from 2000 Watt/person in 1960 to 7000 Watt/person in 2010

Building use of electricity

An average household in Switzerland uses between 3000 and 5000 kwh of electricity per year. Heating, cooling, lighting, cooking, information processing, entertainment, humidification or dehumidification: electricity provides support for all of these processes. Residents, from children to the elderly, are completely aware of the process of turning on and off electricity, with switches or dimmers. Although mishandling can lead to injury or even death, it is totally accepted today as an integral part of our building culture.

Gallery 16.1 Building use of electricity

Bettschart, M. 2010. *Electricity as source of lighting for the interior and exterior of buildings.* [Photograph]. Singapore.

Urban use of electricity

The electrification of cities occurred early on. Extensive streetlighting, electric escalators, trams and buses were the first implementations of electrification. Typically, human, animal, wood or coal powered mechanical systems were replaced with electrically powered engines. Today, electric systems are embedded in every single component of the urban system, from surveillance cameras to above ground or below ground communication lines or power lines, to subways and cooling towers.

Gallery 16.2 Urban use of electricity

Schmitt, G. 2011. *Cooling towers occupy most of the roofs of high-rise buildings in modern cities.* [Photograph]. Seoul, South Korea.

Territorial use of electricity

Electrification played a major role in connecting cities in the territories of the industrialising countries of the 19th and 20th century. Electrified high-speed trains transferred states and countries and also connected nations. Electricity opened up new transportation possibilities in tunnels, because the source of producing electricity is remote from its use. Electrically driven hydraulic pumps regulate water gates on rivers or dams. Electricity in large quantities is needed to produce copper.

Gallery 16.3 Building electricity production

Schmitt, G. 2007. *Electricity from Argentina as essential energy for the production of copper in Chile.* [Photograph]. Atacama desert.

Network use of electricity

Global networks gain importance in the 21st-century. Almost all of these networks are driven or supported by electricity. Transcontinental underwater cables need repeaters to transport information. More prominent in recent years, supercomputers, data storage devices and data centres emerge close to cities or in remote areas all around the world, where cooling is not a problem. The energy consumption of those centres in the form of electricity begins to rival that of international air transport.

Gallery 16.4 Network use of electricity

Schmitt, G. 2011. *The K supercomputer in Kobe, Japan has an installed cooling capacity of almost 30 MW.* [Photograph].

Building electricity infrastructure

In old buildings, free electric cables can be found hanging around the rooms, and in the basements sometimes the electric lines can be followed to reach the fuse boxes. Yet increasingly, the building electricity infrastructure becomes invisible by design, to reduce the danger of accidentally being exposed to high voltage. They only visible elements left are switches and power plugs, secured by different standards worldwide. Nowadays, specialists are needed in order to extend or repair this infrastructure.

Gallery 16.5 Building electricity infrastructure

Schmitt, G. 2009. *Light fixtures and sensors as visible electricity infrastructure in the Monte Rosa shelter.* [Photograph].

Urban electricity infrastructure

Electricity needs to enter the building from the distribution network of the city scale. Tall wooden poles were the first solution to this design problem. They carry the cables transporting electricity and complication beside the streets, and from there inside the building. In advanced cities, the distribution occurs underground. In the future, this network will increasingly transport the electricity back from the building into the network.

Gallery 16.6 Urban electricity infrastructure

Bettschart, F. 2012. *Electricity infrastructure. Multiple lines collect on concrete poles.* [Photograph]. Ho Chi Minh City, Vietnam.

Territorial electricity infrastructure

In territorial level, electricity infrastructure mainly corresponds to high-voltage transmission lines that criss-cross all countries and deliver high voltage electricity. Although they compose an efficient infrastructure of distribution, they often ruin the landscape views. Often, they are under attack from environmental organisations, due to the potential health risks. In general, building sites under high-voltage transmission lines do not have high value. As an alternative, underground distribution is also possible for high-voltage.

Gallery 16.7 Territorial electricity infrastructure

Schmitt, G. 2012. *High voltage power lines crossing oil palm plantations.* [Photograph]. Malaysia.

Network electricity infrastructure

Network electricity infrastructure resembles territorial electricity infrastructure, yet it can develop its own, sometimes surprising, forms. Examples are data centres in the Arctic to avoid high cooling costs, or data centres cattle farms with several thousand cattle providing the biogas to generate the electricity needed to run and cool the centre. Data centres can also contribute to district heating when they are placed inside cities in cool climates.

Gallery 16.8 Network electricity infrastructure

Schmitt, G. 2009. *Train networks as one of the first network electricity infrastructures.* [Photograph]. Rottweil, Germany.

Building electricity production

Photovoltaic and wind are the most popular building electricity production elements. Roofs are most suited to collect the sun‘s energy and to convert about 15 to 20% of it into electricity. After 30 years of research and small-scale tests, photovoltaic is becoming a feasible alternative for building owners to generate their own electricity or even sell it to the grid. Electricity generation with small windmills or light wind constructions is possible, but less popular. All of this might change, once building electricity production becomes part of lifestyle.

Gallery 16.9 Building electricity production

Schmitt, G. 2009. *The Monte Rosa shelter produces all of its electricity with photovoltaic elements.* [Photograph].

Urban electricity production

On the urban scale, electricity production has a long tradition. Water and wind where the first sources, while more recently photovoltaics have become an additional alternative. The fast flowing rivers through cities may be used to generate electricity, but will normally not be enough. Biogas plants, wind farms, or photovoltaic plants may also supplement the electricity needs of the city. However, large cities and megacities need to import most of their electricity from their hinterland or from the territory.

Gallery 16.10 Urban electricity production

Schmitt, G. 2011. *A 265 kW biogas plant supplying electricity for a part of a small town.* [Photograph]. Kastanienhof, Wadern, Germany.

Territorial electricity production

The territory is ideal for large scale electricity production. Gigantic dams, nuclear power plants, coal, oil, or gas power plants are distributed throughout the territory in the most appropriate locations, mostly remote from city centres. Wind farms begin to populate portions of Europe, North America and China, both onshore and offshore. Large biogas or waste to energy plants collect the necessary energy sources and produce electricity centrally. Yet the leftovers of the production are a problem everywhere.

Network electricity production

The electricity grid increasingly transcends national borders, and has already crossed continents. There are powerlines between Africa and Europe, or between Asia and Oceania. This fact increasingly broadens the opportunity for network electricity production. The most well-known are the Desertec initiative in northern Africa, which would be able to supply more than one fifth of Europe's electricity needs, or the gigantic Grenatec network reaching from Australia through the ASEAN countries to China and beyond.

Building electricity storage

Building electricity storage is in its infancy, although it has been a topic of active research since the 1950s. Batteries are the most obvious possibility, but also low scale versions of the large-scale energy storage devices of thinkable, such as compressed air or water tanks on top of high-rise buildings. Building electricity storage will become increasingly important, as a measure to reduce peak loads on the grid, converting buildings into smart elements in the smart grid of the future.

Urban electricity storage

Cities and urban systems have more effective ways to store energy to be converted back, almost loss-free, into electricity. They can use city internal lakes or compressed air tanks, but through incentives and legislation they could increasingly use also the batteries in electric vehicles as a temporary electricity storage, that could reduce the load on the system significantly. Yet more than storing energy, cities will have the opportunity to balance the energy use in a smart grid, by smart pricing.

Territorial electricity storage

On the territorial scale, water is probably the most efficient way to store energy to be converted back into electricity on short notice. This involves pumping water into a reservoir when electricity surplus is sufficient, and retrieving the energy in form of electricity in periods of high demand. Switzerland, Norway, and Germany are actively using this technology on the large-scale. In addition, high-pressure underground air storage is thinkable.

Network electricity storage

As it is difficult on a large scale to store electricity directly, network electricity storage involves the transformation and storage of energy that can be easily reconstructed into electricity. This involves, like into return electricity storage, the use of dams and lakes, but also the production of hydrogen or methane with excessive availability of energy sources at times when there is no demand for electricity. These sources can store the energy that is later rapidly transformed back into electricity.

Gallery 16.11 Network electricity storage

Schmitt, G. 2011. *Sihlsee close to Einsiedeln, as a network electricity storage device with a capacity of 245 MW.* [Photograph]. Switzerland.

Section 2

Photovoltaics

PHOTOVOLTAIC INDUSTRY

The photovoltaic industry is an industry that has grown in double-digits since the beginning of the new millennium. In several countries, the cost of producing electricity from photovoltaic elements has reached parity with other energy transformation technologies, such as natural gas, nuclear or oil. Yet while most experts were monitoring closely development of production costs, others had their doubts about the enormous amount of fossil energy that would go into the production of the actual photovoltaic modules.

Yet the shakeout within the industry after 2010 has led to the necessity to reduce the energy input into the production of photovoltaic modules drastically, which will lead to the fact that after 2015 the net clean electricity production from photovoltaics worldwide will be a reality.

Being a very special technology and crucial for the advance of the use of alternative energies, we dedicate a section to photovoltaics. The principle has been known for decades, and large-scale installations were first implemented in Germany and California already in the 70s and 80s of the last century. But it was not until the German government implemented specific incentives for the production of electricity and it‘s guaranteed purchase price back to the utilities that the installation of photovoltaics took off. Quickly, Germany became a leader in the production of photovoltaic elements, as well as in their widespread installation. While after the first decade of the 21st century factories in China were able to produce and sell photo tag modules at a lower price than any other country, most of the football tight production companies in Germany went bankrupt. However, the installation of photovoltaic elements, based on the attractive incentive by the government to produce energy, continued. In 2013, 40% of the world’s full double photovoltaics production area was installed in Germany, with other countries catching up quickly.

The promoters of photovoltaic had a clear agenda. The opponents argued successfully and often, that the production of the foot will require more energy than it would ever produce. Yet only in 2013, conclusive studies appeared that after 2015 the net energy bands worldwide should be positive. (Golden, 2013)

Section 3

Transport infrastructure

TRANSPORTATION INFRASTRUCTURE

Transportation infrastructure comes in many forms and it is probably the best known of all infrastructures: walkways, paths, elevators, cranes, container harbors, streets, roads, freeways, train tracks, rivers, airports or cosmodromes come to mind immediately.

Transportation infrastructure requires the planning and the investment in future of transportation needs for people or goods. It provides the framework for most human activities and interactions. It is an important element on the building scale in the form of stairs or corridors, on the urban scale in the form of walkways and streets, and upon the territorial scale in the form of highways, trailers and waterways. It has produced its own architectural expressions and will involve rapidly in the coming decade with the emergence of alternative transportation engines.

Transport infrastructure determines to a high degree our interaction with the natural and the built environment on a daily basis. In our apartment building, we use the corridors and stairs to reach the car or bicycle for private transportation or the bus, the train, or the subway for public transportation to get to work. We might use the railway, crossing mountains and rivers in tunnels and bridges to reach our destination. We might arrive at the Seaport to buy fish or to depart for a cruise, or we might just cross the river with the ferry. Transport infrastructure guarantees our mobility, a basic human need.

Transport infrastructure is also an example of the principle of stocks and flows: it guarantees that a stock can be moved from one place to the next in the most efficient and careful way, thus creating a flow of people or goods without accidents or losses. This requires sophisticated maintenance with the goal that the infrastructure has to be kept at the level of performance that it was designed for. This leads to the fact that in countries with excellent transportation infrastructure a significant part of the overall budget is going in to the constant maintenance and update of this infrastructure. Once neglected over a short or extended period of time, it becomes more and more difficult to restore the transport infrastructure to its previous level of performance. This applies to all types of transport infrastructure.

Interactive 16.1 Water Transportation infrastructure

Interactive 16.2 Mass transportation infrastructure