**Web lecture 7.2.2. _transcript**

In the previous modules you have seen that urbanization is a pervasive phenomenon in today's world. This makes it all the more relevant to investigate if urbanization as such is good or bad news for the environment, and to investigate what role infrastructures can play in building eco-cities, and in eco-transformation of existing cities.

Let me briefly go back to the essence of a city. Its physical expression is in the built environment: homes, offices, industrial facilities, and infrastructures. A city is not only defined by its physical dimension. It is also defined by its socio-economic dimension, including for example labor market, jurisdictions, commuting patterns, and by its cultural dimension, which gives it a distinct identity. The city is a socio-technical system, and given the many non-linearities in the interactions between citizens, authorities, industries and other actors, within and with the built environment, it is also a complex adaptive system.

Previously I showed you how the Pearl River Delta changed over the past decades. The NASA satellite images do not leave room for any doubt that the natural environment was drastically changed as a result. Nature made way for buildings and pavements. Habitats have shrunk and been lost. Rural agriculture has been replaced by manufacturing industries. Surface waters have been polluted, and air quality has been affected by particulate and gaseous emissions from industry, power plants and car traffic. Cities worldwide account for nearly 70% of global $CO_2$ emissions, they demand huge amounts of resources and produce huge amounts of waste.

Does all this imply that urbanization is bad news for the environment by definition? The short answer is: it is often so, but it is not inevitably so. Urbanization can be good news for the environment, as cities can achieve higher levels of resource efficiency than can be accomplished in a sparsely populated rural area.

I already explained that cities do more with less, in comparison with rural areas. And the bigger cities get, the more productive and efficient they tend to become, as found by Luis Bettencourt and Geoffrey West (Source: Luis M.A. Bettencourt and Geoffrey B. West, Scientific American, August 17, 2011).

When the size of a city doubles, its material infrastructure—think of the total length of roads, pipelines, or cables—does not. Instead these quantities rise more slowly than population size: a city of eight million typically needs 15 percent less of the same infrastructure than do two cities of four million each. In terms of physical infrastructure needs, cities show a sublinear scaling pattern: the bigger the city, the more efficient its use of infrastructure, leading to important savings in materials, energy and emissions.

Besides Luis Bettencourt and Geoffrey West at the Santa Fe institute, many other research groups in the world are working on a better understanding of cities as complex systems, and on visualizing the emerging structures and dynamics of cities. Let me briefly refer you to

Michael Batty and his co-workers at the Bartlett Centre for Advanced Spatial Analysis, at University College London, and to the work of Juval Portugali, at Tel Aviv University.

Density is of course a factor that influences how efficient a city can be. This can be illustrated from a comparison between cities worldwide of per capita energy consumption for transport. As shown in this graph, the densely populated megacities in Asia are far more efficient than the relatively thinly populated American cities. In the list of 26 megacities that I showed you previously, New York City is the one with the lowest population density, whereas it is relatively densely populated in comparison with other cities in the US. In a denser, more compact city, people consume less energy resources for transportation, as walking, cycling and public transport are viable alternatives to commute for many of them. In a less densely populated city, however, where there is no viable business case for public transport, people keep commuting in private cars, thus using more energy, emitting car exhaust fumes and clogging the city's road system.

According to Mark Roseland and Fiona Harvey, eco-cities should be built according to the following principles:

- Has a well-planned city layout and public transportation system that makes the priority methods of transportation as follows possible: walking first, then cycling, and then public transportation.
- Operates on a self-contained economy, resources needed are found locally
- Has completely carbon-neutral and renewable energy production
- Resource conservation—maximizing efficiency of water and energy resources, constructing a waste management system that can recycle waste and reuse it, creating a zero-waste system
- Restores environmentally damaged urban areas
- Ensures decent and affordable housing for all socio-economic and ethnic groups and improve jobs opportunities for disadvantaged groups, such as women, minorities, and the disabled
- Supports local agriculture and produce
- Promotes voluntary simplicity in lifestyle choices, decreasing material consumption, and increasing awareness of environmental and sustainability issues.

As we can see at a glance, many of these criteria are not easily applicable to megacities.

It is hard to imagine a megacity which is completely self-sufficient in food, water and energy. In rural areas, where people live in a relatively isolated fashion, it may be possible to be self-sufficient. However, the rural model of living off-grid, with solar panels on your roof, cutting your own trees for firewood, pumping water from your own well, disposing of your waste water in your own septic tank, and burning your own waste, or leaving it in your backyard, is not feasible in cities. It does not take much imagination to see what would happen if city dwellers would to the same thing - the city would be unlivable. Only the solar panels would be applicable in the city, but you will understand that the roof surface area available in a dense city with many high rise buildings would probably not be enough to provide electricity to all the people living under those roofs. Renewable energy needs space, and space is a scarce, and therefore expensive commodity in cities.

Densely populated megacities need to harvest their renewable energy resources outside the city, implying that wind parks, PV parks, concentrated solar power plants and hydropower plants located at favourable locations, often far from the city, must supply the city through the transmission grid. Considering the current state of the art in renewable energy technologies, it is hard to imagine a megacity that would be self-sufficient in renewable energy.

The good news is that the provision of water and energy to urban residents and the removal of waste and waste water can be accomplished with higher efficiency and with better quality of service than in rural areas, as infrastructures can do the trick, building on economies of scale and scope. Let me give you an example:

AEB, the Amsterdam Waste and Energy company, owned by the Amsterdam municipal authorities, annually processes 1.4 million tonnes of municipal and commercial waste. In its waste to energy plant, the waste is incinerated, producing 900 kWh of electricity and 91 kWh of heat for district heating per tonne of waste processed. By separation processes before and after combustion, ferrous and non-ferrous metals are separated and recycled. Per tonne of waste, AEB produces 16 kg of iron, 3 kg of other metals (e.g. copper and aluminium), 4.5 kg of gypsum (separated from the flue gas) and 209 kg of construction material (as an alternative for gravel and sand). The company supplies steam to industries in its vicinity (within a 5 km radius) and supplies lower temperature heat to 20,000 homes connected to its district heating network. The ambition is to expand the district heating network to 230,000 homes in 2040.

The Amsterdam water utility, Waternet, which produces drinking water for the city of Amsterdam and treats its waste water, supplies the biogas produced from its wastewater treatment plant to AEB for conversion into electricity and heat. At present, due to improved efficiency in waste water processing and in the collection of organic waste, the amount of biogas produced has increased to the extent that Amsterdam is becoming a green gas producer. The biogas is upgraded to the Dutch natural gas quality standard and sold as green gas in the market.

The distribution of heat, as steam or as hot water, is not economical over large distances. Therefore, the denser the city, the more economically waste heat can be put to use for residential heating. Whereas the Netherlands is just starting on the path of using waste heat from cogeneration units, thermal power plants, waste incineration plants and other industrial sources for district heating, Denmark is a country with a long standing tradition of district heating. Denmark is now using its district heating systems to store energy during days of surplus wind power. For this purpose, they use large immersion heaters to convert electricity to heat, which allows the cogeneration plants to be shut down temporarily, thus reducing fossil fuel use and reducing the overall carbon intensity of the Danish energy system.

In the surroundings of the city of Leeuwarden in The Netherlands, which is situated in an area dominated by dairy farms, biogas is harvested abundantly. The biogas is used to fuel co-generation plants that supply electricity to the local distribution grid and heat to residential districts. The province is the first in the Netherlands where a biogas infrastructure is being developed, enabling a multitude of farms which produce biogas from manure fermentation to feed their biogas into the pipeline system and transport it to a central plant, where the biogas is upgraded to green gas. The green gas is either fed into the natural gas distribution grid, but it is also used as a car fuel.

The Danish city of Sonderborg, with approx. 76,000 inhabitants, is one of the cities in Europe that) made an explicit decision to shift to a zero carbon green economy. Sonderborg's objective is to become carbon neutral by 2029. To this end, the municipality and district heating suppliers established a partnership, with citizen participation. Among the actions already under way are:

- replacement of natural gas in district heating with geothermal, solar, biomass etc.;
- a new pipeline connecting all existing district heating networks;
- generating biogas from pig manure, organic waste and energy crops;
- generating power from biogas, wind and photovoltaic;
- installing photovoltaic cells and heat pumps in rural areas.

However, in the words of Andris Piebalgs, former European Commissioner for Energy: "The cheapest, most competitive, cleanest, and most secure form of energy for the European Union thus remains saved energy." Especially in the built environment, there is tremendous potential for energy saving, by designing homes for better use of natural light, natural ventilation rather than air conditioning systems, and for better heat (or cold) retention. The latter is a matter of building quality, and standards such as LEED and BREEAM are in place to ensure energy saving, both at the level of individual buildings and at the level of neighborhoods, districts and cities. In the existing building stock, much can be improved with thermal insulation, more efficient heating/cooling systems, and low-energy glazing.