Chapter 9
Cities as Organisms

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Abstract Since the UN report by the Brundtland Committee, sustainability in the built environment has mainly been seen from a technical focus on single buildings or products. With the energy efficiency approaching 100%, fossil resources depleting and a considerable part of the world still in need of better prosperity, the playing field of a technical focus has become very limited. It will most probably not lead to the sustainable development needed to avoid irreversible effects on climate, energy provision and, not least, society.

Cities are complex structures of independently functioning elements, all of which are nevertheless connected to different forms of infrastructure, which provide the necessary sources or solve the release of waste material. With the current ambitions regarding carbon- or energy-neutrality, retreating again to the scale of a building is likely to fail. Within an urban context a single building cannot become fully resource-independent, and need not, from our viewpoint. Cities should be considered as an organism that has the ability to intelligently exchange sources and waste flows. Especially in terms of energy, it can be made clear that the present situation in most cities are undesired: there is simultaneous demand for heat and cold, and in summer a lot of excess energy is lost, which needs to be produced again in winter. The solution for this is a system that intelligently exchanges and stores essential sources, e.g. energy, and that optimally utilises waste flows.

This new approach will be discussed and exemplified. The Rotterdam Energy Approach and Planning (REAP) will be illustrated as a means for urban planning, whereas Swarm Planning will be introduced as another nature-based principle for swift changes towards sustainability.

Keywords Sustainable development • Energy neutrality • Carbon neutrality • Biomimetrics • Organisms • REAP • Swarm Planning

9.1 Background

Although the earth receives almost 9,000 times more energy from the sun than that mankind needs, energy is becoming a huge problem. Western societies rely heavily on energy, fossil fuels in particular. The Netherlands for instance produces less than 4% of its energy by means of sustainable sources (CBS 2008). The rest is fossils and a bit of imported nuclear energy. As Mackay (2009) demonstrated, it is very difficult

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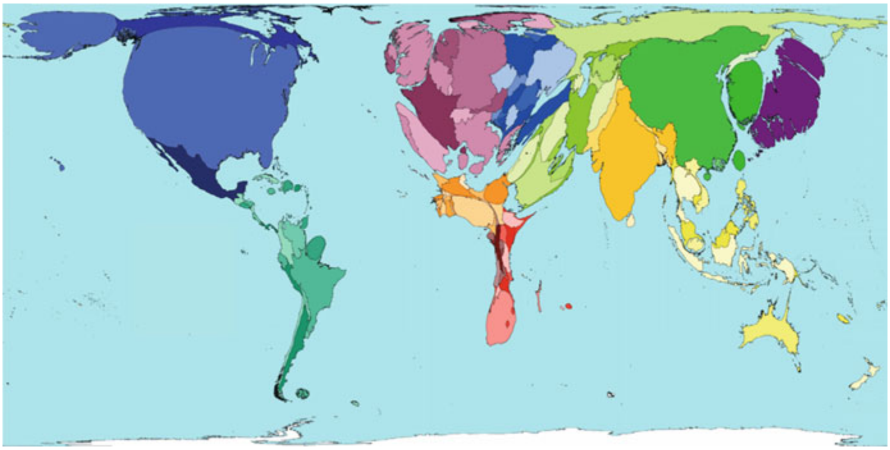

Fig. 9.1 Developed countries above the equator infest on other regions for energy… Countries and the area of land respective to the amount of fuel they consume (Dorling et al. 2009, downloadable from www.worldmapper.org)

to establish a society fully run on renewables. However, Cullen and Alwood (2010) showed that most of the energy we use is lost as non-functional waste energy. So the initial demand can be reduced by more effective usage, such as by low-exergy means (Stremke et al. 2011).

Although estimates of resources fluctuate, it is apparent to both energy experts and oil companies that the end is coming near. We have passed peak oil (ITPOES 2010): these days we consume more oil than can be produced. That this is a literally dangerous situation was demonstrated by the two gulf wars and recent turmoil around gas from Russia (first: Ukraine disconnected, second: Belarus threatening to halt the throughput of Russian gas). Apart from this international perspective and its influence on the price of energy, few people from the West understand how dependent they have become on energy, and that a collapse in the provision would have devastating effects to everyday life.

Last but certainly not least, the western hunger – or rather thirst – for energy is severely limiting the opportunities of developing and emerging regions to catch up in prosperity. As Fig. 9.1 indicates, western countries owe their prosperity to limited use of energy in other parts of the world. Needless to say this situation deviates strongly from the equity goals posed by the Brundtland Committee in 1987.

The abundance – until now – and relatively cheap and easy access to fossil energy has made the world lazy and inactive to search for local possibilities that would avoid demand from alien energy in the first place. We need to learn this again: planning and designing in such a way that local resources are optimally seized before any demand is posed upon other areas. Methods as Energy Potential Mapping (EPM) (Dobbelsteen et al. 2007) can support this.

In addition to and in relation with this new focus needed on local potentials, energy systems better based on (non-squandering) natural principles may support a shift towards more sustainable cities and regions.

9.2 The City as Organism

9.2.1 Introduction

Man has lived in cities for some 8,000 years. During this time cities have become “the most complex thing man has designed” (Richard Rogers and Kenneth Powell), as they draw in resources from many global sources and produce many streams of waste, at one level and function as highly tuned psycho-geographic entities at another. The urban dependence on lands outside the city borders has become irresponsible and will eventually lead to the city’s demise, as many predecessors from the past have experienced (think of the Mayan cities and most of the original classical metropolises). With resources depleting, fossil fuels in particular, the need to become at least partly autonomous and less vulnerable is urgent.

In his book ‘Creating Sustainable Cities’, Herbert Girardet (1999) likened the modern city to a superorganism, rather like a bee-hive or termite mound, and it is this concept that this paper intends to develop. If we are looking for models of sustainability, then life having been on the planet for some 4 billion years should offer some models and ideas for our engagement with the ecology we find ourselves in. However ‘life’ itself is a complex notion and offers many examples of success from viruses to polar bears and trees. With so many different types of engagement by life-forms with their ecologies available, just how do we choose and use these varied exemplars to develop an ecological model of the function and form of the modern city.

Life can be seen, argues Keosian (1964) in his seminal text ‘The Origin of Life’, not only as an individual entity but also as a collective entity. Each view possesses different factors that define the key elements of living things. The superorganism is a particularly interesting concept as it possesses not only the factors of a single life-form but also those of life in a collective sense. This means that if the city is a true superorganism, then its structure and processes will be varied and complex, and nested at a range of scales.

The city may be complex and thus in compliance with the superorganism of Girardet, but it does not necessarily mean that it is an intelligent superorganism. The way in which most of our present-day needs are served resembles a system of infinite throughput without recycling or feeding loops to the places resources initially came from. And this is facilitated by a centralised system that hardly interacts with local circumstances, or reverse. In fact, the city functions as the ‘intensive care of a hospital’ (Dobbelsteen 2010): a collection of individual edifices, which fully rely on the central provision of water, food, materials, gas, electricity, telecommunication, sewage and other waste collection. Disposal of waste heat and discharge of rain water are not considered as the loss of valuable sources or as the burden shift to elsewhere, what these actually are.

Just as sustainable architecture – climatic design in particular – can learn from nature and become a servile form of biomimicry (Benyus 2002), cities and their systems of essential flows (Timmeren 2006) could learn from nature too and copy functional, practical and sustainable elements to become an intelligent anthropogenic superorganism.

9.2.2 A Definition of Life

Let us learn from natural life first.

The living autonomous city will contain both the factors of an individual life-form and those of life as a collective entity. Keosian (1964) defined individual life as an open system, powered by sunlight and having five key defining factors, namely Order, Energy, Separation, Self-perpetuation and Evolution, each being necessary in all living things. In addition to these, life is also a collective thing – working within small open system we call ecologies, this also has defining factors that are subtly different. These are: Order, Energy, Homeostasis, Cybernetic systems and finally Separation. Each of these factors needs to be present for a system to be considered 'alive'.

9.2.3 Features of Individual and Collective Life

9.2.3.1 Order

All living things exhibit order, compared to the chaos of non-living entities. The order expresses itself in the way of structure, and this structure manifests itself in the way of a synergy, where the sum is greater than the parts. In a collective sense, order is characterised by life's structure consisting of a complex system of interdependent organic systems, acting within a closed materials system.

Cities, from their very initiation, have been ordered, sometimes explicitly and sometimes by emergent forces. Good examples of the first are the grids of Manhattan or the *Eixample* of Barcelona. Less formally planned cities also exhibit order, such as Damascus, where courts and narrow streets create shade. This shade then provides cooling for buildings and also niches for various activities to take place. This exhibits the idea of synergy, where the juxtaposition of elements creates extra possibilities. This can be manifest in non-visual structures too such as exergy nets, or closed-cycle planning.

9.2.3.2 Energy

All living things expend energy as life is an open system directly dependent on the sun for its energy. Collective life can be seen as an unsustainable open system of energy, ultimately dependent on solar energy. This use of energy is manifest as a creature's metabolism, a cyclical process, which transports and transforms energy around the entity and makes it useful to do work. Secondly all living things store

Fig. 9.2 A bean plant does not squander its energy: it uses its finite energy source, contained in the bean, to build up a sustainable system of solar panels, the leaves

energy for times of hunger, as food is not always available, and this creates a rhythm based around solar cycles that promote activity and dormancy. In close interrelationship with the features mentioned, an intelligent energy system – which organisms that have survived over a long time demonstrate – needs to be responsive to alterations in climatic conditions, the weather and other circumstances. Homeostasis, comprising a myriad of mechanisms for instance to battle cold or heat, is a means to sustain itself under extreme conditions. Also for collective life it is the constant evolution to regulate the environment at a favourable condition.

In the modern city, the energy issues are more problematic in our definition of 'living' as fossil fuels – which are ancient sunlight - have led to very skewed practices. The living city will be a solar city, collecting, storing and transporting energy within it. This is entirely possible, considering that even in Manchester (United Kingdom, Latitude 54°N) enough energy falls on the city from the Sun in 1 day in June to power the city for a year. The issue is not the amount of energy available, but the methods of collection, storage and utilisation. Individual buildings need to be designed to collect the sun and not shade others (Keeffe and Martin 2007), and a light – stratified – system of development (like a forest) needs to be put in place. Moreover, intelligent cities will be responsive to alterations to circumstances that endanger the sustenance of its being and have mechanisms by which a stable situation can be pertained or returned to equilibrium (Fig. 9.2).

9.2.3.3 Separation

Life exists within and maintains defined boundaries, which act to mediate between the internal-external conditions. Every organism has a protective skin that separates the (vulnerable) inside from the outside. Apart from separation it is the direct intermediary between inside and outside, so interaction can be established best through the skin.

In cities, separation is not as apparent as with individual buildings: the building envelope plays an important role in the separation between indoors and outdoors and should be the building component where intelligent interaction can be performed between the two environments.

9.2.3.4 Self-Perpetuation

Without self-perpetuation living beings would not survive. It is the sole reason for existence: no organism lives to die; it lives to perpetuate its life and produce offspring. In that sense, sustainable development as defined by the World Commission on Environment and Development (Brundtland et al. 1987) has a direct natural, biological foundation.

Cities should be focused on self-perpetuation as well. Currently they are not. For the time being they still snooze under the comfortable condition of abundance outside the city, never questioning the limit to this. Only in the occasional event of misfortune (a power plant that temporarily hampers, a broken drinking water pipe) one experiences the malady of being powerless when dependent on centralised utilities. Self-perpetuation is the quintessence of the sustainable city.

9.2.3.5 Evolution

Standstill is backward development. Creatures need to develop, both as an individual and as a species. Growth not necessarily means more yet better, so evolution's main aim is to make an individual or species stronger. Since life is never constant, also cities need to evolve into better, more efficient, more resilient organisms.

9.2.3.6 Cybernetic Systems

In addition to these characteristics, collective life also has cybernetic systems, active-control systems utilising negative feedback systems, which maintain homeostasis. In a way the human system of a city region perhaps also has a similar cybernetic mechanism but only in a centralised, tardy way. Sustainable cities should have cybernetic control on various scales and responding rapidly to altering conditions (for instance the weather, supply of resources, over-production).

9.2.3.7 Symbiosis

In nature symbiosis occurs a lot. Organisms support one another, such as hippos cleansed from parasites by fish, which in their turn live of the nutrient-rich manure from hippos. This perhaps may not seem easily translatable to cities, but this kind of interaction could be superposed on the use of energy. In cities a lot of energy is used and wasted without symbiosis. The following will describe an urban energy system that is more in accordance with intelligent organisms.

9.3 Cities and Energy

9.3.1 Cities Rather than Buildings

Urban design and the fundamental principles of how to shape our cities, has so far barely featured in the greenhouse debate. The urban dimension and the macro-scale of cities were mostly missing in the debate of the 1980s and early 1990s, as sustainability was predominantly discussed as being about 'alternative lifestyles'. Much of the more recent debate has circled around ideas about active technology for 'eco-buildings' and sophisticated façade technology - rather than about urban issues. Nevertheless, "sustainable architecture is only really effective when set in an urban planning context which itself is based on sustainable principles" (Gauzin-Müller and Favet 2008).

9.3.2 Energy and Climate

The energy system in our cities is mostly based on our winter climate and appears not to be flexible when it comes to seasonal changes. Climate change will bring a shift from mainly heat demand to more cooling demand, since winters will become milder and hot summer days will increase. To be able to maintain comfortable indoor climates the energy system in a city should also be designed on the summer cooling demand.

9.3.3 Excess and Shortage

The way cities consume energy can be very well described as autistic. Only high quality energy is used as input, while many processes can do with lower quality energy. This results in high energy-consumption with a high amount of waste energy. In an intelligent system this waste heat can directly be input for another function. If there is a surplus of heat in the summer season heat can be stored in aquifers and used again in winter.

Fig. 9.3 Energy demand by different urban functions (*W* = heat, *K* = cold, *E* = electricity): different patterns occur at the mean time, causing unnecessary use of energy (Image by DSA)

Another way to increase energy efficiency from sustainable recourses is to respond more to the supply rather than the demand. During windy or sunny periods more energy is available, but because the net cannot deliver extra energy and the cost to store this are too high, wind turbines are halted at a certain speed. Chargeable batteries connected to the net can have an intelligent interface, which starts charging when there is a surplus of energy. An extra stimulation can be given to vary the price according to the available supply. In this way laptops, phones, electrical bikes and in the coming years also cars can function together as a large battery for wind energy (Fig. 9.3).

9.4 Approaches to Becoming Autonomous

9.4.1 The Rotterdam Energy Approach and Planning (REAP)

The New Stepped Strategy (Dobbelsteen 2008), based on the three steps strategy or Trias Energetica (Lysen 1996), runs as follows:

1. Reduce consumption (using intelligent and bioclimate design)
2. Reuse waste energy streams
3. Use renewable energy sources and ensure that waste is reused as food
4. Supply the remaining demand cleanly and efficiently

Of which the latter step may be forgotten when design for a future that will lack these finite resources (Fig. 9.4).

This way it advocates optimal use of waste streams not only for each individual building but also on a citywide scale. Waste streams from one chain may be used in a different chain. For example, wastewater can be purified and the silt fermented to form bio-gas which can be reused in the energy chain.

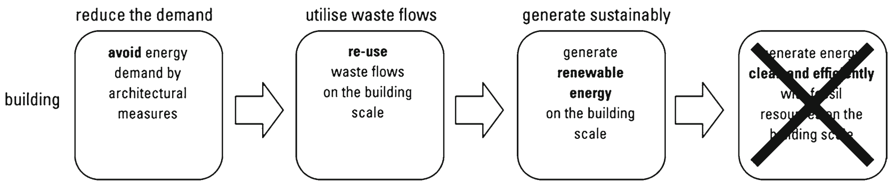

Fig. 9.4 The new stepped strategy

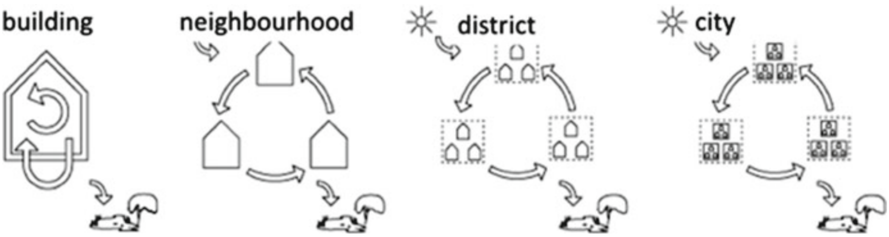

Fig. 9.5 Reuse of waste flows and upscaling from building to city level

9.4.1.1 Exchanging and Cascading Energy

According to the 1st Law of Thermodynamics, energy is never lost, but the second Law describes the increase of entropy, implying the decrease of something else. This is exergy. Exergy is a combination property of a system and its environment because unlike energy it depends on the state of both the system and environment.

When we look at the way our energy system is organized, then you see that 98% of the energy that is consumed is primary produced energy from fossil and nuclear sources. While at the final stage a lot of waste heat is lost in the air, water and soil.

High quality energy like natural gas that has a temperature of 1,200–1,500° should be used for processes that actually require this temperature like some industrial processes. But for the heating of a house to 20° this is not necessary. If the energy system of a house is well designed a temperature between 25° and 40° is sufficient. Therefore waste heat from greenhouses or from supermarkets can heat dwellings and functions, which need higher quality energy can be supplied by even higher processes. In such a low-ex system the consumption of primary energy is much lower because only the highest quality functions use fossil and nuclear energy. A system of cascading of energy qualities can improve our energy system by a factor of 6 (Tillie et al. 2009).

These principles of reusing waste flows from one function in others, which can still profit from them and can be extended by exchanging within neighbourhoods, districts and the entire city, serving the symbiosis principle of nature (Fig. 9.5). This is the key message behind the Rotterdam Energy Approach and Planning (REAP), which is discussed more elaborately else in these proceedings (Tillie et al. 2010), which is used in the Dutch *mainport* city of Rotterdam, yet also in other cities that follow the example. The REAP method is currently even converted to a similar method for other flows than energy: water, materials and food.

9.4.2 Swarm Planning

Not just our consumption of energy demands for radical changes. Climate change is affecting our natural, social and technical systems fundamentally. These changes take place over longer periods and emerge slowly. In contrast, current planning systems focus on short periods and try to enforce immediate changes.

Meanwhile, society is becoming more complex, as are developed ecosystems in nature themselves. This complexity of interactions requires a spatial system to change its conditions rapidly and frequently. In contemporary planning practice designs are mostly fixed images of the future.

To realise energy-autonomous and climate-proof designs in an increasing complex society a new planning paradigm must be developed, which is capable of integrating long term aims and is flexible enough to respond to the complex society. This regional or urban planning approach needs to incorporate future developments and let these single developments influence the entire regional system. Main objective is to make use of these individual changes, instead of trying to reduce the effects of changes. The new planning methodology can be called Swarm Planning (Roggema and Dobbelsteen 2008).

Swarm Planning is a metaphor for a planning method in which the aim is to give incentives at certain points, which change the entire region and society, just like a swarm of birds that changes its shape suddenly as a result of one simple impulse. In this sense Swarm Planning is another unlikely biomimetic principle to be applied to planning.

The hypothesis is that planning in a swarm-way is very useful in complex systems and if the issues are long term oriented. Insights from both complexity theory and marketing are used to build up this new planning method. For Swarm Planning significant parameters of climate change and energy provision need to be thoroughly analysed by their spatial impact. Hence, mapping them can be helpful. The major twist is made in defining the right impulses to adapt the urban or regional society to foreseen changes. Network analysis is one of the tools to be used then.

Swarm planning is currently elaborated and tested on various locations and situations.

9.5 Conclusion

We are only at the start of comprehending natural principles related to life and translating these to the techno-sphere we create: products, buildings and cities. Especially cities can learn from life in nature and copy characteristics that make organisms survive and evolve. This is particularly so with the current and upcoming developments in regards to the availability or resources, such as fossil fuels.

A sustainable city can and should transform from a collection of individual buildings, which jointly rely fully on the provision of essential flows from a distant centralised facility, to an intelligent organism that has all features of life of individual and collective organisms. In this paper we attempted a first step to translate theory on this to urban principles and exemplified it through the Rotterdam Energy Approach & Planning (REAP) and Swarm Planning. It is but a modest start, however important considering the immense changes needed for cities to become sustainable.

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