Cities Ready for Energy Crises - Building Urban energy Resilience

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CITIES READY FOR ENERGY CRISES – BUILDING URBAN ENERGY-RESILIENCE

Summary

Various sources indicate that threats to modern cities lie in the availability of essential streams, among which energy. Most cities are strongly reliant on fossil fuels; not one case of a fully self-sufficient city is known. Engineering resilience is the rate at which a system returns to a single steady or cyclic state following a perturbation. Certain resilience, for the duration of a crisis, would improve the urban capability to survive such a period without drastic measures.

The capability of cities to prepare for and respond to energy crises in the near future is supported by greater or temporary self-sufficiency. The objective of the underlying research is a model for a city – including its surrounding rural area – that can sustain energy crises. Therefore, accurate monitoring of the current urban metabolism is needed for the use of energy. This can be used to pinpoint problem areas. Furthermore, a sustainable energy system is needed, in which the cycle is better closed. This will require a three-stepped approach of energy savings, energy exchange and sustainable energy generation. Essential is the capacity to store energy surpluses for periods of shortage (crises).

The paper discusses the need for resilient cities and the approach to make cities resilient to energy crises.

Keywords: engineering resilience, energy crisis, urban energy system, self-sufficiency, urban metabolism

1. Introduction

1.1 Threats to cities

In 2003, David Godschalk identified the threats to which modern cities are confronted, both from natural hazards and terrorism, recommending a resilient cities initiative [Godschalk 2003]. However, a seemingly much more friendly threat to cities is posed by hampering supplies of food, water, products, and – not least – energy. Depending on the source used, buildings use approximately 30-40% of all energy in our society. In a city, with heavy industries lacking, this contribution can be even estimated at 50-60%. In Western Europe, the urban heat demand is still predominant, approximately 80% of all energy use in buildings [SenterNovem, 2008]. Nevertheless, whether provided by natural gas, mineral oil, wood or industrial waste heat, this heat cannot be delivered to individual buildings without the use of electricity, which is commonly generated outside the city and transported through high-voltage lines. Recent figures of European Wind Energy Association indicate that by 2007 75% of the energy mix in Europe was constituted from fossil energy sources and nuclear power. Between the years 2000 and 2007 there was a considerable growth in the installation of wind turbines but even more in gas-fired power plants [EWEA 2008]. This means that for the coming decades the built environment will still strongly rely on finite resources, of which secure supply may become uncertain in the near future.

Moreover and regardless of the cause of these, the past decade has shown several incidents of power plant black-outs (all over the world), airplane or helicopter crashes into high-voltage lines (e.g. Bommelerwaard, Netherlands, 2007), enforced halting of gas supplies (e.g. Ukraine, 2006 and 2011) and even nuclear meltdowns (Fukushima, Japan, 2011), which temporarily disturbed the functioning of urban areas. Therefore, Godschalk's recommendation to work on resilient cities seems a wise one, although he was not referring to the energy supply.

1.2 Not one self-sufficient city

Despite ambitious climate goals of cities like London, Copenhagen, Hamburg and Amsterdam, not a single European city is fully self-sufficient in terms of energy, which increases the probability of serious problems when energy supplies are hampered by any form of crisis. In order to respond to this by means of resilience, a comprehensive approach to the entire energy system of a city and its environs is needed, but this model or approach is not available yet.

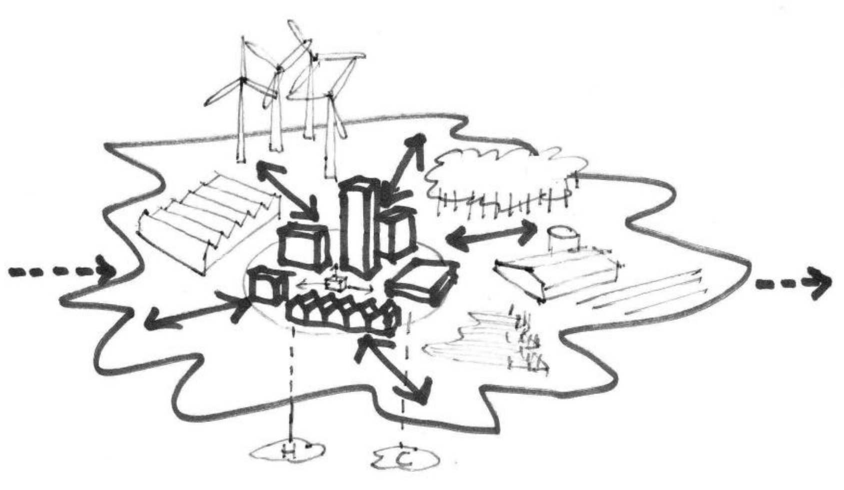

Figure 3: Sketch of the current situation of a city using energy generated outside its boundaries (above) and a more sustainable, resilient situation of a city more self-reliant and in interaction with its surrounding region, which together predominantly generate, reuse and store energy

1.3 Directions

Resource crisis resilience demands for understanding of the current urban metabolism for energy and waste energy. In a resilient, sustainable urban system the energy cycle is better closed. This requires a three-stepped approach of savings, exchange & storage, and sustainable generation. Quintessential is continuous supply and/or capacity to store energy surpluses for periods of shortage (crises). My hypothesis is that this will be most probably achieved only by a comprehensive approach to the interactive system of a city and its surrounding region.

Full self-sufficiency is not necessarily the goal; resilience for the duration of a crisis would however improve the urban capability to survive without drastic measures. Moreover, local provision of energy would help the local economy and significantly reduce greenhouse gas emissions.

The underlying research proposal intends to achieve this goal in an innovative and integrative manner: by creating a comprehensive urban model for an energy system through which a city can sustain itself in a time of crisis or disaster for at least one year.

2. Starting-points

2.1 Resilience

Resilience is an ecological term. Resilience Alliance [www.resalliance.org] describe the term as "the ability to absorb disturbances, to be changed and then to re-organize and still have the same identity (retain the same basic structure and ways of functioning). It includes the ability to learn from the disturbance." Authority in the field of ecology C.S. Holling distinguishes ecological resilience and engineering resilience. He defines ecological resilience as "a measure of the amount of change or disruption that is required to transform a system from being maintained by one set of mutually reinforcing processes and structures to a different set of processes and structures" [Holling 1973], whereas engineering resilience is "the rate at which a system returns to a single steady or cyclic state following a perturbation" [Holling 1996]. Others, such as Pumm [1984], use the term of resilience only by the meaning of engineering resilience. For this research proposal on urban resilience we also use Holling's definition of engineering resilience as the basis, projected at the system of a city or city region. Usually the term is perceived in relationship with climate change and the adaptation to it, a topic currently addressed in various research projects in Europe. This research project however focuses on the urban capability to prepare for, respond to, and recover from hampering energy supplies.

2.2 State of the art

Propelled by cities' ambitions to become climate, carbon or energy neutral in due time, research on the energetic consequences of urban planning is becoming an essential expertise for sustainable development. Merging spatial planning with technical knowledge, energy has increasingly become the topic of methods and approaches to what we may call 'energetic urbanism' [Dobbelsteen & Tillie 2011].

The basis of this probably lies in a meticulous analysis of existing urban areas, as incorporated in Energy Potential Mapping [Dobbelsteen et al. 2011a] and heat mapping [Broersma et al. 2011] (figure 1, left). Based on the New Stepped Strategy [Dobbelsteen 2008], the Rotterdam Energy Approach & Planning [Tillie et al. 2009] was one of the first worldwide methods to approach energetic urban planning in a structured way. REAP was further enhanced by the REAP2 study [Dobbelsteen et al. 2011b], amongst other ideas leading to the proposal of new heat exchanging facilities for neighbourhoods, as well as smart grids that could serve different demands from buildings (figure 2, right).

Other important developments relate to the industrial ecology approach to cities, as applied in Hammarby Sjöstad (Stockholm, Sweden) or Kalundborg in Denmark, taking into account all essential streams in a city.

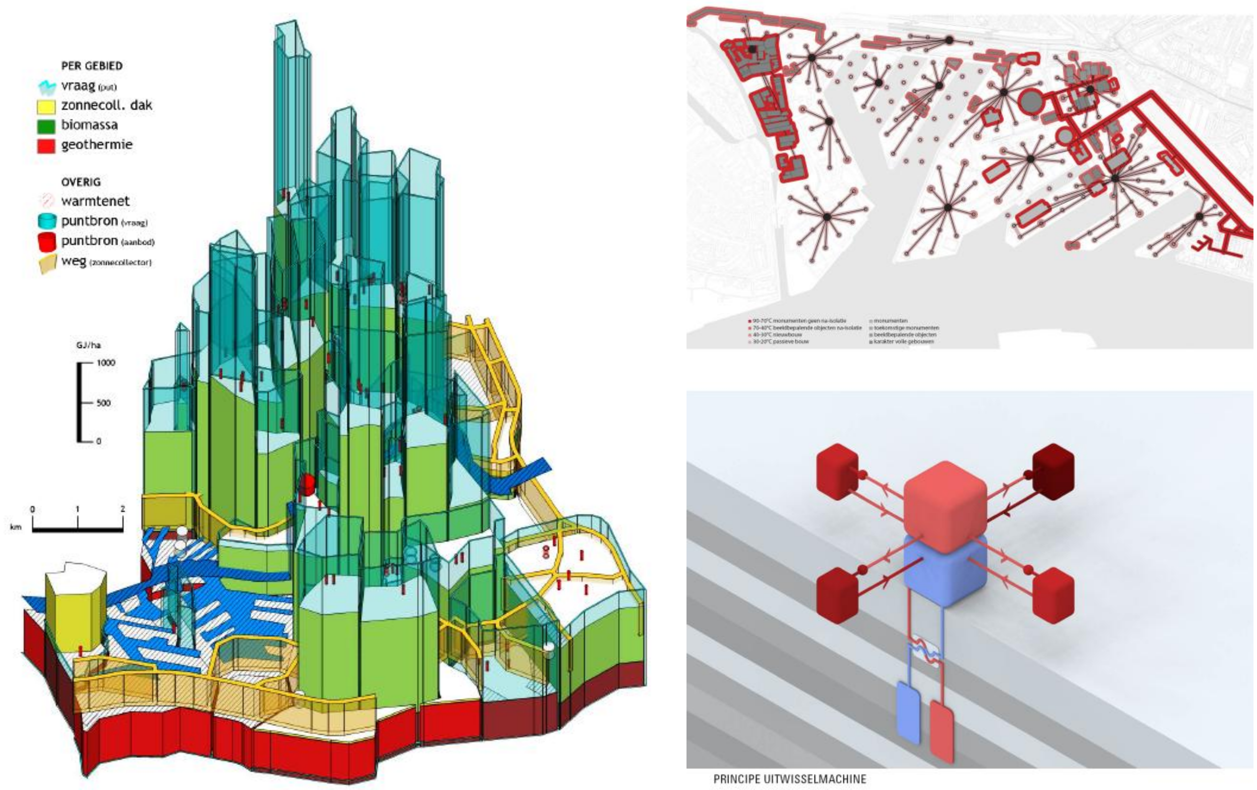

Figure 1: Heat map of the centre of Rotterdam, depicting demand (hollow cores) and supply potentials (full cores, lines and dots) of heat in the city [Broersma et al. 2010] (left) and new ideas for heat exchange and storage on the neighbourhood scale in the Merwe-Vierhavens district [Dobbelsteen et al. 2011b]

2.3 Requirements for a new model

A new model for resilient cities has to comply with certain requirements before it can be effective and realistic. It needs to provide insight in:

- the energy metabolism of the city and its environs
- current energy usage patterns in a city and possibilities to influence them
- solutions for the reduction of the demand for energy in cities
- optimal utilisation of superfluous energy.
- possible interaction of cities with their hinterland for the provision of energy
- possible generation of energy in the city and its hinterland.

2.4 Methodology

Urban resilience to energy crises cannot be tackled by a focus on just one or two elements of the entire system. We attempt to cover the complete energy system of cities and their hinterland, aiming at a systematic approach for each part of the system, as a first scientific step towards detailed elaboration of these separate parts. Consequently, the urban resilience problem cannot simply solved by one or two fields of science. The project therefore is inter-disciplinary, involving disciplines that form the building blocks of the theoretic model presented below: urbanism, architecture, technology and engineering, computation and landscape architecture. And that only regards technical design and planning disciplines (we have to start somewhere…), not the social, economic, legal and political fields, which are quintessential to the actual realisation of the plans involved. This combination of specialisms is a challenge, but all sustainability assignments are.

3. First model for a resilient city

3.1 Theoretic model

Figure 2 illustrates the theoretic model we propose for a resilient city.

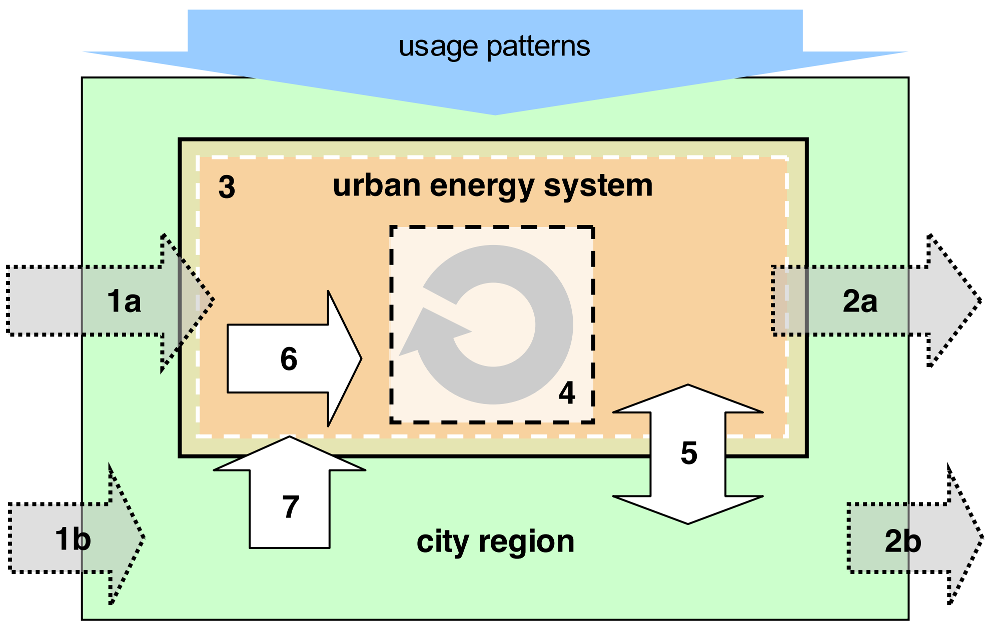

Figure 2: Theoretic model with components of a city as an energy system

In the current situation of a city with its typical energy patterns, externally generated energy is input to the city (1a) or city region (1b), whilst waste (energy) leaves the city (2a) or city region (2b). In a more resilient situation the demand for energy in the city is reduced (3) and internally reused, exchanged, cascaded or stored (4). When not solvable within the urban boundaries, the city region can help to exchange energy and waste (energy) (5). Finally the city can generate renewable energy within its own boundaries (6) or close a deal with its surrounding region, where more space for energy generation is available, for supply of renewable energy to the city (7).

3.2 Usage

At the basis of it, knowledge on energy patterns (demands) and potentials (supplies), as well as their particular problem areas are quintessential – and so is the monitoring of these in a new situation. This can only be supported by a comprehensive computer model, tested and validated on case studies before and after the proposed interventions.

3.3 Energy conservation

Energy saving is probably the most effective and most economical solution to reduce the dependence on fossil fuels. Based on the inventory of demands, plus an analysis of urban morphology and building typology, energy-saving potentials in urban planning, building design, industrial processes and transport can be calculated, leading to design and planning propositions for the case studies.

3.4 Utilising superfluous energy

As resilience to energy crises will largely be based on availability of energy that once was superfluous, focus on optimising the use and storage of residual energy is paramount. Hence, the production of waste energy in cities and the potential to seize this superfluous energy for direct or delayed reuse needs to be accurately determined. This type of energy consequently can be utilised for exchange among urban functions, for cascading to functions that require energy of a lesser quality, or for storage enabling use in later periods of possible shortage, such as in cases of crises.

3.5 Regional exchange

Large cities cannot harness a sustainable energy system on its own: they needs the entire metropolitan area and hinterland to get the balance right. Therefore the city-region interaction needs to be mapped and quantified (for instance, exchange of waste with nutrients from the city, for renewable energy and food in return). Furthermore, propositions can be made regarding the design of energy landscapes by means of which the city's energy system can be completed, using the case studies.

3.6 Local generation

Last but not least, the finalisation of a feasible sustainable city resilient to energy crises lies in the generative capacity of the city and its region. Especially the generation of electricity by renewable energy sources is a challenge that will require a lot of building and land surface. Energy potential maps can chart the site-specific possibilities for the generation of energy. An energy catalogue could contain all technical and spatial possibilities for sustainable production techniques for heat and cold, electricity and fuel. Together these tools lie the foundations for a proposal for spatial and technical interventions.

4. Conclusions and discussions

4.1 Relevance

The capability of cities to prepare for and respond to energy crises in the near future is supported by greater or temporary self-sufficiency. The model for a city – including its surrounding rural area – that can sustain energy crises is very relevant if we take the future limitations serious. Step one is the accurate monitoring of the current urban metabolism is needed for the use of energy. Measuring raises awareness. The Danish island of Samsø, reaching energy-neutrality within ten years after thorough accounting of energy throughput and investments into sustainable technology, demonstrated that this really works. As long as cities can make a vow to become carbon, climate or energy neutral without being accounted for the actual figures, there will simply be no incentive or urgency to accelerate the developments. Monitoring will also pinpoint problem areas where measures are most effective. The steps from the New Stepped Strategy – savings, exchange and sustainable generation – can support this. In the current market the order of the NSS seems to lead to the best results that are feasible. It is however imaginable that if the price of wind turbines and PV panels drops, whereas the construction of infrastructure becomes relatively more expensive, the order might actually change. But in both cases, the capacity to store energy surpluses for periods of shortage (crises) remains essential.

4.2 Impact

The impact of cities attempting to become independent from external provision will be enormous. This applies to all global cities that intend to become energy neutral. A resilient city that relies more on local potentials will demand much less from external sources, having a great impact on the future system of energy supply, which is now supply driven by big energy companies that not necessarily have to strive for a sustainable system as long as economic perspectives for finite resources are still better in the short run. The model and approach resolving from this project can be transferred to other cities, which then could undertake similar endeavours.

4.3 Further research and application

This paper could only discuss the first steps towards the model for cities resilient to energy crises. The work is currently undertaken and will be accelerated within a short timeframe. Then each module can be elaborated and turned into a generic model to be applied anywhere in the world. We notice some reluctance in developed countries to seriously start to work on resilience. Life is probably still too easy. This makes the model ever more important to emerging economies and poor cities of which the reasonably priced supply of energy, water, materials and, not least, food is endangered within the near future. Therefore we embrace any developing country that wants to test and validate the model.

Acknowledgements

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