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Urban sustainability through decentralisation and interconnection of energy, waste and water related solutions: Case EVA Lanxmeer, Culemborg (The Netherlands)

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ABSTRACT

This paper focuses on the need for interconnection of essential urban infrastructures first of all based on another network philosophy and use, to achieve sustainable urban development, or: whole life urban sustainability.
A topic of interest in sustainable urban planning is the lack of integration of the 'essential flows' (water, energy, waste/wastewater). With respect to these flows ecological and spatial conditions in and around cities are under pressure: transportation distances grow, protection and qualities diminish, and (infra)structures get more complex, less robust and less visible, which result in a decline of sustainable commitment and behaviour of users. It also results in growing dependance of the essential utilities. The use of decentralised systems at district, neighbourhood or local scale could introduce new urban functions, options for self-sufficiency of public buildings or entire districts and improved commitment of users.
This will be illustrated with an innovative project under development (partially under construction) in Culemborg, the Netherlands. It concerns the spatial integration and technical solution of a system to connect waste, and wastewater treatment with energy generation inside this residential district. Essential is the integrated approach, closing cycles of nutrients, water and carbon and integrating energy generation and waste management through cascading qualities and use of the concept of exergy. Physically this will be realized in a newly introduced device that is called 'the Sustainable Implant' (S.I.). This S.I. is integrated spatially in a building in an attractive way and works at the intermediate scale of both this semi-public building and the surrounding city-district (approx. 250 houses). The district is situated in an ecologically sensitive area, because it concerns a former drinking water extraction and retention area. The system layout and backgrounds are explained in this paper.

Key words: **Autonomy, Heteronomy, Energy, Sanitation, Urban Sustainability.**

1 INTRODUCTION

There is a common consensus in society about the necessity of fundamental facilities for meeting the most fundamental needs in the own living environment (support, protection, affection, understanding, participation, relaxation, expression, identity, freedom). Support, or maintenance, includes the availability of energy and food, including clean drinking water, and the removal of waste (water). It is no use trying to introduce sustainability measures that harm this fundamental need. Many relevant participants however do not seem to realise that other, more sustainable alternatives can be found by abandoning the specific characteristics of the traditional paradigms rather than following them. The dominant participants have an interest in using existing structures as efficiently as possible and in developing them further with as few risky investments as possible. Looked on from the aim of “sustainable development”, the commong path of expansion selected (centralisation) is not necessarily the optimum as perceived subjectively,

Building infrastructure almost always implies slow and large-scale processes. For a structural solution and preservation, the technical infrastructure should be considered because it will be leading for the design and the allocation of the faster dynamics of the overlying layers: the layer of the overground “networks” and that of “occupation”. The infrastructure strongly correlates with production (supply as well as drainage). A change desired in the infrastructure, e.g. a bottleneck with respect to capacity, can be solved by investing in extending the infrastructure (now often accepted), but often also by adapting the “production” or “treatment” in strategic spots of the (central) grid.

This is the background for the presented research (Timmeren, 2006). It is argued that for a lasting sustainable urban development and a necessary improved network geometry (Watts & Strogatz, 1998; Banavar et al., 1999) with respect to the essential ‘flows’, further development based on the future path of scaling-up of different networks and users will have to be combined with decentralised sub networks, or clusters, aiming at autonomy. The research was commissioned by the Delft University of Technology (T.U.D.) in The Netherlands as part of the DISC Research Programme (Design Integration of Sustainability & Comfort) of the Climate Design group. In addition CORE Int. , Haskoning Nederland, Innogas and Thecogas Biogas B.V., are responsible for the presented Culemborg case related quantitative and qualitative process analysis (battery limits) and the economic implementation study.

2 CENTRALISATION VERSUS DECENTRALISATION

It has turned out that the ongoing processes of liberalization have put pressure on the importance of the certainty of supply of energy, and also removal of waste and waste water. Working certainty of supply and independence out in further detail seems necessary, or even essential. A possibility is connecting or disconnecting (decentralised) sustainable sub production (generation or processing capacity). This may be realised by including sustainability, via reliability, as an added value at relatively little cost, e.g. in the form of a decentralised utility and backup, possibly even aiming at autonomy. Too little advantage is taken of this aspect of sustainability. It may involve short-term interventions for long-term guarantees (sustainability, guarantees for supply/processing and in the end affordability). Such a principle may be useful as a kind of fallback scenario for, for example, a serious and unforeseen dysfunction of the current process of further scaling up and liberalization of sectors.

2.1 Centralisation and growing heteronomy

There are clear differences between the characteristics of the various central networks, in the energy and sanitation sub flows each as well as between the energy and sanitation supply as a whole. They are caused by different “central scales” of application and different extents of visibility, but also by the management structure and the presence or absence of liberalization processes. For sectors that are left to market forces, positive effects are to be expected on the efficient use of the infrastructures, and in Europe, by oligopolistic market types and on the affordability of the accompanying services. However, market participants have no interest in overcapacity, which puts pressure on the reliability of supply (by a maximum bid on the available capacity) (AER, 2003). Pressure can also be put on the other long-term interests, including maintenance of grids and investments in, research into or application of innovations, e.g. those that aim at sustainable development (Künneke et al., 2001). At the same time, main aspects for users are sustainability, a guarantee on supply and processing and affordability (Quist, 1999). Where the essential infrastructures are concerned, the liberalization of the markets shows that the goals set concerning sustainability cannot always be accomplished in an integral way. At a national level, there is too little grip on the developments. The demand for supervision or rules at a supra-national level is being heard, and this causes one of the reasons for liberalization with respect to essential sevices to be surpassed.
The “dialectics of progress” and the so-called “prisoner’s dilemma” force themselves upon us: the deviation from this specific unsustainable (end-of-pipe) type of solution(s) is so expensive and will involve such far-reaching social consequences that there seems to be no other choice than continuing with these relatively expensive infrastructures and systems. Besides of that, the distance created between the (environmental) problem and its solution leads to more and more complexity. The process of changing the interrelated public and private services, systems and infrastructures is becoming more complicated and less predictable. Together with the increased scaling, the convergence of utilities and the growing number of parties and techniques involved have increased the end users’ (consumers’) subjective dependence, or heteronomy (Timmeren, 2006).
In energy supply, there should be more emphasis on increasing the flexibility in the current (infra)structures, including Town and Country Planning in its entirety. The more so since it can be expected that there will not be only one decisive future

technology to solve the coming problem(s) concerning security of supply and sustainable development. Especially with respect to energy this asks for a simplification of the processes, products (or rather: services) and parties involved. A larger concentration on integral provision of services, or, in other words, the supply and management of integral packages, offers possibilities. This seems to be reinforced by the (ongoing) liberalization processes. Another solution is having the level of application attune better to the lifestyle and direct surroundings of the users. With respect to waste water, at present it could be maintained that for the infrastructures there is in the developed world (except for the UK) already one applied centralized technology (Cooper, 2000). Heteronomy of users in this case is even more critical, for it is health related. Emphasis could be put on further improvements with respect to specific purification related problems, such as medicine and hormone rests, and better possibilities for separating qualities (Niemczynowicz, 2001). With respect to both flows, energy and sanitation, decentralised or local systems offer interesting opportunities for more sustainable solutions concerning the stated problems and necessities .

2.2 Decentralisation with the aim of autonomy

The decentralisation and, in some cases, even complete disconnection of central (infra)structures are at the centre of the developing emancipation of systems of which they are a part. The basis of solutions is formed by urban planning that is based on ‘interconnection’, as well as waste management in general, and on closure of the essential cycles (energy, carbon, nutrients and water) inside urban developments, or as close to them as possible (Otterpohl, et al., 1999; Timmeren et al., 2005).
Two development processes concerning decentralised technology, often for the purpose of autonomy, have come forward as topical: viz. first, the efficiency and improvements in the integration of sub techniques and ‘real-time’ co-ordinated (RTC), connected concepts, and, second, a better harmony between supply (input) and demand of the (different) sub flows. Additionally, there are two more general underlying development processes. The first is the environment-technical, environmental and, to some degree, also social optimization of decentralised systems. The second underlying development process concerns the link to economic applications related to the surroundings, often determined by place or users, including taking carbon and nutrients back to nature and/or agriculture (Timmeren et al., 2005). Especially in the field of small-scale Combined Heat Power generation (micro-CHP) and ecological sanitation systems important efforts have been made. The latter, so-called DESAR (Decentralised Sanitation and Reuse) systems, offer an alternative for the current status quo. Basis is their relative simplicity, excellent approach to separation of flow qualities, smaller investment risks and adaptability, and therefore their possibility to create extra (sustainable) capacities. There are still few examples of living and working environments with integrated systems concerning

decentralised sanitation, energy and reuse. In several developed and developing countries examples are realised or close to completion (Hasselaar et al., 2006).
A decentralised system must not be characterized as a static system, since there is an ongoing change of an existing situation. Decentralisation can concern technical decentralisation or administrative decentralisation. Technical (de)centralisation concerns (a change of/in) systems. In case of an administrative decentralisation, there is a distinction according to the nature of the administrative bodies. The 'decentralisation' depends on the technique or the administrative body, the context and the position of the observer. In the case of administrative decentralisation, there is a distinction according to the nature of the administrative bodies: territorial decentralisation (between/ carried out by Government, Province and Municipality) and functional decentralisation (e.g. within the Municipality). As for technical decentralisation, the various flows (energy, waste, water) have different definitions of the scale of sub clusters and of "decentralised" sub networks and systems. Often, there is vagueness even within the various flows (e.g. electricity vs. warm water).
The present-day competitive advantage of "sunk costs" for conventional (centralised) solutions, to what decentralised alternatives will be compared, should be avoided. Strategic niche management can be of help here: Because of the relative new market of (technical) decentralisation, "niches" can be created. In doing this in a planned way, it is called "strategic niche management" (Kemp et al., 1998). The strategic approach should focus on the higher dynamic efficiency of the decentralised systems: changed circumstances are easier to be anticipated with the help of decentralised systems. Investment risks may decrease in this way, which is especially of more importance in liberalizing markets. The use of new, sustainable technology and sub flows leads to larger quantitative fluctuations in supply, the peak load as compared to the average consumption, especially of the energy flows (Willis and Scott, 2000) and to the introduction of various (parallel) qualities, or, in other words, to a differentiation of products and services (Otterpohl et al., 2000).
Almost all decentralised sustainable energy sources have a low energy density and often a variable character. In the case of wastewater treatment, this particularly holds for systems based on natural technologies (Hasselaar et al., 2006). For decentralised energy generation as well as decentralised sanitation systems, this leads to more use of space. This disadvantage is the reason why decentralised systems should be integrated with other architectural and/or natural facilities and functions as much as possible. At the same time, cascading and high-quality recycling and direct reuse is easier to be accomplished in the waste and wastewater flows, as the case study shown in this paper will make clear.
Generally speaking, the two main problems in decentralised solutions are scepticism of the leading (often dominant) parties involved and the larger influence of a fluctuating flow size. The aspect of the flow size (in fact, the basis for the technical "economies of scale") can be met locally by modern techniques of planning and tuning, the so-called "Real Time Control" (Hartman, 2002), and the subdivision into parallel facilities. Thus, the remaining main points of interest for improving the

competitiveness of decentralised systems and actually achieving the advantages for the environment and the users are the organization and implementation of maintenance, exploitation, provision of services and inspection of the various systems, together with the availability of backup provisions if necessary.
Two development processes concerning have come forward as topical to cope with this needs: viz. first, the efficiency and improvements in the integration of sub techniques and co-ordinated, interconnected concepts, and a better harmony between supply (input, e.g. in case of energy, and output in case of waste) and demand of the (different) sub flows (Edinger & Raul, 2000, Raha et al., 2000).
In spite of the potential of the underlying optimization principle of the “scale economy” claimed in much of the literature and projects, and in spite of its importance, which was also proven, it has only been applied to a small extent. Consequently, there still are not many “economies of scale” in this area. However, the sub aspects concerning the application freedom and environmental integration (smaller sizes, fewer secondary demands, etc.) and user-related demands (comfort, ease of use, costs, etc.) are improving noticeably. The second underlying development process concerns the link to economic applications related to the surroundings, often determined by the site, the geniuw loci, by users and the willingness of the existing stakeholders, including taking nutrients back to agriculture and lateral applications or possibilitie (Jelinski et al., 1992; Otterpohl et al., 2000; Timmeren et al., 2005).

3 CASE STUDY ‘EVA LANXMEER’, CULEMBORG (THE NETHERLANDS)

Final case study within the presented research in which interconnection of public utilities and local autonomy has been elaborated is the project EVA Lanxmeer (EVA: Education, Information and Advice; in Dutch: ‘Educatie, Voorlichting en Advies’). It concerns an ecological settlement in the small-scale city of Culemborg.
The location of the EVA project is unique: near the central railway station of Culemborg, on 24 hectares of agricultural land and some orchards (www.eva-lanxmeer.nl).

Figure 1: Urban plan of the Lanxmeer district (left) and images of district with orchard, drinking water extraction area, retention ponds & helophytes (right) and semi-open court yards (middle)

This was the first time in the Netherlands that permission was given to build in the vicinity of, and partially even within the protection zone of a drinking water extraction area. The regional government allowed building at this site only under the guarantee that it would carefully be built according to modern 'deep green' principles. The project has been carried out in different phases and will consist of appr. 250 houses and apartments, (collective) permaculture gardens and ecological office buildings (40,000 m^2 gross floor space). In addition to special functions such as a biological city farm, the EVA Centre (an education, information & conference centre) is also situated in this district, along with a hotel and Sustainable Implant facilities. The overall design of the district Lanxmeer and the architecture of the most of the buildings is based on permaculture and organic design principles.

3.1 Triad EVA district: EVA Centre, Sustainable Implant & Ecological City Farm

There is a gradual transition from private-, semi-private-, and public space towards a more natural landscape in the protected zone of the Water Company. Together these green zones form an environment that displays the diversity and resilience of natural ecosystems and is called the 'Park of the 21st century' (Timmeren and Röling, 2005). Moreover because of the added links to the (waste) water-, energy- and waste concept of Lanxmeer. The natural cycles are paramount within the overall structure.
The triad 'City Farm Caetshage', 'Sustainable Implant' (S.I.) and the 'EVA Centre' form both the important ends (or beginnings) of the main east/west greenbelt that forms the backbone of the district, with in the middle the former 'conventional' water tower. The City Farm is situated in the originally agricultural area in front of the water extraction area (Figure 2). In buying houses the residents of Lanxmeer partly have contributed in the realisation costs. In return the residents can visit the farm freely, and if desired even can help with the maintenance of fields. Nevertheless, the City Farm is supposed to work independently.

Figure 2: Plan of the Lanxmeer district, actual situation (left) and Conceptual plan of the EVA Centre.

An important role is set aside to the maintenance aspects and collection of green waste by the city farmer. Together with the remaining green waste of other green areas of Lanxmeer, the kitchen- and green waste of the houses ('garden waste') and Lanxmeer's sewage effluent, this is being transported to the Sustainable Implant within the EVA Centre by the city farmer. At first the district's energy concept of the district had completely autarkic living as its main principle. Because of the concept of autarky and, consequently, the requirement for energy being available 'on demand', it was decided to use chemically bound energy, in the form of biogas. The production of gas from (organic) waste flows in the district has two positive effects at the same time: not only does gas become available, but also there will be no need for a connection to the public sewage system. For the production processes it is of importance that the percentage of solid substance in the fermenter is as high as possible: the energy content of black water is determined by the solid mass. Therefore, it is of importance to decrease the quantity of flushing water as much as possible. The municipality – in its role as project developer – chose the booster option to achieve this. Since green waste is also included in the process, the need for refuse collection has been reduced. The combination of black water and green waste offers advantages. Firstly, the amount of biomass available will be higher and therefore the gas proceeds will be larger; secondly, the 'fresh black water' implies a constant supply of fermenting biomass, which is good for the stability of the fermentation process.
The fermentation of waste is not the end of the process. Other integral parts of the process include improving the gas to a usable quality, purifying the effluent of the fermenter to a level that it can be discharged into the surface water without major problems, and processing the sludge without odour nuisance. Because of the E for Education in EVA, a Living Machine is taken as a starting point for purifying the effluent (Todd and Josephson, 1996). With respect to the necessary exploitation of the system it has been decided to add two other decentralised concepts, viz. a facility for further separating various waste fractions ('Retourette' or 'Recycle Shop'), and the possibility for joint e-commerce supply ('E- Fulfilment'). The total system is called the "Sustainable Implant" or in short: S.I. (Timmeren et al., 2004).

Figure 3: Longitudinal section over the EVA Centre with integrated Sustainable Implant (left).

3.2 The Sustainable Implant (S.I.)

The S.I. has been planned on the transition of the district into the surrounding (urban) areas, in the same lot as where the EVA Centre and the hotel are to be built. The technical installations will be integrated in an architectural solution, in such a manner that they will take up as little space as possible (Figure 3, Figure 4).

Figure 4: Model of EVA Centre with Sustainable Implant and impression of the Sustainable Implant (preliminary design Atelier 2T, 2006); more detailed information available at: www.evacentrum.com.

The main component concerns the anaerobic treatment of waste and wastewater, producing biogas. Advantages of the biogas installation include getting rid of the inconvenience and cost of the (individual) green rubbish bins. This, however, can only be accomplished if the green waste is collected with a much higher frequency than the current once every fortnight. In Lanxmeer this will be an important role for the 'urban farmer' of the city farm 'Caetshage', who will also perform the management tasks for the installations. The process of producing biogas (energy generation) and wastewater treatment can be divided into various sub processes:

1. Gathering black water on the one hand and green household waste (and to some extent garden waste) on the other, and leading them into the system;
2. The fermentation process, with biogas, effluent and sludge as its output;
3. Purifying and improving the gas into natural fossil gas equivalent;
4. Purifying the effluent until it has surface water quality;
5. Composting sludge into usable garden compost.

In addition a collection facility for waste and e-delivery, and a re-use step concerning the methane (biogas), water and carbon are added:

6. Collection of separated waste flows (Retourette) & e-delivery goods of the district;
7. Using the biogas in a combined heat power plant (CHP), CO_2 in glasshouses and purified water in the spa & vitality facilities.

The biogas is a mixture of 65% methane, 34% CO_2 and some remaining gases (with a maximum of 1%), e.g. sulphur hydrogen. In addition to the biogas, the digestion output of the fermentation process (approximately 5 m^3/day) consists of slurry, that is divided into a solid fraction (approximately 40% solids) and a fluid fraction by a screw press. The fluid fraction is free from pathogens. However, it is still polluted, so that extra purification is necessary before it can be discharged to surface waters (Sidler et al., 2004). This can be done by using helophytes filters. Since there will be a Living Machine as part of the EVA Centre, the effluent will be added to the input flow of the Living Machine (that will also process the black water from the EVA Centre and the hotel). There are two solutions for the solid fraction from the screw press: compost it in heaps in a well-closed compost room, or entering the slurry from the fermenter into the Living Machine. Because of uncertainties with respect to the process quality of this sub flow in the Living Machine, the first option was chosen. An advantage of using a compost room is that also the final maturation can take place there. After the maturation, the compost can be removed and brought back to the city-farm. The air in the compost room is extracted and purified by a bio-filter. There are two options for the biogas from the fermentation tank, the first being its transportation back (as natural fossil gas equivalent) to the homes, the second being burning it in a small Combined Heat Power installation. The latter option has been selected. A net amount of approximately 70 natural fossil gas equivalents remains and electrical energy surplus of 81 kWh/d remains to be sold. From an economic standpoint this net amount of gas to be obtained is too small for the investment and exploitation of the installation, within this context. Therefore energy revenue is introduced and used within the EVA Centre. There is a (small) reduction of CO_2 discharge and some energy saving. In the current configuration with CHP and composting of the sludge in the basement approximately 194 kg/home*year of CO_2 reduction for this district of 250 homes will be prevented (Sidler et al., 2004). To a certain extent there is also some reduction of waste collection and energy saving as a result of transport and pumping energy saved. When this saving is also taken into account, there is a total energy saving of approximately 8 GJ per home produced by the biogas installation (Vries and Timmeren, 2006).

As indicated before the S.I. can be divided into two main components. The first main component consists of the anaerobic fermenter, CHP, Retourette and e-fulfilment mini-load. This part of the installation is situated in a closed, garage-like volume in the southwest corner of the building complex. On top of this mainly closed volume the new ‘water tower’ is situated with storage of biogas (in inflatable bags) in the centre of the tower and retention of the water effluent round about this core in the transparent volume, cascading down in five (repeating) levels. On top of this (new) ‘water tower’ a vertical hub based windmill, named ‘Turby’ is placed for additional electricity generation. The second main component of the S.I. consists of the water retention cisterns, a sealed double skin façade with wastewater treatment of the EVA Centre (Figure 4), the agricultural glasshouses and ‘hanging gardens’ and the heat recovery installations with seasonal storage in aquifer.

4 CONCLUSION

It is important to change the general attitude towards the different components of design, development, use and management of urban areas. A way to do so is the 'interconnection' of different themes and cycles within cities. An example is the linking of sanitation to energy- and food production, preferably at lower scale levels. Specific local circumstances are a strong stimulus for the implementation of whole life urban sustainability concepts based on decentralised systems for closing cycles on a local basis. Decentralised systems turn out to be able to gain efficiency advantages as compared to fully centralised systems, particularly through the design of an integrated system of energy generation and supply, and through the connection of this system to a waste and waste water treatment system coupled to nutrients and carbon recycling. In the presented case study, in which an anaerobic fermenter is used, the necessity of a protected environment for development was evident. The choices made arose mainly from technical and social optimisation. There are several reasons for the decreasing level of ambition for closing the local (waste) water flows in case of larger scales of application. Occupants turn out to have more commitment when systems perform on the scale of a house or apartment, as compared to the scales larger than a district. As scale size increases, the solutions get more and more anonymous and gives less possibilities for integration with its source/users (the buildings / houses), with decreasing commitment as a consequence.
The introduction of solutions on an intermediate scale-level, like in Lanxmeer, Culemborg, offers opportunities for autonomous design of the whole or elaborations in which buildings can be semi-autonomous. Introducing the analogy of the functioning of buildings with respect to energy and sanitation flows with that of a parasite ('waste equals food'). The example of the linking of agriculture, waste(water) treatment and energy production in the urban district Lanxmeer in Culemborg might be exemplary for the potentials of the supposed need for a change in attitude.

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