Rijksdienst voor Ondernemend Nederland

Exergetische analyse in stedelijke sytemen

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1. Introduction

The world is urbanizing: now more than 50 % of the population lives in urban areas, and projections estimate that this will increase. Today, growth and operation of urban areas consumes roughly 75 % of the world's energy consumption [Cola et al., 2005; Bhatt et al., 2010]. And fossil fuel use is still increasing rapidly. Increasing energy consumption and growing urbanization puts increasing pressure on available resources. Urban areas become more and more vulnerable because they depend largely on imported fossil fuels and other resources from across the globe [Cola et al., 2005; Droege, 2002, 2006; Newman and Jennings, 2008].

Urban areas became disconnected from the locations their resources originate from, and synergy is missing between urban areas and their surroundings [Kennedy, et al., 2007]. Furthermore, urban areas use those imported resources in an inefficient manner which results in an outflow of waste to water, air, soil. Result is a decreasing supply of resources, and increasing dependency on a few countries, for the scarce, but very needed resources, like, e.g., oil and gas.

We see a lack of integration between urban planning and resources management, leading to energy conflicts and enlarging climate change effects. To tackle this, urban areas worldwide will soon face the need to find alternative, more locally oriented, sources [Cola et al., 2005; Droege, 2002]. This growing global energy problem, the search for alternatives, and increasing urbanization will lead to a different way of urban organization and structure, both spatially and administrative. This asks for a paradigm shift. We need to aim for a 'renewable city' (urban area), defined by Droege [2006, p. 10] as 'a supportive renewable habitat capable of countering mounting environmental crises'. We therefore need a transition from a fossil-fuel based and linear resource use to a sustainable urban system limiting the huge amounts of waste. A shift to an urban renewable energy, and material, autonomy contributes to lower the impact of urban resources inflow, and disposal of wastes on its surroundings, without exceeding these surroundings carrying capacity [Kennedy et al., 2007].

Urban areas are important to mitigate climate change and urban designs can contribute towards more, national, energy security [Barker et al., 2007]. Urban areas are powerful potential markets, centers of national and regional political power, cultural activities and technological innovation, and play a role in implementing new policies and plans [Droege, 2002; Bhatt et al., 2010]. Energy and environmentally smart strategies, both more efficient and effective, have to be integrated in urban planning and resources management, towards solving many of the sketched problems [Bhatt et al., 2010].

Important for the new approach, is that urban areas look beyond end-of-pipe solutions – there is wasting and that wasting has to be decreased – for sustainable energy. When the focus of the approach lies on a more extensive decrease of energy quality demand, and, partly, supply of sustainable resources within the conventional, current system, there will be a moment that the system can not longer be considered at the component level. To reach more extensive results, the approach should include a check of the potentials at a higher level [see f.i. Dobbelsteen & Tillie, 2009 – REAP-concept]. It is further also important that the system transforms to an efficient, integrative urban resources management in which all the flows – energy, materials, water, etc. – are considered and optimized without compromising the functioning of one of these flows [Rovers et al., 2010].

Towards an effective and sustainable urban resources management, and to use local potentials optimally, we need to look beyond the concept of energy. The ability to do work [Baehr, 1965; Wall, 1977, 2009] is reflected in the quality of energy, the exergy. And the urban area can be seen as a reservoir of unused and untapped remaining energy qualities, both renewable and residual [Leduc et al., 2009]. To more effectively use those remaining urban resources, we need to study technologies and potentials to capture and harvest those resources, and link that to the demand.

A transition to a sustainable future can be possible if urban resources management and the urban energy system become more effective and implement technologies to capture and harvest local alternatives. A broad, systematic approach aiming for energy savings, renewable energy applications, and energy efficiency principles can lead to a successful transition and more autonomy [Duijvenstein, 1997; Droege, 2006]. Multi-functionality and cooperating urban functions, and availability of local production, might improve the potential of urban areas to provide their necessary resources [Leduc & Van Kann, 2010]. Getting or keeping, e.g., industry within the urban area, generates opportunities for local material production and re-use of waste products, e.g. material recycling or use of residual heat. Furthermore, distance, size and densities should be included within urban planning and urban resources management [Leduc & Van Kann, 2010]. Shorter distances and a better connected, multi-functional urban area can result in minimization of motorized transport, contributing to lower energy use, costs and emissions, and being a base for improved health conditions (see a “sustainable mobility paradigm”, as explained by Banister [2008]).

An important message for our research is that all mentioned changes, for urban resources management and urban planning, should add to a transition towards a sustainable urban area which is productive, next to consumptive.

We developed a method to check the potential of urban areas to shift towards more sustainable resource management and planning. We first study the land-use distribution of a certain area. We continue with an overview of the current demand for several energy qualities. The next step is an inventory of local potentials, both renewable and residual. The last step studies the coupling of supply and demand and how that can be done as optimally and sustainably as possible, focusing on an integrative flow-approach.

We will describe results for several case-studies. In the first phase, we checked our method for The Netherlands as a whole and specifically for two regions in The Netherlands: South-Limburg, more specifically Parkstad Limburg, and Southeast Drenthe, more specifically the cluster Emmen-Coevorden. In the second phase, we applied our adapted method for a case within Parkstad Limburg, namely in the district of Kerkrade-West.

We will describe in this report the research we conducted towards more sustainable urban resources management and urban planning. We will first describe some important concepts on which we based our method. In a next chapter, we will describe the developed method, followed by the results. We will state some conclusions and indicate the reasons for the changes in our approach. The second part will again describe some concepts, followed by the altered method and the results for a case-study. We end with a final discussion and conclusions.

2. Problem solving – take 1

In this chapter, we will describe some general concepts on which we based our research. These concepts were used for knowledge building and the development of our method. The method is described in paragraph 2.5. The last two paragraphs show results for a few case-studies in existing built-up environments and the discussion and conclusions. We will end the conclusions with the reasons for the adaptation of our method and conceptual background which leads to the adapted method in chapter 3. In that chapter, we will also describe our method and the results for new-to-built urban environments/districts.

2.1. Sustainability/sustainable development

The World Commission on Environment and Development – Brundtland Commission – of the United Nations [1987, p. 24] defined sustainable development as: “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. Building on this definition, Goodland and Daly [1996] define sustainable development as development without increases in the throughput of materials and energy beyond the capacity of the biosphere to regenerate and assimilate waste.

For our research it is also important that sustainability is a multi-dimensional concept [Korhonen, 2004]. Sustainability has an ecological dimension, e.g. material and energy flows, and biodiversity. Furthermore, there is an economic dimension, e.g. costs and profits, and job creation. And last, but not least, sustainability has a social dimension, e.g. equity, and responsibility. Those multi-dimensional aspects become also clear in the sustainability goal of Newman [1999]: a sustainable urban area aims for the reduction of urban natural resources use and waste minimization. At the same moment, a sustainable urban area aims for improvement of social benefits and health and well being, livability. Urban sustainability should consist of both resource reduction and human livability improvement [Newman, 1999].

To cope with growing urbanization and to transform to a sustainable urban resources management, there is a need for a sustainable urbanization. This is based on the mentioned multi-dimensionality: economic, social and environmental aspects should be integrated and equally impact on future political decisions. Sustainable urbanization should include a sustainable way to use resources. Some important aspects of sustainable urbanization are [Shen, et al., 2005]: first, urban development should be sustainable by supplying enough energy and resources, in an efficient way. Secondly, sustainable urbanization needs to be an ecologically acceptable urbanization: inhabitants need to be involved and convinced of the advantages. Thirdly, sustainable urbanization needs a successful economic and social organization by a just division of income, power and opportunities. Finally, a sustainable urban area should be based on a resource management that is able to supply needed resources without limiting future resource use and without negative environmental impacts.

A sustainable city, urban area, is characterized by several aspects, such as the use of renewable energy sources to power its functioning. Further, a sustainable urban area is characterized by a circular metabolism and a carbon-neutral transportation system [Girardet, 2008]. In a sustainable urban resources management, focus on local remaining energy qualities should go together with energy demand minimization strategies and efficiency improvement in a multi-functional and optimized manner.

2.2. Trias Energetica, exergy, and new strategies

Our current management of resources, e.g. energy, is not sustainable. Distances do not matter and the location or origin of our resources can be anywhere in the world. The management of resources is based on fossil fuels. Those are finite and urban areas need to look for alternatives. This alternative should include proposals to limit demand and technologies to capture and transform renewable energy sources, and should increase efficiency. Duijvenstein [1997] developed a strategy to combine those three steps and to integrate them to reach sustainable urban areas. This strategy consists of three, consecutive steps, and is called ‘Trias Energetica’ [Duijvestein, 1997]. The first step is most sustainable and solutions should be fully exploited. The next step will only be taken when the first step is done, when solutions are exhausted. The same applies for the third step. The steps are:

1. Limit energy consumption and demand by tackling energy wastage;
2. Use renewable energy sources, like sun and wind;
3. Use finite energy resources as clean and efficient as possible, e.g. CHP or high-efficient heat pumps.

There is also a problem with the use of current available technologies, next to the non-sustainable use of finite resources. Those technologies are at the moment used inefficiently and not used to their full potential. That results, e.g., in the use of high quality energy for low quality demands. This can be explained by referring to the inefficiency of current energy system: sources need to be converted to a certain, high, quality that can be feed into the grid to supply several users. Figure 1 shows that this energy system is not very efficient and results in quality surpluses (Qs) and un-used remaining qualities (ΔQr), and emissions.

Furthermore, certain energy sources are not exploited or capturing and transforming technologies are not developed, e.g. local wind or solar potentials. This inefficiency is connected to our knowledge about energy. We need to be aware of the laws of thermodynamics. The first law states that energy can never be lost, and that it will transform in another form . The second laws explains that every time, energy is transformed, quality is lost and entropy is produced . The aspect of quality of energy is important, it indicates the ability to cause change [*see* Baehr, 1965; Dincer and Rosen, 2005; Wall, 1977, 2009]. This energy quality is called exergy. When applying this exergy principle, we see an outgoing flow not as waste, but as a flow with a remaining, lower, quality. This remaining quality of residual flows can be useful for another activity within the urban metabolism (fig. 1).

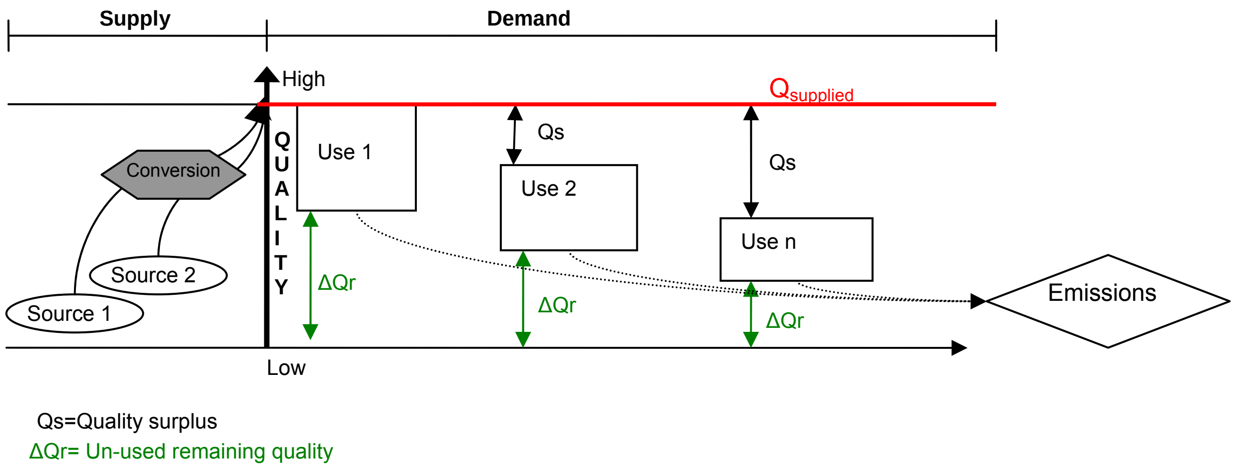


Fig. 1: Schematic view of energy system [Leduc, et al., 2009]

Cities themselves are important to develop new strategies towards increased sustainability. The strategies should be energy and climate friendly, linking different urban functions, using un-used energy qualities and available renewable potentials, and stimulate economic growth by developing new industries and businesses, based on a more green economic system, using renewable resources, e.g. energy and materials [Bhatt, 2008; Bhatt et al., 2010].

Another problem with the mentioned 3-step strategy, is step 3. The option for the use of fossil energy resources is still there. In the future, and if we want to reach more sustainable cities, a strategy based on fossil fuels will not and may not be possible because those resources are finite and with a too high impact on environment. Therefore, Dobbelsteen & Tillie [2009] proposed the New Stepped Strategy. In this strategy, they add an intermediate step in between reduction and development of sustainable sources, and incorporate a waste products strategy, and step 3 of the Trias Energetica is eliminated:

1. Reduce energy consumption by using intelligent and bioclimatic design;
2. Re-use waste energy streams, e.g. residual urban flows – remaining energy qualities;
3. Use renewable energy sources and ensure that waste is re-used as food.
4. ~~Supply remaining demand cleanly and efficiently with fossil resources~~

The strategy can be improved if looking in amore long trun way, when waste resources from fossil fuels will be dry outm, due to the depletion of these resources. By that time its necessary to start from the renewable potential in the area or system, as optimizing and structuring unit. The new strategy then becomes;

1. calculate the maximum potential in renewable energy from within any given system
2. reduce energy demand by organizing functional intelligently
3. reduce energy demand by direct technologies
4. match qualities, cascade and reuse rest flows

The use of these strategies on energy *and system* qualities should lead to a changed urban resources management towards more sustainable cities. This is explored in the next paragraphs. In chapter 3 this will be expanded to be optimized with other resources that will put a claim o land as well.

2.3. Urban Resources Management

Cities are fossilized structures within living environments building on both local ecosystems as land surfaces elsewhere, and on a broad mixture of technologies. Most current cities, urban systems, have a linear, resource-to-waste, resource pattern and show a less efficient use of matter and energy than natural systems [Dunn & Steinemann, 1998; Girardet, 2008]. In such an urban system, nature is source of inputs and sink for outputs, and outputs are not necessarily a possible input for another process. This can cause problems for the natural system to sustain the urban system [Dunn & Steinemann, 1998]: e.g., dispersion of waste products into biosphere (fig. 2, upper part).

The energy situation will change drastically the coming decades, and cities and regions need again to become more self-sufficient within their bioregions and independent of foreign sources to fulfill their energy needs. Urban inputs should be gained locally and within the bioregion, and wastes should be recycled at local and bioregional scales [Newman & Jennings, 2008]. It is possible to study a city as one system that can supply energy, and other resources. The city, or urban system, can be considered and treated as a source, reservoir, of un-used energy qualities, both renewable and residual resources. Those remaining qualities can be in the form of, e.g., wind, heat, solar radiation, un-used labor, transport capacity, or residues. We need to see the city as an urban metabolism, acting as one organism. This was defined by Rovers [2009] as ‘orbanism’. It resembles a biological metabolism, providing a framework for analyzing in-, out-, and throughput flows of a city, providing information about energy efficiency, material cycling, waste management and urban infrastructure, and analyzing the relations with the surrounding environment [Girardet, 2008; Coelho & Ruth, 2006; Kennedy et al., 2007].

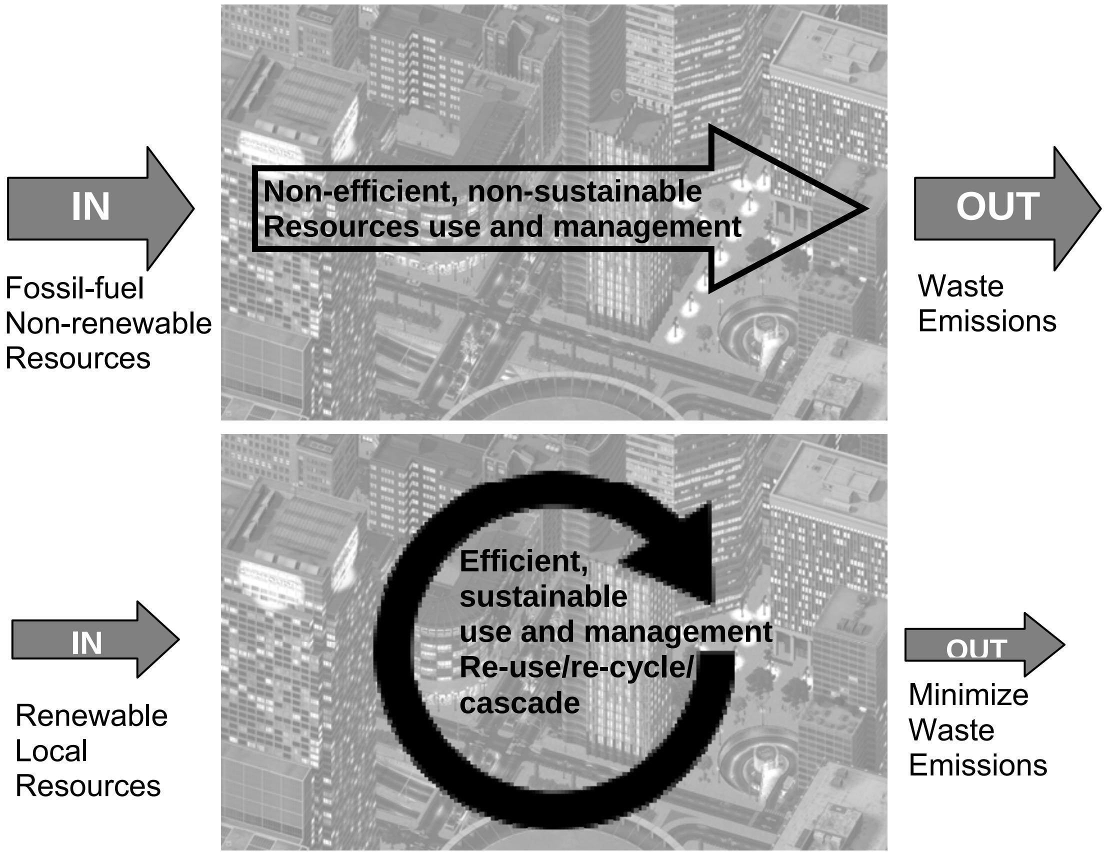


Fig. 2: Linear (upper) and circular (down) urban metabolism [based on Girardet, 2008]

Therefore, urban metabolism should evolve from a linear resource pattern to a circular metabolism to reach a more sustainable city. When cities embrace such a circular metabolism, they will be better able to guarantee their viability on the long run, and the viability of the hinterlands these cities depend on [Girardet, 2008]. Cities should more specifically aim for a closed cycle resource management [Rovers, 2009]. Closing urban cycles implies on the one hand capturing and transforming incoming, renewable, resources for efficient use in the urban region. On the other hand, closing urban cycles implies capturing and using residual resources to minimize waste production, and using, waste, outputs as inputs via, e.g., cascading and re-use (fig. 2, lower part) [Rovers, 2009; Rovers, 2007; Sterr & Ott, 2004; Girardet, 2008]. Bearing that in mind, a city can be seen as one system with a circular urban metabolism.

This circular urban metabolism demands another type of management of urban, energy, resources. The system will be based on a multitude of diverse, differentiated small and medium-scale energy providers, so the entire city becomes a net, renewable, energy producer [Droege, 2002]. A strategy is needed to harvest, capture, transform and use incoming renewable and residual resources in an efficient and effective way. The Urban Harvest (UH) concept is such a strategy that investigates options for local resource harvesting and options for using emissions and wastes within cities to reduce negative effects of consumption and to limit virgin resource inflow [Rovers, 2007]. The strategy for UH consists of six steps:

1. Identify and qualify un-used resources and flows – energy, materials, water, space;
2. Develop a model and system approach to check applicability;

3. Quantify and qualify harvest potentials for urban resources, e.g. energy, materials, water;
4. Investigate and check technologies to harvest those potentials;
5. Study optimization and identify possible adaptations of urban environments to maximize harvest potentials;
6. Develop integrated approaches and organizational strategies to establish harvesting in many areas in an optimized way.

Some cities, villages around the world have taken a more independent, self-sufficient way of resources management and/or circular urban metabolism into account. Those cities developed a strategy to optimally use their renewable and residual potentials to supply their demand:

One such example is Güssing, a small Austrian village [Vadasz, 2010]. The energy supply is self-sufficient, based on regionally available renewable resources and sustainable regional development. First measures were taken to optimize the buildings to lower the energy demand. Energy production is based on local resources: there is a local energy plant on biomass, rapeseed and wood chips; and a district heating system on wood fuel. Nowadays, Güssing produces more energy – heat, fuels, and electricity – than it needs and the surplus energy is exported. The project also focused on other aspects of sustainability: creation of local jobs which resulted in less commuting and allowed returning of people; and local ownership, so everybody feels responsible.

Another example is Hammarby Sjöstad, a district of Stockholm in Sweden. The focus is on water and environment, and a flow-model is developed for the case [Exploateringskontoret, 2007]. This model shows sewage processing, energy cycles, refuse and the stations and plants were treatment takes place. This model shows an example of a circular urban metabolism with connection and interaction between different flows – energy, water and waste – and between urban functions. The system is based on the use of local renewable potentials: sun and biomass, and on CHP and residual heat re-use. The buildings are built (will be) with environmental friendly materials. Waste will be separated, recycled and re-used as much as possible. Proposed traffic solutions are: the installation of public transport connections, on biofuels, provision of pedestrian and bicycle areas, and car limitation and car sharing options.

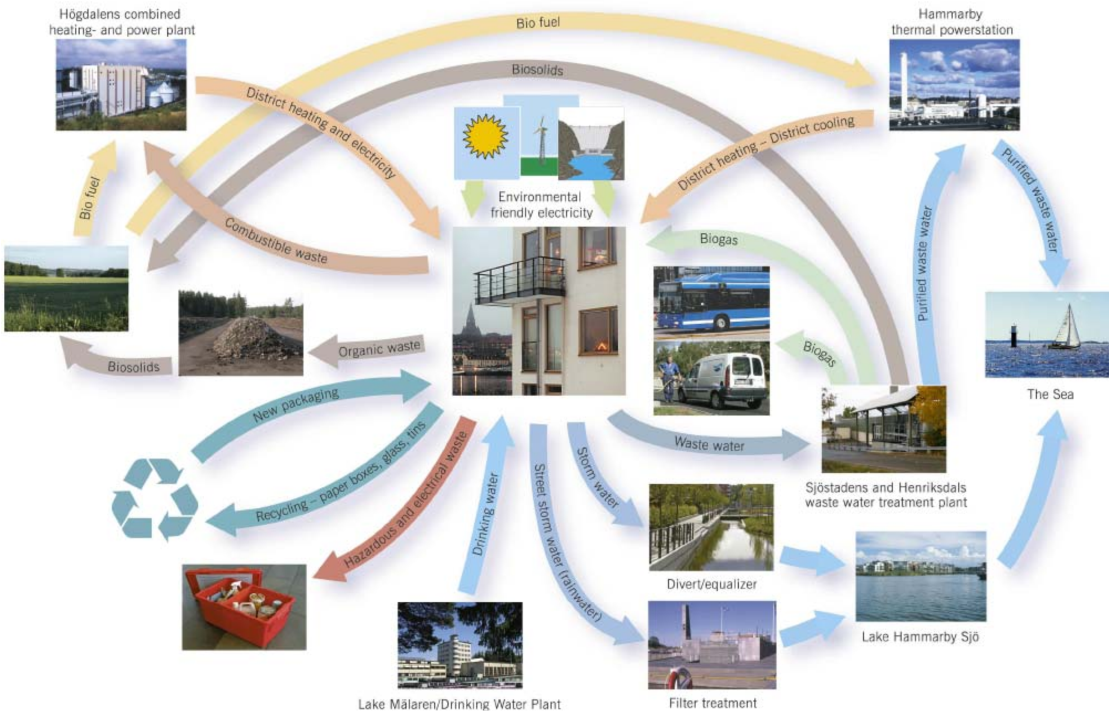


Fig. 3: The Hammarby Model [Exploateringskontoret, 2007]

2.4. Urban spatial and resources planning

Resources planning and management should guarantee reliable resource provision and should maintain the state of the resource for the use of future generations. In present time, with the current urban planning practice, it is common to develop separately energy plans and plans for managing other urban resources, like water or materials. Urban planners and managers face the challenge to combine the output from different approaches used to optimize different urban flows. People simplified the urban complexity by isolation of flows, but there is no guarantee that the sum of optimal single flows is equal to urban sustainability, due to the dependency or competition of the different flows within the urban area.

Integrated resources management should take into account all potential trade-offs and different scales in space and time [Pahl-Wostl, 2007]. To make use of un-used remaining qualities, urban planning, and urban areas, have to optimize coupling of demand and supply, and have to fully use the available potentials. Therefore, we indicated four parameters that should become integrated in planning of urban areas: the quality – exergy – of the available resources and demand, the quantity of resources and demand, the time the resource is available and when it is needed, and the location where it comes available and where it is needed [Leduc et al., 2009]. A local potential is only useful if the available quantity and quality is needed at that moment and close by the demand for that quality and quantity, or if it can be transported or stored.

There is need for a mixture of urban functions – multi-functionality – within urban areas to optimally apply harvesting of available urban resources towards a circular urban metabolism. The functions should be closely connected to use residual and renewable flows in an optimal way. Low-exergy planning, as suggested by Van Kann and de Roo [2009], can be seen as an example (see also [Van Kann & Leduc, 2008]).

Furthermore, to integrate the different urban flows, variables like distances, densities, and system sizes are important for exchanging renewable and residual flows of materials, water, space and energy in a sustainable way [Sterr & Ott, 2004; Van Kann & de Roo, 2009]. Synergies between clusters of spatial functions, size and densities need to be found on appropriate distances and time to make use of infrastructures in an efficient and cost-effective way to couple supply and demand effectively.

In the end, it is important to integrate urban planning and resources, e.g. energy, planning to reform resources consumption, land and space use, and the way transportation and transport is arranged and planned [Bhatt, 2010]. Supplementary, planning should include policies to limit fossil fuel, and virgin resource, use, and negative impacts of climate change towards a transition to a renewable and residual, local, resource use. Policies should include greater resource efficiency in buildings and urban systems, reduction measures for travel and transportation, should provide area as sinks for un-used remaining, former waste, qualities, e.g. carbon, and should begin or strengthen development and use of renewable and residual resources [Crawford & French, 2008]. Strategies towards sustainable urban areas, including application of renewable energy technologies and GHG-emission reduction and absorption measures, need to be community based within a coherent spatial and social context [Droege, 2002]. A focus on local potentials and local supply of resources will contribute to lower the dependency of urban areas on other areas and will increase its self-sufficiency.

2.5. Methodology

The first attempt was to develop a method to scan urban areas and define energy demand, quality and quantity wise. Therefore, we first needed a visual representation of urban land-use distribution. In the next phase, we defined urban energy demand and local supply potential. This paragraph will describe the functional unit and method we developed. Paragraph 2.6 will give the results of tests we performed with our method in certain case-study areas.

We developed the urban tissue (UT) as functional unit to apply the UH-concept. Leduc and Rovers [2008] defined the urban tissue as “a conceptual approach towards visualizing resource demand and resources supply potential of an urban area, in an easy to grasp visualization”. The urban tissue is a standard unit, 1 hectare, that allows identification of the different flows within the urban area, like energy, water, food, etc. The Urban Average Tissue (UrbAT) is a way to express the typologies and land-use distribution of the built environment and can be used as a general benchmark to compare the urban harvest potentials with other cities with different typologies [Rovers, 2007]. The urban tissue represents the complexity of urban areas in a single functional unit. By identifying land uses, it also allows identification and quantification of flows within the urban area, e.g. energy.

2.5.1. Urban Tissue development

An average urban area is quite chaotic and it can be difficult to define/classify the characteristics. That is why the researchers tried to develop a more useful, manageable approach for the classification. The result is a graphical and calculation-technical approach of an average urban surrounding of, e.g., a country or a specific city (see examples in 2.6).

The researchers developed the urban tissue as an approach that can give an indication of the exergy potential of an urban area. It is not easy to grasp the characteristics of an urban area when people can only look at the real scale. This tissue gives a first impression of the potential of a certain urban area. The urban potential is the total of a resource coming available from that tissue [Rovers, 2007].

The approach consisted of four steps:

1. Define the urban tissue by calculating the total urban area with its land-use distribution and translating it into an average hectare;
2. Perform a demand inventory, identifying and calculating energy demand qualities and quantities to get an overview of the urban exergetic demand;
3. Make an overview of local supply, identifying and calculating renewable and residual potential, and untapped energy resource qualities and quantities;
4. Couple energy demand and potential supply (attempt). Try to ensure that demanded energy quality is as high as required for the use but not higher by using the principles of multi-sourcing, re-using and cascading.

In the next phase, when urban planning is involved towards increased self-sufficiency, sustainability and decreased dependency, this should lead to an optimization of this coupling.

2.6. Applied

This paragraph shows the results of the application of our method to certain case-study areas. We started with a study of the average Dutch urban area, followed by tissues for Limburg, South-Limburg , urban Parkstad, and Southeast Drenthe, the urban cluster Emmen-Coevorden. All the selected case-study areas were existing built-up environments (EBE). Next to that, we also looked into the non-urban tissue for The Netherlands to show some differences between urban and rural potentials. It also important for a different conceptual approach: The potential can be fulfilled within a system, or the system can be enlarged to include enough space (and potential) to meet the demand. In that case we have floating bordres of a system, in which urban and rural will overlap, that is, if there is rural overcapacity available. This has to be studied more indepth in follow up research.

2.6.1. The Netherlands

We made a quick-scan of the land-use distribution and connected energy demand and potential supply to that. First some general statistic data: total Dutch surface, in 2003, was 4 152 795 ha, and total Dutch urban surface was 534 632 ha [Statistics Netherlands, 2009a] – 13 % of the total surface of The Netherlands. Urban population is calculated as sum of inhabitants that live in an area with an urbanisation classification of very strong urban, strong urban, or moderately urban [Erwich and Vliegen, 2001; Statistics Netherlands, 2009b; Steenbekkers et al., 2006]. Total number of inhabitants was 16 192 572 in 2003, urban population was 9 586 670, and calculated urban density is 17.9 inhabitants/urban ha.

Figure 4 and table 1 indicate the urban land-use distribution. Tables 2 and 3a-b show the energy demand for two qualities and the potential energy supply for several technologies. Residential area takes the largest share of the Dutch urban area, followed by roads and business. The demand is largest for the industry, followed by the houses combined.

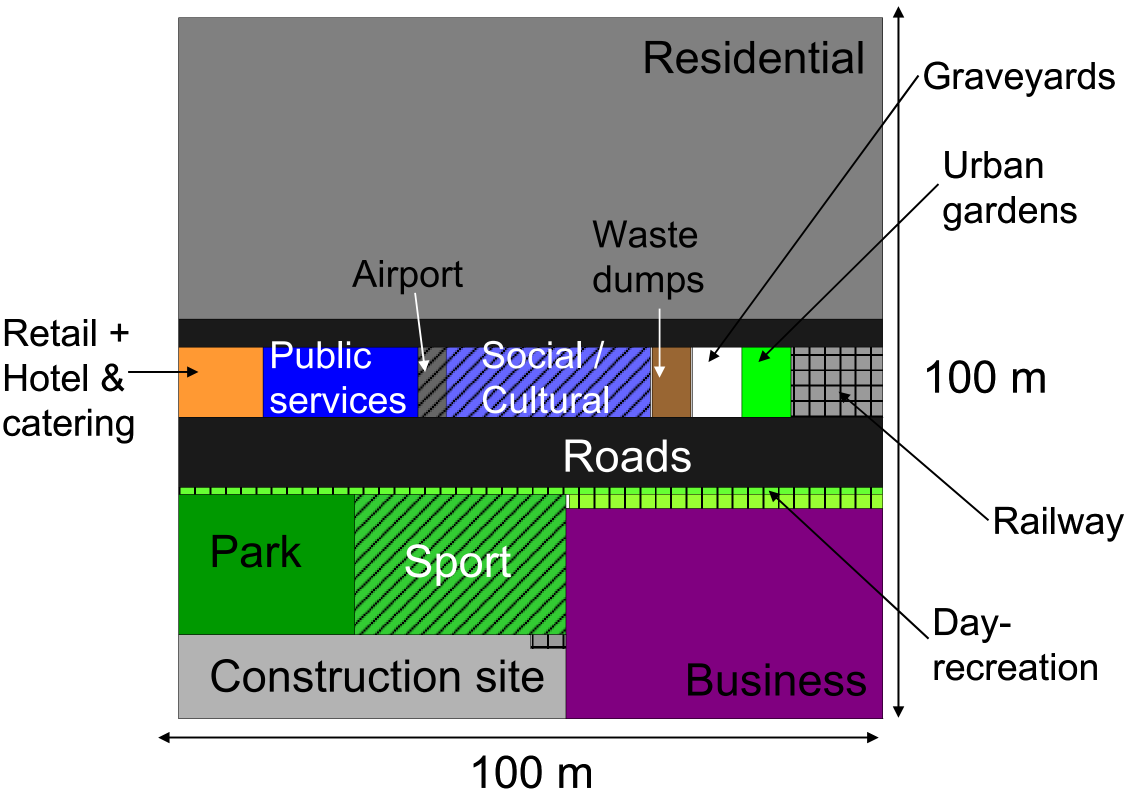


Fig. 4: Dutch urban land-use distribution

In the calculations, two series were tested: first the yearly energy supply potential of current technology, series 1, and second, the potential of improved technology, series 2. To take uncertainty, due to lack of data and future changes, into account, a deviation of 25 % of the available surface or amount of wind turbines, negative (min) and positive (max), is assumed. Other potentials are not further studied: e.g. the subsoil potential, because geothermal and subsoil storage potential are location specific. Average subsoil potential for The Netherlands cannot easily be calculated, because the potential is not homogeneously distributed across The Netherlands.

Table 1: Dutch urban land-use distribution, specification

Urban function		Area (m^2)	%
Residential area		4,188	42
Housing density, *units per type*	Terraced, row	*5*	
	Corner	*2*	
	Semi-detached	*2*	
	Detached	*1*	
	Apartment	*3*	
Retail, hotel & catering industry (H & C)		117	1
Public services		228	2
Social/cultural services		289	3
Business area (industry)		1330	13
Waste dumps		51	*
Graveyards		77	*
Construction sites**		653	7
Parks & public gardens		499	5
Sports terrain		603	6
Urban food gardens		73	*
Day recreational terrain		198	2
Roads		1485	15
Railway		157	2

*: less than 1 %

**: vacant land

Based on: Statistics Netherlands, 2009 a,b,c; Klinckenberg, 2004

Table 2: Dutch urban energy quality demand

Urban functions	Electricity, MWh	Gas, GJ
Houses	42	837
Industry	384*	680*
Hospitals	3	18
Care & nursing centres	2	24
Education	2	22
Retail	9	32
H & C	5	33

*: incl. offices and business buildings, warehouses

Table 3a shows the results for solar and small-scale wind energy supply potential. Photovoltaic-panels (PV) on roofs or vacant land, e.g. construction sites, show a large potential and the heat generating technology for roads also shows large potential. The potential for urban wind turbines (UWT) is very small and therefore we do not study this technology further – no second series or minimum, maximum assumed. The potential for the electricity generating road technology is small compared to PV potential.

Table 3b shows the results for some other potentials. The waste fractions are studied in two groups, but because waste has a low potential a second series was not studied. The wind potential is estimated by calculating for two types of non-roof mountable wind turbines (WT), each type is a series.

Table 3a: Local energy potentials

Technology	Surface (m^2)	Electrical yield (MWh)		Heat yield (GJ)	
		Series 1	Series 2	Series 1	Series 2
PV-roof	1500	150	299		
PV-construction	520	52	104		
UWT	1500	0.2	-		
Roads	1190	30	59	795	1185

Table 3b: Local energy potentials, continued

Technology	Amount	Electrical yield (MWh)	Amount	Heat yield (GJ)
Waste (kg)	5110	3	2905	17
WT, series 1	7.2	282		
WT, series 2	0.34	439		

The following figures (5a-b) show the result of the coupling between energy demand and local supply potentials. The figures indicate to what extend the urban region can supply its own energy demand. Figure 5a shows the results for the calculations of the electricity potential. This figure shows that it is needed to invest in multiple potential sources to fulfil the required electricity demand. PV-potential on roofs and vacant land, construction sites, (series 1 or 2) can be combined with road-potential (Pelt-1 or Pelt-2) and series 1 wind turbines (WT-1). Series 2 wind turbines (WT-2) can fulfil the demand on their own. Figure 5b shows the potential heat supply from roads, for the two series, which is insufficient to fulfil heat demand. Potential supply of waste is very small compared to road potential and therefore not shown.

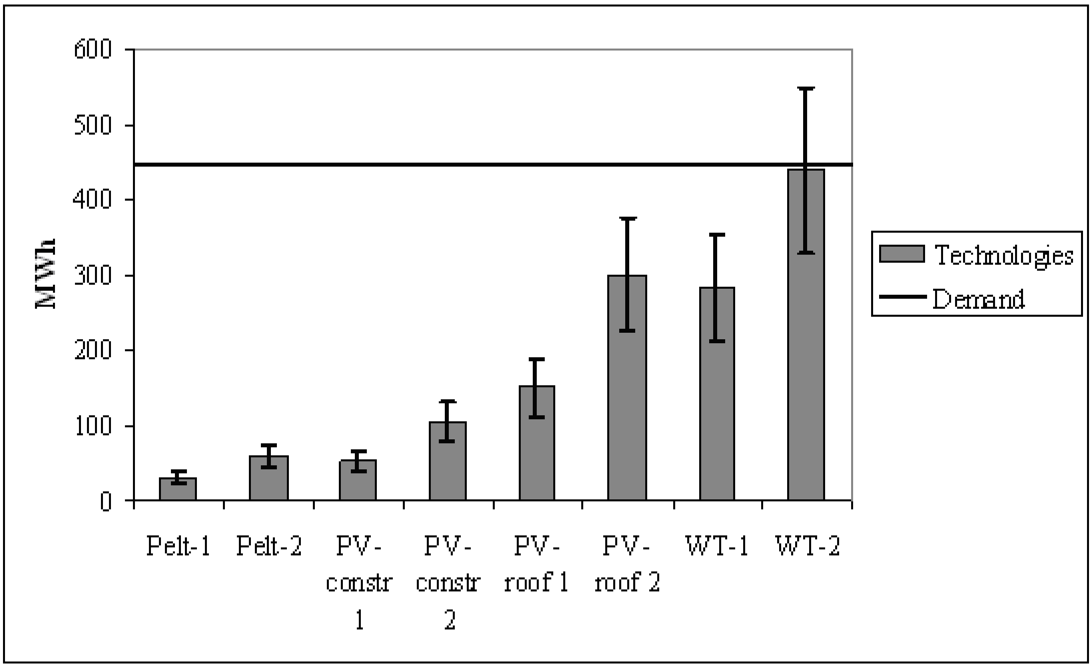


Fig. 5a: Electricity supply potentials vs. demand

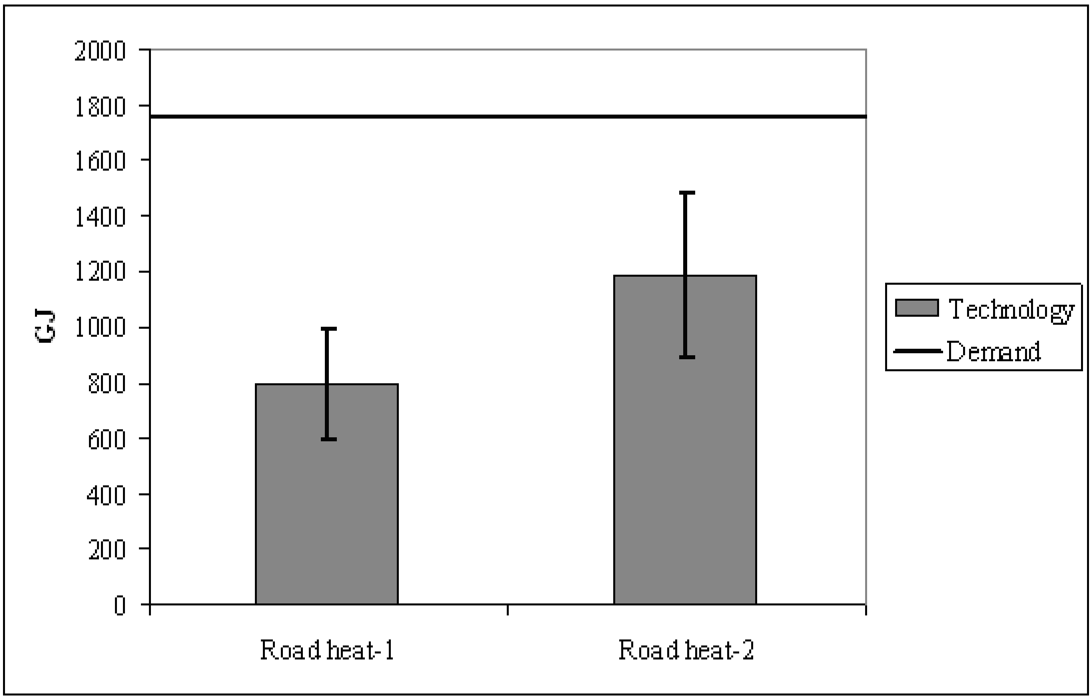


Fig. 5b: Heating supply potential vs. demand

2.6.2. Parkstad Limburg

Parkstad is a combination of 7 municipalities in the South of The Netherlands. It is part of the projects first case-study region, South Limburg. The focus of this work package is on urban areas and therefore urban Parkstad, consisting of Brunssum, Heerlen, Kerkrade and Landgraaf, was selected. Those four municipalities are classified as urban – urbanisation classes: very strong urban, strong urban, or moderately urban – and the other three are classified as non-urban – urbanisation classes: low urban, or non-urban [Erwich and Vliegen, 2001]. Those four municipalities are located within, or at the border of the planned ring road, and are therefore studied as one region. This ring road is a structural element that can have a role in the transition of the area towards a sustainable urban area. Like the name indicates there are a lot of parks and public gardens to be found in the ‘Park-City’.

Some general statistics: total surface of the studied Parkstad-area, in 2003, was 10 965 ha, and total urban surface of that Parkstad-area was 6983 ha – 64 % of the total studied Parkstad-area. Total population was 214 261 inhabitants in 2003, urban population, urban classification as for Dutch average, was 182 770 [Statistics Netherlands, 2009b], and calculated urban density is 26.2 inhabitants/urban ha.

Figure 6 and table 4 indicate the urban land-use distribution. Tables 5 and 6a-b show the energy demand for two qualities and the potential energy supply for several technologies. Residential area takes the largest share of the urban area and is larger than the Dutch average. Other large areas are for business, parks and roads. The demand shows the same distribution as in the Dutch average case.

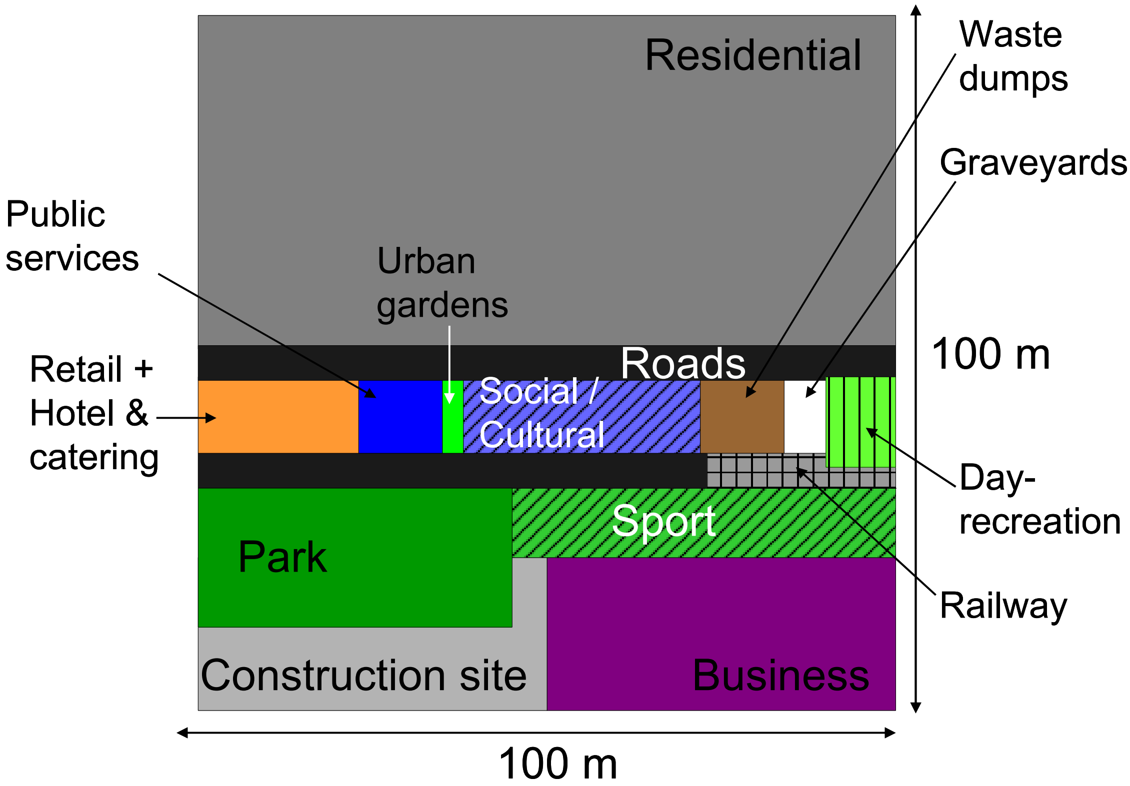


Fig. 6: Parkstad urban land-use distribution

Table 4: Urban Parkstad land-use distribution, specification

Urban function		Area (m^2)	%
Residential area		4,823	48
Housing density, *units per type*	Terraced, row	*6*	
	Corner	*2*	
	Semi-detached	*2*	
	Detached	*1*	
	Apartment	*3*	
Retail, H & C		228	2
Public services		132	1
Social/cultural services		341	3
Business area (industry)		1094	11
Waste dumps		112	1
Graveyards		70	*
Construction sites**		583	6
Parks & public gardens		888	9
Sports terrain		568	6
Urban food gardens		34	*
Day recreational terrain		123	1
Roads		867	9
Railway		126	1

*: less than 1 %

**: vacant land

Yearly energy supply potential of the Parkstad urban hectare is calculated in a similar way as for the Dutch urban hectare, with same assumptions for the series and deviation of 25 % of available surface or amount of wind turbines. For PV-potential on roofs, another calculation was needed, because the amount of total potential roof surface like for the Dutch urban hectare was not available. Potential for UWT was not checked; PV-potential looks more promising. The land-use categories include more space than the specified urban functions claim: this extra space includes space for parking lots, green areas and so on. For PV-potential on vacant land, e.g. construction sites, same assumptions as for the Dutch urban hectare are applied. Table 7 shows the results for yearly solar energy supply potential of the Parkstad urban hectare. PV has a large electricity potential and the roads can generate electricity or heat.

Table 5: Urban Parkstad energy quality demand

Urban functions	Electricity, MWh	Gas, GJ
Houses	45	900
Industry	477*	624*
Hospitals	3	21
Care & nursing centres	2	19
Education	1	14
Retail	15	55
H & C	5	38

*: incl. offices and business buildings, warehouses

Table 6a: Local energy potentials

Technology	Surface (m^2)	Electrical yield (MWh)		Heat yield (GJ)	
		Series 1	Series 2	Series 1	Series 2
PV-roof houses	259	26	52		
PV-roof other	212	21	42		
PV-construction	466	47	93		
Roads	694	17	35	465	690

Table 6b shows the result of yearly potential energy supply of other technologies on the Parkstad urban hectare. Same technologies and assumptions are studied as for the Dutch urban hectare. The composition of the subsoil of this area is not suitable to apply geothermal energy. There are possibilities to apply the former mines for thermal storage.

Table 6b: Local energy potentials, continued

Technology	Amount	Electrical yield (MWh)	Amount	Heat yield (GJ)
Waste (kg)	8500	5	4390	26
WT, series 1	7.2	282		
WT, series 2	0.34	439		

Figures 7a-b show the coupling of demand and supply: a comparison of potential electricity and heat supply of the Parkstad urban hectare and energy demand. Figure 7a shows the results for the calculations of the electricity potential. This figure shows also that it is needed to invest in multiple potential sources to fulfil the required electricity demand. PV-potential on roofs and vacant land, construction sites, (series 1 or 2) can be combined with road-potential (Pelt-1 or Pelt-2) and wind turbines (WT-1). The larger wind turbines (WT-2) can fulfil the demand almost on their own. Figure 7b shows the potential heat supply from roads, for the two series, which is insufficient to fulfil heat demand. The potential supply of waste is very small compared to the road potential and therefore not shown.

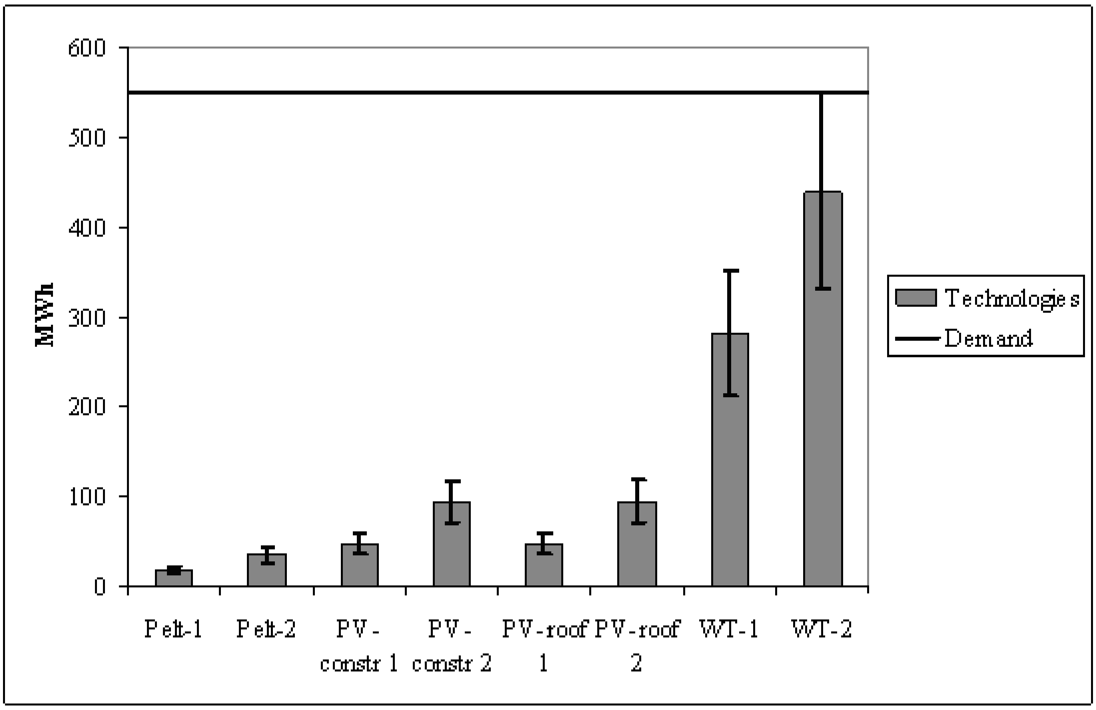


Fig. 7a: Electricity supply potentials vs. demand

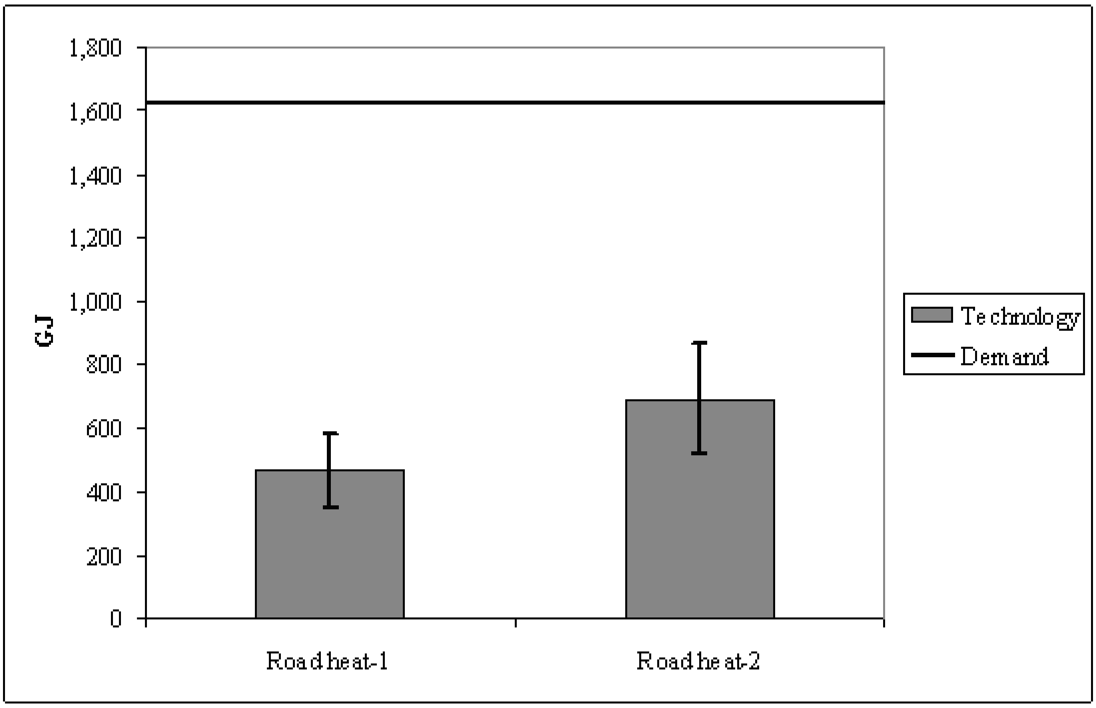


Fig. 7b: Heating supply potential vs. demand

2.6.3. Emmen and Southeast Drenthe

The second case-study region within the project is the North of The Netherlands. We decided to focus on the Southeast of the province of Drenthe, consisting of two municipalities: Emmen and Coevorden.

Some general data for the Emmen-municipality case: total surface (2003) = 34,629 ha; total urban surface = 5,288 ha – 15 % of total surface; number of inhabitants (2003) = 108,198; urban population = 31,100 [Statistics Netherlands, 2009a; Statistics Netherlands, 2009b]; urban density = 5.9 inhabitants / urban ha.

Figure 8 and table 7 show the urban land-use distribution for Emmen-municipality. Tables 8 and 9 show the energy demand for two qualities and the potential energy supply for several technologies.

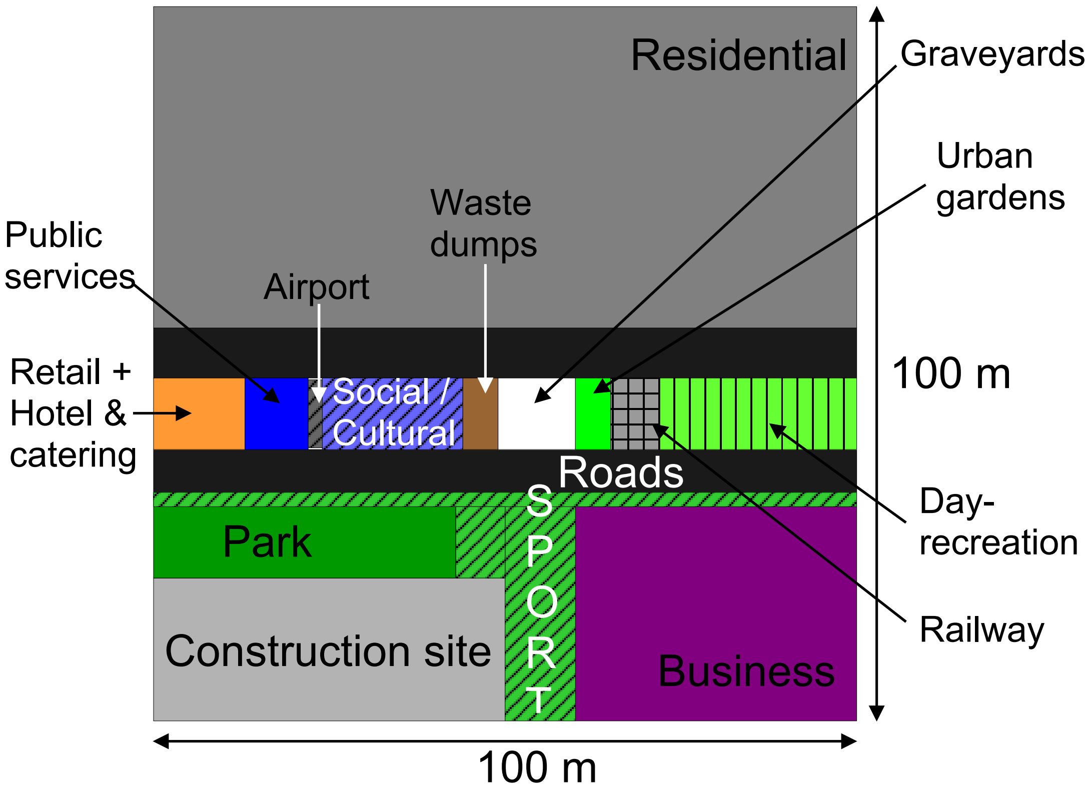


Fig. 8: Emmen municipality urban land-use distribution

Some differences become visible that may influence differences in energy demand and in potential energy supply when comparing the Dutch average urban tissue (fig. 4), the Parkstad-tissue (fig. 6) and the Emmen-municipality urban tissue (fig. 8). A first glance at the percentage urban surface shows that Emmen is about the same as the Dutch average, 15 % over 13 %. Parkstad has a much larger urban surface, 64 % of total surface. Emmen has a larger residential area than the Dutch average, but Parkstad, has the largest residential area (~4,800 m^2). At the other hand has Emmen less houses on that residential area: 9 compared to 13 (NL) and 14 (PS). The lower amount of houses also reflects in the urban density: Emmen, 5.9, has a low density compared to the Dutch average, 17.9, or Parkstad, 26.2. If we look at the other functions, we see that Emmen has a somewhat smaller road area, 1,295 m^2, than the Dutch average, 1,490 m^2, and Parkstad has only 870 m^2. This surface gives possibilities for the application of road energy technologies. The business area is a bit lower than average, 1,200 m^2 over 1,300 m^2 (Parkstad 1,100 m^2) so, the use of empty surface within business area for PV-panels or wind turbines is comparable to the Dutch average. A large difference is visible for the construction site (vacant land): Emmen 1,000 m^2, compared to 650 m^2 (NL) and 580 m^2 (PS). Therefore Emmen may have a large potential for the application of PV-cells constructed in a large field on empty surface, or for construction of wind turbines. For green areas the results show that Emmen has less park and public gardens, and sports terrains compared to Dutch average and Parkstad, but the area for day-recreation is larger. For public and social-cultural services the results show that less area is occupied in Emmen by these functions compared to Dutch average and Parkstad. The lower density, and less people, living in the area may influence this. Fewer people probably need fewer hospitals and other care centers, fewer education facilities, fewer leisure facilities, and so on.

Table 7: Emmen-municipality urban land-use distribution, specification

Urban function		Area (m^2)	%
Residential area		4,520	45
Housing density, *units per type*	Terraced, row + corner	*3*	
	Semi-detached	*2*	
	Detached	*2*	
	Apartment	*2*	
Retail, H & C		132	1
Public services		87	*
Social/cultural services		197	2
Business area (industry)		1199	12
Waste dumps		26	*
Graveyards		112	1
Construction sites**		1042	10
Parks & public gardens		429	4
Sports terrain		533	5
Urban food gardens		53	*
Day recreational terrain		282	3
Roads		1295	13
Railway		57	*

*: less than 1 %

**: vacant land

Table 8: Urban Parkstad energy quality demand

Urban functions	Electricity, MWh	Gas, GJ
Houses	31	630
Industry*	245	495
Hospitals	1	9
Care & nursing centers	2	27
Education	1	16
Retail	6	21
H & C	2	15

*: incl. offices

Table 9 shows results for potential energy supply. PV on roofs and vacant land (construction site = constr.), roads and wind turbines have a large potential for electricity. The main source of heat is roads. An important potential missing is waste heat from industry. The table shows the results for the maximum application of studied technologies. The overview graphs (fig. 9a-b), that compare demand vs. potential supply, show a maximum and minimum. And the graphs show two series for each technology; second series = improved technology.

Table 9: Local energy potentials

Technology	Amount m^2		Potential yield Electricity, MWh	Heat (cold), GJ
PV-roofs, houses	190		19	
PV-roofs, other buildings	150		15	
PV-constr.	1,040		104	
Roads	1,295		32	860 (270)
	Amount		Electricity, MWh	Heat (cold), GJ
Waste (kg)	1,664	1,687	1	9
WT, Proven 15kW, #	9		352	

For PV, Peltier-elements [Combrink et al. 2004] and Road Energy Systems® (RES) [Bondt & Jansen, 2004] results are calculated for the current technology and for future improved technology: PV-series 1 is current, efficiency of 10 %: 1 m^2 = 100 kWh; PV-series 2 is improved, efficiency of 15 %: 1 m^2 = 150 kWh; Peltier-series 1 is current: 1 m^2 = 25 kWh; Peltier-series 2 is improved: 1 m^2 = 50 kWh; RES-series 1 is current, heat: 1 m^2 = 0.67 GJ, cold: 1 m^2 = 0.21 GJ; RES-series 2 is improved (50 %), heat: 1 m^2 = 1 GJ, cold: 1 m^2 = 0.32 GJ. Further, minimum and maximum values are assumed: assumptions are the same for series 1 and 2; PVroof-max: already high level of efficiency assumed, therefore is for max. an improvement of 10 % taken; PVroof-min: a decrease of 25 % compared to average available surface; PVconstr-max: available, empty, construction surface; PVconstr-min: 50 % of available, empty, construction surface; Road-max: available road surface; Road-min: 50 % of available road surface; WT-max: maximum amount of WT that can be build on hectare (= 9); WT-min: feasible amount that can be build on hectare, taken other objects into account (= 3).

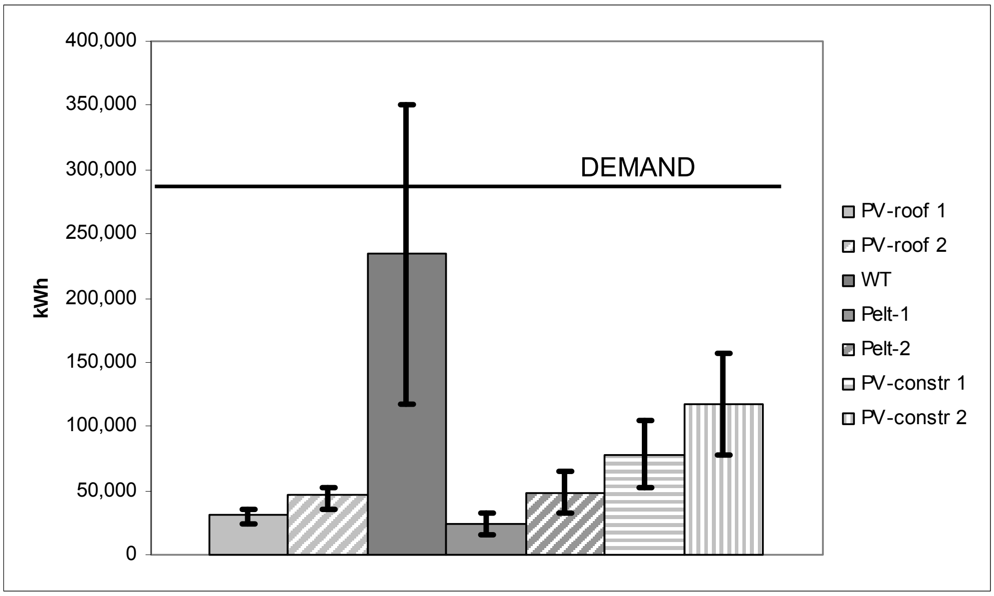


Fig. 9a: Electricity supply potentials vs. demand

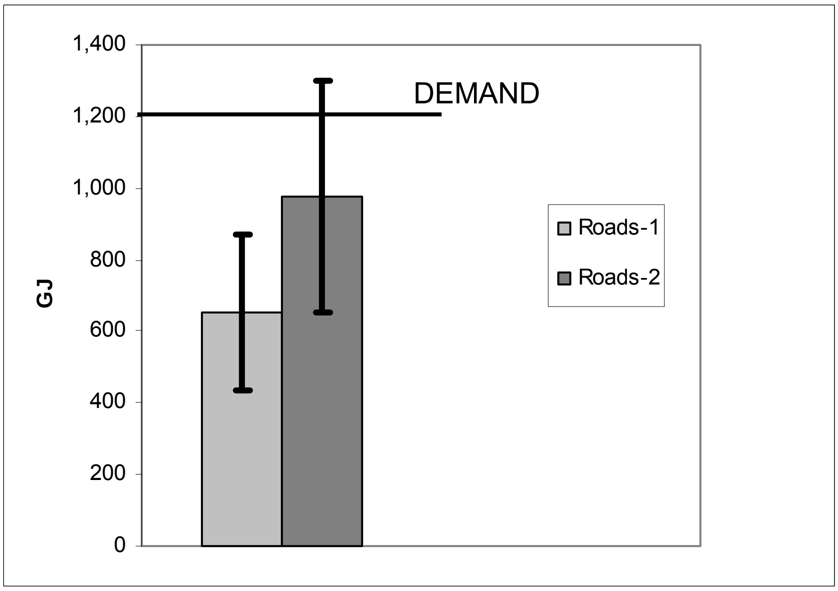


Fig. 9b: Heating supply potential vs. demand

Region Southeast Drenthe (municipalities Emmen and Coevorden)

Table 10 and figure 10 show the results for the whole case-study area, Southeast Drenthe regional tissue [Statistics Netherlands, 2009a]. Some general statistics: 144 206 inhabitants, a density of 2.3 and a housing density of about 1. The visualization gives a quick overview of the land-use distribution and the table gives more specific, statistical input. The region is characterized by a large non-urban area – agricultural and forest area. To get a complete overview of the energy demand, and energy and material supply potential, it is important to have data about those areas. Maintenance of forests and agricultural activity demands energy which can have a large contribution in this case. At the other hand, the substantial area and possible residues can offer ample possibilities to supply energy and materials. In the transition to a more sustainable region, those potentials can play a role.

Table 10: Southeast Drenthe regional land-use distribution, specification

Land area	ha	m^2/ha
Land surface, total	63,390	
Built-up area		688
Semi-built-up area		153
Recreational area		202
Traffic area		309
Agricultural area*		7,512
Forest area		833
Natural area		302

*: of which ~60 m^2 greenhouse area

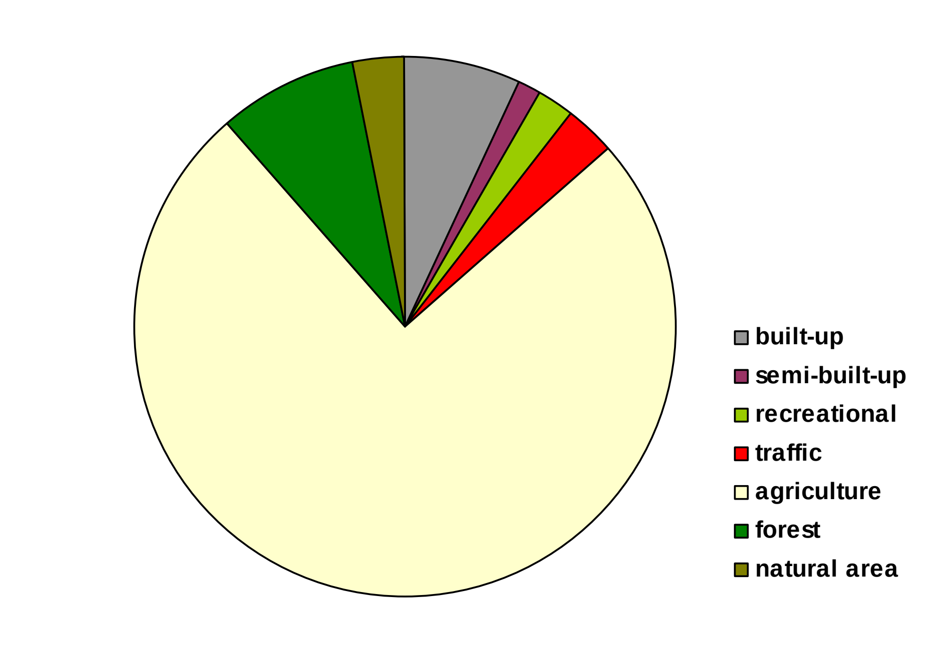


Fig. 10: Southeast Drenthe regional tissue, land-use distribution, 1ha, pie chart

Table 11 presents demands of certain functions for the Southeast Drenthe regional tissue. For the houses, an assumption was made for the whole studied region. Some assumptions about the calculation of surfaces which lead to the energy demand calculations, because more data was lacking:

- Offices: Emmen-Coevorden taken together about 40 % of all facilities classified as industrial used for industrial purposes, like production or handling of materials, other 60 % assumed as office; business area = 136 m^2, 60 % = 81 m^2;
- Retail and Hotel & Catering industry (H & C) = 13 m^2; *heating demand as for H & C* [Klinckenberg, 2004];
- Others: public services and social-cultural services area = 17 m^2; *average of education, hospitals, care & nursing* [Klinckenberg, 2004];
- Industry is missing because good way to calculate occupied surface or amount is not identified yet, and also data of energy demand per surface are lacking;
- Energy demand of agricultural sector and transport also important, but good way to calculate occupied surface or amount is not identified yet.

Table 11: Southeast Drenthe energy demand

Urban functions	Amount total #	Demand Electricity, MWh	Gas, GJ
Houses	61,345	208,570	3,830,000
	m^2/ha	Electricity, kWh	Gas, GJ
Offices	81	9,035	41
Retail + H & C	13	1,410	10
Others*	39	2,560	25

*: public and social/cultural services

Table 12a shows some results for energy supply potential, based on the available area within the hectare. The selected technologies are: PV, Peltier-elements and wind turbines. Assumption was that for PV 15 % of the surface of the built-up area will be available (same assumption as for Dutch average case). An extra assumption was made for recreational area: half of it built-up (buildings) and of that area 15 %. Of the traffic area, about 290 m2 is road area traffic (others railway and airport); this complete surface will be available to apply Peltier-elements. The wind potential for the regional tissue is based on GIS-data about feasible areas with high wind speeds and enough space to build larger wind turbines of 2 to 3 MW each. Table 12b shows some calculations for large wind turbines.

Table 12a: Southeast Drenthe electricity supply potential

Technology	Amount m^2	Potential yield, kWh Current	Improved
PV	120	12,000	18,000
Peltier	290	7,250	14,500

For PV: current efficiency is 10 %; improved efficiency is 15 %;

For Peltier: current technology results in 25 kWh/m2; improved results in 50 kWh/m2.

Table 12b: Southeast Drenthe wind energy supply potential

Wind speed (m/s)	V-52, MWh	V-90, MWh
6.5	2,200	6,500
7.0	2,700	8,100
7.5	3,300	9,900
8.0	4,000	12,050

2.7. Conclusion

We need to use a multifunctional sustainable approach towards a sustainable urban area and urban resources management. The urban area needs to be built up of several urban functions: residential, business and industrial areas, social and cultural functions, retail areas, recreational areas, roads, etc. To use the local potentials optimally and effectively, these functions need to be mixed, connected, and distances may not be too large.

The urban metabolism needs to transform from a linear, resource-to-waste, metabolism to a circular metabolism. Therefore, we need to think in terms of energy qualities, of the potential to do work. And we need to see an urban area as a reservoir of un-used, remaining energy qualities, both renewable and residual. We need to study local renewable potentials, and potentials for re-using, recycling and cascading remaining resources. By applying our method, in which a circular metabolism and UH are incorporated, we can quantify the overall flux – input, transformations and outputs – of resources of a specific region, from global, to country to household level.

We tried to implement in our method the different steps from the New Stepped Strategy [Dobbelsteen & Tillie, 2009]. We tried to include also measures to limit the demand for energy. This can be reached by applying certain technologies at household level, and at a larger scale by connecting several urban functions to cascade remaining qualities and thus limit the demand for virgin energy resources.

Our method gives an overview of the renewable potential and calculates how much this can be.

The urban tissue can add to the study of the exergetic possibilities and the potentials for sustainable energy use and exergy in the urban area. The developed quick scan of an urban area – Urban Tissue – gives an overview of land-use distribution of the studied urban area. Based on this urban land-use distribution, it is possible to quickly calculate energy demand and potential energy supply of a specific urban area.This tissue can help to get a better insight in the characteristics of an urban area. Two cases, one in each of the case-study areas, were compared. This comparison indicates the importance of local characteristics.

The results of the supply inventory show that urban areas have ample energy sources available for a transition towards a sustainable urban energy system. And the results of the coupling with demand show that the energy supply potentials of an urban area – unused energy sources – can fulfil, parts of, the demand for energy of the urban area. The differences can be explained by the fact that energy potentials are context and location dependent. If these results are combined with reduction demand measures, this will provide better overall results, showing that integration of different measures will be the option towards a sustainable urban energy system.

We applied the Urban Tissue approach at multiple scales, country scale or for a specific urban area, because a difference in urban characteristics and land-use distribution results in differences in the application of certain potentials, e.g. some potentials or applied technologies are site-specific or location dependent. Therefore, we also focus on multiple, and improved technologies and try to include as much potentials as possible. Consequently, technology selection should consider different spatial levels from on-site, building level, to centralized systems. Another important aspect is lack of data in certain occasions. Summarising, there is not a single technology that fits entire community's requirements: space, costs, landscape impact, among others; urban energy planning is not about finding the best technology available, but evaluating benefits and trade-offs of each potential implementation within a given local context. For instance, by implementing the largest type of wind turbines studied, a large percentage of urban electricity demand is fulfilled. The drawback of this option is the land demand, due to the large distances required between the turbines and other objects, shadowing effects and possible noise pollution, which can be a problem in an urban area. A combination of the other studied technologies and potentials, with smaller spatial impact and more socially accepted, is also possible, and therefore feasible in an urban area where less space is available. The results show that application of renewable energy technologies has an impact on space and on how to use available surface [Menkveld, 2002].

When the urban area is combined with, e.g., peri-urban areas or rural areas, the scale is broadened and more area becomes available (see the Southeast Drenthe tissue). The exact borders of the studied system do not matter for the flows. There are still flows going in, going through the system, the system tries to capture the flows, and the remaining flows out. Differences can be found in the amounts of the flows, and if more flows through the system and can be captured for re-use. We can expand the urban tissue approach with e.g. agricultural area – containing greenhouses. If we include agricultural area in the urban tissue it becomes broader than urban, a regional tissue. Or we could next to the urban tissue develop a rural tissue to show the impact and potentials of this function. The data for the Southeast Drenthe case give an indication about land-use distribution and about energy demand and supply potential of the region. The results show that wind can have a large contribution to the overall energy supply potential. By showing all regional functions, also more energy demanders are taken into account. A large demander is the greenhouse area in Emmen. But the greenhouses can also have a large potential: energy producing greenhouses, source of non-used energy qualities, closed-off greenhouses, etc.

The urban tissue is a conceptual approach to quickly and interactively scan an urban area. It is an approach that combines both statistical information and spatial distribution. The tissue gives an aggregated overview of demands for energy, of different qualities, e.g. electricity and heat, and of potential local supply, and how much can be captured, transformed, conserved and applied locally. This approach indicates opportunities to use available untapped, local energy sources, and supports coupling of energy demand and supply, according to functions and qualities, so called energy-cascading, resulting in more options for urban areas to fulfil their energy demand, waste less energy and become less dependent on non-local sources [Dobbelsteen et al., 2007]. The multi-scale aspect and multiple technology focus make the impact of the characteristics and land-use distribution of a specific area visible. The studied area can, e.g., have less space available to apply certain energy technologies, which increases pressure to find alternative, untapped sources even more [Cola et al., 2005; Menkveld, 2002].

The described approach has a signalling function, converts studied urban areas into a functional unit, and can quickly adapt to new requests for research of other urban areas, and quickly give new input for urban planning. The approach can help existing urban energy systems, based on one fossil energy source, and therefore more dependent on foreign supply and more prone to risks of energy break-downs, towards sustainable urban energy systems. An urban energy system, based on multiple renewable technologies and sources that are locally available, can act more independent and shows a lower risk of break-down.

We used our method to develop certain possible futures and presented those for the stakeholders within the case-study areas. By doing that, we allowed them to react and give their input. We proposed certain solutions from a scientific, technological point of view. This needs to come together with other viewpoints, with a strong local input, towards a more sustainable urban resources management and planning. Engagement of stakeholders, including local politicians, is critical to effective spatial planning by local authorities [Morphet et al., 2007].

This first part of the research learned us that our method does not guide us completely towards sustainable urban areas. Some important aspects are missing. We talked about urban planning and that it is important to integrate planning and resources management, but our results do not show that yet. Planning is important to tackle the problems about temporal and spatial differences between energy demand and supply. Another aspect that is missing is an integral approach for all urban flows. We indicate that we have to come up with one approach, but we did not prove it yet. For now, we showed the maximization for urban energy flow, but we do not know yet what the effect will be on other urban flows. We will try to tackle those problems in the next chapter.

Chapter 3 will give some additional information about concepts that we need to adapt our method. In the second part the adapted method will be described and results will be given for an EBE, Kerkrade-West, and a NBE. We will end the chapter will a discussion and our final conclusions.

3. Problem solving – take 2

This chapter will describe the transition in the thinking of the researchers. During the research, our method evolved. The background on which we based our method and results changed. Because of that, we also had to adapt our method which we tested in another case-study area, both EBE and NBE.

3.1. Urban Harvest +

This approach is described in Rovers et al. [2010].

3.2. Integrated Urban Resources Management

We need an integrated urban management of resources and urban planning. Maximizing one flow, e.g. energy, to a sustainable, circular, metabolism is not good enough. Maximizing the energy flow can result in negative impacts on other urban flows. Nilsson & Martensson [2003] and Jank [2000] indicated that partial solutions for individual projects and a long-term strategy for the whole municipality have to be optimized simultaneously. We need an integrated and proximal approach tackling water, energy, food, materials, waste, space, etc., at the same time. This will result in an urban area that captures and stores water, energy, food and materials, and recycles wastes. We need to integrate all aspects of energy systems, transport systems, waste and water management, passive and active strategies, natural ventilation and so on, into urban design, to improve the environmental performance of our cities [Lehmann, 2009]. Sustainable urban growth leads to human settlements which enable their residents to live a healthier life, while using minimal natural resources and supporting maximum biodiversity. Some criteria [Lehmann, 2009]:

- Mixed-use urban consolidation: e.g. Vauban-district Freiburg;
- Residential and office typologies that are multi-storey, flexible and compact;
- Buildings that make best use of renewable sources, on-site energy production, and natural cross ventilation, therefore: minimizing primary energy demand of cities and buildings, while maximizing efficiency of energy supply;
- Urban water management strategies are integrated;
- Development on land which has previously been developed and is of little ecological value;
- Integrating existing structures by applying re-use and retro-fitting;
- Developments with high proportion of building materials need to be designed for prefabrication, re-use, disassembly and recycling, to minimize material consumption;
- Planning needs to reflect best practice of compactness, orientation, density, etc.;
- Study, capture and use material, food and other goods resources from sources nearby in an effective way, so supply chains will become shorter and the emission of greenhouse gasses will be limited;

- Apply a strict waste management to reduce waste-to-landfill and waste during construction.

The local use of solar and wind energy allows a reconnection of energy production with the place of final energy consumption. Cities do not exist and grow anymore at the expense of their rural hinterland. Decentralized technologies will be applied and distributed energy generation will become standard. Sustainable city districts themselves will be able to act as 'power stations' to fulfill their own demand.

Towards sustainable, self-sufficient communities, cities can follow a path as described in EREC [2005]. In this report is described how cities can develop to Energy Sustainable Communities (ESC). Those are communities that realize sustainable energy policy measures – application of renewable energy sources and rational use of energy – with contributions of local stakeholders – e.g., general public – to the planning and implementation process [EREC, 2005]. ESC needs implementation of renewable technologies and energy efficiency measures in different sectors, like the transport, industry, and building sector and a participative approach. And application of renewable energy sources has to go together with rational use of energy and energy saving measures. The target is to increase the communities livelihood, without exhausting virgin resources. Cities become more energy independent and self-sufficient when using more renewable energy sources and implementing energy reduction measures. Furthermore, the use of sustainable energy can contribute to economic welfare of cities through local job creation and local income creation. And environmental benefits can result from the use of sustainable energy [EREC, 2005].

To optimally use the available local renewable and residual potentials, the grid has to be able to deal with a mixture of several, possible smaller and decentralized, fluctuating energy sources and a mixture of urban functions in an effective way. The grid is needed to connect energy demand and local supply potential in an optimal way. The grid has to become a 'smart grid' [Droege, 2010]. Figure ? shows an example.

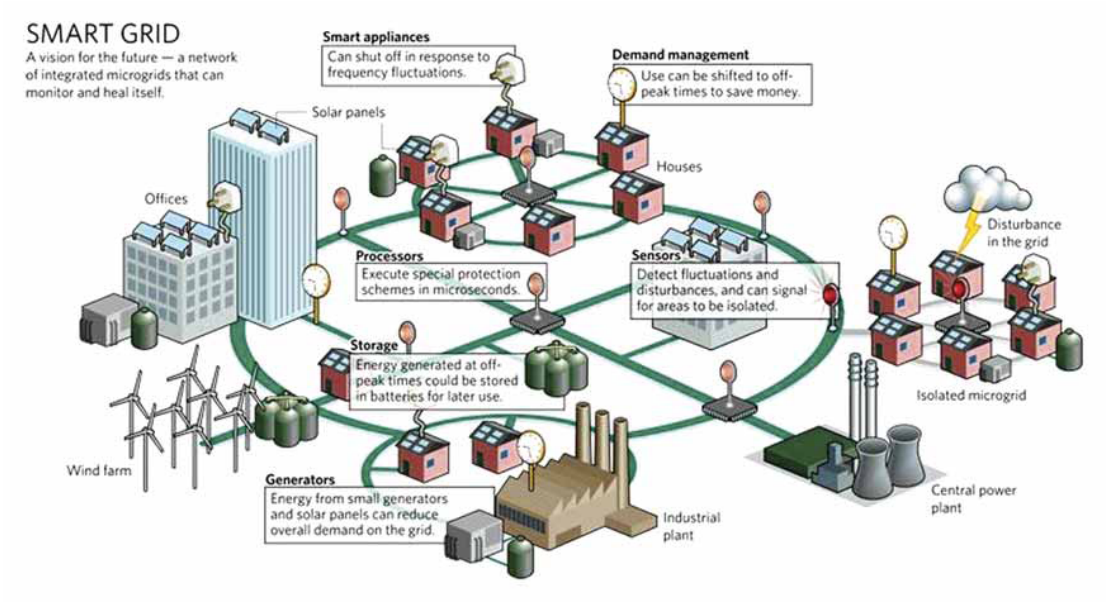


Fig. : Smart energy grid

[urbanecoist.com, in WREC-100% RE for cities]

3.3. Adapted method

The UH-approach uses the Urban Tissue (UT) as functional unit: a quick scan visualizing “urban land-use distribution, resources demand and supply potential” [Leduc & Rovers, 2008]. UT is a standard unit, 1 hectare, that makes identification of several urban flows possible and is a means to express typologies of built environment [Rovers, 2007].

Formula 1 describes the important parameters within the UH-approach:

$$\text{Urban Max Tech Harvest} = \text{Potential Urban Harvest} \times \phi_{tech} \times \phi_{urban} \, .$$

Potential UH is maximum amount of source available, or collectable within boundaries of UT. However, to calculate how much of this maximum potential can be captured, and converted within the city – Urban Maximum Technical Harvest (Urban Max Tech Harvest) – some reduction applies: Øtech relates to technical efficiency restrictions, and Øurban relates to urban characteristics and typology restrictions [Rovers, 2007; Agudelo et al., 2009].

The proposed method builds on description of Dutch Urban Average Tissue, UrbAT-NL [see Rovers, 2007; Leduc & Rovers, 2008]. The method to develop the specific urban energy tissue [see also Agudelo et al., 2009] consists of 5 steps (fig. 2):

1) Urban land-use distribution: Inventory of urban spatial functions and surfaces;
2) Demand inventory: Hierarchical quality identification and quantification of urban energy use;
3) Demand minimization strategies and supply inventory: Inventory of urban demand limiting measures; hierarchical quality identification and quantification of urban energy sources, renewable and residual; calculation of technical feasibility;
4) Couple supply – demand: Try to ensure that quality of energy is as high as required for use, but not higher, by using principles of multi-sourcing and cascading; use decision tree (fig. 3) to define if resource can be applied locally;
5) Optimize supply – demand: Apply recycling principles; identify, localize and connect clusters and install networks; optimize storage and exchange with other systems; calculation of Urban Max Tech Harvest by scenarios development.

This method is used to start analyzing the case Kerkrade West (see next Section). And conclude that we have to change it and propose a adapted version instead.

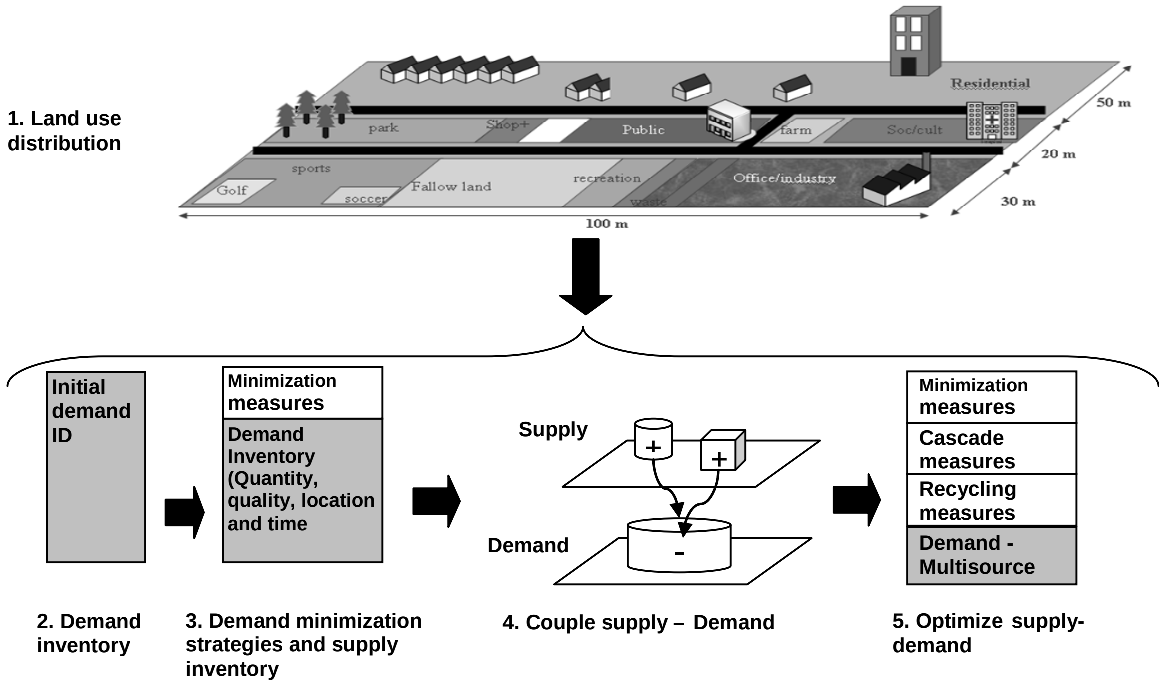
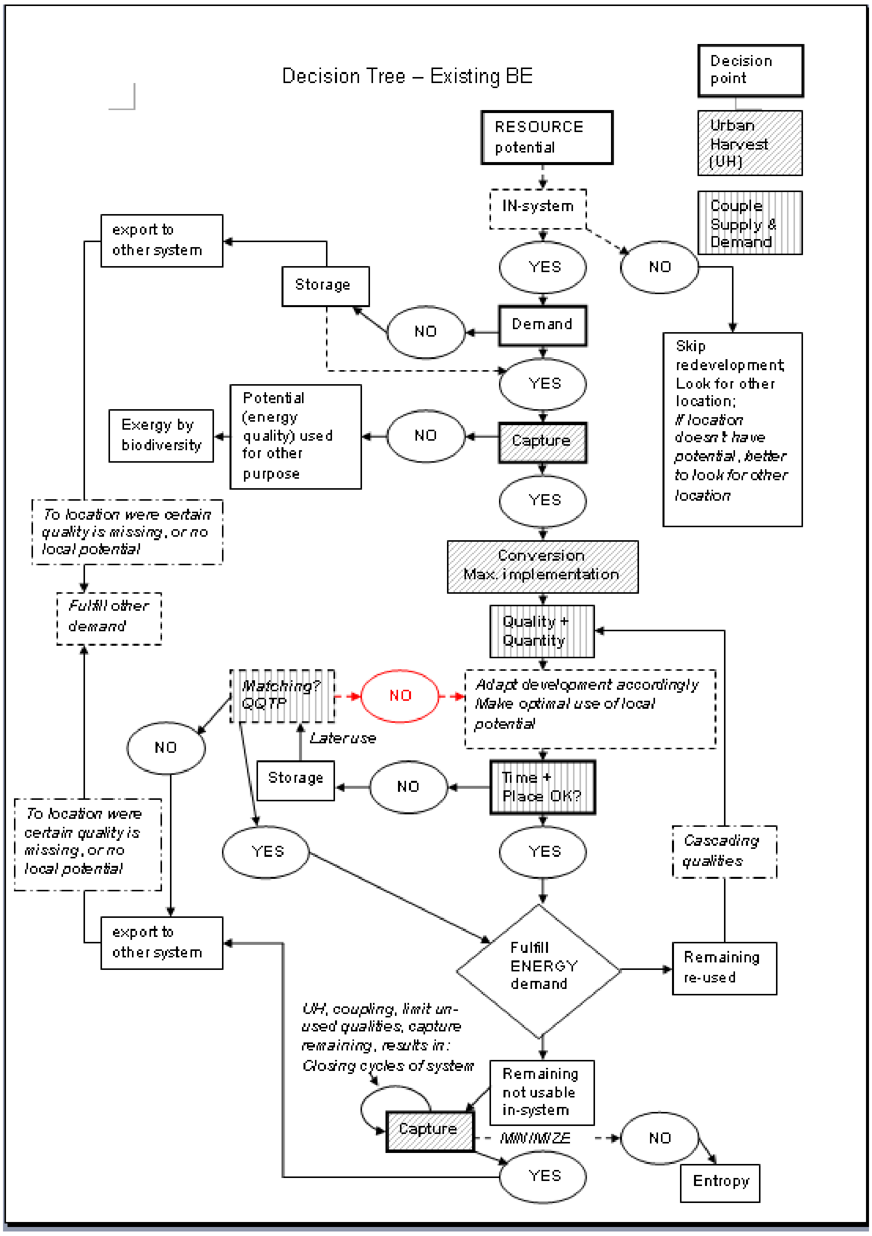


Fig. : Application of UH-approach in cities

The specific urban energy tissue, EN-UrbAT, is developed to support accounting, coupling, and planning of urban energy demand and potential supply. The author defined the tissue for a case-study, Kerkrade-West, based on description of EN-UrbAT by Leduc and Rovers [2008], and Agudelo et al. [2009].

Decision tree used to help in making decisions is shown in fig. ?, for further see also appendix.

Fig. : Decision tree existing built-up environments



In order to introduce our broadened approach, we first describe the way of thought leading to the next level of strategy ad approach.

3.4. Exergy relativity, the role of materials, and Embodied Land

Studying Exergy for the Urban Landscape, with the focus at buildings and infrastructure, the exergy of energy approach so far is not very satisfying. Exergy in fact is not only about energy. Or it is, but then energy is more then energy… In fact energy is mass as well, or mass is energy. Therefore exergy has to deal with the combined qualities of mass and energy, the growth of which is solely depending the external input of exergy, in the earth system in the form of solar radiation, containing and generating energy as well as mass . In some literature energy is also defined as rest mass, or mass as rest energy. Its two manifestations of the same. Its therefore that optimising exergy in a system, relates also to optimising mass. Its of course of great impact for an urban environment whether only energy or energy and mass are evaluated. The Urban environment is estimated to consume up to 40% of all resources globally.

A natural ecosystem , which increases exergy levels in a system is even mainly built on mass and matter, and the ability to optimise solar radiation for its maintenance. Over time the earth ecosystem has constantly maximised its exergy, and organised it in a balance with in and outflows of energy and matter.
Next to the physical exergy concept in this ecosystem (addressing energy and mass) , there is another aspect that is of importance, which is the exchange of information and organisation of networks in a system, which is of importance to the resilience of the system and to maintain exergy levels at its highest.
A natural system is very effective in maintaining a high exergy level, since it as huge networks with information (-exchange) that makes it very robust and adaptable to changes in order to maintain quality, and gradually increase exergy, even from a previous maximum. Exergy (as the thermodynamic approach) and information and communication are always combined in a system: where the information and communication is part of a natural or manmade strategy to increase the effect of a combination of forces. Ie the increase of exergy or avoiding entropy. And as such can have a huge impact on the resulting total balance. .

A well known –network- strategy is cascading of resources, naturally or as a man made approach to slow down entropy in a system. Which is an element in designing direct conversion routes from the resources involved. It can also create short cuts to other processes, and combine different processes into one new integrated system operating at a higher exergy level. (Like the Kalundborg industrial area) .
In natural systems the information to cascade can be naturally embedded in natures organisms and plants, as they co-operate in survival (and have evolved for that purpose). Its even possible that organisms are genetically adapted to provide their part in a chain of man demanded useful conversions .

There is another route, in man made systems, where the processes can be structurally arranged by intelligent management. And not only within one exergy evaluated energy system, but also outside that system, leading to a complete other process. This is the case for instance in the laundry example: A laundry machine operation can be exergetically optimised, even including the production (materials resources) of the machine (And have a A+++ label) but this does not mean this is an intelligent system: (it’s the cascading example) The intelligent option is to have laundry shops in urban districts, that operate with a few industrial size machines, and a man operated distribution system connected, bringing the function, cleaning laundry, to a complete other level of exergy balance . The knowledge to propose and develop this choice is part of the intelligence stored in the system.
Of course, nowadays this knowledge is hardly used, the wealth of easy to deplete stocks has lead us to develop and possess individual machines, but as soon as stress will increase in the distribution of resources, the laundry shop concept will quickly take over again: In other words: if now, in the wealthy situation, we would use laundry shops, a lot of exergy would be freed for other purposes, or better, not used, and reduce entropy growth of society as a whole.
As such the information and communication networks are part of the collective memory of a species, in this case mankind’s overall knowledge, shared in a continuous way over generations. In fact the level of mastering exergy management could be seen as indicator for the level of intelligence of a system or species.

(in fact this example shows that the knowledge is stored in the system, however is not used.. This is mainly related to the fact that we have chosen a complete different model to base our choices on: the economic system, which allows some people to make choices not to benefit the whole but the individual option)

One last word about this: Apart from some local modification of agricultural crops over the ages and some recent attempt to genetically modified food, in generally we assume that we can not change genetic structure of all world species, and therefore as mankind, have to rely on intelligent organisation. Nevertheless, I recently came upon a research project that proposed to not try to improve the efficiency of technological processes, like PV solar cells, , but rather try to improve conversion efficiency of biomass growth, which so far is around 1 percent. If that could be raised is the idea, the problem (of human useful exergy availability) was easier solved. At first sight a open-minded and creative approach, at second thought a dramatic direction: We as mankind have proven not to be able to maintain a (energy) balance in society, while nature (natural ecosystems) has, and if we now start changing parts of nature, both systems go out of balance and disaster is born.

The above described combination of the physical exergy and the information and communication networks can be illustrated by the concepts of growth and and development: (exergy-) growth in a system , can be established by including more energy-mass (stored and used with an increased flow), partly by attracting resources from outside the system regarded, while development can be defined as 'growth' (or increase of exergy) within the regarded system, by intelligent organisation and communication (networks) . Its obvious that for the earth as a whole, growth and development are the same, since resources except for solar radiation are not able to be imported . In a limited system however, growth is possible by lending resources from a neighbouring system, depleting the other systems resources, or decreasing its exergy (potential). Growth from own resources in a (limited) system, or development within the system is the only way to improve the performance, or reduce the burdon, within a regarded system.

The earth as a whole system , as the maximum mankind can influence, seems very large to address, but when we translate that to a level mankind can master, its not that big: we have access to more or less plus or minus 10 km from the earth surface. In fact our system is like a band around the world in which we have to survive and establish maximum maintainable quality for all people in the world. (def uit boek: ….) If the energy *and mass* in the system , consumed and stored, in any year is lower then the year before, loss of exergy takes place, or quality decreases. Its easy to see that even the smallest decrease per year, will ultimately lead to destruction of all exergy, and create equilibrium on short or long term. (Jorgenson, eco exergy as sustainability) In other words, no life or ecosystem will remain, only a dead environment. Its therefore obvious that for any system exergy should never be decreased, or at least stabilised at an agreeable level, , in order to maintain quality, for humans that is.

From there its easy to see that all other approaches at smaller system levels (country, region city, building) are connected as small systems, competing and depleting or feeding each other. And therefore need the same approach, to optimise resources and exergy within their own small system as a start, in growth and development, and only import if any other system has "spare" resources available.

Ill: Leading to a schematic situation as in illustration xx, a system with limited

Its about functions
Its important to realise that in any (eco-) system its not about energy and mass as such that is looked after, nor products : that it merely the capacity to do work. What its al about is, as illustrated before, the work results : the input needed to provide functions in a system, to make the system alive, to meet needs and demands. (And in the case of humans these go beyond the needs for direct survival .) This is the general strategy to increase in exergy: to develop, not in products- even with exergy stored in it, but in organisation of needed or wanted functions.
Our current consumption of functions, mainly by materialised products, consuming large amounts of exergy from within the system, for production as well as operation, is increasing the wealth for a few in the world, but decreasing the (eco-)exergy of the world as a whole. That is, our children will have less exergetic capacity to fulfil the same needs, let alone to provide that to all earth inhabitants. mainly because we destroy exergy already stored in our system. The more if not all is recycled or "kept in the system", but ultimately dispersed as molecules ending up in soil or sea.

The burdon of resources and increased entropy does not imply that quality is lost forever and eternally, it will take however a long time to capture and store solar radiation to restore exergetic capacity, to concentrate resources again, to bring the level back to that of nowadays, for all inhabitants of the earth,: this may take millions of years again. It's a long wait.

Besides the traditional approach of managing our resources in an effective way, in fact there are only two options to at least maintain exergy, or possible increase a bit: development within any system, and use of solar radiation.

The greatest loss in a system comes from two routes: energy lost as heat with ambient temperature, and concentrated mass lost in dispersion, most probably via rivers into the sea ultimately ,both loosing capacity to do work: to add quality. So far so called renewable resources can regenerate themselves: the way a natural ecosystem maintains and develops exergy, but any route leading to re-generating a resource is an option to maintain exergy. It depends on the chosen route and the input of work if it's a "sustainable route, that is, does it generate more in system exergy as it needs work to establish: which as seen above can only come from either solar radiation , as the only non system source, or from intelligent organisation and development. The last one delays exergy losses, and reduces through flows of sources in a system, in volume and driving energy. Which is ultimately needed if the max-human system size, the earth, is already overexploited and losing exergy. These are the four steps of closing cycles: close cycle, reduce volume and speed in the cycle and limit energy to drive the cycle, needing smart development. This leads to a closed cycle within the Max human system MHS, but can only be established by input (to maintain or increase exergy from an external source, not decreasing the MHS quality: solar radiation

Practical approaches for exergy analyses have several roots,. One is the direct input output analyses of a system, the most basic approach. If the system can function with less output and input, the effectivity is higher and exergy loss lower. (for the limited system itself and for the neighbouring system burden) (The UH approach originally followed this model.).
They should be embedded in a total model, to create absolute improvements.

To practice in Urban environments

In an attempt to translate this into a practical approach for all day decisions in urban environments , a few obvious rules and conditions come forward. At first this leads to the notion that we should attempt to manage our resource use in a closed cycle way, using only outside system resource ie solar energy, to maintain and expand the system. However, with 7 billions inhabitants and growing, and exergy decreasing, solar powered closing cycles is not enough, we should handle things intelligently, and organise cycles differently. To summarize this requires us to manage our resources in providing functions by:

- Closing cycles
- Reduce volumes in the cycles (“share”/organise/maintain)
- Reduce speed of goods through the cycles (“last longer”)
- Reduce energy to drive cycles (short connections , local organisation)

1 - Closing the cycle
Meaning that what’s in the cycle, stays in the cycle with as less quality loss as possible. Whatever goes out the cycle, should be equalled in quantity and quality by what comes in from renewable sources.

To add or remove parts of a building for instance , you’ll need materials and energy. These have to be renewable, otherwise supplies will be depleted and the cycle will not be closed anymore. The rate of production of these renewable resources therefore determines how much can be used of it. And added to the exergylevel of the system.

Regarding energy, there exist only one renewable and ‘eternal’ source: solar radiation. (except for some limited use of gravity). Solar radiation supplies about 10.000 times more energy than we use at the moment. Almost all other forms of renewable energy are derived from solar energy, like wind and biomass. Its also the ultimate source for creating Renewable materials. However, renewable materials, like wood, are not sufficiently available to meet the current consumption and their demand has to be reduced:

2 - Reduce volume
Reduce the demand for resources by preventing waste and by making the system more efficient. Sticking to the building example, this requires renovating buildings instead of building new ones. Intelligent organisation can provide solutions as well.

3 - Reduce speed
The rate with which resources travel through the cycle (are consumed) is important. The longer something stays in the cycle, the lower the demand for its resources will be and the longer the time to replenish them. Extending the life time of a building will slow down the circulation, and reduce exergy consumption in the system

4 - Reduce the energy that drives the cycle
To make resources available, and to maintain the system, exergy is consumed, this should be limted in organising systems to require less work to operate and to maintain. Local recycling in stead of global recycling for instance, or at the lowest effective scale level at least.
By re-using products at the highest quality level possible, the energy input needed to process it to its final function is minimized. Or the energy to drive its cycle. \ The energy needed for transport is also included in this element.

In applying this for the built environment, our field of study, the question is, where does the cycles start or end? In comparison to the regular Life Cycle approach which starts with mining of materials and ends with waste treatment, the starting point of the closed cycle theory is not a resource or product, but as explored the function or service provided for which work is needed, for example shelter. Shelter can be provided by a building (stock) and that's a spill of an urban system: providing m2 of shelter. from which parts can be removed and can be added to, see figure 2.

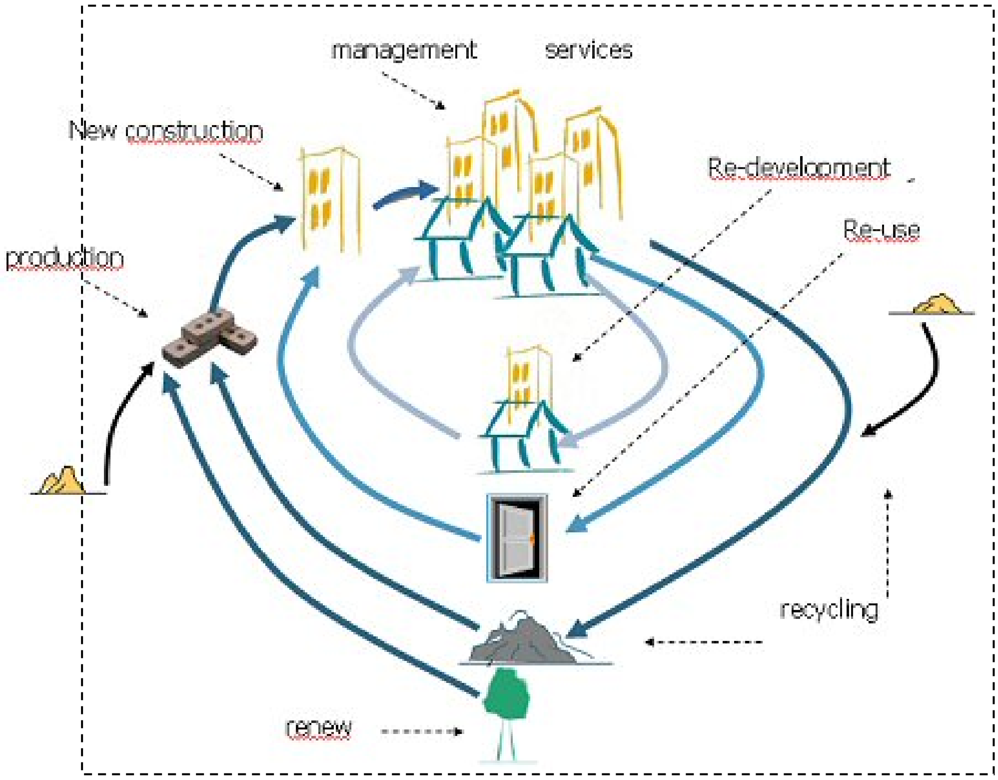


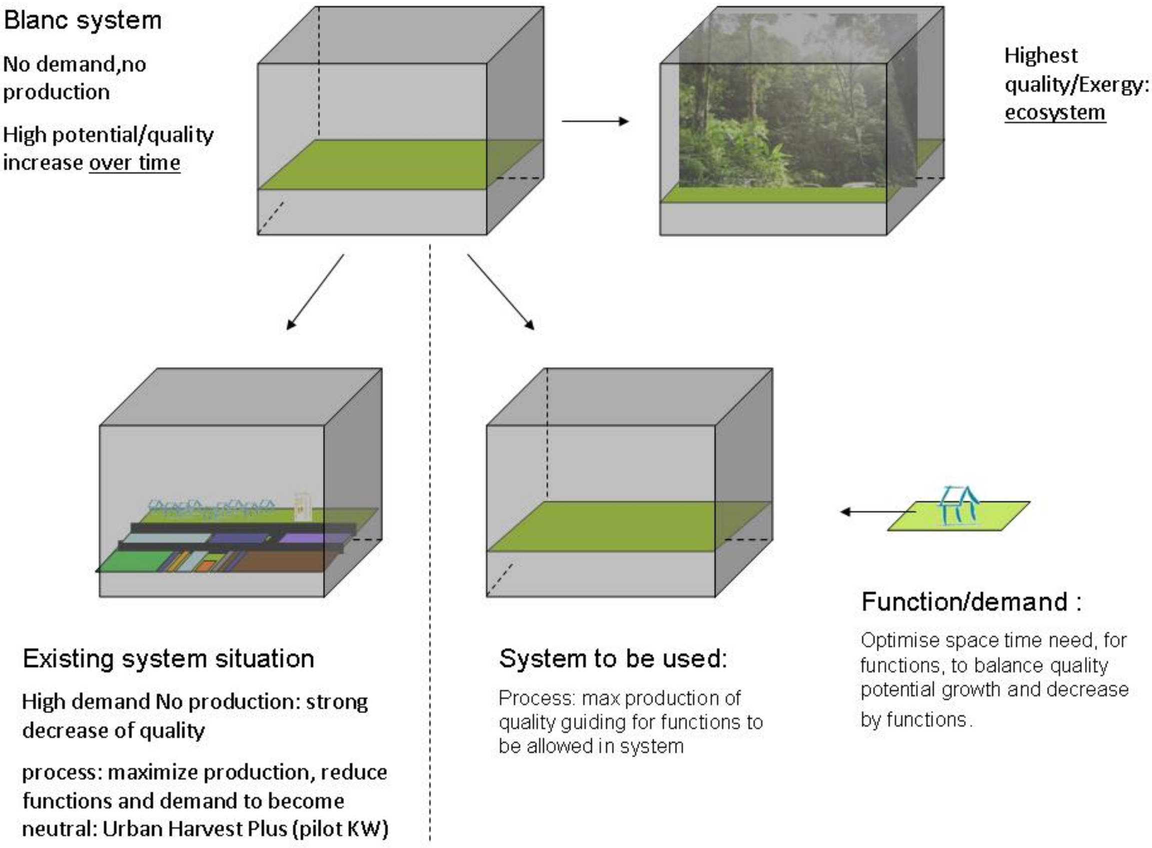
Figure 1 Closing the cycle within the built environment

In the end this leads to the illustrated approach (figure 1), a cycle that "starts" with the existing built environment (the eco/urban-system: a shelter providing system) which is maintained, improved, adapted re-organised, optimised to the needs and constraints and within exergy maximising approaches (as we will show later) . Buildings can be added or subtracted, but only when unavoidable and re-using the resources at the highest level possible. Increase of the volume in the cycle can come from renewables or residues of other functionalities in society. Addition of non renewables should be avoided, since this will deplete stocks and will mostly affect the environment in a negative way, especially from without the regarded system.

Mind that this a a mass based cycle, driven by energy to input work for providing the function: Both have to be regarded jointly: Energy can not be regarded without mass included , and vice versa, they are two of the same. Looking at only one will sub-optimise things. With the solar radiation potential within the system as the limiting factor of exergy input. As we will illustrate below.

The boxes

In further exploring the exergy approach of urban environments , we will use boxes to illustrate this: a box contains in fact system in three dimensions, a new or existing urban environment.
If we regard a system (one of the small systems from ill x) , and we assume its a undeveloped blanc system with potential (rain, solar radiation, nutrients etc) , then its obvious that a natural ecosystem developing in the box creates the highest quality ie exergy in the box, that is : exergy built up and stored and maintained . It does so with input of largely solar radiation maximal intercepted by the available land, which sets seeds and nutrients of to grow a ecosystem, again organised to a maximum reception of solar radiation for maintenance and development in the system. being more or less a reference for a man made urban system in the same box. for a manmade system we can distinguish two different situation in the boxes:
a box with bare land, ready to be inhabited, and a box containing an existing urban area, with inhabitants probably destroying exergy in a large way.



The blanc box
We will have a closer look to both, starting with the empty box. The one and only source that drives the natural system is solar radiation. So a potential for establishing exergy in he box is given by the amount of received solar radiation. In other words, our capacity (*human* available knowledge on technology) to capture , convrt store and use that solar energy is the ultimate measure for the maximum of functions (for human demand/needs) that this box can provide. The more intelligent and organised we do this, the more functions will fit in the box. That is, without inflow/outflow to neighbouring systems, depleting or provisioning these. If there is a surplus we can supply others , if there is a remaining need we can have an inflow, but only form similarly modelled boxes, otherwise is uncontrolled depletion of exergy. In fact this can be seen as the exergetic space available to feed functions demand.

In relation to planning new districts it should be concluded regarding Exergy and planning: *its not so much about where the best location is to plan a new housing district, as well to decide what the exergetic capacity is of any location, and allow only activities/functions within the location that fit within the "exergetic space" available. Which can be more if its intelligent organised, multifunctional, cascaded, managed, and as such has a high (human) development level.!*

This is in contradiction to the original thought of the srex research, to find tools to decide on the best exergetic areas for human inhabitancy.

There might be some little oil stock available within the system: Using that for energy purposes is directly decreasing exergy of the box, at least when at a faster rate then replenished by the solar radiation biomass, sedimentation pressurizing route. Which in the last case will require space in the box for some time to take place, and limit space for other functions. (In XX its calculated that regarding direct resource use the solar PV route is the most effective available on earth, in terms of land use over time to generate 1 kWh end use electricity)

The urban box

Since earth has already 7 million inhabitants, mostly living in cities (over 50 % in 2010) many partial systems will exhibit occupied buildings. Of which the exergy demand to maintain (and still grow!) the system is heavily exceeding the exergetic space in the box, and fast depleting exergetic space in neighbouring systems. There is inflow and outflow of resources, and most probably none is regenerated in a controlled way. The system has developed unintelligently, since mostly mono functions have been provided, and hardly any inter linkages are made in the system. Little information is stored in the system. It could be described as a orbanism (urban organism) but one of the primitive kind, it heavily relies on scavenging distant resources, and hardly anybody is in control of the system anymore. With low information levels it can't maintain itself in cases of disasters or changes in the inflow outflow. It can start re-use some of its resources, and reduce consumption, but that will be hardy enough to maintain the system. There is two ways of approach here: calculate the total exergy need, and expand the system (including more countryside) until a new border has been established that fits the exergetic need, ie the capacity to convert solar radiation in enough quantities of different resource needs to provide the orbanism. This most certainly will conflict with neighbouring urban environments and create overlapping claims on exergetic space. (except for some remote and sparsely inhabited areas. On a worldwide scale its commonly recognised that we have overshoot , and so this is no solution to go for). The second approach is to reduce the exergetic space need until it fits within the given box. Applying all the rules for a maximised ecosystem exergy.

The Urban box methodology: Urban Harvest +

The Urban Harvest-plus method is a straightforward and independent approach for system analyses assuring the reduction of impact on the environment. Its based on exergy and system analyses, but translated into a practical method for area development by major stakeholders, and provide direct and un-weighted parameters to base choices upon. The model and calculation are new, and the case described below is the first large scale case study to test the method. and will therefore be subjected to improvements and adaptations. It was put to its first test at the case study performed on Kerkrade West, described below.

Previous to Urban Harvest-plus (UH+), the Urban Harvest (UH) method was developed at the University of Wageningen in The Netherlands and used in the first part of SREX research, to analyse the vulnerability of built environments and to check in how far they could provide their own demand, and measure the so called 'urban vitality'; the level up to which they could deal with failures in resource chain provisions. Imagine placing a box over an area and investigate what resources go in, what can be produced maximal within the box and which resources that leave the box could be re-used and brought back into the system again. The resources considered were not only energy, but also materials, water and food related, see figure 2.

UH excluded the possibility to change the environment under investigation, only to maximise the use of flows. In the new UH-plus approach developed at RiBuilT, Zuyd University, the target is set to achieve a zero impact situation, zero water, zero materials, zero energy, etc. If the maximum production of the area isn't sufficient to meet the demand, the demand then might have to be reduced drastically until the area is self sufficient. (the demand fits into the exergetic balance of the system) Socio-economic aspects haven't been taken into account as such; they will be included in a follow up study .This was done to split the environmental issues from the societal issues and therefore be able to study the consequences of an actual reduction on the environmental impact. By adding the socio-economic aspects later on, the consequences for the environment can be made comprehensible at once. However, UH+ does try to maintain at least the same level of comfort, only maybe in a complete different organisation.

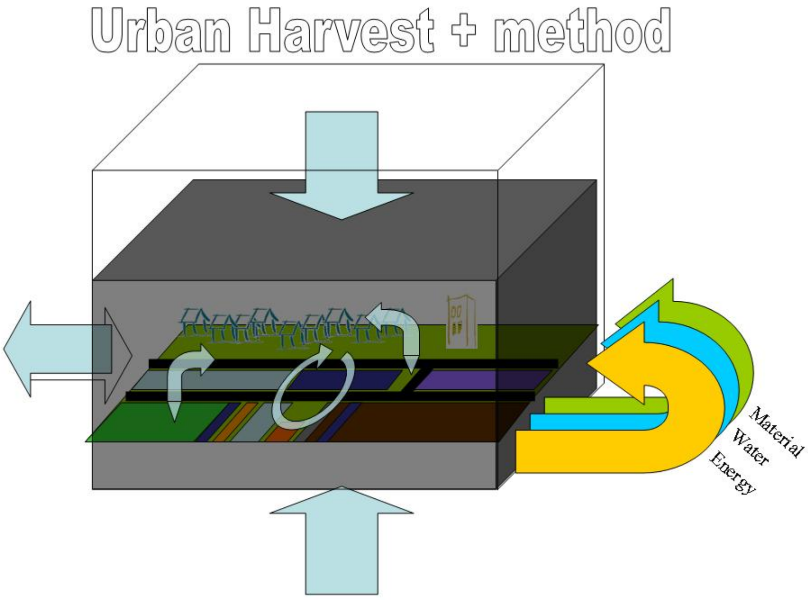


Figure 2 Urban Harvest-plus is all about maintaining a steady resource flow within the system ('box')

The MAxergy 5 Step approach of UH+

The studies preceding the development of the Urban Harvest-plus method, including the exergy analyses, have identified the different steps needed in the practical approach towards 0-impact. This is a change from previous known stepwise methods like the Trias ecologica used in the Netherlands, or other systematic approaches around the world. This new developed step-to-step approach consists of 5 steps, in a specific order: It starts with identifying the maximum potential of the system/district addressed, since that puts a first limit to what can be achieved ie consumed in the area. There is an "exergetic maximum potential" in any system, based on in system resources potentials . A second step, before applying the traditional pure reduction measures, is to investigate different ways of providing the same service or functionality to the area. This is part of the "in system development, that can vreate exergy increase, without committing resources, the information communication/organisation step. The third step is maximising the reduction (including, delaying in time etc.) , and the fourth step is smart combining of needs and flows within a resource category (including cascading and combining) . In this case we not only want to look at energy or materials separately, but we also want to combine all flows together which is the maximisation step, step 5 in the model. Here exegetic decisions have to be made, for which end use a conversion in the system is used.

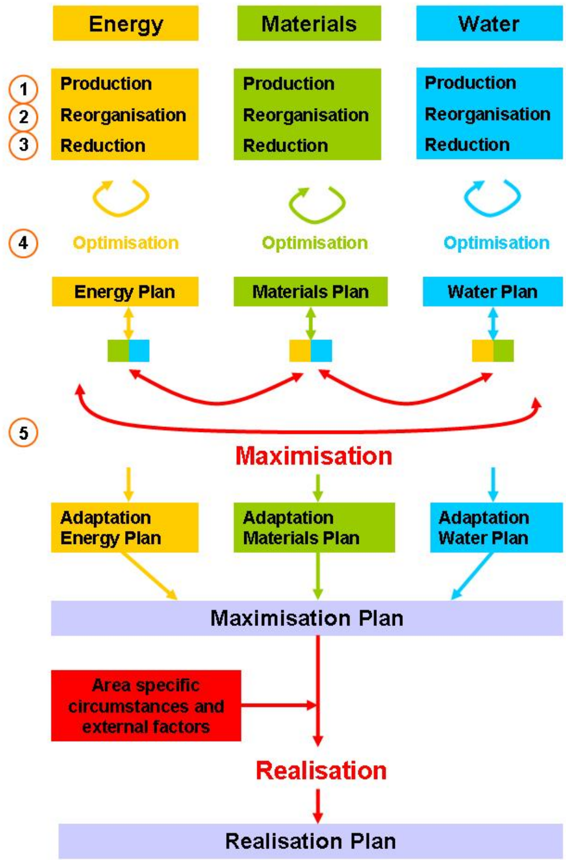


Figure 3 Schematic overview of the systematic of the Urban Harvest-plus methodology

1. Production
Determine the maximum production capacity for each resource (exergetic space)
2. Reorganisation
provide functions alternatively per resource (information, organisation of system)
3. Reduction
Reduce the unavoidable demand directly of a resource (effectivity of functions)
4. Optimisation
Cascade and combine demand and supply for each resource (combination of conversions and functions)
5. Maximisation
Maximise provision of the needs by combining the resources (exergyc based choices for functions.

The steps explained in detail

0. Current situation
The project will commence with an estimation of the current demand, production, import and export of the resources in the system as a reference for the situation as it was before the transition was set in motion.

1. Production
Analysis of the maximum production capacity of the system of renewable resources (like biomass and electricity production) and of waste streams (like ironware and wooden beams from demolition sites). By comparing this capacity with the actual consumption, the necessary reduction becomes clear.

2. Reorganisation
Reorganisation means that a certain service or function will be provided in an alternative way. It requires re-organisation, with a focus on services and

combinations, to fulfil a function(s) Therefore we might have to go back to the basics and first determine the actual needs of a society for services and functions after which we try to fulfil them in the most effective way, with the same end result of course.

For example clothes; everybody needs clean clothes and we mostly use individual laundry machines to clean them. But it would be more efficient to let a laundry shop do our laundry at a central point. It would save energy, water, materials and even space, since we no longer need to occupy at least one cubic meter in every house with a laundry machine. If provided with daily door-to-door services it will create jobs and it would also save the individual time which can be spend on things we like more than doing laundry, thus comfort increases. So reorganisation is about restructuring the way we do things with the same result as before, in this case: clean clothes. (and side effects in labour and local economy, to be explored separately)

3. Reduction

Reduction would only look at how we can do things more efficient by doing the same. To stick to the laundry example; reducing would include more efficient laundry machines without changing the process or behaviour itself. Or even simpler, doing less laundry. Insulating houses also reduces energy consumption but doesn't change the way we live.

4. Optimisation

In the optimisation step we then try to match the remaining demand with the supply of resources available in the area, paying special attention to different qualities of resources needed and available. We could for example use rain water instead of drinking water to flush our toilets, or reusing shower waste water to flush the toilets. Here we also check for double claims on space occupation; solar panels for electricity and solar collectors for heat for instance occupy the same space on roofs. The choice for one of these options will be determined by the principles and rules, discussed below.

5. Maximisation

With a separate plan for energy, for water and for materials, it is still the question if they can be combined to become one plan: in this step the plans for the different resources will be integrated and checked how they affect each other. Again, the principles and rules define the final choice for the conflicting options of the individual plans and the resource plans will be adjusted accordingly.

Principles and rules

Urban Harvest-plus intention was to develop an independent calculation method that specifies the inevitable priorities and therefore standardises the choices that have to be made in this process. Previous smaller (one resource targeted) pilots have pointed out that rules are needed to make choices. Principles are the foundation of these rules and they also represent the basic thoughts of the UH+ method. Below a (preliminary) set of principles and rules is discussed to guide the process of decision making.

Principles

<u>1 Planet</u>

Maintaining a healthy balance for natual ecosystems is a main condition to secure the liveability of the planet on the long term. We should reserve some proportion of the earth surface for nature prohibiting any human intervention.

<u>2 People</u>
Urban Harvest wants to fulfil the needs of human beings (in a sustainable way). If the total demand is too high to be provided by the system addressed, choices have to be made which needs are most important for people

<u>3 Closed cycles</u>
Closing the cycles by using only renewable and local resources is the basic principle of sustainability, applied within UH+.

<u>4 Exergy</u>
UH+ is in fact about making maximum use of the qualities available in a system without depleting or polluting, thereby minimising the loss of quality, and maximising exergy, in the system. The only input from outside the system earth, is the sun, to add quality to our system.

Rules

Planet

- According to the Brundtland report 'Our Common Future' [xx] we should reserve 12% of the earth surface worldwide to maintain a natural balance..

People

- The order of priority for survival of humans is: air/oxygen (dead after minutes), drinking water (dead after days), food (dead after months) and protection against the weather and threats in the form of shelter and clothes which require materials and perhaps, depending on the climate, heating (dead maybe after year(s)) . Lowest priority has electricity for increased comfort.

Closed cycles

- Only renewable and local resources will be used to close the cycles within the system. Everything that enters the cycle has to be renewed during its lifetime. Renewable resources are only renewable if they're actually renewed. Non-renewable resources that are already present in the cycle may be (re-)used and stay in the cycle.

- Reorganisation of processes based on needs/functions and services. We have to define what people really need and want and how we can achieve this in the most effective way.

- The volume and speed with which resources go through the cycle has to be reduced, as well as the energy that is needed to drive the cycle. The option that is most beneficial for the total balance is preferred.

- Mass has to stay mass. Waste does not exist. Mass and energy only exist in different forms, time and space. Therefore qualities have to be re-used on the highest level possible. One can burn biomass for energy, but it will be degraded and lost. If you process biomass however to wooden fibreboard, the quality is retained.

- Exchange of resources between two systems can only take place when both systems comply with the principles of the closed cycle theory and with the maximisation based on exergy. The system boundaries have to be well defined. If not, unaccounted plundering of neighbouring systems takes places.

- Even when exchange with other systems appears possible, qualities and options from within the system are preferred above options of other systems. Making use of the potential to produce useful resources available within the systems is the fundamental thought of the closed cycle theory, and relates directly to the eco-exergy findings, about building strong networks in the system, by combining and multi-using functions and resources

Exergy

- The required space per time unit in relation to the solar input is the main indicator of an effective conversion and makes it the major consideration in the decision for land use. In the end it all comes down to the specific land use for a certain time period to to produce ourselves useful resources out of solar energy (energy, mass, food, water).

- Demand and supply of qualities has to be balanced as close as possible to prevent the loss of certain qualities. You don't need to flush the toilet with drinking water or use high temperature heat to heat houses for instance.

3.5. Pilot Kerkrade West

The approach above described was tested for a existing district at Kerkrade-West; district of Kerkrade municipality, in the south of The Netherlands (map 1). Kerkrade is located in the former coal mining region, and this shaped the municipality. Kerkrade-West has a surface of about 1000 hectares and almost 16,000 inhabitants; various building densities, mix of spatial functions, and also agricultural, forest and water areas. Kerkrade-West was an energy supplier, referring to coal mining, but is now an energy demander and dependent on foreign resources supply.

(We used this case as the real testing area for our approach. It is a further zooming in on the Parkstad case, with Kerkrade being one of the municipalities and Kerkrade-West as one of the districts of the municipality.)

The building area is quite dense which leaves large open spaces for recreation (including the Zoo, nature, agriculture and a lake ('Cranenweyermeer'). On the other hand there are several industrial sites with heavy industry and shopping areas around the foorball stadium next to the highway and in the middle of the recreational area. Table 1 and the URBAT, the Urban Average Tissue (see figure 4), show the average land use of Kerkrade West in hectares.

Recently a integrated vision has been drawn up for the different districts of Kerkrade covering the developments on all policy areas for the time period 2006-2015, formulated by the inhabitants, housing corporations, institutions and other parties. A trend which is spreading among regions in the Netherlands and is already happening in Kerkrade West is a decreasing population. The study assumes a constant level of population, and to vary this figure in a later stadium. Regarding energy, agreements were made with the National Energy Agency on energy savings for the time period 2009-2011.

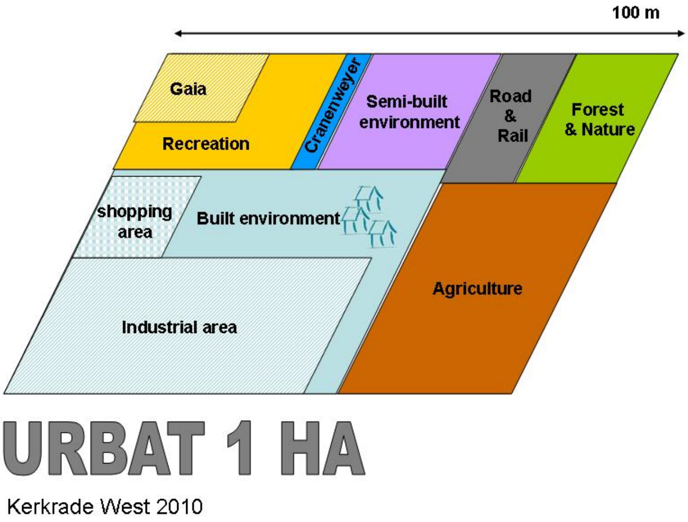


Figure 4 The Average Urban Tissue shows the land use of an average hectare in Kerkrade West in 2010

Table 1 Specification of land use in Kerkrade West

Land use Kerkrade West 2003	
	Hectare
Urban land use	
Built area	445
Semi-built area	88
Road and Rail	53
Recreational	121
Subtotal Urban	*707*
Non-urban land use	
Agriculture	217
Forest and nature	63
Subtotal Non-urban	*280*
Total Land	**987**
Cranenweyermeer	19
Total Water	**19**
Total Surface KW	**1006**

KW 2050

Together with stakeholders Kerkrade West was chosen to act as a test case for the Urban Harvest-plus approach. We have to emphasize that it is only an exploration to see what it means to use this exergy based, and o-impact focussed approach, starting from only renewable and local resources and what should be done to achieve this. To make it workable, ambitions for all three resources were defined:

- Energy producing: the area produces its own renewable energy with a surplus for export.

- Material-transition: meaning the area uses as much renewable and local materials as possible.

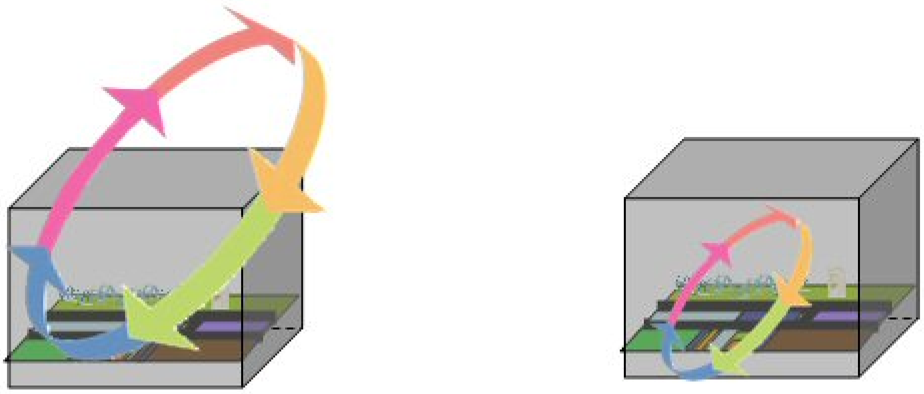
- Water-neutral: the quality of the water flowing out of the system is the same as the water flowing in; no quality is lost or degraded within the system.

The system is bounded by the orange lines in figure 5. For this area we will analyse the flows for energy, materials and water and how these cycles can be closed and reduced in impact. For some resources, this scale might turn out not to be sufficient and the area should be enlarged. Food production in this small urban area for example, which we will consider briefly in during maximisation, will not be enough to feed its population. However, the intention is to take the potential of the area under consideration as a starting point.

Figure 5 Satellite image of Kerkrade West, bounded by the orange line

Analyses

The analyses (UH+ , case Kerkrade West, www.ribuilt.eu) follows the needs for energy, materials and water, with their space time need, (Embodied Land), and try to squeeze the current need, into its own “box”. The process follows the 5 MAxergy steps as described before.



Its about Exergetic space of a any system

In case of an urban system: squeeze the exergetic space need, into the box"

The detailed analyses of the energy water and materials cycles in the area, and their spatial impacts is described in The Report Pilot case KW and partially in the book, Exergy and Spatial Planning by the SREX group. Here we will focus on the analyses of the combination of the resources impacts into one district plan.

Maximisation

In the maximisation steps the three resource plans are integrated and determine how they will affect each other, either positively or negatively. For instance, there might be a double claim on a certain piece of land or surface, like the use of industrial rooftops for solar panels and soccer pitches. Or, one resource might claim another, as is the case for wind turbines for energy production, requiring the materials resource steel. On the other hand, the plans might contribute to one another, like the production of biogas (energy) by fermenting brown water(water). Below we will first describe the existing areas of conflict. All conflicting situations will be discussed and solved in the next paragraph by applying the principles and rules. Consequently, the separate resource plans will have to be adjusted in the final phase of maximisation.

Conflict areas

The below illustrations show the claims and contribution from one resource plan to the other two. The largest claims come from water and energy into materials needed to execute their plans; for wind turbines, sanitation infrastructure, housing insulation etc. As previously mentioned, the list is not complete: we mainly focussed on the built environment, not on goods, and for instance cars.

The maximisation step is introduced to decide on these claims, does the energy plan have to be adapted or the materials plan? The principles and rules are essential in this phase: to preserve natural ecosystems, to decide on the highest priority for human societies, the need for any chosen option to be part of a closed cycle process, and in the end, with equal demands, to find out which is the most effective in transferring solar radiation into the desired performance, with land use over time as the crucial indicator.

Table 5 Effect of the material and water plan on energy demand and supply

to / From	Energy claim	Energy contribution
Materials		• Reduction of industry reduces energy consumption
Water	• Heat source required for biogas installation	• Biogas production through brown water treatment
	• Electricity for purification to potable water	• Extra hydropower with biofiltration effluent

Table 6 Effect of the energy and water plan on material demand and supply

From \ to	Material claim	Material contribution
Energy	• Steel construction for wind turbines	• Secondary waste materials out of office demolition
	• Renovating dwellings to passive houses	• Reed production from the water basin
	• Silicium for solar panels	
	• Metal ducts for asphalt collectors	
Water	• Substrate for the constructed wetlands	• Reed production from the constructed wetlands
	• Materials to replace shower heads, toilets and ducts	

Table 7 Effect of the energy and material plan on water demand and supply

From \ to	Water claim	Water contribution
Energy		
Materials	• Extra water demand for crop irrigation	• Reduction of industry reduces water consumption

Table 8 Claims of the different resource plans directly related to land.

Claim of \ on	Industrial area	Office rooftops	Retail rooftops
Energy	• Solar panels and collectors		
Materials	• Soccer pitches • Demolition	• Demolition	• Demolition
Water	• Rain w ater collection	• Rain w ater collection	• Rain w ater collection

Claim of \ on	Cleared surface by road reduction	Semi-built area	Agricultural area
Energy		• Water basin • Algae pond	
Materials	• Material production	• Material production	• Material production
Water	• Constructed w etlands		

Solutions

The pilot study was the first time we had to use the principles and rules (which were partly developed as a result of this project) , to decide on claims by several resources for space occupation over time (and end with the exergetic optimised space) Here are a few of the issues:

The choice for Vacuum toilets : water savings vs material use

In the Waterplan we had chosen for vacuum toilets since these save 85% of the flushing water and they could produce biogas. However, the vacuum system requires a complete transformation of the sewage system infrastructure, toilets themselves included. The materials, also non-renewables, are just not available in the area and vacuum toilets therefore can not be implemented. From all alternatives, compost toilets on the other hand, have only advantages: they don't require flushing water at all, they need a minimum of materials just to replace the toilets themselves, the sewage system is no longer needed (and its materials can be re-used) and the faeces are processed to form manure for food and biomass production, without additional energy input. Water use will decrease by another 0.04 million m^3.

Agricultural land : Biomass vs Food production

Till so far we claimed all agricultural land in KW for biomass production, but food is higher on the priority list than materials. A small side-study on the province of Limburg found that 85% of the agricultural area is needed to produce enough food for the population, living on a vegetarian diet. This led to the conclusion that food has to be dealt with at a provincial level planning. Therefore 85% of the agricultural area in the KW system will also be appointed to food production (to maintain and add to food security on regional level), reducing the land available in KW for biomass for materials production and the yield from 738 tons a year down to 130 tons.

Cleared land after road reduction : Water purification vs. biomass production

The land that has been cleared after local road reduction has been claimed for biomass production as well as for constructed wetlands for bio filtration of waste water. Since clean water is more important to us than materials, the wetlands are given priority. Fortunately, the wetlands can provide reed at the same time so there's no loss in biomass production. Constructing the wetlands with bio filtration does however require 1.250 tons a year of materials input

Steel: renewable energy production vs depletion

Among others, wind turbines and solar collectors for asphalt roads have a strong impact on steel supplies which is a non renewable resource and only available in small quantities in the district of Kerkrade West as waste material from demolition projects. Even on a Dutch national level scale there are no iron ores available, let alone the energy to produce steel. As a consequence, wind turbines as we know them today are no option for the future. More innovative technologies have to be developed that hardly demand non-renewable materials anymore. Luckily a new technology is under research at the moment; kite-wind turbines. We assume these will be available within the transition period of 40 years.

Semi-built land – biomass production vs. water basin and algae pond

The production of biomass, the water basin (for water storage and energy production and storage) and the algae pond (biofuel production) compete for the same piece of semi-built land. Biofuels are of less importance than materials, so the algae pond drops out. But water has priority over materials, so the option for a water basin is left unimpaired. Again, reed can be produced in the basin so the area isn't lost for biomass production.

Passive houses – biobased materials vs heat production

To renovate all houses to passive standard in order to reduce energy demand (an energy claim), 525 tons of materials are needed each year, equalling 130 hectares (continuously for

20 years to gradually renovate the stock) , putting a claim on materials production. As this production surface is not available in the region, we have two options; use the biomass production meant for other options to renovate the houses or don't renovate but just heat them. This requires applying the ha-year exergy calculation. Heating the none insulated houses based on solar collectors would require about 17,5 hectares permanently, compared to 130 hectares for materials . It therefore seems more efficient to just heat the none insulated houses with solar collectors instead of growing materials for its insulation. Besides, these extra solar collectors can be placed on rooftops where they don't require fertile land. They only compete with the solar panels we already placed there, but electricity is not a basic need.

The existing houses will thus not be renovated in this example[1] and the energy savings that would derive from it (347.231 GJ) have to be undone in the energy plan. And 17.5 hectares of solar panels (242.308 GJ) will be replaced by solar collectors (315.000 GJ).
This is a exploratory result. A detailed calculation has to be amde, including all secondary effects: seasonal storage of heat, materials for collectors, etc. The result might change somewhat with a detailed study.

Industrial sites
Industrial rooftops are being claimed by solar panels for electricity production and soccer fields to clear land for biomass production. As materials are given priority above electricity, the solar panels have to give way and the electricity production will decrease by 48.462 GJ.

Furthermore, 45 hectares of industrial area will disappear because industry relying on fossil fuels will not be allowed in the district anymore. This means a loss of 15 hectares of PV plus an extra 11 hectares of a PV park that will make way for biomass production, totalling 360.000 GJ.

On the other hand, a reduction in industry will also lead to a reduction in electricity, heat and water demand. An estimated 1.661.538 GJ of electricity, 410.000 GJ of heat and 0.3 million m^3 of water can be avoided.

Discussion and conclusions

Conclusions Pilot Kerkrade West

The water supply is not a problem in Kerkrade West. Rain water is falling sufficiently to fulfil the demand and the options to purify water are available. The energy production that is anticipated doesn't suffice, although some potentially interesting options, like using mine water and waste heat, have not been taken into account yet[2]. Regarding materials, we have a small surplus in quantity, but the flow of goods and products in the area have not been included yet. This will increase the demand even further while the production is already at its maximum. Furthermore, since the qualities of materials like steel are not easily interchangeable with renewables like wood, the exact demand and supply of different qualities should be examined thoroughly.

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[1] *This is a surprising finding. It implies that not direct energy, but materials need will be the structuring element for the future! Of course here only direct need is accounted: solar energy versus materials. To produce solar panels, or to process materials , the indirect need, is not yet calculated, nor the seasonal storage of heat. But the difference is that large that it might stand also after indirect inputs are accounted for. Most likely there will be an optimum between heating and insulation, which might be a few centimetres of insulation, without any structural materials need. However, insulating up to the passive standard seems not to be the best strategy. A follow up research should clarify this in detail (being carried out at the moment).*

[2] The region is an old coal mining area. Former mining caves have filled up with water, with a low heatn interesting temperature. A first successful project has been established to heat new housing areas with heat from these mines.

This case study not only shows that we have to go all the way to get even close to becoming environmental neutral, in a sense that the system box does not decrease on exergy over time (Texergy), but also that we really need innovative solutions to make it happen. On the one hand we need innovations in processes and behaviour: how are we going to provide certain needs? On the other hand in technologies: when developing technologies for renewable energy production for instance, we have to take the effect on other resources into account, especially regarding materials. The demand for materials appeared to be leading in the exergy-maximisation phase. Locally the availability of materials is very limited. On a global level, materials are getting scarcer, so we need to find a way to develop the same products with different and renewable resources.

Conclusions Urban Harvest-+

5-step approach
Although the 5-Maxergy step approach sometimes appeared to be difficult to handle in practice and required double work to be done, it proved to be a straight forward approach in exploring how to establish a zero-impact situation, a stable exergetic situation. . Unintentional prejudices didn't get a chance and discussions could be managed consistently. The clinical approach is a good starting point to assure an actual reduction in the environmental impact. It also clarifies the interaction between resources and makes clear that resources should never be considered on their own, but always in relation to each other to avoid sub-optimisation.

The principles and rules
The principles and rules seem workable and assure the study keeps focused on what really is the issue; reduction of environmental load and ultimately achieving a zero impact state. The method provides a fine frame of reference in decision making and in integrating new developments during the transition phase. In case of complex situations with different elements in the game, an extra analysis to make choices more robust would be helpful.

Classification of the resources
The division within the resources can be made more consistent. Energy is divided on its appearance (electricity, heat and fuels), materials on whether they are or are not renewable and water in quality. Since the closed cycle theory is based on functions and needs, it would be more logic to distinguish between the functional characteristics of a resource as well. Lighting, instead of electricity, or transport instead of fuels for example.

Matching qualities
The question is raised in how far we can produce the needed qualities of resources, or to what extent we should adapt our life style to meet the available sorts of qualities. It seems that the latter is the leading choice, since we start from local and renewable sources. However, new technologies might supply us with means to convert to preferred qualities. In this research we have only slightly addressed qualities, especially for materials. The bulk might be sufficient, but not always suitable to materialise the desired functions. Her some more study will be needed.

The m^2 as an indicator
The principle conclusion in the Urban Harvest Plus method is that every square meter in the system area must be evaluated: whether it is the roof area, road surface, dis-used land or football pitch, the central question is how each and every square meter can contribute to a balanced use of resources or reduce the demand for them. Making good use of every square meter (meaning the conversion of solar input into useful resources like food, materials and

energy), and even increasing the output of a m^2, is the main issue to tackle. Consequently, the impact on the environment should be calculated in m^2's[3].

In a parallel project, this m^2 approach is being developed, called the MAxergy-calculation, for new functions to be added . It calculates what the exergetic space of functions is (in hectares). This space is based on the embodied land of materials; the land they need in order to grow or be mined and the land that is needed to produce the energy for processing these materials.

Final Remarks

The exergy approach in terms of space time to convert for functions, and applied to squeeze in a existing districts space need into a given system box, seems to lead to creative solution, integrated as well in to society, as for instance the Laundry model, : this might automatically lead to a social and economical preferable situation. It should be explored more in-depth if the pure physical Exergy approach might also lead to social preferred situations.

Action list and timeline
The original Dutch study contains a translation of the results into an action list for Kerkrade West: the main actions to be taken by each sector and stakeholder. These actions are also put together in a timeline, listing all activities from now, 2011 until 2050, facilitating transition.

Guidelines
A set of rules and design guidelines for different disciplines in the building management is now being developed as spin off from this research

Data and further research
It must be stated that this is still a limited research. Not all data were obtained, national averages or educated guesses had to be used in some instances, also the study did not examine commodities (televisions, furniture, *etc.*) going through the area. The original Dutch report contains more detailed information on the data and includes an extensive list of subjects of interest for further research.

To conclude; the exploration to come to an independent approach for zero impact built environments doesn't end here. Many questions and areas are left for further research, but we believe Urban Harvest-plus represents a strong basis to depart from.
It has revealed new insights, and strong indications that some choices made today are not the most effective ones for the future. Especially the role of materials will become of high importance, and no plan whatsoever should be executed without dealing with the materials implications. This is an area where RiBuilT as a research institute will put its focus and further develop these insights.

4. Reflection and further research

it has been shown that its possible to combine energy and mass in one objective approach and relate directly to the sole sources for both qualities in the earthen system: m2 access to solar radiation, or "Embodied Land" . The model developed proved useful, and shows no un beatable barriers. Nevertheless some issues still have to be specified: The land relation for non renewable materials, as far as they

[3] Taking time into consideration as well: everything is part of a flow, a volume (per space/land unit) per time period

are still used, the valuing of recycled materials , the detailing of choices, using indirect energy and materials, and other issues.

First of all the attempt to combine both energy and materials in one objective calculation has been proven possible though details still have to be settled. It turns out that direct solar access and the space time involved is the real value to relate decisions of environmental effectively and operation within a closed cycle process. Even food can be included in this evaluation (though not explored here) since it is in the same way depending on solar radiation access.
A second conclusion is that materials are as expected to be more influential in the environmental performance as (renewable) energy , though even far more as expected by the researchers.
Further findings and conclusions are:

- Quality is not a direct issue anymore: Since the evaluation starts from the potential available(in a given district) or the potential needed and the land to be included, in case of a new development qualities are to a certain extent given facts, and not directly structuring.
- Embodied Land seems a very good and understandable indicator to judge the impact of any activity .
- Optimising space and time in capturing the needed qualities, is what has to be valued , in order to establish a highest level of materialised welfare . How high is depending on our pattern of consumption of qualities, and the amount of individuals striving for that level of welfare, ie acquiring the useful functionalities.
- Optimising for space time, on the basis of converting energy/mass into useful carriers for human use, leads to a complete different approach as so far. It requires reserving areas of space for generating a meaningful volume of the most wanted quality.
- Preserving the highest quality in a system, is not established by starting from cascading inside sources, but by starting from the system entering energy and capture and convert in the highest valued mix of needed qualities

There is a few consequences to this approach. First of all: The notion “ primary Energy “ has become a historic artefact and thrown in the rubbish bin, since a historic relic from a fossil fuel driven society. When real values and impacts are calculated, the reference has become the sun, and the time space involved to generate quality from its radiation, and the capability to convert that in useful forms for humanity[4].
It also shows that trying to optimise the energy cycle, looking at (renewable) energy alone, is sub optimising. The role of materials is far more important .

So far the exploration has only involved a 2 D approach, in m2 land available for a specific amount in time. However in fact we face a 3D problem: How to deal with shading, how to deal with excavations, quarries in this approach? Or to include

[4] Nature has no qualities. It is however thermodynamic stored potential, however only quality in terms of human use if made available to do “work”) . To explore the human related quality, it is explored in how far humans can make a potential available , and to have maximum use of it, maximum in the sense of lowest exergy loss (or better: to balance exergy consumption with exergy growth in time and space in the addressed system. (from the SREX research)

height in the form of hydropower potential ? A more general approach for this has to be explored, in relation to the study of the use of non renewable materials .

So far the space time approach has been shown viable and useful. Using the exergy principle to locate housing areas (to put demand where the supply is) , which was the original idea behind SREX, has been shifted from an energy evaluation to an integrated approach for different qualities and the access to solar radiation as the guiding principle. Or in other words:

The question of using exergy principles for spatial planning and optimised location of housing area has been turned around: All systems have a maximized exergy potential: (exergy to be maintained over time –Texergy) and any activity planned should stay within that limits, to start with it has become a question of a space time evaluation to decide on the the least land occupied to provide the desired qualities,

Overall, form the start of pure energy evaluation of a district, to a energy mass space time analyses, it can be concluded that that space use over time is indeed the main structuring parameter for the future.

5. References

Agudelo, C., A. Mels, R. Rovers (2009). Urban Water Tissue: Analysing the urban water harvest potential. Smart Building in a Changing Climate. A. Dobbelsteen, van den, M. Dorst and A. Timmeren, van. Amsterdam, Techne Press: 63-78.

Baehr, H. D. (1965). Energie und Exergie. Düsseldorf, VDI-verlag.

Banister, D. (2008). "The sustainable mobility paradigm." Transport Policy 15(2): 73-80.

Barker, T., I. Bashmakov, Bernstein, L., Bogner, J.E., Bosch, P.R., Dave, R., Davidson, O.R., Fisher, B.S., Gupta, S., Halsnaes, K., Heij, G.J., Kahn Ribeiro, S., Kobayashi, S., Levine, M.D., Martino, D.L., Masera, O., Metz, B., Meyer, L.A., Nabuurs, G.-J., Najam, A., Nakicenovic, N., Rogner, H.-H., Roy, J., Sathaye, J., Schock, R., Shukla, P., Sims, R.E.H., Smith, P., Tirpak, D.A., Urge-Vorsatz, D., Zhou, D., 2007. Climate Change 2007: Mitigation. Contribution of Working Group III, in: B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (Eds.), Fourth Assessmen Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.

Bhatt, V. (2008). Integrated Energy Planning for New York City. Municipalika 2008 - Fifth International Conference on “Good Urban Governance for Inclusive and Sustainable Cities”. Mumbai.

Bhatt, V., P. Friley, J. Lee (2010). "Integrated energy and environmental systems analysis methodology for achieving low carbon cities." Journal of Renewable and Sustainable Energy 2(3): 031012-031019.

Bondt, A. H., de and R. Jansen (2004). Energy from asphalt - Road Energy Systems®. Scharwoude, Ooms Avenhorn Holding b.v.

Brundtland, G. H. (1987). Our Common Future. Oxford, United Nations - World Commission on Environment and Development.

Coelho, D. and M. Ruth (2006). Seeking a unified urban systems theory. Sustainable City IV - Urban Regeneration and Sustainability. U. Mander, C. A. Brebbia and E. Tiezzi. Southampton, WIT Press: 179-188.

Cola, F., G. Recine, G. Alessandro (2005). Local New Energy Technology Implementation - Technologies Dossier. Rome, Innova Spa.

Combrink, F. M., R. F. J. Gerwen, van, et al. (2004). Energiek wegdek: het potentieel voor elektriciteitsopwekking uit asfalt. Arnhem, KEMA: 1-49.

Crawford, J. and W. French (2008). "A low-carbon future: Spatial planning's role in enhancing technological innovation in the built environment." Energy Policy 36(12): 4575-4579.

Dincer, I. and M. A. Rosen (2005). "Thermodynamic aspects of renewables and sustainable development." Renewable and Sustainable Energy Reviews 9(2): 169-189.

Dobbelsteen, A., van den and N. Tillie (2009). "Towards CO2 Neutral Urban Planning: Presenting the Rotterdam Energy Approach and Planning (REAP)." Journal of Green Building 4.

Droege, P. (2002). Renewable Energy and the City: Urban life in an age of fossil fuel depletion and climate change. IGES/APN Mega-City Project, Kitakyushu, Institute for Global Environmental Strategies.

Droege, P. (2006). The Renewable City - A Comprehensive Guide to an Urban Revolution. Chichester, Wiley-Academy.

Droege, P. (2010). 100 % Renewable energy - and beyond - for cities. Hamburg, Hafen City University & World Future Council Foundation.

Duijvestein, C. A. J. (1997). Drie Stappen Strategie. Praktijkhandboek Duurzaam Bouwen. D. W. Dicke and E. M. Haas. Amsterdam, WEKA: 20-21-20-10.

Dunn, B. C. and A. Steinemann (1998). "Industrial Ecology for Sustainable Communities." Journal of Environmental Planning and Management 41(6): 661 - 672.
Erwich, B. and M. Vliegen (2001). Nederland Regionaal: Stedeling en Plattelander. Index. Voorburg, Statistics Netherlands: 22-23.
European Renewable Energy Council (2005). Energy Sustainable Communities. Brussels, EREC.
Exploateringskontoret (2007). Hammarby Sjöstad - en ny stadsdel med vatten och miljö i fokus. Stockholm, GlashusEtt.
Girardet, H. (2008). Cities, People, Planet: Urban Development and Climate Change, 2nd edition. Chichester, Wiley-Academy.
Goodland, R. and H. Daly (1996). "Environmental Sustainability: Universal and Non-Negotiable." Ecological Applications 6(4): 1002-1017.
Jank, R., Ed. (2000). A Guidebook for Advanced Local Energy Planning. Bietigheim-Bissingen, FGK.
Kennedy, C., J. Cuddihy, J. Engel-Yan (2007). "The changing metabolism of cities." Journal of Industrial Ecology 11(2): 43-59.
Klinckenberg, F. (2004). Kwalitatieve beschrijving transitiepaden Scope 2030. Sittard, SenterNovem: 1-29.
Korhonen, J. (2004). "Industrial ecology in the strategic sustainable development model: strategic applications of industrial ecology." Journal of Cleaner Production 12(8-10): 809-823.
Leduc, W., C. Agudelo, R. Rovers, A. Mels (2009). Expanding the Exergy Concept to the Urban Water Cycle. SASBE 2009, Delft.
Leduc, W. and R. Rovers (2008). Urban Tissue: the representation of the Urban Energy Potential. PLEA 2008, Dublin, University College Dublin.
Leduc, W. and F. Van Kann (2010). Urban Harvesting as planning approach towards productive urban regions. Scupad 2010, Salzburg.
Lehmann, S. (2009). On the urban scale: City densification, and the need to solve large-scale energy problems. Case study City Campus and Port City. SASBE 2009, Delft.
Menkveld, M. (2002). Duurzame Energie en Ruimte. Petten, ECN: 1-31.
Morphet, J., M. Tewdwr-Jones, N. Gallent, B. Hall, M. Spry, R. Howard (2007). Shaping and Delivering Tomorrow's Places: Effectice Practice in Spatial Planning. London, RTPI.
Newman, P. and I. Jennings (2008). Cities as sustainable ecosystems : principles and practices. Washington, DC, Island Press.
Newman, P. W. G. (1999). "Sustainability and cities: extending the metabolism model." Landscape and Urban Planning 44(4): 219-226.
Nilsson, J. S. and A. Mårtensson (2003). "Municipal energy-planning and development of local energy-systems." Applied Energy 76(1-3): 179-187.
Pahl-Wostl, C. (2007). "The implications of complexity for integrated resources management." Environmental Modelling and Software 22: 561-569.
Rovers, R. (2007). Urban Harvest, and the hidden building resources. CIB World Building Congress, Cape Town, S-Africa.
Rovers, R. (2009). "Post Carbon - or Post crash - managing the Orbanism." World Transport Policy and Practice 14(4): 7-17.
Rovers, R., H. Sap, W. Leduc, V. Rovers, L. Gommans, F. Van Kann (2010). The Urban Harvest Plus approach to 0-impact on built environments, case study Kerkrade West. Toward 0-impact Buildings and Built Environments. R. Rovers, J. Kimman and C. Ravesloot. Amsterdam, Techne Press: 173-182.
Shen, L., S. Cheng, A.J. Gunson, H. Wan, (2005). "Urbanization, sustainability and the utilization of energy and mineral resources in China." Cities 22(4): 287-302.

Statistics Netherlands (2009a). Bodemgebruik in Nederland vanaf 1996. Den Haag, Statistics Netherlands.
Statistics Netherlands (2009b). Regionale Kerncijfers Nederland - Bevolking. Den Haag, Statistics Netherlands.
Statistics Netherlands (2009c). Regionale Kerncijfers Nederland - Wonen. Den Haag, Statistics Netherlands.
Steenbekkers, A., C. Simon, et al. (2006). Thuis op het platteland. Den Haag, The Netherlands Institute for Social Research: 1-396.
Sterr, T. and T. Ott (2004). "The industrial region as a promising unit for eco-industrial development--reflections, practical experience and establishment of innovative instruments to support industrial ecology." Journal of Cleaner Production 12(8-10): 947-965.
Vadasz, P. (2010). Güssing, a model for other regions. Towards 0-impact Buildings and Built Environments. R. Rovers, J. Kimman and C. Ravesloot. Amsterdam, Techne Press: 43-50.
Van Kann, F. and G. de Roo (2009). Scaling of Multi-functional Strcutures as a Spatial Argument for Low-Exergy Planning. 3rd International Conference on Smart and Sustainable Built Environments. Delft.
Van Kann, F. and W. Leduc (2008). Synergy between regional planning and energy as a contribution to a carbon neutral society - energy cascading as a new principle for mixed land-use. SCUPAD 2008. Salzburg.
Wall, G. (1977). Exergy - a useful concept within resource accounting. Göteborg, Institute of Theoretical Physics, Chalmers University of Technology and University of Göteborg.
Wall, G. (2009). Exergetics. Bucaramanga, Exergy, Ecology, Democracy.

6. Appendices

6.1. Planning and questions

I will give an overview of the planning for the last year and will state the questions and how the answers will look like

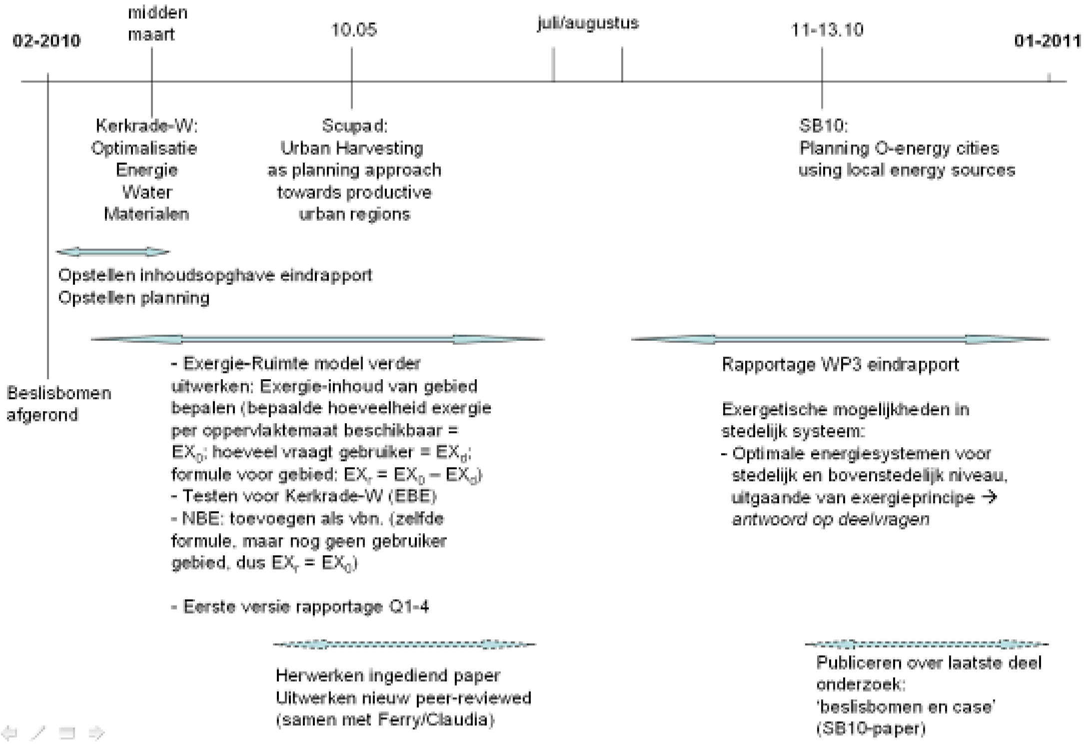

Fig.: Planning last research year

The following will state some ideas about how the equation of the exergy model can look like:

Exergie-Ruimte model:

- **hoeveelheid Exergie per oppervlaktemaat = EX_0**
- **Exergievraag gebruiker = EX_d**
- **Exergieaanbod gebied: $EX_r = EX_0 - EX_d$** (r van residual)

Voor NBE Exergieaanbod gebied: $EX_r = EX_0$, want nog geen gebruiker

In the next paragraph I focus on the sub questions:

<u>Sub questions</u>: short description of answers
Q1: *mogelijke stromen en bronnen binnen stedelijk systee*m
Zie dataverzameling + uitwerking SREX-cases en KW, en de rapporten daarover (Urban Tissue uitwerkingen)

Q2: *exergievraag stad, hoog- tot laagwaardig*
Zie dataverzameling + uitwerking SREX-cases en KW, en de rapporten daarover (Urban Tissue uitwerkingen): elektriciteit- en gas/warmtevraag → geen verdere

specificatie warmte (naar verschillend temperatuurniveau) omwille van ontbreken goede methode voor dataverzameling

Q3: *matching vraag en aanbod*
Zie uitgewerkte resultaten SREX-cases en beslisbomen

Q4: *waarde van bronnen in termen van exergie*
Hangt samen Q1 en Q2: grove indeling bekend, elektriciteit en warmte; specifieker: niet zoveel data (uitgegaan van aanwezigheid netwerken, dus elektra en gas op niveau van huidige stromen)

Q5: *urban harvest toepassen; hoe met planning, inrichting, beheer duurzaam aanpakken*
Beslisbomen geven aanzet, uitwerking tissues geeft quick-scan van stedelijk gebied, Exergie-Ruimte model geeft energiepotenties en gebruikers ruimtelijk weer → waar zijn interessante gebieden, daar moeten we koppelen, iets extra toepassen, optimaliseren