Quadruple the potential
Scaling the energy supply

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ABSTRACT: In times when scarcity and prices of energy increase rapidly the urgency to rely on local and sustainable resources grows as well. In planning practice there is a lack of useful information regarding the availability and local potentials of possible renewable energy sources. Thus, the solutions and a transition towards a sustainable energy supply system are unclear and not very successful. The old-fashioned global market rules dictate what is possible, desirable and realistic. But if the local potentials are studied a different view on energy supply can be distinguished, in which a far larger part of the energy use can be supplied locally, leading to a reduction of greenhouse gas emissions far beyond policy ambitions. Therefore, it is necessary to develop a methodology in which the potentials can be discovered, mapped, used and calculated. This methodology is developed for four spatial scales and for several projects, each of them with their own characteristics. The paper will discuss these spatial scales and the interconnections between them as well as the benefits in term of energy use and greenhouse gas emissions.
Keywords: Energy-potentials, spatial planning, urban design, architecture

INTRODUCTION

The dependency on fossil fuels and the fact that oil, coal and gas are world markets and the rules within these markets dictate what is possible, desirable and realistic, prevent a real transition towards a sustainable energy supply from happening.

The traditional approach aims to make the existing system a little bit more sustainable. But still, world market rules define the framework within which the pace of changes is permitted to take place. This way of thinking generally leads to difficult reached agreements on ambitions. The 2020 objectives of the EU [Commission of the European Communities, 2007] for example, are to reduce greenhouse gas emissions and increase energy efficiency both by 20% and aim to increase the proportion of renewable energy to 20%. The Dutch government formulates its goals alike: save energy by 20% and reduce greenhouse gas emissions by 30% in 2020 [CDA, PvdA and CU, 2007].

However, the transition can be looked at from the opposite direction. If the availability or regional potential for sustainable energy in a certain region decides on the ambitions and the way energy is produced and supplied and not that global market rules dictate the available space for the use of sustainable energy, the usage of local and regional potentials will increase. So far, few studies with the objective to find out how local sustainable potentials can be used are conducted [Roggema et al, 2006, Dobbelsteen et al, 2007, 2008]. These studies make visible by using maps where the potentials for different sustainable energy sources can be found.

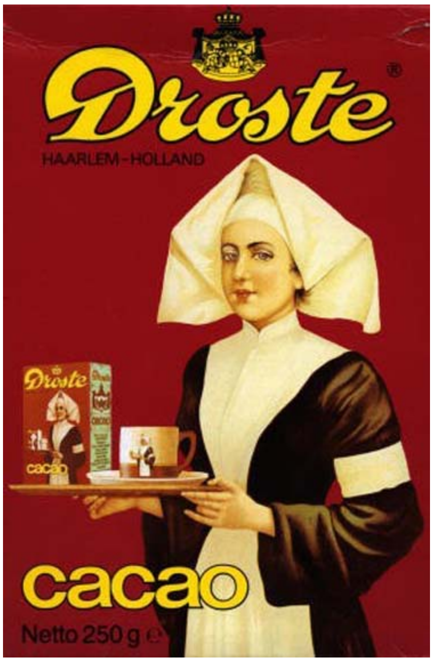

Figure 1 The Droste effect

If these studies are combined a system can be created, which functions like the famous Droste effect (figure 1): findings regarding the potentials for sustainable energy supply on the supra-regional scale determines what the potentials are on the regional scale, which determines what the potentials are on the local scale, which consequently determines what the potentials are on the building scale. Combining the potentials at all scales will result in far higher ambitions than the current policies define.

The most important constraints include the existing cultural setting of decision-making, the ostensible dependency on large energy companies, the addiction to the existing power relations of important meets important, the seemingly immovable trust in existing infrastructure.

Every scale has its own possible contribution and characteristic.

THE SUPRA-REGIONAL SCALE: NORTH NETHERLANDS

On supra-regional scale it is important to create the basis of knowledge: to gain insight on where the different potentials are highest and what a combined energy typology implies [Roggema et al. 2006]. On the supra-regional scale of Northern Netherlands the energy potentials for wind, solar, geothermal, biomass and hydro are mapped (figure 2).

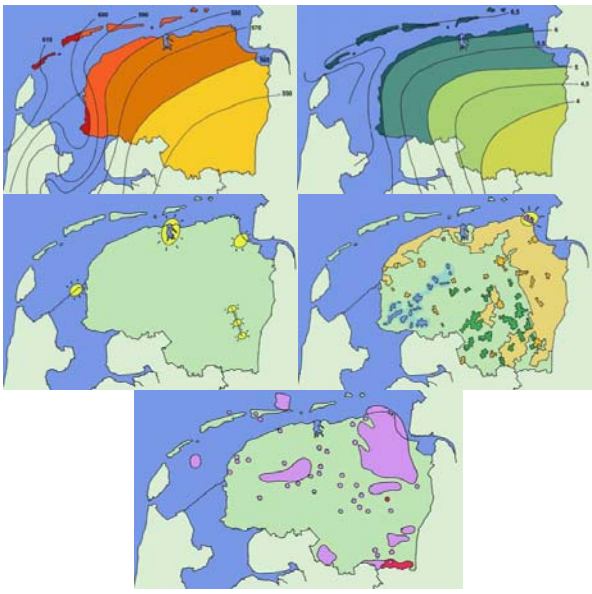

Figure 2 Regional energy potentials in Northern Netherlands: solar, wind, hydro, biomass and geothermal [Source: Roggema et al. 2006]

If these potential maps are combined the so-called energy-mix map emerges (figure 3). This map shows spatial energy typologies: for every sub-region it becomes visible which combination of sustainable energy resources is available. The map does not give a directive for land use. Any function can be located anywhere and can make use of the available resources.

The benefit of the energy potential mapping at the supra-regional scale is that every sub-region knows its specific and most optimal combination of energy resources, which can be used for a planned or an existing function. Making use of this energy potential instead of imported gas or oil reduces the use of fossil energy.

Figure 3 The energy-mix map, showing for each location the optimal mix of energy potentials [Source: Roggema et al, 2006]

The main aim at the supra-regional scale is to identify the available mix of sustainable energy potentials in the region.

THE REGIONAL SCALE: GRONINGEN

The aim on the regional level is to determine the best location for functions from a sustainable energy point of view. For that purpose, the energy potentials are mapped and combined with the *low-ex* principle on the provincial scale [Dobbelsteen et al. 2007].

According to the 1st Law of Thermodynamics, energy is never lost, but the 2nd Law describes the increase of entropy, implying the decrease of something else. This is exergy. By definition, exergy is the maximum work potential of matter or energy in relation to its environment. It can be considered the high-quality part of energy. The low-ex(ergy) principle encompasses reduction of exergy losses in and between processes, the use of high-quality energy for high-graded functions only and the utilisation of waste energy flows from these by lower-graded functions. The low-ex principle assumes cascading of energy qualities, and in a spatial context the mixing and energetic inter-connection of spatial functions such as industries, horticulture, offices and dwellings.

In the province of Groningen the potentials for wind, solar, geothermal, biomass, hydro and the use of rest-heat from buildings and industry are mapped as a result of the existing situation (topography, existing energy system, climate, etc.) and translated into maps that show the potentials for fuel, electricity, heat and cold and CO_2 capture (figure 4).

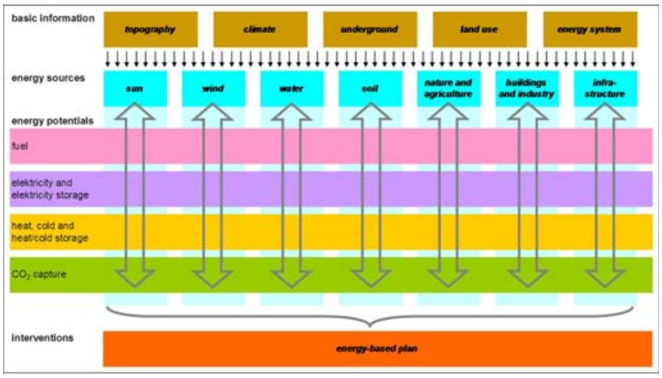

Figure 4 Methodology to combine energy potentials with spatial interventions [Source: Dobbelsteen et al, 2007]

The map for heat and cold (figure 5) shows that the largest combined potentials are found near the northern parts of the province, around the Eems harbour (rest-heat) and the Lauwers Lake (geothermal heat). The electricity potential map (figure 5) shows that two zones are interesting: the coastal zone (wind and hydro) and the central highway zone (central location for biomass processing).

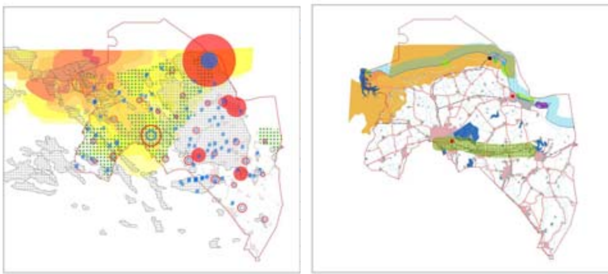

Figure 5 The potentials for heat and cold (left) and electricity (right) in the province of Groningen [Source: Dobbelsteen et al, 2007]

If all sustainable energy and exergy potentials are combined a provincial energy-mix map can be derived (figure 6). This map forms the foundation for decisions about the most optimal positioning of specific functions.

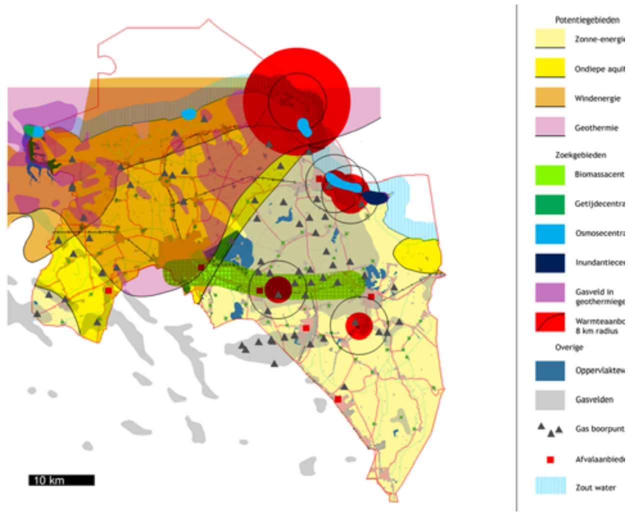

Figure 6 Map of Groningen with the mix of energy potentials [Source: Grinten, 2008]

The energy-mix map shows indications on the most optimal locations for functions or combination of functions. The functions are able to use sustainable resources there or use energy more efficiently.

These potentials can be translated into spatial interventions (figure 7). The map shows the proposed functions: new livig neighbourhoods where geothermal heat is available (near Lauwers Lake), living neighbourhoods and greenhouses where rest-heat can be used (around Eems harbour and Delfzijl) and the different locations for electricity plants (wind, biomass, tidal, osmosis, inundation).

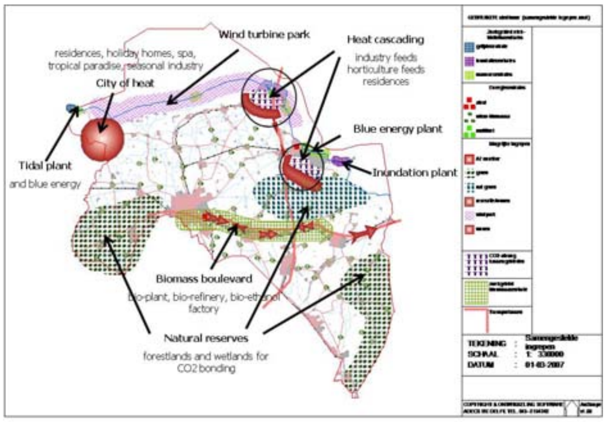

Figure 7 Map with the spatial interventions based on energy potentials [Source: Dobbelsteen et al, 2007]

These spatial interventions are based on energy potentials. Spatial planning can be directed by spatial knowledge about the availability of sustainable energy resources. The best or most efficient locations can be chosen for urban as well as agricultural functions.

The benefits of these spatial interventions are calculated. If all spatial measures are taken 50% of the current energy demand is serviced, which is four times current percentage of the use of sustainable resources in the Netherlands. Besides this, a reduction of 80% CO_2 emission reduction is reached, which is four times the current objectives in EU and the Netherlands.

THE CITY-NEIGHBOURHOOD SCALE: ALMERE EAST & HOOGEZAND

At the local level of a city department or neighbourhood the potentials no longer determine where a certain function can be positioned best, but they influence the lay out of the settlement, city or neighbourhood.

These potentials are mapped and give insights on the organisation of the functions in the urban pattern. Beside the usage of sustainable energy resources, on this scale the exchange of energy via the grid can be taken into account.

The research projects of Almere and *The Green Campaign* in Hoogezand illustrate this.

Almere East

The Dutch city of Almere, near Amsterdam, wants to double in size within the next 15 years and develops extension plans for this. The Delft University of Tcehnology was asked to conduct an energy potential study of the new districts of Almere. Almere East (approximately 4000 ha) was one of these. Here specific local potentials were related to the agricultural hinterland which it is now, as well as good opportunities for wind and sun (fig. 8).

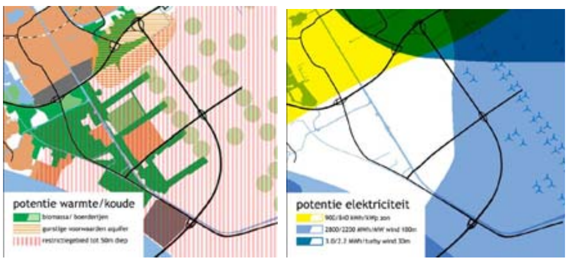

Figure 8 Potentials for heat and cold (left) and electricity (right) in Almere East [Source: Dobbelsteen et al. 2008]

On the basis of the energy potential maps for Almere East, spatial design interventions were suggested. Figure 9 and 10 depict the two main variants proposed. Interesting feature of the first is the deployment of existing agricultural enterprises in the plan, forming the cores of energetically self-sufficient clusters of a farm with 30 dwellings. Greater quantities of housing developments can be combined with offices and light industry in the north of the district, which is the only place where heat and cold can be stored in open aquifer systems.

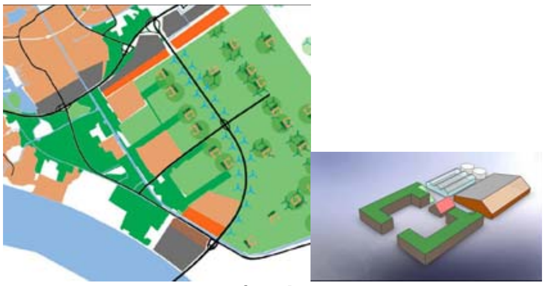

Figure 9 First variant for Almere East

The second variant of figure 10 was more strongly based on a grid connected strip of high-density building along the motorway, simultaneously acting as an acoustic barrier, so that the inner location behind it can be developed in various yet all energy-neutral ways. The high-density building strip is connected to a grid of heat, cold and power, using waste energy flows from the different functions, inclusing the power plant nearby.

Figure 10 Second variant for Almere East

The proposals based on energy potentials deviated considerably from plans already drawn by the urban designer. After presentation the municipality of Almere studied the possibility of adjusting the existing plans to a more energy-effective one.

Hoogezand: The Green Campaign

On a smaller scale than Almere East, the town of Hoogezand-Sappemeer intends to develop a new site for living south of the present built-up area, called The Green Campaign. Similar to Almere East is the current agricultural character. The Green Campaign however has features that make it different from the other location.
There are many limitations regarding noise and odour nuisance zones, high-voltage lines and historic (untouchable) lanes (fig. 11). Nevertheless, there are interesting potentials, for instance, a few 'hotspots' of a specific energy potential: a chicken farm (chicken manure for co-generation of heat and cold), a cartonage factory (waste heat) and a gas drilling station (geothermal heat from 3 km of depth).
Research is ongoing. At the moment of writing three fundamental concepts are elaborated on: one based on interconnections with existing hotspots of energy, one based on self-sufficient neighbourhoods (with decentralised technical utilities) and one with independent autarkic dwellings.

Figure 11   Nuisance zones in The Green Campaign

Experiences with energy potential studies

Energy potentials can influence the lay-out of neighbourhoods. If the energy-mix is known at the supra-regional level and if functions are located at the right positions on the regional level, the lay-out of the city district or neighbourhood can be done accordingly. The use of available potentials can play a directive role in the design for the urban patterns. If, on top of that the exchange between the use as well as delivery of energy to and from the grid is made possible the results can be improved even more.

THE BUILDING SCALE: RIVER HOUSE MILDURA

At the building level the River House Mildura exemplifies how local potentials can be used for the design. The use of local potentials like the need for heat and cold, shadow, the sun, ventilation and wind, shelter and material use, once they are mapped, are integrated in the design. If the sources and circumstances are integrated a net positive energy production is possible, thus deliverance to the grid.

Resources were defined on the site, and their potentials exploited.
- Mapping of the semiarid climatic conditions enabled the design to capture and work with free potential resources.
- Local materials were integrated into the thermal mass earth walls.
- Mapping of the site and adjoining land revealed shading opportunities and informed the designs landscape design response
- Analysis of sightlines informed a more specific and sophisticated response to capturing views
- Re-viewing the brief and mapping the amenity requirements of the client discovered resource savings in terms of reduced built area

Figure 12   Aerial view

Figure 13   Mildura Residence – north/east elevation facing the Murray River

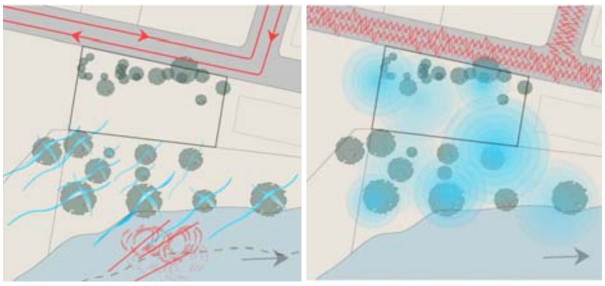

Figure 14   Movement analysis - the poetic resource of nature to be captured (left) and Noise analysis - the chaotic sound of traffic to be controlled, whilst capturing fauna sounds (right)

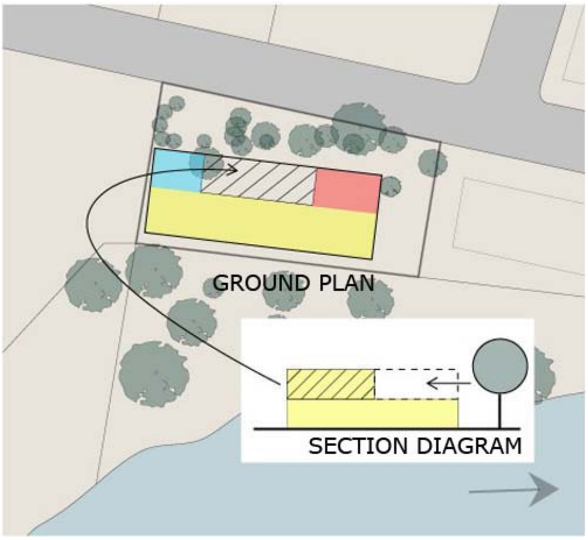

Figure 15   Functional mapping

Mapping the functional requirements of the client (resources) enables a design evolution that reduces the overall area of building. In this case the second level was consolidated and the inserted into the ground level footprint.

Figure 16   Winter sun (left) and summer sun (right) analysis

Mapping the solar path provides an understanding of the spatial relationship between the site and design options.

Figure 17   Mapping of the existing landscape light and shade

The resource of sun requires seasonal control, the design utilises the existing trees to protect from the low morning summer sun.

Figure 18   Labyrinth fan (left) & sensor (right) located in rammed earth wall.

The architecture integrated a subterranean air labyrinth utilising the lower soil temperatures to provide cooling during summer.

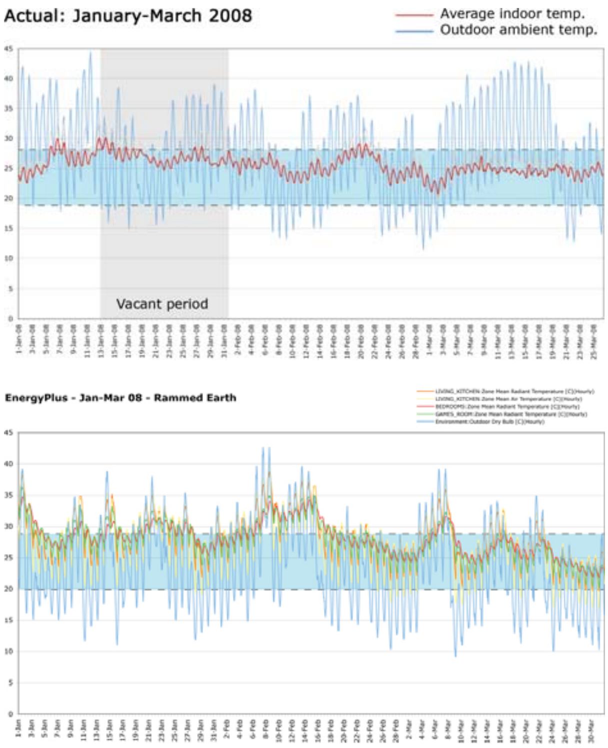

Figure 19   Summer - Actual versus simulated results.

Passive systems provide a greater level of comfort than predicted by the simulated model. The simulation indicated that the living spaces would fluctuate by up to 7.5 degrees and the monitored results were closer to 5 degrees.

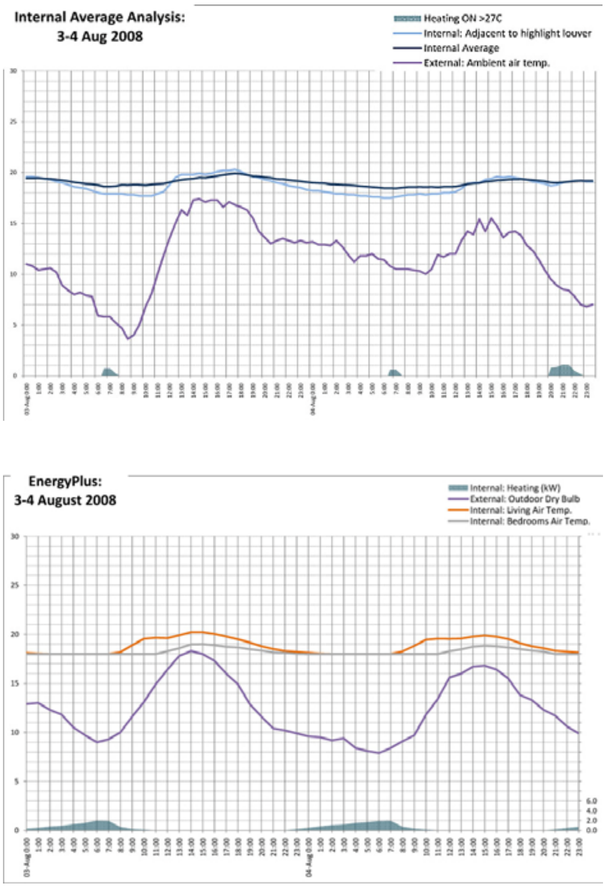

Figure 20 Winter performance

These charts illustrate the Actual versus simulated results Energy Plus. Actual results outperform the simulated. In near zero conditions the building requires negligible heating to maintain a comfortable internal temperature. Energy Plus predicted a much higher heating demand under less severe outdoor temperatures.

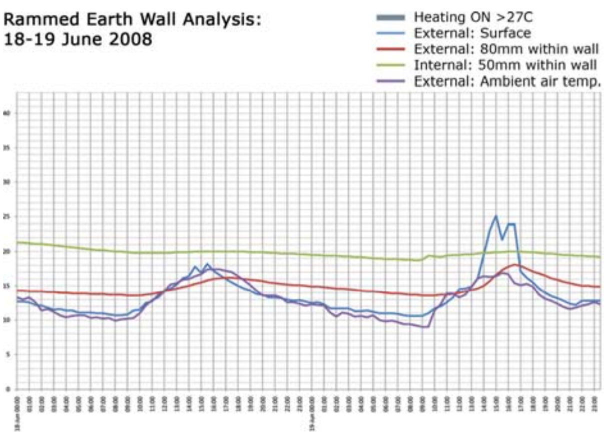

Figure 22 Rammed earth wall analysis.

The graph illustrates effectiveness of 400mm thick insulated rammed earth wall and thermal lag of rammed earth material.

Table 1 Heating and cooling comparison between Mildura River House and average home

	Gas heating & electric cooling	Electric heating & cooling (RCAC)
Energy saving (% saved)*	64.0%	64.0%
Energy use of renewables (as % total use)+	33.0%	33.0%
CO_2 emissions (% less than normal)	73.0%	84.6%

*This figure includes lighting
+This figure excludes the renewable component of the passive climatic systems

Potentials and Outcomes

The success of resource mapping is apparent in this development. The aim was to reduce the energy consumption with 50% over a similar home in a comparable area and exceeded this. This, and even a higher ambition of 64%, was achieved by overlaying the responses to our resource mapping. These included mapping the sun's path (figures 16), the sight lines, the subterranean temperature (used in the development of the labyrinth, figure 18), materials and other potentials. The intended gains from every single system were improved upon when it operated in conjunction with another system. Monitoring revealed by the actual data logging of the property exceeded the simulated model's predicted performance. The interaction between the passive and active systems offers greater gains through the complexity with which each system operates. By responding, finding windows of opportunity and ultimately producing an organic system that works reciprocally within other systems to produce an elastic loop, these gains were reached.

INTERDEPENDENCIES

If energy potential mapping is carried out at several spatial scales lower scales can profit from the knowledge about the availability of sustainable resources at higher levels. At the lower scale better choices can be made on the lay out and order of functions in order to increase the use of sustainable resources. The big win is that if is known what the available sustainable resources at the higher scale are, it can be determined what the useful resources are at lower scales. This way of thinking is not yet practiced and large improvements can be made.

If reaching energy saving or emission reduction objectives are discussed so far, the building is seen as the relevant subject. This leads logically to making the house/building as efficient as possible: energy saving and the provision of sustainable energy as much as possible. If the building is seen as interdependent with higher scales, the positioning and the design of the building in the chain of spatial scales make more ambitious objectives possible.

Table 2 The role and benefits of different scales

Scale	Role	Results
Supra-regional	Which potentials are where	Not relevant
Regional	Which pattern of functions is best Potentials + exergy	Sustainable energy use: 50% CO_2-emission reduction: 80%
Local	How need the lay out of the function be Potentials, exergy + exchange with grid	Energy and CO_2 neutrality or even energy surplus
Building	What is the best design Potentials, exergy, grid & comfort	Sustainable energy used: 33% Energy saving: 64% CO2-emission reduction: 73-84,6 %

There are several interdependencies between the different scales. The characteristics at the highest level mark the possibilities on the regional scale. Once the potentials are known on the regional level the most optimal functional zoning, including the available sustainable resources, can be proposed. At the regional level the principle of exergy is added. If the location for a certain function is known, the spatial design of the urban patterns can be undertaken, making use of the available resources. At the local level the exchange with the grid is added in the process. And once the lay out of the area is chosen the available resources to be used in the design of buildings. At the building level elements such as comfort and beauty are added.

It is possible, with incorporation the higher levels of scale in the energy supply chain to reach much higher levels of use of sustainable energy and reduction of green house gas emissions than current policies aim can be reached. The examples in this paper illustrate that result up to four times higher can be reached. This means that policy objectives can be quadrupled easily.

DISCUSSION

The results in the different studies show that far higher objectives can be reached than in current policies are written down. The added gains at every spatial level offer a quadruple effect. If an energy efficient house is built certain saving objectives are reached. If the same house is built in a sustainable energy directed urban pattern these houses profit from the right circumstances. And if the neighbourhood is planned at the right place in the region and making use of the available resources the results show that the potentials can be quadrupled.

Major constraints to implement the method are the existing power balances between decision-makers. As long as large energy companies remain power over infrastructure their dominance over the decisions on used resources cannot be changed. The hidden agreement between governments and energy companies about a mutual dependency on global market rules and the fact that it is impossible to change anything about is leading to the continuation of the existing system. Finally, it is far more easy for people to decide on what they are used to instead of decide for a breakthrough or an innovation. This makes it hard to start the process of thinking from the other side than the usual and prevents us from reaching quadruple results.

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