SMART VERNACULAR PLANNING: SUSTAINABLE REGIONAL DESIGN
BASED ON LOCAL POTENTIALS AND OPTIMAL DEPLOYMENT OF THE ENERGY CHAIN

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Summary

Energy depletion and climate change require an approach to spatial planning that is radically different from what we are used to. For developed countries, with an ecological footprint exceeding their national territory, it is a moral question to not just depend on supply of energy from elsewhere. For developing countries an economy relying mainly on smart deployment of local qualities will enable sustainable growth without the changeable support of richer countries.

The principle of smart vernacular planning is based on a thorough analysis of local characteristics that can be used in the management of energy, water and other resources. These features can be translated to potential maps depicting, for instance, the opportunities to generate power from local resources.

Furthermore, the depletion of fossil energy requires optimal management of the energy chain: use of sustainable resources (supply) and low-exergy design (demand). At present much waste energy (mainly heat) is emitted unused into the air, water and soil. In addition, high-quality energy is now used for low-grade purposes for which waste energy of a lower quality would suffice. Cascading spatial functions that tune supply and demand would satisfy the principle of effectiveness, creating greater effect than energy efficiency.

A next creative step in smart vernacular planning is the translation of the information gained into interventions in an already existing built, or unbuilt, environment. This process requires ingenuity, knowledge of planning process and, above all, political courage. It is the only way towards a sustainable future within shifting boundary conditions of climate and available resources.

In the paper we will elaborate on the methods of energy potential mapping and matching, energy cascading and climate- and energy-inclusive planning, all of which form the building blocks of smart vernacular planning. We will discuss recent studies that applied this principle.

1. Introduction

1.1 Need for a different approach to energy

While dramatic changes are taking place to our climate, one of its probable causes, consumption of fossil fuel is becoming an uncertain asset in the near future. Natural oil and gas reserves are depleting, or their extraction is becoming complex and expensive. This will make the availability of energy uncertain and very expensive, which will probably affect developing countries the hardest.

The tendency to widely use coal again for the generation of electricity – for instance in China and the Western world – will have a devastating impact on greenhouse emissions and pollutions that seemed to have been banished. Many countries now seek refuge to nuclear power but uranium is also depleting.

Meanwhile, sustainable energy may be expensive yet abundant: based on the potential for energy from the sun, wind and water, Jong et al. (2004) calculated that the Netherlands alone could already sufficiently provide the global economy with energy. However, at this instant local potentials are not effectively seized.
1.2 Sustainable development

Paradoxically, the threats of climate change and energy depletion can be used as a catalyst for sustainable redevelopment. A new paradigm can be found in responding to the inevitable changes in climate rather than fighting them. Spatial planning can be based on local energy potentials and in accordance with an optimal usage of the energy cycle by means of the low-exergy principle. The local potentials for energy generation can be investigated by means of analyses of climatic conditions, landscape and land use typology, local natural, cultural and technical features, and existing 'hotspots' of energy and heat generation.

This new approach to sustainable regional planning leads to 'energy potential maps', depicting the local potentials for energy provision. These can be combined to a map of interventions proposed from an energetic point of view.

1.3 Need for a different approach to energy

Energy depletion and climate change require an approach to spatial planning that is radically different from what we are used to. For developed countries, with an ecological footprint exceeding their national territory, it is a moral question to not just depend on supply of energy from elsewhere. For developing countries an economy relying mainly on smart deployment of local qualities will enable sustainable growth without the changeable support of richer countries. Local strengths therefore should be better used, and vernacular solutions were primarily based on the deployment of these local characteristics, so they will be most helpful.

In addition, we need to acknowledge that many of the current energy systems are close to 100% energy efficiency. Nevertheless, we still seem far off from the desired sustainable development. Energy efficiency, as it seems, is not the solution for a sustainable society. This can be made understandable by the exergy concept, which is rather about effectiveness than efficiency and which will be discussed further on.

2. Smart vernacular planning

2.1 Backtracking, revaluing vernacular solutions in a traditional sense

In order to set the path for future sustainable developments, there are different time-based approaches (figure 1, Dobbelsteen et al. 2006).

- **Forecasting** is needed when we want to estimate the consequences of current developments and our own intervention on long-term effects, such as the issues of climate change and depletion of resources.
- **Backcasting** involves the description of a desired future state (sustainable and based on the needs that need to be met), translating this state back to strategies and measures we need to develop now.
- By means of **backtracking**, solutions are based on historical circumstances at the time when there still was a sustainable equilibrium. This sustainable past may be an instance for planning directions, for which perhaps certain valuable historical, natural or cultural features or circumstances can be brought back to new design.

![Figure 1](image_url) **Figure 1**  Graphical explanation of the forecasting, backcasting and backtracking methods.

Forecasting is useful to predict trends that have developed over some time already, but is not very effective to establish a great leap toward a sustainable future. A better, more effective method for substantial change is backcasting, but one could consider this method rather detached from real life and how it evolved throughout the centuries. Therefore, backtracking can be used to link the present to qualities of the past, embodied by vernacular principles. Backtracking would revaluate vernacular solutions that in itself sustained a way of living in equilibrium with the environs.

None of the methods presented should be applied alone. We found that the simultaneous use of all three of them means synergy, picking the best solutions from history, the present, and the imagined and desirable future.
2.2 Incremental approach to new vernacular principles

Apart from local historical principles, smart vernacular planning needs to be based on a profound analysis of local characteristics that can be used in the management of energy, water and other resources. Therefore, basic information is collected of climate, historical developments, topography, soil and underground, landscape, land use and infrastructure. For instance, the local climate is essential for the determination of potentials of solar and wind energy, and land use gives a clue to the possibilities of biomass.

This basic information then is translated to energy potential maps for fuel, electricity, heat and cold, and CO₂ capture. These maps evolve through a process of deduction, association and creativity. The depletion of fossil energy requires optimal management of the energy chain: use of sustainable resources (supply) and low-exergy design (demand). At present waste energy (mainly heat) is usually emitted unused into the air, water and soil. In addition, high-quality energy is now used for low-grade purposes for which waste energy of a lower quality would suffice. Cascading spatial functions that tune supply and demand would satisfy the principle of effectiveness, creating greater effect than energy efficiency.

A next creative step in smart vernacular planning is the translation of the information gained into interventions in an already existing built, or unbuilt, environment. This process requires ingenuity, knowledge of the planning process and, above all, political courage. It is the only way towards a sustainable future within shifting boundary conditions of climate and available resources.

Figure 2 depicts this generic methodology for charting energy potentials and interventions therefrom.

3 Heat cascading

3.1 Exergy

The First Law of Thermodynamics states that energy is never lost, whereas the Second Law describes that processes develop towards a state of increasing entropy. Hence, entropy embodies the non-useful waste energy evolving during processes. Exergy is the useful part, the part that can perform work. It is a measure of energy quality.

As already stated, processes can be energy-efficient but in terms of exergy this efficiency can be totally different if the initial exergy level is predominantly converted to entropy. For instance, a contemporary boiler may have an energetic efficiency of 95%, but considering the gas flame of 1500°C, a lot more can be done with it than just heating up houses to 20°C. The exergetic efficiency is approximately 10%. If the gas flame heat were used in the metal industry, the exergetic efficiency would approximate 100%. Therefore, energy of a high-quality level should be used for high-grade functions before it transforms into a lower-quality state, which can still be useful to low-grade functions.

Figure 2  Methodology of the energy potential mapping.
3.2 The low-ex approach

The current energy system of a region (figure 3, left) is characterised by an influx of primary energy – fossil fuel – into every function present in the area. A power plant, which is also fuelled by fossil energy, generates electricity and every function produces waste and waste heat. The latter is emitted into the air and water. In this system each step requires high-quality input of exergy.

![Figure 3](image_url)

**Figure 3** Graphical example of energy provision in the current system (left) and in a more sustainable, low-exergy system that uses heat cascading (right).

The low-exergy (low-ex) approach (figure 3, right) limits exergy losses between and during process steps. This would imply feeding an exergy quality close to the demanded level, losing little exergy during the process and finding a secondary function that can make use of the output level. High temperatures would only be used in heavy industrial processes, of which waste heat could be used in lower-grade functions such as manufacturing processes, horticulture, and subsequently for residential heating. Residences and agriculture can eventually again 'feed' the power plant with biomass and waste.

Thus, four to seven instead of just one purpose would be served by the same amount of primary energy.

3.3 An uncommon inventory

In order to get the full picture of heat cascading potentials, a survey needs to be executed of all regional functions, their exact location, temperature levels required for their processes, the demand of energy and the supply of waste energy and other products. In order to make the inventory feasible, for some of these functions – e.g. housing and offices – one may use generic values of energy demand and supply. Specific industrial functions however require individual study of internal processes and energy characteristics. Not every company is willing to give this information, but regional administrations often need the same data for environmental licences, and one can use these in the energy survey.

After the collection of data, the exact location of heat and cold supply and demand can be charted. This will visualise areas with excess and lack of energy, and evoke measures to be taken for closing the heat chain.

3.4 Right form, right place, right time

In order to make heat cascading possible, there is a question of the right energy form needing to be in the right place at the right time (Gommans & Dobbelsteen 2007).

3.4.1 The right energy form

For the mapping of (waste) energy potentials it is necessary to know which forms of (waste) energy can be harvested and for which use. The energy required for certain processes is not always available in the desired form, in which case conversion is necessary. Practical expertise is necessary of this conversion process, including knowledge of efficiency, costs and space requirements. This sometimes requires innovation. For instance, the bio-technology industry still regularly finds new ways, assisted by enzymes and bacteria, to convert certain materials into usable carriers of energy (TI-KVIV 2007). An overview of existing energy conversion processes will clarify which forms of (waste) energy can be converted to a usable form, and provide basic information about the associated costs and practical aspects of the conversion process.
3.4.2 The right place

On the regional scale the low-ex principle has implications for planning. Low-caloric heat cannot be transported over long distances: heat losses would be too big. Therefore, spatial functions should be concentrated and mixed: horticulture near industry, residences near horticulture. The SREX research project (Roo et al. 2005) focuses on this synergy of space and exergy.

Each method of transporting energy has characteristic features. Electrical energy can be transported at high voltage over large distances with relatively little losses. Transport of heat over larger distances however quickly reaches a point where the energy losses exceed the energy content. The losses are partly transmission losses to the environment and partly losses incurred by displacing the energy carrier (e.g. pump losses). Energy carriers in a solid or fluid state (e.g. wood products or liquid gas) can be transported by road, rail or waterways. Every method of transport has a price.

The right place to generate electricity may be disputed. Should this be the place where, for example, biomass is available? Or is it the place where biomass or some other fuel can be easily delivered? Or should it be close to areas of living, where waste heat can be used for space heating? Or should it be at some location in-between? Every location has its pros and cons in terms of logistics, efficiency, public inconvenience, transport losses etc. For a well-deliberated decision on the matching of supply and demand of energy and the location of conversion, it is essential that the characteristics of the possible methods of transport are known.

3.4.3 The right time

Finally, timing can be an obstacle in realising a working energy system. Usable energy may be available in the right amount at the right place, but at the wrong time, necessitating energy storage for a short or long term. For instance, photovoltaic systems may require an overnight storage for electricity generated during the day, for use at night (e.g. lighting). Long-term seasonal energy storage will meet the demand for space heating in winter, with excess solar energy captured during summer. Similarly, waste heat continuously produced by industrial processes may be usable only in winter.

Storing energy is always associated with energy losses and, besides, costs, space and energy (for loading and unloading). Each form of storage has its own characteristics. Fuels such as fossil fuels, plant-based oils, bio-ethanol, but also biomass in general are the highest form of exergy. They essentially are chemical stores from which energy can be released by combustion or in another way. As a result of their energy density they require relatively little space. There are many ways to store heat, such as in the thermal mass of buildings or underground heat buffers. Storage of electricity is more difficult than of heat. The electrical grid is sometimes used, but this is only possible as long as the changeable power from wind turbines or solar systems is relatively limited. An increasing share of electrical energy produced by the sun and wind will require a different solution for storage, possibly hydrogen. The selection of an appropriate energy storage method is determined to a large extent by the form of the energy required and by the duration of storage. Locations and regions will vary in their particular requirements and potentials for storage.

4. Using local features at different scales, two examples

4.1 The regional scale: the province of Groningen

Following the investigation of a new regional plan for the Northern Netherlands (Roggema et al. 2006) based on a sustainable energy system, the northern province of Groningen commissioned an energy potential study. The findings of this study, presented in e.g. Dobbelsteen et al. (2007), would be included in the new provincial development plan, for which climate change was also one of the steering principles.

Figure 4a shows the map of all potentials for electricity generation. It gives the best location for wind parks, a tidal plant and a few ‘blue energy’ plants along the coast, for a biomass-based industrial cluster in the centre, and for a new type of plant: an inundation plant for occasional flooding of the deepest polders in case of emergencies. Furthermore, there are small decentralised bio-digestion installations with combined heat and power (CHP) generation, spread through the country-side which contains many isolated farms and villages. Energy values of solar radiation showed little variance over the province, so use of photovoltaic panels is possible anywhere. For large-scale solar plants, the energy properties of a northern place as Groningen are unfavourable. Local self-supply, however, can be helped by solar panels, as well as small wind turbines.

Figure 4b is the overlay map of heat and cold potentials. The map depicts the potentials of geothermal heat from aquifers at 3000 meters of depth, to be deployed through empty gas fields, shown as grey grids. The drill-holes of gas locations are indicated by small blue triangles. The small dotted areas depict reasonable to favourable. Local self-supply, however, can be helped by solar panels, as well as small wind turbines.

Nevertheless, the largest producer of heat, the Eems harbour area, now has no heat-demanding function close to it. This can be altered through spatial planning that takes these heat potentials into account.
Solar heat, again, is available anywhere and should be seized when possible. This also applies to local exchange of heat and cold with exhaust air, the soil and open water.

Figure 4 Overlay maps of energy potentials of Groningen for the generation of electricity (a, top left), the provision of heat and cold (b, top right) and for CO₂ use in greenhouses, compensation by plants and storage in gas fields (c, bottom left), as well as the map with proposed interventions (d, bottom right) (Dobbelsteen et al. 2007).

The principle of human influence on the climate is quite simple: prehistoric lush jungles that captured carbon dioxide (CO₂) over millions of years evolved into fossil fuels, which are again converted into CO₂ in a time period of two centuries. To compensate for that, new jungles should thrive another couple of million years, but this time man obstructs the natural regeneration of plants. A four-steps strategy may be (1) avoid emission of CO₂ by energy-saving and sustainable energy resources, (2) make CO₂ useful in industrial and horticultural processes, (3) compensate for CO₂ emissions by planting trees and other green absorbers, and finally (4) storing CO₂ underground. This last option is possible in emptying gas fields that are not watered out after abandonment. Figure 4c summarises the last three options for the province of Groningen. The gas drill-holes are again given.

Figure 4d finally represents the interventions proposed on the basis of energy potentials. These proposals involved a wind park, a tidal plant, blue energy (osmosis) plants, an inundation plant, a cluster of biomass-related industrial activities, heat cascading solutions by horticulture and housing developments against industry, and wet biotopes for CO₂ bonding.

4.2 The urban to district scale: Almere East

Almere, a new town near Amsterdam established in the 1970s has gradually grown, to Dutch standards, to middle-sized proportions but continues to grow with the increasing demand for space for living in the Amsterdam metropolitan area. The municipality of Almere intends to make a 'scale leap' to twice the size of
today and therefore is planning three new districts and an upgrade of the inner-city. One of the new districts will be Almere East, to be realised in a predominantly agricultural environment.

Almere has expressed and put into their general policy that all new developments be done in a sustainable way. On April 9th of 2008 they even presented their 'Almere Principles', seven guidelines based on the philosophy of Cradle to Cradle (McDonough & Braungart 2002). Fitting into this town-wide supported ideal was amongst others the study of energy potentials for the new area of Almere East.

The methodology applied to this energy potential study (Dobbelsteen et al. 2008) follows the generic approach presented in this paper. On the basis of fundamental information energy potential maps were drawn, of which figure 5 gives two examples.

**Figure 5** Examples of the energy potential maps for the new district Almere East: potentials of the underground (left) and potentials of biomass (right) (Dobbelsteen et al. 2008).

Using the findings of the energy potentials, two maps with spatial interventions were drawn (figure 6).

The measures proposed for the north side of Almere East in the picture on the left encompass intensive developments alongside the A6 motorway with industry and housing (for the exchange of heat and cold), extension of the heat and cold network from Almere-City and the use of open heat and cold storage in aquifers. The approach for this dense area can be described as heteronomous (Timmeren 2006). For the open agricultural area of Almere East, autonomous clusters are proposed around farms: low-temperature heating dwellings with greenhouses, bio-fermentation with bio CHP, small wind turbines and PV. Alongside the A27 motorway, large windmills will provide additional sustainable power and reed fields will purify water of the area.

**Figure 6** Two possible plans for Almere East that optimally use the energy potentials (Dobbelsteen et al. 2008).

As another option (figure 56, right), only the part west of the A27 motorway is developed, with highly intensive housing against the A27 (noise wall) with a centralised energy infrastructure, and less dense housing towards the west.

These proposals are currently taken into account for the elaboration of Almere East. An energy potential study of the whole Almere region is ongoing, and new studies are expected for two additional new areas for development.
5. Conclusions and discussion

5.1 Conclusions
In this era of energy depletion and climate change, regions throughout the world have become interdependent on energy whilst losing the ingenuity to deploy regional and local features in energy-effective planning systems. Smart vernacular planning enables better use of local potentials of energy provision. Energy potential mapping, on the basis of a profound study of local characteristics and possibilities of reusing waste energy flows, will support this smart vernacular planning, as two case studies demonstrated. The methodology for this is generic yet applicable to different scales, from the region to the building scale. It may be combined with potential maps related to social and economical issues. Studies indicated that significant improvements to energy performance can be achieved where efficiency increases to our current system lead to marginal improvements.

5.2 Consideration
The approach presented in this paper implicitly presumes a direct relationship of spatial planning with meticulously located energy potentials. Submitting to this approach would therefore imply direct spatial consequences to found energy properties. A society based thereon could be considered site-bound. Although drastic in its impact to current plans, with the current developments in energy provision this vernacular planning seems an appropriate shift from the old paradigm of disconnecting functions and planning regardless of place and time, made possible through site-independent fossil fuels. In the near future however society may head in a different direction when a substitute is found for fossil fuels, e.g. sustainably produced hydrogen. In such a situation planning can again be 'footloose' and disconnected from its energetic underground.

These are two entirely different scenarios that lead to fundamentally different spatial planning needs. An intermediate scenario is most probable as the footloose society on e.g. hydrogen will at least partly be tied to the local generation of sustainable energy.

5.3 A message of urgency
The Stone Age did not stop because man ran out of stones; it stopped because man found better material for tools. Likewise, the Fossil Age will not stop because of the depletion of fossil fuels; it will find an ending through better solutions for energy. Our current generation has the great honour to make this transition. We hope the methodology presented in this paper can contribute to that.

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