Sun, Energy, Temperature, Water and Vegetation in Spatial Design

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Abstract[1]

The subjects in the title are studied in different disciplines such as thermodynamics, geophysics, physical geography, hydrology, ecology, medical science, building physics, archaeology and economy. This paper refers to these disciplines and their suppositions simulated in applications to test designs. In urban and landscape design they have to be combined and mutually balanced with many other local factors. How to make even a partial integration of only these subjects relevant for spatial design?

Key words: sun, energy, climate change, light, temperature, vegetation, design, the Netherlands.

Introduction

This chapter refers to many disciplines and their suppositions simulated in applications to test spatial designs. In urban and landscape design they have to be combined and mutually balanced with many other local factors. How to make even a partial integration of only these subjects relevant for spatial design?
This chapter cannot solve that question, it attempts to offer the ingredients for designers.

1 Energy

Comprehensible measures

In spatial design the use of energy often has to be averaged over a year, counting 8766 hours or $31.6{\cdot}10^6$sec. These figures offer opportunities to clarify calculations for more parties involved. A watt *during* a year equals 31.6MW·sec = 31.6MJ. We would like to abbreviate that figure as 1Wa. The 'a' ('annum', 'year') is added like 'h' in 'kWh'.
Occasionally the energy equivalent of $1m^3$ natural gas, 1 litre petrol or 1 kg coal also counts approximately 1Wa. So, that energy measure connects recognisable amounts of fuel to W, kWh and J, easily converted by remembering the two numbers mentioned: W = Wa/($31.6{\cdot}10^6$sec), kWh = 1000 Wa/8766 and J = Wa/($31.6{\cdot}10^6$).
Another happy coincidence is the reciproque value of $1/31.6{\cdot}10^6 \approx 31.6{\cdot}10^{-9}$. So, a GJ equals ample 31.6Wa and GW ≈ 31.6Wa/sec.

Dutch use

The human body uses aproximately 100W.
In the Netherlands the Sun also delivers approximately $100W/m^2$. However, the gross Dutch energy use approaches 100GW or approximately 6000W/inhabitant. So, a Dutch inhabitant has 60 'energy slaves', the equivalent of 6000 Wa or litre petrol per year.
In 2008 at a local petrol station that would cost approximately €10 000.

Footprint: 500% or 10%?

Vegetation converts approximately 1% of solar energy into useful biomass ($1W/m^2$ in the Netherlands). The whole country and its legally assigned part of the sea (100 000km^2) would be required for the current demand of energy produced by biomass; an ecological disaster. So, without further efficiency losses the Dutch ecological footprint would be 100%.

If the same area is filled up every 250m with half a million of wind turbines (100m altitude and width)^2, then the Netherlands could produce 1.5 times its demand, a footprint of 67%. However, the Netherlands receives relatively much wind power accumulated over the sea. The atmosphere converts approximately 2% of the solar constant ($1353MW/km^2$) into wind ($7MW/km^2$), of which 3% could be harvested ($0.2\ MW/km^2$). So, at average it would come down to 20GW for a surface such as the Netherlands, a footprint of 500%.[3]

From the solar constant reaching the Earth's profile from outside, 47% reaches the Earth's surface. The rest is reflected or lost as friction heat. If the world needs 16TW, the sun delivers 5000 times its demand, and solar cells could provide 500 times that demand.
However, that solar power is dispersed over its sperical surface according to the cosine of latitude ($100MW/km^2$ at 52^o in case of the Netherlands). If 10% or $10MW/km^2$ could be harvested, it is still 10 times the Dutch demand, a footprint of 10%.
So, solar power should be the final option.

Solar energy competing petrol

The costs of photovoltaic cells per Wa (the energy content of a litre of petrol) approaches the raising costs of petrol (see *Fig. 1*).
The silicon shortages forcing up the price of photovoltaic cells recently may be overcome coming years, possibly resulting in price drops until 50% in 2010.[4]

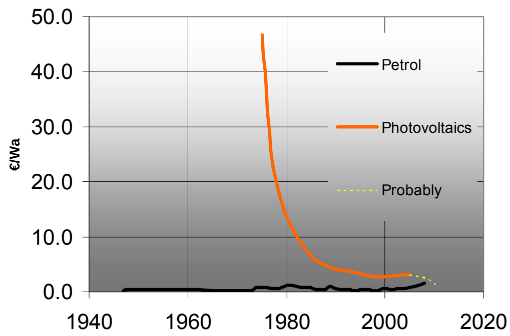

Fig. 1 Costs of photovoltaics approaching the costs of petrol per Wa[5]

The recently increased oil price may be the precursor of shortages[6]. IEA[7] predicted 5 years of extremely high prices. However, there is still much oil to gain in earth layers difficult to exploit such as oil sands (for example in Canada). In 5 years the technology may emerge to make them accessible (an ecological disaster), dropping the oil price after that period. Moreover, the North Pole with its gas reserves is becoming accessible by climate change. So, the competition between these two technologies may determine our future within a decade.

2 Climate change

Economic and political impact

This year (2008), few images impressed me more than *Fig. 2*.

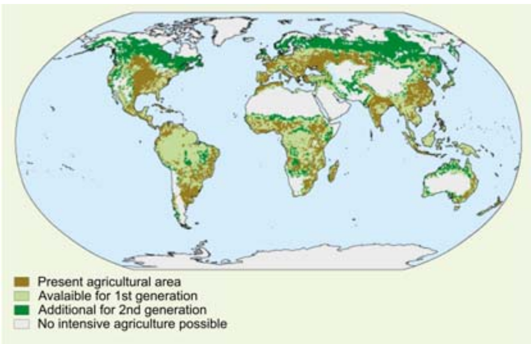

Fig. 2 Future balance of agricultural surface[8]

If these prospects of substantially increasing agricultural land in the Northern countries within half a decennium are true, Russia and Canada are the winners of climate change. Moreover, their newly acquired accessibility form the Northern Ice Sea will cause new harbours for agricultural products (such as biomass for energy) and gas becoming accessible at the melting North Pole.
The economic and political effects may be substantial. In general, the economic centre of gravity will move Northwards. That will be of great importance for any country, in particular for the Netherlands. I will now focus on the ecological consequences.

Ecological impact

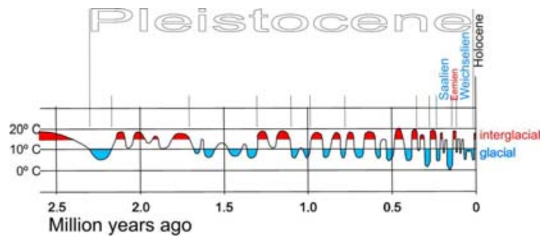

Fig. 3 Ice ages and temperature changes in the past millions of years in the Netherlans.

Raising temperatures occurred many times before (see *Fig. 3*), but never in the current pace since the past 200 000 years (see *Fig. 4* and *Fig. 5*). And, in that period the impact of slow temperature change on the topography of the Netherlands was substantial.

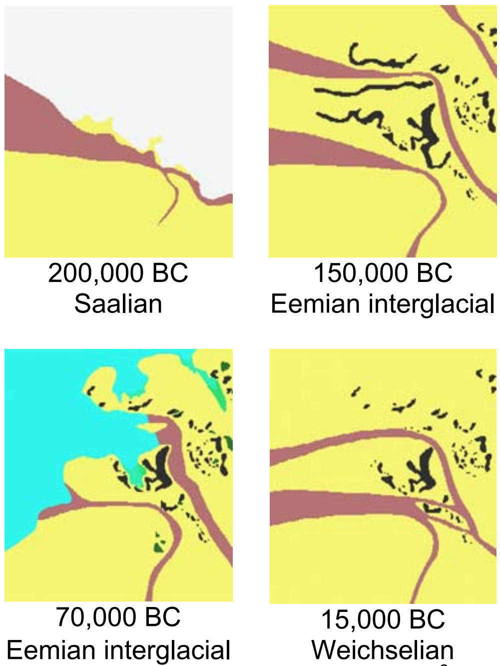

Fig. 4 Ice ages in the Netherlands[9]

Until 1000 AD natural forces determined the sandy soils at the higher parts and the clay, peat and water in the lower parts (see *Fig. 5*).

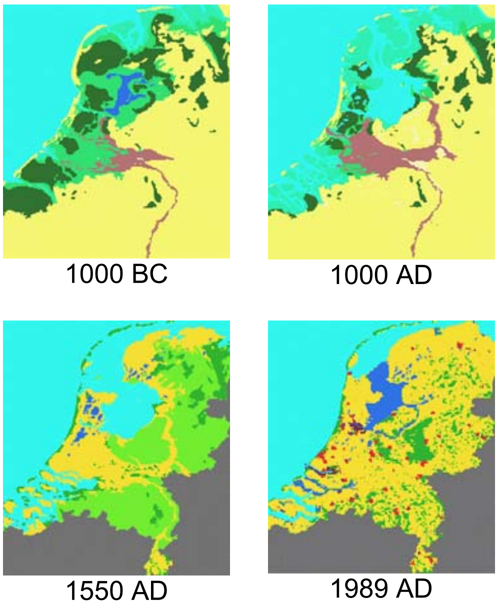

Fig. 5 Topographic history of the Netherlands after the ice ages[9]

In *Fig. 5* the legend changes after 1000 AD from kinds of soil (above) into density of occupation (below). Since then, the human impact prevails nature. Dikes started to protect the ever drying and dropping land against the slowly rising sea. The land was drained by wind mills and from 1850 by steam and electricity (see *Fig. 7*). So, its existence is dependent on a stable supply of energy.

Threads of flood

Threads of flood (see *Fig. 6*), aggravated by the greenhouse-effect, do not only stem from the sea. The Dutch feel safe about coast protection for the coming 100 years. Since the floods of 1953, caused by a rare combination of spring tide and North-Western winds driving North Sea water into the funnel of the Canal, new dikes are built and old dikes are levelled up to resist such incidental occasions.

River discharge now appears to be a greater problem than sea level rising. Since drainage in Switzerland, Germany, Belgium and France have been improved, rainfall (aggravated by the greenhouse-effect in winter) moving from Switzerland along the river Rhine in heavy showers could incidentally cause a wall of water entering the Netherlands. The Dutch Parliament accepted floods at determined periods of returning, for example once in 1250 year, if the river Rhine is expected to discharge 17 000m^3 per second according to the Gumble graph.[10] Such periods are the basis of calculating the required altitude of river dikes to resist such rare discharges.

Fig. 6 Potential threads of flooding[11]

Water management

However, the improvement of river dikes in the Eastern part replaces the problem into the Western part, where the deepest polders are 6m below sea level. Huge pumping stations along the coast competing with the run-off of the rivers have to discharge the water from lower levels than those of the sea in time.

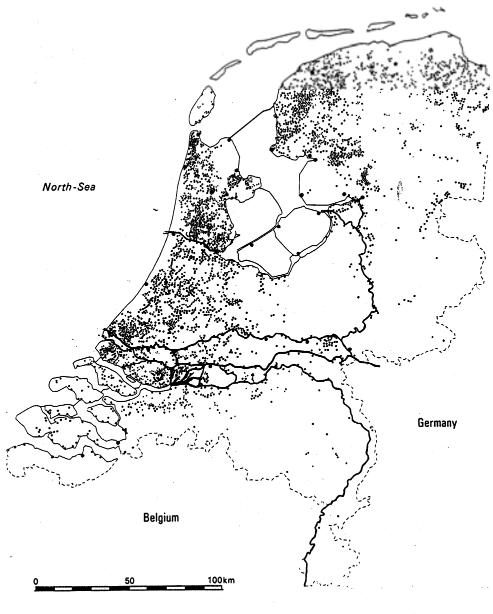

Fig. 7 Pumping stations in the Netherlands[12]

The costs of water management are small compared to the value of property accumulated in that area. However, the political struggle for funding sometimes needs (nearly) disasters. By high discharge of the river Rhine in 1995, 100 000 inland people had to be evacuated; an instructive experience.

Increase of surface water

To slow down the water flow in case the pumping capacity may be not in time, such incidental discharge may require 1km^2 of 1m deep reservoirs per minute.
So, the National Ministry of Water Management has ordered to build water reservoirs wherever possible. By doing so, the surface of water around and within the urban field of the emerging lowland metropolis (Randstad) will increase substantially. That produces challenges for design and nature. Urban designers do have visions a kind of Venice will emerge.

3 Vegetation

According to the primary criteria of rarity (to be expressed in kilometres) and replaceability (to be expressed in years) the artificial Dutch wetlands are unique and difficult to replace compared to the rest of Europe (see Fig. 8).

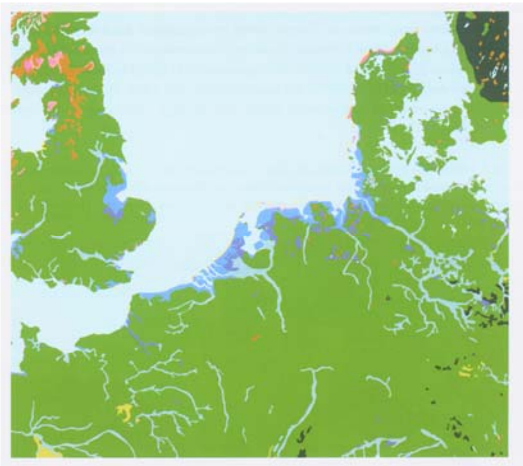

Fig. 8 *Continental ecological typology*[13]

The depicted potential vegetations of dunes, river-mouths, but in particular inland reed moor and moor forests are rare in a radius of 1000 km, mainly covered by oak-beech forests. That kind of nature, caused by human intervention, can only be replaced in 1000 years (see *Fig. 5*). However, its existence competes with the extending urban functions and an agriculture stimulated by rising food prices.

A diversity of small wet ecosystems have emerged through the centuries, not to be named in a closed scientific categorisation. These communities of plants and animals make use of the many water levels, depths, kinds of current, stagnant, salt or fresh water available (see *Fig. 9*).

	SURFACE WATER					
	SALT		BRACKISH		FRESH	
	cur.	stag.	cur.	stag.	cur.	stag.
deep	Oosterschelde, Waddenzee	Grevelingen, Veerse Meer	Haringvliet	Biesbosch	Uiterwaarden Maas Uiterwaarden Rijn	IJsselmeer, Oostvaard-ers plassen
shallow						
bank						
swamp						
bottom						
	GROUNDWATER					

Fig. 9 Kinds of water in the Netherlands[14]

However, that nature will change beyond human intentions as it did long before humans occupied the land (see Fig. 10).

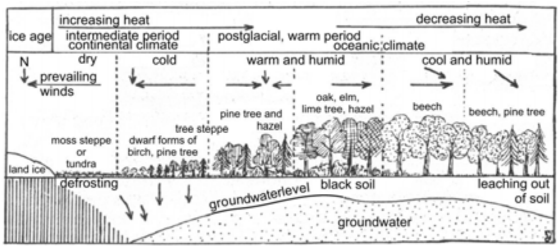

Fig. 10 *The influence of climatic changes on vegetation in the Netherlands*[15]

We may expect a new warm and humid period with a more exuberant vegetation to occur.

4 Light and shadow

Vegetation cools by transpiration and it provides shadow precisely in the seasons cooling is needed most by humans. Moreover, animals utilise a moderate heating system in cogeneration with work.

Fig. 11 The ceiling of the city

Instead of heating, energy demanding cooling may become a major problem in architecture. So, perhaps buildings and factories could use transpiration for cooling as well. However, as soon as buildings have been insulated properly, they need cooling by heat pumps, possibly driven by solar energy, precisely at the moment it is needed most. The superfluous heat could be stored in the ground for colder periods. The many current solutions for energy saving may gradually converge into that kind of system. The public space also needs attention for plantation and the use of water for cooling concerning the casualties occurring by heat waves, indicating serious health problems in populations not used to a warmer climate.

5 Integration in design

Writing this chapter I received a vision on a solar city in the African desert showing many possibilities for the future from my former colleague Dirk Smets asking for remarks.

Fig. 12 Smets' solar city

An abundance of ideas to be found in the legend could challenge specialists and designers:

1 sun tower; **2** trough mirrors; **3** fresnel mirrors with funds at the bottom; **4** desert road with water supply piping; **5** night flow power station and generators; **6** water desalinisation devices and water basin; **7** transformer station; **8** ultra high voltage direct current cable to Europe; **9** hydraulic pump station; **10** algae cultivation; **11** agriculture and horticulture; **12** sylviculture; **13** chemical industry: salt, chlorine, cement, glass.; **14** aluminium production (factory walls are rigid giant trough mirrors); **15** blotter fields with effluent recovery; **16** new founded band shaped city; on central ash keeps on driving electrische shuttle; **17** recreation and tourisme with resorts; **18** olivine-sand plains CO_2 – absorption; **19** supply of gas for nocturnal additional heating at pick charges; **20** zeppelin for transport mirrors and CO_2-arme trips; **21** yacht-basin; **22** connections with intercity road and intercity high tension lines; **23** control and maintenance of the mirrors farms; **24** mobile solar power units with dish mirrors; **25** solar chimney (one-off experimenting because of low output); **26** solar furnace for heat technology; **27** irrigation with desalinated marine water; **28** market in the city with locally extracted products; **29** fish cultuvation in salt and fresh water; **30** combination of tilapia-kalebas-en tomato cultivation under the fresnel mirrors; **31** upper town with traditional shady lanes; **32** upper town for pedestrians and downtown with electric movement; **33** electric supplies from the downtown; **34** nocturnal current downtown information centre; **35** warm marine water health sources; **36** fresh water reservoirs; **37** building blocks and panel bakery with solar heat technology; **38** arrival of goods from Europe; **39** low lake for nocturnal current generation; **40** water turbines in the low lake dam; **41** wind turbines to drain the low lake for nocturnal current generation; **42** CO_2-free cruises to solar city-resorts; **43** xerofites on aride soils for vegetable oil: yatrofa, ricinus etc.; **44** factory pressing feed cakes, oils, greases and biodiesel xerofites.

The solar revolution will probably give rise to such plans for solar plants in areas not utilised before. So, among many geopolitical changes one of them could be an increasing significance and development of Africa. In my view the gained electric energy should be converted into hydrogen locally, but that requires water. So, high voltage transport into the coast may be a good solution indeed. Perhaps producing hydrogen could there be combined with desalinisation. Most interesting is the application of olivine, an abundant mineral heavier than basalt and granite. So, it sunk into deeper layers of the Earth's crust, but it binds CO_2 if granulated into green sand at the surface.
However, if solar energy once will be so abundant as suggested in section 1 of this chapter, what is the assignment then of designers in a wet, increasingly warm country?

6 Conclusion

Still, the main assignment of architecture and urban design remains to provide a proper climate for humans and their artefacts, taking two factors into consideration: biodiversity and health. Health includes well being and prosperity not stealing it from elsewhere or from future generations.[16] Then, architecture and urban design can play with light, air, water and soil in a way people like to stay where they are.
Spatial design determines our environment for many years and many disciplines have to contribute to the result. However, specialists' solutions are often controversial and for the term a built environment will exist, their expectations are not always reliable. The safest strategy of design balancing and integrating so many insights is diversity: possibility of choice for future generations.
Specialists contributing to our environment should increase their sensibility for managerial, cultural, economic, technical, ecological and spatial context. They should look at longer periods and other levels of scale to get a proper awareness of the contributions of the other specialists and to regain a proper scientific modesty. But designers do have the duty to show possibilities of integration with a proper understanding of all specialists involved.

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