TOWARDS CO_2 NEUTRAL CITY PLANNING AND LOW-ENERGY REDEVELOPMENT – PRESENTING THE ROTTERDAM ENERGY APPROACH AND PLANNING (REAP)

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Summary:
By the year 2025 Rotterdam aims to have halved its CO_2 emissions; an ambitious plan that will require a revolutionary approach to urban areas. One proactive response to this challenge is an exploratory study of the Hart van Zuid area. An interdisciplinary team has investigated how to tackle CO_2-issues in a structured way. This has resulted in the Rotterdam Energy Approach and Planning (REAP) methodology. REAP supports initial demand for energy, propagates the use of waste streams and advocates use of renewable energy sources to satisfy the remaining demand. REAP can be applied at all levels: individual buildings, clusters of buildings and even whole neighbourhoods. Applying REAP to the Hart van Zuid has shown that this area can become CO_2 neutral. Best of all: REAP can be applied everywhere.

Key Words: REAP, Rotterdam Energy Approach and Panning, CO_2 neutral city planning, closed cycles, sustainability, sustainable urban planning, sustainable architecture, urban development.

I. INTRODUCTION

1.Prospects for the future

Ten years ago few people thought that the climate was changing and even fewer realised that mankind was influencing the change. Since then opinions have altered and now the world is generally convinced of the seriousness of the situation: the climate is changing at an unprecedented rate, mankind is one of the major causes and fossil fuels are rapidly running out. Because of this, attention is concentrated on energy consumption and the consequences of this. However there are other forms of damage to both the environment and public health that must not be ignored. It is possible to arm ourselves against, or if required to flee, the consequences of climate change. However the biggest social problem is not climate change but the depletion of our energy reserves; a social economic problem rather than a technical one. In September 2008 the so-called 'peak oil' was achieved, the point at which more oil is consumed than can be produced. From now on the situation can only get worse. This will have far reaching consequences for what can and cannot be achieved. We are so dependent on the easy supply of fossil energy that we have imperceptibly become addicted. Just before the start of the current world-wide economic crisis the price of oil reached a previously inconceivably high level (nearly 140 dollars a barrel) and at the time experts expected the price to double. That a price of more than 100 dollars a barrel has serious consequences could be seen in the reduction in sales of petrol guzzling SUVs in America. Energy affects everyone, but especially the poor and the people living the furthest away from amenities. The current economic crisis will come to an end and the price of oil will once again rise to a realistic level. It would be wise to use our time now in develop a different energy system.

2.Energy

The energy crisis does not mean that we have to cut ourselves off from the outside world and only use energy that we can generate ourselves – even if that were possible – but it is wise to make better use of our own energy potential. The surface area of the Netherlands is sufficient to generate enough solar energy to supply the economy of the whole world. Technically it is possible to realise a completely sustainable energy system but for the time being costs are prohibitive. We require a smart way of dealing with what we have and intelligent methods of making use of our resources. In built up areas it is important to target the following measures:

01 Applying renewable energy sources. Within the foreseeable future there will simply be no other sources.
02 Make use of the available energy potential. This is an interpretation of the first measure at local level: renewable energy could be imported but it is far better to make use of local opportunities.
03 Make better use of waste streams. All buildings and urban areas generate waste streams that could be harnessed but rarely are. Making use of these waste streams would reduce the primary demand and so aid the introduction of sustainable energy sources.
04 Intelligent and bioclimatic design of buildings. This refers to making intelligent use of local conditions – climate, land and environment – in the design of buildings and districts. Buildings and neighbourhoods are no longer seen as objects out of context.
05 Energy savings in existing buildings: this will continue to be necessary as in 2025 (the period by which Rotterdam must halve its CO_2 emissions) 80 – 90% of the built-up region will be made up of the buildings that are here today and which are frequently far from energy efficient.

3.The three step strategy

Since the end of the 1980's sustainable approaches to urban areas have followed the three step strategy:

01 Reduce consumption
02 Use renewable energy
03 Supply the remaining demand cleanly and efficiently

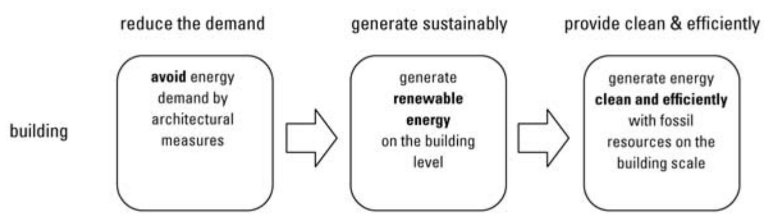

Figure 1: the three step strategy

This strategy towards energy use is known as the Trias Energetica. It forms the guideline for a logical, environmentally conscious approach but in the twenty years that it has been in use it has not led to the required sustainability. In particular, the degree of penetration of renewable energy sources, step two, is minimal. Sustainable building in the Netherlands mainly concentrates on step 3, which in practice is often considered to be step 1. That so little use is made of sun, wind and other renewable energy sources has a lot to do with the step abruptly following a sub-optimal reduction in energy consumption and with the fact that an important intermediate step has not been explicitly mentioned. Time for reformulation.

4.New stepped strategy

The New Stepped Strategy adds an important intermediate step in between the reduction in consumption and the development of sustainable sources, and incorporates a waste products strategy (partially inspired by the Cradle-to-Cradle philosophy):

01 Reduce consumption (using intelligent and bioclimate design)
02 **Reuse waste energy streams**
03 Use renewable energy sources **and ensure that waste is reused as food**
~~***04*** Supply the remaining demand cleanly and efficiently~~

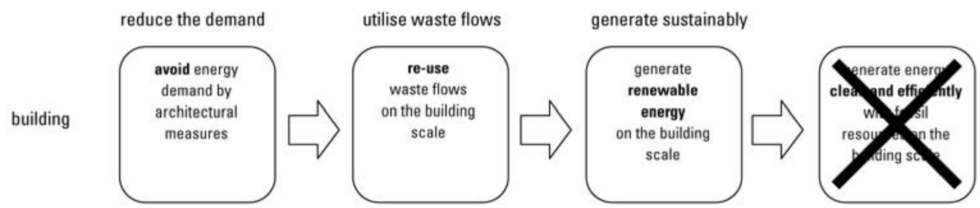

Figure 2: the new stepped strategy

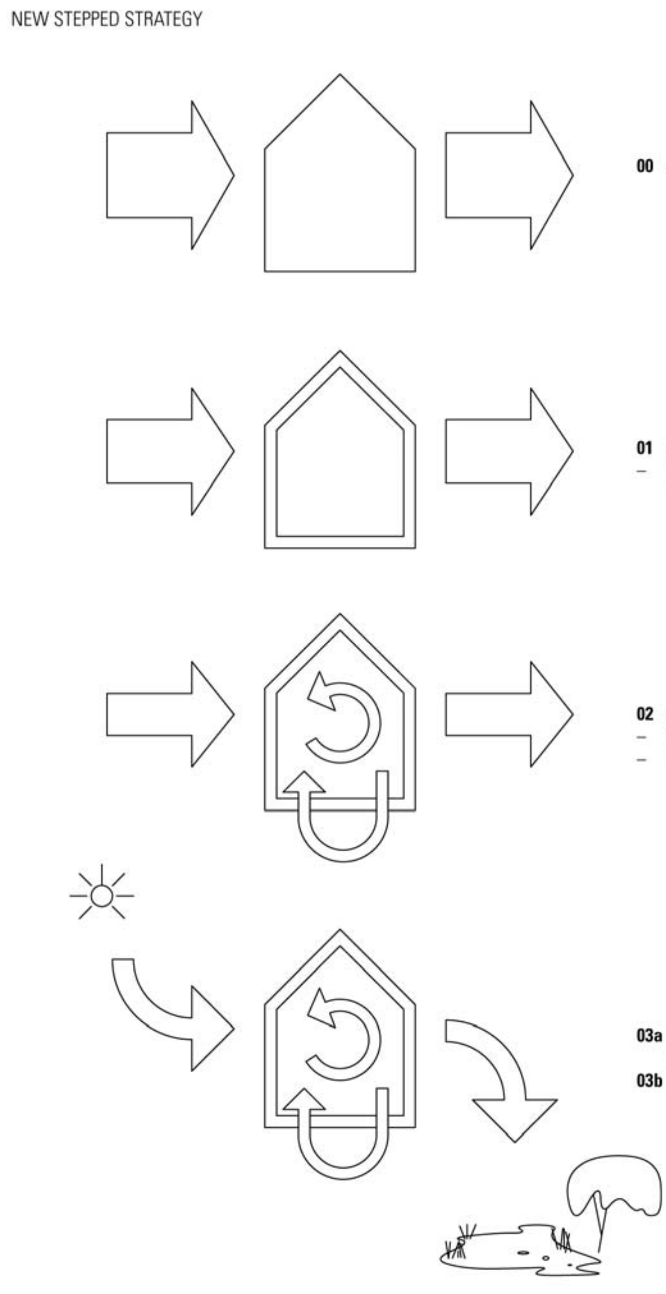

Figure 3: the new stepped strategy at the buildinglevel

As can be seen, the New Stepped Strategy has a new second step that makes optimal use of waste streams – waste heat, waste water and waste material – not only for each individual building but also on a city wide scale. Waste streams from one chain may be used in a different chain. For example, waste water can be purified and the silt fermented to form bio-gas which can be reused in the energy chain. The addition in step 3 (really 3b) concerns waste that can not be processed in our technical waste processing cycle and so must be returned to nature. This can only be done if the waste is safe (non-toxic) and if it can form nutrients for micro-organisms.
Step 4 will continue to be necessary for the coming years, but eventually this will no longer be possible or desired. The development of new areas or the re-development of existing areas should already take this into account because the fourth step will remain a painful necessity in many other regions.

5.Old energy system versus sustainable energy system

If we consider the organisation of our energy system it is clear that a lot of primary energy (98% from fossil or nuclear sources) enters our society but at the same time a lot of heat is lost (in the air, water or ground) and nothing useful is done with many waste products. A source such as natural gas is delivered to all public and private amenities. Taking the quality of energy into account (exergy) this is a significant potential loss of energy. A gas flame of 1.200 – 1.500 ºC is much more appropriate for high-grade industrial processes (that actually require such high temperatures) than for heating a home to 20ºC. If homes are intelligently designed then a temperature of 25 to 40 degrees Celsius is more than sufficient for the heating; this temperature is released as waste heat by many kinds of processes (e.g. greenhouses or cooling systems in offices). Other amenities require higher temperatures, but these could be achieved using waste heat from other even higher-grade processes. A more sustainable system based on the usage of this waste heat (a so-called low-exergetic system) would require significantly less primary energy and this primary energy would only be used by the most high-grade functions. This is not an efficient system but it is very effective: we could become 6 times more sustainable (600% better), while we are currently plodding away at methods to achieve an improvement in efficiency of as little as 10%.

II. THE REAP METHODOLOGY

1.From building to neighbourhood

If the New Stepped Strategy is applied to an individual building it will undoubtedly generate a more sustainable building, but within the whole urban context this would be a waste – or a missed opportunity. No use is made of the direct surroundings. The energy consumption per building can, and must, be reduced. After this it is useful to determine whether waste streams from the building can be usefully employed. This is already being done for example by recycling heat from ventilated air and waste shower water. However, it is much more difficult to purify waste water from each building to reclaim bio-gas. In short: after step 2 there is still a significant demand for energy that according to step 3 must be solved using renewable energy sources. As has already been mentioned, this is technically possible but requires huge investment. A better idea is to consider a cluster of buildings and to determine whether energy can be exchanged, stored or cascaded (see schematic diagram). In other words, if at individual building level all the waste heat has been recycled, the remaining demand for heat or cooling can probably be solved by buildings with a different pattern of energy requirements, buildings with an excess of the required energy or which produce waste heat (or cold).

01 An example of exchange: due to internal heat production, modern offices start cooling as soon as outdoor temperatures exceed 12º C. At these temperatures homes still require to be heated. This provides opportunities for heat exchange during spring and autumn. Another example is the combination of supermarkets (always cooling) with homes (frequent heating).
02 An example of energy storage at cluster level: heat and cold are only available in excess when there is little demand for them. For an optimal energy balance energy should be stored during seasons when the exchange as mentioned in example 1 is not required.
03 An example of cascading: a greenhouse captures much passive solar energy which usually disappears as waste heat into the air. A heat exchanger could enable this waste stream (usually about 30º C) to be used to heat homes, provided these homes are well insulated and make use of a low temperature heating system. If all waste streams at cluster level are being used optimally it then becomes possible to see if primary energy can be generated sustainably. Although solar panels and solar collectors or a heat pump with ground collectorsystems can be installed in each individual building, it is much more economical to set these up at cluster level.

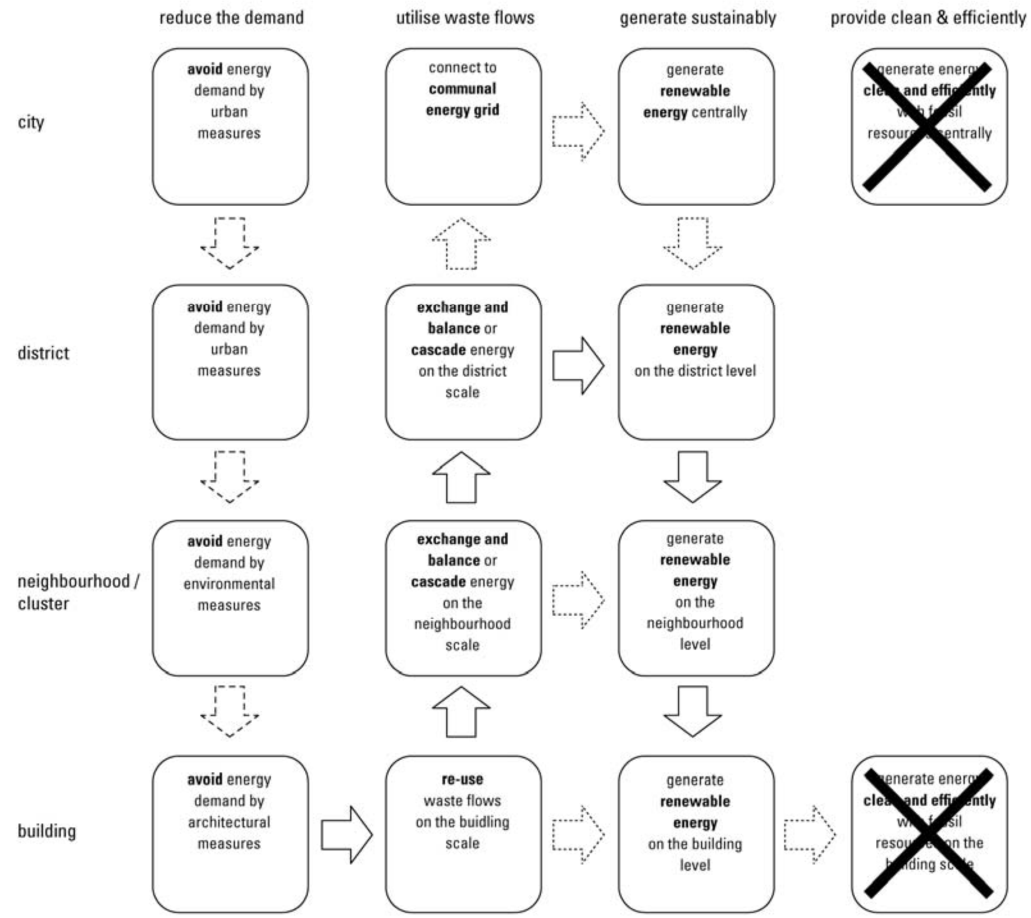

Figure 4: The REAP-methodology

2.From neighbourhood to district

If a project can be tackled at an even higher level, district level, potential discrepancies in the energy balance at neighbourhood level (for example excess demand for waste heat or cold) may be solved. At district level it is reasonable to assume that other functions are available with a totally different demand, and therefore supply pattern. And just as at cluster level, it is also possible to exchange, to store and to cascade energy (see schematic diagram). Certainly at the larger amenities such as shopping centres, swimming pools and concert halls the energy pattern is so specific that by combining a number of these different amenities it is likely that an energy balance can be achieved. Hart van Zuid provides good opportunities for this. In addition to exchange, storage and cascading, another option is possible at neighbourhood level: energetic implants. This is an intriguing term for adding a function to complete missing links in the energy supply chain. Once the existing amenities in the area have been optimally tuned to each other – here as an example we consider only the heat balance - there will be a residual demand for heat or cold (but not both). In this case it is only necessary to look for an amenity that requires extra heat on a yearly basis (for example a swimming pool) or that requires cold (for example an ice rink). The provision of renewable energy can then be tackled at district level. As has already been said, some sustainable measures can be implemented at building or neigbourhood level, but other more capital intensive projects are more appropriate at district level. Examples of this are the bio-gas fermentation installations that recycle bio-gas from waste water and use power-heat coupling (KWK) to generate heat and electricity. Geothermic energy is also only feasible on a grand-scale.

3.From district to entire city and beyond

The next step to a higher level would be the city or region, the scale in which our current amenities are generally centrally regulated. In the city of Rotterdam there is of course the city heating network (fed with waste heat from the electricity generators). City heating provides heat at temperatures between 70 and 90º C. This is perfect for old buildings which are poorly insulated and with central heating systems based on such temperatures. However, in new housing projects the

buildings are much better insulated and they would be better served with a heating system based on lower temperatures, such as floor and wall heating using temperatures lower than 50º C. The most modern homes would even be fine with temperatures lower than 30º C. What a waste to use city heating for these buildings. Once connection to the city heating is necessary or desired, the whole exercise of exchange, storage and cascading at neighbourhood and district level is no longer necessary (see schematic diagram). In that case the city heating takes care of the heating and potentially also the cooling (via absorption cooling).
The problem with this is that the local waste heat can no longer be usefully used and disappears into the environment – the urban surroundings. Given the expected climate change – in which cities will become both directly and indirectly warmer – this situation is not desirable. For this reason the REAP concept aims first at solving the problems of energy demand and supply on a small scale, after which 'help' can be called in from higher levels. In addition the city heating can fulfil a useful role as backup system, or as a loading and unloading system for too much or too little heat in a district or neighbourhood. REAP can help make an existing neighbourhood sustainable, without requiring drastic urban planning measures. The following chapters will not only show that this can lead to CO_2 neutral neighbourhoods but also how this can be done.

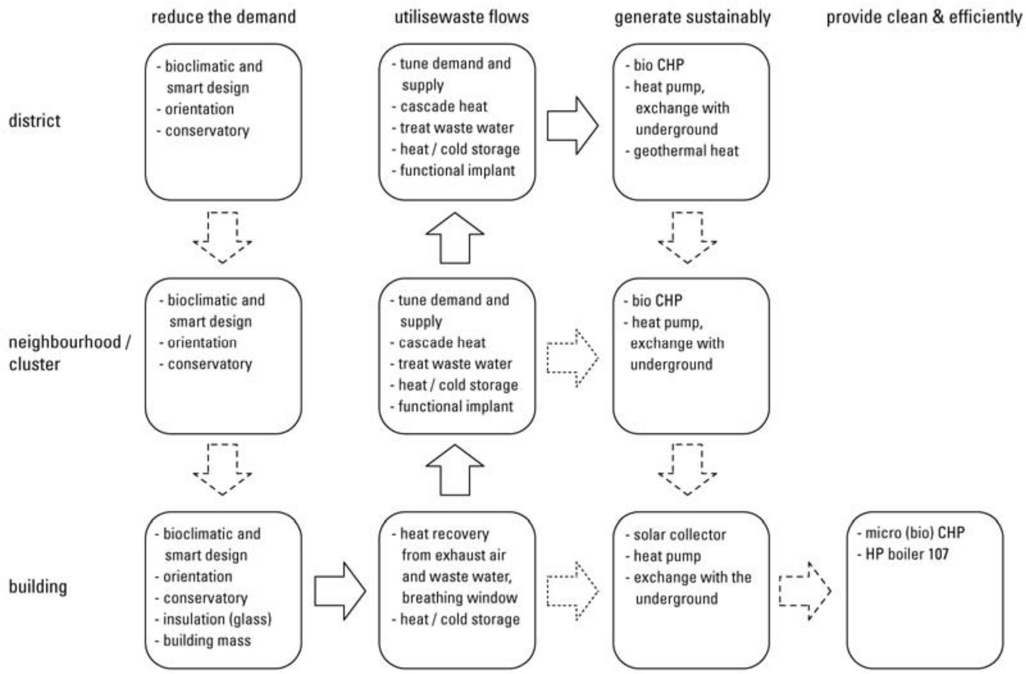

Figure 5: The REAP-methodology applied for heat and cold examples

III. CASE HART VAN ZUID

How can REAP be applied to an existing, complex urban area, in this case the Hart van Zuid? Which decisions within the methodology must be made if the desired reductions in CO_2 emissions are to be achieved, decisions at economic, political, public, urban development and architectural level? And what are the
consequences for the buildings in a city and the open spaces in between? In addition the examples explicitly look for combinations of measures for CO_2 reduction together with sustainable development by means of a combination of functions, social integration and integration of food production in the urban
landscape (urban agriculture). CO_2 reduction as spatial design.
How can this cluster, with its mix of '60s urban development and '80sarchitecture, once again become attractive in and for the city? It is currently mainly a shopping centre, attracting people from the south of the city, with an unusual mix of infrastructure (the second busiest bus station in the Netherlands!) and a theatre but with no activities after opening times and with no links to the surrounding areas. At the same time, the building devours energy; heating in the winter and cooling in the summer. How can this urban development problem, coupled with Rotterdam's CO_2 targets, be transformed into a future oriented, attractive development?

Step 00 Make an inventory of the current energy consumption.
Step 01 Reduce consumption > New functions will be added: 20.000m2 shops, 6.000m2 supermarket. Theatre Zuidplein and the infrastructure intersection will be renewed. Better insulation of the existing shopping centre will in itself already significantly improve the situation.
Step 02 Reuse of waste streams > The addition of housing will create a better heat-cold balance. The use of the waste heat generated by the supermarket and the typical morning and evening energy consumption in homes means that the match is perfect: 1m2 supermarket can heat 7m2 of housing! If 665 apartments are added, the heat-cold ratio becomes 1:1,08 assuming that use is made of heat and cold storage.
Step 03 Renewable energy generation > The remaining demand for heat can be solved by the addition of greenhouses on the first floor, these could be public areas (or greenhouses for growing tomatoes) or by the addition of PVT-panels. PV panels could also be installed on the roof to supply electricity for the whole shopping centre. The remaining energy required could be sustainably generated at a higher scale level.

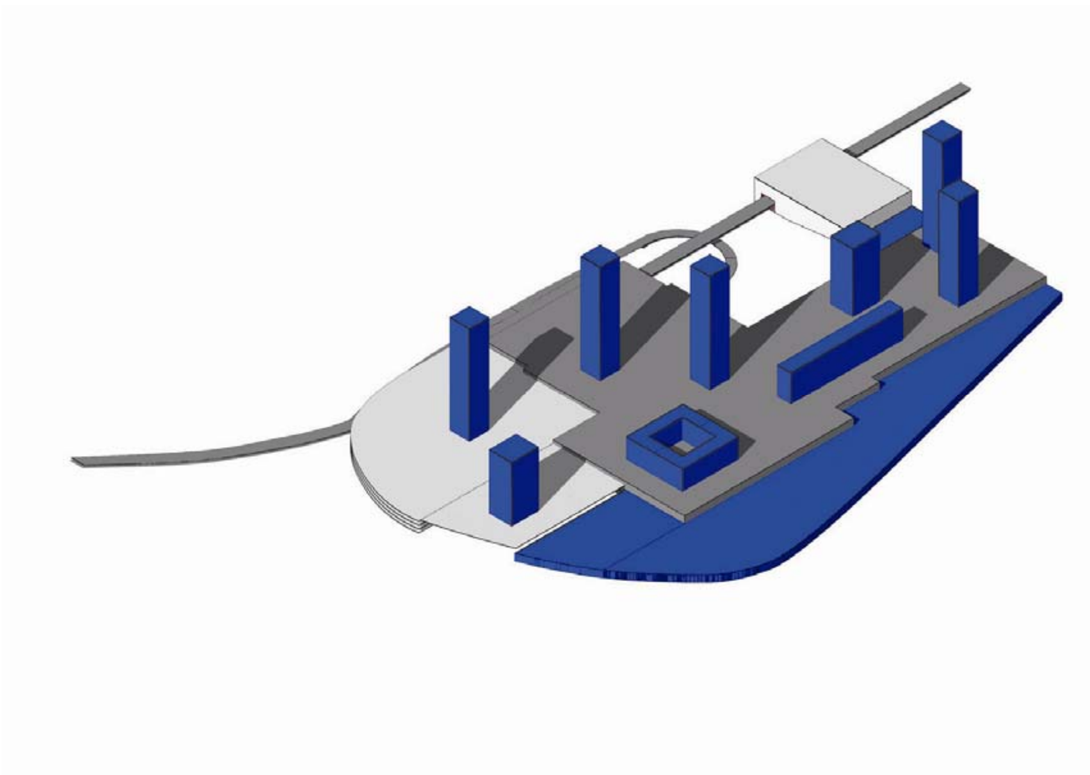

Figure 6: Summer situation energy demand total program, Heat (H), -865 GJ, Cold (C) -5475 GJ, Electricity -7034 GJ

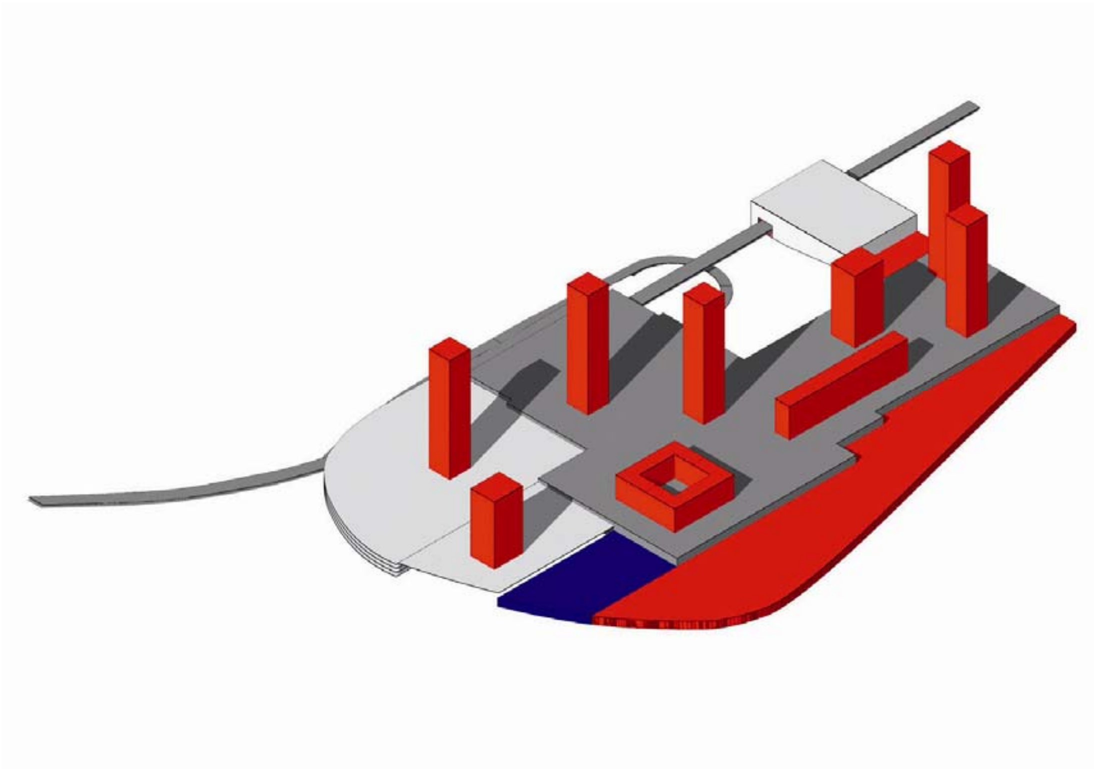

Figure 7: Winter situation energy demand total program, Heat (H), -7788 GJ, Cold (C) -1755 GJ, Electricity -7595 GJ

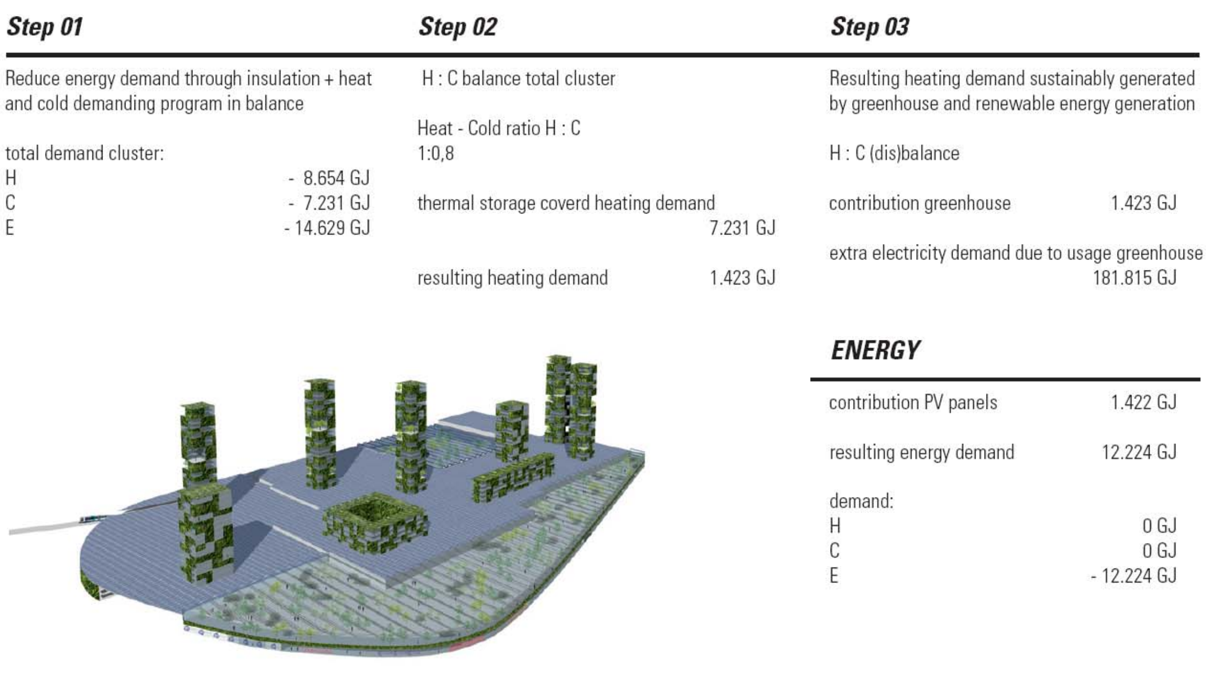

Figure 8:Energy balance and remaining energy demand to be solved at a higher scale

2. Motorstraat Area

The aim is to build two new colleges on the re-developed Motor Street.
This provides an opportunity for developing a balanced, multi-functional cluster. But which functions can be sustainably combined, taking energy, social and economic issues into account? A combination with housing improves social integration in the area by ensuring that the area is used throughout the day. Adding offices strengthens this mix. To achieve an energy balance in this cluster the intended 50m Hart van Zuid swimming pool can be combined with a new ice rink. The waste heat from the ice rink in combination with the swimming pool's permanent demand for heat provide an opportunity for using thermal storage to create energy balance. The remaining demand for heat can be satisfied using a combination of solar collectors and greenhouses.
Step 00 Make an inventory of the current energy consumption> This is to be a newly-built area so right from the start the perfect function mix can be set up. New functions are added to the cluster based around two new intermediate vocational colleges.
Step 01 Reduce energy consumption > The most up-to-date techniques in energy saving will be used.
Step 02 Reuse waste streams > Balancing the heat-cold relationship by the addition of functions: 50 m swimming pool (permanent need for heat), ice rink (permanent need for cooling) as well as homes and offices.
Step 03 Renewable energy generation > The resulting demand for heat can be completely satisfied by the addition of solar collectors on the roofs and the incorporation of a greenhouse in between the various functions. This greenhouse will also provide an additional (productive) space. Any remaining energy requirements will be sustainably generated at a higher scale level.
The cluster as a whole will become a highly efficient complex with a constant daily use and bustling with life both on week days and in the weekend. It will radiate a positive charisma affecting the whole neighbourhood.

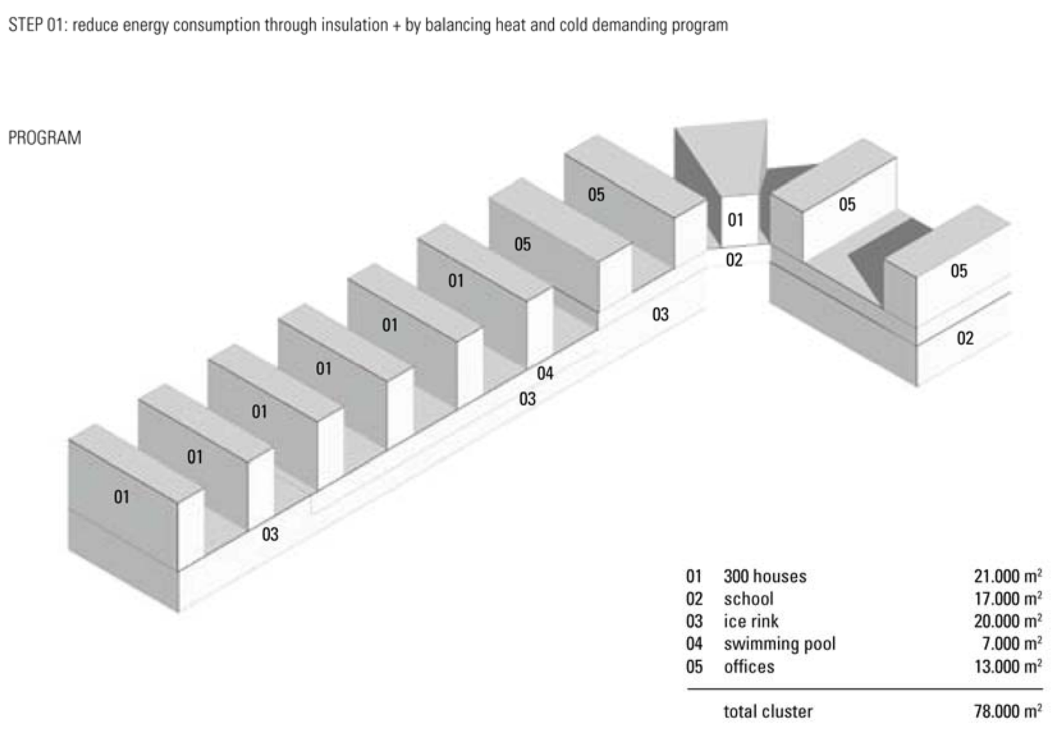

Figure 9: step 01

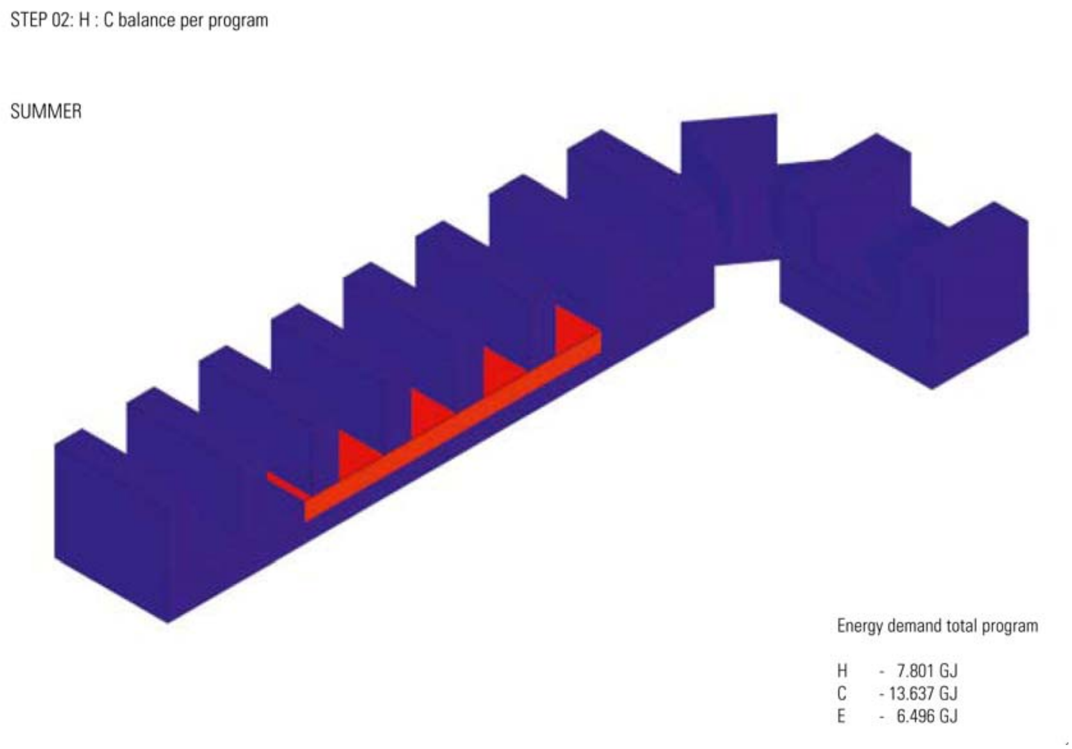

Figure 10: step 02 Summer

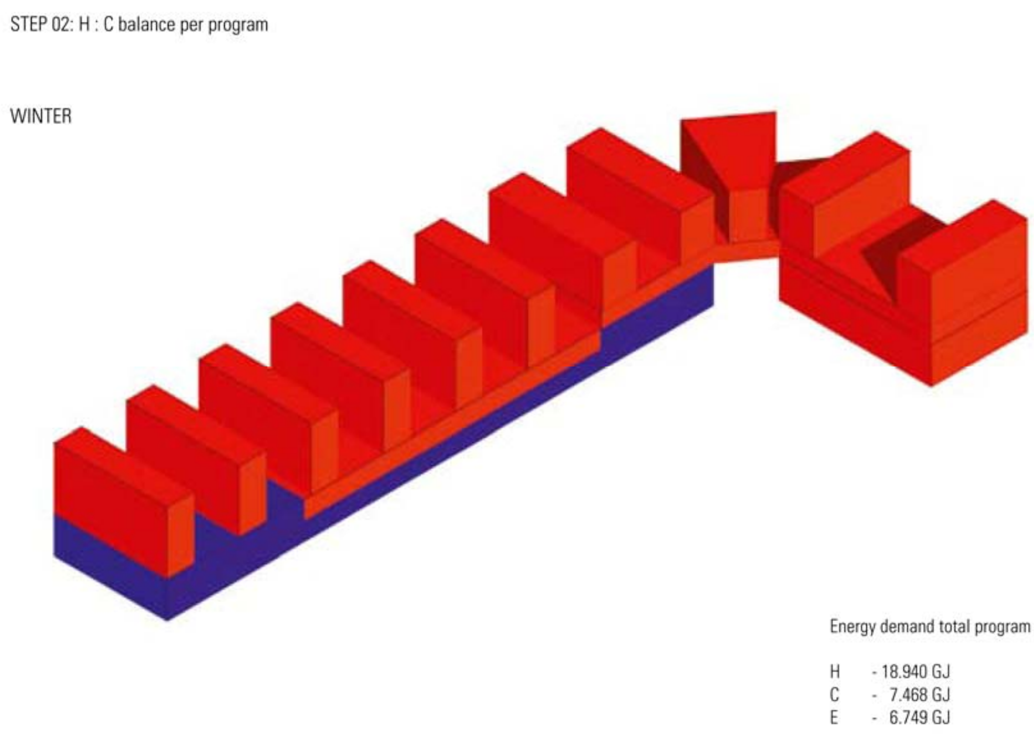

Figure 11: step 02 Winter

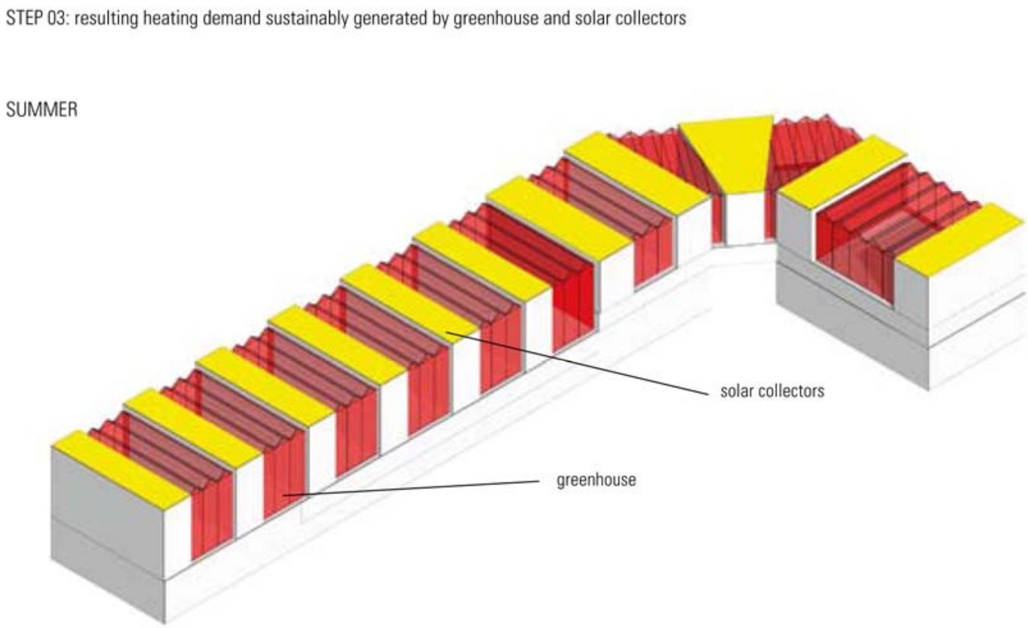

Figure 12: step 03

Step 01

Reduce energy demand through insulation + heat and cold demanding program in balance

total demand cluster:

H	- 26.741 GJ
C	- 21.106 GJ
E	- 13.245 GJ

Step 02

H : C balance total cluster

Heat - Cold ratio H : C
1:0,8

thermal storage coverd heating demand	21.106 GJ
resulting heating demand	5.635 GJ

Step 03

Resulting heating demand sustainably generated by greenhouse and solar collectors + renewable energy generation

H : C (dis)balance

contribution greenhouse	5.635 GJ
extra electricity demand due to usage greenhouse	563.409 GJ

ENERGY

contribution PV panels	1.761 GJ
resulting energy demand	12.047 GJ
demand:	
H	0 GJ
C	0 GJ
E	- 12.047 GJ

Figure 12: Energy balance and energy demand

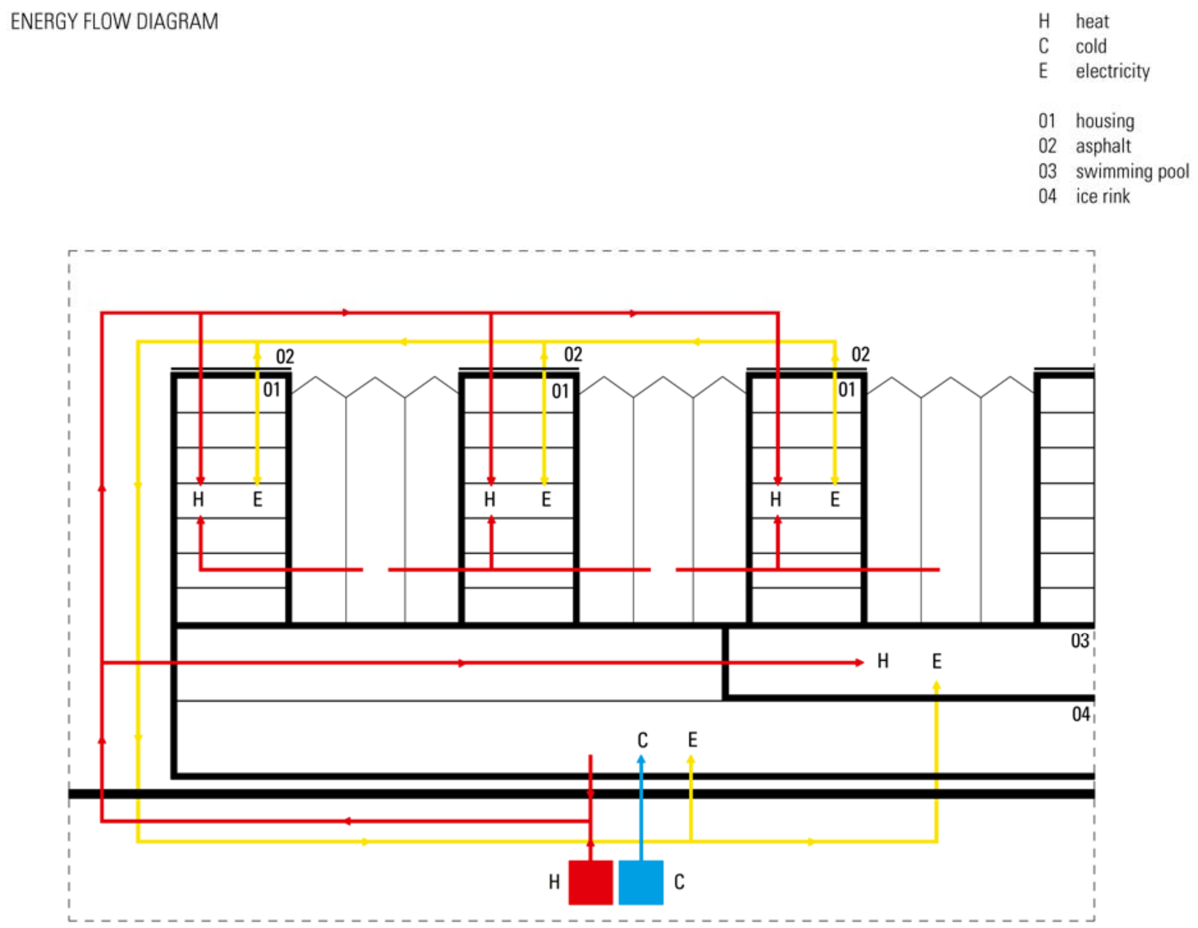

Figure 13: Energy flow diagram

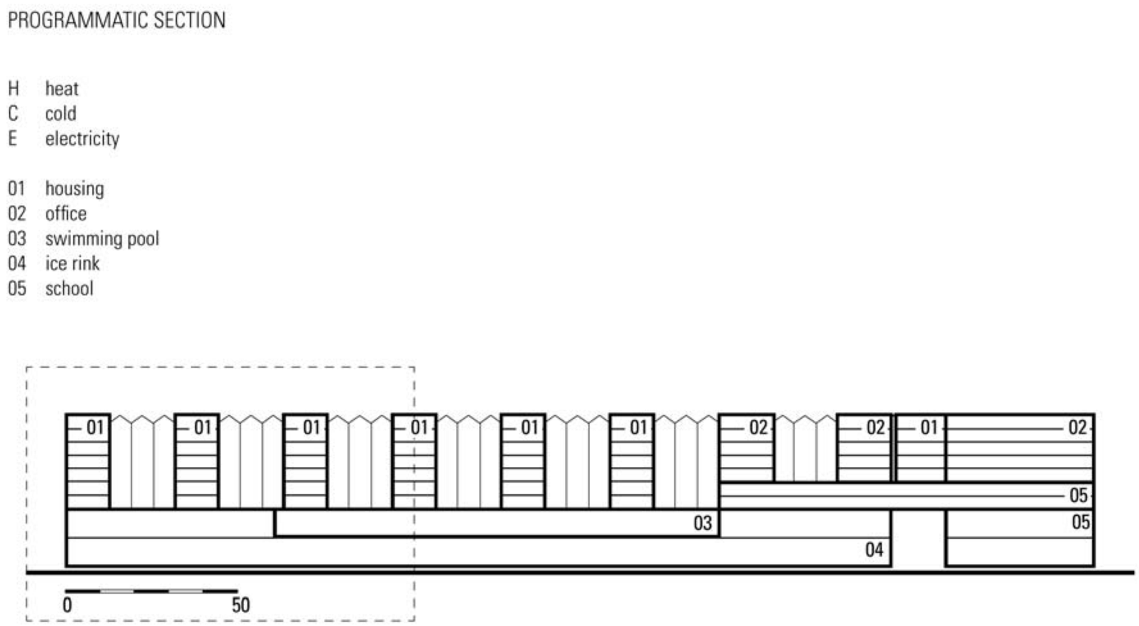

Figure 14: programmatic section

Figure 14: New overall plan with mixed program with optimal energy exchange

IV. CO_2 MAPPING

REAP provides a structure for CO_2 intelligent development of a particular area. If CO_2 issues are to play a role in spatial design and development then sufficient knowledge of the various possibilities must be available. At each step it must be clear what is actually feasible. The CO_2 map has been developed to provide such an insight. The CO_2 map gives a picture of the current situation and provides a toolbox for CO_2 intelligent developments for the area.

In reality the CO_2 map is much more than just a map. It is an instrument providing information for each aspect of REAP in the form of maps and background information. Aspects related to energy saving and renewable energy production are in the form of a geographical map coupled to a GIS-system. All aspects, in particular those related to energy exchange, are in the form of generic information concerning CO_2 intelligent opportunities.

The maps related to energy saving and renewable energy production show the current potential at cluster level. There is an overview of which functions are present at each cluster. In addition, for each separate cluster the map shows how much energy could be saved and the amount of renewable energy that could be produced – heat and cold storage, urban wind, solar electricity and solar heat collection. Whereas the maps visualise the CO_2 intelligent potential for the current situation, the toolbox gives guidelines for demolition, new building or additions to the programme. Such new developments benefit from the generic information in the toolbox. It is even possible to modify the building program based on REAP and in particular on the information in the toolbox. For the first step the toolbox indicates the potential minimum energy consumption per m_2 – and thus the potential energy savings compared to the current situation – that is feasible for the different amenities. The generic

information for the third step is an overview of the pre-conditions for the implementation of various forms of renewable energy production per building – heat and cold storage, urban wind, solar electricity and solar heat collection. The generic information in the toolbox for the second step is an overview of the consumption of electricity, heat and cold per m_2 for the different amenities.

This can be used to determine which functions can be combined energetically – demand and supply of heat and cold – for energy exchange within the program. It is also possible to determine whether it would be beneficial to incorporate an extra function in cases where the demand and supply do not match.

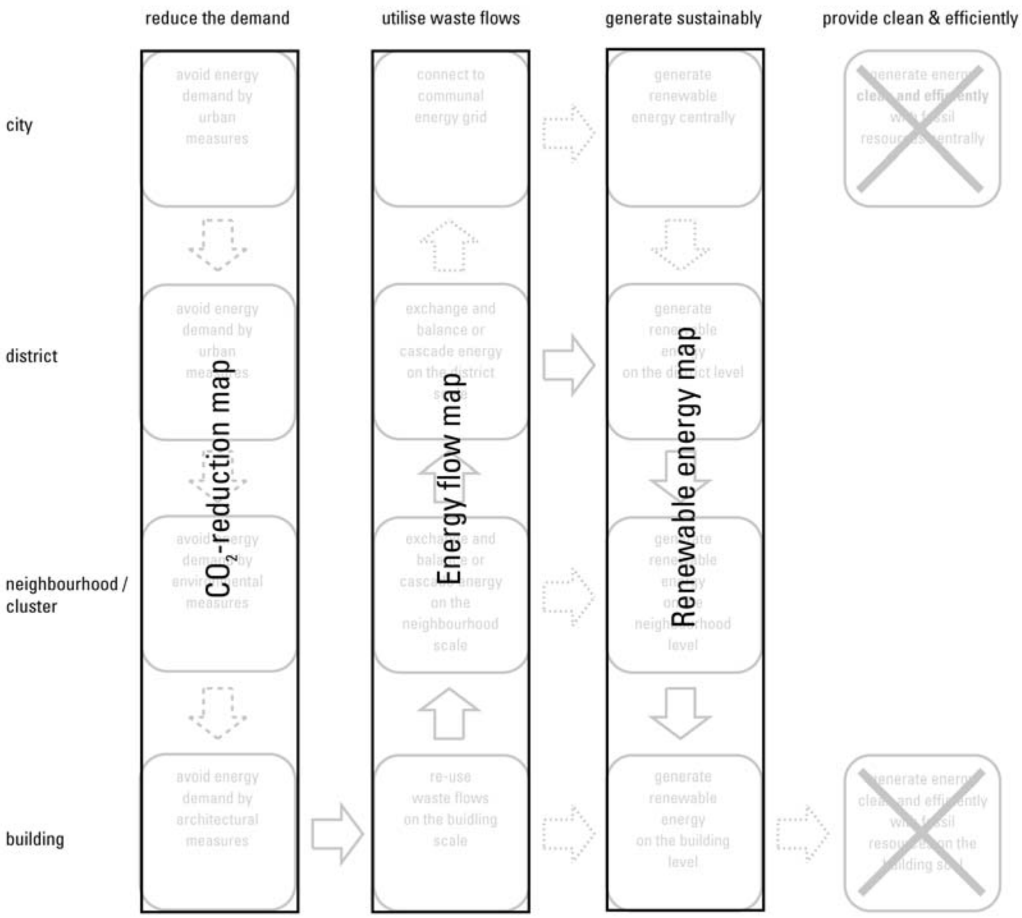

Figure 15: Reduction, Energy flows and renewable energy

Figure 16: CO2 map with reductionpotentials as a result of insulation and other existing solutions

V. CONCLUSIONS

The general aim of this study is to discover whether CO_2 neutrality can be achieved within an existing part of the city, working from the urban planning and spatial design processes. A manageable method is arrived at based on the guiding principle of reduction of both energy consumption and CO_2 emissions. Further, REAP is based on a realistic approach to economic, social, political and organisational structures. As usual a few comments need to be made.

1.Other architectonic styles

The use of REAP has been worked out and depicted in areas and (existing, remodelled and new) buildings with a particular style. The REAP-methodology is however architecturally independent and allows for different solutions – and the associated different architectural expressions.

2.Energy techniques

An inventory of energy production on a city wide scale shows that some techniques are potentially much more profitable than others. This however does not mean that the less profitable techniques are not useful in the development of individual buildings. Although it would appear that wind induced energy in an urban area is of little significance, an effective combination of high rise building and wind turbines is still possible. This goes beyond the scope of this study.

3.Financial, economic and organisational aspects

Designs for the 2020s are based on the current (affordable) technologies. An in-depth study of financial-economic and organisational aspects goes beyond the scope of this report but a few recommendations can be made:

- Develop a joint sustainability target for a particular area together with instruments such as a sustainability index.
- Stimulate the different parties with benefits such as tax rebates to
guarantee that targets are met.
- Ensure that the factor time is taken into account. The best (financial) solution for a particular situation changes with time.
- Develop new structures so that parties can attune energy supply.
- Develop new instruments to guarantee the delivery of energy.

4.Ideal solutions versus time

The search for the perfect solution at the right place depends on different guiding factors – money, technology, organisation, information – which all change with time. In the near future this can lead to a completely different solution to the one suggested in this study. Recently it has become increasingly clear that the choice of projects is mainly determined by economical considerations, together with the available energy techniques. Financially this depends on energy prices, availability of money and potential subsidies. This serves to underline the fact that there are no ideal solutions, at most they are only temporary; the best combination of measures is continually changing. Never the less it is essential to gather more information and gain an insight into the principles involved. When solving issues of renewable energy production, and in particular up-scaling production, it is essential to relate to each individual situation and the above mentioned aspects such as time and money. For each step in the REAP-methodology, it is useful to know which financial and organisational aspects are involved so that a well thought-out decision can be reached.

5.CO2- neutral urban development is possible!

After applying REAP to Hart van Zuid, calculations have shown that CO_2 neutral urban development within the built up area of an existing city region is possible. That is why we, the authors, would like to encourage the reader to always consider where possibilities for small-scale energy exchange lie so that a gigantic effect can be achieved on a much larger scale.