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SUMMARY OF CASE STUDIES

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1 Introduction

1.1 Background

The China National Engineering Research Center for Human Settlements (CNERCHS) is carrying out a REEEP project "Promoting low energy building program in China". This project supports the development of a strategy for the sustainable development of the energy consumption in the construction industry in China.

At present a lot of energy in the building sector is lost due to the application of outdated standards and design practices. In order to reduce energy consumption in buildings, the Chinese government will adopt new standards based on international best practices on energy efficiency technologies and renewable energy use. This should lead to an increased energy efficiency and reduction of GHG emissions in the building sector of China.

As part of the REEEP project, CNERCHS should describe promotion activities in Europe in the field of low energy building. This report provides information on European projects in regard to this topic.

1.2 The built environment

There is little need to explain that there is a worldwide necessity for sustainable buildings. From a technological point of view we are already capable of building houses and offices with a very high-energy performance (in terms of energy efficiency, generation and usage of sustainable energy). However, current building practice shows that often we do not produce the quality we are capable of (and economical issues are not always to blame).

There are many relations between the building construction and its energy supply. An optimal building can hardly be realized when considering the building installations as 'add ons' instead of integral elements of the whole. To make the energy supply a holistic element of the building design requires a vision on various aspects.

The case studies presented here may contribute to the realization of high quality of low energy sustainable buildings in China.

1.3 Trias Energetica

As guiding principle in realising low energy buildings there is the Trias Energetica[1] ('Energy Triangle'). Any amount of energy that can be reduced will not have to be produced.

[1] The term Trias Energetica is commonly used in the Netherlands

So, the first priority should be to avoid waste of energy. Orientation of the building, positioning of the rooms with specific functions, insulation, etc. are good examples of measures that are very economical and can save a great deal of energy. The remaining energy demand should be met by renewable energy as much as possible. Only if necessary the remainder of the energy demand should be supplied by efficient use of fossil fuels.

1. Reduce the energy demand by rational use of energy
2. Use renewable energy
3. Utilize fossil fuels with maximum efficiency

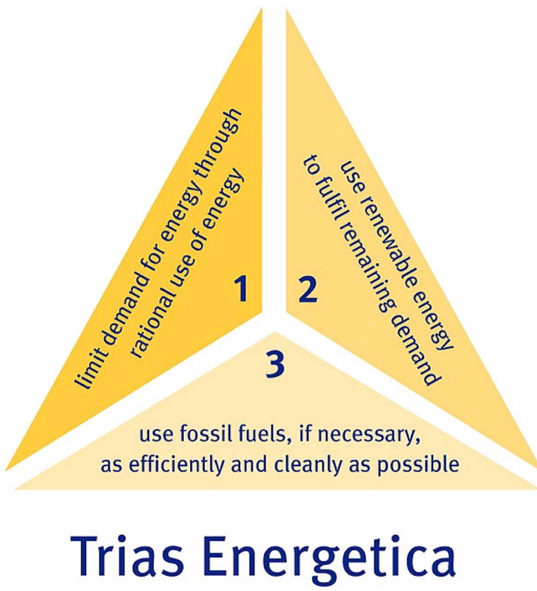

Figure 1 The Trias Energetica

This principle is followed in all of the projects of this case study, and the variety of solutions illustrates the flexibility of the concept.

1.4 Structure and approach

The approach chosen in this report is to summarize the important characteristics of each case study followed by an analysis giving a short conclusion based on those projects. The recurring themes are discussed separately. Some attention is paid to the consequences of the different climate zones.

We discuss the following:

- Chapter 2 – Short description of the principle of each case study and discussion of the different themes
- Chapter 3 - Conclusions

2 Description of the projects

2.1 Projects selected for the case study

For the case study of low energy buildings a selection was made of 10 European projects. Projects in 8 European countries were selected. The locations of the projects all have slightly different climates giving a European range. As well as existing projects or projects in design have been selected and housing projects as well as offices or public buildings. In Table 1 an overview of the projects is given. The basic information of the projects is included in the separate 10 case study reports.

Table 1 Overview of 10 case studies

Nr.	Name	Country	City	Climate	Height of building	Use	Energy Consumption [kWh/m2.yr]
1	Helianthus	The Netherlands	Zwaagwesteinde	Temperate / sea	Low-rise	Houses	29.7
2	Palm Towers	The Netherlands	Nieuwegein	Temperate / sea	90 meter	Offices	0
3	Primary Health Care Centre	Spain	Barcelona	Mediterranean	6 floors	Health care	-
4	Passive houses Lummerlund	Germany	Hannover-Kronsberg	Middle European	Low-rise	Houses	82.4
5	Sustainable Community: Viladecans	Spain	Viladecans	Mediterranean	Low-medium rise	Houses	63.9
6	Solar XXI Building	Portugal	Lisbon	Mediterranean	3 floors	Offices	-
7	BETEK Training and R&D Center	Turkey	Gebze / Kocaeli	Mediterranean	3 floors	Training Centre	102.0
8	Sesac project, Grenoble	France	Grenoble	High mountain /Alpine	Medium rise	Houses	89.4
9	Gneis Moos housing estate	Austria	Salzburg	Middle European	Medium rise	Houses	-
10	Egnahemsbolaget project	Sweden	Göteborg	Northern Europe	Low-rise	Houses	76.9

2.2 Analysis of the individual cases

Each of the 10 cases is shortly described and the main principles are given.

2.2.1 Helianthus, the Netherlands

Project: The project comprises 24 family houses with a reduced demand for energy.

Principle:

- A low energy demand for heating due to high insulation;
- Low temperature heating. Heat is produced via a heat pump, which uses the soil as heat source. No gas fired condensing boilers are used;
- The heat of the ventilation air is recovered (balanced ventilation). By recovering the heat from the ventilation air the energy use of the building is reduced;
- Hot water demand is supplied via the heat pump;
- A grid-connected 2.88 kWp photovoltaic system produces electricity.

2.2.2 Palm Tower, the Netherlands

Project: Zero-energy high-rise office building (22 storeys high).

Principle:

- Space heating and cooling are provided via ventilation air during daytime and thermal activated concrete during the night. .
- Heating is provided by a bio fuel CHP (Combined Heat & Power) and produced via a heat pump with storage in a aquifer;
- For cooling the cold stored in deep underground water layers (aquifers) will be used. A dry cooler is used to store the cold there.
- The ventilation system and the air treatment are also able to function as free-cooling during intermediate seasons.
- HF energy efficient lighting in combination with day-light sensors and presence detection
- A 1800 m^2 building integrated façade photovoltaic system;
- Small wind energy (urban) turbines will be placed on the roof.

2.2.3 Primary Health Care Centre, Spain

Project: Primary health care centre of the Catalan Health Service, with day lighting, innovative cooling, and advanced insulation combined with photovoltaics and solar thermal.

Principle:

- Advanced insulation;
- Low temperature heating through natural gas boiler (35º C instead of 45-70º C). Heat and cold distribution by low temperature radiant ceilings and walls; Cooling through chillers with a COP of 4, temperature range of 15-17º C instead of conventional 7º C;

- Energy efficient liquid desiccant dehumidifier;
- Centralised building energy management and monitoring system;
- Approx. 10 kWp grid-connected photovoltaic system;
- 12 solar thermal panels (24 m2) for heating and sanitary hot water (covers about 65% of hot water demand and contributes to the space heating demand);
- Heat recovery via heat exchangers from the ventilation air, using the energy to pre-heat or pre-cool the inflowing air. The ventilation system and the air treatment are also able to function as free-cooling during intermediate seasons.

2.2.4 Passive houses Lummerlund, Germany

Project: 32 non-basement terraced single family dwellings, with gabled roofs and external storage rooms, in 4 rows; for permanent living.

Principle:

- Very high insulation grade
- Local district heat system fed by combined heat and power (CHP) units
- Use of passive solar energy (even in deepest winter, more solar energy is provided passively than heat energy lost through the windows);
- No cooling system
- All mechanical balanced ventilation with heat recovery (80% efficient);
- 4 m^2 per house solar thermal system (128 m^2 total);
- 2.6 kW share in 1.5 MW wind power plant per house

2.2.5 Sustainable Community: Viladecans, Spain

Project: 2100 apartments of 100 m^2 per apartment in approximately 50 buildings newly built in the eco-district Llevant of Viladecans.
Energy saving measures will be taken at building level, applying renewable energy systems (solar water heaters and PV systems) on buildings and the application of a co-generation plant combined with district heating in which 25% of renewable energy will be used.

Principle:

- For the total area, including Llevant, a combined heat and power station is planned, using 25% renewable energy;
- Good insulation;
- Passive cooling (glass, shading);
- High efficiency heat pumps (COP>3);
- Use of high efficient refrigerators;
- A 2 m^2 solar water heater per dwelling;
- A 6 kWp photovoltaic systems per apartment building.

2.2.6 Solar XXI Building, Portugal

Project: A new office building with laboratories of the INETI organisation. It is a high energy efficiency building with "almost" zero energy consumption for comfort and day-lighting.

Principle:

- Highly insulated walls and windows;
- Building Design allows for optimal use of natural sources of energy: solar energy, cooling sinks, day-lighting and natural ventilation;
- Passive Heating and Cooling Systems, allows to reduce significantly space heating and cooling or self sufficient;
- Use of day-lighting and natural ventilation;
- Cooling of ventilation inlet air by guiding it through pipes buried in the ground. Natural ventilation through the PV panels integrated into the walls, and through the corridor, when necessary assisted by ventilators;
- A 96 m^2 of façade-integrated polycrystalline PV system. The PV is used for pre-heating ventilation air in the winter, by making use of natural convection;
- A solar thermal system for domestic hot water and space heating back-up;
- A 6 kWp PV system, composed of amorphous silicon modules, provides shading for the building's car parking lot.

2.2.7 BETEK Training and R&D Center, Turkey

Project: BETEK Training and R&D Center is a training centre. It consists of a seminar hall, office space and several laboratories. Renewable techniques are high thermal insulation, heat pumps, utilization of natural light and passive solar energy.

Principle:

- Reduction of necessary heating and cooling demand via improved insulation measures;
- Low temperature heating and cooling provided by ground to surface heat pumps (GSHPs);
- Use of natural light in the building by two skylights (190 m^2);
- Higher utilization of passive solar energy by orienting building architecture to sun;
- Two air handling units for fresh air (for basement and other floors zones) equipped with heat exchanger will be fed by three water-to-water heat pumps.

2.2.8 Grenoble Concerto project, France

Project: 495 new houses in 16 new buildings in the De Bonne (8 buildings, 435 houses) and Viscose (8 buildings, 60 houses) neighbourhoods as part of a larger project in Grenoble.

Principle:

- The space demand of the new dwellings is to be cut by 44% and other energy demands by 23% compared to current French regulation;
- 8 Mini co-generation units on natural gas to provide electricity (360 kW) and part of heating needs (590 kW) in De Bonne, complemented by natural gas boilers;
- Biomass district heating for heating and additional domestic hot water in Viscose;
- Electricity in Viscose to be covered by 2.7 MW micro-hydro generator on site Micro-hydro generation;
- Ventilation: valuable flow system with frequency modulation and highly efficient heat recovery;
- Possibility of using geothermal system for cooling;
- Thermal solar collectors for domestic hot water.

2.2.9 Gneis Moos housing estate, Austria

Project: 61 Low energy residential dwellings in Gneis-Moos (City of Salzburg).

Principle:

- Low temperature heating through radiators with temperature spreading;
- Heating through solar plant and additional collective district (block) heating fired with a natural gas boiler;
- Balanced ventilation: decentralised controlled drain-off of exhaust air with heat recovery. Supply air with preliminary heating over south-oriented winter gardens. The waste heat from the air of the dwellings is used for keeping the common rooms at a moderate temperature;
- Solar plant (430 m^2 collector area and 100 m^3 reservoir) will account for approximately 35% of hot water and heating demand.

2.2.10 Egnahemsbolaget project, Sweden

Project: 20 highly insulated terraced houses in 4 rows (two floors and storage attic) with solar collectors and with only a low-power heating system as back-up.

Principle:

- Highly insulated houses;
- Heat is supplied by passive solar gains and internal heat load from occupants and energy efficient appliances. Electric resistance heating in supply air, heat recovery from ventilation air (80%);
- Balanced ventilation with counter flow heat exchanger heating supply air (80% efficiency). Can be turned off in summer;
- 5 m^2 solar collector per house for 50% of the hot water supply;
- Power connection to wind energy facility in Göteborg.

2.3 Climate zones

The climate in Europe is relatively moderate. There are however significant differences between the north and southern parts of Europe. The main climate zones are given in Figure 2. A large part of Europe has a temperate sea climate. This means relatively soft winters with little sunshine and cool, dry summers. The southern countries have a Mediterranean climate. The summers are then warm. A real continental climate is only found in the far eastern regions of Europe. However in these regions low energy buildings are presently almost nonexistent.
Most case studies fall in the categories of the sea climate, with the projects in Spain and Portugal having a Mediterranean climate. The Grenoble project in France has a high mountain climate (Alpine). The projects in North Europe have a high latitude and therefore experience strong summer / winter differences, with very short solar days in winter.

However compared to China the differences between winter and summer are moderate in most parts of Europe. It should also be reminded that the southern part of Europe for instance Lisbon is on the about same degree of latitude as Beijing.

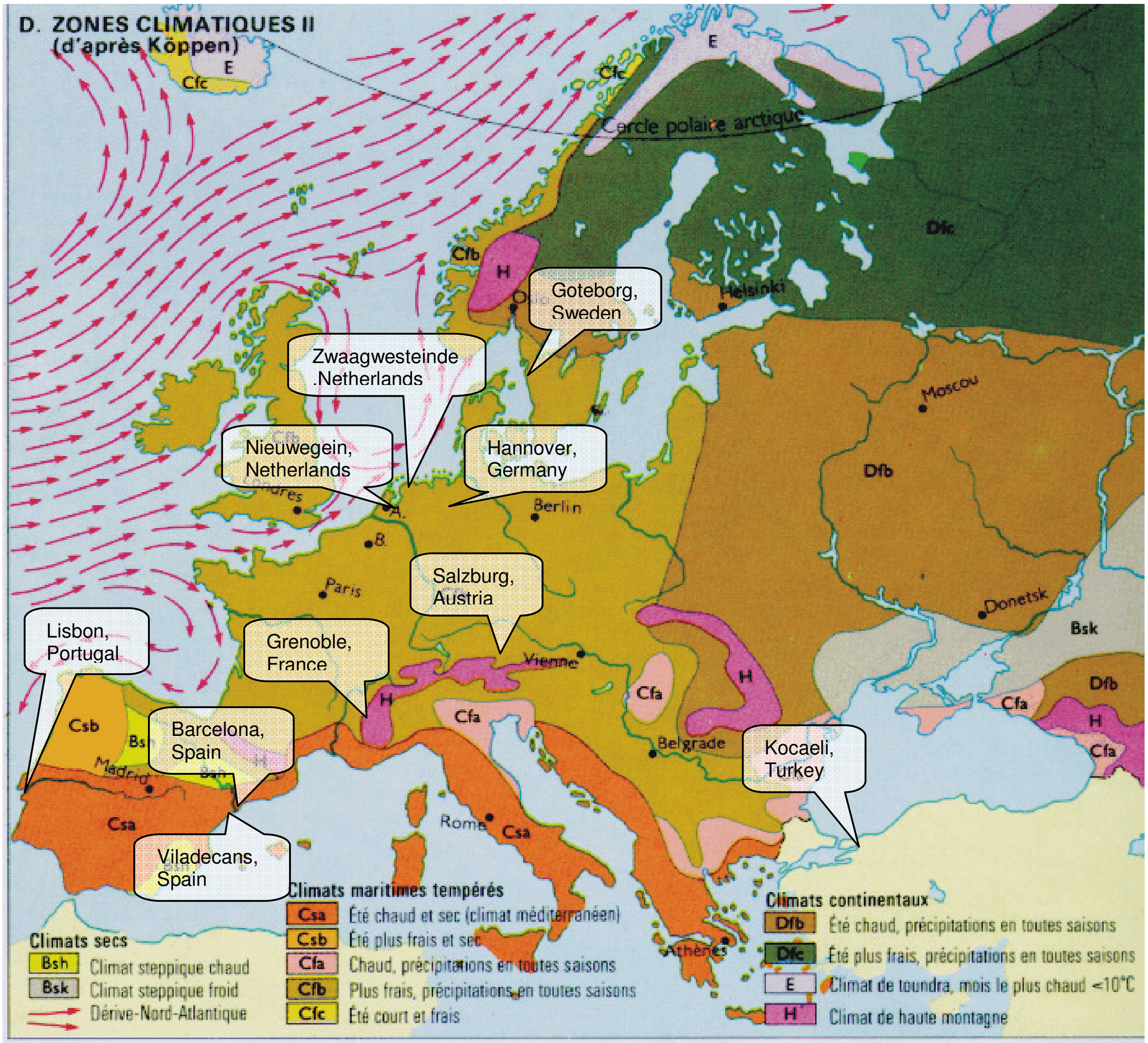

Figure 2 Climate zones in Europe after Köppen

2.4 Analysis

The described projects in the case studies are in general projects of a limited size (number of houses). The design of the buildings is in many cases not very spectacular – this is the result of an approach to integrate low energy building into mainstream building practice.

A trend is visible towards the use of passive solar energy and passive cooling. A common and obvious principle of all the buildings is a very high degree of insulation. For the more northern located buildings balanced ventilation is used. Heat losses through ventilation are then diminished as much as possible. For the more southern countries this is of course not useful. Then cooling via natural ventilation is more appropriate.

The approach toward low energy building is based on two types of measures:

1. Constructional measures
2. Building installation related measures (including renewable energy)

Constructional measures are:

- Good thermal insulation (without thermal bridges; glass, wall, roof, floor);
- Optimal orientation of the building and positioning of windows;
- Enhanced air tightness;
- Solar shading;
- Use of building mass.

Building installation related measures are:

- Use of high efficiency boilers for space heating;
- Low temperature heating in combination with heat pumps;
- Balanced ventilation with heat recovery or used for free-cooling during intermediate seasons;
- Use of natural ventilation
- Use of solar thermal and solar PV.

2.4.1 The case studies

The overall energy use of the buildings is between 0 and 100 kWh /m^{2}yr. Both the houses and the office buildings fall within this bandwidth. Most of the projects use renewable energy systems like solar thermal or solar photovoltaic systems. The energy production by these systems is taken into account when determining the total energy use.

The following principles can be identified in most or all of the projects.

- High degree of insulation
- Passive cooling incl. night ventilation
- Thermal active concrete
- Ground source based heat pumps
- Heat recovery ventilation air
- Solar thermal and solar PV

Solar thermal is mostly used for hot water production and not for space heating. This is connected to the fact that in most parts of Europe the winters are cloudy with short solar days. Solar energy then has low outputs and will not contribute much to the space heating demand.

A principle, that is also used, is compensating the energy consumption by for instance nearby wind turbines or certificates for green energy.

Another important aspect is also the use of certification for low energy houses like:

- the passive house certification, PEP

- the Dutch Solar House Certification
- HQE, a French Certification on sustainable buildings
- The British Code for sustainable homes

A further explanation is given in the report 'European experience on promoting low energy buildings' [1].

The certification makes visible and proves that a building has a good energy performance, and thus ensures the added value to realising a low energy building in the market. Is also helps authorities to stimulate certain measures or even make them obligatory. Furthermore, a system of 'green mortgages' has been developed in some countries among which the Netherlands. This means that the mortgage is provided with a lower interest rate when a house fulfils certain sustainable requirements (green materials, low energy use etc.). In some cases this is linked to a certification system.

For existing building the new European Energy Performance of Buildings Directive (EPBD) will provide a certificate also for existing buildings. It is expected that this tool will become an important market factor that will stimulate the awareness of energy use in buildings by the greater public.
This energy labeling is obliged for residential and non-residential buildings (new and existing). The goal of the EPBD is to create a common framework to promote the improvement of the energy performance of buildings [1].

Finally, as said before, the Trias Energetica is widely used (see 1.3).

2.5 Approach for low energy buildings

To create a successful high-performance low energy building it is important to have as starting point an integrated design approach in combination with an integrated team approach as much as possible. Sustainability should be an integral part of the design of the building. This means that the building is considered as a whole and in each step of the design the several disciplines (like the architect and engineers) are working together. In each design decision the impact on the whole building level is considered. This approach is sometime referred to as the 'Whole Building Design' approach.

In short a summary of the most important themes and examples are presented:

Building design
The design of a building has a significant impact on the material and energy requirements, both, during the construction and operation phases. The orientation of the building and the material used for the construction of the building have an impact on the energy use of the building. A good design can contribute to the reduction in energy demand for cooling, heating and lighting requirements.

Examples:
The Primary Health Care Centre in Spain and the Solar XXI Building are an example of this approach.

Passive solar design
Passive solar design refers to design that uses solar energy to reach a comfortable interior climate in buildings. It encompasses a wide range of strategies and options used in buildings to reduce energy consumption and increase comfort.
The basic intent of a passive design is to allow daylight, heat and airflow into a building whenever beneficial, store and distribute the heat and cool by natural means.
Passive solar design is an architectural design that minimizes the demand for energy by measures such as appropriate building orientation, efficient building envelopes, day lighting design, and thermal mass.
Examples:
The passive houses Lummerlund and the Egnahemsbolaget project in Sweden.

Passive cooling
Passive cooling for buildings is mostly relevant to hot climatic zones, in the South of Europe. The principle of passive cooling is to prevent heat (or reduce heat flux) from entering the building or remove heat once it has entered. These concepts use solar energy or other natural cooling sources (radiative cooling, evaporative cooling, natural ventilation, etc.). The applicability of these depends to a large extent on the prevailing climatic conditions, for instance, evaporative cooling is effective in hot and dry climates only. Passive cooling techniques maximize building envelope efficiency by minimizing heat gain from the external environment and by facilitating heat loss to the external environment.
Examples: the Sustainable Community in Viladecans, Spain and also the Solar XXI Building in Portugal are an example of this approach.

Renewable energy
The use of renewable energy systems in the built environment is in practice restricted to solar thermal and solar photovoltaic energy and small wind turbines.
Beside that the use of heat pumps is sometimes considered as part of the renewable energy system spectrum. A heat pump is used to upgrade low temperature energy to high temperature energy. It is often used in combination with renewable energy sources that produce energy with a low temperature.
Examples:
Almost each of the case study buildings has a form of renewable energy like solar thermal and solar photovoltaic. F.i. the projects in the Netherlands and Turkey use heat pumps in combination with ground source heat exchangers or an aquifer.

3 Conclusions

Low energy building can contribute enormously to reducing the use of fossil energy and the CO_2 emissions. The in this report described case studies present examples of projects realised in Europe in recent years.

Analysing these cases we make the following remarks:

- The overall approach in Europe is to realise 'normal' buildings that don't differ much from mainstream market. In this way, low energy building is gradually integrated into the mainstream building process and market.
- Compared to China the differences between winter and summer are moderate in most parts of Europe. It should also be reminded that the southern part of Europe for instance Lisbon is on the about same degree of latitude as Beijing.
- A trend is visible towards the use of passive solar energy and passive cooling. A common and obvious principle of all the buildings is a very high degree of insulation. For the more northern located buildings balanced ventilation is used. Heat losses through ventilation are then diminished as much as possible. For the more southern countries this is of course not useful. Then cooling via natural ventilation is more appropriate.
- The overall energy use of the buildings is between 0 and 100 kWh /m^2yr for houses and office buildings.

Summarizing the following principles can be identified in most or all of the projects.

- High degree of insulation
- Passive cooling incl. night ventilation
- Thermal active concrete
- Ground source based heat pumps
- Heat recovery ventilation air
- Solar thermal and solar PV
- Compensating the energy consumption by for instance nearby wind turbines or certificates for green energy.

Another important aspect is also the use of certification for low energy houses.
In order to have a successful approach and to reach true low energy buildings, European builders follow the following principles:

1. Reduce the energy demand by a high degree of insulation
2. Use passive solar energy
3. Use passive cooling incl. night ventilation
4. Heat recovery ventilation air
5. Use renewable energy

a. Solar thermal and solar PV
b. Ground source based heat pumps
c. Heat/cold storage in underground water layers (aquifers)

6. Have an efficient control or building management system

Following these principles, with little extra effort highly performing low energy buildings are being realised with high reproducibility value in the construction market.

References

1. 'European experience on promoting low energy buildings', B van der Ree, J. Tetteroo, Ecofys, March 2007, PDCSNL062127.