264: Zero energy housing with low environmental impact: The Trias Materia

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Abstract

This paper deals with a new concept for zero energy housing. This concept is based on 30 years of practical experience with energy efficient building in the Netherlands. Different projects have been analyzed, focussing on the main question: What will work in zero energy housing and what won't. The most important item however are the people that live in the house. Most projects focus only at the energy efficiency while running the house, almost neglecting the people that have to live in the house. This research shows that a lot of lessons can be learned from the past when paying more attention to the occupants and their habits and needs. Also in this research the total amount of energy needed for building a house is considered. This all together will result in a new approach for creating energy efficient housing in the Netherlands.

Keywords: energy, comfort, sustainable materials, integral design

1. Introduction

Global warming is considered a fact. All around the world many people are working to reduce greenhouse gas emissions.
The Dutch government has the aim to reduce the CO2 emissions by 2020 with 30% compared to the 1990 situation.

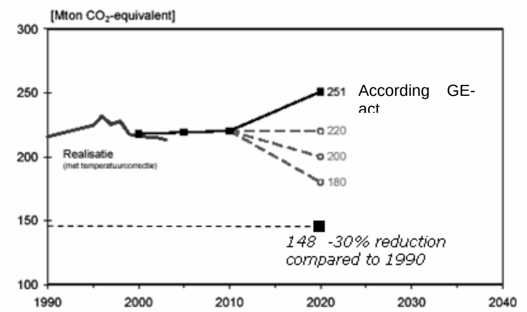

Fig 1. Different scenarios of CO2 emissions in Mton in the Netherlands and the 2020 goal of 148 Mton of the Dutch government

To reach this goal many different parties will have to work together. The build environment is considered to have a great involvement in these emissions, as much as 30-40% [1] of the total emissions are building related. This percentage consists of energy used in the manufacturing industry, construction and operation of buildings.
At this moment the building stock increases with 80.000 newly build dwellings every year in the Netherlands. A standard new house in the Netherlands emits roughly 4500kg [2] CO2 in one year. If all goes well by the year 2020 we will have a million extra houses compared to the 2008 situation. This will also increase the CO2 emissions from houses with 20% due to operating only. It is clear that a change of building our new houses is needed. Houses in the Netherlands are being built according to the current building code. This code is not extremely strict regarding energy efficiency. A new approach for building new zero energy houses in the Netherlands will be provided within this paper.

2. Lessons learnt from the past

2.1 What went wrong?

The technical know how to build a zero energy house is available at this moment. The concept for creating an energy efficient building is at least thirty years old in the Netherlands. As early as in 1982 so called Minimum Energy houses were built in Schiedam. Quite surprisingly these dwellings still outperform new houses in energy performance. So if this whole concept is not so new why does it not work for the Netherlands?
One reason for this is the continuous efforts for new experiments involving also new mistakes that are being made. Limited literature exists about these mistakes as nobody is really interested in telling the world about their own mistakes. When personally visiting the projects and personally discussing with occupant, designers and builders it can be observed that many errors are made over and over again. Many errors in new buildings like ventilation problems would not occur if people would learn from problems in existing projects. The result is that it seems that most project developers are reinventing the concept with all problems attached to this.
Another cause for failures is neglecting the point of view of the person living in a house.

Occupant's behaviour, habits and opinions about energy efficient buildings can turn a perfect passive house design into an uncomfortable home.
In the next paragraphs we different projects are analyzed to derive the technical conditions. These conditions facilitate the creation of zero energy houses for the Netherlands. Two projects in the Netherlands have been visited.
The information gained from interviewing the occupants and using their opinions will be discussed in a later paragraph.

2.2 The "Minimum energy houses" at Schiedam (1982)

These houses were inspired on the "CV-loze woning" concept by Kristinsson [3]. This concept aims to make a comfortable house without a normal heating system. This project was finished in 1982 and had a rough start as the experimental ventilation system showed numerous small malfunctions. These problems have been solved during the first year.

Fig 2. Minimum energy houses at Schiedam

The houses have an energy consumption of approximately 500m³ of natural gas and 3500 kWh of electricity. So the zero energy standard has not been reached but compared to the average consumption of 2500 m3 natural gas in those days quite an achievement.
The technical features for making these dwellings energy efficient were:

- Airtight detailing
- Heat recovery ventilation system
- Separate Compartments
- External Shutters for windows
- Hallway that separates entrances from heated compartments, creating a buffer
- N-value = 1,5
- R-value floor = 3 m² K/W
- R-value wall = 5 m² K/W
- R-value roof = 5 m² K/W
- U-value glass = 1.3 W/ m²K

The shutters are the most striking item in this project. They determine the appearance of these houses and provide coolness in the summer and keep cold outside in the winter.
The houses are built in a way that heat can be stored in the structure of the house. The designed thermal capacity is such that it will take a quite long time for the accumulated heat to be released. This can cause problems in the summer if people keep the doors and shutters open. The thermal resistance of the exterior skin is such that it can take up to 13 hours for the house to lower 0.5 degree Celsius [4].

Fig 3. Shutters and a fly closet for keeping products cool

The air tightness of the houses has potential to be increased. This can be done by improving the connection between the roof and walls and by better sealing the holes used for pipes.

2.3 The "Energiebalanswoning" at Amersfoort (Energy balance, 1997)

These two houses have been built in 1997. The goals were quite ambitious. The aim was to create a comfortable house that will not need energy from the grid to operate.
One of the two houses was used for research during the first few years and gave a lot of information about the performance of the entire house and its installations.

Fig 4. Energiebalanswoning at Amersfoort

The other house was inhabited by the designer. One of the remarkable technical problems that occurred in this project was the leakage of the roof. The roof consisted of a façade tilted at 21 degrees and not 90 degrees as usual for a façade. The result was leakage at several points. With many connections not designed for a 21 degree slope some are bound to fail resulting in leaks. The other problem with the angle of this roof is that the occupants can only see the roof while sitting on the terrace, the outside world is not visible at all. Due to leakage the roof will be entirely replaced coming year (2009).


Fig 5. Leakage from roof

Also the heat pump gave a lot of problems during the last past years. This pump will also be replaced in the months to come.

The main items used for making these houses energy efficient were:

- Thick insulation R > 4,5m²K/W
- Airtight detailing
- Heat recovery ventilation system
- Heat pump
- PV-panels
- Solar collectors

The energy usage can be seen in Table 1.

Table 1: Energy usage during different stages of the "energiebalanswoning"

	Used [kWh]	Gains [kWh]
Calculated	7500	7500
First year	8500	7000
2007	16000	5000

The first year showed quite good performance. The occupants were very aware and really trying to keep the energy use low. In 2007 the energy consumption is completely different. There were problems with the heat pump and with the solar cells. Also, the family consists of five persons who all use computers and other apparatuses. The occupants also admit to be not as dedicated to reduce energy costs as in the first few years.

2.4 Passive House Concept Germany

The passive house concept from Germany has proven to work for this country. The principle is quite simple. Make the house as airtight as possible. Use thick layers of insulation and put a heat recovery system in it.

This can lead to an energy consumption level for heating only of 15 kWh/m²/yr or less. (Fig. 6)

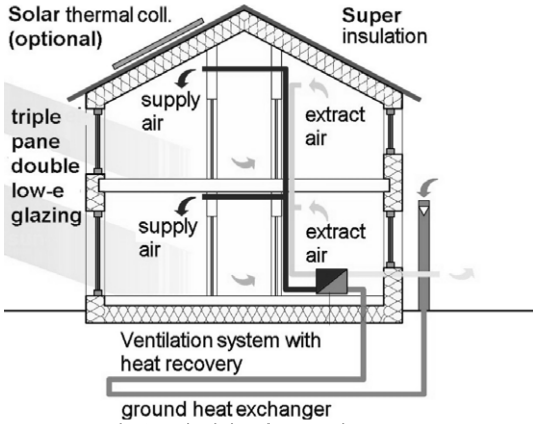

Fig 6. Principle of a Passive House

The technical specifications to create a Passive House are:

- R value > 7.0 m²K/W
- U-value glass = <0,8W/m²K
- Heat recovery system
- N-value = 0,5
- Usage of energy efficient apparatuses
- Ground tube for preheating/cooling

2.5 Lindas Sweden (2002)

The Lindas project of architect Hans Eek in Sweden provides insight in how to make a house without a heating system.


Fig 7. Houses at Lindas Sweden

The principle for creating a house without a heating system is also remarkable simple. Thick insulation and airtight detailing combined with optimal use of passive solar energy provide the basis. A heat recovery ventilation system and the internal heat production provide a comfortable home, even during the winter. The balcony provides shade in the summer and lets the sun through in the winter.

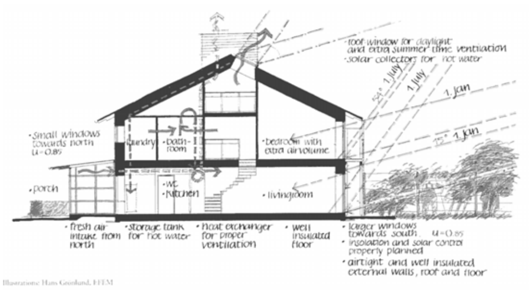

Fig 8. Principle of Lindas Sweden

During the first winters the bathroom got too cold so a small 800 W electric pre heater for the incoming air was installed. [5]

The technical specifications of this project are:

- R-value floor > 11 m²K/W
- R-value wall > 10 m²K/W
- R-value roof > 12 m²K/W
- U-value glass = 0,85 W/ m²K
- Airtight detailing
- Heat recovery system

An average house uses 8000 kWh a year.

2.6 Technical conditions

From the projects as discussed in the earlier paragraphs a list with conditions for creating a zero energy house for the Netherlands can be extracted.
From the Schiedam and the Lindas project it can be concluded that passive solar energy works. The thermal insulation as used in the Lindas case should be enough for the Dutch climate. The separate hallway from Schiedam has proven to be useful. From Amersfoort the usage of active solar energy has proven to be useful. The ground tube and the airtight building envelope from Passive house can also be used for the concept.

This gives us the following technical conditions:

- R-value > 10 m²K/W
- U-value glass < 0,85 W/ m²K
- N-value < 0,5
- Ground tube for preheating/cooling
- Heat recovery ventilation system
- Use of passive solar according Lindas
- Hallway that separates entrance from heated rooms

2.7 Occupants desires

The most important factor for success for a zero energy house is the occupant. The occupant wants to have a home which is comfortable and easy to live in. In many energy efficient houses comfort is limited and installations often are very complicated. If something needs to be repaired a specialist has to be called for the reparation.
A clear system will give the home owner the feeling that he controls the installation, and not the other way around.
One of the common problems is the noise of the ventilation system. This noise is being amplified by the lack of background noise lacking due to the airtight detailing.

In the Schiedam case people do not like the appearances their house. They preferred a more common appearance with brick walls and moere traditional shadings.
The shadings used in Schiedam are made of a wooden structure that keeps sun out in the summer and lets it through in winter.

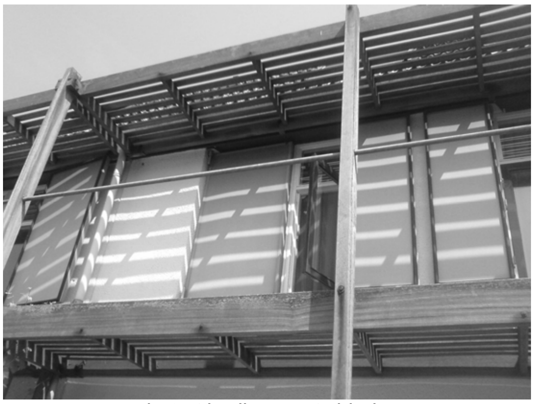
Fig 9. Shadings at Schiedam

Occupants like the idea behind this but also like to have more a functional structure in their garden, like a balcony. This is in line with the Swedish principle as explained before.

In conclusion of this section a summary of points of interest regarding occupants preferences of energy efficient homes can be given:

- Traditional building appearance
- Clear and easy to use installations
- Comfortable ventilation system without persistent noise
- Functional shadings like a balcony

The next paragraph will focus on the materials that are to be used to create a building.

3. Trias Materia

3.1 Total concept energy reduction

Many energy efficient houses are focussed on the energy running costs of a house when it is in use. The importance of looking at the “green side” of house is already proven by B.N Winther [6]. The energy that is put in the building as it is build or demolished is overlooked. The production energy can take as much as 25% of the total energy cost of an energy efficient house over a lifespan of 50 years [7]. If this is taken into consideration and focus on methods to reduce this energy, this can make quite a difference before the building even starts performing.

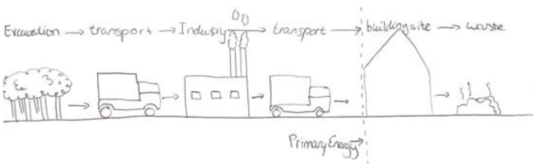

Fig 10. Energy put into a building

Methods like Slimbouwen [1] are used to reduce transport and time to construct a building.
A flexible building system is promoted that can be easily assembled and taken apart at the site.

Transport movements are also reduced because only elements have to be transported and not only small separate materials. In this paper the focus is on the materials that are being used to build houses.

3.2 Trias Materia

As stated in the last paragraph the reduction of primary energy of materials can lead to a huge saving in the total energy. But not only the primary energy of a material should have influence to make a decision to use it or not. The stock of materials and the sustainability of materials are also very important in the decision making.

For this a new Trias is introduced; the Trias Materia. Two Trias that are already known are the Trias Ecologica [8] and the Trias Energetica [8]. These Trias provide help for making a building energy efficient and lets the waste stock become less an impact on the environment.

Trias Energetica:

1. Reduce the need for energy
2. Use durable energy sources
3. Use fossil fuels only if necessary

Trias Ecologica:

1. Avoid waste
2. Recycle waste
3. Process rest of waste with care

The Trias Materia is a system that helps to choose materials in a few steps.

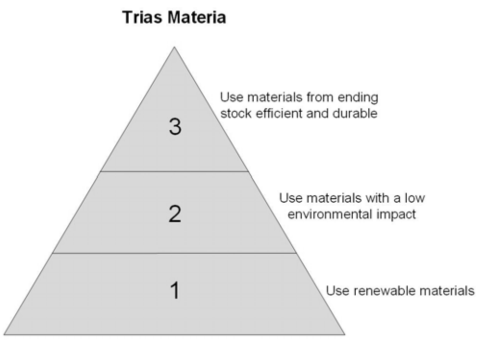

Fig 11. The Trias Materia

1. Use renewable materials:

The first step in this Trias makes sure that the ending stocks of materials are being saved for future generations. Renewable materials can be used without a problem as long they do not have an extensive environmental impact.

2. Use materials with a low environmental impact:

The second step is to use materials with a low environmental impact. This means use materials with a low primary energy or with environmental friendly excavation methods. In this way the ecological footprint can be reduced.

3. Use materials from ending stocks efficient and durable:

Materials that cannot be recycled or have a high environmental impact should be used only if no other option is available or if its possible to use it for a long duration (50> years).

This will lower the total energy that is used for the life-cycle of a building.

Table 2 shows the difference in primary energy between a few materials.

Table 2: The primary energy for different materials, this is the energy used from excavation to building site [9].

Materials:	Kg/m³	GJ/m³
Conifer wood	450	1,7
Laminated conifer wood	450	5,7
Hardboard	1000	17,3
Sand	1700	0,2
Bricks	1700	7,3
Concrete	2400	1,7
Reinforced concrete	2500	4,5
Limestone	1600	0,13
Steel	7850	236
Aluminium	2700	621
Lead	12250	600

This table shows some significant differences between various materials. The difference between limestone and normal bricks is a factor 56. This clearly shows the potential of energy that that can be saved. Being more aware of this potential savings not only in the production but also in the demolishing of a building can bring savings, after all energy that was not in the building cannot be thrown away.

4. Concept Design

For making a concept design the findings from the past paragraphs are used. The opinions of the occupants play a major role in the concept.

The compartments in the house have proven to be valuable in the past. The occupants however, like the freedom to remove walls and doors. So this will work if properly designed. Another problem is the Dutch way of living. In the winter many people leave the windows open and keep the heating system on. They like the comfort of having fresh air, while sleeping under a warm blanket. Obviously this is not beneficial for the heat recovery ventilation systems that are being used in zero energy buildings.

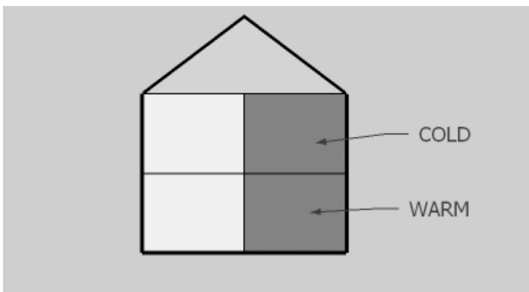

Fig 12. Compartments over different floors

Because of these problems another compartment idea is designed; The first floor and the second floor are separated. Creating a compartment that can be easily kept warm because it has a smaller volume and still can be flexible for its occupants. The second compartment has lesser insulation and can be left much cooler. The rooms on the second floor are mostly used for a small time or for sleeping so the lower temperature is perfect. Figure 13 shows this concept.

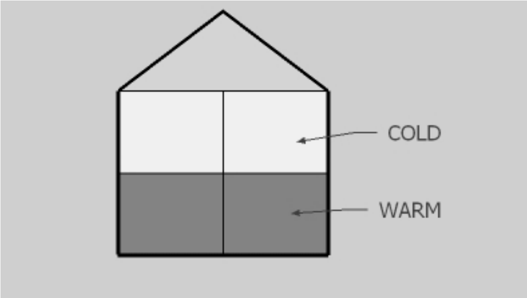

Fig 13. Compartments over one floor

On the ground floor the rooms are placed were people spend most of their time, like the living room and kitchen. The separation between the two compartments is provided by the stairs. The entrance to the stairs is blocked by an air tight door downstairs. In this way a buffer is created between the warm and cold area of the house.
A study room is very appreciated by occupants; it could also be used as extra room.

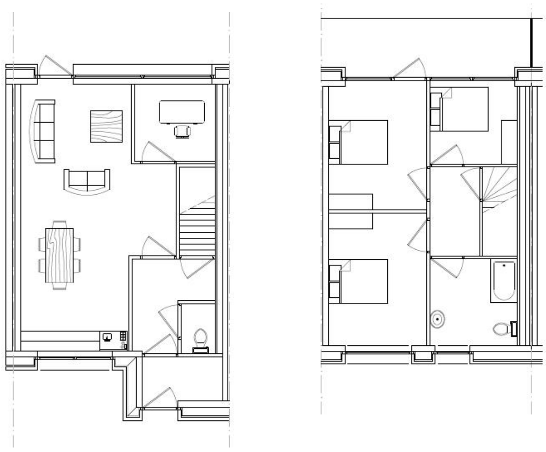

Fig 14. Layout concept

The installations for this zero energy house can be placed on the attic, here also some storage room can be provided. For the pipes of the ventilation system and other utilities a hollow wall is used that goes from the attic to the ground floor.
In the figure below this concept is illustrated.

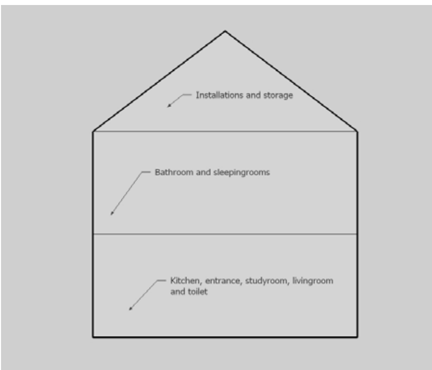

Fig 16. Positioning of functions in the concept

The balconies are based on the angle of the sun during winter and summer. In the figures below can be seen that the sun is blocked during summer and let threw in the winter.

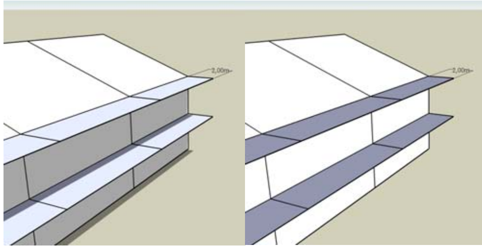

Fig 17. Left 21 june 12.30, right 21 december 12.30

5. Conclusion

The combination of the different projects provide base for creating a zero energy house concept.
The contact with the occupants of the houses in Schiedam and Amersfoort gave critical information for the design. The integral approach of the technical conditions together with the occupant's vision brings a zero energy concept that has the potential to succeed in the Netherlands. Further research is needed to look further into the installations.

6. Acknowledgements

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