Step-by-step plan – Energy Efficiency Improvement Home

Fig. 1: Example of houses

Author: Dr. Ir. G.M.H.J.L. Gadiot, **EG Delft**
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Summary

In the following, a step-by-step plan is presented to make a corner house from the year 1965 with a poor energy efficiency of 129 kWh/m2 more sustainable into an energy-efficient house with a desired energy efficiency < 35 kWh/m2.

1. Introduction

Each home has its own energy consumption that depends on the degree of insulation of the home, the number of residents and the heating behavior of the residents. The energy efficiency in kWh/m2 can be determined from the total energy consumption of a home over a whole year[1] . The resulting energy class of the house then follows from the following table.

Table 1: Residential energy classes

Energy class	Lower limit [kWh/m2]	Upper limit [kWh/m2]
Energy-neutral	--	0
Paris Proof[2]	0	35
Very economical	35	55
Frugal	55	90
Average	90	140
Inefficient	140	170
Very inefficient	170	higher

Newer homes will generally have a better energy rating, which means that they will generally only benefit from making their already energy-efficient home even more energy-efficient by using [3] energy even more efficiently themselves. Ultimately, the "Paris Proof" class (0-35 kWh/m2) is pursued.

Older homes in particular have a higher energy consumption and the residents of those homes will certainly benefit from being informed about the possibilities that exist to reduce energy consumption. In other words: which energy-saving

[1] Total energy consumption of the house divided by the living area of the house.
[2] Paris Proof is the aim of the Dutch real estate market to make the built environment completely climate neutral by 2050. The energy that is still used comes from renewable energy sources.
[3] This step-by-step plan does not elaborate on this specific point, but focuses mainly on homes that still consume too much energy due to poor insulation.

measures are possible and which are most suitable for my home, what are the costs and benefits of those measures, and when[4] does an implemented measure pay for itself?
These questions are partly generic, and partly also depend on the specific condition of the property at the moment.

To show the possibilities and thus arrive at a step-by-step plan, a relatively old house from 1965 is taken as an example. The following matters are discussed in turn: a. description of the house from 1965, b. overview of the possible improvement measures, c. effect of these energy-saving measures on gas consumption and energy efficiency and d. advice on the step-by-step plan.

2. Description of the house from 1965

The corner house viewed here was built in 1965 and has a living area of 165 m2 spread over 3 floors. The house is heated with a central heating system (boiler from 2007). In most rooms there is a radiator and in the living room there are two convectors. Electric cooking is used. The house has a flat roof that is insulated with 6 cm PUR boards. The cavity walls are insulated, as is the crawl space. There is double glazing almost everywhere, but that is not HR++. A number of smaller windows still have single glazing. The glass is found in both aluminum and wooden frames. The aluminium frames act as a thermal bridge[5] , causing water to condense on the aluminium surface and mould[6] to form locally. The house has natural ventilation, which means that a lot of heat can leak out depending on the weather situation. Especially in strong winds and low temperatures outside, this is noticeable in the house in the vicinity of windows.

2.1 Residential consumption figures

In this example, only the heating year 2022 is considered. The electricity and gas consumption of the house for that year was 2,855 kWh and 1,636 m3 respectively. The total energy consumption of the house was 21,427 kWh[7] with weather effects[8] taken into account.

[4] A measure carried out pays for itself in a period of time, by dividing the costs incurred by the energy savings per year. This results in a timeline that is usually expressed in years. For solar panels, for example, the costs are recouped within 6-7 years.
[5] Place with large heat leakage to the outside of the house. Aluminium is a very good conductor of heat.
[6] However, this is easy to remove with a cloth.
[7] The energy content of natural gas (m3) represents about 10 units of electricity (kWh). If 1 m3 of gas costs € 1.35 and 1 kWh of electricity costs € 0.35, then the use of gas is about 2.5 times cheaper than electricity from an energy point of view. Replacing gas with electricity is therefore not a trivial matter.
[8] By including weather effects on an annual basis, the consumption figures on an annual basis can be fairly compared with each other.

Table 1: Residential energy classes

Energy class	Lower limit [kWh/m2]	Upper limit [kWh/m2]
Energy-neutral	--	0
Paris Proof[9]	0	35
Very economical	35	55
Frugal	55	90
Average	90	140
Inefficient	140	170
Very inefficient	170	higher

2.2 Home Energy Efficiency

The house has an energy efficiency of 129 kWh/m2. This puts the house in the "Average" class. This is not very good, which is why the energy consumption must be reduced by about 94 kWh/m2 in order to belong to the desired "Paris Proof" class. This means that much less gas will have to be used and that energy will mainly be used electrically and preferably also self-generated.

3. Overview of measures[10]

3.1 Insulation

The better a home is insulated, the less heat the home loses, and therefore less heating is needed. With good insulation, the house feels (more) comfortable and can therefore be heated more easily at a low temperature. Heating at a lower temperature leads to fewer losses when heating and results in lower costs. To achieve this, there are various options for insulation, such as: cavity wall insulation, roof insulation, basement floor insulation and HR++ glass in combination with insulating window frames and exterior doors.

3.1.1 Roof insulation

The roof is responsible for about 20%[11] of a home's heat loss. Good roof insulation can therefore make a substantial contribution to reducing the heat loss of a home and thus reduce gas costs.

[9] Paris Proof is the aim of the Dutch real estate market to make the built environment completely climate neutral by 2050. The energy that is still used comes from renewable energy sources.
[10] There are many measures that can be taken than those mentioned here, but those mentioned are the most important measures.
[11] These are typical values that change as the isolation has already been (partially).

3.1.2 Cavity wall insulation

Cavity wall insulation will reduce gas consumption by a small[12] percentage. The reason is that the cavity can only contain limited insulation material (cavity width). For corner houses, cavity insulation will result in more savings due to the relatively larger outer surface area than with a terraced house. The costs for cavity wall insulation are relatively low and easy to implement.

3.1.3 Basement insulation

The ground floor of the house is responsible for about 10% of the heat loss from a house to the ground. Good basement insulation can be achieved in several ways and will therefore contribute to reducing the heat loss of the home and thus reduce gas costs.

3.1.4 Interior and exterior wall insulation

Interior or exterior wall insulation is a good addition to the insulation value of a home. Interior wall insulation takes away interior space and leads to a reduction in the size of the house. To properly insulate the house, at least 10 cm of high-quality insulation (PIR boards) is required. Exterior wall insulation can be applied relatively easily to the exterior façade and finished with a layer of brick slips for an optimal appearance of the house.

3.1.5 Insulating frames and exterior doors

Insulating frames and exterior doors are usually thicker than the original frame or door. The window frame[13] or door frame must therefore be replaced. Replacing the door frame is wise because the heat loss through the door frame is also reduced.

3.1.6 HR++ glass

HR++ glazing double glazing is energy-saving and better insulating than single glazing and also the older double glazing. It consists of two sheets of glass with a cavity in between. The gas in the cavity between the glass plates determines the insulating effect of the whole. The insulating effect of double glazing increases comfort in a home and reduces energy bills. Different versions have different insulation values.

3.2 Replacement CV

Energy-efficient central heating boilers are high-efficiency boilers and therefore very economical. These boilers are on average 10% more efficient than the old boilers. In principle, the central heating boiler is replaced after 15 years of use. A

[12] For the house under consideration, the cavity width is 7 cm and it pays to insulate the cavity. When the cavity is 1-2 cm wide (apartment buildings), the costs no longer outweigh the benefits. This also applies if the cavity is too contaminated with mortar.

[13] It is possible to reuse the wooden outer frame of window frames as an adjustable frame. The old window frame can therefore be reused. This ensures better insulation and easy and quick assembly.

high-efficiency boiler achieves increased efficiency because the cold return water is preheated via a heat exchanger by heat extraction from the flue gases.

3.3 Underfloor heating

Conventional heating of houses is based on central heating boiler and radiators. The central heating boiler heats the water that goes to the radiators to about 70-80 ^{o}C. This heating system has been tailored and made suitable for houses that are not so well insulated. A better insulated house can be heated well with a water temperature of 35-55 ^{o}C and a heat pump can deliver this temperature well and efficiently. Underfloor heating[14] has a relatively large output surface and can therefore emit sufficient heat better than a radiator. Underfloor heating therefore feels more comfortable than heating with conventional radiators. There are now also radiators or convectors that are specially designed for low temperature.

3.4 Warmtepomp

A central heating system produces heat at a relatively high temperature (80 ^{o}C), while the heat pump produces water at a lower temperature (35-50 ^{o}C). A heat pump is therefore better suited to a relatively well-insulated home. With a heat pump, gas consumption can be reduced by 50-70%. The energy consumption per square metre can be significantly reduced with a heat pump.

4. Effect of energy-saving measures

An original house from 1965 loses heat to the part of the house, as[15] shown in the table/figure below.

Home share	Share in loss (%)
Roof	30
Refreshed air	20
Walls	20
Windows and exterior doors	15
Cold bridges	5
Floor	10

Table 2: Heat loss in the home

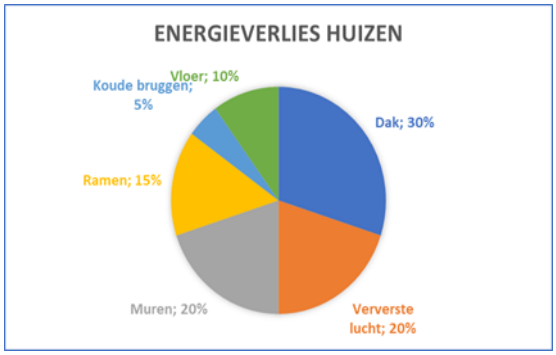

Figure 2: Heat loss in the home

[14] This also applies to wall heating.
[15] The real percentages depend a lot on the way the house is built. In this example, these percentages are used to quantify the impact of energy-saving measures.

A heat loss calculation has been carried out for the house. The state of insulation of the house has already been taken into account[16] . The heat losses amount to about 1,448 m3 over the year 2022. For a distribution of heat losses, see Figure 3a below.

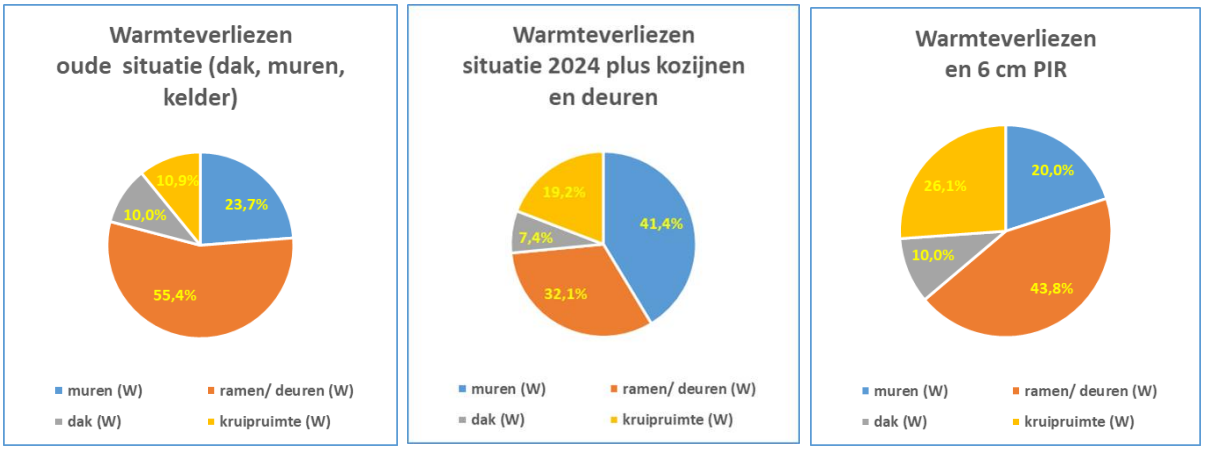

Figure 3a. Current situation b. Roof, windows and doors c. Insulation walls

Several loss calculations have been carried out, namely:

i. Current situation of the property,
ii. Replacement of the roofing with new insulation,
iii. Replacement of window frames and exterior doors and installation of HR++ glass,
iv. Additional insulation of the walls with 6 cm PIR insulation,
v. Additional insulation of the walls with 10 cm PIR insulation,
vi. Replacing the central heating system with a heat pump,
vii. Installation of solar panels.

Improvement	Gas consumption (m3)	Electricity consumption (kWh)	Energy Efficiency[17] (kWh/m2)
i*	1648	3000	131
Ii	1564	3000	125
Iii	1031	3000	88
Iv	852	3000	76
v	809	3000	73
Vi	0	5427	33

* This is the home situation before carrying out insulation measures

Table 3: Results of loss calculations

Ad. ii. Renewing the roof

The roof was already covered with an old layer of PUR insulation material. When renewing the roofing felt, an additional layer of 8 cm PIR was added. The effect

[16] The house has an insulated cavity, the basement is insulated and the roof is insulated with 6 cm PUR.
[17] These are calculated values.

of the new roofing on the insulation of the house is limited because there was already insulation, but mainly because the roof only covers a small part of the house's exterior surface (20%). As a result, it does little to improve the energy efficiency of the home.

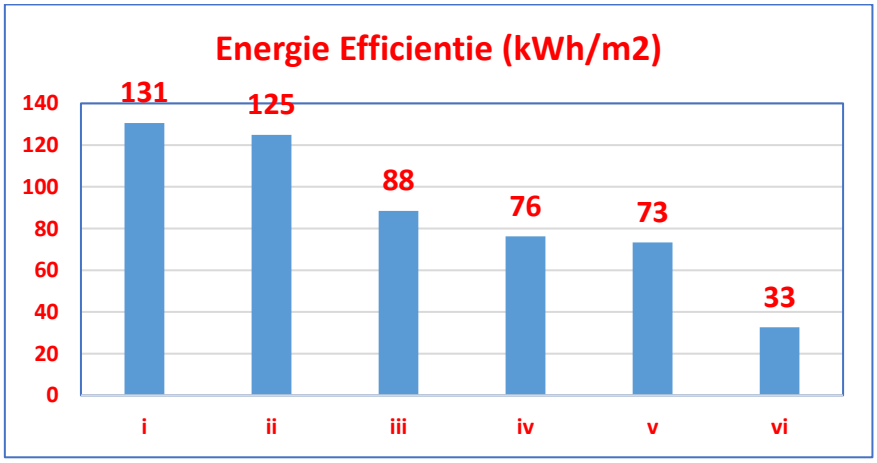

Figure 4: Energy efficiency gains after measures

Ad. iii. Renewing glass, window frames and exterior doors
Renewing the old double glazing with new HR++ double glazing has a relatively large effect on the heat loss of the house because it greatly improves the insulation value of windows, frames and exterior doors. See also Figure b for an overview of the main heat loss items. Figure shows the effect of these measures compared to the other measures.

Ad. IV and V. Insulating the exterior walls with 6 and 10 cm PIR respectively
Two calculations were carried out for the additional insulation of the exterior walls. Installation of 6 cm or 10 cm PIR insulation plates.
The improvement of the insulation of the house is limited in scope. This is not illogical, because in absolute terms, there is less and less to be cut as substantial savings have already been made. From 6 to 10 cm, the improvement is lower. This does not alter the fact that every improvement naturally contributes. See also Figure c for an overview of the most important heat losses.

Ad. vi. Replacing central heating with heat pump
Replacing the central heating with a heat pump effectively takes the house off gas and results in a very economical home with the Paris Proof class. The calculation assumes that 70% less heat is needed and that the energy required for this is sustainably available from solar power. A heat pump extracts heat from the environment and pumps it to the heating system within the home. The electricity can then preferably be generated by solar panels.

Ad. vii. Installation of solar panels
As indicated earlier, the house can still be equipped with 8-12 solar panels. The amount can best be tailored to the needs of the home with or without a heat pump and any other structural needs of the home.

Installing solar panels is not an energy-saving measure, but it is a sustainable one.
Many homes of this type are already equipped with solar panels. This is used to generate clean electricity free of charge. This with the caveat that the investment must first be repaid (TVT = 5-7 yrs) and that the net metering scheme will probably be phased out from 2025 as planned, so that the TVT of an investment will now be slightly longer.

5. Cost/benefit energy-saving measures

Verbe-tering	Subsidy[18] (€)	Price/m2[19] (€)	Total price (€)	Total subs. (€)	Actual price (€)	tvt (years)
i*	--	--	--	--	--	--
ii	30	100	6.016	1.805	4.211	37,1
iii	131	437	17.912	5.374	12.538	17,4
iv	38	127	16.557	4.967	11.590	47,9
v	38	127	16.557[20]	4.967	11.590	38,7
we	--	--	10.000	3.150	6.850	9,0

Table 4: Cost-benefit analysis of measures

Ad. ii. Renewing the roof
This was an old roof[21] that needed to be replaced due to ageing. Since the costs have to be incurred anyway, the long payback period is not a problem. You can see the costs as an investment in the value retention or value improvement of the house, with the added benefit of a reduction in energy costs and an increase in the comfort of the home.

Ad. iii. Renewing glass, window frames and exterior doors
This significant improvement in the insulation value of the house leads to high installation costs. Here too, the house improves in appearance, insulation and resale value and these costs in terms of energy savings are not recouped, but are advantageous in terms of living comfort and in the event of a sale.

Ad. IV and V. Insulating the exterior walls with 6 and 10 cm PIR respectively
More or less the same applies here as for previous improvements.

[18] Subsidies from the government or the municipality are important because they reduce the actual costs for the resident and the measure is more likely to be taken by the resident. The grant is about 30 % (for 2 measures) of the total cost. The amount is based on market research into the cost of insulation measures. In practice, however, the costs appear to vary widely and are often considerably higher. This may be due to market forces when there is a high demand for insulation measures, but it may also be that customization is required for your home. It is always wise to request multiple quotes and compare costs.
[19] This price is derived from the amount of the subsidy and the knowledge that the government grants a 30% subsidy for 2 subsidy applications. The prices are for 2023.
[20] Replacing 6 cm PIR plates with 10 cm sheets is of course more expensive. However, the subsidy scheme does not take this into account.
[21] Older than 20 years.

Ad. vi. Replacing central heating with heat pump
Replacing the central heating system with a heat pump leads to a saving of about 70% of the energy (gas) costs. Given the cost of a heat pump and the subsidy amount, it provides up to an interesting payback period of 9 years.
The electricity for the heat pump can be generated by the heat pump.

Ad. vii. Installation of solar panels
Finally, solar panels lead to a substantial reduction in energy costs.

7. Advice Step-by-step plan

When you have your home calculated energetically, you know what an investment in energy-saving measures can bring you in terms of savings on energy costs. It has recently become clear that the cost of energy can vary greatly due to developments abroad. By becoming less dependent on energy, unless this energy is self-generated, it is possible to reduce the risk of high costs.

The payback period of some measures can be long, but on the other hand, the living comfort of the home improves as a result of the measures and the value of the home also increases. The latter is only noticeable when selling.

About the possible energy-saving measures:
Ii. Replacement of the roofing with new insulation,
Iii. Replacement of *Window frames and exterior doors* and places HR++ glass,
Iv. Additional Insulating the walls with 6 cm PIR insulation,
v. Additional insulation of the walls with 10 cm PIR insulation,
Vi. Replacing the central heating system with a Heat pump,
Vii. Installation of Solar panels.

The following may be noted.

Ad. ii. Replacing old roofing is important if you want to install solar panels on the roofing. Solar panels last about 25 years. With a new roofing material, the chance of leakage is smaller.

Ad. iii. Frames and exterior doors do not always need to be replaced when installing HR++ glass. Wood is a good insulator and the glass in the window frames can be replaced relatively easily. Installing a maximum insulation value at minimum costs is then recommended.

Ad. iv. Insulating the exterior walls can be done from the inside and does not require the entire surface to be insulated at once. A phased approach is financially more sustainable over time and the resident can also easily install insulation himself.

Ad. vi. Replacing the central heating system with a heat pump is recommended in view of the costs and the high subsidy as well as the acceptable payback

period and the high energy savings if the house can handle it. The latter is the case when the house can heat the house properly with the current central heating system at a working temperature of 50 ^{oC} . The resident can easily test this himself.

Ad. vii. Installing solar panels is also a good choice, especially now. The phasing out of the net metering scheme will not start until 2025 and the costs for installation are now (late 2023/early 2024) very favourable relative to the period before.

8. EC Delft's proposal to you

If you are toying with the idea of making your home more sustainable and thus be able to save energy costs immediately and in the longer term, EG Delft advises you the following:

- Ask EG Delft to determine the Energy Efficiency for your home. All you need to do is fill out an Excel form. Determining the Energy Efficiency based on the Excel you have filled in is free of charge and there are no further obligations. THE value of the Energy Efficiency gives you an idea of the possibilities for energy savings of your home.

- If, as a result of the Energy Efficiency value of your home, you decide to take steps to make your home more sustainable, EG Delft can draw up a report specifically for your situation[22] and your wishes. EG Delft charges reasonable costs for this.

- If you want to take steps to actually make your home more sustainable as a result of this report, EG Delft can facilitate you by requesting a number of quotes so that you can make an informed choice for each measure. Of course, it is also possible that you refrain from carrying out one or more measures. EG Delft charges reasonable costs for this support.

- Of course, you always decide when to actually place an order for an energy-saving measure, and EG Delft's advice is always non-binding.

[22] Whenever possible, a thermal imaging camera will be used to clarify situations with suboptimal insulation.