Analysis of energy consumption Voorhof Delft

Fig. 1: Example of houses Voorhof[1]

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Distribution: Participants in the Voorhof Delft neighbourhood survey
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[1] Please note that there are two types of houses in the considered set of houses in Voorhof, the terraced house and the corner house. The corner house has a significantly larger exposed surface area and will therefore lose more heat than a terraced house, regardless of the energy-saving measures taken.

Summary

In the Voorhof district in Delft, a group of about 170 comparable uniform homes from 1965 were compared with each other in terms of energy efficiency. A letter has been sent to 163 residents asking them to participate in this study. 18 residents responded positively and eventually 13 answers were incorporated into this report.

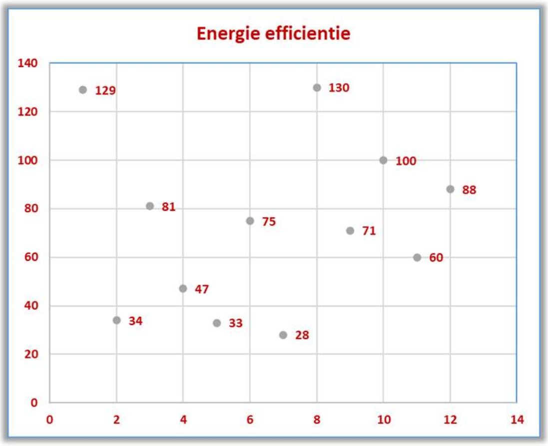


Fig. 5: Energy efficiency

	Class
Energy-neutral	no
Paris Proof	Apartments 2, 5 and 7
Very economical	House 4
Frugal	Property 3, 6, 9, 11, 12 and 13
Average	Houses 1, 8 and 10
Inefficient	no
Very inefficient	no

Table 2: Energy classes for homes

Fig. 5 gives the result in terms of energy efficiency (kWh/m2). Energy efficiency is the total energy consumption of a home, but per square meter. For example, many homes are relatively easy to compare with each other.

High-performing homes are below 35 kWh/m2. The high-performing homes all have a hybrid heat pump, but that may not be enough to have a low energy efficiency as well.

1. Introduction

In the Voorhof district in Delft there is a group of about 170 similar homes from 1965. These uniform, modern homes at the time provide an excellent opportunity to assess the effectiveness of energy-saving measures for this type of housing. By comparing the energy efficiency of these homes, it may be possible to quantify the impact of energy efficiency improvements that some of the residents have already made. This knowledge can then serve as inspiration and motivation to try to implement similar improvements in the other homes. This is expected to have a positive impact on energy costs, but also has a direct positive impact on the environment.

2. Process

A letter was sent to 163 residents[2] with the request to participate in a study into the energy efficiency of the homes. 18 residents responded positively and a simple Excel file / questionnaire was emailed to them. In the end, 13 answers (8%) were processed and the energy efficiency of these homes was determined for 2022[3] and the differences were indicated with the further details about the energy-saving measures taken. Sustainable measures such as wall insulation, insulated windows and ditto exterior doors, energy-efficient heating systems, solar panels, LED lighting, etc. have a direct impact on the energy consumption and related costs of the home. Not all cases have been questioned in detail.

3. Analysis of property data

3.1 Energy consumption per square meter

The energy consumption per square meter is a good measure of the energy consumption of a home. Low energy consumption indicates that a home is economical and has low energy costs. Homes generally have a different surface area and this variable is "taken out" in this way.
The occupants of the house use electricity for equipment (hot water, washing machine, dryer, refrigerator, etc.[4]) and gas for heating[5].
The electricity used can then best be generated sustainably by self-generation with solar panels.

Almost all of the houses in the Voorhof have the option of providing their own electricity.

The Dutch government aims to reduce the natural gas consumption of homes as soon as possible and eventually phase it out. This is the line of the Climate Agreement. The most important short-term goal of the Climate Agreement is to reduce CO2 emissions by 49% by 2030 compared to 1990. By 2050, greenhouse gas emissions must be reduced by 95%. This is necessary in the Netherlands and worldwide to ensure that global warming does not exceed 1.5 ^{oC}. The less gas a home needs, the better it is.

In addition to reducing CO2 emissions, it is also important to reduce energy consumption as much as possible. That's why we look at energy efficiency. The degree of energy efficiency can be expressed in terms of the energy consumption per square meter of a home. That approach is also followed here.

The energy consumption per square meter is calculated as follows:

[2] Seven of the houses considered have been converted into rooms. These homes are not included in the analysis.
[3] The year 2022 is the most recent past year. Anyone can look up their energy consumption data in their energy supplier's annual report.
[4] Electricity for e.g. a charging station for an electric car is not included in energy efficiency.
[5] Of course, there are still several sources of energy, but they are used much less frequently.

$$(E\_geb./m_2)_1 = (E\_geb.,\ elek. + E\_geb.,\ gas + Klimaatcorr.) / Ag \qquad (cf.\ 1)$$

where Ag is the surface area of the house. For this figure, the BAG register is consulted[6] .

Winters have become warmer in recent years. A warm winter means lower energy consumption of the home. In order to be able to compare years energetically in a fair way, this effect is mapped out by means of a so-called Climate Correction[7]. The standard method based on so-called degree days is used for this.

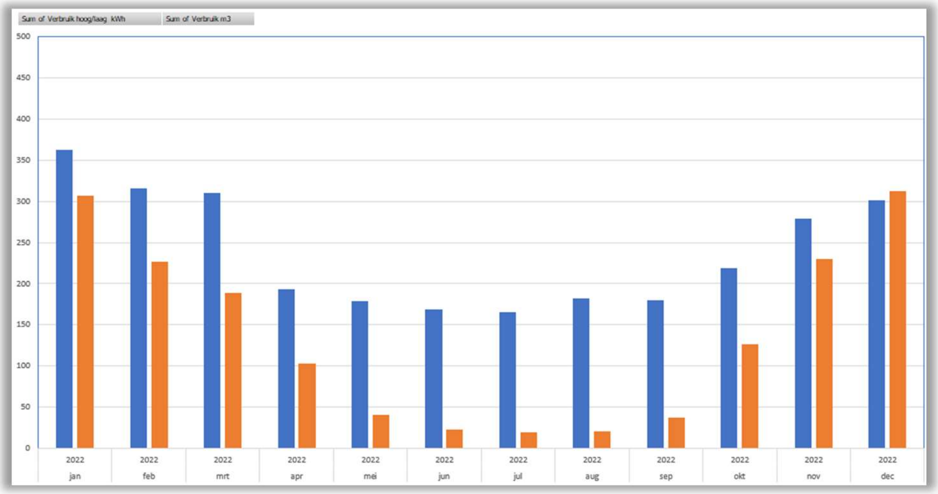


Fig. 2: Typical development of gas and electricity consumption over a year[8]
Orange is gas and blue is electricity

3.2 Gas consumption

Natural gas is mainly used for heating purposes, mainly central heating, but also hot shower/bath water and for cooking.
Fig. 2 shows that the gas consumption mainly takes place in the months of October to April (heating) and also that this part is much larger than the part for hot shower/bath water.

As indicated, the Dutch government wants to significantly reduce fossil natural gas consumption. In a well-insulated home, this is easily possible with a (hybrid) heat pump (HWP). The electric HWP then takes care of the hot water supply for the majority of the year and the gas-operated central heating only works at low outside temperatures when the HWP has too low an efficiency.

[6] All buildings are registered in the BAG with year of construction, surface area, purpose of use and location on the map. In addition, addresses and buildings have a BAC identification number. Just like cars have a license plate and people have a social security number.
[7] Correction of energy consumption to standard climate conditions.
[8] Property with poor energy efficiency.

3.3 Electricity consumption

Electricity can be purchased sustainably, but it can also be generated by solar panels on the roof. Solar panels on your own roof are particularly beneficial for the energy efficiency of a home.

E_geb., elek = E_prod. – E_terug (cf. 2)

When the solar panels are paid off, this renewable energy is free and thus reduces the energy costs of the house (cf. 2).

3.4 Home insulation

The better a house is insulated, the less heat the house loses, so there is no need for heating. With good insulation, the house becomes more comfortable and can therefore be heated more easily at a low temperature and with lower energy costs. There are various forms of insulation that are effective to a greater or lesser extent[9] , such as: cavity wall insulation, roof insulation, basement floor insulation and HR++ glass in combination with insulating frames and insulated exterior doors.

3.5 The hybrid heat pump

A Hybrid Heat Pump is usually an air-to-water heat pump that extracts heat from the outside air to produce hot water for heating the house or for hot tap water.
The heat pump runs on electricity, but the pump generates a multiple
(factor 3 – 5) of heat for the electrical energy used. However, the efficiency of the heat pump decreases when the temperature difference that the pump has to bridge increases.

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. This is shown in section 3.

$(E\_geb./m_2)_2 = (E\_geb./m_2)_1 + (E\_delta - G\_delta)/Ag$ (cf. 3)

3.6 Energy Classes

The energy consumption per square meter of a given home is classified into a number of classes that classifies the degree of energy efficiency of each home. Each property has its own value. Each class has a lower and upper limit, within which the property can be ranked, see table below.

Table 1: Residential energy classes

	Lower limit [kWh/m2]	Upper limit [kWh/m2]

[9] This analysis deals with this in a very limited way.

Energy-neutral	--	0
Paris Proof[10]	0	35
Very economical	35	55
Frugal	55	90
Average	90	140
Inefficient	140	170
Very inefficient	170	higher

3.7 CO2 emissions

Natural gas causes CO2 emissions and electricity can be generated sustainably, i.e. without CO2 emissions. That's why electrification is a good thing. More and more electricity is generated sustainably.

4. Details of the dwellings considered

Detailed information was received for 13 homes. The houses are arranged from 1 to 13. For these 13 dwellings, an energy consumption analysis was carried out in accordance with the approach of Chapter 3.
In order to be able to compare the data, the data for each variable is shown in a graph for all the houses next to each other.
Differences are expected due to the: 1. degree of insulation, having solar panels and having a (hybrid) heat pump.

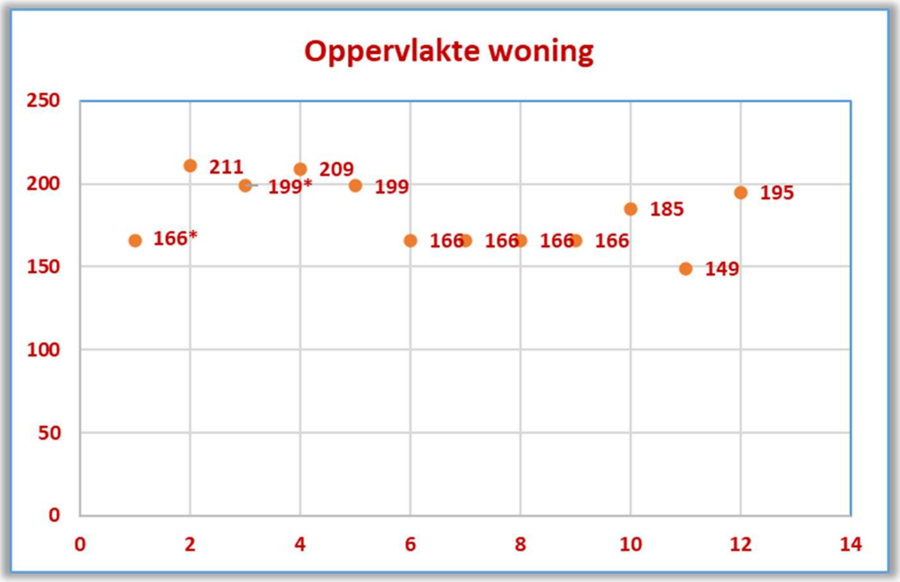
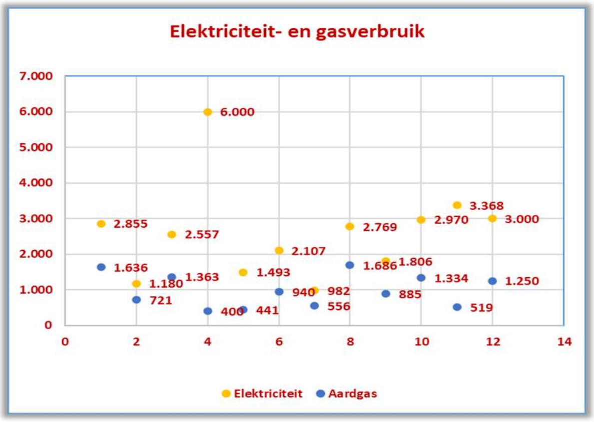


Fig. 3 Surface area of the house (stands for corner house)*

The house is a terraced house or a corner house. Depending on whether the house has a sloping roof, the living space is different. There is no discussion of modifications to the property by the owner. The surface area used for the analysis is the value recorded in the BAG register[11].

[10] 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.
[11] There is no correction for this.

4.1 Gas and electricity consumption



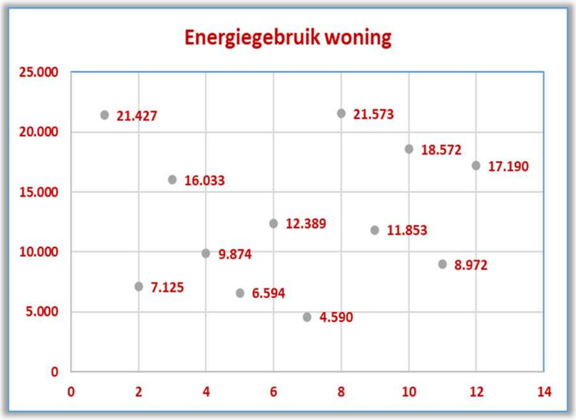


Fig 4a: Gas (m3) and electricity (kWh) (kWh)

Fig 4b: Total energy consumption

All homes consume electricity (kWh) and natural gas (m3). In Fig. 4b, both are grouped together as energy consumption of the home (kWh). The differences are obvious! Of course, we are interested in the low values.

4.2 Energy efficiency in kWh per m2

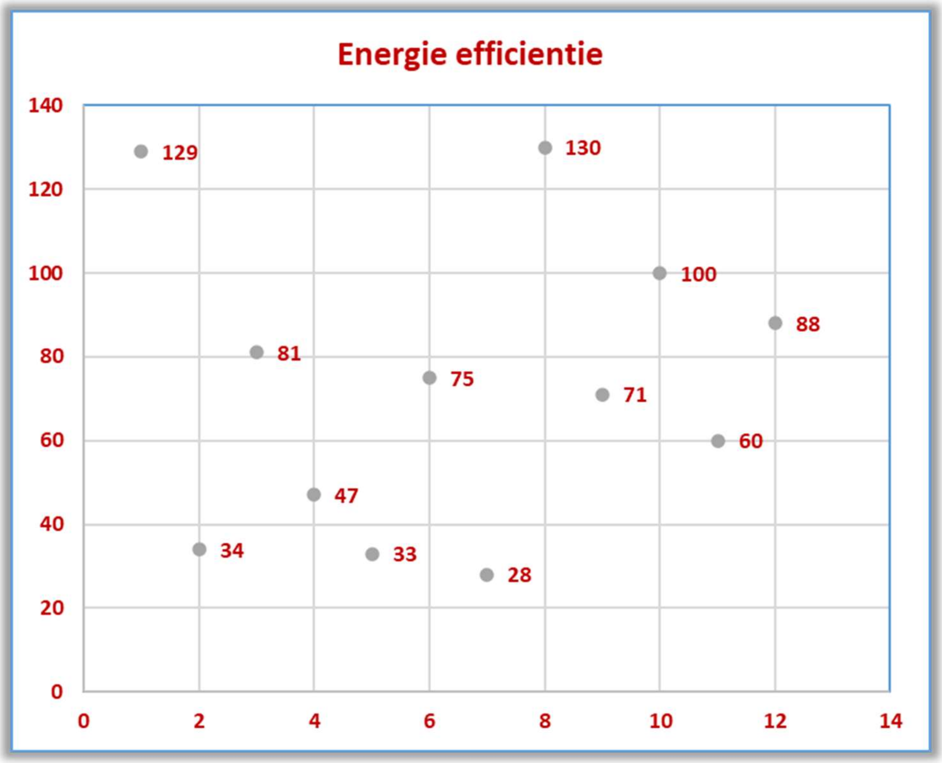


Fig. 5: Energy efficiency[12]

The image of Fig. 5 is similar to that of Fig. 4b. This is because the energy efficiency is based on the value from Fig. 4b divided by the surface area of the house.

[12] According to Verg. 1.

The energy efficiency values determine which class the house falls into. If the heating and living behaviour in the other years is similar (the same number of residents and no energy measures have been taken), then the Energy efficiency value will be almost the same every year. On the other hand, when the resident has taken an energy-saving measure, the effect on energy efficiency is visible in the following year.

Table 2: Energy classes for homes

	Class
Energy-neutral	no
Paris Proof[13]	Apartments 2, 5 and 7
Very economical	House 4
Frugal	Property 3, 6, 9, 11, 12 and 13
Average	Houses 1, 8 and 10
Inefficient	no
Very inefficient	no

The objective for a home is Paris Proof, but most homes do not yet meet this.

4.3 Gas consumption and CO2 emissions per m2

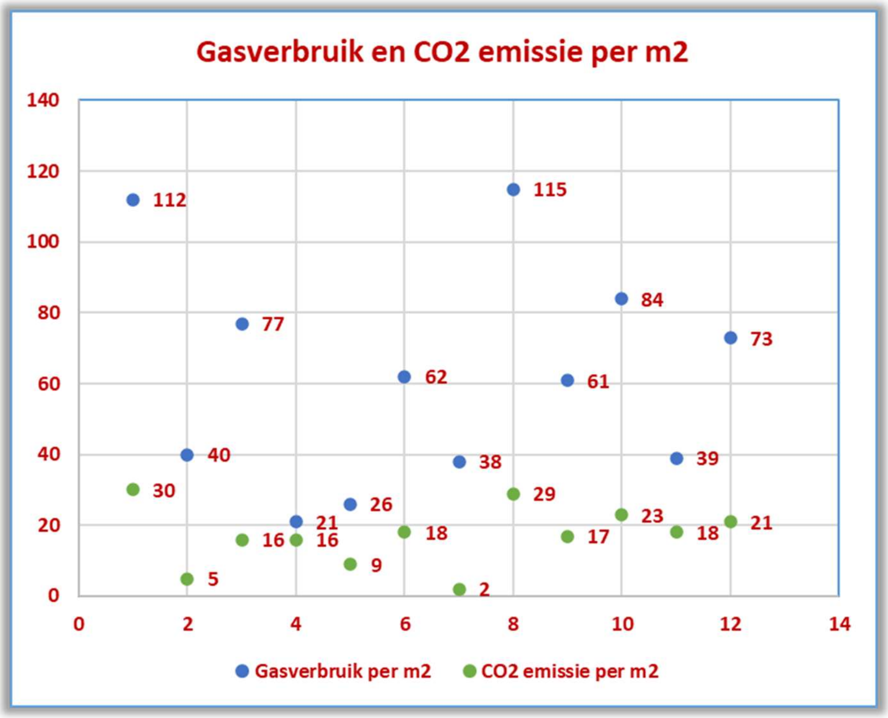


Fig. 6: Gas consumption and CO2 emissions per m2

Gas consumption is the dominant factor for the CO2 emitted.

[13] 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.

4.4 Total CO2 - emissions

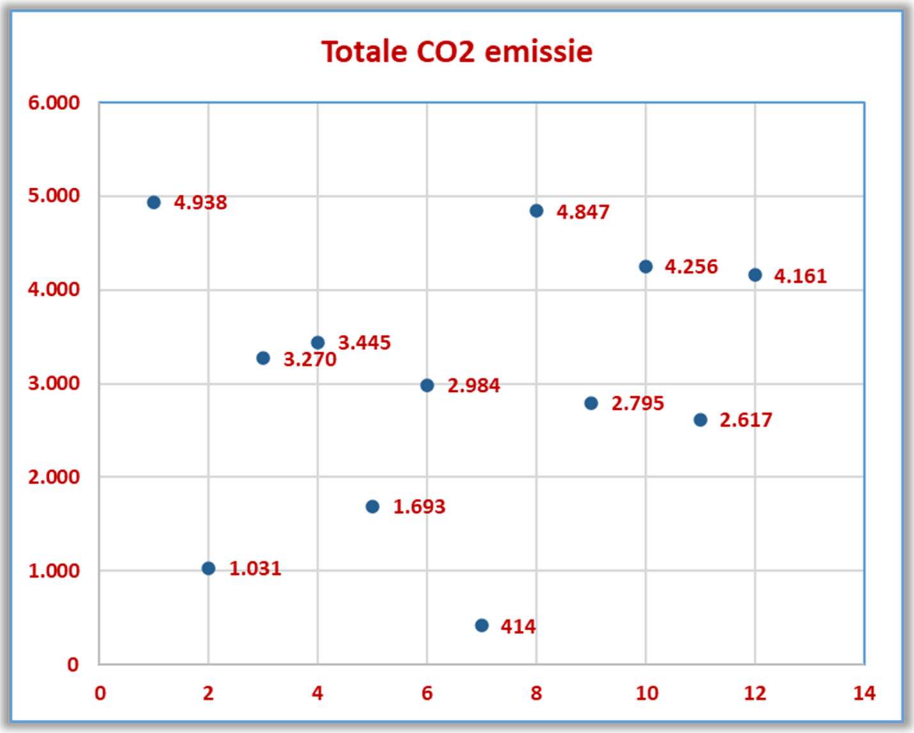


Fig. 7: Total CO2 emissions (kg)

Fig. 7, like Fig. 5, is directly correlated with the data in Fig. 4b.

5. Measures against energy consumption

The graphs in Chapter 4 show that there are large differences between the energy consumption of the houses studied.

The energy consumption of a house can already be influenced by the occupant, his heating behaviour, for example by setting a lower general temperature for the house[14], or by not heating all rooms in the house in the same ways (e.g. not heating the garage[15], bedrooms at 15 ^{o}C).

The purpose of home insulation is to reduce heat loss from the home. When there is less heat loss, the heater does not have to work as hard and gas and therefore costs are saved. Heat loss is caused by conduction loss (conduction) through the walls and windows/frames of the house to the outside, and by heat leakage due to draughts.

Cavity wall insulation will reduce gas consumption by a small percentage. The reason is that the cavity can only contain limited insulation material (cavity width). For a corner house, cavity insulation will result in more savings (larger exterior area) than for a terraced house. The cost of cavity wall insulation is also relatively low.

[14] The house will then feel less comfortable.
[15] However, frost damage can be prevented.

The best insulating glass, insulating window frames and ditto exterior doors insulate less effectively than wall insulation with PIR boards because PIR boards of sufficient thickness have a much more insulating effect. Insulating frames and exterior doors are also more expensive to purchase than wall insulation.

It should also be taken into account that new window frames and exterior doors close the house better and greatly reduce ventilation losses. In addition, with new window frames and exterior doors, the house looks much better aesthetically.

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

Insulation of the basement floor is responsible for about 10% of the heat loss of a home. Good basement insulation can be achieved in several ways and thus also contribute to reducing the heat loss of the home and thus the gas costs.

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 house. To properly insulate the house, about 10 cm of high-quality insulation (PIR boards) is needed. 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.

Solar panels offer the resident the opportunity to provide their own sustainable energy. The desired capacity of the solar panels is the electricity demand on an annual basis of the house. This comes down to the regular electricity requirement of the home and the electricity required for the heat pump. This means that there are no costs for electricity apart from the grid costs, as the excess electricity generated in the summer can be requested free of charge in the winter. Any surplus electricity will be compensated.

Solar panels do not in themselves lead to savings in the energy consumption of the home, but the resident's electricity costs are significantly reduced by self-generation.

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

With a hybrid heat pump, gas consumption can be reduced by 50–70%. The energy consumption per square metre can be significantly reduced with a heat pump.

6. The impact of measures

Table 3 provides an overview of the measures taken by the 13 residents.

	1	2	3	4	5	6	7	8	9	10	11	12	13
Zonnepanelen	0	1	1	1	0	0	1	1	0	0	1	0	0
Spouwmuurisolatie	1	1	1	1	0	0	1	0	0	0	1	1	0
Geisoleerde ramen	1	1	1	1	1	1	1	1	1	1	1	1	1
Geisoleerde kozijnen	0	0	0	1	0	0	0	0	0	0	0	1	0
Binnenisolatie	0	0	0	1	0	0	0	0	0	0	0	0	0
CV	1	1	1	1	1	1	1	1	1	1	1	1	1
HWP	0	1	0	1	0	0	0	0	0	0	1	0	0
Energie efficientie	129	34	81	47	33	75	28	130	71	100	60	88	77

Table 3: Overview of measures

It can be deduced from the data that the heating behaviour of the resident also has a strong effect on the energy efficiency of a home. However, this effect cannot (yet) be quantified with the current level of detail of the data.

A low energy efficiency value can be partly "realized" by economical heating. This is the case with house 5, for example. The residents were only partly at home in 2022 and did not use the heating for a period of time.

Cavity wall insulation is a first easy insulation step, but for terraced houses it only contributes to a limited extent to the energy efficiency of the house. Terraced houses lose little heat to the neighbours when all homes heat in a similar way.

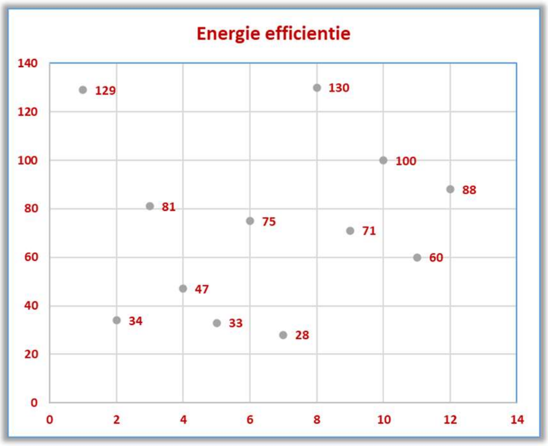
Although it is not entirely determinable, all homes use a high-efficiency boiler. The boilers will be more or less efficient depending on their age, but a difference cannot be determined.

There is one house with insulation inside, but it also uses a hybrid heat pump. All homes with a hybrid heat pump score very well on energy efficiency. When a heat pump is installed, the house must already have a certain degree of energy efficiency.

7. Conclusion

In the Voorhof district in Delft, a group of about 170 comparable uniform homes built in 1965 were compared with each other in terms of energy efficiency. A letter has been sent to 163 residents asking them to participate in this study. 18 residents responded positively and eventually 13 answers (8%) were incorporated into this report.

This amount of data may be too limited to base good reliable conclusions on. More in-depth research / analysis on heating behaviour and more detail on all insulation measures can help to create more clarity.



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House 5 is an "outlier" because the house is only heated for part of the year. The high-performing homes all have a hybrid heat pump, but that may not be enough to also have a low energy efficiency. For example, house 11 also has a hybrid heat pump, but still scores relatively high (60 kWh/m2) on energy efficiency.