Improving the energetic building performance

Renovation measures and strategies for achieving zero-energy 1960's portico-flats

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Abstract

This paper describes a research on measures and strategies for achieving a zero-energy status in the renovation of existing 1960's portico-flats. This because the total primary energy consumption of society exist for a big part of energy consumption by buildings, because the building stock in the Netherlands exist for a big part of portico-flats and because portico-flats dating from before 1975 generally have a bad energetic building performance. This research of measures for the improvement of the energetic building performance classifies these measures in three groups: measures for (1) energy reduction, (2) energy reuse and (3) sustainable energy production. These measures, based on their advantages and disadvantages, are then implemented into four scenario variables: (1) state of habitation, (2) scale of the renovation, (3) the esthetical value and (4) the extent of energy neutrality. After this, the measures are also implemented into two full scenarios, composed out of these variables. This will result in multiple technical renovation strategies. The results show reduction measures in forms of insulation, heating systems and ventilation systems, reuse measure mainly in the form of ventilation heat recovery and production measures in forms of solar-, wind-, bio-mass- and geothermal energy. The renovation strategies differ based on different scenarios.

Keywords: energy performance • energy efficiency • energy neutral • zero-energy building • renovation strategies • portico-flat • portiekflat

1. Introduction

The total primary energy consumption of society exists for approximately 40% of energy consumption by buildings (International Energy Agency). This large consumption is for a big part due to the bad energetic performance of old buildings. Especially the heating demand is high in these buildings (Balaras, Droutsa, Dascalaki, & Kontoyiannidis, 2005, p. 431). In comparison with new buildings, the energy demand of older buildings is five to twelve times bigger (European Commission). This demand is so high because most often these buildings have a poor build quality, a bad thermal insulation and insufficient heating- and ventilation systems. This is also the case in the average portico-flat[1] dwelling in the Netherlands, dating from the 1960's.

[1] The building type of the *portiekflat* is a type defined as a flat-type dwelling with usually about four stories, wherein the front doors are situated at a shared lockable stairwell, a central hall or closed

The average 1960's portico-flat in The Netherlands has a bad energy performance, namely energy label E or F (Agentschap NL, 2011, pp. 68-71). Portico-flats have a market share of approximately 12,5% of the whole building stock in the Netherlands, which corresponds with 847.000 portico-dwellings. This market share exists for nearly 70%[2] of portico-flats built before 1970 (Agentschap NL, 2011, pp. 68-77). This large amount of older portico-flats combined with their bad energy performance results in a big total energy consumption.

From December 31st 2020 forward every new build building project has to be a nearly zero-energy building, also known as a nZEB (Maldonado, 2013, p. 47). As the name suggests, these buildings are not completely energy neutral, but very close to this state wherein the annual energy consumption of the building must be equal to the amount of sustainable energy produced on the building site. This new rule shows the awareness of society on the topic of the large energy consumption by buildings and their willingness to improve this situation.

As of yet, this rule only applies to new buildings, not the existing building stock. Upgrading of the existing building stock is more complicated. This because of the different forms of ownership, different building types and different qualitative states of buildings of the building stock. Because of the building stock is more complicated than new projects it is important to look for suitable strategies and approaches for the improvement of the energetic building performance of different forms, types and states of buildings.

Finding these suitable strategies and approaches for the improvement of the energetic building performance is also important for 1960's portico-flats. Since the building type has a bad energy performance, makes up for a big part of the total building stock in the Netherlands and is very generic, finding suitable strategies would be useful for a large scale energetic renovation of these portico-flats.

Therefore, this paper focusses on the question: In what ways can an existing portico-flat, dating from 1960's, be made energy neutral, and which ways are more suitable?

To answer the main research question, sub-questions are to be answered. These sub-questions are based on a method to accomplish a sustainable building design according to Andy van den Dobbelsteen[3] (2008). The first of these steps is to reduce the energy demand of the building. The next step is the recycling of energy used in the building and the third step is the sustainable production of the energy needed for the building (Yanovshtchinsky, Huijbers, & Dobbelsteen, 2013, p. 45).

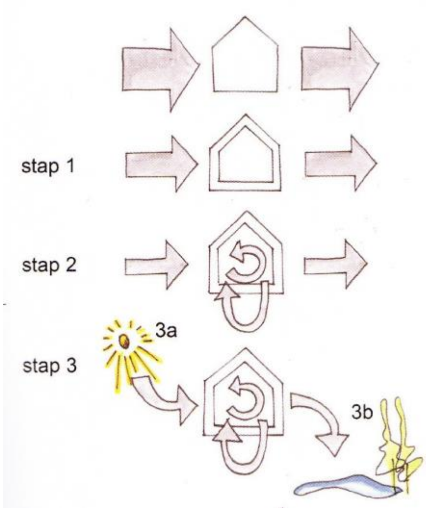

Fig. 1. Stepped strategy by van den Dobbelsteen.

portico (Dutch: *portiek*) (Vrijehuizenmarkt.nl). It is a typically Dutch typology, therefor there is no official English translation for it. Unofficial translations are: portico-housing, portico-dwellings, portiek-dwellings and portico-flat. The latter will be used in this paper.

[2] 256.000 + 267.000 + (0.5*)112.000 = 579.000 = 68,36% of the total 847.000 (Agentschap NL, 2011, pp. 68-77)

[3] Dr.ir. Andy van den Dobbelsteen is Head of the Department of Architectural Engineering and Technology at the TU Delft.

Following these steps, the sub-questions for this paper are: (1) In what ways can the energy demand of the building be reduced? (2) In what ways can the energy used in the building be re-used? (3) In what ways can the energy needed for the building be produced sustainably?

Now that the problem statement and research questions are clear, this paper will continue with the clarification of used definitions and the description of the method used in this research, followed by the results, which are the possible measures for achieving a zero energy building through renovation and suitable combinations of these fitting different scenarios, and finally the conclusion and recommendations.

2. Definitions

To answer the research question, the definition of energy neutral must first be clarified. In general, since a state wherein no energy is needed at all is not practical and hard to achieve, the most often used definition of energy neutral is a state wherein the building should produce as much energy as it uses, or a state where the building has no net primary energy consumption (Jansen & Tenpierik, 2015, p. 2). Other definitions besides 'energy neutral' as used for these kind of buildings are: zero-energy building (ZEB) (Voss, Musall, & Lichtmeß, 2011, p. 56), net zero-energy building (NZEB) and nearly zero-energy building (nZEB) (Attia, Mlecnik, & Van Loon, 2011, p. 251). These definitions are all very closely related, yet the latter one is less strict in its complete neutrality because of the cost-optimal principle (Kurnitski, 2014, p. 2). This principle is based on the fact that complete neutrality can sometimes be more expansive than nearly complete neutrality and therefore.

Besides clearer definitions of energy neutrality in general, the energy the building uses can also be defined further. It can be subdivided in multiple types of energy usages. The energy usage of a building is most often divided in the building related energy (BRE) and the user related energy (URE) (Jansen & Tenpierik, 2015, p. 1). Sometime also a third type is considered: the material related energy (MRE) (Ruuska & Häkkinen, 2014, p. 276). Measures for achieving energy neutrality described in this paper have most often effect on the building related energy. The user related energy is almost fully dependable on the user, the inhabitant. The material related energy consists of all the energy needed to produce, treat and transport the materials need for the building. This is difficult to determine for the existing part of the building, yet very possible for the new materials added to the building during the renovation. Compensating for that energy is most often done through extra sustainable energy production on sight.

3. Method

This study will be done through a mixture of literature research and reference projects analyzes. The literature is chosen based on its relevance to the improvement of the energetic building performance. The reference projects are selected based on their relevance to energy performance renovation and portico-flats in the Netherlands.

The first step of the research is the answering of the three sub-questions concerning energy reduction, -reusing and -production. The answers to these questions will come in the form of a list of possible measures to be used during an energetic building renovation. These measures are preselected before being included in this list based on their likeliness to be used in these situations and suitability for such projects. For example, the use of solar panels is very likely to be used and is very suitable for an energetic renovation of portico-flats, but the use of tidal power[4] or wave power[5] is far less probable. After this list is completed the individual measures will be analyzed for their advantages and drawbacks.

Then, after the list assembly and the measure assessment, scenarios for the circumstances of the renovation will be sketched. These scenarios will be given in the form of variables such as whether the inhabitants will stay or leave during the renovation or whether the building will be renovated per dwelling or in its whole. Four variables will be used. These are selected based on the likeliness of occurrence in actual portico-flats renovations.

After this, the variables of scenarios will be linked to the advantages and drawbacks of the measures, resulting in preferences and impossibilities for the scenarios, resulting in suitable technical approaches.

Also, besides these technical approaches based on the scenario variables, two full possible scenarios will be given. These full scenarios are composed out of the scenario variables and will resemble possible realistic full scenarios.

To finalize, conclusions and recommendations will be made about the energetic performance renovation in general, followed by a discussion of possible improvement of the research.

3. Results

The results of this research comes in two forms: the measures for aiding in the overall achieving of energy neutrality and the strategies, which are a result of combinations of these measures, there advantages and drawbacks and four scenario variables.

3.1 *Measures*

The following measures are sorted by the three stepped strategy of reduce, reuse and produce.

3.1.1 *Energy reduction*

The measures for energy reduction can be subdivided into three groups: measures for improving the insulation, the heating system and the ventilation system. A fourth group could have been incorporated into this research, the improvement of the cooling system, but cooling in dwelling buildings is most often not necessary in the Netherlands, therefor is was not concluded in this research.

Insulation

The improvement of the overall insulation layer is needed to minimize the transmission losses and infiltration losses (Yanovshtchinsky et al., 2013, p. 61) and can be done in three places of the wall: on the outer side of the existing façade, in the cavity of the façade and on the inside of the existing façade (Soes, 2014b).

The improvement of the insulation layer on the outer side will result in a completely new façade that will wrap around the existing. This will result in a different outer layer and therefore with a possible different esthetics. Advantages of this insulation placement is the high energy efficiency it generates (Soes, 2014b) and the possible use of the construction as thermal mass[6] (Yanovshtchinsky et al., 2013,

[4] Tidal power: a form of water power where energy of tides is converted to useful energy (Yanovshtchinsky et al., 2013, p. 52).

[5] Wave power: a form of water power where energy of ocean waves is converted to useful energy (Yanovshtchinsky et al., 2013, p. 52).

[6] Thermal mass: the storage of heat or cold in solid mass of the building (structure).

p. 70). Drawbacks are a high cost, the need for a planning permission (Milieucentraal.nl) and the possible loss of original façade esthetics.

Fig. 2. Placement of outside insulation on the Passive House renovation Nieuwkuijk project by KOW Architecten.

The placement of new insulation in the cavity of a wall does not change the esthetics of the outside nor the inside of the façade. This, together with the lowest costs, are its main benefits. A disadvantage is the limited thickens of the insulation of about 8cm, the size of the average cavity (Soes, 2014b).

Fig. 3. Placement method of cavity insulation.

The placement of insulation on the inside of an existing wall is also known as the box-in-a-box principle (AgentschapNL, 2010a). The strengths of this method are the small scale that it can be used on and no losses of external buildings esthetics. The weaknesses however are the impossibility to use the existing structure for its thermal mass, a bigger chance of occurrence of humidity problems and the relatively high costs (Soes, 2014b).

Beside the closed façade parts, the openings in the façade play an important part in the total heat insulation as well. Mainly the material choices for the window frames material and the quality of the window panes itself determine the energy efficiency of the façade openings.

The three primarily used materials for window frames are wood, steel and aluminum and vinyl or other synthetic materials (Bennema, 2015c). The synthetic materials have the best energy performance and are relatively cheap (Bennema, 2015d), yet the esthetics are commonly favored less. Aluminum frames have the second best insulation and have been improving over the last years (Yanovshtchinsky et al., 2013, p. 75). They are relatively strong and can hold bigger window panes than synthetic frames (Bennema, 2015a), but are also about 20% more expensive than synthetic ones (Bennema, 2015d). Wooden frames have a cost that sits between synthetic and aluminum frames and are easily treatable, yet their insulation value is lower (Bennema, 2015b). Steel window frames have been improved to a good insulation value (Yanovshtchinsky et al., 2013, p. 75), yet they are heavy and cost even 20% more than aluminum frames (Bennema, 2015e).

Placed inside these frames are the window panes, with two primarily used types for high efficiency insulation: double glazed HR++ windows and triple glazer HR+++ windows (Bouwteam Energiebesparing). These window types come in different variants, using different panel coatings and different noble gasses or a vacuum in between glass panels, but the overall essence of HR-glass stays the same. The advantage of HR++ glass is the fact that it costs only slightly more than HR+ glass, yet its insulation value is significantly higher. HR+++ glass has an even better insulation value, yet the costs are significantly higher than HR++ (Soes, 2015a), where the insulation value is only slightly higher (Bouwteam Energiebesparing). Also, HR+++ restricts the amount of natural sun heat to enter, which results in less passive heating (Soes, 2015b).

Besides façade insulation also floors and roofs can get insulation improvements. Roof insulation has a bigger impact on the total energy consumption of a building than floor insulation, because of a larger temperature difference between inside and outside air. With floor, most often the improvement is done through the insulation of the crawl space (Soes, 2014c). With roofs, the insulation can be applied on top, or beneath the roof structure (Soes, 2014a). Since roof structures are most often lightweight, the effect of thermal mass does not apply.

Heating

The improvement of the heating system is often needed to lower the energy needed for the heating of a building. This can be done with both passive and active systems (Yanovshtchinsky et al., 2013, pp. 66-70, 87-138).

Passive heating is primarily done through the use of natural sunlight. The use of the sun heat in the winter, through smart function placement[7] and south facing glazing, and blocking the sun heat in the summer, through sun shading, is the essence of passive heating. Also the possibility to store heat in the building mass, as mentioned before, can help the passive heating (Yanovshtchinsky et al., 2013, pp. 66-70).

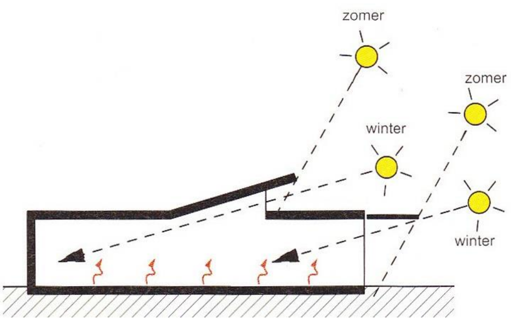

Fig. 4. Passive heating and solar shading principle.

The improvement of the active heating system can be done through the use of many different measures. The simplest measure would be the improvement of the central heating boiler, upgrading it to a high efficiency boiler (Somedjo, 2015). This systems, however, uses high temperature water. This uses a lot of energy. Therefor low temperature heating (LTH) systems are an improvement. The most commonly used low temperature heating system is floor heating (Yanovshtchinsky et al., 2013, p. 128), which is very suitable for dwellings (Yanovshtchinsky et al., 2013, p. 87). The relatively high acquisition costs the system has will compensated by the costs saved by the lower energy consumption (Vloer & verwarming.nl, 2014a).

With floor heating two primary types are used: a heavy wet construction system and a light dry construction system. The former system uses heating pipes poured in concrete. This system is used in most cases and is relatively cheaper (Vloer & verwarming.nl, 2014b). Disadvantages of this system are the longer duration for the actual heating to occur in the rooms and a bigger floor depth needed.

The dry construction system is not poured over with concrete and therefore heats the room more quickly. The systems also need less floor depth which make it very useful for existing buildings (Yanovshtchinsky et al., 2013, pp. 128-129). The main drawback of the system is the relatively higher cost (Vloer & verwarming.nl, 2014b). In the *ENDIS portiekflat renovatie* renovation method for portico-flats, a method developed by the cooperation ENDIS focusing on the energy neutral renovation through a total façade renewal, floor heating is also the favored heating system. Mainly for its

[7] Smart function placement: for example, the living room facing the south and bedrooms facing the north. This way, functions that need the heat the most will benefit from the natural sunlight the most.

low temperature heating properties (ENDIS, 2011).

Ventilation

The improvement of the ventilation system is often needed to minimalize the loss of heat through ventilation. This, like heating, can be done with both passive (Yanovshtchinsky et al., 2013, pp. 150-164) and active measures (Yanovshtchinsky et al., 2013, pp. 165-176).

Passive ventilation measures or often not based on minimalizing the heat losses through ventilation, but on the exclusion of the energy used in ventilation systems themselves.

Passive ventilation can have two different natural driving forces: wind and the stack effect. Passive ventilation driven by wind is simply done through opening a window or two opposing windows. Passive ventilation driven by the stack effect is based on the movement of air as a result of thermal buoyancy, using mainly temperature differences and high open spaces to create natural under pressures which creates natural intake of ventilation air (Macquoy, 2014, p. 2).

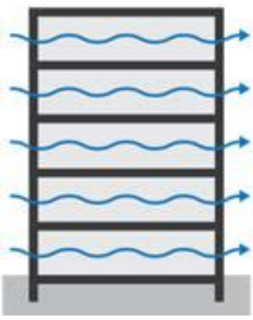

Fig. 5. Cross ventilation as most masic form of wind driven passive ventilation.

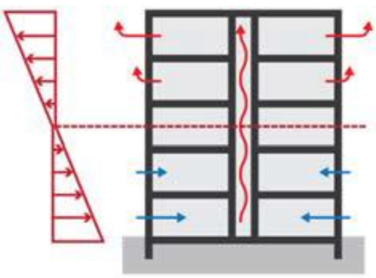

Fig. 6. The stack effect ventilation principle.

The energy reduction of a building through active ventilation systems in most often based on the principle of heat recovery. Since this is a form of energy reuse, these measures will be explained in the next paragraph: energy reuse. Apart from heat recovery ventilation a ventilation measure that reduces the energy demand is the use of CO_2 driven ventilation vents. The advantage of these ventilation vents over regular ventilation vents is that there is only an air intake from outside, when there is need for it. CO_2-sensors in the dwelling make sure that there is an adequate ventilation load. These sensors are also the main drawback of the systems, because of their high costs (Yanovshtchinsky et al., 2013, pp. 168-170).

3.1.2 *Energy reuse*

The reuse of energy within a dwelling can primarily be done through the use of the building related energy and the user related energy.

Building related energy

The main form of energy reuse of building related energy is the heat recovery in active ventilation systems. This is for example the case with balanced mechanical ventilation. With these systems both the intake and the outlet of air is done mechanically. The intake of fresh cold air and the outlet of warm CO_2-rich air pass there heat and cold through a heat exchanger (Yanovshtchinsky et al., 2013, pp. 171-173). Beside this advantage of heat recovery, these systems also have drawbacks. Firstly, since the intake of air is done mechanically most often windows cannot be opened. This may feel unpleasant for inhabitants (Pieters, 2012, pp. 67-68). Secondly, when these systems are installed or controlled incorrectly, they can take polluted air back into the dwelling, with possible health risk for the inhabitants. This was the case in a lot of new build housing in the neighborhood Vathorst in Amersfoort in the Netherlands, which led to a lot of negative publicity (Hendriks, 2009).

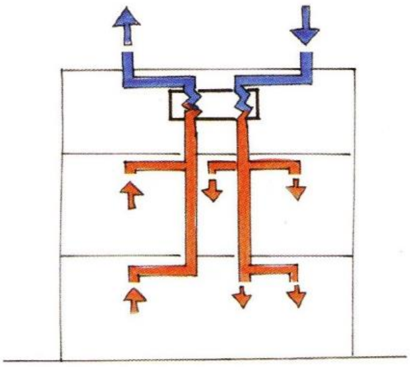

Fig. 7. Balanced ventilation system principles with heat recovery.

Another ventilation system with heat recovery is the breathing window (Kristinsson & Dobbelsteen, 2012, pp. 77-85). This I not a centralized system as the balanced mechanical ventilation is, but a system that primarily supplies the ventilation air per individual room. The system heats, cools and ventilates the room through a unit placed in the façade. It uses a fine-wire heat exchanger (fiwihex) for the heat recovery. The benefits of this systems are the high efficiency heat recovery and ability to climatize each room separately. Disadvantages are the limited capacity and the fact that is can only be used in rooms adjacent to outside air (Yanovshtchinsky et al., 2013, pp. 165-166).

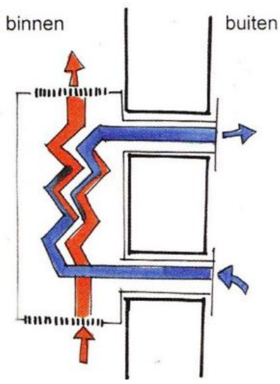

Fig. 8. Breathing window ventilation principle with heat recovery.

<u>*User related energy*</u>

The energy reuse of user related energy will mostly come through measures such as a heat recovery shower. This is a build-in system that uses the use warm showering water to preheat new showering water (Yanovshtchinsky et al., 2013, pp. 104-106). This idea could also be applied to washing machines and dishwashers.

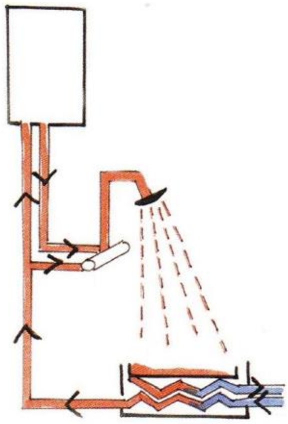

Fig. 9. Heat recovery shower principle.

3.1.3 *Sustainable energy production*

The four most practical ways of sustainable energy production for renovated 1960's portico-flats are solar energy, wind energy, bio mass energy and geothermal heating and storage.

<u>*Solar energy*</u>

Solar energy is one the most commonly known forms of sustainable energy. It can be used to generate electricity through the use of photovoltaic cells (PC-cells) and it can be used to generate warm water through the use of solar thermal collectors (Yanovshtchinsky et al., 2013, pp. 232-234). The main advantage is the sun as inexhaustible source. Drawbacks of solar energy are the relatively low efficiency of the panels and the dependability on the sunshine hours (Conserve Energy Future).

<u>*Wind energy*</u>

Wind energy is another commonly known form of sustainable energy. The most frequent use of wind energy is through the use of larger wind turbines. Smaller scale wind turbines have a lower efficiency and more drawbacks. They are very site specific and are very dependable on a single wind direction. Turbulent air decreases their efficiency drastically (Boxwell, 2015).

Bio mass energy

Bio mass energy is produced through the burning, fermentation or gasification of organic materials such as wood, vegetable oil or manure. Its advantages are the use of renewable sources and a smaller carbon footprint in comparison with fossil fuels (Milieucentraal.nl). Its drawbacks are its labor intensity and the need for storage and processing space and transport of the bio mass itself (Yanovshtchinsky et al., 2013, pp. 237-239).

Geothermal energy

Geothermal energy, also known as soil energy (Kristinsson & Dobbelsteen, 2012, p. 103), is a form of heat and cold production and storage in the ground. The constant ground temperature is used to pre-heat or cool water or to store warm or cold water in, which is later pumped back into the building. Mainly three forms of this system are used: an open system, a closed system and a shallow horizontal system (Kristinsson & Dobbelsteen, 2012, p. 104; Yanovshtchinsky et al., 2013, p. 100).

An open system is based on tubes in the ground connected to an open ground water layer, or aquifer. Drawbacks of this system are the fact that it needs two aquifers of at least 150 meter apart, the possible need to perforate clay layers in the ground and a minimum of $2000m^2$ to make the system profitable (BodemenergieNL, 2012; Kristinsson & Dobbelsteen, 2012, p. 104; Yanovshtchinsky et al., 2013, pp. 100-101).

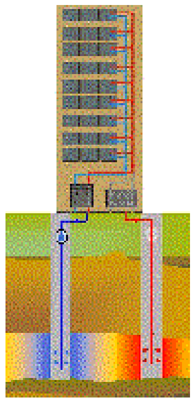

Fig. 7. Principle of geothermal open system making use of two aquifers.

The closed system, also known as vertical heat exchangers (BodemenergieNL, 2012), is based on closed tubes in which water runs through. The temperature of the soil than cools or pre-heats the water that runs through. An advantages of this system is a minimum of one household to make it profitable. The main drawbacks of this system is the need of added anti-freeze and the possibility of it to leak into the ground (BodemenergieNL, 2012; Kristinsson & Dobbelsteen, 2012, p. 104; Yanovshtchinsky et al., 2013, pp. 102-104).

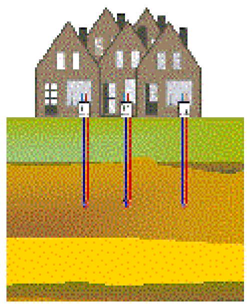

Fig. 8. Principle of geothermal closed system.

As third and final system of geothermal energy for sustainable energy production is the system of shallow horizontal pipes or tubes. These tubes are put underground approximately one meter, spread over a surface of several dozen square meters. These pipes can be used to pre-heat of pre-cool water or ventilation air. Drawbacks of this system are the fact that additional heating is necessary and that the efficiency and total profit are lower than the systems deeper underground (Kristinsson & Dobbelsteen, 2012, pp. 103-104).

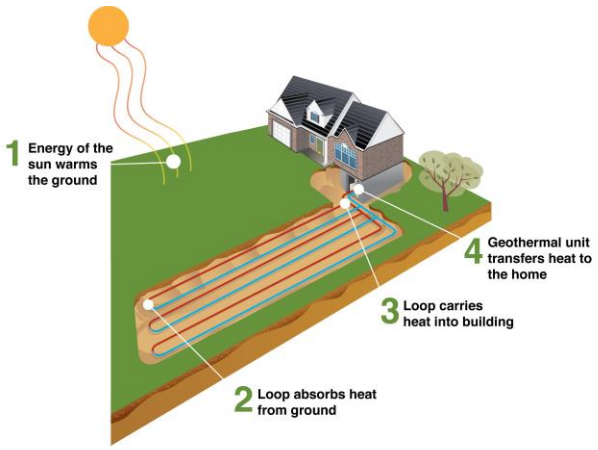

Fig. 9. Principle of geothermal heating system of shallow horizontal field of pipes or tubes.

3.2 *Scenarios*

Now that the measures for energy reduction, reusing and production are formulated the scenarios for the circumstances of the renovation in the form of variables can be determined.

3.2.1 *Scenario variables*

This research uses four scenario variables, with all two forms, resulting in eight individual scenario possibilities.

The first variable concerns the inhabitants of the portico-flat that is to be renovated. The two forms of this variable are that the inhabitants can stay in their homes during the renovation or that they leave, with completely empty dwellings as a result.

The second variable concerns the size of the renovation. The can renovation can either be done as a whole building or per individual dwelling.

The third variable is about the outer esthetics of the building. Even though 1960's portico-flat usually don't have historical or esthetical value, it is possible that this occurs. The two forms of this variable are either an esthetically valued faced or one that is not.

The last variable is about the choice between a zero-energy building (ZEB) of nearly zero-energy building (nZEB). This because the achievement of a ZEB is most often expensive (Becchio, Fabrizio, Monetti, & Filippi, 2014). This is therefore also the reason that the rules of the European Union to achieve a better energy performance in new buildings in 2020 (Maldonado, 2013) are formulated with nZEB's instead of ZEB's.

3.2.2 *Technical strategies*

The technical approaches determined per every form of the four variables resulting eight technical approaches.

Inhabitants stay

To reduce the energy demand of the building, if the inhabitants stay, applying insulation in the inside is nearly impossible. The application on the outside or in the cavity is more practical. The improvement of the heating system can easily be done through the upgrading of the boiler to a high efficiency boiler. The placement van floor heating is very impractical if the dwellings stay inhabited. Small ventilation system improvements can be done through placing CO_2 controlled ventilation vents. Bigger ventilation system improvements, like the application of a mechanical balanced ventilation system can possibly be done, but will create a lot of nuisance for the inhabitants, which makes very unlikely to be applied.

The energy reuse of user related energy could very well be accomplish trough upgrading the shower to a heat recovery shower. Though, the inhabitants would have to shower somewhere else for a couple of days.

The fact that the dwellings stay inhabited has no consequences for the energy production. Solar-, wind-, bio mass- and geothermal energy are all possible, yet the inhabitants could experience sound hindrance.

Inhabitants leave

If the inhabitants would leave the building, there will be no limitations on the possibilities for energy reduction. Also the energy reuse could be achieved through a total new ventilation system with heat recovery. The energy production also would not have any limitations.

Renovation as a whole building

In a situation where the building would be renovated as a whole the energy reduction through insulation would have no impossibilities. The insulation on the outside of the façade, though, would be preferable due to the lower total costs. Also new heating and ventilation systems would have no restrictions. Also the energy reuse and produce measures would have no limitations. Dependable on the size of the building, even geothermal heating with an open system could be profitable.

The *Lienaertsstraat appartments* project by *Frencken-Scholl Architecten* is good example of a building that is renovated as a whole building at once. This resulted in the possibility to incorporate a collective heat production system which makes use of waste ventilation heat from all the dwellings, solar thermal collectors, central heat storage, low temperature heating, passive heating and backup high efficiency boilers (AgentschapNL, 2004).

Renovation per dwelling

When a portico-flat would be renovated per dwelling, new insulation on the outside or in the cavity would be unpractical, therefore leaving a box-in-a-box principle highly preferable. For the heating system, in theory no measures are impossible, for every dwelling can install its on heating system. Yet in reality heating systems are often linked to one another leaving not all central building heating system measures probable. A heating system in which the dwelling completely functions on its own is the breathing window system, which would fit this scenarios variable. This system would also function as the ventilation system, fit for individual dwellings. This would at the same time be a fitting measure for energy reuse. The energy production would face the biggest difficulties in this scenario variable. Depending on the place of the dwelling in the portico-flat, different measures would be preferable. A top floor dwelling, with roof surface, could make use of solar panels, where ground floor dwellings could possibly make use of a closed geothermal system. For floors in-between, solar panels on the façade or a small scale bio mass heater could be a practical option.

High esthetic value of façade

For a building with high façade esthetics or even historical, monumental value one of the obvious priorities is the preservation of the outer façade esthetics. This would result in a box-in-a-box insulation principle and no new heating of ventilation systems in the façade, like a breathing window.

A project where the outside esthetics played a vital role in the renovation design is the *De Koningsvrouwen van Landlust* project by *Archivolt architecten*. Since the building, dating from the 1930's, was listed as a monument, but an energetic improvement was necessary, a box-in-a-box insulation was a fitting solution. Beside this, the project also incorporated passive heating, bio-mass heating, PV-cells and geothermal storage (AgentschapNL, 2010a).

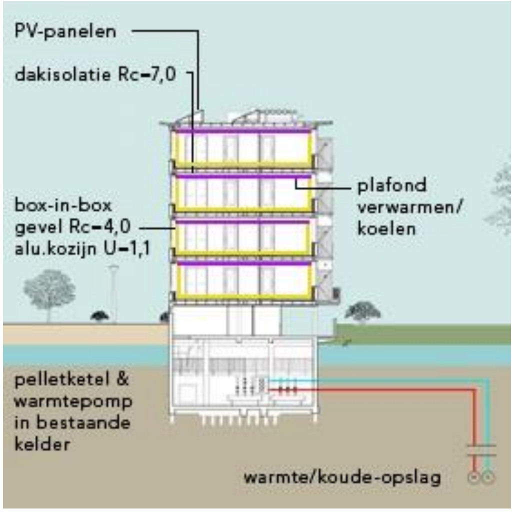

Fig. 10. The energetic renovation principles of the De Koningsvrouwen van Landlust *project by* Archivolt architecten.

Beside these simple measures for an esthetically valuable buildings, it must be said that historical, monumental buildings, often listed as monuments, heritage renovation rules would have to be applied. These rules are far more extensive and strict than the measures as put forward in this paper.

Low esthetic value of façade

A building with a low façade esthetics has no clear limitations like the buildings that do have them. This does not mean that these buildings do not have preferable measures. An outside insulation renovation would at the same time give the opportunity for an esthetic improvement.

This was the case with the project *Passive House renovation Nieuwkuijk* by *KOW Architecten*. This renovation project turned a 1960's two floored portico-dwelling into Passive House dwellings, thus improving both the esthetics and the energetic performance of the building. Another measure used in this project was a balanced ventilation system with heat recovery (AgentschapNL, 2011).

Fig. 11. The new outer facade esthetics of the Passive House renovation Nieuwkuijk *project by* KOW Architecten.

ZEB

If a Zero-Energy Building is the goal, during a building renovation, the choices are often simple: choose the measures that benefit the energy performance the most. The insulation could best be place on the outside, resulting in the possibility to use the existing structure as thermal mass. The façade openings would be filled with synthetic frames and HR+++ glazing. The heating system could make use of passive heating and low temperature floor heating. The ventilation system would require heat recovery, most likely resulting in a balanced ventilation system. Measures like the heat recovery shower would also be implemented. The energy production for the dwellings could be done using solar panels, solar thermal collectors and geothermal heat production and storage. All these measures would benefit the energetic performance, but would also likely result in higher renovation costs.

nZEB

With a nearly Zero-Energy Building as a goal during the renovation, the focus lies on the balance between energetic performance and investment costs. The insulation would preferably be placed on the outside of the façade, due to the lower costs. Also HR++

glazing would be preferred over HR+++, because of the lower costs and only little difference in performance. The heating system could be upgraded to a low temperature heating system using the existing radiators. The ventilation system would likely be upgraded with CO_2 controlled vents, leaving out big system replacements. The energy production would possibly be managed with the use of PV-cells and a high efficiency boiler.

A project where the focus was on the balance between energy performance and investment costs is the *Stedenwijk midden* project by Ymere. In this project multiple dwelling types, including portico-flats, got an upgrade from energy label E to energy label A, using small measures such as improved insulation, HR++ glazing, self-regulating ventilation vents and PV-cells (AgentschapNL, 2010b).

Fig. 12. Some of the smaller measures for an improved energy performance are visible in parts of the Stedenwijk midden *by* Ymere. *Especially all PC-cells.*

3.2.3 *Full scenarios*

Two full scenarios as chosen for this research are composed of the four variables. The first full scenario is a renovation where the inhabitants leave, the building is renovated per dwelling, the façade has low esthetic value and the goal is a nZEB. The second full scenario is a renovation where the inhabitants stay, the building is renovated as a whole, the façade has low esthetic value and the goal is a ZEB.

Both full scenarios have the variable of outside esthetics set on low. This because firstly 1960's portico-flats mostly have low outer esthetics and secondly, as mentioned before, if a building renovation would incorporate a historical monumental façade, heritage renovation rules would have to be applied, resulting in far more extensive and strict rules than the measures as presented in this paper.

Scenario 1: Leave, one dwelling, low, nZEB

The favored technical approach for this scenario would consist of insulation in the form of a box-in-a-box principle, even though this is more expensive than outside insulation and thus possibly less fit for an nZEB approach. Other forms of energy reduction through insulation improvement would be HR++ glazing and synthetic window frames. Balancing between the investment costs and possibilities for an individual dwelling would possibly result in the choice for a small bio-mass heater and CO_2 controlled ventilation vents above the windows. A drawback of a small bio-mass heater would be the fact that it would be a single heating point, instead of multiple, which is the case with common radiator heating. A small personal high efficiency boiler could function as a back-up heating system, combined with the radiators. This could also possibly be a primary heating system. Besides these reduction measures, a heat recovery shower could functions as a reuse measure. The choice of energy production would be dependable on the place of the dwelling in the building, resulting in a choice between solar panels and possibly a geothermal system. All these measures would fit with a scenario of a renovation per dwelling with no esthetic value and no inhabitants, while maintaining a good balance between costs and energy performance.

Scenario 2: Stay, whole building, low, ZEB

A scenario where a total building renovation of an inhabited building with low esthetic value and a ZEB as a goal will most likely result in a total new building layer, wrapped around the existing building. This layer could host the insulation, heating and ventilation, in the forms of an outside insulation layer with HR+++ glass and breathing window units for every room. This new façade would then have the functions of both energy reduction and energy reuse. The energy production could possibly be done through solar panels on the roof which would support the breathing windows.

4. Conclusions & recommendations

4.1 Conclusions

To repeat, the research question of this research is: In what ways can an existing portico-flat, dating from 1960's, be made energy neutral, and which ways are more suitable? Results of this research as answers to three sub-questions, concerning the energy reduction, energy reuse and sustainable energy production have given a list of possible measures. The reduction measures can be categorized in insulation-, heating- and ventilation measures. The reuse measures can be categorized in mainly ventilation measures and minor URE measures. The production measures can be categorized in solar energy-, wind energy-, bio-mass energy- and geothermal energy measures. These measures together form the answer to the first half of the research question. Also, though these measures are labeled as energy neutral, it depends on the used definition of energy neutral, the combination with other measures and whether these measures are part of a self-supporting system or connected to the national electrical grid, whether one could speak of energy neutral or not.

With regard to the second half of the research question, concerning the degree of suitability of these measures, the results show that the suitability is dependable on the circumstances of the renovation. The technical approaches, as a composition of selected measures, based on different circumstances, can differ a lot. Due to this, there is no single answer to this question.

Despite that no single answer can be given, three general conclusions can be made concerning the measures and technical approaches as presented in this paper. The first general conclusion is an overall better suitability of solar energy, geothermal energy and bios-mass energy for portico-flat dwellings than wind energy. Secondly, the energy reuse of the BRE is almost completely limited to heat recovery out of ventilation air and used water. Thirdly, renovation scenarios with an uninhabited building and a renovation per whole building are preferable, because an inhabited building and a renovation per dwelling have multiple drawbacks, which limits the use of multiple measures.

4.2 Limitations & recommendations

In this research the presented measures as a means for the improvement of the energetic building performance have been pre-selected based on their possible suitability. This was done to be able to have a focus in the research, but at the same time this could be a limitation to the research for it could possibly have counted out possible measures beforehand. A possible new research on this topic could possibly benefit from a larger amount of possible measures. This can also be said about the determined scenario variables and the following full scenarios. These scenario variables have been chosen based on their likeliness to appear in a portico-flat renovation and also make a more focused research possible. A possible new research on this topic could also possibly incorporated more scenario variables and full scenarios.

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