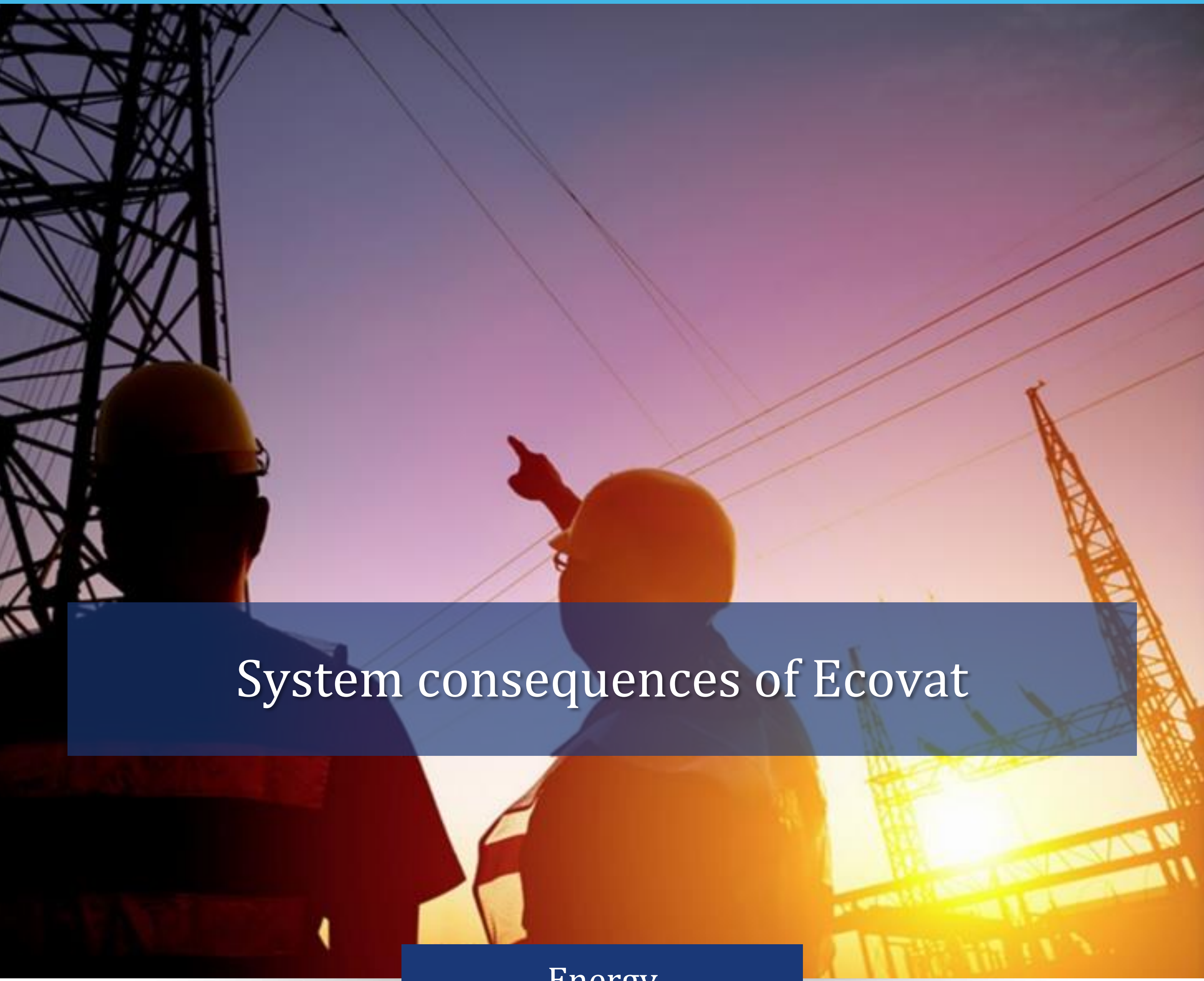

System consequences of Ecovat

Energy

Quantification of costs for grid reinforcement and peaker plants

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Berenschot

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Contents

1. Introduction and background

1.1 Introduction

For various reasons, the heating of 90% of the households in the Netherlands using central heating boilers is not sustainable in the long term. For example, through the Paris Agreement, the Netherlands has committed itself to a CO_2-reduction of 80-95%. In addition to this, with a view to the issues around earthquakes, a stop to the production of low-calorific natural gas has been announced. Both of these prompt a need for a heating transition, where households in the Netherlands will be heated in a fundamentally different way. A number of different technologies are available for a low-CO_2 provision of heating.

These technologies are currently being considered in climate negotiations, which must lead to an integral climate agreement for the Netherlands. Predominantly, all-electric solutions feature strongly, such as Zero-Energy Homes and fully-electric heat pumps. This type of solution places a high demand on the electricity system in use; in a week without wind during winter, a large capacity from peaker plants will be required to secure the supply of electricity and the LV distribution network will need to be relied upon much more. Ecovat offers an alternative supply chain, based on thermal seasonal storage and 100% CO_2 free sources such as solar thermia and wind power. Thermal storage in an Ecovat implies that there is no demand on the electricity system which leads to grid reinforcement or peaker plants. This results in a costs reduction for the energy infrastructure of the Netherlands.

Currently, costs of the electricity system are carried indirectly by society; grid reinforcement and peaker plants are constructed, socialised and, with that, paid for by all users. In addition, the use of grey flex within sustainable initiatives is not taxed. Because of this, the fact that this solution is 100% green at system level does not directly show as a gain when preparing the business case of the supply as envisaged by Ecovat. However, it is indeed the case that, macroeconomically, the costs of energy transition are reduced by the avoiding system costs, and for that reason this should be taken into account as a gain. This exercise aims to quantify this factor in the business case.

1.2 Objective and scope

The objective of this project is to quantify the avoided system costs due to the use of Ecovats. This pertains specifically to costs of grid reinforcement and peaker plants. Other technical system matters, e.g. fuel costs, are out of scope of this project, because these are heavily affected by assumed price scenarios. The fuel consumption level for the power plants is indeed identified. The results are such that they can be used in the preparation of the total business case.

1.3 Method and reading guide

The method used to establish the avoided grid costs is based on a scenario exploration using the open source Energy Transition Model (ETM) by Quintel. The scenario exploration report entitled *Richting 2050: systeemkeuzes en afhankelijkheden in de energietransitie* was used as a basis for his. The following four steps have resulted in the avoided system costs:

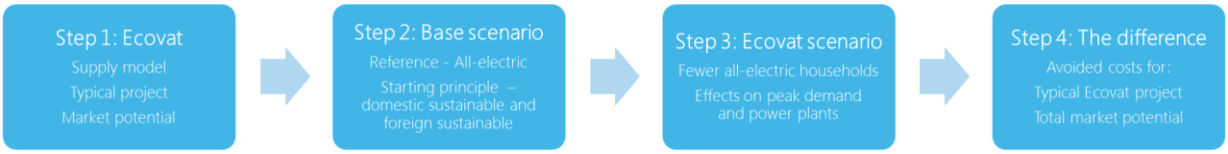

Figure 1 - Method to establish the avoided system costs of the Ecovat

- Step 1: Ecovat; In this step, the relevant information concerning Ecovats is identified, such as the operating principle of the supply model, the dimensions of an example Ecovat project and the total market potential of Ecovats. Results are presented in chapter 2.
- Step 2: Base scenario. We use the scenarios ‘Domestic Sustainable’ [*Binnenlands duurzaam*] and ‘Foreign Sustainable’ [*Buitenlands duurzaam*] from the above-mentioned exploration, with an all-electric heat supply in the built environment. Principles are described in paragraph 3.1.
- Step 3: Ecovat scenario. Here, we assume that the total market potential for Ecovats is used to replace all-electric heat pumps. These principles are also described paragraph 3.1.
- Step 4: The system consequences of Ecovats follow from a comparison between the two scenarios mentioned above. Ultimately, this is expressed in the avoided costs of grid reinforcement and peaker plants. Results are presented in paragraphs 3.2 and 3.3.

In chapters 4 – Discussion - and 5 – Conclusion and recommendations – the results are discussed further in light of the energy transition.

2. An Introduction to Ecovat

2.1 Operating principle of the supply chain

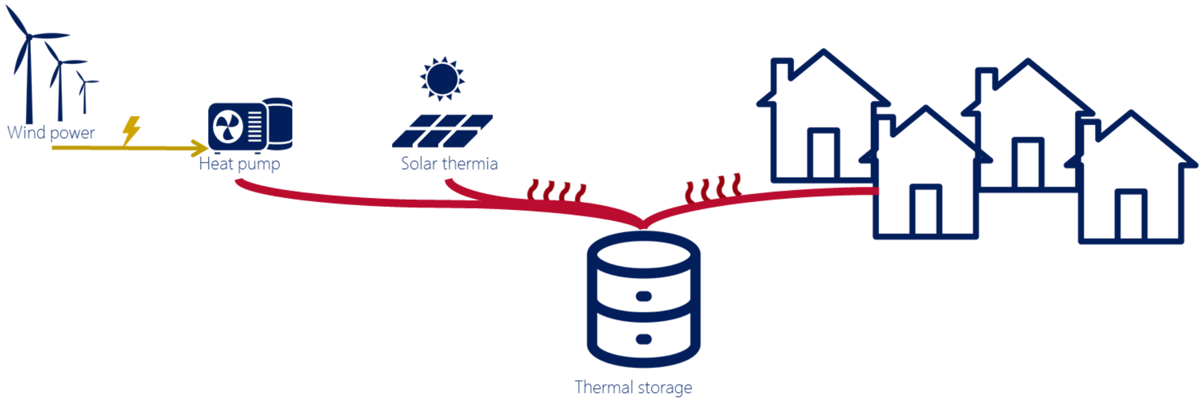

Figure 2 - Operating principle of the Ecovat supply chain

The supply chain of the Ecovat principle is depicted above. It is comprised of the following components:

- **Production;** Half of the thermal energy is produced by solar thermal panels. These can either be located on the residential building or in nearby solar fields. The other half of thermal energy is produced by a heat pump, which follows the supply pattern of wind power. This means that it is certain that this is 100% sustainable power. This leads to 100% sustainable thermal energy.
- **Thermal energy storage;** The supply of thermal energy is intermittent and the demand for thermal energy is also weather dependent. As such, a demand for seasonal storage exists, which, in practice, is allowed to be approximately 2.5 times smaller than the thermal energy supplied. This storage is provided by a large underground thermal energy storage: the Ecovat. Because the solar thermia supplies the thermal energy at a high temperature, the Ecovat is heated to 90 degrees.
- **Usage;** The thermal energy is used in dwellings. For new builds, underfloor heating is the delivery system. In the case of renovation purposes, a label class shift to Class B, preferably with underfloor heating or low-temperature radiators. Radical measures such as carbon-neutral insulation and the installation of underfloor heating are not needed.

2.2 Ecovat within the energy system

In the comparison with an all-electric solution, an Ecovat influences the energy system at various levels:

- **Decentral production;** Much more energy is generated decentrally through the use of solar thermia and wind energy (preferably locally) as sources. Here, solar thermia does not place a demand on the electricity grid, in contrast with solar PV.
- **Lower peak demand of electricity;** In an all-electric scenario, peak electricity demand follows peak heating demand. By using the Ecovat, electricity demand is disconnected from heating demand, which leads to a lower peak demand. The electricity grid is dimensioned on this peak demand, as a result of which the Ecovat leads to reduced grid reinforcement.
- **Less need for back-up power plants.** In the case of an all-electric scenario, there is an electricity demand at the moment when no electricity is supplied by solar and wind energy. This causes a demand for natural gas or hydrogen-fuelled back-up power plants. These power plants are operative a limited number of hours per year, as a result of which this is a relatively expensive investment.

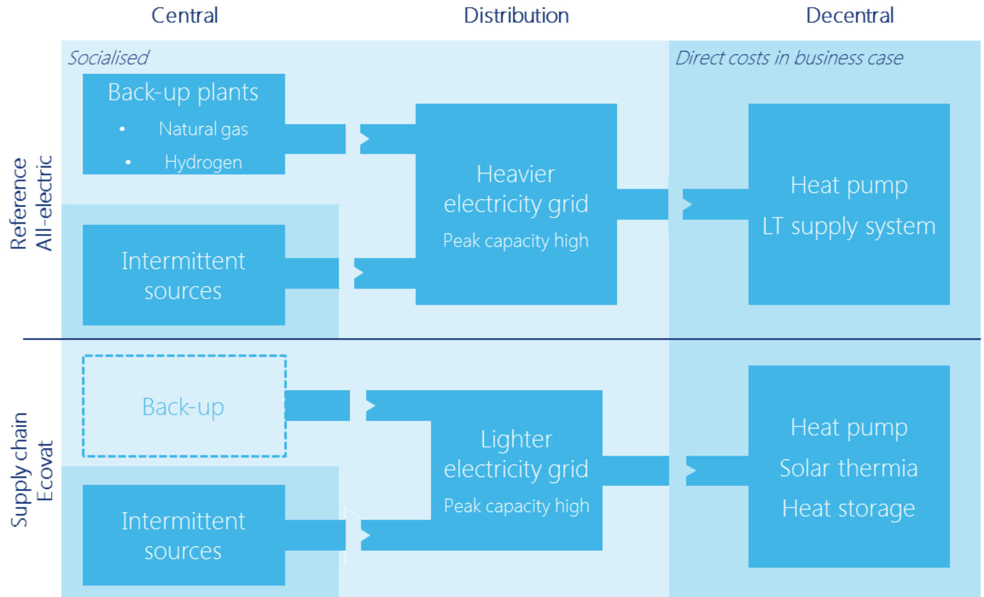

Figure 3 - Impact of Ecovat on the energy system

2.3 Example Ecovat project

For the purpose of this project we have defined an 'example Ecovat project', in order to be able to ultimately present the costs per Ecovat. Its key characteristics are presented below:

- Number of new build apartments: 1,000
- Heat demand per apartment: 10 GJ/year space heating and 7 GJ/year warm tap water
- Losses: 15% per year in heat transport and 7% per year in heat storage
- Number of load cycles per year: 2.5

The above assumptions lead to an Ecovat with a volume of 32,750 m^3. This has a diameter of approx. 36 meter and a depth of 36 meter.

2.4 Total market potential for 2050

This study ties in with the market potential report [*Marktpotentieel Ecovat*], which was produced as input for the temporary Round Table on system integration as part the climate agreement process. It points to a total market potential of 66PJ of annual supply of thermal energy and, with it, an estimated storage capacity of 26.65PJ in Ecovats.

The number of Ecovats depends heavily on the type of Ecovat that is achieved. Ecovat expects that for the market potential as a whole towards 2050, the vessel with a 42-meter diameter and a depth of 43 meters [42/43] will be the most prevalent. A storage capacity of 26.55PJ equates to just over 2,000 of this type of Ecovats [42/43]. It is noted that this is a larger Ecovat than the 'example Ecovat project' mentioned above. More of the latter would have to be commissioned.

The number of dwellings that are supplied is dependent on the demand per property, which is dependent on the insulation. Naturally, homes in renovation projects to label class B will have a higher demand for space heating than newly-built homes. Terraced properties will also demand more heating than apartments. This then means a larger Ecovat for the same number of homes, or fewer homes per Ecovat.

In the scenarios used, two types of homes are considered, each with their own demand; New build homes from after 1991 *(average Rc value 3)* and older properties built before 1992 *(average Rc value 1,8)*. Given that this degree of insulation differs, a choice has to be made as to which houses within the model will convert to the Ecovat system. The following values were used in this project:

	Maximum old dwellings	**Maximum new builds**	**Distribution in the model**	**Best estimate Ecovat**
Old dwellings	2.45 million dwellings	0 dwellings	0.73 million dwellings	Other market potential
New builds	0 dwellings	4.9 million dwellings	3.4 million dwellings	50% new builds

3. Results - System costs avoided by Ecovat

The following four steps have led to the avoided system costs:

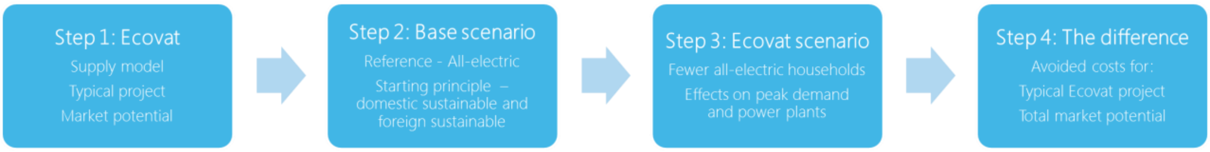

Figure 4 - Method to establish the avoided system costs of the Ecovat

Below we will briefly explain these steps and discuss the results.

3.1 Structure of system

In order to be able to establish the system costs in 2050, the scenarios 'Domestic Sustainable' [*Binnenlands duurzaam*] and 'Foreign Sustainable' [*Buitenlands duurzaam*] from the scenario exploration report entitled *Richting 2050: systeemkeuzes en afhankelijkheden in de energietransitie* were used as a basis. Here, any households that are not connected to a collective district heating system, are heated by an all-electric heat pump.

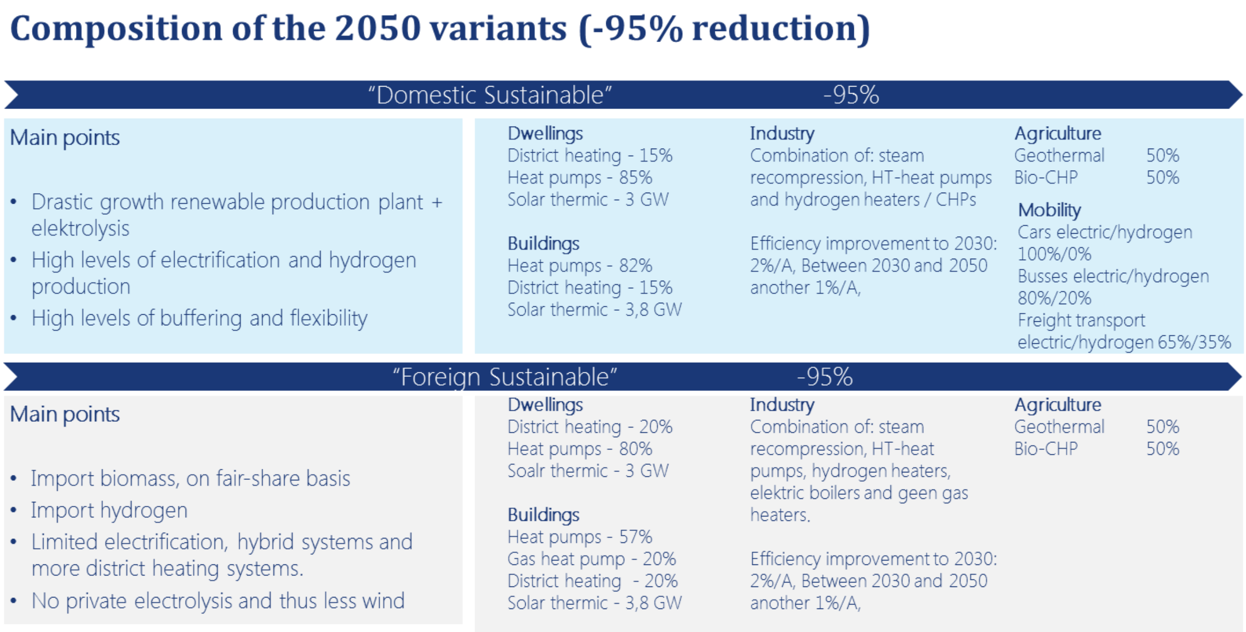

Figure 5 - Structure of system for reference scenarios

We compared these two scenarios with scenarios where in the households the all-electric heat pumps are replaced by Ecovats for the entire market potential of 66PJ in 2050.

These two scenarios give a good illustration of the range of impact of Ecovats. We therefore will discuss the results of this comparison.

3.2 Distribution by insulation value of dwelling

The total thermal energy supplied by Ecovats is kept at the level of the market potential of 66PJ in 2050. How many Ecovats this represents depends on the choice whether dwellings with an average Rc value of 3, or dwellings with an average Rc value of 1,8 are replaced. The heating demand of these two types of dwellings shows a ratio of 1 to 2, respectively.

However, the total energy requirement does not depend on this choice. Consequently, the impact on the energy system in the modelling of the ETM is neither dependent on the choice which dwellings are connected to an Ecovat, but only dependent on the total potential of Ecovat.

3.3 Peak demand

In both scenarios, the impact of Ecovats on the maximum peak demand is a decline of the peak demand by 5 GW. This is a significant decline in peak demand and it decreases the flex gap *(the difference between "demand-driven capacity" and peak demand)* if "demand-driven power plants" (power plants that operate using a given type of fuel and therefore can be commissioned at any moment, contrary to for instance wind and solar) were to be kept.

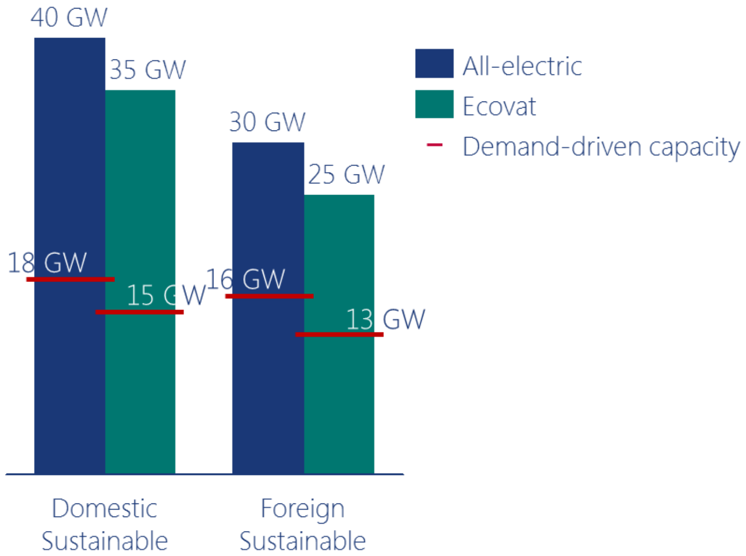

Figure 6 - Peak demand for the two scenarios using, or predominantly using, all-electric heat pumps, or predominantly Ecovat heating of households

3.4 Power plants

If these power plants remain in place, then the full load hours of these plants will actually decrease, which in principle renders these power pants less economically viable. If the full load hours of the plants are kept the same, then, by integrating the Ecovat, the demand-driven capacity can be reduced by approximately 3 GW (Domestic Sustainable) to 3.5 GW (Foreign Sustainable). This leads to an annual saving of between € 90 million and € 160 million. Per example Ecovat project at 17 TJ, this amounts to € 23.000 and € 41.000 annually.

The annual costs of these power plants consist of capita costs, plus management and maintenance (fuel costs are not taken into account here). The differences in annual costs between the scenarios relate to the power plants opted for (hydrogen or green gas plants) and the total reduced capacity. In the case of Domestic Sustainable, 3 GW (28PJ less hydrogen per year) worth of relatively cheap hydrogen plants are replaced and in Foreign Sustainable 3.5 GW (33PJ less green gas per year) worth of more expensive green gas plants are replaced.

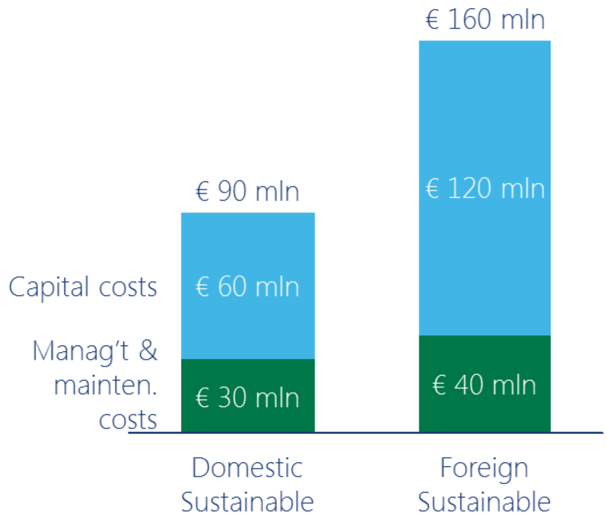

Figure 7 – Annual cost saving by replacing all-electric heat pumps with Ecovats.

3.5 Grid reinforcement

Reduction of peak demand in the electricity grid has major consequences for the cost of this grid.[1] Reduction of peak demand by 5 GW causes an annual cost saving of €560 million for Domestic Sustainable and €220 million for Foreign Sustainable. Total annual costs for these grids equals € 11.1 billion and 4.5 billion Euro respectively, of which approximately 75% of the costs are capital costs and the remaining costs are 25% management and maintenance costs. This represents a saving per example Ecovat project, at 17 TJ, of annually €144,000 and €56,000, respectively.

The deployment of Ecovats ensures a decrease of the electricity demand and peak demand and, with this, less grid reinforcement. The level of local electricity supply determines grid reinforcement that needs to be carried out until 2050. In contrast with Domestic Sustainable, in the case of Foreign Sustainable, local electricity is generated via CHPs using biogas. The deployment of these power plants remains relatively similar in the case of all-electric heat pumps or Ecovats. Because of this, the influence of Ecovats on the electricity grid in Foreign Sustainable is not as large. In the case of Domestic Sustainable, there are no local CHPs, as a result of which the entire avoidance of any grid reinforcement falls to the Ecovats.

In the method used, dwellings have been removed in order to reduce the heating demand. This meant that the total level of local PV generation could not be achieved. This was compensated for by placing PV in a central position. These central solar parks are connected to the high-voltage grid, which leads to a small cost increase in the high-voltage grid. In the Domestic Sustainable scenario, because of this, in the case of Ecovats the costs are in fact slightly higher in the high-voltage grid; in the case of Foreign Sustainable, a slight decrease in costs is found. If this PV generation had been modelled locally, then Ecovats would save more of the HV grid costs and less in the LV grid. The net effect, therefore, is likely to be small.

[1] In cooperation with TenneT and Netbeheer Nederland, Quintel recently improved the modelling of the impact on the grids in the Energy Transition Model. This causes an increase in grid costs compared to previous calculations using the Energy Transition Model.

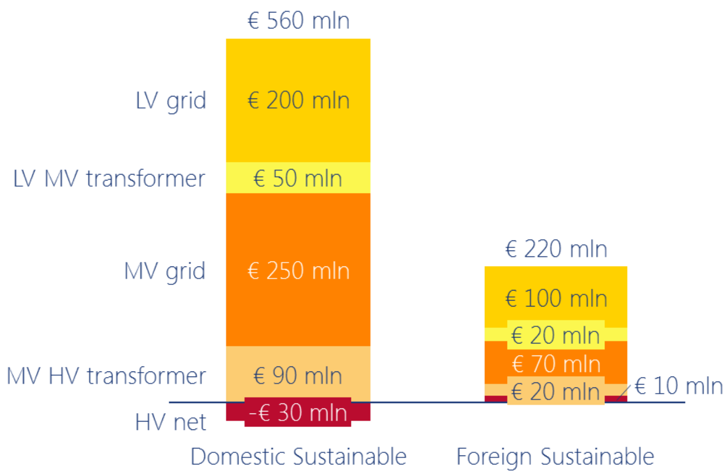

Figure 8 – Energy grid savings by replacing all-electric heat pumps by Ecovats

3.6 Conclusion

The impact of 66PJ energy supply by Ecovats for the heating of households on the energy system is in the range of €380 million and €650 million. Per 17 GJ Ecovat project, this amounts to an annual saving of € 97,000 and € 167,000. These savings increase along with increases in electrification per se, where the impact on the electricity grid then increases.

Ecovat projects have a number of different configurations. Different sizes, new builds versus old buildings, high-rise versus terraced housing. This is why it is useful to recalculate the savings to a fixed indicator that can be used for most configurations. To do this, a cost saving was set per GJ supplied. Given a saving of €380 and €630 million for 66PJ, this yields a saving of approximately 5.80 €/GJ and 9.50 €/GJ.

4. Discussion

4.1 Model reality

As mentioned, the ETM was used in this project. This is a complete model, in which the supply of heat, gas, hydrogen and electricity is modelled on a per-hour basis. However, this model, like other models, is a simplification of reality, and various effects have not been taken into account. Below, we mention some factors which have not been included in the scenarios applied:

- **Grid reinforcement for wind power;** In the Ecovat supply model, heat pumps are installed that operate alongside the production of wind power. For the following reasons, this was not included in this exercise:
  - Firstly, there is the option to connect the large heat pumps to the MV grid. This will inherently avoid grid reinforcement of the LV grid and LV MV transformers. This constitutes a large part of the grid costs.
  - In addition to this, the heat pumps are operative the moment that electricity from wind is available. This is a much more regular pattern than the heating demand from dwellings, as a result of which it will have far less influence on the peak load of electricity grid. To illustrate, the all-electric reference scenario has a heating demand of approx. 1,680 full load hours within the total 8,760 hours in a year. By contrast, inland wind production shows approx. 2,500 full load hours and even more than that at sea, i.e. nearing 4,000.
  - Finally, this is not a standard model function in the ETM and the grid costs have been discounted in the model in such a way that is not easy to correct for this.
- **Commissioning power plants;** The model does not take into power plant start-up times. For instance, this may be important in the case of large solar PV installations. Peak demands tend to be created between the hours of 5 and 8 pm, which is exactly when PV production diminishes. A back-up power plant will be started up. This effect is illustrated by the 'duck-curve' depicted below. This may be mean that there is sufficient power plant capacity, but that it cannot respond fast enough.

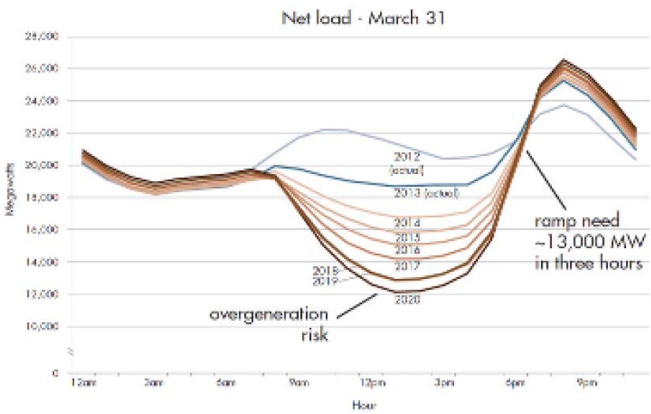

Figure 5 - Example Duck-curve

- **Consumer behaviour;** In the all-electric reference scenario, heating by air source heat pumps was assumed. Because of the COP of these appliances, a siphon is located between the input electricity and the output heating. A situation could arise whereby consumers turn on resistance heaters when it is really cold outside. Peak demand for electricity increases due to this kind of consumer behaviour. This has not been included as such in the model.
- **Number of dwellings or number of Ecovats for the 66PJ.** In the models, it is assumed that the total heat supplied is 66PJ and that, for the avoided system costs, it does not matter how many dwellings this involves. This depends on the degree of insulation of the dwellings connected. This may make a limited difference in the level of avoided costs in the LV grid. By way of illustration, when we compare for instance 4.0 million well-

insulated dwellings with 2.0 million dwellings with poorer insulation, then for the well-insulated dwellings, fewer neighbourhoods will see a higher demand on the LV grid. The costs actually avoided for the 66PJ of heat supplied may thus be greater for 4.0 million dwellings than for 2.0 million dwellings.

5. Conclusion and recommendations

5.1 Conclusions

Compared to heat supply using electric heat pumps, the Ecovat avoids supply chain costs in the energy system. This is due to a decreased peak demand for electricity, as a result of which fewer back-up power plants and a lesser reinforced electricity grid are required. For the two scenarios that were studied, when the entire market potential of Ecovat (66PJ) is used to substitute electric heat pumps, the effects have been quantified as follows:

	Peaker plants	Grid reinforcement	Total energy system
Impact on the energy system	5MW less peak demand 3 to 3.5MW fewer baseload plants	Lower level of reinforcement of the electricity grid	An inherently better-balanced system through the use of thermal storage
Annual avoided costs for the energy system	System: 90-160 M€/year Per example Ecovat project: 23-41 k€/year	System: 220-560 M€/year Per example Ecovat project: 56-144 k€/year	System: 380-650 M€/year[2] Per example Ecovat project: 97-167 k€/year
Avoided costs per GJ heat supplied	1.4-2.4 €/GJ	3.3 – 8.5 €/GJ	5.8 – 9.8 €/GJ

5.2 Recommendation

The above demonstrates that the use of Ecovat has a positive effect on the costs that have to be incurred outside of the energy system. This is due to the fact that an Ecovat solution does not rely on back-up supply provided by the energy system.

However, this is not reflected to that same extent in the business case, because the level of the demand placed on the energy system is not expressed, or hardly so, in the costs. This is a missed opportunity in the quest for a cost-efficient energy transition. We recommend that a level playing field be created for the CO_2 reduction. Part of this is the fact that 100% CO_2-free solutions boast a premium above solutions that rely on the energy system's back-up. It is an opportunity to include such instruments in the implementation of the Climate Agreement.

In order to put the aforementioned on the agenda, the avoided system costs can be seen in the context of the total business case. Steps to realise this are the validation of these costs and the inclusion of this value in the business case that is currently being drawn up. By comparing the business case scenario without avoided costs with the business case that recognises avoided costs and, for instance, with an all-electric scenario, the impact of this effect can be shown. This shows the influence of system costs on the total cost-effectiveness of various climate options.

[2] Costs vary per scenario studied. In the two scenarios studied, the peaker plants were more expensive in one of the scenarios and grid reinforcement was more expensive in the other scenario. As a result, the lowest total does not equal the total of the two lowest values.

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