Case Studies

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ANNEX 57 — Flexibility by implementation of heat pumps in multi-vector energy systems and thermal networks

Demo No.: 18	**Location/City: The Hague**	**Country:** The Netherlands
Project name (short and full title): Couperus Smart Grid		
Quotation: Couperus SG has demonstrated that reduction of peak load in the grids and imbalance is possible with the help of smart grid technology. In addition, practical knowledge has been gained with a completely different design of energy infrastructure		
Schedule of the demo project (research study):.		**Year of realisation:** 2016
Leader organisation (owner, constructor, solution developer, research inst., etc.): Stedin B.V.		
Participating organisations – demonstration project part (involved other organisations): • **ROTTERDAM** Eneco Energy Trade B.V. • **AMSTERDAM** IBM Netherlands B.V. • **SCHIEDAM** Itho Daalderop Netherlands B.V. • **ROTTERDAM** Stedin • **THE HAGUE** Stichting Woonformatie Ypenburg • **THE HAGUE** TNO		
Budget of the demo (invest/monitoring etc.): € 424.989,00		

IEA Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP)

Delivered by:

Team NL

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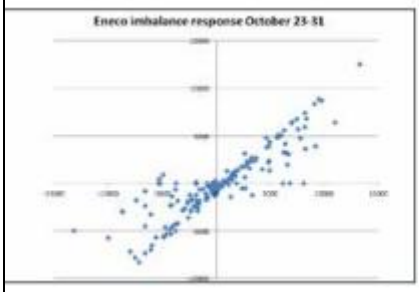
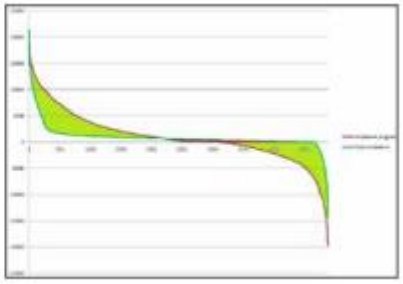
Summary of the project:

1. What is the degree of imbalance reduction with the heat pumps at Couperus 2. What are the technical and business opportunities created by the PowerMatcher

Approximately 150 heat pumps were in operation during the measurement period. The (scaled) imbalance ranged from -10 to +10 kW [November]. The figure below shows that the imbalance has been significantly reduced by the PowerMatcher. Each point on the light green surface represents a decrease in the cost of the imbalance. The actual decrease in costs is determined by the value in the imbalance market at the time the reduction took place. It is considered very likely that reduction in costs during the peaks left to top or right to bottom is greater.





1. How much flexibility do 300 (150 flexible/150 unregulated) heat pumps give (depending on season, time of day)? 2. What is the ratio of the load of the heat pumps to the total power demanded? 3. What is the total potential for peak shaving? 4. Can PowerMatcher ensure that Stedin can exploit this potential? 5. What is the influence of the agent in the distribution station on the load on the grid? 6. What is the influence of the agent in the trading room on the load on the grid? 7. What is required for PowerMatcher to function optimally for Stedin?

In the end, about 21% of the total power of all participating heat pumps (150 units) in this measurement period appears to be flexible, depending on the weather/season. [2] From the measurements it can be deduced that reduction of the Eneco imbalance signal in seasons with some heat demand of the apartments is quite possible. In seasons with little heat demand, the current Couperus VPP is insufficiently able to provide the desired reduction. However, this improves when A) the Couperus apartment building is even better insulated, B) the tap water heating can also take place during the day and C) other Demand Response is also added in the building.

[1] In the end, around 21 % of the total capacity of all participating heat pumps, 150 units in this period, appears to be flexible. This is the result of this specific measurement period and can vary per season (weather dependent) [2] In the evenings, the controllable heat pumps require about 30% of the total power. Together with the 150 non-regulated heat pumps, this would be around 60% in total. This observed behaviour is related to the setting (for all heat pumps) that the boiler for the tap water may only be heated at the nightly rate. The heat pumps not controlled by the PowerMatcher

all switch simultaneously, the controlled heat pumps are distributed over a longer period of time. [3] The total potential for peak shaving depends on the season. In summer, the required power is low, so a low potential. However, due to lower demand, there is no need for peak shaving. In winter, on cold days, it appears that almost all heat pumps in Couperus have to provide heat, so a lower potential. The mid-seasons therefore provide a higher potential. The potential would have been higher if the power of the heat pumps were greater (in Couperus 1kW per heat pump). [4] In order to maximise the potential for peak shaving, a number of factors are important. The power, setting and configuration of the heat pumps, the available time period for heating tap water. Heat pumps with a higher power require less time for heating and therefore more can be shifted in time. As a result, there is more room for peak shaving. However, a higher power of the heat pump may also mean heavier loads for the distribution station. [5] The agent (PowerMatcher) designed for the distribution station has the influence on the load on the grid, given the boundary conditions determined by the heat pumps (uncontrolled and controlled). The distribution station agent also appears to be able to keep the capacity of the distribution station below the maximum, regardless of the required power of the imbalance agent (Eneco). [6] The impact of the imbalance agent on the load on the grid also appears to be small. In the situation that there is peak demand in the distribution station, the distribution station agent ensures that in the event of additional or maximum demand for power by the imbalance agent, this is not granted. [7] In order for PowerMatcher to function optimally for Stedin, a number of conditions are important. (a) The appropriate technical facilities must be available. (b) Optimal use should be made of the intelligence of the heat pump and its alignment. (c) The power of the heat pump must be considered in the planned situation. (d) The maximum capacity of the distribution station will always have to be greater than the real heat demand in extreme cold (-10 °C). (e) Not applying day-night tariff would increase the time limit for heating tap water, creating more flexibility. (f) Insulation between apartments must be present so that energy is not destroyed because differences in 'desired' temperature (cooling vs. heating) between adjacent rooms must be compensated.

1. The extent to which heat pumps and boilers can be used flexibly to control the demand for electrical energy. 2. Quality communication between the heat pumps and the server 3. The role of heat pumps in actively controlling the electricity grid 4. Quality implementation of all necessary communication 5. The implementation of the PowerMatcher agent

At the beginning of the measurement period, HP manufacter asked 6 research questions. At the end of the measurement period Q2 2013 – Q2 2014 we can answer this. [1] The available flexible power varies from month to month. It was found that in the winter months the available bandwidth was between 15 and 40 kW for 80% of the time. In this period there was enough flexible power for the required imbalance reduction. The fact that more flexibility is available in winter can be explained by the greater need for space heating. This is different when the winter is very cold and the heat pumps do not offer flexibility (continuous must-run condition). In the end, about 21% of the total capacity of all participating heat pumps, 150 units in this period, turns out to be flexible. [2;4] The connection between the heat pumps and the server has experienced a number of downtimes. In addition, the communication time for the VPP and 150 heat pumps turned out to be 15 minutes. By

increasing the number of controllable heat pumps (300), more time would be needed, which was not desirable due to slow response to the situation. At a later stage, this was successfully increased to 300 heat pumps. Communication has not been an obstacle to the measurement results, but there is room for improvement [3] Active control of the load in the electricity grid by the heat pumps has proven to be very possible in many situations. No irregularities were detected in reducing the imbalance. An exception to this is the control of the heat pumps when heating the boiler vessels in case peak shearing had to take place. By applying day/night rates, the heat pumps quickly went into a must-run state when the boiler vessels were heated. Given the need for heating water at the time, the suggestion is to provide more flexibility here. So there is room for improvement here. [5] The implementation of an initial version of the PowerMatcher agent has gradually improved, but could be further improved. The improvement can be observed, among other things, in a slightly increased spread of the heating of the tap water buffer in the evening. However, it can still be improved. A further improvement is possible to spread prices issued by the heat pump agents more widely and to use the entire domain (0-127) of the prices. Analysis of the aggregated bid curve showed that of all possible values of prices in the bidding curve, the heat pump agent bid curves generally used only 10 to 15 of these values

Results

• The conclusion is that the PowerMatcher technology offers an efficient and highly scalable system for unlocking energy flexibility from just a few dozen connections. This can be used in aggregate for multiple purposes, including congestion management and imbalance, as demonstrated in Couperus. • Peak shaving by PowerMatcher in combination with imbalance compensation functions as expected. Incidentally, the highest peak in consumption is already dampened by the PowerMatcher's control of the heat pumps when heating water in boilers: without control, they would all start heating up at the same time and thus cause the highest load. • A device such as a heat pump is suitable for making the power used more flexible due to the relatively high energy consumption. But because the possibilities for using this flexibility are limited to certain times of the day and certain seasons, the heat pump itself does not provide sufficient flexible power. • The delayed, but random, control (communication) of the heat pumps (with an average of 20 minutes interval) has had no measurable consequences in the living lab. • The flexibility from heating up the boiler is limited in Couperus to the period with the night rate, while imbalance in the generation of the wind turbine is greater during the day. In another situation, the results would be more favourable. • The energy flexibility per heat pump is unlocked by the PowerMatcher. The variation over time and its value has been successfully measured. • Partly due to the mild winters, the adjustable power was less than previously estimated. However, it has been shown that this system can be used to adjust imbalance, without the resident having to sacrifice comfort. • The variation in flexibility spread throughout the day is great. Especially radiation from the sun greatly limits rotation time.

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Published articles (paper, article etc.): Couperus Smart Grid - Top Sector Energy		
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