CLEAR 2.0
D2.4 Renewable Energy System Optimisation

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 749402

Introduction

As already mentioned in another report concerning the household profiles (D2.1), the current studies already available on savings related to feedback on energy consumption were developed enough in Belgium to allow us to develop a more specific approach:

- Select only families having the most common renewable energy system in Belgium at residential level, this system is a PV installation
- Select the most present, affordable and reliable monitoring system for electrical consumption only
- Use the monitoring system results to give feed-back and advice in order to:
    - Increase awareness over different electrical consumption at home
    - Generate savings through behavioral changes and or investments
    - Increase awareness regarding direct use of PV production vs taking electricity from the grid
    - evaluate in which extend a better self-consumption rate of electricity generated by PV system at domestic level is possible with families showing different profiles.

The netmeetering support scheme just disappeared in January 2020 in the three regions and unfortunately no investigation at all has been carried out by the regions in advance to support the consumers in this change and allow them to understand in which extend they could react to these new conditions.

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Objectives and Project Scope

To be able to support in the best way we can the consumers through this new journey and relationship to their own green photovoltaic production, we only selected families having PV systems in order to study in which extend they could increase significantly their level of self-consumption without any specific technological device.

This study allowed to reach our objective and get a better understanding on:

- The impact on a feed-back monitoring system and advice on the self-consumption rate
- The importance of
    - existing appliances or options to help this change
    - presence at home to displace consumptions non related to domestic appliances.

Photovoltaic Regulation & Self-Consumption data available

During the project the regulation in the three regions has changed.
Before January 2020 :
- In the Flanders a fixed grid contribution was charged to prosumers based on the inverter capacity and the netmeetering was the only support scheme
- In Brussels, green certificate and netmeetering were combined as support scheme and no grid fee was charged
- In Wallonia, incentives combined with netmeetering were applied as support scheme. Incentives were regularly evaluated to guarantee a return on investment below 8 years.

From January 2020:
Net metering has been partially supressed in the three regions. This means that each kWh taken from the grid and also injected back from the photovoltaic system is charged for all tariff components except the energy part itself.
In Belgium average total cost for a kWh is 26 eurocent and the electricity cost is 8 eurocent. Therefore each kWh not directly used from the photovoltaic production and taken from the grid will cost 18 eurocent. We will call this part grid fee

In Brussels the green certificate support scheme is maintained and the grid fee is only applied on the real consumption compensated by production since digital meters allow this calculation and has been installed for each household getting a photovoltaic system. This meter change was mandatory from the beginning of PV installation in the Region.

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Average self-consumption rate measured in Brussels is 55% and is due to the smaller system size in the city related to roof surface availability, power of all residential installations is below 5kWc.

In the two other regions the consumer may chose between real measurement (similar to Brussels) or a fixed fee based on an artificial self-consumption rate for Wallonia (37,76%) and a prosumer tariff in the Flanders (still based on the inverter capacity).

However, there is a major difference. Indeed, in Wallonia, you don't need to choose, the region will apply the more advantageous system depending on your profile. If real measurements show a self-consumption rate above the reference value, the real calculation will prevail, otherwise, the reference value is used.

In the Flanders, your choice is irreversible, which is a pity knowing that people have no idea how they use their production since netmeetering has been stopped at the end of 2019. The only option to select the most beneficial scenario is a simulator : https://simulatordigitalemeter.vreg.be

In any case, we believe that consumers should have the opportunity to understand more what is their self-consumption rate and how they can increase it because it serves their investment and the proper PV production use.

Average and common observed self-consumption reference is around 30% if PV annual production is close to the annual needs which is the most common situation in Belgium due to the net metering support scheme (big cities are exceptions due to the lack in roof surface availability).

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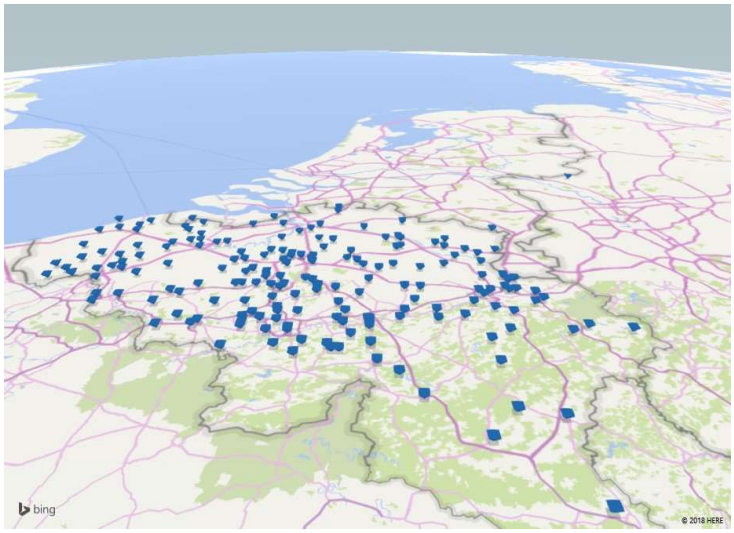
Project Methodology

In the families we have already selected 34 families among 240 subscribers using a freeform questionnaire.

Families subscribing were well distributed over the country:



In the questionnaire we have asked people different questions related to family composition, PV installation, type of dwelling, energy consumption, white goods and their delay function, hot water system.

We have selected different profiles:

Family A:
Annual electricity consumption (around 3500 kWh/year)
PV installation
No system facilitating direct consumption of electricity (hot water boiler, whitegoods with delay function, hybrid or electrical car, heating system electrical based)

Family B:
PV installation
System facilitating direct consumption: whitegoods with delay OR Electrical Boiler Or Electrical Heating system

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Family C:
PV installation
Multiple systems facilitating direct consumption: white goods and or electrical boiler and or hybrid or electrical car and or hot water system using electricity

Family D:
PV Installation
High level of consumption
Heating system using electricity

PV system power was for all families very close to the annual needs in order to have a comparability between families concerning the self-consumption efforts.

The monitoring started in October 2018 until end October 2019.

The first step was to analyse in detail the consumption of each family in order to detect possible energy savings and also to list the most important consumptions.
This was done in April and between April and June the energy saving tips were put in place. Then, each family was able to choose which consumptions they wished to move during the day in order to increase their direct consumption of their photovoltaic production.

Two aspects were taken into account, the ease of movement of consumption and its importance in relation to the family's annual consumption.

Results Summary

Levels of initial self-consumption were quite variable from one family to another compared to the global average (29,7%). These variation from (21 to 47%) were mainly due to the presence of people on weekdays at home and not related to the family profile.

We also compared the average daily needs with the average daily production of the photovoltaic installation for each family in order to define what would be the adequate period to test the consumption displacements that could increase the self-consumption rate.

For all families without exception, the period during which average daily production theoretically covered daily needs was mid-April to mid or late September.
Outside this period, any action to shift consumption could not have contributed to an increase in self-consumption because of the too low production.

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For the same reason, families with electric heating have not been able to use it to increase their rate of self-consumption. Heating was mainly used during the low production period (November to April).

Before we can give some nuances in what has been tested and observed from one family to another, here are the main points that can be generalized to the general population.

SELF-CONSUMPTION	Average SCR increase	Displaced consumptions	kg CO2/year	Average savings €/year	People has done
BOILER hot water - put timer for PV peak use)	13%	660		106	12
WASHING MACHINE - delay function (PV peak use)	1%	49		8	20
TUMBLE DRYER - delay function (PV peak use)	1%	36		6	22
DISH WASHER - delay function (PV peak use)	1%	41		7	25

Average increase in self-consumption is mainly related to domestic appliances and could contribute during April-September to a 3% increase or 126kWh directly used from PV production.

The main contributor is certainly the electrical hot water boiler allowing in average an increase of 13%, 660 kWh per year directly used from PV production.
All other possibilities such as cocking, ironing, bread maker machine,… were more a case by case from a family to another and were not leading to a substantial increase in self-consumption or related to a specific situation (in majority people not working and staying at home). People doing home working were not taking a long lunch break to increase midday consumption because it was not compatible with working schedule.

We were hoping that an electric or hybrid vehicle could also help increase self-consumption. This is indeed the case when the person works from home or can be present during the day for whatever reason. In fact, families with an electric or hybrid vehicle were on the road in the morning and in the evening and were often obliged to recharge the vehicle outside of production hours. Only one person with a hybrid vehicle who had an office at home regularly recharged his vehicle at home.
The average that this family was able to use directly from its production was significant, 450 kWh, 5% self-consumption increase in their case with a 9000 kWh annual consumption.

If we now go deeper in the measure mentioned above in the table, the measure that was easiest for everyone to implement was the use of the dishwasher during the day.
This was followed by the tumble dryer, the washing machine and the electric boiler for sanitary hot water for those equipped with that system.

Dishwasher operation has been very popular mainly because it doesn't really shake up the lifestyle. Most of our participants already had a dishwasher with a delay function and those who did not had the option were working from home once a week or had a family member present in the house during the week to fulfill this task.
In addition, emptying the dishwasher long after use was not a problem for anyone.

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As for the washing machine and dryer, that was another story. Indeed, wet clothes that need to be dried won't wait until the next day. The most motivated families ran their washing machine during the day with a stop before spin function and ran the spin function in the evening or morning and then programmed the dryer for the next day in the morning when the production was just enough in power to feed the tumble dryer. All this is not practical at all. In concrete terms, the habits that have remained are the use of the washing machine with a stop before spin function in order to be able to spin the laundry when returning home (the major consumption part in a washing machine cycle is not related to the spinning) and the dryer was used directly afterwards in the evening or both operations were carried out during the day when someone was present at home. Presence at home when using the tumble dryer was also a kind of absolute prerequisite for most families because of the fear of fire.

The displacement of this consumption of household appliances represents little compared to the annual needs of families. In fact, with an average annual consumption of approximately 350 to 500 kWh per year for these appliances, only cycles that take place during the 6 months of sufficient production can improve self-consumption and these cycles must be able to be carried out within a power range that corresponds to the power delivered by the PV installation, which is not always guaranteed. To sum up, we have observed that about half of these cycles contribute to self-consumption and on average up to 75% of the necessary requirements, since the power demand sometimes exceeds the production. One exception was families using heat pump dryers, whose much lower power allowed them to stay within the photovoltaic production curve.
In average, this displacement allowed families in our project to increase their self-consumption from 2 to 4%.

The most effective measure we tested was the electric boilers supplying hot water daytime programming, either by means of a timer already present in the fuse box or by purchasing a timer to plug (25 euros). The average family consumed 2200 kWh per year for three people to produce hot water, assuming that it had a photovoltaic installation producing 5000 kWh per year, of which 1500 kWh (30%) are already self-consumed by conventional uses including random working hot water boiler, self-consumption is improved by of 660 kWh, now increased to 2160 kWh per year just using a simple timer.
This represents an increase of 13% in the self-consumption rate which rises to 43%. This represents half of the increase that could be reached using a 5kWh battery storage but with a 25 euros investment.
Other options have also been used on a case by case scenario and focused on people present at home for at least 2 days during the week. This allowed other activities various activities (main contributors ironing and baking in oven) and also contributed in self-consumption increase (between 50 and 135 kWh/ year in our project).

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Conclusions

Our project's approach to increase photovoltaic self-consumption was intended to be practical and very low-tech. We also wanted to valorize the average standard equipment that families already had in order to avoid the use of intelligent solutions that would require large investments. In this way, the results of our pilot project are directly exploitable by a majority of families without any need for major upheaval, without investment and leaving intelligence where it belongs, in consumer's brains.

Thanks to a monitoring system allowing us to detect the consumption of each device in the house as well as the flow of photovoltaic production, we have been able to inform each family about its personal situation. We also identified the most important consumptions often linked to the production of cold (refrigerators, freezers, etc.) or to the production of domestic hot water, or to heating when the family was equipped with a system running on electricity.

We quickly noticed two important limitations in the use of photovoltaic production, on the one hand the very low production during the winter months and on the other hand the important number of consumptions which cannot be moved because of the implicit needs in the morning or in the evening or because of the necessary permanent operation of certain equipment such as refrigerators for example.

What we learn from this experience can be summarized as follows:

- Consumption that is easy to move around during the day is mainly related to household appliances with a delayed start function such as the dishwasher, washing machine and tumble dryer, but for the latter requiring the presence of a user as a precaution (fear of fire). These consumptions displaced allowed 126kWh/year increase of direct consumption of photovoltaic production on average in our sample.

- The displacement of the consumption of an electric boiler for domestic hot water during the day is the largest contributor with an average increase of 13% in self-consumption (average of 660kWh/year additional photovoltaic production direct consumption).

- the shift in daytime consumption for the purpose of increasing self-consumption is mainly relevant between April and September due to the very low production in winter.

- electric heating will not help in self-consumption increase because it is used during a low production period.

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- one person's presence at home two days a week contributes in an important way to guarantee that the moved consumptions during the day will last especially for the combination washing machine & tumble dryer. It also help to displace other activies such as ironing and baking in oven.

In practice, it is however difficult to significantly shift permanent consumption or consumption linked to morning and evening activities during the day. The real flexibility focuses on the production of hot water and the household appliances mentioned above and additional activities if presence at home is possible 2 days a week.

If we consider only the household appliances, the average annual consumption represents 10% of the average annual consumption of a Belgian family and could contribute to a 2 to 4% increase in self-consumption depending on the family situation.

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