Profitability analysis of case studies

Community-based PV systems

Author: CREARA

December 2019

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 723636. The sole responsibility for any errors or omissions made lies with the editor. The content does not necessarily reflect the opinion of the European Commission. The European Commission is also not responsible for any use that may be made of the information contained therein.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 764805

Deliverable D4.4: Best practice cases	
Editor (organization):	Andrea Real Ruiz, Paolo Michele Sonvilla (CREARA)
Contributor (organization):	CRES (Anastasios Kyritsis, Elena Taxeris, Kiki Papadopoulou and Evangelos Mathas), EST (Graham Ayling), CREARA (Paolo Michele Sonvilla and Andrea Real), RVO.nl (Otto Bernsen, Wido van Heemstra, Jesper Juffermans and Rebecca van Leeuwen), KAPE (Ryszard Wnuk and Piotr Nowakowski), PROTECH (Juras Ulbikas, Vaidvilė Ulbikaitė and Vitas Maciulis), DENA (Mortiz Robers and Manuel Battaglia)
Period covered:	
Date submitted to Coordinator:	18.11.2019
Document version No.	1.0

Due date	
Actual Date	
Deliverable Number	D.4.4
WP	WP4
Approved by	☒ Rebecca van Leeuwen RVO.nl
Status	☐Draft ☐Working ☒Released ☐Delivered to EC ☐Approved by EC

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 764805

1 GLOSSARY

- **Base case:** the base case describes the current situation of each of the PV cases analysed
- **Discount rate:** interest rate used in discounted cash flow (DCF) analysis to determine the present value of future cash flows. The discount rate considered in all case studies is 3%.
- **Feed-in-tariff rate**: percentage of energy injected that is subject to feed-in-tariffs
- **Internal Rate of Return (IRR):** discount rate that makes the net present value (NPV) of all cash flows from a particular project equal to zero. All cases presented have been analysed considering a 25-year period
- **Net Present Value (NPV):** difference between the present value of cash inflows and the present value of cash outflows over a period of time (25 years)
- **Net-metering rate:** percentage of the solar energy produced that can ascribe to net-metering
- **Payback time:** time required to recover the funds spent in an investment, or to reach the break-even point
- **Self-consumption rate**: ratio of the self-consumed PV energy (the part of the PV electricity that is locally consumed) to the total PVs Energy production (kWh).

$$\mathbf{Self-consumption\ rate} = \frac{\text{self} - \text{consumed PV energy} \quad (\text{kWh})}{\text{total produced PV Energy} \quad (\text{kWh})}$$

All additional energy generated is usually not self-consumed and fed into the grid. Some of the alternative scenarios evaluate the impact of storing said energy.

- **Self-sufficiency index:** ratio of the self-consumed PV energy to the total electrical energy consumption (kWh) of the PV-Community System, regardless if it serviced from the LDN (Local Distribution Network), the PV plant or from both of them

$$\mathbf{Self-sufficiency\ rate} = \frac{\text{self} - \text{consumed PV energy} \ (\text{kWh})}{\text{total electrical energy consumption of the PV} - \text{C.S} \ (\text{kWh})}$$

- **Specific system yield:** ratio of the final energy output (kWh) of the PV plant to that of its nominal power (kWp). The final yield index is typically calculated on a monthly or yearly basis and it is a flexible tool in order to compare the produced energy between PV systems of different size.

$$\mathbf{Final\ yield} = \frac{\text{final AC energy output of a PV plant (kWh)}}{\text{nominal DC power (kWp)}}$$

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 764805

2 Introduction

The overall aim of the EU Heroes project is to enable the continued development of community-owned photovoltaic (PV) systems by developing viable business models (BM) that minimize grid impact. The project will work with relevant stakeholders to develop approaches that will enable subsidy-free solar PV projects that have a neutral or positive impact on network management. Within the work conducted in the project, existing business models for the deployment of solar PV will be identified and cost-benefit analysis and economic feasibility assessments will be carried out.

2.1 Objective and scope of this document

Based on the analysis carried out by the project consortium, the present document presents alternative profitable scenarios for the considered case studies, which describe successful business models with increased self-consumption rates and optimal economic results. The objective of this document is to achieve increasing awareness of such business model solutions.

These alternative profitable scenarios encourage high-quality system development and enhance the likelihood that a system will perform in a way that will improve its economic results and self-consumption rate. The analysis conducted also includes lessons learned, success factors and other relevant considerations. This information was obtained directly from the owners of the PV systems installed in each country (referred to as Case Study Owners throughout the document).

2.2 Summary of outcomes

The main outcome obtained from the analysis conducted are:

- **UK**: Increasing the self-consumption rate using **heat pumps, EV charging and demand side management** could increase financial performance by significant amounts, perhaps by as much as 100%.
- **Greece**: by increasing the capacity of the PV plant, the self-sufficiency rate would increase from 27% to 50%, whilst the self-consumption rate would decrease from 99% to 96%
- **Poland**: using an EV charger to optimize self-consumption could increase the self-consumption rate to as much as 40%
- **Spain**: If the self-consumption rate reached 100%, not only would it be economically beneficial, but impact on the grid would also be reduced as no excess energy would be fed into it
- **Netherlands**: a good outcome in terms of self-consumption resulted from the implementation of demand-side-management and installation of a battery. By applying said changes, the self-consumption sufficiency rate would increase from 38% to 48% and the self-consumption rate would change from 70% to 85%
- **Lithuania**: it is necessary to increase direct consumption of solar electricity via better planning and smart management of usage of household equipment and consumption of heat
- **Germany**: the options for improvement in profitability are limited

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 764805

FACTSHEET: UNITED KINGDOM – THE PHOENIX CENTRE

Description of the case study

The Phoenix Centre is a community enterprise centre located in Townhill in Swansea, Wales. The centre hosts a community café, affordable childcare services, sports facilities, conference rooms and a variety of other services.

Prior to installation of the rooftop PV array, the Phoenix Centre purchased 100% of their energy supply from a licensed electricity supplier, EGNI. In September 2016, a 30 kWp solar PV system was installed by a local solar PV which develops solar energy on community buildings in Wales. It does this by raising funds from its cooperative share offers to pay for the solar panels. Their main purpose is to generate clean energy, enable community projects to be more financially stable and engage the public through its share offers.

KEY FACTS ABOUT THE BASE CASE:

System size: 30 kWp

System yield: 949 kWh/kWp

System production: 28.5 MWh/year

Total consumption: 47.5 MWh/year

Self-consumption rate: 70%

Self-sufficiency rate: 26%

IRR: 9%

Payback: 11 years

Alternative profitable scenarios

Increasing the self-consumption rate using **heat pumps, EV charging and demand side management** could increase financial performance by significant amounts, perhaps by as much as 100%. The use of heat pumps could potentially increase self-consumption by as much as 20%.

Another potential source of improvement for this case study would be charging the self-consumed electricity at the same cost as the standard supply rate, less 20%. This is a model used in other more recent projects across the EGNI Co-Op, which became necessary as the generation and feed in tariffs reduced.

KEY FACTS OF THE ALTERNATIVE SCENARIO:

Self-consumption rate: 90%

Self-sufficiency rate: 50%

NPV: 60% increase

IRR: 19%

A conversation with the owners

Key success-factors driving the model used for this project were the high FiTs (Feed-in-Tariff) rate and the SEIS (Seed Enterprise Investment Scheme) Tax relief on investment in the scheme however, both these support mechanisms have since been removed, which means it is no-longer scalable.

EGNI are now approaching and working with buildings/sites with significant daytime on-site electricity demand (to match peak generation from a PV system) to host PV systems and buy the electricity under a PPA (Power Purchase Agreement). The PPAs currently being negotiated are generally at a discount against the site owner's current electricity tariff. This varies but typically can be around 20%.

EV charging is also being considered as a potential load. This can provide a high value market for selling electricity but has some complexity in ensuring that vehicles are charging during the day. Battery storage is being considered but is not being built into the business model yet. UK regulation of flexibility markets is currently undergoing significant changes that are likely to impact income streams for energy storage. Battery costs are too high to be viable under current market conditions, but this may change in the near future due to cost reductions and regulatory changes.

FACTSHEET: GREECE - STAVROS NIARCHOS FOUNDATION CULTURAL CENTER

Description of the case study

Stavros Niarchos Foundation Cultural Center (SNFCC) is a grid-connected multifunctional arts, education and entertainment complex. The annual electricity consumption of SNFCC is roughly 8.7 GWh, and a notable part of the electricity consumption covered by a rooftop building-integrated-PV system of 1,585 kWp nominal power, which produces over 2 GWh per year. PV energy covers a significant percentage of SNFCC's daily needs, reaching up to 36.5% in certain months. The SNFCC is not allowed to use the local distribution network as a backup system. This means that, under normal operating conditions, PV exports to the local distribution grid should be minimal or non-existent if possible.

Therefore, SNFCC produces and consumes all its PV electricity instantaneously. Bearing in mind that SNFCC's PV system was designed for this application with specialized specifications (which resulted in a significant increase in construction costs) and in order to adapt the SNFCC case study as close as possible to common commercial PV applications, hereinafter and for the purposes of this document, an adapted scenario (which considers mainstream commercial PVs and BOS components) is used.

KEY FACTS ABOUT THE BASE CASE:

System size: 1,585 kWp

System yield: 1,500 kWh/kWp

System production: 2.38 GWh/year

Total consumption: 8.7 GWh/year

Self-consumption rate: 100%

Self-sufficiency rate: 27%

IRR: 14.6%

Payback: 9 year

Alternative profitable scenarios

An alternative theoretical scenario was presented in which the capacity of the PV plant was increased from 1,585 kWp to 3,170kWp. In such a case, there would be intervals where PV production would be higher than SNFCC's electrical consumption and thus energy would be injected to the Local Distribution Grid (LDG). The SNFCC should sign a contract with the LDG under the Law for Net-Metering, in order to exploit energy and economic benefits of the PV exports.

The excess electricity injected into the grid can be used later to offset consumption during times when PV generation is absent or not sufficient, meaning that the grid is used as a backup system for the excess power production.

By doing this, the self-sufficiency rate would increase from 27% to 50%, whilst the self-consumption rate would decrease from 99% to 96%.

KEY FACTS OF THE ALTERNATIVE SCENARIO:

Self-consumption rate: 96%

Self-sufficiency rate: 50%

NPV: 390% increase

IRR: 23.4%

Payback: 5 year

A conversation with the owners

Considering that SNFCC consumes all self-generated electricity and taking into account the Greek legislation on the promotion of renewable energy sources, no other attractive regulatory framework for the operation of the existing PV installation has been identified. The only alternative that could be considered is that of a hypothetical increase in PV capacity to cover a higher proportion of SNFCC's electricity needs. In such a scenario, SNFCC should sign a contract with the Local Distribution Grid Operator under Law 4203/2013, which introduced the necessary legislation to facilitate net-metering for PV systems, in order to exploit the energy and economic benefits of PV exports.

Under the Greek net-metering scheme, excess electricity injected into the grid can be used later to offset consumption during times when PV generation is absent or insufficient, meaning that the grid is used as a backup system for excess power production. The excess energy injected into the grid is compensated with consumed energy; however, regulated charges (e.g. charges for the use of the network) are not avoided. A working meeting with relevant SNFCC's stakeholders was arranged in order to discuss the business model analysed and although the hypothetical PV system enlargement is incompatible with the rules of the existing net metering regime, the participants found the hypothetical scenario quite interesting.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 764805

FACTSHEET: POLAND – PASSIVE HOUSE WITH PV

Description of the case study

This private house was built at the beginning of 2016 when the owner fulfilled his dream of building a zero-energy consumption house. The building is 204.23 m^2 and houses a four-member family. This Passive Residence is equipped with a grid connected rooftop PV installation which serves the annual electrical needs of the residence and ascribes to the Polish net-metering scheme. Although the energy generated is meant to be self-consumed, the surplus energy can be fed into the grid at no cost or compensation. Instead, the Polish regulatory framework gives prosumers the opportunity to get back up to 80% of energy fed without any charge.
The electricity consumption of the passive house as well as PV production are monitored and recorded. Meteorological conditions such as irradiance and outside temperature are also supervised.

Alternative profitable scenarios

Based on the current business model, two possible scenarios were analysed for the Passive House:

- Optimized self-consumption with an electric vehicle (EV)
- Sensitivity to the cost of electricity

Using an EV charger to optimize self-consumption could increase the self-consumption rate to as much as 40%, which is why this is considered the best profitable alternative scenario. By doing this, electricity consumption would increase by 1 500 kwh/year.
Despite the fact that the self-consumption rate would be almost doubled, the impact on economic performance would be minor. However, the combination of the proposed case and the electricity price escalation could bring positive financial results. It is worth to highlight, however, that the chances of electricity escalating 7% (scenario analysed) are quite low.

A conversation with the owners

The owner of the Polish Passive House expressed interest in the purchase of an EV, but his attention steered towards increasing his self-consumption rate. Since the whole family is familiar with PV system functioning, in order to increase self-consumption and therefore profitability, they have changed their daily habits and try to match their electricity-consuming activities with PV generation.
Considering this, the owner stated that "**the limit of increasing the self-consumption rate through changing daily habits has probably been reached already or we are close to it**". The owner also plans to expand his PV plant to meet increasing consumption for cooling during summers which is an alternative case.

KEY FACTS ABOUT THE BASE CASE:

System size: 9.75 kWp

System yield: 1,143 kWh/kWp

System production: 11.1 MWh/year

Total consumption: 10.3 MWh/year

Self-consumption rate: 25%

Self-sufficiency rate: 25%

IRR: 11%

Payback: 10 year

KEY FACTS OF THE ALTERNATIVE SCENARIO:

Self-consumption rate: 40%

Self-sufficiency rate: 37%

NPV: 45% increase

IRR: 27.5%

Payback: 4 year

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 764805

FACTSHEET: SPAIN - INDUSTRIAL MULTI-RES FACTORY MICROGRID

Description of the case study

The project **"Industrial multi-RES Factory Microgrid"** is a demonstrative project that is part of the 2013 European Commission's LIFE+ programme, led by Jofemar and CENER. Its main objective is to demonstrate, through the implementation of a full-scale industrial smart-grid, that microgrids might become one of the most suitable solutions for energy self-generation and management in factories that want to minimize their environmental impact. The microgrid is composed of a 120-kW wind turbine and a 40 kW PV installation.

The microgrid gives service to Jofemar Electromobility, which is the division of Jofemar Corporation specialized in the design, development and implementation of innovative electric mobility systems and battery packs.

Peak consumption of the factory is 230 kW. The project estimates to reduce energy consumption due to the energy management of 100 kW of dispatchable loads, allowing a reduction of 73 million tons of CO_2 emissions per year.

KEY FACTS ABOUT THE BASE CASE:

System size: 40 kWp

System yield: 1,407 kWh/kWp

System production: 56.3 MWh/year

Total consumption: 420 MWh/year

Self-consumption rate: 71.5%

Self-sufficiency rate: 10%

IRR: 18.5%

Payback: 6 year

Alternative profitable scenarios

Various business models were analysed to improve the self-consumption rate of the Microgrid:

- Optimized self-consumption
- Sensibility to cost of electricity
- Peak demand reduction

Between them, the "Optimized self-consumption" business model is considered to be the best alternative profitable case. Because of technical issues, the current system is only generating and, therefore, self-consuming the 71.5% of its theoretical potential generation.

If the self-consumption rate reached 100%, not only would it be economically beneficial, but impact on the grid would also be reduced as no excess energy would be fed into it. In order to achieve this 100% self-consumption rate, it would be necessary to revert the technical difficulties Jofemar has been experiencing for some time now, which is better described in the next section.

KEY FACTS OF THE ALTERNATIVE SCENARIO:

Self-consumption rate: 100%

Self-sufficiency rate: 13%

NPV: 45% increase

IRR: 27.5%

Payback: 4 year

A conversation with the owners

The results obtained by implementing different business model cases were presented to CENER who gave the following feedback:

- Jofemar has experienced technical and monetary difficulties for some months which have made it difficult to make full use of the plant
  - Because of this, only 71.5% of its potential theoretical generation has been consumed. The experts consulted believe achieving 100% self-consumption rate is not in the books right now as the technical issues have not been resolved and will not be resolved in short time
- They currently do not contemplate installing a battery for peak demand reduction because of the high cost it represents, which is why said business model has been disregarded as an alternative profitable case

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 764805

FACTSHEET: NETHERLANDS - COLLEGE PARK ZWIJSEN GRID

Description of the case study

This case study explores the renovation and redevelopment of a former school built in 1954 with no energy efficiency measures, into 115 apartments, located in Veghel. All apartments of the Collegepark Zwijsen Grid Connected PV E.CO have a PV plant, balanced ventilation with energy recovery and an air-to-air heat pump, and a solar thermal installation. Furthermore, owners were guaranteed a zero-energy bill for the first three years.

The apartment owners are organised in a so-called VVE (union of house owners) which is allowed to collectively buy or sell energy and established a private grid on the premises.

The private grid enables the smart supply of central solar PV-generated electricity and solar thermal energy production for heating and warm water supply.

The apartment complex is still connected to the grid, which has been designed according to applicable standards, so the local DSO can take over the private grid in case of eventualities.

KEY FACTS ABOUT THE BASE CASE:

System size: 100 kWp

System yield: 990 kWh/kWp

System production: 99 MWh/year

Total consumption: 180 MWh/year

Self-consumption rate: 70%

Self-sufficiency rate: 38%

IRR: 22.2%

Payback: 5 year

Alternative profitable scenarios

Several business models were analysed to improve the self-consumption rate of the microgrid and limit its impact on the grid. A good outcome in terms of self-consumption resulted from the implementation of demand-side-management and installation of a battery.

An additional investment of EUR 60 000 for a 120kWh battery was considered, with a lifetime of 15 years. With the DSM measures, the main goal was to control the heat pumps.

By applying said changes, the self-consumption sufficiency rate would increase from 38% to 48% and the self-consumption rate would change from 70% to 85%. Nonetheless, it is important to consider the additional costs these changes would bring, which would result in a decrease of the IRR and the NPV and an increase of the payback period.

KEY FACTS OF THE ALTERNATIVE SCENARIO:

Self-consumption rate: 85%

Self-sufficiency rate: 48%

NPV: 40% decrease

IRR: 11.3%

Payback: 9 year

A conversation with the owners

The owners' combined solar PV with solar thermal as heating demand is one of the biggest in the complex. Furthermore, they also included a heat pump for the apartment complex's thermal energy needs. This has a big impact on self-consumption levels and is interesting for the business case. One of the measures that were difficult in this case was to make sure that apartments could use the solar PV electricity behind the meter. This is possible in this case because the VVE has a legal exemption to install a self-controlled grid in the apartment complex. Nonetheless, because a tax is charged on supply of electricity, it was very important that the community could manage its own grid, which they found difficult to reflect on the model.

One thing that they would do differently is to generate heat centrally instead of individually with a heat pump in every apartment, as it is cheaper and easier to control.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 764805

FACTSHEET: LITHUANIA - ON-GRID SOLAR GRID IN BUKCIAI

Description of the case study

The Lithuanian case study is a well-equipped private family house measuring 160 m^2 located in the suburbs of Vilnius. The system consists of a 6.6 kWp PV rooftop installation which is connected to the grid. The household has a legal opportunity to take advantage of the Lithuanian net-metering system. Other than the PV plant, the house is also equipped with a geothermal heat pump. Because of this, solar electricity is consumed not only for general purposes, but also for production of heat and hot water.
The net-metering system allows for the possibility of accumulating solar electricity in the grid during summertime and consume it via the heat pump during wintertime, which allows for the effective production of heat and hot water.
A home management system permits the modelling of various regimes of production and consumption of solar electricity, heat and hot water.

KEY FACTS ABOUT THE BASE CASE:

System size: 6.6 kWp

System yield: 960 kWh/kWp

System production: 6.3 MWh/year

Total consumption: 13 812 kWh/year

Self-consumption rate: 29%

Self-sufficiency rate: 23%

IRR: 6.5%

Payback: 13 year

Alternative profitable scenarios

In order to analyse the viable business models that could apply to the On-grid Solar Power Station in Bukciai, two scenarios were analysed:

- Making the investment with no subsidy
- Subsidy for a 30% of the investment value

Calculations showed that even second case is not very attractive because of a 10-year payback. Therefore, it is necessary to increase direct consumption of solar electricity via better planning and smart management of usage of household equipment and consumption of heat. Participation in energy community with better management of consumption and installation of high capacity batteries could also increase the economic viability of the project.

KEY FACTS OF THE ALTERNATIVE SCENARIO:

Self-consumption rate: 29%

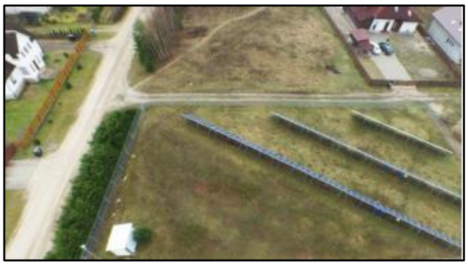
NPV: 20% increase

IRR: 9.9%

Payback: 10 year

A conversation with the owners

The implementation of the business model was discussed with the owner of the house on several occasions. A clear understanding on how the business model works is very important to raise attractiveness of solar energy in everyday life. Modelling of different energy consumption regimes for reaching higher level of direct self-consumption was arranged and discussed.
Another important issue is clear understanding of legal and administration procedures and obstacles in the country. A legal base for energy communities is still not prepared and administrative procedures are not clear. Good results of the project and case studies could be presented for policy makers and would help to understand the necessary changes of the bureaucracy and the need for simplification of the procedure. This will also help to reduce the fear that the implementation of such projects will be very long and not economically viable.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 764805

FACTSHEET: GERMANY - PV SYSTEM ON A SCHOOL ROOFTOP

Description of the case study

The municipality of Warthausen is located in South West Germany. A PV system was installed on the roof of a local primary school and went online in 2013. It is owned and run by a local energy cooperative called Energiegenossenschaft Riss. In order to have the system installed on the local school the energy cooperative is leasing the roof off the municipality.

The energy cooperative is open for everyone and is run as a grass roots democracy. This means that every person who owns shares in the cooperative has got a voting right. The reason for people to join the cooperative is to earn money through renewable energy projects and at the same time it allows them to actively support their local energy transition and contribute to the overall climate change goals.

KEY FACTS ABOUT THE BASE SCENARIO:

System size: 76 kWp

System yield: 1,045 kWh/kWp

System production: 79.4 MWh/year

Total consumption: 59.8 MWh/year

Self-consumption rate: 0%

A conversation with the owners

The PV system is owned and operated by the energy cooperative Riss. The grid connected PV system is set up in a way that some of the electricity that is being generated is consumed directly by the school itself and the surplus energy gets fed into the grid, receiving a feed-in tariff of 0.131 EUR/kWh.

The ratio of energy consumed by the school and feeding into the grid is about 30% to 70%. In 2016, about 37% of the annual electricity consumption of the school was covered by the PV system, whilst the annual electricity consumption of the school was 59 790 kWh.

The energy cooperative has got an electricity contract with the school where the kWh from the PV system for self-consumption costs 15.89 ct/kWh (incl. VAT) plus the EEG (Renewable Energy Sources Act, by its German acronym) levy which is currently at 6.77 ct/kWh. This means that for every kWh sold to the school the energy cooperative receives a net amount of 0.1335 EUR (price excluding a 19% VAT).

Because the difference in price per kWh sold between the FiT and the energy sold to the school is relatively low, the options for improvement in profitability are limited. As the rate perceived for the FiT is slightly higher than that of the PPA, the most realistic possibility would be to feed 100% of the energy generated to the grid and receive higher remuneration. This, however, is not considered to be an alternative profitable case.