MASTER THESIS

ENERGY OPTIMIZATION OF A GRID-CONNECTED VILLAGE UNDER THE DUTCH LOCAL ENERGY COMMUNITY CONTEXT

Final version

15/08/2020

MASTER OF ENVIRONMENTAL AND ENERGY MANAGEMENT

UNIVERSITY OF TWENTE

Academic year: 2019/2020

Presented by: Alba Maqueda Mateos

Supervisors: Dr. M.J Arentsen

Dr. Victoria I. Daskalova

ABSTRACT

A Local Energy Community is established in the town of Daarle with the purpose of providing environmental, economic and social benefits for its members through energy related activities. These activities selected to optimize the energy performance of the village are the adoption of demand-side solutions and renewable generation.

Three types of demand-side solutions are chosen for optimizing Daarle´s dwellings: upgrading the efficiency of every household appliance, adjusting daily habits such as programming the dishwasher and the drier at night when electricity is cheaper and installing an EV charging point. Results show that by adopting these measures 49 % of electricity can be saved while decreasing peak loads and reliving capacity in the local grid. In addition, charging EVs is preferable to do it at daylight in the working place due to less transmission losses and burden for technical the residents of the town.

A PV park is selected to improve the environmental performance of the village. In this manner, the plant is composed by 7.329 monocrystalline modules with a capacity of 300 W each and disposed in 349 modules in series and 21 in parallel. The capacity of the plant reaches 2.200 kWp and a total production of 2.135 MWh per year. By simulating these parameters in PVSyst, it is concluded that the solar park covers 57 % of the total electricity consumption of the village per year from a renewable source.

To conclude a profitability analysis is carried out to evaluate these previous measures. To this end, revenues from the PV plant are calculated so that afterwards they are invested in demand-side solutions. Results indicate a NPV greater than zero, an IRR that exceeds the reference and a Pay-back of 7 years; thus, making the plant profitable. In addition, profits from the first year are decided to be used to replace incandescent lighting with LEDs and upgrading the label of a drier and a fridge-freeze in each household of the community. It is advised to use revenues from the following years in implementing more demand-side solutions such as charging EVs. This way, the energy performance of the village is constantly enhanced.

Key words: Local Energy Community, demand-side solutions, renewable energy

Many thanks to my family for their unconditional support and
for encouraging me to begin with this new phase.
Special mention to my tutor for his involvement and active
collaboration during the development of the project.
Great appreciation is also delivered to my friends for
always helping and supporting me.

TABLE OF CONTENTS

ACRONYMS

BRP	Balance Responsible Party
CPI	Consumer Price Index
DSO	Distributor System Operator
EU	European Union
EC	Energy Community
EV	Electric Vehicle
GHG	Greenhouse Gas
GOs	Guarantee of Origin
HV/MV	High voltage/ Medium voltage
IEMD	Internal Electricity Market Directive
IRR	Internal Rate of Return
LCoE	Levelized Cost of Energy
LEC	Local Energy Community
MPPT	Maximum Power Point Tracking
PCR	Postal Code Rose
PPA	Power Purchase Agreements
PV	Photovoltaic
OECD	Organization for Economic Co-operation and Development
RE	Renewable Energy
REC	Renewable Energy Community
REII	Renewable Energy Directive
SDE	Sustainable Energy Subsidy Scheme
TSO	Transmission System Operator
NPV	Net Present Value
VAT	Value-Added Tax

LIST OF TABLES

LIST OF FIGURES

LIST OF GRAPHS

1. INTRODUCTION

1.1. Background

Energy demand is growing worldwide and will continue to do so in the future. OECD countries are expected to increase 15 % its energy consumption by 2050 (EIA, 2019). This same year, the Netherlands has committed to achieve a carbon-free and complete renewable economy (European Parliament, 2020). However, despite its tradition of harvesting wind power to pump water and grind grain, the Netherlands latest figures on renewable energy share account for only 7,4 % of the total energy production, far from their 14 % official goal for 2020 and the 18,8 % EU average (Eurostat, 2020). In spite of this, the Dutch government has committed to increase the share of renewable energy (RE) to at least 32 % by 2030 (Ministerie van Economische Zaken en Klimaat, 2019). In addition, the government has set in the National Climate Agreement the objective of reducing 49 % of greenhouse gas emissions (GHG) emissions by 2030 (compared to 1990 levels).

The transition towards a renewable and climate neutral system will only succeed if a national effort involving every sector and every level is contemplated. One of the most interesting sectors is the built environment since it allows open participatory and collaborative approaches. Besides, it is expected that cooperatives and particulars play an active fundamental role in climate change mitigation, in particular in the residential sector since it represents 17 % of gross inland energy consumption in the EU (eurostat, 2019).

In this regard, local energy communities (LEC) arise as an emerging player in the future energy system. LEC are legal entities engaged in generating and distributing electricity from renewable sources who are also involved in other activities such as energy efficiency measures, demand-side management, storage and electric vehicle (EV) recharge. Their aim is to provide environmental, economic and social benefits for its members rather than financial profits.

Considering the above, this research considers two of these actions inherent to LEC: adoption of demand-side solutions including EV recharge and renewable energy generation.

Demand-side solutions applied in households are paramount to lower consumption and reduce emissions at a local level. Demand-side measures for mitigating climate change include strategies such as technology, usage, behavior and lifestyles election, coupled production/consumption infrastructures and systems, service provision and associated socio-technical transitions (Creutzig et al., 2018). Residents benefit from applying these measures since total energy expenses decrease.

Regarding renewable energy production, LEC generate a share of the electricity they consume while acquiring ownership of RE installations (Lowitzsch et al., 2020). Therefore, local energy generation allows profits and energy costs to remain inside the region which in turn benefit local value chains (Interreg Europe, 2018). LEC also contributes to lower the cost of electricity in the long run by selling the excess of energy produced while reducing the overall expenditure on energy consumption.

The purpose of this research is to energetically optimize an existing community under the LEC framework by applying these two previous concepts, the adoption of demand-side measures and renewable energy production. This research only evaluates electricity usage due to its increased demand and the electrification of sectors such as mobility, agriculture and built environment which support this trend. Besides, even though gas accounts for a large part of the total energy consumption, the Dutch government has not decided yet about the future prospect of this resource (Duurzaam Thuis Twente, 2018), thus, alternatives such as heat network, green gas or electricity are being considered without any final consensus.

The community selected for developing this research is a town named Daarle situated in the province of Overjissel. This town has a total population of 830 habitants (Rijkswatestraat, 2019). Currently, the amount of households registered in the municipality is 290 (Rijkswatestraat, 2019); these houses are primarily detached and semi-detached houses. In addition, the average household size is 2,9 persons per household which compared to the rest of the Netherlands is quite high, this is consistent with the size of the houses which are also bigger (Rijkswatestraat, 2019). Daarle is a town highly dedicated to agriculture, proof of that is the large amounts of fields destined to this purpose. Dairy and meat farms are also very popular and a tradition that is still prevalent in the community.

To conclude, the optimization of this community surges as an opportunity to enhance its current energy performance as well as its environmental status while providing social benefits to its residents. This endorses the governmental efforts to further tackle climate change mitigation.

1.2. Problem statement

According to the most updated statistics, the total electricity consumed in Daarle is 1.180 MWh (in 2017); per household, this corresponds to an average of 4.400 kWh per year (Rijkswatestraat, 2019). The average consumption scores very high when compared to the average in the Netherlands. This might be due to the large amount of barns and stables which account for a great part of the total electricity consumed. However, it is unknown whether another explanation is its poor energy performance. Therefore, assessing and improving its current status is beneficial, also, in order to prepare this community to the future prospects of the energy sector.

Concerning the deployment of local renewable electricity production, matching demand and supply presents a current challenge often being addressed. Small-scale distributed renewable sources such as PV and the interaction between the existing loads considerably increase the complexity of the electricity system (Sabzehgar, 2017). Hence, this project ensures that to the extent possible, the electricity produced is also consumed locally. This is accomplished by deploying demand-side measures. The goal is thus to establish an LEC where renewable technologies and efficient measures are installed for the optimization of the town and the benefit of its members.

1.3. Research gap

Several efforts from the municipality of Hellendorn (in which Daarle is situated) have been realized. For instance, by giving advice, stimulating/supporting individuals and groups to work sustainable, organizing activities and raising awareness through the municipality (Stichting Platform Duurzaam Hellendoorn, 2018). However, previous research regarding improving the energetic performance of the town has not been conducted.

1.4. Research objective

The objective of this research is to optimize the electricity performance of the town of Daarle within the context of local energy communities by adopting demand-side solutions and renewable sources. The configuration is assessed through a techno-economic analysis from which conclusions are drawn.

1.5. Research questions

Main research question

How to energetically optimize a community by applying demand-side measures and selecting adequate renewable technologies within the context of local energy communities?

Sub-Research questions

1) What legal, regulatory and technical requirements does the existing community need to adopt to become a local energy community?
2) How can the community of Daarle improve its energy performance through the adoption of demand-side solutions?
3) How can the community of Daarle enhance its environmental status through the implementation of renewable technologies?
4) What is the profitability of the selected optimal scenario?

1.6. Research methodology

Depending on the research question, several categories of sources and methods are used in this analysis. Below, the procedure to answer each of them is reviewed.

First of all, to answer the first research question the current state of the art of LEC is examined. This implies research regarding the definition of LEC under the EU and Dutch legal framework, their role in the electricity market, incentives and policies currently in place and values that this type of network foster in a community. Additionally, demand-side measures and technologies used in LEC are reviewed. For this purpose, media, literature and documents are used to consult several relevant official websites from European and national sites. The aim of this section is to investigate what requirements the existing town of Daarle needs to adopt to become a LEC. This research only evaluates two activities inherent to LEC: demand-side solutions and renewable energy technologies.

The second research question considers the type of demand-side solutions available to improve the energy efficiency of the dwellings in the town of Daarle. For this purpose, a representative household located in this village is selected as a model to study these measures. First, electricity bills for the past year are gathered so that together with consumer behavioral performance an hourly consumption pattern is developed. Specifically, this hourly pattern represents the electricity usage of a representative household on an average day. Based on this outcome and considering additional factors relevant to the community, several demand-side solutions are selected in order to improve the household´s efficiency. This is done on an Excel sheet by quantifying the impact the chosen measures have on the current daily usage.

Subsequently, in order to evaluate the impact of demand-side solutions at a community scale these previous results are extrapolated to the whole community. Considering this method, the total electricity consumption of the town for the most updated year is first collected from the distributor operator and relevant local websites. This volume includes the total consumption of the households together with farms and small businesses. Nonetheless, since the aim is to assess the impact of demand-side solutions in households, the consumption of solely dwellings is determined and afterwards compared to the electricity consumption of an ideal community which has already adopted demand-side measures in all its dwellings. By this means, the potential electricity savings for the community when demand-side solutions are adopted are then determined.

Additionally, the role of the EV in the community´s performance is also evaluated so that together with the previous demand-side measures the town´s local grid can be optimized and prepared for the future energy panorama.

The third research question involves selecting a renewable technology to enhance the environmental situation of the town. The selection of an adequate technology is done by assessing multiple criteria such as location, feasibility, cost and maturity of the technology. After selecting the renewable source, the total renewable share expected to partially cover the electricity load of the town is decided. In turn, the capacity of the generator is the one considering the electricity produced is consumed locally to the extent possible. Once the capacity is selected, the technical requirements and components of the renewable source are studied so that the main parameters involved in the design of the technology are determined. To conclude this section, specialized simulation software (PVSyst) is consulted to get an estimation of the monthly electricity generated. This way, the impact of the renewable technology on the energy performance of the community is evaluated.

Lastly, an economic analysis is realized to evaluate the financial impact of adopting these two measures. To this end, the profitability of the renewable generator is first assessed through parameters such as Payback, NVP and IRR. The cash flows considered for this purpose are: the total investment during the lifespan of the generator, revenues and subsides available. By balancing these concepts out, yearly profits are determined. These profits in turn are used to select which demand-side solutions can be adopted in the town to optimize its overall performance. In this manner, revenues are used to exclusively benefit the members of the LEC.

The specific data/information required to answer each research question as well as its accessing method and sources employed are described in the table below.

Table 1. Data/Information required for the research (Source: Own elaboration)

Research Question	**Data/Information required to answer the question**	**Sources of Data**	**Accessing Data**
What legal, regulatory and technical requirements does the existing community need to adopt to become a LEC?	Defining LEC & legal, regulatory and market framework	Documents & Literature	Content Analysis
	Technologies used in LEC & operating mode	Documents & Literature	Content Analysis
How can the community of Daarle improve its energy performance through the adoption of demand-side solutions?	Electricity bills of a representative household in Daarle & consumer behavior	Documents & Reality	Email
	Demand-side solutions and EV theory	Documents & Literature	Content Analysis & Search Method

Research Question	Data/Information required to answer the question	Sources of Data	Accessing Data
How can the community of Daarle enhance its environmental status through the implementation of renewable technologies?	Description of the LEC: current activities, demographic characteristics, load profile and relevant practices	Documents & Reality	Content Analysis
		Media: town´s website & electricity provider	Email & Search Method
	Renewable technology theory (LCoE, feasibility...)	Documents & Literature	Content Analysis & Search Method
	Simulation of PV plant and expected electric production	Simulation Model: PVSyst	Measurement Instrument & Search Method
What is the profitability of the selected scenario?	NPV and IRR calculation to determine overall profits	Documents & Literature	Measurement Instrument & Search Method
	Feasibility of demand-side measures in the village	Documents & Literature	Content Analysis & Search Method
	Profitability of demand-side measures in the village	Media: service provider´s website	Content Analysis

1.7. Reading guide

This research starts with Chapter 1 presenting the background of the topic, problem statement, research objective and research questions and subquestions. Additionally, the methodology adopted to answer each subquestion is explained. Chapter 2 responds to the first research subquestion by reviewing the state of the art and the legal, market and regulatory framework of LEC together with the technologies normally used. Next, energy related activities inherent to LEC are assessed. On the one hand, Chapter 3 evaluates the impact of adopting different demand-side solutions on all dwellings of the village, these are: upgrading the efficiency of the appliances, modifying consumer behaviour and charging EV. On the other hand, Chapter 4 considers a renewable technology that improves the environmental situation of the village. This chapter describes the main components and parameters of the generator and simulates the expected energy production per month. The profitability of the studied scenario is evaluated in Chapter 5 which determines the profits from the renewable generator so that they can afterwards be invested in demand-side solutions. This research finalizes with Chapter 6 summarizing each subquestion and reflecting upon it.

2. LOCAL ENERGY COMMUNITIES

This section first presents the definition of LEC along with the actors involved and the benefits of this type of network. In addition, the overall legal and regulatory panorama as well as the differences and similarities between the EU and the Netherlands regarding LEC´s framework are studied together with the main policy instruments currently in force. To conclude, the section finishes with a more technical approach by describing the operating mode and the technologies often installed in EC.

2.1. Definition of Local Energy Communities

Due to the recent emergence of decentralized energy systems, the term 'local energy communities' is not yet literally specified under the EU legislation. However, under this framework it is currently used in various ways. That is, the EU considers both terms: 'renewable energy communities' and 'citizen energy communities' as a part of the broader concept 'energy communities' (Roberts et al., 2019). Respectively, these two concepts are defined in the Renewable Energy Directive (REDII) and the Internal Electricity Market Directive (IEMD).

The meaning of both concepts is rather similar, although, there are some significant variations. The main differentiation is that the IEMD identifies the role of energy communities in relation to the energy sector, including the collaboration with grid operators. Instead, the REDII focuses more in renewable technologies and their promotion by means of eliminating existent barriers in the policy and regulatory framework.

This project will mainly focus in the term 'Renewable Energy Communities' (REC) as defined under the IEMD since under this term the activities chosen for this research such as energy efficiency measures, distribution of renewable electricity and services for electric vehicles are considered, unlike the definition described in REDII (Caramizaru & Uihlein, 2020).

Therefore, an REC as expressed in the IEMD is described as a legal entity engaged in generating and distributing electricity (preferably from renewable sources) which may also be involved in activities such as supplying, consuming, sharing, storage, aggregation and/or energy efficiency services. It also contemplates implementing infrastructure for charging electric vehicles (EV) and their future role in electricity storage (Touonquet, 2019). It is relevant mentioning, that the term 'supply', given by the IEMD, can be interpreted as selling energy through power purchase agreements (PPAs) or by interacting with either the wholesale or retail market (Roberts et al., 2019). In this sense, the excess of electricity produced by the selected RE in this study will be injected and sold to the correspondent distribution grid operator.

As entities involved in the electricity market, REC must follow the same regulations as other parties such as generators, suppliers, distributors or aggregators while being treated in a fair and non-discriminatory manner (Caramizaru & Uihlein, 2020). Besides, the IEMD allows every party to participate in a citizen energy community unless an actor´s primary commercial economic activity is related to the energy sector (Caramizaru & Uihlein, 2020).

Essentially, the main objective of any EC is to provide environmental, economic and social benefits for its members rather than financial profits; therefore, under the Clean Energy Package released by the EU they are a considered a non-commercial market party (Lowitzsch at al., 2020). Accordingly, EC operate under the principle of 'energy democracy' which aims to grow community involvement on a voluntary and open participatory basis (Comission for the Environment, Climate Change and Energy , 2018). From a socio-technical perspective, these networks contribute to foster the following main values in the community:

Figure 1. Example of energy communities' values proposition (Touonquet, 2019)

- ✓ Local value: through the implementation of LEC not only economic value can be achieved, also improved quality of environment is gained as renewable energy projects are developed and GHG are reduced. These networks can establish a new economic sector by creating jobs and local identity (Caramizaru & Uihlein, 2020). Furthermore, assets such as PV produce earnings locally which can be afterwards reinvested in community funds and different projects.

- ✓ Energy citizenship and democracy: members of the community democratically make the decisions by choosing the type of local network, energy investments and renewable installations that fit the most to their desirable outcome. The participation process can be done either by regular assembly meetings in which it is decide how to precede with the excess/deficits or by a board of directors (Interreg Europe, 2018).

- ✓ Education and social cohesion: by cooperating against climate change the network brings together municipalities, local authorities and citizens. Awareness of the topic and a feeling of trust are values likewise created.

2.2. Markets, incentives and regulations

2.2.1. EU and national legal framework

For the first time in the European Legislation, the Clean Energy Package approved by the EU Commission allows citizens to participate in the energy market by incorporating them as market actors. Therefore, nowadays in the EU, all Member States are required to facilitate local energy communities' implementation by taking them into consideration when planning their RE support schemes. It is also their obligation to provide an effective regulatory framework for developing these networks (Caramizaru & Uihlein, 2020).

The IEMD scheme, under the EU framework, considers the rights and obligations of each actor according to their status. That is, members/shareholders of the community are treated as either customers or prosumers depending on whether they are involved in storing electricity or only generating it, respectively; their status also involves these actors to be financially accountable for the grid imbalances they might induce in the grid. Furthermore, the scheme also allows these participants to leave the community without consequences by guarantying their connection to the community even after they leave.

As stated in the EU legislation, members of an EC have the right to "own, establish, purchase or lease distribution networks and to autonomously manage them in their area of operation" (Touonquet, 2019). Should that happen, both the community and the DSO need to reach an agreement that states separately the charges fed into the grid and the electricity taken from the distribution network. Nevertheless, this agreement is influenced, under the IEMD, by the obligation of the correspondent DSO to cooperate with energy communities in order to promote renewable energy exchange. Besides, the directive requires a previous cost-benefit analysis of the electricity shared in the EC by a competent national authority (Touonquet, 2019).

In short, all Member States should guarantee the implementation of ECs through:

1) an evaluation of possible opportunities and the removal of potential barriers
2) provision of financial mechanisms and access to information
3) support of regulatory framework for enabling public figures to establish ECs
4) assurance of transparent and proportionate charges, exemption of levies and taxation mechanisms and fair registration and licensing procedures
5) authorization of cross-border participation
6) consideration of the particularities of ECs when implementing support schemes to enable them to fairly compete with other market actors

Regarding the national legal framework, it can be stated that it has many similarities with the EU framework. Particularly, the Dutch definition of REC (called 'Energy Cooperative') relates more to the definition of EIMD than the one from REDII provided by the EU. However, due to the recent updates in the European legislation certain requirements are not contemplated or differ from Dutch postulates.

In 2015 the 'Experiments Electricity Law' that recognizes electricity generation from renewable decentralized sources was published in the Netherlands (Campos et al, 2020). In addition to that, a draft modifying certain aspects of this law is expected for the current year (2020). At present, only renewable electric-based cooperatives and associations can build their own EC network; although, the new proposal considers opening up this definition to any legal entity including network operators, suppliers and also aggregators. Moreover, the general assembly of members is currently expected to have the control of the establishment and distribution costs of the project, they must prove as well that they acquire the necessary financial, technical and organizational capacities to implement the entire project. In the Netherlands, participants are also able to agree on their own internal tariffs for supply as long as the energy regulatory office approves (Touonquet, 2019).

In general, the Netherlands aims to promote decentralized small scale renewable sources within a limited area. The projects presented so far mostly consider renewable decentralized sources from PV and small-scale wind power with storage and EV charging.

All and all, in order to become a LEC the town of Daarle is defined under the Dutch framework as an electric-based cooperative which purpose is to provide environmental, economic and social benefits for its members through the adoption of demand-side solutions and renewable energy. Thus, the required investments as well as the profits gained by these measures are distributed amongst its members who are also responsible for the decision-making and organization of the whole project.

2.2.2. Financial support and policies

One of most effective mechanisms for local energy development has been the introduction of the 'postal code rose' (PCR) arrangement which aims at exempting the energy tax for members of local energy cooperatives within the same or adjacent postal codes areas (Verkade & Hoffken, 2019). In this sense, the PCR area is designated by the place (postcode) and adjacent postcodes where the generator is located. The only two conditions are that participants from the local energy cooperatives are connected to the grid via a small consumer connection and that they are allowed to participate in the project up to a maximum of 10.000 kWh (ECoop, 2020). Participants, on the other hand, can be individuals, companies, associations and foundations, i.e everyone can participate in a PCR project. However, companies (VAT entrepreneurs) may participate for a maximum of 20% in the assets of the cooperative (ECoop, 2020). In conclusion, this national policy instrument has resulted in more neighborhoods organizing themselves as cooperatives involved in the renewable electricity generation, although not without going through the obstacles inherent to this complex mechanism (City-zen, 2018). Furthermore, even though the duration of these incentives is not yet known, it is expected that EC, in accordance with recent EU directives, will remain supported by national policies.

Similarly, to support the implementation of EC, the Dutch government under the 'Experiments Electricity Law' has made additional regulatory mechanisms available. Amongst them are the elimination of unfair regulatory and administrative barriers concerning to "tasks and responsibilities of the network operator, tariff structures and conditions, conditions for data-processing, transparency and solvency, measurement device requirements, invoicing and information processing" (Hannoset et al., 2019).

Additionally, the Dutch government provides a financial compensation for renewable energy production under the Sustainable Energy Production (SDE+) scheme which aims at reimbursing the unprofitable difference between the cost price of renewable production and the market price (Netherlands Enterprise Agency, 2020). For photovoltaic sources this is the average annual APX price, corrected with a profile and imbalance factor (CMS Legal Services, 2017). The most important condition to qualify for the SDE+ subsidy is that the connection value must be greater than 3 x 80 Amp, thus only larger consumers are accepted. To conclude, even though this scheme is also applied to local energy cooperatives, it is not compatible with the PCR scheme.

This community is expected to benefit from the PCR arrangement (due to the size of the connections to the grid) and the regulatory mechanisms provided by the government which greatly improves the profitability of establishing renewable technologies.

2.2.3. Market actors

Municipalities are a powerful institution to help the EC panorama develop. Local government might support the establishment of these communities by providing land and roofs to install renewable technologies, funds to organize networking and educational events and assist in the management of the cooperative. Regarding this matter, municipalities often do not possess the financial capacity to help their implementation (Verkade & Hoffken, 2019).

LEC may be managed and controlled by natural persons and/or local authorities such as municipalities or small enterprises (Roberts at al., 2019). Either way, their capacity to be developed successfully and profitably depends on the adequate operational and economic performance of the network. Especially, the proper organization of such communities is paramount for strengthen recognition, cooperation, and support when developing such network. Consequently, the optimal organizational structure appears when every market actor is clearly defined and understood.

Below the different market actors that composed an EC are mention and explained:

- Transmission System Operator (TSO): they are responsible for installing, managing and maintaining the electricity grid. Besides, they keep the balance between the supply and demand, ensure a reliable electricity supply, import and export electricity and maintain the system (Tennet, 2020). TSOs operate in the high voltage grid; therefore, it might not have much impact in smaller energy networks. However, if local energy networks expand, the grid-stability of TSOs gets affected.

- Distribution System Operator (DSO): they are responsible of connecting high voltage grid with production plants and end-users and to assure the quality of the transmission by also maintaining and developing the medium and low-voltage grid. A consumer can choose the producer but not the DSO since this one is a monopoly non-market competitive public entity. In local energy communities the DSO plays a fundamental role. It can function as a market operator by providing electricity and as an end user by taking the electricity surpluses. Its reliability is affected by demand side and storages services (Timmerman & Hendrik, 2017).

- Balance responsible party (BPR): is the entity accountable for imbalances induced in the grid caused by its customers. It is this actor´s responsibility to inform grid operators about the intended electricity injections and withdrawals on the distribution grid.

- Suppliers, aggregators and service providers: suppliers buy and afterwards sell the electricity to end-users through bilateral agreements. In a LEC prosumers are able to get electricity from the grid as well as feed into the grid the electricity they have self-produced. However, weather based generators produce imbalances between generation and consumption, thus prosumers must compensate or be compensated according their deficits or surpluses, respectively (Mendes et al., 2018). Local energy markets enable suppliers to expand their businesses by becoming aggregators or by exchanging electricity according their corresponding surplus/deficit.
  Similarly, aggregating can be done by a service provider or by the local market itself, the latter enable prosumers to participate in the market as well (Timmerman & Hendrik, 2017). Moreover, as smart houses continue to improve and renewable energy becomes cheaper, more capacity will be available for suppliers and aggregators. In turn, this will eventually be translated in more competition against traditional operators and more accessibility for citizen energy communities.

- Consumers, prosumers and active customers: due to their fundamental role the term 'prosumers' or 'active costumers' are notably gaining relevance in this context. 'Prosumers' are consumers who also produce electricity mainly by onsite renewable generators (European Comission, 2017). Differently, 'active customer' is a consumer or a group of them who not only generate and consume but also store or sell electricity within their properties (through aggregators) and participate in demand response or energy efficiency measures (The European Parliament and The Council of the EU, 2019). These groups contribute to the DSOs networking balancing by influencing its capacity through demand response services (Timmerman & Hendrik, 2017). Demand side measures are used by 'prosumers' or 'active customers' to cut down the peaks or align the load curve, thus enhancing the efficiency of the grid by increasing its flexibility and relieving its congestion. Hence, if reliability is increased, on-site generation (combined with storage) could also create redundancy and back-up power to lower the financial losses of unsupplied loads (Stadler at el., 2015). Nevertheless, considering recent developments in energy storage, DSO and TSO will certainly need to provide additional tools to respond to the increasing fluctuation of the grid (European Distribution Ssytem Operators for Smart Grids, 2014).

Accordingly, the community of this research is expected to participate in the market as an active consumer involved in the local renewable generation and consumption of electricity by selling the excess to the grid operator and participating in demand-side measures that optimize the load curve.

The above mentioned actors are the key participants of the local electricity market. However, in addition to those, it is relevant mentioning that within the community relevant figures also need to be appointed. For instance, an energy community manager is needed for assume the responsibility of handling the dairy operations and sharing the benefits earned in an equal and fair manner. Additionally, the meter manager is accountable for the installation, maintenance, testing and approval of the meters. Finally, external services may be engaged to provide knowledge on the management of the community and the benefits this has to offer.

As it has been previously mentioned, even though energy communities do not pursue financial profits, they still need to achieve a successful business model for their members and investors in order to be able to return the initial investment. For this reason, they might reinvest their economic earnings in other activities profitable for the business.

Figure 2 represents the business model of an energy community in which the main actors mentioned above take part.

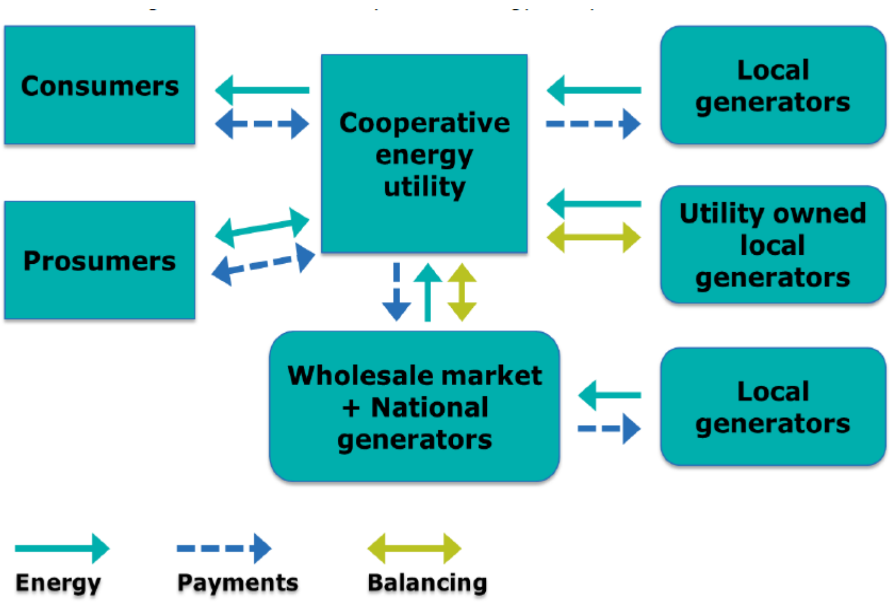


Figure 2. The cooperative energy utility business model (Caramizaru & Uihlein, 2020)

In general, energy communities can be treated as investors whose members need to pay a membership to be able to be part of the cooperative and become energy producers. Energy producers sell the excess of electricity produced through PPA agreements to the electricity market, as a part of the trade also related financial products such as guarantees of origin and green certificates can also be negotiated (Touonquet, 2019).

2.3. Technical considerations

2.3.1. Technologies

The operation of decentralized energy technologies has greatly improved during the past years as a result of recent developments in the IT field. The capacity of controlling simultaneously energy flows and information has led to a real-time effective management of the grid, allowing therefore the integration of activities such as decentralized generation, storage, consumption or demand side flexibility.

There are many technologies that are nowadays being used for decentralized electricity production, amongst others, micro-CHP, heat pumps and the well known solar PV and micro-wind technologies. Energy communities involve both non-renewable and renewable sources; this is because intermittency of renewable sources still presents a challenge for grid-management. Besides, even though the forecasting and efficiency of the systems are in constant development, flexible generation is needed for the adequate performance of the grid, and while is true that some flexible renewable technologies are available such as geothermal or hydropower, these technologies are not always a practical alternative for the community. Hence, the possible need for fossil-fuel based technologies to reduce the fluctuation between demand and supply. Needless to say, renewable technologies take preference over non-renewable on the local balancing of any EC as they are subsided and better alternative for the environment. Their choice is therefore a balance between cost, sustainability and performance.

In addition of the above, enhancing local balancing can be also achieved through demand and supply side management systems. For instance, EV, storage and flexible appliances can be programmed at a real time to hold or deliver electricity according to the demands of the local profiles. However, this sector is restrained by the lack of market incentives, difficult integration of communication and information technologies, the complexity of the process and possible undesirable effects due to loads distortion. On the other hand, main drivers for demand side management are ageing assets, intermittent renewable generation and IT advances. Overall, the relevance of flexible demand approaches will certainly gain weight mainly due to the unstoppable increase of non-dispatchable systems in the future electricity panorama (Prasad Koirala, 2016).

Table 2 presents an overview of the technologies commonly used in local EC at a household and community level.

Table 2. Technologies in ICESs (Prasad Koirala, 2016)

Categories	Technologies	
	Household level	**Community level**
Local generation	Micro-CHP Reciprocating engines Internal combustion engines Fuel cells Heat pumps Pico-hydro Solar PV (rooftop) Solar thermal Micro-wind	Community CHP Reciprocating engines Internal combustion engines Fuel cells Heat pumps Biomass Geothermal Micro-hydro Community PV Solar thermal Community wind
Demand side flexibility	Flexible appliances (e.g. dishwasher, washing machine) Electric vehicles Electric and heat storage Battery energy management system (BEMS) Home/building energy management system (HEMS)	Community electric and heat storage Community BEMS Community energy management system (CEMS)

The selection of demand side flexibility measures and local renewable generator for this research is further explained in Chapter 2 and 3.

2.3.2. Operational mode

The interaction between loads and decentralized technologies is a complex technical process often studied by scholars (Sabzehgar, 2017). The fluctuation of decentralized generators in electricity production is mainly caused by weather variability and the inherent operation of the technologies hence, affecting the local grid-balance process by causing power quality issues that impact the reliability and quality of the local grid network. The adoption of strategies to control local grid exchanges is therefore paramount to establish a secure, reliable, and cost-efficient local grid network (Hirsch, 2018). Summarizing, some of the techniques that need to be considered before realizing the project include: power quality and flow balancing, voltage and frequency control, power management, optimization, stability, reliability and protection (Sabzehgar, 2017).

Since the strategies adopted will greatly impact the efficiency and optimization of the energy community as well as the initial investment is crucial to examine and predict in advance the impact the establishment of any EC may have on the local grid. The aim of this study is therefore to carefully adjusting generation and demand so that power quality issues are not injected into the grid and active customers are not accountable for it. In this way, electricity produced by the renewable technology is intended to be consumed locally without being injected to the high voltage system.

However, if that is to happen the community is connected to the grid. This option is more profitable than installing storage services and it does not have any extra implications or cost to the community.

A potential alternative to lower the impact of intermittent technologies, apart from those already mentioned, is the adoption of energy efficiency measures at a household level which are gaining popularity due to the recent development of smart home energy management systems. The simplicity and affordability of some of these appliances help citizens engage in demand side response activities which in turn, contribute to optimize the local grid balancing process.

An important role in the future energy mix comes similarly with storage systems. Storage devices have the capacity to compensate local electricity exchanges due to its flexible functioning; besides these technologies have been improved in size and capacity so that nowadays they can be tailored according to its final function. Some of the most promising storage technologies are lead-acid, lithium-ion and nickel-cadmium batteries (Al.Katsaprakakis et al., 2019). In addition, the gradual change to plug-in electric, hybrid and vehicle to grid technologies play a key role in future energy mix since these vehicles are expected to boost the energy storage capacity of the LEC while bringing additional benefits such as stability and reliability to the local grid network. It will also provide a flexible back-up to reinforce intermittent renewable technologies.

All these technologies together with smart meters present an opportunity in the future energy system. These electronic devices enable the adequate communication between the utility and prosumers by enabling the access and management of prosumers´ loads remotely so that demand is adjust to the local grid requirements and the price signals of the energy market. Energy consumption is also monitored and saved at a real-time in order to provide users with greater control over their appliances.

Overall, it is crucial considering the impact demand-side solutions and renewable energy generation has on the local grid before carrying out the project. For this purpose, a detailed analysis which evaluates supply and demand balances is necessary to assure a secure, reliable, and cost-efficient local grid network. These analyses are done in the following chapters.

3. DEMAND-SIDE MEASURES

This section responds to the second research question of this study which considers how demand-side measures can optimize the energy performance of a village. To this end, the town of Daarle is selected as a model community for data purposes. Therefore, the analysis is done according to the town´s attributes. The methodology here follows a bottom-up approach where demand-side measures on a single representative household from this town are first analyzed with the purpose of extrapolating the opportunities identified to all the households in the community. For this goal, first, the electricity consumption of a representative household is studied. Then, demand-side measures are applied in order to get a valuable representation of the type of solutions that fit in this community. Finally, the full optimization of the community is completed by applying the studied solutions to all the dwellings in the town and quantifying their impact. The research considers an ideal situation where all types of suitable practices are applied to each dwelling of the community.

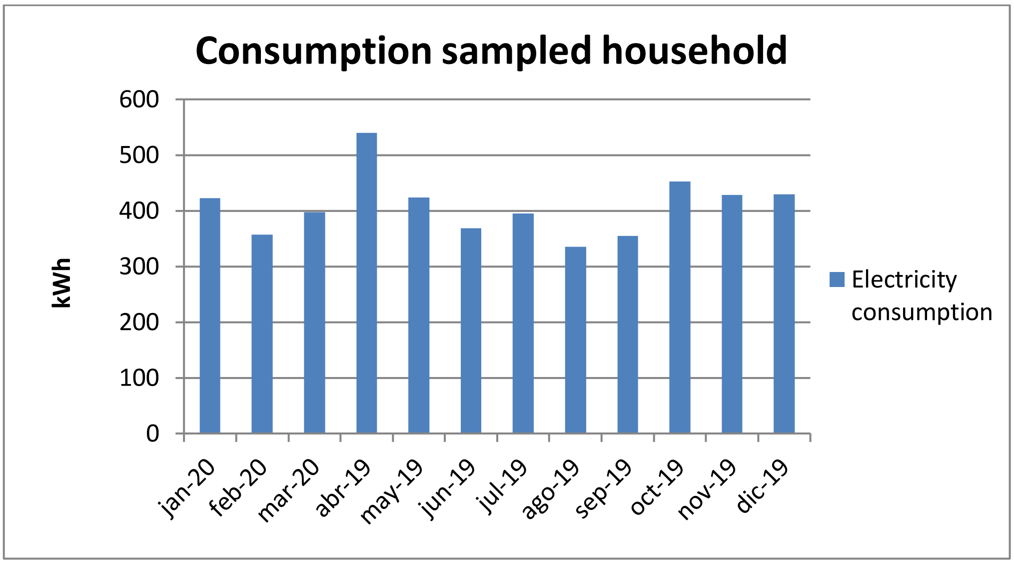
According to L. Niamira the type of demand-side solutions encompassed the following measures: house insulation, solar panels, energy-efficiency appliances, switching off unnecessary devices, regulate inside temperature, adjusting daily habits and switching or changing to a green provider. Additionally, Prasad Koirala also includes EV and storage management under this term.

In this research, measures such as house insulation and inside temperature are not considered since they modify the gas consumption and not the electricity usage. In addition, switching to greener providers does not impact the local level, thus, is not relevant to this study. Therefore, only measures such as replacing inefficient appliances, switching off devices and adjusting daily habits are assessed. This research also includes the role of EV due to its increasing relevance in the future panorama.

3.1. Demand-side measures applied on households

To begin with, a representative household from the town of Daarle is selected for the purpose of this section. The average type of household according to a person from the committee of this town is detached and 3 person capacity, that is in agreement with the official statistics (Rijkswatestraat, 2019). Therefore, the selected household is a detached house where 3 persons reside. The monthly energy bills of the household for the past year have been collected and examined. In a similar manner, the behaving patterns, including the perceptions towards demand-side measures have been, respectively, observed and analyzed. An informal meeting was appointed for this objective.

Below is a representation of the monthly electricity consumption of the model household.



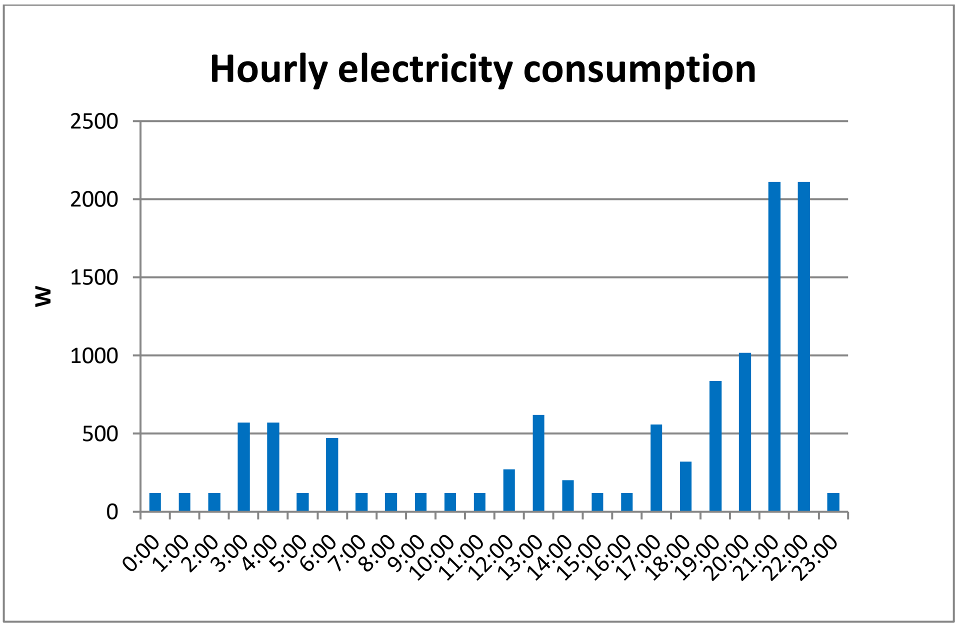
Graph 10. Yearly electricity consumption of a household compared to the average (Source: Own elaboration)

For the purpose of evaluating the efficiency of the dwelling, the hourly consumption on an average day should be determined, otherwise, demand-side measures which purpose is to optimize the usage and flatten the curve cannot be adequately studied. Table 3 represents each appliance, the time that is functioning and its correspondent power. In addition, high consumers are highlighted in red.

Table 3. Power usage per appliance within a day (kWh/day) (Source: Own elaboration)

Appliance	Power (W)	Total usage period		Wh/day	kWh/day	Comments
		min	h			
Oven	2400	20		800	0,800	Not running everyday
Microwave	800	5		66,67	0,067	
Fridge	14,95		24	358,8	0,359	Energy label: A +
Large freezer	24,09		24	578,1	0,578	Energy label: A+
Extra fridge- freezer	82,94		24	1990,6	**1,991**	Energy label: C
Cooker hood	150	45		112,5	0,113	
Kettle	1200	5		100	0,100	
Toaster	700	5		58,33	0,058	
Coffe maker	800	5		66,67	0,067	
Hairdryer	1600	3		80	0,080	
TV	80		5	400	0,400	
Laptop computer	50		2	100	0,100	Plus charging phones and tablets
Vacuum cleaner	450	15		112,5	0,113	
Lighting LED x 8	10		8	640	0,640	
Lighting x 8	60		2	960	**0,960**	
Washing machine	475		2	950	**0,950**	6 times per week - Energy label: B
Dryer	1533		2,28	3495	**3,495**	6 times per week - Energy label: B
Dishwasher	450		2	900	0,900	Once per day - Energy label: A++
TOTAL				11769	**12**	

The previous data is also represented in Graph 2:



Graph 11. Hourly energy consumption in the selected household (Source: Own elaboration)

From the graph above, it can be realized that there is a constant consumption that corresponds to fridges and freezers which run at all times. In the evening, the peak consumption is due to electricity appliances used to make dinner, watch television or do laundry. The rest of the consumption corresponds to lighting and other minor consumers such as laptops or the coffee machine amongst others.

As it was mentioned before, this research will consider three types of demand-side solutions: improving appliances efficiency, switching off unnecessary devices and adjusting daily habits. These types of measures are applied in the representative household presented here.

First, energy efficiency measures are evaluated. Energy efficiency measures are those that decrease the amount of energy use while maintaining a comparable or higher level of service. The European Commission obligates several household appliances to be identified with an 'energy label'. This label shows how the appliances rank on a scale from A to G depending on their energy consumption. This way, class A (green) corresponds to the most energy efficient appliances and class G (red) to the least. Currently, up to three classes are added (A+, A++ and A+++) due to the improved efficiency of many products. Nevertheless, this will be changed on 2021 onwards since it has proven to be confusing for consumers. The new scale will use again the A-G rankings (European Union, 2020).

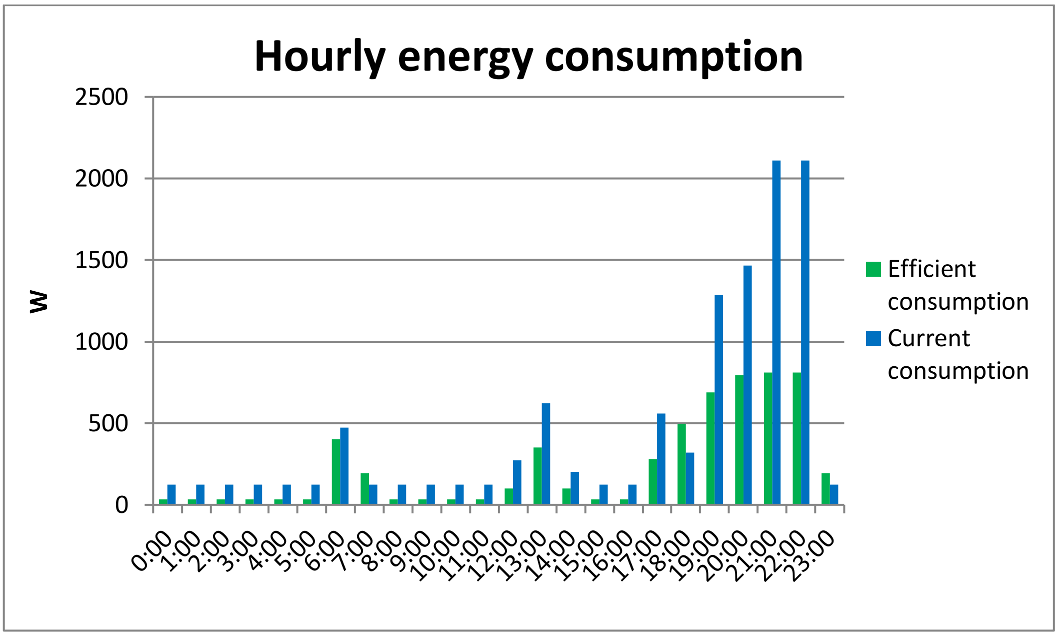
For upgrading the efficiency of the selected dwelling, the same method as the step before is applied. The hourly consumption is again calculated but this time with more energy efficient appliances.

Hence, for each appliance the representative household contains, another more efficient appliance of the same size/capacity is replaced. Hence, an ideal household where all appliances are the most efficient/newest in the market is simulated.

Table 4. Daily power usage when more efficiency appliances are adopted (kWh/day) (Source: Own elaboration)

Appliance	Power of efficient appliances (W)	Usage period		Wh/day	kWh/day	Comments
		min	h			
Oven	870	20		435	0,435	Energy label: A+
Microwave	800	5		66,67	0,067	Energy label: A+++
Fridge	7,88		24	189,12	0,189	Energy label: A +++
Large freezer	18,49		24	443,832	0,444	Energy label: A+++
Additional fridge-freezer	7,65		24	183,6	0,184	Energy label: A+++
Cooker hood	3,46	45	24	83,04	0,083	Energy label: A++
Kettle	1200	5		100	0,100	Energy label: A+
Toaster/sandwhich maker	800	5		66,67	0,067	Energy label: A+++
Coffe maker	900	5		75,00	0,075	Energy label: A+++
Hairdryer	2100	3		105	0,105	Energy label: A+++
TV	66		5	330	0,330	Energy label: A++
Laptop computer	0,13		3	0,39	0,000	Energy star label
Vacuum cleaner	160	15		40	0,040	Energy label: A+++
Lighting LED x 16	10		8	1280	**1,280**	Energy label: A+++
Washing machine	116	158		305,47	0,305	Energy label: A+++
Dryer	434	152		1100,0	**1,100**	Energy label: A+++
Dishwasher	226,4	220		830	**0,830**	Energy label: A+++
TOTAL				5634	5,634	

The results of Table 4 are displayed below on Graph 3. A comparison between the current consumption of the selected characteristic household and the one that results from applying more energy efficient measures is also represented.



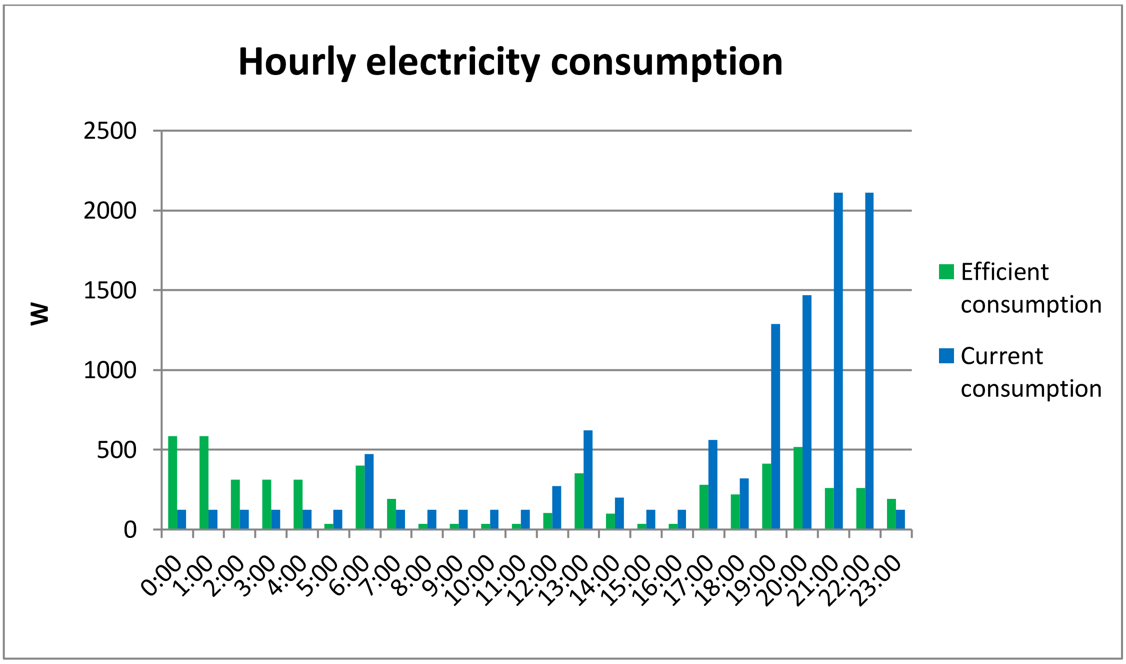
Graph 12. Comparison between a household where energy efficiency measures are adopted and one regular household. (Source: Own elaboration)

It can be easily realized the great impact of adopting energy efficient appliances. The total electricity consumption of this particular house has decreased by 51 %. It is clear then that it is worth considering these improvements at a community scale. However, this is an ideal situation where all appliances are replaced. In real life situation, the adoption of these measures is progressively done at the same time as appliances fail, mainly due to the high investment of some of them. Therefore, this study is carried out to provide a good overview of the major impact of energy efficiency solutions. It is also useful in order to simulate the electricity pattern of households in a few years where more efficient and affordable appliances are available.

The next demand-side solution considers switching off unnecessary devices and adjusting daily habits. Switching off unnecessary appliances is a measure that is very specific to each household; therefore it cannot be generalized to all the households in this community. Nevertheless, this measure is considered in Chapter 5 where different demand-side solutions specific to the selected household are financially assessed.

Adjusting behavior to the necessities of the grid is a mechanism used to relieve some capacity during peak hours and facilitate the injection of electricity produced by renewable intermittent sources. Grid operators already have two different tariffs in order to incentivize electricity usage at night when the grid is less congested. On the other hand, households normally tend to ignore this advantage since revenues are not as high as adopting efficient measures. However, if looked at a bigger scale the impact of adopting demand-side flexibility practices is worth examining.

Programming the dishwasher and the drier at night is considered as the last demand-side measure in this research. From Table 3 it can be realized the drier is the appliance that consumes the most energy on an average day. Thus, it is reasonable to program it at night when electricity is cheaper. In a similar manner, the dishwasher can normally be easily programmed at night with a timer. Accordingly, these two flexibility practices are considered due to their simplicity and impact. Graph 4 shows the electricity pattern on an average day when these practices together with efficient solutions are applied. It also compares this situation with the current average consumption of the household studied here.



Graph 13. Hourly electricity consumption when demand-side solutions are adopted (Source: Own elaboration)

From observing the green bars it is clear that applying these measures greatly flatten the load peaks by making the consumption pattern more constant. This practice in turn, facilitates the management of the grid and consequently, the introduction of intermittent renewable sources.

3.2. Demand-side measures applied on the community

From the previous section, it was concluded that demand-side solutions have the great potential to reduce the electricity usage while flattening the consumption curve. Then, if the measures already investigated at a household scale are to be applied to all the dwellings in the community the impact is obviously much greater. Hereafter, the methodology considered to extrapolate demand-side solutions to the whole community.

From the bills provided by the electricity supplier, the monthly consumption of an average household from the area is known. From this, a percentage of electricity used per month of a representative household can be calculated. This percentage provides a good estimation of the demand deviations from one month to another throughout a year. These percentages are used to extrapolate the impact of demand-side measures in an average household to the whole community. This is done by multiplying the total electricity used by all dwellings in a year per the previous calculated percentage. The result is then the electricity demanded by all dwellings per month.

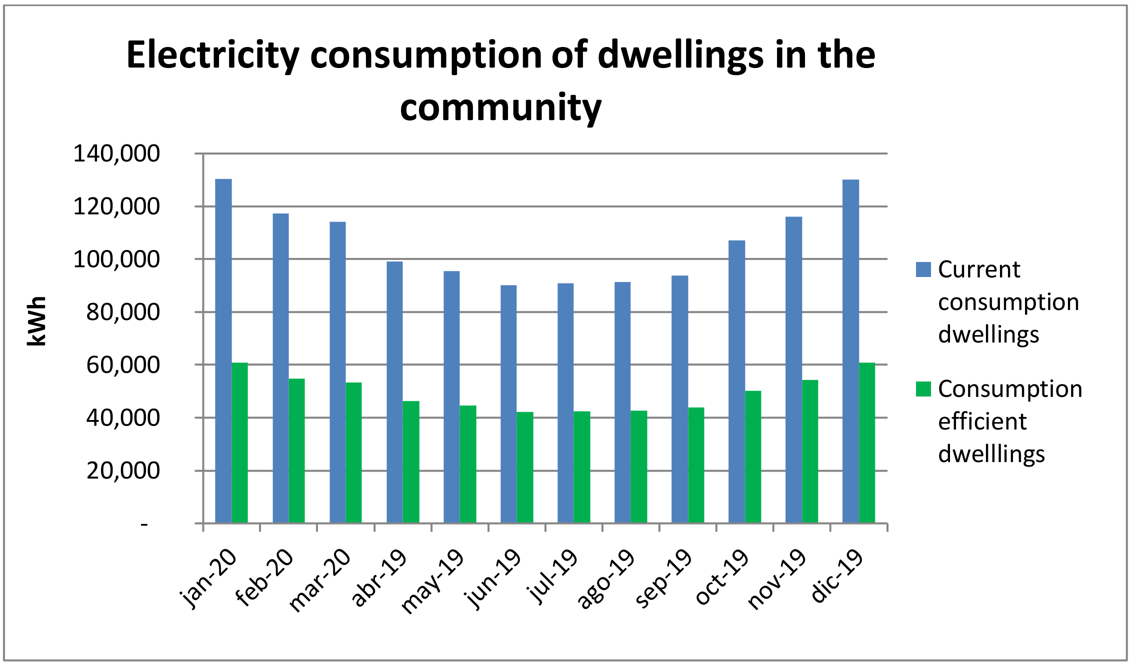
The same procedure is applied to extrapolate the consumption of a dwelling in which energy efficiency measures are applied. In this way, the result of the electricity used in a year after applying demand side measures in the selected household is multiplied by the number of dwellings in the community (209). This number therefore represents the total yearly electricity demand of all dwellings of the town in which efficient measures are applied. Subsequently, this number is multiplied per the percentages previously calculated. Similarly, these results are then the electricity required per month by all dwellings when demand-side measures are adopted.

Table 5 collects the result of both these operations.

Table 5. Results from the extrapolation process (Source: Own elaboration)

	Consumption household from bills (kWh)	Monthly porcentaje (%)	Current electricity consumption all dwellings (kWh)	Electricity consumption efficient dwellings (kWh)
jan-20	427	10,22%	130.379	60.932
feb-20	384	9,19%	117.249	54.796
mar-20	374	8,95%	114.196	53.369
abr-19	325	7,78%	99.234	46.377
may-19	313	7,49%	95.570	44.665
jun-19	295	7,06%	90.074	42.096
jul-19	298	7,13%	90.990	42.524
ago-19	299	7,15%	91.296	42.667
sep-19	307	7,35%	93.738	43.808
oct-19	351	8,40%	107.173	50.087
nov-19	380	9,09%	116.028	54.225
dic-19	426	10,19%	130.073	60.789

The previous table is represented on Graph 5.



Graph 14. Comparison of electricity consumed in the town before and after applying demand-side solutions (Source: Own elaboration)

Again, the great impact of adopting demand-side solutions can be realized from the previous graph. Overall, adopting demand-side measures in the community will decrease the total electricity consumption of the dwellings in Daarle by 51 %.

3.3. Electric vehicle

Due to the role the electric vehicle (EV) is expected to serve in future energy panorama, this research considers its impact in the electricity consumption of an ideal household where demand-side solutions are already adopted. The purpose of considering this device is to assess its feasibility within the energy community since, as it has been explained, the EV can play a fundamental role in the integration of intermittent renewable energy resources by storing or returning electricity according to the grid necessities.

The most up to date best-selling EV in the Netherlands is the Tesla model 3 (Kamer, 2020), therefore the simulation is done with this EV. This automobile has a battery capacity of 50 kWh which can be charged at home with a monophasic power of 3,5 kW or 7 kW in 14 h and 7 h respectively (TESLA, 2020). The type of connection considered is represented in Figure 3.

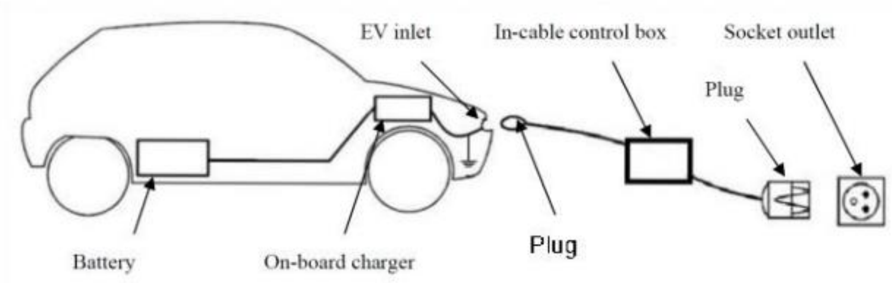
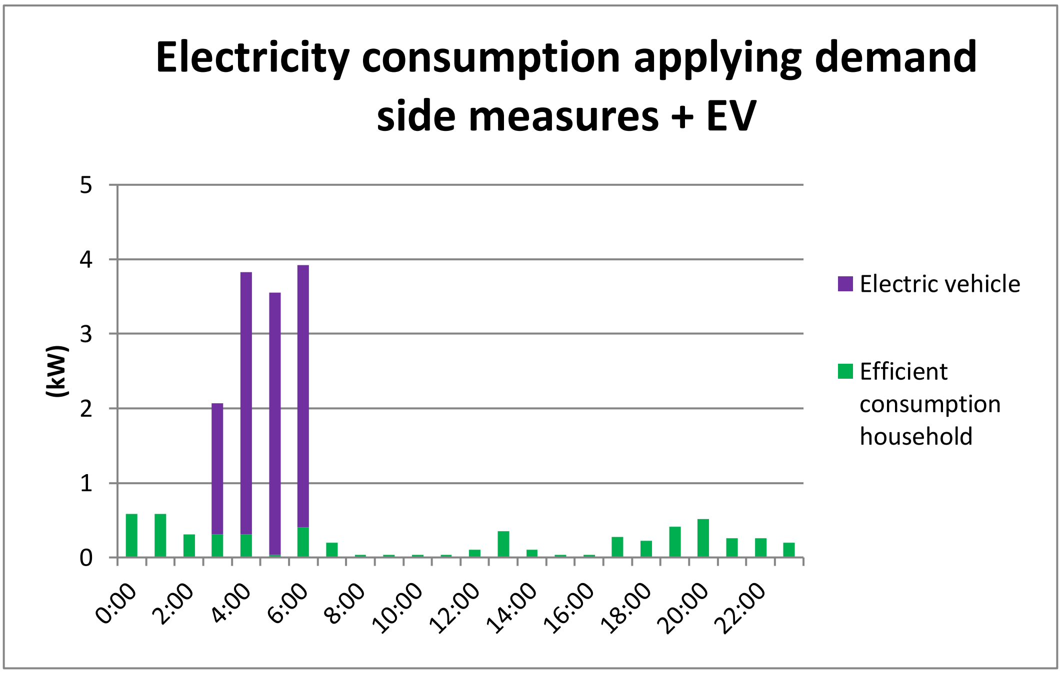


Figure 3. Connection infrastructure of an EV **(Netherlands Enterprise Agency, 2019)**

For this household, a charger capacity of 7 kW (32 A) has been chosen since a full battery charge takes only 7 h instead of 14 h (with 16 A and 3,5 kW capacity). Besides, this model has the capacity to run up to 500 km without recharging; therefore the battery does not need to be fully charged every day since on a normal day it is assumed that an average person travels around 80 km. For this reason, the EV is expected to be fully charged every 6 days to fulfil the travelling requirements.

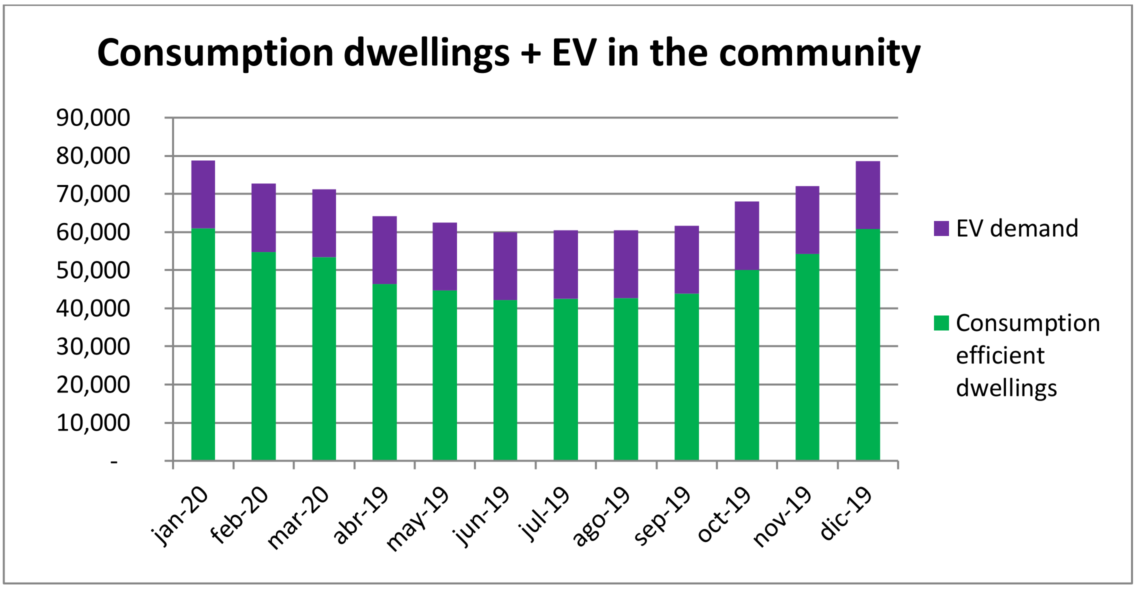
Moreover, in order to represent the hourly load together with the electricity consumption of the efficient household, it is assumed the battery will be fully charged in two days since that way the daily consumption load will significantly decrease, and again, that is sufficient capacity to fulfil travelling requirements every day. To conclude, the energy consumed for charging the battery is represented simultaneously with the rest of the appliances of the household in Graph 6.



Graph 15. Electricity consumption applying demand side measures and electric vehicle load (Source: Own elaboration)

It can be concluded that adding the EV to the household load greatly increases the overall consumption. However, if long travelling distances are not made every day the battery can be partially charged each day as Graph 6 shows, hence facilitating grid balancing to DSOs.

Now, if it is assumed that each dwelling of the community of Daarle buys an EV, the electricity required will increase accordingly. To predict this energy demand, the previous results are projected into all dwellings of the community. Graph 7 shows the total electricity expected per month.



Graph 16. Electricity consumed by efficient dwellings together with EV load (Source: Own elaboration)

In short, the electricity demand of Daarle is remarkably increased by the adoption of the EV.

As charging an EV at home greatly impacts the household´s electricity consumption, it is by contrast assumed that EVs in this community are charged at daylight in the workplace and when the renewable generator, in case a PV plant (see Chapter 4) is generating electricity. This way the injection of large quantities of electricity into the grid is avoided and transmission losses are reduced, thus, making the system more efficient. In addition, households are not left with the burden of installing additional powerful charging infrastructure which most of the times involves upgrading the current electric connection and the electricity tariff.

This approach is supported by the fact that out of 115 companies, 65 are dedicated to the agriculture business, 15 to industry and energy and 10 to hospitality (Bijsterveld, 2020). Hence, since these companies are open at daylight, it is reasonable they consume (in the companies themselves and by charging EVs) all the electricity that is being generated by the PV plant. Thus avoiding the injection of electricity into the grid and optimizing the overall performance of the system.

4. RENEWABLE TECHONOLOGIES

After assessing different energy efficiency measures at a household level, the potential of renewable technologies in the overall electricity consumption of the community is assessed here in this section. This section hence, responds to the third research question defined in this analysis. For this purpose, the current overall consumption of Daarle is first collected so that the impact of any renewable source can be quantified. Afterwards, the most suitable type of renewable energy is chosen to energetically optimize this community. The capacity of the technology as well as relevant technical parameters are explained and justified. Moreover, the impact of this source on the community´s performance is calculated. Finally, conclusions are drawn.

4.1. Overall consumption of the community

To start with, the monthly electricity consumption is collected from the distributor operator which in this particular case is Enexis. This operator is responsible of supplying electricity to the whole province of Overjissel where the town of Daarle is situated. Enexis, similarly to other network operators in the Netherlands, publishes every year the electricity consumption of each city/town broken down per street (to assure individual data protection). Besides, this information is provided as an open source and in an Excel format available to the general public interest. The network operator also provides information about the size of each connection. Particularly for this research, only small users "kleinberbruik" are being considered since the purpose of an energy community is to benefit inhabitants and local businesses rather than large enterprises. Under the "kleinberbruik" term are included those connections that do not exceed 3 x 80 A at the grid access point (ENEXIS Netbeheer, 2020). In other words, the electricity produced by the renewable source is exclusively destined to supply members as well as small farms and businesses of the town.

Other useful information that this operator publishes includes the amount of connections in the town, the connections possessing a double tariff and the direction of delivery. The later is shown as the percentage of connections with a net electricity, hence, this percentage decreases as more feed-in takes place (e.g. due to solar panels).

Instead of providing the total yearly consumption spent by the community, Enexis publishes in its database the yearly average consumption per street of a specific unknown consumer. Therefore, this digit needs to be multiplied by the number of connections per street to get an approximation of the total electricity consumed by the community. The following formula shows this method:

$$Total\ consumption\ (kWh) = Individual\ consumption\ (kWh) * nº\ of\ connections$$

Therefore, in order to find out the total electricity used, the yearly consumption of each street is summed. This is determined by a simple calculation in an Excel sheet. Table 6 shows this procedure.

Table 6. Total electricity consumption in Daarle **(ENEXIS Netbeheer, 2020)**

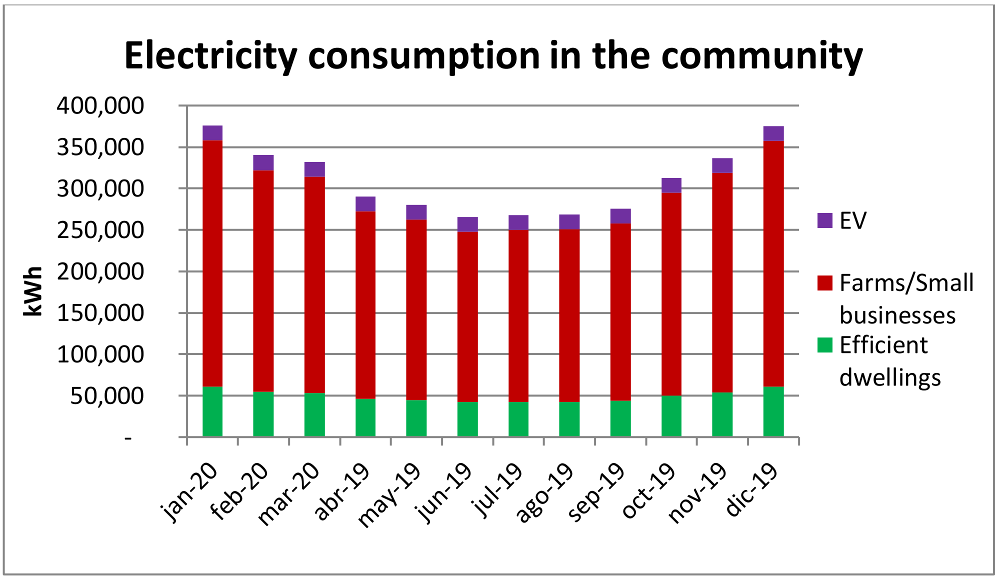
Street	Amount of connections	Average individual usage in kWh	Total consumption kWh
Voombeltweg	13	8.439	109.707
Opgangerweg	22	9.275	204.049
Hellendoornseweg	12	26.926	323.116
Flierdijk	28	8.559	239.653
Piksenweg	21	10.507	220.657
Bruineveldweg	13	12.929	168.077
Wierdenseweg	20	5.644	112.882
Wierdenseweg	17	9.108	154.830
Zandkuilenweg	18	5.537	99.660
E J Boschweg	14	3.026	42.359
Evert Jan Boschweg	17	3.311	56.289
Achterweg	27	5.706	154.070
Dalvoordeweg	19	6.679	126.899
Dalvoordeweg	13	7.655	99.514
Nieuwstadweg	14	7.844	109.819
Watertorenweg	14	8.938	125.127
Watertorenweg	35	9.718	340.121
Esweg	20	12.690	253.802
Groeneweg	10	5.186	51.858
Groeneweg	15	3.034	45.510
Haarweg	12	9.176	110.114
Slagenweg	19	14.650	278.345
Broekweg	27	8.327	224.823
Kotterskamp	14	2.752	38.533
Kotterskamp	14	3.215	45.008
Huttensingel	20	2.866	57.315
Oetbrink	34	3.686	125.309
'n Tip	37	7.252	268.341
TOTAL	539	222.634	**4.185.787**

The bold number is therefore the total electricity consumed in this community in 2019.

After calculating this number, the monthly electricity consumption needs to be estimated so that the potential of the renewable technology chosen can be analyzed in more detail. Due to the intermittency of these sources, a yearly analysis would not be representative as the electricity produced highly varies throughout the year.

The methodology used in Chapter 3 to extrapolate the results from a household to the whole town is again followed here. Therefore, by considering the percentage of the monthly electricity distribution of a household and the total electricity consumption of the community, the monthly consumption of the community can be predicted. Nonetheless, the total consumption of the community in Daarle is associated not only to dwellings but also to small businesses/farms, therefore by subtracting EV and efficient dwellings consumption from the total energy used, this previous concept is known.

Additionally, this research aims to model a future energy situation where sustainability is at the center of attention. Therefore, the electricity consumed by the dwellings is not the actual consumption but the consumption that results from applying demand-side solutions and recharging EVs as specified in Chapter 3. Graph 8 represents the previous findings.



Graph 17. Yearly consumption of the community (MWh) (Source: Own elaboration)

4.2. Selection renewable technology

Once the monthly energy consumption is calculated, a renewable technology is selected in order to make this community more sustainable. In this specific town, there has been an unsuccessful attempt to install a wind turbine due to social discomfort and multiple complaints (regarding the devaluation of housing ground), even though it was planned to be uniquely for the community´s own benefit. Therefore, the second most suitable technology for producing electricity at a big scale in this community is photovoltaic solar energy. This is mainly due to the already maturity of the technology and its lower price when compared to other renewable sources. Specifically, the global weighted-average cost of electricity of solar photovoltaic is slightly higher (0.085 USD/kWh) than onshore wind (0.056 USD/kWh) (IRENA, 2019).

Additionally, cheaper technologies such as geothermal (0.072 USD/kWh) and hydro (0.047 USD/kWh) are not examined since these sources are not suitable for this specific geographical location. Bioenergy, in this case, is not considered since the potential for this neighbourhood is quite low when compared to other locations in the Netherlands (RIVM, 2019). Figure 4 covers different renewable technologies and its current generation costs.

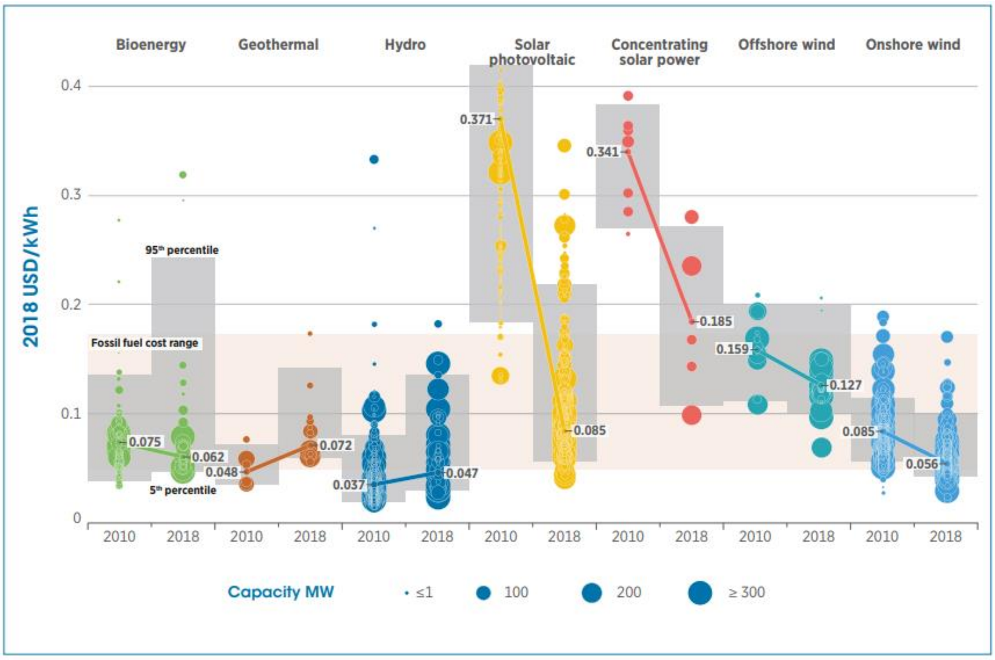


Figure 4. Global LCoE of utility-scale renewable power generation technologies 2010-2018 **(IRENA, 2019)**

Considering the previous facts, the photovoltaic power station is chosen to be installed at the ground level on a currently unused field, this type of installations are called solar parks. The exact location is not purpose of this research since that will imply bid evaluation and the examination of purchasing processes. Nevertheless, the total electricity production slightly varies from nearby fields.

4.3. Design PV plant

Solar parks are usually large-scale PV systems designed to supply at utility level (in this case the community) rather than specific local users. This type of installation is composed by several devices.

First, the PV generator consists of a set of photovoltaic cells responsible of transforming the energy from the sun into electricity. These cells are connected in series and/or parallel to form the photovoltaic panel or module. The majority of solar parks are nowadays built with monocrystalline silicon cells since they have higher efficiencies than polycrystalline (26,7 % vs. 22,3 % respectively) even though they are also more expensive (ISE, 2020). The chosen technology for this project is therefore monocrystalline cells with a power of 300 W supplied from the provider Trinasolar.

In addition, photovoltaic modules are disposed once again in series and/or parallel to form the PV generator. The electricity produced by the PV field is then dispatched to the inverter.

The inverter is the device responsible for transforming direct current into alternating current ensuring the adequate performance of the loads connected to the grid. This device needs to be connected according to the correspondent regulations. Inverters are classified into two categories depending on the number of photovoltaic modules connected to it. The first category is centralized inverters, devices dedicated to cover the entire generator. The second type corresponds to individual inverters assigned to adapt the current of single or several strings. Due to the size of this project is preferable to use more than one inverter to assure electricity is still delivered in case of shutdown/malfunction of any of the other inverters. Besides, the electricity injected into the distribution grid by the inverters is done in low voltage (150 kV or less) which exempts the solar PV park from getting operating permits (CMS Legal Services, 2017). In this way, the plant only needs to be notified to the correspondent distribution operator.

Lastly, protections of the PV plant are those necessary to protect the equipment that composes the installation. All photovoltaic system needs to be protected against overcurrents, surges and direct and indirect contact.

The previous components are shown in Figure 5 which represents a simplified sketch of a photovoltaic solar plant.

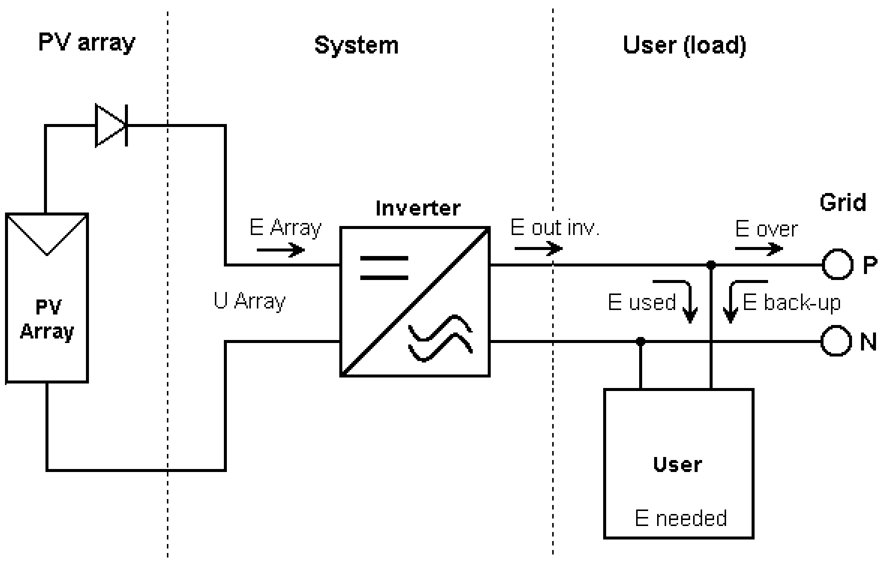


Figure 5. Simplified sketch of a photovoltaic plant **(PVSyst, 2020)**

The solar plant in this research is designed with the purpose of consuming electricity locally. For an accurate selection of the PV system capacity the hourly electricity consumption of the community needs to be analyzed so that generation match demand at any time. However, this is currently not being monitored and if it were, it would be difficult to track due to the diverse loads. Therefore, the power of the PV plant is the one that does not produce excess of electricity in the summer months were the yield of the plant is the highest. It needs to be taken into account that for avoiding the injection of electricity into the grid batteries are needed to store the excess of energy produced on weekdays when people are working and away from home, nevertheless a business model of such capacity is not yet profitable if batteries are considered. Either way, the plant is designed for this capacity in view of promising developments in the battery field. In addition, currently there are not additional permits or taxes that hinder the injection of electricity into the grid. Therefore, if improvements are not sufficient, the selected capacity will still produce revenues to the community.
In general, the electricity generated will first supply loads locally and if it is not possible, it will be injected into the grid. Conversely, the electricity will still be supplied by the distribution operator at times when the PV plant stops generating energy.

For guessing the power of the photovoltaic plant the software PVSyst is used (PVSyst, 2020). This free computer program calculates the power needed for the plant from the desire electricity produced per year which needs to be previously specified as an input. In this manner, the desired capacity is determined through an iterative process in which different inputs are considered. These inputs are the approximate quantities that avoid the generation of any solar excess since it would otherwise need to be injected into the national distribution grid instead of benefiting the members of the community. For this, it has been taking into account the monthly overall consumption demanded by the community. Overall, for this particular project, it has been determined that the optimal capacity of this photovoltaic installation must be approximately 2200 kWp.

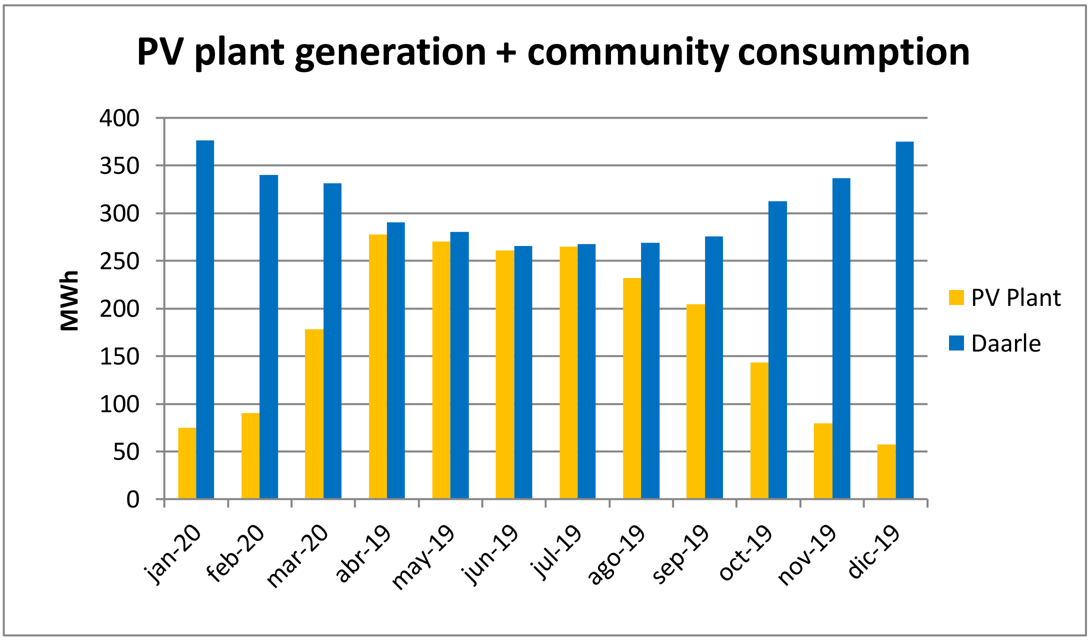
Several parameters need to be taken into account when choosing the definite power, amongst others the power of the inverter, a device which role is to transform the electricity produced by the photovoltaic cells in DC into AC. The size of the inverter is a delicate and discussed issue. Many inverters are undersized as a consequence of certain external requirements (Mermoud & Villoz, 2020). This is the reason why the programme recommends a PV array and inverter size ratio of the order of 1,20 - 1,3 for most well-oriented systems (Mermoud & Villoz, 2020). This parameter is technically defined as the power from the array divided per the power from the inverter. Therefore, if this is considered, the power of the inverter should be around 2000 kW. For this project, four inverters have been chosen to assure security of supply in the event of malfunction of any of them.

The inverter chosen for this project is the model PVS800 provided by ABB with a power of 500 kW. This inverter supports the voltage and current values needed for attaining the desired yearly production at its maximum efficiency.

Next, the number of modules in parallel and series need to be determined. The limits are set by the software itself which considers the maximum voltage and current that can be introduced in the inverters so that they work within the MPPT (Maximum Power Point Tracking) threshold guaranteeing the maximum power output. However, the most suitable option is the one having fewer strings and more modules per string since the higher the voltage the less voltage drops because the current flowing for the same amount of power is less. In other words, the optimal distribution is the one minimizing the modules connected in parallel (or maximizing the modules coupled in series). Considering the previous, the number of modules in parallel is chosen to be 349, which corresponds to 21 modules connected in series.

Once the previous defined parameters are simulated in the software PVSyst, it is then determined that the power plant generates around 2.135 MWh per year, achieving its maximum production on the months of April and May and its minimum on December and January.

Additionally, the Graph below simulates the generation of the solar power plant per month and compares it with the load correspondent to the community. This previous term encompasses both the consumption of all dwellings when demand-side measures and EV are considered and the current consumption of farms/small businesses, meaning, the optimized scenario developed in Chapter 2.



Graph 18. Electricity generated by the PV plant vs. consumed by the community (Source: Own elaboration)

From the comparison between the electricity produced by the PV plant and the electricity consumed by all the community, it is realized that the solar plant covers approximately 57 % of the total demand. It is then concluded that the solar plant greatly enhances the environmental status of the town by providing renewable energy and therefore, reducing GHG emissions.

5. ECONOMIC ANALYSIS

The goal of this section is to determine the profitability of the project. For this purpose, first the total revenues generated each year by the PV plant are calculated; this is done by balancing out the economic benefits and the required investment. Economic benefits account for the renewable electricity that is sold to the distributor operator and the subsidies available from the government. Differently, the required investment of the PV installation includes the initial expenditure of the system as well as the operational costs the generator requires per year. By means of these two concepts, the annual financial returns during the lifespan of the power plant are determined through parameters such as Payback, NPV and IRR.

Next, the type of demand-side measures that the community can afford with the revenues generated by the PV plant are decided. This is done since in LEC earnings can be can be afterwards reinvested in community funds and different projects. Particularly, here it is assumed revenues are invested in demand-side solutions. Following the same methodology as previous sections, this is done by considering one representative household from the town of Daarle. Results, hence, are again extrapolated to the whole community.

5.1. PV Plant

As previously mentioned, the electricity generated by the PV plant is expected to be consumed within the community of Daarle. This reasoning is based on the amount of electricity used by farms/industry/companies which account for a sufficient portion of the electricity consumed in the community when the PV plant is generating electricity. However, further research is needed to determine if this complies at all times. If this is not the case, the injection of any excess of electricity into the grid does not present any additional technical, administrative or financial burden since it is currently allowed to inject renewable electricity into the grid.

The first step in any economic analysis is to define the project's time horizon. For this, variables such as the physical life of the plant or the technological life of the process are taken into consideration. For photovoltaic installations this is usually set at 25 years (HIER opgewekt, 2019).

Secondly, to assess the business case of the project here developed, several parameters need to be considered. These are divided into various categories: investment, operational costs, economic benefits and financial, fiscal and other factors. Each category is broken down by several other concepts here explained and quantified.

An important part of the business case is the investment that must be made for the realization of the project. This investment contains several components used in all PV installations.

To begin with, in order to determine the cost the overall installation of the system a first approximation of 0.8 €/Wp of the total installed capacity can be assumed (HIER oppgewekt, 2019). The system here studied thus results in 1.759 M€. The main connection between the PV plant and the distribution grid needs to be added to this previous concept as well. This is determined by checking with Enexis the cost of a feed-in connection that fits the size of the inverters. Each inverter is set to be connected to the local distribution grid so that high voltages are not formed, this is done since all electricity is consumed locally in small receptors and thus it does not need the conversion into HV/MV. The connections are those capable of transport a current up to 3 x 80 A. These have a price of 895 € each plus 20,5 € for the cables which are assumed to have 25 m length (ENEXIS , 2020). For 4 inverters this accounts for a total of 6.954 €.

The next concept includes research costs concerning for example construction calculations, if data is available such as in here, it usually involves a rate of 500 €. Added to this also the notary and legal costs are included to establish the building rights, which in turn represents an expenditure of approximately 1.750 € (HIER oppgewekt, 2019). If the project is realized by paid employees, it needs to be considered a compensation for their work. Including a budget of 5% of the initial investment of the installation normally provides sufficient space for this. In a similar manner, people will also need to work in recruitment and communication through possibly social media and/or informative fliers; here too it is advised to reserve a budget of 5 % of installation of the plant (HIER oppgewekt, 2019).

The total investment broken down per concept is summed in the following Table.

Table 7. Investment of the PV plant brake down per concept (Source: Own generation)

Investments		
System	1.759.200 €	2.199.000 Wp x 0.8 €/Wp
Main connections	6.954 €	4 connections 3x 80 A
Research	500 €	Construction
Notary	1.750 €	Rights of surfaces
Project development	87.960 €	5 % of system costs
Communication	87.960 €	5 % of system costs
TOTAL	1.944.324 €	

After the initial investment, several operational costs also appear over the duration of the project.

Managing the distribution grid owned by the cooperative has some associate costs every year. Together with the meter necessary to register the electricity injected into the distribution grid, this concept established by the provider reaches 271 € (ENEXIS, 2020). Furthermore, the membership file and financial administration must be kept up to date. It is also required to make available annual documents for the member´s meetings. An adequate estimation of these two terms is to maintain an annual budget of 500 € plus 5 € per member for the administration costs (HIER oppgewekt, 2019).

The members forming the cooperative are those possessing a household or a business/farm in the town. This is assumed since the energy generated aims to beneficiate everyone residing in it. If one participant per building is assumed, it results then in 209 households (Rijkswatestraat, 2019) plus 380 small businesses (BEDRIJVENMONITOR, 2020) that account for 589 members in total who would need to pay 3.445 € on administration costs.

The system must be properly monitored to ensure that everything is working properly. In addition, a maintenance inspection which includes supervising the system, cleaning the panels and checking the inverter must be carried out once every 2-3 years. An annual budget of 0.75 % of the initial investment must be sufficient for this (HIER oppgewekt, 2019). It is also important to properly insure the system with a premium rate assumed to be 0.25 % of the system´s costs (HIER oppgewekt, 2019).

In some cases, the landowner wants a fee for the use of the location. A fee of 1 or 2 Euros per panel is advisable. Here, a fee of 1 € is assumed. During the lifespan of the generator, there will also be communication between members, i.e. people with questions, informative newsletters, meetings etc; these kinds of activities can be proceed reserving 0.5 % of the initial investment (HIER oppgewekt, 2019).

The yearly operational costs broken down per concept are presented in the following Table.

Table 8. Operational costs of the PV plant brake down per concept (Source: Own generation)

Operational costs		
Grid management + meter	271 €	4 connections 3x 80 A
Administration	3.445 €	500 € + 5 € x 589 members
Maintenance	13.194 €	0,75 % of 1.759 M€
Insurance	4.398 €	0,25 % of 1.759 M€
Rent	7.329 €	€ 1 x 7329 solar panels
Communication	8.796 €	0,5 % of 1.759 M€
TOTAL	37.433 €/year	

To complete the analysis, the economic benefits generated by the PV plant are calculated. The earnings are highly dependent on the production of the PV plant e.g. electricity and Guarantees of Origin sale to the distributor operator. However, there are other independent sources such as taxes exempt under the Postal Code Rose (PCR) arrangement that greatly impact the analysis as well.

First, the sale of electricity can be easily calculated every year once the annual electricity produced is known. Since it was determined through the simulation in Chapter 4, this number only needs to be multiplied by the rate at which electricity is sold to the energy supplier. This rate on March 2019 was 4,5 cents per kWh (HIER oppgewekt, 2019). Hence, a benefit of about 96.075€ per year is generated.

Even if the electricity sale generates some significant earnings, the main income of a PV system owned and settled by a cooperative comes from the discount on the energy tax (+VAT) set out in the PCR scheme. Under this scheme each member of the cooperative is exempted of paying the energy tax of the correspondent solar electricity self-consumed on their energy bill up to the maximum of their own electricity consumption and 10,000 kWh per year. The only condition is that participants live in the same postcode area. Since all the electricity generated by the PV plant is expected to be consumed locally, the calculation of this concept is done by multiplying the current electricity tax (0.11822 €/kWh (CBS, 2020)) per the electricity generated throughout the year. By means of this exemption, the profit per year reaches approximately 252.000 €.

Another gain comes from selling Guarantee of Origin (GOs). These are digital certificates which prove that electricity has been generated from renewable sources. One GO is equivalent to 1.000 MWh of sustainable energy. In the Netherlands CertiQ is the body that issues GOs. Suppliers must submit these GOs to get the correspondent issue. According to the director of a company involved in trading GOs (Greenspread), currently prices are about 0,70 €/GOs (2020). Hence, to get the annual profit, the electricity produced is again multiplied by this price. In this way, earnings reach 1.495 € per year.

Summing up, the financial benefits of this project are the ones associated with the sale of electricity, GOs and the energy tax exemptions. On the other hand, the initial investment and the yearly operational costs represent the expenses of the project. The final cash flow results from deducting the inflows (profits) minus the outflows (expenses).

Nevertheless, when a profitability analysis is being developed a number of factors and variables are still important to complete the calculation. These have to do with long-term expectations. For instance, it is relevant considering the production of solar panels decreases over the time. The power guaranteed by the manufacturer can only be maintained to 80 % after 25 years. This amounts to a 0.7 % decrease per year which needs to be applied to any monetary flow (HIER oppgewekt, 2019).

This project determines the profitability of the plant by assessing three different parameters: Pay-back, NPV and IRR.

Pay-back is defined as the time it takes to recover the facility´s initial investment; it results from the ratio of the total investment and the average annual net cash flow. The pay-back of the facility designed in this project is 7,31 ≈ 7 years.

The net present value (NPV) consists of bringing all cash flows to the present by discounting a reference interest, i.e. a future depreciation of money. It is a measure of the economic surplus generated in a project, when its value is positive the project produces benefits; when its value is negative the project should not be carried out.

The internal rate of return (IRR), in turn, corresponds to the annual interest rate at which the funds generated pay back the funds invested. In other words, the interest rate that makes the NPV of a project zero. A project is profitable when the IRR is higher than the reference interest (k).

For evaluating the profitability of the project by means of the previous parameters, the following factors need to be taken into account:

- Reference interest or discount rate (k) is the cost of capital applied to determine the present value of a future payment. It depends on the nature of the project as well as the funds available. Here, a rate of 4,57 % has been assumed based on similar installations (Salvo, Ciuna, Ruggiero, & Marchiano, 2017).
- Consumer Price Index (CPI) or inflation is an indicator of the future increase of prices of goods and services during a certain period of time. At present time Dutch CPI is 1.6 % (CBS, 2020). Inflation will be applied to values such as the sale of electricity, subsidies and tax exemptions, operational costs and updated cash flow.

Note: this project does not study the different financing methods of LEC since it is not purpose of this research. Nonetheless, it could be financed through internal or external financing methods.

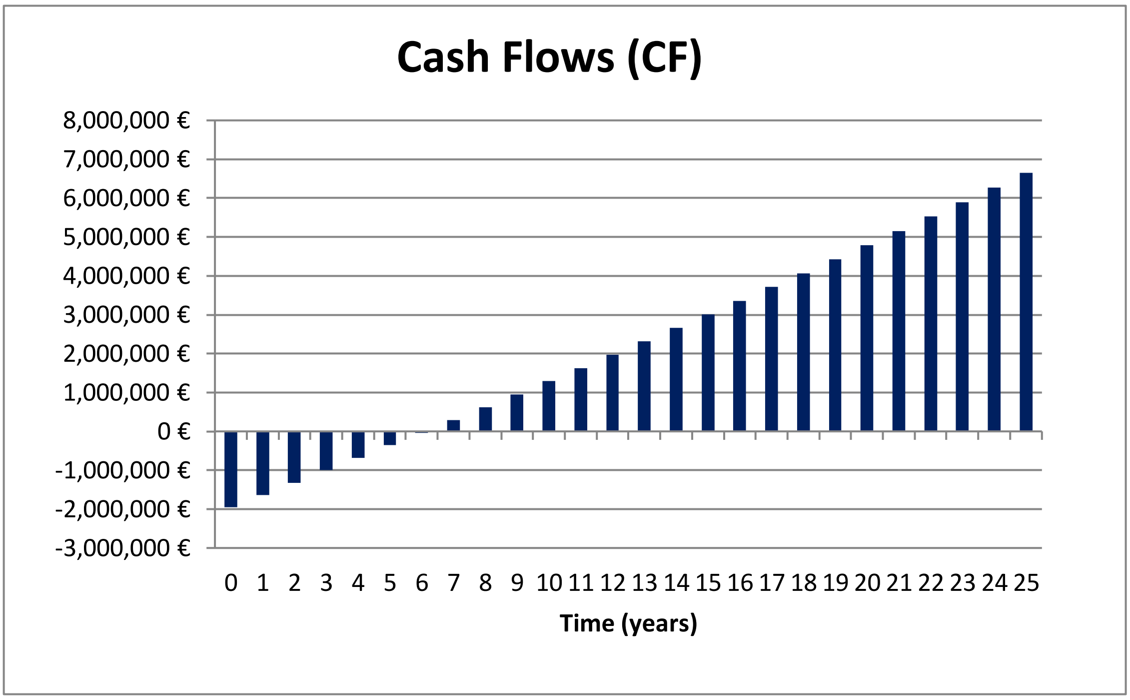
Parameters such as the NPV, IRR and Pay-back are calculated through the correspondent functions in Excel, their inputs are the parameters and concepts that have been already discussed in this section. The final results of the profitability analysis are collected in Table 9:

Table 9. Results from the profitability analysis

NPV	**2.804.701 €**
IIR	**16,40 %**
PAY-BACK	**7**

In view of the results, as the NPV is greater than zero and the IRR exceeds the reference interest (set at 4,7 %) it is concluded that this project is profitable and can be carried out.

The cash flows for the 25-year life of the installation are represented below.



Graph 10. Cash flows over the lifetime of the photovoltaic system

The calculations made are shown on the next page:

Year	0	1	2	3	4	5	6	7	8	9	10	11	12
Investments (€)	1.944.324												
Electricity production (kWh)		2.135.000	2.120.055	2.105.215	2.090.478	2.075.845	2.061.314	2.046.885	2.032.556	2.018.329	2.004.200	1.990.171	1.976.240
Sale of electricity (€/year)		96.075	96.929	97.790	98.660	99.536	100.421	101.314	102.214	103.123	104.039	104.964	105.897
Energy tax discount (€/year)		252.400	254.643	256.906	259.190	261.493	263.818	266.162	268.528	270.915	273.323	275.752	278.203
GOs (€/year)		1.495	1.508	1.521	1.535	1.548	1.562	1.576	1.590	1.604	1.618	1.633	1.647
Total Savings (€/year)		349.969	353.080	356.218	359.384	362.578	365.801	369.052	372.332	375.641	378.980	382.348	385.747
Operational costs (€/year)		38.032	38.640	39.259	39.887	40.525	41.173	41.832	42.502	43.182	43.872	44.574	45.288
Cash Flow (CF) (€)	-1.944.324	311.937	314.439	316.959	319.497	322.053	324.627	327.220	329.831	332.460	335.108	337.774	340.459
Accumulated CF (€)	-1.944.324	-1.632.387	-1.317.948	-1.000.988	-681.491	-359.438	-34.811	292.409	622.240	954.699	1.289.807	1.627.581	1.968.040
Payback (years)	**7,31**												

NPV (€)	2.804.701												
IRR (%)	16,40												
Updated CF	-1.944.324	267.981	232.065	200.961	174.025	150.698	130.497	113.004	97.854	84.735	73.375	63.537	55.017

Annual power losses (%)	0,700
Sale of electricity (€/kWh)	0,045
Sale of GOs (€/MWh)	0,70
Energy tax exemption (€/kWh) incl. VAT	0,1182
Inflation (%)	1,6
Tasa de descuento (%)	4,70

Year	13	14	15	16	17	18	19	20	21	22	23	24	25
Investments (€)													
Electricity production (kWh)	1.962.406	1.948.669	1.935.028	1.921.483	1.908.033	1.894.677	1.881.414	1.868.244	1.855.166	1.842.180	1.829.285	1.816.480	1.803.765
Sale of electricity (€/year)	106.838	107.788	108.746	109.712	110.687	111.671	112.664	113.665	114.675	115.694	116.723	117.760	118.807
Energy tax discount (€/year)	280.675	283.170	285.687	288.226	290.788	293.372	295.980	298.610	301.265	303.942	306.644	309.369	312.119
GOs (€/year)	1.662	1.677	1.692	1.707	1.722	1.737	1.753	1.768	1.784	1.800	1.816	1.832	1.848
Total Savings (€/year)	389.175	392.634	396.124	399.645	403.197	406.780	410.396	414.044	417.724	421.436	425.182	428.961	432.774
Operational costs (€/year)	46.012	46.748	47.496	48.256	49.028	49.813	50.610	51.420	52.242	53.078	53.928	54.790	55.667
Cash Flow (CF) (€)	343.163	345.886	348.628	351.388	354.168	356.968	359.786	362.624	365.481	368.358	371.254	374.171	377.107
Accumulated CF (€)	2.311.203	2.657.089	3.005.717	3.357.105	3.711.274	4.068.241	4.428.027	4.790.651	5.156.132	5.524.490	5.895.745	6.269.916	6.647.022
Payback (years)	7,31												

NPV (€)	2.804.701												
IRR (%)	16,40												
Updated CF	47.640	41.251	35.719	30.929	26.781	23.189	20.078	17.385	15.053	13.034	11.285	9.771	8.460

Annual power losses (%)	0,700
Sale of electricity (€/kWh)	0,045
Sale of GOs (€/MWh)	0,70
Energy tax exemption (€/kWh) incl. VAT	0,1182
Inflation (%)	1,6
Tasa de descuento (%)	4,70

It is relevant to highlight the impact the energy tax exemption flow has on the overall profitability of the PV plant. It has been calculated that if this flow is removed the investment of such a large installation would not be profitable. Therefore, it is crucial that an LEC is formed in which residents of the village commit to all the necessary requirements, including administrative procedures, sufficient capital available and adequate organizational structures in order to get this subsidy on time.

5.2. Demand-side measures

The aim of this section is to evaluate cost-efficient demand-side solutions that the town of Daarle can adopt with the revenues from the PV plant installation. For this purpose, the profitability of several measures are studied on the sample household and then extrapolated to the whole village.

From the investigation L. Niamira et al. recently carried in the province of Overjissel, three energy efficiency measures stood out amongst the Dutch inhabitants of this province. Since Daarle is located in Overjissel, this research is used to select which demand-side solutions are the inhabitants of the community more willing to adapt. The study covered there different types of demand side measures: investments, conservation measures and green energy (providers) switch which respectively corresponds to the blue, orange and green bars of Figure 6.

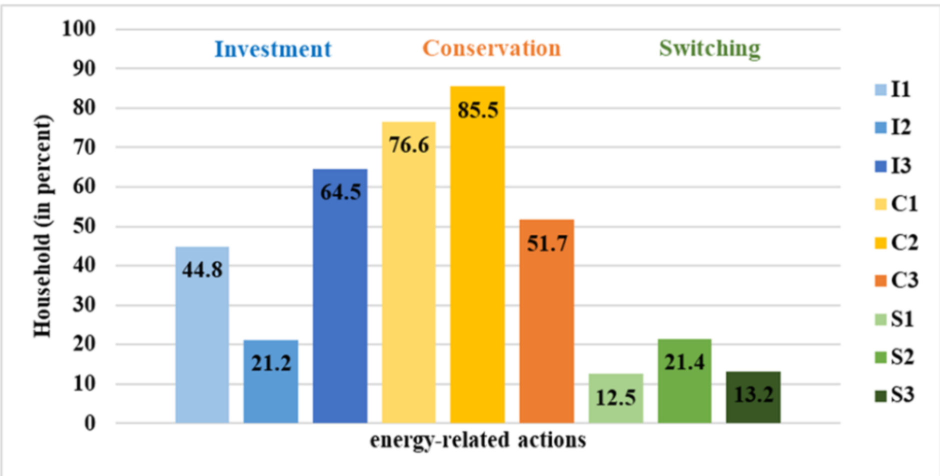


Figure 6. Shares of survey respondents who took energy-related actions in Overjissel (Niamir et al., 2020)

Where each demand-side measure corresponds to the following meaning:

- I1: house insulation
- I2: solar panels
- I3: energy-efficiency appliances
- C1: switching off unnecessary devices
- C2: moderate inside temperature regulation
- C3: adjusting daily habits such as running a full-load washing machine

- S1: switching to green energy
- S2: changing to a green provider
- S3: switching to another conventional energy provider

For this section three types of demand-side measures have been considered, these correspond to the ones that score highest in the survey, hence: replacing inefficient appliances, switching off unnecessary devices and adjusting daily habits are studied in the context of the sample household. Moderate inside temperature has not been studied since even though it scores the highest, it is related to the gas and not to the electricity consumption of a household.

After evaluating the electricity pattern of the sampled household in Chapter 3, it was realized that this family still uses incandescent lighting. Nowadays, replacing incandescent lamps with LEDs is not only good for the environment but also financially worthwhile, up to 90 % of electricity costs can be cut in lighting due to the low power consumption of LED bulbs. Also, the lifespan of LEDs are much longer than incandescent lighting, approximately 15.000 hours compared to 1.000 hours of an incandescent lamp. Moreover, even though, purchasing LEDs is still more expensive, the payback time is estimated in 3 years due to lower power costs (Milieu Centraal, 2020).
Particularly, the chosen household has a total of 8 incandescent lights, which result in 960 Wh per day being consumed. If those lights were to be changed to LED, the consumption per day would decrease to 160 Wh which in turn, will save approximately 64 €/year. Overall, even though, the revenues are not high, replacing incandescent light is highly advised due to its environmental impact and low investment.

From the same evaluation (Chapter 3), It is also noticeable the influence of the drier on the overall energy consumption as it is the highest consumer in the house. This drier has a current energy label of B since it dates from 10 years ago, hence, a more efficient one could be replaced if the sufficient initial investment is available. The results in energy savings would be much higher when compared to the LED replacing measure. An estimation of substituting the drier with a more efficient one (A+ label) results in an energy saving of 650 kWh per year which in turn corresponds to a yearly economic saving of 144 €. For this calculation a drier with a label A+ has been chosen to avoid a higher investment, however nowadays driers hold up until an A+++ label which will make the energy and economic revenues even higher.
Furthermore, it would have additional benefits to the owner and the distribution operator if it is set at 12 p.m. That is, on one hand, the electricity is cheaper during the night which implies a decrease of the total electricity bill. On the other hand, it relieves some capacity on the local grid since most of the energy is consumed during daytime.

The last demand-side measure implies switching off inefficient electric appliances. From Table 3 in Chapter 3, it can be seen that one of the highest consumers is a fridge-freezer located in the garage which purpose is merely to cool down beers. The necessity of having this fridge-freezer on is arguable since the freezer in this case is not being used, if the owner would agree to switching off this device, the energy saved per year would reach 1.051 kWh, which subsequently would produce a financial revenue of 221 € per year. However, since the option of turning off completely this device does not appeal to the owner of the house, replacing this old fridge-freezer with one of a lower capacity and better energy efficiency label (A+) will also have a significant impact. From the calculations, it results in an energy and economic saving of 536 kWh/year and 112 € respectively.

The table below sums up the profitability of different demand-side measures analyzed in this section and their impact on the overall electricity consumption.

Table 10. Impact of demand-side measures in the electricity consumption of the household (Source: Own elaboration)

Measure	Annual energy savings (kWh)	Annual financial savings (€)
LED replacement	160 kWh	64 €
Replacing the drier	650 kWh	144 €
Replacing fridge-freezer	536 kWh	112 €

It is relevant mentioning that for extrapolating these measures to the households in the village a more exhaustive research is needed since each particular household is different. However, these measures are assumed to be representative enough due to their recurrence in any standard household. In addition, these measures are considered in order to provide an overview of the solutions that could be adopted rather than a strict advice of what should be adopted. Different demand-side measures may also be implemented without any impact on the quality of the outcome.

The financial revenues of the PV plant are the ones from the sale of electricity and GOs. The energy tax exemption is not considered revenue but as a discount instead since it is eliminated directly from the consumer's electricity bill. Therefore, even though this flow is necessary in order to evaluate the profitability of the plant and to make the project financially attractive for its members, it is not considered viable capital to invest in demand-side solutions. Hence, from the sale of electricity and GOs around 100.000 € are collected per year.

If it is assumed that the revenues are invested in only the households of the village and that these three studied demand-side measures are adopted in each dwelling, the following calculation is needed to verify revenues of the PV from the first year can be deployed in these measures.

$$Investment = 290\ households \cdot (144 + 112 + 64)€ = \ 92.800\ € < 100.000\ €$$

Therefore, it is concluded that in the first year, revenues can be used to adopt demand-side measures that optimize the energy efficiency of the dwellings placed in the village. It is relevant mentioning that with the revenues from the following years more demand-side solutions can be implemented in business/farms as well such as in charging points for EVs. Revenues are for all members involved in the LEC and in the end, they are the ones deciding on the type of solutions that beneficiate them the most.

6. Conclusions and reflection

The aim of this chapter is to present an overview of the results achieved during the development of this research. As it was mentioned on the first chapter the objective of the project is to energetically optimize a community by applying demand-side measures and selecting renewable technologies under the Dutch local energy community context. To examine this purpose, four research subquestions have been identified. Hereafter, a summary of the results found out for each of these subquestions. To conclude, the chapter provides a reflection on the research where issues and limitations encountered along the project are reviewed.

6.1. Discussion research questions

- *What legal, regulatory and technical requirements does the existing community need to adopt to become a local energy community?*

The aim of a local energy community is to provide environmental, economic and social benefits for its member through energy related activities. The adoption of demand-side solutions and renewable sources are considered in this research as the activities used to optimize the energy performance of the town of Daarle, selected for data purposes. Both activities, inherent to LEC, fell under the term 'Energy community' from the IEMD. In this way, by adopting these two activities along with the described principle the town becomes a LEC which in turn is stated as a legal entity in the Dutch law.

Under the legal and regulatory framework, the community is considered as a market actor accountable of establishing, owning and managing the internal network when a renewable project is established. For that, it must be proved first that they acquire the necessary financial, technical and organizational capacities to implement the entire project. Furthermore, the community and the DSO need to reach an agreement that states separately the charges fed into the grid and the electricity taken from the distribution network. Additionally, this community will benefit from different financial compensations provided by the Dutch government; amongst others the PCR arrangement aimed at supporting the establishment of electricity-based cooperatives within the same adjunct postal code areas. Moreover, it will be eligible for unfair regulatory and administrative barriers.

To conclude, renewable technologies and demand-side solution when combined with plug-in vehicles provide a good alternative to enhance grid´s flexibility while mitigating climate change and reducing emissions growth. However, it is crucial to adjust generation and demand so that power quality issues are not injected into the grid.

- *How can the community of Daarle improve its energy performance through the adoption of demand-side solutions?*

The methodology here follows a bottom-up approach where demand-side solutions on a representative household from the town of Daarle are first analyzed with the purpose of extrapolating the opportunities identified to all the households in the community.

Three different demand-side solutions are applied to the selected household: upgrading the efficiency of every appliance, adjusting daily habits and charging an EV. All are studied on the hourly current load of selected household so that the impact can be elaborately determined.

Energy efficiency measures are evaluated by substituting the actual appliances with ones that scored higher on the energy label. That way, the household scores the highest on efficiency. A comparison has been done between the current situation and the new ideal situation. Results show that by adopting these measures an average household can reduce their electricity consumption by 51 %.

The next measure considers adjusting daily habits such as programming the dishwasher and the drier at night when electricity is cheaper. Adjusting behavior is then done to relieve some capacity from the grid on peak hours, hence facilitating the deployment of renewable intermittent sources.

After analyzing these two measures, the results are extrapolated to all the dwellings in the community. It was then calculated that by adopting these two previous solutions 49 % of electricity savings were generated while reducing households' peak loads, thus greatly optimizing the local grid.

To conclude, charging the EV is also evaluated as the last demand-side solution. Findings show how charging an EV at home greatly impacts the total consumption of the whole community. Therefore, a more efficient alternative is selected in this research which involves charging each EV in the workplace when the PV plant is producing electricity. This way, injections of large quantities of electricity into the grid as well as transmission losses are avoided.

- *How can the community of Daarle enhance its environmental status through the implementation of renewable technologies?*

The purpose of this section is to improve the sustainability of Daarle through the generation of renewable energy. In this manner, the total consumption of this community is collected from the correspondent energy provider (Enexis), this number corresponds to residents but also to small businesses and farms which account for a large amount of the total electricity consumption.

Next, a renewable source is selected. This is done considering various criteria such as feasibility, cost and maturity of the technology. The chosen technology is a solar park situated in the ground of an unused field of Daarle which is connected to the already existing local distribution grid. It is designed so that the excess of electricity is injected into the grid when PV generation surpasses the local loads. At the same time, it assures electricity supply when PV generation is not enough. In any case, the generation is the one that avoids excess of electricity being injected in the hottest month of the year. Nevertheless, an hourly study where generation meets demand needs to be carried out to verify that it complies at any time.

The plant is composed by 300 W monocrystalline cells supplied by Trinasolar which are connected to 4 inverters of 500 kW each supplied by ABB. The plant is also distributed in 349 modules in series and 21 in parallel resulting then in 7.329 modules in total. It has as well an overall capacity of 2.200 kWp and generates around 2.135 MWh per year.

After simulating the performance of the solar plant with the software PVSyst and compare it to the overall consumption of the community of Daarle, it is concluded that the solar PV plant greatly enhances the sustainability situation by providing 57 % of renewable energy per year to the whole community.

- *What is the profitability of the selected optimal scenario?*

The goal of this chapter is to assess the profitability of installing renewable electricity and adopting demand-side measures in the village of Daarle. For this purpose, the revenues from the PV plant are calculated so that they can afterwards be invested in demand-side measures for the dwellings in the town, thus optimizing the overall energy performance of the village.

In order to evaluate the profitability of the PV plant expenses and revenues need to be identified. First, the initial investment, which considers expenses related to the system and its installation, accounts for 1.944 M€. In addition, operational costs, which surge over the duration of the project involves costs related to insurance, maintenance, land rental fees etc. requiring 37.433 € per year. Conversely, revenues come from selling GOs and electricity. GOs are trade as digital certificates equivalent to 1.000 MWh of green energy while electricity is sold per kWh to the correspondent distributor operator. These profits account for 1.495 € and 252.400 € per year respectively.

Another relevant concept is the discount on the energy tax that members get when they are part of the cooperative and live in the same postcode area. Under this scheme each member that participates in renewable generation is exempted from paying the energy tax. It was discovered that without this exemption the plant would not be financially feasible.

After calculations, the PV plant resulted in a NPV greater than zero, an IRR that exceeds the reference interest (set at 4,7 %) and a Pay-back of 7 years; thus, making the plant profitable.

The revenues from the PV plant are afterwards invested in demand-side measures that optimize the efficiency of the households belonging to the members of the cooperative. To this end, the revenues from the first year are decided to be used to replace incandescent lighting with LEDs and upgrading the label of a drier and a fridge-freezer. These measures are particular for the studied household. However, they are assumed they can be extrapolated to all of them. In addition, the revenues from the following years may be used for implementing more demand-side solutions such as charging EVs. This way, the energy performance of the village is constantly enhanced.

6.2. Reflection

Different methods have been employed to develop this research. First, empirical data was collected and afterwards operated through extrapolation methods and simulation software in order to obtain the results. For the purpose of providing a reliable research, it is necessary to stress several issues and limitations that were encountered during its development. Additional remarks are also commented here.

To begin with, the municipality where the research is carried out has not yet decided the strategy to phase out gas. In this manner, several alternatives are being considered such as heat network, green gas or electricity without a final consensus. Considering this, if the future electricity consumption alters, calculations would need to be repeated again to adapt the results to this new situation.

Furthermore, data has been collected from a single household and open sites providing rather wide and general sources which deter the research from achieving more accurate results. Particularly, regarding the extrapolation of the whole electricity usage of the town further research needs to be done to verify if the electricity usage of every dwelling in the village matches the average consumption given by the distributor operator Enexis. However, since the difference with the sample household is not large, it can be assumed this average is representative enough to carry out the study.

In addition, the selection of the renewable source is done without consultation to the members of the community which ultimately are the ones deciding on it. Besides, since a specific field is not selected, someone needs to provide the ground for installing the PV plant as well as deciding on the renting price. Since these two considerations could scupper this project they need to be resolved beforehand.

Similarly, it has been assumed every household in the town participates in the LEC. In turn, the number of members greatly impacts the energy tax flow and thus, the overall revenues. Additionally, the method of financing has not been selected since it is supposed to be a democratic decision taken by all members of the cooperative. In the same way, revenues are only advised for the first year as they should be a collective resolution. Due to their significance, these previous considerations need to be clarified and agreed upon before the development of the project.

To conclude, even though there are certain assumptions and limitations restricting this research, results show the optimization of a community through demand-side solutions together with renewable sources offer a great opportunity to mitigate climate change and reduce GHG. In particular, investing in demand-side solutions and a 2.200 kWp photovoltaic plant have the potential to respectively save 49 % of total electricity consumed in the town and provide 57 % of green energy to Daarle while offering a relatively low Pay-back period of 7 years.

BIBLIOGRAPHY

Al.Katsaprakakis, D., Dakanali, I., Condaxakis, C., & G.Christakis, D. (2019). *Comparing electricity storage technologies for small insular grids*. Energy procedia 2019 , Volume 251, pp.84-89. Retrieved from https://doi.org/10.1016/j.apenergy.2019.113332

BEDRIJVENMONITOR. (2020). *Vind bedrijven in jouw buurt*. Retrieved on 07, 18, 2020, from https://bedrijvenmonitor.info/zoeken?term=daarle%20energie

Bijsterveld, W. v. (2020). *AlleCijfers.nl*. Retrieved on 07, 13, 2020, from https://allecijfers.nl/buurt/daarle-hellendoorn/

Campos, I., Pontes Luz, G., Marin-González, E., Gährs, S., Hall, S., & Holstenkamp, L. (2020). Regulatory challenges and opportunities for collective renewable energy prosumer in the EU. *Energy Policy* , Volume 138. Retrieved from https://doi.org/10.1016/j.enpol.2019.111212

Caramizaru, A. and Uihlein, A., *Energy communities: an overview of energy and social innovation*, EUR 30083 EN, Publications Office of the European Union, Luxembourg, 2020,ISBN 978-92-76-10713-2, doi:10.2760/180576, JRC119433.

CBS. (2020). *Gemiddelde energietarieven voor consumenten*. Retrieved on 07, 15, 2020, from https://www.cbs.nl/nl-nl/cijfers/detail/84672NED

CBS. (2020). Jaarmutatie consumentenprijsindex; vanaf 1963. Retrieved 07, 15, 2020, from https://www.cbs.nl/nl-nl/cijfers/detail/70936ned

Winters, E. (2018). *Report on Energy policy and legal context (D4.1) and on Financial and ownership (D4.2) - Part 2: Full Report.* Amsterdam, ,2017, New Urban Energy, City-zen-GA 608702. Retrieved from https://www.uu.nl/sites/default/files/rebo-city-zen-energy_policies_legal_context_financing.pdf

CMS Legal Services. (2017). *Practical legal aspects of solar PV projects in the Netherlands.* pp.5-9.

Gancheva, M., O´Brien, S., Crook, N. and Monteiro, C . (2018). *Models of Local Energy Ownership and the Role of Local Energy Communities in Energy Transition in Europe.* Publications Office of the European Union, Milieu Ltd, Belgium, ISBN 978-92-895-0989-3, doi: 10.2863/603673

Duurzaam Thuis Twente. (2018). Duurzame maatregelen. Retrieved on 5, 15, 2020, from https://www.duurzaamthuistwente.nl/duurzame-mogelijkheden/duurzame-maatregelen/

ECoop. (2020). *Postcoderoosregeling*. Retrieved 07, 17, 2020, from https://www.postcoderoosregeling.nl/wat-houdt-de-pcr-regeling-precies-in/

Energie Beheer Nederland B.V. (2018). Infographic 2020: Energie in cijfers. Retrieved on 03, 21, 2020, from https://www.ebn.nl/het-nederlandse-energiesysteem-in-een-oogopslag/

ENEXIS Netbeheer. (2020, 01, 01). *Kosten werkzaamheden aan uw aansluiting of meter.* Retrieved on 07, 15, 2020, from https://www.enexis.nl/consument/aansluiting-en-meter/tarief/kosten-werkzaamheden?stap=Waarvan%20wilt%20u%20de%20kosten%20weten_1_2

ENEXIS Netbeheer. (2020). *Open data*. Retrieved on 06, 05, 2020, from https://www.enexis.nl/over-ons/wat-bieden-we/andere-diensten/open-data

dos Santos Silva, M., & Santos Silva, M. (2017). *Study on "Residential Prosumers in the European Energy Union"*. Retreived from https://ec.europa.eu/commission/sites/beta-political/files/study-residential-prosumers-energy-union_en.pdf

Scarlat Ni.,Dallemand J., Taylor N., Banja M., Sanchez Lopez J. and Avraamides M. (2019). *Brief on biomass for energy in the European Union*. Publications Office of the European Union, Belgium, ISBN: 978-92-79-77235-1, doi: 10.2760/546943

European Distribution Sytem Operators for Smart Grids. (2014). *Flexibility: The role of DSOs in tomorrow´s electricity market.* European Distribution System Operators for Smart Grids, p.p. 8. Retrieved from http://www.edsoforsmartgrids.eu/new/wp-content/uploads/EDSO-views-on-Flexibility-FINAL-May-5th-2014.pdf

EU Directorate-General for Internal Policies. (2010). *Decentralized Energy Systems*. Policy Department A: Economic and Scientific Policy, B-1047 Brussels, pp 77-81. Retrieved from www.europarl.europa.eu/document/activities/cont/201106/20110629ATT22897/20110629ATT22897E)N.pdf.

European Parliament. (2020). *European Parliament resolution on the European Green Deal (2019/2956(RSP)).* Retrieved on 06, 06, 2020, from https://www.europarl.europa.eu/doceo/document/TA-9-2020-0005_EN.html

European Union. (2020, 04, 08). *Your Europe*. Retrieved on 07, 03, 2020, from https://europa.eu/youreurope/business/product-requirements/labels-markings/energy-labels/index_en.htm#:~:text=Energy%20labels%20show%20how%20the,G%20(red)%20the%20least.

Eurostat. (2019, May). *eurostat - Statistics Explained*. Retrieved on 06, 20, 2020, from https://ec.europa.eu/eurostat/statistics-explained/index.php/Energy_consumption_in_households#Energy_products_used_in_the_residential_sector

Eurostat. (2020, 03, 06). *Eurostat. Statistics Explained.* Retrieved on 03 20, 2020, from https://ec.europa.eu/eurostat/statistics-explained/index.php/Renewable_energy_statistics

Creutzig, F., Roy, J., Lamb, W.F. et al. Towards demand-side solutions for mitigating climate change. Nature Climate Change 8, p.p 260–263 (2018). Retrieved from https://doi.org/10.1038/s41558-018-0121-1 (2018)

Hannoset, A., Peeters, L., & Tuerk, A. (2019). *Energy Communities in the EU - Task Force Energy Communities.* Retrieved from https://www.h2020-bridge.eu/wp-content/uploads/2020/01/D3.12.d_BRIDGE_Energy-Communities-in-the-EU-2.pdf

HIER oppgewekt. (2019, 03, 21). *Voorbeeld businesscase postcoderoos*. Retrieved on 15, 07, 2020, from https://www.hieropgewekt.nl/kennisdossiers/voorbeeld-businesscase-postcoderoos

Hirsch, A. e. (2018). *Microgrids: A review of technologies, key drivers and outstandng issues.*Renewable and Sustainable Energy Reviews July 2018, Volume 90, pp. 402-41. Retrieved from https://doi.org/10.1016/j.rser.2018.03.040

Interreg Europe. (2018). *Renewable Energy Communities. A Policy Brief from the Policy Learning Platform on Low-carbon economy.* Retrieved from: https://www.interregeurope.eu/fileadmin/user_upload/plp_uploads/policy_briefs/2018-08-30_Policy_brief_Renewable_Energy_Communities_PB_TO4_final.pdf

IRENA (2019), Renewable Power Generation Costs in 2018, International Renewable Energy Agency, Abu Dhabi. ISBN 978-92-9260-126-3

Kamer, L. (2020, 02, 21). *Statista*. Retrieved on 05, 28, 2020, from https://www.statista.com/statistics/654460/leading-registered-fully-electric-passenger-cars-the-netherlands/

Lowitzsch, J., Hoicka, C.E., and van Tulder, F.J., (2020). *Renewable energy communities under the 2019 European Clean Energy- Governance model for the energy clusters of the future?*. Renewable and Sustainable Energy Reviews April 2020, Volume 122, 109489. Retrieved from https://doi.org/10.1016/j.rser.2019.109489

Mendes, G., Jere, N., Annala, S., Honkapuro, S., Kilkki, O., & Segerstam, J. (2018). *Local Energy Markets: Opportunities, Benefits and Barriers.* CIRED Workshop - Ljubljana, 7-8 June 2018. Paper No. 0272. Retrieved from http://www.cired.net/publications/workshop2018/pdfs/Submission%200272%20-%20Paper%20(ID-21042).pdf

Mermoud, A., & Villoz, M. (2020). *PVSyst Photovoltaic software*. Retrieved on 6, 8, 2020, from https://www.pvsyst.com/help/

Milieu Centraal. (2020). *Milieu Centraal Praktisch over duurzaam*. Retrieved on 05, 15, 2020, from https://www.milieucentraal.nl/energie-besparen/apparaten-en-verlichting/energiezuinig-verlichten-kies-led/

Ministerie van Economische Zaken en Klimaat. (2019). *Integraal Nationaal Energie- en Klimaatplan 2021-2030.* Den Haag. Publicatie-nr 19410647

Netherlands Enterprise Agency. (2019). *Electric vehicle charging: Defintions and explanation.* Utrecht. RVO-169-1801/RP-DUZA

Netherlands Enterprise Agency. (2020, March). *SDE+ Spring 2020. Instructions onhow to apply for a subsidyfor the production of renewable energy.* Zwolle. RVO-186-1901/BR-DUZA

Prasad Koirala, B. e. (2016). *Energetic communities for community energy: A review of key issues and trends shaping integrated community energy systems.* Renewable and Sustainable Energy Reviews April 2016, Volume 56, pp. 722-744. Retrieved from: https://doi.org/10.1016/j.rser.2015.11.080

PwC. (2016). *Tax benefits for innovative and sustainable buisness practices - Investment facilities 2016.* Rotterdamn: Knowledge Center Task

Rijkswatestraat. (2019). *Klimaatmonitor*. Retrieved on 06, 15, 2020, from https://klimaatmonitor.databank.nl/jive?presel_code=rap_buurt_1&geoitem_codes=wijk19_016305&geosplit=buurt19

RIVM. (2019). *Nationale EnergieAtlas*. Retrieved on 07, 12, 2020, from https://www.nationaleenergieatlas.nl/kaarten?config=418d0f56-0f0c-4fd4-9001-2ead4e1e22d6%3F%3Fconfig&gm-x=146095.19999999998&gm-y=447035.20000000007&gm-z=5&gm-b=1542632922900%2Ctrue%2C1%3B1555073323297%2Ctrue%2C0.8%3B

Roberts, J., Frieden, D., & d´Herbemont, S. (2019). *Energy Community Definitions.* Brussels. Nr H2020-824424

Sabzehgar, R. (2017). *Overview of Technical Challenges, Available Technologies and Ongoing Developments of AC/DC Microgrids.* IntechOpen. ISBN: 978-953-51-3400-8. DOI: 10.5772/65582

Salvo, F., Ciuna, M., Ruggiero, M. D., & Marchiano, S. (2017*). Economic Valuation of Ground Mounted Photovoltaic Systems.* Buildings 7(54):54

Stadler, M., Cardoso, G., Mashayekh, S., Forget, T., DeForest, N., Agarwal, A., et al. (2015). Value Streams in Microgrids: A literature. Applied Energ, Volume 162, pp 980-989. Retrieved from https://www.researchgate.net/publication/284133141_Value_streams_in_microgrids_A_literature_review

Stichting Platform Duurzaam Hellendoorn. (2018, March). *Duurzaam Hellendoorn*. Retrieved on 06 22, 2020, from https://www.duurzaamhellendoorn.nl/

Tennet. (2020). *Tennet - taking power further*. Retrieved on 03, 26, 2020, from https://www.tennet.eu/our-key-tasks/system-services/maintaining-balance/

TESLA. (2020). *Model 3*. Retrieved on 05 28, 2020, from https://www.tesla.com/nl_nl/model3

The European Parliament and The Council of the EU. (2019). *Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU.* Retrieved on 15, 05, 2020, from https://eur-lex.europa.eu/eli/dir/2019/944/oj

The Netherlands Ministry of Foreign Affairs. (2018). *The Netherlands compared.* The Hague

Timmerman, W. H. (2017). *Facilitating the Growth of Local Energy Communities*. Groningen: University of Groningen, SOM research school. Advanced System Studies for Energy Transition.

Retrieved from https://asset-ec.eu/wp-content/uploads/2019/07/ASSET-Energy-Comminities-Revised-final-report.pdf

Trading Economics. (2016). *Trading Economics*. Retrieved on 03, 21, 2020, from https://tradingeconomics.com/netherlands/agricultural-land-percent-of-land-area-wb-data.html

U.S. Energy Information Administration. (2019). *International Energy Outlook 2019 with projections to 2050.* US, Washington. Retrieved from https://www.eia.gov/outlooks/ieo/pdf/ieo2019.pdf

Verkade, N.; Höffken, J. *Collective Energy Practices: A Practice-Based Approach to Civic Energy Communities and the Energy System*. Sustainability 2019, 11, 3230. Retrieved from https://www.mdpi.com/2071-1050/11/11/3230#cite

APPENDIX

Grid-Connected System: Simulation parameters

Project : **Daarle PV solar plant**

Geographical Site		**Daarle**	Country	**Netherlands**
Situation	Latitude	52.43° N	Longitude	6.52° E
Time defined as	Legal Time	Time zone UT+1	Altitude	10 m
	Albedo	0.20		
Meteo data:	**Daarle**	Meteonorm 7.3 (2006-2015), Sat=100% - Synthetic		

Simulation variant : **2800 kWp**

Simulation date 02/07/20 21h35

Simulation parameters	System type	**No 3D scene defined, no shadings**		
Collector Plane Orientation	Tilt	40°	Azimuth	0°
Models used	Transposition	Perez	Diffuse	Perez, Meteonorm
Horizon	Free Horizon			
Near Shadings	No Shadings			
User's needs :	Unlimited load (grid)			

PV Array Characteristics

PV module	Si-mono	Model	**Mono 300 Wp 60 cells**		
Original PVsyst database		Manufacturer	Generic		
Number of PV modules		In series	21 modules	In parallel	349 strings
Total number of PV modules		nb. modules	7329	Unit Nom. Power	300 Wp
Array global power		Nominal (STC)	**2199 kWp**	At operating cond.	1951 kWp (50°C)
Array operating characteristics (50°C)		U mpp	589 V	I mpp	3313 A
Total area		Module area	**11923 m²**	Cell area	10422 m²
Inverter		Model	**500 kWac inverter**		
Original PVsyst database		Manufacturer	Generic		
Characteristics		Unit Nom. Power	**500 kWac**	Oper. Voltage	320-700 V
Inverter pack		Total power	**2000 kWac**	Pnom ratio	1.10
		Nb. of inverters	4 units		
Total		Total power	**2000 kWac**	Pnom ratio	1.10

PV Array loss factors

Thermal Loss factor	Uc (const)	20.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s
Wiring Ohmic Loss	Global array res.	3.0 mΩ	Loss Fraction	1.5 % at STC
Module Quality Loss			Loss Fraction	-0.8 %
Module Mismatch Losses			Loss Fraction	1.0 % at MPP
Strings Mismatch loss			Loss Fraction	0.10 %

Incidence effect (IAM): Fresnel AR coating, n(glass)=1.526, n(AR)=1.290

0°	30°	50°	60°	70°	75°	80°	85°	90°
1.000	0.999	0.987	0.962	0.892	0.816	0.681	0.440	0.000

Grid-Connected System: Main results

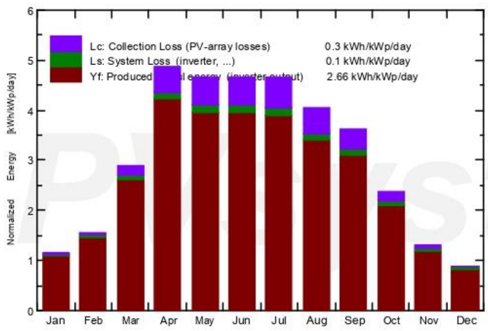
Project : **Daarle PV solar plant**

Simulation variant : **2800 kWp**

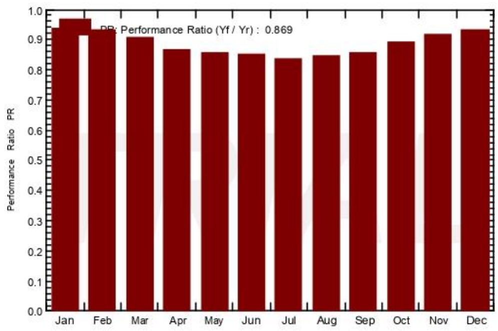
Main system parameters	System type	**No 3D scene defined, no shadings**		
PV Field Orientation	tilt	40°	azimuth	0°
PV modules	Model	Mono 300 Wp 60 cells	Pnom	300 Wp
PV Array	Nb. of modules	7329	Pnom total	**2199 kWp**
Inverter	Model	500 kWac inverter	Pnom	500 kW ac
Inverter pack	Nb. of units	4.0	Pnom total	**2000 kW ac**
User's needs	Unlimited load (grid)			

Main simulation results				
System Production	**Produced Energy**	**2135 MWh/year**	Specific prod.	971 kWh/kWp/year
	Performance Ratio PR	86.86 %		

Normalized productions (per installed kWp): Nominal power 2199 kWp



Performance Ratio PR



2800 kWp

Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR ratio
January	18.5	12.37	3.28	36.2	35.5	78.2	74.7	0.938
February	30.2	21.02	3.71	44.0	43.3	94.1	90.1	0.931
March	67.6	39.23	5.57	89.6	87.1	185.0	178.5	0.906
April	121.6	54.04	9.47	145.5	140.9	287.1	277.9	0.869
May	142.4	75.43	13.50	143.8	138.8	280.0	270.6	0.856
June	145.8	77.55	15.92	139.6	134.7	270.0	260.8	0.850
July	147.1	75.42	17.86	144.5	139.2	274.8	265.2	0.835
August	115.2	65.00	17.55	125.0	121.3	240.4	232.1	0.844
September	83.5	39.64	14.31	109.0	105.7	212.1	204.7	0.854
October	49.8	29.67	10.53	73.3	71.8	149.1	143.6	0.891
November	22.3	14.95	6.92	39.5	38.8	83.2	79.5	0.916
December	14.1	10.19	3.23	28.0	27.5	60.6	57.5	0.934
Year	958.1	514.53	10.19	1118.0	1084.6	2214.6	2135.1	0.869

Legends:

GlobHor	Global horizontal irradiation	GlobEff	Effective Global, corr. for IAM and shadings
DiffHor	Horizontal diffuse irradiation	EArray	Effective energy at the output of the array
T_Amb	T amb.	E_Grid	Energy injected into grid
GlobInc	Global incident in coll. plane	PR	Performance Ratio

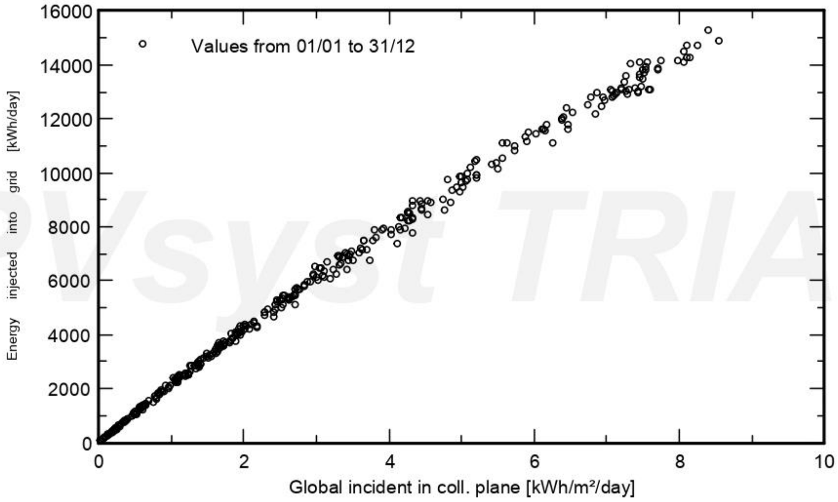
Grid-Connected System: Special graphs

Project : **Daarle PV solar plant**

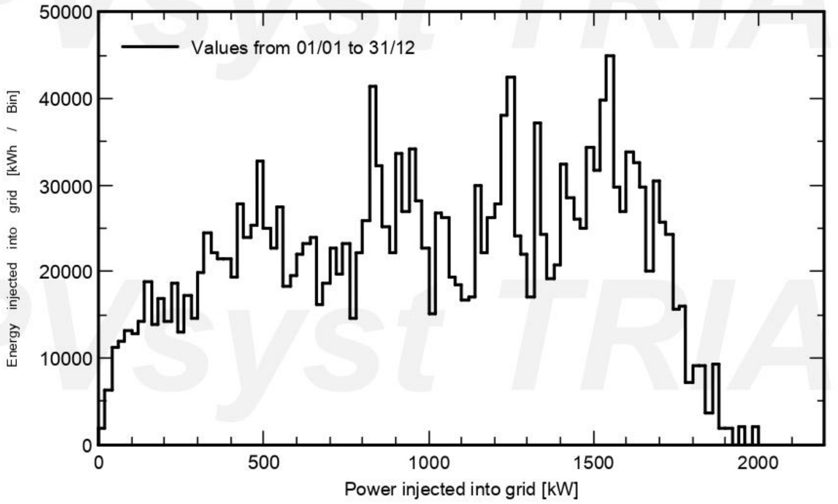
Simulation variant : **2800 kWp**

Main system parameters	System type	**No 3D scene defined, no shadings**			
PV Field Orientation	tilt	40°		azimuth	0°
PV modules	Model	Mono 300 Wp 60 cells		Pnom	300 Wp
PV Array	Nb. of modules	7329		Pnom total	**2199 kWp**
Inverter	Model	500 kWac inverter		Pnom	500 kW ac
Inverter pack	Nb. of units	4.0		Pnom total	**2000 kW ac**
User's needs	Unlimited load (grid)				

Daily Input/Output diagram



System Output Power Distribution



Grid-Connected System: Loss diagram

Project : **Daarle PV solar plant**

Simulation variant : **2800 kWp**

Main system parameters	System type	**No 3D scene defined, no shadings**		
PV Field Orientation	tilt	40°	azimuth	0°
PV modules	Model	Mono 300 Wp 60 cells	Pnom	300 Wp
PV Array	Nb. of modules	7329	Pnom total	**2199 kWp**
Inverter	Model	500 kWac inverter	Pnom	500 kW ac
Inverter pack	Nb. of units	4.0	Pnom total	**2000 kW ac**
User's needs	Unlimited load (grid)			

Loss diagram over the whole year