MASTER

Community based Virtual Power Plants
Aligning technical functions with social motivations

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Community based Virtual Power Plants: Aligning technical functions with social motivations

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PREFACE

This document is the result of the cumulative and sustained effort of a lot of people. Without them, it would never have been written. Three years ago, if someone told me that I would be studying sustainability and renewable energy and I would one day do my thesis on Virtual Power Plants, I would have laughed, and then asked what exactly they meant by Virtual Power Plants. Standing on the cusp of graduation, this is a very proud moment for me. 8 months of hard work has led to this moment.

I want to thank Prof. Anna, Prof. Vladimir and Prof. Geert, without whom this thesis would not have been possible. Anna's timely advice and practicality is what pushed this thesis forward at a blistering pace. I am a technical engineer by education and did not have much experience in the social aspects of things. But I never doubted myself because I knew I could bank on Anna's guidance and expertise.

I feel that the mix of social and technical aspects is what makes this a unique work, and this would not have been possible without Vladimir's guidance. Even though technical part was challenging, Vladimir's advice made it possible.

Both Anna and Vladimir always had time to spare for me even though they had busy schedules. This is no small thing as I have heard from my peers that they found it difficult to meet with their professors. Through the course of my thesis, I got to know them more personally and it was always nice to walk into their office and be greeted by a big smile and a cheerful "How are you Sid?".

I received a lot of support from Andre and Nynke for their support in the interview phase. Han Meurs, Femke Jochems, Xandra Van Lipzig, Hansjurgen Heinen, Willem De Zanger and Ivo Smits for agreeing to be interviewed. Michiel Nijhuis for allowing me to use his load model. Fred and Ronald from Alliander for giving me a lot of data and support.

I also want to thank mum, dad and Hari for their infinite patience and for putting up with me during my difficult phases. Aunt, Uncle, Grandpa and Grandma for brightening up my day from time to time. Haresh and Lauren Anand for being a source of joy and light when things looked bleak. Katharina for always believing. And finally Ginger, Ozzy, Candy, Brownie, Jacky and Daisy for giving me something to work towards.

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EXECUTIVE SUMMARY

Currently, the electricity distribution system is undergoing a transition. The system is changing from a traditional centralized model, with utilities producing electricity in large plants at specific locations to a decentralized model where distributed generation (especially with renewables like solar PV) is favoured and the generation is closer to the end user. This increase in distributed generation, is an indicator of the socio-technical transition taking place in the electricity regime. The transitions in the socio-technical system lead to the alteration of different aspects of the system. These include changes in aspects like the technology used, the policies surrounding it, the markets, consumer practices, infrastructure and cultural meaning. The transition to renewable distributed generation is being spearheaded by the end consumer. The awareness about sustainability and the traditional distrust for utility companies are 2 of the major drivers for this transition.

This transition to a more decentralized structure leads to different challenges. In the electricity grid, the generation and consumption of energy must always be balanced. The prevalence of distributed generation introduces variability due to the stochastic nature of renewables. It became harder to ensure the balance between generation and consumption. This lead to the rise of innovative grid concepts which were created to manage the variability of renewable distributed generation.

Theory

Innovative concepts like the Virtual Power Plant (VPP), was developed due to the increasing prevalence of distributed generation. A VPP is a network structure in which different distributed generation sources (like solar PV) and controllable loads (like boilers, refrigerators etc) are interconnected using software (termed as Energy Management Software – EMS). The pre-existing interconnections of the electricity grid is used as the physical link between these different assets. The distributed generation sources and controllable loads are collectively called Distributed Energy Resources (DER).

Even though, the development of VPP was a reaction to the adoption of distributed generation by the end users, the VPP projects were not end user focused. Most of the previous VPP projects were initiated by large energy companies in a top-down manner. VPP projects served to preserve the dominance of big energy companies over the changing electricity regime. Most of the projects served as an extension of the portfolio of the big energy companies. Their main aim was to understand the possible technical and economic benefits that the energy companies could derive from these projects. Even though, it is the decision of the end user to embrace decentralized generation that led to this transition and the rise of the VPP, the end user is seen as a minor entity in this process. Most of the previous research into VPP assumes that the primary motivation of the end user in taking part in a VPP project is profitability.

This is where the novel concept of the community based VPP comes in. Since the transition towards decentralization (which lead to the rise of the VPP concept) was initiated by the actions of the end user (the increased adoption of distributed generation), it is reasonable to suggest that the motivations of the end user must play a central role in informing what technical functions the new cVPP concept must focus on.

Method

This thesis has a social aspect and a technical aspect. This thesis initially identifies a general set of social motivations present within a community that could lead to the inception of a community-based project like the cVPP:

- Deriving economic profitability from the project
- Asserting community control over energy supply
- Improving social cohesion
- Improving perception of sustainability within the community

After this, a general set of technical functions that the cVPP could perform is identified:

- Trading in the wholesale electricity markets
- Offering ancillary services to the national grid
- Offering local grid management to the DSO
- Setting up local community energy markets

A framework is built which matches the different technical functions to the level of satisfaction of each social motivation. Once this general framework has been built, the focus shifts to the case study of a specific community where a cVPP project is being planned. From the list of general social motivations created previously, a set of social motivations specific to the community is identified. The framework is used along with these specific social motivations to identify specific technical functions that could satisfy them. Finally, a techno-economic analysis is done to ascertain the technical feasibility and the economic viability of the selected technical functions.

For determining the general list of social motivations, a literature study was undertaken. To identify the social motivations that are specific to the community that is part of the case study, 6 semi-structured interviews were conducted with key stakeholders. The interview candidates included employees of the organizations setting up the cVPP and members of the local community where the project is planned. To identify the general technical motivations, another literature review was carried out. The social motivations and technical functions were combined to form a framework matrix that matched the different technical functions to a level of satisfaction of each of the social motivations. This helped in choosing the 2 technical functions – offering local grid management for the DSO and setting up a local community energy market – as the technical functions that satisfy the social motivations found within the community. A techno economic analysis was done to understand if these functions were practical to implement from a technical perspective (by considering the existing infrastructure and amount of distributed generation and loads) and if these technical functions made economic sense. The technical part of the analysis was partially done using Gaia software and grid network models provided by the local DSO. The economic part of the analysis relied on concepts like NPV and discounted payback times.

Results

The techno-economic analysis indicates that both chosen technical functions – managing the local grid for the DSO and setting up a local community energy market – was technically and economically feasible. The success of this initiative was found to be dependent on other factors. For setting up a local community energy market, even though this was technical feasible, the current government legislation does not allow trading energy between a prosumer and consumer. The current feed in tariff structure in the Netherlands is expected to be stopped in 2020. Even though there is uncertainty regarding what the new legislation will be, things look favourable for peer to peer energy trading and local energy markets due to the large number of experimental pilot projects incorporating these two aspects. For managing the local grid for the DSO, the amount of participation is key. It was found in the techno-economic analysis that at least 48% of the community in the case study must participate for the project to show economic returns in 40 years (this is the expected lifetime of grid components before they are upgraded). The payback time of the project is very dependent of the amount of participation.

Conclusion

After the techno economic analysis, it was suggested that the community focus on setting up the local community energy market as a first step. Once this has been accomplished the amount of participation would increase with time. After sufficient amount of participation is attained, the second technical goal of offering local grid management for the DSO could be accomplished. It is important to start this initiative after major grid upgrades so that the local grid can be managed to extend the time gap till the next major grid upgrade.

The thesis also analyses how the social motivations affect the technical functions. The technical functions can be grouped into 2 categories:

- Internally focussed technical functions: These technical functions use the locally generated energy internally within the community. The following 2 technical functions are internally focussed:
  - Offering local grid management for the DSO
  - Setting up a local community energy market
- Externally focussed technical functions: These technical functions use the locally generated energy externally to benefit the community as well as the external system. The following 2 functions are externally focussed:
  - Trading in the wholesale energy markets
  - Offering ancillary services

Comparing the technical functions with the level of satisfaction of social motivations, it is seen that if profit is the primary motive of a community and other motivations like community control and social cohesion is not as important, then externally focussed goals would be the best fit. On the other hand, if community control, social cohesion and the perception of sustainability is as important (or more important) to the motivation of profitability, then internally focussed technical functions would be a better fit.

This thesis aims to align the technical functions of a cVPP project with the social motivations of a community. It then proceeds to quantify the benefits of the technical functions that were chosen to satisfy the social motivations. The framework that was built to align the technical and social aspects could be used for other cVPP projects in different communities. The list of basic social motivations that were identified could also be applied to any community-based energy project.

This thesis provides cost estimates for a cVPP project which is a novelty as the cVPP field is very nascent and data regarding the costs is hard to obtain. Finally, most of the precious research of VPPs assign a very minor role to the ned user. The end user is assumed to have profit as the primary motivation for participation. This thesis shows that there are other motivations that are equally important. These motivations must also be considered when designing such projects to achieve community acceptance.

Contents

List of abbreviations

aFRR	Automatic Frequency Restoration Reserve
BRP	Balance Responsible Party
CCVPP	Centralised Controlled Virtual Power Plant
CHP	Combine Heat and Power
cVPP	Community based Virtual Power Plant
DCVPP	Decentralized Controlled Virtual Power Plant
DER	Distributed Energy Resources
DG	Distributed Generation
DSO	Distribution System Operator
FCR	Frequency Containment Reserve
FDCVPP	Fully Decentralized Controlled Virtual Power Plant
LEN	Loenen Energie Neutraal
mFRR	Manual Frequency Restoration Reserve
OVIJ	Omgevingsdienst Veluwe Ijssel
PV	Photovoltaics
TSO	Transmission System Operator
USEF	Universal Smart Energy Framework
VPP	Virtual Power Plant
VPP-com	Commercial Virtual Power Plant
VPP-tech	Technical Virtual Power Plant

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1 Introduction

1.1 Socio-technical systems and transitions

The smooth functioning of modern society is dependent on complex systems like transportation and electricity supply. These systems are created through the interaction between different elements like technology, user practices, markets, infrastructure etc (Geels, 2006). These elements work together to form the system, and a single element on its own cannot perform the intended function of the system. These systems are termed as socio-technical systems because the technological and societal elements must work together for the functioning of the system. When there is a change in the way these elements interact with each other, the system is said to be undergoing a transition.

Sustainability has become a buzzword nowadays. It is one of the aspects that is defining the direction of transition in different socio-technical systems (Geels, 2011). These transitions are not overnight events. They are the cumulative result of interactions between different actors and are long term processes. A transition in a socio-technical system occurs when the needs of the society evolves, and the system itself has to transition to meet these needs. This transition is shaped by the interaction between the different elements within the system.

These transitions in the socio-technical system lead to the alteration of different aspects of the system. These include changes in aspects like the technology used, the policies surrounding it and cultural meaning (Geels, 2011). Hence, it can be concluded, that the needs of society lead to the interaction between society and technology, which is one of the main drivers for transitions in established systems.

The increasing prevalence of renewables (Johnston, 2017) is an indicator of the socio-technical transition taking place in the electricity system. Traditionally, the electricity system was very centralized and involved large utilities producing electricity in large plants at specific locations. The electricity is then transmitted across vast distances towards customers and they use it according to their requirements.

The electricity system is now transitioning towards distributed generation (DG) which is a step away from the prevalent centralized generation models. DG is defined as the small-scale generation of energy and is usually close to the point of consumption itself (Bloomenergy, 2016). The different kinds of DG include (Musa, 2015):

- Wind turbines
- Photovoltaic cells
- Fuel cells
- Micro Turbines
- Internal Combustion Engines

Even though technically, DG also includes fossil based electricity generation sources, the falling costs of renewables due to technological innovations and liberalization of electricity markets have led to prevalence of sustainable DG (IEA, 2002). The increase of sustainable DG can also be attributed to the following 2 needs exhibited by the end users:

- Research (Bang, Ellinger, Hadjimarcou, & Traichal, 2000) suggests that many consumers are driven to adopt renewable DG due to the need to be more environmentally friendly.
- Historically there has also been low trust in utility companies (Accenture, 2013). A recent survey (Edelman, 2016) showed that globally, energy companies are ranked third from the bottom (above financial services and pharmaceuticals) in terms of public trust. This is another driver for end users to desire less reliance on utilities and more energy independence by producing their own energy.

As a result, many home owners began installing these systems and their reliance on traditional electricity producers reduced. Yet, centralized electricity producers still remained important because, even though renewables could displace some of the electricity production from centralized plants, they were inherently stochastic in nature and dependent on external factors like the weather. The centralized electricity generation plants were still required when renewables were not producing electricity.

The connection of DG devices to the grid followed a 'fit and forget' model (Pudjianto et al., 2007). Under this model, even though the DG can displace some of the energy produced by major power plants, it cannot displace their capacity for reliable energy production. It also cannot perform actions of systems support (for example, coordination for frequency and voltage regulation). This is because the DG is not visible to the electric system. The system operator cannot keep track of the generation of each individual DG device.

This passive 'fit and forget' model led to increasing costs for network operators because more money would be needed to increase the capacity of the grid to accommodate both the renewable DG and centralized generation sources. Hence there was a need from the system operator side (who form an important actor group in the electricity system) to reduce costs while accommodating the need of end users to produce energy by installing their own renewable DG devices.

1.2 Virtual Power plants

The concept of Virtual Power Plants (VPP) has emerged as one of the approaches to tackle the growing prevalence of distributed generation in the grid at a more active level. Under this scheme, many DG sources and controllable loads[1] (like refrigerators, heaters, air condition systems etc) are aggregated together. These are termed as distributed energy resources (DER). When aggregated together under a VPP, they resemble a traditional power plant and have similar characteristics (Pudjianto et al., 2007). Some of these characteristics are:

- Schedule of generation – The generation of energy can be scheduled ahead of time based on the expected requirements. If a high amount of load is predicted, the generation can be scheduled to increase to meet it.

[1] Controllable loads refer to devices whose electricity consumption can be controlled by altering different aspects of their operation. For example, the heating temperature of an electric heater can be decreased to reduce the energy consumption. Controllable loads make the energy requirements more flexible and allow matching of energy supply and demand.

- Ramp rate – The rate or speed at which the amount of energy that is generated can be increased or decreased (Watts / minute). In case of load fluctuations, the power generated must be varied to match the fluctuation to ensure balance of demand and supply.
- Schedule of load – The load can also be controlled according to the needs. In case the generation is low at a particular time for some reason, the load can be lowered to balance the grid.

One of the earliest pilot projects of a VPP was in 2008, in Kassel University (Schlögl, 2012). The VPP concept has been gaining popularity with several newer projects being announced, especially by major electric utilities in Europe (E.ON, 2017).

2 Problem definition

Most of the VPP projects follow a top down development structure with emphasis placed on the needs of the big utilities developing them. Most of the existing research on VPPs focuses on the economic and technical benefits that utilities gain by implementing a VPP. The DERs can be aggregated to reduce costly energy peaks and to limit maintenance and expansion costs of the grid (Werner & Remberg, 2008). When research does focus on the end user, it is assumed that financial incentives is the main driver for participation in a VPP (El Bakari & Kling, 2011). In essence, currently VPPs are seen as a means of energy utilities to maintain their dominance over the transitioning electricity system while the end user is seen as a minor actor, whose main motivation to take part in the VPP is of an economic nature.

Even though the electricity generation is becoming more distributed, the development and control structure of the VPP is still centralized and top-down. The VPP is treated as an extension of the product portfolio of the utilities. Research around VPPs focus on the economic and technical benefits that the utilities gain by implementing this concept. This centralized top-down development of the VPP does not meet the need of energy independence of the end user. The VPP needs to focus on the end user from the development stage itself. This is where the novel concept of a community based Virtual Power Plant is needed (cVPP).

Unlike a typical VPP, the social motivations of the community play a central role in the design of the cVPP. Since the community forms an integral part of the cVPP, it becomes necessary to fix a definition for “Community” that will be followed for the remainder of this thesis.

There have been various definitions proposed in research. All of these definitions are similar in one aspect, communities are groups of people connected by a common characteristic. These common characteristics could be(Puja Mondal, n.d.):

- There might or might not be of a geographical nature
- There is a common culture or a social system around which some of their activities are organized
- There is a general consciousness among members about their unity and there is a general sense of belonging
- They usually act collectively to further shared interests

According to literature, there are different interpretations of the term “community” and some of the proposed definitions are as follows:

- A community is a group of people defined by a “spatially bound locality”. It includes people living in the same geographical area, like a village or a street (Clark, 2007).

- A community can refer to a system of relationships that are interconnected (Puja Mondal, n.d.)
- A community is a group of people who share similar beliefs or are engaged in a similar activity. This definition does not have a spatial component. For example, people involved in a renewable energy project can be defined as a community (Clark, 2007).

(Klein & Coffey, 2016) takes a step further and defines a community energy project as something initiated by a group of individuals who share similarities like a common location and/or a common set of interests or goals. The costs and benefits of this initiative are usually distributed among the participants.

For the purposes of this thesis, inspiration is drawn from this interpretation and the simple definition of a community being a group of people connected by a shared geographic area and shared interests (participation in the cVPP project) is adopted.

Technically the cVPP is similar to a VPP, but in terms of the management and design aspects it is similar to a community energy project as it is more community focused. This means that a cVPP needs to translate the social motivations of a community into its technical functions.

Since the cVPP is end user focused and has a bottom up development process, it becomes important to understand the different social motivations that are present in a community and identify a technical function for the cVPP project that would satisfy these motivations as much as possible. But it is important to acknowledge that motivations would differ depending on the community in question. Hence, initially, after a general understanding of possible social motivations and technical functions to satisfy them is built, the focus must shift to a specific community. The social motivations of this community will be taken into account to identify the technical functions that will best satisfy them. The community of Loenen in the Netherlands is taken as the case study on which this thesis is based upon.

This thesis is being done as part of an international consortium that initially aims to establish cVPP projects in 3 different locations - in the Netherlands, Belgium and Ireland (Interreg_NWE, 2017). The consortium hopes to start pilot cVPP projects individually (and simultaneously) in these three locations and eventually scale up the project to include more locations. The consortium plans to implement the cVPP project by following the Universal Smart Energy Framework (USEF) (USEF Foundation, 2015). This framework tries to establish common standards when setting up smart energy systems like a VPP. It defines specific functions for different entities in the system which makes the establishment of smart energy systems uniform. One end goal of the consortium will be to interconnect the cVPP in these different locations.

In the Netherlands, Loenen village has been chosen as the location where the cVPP will be implemented. Loenen village is located in the Dutch province of Gelderland. The municipality of Apeldoorn is responsible for its administration. It is home to about 3200 inhabitants according to the official website (Loenen, n.d.). This community is actively involved in renewable development. In 2013, they were the recipients of funding for a community project to subsidize the installation of residential solar panels (Apeldoorn, 2015). The project was spearheaded by the local energy collective called Loenen Enrgie Neutraal (LEN). After the success of previous renewable energy projects in Loenen, the cVPP project is the next undertaking by LEN with the help of other partners in the consortium.

3 Research Question

This study is focussed on developing the technical functions of the cVPP project according to the social motivations behind the inception of the project. Since the social motivations will vary according to the community, there is a need to focus on a specific community for the purpose of the study. The main research question dealt with in this study is:

How can the technical functions of a cVPP project be aligned to the social motivations of a specific community and what are the technical and economic benefits derived from these technical functions?

To answer the research question, the following 6 sub questions must first be answered.

First, the possible social motivations for the inception of the cVPP project must be understood. This leads to the first sub question.

SQ1: What are the possible social motivations behind setting up a cVPP project?

Once these general social motivations have been identified, the next task is to determine the possible technical functions that the cVPP can have. Hence, the next sub question deals with this.

SQ2: What are the possible technical functions that can be satisfied by a cVPP project?

Different technical functions would fully or partially satisfy different sets of social motivations. The next sub question deals with matching each technical function identified by SQ2 to different levels of satisfaction of the social motivations identified by SQ1.

SQ3: How can the different possible technical functions of the cVPP project be matched to the level of satisfaction of the different social motivations in a community?

The framework to match the level of satisfaction of social motivations to the technical functions of the project is general in nature and can be applied to different communities. This is because the social motivations would vary from community to community. This thesis applies the framework in the context of the Loenen community.

A set of social motivations that are specific to the Loenen community is derived. Then this is applied to the framework developed in SQ3 to derive the specific technical functions that can satisfy the social motivations found in the Loenen community.

SQ4: What are the specific social motivations in the Loenen community and what specific technical functions of the cVPP can satisfy these motivations?

Specific technical functions were chosen when answering the previous sub question because these functions satisfied different social motivations and were beneficial from the social stand point. The benefit of the chosen technical functions is then analysed from an economic and technical perspective to make sure that their implementation is feasible and practical. This leads to the final sub question.

SQ5: What are the technical and economic benefits derived by the Loenen community from the chosen technical functions?

4 Research Design

The following section gives a brief description of how the research is structured, to answer the different sub-questions and ultimately, the main research question. A pictorial representation of the research design is shown below:

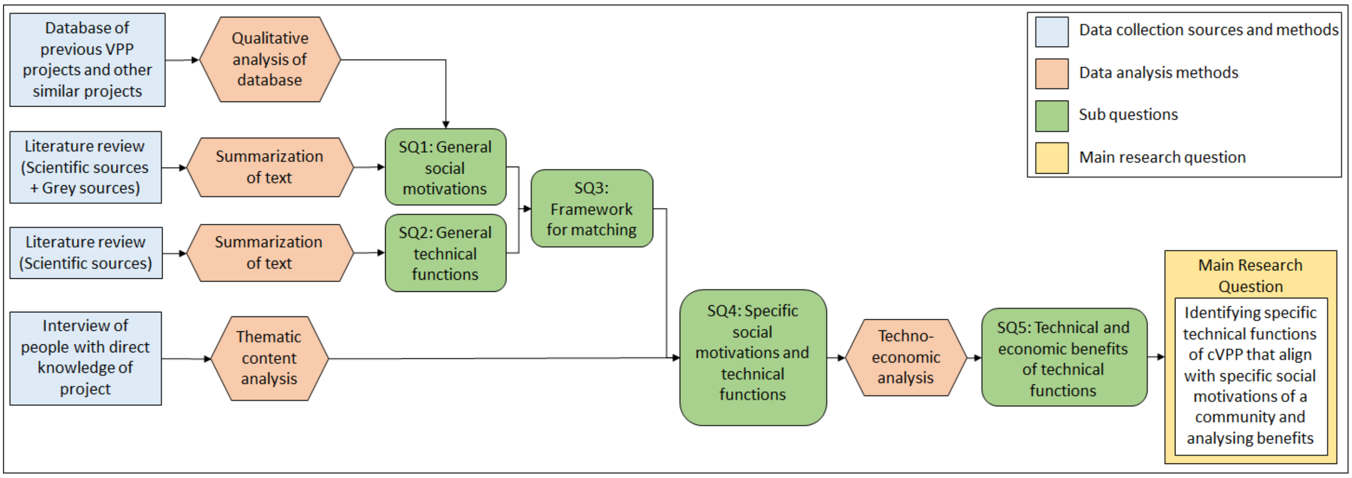

Figure 1: Research design overview

Details of the various steps in the research follow in the upcoming subsections.

4.1 Answering SQ1 – Database analysis and literature review

For determining the general social motivations behind a cVPP project (SQ1), a database containing details of pre-existing VPP projects is analysed and a literature review is done.

As mentioned in section 2, the cVPP project that is used as a case study for this thesis, is being implemented in the Netherlands, by an international consortium that is setting up similar cVPP projects in Ireland and Belgium (Interreg_NWE, 2017). As part of the initial research into the cVPP topic, a database of 50 previous European VPP projects, microgrid projects and platforms that function similar to a VPP, was made by the consortium. For each project that was added to the database, general information and information corresponding to the FIETS dimensions were identified and recorded (WASH_Alliance, n.d.). The FIETS dimensions consist of Financial, Institutional, Environmental, Technological and Social aspects of the project. As part of this thesis, the database is jointly analysed with the consortium members[3] to provide a starting point to understand the possible social motivations in a community, behind the inception of a cVPP project.

For the analysis, the details of each project in the database is examined based on the FIETS dimensions. Projects having similar characteristics are grouped together. Conclusions are drawn from this group which shed light on the current trends in this sector. Even though the database contains only 50 projects, it can be considered as a representative list, because the VPP concept is still relatively new and the number of test projects dealing with this topic is limited.

After the analysis of the database, it is found that most of the pre-existing VPP projects are not community focused, and hence cannot be used to derive social motivations. For the literature review, papers dealing with communal energy projects are focussed upon. It is reasoned that the

[3] The database is jointly analysed with Luc F.M. van Summeren, a PhD student at Eindhoven University of Technology working with the cVPP consortium. The cVPP consortium intends to use the results from the database analysis in Deliverable 1.2 – "The Suitable transnational/European cVPP platform framework". He also plans to publish the results in a future research paper.

social aspects of community energy projects will be similar to a cVPP (explained in section 5) hence the social motivations derived from community energy projects can be extended to the cVPP also.

In the literature review, both scientific and grey literature sources are used for the identification of general social motivations. For scientific papers, Scopus is used as the main source. Relevant scientific papers were found in the domain of social sciences and energy generation. The papers were selected based on the occurrence of the following key words (or variations of it):

(Community OR Communal OR Societal OR Collective) AND (energy OR energy projects), social AND (motivation OR needs)

Once a relevant paper is identified, the technique of snowballing is used to find more relevant papers (Wohlin, 2014). In this technique, the bibliography list of the selected paper is used to identify additional papers of interest.

Study of grey literature is needed because many of the case studies of VPP projects are often part of reports published by non-academic organizations. Many reports are published by governmental bodies themselves or by external organizations for these governmental bodies. Such reports are targeted as they would have high levels of reliability due to the involvement of official organizations in it.

Once the relevant documents and publications are identified short summaries of the different projects mentioned in these documents are made and the social motivations that lead to their inception are identified.

After identification of the different social motivations from literature review, they are verified by comparing them with the social motivations of pre-existing community-based projects.

4.2 Answering SQ2 – Literature review

To identify the general technical functions of a cVPP project, a literature review is done using scientific papers from the Scopus database. The technical functions of a cVPP are reliant on its primary characteristic, namely the interconnection of different DERs. Hence, when listing out the technical functions that could be performed by a cVPP, the functions of different electricity network concepts that also rely on interconnection of assets– smart grids and VPPs – are also analysed.

A literature review of papers in the domain of energy generation and electrical engineering is done. Papers that deal with new models of energy generation, new structures of the grid and the VPP and related concepts are focused upon. The papers are selected based on the occurrence of the following key words (or variations of it):

Virtual Power Plants OR VPP, grid integration AND (renewables OR Distributed Generation OR DG OR Distributed Energy Resources OR DER)

The method of snowballing mentioned previously (section 4.1) is also used here, on selected papers to identify more papers of interest.

Information is collected from the different relevant documents by summarizing the contents. As a result of the literature review, a general list of technical goals is derived.

4.3 Creating the framework – Answering SQ3

This is one of the key steps in the research. The set of general social motivations behind the inception of the cVPP and the technical functions of the cVPP is matched using a framework.

A cVPP needs to translate the social motivations of a community into its technical functions. Social motivations will vary depending on the community. In many cases, there will be multiple social motivations present with varying degrees of importance. Also, different technical functions might not completely satisfy every social motivation that the community might have. There will be instances where a particular technical function might satisfy some social motivations to a high extent while other motivations might be neglected. Hence the "satisfaction aspect" of technical functions satisfying social motivations cannot be considered in binary terms (that is if the motivations are satisfied or not). Instead the extent to which each motivation is satisfied must be considered. This can be expressed in terms of high, medium or low degree of satisfaction of a particular social motivation.

This framework would answer SQ3. This general framework will then be applied to the specific case of the cVPP project in the Loenen community.

4.4 Interviews and application of results to framework – Answering SQ4

To apply the framework to the Loenen community, the specific social motivations of the community must be understood. This is achieved with the help of a series of interviews.

The interviews will specifically focus on people who are closely involved with the implementation of the project. This will include people who have a direct authority over the project like members of the city council and people who are more knowledgeable about the project like members of local energy collectives.

For the interview candidate selection, care is taken to choose people who have the following characteristics:

- Interview candidates must have a better understanding than the average citizen about the contextual aspects of the project like bureaucratic aspects, the funding aspects etc which would ultimately dictate what was possible (with regards to the technical goals).
- Interview candidates must be in a position, where they interact with the community as a whole, so that they have an understanding of the different motivations that the community could have and would be able to judge the general needs.

The candidates who are interviewed and their respective positions are as follows:

Table 1:List of interview candidates and their positions

Name	Position
Han Meurs (HM)	Loenen resident, member of LEN and local entrepreneur
Femke Jochems (FJ)	Project coordinator cVPP, OVIJ employee
Xandra van Lipzig (XL)	Program manager Apeldoorn Energy Transition, Gemeente Apeldoorn employee
Hansjurgen Heinen (HH)	Loenen resident, OVIJ employee, LEN member
Willem de Zanger (WZ)	Loenen resident, Chairman of Loenen village council
Ivo Smits (IS)	Loenen resident, Alliander employee

LEN refers to Loenen Energie Neutraal, the local citizen led energy group and OVIJ refers to Omgevingsdienst Veluwe Ijssel, an organization that helps communities and business become sustainable. OVIJ is working with Gemeente Apeldoorn to make Apeldoorn and its neighbouring villages more sustainable.

The intended outcomes of the interviews are:

- Understand the ranking according to importance, of the different social motivations within the Loenen community
- Understand which technical goal or mix of goals are feasible and ideal for the Loenen community

The interview also serves to get the opinions of stakeholders for the different technical scenarios used to generate randomized load consumption profiles used in the technical analysis. More details are provided in the section dealing with the technical analysis.

An interview protocol was created that covered the essential questions (appendix Appendix C) and the candidates were sent a consent form for recording the interviews (appendix Appendix D). Even though the candidates have different opinions, all of them are supporters of sustainability measures and think that the cVPP project is a good initiative. It proved difficult to find a person who might be against the cVPP project. Each of the candidates were asked after the interview if they could suggest someone to reach out to for a different opinion. One of the candidates suggested that the difficulty to find a person opposed to the cVPP project was because:

- The project is being spearheaded by LEN and they enjoy a high degree of trust and respectability within the local community due to their successful implementation of previous renewable energy projects.
- The concept of the cVPP might be a bit abstract for the laymen to grasp. Hence, there are very few people who are opposed to the idea in the pre-implementation phase. Maybe after implementation, once people are more familiar with it there might be different opinions about it.

There are many methods to qualitatively analyse an interview. The interviews are analysed using the Taylor-Powell & Renner approach (Burgess & Bryman, 1994). A brief summary of the analysis steps is given below:

- After the interview is conducted, a transcript of the interview is made
- The unit of analysis is decided. This can be a paragraph, a line or even a portion of a line. Each transcript is analysed unit by unit.
- For each unit of analysis ascertain a topic that relates to it.
- Make a list of all topics across all the transcripts.
- Highlight similar topics across different transcripts.
- Choose a primary theme for each cluster of related topics.
- Make a table with the primary themes, the individual topics and the quotes from th transcripts that relate to this individual topic.
- Tally the number of participants who mentioned a theme, find commonalities and differences

The interview transcripts and the steps of the qualitative analysis done are presented in the appendix (Appendix E).

After the social motivations that are specific to Loenen have been identified via the interviews, the technical functions of the cVPP, that satisfy these social motivations are identified by applying the specific social motivations to the frame work that has been developed previously.

4.5 Techno-economic analysis of selected technical functions – Answering SQ5

Once the specific technical functions that satisfy the social motivations of the community are identified, the practical feasibility of these technical functions needs to be checked to see if it is implementable. A techno-economic analysis which looks at the technical aptness and the economic validity of the chosen function of the cVPP will be used for this.

To judge the technical aptness of the function, the technical part of the analysis would strive to answer questions like:

- Considering the current situation of the technical aspects like the local grid, the generation and the consumption, does the proposed technical function make sense?
- Is the chosen technical function feasible to implement?

To judge the economic validity of the function, the economic part of the analysis would answer questions like:

- How can the economic benefits of the proposed technical functions be quantified?
- Is the project economically viable?

The techno-economic analysis will have the following common inputs:

- A gird model of Loenen
- Aggregated consumption of Loenen
- Consumption profiles of different households in Loenen
- Streetwise number of PV panels
- Generation of PV panels

The street wise grid model of Loenen, is obtained from Alliander, who is the DSO catering to Loenen. The grid model was shared without the usage profiles of the individual households due to privacy concerns.

Hence simulated usage profiles that can be representative of the actual usage is needed. To analyse the flexibility per household, the usage profiles must also be dis-aggregated at the device level so that devices with flexible consumption can be focussed upon. The household load model developed in (M. Nijhuis, 2017) is used to get representative profiles for each household.

The aggregated consumption for Loenen for the year of 2017 and the number of PV panels (and capacity) per street is provided by Alliander.

The total generation of these PV panels is calculated using (Renewables.Ninja, n.d.), which is an online tool that has solar insolation data for all locations in Europe and can provide an accurate estimate of PV generation.

5 Social motivations

This section identifies the list of possible general social motivations, behind the inception of a cVPP project. The main purpose of this section is answering **SQ1** (explained in section 3):

What are the possible social motivations behind setting up a cVPP project?

As explained in the research design (section 4), the database created by the consortium setting up the cVPP project, research papers in the domain of social sciences and energy generation (keywords have been specified in the research design section 4.1) and grey literature published by non-academic sources related to VPP projects and community energy projects have been used to ascertain possible general social motivations that a community could have behind setting up a cVPP project.

5.1 Previous VPP projects and community energy projects

Research began with the qualitative analysis of the database created by the consortium. The database consists of 50 previously implemented VPP projects, Microgrid projects and projects that are not specifically termed as VPP but nevertheless act as a VPP.

The database gathered general information about the project and the goals and objectives specified on the official websites of each project. Additional information corresponding to the FIETS dimensions are also identified and recorded (WASH_Alliance, n.d.). The FIETS dimensions consist of Financial, Institutional, Environmental, Technological and Social aspects of the project. An analysis of the projects in database is done in collaboration with the consortium members.

For the analysis, the details of each project based on the FIETS dimensions are examined. Projects having similar characteristics are grouped together. The general trends that emerged from grouping together similar projects are used to draw conclusions about the database.

The 50 projects in the database were analysed and the following results were obtained:

- 38 projects were initiated by the Transmission System Operator (TSO) or the Distribution System Operator (DSO) in a top-down manner.
- Most projects had technical goals like assessing the feasibility of grid balancing (37 out of the 50 projects) or congestion management of the local grid (36 out of the 50 projects).
- Out of the 50 projects in the database, only 6 explicitly specified that community benefits are also being aimed for.

It can be summarized that since the main instigators of the pre-existing VPP projects were the TSO and the DSO, the projects would be more technically oriented to understand the benefits to the TSO and DSO.

A summary of some of the project selected randomly from the database is given in the appendix (Appendix B).

A general trend seen in the database is that, most of the VPP projects (or projects that are not explicitly called a VPP but has similar functions) are initiated in a top down manner and mainly focusses on the technical aspects, and less on the social side. Hence to understand the social motivations that could lead to the inception of a cVPP project, merely analysing previous VPP projects will not suffice. Instead the focus is shifted to community energy projects.

To identify the probable list of social motivations behind a cVPP, the motivations that lead to the inception of community projects are analysed. This is because in terms of development and operation, the cVPP is similar to a community project as both have a bottom up, community centric focus. 12 different community energy projects are analysed as part of the literature review. Details of these projects are derived from grey literature sources (derived by “snowballing” from the bibliography of scientific papers, as discussed in the methodologies section 4.1). The projects were chosen because they are similar to a cVPP in terms of design and operation due to the following characteristics:

- They are all community projects; hence they have a community centric, bottom up design similar to a cVPP.

- They are all energy projects. Since the cVPP also deals with the production and distribution of energy, the social motivations behind the inception of a cVPP and these community energy projects would be similar.
- They are all projects within Europe. Since the cVPP is being implemented in a European setting, the social motivations identified in these European case studies can act as a reference for the social motivations that leads to the inception of a cVPP project.

A literature review was done by constructing short summaries of the 12 different community energy projects. The summary is presented in the appendix (section Appendix B).

5.2 Synthesis of social motivations

Based on the case studies of the community energy projects, the following 4 social motivations can be identified behind the inception of community energy projects. These motivations can be extended to a cVPP due to its similarity to community energy projects as explained in the previous section.

5.2.1 Profitability

The need for economic profitability is a common motivation in many of the case studies. The term profitability can be viewed from the context of the community as a whole and from the context of the individual end user. From the community context, the project can be used as a means to fund further development in the local area. The degree of economic need that the community has would dictate how profit oriented the community project would be. For example, in the Hvide Sande case study, there was a dire need to develop the local harbour as this was the main source of income for many of the local residents, hence the community energy project was very profit oriented. The energy generated from the windmills was fed directly in the Danish national grid.

In some of the projects, the aim was to ensure cheap supply of heat and electricity for the residents. This is profitability from the context of the individual consumer. For example, the main concern of the participants in the Jühnde bio energy project was ensuring a reliable and reasonably priced heating and electricity supply. This took precedence over setting up a community fund for local development. The Jühnde project was not very profit oriented as the heat and electricity was bought by the residents themselves.

Profitability from the context of the community and the individual are intertwined. Ensuring widespread participation and aiming for profitability from the community context would in turn benefit the individual participants too. For example, in the Hvide Sand case, when the local harbour is revived, this will create more opportunities for the local residents which would translate into profitability for them. Hence in this thesis, the general term of profitability is used to refer to profitability from both the community and individual end user context.

It is interesting to see that among the 12 case studies, none of the communities were purely economically motivated. There is often another need coupled with the economic aspect that led to the establishment of the community energy project. This shows that the need for profitability is not the only motivation behind the inception of community-based energy projects like a cVPP.

5.2.2 Community control

This motivation was explicitly mentioned in 8 out of the 12 case studies of community energy projects (Appendix B). Starting a community energy project is seen as a means to minimize external influences on the community in some of the projects. Many of the projects were started as a means of protest against proposals by private players to set up energy generation systems like wind turbines. In the case of the Gigha windfarm project, the locals were facing uncertainty due to the frequent changes in ownership of their island. They desired control over their own lands and hence took a loan to buy the island from the private bank that owned it. The community wind project was started as a means to repay this loan.

5.2.3 Social cohesion

Many of the community energy projects are started to promote social cohesion within the community. Social cohesion is defined as the willingness of members of a community to work together towards the common goal of achieving prosperity (Stanley, 2013). The sense of belonging to a community and a shared community identity is a key aspect of social cohesion (UN Department of Economic and Social Affairs, 2012). The frequency of social interaction is seen as an indicator of social cohesion. Research suggests that when a community is involved in a common social enterprise, there is an increase in the social cohesion within the community due to the increase in interaction among the individuals in the community (Woolley, 1998). The level of social interactions can be used as a proxy for social cohesion within a community. The sense of belonging or community identity is increased when there is increased social cohesion.

Improving social cohesion was the primary motivation behind the Brixton energy project. Some sections of the community were not economically stable. They lived in fuel poverty and the youth lacked opportunities for education. Providing economic electricity and heating and offering internship and employment opportunities to youngsters within the community were the primary goals of the Brixton energy project. It aimed at increasing social cohesion by making opportunities for interactions between members of the community.

The Abergwyngregyn Regeneration Company which developed the Anafon community hydro project was established to promote social wellbeing. They have been involved in numerous other activities like the developing a community centre and community cafes which provides opportunities for interaction among members of the community. The hydro project was also seen as a means of increasing social cohesion (Walton, 2012).

A similar motivation is also seen in the Point and Sandwick case study. The community is remote in nature and was facing lack of employment opportunities and depopulation (Couston, 2012). The community energy project was seen as a means to improve the amenities and revitalize the community. The community energy projects financed the development of common amenities which provided a common space for residents to interact with each other. This interaction would promote social cohesion.

5.2.4 Perception of sustainability within the community

Some of the projects are started to make the community more sustainable by increasing the renewable energy generated and used within the community. The Burntisland, Middlegrunden and Fintry island project all had strong environmental motivations behind them. In these projects, using the locally generated energy within the community was seen as making the community more sustainable. In other projects which are more profit driven like the Hvide Sande project, using locally generated energy within the community was not a priority hence the energy was sold in the Danish electricity market. A pattern that emerges from many of the case studies is the fact that using local renewable energy in the locality itself is seen as being more sustainable from a community perspective than selling it in the external markets. A similar pattern is found in (Haggett, Creamer, Harnmeijer, Parsons, & Bomberg, 2013) which studies 276 Scottish community energy projects. It is found that 15% of the projects emphasised on reducing the carbon footprint of the community by using locally produced energy for meeting the local loads.

Hence to summarize, from the analysis of community energy projects done previously, the following 4 social motivations can be derived, which can be extended to a cVPP (due to the similarities between a cVPP and community energy project as explained in section 5):

- Deriving economic profitability from the project
- Asserting community control over energy supply
- Improving social cohesion
- Perception of sustainability

This answers SQ1 (section 3), namely – "What are the possible social motivations behind setting up a cVPP project?".

The list of the different motivations (listed above) behind community projects is similar to the motivations identified in other studies. For example, (Haggett et al., 2013)surveyed 276 Scottish community energy projects and identified the following primary motivation that lead to the inception of the project:

- Environmental motivations
- Control/Autonomy motivations
- Economic motivations
- Other motivations

Similarly, (Seyfang, Park, & Smith, 2013) surveys a sample of 190 community energy projects from the UK and came up with an exhaustive list of the objectives of these projects. These objectives can be split among the 4 social motivations as follows:

- The paper identifies the following objectives which can be put under the social motivation for economic support:
    - Saving money on energy bills
    - Community building refurbishment
    - Generating income for the community
- The following objectives identified in the paper can be put under the motivation for community control:
    - Tackling fuel poverty
    - Community empowerment
    - Influencing sustainability/energy policy
    - Community leadership
    - Improving energy independence
- The following objectives identified in the paper can be put under the motivation for social cohesion:
    - Improving local economy
    - Skills development
    - Local jobs creation
    - Improving education / increasing awareness
    - Social inclusion
    - Creating volunteer opportunity
- The following objectives identified in the paper can be put under the motivation for increasing the perception of sustainability within the community:
    - Reducing carbon dioxide emissions
    - Improving local economy

Hence the 4 social motivations that have been synthesized from the case studies is an exhaustive list that is corroborated by other research into community energy projects.

6 Technical functions of a cVPP

The general social motivations that can lead to the inception of a community project like the cVPP have been determined in the previous section. This section focuses on understanding the general technical functions that can be satisfied by a cVPP project, thus answering **SQ 2** (section 3):

What are the possible technical functions that can be satisfied by a cVPP project?

To understand the possible technical functions that a cVPP can have, initially, the different categories of the VPP needs to be understood. This will lead to the understanding of the possible functions of the VPP which can then be extended to a cVPP.

Based on the different objectives of the VPP, many researchers (Kieny, Berseneff, Hadjsaid, Besanger, & Maire, 2009; Olejnczak, 2011; Othman, Othman, & Hegazy, 2015; Pudjianto et al., 2007; Ramsay, Pudjianto, Srbac, & Durstewitz, 2008; Saboori, Mohammadi, & Taghe, 2014) have classified the VPP into the following 2 categories:

- Technical VPP (VPP-tech): The main objective of this type of VPP is grid stabilization. The balance of energy injected into and withdrawn from the grid needs to be maintained at all times. Imbalance can have detrimental effects like shifting the grid frequency from the optimal value of 50Hz. A VPP-tech offers system balancing services by offering local grid management to the DSO and by bidding in the balancing market from which the TSO procures help for grid balancing. A few key characteristics are defined in research for a VPP-tech:
    - The DERs aggregated under a VPP-tech are often limited to a geographic area using which a VPP-tech could offer grid management for that portion of the grid.
    - Real time network data is essential for the operation of a VPP-tech which can be obtained from the DSO.
    - Grid management necessitates the procurement of flexibility from the supply and demand side. The VPP-tech does this by demand side and supply side management.
- Commercial VPP (VPP-com): (Kieny et al., 2009) refers to the commercial VPP as a “VPP for market features”. A commercial VPP has the goal of facilitating the participation of its constituent DERs in the commercial energy markets. Commercial energy market participation can range from participating in the national wholesale energy market to organizing a market for members of a particular community[5]. The wholesale energy market has barriers to entry (like minimum energy that can be bid) that makes it impossible for a single DER unit to participate. There will also be risks involved when promising delivery of a certain amount of energy for a future time, as the generation in DERs is usually dependent on stochastic renewable resources. By aggregating different DER units, the VPP-com enables participants to overcome entry barriers to the market and ensures that the risks are spread out and hence minimized from the point of view of an individual DER. Some of the key characteristics of the VPP-com are:
    - The VPP-com does not have a geographic limitation. The DERs aggregated under the VPP-com can be separated by vast distances.

[5] The definition of the term “community” has been specified in section 2

- The VPP-com takes real time market inputs into consideration. This is because the VPP-com tries to maximize the profits of the DERs operating within it. The VPP-com does not consider the impact it has on the distribution network (real time grid status is not required as an input) unlike a VPP-tech (Ramsay et al., 2008).

The categorization of VPPs according to objectives can be summed up in the following figure:

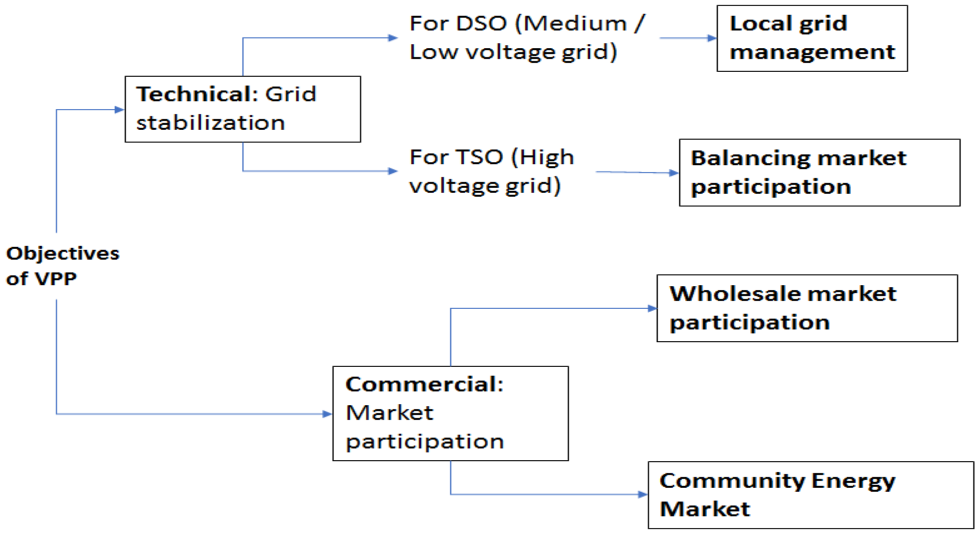

Figure 2: Categorization of a VPP based on objectives

Based on the control architecture of the VPP, the following 3 classifications have been made (Olejnczak, 2011):

- Centralised controlled VPP (CCVPP): As the name suggests, this kind of VPP has a single control centre that controls the operation of all the DERs aggregated under the VPP.
- Decentralised controlled VPP (DCVPP): This involves a group of local controllers each managing clusters of DERs. These local controllers are then controlled by one single controller which ensures optimum operation of all the DERs by enabling coordination between the local controllers.
- Fully Decentralised Controlled VPP (FDCVPP): This is an extension of a DCVPP. Here the centralized controller which manages the local controllers is replaced by entities which only provide information like market prices, weather forecasts etc. This data enables the local controllers to optimise their individual DERs better.

For the purposes of this research, focus is given on the categorization based on the objectives of the VPP. A detailed explanation of the 4 objectives identified in Figure 2 follows in the next subsections.

6.1 Trading in the wholesale electricity market

The VPP can be split into 2 types based on the services they offer (Pudjianto et al., 2007). The first type is the Commercial VPP (VPP-com) which allows aggregation of the DERs so that the energy can be traded in the wholesale electricity market. There are 3 main wholesale electricity markets which are categorized based on the time frame when the traded electricity is delivered. In the forwards and futures market, the electricity is traded years in advance to the actual date of delivery. Organizations use this market to safeguard themselves against the fluctuations of the costs of electricity. This market is risky for renewable generation sources because of their inherent stochastic nature. Prediction of generation is not very accurate as the time periods increase and the large time periods involved in the forwards and futures market makes participation risky (Klessmann, Nabe, & Burges, 2008). The forwards market has not been considered further in this study.

The day ahead market trades electricity a day before its date of delivery. Sellers offer electricity to buyers in blocks of 1 hour(EPEXSpot, 2018b). This market usually has the highest trading volumes and is of prime importance (TenneT, 2016a). The third market is the intra-day market. Here, electricity is traded on the same day on which delivery is expected. Sellers offer electricity to buyers in blocks of 1 hour (EPEXSpot, 2018a). The intra-day market is used to correct mismatches in demand and supply of electricity after the day-ahead market closes. On the day-ahead and intra-day market, the minimum bid that can be offered is 0.1MWh. Since the minimum block size in both the markets is 1 hour, only an energy generator with a minimum capacity of at least 0.1MW can trade in the day-ahead and intra-day market (APX, 2016).

Aggregating DERs using a VPP is beneficial because it increases the net capacity that can be offered in the wholesale market. Aggregation of renewable sources also ensures that there is less fluctuation in the output when compared to the output of a single source. When different types of DERs are aggregated, the generation portfolio becomes more diverse and reduces the risk of not producing energy when it is needed in the market. But there is still an inherent risk in the wholesale markets because the prices are very volatile (Jonsson, Lorentzen, & Dahl, 2017). Even after aggregation, the group of prosumers will be competing with other larger traditional energy producers offering hundreds of mega-watts of energy. Hence the prosumers will remain as price takers[6] unless aggregation can be achieved on a massive scale.

In a VPP-com, it is not necessary that the DERs need to be from the same locality. DERs from different geographical locations can be aggregated together. The VPP-com uses the following inputs from DERs and external sources (Pudjianto et al., 2007):

- Operating parameters of the DERs
- Marginal costs of energy generation of DERs
- Load forecasts of DERs
- Price forecasts in the wholesale market

Using this data, the VPP-com aggregates the DERs and gives a single generation and load profile for the entire portfolio of DERs. A third-party organization can use this to trade in the wholesale market.

6.2 Offering ancillary services

The second type of VPP based on the services offered (Pudjianto et al., 2007) is the Technical VPP (VPP-tech). The VPP-tech can make the DERs available for ancillary services (Olejnczak, 2011). The generation and consumption capacity of DERs can be aggregated and utilized for balancing operations.

Numerous services fall under the broad category of ancillary services. Among them, the regulation of the network frequency is a very important task (Olejnczak, 2011). The frequency of the electricity grid is dependent on the generation and consumption of electricity. It needs to be maintained at 50Hz for the proper functioning of the network. If the frequency exceeds 50Hz then there is excess electricity production on the grid. If the frequency is below 50 Hz then the demand for electricity is exceeding the supply. Hence the generation and consumption of electricity needs to be balanced.

[6] Price-taker – An entity that must accept prevailing market prices because it lacks the market share to influence the price (Investopedia, n.d.).

This balance is maintained with the help of the balancing market. There exist 3 separate products that are traded in the balancing market (Peters, 2016):

- Primary control (Frequency Containment Reserve – FCR): The European electricity grid is interconnected to a large extent. When there is an imbalance in the grid, and the frequency deviates from 50 Hz, this deviation impacts the entire grid (and not just the area where the imbalance occurs). FCR is activated automatically by all the TSOs after an imbalance event destabilizes the grid. FCR is a system wide response and is not limited to the area where the imbalance occurred (TenneT, GEN, & E-Bridge, 2011). The FCR must be fully activated within 30 seconds of the imbalance occurring. Market participants offer capacity (MW) as FCR in a bidding system and the TSO procures the needed capacity form this (Hoogvliet, Litjens, & van Sark, 2017). The minimum bid size is 1 MW (TenneT, 2015) and the bids are placed for a time period of 1 week (Hoogvliet et al., 2017).
- Secondary control (automatic Frequency Restoration Reserve – aFRR): The aFRR is designed to replace the activated FCR within one PTU (Programme Time Unit). The FCR is then freed up to deal with other imbalances. Unlike the FCR which is a system wide response, the aFRR is activated only within the control area of the TSO where the imbalance occurred (TenneT et al., 2011). The aFRR must be fully activated within 30 seconds after the activation order is received from the TSO (TenneT, 2016b). Market participants can offer both capacity and energy in the aFRR bidding market (Hirth, Lion; Ziegenhagen, 2015). A market participant must have at least 4MW of capacity to bid in the aFRR market (TenneT, 2016b). aFRR bids are offered for in time blocks of 15 minutes and can be submitted until one hour before dispatch (Hoogvliet et al., 2017).
- Tertiary control (manual Frequency Restoration Reserve – mFRR): mFRR is used to replace the activated aFRR so that it can be freed up to correct future imbalances (TenneT et al., 2011). Bids for tertiary control are made for a time period of quarter or full year. The minimum bid size of tertiary control is 20MW (Hoogvliet et al., 2017) which is significantly higher than the bid size of FCR and aFRR.

Among the 3 balancing markets, the secondary control market (aFRR) is the most suitable for a VPP-tech. As mentioned earlier, the VPP-tech involves interconnection of DER, a large portion of which is renewable generation (which is stochastic in nature). To place a bid in the balancing markets, the generation from these sources must be forecasted to a high degree of accuracy.

In the FCR market, the balancing capacity must be bid for a period of one week and in the mFRR market the balancing capacity must be bid for a full year or quarter of a year. This means that the generation from these renewable units must be forecasted accurately for these time periods. Over these large time horizons, there will be a large degree of uncertainty and committing to an FCR or aFRR agreement can be risky. On the other hand, since in the secondary control (aFRR) market, the time periods are significantly less (bids can be submitted until one hour from dispatch), a high degree of accuracy can be ensured in the prediction of generation from renewables. (Hoogvliet et al., 2017) citied this reason for choosing the aFRR market as the most ideal balancing market for Dutch electric vehicle owners to offer balancing services. A similar reasoning can be extended to the VPP-tech. From this point onwards, when offering ancillary services is mentioned, it refers to bidding in the secondary control (aFRR) market.

The Dutch TSO Tennet is tasked with procuring balancing services in the Netherlands. This responsibility is delegated by Tennet to Programme Responsible Parties[7] (PRP) who are assigned

[7] Programme Responsible Parties are also called as Balance Responsible Parties (BRP).

portfolios consisting of various electricity generators and consumers. The PRP is tasked with maintaining the balance of consumption and generation of electricity in their individual portfolios.

After the end of trading in the day-ahead market, the PRPs submit the schedules of generation and consumption (called an e-programme) to the TSO (Lampropoulos et al., 2012). This e-programme is compared with the actual generation and consumption on the next day to see if there is any deviation. When an imbalance occurs the PRP can act internally within its portfolio to solve the imbalance. The local grid management services offered by the VPP-tech can help reduce the imbalance. If the imbalance is still not resolved, the PRP would have to pay imbalance fees.

The imbalance in the network can occur either due to an excess or shortage of electricity in the grid. Hence, in the aFRR balancing market, participants can offer regulation in 2 directions, upward (they will supply electricity when there is a shortage of electricity in the grid) and downward (they will take electricity from the grid when there is an excess of electricity in the grid) (Hoogvliet et al., 2017). For each imbalance direction, a separate bidding ladder is maintained where capacity and energy for imbalance correction is offered. They have different prices based upon the bids that have been offered by the market participants (TenneT, 2004). Participants bid upward or downward regulation in time blocks of 15 minutes (referred to as a Programme Time Unit).

A supplier of upward regulating power has to supply energy to the grid to neutralize the shortage in the grid. If the settlement price is positive, the supplier gets compensation from the TSO for this service.

The supplier of downward regulating power has to consume excess energy from the grid and if the settlement price is positive, the supplier must pay compensation to the TSO. The downward supplier can then sell the energy they procure form the grid to a third party to make a profit (the downward supplier saves on the production costs of the energy as they procure it from the surplus present on the grid, this enables them to make a profit when they sell this energy to a third party) (TenneT, 2017). When the settlement price is negative, the direction of cash flow is reversed for both the upward and downward regulation scenario. The following figure summarizes the cash flow direction depending on the sign of the settlement price (bid price) and the direction of regulation offered:

Table 2: Balancing regulation cash flow direction (modified from (Tennet, 2017)*)*

	Settlement price > 0	Settlement price < 0
Upward regulation	TenneT pays upward regulation supplier	Upward regulation supplier pays TenneT
Downward regulation	Downward regulation supplier pays TenneT	TenneT pays downward regulation supplier

A VPP-tech can passively contribute to system balancing by placing bids for upward or downward regulations in the aFRR balancing market.

The inputs needed by the VPP-tech to provide ancillary services are as follows (Pudjianto et al., 2007):

- Operating schedules of the DERs in the local network. In case there is a pre-existing VPP-com which has aggregated these local DERs, this information can be obtained via the VPP-com. Hence, a VPP-tech can be established over a pre-existing VPP-com.

- Real time network status. This is necessary to determine the network management actions that are needed. The real time network status for determining voltage control activities is provided by the DSO while the status for determining frequency control activities is provided by the TSO (as frequency control is not a location specific phenomenon but rather affects the entire grid).

6.3 Offering local grid management

The VPP-tech can also offer ancillary services at a more local level, by providing local grid management services to the DSO (Olejnczak, 2011). Unlike a VPP-com, the DERs in VPP-tech are usually within the same geographic location. This makes them ideal to be utilized to manage congestion in the local grid (Kieny et al., 2009). In case of network congestion, the local DSO can send a call to the VPP-tech to ask for assistance. The VPP-tech can factor in the expected generation and production of all the assets within its control and try to alleviate the network congestion by varying the schedule of the individual DER sources. The VPP-tech can offer this as a service to the DSO in return for an economic remuneration.

Usually demand response techniques are applied to get flexibility which can then be used to alleviate local grid congestion. These demand response techniques can be categorized into 2 (Smart Energy Demand Coalition, 2015):

- Explicit demand response: The end user gets direct monetary benefits to change his consumption profile. In many EU countries like the Netherlands, the DSO is not allowed to directly control the end user devices. To enable explicit demand response, the DERs need to be aggregated by an aggregator. The aggregator can offer the flexibility obtained by controlling the devices of its participants to the DSO. The DSO will pay for this which gets passed on to the participating end users.
- Implicit demand response: The consumer is encouraged to change his consumption behaviour by using tools like time varying tariffs. This is an indirect way of achieving demand response when compared to explicit demand response. The time varying network tariffs depend on the congestion present in the grid and the marginal costs and generation costs of electricity. Hence, the time varying tariff often closely mirrors the trends in the wholesale electricity market (Lavrijssen & Parra, 2017). The customer is free to react to the prices and there are no commitments from the end users side. Implicit demand response does not require aggregation of end users and can be implemented by the DSO by providing price signals directly to the end user.

The use of both implicit and explicit demand response in the residential sector is limited among the EU member states. Implicit demand response in the residential sector, in the form of dynamic (time-varying) tariffs is only implemented in Finland, Estonia, Norway, Denmark and Spain as of now (Eurelectirc, 2017). On the other hand, in the industrial sector, dynamic pricing is common. There are no regulatory barriers to the implementation of implicit demand response for the residential sector, yet there is a low uptake because of other factors (Eurelectirc, 2017):

- The price signals provided by the wholesale markets are weak. 2/3rd of the electricity bill of an average EU consumer consists of network costs and taxes. This further distorts the price signals provided by the actual cost of electricity in the wholesale market (which is only the remaining 1/3rd of the electricity bill).
- Demand response requires upfront investments in ICT equipment like smart meters. These costs might be prohibitive. But, some retailers offer various financial models that help bring down the purchase cost of these equipment.

- The collection of consumer data also brings the concerns of data security.
- Implicit demand response strategies like dynamic pricing can have a negative effect on vulnerable consumers with low purchasing power and consumption patterns that are less flexible (Neuteleers, Mulder, & Hindriks, 2017).

There are more regulatory barriers for explicit demand response. In the Netherlands, the DSO is not allowed to directly control the end user assets like DERs (SEDC, 2017). Dutch law dictates that, the aggregation of devices for demand response and the sale of electricity is bundled together as one service. Hence, an end user cannot get electricity from a retailer and demand response services from another aggregator. A third-party aggregator who wants to serve a specific customer must have an agreement with the customers retailer and BRP (SEDC, 2017). This is a barrier for new entrants into the market, which in turn acts as a barrier for the wide-spread implementation of demand response.

Dutch DSOs are bound by the Universal Service Obligation (USO) specified in the Dutch Electricity Act of 1998. The USO implies that DSOs must give all its customers equal opportunity to participate in explicit demand response programmes. But, many customers might reside in an area with no grid congestion and with no need for demand response programs. Hence offering this to these end users is not financially attractive to DSOs. This is another barrier to the implementation of explicit demand response (Weck, van Hooff, & van Sark, 2017).

Currently, discussion is ongoing with regards to identifying the exact role of the aggregator in the entire system. There are some projects ongoing, that provide demand response to residential end users, but these are often experimental in nature. The profit that the end user gets from participation in the demand response programs depends on the agreement between the aggregator and the end user.

One important thing to note is that local grid management is not a permanent solution to grid congestion. Consumption always comprises of base load and flexible consumption. Even if the flexible consumption can be effectively shifted, the base load consumption remains. Since the total loads grow over time, the baseload will also increase over time. There will come a point when grid upgrades will be needed. Local grid management through demand response is a way of postponing these gird upgrades (Wilks, 2011).

6.4 Setting up local community energy market

The interconnection of the different devices can facilitate the set-up of local energy markets where peer to peer energy exchange between community members can happen. Projects which allow energy sharing are already being implemented now. The German company Sonnen has started the SonnenCommunity project for customers of its photovoltaic systems and batteries (Zhang, Wu, Long, & Cheng, 2017). The end users join the community and can share their surplus energy with each other. A central software system monitors and balances the production and consumption of all SonnenCommunity members.

Even though this is a promising development, the growth of actual P2P markets where prosumers trade energy with each other for money, still needs a lot of changes in existing rules. In the Netherlands, existing energy regulations make such energy markets impractical. Dutch regulations dictate that an energy supplier license is needed to supply energy to small and medium consumers[8]. This rule was made earlier (when prosumers were almost non-existent) to ensure that the organization that acts as an energy supplier is able to give a reliable performance to the consumers

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[8] Article 95a of Dutch Electricity Act 1998 and Article 43 of the Dutch Gas Act 2000

(Lavrijssen & Parra, 2017). But this has a negative effect in the current scenario where prosumers are an important part of the system.

Individual prosumers wishing to act as energy suppliers to other prosumers must apply for the energy supplier license from the Dutch national regulator ACM (Autoriteit Consument en Markt). The prosumer needs to prove that he has the "minimum organizational, financial and technical characteristics necessary for the performance of the task of an energy supplier" (Butenko, 2016). These licenses are geared towards larger more traditional energy suppliers. Even if a prosumer decides to sell energy to a local energy market and other prosumers buy energy from here, the seller still needs an energy supplier license (Butenko, 2016). Hence the current regulatory system existing in the Netherlands (and in most European countries (Lavrijssen & Parra, 2017)) makes P2P markets unviable.

Numerous research papers have made recommendations to the government to change these strict regulations. In the "Proposal for a Renewable Energy Directive" issued by the European Commission (European_Comission, 2016), article 21 states that household consumers who feed in less than 10MWh in to the grid on an annually basis cannot be classified as energy suppliers. This exempts prosumers wanting to participate in P2P trading from the Universal Service Obligation (USO). USO states that any energy supplier has the obligation to supply any consumer who desires it (European Union, 2009). Previously, when prosumers were classified as energy suppliers, they were obliged to supply anyone who desires it even though their generation was limited. The new rule in the "Proposal for a Renewable Energy Directive" is a step in the right direction, but other regulations like the mandatory energy supplier license still act as barriers. But it can be expected that these regulations will also be relaxed in time and that P2P trading will become a reality.

Local energy market trading will have numerous benefits:

- Setting up a local energy market provides a platform where community members can interact actively.
- Facilitating trade of excess energy within the community would provide an alternative way of monetizing their excess production. Similarly, the local energy market can also be viewed as an alternative source from where community members can buy energy apart from the retail electricity market.
- Setting up a local energy market is one way to reduce the dependency of the community on retail electricity.

There are also numerous difficulties that arise when a local energy market is set up:

- It is a challenge to make the local energy market inclusive. There needs to be enough prosumers to supply excess energy to the consumers. Becoming a prosumer requires additional investment in generation assets, which might not be accessible for everyone. There is a danger of excluding the economically weaker section of society which would be detrimental to community unity.
- Even though a local energy market reduces the dependency on retail electricity, end users need to rely on the existing network infrastructure. Hence some form of dependency to the bigger grid always remains.
- A major hurdle is the presence of legislation in many EU countries that make setting up a local energy market and enabling P2P trading unfeasible. This is bound to change as time progresses.

This section lists out the possible technical functions that can be satisfied by a cVPP project, thus answering SQ2 (as mentioned in section 3). Since these technical functions have been derived from pre-existing research on VPPs, this itself acts as a form of validation. Hence unlike the social motivations (section 5.2), extra validation is deemed unnecessary.

7 Aligning the technical functions to the social motivations

This section aligns the technical functions of a cVPP project to the level of satisfaction of the social motivations that a community can have, which can lead to the inception of the project. The general framework built will answer **SQ 3** (as mentioned in section 3):

How can the different possible technical functions of the cVPP project be matched to the level of satisfaction of the different social motivations in a community?

The different social motivations that can lead to the initiation of a cVPP and the different technical functions of a cVPP project have been identified in the previous sections. They are as follows:

- 4 possible social motivations that a community can have to start a cVPP project (section 5.2):
  - Deriving economic profitability from the project
  - Asserting community control over energy supply
  - Improving social cohesion
  - Improving perception of sustainability within the community
- 4 possible technical functions that a cVPP can have are as follows (section 6):
  - Trading in wholesale electricity markets
  - Offering ancillary services to the national grid
  - Offering local grid management to the DSO
  - Setting up local community energy markets

7.1 Ranking profitability

The level of profitability that can be derived from the 4 technical functions of the cVPP has been discussed in this sub-section. Profitability can be seen from the context of the community or from the individual context. As explained in section 5.2.1, profitability from the community and the individual aspect are intertwined. Ensuring widespread participation and aiming for profitability from the community aspect would in turn benefit the individual participants too. The general term of profitability is used to refer to profitability from both the community and individual end user context.

Trading in wholesale energy markets

Among the 3 wholesale electricity markets (as explained in section 6.1), the day-ahead electricity market sees the highest trading volume and the most number of participants. The large volumes of energy being traded makes the day-ahead market very profitable (TenneT, 2016a). The average base price of electricity in the Dutch day ahead market for the year of 2016 was €32.24/MWh (EPEX, 2017). The intra-day market sees lesser volumes being traded when compared to the day ahead market but had a higher average base price of €34.43/MWh (EPEX, 2017) when compared to the day-ahead market. As discussed previously, wholesale electricity markets are characterised by large price volatility (Jonsson et al., 2017).

Local grid management for DSO

Local grid management is usually facilitated from the customer side using demand response methods. Local grid management has a lot of benefits for the parties involved. Local grid management can be performed by the cVPP to help the PRP avoid grid imbalance fees. As mentioned in the previous section, the current regulations and market conditions are not conducive for demand response programs. The fact that as of now, local grid management-based business models do not exist and that even if they did, the economic remuneration for this service is dependent on the agreement between the PRP and the cVPP operator means that a single average price value cannot be specified for comparison with the other services. Hence comparing the profitability of local grid management is difficult.

Offering ancillary services

With regards to the ancillary services that can be offered, the task of frequency regulation by bidding in the secondary control (aFRR) market is considered. As mentioned previously, to regulate the frequency the generation and consumption of electricity needs to be balanced. Market participants can bid in the secondary control balancing market to supply upward or downward regulation. In the case of upward regulation, the market participant gets paid by the TSO for supplying energy to the grid. In the case of downward regulation, the market participant needs to pay the TSO to use the surplus energy present in the grid (the market participant can then sell this energy to a third party and make a profit on the price difference). For the ease of comparison with the wholesale market, the average price in 2016 for upward regulation has been considered. This amounts to €32.77/MWh in 2016 (TenneT, 2018).

Local community energy market

To understand the profitability of a local energy market when compared to the ancillary services and wholesale market, a simple straightforward comparison based on the €/kWh price might not be correct. This is because unlike a wholesale and ancillary services market, where the infrastructure has been funded and built by the government (it is indirectly paid by the small consumer via taxes), setting up a local energy market would require separate investments. This must be factored in to get a complete view of the profitability. Hence to understand the profitability of local energy markets, instead of a quantitative comparison, a qualitative method is used. This qualitative comparison will be done from the point of view of a single prosumer selling in the local energy market.

In a local community energy market, the prices at which the electricity is exchanged is usually negotiated between the buyer and the seller. It can be expected that when selling energy in the market, sellers would offer energy cheaper than the retail prices in the distribution grid (otherwise, the buyer would buy energy from the grid rather than the over-priced local energy market). The retail price of electricity for a customer is higher than the wholesale prices due to the added taxation, transmission grid charges and the fees of the DSO who procures the energy from the generators and supplies it to the end user (Eurostat, 2017). Even if the prices in the local community market are cheaper than the retail prices, it can be assumed that it would still surpass the prices in the wholesale electricity market and the balancing market (from the point of view of an energy seller). The prosumer would still have to pay for the use of the infrastructure (that is, taxation will still be present). This has been discussed in later chapters dealing with the techno-economic analysis.

Comparison of technical goals

As discussed, the wholesale market is prone to large price fluctuations which makes it risky for prosumers. Even after aggregation, prosumers will be price-takers as they will be competing with larger power producers offering hundreds of mega-watts. Hence the profitability potential would be higher in the local community market trading scenario. But, the current regulations make the trading of energy between individuals impractical as explained in section 6.4. Hence, in the current regulatory situation in the Netherlands (and many other European countries) setting up a peer to peer local community market would be less profitable (because of impracticality) than trading in the wholesale energy and balancing markets. But this would surely change in the future when these regulations will be relaxed (Lavrijssen & Parra, 2017). As explained previously, comparing the profitability from the point of view of the community, of managing the local grid for the DSO is difficult and hence has been excluded from the ranking.

Hence, the level of profitability of the different technical functions can be ranked as follows:

Wholesale electricity market, ancillary services > Local community markets

7.2 Ranking community control

The level of community control offered by the 4 technical functions has been discussed in this sub-section. The involvement of external organizations in the cVPP project is taken as an indicator of the level of community control that a technical function provides.

Trading in wholesale energy markets

For trading in the wholesale electricity market, a single organization with wholesale market access that aggregates the different generation devices and the controllable loads within the cVPP is required. This organization can either be a community organization or an external organization. There will be more community control if a community organization acts as the aggregator when compared with an external third-party organization performing this task.

Offering ancillary services & local grid management for DSO

Similar to trading in the wholesale energy market, for offering ancillary services or local grid management, a single organisation that aggregates all the DERs is required. Depending on whether the organization is managed by the community or not, the level of community control would vary.

Local community energy market

Like for the previous 3 technical functions, when setting up a local community energy market a central organization or platform is required to facilitate the energy trade. But since a community energy market involves close collaboration between residents, irrespective of the central facilitating organization, there will be more community control The fact that the community residents who are prosumers decide when to sell their excess energy and the community residents who are consumers decide when to buy energy means that there is very little involvement of external entities in the daily operations (even if a third party, non-communal organization is managing the platform that facilitates the trade). A local energy market involves close interaction between the local community members and hence have a very high degree of community control.

Comparison of technical goals

As discussed, the level of community control of the technical functions of trading in the wholesale markets, local grid management for the DSO and offering ancillary services, depends on the structure of the central organization that is managing the services. If this is a community-based organization, there will be more community control. On the other hand, if this is a non-community based external organization, there will be less community control. The technical function of setting up a local community energy market has a high level of community control irrespective of the nature of the central organization because it inherently involves close collaboration of the residents during energy trading.

Hence, the level of community control of the 4 technical functions can be ranked as follows:

Local community energy markets > Remaining technical functions managed by community organisation > Remaining technical functions managed by non-community organisation

7.3 Ranking social cohesion

The level of social cohesion promoted by the 4 technical functions has been compared in this sub-section. The frequency of interaction among community members defines the level of social cohesion (Woolley, 1998). A technical goal that presents the opportunity for a higher frequency of interaction among community members has the potential to create more social cohesion.

Trading in wholesale energy markets & offering ancillary services

When trading in the wholesale energy market or in the ancillary services market, a central organization would be in-charge of aggregating all the devices. The main interaction of the participants would be with this central organization and there will be limited interaction between participants.

Local grid management for DSO

Offering local grid management for the DSO also promotes a similar level of social cohesion as trading in the wholesale energy markets and offering ancillary services. In this case, a central organization would act as the link between the DSO and the individual end users. Different demand response measures would be taken by the central organization in response to the requests from the DSO. The interaction of the participants would mainly be with this central organization.

Local community energy market

This technical function is the most conducive to promote interaction among community members. If there is direct trading between members, this would promote social cohesion. In case the trade is done via the organization that facilitates the energy market, there is still an indirect interaction between community members. This level of interaction is more than that facilitated by the other 3 technical functions.

Comparison of technical goals

Among the 4 technical goals, the goal of setting up a local community market has the most potential to improve social cohesion. This is because community members interact with each other more frequently when they trade electricity. For trading in the wholesale electricity market or for offering ancillary services and local grid management, the individual community member would interact predominantly with the cVPP operator or central organization that facilitates the technical function. Interaction between community members would be low.

Hence, the level of social cohesion induced by the 4 technical goals can be ranked as follows:

Local community markets > Wholesale electricity markets, ancillary services and local grid management

7.4 Ranking perception of sustainability within the community

The perception of sustainability within the community that is promoted by the 4 technical goals is compared in this subsection. In some of the case studies that were analysed previously, it is seen that using locally generated electricity in the local community was considered as being more environmentally sustainable from a community perspective. Hence, the usage of local generated electricity for local needs is used as an indicator to determine the level of perception of sustainability within the community.

Local grid management for DSO & trading in wholesale energy markets

The increase of renewable distributed generation leads to increasing difficulties in matching generation and consumption of energy, among other problems. Due to this, the maximum capacity of renewables that can be installed is limited and the generation from renewable sources might also be curtailed when there is congestion in the grid (Zwaenepoel, Vandoorn, Van Eetvelde, & Vandevelde, 2014). This problem of congestion is alleviated to some extent by a VPP-tech that offers local grid management. On the other hand, a VPP-com does not take constraints of the local grid into account (Saboori et al., 2014). It is mainly concerned with the aggregation of the DERs for commercial purposes. Hence, the implementation of a cVPP that offers local grid management could indirectly facilitate the installation of more renewables in the local grid when compared to a cVPP that only trades in the wholesale energy markets.

Offering ancillary services

Even though offering ancillary services to the national grid has an impact on the local grid stability (because effects like frequency deviations is a global phenomenon across the entire grid as discussed previously), the impact is not direct like the technical goal of local grid management. Hence it has been ranked lower than the technical function of local grid management.

Local community energy market

In a local community energy market, prosumers sell their excess energy and consumers buy it from them. Setting up local community markets give a high perception of community sustainability because the renewable energy generated in the community is used within the community itself.

Comparison of technical goals

As discussed, the level of perception of sustainability is the highest in the technical function of setting up a local community energy market, as the locally generated energy is used for local needs. Managing the local grid for the DSO comes next followed by offering ancillary services and wholesale services.

The level of perception of sustainability within the community that is offered by the 4 technical functions can be ranked as follows:

Local community energy market > Local grid management > Ancillary services, Wholesale electricity markets

The following matrix answers SQ3 by summarizing the interconnection between the social motivations behind setting up a community energy project and the technical functions of a cVPP.

		Technical functions of cVPP						
		Offering ancillary services (Balancing market participation for frequency regulation)		Offering local grid management to the DSO		Trading in wholesale energy markets		Local community energy market
Social motivations of community	Profitability	Highest		profitability unknown as no business models exist as of now		Highest		Medium
	Community control	Highest (Local communal organization acting as cVPP operator)	Lowest (External non communal organization acting as cVPP operator)	Highest (Local communal organization acting as cVPP operator)	Lowest (External non communal organization acting as cVPP operator)	Highest (Local communal organization acting as cVPP operator)	Lowest (External non communal organization acting as cVPP operator)	Highest
	Social cohesion	Lowest		Lowest		Lowest		Highest
	Perception of sustainability in the community	Lowest		Medium		Lowest		Highest

Figure 3: Matrix aligning technical goals of cVPP project to the social needs of a community

The degree of meeting each motivation is specified as “Highest”, “Medium” and “Lowest”. These are comparative in nature and is meant to provide an indication of where each technical function stands in terms of satisfying the different motivations that have been identified.

8 Determining specific social motivations and technical functions

In the previous section, a general framework was constructed to match the general technical functions and social motivations. In this section, the specific social motivations present in the Loenen community is analysed and then applied to the general framework constructed in the previous section. After that, specific technical functions that satisfy these social motivations are derived by applying the specific social motivations to the framework.

This section answers **SQ4** (mentioned in section 3):

What are the specific social motivations in the Loenen community and what specific technical functions of the cVPP can satisfy these motivations?

To identify the specific social motivations found in the Loenen community, six key stakeholders of the cVPP project were interviewed as mentioned in section 4.4. All of the candidates interviewed are involved with sustainable or social projects or are active users of sustainable technology like solar PV in their own houses. They are also actively involved in the cVPP project at Loenen. Many of them occupy key positions in society or work with energy or more specifically renewable energy in their profession. This acts as a validation that the candidates are knowledgeable in the domain of social projects or sustainable energy projects and that their words and opinions carry weight.

The Taylor-Powell and Renner approach described in section 4.4, is used to analyse the transcripts of the interviews (found in Appendix E). As per this approach, deciding upon the unit of analysis is a primary step. A part of the sentence is selected as the unit of analysis. Each transcript is analysed individually, unit by unit (sentence by sentence), and topics are identified. Topics across different transcripts are then grouped together under a common theme. Finally, analysis like the commonalities and differences between interviews and the number of candidates who mentioned a specific theme is done.

The primary themes, sub-themes and supporting quotations from the interviews of the stakeholders are presented below:

Primary theme 1: All of the candidates have experience with regards to sustainable or social projects. This gives more credibility to their opinions (5 out of 6 stakeholders)

- Involvement / experience in sustainability activities
    - "I am a member of Loenen Energy Neutral, from the start, so up till 2013 I think. I have been a member of DEA, Duurzame Energie Apeldoorn" – HM
    - "I work at the OVIJ" – FJ
    - "I run the programme, for the transition from fossil to renewable energy" – XL
    - "(Studied) Energy and environmental sciences in the university of Groningen" – HH
    - "my work is in renewable projects" - IS
- Owns devices producing or working on renewable energy
    - "I have PV from 2011" – HM
    - "From 2013, I have a solar water heater. I had a semi-electric vehicle from my job (a company car) and last Friday I bought my own hybrid car" – HM
    - "So I bought solar panels and everything in my house I measured what the energy consumption is" – HH
    - "I am building a house in Loenen. An own design. Its an all-electric house. And its energy positive" - IS
- Involvement / experience with social projects
    - "I have worked with other civilian projects in the city" - XL

Primary theme 2: Profitability is a major driver for people (6 out of 6 stakeholders)

- Project has to be economically sustainable also
    - "And with my banking background, I know that it also has to be economically sustainable" – HM
    - "sustainability and measures for the environment, not only for the future generations but it has to make sense for the current generation" – HM
    - "when you do only ideologic, the whole mother planet and all, that's not going to work. For a long term. So economic sustainability is important" – HM
    - "Well economic is important, I think they must earn money from the project" – FJ
    - "to get the project done sometimes they need to have a business case ready" – XL
    - "they participate because they get some money to make their transition cheap" – HH
    - "I think a lot of people are economically driven" – HH
    - "I think there are maybe 30 or 40 people for whom those motivations (non-profit related motivations) are really important" – HH
    - "Bottom line, economic, is for many people a good motivation" – HH
    - "We are Dutch, so we want our money back" – WZ
    - "I think it should be possible to generate revenue from the energy you produce" - IS
- Attractive economic opportunities in the cVPP project
    - "some years back it was not easy to make money from it, so now its good that my energy can be used to provide to my neighbours" - HH

Primary theme 3: Aspirations for the cVPP project (3 out of 6 stakeholders)

- Wants to become an energy producer in the cVPP project
    - "I have a roof free. So I can put more PV panels" – HM
    - "I want to be an energy producer in this cVPP situation. This was my goal from five six years ago" – HM
    - "I thought, my neighbour has a roof where he can not lay panels so I sell my excess energy to my neighbour - HM

- “nice opportunity to be an early adapter” – HM
- Cheap and secure energy is the main motivation
    - “As a customer I want to be sure that I get electricity, but I don’t want to pay a lot. Very simple not more than that” - HH
    - “As a customer, as I said, I would like to have cheaper energy” – HH
- Being sustainable can be a way to attract tourists
    - “lot of green villages and some of these villages they attract a lot of tourists, and you can pinpoint yourself on the map” – IS

Primary theme 4: Characteristics of Loenen conducive to sustainable energy community projects (4 out of 6 stakeholders)

- “we have a few people who are really good with their background in the energy transition so all together that is a nice opportunity to get such a goal done here” – HM
- “Loenen which has been a front runner village, which already has a lot of solar PV installed” – FJ
- “Because people are really aware and are really moving fast” – XL
- “they also have very good circumstances with solar panels and industry and there is also a lot of social cohesion, so if they can get it done, then it gives hope that it can be done in other places” – XL
- “Everybody understands that we need to do something for the environment and I think in Loenen more people understand that and its important that we have this initiative” - WZ

Primary theme 5: Community working together, and social cohesion is important (5 out of 6 stakeholders)

- “You have to fix it in your own situation and the best is to get it on a community scale” – HM
- “I really like the concept that as a community you can be off the grid and independent” – FJ
- “with all the discussion in the village I think there will be more understanding and commitment” – XL
- “It was bottom-up, how we can do it better as a village than a big city like Apeldoorn. Nothing was coming from the government” – WZ
- “I absolutely like when things are, you call it unity, I think it’s absolutely important when the community comes up with a bottom up plan and this is an absolutely bottom up plan” – WZ
- “I think it’s nice to help each other. Not only in physical but also in energy” - IS

Primary theme 6: Having full community control might not be necessary / important (3 out of 6 stakeholders)

- Cooperation with the big companies is necessary
    - “You can’t without Alliander and the companies who have the infrastructure. You can’t do it without them.” – HM
    - “Alliander is already there, like I said before and you can help them because they need to do something (about grid congestion)” – HM

    - “I think, once we have done that step (ensuring that there is mutual trust between project partners), so grow a little bit and then people are probably going to say that we should sell it as a group.” - WZ
- For a project of this scale, working with other communities will be necessary
    - “Loenen is too small for the future to do this energy neutral thing so we need more villages” – WZ
- Organizing trade in the wholesale energy market or ancillary services might be difficult for the volunteers due to lack of specialized knowledge, hence complete community control might not be ideal
    - “I am not really sure if the local community with a lot of volunteers they want to go into the trade” – XL

Primary theme 7: Influence of big energy companies must be reduced (4 out of 6 stakeholders)

- Loenen must have control over their energy sources
    - “be really self-sufficient and in control of themselves” – FJ
    - “the criticism of it is that it is from a large company. Basically, more a business model or a marketing strategy than a community initiative.” – FJ
    - “for the first 5 years the people want to see what is happening, if the partners are trust worthy before going big scale” – WZ
    - “the village itself can benefit and use its own green energy and you do it as a community together without big firms” – IS
    - “you wont have to fully rely on large energy companies like E.On, Nuon and Vattenfall” - IS
- Pursuit of goals like trading in the wholesale energy market or offering ancillary services might give way for external companies to get involved
    - “I wonder a little bit if there will come more professional companies that will step into this trade spot” – XL
    - “And if the VPP starts to grow and then there is a big company going, I am not sure that’s the way, maybe regional you can do something but I don’t think for the whole of Holland. Not for the coming years” - WZ

Primary theme 8: Start with local functions first and then consider other external functions (3 out of 6 stakeholders)

- The first step is to implement local functions of the cVPP like local energy market and managing the local grid
    - “First base is to get our own local energy need filled out. And when that is fixed, yeah then you can look further” – HM
    - “And I think this is a more easy one (the energy market). If you make it very big, like the (wholesale) trade for example (it might not be so easy)” – XL
    - “first have to start in your own village, so to use as much locally produced energy as possible to get the best balance in the village level” - IS
- Functions external to Loenen like trading in the wholesale market and offering ancillary services should be considered after the local functions are established
    - “that “sell on the market thing “(trading in the wholesale market), that is a few stations further away, when we have a great over capacity then it can be actualized” – HM

Primary theme 9: Regulations will change with time (2 out of 6 stakeholders)

- Community projects help change regulations
  - “I think from a right bottom up process, you can also influence politics” – HM
  - “political sense of urgency, its every day in the papers that we need to make action, because we don’t get it fixed in the real term” – HM
  - “I think that this kind of initiatives (the cVPP project) can help to make the changes” – HM
  - “So first you should have a project in which people believe and then you should say there is a barrier, can we discuss how to get rid of that barrier. Its not the other way around” – XL
  - “we need to get these kind of projects to start the discussion” - XL

Primary theme 10: The motivation of social cohesion can also be considered to be a result of community projects (3 out of 6 stakeholders)

  - “I can imagine that social cohesion will be a by-product and if your motivation is to increase social cohesion then the VPP might not be the project you would choose because it is quiet complex and you may have simpler projects to choose from if you aim at increasing social cohesion.” – FJ
  - “For social cohesion you can do other things like sports or whatever” – XL
  - “And then we have social cohesion. I think its more not a goal but an outcome” - IS

Primary theme 11: Sustainability is seen as both a driver of renewable energy projects and inconsequential in day to day life.

- Sustainability is a major driver (2 out of 6 stakeholders)
  - “I think it starts probably, with an idealistic idea about the need for sustainable energy” – XL
  - “I think a motivation of course is money, but also a big motivation is a better environment” – WZ
- Sustainability might not be so important in practical day to day life (1 out of 6 stakeholders)
  - “They don’t care how they get energy, they want it when they want to take a cup of coffee, that’s it” – HH
  - “Most people do not have a motivation of being green” - HH

Primary theme 12: Energy self-sufficiency is the ultimate long-term goal (3 out of 6 stakeholders)

  - “that they could really develop into, instead of being a village with a lot of solar PV, become a village that has their own energy. And can be really self sufficient and in control of themselves” – FJ
  - “The bigger picture, it would be nice when Loenen can be off-grid” – HH
  - “they had the aim to produce 80% of the personal electricity use by solar power” - IS

Primary theme 13: High penetration of solar PV within Loenen. Expected to continue in the future. (4 out of 6 stakeholders)

  - “because of our initiative (the initiatives started by LEN) we have more than average solar panels (when compared to the rest of the Netherlands)” – HM
  - “residential PV would be high, because it will be cheaper and cheaper and the Dutch are traders, so they will adopt it” – FJ
  - “we have quiet a lot of PV and I think it will be more because the price of PV keeps dropping” – IS

- In a small village like Loenen, there is peer pressure to become sustainable. This is a contributing factor to the prevalence of PV.
    - "So if neighbour X says I am having a lot of solar panels then the other neighbour also wants it" – WZ
    - "I think when your neighbour has got something, you also want it." – WZ

Primary theme 14: Heat pumps will not become 100% electric. It will be a hybrid system (4 out of 6 stakeholders)

- "because in this country we cant go all electric. Because they have to increase the grid capacity a lot, and that's not possible" – HM
- "So the existing infrastructure which use natural gas can be used for other gases like biogas etc because we can not use 100% electricity" – HM
- "And one of the options is green gas and if I understand it correctly is a very good option for Loenen" – FJ
- "The reason for not using 100% electric is it takes too much of the network to make the transition complete" – HH
- "the use of gas in households (for heating) make no sense (in terms of efficiency)" – HH

- Having 100% electric heat pumps is only economically beneficial in the situation where houses have good insulation
    - "When your home is ready for it (with good insulation) that is the tricky bit, it will be cheaper" – IS

Primary theme 15: Electric vehicles or hydrogen-based vehicles will be widely adopted (4 out of 6 stakeholders)

- "So back to your question, I think electric vehicles will be a major part, but it is a mid term solution and finally it will go to hydrogen gas vehicles" – HM
- "But I think that hydrogen cars will also be there and fuel cell cars, so electricity will not be the end all for it" – FJ
- "I think the EV would be higher than average because they may use it as a battery" – XL
- "I think EV is absolutely the future" – WZ

Primary theme 16: Demand response is interesting, but concerns about if it will be implemented in a non-intrusive way (1 out of 6 stakeholders)

- "so the system can put on my washing machine in the night when there is power that is not used" – HM
- "Like my car, I put it on the charger and it charges at the moment when the grid says there is too much power but this might be difficult because I need energy when I need to go somewhere, so I cannot let the grid dictate when the car gets charged" – HM

Primary theme 17: Differences in opinions regarding wind energy (2 out of 6 stakeholders)

- Wind energy is necessary and must be included in the cVPP portfolio
    - "Otherwise we will have less production in winter and the night. And combined with a battery system there is so much to do in that business." – HM
- General resistance to the idea of wind mills

- "there were plans to build a wind mill and there was lots of resistance and now the plan is dropped" – FJ

The social motivations identified previously by literature review have been reaffirmed by the stakeholders. Three stakeholders felt that the social motivation of social cohesion can also be thought of as one of the results of a community project. This is a valid point of view. In the case studies analysed in section 5.2.3, in the Brixton community energy case, the Anafon community hydro project and the Point and Sandwick project, improving social cohesion was one of the specific motivations for starting the project.

On the other hand, social cohesion is also a natural result of any project where the community works together. As mentioned in section 5.2.3, when a community works together and is involved in an activity towards a common goal, there is an increase in social cohesion within the community due to increase in interaction between community members (Woolley, 1998).

The results of the interview analysis are now summed up. A common consensus among key stakeholders who are also Loenen residents is that the project must have a local scope initially. The technical functions performed by the project must aim to first maximize the benefits of the local community before expanding to a bigger scope. Many of the stakeholders agreed that energy self-sufficiency is the ultimate goal that Loenen should strive for. This idea of putting the community first is in sync with the philosophy behind the community virtual power plant – designing a virtual power plant with the community as its focus.

All of the stakeholders who were interviewed agreed that profitability is an important aspect of the project. They recognized the lucrative opportunities that could become available for Loenen residents once the project is started. This ties back to the belief that the main beneficiary of the cVPP project must be the community itself (as discussed in 5.2.1, if individual profit is ensured and the project is socially inclusive, the community as a whole benefits). Many of the Loenen residents who were interviewed are already thinking of ways to maximize their economic gains from the project. For example, one candidate mentioned that he is considering installing a mini windmill so that he is able to sell energy to his peers even during winter.

Only one interview candidate said that sustainability might not be the primary motivator for the initiation of the project. Many of the other candidates agreed that the idea of becoming more sustainable is one of the sparks that led to the inception of the project.

A majority of the candidates who were interviewed agreed that, ideally, the influence of big energy companies on the local energy supply must be reduced. They recognized the fact that people want to be in charge of the procurement of the basic goods like energy and there is some lack of trust when dealing with big companies. One stakeholder mentioned that big energy companies usually have their own profit motive which might not always align with the motivations of the community. Even though reduced influence of big energy companies was considered to be ideal, it was recognized that it would be difficult for the community to be fully independent. The community would still have to rely on the big companies for infrastructure and maintenance. For accomplishing the technical functions that have a bigger scope, like trading in the wholesale market, more professional expertise would be required, which might not be found within the community itself.

Some stakeholders felt that trust is a key issue that must be considered. They believed that in the initial phase community control is necessary, but later on, once the community has built enough trust on the project partners, it is possible to delegate some of the control to other entities. They believed that a project like the cVPP might grow to become too big for a village like Loenen and joint cooperation with other villages and the Gemeente Apeldoorn is absolutely necessary in the long run.

To sum up the analysis, there was a general consensus that the technical function must primarily benefit the community first, paving way for the ultimate goal of Loenen becoming energy self-sufficient. The profitability and perception of sustainability were key factors that were important to most of the stakeholders.

To determine the ranking given by the stakeholders, for the different social motivations, the following table is constructed. The motivation that is ranked first by a stakeholder is given a score of 4, the motivation ranked second is given a score of 3 and so on. This was done for each stake holder and the scores are summed up.

Table 3: Ranking of social motivations (4 indicates a higher ranking than 1)

	Profitability	Perception of sustainability in the community	Social cohesion	Community control
HM	4	3	2	1
FJ	2	4	1	3
XL	1	4	2	3
HH	4	2	1	3
WZ	4	3	1	2
IS	2	3	1	4
Score	17	19	8	16

Perception of sustainability in the community is deemed to be the most important, followed by profitability and then community control.

As mentioned previously, many of the stakeholders believed that the ideal technical goal for the cVPP must have a scope that starts within Loenen and then slowly branches outwards.

Accounting for this preference of a local scope, **setting up a local energy market and managing the local energy grid for the DSO would be a good starting point for the cVPP**. Combining the ranking of the social motivations by the stakeholders (Table 3), along with the general framework matrix (designed in section 7) leads to a similar conclusion – that the technical functions that can satisfy the social motivations expressed by the Loenen residents are setting up a local energy market and managing the local energy grid for the DSO. It must be pointed out that to ensure less influence of external entities, a community-based organization must be tasked with managing the local grid for the DSO.

This section serves to determine the specific social motivations that are present in the Loenen community and the specific technical functions of the cVPP that can satisfy these social motivations and answers SQ4. The interview transcripts can be found in Appendix E.

9 Techno-economic analysis

From the interviews, the general consensus of the key stakeholders is that the technical functions that are more “local in nature” – managing the local grid and setting up a local community energy market – needs to be focussed upon first. A techno-economic analysis has been done for both of the chosen technical functions. This analysis serves to answer **SQ5:**

What are the technical and economic benefits derived by the Loenen community from the chosen technical functions?

by considering the technical and economic aspects of the proposed functions of the cVPP. The technical part of the analysis judges the technical aptness of the selected functions. It answers questions like:

- Considering the current situation of the technical aspects like the local grid, the generation and the consumption, does the proposed technical function make sense?
- Is the chosen technical function feasible to implement?

The economic part of the analysis judges the economic validity of the chosen functions. It answers questions like:

- How can the economic benefits of the proposed technical functions be quantified?
- Is the project economically viable?

The aim of this techno-economic analysis is to understand the practical feasibility of the technical functions that have been selected and to help the community to set up the cVPP by acting as a starting point for the practical design of the cVPP.

9.1 Offering local grid management to the DSO

As mentioned in section 6.3, demand response techniques can be used to shift flexible loads to manage local grid congestion. The technical analysis of the feasibility of local grid management by the cVPP can be split into the following steps with the specified inputs:

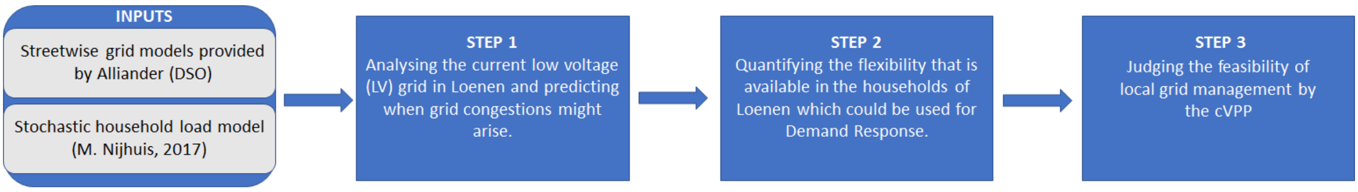

Figure 4: Steps of techno-economic analysis of local grid management for DSO

Since the streetwise grid model by Alliander was provided without individual household consumption data due to privacy concerns, a stochastic household load model is used for the analysis (M. Nijhuis, 2017).

This household load model had the following characteristics that make it a good fit for the analysis being done:

- The model is built using data specifically for the Netherlands. The output of the model was also compared with real usage profiles and it is found that there is a very high correlation between them.
- The model factors in various aspects like the household size and wealth and age of occupants to estimate the appliances present and their usage patterns. The usage patterns of different appliances are also built using time use surveys conducted in the Netherlands (Sociaal en Cultureel Planbureau (SCP) & Centraal Bureau voor de Statistiek (CBS), 2011). It considers the weather data to account for PV production in case PV is present. Hence this model is very comprehensive.

- The model can be disaggregated at the device level which is important to quantify the flexibility in each household.
- The model incorporates different scenarios like the expected future penetration levels of PV, Heat Pumps, Electric Vehicles, Micro-Combined Heat and Power (CHP) and the expected economic growth and the appliance efficiencies.
- The model is stochastic in nature. Hence the profiles generated have their attributes randomized, but when all the profiles are considered together, there is a high correlation with real household consumption in the Netherlands.

During the interviews held with the key stake holders, their opinion regarding the penetration of different technologies like PV, Electric Vehicles, Heat Pumps and Micro-CHP where asked. This was used as input to the household load model to get the usage profiles. The following technology penetration inputs are used to get the household load profiles:

- PV Penetration: High
- EV Penetration: Low
- Heat Pump Penetration: Medium
- Micro-CHP Penetration: Medium
- Economic growth: Medium
- Appliance efficiency growth: Medium

From these profiles, 2 separate subgroups are made. For prosumer profiles, the generation from PV was kept as it is. For consumer profiles the generation from PV was omitted.

9.1.1 Step 1: Estimating when grid congestions would arise in the Loenen LV network

For estimating when grid congestion might arise in the Loenen LV network, a Load Flow Analysis (LFA) is done using Gaia software and the household load profiles (M. Nijhuis, 2017) mentioned in the last section. LFA calculates the voltage drop at each feeder in the network, power flow and losses at each branch and feeder circuit and the voltage at each bus. The LFA can be used to see if the system voltages stay in the safe range of values. It is useful to understand if the transformers or cables are overloaded.

An LFA is done for each street-wise network model of Loenen. Prosumer and consumer profiles are assigned to the different households, depending on if they had PV panels or not (as indicated by the Gaia model). A yearly exponential growth rate of 2.4% is assumed for the loads as per (PhasetoPhase, 2015) which is the Dutch average. The year when the first anomaly occurs is noted for each of the models. A scatter plot showing the number of connections in each street-wise network model and the year when the first element in the model gets overloaded is seen below:

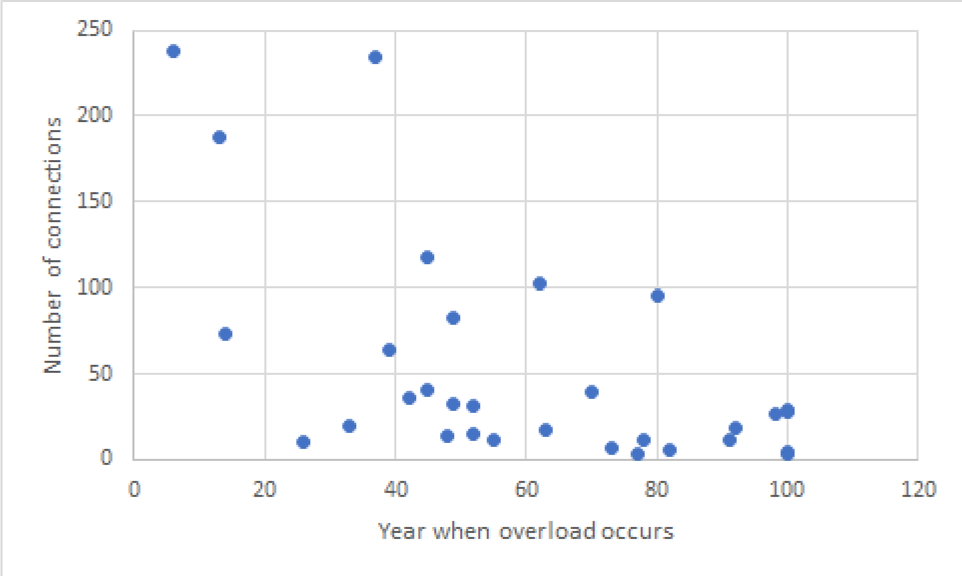

Figure 5: Number of connections per grid model VS year when first anomaly occurs

According to the Union of Electrotechnical Entrepreneurs and Association of Dutch Installation Companies (Uneto-VINI), grid planning is often done for a time period of 40 years, as most of the major grid components have a lifetime of 40 to 70 years (Uneto-VINI, 2008). During the LFA of Loenen, 77.4% of all the anomalies first appeared after a period of 40 years.

The following scatter plot depicts when the transformer gets overloaded in each of the street-street wise network models:

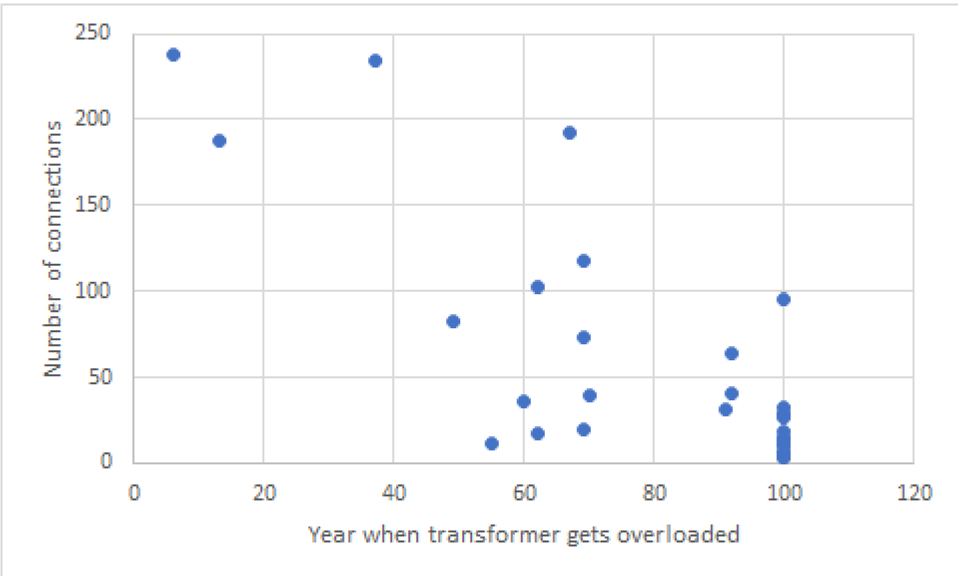

Figure 6: Number of connections per grid model VS year when transformer gets overloaded

90.6% of all the transformers only get overloaded after 40 years.

From the Load Flow Analysis, it becomes clear that there are only a few weak spots in the Loenen grid.

9.1.2 Step 2: Quantifying the flexibility available in Loenen

Many research papers have tried to quantify the end user flexibility present within a local grid. For this, the historic consumption data of the households disaggregated at the individual household level is required. Since, real consumption data is not available due to privacy concerns, the stochastic household load models used in the previous section are relied upon.

Based on other research (Abdisalaam, Lampropoulos, Frunt, Verbong, & Kling, 2012; Gottwalt, Gärttner, Schmeck, & Weinhardt, 2017; Gottwalt, Ketter, Block, Collins, & Weinhardt, 2011; Hoogsteen, Molderink, Hurink, & Smit, 2016; Lampropoulos, Frunt, Pagliuca, De Boer, & Kling, 2011; Neupane, Šikšnys, & Pedersen, 2017), it is found that the following common household devices have the potential for flexibility of operation to aid demand response:

- Refrigerator
- Dishwasher
- Washing machine
- Electric heat pump
- PV

The loads of these devices can be categorized as flexible loads. As mentioned initially, the stochastic household load model built by (M. Nijhuis, 2017) is used to get an approximation of individual household consumption profiles. The model is built in such a way that it assigns different devices to different households based on the age of the occupants, the household size and wealth (M. Nijhuis, 2017). The profile obtained from the model is disaggregated to show the consumption of these devices separately. Following this disaggregation of each model, the consumption of the afore mentioned devices is taken together to find the flexible load.

The following graphs show the hourly total load and the flexible load of 100 households for a week in summer and winter (the values are derived from the stochastic load model):

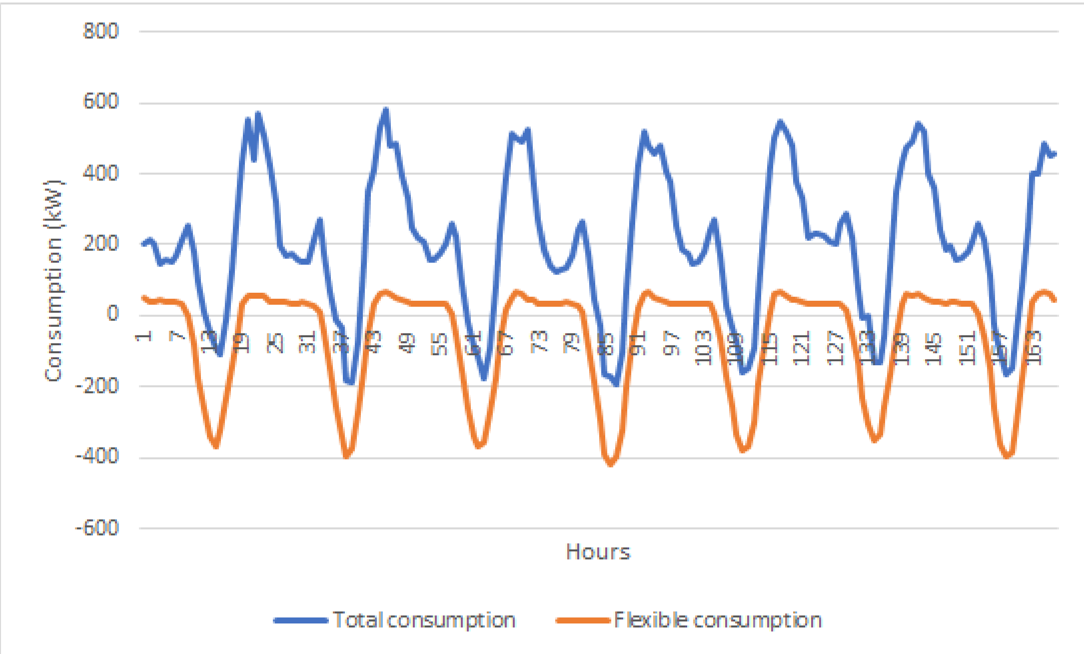

Figure 7: Total consumption and flexible consumption of 100 households for a week in summer (-ve values due to generation by PV)

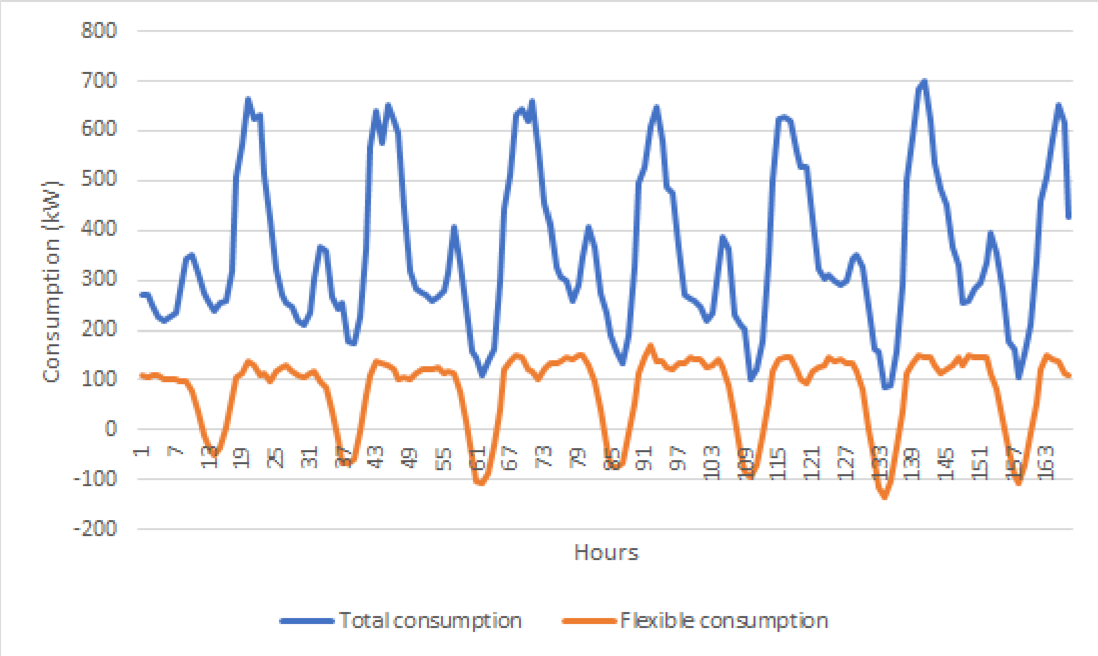

Figure 8:Total consumption and flexible consumption of 100 households for a week in winter from stochastic load model (-ve values due to generation by PV)

In the previous 2 figures, total consumption denotes the electricity usage of all the devices in the household along with the PV. Flexible consumption denotes the electricity usage of the refrigerator, dishwasher, washing machine, electric heat pump and PV.

When the total consumption and flexible consumption of all the profiles used in the Load Flow Analysis are compared on an hourly basis, it is seen that on average 19.29% of the total consumption is due to flexible loads.

But, this entire 19.29% cannot be always counted as flexibility, because:

- Shifting all of the loads at once could cause another peak to happen at a different time (Gombert, 2014)
- Demand response can be done automatically with ICT equipment, or certain signals (like price signals) can be given to the end user so that he shifts the consumption himself. For the second case, the end user need not always shift his consumption. (Michiel Nijhuis, Babar, Gibescu, & Cobben, 2017) calculated the price elasticity of electricity and found that on average, in the Netherlands, only 30% of the flexible loads present at a household level would respond to demand response induced price changes. This paper uses the stochastic household load model developed by (M. Nijhuis, 2017) to calculate the price elasticity. This same stochastic model is used in the techno-economic analysis.

Another factor to consider is participation in the cVPP programme. Even though the people interviewed were supportive of the cVPP, this cannot be generalized for the whole community.

When the household load profiles are considered together, the maximum total consumption for a time period of 1-hour is found to be 10484.729 kW. The gird must be robust enough to meet this maximum consumption even if it happens once a year, and this means that extra investment is required to strengthen the grid. If some of this consumption can be shifted (be made flexible) the grid investments would be lower as the maximum consumption that the grid must meet at any point of time would be lower.

The flexible consumption that can effectively be shifted from this maximum consumption (that occurs for a time period of 1 hour) can be calculated as:

$$Flexible\ consumption\ that\ can\ be\ shifted\ from\ the\ maximum\ total\ consumption$$
$$= Maximum\ total\ consumption\ (at\ any\ point\ of\ time)\ X\ 19.29\%\ X\ 30\%\ X\ Participation\%$$

The flexible consumption that can be shifted from the maximum total consumption of 10484.729 kW (that occurs for 1 hour) in the year under consideration, using demand response will vary with the participation % as follows (using the previous equation):

Table 4: Participation % in cVPP project and corresponding flexible consumption that can be shifted from the maximum consumption

Praticipation %	Flexible consumption (kW)	Flexible consumption as a % of the maximum consumption that occurred in 1 hour in a span of 1 year
10	60.68	0.58
20	121.35	1.16
30	182.03	1.74
40	242.70	2.31
50	303.38	2.89
60	364.05	3.47
70	424.73	4.05
80	485.40	4.63
90	546.08	5.21
100	606.75	5.79

The goal of local grid management is to postpone grid upgrades (Wilks, 2011). The DSO needs to ensure that the gird can supply peak power at all times even if the peak happens rarely. This means that grid investments are often determined by the peak consumption (among other things). Hence, reducing the peak, would mean a reduction in grid investments for the time being. The grid investments can be postponed by using demand response techniques, till it becomes necessary due to the increasing base loads.

It is estimated that for a 1kW peak capacity increase of the grid, grid investments of €2500 is required (Gombert, 2014). Regulations consider the lifetime of a grid component to be 40 years and the asset is depreciated accordingly. Hence spreading out the €2500 investment over a period of 40 years amounts to €62.5 / kW / year (without considering the depreciation). This is the amount saved per kW of peak consumption that is avoided per year (Gombert, 2014).

9.1.3 Step 3: Judging the feasibility of local grid management by cVPP

An economic analysis is done to understand the feasibility of managing the local grid by the cVPP. The capital expense and operational expense incurred to set up the cVPP is compared with the estimated savings in deferred peak capacity from local grid management. Since the VPP concept is still relatively new, research into the economics of setting up a VPP is scarce. A VPP usually consists of 3 main components (Othman et al., 2015):

- Distributed energy resources
- Energy storage systems (not all VPPs may have this)
- ICT technology

In the Loenen case, there are already PV panels installed and as the project is still in a very early stage, there is no discussion of energy storage. Hence the focus shifts to ICT technology. For the economic analysis, the costs of the ICT technology have been considered.

The Energy Management System (EMS), forms the core component of the ICT technology (Othman et al., 2015). It can be considered as the "brain" of the VPP and manages all operations – from forecasting and managing loads to controlling the operations of the distributed generation sources.

There are a few companies that are successful in the VPP field in Europe, but they do not openly publish the costs of set-up. Contact was established with one of these companies who is in the forefront of the VPP market. They offer EMS (Energy Management Software) and ICT devices connected to the generation sources that allow them to be controlled remotely as a VPP solution. Via email correspondence, the company gave an estimated capital expense of €80000 and yearly maintenance expenses of 20-30% (the higher value of 30% was taken for the analysis for getting a conservative estimate). Even though this is an approximation, this is the best number to use, given that costs for the VPP would vary on a case by case basis, and the difficulty in finding other sources of cost information.

Another assumption made was the growth in load in Loenen, which would affect the amount of flexibility in the years to come and hence the money saved each year due to deferred capacity investments. (PhasetoPhase, 2015) suggests that loads in the Netherlands grow exponentially at the rate of 2.4% per year.

The expected cash flow of the project is calculated in the Appendix F. The calculation was done for different participation percentage in the cVPP project. The appendix shows the calculation for a participation percentage of 60%. It is seen that the Net Present value (NPV) of the project (for participation of 60%) becomes positive after the 23rd year, hence the project becomes profitable after the 23rd year.

The different participation percentages and the corresponding years when the NPV becomes positive (the year when the project becomes profitable) is as follows:

Table 5: Participation % in cVPP project and corresponding year when local grid management becomes profitable

Participation %	Year when project becomes profitable
10	>40
20	>40
30	>40
40	>40
50	37
60	23
70	15
80	10
90	8
100	6

The participation % at which the year of profitability is exactly 40 years is 48%. It can be seen that when there is wide spread participation in the project, the waiting time before projects become profitable can be drastically cut down.

The period of time for profitability is just an estimate because of the following assumptions:

- The assumption that the percentage of flexibility in the peak consumption remains a constant 19.29%. As devices become better, their energy consumption would reduce, and more flexibility can be harnessed from them.
- During periods when there is no grid congestion, the flexibility from local grid management can be traded in the Dutch ancillary markets. This will be an added income that has not been considered in the analysis.

The economic analysis can be considered as a “worst case scenario” due to the above assumptions. Even so, the project becomes profitable before the 40-year life time of grid upgrades as long as the participation in the project is greater than or equal to 48%, hence it is a worthwhile investment. The economic analysis is from the point of view of the DSO. Since the project has potential for profit, the DSO can incentivise participation by offering a portion of the expected profits as economic remuneration. This will still ensure that the DSO themselves are profitable from the project while incentivising more participation from consumers. Once a considerable amount of flexibility has been aggregated, when the DSO does not need the flexibility for local grid management, it can trade this in the ancillary services market for further profits. Hence, there is an incentive for the DSO to increase participation as this means that more flexibility can be achieved.

The 40-year payback time period might not be very attractive to the communities, but from the perspective of the DSO, postponing grid upgrades is valuable. It is up to the community (in case they are opting to managing the local grid for the DSO via a community-based organization) to work out a deal with the DSO that is also favourable to them.

9.1.4 Summary of analysis

The techno-economic analysis of the technical function of the cVPP offering local grid management was conducted. When judging the technical aptness of the function, the following points need to be considered:

- The local grid of Loenen has a lot of spare capacity at this point of time. Hence, managing the local grid is unnecessary now. Things may change in the future, when the transition from gas heating to electric heating becomes complete.
- The timing of this project is critical. Even though local grid management is unnecessary at this point of time, implementing this function after the next major grid upgrade could be useful to prolong the life of the newly upgraded components. This is an attractive proposition from the DSO’s point of view.
- Local grid management is not a permanent fix for grid congestion. Local grid management only tries to shift the flexible portion of the loads to off peak times. The in-flexible loads (for example the base load) would remain unaffected and would continue to grow with time. Local grid management is a tool to ensure that the lifetime of the gird components is maximized to increase the time till the next inevitable grid upgrade.
- The amount of flexibility that can be shifted to manage the local grid is highly dependent on the amount of participation in the initiative by the local community.

To sum up the technical part of the analysis: Local grid management is useful as long as it is timed to initiate after the next major grid upgrade, provided that there is enough participation by the local community.

When judging the economic validity of the local grid management function, the following points need to be kept in mind:

- There is potential for profitability from local grid management by reducing the peak loads and hence reducing the investment in the peaking capacity of the grid.
- The profitability of the local grid management project is highly dependent on the participation in the project. The project can become profitable in around 6 years if there is full participation by the community.
- At least 48% participation is needed for the project to become profitable before the major grid components need to be upgraded (assuming that these components have a 40-year lifetime).
- Quick returns cannot be expected. The project will become profitable within the 40-year lifetime of grid components assuming that participation in the project is 48% or more, hence the organization that takes up this function must be ready to wait for some time before it starts to see returns.
- As mentioned in the technical part of the analysis, the timing of the project is critical. If local grid management is implemented after the next upgrade cycle of the grid, the gains from deferred peaking capacity investment can be maximized.

Managing the local grid can be a secondary objective of the cVPP once the participation in the project increases substantially.

Another important aspect to consider is the structure of the entity that will manage the local gird. Even though the DSO will benefit the most from this technical function, according to the existing regulations, the DSO cannot directly control appliances of clients to mobilize flexibility. A separate organization must act as the link between the DSO and the ned user. This organization will act as an aggregator as described in (USEF Foundation, 2015). The organization can be a profit oriented third party or be formed from within the community itself.

As mentioned in section 7.2, a community-based organization ensures more community control. But as mentioned by some of the interview candidates it is important to consider if the community-based organization would have enough technical expertise to manage the local grid. Even though this might be hard for a community-based organization, there are 2 major factors that work in its favour:

- It has been established via the techno-economic analysis that the payback time of local grid management might be long. An independent profit oriented third-party organization might not find this proposition very attractive. On the other hand, a community-based organization would see this as an opportunity to invest in the community. As per the interviews with the key stakeholders, perception of sustainability within the community and ensuring community control is as important as profitability. Hence the long payback time might not act as a deterrent for a community-based organization.
- The payback time is linked closely with the amount of participation from the local community. It will be easier for a community-based organization to mobilise support compared to a private third-party organization.

To sum up, a community-based organization could offer local grid management to the DSO after the next major grid upgrade. Discussion with consortium members suggested that the DSO considered multiple factors like the economy, expected changes in government legislation etc apart from overloading of grid components to decide when the grid upgrade must occur.

As mentioned earlier even though a 40-year payback time might not be very attractive to a community-based organization, postponing grid investments is very attractive for the DSO. Hence it is up to the community-based organization to negotiate with the DSO to make the economic aspects more favourable.

To ensure that there is enough expertise for this task within the organization, external experts could be hired, but the majority of the organization would consist of the local residents. It will be easier for such an organization to mobilize more participation to ensure more flexibility.

9.2 Local community energy market

Creating a local energy market is one of the technical functions that is considered to be important by the participants of the interviews. As mentioned in section 6.4 even though there are numerous benefits, a local energy market where community members can trade with each other is not allowed by the regulations as of now. This is bound to change in the future. The analysis of the feasibility of a local community energy market can be broken down into 2 steps, each involving the following inputs:

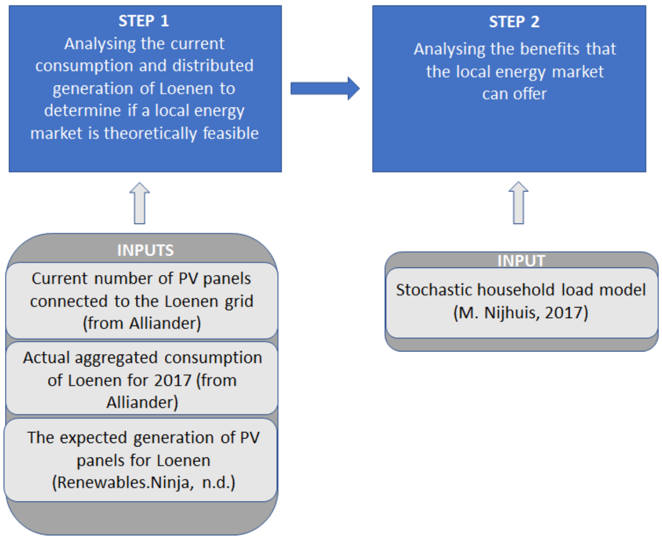

Figure 9: Steps of techno-economic analysis of establishing a local community energy market

9.2.1 Step 1: Analysing the current consumption and distributed generation of Loenen

As per the data provided by Alliander, currently there are 152 solar PV connections to the LV Loenen grid with a total generation capacity of 823 kW. A single PV connection in Loenen ranges from 1 kW to 5kW.

The load of Loenen obtained for the year 2017 from Alliander, has been split into the different types of connections namely (EnergyMarktInformatie, n.d.):

- E1A: Consumers with a transmission value less than or equal to 3 X 25 A having a single fixed tariff for all hours.
- E1B: Consumers with a transmission value less than or equal to 3 X 25 A having a double tariff (different rates for the night).
- E1C: Consumers with a transmission value less than or equal to 3 X 25 A having a double tariff (different rates for the evening hours).
- E2A: Consumers with a transmission value above 3 X 25 A up to and including 3 X 80A having a single fixed tariff for all hours.
- E2B: Consumers with a transmission value above 3 X 25 A up to and including 3 X 80A having a double rate tariff (different tariffs for peak and off-peak hours).

- E3A: Consumers with a transmission value above 3 X 80 A and not provided with continuous measurement, with operating time less than or equal to 2000 hours.
- E3B: Consumers with a transmission value above 3 X 80 A and not provided with continuous measurement, with operating time greater than 2000 less than or equal to 3000 hours.
- E3C: Consumers with a transmission value above 3 X 80 A and not provided with continuous measurement, with operating time greater than 3000 less than 5000 hours.
- E3D: Consumers with a transmission value above 3 X 80 A and not provided with continuous measurement, with operating time greater than or equal to 5000 hours.
- E4A: For public lighting

The following graph shows the consumption in Loenen on a typical day. This data is part of the information obtained from Alliander of the actual load of Loenen for 2017.

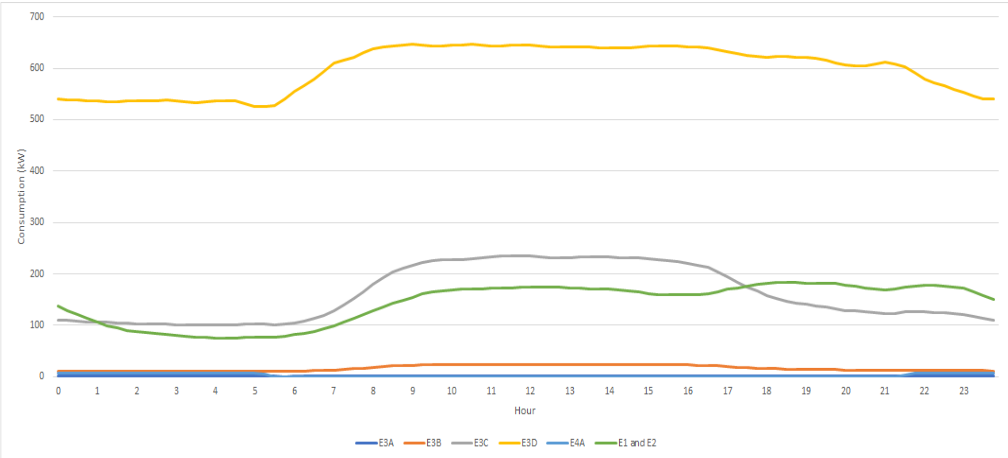

Figure 10: Example of the actual load of Loenen for a typical day in 2017

A local energy market facilitates the local demand to be met by the local generation, hence it promotes the self-balancing of the local network. (Long, Wu, Zhang, Cheng, & Al-Wakeel, 2017) takes this into account and comes up with a P2P (peer to peer) index that can be used to determine the feasibility of energy trading within a low voltage network.

The P2P index is defined as follows:

$$I_{P2P,t} = \frac{G_{PV,t}}{L_t} \qquad (1)$$

Where $G_{PV,t}$ is the generation of PV at time t given by:

$$G_{PV,t} = \sum_{n=1}^{n_1} P_{n,t}^{PV}$$

Where $P_{n,t}^{PV}$ is the generation of the nth PV panel at time t and n_1 is the total number of PV panels in the system. L_t is the load at time t. For optimal energy trading, the P2P index needs to be as close to 1 as possible (the supply of energy from distributed generation needs to match the demand of energy).

Two simplifications are made with this equation – it is assumed that the generation profile of all the panels in the LV network is the same due to the relatively small area (a similar simplification is made in the research paper from which this optimization equation is taken (Long et al., 2017)) and all the panels are considered to be of the same capacity. After these simplifications, equation (1) can be written as:

$$G_{PV,t} = n_1 \, X \, P_t^{PV} \qquad (2)$$

To ensure that there is enough PV generation to balance the demand of the LV network, the P2P index must be close to 1. The following objective function must be minimized:

$$Min \sum_{t=0}^{24} (I_{P2P,t} - 1)^2$$

The objective function can be rewritten as below, by using equation (1) and (2):

$$Min \sum_{t=0}^{24} (\frac{n_1 \, X \, P_t^{PV}}{L_t} - 1)^2$$

By minimizing this equation, we can find n_1 which is the optimum number of PV panels of a particular capacity that must be present for the local energy market to function properly by balancing the generation and demand. We can then find the optimal total capacity of PV that needs to be present.

The objective function is minimized in the Optimization Toolbox of MATLAB using different sets of scenarios:

- the generation of both 1kW PV panels and 5kW PV panels are considered as separate scenarios for supplying the value of P_t^{PV}. The generation of both the PV panels is obtained from (Renewables.Ninja, n.d.) which is an online tool that has solar insolation data for all locations in Europe and can provide an accurate estimate of PV generation.
- the loads of only small consumers (E1 and E2 connections), and all the connections aggregated together are considered for L_t.
- The generation and consumption are considered for both a week in summer and winter.

The objective function is minimized using MATLAB to obtain the value n_1 which is the total number of PV panel. The total number of panels (n_1) and the net generation capacity (net generation capacity = kW capacity of 1 panel X number of panels) that they are capable of for each of these scenarios is given in the matrix below:

Table 6: Optimization results for 5kW panels

	5kW panels	Number of panels	kW of generation capacity
Summer	Small consumers (E1 & E2)	219	1095
	All consumers	1523	7616
Winter	Small consumers (E1 & E2)	386	1930
	All consumers	2195	10976.5

Table 7: Optimization results for 1kW panels

	1kW panels	Number of panels	kW of generation capacity
Summer	Small consumers (E1 & E2)	1093	1092.9
	All consumers	7617	7617.1
Winter	Small consumers (E1 & E2)	1928	1928.1
	All consumers	11038	11038

The optimal kW of generation capacity required to enable a local energy market, remains almost the same (approximately 1095 kW for small consumers and 7617 kW for all consumers) in the summer scenario when either 5kW or 1kW panels are used. Similarly, the optimal kW of generation capacity remains almost the same (approximately 1930 kW for small consumers and 11038 kW for all consumers) in the winter scenario when either 5 kW or 1 kW panel are used for generation. The variations are because during the calculation of the amount of generation per hour for each PV panel (1 kW and 5 kW) slightly different generation efficiencies were considered.

9.2.2 Step2: Analysing the benefits that the local community market can offer

As mentioned in section 6.4, peer to peer trading is still not possible in the Netherlands, and the prosumer generally prefers to feed the surplus energy back to the grid because:

- peer to peer energy trading is not allowed by regulations
- feed in tariff scheme exists, where the prosumer can offset the energy he consumes from the grid by feeding in self-generated electricity back to the grid. When the generation is more than the consumption (net positive), the prosumer gets a particular rate per kWh for the excess electricity (Energieleveranciers, 2018).

This situation is set to change soon. There is common consensus that peer to peer trading will be allowed in the near future[9]. And, by 2020, the Dutch government plans to stop the current feed in scheme (Zelfstroom, 2017). At this point of time it is unclear what the new scheme will be.

The feed in tariff schemes of other countries can be analysed to get an idea of what the future might hold for the Netherlands. Germany is the first European country to introduce feed in tariff schemes (in 1991) (Building_Efficiency_Initiative, 2010) and the German feed in tariff model has underwent a lot of changes to keep up with the pace of development.

A common feature of feed in tariffs is tariff degression – the feed in tariff rates decline with time to reflect the cost reduction of renewable energy generation equipment due to technological advance (among other things) (Energypedia, 2016). This can be seen in the following graph which depicts the feed in tariff for small PV installations and the domestic electricity price (retail price) for Germany:

[9] This is a personal opinion based on interaction with different people in the renewable energy and sustainability field. The large number of experimental projects in Europe which involve energy trading / sharing also points towards this future trend.

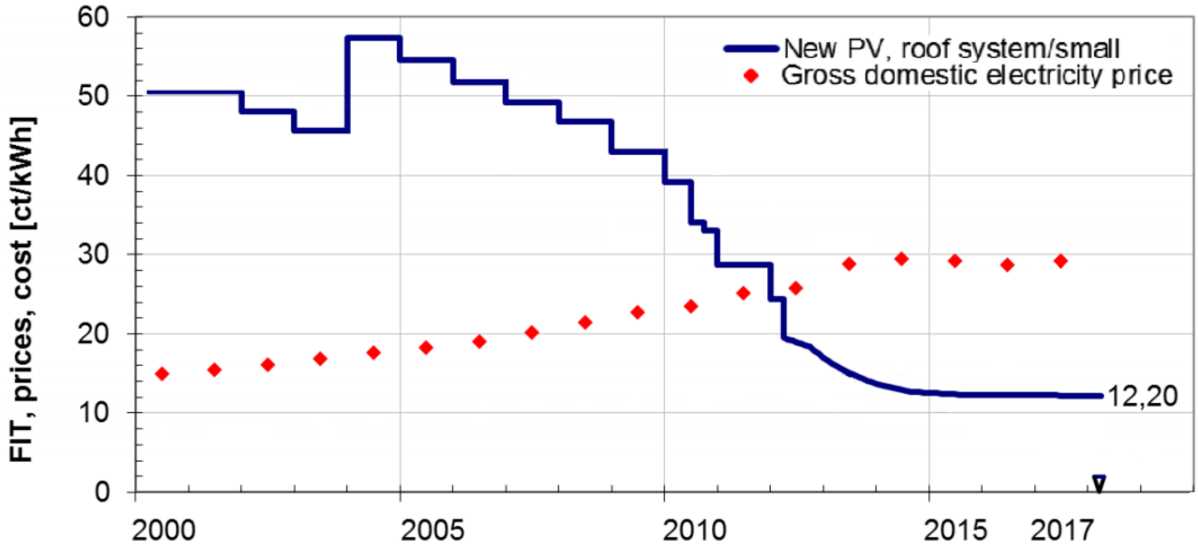

Figure 11: Feed in tariff rates and domestic electricity price - Germany. Modified from (Wirth, 2015)

It can be seen that there is a general trend of the feed in tariff rates falling lower than the domestic electricity retail price. It is reasonable to assume that a similar trend will be seen in other European countries with time. Hence when the current feed in scheme in the Netherlands is changed in 2020, it could be expected that the payment for surplus energy generation will be lower than the retail price of electricity.

A peer to peer energy trading market will make financial sense because:

- it will be financially attractive for the prosumer to sell the excess energy for a price above the feed in price but below the retail price
- it will be financially attractive for consumers to buy the surplus energy from prosumers at a rate below the retail price

Even though there are clear benefits for implementing a peer to peer energy trading market, there are still a lot of uncertainties. For example:

- There are always transportation losses that need to be accounted for when considering a P2P trade. For example, if the seller transfers 100W to the buyer, only 95 W might arrive due to cable losses. But if the buyer pays for the 100W he will be incurring a loss and if the seller transfers 105W to account for cable losses but only is payed for 100W, he will be incurring a loss.
- Taxes will be unavoidable even in a P2P system. Unless there is a separate dedicated system for the P2P market (which does not make financial sense) the players in the market must pay for the usage of the grid infrastructure.

Hence the key to establishing a successful P2P market is to ensure that the pricing and policies are balanced.

To analyse the benefits offered by the local community market, the profiles of one prosumer and one consumer have been considered. These profiles have been taken from the household load model (M. Nijhuis, 2017) used in section 9.1. The following is a graph of the consumption and PV generation of a prosumer and the consumption of a consumer for a week chosen at random.

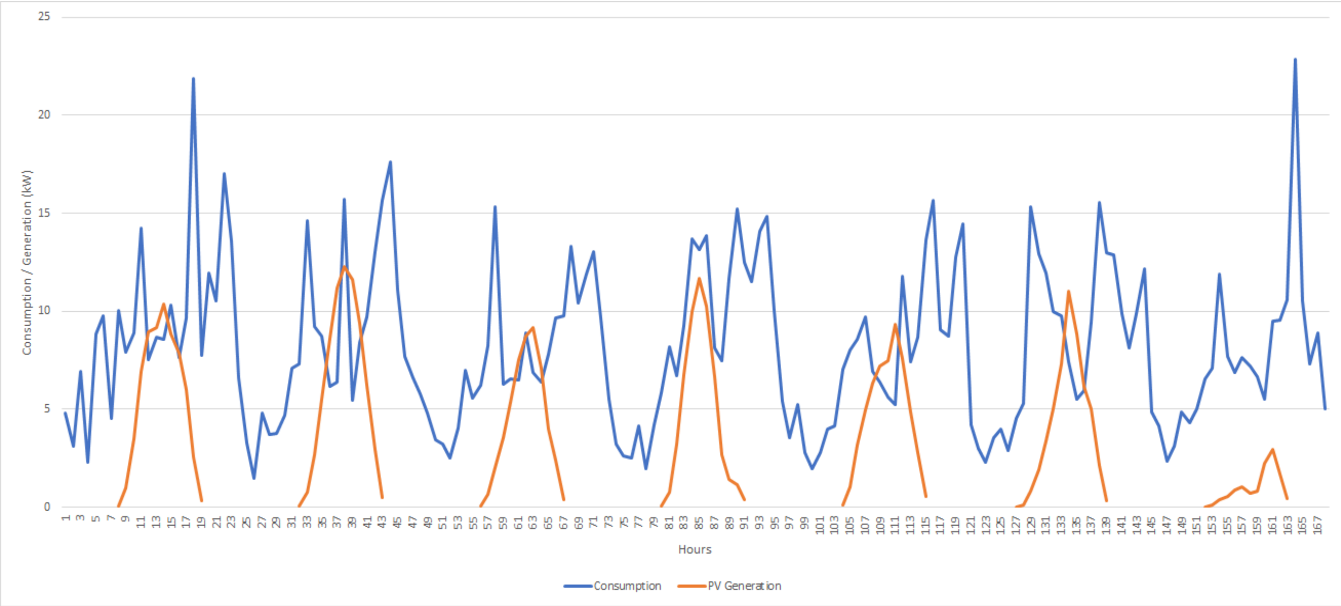

Figure 12: Energy consumption and PV generation of prosumer for a week

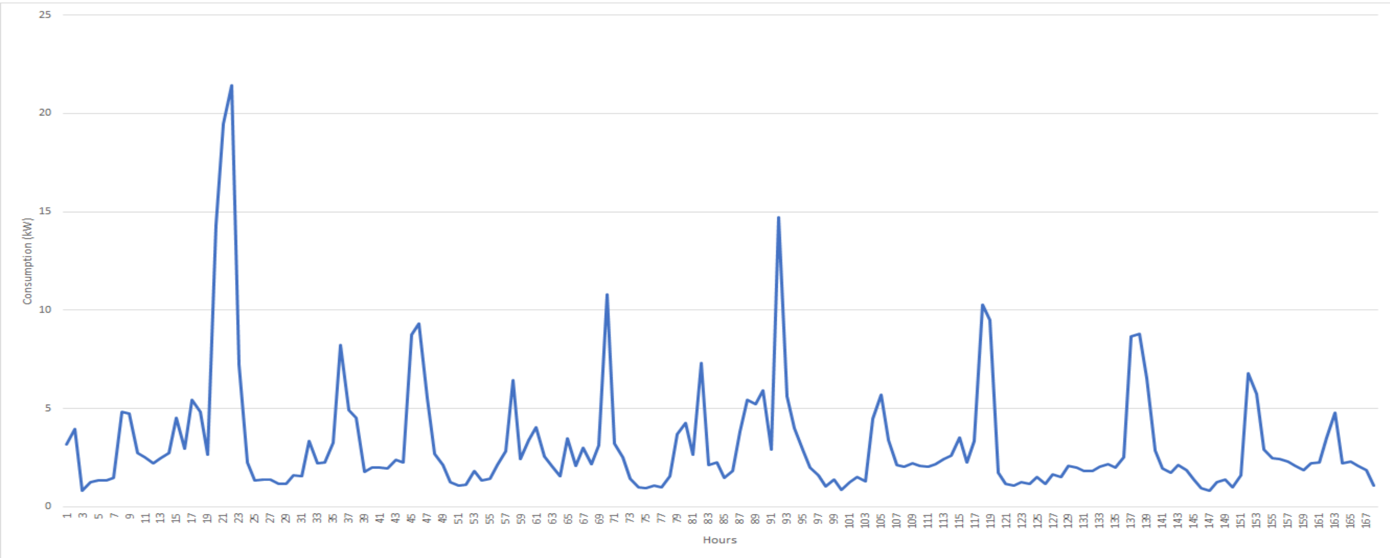

Figure 13: Energy consumption of consumer for a week

It can be seen in Figure 12 that at some instances, the prosumer has a surplus of energy. Assuming that the following three conditions are met:

- peer to peer energy trade is possible
- the feed in tariff scheme changes so that consumed energy cannot be offset by surplus energy fed back into the grid
- feed in tariff renumeration is lower than the retail price of electricity

then the prosumer can profit by selling the surplus energy for a price higher than the feed in tariff rate and lower than the retail price. The consumer would benefit by getting the opportunity to purchase the energy for a price lower than the retail price.

Comparing the prosumer and consumer profiles depicted in Figure 12 and Figure 13, it can be seen that the consumers electricity consumption from the grid can be partially reduced using the prosumers surplus energy:

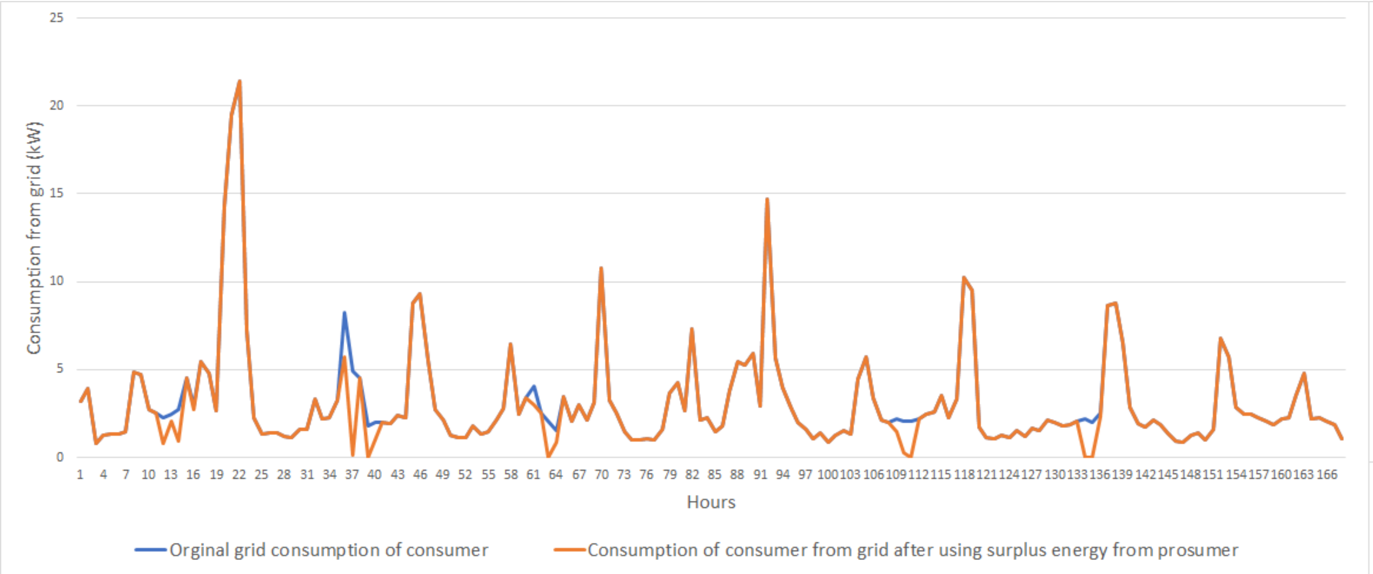

Figure 14: Reduction of consumers consumption using surplus energy from prosumer (for a week)

In this particular example, the consumption of electricity from the grid of the consumer reduces by 26.8 kWh, which is 4.9% of his total consumption for the week chosen at random for the analysis. With more prosumers and consumers participating, more efficient consumption of surplus energy can be facilitated.

9.2.3 Summary of analysis

The previous subsection dealt with the techno-economic analysis of setting up a local community energy market using the cVPP. When judging the technical aptness of this function the following points need to be kept in mind:

- The current installed capacity of PV panels in Loenen is approximately 823 kW. To implement a local community energy market among small consumers (connection types E1 and E2 from Table 6 and Table 7), where the local demand of small consumers can be met by local generation of small consumers, approximately 1095 kW installed PV capacity is needed in the summer and 1930 kW installed PV capacity in the winter. Loenen Energie Neutraal plans to increase the installed PV capacity to approximately 7MW in the next decade. It is reasonable to assume that the installed capacity will surpass the requirements for establishing the local community energy market for small consumers within a shorter period of time. Hence, this is technically realistic.
- One aspect that must be kept in mind is the uncertainty regarding the support policies for PV. The growth in adoption of PV can mainly be attributed to conducive economic policies by the government like the feed in tariff. But, the government has announced policy changes, for example the feed in tariff scheme will change in 2020 (Zelfstroom, 2017). There is uncertainty regarding what the new policy will be. This could have a negative effect on the adoption of PV which might impact the local community energy market.

When judging the economic validity of setting up a local community energy market, the following points need to be kept in mind:

- The profitability of the local community energy market is closely related to the policies instituted by the government. Even though there is uncertainty in the Dutch policies at this point of time, looking at the polices of other countries who have a more mature renewable energy / prosumer situation, it is reasonable to assume that the Dutch policies might also follow the same trend.

- In Germany, which was the first European country to institute feed in tariff schemes in 1991, the remuneration for feeding into the grid is much lower than the retail price of electricity for the end user. The German system reached this point after many changes in policy. The current Dutch system considers the net energy consumed that is, the difference between the energy consumed from the grid and the energy fed back into the grid is what the end user pays for. So currently, the energy fed back into the grid is remunerated at the same price as the retail cost of electricity (when energy generation exceeds consumption, the prosumer is paid a fixed renumeration which is lower than the retail price and varies according to the energy supplier) (Energieleveranciers, 2018). It is reasonable to assume that the Dutch system will also follow the German trend of making the feed in tariff lower than the retail price of electricity. At this point, there is a lot of economic incentive for starting a local community energy market.
- During the interviews with different stakeholders, there was a lot of enthusiasm regarding the new economic opportunities that would open up when a community energy market gets set up. For example, one candidate was considering installing a mini wind turbine in his garden, which would give him an advantage by allowing him to produce energy throughout the winter. The economic opportunities offered by a local community energy market coupled with the entrepreneurial spirit of the local residents is a potent mixture for success.

To sum up, the establishment of a local community energy market holds a lot of promise provided that the policies are conducive. Given the large number of government funded experimental projects that are incorporating the provision for peer to peer trading, it is reasonable to assume that the policies will be become friendlier towards local energy markets. Currently there are many projects/organizations that are circumventing the barrier posed by the policy that prohibits direct exchange of energy between two end users. For example the CRES (Community Renewable Energy Supply) organization from Ireland buys electricity from prosumers and sells it to consumers (CRES, n.d.).

Similar to the case of the local grid management function, a new entity is required to facilitate the local community energy market. This entity could be directly involved in the market by buying energy from the prosumers and selling it to the consumers or by acting in the side-lines by facilitating the exchange of the energy directly between two end users via a platform.

Setting up a local community energy market would ensure community control over the energy needs of the residents (as explained in 7.2). The local community energy market also involves using locally generated energy, hence there is a high perception of sustainability within the community.

Hence, to sum up, local community energy market will be economically viable provided that the regulations are favourable. Since the changes are expected in 2 years' time (by 2020), the time frame is ideal. This is because the cVPP project being proposed is Loenen is also estimated to take 2 years before it becomes operational. The cVPP project can be established in that time to facilitate a community energy market. Creating a local energy market can be the primary objective of the cVPP project.

9.3 The way forward for Loenen – summing up the techno-economic analysis

This research study indicates that the residents of Loenen have sustainability, followed by economic profitability and asserting community control as intrinsic motivations in the community which needs to be addressed by the cVPP. Based on the analysis done, establishing a community energy market as a first step and then managing the local grid for the DSO as the next step was seen to fulfil the motivations of the residents while also being economically sustainable.

The plan for setting up the community energy market hinges on regulation becoming more favourable for peer to peer trading. Due to the large number of pilot projects focussing on peer to peer energy trading (Zhang et al., 2017), the increasing prevalence of blockchain technology (which can facilitate local energy markets) and the fact that the cVPP project is estimated to take 2 years to become operational, there is a possibility that regulations would change to facilitate establishment of a local energy market.

The amount of participation is key for the success of using the cVPP for managing the local grid. It is also important that local grid management must start soon after the next grid upgrade cycle for maximum effectiveness. Since the Loenen grid has a lot of spare capacity, the grid upgrade will not be happening for years to come. Hence during this wait time, it can be assumed that the participation in the cVPP project will increase as the local energy market will be set up first. When the grid upgrades eventually happen, there would be enough participation to ensure the profitability of the local grid management initiative too.

The cVPP project at Loenen is a game-changing initiative that tries to tackle the challenges brought up by decentralized generation. One important aspect that must be kept in mind is the fact that this is a pilot project with funding from the EU. Due to the availability of funding, the process of setting up the cVPP and convincing people to become a part of it is easier. The experience would be different if a project is started by members of a community, without large external funding or support. Even though the basic motivations mentioned in this report would be present in varying degrees, convincing people to take collective action would be more difficult. So, even though the framework matrix, that matches social motivations to technical functions is designed to be general in nature, the difficulty of getting a common consensus and actually implementing the project would vary depending on if it is a pilot project with economic backing or not.

10 Limitations of the study

Great care was taken to ensure data accuracy during the different analysis conducted in this thesis. Nevertheless, there are some limitations that must be kept in mind before discussing the results of the thesis.

The thesis composes of a social part and a technical part. The social part is prone to biases as many of the opinions expressed (for example in the interviews) are very subjective in nature. In the technical part, difficulties were faced when obtaining technical data like the actual energy consumption of individual households (due to privacy concerns) and economic data like the actual cost for setting up a VPP (due to the sensitive nature of such data from the point of view of companies in the VPP sector).

This section discusses the different limitations of this thesis that must be kept in mind before discussing the main conclusions. The following are some of the general limitations:

- The thesis started by analysing a database of pre-existing VPP (or similar) projects that was made by the consortium developing the cVPP (Interreg_NWE, 2017). Even though the database had 50 different projects in it, the majority of them were from the Netherlands, Ireland and Belgium as the cVPP consortium is currently focused on setting up pilot projects in these 3 locations.

- To determine the specific social motivations, present in the Loenen community 6 key stakeholders involved with the cVPP project were interviewed. Even though each candidate was knowledgeable about the cVPP project, the social dynamics in Loenen and renewable energy in general, the number of interviewees is still limited, and their opinions would carry personal biases. It also proved difficult to find an interview candidate who is opposed to the cVPP project. Since this is a very new concept, there was not enough knowledge among the community during the inception phase to form views that oppose this project. Conducting more interviews after the project has been established and finding points of opposition against the project has been stated as an interesting avenue in the future works section. The scoring of the different social motivations by the interview candidates are also susceptible to biases.

Apart from these general limitations, the next two subsections list out the limitations that are specific to the techno-economic analysis. The last subsection deals with the storage aspects of the cVPP.

10.1 Limitations of local grid management analysis

The following are the limitations of the analysis for the local grid management by the cVPP:

- Since the real house wise consumption data of Loenen is not available, a model is used to obtain the consumption profiles. Even though this model was proven to be accurate, there are still some uncertainties as this is an approximation.
- In the Gaia network model of Loenen we cannot distinguish between residential and non-residential customer. The connections which had E1 and E2 profiles are switched with the new profiles from the residential load model, because these are categorized as “small customers”.
- The costs for grid upgrades found in (Gombert, 2014)is an approximation by a major Dutch DSO.
- The capital costs and the maintenance costs of a VPP obtained from the VPP company are approximations. Given the difficulty of obtaining actual costs for a VPP, this is the best assumption to use.
- The 2.4% exponential growth load per year is an assumption from (PhasetoPhase, 2015).

10.2 Limitations of local energy market analysis

The following are the limitations of the analysis for the local energy market:

- Like the previous analysis, a model was used for the house wise consumption profile due to lack of real data.
- The estimated generation of the PV panels in Loenen is taken from an online source (Renewables.Ninja, n.d.).
- To simplify the analysis, it was assumed that all the panels in the area have the same solar insolation on it (that is they have similar generation profiles). A similar assumption is made in the research paper (Long et al., 2017) where the optimization equation for the number of PV panels is developed.
- There is uncertainty on how the Dutch feed in tariff will change in 2020.

Most of the limitations were due to the lack of real data. Substitute data was taken from reliable sources to circumvent this issue hence the error would be low.

10.3 The question of storage

Storage is a very important component in many of the VPP projects. Any project involving renewable energy would benefit from the inclusion of storage assets due to the inherently stochastic nature of renewable energy generation. Storage also plays an important role in mobilizing flexibility for local grid management and demand response.

This thesis uses the cVPP project being developed in Loenen village as a case study. The consortium that is building this cVPP project does not plan on using storage assets in the first phase of this project. Since this thesis intends to make the consortium aware of the general social motivations in the Loenen community and the possible ways in which it can be met, storage aspects have not been considered in the techno-economic analysis.

In the case of local grid management, inclusion of storage assets would enable the option of storing excess energy during off peak times and using it during peak times. This will allow a more efficient method of flexibility utilization. In the case of local energy markets, storage would enable prosumers to store energy when the selling price of electricity is lower and sell when the prices are higher. Likewise, the consumer can buy excess energy and store it when the prices are lower and to avoid buying electricity when the prices are higher. Even though the addition of storage assets would cause the initial investment to go up, the benefits mentioned above along with the fact that the prices of batteries is expected to drop (Zart, 2017) makes storage assets an attractive option.

Analysing the potential of storage in the Loenen cVPP project, once the initial phase of the project has been completed would be an interesting exercise and has been mentioned in the future works section.

11 Conclusion – Aligning the social motivations and technical functions

The main aim of this thesis is to understand how the technical aspects of a cVPP can be modelled to satisfy the social motivations that are expressed by the community. This is expressed through the main research question – "*How can the technical functions of a cVPP project be aligned to the social motivations of a specific community and what are the technical and economic benefits derived from these technical functions?*".

After understanding how the technical functions and social motivations interconnect (through the matrix framework developed in 7), specific technical functions for the Loenen cVPP project is suggested after analysing the motivations within the Loenen community. Finally, the technical aptness and the economic validity of the proposed technical functions is assessed.

It is seen that a cVPP can have 4 basic technical functions:

- Offering ancillary services by participating in the balancing market
- Trading in the wholesale energy market
- Offering local grid management
- Setting up a local community energy market

Out of these 4 technical functions, the first 2 (ancillary services and wholesale energy market) are functions that are more external focussed with respect to the community. The locally generated energy is used externally to benefit the entire system as well as the community. The last 2 technical functions (local grid management and local community market) are more internally focussed. The locally generated energy is used within the community itself.

When cross checking the social motivations and the technical functions in light of this classification of being internally focussed or externally focussed, it is seen that, if profit is the primary motive of a community and other motivations like community control, social cohesion and using self-generated renewable energy (and improving the perception of sustainability within the community) is not so important, then the externally focussed goals would be the best fit. On the other hand, if community control, social cohesion and using locally generated renewable energy within the community is similar (or greater) in importance to profitability, then the internally focussed goals would be a better fit. This is summarized in the figure below:

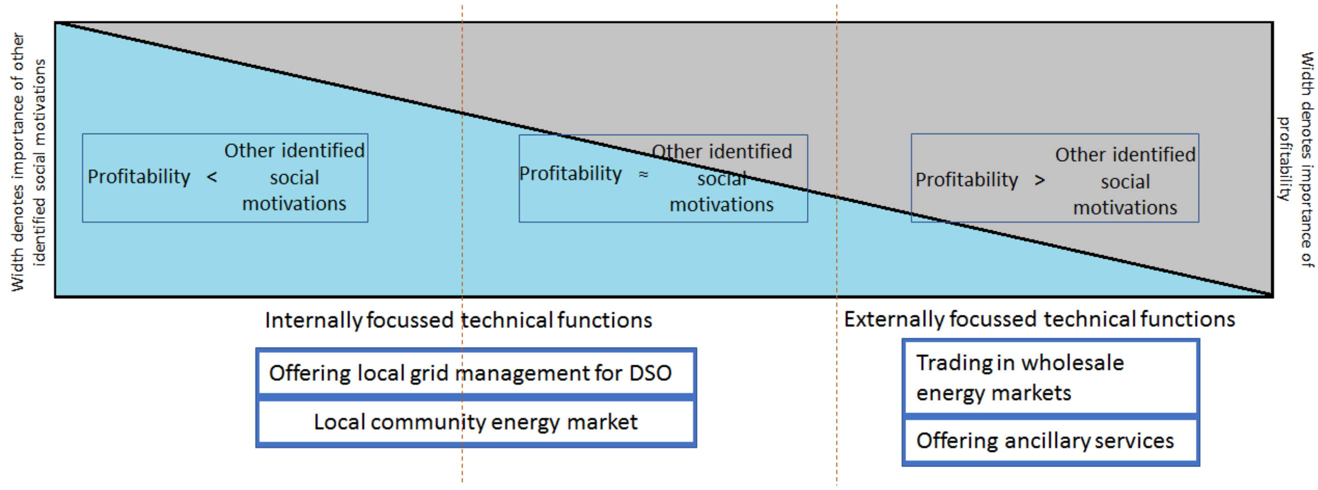

Figure 15: Effect of the balance between importance of profitability and other social motivations on the choice of the ideal technical function

The width of the blue part in the figure denotes the importance of the social motivations of community control, social cohesion and perception of sustainability within the community. The width of the grey part in the figure denotes the importance of the social motivation of profitability. In the region where profitability is less important to the other social motivations or is as equally important to the other social motivations; internally focussed technical functions are ideal. In the region where profitability is deemed to be more important than the other social motivations, externally focussed technical functions are ideal.

At the start of this thesis, a community energy project is defined as a project related to energy, initiated by a group of individuals who share similarities like a common location and/or a common set of interests or goals (Klein & Coffey, 2016). An important aspect is that the costs and benefits of this initiative are usually distributed among the participants. It can be argued that the benefits are more distributed among the community in the case of the internally focussed goals. Hence projects with internally focussed goals are more community oriented.

This can be seen in a different light when considering that many of the existing VPP projects are top down and externally focused. Profit is assumed to be the main driver of the end user, and there is a lack of the sense of community in these projects.

This dichotomy of internal and external focus can be extended to any community project. The more internally focused a project is the more benefit the community derives from the project.

Another key aspect to keep in mind is that social motivations are not fixed. They evolve with time. For example, an interview candidate commented that at the initial stage of the cVPP project, community control is very important. But once the project progresses and the participants see that they can trust the project partners, the importance of community control decreases. Hence it is reasonable to expect that a project can start by being very internally focussed but eventually grow to develop a broader, external focus.

There are some novelties in this thesis, for instance:

- The interconnection of the social motivations and technical functions is done through the help of a framework that is defined after research (explained in section 7). This framework is initially designed to be general in nature and then it is modified to fit the context of the case study. The general framework can be applied to any community based VPP project to understand which technical functions to focus on. Before application of the framework, it must be adjust based on the political context (based on the current policies).
- The list of basic social motivations (explained in section 5.2) that are used to build the general framework would hold true for any community-based energy project. This would be a valuable starting point when initiating such projects.
- Most of the previous research on VPPs assign a very inconsequential role to the end user. The primary driver for their participations is assumed to be economic motivations. This thesis shows that while profitability is an important driver, there can be other drivers that are equally relevant and hence must be accounted for.
- The cost estimates for a cVPP project are novel in nature. Most of the previous research focuses on the technical aspects. The cost estimates can be a valuable reference for future research into the cVPP concept.

This thesis is intended as a starting point for communities designing a cVPP project. The intention is to make them aware of the social motivations that might be present in the community and the possible ways that they can be satisfied. It is up to the community to make an informed decision after assessing the requirements of the different course of action.

The social acceptance of the cVPP concept will be better because the social motivations of the community is gauged before it is designed. A follow up study on how far the motivations have been met would be interesting (and has been mentioned in section 12).

This is also a model for other communities on how to go about establishing a community project – starting by understanding the needs within the community and how the project could be structured to meet these needs and motivations.

12 Future work

One of the main challenges faced when getting opinions of the residents of Loenen regarding the cVPP was lack of knowledge. Since the cVPP was a new and technical concept, people did not know what to expect. When respondents of the interviews were asked if they had any reservations regarding the cVPP project, even though, most of them were optimistic, many admitted that the concept was so new that people really didn't know what to expect.

A follow up study once the project has been fully established and running for a while would be ideal to gauge the reactions of the people.

Since the cVPP project in Loenen is being done as part of a consortium which has other similar projects in Belgium and Ireland, it will be interesting to apply the matrix framework that matches the social motivations and the technical needs to these projects. Since the framework was designed with the Dutch regulations in mind, it would need to be modified to fit the context of the different projects. Still the core of the framework, namely the basic social motivations and the technical functions would remain the same. This would help strengthen the framework and validate it.

The consortium has decided to not use storage assets like batteries in the first phase of the project. This is why, even though storage has many benefits, it has not been considered in the techno-economic analysis. In later stages of the project when storage assets are introduced, it would be interesting to recalculate the profitability and economics of the project. Comparing the economics of the scenario mentioned in this thesis (without storage) to a scenario with storage would help in understanding the added benefits of storage assets and help the community make a decision regarding storage assets.

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Appendix

Appendix A - Summary of a random sample of projects from the cVPP consortium database

Short summaries of a sampling of projects selected randomly from the cVPP consortium database are presented below:

Fenix project

This was a project primarily focused on R&D. The development was led by Iberdrola (Spanish utility) and was partially funded by the European Commission (Kieny et al., 2009). The concept was tested in the UK and in Spain. The main aims of the project were (Olejnczak, 2011):

- Identifying the contributions that DERs could offer to existing networks
- Investigating the feasibility of using aggregation of renewable generation as a strategy to overcome the challenges posed by size limitations and stochastic generation
- Understanding the interactions between stakeholders
- Developing software to facilitate the architecture

RWE Smartpool project

This was a project initiated in 2008 in Germany. It was a joint collaboration between German utility, RWE and Siemens. The project is mainly aimed to develop the IT system of this architecture (Bayar, 2015) and to prove the technical and economic feasibility of the project (Olejnczak, 2011). The project was mainly aimed to convince the utilities and grid operators about the feasibility of this concept.

DeMo Tec VPP

This was a project carried out by ISET (Institute for Social and Economic Transition) in Germany in 2009. This project focussed on the technical aspects of a virtual power plant architecture (Braun & Ringelstein, 2009). The project studied how effective different control strategies were to achieve management of active and reactive power on the network.

GasUnie Micro-CHP VPP

This was an experimental project carried out in 2007 involving 10 households in Meerstad, North Netherlands (Leduc, Wouter R.W.a., 2006). It was carried out by GasUnie, the Dutch natural gas and infrastructure company. The aim of the project was to determine the level of peak load reduction by deploying micro-CHP units connected in a VPP. This could lead to avoidance of network expansion investments to meet the growing peak load demands.

City-Zen Amsterdam

This is a recent project the project was initiated by Alliander and Greespread, a large scale solar PV developer in the Netherlands. The project aims to improve the energy yield of the residential solar panels connected in the project and enable a local exchange for surplus energy among the participants. The project mainly aims to test the VPP concept and scale it up (AmsterdamCity, 2017). The project looks at the positive impact that the VPP can have on the grid and tries to answer the question – should a DSO (Distribution Service Operator) invest more on financial incentives for end user participation is such programs instead of focussing entirely on grid expansion?

AGL VPP

This is an ongoing project by the Australian government in collaboration with Sunverge, a company that provides energy management and storage solutions. The project aims to connect 1000 individual solar battery systems located in both residential and commercial premises. Australia is having a very large penetration of renewables and is facing grid management challenges. The main goal of the project is to test the potential for the VPP architecture to help stabilize the grid (Abramowitz, 2017).

DR BOB

This is an ongoing project that has been rolled out in multiple locations – in UK, France, Italy and Romania (Teesside University, 2016). The main aim of this project was to develop and validate ICT solutions for demand response in blocks of buildings. Different assets like CHP, solar panels and woodchip boilers are interconnected to enable demand response.

Hybrid PP4DSO

This project ran from 2015 to 2017 lead by the Austrian Institute of technology. The main goal was to identify how VPPs could be of use to meet the challenges caused to the distribution grid due to the proliferation of renewable generation (Austrian Institute of Technology, 2014).

Appendix B - Summary of pre-existing community-based energy projects

A brief summary of pre-existing community-based energy projects is given below. The social motivations behind community energy projects have been synthesized by analysing these projects.

Burntisland Energy Master Plan:

The Burntisland Energy Master Plan was developed by the Fife county in Scotland to reduce the carbon foot print of the local community in Burntisland (Fife Council, 2016). The project was conceived in response to the environmental targets set by the Scottish government. The government had set targets of achieving a 80% reduction in greenhouse gases by 2050 (Fife Council, 2017).

The plan developed for Burntisland ultimately aims to reduce the carbon emissions of the community by 80% by 2032. The project looks at different aspects of the community like energy consumption, transportation etc and identifies different strategies to reduce the carbon emissions.

The main motivation behind this project was the reduction of carbon emissions of the community to meet the goals of the Scottish government.

Middlegrunden Wind Farm:

This is a Danish wind farm project that has been operational since 2001. 20 wind turbines were installed off shore near the Copenhagen harbour as part of the project (Simcock, Willis, & Capener, 2016). The project was conceived by the Environment and Energy Offices (EEO) established by the Danish government to provide support for energy saving measures and sustainability practices in the country.

The project was also developed in close collaboration with the residents of Copenhagen. They were involved from the planning phase of the project. The opinions of the residents were a major influencing factor in the development of the project. For example, number of turbines were reduced from 27 to 20 and the layout of the turbines were altered after consultation of the residents. The turbines were placed in a curved formation to mimic the historic defences that Copenhagen had in the past. The residents felt that this layout would fit with the city's history and identity (Simcock et al., 2016).

This project was conceived as a result of the Danish governments need for sustainability and was implemented smoothly because the local community's opinion was valued from the start of the project. The local community was also allowed a large amount of control on the development of the project.

Hvide Sande Wind Farm:

This was another Danish project that installed 3 wind turbines in the port town of Hvide Sande (Simcock et al., 2016). In 2006, private investors approached the community to ask permission for building windmills. There was a prevalence of private developer led wind farms in Denmark during this time. The Hvide Sande community resisted the influence of external players because they felt that the benefits they received would be less. Instead they decide to form a charitable trust and set up the windmills themselves.

Hvide Sande was a rural community and it was dependent on the local harbour for jobs and income. The harbour was in need of modernisation but there was a lack of funds for this. Setting up the windmills and selling the energy in the Danish national grid was seen as a method to finance the modernization of the harbour which would revitalize the community.

In summary, the Hvide Sande Wind Farm was set up to resist the influence of external entities on the community and to generate income for modernizing the harbour which was critical for the community.

Jühnde bio energy project:

The project was started to make the Jühnde community in Germany, self-sufficient in terms of heat and electrical energy. The village is located in a remote area and they had to depend on unreliable supplies of heating oil. The prices were also high. This was the spark that led to the bio energy project. The case study says that rather than using money from the project to invest in other community projects, the main aim was to provide low cost heating and electricity (Simcock et al., 2016).

The residents of the village who bought shares were the producers and consumers of heat and the electricity. These shareholders could purchase cheap heat and electricity at prices that was determined by the residents themselves. This meant that the profit margins were low, but the need for cheap heat and energy was satisfied.

Ensuring cheap electricity and heat was the main motivation behind the inception of the Jühnde bio energy project. The profitability of the project was not of concern.

Wiltshire Wildlife Community Energy Project:

This is a British project that was started primarily to safeguard the local landscape (Simcock et al., 2016). The local community was against wind turbines because they believed that these would spoil the natural beauty of their surroundings. Instead of wind turbines, they opted for ground mounted PV farms which they deemed to be less visually intrusive. The profits generated from the sale of energy was used for local development projects. A wildflower meadow was incorporated with the PV farm so that the landscape retains its natural state.

The main reason for the inception of the Wiltshire project was to control the changes of the local landscape by preventing the installation of wind turbines.

Brixton Energy Project:

This is a project that has led to the establishment of rooftop solar PV panels on various residential buildings in the district of Brixton in London (Simcock et al., 2016). Some sections of the Brixton community faced fuel poverty and were not economically strong. The project aimed to supply renewable energy to the community members in need and sell the excess energy to the grid. The profits from this was fed back into the community and used for community development.

Another driver behind the project was to address the lack of opportunities in the economically poorer section of the community. The project provided internships and vocational training to youngsters within the community which contributed to their development.

The 2 primary motivations behind the inception of the Brixton project were the need to address fuel poverty and lack of opportunities in some sections of the community.

Cwm Arian Renewable Energy Project:

This is a community wind energy project that was planned in the Cardigan area of West Wales. The local school was closed in 2003 and the local community staged a protest against this. There was a need for funds for community development. A wind energy project was planned so that the energy generated can be sold to the grid and the profits could be used for community development (Simcock et al., 2016). The project was unsuccessful because the community was denied planning permission by the local council.

The lack of funds for community development was the main motivation behind the inception of the project.

Horshader Community Wind Project:

This is a Scottish community energy project that was started to resist private wind farms similar to the Hvide Sande project described previously. The Horshader community was approached by private wind farm developers with a proposal to set up wind turbines. The community was offered a financial incentive for the use of their land. The locals resisted the proposal and this acted as a catalyst for them to start planning their own community owned wind project (Simcock et al., 2016).

A 900kW turbine was established in 2012 and the community established an energy trading company that sells the generated energy on the national grid. The income was used for community development projects like alleviating fuel poverty, revitalizing the local shops and the local museum.

The main driver for the establishment of the Horshader project was the resistance to the influence of external wind farm developers.

Gigha Windfarm Project:

The isle of Gigha is a small island off the west coast of Scotland. Historically the island was owned by wealthy landlords since the 1860s who allowed the community to live on the island (Couston, 2012). The island was bought and sold numerous times. The last private owner went bankrupt and for a period of time, the island was owned by a national bank. This caused many problems for the residents as they began receiving eviction notices from the bank. This history of numerous owners who were mainly profit oriented meant that the island was treated as a commodity and the development of the local community was not prioritized. The population of the island declined as residents left their homes in search of more stable living conditions.

The community decided to buy the island from the bank. They borrowed money from external organizations to purchase the island and regained control over it. To repay the loans they decided to set up 3 wind turbines on the island (Hielscher, 2013). The energy generated from the turbines was sold on the national grid and the profits were used to repay the loan and develop the community.

The Gigha community wanted to regain control of their land from private owners. The need for control lead to the establishment of the energy project on the island.

Anafon Community Hydro Scheme:

This project was established in the small village of Abergwyngregyn in Wales (Walton, 2012). This rural community was facing the withdrawal and underdevelopment of local services like pubs and shops. The community decided to establish a hydroelectric project to get economic resources for local development and revitalization of the community. The project was headed by the Abergwyngregyn Regeneration Community which was established to improve the social and economic wellbeing of the residents.

The primary motivation behind the inception of the project was the need for funds for community revitalization.

Fintry Wind Farm Project:

Fintry is a small village in central Scotland. The community is rural in nature and was not very wealthy. A large portion of the residents faced fuel poverty because the village was not connected to the main electricity grid and was dependent on fossil fuels for their energy supply. There was also a lack of development of local amenities in the village. This lead many residents to move away from the village in search of better living conditions.

The Fintry development trust was established to revitalize the community and reduce its dependence on fossil fuels. They entered into a partnership with a private wind farm developer and gave them permission to set up a wind farm on their land. The trust used the money it got from this project to develop the local amenities of the village (Couston, 2012).

Two critical goals of the Fintry community, namely the development of local amenities and reduction of dependence on fossil fuels were met by the Fintry windfarm.

Point and Sandwick Wind Farm Project:

This project is located on the Isle of Lewis, near the north west coast of Scotland. Like the previous case studies in rural communities, this community too faced the lack of amenities and jobs. The residents were moving out of the community in search of better opportunities elsewhere. Being remote in nature, the community was also affected by fuel poverty. The locals established the Point and Sandwick Development Trust and created an energy trading entity within the trust. They built a 9MW turbine and the energy from this is sold on the national grid. The profit from the sales was used for community development projects. The community tries to minimize outside influences on their projects by using the trust structure (Couston, 2012).

The main driver for setting up the wind project was to give the community a sustainable source of income to support local development.

Appendix C - Interview protocol

Opening statement:

(Explain the concept of a community Virtual Power Plant to the interviewee and answer any questions that might arise. Hand over the interview aid. Hand over the consent form and get approval for the interview.)
Good morning. Thank you for agreeing to participate in this interview. I am a master student at Tu Eindhoven, under the Sustainable Energy Technology program and this interview will be used as a part of my graduation thesis. As I explained earlier, my thesis focuses on matching the social motivations that Loenen community might have to set up this community virtual power plant project, to the technical goals that can be achieved by the community virtual power plant. The main purpose of this interview is to explore possible social motivations the community could have and the technical goal that is apt for the community from the point of view of a key stakeholder such as yourself. If you are ready, we can commence the interview.

Questions:

<u>Question 1:</u> Could you please start by saying a bit about yourself? Are you (personally) or the organization you represent involved in any sustainable energy related activities?

<u>Question 2:</u> Do you think this community Virtual Power Plant project is beneficial for Loenen? Why/ why not?

<u>Question 3:</u> As I mentioned, in my explanation, I have identified different reasons that a community as a whole could have, that motivates the setting up of a project like the cVPP. According to you, is there any other possible motivation that could be added to the list?

<u>Question 4:</u> Working with these motivations that have been identified, how would you rank them according to importance, in the context of Loenen? Could you also explain why you have made these rankings?

<u>Question 5:</u> During my research, I have also identified different technical goals that the virtual power plant project could satisfy. Do you feel there can be other technical goals that could be accomplished?

<u>Question 6:</u> Keeping in mind the previous social motivations that have been ranked according to importance and the existing practical constraints like the government rules and regulations, which technical goal or mix of goals do you think is suitable for Loenen? Could you explain why?

<u>Question 7:</u> With your knowledge regarding government policies and the existing uptake of PV panels in Loenen, how would you grade the uptake of PV panels in 20 years on a scale of high, medium, low?

<u>Question 8:</u> As you probably know, there are plans by the Dutch government to gradually phase out gas heating. There are alternatives like electric heating, district heating, using biogas etc. On a scale of high, medium, low how do you rate the level of adoption of electric heating in Loenen in the next 20 years?

Question 9: Electric vehicles are becoming more prominent nowadays. With your observation of current trends and/or policy, how would you grade the adoption of EV in Loenen?

Question 10: Micro-CHP systems allow home owners to generate their own heat and electricity. With regards to your knowledge of current trends and/ or policies, how would you grade the adoption of Micro-CHP in Loenen?

Appendix D - Interview consent form

The following consent form was given to each of the interview candidates to get their permission to use their names in this report.

Interview consent form

Research project title: Implementation of Community Based Virtual Power Plant

Research investigator: Siddharth Raghav Murali (Student ID: 1283030)

Research participants name:

This interview is being conducted as part of an academic **master thesis** to satisfy the criteria in the program, **Sustainable Energy Technology** offered by **Eindhoven University of Technology**. By signing this form, you agree that you have understood the following:

- You have the right to stop the interview and withdraw your participation at any point of time.
- You have had the purpose of the project explained to you and have had the opportunity to ask questions about the project.
- You can choose to be anonymous (in which case a pseudonym will be used when referring to you). Please state if anonymity is desired: **Yes / No**
- This interview will be recorded, and a transcript will be produced which will be used for the master thesis. Access to the interview transcript will be limited to Siddharth Raghav Murali and academic mentors and colleagues with whom he might collaborate as part of the research.
- You can request for a copy of the transcript from the research investigator, to verify the contents.
- You will receive a signed copy of this consent form.

Research participant's signature: **Date:**

Research investigator's signature: **Date:**

Appendix E - Interview transcripts

In the transcripts the researcher is referred by the letter R and the stakeholders are referred by their initials.

Han Meurs

R: Thank you for agreeing to participate in the interview. The first question is, could you start by saying a bit about yourself and more specifically about your involvement with renewable energy?

HM: Well, I am a member of Loenen Energy Neutral, from the start, so up till 2013 I think. I have been a member of DEA, Duurzame Energie Apeldoorn, that's the cooperation in Apeldoorn and I work now for the community in Apeldoorn. Because I am a member of DE, this is why I got the opportunity to work for the community in Apeldoorn, starting this April for the next 2 or 3 years. I have PV from 2011.

R: Oh, did you get it as part of the scheme started by LEN?

HM: No, I was an early adopter. I am always too fast or too slow. They are on top of the cow shed, there are 64 PV panels. In 2011 and 2013, 2 installations, together 64 in total. From 2013, I have a solar water heater. I had a semi-electric vehicle from my job (a company car) and last Friday I bought my own hybrid car. So it runs on fuel and electric. I use my own energy because I have over-capacity (from the PV panels).

R: Oh, you don't have a battery in your house?

HM: No I don't have one. I feed energy back to the grid. I am a member of the DEA which is also an energy company labelled under Green Choice. So for the first 1000kWh of over capacity you get a regular price, you get 21 cents or something. But since I have this car, I am self-sufficient. A little bit over capacity now but that's minimal. So that is also why I got involved in Loenen, because it is a necessary thing. I find it interesting. And with my banking background, I know that it also has to be economically sustainable. So that's what I have been involved with, in terms of sustainability and measures for the environment, not only for the future generations but it has to make sense for the current generation.

R: Ok. So, I know that the cVPP is in the planning phase, but are you involved with that too?

HM: yes, I have a roof free. So I can put more PV panels and coincidentally yesterday on… I am pro wind energy, and this topic is a heavy discussion in this country. Yesterday in my LinkedIn network I saw one posting, a mini windmill system. Not one that's 150m high but with an acceptable output – 1000 W. So I was triggered. I am looking at this option. I want to be an energy producer in this cVPP situation. This was my goal from five six years ago. I have a big roof, and I have a business unit in my house (he grows meat cows and packages and sells the meat) so for permits etc, for me it is easier than when you are a citizen. So that is ideas that I have and I hope to bring into the virtual power plant solution.

R: I don't think there is wind now in Loenen right?

HM: Yes, but it is necessary. Other wise we will have less production in winter and the night. And combined with a battery system there is so much to do in that business. And there is so much evolution happening every day and there are new things daily. I think that hydrogen gas is the future.

R: Ok. Do you think the cVPP is beneficial for Loenen? Why? Why not? What is your opinion on it?

HM: It is a very nice opportunity to be an early adapter. When you read about it there are many more kinds of that project in Holland. But I think, because we did something very good with Loenen Energy Neutraal we have a good standing in the community and we have a few people who are really good with their background in the energy transition so all together that is a nice opportunity to get such a goal done here.

R: And you think that it will benefit the community?

HM: Oh yeah, certainly. Because in the past there was no gas or electricity. You have to fix it in your own situation and the best is to get it on a community scale. That could be something for the future, I think.

R: Ok, so its more like the strength of the community that is on the topmost.

HM: Yeah.

R: Ok, as I mentioned in my explanation I have identified the four motivations – the economic one, the community control, social cohesion and using renewable energy within the community. Do you think there could be something else added to this list?

HM: My opinion this is very complete. You have mentioned the most important things. At this moment I cant think of anything that might be missing from this list. Only in the ranking of this but..

R: Yeah that's the next question actually. How will you rank it?

HM: It needs to be economic otherwise it is not sustainable.

R: Ok, there could be a difference maybe, that you can draw between being economic and making it for profit.

HM: There is equipment you invested in and you have to earn it back. Because with time they go down (degrade) and you have to reinvest. So that profit you need to make and when you participate in it you have the cost of capital. So that's the situation we live in in this world. I cant make it worse or more or beautiful than its is. So that's also, when you do only idealogic, the whole mother planet and all, that's not going to work. For a long term. So economic sustainability is important and that what I rank first. Then you come with the community thing, (using renewable energy within the community) to do it together for the whole community, so the social cohesion comes out of that. When you do things together, you get the social cohesion and then the control thing (community control). Its already there. You cant without Alliander and the companies who have the infrastructure. You cant do it without them.

R: So to sum it up, you ranked the economic aspect first, then perception of sustainability, then social cohesion and finally community control?

HM: Yes, that's correct.

R: So, when you rank it like that, looking at the technical things that you can do with the VPP do you think that there is something else that can be done? Other than the technical functions that I explained to you previously? Was there some other discussion in LEN regarding other goals?

HM: Not that I know of at this moment. Also, you have prepared it well and these are things that I could think of. And I see it, with my knowledge like this – Alliander is already there, like I said before and you can help them because they need to do something (about grid congestion). I think the higher goal is that you need to manage on a local scale, input and output so that you have an efficient system. And that “sell on the market thing “(trading in the wholesale market), that is a few stations further away, when we have a great over capacity then it can be actualized but not on first base. First base is to get our own local energy need filled out. And when that is fixed, yeah then you can look further. But this is my way of thinking, we can make it very big and then Loenen delivering the whole power production of Apeldoorn, that is too opportunistic (too high of a target to set initially). So I stand a little bit with 2 feet on the ground and I like looking forward, forward thinking, but it has to be practically done.

R: So, when you say local, then the things would be – the local energy market and helping Alliander manage the local grid. But the problem right now with the regulations, for example the local energy market, you cannot trade energy with someone else, that is how the government regulations are. So keeping these in mind, then are you saying that ok, its ok to wait a bit till the regulations change. And I think they will change soon.

HM: No, politics and regulations… I like bottom up. Everything that is going top down, you don’t get accepted in the community and it takes time. I think from a right bottom up process, you can also influence politics and those who make the rules that you cant sell energy at this moment to your neighbour. I think 6 or 7 years ago, I laid 64 panels but I needed only 30, I thought, my neighbour has a roof where he can lay panels so I sell my excess energy to my neighbour. And he thought – good idea, but this is not possible. That’s why there is the postcode roos[10] that is necessary for that kind of solutions. But we are five years further and now its coming up and its possible, but you need to do a lot of paper work and it takes a long time. I think you need to deal with the regulations, but the political sense of urgency, its every day in the papers that we need to make action, because we don’t get it fixed in the real term. They talk about 2050, I am dead already I think, so we need action now. I think politically, we need a lot of help even for the VPP solutions and I think that this kind of initiatives (the cVPP project) can help to make the changes.

R: Ok, so the next part is regarding the scenarios, how you think the technology will develop in Loenen. For example, PV I think you guys are really far ahead.

HM: Yes definitely, because of our initiative (the initiatives started by LEN) we have more than average solar panels (when compared to the rest of the Netherlands).

R: Ok, but I wanted to ask you about what you think regarding electric vehicles and heat pumps. Looking at the current regulations and how you think it might work out in the future? Like what the scenario will be?

HM: Basically a combination, because in this country we cant go all electric. Because they have to increase the grid capacity a lot, and that’s not possible. So I think that in the future it will be a mix between, PV, hydrogen gas,, and the heat pumps, we have a combination. Depends on if you have an existing house or building a new one. They are building new houses here (in Loenen) and they are building in an old fashioned way. Not energy neutral. That was ok by the policy 1 or 2 years ago. And now they are talking about no gas (natural gas for heating) but one year ago it is legally required that you get a gas connection. This is going to change. So the existing infrastructure which use natural gas can be used for other gases like biogas etc because we can not use 100% electricity. And in my situation I also have a solar water heater and even there you can put a hybrid heat pump. So I can use my solar electricity in the heat pump and I use less gas or wood. Also I am a big supporter of

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[10] A Dutch system where citizens can invest in installing solar panels with building with large roof areas (in the scenario where their own roofs are unsuitable) like the local town hall or industries etc and they receive a tax break instead.

wind, I am looking to put a mini wind turbine in my back garden. But I don't know the economic consequences.

R: Well I surely think that if the local energy market happens in Loenen, it will be advantageous to have a wind turbine. Especially during the peak hours in the night, and it makes economic sense if you can sell energy in the night.

HM: Yes, that the virtual power plant idea, so the system can put on my washing machine in the night when there is power that is not used. I understood this is also possible in the cVPP. But I heard it is some what sophisticated. Like my car, I put it on the charger and it charges at the moment when the grid says there is too much power but this might be difficult because I need energy when I need to go somewhere, so I cannot let the grid dictate when the car gets charged. This is why I think that this (the demand response) is a bit sophisticated.

R: Sure this is called demand response and there are companies working on this. But the problem is sometimes people don't want Alliander to say when you can run your washing machine.

HM: True, so I thought batteries can be a solution. But its production places a lot of demand on the environment. This is why I said earlier that H2 can be a good solution. In the future, they will make H2 with the excess electricity. So then we don't need batteries anymore. So back to your question, I think electric vehicles will be a major part, but it is a mid term solution and finally it will go to H2 gas vehicles. And as I said it wont be 100% electric heat pumps but hybrid systems.

R: Ok, thank you so much. This was a great first interview.

HM: Your welcome.

Femke Jochems

R: So, please explain your role with renewable energy.

FJ: Im Femke Jochems, and I work at the OVIJ. There are several OVIJs in the Netherlands and they carry out tasks for municipalities and provinces with regards to the environment. And sometimes also sustainability, so the Gemeente Apeldoorn has asked us for advice regarding energy and sustainability. And I am a project coordinator for the Interreg project on cVPP so I try to gather everyone at the municipality and get everyone to the table and organize the projects. But I am not as such someone who makes policy in the Gemeente Apeldoorn. I am really more like a facilitator.

R: So basically then you have the overview of the going ons.

FJ: Yes, but I am very focused on the cVPP project.

R: I wanted to just hear your comments. Do you think that the virtual power plant is a good idea for Loenen and why or why not?

FJ: For Loenen specifically?

R: Yeah

FJ: Ok, I think it's a good idea. I thinks it's a very nice concept and as I have been involved in this project I have been reading up on concepts like VPP and smart grids and I am not a technician myself so I understand it somewhere half way. But from what I understand I think it's a very good idea for Loenen and for the community. They are already very much involved with solar PV themselves and I think they can really benefit from it. And I like the concept. So for me personally, I really like the concept that as a community you can be off the grid and independent.

R: As I mentioned I have identified the different social motivations, do you think there should be something that can be added?

FJ: Well economic is important, I think they must earn money from the project. Community control, perhaps you can think that community control can be from different motivations. So it can be positive, like you want to make your own energy. But it can also be a negative, like it can be in response to not being in control of your energy, or you have to pay too much or you feel like you don't have any energy security. So its more of a negative reaction to something than an intrinsic value. Social cohesion, well I understand that it might be a motivation for a sustainability project but what I understand from VPP in general now is that it might be a complex process so I can imagine that social cohesion will be a by-product and if your motivation is to increase social cohesion then the VPP might not be the project you would choose because it is quiet complex and you may have simpler projects to choose from if you aim at increasing social cohesion. And the perception of sustainability, I think that's a very good one. I had a meeting in Apeldoorn last week also about the VPP and you get the sense from the people working with it that it is an increasingly important idea. And they also mentioned powerpeers- a local energy market. In the Netherlands it is created by Vattenfall and Nuon. So basically it is created by large companies and the idea is that you can subscribe or buy your energy from someone in your vicinity. Like from the solar PV on their roof across town. It is more of a perception of a community on the internet, but the criticism of it is that it is from a large company. Basically more a business model or a marketing strategy than a community initiative.

R: Ok, so given these different motivations, that you have identified, how would you rank it with regards to Loenen?

FJ: I would say that community control would be the first motivation and.. oh no I think the perception of sustainability within the community would be the first and then community control, then economic support and then social cohesion, but that's because I see social cohesion mainly as an outcome.

R: You would have an idea of the policy and things like that right?

FJ: Yeah.

R: So, for example P2P energy trading is not possible as of now because of the regulations. So, with that view, what do you think is the best outcome of the VPP?

FJ: For Loenen?

R: Yeah

FJ: I think it would be great if the technical goals can be met, like avoiding congestion, have a stable grid and trade energy, you can get payed for that. But for me, I think the best outcome would be that Loenen which has been a front runner village, which already has a lot of solar PV installed, that they could really develop into, instead of being a village with a lot of solar PV, become a village that has their own energy. And can be really self sufficient and in control of themselves.

R: Ok, so if we get a bit more specific. So, ok village being more self sufficient, one people should be able to exchange excess energy, but the rules wont permit it. So to get more into details about the technical goals, what would you say would be important?

FJ: With regards to regulation or generally?

R: No, as in what technical goals need to happen irrespective of regulation. Cause I feel that the P2P thing is going to be possible in the future, pretty soon. So with regards to that, in one or two years, what do you think is a good technical goal or a mix of goals?

FJ: Well then I would say the energy market within Loenen and the trading of the excess energy and energy services in the Dutch national energy market.

R: Oh ok. So this is interesting because the first interview I had back in Loenen, he said I want to start locally from Loenen and then look at the national market. So he said, energy trading within Loenen and also helping Alliander manage the local grid and then look at the national market. So I am just curious why you said that. Of course there is no right or wrong answer.

FJ: Oh, I just said that because last week we had a meeting and Andre was also there and he talked about how he discussed the grid in Loenen with Alliander and he mentioned that the grid in Loenen is relatively stable and there are only a few week spots. He mentioned the grid is stable but there is just one neighbourhood were there was one transformer where it is up to its max. So that's why my interest was now directed towards the energy market within Loenen and the Dutch wholesale market.

R: Ah, ok. This is interesting. So now is when we move to the future scenarios. So with your knowledge of the policies, how do you think the penetration, like from high medium low, the residential PV, EV, heat pumps and micro CHP.

FJ: Well the Gemeente's plans are always in consultation with the people. Like for example there were plans to build a wind mill and there was lots of resistance and now the plan is dropped. For Loenen or the Netherlands, how I would predict the future, I would say that residential PV would be high, because it will be cheaper and cheaper and the Dutch are traders, so they will adopt it. The question is for residential rental buildings, because most solar PV now is on owned houses. So if you buy a house you put PV on it. But if you rent a house what do you do? Electric vehicles I find it difficult, because my father works in the automotive industry and he is very involved in electric vehicles and he thinks that EV is the future. But I think that hydrogen cars will also be there and fuel cell cars, so electricity will not be the end all for it. So I have to say medium.

R: For the heat pumps, I remember Andre telling me that they didn't want to tax the grid too much by putting a lot of electric, so they were considering biogas, district heating etc. So, with regards to that how would you rank the penetration of electric heat pumps then?

FJ: I think the heat pumps in Loenen will be medium, and I think across the Netherlands as well, but that's just a very safe estimate. And micro-CHP, in Loenen, if they go with the green gas then it might be high of course.

R: Ok, and I am just curious, because Andre just mentioned the green gas thing to me. Do you know what stage it is at? Is LEN just planning it out? Im just curious how that's going on, the green gas part.

FJ: I don't know about Loenen specifically, but I know that in the Netherlands as a whole, we are trying to get over our addiction of Groningen gas and green gas is one option. I think there are multiple initiatives now to see where you can make gas. Regarding how far it is in Loenen, I think Andre and Nynke are now mapping what the possible solutions might be to provide heat in Lonen instead of Groninge gas. And one of the options is green gas and if I understand it correctly is a very good option for Loenen. Due to the availability in the surrounding area and if you talk about district heating, because it's a village and there is not many high rise buildings and they are kind of spread out, then district heating gets really expensive. And also already the gas infrastructure is there we just need to replace the gas. So green gas could be a good solution for Loenen. But it is also dependent on the future developments, because if green gas is seen as a solution for a lot of areas there will be high demand and hence high price. Its very hard to predict I think for me to know where its going. Also because you have industry which needs gas and in Loenen there is a lot of paper mills and they use so much gas. And their whole technological infrastructure is built for local gas so if they see a cheap alternative for gas (in green gas) that would create demand.

R: Ahh ok. That's about all the things I wanted to ask. Thank you for your time.

Xandra van Lipzig

R: As I said, I am looking at social motivations and connecting to technical goals. I have identified some basic social motivations that drive people. So, before I show you that list, for a community energy project, what do you think according to you is the main motivators for people to start such a project?

XL: I have worked with other civilian projects in the city and I think their main motivation is, because they are really connected, to do, I think its idealism, so they are really connected to change the world together. That's why they do it. And they spend a lot of spare time on it, so they do a lot of voluntary work.

R: Ok, and its interesting you say that because the 4 main motivations I identified are, one was the economic part of it, maybe the community wanted some money for local development and they started the project for that. Then there is community control, so they want less external influence of big energy companies and want energy independence. And then it is what you said, they want social cohesion, so they want more interaction with each other and build something together. And finally the perception of sustainability, that is the community feels that is the community feels that if they use the renewable energy within the community, it is more green other than just selling the energy. So this is the list I came up with.

XL: Yeah I think it starts probably, with an idealistic idea about the need for sustainable energy and then they have the story about community control and geo-politics. It brings them social cohesion and to get the project done sometimes they need to have a business case ready. I think its mostly the last one. For social cohesion you can do other things like sports or whatever. And this group is very connected to sustainable issues.

R: Ah ok, that's a fair way of ranking. And I skipped a question, can you tell me more about your involvement with sustainable energy activities?

XL: Yeah. I run the programme, for the transition from fossil to renewable energy. So, we make policy, we influence our elderman, politics and we have created an atmosphere that has committed much more money on the project. So 2 years ago it was 100 thousand euros a year and it will go up to 2 millions a year in 2021. I have a lot of networks in this local community but also in Holland in the region. And I am working now on a project, its called the district of the future, so we change to an approach where we don't talk about specific houses but the transition in a whole area. So we are really focussed on results and not just talking. We are really focussed on creating local steps towards transition.

R: Right, so back to the questions. So I had come up with possible functions of a virtual power plant by research as I mentioned earlier, So with how we defined the social motivations and how we ranked it, what do you think is for a community like Loenen the best goal or a best mix of goals?

XL: It depends on the local context, so I don't want to talk for them, and the whole real scaling up to three other districts in Apeldoorn. And I think our goal as the government is to explain the people what it can bring and explain why we do and in the specific local context, make the decision with the people living there, what suits best for them. And I think this is a more easy one (the energy market). If you make it very big, like the (wholesale) trade for example, then yeah, the people in Loenen are very special people and if you do the trade, I wonder a little bit if there will come more professional companies that will step into this trade spot. I am not really sure if the local community with a lot of volunteers they want to go into the trade.

R: You mean the trade would require some special expertise?

XL: Yeah. So its mainly one (local energy markets) and two (managing the local grid).

R: So ok for the next part of the interview, I would like to ask you about the scenarios I talked about previously. I wanted to get your opinion on the different levels of penetration of technology like PV, EV , heat pumps and micro-CHP.

XL: I think the EV would be higher than average because they may use it as a battery. So with all the discussion in the village I think there will be more understanding and commitment to move towards electric vehicles. But in general in our cities, we think that the change from regular vehicles to electric vehicles is a little bit beyond our control. So its mainly something moving in the Netherlands and the fisicalities are very important but in Loenen I think above the average. Heat pumps, I think its all above average, just because the context in Loenen. Because people are really aware and are really moving fast. So I would say above average. People really move when they have to. So I believe first the fiscalities must change and the costs must come down. I think the micro-CHP will penetrate before the heat pumps, because heat pumps need a lot of good insulation and its also very costly.

R: Ok, so the micro-CHP would pickup faster than heat pumps.

XL: Yes.

R: Ok, so generally what do you think about the VPP project. Do you think its suitable for Loenen?

XL: Yeah I think it's a good idea because otherwise we (OVIJ) wouldn't participate. It's a part of the bigger puzzle, the question about balancing supply and demand, we don't have the answers yet. So this is one building block to find the answers. It is a good project, but they also have very good circumstances with solar panels and industry and there is also a lot of social cohesion, so if they can get it done, then it gives hope that it can be done in other places.

R: Ok, so you had mentioned that the local energy market is suited for Loenen. But the current regulations doesn't allow it. So what do you think of this?

XL: So first you should have a project in which people believe and then you should say there is a barrier, can we discuss how to get rid of that barrier. Its not the other way around. We cannot solve all the problems in the Netherlands without projects so we need to get these kind of projects to start the discussion. But that's also, in general it gives a lot of tension, if you go into a society, its also for the government they will deal with the same I think, if you talk to the people and maybe they are antigestic, and you might go with right intentions but now its complicated and it may take 3 years to solve the issues, that's difficult to manage.

R: So basically there is a need of projects like these which shows that so much can be done and sometimes there might be little things standing in the way and the projects will help in removing these barriers.

XL: Yeah. We are also looking for experimental areas and to find out where should we go next in this movement.

R: But im curious, you said that the project is being scaled up to 3 other locations in Apeldoorn, is that the cVPP project?

XL: Yeah, Loenen works upfront and our intention is that at the end of the EU project we have 3 urban areas in Apeldoorn where they are going to do the same. So we learn and copy from Loenen to the city.

R: Ahh, ok. Anyway, that's all my questions. Thank you for your time.

Hansjurgen Heinen

R: Could you start by telling your experience, sustainable energy wise?

HH: Ok, I studied, um.. oh that's a long time ago. 20 years ago. Energy and environmental sciences in the university of Groningen, and then I became an engineer for 2 years. A couple of years ago, I get opportunity to do something with sustainable energy to be adopted in companies in connection with OVIJ because of the Dutch legislation. And when I got this experience I thought I will do something similar for my own house. So I bought solar panels and everything in my house I measured what the energy consumption is. I asked myself, was it really needed? With that program I could reduce my energy consumption by 70%. So now I have 1000 excess energy consumption. I got the solar panels with the help of LEN.

R: Ok, so starting with the VPP, do you think it's a good idea for Loenen? Why / why not?

HH: I think its important to have a VPP because now I can deliver my energy back to the grid, but some years back it was not easy to make money from it, so now its good that my energy can be used to provide to my neighbours. And I think its one good reason to have a VPP, I think its also important because in some years there will be a lot of solar panels and the network is not built to handle all that energy. But this is an argument more from the DSO side.

R: Ok, could you think of motivations why people would want to start such a project? Like for example, you told about the excess solar panels and how the grid cannot handle it so it will be good to have a VPP.

HH: But that's not an argument from the customer side. As a customer I want to be sure that I get electricity, but I don't want to pay a lot. Very simple not more than that. How other people manages the distribution, it doesn't matter for me.

R: Ok, so the social motivations that I have identified are as follows, the economic motivations, so a community might be in need of money for some other development and they use these energy projects as a way to fund it.

HH: So from the point of view of the community, and not the end user?

R: Ah, I see what you mean. I was just looking at what the individual members of the Loenen community have to say regarding this.

HH: I think a lot of citizens of Loenen, doesn't matter what LEN does, they participate because they get some money to make their transition cheap. But I think a lot of people are economically driven, and want to spend more money on other things than energy. But I think it's a good motivation (profitability) for the community.

R: Yeah ok, so the 4 motivations I have, as I explained before the interview, are economic, community control, social cohesion and..

HH: Hmm.. do you think, when I look to Loenen I think there are maybe 30 or 40 people for whom those motivations are really important. But when I look to my friends, my family, they don't care. They don't care how they get energy, they want it when they want to take a cup of coffee, that's it and they don't want to pay a lot. That's it and no more. My opinion, these are good motivations but not for the mass.

R: Ahh ok, so the reason I was looking at the motivations is because I was trying to connect the technical goals with these as I explained before. That's why I want to get a sense of the motivations.

HH: Bottom line, economic, is for many people a good motivation. At first sight. Maybe later on the other motivations are important.

R: Its interesting that you said that the activities of LEN is just a cheaper way to get sustainable transition. So would you say that for most people, it is just cheaper sustainability than actually going green and all that?

HH: Most people do not have a motivation of being green. When I look at my friends, family and also when I look to myself, I would like to invest in a measure I also look to payback time. So economic is very important, also for me. I am in the green business and most people do not work in the green business. There are a lot of motivations, and one is very common, that is economic.

R: Ok so its clear that economic is important. So if you have to rank the motivations then how will you do it?

HH: For myself, community control is most important. I think the control for energy and water is important. This is my personal view. Then using renewable energy in the community, economic and then social.

R: Ok, and I am just curious how you think the general motivation for the community would be.

HH: Well economic, control, then the fourth (perception of sustainability) and then the third (social cohesion).

R: Ok, so next I laid out the technical goals that I could find. So what do you think is a good goal for the VPP. When the VPP happens, what do you want to do with it?

HH: The bigger picture, it would be nice when Loenen can be off-grid. As a customer, I said , I would like to have cheaper energy.

R: Hmm, so the goals can be split into goals within Loenen and outside Loenen, so for you I get he sense that you want things to happen in Loenen first and then look outside?

HH: Ahh, so you mean when you say selling in the whole sale market, that we create something like an energy company?

R: Yes

HH: Ok, but that's part of the job don't you think? When you have a VPP you know whats going out and what you have to buy. So trade in the market I think its part of the job. Thats not a goal.

R: The reason I was calling it a goal is because you can do al of this simultaneously, but you would need different resources here and there for the different goals. For example, the local energy market you will need a platform, billing etc.

HH: The goal of LEN is for Loenen to be Energy Neutral. Its nice that we can mange it like this. That we can create our energy and get some benefits from it. But the bigger picture is to be energy neutral.

R: Ah ok, so to be energy neutral, you need for example, battery storage in all the house or you should have the facility of trading between neighbours. Because each house cannot always produce what it needs.

HH: Correct.

R: So this is the second part of the interview where I wanted to discuss more on the scenarios I talked about earlier.

HH: Ahh.. well I am not a good representation of the common citizen of Loenen, but if I could I would like an electric vehicle tomorrow. Also heat pumps, because I need to kick out the wood heating. It is not good for the environment. And I think that heat pumps in general, will be adopted faster than EV.

R: Ok, so this is just out of curiosity. Andre was telling me when I was talking to him that there was also discussion in LEN to set up green gas network. Do you know exactly what the plans are?

HH: Hmm…we are investigating now. We are looking at what should we do to fill in the heat need and the electric need. And he concluded that green gas should always be part of the transition. But now there are no further solid plans to implement green gas in the distribution.

R: So basically the conclusion is that heat pumps cannot be fully electric.

HH: No.

R: I am guessing that the grid might be taxed. Is that the reason why you are opting out of 100% electric heating?

HH: The reason for not using 100% electric is it takes too much of the network to make the transition complete. Maybe on the longer term its possible, but we have to go from green gas and then maybe to 100% electricity.

R: What about micro-CHP?
HH: Personally I never invest in a CHP. I think that's its better to cut off the natural gas network with some extra solar panels. And with a good heat pump its not that difficult to heat your house. CHP is both parts nothing. I think that gas should finally be combusted in central units to make electricity. Thats my opinion. When you count the efficiency of heating with gas with the efficiency of heating with heat pump, heat pump is more. I think heating with gas or micro-CHP is ..the use of gas in households make no sense. You can use gas in central facilities (to make electricity) because you can make the temperature to higher temp and use the energy a lot more than combusting in the households and make water to 60 degrees. It doesn't make sense. But now it doesn't make economic sense, it is cheaper to invest in a gas heater than in a heat pump. The regulations need to change to make the price of heat pumps go down. On the longer term I think heat pumps will be standard.

Ivo Smits

R: Can you give a brief introduction about your self and also tell me more about your experience with renewable energy?

IS: I think I will begin, when I came to Loenen. It was 2 years ago. And since half a year, I am building a house in Loenen. An own design. Its an all electric house. And its energy positive, so its, I don't know if you know the concept of passive houses from Germany. In Germany you have the label "Passive House" and its very strict. You can only use 15kWh per square meter for heating in your house. That was the target but I didn't realize that because it was quiet expensive. But I used the basics, so lots of glass on the south. Thick insulation for Dutch conditions, and I am around 25 or 30 kWh per square meter. Probably I will produce twice as much energy as I will use. I will use approximately 5000kWh per year I think and my production should be around 10000kWh.

R: Wow, so you have mainly solar panels and do you also plan to have a battery system?

IS: Yes, but not yet because in the Netherlands its quiet feasible to, because you get, some basic return (an allowance) on your electricity bill.

R: Its 21 EUR per kWH I think right?

IS: Yes and also from the Dutch government you get 370 EUR back on your electricity bill, they say it's a basic need so it's a basic revenue everyone gets in the Netherlands.

R: Huh, thats really cool that your house produces so much surplus. But also in your professional experience have you worked in renewable energy projects or things like that.

IS: Yes, my work is in renewable projects. I am a consultant in district heating, to check out whether or not it is feasible to connect local heat demand or heat supply and how you can design such systems. And whether it is interesting for the community to construct heating networks. I work at Liander.

R: Ok, so what are your general thoughts on this VPP for Loenen? Do you think it's a good idea?

IS: Yes I think it's a good idea because one year ago I saw a presentation of Andre, and they had the aim.. I don't really remember the exact number but they had the aim to produce 80% of the personal electricity use by solar power. And when you do that there will be problems in the network so that's one, you need to balance. Otherwise in summer you get a lot of over production and in winter a lot of demand. And second, it is more nicer to make efficient use of local energy.

R: Can you think of some social motivations why the community would want to participate in the VPP project?

IS: Yes, I think its nice to help each other. Not only in physical but also in energy. That as a member of Loenen I can also participate in energy production and energy use and the village itself can benefit and use its own green energy and you do it as a community together without big firms and that's quiet interesting.

R: Right, so this is kind of the different social motivations that I had. As you can see in the interview aid. Do you think there should be more added to this list?

IS: Yeah I think the first that is here on the list, economic support is quiet true and maybe with time it can also generate jobs. I don't know if that is also behind it.

R: Yeah, I have tagged creation of jobs, internships etc under social cohesion because this way the community members are interacting with each other and the community identity is growing.

IS: Ah, ok. And also I am thinking, in Germany there are lot of green villages and some of these villages they attract a lot of tourists, and you can pinpoint yourself on the map so that people know. I don't what the motivation should look like but.

R: So basically, it is like a publicity also that the village is green.

IS: Yes.

R: Ok, so working with these motivations. How would you rank it in terms of importance for Loenen?

IS: The most important, I think first its community control, then I am doubting between perception of sustainability and economic support…

R: Yeah could you also explain your line of reasoning?

IS: The first is community control. I think it is nice as a village to be able to control your own electricity supply. That you know that you wont have to fully rely on large energy companies like E.On, Nuon and Vattenfall. I think that's interesting and also to know that your capable to produce your own electricity. And I think perception of sustainability is second, because nowadays there is a lot of discussion in Holland about how green our green electricity is. Is saw once on television in this famous morning show, 69% of what Dutch people buy is green electricity, but we only produce 6 to 9%, not even that. So I think it is useful when you make it as a community. And third, economic support. I think it should be possible to generate revenue from the energy you produce. And then we have social cohesion. I think its more not a goal but an outcome.

R: Ok, so that's the social part. I have also identified the technical goals that might be possible. You can see it in the list. What do you think is more important or ideal for Loenen?

IS: I think the first tow (local energy market and managing local grid) are the main goals. Its more like the steps you make, so you first have to start in your own village, so to use as much locally produced energy as possible to get the best balance in the village level. I think when you are able to do so it will also help the DSO to keep the unbalance as low as possible. I think the third one (trading in the wholesale energy market) can be different, because I think this is the most interesting one I think. Because sometimes the third one I opposite to the first one (the imbalance in the local grid can be in the opposite direction of the national grid) I don't know if they always help each other. So it wont be fully optimal.

R: Many of the people I interviewed also said the same thing. You start in Loenen and then you move to other goals. Right now the regulations don't allow much. But I think this will change. What is your opinion about this?

IS: I think it will change. Because like in Utrecht they has some small, very small, neighbourhoods that interchanges energy. So I think it will change. I don't know for sure but it would be nice. Because personally, when I have too much energy and I am not using it then my neighbour needs energy.

R: Ok, now it's the last part of the interview. As I explained, I am also looking at the scenarios of different technologies. With your knowledge of the different technology and the policy can you predict how things will be adopted in Loenen?

IS: I think, we already saw in one small presentation from Andre, that we have quiet a lot of PV and I think it will be more because the price of PV keeps dropping. I think almost everybody will have it, in the future only when your roof is bad, then you wont put PV. So it will be high. I am not sure about electric vehicles, a couple of years ago I would have said high, but I think it would develop, I would say medium.

R: Ok, what about electric heat pumps?

IS: Personally I think there will be a lot of electric heat pumps. Because I have one myself. When your home is ready for it (with good insulation) that is the tricky bit, it will be cheaper. And in the coming year the price of gas is going to rise. So it will be getting interesting. I think it is like PV but only some years back.

R: Hmm, ok another thing that many people I interviewed said is that you cant have 100% electric PV because it will tax the grid a lot. So they were suggesting a mix of green gas and electric etc. What do you think about this?

IS: Yeah, for old house its much more difficult. 2 weeks ago I was on holiday in Austria and there was a house that was renovated in 2007, a farm. And all the windows had triple glazing, and there was floor heating everywhere and we are just a little behind Germany and Austria in technology used in dwellings but I think nowadays, everyone uses atleast double glazing so things will change in the years. And together with green gas or maybe in the future hydrogen. But my personal opinion is that its more going to be like hybrid.

R: Ok, so for electric heat pumps how will you give the penetration?

IS: I think high.

R: and for micro-CHP?

IS: It doesn't matter that much, I think it will be medium or something. Or low.

R: Ok that's pretty clear. That's about all I wanted to ask. Thank you for your time.

IS: Your welcome.

Willem De Zanger

R: One of the main reasons for VPP idea to come is because people are putting their own solar panels and they are doing this because they want their own energy.

WZ: Not only this but they believe in a green future.

R: Oh yeah. That too. So, you told me that the village council is working closely with LEN. Could you tell me more about the renewable energy related projects that you have been personally related with?

W: When we started this project with the village council, basically the whole village has been participating. It was bottom-up, how we can do it better as a village than a big city like Apeldoorn. Nothing was coming from the government, We read a couple of things about participation process, so we did a bottom up plan. And one of the key things we thought was durability (sustainability), that's why LEN has been involved. Nynke helped us, she is brilliant, when you have a certain thought about something, she puts it in a beautiful schedule. And Andre, he is a clever guy. One of the big issues we had is that the people are getting older, and the average age is getting higher and higher. That was the problem, the national care for those people, is a big worry. So we thought of a lot of things, do we have enough young people, about the roads, about the woods, so we made a plan for that. But one of the key issues was durability. Thats why we work with LEN, thats also because before we started this we had a project from LEN, as I said it started with the village council and we won at that time 200 thousand euros that was going into a revolving fund for solar panels. So we were thinking, what can we do for the future, and so Andre, Nynke and myself, talked to the farmers about bio-gas and also about solar panels on the stables and things like that. We want to have more and more solar panels. Yeah, it's a small village, so everybody knows everybody and it is easy to do it that way. For the future, we also have a council, so all the villages around Apeldoorn talk on a regular basis from there we got more and more response from Apeldoorn and from other villages. That's good to know, because Loenen is too small for the future to do this energy neutral thing so we need more villages. To put solar panels in the meadows and things like that. Thats the long term thought, to get energy for all the villages around Apeldoorn but also Apeldoorn itself.

R: Ok, can I have your general thoughts regarding the cVPP. Do you think it's a good idea for Loenen?

W: I absolutely like when things are, you call it unity, I think its absolutely important when the community comes up with a bottom up plan and this is an absolutely bottom up plan. Everybody understands that we need to do something for the environment and I think in Loenen more people understand that and its important that we have this initiative. I think its very important, thats why we have solar panels on our roof as well.

R: As I mentioned, I am trying to identify the social motivations in Loenen and connect it with the technical functions. Before I show you the list of motivations I have, could you come up with some motivations that are there for making this VPP?

W: I think a motivation ofcourse is money, but also a big motivation is a better environment. We live around in the woods and also the fathers and grandfathers are also people who lived here and worked in the woods. But also it sounds a bit stupid, but it is a small village so everybody is looking at everybody. So if neighbour X says I am having a lot of solar panels then the other neighbour also wants it. I think also the way it looks like, there is a big win-win after 7 years (the payback of the PV), I think when your neighbour has got something, you also want it. We still think in Loenen that we can do a lot more than we do now.

R: Ok, so what I found out is also similar. So one is economic motivation, community control, social cohesion, and perception of sustainability.

W: For us in Loenen, we have to focus on sustainability. We get a lot of tourists in this area. We do enough tourism business with three small villages (including Loenen) as much as the city of Apeldoorn is doing. People are camping, or having a small house for vacations.

R: So next I want to ask how you will rank them according to importance?

W: I think the money is first. Then onto, I probably think the perception of sustainability. And community control. And at last is the social cohesion.

R: Ah, that's interesting you rank it like that because you had said that working together as a community, is…

W: It is important but I think that those three (social cohesion, perception of sustainability and community control) are equally important.

R: Oh ok, but you would surely put the economic part first?

W: Oh yeah. We are Dutch, so we want our money back.

R: So moving on to the technical part of it, I have identified the basic things that can be done by the VPP. Two goals within Loenen and 2 outside Loenen. You said that the money aspect is important but sometimes there will be a situation where if you trade in the bigger wholesale Dutch electricity market you will get more profit. Maybe. But you might have to have a third party company manage everything. So you are giving over control to someone else. So how will you balance this (control VS profitability)?

W: No I think its, you forget one thing and that's trust. You need to trust the company that's doing this. I think trust is a key issue here and they have to grow a little bit more. I think we have to do this with other villages and probably with a part of Apeldoorn. Then you can understand what Alliander is doing and are they ok, are they clean, are they trust worthy. I think, once we have done that step, so grow a little bit and then people are probably going to say that we should sell it as a group. But I think for the first 5 years the people want to see what is happening, if the partners are trust worthy before going big scale. And how that's going to happen I don't know. At the moment for a lot of people, it is like, can I trust them, how is it going, it's a big step. People want to understand if they are trust worthy. That is the key issue for the future I think.

R: Ok, then for the initial stage of the first 5 to 6 years. What do you think is the outcome of the VPP?

W: First of all I think that we have to do a good calculation if there is a new type of solar panel which is better. Then LEN has to make a calculation for everybody if its ok to change it or not change it. Those are the things that are very important. Lets say that we can get twice as much energy out of it., then people have to be informed about that. After that I think we have to be very careful that somebody in the process is not using it the wrong way. I think that it is very important. The way people are over here. They don't believe everything that the government is saying. That's why also we did the bottom up process, so that we have the control ourselves. And if the VPP starts to grow and then there is a big company going, I am not sure that's the way, maybe regional you can do something but I don't think for the whole of Holland. Not for the coming years.

R: I heard similar things from people I talked to yesterday. They said that it makes sense to first do something for Loenen, like make the local market and manage the local grid and then after that look outside.

W: Yeah do the first in the region, but then the steps after that see how it goes.

R: Hmm ok, that's a sensible plan. Actually everyone I interviewed was saying this. So this is the last part of the interview. I am looking at future conditions. So with your knowledge of government policies etc I want you to rank the level of PV, EV , heat pumps and micro-CHP in Loenen.

W: PV is surely high. There is a lot of work going on. For EV, it depends on the radius. How far you can drive. I think EV is absolutely the future. Heat pumps, most of the heating is by gas here and most of the devices it's a combination of warm water and central heating. So if you want to get rid of gas, then heat pumps are interesting.

R: I am just curious cause when I was talking with Andre he told me that for heat pumps they were considering electric, but they were also looking at bio-gas, district heating etc for Loenen. I just wanted to know what your opinion is about that.

W: I think electric.

R: Ok, because the main concern that people have regarding electric is that suddenly if you have all the houses running on electric, the grid will get too loaded.

W: I think in the future when you are building new houses, earth heat is also an interesting option.

R: Hmm ok. So basically a combination of electric and something else. Yeah I think that's about all I wanted to ask. Thank you.

Appendix F - Economic analysis of local grid management for DSO function

The expected growth in total loads and flexible loads is 2.4% exponentially per year (PhasetoPhase, 2015). Assuming a participation of 60% in the cVPP local grid management project, the total peak load and the corresponding flexible load for the first 6 years is as follows (using the formula in section 9.1.2):

Table 8: Peak consumption per year and the corresponding flexible consumption that can be shifted

Year	Peak consumption (kW)	Shifted flexible consumption (kW)
1	10484.73	364.05
2	10739.41	372.89
3	11000.27	381.95
4	11267.47	391.23
5	11541.16	400.73
6	11821.50	410.47

Assuming that the economic value of shifting flexible consumption and avoiding peaking capacity is €62.5 / kW / year (Gombert, 2014), and taking the capital expense of setting up a VPP as €80000 with yearly maintenance to be 30% of that (as per the information from the VPP company), a cash flow is built below. The 0th year is assumed to be 2017. For discounting the cash flows, a discount rate of 3.6% is used till 2020 and 3% from 2020 onwards, which is the ACM approved WACC (Weighted Average Cost of Capital) for grid expansion investments by system operators (ACM(Autoritiet Consument & Markt), 2017).

Table 9: Discounted cashflow for local grid management by cVPP (participation percentage is assumed as 60%)

Year (n)	Investment cost	Recurrent cost	Revenues	Total cashflow	Discount factor (1/(1+i)^n)	Discounted cashflow
0	-80000			-80000	1	-80000
1		-24000	22753.17	-1246.83	0.965250965	-1203.499752
2		-24000	23305.86	-694.144	0.931709426	-646.740421
3		-24000	23871.96	-128.037	0.899333423	-115.1481816
4		-24000	24451.82	451.8203	0.888487048	401.4364935
5		-24000	25045.76	1045.763	0.862608784	902.0841763
6		-24000	25654.13	1654.132	0.837484257	1385.309792
7		-24000	26277.28	2277.279	0.813091511	1851.636523
8		-24000	26915.56	2915.563	0.789409234	2301.572227
9		-24000	27569.35	3569.35	0.766416732	2735.609882
10		-24000	28239.02	4239.019	0.744093915	3154.22802
11		-24000	28924.95	4924.953	0.722421277	3557.891153
12		-24000	29627.55	5627.55	0.70137988	3947.050174
13		-24000	30347.21	6347.212	0.68095134	4322.14276
14		-24000	31084.36	7084.356	0.661117806	4683.593757
15		-24000	31839.4	7839.405	0.641861947	5031.815552
16		-24000	32612.79	8612.794	0.623166939	5367.208436
17		-24000	33404.97	9404.969	0.605016446	5690.16096
18		-24000	34216.39	10216.39	0.587394608	6001.050273
19		-24000	35047.51	11047.51	0.570286027	6300.24246
20		-24000	35898.83	11898.83	0.553675754	6588.09286
21		-24000	36770.82	12770.82	0.537549276	6864.94638
22		-24000	37664	13664	0.521892501	7131.137803
23		-24000	38578.87	14578.87	0.506691748	7386.992079
					NPV	3638.813407

For a participation pf 60% in the cVPP local grid management project, the NPV becomes positive after the 23rd year.