MSc Program
Renewable Energy Systems

Empowering corporate customers' "photovoltaics virtual private network" business models

An opportunity to increase the potential amount of electricity generated from corporate customers' photovoltaic systems by introducing the concept of "utility-owned virtual storage"

A Master's Thesis submitted for the degree of
"Master of Science"

Univ.Prof.Dr.techn. Reinhard Haas

MMag. Antonietta Di Chio

09300992

15 October 2017, Vienna

Affidavit

I, **MMag. Antonietta Di Chio** hereby declare

1. that I am the sole author of the present Master's Thesis, "Empowering corporate customers' *photovoltaics virtual private network* business models", 86 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master Thesis as an examination paper in any form in Austria or abroad.

Vienna, 15 October 2017 ______________________________

Date Signature

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Additionally, I would like to thank my colleague Rusbeh Rezania, Business Developer and member of the Faculty, for his mentoring advice.

To Gerhard,

the most genuine source of renewable energy in my life.

Abstract

In the current electricity market situation and under current legal provisions in Austria, corporate customers are not encouraged to exploit the space on the roofs of their buildings for self-generation with photovoltaics. Typically, they tend to reduce the dimensions of their photovoltaic systems in order to avoid excess generation being fed into the grid, because this is regarded as a financial loss. This condition is particularly evident when high total electricity consumption is spread across several customer sites.

In the present work, a new business model offered by utilities was designed, using the data 2016 of an actual large corporate customer in Austria, in the grid area of Vienna. In 2016, the customer had a total electricity consumption of 40,000,000 kilowatthours, spread across five metering points. By using a typical telecommunication terminology, the new model can be described as a “virtual private network” covering electricity supply by the utility, a customer-owned decentralized photovoltaic system and a utility company-owned “virtual” storage. The “virtual private network” model was compared with the self-generation solution the customer would be able to implement under current market and regulatory conditions.

Research question was whether and to what extent the new business model is able to make it economically attractive for the corporate customer to dimension its rooftop photovoltaic system in such a way that a large electricity surplus is generated and that production and consumption are net metered among the customer’s sites, either simultaneously or with a time-shift.

The comparison of the two models has revealed that the “virtual private network” is economically attractive for the corporate customer, under the condition that existing network charges can be amended.

The new model enables an installed capacity of 7,700 kilowattpeak for self-generation with photovoltaics, against 3,740 kilowattpeak in the case of the “status quo” model. Furthermore, both self-generation volumes and savings on operational expenditures (OPEX) double in the case of the “virtual private power network”, while capital expenditures (CAPEX) required for implementation only increase by 60%, due to the positive effect of economies of scale. As a second step, we proposed that the customer shares the mentioned savings with the utility and with the grid operator, and that current network charges are replaced by a “Virtual Private Network Access Fee”. The fee collected by the grid operator has to cover the access to the private network, smart data metering and invoicing. Additionally, the utility is paid a price for the services rendered with the “virtual private network” model.

The present work could show that new business models like the “virtual private network” developed will help re-think the role of utilities and of network operators as future business partners for so called “prosumers” (when the same entity is contemporarily consumer and producer). Otherwise, traditional players will be replaced by new ones more eligible to meet changed customer requirements, such as electricity storage vendors. This new understanding of the role of utilities and of network operators as enablers of decentralized electricity generation will have a positive influence on the achievement of the EU climate goals 2030 and 2050, to which Austria has committed.

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1 INTRODUCTION

1.1 Motivation

In the Austrian electricity market, large corporate customers in every line of business, with high electricity consumption and more than one business location, are more and more interested in giving a direct contribution with own decentralized energy generation. What they usually expect in return is the optimization of their energy costs.

The positive attitude of these corporate customers towards decentralized generation complies with the energy strategy proposal of “Österreichs Energie”, an entity representing the interests of the power industry in Austria. In its strategy paper, “Österreichs Energie” strives for more active customer participation in electricity generation, in order to make production more flexible and secure through diversification. The strategy paper was published in 2017. [1]

According to several studies, photovoltaics (PV) is the most suitable technology to support the contribution to decentralized electricity generation by large non-residential customers. Furthermore, PV is expected to be the largest and least cost source of energy in the long-term for the global energy supply (cf e.g. Fechner et al., 2016 and Breyer et al., 2017).

In Austria, the rooftop surface of industrial buildings available for building integrated PV (BIPV) amounts to 230 km^2. Just 170 km^2 would be sufficient to cover 27% of total domestic electricity demand by 2050 (in 2016 only 1.8% of demand was met by BIPV).

In the capital, Vienna, the total building integrated availability amounts to 29 km^2 and the rooftop surface on industrial plants is estimated at 2,000 hectare (ha). Assuming a yield of 0.6 Gigawatthours per hectare per annum, the potential decentralized electricity generation from the available surface would be 1,200 Gigawatthours per annum (GWh/a)[2]. This value would be able to meet more than 1/3 of the total energy demand of the industrial sector in Vienna (Fechner et al., 2016: 9-13, 26-29).

PV is a semiconductor technology that converts light to DC[3] electricity without “moving parts” (Fechner, Introduction, 2016: 2/21). Most of commercial PV cells are made of silicon, the availability of which is considered unlimited (Xakalashe, 2011: 83). In Central European latitudes (to which Austria belongs) the yield for 1 kilowattpeak (kWp)[4] installed capacity is around 1,000 kWh.

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[1] Cfr. Österreichs Energie - Schmidt B. (2017): Empowering Austria - Die Stromstrategie von Österreichs Energie bis zum Jahre 2030.

[2] 1 Gigawatthour corresponds to 1,000,000 kWh (Kilowatthours).

[3] „DC“ stands for „Direct Current“ (in contrast to „AC“, „Alternate Current“).

[4]“ Kilowattpeak” (kWp) is the installed capacity of the system. The word „peak“ refers to the nominal output of a module under standard conditions in a laboratory.

As most of the generation concentrates in the sunniest months of the year, large prosumers[5] generating electricity at several sites can hardly be autarkic without access to the electricity grid.

Nonetheless, PV-technologies (especially BIPV) are particularly attractive to prosumers because they are space-saving and easily applicable to any kind of business requiring electricity.

Unfortunately, in the current electricity market situation and under current legal provisions in Austria, if large corporate customers decide to contribute to decentralized generation by installing a PV-system on the roof of one of their buildings, they tend to reduce the dimension of the system in such a way that hardly any overproduction is fed into the grid. This is a very common situation, even though theoretically the roof space would allow the installation of larger PV systems and, therefore, more yield.

The reason for this is the fact that, today, any feeding of an excess generation into the grid is regarded as a financial loss. In fact, for every single kWh of bought-in consumption, customers pay a gross price including grid costs, while for every kWh of generation, not directly consumed but fed into the system, the compensation is only equivalent to the net electricity price.

Through a storage facility and a “re-use” of the PV-surplus the problem could be partially solved in the case of one single customer site. Regrettably, large businesses with a high total consumption across more than one location cannot take advantage of economies of scale, neither for the PV-systems, nor for the storage units. Overall storage costs are currently too high and their environmental impact very questionable.

In order to eliminate these disadvantages, we suggest to unify all customer’s locations in a so called “virtual private network” (VPN) using a “utility-owned virtual storage”, within which electricity can be stored and re-used or attributed to another customer location.

The utility company has an electricity agreement with the customer, is part of the customer’s VPN and is responsible for the storage. It is irrelevant for the customer which kind of storage the utility company uses. The “back up” can be a flexible pump storage hydro power plant, a flexible combined cycle gas turbine (CCGT with steam), a network of charging stations for e-cars, power2heat solutions such as electricity heaters, or a combination of the four.

The concept of a customer´s VPN only works if no grid fee is paid for storing electricity generated by the prosumer, for shifting it virtually from one location to the other or for using it later on. That is, this business model necessarily implies a modification of the understanding of the current grid fees according to ElWOG.[6].

The aim of this business model is to encourage the prosumer to increase the amount of its decentralized electricity generation. Furthermore, we intend to show that such a business model is an opportunity, both for utilities and for the grid operator itself, to contribute to the

[5] Role of consumer and producer at the same time.

[6] ElWOG: Elekrizitätswirtschafts- und organisationsgesetz 2010 (Electricity Act 2010).

achievement of the climate goal to increase decentralized electricity generation from renewable sources[7].

1.2 Core objective and research question of this work

The core objective of the present work is the development of a new business model for large corporate customers in Austria which encourages a higher level of decentralized electricity generation with PV. The customer consumes electricity at several sites, which are located in the area of one regional distribution system operator (e.g. *Wiener Netze* for Vienna and surroundings). The electricity supplier is a regional utility.

By using typical telecommunications terminology, we can describe the business model as a "virtual private network" (VPN), becoming thus a “virtual private POWER network (VP**P**N), covering electricity supply by the utility, a customer-owned decentralized PV-generation system, and a utility-company-owned storage “cloud”.[8]

The main research question is whether and to what extent this “PV-VPPN” business model is able to make it economically attractive for the corporate customer to dimension its rooftop PV-systems in such a way that a large electricity surplus is generated and that production and consumption are net metered among the customer’s sites, either simultaneously or with a time-shift.

The “PV-VPPN” business concept introduces a new understanding of the grid operator’s role and of the related system usage costs. Here, the grid operator takes on the role of enabler of new commercial business models, of a market facilitator. In this regard, we intend to verify whether the current legal provisions and discussions about future amendments to the grid charges in Austria are in a position to support the role of market facilitator for the grid operator.

In a further step, we will propose our understanding of network fees able to make the new business case possible.

[7] Cf Chapter 2.

[8] Definition of “cloud computing” in Wikipedia, https://en.wikipedia.org/wiki/Cloud_computing, retrieved 6.8.2017): “(Cloud computing) is a model for enabling (…) on-demand access to a shared pool of configurable computing resources (e.g., computer networks, servers, storage, applications and services) (…). Basically, Cloud computing allows the users and enterprises with various capabilities to store and process their data in either privately owned cloud, or on a third-party server in order to make data accessing mechanisms much more easy and reliable. Data centres (…) may be located far from the user – ranging in distance from across a city to across the world. Cloud computing relies on sharing of resources to achieve coherence and economy of scale (…). Advocates claim that cloud computing allows companies to avoid up-front infrastructure costs (e.g., purchasing servers). As well, it enables organizations to focus on their core businesses instead of spending time and money on computer infrastructure”.

Finally, we will analyze if, under current conditions, physical electricity storage could be a valid alternative to the VPPN for our prosumer.

Key questions of the present work are the following:

- How far is the new model in a position to support the strategy paper of “Österreichs Energie” and the EU climate goals 2030?
- Why should the utility start a new business?
- Why should a network operator accept the new model?
- What would be the alternatives for the prosumer if this does not take place? Would these alternatives be sufficiently attractive for the prosumer?

The analysis of the ideal combination of storage solutions the utility can offer in the developed model is an important derived objective. This could be pursued in future studies.

1.3 Major references and literature with regard to the research question

The present work is an analysis of the existing metering points (locations) of a large Key Account (KA). All his data are real and, at his request, left anonymous: company name, site addresses, yearly consumption at each site, load profiles.

For the dimensioning of the PV models, existing tools have been used: the publicly available PV-GIS[9] and a utility-developed PV-dimensioning tool for corporate customers. Direct consultations with experts at regional utilities provided more detailed information.

For monetizing results, real electricity prices for supply year 2016 at the EEX or EPEX (electricity exchanges) were used.[10]

Legal documents such as the Austrian Green Electricity Act 2012 or the Austrian Electricity Act 2010[11] were consulted.

Several scientific articles, mostly peer-reviewed papers published in specialist journals, provided significant inspiration for the present work. To mention some of the journals: “Current Sustainable Renewable Energy Report”, “Zeischrift für Energiewirtschaft (Springer Verlag) and “Progress in Photovoltaics” (John Wiley & Sons, Inc.).

Further studies, mostly presented in February 2017 during the 10th International Energy Economics Symposium at the University of Technology in Vienna, were referred to.

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[9] PV-GIS: https://www.wien.gv.at/umweltgut/public/grafik.aspx?ThemePage=9.

[10] www.eex.com and www.epexspot.com.

[11] Ökostromgesetz (Green Electricity Act) 2012, ElWOG (Austrian Electricity Act) 2010.

Main topics discussed in those papers are e.g. the legal framework for and the cost-effectiveness of electricity storages, in particular in the case of community storages and of storage facilities for non-residential customers, and the integration of decentralized PV generation into distribution networks.[12]

Further literature on the development of a new co-operation between utilities and non-residential customers, and on connected topics such as the implications of the role of "blockchain" technologies, was referred to (cf PWC - Hasse F. et al. (2016).

For backup information about international climate goals, publications by different institutions were used.

1.4 Structure of this work

This work was structured as follows:

1) Background information

- Implementation of international and European climate goals in Austria.
- Presentation of the strategy paper 2030 published by Österreichs Energie in 2017 including data on PV penetration in Austria.
- Current discussion about legal provisions in Austria ("Kleine Ökostromnovelle", Große Ökostromnovelle, Amendment of "ElWOG").

2) Description of method of approach

- Description of two models for electricity generation from PV for corporate customers. The so called **"status quo"** case is feasible with the current regulatory premises, the new model (**"PV-VPPN"**) is only theoretical and would require a change in regulatory provisions.
- Application to the sites of an existing Key Account (KA) who gave permission to use his data but wishes to remain anonymous.
  - **Evaluation of the "status quo" case:**
    - The KA has 5 sites in Vienna. Their roofs are suitable to house large PV systems in the network level 5: Analysis of on-site electricity consumption, electricity prices, roof size, costs and revenues.

[12] For an exhaustive list of this literature cf the Bibliography at the end of this work.

- ➢ How would the KA, whose aim is to cover part of his electricity consumption with own generation from PV on roof, dimension his PV systems according to today´s premises (law, investment costs, savings)?
- ➢ Does his decision match his potential?

- o **Evaluation of the “PV-VPPN” business model:**
  - ➢ Model description and description of the regulatory requirements for its implementation.
  - ➢ How would the KA dimension its PV systems if the suggested regulatory amendments were introduced?
  - ➢ Results: Additional electricity generation from PV, additional savings both on electricity supply and on network side. Comparison with additional investment costs.

3) Description of research topic and data used

- **Research topic:**
  - o We compared the two business models: Additional self-generation, savings in network access and network usage costs and in electricity purchase costs from the utility, additional investment costs.
  - o Why a VIRTUAL storage? Usage optimization, commercialization opportunities, seasonality of storage, losses, environmental implications.
  - o Would the KA really “use the network less” with the VPPN model?
  - o Why does the VPPN model represent a new opportunity for the network operator and for the utility?
  - o Alternative scenario: Physical storage (LI-ION-batteries[13]). Future cost degression of electricity storage facilities.

- **Data used**
  - o The KA gave permission to use his data on condition of anonymity.
  - o We assumed that the customer has an electricity supply agreement with the utility based 100% on spot prices (hourly day-ahead) plus a mark-up for the whole electricity supplied by the utility.
  - o We took into consideration load profiles of the KA in the supply year 2016.
  - o We took into consideration spot prices in the supply year 2016.

[13] Lithium Ion

- We assumed that the KA is the owner of the PV system and that no PV or storage subsidies are involved.
- We analyzed the PV solar rooftop potential with the tool PV-GIS.
- We dimensioned the PV systems with a utility-owned tool.

4) Results, suggestions for solutions

- Generalization of results.
- Advantages and disadvantages of the new business model for the parties directly involved:
    - Prosumer
    - Utility
    - Network Operator
    - Environment
    - PV system operators and storage operators.

5) Conclusions (critical approach, outlook)

- Future role of network operators as enablers of climate goals
- Future role of utilities
- Contribution of large prosumers to reaching climate goals.

2 BACKGROUND INFORMATION

In this chapter, the current level of implementation of international and European climate goals in Austria is described.

Afterwards, the main topics in the current discussion about an energy strategy in Austria are presented: the “Green Paper” published by the Austrian Federal Ministry for Economics in 2016, the strategy paper 2030 published by “Österreichs Energie” in 2017, and the most significant planned amendments to domestic legal provisions related to the grid.

2.1 International climate goals

2.1.1 The Paris Climate Change Conference 2015

The most recent developments related to an energy policy in Austria should be seen in connection with the Paris Climate Agreement, which was adopted by countries worldwide at the International Climate Summit in December 2015, and which entered into force on 4 November 2016. No possibility of a blocking minority by big players was foreseen.

As of December 2016, 196 participants (195 UN Member States **and the EU**) had signed the treaty, which is the agreement between national delegations. The next step after signature is the ratification, the approval of the agreement within the States, according to national provisions. As most of the European Union states had already ratified the agreement in October 2016, this was sufficient to cover enough of the world's greenhouse gases for the agreement to enter into force.

Figure 1: Logo of the 21st UN climate change conference in Paris, 2015[14]

[14] COP21-logo on https://www.bmlfuw.gv.at/umwelt/klimaschutz/internationales/cop21paris.html, retrieved 18.8.2017

The participants committed to the goal of keeping global warming well below 2 degrees Celsius above pre-industrial levels and of pursuing efforts to limit the temperature increase to 1.5 degrees Celsius.

The Paris Agreement is the first of the 21 climate agreements to date which places obligations on the single countries. The contractual parties commit to produce their contributions, which must be more ambitious than in the past, and to update information about them regularly. All States are urged to report regularly the level of their Greenhouse Gas (GHG) emissions and their efforts to reduce them (with some flexibility granted to certain developing countries).[15]

In the long run (after 2050), the achievement of net zero emissions through a comprehensive exit from the use of fossil fuels is targeted by the participants.

2.1.2 The EU energy strategy

The reduction of GHG emissions is only one of the five pillars of the EU climate policy.[16]

Here are the five targets of the EU energy strategy:

1) Security of supply through solidarity among the EU member States and through the diversification of energy sources
2) A fully integrated internal energy market
3) Energy saving through energy efficiency
4) Research and innovation in industrial policy with the aim to foster renewable energy
5) Decarbonisation

Between 2020 and 2030 all targets (related to base year 1990) have been sharply intensified: The percentage of renewable energy in total electricity generation has to be increased to 27% and emission reduction goals have been doubled (cf Figure 2).

In 2016, the EU countries agreed on a new 2030 Framework for climate and energy for the period from 2021 to 2030. According to the European Commission, **those “targets (encourage) private investment in new pipelines, electricity networks,** and low-carbon technology” and are seen as a first step to achieve decarbonisation by 2050. Furthermore, “(t)he cost of meeting the targets does not substantially differ from the price we will need to pay in any case to replace our ageing energy system. The main financial effect of

[15] BMLFUW, “Die Klimakonferenz COP 21 in Paris”, https://www.bmlfuw.gv.at/umwelt/klimaschutz/internationales/cop21paris.html, retrieved 18.8.2017

[16] European Commission, “Energy Union and climate”, https://ec.europa.eu/commission/priorities/energy-union-and-climate_en, retrieved 18.8.2017

decarbonisation will be to shift our spending away from fuel sources and towards low-carbon technologies. [17]

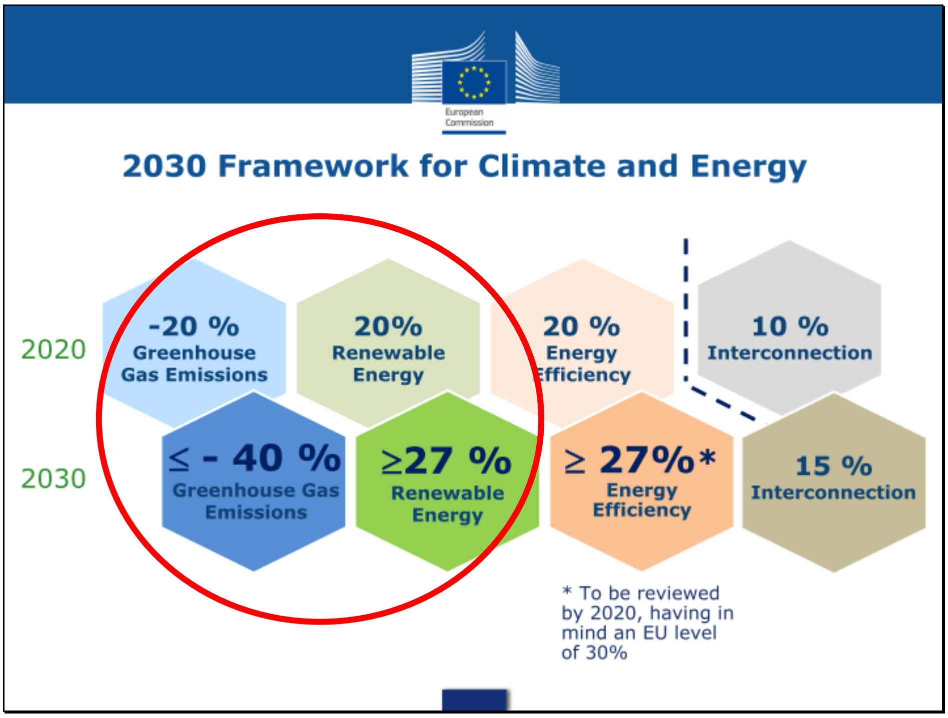

Figure 2: EU Framework for Climate and Energy: Comparison 2020 with 2030 (Framework version 2014)[18]

The new 2030 Framework 2016 differs from the commitment of 2014 insofar as the collective GHG emission reduction goal, of at least 40% by 2030 compared to 1990, is broken down into **economy sectors** and into binding annual targets **for the single Member States**.

This amendment has to be seen as a first level of **implementation of the Paris Agreement for the EU** Member States.

[17] European Commission: "EU energy strategy 2030", on http://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/2030-energy-strategy, retrieved 16.08.2017

[18] Holzleitner, 2015: 14. Base year: 1990

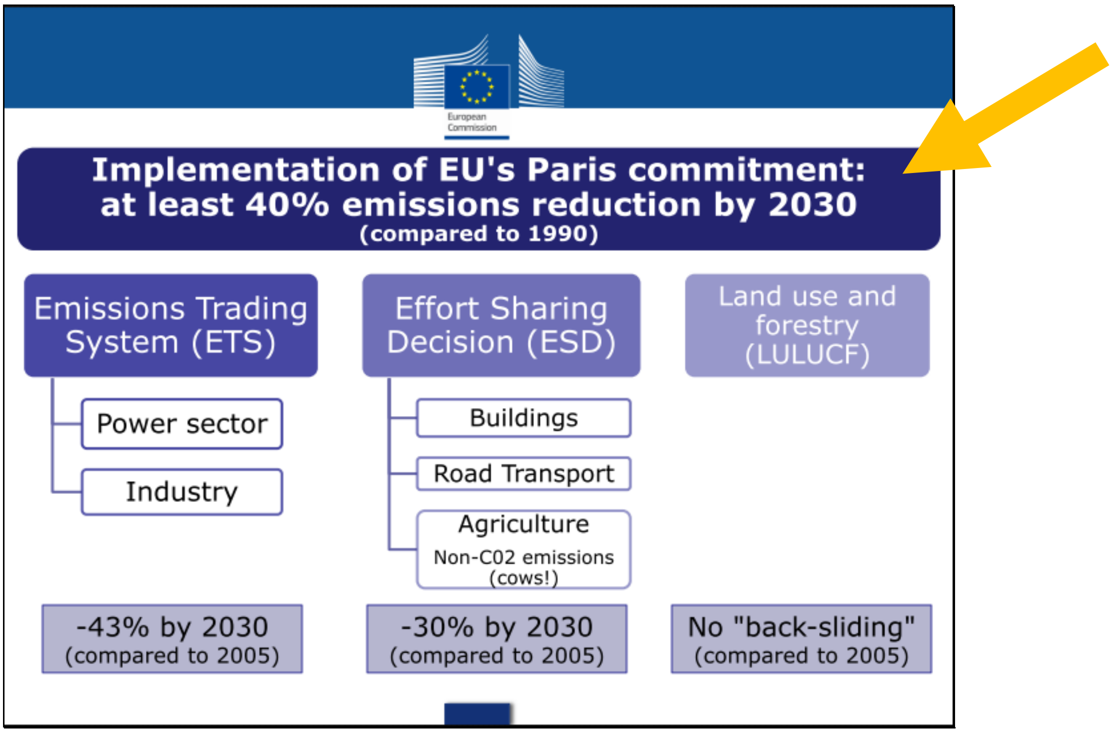

Figure 3: EU Framework for Climate and Energy 2030 – Emission reduction (Framework version 2016)[19]

In the updated Framework 2016, the domestic emission reduction targets are not compared to 1990 anymore, but to 2005. Moreover, **every economic sector** receives explicit targets to be achieved. For the first time, “low-emission mobility” (transport) is expressly mentioned (cf Figure 3).

Additionally, every Member State has proposed emission reduction targets for the sector of buildings, road transport and agriculture. Austria’s proposal amounts to -36% and is thus higher than the general target of -30%.[20]

2.2 Current discussion in Austria about an energy strategy for the future

2.2.1 The Green Paper 2016

In May 2016, the Austrian Federal Ministry for Economics published a Green Paper as a basis for consultation for all stakeholders on the topic “Integrated energy and climate

[19] Holzleitner, 2015:15.

[20] European Commission: “Energy Union and Climate Action: Driving Europe’s transition to a low-carbon economy”, http://europa.eu/rapid/press-release_IP-16-2545_en.htm, retrieved 18.8.2017

strategy”.[21] The Green Paper introduces an open consultation phase, which will end in the compilation of a White Paper describing a framework strategy for the achievement of long-term emission reduction targets.

In comparison with other EU countries, Austria has the advantage of having been able to exploit its existing high hydro potential. For this reason, 70% of Austria’s electricity is already generated from renewable sources (around 60% from hydro). Nevertheless, at the same time, electricity imports have been increasing since 2001 and, starting from 2011, have reached around 13% of the total mix.[22]

Due to the high percentage of electricity from renewable sources, Austria has a positive yearly emission balance. Nevertheless, the peculiarity of its status has to be attributed to the so called “costs-by-cause” principle: Usually, GHG emissions are imputed to the producer, not to the consumer of the energy.

The worst emission values in Austria arise from the transport sector. Nevertheless, due to the fact that in this sector Austria is a net exporter (e.g. Italian drivers living in neighboring regions fill up their vehicles on the other side of the border for cost reasons), emission values stay low.[23] Therefore, it is widely accepted that the most urgent intervention in Austria is required in the transport sector. It is expected that the intensification of this kind of intervention will result in subsidizing e-vehicles, with the consequence that electricity consumption will increase correspondingly.

2.2.2 Planned Amendments to the most relevant domestic legal provisions

In Austria, the target to increase the level of electricity generation from renewable sources is pursued especially through the regulation of subsidies in the **Green Electricity Act 2012.**[24]

Changes to the Green Electricity Act were recently finalized in the so called “Kleine Ökostromnovelle”.[25] For many months, the first version of this amendment could not be adopted by the National Assembly because the necessary 2/3 majority was not supported by the Austrian Green Party. A modified version was finally agreed upon on 29 June 2017.

The most important changes to the Green Electricity Act provide additional subsidies for PV, for small hydro power, for wind turbines and for biogas power plants with a high level of

[21] BMWFW (2016): „Grünbuch für eine integrierte Energie- und Klimastrategie“.

[22] BMWFW (2016: 25-26), „Grünbuch für eine integrierte Energie- und Klimastrategie“.

[23] BMWFW (2016: 6-10), „Grünbuch für eine integrierte Energie- und Klimastrategie“. In 2014 GHG emissions in Austria amounted to 76.3 million ton CO2e.

[24] Ökostromgesetz 2012

[25] „Small Amendment of the Green Electricity Act“.

efficiency. Moreover, solar PV systems receive additional subsidies if they are combined with storage facilities.[26]

The “Kleine Ökostromnovelle” is a package of law amendments which includes, among others, provisions regarding the Electricity Act 2010.[27] One important approved change is the possibility, for the first time, to allocate the electricity generation by a PV system on the rooftop of a condominium to its tenants.[28]

The “Kleine Ökostromnovelle” is the first step in the direction of a deeper planned amendment, the so called “Große Ökostromnovelle”[29] which will stem from the suggestions in the White Paper (cf 2.2.1). The “Große Ökostromnovelle” is planned to be finalized by the Austrian National Assembly by the end of 2017.

In April 2017, the **Austrian Regulatory Board**[30] presented its proposals for a new understanding of **Grid Charges**. The new understanding should be able to cope with the massive changes currently taking place on the electricity market in terms of higher decentralized generation, of higher flexibility in the behavior of the consumers and of the high volumes of electricity fed into the system.[31]

Major suggestions by the Austrian Regulatory Board are the following:

- Increase in the importance of power-related (kW) network charges in comparison to volume-related charges (kWh).
- Changes in the current Charge for System Services[32], which today represents an additional cost for all producers with installed capacities higher than 5 MW, and which is currently levied to cover the costs of frequency control. In the future, those costs will be covered directly by the Balancing Groups.

2.2.3 “Österreichs Energie”’s concept of „Empowering Austria“: A contribution to the implementation of climate goals in Austria

“Österreichs Energie” is an entity representing the interests of the power industry in Austria. At the beginning of 2017, “Österreichs Energie” published a strategy paper 2030 called

[26] Public Affair Department of a regional utility: Newsletter 6/2017.

[27] ElWOG 2010.

[28] The so called „Gemeinschaftliche Erzeugungsanlage“ (ElWOG, §16a).

[29] “Big Amendment of the Green Electricity Act”.

[30] “E-Control”.

[31] Public Affair Department of a regional utility: Newsletter 5/2017.

[32] „Systemdienstleistungsentgelt“.

“Empowering Austria”[33], with the aim of contributing to the domestic discussion about the international climate goals and about the “Große Ökostromnovelle”.

In this paper, “Österreichs Energie” strives for an enhancement of Austria’s role as an attractive location for businesses, with low electricity prices and security of electricity supply. This main goal should be realized by reducing electricity imports and increasing domestic production, not only by centralized power production units. A more active customer participation (in the role of a prosumer) should be made possible by new business models ensuring an innovative method of customer retention.

Furthermore, the recent decision to separate the common bidding zone German/Austria as of October 2018 by, at the same time, keeping a rather high level of long-term available capacity at the border, has reinforced the intention to reduce electricity imports to Austria.

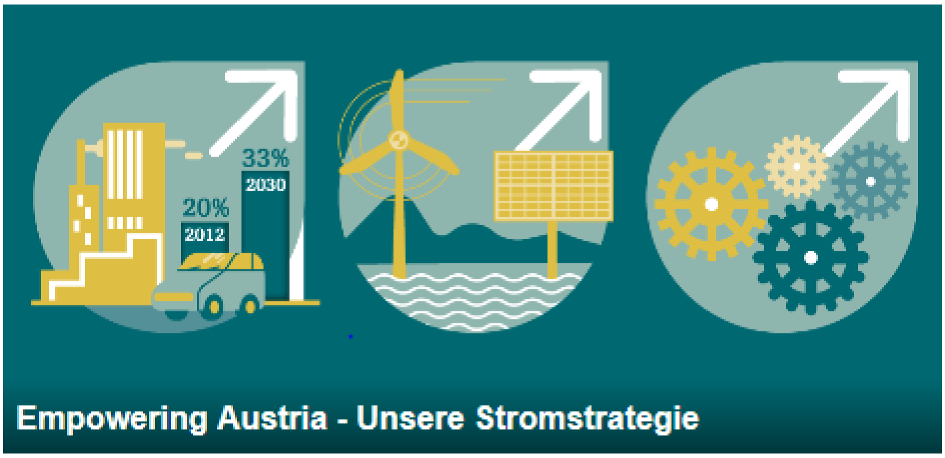

Figure 4: “Empowering Austria”[34]

The concept of “Empowering Austria” predicts that “power” (electricity) will become the most important form of energy in the Austrian energy system (cf 2.2.1).

As far as **PV** is concerned, according to “Österreichs Energie” the current 1.8% share of electricity generation could be increased to 15.3% by 2030, due to the availability of sufficient space, mostly on-roof, and to the positive attitude towards PV in Austrian society. Nevertheless, in order to reach this strategic goal, Austria requires the support of those customers who are in a position to install generating capacity on their roof space.

[33] Österreichs Energie - Schmidt B. (2017): „Empowering Austria - Die Stromstrategie von Österreichs Energie bis zum Jahre 2030“.

[34] Picture on the concept of “Empowering Austria, on http://oesterreichsenergie.at/home.html, retrieved 18.8.2017

2.3 Summary

The present Master’s Thesis will examine how far the newly developed business model is able to support “Österreichs Energie”’s target of “Empowering Austria”, and will evaluate advantages and disadvantages for all stakeholders involved. These are shown in Figure 5.

The bigger size of the circle representing the role of the Regulator and of the grid operator in Figure 5 intends to express that, in our view, the provisions currently applied by the network operator have the biggest influence on the future development of a decentralized electricity generation in Austria.

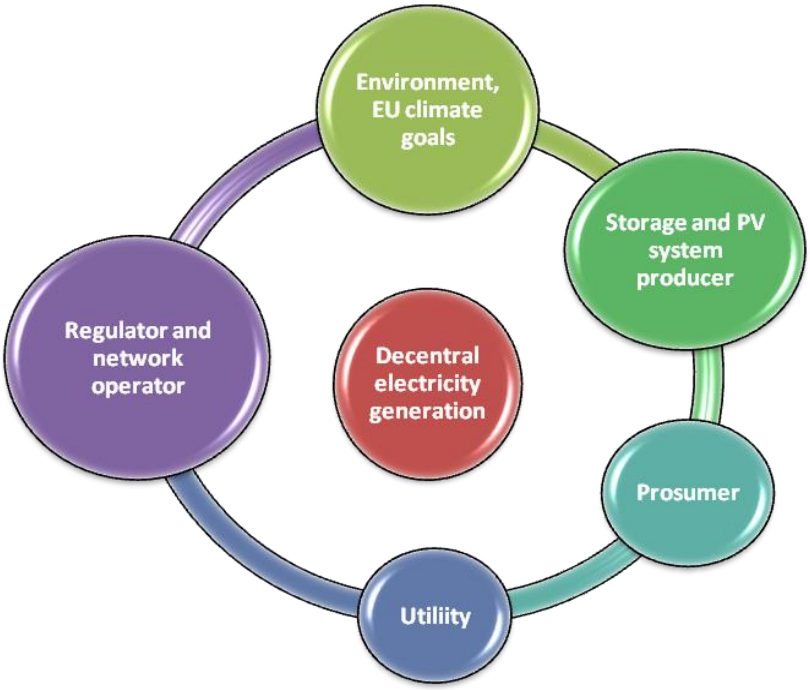

Figure 5: Parties involved in decentralized electricity generation today (own figure)

Traditionally, electricity grids have been designed to a vertically connected scheme characterized by centralized generation, distributed consumption and limited interconnection capabilities between the different grid control areas. These have remained the same for most of last century, without major architectural improvements (Moura et al., 2013: 621).

In the meantime, “(t)he installed capacity of photovoltaic (PV) systems has (…) increased at a much faster rate than the development of grid codes to effectively and efficiently manage high penetration of PV within the distribution system” (Braun et al., 2011: 681).

With the words of Caamaňano-Martín: “In the long run, increasingly decentralized patterns of production and consumption call for novel and decentralized approaches to energy and power management in production, transmission, storage and consumption of electricity. (…) **Changes in regulatory frameworks** will allow PV technology to become “an active part of tomorrow’s electricity networks” (Caamaňo-Martín et al., 2018: 639).

3 METHOD OF APPROACH

The core objective of the present Master’s Thesis is the development of a new, still theoretical, business model for large corporate customers encouraging a higher level of decentralized electricity generation, where the customer consumes electricity at several sites within the Greater Vienna area.

The analysis focuses on the empirical data of an existing Key Account (KA), who has been left anonymous at his own request. The electricity consumption of the KA takes place on his production sites, in his office buildings and in his data centre, all of them located in the Greater Vienna area.

This chapter describes the working method applied.

3.1 The “status quo” case

With the support of a planning tool used by a regional utility, PV systems will be designed for each roof.

Although the KA has large roof surfaces at his disposal for self-generation from PV, he dictates the condition that the PV systems shall be designed in such a way that the whole generation can be consumed on site and that hardly an amount of excess electricity is generated and fed into the grid.

We will call this decision the “status quo” case, which, according to the KA, was taken for the following two reasons:

- Current regulation does not allow to offset the self-generation on one site against the consumption on another site, even if the sites belong to the same KA and to the same frame contract for electricity supply.
- Every kWh of electricity generated on site which cannot be consumed on site is considered a loss by the KA. In fact, for every single kWh of bought-in consumption the KA pays a gross price including grid costs, while for every kWh of generation, not directly consumed but fed into the system, the compensation is only equivalent to the price for electricity supply. In contrast, if self-generation can be consumed on site, electricity supply and network costs are saved.

In a first step, we will design the **“status quo”** case according to the KA´s plans by analyzing the availability on his roofs, the investment costs for the installation of the PV systems, the respective electricity consumption on site, the estimated electricity costs and the estimated savings from self-generation[35].

3.2 The new “PV - VPPN” business model

In a second step, we will put forward a new business model to be offered by **utilities**, which we will call “PV-virtual private power network” (**PV-VPPN**) by adding a “P” for “power” to the typical telecommunications term “VPN” (virtual private network). The new business model covers electricity supply, a customer-owned decentralized PV-generation and a utility-company-owned storage “cloud” (cf footnote 8). For the time being, the application of this new model is only theoretical, as it would require a change in current regulatory provisions.

In our work, we will analyze how far the new model can encourage the KA to exploit his rooftop PV potential: we will dimension the PV systems according to the full space available on the main roofs and assume that self-generation can be allocated to other KA sites if consumption is immediate. After that, we will calculate how much of the generation needs to be virtually stored by the utility in order to be consumed at a later point in time.

As with the “status quo” case, we will analyze quantities, costs and savings: investment costs for the installation of the PV systems, total net cumulated electricity consumption, the increased self-generation and savings from self-generation.

3.2.1 How does the „PV-VPPN“ work?

The “PV-VPPN” is a business model offered by the **utility**, which has a contract for electricity supply with the KA. The utility is part of the “PV-VPPN” and is responsible for electricity supply and for the storage. The model includes **the following services in a “package offer**”:

- Offsetting generation/consumption within the KA´s locations as if this took place at the same location, when consumption on one site and generation on another site are contemporary.
- Temporary virtual storage of the self-generation which can only be consumed with a time shift by the KA: The stored electricity is purchased by the utility from the prosumer at the moment of generation, at hourly spot prices plus a markup (the same markup as for the price charged for electricity supply).
- Electricity supply for the net power demand (including the repurchase by the KA of the “stored” electricity).

[35] For the dimensioning of the PV system the publicly available PV-GIS-tool will be used (https://www.wien.gv.at/umweltgut/public/grafik.aspx?ThemePage=9). For the analysis of the load profiles, a utility-owned tool will be used.

In this model, it is irrelevant for the KA how/if his electricity is stored: The “back up” can be the commercialization as frequency control power, a flexible pump storage hydro power plant, power2heat solutions such as electricity heaters, storage in a network of e-mobility charging stations or in community batteries. Alternatively, the electricity can be directly sold to another KA by the utility without storing it beforehand.

3.2.2 How will we proceed with calculations in the case of the „PV-VPPN“?

- We design the rooftop PV solar systems by exploiting the capacities of the big roofs.
- We decide not to include the smaller roofs, and concentrate only on the advantages of economies of scale.
- We sum the KA´s consumption load profiles of all 5 metering points.
- We sum the profiles of the electricity generation on all sites.
- We offset the PV-generation against the consumption taking place at the same time within the VPPN.
- We calculate what proportion of the generation is temporarily stored and its monetary value.
- We calculate savings for the KA.

3.3 Comparison of results

The next step will be to compare the results of the two models: does the new model make it economically attractive for the KA to increase self-generation?

We will quantify the additional electricity generation from PV and the additional savings both on electricity supply and on the network side. We will also estimate additional investment costs.

Afterwards, we will describe what concrete changes to the Electricity Act will be required in order to be able to offer this new model.

3.4 Assumptions and calculation decisions

In this work, we assume that the KA has an electricity supply contract with its utility consisting of a mark up in eurocent/kWh on top of EPEX-spot hourly prices for the whole supply year 2016.

Electricity supply costs are calculated hourly at hourly prices and invoiced (monthly) accordingly.

In the case of the network charges, for the sake of simplicity the following assumptions and calculation decisions are made:

- All five metering points, including the smaller ones, are at network level 5 and related fees are applied[36].
- We will concentrate on the savings related to the following grid fees: capacity-related **System Utilization Charge** (kW), volume-related **System Utilization Charge** (kWh) and volume-related **Charge for System Losses** (kWh).
- No taxes and levies will be considered in the calculation.
- Metering points 1 and 2 (the largest ones) will be described in depth and analyzed. Otherwise, overall data related to the sum of the 5 metering points will be used for discussion.[37]
- We will concentrate on the comparison of system utilization data related to the monthly power peaks (kW) relevant for grid invoicing.
- As all metering points already exist, possible implications for already paid **System Provision Charges**[38] will not be taken into consideration for the time being.

[36] For network levels and related fees cf appendix 6.

[37] For detailed data cf appendix 7 and appendix 8.

[38] „Netzbereitstellungsentgelt“ is the one-time cost for new connections.

4 DESCRIPTION AND DISCUSSION OF THE DATA COLLECTED AND USED

In this chapter, both the “status quo” case and the “VPPN” business model are applied to the KA’s sites and results are described for each model. Results will be compared in the next chapter.

The KA has 5 sites spread across the 21st, the 14th and the 11th district of Vienna, for which we assume that it has signed a frame contract with the local utility for electricity supply. The five sites are identified with 5 metering points and have the following on site consumption per year:

Table 1: The Key Account´s consumption on each site (own table)[39]

	Metering point 1	Metering point 2	Metering point 3	Metering point 4	Metering point 5	Total
kWh	26,540,760	9,691,251	2,494,409	945,034	111,989	39,783,443

According to “PV-GIS”, the online tool showing the PV potential of roofs in Vienna, all metering points, except for one, can contribute to self-generation with PV. The fifth one cannot, because the building is a designated listed monument.

[39] Based on real load profiles in 2016

Metering point 1 has the highest yearly consumption:

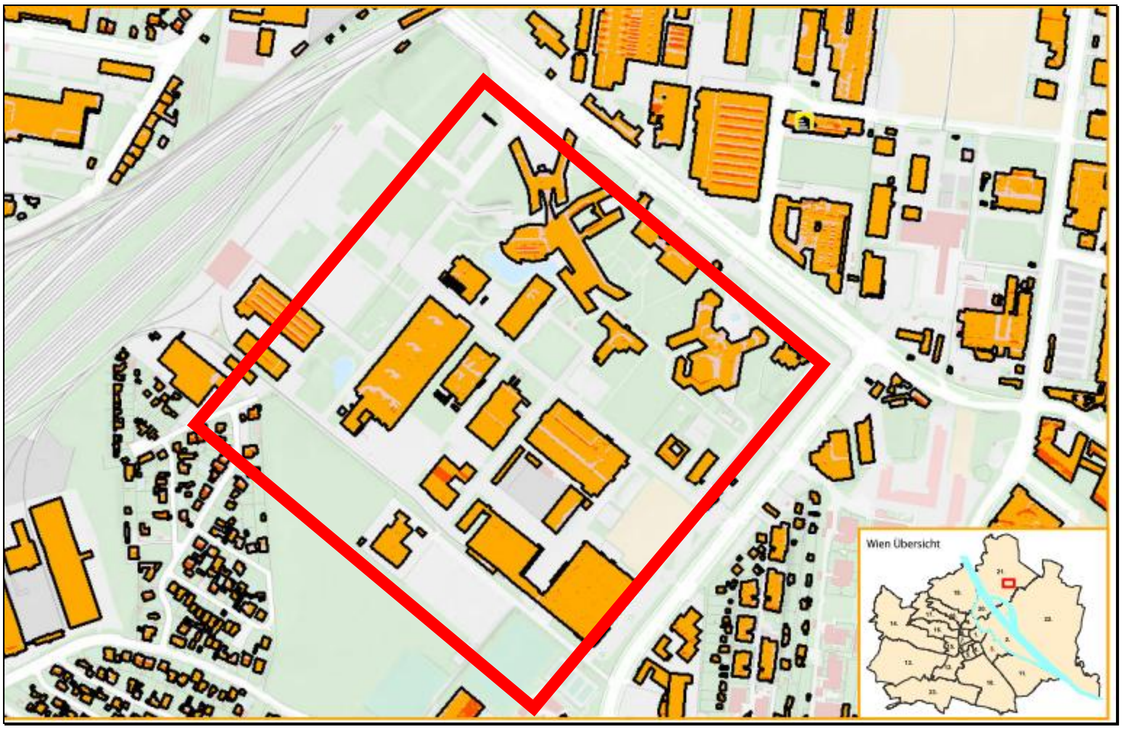

Figure 6: Metering point 1 in the 21st district of Vienna (from PV-GIS)

Metering point 2 has the second highest yearly consumption and the biggest potential for self-generation with PV:

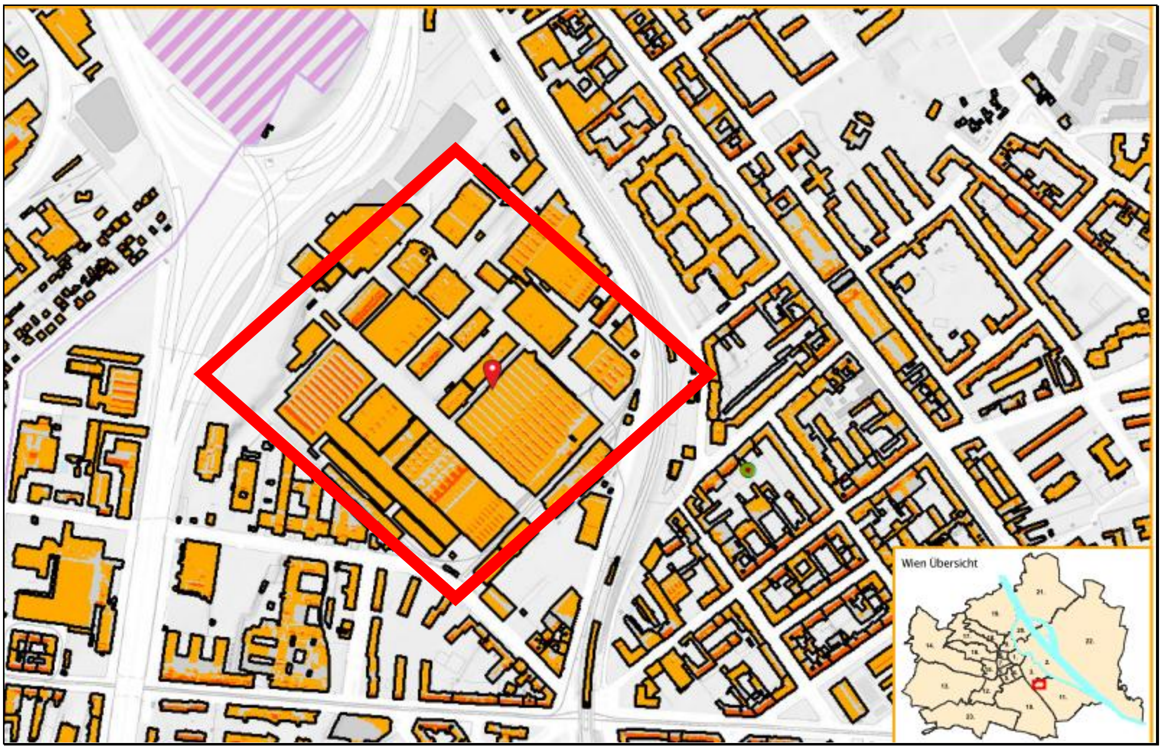

Figure 7: Metering point 2 in the 11th district of Vienna (from PV-GIS)

Metering point 3 has a high consumption and a small roof surface:

Figure 8: Metering point 3 in the 21st district of Vienna (from PV-GIS)

As with metering point 3, metering point 4 has a very small roof surface available for self-generation:

Figure 9: Metering point 4 in the 21th district of Vienna (from PV-GIS)

Metering point 5 has neither a high yearly consumption nor the ability to contribute to self-generation because the building is a designated listed monument in Vienna and it is not allowed to undertake visible changes to the building:

Figure 10: Metering point 5 in the 21st district of Vienna (from PV-GIS)

The roof surface and an estimation of the PV potential on each roof of the five sites are shown in the following table:

Table 2: Surface of roofs (own table)[40]

	Metering point 1	Metering point 2	Metering point 3	Metering point 4	Metering point 5	Total
m^2	43,600	75,280	1,100	500	Declared listed monument (PV not allowed)	**120,480**
m2/kWp	15	15	15	15	15	
kWp	2,907	5,019	73	33	none	**8,032**

Table 2 shows that, although metering point 1 has by far the highest electricity consumption per year, it has a surface constraint for self-generation with PV.

[40] The surfaces are measured by the PV-GIS tool

The dimensions of the PV-systems (kWp) in Table 2: Surface of roofs (own table)Table 2 are based on the following standard parameters:

Table 3: Standard parameters of the utility owned PV-tool

Orientation: South, 180°
Inclination of the PV-arrays: 15°

The yield of the PV-systems is calculated according to the following equation:

(1)

$$Y = 1{,}060\ h/a \times \frac{100 - X\%}{100} \times C$$

Where:

Y = Yield (kWh/a)

1,060 h/a = Full load hours per year (constant value)

X% = percentage of shadowing

C = Nominal value of installed capacity (kWp)

The followng equation is the basis for the calculation of the nominal capacity available on the roof:

(2)

$$A = \frac{RS}{15}$$

Where:

A = Available nominal capacity (kWp)

RS = Roof surface (m^2)

15 = 15 m^2 [41]

[41] The assumption of 1 kWp/15 m^2 relies on the consultation with a designer of PV systems for large companies.

The surface of the roof is the result of a measurement with a PV-tool[42] made publicly available by the City of Vienna.

4.1 Data related to the “status quo” case

In the following paragraphs, the key data of the PV-systems at each site are shown.

4.1.1 Key data metering point 1

At metering point 1 the roof size does not allow more than 2,900 kWp, even if theoretically a larger PV-system without excess generation would be possible.

	Orientation	Inclination	Share				Shadowing
Metering point 1	Süd (180°)	15°	100%				3%
Generatios surplus	0.1%	1%	5%	10%	15%	20%	0%
PV dimensioning for related surplus	3,933 kWp	4,647 kWp	6,769 kWp	8,371 kWp	9,725 kWp	11,004 kWp	
Total power	3,933 kWp	4,647 kWp	6,769 kWp	8,371 kWp	9,725 kWp	11,004 kWp	2,900 kWp

*zugrunde liegende Einstellungen: Anlage 1: 100% Süd (180°) 15°.

Site	Chosen PV dimension	PV generation	Specific yield/year
Metering point 1	2,900 kWp	2,978,920 kWh/Jahr	1,027 kWh/(kWp*Jahr)

Summary 2016			
Tot electricity demand on site	26,540,760 kWh/Jahr	**Surplus in %**	**0%**
Surplus	0 kWh/Jahr	Solar cover ratio	11%
Consumption from PV generation on site	2,978,920 kWh/Jahr		

Figure 11: Basic data metering point 1[43] (from a utility-owned tool)

[42] PV-GIS-Tool

[43] Not every part of the tool used is modifiable. Therefore, only the parts which are, were translated into English.

PV generation is only able to cover a small portion of demand, mostly during the summer:

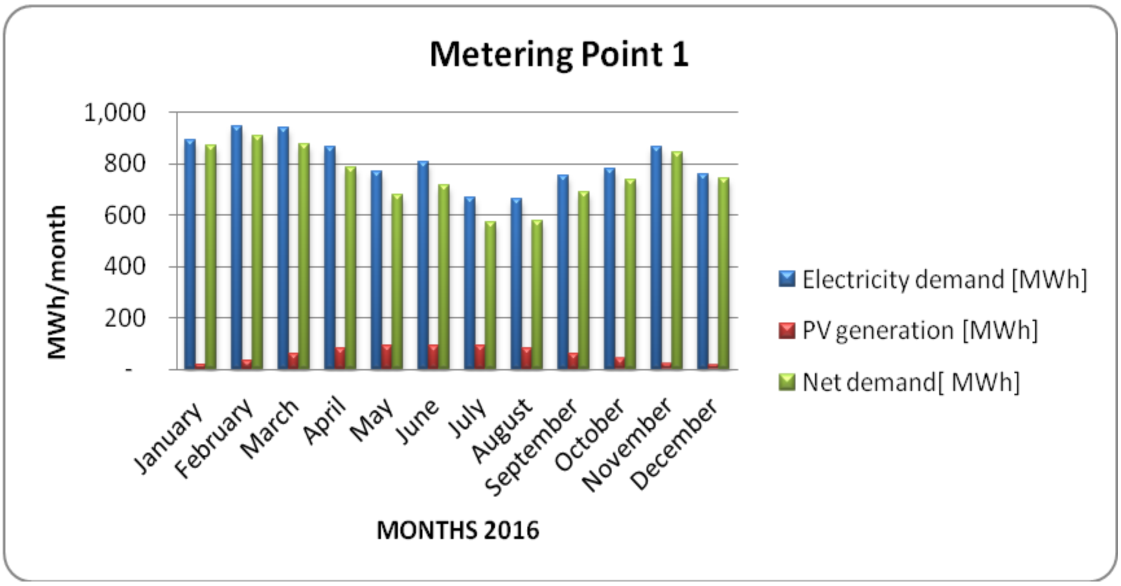

Figure 12: Data of metering point 1 with self-generation from a 2,900 kWp PV system (own chart)[44]

During the year, the PV system is able to cover**,** at the most, 14% of the monthly demand:

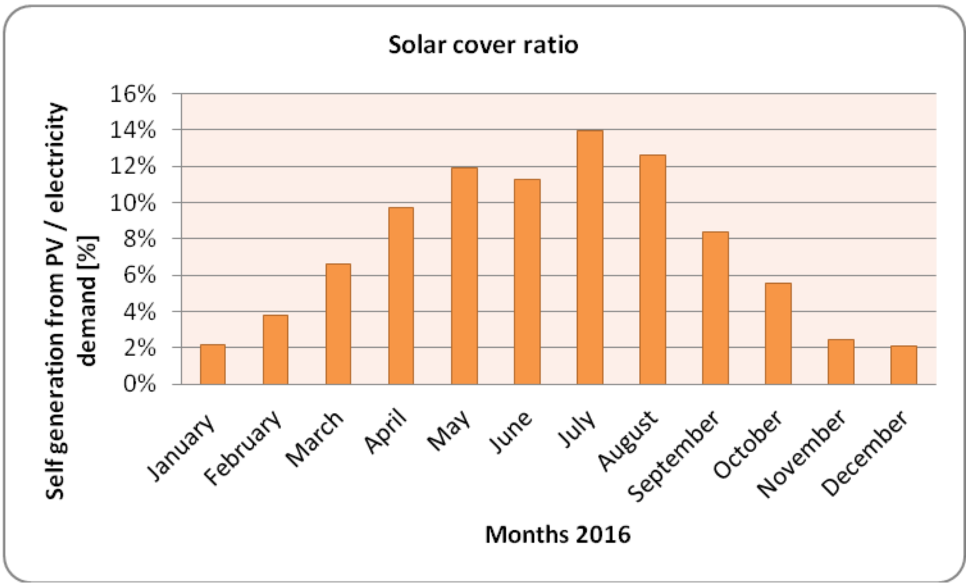

Figure 13: Solar cover ratio of metering point 1 (own chart)

As shown in the following equation, the “solar cover ratio” is the result of the monthly self-generation (MWh) at metering point “x” divided by the monthly electricity demand (MWh) at the same metering point:

[44] For detailed data cf Appendix 1: Key Data of Metering Point 1.

(3)

$$SCR = \frac{PV_{gen}(m)}{D(m)}$$

Where:

SCR = solar cover ratio (%)

PV_{gen} (m) = Self-generation from PV in a month (MWh)

D (m) = Total electricity demand in a month (MWh)

4.1.2 Key data metering point 2

	Orientation	Inclination	Share				Shadowing
Metering point 2	Süd (180°)	15°	100%				10%
Generatios surplus	0.1%	1%	5%	10%	15%	20%	0%
PV dimensioning for related surplus	780 kWp	1,022 kWp	1,594 kWp	2,274 kWp	3,076 kWp	3,997 kWp	
Total power	780 kWp	1,022 kWp	1,594 kWp	2,274 kWp	3,076 kWp	3,997 kWp	740 kWp

*zugrunde liegende Einstellungen: Anlage 1: 100% Süd (180°) 15°.

Site	Chosen PV dimension	PV generation	Specific yield/year
Metering point 2	740 kWp	702,924 kWh/Jahr	950 kWh/(kWp*Jahr)

Summary 2016			
Tot electricity demand on site	9,691,251 kWh/Jahr	**Surplus in %**	**0%**
Surplus	624 kWh/Jahr	Solar cover ratio	7%
PV generation on site	702,300 kWh/Jahr		

Figure 14: Basic data metering point 2 (data from a utility-owned tool)

At metering point 2, the KA decides to dimension the PV system in such a way that no excess generation occurs. Doing so, the KA decides deliberately, for profitability reasons, to exploit only 15% of roof potential, which is 740 kWp instead of the available 5,019 kWp:[45]

[45] Cf values in table 2. The surplus value according to data is irrelevant and will not be taken into consideration for calculations.

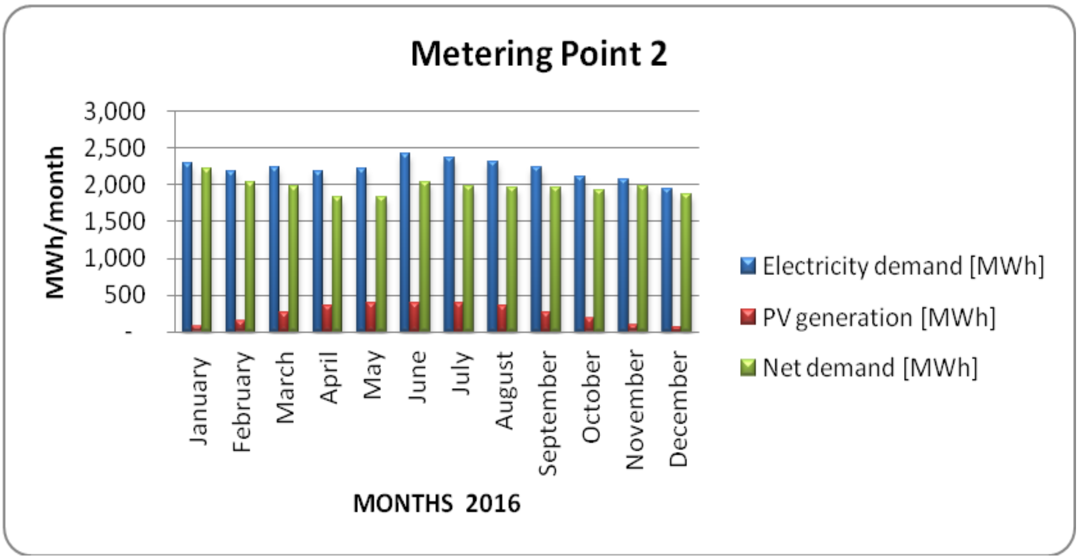

Figure 15: Data of metering point 1 with self-generation from a 740 kWp PV system (own chart)[46]

During the year, the PV system is able to cover, at the most, 18% of the monthly demand:

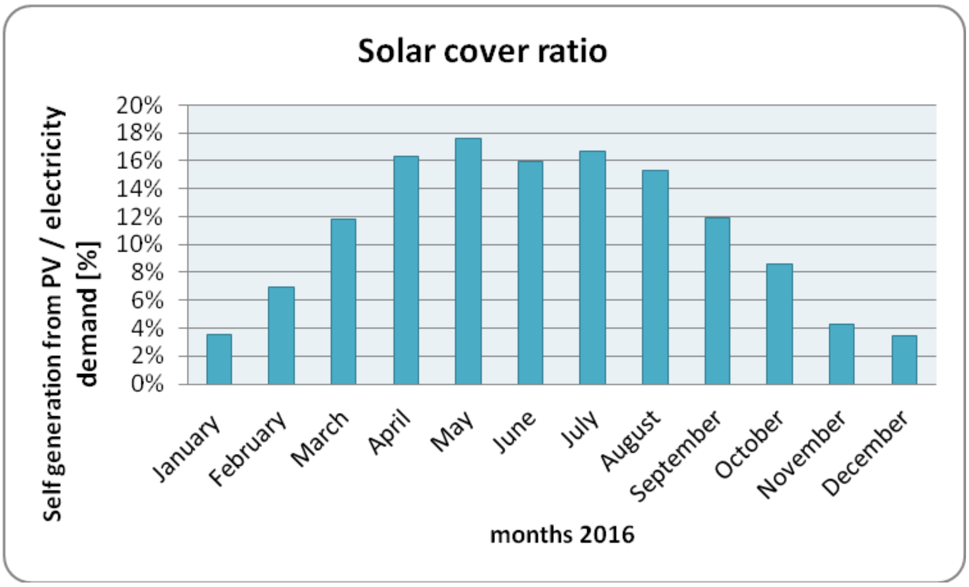

Figure 16: Solar cover ratio of metering point 2 (own chart)[47]

[46] For detailed data cf Appendix 2: Key Data of Metering Point 2.

[47] Cf equation (3)

4.1.3 Key data metering point 3

	Orientation	Inclination	Share				Shadowing
Metering point 3	Süd (180°)	15°	100%				3%
Generatios surplus	0.1%	1%	5%	10%	15%	20%	0%
PV dimensioning for related surplus	780 kWp	1,022 kWp	1,595 kWp	2,274 kWp	3,076 kWp	3,997 kWp	
Total power	780 kWp	1,022 kWp	1,595 kWp	2,274 kWp	3,076 kWp	3,997 kWp	70 kWp

*zugrunde liegende Einstellungen: Anlage 1: 100% Süd (180°) 15°.

Site	Chosen PV dimension	PV generation	Specific yield/year
Metering point 3	70 kWp	71,905 kWh/Jahr	1,027 kWh/(kWp*Jahr)

Summary 2016			
Tot electricity demand on site	2,494,409 kWh/Jahr	**Surplus in %**	**0%**
Surplus	0 kWh/Jahr	Solar cover ratio	3%
Consumption from PV generation on site	71,905 kWh/Jahr		

Figure 17: Basic data metering point 3 (data from a utility-owned tool)

As with metering point 1, the limitation for metering point 3 is given by the roof size. The potential is not higher than around 70 kWp. Nevertheless, as the KA intends to generate as much as possible provided that there is no excess generation, the construction of this PV system is considered.

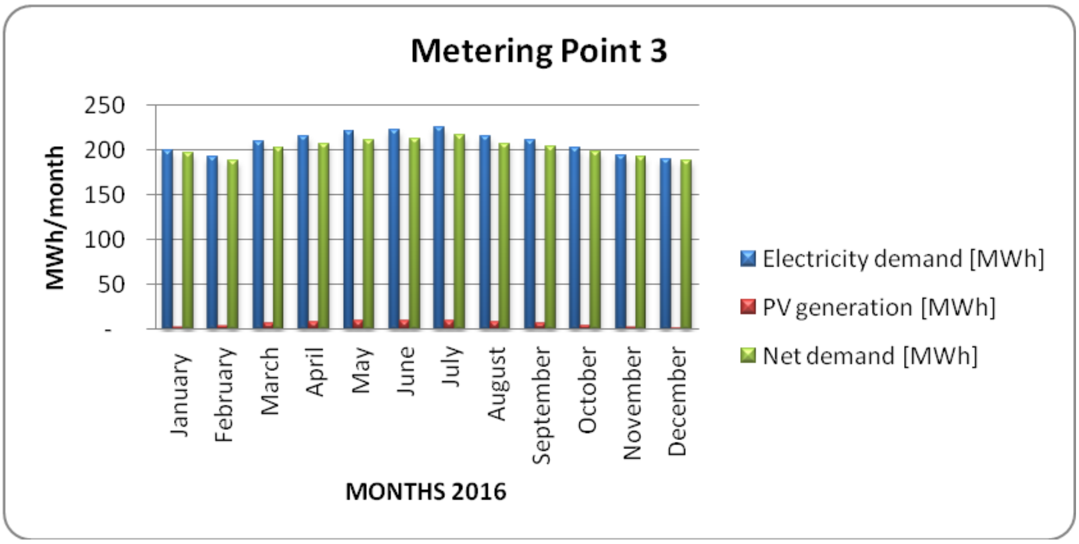

Figure 18: Data of metering point 3 with self-generation from a 70 kWp PV system (own chart)[48]

[48] For detailed data cf Appendix 3: Key Data of Metering Point 3.

During the year, the PV system is only able to cover a very small portion of the demand, due to the fact that the PV system is very small.

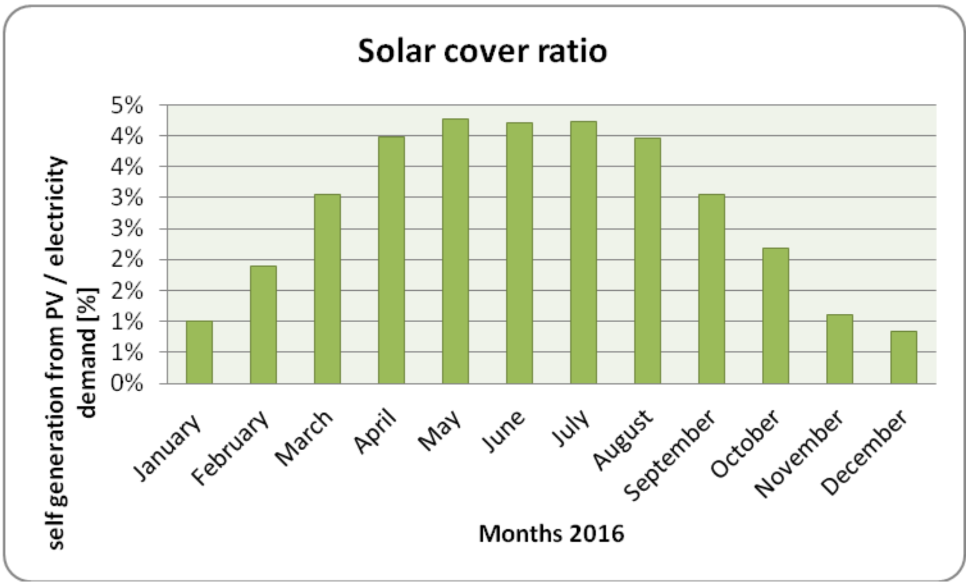

Figure 19 Solar cover ratio of metering point 3 (own chart)[49]

4.1.4 Key data metering point 4

	Orientation	Inclination		Share			Shadowing
Metering point 4	Süd (180°)	15°		100%			3%
Generatios surplus	0,1%	1%	5%	10%	15%	20%	0%
PV dimensioning for related surplus	136 kWp	165 kWp	221 kWp	266 kWp	308 kWp	350 kWp	
Total power	136 kWp	165 kWp	221 kWp	266 kWp	308 kWp	350 kWp	30 kWp

*zugrunde liegende Einstellungen: Anlage 1: 100% Süd (180°) 15°.

Site	Chosen PV dimension	PV generation	Specific yield/year
Metering point 4	30 kWp	30,816 kWh/Jahr	1,027 kWh/(kWp*Jahr)

Summary 2016			
Tot electricity demand on site	945,034 kWh/Jahr	**Surplus in %**	**0%**
Surplus	0 kWh/Jahr	Solar cover ratio	3%
Consumption from PV generation on site	30,816 kWh/Jahr		

Figure 20: Basic data metering point 4 (data from a utility-owned tool)

As with metering points 1 and 3, the limitation for metering point 4 is given by the roof size. The potential is no higher than around 30 kWp. Nevertheless, as the KA intends to generate

49 Cf equation (3)

as much as possible provided that there is no excess generation, the construction of this PV system is considered.

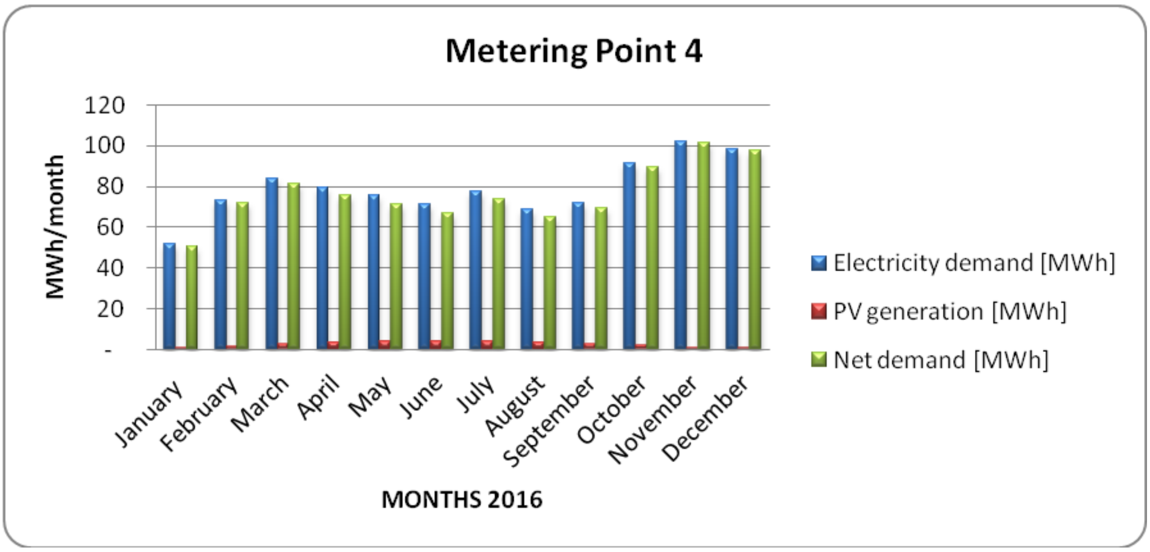

Figure 21: Data of metering point 4 with self-generation from a 30 kWp PV system (own chart)[50]

During the year, the PV system is only able to cover a very small portion of the demand, due to the fact that the PV system is very small.

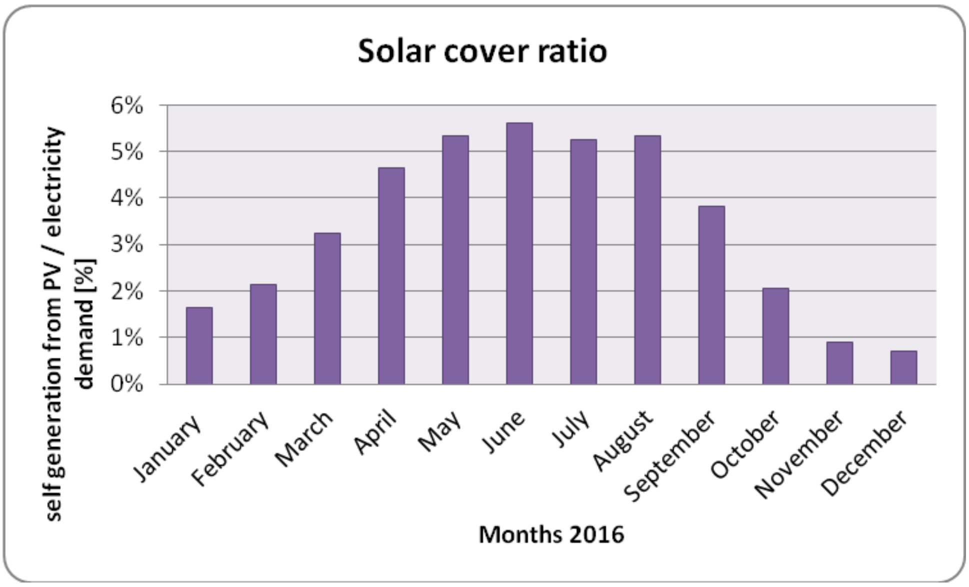

Figure 22: Solar cover ratio of metering point 4 (own chart)[51]

[50] For detailed data cf Appendix 4: Key Data of Metering Point 4.

[51] Cf equation (3)

4.1.5 Key data metering point 5

As mentioned previously, no portion of the yearly electricity demand of kWh 111,989 can be covered by PV generation on site:

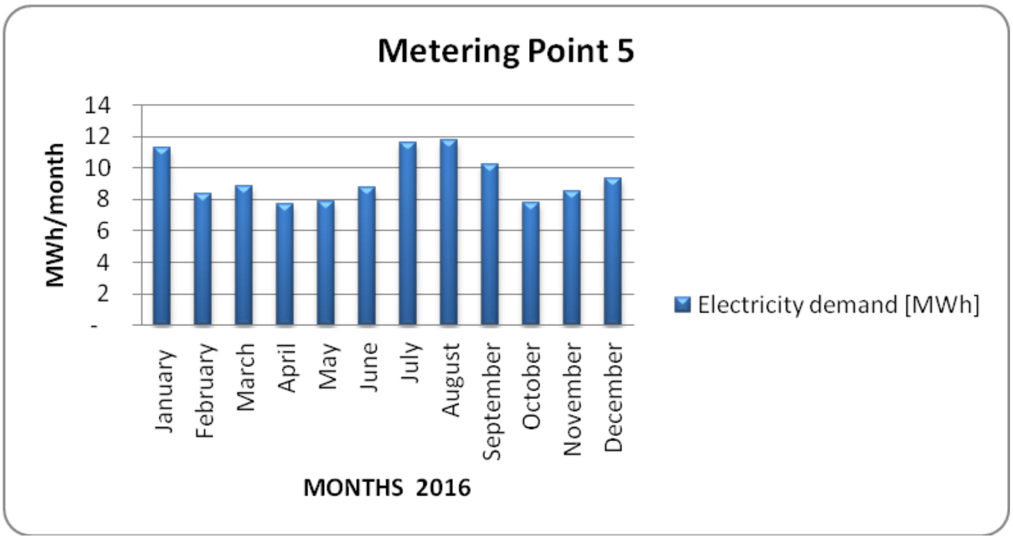

Figure 23: Data of metering point 5 with no self generation (own chart) [52]

In the next sections we will determine the total electricity savings (electricity supply **and** network costs) for the customer in 2016. Firstly, we will calculate the total costs of gross demand (before decentralized generation) as follows:

(4) Equation for costs of electricity supply**:**

$$E_{2016} = \sum_{k=1}^{8784} D(k) \times (p_{EPEX}(k) + M)$$

Where:

E_{2016} = Costs of electricity supply in 2016 (EUR)

$\sum_{k=1}^{8784}$ = All hours in the year 2016

k = One hour

D = Hourly power consumption (kWh)

P_{EPEX} = Hourly Spot price at the EPEX energy exchange (€ct/kWh)

M = Markup added to the EPEX Spot price (€ct/kWh)

[52] For detailed data cf Appendix 5: Key Data of Metering Point 5.

(**5)** Equation for network costs:

$$N_{2016} = \sum_{m=1}^{12} (Peak(m) \times p_{kW}) + D_{2016} \times p_{kWh}$$

Where:

N_{2016} = Network costs in 2016 (EUR)

$\sum_{m=1}^{12}$ = All months in 2016

Peak(m) = Highest power value in month m (kW)

p_{kW} = Capacity-related network price (€ct/kW)

D_{2016} = Total electricity demand in 2016 (kWh)

p_{kWh} = Volume-related network price (€ct/kWh)

After that, the same calculation will be made for the net demand (after subtracting self-generation) and values will be compared (subtracted).

4.1.6 OPEX savings from PV generation on site: electricity supply costs

In the “status quo case” the KA is able to self-generate an overall volume of 3.8 GWh/a in a year. This value is able to replace 10% of the supply from the utility.

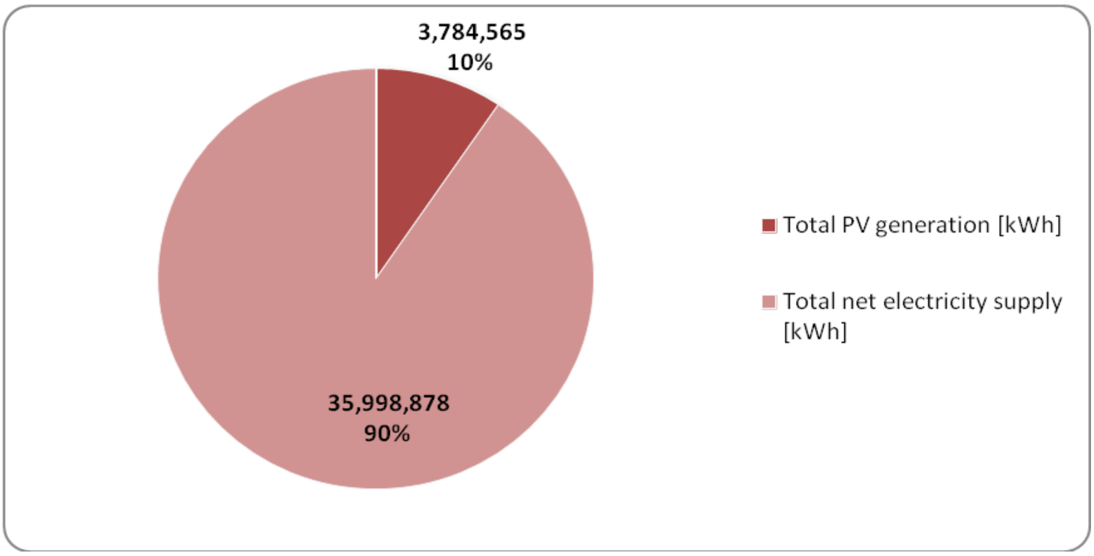

Figure 24: “Status quo case”: Total electricity generation from PV in relationship to consumption (own chart)

The total savings for all 5 sites (due to reduced electricity demand from the utility as a consequence of self-generation) can be summarized in the following graph:

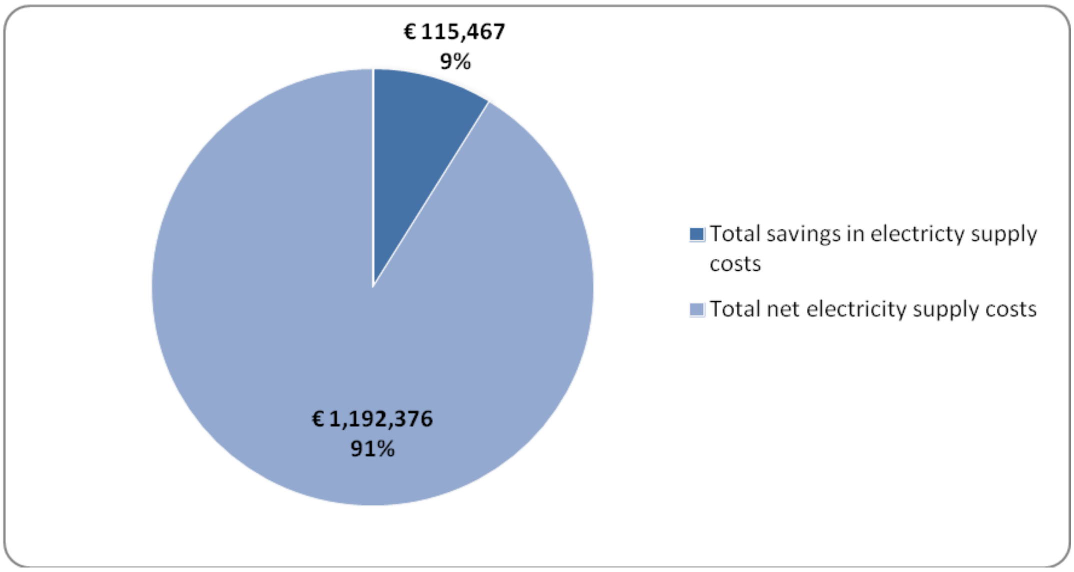

Figure 25: “Status quo case”: Total savings in electricity supply costs as a result of PV generation (own chart)

Total cost savings from electricity supply amount to 9% of total yearly costs.

It is noteworthy that the savings are exclusively due to the quantities (which are reduced through self-generation) and not to the level of hourly prices saved. In fact, the weighted average of customer prices for the net supply is eurocent 3.31/kWh, while the weighted average of customer prices at the time of PV generation is lower and amounts to eurocent 3.05/kWh.[53]

For the sake of completeness, it is worth mentioning that the arithmetic mean value of the spot prices plus margin during 2016 amounted to eurocent 3.15/kWh.

4.1.7 OPEX savings from PV generation on site: grid costs

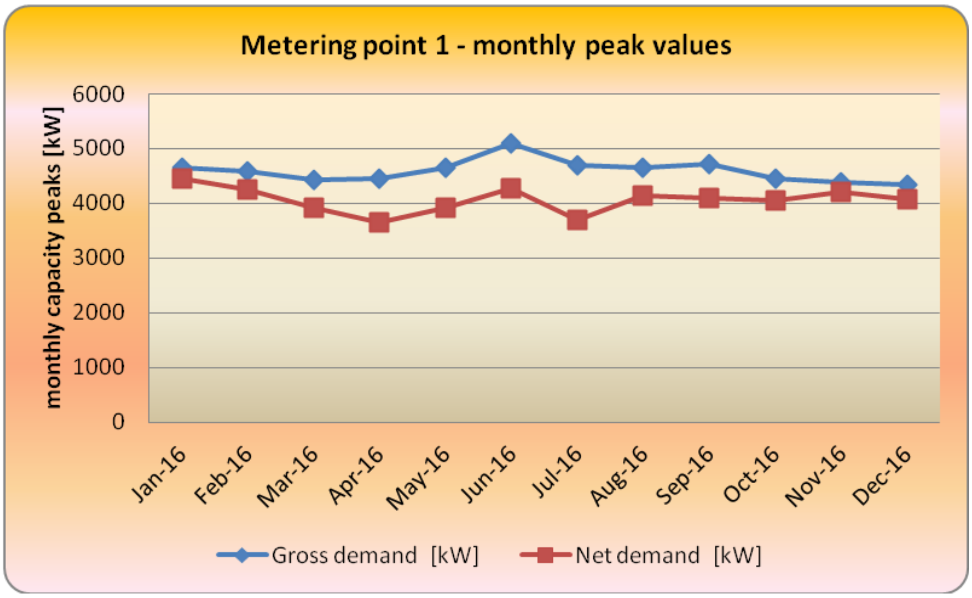

Figure 26: Metering point 1: Monthly peaks of power demand with and without PV (own chart)

The capacity peak is the highest monthly capacity value relevant for invoicing the capacity-related System Utilization Charge. It is an average of 15-minute values. The previous chart (Figure 26) refers to metering point 1. Here we have compared the monthly demand peaks with and without the installation of a PV system. The same can be seen in the next chart (Figure 27) for metering point 2:

53 The mark up used is the same.

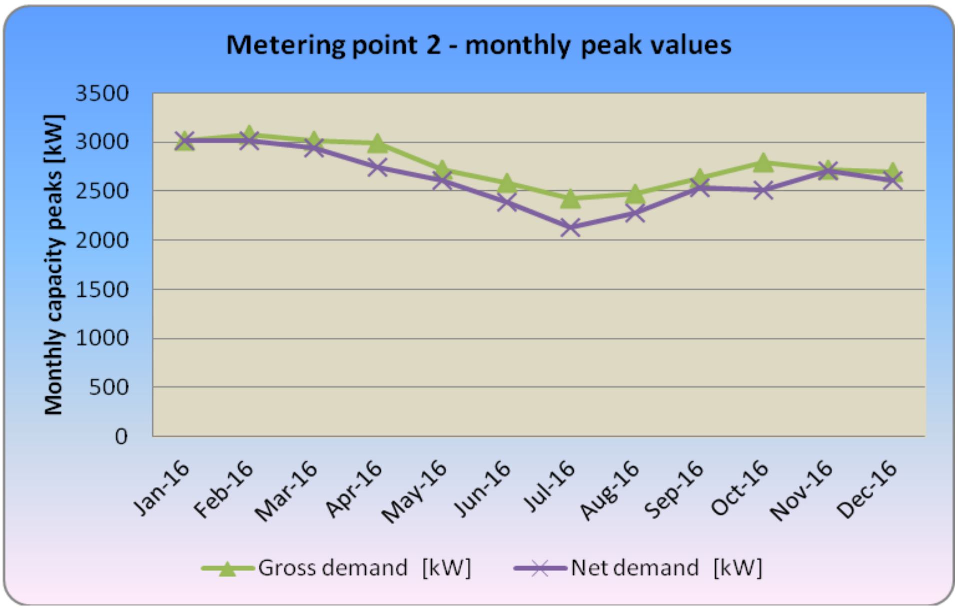

Figure 27: Metering point 2: Monthly peaks of power demand with and without PV (own chart)

The above charts show, in a very striking manner, the influence of PV generation on site on the monthly grid fees. The monthly power peaks for net demand are lower, especially in the summer.

Total savings of grid costs are summarized in the following table:

Table 4: Total savings in grid costs with “status quo case” (own table)

GRID COSTS	€/kW	€/kWh	Savings 2016
System utization charge	44.28		€ 30,714
System utization charge		0.00880	€ 33,304
Charge for system losses		0.00149	€ 5,639
TOTAL SAVINGS			**€ 69,657**

These were calculated according to the following equation[54]:

(6)

$$\sum_{MT=1}^{5} Sv_{N\,2016} = \sum_{m=1}^{12} (\Delta Peak(m) \times p_{su\,kW}) + \Delta D_{2016} \times (p_{su\,kWh} + p_{sl\,kWh})$$

[54] For detailed numbers cf appendix 8

Where:

$\sum_{MT=1}^{5} Sv_{N\,2016} =$ Total network savings in 2016 for all 5 metering points (EUR)

$\sum_{m=1}^{12} =$ All months in 2016

ΔPeak(m) = Difference between gross (without PV-generation) and net (after PV-generation) highest power value in month m (kW)

$p_{su\,kW}$ = Capacity-related system utilization price (€ct/kW)

$p_{su\,kWh}$ = Volume-related system utilization price (€ct/kWh)

$p_{sl\,kWh}$ = Price for system losses (€ct/kWh)

ΔD_{2016} = Difference between gross (without PV-generation) and net (after PV-generation) total electricity demand in 2016 (kWh)

It is noteworthy that here network charges invoiced per kWh have a bigger cost impact than network charges in kW.

4.2 The “PV-VPPN” model

In this chapter we will try to understand if the new “PV-VPPN” model is able to make it economically attractive for the KA to exploit its full on-roof potential, regardless of whether this exceeds or not the on-site consumption at certain points in time.

That is to say, we aim to verify if the prosumer can be incentivized by the “PV-VPPN” model to act in support of the climate goals by self-generating as much electricity as possible.

4.2.1 Differences in PV size in comparison to the „status quo case“

As the maximum size capacity for PV at metering point 1 was already reached in the “status quo case”, the only big change will take place at metering point 2.

	Orientation	Inclination	Share				Shadowing
Metering point 2	Süd (180°)	15°	100%				10%
Generatios surplus	0.1%	1%	5%	10%	15%	20%	25%
PV dimensioning for related surplus	780 kWp	1,022 kWp	1,595 kWp	2,274 kWp	3,076 kWp	3,997 kWp	
Total power	780 kWp	1,022 kWp	1,595 kWp	2,274 kWp	3,076 kWp	3,997 kWp	4,826 kWp

*zugrunde liegende Einstellungen: Anlage 1: 100% Süd (180°) 15°.

Site	Chosen PV dimension	PV generation	Specific yield/year
Metering point 2	4,826 kWp	4,584,432 kWh/Jahr	950 kWh/(kWp*Jahr)

Summary 2016			
Tot electricity demand on site	9,691,251 kWh/Jahr	**Surplus in %**	**25%**
Surplus	1,149,326 kWh/Jahr	Solar cover ratio	35%
Consumption from PV generation on site	3,435,107 kWh/Jahr		

Figure 28: New PV dimension at metering point 2 (data from a utility-owned tool)

We assume that the KA decided to dimension the PV system slightly below 5,000 kWp. In fact, 5,000 kW is the lower threshold in electricity generation for exemption from the Charge for System Services, which is collected and used by the grid for covering the costs of balancing power loads.[55]

In the following table, we can see the impact of the new system on self-generation and self-consumption:

Table 5: Metering point 2 PV dimensions old and new[56]

Metering point 2 (year 2016)	OLD	NEW
Total demand on site [kWh]	9,691, 251	9,691, 251
PV-Dimension [kWp]	**740**	**4,826**
Total generation on site [kWp]	**702,300**	**4,584,433**
Self-consumption on site [kWh]	702,300	3,435,107
Surplus [kWh]	0	1,149,326
Surplus in % generation	0	25%
Solar cover ratio %	**7%**	**35%**

[55] The Charge for System Services (“Systemdiensleistungsentgelt”) amounts to eurocents 0.198/kWh.

[56] For the calculation of total generation on site cf equation (1). For the calculation of the percentage of solar cover ratio cf equation (3).

The surplus 2016 in kWh is calculated with the following equation:

(7)

$$Sur_{2016} = \sum_{k=1}^{8784} (PV_{gen}(k) - D(k)) > 0$$

Where:

Sur_{2016} = Total surplus (excess generation) in 2016 (kWh)

$\sum_{k=1}^{8784}$ = All hours in 2016

K = One hour

PV_{gen} (k) = PV-generation per hour

D(k) = Electricity demand per hour (kWh)

4.2.2 „Cumulated PV-VPPN“ values

Thanks to the new model, the KA is in a position to install **in total** almost twice as many kWp as was the case for the “status quo” data (7,726 kWp instead of 3,740 kWp). This, at just 2 metering points (the ones with the largest roof surfaces). Excess generation is allocated to the other sites, or temporarily stored.

Nevertheless, in the case of our KA, it seems that with his load profiles only a very low proportion of generation needs to be stored to be used at a later point in time.

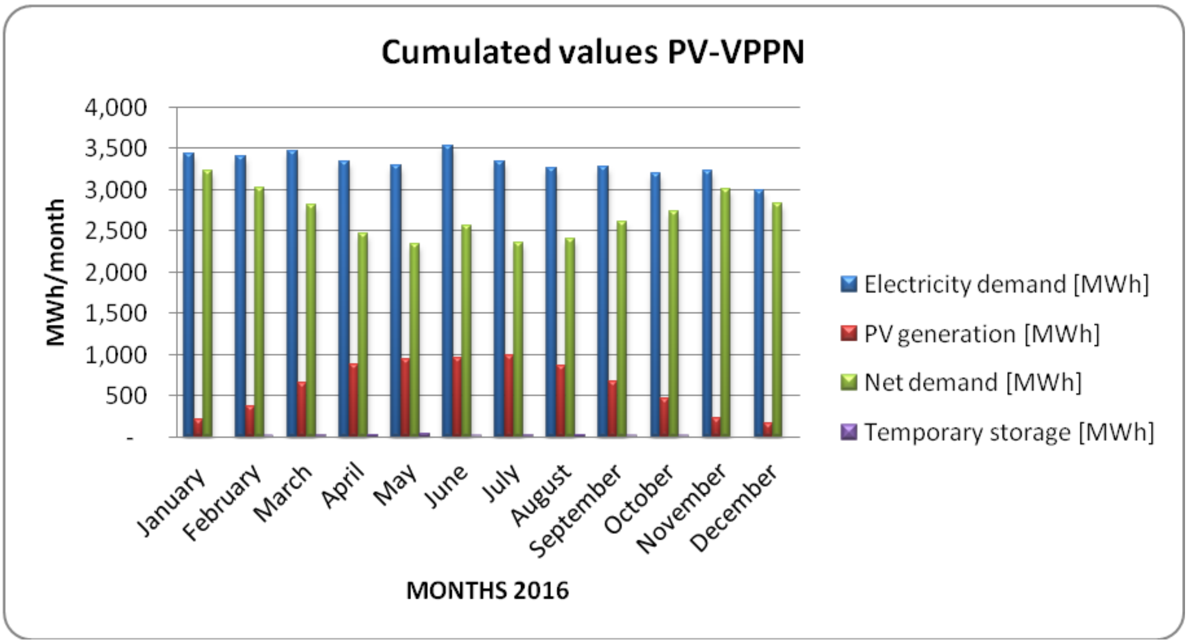

Figure 29: Data of the "VP-VPPN" model with a "cumulated" value of capacity installed for PV solar generation of 7,726 kWp (own chart)

Solar cover ratio increases here to 30% during summer months (in comparison to 5-18% in the previous cases).[57]

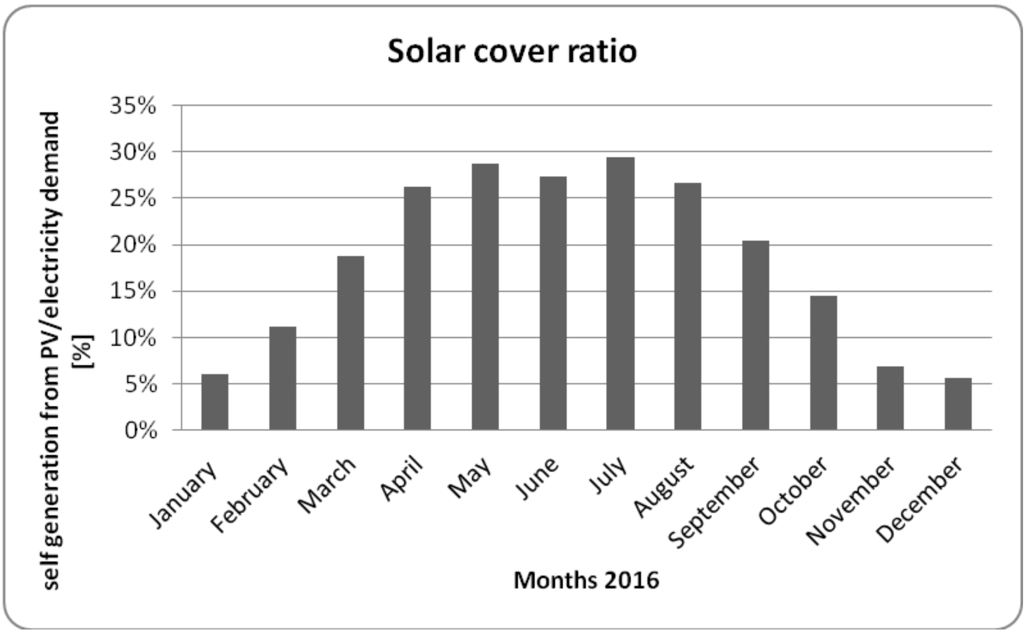

Figure 30: Total solar cover ratio of PV-VPPN (own graph)[58]

[57] For detailed data cf Appendix 9.

[58] Cf equation (3)

4.2.3 OPEX savings from PV generation on site: electricity supply costs

By choosing the "PV-VPPN" model, the KA is able to generate in total around 7.6 GWh/a from PV. This value is able to replace 19% of the electricity supply from the utility.

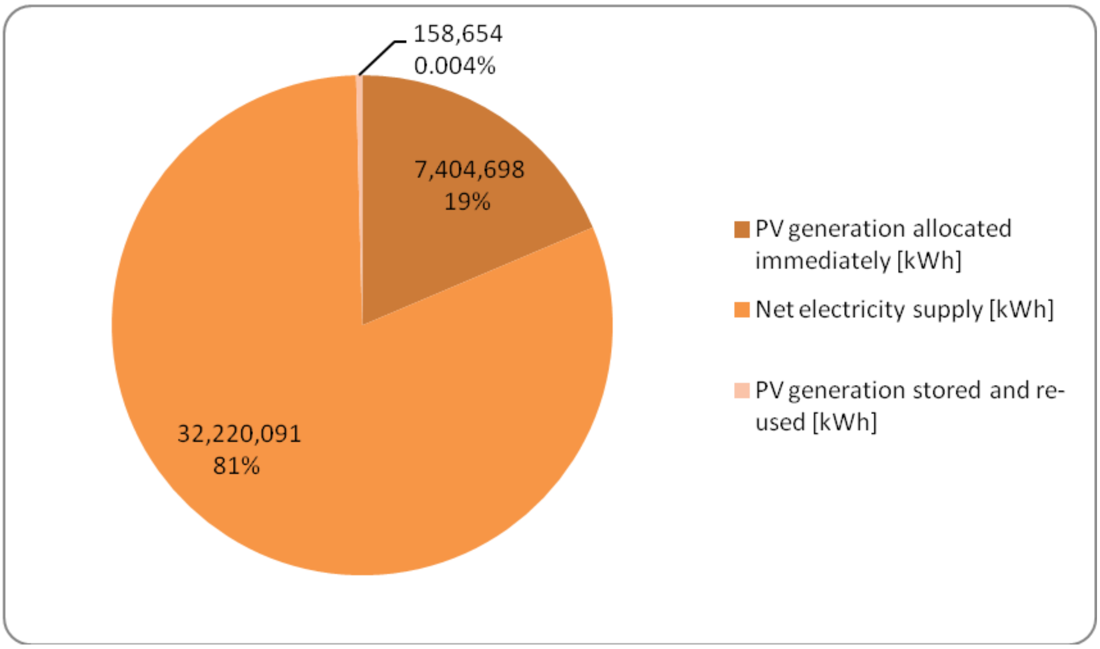

Figure 31: "PV-VPPN": Total electricity generation from PV in relationship to consumption and to storage (own chart)

In the following equation, the calculation of the monetary value of the stored volumes is shown:

(8)

$$S_{2016} = \sum_{k=1}^{8784} \left[\left(PV_{gen}(k) - D_{VPN}(k) \right) > 0 \right] \times \left(p_{EPEX}(k) + M \right)$$

Where:

S_{2016} = Yearly storage revenues related to data 2016 (EUR)

$\sum_{k=1}^{8784}$ = Sum of all hours of the year 2016

k = One hour

PV_{gen} = Decentralized hourly electricity generation of the VPPN (kWh)

D_{VPN} = Total hourly electricity demand of the VPPN (kWh)

P_{EPEX} = Hourly Spot price at the EPEX energy exchange (€ct/kWh)

M = Markup added to the EPEX Spot price (€ct/kWh)

For this profile of consumption and generation, the storage solution seems to be something of a bonus extra, a “nice to have”, while direct generation allocation to other sites makes the model attractive **for our KA**.

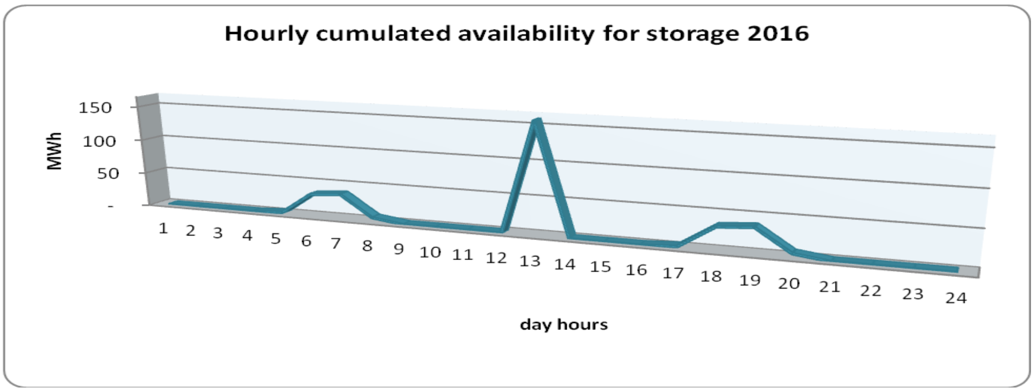

Figure 32: “PV-VPPN”: Cumulated hourly availability for utility storage (own chart)

As we can see in the chart above (Figure 32), the storage solution is applied almost exclusively at 1 p.m., with some lower values in the early morning and in the early evening.

According to the following chart (Figure 33), the portion of cost savings for the customer increased from 9% to 17%. In this case, the revenues from the sale of additional generation are very marginal, not just because the volumes are irrelevant.

It is interesting to notice that spot prices at the time of storage were considerably lower than the average prices for the electricity purchased from the utility. The average price paid by the utility for the purchase of this electricity amounts to around eurocent 1.80/kWh, which is much lower than the price for electricity supply. This is due to the fact that the excess generation, in general, occurs on very sunny days in summer, usually between 10 a.m. and 1 p.m., when large amounts of intermittent electricity from renewable sources are produced in Europe.

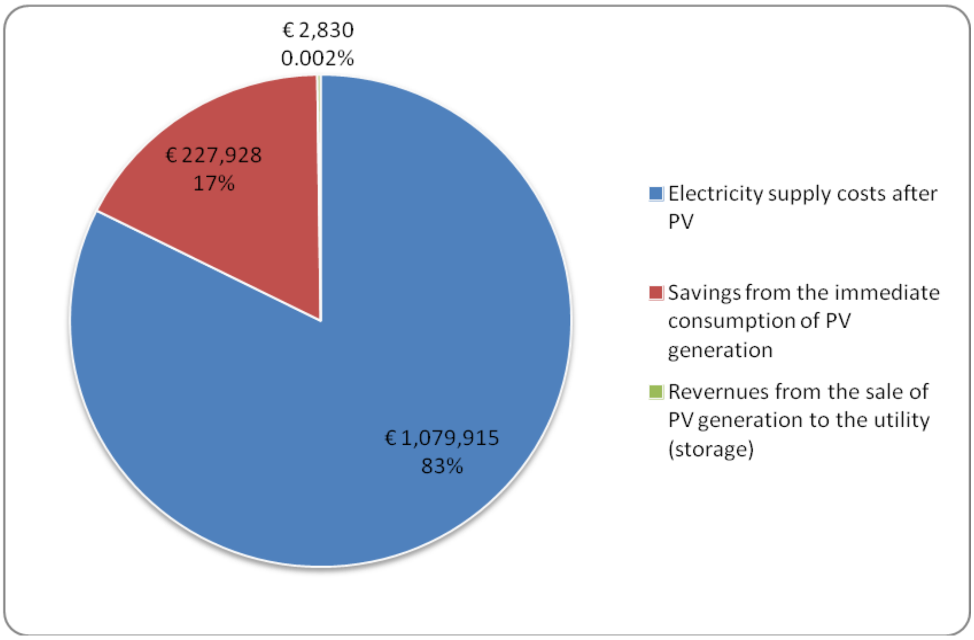

Figure 33: "PV-VPNN": Total savings in electricity supply costs and additional revenues thanks to PV generation (own chart)

As in the "status quo" case, it is noteworthy that the savings are exclusively due to the lower consumption and not to higher hourly supply prices saved with production. In fact, the weighted average of customer prices for the net supply is eurocent 3.33/kWh, while the weighted average of customer prices at the time of PV generation is lower and amounts to eurocent 3.1/kWh.[59]

4.2.4 OPEX savings from PV generation on site: grid costs

Due to the possibility to offset generation against consumption, in summer the monthly capacity peak values can be cut by as much as 30-35%.

As with the "status quo" case, note that network charges invoiced per kWh have a bigger cost impact than network charges invoiced per kW. The savings in volume-related grid charges in the "status quo" case represent around 56% of overall grid savings. With the "PV-VPPN" model the impact is even higher, representing around 63% of overall grid savings.

[59] The mark up used is the same.

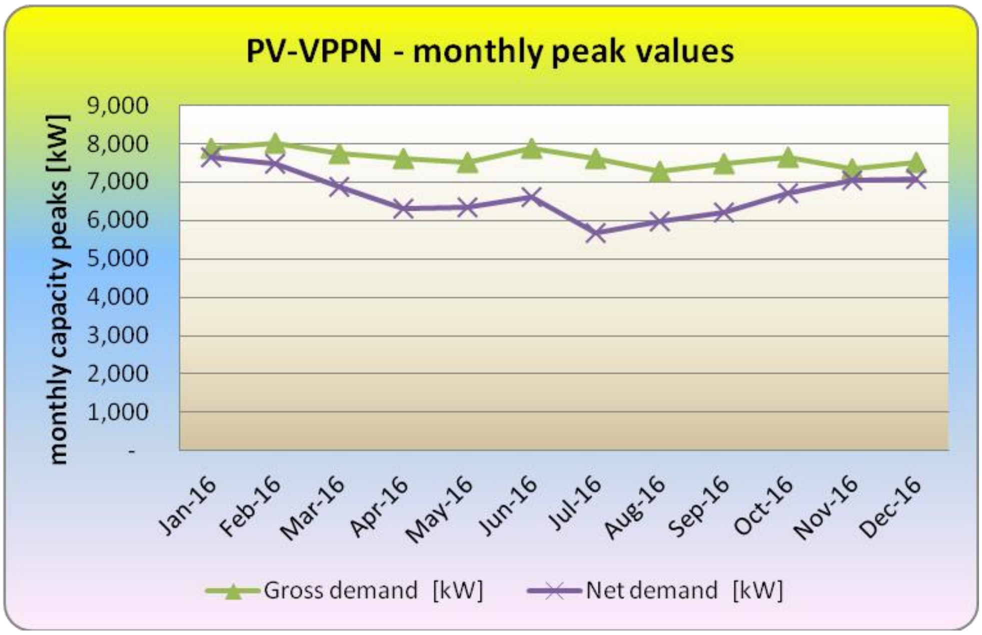

Figure 34: "PV-VPPN": Monthly peaks of power demand with and without PV (own chart)

With the new model, the total savings in grid costs increase by more than 70%, from around € 70,000 to around € 120,000 in only one year.[60]

Table 6: Total savings in grid costs with "PV-VPPN" (own table)

GRID COSTS	€/kW	€/kWh	Savings 2016
System utization charge	44.28		€ 42,936
System utization charge		0.00880	€ 65,161
Charge for system losses		0.00149	€ 11,033
TOTAL SAVINGS			**€ 119,130**

For calculating the total savings in grid costs with the "PV-VPPN", the following equation was applied:

(9)

$$\text{VPN } Sv_{N\,2016} = \sum_{m=1}^{12} (\Delta Peak(m) \times p_{su\,kW}) + \Delta D_{2016} \times (p_{su\,kWh} + p_{sl\,kWh})$$

[60] For details cf Appendix 10.

Where:

VPN $Sv_{N\ 2016}$ = Total network savings in 2016 for the virtual private network (EUR)

$\sum_{m=1}^{12}$ = All months in 2016

ΔPeak(m) = Difference between gross (without PV-generation) and net (after PV-generation) highest power value in month m (kW)

$p_{su\ kW}$ = Capacity-related system utilization price (€ct/kW)

$p_{su\ kWh}$ = Volume-related system utilization price (€ct/kWh)

$p_{sl\ kWh}$ = Price for system losses (€ct/kWh)

ΔD_{2016} = Difference between gross (without PV-generation) and net (after PV-generation) total electricity demand in 2016 (kWh)

5 PRESENTATION OF THE RESULTS OF THE THESIS

In this chapter we will compare the results of the two models applied, show the additional savings following the application of the “VPPN” model and suggest a solution for a modification of the grid fees currently in place. Afterwards, we will consider advantages and disadvantages of the new business model for all stakeholders involved.

5.1 Comparison of the two models

Figure 35 clearly illustrates that, with the new model, the KA doubles his PV generation and reduces further his electricity demand from the utility. As a next step, we will compare the savings in operating expenditures (OPEX), resulting from a decentralized generation, with the capital expenditures (CAPEX) necessary for the implementation of the model.

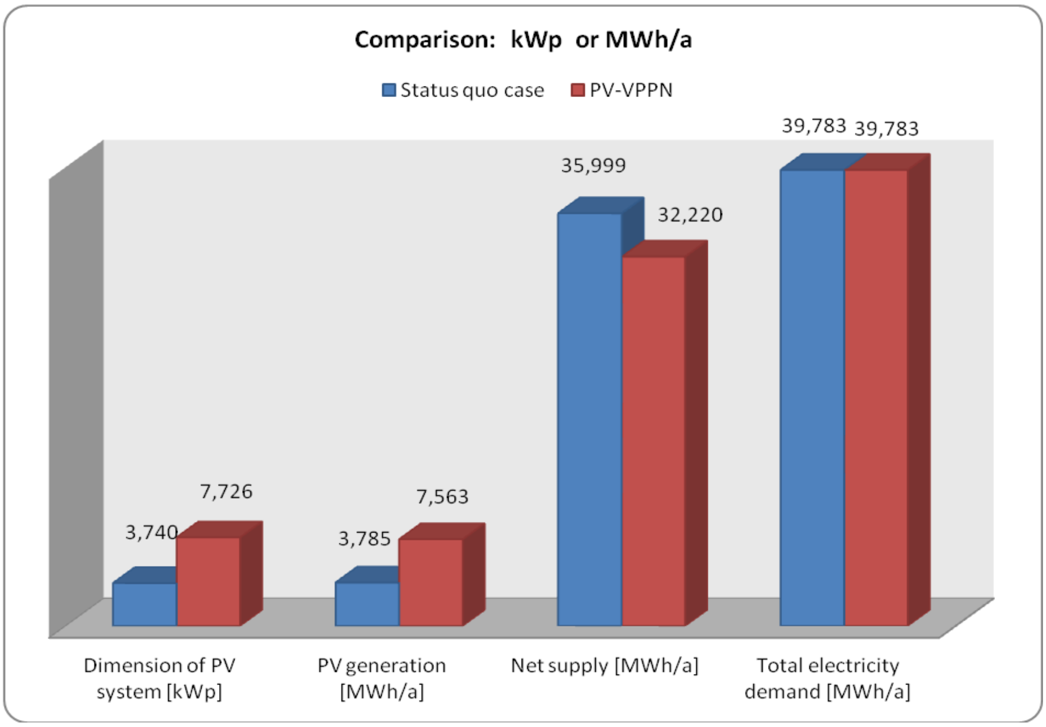

Figure 35: Comparisons of the two models: MWh/a and kWp (own chart)

In calculating investment costs and yearly cost savings, we assume that the KA is the owner of the PV system and that no subsidies are involved. In the “status quo” case we considered PV investment costs of **€ 0.098/kWh,** for the “PV-VPPN” **€ 0.079/kWh**, on the assumption that the two smaller PV systems of metering points 3 and 4 are more expensive and that the larger dimensioning of the PV systems can take advantage of economies of scale (Fechner et al., 2016: 13).

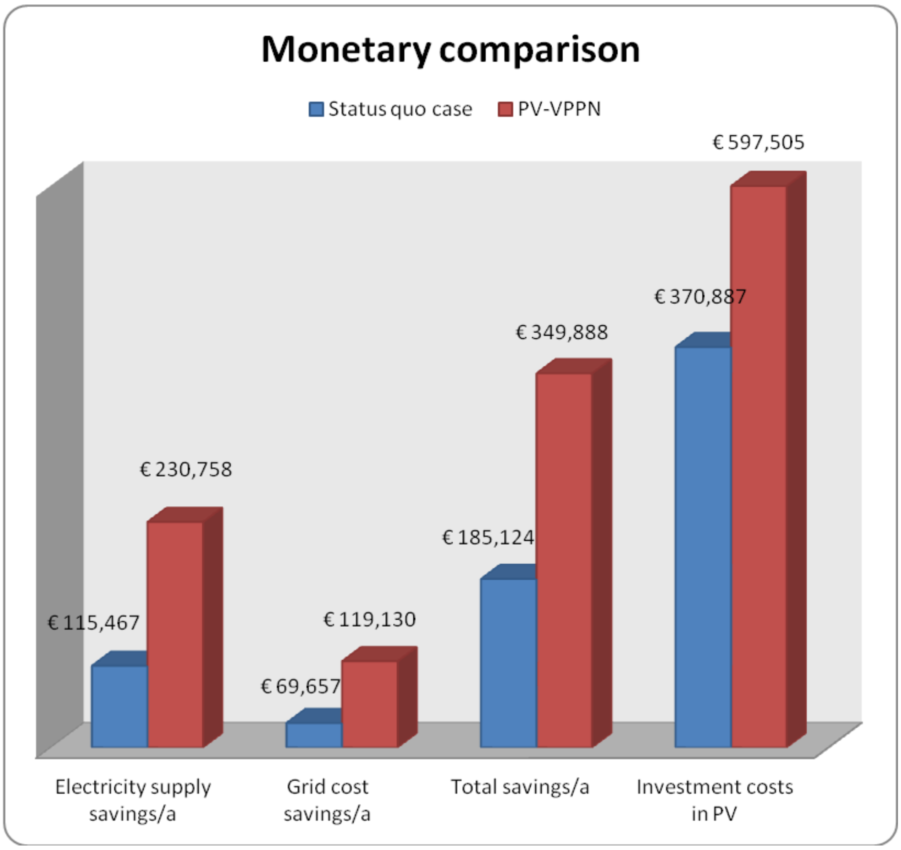

Figure 36: Comparisons of the two models: Euros (own chart)[61]

From Figure 36, it becomes apparent that the KA should not hesitate to choose the new model: Savings per year almost double, while investment costs only increase by 60%. In both cases, investments are depreciated within 2 years. Given these clear benefits, why is further discussion necessary?

The simple fact is that the new model cannot be implemented under the current state of legislation and would require substantial regulatory amendments, which will be described in the following section.

[61] In the case of the energy savings for the “PV-VPPN” model, also the revenues for the sale of electricity to the utility are considered.

5.2 Status quo of regulatory framework

Today, **“net energy metering”** is not applied in Austria. “Net energy metering” is described as the possibility for consumers who generate some or all of their own electricity, to use that electricity anytime, instead of when it is generated”[62].

Furthermore, according to the Electricity Act, the **“**aggregation” of data from physical metering points in a “**virtual metering point”** is not admitted. An exception is made for the light-rail system.[63]

A possible makeshift for, in some way, implementing our model would be to make sure that our five metering points share a large **electricity storage facility** altogether and with the utility. In this case, all parties including the storage facility would be connected to the grid. Unfortunately, as soon as the storage is connected to the grid, the individual metering points become liable to pay grid fees and this situation makes the business model economically prohibitive (Scheller, 2017: 23).

As a matter of fact, storage facilities are not legally seen as an independent asset class yet. At the same time, they are neither part of transmission or distribution, nor generation or consumption (Berger, 2017: 15-18).

In the proposal for a revision of the **EU-Guideline for a common electricity market**, electricity storages are defined as follows:

> *Energy storage means, in the electricity system, deferring an amount of the electricity that was generated to the moment of use, either as final energy or converted into another energy carrier* .[64]

Under **current Austrian legislation,** “storage” is described both from the charging and from the discharging perspective:

> *When charging, a storage is a “consumer” or a “withdrawing party”,*
>
> *When discharging, a storage is a “producer” or an “injecting party*”.[65]

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[62] Definition of the term “net energy metering”, https://en.wikipedia.org/wiki/Net_metering, retrieved 15.8.2017

[63] The so called „Virtuelle Saldierung“in Elektrizitätswirtschafts- und organisationsgesetz, Section 7. (1), item 83: „metering point means any injection or withdrawal point where electricity volumes are metered and registered. (…) Combining several metering points shall not be admissible.

[64] Cited by Urbantschitsch W. (2017:14): Speicher für die Netze.

[65] ElWOG (2010), section 7 (1), items 10-17. Cfr also Urbantschitsch W. (2017:7): Speicher für die Netze. **Definitions: Item 10:** „injection party“ means a producer or an electricity undertaking which feeds electrical energy into a system. **Item 12:** “consumer” means a natural or legal person or a registered partnership purchasing electricity from own use. **Item 14:** “withdrawing party” means a consumer or a system operator taking off electricity from a transmission or distribution system. **Item**

If we categorize storage facilities using the definitions above, the following grid fees apply:

- In the case of a “producer” or of an “injecting party”:
  - One-time System Admission Charge at construction/implementation
  - Charge for System Losses at operation
  - Charge for System Services (if it is > 5MW) at operation.

- In the case of a “consumer” or of a “withdrawing party”:
  - One-time System Provision and one-time System Admission/Access Charge at implementation
  - System Utilization Charge and Charge for System Losses at operation.[66]

Also, no legal definition of a **virtual storage** exists and no exemptions are made for self-consumption within a **“community” storage** solution.

New contributions to the ongoing discussion, both in Austria and in Germany, tend to approve of storage facilities **operated by the distribution grid**. Nevertheless, this opinion is advanced only for storages having a “grid-beneficial” functionality (“netzdienlich-betriebene Speicher” in German), not for commercialization purposes (cf e.g. Lühn and Geldermann, 2017 and Zeh et al., 2014).

5.3 The KA´s perspective

In supporting the idea of exempting the “VPPN” model from the payment of grid fees, we need to determine whether the KA would really “use the network less”. As a matter of fact, he would not, because “such a model tends to return much of its electricity back to the distribution grid” (Pitt and Michaud, 2015: 108).

As can be seen in Figure 37, the KA´s sites are scattered across Vienna and the private network is just virtual. If new business models like this are to become feasible in the future, the need for a reinforcement of the **“bi-directionality”** of the distribution network (in our case **at middle voltage level**) cannot be ignored. And the reinforcement has a cost.

17: “producer”, aka “generator” means a legal or natural person or a registered partnership which generates electricity.

[66] For the sake of simplicity we are not considering taxes and levies.

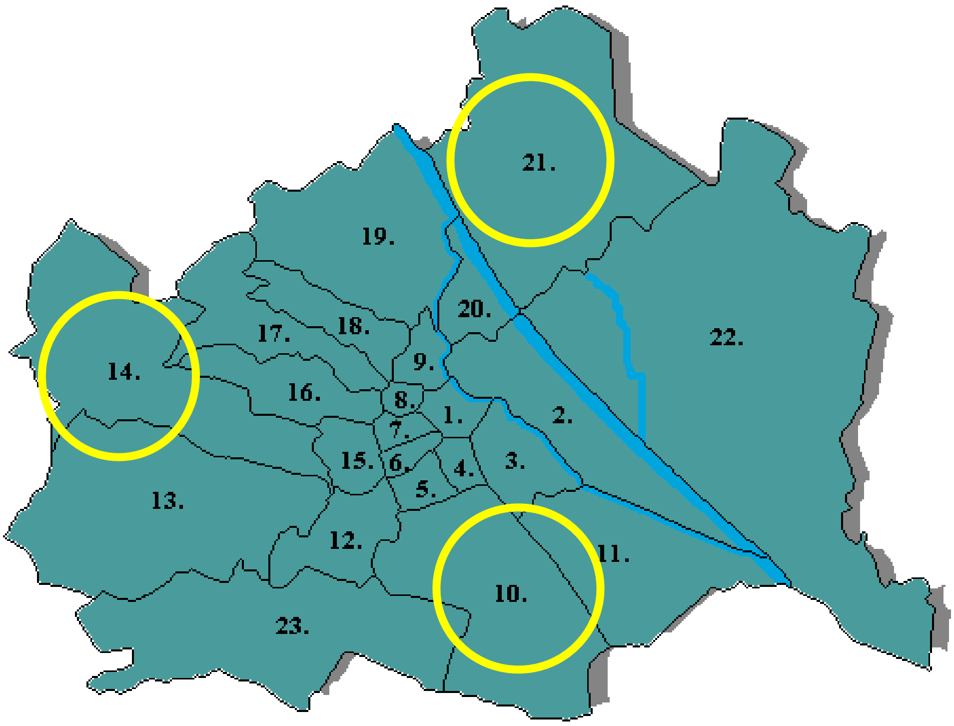

Figure 37: Key Account locations in Vienna[67]

To what extent would it be economically profitable for the KA to financially contribute to the reinforcement of the network?

By increasing self-generation, the KA is in a position to save energy supply and grid costs, more than in the “status quo” case, but only provided that the network of his business model is considered “private”, as if it were a generation/consumption ”island”, similar to a “microgrid” (cf GTM and ESA, 2015:9).

As shown in the previous chapters, with the new model, the KA would save an **additional** € 165,000 per year, this giving the possibility to depreciate the **additional** investment costs in less than two years.

Table 7: ADDITIONAL savings with the “PV-VPPN” (own table)

	Status quo case	PV-VPPN	Difference
Electricity supply savings/a	€ 115,467	€ 230,758	€ 115,291
Grid cost savings/a	€ 69,657	€ 119,130	€ 49,473
Total savings/a	**€ 185,124**	**€ 349,888**	**€ 164,764**
Investment costs in PV	€ 370,887	€ 597,505	€ 226,617

[67] Vienna map on google, retrieved 12 August 2017

Table 8 shows, for the new model, the net present value (NPV) of the additional yearly savings and of the additional investment costs, converted into an annuity value.[68] For our calculation, we considered a time frame of 10 years, in order to make it comparable with the average lifetime of a physical electricity storage, which we will evaluate in a second step.

Table 8: Net present value (NPV) and annuity value of additional savings

Net present value	€ 1,045,648
Discount rate	0.05
Annuity factor	0.13
Lifetime in years	10
Annuity value	**€ 135,416**

The net present value is calculated with the following equation:

(10)

$$\mathrm{NPV} = \mathrm{I} - \mathrm{CF}\ \mathrm{x}\ \frac{1-(1+r)^{-T}}{\mathrm{r}}$$

Where:

NPV = Net Present Value of additional savings (EUR)

I = Additional CAPEX (EUR)

CF = Additional OPEX savings per year (EUR)

r = Discount rate (%)

T = Lifetime of the project

[68] For detailed values cf Appendix 11.

The annuity value is calculated as follows:

(11)

$$a = \mathrm{NPV} \times \frac{(1+r)^T \times r}{(1+r)^T - 1}$$

Where:

NPV = Net Present Value of additional savings (EUR)

r = Discount rate (%)

T = Lifetime of the project

On the basis of those values, we come to the **conclusion** that the KA is willing to invest in a new model as long any kind of additional costs due to the implementation of “VPPN” stay below the annuity value of **€ 135,000** calculated above. This investment will give him the opportunity to “upgrade” his role as a prosumer.

A fee will be paid by the customer to the **utility** for the implementation and the operation of the “VPPN”, including the virtual storage facility.

An additional contribution is to be paid to the **distribution network operator** for the services rendered directly to the KA. These are the following: access to the “virtual private network”, smart data metering and invoicing.

A possible approach would be to “share” 50/50 the additional savings of € 135,000 with the other parties (50% for the KA and 50% for the other parties).

Instead of the fees currently in place on the grid side, we suggest the payment of a “**Virtual Private Network Access Fee**” to be charged by the **distribution network operator**. The “Virtual Private Network Access Fee” could be a one-off payment, a yearly fee or a combination of both.

We support a solution in line with the Regulatory Board’s current proposals relating to a new network fee structure. The proposal aims at unifying the current System Provision Charge and System Admission Charge on the one hand, and to award more importance to capacity-oriented (kW) System Utilization Charges in contrast to volume-oriented ones (kWh).[69]

[69] Cf E-Control (2017): „Tarife 2.0“. Weiterentwicklung der Netzentgeltstruktur für den Stromnetzbereich. Positionspapier der ECA Austria für die Regulierung der Elektrizitäts- und Erdgaswirtschaft (E-Control). (lecture in April 2017)

5.4 The alternative of a physical storage

If no legal amendments occur, we believe that our KA would consider an alternative scenario with **physical storage facilities** (**LI-ION batteries**[70]).

In order to analyze the profitability of an investment in physical batteries, we proceeded as follows:

We analyzed the only PV solar system within the "PV-VPPN" model which produces excess generation (metering point 2) and calculated the level of this excess generation **on site**.

As a second step, we calculated how much of the daily excess generation could be consumed the next day (or night) if a daily electricity storage facility were on site.[71] Solutions different from "day-storages" were not evaluated because scientific literature does not considered them to be economically feasible in combination with PV for the time being (cf ISEA, 2015: 63).

Potential daily storage volumes were calculated with the following equation:

(12)

$$S(k) = (D(k+1) - PV_{gen}(k+1)) > 0$$

Where:

S(k) = Potential daily storage volumes (kWh)

D(k+1) = Daily electricity demand on the next day (kWh)

PV_{gen} (k+1) = Daily PV-generation on the next day (kWh)

[70] Lithium Ion.

[71] Storage losses were ignored for simplification reasons.

Figure 38 shows that the daily excess generation could be stored and re-used on 211 days during the year:

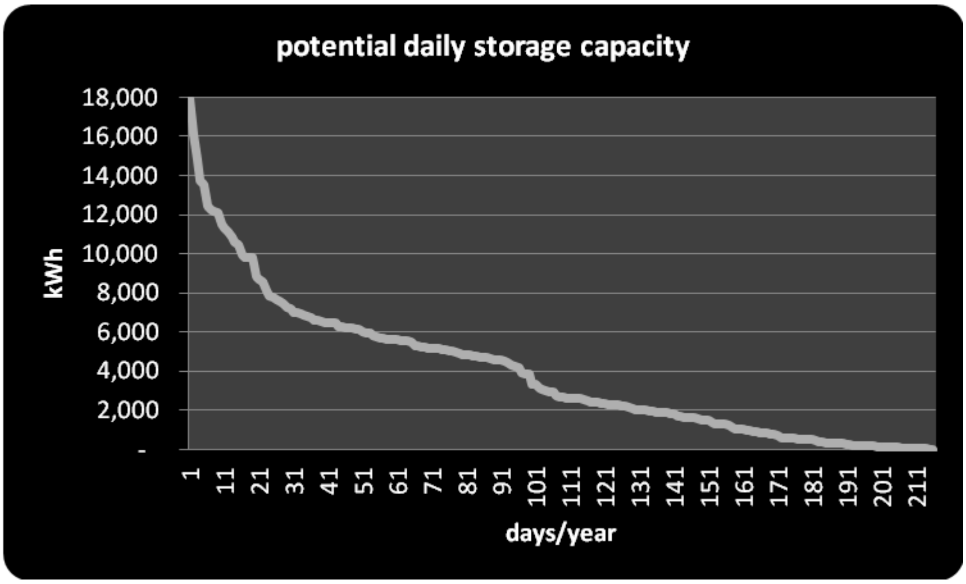

Figure 38: Potential daily storage capacity at metering point 2 (own chart)

We chose two storage dimensions able to cover most of the days during the year: **2,000 kWh and 4,000 kWh.**

We then analyzed the OPEX savings, due to the combination of PV generation and storage, and the related investment costs using the net present value method.[72] For this calculation, an average gross electricity price (electricity supply and grid costs excluding taxes) of € 0.0545/kWh was used.[73]

We compared the same solution in 2015 and in 2030, in order to evaluate the impact of investment cost degression for storage facilities. According to literature, the following CAPEX values were selected[74]:

- Electricity storage costs in 2015: € 700/kWh
- Electricity storage costs in 2030: € 200/kWh.

The investment costs of PV were not changed in the two years in order to make the storage comparison more evident.

[72] 10 years, 5%. Cf equation (10).

[73] This value consists of € 0.0315/kWh which is the average KA price for electricity supply based on spot prices 2016 plus the average grid costs of metering point during 2016 according to real invoices.

[74] Berger, 2017: 12 .

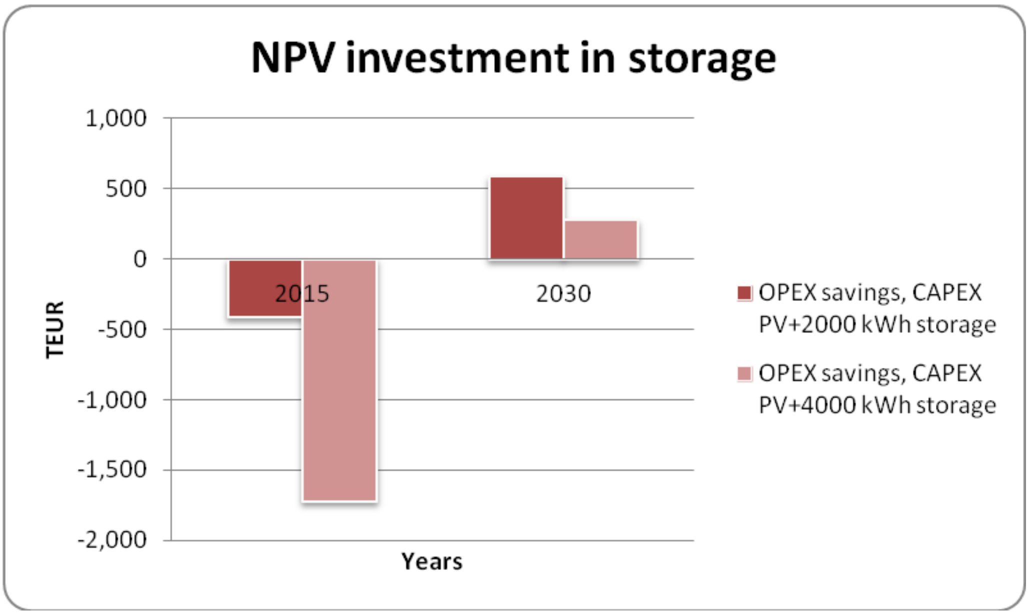

Figure 39: Comparison of net present values (NPV) from investment in LI-ION batteries at metering point 2, two storage dimensions, respectively year 2015 and year 2030 (own chart)

The results in above graph show that currently the choice of a large electricity storage facility as an alternative solution to a “VPPN” model **is not economic**, due to the high investment costs (in 2015 the net present value of this solution was still negative).

Nevertheless, this situation could change rapidly: the faster this technology develops, the lower the storage prices and the more attractive the choice of a physical storage will become. When this phase is achieved, **the income of grid operators and of utilities with large corporate customers will decrease further**, while lower storage prices will advantage producers and vendors of PV systems and of storage facilities.

5.5 Why “PV-VPPN”?

The figure below summarizes the advantages and disadvantages for the stakeholders:

STAKEHOLDERS	ADVANTAGES	DISADVANTAGES
EU	Support of climate goals	New guidelines required
Environment	Virtual storages are less polluting because optimized. More decentral generation from renewable sources	Need for network reinforcement
Network operator	Compensation of income losses (due to higher decentral generation) with income from new business models	Necessity to get used to a new understanding of network reinforcement: bilaterality. Legislation amendment required
Utility	Compensation of income/gain losses due to higher decentral generation with new income from new business models	New business models require more co-operation with external players such as storage producers
Prosumer	Higher self-consumption, optimization of investments	New business models are more complex and could cause new dependencies
Storage and PV system producers	The bigger the variety of business models, the wider the business	Will not be alone on the market

Figure 40: Stakeholders advantages and disadvantages (own figure)

5.5.1 The utility

As mentioned above, with the “PV-VPPN” the utility can compensate losses from its traditional business with revenues/profit from a new commercial opportunity.

The advantage of a **virtual storage** operated by the utility (in contrast to a single electricity storage operated by the customer) would be the wide range of storage facilities available, from pumped storage power plants[75], CHP systems, power2heat solutions, “community” storage facilities to e-car charging station networks[76].

Corporate customers could have easy access to a **seasonal** storage, while otherwise they would only optimize daily or weekly demand. The **optimization** of storage facilities leads to **lower storage losses** and to a **less questionable environment impact**.

Moreover, a virtual storage would offer additional revenue streams in the business of **frequency control** or of **electricity trading,** as the utility could purchase electricity in summer at low spot prices and re-sell it in winter at higher prices.

5.5.2 The network operation (and the Regulator)

The most work to be done is on the grid’s side. In our view, for the distribution network operator, the EU climate goals represent the biggest challenge since the liberalization of the energy market in 2001. The “PV-VPPN” model could represent a new opportunity for the network operator to actively contribute to the energy transition currently taking place.

Furthermore, maintaining the status quo in legal provisions will not necessarily make **network reinforcements** superfluous, whether at transmission or distribution level, low or middle voltage. In fact, on the one hand, more and more households connected to the grid at a low voltage level are increasing self-generation with their own PV systems, on the other hand, electricity imports require a reinforcement of connections at transmission level.

The “BVES” in Germany even argues that household storages are currently privileged in comparison to community storages for larger prosumers, due to the fact that household storage facilities do not require a grid connection.[77]

Currently, the storage and PV industry is growing, and it is in a position to reduce the income sources of both the network operator and the utility. As a matter of fact, with the “status quo” model, the distribution network operator is losing €70,000 per year from our corporate customer, due to the fact that part of the KA´s demand is covered by self-generation. Furthermore, it is likely that storage producers will soon be able to further develop the current technology and achieve a cost degression. As soon as this happens, the loss will be even higher.

[75] Cf Baumgartner et al. (2010). In this case study the authors suggest that PV surplus generated in the greater Zürich area (Switzerland) is stored by pumped hydro plants in the Swiss Alps.

[76] By including e-car charging station networks into the virtual storage system a step forward is made in the support of the emission reduction goal of the EU for the transportation sector. On the integration of e-mobility into the electricity system cf. Rezania and Prüggler (2012).

[77] „Federation of energy storage industry“, „Bundesverband Energiespeicher“, cited in Scheller (2017: 4-5).

Finally, **future** prosumers with large decentralized electricity generation will require smaller grid connections for consumption.

In order to avoid revenue losses for grid operators, the Austrian Regulatory Board proposed recently to unify System Provision and System Admission Charge in a single fee, and to apply the unified fee both to consumers and to producers (currently, producers pay only the System Provision Charge). In the perspective of the next regulation period for electricity in Austria, which will start in 2019, this proposal does not seem to be particularly “disruptive”.

As mentioned, the need for investments in network stability will occur anyway, and regulatory decisions can determine if the focus will be more on a lower or on a higher network level. As far as our new business model is concerned, it is the middle voltage distribution level which needs to reinforce its capability to handle **two-way, reversible power flows**.[78]

As suggested by Dracler/Regehr, an appropriate amendment to network charge provisions able to provide support for the new “PV-VPPN”-business model would be to extend the understanding of **“private networks”,** currently only superficially touched by the existing Electricity Act (Dracler/Regehr, 2008: 155).

5.5.3 The environment

Apart from the already mentioned environmental advantages of virtual storages in contrast to physical ones, the most obvious public health benefits of solar energy are the avoided air pollution and GHG emissions from fossil fuels and the avoided impacts from fuel extraction (Pitt and Michaud, 2015: 109).

The following contribution to the topic of “**net metering**” currently under discussion should be additionally mentioned:

“Renewable advocates point out that while distributed solar and other energy efficiency measures do pose a challenge to electric utilities' existing business model, the benefits of distributed generation outweigh the costs, and those benefits are shared by all ratepayers. Grid benefits of private distributed solar investment include reduced need for centralizing power plants and reduced strain on the utility grid. They also point out that, as a cornerstone policy enabling the growth of rooftop solar, net metering creates a host of societal benefits for all ratepayers that are generally not accounted for by the utility analysis, including public health benefits, employment and downstream economic effects, market price impacts, grid security benefits, and water savings. (...).”[79]

[78] Cf Martinot (2015)

[79] Definition of “net metering” on wikipedia, https://en.wikipedia.org/wiki/Net_metering, retrieved 15.8.2017

Some member states in the European Union are already applying or have already applied this solution. Among them: Denmark, The Netherlands and Slovenia. Italy introduced a “net energy metering” scheme in combination with solar PV, called “Scambio sul Posto” (SSP), in 2009. In Spain and France the idea of net metering was proposed recently (cf IRENA, 2015:16). Furthermore, in the United States a lively scientific discussion is taking place about the impact of different net metering rate options on the development of renewable energy distributed generation from PV (cf . Klein and Noblet, 2017 and Darghonouth, 2016).

5.5.4 Summary

In Figure 5, shown in the introduction to this work, the Regulator and the network operator have the most significant influence on the future development of decentralized generation from renewable energy sources, especially when prosumers wish to become more initiative.

In Figure 41 we intend to show an improved understanding of the role of all stakeholders in the future, where all parties will have reached a balanced importance in the implementation of EU climate goals.

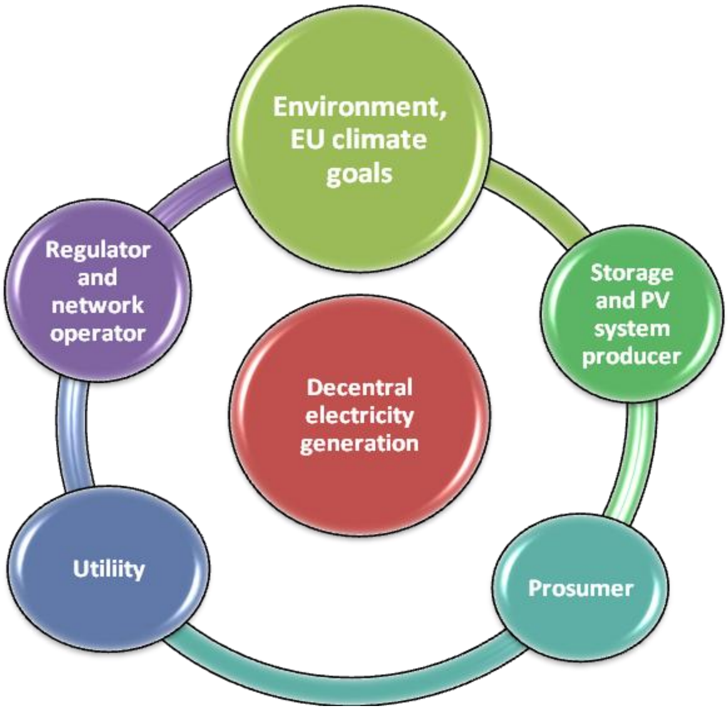

Figure 41: “PV-VPPN”: The weight shift to a more equalized balance of all stakeholders (own figure)

In summary, we are convinced that enabling a “PV-VPPN” can contribute balancing the influence of the parties on the increase in decentralized electricity generation, with a weight shift in favour of the achievement of the climate goals.

6 CONCLUSIONS AND OUTLOOK

"Österreichs Energie" underlines the efforts that should be undertaken to improve Austria's attractiveness as a location for businesses: electricity imports should be reduced consistently by increasing domestic production by 20 TWh by 2030. According to "Österreichs Energie", corporate customers in the role of producers can significantly contribute to this goal and a business partnership of utilities with prosumers shall be strived for (Österreichs Energie, 2017: 4-5)

This new partnership requires a new understanding of the grid operator's role and of related system usage costs. From this perspective, we see the grid operator take on the roles of market facilitator, of enabler of new commercial business models and finally, of supporter of the EU climate goals.

With the words of the International Renewable Energy Agency (IRENA), the power sector has been dominated until now by a network structure able to match centralized electricity production with the fluctuating consumption behavior of end-users. Now, the rapid growth of decentralized renewable power generation can truly trigger a revolutionary understanding of the network structure. Technological development should be complemented by an adequate regulatory environment, enabling new business models to be deployed and to compete with traditional alternatives. Conversely, "the creation of new and in some cases disruptive services through electricity storage systems in transmission and distribution will prompt a rethink or create new business models". [80]

In the present work we have developed a new business case which we have called "PV-VPPN" (Virtual Private **Power** Network with PV self-generation). The new model is capable to encourage self-generation from PV, to enhance the status of prosumers in their contribution to climate goals, and to promote a new business partnership between utilities and prosumers. The model relies on a virtual understanding of storage facility combined with self-generation from PV, and is still theoretical because it requires relevant law amendments before implementation.

After quantifying the economic advantage of the new model for the prosumer, in comparison to a status quo scenario, we proposed to replace current System Charges with a "Virtual Private Network Access Fee", to be charged by the distribution network operator and covering access, smart data metering and invoicing. In this respect, it was suggested that the economic advantage of the new model is shared by the prosumer with the utility and with the grid operator. In further steps, the "VPPN" model could be even extended to self-generation from other sources of renewable energy.

In reality, the corporate customer analyzed in this work has not implemented any model for decentralized electricity generation yet, and is looking forward to more attractive conditions to come.

[80] IRENA, 2015: 4, 9-10, 37

If cost degression works fast, our KA and many more will presumably start implementing own solutions for self-generation in combination with physical storages, even if these are not regarded as the most yielding and the most environment-friendly opportunity.

If this happens, corporate customers will start neglecting the traditional importance of utilities and of network operators for their business choices, while other business players like storage vendors will become more and more interesting. Additionally, due to the development of new technologies such as blockchain, sooner or later prosumers might no longer need utilities for commercializing their self-generation.

While decentralized PV-generation keeps growing, the future implications of a high solar PV market penetration need to be anticipated both by utilities and by grid operators. This “anticipation” should be followed by models avoiding overloaded electricity distribution networks and enabling large community or shared solar PV projects (Pitt and Michaud, 2015: 110).

In our view, utilities are required to radically reconsider their future business models, otherwise they will dramatically lose revenue streams to upcoming new business players (Edelmann, 2014: 5-7) and might not be able to “survive as profitable entities” (Martinot, 2015:50).

In their intent to keep up with future changes in the electricity market, utilities need the backup of the Law. The legal intervention of the Regulatory Board needs to become more substantial in the effort to increase decentralized electricity generation by prosumers. The introduction of a new understanding of Network Charges will help use financial means for reinforcing grid stability at different layers and its capability to handle two-way, reversible power flows.

Those radical changes will strongly contribute to the achievement of the EU climate goals, to which Austria has committed.

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Consultation with the business developer at a regional utility

Customer´s load profiles left anonymous

Customer´s grid invoices left anonymous

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List of abbreviations, terms and symbols

/a	per annum (per year)
AC	Alternate Current
BIPV	Business Integrated PV
CAPEX	Capital Expenditures
CO2e	CO2 equivalents
DC	Direct Current
ElWOG	Elektrizitätswirtschafts- und organisationsgesetz 2010 (Electricity Act)
ha	hectare
KA	Key Account
kWp	Kilowattpeak
LI-ION-batteries	Lithium Ion batteries
MP	Metering point
NPV	Net present value
Netzbereitstellungsentgelt	System provision charge
Netznutzungsentgelt	System utilization charge
Netzverlustentgelt	Charge for system losses
Netzzutrittsentgelt	System admission charge
OPEX	Operating Expenditures
Prosumer	Consumer+Producer
PV	Photovoltaics
Systemdienstleistungsentgelt	Charge for system services
VPN	Virtual Private Network
VPPN	Virtual Private Power Network

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APPENDIX 1: “STATUS QUO CASE”: KEY DATA OF METERING POINT 1

Metering Point 1

MONTHS 2016	Electricity demand [MWh]	PV generation [MWh]	Net demand[MWh]
January	889	19	870
February	942	36	907
March	939	62	877
April	866	84	782
May	770	92	678
June	807	91	716
July	667	93	574
August	662	83	579
September	750	63	687
October	780	43	737
November	863	21	842
December	757	16	742

MONTHS 2016	Solar cover ratio (self generation from PV / electricity demand)
January	2%
February	4%
March	7%
April	10%
May	12%
June	11%
July	14%
August	13%
September	8%
October	6%
November	2%
December	2%

APPENDIX 2: "STATUS QUO CASE": KEY DATA OF METERING POINT 2

METERING POINT 2

MONTHS 2016	Electricity demand [MWh]	PV generation [MWh]	Net demand [MWh]
January	2,293	82	2,211
February	2,183	151	2,032
March	2,235	264	1,971
April	2,177	356	1,821
May	2,213	389	1,824
June	2,420	386	2,034
July	2,366	395	1,972
August	2,309	354	1,955
September	2,232	266	1,967
October	2,110	182	1,928
November	2,063	89	1,975
December	1,939	66	1,873

MONTHS 2016	Solar cover ratio (self generation from PV / electricity demand)
January	4%
February	7%
March	12%
April	16%
May	18%
June	16%
July	17%
August	15%
September	12%
October	9%
November	4%
December	3%

APPENDIX 3: “STATUS QUO CASE”: KEY DATA OF METERING POINT 3

METERING POINT 3

MONTHS	Electricity demand [MWh]	PV generation [MWh]	Net demand [MWh]
January	199	2	197
February	192	4	188
March	209	6	202
April	215	9	207
May	220	9	211
June	222	9	213
July	225	10	216
August	216	9	207
September	210	6	204
October	202	4	198
November	194	2	192
December	190	2	188

MONTHS	Solar cover ratio (self generation from PV / electricity demand)
January	1%
February	2%
March	3%
April	4%
May	4%
June	4%
July	4%
August	4%
September	3%
October	2%
November	1%
December	1%

APPENDIX 4: "STATUS QUO CASE": KEY DATA OF METERING POINT 4

METERING POINT 4

MONTHS	Electricity demand [MWh]	PV generation [MWh]	Net demand [MWh]
January	52	1	51
February	73	2	72
March	84	3	81
April	79	4	76
May	75	4	71
June	71	4	67
July	78	4	74
August	69	4	65
September	72	3	69
October	91	2	90
November	102	1	101
December	98	1	98

MONTHS	Solar cover ratio (self generation from PV / electricity demand)
January	2%
February	2%
March	3%
April	5%
May	5%
June	6%
July	5%
August	5%
September	4%
October	2%
November	1%
December	1%

APPENDIX 5: “STATUS QUO CASE”: KEY DATA OF METERING POINT 5

METERING POINT 5

MONTHS	Electricity demand [MWh]	PV generation [MWh]	Net demand [MWh]
January	11	-	11
February	8	-	8
March	9	-	9
April	8	-	8
May	8	-	8
June	9	-	9
July	12	-	12
August	12	-	12
September	10	-	10
October	8	-	8
November	9	-	9
December	9	-	9

APPENDIX 6: Network charges with validity 2016

WIENER NETZE

Ab 01.01.2016 exkl. 20 % Ust

* nur für Anlagen im Wr. Gemeindegebiet (ausgenommen Trafomieten)

Ebene	Bereitstellungs-Entgelt €/kW Jahr 2015 Alt	Bereitstellungs-Entgelt €/kW Jahr 2016 Neu	Netznutzungsentgelt Leistungspreis €/kW Jahr 2015 Alt	Jahr 2016 Neu	Monat 2015 Alt	Monat 2016 Neu	Arbeitspreis Cent/kWh ST 2015 Alt	ST 2016 Neu	SN 2015 Alt	SN 2016 Neu	WT 2015 Alt	WT 2016 Neu	WN 2015 Alt	WN 2016 Neu	Netzverlustentgelt Cent/kWh 2015 Alt	Netzverlustentgelt Cent/kWh 2016 Neu	Wiener Gebrauchsabgabe* % 2015 Alt	Wiener Gebrauchsabgabe* % 2016 Neu
3	10,29	10,29	29,28	30,24	2,44	2,52	0,32	0,33	0,32	0,33	0,32	0,33	0,32	0,33	0,048	0,113	6	6
4	52,76	52,76	30,54	31,56	2,55	2,63	0,52	0,54	0,52	0,54	0,52	0,54	0,52	0,54	0,074	0,130	6	6
5	90,26	90,26	42,84	44,28	3,57	3,69	0,85	0,88	0,85	0,88	0,85	0,88	0,85	0,88	0,119	0,149	6	6
6	113,81	113,81	45,78	47,28	3,62	3,94	1,47	1,52	1,47	1,52	1,47	1,52	1,47	1,52	0,212	0,240	6	6
7	235,47	235,47	46,08	47,52	3,84	3,96	1,95	2,01	1,95	2,01	1,95	2,01	1,95	2,01	0,320	0,396	6	6
						gemessene Leistung												
			19,26	24,60		2,05	3,93	3,88	3,93	3,88	3,93	3,88	3,93	3,88	0,320	0,396	6	6
						nicht gemessene Leistung												
			0,00	0,00	0,00	0,00	1,97	2,03	1,97	2,03	1,97	2,03	1,97	2,03	0,320	0,396	6	6
						unterbrechbar												

APPENDIX 7: “Status quo case”: Difference in power peak values (kW)

GRID

Old model: Monthly power peaks [kW]

		Available capacity according to grid invoice														
		NE 5	Plan		NE 5	Plan		NE 5	Plan		NE 5	Plan		(NE 7)	Plan	
		14000 kW	2900 kWp		3080 kW	740 kWp		1507 kW	70 kWp		1500 kW	30 kWp		220 kW	0 (site protection)	
		kW	kW	kW	kW	kW	kW	kW	kW	kW	kW	kW	kW	kW	kW	kW
		MP 1	MP 1	MP 1	MP 2	MP 2	MP 2	MP 3	MP 3	MP 3	MP 4	MP 4	MP 4	MP5	MP5	MP5
Months	**d/m**	**Demand**	**With PV**	**Diff**	**Demand**	**With PV**	**Diff**	**Demand**	**With PV**	**Diff**	**Demand**	**With PV**	**Diff**	**Demand**	**With PV**	**Diff**
Jan-16	31	4650.00	4446.40	203.60	3013.00	3012.44	0.56	419.4	414.05	5.35	144.5	144.00	0.50	42.02	42.02	0
Feb-16	29	4575.00	4253.96	321.04	3077.00	3013.25	63.75	405.6	390.94	14.66	208.5	208.55	-0.05	29.3	29.3	0
Mar-16	31	4425.00	3915.54	509.46	3010.00	2941.93	68.07	455.4	439.79	15.61	204	203.55	0.45	33.16	33.16	0
Apr-16	30	4455.00	3650.37	804.63	2985.00	2745.69	239.31	495.6	456.12	39.48	195.5	195.41	0.09	20.34	20.34	0
May-16	31	4650.00	3922.30	727.70	2716.00	2603.74	112.26	487.8	467.68	20.12	190	180.41	9.59	20.36	20.36	0
Jun-16	30	5100.00	4272.80	827.20	2586.00	2394.22	191.78	448.8	418.74	30.06	153.5	152.62	0.88	20.9	20.9	0
Jul-16	31	4695.00	3695.39	999.61	2424.00	2133.60	290.40	475.2	441.05	34.15	196	191.31	4.69	29.64	29.64	0
Aug-16	31	4650.00	4129.72	520.28	2478.00	2282.39	195.61	418.8	387.13	31.67	166.5	165.19	1.31	27.18	27.18	0
Sep-16	30	4725.00	4092.66	632.34	2630.00	2534.65	95.35	450	418.09	31.91	180.00	180.05	-0.05	21	21	0
Oct-16	31	4455.00	4048.47	406.53	2797.00	2514.86	282.14	399	368.92	30.08	213.5	213.55	-0.05	19.96	19.96	0
Nov-16	30	4380.00	4206.00	174.00	2723.00	2712.41	10.59	431.4	426.36	5.04	240.5	240.50	0.00	19.7	19.7	0
Dec-16	31	4350.00	4084.74	265.26	2700.00	2610.30	89.70	390	382.19	7.81	249	249.00	0.00	26.6	26.6	0
	366															

APPENDIX 8: “Status quo case”: Savings in network charges (€)

SAVINGS - GRID CHARGES 2016

		MP1	MP2	MP3	MP4	MP5	
S. Utilization charge, NL 5 (€/kW)	44.28	**€/year**	**€/year**	**€/year**	**€/year**	**€/year**	
Jan-16		€ 764	€ 2	€ 20	€ 2	€ 0	
Feb-16		€ 1,126	€ 224	€ 51	€ 0	€ 0	
Mar-16		€ 1,911	€ 255	€ 59	€ 2	€ 0	
Apr-16		€ 2,920	€ 869	€ 143	€ 0	€ 0	
May-16		€ 2,729	€ 421	€ 75	€ 36	€ 0	
Jun-16		€ 3,002	€ 696	€ 109	€ 3	€ 0	
Jul-16		€ 3,749	€ 1,089	€ 128	€ 18	€ 0	
Aug-16		€ 1,951	€ 734	€ 119	€ 5	€ 0	
Sep-16		€ 2,295	€ 346	€ 116	€ 0	€ 0	
Oct-16		€ 1,525	€ 1,058	€ 113	€ 0	€ 0	
Nov-16		€ 632	€ 38	€ 18	€ 0	€ 0	
Dec-16		€ 995	€ 336	€ 29	€ 0	€ 0	
		€ 23,599	**€ 6,069**	**€ 981**	**€ 65**	**€ 0**	**€ 30,713.68 TOTAL €/year**
S. Utilization charge, NL 5 (€/kWh)	0.00880	€ 26,214	€ 6,186	€ 633	€ 271	€ 0	**€ 33,304.17 TOTAL €/year**
S. Losses, NL 5 (€/kWh)	0.00149	€ 4,439	€ 1,047	€ 107	€ 46	€ 0	**€ 5,639.00 TOTAL €/year**

(NL= Network level)

Lower income for the distribution network operator: **€ 69,656.85 TOTAL €/year**

APPENDIX 9: “PV-VPPN”: KEY DATA

"PV-VPPN"

MONTHS 2016	Electricity demand [MWh]	PV generation [MWh]	Net demand [MWh]	Temporary storage [MWh]
January	3,444	209	3,235	-
February	3,398	379	3,019	4
March	3,475	653	2,822	17
April	3,345	877	2,468	27
May	3,286	944	2,342	44
June	3,528	965	2,564	16
July	3,348	984	2,364	18
August	3,267	870	2,397	28
September	3,275	670	2,605	5
October	3,191	462	2,729	1
November	3,231	225	3,006	-
December	2,994	168	2,827	-

MONTHS 2016	Solar cover ratio (self generation from PV / electricity demand)
January	6%
February	11%
March	19%
April	26%
May	29%
June	27%
July	29%
August	27%
September	20%
October	14%
November	7%
December	6%

APPENDIX 10: “PV-VPPN”: SAVINGS IN NETWORK CHARGES

Months	d/m	demand [kW]	With PV [kW]	Diff [kW]	€/year
Jan-16	31	7,873	7,646	227	€ 852
Feb-16	29	8,026	7,465	561	€ 1,969
Mar-16	31	7,756	6,876	881	€ 3,303
Apr-16	30	7,628	6,308	1,320	€ 4,791
May-16	31	7,519	6,358	1,160	€ 4,351
Jun-16	30	7,887	6,601	1,286	€ 4,666
Jul-16	31	7,609	5,668	1,942	€ 7,282
Aug-16	31	7,271	5,988	1,283	€ 4,811
Sep-16	30	7,485	6,221	1,263	€ 4,585
Oct-16	31	7,648	6,698	950	€ 3,564
Nov-16	30	7,332	7,034	298	€ 1,081
Dec-16	31	7,524	7,076	448	€ 1,679
	366				
			S. Utilization charge, NL 5 (€/kW)	44.28	**€ 42,936 TOTAL €/year**
			S. Utilization charge, NL 5 (€/kWh)	0.00880	**€ 65,161 TOTAL €/year**
			S. Losses, NL 5 (€/kWh)	0.00149	**€ 11,033 TOTAL €/year**
			(NL= Network level)		

Lower income for the distribution network operator:	**€ 119,130 TOTAL €/year**

APPENDIX 11: NPV and annuity value of additional savings with new model

	Status quo case	PV-VPPN	Difference
Electricity supply savings/a	€ 115,467	€ 230,758	€ 115,291
Grid cost savings/a	€ 69,657	€ 119,130	€ 49,473
Total savings/a	**€ 185,124**	**€ 349,888**	**€ 164,764**
Investment costs in PV	€ 370,887	€ 597,505	€ 226,617

NPV

0	1	2	3	4	5	6	7	8	9	10
-€ 226,617										
	€ 164,764	€ 164,764	€ 164,764	€ 164,764	€ 164,764	€ 164,764	€ 164,764	€ 164,764	€ 164,764	€ 164,764
1.00	0.95	0.91	0.86	0.82	0.78	0.75	0.71	0.68	0.64	0.61
-€ 226,617	€ 156,918	€ 149,446	€ 142,329	€ 135,552	€ 129,097	€ 122,950	€ 117,095	€ 111,519	€ 106,208	€ 101,151

Net present value	€ 1,045,648
Discount rate	0.05
Annuity factor	0.13
Lifetime in years	10
Annuity value	**€ 135,416**