D4.2 IMPACTS OF PVP CONCEPTS ON GRID SYSTEM

Summary Report

PVP4Grid

D4.2

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AT	Austria
BE	Belgium
BESS	battery energy storage system
BIPV	Building Integrated Photovoltaic
CEER	Council of European Energy Regulators
DE	Germany
DER	distributed energy resources
DSOs	distribution system operators
ENTSO-E	European Network of Transmission System Operators for Electricity
ES	Spain
ESCOs	energy service companies
EU	European Union
EVs	electric vehicles
FR	France
FU	full unbundling
GW	gigawatt
H2020	Horizon 2020
ISO	independent system operator
IT	Italy
ITO	independent transmission operator
kW	kilowatt
kWh	kilowatt hour
NECPs	National Energy & Climate Plans
NL	the Netherlands
OU	ownership unbundling
PPAs	power-purchase agreements
PT	Portugal

PV	photovoltaic
PVP	photovoltaic prosumers
RES	renewable energy sources
TSOs	transmission system operators
TWh	terawatt hour

SUMMARY

The recent Clean energy for all Europeans package (CE4AE Package) introduced a comprehensive update to the European Union (EU) energy policy. Along with other important changes, the new rules facilitate individuals and collectives to become energy prosumers i.e. to produce, store or sell their own energy from renewable sources. The PVP4Grid project explores photovoltaic (PV) energy prosumer concepts, particularly in terms of energy communities, by carrying out qualitative analyses, quantitative simulations and testing of PV prosumer concepts in eight different EU countries. The overall objective of the project is to gain better understanding of those factors that can potentially enable or hinder the process of consumers becoming PV prosumers in economically viable and environmentally sustainable and system-friendly manner.

This report looks at PV prosumer concepts and their implications for the electricity grid system and its actors. In a broader sense, the so-called “grid actors” include the most relevant stakeholders such as regulatory bodies, Distribution System Operators (DSOs), Transmission System Operators (TSOs), electricity commercialisation companies (particularly retailers), energy service companies (ESCOs), energy communities, consumers associations, aggregators, etc. The emergence of prosumers and energy communities proposes new challenges in terms of technical requirements for the network system and its management, changes in business models, as well as energy policy and regulatory challenges to set the optimal framework conditions. The report presents a summary of the eight country reports in terms of describing the grid landscape in each country, the key results of the simulation of several prosumer concepts as well as stakeholder views and perceptions discussed at the PVP4Grid workshops.

The report is structured as follows:

- The first chapter gives an overview of the PVP4Grid project and the specific aim of this report.
- The second chapter describes the grid system and its actors providing a snapshot of the current landscape in the EU, focusing on the eight PVP4Grid countries, a summary of the new EU regulatory framework and changes it proposes for the grid system as well as an overview of challenges and drivers of energy-self consumption from the grid perspective.
- The third chapter presents the key results and discussions of quantitative simulation of PVP4Grid concepts.
- The fourth chapter collects the key findings of the workshops organised in the PVP4Grid countries, summarising the stakeholder views on PVP4Grid concepts, as well as the related benefits and challenges.

Overall, the document builds an overview of the EU grid landscape and the very heterogeneous background factors, drivers and challenges of the PV prosumer concepts from the perspective of the distribution networks.

1 INTRODUCTION

1.1 Objectives of the PVP4Grid project and purpose of this report

PVP4Grid is a Horizon 2020 (H2020)-funded project involving 12 partners from eight European countries, beginning in October 2017 and running until March 2020. The main objective of the project is to facilitate the increase the market share and market value of PV by enabling consumers to become PV prosumers (PVP) in an efficient and system-friendly manner. The project looks at and assesses new management and business models to combine PV, storage, flexible demand and other technologies into a commercially viable product. To achieve this, a rigorous quantitative analysis of prosumer concepts was carried-out to collect country-specific evidence of the factors influencing the uptake of PV self-consumption in different target countries. To adequately disseminate the results and achieve the desired impacts, detailed guidelines for PV prosumers, implications to grid actors, as well as policy recommendations for national and European policy makers on how to achieve the suitable regulatory framework for prosumption, are developed.

This report *D4.2: Impacts of PVP concepts on grid system - Summary report* is part of Work Package 4 (WP4) of the PVP4Grid project, which aims to bring the results of the qualitative and quantitative analysis of the prosumer concepts to the attention of a wider audience. The D4.2 consists of eight country reports, which followed a predefined common template and guidelines but at the same time allowed the report to be tailored for country-specific needs[1]. This summary report aims to present an overview of the distribution network landscape in the eight PVP4grid countries and bring the country-specific findings together. It complements the other WP4 deliverables i.e. *D4.1: Prosumer guidelines* by providing the perspective of the grid system and sets ground for designing and *D4.3: Policy recommendations* from a holistic perspective. Thus, the objective of this report is to look at the self-consumption of photovoltaic electricity from the perspective of the grid system. To do so, the study describes the context of the grid system landscape, changes the new EU regulation framework and suggests a summary of the quantitative analysis of improved prosumer concepts and their implications from the perspective of the grid. To conclude, the study presents the key findings of stakeholder workshops held in different PVP4Grid target countries during the fall 2019.

[1] The D4.2 country reports are available at PVP4Grid webpage (https://www.pvp4grid.eu/guidelines-policy-papers/)

1.2 PVP4Grid country coverage

The PVP4Grid project analyses and provides qualitative and quantitative evidence of prosumer concepts in eight EU countries including Austria (AT), Belgium (BE), France (FR), Germany (DE), Italy (IT), the Netherlands (NL), Portugal (PT) and Spain (ES), as shown in the Figure 1 below.

Figure 1: PVP4Grid country coverage. Source: Google[2].

[2] Edited screenshot of Google Maps (Google Inc., 2019)

2 DESCRIPTION OF THE GRID SYSTEM LANDSCAPE IN THE EU

This chapter provides a brief overview of the context, i.e. how the grid system is organised in Europe and especially in the eight PVP4Grid countries. The chapter considers also the changes suggested by the Clean energy for all Europeans package.

2.1 Overview

Transmission and distribution are key activities of an electricity system as they physically link the electricity production with electricity users. Conventionally, the European electricity sector was characterised by vertically integrated state or privately-owned monopolies spanning over all different activities of the electricity system[3]. Generation, transmission, distribution and supply (retail) were activities of a typical integrated electricity utility company. Over the last decades, the sector has seen important changes including a gradual process of opening the European electricity markets to competition to achieve more competitive prices and establish a unified European energy market. In many European countries, the vertically integrated utilities have been divided into competitive generation and supply of electricity and non-competitive transmission and distribution networks. This development was reinforced by series of directives[4] which defined the EU electricity market legislation. Among other things they defined the unbundling requirements, which obliged Member States to ensure the separation of vertically integrated energy companies into the domain of market roles (generation, retail) and the domain of grid operation roles (transmission, distribution). Electricity generation and wholesale market were duly opened to liberalisation as competitive activities, whereas transmission and distribution, which are considered to be natural monopolies, were defined as subject to regulatory control and thus were exempted from competition. The unbundling requirements mandated to separate the distribution system operator (DSO) activities in functional and legal level (particularly in terms of separate accounting) but did not however oblige to separate the ownership of assets. These requirements were set as non-obligatory for the DSOs serving fewer than 100,000 customers or small isolated systems. The liberalisation was followed by establishment of independent regulatory authorities in national level whose responsibility is to ensure the implementation of the directives and the establishment and

[3] See for a more comprehensive overview Prettico, G., Flammini, M. G., Andreadou, N., Vitiello, S., Fulli, G., and Masera, M. (2019) Distribution System Operators Observatory – Overview of the electricity distribution system in Europe. EUR 29615 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-79-98738-0, doi:10.2760/104777, JRC113926.
[4] Directive 96/92/EC; Directive 2003/54/EC; and Directive 2009/72/EC

development of a competitive European electricity market. This particularly includes non-discriminatory grid access for all users, recogniton of grid costs reported by the grid operators, and allocating these costs to the users of the grid in terms of network charges.

As a result of different degree and pace of implementing the unbundling requirements in different Member States, big differences exist how the system operators are organised and regulated in the European countries. The unbundling regimes allowed the utilities choosing between a full unbundling (FU) model or an independent transmission operator (ITO) model. Furthermore, the FU model provides for two conceivable options: ownership unbundling (OU) or an independent system operator (ISO)[5].

The European **transmission system operators** (TSOs) are the actors responsible for transmission of electric power on the main high voltage electric networks, including transnational interconnectors. Their role is to provide grid access to electricity generating companies, traders, suppliers, and distributors according to non-discriminatory and transparent rules[6]. In order to ensure quality (particularly in terms of frequency) and security of supply, they also guarantee the physically stable operation as well as maintenance and development of the system infrastructure. According to the European Network of Transmission System Operators for Electricity (ENTSO-E) there are 43 electricity transmission system operators (TSOs) in 36 countries across Europe. They have followed different models of unbundling, have different ownership structures i.e. state vs. private ownership as well as regulatory schemes varying between cost-based models or incentive-based models, or combinations of thereof. The Table 1 below lists the TSOs in the PVP4Grid countries including the year unbundling, unbundling model, regulatory scheme and ownership structure.

Table 1: Transmission system operators in the PVP4Grid countries. Source: ENTSO-E, 2019; Meletiou et al., 2018

Country	Transmission system operator (TSO)	Year of legal unbundling	Unbundling model	Regulatory scheme	Ownership
Austria	Austrian Power Grid AG	2012	ITO	Incentive-based	Mostly state owned
	Vorarlberger Übertragungsnetz GmbH	2012	OU		
Belgium	Elia System Operator SA	2012	OU	Cost-based	Mostly privately owned

[5] CEER (2019) Status Review on the Implementation of Transmission System Operators' Unbundling Provisions of the 3rd Energy Package. CEER Status Review; Meletiou et al. (2018) Regulatory and ownership determinants of unbundling regime choice for European electricity transmission utilities. Utilities Policy, Vol. 50, February 2018, pp. 13-25.

[6] ENTSO-E (2019) TSO–DSO Report: An integrated approach to active system management with the focus on TSO–DSO coordination in congestion management and balancing

France	Réseau de Transport d'Electricité	2012	ITO	Hybrid	Mostly state owned
Germany	TenneT TSO GmbH	2011	OU	Incentive-based	Mostly privately owned
	TransnetBW GmbH	2012	ITO		
	50Hertz Transmission GmbH	2011	OU		
	Amprion GmbH	2012	ITO		
Italy	Terna - Rete Elettrica Nazionale SpA	2004	OU	Hybrid	Mostly state owned
Netherlands	TenneT TSO B.V.	2002	OU	Incentive-based	Fully state owned
Portugal	Rede Eléctrica Nacional, S.A.	2003	OU	Hybrid	Fully state owned
Spain	Red Eléctrica de España S.A.	2002	OU	Hybrid	Mostly state owned

Similarly to TSO landscape, big differences exist also among **distribution system operators** (DSOs) in Europe. The DSOs are responsible of operating, maintaining and developing the distribution network to ensure that electricity is physically delivered to end-users in a secure, reliable and efficient manner, meeting physical quality criteria (particularly of voltage). Altogether there are approximately 2,400 DSOs in Europe, out of which 90% are serving beneath 100,000 grid customers. On the other hand, it has been estimated that the large DSOs (10%, approx. 240 DSOs) serve more than 70% of the European population. Nevertheless, the EU countries show a great variety in how the DSO landscape is organised and governed, varying from a single DSO to hundreds of DSO in a country, and from fully state owned to entirely privately owned.

Table 2: Number and characterisation of distribution system operators (DSO) in the PVP4Grid countries. Source: Eurelectric, 2013 but also Prettico, 2019. below lists the number of DSO and the landscape characterisation in the PVP4Grid countries. The number of DSOs per country varies from 11 in the Netherlands to 880 in Germany. Similarly, the concentration of DSO activTable 3ities differs among the PVP4Grid countries. Austria, Belgium, Germany are characterised by low concentration involving mainly small DSOs. In France, Italy and Portugal there is one dominant DSO accounting for more than 80% of the distributed power, whereas the Netherlands and Spain are characterised by medium concentration where the three largest DSOs account for more than 60% of the distributed power. The ownership of the DSOs shows largely public models including national and local levels of ownership in all the other countries except for Portugal and Spain, where the DSO are largely privately owned.

Table 2: Number and characterisation of distribution system operators (DSO) in the PVP4Grid countries. Source: Eurelectric, 2013 but also Prettico, 2019.

Country	Number of DSOs (Number of DSOs > 100,000 customers)	Characterisation of the DSO landscape
Austria	138 (13)	**Low concentration**: Mainly small, local DSOs. The three largest DSOs usually deliver less than 50% of distributed power **Largely public – national level ownership**
Belgium	24 (15)	**Low concentration**: Mainly small, local DSOs. The three largest DSOs usually deliver less than 50% of distributed power **Largely public – municipalities ownership**
Germany	880 (75)	**Low concentration**: Mainly small, local DSOs. The three largest DSOs usually deliver less than 50% of distributed power **Largely public – municipalities ownership**
France	158 (5)	**Medium concentration**: One dominant DSO (more than 80% of distributed power) and several smaller local DSOs **Largely public – national level ownership**
Italy	144 (3)	**Medium concentration**: One dominant DSO (more than 80% of distributed power) and several smaller local DSOs **Largely private ownership**
Netherlands	11 (8)	**Medium concentration**: A mix of DSOs, with the three largest accounting for more than 60% of distributed power **Largely public – municipalities ownership**
Portugal	13 (3)	**Medium concentration**: One dominant DSO (more than 80% of distributed power) and several smaller local DSOs **Largely private ownership**
Spain	340* (5)	**Medium concentration**: A mix of DSOs, with the three largest accounting for more than 60% of distributed power **Largely private ownership**

*Source: CEER, 2019 (2018 data)

The DSOs are entitled to collect charges from the end customers according to the national regulation. A typical structure of these charges includes:

1) a connection charge for a new or extended grid connection,
2) a grid charge paid periodically including a variable (Euros/kWh) and a fixed part based on measured or contracted power (usually Euros/kW), and
3) a management and support charge (including metering charge)[7].

[7] Prettico, G., Flammini, M. G., Andreadou, N., Vitiello, S., Fulli, G., and Masera, M. (2019) Distribution System Operators Observatory – Overview of the electricity distribution system in Europe. EUR 29615

Although the grid tariff design varies between the EU countries, majority of household grid tariffs are based on the variable energy amount (kWh) withdrawn from the grid. This holds true also in the PVP4Grid countries as seen in Table 3. The exceptions are the Netherlands and Spain where the fixed component forms 100% and 80% of the network tariffs respectively[8].

Table 3: Household sector grid tariff components in the PVP4Grid countries. Source: Eurelectric, 2016[9].

Grid tariff component	0%	0-25%	25-50%	50-75%	75-100%	100%
Energy-based component	Netherlands	Spain		Italy Portugal	Austria, France, Germany	
Fixed + capacity component		Austria, France, Germany	Italy Portugal		Spain	Netherlands

At the moment, the European system is requested to face and cope with several challenges including increased generation from renewable sources, integration of electric vehicles, demand-side flexibility and the changing role and behaviour of consumers. The Figure 2 below explains the conventional and emerging scenarios for the electricity system and its actors[10]. In the conventional scenario, the electricity system is divided into linear one-directional chain of steps including generation, transmission and distribution, and consumption. This conventional scenario is challenged by the emergence of distributed energy resources (DER) including a variety of technologies that generate electricity at or near where it will be used such as rooftop solar photovoltaic generators (PV) or battery energy storage system (BESS) or electric vehicles. These new technologies have allowed the emergence of new actors and business models including prosumer and energy community concepts under scrutiny of the PVP4Grid study.

EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-79-98738-0, doi:10.2760/104777, JRC113926.

[8] Eurelectric (2016) Network Tariffs: A Eurelectric position paper. Available: paperhttps://www3.eurelectric.org/media/268408/network_tariffs__position_paper_final_as-2016-030-0149-01-e.pdf. Accessed: March, 2020.

[9] Ibid.

[10] IRENA (2019) Future role of distribution system operators: Innovation landscape brief.

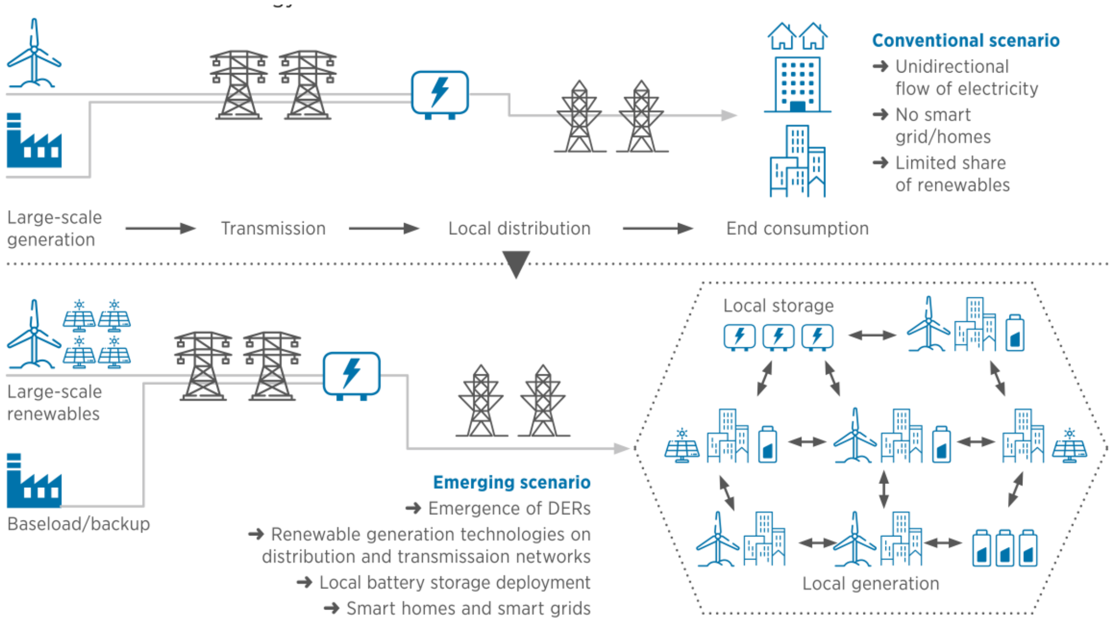

Figure 2: Conventional and emerging scenarios of the power system. Source: IRENA, 2019

The tasks of both TSOs and DSOs are subject to important changes as shown in the Table 4. Especially DSOs are facing additional duties as "neutral market facilitators" and responsibilities related to peak load management through distributed energy resources (DER) which are small or medium-sized power sources that are mainly connected to the low voltage levels of the system (distribution grid), near the end users[11]. In the context of solar PV, distributed generation constitutes of installations in low and medium voltages, such as rooftop solar PV units. Similarly, the DSOs are expected to take a more active role in network congestion management, and they are responsible for increasing coordination and collaboration with TSOs in grid system operation and active system management[12].

Table 4: The conventional and emerging tasks of distribution system operators Source: own elaboration based on IRENA, 2019

Conventional tasks of DSOs	**Emerging additional tasks of DSOs**
• Connection of loads and generators (DERs) • Defining and applying technical rules for the interconnection of loads and generators (DERs) to the grid	• Peak load management through DERs • Network congestion management • Provide reactive power support to TSOs • Procure voltage support

[11] IRENA (2019) Future of solar photovoltaic: Deployment, investment, technology, grid integration and socio-economic aspects. November 2019.
[12] ENTSO-E (2019) TSO–DSO Report: An integrated approach to active system management with the focus on TSO–DSO coordination in congestion management and balancing

• Planning, enlargement, reinforcement, maintenance and physical operation of networks • Management of supply outages • Metering • Energy billing (only if vertically integrated)	• Technical validation for power market

Apart from system operators, also the roles and responsibilities of other market actors such as balance responsible parties, balancing service providers, independent aggregators, ancillary services and energy service companies (ESCOs) are under discussion. These actors are (and will increasingly be) supporting the TSOs and DSOs in better integration of renewable energy resources to the grid by providing e.g. balancing, demand-side flexibility services or adequate data exchange services to the grid. Due to the large heterogeneity of the DSO landscape in the EU countries, there is not a single solution how to organise the grid landscape in the future.

The Clean Energy Package (presented in Chapter 2.3 of this document) provides key rules relating to the organisation and functioning of the European electricity sector, in particular new rules related to consumer involvement, protection and on open access to electricity markets.

2.2 Grid system landscape in PVP4Grid countries

The sub-chapters below provide a summary of the grid system landscape in PVP4Grid countries based on the D4.2 Country reports (in national languages). The text summarises the Chapter 2.1 of the D4.2 Country reports (in national languages) and includes the description of the grid system in Austria, Belgium, France, Germany, Italy, the Netherlands, Portugal and Spain. The D4.2 Country reports followed a predefined common template and guidelines but at the same time allowed the report to be tailored for country-specific needs. This is the reason why the country descriptions presented below are not following the same structure for each country.

2.2.1 Austria

The Austrian electricity supply industry has been fundamentally restructured over the past three decades. The overall goal was to implement competition or at least competitive elements wherever possible. Throughout the process, it has been discovered that some elements of the power supply chain - the grids - remain regulated natural monopolies. As a result, clearly defined and separated roles were introduced. The competitively organised market roles include, for example, power plant operators, balance group managers and electricity suppliers. A company can fulfil several market roles. The roles of grid operation (distribution and transmission system operators), on the other hand, are usually exercised by (legally) independent companies. This is called the (legal) unbundling of previously monopolistic, vertically integrated companies. The original overall objective of this separation was to ensure, non-discriminatory access by independent producers to the grid infrastructure and to avoid cross-subsidisation between the competitive market domain and the regulated segments of the grid domain. Clear rules of the game are needed for all market participants for competition to develop. To ensure the functioning of the market model, a regulatory authority, called E-Control, was established.

For electricity, supply and electricity demand must always be in balance in the electrical energy system, balance groups were introduced to (in terms of energy accounting) connect consumers, producers, suppliers and others. Essentially, this balance is created by the balancing group managers, who group producers and consumers into predictable groups and keep production and consumption balanced. The balance groups are managed by a balancing group coordinator (BKO). This is defined as a legal entity which acts as a clearinghouse for all electricity amounts put through public grids and organises the settlement of balancing energy. In the case of Austria, the clearing is managed by "Austrian Power Clearing & Settlement (APCS)" and "Balancing Energy & Balance Group Management (A & B)". Each grid user, essentially all producers and all consumers, must join a balance group (or set up their own). In addition, suppliers, producers and aggregators can be mentioned here. The latter are new actors, whose role in Austria has not yet been defined independently. The members of a balance group can buy and sell energy in various markets (power exchanges or bilaterally via OTC or PPA). Furthermore, certified power plants can offer control reserve to the TSO. The marketing of flexibility is in particular the business model of aggregators.

Imperfections in the electricity market, for example caused by forecast deviations, are compensated for by regulatory power competitively procured and activated by the transmission system operator Austrian Power Grid (APG). Thus, the TSO is responsible for frequency control due to its role as control area operator. The energy flows of electricity are measured and forecasted in 15-minute-intervals. For producers and consumers with a connected electrical power of less than 50 kW or an annual consumption or production of less than 100,000 kWh (i.e. mainly households and small businesses) usually only annual energy values are recorded and converted into synthetic power profiles. Introduction of smart meters (on residential consumer level) allows daily and even quarter-hourly measuring of data. However, there is no obligation for clearing and billing energy amounts on a basis other than standard load profiles (below the threshold values above).

All customers (or producers) have an energy supply contract with an electricity supplier (retailer) and are thus assigned to a balance group. With respect to energy community models, locally generated electricity can be shared within a particular building free of network charges (i.e. without using the public grid and thus without accounting the community energy in the balance group model). This was legally enabled by an amendment of the Austrian Electricity Industry and Organisation Act (ElWOG, § 16a) in 2017. Following the EU Clean Energy Package, new community models, which might use the public grid at reduced network charges, are expected to be integrated into the legal framework. The implementation into national law is planned for early 2021.

All grid users also have a contract with the (regulated) distribution system operator (DSO) who operates the distribution grid to which they are physically connected. DSOs are mainly responsible for the technical quality of the power supply (in terms of voltage) and the safe operation of the grid at lower voltage levels, the data collection (metering) and the management of grid user data. It is expected that the implementation and introduction of the Clean Energy Package will broaden the role of DSOs. Aspects such as the use of flexibilities, optimisation of grid planning and expansion as well as digitisation will be driven forward.

The network charges, allocating grid costs to grid users, have been under discussion in recent years. This is driven by the ongoing rollout of smart metering as well as by the changing consumer behaviour due to new assets such as electric vehicles, heatpumps, or generation units. In order to take account of the costs-by-cause principle, the future design of prosumer network charges is expected to reflect peak power consumption to an increased degree.

2.2.2 Belgium

The Belgian electricity landscape is based on a liberalised market with separation between

- **Producers**: They can be private and/or organised in cooperatives,
- **Electricity suppliers**: They have to source a portion of their electricity supplies from renewable energies (RPS system).
- **Traders**: Electricity suppliers who are not producers buy their energy from a producer or on the power markets.
- **Balance responsible**: There must be a constant balance between the electricity production and the consumption of electricity. This is the responsibility of the Access Responsible Party. Imbalances can even result in power outages.
- **Transmission Grid Operator (TSO)**: ELIA transmits energy from the transmission grid and from abroad to the distribution network
- **Distribution grid operators (DSO)**: There are 24 DSO in Belgium (11 in Flanders, 12 in Wallonia and 1 in Brussels manage). They develop and maintain the electricity distribution network for a specific territory and transmit, at the supplier's request, the energy to the end

users. They provide new connections to the network and are responsible for reading your electricity.

The first driver of regional differences is caused by so-called regional public service obligations that are a consequence of the grid connection levels. The regions can impose public service obligations on grid operators below or equal to 70 kV located on their territory (which includes both profiles). The second regional impact within Belgium is caused by the certificate schemes that stem from the regional competence in terms of renewable energy obligations on their territory. Flanders, Wallonia and the Brussels Capital Region each impose their own green certificate scheme on all electricity consumers within their region (both profiles under review).

- **Regulators**: They monitor and regulate the liberalised energy market. In Belgium there is one federal regulator, the Commission for Electricity and Gas Regulation (CREG), and three regional regulators:
    - VREG in Flanders.
    - CWaPe in Wallonia
    - Brugel in Brussels

2.2.3 France

The French electricity landscape is based on a liberalised market since 2008 with separation between

- **Producers and suppliers:** It’s a concurrent market with different new actors, but EDF, the historical actor, still supplied 78% of the clients and 65 % of the electricity in 2018.
- **Transmission Grid Operator (TSO)**: the transmission system is owned by RTE, whose mission is always to ensure a balance between generation and consumption. To do this, RTE must anticipate the investments to be made in transmission network infrastructures and must know in real time the state of its network, as well as the injections and extractions on this network.
- **Distribution grid operators (DSO)**: The distribution network, owned by local authorities, is 95% managed by Enedis. The remaining distribution network is managed by Local Distribution Companies (LDCs). There are approximately 170 LDCs today.
- **Regulator**: The Commission de Régulation de l'Energie, CRE, is the independent administrative authority responsible for ensuring the proper functioning of the energy markets. Its competences also concern the electricity network and the connection of users to it. It has the following missions in particular:

- It sets the methodologies used to establish the Tariffs for the Use of Public Electricity Networks (TURPE),
- It decides on the evolution of these tariffs,
- It specifies the conditions for connection to the public electricity transmission and distribution networks, and
- It approves the connection scales for System Operators serving more than 100,000 customers.

2.2.4 Germany

To implement the liberalisation of the electricity market, the Energy Industry Act defines various roles (selection): electricity producer/producers, electricity supplier/supplier (intermediary between customer, electricity producer and electricity grid), balancing group manager, grid operator (infrastructure incl. meters if basic responsibility and transport routes), metering point operator (basic responsibility or competitive). In addition, a regulatory authority was established.

Wherever possible, competition in the electricity market is to be ensured. However, the electricity grids represent a "natural monopoly" without any meaningful possible competition and are therefore subject to state regulation, for which the Bundesnetzagentur (BNetzA) is responsible. With the help of the incentive regulation (ARegV), the network operators are regularly put into a mutual comparison by the regulator, which is similar to competition. The BNetzA also monitors non-discriminatory access to the electricity grids.

Grid voltage levels

In Germany, the electricity grid is divided into different grid voltage levels. The nominal network voltage ranges from 400 kV in the extra-high-voltage network to 110 kV in the high-voltage network and from 10 kV, 20 kV and 30 kV in the medium-voltage network to 400 V in the low-voltage network. In these networks, the network frequency is 50 Hertz. In the near future, several high-voltage direct-current transmission lines for north-south electricity transport will also be built, which represent point-to-point connections and will be assigned to the extra-high voltage network. There is also a traction power grid with a grid frequency of 16.7 Hz.

In addition to the nominal grid voltage and frequencies, a distinction is also made with regard to the tasks or function in mains operation. Transmission grids transport electricity supra-regionally using the extra-high voltage level and are managed by 4 transmission system operators (TSOs) in Germany. The distribution networks distribute the electricity from the transmission network at regional and local level to the individual consumers (or from individual producers), using the various network levels below the extra high voltage level. The distribution networks are managed by more than 800 distribution system operators (DSOs). The majority of renewable energy systems are connected to the grid levels of the distribution grid. A large part of the sector coupling applications will also be supplied via these grids. The distribution grids are very different according to the regional characteristics and the local design of the grid. For example, the characteristics and future challenges of urban, heavily meshed networks are different from those of rural networks.

The core task of energy policy is to create suitable framework conditions for a secure, stable, cheap, non-discriminatory and competitive energy market, increasingly based on renewable energies. A technically reliable and at the same time economically efficient electrical grid infrastructure is needed to ensure that the transactions carried out on the electricity market can actually be executed. Due to the high importance of grid operation for the German economy and the "natural monopoly position" of the grids, regulatory, economic and technical framework conditions are set (Energy Industry Act (EnWG), Incentive Regulation (ARegV), Technical Connection Rules (TAR)). The Forum Netztechnik/Netzbetrieb FNN in the Association of Electrical, Electronic & Information Technologies (VDE) has been commissioned with the technical regulation and standardisation in this area. The Federal Ministry of Economics and Energy (BMWi) is responsible for the legal framework for electricity producers/suppliers and electricity supply companies and for the specifications for BNetA.

Increasing share of renewable energies and flexible loads

The expansion of renewable energies in the electricity sector plays an important role within the framework of the German government's climate protection targets. To date, renewable energy systems with a total installed capacity of around 114 GW have been connected to the German electricity grid. The more than 1.7 million photovoltaic systems with an installed solar module capacity of 49 gigawatts on the German power grid in 2019 generated 8.2 percent of the gross electricity consumption in Germany. On individual sunny days, the photovoltaic systems already cover around 50 percent of the electricity requirement during the lunch hours. Together with other renewable energies such as wind power, biogas and hydropower, around 43 percent of Germany's gross electricity consumption can already be covered over the year. The increased motivation of prosumers to cover their own electricity, heat and mobility needs with their own PV electricity promotes and accelerates the switch from fossil fuels to renewable energies. Photovoltaics is the most decentralised of the renewable energies: a large number of solar systems feed into the low-voltage networks close to the consumers, increasingly together with modern battery storage and energy management systems as so-called "prosumer" systems. Locally directly consumed electricity is not fed into the grid at all.

Stable network operation - System services

The implementation of the Energiewende has implications for grid operation and grid expansion planning, because the integration of the various renewable energy systems and the increasing demand for electricity due to the targeted electrification of the heating and transport sector is changing load profiles and regional and supraregional load flows, not only in terms of the amount of electricity but also in the direction of electricity.

In order to keep the grid secure and stable, grid operators use the System Services (SDL) frequency maintenance, voltage maintenance, grid restoration and operational management. These services may be provided by grid operators themselves (e.g. reactive power from reactors), or they may be required by grid users within the framework of the grid connection conditions or procured competitively (e.g. balancing power products). The further development of competitive procurement of SDL is also required by European law. A paradigm shift has taken place: Whereas in the early days solar systems only fed fluctuating active power into the grid and were switched off when the frequency or voltage was outside the permissible range, today new solar systems can and must actively support the frequency and voltage of the power grid in line with demand. This is where renewable energy systems and flexible loads and prosumers will also make a contribution and will be integrated into the procurement and provision of SLDs in order to enable safe grid operation in the future. Especially due to the decentralised character of the renewable feed-in and also the sector coupling, the provision of SDL from these plants can react to local challenges and thus reduce the need for grid expansion in the distribution grid.

In order to ensure stable network operation with increasing decentralised feed-in and flexible loads, it must therefore be examined at every level whether the existing infrastructure is sufficient, can be better utilised or whether further measures must be taken. To this end, network operators have various technical options at their disposal, including the optimisation of network planning and operation by means of collecting and analysing real network status data, network upgrading, intelligent control or network expansion. In the future, all connected producers will also have to make a contribution in terms of system services. Here, too, the aim, also of the EU, is to realise as many of these system services as possible via market processes. In addition, the EU Renewable Energy Directive clearly supports the role of prosumers and producer/consumer communities.

Network connection conditions

The technical requirements for the connected RE plants, storage facilities and flexible loads, are also regularly adapted. The FNN was commissioned with the implementation of the technical requirements for the grid connection of renewable energy systems. Finally, the technical connection conditions were adapted in April 2019 in implementation of the Network Code Requirements for Generators. For this purpose, specific but coordinated application rules were drawn up for all grid voltage levels and defined and published in the VDE AR N 41XX series.

Network development plans are developed by the Federal Network Agency in cooperation with the transmission system operators for the supra-regional network expansion planning. Here, political expansion targets and expectations of the various stakeholders regarding the development of the energy system over a period of approx. 15 years are taken into account. At the distribution grid level, where most PV systems and also the charging infrastructure for electromobility are connected, the distribution grid operators must adapt their grids to the new requirements. However, system-integrated prosumer concepts also provide new degrees of freedom that can be used with regard to grid operation and expansion, provided that the regulatory framework for this is developed further accordingly.

One of the central challenges is the balancing act between the continuation and expansion of the EU internal market for electricity on the one hand, and the balancing of production and consumption at regional to local level on the other. The large-scale internal electricity market depends on an efficient transmission network infrastructure but offers the advantage of high market liquidity for the supra-regional balancing of generation and consumption. However, bottleneck situations in the distribution grid may require measures at regional to local level. Furthermore, the introduced distinction between market (competition) and grid (natural monopoly) should not be diluted.

In order to make optimum use of the existing network infrastructure and to avoid bottlenecks, a decentralised energy system can aim to balance fluctuating generation and flexible loads. The framework conditions under which an overall optimum can best be achieved here are controversial and still under discussion and development in Germany. The responsible ministry has set up various processes for this purpose.

Flexibilities

On the one hand, a wide range of technical and market opportunities and business models based on them are available to enable consumers to shift their consumption to times of high generation and to operate with this flexibility. This includes, for example, variable tariffs or flexibility markets, the applicability of which is currently being tested in research projects. On the other hand, many network operators consider it necessary and possibly economically preferable (compared to network expansion) to give network operators the possibility to intervene directly on the flexible loads and to restrict the use of these loads over time, as is already the case today with heat pumps with a heat pump tariff on a voluntary basis. The technical implementation of the control is to be ensured by a control box, which is connected between the producer or consumer and the Smart Meter Gateway (SMGW). An energy-law basis is provided here by the EnWG with § 14 a for controllable loads, which must then be developed within the framework of a regulation. This design of § 14 a is currently being further developed and discussed within the framework of the concept of "peak smoothing" in the low-voltage network. Depending on the form it takes, however, this may also mean an encroachment on the autonomy of prosumers.

Communication - intelligent metering

All these approaches require secure and to a large extent standardised communication between operators of generation and flexible consumption facilities and network operators. Smart grids, smart mobility and smart metering are the keywords in this discussion.

An important project of the Federal Government is therefore digitisation in the energy sector and in network operation. With the Act on the Digitisation of the Energy Turnaround, which also includes the Metering Point Operation Act, the Federal Government has set out a way of implementing such secure communication between generation and consumption plants and the grids. The Federal Ministry of Economics and Energy and the Federal Office for Information Security (BSI) are in charge of this project. Star-shaped communication via intelligent measuring systems (iMSys) is planned, consisting of modern measuring equipment in combination with a secure communication platform, the Smart Meter Gateway (SMGW). The latter must be certified by the BSI. For this purpose, the BSI regularly conducts a market analysis and determines in a market declaration which functions the SMGW can fulfil and which application cases must be operated via iMSys from this point on, provided that mandatory installation cases exist. This secure communication platform should also be the basis for innovative business models with the plant data. However, this is hardly possible today.

On the one hand, the technical implementation has not yet been completed, in some cases it needs to be supplemented, and there is criticism from various stakeholders that the new digital communications infrastructure in the energy industry is not powerful enough for the challenges ahead. The first three smart meter gateways from different manufacturers have now been certified, so that the rollout was started with the market declaration of the BSI at the end of January 2020. However, the functions of controlling renewable energy plants or flexible loads are not yet part of the market declaration, so that corresponding plants are excluded from the mandatory rollout. The BMWi and the BSI will manage the further process regarding the technical development by involving the affected industries in the AG Gateway Standardisation. Selected experts from the sectors discuss in the Smart Grid, Smart Home and Smart Metering/Sub-Metering Task Forces. The results of various research projects (e.g. SINTEG projects), in which various technical applications and market models are being tested, are also to be incorporated here. In this process, many stakeholders hope that the new digital infrastructure will be decisively improved in its performance and practical suitability.

Regulatory framework

The regulatory framework required for the implementation of various business models has not yet been completed either. Here too, the BMWi has initiated an intensive process involving the sectors in the Working Group on Smart Meters and Grids (AG INuZ). The expert reports commissioned are evaluated in expert workshops and meetings and an associated process. The BMWi's aim is to define both the technical requirements and the regulatory framework by the end of 2020 and to create the corresponding legal basis.

2.2.5 Italy

Almost 70% of the Italian electricity grid is made up of low-voltage (LV) lines, i.e. below 1 kV. The rest is divided between medium and high voltage (MV and HV). This corresponds to around 800,000 km of extension of the LV network and about 350,000 km for the MV and HV networks. The EURELECTRIC report mentioned in the note includes Italy among the countries defined as 'medium concentration', characterised by a dominant DSO managing more than 80% of the energy distribution and by many small local operators.

In fact, Italy is characterised by a high presence of small and medium sized DSOs. In 2010, according to the same report, there were 135 operators of this type, while only 2 were DSOs with more than 100,000 customers. The total electricity distributed by all these parties amounted to 264 TWh/year and the number of users to 31,423,623, of which 31,331,656 were below 1 kV, 90,949 between 1 and 100 kV and, finally, 1,018 above 100 kV. From the point of view of corporate structure, then, Italy is dominated by private DSOs, unlike what happens in other countries such as Austria or France, where the distribution is borne by public companies at national level. The ownership of the entities that manage the distribution is in Italy, as in most European countries, borne by national companies.

DSOs only operate MV and LV networks, while the transmission system operator operates all mesh networks, which helps to simplify the roles and procedures for resolving high-voltage congestion. There are more than 1,700 connection points between DSO and TSO in Italy. In Italy, DSOs can interact directly with new connections, but not in the case of services requested by existing customers that should instead be carried out through the supplier. Currently, Italian law provides that no investment made by DSOs in energy storage systems may be transferred to distribution network tariffs, unless the DSO submits a proposal to the regulator providing a cost-benefit analysis justifying such investments.

Italy is also one of the most advanced European countries in terms of rolling up smart meters. The introduction of smart meters started in 2001, reaching a penetration of 95% by 2011. This introduction started well before the entry into force of any regulation and was carried out exclusively for economic reasons without a prior cost-benefit analysis by the regulatory authority. Thanks to a greater efficiency in the measurement operations, in fact, it allowed a quick return on investment for DSOs. The main reasons behind this massive deployment were the possibility of efficient remote reading, the reduction of electricity losses, the limitation of fraud, the improvement of reactions to delays or non-payments by users, as well as, finally, the opportunity to offer new services including energy efficiency measures.

The measurement service is carried out in Italy by the DSOs, who own the meters and are fully responsible for installation, maintenance, meter reading and data management activities.

In most cases, hourly data resolution is used. A higher resolution, for example fifteen minutes, while benefiting some specialist services, considerably complicates the process. Moreover, the availability of more frequent data does not necessarily reduce consumption if there are no home automation devices capable of analysing consumption profiles.

2.2.6 The Netherlands

The liberalisation process of the electricity market and the directives for non-discriminatory access to the network, implemented in Europe, have contributed significantly towards the creation of competitive markets and a restructuring of the electricity sector. In Europe, each control area of the interconnected power system, is operated by the associated Transmission System Operator (TSO), the legal institution that monitors the transmission network, ensures the connections with other control areas, and organises the markets for operating reserves and cross-border capacity and exchanges. The Netherlands is operated as a single control area, and TenneT TSO is the responsible authority to ensure security of supply and to facilitate electricity markets operation. A single control area might involve one or more Distribution System Operators (DSO), but every regional distribution system is associated to a single DSO company that operates as a natural monopoly. DSO companies connect individual system users to the transmission network and provide the distribution of electricity through medium voltage (MV) and low voltage (LV) networks, which subsequently feed a large number of system users at the LV distribution level. There are currently 8 DSOs active in the Netherlands, while 3 dominant DSOs manage 95% of all customer connections, i.e. Enexis, Alliander (Liander/Endinet) and Stedin (Eneco).

The Dutch electricity market has been fully open to competition since July 2004, and TenneT recognises Balance Responsible Parties (BRPs) as the market parties that can nominate energy at the wholesale level. Other main stakeholders in the Dutch power market are the regulator, i.e. the Authority for Consumers and Markets (ACM), and the European Power EXchange (EPEX) which is a power exchange providing trading and clearing services for the wholesale market in Germany, France, the United Kingdom, the Netherlands, Belgium, Austria, Switzerland and Luxembourg. Furthermore, the association Energie-Nederland represents energy producers, traders and supply companies in the Netherlands.

In the Netherlands, the transmission grid (>110 kV) is operated by the TSO, TenneT, whereas the distribution grids (<110 kV) are operated by DSOs. Cross-border connections encourage free-market operation in the energy sector, and the Dutch power system is highly interconnected (within the ENTSO-E area. Grid operators, i.e. TSO and/or DSOs companies, are potential users of flexibility services, through the procurement of ancillary services, to perform their core tasks, to defer network reinforcements and investments, and to reduce grid losses.

2.2.7 Portugal

The grid system in Portugal, with the main high voltage lines and interconnections with Spain, is characterised by a North – South high Voltage system connecting the main cities situated mainly in the coastal zone, and horizontal branches that connect to the interior part of the country and to Spain. From these main branches the distribution grid provides a practically 100 % supply of electricity to all the population. The Country has, for the time being, good interconnections with Spain with 2.1 GW for importing and 3 GW for exporting corresponding to about 13 % of the whole installed capacity. However, the strong ambitions of Portugal in the framework of the National Energy and Climate Plan (PNEC2030), with 80 % of Renewables for electricity in 2030, and in particular about 9 GW for the total PV installed capacity in 2030, calls for important changes in the electric grid with improvements both at regional level and at the level of interconnections. In fact, the geographic dispersion of RES generation requires a strategic development of the grid, including environmental and spatial planning aspects. Currently, demand and supply are characterised by a more or less constant demand around 50 TWh a year and a supply with already a strong component of Renewables of the order of 30 % which, for the time being, has an annual dependency on the precipitation and hydro conditions.

The Portuguese Electricity System incorporates six major functions: production of electricity, transmission, distribution, operation of the electricity market and the logistical operations between producers and consumers of energy. The Portuguese Electricity System is nowadays totally unbundled, a process that started in 1995 inspired in the same principles of the European Directive 96/92/EC, December 19th that defines common rules towards the founding of the Internal Electricity Market. The former vertical structure of the state-owned company EDP was privatised under a holding Company.

The Energy Services Regulatory Authority (ERSE) was created in 1995 with the aim to protect the consumers, to guarantee an adequate commercial and technical quality of supply, to promote an open access to information among all the actors of the system, namely market players, producers and network operators, ensuring a fair remuneration for the market stakeholders through the definition of a transparent tariff for consumers. Supply to final consumers is also fully liberalised, although a regulated supplier of last resort is being kept for social reasons (people with low income. OMIE and OMIP are the regional daily and forward electricity trading platforms, respectively. As from 1 July 2011 OMIE assumed the management of the bidding system for the purchase and sale of electricity on the spot market within the sphere of MIBEL (Iberian electricity market). OMIP, constituted on June 16th, 2003, is the derivatives exchange market for Iberian and non-Iberian products (including MIBEL), that ensures the management of the market jointly with OMIClear, a company constituted and totally owned by OMIP. The Transmission and Distribution activities are regulated and developed through a concession endorsed, respectively, to REN (Transmission System Operator) and EDP Distribution (Distribution System Operator), both nowadays private companies and regulated by ERSE. The Directorate General of Energy and Geology (DGEG) is the body responsible for the development and implementation of policies related to energy and geological resources within a framework of sustainability and security of energy supply.

On the 25th October 2019, the new decree of law for self-consumption and energy communities was published and will come into force on the 1st of January 2020. The additional technical guidelines supporting this new legal document are expected to be issued until the end of 2020. This document substitutes the former decree of law 153/2014, allowing also energy communities. The former internet platform SERUP (where all the legal procedures had to be requested) was also completely renewed and the PV sector is waiting for it to be fully operational. Energy Storage and Peer to Peer electricity commercialisation was also introduced in the new legislation. The main actors in this legislation are the Directorate General of Energy and Geology (DGEG) that will have the role of decision, coordination and supervision of the activities of electricity production in self consumption; the National Entity for the Energy Sector (ENSE) will supervise the compliance of the rules of the process; the Regulator (ERSE) will define the tariffs for grid access and the technical guidelines (together with DGEG).

2.2.8 Spain

The first years of the Spanish's Energy Transaction have been seen as truncated due to the policy framework considered as lagging which did not encourage the development of renewable energies, especially photovoltaic solar energy, with actions such as the tax on self-consumption, the so-called "sun tax" as well as a long list of tedious and complicated administrative processes. However, the new government in 2018 supposed a turning point during this energy transaction period as a new radical change was introduced in the country, with clear and defined objectives for the 2030 Horizon, high support on energy self-consumption, a new renewable energy mix and the reduction of CO2 emissions.

With the approval of the Royal Decree 15/2018, on October 5th, 2019, new measurements were put into place for the transaction and the protection of customers in reference to electricity consumption and self-consumption. It also defined renewable self-consumption as “an essential element to ensure that the consumer can obtain a cleaner and cheaper energy.” The new law eliminated the regulatory barriers which have prevented the self-consumption activity in Spain and has based its content in three fundamental principles: the right to self-consume, the right to shared self-consumption and an administrative and technical simplification of the conditions of access and connection for self-consumer installations with less than 15kW power. Not long after the release of the previous Royal Decree (RD), another one, 244/2019, on April 5th, 2019, established the administrative, technical and economic conditions for the practice of electric self-consumption. It included new terminology, new grid conditions, started the development of collective and individual self-consumption, determine the liquidation and treatment of surpluses, as well as establish a registration and communication system for self-consumption facilities.

The operation of the Spanish Grid system is defined by 24/2013, approved on December 26th, as the law of the electrical sector. Its main objective is “*to establish the regulation of the electric sector, guaranteeing the electric supply with the required quality levels and minimum possible cost, ensuring economic and financial sustainability of the system, allowing a level of effective competence in the electrical sector within the principles of environmental protection*.” This RD settles all the activities related to electric supply, generation, transport and distribution, as well as energy market and, economic and technical management of the electric system. The main actors of the Spanish electric system are defined by Article 6 of the already named law which is divided into seven groups. (1) **Producers**, which produce electric energy using their installations and equipment, which must be registered in the administrative register of electrical energy production facilities (RAIPRE). (2) The **market operator**, the mercantile company that assumes the management of the system of offers for the purchase and sale of electric energy in the daily market of electric energy in the terms established by regulation. (3) The **operator of the system**, Red Eléctrica de España (REE), is the manager of the transport network and the system operator with the main function of guaranteeing the continuity and security of the electricity supply and the correct coordination of the production and transport system. (4) The **transporter**, a mercantile company that has the function of transporting electricity, as well as building, maintaining and maneuvering the transport facilities, in addition, to grant connection permits to the transport network following the instructions given by the system operator for the operation of the transport network and grant connection permits to it. (5) **Distributors**, which are those mercantile societies or cooperative societies of consumers and users, whose function is the distribution of electrical energy. They will have to build, maintain and operate the distribution facilities destined to place the energy in the points of consumption and will analyse the requests for connection to their network, granting or denying access to it. (6) **The suppliers**, which are those mercantile societies, or cooperative societies of consumers and users, which, accessing the transport or distribution networks, acquire energy for sale to consumers, other subjects of the system or to carry out exchange operations international in the terms established in this law. (7) **Consumers**, who acquire the energy for their own consumption and the recharge of electric vehicles.

Self-consumption has brought new terminology and actors to the electric system such as associated consumer, associated producer, owner of self-consumption generation installation and holder of the self-consumption installation.

2.3 New EU regulatory framework and its grid related provisions

A recently adopted new set of EU rules – the so-called “Clean Energy for All Europeans” Package[13] - is aiming to further develop one of the EU’s major long-term policy initiatives, namely the EU Energy Union[14]. Major objectives of this Union include, among others, to place renewable energy and energy efficiency into the centre of a new internal energy market and put citizens at the core of the Energy Union. It includes European-wide targets, inter alias, to increase the share of renewables in the EU energy mix to 32% by 2030.

The new framework shall enable citizens to actively participate on a level playing field across the market and to benefit from Europe’s energy transition. It aims at empowering and protecting consumers through better information on energy consumption and costs and helps issuing a tighter safety net to addresses energy poverty and vulnerable consumers. In addition, energy labels and eco-design measures are directed to increase cost savings and energy-efficient behaviour. Also, consumers are given more choices in their homes, making it easier to play a more active role and engage as self-consumers – or “prosumers” - in electricity markets, by investing in renewable energy, most obviously PV generation units, and then consume, store or sell the energy they produce, and benefit from functioning and organised electricity markets.

[13] https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/clean-energy-all-europeans
[14] https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union

The necessity to further decarbonise the world’s economies to counter climate change and the ambition to make Europe become the first climate-neutral continent should be further endorsed by what the President of the European Commission, Ursula von der Leyen, chose to call the “European Green Deal” – a set of new policy initiatives announced for the new legislation period 2019 to 2024 “to reduce emissions further and faster, and by at least 50% for 2030”.

In parallel, each EU Member State must transpose the new EU rules into national law and reflect them in their national energy and climate plans. Such an ambitious trajectory will need citizens and cooperatives to play an increased role in the take-up of renewables through self-consumption. To give support to the upcoming policymaking in this respect, the PVP4Grid project results and recommendations can be used to address and reduce barriers beyond existing regulatory frameworks across the EU.

2.3.1 New EU regulatory framework for self-consumption

Although self-consumption is not a new concept, and individual self-consumers are relatively widespread across Europe, the EU now obliges its Member States to adopt enabling legislative frameworks in this respect until the end of 2019 – and demonstrates its vision that consumers shall participate in energy markets as equals among all market players. By introducing new provisions and its corresponding definitions, the EU for the first time formally recognises self-consumers, as “renewable self-consumers” and “active customers”, entitled to generate, store and consume electricity from renewable sources but also to carry out activities beyond the self-consumption, such as the participation in flexibility or energy efficiency schemes. Hence electricity, produced either individually or collectively, can be fed into the grids and in return make self-consumers receive remuneration that reflects market value. Nevertheless, this is not supposed to represent one’s primary commercial or professional activity. Electricity behind the meter is not being charged including levies, taxes and network tariffs, although exemptions are foreseen for installations larger than 30 kW, for electricity that benefits from support schemes, or if there’s system risks resulting from increasing amounts of the electricity fed into the grid (from 2026 onwards). Such active participation in energy markets is further enhanced by facilitating power-purchase agreements (PPAs), peer-to-peer trading and demand response schemes.

Furthermore, the new provisions aim at tackling barriers related to over-burdensome bureaucracy by preventing consumers from being subject to disproportionate technical and administrative requirements and procedures. For instance, self-consumers owning energy storage facilities have the right to a grid connection within reasonable time.

2.3.2 Grid related provisions

From a macro-economic perspective, the most pressing challenge results from integrating renewables into the electricity networks, and in particular at distribution level where more than 90% of RES are connected. The overall electricity system costs need to be allocated among all network users while striking a balance for pursuing the two overarching – and potentially conflicting - principles of sustainability and affordability. Sustainable, because incentivising active customers and renewable self-consumers (as well as consumer engagement in other forms, such as citizens' and renewable energy communities) increases the renewable energy sources (RES) share in the EU's energy mix and contributes to achieving the EU's decarbonisation targets. And affordable, because most of Europe's network costs are socialised among all system users and paid in form of network tariffs to ensure the network operators' revenue stream. When now an increasing number of consumers gains a higher energy autonomy and in consequence contributes less to covering the network costs - while in most cases remaining connected to the distribution networks for times without sun or wind - the "passive" consumers or those without means or access to renewable self-consumption will need to afford a higher share of the grid cost and might face increasing energy bills. The new EU rules acknowledge and address the need to outbalance this conflict of interests:

- Network charges need to be cost-reflective and contribute to the overall cost sharing of the system, and account separately for electricity consumed from the grid and electricity fed into the grid, phasing out net metering schemes beyond 2023, to make sure that self-consumers pay the full cost of service to use the grid and do not shift their share of the costs onto customers without renewable self-consumption.
- Principles for network charges and tariffs are being introduced - such as for connecting consumers to the networks – according to which citizens shall not be discouraged from becoming self-consumers. Also, distribution tariffs may be differentiated, based on the system users' consumption or generation profiles.
- Active customers are financially responsible for the imbalances they cause in the electricity system but can delegate their balancing responsibility to market actors offering such services (so-called "aggregators"). Regarding demand response, consumers have to pay a compensation to other market participants or their balancing responsible party that are directly affected by their demand response activity.

Many of the new provisions in this respect are kept at rather general level, as the cost allocation and financing of accessing and using energy networks differ to large extent across the EU. Much depends on how Member States will proceed and transpose the new EU rules into national legislation, while more legal clarifications are expected to be defined in a Network Code on demand response, including aggregation and energy storage - which is likely to further develop also the framework for active customers and renewable self-consumers. Network Codes are legally binding European Commission implementing regulations to govern all cross-border electricity market transactions and system operations.

From the perspective of the electricity network, the increasing decentralisation of Europe's energy system has a major impact on how to operate networks in an affordable, sustainable and secure way. Large shares of RES, including electricity produced by self-consumers, are connected at medium and low voltage level and integrated by the distribution system operator (DSO) into the networks. Therefore, the EU has assigned new roles and responsibilities to DSOs who in their function as regulated monopolistic entities (there is no parallel electricity grids, for good reasons) shall become "neutral market facilitators" and will need to carry out more active system management, but without interfering in existing and functioning markets. While not explicitly referring to active customers and renewable self-consumers, this is reflected in the new EU regulatory framework for DSOs and designed to incentivise the development of "smart, flexible and digitalised" networks. This entails, in particular for intermittent electricity, the use of flexibility for shifting loads and matching generation and demand (the European interconnected electricity network must be in balance at all times), access to storage facilities, rules for congestion management (in times with lots of sun or wind), data exchange and management models, the further roll-out of smart meters and a better cooperation between Transmission System Operators (TSOs, operating high voltage and long distance networks) and DSOs, as well as the interaction with market parties.

All in all, with the new EU framework on self-consumption, the principles on network charges and tariffs, as well as for the new rules for the operation of electricity distribution networks, the EU is trying to establish a fair balance between customer and the electricity system needs – which the Member States will now need to reflect when implementing the "Clean Energy for All Europeans" Package into national legislation.

2.4 Challenges and drivers of energy-self consumption from the grid perspective

One of the core elements of the Clean Energy Package is the active involvement of consumers as showed in the previous Sub-Chapter 2.3. The role of consumers is expected to change from passive consumers into active consumers and prosumers. This development however sets some challenges to the distribution network. Although energy self-consumption and different prosumer concepts have received growing attention of recent academic literature and practitioners' reports, less is known about the effects of self-consumption on the distribution networks to which most of the prosumers are connected to[15].

According to a recent study, based on a survey to the EU DSOs[16], only less than one third (28%) of the DSOs currently handles with prosumers[17] but rather the prosumers are treated as normal connection points. The study however states that the prosumers are considered to become more important actors in the future, and currently they are handled in pilot projects. The reasons why the prosumers are not currently managed by the DSOs varies depending on the country-specific context. Some DSOs mention that although they manage distributed generators larger than 100 kW, these are not used for ancillary services, whereas others cannot handle prosumers because of the current regulatory framework not allowing them to do so, or that the regulatory framework is still under definition regarding the management of prosumers and active consumers, or simply there is no need for prosumer management.

The following points aim to describe the current challenges and drivers influencing the energy self-consumption and its implications to the distribution network.

The RES target-setting and progress depends on the historic energy-mix and country specific RES potential. The EU target is to fulfil at least 20% of its total energy needs with renewables by 2020[18]. This target was revised with the Clean Energy for all Europeans Package in 2018 and the new target is to achieve at least 32% by 2030[19]. To implement these targets, the EU countries are required to draft 10-year National Energy & Climate Plans (NECPs), outlining how they will reach the targets, considering the country specific starting point and overall potential for renewables[20]. The Member States submitted the final plans for 2021-2030 to the European Commission by the end of 2019. According to the latest progress report, the renewable energy shares reflect the large diversity among the Member States in respect to energy mix and renewable

[15] Mateo, C. et al. (2018) Impact of solar PV self-consumption policies on distribution networks and regulatory implications. Solar Energy, Vol 176, Dec, 2018, pp. 62-72.
[16] The survey covered 190 DSOs that have to comply with the unbundling requirements set out in the EU Electricity Directive (i.e. the DSOs serving more than 100,000 customers, also referred to in the report as "larger DSO"). 79 out of the 190 larger DSOs responded to the survey.
[17] Prettico, G., Flammini, M. G., Andreadou, N., Vitiello, S., Fulli, G., and Masera, M. (2019) Distribution System Operators Observatory – Overview of the electricity distribution system in Europe. EUR 29615 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-79-98738-0, doi:10.2760/104777, JRC113926
[18] Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC
[19] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources.
[20] European Commission (2020) Renewable energy directive. Webpage available at https://ec.europa.eu/energy/en/topics/renewable-energy/renewable-energy-directive/overview

energy generation potential as shown in the Figure 3 below. In the PVP4Grid countries, the target setting for 2030 varies from 25% in Belgium and the Netherlands to 45% in Austria.

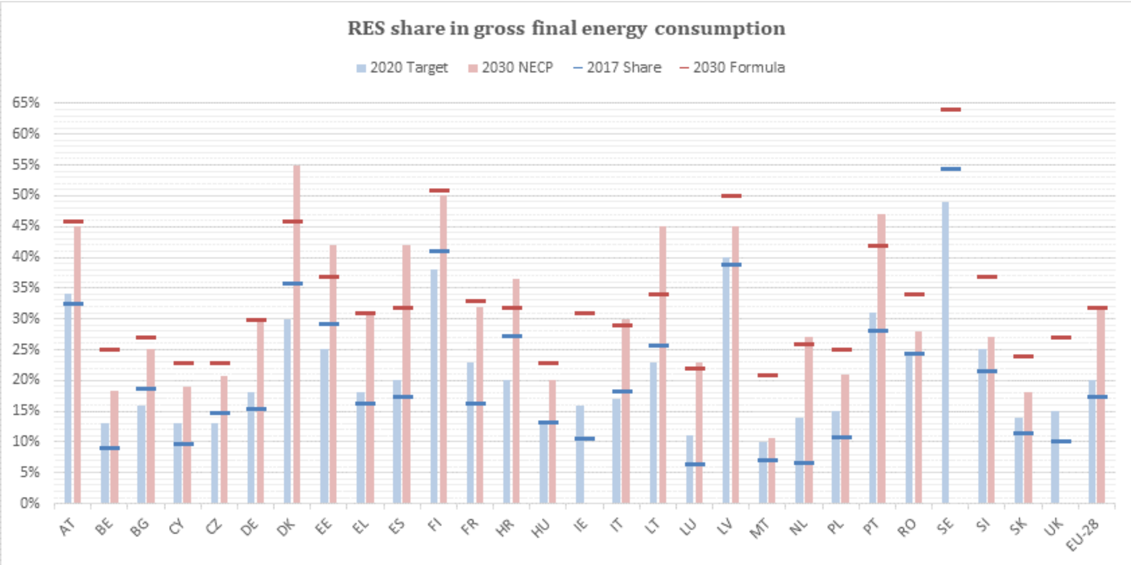

Figure 3: National renewables contributions based on draft NECPs. Source: EC, 2019[21]

The total installed PV capacities varies among the EU countries. The EU reached a total installed PV capacity of 132 GW at the end of 2019[22].The EU countries however vary significantly in terms of total installed PV capacity as shown in the Figure 4 below, Germany having the highest capacity with 49.9 GW of total installed capacity followed by Italy reaching 20.5 GW. From the PVP4Grid countries, also Spain and France have around 10 GW installed PV capacity (10.6 GW, 9.97 GW respectively) followed by the Netherlands with 6.7 GW and Belgium with 4.7 GW – while the Austria and Portugal have lower installed capacity (1-2 GW).

[21] European Commission (2019) United in delivering the Energy Union and Climate Action - Setting the foundations for a successful clean energy transition. COM(2019) 285 final.
[22] SolarPower Europe (2020) EU Market Outlook for Solar Power / 2019 – 2023.

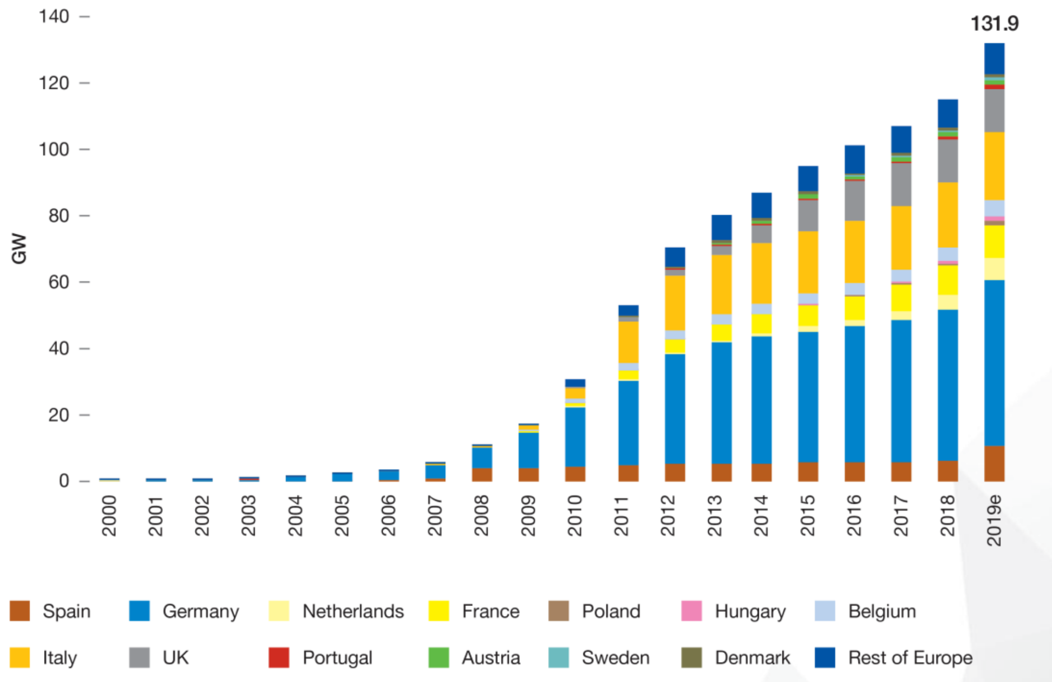

Figure 4: EU28 total solar PV installed capacity (GW) 2000 – 2019. Source: SolarPower Europe, 2020.

The distributed PV generation is increasing. The deployment of rooftop solar PV systems has increased significantly over the last years due to decreasing costs of PV and supportive policy initiatives, mainly net metering and fiscal incentives[23]. It has been estimated that the distributed PV capacity will increase 320 GW by 2024 presenting close 50% of the total PV growth globally[24]. In Europe by the end of 2018, 19% of the cumulative PV system capacity was installed on residential rooftops and about 30% on commercial roofs, while the industrial segment accounted for 17% and the utility-scale market for 34%[25]. The Figure 5 below presents the PV capacity segments in selected EU countries. The PV installations are still dominated by utility-scale PV installations in countries such as Spain where very attractive feed-in tariffs were in place over ten years ago. In the new growth phase (since November 2018), significantly more PV self-consumption has been installed. In Germany the distribution among the utility-scale PV capacity vs. PV self-consumption is much more balanced. From the PVP4Grid countries, Belgium, Austria and the Netherlands have the highest non-utility scale PV capacities respectively.

[23] IRENA (2019) Future of solar photovoltaic - Deployment, investment, technology, grid integration and socio-economic aspects. International Renewable Energy Agency, November 2019.
[24] IEA (2019) Renewables 2019: Market analysis and forecast from 2019 to 2024. International Energy Agency, October 2019. Available: https://www.iea.org/reports/renewables-2019
[25] SolarPower Europe (2020) EU Market Outlook for Solar Power / 2019 – 2023.

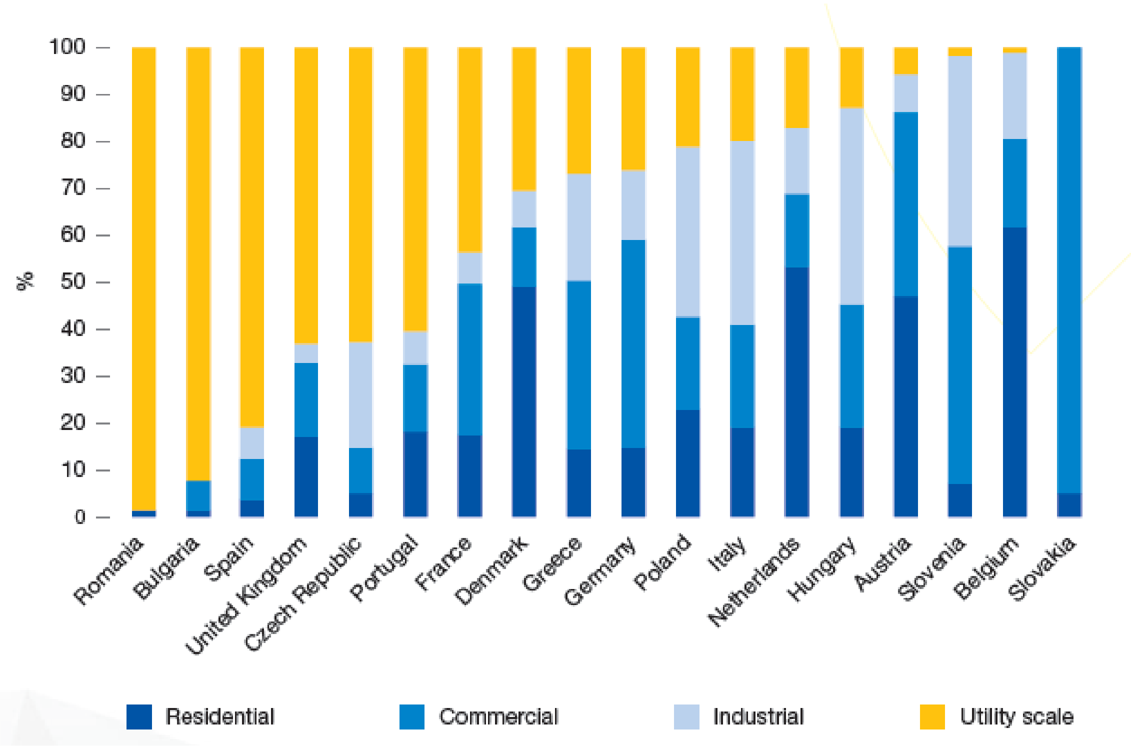

Figure 5: EU solar PV total capacity segments (%) until 2018 for selected countries. Source: SolarPower Europe, 2020.

PV self-consumption potential is huge but also varies among the EU countries. A recent study that applied satellite imagery, electricity prices and lending data to assess the untapped rooftop PV potential in the EU[26]. The results show that the EU rooftops could potentially produce 680 TWh of solar electricity annually, representing 24.4% of current electricity consumption, two thirds of which at a cost lower than the current residential tariffs. The study however shows that Cyprus, Portugal, Malta, Greece and Italy have the highest potential, closely followed by France, Spain and Germany. Countries in eastern Europe lag behind because of barriers to installing PV on rooftops. The available building surface area that could be used for PV installations is even greater when considering Building Integrated Photovoltaic (BIPV) materials that can be applied beyond rooftops on building façades[27]

Grid connected distributed generation, in absence of self-consumption, may challenge the grid capacity and suggests new roles for DSOs. The EU distribution system operators (DSOs) face a growing need for investment to cope with moves to more distributed forms of generation[28].

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[26] Bódis et al. (2019) A high-resolution geospatial assessment of the rooftop solar photovoltaic potential in the European Union. Renewable and Sustainable Energy Reviews, Vol. 117, October 2019, 109309.
[27] SolarPower Europe (2020) EU Market Outlook for Solar Power / 2019 – 2023.
[28] GreenTechMedia (2019) European Distribution System Operators Seek Cash for Grid Transformation. Available: https://www.greentechmedia.com/articles/read/european-dsos-seek-cash-for-grid-transformation

According to Eurelectric, over 90% of all distributed renewable electricity generation is and will most likely continue to be connected at distribution grid level. This has become a challenge for grid planning and operation in countries where the capacity for distributed generation has increased rapidly and is prone to become a challenge in other countries. For instance, in Germany where the PV capacity increased from initial 0.4 GW in 2003 to 40 GW in 2015, the vast increase of PV connected to the low voltage network caused saturation of the grid when the PV generation exceeded the power demand in an area, e.g. during peak hours of sunny days[29]. Despite that the legal framework ensured electricity from renwable sources a priority access to the grid ahead of conventional power, the DSOs were authorised to curtail certain PV systems in specific operational situations to prevent their network from overloading (particularly at situations of operational changes of the local to regional grid topology. At the same time, the regulation also encouraged the DSOs to enhance their networks to allow more renewable capacity to be injected to the grid.

Another recent study looked at the impact of increasing levels of renewable electricty penetration on the grid[30]. The results suggest that limiting the size of the generation units would allow mitigating voltage and congestion problems, maximising renewable penetration with no need of additional network investments. In general, the study highlights that “a careful consideration of the local conditions of each distribution area as well as of the different connection patterns, including aspects such as unit sizes, technologies and location within the network is therefore of paramount importance to minimise adverse impacts on the network[31]”.

Power grid modernisation has taken different paces among the EU Member States. The future distribution system will need to handle new load and generation patterns introduced by the distributed generation such as electricity self-consumption. Smart metering infrastructure and other technologies driving the power grid modernisation are essentially enabling technologies for self-consumption as they allow a two-way flow of electricity and data facilitating consumer participation in the electricity market. At the same time, modern power grid technologies such as sensors, Internet of Things and new communication systems allow availability of new operational data, control systems and digital communications tools enabling to detect, react and proact to changes in usage. This provides for DSOs better and new planning options, including demand response, electrical energy storage, vehicle to grid communication etc. The so-called self-healing capabilities

[29] Rakhau, E. and Collins, C. (2019) The rapid growth of solar integration into grids: learn from Germany. Available: https://energypost.eu/the-rapid-growth-of-solar-integration-into-grids-learn-from-germany/

[30] Prettico, G., Flammini, M. G., Andreadou, N., Vitiello, S., Fulli, G., and Masera, M. (2019) Distribution System Operators Observatory – Overview of the electricity distribution system in Europe. EUR 29615 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-79-98738-0, doi:10.2760/104777, JRC113926

[31] Ibid.

maximise the performance and stability of the grid by allowing continuous self-assessment which inspect, analyse, react to, and automatically respond to problems in real-time[32]. The first step of power grid modernisation includes the roll-out of smart metering systems. The EU aims to replace at least 80% of electricity meters with smart meters by 2020[33]. The Member States have committed to rolling out close to 200 million smart meters for electricity and 45 million for gas by 2020 at a total potential investment of EUR 45 billion[34], although the development has been uneven among the EU Member States as it can be seen from the Figure 6 below.

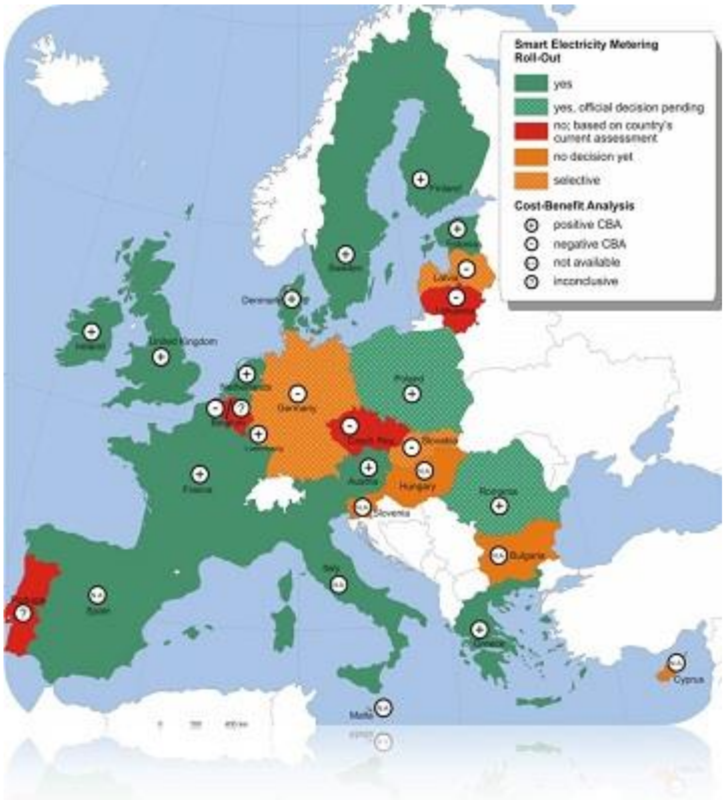

Figure 6: Smart electricity metering roll-out in 2014. Source: JRC, 2020[35]

The barriers for PV self-consumption are mainly not technical by nature, but regulatory. In a large majority of the EU countries, PV self-consumption has been limited to the owners or tenants of single-family homes or small PV systems in apartment buildings. The rooftops of multi-apartment buildings or office buildings with multiple ownership represent a large share of the total available

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[32] i-SCOOP (2020)-Smart grids: what is a smart electrical grid – electricity networks in evolution. Internet article. Available: https://www.i-scoop.eu/industry-4-0/smart-grids-electrical-grid/. Accessed: March 2020.
[33] European Commission (2020) Smart grids and meters. Available: https://ec.europa.eu/energy/en/topics/markets-and-consumers/smart-grids-and-meters/overview. Accessed: March 2020.
[34] Joint Research Centre (2014) Smart Metering deployment in the European Union. Available: https://ses.jrc.ec.europa.eu/smart-metering-deployment-european-union. Accessed: March, 2020.
[35] Ibid.

rooftop and thus until recently was untapped potential. Despite that the use of PV systems in multi-apartment and commercial buildings have become more popular over the last years, the existing differences in administrative provisions as well as technical regulations end electricity codes for self-consumption make the implementation highly complicated. In a recent study, the current situation of nine different countries were studied[36]. As a generalised conclusion, the study finds that the multi apartment buildings are still facing a lot of administrative and regulatory challenges for PV self-consumption. Similar conclusions have been achieved by the previous PVP4Grid deliverables.

Change of ownership of power generation capacity. The new regulatory framework introduced by the Clean Energy Package stipulates that the DSOs can own flexible distributed energy resources only under specific circumstances. This means that the primary role of future DSOs is to act as system operators and neutral market facilitators[37]. At the same time, the self-consumption suggests that the electricity generation units are installed at the premises of the consumer or at least near the location of consumption (e.g. local energy communities). This development is also prone to change the renewable energy investment patterns. For example, in Germany, the large utilities are owners of only a small share (5%) of the installed renewable capacity[38].

New incentives schemes for regulating the DSOs. Despite the changing role of the DSOs, their activities will maintain to be guided by regulation. Although the regulation varies depending on the country context, the general drivers of the regulation are common across the European national regulatory authorities. The incentive schemes for DSOs are typically based on economic performance, and thus the conventional regulatory objectives guiding the DSO activities include cost efficiency, network quality and reliability, whilst allowing a defined level of profit for the network operator[39]. The increasing distributed generation sets a challenge for DSOs, particularly in terms of their ability to upgrade the grid infrastructure and to make best use of new technologies and innovative solutions, whilst ensuring quality of operation of the network. Future incentive schemes should thus better encourage the DSOs for development and integration of new innovative technologies. The considerations for new regulatory principles are on-going and include aspects encouraging to enhanced innovation delivering most efficient long-term outcomes for consumers[40]. Aspects such as smart solutions, such as smart grids and smart meters, better data and information flows, and coordination with TSOs are discussed. Another aspect considered important to guide

[36] Jager-Waldau et al. (2018) Self-Consumption of Electricity Produced from PV Systems in Apartment Buildings - Comparison of the Situation in Australia, Austria, Denmark, Germany, Greece, Italy, Spain, Switzerland and the USA. Conference: Presented at the 2018 IEEE 7th World Conference on Photovoltaic Energy Conversion (WCPEC), 10-15 June 2018, Waikoloa Village, Hawaii.
[37] IRENA (2019) Future role of distribution system operators: Innovation landscape brief.
[38] https://www.cleanenergywire.org/factsheets/citizens-participation-energiewende
[39] CEER (2017) Incentives Schemes for regulating DSOs, including for Innovation: Consultation Paper
[40] Ibid.

the future DSO regulation is access to and proper use of flexibility services allowing increasing volumes of renewable generation.

Need to redesign the grid tariffs. Electricity self-generation can decrease the amount of grid-distributed electricity and consequently the volumetric tariffs charged from the consumers for the total volume of electricity taken from the grid. The electricity self-generation does not however necessarily reduce grid development and management costs bared by DSOs[41]. In some cases, these costs can actually increase due to electricity self-generation due to the need for connection and use of the distribution grid or further network extension or increased automation. Consequently, the network tariffs should allocate distribution costs in a fair way among different type of grid users, considering electricity volume (€/kWh) and capacity (€/kW), but also their impact on the grid thus incentivising efficient grid usage[42]. Others argue that the grid costs need to be shared in an equitable and non-discriminatory way among grid users not favouring PV-owners over non-PV owners avoiding situations in which non-PV owners would have to deal with an increase in the tariffs, paying for part of the network costs that PV-owners would avoid through support schemes such as net metering[43]. The grid tariff design is thus a complex issue that need proper attention to avoid cross-subsidising, unfair treatment of consumers or providing wrong incentives for DSOs.

Coordination among the actors, policies and regulations. The design of policies for incentivising PV prosumption needs to be well coordinated with the regulation guiding the grid system in order to avoid misaligned or even conflicting effects. For example, even though net-metering may have positive effect on PV deployment, the overall impact on the system may not be only positive by leading to favouring PV-owners over non-PV owners, challenges of the operational limits of the network, curtailment, etc. Similarly, when designing incentive schemes for DSOs, a holistic approach, considering the implications to the whole power system is needed. Therefore, it is very important to further define the roles and responsibilities of DSOs and TSOs, but also consumers to allow optimal functioning of the system and fair distribution of the costs and benefits.

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[41] Eurelectric (2016) Network Tariffs. A EURELECTRIC position paper.
[42] Ibid. and E.DSO (2015) Adapting distribution network tariffs to a decentralised energy future. Available: https://www.edsoforsmartgrids.eu/adapting-distribution-network-tariffs-to-a-decentralised-energy-future/
[43] Mateo, C. et al. (2018) Impact of solar PV self-consumption policies on distribution networks and regulatory implications. Solar Energy, Vol 176, Dec, 2018, pp. 62-72.

3 KEY MESSAGES OF PVP4GRID SIMULATIONS FROM THE PERSPECTIVE OF THE GRID SYSTEM

One of the objectives of the PVP4Grid project is to provide quantitative analysis of the PV prosumption concepts, especially related to energy communities. Based on a standard method, a simulation of the different PV self-consumption and energy community concepts was carried-out in the eight PVP4Grid target countries. This chapter provides a brief overview of the findings. The full specifications of the method and explanation of the results is presented in the D3.2 Quantitative analyses of improved PVP4Grid concepts[44].

The chapter is structured to first summarise the prosumer concepts considered by the PVP4Grid project. Then the set-up and configurations for the simulations are briefly presented, followed by an overview of the main results and discussion of the main findings.

3.1 Summary of the PVP concepts

As stated in the PVP4Grid Deliverable 2.1, PV self-consumption can be defined as “the use of PV electricity aimed at reducing the purchase of electricity from other producers”[45]. One aim of the project PVP4Grid is to classify, improve and test new concepts for photovoltaic prosumers. The new concepts or business models include different ways how individuals or collectives can become PV prosumers. Accordingly, the PVP4Grid concepts entail both single direct use of the generated PV electricity on site, and different models of local collective use of PV (collective self-consumption and energy community), as well as different investments to technological components, namely distributed generation units (such as photovoltaic systems) and energy storage systems (e.g. batteries)[46]:

(1) Single use (Group 1): One consumer directly uses the generated PV electricity on site (both cases are conceivable in this context: (i) generator legally identical to consumer, (ii) generator legally not identical to consumer). The public grid is only used for the residual electricity consumption and possible feed-in of excess electricity. Self-consumption can be increased due to the implementation of energy storage systems, electrification of heat production (heat pumps, boilers), demand side management (DSM), etc.

[44] Fleischhacker, A., Radl, J., Revheim, F., Lettner, G., Schwabeneder, D. and Auer, H. (forthcoming) Quantitative analyses of improved pvp4grid concepts and report on testing. D3.2 Public Deliverable PVP4Grid project, Technische Universitaet Wien, Vienna, November 2019.
[45] https://www.pvp4grid.eu/wp-content/uploads/2018/12/D2.1_Existing-future-prosumer-concepts_PVP4G-1.pdf
[46] https://www.pvp4grid.eu/wp-content/uploads/2018/12/D3-1_improvement-of-PVP4Grid-concepts_final.pdf

(2) Local collective use of PV in one place (e.g. in one building) (Group 2): Several consumers share the generated PV electricity using the public or private grid (owned and/or operated by DSOs). The public grid is used for the residual electricity consumption and possible feed-in of excess electricity. Each consumer can increase the share of self-consumption by specific measures (storage, demand-side management, etc.).

(3) District power models (Group 3): Several consumers directly consume locally generated PV. The PV energy is shared using the public or private local grid on low voltage level. District storage devices can be used to increase the share of self-consumption, in addition to the individual measures.

3.2 Set-up of the simulations

The simulations assess the theoretical advantages of sharing energy produced by photovoltaic systems in two configurations:

- A single building with different apartments and a commercial area (Group 2) and
- European village: multiple houses including group 2 and commercial buildings (Group 3).

The Figure 7 below describes the differences of the Group 2 and Group 3 set-up.

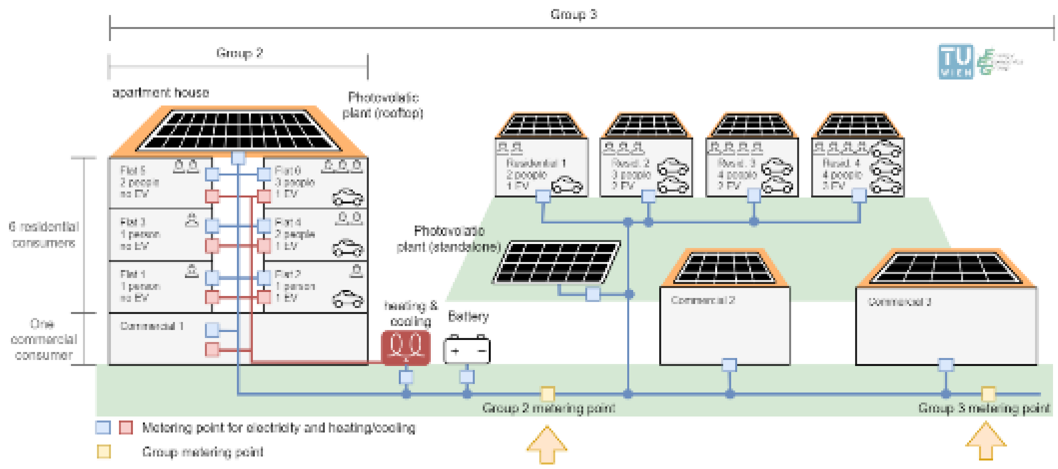

Figure 7: Set-up of Group 2 and Group 3

Apart from the two configurations, the simulations consider different community and demand scenarios. As described in the Table 5 below, the **community scenarios** include (1) *Grid consumption scenario* without PV and battery energy storage system (BESS), (2) *No community* scenario with PV and BESS but no option for energy sharing and (3) *Community scenario* with PV and BESS allowing energy sharing and group metering.

Table 5: Overview of the community scenarios

Community scenario	Metering point	Investment options	Energy sharing
Grid consumption	Individual metering (per household)	None	No
No community	Individual metering (per household)	PV and BESS	No
Community	Group metering	PV and BESS	Yes

The two **demand scenarios** reflect the effect of energy sector coupling in future as shown in the Table 6 below. The scenario with low electricity consumption is called *baseline scenario* considering a “normal” electricity consumption where fossil fuels are used for heating and hot water, whereas an individual cooling load is considered within the electricity consumption. The *future scenario* consists of all loads in the baseline scenario, but additional loads for heat pumps and electric vehicles (EV’s) are considered. Therefore, the electricity consumption of the *future scenario* is much higher.

Table 6: Overview of the demand scenarios

Demand scenario	Floor heat & hot water	Individual Transportation
Baseline	Fossil (not considered in the model)	Fossil (not considered in the model)
Future	Electric Heat-Pumps	Electric Vehicles

The simulation utilises the optimisation model HERO^{community} and applies the same setup for each target country but includes country specific data (e.g. retail prices, energy demand, PV full load hours). The full specifications of the simulation method, concepts, scenarios, and calculation of input data can be found in Chapters 2 and 3 of the D3.2 Quantitative analyses of improved PVP4Grid concepts.

3.3 Overview of the key results

3.3.1 Results for Group 2 – Building with multiple apartments

The simulation results for Group 2 i.e. for a building with multiple apartments show how the **total costs and revenues** change when comparing the baseline and future scenarios. The total costs include investment costs to cover PV and energy storage systems , grid procurement cost i.e. the costs of purchasing electricity from the grid and annual fixed cost including yearly maintenance costs for the invested technologies, and fixed costs related to grid consumption. In addition to the costs, the model takes into account revenues related to sale of excess electricity to market. The

Figure 8 below demonstrates the cost and revenue components in different community and demand scenarios for Germany.

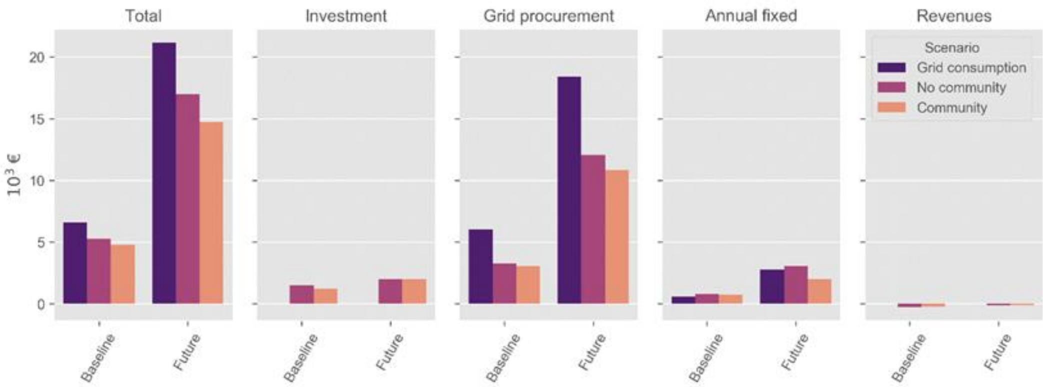

Figure 8: Composition of total costs for Germany (Group 2)

The cost and revenue composition in the figure above show a clear cost reduction between the scenario without PV and energy storage (Grid consumption) and the scenarios involving PV and storage (No community and Community) despite associated invesment related to the latter two scenarios. The grid procurement, considered as operational costs, is the largest cost component for all the community scenarios, and the cost savings are even clearer for the future demand scenarios.

The two following figures (Figure 9 and Figure 10) summarise the results in terms of total costs and change of costs for the baseline and the future demand scenarios. For the baseline scenarios the electricity demand differs between the countries due to country specific cooling demand resulting to different total cost levels. The total costs for the future scenarios include additional costs related to electric vehicles and heat pumps leading to higher levles of total costs for the future scenarios. The highest total costs in the baseline scenario can be found in Spain, whereas in the future scenario Germany shows the highers total costs. The full load hours of solar PV are higher in the southern PVP4Grid countries Italy, Spain, and Portugal (due to better solar radiation conditions), resulting to higher relative cost savings than in other countries. Germany has high savings due to the highest electricity prices (€/kWh), whereas in Austria and France the prices (€/kWh) are the lowest leading to low costs for grid consumption scenario as well as to lower incentives to invest into PV due to limited cost reduction potential.

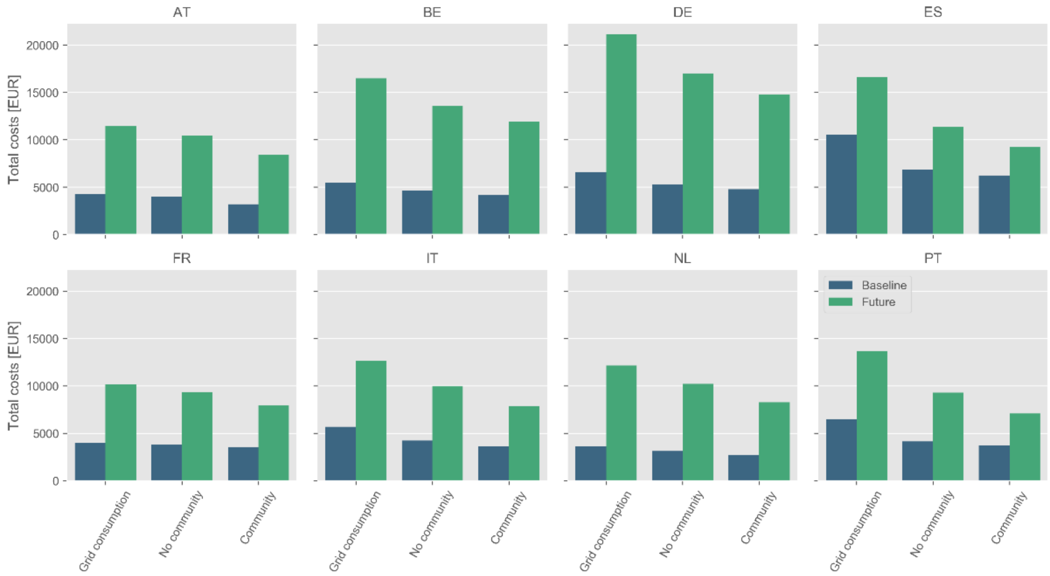

Figure 9: Total costs for all target countries (Group 2)

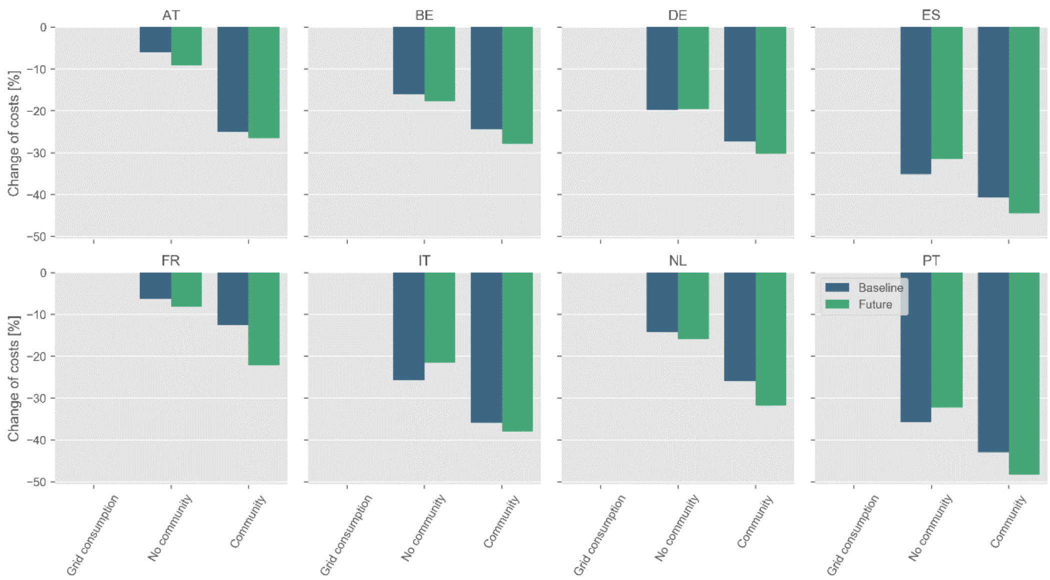

Figure 10: Change in relative total cost for all target countries (Group 2)

The following two figures show the results in respect to optimal investments in PV and energy storage. The results of the simulations suggest that in respect to PV the optimal investment level is the maximum available generation, having the limitation of available rooftop area (see Figure

11). The roof size limits the PV investments in all PVP4Grid countries except for Austria and France.

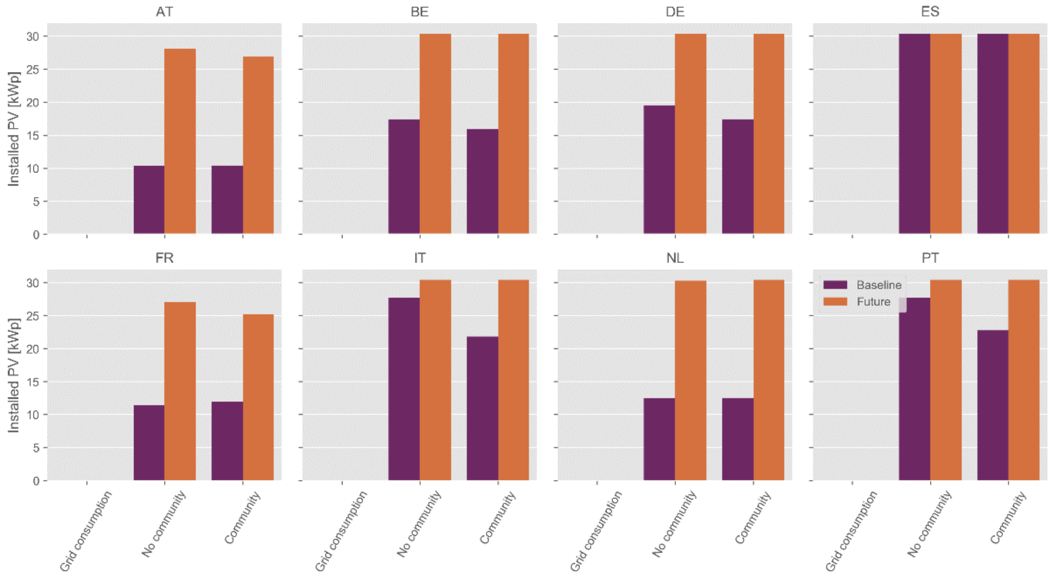

Figure 11: Investments into solar PV for all target countries (Group 2)

The investments in battery energy storage systems are limited by the currently high market prices. The investment in energy storage is economically beneficial only in Spain and Portugal as a result of high correlation between PV generation and cooling demand in these countries as shown in the Figure 12. The results show however that energy community model decreases the need for storages due to the option of selling excess electricity to other consumers instead of storing it.

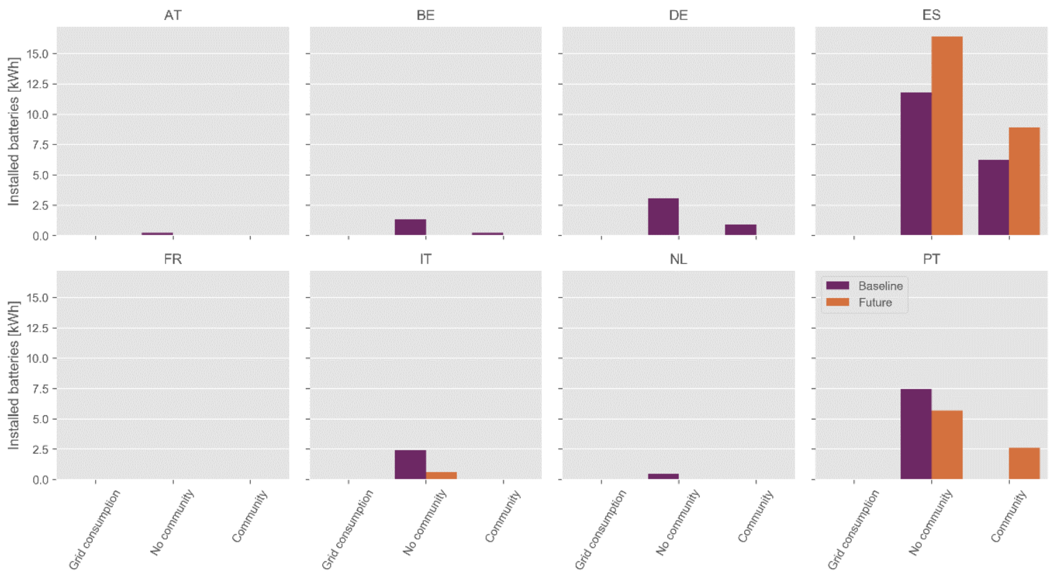

Figure 12: Investments into batteries for all target countries (Group 2)

3.3.2 Results of Group 3 – Energy Community

This section presents the results for Group 3 i.e. for energy community or so-called European Village. Basically, the results show similar tendencies as for the Group 2, with two main differences both related to economies of scale:

- The Energy Community involves a higher number of consumers, which leads to higher total energy demand but also to higher flexibility as well.
- Higher availability of local resources, which implies that the investments in PV are not only limited to the roof area.

The Figure 13 and Figure 14 below show the **total costs and revenues** as well as relative change of costs in all the PVP4Grid countries. Spain, Portugal and Italy show the highest cost reductions when comparing the scenarios between no PV (Grid consumption) and PV (No community and Community), followed by Germany due to high electricity prices (€/kWh). As seen in the Figure 11 below, in some countries e.g. Belgium, Germany and France the reduction of total costs between the No community and Community scenarios remains rather marginal suggesting that for the European Village, the community model does not bring large additional cost savings in these countries.

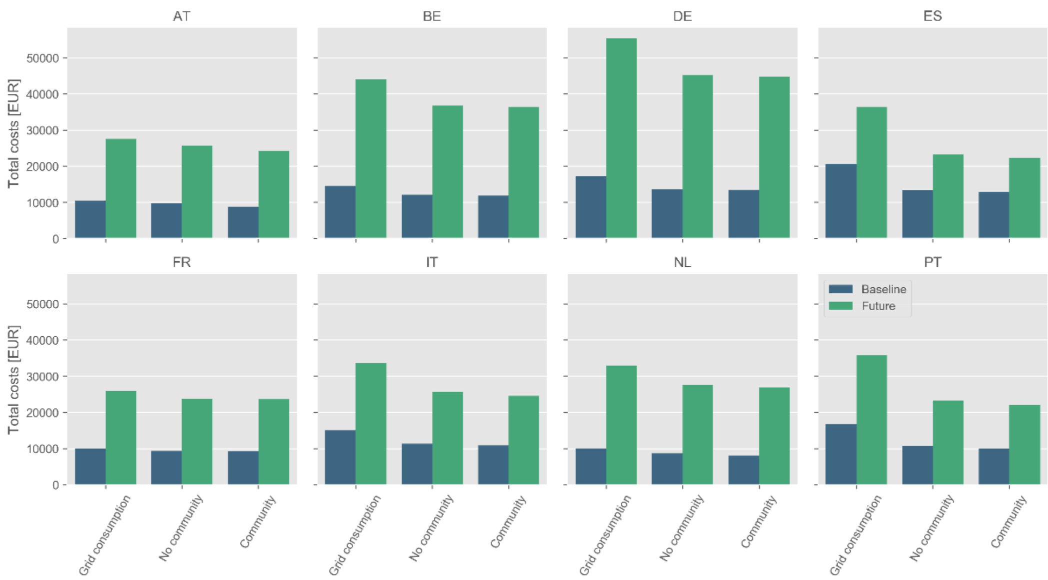

Figure 13: Total costs for all target countries (Group 3)

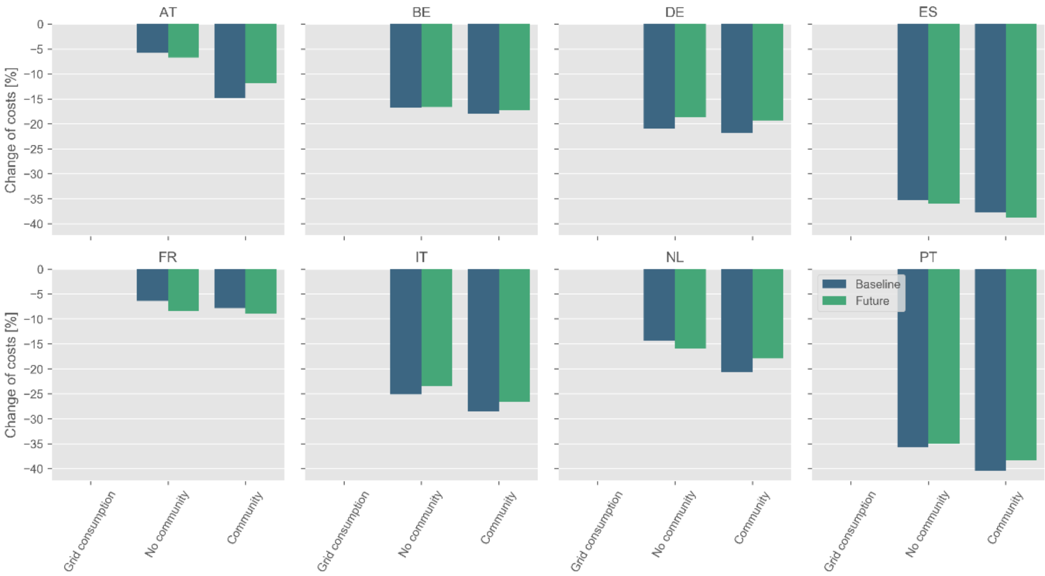

Figure 14: Change in relative total cost for all target countries (Group 3)

Compared to the Group 2, the Group 3 has the advantage that solar PV **investments** are not limited to the rooftop area of a single building but includes all the roof areas and greenfield, leading to higher investments in solar PV are more significant. The Figure 15 shows the importance of PV investments for the Future scenario i.e. more electrified system. When compared to the Baseline, the Future scenarios suggest much higher investments to PV.

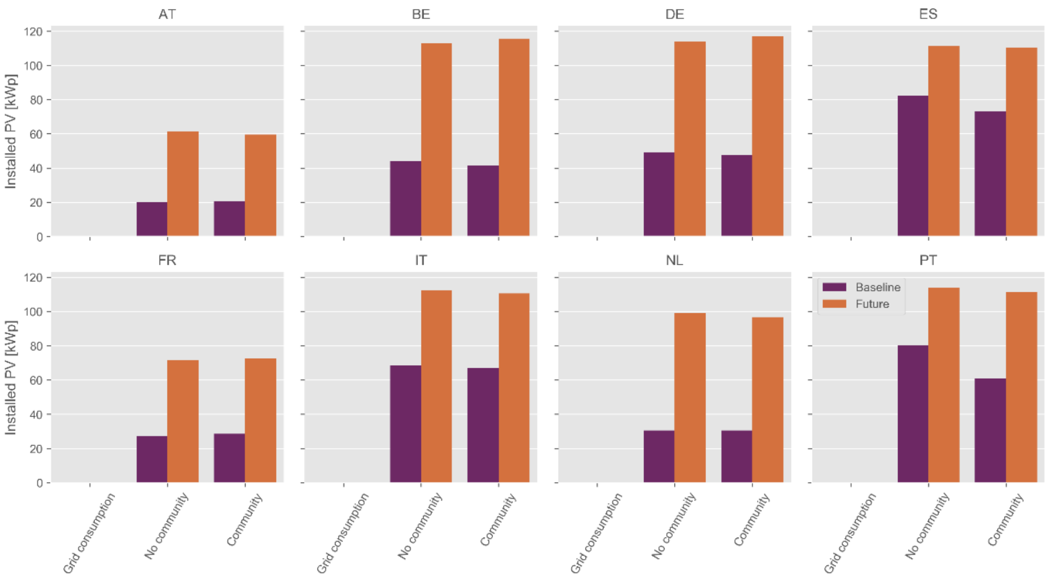

Figure 15: Investments into solar PV for all target countries (Group 3)

In respect to investments in energy storage, the Group 3 results show similar patterns as the results for Group 2, as shown in the Figure 16. Interestingly, there are countries where the investments to

PV and energy storage increase (e.g. Austria) or decrease (e.g., Portugal). This can be explained by:

- Again, by correlation of PV generation and demand. In the Southern European countries have a significant cooling demand at the same time when the PV generation is at highest (i.e. at noon). On the contrary, in other countries the demand is higher during the evening hours. This increases the value of energy storage because they allow arbitrage by "coupling" demand and generation.
- The energy storage can be economically beneficial when aiming to avoid high power prices. Nevertheless, there is no correlation between battery investments and countries with high power prices.

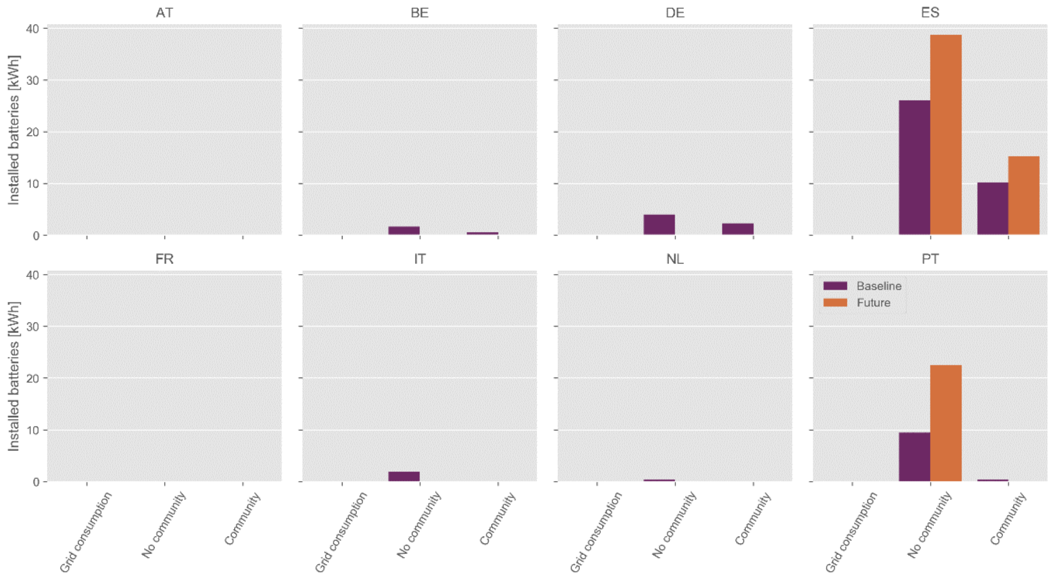

Figure 16: Investments into batteries for all target countries (Group 3)

3.3.3 Discussion of the findings

The aim of the simulations was to gain enhanced understanding on how certain factors may drive or hinder the uptake of energy communities in different PVP4Grid countries. The study focused on PV integration in buildings or establishing a renewable energy community, and economic benefits related to investments in PV and energy storage.

The PVP4Grid countries show a great variety in many of the aspects. From the results it can be seen that both the number of PV full load hours as well as grid tariff design can drive or hinder further PV integration. The high PV full load hours and/or high energy prices (on residential consumer level) supports the investments into PV, whereas low energy prices hinder the investments. The grid tariff design considers multiple objectives and "optimal tariff composition" is difficult to achieve. However, the grid tariff design in future should encourage to “grid friendly” behavior of energy consumers and prosumers.

The study also considered different positions for the metering points, i.e., household or community metering points. The power pricing allows the energy community to seek local balancing and reduction of power peaks of the community metering point. To encourage local balancing, community metering points could be an additional measure for the future grid tariff design.

The results also show how the energy communities increase the profitability of investments in PV and batteries. The energy community approach allows benefitting from economies of scale related to more efficient and flexible use of resources, more optimal investment decisions and reduced administrative costs. Energy communities may also provide access to renewable distributed generation for wider group e.g. residents of multi-apartment buildings. The energy communities should involve the stakeholders broadly i.e. apart from energy suppliers, investors, and consumers, also the DSO or other actors should get involved, especially in the process of launching of an energy community and the installation of technologies (e.g., the position of solar PV and batteries). In this way, the grid topology and characteristics can be considered already at the planning and implementation stage of the energy community.

4 KEY MESSAGES FROM THE PVP4GRID COUNTRY WORKSHOPS

This chapter looks at the main findings of the PVP4Grid workshops organised in each target country to collect stakeholder perceptions on the changing EU regulatory framework and results of the PVP4Grid simulations. The chapter presents first a summary of the workshop concept, targeted stakeholders and implementation in different countries. Then we present an overview of the findings followed by key messages per country.

4.1 PVP4Grid workshops

The country specific workshops were organised as part of activities of WP3, D3.4 National events. The workshops were targeted to disseminate the results of WP3 related to prosumer concepts (*D3.1. Report on improved PVP4Grid concepts for PV prosumers*) and results of the simulation and testing (*D3.2 quantitative analysis of improved PVP4Grid concepts*) to relevant national level stakeholders. In addition, the workshops had the aim to gather stakeholder perceptions on the impact of PVP concepts on the grid system (especially to DSOs) and their views of the new EU legislative framework.

The workshops were targeted to a maximum of 40 participants involving the key national stakeholders including regulatory bodies, government officials (focal points in charge of NECPs, renewable energy policies, finance ministries, etc.), DSOs, TSOs, grid operators, electricity commercialisation companies, energy communities and cooperatives, consumer associations, technical advisors, and renewable energy stakeholders. The selection and configuration of important stakeholders varied between the PVP4grid countries, depending on the country context.

The workshops followed the basic structure including:

- Presentation of the country specific results of Task 3.3 Simulation of improved PVP4Grid concepts
- Presentation of the new EU legislative framework and current stage of the national legislative framework
- Discussion and gathering stakeholder views on the main results and key messages from the perspective of the grid systems and grid stakeholders at country level

The expected impacts of the workshops were to achieve enhanced understanding of the country context and challenges related to PVP concepts from the perspective of grid system as well as involvement of most important stakeholders at national level (may vary from country to country). In addition to country workshops, two EU event was organised in Brussels.

The following Table 7 lists the workshops organised[47].

Table 7: PVP4Grid workshops targeted to grid actors.

Country	Place	Date
Spain	Madrid	19th September 2019
Italy	Milan	25th September 2019
Austria	Vienna	26th September 2019
Portugal	Lisbon	27th September 2019
Belgium	Brussels	10th October 2019
France	Lyon	17th October 2019
EU Workshop	Brussels	21st November 2019
Netherlands	Utrecht	19th December 2019
EU Workshop	Brussels	10th March 2020
Germany	Berlin	12th March 2020

4.2 Key findings of the workshops

In general, the workshops were highly appreciated by the stakeholder communities of different countries. It was considered that the workshops brought different stakeholders together to discuss important aspects of future developments requesting changes and close collaboration among the key actors. In some countries, it was even suggested that these types of events should be organised in regular basis to ensure continued dialogue.

Although the workshops followed a commonly agreed, standardised structure the discussions were strongly influenced by the country specific context. The PVP4Grid countries show a great variety in terms of:

- Legal and regulatory frameworks, and current status on-going changes/updates;
- Roles and responsibilities of key stakeholders;
- Level of application or maturity of energy self-consumption and energy community concepts.

[47] Based on PVP4Grid D3.4 Minutes of the national workshops.

The PVP4Grid simulation results were highly welcomed and positively received by the workshops audience. It was considered to be very useful to have country-specific quantitative evidence on the prosumption and its impacts on the grid.

In many countries the issues discussed at the workshops were not technical by nature but rather related to regulatory and administrative issues. In respect to technical challenges, the roll-out of smart-meters was mentioned in one workshop as an essential precondition to allow the operator to follow the electricity flows. In another workshop, the discussion concluded that when implementing the digitisation strategy, cost/benefit efficiency must be taken into account and alternatives must be considered. Grid development and increased grid flexibility were however recognised as important challenges to facilitate increasing distributed generation. In many PVP4Grid countries, there is a debate around the evolution of the grid tariff design. As also shown by the simulation results, it could have important impact on the prosumer business models. The traditional model of volumetric tariff with net metering will not be viable for covering the distribution network maintenance and investments costs in long-term perspective assuming the simultaneous trends of increasing renewable energy self-consumption and increasing electrification of transport and heating needed to welcome the huge amount of new RES capacity (mainly PV and wind) needed to accomplish with Green Deal targets of full decarbonisation by 2050. Although net-metering and net-billing schemes may have positive effect on PV deployment, the overall impact on the system may not be only positive e.g. favouring PV-owners over non-PV owners, challenges of the operational limits of the network, curtailment, etc. The workshops have discussed different challenges related to the future grid tariff design such as tariffs linked to the peak-power (power capacity), reduction on grid fees for shared energy (fees only for the part of network actually used), EU level harmonisation system charges costs, etc. Also, the role of new actors and new business models, e.g. energy communities or aggregators as well new role of existing actors have been discussed in many workshops. The following sub-chapters provide a summary of the key messages per country[48].

4.2.1 Austria

The Austrian workshop was organised in Vienna on 26th of September 2019. After the introduction to the project PVP4Grid, the main findings of deliverable D3.2 of the simulation and testing were presented. The purpose of the simulation part was, to show the differences in electricity demand of

[48] The text summarises the Chapter 3 of the D4.2 Country reports (in national languages) and includes the key findings of the national workshops organised in Austria, Belgium, France, Italy, the Netherlands, Portugal and Spain. The D4.2 Country reports followed a predefined common template and guidelines but at the same time allowed the report to be tailored for country-specific needs. This is the reason why the information is not following the same structure for each country.

a sector coupled system (EV charging, heating and cooling), the solar irradiance (PV full-load hours) and grid tariff design of the 8 target countries. The outcome was, that the optimal PV investments (kWp per consumer or community) for southern countries and northern countries are often similar, due to the high solar irradiance in some southern countries (e.g. Portugal and Spain) and the higher energy prices in terms of €/kWh in some northern countries (e.g. Germany, Belgium and the Netherlands). In Austria the optimal PV investments (kWp) are lower compared to other countries, since electric energy (in terms of €/kWh) on lowest grid level (Netzebene 7) is very cheap. In many cases it is still profitable to invest into PV but less profitable when comparing it to other countries. Renewable energy communities can decrease costs even further, depending on the price for exchanging electricity, mainly the energy-component (€/kWh). The testing section showed some real use-cases in Austria where the optimal PV investments were calculated or the optimal renewable energy community was discussed, including their benefits.

By beginning of 2018 a law[49] came into effect to create a legal framework for the community use of PV systems called “Gemeinschaftliche Erzeugungsanlagen”. It is possible by a legal entity to create and/or operate a PV system which is used by a community as long the public grid is not used for power exchange. Grid fees for energy flows from the PV system to the community do not apply. This law encourages community PV systems which makes some PV systems more profitable than before, due to the community use which can increase the self-consumption. Sharing energy when using the public grid is not profitable (by 2019), since all grid fees and taxes apply. Depending on the reduction on grid fees for shared energy (e.g. on district level), larger energy communities could be profitable and could increase the share of PV in the system.

Nevertheless, an ongoing issue is the high protected property law, where one single owner of a community property (e.g. an apartment building) can hinder the majority decision to install a PV system on the community roof. A recommendation to encourage the installation of PV systems on community properties is to adapt the law to neglect such objections in case of (profitable) PV installations. A further step would be to allow PV systems if only one entity is in favour of a PV system, as long it doesn’t cause monetary disadvantages to the community which can be achieved by contracting systems.

On regional levels there are discussions on mandatory PV systems for new buildings. This is to be supported but a law on federal level would unify efforts to achieve renewable energy targets.

Power pricing for low energy consumers (e.g. most residential consumers) is already decreed in a regulation but not yet applied. It is expected to be applied after the full rollout of smart meters. Consumers with a community-shared PV system should only be charged the (real) applied

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[49] Electricity Industry and Organization Act (ElWOG, § 16a), 2017

maximum power (production minus consumption per time interval) in order to benefit from using shifting potentials for the effective use of PV. If this wouldn't be changed, the community has no monetary reason to shift flexibilities and reduce peak powers during PV self-consumption. Through the discussion, this aspect was noted by a member of a DSO-workgroup and was discussed within the next DSO-workgroup meeting. There, they agreed on using not the measured power of the smart meter for power pricing but changing it to the residual power based on the procured power minus the used power from the community PV system in Austrian community-tariffs.

4.2.2 Belgium

The Belgian DSOs deal with PV prosumers since more than 10 years reaching today one of the highest penetration rate in the world : more than 10% of the households have PV, which is quite unique in Europe.The development of energy communities is a new chance for the DSOs to do a step forward into the energy transition, but it comes with challenges and benefits. These main elements highlighted during the national workshop organised in October 2019:

The 3 Regions of Belgium are evolving at different speed in terms of legislation around energy communities. Since end 2018, Wallonia has a legislation and is working on application decrees. The other two regions only allow pilot projects until now.

The **legislative framework** should be simple and evolutive. Simple because creating the energy community, bringing people together is already a difficult challenge. The extra layer of administrative aspects should be reduced to its minimum in order to facilitate their development.

Evolutive because it must consider the main factors that influence the financial feasibility of such projects: the electricity tariffs. The actual discussions about the tariff structures must be considered. As the two legislations are evolving in parallel, there is a high risk of developing a support for EC that could lose all logic if the tariff structure changes.

In respect to **technical issues**, the roll-out of smart-meters is an essential precondition to allow the operator to follow the energy flows inside the EC.

For **financial aspects**, the workshop concluded that the financial attractiveness of ECs needs to be guaranteed. Different ways to achieve it:

- Incentive per kWh self-consumed.
- Reduction of the grid fee. This has also a physical sense since the use of the net is limited if electricity is used inside the EC.

SIBELGA for instance is analysing 3 tariffs reductions linked to the area of the EC:

- Tarif A: In the same building: maximal reduction of grid fee. No transport fee.
- Tarif B: under the MT-BT transformation post: smaller reduction of grid fee, No transport fee
- Tarif C: under the HT-MT transformation post: only =o transport fee

Next to these advantages, an extra charge for DSOs related to the management of these ECs (management of participants, split key, etc.) could be taken into account. Two ways to do it:

- Included an extra charge into the grid cost per kWh for the electricity self-consumed inside the EC and extra annual fixed fee for EC participants or for the EC community.

4.2.3 France

A workshop was organised on October 17th, 2019 in Lyon by Hespul and Becquerel Institute, to present the results of the PVP4Grid study and to collect comments and suggestions from the stakeholders who took part in the discussion.

The main outcomes of the workshop are summarised in the following lines, grouped by topic.

- **Comments on the PVP4Grid Simulations:** In general, the results were highly appreciated because it put numbers on collective self-consumption (CSC) and its impacts on the Grid. The actual French legislation on CSC was one of the first developed in Europe. France decided to design it before doing some experimental test case. The main consequence of this is that the 16 existing projects have some real difficulties with the legislation and have been created mainly with extra local support.

- **Electricity prices inside the REC**: One of the main blocking elements is that the electricity shared inside the energy community at the exact same level of tariff than the electricity coming from outside. It makes the economic viability of collective self-consumption operation very tricky. A specific tariff (TURPE specifique) is foreseen in the law and can be activated to have a lower grid tariff for this electricity but it is linked to a higher tariff for the remaining electricity. None of the existing collective self-conception operations have used this specific tariff.

- **Power tariff vs Energy costs:** In France as in many European countries, there is a debate around the evolution of the tariffs, and it could impact all the business models around self-consumption. In a long-term perspective, with a 100% renewables energy mix, and if the grid must still be financed by the electricity bill, it needs to be mainly financed by tariffs linked to the peak-power. A 100 % power tariff is nevertheless not the best solution because it could induce energy spilling. The solution must be in a mix between these two aspects but with a greater part linked to the peak power.

- **Impact on the Grid:** For now, the tariffs for CSC aren't linked at all to the peak-power. In consequence, as the sensitivity analysis of the simulations shows it, there is no reduction of the peak-power with (collective) self-consumption operations. The regulator uses this argument to justify the full tariff on electricity exchanged inside the REC. RTE, the local TSO, in its vision paper, affirms that the main impact of collective self-consumption operations is linked to the smaller distance between production and consumption. A High self-consumption ratio doesn't change anything in terms of grid dimensioning. It only has impacts on the financial aspects They also inform that distributed PV (on buildings) has a much lower impact than centralised PV (ground-mounted power plants) in terms of costs for the adaptation of the grid (70% less).

- **Batteries:** During the workshop, there was a debate around the individual batteries. Different participants see it as wrong path. Main arguments:
  - If it is not well designed in a law/tariff, individual batteries will have no positive impact on the grid. It will not reduce the peak power (see example in Germany).
  - RTE, the French TSO also sees almost no positive impacts of individual batteries in its vision paper.
  - Hespul thinks the regulator (CRE) has an ideological position too much market oriented instead of being general interest oriented. The use of collective batteries could be more interesting for the grid and managed by the DSO, or another body instead of multiplying single batteries.

- **New laws, recent changes:** The Area of collective self-consumption operation has been changed. There will be two situations:
  - Normal: at the building level. It is in line with the new European directive.
  - Extended: 2 km of diameter, on low voltage grid, for 5 years.

  The extended area raises a lot of questions. What will happen after the 5 years? How do you measure the distance: from meter to meter? The choice of a diameter will allow a REC with participants that aren't on the same low voltage network and so invalidate the argument pushing for a lower grid tariff for self-consumed electricity inside the REC because it could reduce the use of Medium and High voltage transformation cabins and grid.

  Finally, the new law will allow social landlords to manage energy communities and benefit recipients will be included in the REC by default. It opens a big potential for social REC.

4.2.4 Germany

The workshop took place at the 12th March 2020. The key messages include:

- Grid-compatible and grid-serving behaviour, especially of prosumer plants, is possible and must be encouraged. A suitable regulatory framework must be developed. The present concept of peak smoothing is a first approach but needs to be further developed.
- Energy management systems play an important role in making the flexibilities of prosumers usable.
- With regard to the data acquisition and processing associated with the control of prosumers, the various regulations associated with the Basic Data Protection Regulation must be observed, including the Federal Data Protection Act (BDSG), the BSI-Kritis Regulation (BSI-KritisV), the Product Liability Act (ProdHaftG) and the Criminal Code (StGB).
- The direct intervention of the network operators in complex prosumer plants is only possible with a high effort. Well-known and proven alternative measures are, in particular, time pricing in the event of grid bottlenecks for certain consumer groups or for all small consumers (e.g. variable tariffs).
- When assessing the grid effects of electromobility, the generation side and the interplay between generation and consumption, i.e. flexibilisation, must be taken into account to a greater extent than is currently the case.
- Local or regional flexibility markets are also possible in the low-voltage sector and have already been tested in SINTEG projects.
- When implementing the digitisation strategy, cost/benefit efficiency must be taken into account and alternatives must be considered.
- With regard to the control of generators and loads, the functionality of the control box (relay circuit) of the smart meter gateway is not sufficient to control prosumer plants in a grid-compatible manner.
- From the point of view of many network operators, the networks are ready for roll-out
- Network condition monitoring is necessary through functional expansion of existing IT systems and the addition of measurement technology and its connection via secure communication channels

4.2.5 Italy

A workshop, in the form of a private round table, was organised on September 25th, 2019 in Milan by Ambiente Italia, in collaboration with the national photovoltaic association Italia Solare, to present the results of the PVP4Grid study and to collect comments and suggestions from the 11 key market stakeholders who took part in the discussion.

The main outcomes of the workshop are summarised in the following lines, grouped by topic.

Comments and remarks to the PVP4Grid study

- Studies of this kind are crucial for interacting with policy makers in order to base their decisions on scientific bases.
- It would be interesting and necessary to add some sensitivity analyses, for example regarding the inclusion in economic calculations of general system charges and other tariff components, also taking into account their possible future reduction due to the reduction of incentives in the ‘Conto Energia’ scheme, and therefore their impact on the bill, from 2025.
- Again, with regard to sensitivity analyses, it would be useful to assess the impact of eliminating the ‘scambio sul posto’ scheme, a mechanism that is likely to be cancelled within a few years.
- Although it is correct to focus the results on the energy produced (kWh), this could be incomplete because, when we think about tariffs for grid costs, we must also consider the reduction of the costs borne by the community, as the profile of withdrawal of the network is reduced thanks to the contribution of photovoltaic production.
- It is not certain that, as instead assumed in the study, the increase in electricity costs due to the increase in demand in a future scenario of high electrification really takes place since a political priority, shared by all the players involved, is that energy costs for end users do not increase.
- Actually, it is not correct to say that the increase in self-consumption reduces revenues for DSOs because they are, in essence, clearing houses. If, therefore, the total amount for the management of the system is spent, this cost is still covered in full.
- The increase in self-consumption does not constitute any 'danger' to the electricity grid.

Proposals for the future regulation in Italy

- **General aspects**
  - The transposition of the new European legislation is an opportunity not to be missed to revisit the national legislation by focusing on the end user and his right to self-consumption.
  - First of all, it is important to understand which elements of the regulations of other European countries that have anticipated the legislation on collective self-consumption and on energy communities can be borrowed and transferred to Italy.

- The new legislation must be able to create a system that works at full capacity and not on the basis of spot investments.
- The energy transition confronts us with a revolution and, therefore, a new infrastructure of the system will also be required.
- The support and openness to new configurations of self-consumption from renewable energy sources must be accompanied by a clear and firm disincentive to the use of fossil fuels, obviously motivated by the 'hidden' costs that they generate for society.
- It is important to keep separate, on the one hand, the regulation that must always be neutral and aims only at the adequacy of the system and, on the other hand, any incentive mechanisms of individual technologies or solutions.
- The new rules must give great flexibility to the operators and, therefore, the energy communities will derive from them as the most efficient choice, as the natural result of these rules.
- The transposition of the new European legislation at national level could be based on four key elements: 1) Who is the final electricity customer we want in the future? This may lead to a change in the current rules. The smaller this brick is, the more it can be combined with others. If, on the other hand, the initial brick was too large, there would be a risk of losing the elements underneath it. 2) What is the nature of the network to which this subject is connected? This may also include a possible revision of the concession regime. When and where does it make sense to set up private networks? The current definition of CDS (Closed Distribution System) is important because it usefully contextualises private networks. 3) Regulation must remove inefficiencies while remaining technologically neutral so that everyone can participate in the system, including ancillary services. Self-consumption, in fact, is a technical aspect independent of the source of generation. As it reduces network losses, network tariffs must be increasingly cost-reflective, as must dispatching. 4) Incentives must be as explicit as possible to be able to capture externalities and efficiency.

* **Public and private grids**
  - The main direction will probably not be towards private networks because they almost always entail higher costs than public networks and also because local ancillary services will become increasingly important and, therefore, it is crucial that the providers of these services are connected to the central system in order to optimise the management of energy flows.
  - Practical experience shows that, where there are clear economies of scale, the natural monopoly in network management is more efficient.

    - On-site self-consumption has no correlation with whether the network at stake is public or private.
- **Grid tariffs**
    - The economic and financial viability of energy communities cannot and should not be based on the exemption of grid and system charges because, being more efficient than other solutions, it does not need that at all.
    - It could be useful for Europe to lead and steer the regulation and management of system charges costs, leading to some sort of harmonisation.
    - The 'counter-interest' parties in the exemption of charges for self-consumption are the other customers, i.e. those who cannot afford, or simply do not want to choose, certain solutions.
    - The fixed cost, which today is based on the power, could in the future be moved to the peak demand of a whole multi-family house (condominium).
- **Collective self-consumption and energy communities**
    - The new regulation will have to distinguish between two very different elements, namely collective self-consumption, for example in a condominium, and the more complex configuration of the energy community.
    - The obstacles encountered so far by pioneering developers of energy communities have never been of a technical nature but, rather, related to regulatory and bureaucratic aspects. It is therefore essential that the new legislation removes these barriers.
    - The fact that the energy community stimulates an active role of consumers and also increases their awareness of energy issues must be enhanced.
    - The new rules must not create a de facto monopoly of large utilities in the management of energy communities.
    - At the same time, the new legislation should seek to change the governance of condominiums by facilitating certain aspects that are still too cumbersome, such as, for example, the way in which expenditure is shared between the inhabitants.
    - It will be necessary to stimulate, facilitate and incentivise the demand-response mechanisms, which substantially help the efficiency and, therefore, the economic convenience of an energy community.
    - It is necessary to avoid that energy communities exercise a sort of 'cannibalism' with respect to the law of the individual self-consumers.
    - An attitude that is still quite widespread among utilities is that of not seeing self-consumption at the condominium level with a good eye.
    - There is no doubt that DSOs will have to be able to provide new services to final consumers and this could also represent an opportunity for these subjects. An example

of these new services is the measurement of energy consumption provided by DSOs to users in photovoltaic systems serving apartment buildings in Austria in collective self-consumption configurations.

4.2.6 The Netherlands

The national workshop "The impact of PV prosumer concepts on the electricity grid" (in Dutch "de impact van PV prosumenten concepten op het elektriciteitsnet") with national DSOs and other relevant stakeholders took place on Thursday 19 December 2019, in Utrecht, at the offices of the association Holland Solar at Arthur van Schendelstraat 550 in Utrecht.

The purpose of the workshop was to

- Gather technical input from national stakeholders for the project report on the implications of PVP concepts on grid systems (D4.2, this report)
- Enhance understanding of the country context and challenges related to PVP concepts from the perspective of grid system
- Involve of most important stakeholders at national level

In total nine persons representing all relevant stakeholders in the Netherlands (DSOs, associations on solar and on renewable energy, energy consultants, funding bodies) attended the workshop (see Deliverable 3.3).

The PVP concepts have been presented as well as the new legislation of the EU energy union. In addition, a case study on prosumers in Amsterdam was presented. Finally, a SWOT analysis was carried-out.

Th attendees commended on the work done regarding the PVP concepts and the timeliness of the results in relation to the new EU legislations regarding prosumer involvement. In their opinion, this will assist national policymakers in formulating new, more prosumer directed, legislation needed to realise the greenhouse gas emission reductions nationally and Europe-wide. The attendees agreed that PVP concepts were not at the forefront of attention of policy makers in the Netherlands, as at the moment other sectors have higher potential in greenhouse gas reductions, which is central in the national Climate Agreement, and as the Netherlands is short on reaching the national targets in greenhouse gas reductions that have been agreed between Member States of the EU. In the national Climate and Energy Exploration (nationale Klimaat en Energie Verkenning) 2030/2050 flexibility is not even mentioned. This is a great shortcoming. Perhaps this may have to do with the PBL (Netherlands Environmental Assessment Agency) models not having high enough spatial resolution to account for local energy management and flexibility.

It seems that in the Netherlands the built environment is not really treated seriously in relation to the potential greenhouse gas emission reduction, as the industrial and agricultural sectors emit considerably more greenhouse gases. The lobby to the government in the interest of prosumers is mostly missing, but lobby efforts may be intensified as net metering will be abolished at the end of the decade. The national consumer association (Consumentenbond) and the Homeowners Association (Vereniging Eigen Huis) should be more active in this, as well as social housing organisations. Perhaps it should be made clearer that if prosumerism is not recognised as potentially assisting grid stability, customers will be paying more for the electricity they consume due to higher networking cost.

Nevertheless, in the national Climate Agreement district heating, energy savings and electrification of the built environment are measures identified to be needed to realise greenhouse gas emission in the built environment. In the EU Clean Energy package, the role of consumers is mentioned though, and the Dutch government should take that much more seriously.

Abolishment of net metering will start from 2023 with a gradual, linear decrease to a zero-settlement price in 2031. This start coincides with the moment that large-scale smart meter roll-out is expected to have been realised. Abolishment of net metering is expected to negatively influence the residential PV market, while it may also lead to increased self-consumption as batteries will become cheaper in that period. We do note, however, that in many Dutch pilots with PV/storage it is found that the battery storage is full even before the PV peak that occurs at noon.

Proper energy management is required. Many pilot projects on energy management in local grids, including PV/EV/V2G are being performed, however lessons learnt could be shared in a better way. Also, integral approaches are needed. Research and innovation funding will be modified for that. A difficult situation will be the ‘dunkelflaute’ days/weeks in winter, without wind and solar energy, while heat (pump) demand will be high.

A steady increase in the number of energy communities in the Netherlands is observed, due to the postal rose policy scheme, experiments with peer2peer trading, and in the framework of the so-called experimental arrangement (experimenteerregeling) that allows bypassing regulations in testing out new ideas/technologies. This societal movement has been growing and in new legislation even local ownership or participation will be required of about 50%.

PVP concepts can provide flexibility to the local grid to address congestion, which DSOs need to be able to handle, but probably only to a limited extent. One of the solutions could be peer2peer trading between prosumers. Physically this is possible on the same cable/transformer (any surplus at the moment will be injected in the grid anyway and is settled based on the net metering policy in force), but it is economically not interesting due to double taxation: exporting surplus energy requires that one pays energy tax, and someone else importing will also need to pay energy tax. Grid fees also apply, but that is making sense, as one uses the grid.

However, peer2peer trading will not help in addressing congestion, and perhaps it may lead to local increased power fluxes that go beyond cable capacity. Proper management is required, but it is unclear who will do that. DSOs are involved as grid manager, but legally DSOs presently are not allowed legally to act as peer2peer facilitator. An aggregator may need to step in for this, and/or legislation need to be adapted for that.

Presently, most DSOs plan new or extensions of distribution grids based on the needed capacity on a winter day, not taking EVs and heat pumps into account (yet). In the future, flexibility is deemed to be necessary, but this will require energy management at the LV level. It is yet unclear how that will happen. Flexibility will help DSO in managing congestion, while peer2peer trading does not necessarily alleviate congestion. Other, perhaps more visionary DSOs may already take future developments into account in new grid design.

It was also mentioned that perhaps flexibility may not be the solution, while the built environment must contribute to flexibility (services) in some way. On a local level, the potential of flexibility may not be large, but on a higher system level (HV grid) it certainly is.

The effects or prosumption on costs/revenues for the DSO are not clear. Neither on state level, however, if the tax regime is changed, the state will see a decrease in tax-based incomes. Question is to find the optimum for the whole society, which requires a societal cost/benefit analysis. Increased self-consumption, be it individual or within a community, would lead to lower demand, thus helping to prevent congestion. DSOs are supportive of this, but it is not their core business.

The discussions in the workshop resulted in the following SWOT analysis:

Strengths: • Local generation leads to potential lower demand and peaks at medium voltage grids (and to a lower extent at the low voltage grid • Lower costs for prosumer and DSO • Influence of electricity consumer on cost is enlarged	Weaknesses: • Not urgent • Not visible • Impact is low (short term) • Not on radar of policy makers
Opportunities: • New businesses for SME, regarding flexibility services • Peer-to-peer trading (smart)	Threats: • Grid extension/reinforcement • Peer-to-peer trading (smart) • Available personnel (human capital agenda)

4.2.7 Portugal

The Portuguese workshop took place on the 27th September 2019. The main objective of the workshop was to share the last results of the project, aiming at discussing the challenges which

Portugal will face in the near future, with the introduction of the new self-consumption legal framework, namely in terms of collective prosumers and energy communities.

Important Portuguese stakeholders related to PV and self-consumption were present, namely policy makers (DGEG), regulators (ERSE), DSOs (EDPD), sector associations (APESF and APREN); researchers (LNEG and INESCTEC) installer companies (Gildemeister) and energy traders (Elergone).

A general and very interactive discussion between the several stakeholders followed the introductory presentations. Some of the main topics of this discussion are summarised in the following lines:

- The situation of PV Prosumers, until now had DL 153/2014 has the legal framework, and though actually the market reacted well to the new concept of prosumers and an electronic portal was created to deal with the self-consumption process, only individual prosumers were considered and the whole process was considered very bureaucratised.
- Related to the new legal framework that was, by the time of the workshop, still not published, the stakeholders showed some of the expectations on this new legal framework namely, the introduction of collective prosumers and of energy communities, the need for some concept clarifications, the need for creation of the aggregator entity, the need for technical guidelines that have already been produced but are not yet officially published, the need for installers qualification, and the need for a simple and efficient electronic portal.
- The DSO mentioned the production of general guidelines on the independent production of electricity.
- The association of renewable enterprises mentioned that having in mind the important targets for renewables and namely solar in the new National Energy and Climate Programme for 2030 (around 9 GW for Solar) it is important to know the share of centralised and decentralised installations and to have a good grid planification.
- However, grid planification probably will be more important if the share of centralised is bigger. Decentralised production will not call for great grid modifications.
- The market must have clear information on the tariffs.
- According to the new legal framework energy communities will start to appear during 2020 and there is the need to regulate, not only the pure electrical issues, but also the way to collect data and how it will be the flow of information between these communities and also the role of the aggregators.
- It is expected a great impact in the grid of the new decentralised production and voltage control will have to increase namely through the storage system.

- The grid operators have an important role in controlling and supervising the safety of the grid.
- Technology development will have also an important role in this topic namely in terms of new transformers and smart inverters will also have an important role in this issue.

There was a very good discussion on the expectations that each participant/representative had related to the new coming self-consumption legislation.

As a global evaluation the workshop was very profitable, and the discussion generated by the participants was very open and cooperative.

4.2.8 Spain

As part of PVP4Grid project, a national workshop was organised on September 19th, 2019 with a total attendance of 50 professionals from the sector. During the session, there was an introduction of the Spanish grid system, self-consumption and its legal framework and the functioning of the electric market.

The general perspective of the workshop highlighted the positive impact of the new legislative documents by the Spanish government, considered as a turning point for the development of distributed generation in the national territory. However, the assistants also commented the lack of all the needed mechanisms for the complete development of self-consumption such as communication protocols and national registers of self-consumption. In addition, the number of administrative stages and permissions was criticised for being too long, dull and complicated. Some companies working in distribution named various difficulties found in the new system, with the introduction of new distributed resources and the apparition of bidirectional fluxes as well as new agents such as the electric vehicle and batteries. The same companies presented in the workshop some pilot projects of which objectives were improving the grid's operation and the digitalisation of the same one with virtual assistants, intelligent electricity meters and optical fiber. Other covered topics were collective self-consumption without excess and the management of it and the electric market and the doubts about its functioning, prices' volatility and curtailment management.

Finally, it was remarked the importance of the management of the demand as a key component of the energy transaction as well as for the achievement of the energy efficiency objectives proposed in the PNIEC, as well as the importance of the grid system as the key element for the development of distributed generation.

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