evolvDSO

Development of methodologies and tools for new and evolving DSO roles for efficient DRES integration in distribution networks

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Deliverable 1.1

Definition of a Limited but Representative Number of Future Scenarios

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Executive Summary

The objective of deliverable 1.1 is the definition of a limited, but representative set of future scenarios for the evolution of distribution systems in the majority of countries represented by the evolvDSO consortium: Belgium, France, Germany, Ireland, Italy, Portugal and the UK.

The scenarios describe the potential evolution of the electricity system and consider the generation mix, the evolution of demand and the available degrees of technological freedom[1], and thus, the scenarios delineate the possible requirements that may be placed upon future energy systems. Regulatory and market aspects will not be included in the scenarios since they follow the needs defined in this deliverable.

Each country participating in the evolvDSO project defines three scenarios to bracket the uncertainty of future developments. The upper and lower limits are related to an "over-expected" and an "under-expected" scenario. Three time horizons (short-term, mid-term and long-term) encode the chronological development of the scenario parameters.

The analysis and comparison of the current status of the energy systems reveals the differences between the analysed countries, especially concerning the generation mix present in their distribution systems. The share of distributed renewable energy sources (DRES) is particularly significant. In *Germany* and *Portugal*, the share of energy generated from DRES connected to distribution systems is above 20% of the total electrical energy consumption in those countries. In *Ireland*, *Belgium* and *Italy*, this share falls in the range of 10-20%, while in the *UK* and *France*, it is 10% or lower. It should be noted that one main reason for the different DRES shares is related to not only the penetration of renewable energies on the distribution network, but also different understandings and definitions for distribution systems. That is, depending on the country, different maximum nominal voltage levels are considered part of the distribution network. For example, German distribution networks encompass voltages up to 110kV, while in Italy and France the highest voltage at distribution level is 20kV[2]. Another focus of the analysis of the status quo is the role of the distribution networks with regard to generation capacity. The share of generation capacity connected to the distribution systems in *France, UK, Ireland* and *Italy* is low, while this share is higher in *Germany, Belgium* and *Portugal*.

The scenarios show that the share of DRES will increase significantly in all participating countries. *Portugal* and *Germany*, already having a high penetration of DRES, envision a low to medium annual growth rate, while in the *UK, Ireland*, *France* and *Italy*, where there is currently a low to medium share of DRES, the annual growth rate is expected to be significantly higher. Predictions of future distribution-connected generation is therefore subject to a certain degree of uncertainty, which is analysed for each country.

[1] Technological degrees of freedom comprise the use of innovative new and existing assets or technologies of the distribution system. These technologies are grouped in families and include Demand Side Management, storage, electrical vehicles, controllability of DRES and other innovative technologies.
[2] Some residual portions of the Italian distribution network have higher voltages (30kV, 50kV)

The development of demand does not vary widely in the majority of the participating countries. In *France* and *Germany*, a stagnation of load is expected, while in *Belgium*, a slight reduction of load is forecast. Only in *Portugal* is an increase of load anticipated in all scenarios.

In the future, it is expected that the technological developments will offer greater freedom in managing and operating the distribution system. While electrical storage systems in distribution networks are expected to play a minor role, it is predicted that an enhanced controllability of generation will bring novel opportunities in distribution system management.

The scenarios and their analysis lay the groundwork for further work in the evolvDSO project and for the necessary tools to be developed.

Table of Contents

List of Figures

List of Tables

List of Abbreviations and Acronyms

CHP	Combined Heat and Power
DRES	Distributed Renewable Energy Source(s)
DSI	Demand Side Integration
DSM	Demand Side Management
DSO	Distribution System Operator
DSR	Demand Side Response
EV	Electric Vehicle
FCI	Fault Current Indicator
FDIR	Fault Detection Isolation and Restoration
HV	High Voltage
IED	Intelligent Electronic Device
LV	Low Voltage
MV	Medium Voltage
OLTC	On-Load Tap-Changer
PV	Photovoltaic
RES	Renewable Energy Source(s)
SCADA	Supervisory Control and Data Acquisition
TSO	Transmission System Operator
WP	Work Package

Table 1: List of Abbreviations and Acronyms

1 Introduction

The growing quantities of distributed renewable energy sources (DRES) connected to distribution systems, alongside the development of responsive demand, have created the need for an evolution in the way that distribution systems are managed and operated. Addressing these developments in the most efficient way is the principle motivation behind the evolvDSO project.

Task 1.1 defines a limited, but representative, number of plausible future scenarios. These future scenarios encompass differing levels of DRES integration in local power systems as well as varying degrees of technological freedom envisaged per country. The deliverable begins with the definition of the scenarios, their key parameters as well as a definition of the technical and regional scope for consideration. Furthermore, this report elaborates on the methods used with regards to the categorisation of the participating countries, the assessment of their current status as well as the evolutionary paths described in the different scenarios.

1.1 Objectives

The objective of task 1.1 is the definition of a limited but representative set of future scenarios for the evolution of the distribution system in the participating countries, with a view to applying the results more widely. The scenarios cover the evolution of the electricity systems, demand, generation as well as degrees of technological freedom, and thus seek to delineate the evolution of the requirements that may be placed on our distribution systems. The regulatory framework and political factors are covered explicitly in deliverables 1.2 and 1.3 and do not fall within the scope of this document.

Parameters are necessary to describe a future scenario. These parameters describe the evolution of the electrical system and can be divided into direct and indirect factors. The first objective is thus to identify the relevant parameters. Each of the scenarios represents a combination of different parameter values. To ensure the robustness and applicability of the scenarios for different situations in Europe, the scenarios cover a range of different levels of ambition of DSOs with respect to hosting capacity of DRES.

Further to a definition of the future representative scenarios to understand the evolution of the electricity system, the objective of this deliverable is to compare the major drivers of distribution system evolution by analysing the current situation against the forecasted evolution of DRES.

The defined scenarios will be applied in task 1.2 to identify the limitations and possibilities of the current market architectures and regulatory frameworks. Furthermore, they serve as an input to the data set configuration in task 2.3 and for the development of tools and methods in WP 3.

2 Methodological Approach

This section presents the methodological approach applied to reach the objectives of task 1.1. First of all, the scope of countries considered is defined in section 2.1. Section 2.2 gives an insight into the definition and parameters of the scenarios. Section 2.3 introduces the survey used to gather the data for each participating country to be used in the determination of scenario parameters. Section 2.4 explains the methods used to cluster and categorise the participating countries in terms of their status quo and their future distribution network development.

2.1 Scope of Consideration

The electricity systems in the consortium member countries are the focus of consideration. It is considered that each scenario will be linked to real grid data and that each participating entity has the best insight into the future development of the distribution system in their specific country.

Figure 1 shows the countries for which the status quo and the scenario set will be obtained. Therefore the electricity systems of Belgium, Italy, Germany, Portugal, France, Ireland and the UK are covered in this document.

Figure 1: Scope of consideration for scenario sets

The main focus of the evolvDSO project is in the future evolution of distribution systems. The scenarios cover technical aspects of the distribution system. Therefore, the scenarios cover only parameters related to this in detail, while the rest of the electricity transportation system (like transmission networks) are only covered when necessary and in less detail.

It should be noted that the scenarios defined in task 1.1 only cover parameters of the electricity system and do not undertake an analysis of regulatory frameworks and political incentives, as these are explicitly considered in tasks 1.2 and 1.3. The results of the study will be used to develop and support proposals to change the regulatory framework in various EU Member States.

Finally, it should be noted that the data used in this analysis is at each country's aggregate system level. Therefore, the results are averaged across the countries and are not detailed at regional level per country. Having a more local view of the integration of DRES (e.g. at substation level) will be particularly important for task 2.3. Therefore, the data sets to be defined in task 2.3 are anticipated to require data allowing a more local view of the distribution systems.

2.2 Definition of Scenarios

This chapter gives an overview of how scenarios are defined. A scenario can be defined as follows.

- A **scenario** describes one possible development of certain quantities into the future or the size of certain quantities at a given point in time

Each scenario is developed according to a set of parameters, which vary with time. Since the development of quantities over time is uncertain, the definition of a scenario funnel helps to describe the uncertainties.

- A **scenario funnel** delineates the boundary of extreme scenarios, so that each scenario lies within the scenario funnel

The above definitions can be clarified by means of Figure 2, where a scenario funnel including one specific scenario is shown. When considering the system today every parameter/quantity of interest is known. Looking deeper into the future, reveals an uncertainty of those parameters/quantities as they have to be predicted. Hence, there could be a possible increase or decrease of a certain parameter from today. Points more remote in time entail greater forecast uncertainty, and so potential deviations are larger. The boundary of the uncertainty is then defined as the funnel. One possible scenario, as shown in Figure 2, lies within the funnel. It describes one possible and certain evolution path for the system, where the quantities are known. In order to cover the uncertainty of the scenario funnel a certain set of possible scenarios is necessary.

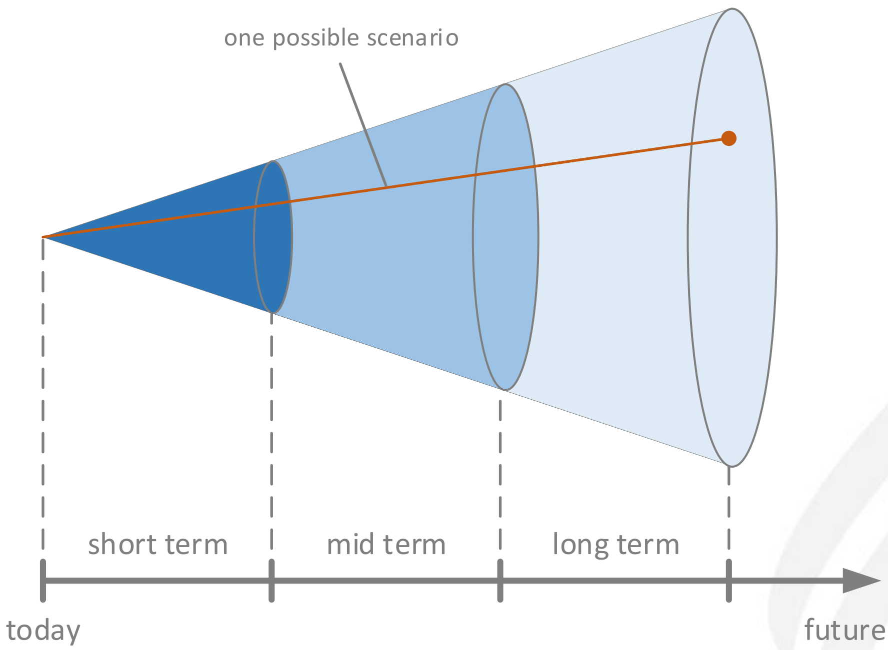

Figure 2: Scenario funnel and time horizons

In order to gain insight into the development of distribution systems at different points in time, **time horizons** are defined. For the scenarios defined in evolvDSO, three time horizons will be considered:

- ***short-term***: 1 to 4 years
  The short-term time horizon is close to the status quo with respect to the requirements on the energy system. The tools and methods to be developed through the evolvDSO project will not yet be widely available.

- ***mid-term***: 8 to 10 years
  In a mid-term time horizon, the needs on the energy systems will have increased, but by then, the tools and methods developed by evolvDSO should be available to aid DSOs.

- ***long-term***: 20 years
  The long-term time horizon comes with the highest level of uncertainty but also the greatest challenges on the system. Considering the degrees of technological freedom, further tools and methods developed in evolvDSO could be used in the management of distribution systems.

The different time horizons are also depicted in Figure 2. In order to deal with the issue of uncertainty, a limited number of scenarios is defined. This makes categorisation necessary, which is described in the following section.

2.2.1 Categorisation

The main variable used to define the scenarios is the development of DRES in distribution systems. Three different levels of new DRES to be connected to distribution networks will be covered in the scenarios:

- ***Under expected*** – DRES evolution is slower than expected
- ***Most likely*** – Best guess of future DRES development
- ***Over expected*** – DRES evolution is faster than expected

The "***most likely***" scenario describes the most realistic development of DRES penetration, as expected by the participating partners. This means that this scenario has the highest probability of becoming reality in the future.

As the future is highly uncertain, it is important to analyse deviations from this most likely development. Hence the "***over expected***" scenario was developed. This scenario covers the most extreme case of DRES penetration and therefore lies on the upper boundary of the scenario funnel.

The "***under expected***" scenario covers the lowest possible development of DRES penetration. This scenario lies on the lower boundary of the scenario funnel.

The scenarios need to be scanned at each time horizon and each value of the set of parameters needs to be determined. The following section derives the necessary parameters, which need to be covered by a scenario.

2.2.2 Parameters

All relevant parameters of a scenario have to be identified in order to describe a future scenario.
Figure 3 shows the way to derive the relevant parameter categories.

There are several high level (indirect) factors on the left hand side of Figure 3 which should be considered. These include EU targets (such as the climate and energy targets to 2020), expected customer acceptance and the future economic situation. These factors cannot be quantified in terms of direct influence on the electricity system, so their influence on direct factors is instead assessed. These direct factors are, for example, needs, investments, costs and technological progress.

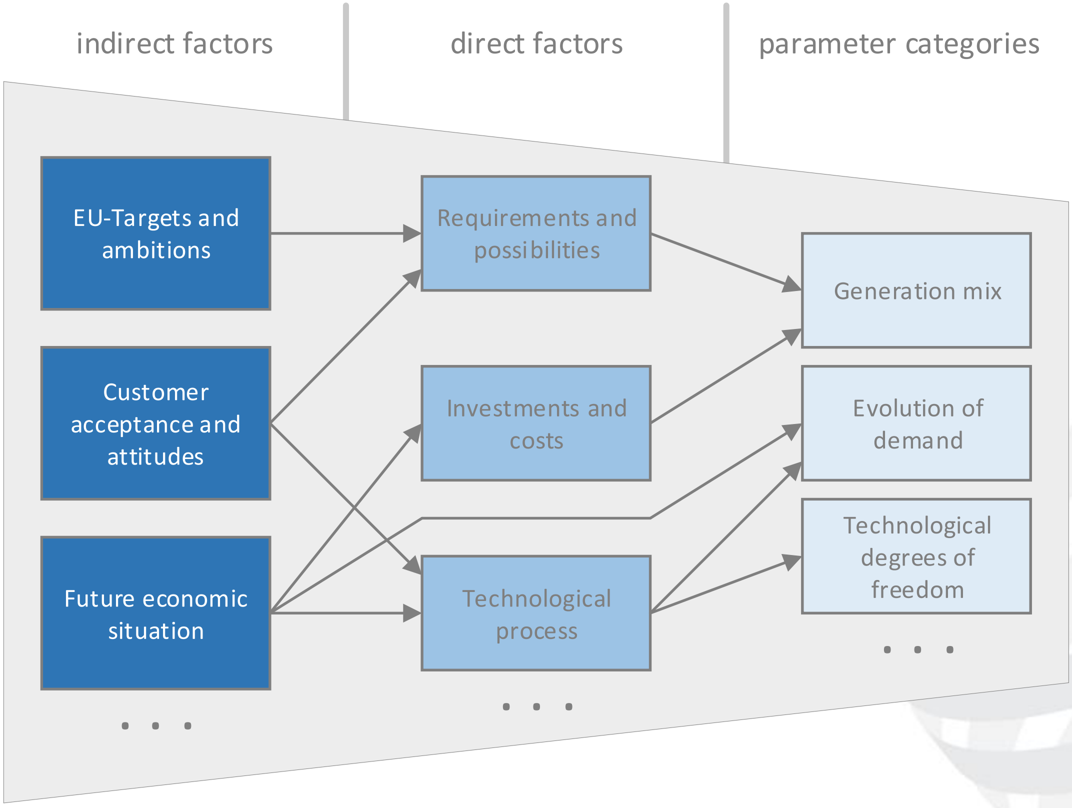

Figure 3: Scenario parameter definition

Based on the approach of indirect and direct factors, three final parameter categories describing the future scenarios were identified:

- ***Generation mix***
- ***Evolution of demand***
- ***Technological degrees of freedom***

For each of the parameter categories listed above, a list of sub-parameters have been defined. The evaluation of the parameters has been conducted separately for each voltage level (low-voltage, medium-voltage and high voltage) in the distribution network. Ultra-high voltage networks are not covered as this is not the focus of the project.

The category "**Generation mix**" consists of sub-parameters for installed generation capacity, subdivided by generation technology and the full load hours for each generation technology (and thus the annual energy production). Furthermore, the installed capacities for each generation technology are subdivided by the different voltage levels (*low-voltage*, *medium-voltage*, *high-voltage*) in distribution grids.

The category "**Evolution of demand**" contains sub-parameters subdivided into demand-categories: *residential*, *commercial*, *industrial* and *agricultural*. These parameters include peak load, annual energy consumption and the number of customers for each group. Again, the parameters are subdivided by the different voltage levels.

The category "**Technological degrees of freedom"** comprises the use of innovative new and existing assets or technologies of the distribution system. These technologies are grouped in families and include demand side management, storage, electrical vehicles, controllability of DRES and other innovative technologies.

The description above can be further described in tabular form:

- **Generation mix**
  - Installed capacity
    - subdivided by technology: lignite, hard coal, gas, oil, wind, PV, combined heat and power (CHP), run-of-river, pumped, biomass, geothermal, other renewables, other fossil fuels
    - subdivided by voltage level
  - Average power rating
  - Full load hours
- **Evolution of demand**
    - Subdivided into groups: residential, commercial, industrial, agricultural;
    - subdivided by voltage level
  - Peak load
  - Annual energy consumption
  - Numbers of customers
- **Technological degrees of freedom (only for the "most likely" scenario)**
  - DSM potential
    - Amount that can be shifted
    - Range in time during which the demand can be shifted
  - Storage amount (MW / MW h)
    - Total connected electrical storage
    - Typical size of one storage unit
  - Network utilities
    - i.e. active voltage conditioner, on-load tap-changer for transformers
  - Electric vehicles (E-Mobility)
    - Total capacity of connected electric vehicles (MW)
    - Simultaneity factor
    - Subdivision by fast charging / slow charging with typical power ratings
  - Controllability of DRES
    - Percentage of DRES that can be controlled

As the controllability of DRES has been identified as an important aspect of the future development of distribution systems, a uniform definition of controllability has to be applied to allow a comparison between the distribution systems in the participating countries.
Within this document, controllability of DRES refers to the ability to directly control / manage a DRES generation unit under predefined and agreed conditions by a third party different from the owner of the unit[3]. Controllability implies that the third party (in this case often the DSO) is able to remotely control the active and reactive power output of the unit, or even disconnect it.

To expand further on questions that require numerical input, text-based questions were also included to more comprehensively cover potential new degrees of technological freedom, e.g.: *"Do you foresee any kind of innovative offer for demand response?"* or *"Which are other innovative technologies in your network? Describe their work scheme and indicate their relevance. (E.g. on-load tap-changer for distribution transformers)"*.

Values for the named parameters were asked for each scenario and each time horizon so that the range of the evolution of the future requirements on distribution systems, as shown in Figure 4, can be considered.

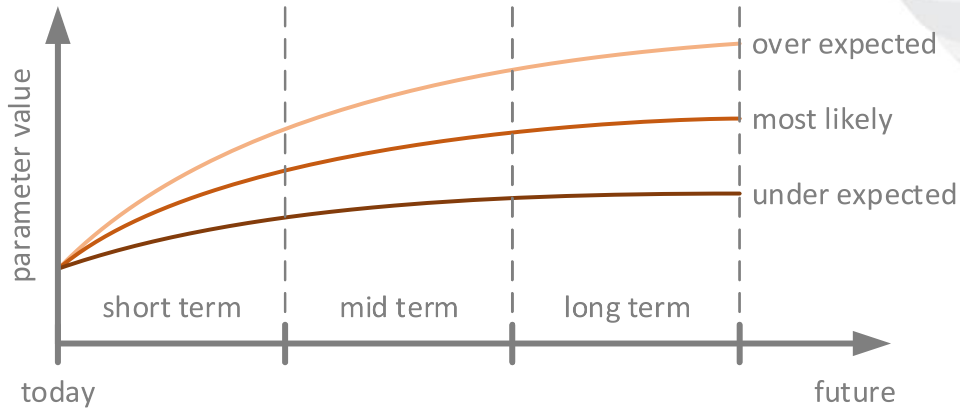

Figure 4: Notional parameter value in different scenarios

[3] In D1.2 the discussion is mainly focused on controllability of DRES by a DSO as third party and when the regulatory framework allows the control of the DRES output (e.g. only in case of emergency)

2.3 Data Enquiry (Survey)

To gather all required data for the parameters and scenarios defined in section 2.2, a survey was created and sent out to the participating members of this task. The responsible consortium partners taking part in the survey are shown in Table 1.

Partner	Country
VITO	Belgium
RSE	Italy
ENEL Distribuzione	Italy
RWTH	Germany
RWE	Germany
EDP Distribuição	Portugal
INESC Porto	Portugal
ESB	Ireland
UCD	Ireland, UK
RTE	France
ERDF	France

Table 1: Responsible partners for survey filling

The template for this survey was discussed among the participants and has been adjusted to capture all information with the required and available details. All data collected in the surveys only concerns the distribution networks, therefore, generation units or demand directly connected to the transmission system are not considered in the survey.

Each participant has provided background information about the sources used to complete the survey. This includes the sources providing information on the status quo as well as for the forecasts made. For the status quo a delineation of voltage levels within the distribution system for the specific country was necessary. For prediction of the future development the information on the methods (e.g. historic extrapolation) and assumptions used to generate the scenarios were also provided by the participants.

In terms of the status quo of generation and demand, all information regarding the defined parameters was gathered for the year 2012 and predicted for the defined time horizons (short-term, mid-term, long-term). In the case of future predictions, information also had to be completed for these defined scenarios based on the evolution of DRES (under expected, most likely, over expected).

The following sections present the results obtained from the completed surveys. Section 3 presents the results regarding the status quo. Section 4 covers future developments. The data is at first presented separately for each country in order to get a country specific insight. As a second step, the country specific data is compared, where data is comparable. This comparison includes the clustering of similar countries with respect to their current situation as well as to their anticipated development path. The method used for clustering and categorisation is presented in section 2.4.

2.4 Analysis and Clustering

To identify similarities between the participating countries and to describe the current state of the electricity system and the potential evolution of the distribution networks, comparisons were made between key characteristics and parameters. These parameters were used to cluster countries that have similar values for these parameters in their scenario set. This allows the definition of certain scenarios that are valid across a group of countries.

For the status quo, the annual generation of DRES and the annual electricity consumption in the distribution networks allow for the categorisation of the different countries. Furthermore, the ratio of these values allows for the clustering of countries with respect to the installed share of DRES in the distribution network.

To identify countries with similar evolutionary pathways, it is advantageous to compare the ratio of the annual DRES generation and the annual electricity consumption (as used for the status quo) with the expected annual increasing rate of DRES in the distribution network. This allows for clustering based on the current situation in combination with the expected evolution path of DRES, which has been identified as the main driver of this project.

A further analysis was carried out by comparing the installed capacities of DRES in each country for the status quo and the three time-horizons defined for the scenarios. To allow for a better comparability between smaller and bigger countries, the values can be normalised with the peak-power or the total annual energy consumption.

To create a link to developments expected for the whole electricity system (transmission and distribution network) some survey results are compared to values given by ENTSO-E in the *"Yearly Statistics and Adequacy Retrospect 2012"* and the "*Scenario Outlook and Adequacy Forecast 2013-2030 (SOAF)*", where the expected and actual values of the whole electricity system are provided by the transmission system operators. This is aimed at showing similarities and/or differences between the expected evolutions of the whole electrical system with respect to the evolutions in just the distribution system.

3 Current Status of Distribution Systems

This section presents the status quo of DRES integrated into the electricity systems of the participating countries. All data presented in this section is related to the surveys filled out by the responsible project members.

The data collected only refers to distribution systems and does not include transmission systems. Therefore, generation units and demand directly connected to the transmission level will not be considered.

In the first part of this section, the gathered information regarding the current status of distribution systems in the participating countries will be presented in detail for each country separately. In the next step, the relevant parameters will be compared between the participating countries.

The current status is presented in terms of the abovementioned parameter categories used to describe a scenario. These are ***Generation Mix***, ***Demand***, and **Degrees of technological freedom**.

As the nominal voltages associated with the terms low-voltage, medium-voltage and high-voltage differ between the participating countries, the voltage-levels for each country are also defined in this section.

To allow comparison of the values gathered from the specific distribution systems with the values associated with the full electricity system (covering a country), data has been used from the "*Yearly Statistics & Adequacy Retrospect 2012*"[4] produced by ENTSO-E.

[4] https://www.entsoe.eu/publications/statistics/yearly-statistics-adequacy-retrospect/

3.1 Belgium

The Belgian distribution system covers all voltage levels up to 70 kV. Voltage levels above 70 kV are considered to belong to the transmission system.

Generation Mix

Figure 5 shows the installed generation capacity in Belgium[5] for the year 2012 based on ENTSO-E data[6]. The total installed generation capacity connected to the distribution system of 14,3 GW represents 68,8% of the total installed capacity in Belgium of 20,8 GW.

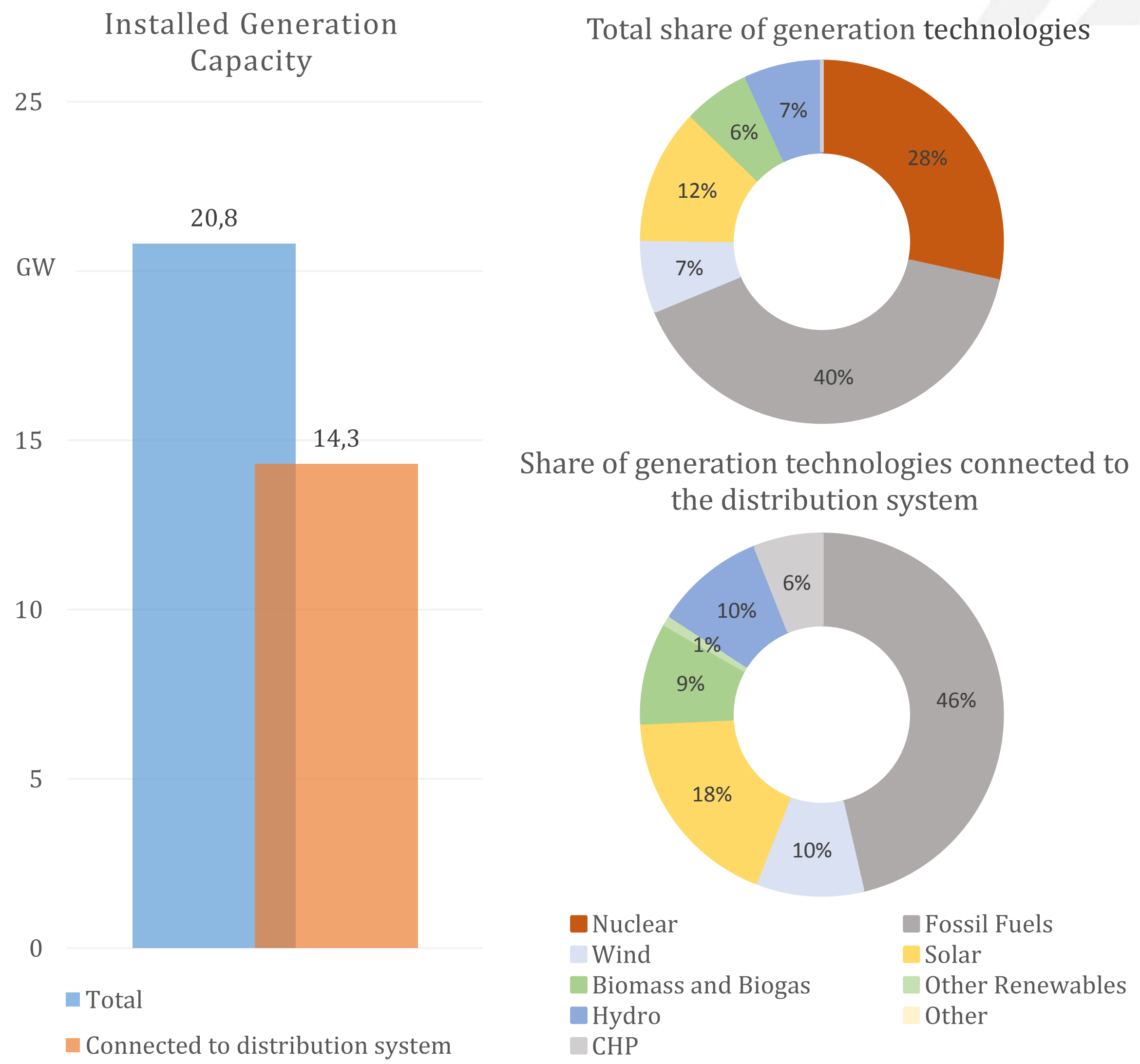

Figure 5: Installed generation capacity in Belgium

[5] The status quo of Belgium is mainly determined by information of the TSO Elia and the Flemish regulator VREG.
[6] https://www.entsoe.eu/publications/statistics/yearly-statistics-adequacy-retrospect/

The main share of generation capacity connected to the system is from nuclear installations, which are solely connected to the transmission system. The share of the overall installed generation capacity from nuclear is 28% in Belgium.

The 6,6 GW of generation from fossil fuel installations connected directly to the distribution system represents the highest share of total generation connected at distribution level and is solely connected at the high-voltage level.

The PV generation units in Belgium are mainly connected to the medium-voltage and low-voltage levels. Biomass generation units are connected to both the high-voltage level (438 MW) and the medium-voltage level and low-voltage level (855 MW). PV generation units represent a share of 18% of generation and are the dominant DRES in the Belgian distribution system in terms of generation capacity. In 2012, wind (1,38 GW) and hydro (1,4 GW) generation units each accounted for 10% of the installed generation capacity, while biomass (1,3 GW) accounted for 9% of the installed capacity at distribution level.

The aggregated share of DRES (including PV, Wind, Biomass, Other Renewables and Hydro) in the distribution system of 47,6% prevails the share of DRES in the total system of 31,2%.

Demand

Based on ENTSO-E data, the annual total electricity demand of Belgium for 2012 was 84,8 TWh with an instantaneous peak load of 14,2 GW. On distribution system level, detailed data was only available for the region of Flanders that covers with 49,8 TWh about 59% of the total load. Figure 6 shows the share of demand connected to the distribution system in the region Flanders according to the four categories residential, commercial, industrial and agricultural.

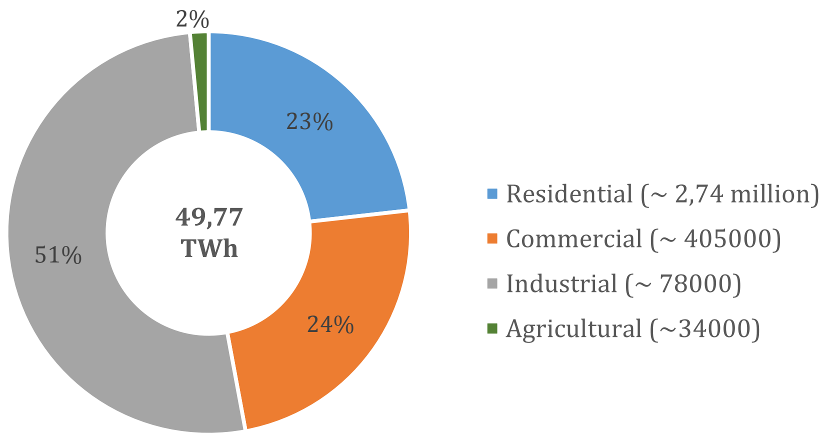

Figure 6: Share of Demand in the Belgian Distribution System (Only Flanders)

The highest number of customers belong to the residential category (ca. 2,74 million), although they cover only 23% of the annual energy demand. Another 24% of the annual demand belongs to commercial loads. The highest share of the demand (51%) results from industrial loads (~77800) connected to the distribution system.

Degrees of technological freedom

In terms of ***demand side management*** the responsible partners for Belgium identified a ***shift potential*** for peak-load in the low-voltage level of 29% of the households and a shift potential of 1,7% for industrial loads connected to the high-voltage level. The timeframe in which the demand can be shifted varies for the industrial loads between 15min and 8h, depending on individual contracts. Furthermore, the number of activations is limited to a maximum of two to four per year.

Innovative offers for demand response exist in the form of aggregators acting within pilot projects and focusing on industrial consumers. Other aggregators are expected to come into play, focusing on tertiary services buildings. Furthermore, aggregators active in other countries are looking to enter the Belgian market.

The Belgian TSO[7] is inviting tenders for reserves contracts with demand side resources, so far R1 and R3 reserves[8] can be contracted in this way. The contracted parties receive a payment for availability and a payment for energy in case of activation. At the moment, only customers with automatic control equipment and offering a minimum of 5 MW over the contract period are eligible.

The only ***type of storage*** identified in the distribution system is pumped hydro storage with a total capacity of 1 GW connected at the high-voltage level.

As ***other innovative technologies*** used in the distribution system today, the monitoring of the transformer (oil) temperature, the deployment of static synchronous compensators and projects using smart meters have been identified.

[7] Belgium TSO: Elia
[8] R1 load frequency control, R3 dynamic profile by aggregation or aggregated power plants for free bids as balancing reserves

3.2 Germany

In the German distribution system, the low-voltage level has a nominal voltage of 0,4 kV. The nominal voltages for the medium-voltage levels are 10 kV in residential and 20 kV in rural areas. The high-voltage level belonging to the distribution system has a nominal voltage of 110 kV.

Generation Mix

The total installed generation capacity connected to the distribution system of 98,7 GW represents 57,5% of the total installed capacity in Germany[9]. Figure 7 shows the installed generation capacity in Germany for the year 2012.

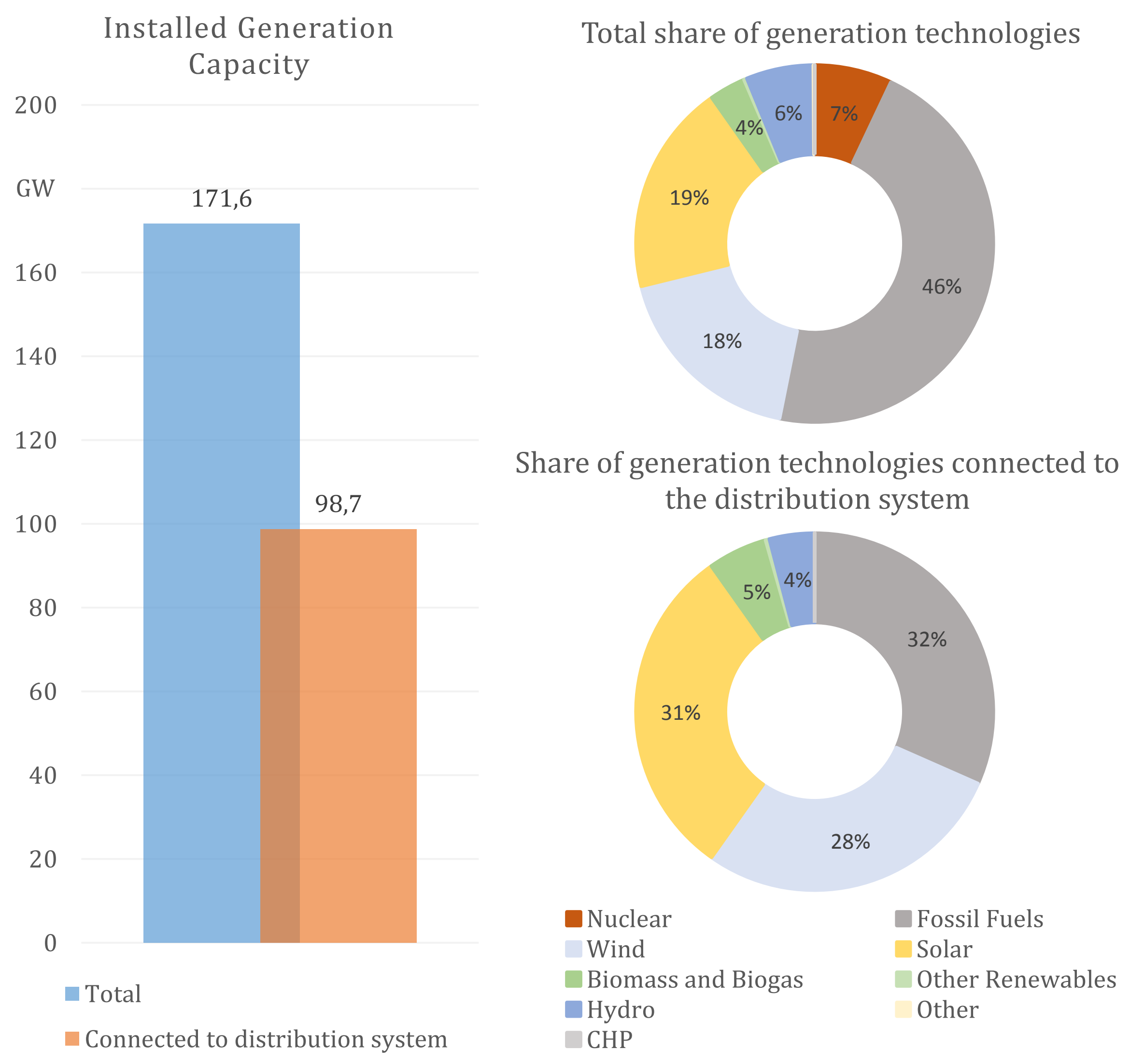

Figure 7: Installed generation capacity in Germany

[9] The status quo is based on the information provided by the German regulator (Bundesnetzagentur) and the register for renewable power plants (EEG Anlagenregister).

The main difference between the distribution and transmission system is that fossil fuel and nuclear generation units are directly connected to the transmission level. Furthermore, a subset of hydro generation units, mainly pumped hydro, are connected directly at transmission level.

In terms of capacity connected to the distribution system, fossil fuel generation capacity with a share of 32%, PV generation with a share of 31% and wind generation with a share of 28% are the dominant generation technologies.

The majority of fossil fuel generation technologies are connected to the high-voltage level. Only gas generation units show a relevant installed capacity of 3,8 GW in the medium-voltage level.

In contrast, the solar generation units are mainly connected to the lower voltage levels: 69% of the PV capacity (20,7 GW) is installed in the low-voltage level, 26,3% (7,9 GW) is installed in the medium-voltage level and 4,7% (1,41 GW) is connected to the high-voltage level.

The wind generation at distribution level is mainly connected to the medium- and high-voltage level. 46,9% of wind generation capacity is connected at high-voltage level and 52,6% is connected at medium-voltage level.

Hydro generation units account for 4% of the generation capacity connected to the distribution system. They are divided with respect to "run-of-river" connected to medium-voltage (2,4 GW) and high-voltage (1,3 GW) level and "reservoir" (0,3 GW) mainly connected at the high-voltage level[10].

Biomass (5,3 GW) accounts for 5% of the generation capacity and is mainly connected to the medium-voltage level. A share of 77,6% is connected to medium-voltage, while smaller shares are connected to the low-voltage level (10,7%) and the high-voltage level (11,8%).

The overall share of DRES capacity in the German distribution system of 68% exceeds the share of 47% of DRES in the total system.

Demand

Based on data from ENTSO-E[11], the annual electricity demand in Germany is 559,3 TWh and the instantaneous peak load is 81,9 GW. The energy consumption at distribution level was 460,2 TWh accounting for 82% of the total demand[12]. From this portion, 126 TWh (27,4%) belong to residential customers, while 334,2 TWh (72,6%) belong to industrial and commercial customers.

Degrees of technological freedom

In terms of ***controllability,*** PV units with a capacity over 30 kW have to provide the technical ability to allow the DSO to read the current power feed-in and to remotely reduce the active

[10] Hydro Pumped Capacity of 2,3 GW connected to the high-voltage level is not included in the graphic
[11] https://www.entsoe.eu/publications/statistics/yearly-statistics-adequacy-retrospect/
[12] BNetzA, Monitoring Bericht 2012

power feed-in in case of congestions and according to German law[13]. The operators of PV units with a capacity under or equal to 30 kW have the choice not to meet the above defined rules. In that case they are obliged to reduce their active power feed-in at the connection point with the grid to 70% of their nominal power.

So far, the majority of the PV generation units connected to the high voltage level and to the medium-voltage level are controllable. In the high-voltage and medium-voltage level 80% to 90% of the installed capacity is considered to be controllable, while in the low-voltage level, only 15,8% is. Therefore, in total, 38% of the PV capacity connected to the German distribution grid is considered to be controllable[14].

Nevertheless, all wind generation units connected to the German distribution system are considered to be controllable. By German law[15], all wind generation units with a nominal power above 100 kW have to provide the technical ability to allow the DSO to read the current power feed-in and to remotely reduce the active power feed-in in case of congestions. Nowadays, only a negligible share of 0,02% or 3 MW of wind capacity is not controllable. The same rules for generation units with a capacity above 100 kW apply to CHP generation units.

At present, the German law regulating the installation of ***smart meters*** has not led to a significant increase of smart meters installed in Germany. So far, smart meters only have to be installed for customers getting a new connection to the system, existing customers with a total annual consumption over 6000 kWh, and operators of DRES generation units and small CHP units with a nominal power above 7 kW, but only if this is technically possible and economically feasible[16].
The generally subdued development is caused by missing clarifications of financing issues as well as final definitions of security and privacy of implemented communication protocols. Finally, a clarification of the threshold level of residential smart meters based on a cost benefit analysis is expected by the federal ministry. Based on current prerequisites, about one million potential metering points have been identified in the German residential sector. However, these only account for less than 3% of all residential metering points in Germany[17].

[13] Gesetz für den Vorrang Erneuerbarer Energien (Erneuerbare-Energien-Gesetz - EEG), §6
[14] The controllable PV and wind capacity has been determined using the register for renewable power plants (EEG Anlagenregister) providing the installed capacity, the voltage level and the installation date of each unit combined with the regulations given in the EEG and EnWG.
[15] Gesetz für den Vorrang Erneuerbarer Energien (Erneuerbare-Energien-Gesetz - EEG), §6
[16] Gesetz über die Elektrizitäts- und Gasversorgung (Energiewirtschaftsgesetz - EnWG), § 21c
[17] http://www.effiziente-energiesysteme.de/themen/smartmeter/marktentwicklungsmartmeter.html

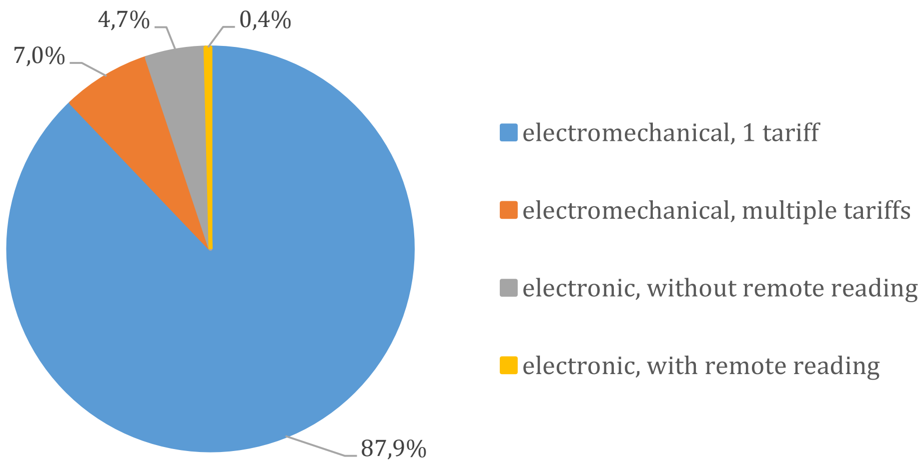

Figure 8: Metering technologies for residential customers in Germany (2012)

There has not been a nationwide roll-out of smart meters in Germany, as can be seen in Figure 8, which shows the share of metering technologies deployed for 44,5 million residential customers in the year 2012. The recent negative cost benefit analysis[18] in this regard means that Germany will not aim to install 80% of connection points with smart meters by 2020, as will be in the case in most member states.

The operation and testing of smart meters is limited to a number of pilot projects in different areas of Germany[19]. An example of a pilot projects deploying large numbers of smart meters can be found in the city of Mühlheim[20] where 100.000 smart meters have been installed for residential and commercial customers from 2008 to 2012. Other pilot projects in Berlin[21] and Bavaria[22] are deploying 10.000 smart meters each in the residential sector.

Today only a few companies offer ***flexible tariffs*** including the installation of a smart meter or other additional services with contracts differing between the different suppliers. However, from the beginning of 2011 the suppliers in Germany have to offer tariffs that are load or time dependent[23].

A study on ***demand side integration (DSI)*** in Germany conducted by the VDE[24] differentiates between ***demand side management (DSM)*** and ***demand side response (DSR)***. Demand side management allows the direct manipulation of the demand, while demand side response only covers the reaction of demand to an incentive signal (typically monetary). Furthermore, a distinction between the theoretical, technical and economic potential of demand side integration has been performed.

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[18] Ernst & Young – Kosten-Nutzen-Analyse für einen flächendeckenden Einsatz intelligenter Zähler
[19] http://www.effiziente-energiesysteme.de/nc/projektlotse.html
[20] http://www.rwe.com/web/cms/de/368410/muelheim-zaehlt/
[21] http://www.gesobau.de/wohnungsangebote/wohnquartiere/maerkisches-viertel/leben-im-maerkischen-viertel/pilotprojekt-smart-meter/
[22] http://www.effiziente-energiesysteme.de/projektlotse/eon-pilotprojekt-10000-smart-meter-programm-in-bayern.html
[23] Gesetz über die Elektrizitäts- und Gasversorgung (Energiewirtschaftsgesetz - EnWG) § 40
[24] VDE Studie: Demand Side Integration – Lastverschiebungspotenziale in Deutschland (https://www.vde.com/de/fg/ETG/Arbeitsgebiete/V2/Aktuelles/Oeffenlich/Seiten/StudieDSI.aspx)

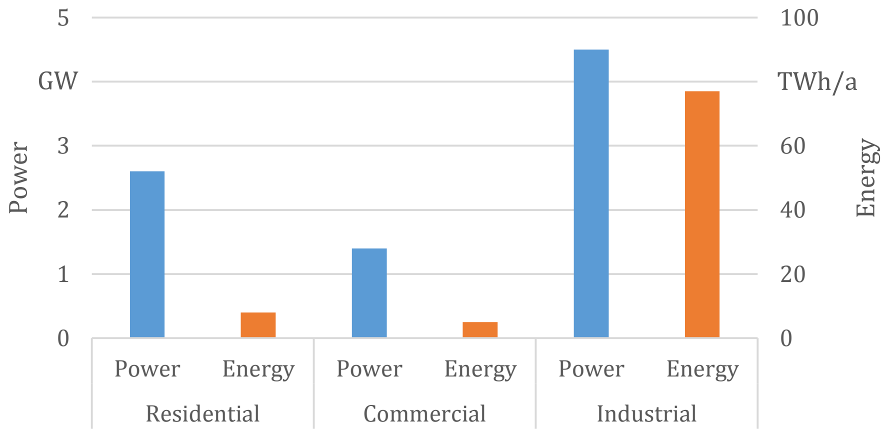

Figure 9: Technical Demand Side Integration potential in Germany (2010)

A potential for ***load shifting*** has been identified for residential, commercial and industrial consumers. However, only in the industrial sector is a part of this potential already used today due to existing incentives for peak load reduction and optimisation of electricity purchases. Additionally, some chemical facilities in particular are already taking part in the market for tertiary control today. Nowadays, the potential in the other sectors has been identified as being not beneficial under current economic considerations. Figure 9 shows the identified technical potential for DSI in Germany in the year 2010.

The status quo regarding ***storage*** capacity, and referring to pumped storage power plants, is 9.2 GW in total. The capacity installed in the ultra-high voltage grid is 7.4 GW. In the high-voltage network 1.8 GW of pumped hydro power plants is installed.

The number of ***electric vehicles*** in Germany in 2012 was roughly 5.500, with a total number of 2800 public charging stations. The rating for charging goes up to 22 kW for electric vehicles with batteries up to 25 kWh.

3.3 France

In the French distribution system, the low-voltage level has a nominal voltage of 0,4 kV. The main nominal voltage in the medium-voltage level is 20 kV, but other nominal voltages (8,5 kV / 10 kV / 15 kV and 33 kV) are also existing in the medium-voltage distribution system. The DSO in France is only in charge of the low-voltage and medium-voltage system and the HV/MV substations, while the high-voltage level is managed by the TSO.

Generation Mix

The total installed generation capacity connected to the distribution system of 15,5 GW represents 12% of the total installed capacity in France, as shown in Figure 10. This large difference arises mainly from nuclear generation units solely connected to the transmission level.

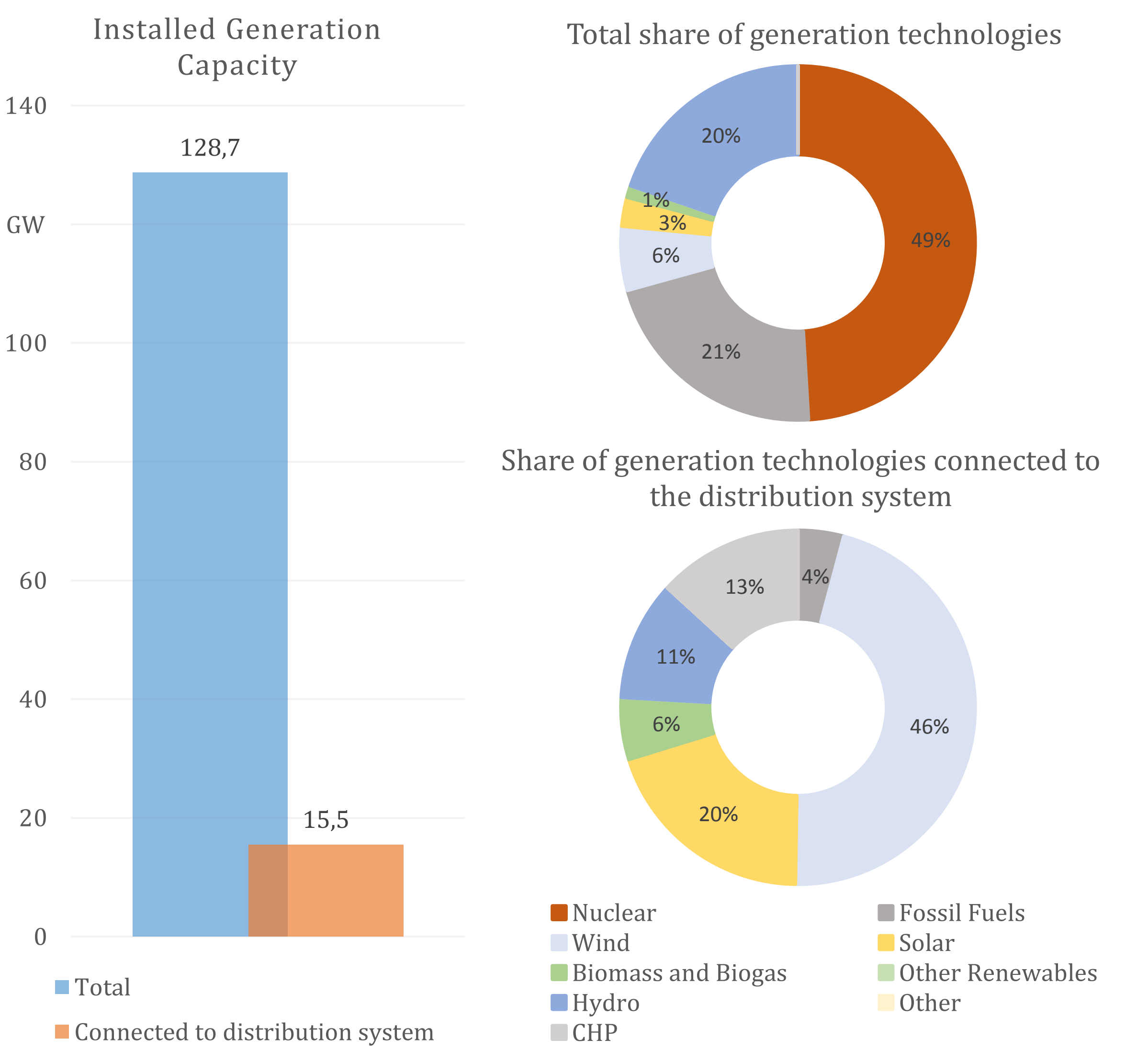

Figure 10: Installed generation capacity in France

Furthermore, 97,7% of the fossil generation capacity and 93,4% of the hydro generation capacity is connected directly to the transmission system.

In the distribution system, the highest share of generation capacity is wind generation capacity with a share of 46% representing an installed capacity of 7,1 GW. PV capacity has a share of 20% of the installed capacity in the French distribution system with an installed capacity of 3,1 GW. In the distribution system, the total wind capacity is installed in the medium-voltage level with no wind generation being connected to the low-voltage level. In contrast, 66% of PV capacity is installed at the low-voltage and 34% at the medium-voltage level.

Another technology with a relatively high share of capacity (13%) in the French distribution system are combined heat and power (CHP) generation units, which are connected mainly to the medium-voltage level. Hydro generation (run of river) has a share of 11% with a capacity of 1,7 GW connected to the distribution system, mainly at the medium-voltage level.

The overall share of DRES capacity in the French distribution system of 83% exceeds the share of 30% of DRES capacity in the total system.

Demand

Based on the ENTSO-E[25] data, the total annual electricity demand of France is 489,4 TWh and the instantaneous peak load is 102,1 GW.

For the distribution system, only data for residential and commercial loads connected to the low-voltage network is available. In 2012, about 27,5 million residential loads accounted for an annual energy consumption of 158,2 TWh with a peak load of 44,9 GW. The commercial loads accounted for an annual energy demand of 138,4 TWh with a peak load of 25,7 GW.

Degrees of technological freedom

In the past, a certain degree of ***load shifting potential*** in France was used by mobile peak load tariffs that are still in use: A mobile peak load tariff (EJP) was offered until 1998 (still offered for companies with subscription between 42 and 240 kVA), with a high energy price for 22 days during the winter period. This option is still used by 600.000 residential customers and represents an equivalent of 1500 MW of peak shaving value (excluding electricity losses). In addition, a similar type of tariff (TEMPO) was offered to professional customers until 2004 (but still offered to residential customers) and represents an equivalent of 500 MW (typical values for cold days; variable with temperature) of peak shaving value. Another 400 MW of shifting potential was accessed by different market mechanisms in 2012.

In France, ***peak- and off-peak-rates*** coupled with automatic activation of load have been offered over the last 40 years. The DSO has the ability to define these peak and off-peak periods. So far, 12 million customers are using this option, representing a peak-load of 12 GW.

[25] https://www.entsoe.eu/publications/statistics/yearly-statistics-adequacy-retrospect/

This load, mainly consisting of water heaters, is allocated off peak which results in a saving 6 GW during the morning peak and 6 GW during the early night peak.

By 2013, about 70.000 ***hybrid electric vehicles*** and 30.000 ***electric vehicles*** have been registered in France. Furthermore, 36.000 normal charging stations with a charging power of 3,8 kW and about 500 quick-charging stations with a nominal power of 44 kW are in operation. This results in a total of 140 MW of normal charging capacity and 22 MW of quick-charging capacity.

A share of 71% of the DRES connected to the distribution system at medium-voltage level in France is considered as observable and controllable[26]. This corresponds to generation units with a nominal capacity above 5 MW.

In terms of other ***innovative technologies*** in the distribution system, an increasing number of ***remotely operated switches*** in the medium-voltage level was identified. Furthermore, in initial trials, about 300.000 ***smart meters*** have been installed. The national targets are to deploy 3 million smart meters in 2016 and 35 million by 2020.

[26] DEIE control system (Dispositif d'Echanges d'Informations d'Exploitation): device installed inside some MV power plants, allowing exchanges between the plant and the ERDF control center (remote measurings, signallings, setpoints). DEIE can also be used in some emergency situations (congestions on the MV and/or HV network) to send an order of decoupling.

3.4 UK

In the UK, the low-voltage level of the distribution system has a nominal voltage of 0,4 kV. The nominal voltages for the medium-voltage level are 11 kV and 6,6 kV. The high-voltage level belonging to the distribution system has nominal voltages of 33 kV / 66 kV or 132 kV.

Generation Mix

Figure 11 shows the installed generation capacity in the UK[27] for the year 2012. The total installed generation capacity connected to the distribution system of 14,7 GW represents 18,9% of the total installed capacity in the UK. This difference mainly arises from fossil fuel generation units connected directly to the transmission system. Furthermore, nuclear generation units are solely connected at transmission level.

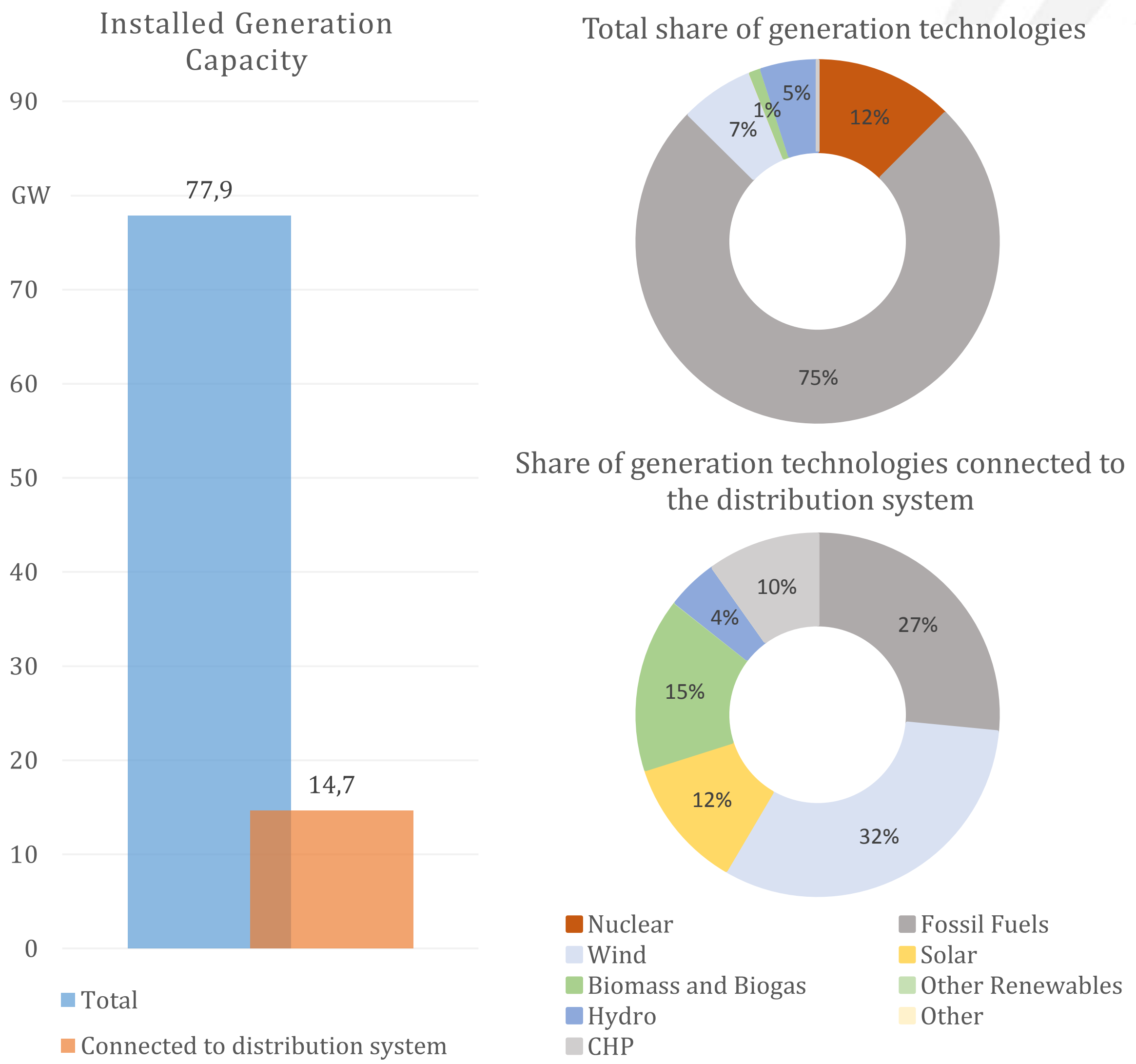

Figure 11: Installed generation capacity in the UK[28]

[27] The status quo of the UK is based on the Digest of UK Energy Statistics (DUKES).
[28] Data from entso-e "Statistical Yearbook 2012" does not list PV generation capacity for the UK for 2012.

In the UK, 3,89 GW of fossil generation units are connected to the distribution system. This represents 6,7% of the total available fossil fuel generation capacity. Another 10% of the connected capacity belongs to combined heat and power units (CHP). The largest share of generation connected to the distribution system is from wind, with a share of 32% (4,7 GW). PV capacity accounts for 12%, biomass and biogas for 15% and 4% for hydro generation units. Other renewables with an installed capacity of 0,7 GW are wave and tidal generation units.

The overall share of DRES capacity in the UK distribution system of 63% exceeds the share of 13% of DRES in the total system.

Demand

Based on the ENTSO-E[29] data, the annual electricity demand of the UK is about 325.24 TWh[30] and the instantaneous peak load is 59 GW.

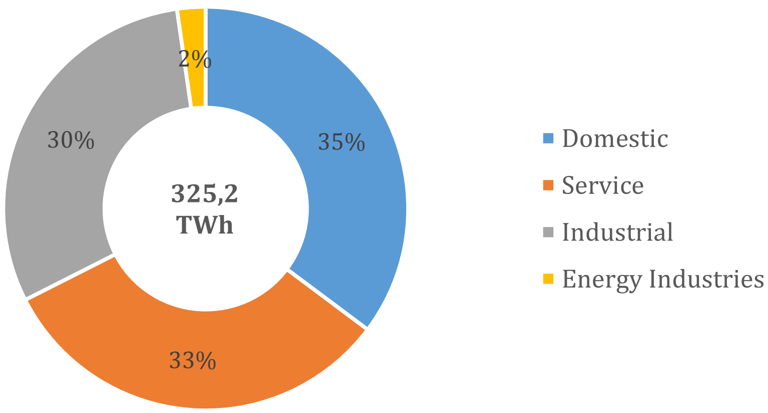

Figure 12: Share of demand in the UK electricity system

For the allocation of the demand to different sectors, no separate data for the distribution system is available. Figure 12 presents the share of demand for domestic customers, service buildings, industrial customers and energy industries for the total electrical energy system in the UK. In the UK, domestic users, services and industry each account for 30% to 35%.

[29] https://www.entsoe.eu/publications/statistics/yearly-statistics-adequacy-retrospect/
[30] The value in the entso-e Statistical Yearbook only has a representability of 94 %

3.5 Ireland

The high-voltage network is operated with two nominal voltages, 110 kV as well as 38 kV, the medium-voltage level has a nominal voltage of 10 kV or 20 kV, while the nominal voltage at low-voltage level is 0,4 kV.

Generation Mix

Detailed information about the generation mix in Ireland[31] is shown in Figure 13. The total installed generation capacity adds up to 8.6 GW, whereas the installed capacity at distribution level is much lower and has value of 1.3 GW. This means that 15% of the generation capacity is installed at distribution level.

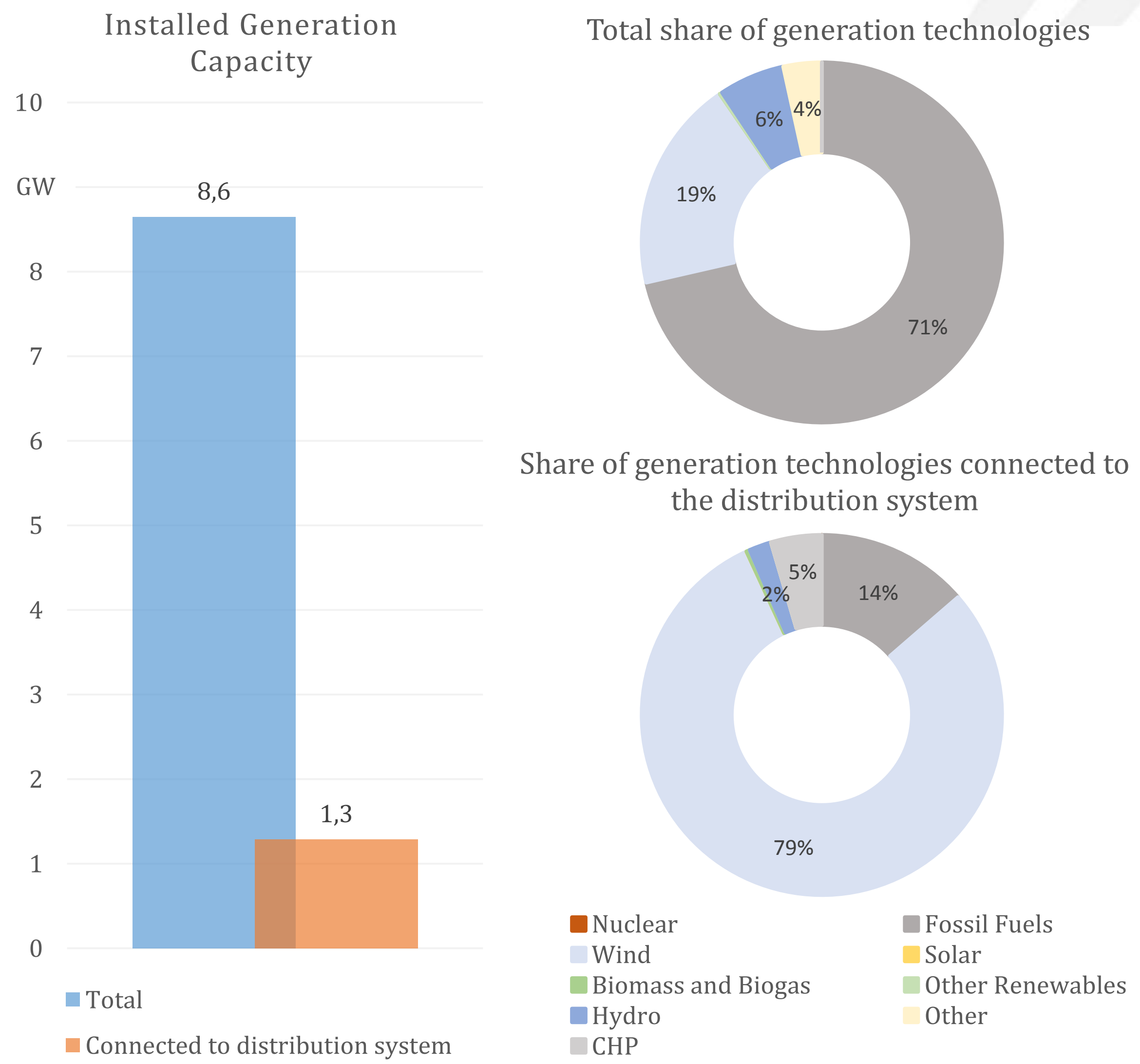

Figure 13: Installed generation capacity in Ireland

[31] The status quo is determined by data from ESB Networks.

The generation system is dominated by fossil fuel based generation units with a share of 71%. The remaining part is mainly comprised by wind power plants, which have a share of 19% of the generation capacity and by hydro power plants with a share of 6%.

Demand

Based on the ENTSO-E[32] data, the annual electricity demand of Ireland is 25.7 TWh and the instantaneous peak load is 4,6 GW. The annual demand in the distribution level is 22 TWh. The share of residential customers for the demand in the distribution network is 33.6%. The part of the commercial customers adds up to 26% and for the industrial customers the share is 37.9%. The part of the agricultural customers is rather small with 2.3%.

Degrees of technological freedom

There is no ***demand side management*** in effect in Ireland today. A possible ***shift potential*** is seen for residential customers and has a value of 10% to 15% of the total demand for all distribution system voltages. Nevertheless, there is no innovative offer for demand response in Ireland at the moment.

The only ***storage*** technology in place in Ireland is in the form of pumped hydro stations. The total installed capacity is 292 MW and is connected to the transmission network at 220 kV. The amount of ***electric vehicles*** in Ireland is 260 cars. Each EV has an average power rating of about 3.6 kW, which means that almost 1 MW of EV is connected to the network of Ireland. The batteries have a capacity of 20 kWh each, so that the total storage capacity is about 5.2 MW h. About 6% of the EV are fast charging with a typical power rating of 50 kW. 94% of the EV are slow charging, with a typical rating of about 22 kW.

Furthermore, as ***innovative technology***, on load tap changers are typically used at the voltage levels of 38 kV, 20 kV and 10 kV. ESB is currently engaged in the roll-out of smart networks using loop automation at the medium-voltage level. Suitable pairs of medium voltage feeders are selected from worst-performer lists and automation schemes incorporating NULEC-Reclosers are then designed. This is to ensure maximum continuity of supply during faults and minimises customer minutes lost.

[32] https://www.entsoe.eu/publications/statistics/yearly-statistics-adequacy-retrospect/

3.6 Italy

The transmission system in Italy covers nominal voltages of 380 kV, 220 kV, 150 kV, 132 kV and 110 kV being managed by the TSO. In the distribution system, the medium-voltage level has nominal voltages of 15 kV and 20 kV. The nominal voltage in the low-voltage level is 0,4 kV.

Generation Mix

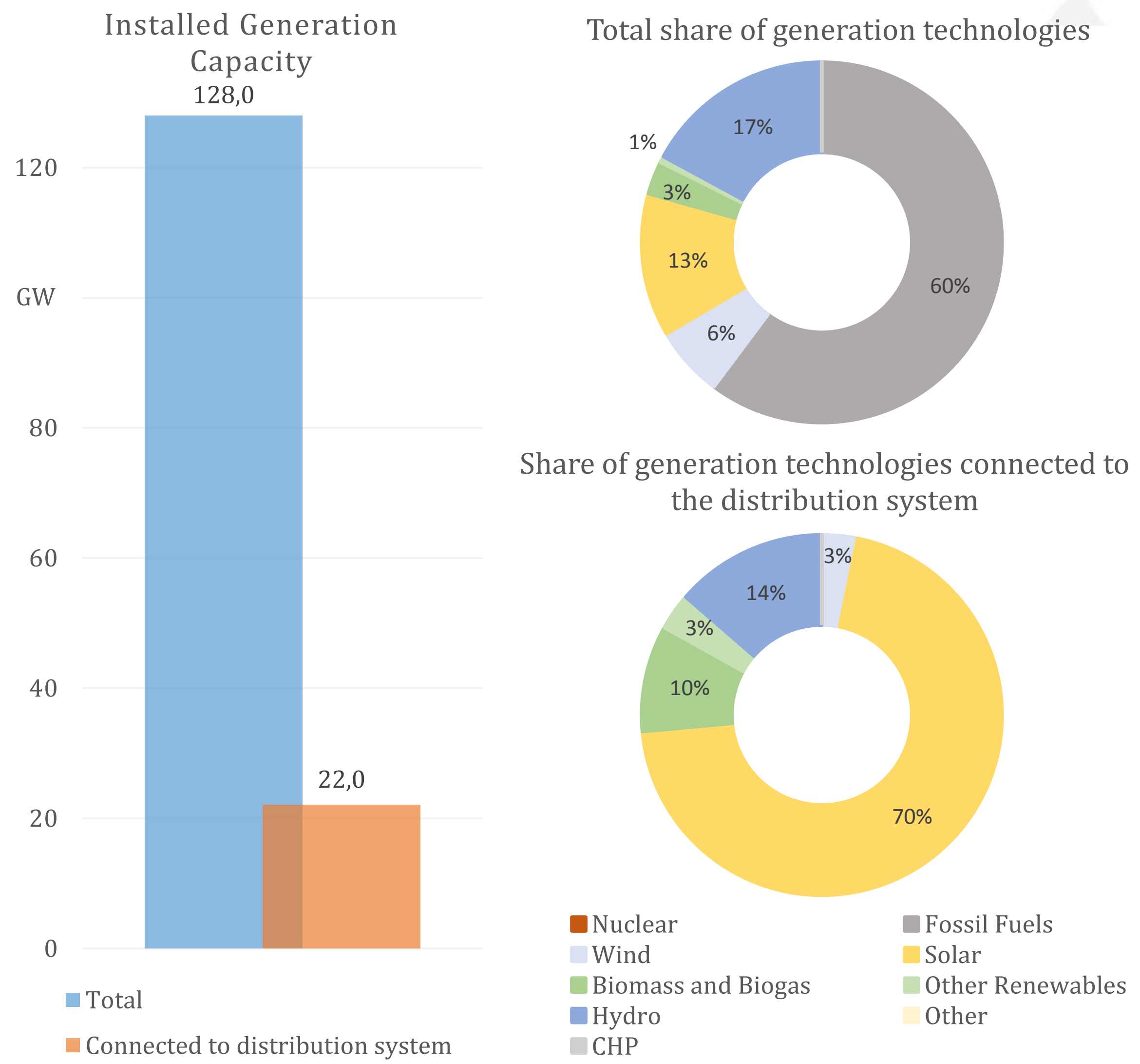

Figure 14: Installed generation capacity in Italy

The total installed generation capacity in Italy[33] in 2012 was about 128 GW [34] while the installed capacity in the distribution systems was approximately 22 GW [35].

[33] The status quo of Italy is determined by the National Regulatory Authority (AEEG), the Italian TSO Terna and the Gestore di Servizi Elettrici (GSE).

[34] Entso-e states 124,2 GW of total capacity in 2012, but is missing detailed information about biomass / biogas.

The installed capacity for fossil fuel power plants is 60% of the overall installed generation capacity (approximately 77 GW) and is entirely connected to the transmission system. In terms of renewable energy sources connected to the Italian network (transmission & distribution), renewable hydro power has the highest share with 14,7% (18 GW) while the total hydro power is 22 GW (17%). PV has a share of 13% (16,4 GW) and wind power has a share of 6% (8,1 GW) of the total installed capacity (Transmission & Distribution). Finally, geothermal plants total 772 MW.

Wind power units are mainly connected to the high-voltage system (98,7% in 2011) which is considered to be part of the transmission system, whereas PV is mainly connected to the distribution system (94,2%) at the medium-voltage and low-voltage level. Therefore, the share of PV generation capacity in the distribution system equals 70% of the total generation capacity connected to the distribution system. Hydro power generation units account for 14% (3 GW) of the distribution system generation capacity, while wind generation only accounts for 3% (less than 1GW).

Demand

Based on the ENTSO-E[36] data, the annual electricity demand of Italy is 328 TWh (307 TWh net of losses) and the instantaneous peak load is 54,1 GW. The residential customers have a share of 22% of the total distribution demand (approx. 70TWh) and are only connected to the low-voltage network. The commercial customers have an annual demand of roughly 33% of the total demand and the industrial customers have a share of 43%. The share of the agricultural customers sums up to 2% of the total.

Degrees of technological freedom

Through the "Telegestore Project" (remote management system), Enel Distribuzione has provided for the installation of more than 32 million ***smart meters*** since 2001 in Italy. The number of concentrators installed was 358.000 reaching 100% of Enel Distribuzione's customers at the end of the project in 2006.

It should be mentioned that the Enel Telegestore project started in 1999 as a voluntary project and before 2006 when the Italian Regulator (AEEG) set a mandatory installation programm of electronic meters, with minimum functional requirements for all the DSOs and LV customers starting from 2008 and reaching 95% of them in 2011.

Regarding increased ***customer awareness***, Enel Distribuzione is also installing a Smart Info device, certified by Enel in July 2011, which establishes a direct connection between the grid and the customer and enables easy access to the information recorded by their meter. Thanks to Enel Smart Info, consumers can monitor their consumption to match their needs while saving on their electricity bills. The Smart Info project started in 2010 and will end in 2014 and is currently being tested in some local authorities in the province of Isernia in the Molise region. The pilot involves a few thousands families, each of them receiving at no cost the "Enel

[35] 22GW corresponds to the official statistics given by the Italian Regulator (AEEG) in report *"RAPPORTO ANNUALE DELL'AUTORITÀ PER L'ENERGIA ELETTRICA E IL GAS IN MATERIA DI MONITORAGGIO DEI MERCATI ELETTRICI A PRONTI, A TERMINE E DEI SERVIZI DI DISPACCIAMENTO: ANNO 2012 CONSUNTIVATO"*
[36] https://www.entsoe.eu/publications/statistics/yearly-statistics-adequacy-retrospect/

info+ kit – smart info", a dedicated display and software for their computers and smartphones.

Related to ***distribution grid automation*** issues, approximately 2200 primary substations are automated and about 120.000 secondary substations are telecontrolled in the network under the responsibility of Enel. Furthermore, approximately 70% of MV lines are automated, and this figure represents an optimal percentage of required automation to respect current regulatory Quality of Service Indicators (SAIDI/SAIFI).

Currently, only 2.5% of the renewable generation units connected to the medium-voltage level are ***remote controllable***[37]. Units connected to the low-voltage level are not controllable.

Furthermore other innovations are involved in the operation of the network such as ***Work force management***. In particular, Enel workers' activities are planned with the support of a computer system that helps to organize the most important daily works, allowing an optimization of logistical aspects and related efficiency. These daily schedules are fed to workers' tablets. At the same time, with this system it is possible to locate the real time position of the fleet, guaranteeing increased safety and an optimized division of work.

The ***demand side management*** potential identified for the whole customer group in Italy corresponds to a total shift potential of 4.400 MW in Italy, equalling 8% of the Italian load.

With regard to ***demand response*** schemes in Italy today, the wholesale market operators can act as a demand aggregator only in the Day-Ahead Market (since 2005). The framework for the participation of demand in the Balancing Market is not yet complete. Resolution ARG/elt 98/11, which identifies the criteria and principles for the future capacity market mechanism, opened the way for demand to directly participate in the market.
At present, two interruptible contracts schemes are already applied:

- At national level, a descending price auction is managed by the TSOs for an average maximum interruptible load equal to 3.900 MW per year. Industrial customers are committed to providing 10 load interruptions per year. A bonus/malus mechanism is applied in case customers provide a differing number of interruptions by charging an additional fee or crediting a payback fee.
- Due to infrastructure related issues (e.g. poor interconnection with the mainland), a new scheme[38] for the islands of Sicily and Sardinia has been introduced. The maximum interruptible load is 500 MW in each island. The tender procedure is the same described above.

In Italy today there exist different pilots where ***electrical storage*** are used. In particular, the most important storage units are installed in Isernia (1MW), Forlì (1MW), and Chiaravalle (2MW).

[37] Data only available for the network under operation by Enel Distribuzione
[38] AEEG order nr.15/10

The total amount of ***electrical vehicles*** in Italy adds up to about 1.650. All cars have a slow charging procedure requiring 22 kW AC. Approximately 350 public and 500 private recharging stations have been installed.

3.7 Portugal

The high-voltage level belonging to the distribution system in Portugal has a nominal voltage of 60 kV, while the nominal voltages of 110 kV and 150 kV belong to the transmission system. The medium-voltage level is operated with nominal voltages of 10 kV, 15 kV and 30 kV. The low-voltage level has a nominal voltage of 0,4 kV.

Generation Mix

The installed capacity in Portugal is 18,5 GW compared to 6 GW installed capacity in the distribution network. This means that nearly one third of the installed generation capacity is connected to the distribution network in Portugal. Figure 15 shows that the share of fossil fuels (43%) is almost the same as in the overall system as well as in the distribution system (37%).

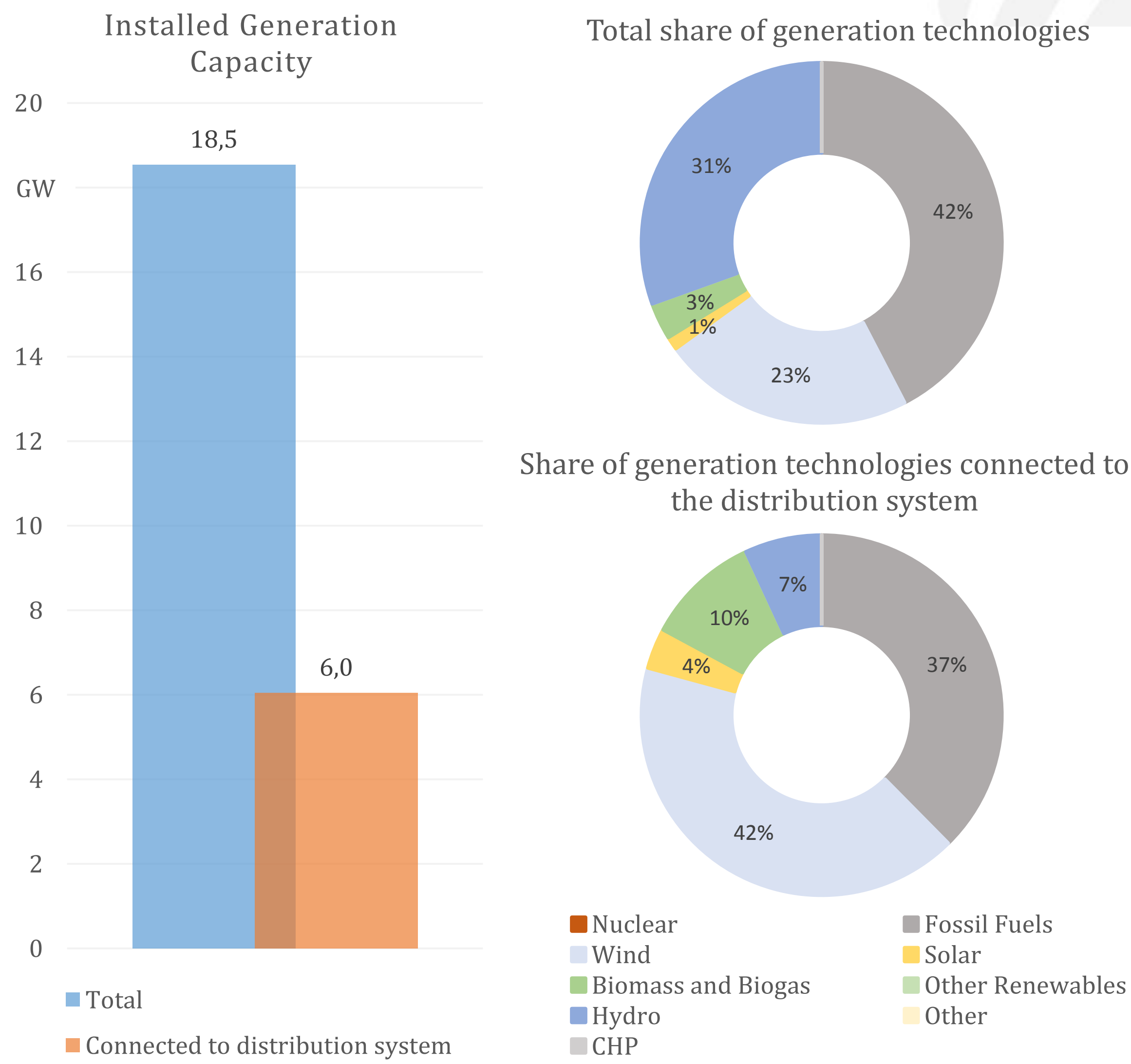

Figure 15: Installed generation capacity in Portugal

The share of wind power of the installed capacity in the whole system is 23% whereas the share in the distribution system is 42%. For hydro power plants, the share in the whole system represents 31% and the share in the distribution system 7%, so that hydro power plants are mainly connected to the transmission network. The share of solar power in Portugal is in general quite small and adds up to 1% in the whole system and to 4% in the distribution network. Biomass and biogas have a share of 3% in the whole power system and 10%, when only considering the distribution network.

Demand

Based on the ENTSO-E[39] data, the annual electricity demand of Portugal is 49 TWh and the instantaneous peak load is 8,6 GW. The energy demand in the distribution network is 43 TWh, which is around 88% of the total energy consumption. The share of the demand in distribution networks can be analysed in more detail. The share of the residential customers is 32%, of the commercial customers 27%, of the industrial customers 38,5% and of the agricultural customers 2,5%.

Degrees of technological freedom

Presently in Portugal, there are only ***demand side management*** programs (i.e. contracts for load curtailment) for industrial consumers in effect. On the high voltage side, 30% of the industrial customers connected have a shift potential. On the medium voltage level 70% of the industrial customers have a shift potential and there is no potential for the customers on the low-voltage level. The range in time the demand that can be shifted is 3 h for the high and the medium voltage industrial customers.

For low-voltage consumers, the only schemes that foster ***demand response*** are time-of-use-tariffs (ToU), which divide the day into peak and valley hours. In 2010, new legislation was approved to increase the possibility of using demand reductions to deal with emergency situations and to increase the flexibility of system operation. The current legislation establishes that all consumers connected at extra high-, high and medium-voltages that procure their energy in the daily market, through bilateral contracts, or via contracts with the regulated retailers, can provide this service. The remuneration of this service is obtained through the addition of a monthly amount that considers the investment and fixed operation costs of gas combined cycle turbines plus a term depending on the usage of the service. This variable term depends on the electricity market prices during the hours the service was used and on the number of hours the service was used in each month. If the order to reduce the power issued by the TSO is not followed by a consumer contracted to provide this service, the legislation specifies a number of penalties. For instance, if no non-compliances occurred in the most recent 12 months, the penalty is equal to the base monthly remuneration of 4 months. If one non-compliance occurred in the last 12 months, then the penalty increases to the monthly base remuneration of 12 months. Finally, if 2 or more non-compliances occurred in the last 12 months, then the penalty corresponds to the value of the monthly base remuneration of the last 12 months and the contract established with the TSO to provide this service is eliminated.

Other demand related projects in Portugal deal with ***energy efficiency*** as one of the main factors of the smart grid. In a test-pilot in the city of Évora, those customers supplied with

[39] https://www.entsoe.eu/publications/statistics/yearly-statistics-adequacy-retrospect/

home display units connected with the EDP Box, which provides real time information about energy consumption, reduced consumption by 3.9% in the test group (vs. the control group) with an error margin of 2.1%, using one full year of data. Other pilots are implementing new ToU programs and "target kWh" tariffs, making customers more aware of their energy consumption throughout.

In Portugal there is no ***electricity storage*** connected to the distribution network and only 983 MW of hydro-pump storage connected to the ultra-high voltage level.

In 2013, about 500 ***electric vehicles*** have been registered in Portugal. Furthermore roughly 1200 normal charging points with a charging power of 3,7 kW and about 9 fast charges with a nominal power of 50kW are in operation.

In addition, the ***controllability*** of wind and solar power plants, connected to HV and MV, is allowed by the current grid-code. In the high-voltage network all of the wind and solar power plants can be controlled. In the medium-voltage level only 60% of those are controllable excluding the older wind farms. The low-voltage has no controllability since there is no grid-code for the micro generation connected at the low-voltage network.

Furthermore, Portugal has tested ***other innovative technologies*** in smart-grid pilot projects. The smart grid infrastructure from the InovGrid project, promoted by EDP Distribuçao, resulted in a large-scale demonstration pilot in the city of Évora named InovCity. The main components of this infrastructure are:

- EDP Box (EB): smart meter with load and generation management functions, located at each delivery point, which can interact with other devices through a home area network.
- Distribution Transformer Controller (DTC)[40]: Remote Terminal Unit (RTU) located at the secondary substation level, comprising modules for measurement, remote control and communication actions. It collects data from the EB and the secondary substation.
- Both the EB and the DTC are part of a hierarchical control and communication architecture. Each EB has a bi-directional communication with the corresponding DTC through GPRS (General Packet Radio Service) or PLC (Power Line Communications), and the DTC communicates with the SCADA/DMS through a wide area network based on GPRS.
- Smart Substation Controller (SSC): installed at the primary substation level (HV/MV) and is responsible for aggregating and managing the operational data from EB and DTC, and for applying demand-side management, self-healing and generation management strategies.
- The SSC communicates with the central management system of the DSO through fibre optics technology.

This infrastructure allows for the remote disconnection of LV clients and to modulate the contracted power of each client. There is also a dispatch centre for wind power, operated by

[40] The controller (DTC) itself is unable to remotely control the network. Therefore another device, the DTC-Cell is needed to ensure this functionality.

the TSO, capable of monitoring and sending active and reactive control signals to each wind farm.

In terms of ***distribution grid automation***, there are around 4,000 automated distribution devices installed on the 60,000 km of overhead MV lines. Two types can be found: load break switches with actuators and telecommunications that provide dispatchers remote operation and monitoring capability and devices with fault interrupting capability, designed to operate automatically based on voltage sensors and timers which also have telecommunication capabilities.

3.8 Summary of Current Situation

In this section, the current situation of distribution systems in the previously presented country synopses will be compared in order to show the differences, and similarities, between the analysed systems. Furthermore, the differences between the distributions systems in terms of nominal voltage levels covered by the distribution system will be shown in order to explain some of the noted differences.

Figure 16 displays the maximum nominal voltage that is considered to belong to the distribution system for each country. It is obvious that within Europe different understandings and definitions for distribution systems exist.
These varying definitions of the distribution systems contribute to some differences that can be observed in the presentation of the current status of distribution systems.

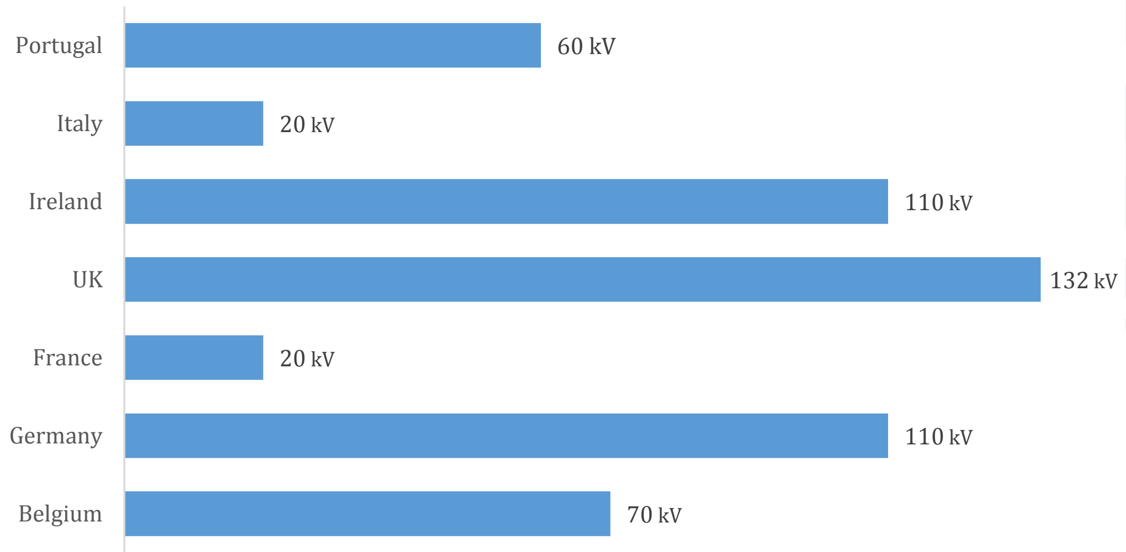

Figure 16: Maximum nominal voltage belonging to the distribution system[41]

As the various generation technologies are usually connected to certain typical voltage levels, the nominal voltage levels belonging to the distribution system influence both the total generation capacity connected to the distribution system as well as the share of generation technologies within the distribution system.
The share of fossil generation technologies in the distribution system is strongly influenced by the voltage levels embraced: countries with the high-voltage level belonging to the distribution system show a high share of fossil generation units in the distribution system. In Germany the share is 32%, in Belgium the share is 46%, in the UK the share is 27% and in Portugal the share is 37%. In other countries only covering the medium- and low-voltage levels in the distribution systems, a smaller share of fossil generation units can be observed: Italy for example does not have a significant share of fossil generation in the distribution

[41] In Ireland the 110 kV nominal voltage usually belongs to the transmission system, with just some 110 kV circuits around Dublin being operated by the DSO.

system. In France the share of 4% is very small. However, in France another 14% of generation capacity is covered by combined heat and power units including natural gas, biogas and waste.

Figure 17 shows the total generation capacity in each country compared to the generation capacity that is connected at distribution system level. The total generation capacities show the large difference in the total system size for each country.
Comparing the capacity connected at distribution system level, one can observe large differences in the share of capacities connected at distribution system level in comparison to the total system capacity. As explained before, to a certain degree, these variations can be explained by the voltage levels belonging to the distribution system. In Germany and Belgium for example, 31,3 GW and 6,6 GW, respectively, of fossil generation capacity is connected at distribution system level.
For other countries like France which have a high nuclear and/or fossil generation capacity connected directly at the high-voltage or ultra-high-voltage level, belonging to the transmission system, a significantly smaller share of generation capacity connected at distribution system level can be observed.
However, countries with a part of the high-voltage level belonging to the distribution system, like the UK or Ireland, can have only a small share of generation capacity connected at distribution system level.

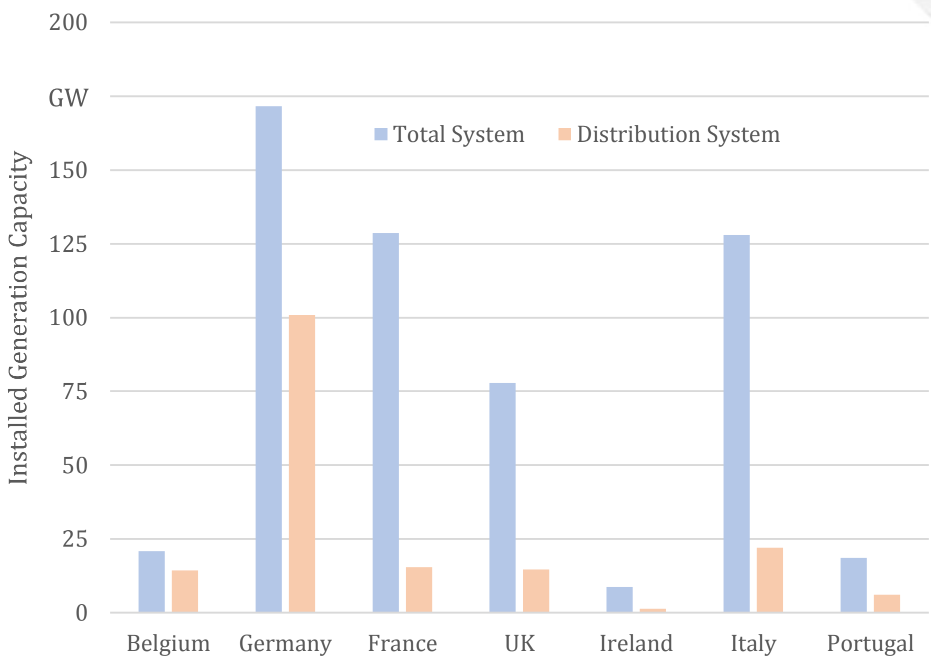

Figure 17: Installed generation capacities in the distribution system compared to the total generation capacities

As one focus of this project lies on the evolution of the DRES capacity in the distribution system, Figure 18 compares the DRES capacity currently connected at distribution system level among the different countries. As mentioned before, the different systems vary widely in terms of the total installed capacity. Therefore, Figure 18 shows the installed DRES capacities in the distribution system normalised by the total peak power of the system in order to allow a better comparability between the different countries.

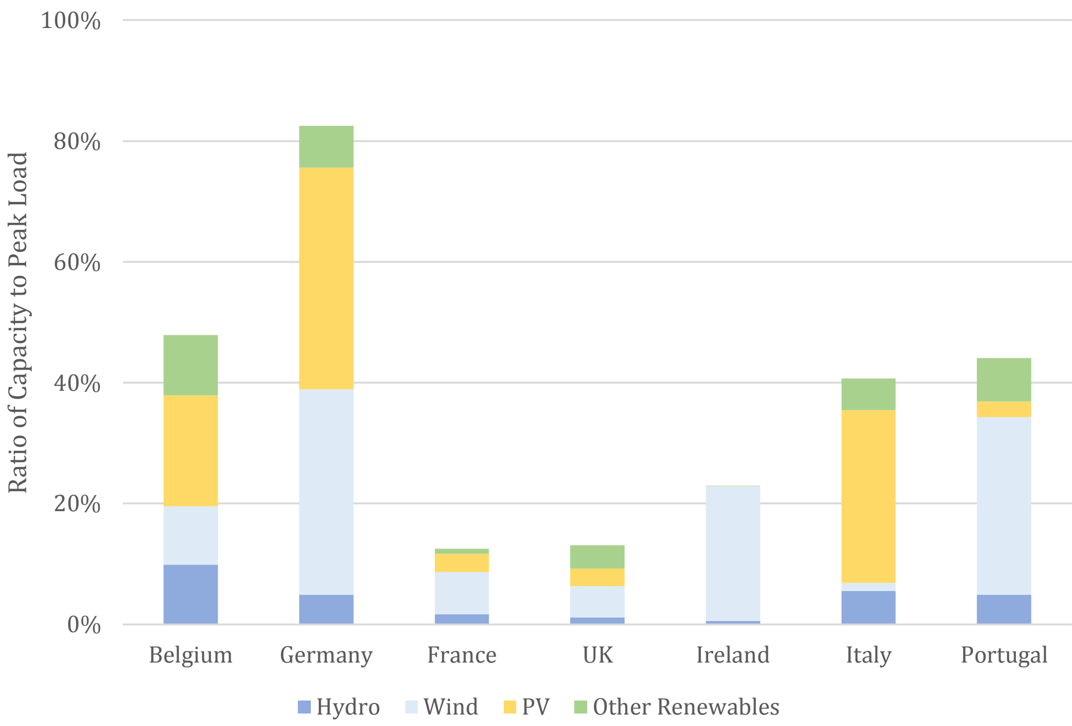

Figure 18: Ratio of DRES capacities in the distribution system to the total peak load

Figure 18 shows the different situation in terms of DRES capacity in the distribution systems today. The DRES capacity installed in the German distribution system exceeds 80% of the German peak load. In Italy, Portugal and Belgium the DRES generation capacity in the distribution system equals 40% to 50% of the peak load and in France, the UK and Ireland, the DRES capacity in the distribution system lies under 25% of the total system's peak load.

Regarding the different generation technologies, Figure 18 shows that in terms of DRES generation some countries like Ireland or Portugal are clearly dominated by wind generation units, while others like Italy are PV dominated. Other countries like Germany or Belgium do not have one clearly dominating DRES generation technology. However, for all countries it can be stated that wind and PV generation currently cover the main share of DRES capacity in the distribution systems.

4 Future Development in Distribution Systems

Based on the presentation of the current status of electricity systems, the following section will present potential future developments in distribution systems. Three scenarios, "***most-likely***", "***under-expected***" and "***over-expected***", have been defined for each participating country for different timeframes: "***short-term***", "***mid-term***" and "***long-term***".

The anticipated development of DRES such as hydro power, wind power and PV generation units, will be presented for each country. Where data was available, generation from biomass will be presented separately, otherwise it will be aggregated with other types of renewable generation such as geothermal power generation.

Furthermore, the evolution of demand and future available innovative technologies are presented for each country.

This lays the basis to compare the considered energy systems and the DRES evolution.

4.1 Belgium

Generation Mix

As presented in Figure 19, the main driver for changes in the generation capacity in the distribution system in Belgium[42] is expected to be the growth of installed PV capacity followed by an increase in wind generation. In contrast, no large increases in the installed hydro and biomass generation capacity are expected.

All scenarios predict a strong increase of installed PV capacity for the short-term: the under-expected scenario predicts an increase of 1 GW while the over-expected scenario even predicts 1,8 GW. Furthermore, all scenarios expect an ongoing growth over the mid-term and long term.

Based on the installed generation capacity in 2012, the most-likely scenario predicts a short-term growth of 1,4 GW from 2,6 GW to 4,0 GW and a further growth to 5,1 GW in the mid-term perspective and 6,1 GW in the long-term one. This corresponds to a long-term growth of installed PV capacity of 133% of the presently installed capacity. However, all scenarios show a high uncertainty in the expected growth of PV capacity. For short-term, the difference between under-expected and over-expected is 0,8 GW, while the uncertainty increases for longer time horizons to a significant number of 1,2 GW. Furthermore, a phase-out of fossil generation units connected to the distribution system is foreseen in the mid-term and long-term scenarios.

[42] The future scenarios of Belgium were calculated based on historical data (from 2008 or 2005 depending on the data available). A trend line was fitted and extrapolated until the time horizon of 2030. The over expected scenario and the under expected scenario was calculated as + and - 10% of the most probable case as employed in some studies (e.g. http://www2.vlaanderen.be/economie/energiesparen/milieuvriendelijke/Cijfers&statistieken/Prognosestudie _HEB_WKK_tot_2020.pdf). This methodology was followed, when no other estimations were available.

For the installed wind power generation capacity, the most-likely scenario predicts an increase from 1,4 GW installed today to 1,7 GW in the short-term. Further growth is expected to 1,98 GW in the mid-term and 2,25 GW in the long-term. The uncertainty of wind generation growth is less pronounced than for PV: For long-term expectations, the difference between under-expected and over-expected is 0,45 GW.

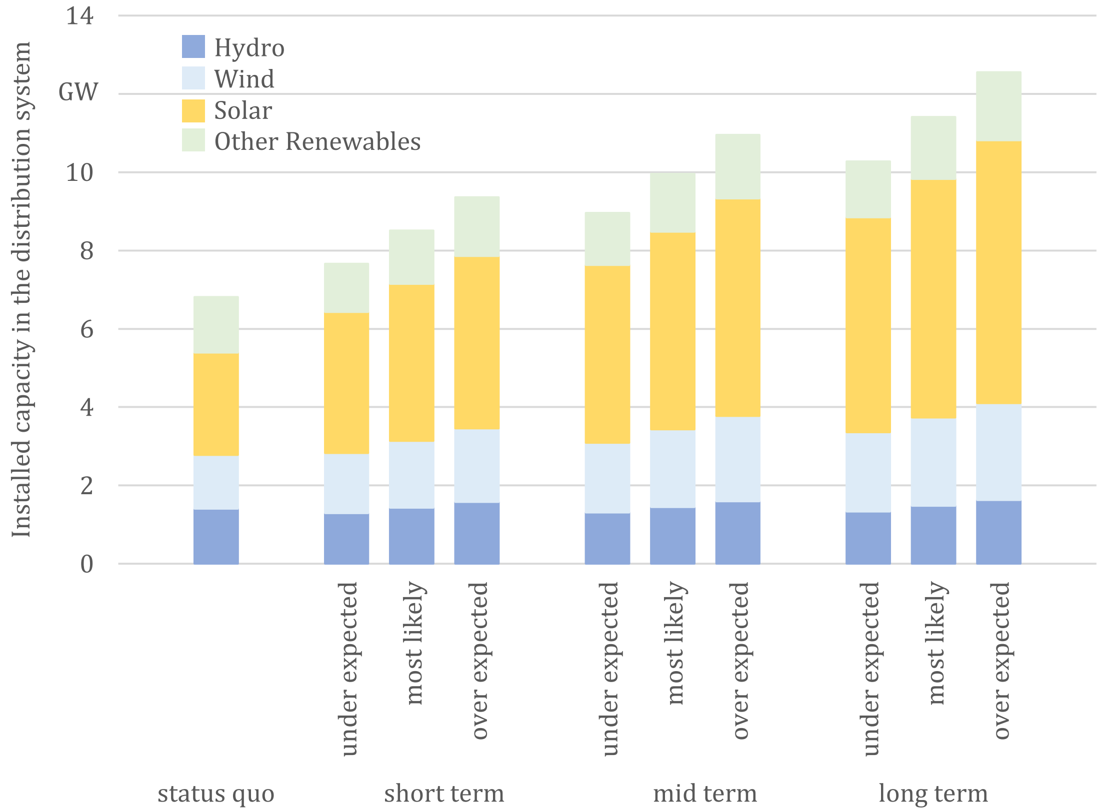

Figure 19: Scenarios for the generation capacity in Belgian distribution systems

Regarding the installed hydro generation capacity, almost no change is expected. In the most-likely scenario the short-term increase in capacity is 30 MW and the long-term increase is 74 MW. Only the over-expected scenario shows a higher long-term increase of 221 MW.

Moreover, the anticipated change in generation capacities from other renewables which mainly include biomass is small also: The most-likely scenario expects an increase of capacity from 1,42 GW to 1,58 GW. The uncertainty for the long-term evolution is small as well with a difference of 0,3 GW between under- and over-expected.

Demand

For the evolution of demand no detailed scenarios on the distribution system level are available. However, the scenarios cover the total annual electricity demand. Figure 20 shows expectations for the overall demand evolution in the different scenarios.

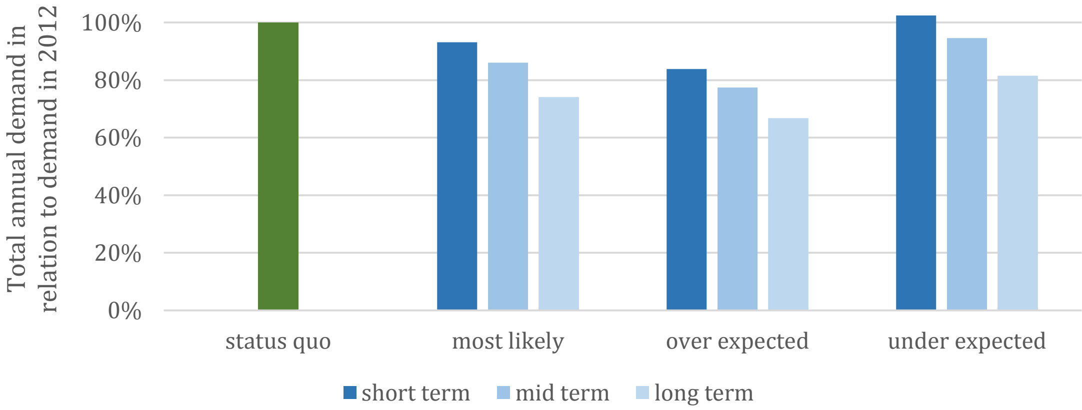

Figure 20: Scenarios for the evolution of demand in Belgium

All scenarios predict a decrease of demand over time. Only in the under-expected scenario a growth of demand in the short-term is predicted. The most-likely scenario predicts a long-term decrease in demand of 26% compared to the 2012 value. The over- and under-expected scenarios predict a demand decrease of respectively 33% and 18%.

Degrees of technological freedom

For the ***shift potential*** resulting from ***demand side management*** the responsible partners for Belgium expect an increase in the shift potential of residential demand. This results in a shift potential of the residential demand of about 33% - 35% for the mid- and long-term time horizon. Furthermore, an increase in industrial shift potential from 1,7% to 6% is expected. For the mid-term timeframe this allows 7% of the total peak load to be shifted. In long-term, an additional shift potential of 10%-20% for commercial loads is expected.
However, there is uncertainty regarding the shift potential as less optimistic predictions only expect 5% of households to get involved in demand response programmes by 2020[43].

In terms of ***innovative offers for demand response,*** the emerging aggregator activities existing today are expected to further develop. About two to four emerging new companies are starting or carrying out aggregating activities. Their focus is on consumers at transmission level or industrial companies on the higher voltage levels of the distribution system.

Furthermore, the Belgian TSO is working towards new products specially designed to allow ***aggregation of loads*** or DG to offer generation and consumption increase/decrease in different timeframes (e.g. R1 load frequency control, R3 dynamic profile by aggregation or aggregated power plants for free bids as balancing reserves). In some cases this will allow systems connected to the distribution grid to participate in these offers. For the Winter of 2015, the Belgian TSO is intending to contract a strategic demand reserve (directly or via aggregators) to ensure generation adequacy.
In addition, the Belpex[44] is adjusting its products on the day ahead market to add more levels of flexibility like conditional bids. For the mid-term and long-term development, a further increase of flexibility products from aggregators, including resources connected to the

[43] Information provided by EDSO and ORES.
[44] Belpex is a short term, physical power exchange for the delivery and off-take of electricity on the Belgian hub

distribution system, is expected. This includes an expansion of flexibility products to the commercial and residential sectors.

For the long-term development a possible increase in ***demand response*** due to electric vehicle penetration and further electrification of heat supply in commercial and residential buildings is expected.

Additionally, ***smart meters*** on residential level are expected to be largely rolled-out by 2018.

In terms of ***storage devices*** on distribution system level, no plans for further installations have been identified for future scenarios. However, for the long-term time horizon, new and improved storage technologies (both thermal and electrical energy storage) are expected to be available at reasonable prices.

For ***electric vehicles***, targets are set by the different regions. Until now, only Flanders has a plan which foresees 3% of the passenger cars to be electric in 2020 and 15% to be electric in 2030. So far, no specific measures are in place.

New ***innovative technologies*** expected in the mid-term and long-term evolution include an increased communication between DSO and TSO to offer a more efficient management of the total system. This will lead to a higher degree of automation in the distribution system to allow the use of potential flexibility in the distribution grids. Another innovation foreseen in the mid-term is the load pattern control of low voltage distribution transformers and voltage control in low voltage lines potentially using the reactive power of PV inverters at medium and low voltage level.

4.2 Germany

Generation Mix

The main driver for changes in the generation capacity in the distribution system in Germany[45] are expected to be the growth of installed wind and PV generation capacity, as shown in Figure 21. Furthermore, slight increases for hydro generation and biomass are expected.

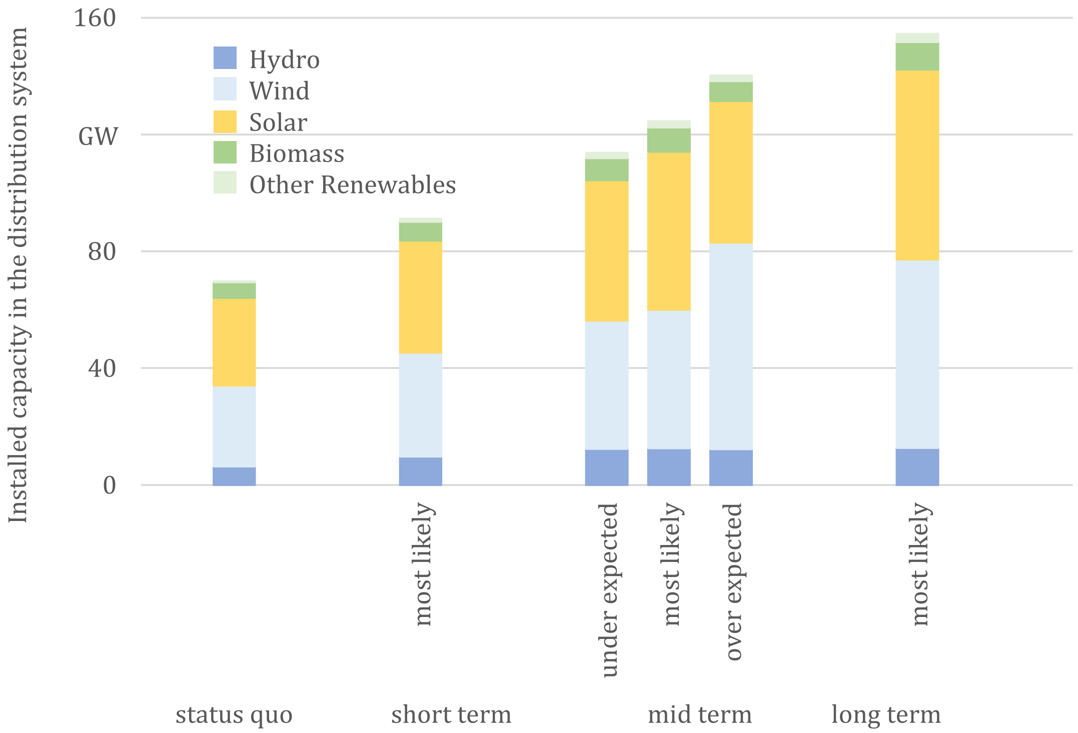

Figure 21: Scenarios for the generation capacity in German distribution systems

The most-likely scenario for Germany predicts a short-term growth of wind capacity of 7,8 GW, representing 28% of the currently installed generation capacity. For mid-term a growth of 19,7 GW (71,1% of 2012 capacity) and for long-term a growth of 36,7 GW (132% of 2012 capacity) is anticipated.

For PV generation, a similar increase in generation capacity is anticipated. In short-term, the installation of 8,4 GW (28% of today's capacity) is expected. For mid-term a growth of 24 GW (80%) and for long-term an increase of 35 GW (117%) is expected.

The uncertainty represented by the under-expected and over-expected scenarios for the mid-term time horizon shows different expectations for wind and PV generation. The under-expected scenario for wind generation only shows a relatively small deviation of 3,6 GW compared to the most likely scenario. This represents 18% of the predicted capacity increase in the most-likely case. However, the over-expected scenario for wind generation capacity

[45] The scenarios of the future development of Germany are based on data of the German Network Development Plan (Netzentwicklungsplan 2012) and the Dena study (Dena Verteilnetzstudie).

assumes 23,3 GW of additional capacity will be installed. This is 118% more than in the most-likely scenario. Therefore the uncertainty of installed wind capacity is decisive for a growth of generation capacity above the most-likely case.
The uncertainty for PV generation differs noticeably to the wind power uncertainty. For both, the under-expected and the over-expected scenario, the expected capacities for PV generation fall below the most-likely scenario. Both scenarios predict mid-term capacities of 48 GW (under-expected) and 46,8 GW (over-expected) while the most-likely scenario predicts 54 GW.

The most-likely scenario furthermore predicts a mid-term increase of 58% for biomass from 5,3 GW to 8,4 GW and a mid-term increase of hydro generation of 99% from 6,3 GW to 12,5 GW.

The uncertainty for hydro generation is quite low, as the difference between maximum and minimum expected values for the mid-term is 0,3 GW or 5% of the most-likely prediction of the capacity increase.

The uncertainty for biomass is slightly higher. The under-expected and the over-expected scenario both predict lower values for biomass: 26% (under-expected) and 55% (over-expected) under the most-likely values.

Overall, the over-expected scenario represents a scenario clearly focusing on an increase in wind generation capacity, resulting in a reduced increase of other renewable sources. For the total capacity of renewable generation, the most-likely scenario predicts a short-term increase of 30,7%, a mid-term increase of 78,7% and a long-term increase of 121,5% mainly based on PV and wind capacity.

Demand

The annual electricity demand in Germany is 559,3 TWh, while the demand connected at distribution level is 460,2 TWh accounting for 82% of the total demand.

Concerning the development of load in Germany, contradictory trends are observed. While energy efficiency measures should lead to a load reduction, the increasing use of electricity in households, like home entertainment systems etc., can lead to an increased load. Thus a stagnation of load in Germany is predicted.

Degrees of technological freedom

Following decisions and recommendations of the EU concerning ***smart meters***, the member countries should equip at least 80% of domestic customers with smart meters by 2020[46]. As an alternative they can conduct an efficiency analysis to determine differing, country specific, rollout strategies. In the case of Germany, an analysis performed in 2013[47] came to the conclusion that a nationwide rollout of smart meters by 2020 is not cost efficient, especially for customers with a low annual demand. Furthermore, the analysis suggests to equip only

[46] Directive 2009/72/EC Annex 1 (2)
[47] Ernst & Young GmbH: Kosten-Nutzen-Analyse für einen flächendeckenden Einsatz intelligenter Zähler (http://www.bmwi.de/DE/Mediathek/publikationen,did=586064.html)

one third of the metering points in Germany with smart meters. The choice of the metering points should be based on the positive effect of the measurements for the electricity system. Metering points with a connected in-feed of DRES would be equipped with smart meters. The other metering points will be progressively equipped with smart meters by 2029[48]: all antiquated or malfunctioning meters will be replaced by smart meters until all metering points are covered. However, a change of the German regulation is expected during the year 2014 which will concretise the government's strategy for smart meters rollout. Therefore, the development of smart meters in Germany is subject to large uncertainties.

A study on ***demand side integration (DSI)*** in Germany conducted by VDE[49] identified the technical potential for DSI in Germany 2020 and 2030. As presented before, by 2010 only in the industrial sector a part is of the potential already in use. The study foresees a significant increase in the theoretical and technical potential of residential customers. Furthermore an increase in the potential of the commercial sector is predicted. The main potential in these sectors is based on thermic processes like heating and cooling offering thermal storage capacities. The industries with the highest identified DSI potential are the chemical, steel and paper industries allowing a significant amount of demand to be shifted.

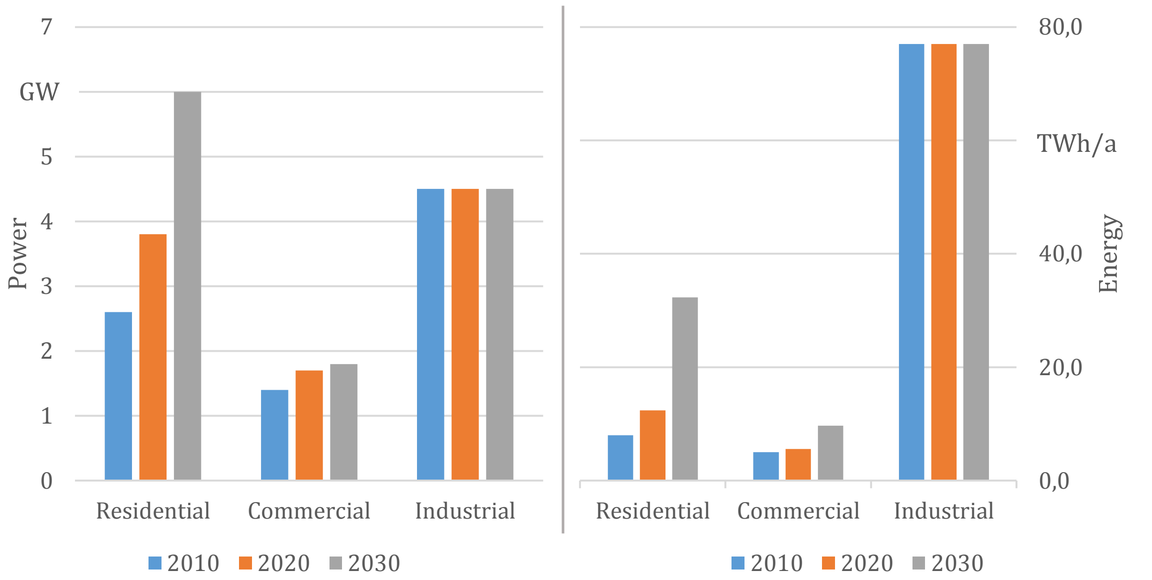

Figure 22: Evolution of Demand Side Integration (DSI) potential in Germany

Figure 22 shows the predicted evolution of the technical DSI potential in Germany. The study points out that a further deployment of smart meters and communication technology and new flexible tariffs offering incentives are necessary to be able to use the DS potential, especially for the residential sector.

Another study (dena-Netzstudie II) highlights the DSI technical potential of the residential and commercial sector of 15 GW in 2015. Furthermore, the study estimates the DSI potential from industrial processes will reach 2 GW by 2020. Again, the deployment of further DSI

[48] http://www.effiziente-energiesysteme.de/index.php?id=867
[49] VDE Studie: Demand Side Integration – Lastverschiebungspotenziale in Deutschland (https://www.vde.com/de/fg/ETG/Arbeitsgebiete/V2/Aktuelles/Oeffenlich/Seiten/StudieDSI.aspx)

potential is coupled with the rollout of smart meter and the increasing deployment communication technology.

The political goal of ***electric vehicles*** in Germany is to reach 1 million EV connected to the network by the year 2020. The prognosis for the number of public charging points for the stated year is 150.000 stations.

Regarding the ***storage*** capacity of pumped storage power plants studies like the national network expansion plan in Germany (Netzentwicklungsplan) foresee an increase by 40% in the next 10 years.

4.3 France

Generation Mix

The scenarios for the evolution of the generation mix connected to the distribution system in France are shown in Figure 23. In order to predict the future scenarios for France, the adequacy study of RTE was used. The most likely scenario corresponds to the *"Médian"*, the over expected to the *"Nouveau Mix"* and the under expected to the *"Croissance faible"* scenario.

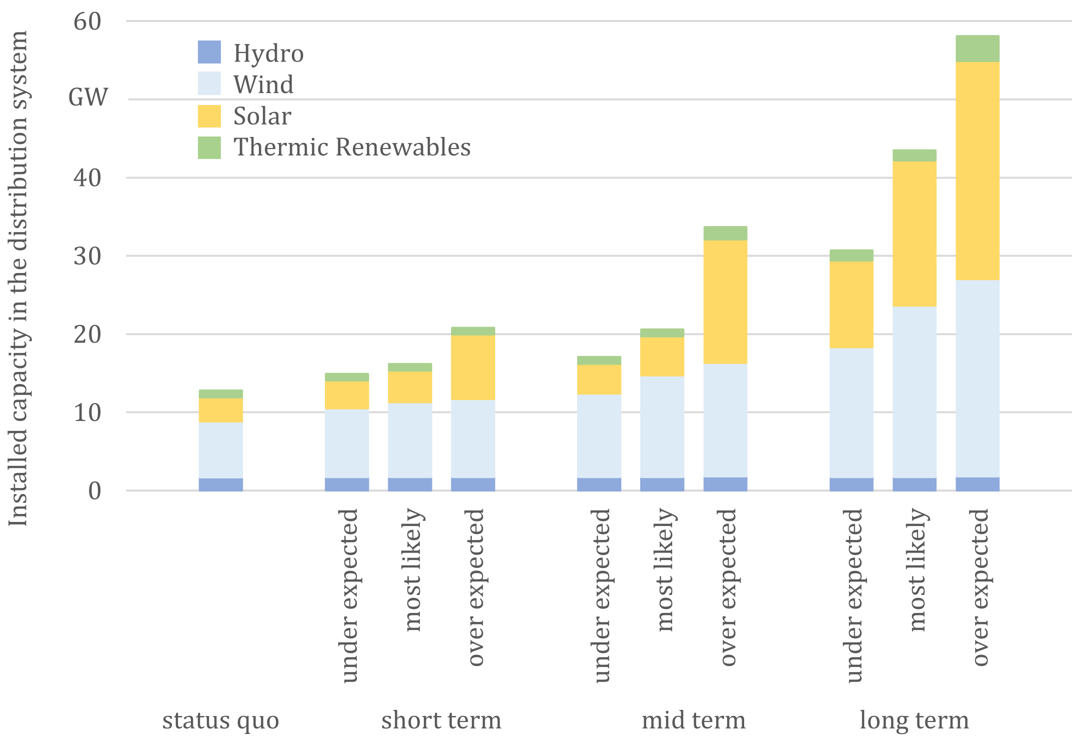

Figure 23: Scenarios for the generation capacity in French distribution systems

The main growth in capacity in France is expected from PV and wind energy, especially for the long-term time horizon.
The under-expected scenario and most-likely scenario expect a moderate growth in PV for short-term and mid-term with a higher increase in the long-term. The over-expected scenario predicts a significantly higher increase in PV capacity for all time horizons. For mid-term, the under-expected and the most-likely scenario predict an increase of 0,7 GW (23%) and 1,9 GW (62%) respectively, while the over-expected scenario predicts an increase of 12,7 GW equalling 411% of todays installed capacity.

For wind energy, the uncertainty among the different scenarios is smaller than for PV generation. The expected increase in capacity for mid-term lies between 50% (3,6 GW) of today's capacity for the under-expected and 104% (7,4 GW) for the over-expected scenario. The most-likely scenario predicts a mid-term increase of wind capacity of 5,9 GW representing 82,5% of today's capacity. For PV capacity, the difference between the under-expected and the over-expected scenario is 54% of the capacity installed today.

In case of thermoelectric renewables (mainly biomass and biogas) only the over-expected scenario is predicting a relevant increase in capacity. For mid-term, a growth of 0,7 GW representing 83% of todays installed capacity is predicted.

Both the under-expected, and most-likely scenario, show a stagnation of the hydro capacity, while in the over-expected scenario, a small growth in capacity of 6,4% (108 MW) is foreseen in the mid-term horizon.

To conclude, the increase in PV and wind capacity are the relevant components of the presented forecasts. All scenarios predict the highest increases for the mid-term and long-term time horizon. The over-expected scenario substantially exceeds the other scenarios in terms of installed PV capacity.

Demand

In terms of the evolution of demand, scenarios are only available for residential and commercial loads connected to the distribution system. In 2012 these loads accounted for an annual consumption of 296,6 TWh representing 61% of the total annual (2012) demand of 489,4 TWh in France.

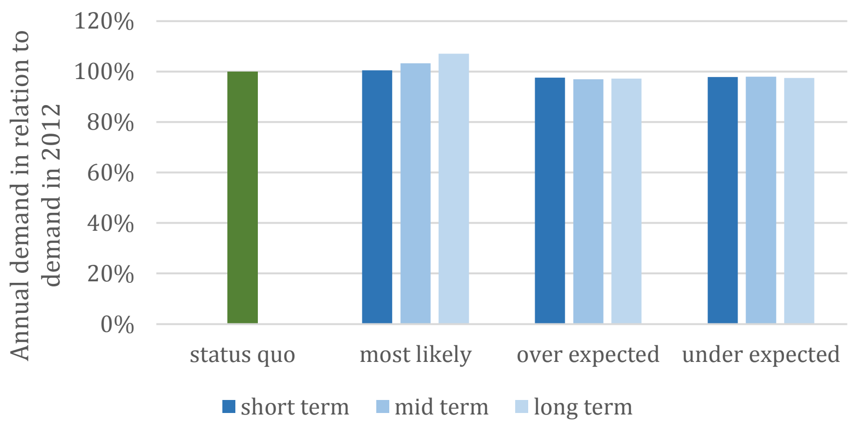

Figure 24: Demand evolution in the French distribution system (residential, commercial)

The most-likely scenario indicates a slight increase of demand of 7% for residential and commercial customers in the long-term. The over-expected and the under-expected scenarios however predict a slight decrease for the annual energy consumption of less than 3%. In both scenarios, the most-likely and the over-expected scenario, the same number of customers is expected. However, the over-expected scenario predicts a decreasing energy demand per customer resulting in an overall load decrease.

Degrees of technological freedom

At present in France, 300.000 ***smart meters*** have been installed as part of initial experiments. In 2016, about 3 million smart meters will be deployed in the distribution system. The national target is to reach an installation of 35 million smart meters by 2020[50].

Several types of ***electric storage devices*** are expected to be installed in the distribution system in the medium- and long-term time horizon. For batteries, an installed capacity of 0,5 GW mid-term and 1 GW long-term in the medium- and low-voltage system is expected. Furthermore, 1 GW of compressed air systems and 1 GW of flywheel systems are expected to be available long-term at the medium-voltage level. Another 3 GW capacity of existing domestic electric water heaters connected to water storage tanks for storing thermal energy is foreseen to be available as storage capacity at the low-voltage level.

The scenarios defined for ***electric vehicles*** present a large uncertainty in terms of the number of installed electric vehicles for future time horizons. Figure 25 shows the expected number of hybrid vehicles and electric vehicles in France.

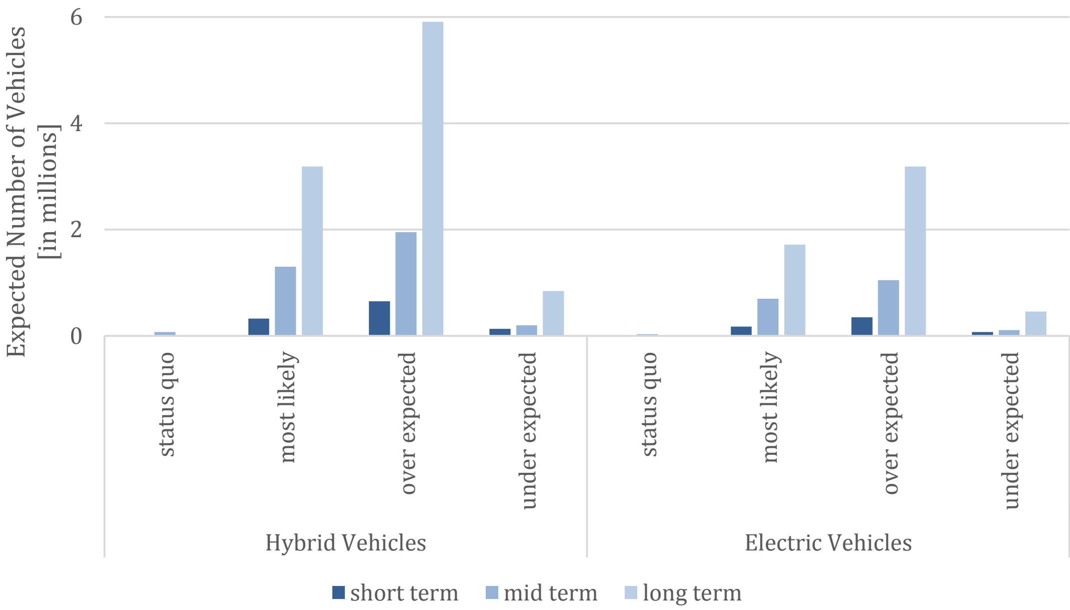

Figure 25: Scenarios for the number of electric vehicles in France

In 2013, about 70.000 ***hybrid electric vehicles*** (VHR) and 30.000 ***electric vehicles*** (VE) have been registered in France. The expected long-term number of hybrid electric vehicles varies between 0,85 million (under-expected scenario) and 5,9 million (over-expected scenario) with a most-likely value of 3,2 million. For electric vehicles, the expected number lies between 0,46 million (under-expected scenario) and 3,2 million (over-expected scenario) with a most-likely value of 1,7 million. Compared to the currently register number of (hybrid) electric vehicles, all scenarios predict a large increase in the number of vehicles. The differences between the scenarios show a degree of uncertainty.

[50] http://www.erdf.fr/Linky

4.4 UK

Generation Mix

The scenarios for the evolution of generation capacity in the UK[51] indicate a steady increase in wind, PV, biomass and hydro generation capacity. These scenarios are depicted below, in Figure 26.

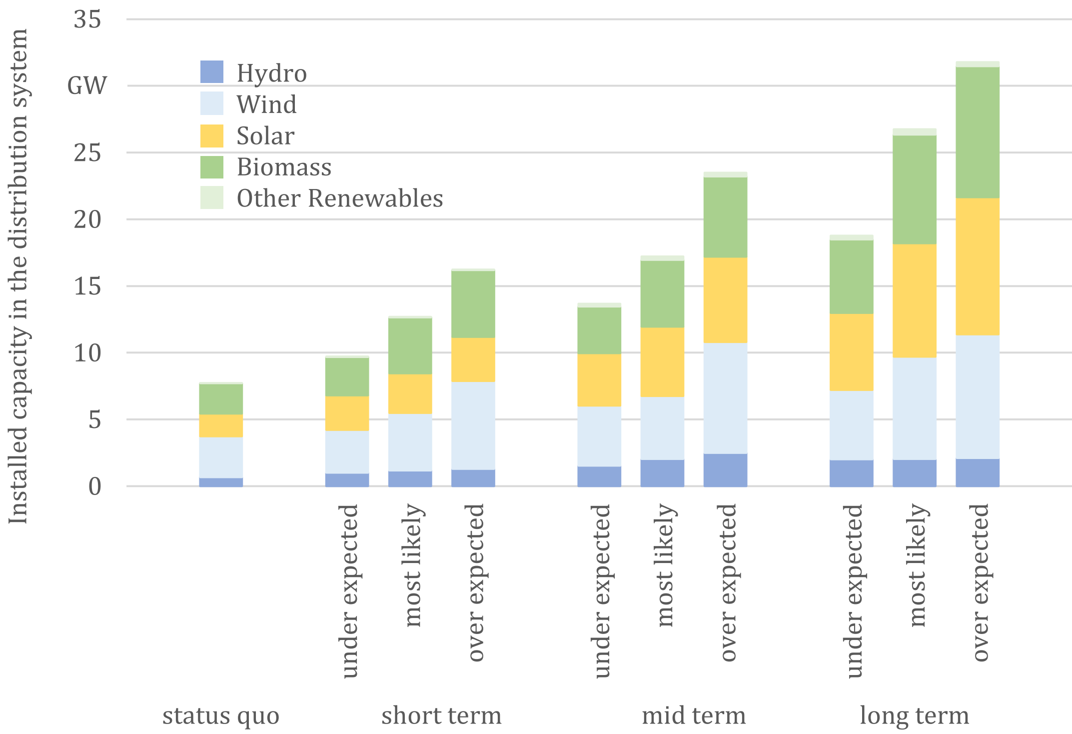

Figure 26: Scenarios for the generation capacity connected to the UK distribution system

The predicted growth of wind capacity in the distribution grid only accounts for onshore wind generation units connected to the distribution system. As such, the data for the status quo also only includes the onshore wind capacity. The expected onshore wind generation capacity connected at distribution level for the mid-term scenario varies between 4,5 GW in the under-expected and 8,3 GW in the over-expected scenario with a most-likely value of 4,7 GW. Hence, the uncertainty mainly lies in the fact that the installed capacity of wind power can be much larger compared to the most-likely scenario with an additional increase of 3,6 GW.

For PV capacity, the mid-term expectation lies between 3,9 GW (under-expected) and 6,4 GW (over-expected) representing an increase in capacity of 130% to 276% compared to the installed PV capacity in 2012. In the most-likely scenario, an installed PV capacity of 5,2 GW is foreseen, representing an increase of 206% compared to 2012.

[51] The scenarios of the UK are based on the growth projections for DRES from the UK renewable energy roadmap: 2011 by Gov.UK. It assumes that current ratios of transmission and distribution connections hold.

Furthermore, an increase of installed biomass generation capacity is foreseen in all scenarios. The most-likely scenario predicts an increase of 120%, from 2,3 GW in 2012 to 5 GW in the mid-term. The uncertainty reveals that the possible increase of biomass in mid-term compared to the status quo can only be 54% (under-expected scenario) or can be even higher of 164% (over-expected scenario).

Additionally, for the mid-term and long-term horizon, an increase of hydro generation units, mainly run of river, is predicted. The most-likely, mid-term expectation shows an increase in hydro generation from 0,66 GW to 2,03 GW equalling an increasing rate of 206%.

Other renewable technologies, mainly represented in the over-expected scenario, include marine resources such as wave and tidal energy.

4.5 Ireland

Generation Mix

The generation mix for the scenarios for the different time horizons as well as the status quo for Ireland[52] is shown in Figure 27. It can be seen that wind power is the main driver of renewables today and it will still be in the future. In all scenarios, the installed capacity of hydro power plants will remain stable. At present and in the near future, the share of solar power in Ireland is so small (< 100 kW) that it can be neglected. The same holds true for the biomass category. Note that biogas is here included in the category "Other Renewables". The installed power of hydro power plants is 25 MW, which is not significant in the power system.

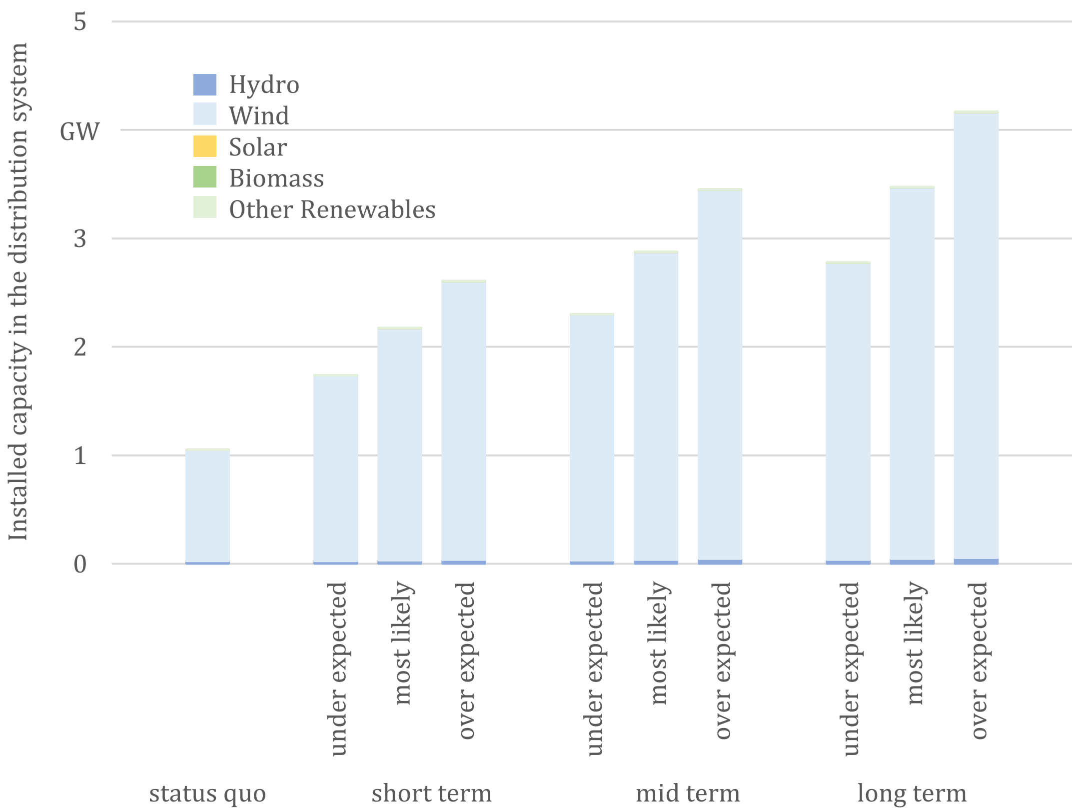

Figure 27: Scenarios for the generation capacity in Irish distribution system

At status quo the connected capacity of wind power at distribution level is around 1,02 GW. In the most-likely scenario, in the short-term, the installed power increases by 109% compared to the status quo and reaches 2,1 GW. When the under-expected scenario is considered, the installed wind power is 1,7 GW and for the over-expected scenario it is 2,6 GW. This uncertainty means that the installed power of wind generation units could be 20% higher or lower than the most-likely prediction.

[52] The scenarios given for Ireland are based on values provided by ESB Networks

In the mid-term, the installed wind capacity for the most-likely scenario increases further to a value of 2,8 GW. In the most-likely scenario the installed wind capacity in the long term is 3,4 GW, which equals 335% of the installed capacity today.

Demand

The estimated growth of demand at distribution level is 2% per annum. The demand in the distribution network at status quo is 22 TWh. Therefore the demand will increase by almost 5 TWh in 10 years.

Degrees of technological freedom

The estimated ***demand side management*** potential seen short-term in Ireland is shown in Table 2. A regulator decision on smart metering could see a large scale roll-out commencing from 2015. The exact characteristics are difficult to gauge at present. Therefore conservative values are given in the table.

Amount that can be shifted			
[percentage with respect to total demand]	high-voltage	medium-voltage	low-voltage
Residential [%]			2
Commercial [%]	3	2	1
Industrial [%]	3	2	1
Agricultural [%]	3	2	1
Range in time the demand can be shifted			
Residential [h]	1	1	1
Commercial [h]	1	1	1
Industrial [h]	1	1	1
Agricultural [h]	1	1	1

Table 2: Short-term demand side management potential in Ireland

When the mid-term horizon is considered, the values for the load shifting potential as well as the range in time the demand can be shifted double compared to Table 2. In case of the long-term time horizon the load shifting potential will again double from the values of the mid-term time horizon, but the range in time the demand can be shifted will stay the same as in the mid-term time horizon.

The ***electric vehicles*** connected today to the distribution network have a total capacity of 1 MW. For short-term it is foreseen that the amount will increase to 3 MW. The total capacity of EV increases further in the mid-term time horizon to 10 MW, which already means that there is ten times the amount of EV in the system compared to the status quo. When the long-term is considered the amount is predicted to be 20 MW in the distribution network.

The controllability of DRES foreseen for the various time horizons is displayed in Table 3. The controllability increases from the short to the long-term especially for the high and medium voltage level. In the long term almost all (95%) of the DRES connected at a high-voltage level can be controlled and even 75% are controllable in the medium-voltage.

Controllable DRES			
% refers to the total	high-voltage	medium-voltage	low-voltage
short-term [%]	50	10	0
medium-term [%]	75	50	5
long-term [%]	95	75	15

Table 3: Controllability of DRES in Ireland

4.6 Italy

Generation Mix

The expected development of the installed DRES capacity in the distribution system in Italy[53] is shown in Figure 28. It can be seen that the main driver of the future development of distribution systems in Italy is PV generation.

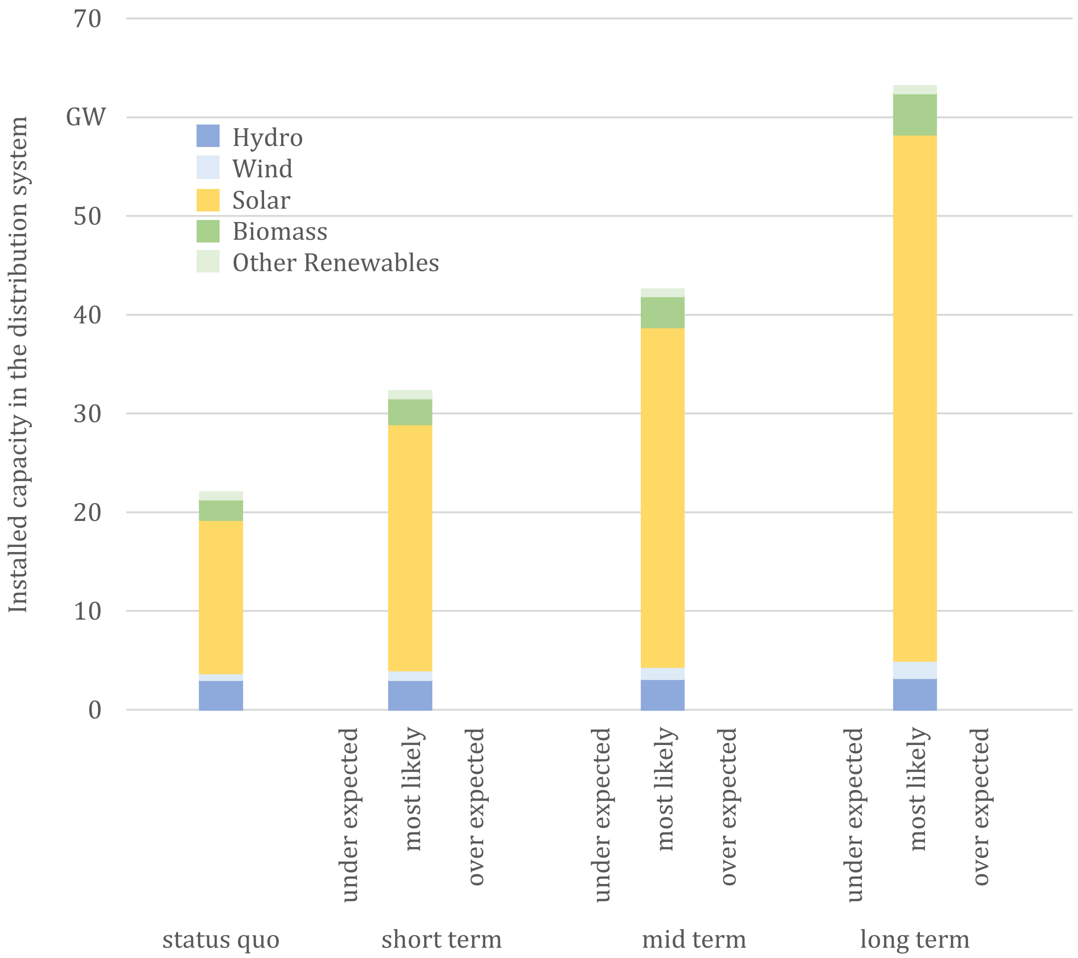

Figure 28: Scenarios for the generation capacity in Italian distribution systems

As predictions were only available on a total system level for short-term and mid-term, the scenarios are based on the following assumptions: as the share of generation technologies in the distribution system was given only for the status quo, it was assumed that the share of generation technologies does not change over time. This explains the low share of wind capacity in the distribution system, as most of the wind capacity today is installed at the high-voltage level belonging to the transmission system.
To obtain a long-term prediction, the data for status-quo and mid-term has been extrapolated linearly to the long-term time horizon.

[53] The scenario for Italy for the generation mix is predicted by the Italian Ministry Piano di Azione Nazionale. For the demand the information provided by the Italian TSO Terna is used.

In the short-term, the installed capacity of PV in the distribution system will increase from 15,5 GW in status quo to 24,9 GW. In the mid-term, the installed capacity will rise further to a value of 34,4 GW. This means that compared to the status quo the PV capacity will increase by 122%. Currently, the wind power capacity in the distribution system is 0,7 GW and will increase to 1,2 GW in mid-term. However, the total wind power capacity is expected to increase from 8,1 GW today to about 14,3 GW in the mid-term time horizon[54].

The total increase of renewable hydro power plants is expected to go from a total of 18,2 GW installed in 2012 to a forecast of 19,4 GW in the mid-term. The share of hydro power connected to the distribution system is expected to increase slightly from 3 GW today to 3,1 GW in the mid-term.

Demand

The demand in Italy was 307 TWh per year (net of losses). There are two possible scenarios for the evolution of demand. Most likely the demand will stay constant in the short-term (with a possible minor decline) and slightly increase to 320 TWh in the mid-term. Another possible (over-expected) development of demand is an increase to 317 TWh in the short-term and further to 350 TWh in mid-term[55].

Degrees of technological freedom

All the connected generators at the medium-voltage level since 2011 have the potential to be ***remote controlled***. The trend is that an increasing number of generators at the medium-voltage level will be remote controlled. Regarding the remote control of generators connected to the low voltage, today there are no technical reasons for which this technology could not be widely applied.

For the management of the low-voltage network, and on the basis of the gained experience in network automation in the medium-voltage network, pilot projects are being launched regarding the testing of ***distribution grid automation*** technologies for the ***low voltage network***. It is foreseen that for certain low voltage networks, grid automation technologies will be installed.

With regards to ***electricity storage***, Enel Distribuzione has already pinpointed a total of approximately 40 primary substations where this flexibility tool could be installed in the future. These storage units have different proposed sizes (2MW - 2MWh; 2MW – 1MWh; 1MW – 1MWh).

On innovative ***communication technologies***, there are many different options currently being explored (various pilots), that could be widely deployed in the future for the operation of the distribution system. These include WiMAX, HSDPA, LTE, and Optical Fiber.

[54] Forecast is based on the Italian Ministry Piano di Azione Nazionale which predicts an average of 2GW of new PV connections and 621MW of wind connections per year.
[55] Forecast based on TERNA predictions in report "Previsioni della domanda elettrica in Italia e Fabbisogno di Potenza necessario: ANNI 2013-2023"

Although by today there are only about 1.650 electrical vehicles registered in Italy, 700.000 ***electric vehicles*** are expected to be connected to distribution networks by 2020. Distribution companies in Italy such as Enel Distribuzione are supporting this trend with the massive installation of recharging stations throughout Italy.

Regarding ***home energy management*** systems that provide customers with new value added services ranging from simple energy consumption awareness, up to a fully integrated energy management system, these are being tested in pilot sites. If considered successful and useful, these could be spread throughout the entirety of Italy.

Voltage regulation technologies are being tested in different projects (GRID4EU, Isernia, etc.) with the goal of optimally regulating the bidirectional flow of energy generated by renewable resources on the medium voltage grid, and integrate distributed energy resources while ensuring high system reliability and security. These solutions test the regulation of both active and reactive power of distributed generators. In the future and if regulatory rules are adapted, one of the possibilities that are being explored is the possibility to modulate active power of generators in case of emergency situations (in both, the distribution and the transmission network), creating the technical basis for novel dispatching activities under new DSO roles.

4.7 Portugal

Generation Mix

Figure 29 shows the installed capacity of the generation technologies in the distribution system for Portugal[56] for the status quo as well as for the short, mid and long-term. The installed capacity will significantly increase in the future with wind power as the main driver.

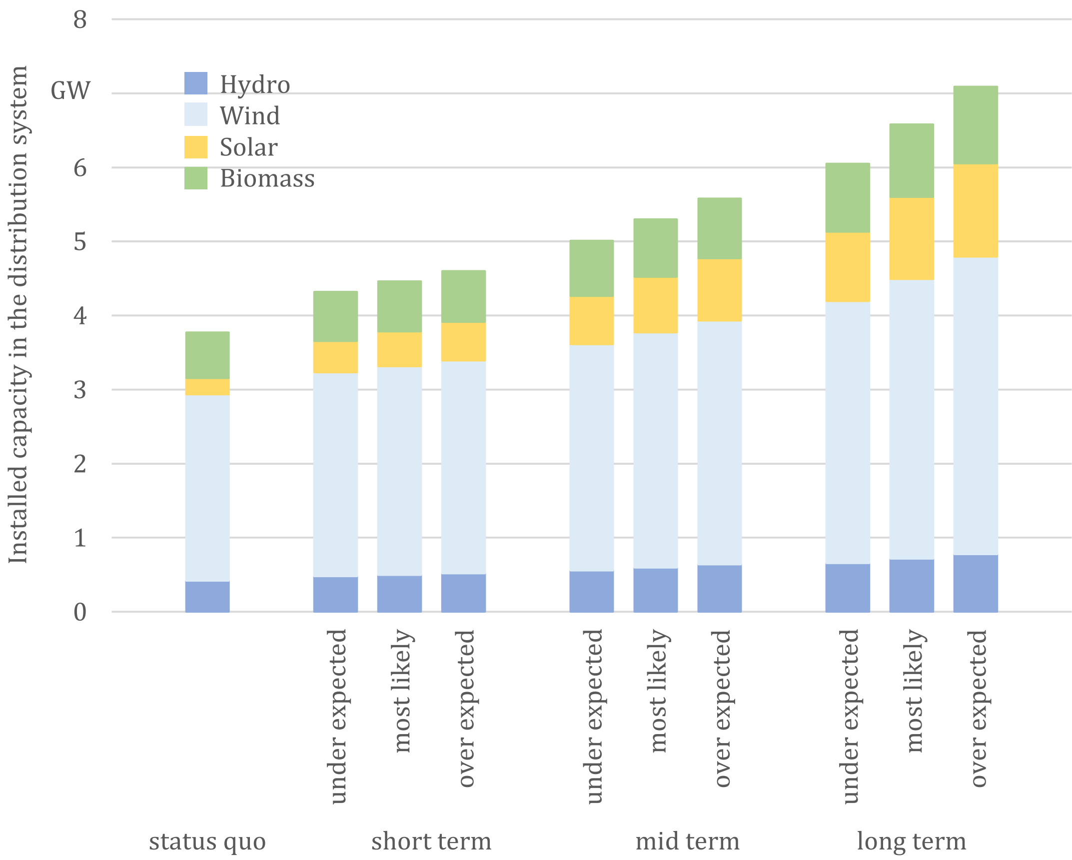

Figure 29: Scenarios for the generation capacity in Portuguese distribution system

The installed capacity of wind power plants in status quo is 2,5 GW. In the short term, the capacity increases in the most-likely scenario to 2,8 GW (+12%). The deviation between the over expected and under expected scenario from this value is 100 MW in the short-term.
In the mid-term, the installed capacity of wind power plants further increases to a value of 3,2 GW in the most-likely scenario and is 30% higher compared to the status quo. The uncertainty has a similar value than in the short-term (±100 MW). In the long-term the installed capacity reaches a value of 3.8 GW, which means an increase of 1,3 GW (+52%) compared to the status quo. The possible deviation accounts ± 250 MW.

[56] The method for defining the generation and consumption scenarios in Portugal consists in historic extrapolation based on the scenarios from the National Renewable Energy Action Plan (NREAP), defined by the Portuguese Government. This gives a reliable picture for the future generation and consumption mix since it is in line with government policies/targets and corresponding support schemes.

Regarding solar power plants, the installed capacity at status quo is 0,22 GW. A significant increase of up to 0,47 GW in the most-likely scenario is possible. The uncertainty is represented by the under and over expected scenario, which means that in the short-term, the capacity could be 50 MW higher or lower. In mid-term, the installed capacity reaches a value of 0,75 GW, which is an increase of 250% compared to the status quo. In long-term, the installed capacity reaches a value of 1,11 GW in the most-likely scenario.

For biomass, a slight increase is expected in the most-likely scenario. In mid-term, the capacity increases to 0,78 GW compared to 0,6 GW in status quo. The possible deviation from this value in the different scenarios is small. In the long-term, the installed capacity reaches a value of 0,98 GW, which equals an increase of 58%.

The installed capacity of hydro power plants is 0,42 GW in the status quo and increases in the most-likely scenario to 0,5 GW in short-term and to 0,6 GW in the mid-term and 0,72 GW in the long-term.

In Portugal, all renewable energy sources in the distribution system will increase in terms of capacity. PV has the highest increase rate with 400% growth forecast, compared to the current situation.

Demand

The demand at status quo in the distribution network of Portugal is 43 TWh. The expected values for the various time horizons as well as for the different scenarios are shown in Table 4.

Evolution of demand			
Distribution level	most-likely	over-expected	under-expected
short-term [TWh]	50.3	51.8	48.8
mid-term [TWh]	56.9	60	53.9
long-term [TWh]	73	80.7	65.7

Table 4: Demand at distribution level in Portugal

It can be seen that the demand is expected to significantly increase in all scenarios. The increase varies between 53% and 88% compared to status quo.

Degrees of technological freedom

Compared to status quo, the ***demand side management*** potential is expected to slightly increase in short-term. 40% of the industrial customers connected to high voltage and 70% of the customers connected to medium-voltage have a shift potential of 3 h. In mid-term, the demand side management potential of the industrial customers in the high-voltage level can further increase so that 90% of the customers can be shifted. Furthermore 15% of the residential customers on the low-voltage level can be shifted by 8 h and 30% of the agricultural customers of the low-voltage level can be shifted by 6 h. In long-term, the potential for the industrial customers stays the same, while the potential for the residential customers increases to 40% and for the agricultural customers to 70% with the same range in time stated for the mid-term.

In terms of ***dynamic electricity retailing tariffs***, the revision of the Tariff Code by the Portuguese Energy Regulator (ERSE) establishes that the network operators (TSO and DSO) shall present a study to ERSE on the viability of introducing dynamic tariffs. Therefore, it is possible that, by the end of this three year period ending in 2014, a regulatory framework for this type of tariffs may be in place.

There is no ***electrical storage*** potential foreseen in Portugal in the short-term. In the mid-term, the storage capacity on the high-voltage level is expected to be 20 MWh with a power of 10 MW, on the medium-voltage level 5 MWh with a maximum power of 4 MW and for the low-voltage level of 60 MW h with a power of 5 MW. The long-term values for electrical storage can further increase. This means that on the high-voltage level 600 MWh with a power of 200 MW, on the medium-voltage level 400 MWh with a power of 150 MW and on the low-voltage level 800 MW h with a power of 100 MW are available.

The currently installed capacity of ***electrical vehicles*** in Portugal is 1,7MW[57]. In the short-term, this value is forecast to increase to 64,7 MW. Also, the amount of fast charging vehicles has increased from zero to 5% with a typical power rating of 20 kW. The mid-term installed EV capacity reaches a value of 413 MW. The vehicles with a fast charging capability represent 15% of the fleet, in the mid-term, with a typical rating of 50 kW. The long-term installed capacity of EV is about 1800 MW and 30% of the vehicles are anticipated to be fast charging with a typical power rating of 50 kW.

Table 5 shows the ***controllability of DRES*** in distribution systems. Already, under the status quo, 100% of the DRES can be controlled in the high voltage level. In the long term, nearly all DRES units are expected to be controllable.

Controllable DRES			
% refers to the total	high-voltage	medium-voltage	low-voltage
status quo [%]	100	60	0
short-term [%]	100	75	0
mid-term [%]	100	80	15
long-term [%]	100	100	80

Table 5: Controllability of DRES in Portugal

Over the coming years (short-term) Portugal foresees a deployment of the ***Smart Grid technologies*** being currently developed and tested in pilot-projects (e.g. InovGrid project) at a national scale. Furthermore, the adoption of different ***communication technologies*** is expected to allow “minute-to-minute” communication between the remote units (e.g. EDP Box) and a substation controller.

[57] Considering all cars are charged in slower chargers with a simultaneity factor of 0.92.

As the information available from smart meters increases, it will be included in systems for the ***maintenance management*** of the distribution grid assets and in ***workforce management*** systems.

Transformers with ***on-load tap-changer*** (OLTC) installed in the secondary substations (MV/LV) have been identified as an important asset for voltage contro. For the short-term time horizon, this technology will be demonstrated at a pilot-test level.

Other pilot-tests in the near future deal with ***large-scale distributed storage*** mainly based on two different technologies: a redox flow battery system (a system of 5 kW and 60 kWh of storage capacity is under demonstration in the University of Évora). Furthermore, Lithium-Ion batteries with rated powers between 0,3 and 0,8 MW and storage capacities between 0,4 and 1MWh are currently under test.

Furthermore, new types of devices for ***distribution grid automation*** are expected to be deployed. These devices are similar to devices used for voltage and current sensing and are intended to be used in two different operating modes as a recloser or a sectionalizer. In the recloser mode the device works as a circuit breaker with full protection and reclosing functionality, while in sectionalizer mode, an automatic sectionalizing functionality is implemented.

Looking at a longer time horizon (mid-term) a further increase in the use of smart-grid technologies is expected: for the DRES units installed in the low-voltage a ***local control*** (i.e. droops for frequency and voltage control) will be implemented. The deployment of the previously mentioned technologies "***on-load tap-changer*** in secondary substations" and "***distributed large-scale storage technology"*** will be further implemented.

Also the ***communication technologies*** applied within the network will advance, allowing remote control (to set active and reactive power control set points) to load and micro-generation located at the LV level in case of disturbances. This also facilitates the integration of electric vehicles in the network.

Furthermore, the installed smart grid technologies or "intelligent electronic devices" (IED) in combination with the advanced communication infrastructure will increase the information available for a ***centralized monitoring*** of the distribution network including information about health, performance and history of the overall distribution grid and specific assets such as transformers and breakers. This information can improve state estimation tools and voltage control functions.

The IED can also be used for further automation in the distribution system, such as for reliable detection of islanding, coordination of the operation of OLTC, storage coordination, reactive and active power of distributed generation or to actively change the network topology.

Other devices expected to be available in the distribution system in the mid-term time horizon deal with an ***improvement in the handling of faults*** in the distribution system: ***Fault Current Indicators*** (FCI) with communication capability that improve the quality of information to give a more accurate location of a fault. ***Fault Detection Isolation and***

Restoration (FDIR) systems, using FCIs and remotely operated switches, will be installed at the primary substation level in order to provide self-healing capability that minimizes outage times, reduce technical losses and allow an increasing renewable energy penetration. The EDP Box will be capable of identifying outages in the low-voltage system and the zone where such outages occurred.

Another technology expected to be available is ***Dynamic Line Rating*** for overhead power lines at distribution system level. This technology is important for investment deferral and depends on the expected installation of temperature sensors as well as of weather sensors in substations.

For the long term time horizon, a full monitoring of the distribution network assets and complete knowledge of the LV network topology is foreseen in Portugal. This is accomplished by the installation of ***Phase Measurement Units*** at the distribution grid level and ***SCADA systems*** for the LV level with advanced functions for network topology processing and management of alarm signals including high-speed monitoring of load and generation with new communication technologies. This new SCADA system is expected to enable the ***coordinated control*** of distributed energy resources at different voltage levels of the distribution network.
In terms of ***large-scale distributed storage***, systems based on storage units owned by the DSO and small-scale distributed storages owned by domestic consumers and buildings are predicted.

The previously described new technologies are expected to improve: a centralized dispatch-center, operated by the DSO, for DRES connected to medium-voltage and low-voltage networks will be in place. Adaptive protection systems will be capable of receiving remote signals for adjusting their settings. Electric vehicles are expected to use vehicle-to-grid technology and droop control.

Home energy management systems at the consumer level will be capable of optimal control of loads and micro-generation to follow price signals or other control signals from the DSO.
Distributed FACTS, such as distributed series impedance and a distributed static series compensator, which can change the impedance of the line so as to modulate the power flow could be in place. These devices can sustain the operation of the system even during contingency conditions and can be usefully combined with storage units.

5 Analysis

The following sections analyse the presented data regarding the current situation and the future development of distribution systems in the participating countries.

As a first step, the main similarities as well as the main differences between the different countries will be identified for both, the current situation of the system and their possible evolution according to the different scenarios.

Based on these findings, the main drivers for the future evolution of distribution systems will be identified. The analysis of the drivers will take into consideration different groups of countries identified beforehand in terms of the current situation and the future development defined by the derived scenarios.

5.1 Similarities and Differences in the Considered Countries

The current situations in the distribution systems are compared based on the installed DRES capacity in the distribution systems as well as the energy generated from DRES. Furthermore, the annual energy consumption and the peak load in the total electricity system of the country have been considered.

5.1.1 Current Situation of Distribution Systems

Due to the large differences in the size of the different systems, especially in terms of total demand and total DRES generation, these values are not suitable for a direct comparison between different countries. Therefore, the ratio of DRES generation to the total energy consumption has been calculated to allow the comparison between smaller and bigger electricity systems. The DRES generation has been calculated based on the installed capacities and the full load hours given for each technology in each country. The total annual energy consumption is based on data given by ENTSO-E for each total system.

Based on this ratio, countries can be grouped into countries with a low, medium and high share of renewable energy production in the distribution network compared to the total annual energy consumption.

Figure 30 presents the total annual electrical energy consumption for each country compared to the annual energy generation from DRES connected to the distribution system.

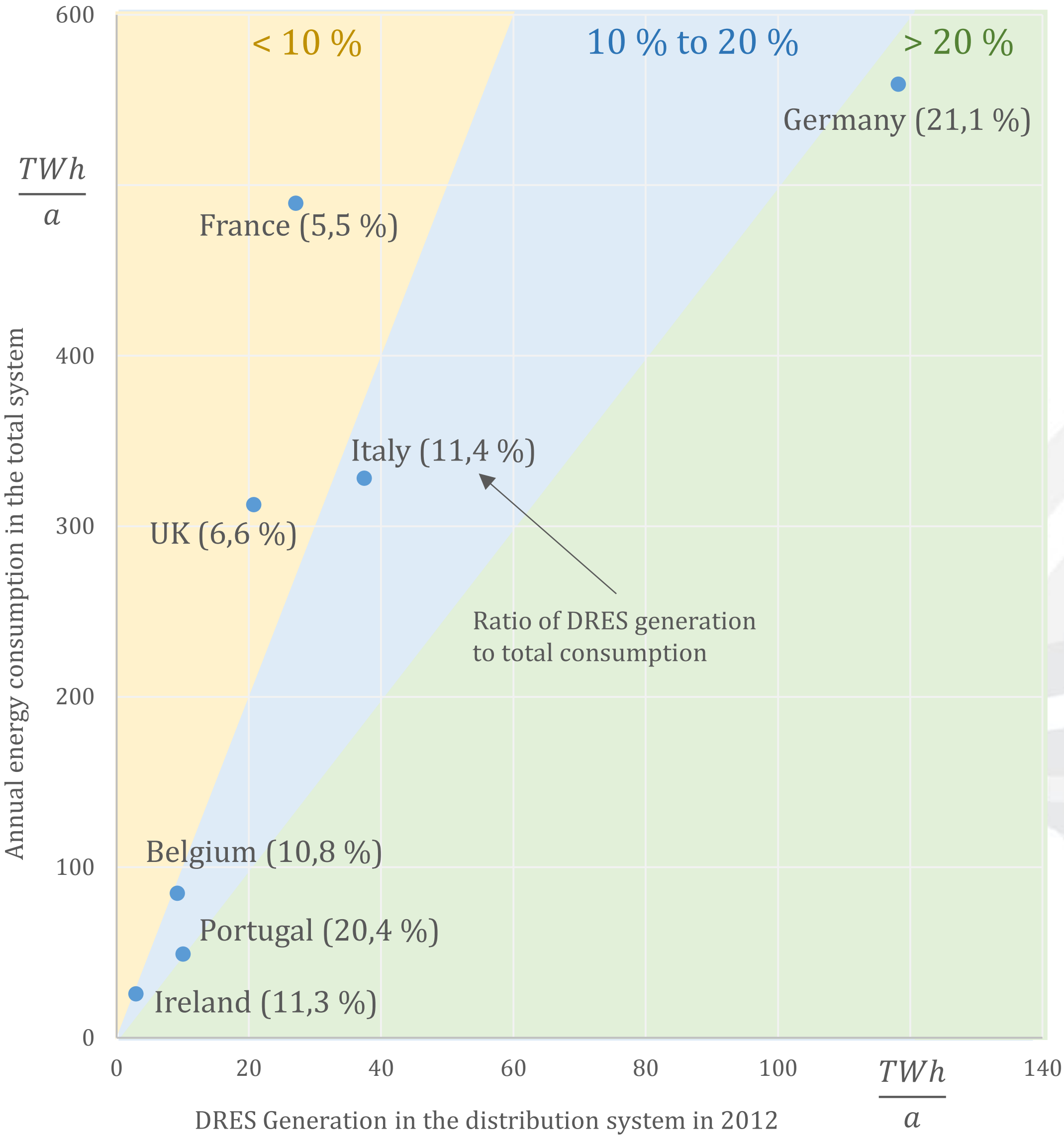

Figure 30: DRES in distribution systems compared to annual energy consumption

Germany and Portugal have a high ratio of over 20% of DRES energy generation in distribution system compared to their total annual energy consumption. Belgium, Italy and Ireland currently have a medium ratio of DRES generation to the total consumption of about 11% and the UK and France currently have a low ratio between 5% and 7%.

Another measure to describe the current situation in distribution systems is the DRES capacity connected at the distribution system level. Therefore, Figure 31 shows the installed DRES capacity at distribution system level compared to the total peak load of the respective system. The total peak load of the systems is based on the ENTSO-E data.

As mentioned previously, the absolute values are not suitable for a direct comparison due to the large difference in the size of the electrical systems. Therefore, the ratio of DRES capacity in the distribution system to the total peak load of the system has been calculated.

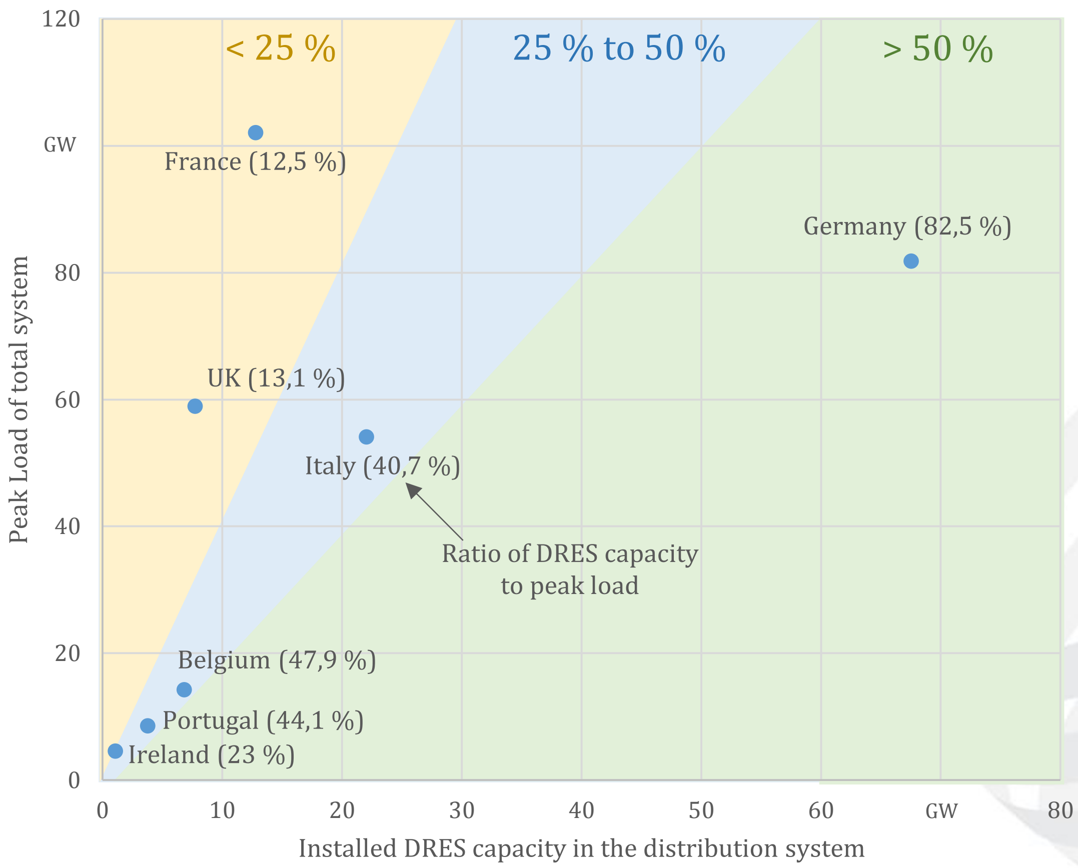

Figure 31: Installed DRES capacity in the distribution system compared to peak load

This plot shows a similar classification for the participating countries. France, UK and Ireland have a low ratio of under 25% of installed DRES capacity compared to the peak load. Belgium, Portugal and Italy have a medium ratio between 25% and 50% and Germany has a high ratio of over 80%.

5.1.2 Future Evolution of Distribution Systems

To analyse the future evolution of the distribution systems defined by the scenarios given in chapter 4, the annual growth rates for the different scenarios have been derived. The growth rates have been calculated for both, the mid-term and the long-term scenarios. The growth rates are defined by the difference between the installed capacities in the scenarios and the currently installed DRES capacities related to the currently installed capacities.

Figure 33 shows the average annual increase rate in comparison to the share of DRES energy at the total demand. The figures are shown for the most-likely scenario and the mid-term time horizon[58].

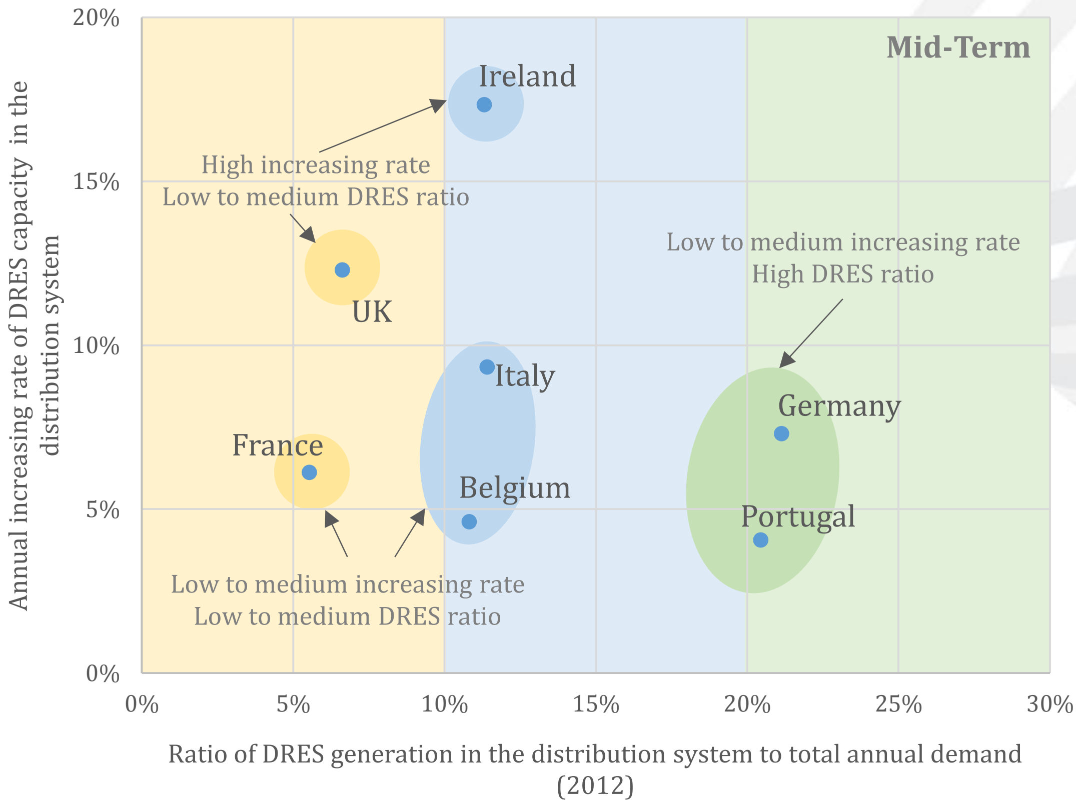

Figure 32: Increasing rate of DRES in distribution systems (most-likely scenario, mid-term)

The countries displayed in Figure 32 can thus be clustered into different groups:

The UK currently has a low ratio of DRES generation, but anticipates a high growth rate for the mid-term, in the most-likely scenario. Similar to that, Ireland currently has a medium DRES ratio and anticipates a high growth rate.

[58] For the UK, no offshore wind generation is included in the increasing rate, as no scenarios for offshore generation connected to the distribution system were available (It is assumed that offshore wind will be connected directly at transmission level)

The other countries with a low to medium DRES ratio (France, Belgium and Italy) can be further divided in countries expecting a low DRES growth rate (France and Belgium) between 4,6% and 6,1% and countries expecting a medium growth rate (Italy) of about 9%.

The countries with a high share of DRES generation in the distribution systems (Germany and Portugal) predict a low to medium growth rate of 4,1% to 7,3% for the mid-term, most-likely scenario.

The same investigation was performed for the long-term, most-likely scenario. The results, displayed in Figure 33, show slightly different results for the long-term scenario compared to the mid-term scenario.

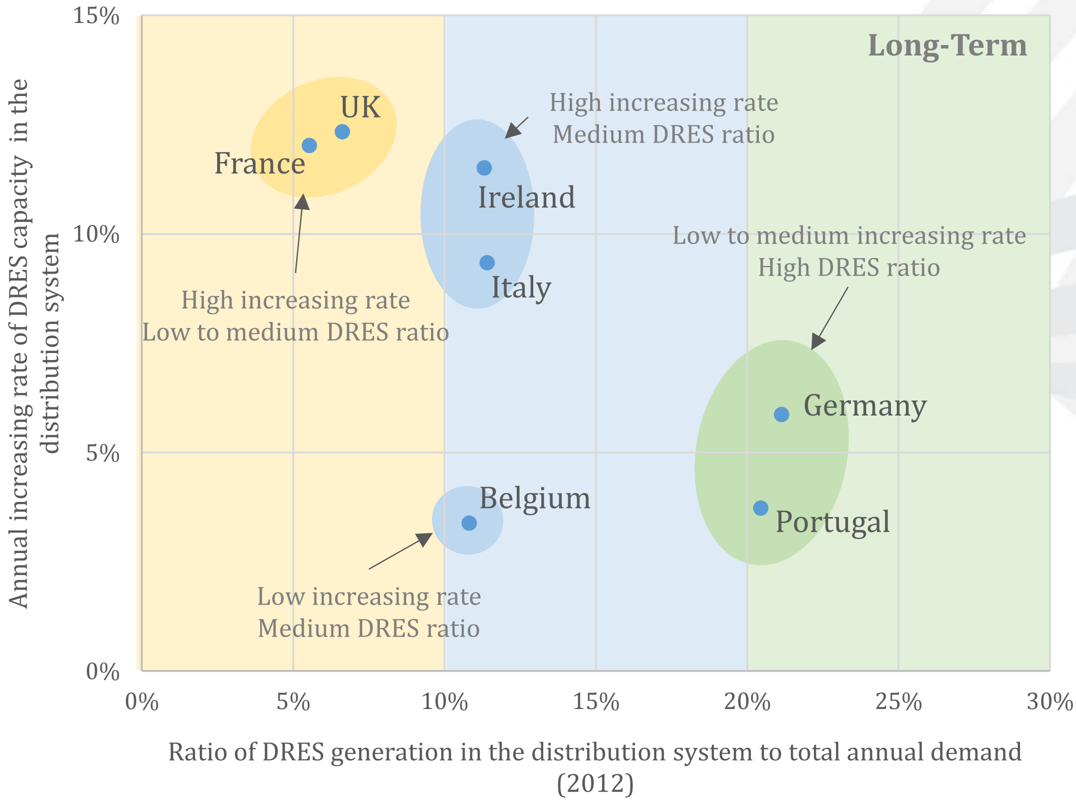

Figure 33: Increasing rate of DRES in distribution systems (most-likely scenario, long-term)

Aside from France, all countries anticipate the DRES capacities to grow faster over the mid-term horizon, with reduced growth rates in the long run.
As France shows a significantly higher growth rate for the long-term of 12% compared to the mid-term value of 6,1% and Ireland and Germany show significantly lower growth rates for the long-term, slightly different groups can be identified:

For the long-term time horizon, France and the UK can be grouped as countries with a currently low to medium share of DRES capacity but expecting high increasing rates over 9% per year.

Also Italy and Ireland, with a currently medium DRES penetration ratio, expect high long-term increasing rates between 9% and 11,5%.

Belgium expects a low increasing rate under 5% while currently having a medium DRES ratio at distribution system level.

Portugal and Germany as countries with a currently high share of DRES capacity expect a low to medium annual growth rate of DRES capacity for the long-term, most-likely scenario.

The same clustering has been performed for the alternative description of the current status of distribution systems used in 5.1.1. Figure 34 shows the growth rate of DRES capacity compared to the current ratio of DRES capacity in the distribution systems to the peak load of each country.

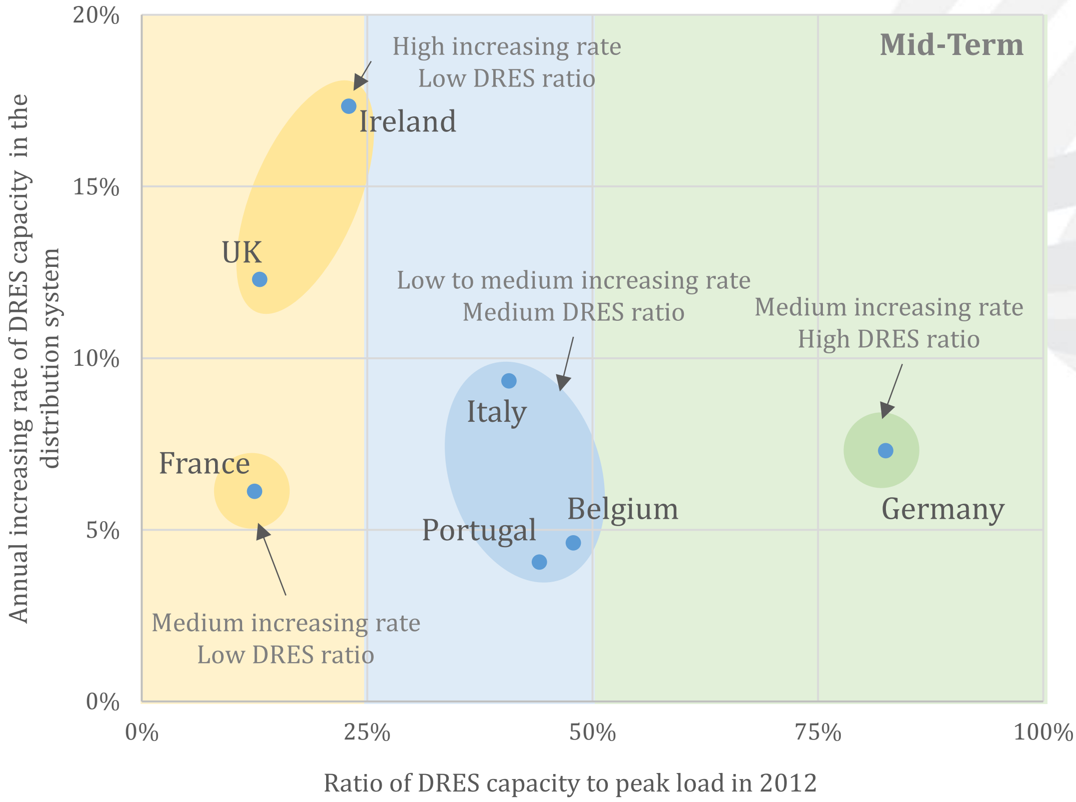

Figure 34: Increasing rate of DRES in the distribution system over DRES capacity ratio (mid-term, most-likely)

Considering the installed capacity and the peak load, some minor differences can be seen:

Germany is the country with the currently highest ratio of DRES capacity to the peak load with a value of over 80% and expects a medium growth rate.

Belgium, Portugal and Italy currently have a medium DRES capacity ratio. Portugal and Belgium predict a low growth rate under 5% while Italy anticipates a higher growth rate of over 9%.

Countries with a low current DRES capacity ratio under 25% can be further subdivided: while France predicts a low growth rate for the mid-term scenario (most-likely), Ireland and the UK anticipate high growth rates for the mid-term time-horizon.

5.2 Major Driver of the Future Evolution

This section identifies the main drivers for the future evolution of distribution systems. As the previous section has shown, the situations of distribution systems vary between different countries both in terms of current status and in terms of predicted evolution of DRES capacity.

Figure 35 shows the expected share of DRES technologies in each country for the mid-term, most-likely scenario. Two conclusions can be derived from this figure:

At first, the technological focus varies between countries from wind power driven systems in Ireland or Portugal to PV driven systems like Italy and Belgium. Other countries like UK and Germany expect a more balanced share of wind and PV capacity.

Secondly, wind power and PV are clearly the main drivers for the future network requirements as all countries expect wind and PV generation to represent the major share of DRES generation technology installed at distribution system level.

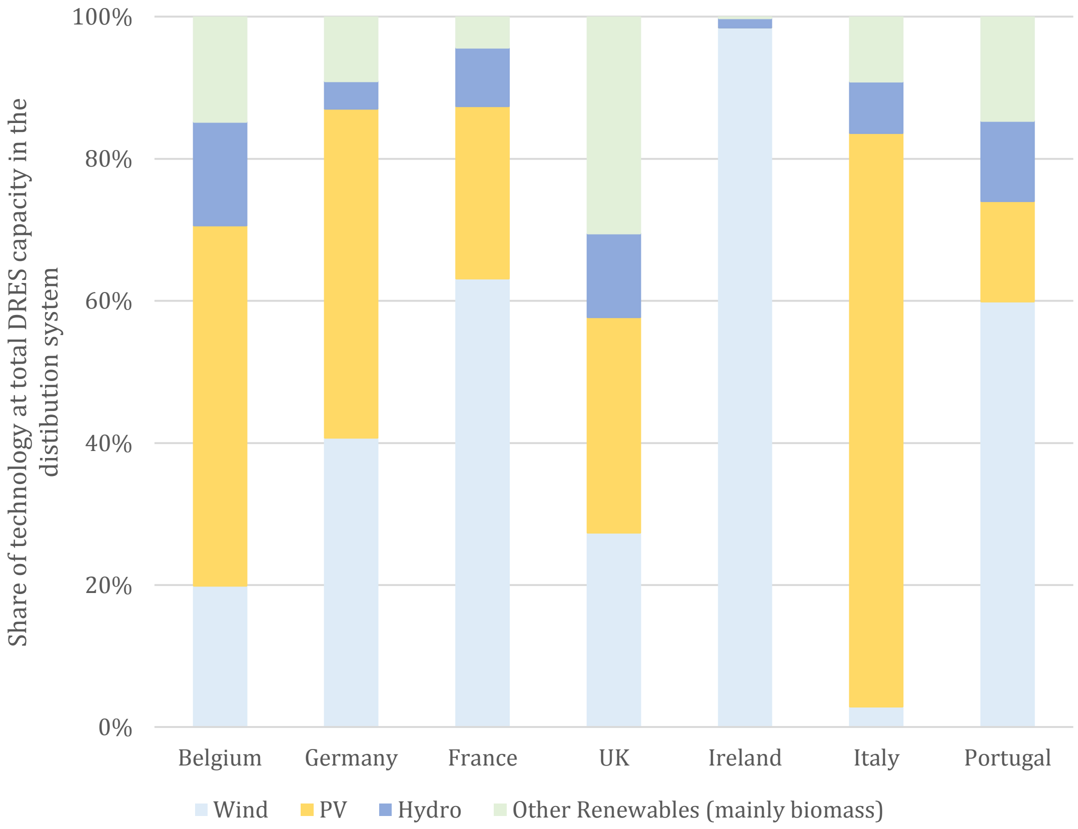

Figure 35: Share of DRES technologies in the distribution system (most-likely, mid-term)

5.3 Uncertainties in the Future Development

To cover uncertainties in the evolution of the DRES capacity connected at distribution system level, the extreme-scenarios “over-expected” and “under-expected” will be analysed in comparison to the most-likely case.

Figure 36 presents the total increase of DRES capacity in the distribution system divided by the peak load compared to the current ratio of DRES capacity in the distribution system. The increase shown on the y-axis of Figure 36 represents the absolute increase of DRES capacity over the given time horizon divided by the present peak power to allow the analysis of the absolute uncertainties of the DRES capacity growth.

For each country, three values representing the most-likely scenario, the over-expected scenario and the under-expected scenario are shown. The distances between the three points for each country are a measure for the uncertainty described by the scenario funnel in terms of the extreme scenarios. All values in Figure 36 have been calculated for the mid-term time horizon.

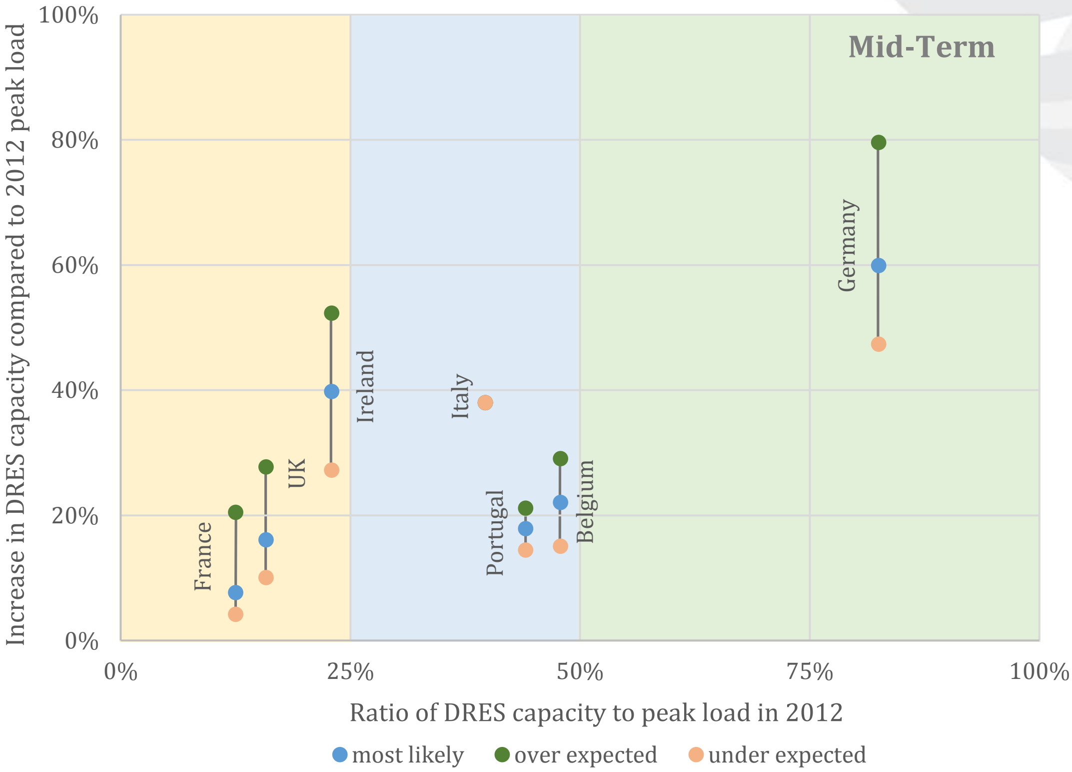

Figure 36: Increase in DRES capacity compared to ratio of DRES capacity (mid-term)

The results show that the forecast uncertainties vary between the countries: the difference between the under-expected and over-expected scenario for Germany is 32% of the current peak load. Ireland shows a difference of 25% between the over- and under-expected values. For France, Belgium and the UK, this difference is between 14% and 18%. Portugal shows a significantly smaller difference of 5% to 7% of their current peak load. As for Italy there was only a most-likely scenario available, no statement regarding the uncertainty can be made.

Regarding the uncertainties, the countries can therefore be grouped into countries with a low, a medium and a high uncertainty regarding the growth of DRES capacity in the distribution systems.

Furthermore, Figure 36 shows that the uncertainties from the most-likely scenario towards the extreme scenarios are different regarding the over- and the under-expected scenarios. Especially for France and the UK, the most-likely scenario is significantly closer to the under-expected scenario resulting in a higher uncertainty around the over-expected scenario.

PV and wind generation have been identified as the main driver of future changes in distribution systems. Therefore, the increase in wind and PV capacity divided by the peak load is displayed separately in Figure 37. Again, the uncertainty is represented by the most-likely, the over-expected and the under-expected scenario. Using this presentation, the evolution paths for each country can further be separated by the different generation technologies.

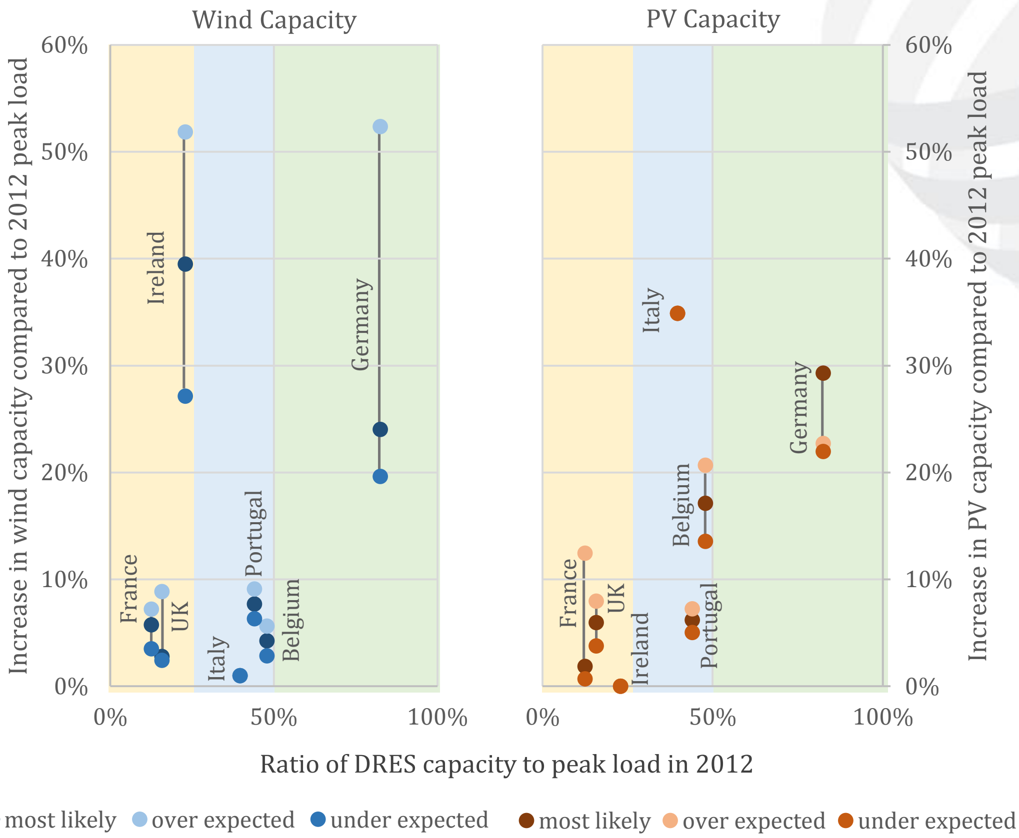

Figure 37: Increase in wind power and PV compared to DRES ratio (mid-term)

The DRES evolution of Ireland is clearly based on the increase of wind capacity while Italy shows a focus on the growth of PV capacity. Also for Belgium, the expected growth in PV capacity exceeds the growth of wind capacity. Both, Portugal and the UK, expect a similar increase of wind and PV capacity connected to the distribution system compared to their peak loads. Germany expects a high increase in wind and PV capacity compared to its peak load.

Figure 37 also highlights the difference in the uncertainties regarding the different generation technologies. Especially for Germany, the uncertainty for wind energy in the over-expected scenario is dominant. For France the uncertainty regarding the PV capacity is significant.

As mentioned before, the uncertainties not only vary within one time horizon for the different scenarios but also change for the different time horizons. Therefore, Figure 38 presents the expected capacities installed in the distribution system for the status quo and for each time horizon of the most-likely scenario.

According to Figure 38 France and the UK, for example, expect a large increase in PV capacity for the long-term scenario which is not foreseen in the mid-term scenario.

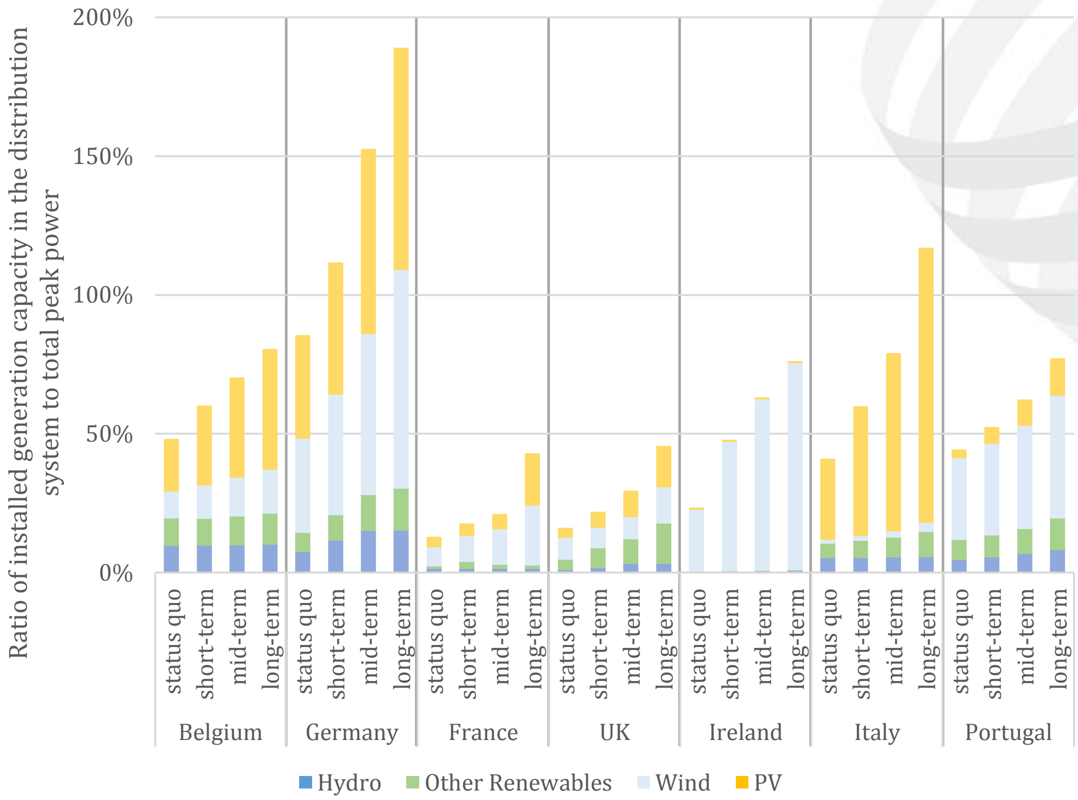

Figure 38: Ratio of installed capacity in the distribution system to the 2012 peak power

6 Summary

The objective of task 1.1 is the definition of a limited but representative set of future scenarios for the evolution of the distribution system in the participating countries.

The scenarios describe the evolution of the electricity system in Europe by quantifying the generation mix, the evolution of the demand as well as the technological degrees of freedom available. The scenarios thus define the future challenges imposed on the electricity system. The regulation framework as well as the market design and the future role of DSOs are not described in the scenarios since this is a degree of freedom requiring input from the evolvDSO project.

Each country participating in the evolvDSO project defines three scenarios to cover the uncertainty in the future development. The upper limit and the lower limit are considered with an "over-expected" and an "under-expected" scenario. Three time horizons (short-term, mid-term and long-term) show the chronological development of the scenario parameters.

The analysis of the current status in distribution systems renders differences between the analysed countries visible, especially concerning the generation mix in distribution systems. It can be seen that the share of distributed renewable energy sources (DRES) in the distribution system is a suitable attribute to characterize the countries. In Germany and Portugal, the share of DRES in the total electrical energy consumption in the country is above 20%. In Italy, Ireland, Belgium the share is between 10% and 20% while in the UK and France, the share of DRES in distribution systems compared to the annual electricity demand is currently less than10%. The major driver in the existing system differs from country to country. In Italy, for example, photovoltaic has the highest share of DRES, while Ireland and Portugal are mainly driven by wind power. In Germany and Belgium, a mix of both can be identified. Another focus of the analysis of the status quo is on the role of the distribution systems in the overall energy systems of each country concerning the generation capacity. The share of generation capacities connected to the distribution systems of the overall generation capacity is low in France, the UK, Ireland and Italy, while this share is high in Germany and Belgium. Finally, the analysis has shown that different European countries have varying understandings and definitions for distribution systems, which implies different penetrations of DRES, which therefore are not totally comparable from country to country.

The scenarios show that DRES capacity will increase significantly in all participating countries. The growth of DRES is thereby linked to the current status in each of the countries. Germany, with currently has a high penetration of DRES, proposes a medium annual growth rate, while Portugal, that also has a high DRES penetration, expects only a low growth rate. In the UK, Ireland, France and Italy, which currently possess a lower ratio of DRES, the annual growth rate is expected to be significantly higher. While most of the countries anticipate the highest increasing rates for the mid-term scenarios, France and the UK predict a higher increase for the long-term scenarios.

By looking at three different scenarios for each time horizon, the prediction of future generation in distribution systems is linked with an uncertainty, which is analysed for each country. The highest uncertainty is identified for the development wind power in Germany and Ireland. For France, the major uncertainties are given by the future development of PV capacity.

The development of demand in the countries does not vary widely in the majority of the considered countries. In France and Germany, a stagnation of load is expected, while in Belgium even a slight reduction of load is predicted. Only in Portugal the prognosis anticipate an increase of load in all scenarios.

The technological degrees of freedom are expected to develop comprehensively in the future. While electrical storage systems in distribution systems are expected to play a minor role, it is especially the controllability of the generation which opens opportunities for novel approaches to distribution system management and operation.

The presented scenarios and their analysis lay a groundwork for the further development in the evolvDSO project and draft the future needs for DSOs, which will significantly increase in the future.