INTERPLAN
INTEgrated operation PLAnning tool towards the Pan-European Network

Work Package 2

Technical assessment and regulatory status of the European electricity grid

Deliverable D2.1

Limitations in the analytical tools of the interconnected grid

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Abbreviations

APG	Austrian Power Grid
ASAP	Other self-production systems
BDEW	Bundesverband der Energiewirtschaft e.V.
BMWi	Federal Ministry for Economic Affairs and Energy
BRP	Balance Responsible Person
CERA	Cyprus Energy Regulatory Authority
CHP	Combined Heat and Power
DER	Distributed Energy Resource
DSO	Distribution System Operator
DSR	Demand Side Response
DR	Demand Response
EAC	Electricity Authority of Cyprus
EEG	Renewable Energy Law
EHV	Extra High Voltage
ERO	Energy Regulatory Office
EV	Electric Vehicle
FNN	Forum Network Technology / Network Operation
GME	Gestore dei Mercati Energetici S.p.A.
GSE	Gestore dei Servizi Energetici
IPEX	Italian Power Exchange
MGP	Day-ahead auction market
MISE	Ministry of Economic Development of Italy
MTE	Forward Physical Market
MPEG	Market for the trading of daily product
NRA	National Regulatory Authority
OLTC	On Load Tap Changer
PC	Project Coordinator
REMIT	Wholesale energy market integrity and transparency
RES	Renewable Energy Sources
RfG	Requirements for Generators
SAP	Auto production systems
SEU	Efficient User Systems
SO	System Operator
TAR	Technische Anschlusssrichtlinien
TIC	Integrated text for connections
TIDE	Integrated Text for electrical dispatching
TIME	Integrated Code of the Italian Regulatory Authority for Energy, Networks and the Environment
TISSPC	Integrated Text of simple production and consumption systems
TOR	Regulation for the technical and organisational rules for the electricity market
TSO	Transmission System Operator
UCY	University of Cyprus
VDE	Association for electrical, electronic & information technologies

Executive Summary

The purpose of this document is to cover in detail all the available tools and models including related limitations and criticalities for interconnecting the emerging technologies in the countries of the consortium extended to cover all member states. The emerging technologies would be intermittent Renewable Energy Sources (RES), storage (including EVs) and flexible demand response.

The regulations and policies applied in every country of the consortium which influence the implementation of the emerging technologies into the grid have been presented as a reference and as an assisting tool in the future steps of the project. Shortcomings to be addressed by INTERPLAN and responding national practices that are worthy of picking up to extend and replicate have been proposed by the countries of the consortium and are also presented in this report as assisting information for the following work packages. The report will also include a list of projects that address issues relevant to INTERPLAN which are conducted in the countries of the consortium.

In addition, a list of the tools, models and scenarios for interconnecting the emerging technologies to the grid are also presented and detailed. Finally, the limitations and criticalities of these tools and models are identified and documented.

1. Introduction

The goal of the INTERPLAN project is to provide an INTEgrated opeRation PLANning tool towards the pan-European network, to support the European Union in reaching the expected low-carbon targets, while maintaining the network security. A methodology for proper representation of a "clustered" model of the pan-European network will be provided, with the aim to generate grid equivalents as a growing library able to cover all relevant system connectivity possibilities occurring in the real grid, by addressing operational issues at all network levels (transmission, distribution and TSOs-DSOs interfaces). In this perspective, the chosen top-down approach will lead to an "integrated" tool, both in terms of voltage levels, going from high voltage down to low voltage up to end user, and in terms of building a bridge between static, long-term planning and considering operational issues by introducing controllers in the operation planning. Proper cluster and interface controllers will be developed to intervene in presence of criticalities, by exploiting the flexibility potentials throughout the grid.

To facilitate the work targeted through the project it is necessary to identify the current policies, regulations and practices in the Member Countries and relate these to the needs of the grid to merge with the specific characteristics of the emerging technologies: distributed intermittent RES, storage systems, EVs including smart charging and Demand Response. These findings will then be related to the required system functionalities, which is work in progress in WP3 and relate these to possible scenarios that have been put forward through parallel work in other projects and identified through parallel work in WP3. These scenarios are to be finalized in WP3 and used in WP4 and 5 for developing the targeted solutions of INTERPLAN for effectively handling the above referred emerging technologies.

The above process will lead us to real shortcomings that today the industry is facing, which will gradually grow into substantial limitations that will hinder the optimal development of the grid and its effective operation in the day to day work of System Operators. The objective of the work within Task 2.1 and reported here is to identify these shortcomings and limitations which will be needed to facilitate the development work of WPs 4 and 5.

1.1 Purpose and Scope of the Document

The main objectives of the D2.1 deliverable are the following:

- Assessment of every country of the consortium in the following topics:
  - Intermittent RES
  - Storage including EVs
  - Flexible Demand Response
- Definition of an initial list of functionalities to be analysed through INTERPLAN together with selected scenarios that were populated in WP3 from project sources in progress.
- Identification of shortcomings and gaps identified that are required to be addressed through INTERPLAN with reference to intermittent distributed generation, storage, EVs and Demand Response
- Presentation of the limitations and criticalities that need to be addressed in INTERPLAN and tested using the scenarios mentioned in this report.

1.2 Structure of the Document

In the remainder part of this report the following are covered. The methodology adapted for the compilation of this report is presented in Section 2. Country-based assessments are presented in Section 3 which cover the emerging technologies including relevant projects to INTERPLAN. Models and tools are presented in Section 4. The limitations and criticalities of the models and tools are identified in Section 5. Discussion and conclusions appear in Section 6.

2 Methodology

In this section, the procedure adapted for collecting the information of the countries of the consortium is presented.

2.1 Country Assessment

A template has been created to be completed by the countries of the consortium, in order to produce a country-based assessment. The partners who were involved in completing this template were UCY, ENEA, AIT, FRAUNHOFER and IEn. The template allowed the analysis of the current practices in all countries of the consortium through the prevailing grid rules and enacted regulations aiming to:

- Identify adapted policies in handling the three main constituents of the emerging technologies that promise to play a leading role in the years ahead, which are intermittent RES generation, storage of all technologies including EVs and flexible demand response (DR).
- Qualify shortcomings in current practices that need to be addressed in developing and operating the emerging grids.
- Identify responding practices that lead the way to the adoption of the emerging technologies referred to above, and how these can be extrapolated and adapted to play a wider role in the scenarios to be developed under INTERPLAN.

The information from each template was analysed to produce a single document representing all of the countries of the consortium regarding:

- Regulations.
- Policies-Codes.
- Shortcomings required to be addressed by INTERPLAN.
- Responding National Practices that are worthy of picking up to extend and replicate related to the following technologies:
    - Intermittent Renewable Energy Sources;
    - Storage including Electric Vehicles, heat pump solutions for heating and cooling,
    - Flexible Demand Response including Electric vehicles, heat pump solutions for heating and cooling, hot water and so on.

In addition, each country of the consortium provided a list of projects and a brief description of them which are in progress and address issues relevant to INTERPLAN and the three technology developments mentioned above.

2.2 Scenarios and their Limitations

A list of functionalities was collected to be analysed through INTERPLAN together with selected scenarios that were populated in WP3, together with their respective sources. Through this analysis, the limitations and respective criticalities of the scenarios to be investigated, including the tools and functionalities that will be of support would be identified and presented to be used as input to the following work packages for their development work.

3 Country-based assessment

Every country of the consortium has provided the related energy status, regulations, policies, shortcomings and useful responding national practices for all the emerging technologies, including projects in progress that address issues relevant to INTERPLAN and the development of the corresponding technologies. All the collected information has been analysed and is presented below.

3.1 Energy Status

3.1.1 Austria

E-control is Austria's regulator and was founded in 2001, and in 2011 was transformed into a public authority. E-control is responsible for the market functioning of electricity and gas and its monitoring and supervision.

The Austrian Transmission Grid Operator is APG (Austrian Power Grid). It is an independent control area manager and the operator of the extra-high voltage grid of the country. APG complies with the regulatory framework set by E-control.

In the beginning of April, the Austrian government published the latest draft of its future climate and energy strategy until 2030. It is planned to publish the final version in June 2018. Austria plans to cut CO_2 emissions by 36% in 2030 compared to 2005. To reach this targeted CO_2 emissions reduction, 10 lighthouse projects were defined, including an e-mobility initiative, renewable heating, 100,000 PV roof program (and small-scale storage) among others.

In Table 1, statistics of the used cable technology (over-headlines and underground cables) are given per voltage level. In Table 2, the generation portfolio of power plants in Austria is listed by technologies. In 2016, the aggregated nominal power of all installed solar PV generators surpassed the 1 GWp threshold. All PV generators installed in Austria have a nominal power below 1 MW. In the same year, the maximum generation capacity of wind parks was 2.73 GW. In Table 3, the annual electricity generation by technologies is listed. In Table 4, statistics on the transformers in the Austrian transmission grid are given. The total apparent power of all transformers was almost 73 GVA. Finally, the number of transformers in the distribution grid (MV to LV) are listed in Table 5. In total, there were 78,530 substations with a total apparent power of 31.3 GVA in the year 2016.

Table 1 - Over-head line and cable statistics in the Austrian electricity grid

Line length					
Voltage level	Over-head lines		Underground cable		Sum
	km	Share	km	Share	km
380 kV	1,371	0.6%	55	0.0%	1,426
220 kV	1,880	0.8%	7	0.0%	1,886
110 kV	6,066	2.5%	617	0.3%	6,683
from 1kV to 110 kV	25,730	10.7%	40,738	17.0%	66,468
1 kV and below	32,982	13.8%	130,04	54.3%	163,028
Total	68,029	28.4%	171,46	71.6%	239,491

Table 2 - Generation capacity in Austria

Nominal power class	**Maximum capacity in MW**							
MW	Run-of-river hydro power	Pumped-storage power	Hydro power (all)	Thermal power	Wind	PV	Geothermal	Total
Up to 1.0	438	6	443	115	20	1,031	1	1,610
1.0 to 2.5	313	26	339	81	158	-	-	578
2.5 to 5.0	230	40	271	157	691	-	-	1,119
5.0 to 10.0	216	114	330	179	323	-	-	832
Up to 10	1,197	186	1,382	533	1,192	1,031	1	4,139
10 to 20	583	192	775	337	747	-	-	1,859
20 to 30	490	266	756	231	532	-	-	1,520
30 to 40	179	200	379	307	258	-	-	1,618
40 to 50	486	188	674			-	-	
50 to 80	432	495	926	582	-	-	-	1,508
80 to 100	264	279	543	1,309	-	-	-	3,624
100 to 200	706	1,066	1,772		-	-	-	
200 to 300	1,027	1,782	2,809	4,023	-	-	-	10,932
Above 300	328	3,772	4,100		-	-	-	
Above 10	4,496	8,238	12,734	6,790	1,538	-	-	21,062
Total	**5,692**	**8,424**	**14,116**	**7,323**	**2,730**	**1,031**	**1**	**25,201**

Table 3 - Annual Energy Generation in Austria

Bottleneck capacity class	**Annual production (GWh)**							
	Run-of-river hydro power	**Pumped-storage power**	**Hydro power (all)**	**Thermal power**	**Wind**	**PV**	**Geothermal**	**Total**
Up to 1.0	1,950	18	1,968	656	26	669	0	3,320
1.0 to 2.5	1,379	108	1,487	475	205	-	-	2,168
2.5 to 5.0	1,051	143	1,194	879	1,419	-	-	3,492
5.0 to 10.0	986	307	1,292	1,140	629	-	-	3,061
Up to 10	5,366	576	5,942	3,150	2,280	669	0	12,040
10 to 20	2,680	604	3,284	1,542	1,451	-	-	6,276
20 to 30	2,305	584	2,889	1,062	984	-	-	4,935
30 to 40	825	386	1,210	938	517	-	-	5,340
40 to 50	2,276	399	2,675			-	-	
50 to 80	1,879	1,385	3,263	1,232	-	-	-	4,496
80 to 100	1,179	773	1,952	3,908	-	-	-	12,100
100 to 200	4,523	1,717	6,241		-	-	-	
200 to 300	6,191	2,920	9,111	7,212	-	-	-	22,662
Above 300	2,045	4,294	6,339		-	-	-	
All Above 10	23,903	13,061	36,964	15,893	2,951	-	-	58,484

Total	29,268	13,637	42,906	19,043	5,231	669	0	70,524

Table 4 - Overview on transformers in the transmission grid

Voltage level: HV	Number of transformers	Total apparent power in MVA
Primary voltage up to 200 kV	1,028	42,834
Primary voltage above 200 kV	87	29,945
Transformers to HV, MV or LV	1,115	72,779

Table 5 - Overview on transformers in the distribution grid

Voltage level: MV	Number of transformers	Total apparent power in MVA
Transformers to MV or LV	78,530	31,275

3.1.2 Cyprus

In Cyprus, the distribution system is operated by the DSO who is an independent entity in management and accounting terms within the vertically integrated utility of Cyprus the EAC (Electricity Authority of Cyprus). The transmission system is operated by the Transmission System Operator of Cyprus (TSO-Cyprus) which is a legally independent entity covered by the electricity law of Cyprus N.122(I)/2003-2012. EAC is the only generator using conventional fuel in Cyprus and it owns and operates 3 main power stations of a total installed capacity of 1478MW which run on imported fuel, mainly heavy fuel oil. Below the statistics of 2016 are presented (Tables 6 - 8).

Table 6 - Distribution grid in Cyprus

DISTRIBUTION EQUIPMENT					
MV Overhead Lines	km	5,860.55	37.21	11.98	5,885.78
MV Underground Cables	km	3,785.39	38.48	11.83	3,812.05
LV Overhead Lines	km	9,844.32	97.93	20.85	9,921.41
LV Underground Cables	km	5,971.78	66.43	-	6038.21
22000-11000/433/250V P.M. Transformers	No	10,239	123	35	10,327
	kVA	953,892	8,957	3,341	959,508
22000-11000/433 V GM Transformers	No	6,251	39	40	6,250
	kVA	3,500,790	25,930	3,130	3,523,590

Table 7 - Transmission grid in Cyprus

Transmission equipment	
220kV Transmission Lines operated at 132kV	
Route Length km	43.89
132kV Transmission Lines	
Route Length km	447.4
132kV Underground Cables	
Route Length km	211.74
66kV Underground Cables	

Route Length km	0.49
132kV Transmission Lines operated at 66kV	
Route Length km	42.57

Table 8 - Generation Capacity of Cyprus

Generation capacity in Cyprus	2016
Total units generated (GWh)	4,455.2
Installed capacity (MW)	1,478
Peak load (MW)	968
Thermal efficiency of generation (%)	36.3
Fuel consumption of generation (tonnes)	1,032,644
Cost of fuel (million €)	245.9
Load Factor (%)	52.7

Cyprus is aiming for 13% of RES contribution to the final energy consumption by 2020, 16% to be the contribution of electricity. In 2016, the renewable installed capacity from wind, solar and biomass was 157.5 MW, 85.7 MW and 9.7 MW, respectively.

CERA (Cyprus Energy Regulatory Authority) was established in 2003 in line with the directives of the European Union and it operates as the national independent regulatory authority for energy in Cyprus. Thus, it regulates the electricity and gas markets in Cyprus with the task of ensuring sustainable competitive markets as well as safety, quality and reliability in the energy supply. It is also responsible for the expansion policies of Cyprus in RES.

3.1.3 Germany

Germany's electric transmission system is operated by the four independent TSOs, i.e. Amprion, Transnet BW, Tennet and 50hertz. The distribution systems are operated by more than 800 DSOs, part of which have emerged from urban energy providers due to market unbundling. However, the major part of the DSOs is still not unbundled since they have less than 100,000 customers. On the other side, there are over 30 DSOs operating high voltage networks (110 kV). The grid operators are independent companies but need to comply with a variety of acts and regulations. The executive regulatory body with regards to electricity is Bundesnetzagentur (federal grid agency), which has the core task of ensuring the German electricity, gas, telecommunication, postal and rail infrastructure and networks' compliance to Energy Act, Telecommunications Act, and Postal Act.
The following table (Table 9) gives the share of installed generation capacities and electricity production in Germany per technology. The share of renewable generation in the total net generation is 33%.

Table 9: Power generation in Germany (gross capacity as of April 2018 acc. to www.energy-charts.de net generation for 2017 acc. to [1])

	Gross capacity [GW]	Net generation [TWh]
Coal	46.25	242
Nuclear	9.52	76
Gas	29.55	86
Oil	4.44	6
Solar	43.41	40

Wind	56.89	106
Hydro	5.49	20
Biomass	7.39	46
Residential Waste		6
Others		28

Table 10 shows that the great majority of RES in Germany today is connected to the distribution grids, mainly medium and high voltage. The same is the case for storage systems (excluding pump storages). Also, controllable loads available for demand side management are primarily found there. The German government aims at providing 50% of the electrical energy consumption from renewables in the year 2030, and 80% in 2050. As of 2018, seven nuclear power plants are operated in Germany. The last ones are to be switched off in 2022.

Table 10: Installed Capacity of Renewables per voltage level, 2015, acc. to Bundesnetzagentur: "Installierte EE-Leistung zum 31.12.2015 (vorläufig)"

Voltage Level		Installed Capacity
380/220 kV	Transmission Grid	4%*
110 kV	Distribution Grids	20%
10/20 kV		50%
0.4 kV		27%

* *almost only wind power*

The network line lengths in Germany are not known in detail, but only per voltage level as indicated in the Table 11. The data is for the year 2015 as provided by the Bundesverband der Energie- und Wasserwirtschaft e.V. According to [G2], 87% of the low voltage lines were underground cables at that time.

Table 11: Length of network lines per voltage level in Germany

	Length [Million km]
Low voltage	1,189
Medium voltage	0.517
High and extra high voltage	0.1179

The key responsible body for implementation of European grid codes in German national regulation is FNN (Forum Network Technology / Network Operation) at VDE (Association for electrical, electronic & information technologies), a committee for technical regulation of power grids in Germany. FNN has the task of structuring European regulation under national law on behalf of the Federal Ministry for Economic Affairs and Energy (BMWi) and in coordination with the Bundesnetzagentur. Harmonization between national rules and grid codes as well as definition of concrete technical codes of practice are part of this task. In addition, FNN publishes recommendations, studies and position papers, striving for implementation of the energy transition. With its "national implementation concept", VDE/FNN plans to transfer the relevant grid codes for all voltage levels into technical connection rules and formulate according VDE implementation rules for all energy market players. It is important to know that VDE implementation rules are not binding by law, but their application provides legal compliance since they generally define the "recognized state of the art", which is again referenced by the laws. They are also

oftentimes referenced in contracts between market players and in technical connection requirements defined by grid operators, which again makes compliance to the rules legally binding. Hence, in practice market actors will want to strictly adhere to the VDE implementation rules, giving them the status of “de-facto” binding.
The FNN/VDE technical connection rules (“Technische Anschlusssrichtlinien”, TAR) are not specifically dedicated to intermittent RES, storages or demand side management. Instead, there are TAR for each grid voltage level, and additional ones for specific topics, all of which are more or less influenced by the requirements posed by intermittent RES, storages and demand side management. The TAR for the four voltage levels - low-voltage (0.4 kV, LV), medium-voltage (10 or 20 kV, MV), high-voltage (110 kV, HV) and extra high- voltage (380 or 220 kV, EHV) are - or soon will - replace existing regulation documents, part of which were previously provided by other bodies, namely the BDEW (Bundesverband der Energiewirtschaft e.V.). Additional relevant regulation is given by national laws and acts. The Renewable Energy Law is dedicated to intermittent RES and covers storages (especially photovoltaic-battery systems) but addresses economical aspects more than technical grid operation. The Act on Disconnect-able Loads can be attributed to the topic of demand side management. Information as related to Germany found in this deliverable was compiled using the latest publicly available TAR drafts, dated between February and September 2017, as well as the latest available legislative publications.

3.1.4 Italy

The Italian electricity grid is divided into transmission grids (high and extra-high voltage energy transmission) and distribution grids (medium and low voltage energy transmission).
The HV Italian transmission grid is managed by Terna, which operates, in a natural monopoly, about 72,000 km of EHV-HV lines, by ensuring the transmission and dispatching of electricity in Italy. The TSO role is separate from the transmission asset owner. Terna - Rete Elettrica Nazionale performs the TSO role whereas Terna Rete Italia owns and manages most of the transmission assets (99.7%). Italian TSO guarantees the transmission of electricity in Italy and, additionally, has to maintain the balance between the supply and demand of electricity (dispatching) as well as ensuring the security of supply, preventing and resolving large-scale disruptions. Terna electricity transmission and dispatching services are remunerated via a tariff system established by the Italian Regulatory Authority for Energy, Networks and the Environment (Autorità di Regolazione per Energia Reti e Ambiente, ARERA) Resolutions established by the Authority are the basis for remuneration for electricity transmission (resolution No. 199/11), and dispatching (resolution No. 204/11). In total, Terna accounts approximately 3% of the total Italian electricity bills.
The Italian transmission grid is one of the most modern and technologically advanced in Europe, by integrating coordinated management automatic systems based on a complex communication network. An automatic three-hierarchical voltage control system, using unconventional regulation apparatuses, for example, ensures an improved voltage quality, networking security and operation efficiency [3].
The Italian distribution grid constitutes about 94% of overall Italian Power System Network (1,130,000 km). Italian DSOs are responsible for connecting the customer and prosumer to the distribution grid; transporting both the energy picked-up from the distribution grid and the energy put into it by the prosumers; measuring energy flows, also providing to the installation and maintenance of smart meters and load profile recording.
Since the 1990s, the market liberalization has tried to limit the monopoly in power generation, unbundling the generation, transmission, distribution and retail companies. Today, the Italian power market is fairly dispersed (approximately 140 DSOs operate the electricity distribution networks in Italy) but it is still dominated by Enel Group, the Italy’s biggest utility and also the second largest DSO in Europe with over 32 million consumers and more than 1,100,000 km lines (345,214 km MV lines, 758,387 km LV lines). Enel is the main generation company by share contribution to Italian

national generation (22.1%) and the main company in the Italian distribution market, by covering 85% of the volume of energy distributed in Italy with e-distribuzione (a company of Enel group). Enel plays thus a key role in developing the Italian distribution grids. This company started to digitize its distribution network in 2005 by adopting smart meters, by automating the electricity network and introducing modern asset management systems. It completed the rollout of smart meters in Italy in few years (ab., 32 million of smart meters in 2006), anticipating by 15 years the European regulatory mandate. The first-generation meters are now reaching the end of their expected service life and Enel is launching a second generation of smart meters for their replacement. This new generation of smart meters ("open meters") are characterized by higher performances and advanced functionalities, by allowing innovative new services that will enhance customers' participation in the energy system. With these new assets, Italy could become leader in the network digitalization sector moving an important step towards the smart grids, where smart meters are the first basic pillar. The key Italian Power Generations and Consumptions information are summarized in Tables 12 and 13.

Table 12 - Main Italian Electricity Grid Characteristics (as of 31.12.2016)

Italian Electricity Grid	**Voltage Levels**	**Total Length (approx.) [km]**	**Transformer Stations**	**Distribution Substation**
Transmission Equipment [4]				
Total		**71,085.8**	**835 Total Transformers Rated Power: 135,209 MVA**	**584**
Extra high voltage (EHV)	380 kV	11,211.4	163	
Extra high voltage (EHV)	220 kV	11,042.5	154	24
High Voltage (HV)	**150 - 120 kV**	**45,284.5**	**497**	**560**
Other High Voltage Lines	< 120 kV	3,547.4	48	
Distribution Equipment [5]				
Total Lines		**1,130,000**		
Medium Voltage (MV)	20-15 kV	350,000		
Low Voltage (LV)	400 V	780,000		
Installed Smart Meters	32,000,000 smart meter 1G 41,000,000 smart meter 2G over next 15 years (replacement + new customers)			
Primary Substations HV/MV (100% remote controlled)	2,188			
Secondary Substations MV/LV (30% rem. controlled)	441,056			

Table 13 - Installed capacity and electricity generation in Italy (as of 31.12.2016)

	Gross Capacity [MW]	Net Generation [GWh]
Total	**117,080.8**	**279,702.6**
Hydro	22,658.0	43,784.6
Thermal Power Plants of which: • Conventional • Geothermal	65,729.80 64,915.2 814.6	196,638.2
Wind	9,409.9	17,522.5
PV	19,283.2	21,757.3

Table 14 - Electricity consumption in Italy (as of 31.12.2016)

	Total [GWh]	%
Final Consumption	**295,508.3**	
Hydro	41,075.7	13.9%
Thermal Power Plants of which: • Conventional • Geothermal	65,729.80 160,165.5 5,614.7	56.1% 54.2% 1.9%
Wind	16,548.5	5.6%
PV	20,390.1	6.9%
Bioenergy	16,844.0	5.7%
Electricity Import	34,870.0	11.8%

The Italian photovoltaic market consists of a great number of small-size plants (plants number: 732,000; installed capacity: 19.3 GW at the end of the year 2016 - PV energy production during the 2016: 21.7 TWh), which are spatially distributed in the country, and mainly connected directly to the distribution system at LV level (97.4%). Only one-third of the PV production met local needs and was used on-site for local consumption [6]. This confirms the evolution of the national electricity system from few large-size plants to a great number of widespread smaller facilities, connected at LV level. Additionally, wind installations have raised some concerns regarding the network functioning. The share of wind farms installed in Southern Regions amounted to 87% at the end of the year 2016; in last years, to relieve the weaker part of the network by avoiding congestion problems, TERNA forced the curtailment of wind turbine operation in summer season. Moreover, to increase the reliability of the network, in the last five years, TERNA has installed several storage systems (both energy intensive and power intensive type) to evaluate the benefits in terms of:

- Providing ancillary services to improve the stability and resilience of the electric grid without production of curtailments (power intensive storage);
- Meeting the peak demand (energy intensive storage);
- Postponing or avoiding upgrades to the grid infrastructures.

The Italian energy storage market grows at a progressive and stable rate, estimated at 8000 new installations per year of which about 90% will be represented by all-in-one and modular single-phase solutions used for residential applications up to 6 kW [7].

The Italian electric vehicle market is currently static due the EV costs which are still high in the absence of incentive mechanisms. In Italy, during 2016, 2,800 EVs were sold, achieving the 0.16% market share over the entire Italian automotive market. This value is smaller than other European countries market share (Germany: ab. 0.7%; UK: ab. 1%; France: 1.2%; Sweden: 2.4%; Netherlands: 9.7%; Norway: 23.3% of the total registered cars at the end of 2016). The main Italian National Regulatory Authorities (NRAs) in the Energy area are:

- ARERA, which is an independent body created under the Italian Law No. 481 of 14 November 1995 for the purpose of protecting consumer’s interests and promoting the competition, efficiency and distribution of services with adequate levels of quality, through regulatory and control activities. Initially limited to electricity and natural gas, the Authority's scope of action has been extended through some regulatory interventions.
- Energy Services Manager (Gestore dei Servizi Energetici, GSE). GSE is the company with the role to pursue and achieve environmental sustainability through the two pillars of RES and energy efficiency. In detail, this state-owned company promotes and supports RES deployment, and provides support for the integration of renewable electricity generation in plants fuelled by renewable sources in Italy. The company verifies the technical features, qualifies them, and manages the proper support schemes. Its activities also include assistance to institutions in implementing their energy policies by providing studies, data, and consulting services, as well the public administration by supplying specialist services in the energy sector.
- Electricity Market Operator (Gestore dei Mercati Energetici S.p.A., GME). GME was set up GSE S.p.A., as a company wholly owned by the Ministry of Economy and Finance. GME carries out its activities in accordance with the guidelines given by the Ministry of Economic Development and the regulatory provisions issued by ARERA. GME operates power, gas and environmental markets. As part of the process of liberalization of the electricity sector, GME was initially vested with the organization and economic management of the wholesale market under the principles of neutrality, transparency, objectivity and competition. On the electricity market platform managed by GME (also known as Italian Power Exchange, IPEX), producers and purchasers sell and buy wholesale electricity. With reference to power, GME operates a forward physical market (MTE), a market for the trading of daily products (MPEG) with continuous trading mode, a day-ahead auction market (MGP), an intraday auction market (MI) based on 5 sessions. GME plays a specific role in market monitoring towards the Italian NRA, originally stemming from the Italian NRA regulation 115/2008, setting up specific provision for the monitoring of power market in Italy, and then reinforced by the provision included in Regulation (EU) No 1227/2011 on wholesale energy market integrity and transparency (REMIT).
- Ministry of Economic Development (Ministero dello Sviluppo Economico - MISE). The MISE oversees Italy’s energy policy and has the regulatory power to implement any relevant legislation passed by the Italian Parliament.

3.1.5 Poland

The distribution system is operated by five main DSOs: RWE Stoen Operator, Energa Operator, Enea Operator, PGE Dystrybucja and Tauron Dystrybucja. In the territory of the Republic of Poland, there is one TSO for electricity (PSE S.A), whose 100% of shares belong to the State Treasury. Since 2015, the rights of the State Treasury attached to PSE S.A.'s shares have been exercised by the Government Plenipotentiary for Strategic Energy Infrastructure. PSE S.A. runs business activity under a license for electricity transmission granted with the decision of the President of the Energy Regulatory Office (ERO) and valid until 31 December 2030.

PSE performs the duties of the TSO, by using its own transmission grid of the highest voltage, which consists of (as at 1 January 2018):

- 258 lines with a total length of 14,195 km, including:
- 1 line of 750 kV voltage with a length of 114 km,
- 93 lines of 400 kV voltage with a total length of 6,326 km,
- 164 lines of 220 kV voltage with a total length of 7,755 km,
- 106 extra-high voltage (EHV) substations
- under-sea 450 kV DC connection between Poland and Sweden, with a total length of 254 km (127 km belongs to PSE).

Table 15 - Power generation in Poland (as of 31.12.2017)

Generation	Installed [MW]	Net Generation [GWh]
Total	43,421	165,852
System Generation including	34,268	141,790
• Hydro generation	2,328	2,767
• Thermal generation	31,939	139,023
Wind Power and other RES	6,341	14,005
Industrial Power Plants	2,813	10,057

Total domestic consumption in 2017 reached 168 TWh, with a peak load of 26,231 MW. In 2017, electricity was imported mainly from Germany, Sweden, Lithuania and Ukraine and totaled 13,270.7 GWh.

The President of ERO is a central body of state administration nominated on the basis of the Energy Law (The Energy Law Act of 10 April 1997; Journal of Law of 1997, No. 54 item 348, as amended), responsible for regulation in energy sector as well as promotion of competition. The President of ERO regulates activities of energy enterprises aiming to balance interests of energy companies and customers. The activities undertaken by the Regulator are aimed at meeting the goals set out by the Legislator, i.e. creation of sustainable economic growth in the country, ensuring energy security, economical and rational use of fuels and energy, development of competition, counteracting negative effects of natural monopolies, environmental protection as well as fulfilling obligations resulting from international agreements.

3.2 Intermittent Renewable Energy Sources

3.2.1 Regulations

The main regulations of the countries of the consortium that have an influence or are related to intermittent RES are discussed below.

3.2.1.1 Austria

The regulation for the technical and organisational rules for the electricity market (TOR), is defined by the regulation body e-control. Currently, the TOR consists of 4 parts (A-D). The regulations system which is relevant to intermittent RES are defined in Part D, section 2 and 4. Section 2 covers the regulations for the assessment of network disturbances, and section 4 covers the operation of generating stations in parallel with the distribution grid.
In section D2, the connection assessment covers the following aspects:

- the voltage rise in a grid section
- voltage changes due to switching events
- flicker
- harmonics
- commutation notches
- single-phase connection (The nominal power is limited to 3,68 kVA for single-phase installations)
- reactive power compensation
- influence on signal transmissions in the distribution grid.

In section D4, the grid support functions are defined as below:

- Reactive power:
  - static and dynamic reactive power support
- Active power
  - P(f)
  - P(U)
- Active power setpoints

3.2.1.2 Cyprus

- Renewables up until now are entitled of dispatch priority. Current call however, and future ones will require prospective RES generators to operate through the market rules like any other generator.
- Net Metering: It involves the calculation of the difference between annual imported energy from the grid and the exported energy into the grid from the PV system installed, and the consumer is billed that difference. It includes a capacity payment reflecting the cost of using the grid as a physical storage, complemented with government levies in support of handicapped families and green electricity. The purpose of this method is to facilitate the development of PV generation behind the meter in support of the RES policies of the country.
- Auto-production: It involves the installation of PV and biomass systems, which are used in commercial and industrial units for the production of electric energy for own-use. The range of power installed is 10kW to 10MW and the maximum power of each system

cannot exceed the 80% of the maximum demand of the consumer, except for the installations that provide adequate storage systems that are allowed to go up to 100% of their maximum demand. In this tariff a capacity payment is in place for covering the cost of the grid in support of the needs of the consumer throughout the night and year. This capacity payment is further complimented with the corresponding levies for handicapped families and green electricity.

- Autonomous PV systems: It involves installations of PV systems on houses or piece of land that will not be connected to the grid.
- Grid rules of Cyprus require as mandatory all the technical requirements of the VDE and BDEW standards / codes of practice offering the quality service to the grid for the smooth penetration of intermittent PV:
  - VDE AR-N4105 and the BDEW Technical Guideline Generating Plants Connected to the Medium-Voltage Network.

3.2.1.3 Germany

Great majority of intermittent RES and storage systems (excluding pump storages) is connected to distribution grids, mainly medium and high voltage.

- The Renewable Energy Law (EEG) defines grid connection priority for RES generators: RES must be generally connected even if electricity transport makes grid reinforcement necessary
- Grid operators are allowed to control intermittent RES which are directly or indirectly connected to their grid in order to avoid grid congestions in the respective grid area, including the upstream grid (“feed-in management”). However, grid operators are obliged to ensure that the largest possible amount of electricity from renewable energies and combined heat and power can be fed into their networks.

3.2.1.4 Italy

The Italian regulations, which are relevant for intermittent RES are summarized below:

- The Renewables dispatch priority based on the Legislative Decree of 3 March 2011, no. 28.
- The Net Metering based on the TIME. - Integrated Code of ARERA provisions for the regulation of electricity metering activities.
- Auto-production based on the TISSPC - Integrated Text of simple production and consumption systems), valid for:
  - Auto-production systems (SAP): historical cooperatives with their own networks, historical consortia with their own networks and other self-production systems (ASAP)
  - ASAP: systems where a physical or legal person generates electricity and, through private connections, uses it no less than 70% per year for self-use.
  - Efficient user systems (SEU): system where one or more electricity production plants powered by RES or in high-efficiency cogeneration asset, managed by the same producer, possibly different from the end customer, are directly connected, through a private connection without obligation of connection of third parties, to the consumption unit of a single end customer.
- For autonomous systems (CEI-0-21): possibility of feeding an island network by using a production plant (also RES). The island operation is distinguished in:

  - on the user's network (admitted in all conditions);
- on the DSO network (it is never admitted, except in the cases regulated on specific request by the DSO): Energy market (Legislative Decree of 1 June 2011, no. 93):
  - Implementation of 2009/72/EC, 2009/73/EC and 2008/92/EC Directives on common rules for the internal market for electricity, and natural gas and on a community procedure for transparency of prices for industrial final consumers of gas and electricity, as well as the repeal of 2003/54/EC and 2003/55/EC Directives.

3.2.1.5 Poland

The regulations in Poland which are relevant for intermittent RES are summarized be

- Energy Law Act (dated 10.04.1997 with further amendments)
  - Rules for shaping national energy politics and conditions of supply and usage of fuels and energy, including heat
- Renewable Energy Sources Act (dated 20.02.2015)
  - Rules and conditions for electric power generated from RES, support mechanisms for RES generation, issuing of electricity origin guarantees, rules for implementation of the national plan in scope of RES, rules for international cooperation in scope of RES and international investment projects.

3.2.2 Policies-Codes

The main policies and codes of the countries of the consortium that have an influence or are related to intermittent RES are summarized below.

3.2.2.1 Austria

- TOR in particular section D2 and D4 (*https://www.e-control.at / en / marktteilnehmer/strom/marktregeln/tor*)
- The practical implementation of grid connection requirements up to the nominal voltage of 1kV may not be completely specified in detail in policies, codes or the general conditions for the mains connection. For this purpose, within the document TAEV (Technische Anschlussbedingungen für den Anschluss an öffentliche Versorgungsnetze mit Betriebsspannungen bis 1000 Volt), the technical connection conditions for grid connection to nominal voltages up to 1kV are specified.
- ÖVE/ÖNORM E 8001-4-712: "Erection of electrical installations with rated voltages up to AC 1000V and DC 1500 V"
- ÖVE R25: "Prüfanforderungen für Erzeugungseinheiten für den Anschluss an Niederspannungsnetze"; Inspection requirements for generators connected to low-voltage networks. It is foreseen, that this guideline will be published in the next month and was not available while this deliverable was written.

3.2.2.2 Cyprus

- VDE-AR-N 4105:2011-8: "Power Generation systems connected to the low-voltage distribution Network: Technical minimum requirements for the connection to and parallel operation with low-voltage distribution networks"
- DIN VDE 0126-1-1 (6-2006) for active protection of the grid from islanding.

- BDEW: Generating Plants connected to the medium voltage network: Guideline for generating plants connection to and parallel operation with the medium-voltage network, June 2008 Edition.
- IEC 60364-7-712: Title: Requirements for special installations or locations - Solar photovoltaic (PV) power supply systems.
- IEC 60364-4-44: Title: Low voltage electrical installations
- IEC/TR 60755: Title: General requirements for residual current operated protective devices.
- IEC 61400-21 and EN50160 standards need to be satisfied concerning the quality of power.
- "Technical conditions for connection to the Medium-Voltage network, May - June 2008 Issue"
- EN 62446(2009): Grid connected photovoltaic systems - Minimum requirements for system documentation, commissioning tests and inspection (IEC 62446:2009), IEC 60364 (all parts): Low-voltage electrical installations
- For the inverters of PV systems, the power factor is adjusted based on the power produced
- Low Voltage Fault Ride Through (LV-FRT) Capability does not apply for PVs connected in a Low-Voltage Network.
- Adjustment of active power based on the frequency: If the frequency of the system exceeds the limit of 50.2Hz, then the active power of the PV system will decrease by 4% for every 0.1Hz increase. If the frequency reached 51.5Hz then the PV is disconnected within 200ms.
- In cases of automatic disconnection, the re-connection of the PV system will take place after the passing of 3 minutes from the restoration of the electric power and according to a gradual increase of power which will be 10% of the maximum power per minute.

3.2.2.3 Germany

- By the Act on system services on wind turbines, operators of onshore wind turbines connected to the medium or high voltage networks need to adhere to FNN/VDE TAR. The main requirement is that during a grid fault, the grid voltage has to be stabilized by feeding a reactive current in the grid.
- In the German EHV grid, the majority or intermittent RES are on- and off shore wind power plants. VDE-AR-N 4130 contains a few special rules for them, but mainly, general rules for generators apply. For intermittent RES, general rules considering delivery of a certain active power are only valid if primary energy is sufficiently available. An exception to the latter rule is provision of balancing power. Considering active power adaptation on frequency deviations, special rules concerning the reaction time apply for wind power plants. For offshore wind power, there are additional requirements for the reactive power provision, fault ride through and active power changes because of grid security management. The switch-on of network transformers for such units is to be implemented by controlled switching.
- In the high voltage level, general requirements for generators are similar as in the EHV level, with adapted parameter values.

- For the medium voltage level, general requirements are similar, but the allowed voltage increase at the grid connection point caused by all generators and storages connected there is limited to 2%. In addition, reoccurring voltage changes caused by connected units (also loads) are limited by number per time, depending on the absolute percentage of the change. General generator rules for the medium voltage level are again very similar to the HV level. However, in quasi stationary operation, the connection times for over- and under-voltage situations are considerably shorter than in the high voltage level - in the range of seconds instead of minutes. Different from the HV regulation, the medium voltage TAR draft does not explicitly allow island operation of generators. It implicitly allows such operation but mentions that island operation capability is not a requirement. Another difference is that there are no requirements for operation in subnetworks.
- Generators in the LV grid are required to substantially take part in supporting grid operation. In undisturbed grid operation, the voltage change caused by all generators and storages connected to a low-voltage grid may not exceed ±3% at any point of common coupling, when compared to the same grid without storages and generators. The installed power of units (eventually composed of multiple generators and/or storages) may be different from the connection power agreed with the grid operator for the given point of common coupling. In that case, the power infeed must be limited to that connection power by a supervision, which eventually switches off generation. This supervision needs to monitor all three phases, and the switch-off needs to be done within 200 ms.
- In the LV grid, the requirements for grid security management are depending on the type of the unit. For photovoltaic generators, three peak active power classes are differed: (i) 0 to30 kWp (ii) 30 to100 kWp (iii) >100 kWp. For class (i), the PV operator may select either to limit the maximal active power infeed to 70% of the installed peak power, or to install a means for remote power deration by the grid operator, e.g. by ripple control. Class ii and iii generators must be equipped with such means. Class iii generators must additionally be equipped with a supervision for the current active power infeed, which can be remotely read by the grid operator. PV generators, which are extended may need to be retrofit. For CHP generators over 100 kW, the same technical means as for class iii PV generators are required. The same is the case for storages, which store energy from units according to EEG or KWKG, as well as all other generators with installed power of more than 30 kW.
- Generators and storages in the low voltage grid must contribute to frequency control with the same principles as in the medium voltage. Exceptions: on over-frequency, units must disconnect if f>51.5 Hz (in the medium voltage, they may disconnect). On under-frequency, active power reductions needed for generator protection are allowed. Finally, for low voltage grid connected units it is also allowed to reduce power infeed on overvoltage to avoid grid disconnection.

3.2.2.4 Italy

- Code for transmission, dispatching, developing and security of the grid (TERNA Grid Code) 1 November 2005, updated version (27 November 2015)
  - 1B.4.12: System services for generation plants (The SO has the right to request, for needs related to the safety of the National Electricity System, also for the

relevant generation plants powered by non-programmable RES, the following system services: Primary voltage regulation, Secondary voltage regulation.
  - 1B.5.6.1 Primary Frequency Regulation (Annex A.17 "Control systems and protection of wind power plants" and Annex A.68 "PV generation plants - minimum requirements for connection and operation in parallel with the HV network"
- Unified Text for energy production (ARERA updated version of 4 August 2017). The document contains the collection of the main provisions adopted by the Authority concerning the electricity production, with particular reference to RES and high-efficiency cogeneration plants.
- CEI 0-16: Reference technical rules for the connection of active and passive consumers to the HV and MV electrical networks of distribution Company.
- CEI 0-21: Reference technical rules for the connection of active and passive consumers to the LV electrical networks of distribution Company.

3.2.2.5 Poland

- Instruction of Transmission System Operation and Maintenance (PSE Grid Code) Terms of use, operation, maintenance and planning of the network development, Version 1.2, *https://www.pse.pl/documents/31287/fd6e904e-90de-4dda-aad5-d8486a885eec?safeargs=646f776e6c6f61643d74727565*
- II.B.3.3.3: "Technical requirements and operating conditions for wind farm": Active power control, operation depending on the frequency and voltage, switching operations and operation under disturbances in the meshed network, voltage and reactive power control, maintenance of the power quality standards, power system protection automatics, monitoring and communicating of wind farms with TSO, verification tests.

3.2.3 Responding National Practices

Responding national practices that worthy of picking up to extend and replicate regarding intermittent RES are mentioned below.

3.2.3.1 Austria

P(U), Q(U), cos(ϕ)(P), cos(ϕ) (fixed) controls and also statistical approaches (voltage will remain with a confidence interval of X% below the limits) for the connection assessments are valid and described in the technical and organizational rules defined by the regulator. The P(U)-control allowed to increase the hosting capacity of distribution grids significantly.

3.2.3.2 Cyprus

Cyprus has no specific national practices that respond adequately to the emerging technologies discussed in this chapter or that can be classified as best practice and worth to be noted here.

3.2.3.3 Germany

In Germany, first activity of adapting grid codes to the requirements caused by the increased share of renewables was started in the early 2000s [1]. Since then, new regulation was issued demanding i.e. fault ride through, voltage and frequency support and extended control and supervision capabilities for RES generators. Partly, existing generators needed to be retrofitted with according technical means. This has led to significant additional cost.

Hence as of today, all regulation aspects mentioned in subchapter 3.2.2.3 refer to national practices that respond to the emerging technologies. Ongoing activities picking up and extending those practices include enhancing the DSO/TSO interaction for improving stability of supply, cellular operation of grids, SCADA and state supervision on all grid levels and (in the transmission grid) dynamic line loading.
The general need for further development of regulation is also addressed by the roadmap “From grid to system” published by the German regulation body FNN. The paper highlights upcoming FNN activities related to the energy transition until 2021. Based on the goal of the German government to increase the share of renewables for electricity supply to 80% until the year 2050, various high-level activities are defined which could be picked up by INTERPLAN.

3.2.3.4 Italy

In Italy, to expand the scope of European DER connection standards, the technical specifications in CEI 0-21 for LV connections and CEI 0-16 for MV specify that all DER generators have to participate in voltage control [LV connection - Direct control of Q(U): >11.08 kW]. However, for wind generators the requirements are not defined yet.

3.2.3.5 Poland

In Poland, system operators are obliged to publish values of available power that can be connected in each node without causing overloading or voltage problems. One way to calculate this power is to use the concept of coherent nodes, which groups the nodes based on given criterion. This method can also be used to identify parts of the network that can be substituted by simplified equivalent.

3.3 Storage

3.3.1 Regulations

The main regulations of the countries of the consortium that have an influence or are related to storage, electric vehicles, and heat pump solutions for heating and cooling are listed below.

3.3.1.1 Austria

- No specific regulations exist regarding storage at the moment. Therefore, it is considered as generator with the rated power for power injection and as load, respectively, according to the TOR (technical and organizational rules) OVE R20 R 20:2016-11-01: "Stationary electrical energy storage systems intended for fixed connection to the low voltage grid"
- Heat pumps for household usage have a typically rating of 2 to 3kW. According to the TOR, no specific connection assessments are required. Nevertheless, the highest rating for single-phase connected heat pumps is limited. Furthermore, since the initial starting current of the heat pumps can be significantly higher than the nominal current, DSOs want to capture the number of installed heat pumps. Therefore, special tariffs are offered to provide an incentive for heat pump owners to register their devices.

3.3.1.2 Cyprus

- No regulations exist regarding storage
- Limited electric charging points but spread throughout Cyprus with a central system that offers all automated facilities to manage charging options and variations in tariffs.

- E-charging is allowed using the normal commercial tariff system.

3.3.1.3 Germany

- German regulation defines three basic operation modes for storages: (i) operation as energy consumers, (ii) operation as energy producers or (iii) operation within a customer island grid disconnected from the public grid. Most EHV and HV general rules for generators also apply to storages. This is particularly the case for frequency support.
- A specific part of the regulation considers the origin of the stored energy. If the stored energy is attributable for collecting feed-in compensation, it must be separately measured per type of primary energy source. It is generally forbidden to use the storage to collect feed-in compensation (e.g. according to EEG or KWKG) for energy which was previously sourced from the public network. There is a FNN application note for connection and operation of storages at the low voltage grid. For stationary storages, the customer also needs to provide a datasheet to the grid operator. The data sheet i.a. includes information about phase connection type, storage capacity, protection, nominal powers, connection concept, and implementation of active power limitation. Storage units may take part in a demand side management according to specifications of the grid operator. Regarding asymmetry, the rules mentioned above are to be respected when storages are connected single phased even when a generator unit is connected at the same point of common coupling. In order to ensure this, a measurement and control system which limits the total asymmetry for generation and storage may be used, involving also communicative coupling between storage and generator. A storage unit may have to be equipped with a means of derating active power infeed if required so by specific laws (e.g. EEG)
- Chapter 8.10 of VDE-AR-N 4120 is dedicated to special requirements to the operation of storages in the HV grid. In general, three operation modes are differed: (i) charging from the public network or a customer owned generator, (ii) energy delivery into the public or customer owned grid and (iii) operation in the customer island grid. It is generally forbidden to use the storage to collect feed-in compensation (e.g. according to EEG or KWKG) for energy which was previously sourced from the public network. If the storage was charged from customer owned generators using energy sources for which such compensation is provided, then the stored energy must be separately measured per type of primary energy source. To obtain the compensation if storage and generator are connected to the same point of common coupling, either the storage must not be charged from the public grid, or it must be technically ensured that charging energy obtained from the public grid is not re-fed in.
- For the LV grid, VDE-AR-N 4100 specifies that for storages and charging units for electric vehicles with input current of not more than 75 A, requirements for grid feedback, harmonics and flicker are covered in DIN EN 61000. For such units with higher input current, the TAR defines permitted harmonic currents. Also, storages must reduce their charging power in case of under-frequency, and - if possible by the state of charge - even have to feed power back into the grid, even if they are not allowed to do so in normal grid operation. Notably, the last rule is not yet present in the medium voltage TAR.
- Chapter 10.6 of VDE-AR-N 4100 contains specific regulation for electric vehicle charging units. Such units are required to fulfil VDE-AR-N 4105 with regards to reactive power provision during discharging. During charging, fixed cos phi ranges are to be kept depending on the current active power. If the charging station’s nominal apparent power

is higher than 4,6 kVA, the grid operator may also define a method for reactive power control (e.g. Q(U), cos phi (P) or fixed cos phi) for the charging operation mode. For implementation, the norm DIN EN ISO 17409 is relevant, which specifies electric (safety) requirements for EV which are connected to an external power supply by cable. For charging stations with nominal power over 12 kVA, the grid operator may deny connection unless they are equipped with a controller which enhances grid integration and accordingly allows for shut-down of the charging station by the grid operator in case of emergency.

- With regards to active power provision during over- and under-frequency and reactive power provision, storages in the low voltage grid are handled like generators according to VDE-AR-4105 in case they are discharged. While charging, cos phi is limited to 0.95 (inductive)..1. Related to this, charging applications for storages (be it stationary or mobile) are to be equipped with controllable power such that the power reacts to over- and under-frequency.

3.3.1.4 Italy

The Italian electricity system is characterized by a structural transition described in 2015-2018 Triennial Strategic Plan of ARERA, based on the decentralization of energy production and on the development and deployment of plants powered by non-programmable RES, also for self-consumption. This evolution is today accompanied by a technological development that is difficult to foresee, which could lead to a significant development of storage systems or new uses in the transport sector (diffusion of electric vehicles) or in thermal uses (diffusion of electric heat pumps), up to the possibility for the demand to participate actively in the energy market and / or services on a large scale (demand side response). In this highly dynamic scenario, which has a significant impact both on the technical management of the system and on the market structures, safety remains at the center of the regulatory priorities, in terms of both the operational security of the system in the short-term and in terms of adequacy of the system in the long-term.

- With specific reference to the storage, the Concession for the transmission and dispatching of electricity in the national territory, of which Terna is the owner, provides that the Concessionaire can build and manage electrical storage plants in order to guarantee the security of the National Electricity System and its proper functioning, as well as the maximum exploitation of power generation from RES and the procurement of resources for dispatching services. The Legislative Decree of 3 March 2011, no. 28 and the Legislative Decree of 1 June 2011, no. 93 thus follow up the extension of the concession activity, providing for the possibility to Terna to include battery storage facilities in its National Transmission Grid Development Plan. Through the Resolution 288/2012/R/eel and the related Determination n.08/2012, the Authority has specified the minimum and optional requirements for the selection of pilot projects investigating the experimental analysis of energy storage, as well as the minimum requirements for submitting applications. The Resolution 66/2013/R/eel of 21 February 2013 thus approved the pilot projects presented by Terna included in the 35 MW program planned in the 2011 Development Plan and approved by the Ministry for Economic Development (MiSE) on 2 October 2012. The Resolution 43/2013/R/eel of 11 February 2013 approved the Pilot Projects "PowerIntensive" presented by Terna and included in the first phase (16 MW) envisaged in the 2012 Defense Plan and approved by the Ministry on 2 October 2012.

The CEI 0-16 and CEI 0-21 standards defining dispositions at National level for the connection of passive and active users to HV and MV networks (CEI 0-16) and LV ones (CEI 0-21) have been updated to include the aspects related to electric storage systems. One of the first updates (on December 2013) included the regulations for the definition of electric storage system, connection schemes, as well as the characteristics and the placement of metering systems. On December 2014, these regulations were further updated through proper variations, by including the network services required by the storage, dispositions regarding the capability features, and for the CEI 0-16 the trial modes to be applied to prove the compliance of the storage systems to the standard requirements. The related new legislation and regulatory measures (Resolutions 574/2014/R/eel and 642/2014/R/eel) led to a well-defined technical/regulatory framework for storage. In detail, with Resolution 574/2014/R/eel, the Authority defined the methods for integration in the electrical system of storage systems made by subjects different from the System Operators (SOs), by extending the same regulation to all types of storage systems (already previously applied to pumped-storage). In defining this regulation, the Authority did not introduce any distinction between the different technologies for storage so as not to promote the development of some solutions to the detriment of others. Therefore, from the regulatory point of view, there are no differences between electrochemical storage, pumped-storage plants or other solutions. In addition, the Authority defined that the storage systems are treated as individual generation plants or generation groups that constitute a generation plant (if present), since they can inject electricity into the grid. Moreover, this choice, with reference to the market, allows the easier integration of storage with plants powered by non-programmable RES. This approach represents a prime example of *technology neutral regulation*, as a key principle that will inspire the evolution of the regulation of services for the electricity system in the near future. The Resolution 642/2014/R/eel, published on December 2014, prescribed the application of the technical requirements defined in the Technical Rules for Connection to the electric storage systems, for which a request for connection to the network is presented since 21 November 2014.

- With the Resolution ARG/elt 56/10, the Authority defined the regulations for connection of EVs and heat pumps for residential applications. This Resolution contains the modifications of Annexes A and B related to the deliberation of ARERA of 29 December 2007, no. 348/07. In detail for EVs, the Authority introduced the tariff for the private charging occurring directly at private garage or condominium parking, and eliminated the regulatory constraints getting in the way the predisposition of charging stations in private places. Based on the previous regulation, it was forbidden for residential consumers having a charging station in the own apartment. Instead, now it is possible to request to energy providers more supply points, each of them with its meter system, to be used as charging stations. This regulation is also valid for industry areas used as parking. The Authority planned also to apply the same transport tariff to the charging stations for all types of consumers, whereas the energy price can vary depending on the economic offer which will be selected among those of the different providers.
- With specific reference to the heat pumps, in order to favor their deployment and the achievement of the related energy savings, the Authority disposes the elimination of the available power constraint (paragraph 5.2 of the Integrated text for connections ((TIC), which today does not allow the separate supply of heat pumps compared to the main supply for domestic utilities with available power larger than 3.3 kW. Moreover, it

provides for the possibility of using the same withdrawal point used for the supply of heat pumps for space heating purposes, also for the supply of private charging infrastructures for EVs.

3.3.1.5 Poland

- Renewable Energy Sources Act (dated 20.02.2015): This act mentions energy storage only as a part of a RES installation and does not provide any specific rules regarding energy storage itself.
- Power Market Act (dated 03.01.2018): Organisation of the Power Market and rules for availability and provision of additional electric power during periods in which power system stability is in danger
- Electromobility and Alternative Fuels Act (dated 11.01.2018): It introduces changes to the Energy Law Act with a reference to EVs and energy storage:
  - addition of following definitions: energy storage, public charging point, infrastructure for charging public transportation vehicles
  - energy storage services shall be provided in accordance to a relevant agreement
  - supply of electric power through energy storage shall be reliable and compliant with quality requirements

3.3.2 Policies-Codes

The main policies and codes of the countries of the consortium that have an influence or are related to storage (including electric vehicles, heat pump solutions for heating and cooling) are listed below.

3.3.2.1 Austria

- VDE 0100 part 722 for charging points
- DIN EN 61851 for all-charging aspects
- VDE-AR-E 2122-4-1 inductive charging
- VDE-AR-N 4102 charging stations
- TAEV requirements for grid connection to nominal voltages up to 1kV which are not specified in detail in policies, codes or the general conditions for the mains connection and its use.
- TOR (technical and organizational rules)

3.3.2.2 Cyprus

There are no policies or codes in place for storage in Cyprus.

3.3.2.3 Germany

- Great majority of intermittent renewable energy resources (RES) and storage systems (excluding pump storages) are connected to distribution grids, mainly medium and high voltage.
- Generators and storages in the low voltage grid must contribute to frequency control with the same principles as in the medium voltage. Exceptions:
  - On over-frequency, units must disconnect if f>51,5 Hz (in the medium voltage, they may disconnect).

  - On under-frequency, active power reductions needed for generator protection are allowed.
  - Finally, for low voltage grid connected units it is also allowed to reduce power infeed on overvoltage in order to avoid grid disconnection.
- VDE-AR-N 4105 proposes several metering connection schemes for PV and PV battery systems in the low voltage network.

3.3.2.4 Italy

Storage:

- CEI 0-16: Reference technical rules for the connection of active and passive consumers to the HV and MV electrical networks of distribution Company (updated version for electric storage rev 2 2016/07)
- CEI 0-21: Reference technical rules for the connection of active and passive consumers to the LV electrical networks of distribution Company (updated version for electric storage rev 2 2016/07).

Electric Vehicles:

- CEI EN 61851: For all charging aspects for EVs
- CEI EN 62196: For connection points of charging stations
- CEI EN 61439-7: For charging electrical switchboards
- CEI 64-8-7-722: For electrical installations for charging
- CEI 20-106: For charging cables

3.3.2.5 Poland

Storage encompassing pumped-storage hydro power plants is subjected to the same provisions of the grid code that applies to the conventional generation:

- Instruction of Transmission System Operation and Maintenance (PSE Grid Code)
- Terms of use, operation, maintenance and planning of the network development, Version 1.2, https://www.pse.pl/documents/31287/fd6e904e-90de-4dda-aad5-d8486a885eec?safeargs=646f776e6c6f61643d74727565
- Grid codes specific for EVs are not available for as EVs are present on a very small scale in Poland.
- There are no specific policies or codes regarding electric supply of heat pumps even though heat pumps are relatively popular in Poland (more than 136000 of units installed by the end of 2016). There are policies and codes regarding non-electrical aspects of heat pumps installation.

3.3.3 Responding National Practices

Responding national practices that worthy of picking up to extend and replicate regarding storage, are mentioned below only for Italy, since in the rest of the countries no specific practices can be classified as best practice worthy of replication. Moreover
, no national practices worthy to be replicated are found for electric vehicles and heat pumps.

3.3.3.1 Italy

- The storage systems are treated as individual generation plants or generation group, since they can inject electricity into the grid.
- The methods for integration in the electrical system of storage systems made by subjects different from the System Operators are the same for all types of storage systems. In defining this regulation, there is no distinction between the different technologies for storage in order not to promote the development of some solutions to the detriment of others. From the regulatory point of view, there are no differences between electrochemical storage, pumped-storage plants or other solutions. This approach represents a prime example of technology neutral regulation, as a key principle that will inspire the evolution of the regulation of services for the electricity system in the near future.
- The technical specifications in CEI 0-21 for LV connections specify that storage systems must participate in voltage control (section 8.5.2 - CEI 0-21) and frequency control (active power regulation and active power limitation for voltage values close to 110% (section 8.5.3). In addition, the storage charging/discharging cycles must be controllable/ interruptible.

3.4 Flexible Demand Response

3.4.1 Regulations

The main regulations of the countries of the consortium that have an influence or are related to flexible demand response are shown below. The countries Cyprus, Germany and Austria have no regulations for flexible DR.

3.4.1.1 Austria

Currently DR is not covered by regulation nor the Grid Rules or the Market Rules of the country

3.4.1.2 Cyprus

Currently DR is not covered by regulation nor the Grid Rules or the Market Rules of the country. It is currently being discussed to be introduced in the Summer of 2019.

3.4.1.3 Germany

The German Act on Disconnectable Loads ("Verordnung zu abschaltbaren Lasten", "AbLaV") can be attributed to the topic of demand side management. “Disconnectable loads” are consumption units that can reliably reduce their consumption power at the request of TSOs by a certain amount. TSOs are obliged to publish invitations for bids for disconnectable. The German TSOs issue a weekly tender for immediately disconnectable loads and fast disconnectable loads via the joint tendering platform of www.regelleistung.net. Immediately disconnectable loads are for automated frequency-control with a reaction time of max. 350 milliseconds when falling below a given grid frequency (49.2 Hz - 48.2 Hz based on the FNN-Document “Technical requirements for the automatic frequency reduction”) or be instantaneously remote-controlled by the TSO. In comparison, fast disconnectable loads have to be remotely controllable by the TSO only within 15 minutes reaction time. Load operators can submit their bids individually according to the technical capabilities of their loads. With the revision of the Act from August 16th, 2016, the requirements for the contractual obligation of switchable loads were adapted to developments in the German electricity market. The requirements were redesigned such that loads of only 5 MW or more with predictable load characteristics can be prequalified as disconnectable loads. Pooling of disconnectable loads is allowed, but they have to be situated in the same control zone of the transmission grid. Disconnectable loads in the distribution grid can only be included in consultation with the concerned DSO. There is no further specification as to how the consultation is to be organized.

So far only 3 vendors for immediately disconnectable loads with a total of 881 MW and 7 vendors for fast disconnectable loads with 1052 MW have been prequalified. During 2014-2017, a total of 110 load disconnections were utilized by German TSOs, over 80% of which by the TSO Amprion and mostly for a duration of 60 minutes (source: https://www.regelleistung.net/ext/static/abla).

Also connected with demand response, VDE-AR-N 4130 for the EHV grid refers to an FNN application advice about frequency dependent load shedding [4].

Chapter 8.11 of the current VDE-AR-N 4120 draft relates to demand response in the high voltage grid. It concerns continuously controllable loads with electronic control, e.g. charging applications for storages or electronically controlled thermoelectric appliances. Such loads are to reduce their consumption power on over frequency resp. increase it on under frequency. Storages may take part in demand side management according to requests by the grid operator, e.g. by remote switching.

In the medium voltage grid, the drafted VDE-AR-N 4110 requires that synchronous switching of a big number of customer loads must not cause undue voltage changes. This is ensured by introducing a maximum active power gradient, which is the same as the one for generators and storages. In addition, there is a special regulation for continuously controllable loads, which are equipped with electronic control. Such units must provide primary reserve by modifying their active power on under- or over frequency, just as generators or storages. With regards to the avoidance of grid failures by frequency dependent load shedding, the rules in [4] apply.

According to the drafted VDE-AR-4105, continuously controllable consumption units, electric load appliances with storage capacity and appliances with electronic control of consumption must adapt their maximal active power demand on under frequency in the range between 49,8 Hz and 48,8 Hz as long as secure operation is not impeded.

3.4.1.4 Italy

In the 2015-2018 Triennal Strategic Plan defined by ARERA, the regulation of retail markets must also consider the ongoing evolution linked to the profound changes driven by technological development promoted by the decarbonization policies of the European and national energy system (e.g.: smart meters and smart grids, electro-technologies). In such a context, the new figure of consumer-producer emerges, which can sell back into the grid what is produced in excess of its consumption needs (prosumer). Therefore, the capacity of the consumer takes a further dimension, which is linked to the need to improve his knowledge, as well as the ability to control, rationalize and increase efficiency of his consumption and thus his energy costs. The technological evolution favors at the same time the development of the offers of new services for savings, energy efficiency and active demand management (demand response). In this market, not only third parties such as energy service companies, demand aggregators and IT operators will take part, but also traditional retail energy sellers wishing to diversify through combined energy services for their customers, and to conquer new market shares.

In such a context, non-discriminatory access to data and information on energy consumption and the parallel development of smart meters, become central hubs for competitive retail markets. For consumers, the access to detailed information on their withdrawals is a prerequisite for both a more active and aware participation in the market, and to adapt their consumption behaviour and investment choices towards a more rational and efficient energy use. For third parties (e.g., sellers, ESCOs and aggregators), non-discriminatory access to consumer information and collection data, while guaranteeing privacy and data security, is an indispensable condition for the competitive development of the market services for energy efficiency and active demand-side management. Accordingly, through the Resolution 87/2016/R/eel, the Authority defined the functional specifications enabling LV smart meters and performances of the related 2G smart metering systems in the electricity sector. This would allow in the near future to enable some additional services with real-time operation (e.g., demand response-based flexibility services) and data validation also on a continuous basis.

In addition, with the consultation document 298/2016/ R/eel the Authority illustrates the guidelines with reference to the first stage of the project for the implementation of the market reform for the dispatching service, where a rapid expansion is expected - to demand, non-programmable RES and DG - of the audience which can participate in the provision of dispatching resources, even without an established European regulatory framework.

More recently, through the consultation document 865/2017/R/efr, the Authority defined the guidelines for making data on the historic electricity consumptions (so-called energy footprint) accessible to the end-user in digital format, thereby favouring the development of innovative services for energy efficiency and the active demand management. The availability of own withdrawal data of final customers (whose rights were reiterated by the Legislative Decree of 4 July 2014, No. 102, in implementation of the European Directive 2012/27/EU) allows to make better assessments of expenditure and environmental impacts deriving from their electricity consumption.
Finally, with the Resolution 300/2017/R/EEL, the Authority defined the guidelines for the first opening to the market of the dispatching service for the demand and generation plants also powered by RES (which have been not enabled yet) as well as for storage systems. Institution of pilot projects in view of the definition of the Integrated Text for electrical dispatching (TIDE) in consistence with the ENTSO-E Network code on Electricity Balancing. The new figure of the Aggregator has been outlined.

3.4.1.5 Poland

Electromobility and Alternative Fuels Act (dated 11.01.2018): Definition of a demand response installation is added: "end users' installation, which allows a change of energy consumption profile when requested by a SO, in particular including energy storage, generation facility not coordinated by the grid operator, or charging point, in accordance to Electromobility and Alternative Fuels Acts of 11 January 2018, Article 2.17"
The main policies and codes of Poland that have an influence or are related to flexible demand response including electric vehicles, heat pump solutions for heating and cooling and hot water are shown below.

- Instruction Of Transmission System Operation And Maintenance (PSE Grid Code): System balancing and managing system constrains (Bilansowanie systemu i zarządzanie ograniczeniami systemowymi - only in Polish), Version 1.0 *https://www.pse.pl/documents/20182/44303162-6b89-488b-91f1-6947e795d244?safeargs=646f776e6c6f61643d74727565*
- 4.2.6 Rules for DR usage and its incorporation during planning of electrical system operation. Attachments 1 and 3 to the agreement concerning services for demand reduction on the TSO request (only in Polish) provide information on:
    - Rules for managing DSR participants
    - Rules concerning DSR service delivery

- The above-mentioned documents specify two available DR programmes:
  1. Guaranteed (disposable power for every hour of the guarantee range: 500 MW; one or more products of guaranteed power between 10 MW and 200 MW; two periods of the service delivery: 1) summer, Monday to Friday between 10 AM and 6 PM 2) winter, Monday to Friday between 4 PM and 8 PM).
  2. Current (unit price (pln/MWh); price for hypothetical product of 10 MW for 1 hour and one reduction; delivery of the service - 12 months; possibility to make sale proposals for products of power between 10 MW and 200 MW).

3.5 Projects in progress that address issues relevant to INTERPLAN

3.5.1 Austria

- DeCAS: The aim of the project is to develop approaches and concepts for a coordinated control considering the different objective functions of individual voltage levels. It will include the integration of monitoring and control technologies in process control systems as well as the integration in existing and future flexibility markets. LV grids are usually not automated yet and there are hardly any measurements available. Thus, the project will evaluate promising concepts for LV grid operation tools and processes, and how they can interface with MV/HV SCADA (supervisory control and data acquisition) DMS (distribution management system).
- InteGrid: It’s vision is to bridge the gap between citizens and technology/solution providers such as utilities, aggregators, manufacturers and all other agents providing energy services, hence expanding from DSOs distribution and access services to active market facilitation and system optimisation services while ensuring sustainability, security and quality of supply.
- InterFlex: It investigates the INTERactions between FLEXibilities provided by energy market players and the distribution grid, with a focus on energy storage, smart charging of electric vehicles, demand response, islanding, grid automation and the integration of different energy carriers (gas, heat, electricity).
- SmatNet: The project arises from the need to find answers and propose new practical solutions to the increasing integration of Renewable Energy Sources in the existing electricity transmission network. The subsequent technological (r)evolution is not only affecting the structure of the electricity markets, but also the interactions between TSOs and DSOs. The SmartNet project aims to provide optimised instruments and modalities to improve the coordination between the grid operators at national and local level (respectively the TSOs and DSOs) and the exchange of information for monitoring and for the acquisition of ancillary services (reserve and balancing, voltage balancing control, congestion management) from subjects located in the distribution segment (flexible load and distributed generation).

3.5.2 Cyprus

No projects run in Cyprus that cover issues related to INTERPLAN. However, the following projects address issues related to DR, Aggregators and smart platforms for managing them:

- BestRES: It aims is to develop business models for integration of renewable energy sources by aggregating distributed generation such as wind, PV, biogas, biomass, hydro, Combined Heat and Power (CHP) and combining this with demand side management and energy storage.

- GOFLEX: It aims to accelerate the GOFLEX technology solution in Europe by developing and demonstrating mature and commercially viable, scalable and easy-to-deploy solutions for distributed flexibilities and automated dynamic pricing enabling sustainable and flexible and establish a market for distributed flexibilities and automated dynamic pricing to improve the secure energy supply at local level and increase the economic efficiency of the overall energy system.
- InteGRIDy: It aims to integrate cutting-edge technologies, solutions and mechanisms in a scalable Cross-Functional Platform connecting energy networks with diverse stakeholders, facilitating optimal and dynamic operation of the Distribution Grid (DG), fostering the stability and coordination of distributed energy resources and enabling collaborative storage schemes within an increasing share of renewables.
- DELTA: It aims a DR management platform that distributes parts of the Aggregator's intelligence into lower layers of a novel architecture, based on VPP principles, in order to establish a more easily manageable & computationally efficient DR solution, ultimately aiming to introduce scalability & adaptiveness into the Aggregator's DR toolkits.
- DRIMPAC: It offers a comprehensive solution to empower consumer to become active participants in the energy markets. It comprises three main pillars: a) A legacy and Standards-compliant interoperability framework to interconnect building energy loads/appliances and expose their demand flexibility as price-responsive demand to the grid or for market actors to aggregate and bid in ancillary service markets. b) A human-centric, intelligent building energy management system, c) Innovative business models and service offering for energy retailers.

Moreover, the following projects are handling issues related to Distributed Storage behind the meter and at local substation level.

- StoRES: It foresees the development of an optimal policy for the effective integration of photovoltaics (PV) and energy storage systems (ESS) via testing smart solutions in 5 MED islands and rural areas. StoRES aims to increase the PV penetration in the energy mix of islands and rural areas in the MED by integrating PV and ESS under an optimal market policy by removing the constraints of grid reliability and RES intermittency. The challenge is to achieve high PV penetration in their energy mix through solving all market/technical/grid/tariff issues without compromising grid stability or security of supply.
- PV-ESTIA: Enhance the integration of Photovoltaics and Energy Storage Systems in the building environment in 5 pilot areas, thus facilitating the transition towards Nearly Zero Energy Buildings.

3.5.3 Germany

The projects that in Germany partly address issues related to INTERPLAN are presented below:
H2020 projects:

- TDX Assist (TSO/DSO interfaces). "Coordination of Transmission and Distribution data eXchanges for renewables integration in the European marketplace through Advanced, Scalable and Secure ICT Systems and Tools. This project aims to design and develop novel Information and Communication Technology (ICT) tools and techniques that facilitate scalable and secure information systems and data exchange between Transmission System Operator (TSO) and Distribution System Operator (DSO). The three novel aspects of ICT tools and techniques to be developed in the project are: scalability - ability to deal with new users and increasingly larger volumes of information and data; security - protection against external threats and attacks; and interoperability -information exchange and communications based on existing and emerging international smart grid ICT standards.” (www.tdx-assist.eu).

- EU-SysFlex: “EU-SysFlex will make an important contribution in meeting the European Union (EU) world leading RES objectives. The results and later impacts of the project will be decisive for the cost-effective transformation of the electricity system, by enhancing the flexibility required, while maintaining the level of resilience that consumers and society expect from the European electricity system.” (https://www.h2020-bridge.eu/projects/eu-sysflex-lce-4-2017/)

German national projects:

- SysDL 2.0: Ancillary services from wider area distribution grids, Oct 2014-March 2018, develops technologies for provision of ancillary services by operators of DER connected to the distribution grids. Development, Simulation and test of operation technologies of the control values U/Q/P for decentralized production of ancillary services in the distribution network. Reactive power exchange between transmission and distribution grids, development of operation planning tool for redispatch and congestion control. (https://www.sysdl20.de/projekt/l%C3%B6sungsansatz/)

- DEAStabil: Apr 2013-May 2016. Requirements on photovoltaic and wind power plants for providing a contribution to grid stability and secure grid operation. Development of methods for grid stabilization, practical test by a demonstrator. Focus on fast local control technologies, e.g. for reaction of PV and wind power plants onto sudden voltage drops. Development of proposals for European harmonized standards and grid connection guidelines, with the focus on effects of DER connected to the low- and medium voltage grids onto the higher-level transmission network. (https://www.iee.fraunhofer.de/de/projekte/suche/laufende/dea-stabil.html)

- Netzregelung 2.0, Dec 2017-Oct 2021. Researches stable operation of the electrical supply system (as well as subnetworks which are disconnected in case of grid failures) with high shares of inverter-coupled generators. Dynamic simulation models, techno-economic assessment of inverter-based control, interaction of new inverter-based control with existing synchronous generators. Development of dynamic grid equivalents for usage in grid studies, concept and implementation of a partly automated software for stability assessment of inverter-based grid stability control methods, simulation and laboratory demonstration.

- NEW 4.0, 2016-2020. Large scale demonstration of 100% RES supply of a region in northern Germany with a total of 4,5 million inhabitants. Involving OpSim for simulation of the supply system.

- Netzkraft, Jan 2015-Jun 2018. New Concepts for grid reconstruction with future power plant structures and integration of renewable generation. Further development of existing grid reconstruction concepts considering the behaviour of RES. Basic research of methods to use decentralized generation in island subnetworks in the distribution grid for shortening black out times.

3.5.4 Italy

No national projects run in Italy that cover issues related to INTERPLAN. However, the following projects, involving Italian partners, address issues related to INTERPLAN:

- SmartNET which was described earlier.
- NobelGrid: The project aims to provide new tools and ICT services for all actors of the electricity distribution grid and retail market, providing more secure and stable Smart Grids and cleaner and affordable energy.
- Green-ME: The project aims to enhance RES integration by implementing automation, control and monitoring systems in HV and HV/MV substations, advanced communicating with the renewable generators and storage in primary substations.
- WiseGRID: The project aims to provide a set of solutions and technologies to increase the smartness, stability and security of an open, consumer-centric European energy grid. The project will combine an enhanced use of storage technologies, a highly increased share of RES and the integration of charging infrastructure to favour the large-scale deployment of electric vehicles.

3.5.5 Poland

There are no public projects that directly address or focus on issues tackled within INTERPLAN. There are some internal initiatives undertaken by Polish TSO to improve some elements of operation planning. Examples less directly in scope of INTERPLAN are:

- Program GEKON: This programme is a platform for projects in five different areas:
  - Environmental aspects of shale gas extraction,
  - Energy efficiency and storage,
  - Protection and rationalisation of water,
  - Obtaining energy from clean resources,
  - Innovative methods for fuels, energy and materials extraction from waste and waste recycling.
- TAURON (DSO) Programmes:
  - Development of a platform for RES, energy storage and DR participants aggregation in terms of their generation and regulation potential
  - Model of distributed energy sources functioning 2.0 - self-balancing areas of the grid
- iDistributedPV
  - Its aim is to develop affordable integrated solutions to enhance the penetration of distributed solar PV (buildings) based on the effective integration of solar PV equipment, energy storage, monitoring and controlling strategies and procedures, active demand management, smart technologies and the integration of procedures in the power distribution system according to market criteria).

4 Use Cases (Tools or Functionalities)

The identified emerging technologies that are going to be found in abundance in the integrated grid in the years ahead that are distributed RES, storage, EVs and DR call upon enhanced functionalities requiring system means to utilise efficiently but also exhaustive use cases through which the grid needs will be validated to safeguard security and quality of supply. The list below gives a good sample of the use cases to be utilised in INTERPLAN with the aim to test developed solutions and will be further elaborated in WP3 to form the basis for WP4 and 5. These use cases are addressed in the content of this task since an initial indication of what is expected is a need for identifying the targeted limitations and shortcomings of the current models and analytical tools.

- Voltage and reactive power control, controlling overall grid voltage by using reactive power from the distributed grid, optimal power flow
- Congestion management involving assets in the distribution grid
- Equivalenting: use of benchmark networks / reference networks
- Grid security management including distribution and active components
- Control of circuits / grid peak power including of individual components such as transformer load
- Optimization of power losses
- Operational planning schedule (<= 3-day-ahead)
- Control regimes: system restoration and controlled islanding
- Frequency control adjustment to a network with low system inertia
- Balancing energy provision by assets in the distribution grid (connected with grid security management and TSO/DSO/BRP interactions)
- Incorporating flexibilities including DR to manage unplanned generation shortage or over capacity
- Self-healing of grid infrastructure: response architecture of failure of grid assets including DSO/TSO interconnections
- On-Load Tap Changers (OLTC) on transformers in the medium voltage network
- Enhanced modelling of distribution grid including clustering of:
    - Demand response
    - EV smart charging / discharging
    - Storage with selected modes of operation
    - Distributed generation covering all available technologies
    - Interface controllers
    - Cluster modulations/analysis

5 Scenarios to be investigated through INTERPLAN of future grids with DR, EVs, storage and intermittent RES populated from results of existing and completed EU projects

As indicated in paragraph 2.6 above, Task 2.1 has as a main objective of identifying the limitations and shortcomings of current regulations, models and operational tools in handling efficiently the emerging technologies RES, storage, EVs including smart charging and DR. To help identifying these limitations and shortcomings, it is necessary to have an initial knowledge of the targeted scenarios in the evolution of the integrated grid for the years 2030 / 2040 and beyond. For this reason, the initial list populated in WP3 is given below to assist the work objectives of Task 2.1.

5.1 100% RES - Covered by E-Highway, ELECTRA1 and GRID4EU

This scenario relies only on RES, thus nuclear and fossil energy generation are excluded. High GDP, high electrification and high energy efficiency are assumed. Storage technologies and demand side management are widespread.

5.2 Distributed generation - E-Highway, 2018 ENTSO-E TYNDP, All EUCO, ELECTRA, GridTech and GRID4EU

- These scenarios place prosumers at the centre. They represent a more decentralised development with focus on end user-technologies. Smart technology and dual fuel appliances, such as hybrid heat pumps, allow consumers to switch energy depending on market conditions. Electric vehicles see their highest penetration with PV and batteries widespread in buildings. These developments lead to high levels of demand side response available.
- Considerations on how the electricity grid will look like in 2030 / 2040: Small-scale generation technologies costs will rapidly decline. Technologies as solar will offer a non-subsidised option for "prosumer" in most parts of Europe. Major advances in batteries will enable "prosumers" to balance their own electricity consumption within a day. Nuclear mostly will depend on country specific policies. Small-scale generation will challenge large-scale power generation, pressurizing the profitability of traditional power plants. System balance will be maintained through a centralized mechanism that retains enough peaking capacity. district heating CHPs will be suitable for both heating and electricity balance. Electricity demand flexibility will substantially increase, both in residential and industrial solutions, by helping electric power adequacy. Yearly electricity demand will increase in heating (e.g., heat pumps) and transports (e.g., EVs) sectors. The overall electricity demand growth will reduce in the residential sector due to the "prosumer" behaviour. Demand will respond well to market price, and the peak electricity demand will reduce.

5.3 Distributed generation description of GRID4EU

- Solutions related to voltage and load control are beneficial resources to increase network hosting capacity in European distribution grids. The advanced control of On Load Tap Changer at MV level in the Italian Demonstrator and at MV/LV level in the French Demonstrator is a major resource for increasing the Hosting Capacity (even the most beneficial one tested in the Italian Demonstrator where it has been increased by up to more than 50% in a specific experimentation). But, it is useful to highlight that an OLTC only acts on voltage constraints, not on power constraints. Also, in case of voltage imbalances due to the presence of “active” (i.e. Pgen >> Load) and “passive” (i.e. Load

>> Pgen) MV feeders connected to the same HV/ MV substation's bus-bar, the action of the On Load Tap Changer can be ineffective thus, requiring the introduction of the control of DERs connected along the feeders (e.g. distributed generators, storage systems, etc.).

- The Scalability and Replicability Analyses performed in GRID4EU also point out that the interaction of Distributed Generation (DG) and demand curves is a key aspect to increase network hosting capacity. While this aspect depends mainly on the type of consumers and Distributed Generation technology, energy storage and flexible demand can help increase network hosting capacity.
- For higher grid resiliency, it is technically feasible to operate the grid in islanding mode during more than 4 hours, with and also without rotating machines, while complying with strong requirements in terms of continuity of supply.

5.4 Global Climate Action / Integrated grid: E-Highway, 2018 ENTSO-E TYNDP, EUCO+40, ELECTRA, GRID4EU

- These scenarios represent a global effort towards full speed decarbonisation. The emphasis is on large-scale renewables and even nuclear in the power sector. Residential and commercial heat become more electrified, leading to a steady decline of gas demand in this sector. Decarbonisation of transportation is achieved through both electric and gas vehicle growth. Energy efficiency measures affect all sectors. Renewable gases see their strongest development within this scenario.
- Considerations on how the electricity grid will look like in 2040: A CO_2 market price will provide the correct market signals that trigger investments in low-carbon power generation technologies and for flexibility services. A technology-neutral framework will be established, which will support investment in RES. Gas-fired units will provide flexibility needed within the power market, helping facilitate intermittent RES within the market. Nuclear will mostly depend on country specific policies. System adequacy will be driven by price signals, which allows market-based investments in peaking power plants to be made. The impact of electrification will be that demand for electricity use in private and small commercial transportation sector will increase. Demand response in both industrial and residential sectors will increase. Increased automation of things and the internet will give consumers the option to move their demand to the lower-priced hours. Demand flexibility will be a key factor ensuring system adequacy to its ability to shift demand peaks. Yearly electricity demand will increase in various sectors. The overall electricity demand growth will be limited by increasing energy efficiency.

5.5 Global Climate Action / Integrated grid - Vision 2050 description from GRID4EU

- Energy systems are systems of systems, including the electricity systems, the gas systems, the liquid fuel systems, the heating and cooling systems as well as all other systems. The pan-European energy system is a system of energy systems, with connections from cross-border to local level.
- In 2050, the impact of the European energy systems on the climate is almost fully tackled. A combination of climate protection measures, including technology deployment for energy generation, storage and conversion and operational procedures help mitigate global and local environmental impacts, making sure that they offset the effects of increasing complexity of the energy systems.

- Innovative public policies ensure social participation. They include energy savings and energy efficiency measures, supported by up-to-date communication media. The public is informed through massive communication that the costs associated to the energy transition are efficient at mitigating environmental impacts and satisfying its needs. Citizens participate actively in the energy transition.
- By 2050, the use of fossil fuels is very law for any energy use. Use of crude oil for all domestic, industrial and mobility needs is low thanks to substitution of crude oil with biomass and other renewable energy sources. This has resulted in low-carbon energy systems, even CO2-neutral electricity system and liquid fuels. A low carbon pan-European energy system paves the way for a fully decarbonized and circular European economy beyond 2050.
- By 2050 energy markets will operate capable of storing or converting excess power from renewable generation (mainly wind and solar). Energy stored in batteries (stationary or through electric vehicles) is used to shift energy demand during the day. Energy stored in the form of gas is used on a weekly to seasonal basis for shifting excess of energy (such as in summer due to PV production) to those periods where more energy is needed (winter in many parts of Europe). Excess electrical energy is converted to CO2-neutral Gas in summer and converted back in winter.
- Retail markets are fully integrated with local and wholesale markets. Prosumers' willingness to provide flexibility is achieved by adequate market signals and innovative services guaranteeing a high level of comfort, by high power quality both in terms of satisfying norms (e.g. voltage and frequency within upper and lower limits) and over time (e.g. no blackouts, fast restoration after blackout). Prosumers of any size can access market offers to sell energy or power and to satisfy their needs via communication and internet services. These ICT-based services, which can be integrated with other information services, not directly related to energy, are also used to provide dynamic information (price, quality, state of the system, incentives for energy systems-friendly actions, etc.) to the prosumers for any of their energy related needs, be it selling or buying energy.
- In 2050, Europe satisfies all energy needs by using only energy sources located within Europe. This means that Europe does not depend on fuel, raw materials and knowledge sources from outside Europe. This is achieved by avoiding import of primary fuels such as gases, liquid fuels and renewable energy from outside of Europe. To that purpose, a fully circular, carbon-free economy has been designed - in the long run and beyond 2050 - for the energy systems with all sources available in Europe.
- In 2050, the energy systems planning, and operation processes ensure the overall system reliability. It enables at any time and location and under normal threats, a level of quality of energy supply adequate to the needs of the different users. Moreover, the energy systems is resilient against single and multiple contingencies linked with extreme, rare natural events (heavy snowfalls, flooding, draughts, storms and wind whirls) and intentional man-related attacks (acts of terrorism, cyberattacks, etc.). In these circumstances, the energy systems is capable of automatically and dynamically reconfiguring itself to ride through any disturbances (self-healing energy networks) or to operate in a partly degraded mode to safeguard essential energy services. A holistic, system approach to security of supply is applied over the whole energy systems, with a focus on efficient redundancy to support system reliable operation in case of deviation from planned energy consumption and energy infeed into the various energy grids and resilient operation in case of unforeseen events. Energy systems reliability and resilience

are part of an integrated strategy for all modes of energy systems use. Risk assessment is integrated into the energy systems security for all types of users.

- In 2050, the subsidiarity principle applies in the European energy systems with trusted, dynamically-sized, cell-based monitoring and controlling of generation and customers supply in all energy sectors, in an integrated way. (The subsidiarity principle means that energy systems are operated in such a way that actions are optimized locally (at the most immediate level). Actions that cannot be handled locally should be transferred to the next level.) Some local system parts are fully automatized, with islanding capabilities and re-connection to the various grids especially, when local energy balancing can provide support to the upstream parts of the energy systems. The number of micro-grids have increased significantly and can be monitored and controlled by smart, automatized systems under the supervision and responsibility of qualified network operators.

6 Limitations and Shortcomings

The country analysis has shown that countries address adequately in terms of Regulation, policies and codes the installation and operation of RES systems. However, storage and DR are issues that are still not covered adequately through regulations, policies and codes and in some countries, they are non-existent. For all three technologies, modelling and system tools are not available and hence, operators do not have the means to plan and operate the active network that is emerging and growing, in an efficient and optimal way. These create shortcomings that call for urgent attention.
What conclusions do we reach as shortcomings of our industry based on the country assessments? From the detailed analysis presented in the previous paragraphs, the following shortcomings transpire that need to be addressed through INTERPLAN and tested using exhaustive scenarios and use cases. A sample is given in this report, but these are needed to be further enriched in WP3.

6.1 Intermittent RES

The installation of intermittent RES generators at the end of long radial lines or in less developed parts of the power system can cause a voltage violation of the allowable voltage variation envelope that defines the operational limits of the grid due to variation in generation over the time of the day or depending on area cloudiness. The voltage limits in LV networks and MV networks vary and a compensation is required to meet the voltage levels. The ability to maintain the voltage levels in the grid is combined with reactive power controllers and power generation curtailment that should be enforced only in extreme cases.

6.2 Lack of observability for distributed RES in planning and operational practices

The evolution of the active grids with distributed RES is not simulated correctly in the planning and operational practices of operators and hence lack in effective solutions for managing them. The aggregated effects of distributed RES are not taken into consideration due to lack of appropriate models and analytical tools.

6.3 Advanced features of power electronics in inverters are not fully utilized

The operational benefits of the advanced features of power electronics in inverters and similar connecting apparatus are not utilized by operators in mitigating the negative effects of intermittent generating systems due to lack of models and analytical tools. The aggregated effect of the provided features is not taken into consideration when planning or operating the system leading to underutilization of costly infrastructure.

6.4 Storage

Storage in Member States has entered the energy mix and it is used generally as flexible demand and partly as an ancillary service for frequency control. More, recently storage is used as support to intermittent RES for improved load profile of prosumers and other industrial and commercial loads. Storage is to some extend covered by Grid Rules and Market Rules of some of the Member States covering the above referred applications. In all Member States storage is addressed individually as a technology in support of specific needs of the system or end users and its complementary attributes have not been taken up yet. Moreover, the specific attributes and characteristics of EVs and heat pumps capable of responding in system terms as active storage have not been considered or addressed in any capacity. Successful demonstration projects have been conducted and knowledge has grown but commercialisation is still behind calling for developments in a lot of directions.

Similarly, it is true to say that, irrespective of this gradual growth in use, none of the Member States has developed models and / or operational tools for effective planning and operation of the integrated grid with storage being an active component.

6.5 The aggregated benefits of storage systems with EVs and heat pumps are not used

From the practices depicted in 5.1.4 the aggregated benefits of storage, EVs and heat pumps are underutilized in efficiently complimenting the needs of intermittent RES due to lack of adequate models and analytical tools. Optimal planning of the systems requires such analysis through accurate modelling of the active components of the interconnected system.

6.6 Storage as a commodity for ancillary services to the system

The practices described in 5.1.4 and the lack of regulation and grid rules in Cyprus and elsewhere indicate that storage is underutilized in the interconnected grid. The versatility of storage systems with the varied services that they can offer in managing frequency, voltage, harmonics and other system quality issues are not taken up by operators due to lack of models and analytical tools to assist operational and planning practices.

6.7 Optimal use of storage and effecting siting

Storage can be sited behind the meter, distributed in substations or centrally. It can be a combination of DC connected and AC connected, a combination of standalone as compared to aggregated with EVs and heat pumps. Where it is highly system dependent and for this reason detailed models and analytical tools are required to optimally design the systems of tomorrow. This is the reason why we lack decisions and policies in this direction as indicated by the national investigations above and it is an identified shortcoming that INTERPLAN should address.

6.8 Flexible Demand Response

In Poland, TSO assumes utilization of demand response as a regular means for balancing purposes, however there is no standard model allowing for incorporation of the methods used by the TSO to acquire the DR service. The same applies for the aggregator model who incorporates many loads in the system and can share reduction order differently amongst its service providers.

6.9 Demand Response in support of system needs

The practices in Poland and the lack of action in the rest of the countries in harvesting the benefits of demand response for managing the needs of the system due to the aggravating effect of intermittent generation but also due to the advanced capabilities of the system since going smart is the result of lack of models and analytical tools that can reveal the huge benefits of this embedded system possibility. DR can take various forms with evolving technologies, but these will take the form that is beneficial when the worth is proven through effective analysis. Operators and system planners can learn to utilize this huge benefit and offer to the system stability and growth by using efficiently the inherent strength of demand as required without violating comfort and needs.

6.10 Demand Response complementary to storage for aggregated support to RES

The investigation carried out in the countries of the consortium has revealed that there is a static approach to the distribution grid meaning that the technologies that are matured to offer services to the integrated grid in meeting the targeted low carbon economy are not dynamically present in the plans of operators and planners due to lack of models and analytical tools that will allow them to accurately analyze and operate this active distribution grid.

6.11 Demand Response in support for the paradigm shift to load follows generation

From the analysis done it is seen that there is interest to use DR, storage, EVs and heat pumps as acting in an aggregated and coordinated system dynamic component capable of managing the intermittent generation and avoiding curtailment and sustained bad quality of system characteristics. To achieve this accurate models and analytical tools are required capable of accurately analysing and operating the system for the benefit of all connected users. This will allow technologies to develop further and system solutions to be pursuit that will offer optimal solutions at minimum infrastructure cost.

7 Discussion and Conclusions

The low carbon legislative package that is currently being discussed by the various European Institutions is addressing all issues related to high RES penetration, storage (including EVs) and Demand Response that characterises the evolution of the electrical grid into an active integrated grid that empowers end users with appropriate tools and means to effectively manage their resources and needs. From the investigation carried out by the consortium through this work, it is evident that:

- Countries have adequately addressed issues related to RES penetration including utilization of the advanced features of inverters / power electronics but still lacking in models and analytical / operational tools that will facilitate system planning and operation at a responsive and reliable level.

- Countries have done little in addressing regulatory and codes needs of storage and DR requiring major legislative procedures to respond to the demanding requirements of the low carbon package. As far as models and analytical / operational tools the situation is well behind treating the grid as still non-active on the Distribution and radial in nature with central control all the way.

The above limitations have been elaborated in the above paragraphs together with identified shortcomings that the INTERPLAN project should address. These shortcomings will be tackled in WPs 4 and 5 and validated using an extensive list of scenarios and use cases. Initial lists of use cases and scenarios have been presented in this report but require to be finalised and further elaborated in WP3. All this development work requires to respond to the grid functionalities listed in Section 4 and to be further enriched in WP3.

Based on the developed solutions within WPs 4 and 5, it is envisaged that WP2 will pick up the findings of D2.1 and build through them all the required modifications in Grid Rules and Regulations, capable of handling the developed solutions of INTERPLAN. This work will be undertaken in Task 2.4 from month 18 onwards and deliver the final recommendations by month 36 following direct consultations with selected stakeholders.

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9 Annex

List of Tables