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Newsletter 3

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Abstract

The aim of this document is to provide in a document the contents of the Third Newsletter from the IGREENGrid Project.

The main topics presented are:

- Selecting the most promising solutions for DRES integration using results from demonstration projects
- KPI results for the most promising solutions and recommendations about KPI methodology
- Technical evaluation
- CA and BA
- Recommendations

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1 Introduction and scope of the document

This document provides the contents of the Newsletter 3 of the IGREENGrid Project.

The newsletter 3 is organized as follows:

- Selecting the most promising solutions for DRES integration using results from demonstration projects (leader: ENEL).
- KPI results of these most promising solutions and recommendations about KPI methodology (leader: RSE).
- Technical evaluation methodology/results (leader: AIT).
- CA and BA methodology/results (leader: TECNALIA).
- Recommendations methodology/results (leader: IBERDROLA).

2 The words of the Project Coordinator

Project Coordinator
Jesus Varela Sanz
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Selecting one perfect and cost effective solution for any context from a wide set of them was never the objective of IGREENGrid. If the "magic solution" existed it would probably be present in the grids of many countries. The objective was to find "the most promising solutions" and to understand how and under which conditions, each one of these proposals can contribute to Distributed Renewable Energy Sources (DRES) integration, in different contexts.

The project team reviewed the solutions proposed throughout Europe to better integrate DRES, and then the team faced the challenge of selecting the "most promising solutions". Maybe the first question was... "The most promising solution regarding what? Performance, cost efficiency, social acceptance,... Maybe a balance among all technical, economical, and social aspects?

The selected approach was to evaluate all solutions classifying them for each aspect (complexity, costs, replicability, social issues,...). These results were combined and we obtained a ranking that could be a good balance between the opinions of experts from different countries. We then asked the Distribution System Operators (DSOs) which of these solutions they would consider as potential solutions to be installed in their grids. The answers differ among companies, but the average selection was very similar to the ranking obtained analytically.

In parallel an enormous analysis effort through simulations was made to produce objective information about the technical performance of the main solutions. The Key Performance Indicators (KPIs) designed during the first steps of the project, were calculated and applied to the solutions under study obtaining interesting and measurable results. The most promising solutions were also analysed from the economic point of view.

In this IGREENGrid newsletter we are presenting a brief summary of the technical and economic analysis made and the results which the whole team expect will be interesting for you.

3 Selecting the most promising solutions for DRES integration using results from demonstration projects

The results and experience gained from the six demonstration projects were used to identify which solutions showed the most potential for large scale deployment, on a European scale, to address the challenges presented by the integration of DG (Distributed Generation). It was possible to identify commonalities between the problems that need to be addressed on different networks. An evaluation of the deployment potential of each solution on a different network would have to be completed using simulation studies and a CBA (Cost-Benefit Analysis). From the results of the demonstration projects it was possible to identify potential opportunities that could be realised over a range of different networks and the benefits of these solutions, when deployed to different networks. This is being completed within Work Package 5 of the IGREENGrid project.

Most of the demonstration projects that were studied are both Medium voltage (MV) and Low Voltage (LV) rural networks with increasing requests for PhotoVoltaic (PV) and/or wind turbine generators connection. These types of networks can be typically characterised as having relatively low levels of load compared to a high potential for Distributed Generation (DG). This, coupled with long feeder lengths that would be typical for these types of networks, would result in a potential for problems maintaining a voltage profile within the statutory limits when connecting increased amounts of DG. These problems, associated with maintaining voltage profile in certain scenarios, were considered as the first bottle neck for DG integration on rural networks.

In many cases the most effective approach for addressing this problem would be to control the voltage at the primary substation using the On-Load Tap Changer (OLTC) transformer. Improved control would be expected and was demonstrated when using a control system and automating the operation of the OLTC. The controller was typically an additional function to the existing Supervisory Control And Data Acquisition (SCADA) and in some cases would be a product of the manufacture of the SCADA and in other cases was a bespoke system developed by the DSO. A similar approach was also used for LV networks where MV/LV transformers equipped with OLTC are currently available from a limited number of manufactures.

In some cases the amount of control provided by the OLTC could be limited by load / generation diversity amongst the MV feeders. Some feeders could be mainly supplying load, while others, connected to the same MV busbar, would be mainly connecting generation, with little or no load being supplied. This would cause an increased voltage bandwidth at the MV busbar and increasingly difficult for the voltage profile to be maintained using the OLTC. Several solutions were demonstrated to address this problem including controlling the reactive power of the DG invertors and reactive power injection using Static Compensator (STATCOM), Automatic Voltage Regulator (AVR) and storage (Li-Ion batteries and Combined Heat Power (CHP) plant). These could be controlled by either local or centralised control system. The centralised control system would most likely increased the DG hosting capacity but at a higher cost given the communications requirements. The selection of which technology to deploy would be based on cost. Controlling the reactive power of the DG using the inverter was the most common approach used in the demonstration projects. The type of communication system would be based on both the expected requirements of the network, in terms of future DG connections, and the evolution of the system. A centralised control system could be more economically feasible if it is applied to a range of additional functionalities and not just voltage control. These additional functionalities could be network management, fault detection and automation.

When considering the sheer scale of LV networks, centralised control systems are currently not considered to be economically feasible for most cases. In addition to using an OLTC to maintain voltage profile, autonomously controlled DG invertors could be used. Potential benefits were also identified for LV networks with three phase connections to residential properties. Meter data could be used to better understand the network and strategically plan the connection of new DG to avoid phase-to-phase imbalance and improve the voltage profile. This could potentially provide a cost effective solution where an AMI already exists and the meters are capable of capturing and storing or communicating voltage measurements. This data would be used to plan future DG connections so would not have to be available in real-time.

4 KPI results of the most promising solutions and recommendations about KPI methodology

The technical evaluation of smart grid technologies has played one of the most important roles within the activities of IGREENGrid. In particular, a numerical representation of the experience of demonstration projects (introduced in the previous newsletters) has been implemented by means of dedicated Key Performance Indicators (KPIs) based on the recommendations of European smart grid initiatives (i.e. European Electricity Grid Initiative (EEGI), Smart grid Task Force (SGTF)) and development plans (i.e. Ten Year Network Development Plan (TYNDP)) (available on http://www.gridplus.eu/Documents/Deliverables) [1].

According to the investigation objectives of IGREENGrid, three main aspects have been selected for the evaluation of the performance of smart grid solutions in terms of DRES integration: impact on **hosting capacity**, **quality of supply** and **energy efficiency** of distribution networks.

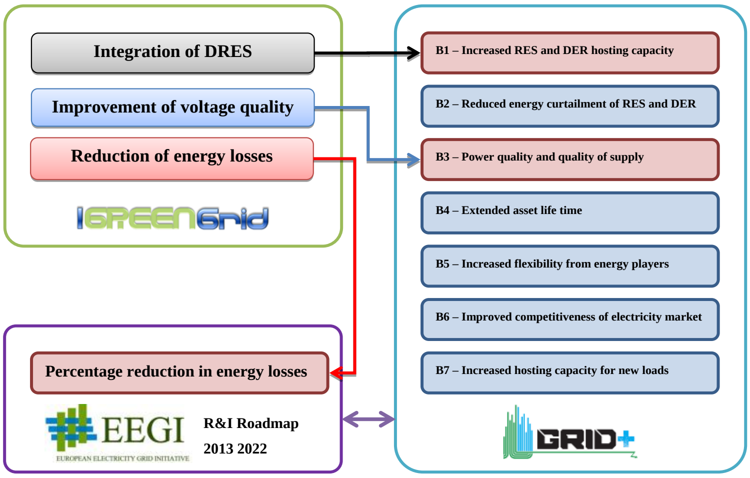

Figure 1: (Connection between EEGI, GRID+ and IGREENGrid KPIs)

From the very beginning of the project, the applicability of the KPIs proposed at European level for the evaluation of large scale demonstration projects (such as the ones grouped by IGREENGrid) has been investigated. This analysis is reported in the public deliverable D4.1 (available on: http://www.igreengrid-fp7.eu/deliverables) [2], together with few details on the selected performance indicators (subdivided in different categories).

The issues related to gather the practical experience of DSOs on demonstrators and KPIs calculation procedures have been constantly faced, especially agreeing on a methodology to project the current distribution networks in future scenarios (in which higher penetration of DRES is expected). In particular, the problem of uncertain amount and location of distributed generation has been analysed by means of Monte Carlo simulations [3]. In the reported graphs (Figure 2), exemplificative simulation results concerning the impact of reactive power control in a LV distribution grid are represented for 1000 different DRES integration scenarios.

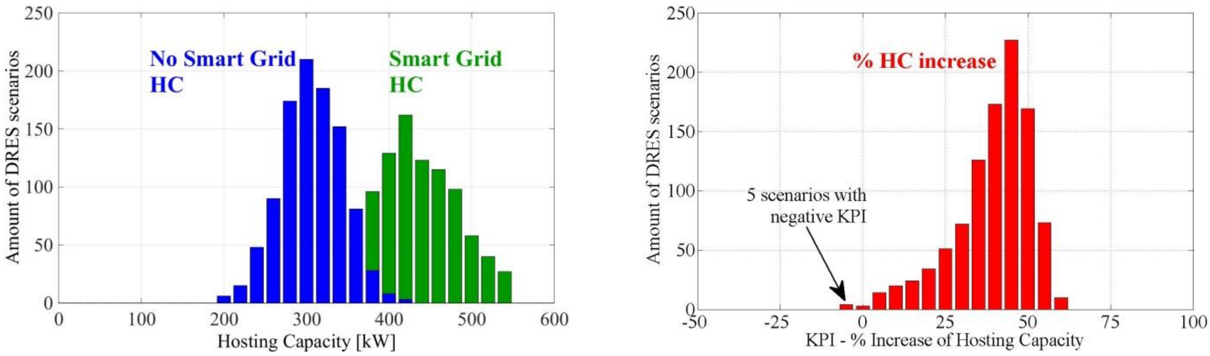

Figure 2: (Exemplificative results of the Hosting Capacity KPI)

Considering multiple scenarios has allowed the extraction of the situations in which the performance of the solution is far from the expected one. In particular, looking at the exemplificative results reported in the figure above, the scenarios in which smart grid technology features a negative performance can be further investigated (for instance in scalability and replicability evaluation).

This simulation approach has been repeated for all the IGREENGrid demonstrators with the objective of evaluating the performance of the tested solutions. The hypothesized scenarios have been replicated for the calculation of all the selected KPIs and the final results are available on the public deliverable D4.2 (available on: http://www.igreengrid-fp7.eu/deliverables) [4].

The application of the same calculation approach and the common network/solution modelling assumptions has increased the comparability of the results. However, in spite of the adoption of an harmonized calculation procedure, KPIs seem to be strongly affected by the network boundary conditions (loading level, grid characteristics, loads distributions, etc.) and, from the practical experience, a KPIs based comparison of solutions from demonstration projects to determine those with the highest large scale deployment potential cannot be exhaustively completed [5]. Although KPIs could be a useful tool to evaluate certain performance criteria when applying similar solutions to the same network, when evaluating the scalability and replicability of solutions from different demonstration projects and their potential for large scale deployment, an approach that is more representative such us an investment decision making process would be expected. This approach would include medium to long term network planning, a cost benefit analysis and risk assessment. Other criteria such as environmental impact, social acceptance should also be considered.

5 Technical evaluation methodology/results

The ambition of this part of the project is very high: a quantitative evaluation of the deployment potential of smart grids solutions aiming at enhancing the hosting capacity of existing distribution networks is expected. This is a major step from the usual case-study approach followed by most demonstration projects consisting in generalising the results obtained by demonstration projects.

The technical evaluation (scalability and replicability) of the most promising smart grids solutions is based on a three steps methodology with an increasing level of complexity (Figure 3). In a first step, network and feeders are characterized according to their hosting capacity determined on a probabilistic way (feeder screening). In a second step, time simulations considering consumption and generation profiles are performed to identify critical operation conditions without control action (AsIs) and to determine the reachable increase of hosting capacity for different smart grids solutions such as VoltVAr control or optimal power flow for example. The third step consists of full probabilistic load flow simulations (Monte Carlo simulations) with consumption and generation samples generated from real measurements. These detailed simulations allow evaluating the actual performance of the smart grids solutions (e.g. accuracy of observers) and to evaluate other key performance indicators (e.g. network losses or active power curtailment).

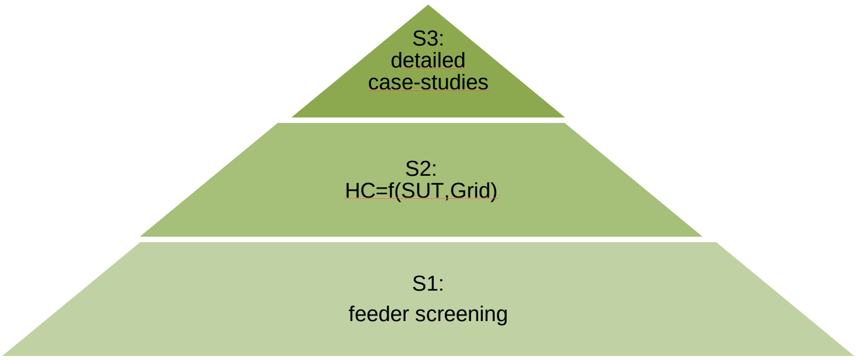

Figure 3: (General overview of the three steps for Scalability and Replicability analysis (SRA))

An important result of Step 1 is the expected hosting capacity per feeder without smart grids solution as well as the classification of the feeders into voltage-constrained feeders (blue on Figure 4) and current-constrained feeders (magenta on Figure 4).

The results of the technical evaluation of the deployment potential of smart grids solutions (e.g. hosting capacity increase for each most promising solution for more than 120 feeders) will be published in deliverable D5.1 in the next weeks. In addition, the results of a statistical assessment of the benefits of selected smart grids solutions on a very large dataset of LV networks (>37.000 LV feeders) will be presented.

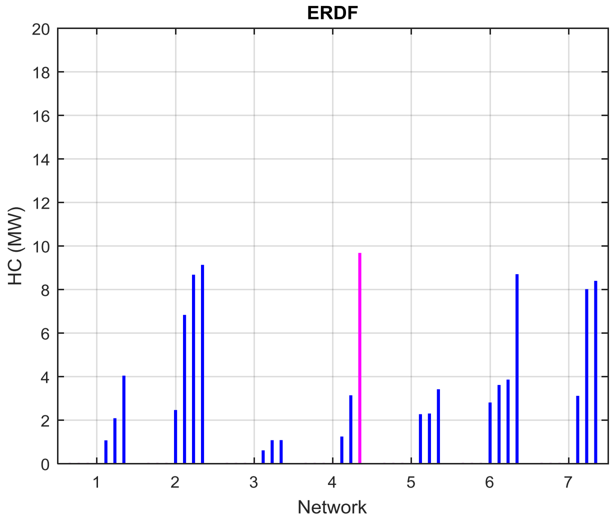

Figure 4: (Hosting capacity per feeder for the ERDF networks - example))

6 Cost Analysis (CA) and Benefit analysis (BA) methodology/results

The methodology of evaluation of costs and benefits in the IGREENGrid project is based on the "Guidelines for conducting a cost-benefit analysis of Smart Grid Projects" proposed by the EC Joint Research Centre (JRC), but many adaptations have been done in order to manage the number of DRES integration solutions and reference networks. In summary, the main differences are:

- The JRC methodology considers the smart grid project as a whole taking into account all possible functionalities, services and benefits expected from every single component of the solution. Instead, IGREENGrid focuses on the expected functions for the targeted objective and introduces a share factor on the cost attribution.
- The JRC methodology suggests a list of up to 22 benefits and formulae to be quantified following the "Guidebook for Cost/Benefit Analysis of Smart Grid Demonstration Projects" by the Electric Power Research Institute (EPRI). A second list of 54 KPIs/Benefits hard to be monetized is also introduced. IGREENGrid identifies both types of expected benefits, either direct or either side for comparison and further reference but it is impossible to accurately evaluate them.
- This is in line with the European Network of Transmission System Operators for Electricity (*ENTSO*-E) "Guideline for cost-benefit analysis of grid development projects", that argues that most of the investment decisions are not purely economic. Therefore, the side by side comparison of costs and benefits is discarded.

The methodology of evaluation of costs and benefits in the IGREENGrid project, CA&BA, is shown in the Figure 5:

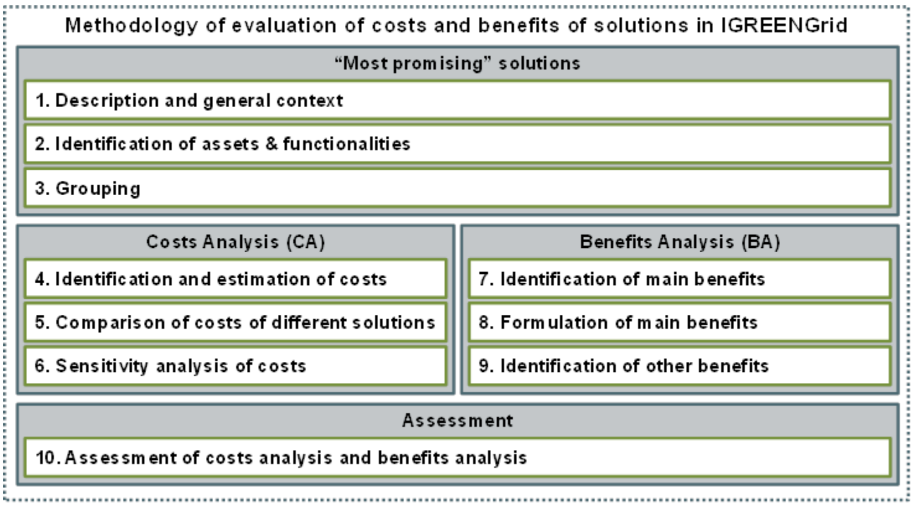

Figure 5: (Methodology of evaluation of costs and benefits of solutions – CA&BA)

It is important to underline that the IGREENGrid CA&BA is not aimed to support the selection of the best solution for every country and any network because the studied distribution networks are not representative of the country they belong to and too many factors are intentionally left out for simplification purposes (i.e. residual value of network assets).

The purpose of the Benefits Analysis (BA) is to identify potential benefits that may be provided by the smart solutions. On the one hand, main benefits are identified (taken from the list of 22 potential benefits of JRC methodology). On the other hand, other benefits are also identified (taken from the list of 54 KPIs/Benefits proposed by JRC methodology), such as the lower environmental impact of electricity grid infrastructure, benefit which is impossible to be accurately monetized.

The purpose of the Cost Analysis (CA) in IGREENGrid is to analyse the negative cash flow (that is the costs) incurred by DSOs when deploying the DRES integration solutions into the field considering a period of twenty years. In order to compare the conventional solutions based on grid deployment with the smart grid approaches, the network simulations produce a rough estimation of the number and length of circuits required to reach the same increase of the hosting capacity as the "best" smart solution being studied.

A MS Excel workbook is used to generate the summary figures and the graphical representation of the main results. A set of customized sheets are in charge of adding the individual Capital Expenditures (CapEx) and Operating Expenditures (OpEx) of the main assets required for each of the considered solutions to the target network applying the cost figures supplied by some DSOs and the outcomes of the technical simulations (i.e. approximate reinforcement).

Some conclusions of the analysis are the following:

- The inclusion of the life expectancy of network assets (est. 40-50 years) on the DSO negative cash flow (20 years) may be required to properly compare costs (as an asset that is more expensive but has a much longer life expectancy could end up more profitable). As costs are clearly related to network characteristics, in some other cases the business as usual cost –deploying network assets- is either much more expensive or much cheaper than some smart grid solutions.
- The calculation of network reinforcement costs may lead to misleading results, for instance the cost of a MV network is high enough as to ask for an alternative HV network reinforcement.
- If only the needs of one network are considered, centralized solutions tend to be far more expensive than distributed solutions because of the individual cost of some components (i.e. State Estimation).
- The correct attribution of the share of the cost of some components (i.e. State Estimation) becomes the key for the feasibility of some approaches when deployed to several of the studied networks. These components –network management supporting tools- enable other functions not considered in the cost analysis.
- When addressing the specific requirements of one case, applying distributed solutions (mostly based on local actuators) with lower communication needs seems to be the most cost effective alternative. If the addressed issues are general for the distribution network then centralized approaches may prevail.
- Each DSO case is different; there is a wide range in the variation of some elements. For instance and following with the example, the State Estimation may be a commercial product integrated into the distribution management system but, on the other extreme, it can also be custom development lacking of full integration: the cost and the amortization period vary and affect the final cost figures.
- Each network case is different; if the studied networks were representative for the country the results could be extrapolated but it is almost impossible given the way distribution

networks have been developed.

In summary, the cost analysis done in IGREENGrid confirms that the set of most promising solutions identified earlier in the project should be considered as a group of available tools. Each concrete network should be studied with detail to identify the most suitable approach to solve the issues raised from the increased share of renewables into that distribution network.

7 Recommendations for DRES integration

The transition to a low carbon economy requires new approaches and solutions to integrate DRES at distribution level. In response to this challenge, IGREENGrid project delivers rules of thumb for the future massive integration of DRES. It is also expected that this study will be a baseline paper for future initiatives and projects regarding to the widespread connection of DRES.

Then, what are the next steps to be followed in order to facilitate the integration of DRES?

- Implement new solutions to allow the increase allocation of DRES at distribution level without compromising proper network operation.
- Consider recommendations to foster the widespread connection of DG units, regarding to most relevant stakeholders.
- Introduce criteria to establish hosting capacity and to manage curtailment procedures.
- Build up methodologies and tools to develop technical and economic assessments of smart grid solutions.

Solutions to integrate DRES

As a result of the work done during this project a group of solutions to improve the integration of DRES has been delivered, clustered by functionality among prosumer side, network operation, network planning, asset management and regulatory matters. These solutions are organized within a matrix, which shows stakeholders involved during its exploitation plan.

	Stakeholder involved												
Solutions to integrate DRES	Prosumers	Generators	Investors	Manufacturers	Aggregators	Retailers	Research centres	EEGI	European Commission	Standardisation working groups	Regulators	DSOs	TSOs
Prosumer side (Generation, storage & demand)													
Non-firm connection contracts		X					X				X	X	
Inverters providing reactive power at any time (inductive and capacitive)	X	X		X							X	X	
EV-charging optimisiation by DSO/TSO	X		X	X	X	X		X	X		X	X	X
Development of cheap Storage	X						X	X	X		X		
Network operation													
Harmonised network operation data format for exchange (including TSO, DSO)							X	X		X		X	X
Interface DSO / Customer	X	X	X	X	X	X		X	X	X	X	X	
Improve the observability of the distribution network	X	X		X							X	X	
Control of DRES' reactive power	X	X		X							X	X	X
Use of devices for voltage control (STATCOM or AVR)	X			X							X	X	
Curtailment of DRES		X		X							X	X	
Network planning													
Harmonized Connection rules								X	X	X	X	X	X
Voltage & Load Monitoring (MV & LV)				X								X	
Advanced planning (more data used) including new operation concepts/tools				X								X	
Asset management & regyulatory matters													
Assess the suitability of a traditional replacement compared to smart grid solutions				X			X	X				X	
Allow the proper allocation of costs (infrasctructures and systems) among the agents	X	X			X				X		X	X	X
Adaption of DSO cost recovery/remuneration framework to foster innovation		X									X	X	

Recommendations to stakeholders

IGREENGrid project has delivered a set of recommendations to the most relevant stakeholders involved in the widespread integration of DRES. In this context, this chapter summarises next steps to facilitate DRES penetration and assist decision makers for future distribution network operation and planning. Hereafter, the recommendations are mentioned by stakeholder group:

STAKEHOLDER	RECOMMENDATIONS
Prosumers	Be “smart grid ready”
	Use generated surplus for local supply
	Implement technology supporting increased self-consumption
	Install cheap storage like cooling, heating or boilers
Generators	Allow DSO to manage reactive power with power electronics
	Accept that DSOs can control DG in case of necessity and for unexpected congestions and/or actions devoted to the electricity system stability
	Participate in new flexibility mechanisms/market to provide services to the electricity system
	Grouping into one large generator (aggregator) and participate in energy markets composing virtual power plants
	Provide ancillary services
Investors	Stay well-informed and invest in new technologies
	Invest in innovation
	Invest in telecommunication infrastructure
	Adapt to changing regulation and market framework
Manufacturers	Develop inverters able to provide reactive power at any time
	Develop Electric Vehicle (EV)-charging stations able to optimise of the charging/discharging processes
	Develop cheap storage
	Develop control systems for Smart home and buildings
	Develop advance tools which allow the implementation of new functionalities of the smart grid
	Take part in the development of harmonized network data format for exchange
Aggregators	Take part in the definition of common interfaces for the use of flexibility
	Be prepared for new contracts of prosumers
	Be prepared for curtailment solutions
	Avoid a geographical concentration of contracted prosumers
	Smart technologies and appliances will enable flexibility users and procurers to develop grid and retail products and services tailored to the needs of the flexibility service providers
	Aggregators and suppliers should have the same ability to extract the value of flexibility services on behalf of their customers

Retailers	Offering of easy-to-use flexibility products
	Take part in the definition of common Communication Interfaces for the usage of flexibility
	Retailers should focus on CO_2-Potentials of products
Research Centres	Development of tools for the optimal planning of distribution networks
	Development of tools for the optimal operation of distribution networks
	Improvement of storage cost/benefits ratio
	Identification of new renewable sources/energy converters to be exploited for distributed generation
	Provision of foreseen future scenarios of DRES penetration
EEGI	Rely on adequate simulations to reconstruct realistic situations of network operation.
	To define a standard way to calculate KPIs in order to obtain results in line with realistic network situations
European Commission	Support the Research and Innovation (R&I) projects (Pilots, demonstrators, research, etc.)
	Focus on the cost of new technologies
	More focus on expert knowledge and less on methodology based approach for evaluating the deployment potential of different solutions
	Support process for establishing new regulation and addressing commercial aspects that need to be addressed to realising the full benefits if some of the available technologies
	Promote standardisation process at European level for new technologies
Standardisation working groups	Define a uniform and clear regulation framework for distribution grid: “Harmonised connection rules”
	To agree on a standard for DRES communication with DSOs (to homogenize interfaces)
	To agree on a common network data exchange format
	To develop a standard for the provision of reactive power by DRES
	To propose a standard-compliant automation approach using the International Electrotechnical Commission (IEC) 61850 interoperability concept for power systems together with the distributed automation model IEC 61499
Regulators	Promote Smart Grids Initiatives
	Adapt the regulatory framework for steering the most cost-efficient solutions
	Define a proper allocation of network costs
	Adapt the regulatory framework to enable RES integration
	Regulate the DRES reactive power contribution
	Regulate the DRES active power curtailment
	Create an appropriate regulatory and market framework

	allowing/incentivising the use of distributed flexibilities by the DSO
DSOs	Implement new non-firm connection contracts for generators
	Pro-active system management
	Forecast the generation and demand-side at distribution grid level
	Consider the implementation of Information and Communication Technology (ICTs) to improve the management of network flexibilities
	Improve investment models considering new necessities and scenarios
	Optimise the use of flexibilities to solve network constraints
	Use the reactive power provided by DRES for voltage control and congestion management
	Improve network planning and operation.
	Implement network voltage and loading monitoring.
	Facilitate the access to the electricity markets by flexibility operators (aggregators, storage operators, EV operators, etc.)
	Flexibility support DSO-TSO for voltage issues and for frequency issues
Transmission System Operator (TSO)	Reinforce TSO-DSO cooperation
	Adapt interfaces with DSO to improve the monitoring of DRES connected MV networks
	Accept ancillary services provided by DRES

Table 1: (Recommendations by Stakeholder)

8 References

[1] GRID+ FP7 European project, Public deliverable 3.4 “Define EEGI Project and Programme KPIs”, available on http://www.gridplus.eu/Documents/Deliverables

[2] IGREENGrid FP7 European project, Public deliverable 4.1 “Report listing selected KPIs and precise recommendations to EEGI Team for improvement of list of EEGI KPIs”, available on http://www.igreengrid-fp7.eu/deliverables

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[4] IGREENGrid FP7 European project, Public deliverable 4.2 “List of reference targets (country-specific & EU-wide) for grid integration of DER based on selected “best” KPI”, available on http://www.igreengrid-fp7.eu/deliverables

[5] Rossi M., Bletterie B., Sebastia Viana M., Varela Sanz J., “On the Definition and Applicability of Key Performance Indicators for Evaluating the Performance of Smart Grid Concepts”, International conference and exhibition on Electricity Distribution, 2015