IGREENGrid

WP6: D6.3

Commercial and Exploitation Plan

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This document presents the exploitation plan of the IGREENGrid partners taking in account the most relevant results of the project. Moreover it is analyzed the Replicability, Scalability and Interoperability of the most promising solutions.					
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Abstract

The deliverable D6.3 “Commercial and exploitation plan” has been produced by task 6.3 of the IGREENGrid project. The overall goal of this task is to present a commercial and exploitation plan which include most relevant results of the economic evaluation of the promising solutions developed during the project and identify their potential market. The exploitation plan will be mainly focused on Replicability, Scalability and Interoperability of the solutions.

IGREENGrid has increase the knowledge and experience in DRES to the partners involved and has given to them an advantage for further projects implementation. Companies participating in IGREENGrid have improved the knowledge and experience in DRES integration. Moreover the project has been a perfect framework for methodologies and tools development and deployment. Finally, the professional network knitted during the project allows partners to be aware of other similar initiatives in Europe and disseminate their own experiences.

Regarding the CA and BA, the analysis 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 in order to identify the most suitable approach to solve the issues raised from the increased share of renewables into that distribution network.

For IGREENGrid Most Promising Solutions the impact of ICT is a constant in all of them. Real-time data is critical when the aim of the solutions is to operate the grid, and for that reason, communications impact directly to the quality of service.

In general, technology is mature enough for developing devices, equipment and services analyzed, but the deployment of the solutions implies important investment and in some cases the feasibility under current regulatory conditions.

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1 Introduction and scope of the document

This deliverable presents how the consortium can take commercial advantages of the results obtained during the project. Starting from the experience gained in several demonstration pilot developed by DSOs in six countries. IGREENGrid has successfully defined a pack of novel 'most promising' technical solutions to address DG integration. Once 'most promising' solutions have been defined, IGREENGrid completed an evaluation of scalability and replicability.

At this point of the project, IGREENGrid proposes a commercial and exploitation plan that translates the results obtained within the project to sector players as e.g. DRES promoters, manufacturers, research institution, DSOs, TSOs...

Firstly in this document, on the chapter 2, it is detailed how partners are going to exploit the results obtained during IGREENGrid. After that, on the chapter 3, Most Promising Solutions are evaluated from an economic point of view in first place and attending their reliability and interoperability afterwards on the chapter 4.
On the chapter 5, a brief overview of European Smart Grid situation is showed. Finally chapter 6 is dedicated to Conclusions.

1.1 Notations, abbreviations and acronyms

AMI	Advanced Metering Infrastructure
AMR	Automatic Meter Reading
AVR	Automatic Voltage Regulator
CA	Cost Analysis
CBA	Cost Benefit Analysis
D&D	Deactivation and Decommissioning
DER	Distributed energy resource
DG	Distributed Generation
DRES	Distributed Renewable Energy Sources
DMS	Distributed Management System
DSM	Demand side management
DSO	Distribution System Operator
GPRS	General Packet Radio Service
HV	High Voltage
IEEE	Institute of Electrical and Electronics Engineers
EEGI	European Electricity Grid Initiative
EU	European Union
ICT	Information and communication technology
JRC	Joint Research Centre

KPI	Key performance indicator
LV	Low Voltage
MV	Medium Voltage
OLTC	On-Load Tap Changer
OPF	Optimal Power Flow
PLC	Power line communication
PLF	Probabilistic Load Flow
PV	Photovoltaic
R&D	Research & Development
RTU	Remote Terminal Unit
SCADA	Supervisory control and data acquisition
SM	Smart meter
SE	State Estimator
SRA	Scalability & Replicability Analysis
STATCOM	Static Compensator
STR	Storage Solution
TSO	Transmission System Operator
V2G	Vehicle-to-grid
WP	Work Package

Table 1 Acronyms

2 Exploitable Foreground of the Project

Exploitable foreground of IGREENGrid could be classified into different areas:

1. Knowledge:
   Knowledge is intangible and difficult to measure. Partners involved in the project had the opportunity to share their experience among them and to improve their knowledge in DRES integration.
   IGREENGrid has defined, identified and analyzed a list of most promising solutions for DRES integration. Afterward a study of its replicability, scalability and interoperability has been done.
   The project has showed its works in different forums and diverse audience in order to publish its progress and to serve as a basis for future initiatives, as projects or deploys. This share of knowledge will help to faster development of subsequent standards.
   Moreover people involved in IGREENGrid have contributed to make their companies more "Smart" and to extend their markets and portfolio.
   Finally knowledge has turned into know-how which gives advantage to IGREENGrid participants for commercial approaches in Smart Grid technologies and consultancy.

2. Methodology:
   Some methodologies related to DRES integration have been developed within the project IGREENGRID. Some of these methods are based in the comparison among Smart Grid solutions implanted in different countries or scenarios.

3. Tools:
   IGREENGrid has developed three tools for DRES integration:
   - A data repository.
   - A technical evaluation tool.

4. Professional Network:
   IGREENGrid has been in contact with similar initiatives in Europe. IGREENGrid participants have improved its relationships with people working in Smart Grid fields and more particular for DRES integration. IGREENGrid has been in contact with manufacturers, DSOs, scientific community, national authorities/regulators...

Target audience influenced by IGREENGrid can be divided into the following categories:

- *Core target*: European Commission & partners.
- *Primary audience*: National regulatory authorities & policy makers; Local authorities & Members States; TSOs, other DSOs not involved in the project; Researchers & scientific community, Energy Suppliers /Retailers; Industrial equipment Manufacturers, ICT, Manufacturers and Distributed Generation operators.
- *Secondary Audience*: End-User, general populations and educational sector.

The Table 2 shows a detailed list of exploitable foreground of the project.

Exploitable Foreground	Exploitable Knowledge	How Exploit it	Main Target Group	Expected Impact
D1.4 Final Report	IGREENGrid work and conclusions.	Show IGREENGrid project conclusion and methodologies.	• Distribution system operators (DSOs). • Scientific community. • Technology providers. • National authorities/ regulators. • European Commission.	Use it as a baseline for further project and current processes related with DRES integration.
D1.5 D1.6, D1.7 coordination with SINGULAR & SusTAINABLE Projects	Analysis of: • Methodologies used. • Demos implemented. • Solutions tested. • Results obtained.	Compare methodologies and use cases.	• Partner involved in the three projects.	Improve new project starting from a higher baseline.
D2.1: Barriers for connection of DRES in distribution grids	Set of Barriers identifying the difficulties the integration of DRES.	Presentation of the solutions that could minimize the actual barriers.	• DSOs. • National authorities/ regulators. • European Commission.	Ease the integration of DRES generation.
D2.2: Assessment methodology based on indicative Key Performance Indicators	Homogeneous KPIs evaluation methodology.	Allow a reference frame to compare different solutions that address same problems.	• Scientific community • DSOs. • European Commission.	Technical and evaluation framework to assess about effective DRES integration in medium and low voltage grids.
D2.3: Suggestions and comments regarding the use of EEGI KPIs in real Demo Projects (first step)	Identification of main issues to considerer in EEGI KPIs.	Use the analysis as a baseline for further project.	• EEGI. • Other project coming.	Improve quality of next EEGI KPIs identification.
D3.1: Individual reports on the evaluation of local Pilot projects	Collect quantitative and qualitative information from Pilot	Allow to know and even compare different	• Partner involve in the project. • DSOs.	Share information among different

	projects.	solutions.	• Research centers.	initiatives in Europe and identify countries peculiarities.
D3.2: Evaluation of EEGI labelled demonstration projects	Collect information from demonstrations projects.	Allow to know different solutions and technologies.	• DSOs. • Research centers. • EEGI.	Share information among different project.
D3.3: Evaluation of other relevant demonstrations initiatives	Collect quantitative and qualitative information from demonstrations initiatives.	Allow to know different initiatives.	• Partner involve in the project. • DSOs. • Research centers. • EEGI.	Share information among different project.
D4.1: Report listing selected KPIs and precise recommendations to EEGI Team for improvement of list of EEGI	Experience obtained from the designing of the KPI methodology.	Use the analysis as a baseline for further project.	• European Commission.	Precise knowledge to evaluate solutions.
D4.2: List of reference targets (country-specific & EU-wide) for grid integration of DER based on selected solutions	• Selection of effective solutions. Reference Targets for KPIs. Methodology and criteria of evaluation. • Parameters affecting efficacy. • List of detected opportunities. • Scenarios of Simulations. • Best Practices Identification.	Use the analysis as a baseline for further project.	• DSOs. • Scientific community. • Technology providers. • National authorities/regulators. • European Commission.	Identify effective solutions for DRES integration in distribution grids that could be scalable and replicable.
D5.1: Technical and economic evaluation of replicability and scalability of solutions to	• Methodology for tool designing. • Solutions classification.	Use the methodology and tools for coming project or technical	• Technology providers. • National authorities/regulators.	To improve technical solution deployed in other countries or

increase the DER	• Simulated and Validated Catalogue of solutions. • Replicability and Scalability Evaluation. • Reference Values Simulation. • Best Practices Simulation.	solutions deploy.	• European Commission.	scenarios.
D 5.2: IGREENGrid simulation & evaluation framework (methodology and tools) to assess about the penetration	• Methodology and Evaluation Tools. • Simulated Cases. • Economical and Technical evaluation.	Use the methodology and tools for coming project or technical solutions deploy.	• DSOs. • Scientific community. • Technology providers.	To improve technical solution of DRES in distribution grids deployed in other countries or scenarios.
D6.1: Guidelines for future Massive Integration of DRES in distribution grids	• Recommendations about rules and criteria to manage properly distribution systems focused on increasing DRES integration in low and medium voltage grids. • Criteria to establish hosting capacity and to manage curtailment procedures. • Technical requirement to DRES, requirements for manufacturers of equipment and technology providers. • Methodologies and tools to develop accurate technical and economic	Incorporate recommendation in operational & maintenance processes.	• Software development companies. • DSOs). • Scientific community. • Technology providers. • National authorities/regulators. • European Commission.	To be a baseline for future project and initiatives.

	assessments.			
D6.2 Report on DSOs` business evolution	Identification of the current state in DRES integration and IGREENGrid vision concerning economical, technical and regulatory aspect.	• Baseline for R&D project. • Identify aspect where national regulations need advance.	• DSO. • European Commission. • National authorities/ regulators.	Identify the aspect where regulator need pay attention and the needs of DRES integration for further regulations.
D6.3 Exploitation Plan	Identification of knowledge gained during the project.	Baseline for further project	• Partners.	Identify partners' knowhow and portfolio.
D7.6, D7.7, D7.8 & D7.9 IGREENGrid workshop	Experience taken from other initiatives in DRES integration.	Smart Grid and DRES integration knowledge	• DSOs. • Scientific community. • Technology providers. • National authorities/ regulators. • European Commission.	Improve knowledge about Smart Grids technologies, companies involved, etc...
Stakeholders Committee meetings minutes	Experience taken from other initiatives in DRES integration.	Smart Grid and DRES integration knowledge.	• DSOs. • Scientific community • Technology providers. • National authorities/ regulators. • European Commission.	Improve knowledge about Smart Grids technologies, companies involved, etc.
Data Repository (Tool)	• Data Model needed to develop new tools. • Guidelines to manage available data. • Integration of KPIs tools calculation. • Grid Topologies.	• Guidelines for tool designing. • Data required and data acquisition requirements.	• Software development companies. • DSOs. • Scientific community. • Technology providers. • National authorities/regulators. • European Commission.	Gain experience in this kind of tool and improved the methodology in coming projects.

Technical Evaluation Tool	Methodology and the tool itself.	Future project. Analyse and improve DSO networks.	• DSOs. • Scientific community.	Gain experience in this kind of tool and improved the methodology in coming projects.
CBA approach	Methodology for CBA.	Future R&D projects Develop and improve generic tool	• R&D projects. • DSOs.	Gain experience in CBA methodology and analysis.
Specific Knowledge of DRES integration	Knowledge of State of the art, Smart Grid technologies and commercial solutions.	Improve Smart Grid capacities and knowledge of the partners	• Partners. • Stakeholders.	Develop Smart Grid Consultancy.

Table 2 Exploitable Foreground

2.1 INDIVIDUAL EXPLOTATION STRATEGY

This section presents how each partner individually is taking advantage of the experience and knowledge gained during the project.

2.1.1 IBERDROLA

Exploitable Foreground	Exploitable Knowledge	How Exploit it	Expected Impact
D1.4 Final Report	IGREENGrid work and conclusions.	Show IGREENGrid project conclusion and methodologies.	• Use it as an example and baseline for further project within the company. • Show how the tendencies of other DSOs in Europe. • Improve IBERDROLA knowledge of DRES integration.
D1.5 D1.6, D1.7 coordination with SINGULAR & SusTAINABLE Projects	Analysis of methodologies and results obtained.	Compare methodologies and use cases with other DSOs.	• Improve the knowledge will help in new project; the start point will be from a higher baseline. • Improve IBERDROLA knowledge of methodologies.
D2.1: Barriers for connection of DRES in distribution grids	Set of Barriers identifying the difficulties the integration of DRES.	Focusing the company effort in try to solve the finding barriers.	• Identify areas to focus on and put the resources on them. • Ease the integration of DRES generation. • Let show other stakeholders the barriers in DRES integration.
D2.2: Assessment methodology based on indicative Key Performance Indicators	Homogeneous KPIs evaluation methodology.	Using the developed methodology in further project.	• Facilitate the technical and evaluation framework to assess about effective DRES integration in medium and low voltage grids.

			• Improve evaluation methodologies within the company.
D3.1: Individual reports on the evaluation of local Pilot projects	Collect quantitative and qualitative information from Pilot projects.	Allow to know and even compare different solutions.	• Improve the knowledge of Iberdrola on how other countries are improving their DRES integration. • To show Iberdrola´s pilot to other companies Share.
D4.1: Report listing selected KPIs and precise recommendations to EEGI Team for improvement of list of EEGI	Experience obtained from the designing of the KPI methodology.	Use the analysis as a baseline for further project and initiatives.	• To improve the knowledge of KPIs.
D4.2: List of reference targets (country-specific & EU-wide) for grid integration of DER based on selected solutions	• Selection of effective solutions Reference Targets for KPIs. Methodology and criteria of evaluation. • Parameters affecting efficacy. • List of detected opportunities. • Scenarios of Simulations. • Best Practices Identification.	Use the analysis as a baseline for further project.	• Identify effective solutions for DRES integration in distribution grids that could be scalable and replicable.
D5.1: Technical and economic evaluation of replicability and scalability of solutions to increase the DER	• Methodology for tool designing. • Solutions classification. • Simulated and Validated Catalogue of solutions. • Replicability and	Analyse the results of IBERDROLA Grid and identify areas to improve.	• To improve the knowledge of the company in technical and economical methodologies. • Identify areas to focus on for DRES integration.

	Scalability Evaluation. • Reference Values Simulation. • Best Practices Simulation.		
D 5.2: IGREENGrid simulation & evaluation framework (methodology and tools) to assess about the penetration	• Methodology and Evaluation Tools. • Simulated Cases. • Economical and Technical evaluation.	Use the methodology and tools for coming project or technical solutions deploy.	• To improve the knowledge of technical solution of DRES in distribution grids deployed in other countries or scenarios. • Identify areas to focus on for DRES integration.
D6.1: Guidelines for future Massive Integration of DRES in distribution grids	• Recommendations about rules and criteria to manage properly distribution systems focused on increasing DRES integration in low and medium voltage grids.). • Criteria to establish hosting capacity and to manage curtailment procedures. • Technical requirement to DRES, requirements for manufacturers of equipment and technology providers. • Methodologies and tools to develop accurate technical and economic	Incorporate recommendation in operational & maintenance processes.	• To be a baseline for future project and initiatives. • To identify areas to focus on and put the resources on them.

	assessments.		
D6.2 Report on DSOs` business evolution	Identification of the current state in DRES integration and IGREENGrid vision concerning economical, technical and regulatory aspect.	Baseline for R&D project. Identify aspect where national regulations need advance.	• Identify the aspect where regulator need pay attention and the needs of DRES integration for further regulations.
D7.6, D7.7, D7.8 & D7.9 IGREENGrid workshop	Experience taken from other initiatives in DRES integration.	Smart Grid and DRES integration knowledge.	• Improve knowledge about Smart Grids technologies, companies involved, etc...
Stakeholders Committee meetings minutes	Experience taken from other initiatives in DRES integration.	Smart Grid and DRES integration knowledge.	• Improve knowledge about Smart Grids technologies, companies involved, etc...
Specific Knowledge of DRES integration	Knowledge of State of the art, Smart Grids technologies and commercial solutions.	Improve Smart Grid capacities and knowledge of the partners.	• Develop Smart Grid Consultancy. • Improve knowledge about Smart Grids technologies, companies involved, etc...

Table 3 Iberdrola Exploitable Foreground

2.1.2 ERDF

The IGREENGrid project shares the results of six smart grids demonstration projects related to the DRES integration in six European countries. The results and the comparison of the different solutions present a very high interest for ERDF.

Exploitable Foreground	Exploitable Knowledge	How Exploit it	Expected Impact
D1.4, D1.6, D1.7 coordination with SINGULAR & SusTAINABLE Projects	Analysis of: • Methodologies. • Solutions tested. • Results obtained.	• Compare methodologies, devices, (regulatory and market) frameworks and use cases. • Use the analysis as a baseline for further project.	• Improve the knowledge inside ERDF about different smart grids solutions tested in other countries/projects. • Learn about the experiences of other projects/experiences.
D2.1: Barriers for connection of DRES in distribution grids	Identification and definition of a set of common barriers on the six countries participating on the project; identifying the difficulties the integration of DRES. These barriers have been organized in three categories: technical, economical and regulatory.	• Presentation of the solutions oriented to minimize the actual barriers. • Use as a basis of the negotiation with French Regulator Authority. • Use of a basis for the discussion with generators, manufacturers.	• Facilitate the integration of DRES generation. • Facilitate the evolutions needed on the regulatory and market frameworks. • Facilitate the standardisation of the devices, protocols, ...
D2.2: Assessment methodology based on indicative Key Performance Indicators	• Homogeneous KPIs evaluation methodology. • Technical and evaluation framework to assess about effective DRES integration in medium and low voltage grids. • Identification of main issues to considerer in EEGI KPIs.	• Allow a reference frame to compare different solutions that address same problems. • Take into consideration the limit of use of the EEGI KPI.	• Improve knowledge about EEGI methodology. • Improving knowledge about KPI.

D3.1: Individual reports	Analysis of: • Methodologies. • Solutions tested. • Results obtained.	• Compare methodologies, devices, (regulatory and market) frameworks and use cases. • Use the analysis as a baseline for further project.	• Improve the knowledge inside ERDF about different smart grids solutions tested in other countries/projects. • Learn about the experiences of other projects/experiences.
D4.1: Report listing selected KPIs and precise recommendations to EEGI Team for improvement of list of EEGI	• Experience obtained from the designing of the KPI methodology.	• Use the analysis as a baseline for further project.	• Improving knowledge about KPI. • Facilitate the evolutions needed on the regulatory frameworks. Facilitate the discussions with the French regulator.
D4.2: List of reference targets (country-specific & EU-wide) for grid integration of DER based on selected solutions	• Selection of effective solutions Reference Targets for KPIs Methodology and criteria of evaluation. • Parameters affecting efficacy. • List of detected opportunities. • Scenarios of Simulations. • Best Practices Identification. • Qualitative SRA.	• Use the analysis as a baseline for further project.	• Identify effective solutions for DRES integration in distribution grids that could be scalable and replicable. • Facilitate the comparison of the solutions tested also in the French demonstrators. • For the new demonstrators, identification of the “instrumentation” needed to follow/calculate the KPIs.
D5.1: Technical and economic evaluation of replicability and scalability of solutions to increase the DER	• Methodology for tool designing. • Solutions classification • Simulated and Validated Catalogue of solutions. • Replicability and Scalability Evaluation. • Reference Values	• Use the methodology for coming project or technical solutions deploy in order to identify the right place to test the different solutions.	• To improve technical solution deployed in other countries or scenarios. • Definition of reference networks for each kind of problem. • Improve the knowledge about the CBA analysis.

	Simulation. • Best Practices Simulation.		
D 5.2: IGREENGrid simulation & evaluation framework (methodology and tools) to assess about the penetration	• Methodology and Evaluation Tools. • Simulated Cases. • Economical and Technical evaluation.	• Use the methodology and tools for coming project or technical solutions deploy.	• To improve technical solution of DRES in distribution grids deployed in other countries or scenarios.
D6.1: Guidelines for future Massive Integration of DRES in distribution grids	• Recommendations about rules and criteria to manage properly distribution systems focused on increasing DRES integration in low and medium voltage grids. • Criteria to establish hosting capacity and to manage curtailment procedures. • Technical requirement to DRES, requirements for manufacturers of equipment and technology providers • Methodologies and tools to develop accurate technical and economic assessments.	Incorporate recommendation in operational & maintenance processes.	• Improve the knowledge inside ERDF about different methodologies used in other European countries. • Facilitate the discussions with French regulator, manufactures, generators associations,...
D6.2: Gap analysis & evolution of DSOs business	Identification of technical, economic and regulatory actions that should be implemented in each country by the different involved players to integrate the new	Prepare the evolutions needed.	• Anticipate the evolutions needed to put in place the new roles from a technical, regulatory and economic point of view. • Facilitate the exchanges.

	DSO roles.		
Final Report	IGREENGrid work and conclusions.	Capitalisation of the experiences.	• Use it as a baseline for further project and current processes related with DRES integration.
Specific Knowledge of DRES integration	Knowledge of State of the art, Smart Grid technologies and commercial solutions.	Improve Smart Grid capacities and knowledge of the partners.	• Develop Smart Grid Consultancy.
Stakeholders Committee meetings minutes	• Minutes of the meetings. • Feedbacks.	Capitalisation of the experiences.	• Improve our knowledge about smart grids solution taking into account the experience brought by the experts during the committees.
D7.6- IGREENGrid workshop 1	Minutes of the meetings.	Capitalisation of the experiences.	• Improve the knowledge inside ERDF about different smart grids solutions tested in other countries/projects. • Learn about the experiences of other projects/experiences.
D7.7- IGREENGrid workshop 2	Minutes of the meetings.	Capitalisation of the experiences.	• Improve the knowledge inside ERDF about different smart grids solutions tested in other countries/projects. • Learn about the experiences of other projects/experiences.
D7.8- IGREENGrid workshop 3	Minutes of the meetings.	Capitalisation of the experiences.	• Improve the knowledge inside ERDF about different smart grids solutions tested in other countries/projects. • Learn about the experiences of other projects/experiences.
D7.9- IGREENGrid workshop 4	Minutes of the meetings.	Capitalisation of the experiences.	• Improve the knowledge inside ERDF about different smart grids solutions tested in other countries/projects. • Learn about the experiences of other projects/experiences.

Table 4 ERDF Exploitable Foreground

2.1.3 GAS NATURAL FENOSA

Exploitable Foreground	Exploitable Knowledge	How Exploit it	Expected Impact
D1.4, D1.6, D1.7 coordination with SINGULAR & SusTAINABLE Projects	Analysis of: • Methodologies. • Solutions tested. • Results obtained.	• Analyze methodologies, solutions and results obtained in other countries with the methodologies and devices deployed in our project, and extract conclusions and potential improvements of our solution.	• Learn about the experiences of other projects/experiences. • The results from other projects helped to identify the technologies that better fit the requirements, push the technology evolution and increase the interoperability, thus reducing the overall costs of implementation in further deployments.
D2.1: Barriers for connection of DRES in distribution grids	• Identification and definition of a set of common barriers on the six countries participating on the project; identifying the difficulties the integration of DRES.	• Improve knowledge about technical, economical and regulatory issues regarding the integration of DRES generation.	• Speed up the integration of DRES generation and the implementation smart solutions.
D2.2: Assessment methodology based on indicative Key Performance Indicators	• Homogeneous KPIs evaluation methodology.	• Use the homogeneous KPIs evaluation in order to assess Smart Grid use cases.	• Improve knowledge about EEGI methodology.
D3.1: Individual reports	Analysis of: • Methodologies. • Solutions tested. • Results obtained.	• Analyze methodologies, solutions and results obtained in other countries with the methodologies and devices deployed in our project, and extract	• Learn about the experiences of other projects/experiences. • The results from other projects helped to identify the technologies that better fit the requirements, push the technology evolution and increase the interoperability, thus reducing the overall costs of implementation in further

		conclusions and potential improvements of our solution.	deployments.
D4.1: Report listing selected KPIs and precise recommendations to EEGI Team for improvement of list of EEGI	• Experience obtained from the designing of the KPI methodology.	Use the experience obtained in order to assess smart grid use cases.	• Improve knowledge about EEGI methodology.
D4.2: List of reference targets (country-specific & EU-wide) for grid integration of DER based on selected solutions	• Selection of effective solutions Reference Targets for KPIs Methodology and criteria of evaluation. • Best Practices Identification.	Use the experience gained in order to improve our Smart Grid solution, as a baseline of new Smart Grid projects.	• Identify effective solutions for DRES integration in distribution grids that could be scalable and replicable.
D5.1: Technical and economic evaluation of replicability and scalability of solutions to increase the DER	• Replicability and Scalability Evaluation of solutions to increase the DER. • Reference Values Simulation. • Best Practices Simulation.	Use the experience gained in order to improve our Smart Grid solution, as a baseline of new Smart Grid projects.	• Identify effective solutions for DRES integration in distribution grids that could be scalable and replicable.
D 5.2: IGREENGrid simulation & evaluation framework (methodology and tools) to assess about the penetration	• Methodology and Evaluation Tools. • Simulated Cases. • Economical and Technical evaluation.	Use the experience gained in order to improve our Smart Grid solution, as a baseline of new Smart Grid projects.	• Identify effective solutions for DRES integration in distribution grids that could be scalable and replicable.
D6.1: Guidelines for future Massive Integration of DRES in distribution grids	• Recommendations about rules and criteria to manage properly distribution systems focused on increasing DRES integration in	Use the experience gained in order to improve our Smart Grid solution, as a baseline of new Smart Grid projects.	• Identify effective solutions for DRES integration in distribution grids that could be scalable and replicable.

	low and medium voltage grids. • Criteria to establish hosting capacity and to manage curtailment procedures. • Technical requirement to DRES, requirements for manufacturers of equipment and technology providers. • Methodologies and tools to develop accurate technical and economic assessments.		
D6.2: Gap analysis & evolution of DSOs business	• Identification of technical, economic and regulatory actions that should be implemented in each country by the different involved players to integrate the new DSO roles.	Use the experience gained in order to define the new roles of the DSO in our company.	• Anticipate the evolutions needed to put in place the new roles from a technical, regulatory and economic point of view.

Table 5 Gas Natural Exploitable Foreground

2.1.4 RWE

Exploitable Foreground	Exploitable Knowledge	How Exploit it	Expected Impact
D2.1: Barriers for connection of DRES in distribution grids	Agreed and common list of barriers at European level for integration of RES.	Information source when required.	Increase know-how and increase awareness in other stakeholders both European and national level.
D3.1: Individual reports on the evaluation of local Pilot projects	Tested and validated solutions in different environments.	Information source when required.	Increase Know-how.
D5.1: Technical and economic evaluation of replicability and scalability of solutions to increase the DER	Methodology.	Use of experience gained for future projects.	Increase know-how.
D6.2: Report on DSOs business evolution	Identification of the current state in DRES integration and regulatory framework in different European countries.	Use of experience for upcoming questions regarding regulatory and technical aspects.	Increase of know-how.

Table 6 RWE Exploitable Foreground

2.1.5 RSE

Exploitable Foreground	Exploitable Knowledge	How Exploit it	Expected Impact
Methods for the evaluation of Smart Grid Solutions applied on real demonstrators	• Knowledge on existing evaluation methods which have been developed and applied on IGREENGrid demonstrators [D2.2] and [D3.1] as well as other European initiatives and projects [D3.2] and [D3.3], including EEGI [D2.3] and [D4.1]. • Development of dedicated assessment methodology based on Key Performance Indicators for the quantification of technical benefits deriving from the application of Smart Grid solutions [D2.2] and [WP4–IGREENGrid KPIs Report].	• Definition of backgrounds for the design of Smart Grid evaluation procedures. • Studies to improve the completeness and level of details of performance indicators will be carried out, with the support of simulations and measurements from the real field.	• Methodologies based on KPIs are expected to be further investigated within the next R&D projects, and the experience of IGREENGrid (as well as the feedbacks provided to the EEGI [D4.1]) represents a solid basis.
Distribution systems planning and operation strategies	• Basic knowledge on the currently adopted for the design and operation of distribution networks in the IGREENGrid involved countries.	• Definition of the Business As Usual (BAU) level of European distribution systems. • Modelling of distribution networks for simulation environment and Smart Grid studies	• The gained background will define the baseline for Smart Grid evaluation techniques based on the comparison of different scenarios (i.e. KPIs, CBA).
Barriers in integrating DRES in distribution networks	• Knowledge on the most limiting factors and difficulties to the integration of renewable energy resourced in distribution systems of IGREENGrid involved countries [D2.1].	• Participation in action plans devoted to the removal of barriers limiting renewables integration. • Studies to identify the best trade-off between regulatory changes and Smart Grid technologies exploitation.	• Collaboration with system operators and regulatory parties in order to promote the technical and economic progress of electricity systems.

Most recent Smart Grid solutions oriented to DRES integration	• Knowledge on the Smart Grid solutions currently investigated for a near-future large scale implementation [D3.1]. • Detailed description of these solutions as well as their real field implementation and performance evaluation [D3.1], [WP4–IGREENGrid KPIs Report]. • Modelling and simulation approaches aimed to Smart Grid studies [WP4–IGREENGrid KPIs Report], [D5.1] and [D5.2]	• Identification of next-future scenarios and coherent upgrading of research tools and methods for Smart Grid studies.	• Development of innovative tools and standard techniques for the operation and planning of Smart Grid systems.
Scalability, Replicability and Cost Benefit Analysis procedures for Smart Grid solutions	• Knowledge on the application of techniques for the assessment of scalability, replicability (SRA) and cost/benefits ratios (CBA) with different level of details (qualitative analysis [D4.2] and comprehensive evaluation [D5.1] and [D5.2].	• Application and upgrade of the existing SRA and CBA methodologies for the evaluation of Smart Grid solution impacts on real networks.	• SRA and CBA methodologies are expected to be further investigated within the next R&D projects.

Table 7 RSE Exploitable Foreground

2.1.6 ENEL

Exploitable Foreground	Exploitable Knowledge	How Exploit it	Expected Impact
D1.4, D1.6, D1.7 coordination with SINGULAR & SusTAINABLE Projects	Analysis of: • Methodologies. • Demos implemented. • Solutions tested. • Results obtained.	• Review methodologies alternative approaches for evaluating results from demonstration projects. • Contribute towards knowledge based when	Learn about the experiences of other projects/experiences.

		developing research projects and corresponding methodologies best practice.	
D2.1: Barriers for connection of DRES in distribution grids	Common and different barriers have been identified	• Using the obtained knowledge for developing strategies together with relevant stakeholders.	Strategic development of standards and legal framework coordinating European and national processes for efficient design and use of distribution grid.
D2.2: Assessment methodology based on indicative Key Performance Indicators & D2.3: Suggestions and comments regarding the use of EEGI KPIs in real Demo Projects (first step)	Common KPIs providing standard methodology to compare the DEMOs involved (but KPIs regarding economic matters and asset management are missing).	• Using the experience for development of further KPIs.	Increase alignment to approaches used throughout Europe and objectives defined by the EEGI.
D3.1: Individual reports	Analysis of: • Methodologies. • Demos implemented. • Solutions tested. • Results obtained.	• Knowledge sharing.	Increased knowledge over a wide range of projects will contribute towards improving the way future projects and activities are conducted.
D4.1: Report listing selected KPIs and precise recommendations to EEGI Team for improvement of list of EEGI	Experience obtained from the designing of the KPI methodology	• Use the analysis as a baseline for further projects and work.	• Improving knowledge about KPIs and EEGI.
D4.2: List of reference targets (country-specific & EU-wide) for grid integration of DER based on selected solutions	• Selection of most promising solutions. • Parameters affecting efficacy. • Qualitative SRA.	• Identify effective solutions for DRES integration in distribution grids that could be scalable and replicable. • Share knowledge.	• Facilitate the selection of technical solutions to be tested/implemented in the network. • Facilitate the design and implementation of new Smart Grid demonstration projects. • Increase awareness about best practices on grid integration of DER.

		• Use knowledge as a baseline for further R&D projects.	• Increase acknowledgement inside ENEL experts.
D5.1: Technical and economic evaluation of replicability and scalability of solutions to increase the DER	Gives results about the probability of successful implementation for the different solutions of the demos.	• Used as background knowledge for research studies to support medium to long term investment.	• Learn from experience gained on other networks in terms of both technical and economic feasibility.
D 5.2: IGREENGrid simulation & evaluation framework (methodology and tools) to assess about the penetration	• Methodology and Evaluation Tools. • Simulated Cases. • Economical and Technical evaluation.	• Methodology and tools could be used for planning and evaluation of deploying new solutions.	• Improve methodology and tools used for network analysis and planning.
D6.1: Guidelines for future Massive Integration of DRES in distribution grids	• Recommendations about rules and criteria to manage properly distribution systems focused on increasing DRES integration in low and medium voltage grids. • Criteria to establish hosting capacity and to manage curtailment procedures. • Technical requirement to DRES, requirements for manufacturers of equipment and technology providers • Methodologies and tools to develop accurate technical and	• Incorporate recommendation in operational & maintenance processes.	• The network of relevant stakeholders will proceed developing the energy system based on action plans and road maps derived from a set of social, economic and technical frameworks. The recommendations will support the design of strategies for dealing with the challenge of climatic change consistent with successful European society and economy.

	economic assessments.		
D6.2 Report on DSOs` business evolution	Identification of the current state in DRES integration and IGREENGrid vision concerning economical, technical and regulatory aspect.	• Baseline for R&D project. • Identify aspect where national regulations need advance.	• Identify the aspect where regulator need pay attention and the needs of DRES integration for further regulations.

Table 8 ENEL Exploitable Foreground

2.1.7 HEDNO

Exploitable Foreground	Exploitable Knowledge	How Exploit it	Expected Impact
Coordination with IGREENGrid family projects (SINGULAR & SuSTAINABLE) D1.4, D1.6 and D1.7	Analysis of: • Methodologies used. • Demos implemented. • Solutions tested. • Results obtained.	• Study the several methodologies, frameworks, use cases and results obtained and internally disseminate. • Use the analysis as a baseline for further R&D projects.	• Increase awareness about the experiences of other EU projects • Share knowledge inside HEDNO. • Improve professional networking (other DSOs, manufacturers, etc).
D2.1: Barriers for connection of DRES in distribution grids	Identification and definition of a set of major barriers on EU countries for DRES connection.	• Share knowledge. • Use knowledge as a basis during discussions with stakeholders.	• Facilitate the integration of DRES. • Accelerate the discussions on the regulatory and market frameworks.
D2.2: Assessment methodology based on indicative Key Performance Indicators	• KPIs evaluation methodology.	• Use KPIs to compare different solutions that address same problems and select the most appropriate.	• Improve knowledge about EEGI. • Improve awareness about KPIs.
D3.1: Individual reports	Analysis of: • Methodologies. • Demos implemented. • Solutions tested. • Results obtained.	• Study the several technical solutions implementation and results obtained. • Share knowledge. • Use knowledge for further projects and work.	• Facilitate the design and implementation of new Smart Grid demonstration projects. • Improve professional networking.
Evaluation of EEGI labelled and other relevant demonstration projects (D3.2 and D3.3)	Information gathered from other projects.	• Share knowledge. • Use knowledge for further work.	• Facilitate the design and implementation of new Smart Grid demonstration projects. • Raise awareness of new technologies/products for DRES integration. • Improve professional networking.
D4.1: Report listing selected	Experience obtained from the	• Use the analysis as a baseline for	• Improving knowledge about KPIs.

KPIs and precise recommendations to EEGI Team for improvement of list of EEGI	designing of the KPI methodology.	further projects and work.	
D4.2: List of reference targets (country-specific & EU-wide) for grid integration of DER based on selected solutions	• Selection of most promising solutions. • Parameters affecting efficacy • Qualitative SRA.	• Identify effective solutions for DRES integration in distribution grids that could be scalable and replicable. • Share knowledge. • Use knowledge as a baseline for further R&D projects.	• Facilitate the selection of technical solutions to be tested/implemented in the network. • Facilitate the design and implementation of new Smart Grid demonstration projects. • Increase awareness about best practices on grid integration of DER. • Increase acknowledgement inside HEDNO experts.
D5.1: Technical and economic evaluation of replicability and scalability of solutions to increase DER installation	• Solutions classification. • Replicability and Scalability Evaluation. • Best Practices Simulation.	• Identify effective solutions for DRES integration in distribution grids that could be scalable and replicable. • Share knowledge. • Use results for upcoming projects or technical solutions deployment.	• Facilitate the selection of technical solutions to be tested/implemented in the network. • Facilitate the design and implementation of new Smart Grid demonstration projects. • Increase awareness about best practices on grid integration of DER. • Increase acknowledgement inside HEDNO experts.
D5.2: IGREENGrid simulation & evaluation framework (methodology and tools)	• Methodology and Evaluation Tools.	• Use the methodology and tools for upcoming projects or technical solutions deployment. • Share knowledge.	• Increase acknowledgement inside HEDNO experts. • Include methodologies and tools in the available tools.
D6.1: Guidelines for future Massive Integration of DRES	• Recommendations about rules and criteria to manage	• Share knowledge inside HEDNO • Adapt recommendations at	• Incorporate recommendations in operational & maintenance

in distribution grids	properly distribution systems focused on increasing DRES integration in low and medium voltage grids. • Technical requirements to DRES, requirements for manufacturers of equipment and technology providers.	national level	processes.
D6.2: Report on DSOs business evolution	• Identification of the requirements, the current status, and the technical, economic and regulatory actions that should be implemented in each country by the different involved players in order to integrate the new DSO roles.	• Share knowledge. • Analyse and use knowledge as a baseline for further elaboration and discussions at national level. • Use knowledge as a basis during discussions with stakeholders.	• Share knowledge inside HEDNO. • Adopt a national action plan.
Final Report	• IGREENGrid work and conclusions.	• Share knowledge and results.	• Use knowledge for further projects.
Technical evaluation and CBA approach	• Results on economic and technical evaluation.	• Identify effective solutions for DRES integration. • Share knowledge. • Use results for upcoming projects or technical solutions deployment.	• Facilitate the selection of technical solutions to be tested/implemented in the network. • Facilitate the design and implementation of new Smart Grid demonstration projects. • Increase awareness about best practices on grid integration of DER. • Increase acknowledgement inside HEDNO experts.
Stakeholders Committee meetings	• Experience. • Feedback from the stakeholders.	• Share knowledge • Produce informative material for internal (HEDNO) use.	• Share knowledge. • Learn about best practices. • Improve professional networking.
IGREENGrid workshops 1,	• Experience.	• Share knowledge.	• Learn about experiences of other

2, 3 and 4 (D7.6, D7.7, D7.8 andD7.9)		• Produce informative material for internal (HEDNO) use.	projects/practices. • Improve professional networking (other DSOs, manufacturers, etc).
Specific Knowledge of DRES integration	• Knowledge of State of the art, best practices in Smart Grid technologies and solutions.	• Share knowledge • Produce informative material for internal (HEDNO) use. • Training courses. • Use knowledge for further projects and work.	• Facilitate the design and implementation of new Smart Grid demonstration projects. • Facilitate the design and implementation of new Smart Grid demonstration projects. • Involvement in new R&D projects.
Data repository tool	• Guidelines to manage available data. • Grid topologies. • Integration of KPIs tools calculation. • Automatically calculate KPIs and facilitate the comparison between technical solutions. • Flexible mechanism to store data from different sources/systems.	• Assess the feasibility and the efficiency, by using KPIs calculation, of technical solutions towards the target of increasing the DRES penetration in distribution grids. • Store data from different sources/systems and perform comparisons between different solutions.	• Facilitate the comparison of technical solutions towards the target of increasing the DRES penetration in distribution grids.

Table 9 HEDNO Exploitable Foreground

2.1.8 AIT

Exploitable Foreground	Exploitable Knowledge	How Exploit it	Expected Impact
D2.1: Barriers for connection of DRES in distribution grids	Identification and definition of a set of common barriers on the six countries participating on the project; identifying the difficulties the integration of DRES, organized in three categories: technical, economical and regulatory.	• Presentation of the solutions oriented to minimize the actual barriers. • Use as starting point to develop solutions to overcome these barriers.	• Basis for further R&D work.
D2.2: Assessment methodology based on indicative Key Performance Indicators	• KPI evaluation methodology. • KPI definition. • Experience on the usability of KPIs.	• Use the proposed KPIs on a large set of networks to gain experience on their relevance	• Improve knowledge about the EEGI methodology. • Improving knowledge about KPI and have a implement their automated calculation on the basis of real case-studies.
D3.1: Individual reports	• Analysis of the pilot projects, the solutions tested and the results obtained. • Outcome of bilateral discussions with demo-experts on the challenges related to specific solutions.	• Compare solutions and experiences within the national demonstration projects to gain experience for further projects. • Understand solutions coming from other demos to be able to investigate their scalability and replicability potential.	• Implement solutions developed and tested in other demonstration projects into other networks. • Investigate issues which were not investigated in the demonstration projects (e.g. accuracy of observers).
D4.2: List of reference targets (country-specific & EU-wide) for grid integration of DER	• Selection of solutions on the basis of a qualitative evaluation.	• Use this type of analysis for other problems.	• Support for further projects.

based on selected solutions			
D5.1: Technical and economic evaluation of replicability and scalability of solutions to increase the DER	• Methodology for tool designing. • Solutions classification • Simulated and Validated Catalogue of solutions. • Replicability and Scalability Evaluation. • Reference Values Simulation. • Best Practices Simulation.	Use the methodology for coming project or technical solutions deploy in order to identify the right place to test the different solutions.	• To improve technical solution deployed in other countries or scenarios. • Definition of reference networks for each kind of problem. • Improve the knowledge about the CBA analysis.

D 5.2: IGREENGrid simulation & evaluation framework (methodology and tools) to assess about the penetration	• Methodology to evaluate the deployment potential of smart grids solutions.
	• Probabilistic load flow simulations applied to the hosting capacity determination.
	• Automatization of simulations to run a high number of simulations on a high number of networks.
	• Implementation and use of parallelisation of simulations on a high performance computing cluster.
	• Methods to analyse results and compare the performance of solutions on different networks.
	• Visualisation methods to
		• Use the methodology and tools for coming project.
		• Further develop the simulation environment.
			• Knowledge and experience will be used for further projects (research and customer projects).
			• Consultancy for DSOs on the potential of smart grids solutions for their networks.
			• Generic studies for public organisations.
			• Papers to be published out of this work:
			  ○ Expected conference papers: 5-10.
			  ○ Expected journal papers: 1-3.

	condense results and display important results for DSOs. • Increased knowledge and experience on state estimation (dedicated implementation in the simulation environment). • Quantitative statements on the deployment potential of smart grids solutions. • Simulation framework involving several tools (e.g. PowerFactory, Python, Matlab). • Statistical methods to investigate the deployment potential of smart grids solutions on a very large set of LV networks. • PowerFactory scripts to automatically evaluate key indicators of LV feeders and networks. • Machine learning (supervised learning) applied to the classification of LV feeders. • Increased knowledge and experience in network data exchange between different tool		

	(Neplan, PSSE, Sincal, OpenDSS, Matpower->PowerFactory).		
D6.1: Guidelines for future Massive Integration of DRES in distribution grids	• Recommendations about rules and criteria to manage properly distribution systems focused on increasing DRES integration in low and medium voltage grids. • Technical requirement to DRES, requirements for manufacturers of equipment and technology providers. • Methodologies and tools to develop accurate technical and economic assessments.	• Support DSOs in the implementation of some of the developed functions / scripts / … in their tools.	• Acquire customer projects to make use of the gained know-how and experience.
D6.2: Gap analysis & evolution of DSOs business	• Identification of technical, economic and regulatory actions that should be implemented in each country by the different involved players to integrate the new DSO roles.	• Advise DSOs.	• Acquire customer projects.
• Final Report	• Overall results and conclusions.	• Dissemination in national events.	• Organise a session during the smart grids week 2016 in Linz.

Table 10 AIT Exploitable Foreground

2.1.9 ICCS-NTUA

Exploitable Foreground	Exploitable Knowledge	How Exploit it	Expected Impact
Data Repository for Smart Grid projects. (D2.2 , D2.4, D3.1 and D 3.2)	A data repository that is used to store and study scenarios from the six smartgrids demonstration projects that are analyzed within the IGREENGrid project has been designed and implemented by ICCS. The data repository is flexible and scalable and can be used to automatically calculate KPIs and facilitate the comparison between technical solutions. The efficiency of the solutions is depicted in the KPIs' results, which are automatically calculated by the data repository, as will be presented later. In the future, the KPIs formulas can be updated and the total set of KPIs can be extended in new versions of the data repository following the stakeholders' requirements.	ICCS plans to exploit the knowledge and experience of data repository in future R&D projects. The objective will be to further develop and improve the tool, so that it could be transformed into a more generic tool applicable to other Smart Grid projects. The main characteristics of the data repository are: • A flexible mechanism to store data from different sources/systems. The data sources may be exports from DMS, Databases or other software platforms in different format types such as Excel, text, CSV or XML provided the format is known beforehand. • The data may contain both static data (e..g. network description, DG technical characteristics etc) or measurements/ calculations (e.g. voltages on feeders, production of DGs etc). • Automated KPI calculations according to standard formulas.	The IGREENGrid data repository can become the basis for the development of a valuable tool, which can be used by DSOs and other Smart Grid vendors to assess the feasibility and the efficiency of their technical solutions towards the target of increasing the DRES penetration in distribution grids.

	Furthermore, a set of typical/representative Smart Grid technical solutions can be stored in the data repository as a reference. The default Smart Grid topologies accompanied with related measurements/calculations can be conveniently used as a basic scenario to perform comparisons between the technical solutions. In order to obtain meaningful KPIs values, the DRES production profiles and the technical characteristics of the grids have to be input. A set of preloaded data in the data repository can simplify the procedure and operate as comprehensive example.	• Extensible framework for facilitating data needs for future KPIs and further standardized calculations. This has been achieved by designing a database that will easily integrate other type of measurements or new characteristics in the DGs. • User friendly environment with extra supporting functionalities such as view/search data or save accompanying files. The environment is Web Based and the user depending on the access rights may read the KPI (simple user) or add/manage data (advanced user). The calculation of the KPIs includes standard step-by-step procedures which are implemented in the dataset of the IGREENGrid demonstration projects and are described in [D 2.1]. The KPIs can rely on simulations based on real measured inputs, considering cases in which the grid is facing extreme situations and Smart Grid solutions that improve the grid's performance. KPIs can also be used to compare the performance of a Smart Grid application in different networks or	

		to compare the performance of different approaches in a specific grid configuration.	
Advanced algorithms for Probabilistic Load Flow, and Probabilistic RES forecasting for the demonstration project of Sperchiada in collaboration with HEDNO, enhanced tools for monitoring and operational planning. (D3.1, D5.1cand D5.2)	The background functions for the deployment of the Greek Demonstration project of Sperchiada, are RES (PV) Forecasting and Probabilistic Load Flow. The basic idea behind the developed probabilistic tools is to use the data available from two different systems, the DMS (Distribution Management System) and the AMR system.	ICCS plans to exploit the usage of these background functions for providing enhanced monitoring and early warning functionalities for several substations in collaboration with HEDNO. In the long term these functionalities will be proposed as an add-on for advanced monitoring and control of active distribution grids with low monitoring capabilities.	The wider exploitation of probabilistic functions will provide advanced functionalities for the DSO operators and planners, such as the enhanced identification of reverse power flows at the primary substation and the identification of the flow composition and direction while using a powerful and low-cost tool. One of the most important achievements for the grid operators will be the timely warning about potential limit violations, while giving them the opportunity to increase the RES hosting capacity without major investments. The combination of past measurements and probabilistic techniques can be a more objective assessment of technical constraints by providing safety margins.

Table 11 ICSS-NTUA Exploitable Foreground

2.1.10 SAG & EAG

Exploitable Foreground	Exploitable Knowledge	How Exploit it	Expected Impact
D1.5 D1.6, D1.7 coordination with SINGULAR & SuSTAINABLE Projects	• Methods for prognosis & forecasting, generation curtailment • Technology of energy storage, • demand side management, voltage control - Monitoring	Implementation step by step on demand within the development of future grid. Preparing regulatory and legal framework.	Development of economic increasing hosting capacity for DG and upcoming loads based on modern technologies. Important input for ongoing new DEMOS.
D2.1: Barriers for connection of DRES in distribution grids	• Common and different barriers have been identified.	Using the obtained knowledge for developing strategies together with relevant stakeholders.	Strategic development of standards and legal framework coordinating European and national processes for efficient design and use of distribution grid.
D2.2: Assessment methodology based on indicative Key Performance Indicators & D2.3: Suggestions and comments regarding the use of EEGI KPIs in real Demo Projects (first step)	• Common KPIs providing standard methodology to compare the DEMOs involved. • (but KPIs regarding economic matters and asset management are missing).	Using the experience for development of further KPIs also regarding economy and asset management more detailed.	Later application at further stage of technological development- especially when economic evaluation can be better established.
D3.1: Individual reports on the evaluation of local Pilot projects	• Looking deep inside the demos involved important details beside KPI evaluation improved the knowledge.	Detailed knowledge will be applied at planning and performing further demos.	Further Demo projects will be set up at higher level of quality based on experiences shared by the partners. Specifications for components will become improved in detail.
D4.1: Report listing selected KPIs and precise	• Experience obtained from the designing of the KPI	Use the analysis as a baseline for further	BAU as well as results of further demos can be better evaluated and compared.

recommendations to EEGI Team for improvement of list of EEGI.	methodology.	project.	
D4.2: List of reference targets (country-specific & EU-wide) for grid integration of DER based on selected solutions.	• Selection of effective solutions Reference Targets for KPIs Methodology and criteria of evaluation. • Best Practices Identification. • Qualitative SRA.	Use the analysis as a baseline for further project.	Technologies based on simple or few ICT solutions seem to be relevant in near future for DSOs. Components for distribution grids will support monitoring and supervision functionalities – but only in few cases become part of a closed loop operation.
D5.1: Technical and economic evaluation of replicability and scalability of solutions to increase the DER	• Gives results about the probability of successful implementation for the different solutions of the demos.	Analysis of potential economic improvement using a standardized solution in a certain number of cases.	Further application within wide area and multiple installation demos will focus on increased total benefit by applying standardized applications–even if efficacy is lower in single cases.
D 5.2: IGREENGrid simulation & evaluation framework (methodology and tools) to assess about the penetration	• Methodology and Evaluation Tools. • Simulated Cases. • Economical and Technical evaluation.	Use the methodology and tools step by step for network analysing and planning tools used in everyday business of DSO.	Effective deployment of solutions requires efficient tools which can be used without deep knowledge and special know how. The management of data from SCADA, monitoring systems and metering will be improved to enable access for advanced analysis and planning.
D6.1: Guidelines for future Massive Integration of DRES in distribution grids	• Recommendations about rules and criteria to manage properly distribution systems focused on increasing DRES integration in low and medium voltage grids. • Criteria to establish hosting capacity and to manage curtailment procedures. • Technical requirement to DRES, requirements for	Incorporate recommendation in operational & maintenance processes.	The network of relevant stakeholders will proceed developing the energy system based on action plans and road maps derived from a set of social, economic and technical frameworks. The recommendations will support the design of strategies for dealing with the challenge of climatic change consistent with successful European society and economy.

	manufacturers of equipment and technology providers. • Methodologies and tools to develop accurate technical and economic assessments.		
D6.2 Report on DSOs` business evolution	• Identification of the current state in DRES integration and IGREENGrid vision concerning economical, technical and regulatory aspect.	Baseline for R&D project. Identify aspect where national regulations need advance.	Identify the aspect where regulator need pay attention and the needs of DRES integration for further regulations.

Table 12 SAG & EAG Exploitable Foreground

2.1.11 TECNALIA

Exploitable Foreground	Exploitable Knowledge	How Exploit it	Expected Impact
D2.1 Barriers for connection of DRES in distribution grids	• Knowledge about the regulatory, technical and economic barriers encountered when interconnecting distributed renewable energy resources into the distribution network.	• Share knowledge. • Use knowledge as a starting point for further R&D projects focused on the development of solutions to overcome these barriers.	• Facilitate the integration of DRES generation. • Facilitate the evolutions needed on the regulatory and market frameworks.
D2.2 Assessment methodology based on indicative Key Performance Indicators	• Knowledge on KPIs for the quantification of technical benefits deriving from the application of Smart Grid solutions.	• Use knowledge for R&D work focused on further development of KPIs.	• Contribute to the development of a standard methodology for the evaluation of Smart Grid solutions in different demonstration projects • Improve awareness about KPIs.
D3.1 Individual reports on the evaluation of local Pilot projects	• Knowledge about methodologies, solutions tested and results obtained from the different demonstration projects.	• Use knowledge for further R&D work.	Learn about the experiences of projects implementing Smart Grid solutions oriented to increase DRES integration.
D4.2 List of reference targets (country-specific & EU-wide) for grid integration of DER based on selected solutions	• Knowledge about qualitative approaches for the evaluation of the Smart Grid solutions including the scalability and replicability point of view.	• Use the gained knowledge for future R&D projects focused on the assessment of the scalability and	• Contribute to the definition of methodologies for the evaluation of the scalability and replicability potential of the solutions.

		replicability potential of different Smart Grid solutions for DRES integration. • Use the knowledge for future R&D work focused on further development of the developed approach for the SRA.	
D5.1 Technical and economic evaluation of replicability and scalability of solutions to increase the DER (Public) & D5.2 IGREENGrid simulation & evaluation framework (methodology and tools) to assess about the penetration (Public)	• Knowledge on the application of techniques based on simulations for the technical assessment of the scalability and replicability potential of Smart Grid solutions. • Knowledge on the application of techniques for the evaluation of costs and benefits of Smart Grid solutions.	• Use the knowledge gained as a baseline for future R&D projects. • Further development of the developed approach for the cost and benefit analysis under the framework of future R&D projects.	• Identify effective solutions for DRES integration in distribution grids that could be scalable and replicable. • Contribute to the knowledge of CBA of Smart Grid solutions and the development of approaches for its quantification.
D6.1 Guidelines for future Massive Integration of DRES in distribution grids	• Knowledge on recommendations to the different stakeholders about rules and criteria to manage properly distribution systems focused on increasing DRES integration in distribution networks.	• Share knowledge. • Use knowledge as a starting point for future R&D projects.	• Facilitate the integration of DRES generation. • Facilitate the evolutions needed on the regulatory and market frameworks. • Improve awareness of the different stakeholders about how they can contribute to the integration of DRES.

D6.2 Report on DSOs' business evolution	• Knowledge about the technical, economic and regulatory actions that should be implemented in each country by the different involved players to integrate the new DSO roles.	• Baseline for R&D projects. • Improve knowledge regarding the aspects where national regulations need to advance.	• Anticipate the evolutions needed to put in place the new roles from a technical, regulatory and economic point of view.
Stakeholders Committee meeting minutes	• Knowledge about the experience taken from other initiatives in DRES integration.	• Smart Grid and DRES integration knowledge for future R&D projects.	• Improve knowledge about Smart Grid technologies, companies involved, etc.
Knowledge on Cost-Benefit Analysis (CBA) of Smart Grid projects	• Analysis of different approaches for the CBA of Smart Grid projects (EC JRC, ENTSO-E and DOE – U.S. Department of Energy…). As a result, knowledge about the different approaches for CBA has been built. • Development of a particular CBA approach to be applied to the solutions identified within the IGREENGrid project as the "most-promising" ones for DRES integration into distribution networks based on EC JRC methodology.	• Use the gained knowledge and the developed very first prototype of the CBA approach in future R&D projects for the economic evaluation of Smart Grid solutions. • Further development and improvement of the prototype into a more generic tool that could be applicable to other Smart Grid projects.	• The main added value of this knowledge lies on the adaptations made to the methodology for the analysis of costs and benefits for IGREENGrid project. This methodology fits the reality or characteristics of IGREENGrid project as much as possible, as it reflects partners and stakeholders interests, according to the information availability. It represents a good base to continue working on the preparation of a CBA methodology. • Due to the high costs related to innovative technologies and the relative lack of necessity to implement them, this approach will be at this stage mainly interesting within R&D projects

Table 13 TECNALIA Exploitable Foreground

3 Economic Evaluation of Most Promising Solutions

The economic evaluation of the most promising solutions selected in IGREENGrid project has been performed by applying a methodology to evaluate of costs and benefits associated to the deployment of these solutions in the distribution networks. This methodology, called CA&BA, is based on the EC JRC CBA methodology [4]. However, several modifications have been made performed with the aim of simplifying the scope and making it more suitable for the characteristics of the project [D5.2].

IGREENGrid CA&BA do not pursue the objective to support the selection of the best solution for every country and any network because the studied distribution networks may not be 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 and deployed smart grid equipment).

The first accomplished task in the IGREENGrid CA&BA consists on the description of the solutions and then, two different and parallel analyses are carried out: The Costs Analysis (CA) and the Benefits Analysis (BA).

The aim of the CA is to compare the costs incurred by the DSOs when deploying conventional solutions based on grid deployment with the smart grid approaches in the distribution networks. The purpose of the BA is to identify potential benefits that may be provided by the smart solutions.

The results of the CA allow drawing purely economic conclusions about the deployment of the most promising solutions, while the BA identifies more qualitative benefits or advantages provided by the solutions from the point of view of the whole system.

3.1 Most Promising solutions

The solutions identified as most promising solutions[1] [D4.2] have been grouped into families of solutions for the purpose of the technical assessment of the scalability and replicability potential. The reason for this is that the particular implementation of the solution done at the different demonstrators does not provide enough information for the evaluation of the performance of the solution in terms of e.g. hosting capacity, impact on network losses… on other networks.

The list of smart solutions considered in for the economic evaluation in IGREENGrid is this[2]:

- **Medium Voltage Monitoring**
    - MV Voltage Monitoring (PLF).
    - MV Voltage Monitoring (RTU).
    - MV Voltage Monitoring (SE).
- **Low Voltage Monitoring**

[1] Check [D4.2] for more information about the most promising solutions.
[2] The list of "most-promising" solutions includes also the functionality "Medium Voltage Congestion Management", but due to the uncertainty of the possibility to deploy this kind of solutions and the required regulatory changes in European countries, this functionality is out of the scope of the CA&BA.

- LV Voltage Monitoring (AMI).

- **Medium Voltage Control**
  - MV Centralised (field measurements) Voltage Control with OLTC.
  - MV Centralised (SE & OPF) Voltage Control with OLTC.
  - MV Centralised (SE & OPF) Voltage Control with OLTC & DG.
  - MV Centralised (SE) Voltage Control with OLTC.
  - MV Distributed Voltage Control with OLTC.
  - MV Distributed Voltage Control with OLTC, DG.
  - MV Supervised (field measurements) Voltage Control with OLTC & DG.
  - MV Supervised Voltage Control with OLTC & DG.

- **Low Voltage Control**
  - LV Distributed (field measurements) Voltage Control with OLTC.
  - LV Distributed Voltage Control with DG.
  - LV Distributed Voltage Control with OLTC.
  - LV Distributed Voltage Control with OLTC, DG.

All the solutions listed above are aimed to solve voltage constraints due to the increase of DRES penetration in both medium and low voltage distribution networks.

3.2 Economic Evaluation of MV solutions

In this subchapter the three solutions within the functionality “MV Voltage Monitoring” and the eight implementations within the solution group “MV Voltage Control” are assessed.

3.2.1 CA of “MV Voltage Monitoring” & “MV Voltage Control” solutions

As mentioned before, the CA compares costs incurred by the DSOs when deploying conventional solutions based on grid deployment with costs related to the deployment of the smart grid approaches in the MV distribution networks.
One of the difficulties found in the technical analysis of the networks is the complexity of the calculation of needed network reinforcement to reach a given hosting capacity (limited as the highest HC that can be reached with the “best” smart solution). A simplified common approach has been proposed and in consequence, the results must be carefully interpreted.
In addition, the characteristics of the countries (regulation, topography, etc.) and the planning approaches of DSOs are different, i.e. each DSO case is different. In line with this, the results of the analysis are based on large number of network / feeders but cannot fully reflect the actual situation of each and every DSO. A simple extrapolation of the results is not reasonable.
Spread spectrum of the values of the theoretical costs of network reinforcement is calculated from the data coming from the technical simulations, as high differences are detected about the needed network reinforcement to reach a given hosting capacity. The clear conclusion drawn from this fact is that for a non-negligible share of networks, the costs of the network reinforcement are in the

range of the typical solutions for a new primary (or secondary in LV networks) substation (if feasible, in some cases the cost of substation is not typical at all due to a lack of space for instance). It should be kept in mind that the considered DRES penetration are very high (hosting capacity for the most performant solution), which explains why major reinforcement are necessary for some networks. In some cases, the considered penetration may not be realistic (e.g. DRES potential limited by the available roof area).

Although the initial costs of the network reinforcement may be higher than initial investment costs of smart solutions, it has to be taken into account that operational and maintenance costs of conventional solutions are usually lower than smart assets operation.

Additionally, the estimated lifetime of typical network assets (such as cables) exceeds the time horizon of 20 years considered in the Cost Analysis. As the life expectancy of typical network assets is estimated around 40-50 years, taking into account this longer lifetime on the costs analysis may be required to properly compare costs, as a solution that includes a more expensive asset with a much longer life expectancy could end up more profitable. This longer life expectancy tends to be more favourable to network reinforcement. This can bring more complex solutions (centralized solutions with extension of the SCADA-DMS) to be more expensive than network reinforcement.

Within MV solutions, some solutions have a centralized control and other distributed (mostly based on local actuators). When addressing the specific requirements of one case, applying distributed solutions with lower communication needs seems to be the most cost effective alternative (lowest costs per MW additionally installed – as long as the gained hosting capacity is enough for the considered solution). If the problem to be solved with the distributed smart grids solution occurs in multiple locations within the distribution network, then centralized approaches may prevail, due to the other functions that network management systems (i.e. State Estimation) could contribute to the system.

In general terms, centralized solutions tend to be significantly more expensive than distributed solutions because of the individual cost of some components. In any case, some assets used at these centralized solutions (i.e. State Estimation) enable other functionalities for DSO operation:

- More precise network planning, thanks to the knowledge of the real status of the network.
- Improved operation of the network, enabling to solve problems on real time.

The correct attribution of the share of the costs of these components becomes the key for a fair comparison of costs among solutions.

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. Other smart grids solutions applied at the demonstration projects were discarded for further analysis in IGREENGRID due to the limited resources, but they may also be included among the possible alternatives: the AVR deployed to the German demonstrator, the STATCOM at the Spanish demonstrator or the battery based storage system studied at the Italian and French demonstrators.

Each concrete network should be studied with detail in order to identify the most suitable approach to solve the issues raised from the increased share of renewables into that distribution network.

3.2.2 BA of “MV Voltage Monitoring” & “MV Voltage Control” solutions

The BA identifies the benefits that smart solutions could provide to the system. These are selected from the list of 22 potential benefits and the list of 54 KPIs / Benefits proposed by JRC [4].

It has been concluded that the “MV Voltage Monitoring” and “MV Voltage Control” solutions would result on deferred distribution capacity investments because they allow to better estimate and to use the real remaining hosting capacity of the network. In general terms, the planning of distribution network applies quite conservative limits aimed to handle risks and ensure that the quality of supply is always guaranteed leaving wide security margins that could be used if more information is available (monitoring). The margins are also due to other factors such as: the limited number of product ranges (when reinforcing e.g. a substation), or the costs of cable laying in urban areas urging the DSO to (over)reinforce the network in order to meet future needs and avoid frequent construction work in the streets.

"Voltage Monitoring" contributes to a higher DRES penetration but also permits to obtain better levels of security and quality of supply as voltage monitoring is the first step for voltage control, which can ensure a higher voltage quality.

The main objective of "MV Voltage Control" is to ensure that increased levels of DRES (i.e. higher penetration of renewable energy sources into the network and into the generation mix) do not lead to voltage constraints that otherwise would have required network development to be solved. In this sense, additional wires and electrical infrastructure are delayed or even substituted by communications and intelligence in order to ensure security and quality of supply.

Some side effects could also be expected but it is unclear what the real impact could be, for instance, in terms of losses: increased levels of generation close to consumption nodes could reduce transmission network losses but also increase distribution network losses.

The reduction of electricity losses and maintenance cost would come for the improved observability of the network, i.e. more accurate information about the real state of the network, device loading, applied voltages, etc. Reinforcing the network would also reduce the losses. Indeed, the comparison of the losses in the "network reinforcement" scenario and in the "MV Voltage monitoring" scenario could actually show that MV monitoring could end up increasing the losses as hosting capacity may increase if some reserves are actually available. In any case, these would be side benefits quite difficult to estimate and measure.

The increase of sustainability is a direct benefit of the "MV Voltage Control" due to the reduction of environmental impact of electricity grid infrastructure. In other words, the improvement of hosting capacity for DER in distribution grids is based on communications and intelligence so it defers the need to install additional infrastructure. At the same time, tighter control of the MV network voltage improves the voltage quality performance. Some of the side effects are due to the expected higher penetration of renewable energy sources into the network and into the generation mix.

To sum up, increasing the hosting capacity of the existent distribution grids helps to optimize the use of the capital and assets as with a same infrastructure the system can be able to manage (Voltage Control) a higher number of DER generators due to the better knowledge of the state of the network provided by the Voltage Monitoring. The idea is to exploit network assets closer to the technical limits by advanced monitoring and control.

3.3 Economic Evaluation of LV solutions

In this subchapter the economic evaluation of the solutions within the functionalities "LV Voltage Monitoring" and "LV Voltage Control" are exposed.

3.3.1 CA of "LV Voltage Monitoring" & "LV Voltage Control" solutions

In the case LV solutions, the same comparison is carried out between the costs incurred by the DSOs when reinforcing the network and the smart grid approaches for the LV networks.

The major factor limiting DRES penetration in the studied LV networks is the voltage rise produced by DRES power injection.

In the technical simulations, "highly distributed" DRES penetration scenarios are used, i.e., PV based DRES are simulated across most of the nodes of the LV distribution network. In particular, the technical analysis shows that the penetration of DRES leads to higher voltage levels, but for some DSOs, the allowed voltage rise for LV distribution networks is very low, which strongly limits the hosting capacity.

The planning rules applied by each DSO could have a significant effect on the hosting capacity. The maximum acceptable voltage raise can cover a wide range, from 1% to more than 3%, depending on the DSO. In other words, similar networks will allow several times higher DRES penetration just because of the normal planning practices of the DSOs (when considering the LV level only). The OLTC artificially benefits from these margins since it completely changes the way to deal with MV voltage variations and these LV margins are not taken into account anymore and the reference is changed, so this should be taken into account in the way the results are understood and interpreted.

The effect of these limits can also be observed on the total reinforcement length and costs of the business as usual cost: targeting the same hosting capacity with very restrictive voltage limits needs so major reinforcements that, in some cases, total reinforced cable / line lengths are close to effectively duplicating the network. Obviously, in these cases, when comparing total costs of smart solutions and total costs of network reinforcement, it would be cheaper to build a dedicated secondary substation and that would be the preferred solution to reach the same DRES penetration.

The transformers equipped with OLTC are a very effective solution to decouple voltage levels (MV/LV) and free part of the voltage band allocated to the upper voltage level and to loads for generation embedded in LV networks. The use of OLTC equipped transformers in secondary substations provides therefore an important increase of the hosting capacity in LV networks.

In line with this, the lengths needed for network reinforcement solution tend to be very long for some of the LV networks studied, as a very significant increase of HC is reached thanks to the smart grids solutions using both the OLTC and the P&Q control in generation units. However the simulated situation is not completely realistic since HC is maximized and all the feeders therefore may require reinforcements which are usually very expensive. In some more realistic situations with reasonable penetration of DRES, the costs of the reference situation would be much smaller compared to OLTC for example.

In the tested networks, according to the results of the technical simulations, the HC increase obtained by the OLTC is larger than the HC obtained with locally controlled DRES inverters adapting reactive power injection / consumption to the sensed voltage and curtailing active power if needed.

Then, the deployment of one smart grids solution such as the MV/LV transformer with OLTC leads to a significant increase of the hosting capacity in an easy but costly way as the average European secondary substation is equipped with conventional off-load tap changing transformers and the cost of a comparable on-load tap changing transformer is in a ratio of roughly 2 to 3 without taking account the costs of required sensors on the network and the additional costs for the installation and maintenance of the OLTC compared to conventional transformers.

It is also important to note that in some countries these assets are not considered as distribution assets, so DSOs do not receive neither incentives nor payments for them; making necessary a regulatory change in the DSO retribution scheme.

The additional hosting capacity introduced by advanced controls on the DRES power interface should not be neglected because it also brings an important benefit with little additional costs: DRES would adapt themselves to the local voltage measure in a distributed and unattended manner contributing to the network operation.

3.3.2 BA of "LV Voltage Monitoring" & "LV Voltage Control" solutions

"LV Voltage Monitoring" solutions provide interesting information that will improve the design and the operation of the LV networks, identifying potential voltage constraints appearing at LV network.

The main impact or benefit of the "LV Voltage Control" solutions is enabling higher integration of DRES without network reinforcements, i.e. delaying or limiting the need for investments on distribution network assets, as the more accurate information about the real state of network (monitoring).

Some other side benefits could be obtained thanks to these solutions for LV networks solutions but, as occurs in the case of solutions for MV networks, they are difficult to evaluate. For instance, increasing the penetration of local generation should reduce the power flows in transmission and distribution networks, but depending on the specific production and consumption profiles the opposite effect could be attained.

4 Reliability & Interoperability of Most Promising Solutions

This chapter analyses how *most promising solutions* defined in IGREENGrid can be exploited taking into account the technical reality of DSOs and countries. Solutions are grouped attending main categories, according to the Deliverable D4.2.

1. **MV Voltage Monitoring.**
   Regarding MV Voltage monitoring, three most promising solutions of this category have been identified with a high deployment potential:
   - MV Voltage Monitoring (PLF).
   - MV Voltage Monitoring (RTU).
   - MV Voltage Monitoring (SE).

   Although MV Voltage Monitoring is not a solution of high technical complexity, it has a great dependency of ICT and Communications. The impact of an ICT failure on these solutions, which is entirely based on field measurements, would degrade the functionality of the monitoring system. The extent of the impact of an ICT failure would depend on the type and location of the fault.

   Duration of loss of communication impacts the quality of the service. When real-time data is mandatory a long period without communication will have a high impact. This is the case for MV Voltage Monitoring based on Remote Terminal Units and MV Voltage Monitoring based on State Estimator. It is possible to reduce the time of lack of communication designing a network that includes duplication of routes and equipment, but in this case, more investment will be needed.

   Regarding measurement devices failure, its overall reliability is considered to be high. The technologies or application of these devices are not new to power systems and companies normally have maintenance plans to minimize degradation of these devices.

   MV monitoring is a prerequisite for Voltage Control. The increase of the quantity of real-time measurements, decreases the operational risk the grid. Thus, the highest performing solution for MV monitoring is the one based on State Estimate. SE uses quasi-real time measurements, and that allows the operator knowing the real state of the grid at any moment. The advantage of the SE when compared with the use of Remote Terminal Units (RTUs), which are also able to provide real-time information, is that SE provides the added value of correcting wrong and incoherent values. SE has been considered more accurate than Probalistic Load Flow (PLF), because the last one, even working with more data (historical grid and generation information from years, months, days), it works with a low amount of sensors that provide, in the best case, data from the day before. This solution is especially useful for grids with a low degree of automation.

   The PLF solution is the most scalable one, because it is totally based on off-line studies, using load and generation profiles from the existing sensors, off-line voltage measurements and Advanced Metering Infrastructure (AMI) data, whichever is available. Due to the use of historical data, it does not lay on the use of a large amount of sensors. SE and RTU solutions could be less scalable because they involve a large amount of sensors in their deployment and they work in real-time demanding new telecom infrastructure development but they allow improving the voltage control performances.

2. LV Voltage Monitoring

This category includes just one promising solution, which presents a high deployment potential:

- LV Voltage Monitoring (AMI).

LV monitoring (AMI) technical requirements are higher than in MV. This is due to the fact that there is a higher rate of voltage fluctuations, and that measurement must be made in three phases. It is therefore expected that the communications bandwidth or memory storage and data processing requirements would be very high compared to similar solutions that are developed for the MV network.

Regarding the loss of communication and device failure, the reliability of the LV monitoring solutions would be expected to be very similar to the MV voltage monitoring solution. But LV monitoring will require the installation of more devices which increases the probability of failure.

The use of AMI to provide voltage profile monitoring it is not easy nowadays, as voltage monitoring functions are not standard for meters and in some countries the DSO is not responsible for metering (e.g. Germany, UK) and would have to request data from each customer. However, AMI would provide statistical data to reduce bandwidth/memory/data processing requirements. A solution providing data only for relevant intervals regarding maximum & minimum or certain percentiles of voltage levels all over the LV-grid would perfectly meet the requirements in respect to network planning.

If the solution based on AMI is going to be applied on a network that has already deployed the Smart Metering (SM) and provided that these meters are capable of measuring voltage, it becomes very easy to be scaled up, given that is basically software based. If the DSO has not deployed SM yet, which is the habitual case in Europe, the implementation implies an enormous amount of equipment to be installed. Another relevant aspect is the low standardization level of these solutions.

3. MV Voltage Control

Regarding MV Voltage Control eight most promising solutions of this category have been identified with a high deployment potential:

- MV Centralised (field measurements) Voltage Control with OLTC.
- MV Centralised (SE & OPF) Voltage Control with OLTC.
- MV Centralised (SE & OPF) Voltage Control with OLTC & DG.
- MV Centralised (SE) Voltage Control with OLTC.
- MV Distributed Voltage Control with OLTC.
- MV Distributed Voltage Control with OLTC, DG.
- MV Supervised (field measurements) Voltage Control with OLTC & DG.
- MV Supervised Voltage Control with OLTC & DG.

Solutions using control systems, centralised or distributed, present a relatively high technical complexity. When these systems are already available in DSOs, the introduction of new measurement or algorithms are more easily deployed.

Again, communication and device failure is an important factor to consider. Although the impact is high, the probability of a SCADA or communications failure is very low. The SCADA and communications systems are not new technologies and there is therefore very low risk of uncertainty that might be expected from using new technologies. Since transformers with

OLTC are standard in most networks across Europe, in most cases the transformer itself would not be considered as part of the solution. Failure of the transformer (OLTC) would also prevent functionality of the solution; however the likelihood of such a failure is very low. Again, the OLTC transformer is nothing new at this voltage level.

The MV Voltage Control solutions can be categorised in terms of control system and technology used. Distributed control systems would generally have a low investment and operational cost due to the reduced need for communications infrastructure however centralised control systems are being developed for improved levels of control, in any case both approach would usually provide an increased hosting capacity for DG and also where the communications infrastructure can be used for additional functionalities, such as automation, DSO-TSO interface.

A range of different technologies are available, such as DG invertors with capability to control the injected power (either active or reactive), STATCOM, OLTC (generally considered to already exist on nearly all MV networks), AVR and storage facilities. In many cases either of these technologies could provide the required performance and be technically feasible. The comparison of which solution would be the most promising would mainly be a question of cost (it is for this reason that some of them as the STATCOM, the storage or the AVR are not identified as most promising solutions) and in some cases the feasibility under current regulatory conditions. In terms of reliability, technologies that have been tried and tested for many years (such as the OLTC) and those that use the fewest number of components (such as controlling the DG invertors) are considered to have the greatest reliability.

Finally systems including also State Estimation or /and OPF algorithms helps to complete its functionality and performance.

4. LV Voltage Control

Regarding LV Voltage Control, four most promising solutions have been identified with a high deployment potential:

- LV Distributed (field measurements) Voltage Control with OLTC.
- LV Distributed Voltage Control with DG.
- LV Distributed Voltage Control with OLTC.
- LV Distributed Voltage Control with OLTC, DG.

LV Voltage control faces the same situation as MV Voltage Control: a relatively high technical complexity and the same communication dependency. The reliability of the LV control solutions would be expected to be very similar to the MV voltage control solution.

In general DSOs have more advance SCADA systems in MV than in LV, which makes the deployment of control system more difficult in LV grid.

Similar to MV, centralised control is less scalable than distributed one, mainly because of the large amount of sensors and telecom equipment. DG Flexibility (active power modulation) is not easy to scale and replicate due to the need of modifying contracts and regulation requirements.

5. MV Congestion Management

Finally, two most promising solutions of this category have been identified with a high deployment potential regarding MV congestion management.

- MV Congestion Management with DG non-firm grid connection contracts (including DG modulation).
- MV Congestion Management with Use of Flexibility (DG, DSM, STR ...).

The MV non-firm contracts require fewer devices to be monitored and managed, than the use of flexibilities. Both need a SCADA integration in order to simulate and calculate the flexibility needed. Concerning the non-firm contracts, they need a bilateral communication between the DSO and the generator. For the use of flexibility, a communication between the DSO and one aggregator could be enough but it needs a “market platform”.

The highest performing implementations are ones using all kind of flexibilities that DSO may contract: curtailment of generation, demand side management, storage, aggregators, etc.

Solutions using all kind of flexibilities are less easy to scale up and replicate than the solutions using only ”non firm grid contracts”. It is due to the fact that the need of communications is higher, as well as the need to involve a lot of participants.

5 Potential Markets

The figures in this chapter derive from the JRC SCIENCE AND POLICY REPORTS: “Smart Grid Projects Outlook 2014” [3].

Since 2002 up to 2014, 459 Smart Grid projects in 47 countries have been launched, which amount €3.15 billion in investments. 287 of them are national projects and 172 are multinational projects (with an average of 6 countries per project). From these 459 projects, 221 projects are still on going and 228 have already been completed.

There are 1.670 different organizations, where the most active ones are Universities - Research Centers- Consultancies and DSOs. The most active companies are from Denmark.

The largest investments are made in France and the UK.

In the period 2008-2013, investment in Smart Grid projects was consistently above €200 million per year, reaching €500 million in 2011 and 2012. The number of Research and Development (R&D) projects is around the same as that of Demonstration and Deployment (D&D) projects, but the total investment in D&D is almost three times larger (the average D&D budget per project is usually two times larger than R&D). By far, the largest investment comes from organizations in the EU15 Member States.

There are a total of 578 demonstrator sites (532 within EU territory). Half of their allocated budget goes to three countries: France, United Kingdom and Spain. The countries with more different implementation sites are Germany and Italy.

Funding still plays a crucial role in stimulating private investment in Smart Grid R&D and D&D projects. More than 50 % of the total Smart Grid budget originates from four countries: France, United Kingdom, Germany and Spain. 49 % of the total budget for the Smart Grid projects surveyed comes from private capital and the remaining 49 % from various sources of funding (national, EC, regulatory) - 22 % of budgets come from EC funding, 18 % from national and 9 % from regulatory funding (e.g. Low Carbon Network Fund in the UK, OFGEM); 2 % is unclassified funding. More than half of the budget is managed by universities and DSOs; DSOs spend 10 times more money in D&D than in R&D.

Smart Network Management and Smart Customer / Smart Home are the most targeted applications. New control/automation systems to improve the controllability and observability of the grid are quite consolidated and widespread. Electric Vehicles to Grid integration is the main targeted application in Germany and Austria; the current focus is still on ensuring that the charging and communication infrastructure works rather than on testing sophisticated applications with vehicle-to-grid (V2G) services. Use of storage as additional source of grid flexibility is one of the key themes of the main projects that started in 2012 and 2013.

Around 200 million smart meters in Europe (ca. 72 % of EU customers) are expected to be deployed by 2020 with an estimated investment of €35 billion. According to the survey in (European Commission 2014), only 16 Member States (Austria, Denmark, Estonia, Finland, France, Greece, Ireland, Italy, Luxemburg, Malta, Netherlands, Poland, Romania, Spain, Sweden and United Kingdom) planning to proceed to a large-scale roll-out before 2020. Italy and Sweden have already carried out a full deployment of smart meters, France and Spain are within this process; Germany is undergoing a partial roll-out for some categories of consumers along with

Latvia and Slovakia. Four Member States (Belgium, Czech Republic, Lithuania and Portugal) recently decided not to proceed with nation-wide smart metering deployment. In particular, Czech Republic will not proceed to a large-scale roll-out due to a negative CBA result. The most common smart metering communication technology intended to be used is revealed to be PLC in combination with GPRS.

An increasing number of projects are focusing on the smart customer; however consumer participation in these projects is still limited in size (typically up to 2000 customers). Most of the smart customer projects are concentrated in a few countries: Denmark, France, UK and the Netherlands.

6 Annex: Description of Most Promising Solutions

Description of most promising solutions:

MV Voltage Monitoring

MV Voltage Monitoring (RTU): It is based on transmitting real-time remote measurement from a few critical nodes to the SCADA system located in the distribution control centre.

MV Voltage Monitoring (SE): A State Estimation (SE) algorithm calculates the most probable status of the system based on the gathered data from SCADA. The SE requires a larger set of measurements and pseudo-measurements but improves network observability.

MV Voltage Monitoring (PLF): It is an off-line calculation. A Probabilistic Load Flow (PLF) algorithm carries out probabilistic predictions of voltage profiles at network buses and feeder power flows based on forecasted demand and generation.

LV Voltage Monitoring:

LV Voltage Monitoring (AMI): It is an off-line calculation. A process/algorithm analyses the values of voltage measurements recorded by the smart meters.

MV Voltage Control:

MV Distributed Voltage Control with OLTC: The local control of the primary substation adjusts the turn ration of the HV/MV transformer based on local measurements to maintain desired voltage level at the MV network.

MV Distributed Voltage Control with OLTC, DG: This solution is based on the conventional management of the OLTC of the HV/MV transformer adding a local control mechanism at MV DGs so reactive power injection is adjusted depending on the local voltage.

MV Centralised (field measurements) Voltage Control with OLTC: This approach improves the control of the transformer OLTC at the HV/MV substation by adding remote measurements from some critical nodes of the MV network. The control is triggered when some of the sensed voltages are out of the statutory limits bringing the MV voltage levels back within the threshold.

MV Supervised (field measurements) Voltage Control with OLTC & DG: The solution is based on a distributed control placed at the HV/MV substation. The control algorithm manages the HV/MV transformer OLTC based on field measurements from the MV to ensure that MV voltage level is adequate and is also able to issue reactive power commands to MV DGs when needed.

MV Supervised Voltage Control with OLTC & DG: This implementation is based on a central SCADA system receiving filed measurements and alarms. Under normal operation, MV DGs adapt their reactive power injection to the local conditions of the grid and send an alarm when reaching their limit. A centralized algorithm adjusts the HV/MV transformer OLTC and the reactive power provision from the remaining MV DGs as to satisfy the expected quality of supply target.

MV Centralized (SE) Voltage Control with OLTC: This implementation employs a SE to build a reliable snapshot of the MV network situation and issues control orders to modify the turn ration of the HV/MV transformer through the OLTC tap if needed. The distribution SE runs over the measurements acquired by the central SCADA system.

MV Centralised (SE & OPF) Voltage Control with OLTC: The DMS includes a distribution SE to calculate a network image used latter on to feed an OPF on charge of solving any network constraint and defining the set of actions as to achieve some objective function (e.g. losses reduction, minimization of reactive power…).

MV Centralised (SE & OPF) Voltage Control with OLTC & DG: This is the most complex solution in terms of tools. The DMS includes a distribution SE to calculate a network image used latter on to feed an OPF on charge of solving any network constraint and defining the set of actions as to achieve some objective function (e.g. losses reduction, minimization of reactive power…). The set of conventional network elements used to manage MV voltage levels (HV/MV transformer OLTC, capacitor banks…) is widened as to include the reactive power support from MV DGs.

LV Voltage Control:

LV Distributed Voltage Control with OLTC: This alternative applies a local controller located at the MV/LV substation managing the MV/LV transformer OLTC from local measurements.

LV Distributed Voltage Control with DG: This implementation applies the local LV DG controller to modify Q (and P&Q) considering the local voltage measured at the DG connection point.

LV Distributed Voltage Control with OLTC, DG: it is a distributed control that comprises first a local controller located at the MV/LV substation managing the MV/LV transformer OLTC from only local measurements. In parallel, the local LV DG controller modulates Q (and P&Q) depending on the local voltage.

LV Distributed (field measurements) Voltage Control with OLTC, DG: it is a distributed control that comprises first a local controller located at the MV/LV substation managing the MV/LV transformer OLTC from both local measurements and some LV network measurements. In parallel, the local LV DG controller modulates Q (and P&Q) depending on the local voltage.

MV Congestion Management

MV Congestion Management with DG non-firm connection contracts (including DG modulation): The DSO sends set points for modulation to each individual DG generator connected to the MV as planned on its DG connection contracts.

MV Congestion Management with Use of Flexibility (DG, DSM, Storage…): it includes all kind of flexibilities that a DSO may contract through a “market platform”: modulation of generation, DSM, Storage, Aggregators...

7 References

7.1 Project Documents

List of reference document produced in the project or part of the grant agreement

[DOW] – Description of Work

[GA] – Grant Agreement

[CA] – Consortium Agreement

[D4.2] – WP4: D4.2. List of reference targets (country-specific & EU-wide) for grid integration of DER

[D5.2] – WP5: D5.2. IGREENGrid simulation and evaluation framework

7.2 External documents

[1] COM (2008) 30 final. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. "20 20 by 2020, Europe's climate change opportunity". Available: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2008:0030:FIN:EN:PDF

[2] EEGI Roadmap and Implementation Plan. Available at http://www.smartgrids.eu/

[3] JRC SCIENCE AND POLICY REPORTS: “Smart Grid Projects Outlook 2014”.

[4] V. Giordano, I. Onyeji, G. Fulli, M. Sánchez-Jimenez and C. Filiou, Guidelines for conducting a cost-benefit analysis of Smart Grid projects, Joint Research Centre, JRC Reference Reports, ISBN 978-92-79-23339-5, 2012