Technical analysis of past and on-going projects

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"Support to R&D strategy in the area of SET Plan activities in smart grids and energy storage"

Deliverable D3.2

by

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Table of contents

Table of illustrations

EXECUTIVE SUMMARY

The present document, the *Technical analysis of past and on-going projects*, displays a thorough monitoring of a sample of 177 projects (123 European projects, either funded at national or EC level and 54 international projects, i.e. funded and carried out outside Europe). The analyses of the projects presented in this report are one of the two key processes for the drafting of the *Final 10 year ETIP SNET R&I roadmap covering 2016-25* (RIR). The monitoring process has been used to specify the future R&I activities to be undertaken during 2016-2025 and make sure that the specified R&I activities correspond to research and innovation work which was not (or partially) covered at the time of analysing the projects.

The monitoring methodology is based on a five-step approach:

- Selection of the projects to be monitored, so as to set up a database with no (or low) statistical bias;
- Data collection from each considered project (based on a common template and interviews) and construction of the database of results (the analysis has been carried out in terms of achievements, i.e. a specific result for a given project);
- Description of achievements in terms of descriptive features (clusters and functional objectives addressed, typology, input and output TRLs) and projective features (foreseen implementation and next steps) so as to provide the main trends in terms of knowledge coverage and progress;
- Coverage analysis of the previous EEGI 2013-2022 R&I roadmap with the set of achievements available in the data base;
- Recommendations in terms of evolutions as an input to the specifications of the R&I activities of the RIR.

In complement to this five-step analysis, the monitoring of international projects has been used to detect the main differences in terms of coverage between R&I activities carried in Europe and outside Europe so as to provide recommendations for policy makers, i.e.:

- R&I activities where Europe is leading and which are not (or partially) addressed outside Europe;
- And, on the contrary, R&I activities carried out outside Europe for which the existing knowledge in Europe is below the international state-of-the-art.

The analyses are presented in a systematic way in four different parts:

- The three first part are dedicated to the monitoring of the transmission (part I), distribution (part II), joint transmission-distribution activities (part III);
- And, a fourth part (IV) for the international projects.

INTRODUCTION

1. Background

The present report is part of the monitoring activity carried out in Work Package 3 of the Grid+Storage service contract **"Analysing the ongoing R&I activities on grids, grid connected storage and other energy networks at national, EU and world level".**

Monitoring activities are pivotal to the project since they provide a dynamic picture of research and innovation (R&I) activities related to smart grids and energy storage integration.

A first monitoring report (deliverable D3.1) was published in June 2015. Its aim was to support the topic selection of the implementation plan 2016-2018 of the current EEGI R&I roadmap. The main projects with European added value were monitored to demonstrate that the topics selected for the implementation 2016-2018 (i.e. identified as mid-term research and innovation needs), were not already covered by past or ongoing projects in Europe. This report has covered 54 R&I projects.

The present document corresponds to the deliverable D3.2 of the contract. It aims at supporting the construction of the new 10-year R&I roadmap (for the period 2016-2025) by assessing for completed, on-going and planned projects in Europe, the scope of the R&I activities, i.e. the coverage of the R&I activities (the results of the completed and ongoing projects as well as the expected outputs of the planned projects) specified in the previous EEGI 2013-2022 roadmap. This gap-like analysis is key to specify the new R&I activities to be listed in the new 2016-2015 roadmap:

- R&I activities which have not been addressed in completed and ongoing projects are specified again in the new integrated roadmap;
- R&I activities which have been partially addressed in completed and ongoing projects are specified again in the new integrated roadmap with the relevant modifications.

To implement the monitoring of such a large number of projects (123 projects in Europe, and 54 projects outside Europe), the Grid+Storage partners have elaborated a robust methodology based on interviews of project coordinators. This "monitoring methodology" is described in the next section.

2. The Monitoring Methodology

2.1 Overview of the five-step methodology

The monitoring methodology is built upon five successive steps, with a specific focus on the achievements of the projects (i.e. the different results of the projects):

1. Identification of the scope: the projects to be selected for monitoring.
   Which nature? Which origin? Which features?
2. Data collection from each considered project and construction of the achievements' database.
   Which type of data constitute the minimal necessary inputs to extract meaningful statements in terms of coverage with regard to the EEGI 2013-2022 roadmap?
3. Description of achievements in terms of a few features.
   To which extent are achievements the appropriate description level to provide high level information on coverage status and trends?

4. Coverage analysis of the EEGI 2013-2022 R&I roadmap by these achievements.
   How to identify functional objective per functional objective the coverage provided by the project achievements?
5. Recommendations in terms of evolutions of the future R&I roadmap.
   Which evolutions should result from the coverage analysis and the characterisation of the portfolio achievements?

The coverage analyses for each functional objective have been performed on a selected portfolio of European projects, i.e. projects financed at national level and by the European Commission (EC). Selected projects carried out outside Europe (mainly North-America, China and Japan), have also been assessed in order to appraise the main differences between the storage integration activities conducted outside Europe and in Europe and therefore detect R&I activities not covered in Europe which could become strategic for European players.

2.2 The database of R&I projects and achievements (steps 1 to 3)

2.2.1 Initial selection of projects

The database of projects subject to the present monitoring exercise is constructed as presented on Figure 1 below. Regarding projects running in Europe (the main scope of this report), the initial databases of projects have been provided by the Grid+Storage partners and more especially the three associations (ENTSO-E, EDSO and EASE)[1,2]. For EDSO and EASE, the sampling was performed with the following criteria:

- budget (project with insufficient budget to reach ambitious goals were not selected[3]);
- coverage of functional objectives;
- funding schemes (national or European);
- available information (projects with insufficient info are not retained);
- geographical coverage (the number of Member States was used as a proxy);
- projects addressing specific technologies with no system integration component (mainly recharge technologies for storage) are not eligible;
- redundant projects (i.e. addressing similar topics such as VPP, etc. or sometimes the same project , cf. Smart Grids In France and Linky) are sorted out (keep the projects with the widest scope);
- elimination of national projects with the same scope (roll out of smart meters for instance) when there is no geographical specificity;
- projects with no obvious R&I component or addressing well-known applications (e.g. with lead-acid batteries) are not considered;
- for projects proposed by EDSO and where no EDSO member were involved, only projects with a real added-value, compared to the selected projects in which EDSO members were involved, were selected (typically ICT projects, i.e. connection with DG Connect and countries not covered).

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[1] There was some overlap between the three databases. For example, projects related to joint transmission and distribution activities were included both in EDSO and ENTSO-E databases.

[2] The associations complemented their databases with other available databases, especially the comprehensive database of the JRC in order to check that no European and national projects of importance (in the time frame set by the Grid+Storage contract) were omitted. When selecting projects in the JRC database, the same criteria for selection as in the present report were applied. In addition, since the available information in the database of the JRC is not comprehensive enough for the needs of the present exercise, it was completed by further inquiries with inputs from e.g. the GRID+ database for some of the completed projects.

[3] Projects with a small budget (order of magnitude of 100 k€) are, most of the time, not considered when deemed too academic with no real life application(s).

A parallel work was performed by ENTSO-E for the transmission part. The samples are not identical, however, a high correlation is observed between the ENTSO-E monitoring and the present document. One should mention the following:

1. A few projects from EASE database have been added to the ENTSO-E sample;
2. Some projects considered by ENTSO-E have not been proposed as inputs to the present work[4].

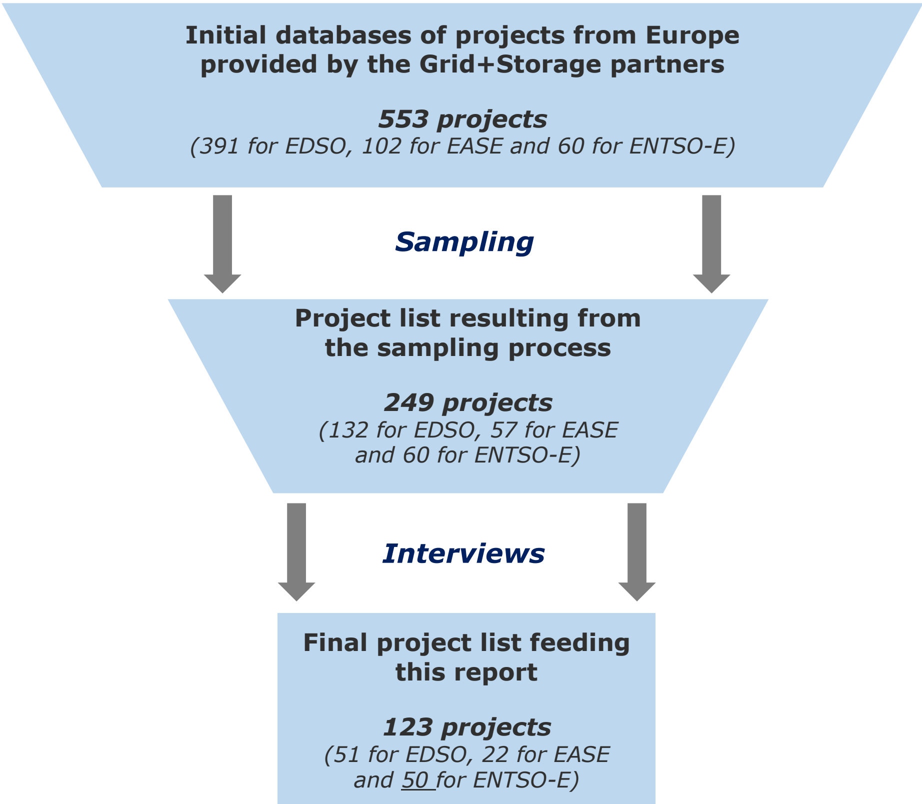

Figure 1: Construction of the database of R&I projects and achievements

2.2.2 Questionnaires addressed to project coordinators

The analysis is based on interviews with the selected projects' representatives (coordinator, WP leaders, etc.) by means of a dedicated questionnaire.

Interviews have been conducted between December 2015 and June 2016 by the following Grid+Storage partners:

- ENTSO-E assisted by TECHNOFI and RSE for transmission projects in Europe;
- EDSO for distribution projects in Europe;
- EASE for storage projects in Europe.

Within this approach, projects' representatives have been asked to identify the main achievements (reached or expected) of their projects, many project results being considered as intermediate steps towards these main achievements.

[4] Some of the projects considered by ENTSO-E have been completed before 2012 and have not been considered in coherence with the specifications of the Grid+Storage contract. It is assumed that the differences between the two samples do not generate significant statistical bias in the analyses of the projects' results.

The questionnaire included the following questions:

- At project level:
    - TSOs and DSOs involved[5];
    - Addressed clusters and functional objectives;
    - Objectives of the project;
    - Total budget and if relevant, part of public funding and funding source;
    - Start and end dates;
    - List of main project achievements, "completed" or "expected" (for ongoing projects);
    - Summary of the interview;
- For each achievement:
    - Type:
        1. Methodology,
        2. Software,
        3. Hardware,
        4. Database,
        5. Policy, regulation, market,
        6. Other;
    - Short description;
    - Related functional objectives;
    - Input and output Technology Readiness Level (TRL);
    - Status of implementation as of 2016;
    - If relevant, characterization of the next steps following the achievements:
        1. Further research,
        2. Further development,
        3. Demonstration,
        4. Deployment.

Around half of projects in the list of 249 projects resulting from the sampling step have not been interviewed (Figure 1). In some cases, the project coordinator could not be reached or was not available for an interview. In total, **123 interviews** have been carried out, resulting in the same number of completed questionnaires.

2.2.3 Construction and processing of the database

The database of projects and achievements has been built on the 123 collected questionnaires. Intensive processing has been made to ensure a sufficient level of quality, completeness and consistency of all questionnaires.

An automatic processing of the questionnaires has been set up to collect quantitative information for statistical purposes.

Questionnaires have also been analysed one by one to assess how each individual project and related achievements contribute to the coverage of the existing roadmap (cf. next section).

2.3 Assessment of the coverage of the current roadmap and recommendations for the new roadmap (steps 4 and 5)

For each functional objective (FO), the contributions from completed and ongoing projects have been listed. European projects and national projects have been addressed separately.

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[5] In some of the projects provided by EASE, no network operators were (are) involved.

This thorough review has resulted in the appraisal of the coverage of each functional objective: have the specific R&I activities (tasks) foreseen for this FO been tackled by those projects? Have they been addressed in a sufficient manner so that no more work is needed in this area? Or have they been addressed only in a partial manner, leading to continue the work in this area?

This detailed "coverage analysis", complementing a global statistical analysis of the achievements' features, is used to provide recommendations about the content of each FO of the new R&I roadmap.

2.4 Comparison with R&I activities carried out in non-European countries

Projects from non-European countries have also been monitored to position the ongoing and planned research work with respect to the proposed R&I roadmap and to underline the European added value of the proposed objectives. Partners in charge of this international review were VITO (for distribution-related projects) and RSE (for transmission-related projects).

2.4.1 Selection of projects

For distribution-related projects

The following sources were used to come up with an initial list of projects: the DOE energy storage database for projects in the US, Japan and China, and the IEASA database for projects in India. Only the projects which received RD&D Funding were considered for further investigation as these projects are supposed to have innovative aspects. In addition projects from the Clean Energy Fund Program for projects in Canada and storage projects funded by ARENA for projects in Australia were added to the list.

From these projects, only the projects with storage at distribution level where considered for further investigation, leading to a list of about 60 projects.

Out of these projects, only the projects with information on expected or realized achievements were finally reviewed.

Other reasons for omitting certain projects were:

- the relevance of the project (e.g. projects which didn't cover any functional DSO objectives),
- de-commissioned projects,
- projects with an unclear status,
- test centres for education purpose only, and
- projects which were very similar to other projects already reviewed.

This finally led to a review of a total of **20 projects** (2 Australian, 4 Canadian, 3 Indian, 1 Japanese and 10 US projects). In the end no Chinese projects have been reviewed as it was difficult to find information in English.

For transmission-related projects

Due to the different degrees of information available, the selection of R&I grid and grid connected storage projects relevant to transmission in US, China and Japan was accomplished in different ways depending on the involved country. The same criteria for omitting projects from the selection were used as in the case of distribution-related storage. Mostly, for each country similar projects with lower innovation and/or performance compared to other projects already reviewed were ruled out from the selection.

- US: The transmission projects co-financed by the U.S. Department of Energy (DOE) were analysed first. Concerning the "SGIG (Smart Grid Investment Grant)" projects, starting from the comprehensive 2013 Progress Report, the most updated documentation available about the single projects was taken into consideration. The selection process started from the projects with the highest budgets, but then it was also verified that no significant project covering the transmission Functional Objectives was missing from the selection. Then all projects from the "Smart Grid Demonstration Program" (including "Smart Grid Regional Demonstrations" and "Energy Storage Demonstrations": were analysed and the projects relevant to transmission were selected.
- CHINA: The DOE energy storage database was analysed and all projects relevant to transmission were selected for further investigation. Then, starting from some publicly available presentations of projects by the biggest Chinese utility State Grid Corporation of China (SGCC) (e.g., "SGCC Developments, Challenges, Opportunities & Prospects of Smart Grid in China") it was possible to retrieve the information available on the SGCC website. Based on this an in-depth literature search concerning SGCC was carried out in order to find significant projects related to the transmission Functional Objectives.
- JAPAN: The DOE energy storage database was analysed and all projects relevant to transmission were selected for further investigation. Then, also in this case further sources of information were some publicly available presentations (e.g., Tetsuji Tomita: "Policies and regulation for electricity storage in Japan" and Satoshi Morozumi – NEDO: "Japanese Island Grid Experience".

As a result, out of 56 projects analysed, **34** projects were selected for the final review: 13 US, 12 Chinese and 9 Japanese.

2.4.2 Analyses

The same questionnaire template has been used for those projects, to allow comparative analyses with the projects conducted in Europe. However, the analyses have been carried out with a different objective (compared with the ones for European projects): the coverage (of the previous EEGI 2013-2022 roadmap) in terms of generated knowledge by these projects has not been assessed. Instead, attention has been focussed on the main differences between the coverage of the whole EEGI 2013-2022 roadmap and the coverage of these international projects so as to detect:

- R&I activities where Europe is leading and which are not (or partially) addressed outside Europe;
- And, on the contrary, R&I activities carried out outside Europe for which the existing knowledge in Europe is below the international state-of-the-art.

These first analyses should help policy makers in Europe to sketch a policy for international R&I collaborations.

2.5 Methodological challenges and mitigation actions

An overview of the methodological challenges and assumptions are reported in Table 1 hereafter.

Table 1: Methodological challenges of the monitoring approach and mitigation actions

Main step	Methodological challenge	Proposed assumptions to mitigate the methodological challenge
1. Identification of the scope	Partial coverage of the R&I activities addressed by the selected projects	The set of selected projects represent a significant share of all European, national and international projects. When important projects have not been monitored (no questionnaire), an assessment has been performed by TECHNOFI.
2. Data collection and construction of the achievements' database	Bias in the answers of the project coordinators due to a misunderstanding of questions	This risk was mitigated by direct interactions with the project coordinators to better explain the meaning of each reply. However, as shown in the analyses in the next sections, some interpretation bias remains (in particular in the given TRL).
3. Achievements description: a- descriptive features	Impact of projects: number of achievements for each project (bottom-up bias)	It was decided to let project coordinators express their own view of achievements in their project, including the number. However to avoid extreme situations on the number of achievements per project, it was recommended to project coordinators to stay in the range of 2 to 5 (except specific situations with large projects gathering several distinct demonstrations).
3. Achievements description: b- projective features	Uncertainty of future funding which may impact implementability	When specifying possible future routes beyond the current achievements, project coordinators made most of the time the implicit assumption that funding (R&D, deployment) was available.
4. Coverage analysis per Cluster	Interpretation bias of achievements with respect to R&I roadmap activities foreseen for each cluster	The correspondence between achievements and activities is sometimes complex, for instance due to contributions to multiple activities. To mitigate this risk, the coverage analysis has been performed in a collective manner with the involvement of a pool of experts, including members of EASE, EDSO and ENTSO-E.
5. Formulation of recommendations	A too strong continuity with the current R&I activities which may impede the integration of new important topics	Recommendations to a new R&I roadmap have to include the changes in policy and the developments in other sectors. The structural changes in the roadmap result from the needs to address the challenges of ambitious RES development scenarios at 2030/2050 horizons, and the challenges resulting from an integrative and system needs driven approach. This necessary adaptation is taken into account by Grid+Storage partners and complement the present monitoring exercise.

3. How to read this document

3.1 Terminology

A detailed terminology is presented in the Glossary section: it include a series of generic terms related to the previous R&I roadmap (the EEGI 2013-2022 roadmap) such as **Functional Objective** (FO), **Cluster** as a set of Functional Objectives organizing the R&I Roadmap, **Achievement** as any output of a project that contributes to the scope of the EEGI 2013-2022 roadmap. Achievements might be either "completed" or "expected".

Achievements are also characterized by descriptive and projective features. **Descriptive features** include information for achievement categorization (Clusters, Functional Objectives and typology) as well as an estimation of the maturity (measured in TRL units at the beginning and at the end of the project). The typology of achievements include six predefined types: 1. Methodology, 2. Software, 3. Hardware, 4. Database, 5. Policy, regulation, market, 6. Other.

Projective features include an information on the status of implementation as of 2016 as well as a characterization of the next steps. The possible next steps are **further research** (FRes), **further development** (FDev), **demonstration** (Dem), **deployment** (Depl) or a combination of these options.

3.2 Projects and achievements' id codes

In order to abbreviate projects' names and their associated achievements', a specific "**id code**" for each project and each project's achievement has been provided.

- For each project, a project id code has been created. For most EC-funded projects, it corresponds to the existing acronym. When the title of the project is too long (or when the acronym is too long), a set of characters has been chosen. The project's id codes can be found for transmission in Table 4, for distribution in Table 6 and for joint TSO-DSO activities in Table 8. The correspondence between the project title and the id code is provided in the Annex.
- The project id codes have been supplemented with other data, i.e. the achievements' id code:
    - A (**A**chievements so far during the project's lifetime),
    - R (achievements **R**eached after the end of the project),
    - E (**E**xpected achievements for projects which have recently started),

  associated with a number (in case of several achievements of the A, R end E types for a given project) and two character strings,

    - One for *Completed* or *Expected* achievements,
    - And another one for the typology (*Methodology, Software, Hardware, Database, Policy, Regulation, Market, Other*).

  For example, typical id codes are:

    1. *Biocat A1-Completed-Database*, which means the first achievement of type "*A*" dealing with a *Database* of the *Completed* project *Biocat*;
    2. Or *Humber-A1* which means the first achievement of type "*A*" of the *Humber* project.

The first type of id code has been used to present the progress in terms of maturity for each achievement (input and output TRL) [6] whereas the second one has been used to display the projective features of each achievement[7]. All information given in the id codes is summarized in Annex together with the full title of the project and a short description of the achievement.

3.3 Organisation of the report

The report is organized in four main parts:

- Part I: monitoring of projects relative to transmission network R&I activities,
- Part II: monitoring of projects relative to joint transmission and distribution R&I activities,
- Part III: monitoring of projects relative to distribution activities,
- Part IV: review of projects outside Europe.

The first three parts are structured in a similar manner. Each of them includes three types of chapters:

- An introductory chapter presenting the R&I projects and giving an overview of the corresponding achievements;
- One chapter per cluster (5 chapters in each of the transmission and distribution parts, 1 chapter for the joint TSO&DSO part). Such chapters are structured as shown in Figure 2:
  - The descriptive and projective features of the achievements are presented;
  - For each functional objective, a review of the related achievements is carried out and the coverage of the FO is assessed;
  - Recommendations for the new R&I roadmap are given;
- A concluding chapter.

Figure 2: Example of the sequence of sections in a given cluster

Part IV about projects outside Europe is structured in the same way, but comparative analyses with the projects from Europe are carried out instead of a detailed description of individual projects and achievements.

[6] transmission (cluster 1-Figure 11, cluster 2-Figure 17, cluster 3-Figure 23, cluster 4-Figure 29 and cluster 5-Figure 35), distribution (cluster 1-Figure 47, cluster 2-Figure 52, cluster 3-Figure 59, cluster 4-Figure 66 and cluster 5-Figure 71) and joint TSO and DSO activities (Figure 78).

[7] transmission (T1-Figure 12, T14-Figure 13, T2-Figure 14, T3-Figure 18, T4-Figure 19, T5-Figure 20, T6-Figure 24, T7-Figure 25, T9-Figure 26, T10-Figure 30, T11-Figure 31, T12-Figure 32, T15-Figure 36, T16-Figure 37 and T17-Figure 38), distribution (D1-Figure 48, D2-Figure 49, D3-Figure 53, D4-Figure 54, D5-Figure 55, D6-Figure 56, D7-Figure 60, D8-Figure 61, D9-Figure 62, D10-Figure 63, D11-Figure 67, D12-Figure 68 and D13-Figure 72) and joint TSO-DSO activities (TD1-Figure 81, TD2-Figure 82, TD3-Figure 83, TD4-Figure 84 and TD5-Figure 85).

3.4 Visual identity of the monitoring exercise

A colour code for the text and graphics have been adopted to guide the presentation of the results.

3.4.1 Text

Plain text is used for introductions and conclusions.

Methodological issues are presented in a brown text:

> This is a methodological note

Highlights are presented in the following format after each graph:

Highlights:

- This is a statement extracted from a figure or a table.

3.4.2 Types of charts

The following conventions have been adopted:

1. Horizontal bar charts have been used to report occurrences of achievements;
2. Vertical bar charts have been used to represent TRL and evolutions of TRL;
3. Pie charts have been used to represent relative shares in a Cluster;
4. Next steps diagrams have been intentionally designed to look like planning with horizontal bars (from the left: further research to the right: deployment with two intermediate steps) using the colour nuances within each cluster.

3.4.3 Pie and bar chart colours

Multicolour charts have been used according to the type of figure:

1. Blue/grey: for bicolour figures representing two opposite concepts (for example completed and expected achievements);
2. Five contrasted colours to represent five Clusters for transmission (part I) and for distribution (part III), as displayed in Table 2.
3. To represent the different FOs of a given Cluster, variations in the nuances of the cluster's colour have been used.

Table 2: Colour codes used in the charts

Colours	Transmission clusters	Distribution clusters
Violet	Grid Architecture	Integration of smart customers
Orange	Power technologies	Integration of DER and new uses
Green	Network operation	Network operations
Red	Market design	Network planning and asset management
Yellow	Asset management	Market design

3.4.4 Colour code for coverage analysis

The colours shown in Table 3 have been chosen to present the coverage assessment of each task of the different FOs of the EEGI Roadmap by the selected European and national projects.

Table 3: Colour codes used in the coverage assessment of FOs' tasks of the EEGI Roadmap

Colours	Coverage assessment of FOs' tasks
Green	Very well covered
Yellow	Partially covered
Red	Minor coverage or not covered at all

Part I TRANSMISSION

4. The portfolio of R&I projects in relation with the transmission activities of the Roadmap, and related achievements

4.1 Assumptions ruling the portfolio selection

The methodology of monitoring is described in the introduction. Here, the main assumptions ruling the selection of the projects which were retained in the portfolio are reminded.

A1) **Consistency with the roadmap:** selected projects have achievements which contribute(s) to at least one of the Functional Objectives (FO) of the EEGI 2013-2022 R&I roadmap.

A2) **Recent:** selected projects have been completed not later than 2011.

A3) **Funding:** EC Framework Programme or national support have been considered.

A4) **Budget:** a minimum threshold has been set at 0.1 M€ for national projects and 1 M€ for EC supported projects (order of magnitude).

A5) **Explicit intention for further exploitation:** project coordinators have expressed their intention to exploit their achievements by contributing to this monitoring exercise through questionnaires.

The above assumptions allow the selection of a representative sample a projects among all recent R&I transmission projects to carry out the coverage analysis of each FO.

4.2 The portfolio of transmission projects

Forty-eight (48) R&I projects fitting with the above criteria have been identified and are used for the coverage analysis. They represent a total budget of approximately 434 million Euros for a public funding of 262 million Euros, cf. Table 14[8].

Methodological issue:

A first methodological issue to be addressed is to evaluate the impact of the non-selected projects. An ex-post evaluation will be performed by assessing the overall budget of the project portfolio with respect to the transmission activities of the roadmap. This will guarantee that the induced bias of the sample does not jeopardize the coverage analysis.

The set of selected projects is shown in Table 4 below.

Table 4: Portfolio of projects source of achievements in transmission

61850 substation	**EcoGRID**	**ICOEUR**	P2G	SSSC
AFTER	**eHighway2050**	ImpactEV	PoStaWind	STORE
ANEMOS	EnergyLab	**INSPIRE**	**Promotion**	SUMO
BESTGRID	Estfeed	**iTesla**	**REALSMART**	**TWENTIES**
BESTPATHS	**EWIS**	KÄVA2	**SAFEWIND**	**UMBRELLA**

[8] These figures do not represent the exact total budget and the corresponding public funding since for some projects some of the data is missing (for some projects the budget figure is available and not the corresponding public funding and vice-versa).

Class_project	**FutureFlow**	**LIFE Elia-RTE**	SAMREL	VENTOTENE
Concept2025	**GARPUR**	**Market4RES**	SECONOMICS	WAMPAC_Elering
DevMarketModelling	**GridTech**	**MERGE**	**SmartNet**	WAMPAC_Eles
DSR	Humber	**MIGRATE**	SmartSub	
eBADGE	**HyUNDER**	**OPTIMATE**	SOSPO	

NB: As explained in the section 3.2, due to practical reasons id codes were used as references in order to abbreviate projects' names all along the document.

The colour code for each project acronym corresponds to the source that has provided the filled-in questionnaires (**EU projects** are displayed in bold text while projects funded at national level are displayed in plain text):

EASE	ENTSO-E

4.3 The corresponding achievements in transmission

4.3.1 Methodology reminder

Definition of an achievement:

Achievements correspond to the lowest scale of our analysis and are generated by a completed (or on-going) project.

An achievement is a project result which can be one project deliverable, or a part of a project deliverable, or an aggregation of various project deliverables.

The formulation of the appropriate level for each achievement was under the responsibility of the project coordinator who is in the best position to select a few (typically 3-5) achievements synthesizing the key project results.

Through direct questions to the project coordinators, it was possible to identify a number of achievements for each project and to characterize each achievement first according to some key *descriptive features*, viz.

- To which cluster and functional objective does it contribute?
- What is its typology (nature)?
- What is its estimated impact on a maturity scale (TRL)?

and second, to some *projective features* on next steps as seen by the projects' coordinators:

- Is any implementation foreseen?
- If yes, through which route?

Methodological issue:

Available data on the descriptive and projective features presented some inconsistencies that have been corrected as much as possible (direct correction or exclusion from the sample) to avoid erroneous conclusions.

The information provided by coordinators have been considered as the best source of information to characterize an achievement. The potential bias due to the large variety of project coordinators should thus be rather limited on the descriptive features. However, the conclusions that could be drawn from the processing of projective features may be subject to such interpretation bias on future exploitation routes.

4.3.2 Overview of achievements in transmission

The portfolio of 50 projects contains 155 achievements. In the EEGI 2013-2022 R&I roadmap, the transmission R&I activities are organized into 5 Clusters:

Cluster 1: Grid Architecture
Cluster 2: Power Technologies
Cluster 3: Network Operation
Cluster 4: Market designs
Cluster 5: Asset Management

Descriptive features of achievements in transmission

Descriptive features include information for categorization and an estimation of the maturity increment (difference between the output and the input TRLs) of achievement.

Table 5: Descriptive features in transmission

Descriptive features	Rationale	Categories
Clusters and functional objectives	Clusters and FO are given in the roadmap	Cluster: C1 to 5 FO: from T1 to T17
Typology	Six types have been predefined according to the nature of the achievement	1. Methodology, 2. Software, 3. Hardware, 4. Database, 5. Policy, regulation, market, 6. Other
Estimated impact	Technology Readiness Level (TRL) scale	Index (input/output) from 1 to 9

Categorization in clusters

The graphs below characterize the sample of achievements of all types for all clusters in transmission.

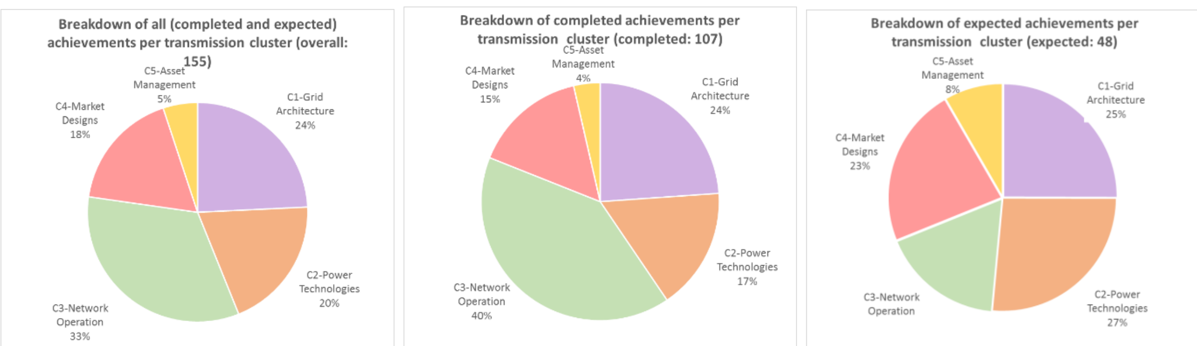


Figure 3: The portfolio of achievements in transmission per cluster (left: overall; middle: completed; right: expected)

<u>Highlights:</u>

- When considering all achievements (completed and expected), it is observed that the most addressed clusters over the considered time period are clusters C3 (33% of the sample) and C1 (24% of sample) while the C2 cluster amounts to 20% of the achievements. The less addressed cluster is asset management with a share of only 5%.
- There is a time dimension in the above figure: for instance, when considering separately the completed achievements from the on-going ones, asset management achievements represent different shares (8% of expected vs 4% of completed). This is visible in Figure 4 which highlights the evolutions in time per cluster.

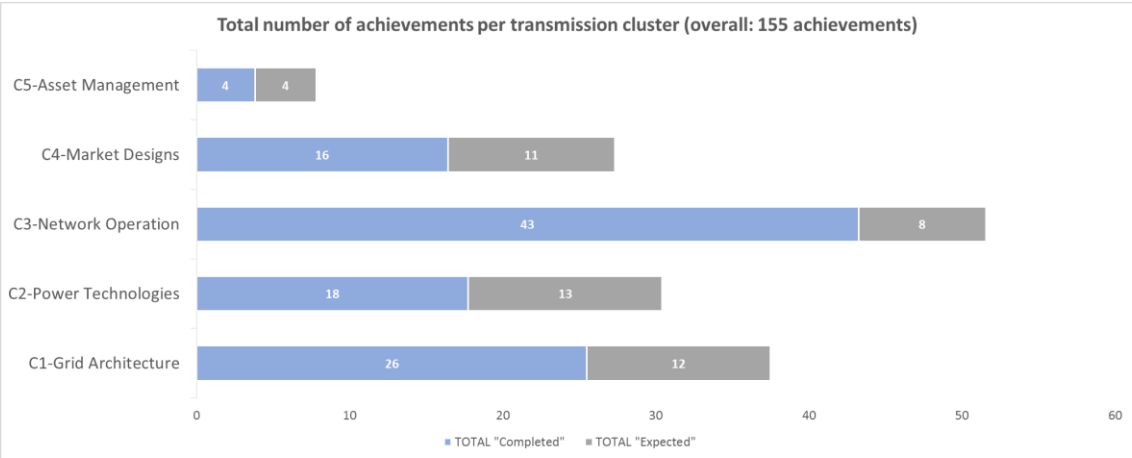


Figure 4: Number of achievements per cluster in transmission

Typology of achievements

The breakdown per type is provided in the figure below.

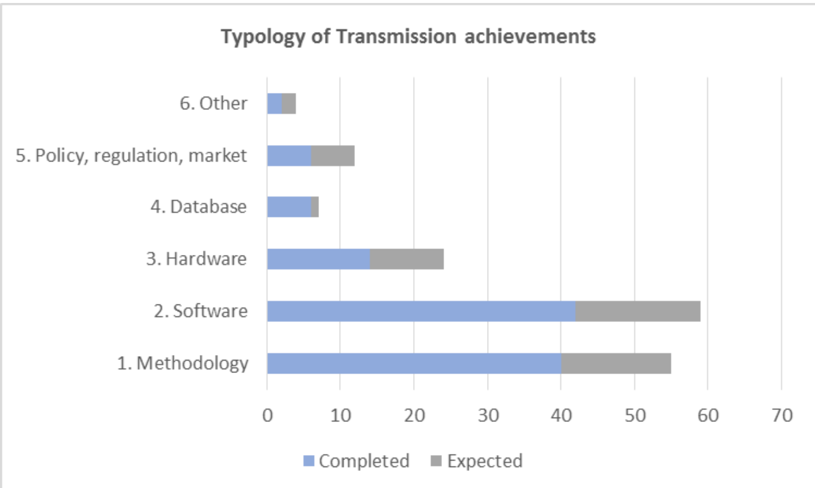


Figure 5: Typology of achievements in transmission

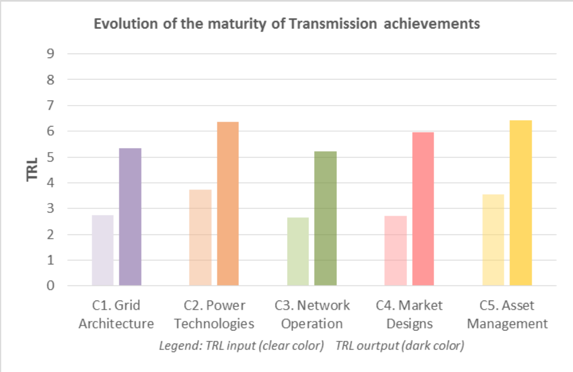
<u>Highlights:</u>

- Most achievements are, by far, related to methodology and software issues, the third category being the hardware achievements.

Evolution of the maturity of achievements

Innovations involved in the considered transmission projects are now characterized by their degree of maturity. The TRL scale is the metric used that captures such a maturity (the distance to the market or to an exploitation stage).

Two levels of TRL have been assessed: before the project starts (in a light colour code), and at the project's end (darker colour code). This is depicted in the figure below.



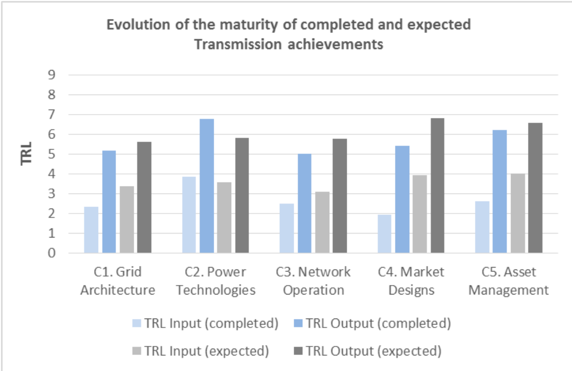


Figure 6: Evolution of the maturity of achievements measured in TRL units (left: average per cluster; right: per cluster for the completed in blue and for the expected in grey)

Highlights:

- On average, for each cluster, an increment of two to three units in the TRL scale is observed (left diagram), the increment being higher for the market designs cluster (C4)
- The diagram in the right distinguishes the completed achievements from the expected ones for each cluster. In general the TRL input for expected achievements is higher than the TRL input for completed achievements: this is not the case for cluster 2, probably due to the heterogeneity of the considered technologies in this cluster.

Projective features of achievements in transmission

Projective features of each achievement refer to possible implementations and next steps as formulated by project coordinators.

Projective features	Rationale for categorization	Categories
Foreseen implementation	Either the achievement is already implemented or if it not the case, is there any plan for a future implementation of such achievement. If no for both questions, an explanation is requested. In case of next steps, explanations must be provided	Already achieved: Y, N, N/A Future implementation: Y, N, N/A Explanation(s) for "No & No" Explanation(s) for the "next steps"

Route for the next steps	Next steps include further research (FRes), further development (FDev), demonstration (Dem), deployment (Depl) or a mix of these options	12 different combinations can be encountered: • One and only one of the following: FRes, FDev, Dem, Depl (4) • Two of them: FResFDev, FResDem, FResDepl, FDev, Dem, FDevDepl, DemDepl (6) • Three of them: RDD or DDD (2)

Next steps with regard to achievements' implementation

The graph below is based on 84% of the completed achievements (92 of 110 completed achievements) which constitutes a representative sample. Expected achievements are not included in this analysis.

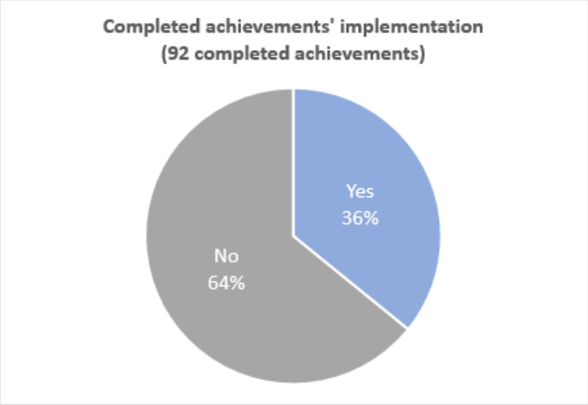


Figure 7: Implementation and next step actions carried out for completed achievements in transmission

Highlights:

- More than one third of the completed achievements have already resulted in an implementation action.
- From the analysed questionnaires, it may occur that implementation actions are foreseen but have not started yet: in such situations they are accounted for in the "next steps" diagrams.

The diagram below details the project coordinators intentions with regard to the next steps (either further research, further development, demonstration or deployment).

> Methodological issue:
>
> In the computation, it has been considered that one achievement could generate next steps for strictly more than one type of "next step": for example, if one achievement contributes to both further research and demonstration, it is then counted twice, once for further research and once for demonstration.
>
> Project coordinators have been consulted with three options to be ticked out of the four possible options (further research, further development, demonstration or deployment).

Figure 8: Next steps as seen by project coordinators in transmission

Highlights:

- For completed and expected achievements, project coordinators expect that achievements will require further development (28% of all answers: formulated intentions of next steps) and demonstration (28% of all answers) followed by deployment (24% of all answers).
- Only 19% of the answers concern further research according to the project coordinators.

5. Transmission Cluster 1: Grid Architecture

Cluster 1 is organized into 3 Functional Objectives: T1, T2 and T14.

T1. Definition of scenarios for pan-European network expansion
T2. Planning methodology for future pan-European transmission system
T14. Towards increasing public acceptance of transmission infrastructure

5.1 Features of achievements in Cluster 1

5.1.1 Descriptive features

<u>Categorization in functional objectives</u>

The graphs below characterize the completed (25) and expected (12) achievements of cluster 1 (the purple colour is dedicated to Cluster 1).

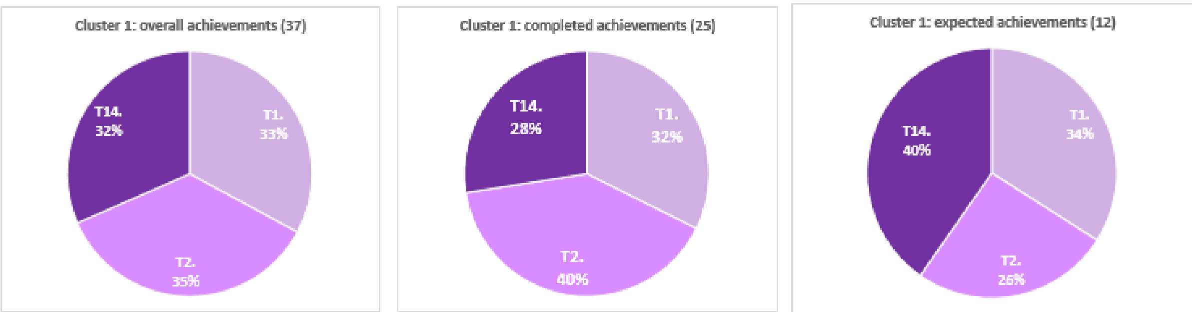


Figure 9: portfolio of achievements in Cluster 1 (left: overall; middle: completed; right: expected)

<u>Highlights:</u>

- The first diagram in the left provides the overall number of achievements in this cluster.
- When comparing the two other diagrams with first one (overall number of achievements), one can detect some variations in the relative number of achievements contributing to each Functional Objective: for instance, T14 represents the highest share of achievements for expected achievements but one should have in mind that the sample of expected achievements is about 1/3 of the overall sample (12 out of 37).

Typology of achievements in Cluster 1

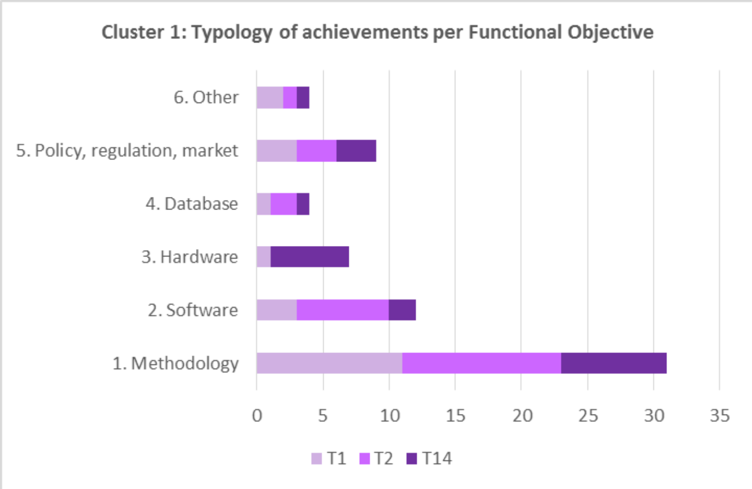


Figure 10: Typology of achievements in Cluster 1 in transmission

Highlights:

- The above diagram highlights the dominance of methodology-type achievements.
- One can notice that the breakdown per type is very dependent on the functional objective: for example, in T14, the achievements are quite balanced among methodologies, hardware and policy, regulation, market types.

Evolution of the maturity of achievements in Cluster 1

> Methodology used to present the evolution of the maturity of achievements for each Cluster:
>
> The figure below presents the evolution of maturity in TRL units of each project’s achievement regarding cluster 1. The id code which represent each project’s achievement has been explained in section 3.2 and is detailed in the Annex.

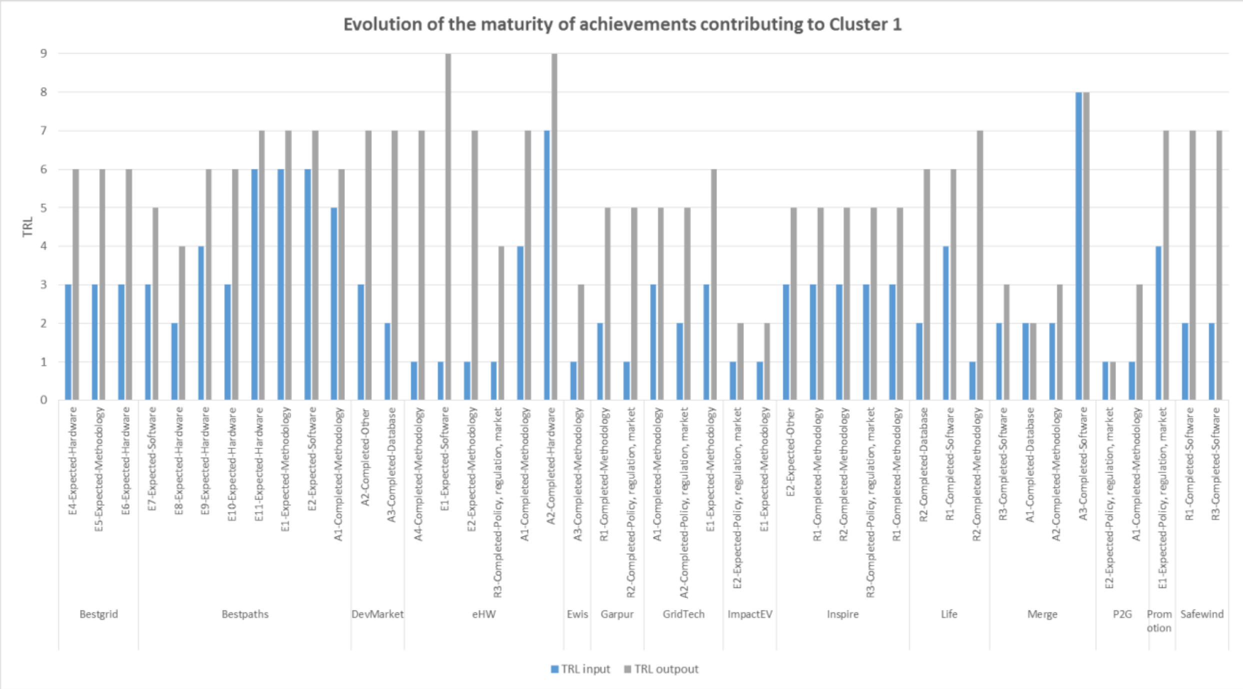


Figure 11: Evolution of the maturity of achievements contributing to Cluster 1 measured in TRL units (blue: TRL input, grey: TRL output)

<u>Highlights:</u>

- All achievements (completed and expected) of cluster 1 have been reported in the above figure with respect to their maturity increment (the difference between the grey and the blue bar). Achievements are organized per project and per type: it may occur that one project includes several achievements of the same type, which explains some redundancy in the labels (horizontal axis).
- On average, for cluster 1, the increment in maturity is estimated at about 2.5 but with some variability depicted in the above chart. The most important maturity gains are for methodology-type achievements corresponding to ready-to-be-used approaches (such as eHighway2050). For some achievements, there is no gain in maturity which is counter-intuitive and is simply due to some interpretation bias in the questionnaire.

5.1.2 Projective features (next steps)

A common method has been used for all clusters to describe the next steps considered **from the point of view of project coordinators** (sections *.2). The highlights resulting from the projective features will have to be combined with the conclusions of the gap analysis (sections *.3) which represents **the point of view of the Grid+Storage partners in charge of the implementation of the new R&I roadmap.** Both views will be necessary to formulate recommendations for the new R&I roadmap (sections *.4).

> <u>Methodology used to present the projective features for each Cluster:</u>
>
> The series of figures below (in the current section 3.1 and in all sections dealing with projective features) detail the next steps as specified by the projects' coordinators.

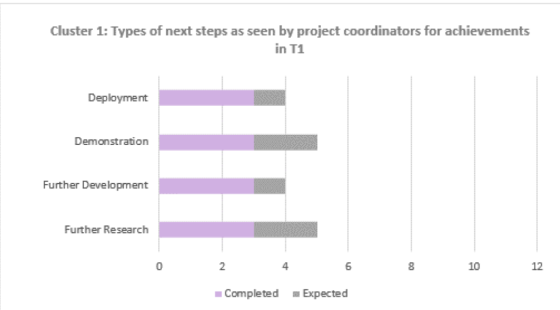
- Each figure on the left provides an estimation of the number of future actions that would be needed to complement/continue/demonstrate/deploy the achievements contributing to the functional objective.
- Each figure on the right provides a detailed view of the considered achievements[9] in a pre-roadmap view (for four main possible future stages from "further research" to "deployment").
- The colour code that was used refer to the colour of the cluster for the completed achievements in that cluster (purple colour for Cluster 1, etc.), while the grey colour refers to the expected achievements as seen by project coordinators.

Each pair of figures allows to highlight some key features on future R&I necessary actions from the point of view of the project coordinators having contributed to a given functional objective. Such conclusions result directly from an analysis of:

- The total number of achievements in the functional objective;
- The split between completed and expected achievements;
- The split between the four types of next steps considered for the completed (resp. expected achievements);
- The relative contribution of each project in the considered functional objective.

From the data collected in cluster 1 for each Functional Objective (T1, T2, T14) one can formulate the following highlights:

- Next steps for achievements in T1 are well balanced, whereas for achievements in T2 and T14 efforts for further research appear as less intensive.
- In T14 next steps for demonstration are dominant, while in T2 three "next steps" are quite balanced: development, demonstration and deployment.
- Expected achievements represent about 25% of all considered achievements.



Achievements in T1	Status	Further Research	Further Development	Demonstration	Deployment
eHW-A1	Completed		X		X
eHW-A2	id		X		
MERGE-A3	id	X			
P2G-A1	id	X			
DevMarket-R1	id				X
DevMarket-R2	id			X	
EWIS-R3	id	X			
GridTech-R1	id		X	X	
GridTech-R3	id			X	X
eHW-E2	Expected		X		
GARPUR-E1	id	X		X	X
GARPUR-E2	id	X			
P2G-E1	id			X	

Figure 12: Next steps as seen by project coordinators in T1

[9] For the id code of achievement: see section 3.2 and Annex.

Achievements in T14	Status	Further Research	Further Development	Demonstration	Deployment
eHW-A2	Completed		X		
INSPIRE-A1	id	X	X		
INSPIRE-A2	id		X	X	
INSPIRE-A3	id		X	X	X
LIFE-A1	id			X	
LIFE-A2	id			X	
BESTGRID-R2	id			X	
BESTGRID-R3	id			X	
eHW-E2	Expected		X		
INSPIRE-E1	id				X
INSPIRE-E2	id			X	X
LIFE-E1	id			X	X

Figure 13: Next steps as seen by project coordinators in T14

Achievements in T2	Status	Further Research	Further Development	Demonstration	Deployment
eHW-A1	Completed		X		X
eHW-A2	id		X		
eHW-A3	id				X
eHW-A4	id	X	X		
INSPIRE-A2	id		X	X	
INSPIRE-A3	id		X	X	X
DevMarket-R1	id				X
DevMarket-R2	id			X	
GridTech-R1	id		X	X	
GridTech-R2	id			X	X
GridTech-R3	id			X	X
SAFEWIND-R1	id		X	X	
SAFEWIND-R3	id		X	X	X
eHW-E1	Expected	X	X		
eHW-E2	id		X		
GARPUR-E1	id	X		X	X
GARPUR-E2	id	X			
INSPIRE-E2	id			X	X
Promotion-E1	id	X	X		

Figure 14: Next steps as seen by project coordinators in T2

5.2 Coverage analysis of Cluster 1 with past and ongoing projects

5.2.1 T1 "Definition of scenarios for pan-European network expansion"

Contributions from completed and ongoing projects to T1

From EU projects

- The overarching scope of the **EWIS** project was to evaluate short-term network issues arising from wind generation in the period running between 2007 and 2015 while preparing the ground work for future plans up to 2020 and providing concrete recommendations. Another EWIS objective was to quantify and clearly demonstrate the costs related to inaction.
- The **eHighway2050** project has delivered a systematic methodology to build 2050 energy scenarios, which should be used by ENTSO-E in future TYNDP exercises and can also be used by other stakeholders (non TSOs): professional associations, NGOs and institutions at the EU level in their missions. The methodology for scenario quantification covers the assessment of solar and wind potentials, the distribution of generation, the adaptation of the number of thermal plants and the consideration of demand-side management.
- The **GRIDTECH** project has developed a zonal tool and model (with 2020, 2030, 2050 data) for pan-European system planning studies and a toolbox for transmission expansion planning with storage, demand response and EV (Electric

Vehicles).

- The **MERGE** project has identified and prepared solutions for the operational problems that will be caused on the electric grid, to the generation sub-system and to its commercial operation as a result of progressively increasing deployment of EV. Different scenarios on EV deployment have been considered and a tool used by the TSO to perform grid planning has been developed.
- The ongoing **GARPUR** project is developing a new reliability management approach and criteria (RMAC) for the pan-European electric power system. Such new RMAC should be implemented in priority to grid planning activities and notably incorporate the possibility of using demand-side management to secure system operations.

From national projects

- The Baltic TSOs Elering, Litgrid and AST have developed long-term energy scenarios for the region and developed a methodology, database and market models for increasing **market modelling capacity**. Further improvements and expansions of the methodology are needed to also include, for example, flow-based allocation for transport capacities assessment.
- Elering, in its double role of both electricity and gas TSO, is investigating the feasibility of **Power to Gas** (P2G) systems in Estonia. In principle P2G systems would be able to encourage RES-E penetration, by using the possible excess in RES-E production and the CO_2 captured from traditional power systems in order to produce methane to be injected in the gas network or used as automotive fuel. Studying the financial viability of such systems and enlarging the study at European scale is needed.
- Elering is also studying the **impact of electric and gas vehicles** and developed a methodology to evaluate the impact of electric transport on grid operation. Link with high-speed train, involving neighbouring countries, needs to be further explored.

Assessment of the coverage of T1

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective T1. The left-hand traffic-light colours correspond to the estimated coverage of each of these tasks by the above-described projects, according to the colour code defined in Table 3.

- **T1a.** To define pan-European network expansion scenarios, identify maximum volume of RES and DER for pan-European network, and analyse a combination of electricity and gas.
- **T1b.** To identify investments required to achieve the 2050 vision with different decarbonisation scenarios of generation mix, storage, and demand mix.
- **T1c.** To develop methods for integrating transmission systems with growing amounts of RES based generation, considering optimal rates of storage needed at the pan-European level.
- **T1d.** To provide an offshore grid design: optimisation methods for grid capacity, technology, and topology considering wind power characteristics (i.e., low capacity factor).

Coverage assessment

It is considered that all the R&I activities considered in these specific tasks are covered by completed and ongoing projects. However, there is still work to do on the combination of electricity and gas at the EU level (interactions between gas and electricity networks), although this has been addressed at the national level in some member states. We therefore estimate that this functional objective has been covered at about 90%.

5.2.2 T2 "Planning methodology for future pan-European transmission system"

Contributions from completed and ongoing projects to T2

From EU projects

- The achievements of the **eHighway2050** project are of utmost importance with regards to this functional objective, with the delivery of a top-down planning methodology organised in modular blocks; the modular plan of pan-European grid architectures at 2050 (including data); a database of cost and performances of power system technologies and enhanced transmission expansion planning based on optimisation methods. A methodology to propose and validate transmission reinforcements for each scenario has been developed based on grid simulations with 100 nodes. Governance models, regulatory options and methodologies for cost-benefits analyses have also been explored.
- The **GRIDTECH** project has developed a methodology for transmission planning which consists in an integrated and strictly correlated combination of the top-down (pan-European zonal study) and the bottom-up (7 regional case studies) approaches for transmission planning and for innovative grid-impacting technologies assessment in Europe. The methodology could be now further improved (e.g. by including internal zones for the biggest countries). In addition, the tools developed within the project are compatible with innovative grid-impacting technologies (including HVDC, FACTS/PST), storage and demand-response.
- The **GARPUR** project is developing new reliability management approach and criteria (RMAC) or the pan-European electric power system. With regards to planning methodology, the project has described the current practices and identified opportunities for improvement, and is developing a new methodology for system development assessment - also considering the data and modelling requirements.
- The **MERGE** project has developed a methodology to identify the possible changes in the load profiles due to the charge of EV. A reference architecture for EV charging has been studied and described, with a particular attention on grid connection and communication aspects.
- The **SAFEWIND** project has worked on methods and pieces of software for probabilistic forecasting of wind power and for predicting extreme events. Wind power predictability maps for spatial planning of wind energy at European scale have been delivered.
- The ongoing **INSPIRE-Grid** project is working on the decision making process for the development of future grid infrastructures.
- Within the recently started **PROMOTION** project, a deployment plan for offshore grid development in the northern seas is being developed, including technology for offshore wind connection, HVDC protection systems, grid policy and financial regulation. An offshore grid architecture for optimised wind resources facilitation

and market extension is proposed.

From national projects

- The Baltic TSOs have developed a methodology, database and market models for increasing **market modelling capacity**.
- Elering is studying the **impact of electric and gas vehicles** on the grid. The project mainly deals with technical and socio-economic issues related to the development of electric vehicles and of the high speed railway in Estonia. A detailed model to evaluate these impacts is being developed. Policy and regulation aspects are also being tackled: requirements and principles for connecting these loads to the grid have been identified.

Assessment of the coverage of T2

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective T2:

- **T2a.** To investigate state-of-the-art planning software, technology portfolios and different regulatory frameworks.
- **T2b.** To define input data requirements and data interfaces (to/from cost-benefit simulators, power flow tools etc.).
- **T2c.** To develop new algorithms and database functions for network simulation; enabling the integration of new emerging technologies such as HVDC, GIL, FACTS and storage.
- **T2d.** To model embedded HVDC/HVAC grids for planning simulation.
- **T2e.** To develop software tools for cost-benefit assessments of expansion options and validating impact on grid planning for coordinated design of architecture, power flow control devices, and other technologies.
- **T2f.** To provide coordinated grid design involving new network architectures, power flow control devices, storage and other technologies to achieve sustainable and efficient networks.
- **T2g.** To develop planning software to optimise location, coordination, control and integration of technologies within existing and future system architecture and operation.
- **T2h.** To develop long-term planning methods to combine electricity market analyses, production capacities (all types including RES) and infrastructure in view of strengthening expected weak points on the grid.
- **T2i.** To propose network investment mechanisms at EU level.

Coverage assessment

All the topics considered in this functional objective are covered by completed and ongoing projects. We consider that this functional objective has been covered at about 80% since planning issues addressing the full picture of the energy system have not been performed.

5.2.3 T14 "Increasing public acceptance of the transmission infrastructure"

Contributions from completed and ongoing projects to T14

From EU projects

- The **BEST GRID** project, gathering TSOs and environmental NGOs, aimed at improving local public acceptance for grids by applying best practices in participation and transparency in pilot projects, speeding up permitting procedures while respecting environmental protection standards in pilot projects and supporting implementation of best practices in future electricity grid projects of common interest (PCIs). Two handbooks have been delivered, about "Public Participation and Transparency in Power Grid Planning" and "Protecting Nature in Power Grid Planning". The project has also published the most valuable lessons learned and overall recommendations, e.g. the collaboration between TSOs and NGOs should be pursued regarding nature protection and grid development, provided that NGOs can be funded for that purpose.
- The ongoing **INSPIRE-Grid** project is aimed at enhancing stakeholders' participation in the development of future grid infrastructures. Stakeholders' concerns and needs have been mapped and methodologies for stakeholders' engagement have been assessed. An online Geographical Information System (webGIS) has been developed to allow users to access relevant information about a new power line and the crossed area through a geographical interface.
- Within the ongoing **LIFE Elia-RTE** project, guidelines on "vegetation mapping of powerline corridors in forests" have been delivered, and a cost-benefit analysis on alternative vegetation management in forest corridors has been carried out. The project will also deliver policy recommendations on the integration of biodiversity preservation into the vegetation management under overhead electrical lines.
- The **TWENTIES** project, focused on wind integration issues, and addressed public acceptance concerns.
- With the modular plan of pan-European grid architectures at 2050, the **eHighway2050** project has also contributed to this functional objective.
- The **BEST PATHS** demonstrations aiming at increasing the pan-European transmission network capacity and the system flexibility also take into account public acceptance issues.

Assessment of the coverage of T14

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective T14:

- 🟢 **T14a.** To investigate public perception of the power infrastructure and to improve the relationship between TSOs and the public with valuable feedback and signals in both directions.
- 🟢 **T14b.** To contribute to developing and/or updating European guidelines on good practice in transparency, public engagement, and the permit process.
- 🟢 **T14c.** To produce guidelines for the construction of overhead power lines with reduced visual and environmental effects compared to existing construction guidelines and to ensure these guidelines are applicable across Europe.
- 🟡 **T14d.** To analyse new technologies with reduced visibility of conductors, using coatings and nano-technologies.

- **T14e.** To propose new tower designs for overhead power lines with less visual effect, audible noise, and EMF and in some cases, also with reduced sag of overhead lines.
- **T14f.** To develop methodologies and software to evaluate bird collisions, human and animal exposure to EMF, audible noises, etc., and reduction of effects.
- **T14g.** To provide methods for physical protection of the grid infrastructures against potential dangers: natural catastrophes, terrorism, cyber-attacks, etc.

Coverage assessment

The above-mentioned projects have broadly contributed to these specific tasks. However, there is still no specific work on environmental impacts due to, for example, coating and nanotechnologies, audible noise and electric and magnetic fields (EMF). In addition, there is still work to do on natural catastrophes and on extending the results to the EU level. It is therefore considered than one third (30%) on this functional objective has been covered by projects' achievements; ongoing work should allow covering one additional third.

5.3 Recommendations for the new R&I roadmap

The high degree of coverage in this cluster, especially in T1, T2 will push for reorganizing the current Cluster 1. Planning tools and methodologies still need to be further developed so as to fully account for the full picture of flexibility options, e.g. new technologies (such as storage), demand-response, etc. T14 being less covered, the actions not yet covered or partially covered might be distributed to the new cluster dealing with modernization of the network (new C1) since public acceptance (and stakeholder involvement) and environmental impact assessments still remain an issue.

6. Transmission Cluster 2: Power technologies

Cluster 2 is organized into 3 Functional Objectives: T3, T4 and T5.

T3. Demonstration of power technology to increase network flexibility and operation means
T4. Demonstration of novel network architectures
T5. Interfaces for large-scale demonstration of renewable integration

6.1 Features of achievements in Cluster 2

6.1.1 Descriptive features

Categorization in functional objectives

The graphs below characterize the completed (18) and expected (13) achievements of the monitored projects of cluster 2 (a brown orange colour was dedicated to Cluster 2). The first diagram on the left details the overall number of achievements in this cluster, while the two diagrams on the right show some variations in the relative number of achievements contributing to each Functional Objective.

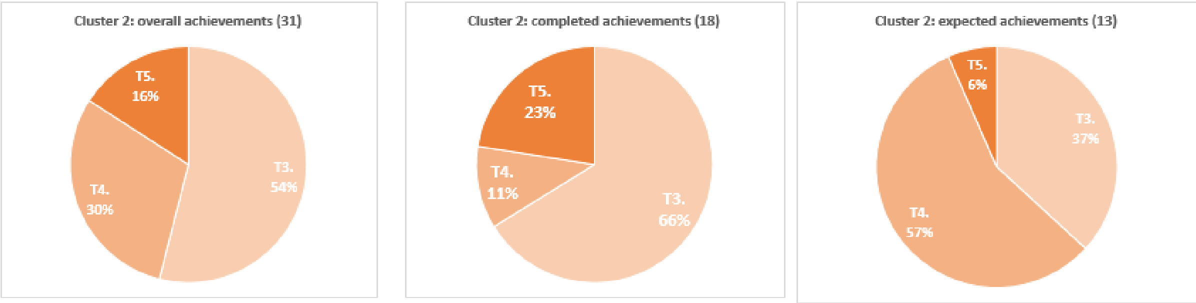


Figure 15: The portfolio of achievements in Cluster 2 (left: overall; middle: completed; right: expected)

Highlights:

- T3 was clearly the most important functional objective on the completed sample, but is only in 2nd position when considering the expected achievements.
- T5 is marginal in the subset of expected achievements but represents almost 25% of the completed ones.
- T4 is by far the most important in terms of expected achievements as seen by project coordinators.
- The sample of expected achievements represents more than 30%3 of the overall sample (13 out of 31).

Typology of achievements in Cluster 2

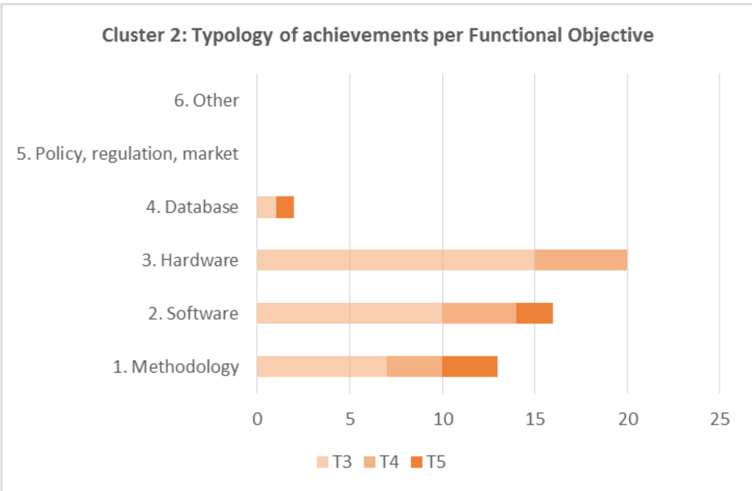


Figure 16: Typology of achievements in Cluster 2 in transmission

Highlights:

- In Cluster 2, hardware type achievements are dominant, immediately followed by software and methodology.
- Database (resp. policy, regulation, market) are marginally (resp. not) represented.

<u>Evolution of the maturity of achievements in Cluster 2</u>

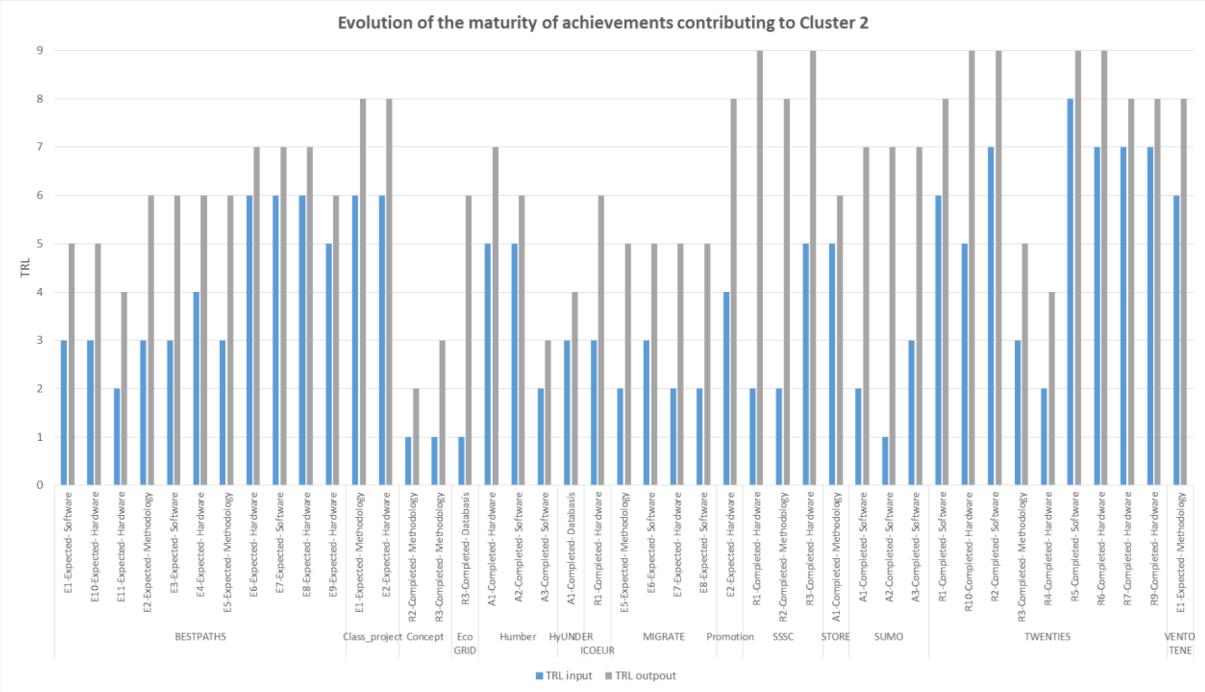


Figure 17: Evolution of the maturity of achievements contributing to Cluster 2 measured in TRL units

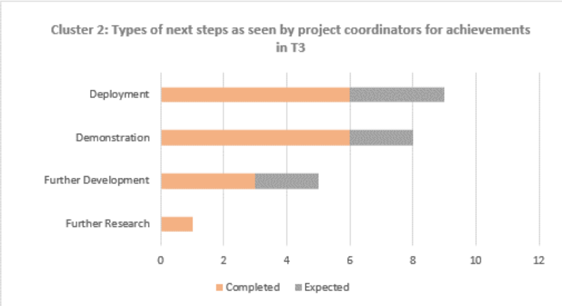
<u>Highlights:</u>

- In the above table most of achievements present a maturity increment of 2 to 3 units in the TRL scale.
- Some projects coordinators however consider a higher maturity gain in the achievements of their project (e.g. EcoGRID, SSSC, SUMO).

6.1.2 Projective features (next steps)

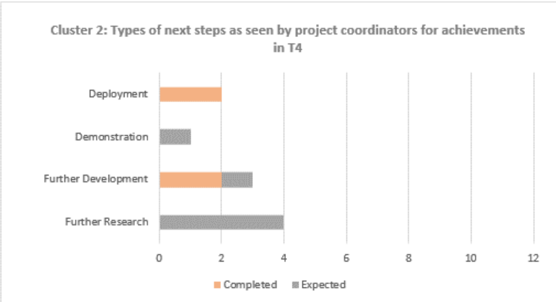
Following the same methodology described in section 3.1, and from the data gathered for each functional objective (T3, T4, T5) the following highlights can be formulated:

- T3 appears as the most active FO in terms of next steps while T5 is the less active.
- In T3, the SUMO and HUMBER projects have a need for demonstration (3 types of "next steps" each).
- The next step "deployment" is the most quoted in T3 and T5 while the "further research" route appears as not necessary for achievements in these two FOs.
- In T4, the "research" route is addressed by the expected achievements of the MIGRATE project.



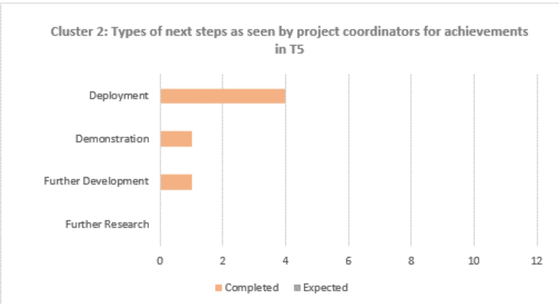
Achievements in T3	Status	Further Research	Further Development	Demonstration	Deployment
Humber-A1	Completed			X	
Humber-A2	id			X	
Humber-A3	id			X	
STORE-A1	id				X
SUMO-A1	id			X	X
SUMO-A2	id			X	X
SUMO-A3	id			X	X
Concept-R2	id		X		
EcoGRID-R3	id	X			
ICOEUR-R1	id				X
TWENTIES-R3	id		X		
TWENTIES-R4	id		X		
TWENTIES-R5	id				X
Class_project-E1	Expected			X	X
Class_project-E2	id		X		X
VENTOTENE-E1	id		X	X	X

Figure 18: Next steps as seen by project coordinators in T3



Achievements in T4	Status	Further Research	Further Development	Demonstration	Deployment
SSSC-R1	Completed				X
SSSC-R3	id				X
TWENTIES-R3	id		X		
TWENTIES-R4	id		X		
MIGRATE-E5	Expected	X			
MIGRATE-E6	id	X	X	X	
MIGRATE-E7	id	X			
MIGRATE-E8	id	X			

Figure 19: Next steps as seen by project coordinators in T4



Achievements in T5	Status	Further Research	Further Development	Demonstration	Deployment
HyUNDER-A1	Completed		X	X	
STORE-A1	id				X
Concept-R3	id				X
SSSC-R2	id				X
TWENTIES-R5	id				X

Figure 20: Next steps as seen by project coordinators in T5

6.2 Coverage analysis of Cluster 2 with past and ongoing projects

6.2.1 T3 "Demonstration of power technology to increase network flexibility and operation means"

Contributions from completed and ongoing projects to T3

From EU projects

- The **TWENTIES** project, with six different demonstrations, addressed the removal of several barriers preventing the electric system from welcoming more wind electricity, and wind electricity from contributing more to the electric system. The full scale demonstrations aim at proving the benefits of novel technologies (most of them available from manufacturers) coupled with innovative system management approaches. Combinations of methodologies, software and hardware devices allowed the consortium bringing answers to the following questions:

- *What are the valuable contributions that intermittent wind generation and flexible loads can bring to system services?* For this, tools and methodologies to allow wind generation smart control to deliver system services were developed, as well as a centralised control/co-optimisation software across the value chain (wind, CHPs, local generation and load) to obtain cost efficient system services and wind balancing (inter- and intraday energy markets/ancillary services).
- *What should the network operators implement to allow for offshore wind development?* Secure architecture and controls for meshed HDVC network, a circuit breaker technology adapted to secure meshed HVDC offshore networks as well as storm controllers for offshore wind farms were developed and demonstrated.
- *How to give more flexibility to the transmission grid?* It was demonstrated that adequate coordination mechanisms between Dynamic Line Rating (DLR), Power Flow Controlling Devices and Wide Area Monitoring Systems (WAMS) bring more flexibility to the electric system within affordable capital and operational costs.

• The ongoing **BEST PATHS** project aims at developing novel network technologies to increase the pan-European transmission network capacity and the electricity system flexibility. It addresses the following questions:
  - *What are the routes to move from HVDC lines to HVDC grids?* Control strategies to improve the interaction between HVDC links and wind turbine generators are proposed. Interoperability standards of multi-terminal VSC HVDC are developed. The performance of coupled VSC units from different manufacturers is tested based on a full scale, hardware-in-the-loop test setup involving worldwide market leaders. New multilevel VSC converter and operations strategies integrating XLPE submarine and land cables, HTLS DC conductors, DC insulators and DC fault management systems are demonstrated. Finally, a methodology for high performance upgrading of existing DC links is being provided.
  - *What are the new promising capacity upgrading techniques for the existing AC parts of the network?* For repowering existing AC overhead lines (OHL), innovative HTLS conductors, DLR systems, tower design and field work are developed.
  - *How replicable are the promising demonstrations results within the entire pan-European electricity system?* The manufacturing of new (MgB2) superconducting cables and a technology to integrate DC superconducting links within an AC meshed network (design, manufacturing and grid operations) are being proposed.

• The **ICOEUR** project has developed, implemented and upgraded low voltage large-scale WAMS which have been put in operation by several TSOs worldwide.

• The **EcoGRID EU** project has developed and demonstrated, on a large scale, a real-time market concept for active user participation in order to reduce the need for costly flexibility on the production side. The project has delivered a database collecting the results obtained by the field implementation.

• The **PROMOTION** project is working on demonstrating innovative offshore converter topology. It is also developing and demonstrating HVDC grid protection systems (software and hardware).

From national projects

- In Denmark, the project **Concept2025** for the management of the future electricity system developed a methodology for active power grid control in relation with the issue of how the power grid can efficiently ensure that the traded electricity is transported.
- The Italian **VENTOTENE*** project is realising a pilot project that involve 500kW/600kWh lithium-ion battery that will be integrated with diesel generators that provide electricity to the island and will store electricity for use during demand peaks. A methodology is being developed to operate batteries in parallel with diesel generators and renewables.
- In Spain, the objective of the **STORE*** project is to demonstrate the technical and economic viability of large-scale energy storage systems (electrochemical storage, flywheel, ultracapacitor) in island environments. A methodology to provide inertia and active power for primary regulation is being developed, validating technology's ability to prevent outages due to unforeseen faults in generation units, as well as assistance in continuously stabilising voltage.
- In Great Britain, the ongoing **Humber Smartzone Pilot Project** aims to develop and demonstrate a proof of concept to provide flexible enhanced boundary capacity using a combination of wide area monitoring, predictive ratings and dynamic security analysis. It will deliver tools to monitor and predict the thermal capacity of a circuit, an application to estimate and predict thermal capacity margin in a region and a decision support system to coordinate plant and equipment maximising the utilisation of the network.
- In Slovenia, with the ongoing **SUMO** project a system for real-time and short-term forecast assessment of power grid operating limits is being developed. Methods and software tools are developed for evaluating DTR in real time and with a temporal horizon of 3 hours ahead. The allowable current is computed using air temperature, wind speed and direction, air pressure, global solar irradiation, air humidity and precipitation. An alarm system for extreme weather conditions (such as lightning, high winds, extreme air temperatures and heavy precipitations) that could lead to powerline outages is being implemented.
- Also in Italy, the **CLASS*** project is studying the integration and operation of liquid and compressed air storage system (LAES and CAES) in conventional power plants. It addresses:
  - the integration of CAES/LAES systems in conventional power plants that will be competitive from economic and energy points of view;
  - reliability of materials used in CAES/LAES critical components and in heat exchange and storage components;
  - an increase of CAES/LAES efficiency through the study of innovative and advanced configurations;
  - the critical points of the relevant control system;
  - the synergies between conventional power plants and CAES/LAES systems.

Note: Projects marked with an * do not count any TSO on board. They have been provided by EASE members.

Assessment of the coverage of T3

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective T3:

- **T3a.** To demonstrate the degree to which transfer capacity can be increased at the cross-border level and present new operating schemes available through the implementation of different approaches and technologies, to investigate all possible technical solutions within the domain of each application, and to perform cost-benefit analyses of different case studies.
- **T3b.** To demonstrate power flow control devices that offer increased flexibility with respect to energy flow across multiple transmission zones and borders.
- **T3c.** To demonstrate controllable offshore and onshore solutions for vendor-independent, HVDC multi-terminal networks used to coordinate power flow, frequency control, protection, and communications requirements.
- **T3d.** To implement solutions for wide-area monitoring (WAM) systems and demonstrate how to utilise such information in a coordinated manner during operations.
- **T3e.** To investigate the influence of parallel routing of DC and AC lines on the same tower or parallel paths in order to facilitate existing infrastructure paths in an optimal manner.

Coverage assessment

Completed projects have allowed covering about half of the tasks within this functional objective. Ongoing projects should allow covering an additional share of 30%. There is still a need for a multi-vendor installation regarding HVDC multi-terminal networks. More work should also be done at the EU level on WAMS and PMU coordination. In addition, issues related to the utilisation of DC lines within an AC grid using the same infrastructure have yet to be covered.

6.2.2 T4 "Demonstration of novel network architectures"

Contributions from completed and ongoing projects to T4

From EU projects

- Within the **BEST PATHS** project, novel network architectures are tested in terms of routes to move from HVDC lines to HVDC grids. Three demonstrations contribute to this objective: 1. HVDC links in offshore wind farms and offshore interconnections; 2. HVDC-VSC multivendor interoperability; and 3. Upgrading multi-terminal HVDC links using innovative components.
- The **PROMOTION** project contributes to this functional objective by working on innovative offshore converter topology.
- The recently started **MIGRATE** project is addressing the issues resulting from the extremely high penetrations of Power Electronics (PE) in several areas of the HVAC pan-European transmission system. In terms of novel network architectures, the project is working on KPIs to measure the distance to instability under different PE scenarios, new parameters (retuned controllers) for a few types of instabilities (generic test cases), new control strategies for transmission networks operated at 100% PE, the adaptation of existing protection schemes, new protection schemes in transmission networks and power quality analyses.

From national projects

- In Spain, the "**220 kV SSSC device for power flow control**" project aimed at designing, constructing, setting up in operation and testing a SSSC (Static

Synchronous Series Compensator) device to prevent overload situations in the Spanish 220 kV transmission grid due to boosting RES distributed penetration. This is the first ever implementation of a key FACTS device such the SSSC in the European transmission system. It includes power electronics components (VSC, protection system); control methodology; coupling transformer.

Assessment of the coverage of T4

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective T4:

- **T4a.** To demonstrate new power technologies on a large scale (including new materials), such as HVDC VSC, superconductivity, energy storage, fault current limiters, and other promising technologies for joint management of onshore and offshore networks.
- **T4b.** To validate various technology options to increase transmission capacity through selective reinforcement or implementation of an ultra-high-voltage transmission system (Super Grid) or DC backbone.
- **T4c.** To propose new schemes to extend synchronous areas in the pan-European grid and connect these with back-to-back HVDC to increase their utilisation and reduce the complexity of balancing, planning, and operation.
- **T4d.** To do research on the devices and concepts required to materialise multi-terminal DC grids that can cope with current system needs and sources, such as offshore generation.
- **T4e.** To coordinate offshore networks interconnected with various control areas, load-frequency control, DC voltage control, and other technologies required for DC (VSC) networks.
- **T4f.** To implement HVDC solutions to enhance reliability – bi-polar or mono-polar DC schemes.
- **T4g.** To determine standard DC voltage. Since VSC technologies eliminate the need for transformers, investment and maintenance costs will be reduced significantly. Weight and space are cost drivers, particularly for offshore installations.

Coverage assessment

Completed projects have allowed covering about 15% of these tasks. The big European projects which are ongoing should allow covering 40% more. There is still work to do on fault current limiters and other promising technologies, ultra-high voltage, extension of synchronous areas and their connection with back-to-back HVDC, methods for coordinating load frequency control in off-shore networks, reliability and standard DC voltage.

6.2.3 T5 "Interfaces for large-scale demonstration of renewable integration"

Contributions from completed and ongoing projects to T5

From EU projects

- The **TWENTIES** project has worked on the valuable contributions that intermittent wind generation can bring to system services. It has been shown that aggregating wind production with flexible loads at large scale within appropriate regulatory schemes leads to a more secure and efficient electricity system having high scalability potential. The project has delivered a centralised control and co-optimisation across the value chain (wind, CHPs, local generation and load) for cost efficient system services and wind balancing (inter- and intraday energy markets/ancillary services provided by VPP mobilisation and control of local assets).

- The **HyUNDER*** project aimed at providing a joint assessment of the European potential for large scale underground hydrogen storage to ensure network reliability and flexibility and compensate the fluctuating renewable. While short term energy storage can be met by small decentralized storage systems, mid to long term electricity storage technologies are still lagging behind. The project has delivered a database with the assessment of the potential, the actors and relevant business cases for large scale and seasonal storage of renewable electricity by hydrogen underground storage in Europe.
- The **BEST PATHS** project contributes to this functional objective with the demonstration of HVDC links in offshore wind farms and offshore interconnections. Control strategies to manage the interactions between HVDC links and wind turbine generators are being designed and tested.

From national projects

- The Spanish **220 kV SSSC device for power flow control** project contributes to this functional objective with a control system methodology.
- The Danish project **Concept2025** developed a methodology for intelligent resource activation and control. Secure and internationally standardised communication using IEC 61850 between DER and DSO, TSO, BRP has been demonstrated, and is now going into a final design/specification phase.
- The Spanish **STORE*** project is also contributing to this functional objective.

Note: Projects marked with an * do not count any TSO on board. They have been provided by EASE members.

Assessment of the coverage of T5

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective T5:

- **T5a.** To validate the contribution of RES to voltage and frequency control, balancing using VPP.
- **T5b.** To monitor and control the network in order to avoid large-scale intra-zone oscillations.
- **T5c.** To validate integration scenarios where the network becomes more user-friendly and copes with variable generation from RES.
- **T5d.** To demonstrate various technologies for deploying energy mix from conventional and renewable resources to stakeholders.

Coverage assessment

This functional objective has been widely covered by completed projects 80% of the task are assessed as covered. Ongoing projects should complement this coverage by 10%. Regarding the monitoring and control of the network in order to avoid large-scale intra-zone oscillations, a large EU-level demonstration project is still necessary.

6.3 Recommendations for the new R&I roadmap

Coverage rates in this Cluster 2 of transmission appear heterogeneous, due to the wide spectrum of involved technologies in that cluster. This is one reason that has motivated the change of organisation of the transmission roadmap by ENTSO-E: from an action driven roadmap to a challenge-oriented roadmap with a systemic dimension and close to the system needs.

To that purpose, in the new roadmap the actions related to the previous Cluster 2 on power technologies will not appear any longer in a dedicated cluster. Two clusters should address new technologies: a cluster dealing with the modernisation of the network where new materials, new devices (such as storage) should help improve the performance of the transmission system and another cluster dealing with flexibility options (DLR, power electronics, etc.).

7. Transmission Cluster 3: Network operation

Cluster 3 is organized into 4 Functional Objectives: T6, T7, T8 and T9.

T6. Innovative tools and methods to observe and control the pan-European network
T7. Innovative tools and methods for coordinated operation with stability margin evaluation
T8. Improved training tools and methods to ensure better coordination at the regional and pan-European levels
T9. Innovative tools and approaches for pan-European network reliability assessment

7.1 Features of achievements in Cluster 3

7.1.1 Descriptive features

<u>Categorization in functional objectives</u>

The graphs below characterize the completed (43) and expected (8) achievements of the projects' results of cluster 3 (a light green colour was used for Cluster 3). As for previous clusters, the first diagram on the left details the overall number of achievements in this cluster, while the two diagrams on the right show the evolutions (completed vs expected) in the relative number of achievements contributing to each Functional Objective

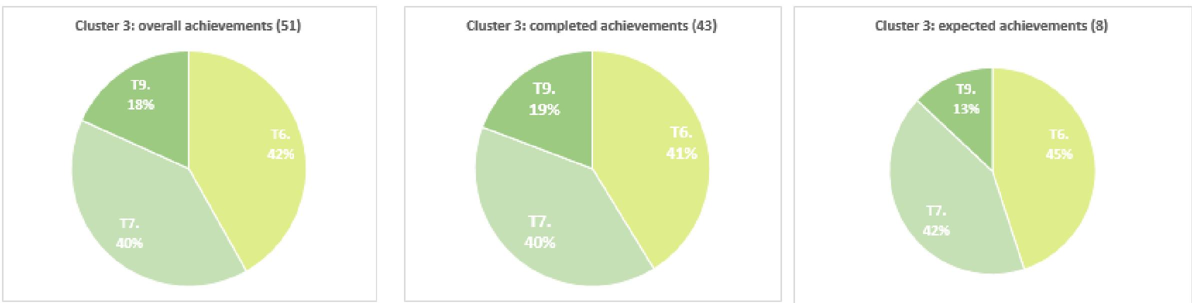


Figure 21: The portfolio of achievements in Cluster 3 (left: overall; middle: completed; right: expected)

<u>Highlights:</u>

- Cluster 3 is the most populated cluster in terms of achievements, especially for completed achievements. However only 8 out of 51 refer to expected achievements.

- There is no particular distortion in the general balance in the three diagrams: T7 and T6 are representing the same share (slightly above 40%) while T9 represents less than 20% of the sample.

Typology of achievements in Cluster 3

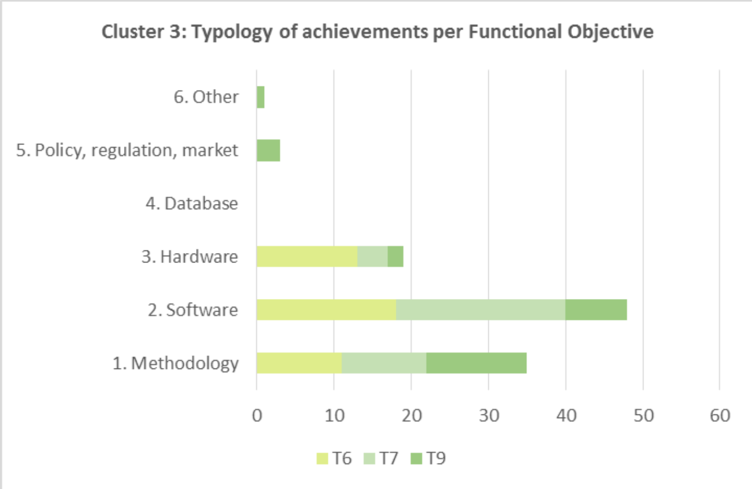


Figure 22: Typology of achievements in Cluster 3 in transmission

Highlights:

- Software type achievements followed by the methodology type are the most quoted in Cluster 3.
- No (or very marginal) mention of database, policy, regulation, market in that cluster.

Evolution of the maturity of achievements in Cluster 3

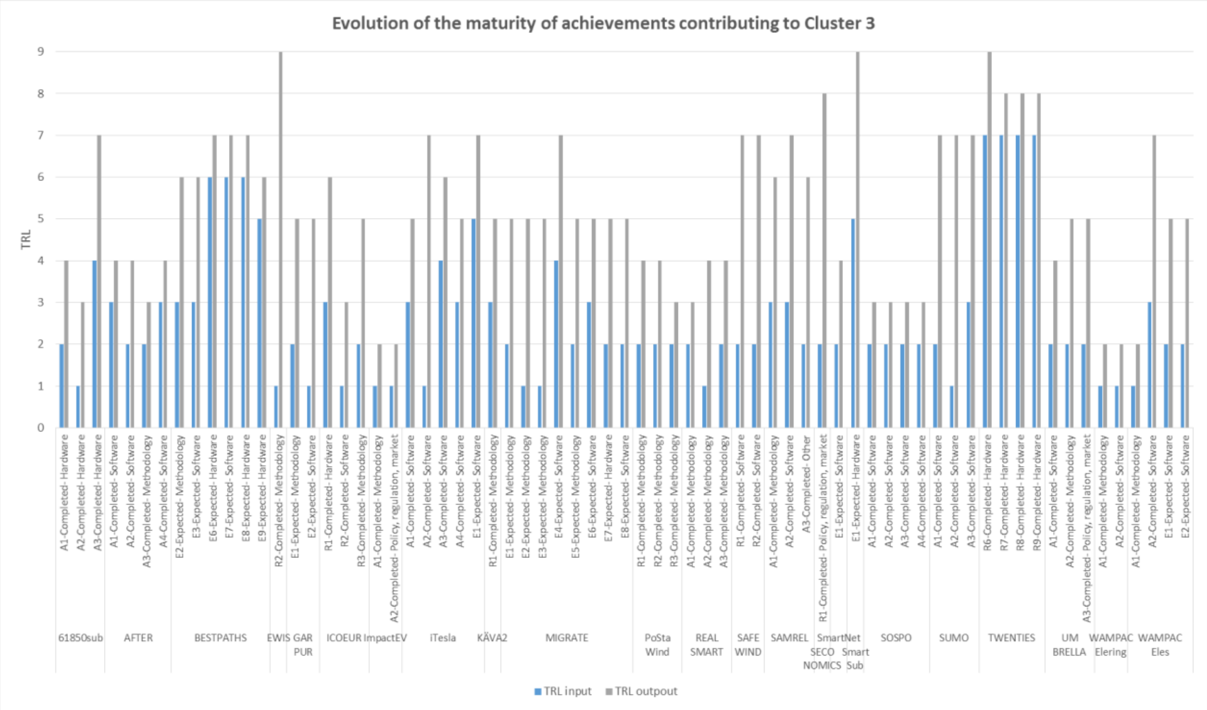


Figure 23: Evolution of the maturity of achievements contributing to Cluster 3 measured in TRL units

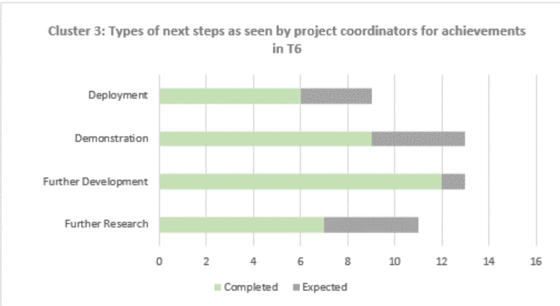
Highlights:

- The graph shows the variability of the maturity increments per project achievement: most of the considered achievements have a maturity gain between 2 and 3 units.

7.1.2 Projective features (next steps)

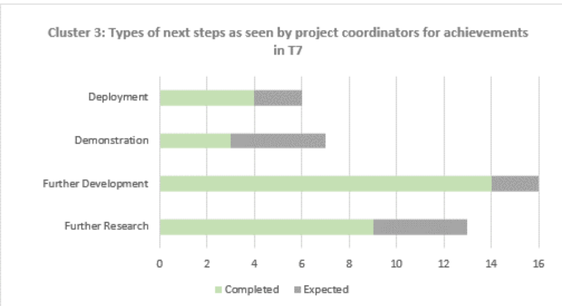
From the data collected in Cluster 3 for each functional objective (T6, T7, T9) one can formulate the following highlights:

- In T6 the four types of "next steps" are well-balanced.
- In T7 achievements appear to be more upstream since the "further development" and "further research" routes are dominant.
- The situation is the same in a higher degree in T9 where the "further research" route is the first option considered by on-going projects with expected achievements (MIGRATE, GARPUR).



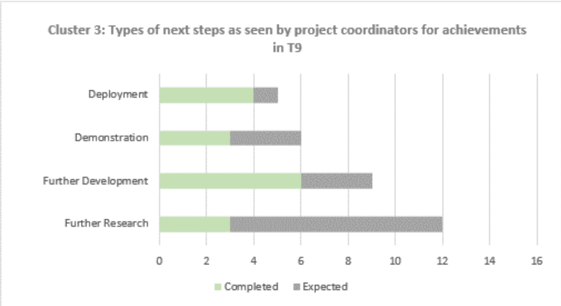
Achievements in T6	Status	Further Research	Further Development	Demonstration	Deployment
61850sub-A1	Completed			X	
61850sub-A2	id		X	X	
61850sub-A3	id			X	
AFTER-A2	id	X			
AFTER-A3	id		X		
REALSMART-A1	id	X			
REALSMART-A2	id		X		
REALSMART-A3	id		X		
SOSPO-A1	id		X		
SOSPO-A2	id		X		
SOSPO-A3	id	X			
SOSPO-A4	id	X			
SUMO-A1	id			X	X
SUMO-A3	id			X	X
UMBRELLA-A1	id			X	
WAMPAC_Elering-A1	id	X	X		
WAMPAC_Elering-A2	id			X	X
WAMPAC_Eles-A1	id	X	X		
WAMPAC_Eles-A2	id		X		
EWIS-R2	id				X
ICOEUR-R1	id				X
ICOEUR-R2	id		X		
ICOEUR-R3	id	X			
SAFEWIND-R1	id		X	X	
SAFEWIND-R2	id		X	X	X
MIGRATE-E5	Expected	X			
MIGRATE-E6	id	X	X	X	
MIGRATE-E7	id	X			
MIGRATE-E8	id	X			
SmartSub-E1	id			X	X
WAMPAC_Eles-E1	id			X	X
WAMPAC_Eles-E2	id			X	X

Figure 24: Next steps as seen by project coordinators in T6



Achievements in T7	Status	Further Research	Further Development	Demonstration	Deployment
AFTER-A1	Completed	X	X	X	
AFTER-A2	id	X			
AFTER-A4	id		X		
iTesla-A1	id		X		
iTesla-A2	id		X		
iTesla-A3	id				X
iTesla-A4	id	X	X		
SOSPO-A1	id		X		
SOSPO-A2	id		X		
SOSPO-A3	id	X			
SOSPO-A4	id	X			
UMBRELLA-A1	id			X	
UMBRELLA-A2	id	X			
WAMPAC_Elering-A1	id	X	X		
WAMPAC_Elering-A2	id			X	X
WAMPAC_Eles-A1	id	X	X		
WAMPAC_Eles-A2	id		X		
EWIS-R2	id				X
ICOEUR-R1	id				X
ICOEUR-R2	id		X		
ICOEUR-R3	id	X			
PoStaWind-R1	id		X		
PoStaWind-R2	id		X		
PoStaWind-R3	id		X		
MIGRATE-E4	Expected		X	X	
MIGRATE-E5	id	X			
MIGRATE-E6	id	X	X	X	
MIGRATE-E7	id	X			
MIGRATE-E8	id	X			
WAMPAC_Eles-E1	id			X	X
WAMPAC_Eles-E2	id			X	X

Figure 25: Next steps as seen by project coordinators in T7



Achievements in T9	Status	Further Research	Further Development	Demonstration	Deployment
SAMREL-A1	Completed	X	X		
SAMREL-A2	id		X		
SAMREL-A3	id	X	X		
SUMO-A2	id			X	X
UMBRELLA-A1	id			X	
UMBRELLA-A2	id	X			
UMBRELLA-A3	id			X	X
ICOEUR-R1	id				X
PoStaWind-R1	id		X		
PoStaWind-R2	id		X		
PoStaWind-R3	id		X		
SECONOMICS-R1	id				X
GARPUR-E1	Expected	X		X	X
GARPUR-E2	id	X			
MIGRATE-E1	id	X			
MIGRATE-E2	id	X			
MIGRATE-E3	id	X			
MIGRATE-E4	id		X	X	
MIGRATE-E5	id	X			
MIGRATE-E6	id	X	X	X	
MIGRATE-E7	id	X			
MIGRATE-E8	id	X			
SmartNet-E1	id		X		

Figure 26: Next steps as seen by project coordinators in T9

7.2 Coverage analysis of Cluster 3 with past and ongoing projects

7.2.1 T6 "Innovative tools and methods to observe and control the pan-European network"

Contributions from completed and ongoing projects to T6

From EU projects

- The **EWIS** project developed a methodology for real time data exchange between network operators and day-ahead data exchange concerning solar and wind production forecast. This has contributed to the development of regional control centres. Even though network operators have been exchanging data for decades, the EWIS project proved that it is fundamental to exchange in real time a broader set of data to ensure the safe operation of a large system in presence of high RES penetration.
- **TWENTIES** addressed this functional objective with the demonstration of power technologies contributing to better observing and controlling the network (storm controllers for offshore wind farms, Dynamic Line Rating, Power Flow Controlling Devices, WAMS, overhead line controller).
- The **ICOEUR** project also contributed to this functional objective by developing and implementing low voltage large-scale WAMS system, developing distributed coordination system for real-time power flow control and evaluating interconnection concepts for system stability by the development of models and tool for large-scale power system inter-area oscillation analysis.
- Within the **SAFEWIND** project, methods and software tools have been developed for probabilistic forecasting of wind power, for forecasting the level of wind power predictability in the next hours or days as well as for alarming producers, DSOs and TSOs in case of extreme situations (high wind speeds, weather fronts, any situations producing large forecast errors).
- The **AFTER** project has allowed improving physical security by innovative techniques for early warning of substation intrusion events.
- The **REALSMART** project has delivered methods for enhancing power transmission

system security and an analytical methodology for understanding the interactions between industrial loads and the grid.

- The recently completed **UMBRELLA** project has delivered an innovative toolbox prototype to support the decentralised grid security approach of TSOs.
- The ongoing **BEST PATHS** project is also contributing to better observing and controlling the network with the demonstration of innovative HTLS conductors, Dynamic Line Rating, innovative tower design and new (MgB2) superconducting cables.
- The recently started **MIGRATE** project is looking at operating existing PMUs in real time to provide reliable stability KPIs.

From national projects

- The Danish **SOSPO** project aimed at developing systems to monitor the overall power system state and alert system operators for critical situations in the power system. It delivered software tools for dynamic and static security assessment in real-time, long-term Voltage Stability Assessment (VSA), Wide Area Prosumtion Control (modelling of aggregated prosumption as a controllable reserve; wide area prosumption control algorithms), Wide Area Emergency Control (adaptive control for small signal instability; state and parameter estimation; Transient Stability Emergency Control) and dynamic voltage and rotor angle stability assessment.
- The Spanish project "**A complete and normalised 61850 substation**" has used the standard IEC61850 as a means to improve the design, maintenance and operation of the substation automation systems. It has designed a standard substation considering the existing and new solutions developed by the vendors collaborating in the project. An IEC61850 HV substation has been built and set-up in operation.
- The Estonian project **Impact of electric and gas vehicles** also contributes to this functional objective with the evaluation of the impacts of electric transport on grid operation.
- Again in Estonia, the **WAMPAC** project has studied applications of the WAMS system and possible development trends for the future and assessed the possibilities of a wide-area measurement system for use in system protection. It has delivered PMU deployment algorithms for selection of PMUs optimal location and grid losses assessment, and software modules to improve network observability and to assess grid losses.
- In Slovenia, another **WAMPAC** project is currently developing protection and control functions to upgrade the existing WAMS and investigating relevant critical operation scenarios. Dynamic phenomena and their impact on Slovenian network have been studied. The project will also deliver software tools for fault identification and localisation, and operator support tool for island management after severe fault in network leading to network separation.
- The French ongoing project **Smart Substation** is deploying a smart HV substation in order to bring new functionalities, manage redundancy and move away from hardwiring and manage inter-substation automation. The deployment of the smart substation will allow testing in real operations the following functions: a local state estimator, weather-based dynamic rating for transformers and OHL, digital paralleling of voltage regulation, WACU (Wide Area Control Units) and 61850 WAN for extended benefits across neighbouring substations, automatic fault analysis and location. The deployed solution will allow network operators to better manage congestions thanks to local optimisation and distributed intelligence and to host

more renewables such as wind power.

Assessment of the coverage of T6

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective T6:

- **T6a.** To assess and validate the performance of intelligent local sensors and data processing equipment (with sensor manufacturers) against the requirements of state estimation and dynamic simulation.
- **T6b.** To develop a toolbox to increase awareness of pan-European operation/optimisation vs. local and regional approaches.
- **T6c.** To develop local state models with a sufficient level of intelligence at the substation level and to use this valuable information with state estimators and dynamic simulation tools. These models will be aggregated for assessing the observability and controllability at the pan-European level.
- **T6d.** To increase observability and improve state estimation accuracy (both steady-state and dynamic) through adequate modelling (including not only modelling protection and system automatic schemes to some extent, but also by merging transmission and distribution models).
- **T6e.** To exploit the information provided by forecasts of variable generation and flexible demand for observability and controllability purposes.
- **T6f.** To increase network controllability by proposing methods and tools for optimal and coordinated use of flexible equipment such as FACTS, PSTs and HVDC links, resulting in safe and cost-effective system operations (e.g., maximising the global social welfare).

Coverage assessment

We estimate that completed projects have covered about 60% of those specific tasks. An additional 20% should be covered by ongoing projects. Local state models still need to be aggregated for assessing observability and controllability at the pan-European level. There is still some work to do on flexible demand forecast at the TSO level.

7.2.2 T7 "Innovative tools and methods for coordinated operation with stability margin evaluation"

Contributions from completed and ongoing projects to T7

From EU projects

- **TWENTIES** delivered a centralised control and co-optimisation across the value chain (wind, CHPs, local generation and load) for cost efficient system services and wind balancing (inter- and intraday energy markets/ancillary services provided by VPP mobilisation and control of local assets). Demonstrations of Dynamic Line Rating systems, Power Flow Controlling Devices and WAMS brought solutions to increase the existing network capacity and flexibility at affordable investment costs, while ensuring that stability and security margins remain within acceptable ranges and promoting regional coordination approaches to increase the network flexibility.
- **AFTER** delivered methods and tools for global vulnerability analysis and risk assessment of power systems, physical security improvement by innovative techniques for early warning of substation intrusion events, advanced defence of

power system operation following severe grid outages by innovative defence plans techniques and a software tool for system restoration after major disruptions by adaptive and efficient restoration plans.

- The data exchange methodology developed by the **EWIS** project contributes to this functional objective.
- The **ICOEUR** project also contributed to this functional objective.
- The recently finished **iTesla** project aimed at improving network operations with a new security assessment tool able to cope with increasingly uncertain operating conditions and take advantage of the growing flexibility of the grid. The developed toolbox supports the decision making process for network operation from two-days ahead to real time, based on three main features:
  - provide a risk-based assessment taking into account the different sources of uncertainties (in particular intermittent power generation), the probabilities of contingencies and the possible failures of corrective actions;
  - perform accurate security assessment taking into account the dynamics of the system using time-domain simulations;
  - provide operators with relevant proposals of preventive and curative actions to keep the system in a secure state.

1. The toolbox will allow TSOs to address network simulations of their own system, of coordinated regional systems or of the whole Pan-European system. Further developments will be necessary to make it a fully operational toolbox for system operators and to demonstrate in economic and operational terms the added value of the iTesla concept.

- The recently finished **UMBRELLA** project has provides a toolbox prototype for TSOs to ensure secure grid operation in future electricity networks with high penetration of intermittent renewables. It enables TSOs to act in a coordinated European target system where regional strategies converge to ensure the best possible use of the European electricity infrastructure. Risk-based security assessment methods, deterministic and probabilistic approaches have been developed.
- The ongoing **BEST PATHS** project is also contributing to this functional objective.
- The recently started **MIGRATE** project will deliver recommendations on network connection code. There is no existing methodology providing guidance on how to implement mitigation measures when facing PE generated instabilities during operations. Mitigation measures to address stability issues when operating a transmission network with high PE penetration will be proposed. Recommendations on network connection code implementation will also be proposed.

From national projects

- The Finnish **KÄVA2** project developed a methodology to estimate probability-based security levels, in order to increase the knowledge and understanding of probability-based security in planning and operation.
- In Finland, Norway and Sweden, the **PoStaWind** project studied wind power integration in the Nordic transmission system (inter-area power oscillation, synthetic inertia from wind farms, transient reactive power).
- The Danish **SOSPO** project, the **WAMPAC** project in Estonia and the other **WAMPAC** in Slovenia are also contributing to this functional objective.

Assessment of the coverage of T7

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective T7:

- **T7a.** To assess the effectiveness of control actions that deliver the right level of reliability while facing uncertainties from the large-scale deployment of RES and market integration.
- **T7b.** To develop approaches for optimal provisioning, dimensioning and sourcing of reserves together with local and/or regional distribution in order to maintain security of supply; to deliver dynamic management of system reserves at regional and pan-European levels.
- **T7c.** To implement stochastic approaches to critical optimisation variables (larger dispersions around the deterministic values obtained from the current steady state simulation tools) in order to cope adequately with uncertainties.
- **T7d.** To facilitate converging policies for operational planning and to support the harmonisation of operating rules across Europe.
- **T7e.** To propose data exchange procedures for adequate system simulation; to identify critical contingencies and to assess residual risks while taking into account effectiveness and availability of control actions and automatic protection schemes while identifying action paths to be implemented.
- **T7f.** To enable real-time detection of instabilities and prevent limit transgression in transmission systems and to develop new approaches to coordinate defence and restoration plans.

Coverage assessment

The specific tasks in this functional objective have all been tackled by past and ongoing projects. We assess that 80% of the tasks have been covered, while 10% should be covered by ongoing projects. There is still some work to do on new approaches to coordinate defence and restoration plans.

7.2.3 T8 "Improved training tools and methods to ensure better coordination at the regional and pan-European levels"

Contributions from completed and ongoing projects to T8

Within our project database, no achievement (past nor expected) is linked to this functional objective.

Assessment of the coverage of T8

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective T8:

- **T8a.** To deliver real-time simulation of the entire interconnected European power system for training purposes.
- **T8b.** To train dispatchers to reproduce and understand large-scale incidents.
- **T8c.** To provide training and certification to operators on a validated European power system model and to improve emergency response procedures.

- **T8d.** To make the dispatching training simulation facility available to other operators, such as power plant operators and distribution network operators in order to improve the network interfaces between transmission/generation and transmission/distribution.
- **T8e.** To develop and test common procedures for emergency scenarios.
- **T8f.** To enable operator training by specifying the training simulator of the future, including the validation of critical algorithms.
- **T8g.** To enable experimentation on what future training should include and who should be involved in order to learn and test the benefits of coordination mechanisms in stable and critical situations.
- **T8h.** To establish, validate, and deliver default data to fill all the gaps in such a way that simulations are realistic enough for the targeted use.

Coverage assessment

The coverage of these specific tasks was not assessed since no project linked to this functional objective was found in the questionnaires filled in by the project coordinators[10]. However, ENTSO-E in its R&D monitoring report 2015 considers that 21% of this functional objective is covered. According to ENTSO-E, further R&I work should be conducted for:

- RT8a, where a simulation of the entire interconnected European power system is needed;
- T8b, where there is still work to do on the training.
- T8d, for which the training facility is not available yet.
- T8c, T8e, T8f, T8g and T8h which have not been addressed yet.

7.2.4 T9 "Innovative tools and approaches for pan-European network reliability assessment"

Contributions from completed and ongoing projects to T9

From EU projects

- With the **SECONOMICS** project, a toolkit to security policy-makers seeking to understand their policy alternatives and the potential impact of their decisions has been developed. Recommendations for a policy framework for comparing the effect of different security regulations have been delivered.
- The low voltage large-scale WAMS developed within the **ICOEUR** project also contributes to this functional objective.
- The **UMBRELLA** project has developed risk-based security assessment methods and recommendations to ENTSO-E regarding TSO and Regional Security Coordination Initiatives (RSCI) rules for business processes and data exchange.
- The ongoing **GARPUR** project is developing new reliability management approach and criteria (RMAC) for the pan-European electric power system, which should

[10] Project coordinators have chosen themselves the functional objectives linked to the achievements in their projects. They may have overlooked this functional objective. Some projects considered in the ENTSO-E R&D monitoring report 2015 are not in the Grid+Storage database, like for instance the PEGASE project for which the interview of the coordinator could not be performed in due time.

   - be aware of the spatial-temporal variation of the probabilities of exogenous threats and take into account the socio-economic impact of its decisions,
   - explicitly take into account corrective control measures and their probability of failure,
   - incorporate the possibility of using demand-side management to secure system operations,
   - cover both normal threats, as well as low-probability high-impact threats,
   - cover the multiple decision making contexts and timescales (long term planning, mid-term & asset management, short-term planning to real-time operation),
   - take into account the multi-agent and multi-area nature of the organisation of the pan-European electric power system (several TSOs, DSOs, MOs, regulatory regimes, etc.).

  The project is also developing a prototype software tool (the GARPUR Quantification Platform) to evaluate the socio-economic impact of the new RMAC. The GQP will include the modelling of TSO decision-making processes in day-ahead and intraday and of TSO short-term reliability management candidate decisions.

- The recently started **SmartNet** project aims at providing architectures for optimised interaction between TSOs and DSOs in managing the exchange of information for the acquisition of ancillary services (reserve and balancing, voltage regulation, congestion management) from distributed resources (DSM, scattered generation), both at national level and in a cross-border context. A software tool for such optimised architectures is being developed.

From national projects

- In Norway, Denmark and Finland, the **SAMREL** methodology provides an integration of the power market simulator (EMPS) and a newly developed methodology for reliability and interruption cost assessment (OPAL) with power flow models. Such an integration is required to provide a comprehensive and consistent approach for security of electricity supply analysis. A methodology for the chain of analyses from power market analysis to reliability of supply analysis, a prototype tool for security of supply and vulnerability analysis, tested on a regional, national and Nordic level, and the evaluation and grouping of power market scenarios have been delivered.
- The **KÄVA2, PoStaWind** and **Impact of electric and gas vehicles** projects also contribute to this functional objective.

Assessment of the coverage of T9

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective T9:

- **T9a.** To evaluate the current performance of the (N-1) criteria security principles and the required level of reliability from the customer's perspective.
- **T9b.** To identify the possible options for replacing (or complementing) the current reliability principles using a system approach to be used in different aspects of TSO business: grid development, markets, reserve planning, etc.
- **T9c.** To define the additional information to be exchanged and the additional coordination needed to support deployment and to ensure effective and sufficient security margins during operation and operational planning.
- **T9d.** To provide an appropriate approach to risk assessment for the evaluated criteria based on probabilistic analyses which takes correlations in the power system.

T9e. To develop indicators for the evaluated criteria for network operators to help them make decisions for preventive and curative actions.

Coverage assessment

We consider here that past achievements cover around half (50%) of these specific tasks. Ongoing projects should allow covering one additional quarter (25%) with no clear view on the application of the new reliability principles by the TSOs. In addition, there is a need for further work on information exchanges.

7.3 Recommendations for the new R&I roadmap

Coverage ratios are rather high for T6 and T7, but lower for T8 and T9. Here again the network operations actions referring to various challenges motivated ENTSO-E to redispatch them into clusters dealing with the network security or to its flexibility. The challenges mentioned for each cluster should be coherent with the specifications of the integrated roadmap, e.g. storage as a new flexibility option or demand response as a way to achieve a customer centric power system. Regarding security, the ever increasing share of renewables calls for R&I work regarding ancillary services provided by RES as well as defence and restoration plans involving RES.

8. Transmission Cluster 4: Market design

Cluster 4 is organized into 3 Functional Objectives: T10, T11 and T12.

T10. Advanced pan-European market tools for ancillary services and balancing, including active demand management
T11. Advanced tools for capacity allocation and congestion management
T12. Tools and market mechanisms for ensuring system adequacy and efficiency in electric systems integrating very large amounts of RES generation

8.1 Descriptive features of achievements in Cluster 4

8.1.1 Descriptive features

Categorization in functional objectives

The graphs below characterize the completed (16) and expected (11) achievements of the projects' results of cluster 3 (a salmon colour is used for Cluster 4). Again, comparing the first diagram on the left with the two on the right allows detecting some evolutions in the relative number of achievements contributing to each Functional Objective.

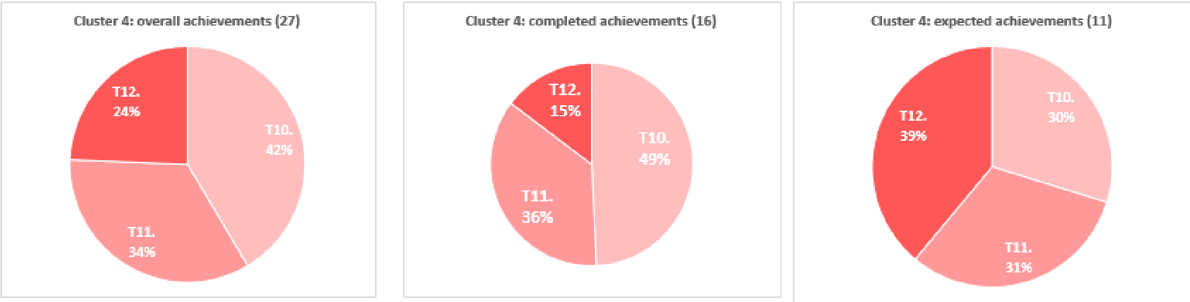


Figure 27: The portfolio of achievements in Cluster 4 (left: overall; middle: completed; right: expected)

Highlights:

- Cluster 4 is clearly subject to evolutions when comparing the respective share of completed and expected achievements. Expected achievements represent 11 units out of a total of 27 which is significant compared to the other clusters.
- About half of the completed achievements belong to T10.
- For the expected achievement, the distribution is more balanced with shares in the range of 30-40% with an increasing relative share of T12.

Typology of achievements in Cluster 4

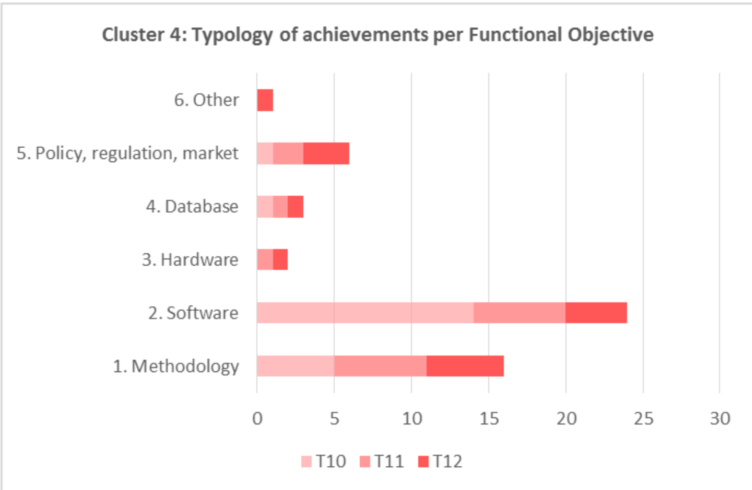


Figure 28: Typology of achievements in Cluster 4 in transmission

Highlights:

- Achievements in this cluster consist mainly in software and methodologies, while the “policy, regulation and market” type slightly emerges which is consistent with the R&I activities to be addressed in the cluster.
- Database and hardware types remain marginal.

Evolution of the maturity of achievements in Cluster 4

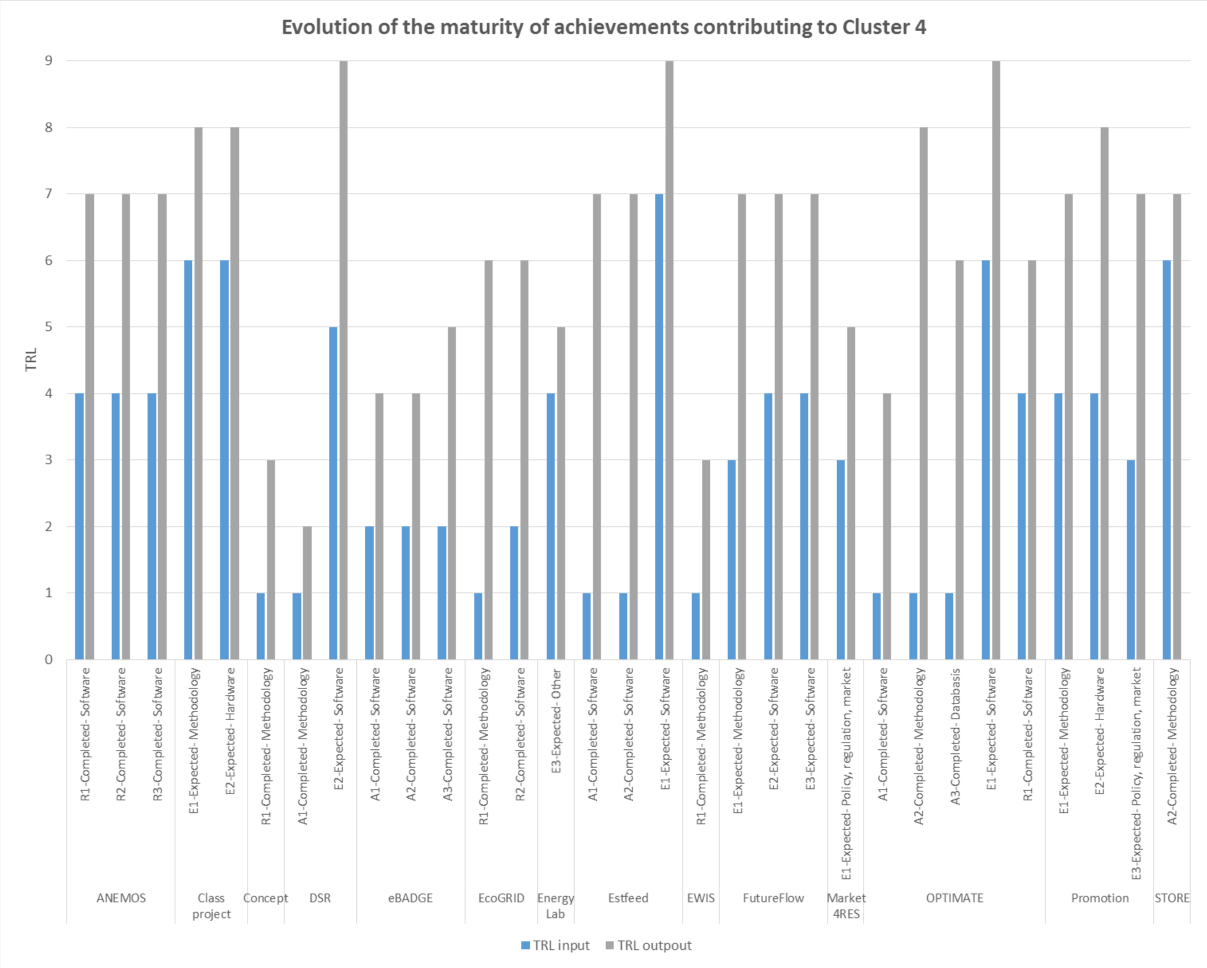


Figure 29: Evolution of the maturity of achievements contributing to Cluster 4 measured in TRL units

Highlights:

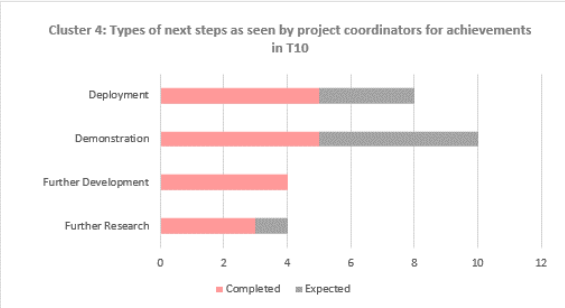
- The same remarks as for the previous clusters on the average maturity gain applies here.
- One should however notice the important maturity step resulting from the OPTIMATE achievements (software, methodology, database).
- The Estfeed and EcoGRID achievements present similar features in the maturity scale.

8.1.2 Projective features (next steps)

From the available data for each functional objective (T10, T11, T12), one can formulate the following highlights:

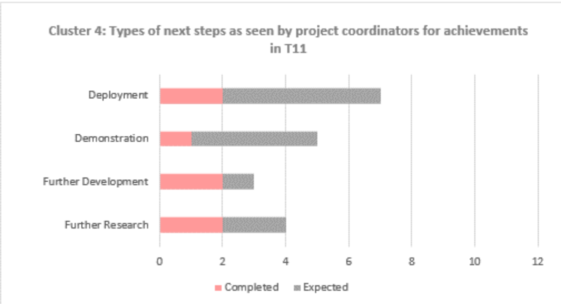
- The relative share of the expected achievements compared to the whole Cluster achievements appears higher in Cluster 4 than in previous Clusters (more grey vs. salmon colour)

- In T10, the four next steps routes are quite balanced for the completed achievements. When considering the expected ones, "demonstration" ha the highest number of occurrences (FutureFlow, DSR, Estfeed) followed by "deployment" (DSR, Estfeed, Optimate).
- In T11 a similar trend is observed: the difference is made by the expected achievements (in grey colour) for "deployment" (Class_project, DSR, Optimate) and "demonstration" (Class_project, DSR, FutureFlow).
- In T12 such a trend has to be slightly adjusted for the expected achievements with "deployment" (4 occurrences for DSR, Optimate, Promotion) followed by "further research" (3 occurrences for DSR, Market4RES, Promotion).



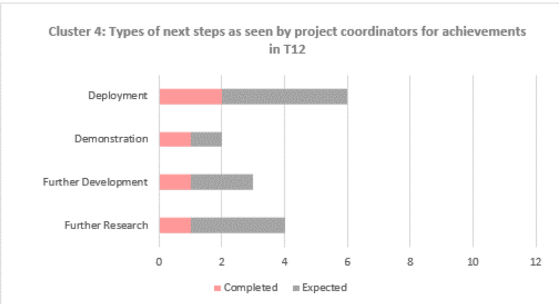
Achievements in T10	Status	Further Research	Further Development	Demonstration	Deployment
DSR-A1	Completed	X			X
eBADGE-A1	id		X		
eBADGE-A2	id		X		
eBADGE-A3	id		X		
Estfeed-A1	id			X	X
Estfeed-A2	id			X	X
ANEMOS-R1	id				X
ANEMOS-R2	id			X	X
ANEMOS-R3	id		X	X	
Concept-R1	id			X	
EcoGRID-R1	id	X			
EcoGRID-R2	id	X			
DSR-E2	Expected			X	X
Estfeed-E1	id			X	X
FutureFlow-E1	id			X	
FutureFlow-E2	id			X	
FutureFlow-E3	id			X	
Market4RES-E1	id	X			
OPTIMATE-E1	id				X

Figure 30: Next steps as seen by project coordinators in T10



Achievements in T11	Status	Further Research	Further Development	Demonstration	Deployment
DSR-A1	Completed	X			X
Estfeed-A2	id			X	X
OPTIMATE-A1	id		X		
EcoGRID-R1	id	X			
EWIS-R1	id		X		
Class_project-E1	Expected			X	X
Class_project-E2	id		X		X
DSR-E1	id	X			X
DSR-E2	id			X	X
FutureFlow-E1	id			X	
FutureFlow-E3	id			X	
Market4RES-E1	id	X			
OPTIMATE-E1	id				X

Figure 31: Next steps as seen by project coordinators in T11



Achievements in T12	Status	Further Research	Further Development	Demonstration	Deployment
DSR-A1	Completed	X			X
OPTIMATE-A1	id		X		
STORE-A2	id				X
Concept-R1	id			X	
DSR-E1	Expected	X			X
DSR-E2	id			X	X
EnergyLab-E3	id		X		
Market4RES-E1	id	X			
OPTIMATE-E1	id				X
Promotion-E1	id	X	X		
Promotion-E3	id				X

Figure 32: Next steps as seen by project coordinators in T12

8.2 Coverage analysis of Cluster 4 with past and ongoing projects

8.2.1 T10 "Advanced pan-European market tools for ancillary services and balancing, including active demand management"

Contributions from completed and ongoing projects to T10

From EU projects

- The **ANEMOS.plus** project aimed at the development and demonstration of probabilistic approaches for the optimal management of electricity grids integrating large-shares of wind power generation. In particular, new operational tools for managing wind generation and for trading in electricity markets have been developed. The project also focused on demonstrations identified as key challenges for large-scale integration of wind power into the electricity supply including 1) allocation of balancing power and definition of reserves for TSOs, 2) Optimal scheduling of power systems with high wind penetration, 3) Congestion management in large power systems as well as local grids, 4) Trading of wind power in electricity markets using advanced bidding strategies and 5) Management of storage associated to wind farms.
- The **OPTIMATE** project has developed a numerical test platform to analyse and to validate new market designs, based on an innovative approach consisting in modelling in a sequential manner short-term electricity markets from day-ahead through intraday to real-time. It embeds an extensive database gathering information about technical and economic features of thermal plants, half-hourly forecasts of intermittent generation, network parameters… It also allow the modelling of active demand as load shedding in response to market price signals. The FP7 project OPTIMATE ended in 2012 with the delivery of a prototype tool with limited functional scope; an industrial version of the tool is expected with full functional scope and high robustness.
- The **EcoGRID EU** project has developed and demonstrated a generally applicable real-time market concept for smart electricity distribution networks with high penetration of renewable energy sources and active user participation. The main achievements of EcoGrid EU are:
  - *Market concept (real time - 5 min):* The general concept is based on a real-time market approach that lets distributed energy resources and flexible electricity demand receive and respond to variable electricity prices.
  - *Development of software to manage market places:* Different applications were developed on cloud computing for developing a software that controls the equipment installed in the customers' houses and provide an automated response to real time signals marketplace. The software includes also a forecasting model for Demand Response.
  - *Development of a database that collects the results obtained by the field implementation.*
- The recently finished **eBADGE** project has proposes an optimal pan-European Intelligent Balancing mechanism, piloted on the borders of Austria, Italy , Slovenia and Germany , that is also able to integrate Virtual Power Plant (VPP) Systems that can assist in the management of the transmission and distribution grids in an optimised, controlled and secure manner. The main achievements of the project are:
  - *A transnational balancing market simulator* (open to public usage);
  - *A message Bus enabling communications among all involved parties*: home energy hubs (HEHs), VPPs, DSOs, TSOs and possibly others;
  - *An optimal planning of VPP resources activation*, using an evolutionary

algorithm.

- The ongoing **Market4RES project** is working on recommendations for the implementation of policy, legislation and regulation across the renewable energy sector, based on qualitative and quantitative analyses. In particular, different design options for demand response (both explicit and implicit) have been studied and assessed, and the impacts on electricity markets outcomes of a large-scale deployment of demand response have been quantified with the OPTIMATE tool. Regarding balancing, the project has also studied different aspects of the balancing market design, including procurement of balancing services and calculation of imbalance prices. Different options for the procurement of balancing capacity have been subject to a quantitative analysis.
- The recently started **FutureFlow** project is designing and testing comprehensive techno-economic models for open and non-discriminatory access of advanced consumers and distributed generators to a Regional Platform for ancillary/balancing and redispatching services. In particular, the project will deliver a prototype demand response (DR) and distributed generation (DG) flexibility aggregation platform (or VPP), based on an innovative software solution able to deliver secure and reliable frequency restoration reserves with automatic activation (aFRR) offers to the TSOs. This innovative approach allows for a seamless integration of the biding part on the one side, together with the automatic execution of the aFRR services on the other side.

From national projects

- The Danish project **Concept2025** investigated several issues touching different aspects for managing the system with very high variable RES (wind) penetration, such as active power control, balancing, information exchange, flexible load, DER.
- In Estonia, the ongoing **DSR** project has identified the demand-side response (DSR) potential for Estonia and studied the opportunity to use DSR as a source of flexibility. The study outcomes represent a base on which a competitive market for demand management could be implemented. The future expected achievements are related to the development of a market model for DSR and software solutions for concretely manage DSR aggregation.
- Again in Estonia, the **Estfeed** open software platform (managed by the TSO) is being developed for energy consumptions monitoring and management from customer perspective, capable to interact with grids and to provide data feeds to service providers for an efficient use of energy.

Assessment of the coverage of T10

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective T10:

T10a. To model aggregated RES/DER, flexible conventional generation, demand and storage systems to be used for market design, market mechanisms, and simulation tools for planning and operation purposes.

T10b. To design market mechanisms for incentivising both the maximisation of the provision of ancillary services (including aggregated RES, cogeneration and high-efficiency production, demand, storage, etc.) and the minimisation of the use of ancillary services. The aim is to harmonise the requirements of provider licences with supervision, control, and recording of services provided.

- **T10c.** To develop a new tool for detailed analyses of various balancing market designs to identify best practices and to perform large-scale experiments with metered customers that demonstrate the costs and benefits of demand-side management required at the pan-European level.
- **T10d.** To design and develop mechanisms and platforms for cross-border balancing and power reserve services, moving towards possible future development of regional/panregional platforms and even markets based on economic and technical analyses, all the while operating within the required security margins.
- **T10e.** To develop a set of data exchange templates and information and communication technology (ICT) infrastructure to enable ancillary and balancing services at the EU level.

<u>Coverage assessment</u>

We consider that half (50%) of this task is covered by completed projects. Ongoing work should allow covering an additional third (~30%). Task 10b is quite wide and needs further work. Regarding task 10e, there is still some work to do on the development of data to be exchanged at the EU level.

8.2.2 T11 "Advanced tools for capacity allocation and congestion management"

<u>Contributions from completed and ongoing projects to T11</u>

From EU projects

- The **EWIS** project had evaluated short- to mid-term network issues arising from wind generation. A methodology was developed to link market based simulations (zonal) and network simulations (nodal).
- The **OPTIMATE** simulation platform models cross-border exchanges (both NTC and flow-based).
- The **EcoGRID EU** real-time market concept is also contributing to this functional objective. The next project steps include further research to come up to a European harmonisation of the concept but also to improve the acceptance of this concept by customers and TSOs.
- The ongoing **Market4RES project** has studied (in a qualitative manner) different network representation options: nodal pricing, zonal pricing, hybrid zonal pricing (zones are subdivision of control areas), single node dispatch + redispatch and full network representation + average zonal prices).
- The recently started **FutureFlow** project is designing a cross-border cooperation scheme, consisting in a cross-border balancing and redispatching mechanism taking into account congestions (cross-border procurement of balancing reserves) and a common activation function, used for modelling and simulation in such a way that socio-economic efficiency is maximised within the countries addressed by the project (cross-border activation of balancing reserves). In addition, the project will deliver a prototype Regional Balancing and Redispatching Platform, enabling each balancing and redispatching service provider (flexibility aggregation platforms and conventional market players) to provide cross-border balancing and redispatching services to control zones outside its Member State borders, including aFRR services. It will embed a Common Activation Function (CAF), compatible with the

requirements of several Network Codes: each TSO connected to this Regional Platform will then be able to perform its activities (including aFRR) by using the offers from generators and consumers possibly located in the control area of another TSO also connected to the Regional Balancing and Redispatching Platform.

From national projects

- In Slovenia, the ongoing **SUMO project** deals with methods and software to evaluate dynamic thermal rating (DTR) in real time and with a temporal horizon of 3 hours ahead (15, 30 45, 60, 120, 180 minutes ahead). The weather information is integrated with current measurements, short-term load flow forecasts, and the day ahead congestion forecasts (from ENTSO-E). In addition, fast methods are developed to evaluate N-1 loading of the elements. In this case, beside weather data, are also used: live measurements of power nodal injections across power grid, live topology data, day-ahead congestion forecasts, hourly production, demand and transit forecasts. The method developed is accurate enough for TSO purposes, and very fast (1-2 minutes to obtain the response).
- The Estonian **DSR**, the Spanish **STORE*** and the Italian **CLASS*** and **VENTOTENE*** projects are also contributing to this functional objective**.**

> Note: Projects marked with an * do not count any TSO on board. They have been provided by EASE members.

Assessment of the coverage of T11

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective T11:

- **T11a.** To investigate interactions between system operations and dynamic capacity and reserve allocation methods at the regional and pan-European levels to cope with uncertainties from RES and load and system disturbances.
- **T11b.** To model strategies in view of improved congestion management and to analyse the possibility of more efficient options, if any exist, for the pan-European electricity market.
- **T11c.** To expand flow-based market coupling in areas with interdependent flows, based on successful experience.
- **T11d.** To develop an algorithm for computing potential extra capacities in real time or as closely as possible, considering security criteria without the need for counter-trading issues.
- **T11e.** To perform risk-benefit analyses and develop an interface using the Congestion Management Module (CMM).

Coverage assessment

In our views, only 20% of the tasks in this functional objective are covered by past project achievements. Ongoing projects should allow covering an additional 20%. Most of the activities in this functional objective need further work at EU level. In particular, the possibility of more efficient options for congestion management have to be analysed for the pan-European electricity market.

8.2.3 T12 "Tools and market mechanisms for ensuring system adequacy and efficiency in electric systems integrating very large amounts of RES generation"

Contributions from completed and ongoing projects to T12

From EU projects

- The **OPTIMATE** simulation platform allows testing and comparing new market designs which may allow integrating massive flexible generation dispersed in several regional power markets.
- In relation with long-term markets, the ongoing **Market4RES project** is issuing recommendations about the effects of RES support schemes, capacity remuneration mechanisms, participation of demand in long-term markets, long-term cross-border products, etc.
- The recently started **PROMOTION** project, focused on offshore grid development in the northern seas, will deliver recommendations for policies and market mechanisms in order to boost investment in offshore HVDC systems.

From national projects

- The Danish **Concept2025** as well as the Estonian **DSR** project are also contributing to this functional objective**.**
- In Denmark, the ongoing **EnergyLab Nordhavn*** project is developing new business models for renewable energy integration. The project utilizes Copenhagen's Nordhavn (Northern harbour) as a full-scale smart city energy lab and demonstrates how electricity and heating, energy-efficient buildings and electric transport can be integrated into an intelligent, flexible and optimized energy system. The energy storage components of the project are thermal storage and electrochemical storage in large batteries as well as batteries of electric vehicles.

Note: Projects marked with an * do not count any TSO on board. They have been provided by EASE members.

Assessment of the coverage of T12

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective T12:

- **T12a.** To design market mechanisms that allow participation of RES (active and reactive power control), storage devices, and conventional generation shift to ensure system adequacy and efficiency.
- **T12b.** To design investment incentive regimes that promote conventional and RES generation flexibility, new transmission capacity, and to foster storage systems.
- **T12c.** To design grid tariff mechanisms for active demand-side management to correlate the load curve and RES integration.

Coverage assessment

We consider that 25% of these tasks have been covered, and that an additional share of 10% should be covered thanks to the ongoing projects. In particular, there is still work to do on the participation of storage devices in day-ahead and in intraday markets as well as on RES active and reactive power control. Investment incentive regimes have not really been tackled yet. In addition, concrete proposals for grid tariff mechanisms for active demand-side management are still needed.

8.3 Recommendations for the new R&I roadmap

The four coverage ratios in Cluster 4 appear rather low. Furthermore, the formulation of Cluster 4 (Market design) is fully consistent with a challenge-oriented cluster. This is why no major modifications in structure of Cluster 4 should be necessary, except an extension of scope to include not only tools but also their applications embedded in appropriate business models.

9. Transmission Cluster 5: Asset management

Cluster 1 is organized into 3 Functional Objectives: T15, T16 and T17.

T15. Developing approaches to determine and to maximize the lifetime of critical power components for existing and future networks
T16. Development and validation of tools which optimize asset maintenance at the system level, based on quantitative cost/benefit analysis
T17. Demonstrations of new asset management approaches at EU level

9.1 Features of achievements in Cluster 5

9.1.1 Descriptive features

Categorization in functional objectives

The graphs below characterize the completed (4) and expected (4) achievements of the projects' results of cluster 5 (a light brown yellow colour is used for Cluster 5).

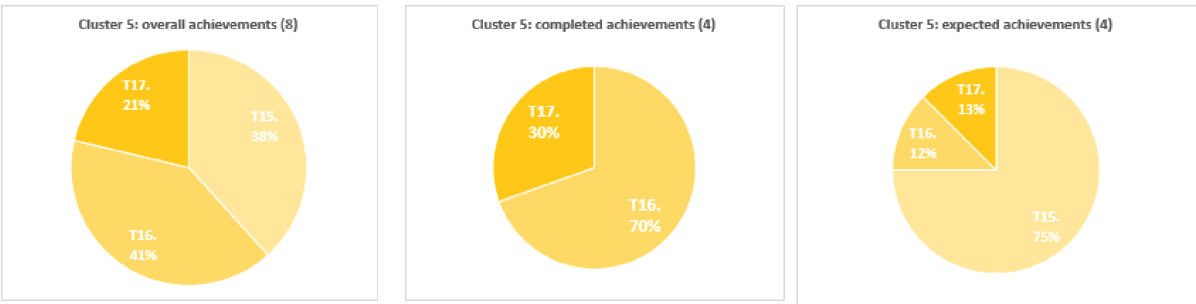


Figure 33: The portfolio of achievements in Cluster 5 (left: overall; middle: completed; right: expected)

Highlights:

- This is the least documented cluster by project leaders. Only 8 achievements have been quoted (4 completed and 4 expected) which decreases the value of statements drawn for the sample analysis.

- The absence of completed achievement in T15 (3 occurrences out of 4) in the expected achievement subset should be noticed.

<u>Typology of achievements in Cluster 5</u>

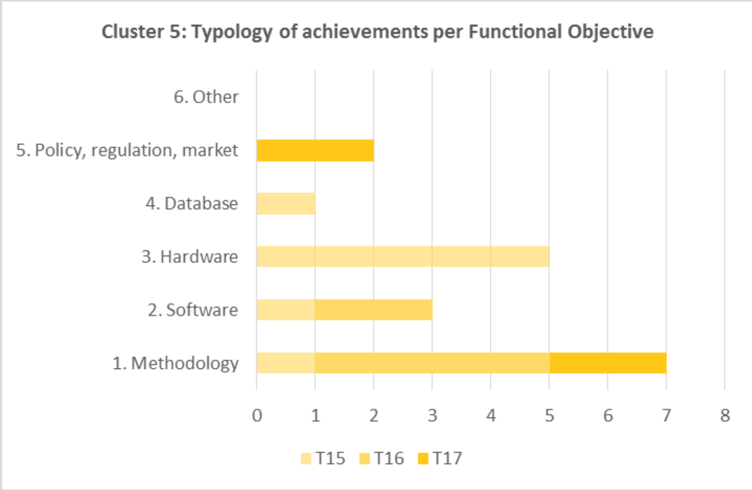


Figure 34: Typology of achievements in Cluster 5 in transmission

<u>Highlights:</u>

- The Cluster achievements are mainly composed by methodology and hardware.

Evolution of the maturity of achievements in Cluster 5

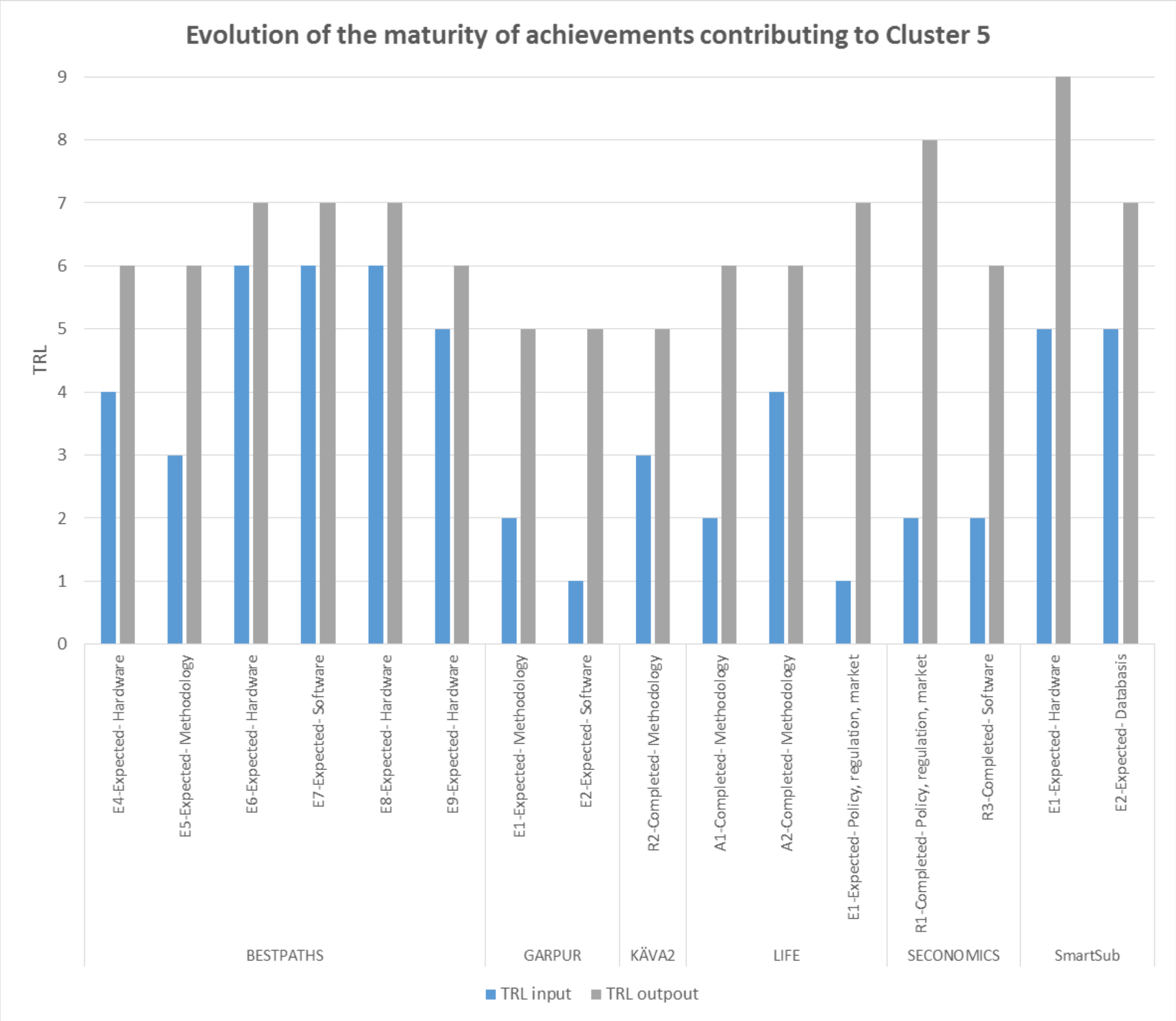


Figure 35: Evolution of the maturity of achievements contributing to Cluster 5 measured in TRL units

Highlights:

- The variability of maturity gains in Cluster 5 appears on average as lower as the one observed in the previous clusters. A gain of 5 is claimed by one achievements of SECECONIMICS, while some achievements of GARPUR, Life and SmartSub reaches an increment value of 4.

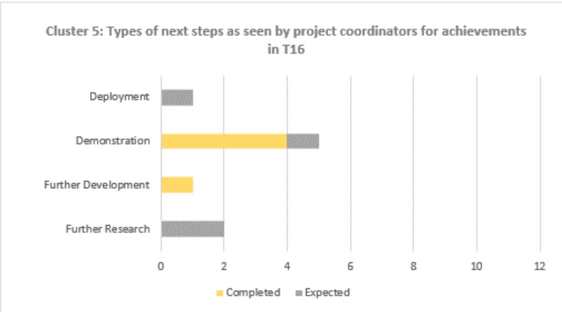
9.1.2 Projective features (next steps)

From the available data for each functional objective (T15, T16, T17), one can formulate the following highlights:

- Achievements in Cluster 5 are mainly concentrated in T16 and T17.
- In T15 only two expected achievements of the Smart Substation project (SmartSub) are quoted.
- It is difficult to draw trends due to the limited size of the Cluster 5 sample.

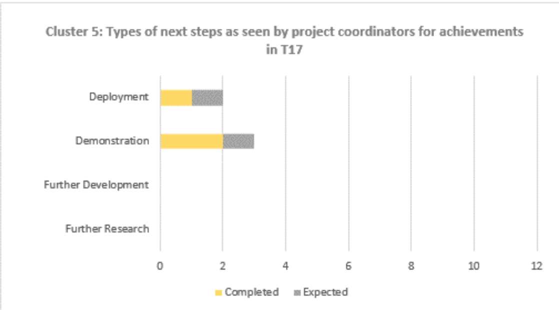
Achievements in T15	Status	Further Research	Further Development	Demonstration	Deployment
SmartSub-E1	Expected			X	X
SmartSub-E2	id	X			

Figure 36: Next steps as seen by project coordinators in T15



Achievements in T16	Status	Further Research	Further Development	Demonstration	Deployment
LIFE-A1	Completed			X	
LIFE-A2	id			X	
KAVA2-R2	id			X	
SECONOMICS-R3	id		X	X	
GARPUR-E1	Expected	X		X	X
GARPUR-E2	id	X			

Figure 37: Next steps as seen by project coordinators in T16



Achievements in T17	Status	Further Research	Further Development	Demonstration	Deployment
LIFE-A1	Completed			X	
LIFE-A2	id			X	
SECONOMICS-R1	id				X
LIFE-E1	Expected			X	X

Figure 38: Next steps as seen by project coordinators in T17

9.2 Coverage analysis of Cluster 5 with past and ongoing projects

9.2.1 T15 "Developing approaches to determine and maximise the lifetime of critical power components for existing and future networks"

Contributions from completed and ongoing projects to T15

From EU projects

- Two of the **BEST PATHS** demonstrations are touching upon this functional objective: the upgrade of multi-terminal HVDC links using innovative components, and the innovative repowering of AC corridors.

From national projects

- The French ongoing project **Smart Substation** is addressing this topic. Asset management functions will be tested in real operations, such as:
  - monitoring of bushings: GE's intellix BMT 300 solution installed on a three phase transformer (monitoring of bushings),
  - analysis of dissolved gases,
  - monitoring of temperatures and pressures of SF6 in the breakers,
  - monitoring of inlet and outlet temperatures of heat exchanger,
  - monitoring of the thermal state of the transformer with infra-red cameras,
  - monitoring of the torque of electric motors for disconnectors, breakers and the auxiliaries (pumps and fans).

  The construction of databases for long term analysis is performed by using the latest IT technologies (IoT, BigData).

Assessment of the coverage of T15

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective T15:

T15a. To identify the parameters (climate conditions, operating conditions, potential for hardware and software, among others) that affect the life span of components.

T15b. To establish evaluation/estimation protocols for component statuses that are comparable across TSOs with in-depth analyses and shared experiences.

T15c. To develop a methodology to determine and expand the life span of components, including conventional components (conductor, insulator, tower, breaker, etc.) and new components, such as power electronic devices and digital devices.

T15d. To propose dedicated, intelligent monitoring and analysis of results from equipment operation.

T15e. If necessary, specify new measurement devices and associated ICT systems.

T15f. To assess the environmental effects (noise, leakage, etc.) and safety for workers or nearby inhabitants (especially in the case of failure), considering the ageing processes and technical obsolescence.

T15g. To validate the added value of individual lifetime assessment compared to an average assessment of several similar components based on generic parameters (age of equipment, switching steps, etc.).

T15h. To assess the benefits of partially renewing small components (joints, etc.) or adding new protective layers (paint coating) to extend life span. A methodology is to be developed that assesses the capability of each component to be partially repaired or where the coating is to be replaced.

T15i. To develop new ways of detecting component failure based on failure models.

Coverage assessment

We assess that less than 10% of the tasks have been covered. Ongoing projects should allow covering very few more. There is work to do on the lifespan of power lines, on evaluation/estimation protocols for component statuses, on methodologies to expand the lifespan of components, on monitoring and analysis of the results from equipment operation, on new measurement device specifications, on environmental and workers' safety issues, etc.

9.2.2 T16 "Development and validation of tools which optimize asset maintenance at the system level, based on quantitative cost/benefit analysis"

Contributions from completed and ongoing projects to T16

From EU projects

- The contribution of the **SECONOMICS** project is in developing and furthering the state of the art in modelling security problems in a technological and socio economic context and then applying state of the art risk assessments and analysis of the social context to develop optimal policies.
- The ongoing **GARPUR** project designs a probabilistic reliability management approach which covers the multiple decision making contexts and timescales (long-term planning, mid-term & asset management, short-term planning to real-time operation). Regarding asset management, the project is working on finding the right a balance between the money invested in asset management to reduce the failure rates of the grid components, and the resulting reliability at the system level. Description of current practices and identification of opportunities for improvement have been delivered, and new methodologies (mid-term) outage scheduling probabilistic assessment and (long-term) maintenance policy probabilistic assessment are being developed, while keeping the data/modelling requirements in mind.
- The ongoing **LIFE Elia-RTE** project, aiming at creating green corridors under overhead electrical lines in wooded areas in Belgium and France, is also taking into account asset management issues and is therefore contributing to this functional objective.

From national projects

- The Finnish **KÄVA2** project is contributing to this functional objective. A methodology has been developed to evaluate components' failure rates for asset management.

Assessment of the coverage of T16

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective T16:

T16a. To define methods and tools to optimise asset management at the system level. The proposed methodology provides an assessment of the costs and benefits of different asset management strategies. The methodology proposes a risk-based approach at the system level, including interactions between equipment, effects on security and the quality of supply, and on environmental and safety constraints. The organisation of maintenance work and availability of spare parts (supply chain, quantity of spare parts, and location) are parts of the global optimisation challenge.

T16b. To provide tools for dynamic management of outage planning and maintenance schedules.

Coverage assessment

It is considered that around 30% of these tasks are being covered. Some work is ongoing but most of the tasks have not been addressed yet.

9.2.3 T17 "Demonstrations of new asset management approaches at EU level"

Contributions from completed and ongoing projects to T17

From EU projects

- The **SECONOMICS** and **LIFE Elia-RTE** projects are contributing to this functional objective**.**

Assessment of the coverage of T17

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective T17:

T17a. To utilise embedded ICT to monitor individual assets and to define a method of supervision based on this information at the system level for several TSOs in parallel.

T17b. To implement robotics for problem detection as well as to intervene in hostile environments and avoid the need for human maintenance. These include UAV to inspect overhead lines and robots that move while 'grabbing' the conductors.

T17c. To implement maintenance activities with the network 'on', especially for DC equipment.

T17d. To propose scaling-up and replication rules for new asset management approaches at the pan-European level.

Coverage assessment

It appears that most of the activities considered in this functional objectives are not covered yet, or even not addressed.

9.3 Recommendations for the new R&I roadmap

Coverage ratios in this cluster when analysing project achievements are very low. Some reorganization is necessary.

It is recommended, as decided by ENTSO-E, to combine all R&I activities related to Asset Management in a single functional objective included in a new cluster dealing with network modernization.

10. Conclusion for Transmission

ENTSO-E, with the support of the Grid+Storage partners, decided to modify the general organisation of the new R&I roadmap, going from a point of view driven by actions and R&I activities to a point of view driven by challenges for the transmission system at the pan-European level.

More specifically the previous Cluster 1 to 5 are modified as follow[11]:

- **EXPAND** the previous Cluster 1 “Grid Architecture” into a new Cluster 1 “Modernization of the Network” enriched by asset management issues (integration of the old cluster 5) and R&I activities dealing with new materials and power technologies.
- **REMOVE** the previous Cluster 2 due to the change of perspectives from an activity-driven roadmap to a challenge-oriented roadmap. Some of the R&I activities previously covered in this cluster are now distributed in the new Cluster 1 (cf. above) and the new Cluster 3 “Power System Flexibility”.
- **SPLIT** the previous Cluster 3 “Network Operation” into the new Cluster 2 “Security and system stability” and the new Cluster 3 “Power System Flexibility” in order to be coherent with the specifications of the integrated roadmap, e.g. storage as a new flexibility option or demand response as a way to achieve a customer centric power system. Regarding security, the ever increasing share of renewables calls for R&I work regarding ancillary services provided by RES as well as defence and restoration plans involving RES.
- **EXPAND** the previous Cluster 4 “Market designs” to the new Cluster 4 “Economic Efficiency of Power System” taking into account not only tools, but also market applications and business models.
- **INTEGRATE** the previous Cluster 5 “Asset Management” into the new Cluster 1 “Modernization of the Network” as a functional objective, together with three other functional objectives dealing with optimal grid design, new materials and technologies as well as public acceptance.
- **CREATE** a new cluster 5 “ICT and Digitization of Power System” mainly to address three key topics: big data, IoT (Internet of Things) and cybersecurity.

[11] Five types of modifications/updates are made: **SPLIT, REMOVE, EXPAND, INTEGRATE, and CREATE.**

Part II DISTRIBUTION

11. The portfolio of R&I projects in relation with the DSO activities of the Roadmap

11.1 Assumptions ruling the portfolio selection

The same five assumptions as the ones presented in section 4.1 (consistency with the roadmap, recent, funding, budget, explicit intention for further exploitation) have been used. As a result a representative sample a projects among all recent R&I distribution projects was built.

> Methodological issue:
>
> It should be noticed that some projects may appear in Part I and Part II or in Part II and Part III or in Part I and in Part III. This apparent double counting is due to the fact that some the source of information for projects at the interface of transmission and distribution may be ENTSO-E, EDSO or EASE.

11.2 The portfolio of distribution projects

Preliminary remark about the portfolio of projects

Out of the set of 132 projects which were considered as a representative sample and selected for analysis, only 51 have been monitored. Some important projects may not have been monitored, for example for the D6 functional objective (Integration of infrastructure to host electrical vehicles), the COTEVOS and Green eMotion projects. For each FO, when such missing projects were detected, they were accounted for in the coverage analysis but not reported in the present document since no questionnaire was provided by the projects' coordinators

The 51 analysed projects represent a total budget of approximately 783 million Euros for a public funding of 245 million Euros, cf.

Table 15[12].

Table 6: Portfolio of projects source of achievements in distribution

ADDRESS	DNAT	**HyUNDER**	**METER_ON**	Smart_Storage
ADVANCED	**DRIP**	**IGREENGrid**	NiceGrid	Smart_Toruń
Alia2	E-DeMa	**INCREASE**	NINES	SOGRID
Ampacity	Electrogas	**INGRID**	**OPEN_NODE**	SOLENN
ATENEA	EnergyLab	Isernia	**PlanGridEV**	stoRE (Denmark)
BIENVENU	Evora	Judenburg	PRICE	STORE (Spain)
BioCat	**FINSENY**	**Life Factory**	Proaktives	**STORY**
CAES_Larne	FLEXe	LINKY	Puglia	**TILOS**
CHPCOM	**G4V**	Local	PV-KWK	**TRANSFORM**
Control	Gigha	LODIS	Smart Grid Vendée	**UPGRID**

[12] As for transmission, these figures do not represent the exact total budget and the corresponding public funding since for some projects some of the data is missing (for some projects the budget figure is available and not the corresponding public funding and vice-versa).

CryoHub	Gorona	MERGE	Smart_Country	V/Q_regulation
Dezentrale	Heat_Pumps	**MESHARTILITY**	Smart_grids	VENTEEA
DISCERN	Heimschuh	**METAPV**	Smart_Operator	VENTOTENE

NB: As explained in the section 3.2, id codes were used as references in order to abbreviate the projects' names all along the document.

The colour code for each project acronym corresponds to the source that has provided the filled-in questionnaires (**EU projects** are displayed in bold text while projects funded at national level are displayed in plain text):

EDSO	EASE

11.3 The corresponding achievements in distribution

11.3.1 Methodology reminder

A similar approach has been followed in distribution as in transmission. The same colour chart was kept (the purple colour being dedicated to the first cluster of distribution, etc.). Descriptive and projective features are detailed in next section.

11.3.2 Overview of achievements in distribution

As a result, the portfolio of 64 projects in relation with distribution has allowed to identify 219 unit achievements.

Distribution is organized into 5 Clusters:

Cluster 1: Integration of smart customers
Cluster 2: Integration of DER and new uses
Cluster 3: Network operations
Cluster 4: Network planning and asset management
Cluster 5: Market design

Descriptive features of achievements in distribution

Table 7: Descriptive features in distribution

Descriptive features	Rationale	Categories
To which cluster and functional objective it contributes?	Clusters and FO were fixed in the roadmap	Cluster: C1 to 5 FO: from D1 to D13
Typology of achievement?	Six types have been predefined according to the nature of the achievement	1. Methodology, 2. Software, 3. Hardware, 4. Database, 5. Policy, regulation, market, 6. Other
Its estimated impact on a maturity scale?	Technology Readiness Level (TRL) scale	Index (input/output) from 1 to 9

Categorization in clusters

The graphs below characterize the sample of achievements of all types for all clusters in distribution.

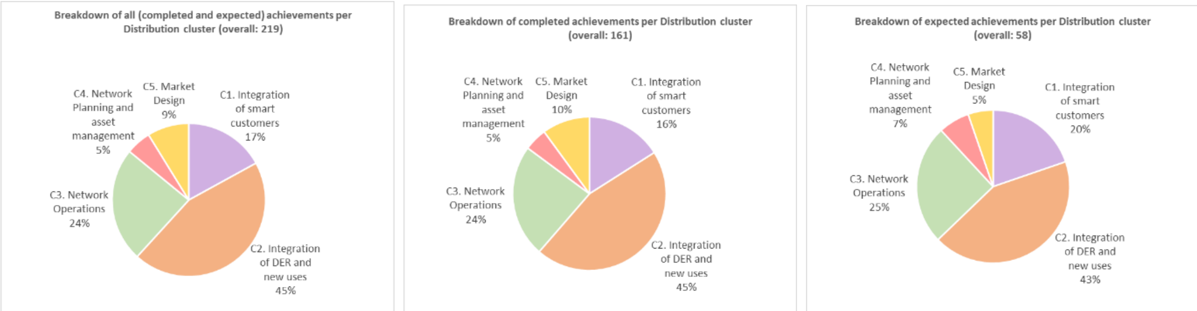


Figure 39: The portfolio of achievements in distribution per cluster (left: overall; middle: completed; right: expected)

<u>Highlights:</u>

- When considering all achievements (completed and expected), it is observed that the most developed clusters over the considered period are the clusters C2 (45% of sample) and C3 (24% of sample) while the C1 cluster amounts to 17% of achievements. The less represented cluster is C4 – Network planning and asset management with a share of only 5%.
- The time dimension is not so significant when comparing the breakdown in the middle and in the right figures showing that no major evolutions is on-going
- The next view illustrates in absolute numbers the respective shares of completed vs. expected achievements.

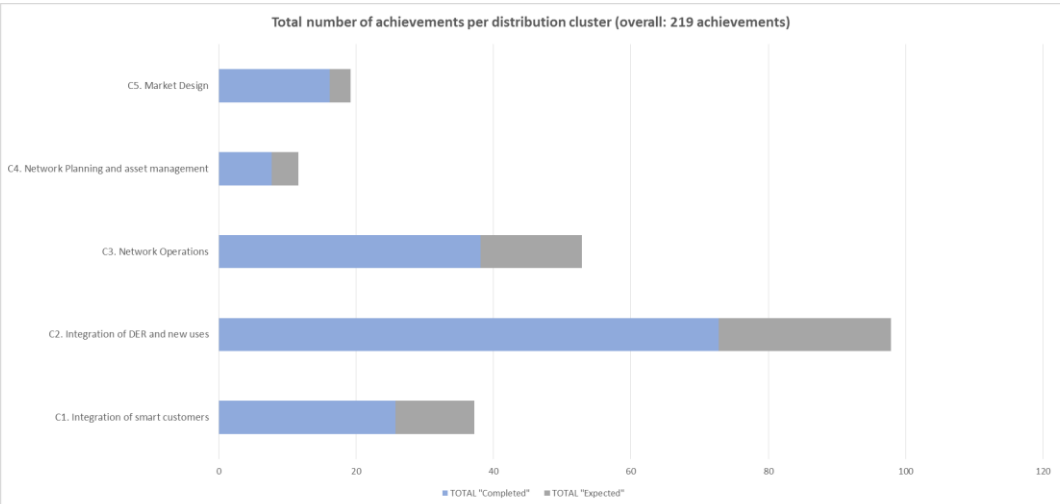


Figure 40: Number of achievements per cluster in distribution

Typology of achievements

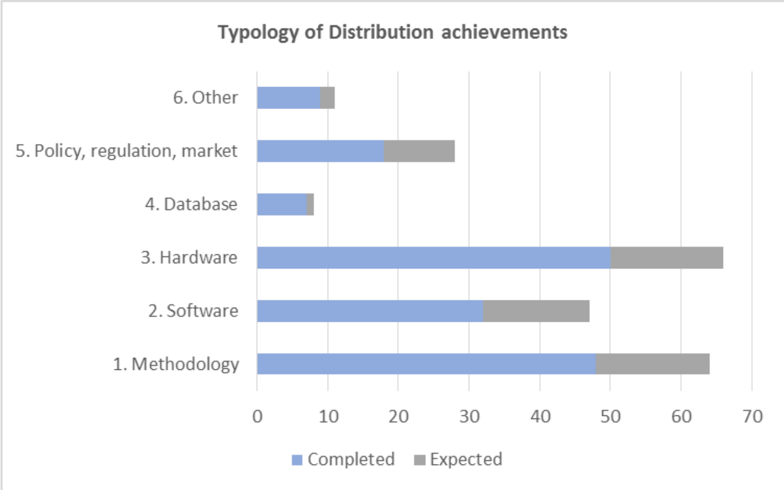


Figure 41: Typology of achievements in distribution

<u>Highlights:</u>

- Unlike transmission, the hardware type of achievement is leading in distribution. Policy, regulation, market are also more quoted than in transmission.
- For methodology, software and database the shares appear in distribution similar to transmission

Evolution of the maturity of achievements

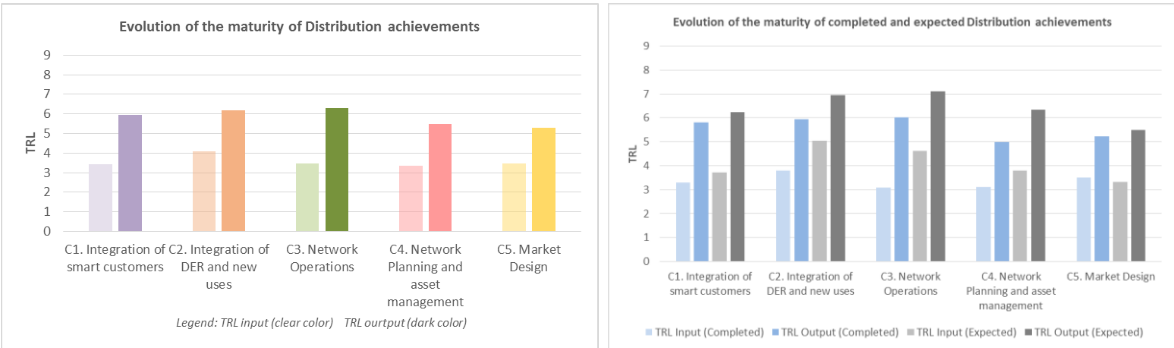


Figure 42: Evolution of the maturity of achievements measured in TRL units (left: average per cluster; right: per cluster for the completed in blue and for the expected in grey)

<u>Highlights:</u>

- For cluster C2, C4, C5, an increment of about two units in the TRL scale is observed (left diagram), the increment being higher for the Integration of smart customer Cluster (C1) and Network operations Cluster (C3)
- The diagram in the right distinguishes the completed achievements from the expected ones for each cluster. In general the TRL input for expected achievements is higher than the TRL input for completed achievements: this is however not the case for the cluster 5 (this might be an effect of the reduced size of C5).
- In this diagram typical TRL of completed achievements range from 3+ to 6 (resp. input, output, blue bars) while typical TRL of expected achievements range from 3.5 to 7 (resp. input, output, grey bars).

Projective features of achievements in distribution

Next steps with regard to achievements' implementation

The graph below is based on 87% of the completed achievements for which valuable data provided by project coordinators (143 of 164 completed achievements) which constitutes a solid and representative sample. Expected achievements are not included in this analysis.

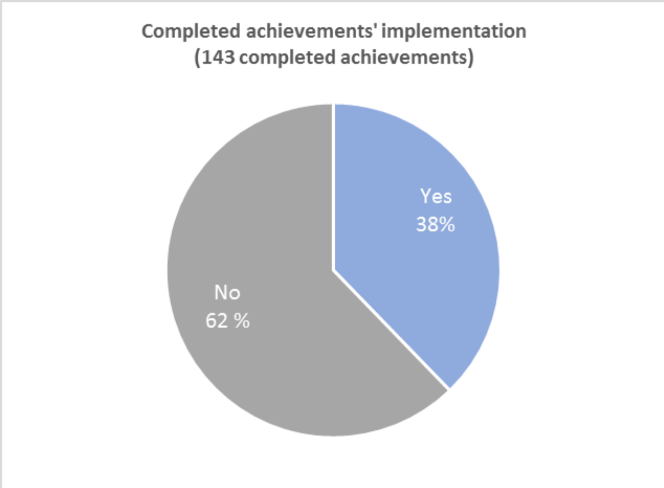


Figure 43: Implementation actions carried out for completed achievements in distribution

Highlights:

- Almost 40% of completed achievements are already object of an implementation action
- From the analysed questionnaires, it may occur that implementation achievements are foreseen but have not started yet, in such situations they are counted in the next steps diagrams.

The diagram below details the project coordinators' intentions with regard to likely further steps (either further research, further development, demonstration or deployment). The same methodological note on accounting multiple modalities of next steps "per achievement" as for transmission is valid here (see section 4.3).

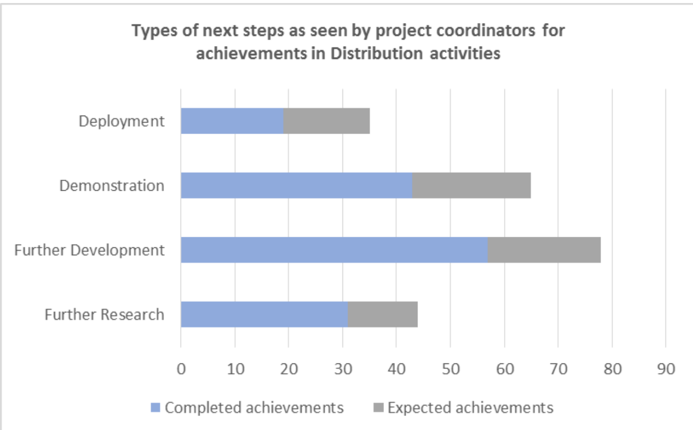


Figure 44: Next steps as seen by project coordinators in distribution

Highlights:

- For completed and expected achievements, project coordinators expect that achievements will require further development (35% of all replies: formulated intentions of next steps) and demonstration (29% of replies) followed by further research (20% of replies).
- According to them only 16% of replies appear ready for deployment according to the project coordinators, which is a lower rate than for transmission (it was 24%: see 0).

12. Distribution Cluster 1: Integration of smart customers

Cluster 1 is organized into 2 Functional Objectives: D1 and D2.

D1. Active Demand for increased network flexibility
D2. Enabling maximum energy efficiency in new or refurbished urban districts using smart distribution grids

12.1 Features of achievements in Cluster 1

12.1.1 Descriptive features

Categorization in functional objectives

The graphs below characterize the completed (26 achievements) and expected (12) achievements of projects' results of cluster 1, the purple colour was dedicated to Cluster 1.

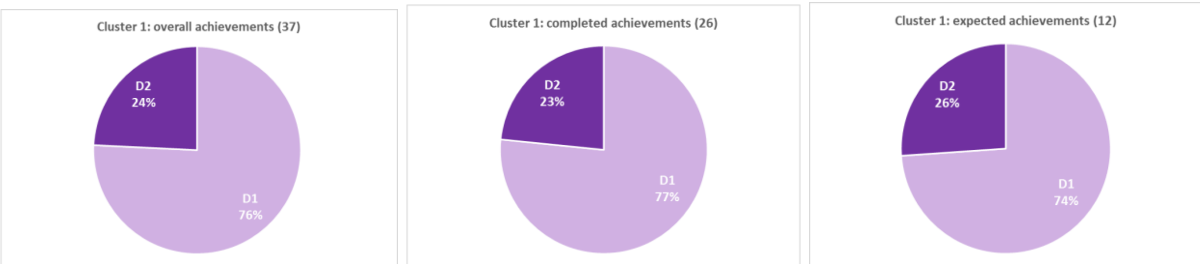


Figure 45: The portfolio of achievements in Cluster 1 (left: overall; middle: completed; right: expected)

Highlights:

- Some minor consistency discrepancies may appear in counting achievements since some of them have been counted for 1/2 (resp. 1/3, 1/4) if they contribute to two (resp. 3, 4) functional objectives.

Typology of achievements in Cluster 1

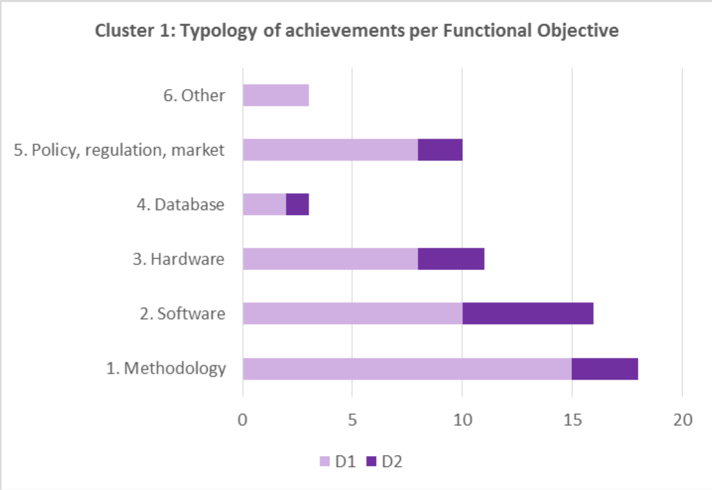


Figure 46: Typology of achievements in Cluster 1 in distribution

Highlights:

- In D1 achievements are quite well-balanced in nature (Database excepted)
- In D2 there are less achievements (software is leading) again with a well-balanced split.

Evolution of the maturity of achievements in Cluster 1

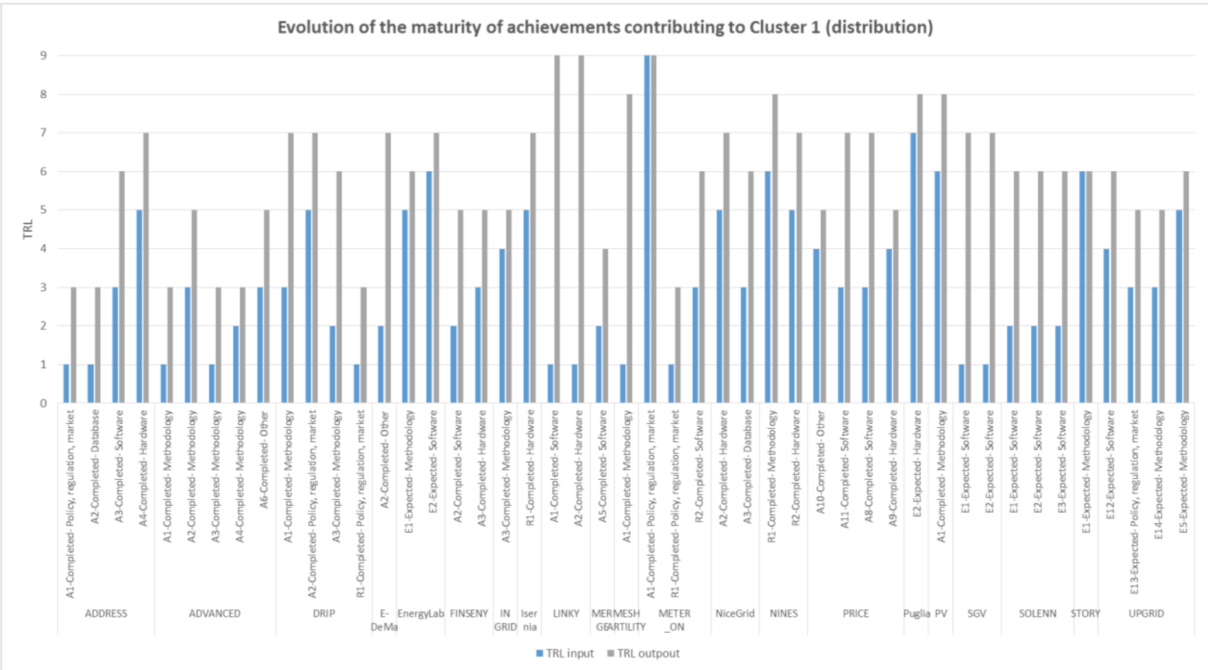


Figure 47: Evolution of the maturity of achievements contributing to Cluster 1 of distribution measured in TRL units

Highlights:

- All achievements (completed and expected) of cluster 1 have been reported in the above figure with respect to their maturity increment (the difference between the grey and the blue bar). .
- The average increment in maturity increment is slightly above 2.5 for Cluster 1 but subject to some variability depicted in the above analytical chart.

12.1.2 Projective features (next steps)

The same methodology has been used in distribution to describe the next steps focusing on **the point of view of project coordinators**.

From the data collected in cluster 1 for each functional objective (D1, D2) one could formulate the following highlights:

- Achievements in D1 are expected to be continued in only three out of the four possible modalities: almost no deployment is foreseen, which might appear as surprising. Further development is almost systematically mentioned as a necessary need.
- The size of sample in D2 is too limited to draw some generic meaningful statement beyond the particular replies reported below.

Achievement in D1	Status	Further Research	Further Development	Demonstration	Deployment
ADDRESS-A1	Completed	X	X	X	
ADDRESS-A3	id	X	X	X	
ADDRESS-A4	id		X	X	
ADVANCED-A6	id	X	X	X	
FINSENY-A2	id	X	X	X	
NiceGrid-A2	id		X	X	
NiceGrid-A3	id		X	X	
PRICE-A10	id		X	X	
PRICE-A11	id	X	X		
PRICE-A8	id	X	X		
PRICE-A9	id	X	X		
PV-KWK-A1	id		X		
NINES-R1	id		X	X	
NINES-R2	id		X	X	
EnergyLab-E1	Expected	X	X		X
EnergyLab-E2	id		X		
Puglia-E2	id				X
STORY-E1	id	X	X		
UPGRID-E12	id		X	X	
UPGRID-E14	id	X	X	X	
UPGRID-E5	id	X	X	X	

Figure 48: Next steps as seen by project coordinators in D1

Achievement in D2	Status	Further Research	Further Development	Demonstration	Deployment
ALIADOS-A1	Completed		X	X	X
FINSENY-A2	id	X	X	X	
NiceGrid-A3	id		X	X	

Figure 49: Next steps as seen by project coordinators in D2

12.2 Coverage analysis of Cluster 1 with past and ongoing projects

12.2.1 D1 "Active Demand for increased network flexibility"

Contributions from completed and ongoing projects to D1

From EU projects

- The **ADDRESS** project targeted the active participation of small and commercial consumers in power system markets and provision of services to the different power system participants. The project delivered:
  - Market design to facilitate demand side management: market-based proposals and economic analysis;
  - Questionnaires to validate social acceptance and customers' commitment: Different questionnaires completed during the field test period (pre/during/post trials);
  - Aggregator toolbox: Full validation of aggregator functionality and 'core business model' through the validation of the Aggregator Toolbox functionality;
  - Technical validation of the proposed solutions and prototypes for the Home System: Validation of home system communication; Validation of equipment operation; Collection and processing of metering information.
- The **METER ON** project worked on supporting the development and deployment of advanced metering infrastructures in Europe. In particular exchange and interaction were carried out with the most representative projects carried out within the smart metering field in Europe (21 EU projects analysed – 15 countries covered). After the end of the project, a set of recommendations to the most important stakeholders and a toolkit to manage economic data were delivered.
- The goal of the **ADVANCED** project was to increase the understanding on how to deploy efficiently Active Demand (AD). An omni-comprehensive (holistic) view of all the components that intervene in the value chain was developed. The main project's achievements include: A target matrix to know what and how should be measured; Validated and operationalised KPIs both at pilot and household level; Qualitative & Quantitative surveys; Actionable framework. The project also concluded that AD has highest potential if network expansion is driven by load growth and is used in highly utilised urban networks which are already constrained.
- The **DRIP** project carried out a technical, ecological and economic evaluation for the industrial customers of the flexibility potential that is available in its energy consuming processes. Potential benefits for the customer according to external conditions and inputs (external weather conditions, market prices, balancing prices, etc.) and for energy retailers as well as TSOs and DSOs (e.g. network stability at peak feed-in of RES) were demonstrated. DRIP provided a novel approach to the flexibility of industrial customers by means of an exhaustive analysis based on processes. New business opportunities have been identified for the adequate trading of Demand Response resources in the market. New tools and techniques have been developed to determine, quantify and certify demand response resources in the industrial production. A roadmap for the implementation of Demand Response has been provided to industrial customers and policy makers to promote the active participation of DR resources into the European electricity market.
- The **MERGE** project developed simulation tools to be used by TSOs, DSOs and Market operators to assess the impact of increased EV penetration at distribution level, transmission level and also generation and market operation.
- The **FINSENY** project's objective was to demonstrate how open Future Internet

Technologies could enable the European energy systems to combine adaptive intelligence with reliability and cost-efficiency. It identified the ICT requirements coming from the energy sector and developed the key building blocks of the architecture of the Smart Grid system.

- The almost finished **INGRID** project combines the recent advances in Smart Grids and hydrogen-based energy storage to match energy supply and demand and optimize the electricity generated by intermittent RES while ensuring security and stability of the power distribution network. The project has gained extensive experience on control of grid-connected electrolysers.
- With four demonstrations, the ongoing **UpGrid** project is developing and validating solutions to enable the implementation of advanced functionalities over existing technology, to form a truly integrated intelligent system. In terms of active demand, the project targets the participation of customers in network management, the improvement of customer capacity building web-based systems, the development of interactive communication campaigns and societal research on the socio-economic impact of Smart Grid solutions on the demo regions. The project also expects to improve the quality of service (QoS) to customers.
- The ongoing **STORY*** project aims to show the added value storage can bring in the low and medium voltage grid. 8 demonstrations are set up to feed knowledge into the further analysis on large scale impact. Household/neighbourhood increased self-supply by using heat and electricity production and storage will be demonstrated and evaluated.

From national projects

- The Spanish **PRICE** demonstration project[13] aimed at acquiring the experience and knowledge on implementing and manage transmission and distributions systems. In terms of active demand, were developed:
  - Remote Demand management System (Consumption viewer),
  - Smart Household Appliances and loading manager
  - Platform management and mobility applications
  - Smart system for demand-side management.
- Within the Italian **ISERNIA** project[14], 'Customer Information' using 'Smart Info' devices was demonstrated.
- The German **E-DeMa** project developed innovative products and end customer tariffs including an analysis of market potentials and consumer acceptance. The project showed that price benefits are only motiving few customers to adapt their behaviour.
- In France, the ongoing **Nice Grid** project consists in a pilot smart solar district in the southern French town of Carros. In terms of active demand, the project involves residential and industrial consumers in energy efficiency in order to solve local energy constraints and to optimize the operation of a network integrating a massive production of photovoltaic energy.
- The ongoing French **SOLENN** project contributes to manage electricity demand and to secure power supply for consumers and communities in the French region of Britany. The project will provide new tools using curtailments via smart meters avoiding load shedding near real time operations.

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[13] This project actually was part of the EU FP7 project IGREENGrid.
[14] It was also part of the IGREENGrid project.

- The other ongoing French **Smart Grid Vendée** project is implementing a Web portal for energy shaving purposes.
- In Poland, the ongoing **Smart Torun** project includes the development of an application to remote communicate with meters and the preparation of special systems for the operation and management of the network. 92,600 smart meters are being deployed. Smart grid lighting with energy-saving lamps operated by dedicated software are being implemented.
- In Scotland, the ongoing **NINES** project aims to address some of the most pressing energy challenges Shetland currently faces by allowing small scale renewable generation to play a much more significant role in meeting the islands' energy needs. The NINES project consists various elements totalling to an estimated 150MWh of energy storage and one of these elements is the installation of the Quantum space and water heating system being installed in up to 750 homes.
- Within the ongoing Portuguese **Dynamic Network Access Tariffs** project, an analysis of the periods of highest network congestion has been carried out. The project expects to see how customers react to the dynamic pricing scheme. A cost-benefit analysis of such pricing scheme will be carried out. If proved beneficial, it should allow decreasing peak hour consumption, in order to lower the need to invest in grid expansion.
- In Italy, the ongoing **Puglia Active Network** project is deploying 'Smart Info' devices to provide customer with information to enable demand response strategies.
- In Denmark, the ongoing **EnergyLab Nordhavn*** project is developing new business models for renewable energy integration. The project utilizes Copenhagen's Nordhavn (Northern harbour) as a full-scale smart city energy lab and demonstrates how electricity and heating, energy-efficient buildings and electric transport can be integrated into an intelligent, flexible and optimized energy system.
- The goal of the ongoing German **PV-KWK*** project is to develop optimised system solutions that create the most effective combination of photovoltaics and CHP plant/heat pump systems, open up synergies, and are suitable for multiple applications in buildings. Another aim is the optimisation of load control for electrical appliances and the use of energy storage in pure solar systems through to intelligent incorporation of eMobility.

Note: Projects marked with an * do not count TSOs nor DSOs on board. They have been provided by EASE members.

Assessment of the coverage of D1

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective D1:

D1a. **Scientific**:

- (green) Systems/solutions for demand modelling and forecasting
- (amber) Solutions for demand aggregation and implementation of Virtual Power Plants combined with local energy management
- (red) Power market modelling to size the benefits of massive deployment of AD in distribution networks

- Optimal sizing for medium/large scale demonstration (generic topic)

D1b. Technology:

- Smart Metering Infrastructure to measure energy consumption and apply time-of use tariffs
- Devices enabling visualization and control of consumers' consumption using the latest technology (e.g. In-Home displays...)
- Smart Energy management boxes, smart plugs, smart appliances, interfaces for load control and solutions to communicate with consumers and with the smart appliances in the domestic environment
- A communication infrastructure to support the whole system interoperable and standard solutions enabling AD

D1c. Market and regulation:

- Application of time-of use/dynamic tariffs and real time prices
- Definition of appropriate incentives to motivate consumers to participate in AD

Coverage assessment

Completed and ongoing projects have covered about 50% of this functional objective's tasks. Only one scientific task concerning demand modelling and forecasting has been well-covered. There is still work to do for several subjects such as demand aggregation, VPPs, smart metering, smart appliances, time-of-use tariffs and incentives for customers. On the other hand, power market simulations in order to measure the benefits of massive deployment of AD in MV and LV networks should be addressed more intensively.

12.2.2 D2 "Enabling maximum energy efficiency in new or refurbished urban districts using smart distribution grids"

Contributions from completed and ongoing projects to D2

From EU projects

- The IEE project **MESHARTILITY** aimed at the development of solutions and tools facilitating exchange of energy data between energy utilities and local authorities in order to support the development of Sustainable Energy Action Plans (SEAPs) to be submitted under the Covenant of Mayors. An Open Data Platform for the Sustainable Energy Action Plans has been set up. The energy data issues explored included data ownership, access to data, quality of data, regular update of data, approach (if any) to top-down and bottom-up data correlation.
- The **TRANSFORM** project aimed to define a methodology process to identify the measures to be put in place in order to enable the European cities to move toward a more sustainable and efficient energy system. A handbook to pave the way toward a Smart City was delivered. Although smart grids measures (such as advanced automation and control functionalities, RES integration, EV recharge infrastructures, customer awareness technologies…) have been identified as crucial in the transformation process toward a Smart City, there are still important barriers that hamper the implementation of the smart grids measures, notably the lack of regulatory framework and financial, Legal and business model issues.
- The **METER ON** and **FINSENY** projects have also contributed to this functional

objective.

From national projects

- The Spanish **Alia2** project tested storage solutions for renewable generation plants. The development of three building management systems (module, cabinet and container) was achieved during the project. The new solution represents a reliable alternative source of electricity in case of supply failure at hospitals, trains, shopping centres, etc.
- The ongoing French **Nice Grid** smart solar district pilot project contributes to this functional objective with the involvement of residential and industrial consumers in energy efficiency in order to solve local energy constraints.
- The other ongoing French **SOLENN** project which aims at contributing to manage electricity demand and to secure power supply for consumers and communities in the French region of Britany also contributes to this functional objective. The project is developing solutions to provide volunteer customers with own and collective electric data in order to develop new Energy Efficiency dynamics. It will also provide local communities with an IT tool helping the definition and implementation of local energy policies.
- In France, the roll-out of the **Linky** smart meters is ongoing (35 million of units). The smart meter will support bi-directional communications in order to automate meter-reading, improve grid management, prevent fraud, while improving demand response and paving the way for smart grids roll-out.
- By developing tools devoted to techno-economic analysis in order to help decision making, the ongoing French **Smart Grid Vendée** project is contributing to this functional objective.

> Note: Projects marked with an * do not count TSOs nor DSOs on board. They have been provided by EASE members.

Assessment of the coverage of D2

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective D2:

D2a. Scientific:

- Advanced energy management systems to enable load/production forecasting and active customer participation taking advantage of an automated metering infrastructure
- Measuring customer awareness and customer willingness to go for energy sobriety
- Optimizing energy networks at district levels
- Analysing possibilities of interaction between gas, electricity and heat networks.

D2b. Technology:

- New approaches to size and operate distribution networks in districts, with new architectures, considering "city master planning", limiting the sizing of physical infrastructure and taking into account boundary conditions such as available space.

- Development of tools to design and sizing this kind of integrated energy networks.
- Multilevel system operation of a distribution network
- Secondary substation with an islanding capability of parts of a district to be activated in emergency situations
- The district covering several neighbouring secondary substations on the same feeder (active approach taking into account demand side management and local storage, use of power electronics to facilitate grid integration (voltage management, fault current management) ;
- The feeder connected to the district and other loads of a city where the energy management system simultaneously responds to the needs coming from the network and ensures local operation of the feeder (optimal split of total load between primary substations)
- Interfaces to enable two way communication between DSO's/TSO's central systems, Home automation and energy management systems
- Web portals, in-home displays and Smartphone apps
- Smart Plugs and voltage clamps
- Smart appliances
- Solutions for direct load control
- Smart Energy boxes

D2c. Market:

- Regulatory recommendations in order to enable customer participation in electricity markets
- Mapping of privacy and data protection issues and strategies/solutions to mitigate risks
- Market models for ESCOs, aggregators at district level

D2d. Social:

- Understanding customer behaviour at district level with interdependence between several activities
- Change customer behaviour through price or other signals that favour energy sobriety
- Customer acceptance of the various technologies

<u>Coverage assessment</u>

It is considered that this FO has been covered at about 50%. In particular, there are three tasks which have been less tackled by EU and national projects concerning technological (the feeder and real-time EMS relation), market (models for ESCOs and aggregators) and social (customer behaviour) issues at the district level.

12.3 Recommendations for the new R&I roadmap

The R&I activities specified in Cluster 1 have been addressed in many projects, which has resulted in a good coverage for both functional objectives (around 50%). However, there are still many topics to be dealt with to promote active demand (AD) and make it a usable flexibility option for DSOs as well as a source of new business models -and revenues- for (new) market players. For instance, power market modelling to size the benefits of massive deployment of AD in distribution networks is still needed. Energy efficiency in new or refurbished urban districts using smart distribution grids is a major issue in Europe: understanding customer behaviour will help to promote new energy demand schemes.

For the new roadmap, it is recommended to keep Cluster 1 "Integration of smart customers and buildings"[15] with the two existing functional objectives (FOs) since they represent major challenges for the stakeholders of distribution networks. New R&I activities should be promoted in the FO dealing with AD so as to foster end-consumers' participation in the retail electricity markets, and enable the provision of system services for network flexibility (e.g. the real-time optimisation of power flows at distribution level) and possible transmission level (system services provided to TSOs through DSOs). For the second FO, R&I activities should focus on the deployment of smart grid technologies in urban areas in order to reach the goals set by the EC in terms of energy efficiency in buildings (and empower end customers).

Furthermore, as explained in the new roadmap, it is also recommended to specify the R&I topics of each FO in terms of cross-cutting challenges (instead of their characteristics, i.e. scientific, technology, market and regulation, social) so as to improve the readability of the functional objectives and more generally of projects addressing these cross-cutting challenges (i.e. a matrix structure where on the one side there are the clusters/FOs and on the other side cross-cutting challenges). The cross-cutting challenges cover R&I activities related to the **upgrading of the network,** the **Power system flexibility,** the **Power system reliability, ICT and digitalization, Market design, and** the **DSOs regulatory environment**.

13. Distribution Cluster 2: Integration of DER and new uses

Cluster 1 is organized into 4 Functional Objectives: D3, D4, D5 and D6.

D3. Integration of DER at low voltage
D4. Integration of DER at medium voltage / high voltage
D5. Integration of storage in network management
D6. Integration of infrastructure to host Electrical Vehicles

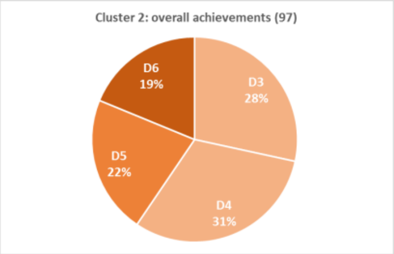
13.1 Features of achievements in Cluster 2

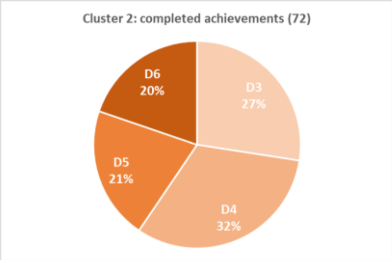
13.1.1 Descriptive features

Categorization in functional objectives

The graphs below characterize the completed (72 achievements) and expected (25 achievements) achievements of projects' results of cluster 2, the orange colour was dedicated to Cluster 2.

[15] The titles of the cluster and the D2 functional objectives should be slightly changed to make the connection to energy efficiency policies in buildings more explicit.





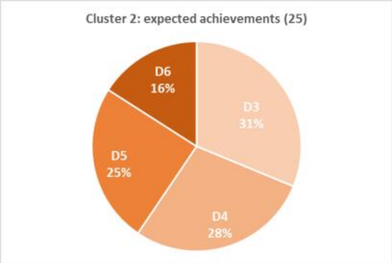


Figure 50: The portfolio of achievements in Cluster 2 (left: overall; middle: completed; right: expected)

Highlights:

- D4 was the most important functional objective on the completed sample, immediately followed by D3, then by D5 and D6
- The share between the four FP is well-balanced
- There is no major change when shifting from completed achievemnts to the expected ones
- The sample of expected achievements is at about ¼ of the overall sample (25 out of 97).

Typology of achievements in Cluster 2

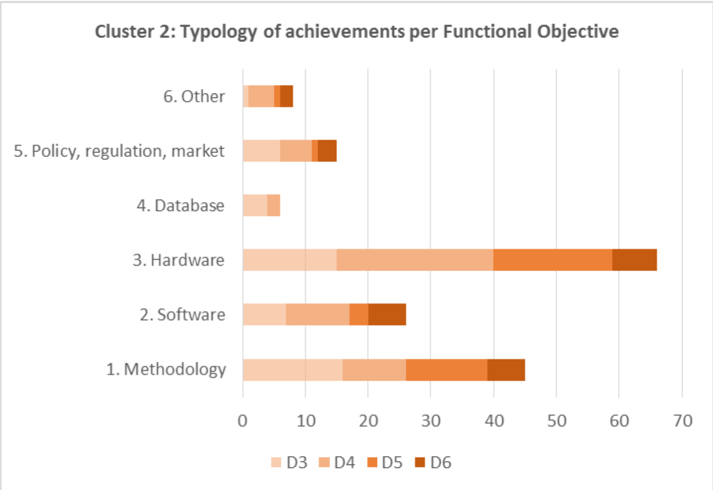


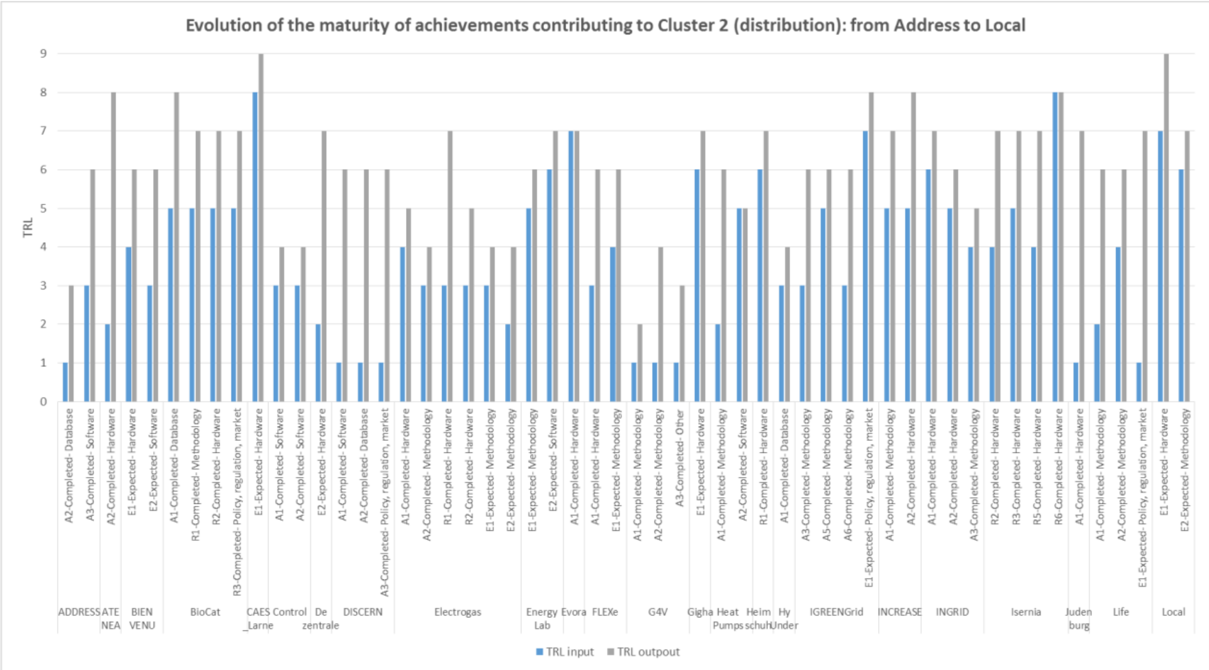
Figure 51: Typology of achievements in Cluster 2 in distribution

Highlights:

- In Cluster 2 hardware type achievements are leading, immediately followed by methodology and software types
- Policy, regulation, market and database types are less represented.

Evolution of the maturity of achievements in Cluster 2

Due to the high number of achievements in that cluster, two bar charts are presented to display in a readable way the maturity increments.



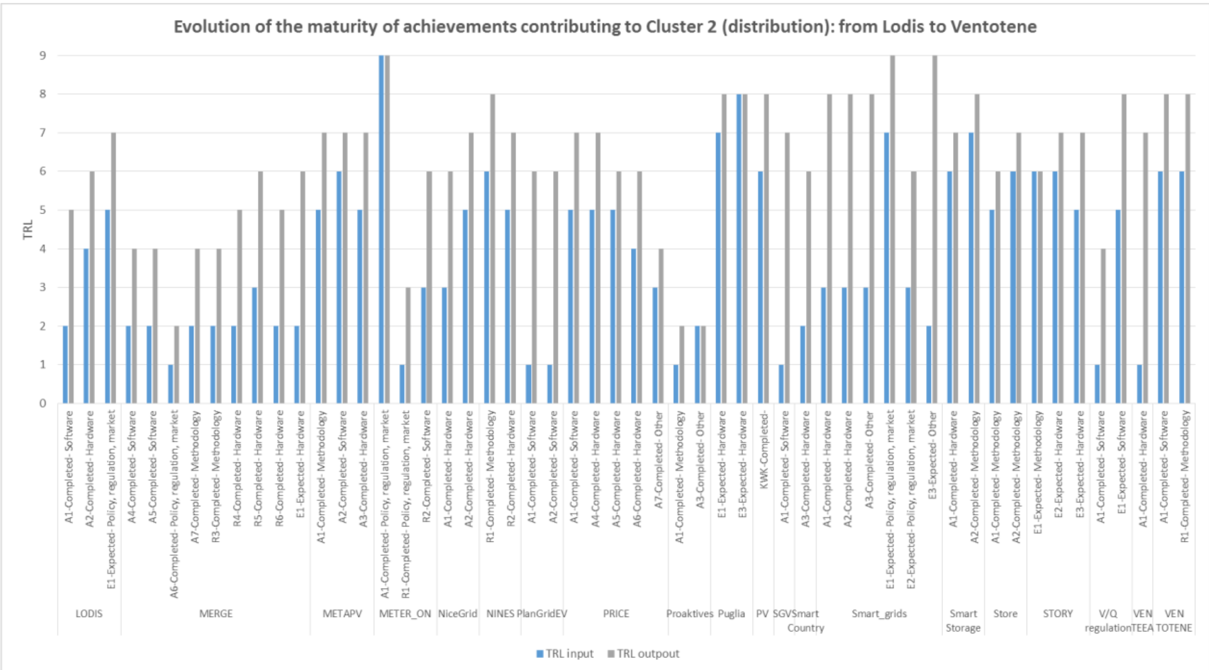


Figure 52: Evolution of the maturity of achievements contributing to Cluster 2 of distribution measured in TRL units

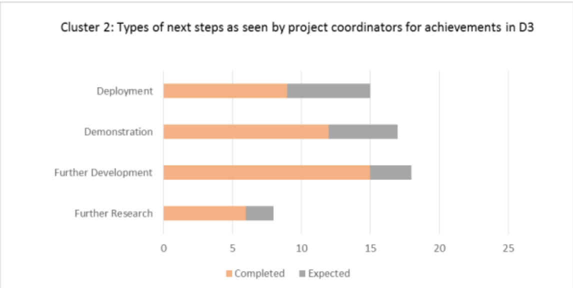
<u>Highlights:</u>

- In the two above tables most of achievements present a maturity increment of 2 to 3 units in the TRL scale.
- Some projects coordinators however consider a higher maturity gain in the achievements of their project, some zero gain situation are also presented but probably resulting from an interpretation bias from project coordinator.

13.1.2 Projective features (next steps)

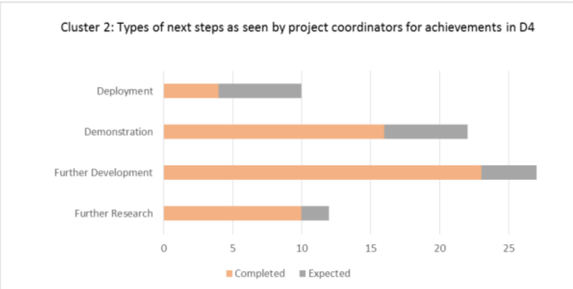
Following the same methodology described in section 3.1, and from the data collected in cluster 2 for each functional objective (D3, D4, D5, D6) one could formulate the following highlights:

- D3 and D4 are the most active FO in terms of next steps while D5 is the less active.
- In D3 all downstream routes (deployment, demonstration, further development) represent a significant share of next steps replies, while the "further research" route is less preferred
- In D4, the demonstration, further development routes are the ones that are the most considered, followed by further research
- In D5 and in D6, a similar scheme as for D4 is reproduced, however will less occurrences



Achievement in D3	Status	Further Research	Further Development	Demonstration	Deployment
ALIADOS-A1	Completed		X	X	X
ATENEA-A2	id				X
DISCERN-A1	id				X
DISCERN-A2	id			X	
Heat_Pumps-A2	id			X	X
HyUNDER-A1	id		X	X	
IGREENGrid-A3	id		X	X	
IGREENGrid-A5	id	X	X		
IGREENGrid-A6	id		X	X	X
LODIS-A1	id	X			
METAPV-A3	id	X	X		
NiceGrid-A1	id			X	
NiceGrid-A2	id		X	X	
Proaktives-A1	id		X	X	X
Proaktives-A3	id	X	X	X	
PV-KWK-A1	id		X		
Smart_Storage-A1	id		X		
Smart_Storage-A2	id		X		
Store-A1	id				X
Store-A2	id				X
TILOS-A1	id	X			
TILOS-A2	id	X			
V/Q_regulation -A1	id				X
NINES-R1	id		X	X	
NINES-R2	id		X	X	
VENTOTENE-R1	id		X		
Dezentrale-E2	Expected			X	
FLEXe-E1	id	X	X	X	
IGREENGrid-E1	id			X	X
Life-E1	id			X	X
Local-E1	id			X	X
Local-E2	id		X		X
STORY-E1	id	X	X		
STORY-E2	id				X
STORY-E3	id				X

Figure 53: Next steps as seen by project coordinators in D3



Achievement in D4	Status	Further Research	Further Development	Demonstration	Deployment
ADDRESS-A3	Completed	X	X	X	
ALIADOS-A2	id	X			
Control-A1	id		X	X	
Control-A2	id		X	X	
DISCERN-A1	id				X
DISCERN-A2	id			X	
Evora-A1	id	X	X	X	
HyUNDER-A1	id		X	X	
IGREENGrid-A3	id		X	X	
IGREENGrid-A5	id	X	X		
IGREENGrid-A6	id		X	X	X
INGRID-A1	id	X	X	X	
INGRID-A2	id	X	X		
Local-A1	id		X	X	
NiceGrid-A2	id		X	X	
PRICE-A1	id		X	X	
PRICE-A4	id		X	X	
PRICE-A5	id		X		
PRICE-A6	id	X	X		
PRICE-A7	id	X	X		
Proaktives-A1	id		X	X	X
Proaktives-A3	id	X	X	X	
SGV-A1	id		X		
Smart_Country-A3	id				X
VENTEEA-A1	id		X		
ALIADOS-R2	id		X	X	
BioCat-R2	id	X	X		
ALIADOS-E1	Expected	X	X		
ALIADOS-E2	id		X	X	
Dezentrale-E2	id			X	
FLEXe-E1	id	X	X	X	
IGREENGrid-E1	id			X	X
Local-E1	id			X	X
Local-E2	id		X		X
Puglia-E1	id				X
Smart_grids-E1	id				X
Smart_grids-E2	id			X	
Smart_grids-E3	id				X

Figure 54: Next steps as seen by project coordinators in D4

Achievement in D5	Status	Further Research	Further Development	Demonstration	Deployment
ALIADOS-A1	Completed		X	X	X
ALIADOS-A2	id	X			
ATENEA-A2	id				X
Evora-A1	id	X	X	X	
INGRID-A1	id	X	X	X	
INGRID-A2	id	X	X		
Life-A1	id			X	
NiceGrid-A1	id			X	
NiceGrid-A2	id		X	X	
Proaktives-A1	id		X	X	X
Proaktives-A3	id	X	X	X	
Smart_Storage-A1	id		X		
Smart_Storage-A2	id		X		
Store-A1	id				X
Store-A2	id				X
TILOS-A2	id	X			
VENTEEA-A1	id		X		
ALIADOS-R2	id		X	X	
BioCat-R1	id	X	X		
ALIADOS-E1	Expected	X	X		
ALIADOS-E2	id		X	X	
Electrogas-E1	id		X		
Electrogas-E2	id	X			
EnergyLab-E1	id	X	X		X
EnergyLab-E2	id		X		
STORY-E1	id	X	X		
STORY-E2	id				X
STORY-E3	id				X

Figure 55: Next steps as seen by project coordinators in D5

Achievement in D6	Status	Further Research	Further Development	Demonstration	Deployment
Life-A2	Completed			X	
MERGE-A6	id	X	X	X	
MERGE-A7	id	X	X		
Proaktives-A1	id		X	X	X
Proaktives-A3	id	X	X	X	
MERGE-R3	id	X	X	X	
MERGE-R4	id	X	X	X	
MERGE-E1	Expected		X	X	X

Figure 56: Next steps as seen by project coordinators in D6

13.2 Coverage analysis of Cluster 2 with past and ongoing projects

13.2.1 D3 "Integration of DER at low voltage"

Contributions from completed and ongoing projects to D3

From EU projects

- The **ADDRESS** project targeted the active participation of small and commercial consumers in power system markets and provision of services to the different power system participants. With a database of questionnaires to validate social acceptance and customers' commitment, the project has contributed to this functional objective.
- The **metaPV** project has demonstrated the provision of electrical benefits from photovoltaics (PV) on a large scale. Additional benefits for active grid support from PV have been demonstrated at two sites: a residential/urban area of 128 households with 4 kWp each, and an industrial zone of 31 PV systems with 200 kWp each. A methodology was developed to increase the grid capacity by 50% against 10% of the costs (via distributed control of the PV inverters). A software was developed to control the PV inverters connected to the DNS-system of the DSO.
- The aim of the recently finished **DISCERN** project was the enhancement of electricity networks through use of distributed intelligence. The project has developed novel software tools and methodologies, a database for the facilitation of knowledge sharing on cost-effective technological solutions through field-tests and simulations and has contributed to standardisation activities. The field trials undertaken during the project have been used both to test innovative Smart Grid solutions and to evaluate the applicability of the DISCERN methodology and tools in the development phases of a Smart Grid project. The use of the material developed within DISCERN, such as Use Cases, SGAM representations and catalogues of functional and non-functional requirements, has promoted and supported discussions amongst DSOs and between DSOs and vendors, allowing efficient communication and elicitation of requirements.
- The recently finished **IGREENGrid** project's focus was on increasing the hosting capacity for Distributed Renewable Energy Sources (DRES) in power distribution grids without compromising the reliability or jeopardizing the quality of supply. The project has notably delivered guidelines for future massive integration of DRES, which should improve the current European regulation framework to foster DRES integration.
- The **HyUNDER*** project aimed at providing a joint assessment of the European potential for large scale underground hydrogen storage to ensure network reliability

and flexibility and compensate the fluctuating RES. While short term energy storage can be met by small decentralized storage systems, mid to long term electricity storage technologies are still lagging behind. The project has delivered a database with the assessment of the potential, the actors and relevant business cases for large scale and seasonal storage of renewable electricity by hydrogen underground storage in Europe.

- The ongoing **INCREASE** project is focused on the management of RES in low and medium voltage networks by implementation of smart (three-phase grid-connected) inverters. Relevant solutions are being delivered to address grid stability confronted with instable generation flows from PV.
- The ongoing **TILOS** project is developing a smart microgrid on the remote island of Tilos in Greece. The project is developing software tools to forecast RES and load and will deliver policy recommendations for the distinction of storage technologies in the Greek regulation and the permission to run islands diesel-free.
- The main objective of the ongoing **Life Factory Microgrid*** project is to demonstrate that microgrids are the electricity generation solution for industry in terms of environmental impact, especially in areas with a high share of RES. The proposed approach involves a first full-scale demonstration of a microgrid in a factory in Peralta (Navarra, Spain), where near 80% of electricity comes from renewable intermittent sources. The project shall validate energy management strategies capable of using or storing all produced renewable energy.
- The ongoing **STORY*** project aims to show the added value storage can bring in the low and medium voltage grid. Eight demonstrations are set up to feed knowledge into the further analysis on large scale impact. The eight demonstration cases have each different local / small-scale storage concepts and technologies, covering industrial and residential environments. These demonstrations feed into a large-scale impact assessment, with the central question being: "What could be the added value of storage in the electricity distribution grid?". Expected achievements are notably the demonstration and evaluation of a household/neighbourhood increased self-supply by using heat and electricity production and storage; medium scale battery system introduced in the distribution network and in industrial environments; a CAES unit.

From national projects

- The Spanish **Alia2** project tested storage solutions for renewable generation plants. The development of three building management systems (module, cabinet and container) was achieved during the project.
- The Spanish **ATENEA Microgrid*** project developed of a microgrid for industrial applications that operates in on- and off-grid modes and is used as test bench for new technologies, generation, storage and control systems. In order to manage the plant in a proper way, a Control and Energy Management Systems and a SCADA have been developed, implemented and tested. Furthermore, tools (ICTs) for smart management of LV networks are envisaged within the project.
- In Czech Republic, the **LODIS** (Czech abbreviation for Local Management of Distribution Grid) focused on the integration of DER at local level and elimination of overflow of surplus energy (local peak shaving and reduction of losses). It delivered an intelligent data concentrator and a software to use it. A scheme allowing absorption of surplus of generated energy (PV) at the local level through load management has been delivered too. However, these solutions require full roll out of smart meters which is not expected in near future in Czech Republic.

- Again in Czech Republic, the **V/Q regulation** project delivered an advanced software allowing voltage regulation through reactive power. The tested solution is relevant for deployment and is expected to meet its goal by enhancing the capacity of the grid to integrate additional DER.
- In Denmark, within the **storE** project, pumped hydro trading in day-ahead market was modelled, and a modelling software to use pumped hydro in the balancing market was developed.
- The Italian **VENTOTENE*** project realised a pilot project that involved 500kW, 600kWh lithium-ion battery to be integrated with diesel generators providing electricity to the island and to store electricity for use during demand peaks. A methodology has been developed for designing new hybrid generation assets.
- In Denmark again, the overall objective of the recently finished **BioCat*** project was to design, engineer and construct a commercial-scale power-to-gas facility and demonstrate its capabilities to provide energy storage services to the Danish energy system.
- In Scotland, the ongoing **Gigha*** project consists installing 1.26 MWh of vanadium redox flow batteries (VRB) specifically to store power from the wind turbines. The project will deliver knowledge on how to operate a grid-connected VRB in conjunction with wind turbines in island mode. Opportunity for the project has been created by the limitation imposed to a wind turbines by grid constraints (output of the turbine is restricted to 225kW rather than its designed 330kW output): to release the full potential of the turbine researching and prototyping an innovative Energy Storage System were needed. This innovative solution to an increasingly common problem will allow a behind the meter flow battery to store any excess power and release this power when the wind drops and the capacity on the grid is available. This is the first battery of this type to be installed at this size in a working capacity. It will provide valuable insight into the technology and its real world implementation. However regulatory barriers will need to be overcome: a clear definition of Energy storage, especially at regulation level, is still missing and it creates an obstacle also to the market of energy storage.
- In Scotland again, the ongoing **NINES** project aims to address some of the most pressing energy challenges Shetland currently faces by allowing small scale renewable generation to play a much more significant role in meeting the islands' energy needs. The main components of Shetland's Smart Grid under NINES are:
  - Sophisticated modelling (related to planning, operation, residents' interaction with energy systems, and the impact of implementing innovative energy technology);
  - Demand Side Management: installation of new "smart" water and space heating in 234 homes providing the ability for the grid to cope at peak times when more energy is being generated than used; smart heating systems to provide flexible and cost-effective heating for individual households; 4MW of thermal storage connected to the existing district heating system, allowing the expansion of the district heating system to supply up to 300 more homes and 30 more businesses;
  - A large-scale battery energy storage system to provide energy storage and help balance the energy supply and demand;
  - An Active Network Management system, to provide the information flows and control needed on the network to make these new technologies and arrangements work.

  By utilising the grid capacity freed up by the measures above, increased connection of renewable generation – approximately 10MW – has been facilitated. The generators connect under a new 'flexible' connection agreement, which allows their output to be reduced at times when the system cannot accommodate their full output.

- The ongoing French **Nice Grid** project is experimenting local and temporary islanding and reconnection of a subnetwork energized through storage and solar generation. It also seek to optimize the operation of a network integrating a massive production of photovoltaic energy.
- In Germany, the ongoing "**Dezentrale Netzintelligenz**" project also contributes to this functional objective.
- The other ongoing German **PV-KWK*** project is exploring new optimized strategies and solutions for compatible PV Energy Management Systems (EMS), choosing a few of them exemplary and evaluating them in a field test. Possibilities of intelligent coupling of photovoltaic systems with CHP (combined heat and power) plants and heat pump heating systems are being explored. Expansion and optimisation of EMS as well as drafting open interface standards are the first achievements of the project.
- Again in Germany, the ongoing **Proaktives Verteilnetz** project aims at delivering:
  - reliable state estimation and forecasting of the distribution (based on a small number of measuring points and use of environmental data (e.g. weather),
  - conceptual and technical design of the traffic light concept (especially the yellow light phase),
  - safe and non-discriminatory coordination of network and market actors,
  - utilization of flexibility for the distribution grid, as an alternative to avoid unnecessary network expansion.

  In particular the definition of operation mode for "yellow traffic light-phase" and a market model for flexibilities in yellow light phase have been delivered.
- The ongoing Danish **Local Energy Storage** project is developing a local power storage solution based on a new electronic power conversion and control concept and commercial batteries. The aim is to enable higher production of grid connected renewable power and giving the user full advantage of own power production and simultaneously stabilize low voltage feeder lines.
- In Denmark again, the ongoing project "**DSO challenges from introduction of heat pumps**" will result in recommendations for integration of heat pumps in existing distribution grid, which otherwise risk to be overloaded. The recommendations will be based on analysis of comprehensive data from LV grids with many heat pumps. The project will also develop new heat pump technology that can in fact help to improve future grid operation. A model to forecast the impact of mass uptake of heat pumps on LV grids has been delivered, as well as a power electronics algorithm to prevent overload of LV grid with many heat pumps.
- The ongoing Dutch **Smart Storage** project's objective is to gain operational experience with local, distributed electricity storage within low voltage grids. The first result of the project was the development of the Smart Storage Unit (SSU), which is part of the greater Smart Storage System (SSS), and currently in operation as electricity storage system.
- The ongoing Finnish **FLEXe** project's aim is to create novel technological and business concepts enhancing the radical transition from the current energy systems towards sustainable systems. FLEXe combines smartness, flexibility, environmental performance and economic success with customer acceptance and engagement. The project has delivered an optimal heat system component design (to be installed for instance by customers at smart homes with wind or solar connection). It also expects to deliver a methodology for optimized and secured integration and

operation of future energy networks.

Note: Projects marked with an * do not count DSOs on board. They have been provided by EASE members.

Assessment of the coverage of D3

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective D3:

D3a. Scientific:

- Models for simulating and studying the new systems' impacts on LV network
- Models and methods for evaluation of power quality focused mainly on harmonic distortion and power oscillations in LV network
- Development of models to compare the cost effectiveness of different active control options of DER (responsive loads, storage).

D3b. Technology:

- Grid support capabilities inverters adapted to distribution network requirements and needs
- Network monitoring systems and related communication infrastructure supporting small scale DER integration in low voltage networks
- Unification of new cheap communication interfaces between network and SDER, reminding a cost/benefit ratio and an ENTSO-E network code requirements (e.g. ON-OFF signal down to 400W installations)
- ICT infrastructure in low voltage networks for monitoring and control of SDER
- Bi-directional communication systems possibly integrated with AMM system
- Network management/control systems with, inter alia, self-healing capabilities for fault management in LV network
- New actuators (e.g. switches) and new sensors (e.g. fault detectors, voltage and New tools for network planning and design with the ability to integrate conventional (passive) network simulations (load flow, etc.) with the simulation of active components and control algorithms

D3c. Market:

- Recommendations for valuation of ancillary services brought by SDER
- New market rules to continue promoting the deployment of distributed generation based on renewables (replacing feed-in tariffs)
- Recommendations for new tariff systems in support of the above market rules

D3d. Social:

- Changing the behaviour of private SDER owners to join electricity markets

Coverage assessment

Several tasks of this FO have a minor coverage regarding technological aspects, for instance, the unification of new cheap communication interfaces between network and SDER; and the development of new tools for network planning such as actuators and sensors. In addition, there is still important work to do in order to integrate private SDER into the electricity markets. The coverage assessment of this functional objective has been estimated at 40 %.

13.2.2 D4 "Integration of DER at medium voltage / high voltage"

Contributions from completed and ongoing projects to D4

From EU projects

- With an aggregator toolbox (full validation of aggregator functionality and 'core business model'), the **ADDRESS** project contributed to this functional objective.
- The **HyUNDER*** project as well as the recently finished **DISCERN** and **IGREENGrid** projects have also contributed to this functional objective.
- The almost finished **INGRID** project aims at demonstrating the efficient usage of safe, high-density, solid-state hydrogen storage systems for power supply and demand balancing within active power distribution grids with high penetration of intermittent Distributed Generation (RES in particular). The main project innovation is combining hydrogen solid-storage systems with Smart Grid cutting-edge ICT-based active network control technologies for balancing highly variable power supply and demand in a scenario of high penetration of RES. The INGRID Energy Management System (EMS) is based on the multi-carrier hub paradigm for modelling the behaviour of the entire plant. An optimiser, built upon this model and based on genetic algorithm, is responsible for elaborating the optimal power flow inside the plant, every hour. Indeed, the EMS is able to merge and harmonise the contrasting requirements coming from the DSO, in terms of expected power consumption profile, and the ones linked to the actual business of the plant. In this way, the INGRID plant is able to chase its own profit, providing ancillary services to the grid at the same time.

From national projects

- The Spanish **Alia2** project tested storage solutions for renewable generation plants. In particular, black-start based on batteries for small-hydro plants was tested. The project partners expect to develop a new product with 1MW capacity and to integrate it in grids and in generation plants (PV and wind). Services to small industries, neighbourhoods, EV recharging and induction furnaces are also envisaged.
- The Spanish **PRICE** project demonstrated:
  - MV/LV dispatch prototype & Distribution Management System for DG;
  - Static synchronous compensators (STATCOM) installation in a MV and LV grid for renewable integration and distributed generation dispatch.
  - State Estimator algorithm & voltage control algorithm.
- In Italy, the **ISERNIA** project demonstrated voltage regulation by remote control of DER and storage (Li-ion battery) using centralised control system, and island detection device.

- The French **VENTEEA** demonstration project[16] was focused on improving the integration of large wind energy in distribution networks by the use of battery storage systems.
- In Denmark, the project "**Control and regulation of modern distribution system** studied two issues in distribution systems:
  - Normal Operation Optimization to model the load optimal response to electricity price, power system constraint impacts;
  - Control Strategies in Abnormal Operations to derive an islanding detection method, propose control and protection schemes for a varying status power system.
- In Portugal, the **Storage in Evora** project consisted in an MV Storage system demonstrator, connecting Li-ion batteries to the MV grid to improve voltage quality and energy management. Islanding mode in grid operation has been explored within the project.
- The Belgian project "**Smart grids: Back End Systems**" consisted in the segmented roll-out of smart meters and associated systems. It delivered:
  - The implementation of operating management systems with full roll-out in operating centres,
  - The roll-out of the new operations to the DSO field crew,
  - Automatic wind curtailment and load shedding.

  Next project steps should include:
  - The integration of DSM as system reserve (DSO/TSO) to allow MV customers to participate via aggregators in the TSO's balancing mechanism,
  - The integration of storage, including for providing ancillary services,
  - The integration of the outage management for LV networks.
- In Spain, the **Gorona del Viento El Hierro** project's aim was to pave the way to reach 60-80% of the energy consumption of the El Hierro island covered by renewable sources. The project has designed, developed, constructed and put in service a system Hydrowind able to cover the electrical demand in the island, turning this island into a territory electrically supplied by renewable energies in a high percentage. The system is composed by two water tanks, a wind farm, a hydroelectric power station, a pump station and a power diesel plant. The Hydrowind plant transforms an intermittent source of energy into a controlled supply of electricity, maximizing the utilization of the wind power. In terms of software tools the project carried out a simulation of the system, stability studies and energy studies, and an Automatic Generation Control (AGC) of the plant. The objective of reaching 60-80% consumption of the island covered with RES was not achieved due to some control systems that should be improved. The project achieved around 50% during the summer period.
- In Austria, the **Smart Grid Judenburg** aimed at reducing connection costs for new DG installations (hydro plants) connected to the MV network by means of a centralised controller.
- The other Austrian **Smart LV Grid – Heimschuh** project aimed at reducing connection costs for new DG installations (rooftop PV panels, private households) connected to the LV network by means of an On-Load Tap Changer (OLTC) installed at secondary substation level to regulate voltage profile on LV network and increase capacity for the network to connect increasing amounts of PV at a reduced cost instead of resorting network reinforcements.

[16] It was also part of the EU FP7 project IGREENGrid.

- The ongoing French **Smart Grid Vendée** project has implemented consumption and generation forecasting tools at primary substation scale.
- In Poland, the ongoing **Smart Torun** project includes the extension of the MV network automation and the development of new AMI system functionality. In addition, 3.77 MW of PV are being installed.
- In Germany, the ongoing "**Dezentrale Netzintelligenz**" project also contributes to this functional objective with line voltage regulators in MV network.
- The ongoing Danish **Local Energy Storage** project is developing a local power storage solution based on a new electronic power conversion and control concept and commercial batteries. The aim is to enable higher production of grid connected renewable power and giving the user full advantage of own power production and simultaneously stabilize low voltage feeder lines. An hourly based economic model for PV/storage/usage/grid has been developed in the early phase of the project.
- The ongoing Italian **Puglia Active Network** project is developing active management of MV network.
- The ongoing German **Smart Country** project[17] is demonstrating how biogas storage in Coordination with PV generation can work as a Virtual Electricity Storage.
- In Northern Ireland, the **CAES Larne*** project will be the first Compressed Air Energy Storage Station in the world optimised to integrate increased RES into the system. It is planned for commissioning in 2021 on Islandmagee, Larne, Northern Ireland[18].
- The Danish **BioCat*** project, the ongoing Finnish **FLEXe**, German **Proaktives Verteilnetz** and French **Nice Grid** projects also contribute to this functional objective.

Note: Projects marked with an * do not count TSOs nor DSOs on board. They have been provided by EASE members.

Assessment of the coverage of D4

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective D4:

D4a. Scientific:

- Models for simulating and studying the new systems impacts on MV network
- Models and methods for evaluation of power quality with main focus on harmonic distortion and power oscillations in MV networks

D4b. Technology:

- Grid support capabilities of PV inverters adapted to distribution network requirements and needs
- Network monitoring systems and related communication infrastructure supporting DER integration in MV networks

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[17] It is also part of the EU FP7 project IGREENGrid.

[18] This project is not a research project as such but will build up a real storage plant. The research part of this project has been done in the SPIRE project.

- 🔴 Unification of new cheap communication interfaces between network and SDER, reminding a cost/benefit ratio and ENTSO-E requirements (e.g. ON-OFF signal down to 400W installations)
- 🟡 ICT infrastructure in medium voltage networks for monitoring and control of DER
- 🟡 Network management/control systems with, inter alia, self-healing capabilities for fault management in MV network
- 🟡 New actuators (e.g. switches) and new sensors (e.g. fault detectors, voltage and current sensors) for MV network, leading to new protection and control strategies
- 🟡 New tools for network planning and design with the ability to integrate conventional (passive) network simulations (load flow, etc.) with the simulation of active components and control algorithms

D4c. Market:

- 🟡 Recommendations for valuation of ancillary services brought by DER
- 🟡 New market rules to continue promoting deployment of DER based on renewables (replacing feed-in tariffs)
- 🟡 Recommendations for new tariff systems in support of the above market rules

D4d. Social:

- 🟡 Training to increase the skills of dispatchers

Coverage assessment

The assessment of FO D4 has led to an estimate of coverage at 40%. The contribution of ongoing EU and national projects' expected results will allow the increase of the coverage up to 50 %. There is only one critical point that has not been addressed concerning the unification of new inexpensive communication interfaces between network and SDER at MV/HV level, which is in agreement with the work effected at LV level as indicated in the previous FO (D3).

13.2.3 D5 "Integration of storage in network management"

Contributions from completed and ongoing projects to D5

From EU projects

- The almost finished **INGRID** project aims at demonstrating the efficient usage of safe, high-density, solid-state hydrogen storage systems for power supply and demand balancing within active power distribution grids with high penetration of intermittent Distributed Generation (RES in particular). The scientific and technological objectives were:
  - To effectively integrate larger yet decentralized, fluctuating renewable energy sources (within the 30-50% penetration level) without compromising grid reliability and security, based on effective rapid and safe hydrogen-based energy storage and on the delivery of solutions capable to timely and instantaneously accept and manage any RES fluctuation and variability;
  - To design and make available advanced ICT monitoring and control tools aimed at simulating, managing, monitoring, controlling power dispatching in

compliance with the power request of the grid, allowing a correct balance between variable energy supply and demand;
 - To demonstrate the usage of an innovative hydrogen solid-state storage technology, as safe and high-density energy storage systems, to be integrated in a closed loop coupled with water electrolysers and fuel cell systems with the objective of achieving a highly efficient regenerative loop (larger than 50-60%) with a reasonable cost;
 - To perform a limited demonstrative scaled-down test case in Puglia region for assessing the storage system' high balancing capabilities in presence of high variable electricity demand consisting in a small pilot version of a green urban mobility system integrating conventional public transport designed to be self-sustainable and increase the environmental sustainability.

- The ongoing **STORY*** project aims to show the added value storage can bring in the low and medium voltage grid. Eight demonstrations are set up to feed knowledge into the further analysis on large scale impact. The storage technologies involved are thermal storage, electrochemical and CAES. The main challenge is to demonstrate and evaluate innovative approaches for thermal and electrical energy storage systems and to find affordable and reliable solutions that lead to an increased electricity self-supply. STORY is about showing the added value storage can bring for a flexible, secure and sustainable energy system. The demonstrations therefore compose the key activity on which all further analysis builds. Each of the demonstrations brings a different technology, context or business case.
- The ongoing **TILOS** project is developing policy recommendations for the distinction of storage technologies in the Greek regulation and the permission to run islands diesel-free. The existing regulatory framework for hybrid power stations in the non-interconnected island part of Greece has been built upon the technology of pumped hydro, missing essential elements with regards to battery storage operation and requirements. Battery storage could provide a valuable asset for the island DSO in terms of ancillary services and should thus be treated accordingly. At the same time, the local regulation does not allow for completely diesel-free operation of an island grid which is also challenged in the context of the project.
- The ongoing **Life Factory Microgrid*** project will provide experience feedback on the operation of Zn-Br flow battery technology.
- The recently started **CryoHub** project is developing Cryogenic Energy Storage (CES) in form of liquid air at Refrigerated Warehouses as an Interactive Hub to integrate energy in industrial food refrigeration and to enhance power grid sustainability. The intention is to use cheap, off-peak electricity to convert air into a liquid, which can then be stored over a long period of time in a storage vessel. Turning the liquid back to gas, by removing it from the store and applying heat to it, will produce a huge increase in volume and pressure – enough to power a turbine to generate electricity which can then be supplied back to the grid.

From national projects

- In Italy, the **ISERNIA** project implemented of storage facility (Li-ion battery) on real network.
- The other Italian **VENTOTENE*** project realised a pilot project that involved 500kW, 600kWh lithium-ion battery to be integrated with diesel generators providing electricity to the island and to store electricity for use during demand peaks. New power electronics control rules have been designed.
- The Spanish **Alia2** project tested storage solutions for renewable generation plants (design and manufacture of a 150 kW, lithium-ion storage system). One of its

technological innovations is a concept called the battery pack, which has a cooling unit incorporated into a modular system where the lithium-ion cells are inserted. It also includes protection systems for the components and overall is able to reach the required level of voltage and capacity. A control module which manages the system has also been developed; it will guide the interfaces with other modules and external grids. This new solution should allow the provision of grid services to DSOs and TSOs.

- The Spanish **ATENEA Microgrid*** project developed of a microgrid for industrial applications that operates in on- and off-grid modes and is used as test bench for new technologies, generation, storage and control systems. The technologies tested include power generation systems but most important many different energy storage systems (ESS) such as advanced batteries or supercapacitors.

- The French **VENTEEA** demonstration project addressed the network constraints created by wind turbines. Some services were made possible through the Venteea battery storage system (2 MW / 1,3 MWh), facilitation the integration of the wind energy on the network. One of these services is the short-term power smoothing, avoiding too strong and too fast variations of the power injected on the network. The storage plays the role of "buffer" to the variations and improves the quality of supply. Another service relates to the energy surplus management, in case injection of the whole wind generation into the network would lead to heavy constraints on the network. The stored surplus of production would be delivered later, once the risk of constraint disappears.

- In Portugal, the **Storage in Evora** project consisted in an MV Storage system demonstrator, connecting Li-ion batteries to the MV grid to improve voltage quality and energy management.

- In Denmark, the overall objective of the recently finished **BioCat*** project was to design, engineer and construct a commercial-scale power-to-gas facility and demonstrate its capabilities to provide energy storage services to the Danish energy system. Five key components of Power-to-Gas Facility are used in the project:
  - Hydrogen Production Unit: advanced alkaline electrolyser;
  - Methanation System: a biological methanation system located at the wastewater treatment plant Avedøre south of Copenhagen;
  - Gas Injection: 4-bar gas distribution grid operated by HMN Naturgas A/S;
  - Heat Recycling: in on-site buildings and for sludge pre-heating;
  - Ancillary Services: frequency regulation to Danish power grid.

  The facility also acts as a demonstrator of the technical capability and economic viability of oxygen and heat recycling in the on-site wastewater operations. An optimized trading strategy mimicking the intermittent nature of wind and solar energy production has been developed in order to maximize economic value capture.

- The ongoing French **Nice Grid** project is experimenting local and temporary islanding and reconnection of a subnetwork energized through storage and solar generation. It also seek to optimize the operation of a network integrating a massive production of photovoltaic energy.

- The specific aims of the ongoing Danish **EnergyLab Nordhavn*** project EnergyLab Nordhavn is to develop new innovative business models, new energy technologies and intelligent operating solutions, such as integrated and flexible energy markets, coordinated operation of electricity and heating systems, energy storage, energy-efficient buildings—subject to immediate optimization in relation to energy markets—and technologies offering flexible switching between energy sources. The aim is for tomorrow's sustainable, densely populated energy-efficient cities all over the world to benefit from the derived solutions. The energy storage components of the project are thermal storage and electrochemical storage in large batteries as well as batteries of electric vehicles. The project expects to deliver both methodologies (experience on integration of different energy sectors - electricity, heat) and IT solutions for optimal control of system operation.

- The ongoing Danish **Electrogas** project is developing knowledge and technology which can take surplus electricity from renewable energy and use it to upgrade CO_2 to CH_4 by feeding it to microorganisms present in biogas reactors. ElectroGas use recent advances in fundamental microbial ecology, bioelectric synthesis, ion permeable membranes, gas-liquid mixing and anaerobic digesters engineering to overcome the microbial limitations and engineering constraints for biogenic energy conversion. Two approaches on different TRL's will be used:
    1. Electrolysis of H_2O to H_2, subsequently added to the anaerobic digesters (TRL3 to TRL6). Main scientific work will be on microbial community dynamics upon pulse H_2 additions and microbial kinetics when CO_2 is limited;
    2. Microbial electrosynthesis (ME) using direct electron transfer (DIET) to a biofilm on a biocathode, ideally inside the anaerobic digesters (TRL2 to TRL4). Scientific work includes investigation of biofilms and their mechanisms capable of DIET and the potential surface specific current densities.
- Within the ongoing Dutch **Smart Storage** project, a Smart Storage System (SSS) is operated to enable field-testing and research of advanced smart storage technologies in low voltage (LV) distribution grids and to gain experience on operation of LV grid-connected battery. The SSS was installed in the LV distribution grid for the purpose of enabling applications such as, but not limited to: the increase of local PV consumption, improvement of reliability and flexibility, reduction of losses, and maximizing the utilisation of local infrastructure. As the Smart Storage project was intended to provide operational experience, the system was installed into a live LV network in the Netherlands. Regarding the integration in Grid System, discussions are ongoing in The Netherlands about how to integrate successfully the battery system in grid.
- In Denmark, within the **stoRE** project, pumped hydro trading in day-ahead market was modelled, and a modelling software to use pumped hydro in the balancing market was developed.
- The ongoing German **Proaktives Verteilnetz** project also contributes to this functional objective.

> Note: Projects marked with an * do not count TSOs nor DSOs on board. They have been provided by EASE members.

Assessment of the coverage of D5

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective D5:

D5a. Scientific:

- Market and network models to value the potential benefits of storage and their optimal location (e.g. close to generation, or close to load) and size
- Dedicated forecasting tool to optimally manage distributed generation and storage

- New tools for network planning and design with the ability to integrate conventional (passive) network simulations (load flow, etc.) with the simulation of storage systems with active control algorithms

D5b. Technology:

- Different storage technologies (assessment in terms of technical characteristics, ability for network support, etc.)
- Movable storage
- Power electronic devices that equip storage systems
- Central systems (i.e. Distribution Management System, DMS), distributed and centralised intelligence systems for implementing the functionalities described in the "Functional Objectives" section
- ICT infrastructure for connecting the storage devices to the central control system
- New actuators (e.g. remotely managed switches and relays), new sensors (e.g. fault detectors, voltage and current sensors) and new algorithms (e.g., fault detection and power flow optimisation)
- Integration issues (minimisation of integration costs into distribution network, etc.)

D5c. Market:

- Development of different business models (technical virtual power plant vs. market virtual power plant, distributed storage and active demand for domestic applications, movable storage), adapted to different regulatory schemes
- Analysis and simulations of market models considering distribution network storage and residential storage, addressing "certification" of storage solutions for grid compliance (features, communication options...)
- Provide recommendations for new regulatory mechanisms addressing storage ownership and operations
- Cost-benefit analysis considering other storage alternatives such as hydrogen, power-to-gas and thermal storage as relevant benchmarks.

D5d. Social:

- Social acceptance of storage related to potential security and environmental impacts

<u>Coverage assessment</u>

Completed and ongoing projects have allowed covering only about a third (33%) of the tasks within this functional objective because some critical points have not been addressed yet. There is still a need for new tools for network planning and design accounting for the flexibility options brought by storage. Movable storage has not been addressed either. In addition, issues related to market models regarding storage integration and new regulatory mechanisms dealing with storage ownership and operations have yet to be covered. R&I activities relative to customers' sensitisation about storage and its social acceptance must be conducted.

13.2.4 D6 "Integration of infrastructure to host Electrical Vehicles"

Contributions from completed and ongoing projects to D6

From EU projects

- The **Grid for Vehicles (G4V)** project analysed the impact and possibilities of a mass introduction of electric and plug-in hybrid vehicles on the electricity networks in Europe. The project:
  - developed an analytical method to assess the impact of the mass introduction of EV and PHEV on the electricity grids,
  - elaborated recommendations for technological upgrading of the grid infrastructure and related ICT system solutions for grid management,
  - elaborated recommendations for policy makers to foster electric mobility (in terms of regulations and incentives),
  - identified and seized business opportunities for different stakeholders groups
  - elaborated standardisation proposals for a joint European approach,
  - defined future required RTD activities and projects.

- The **MERGE** project's aim was to prepare Europe's Grid for Electric Vehicles. The project has delivered:
  - *A methodology for optimal EV charging management;*
  - *Software tools:*
    - Adaptation of existing simulation tools with EV models to perform analytical studies;
    - Development of simulation tools that can be used by TSOs, DSOs and market operators to assess the impact of increased EV penetration at distribution level, transmission level and also generation and market operation;
  - *Regulatory proposals* for market uptake (of EV) in Spain, Ireland, Greece and Germany, UK and Portugal;
  - *An EU roadmap for EV's development;*
  - *Hardware installations:*
    - Development of EV charging stations and back-office management system,
    - Pilot installation of EV charging stations and charging monitoring systems. (Green E-motion),
    - (Fast in charge) Wireless charging infrastructure.

- The **METER ON** project was aimed at supporting the development and deployment of advanced metering infrastructures in Europe. This included the integration of plug-in electric vehicles.

- The main objective of the recently finished **PlanGridEV** project was to design new planning rules and operational principles for the optimal integration of EV for different network topologies and with different levels of DER penetration such as PV, wind and solar energy and micro CHP. Software tools were developed:
  - Optimised and enhanced grid architecture for EVs in Europe; the developed architecture provides a useful framework which is applicable for different European DSOs;
  - Prototype tool for optimising existing assets and grid planning using controllable loads and to maximise integration of EVs and DER in distribution grids.

- The ongoing **Life Factory Microgrid*** project, focused on microgrid demonstration for industry in areas with a high share of RES, is also testing vehicle to grid (V2G) integration in microgrids. The project will integrate six V2G bidirectional charging points for electric vehicles and one 50 kW fast charge point.

From national projects

- Within the Italian **ISERNIA** project, EV charging stations were installed.
- The French **BIENVENU** project is experimenting a solution for the integration of EVs in residential buildings (controlled charging solution adapted to the parking lots as well as car sharing solution of EVs). The project expects to optimise EV charging in collective housing, taking into account both EV needs and the impact on the distribution network.
- Within the Italian ongoing **Puglia Active Network** project, recharging infrastructure for Electric Vehicles are being installed.
- The ongoing German **Proaktives Verteilnetz** project also contributes to this functional objective.

> Note: Projects marked with an * do not count TSOs nor DSOs on board. They have been provided by EASE members.

Assessment of the coverage of D6

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective D6:

D6a. Scientific:

- Network modelling and optimization tools in the presence of massive integration of EVs
- Optimization tools for power flow calculation capable of simulating the active behaviour of on board battery chargers with advanced control algorithms (e.g. implementing V2G dispatch strategies)

D6b. Technology:

- Development of EV charging infrastructures (for EV charging in public and private areas)
- Development of centralized remote management system enabling smart grids integration of EV charging infrastructures, supporting business-to-customers and business-to-business relationships and ensuring easy and secure payments for customers
- Smart EV charging solutions in accordance to energy availability and network constraints and electricity prices
- Development of standard charging solutions to ensure interoperability and recharging of current and future vehicles generation
- Fast, very fast, and inductive recharge
- V2G technology solutions

D6c. Market:

- Creation of a common marketplace in order to provide common services across EU and in particular enabling roaming services
- Definition of business models for electric mobility

- Recommendations for tariff schemes and incentives to promote optimized charging and facilitate customer engagement
- Regulatory recommendations to support electric mobility market penetration
- Market mechanisms for V2G

D6d. Social:

- Understanding of costumer behaviour and social acceptance

Coverage assessment

On a scientific point of view, network modelling and optimisation tools have been developed with a satisfactory maturity, whereas for technologies (D6b) there is still a significant gap to reach applicable results, notably in terms of the development of centralized remote management systems and smart EV charging solutions accounting for energy availability and network constraints as well as electricity prices. Market aspects have been touched but research activities are still needed for the creation of a common market place.

Therefore, the coverage of this functional objective is estimated at around 40%.

13.3 Recommendations for the new R&I roadmap

As for Cluster 1, the R&I activities specified in the four FOs have been addressed in many projects, which has resulted in a good coverage of Cluster 2 (around 40%). However, there are still missing knowledge blocks for each FO. For the integration of EVs (D6), there are no answers regarding the "market place" and the associated standardised infrastructures which could allow citizens to travel across the EU. For storage (D5), for instance, market players still need a clear regulatory framework for storage ownership and operations. For the integration of DER at both the MV and LV levels, there is still a lack of integrate solutions (both hardware and software) to increase the penetration of DER, covering the full range of encountered combinations between generation portfolios and network topologies, while complying with power quality limits and keeping the network within its stability limits.

For the new roadmap, it is recommended to keep Cluster 2 and to expand the scope of R&I activities with one additional FO covering the connections with other energy networks. The new name of the cluster should be "Integration of DER and EV, storage, **other networks**". The scope of D6 should also be extended to cover not only issues related to the integration of EVs, but also all issues related to the electrification of (public) transport. For the other FOs, the remaining gaps in terms of coverage should be filled in by re-specifying the non-covered R&I activities[19].

[19] As explained for Cluster 1, it is also recommended to specify the R&I activities of each FO in terms of cross-cutting challenges: upgrading of the network, Power system flexibility, Power system reliability, ICT and digitalization, Market design, and DSOs regulatory environment.

14. Distribution Cluster 3: Network operations

Cluster 1 is organized into 4 Functional Objectives: D7, D8, D9 and D10.

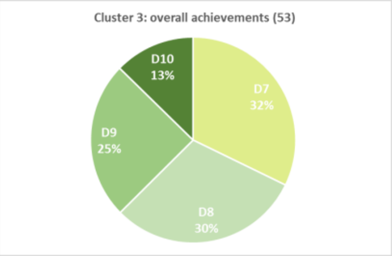
D7. Monitoring and control of LV networks
D8. Automation and control of MV networks
D9. Network management methodologies for network operation
D10. Smart metering data utilisation

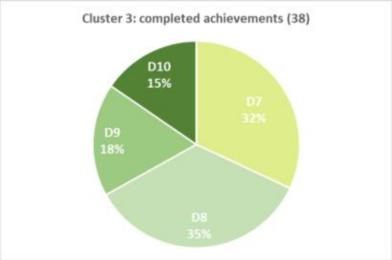
14.1 Features of achievements in Cluster 3

14.1.1 Descriptive features

Categorization in functional objectives

The graphs below characterize the completed (38 achievements) and expected (15 achievements) achievements of projects' results of cluster 3, the purple colour was dedicated to Cluster 3.





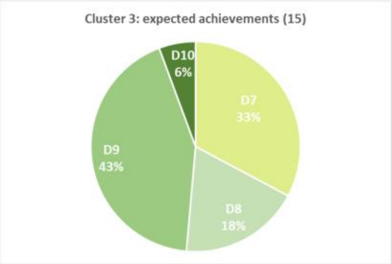


Figure 57: The portfolio of achievements in Cluster 3 (left: overall; middle: completed; right: expected)

Highlights:

- Cluster 3 includes four FO that are quite well-balanced in term of achievements.
- There is no major distortion in the general balance in the three diagrams, except for D9 and D10 when moving from the completed to the expected achievements.

Typology of achievements in Cluster 3

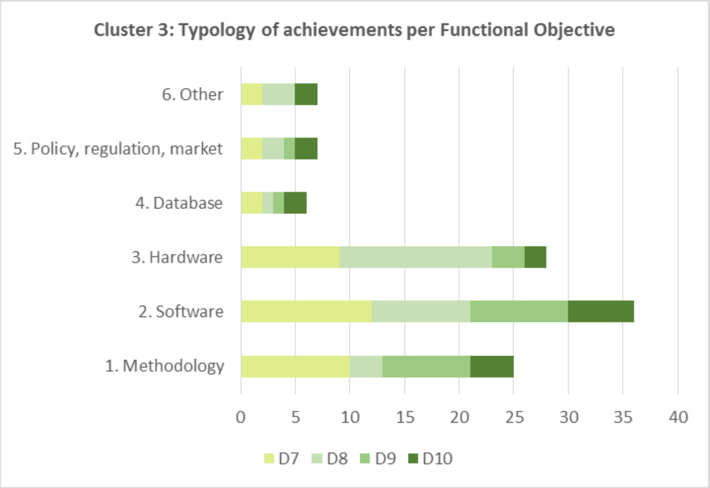


Figure 58: Typology of achievements in Cluster 3 in distribution

Highlights:

- The profile of the breakdown per nature indicates that the Software type achievements followed by the hardware type and the methodology type are the most quoted in Cluster 3.
- Mentions of policy, regulation, market and of database types remain limited in that cluster.

Evolution of the maturity of achievements in Cluster 3

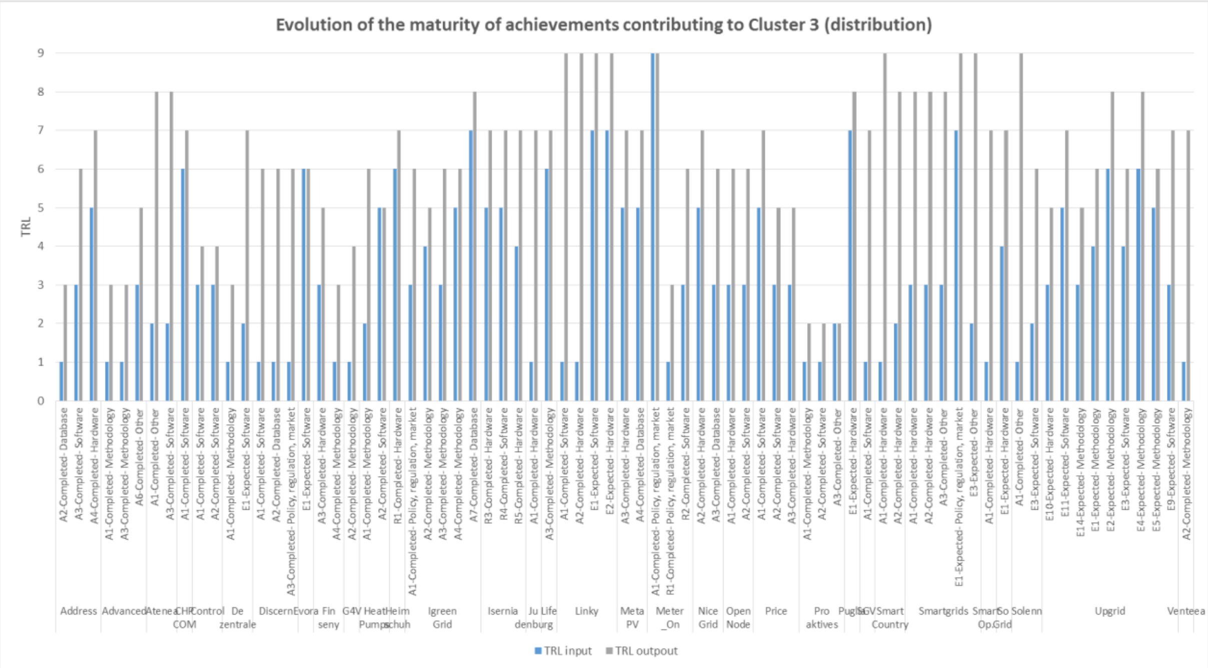


Figure 59: Evolution of the maturity of achievements contributing to Cluster 3 of distribution measured in TRL units

Highlights:

- The graph shows the high variability of the maturity increments per project achievement in Cluster 3 of Distribution: several of the considered achievements have a maturity gain strictly higher than 3 units.
- This is consistent with the average maturity increment of the Cluster which is the highest compared to the other average maturity increments in distribution clusters (almost 3 TRL units: see section 11.3).

14.1.2 Projective features (next steps)

From the data collected in Cluster 3 for each functional objective (D7, D8, D9, D10) one could formulate the following highlights:

- In D7 the most preferred routes are demonstration and further development.
- In D8 the three downstream routes are the most quoted: further development, demonstration and deployment, the further research route is marginal.
- In D9, as for D7, the most preferred routes are demonstration and further development.
- In D10, the three upstream routes are the most quoted: further research, further development, demonstration, while the deployment option is never mentioned.

Achievement in D7	Status	Further Research	Further Development	Demonstration	Deployment
ADDRESS-A3	Completed	X	X	X	
ADDRESS-A4	id		X	X	
ATENEA-A1	id			X	X
Control-A1	id		X	X	
Control-A2	id		X	X	
DISCERN-A1	id				X
DISCERN-A2	id			X	
Heat_Pumps-A2	id			X	X
IGREENGrid-A2	id	X	X		
IGREENGrid-A3	id		X	X	
IGREENGrid-A4	id		X	X	
METAPV-A3	id	X	X		
NiceGrid-A2	id		X	X	
PRICE-A2	id	X	X		
PRICE-A3	id		X	X	
Proaktives-A1	id		X	X	X
Proaktives-A2	id		X	X	
Proaktives-A3	id	X	X	X	
LINKY-E1	Expected			X	X
LINKY-E2	id			X	X
UPGRID-E1	id	X	X	X	
UPGRID-E10	id		X	X	
UPGRID-E11	id		X	X	
UPGRID-E14	id	X	X	X	
UPGRID-E4	id	X	X	X	
UPGRID-E5	id	X	X	X	
UPGRID-E9	id	X	X	X	

Figure 60: Next steps as seen by project coordinators in D7

Achievement in D8	Status	Further Research	Further Development	Demonstration	Deployment
Control-A1	Completed		X	X	
Control-A2	id		X	X	
Dezentrale-A1	id		X		
DISCERN-A1	id				X
DISCERN-A2	id			X	
NiceGrid-A2	id		X	X	
PRICE-A1	id		X	X	
Proaktives-A1	id		X	X	X
Proaktives-A2	id		X	X	
Proaktives-A3	id	X	X	X	
Smart_Country-A1	id				X
Smart_Country-A2	id				X
Evora-E1	Expected		X	X	X
Puglia-E1	id				X
Smart_grids-E1	id				X
Smart_grids-E3	id				X

Figure 61: Next steps as seen by project coordinators in D8

Achievement in D9	Status	Further Research	Further Development	Demonstration	Deployment
CHPCOM-A1	Completed				X
IGREENGrid-A1	id		X	X	X
IGREENGrid-A2	id	X	X		
IGREENGrid-A3	id		X	X	
IGREENGrid-A4	id		X	X	
IGREENGrid-A7	id	X	X		
Life-A3	id			X	
Proaktives-A2	id		X	X	
SGV-A1	id		X		
VENTEEA-A2	id		X		
Evora-E1	Expected		X	X	X
LINKY-E1	id			X	X
LINKY-E2	id			X	X
UPGRID-E10	id		X	X	
UPGRID-E11	id		X	X	
UPGRID-E14	id	X	X	X	
UPGRID-E3	id	X	X	X	
UPGRID-E5	id	X	X	X	
UPGRID-E9	id	X	X	X	

Figure 62: Next steps as seen by project coordinators in D9

Achievement in D10	Status	Further Research	Further Development	Demonstration	Deployment
ADVANCED-A6	Completed	X	X	X	
NiceGrid-A3	id		X	X	
Proaktives-A2	id		X	X	
SOLENN-A1	id		X		
TILOS-A1	id	X			
UPGRID-E14	Expected	X	X	X	
UPGRID-E5	id	X	X	X	

Figure 63: Next steps as seen by project coordinators in D10

14.2 Coverage analysis of Cluster 3 with past and ongoing projects

14.2.1 D7 "Monitoring and control of LV networks"

Contributions from completed and ongoing projects to D7

From EU projects

- The **ADDRESS** project targeted the active participation of small and commercial consumers in power system markets and provision of services to the different power system participants. In terms of monitoring and control of LV networks, the project delivered an aggregator toolbox and technical validation of the proposed solutions and prototypes for the Home System.
- Through field trials, the recently finished **DISCERN** project has demonstrated replicable and cost-effective solutions for the enhancement of network observability that enables DSOs to address current and future challenges for network management. To provide DSOs with a greater understanding of innovative systems for the monitoring and control of LV and MV grids, a set of novel Smart Grid solutions that achieve the DISCERN sub-functionalities has been implemented at four demonstration sites during the course of the project. The tested sub-functionalities were:
  - Enhanced monitoring and control of MV and LV network,
  - Real time monitoring of LV network,
  - Optimised Advanced Meter Reading data collection and analysis using virtualised as well as physical concentrators,
  - Calculation and separation of technical and non-technical losses.
- The **metaPV** project has demonstrated the provision of electrical benefits from PV on a large scale. The enhanced control capacities implemented into PV inverters and demonstrated were active voltage control, fault ride-through capability, autonomous grid operation, and interaction of distribution system control with PV systems. The detailed project achievements contributing to this functional objective are:
  - The Development of remote controlled and monitored inverters,
  - The available DNS and SCADA systems of the DSO used for the steering of the inverters,
  - Proposals for new policy principles and technical rules for DSOs and PV owners.
- The **Grid for Vehicles (G4V)** project analysed the impact and possibilities of a mass introduction of electric and plug-in hybrid vehicles (EV and PHEV) on the electricity networks in Europe. The project demonstrated that without control, the

charge of EVs can have significant impacts on the use of generation plants and increase network constraints.

- The **Open Node** project's goal was the design and development of an Open Common Reference Architecture (both in hardware and software aspects) for the inner parts of the distribution grid, namely the smart Secondary Substation Nodes (SSN). A prototype to concentrate measurements (smart metering) for the secondary substation and a metering management collector (MMC) were developed.
- The **IGREENGrid** project has carried out a study for improving the DRES hosting capacity in European distribution grids by using smart grid solutions. Scalability and replicability analysis have been applied to the most promising solutions. An economic analysis of most promising solutions for DRES integration has been carried out.
- With the ongoing **UpGrid** project, the improvement of the monitoring and controllability of LV and MV grids is expected, as a way to anticipate technical problems associated with large scale integration of DER, bringing also end users closer to system operation and planning. In terms of monitoring and control of LV networks, the project expects to achieve a sound LV network representation, to improve operations and maintenance of LV grid, to integration and process meter events in the Outage Management System (OMS) within SCADA systems, to deploy Multiservice PRIME subnetwork and to develop LV grid remote control operation over Smart Metering PRIME infrastructure.

From national projects

- The Spanish **ATENEA Microgrid*** project developed of a microgrid for industrial applications that operates in on- and off-grid modes and is used as test bench for new technologies, generation, storage and control systems. In order to manage the plant in a proper way, a Control and Energy Management Systems and a SCADA have been developed, implemented and tested. Furthermore, tools (ICTs) for smart management of LV networks are envisaged within the project.
- The Danish project "**Control and regulation of modern distribution system** has also contributed to this function objective with a Normal Operation Optimization model and Abnormal/Emergency Operations Control Strategies.
- The ongoing French **Nice Grid** project seeks to optimize the operation of a network integrating a massive production of photovoltaic energy.
- In France, the roll-out of the **Linky** smart meters is ongoing (35 million of units). The smart meter will support bi-directional communications in order to automate meter-reading, improve grid management, prevent fraud, while improving demand response and paving the way for smart grids roll-out.
- In Denmark, the ongoing project "**DSO challenges from introduction of heat pumps**" has delivered a model to forecast the impact of mass uptake of heat pumps on LV grids and a power electronics algorithm to prevent overload of LV grid with many heat pumps.
- The ongoing Polish **Smart Torun** project also contributes to this functional objective with the distribution network automation and metering infrastructure deployment.
- The Spanish **PRICE** demonstration project has also contributed to this functional objective.
- With grid state estimation, the ongoing German **Proaktives Verteilnetz** project also contributes to this functional objective.

- The Austrian **Smart LV Grid – Heimschuh** project aimed at reducing connection costs for new DG installations (rooftop PV panels, private households) connected to the LV network by means of an On-Load Tap Changer (OLTC) installed at secondary substation to regulate voltage profile on LV network and increase capacity for the network to connect increasing amounts of PV at a reduced cost compared to using network reinforcements. Although the MV/LV transformer with OLTC was an existing technology, it had only been tested on a small scale, with a few other demonstration projects in Austria.

> Note: Projects marked with an * do not count TSOs nor DSOs on board. They have been provided by EASE members.

Assessment of the coverage of D7

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective D7:

D7a. Scientific:

- Information model aggregation (using IEC 61850)
- Data protection and cyber security methodologies
- Automatic control concepts for LV networks
- New control architecture for optimized operation
- New algorithms to identify system topology

D7b. Technology:

- Protection schemes and control systems for two-way power flows in LV
- Communication infrastructure supporting integration in LV network
- Communication interfaces on secondary substation level
- New operational scheduling tools that provide an indication of optimal grid configuration based on day-ahead forecasting and real network data to maximize certain objective functions (i.e. avoid network congestions, minimize network losses, reduce reverse power flows to TSO, etc.).
- Accurate frequency and voltage measurement devices adapted to the distributed needs of LV networks. They should have a small footprint (to be easily integrated) and low-cost (in view of the large number of measured points).
- Investigate and evaluate how the communication structure for AMM could be used as an information channel and for load control. Load control can be used to inform certain loads, on the basis of network capacity, when it is appropriate to increase or decrease consumption. This could also involve pricing.
- Develop remote control systems for LV network switches

D7c. Market:

- Recommendations on market rules and mechanisms for provision of ancillary services provided by LV network
- Recommendations on new market rules for islanding modes of operation
- Coordination between technical grid control and market based power balancing (e.g. technical virtual power plants vs. market based virtual power plant)

D7d. Social:

- New mechanisms to encourage prosumers for proper connection of DER (individual vs aggregation)
- Training of field operators to cope with new ways of addressing LV network reliability/services to the electric systems

Coverage assessment

Monitoring and control of LV networks are starting to be addressed by R&I projects, but many tasks are still untouched (by contrast with MV networks for which more advanced activities have been conducted, see next FO). Overall, it is considered that this FO is covered at about 30%.

14.2.2 D8 "Automation and control of MV networks"

Contributions from completed and ongoing projects to D8

From EU projects

- The set of novel Smart Grid solutions developed by the recently finished **DISCERN** project have provided DSOs with a greater understanding of innovative systems for the monitoring and control of LV and MV grids.
- The **FINSENY** project's objective was to demonstrate how open Future Internet Technologies could enable the European energy systems to combine adaptive intelligence with reliability and cost-efficiency. It identified the ICT requirements coming from the energy sector and identified the generic ICT platform suppliers, and prepared pan-European use case trials.
- The **Open Node** project, which designed and developed an Open Common Reference Architecture for the Secondary Substation Nodes (SSN), also contributed to this functional objectives.

From national projects

- The Spanish **PRICE** demonstration project implemented an MV/LV dispatch prototype and a Distribution Management System for DG.
- In Italy, the **ISERNIA** project demonstrated voltage regulation by remote control of DER and storage (Li-ion battery) using centralised control system, implementation network automation algorithms and demonstrated island detection devices.
- In Portugal, the **Storage in Evora** project developed automated support for grid management using specialized algorithms. Li-ion batteries were connected to the MV grid to improve voltage quality and energy management.

- In Austria, the **Smart Grid Judenburg** aimed at reducing connection costs for new DG installations (hydro plants) connected to the MV network. It also demonstrated deployment of centralised control system for regulating voltage profile by controlling reactive power control of hydro generators. Simulation studies were used to determine a reduced number of nodes for real time measurements from meter data and RTUs using GPRS communication system. The allocation of set points to the generators was accomplished using manual instructions, however, if required, further capacity for connecting more DG could be achieved by implementing an automated control.
- The Danish project "**Control and regulation of modern distribution system** has also contributed to this functional objective with a Normal Operation Optimization model and Abnormal/Emergency Operations Control Strategies.
- The ongoing French **Nice Grid** project seeks to optimize the operation of a network integrating a massive production of photovoltaic energy.
- In Poland, the ongoing **Smart Torun** project includes the extension of the MV network automation and the development of new AMI system functionality.
- In Germany, the "**Dezentrale Netzintelligenz**" project is using automated secondary substations to reduce/shorten outages in the grid and a regional controller to monitor and control a part of the MV grid.
- The Belgian project "**Smart grids: Back End Systems**" also contributed to this functional objective, with the following actions:
  - segmented roll-out of smart meters,
  - building of the necessary back-end systems for data acquisition and monitoring,
  - implementation of SCADA and Telecontrol for the network,
  - tests to avoid faults,
  - automatic load transfer (curtailment),
  - response to Blackouts,
  - optimal solution for several feeders,
  - connection actions at LV to improve the controllability of the network.
- The ongoing German **Smart Country** project has developed active voltage regulator for MV network to a product manufactured in series and implemented a wide area control in further primary substations.
- The other ongoing German **Smart Operator** project is aimed at the development of a Smart Operator working as an autonomous controlling and switching point in the grid, detecting and coordinating the electricity supply and demand, and coordinating the voltage quality. It directly controls the intelligent grid components - developed inside the project: local grid transformers, LV circuit breakers, battery storages, E-mobility charging stations and via another interface, the "Home Energy Controller" smart domestic appliances of households.
- The ongoing Italian **Puglia Active Network** project is developing active management of MV network.
- With grid state estimation, the ongoing German **Proaktives Verteilnetz** project also contributes to this functional objective.

Assessment of the coverage of D8

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective D8:

D8a. **Scientific**:

- Information model aggregation using IEC 61850
- Data protection and cyber security methodologies
- Automatic control concepts for MV networks
- New control architecture for optimized operation in the close to real time process
- New algorithms to optimize system topology
- New concepts for voltage control and congestion management in the MV network
- Improved generation and load forecasting tools for appropriate MV control
- New tools for MV/LV power system stability analysis

D8b. **Technology:**

- Network management optimization thanks to greater knowledge of power flows, loads and power quality parameters
- New operational scheduling tools that provide an indication of optimal grid configuration based on day-ahead forecasting and real network data to maximize certain objective functions (i.e. avoid network congestions, minimize network losses, reduce reverse power flows to TSO, etc.).
- New actuators (e.g. switches) and new sensors (e.g. fault detectors, voltage and current sensors) for MV network
- Bi-directional and always-on communication systems
- Protection schemes and control systems for two-way power flows in MV
- Communication infrastructure supporting integration in MV network
- Communication interfaces at smart substation level
- Develop remote control systems for MV network switches
- Automatic fault clearing procedures that will include automatic power restoration of the healthy sections
- Active and reactive power management techniques for MV generators and loads
- Dedicated ICT infrastructures for MV network management
- Decision tools for MV refurbishment/revamping
- Improved fault localization, isolation and management processes

D8c. **Market:**

- Recommendations on market rules and mechanisms for provision of ancillary services (e.g. reactive power provision) provided by MV network
- Coordination between technical grid control and market based power balancing (e.g. technical virtual power plants vs. market based virtual power plant)

D8d. Social:

- Training of field operators to cope with new ways of addressing MV network reliability/services to the electric systems

Coverage assessment

Most of the tasks in this FO have been tackled. However some remain almost untouched, regarding for instance data protection, cyber security methodologies, control architecture for optimized operation close to real time, algorithms to optimize system topology and automatic fault clearing procedures. By contrast, automatic control concepts for MV networks and related technology-oriented activities like network management optimization and communication infrastructure supporting integration in MV network, are well developed.

Overall, it is considered that half (50%) of the tasks in this FO are covered.

14.2.3 D9 "Network management methodologies for network operation"

Contributions from completed and ongoing projects to D9

From EU projects

- The recently finished **IGREENGrid** project has also contributed to this functional objective. A repository to collect operating data from different sources has been set up.
- The ongoing **Life Factory Microgrid*** project is developing strategies for a microgrid with 3 storage technologies and V2G. This microgrid will test and validate different energy management strategies, generating 160,000 kWh/year free of greenhouse gases, avoiding at the same time the emission of 96 Tm of CO_2 thanks to the management of dispatchable loads and the use of electric vehicles. The project also aims at offering ancillary services (voltage and frequency control) to the distribution grid, contributing to grid stability, and reducing the need of generation reserve capacity (gas combined cycles, fuel, or carbon generators).
- The ongoing **UpGrid** project is contributing to this functional objective, in particular with the development of functional specification of LV dispatch and the deployment of tools to support LV operation of field crews.

From national projects

- The Spanish **ATENEA Microgrid*** project developed of a microgrid for industrial applications that operates in on- and off-grid modes and is used as test bench for new technologies, generation, storage and control systems. A Microgrids & Energy Management Strategies Simulation Platform has been developed to simulate, control and operate the plant and the whole system is part of the methodology to design and develop microgrids proposed by the project.
- The Danish **CHPCOM** (Combined Heat and Power Communication) project analysed, developed and demonstrated through practical experience, the use of international Smart Grid related data communication standards, specifically IEC 61850 and IEC 62351 for IT security. CHPCOM focused on distributed generation, specifically CHPs and their business partners. The main project achievement consists in TSO/DSO system integration communications, including security keys, for CHP power plant management.
- The French **VENTEEA** project also contributed to this functional objective.

- In France, the ongoing **SoGrid** project is developing a comprehensive approach aiming at developing a full powerline communications (PLC) chain over power distribution grids (LV and MV network).
- The ongoing French **Smart Grid Vendée** project has implemented consumption and generation forecasting tools at primary substation scale, thus contributing to this functional objective.
- In France, the roll-out of the **Linky** smart meters is ongoing (35 million of units). The smart meter will support bi-directional communications in order to automate meter-reading, improve grid management, prevent fraud, while improving demand response and paving the way for smart grids roll-out.
- The completed **Storage in Evora** project and the ongoing German **Proaktives Verteilnetz** project also contribute to this functional objective.

Note: Projects marked with an * do not count TSOs nor DSOs on board. They have been provided by EASE members.

Assessment of the coverage of D9

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective D9:

D9a. Scientific:

- (red) Opportunities for local DC networks
- (yellow) Real time appraisal of status of DSO network
- (yellow) Novel tools for observability
- (yellow) Improvement of forecasts for PV power (1 hour, 3 hours, 12 hours, 1 day, 3 days) for scheduling of conventional power plants taking into account the different technologies (flat panels, concentrated PV) and the different possibilities (satellite, sky cameras, etc...)
- (yellow) Tools for reliability assessment

D9b. Technology:

- (red) IT solutions for real time simulation tools that are cheap and reliable

D9c. Market/social:

- (yellow) Training tools for emergency management (how do you coordinate in emergency)
- (yellow) Innovative capacity building methods to enable the mission shift of DSOs

Coverage assessment

Within this FO, opportunities for local DC networks and IT solutions for real-time simulation tools have not been addressed, while other tasks have been partially covered. We assess that around one third (33%) of this FO has been covered so far.

14.2.4 D10 "Smart metering data utilisation"

Contributions from completed and ongoing projects to D10

From EU projects

- The **ADDRESS** project targeted the active participation of small and commercial consumers in power system markets and provision of services to the different power system participants. With a database of questionnaires to validate social acceptance and customers' commitment, the project has contributed to this functional objective. The developed platforms and mechanisms should allow DSOs and end users to use smart metering data to improve energy efficiency and demand management.
- The **ADVANCED** project aimed at increasing the understanding on how to deploy efficiently Active Demand (AD). A target matrix was developed to know what should be measured and how. This matrix explains which are the variables to take into account to build large scale AD programs. Qualitative and quantitative surveys were carried out.
- The **METER ON** project worked on supporting the development and deployment of advanced metering infrastructures in Europe. In particular exchange and interaction were carried out with the most representative projects carried out within the smart metering field in Europe (21 EU projects analysed – 15 countries covered). After the end of the project, a set of recommendations to the most important stakeholders and a toolkit to manage economic data were delivered.
- The ongoing **UpGrid** project contributes to this functional objective, notably through the improvement of quality of service (QoS) to customers.
- The **Open Node** project and the ongoing **TILOS** project are also contributing to this functional objective.

From national projects

- The ongoing French **Nice Grid** project, by involving consumers in energy efficiency in order to solve local energy constraints, contributed to this functional objective.
- The ongoing French **SOLENN** project contributes to manage electricity demand and to secure power supply for consumers and communities in the French region of Britany. The project has already organized the roll-out of 10,000 smart meters and consumers' recruitment. It also intends to provide new tools using curtailments via smart meters avoiding load shedding near real time operations.
- In France, the roll-out of the **Linky** smart meters is ongoing (35 million of units). The smart meter will support bi-directional communications in order to automate meter-reading, improve grid management, prevent fraud, while improving demand response and paving the way for smart grids roll-out.
- The ongoing German **Proaktives Verteilnetz** project also contributes to this functional objective.

Note: Projects marked with an * do not count TSOs nor DSOs on board. They have been provided by EASE members.

Assessment of the coverage of D10

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective D10:

D10a. Scientific:

- Large data mining processes
- Data protection tools (access, authentication, encryption)
- Distributed online analytical stream processing system with spatial and temporal dimensions
- Development of mathematical approaches to describe consumption behaviour
- Mathematical models of the network using data from smart meters

D10b. Technology:

- Standardisation of data models
- New IT solutions to process large data streams (cooperation with the bank industry)
- Data publishing systems
- Data storing systems (E.g. web dashboards for data managing, etc.)
- Ageing and lifespans of respective components (smart meters, communication infrastructures, grid)

D10c. Market:

- New business models for providing new energy services
- Recommendations for new regulations to provide personalized services and tariffs to individual customers
- Recommendations for data privacy and data use by the different stakeholders of the electric system

D10d. Social:

- Best practices for ensuring data privacy and customer acceptance

Coverage assessment

The majority of the tasks in this FO have been tackled (slightly addressed for some of them). However, the most advanced ones remain almost untouched, namely: large data mining processes, data protection tools, mathematical models of the network using data from smart meters, new IT solutions to process large data streams, data publishing systems, ageing and lifespans of components.

We assess that this FO is being covered at around 30%.

14.3 Recommendations for the new R&I roadmap

As for Cluster 2, the R&I activities specified in the four FOs have been addressed in a significant number of projects, which has resulted in a partial coverage of Cluster 3 (under 40%). However, as previously observed in Cluster 2, there are many missing knowledge blocks for each FO. In D10 (Smart metering data utilisation), there are no monitored R&I activities related to big data applications and cyber security when it comes to data privacy for end-users for instance. In D7 (Monitoring and control of LV network) and D8 (Automation and control of MV networks), there are no (or very few) R&I activities related to data protection and cyber security methodologies, new algorithms to optimize system topology and optimized operation close to real time. There is also an unbalance between these two FOs: automation and control of LV networks still remains an issue whereas many hardware/software solutions have been demonstrated and deployed at MV level.

For the new roadmap, it is recommended to keep Cluster 3 and to expand the scope of R&I activities with one additional FO covering cybersecurity issues, i.e. "Cyber security (system approach)" so as to map and appraise cyber-security issues for the distribution grids, and propose solutions to mitigate these risks, ideally in an integrated manner in order to solve the problem in a systematic way. It is also suggested to extend the scope of D10 by including all R&I activities dealing with big data topics and rename D10 "Smart metering data processing **and other big data applications**". It is advised to delete D9 (Network management methodologies for network operation) and distribute the associated R&I activities in other existing FOs dealing with the integration of intermittent generation units (D3 and D4), the new loads (D6) as well as the monitoring and control of the LV and MV networks (D7 and D8). For the other FOs, the remaining gaps in terms of coverage should be filled in by re-specifying the non-covered R&I activities[20].

15. Distribution Cluster 4: Network planning and asset management

Cluster 4 is organized into 2 Functional Objectives: D11 and D12.

D11 New Planning approaches for distribution networks
D12 Novel approaches to asset management

15.1 Features of achievements in Cluster 4

15.1.1 Descriptive features

Categorization in functional objectives

The graphs below characterize the completed (8 achievements) and expected (4 achievements) achievements of projects' results of cluster 4, the purple colour was dedicated to Cluster 4. As for cluster 1 some rounding errors explains the minor consistency gap among the three graphs.

[20] As explained for Cluster 1, it is also recommended to specify the R&I activities of each FO in terms of cross-cutting challenges: upgrading of the network, Power system flexibility, Power system reliability, ICT and digitalization, Market design, and DSOs regulatory environment.

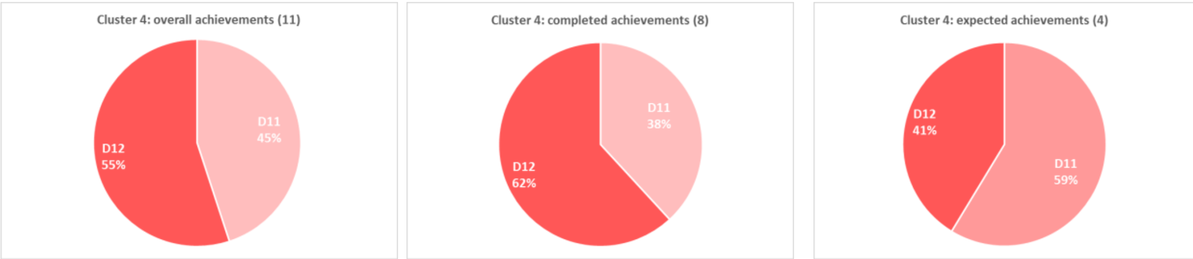


Figure 64: The portfolio of achievements in Cluster 4 (left: overall; middle: completed; right: expected)

Highlights:

- The number of achievements of the cluster is rather low but Cluster 4 is clearly subject to evolutions when comparing the respective share of completed and expected achievements.
- The share between D11 and D12 is equilibrated when considering all achievements but conclusions are opposite when considering only the completed or the expected ones.

Typology of achievements in Cluster 4

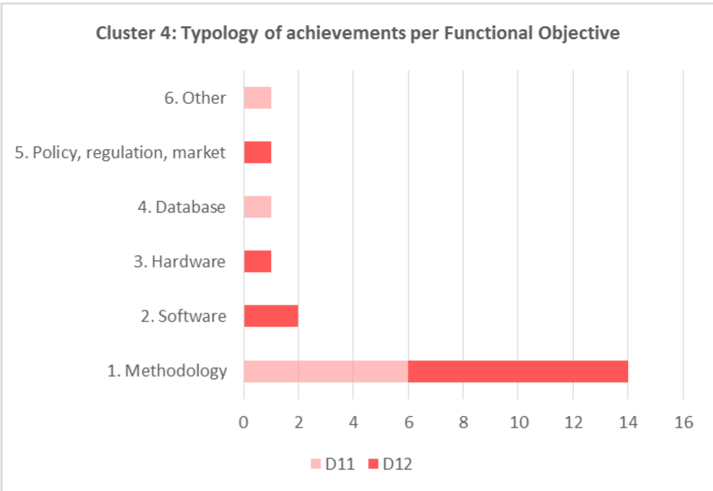


Figure 65: Typology of achievements in Cluster 4 in distribution

Highlights:

- The majority of achievements in this cluster consists in methodologies.
- The statement is valid for both completed and expected achievements.

Evolution of the maturity of achievements in Cluster 4

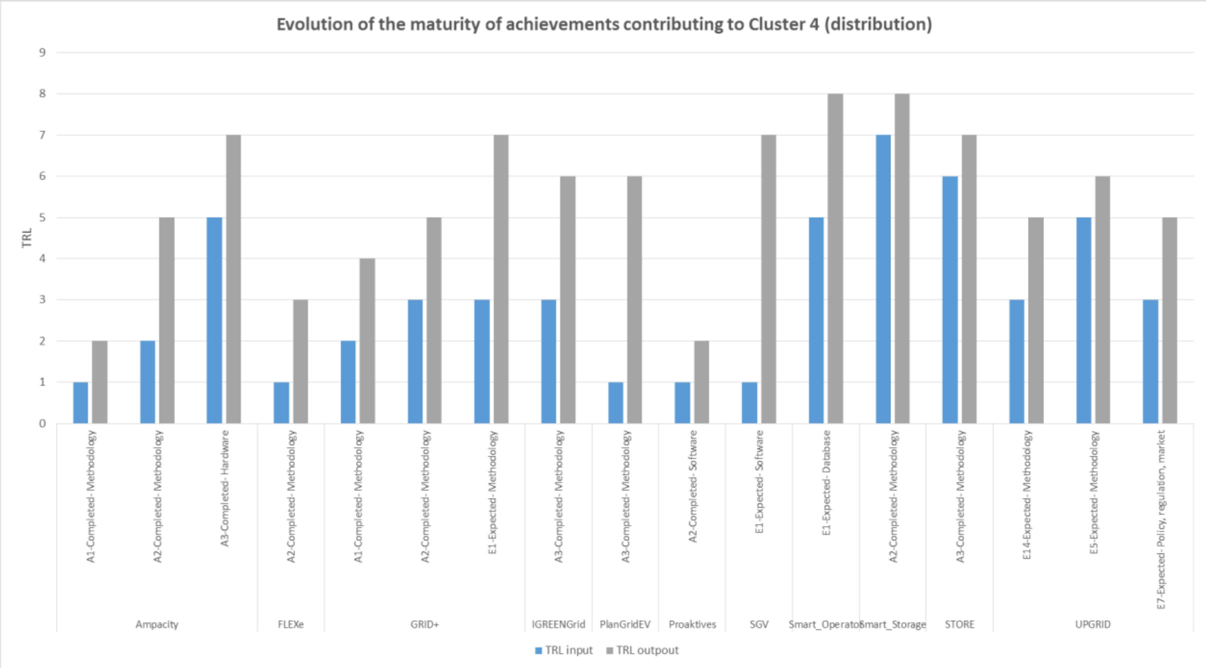


Figure 66: Evolution of the maturity of achievements contributing to Cluster 4 of distribution measured in TRL units

Highlights:

- The same remarks as for the previous clusters on the average maturity gain applies here.
- Maturity steps vary from 1 (for achievements in Ampacity, Proaktives, Smart_Storage, Store, UpGrid) to 6 (Smart Grid Vendée).

15.1.2 Projective features (next steps)

From the data collected in Cluster 4 for each functional objective (D11, D12) one could formulate the following highlights:

- Cluster 4 is less populated than previous distribution clusters and general statements are hardly to be drawn.
- However both in D11 and D12 formulated next steps are quite balanced.

Achievement in D11	Status	Further Research	Further Development	Demonstration	Deployment
Ampacity-A1	Completed			X	
FLEXe-A2	id	X		X	
GRID+-A2	id	X			
IGREENGrid-A3	id		X	X	
Smart_Operator-E1	Expected				X

Figure 67: Next steps as seen by project coordinators in D11

Achievement in D12	Status	Further Research	Further Development	Demonstration	Deployment
Ampacity-A2	Completed			X	
Ampacity-A3	id		X		X
GRID+-A2	id	X			
Proaktives-A2	id		X	X	
Smart_Storage-A2	id		X		
STORE-A3	id				X
UPGRID-E14	Expected	X	X	X	
UPGRID-E5	id	X	X	X	

Figure 68: Next steps as seen by project coordinators in D12

15.2 Coverage analysis of Cluster 4 with past and ongoing projects

15.2.1 D11: "New Planning approaches for distribution networks"

Contributions from completed and ongoing projects to D11

From EU projects

- The recently finished **PlanGridEV** project have designed novel planning rules for the optimal integration of EVs.
- The **IGREENGrid** and the **metaPV** projects have also contributed to this functional objective.

From national projects

- The recently finished German **Ampacity** project examined the technical suitability of superconducting technologies (cable and current limiter) in the distribution area. A 10-kV high temperature superconductor (HTS) cable with integrated superconducting current limiter (SSB) has been assessed as an alternative to a 110 kV cable system.
- The ongoing Finnish **FLEXe** project has delivered a methodology to compare costs and benefits of flexibility options in future systems with high shares of variable generation.
- The ongoing German **Smart Operator** project aims at delivering a database for improved future grid planning.

Note: Projects marked with an * do not count TSOs nor DSOs on board. They have been provided by EASE members.

Assessment of the coverage of D11

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective D11:

D11a. Scientific:

- New network modelling and stochastic optimisation tools
- Intelligent network planning

- Simulation tools giving indication of DSOs of where to connect new generators on the basis of different criteria

D11b. Technology:

- System integration of new power technologies and impact on network planning
- Active distribution network
- Dynamic rating
- Micro grids
- Standardisation of technologies and infrastructures

D11c. Market/social:

- Streamlined permitting procedures
- New ways of preventing/minimising public opposition to network investments, integrating if appropriate in decision processes
- Organisation of public consultation

D11d. Social:

- New mechanisms to encourage clients in the perception of benefits and repercussions of new systems

Coverage assessment

Most of the scientific and technology-oriented tasks have not been addressed yet. In terms of social activities, mechanisms to facilitate the positive perception of new systems have not been developed so far. Overall we consider that 20% of this FO have been covered.

15.2.1D12 "Novel approaches to asset management"

Contributions from completed and ongoing projects to D12

From EU projects

- The ongoing **UpGrid** project is contributing to this functional objective.

From national projects

- The ongoing French **Smart Grid Vendée** project is also contributing to this functional objective.
- With experience feedback on operation of LV grid-connected battery, the ongoing Dutch **Smart Storage** project contributes to this functional objective.
- In Spain, the objective of the **STORE*** project was to demonstrate the technical and economic viability of large-scale energy storage systems (electrochemical storage, flywheel, ultracapacitor) in island environments. Cost reduction was observed for of electrical system in islands.
- The ongoing German **Proaktives Verteilnetz** project also contributes to this functional objective.

- The recently finished German **Ampacity** project examined the technical suitability of superconducting technologies (cable and current limiter) in the distribution area. Field tests were carried out in real grid operation, proof of reliable working both in normal operation and also in fault cases.

> Note: Projects marked with an * do not count TSOs nor DSOs on board. They have been provided by EASE members.

Assessment of the coverage of D12

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective D12:

D12a. Scientific:

- Ageing modelling under real network conditions, with the arrival of DER, EV, and storage
- Change in asset management with new environment (DER, AD, EV, storage, etc.)
- Conditional and risk-based maintenance models
- Real time compensation system to avoid expensive grid upgrades
- Algorithms to identify system topology
- Enhancing efficiency in day-to-day grid operation
- Appropriate levels of operational control vs. planning measures

D12b. Technology:

- How to provide conditional and risk-based maintenance with new IT solutions
- New IT systems and solutions that make use of large new quantities of data and are used for conditional and risk-based maintenance purposes
- New systems for field components wear and tear monitoring in order to "predict" failures
- Oil level in transformer oil pits and SF6 level in switchgear improving maintenance effectiveness and reduces environmental risks

D12c. Market/Social:

- Capacity building methodologies including :
    - Methods for training of operators
    - Innovative methodologies to educate maintenance operators to new digital era
    - Innovative methods for training of new required skills
    - Education issues of operators
    - Change of skills of operators
    - Change of technology era from Analogue to Digital
    - Active customer with impact on energy efficiency

<u>Coverage assessment</u>

Some tasks in this FO have not been addressed so far. In terms of scientific activities, ageing modelling under real network conditions, change in asset management with new environment and real-time compensation system remain almost untouched. Regarding technology-oriented activities, big data solutions for conditional and risk-based maintenance purposes and systems for failure prediction have not been tackled. Other tasks have been addressed but the observed coverage is partial. We therefore consider that around 30% of the FO has been covered so far.

15.3 Recommendations for the new R&I roadmap

Contrarily to the previous clusters, the coverage of Cluster 4 is rather low (25%). The low coverage of D12 (20%) shows that there is an urgent need to develop the next generation of planning tools able to account for the fast evolving environment of distribution networks (storage, active demand, new loads, power electronics, etc.). In addition, DSOs still need to deploy new IT systems and solutions that make use of large quantities of data for conditional and risk-based maintenance purposes.

It is recommended to keep Cluster 4 as it is (with two FOs) since both planning and asset management issues need to be further investigated. An emphasis should be put on the need for new planning approaches and simulation environments able to cope with the full complexity of the distribution networks (the title of D12 could be modified, e.g. "New planning approaches **<u>and tools</u>**"). For the other FOs, the remaining gaps in terms of coverage should be filled in by re-specifying the non-covered R&I activities[21].

16. Distribution Cluster 5: Market design

Cluster 4 is organized into 1 Functional Objective: D13.

D13. Novel approaches for market design

16.1 Features of achievements in Cluster 5

16.1.1 Descriptive features

<u>Categorization in functional objectives</u>

The graphs below characterize the completed (16 achievements) and expected (3 achievements) achievements of projects' results of cluster 5. There is only one Functional Objective D13 in that cluster.

[21] As explained for Cluster 1, it is also recommended to specify the R&I activities of each FO in terms of cross-cutting challenges: upgrading of the network, Power system flexibility, Power system reliability, ICT and digitalization, Market design, and DSOs regulatory environment.

Figure 69: The portfolio of achievements in Cluster 5 (left: overall; middle: completed; right: expected)

Highlights:

- The diagrams have been reported for completeness sake, the only meaningful information is the size of the sample: 16 completed achievements and 3 expected achievements.

Typology of achievements in Cluster 5

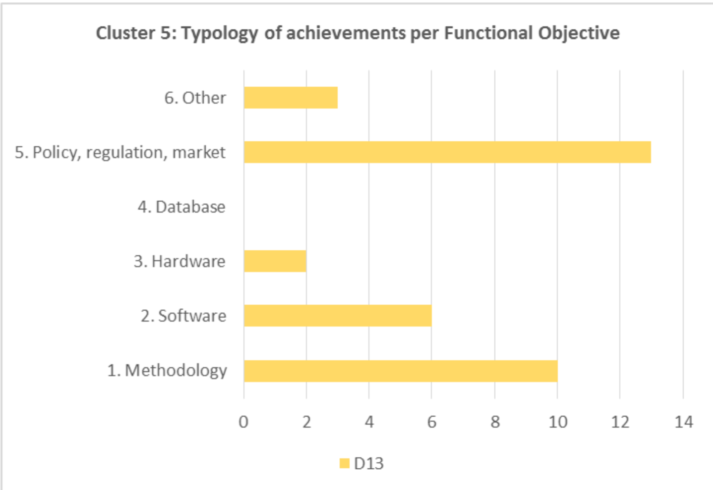


Figure 70: Typology of achievements in Cluster 5 in distribution

Highlights:

- The Cluster achievements is mainly composed by "policy, regulation, market" type followed by methodology type achievements: this split is specific to the Market Design cluster in distribution
- There are however some differences with the typology of the Cluster 4 Market design in transmission (see 0) in which the policy, regulation, market topics were not so developed.

Evolution of the maturity of achievements in Cluster 5

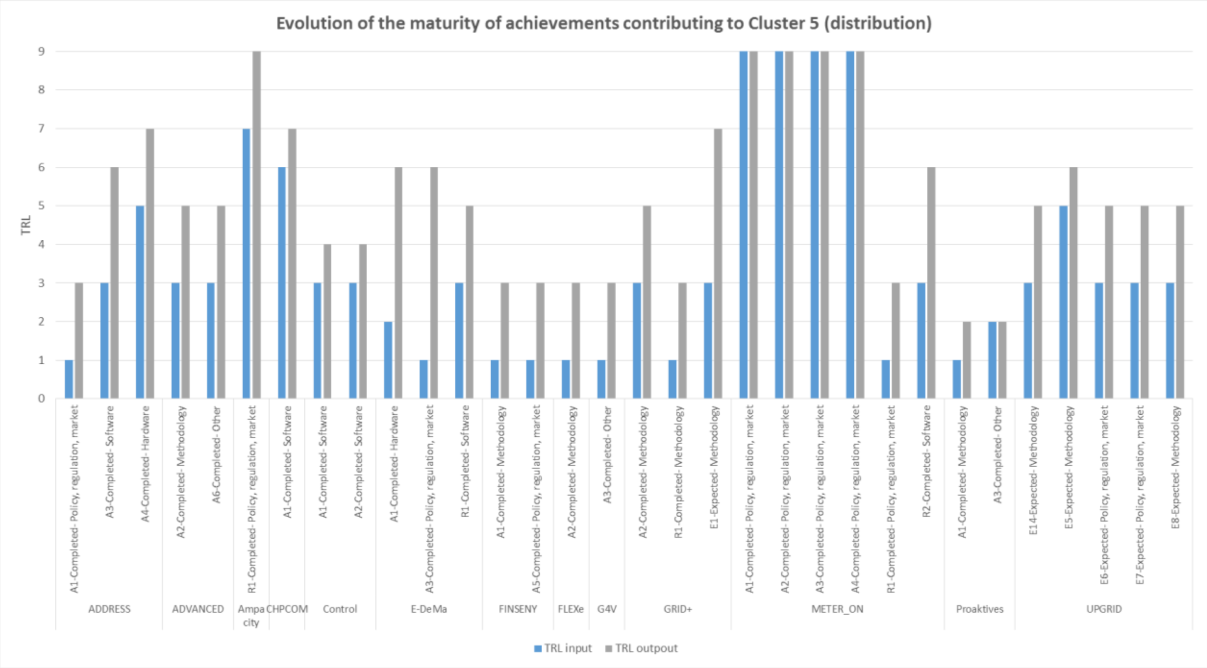


Figure 71: Evolution of the maturity of achievements contributing to Cluster 5 of distribution measured in TRL units

Highlights:

- The variability of maturity gains in Cluster 5 appears as lower as the one observed in the previous clusters.
- No increment is however observed for some achievements in METER_ON (A1 to A4) and one achievement in Proaktives: this might result from an interpretation bias in the questionnaire.

16.1.2 Projective features (next steps)

From the data collected in Cluster 5 in functional objective D13 one could formulate the following highlights:

- Next steps include in a quite balanced way the downstream routes that are further development, demonstration and deployment, further research option being less represented
- Next steps for Expected achievements are only mentioned by the UPGRID project.

Achievement in D13	Status	Further Research	Further Development	Demonstration	Deployment
ADDRESS-A1	Completed	X	X	X	
ADDRESS-A3	id	X	X	X	
ADDRESS-A4	id		X	X	
ADVANCED-A6	id	X	X	X	
CHPCOM-A1	id				X
Control-A1	id		X	X	
Control-A2	id		X	X	
E-DeMa-A1	id			X	X
FINSENY-A5	id	X	X	X	
FLEXe-A2	id	X		X	
GRID+-A2	id	X			
Proaktives-A1	id		X	X	X
Proaktives-A3	id	X	X	X	
TILOS-A2	id	X			
PlanGridEV-R1	id				X
UPGRID-E14	Expected	X	X	X	
UPGRID-E5	id	X	X	X	
UPGRID-E6	id	X	X	X	
UPGRID-E8	id	X	X	X	

Figure 72: Next steps as seen by project coordinators in D13

16.2 Coverage analysis of Cluster 5 with past and ongoing projects

16.2.1 D13: "Novel approaches for market design"

<u>Contributions from completed and ongoing projects to D13</u>

From EU projects

- The **ADDRESS** project developed a market design proposal to facilitate demand side management (market-based proposals and economic analysis). The developed platforms and mechanisms should allow DSOs and end users to use smart metering data to improve energy efficiency and demand management.
- The **ADVANCED** project aimed at increasing the understanding on how to deploy efficiently Active Demand (AD). Validated and operationalised KPIs both at pilot and household level were produced, to measure in a standardized way:
  - energy savings,
  - consumption flexibility,
  - monetary savings,
  - customer satisfaction.
- The **FINSENY** project analysed different scenarios and provided a cross-industry standardisation strategy in order to demonstrate how open Future Internet Technologies could enable the European energy systems to combine adaptive intelligence with reliability and cost-efficiency.
- The **Grid for Vehicles (G4V)** project analysed the impact and possibilities of a mass introduction of electric and plug-in hybrid vehicles on the electricity networks in Europe. The project demonstrated that the revenues from V2G (ancillary services) with battery discharge are nowadays insignificant, but future market development may open new opportunities.
- The **METER ON** project was focused on the development and deployment of advanced metering infrastructures in Europe. Were achieved in particular:
  - Exchange and interaction among the most representative projects carried out within the smart metering field in Europe (21 EU projects analysed – 15 countries covered);
  - 360 degree analysis covering all the relevant aspects of smart metering;
  - Analysis of viable business models for the implementation of smart metering roll-out;

   – Adaptation of the project workflow based on the expectations of the stakeholders' community, including the analysis of compliance to EU/148/2012 minimum functionalities and viable Business Models.

- The main objective of the recently finished **PlanGridEV** project has designed new planning rules and operational principles for the optimal integration of EV, and provided a roadmap and recommendations for innovation, regulation and policies in this area.
- The ongoing **UpGrid** project is contributing to this functional objective, in particular thanks to the identification of investment alternatives for UpGrid innovative concepts, the assessment of optimal business models for market participants, and societal research on the socio-economic impact of Smart Grid solutions on the demo regions.
- The policy recommendations that will be delivered by the ongoing **TILOS** project will also contribute to this functional objective, notably in terms of ancillary services provided by battery storage.

From national projects

- The German **E-DeMa** project analysed processes for the integration and control of DER. A Marketplace system, including all relevant market roles, was developed and operated, together with innovative products and end customer tariffs, and new value chains and business processes were tested.
- The Danish project "**Control and regulation of modern distribution system** has also contributed to this function objective with a Normal Operation Optimization model and Abnormal/Emergency Operations Control Strategies.
- With a methodology to compare costs and benefits of flexibility options in future systems with high shares of variable generation, the ongoing Finnish **FLEXe** project contributes to this functional objective.
- The completed Danish **CHPCOM** project as well as the German recently finished **Ampacity** and ongoing **Proaktives Verteilnetz** projects also contribute to this functional objective.

Note: Projects marked with an * do not count TSOs nor DSOs on board. They have been provided by EASE members.

Assessment of the coverage of D13

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective D13:

D13a. Scientific/Technology:

Simulation of new market designs in order to assess benefits and costs of the studied scenarios based on innovative numerical simulation platforms which go beyond the existing ones (modelling in particular demand response and storage)

D13b. Market/Regulatory:

New business models for providing new energy services and recommendation of new tariff systems

- Regulatory recommendations to support new electric market penetration (e.g. EV)
- New market rules to continue promoting the deployment of distributed generation based on renewables (replacing feed-in tariffs)
- Coordination between technical grid control and market based power balancing (e.g. technical virtual power plants vs. market based virtual power plant)
- Recommendations to reduce possible commercial and regulatory barriers that limit smart grids solutions
- Recommendations on new market rules for islanding modes of operation
- Assessment of possible impacts and benefits of new market models according to different locations or timeframe
- Recommendations of appropriate incentives to motivate new players to participate in energy markets
- Recommendations for valuation of ancillary services brought by SDER

D13c. Social:

- Understanding customer behaviour at district level with interdependence between several activities

Coverage assessment

Most of the projects monitored are addressing market and regulatory tasks. We therefore consider that D13b already tackled in general, but only partially covered. By contrast, in terms of scientific tasks, no innovative simulation platform has been developed to assess market designs at distribution level. Regarding social aspects, the understanding of customer behaviour at district level has not been addressed.

We therefore consider that around 40% of this FO has been covered.

16.1 Recommendations for the new R&I roadmap

It is recommended to remove Cluster 5 since market design is a cross-cutting challenge impacting most of the activities of the DSOs. As explained for Cluster 1, R&I activities of each FO should be specified in terms of cross-cutting challenges: upgrading of the network, Power system flexibility, Power system reliability, ICT and digitalization, **Market design**, and DSOs regulatory environment. Therefore, the activities of Cluster 5 should be distributed in each FO of the new roadmap when relevant in the *Market Design* cross-cutting challenge.

17. Conclusion for distribution

Contrarily to the transmission clusters, four of the distribution clusters have been kept (Cluster 5 has been deleted since it is a cross-cutting challenge) in the new roadmap[22]. Few FOs have been added and deleted: the contents of the remaining FOs have been modified based upon the respective estimated coverages. A second dimension has been included in the description of the distribution network R&I activities for each FO: they have been specified in terms of cross-cutting challenges[23].

In summary, the previous Clusters 1 to 5 have been modified as follow[24]:

- **EXPAND** Cluster 1 "Integration of smart customers" by enlarging the scope of the FO dealing with AD so as to foster end-consumers' participation in the retail electricity markets, and enable the provision of system services for network flexibility.
- **EXPAND** Cluster 2 "Integration of DER and new uses": **CREATE** one additional FO covering the connections with other energy networks and enlarge the scope of the FO related to the integration of EVs (electrification of -public- transport).
- **EXPAND** and **INTEGRATE** Cluster 3 "Network Operations": **CREATE** one additional FO covering cybersecurity issues, i.e. "Cyber security (system approach)" and **EXPAND** the scope of R&I activities related to smart meters by including all R&I activities dealing with big data topics, i.e. "Smart metering data processing and other big data applications". **DELETE** the FO dealing with "Network management methodologies for network operation" and **INTEGRATE** the associated R&I activities in other existing FOs.
- **EXPAND** Cluster 4 "Network planning and asset management" by enlarging the scope of the FO related to planning.
- **REMOVE** Cluster 5 "Market design", since market design is a cross-cutting challenge impacting most of the activities of the DSOs, and **INTEGRATE** the activities of Cluster 5 in each FO of the new roadmap when relevant in the *Market Design* cross-cutting challenge."

[22] D2.6, *Final 10 year EEGI R&I roadmap covering 2016-25*, July 2016 (www.gridplusstorage.eu).

[23] Cross-cutting challenges: upgrading of the network, Power system flexibility, Power system reliability, ICT and digitalization, Market design, and DSOs regulatory environment.

[24] Five types of modifications/updates are made: **SPLIT, REMOVE, EXPAND, INTEGRATE, and CREATE.**

Part III JOINT TSO & DSO ACTIVITIES

18. The portfolio of R&I projects in relation with the TSO/ DSO activities of the Roadmap

18.1 Assumptions ruling the portfolio selection

The same five assumptions as the ones presented in section 4.1 (consistency with the roadmap, recent, funding, budget, explicit intention for further exploitation) have been used. As a result a representative sample a projects among all recent R&I transmission/distribution projects was built.

> Methodological issue:
>
> It should be noticed that some projects may appear in Part I and Part II or in Part II and Part III or in Part I and in Part III. This apparent double counting is due to the fact that some the sources of information for projects at the interface of transmission and distribution may be ENTSO-E, EDSO or EASE.

18.2 The portfolio of transmission/distribution projects

Twenty-six (26) R&I projects have been identified and are used for the coverage analysis. They represent a total budget of approximately 264 million Euros for a public funding of 122 million Euros, cf. Table 14[25].

Table 8: Portfolio of projects in transmission/distribution

61850 substation	Belgium East Loop	EnergyLab	NiceGrid	Smart_grids
ADVANCED	**BESTPATHS**	Estfeed	PROBA	**SmartNet**
AES_Netherlands	Cell Controller	GREDOR	**RealValue**	
AES-KBS	CHPCOM	**GridTech**	**SAFEWIND**	
Alia2	DSR	**INCREASE**	**SECONOMICS**	
ATENEA	E-DeMa	**INGRID**	Smart Grid Vendée	

> NB: As explained in the section 3.2, id codes were used to abbreviate projects' names all along the document.
>
> The colour code for each project acronym corresponds to the source that has provided the filled-in questionnaires (**EU projects** are displayed in bold text while projects funded at national level are displayed in plain text):

EDSO	EASE	ENTSO-E

[25] These figures do not represent the exact total budget and the corresponding public funding since for some projects some of the data is missing (for some projects the budget figure is available and not the corresponding public funding and vice-versa).

19. Joint TSO/DSO cluster

There is a unique cluster gathering all these activities: the joint TSO/DSO cluster is organized into five Functional Objectives: TD1, TD2, TD3, TD4, TD5.

TD1. Increased observability of the distribution system for transmission network management and control
TD2. The integration of demand side management at DSO level into TSO operations
TD3. Ancillary services provided through DSOs
TD4. Improved defence and restoration plan
TD5. Methodologies for scaling-up and replicating

An overview in terms of achievements is first given overall, then in a second stage a view per functional objective is proposed.

19.1 Descriptive features of achievements in the joint TSO/DSO cluster

19.1.1 Overview of achievements in the joint TSO/DSO cluster

42 achievements have been counted in the joint TSO/DSO cluster with the following split in 29 that have been completed and 13 expected.

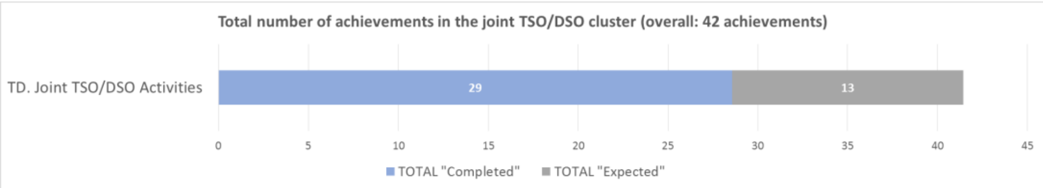


Figure 73: Number of achievements in the joint TSO/DSO cluster

Most of achievements in the cluster consists in software or in methodologies.

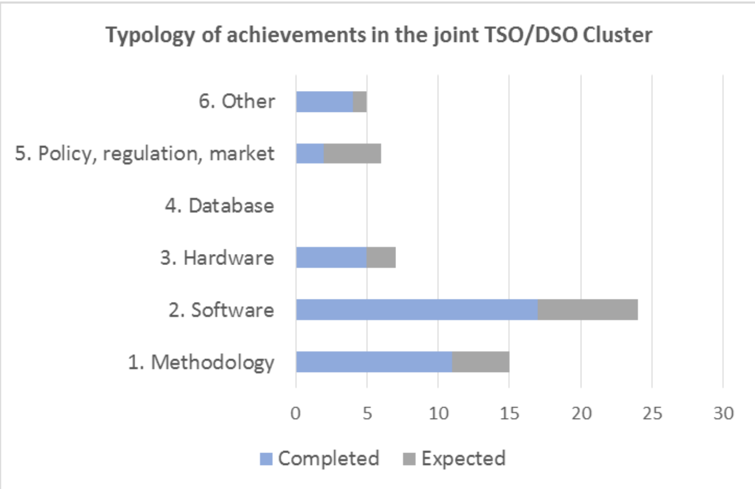


Figure 74: Typology of achievements in the joint TSO/DSO cluster

> NB: It should be noted that achievements that contribute to 2 or more FO have been counted separately in each FO which explains some differences in the sums.

When considering the impact of the project in terms of "maturity improvement", an average gain of about 2.5 is observed (next figure, left): this gain is slightly higher for the completed achievement than for the expected ones (in grey, next figure, right).

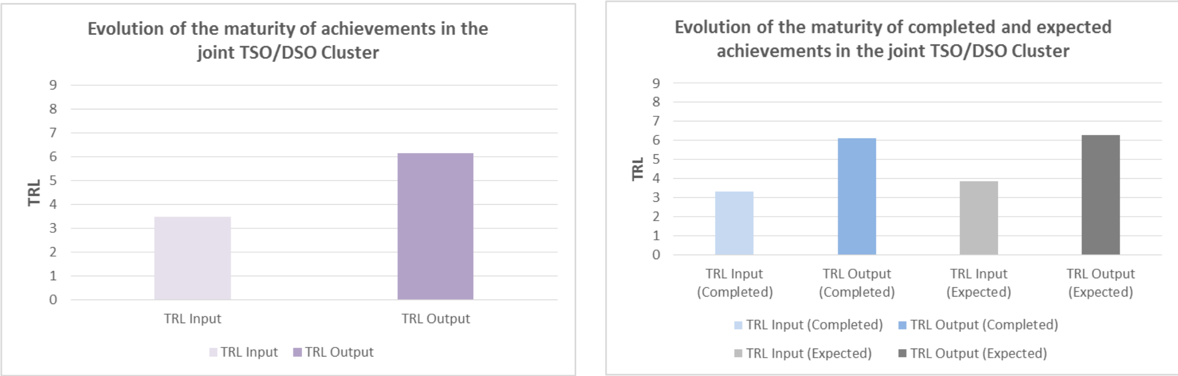


Figure 75: Evolution of the maturity of achievements measured in TRL units (left: average; right: completed in blue and expected in grey)

19.1.2 The joint TSO/DSO cluster per Functional Objective

A breakdown of achievements in this joint cluster in terms of Functional Objectives is depicted in the figures below using our convention (left=middle+right). There are clear evolutions: TD1 and TD5 shares are reduced significantly when moving from the completed to the expected achievements while the relative share of TD3 achievements is more than doubled.

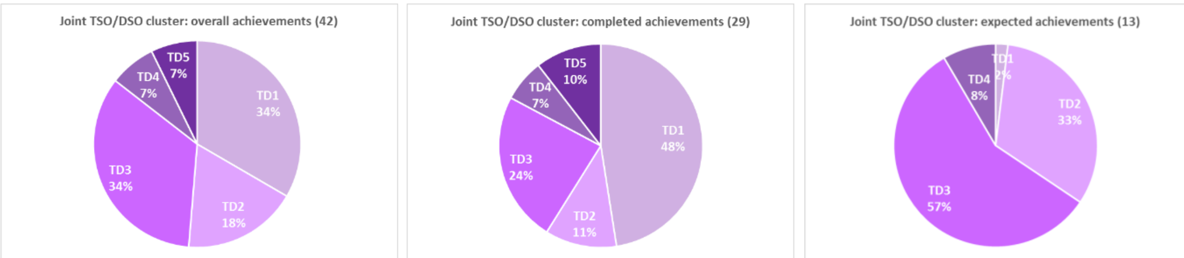


Figure 76: The portfolio of achievements in the joint TSO/DSO cluster (left: overall; middle: completed; right: expected)

The dominance of software and methodologies in this cluster is confirmed by another view of the typology of achievements.

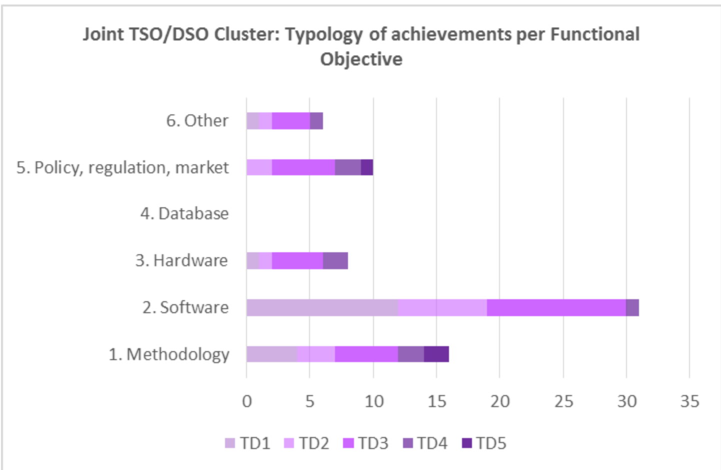


Figure 77: Typology of achievements per Functional Objective in the joint TSO/DSO cluster.

The detailed analysis is completed by the view detailing the TRL improvements as a result of the project portfolio contributing to the joint TSO/DSO cluster. This illustrates that the average gains of about 2.5 remains subject to a high variability according to the project and as seen by project coordinators.

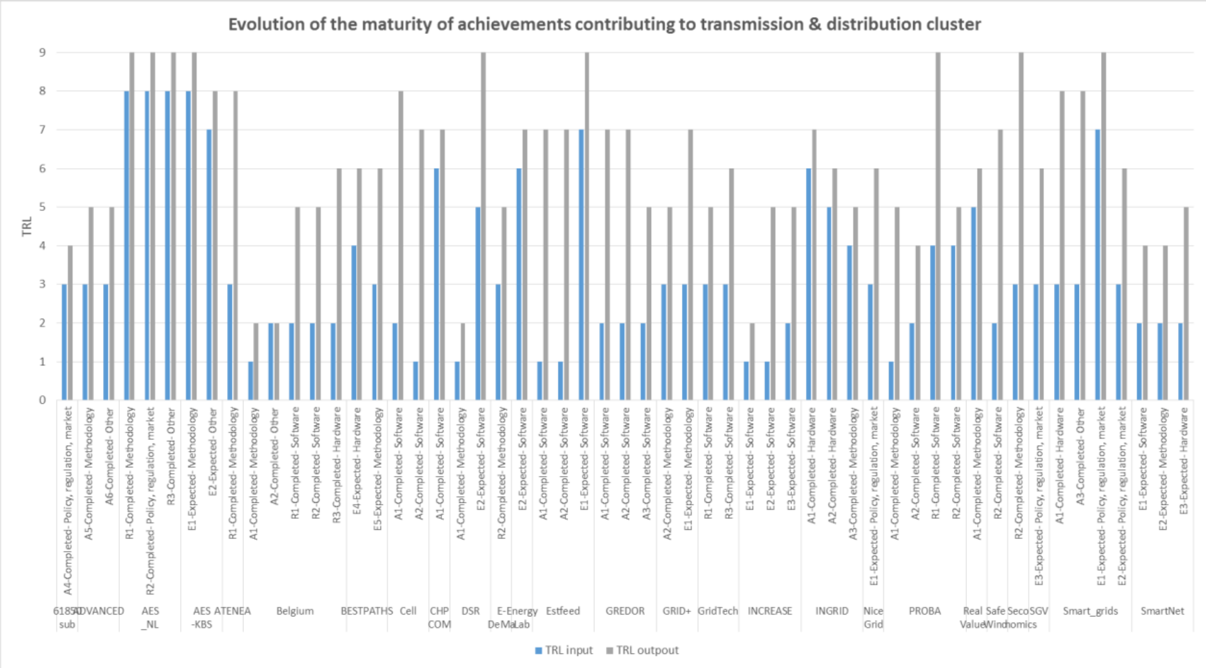


Figure 78: Evolution of the maturity of achievements contributing to the joint TSO/DSO cluster measured in TRL units

19.2 Projective features of achievements in the joint TSO/DSO cluster

Out of the sample of 42 achievements in the joint cluster, only 38 sources have documented this question and results show a majority of no. This refers to the past and does not impede any future implementation action.

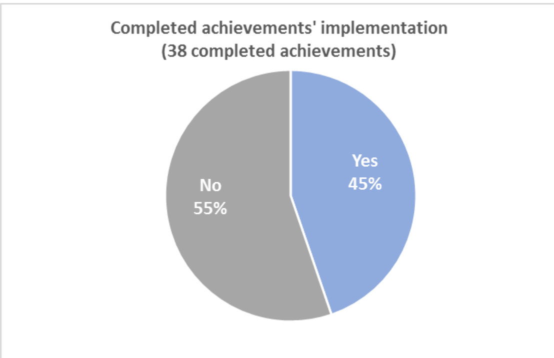


Figure 79: Implementations actions carried out for completed achievements in the joint TSO/DSO cluster

The future implementation actions are shown in next figure. Clearly the deployment, demonstration and further development actions are leading in a well-balanced way, while further research activities are less considered by project coordinators.

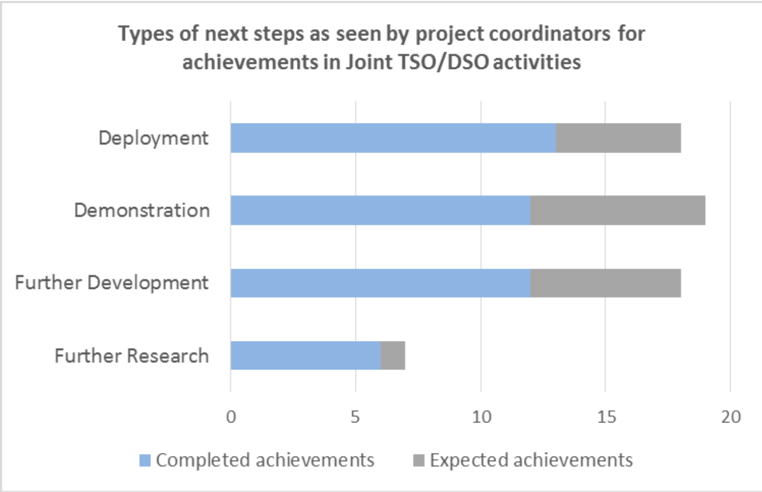


Figure 80: Next steps as seen by project coordinators in the joint TSO/DSO cluster

These results have however to be specific to each Functional Objective with the future contributions of each project as seen by its project coordinator. In each view the color code enables to distinguish the completed (in the colour of the cluster, here purple) from the expected achievements (in grey colour as usual).

From the data collected in the joint TSO/DSO Cluster for each Functional Objective (TD1 to TD5) one could formulate the following highlights:

- TD1 consist only in completed achievements (no expected ones) which means that no on-going project is deployed in this FO. Among the TD1 next steps, further research is the less quoted, while the other are quite balanced
- In TD2 the picture is rather different with a focus on downstream activities (demonstration and deployment for the completed achievements, further development and demonstration for the expected achievements)
- TD3 is the FO presenting the highest number of next step actions in the joint cluster. They are quite well-balanced between completed and expected. Among them the further research type is the less quoted.
- TD4 and TD5 present the lowest number of next step actions.

Achievement in TD1	Status	Further Research	Further Development	Demonstration	Deployment
Cell-A2	Completed		X	X	
CHPCOM-A1	id				X
GREDOR-A1	id			X	
GREDOR-A2	id				X
GREDOR-A3	id			X	
GRID+-A2	id	X			
PROBA-R2	id		X		X
SAFEWIND-R2	id		X	X	X

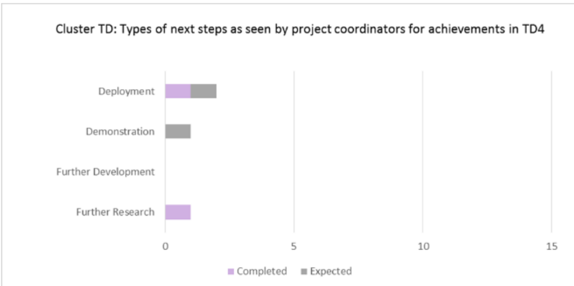
Figure 81: Next steps as seen by project coordinators in TD1

Achievement in TD2	Status	Further Research	Further Development	Demonstration	Deployment
ADVANCED-A6	Completed	X	X	X	
Estfeed-A1	id			X	X
RealValue-A1	id				X
GridTech-R1	id		X	X	
GridTech-R3	id			X	X
Estfeed-E1	Expected			X	X
INCREASE-E1	id	X	X		
INCREASE-E2	id		X	X	
SmartNet-E1	id		X		
SmartNet-E2	id		X	X	
SmartNet-E3	id			X	

Figure 82: Next steps as seen by project coordinators in TD2

Achievement in TD3	Status	Further Research	Further Development	Demonstration	Deployment
ALIADOS-A1	Completed		X	X	X
Cell-A2	id		X	X	
DSR-A1	id	X			X
Estfeed-A1	id			X	X
Estfeed-A2	id			X	X
GREDOR-A1	id			X	
INGRID-A1	id	X	X	X	
INGRID-A2	id	X	X		
AES_Netherlands-R1	id		X		X
AES_Netherlands-R2	id		X		X
AES_Netherlands-R3	id		X		
AES-KBS-E1	Expected				X
AES-KBS-E2	id				X
DSR-E2	id			X	X
EnergyLab-E2	id		X		
Estfeed-E1	id			X	X
INCREASE-E2	id		X	X	
INCREASE-E3	id		X	X	
Smart_grids-E1	id				X
Smart_grids-E2	id			X	
SmartNet-E1	id		X		
SmartNet-E2	id		X	X	
SmartNet-E3	id			X	

Figure 83: Next steps as seen by project coordinators in TD3



Achievement in TD4	Status	Further Research	Further Development	Demonstration	Deployment
ALIADOS-A2	Completed	X			
SECONOMICS-R2	id				X
Smart_grids-E1	Expected				X
Smart_grids-E2	id			X	

Figure 84: Next steps as seen by project coordinators in TD4

Achievement in TD5	Status	Further Research	Further Development	Demonstration	Deployment
61850sub-A4	Completed		X	X	

Figure 85: Next steps as seen by project coordinators in TD5

19.3 Coverage analysis of the joint TSO/DSO cluster with past and ongoing projects

19.3.1 TD1 "Increased observability of the distribution system for transmission network management and control"

Contributions from completed and ongoing projects to TD1

From EU projects

- Within the **SAFEWIND** project, methods and software tools have been developed to assess the level of predictability of wind generation for the next hours and for warning and alarming producers, DSOs and TSOs in case of difficult extreme situations (high wind speeds, weather fronts, any situations producing large forecast errors, …).

From national projects

- The Danish **Cell Controller Pilot Project** built up a software application able to coordinate distributed energy resources (DER) for control purpose in normal grid operation and support ancillary services from DSO. The main two project achievements are an online field data monitoring system and an online automatic grid controller.
- The Danish **CHPCOM** (Combined Heat and Power Communication) project analysed, developed and demonstrated through practical experience, the use of international Smart Grid related data communication standards, specifically IEC 61850 and IEC 62351 for IT security. CHPCOM focused on distributed generation, specifically CHPs and their business partners. The main project achievement consists in TSO/DSO system integration communications, including security keys, for CHP power plant management.
- Within the **Belgium east loop active network management** project, a methodology was developed to determine the theoretical maximum feasible capacity of new generation that could be connected to the East Loop, following different principle of access and different utilization factors. The project implemented software tools for the automatic centralized curtailment of generators in case of congestion in HV network or in HV/MV transformers, and installed a directional overcurrent protection device that disconnects the generator in case of problem on the transformer.
- In Belgium, the **PROBA** project focused on the development of a methodology to assess the risks (from the Tso point of view) of accepting the connection of a new distributed generation (DG) unit. The project delivered a probabilistic method based on a quasi-systematic search of the space of uncertainties. A software tool supporting the methodology was developed to assess risk indices and thermal constraints on Elia grid and/or TSO/DSO interface due to the connection of a new DG unit on one hand and risk indices related to the produced power of the DG unit. Software tools for the localization of congestions in HV/MV transformers and in HV grid were also developed.
- Again in Belgium, the ongoing **GREDOR** project aims at redesigning in an integrated way the whole decision chain used for managing distribution networks in order to perform active network management optimally (i.e., maximisation of social welfare). The project has delivered a market design tool for modelling the interaction between the users of the grid and the DSO in presence of DER and DSR, an optimal investment strategies tool for distribution expansion planning in

presence of increased flexibility needs and an operational planning tool for distribution networks.

Assessment of the coverage of TD1

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective TD1. The left-hand traffic-light colours correspond to the estimated coverage of each of these tasks by the above-described projects, according to the colour code defined in Table 3.

- **TD1a.** To improve short-term (15 min, 1 h, 3 h) and long-term (five-day) forecast engines for PV, wind, CHP, and loads.
- **TD1b.** To develop new modelling methods and tools for steady-state (static parameters) and dynamic analyses (capacities up to 1 MW).
- **TD1c.** To deliver methods and tools for planning new DER connections at the TSO/DSO boundary (response to new connection requirements).
- **TD1d.** To develop new methodologies for data processing at various system levels (DSO, TSO).
- **TD1e.** To design new architecture, control systems, and communications (including GIS assistance) that allow multiple new generators to be connected and share information with TSOs.
- **TD1f.** To provide new integrated functions (scaling-up techniques) and solutions for technical aggregation of DER data acquisition capabilities for improved DER production observability.

Coverage assessment

In general, the activities in this functional objective have not been well covered. Regarding TD1a, there is still work to do on load and PV forecasting. For TD1c, further work should be done after the RfG code is adopted. An EU-level project would be needed to properly cover TD1f. Other tasks have almost not been addressed. We assess that around 15% of this FO have been covered.

19.3.2 TD2 "The integration of demand side management at DSO level into TSO operations"

Contributions from completed and ongoing projects to TD2

From EU projects

- The goal of the **ADVANCED** project was to increase the understanding on how to deploy efficiently Active Demand (AD). Amongst the main project's achievements, communication umbrellas were delivered, providing suggestions for third parties (retailers, aggregators…) on how to encourage residential and industrial clients to participate in AD programs. The project also concluded that AD has highest potential if network expansion is driven by load growth and is used in highly utilised urban networks which are already constrained.
- The **GRIDTECH** project has developed a zonal tool and model (with 2020, 2030, 2050 data) for pan-European system planning studies and a toolbox for transmission expansion planning with storage, demand response and EV.
- The ongoing **INCREASE** project will deliver a decision support model, based on probabilistic and stochastic analysis of (LV) distribution network operation and technological solutions to increase the RES penetration. In case of LV network issues

(congestion, overvoltage, undervoltage), the model will support DSOs to decide between new investments into LV network or exploration of other solutions such as PV curtailment and demand-side management (DSM).

- The main aim of the ongoing **RealValue** project is to demonstrate how small scale energy storage systems (e.g. Smart Electric Thermal Storage Systems 'SETS') can provide benefits to the whole electricity supply chain, from generation and distribution, through to wholesale markets and suppliers and ultimately to the end consumer. To achieve this aim RealValue will provide an innovative means to mitigate the challenges associated with, and maximise the value of clean energy from renewable sources. The sectors interested in the project process are:
  - *Generation:* Efficient Dispatch of Generation; Renewable Energy Integration; Minimise Installed Capacity;
  - *Transmission:* Quality of Supply; Security of Supply; Distribution Network Capital Expenditure;
  - *Wholesale:* Price Arbitrage; Ancillary Services; System Flexibility;
  - *Supply:* Demand-Side Management; Collective Purchasing; Tariff Development;
  - *Societal:* Energy Affordability; Carbon Reduction; Market Design.
- The recently started **SmartNet** project aims at providing architectures for optimised interaction between TSOs and DSOs in managing the exchange of information for the acquisition of ancillary services (reserve and balancing, voltage regulation, congestion management) from distributed resources (DSM, scattered generation), both at national level and in a cross-border context. A software tool for such optimised architectures is being developed.

From national projects

- In Estonia, the **Estfeed** open software platform (managed by the TSO) is being developed for energy consumptions monitoring and management from customer perspective, capable to interact with grids and to provide data feeds to service providers for an efficient use of energy.
- The French **Nice Grid**[26] and **Smart Grid Vendée** projects are distribution-oriented but are also involving the French TSO. From the TSO's point of view, the main expected achievements lie in the economic and market design aspects about the use of DER (from storage devices, RES producers and consumers) as flexibility sources for the TSOs.

Assessment of the coverage of TD2

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective TD2:

🔴 **TD2a.** To define demand requirements and data required by TSOs for the pan-European planning tool.

🔴 **TD2b.** To demonstrate active customer involvement with indirect feedback (provided post-consumption) and direct feedback (real time) and suitable operations designed to achieve a reduction in peak demand (10%–15%).

🟡 **TD2c.** To model customer/load behaviour and segmentation and quantify the degree of flexibility provided by distribution networks (e.g., through reconfiguration or other methods).

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[26] It is also part of the EU FP7 project Grid4EU coordinated by ErDF (now Enedis) within which Nice Grid is the French demonstrator (DEMO6).

Coverage assessment

Projects are addressing the various tasks in this FO, but still at a preliminary stage. We therefore consider that around 20% of the FO is covered.

19.3.3 TD3 "Ancillary services provided through DSOs"

Contributions from completed and ongoing projects to TD3

From EU projects

- The model delivered by the ongoing **INCREASE** project will support DSOs to decide between new investments into LV network or exploration of available ancillary services such as PV curtailment and demand-side management (DSM). Decisions are made based on large set of metrics (technical and economical parameters). In case of adequate operation of the LV network, the possibilities for provision of the available PV and DSM active power as the reserve for TSO are observed. The amount of available reserve for TSO is provided in probabilistic form. Main achievement of the tool development will be optimal decision for reliable (long term) operation of the LV network and observation of potential amounts of ancillary services that could be offered to TSO from distributed renewable energy sources (DRES) and DSM.
- The ongoing **INGRID** project is combining the recent advances in Smart Grids and hydrogen-based energy storage to match energy supply and demand in a context of increasing variable RES. The project has delivered improved electrolyser technology, improved solid state hydrogen storage devices and materials, and experience feedback on control of grid-connected electrolysers. The INGRID Energy Management System (EMS) is based on the multi-carrier hub paradigm for modelling the behaviour of the entire plant. An optimiser, built upon this model and based on genetic algorithm, is responsible for elaborating the optimal power flow inside the plant, every hour. Indeed, the EMS is able to merge and harmonise the contrasting requirements coming from the DSO in terms of expected power consumption profile, and the ones linked to the actual business of the plant. In this way, the INGRID plant is able to chase its own profit, providing ancillary services to the grid at the same time. The results of the optimisation phase feed a Decision Support System (DSS) which allows its users to send the desired set points to the plant devices.
- The recently started **SmartNet** project is developing a software tool for optimised architecture(s) for TSO-DSO interaction to allow participation to ancillary services market by distributed resources. Through an in-depth analysis and a simulation in a lab-environment, answers are sought for the following questions:
  - Which ancillary services could be provided from distribution to the whole system (via transmission)?
  - Which optimised modalities could be adopted for managing the network at the TSO-DSO interface and what monitoring and control signals could be exchanged to carry out a coordinated action?
  - How the architectures of real time markets (in particular balancing markets) could be consequently revised?
  - What information has to be exchanged and how (ICT) for the coordination on the distribution-transmission border, starting from monitoring aspects, to guarantee observability and control of distributed generation, flexible demand and storage systems?
  - Which implications could the above issues have on the ongoing market

coupling process that is going to be extended to real-time markets in the next years, according to the draft Network Code on Electricity Balancing by ENTSO-E?

From national projects

- The Spanish **Alia2** project tested storage solutions for renewable generation plants. The development of three building management systems (module, cabinet and container) was achieved during the project. The new solution should allow the provision of grid services to DSOs and TSOs.
- From the TSO's point of view, the French **Nice Grid** and **Smart Grid Vendée** projects main achievements lie in the economic and market design aspects about the use of DER as flexibility sources for the TSOs (ancillary services, tertiary reserve).
- The Danish **Cell Controller Pilot Project** built up a software application able to coordinate distributed energy resources (DER) for control purpose in normal grid operation and support ancillary services from DSO.
- Again in Denmark, the ongoing **EnergyLab Nordhavn*** project intends to show how electricity and heating, energy-efficient buildings and electric transport can be integrated into an intelligent and optimized energy system.
- Within the Belgian project "**Smart grids: Back End Systems**" consisting in the segmented roll-out of smart meters and associated systems, the automatic curtailment of wind and automatic load shedding, the integration of DSM as system reserve (DSO/TSO) and the integration of storage (including ancillary services provided by storage solutions) have been implemented.
- In Estonia, the ongoing **DSR** project has identified the demand-side response (DSR) potential for Estonia and studied the opportunity to use DSR as a source of flexibility. The **Estfeed** open software platform (managed by the TSO) is being developed for energy consumptions monitoring and management from customer perspective, capable to interact with grids and to provide data feeds to service providers for an efficient use of energy.
- The **AES** projects in the Netherlands and in Northern Ireland consist in 10 MW battery systems installed in the distribution grid to balance supply and demand by providing Primary, Secondary & Tertiary Reserve. The advanced battery based storage arrays are designed to deliver reliable power and improve flexibility of the transmission systems.
- The ongoing Belgian project **GREDOR** is also addressing this functional objective. A specific tool has been developed: DSIMA is an open-source testbed to simulate interaction models governing the exchange of flexibility services located within a distribution network. The testbed is an agent-based system in which the DSO, the TSO, producers and retailers take their decisions based on mixed-integer linear programs. Three interaction models are considered: "Unrestricted" access: Let the grid users access to the network without restriction, "Restricted" access: Restrict the grid users so that no problems can occur and "Flexible" access: Let the users produce/consume as they wish but if they are in the flexible range, they are obliged to propose flexibility services to the DSO.

Note: Projects marked with an * do not count TSOs nor DSOs on board. They have been provided by EASE members.

Assessment of the coverage of TD3

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective TD3:

- **TD3a.** To discover novel ways of providing ancillary services through loads and their effect on transmission networks. The highly variable and unpredictable nature of DER and RES places new constraints on these ancillary services.
- **TD3b.** To ensure simulation environments to demonstrate the viability and options of ancillary services provision by aggregated loads at DSO level.
- **TD3c.** To provide technologies and tools for active and reactive power control of DER, with TSO/DSO coordination to provide extra power flow control, load management, and islanding.
- **TD3d.** To ensure new actors and market models that enable DER to provide ancillary services.
- **TD3e.** To provide new models that describe products and services to be tested on selected segments of customers and their effects on future ancillary services in the presence of large scale DER integration.
- **TD3f.** To provide new market models that account for the price-sensitive nature of loads and consequently their increased flexibility.
- **TD3g.** To analyse the legal, contractual, and regulatory aspects of ancillary services provided by distributed generation and/or loads, allowing for more aggregated business models.

Coverage assessment

Work is ongoing regarding this FO. In particular, there is still work to be done regarding the provision of ancillary services through aggregated loads.

We assess that around one third of the FO has been covered, and one additional third should be provided by ongoing projects.

19.3.4 TD4 "Improved defence and restoration plan"

Contributions from completed and ongoing projects to TD4

From EU projects

- With the **SECONOMICS** project, a toolkit to security policy-makers seeking to understand their policy alternatives and the potential impact of their decisions has been developed. A risk assessment methodology for security vulnerability has been delivered.
- The ongoing **BEST PATHS** project aims at developing novel network technologies to increase the pan-European transmission network capacity and electricity system flexibility. The third project demonstration contributes to this functional objective with a focus on HVDC lines.

From national projects

- The Spanish **Alia2** and the Belgian "**Smart grids: Back End Systems**" projects are also contributing to this functional objective.

Assessment of the coverage of TD4

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective TD4:

- **TD4a.** To develop simulation tools and methods that detect weaknesses in the system with respect to reconnecting DER and storage systems.
- **TD4b.** To develop simulation tools and methods of assessing the risk of breakdowns during reconnection.
- **TD4c.** To develop simulation tools for interactive system restoration, including advanced forecast tools developed in TD1 for wind, solar PV, and other variable RES.
- **TD4d.** To address regulatory and technical challenges that implement restoration plans at the pan-European level.
- **TD4e.** To investigate the contribution of DER for system restoration and its contribution to immediate power reserves; this is relevant from the TSO perspective (e.g., black start capability and coordination of wind turbine generators). This will be assessed considering efficacy and cost-effectiveness when compared to the traditional or usual black-start approach.
- **TD4f.** To investigate the impact of micro-grids and islanding capabilities.
- **TD4g.** To train operators about the evolution of national regulatory schemes in order to foster coordination efforts.

Coverage assessment

Most of the topics considered in this FO are not addressed yet or only very partially. Micro-grids and islanding capabilities have been addressed by completed and ongoing projects but wider tests are needed. Furthermore there is still work to do on training.

We therefore consider that around 15% of this FO have been covered by the R&I activities so far.

19.3.5 TD5 "Methodologies for scaling-up and replicating"

Contributions from completed and ongoing projects to TD5

From EU projects

- No EU R&I project has been reported here. It is however important to mention the coordination and support action (CSA) **Grid+** which has delivered a methodology to assess the scalability and replicability of smart grid solutions.

From national projects

- The Spanish project "**A complete and normalised 61850 substation**" has used the standard IEC 61850 as a means to improve the design, maintenance and operation of the substation automation systems. It has designed a standard substation considering the existing and new solutions developed by the vendors collaborating in the project. Application Guides, Software Tools and Migration Strategies for the Implementation of the IEC 61850 Standard have been delivered.
- The Spanish **ATENEA Microgrid*** project has delivered a methodology for the design and the deployment of microgrids.

- The German **E-DeMa** project aimed at designing ICT-based solutions enabling the intelligent utilisation of all available regional resources. Additionally, the project targeted the optimisation as well as the integration of the energy system starting from generation to storage, up to the distribution of electricity leading to an efficient final consumption through new services based on metering data and energy management services. The methodology delivered can be used for further projects.

> Note: Projects marked with an * do not count TSOs nor DSOs on board. They have been provided by EASE members.

Assessment of the coverage of TD5

The EEGI roadmap 2013-2020 had foreseen the following specific tasks in the functional objective TD5:

- **TD5a.** To investigate the acceptable levels of risk and uncertainty in studies in order to adequately assess the scaling-up and replication potentials of solutions and their requirements.
- **TD5b.** To document the methodology for future project participants so that they can assess the experimental data requirements required to design a smart grid demonstration.
- **TD5c.** To develop information models for smart grid security, considering business interactions and the physical processes of delivering electricity, and the disruption of business communications or of the delivery of electricity.
- **TD5d.** To analyse data exchange protocols that reinforce interoperability constraints at the pan-European level with an adequate level of security.
- **TD5e.** To study appropriate confidentiality constraints in the developed toolbox to ensure appropriate sharing of results, while preserving stakeholder interests.
- **TD5f.** To define open standard data models that ensure interoperability between different data exchange protocols for smart grid applications and to increase competitiveness.

Coverage assessment

Most of the topics of this FO have been untouched by ongoing R&I activities. Our assessment of the coverage is therefore at around 10%.

19.4 Recommendations for the new R&I roadmap

The coverage of projects addressing R&I activities related to TSO/DSO activities is very low (around 20% on average). As a consequence, it is recommended to delete this joint TSO/DSO cluster: there should be a seamless integration between TSO and DSO activities, and therefore R&I activities related to TSO and DSO collaborations should be included in their respective R&I portfolios and not in a specific portfolio to be dealt with and set aside the other R&I activities.

20. Conclusion for joint transmission and distribution activities

The joint TSO/DSO Cluster has been **REMOVED** and the activities related to the five functional objectives have been **INTEGRATED** as follows[27].

- FO TD1 (Increased observability of the distribution system for transmission network management and control) has been integrated in the new FO T5 (Grid observability) of Cluster 2 (Power system flexibility) for TSOs and in the new FOs D4 (System integration of medium DER) and D9 (Automation and control of MV network) of Clusters 2 (Integration of DER and EV, storage, other networks) and 3 (Network operations) respectively, for DSOs.
- FO TD2 (The integration of demand side management at DSO level into TSO operations) has been integrated in the new FO T11 (Demand response) of Cluster 3 (Security and system stability) for TSOs and the amended FO D1 (Active demand response) of Cluster 1 (Integration of smart customers and buildings) for DSOs.
- FO TD3 (Ancillary services provided through DSOs) has been integrated in the new FO T9 (Enhanced ancillary services) of Cluster 3 (Security and system stability) for TSOs.
- FO TD4 (Improved defence and restoration plans) has been integrated in the new FO T8 (Reliability and resilience) of Cluster 2 (Power system flexibility) for TSOs.
- FO TD5 (Methodologies for scaling-up and replicating) has not been integrated in the new roadmap.

[27] A detailed mapping of this integration is provided in D2.6.

Part IV COMPARISON WITH NON-EUROPEAN SELECTED PROJECTS

21. The selected portfolio of non-European R&I projects

21.1 Reminder: project selection

The methodology of monitoring is described in the introduction (2.4). Here, the main assumptions for the selection of the projects which were retained in the portfolio are reminded.

Table 9: Methodology followed to select the portfolio of non-European projects

Transmission	Distribution
USA -Projects' sources: U.S. Department of Energy (DOE), SGIG (Smart Grid Investment Grant) projects (2013 Progress Report) and projects from the "Smart Grid Demonstration Program" (including "Smart Grid Regional Demonstrations" and "Energy Storage Demonstrations"). -Selection process: projects with the highest budgets and verification that no significant project covering the TSO Functional Objectives was missing from the selection. CHINA -Projects' sources: DOE energy storage database and State Grid Corporation of China (SGCC). -Selection process: all projects relevant to transmission and related to TSO Functional Objectives were selected for further investigation. JAPAN -Projects' sources: DOE energy storage database and some publicly available presentations (e.g., Tetsuji Tomita: "Policies and regulation for electricity storage in Japan" and Satoshi Morozumi – NEDO: "Japanese Island Grid Experience". –Selection process: all projects relevant for transmission were selected for further investigation. As a result, out of 56 projects analysed, **34** projects were selected for the final review: 13 US, 12 Chinese and 9 Japanese.	Projects' sources: DOE energy storage database for projects in the USA and Japan, the IEASA database for projects in India, the Clean Energy Fund Program for projects in Canada and storage projects funded by ARENA for projects in Australia. From data bases, only the projects with a storage component at distribution level were considered for further investigation, leading to a list of about 60 projects. Out of these projects, only the projects with significant information on expected or realized achievements were finally reviewed. Other reasons for omitting certain projects were: • the relevance of the project (e.g. projects which didn't cover any distrution functional objectives), • de-commissioned projects, • projects with an unclear status, • and, projects which were very similar to other projects already reviewed. This finally led to a review of a total of **20 projects** (2 Australian, 4 Canadian, 3 Indian, 1 Japanese and 10 US projects).

NB: the colour code highlighting each methodology corresponds to the source that has provided the information:

RSE	VITO

21.2 Overview of the selected portfolio

Table 10: Selected portfolio of non-European projects

<table>
<tr><th>TRANSMISSION</th><th>COUNTRY</th></tr>
<tr><td>Seneca Compressed Air Energy Storage</td><td rowspan="13">USA</td></tr>
<tr><td>Advanced Underground Compressed Air Energy Storage</td></tr>
<tr><td>Isothermal Compressed Air Energy Storage</td></tr>
<tr><td>Notrees Wind Storage Demo</td></tr>
<tr><td>Dynamic Line Rating</td></tr>
<tr><td>Western Interconnection Synchrophasor</td></tr>
<tr><td>New York State Capacitor/Phasor Measurement</td></tr>
<tr><td>Enhanced SCADA and PMU Communications Backbone</td></tr>
<tr><td>Energy Management Infrastructure</td></tr>
<tr><td>Boeing SGS (Smart Grid Solution)</td></tr>
<tr><td>Waukesha Electric Systems/SuperPower</td></tr>
<tr><td>Flywheel Energy Storage Demonstration</td></tr>
<tr><td>20MW Flywheel Frequency Regulation Plant</td></tr>
<tr><td>Fengning Pumped Storage Hydroelectric Power Station</td><td rowspan="12">China</td></tr>
<tr><td>Jiangxi Hong Ping Pumped Storage Power Station</td></tr>
<tr><td>UPFC key technology and core equipment</td></tr>
<tr><td>Zhangbei National Wind and PV Energy Storage and Transmission</td></tr>
<tr><td>Zhoushan Five-terminal Flexible DC</td></tr>
<tr><td>Sino-Russia B2B Converter Station in Heihe</td></tr>
<tr><td>1000kV Jindongnan- Nanyang-Jingmen UHV AC Pilot</td></tr>
<tr><td>Xiangjiaba-Shanghai +/-800 kV UHV DC Transmission Pilot</td></tr>
<tr><td>Qinghai-Tibet 750kV/+/-400kV AC/DC Grid Interconnection</td></tr>
<tr><td>Shenzhen Baoqing Energy Storage Station</td></tr>
<tr><td>Qingdao XueJiadao Battery Pilot</td></tr>
<tr><td>Ningdong-Shandong +/-660kV DC Project Double Polar</td></tr>
<tr><td>Tomamae Wind Farm</td><td rowspan="2"></td></tr>
<tr><td>Tanegashima Island Toshiba Li-Ion</td></tr>
</table>

Amamioshima Island Toshiba Li-Ion	
Miyako Island Mega-Solar Demo: NaS	
Storage demonstration project on Niijima island	
Wakkanai Mega-Solar Project	
Nishi-Sendai Project	
Minami-Soma Substation Project	
Redox flow battery system in Minamihayakita	
DISTRIBUTION	**COUNTRY**
UCSD BMW second life EV energy storage system	**USA**
EnerVault Redox Flow Battery Demo Project	
DTE Community Energy Storage for Grid Support	
Battelle Memorial Institute Pacific Northwest Smart Grid Demonstration	
NEDO New Mexico Smart Grid Demonstration Project	
DOD Marine Corps Air Station Miramar Microgrid Energy Storage System	
UC San Diego CPV Firming	
2 MW Potsdam, New York - Microgrid	
Hybrid Compressed Air Energy Storage and Thermal Energy Storage	
Stapleton Neighborhood Energy Storage	
Wind R&D Park and Storage System for Innovation in Grid Integration	**Canada**
Cowessess First Nation High Wind and Storage Project	
Energy Storage and Demand Response for improved reliability in an outage-prone community	
Utility Scale Electricity Storage Demonstration Using New and Re-purposed Lithium Ion Automotive Batteries	
Trialling a new residential solar PV and battery model	**Australia**
Solar and storage trial at Alkimos Beach residential development	
Niijima Island Microgrid	**Japan**
Sun-carrier Omega Net Zero Building in Bhopal	**India**
Gram Power Khareda Lakshmipura Microgrid	
India One Solar Thermal Plant	

NB: the colour code highlighting each project acronym corresponds to the source that has provided the information questionnaire:

RSE	VITO

22. R&I achievements from selected non-European projects in transmission

22.1 Features of achievements from selected non-European projects in transmission

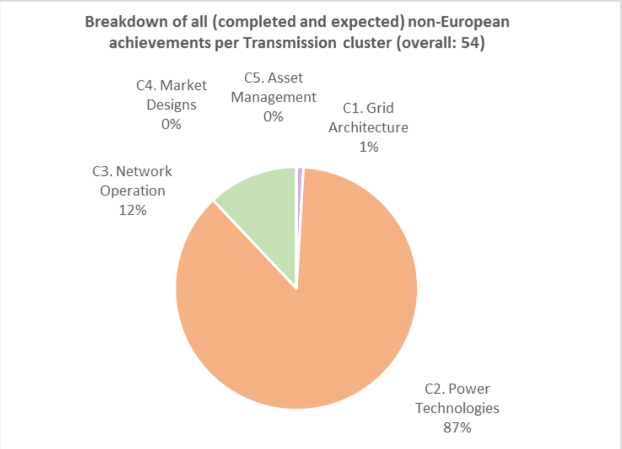
22.1.1 Descriptive features of achievements

Descriptive features of R&I achievements include information for categorization and an estimation of the maturity increment of each considered innovation (see Table 5):

- Categorization in clusters of the roadmap;
- Typology of achievements (1. Methodology; 2. Software; 3. Hardware; 4. Database; 5. Policy, regulation, market; 6. Other);
- Input and output Technology Readiness Levels (TRL).

Categorization in clusters

The graphs below characterize the sample of achievements of non-European R&I projects for all clusters in transmission. A comparison with the achievements from R&I projects in Europe is provided.



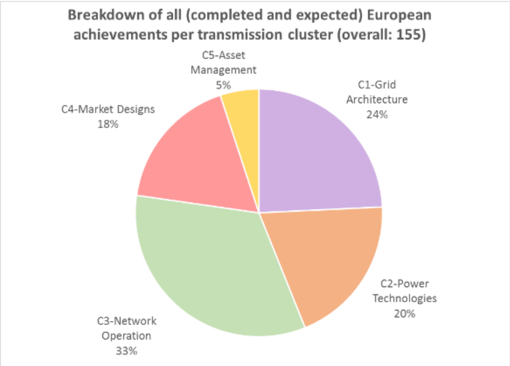


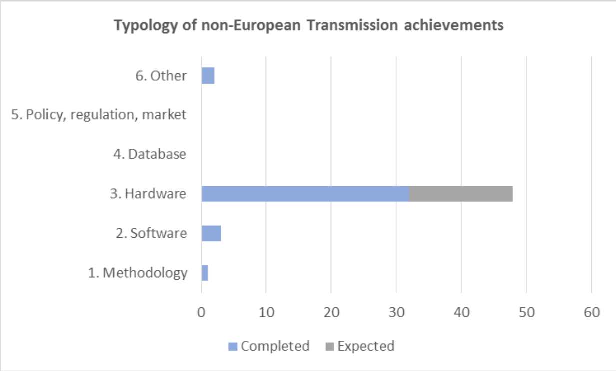
Figure 86: Achievements of non-European projects related in relation with each transmission cluster (left), compared to the achievements of R&I projects in Europe (right)

Highlights:

- When considering all non-European achievements (completed and expected), it is observed that the most addressed cluster is C2 (Power technologies) with 87% of the monitored sample. C3 Network Operation takes 12% while the C1 Grid Architecture cluster amounts barely 1% of the achievements. In the reviewed projects there was no achievement related to clusters C4 and C5 (Market Designs and Asset Management).
- It can be concluded that power technologies in non-European projects have been tackled intensively in order to achieve storage integration at the transmission level successfully, while European projects, focus a larger scope of transmission activities, which will spread the effort set in all different clusters.

Typology of achievements

The breakdown per type of achievements is provided in the figures below.



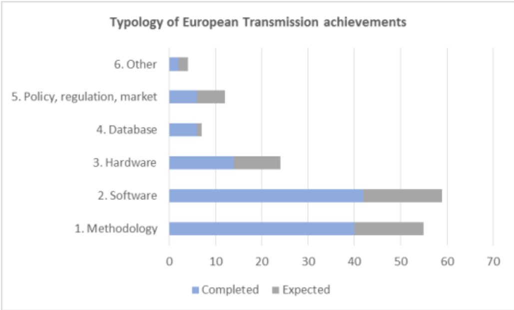


Figure 87: Typology of achievements from non-European R&I projects in transmission (left), compared to the achievements of R&I projects in Europe

Highlights:

- Non-European achievements address hardware topics principally, while European projects concern methodology and software issues mostly; and then, in a third place, achievements related to hardware aspects.
- There were no results at all linked to database, policy, regulation and market categories in the monitored non-European projects, which is in agreement with the addressed clusters, as shown before (Figure 86).

Evolution of the maturity of achievements

Innovations involved in the considered transmission projects could be characterized by their degree of maturity. The TRL is the metric used that captures such maturity (and the distance to the market or to an exploitation stage).

We have assessed two levels of TRL: inputs before the project starts (in a clear colour code), and at the project end (darker colour). This is depicted in the figure hereafter, with again a comparison with the achievements from R&I projects in Europe.

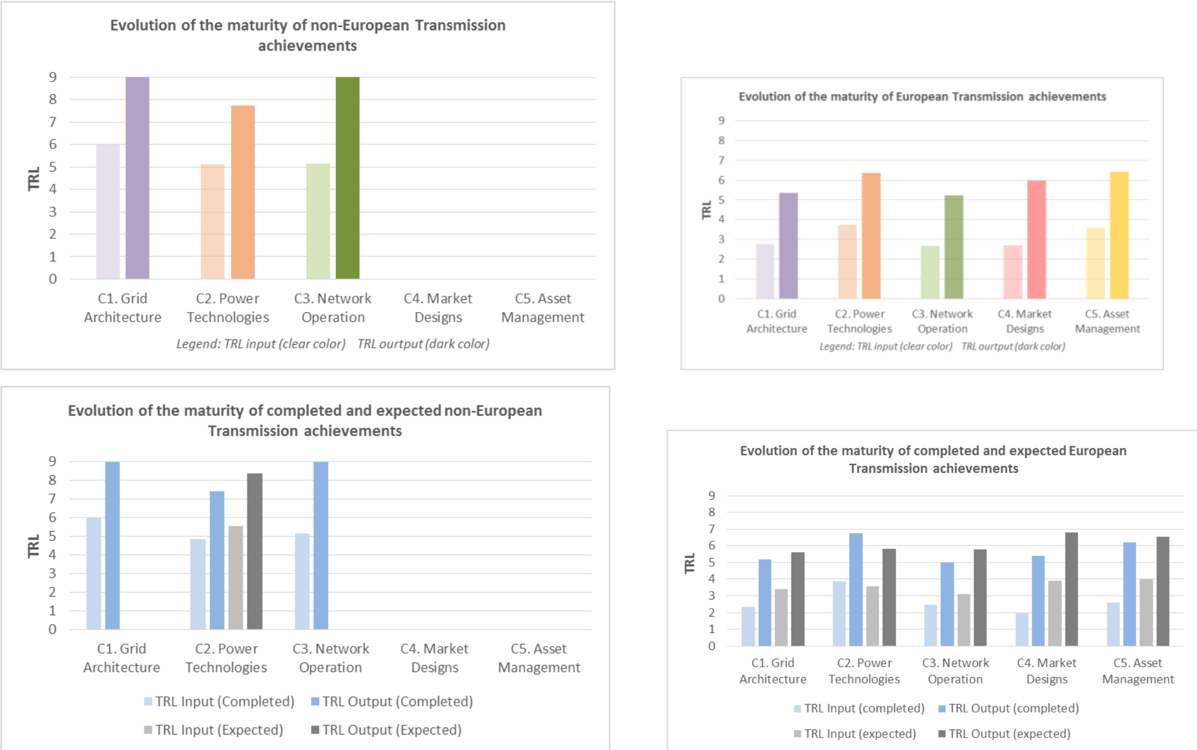


Figure 88: Evolution of the maturity of achievements from non-European projects measured in TRL units (left), compared to the achievements of R&I projects in Europe (right)

Highlights:

- On average, for each addressed cluster of non-European projects, an increment of three to four units in the TRL scale is observed (left diagrams), the increment being higher for the Network Operation cluster (C3).
- C1 and C3's achievements having reached a TRL of 9 are ready to be tested in operational environments. As we can see on the charts of the right, none of the clusters of the European achievements (completed or expected) is at the highest readiness level.
- The lowest TRL for a non-European cluster belongs to C2 Power Technologies with a remarkable (above) 8, even if it is the cluster which comprises 87% of the monitored sample.

22.1.2 Projective features of achievements

Projective features of each achievement refer to possible implementations and next steps as formulated by expert members of the Grid+Storage consortium. RSE was the partner in charge of the evaluation for non-European projects related to transmission. Non-European achievements' implementation and their further steps have been determined by RSE's experts as follows:

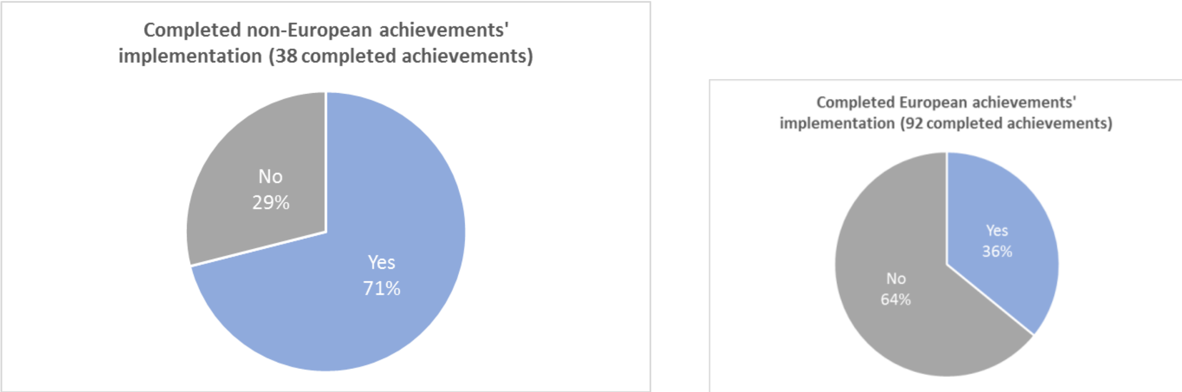


Figure 89: Implementation for non-European completed achievements in transmission (left), compared to completed achievements of R&I projects in Europe (right)

<u>Highlights:</u>

- In contrast with European completed achievements' implementation, almost three quarters of the non-European completed achievements have already been implemented by a transmission operator. Only, 29% of the monitored results have not been implemented yet.
- It may occur that implementation actions of some achievements are foreseen but have not started yet: in such situations they are accounted for in the "next steps" diagrams.

The diagrams below detail the next steps of non-European and European achievements (either further research, further development, demonstration or deployment).

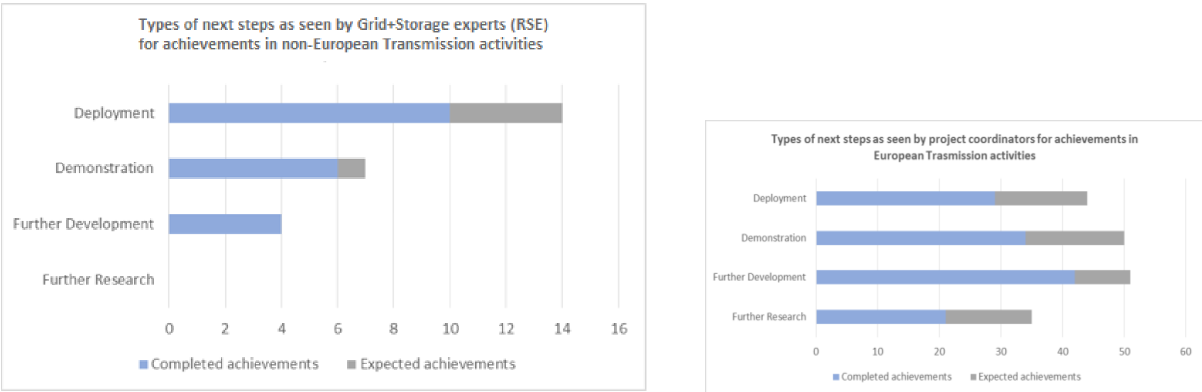


Figure 90: Implementation actions carried out for achievements from non-European R&I projects in transmission (left), compared to the achievements of R&I projects in Europe (right)

<u>Highlights:</u>

- For completed and expected non-European achievements, it was estimated that it will not be necessary to perform further research for any of the monitored projects (19% of the monitored European achievements sample still concerns further research according to the project coordinators). It was estimated that 16% of the international results will require further development, 28% will need demonstration and 56% are already at the deployment stage.

22.2 Description of each project of the selected portfolio

22.2.1 From the USA

13 transmission projects from the USA have been monitored.

- **Seneca Compressed Air Energy Storage** (DOE/New York State Electric & Gas). The aim of this project was to build an advanced compressed air energy storage (CAES) plant with a rated capacity of 150 MW using an existing 4.5 million cubic foot underground salt cavern. The plant was designed to have the capacity to operate 16 hours a day and to provide energy arbitrage for approximately 2,300-2,500 hours each year. The plant should have been tied to NYSEG's cross-state 230 kV/345 kV transmission system that feeds major metropolitan centres in Central New York. The market price forecasting and dispatch modelling completed during the project indicated that the CAES technologies would operate at only 10 to 20% capacity factors. The output was limited by the night time transmission system capability. The plant operating profiles tended to be patterned after the operational duty cycle of a natural gas fired peaking unit. Given that the capital cost of this plant was estimated at two to three times the cost of a simple cycle natural gas combustion turbine, in all but six years of the 30 years of the study period, the total market revenues received from plant operation would be less than the total revenue requirement of the plant. As a result, it was recommended that NYSEG should not proceed with further development of the Seneca CAES project. However, this conclusion is site-specific and may not necessarily indicate that CAES plants cannot be profitable in other places in New York State or in the world.
- **Advanced Underground Compressed Air Energy Storage** (DOE/Pacific Gas and Electric Company). Pacific Gas and Electric Company's (PG&E) advanced underground, Compressed Air Energy Storage demonstration project is intended to validate the design, performance and reliability of a CAES plant rated at approximately 300MW with up to 10 hours of storage. The CAES demonstration project is scoped to test the suitability of a porous rock formation as the storage reservoir in California, and demonstrate the technological improvements in the design of such plants. Porous rock formations are much more plentiful than the salt domes now used by the two operational plants in Alabama and Germany. If this geology is proven viable, this technology has the potential to be replicated throughout California and elsewhere in the United States. The project is also differentiated by its potential use of a new CAES plant design that is much more efficient than the first generation Alabama and German designs. The final aims of the plant are to integrate intermittent renewable resources, maintain emergency spinning/non-spinning reserve and allow volt-ampere reactive/voltage support. Phase 1 of the project, i.e., reservoir feasibility including site control, reservoir performance, economic viability, and environmental impacts is currently funded. It is envisioned that in the 4th Quarter of 2015 a decision will be made on whether to move forward with seeking the required regulatory approvals to proceed to Phase 2 (commercial plant engineering, procurement and construction, and commissioning).
- **Isothermal Compressed Air Energy Storage** (DOE/SustainX). The project developed and demonstrated a MW-scale Energy Storage System that employs compressed air as the storage medium. An isothermal compressed air energy storage (ICAES^{TM}) system rated for 1.5 MW was demonstrated in a full-scale prototype unit. The system is designed for a 20-year lifetime. The use of proprietary methods for isothermal gas cycling and staged gas expansion implemented using industrially mature, readily-available components can yield breakthrough cost-effectiveness. The ICAES approach uses an electrically driven mechanical system to raise air to high pressure for storage in low-cost pressure vessels, pipeline, or lined-rock cavern. This air is later expanded through the same mechanical system to drive

the electric motor as a generator. The approach incorporates two key efficiency-enhancing innovations: (1) isothermal (constant temperature) gas cycling, which is achieved by mixing liquid with air (via spray or foam) to exchange heat with air undergoing compression or expansion; and (2) a novel, staged gas-expansion scheme that allows the drivetrain to operate at constant power while still allowing the stored gas to work over its entire pressure range. SustainX's ICAES power and energy can be scaled independently, enabling an optimized solution for any application. The power needs of a project can be met in MW increments by selecting the number of ICAES compressor/expander modules. Similarly, energy can be optimized by sizing the volume of pipe-type air storage to the specific needs of a project.

- **Notrees Wind Storage Demo** (DOE/ERCOT). The objective of the Notrees Wind Storage Demonstration Project is to validate that energy storage increases the value and practical application of intermittent wind generation and is commercially viable at utility scale. The project incorporates both new and existing technologies and techniques to evaluate the performance and potential of wind energy storage. In addition, it could serve as a model for others to adopt and replicate. The Project is installing an advanced battery energy storage system (BESS) with a capacity of 36 MW/24 MWh to optimally dispatch energy production from the wind farm. This optimization will help energy storage operators capture energy arbitrage, improve grid stability, and demonstrate renewable firming value. Additional CO_2 reduction benefits are anticipated, as energy storage will eliminate the need for fossil-fuel-based secondary generation. The BESS selected for the project is Xtreme Power's 36-MW/24-MWh Dynamic Power Resource™ (DPR) advanced lead-acid unit. Building construction was completed and all battery/PCS (Power Conditioning System) units were put in place. The BESS completed commercial operation testing. Integrated Module Testing was also carried out. The Notrees Wind Storage Demonstration Project provided FRRS (Fast-Responding Regulation Service) service to ERCOT interconnection through a two-year pilot program. The project provides 32 MW of FRRS Up capacity and 30 MW of FRRS-Down capacity. Initial results showed good FRRS service capability. The final documentation is yet not available.
- **Dynamic Line Rating** (DOE/ Oncor). The project developed and deployed an extensive and advanced DLR (Dynamic Line Rating)[28] installation to demonstrate that DLR technology is capable of resolving many transmission capacity constraint problems with a system that is reliable, safe and very cost competitive. The integrated dynamic Line Rating (iDLR) collects transmission line parameters at remote locations on the lines, calculates the real-time line rating based on the equivalent conductor temperature, ambient temperature and influence of wind and solar radiation on the stringing section, transmits the data to the Transmission Energy Management System, validates its integrity and passes it on to Oncor and ERCOT (Electric Reliability Council of Texas) respective system operations. The iDLR system operates in parallel with all other system status telemetry collected through ERCOT Supervisory Control and Data Acquisition (SCADA) employed across the company. Real-time transmission line capacities were observed above ambient-adjusted ratings by 8%-12% for 138 kV lines and by 6%-14% for 345 kV lines 84%-91% of the time. As evidence of the extensibility of DLR technology, Oncor has deployed an additional twelve DLR devices in the Odessa-Midland region of Texas and incorporated them in the iDLR system operating telemetry feed.

[28] IDLR (Integrated Dynamic Line Rating) is Oncor's designation for real time ratings that account for the full impact of ambient temperature, solar radiation, and wind variations and integrating the data into the system's status telemetry for operations. DLR refers to the determination of a line rating based on real-time parameters

- **Western Interconnection Synchrophasor Program** (DOE/Peak Reliability). The main objectives of the Western Interconnection Synchrophasor Program (WISP) were to improve electric system reliability and enable better grid integration of renewable resources. The project installed or upgraded 584 Phasor Measurement Units (PMUs), 77 Phasor Data Concentrators (PDCs), a wide-area communications network to support PMU data transfer, information technology infrastructure and advanced transmission software. The developed advanced transmission applications have enabled angle and frequency monitoring; post-mortem analysis; voltage and voltage stability monitoring; oscillation energy and mode meter monitoring; reactive reserves monitoring and device control; model baselining, validation, and improvement; path loading and congestion management techniques. Together, these systems increase grid operators' visibility into bulk power system conditions in near-real time, enable earlier detection of problems that threaten grid stability or cause cascading outages and facilitate sharing of information with neighbouring control areas.
- **New York State Capacitor/Phasor Measurement Project** (DOE/New York Independent System Operator, Inc.). The project main objectives were to improve electric service reliability and power stability and to reduce costs associated with line losses. Phasor measurement units (PMUs), Phasor Data Concentrators (PDCs) and smart grid-enabled capacitors were deployed along with new software to assist in determining real-time grid stability margins. The project has improved the New York Independent System Operator (NYISO) grid operators' visibility into and across New York's bulk power systems, allowing them to monitor in near-real time and enabling earlier detection of disturbances that could result in instabilities or outages. In addition, the NYISO is working on sharing synchrophasor data with neighbouring regional control areas. Capacitor banks (compatible with the advanced monitoring and control capabilities provided by the PMUs and advanced applications) further improve the ability of the NYISO and the NYCA (New York Control Area) TOs to regulate transmission voltage.
- **Enhanced SCADA and PMU Communications Backbone Project** (DOE/ American Transmission Company LLC). The project deployed new fibre optic transmission communications infrastructure across American Transmission Company's (ATC) Wisconsin footprint. The interconnection of the new fibre segments integrated a total of 149 substations within ATC data communications and collection networks and expanded ATC data transfer capability. ATC interconnected new substation fibre optic segments with pre-existing leased fibre optic cable or cable capacity for a more integrated and reliable communications system. The leased fibre is also connected with pre-existing optical fibre ground wire (OPGW). The project deployed new OPGW to complete the fibre optic backbone network. These capabilities have been enhanced by installing satellite communication links that transmit electric transmission system operating data to the communications satellites and back to ATC's system control centres. In addition to reduced operating and maintenance costs, the project enabled improved communications network reliability and increased bandwidth. The results are fewer unplanned outages, increased ability to maintain visibility of the grid's behaviour in near-real time, better physical security at substations and the ability to remotely monitor and control.

- **Energy Management Infrastructure Project** (DOE/ Georgia System Operations Corporation, Inc.). The objective of the project was to install or upgrade the infrastructure necessary to support smart grid applications deployed by Georgia System Operations Corporation's (GSOC) rural electric distribution cooperatives to increase the reliability, security, interoperability and efficiency of their distribution systems. The project implemented advanced analysis software for improved monitoring, planning and electricity cost analysis. GSOC upgraded both the hardware and Energy Control System (ECS) software so that it is now capable of implementing the latest security technologies, has an open communications platform that allows for implementation of future industry standard protocols and interfaces with new Smart Grid devices. The communications infrastructure was also improved by adding a dual-path fibre network between the primary and backup control centres, updating its telecom internet routing equipment and upgrading its Gateway routers to accommodate the new ECS's increased data capacity requirements. The improvements to wide-area monitoring, visualization and control system capabilities enable GSOC to rapidly analyse operations across its entire transmission system and automatically communicate information about disruptions or changes in power flow on the grid to its member electric cooperatives.
- **Boeing SGS (Smart Grid Solution)** (DOE/ The Boeing Company). Boeing and its partner, PJM Interconnection, teamed to bring advanced "defense-grade" technologies for cyber security to the US regional power grid through demonstration in PJM's energy management environment. Under this cooperative project with the Department of Energy, Boeing and PJM have developed and demonstrated a host of technologies specifically tailored to the needs of PJM and the electric sector as a whole. The team has demonstrated to the energy industry a combination of processes, techniques and technologies that have been successfully implemented in the commercial, defence, and intelligence communities to identify, mitigate and continuously monitor the cyber security of critical systems. Guided by the results of a Cyber Security Risk-Based Assessment completed, the Boeing-PJM team has completed multiple iterations, i.e. multiple cyber security solutions have been validated across a variety of controls including: Application Security, Enhanced Malware Detection, Security Incident and Event Management (SIEM) Optimization, Continuous Vulnerability Monitoring, SCADA Monitoring/Intrusion Detection, Operational Resiliency, Cyber Range simulations and hands on cyber security personnel training. All of the developed and demonstrated solutions are suitable for replication across the electric sector and /or the energy sector as a whole.
- **Waukesha Electric Systems/SuperPower** (DOE/ SuperPower [formerly Waukesha Electric Systems]). The project is aimed at developing the key technologies necessary to produce a Fault Current Limiting (FCL) Second Generation (2G) High Temperature Superconducting (HTS) transformer commercial prototype. The proposed 28MVA Utility Transformer will occupy approximately 50% of the physical size/weight of a conventional transformer, lower power consumption through reduction of losses, and increase the reliability of the Nation's Grid. SuperPower (formerly Waukesha Electric Systems) and its partners originally intended to design, develop, manufacture, install, and demonstrate a Smart Grid compatible Fault Current Limiting (FCL) Superconducting transformer on a live grid utility host site. However, when the transformer manufacturer decided to leave the project, the team effort was refocused to develop the key technologies necessary to produce a FCL Second Generation (2G) High Temperature Superconducting (HTS) transformer commercial prototype. The technology portfolio includes a completed FCL HTS transformer design, proven integrated FCL operation, 2G conductor bonding to a stronger substrate material, 2G conductor to bushing terminations, AC loss mitigation and improved 2G conductor performance, piece lengths and cost

improvements. As of October 2015, the prototype FCL HTS transformer design is complete, the integrated FCL operation has been tested and validated using a winding design created for a commercial superconducting FCL transformer. A 2G conductor bonding to a stiffer substrate has been perfected for long lengths and the 2G conductor to bushing termination technology has been developed. The 2G conductor performance and piece lengths have doubled without the loss of high-end current carrying capacity, resulting in the expected conductor cost benefits. AC loss mitigation techniques have been tested and more are being developed in an attempt to reduce the heat load generated by the fields surrounding the windings inside of the transformer during operation.

- **Flywheel Energy Storage Demonstration** (DOE/ Amber Kinetics). The project aimed at developing a flywheel system from sub-scale research prototype (5kWh) to full-scale mechanical flywheel battery (25kWh) and will conduct both a commercial-scale and a utility-scale demonstration. The goal is to deliver a cost-effective prototype flywheel system that can be grid connected and electrically charged and discharged. The system will have built-in sensing components that can determine frequency and voltage characteristics of the grid and can override the grid signal to manage the amount of electricity discharged. The project will improve the traditional flywheel system by engineering breakthroughs in three areas, resulting in higher efficiency and radically reduced cost: magnetic bearings, low-cost rotor, and high-efficiency motor generator. This technology can also be used to optimize existing infrastructure. The commercial-scale 25 kWh system underwent basic functional qualification testing before being installed, sequentially, at the company's outdoor test site for full-speed field-testing. Field demonstrations confirmed that the system met major design specifications. Low-cost manufacturing techniques of flywheel rotors using high strength steel wire was confirmed. Balance of system costs (bearings, motor, vacuum vessel, power electronics) make up the majority of the cost of an anticipated commercial system. The product is now at the stage of final development and testing. Future Plans are to complete development and testing of the commercial-scale flywheel system, activate and test one or more flywheel systems and connect the systems to the utility grid for Metrics and Benefits data collection and reporting.
- **20MW Flywheel Frequency Regulation Plant** (DOE/ Beacon Power). The project aimed to demonstrate the technical, cost and environmental advantages of fast response flywheel-based frequency regulation to grid operators and to reduce the cost of development of a 20 MW flywheel-based energy storage facility compared with that previously incurred by Beacon Power Corporation in the development of the flywheel-based energy storage facility in Stephentown, NY. Hazle Spindle. LLC (plant owner/operator) designed, built, commissioned, and operates a utility-scale 20 MW flywheel energy storage plant in Hazle Township, Pennsylvania (the Hazle Facility) using flywheel technology developed by its affiliate, Beacon Power, LLC (Beacon Power). To achieve its 20 MW capacity, the Hazle Facility is comprised of two hundred of Beacon Power's 100 kilowatt (kW)/25 kilowatt hour (kWh) flywheels connected in parallel. The Hazle Facility can fully respond to a signal from PJM in less than 2 seconds. The Hazle Facility has successfully demonstrated its technical, cost and environmental benefits to the PJM grid. Average performance score of 97% and average availability of 98% in providing frequency regulation services were achieved. The cost of developing the Hazle Facility (around $53 million) was approximately 38% less than the cost of developing a 20 MW flywheel-based energy storage facility using Beacon Power, LLC flywheel technology in Stephentown, NY (approximately $69 million). The Future plans are to monitor performance (primarily maximum capacity, availability and performance scores, which affect revenues) as well as maintenance cost to assure maximum profitability.

22.2.2 From China

12 transmission projects from China have been monitored.

- **Fengning Pumped Storage Power Station** (State Grid Xinyuan Company – State Grid Corporation of China). The project is aimed at building a Pumped Storage hydroelectric Power Station with 3.6GW installed capacity, which is to be the world's largest pumped storage facility to date. The first phase will install 6 reversible pump turbine units, each with a capacity of 300MW, which totals 3.6GW. The designed annual power generation is 3.424TWh with 4.565TWh of corresponding pumped water. Upon its completion, the station will be connected to Beijing-Tianjin-North Hebei grid with two 500kV lines for peak shaving, frequency modulation, phase modulation and emergency backup. It will also be used as large-capacity power storage for the system, which will play an important role to accelerate scaled development of wind power, solar power and other RES in northern Hebei, meet the need for grid peak shaving, maintain the safe and stable operation of the grid, enhance power supply quality and the economy of grid operation.
- **Jiangxi Hong Ping Pumped Storage Power Station** (SGCC). The pumped storage hydroelectric power station bears the tasks of peak shaving, valley filling, frequency modulation, phase modulation and accident reserve. The power station construction can meet the needs of the fast-growing power, optimize the power structure and satisfy the increasing peak load of the power grid. In addition, it is helpful for power grid's operation security and stabilization. In order to match the rapid development of the nuclear power, wind power, solar, and other renewable energy, SGCC plans to reach 21 GW by 2015, and 41GW by 2020.
- **UPFC key technology and core equipment** (State Grid Smart Grid Research Institute). The project aimed at developing Unified Power Flow Controller (UPFC) technology, which is an advanced technology in flexible AC transmission. Flexible AC transmission technology allows the three main electrical parameters (voltage, line impedance and power angle) that affect flow distribution in power system to adjust quickly in accordance with system needs to greatly improve the system stability and reliability. This technology is an important means to achieve economic safety and comprehensive control of the power system. UPFC can flexibly control system power flow, maximize grid transmission capacity and improve system stability. It is the stabilizer of grid operation and multiplier of grid transmission. A UPFC converter valve, valve prototype and laminated distributed control and protection system for the 220kV grid based on modular multilevel, were developed. Platforms for UPFC converter valve equivalent synthetic test, high-capacity hardware-in-loop simulation test and multi-timescale hybrid real-time simulation test were built up. State Grid Smart Grid Research Institute will speed up the achievement transformation and application of UPFC technologies to serve the construction of smart grid and to promote the development of high-end equipment and technology.
- **Zhangbei National Wind and PV Energy Storage and Transmission** (SGCC). The project aimed at demonstrating a stable solution for transferring large amounts of predictable, dependable and dispatchable renewable electricity to the national transmission grid on an unprecedented scale. In addition, the project is focused on using battery energy storage to enable interactive management of the electric power grid (also with frequency regulation and voltage support). The 216 MW Zhangbei National Energy Storage and Transmission Demonstration Project was put into operation in 2011 and includes wind turbine generation (100 MW), solar PV generation (40 MW), battery power storage (20 MW to 36 MW) and intelligent transmission technologies. SGCC chose the BYD Company's lithium-ion iron-phosphate battery technology because of its superior service life (projected to be

20-years), since the use of phosphates avoids the cost and environmental concerns of the use of cobalt and since batteries have higher current or peak-power ratings than typical lithium-ion technologies. In 2014 the project grew to include 500 MW of installed wind capacity, 100 MW of installed solar PV capacity and 110 MW of energy storage.

- **Zhoushan Five-terminal Flexible DC** (SGCC). The main aim of this VSC (Voltage Source Converter)-HVDC demonstration project was to bring to operation the technological advantages of flexible DC transmission in island power supply, i.e., the improvement of power system stability, dynamic reactive power repertory, power quality, system's accommodating capability of clean energy, and distribution grid's reliability and flexibility. In 2014 the ±200kV five-terminal flexible DC transmission system was officially put into operation, which featured the highest level of voltage, largest number of terminals and biggest capacity for single terminal among world's multi-terminal flexible DC transmission projects. Through the construction of the Zhoushan multi-terminal flexible DC demonstration project, SGCC has comprehensively acquired the set design for system digital simulation, converter electrical design, equipment parameter selection, and coordination control protection strategy. Breakthroughs have been achieved in HV large-capacity converter valve (400 MW) and HVDC submarine cable. The company successfully developed flexible DC converter valve with the largest capacity and DC submarine cable with the highest voltage in China, and accomplished system test despite of many core technical difficulties in dynamic simulation experiment and joint operation and commissioning of the multi-terminal flexible DC control protection system.
- **Sino-Russia B2B Converter Station in Heihe** (SGCC). The project aims at putting in operation a DC transmission station equipped with a back-to-back converter, with a transmission capacity of 750MW, in order to transport clean power purchased by SGCC from Russia to China. It is SGCC's first international DC transmission project. After some issues of exceedingly high voltage in the AC system in situations of low load during the first phase of trial operation, the system successfully passed the first tests of the second trial phase.
- **1000kV Jindongnan- Nanyang-Jingmen UHV AC Pilot** (SGCC). The project aimed at installing a UHVAC transmission system connecting 640 km lines at 1100 kV, with transforming capacity of 6000MVA. The equipment is in stable operation. It represents a major breakthrough in China's long-distance, large-capacity, low-cost UHV power transmission core technology and the domestic production of power transmission equipment. Through the project's practice, China has established a first-class UHV research system, mastered the core technology and formed a set of standards on UHV AC power transmission. The project has also upgraded the manufacture industry of power facilities, trained and nurtured a team of technological and managing experts and validated the technical feasibility, equipment reliability, system safety and environmental friendliness in the UHV AC transmission.
- **Xiangjiaba-Shanghai +/-800 kV UHV DC Transmission Pilot** (SGCC). The project aimed at installing a +/-800 kV UHV DC transmission system. By the end of the project it was the world's most advanced UHV DC transmission project with the highest capacity (6400 MW), longest distance (1907 km), most-advanced technology and highest voltage. It's a world-class innovative achievement made by China in the field of energy (thanks to the 800kV, 4500A, 1.8GW thyristor valves that SGCC invented) and represents the highest level of the DC transmission technology in the world. Its operation signified the full access into the era of UHV AC and DC hybrid power grid in China. It will provide 32TWh clean energy to

Shanghai per year. The completion of the project validates the technical feasibility, equipment reliability, system safety and environmental friendliness in the UHV transmission. It is for SGCC another significant achievement after the successful operation of the UHV AC pilot project. It was the first UHV DC link to go into commercial operation.

- **Qinghai-Tibet 750kV/+/-400kV AC/DC Grid Interconnection** (SGCC). The Qinghai-Tibet Grid Interconnection project is composed of the Xining-Riyue Mountain-Wulan- Gomud 750kV AC project and the Gomud- Lhasa +/-400 kV DC power transmission project and other auxiliary projects. The project is a transmission project with the highest altitude and the largest construction scale in an alpine region in the world. Through this project, the Tibet grid will be interconnected with the northwest grid. The power lines have been operated since December 2011.
- **Shenzhen Baoqing Energy Storage Station** (China Southern Power Grid). The project is the key research platform and test pilot project and key technical project for generation peak load shaving of Southern Power Grid Company's Twelfth Five-year Plan. The planned construction capacity is 10MW, 20 sets of 500kW energy storage subsystems. The project consists of 2 periods. For the 1st period, 5 MW was the target. On Jan. 23, 2011, grid connected operation was enabled. It became the first national MW level battery energy storage station. In 2014, the Storage Station was upgraded and became capable of charging or discharging over 12 Mega-Watt-hours or 3 Mega-Watts for 4 hours off or onto the grid. The station is based on Lithium Iron-phosphate batteries from BYD technology. Its main function is peak load shaving. It will discharge in case of a peak period for the main transformer and charge in case of low load for the main transformer each day to improve the load rate and reduce the difference between peak load and low load of the main transformer. At the same time, the station can allow peaking modulation, voltage reactive power control, black start functions.
- **Qingdao XueJiadao Battery Pilot** (SGCC). The Xuejiadao intelligent charging for the storage integration demonstration power plant in Shandong is currently the world's largest, most versatile and strongest electric vehicle charging station. Its aims are to implement the national energy development strategy, accelerate the construction of a strong intelligence network, provide system services, economic and social development. Lithium Iron Phosphate Batteries are used for a 7 MW storage facility. The project was put into trial operation on July 11, 2011, for charging electric buses, cars, and a centralized energy storage connected to one of the electric vehicle charging station. By the end of May 2013, the Xuejiadao demonstration power plant had safely operated during 695 days.
- **Ningdong-Shandong +/-660kV DC Project Double Polar** (SGCC). This project is the most recent development in UHV DC systems: on the 11^{th} of January 2016, the construction of a UHV DC line from Zhundong in Xinjiang to Huainan in Anhui started (3,324 kilometres with a maximum transmission capacity of 12 GW). This line positions Xinjiang to become China's power and energy supply hub in the future. This new line will be about 1000 km longer and will operate at a higher rating (±1100 kV vs ±800 kV) than the previous longest one which runs from Jiuquan to Xiangtan.

22.2.3 From Japan

9 transmission projects from Japan have been monitored.

- **Tomamae Wind Farm** (J-Power). The Tomamae Wind Villa Power Plant continues to be one of the world's largest vanadium redox flow battery energy storage installations and, at the time of commissioning in 2000, was Japan's first and largest wind power plant. In 2005, Sumitomo Electric International (Osaka, Japan) was contracted to install a vanadium flow battery system at the existing 30.6 MW Tomamae Wind Villa on the island of Hokkaido, Japan. The primary intent of the battery system was to provide "wind smoothing" for the wind power plant. The facility has operated well since January 2005, sometimes performing over 50 charge-discharge cycles per hour. By acting as a rapid source and sink for the variable wind energy production, this facility has smoothened the ramping rates of the wind farm's output with respect to the rest of the island's grid by reducing the peaks and valleys of the wind farm energy output. The environmental impact has been considered by burying the power cables and installing transformers in the turbine towers. The energy storage facility is configured with 16 modules rated at 250 kW each, which gives the entire facility a 4 MW rated power with 6 MWh of storage (90 minutes).
- **Tanegashima Island Toshiba Li-Ion** (Kyushu Electric Power Co., Inc.). Toshiba Corporation has delivered a battery energy storage system integrating the company's SCiB™, a Lithium-ion Titanate secondary battery, to Kyushu Electric Power Co., Inc., for a demonstration project to allow the penetration of high share of renewable energy sources on remote islands. The system has been installed in a substation on the Tanegashima Island, and will be used to demonstrate the integration and optimum control of battery energy storage systems deployed to manage frequency regulation and maintain stable power supply on remote islands, which are increasingly turning to renewable energy sources. The demonstration program is going to run for three years until the end of 2016.The maximum output and capacity of the system are 3MW and 1,161MWh respectively. The system integrates a Toshiba's SCiB™ lithium-ion secondary battery, which is known for its long-life and excellent performance: support for over 10,000 charge-discharge cycles; rapid charging and discharging; high level reliability and operational safety.
- **Amamioshima Island Toshiba Li-Ion** (Kyushu Electric Power Co., Inc.). Toshiba Corporation has delivered a battery energy storage system integrating the company's SCiB™, a Lithium-ion Titanate secondary battery, to Kyushu Electric Power Co., Inc., for a demonstration project to allow the penetration of high share of renewable energy sources on remote islands. The system has been installed in a substation on the Amamoioshima Island, and will be used to demonstrate the integration and optimum control of battery energy storage systems deployed to manage frequency regulation and maintain stable power supply on remote islands. The demonstration program is going to run for three years to the end of 2016. The maximum output and capacity of the system are 2MW and 774kWh respectively. The system integrates a Toshiba's SCiB™ lithium-ion secondary battery, which is known for its long-life and excellent performance: support for over 10,000 charge-discharge cycles; rapid charging and discharging; high level reliability and operational safety.
- **Miyako Island Mega-Solar Demo: NaS** (METI/Okinawa Electric Power Company). The project aimed at understanding what impacts the widespread introduction of solar power generation, whose output fluctuates widely, would have on the power transmission and distribution network and at verifying the control function that benefits grid stabilization using secondary batteries. The system utilizes 8 sets of 0.5 MW NaS batteries (combined with 4MW solar panels). In addition, a 100kW Li-

ion secondary battery was installed. The 4MW NaS and 100kW Li-ion cells are connected with the transmission grid of Okinawa Electric Power Co Inc and the distribution grid, respectively. The following functions were demonstrated:

  - Smoothing-Out Effect of PV Output Power;
  - Smoothing-Out Effect of Frequency;
  - Scheduled Operation of PV;
  - Optimal Control Hierarchy Using Test-use Power Distribution Lines.

- **Storage demonstration project on Niijima island** (Takaoka Toko Co. Ltd.). Takaoka Toko Co. Ltd. has selected Saft's Intensium Max 20 M Medium power Li-ion containerised battery system to provide energy storage for a demonstration microgrid project - aimed at expanding the installation of renewable energy using systems - on the remote Japanese island of Niijima in the Tokyo prefecture. The ESS (Energy Storage System) will ensure operations such as ramp and frequency smoothing for Takaoka Toko Co., Ltd. – a subsidiary of Tokyo Electric Power Company (TEPCO). The demonstration project on NiiJima Island will comprise diesel generators, solar panels and wind power installations working in various combinations to optimize the usage of renewable energy resources. For an experimental period of 5 years, this project has as its principal objective to highlight the technical challenges (such as expected electric power quality and grid management) that need to be addressed when renewable energies – especially wind generation – are associated with electric power systems and to study the related solutions. The small area and population of around 3,000 people of the Niijima Island make it the perfect location for such a demonstration project as a miniature model of Japan in anticipation for 2030. The ESS will comprise one of Saft's well proven Intensium Max 20 M Medium Power containerised Li-ion battery systems, modified to offer a nominal storage capacity of 520 kWh and 1 MW peak power output. The battery will operate in combination with Takaoka-Toko's intelligent control systems that enable large amounts of wind and other renewable energy based power to be integrated into diesel powered grids, ensuring system stability and smooth control of the gensets. The use cases to be demonstrated are the following: Frequency Regulation; Microgrid Capability; Onsite Renewable Generation Shifting; Ramping; Renewables Capacity Firming. The installation and commissioning of the Saft ESS is expected to be completed in 2016.
- **Wakkanai Mega-Solar Project** (NEDO/HEPCO). The mega-solar demonstration project named "Verification of Grid Stabilization with Large-scale PV Power Generation systems" began in 2006 at Wakkanai on Hokkaido Island, the northernmost city of Japan and was completed in 2010. NEDO, New Energy and Industrial Technology Development Organization of Japan, financed this project and HEPCO, Hokkaido Electric Power Co., Inc managed the project. NEDO funded a 5 MW PV and 1.5 (1.0+0.5) MW NaS battery which is connected to the utility's (HEPCO's) 33kV power grid. The NaS battery smoothens the fluctuations of PV generation within its limit of power and energy capacities. For more efficient and effective operation of the NaS battery, several control algorithms for smoothing the PV output and for scheduled operation using solar radiation forecast were developed and tested. Meteorological equipment were also installed in and around the power plant, and the observed data was used for solar radiation forecasts. The control method could reduce the maximum fluctuation width in periods of less than 1 min from 33.6% to 3.2% and, over less than 30 min, from 65.1% to 12.4%. Thus, it became possible to continuously reduce output fluctuations in the suitable SOC (State of Charge) of the NaS battery by changing the control mode appropriately in charge and discharge time. The following use cases were demonstrated: frequency regulation, electric energy time shift and electric supply capacity.
- **Nishi-Sendai Project** (New Energy Promotion Council [NEPC]). The aim of the

Nishi-Sendai project, in the Miyagi prefecture, north of Fukushima was to regulate frequency changes caused by power output fluctuations. The project was supported by the New Energy Promotion Council (NEPC) under its "FY2014 project". A 40MW-20MWh lithium-ion Battery Energy Storage System was delivered in 2014 by Toshiba to Tohoku Electric Power Company. Tohoku-Electric Power Co Inc. announced on February 20, 2015, that it had started commercial operation of the large-size storage battery system installed at the Nishi-Sendai Transformer Station. Tohoku-Electric Power will check the improvements of the effects of the battery system on the adjustment of frequency by automatically controlling the charge/discharge of the storage battery at the "Central Power Supply Direction Center" and combining the frequency adjustment function, which has been provided mainly by thermal power plants, and the storage battery system. The company plans to continue the verification test until the end of 2017. This is the first time that such a large-scale battery system has been installed for a power grid in Japan. During the verification tests, Tohoku-Electric Power will (1) perform the development of frequency control algorithms combining the storage battery system and thermal power generator, (2) check the effects on the improvement of frequency adjustment, (3) verify the effects on penetration of renewable energy, (4) measure the charge/discharge levels of the rechargeable battery, losses made at the time of charging/discharging, battery estimated lifetime, etc.

- **Minami-Soma Substation Project** (New Energy Promotion Council [NEPC]). The Minami-Soma Substation Project aims at verifying the improvement of supply-demand balance with large-capacity power storage systems. The project is supported by the New Energy Promotion Council (NEPC) under its "FY2014 project". Tohoku Electric Power Company has deployed the BESS in a power transmission substation in Minami-Soma, on Japan's east coast in the Fukushima prefecture. The battery energy storage system (BESS) started to operate in February 2016. The 40MW-40MWh lithium-ion BESS is one of the largest BESS in the world.
- **Redox flow battery system in Minamihayakita** (METI). The aim of the project is to study the installation and utilization of large scale batteries in electricity grid substations so as to manage the integration of renewable energies, as well as to develop the technology to optimally control and manage such batteries. Hokkaido Electric Power Co., Inc (HEPCO) and Sumitomo Electric Industries, Ltd. collaborated to install a 60 MWh redox flow battery in the Minamihayakita substation on the island of Hokkaido. These companies also developed the battery control and management technology. The installation of the redox flow battery-based energy storage system with a rated output of 15MW was completed in December 2015. The project was, at the time it was first announced in August 2013, the largest of its kind in the world. The redox flow battery storage system was built and installed by Sumitomo Electric Industries (SEI). The Minamihayakita substation is located close to Japan's biggest solar power station to date, a 111MW facility in the town of Abira which was also connected to the grid in December 2015.

22.3 Recommendations and final remarks for R&I policy makers

In general, the analyses presented above show that R&I projects carried out outside Europe at transmission level have reached much higher TRL levels than in Europe, for similar R&I activities. This tends to suggest that the funding mechanisms and the associated policies are focused on the deployment and market uptake of new technologies by the market makers (network operators) and the market players.

Regarding projects with no storage component, the following specific remarks can be made:

- A significant effort (in the US) is made to install, test and validate the use of PMUs for network operations. Hundreds of PMUs have been deployed and are now operational. This deployment is done with the upgrade of the hardware and software layers for communications (with an emphasis on communication protocols and standards);
- China has already installed, tested, validated and operated large-capacity UHV power transmission core technologies (both for AC and DC). This has allowed Chinese players to develop and upgrade their manufacturing capabilities for power components, and to gather R&I knowledge in the associated fields (training of operators, tests of equipment reliability and system safety, etc.).

For projects with a storage component, the following specific remarks can be made:

- Some major efforts are still made in the US on storage technologies which are not the main focus of R&I activities in Europe: CAES (system services) and flywheels (frequency control) with demonstrators at industrial scale;
- Demonstration projects related to BESS integration address the same issues as in Europe but at a larger scale (the batteries have capacities of several tens of MW - one system over 100 MW in China-);
- Japan is probably the most advanced country in terms R&I activities relative to the use and integration of BESS in transmission networks: several technologies have been tested (redox flow, Li-ion, NaS) at an industrial scale for different system services.

R&I policies in Europe for storage integration should focus on large scale demonstrations which can be replicated rapidly in the power system. Emphasis should be put on developing knowledge which can be exported: design, simulations, and integration devices. Regarding equipment, especially BESS manufacturers, Asian and American players have a clear lead time.

23. R&I achievements in distribution

23.1 Features of achievements from selected non-European projects in distribution

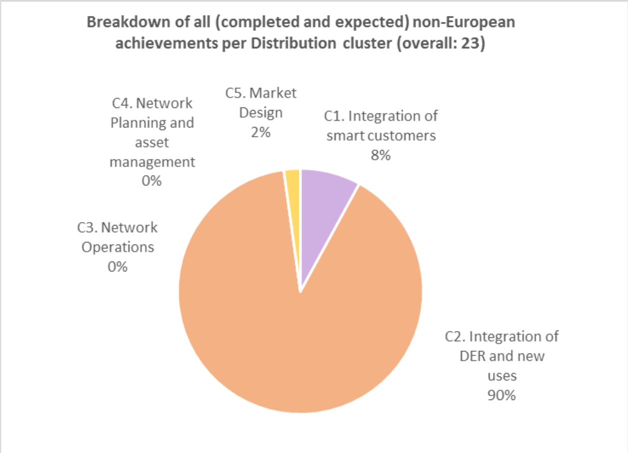
23.1.1 Descriptive features of achievements

Descriptive features of R&I achievements include information for categorization and an estimation of the maturity increment of each considered innovation (see Table 5):

- Categorization in clusters of the roadmap;
- Typology of achievements (1. Methodology; 2. Software; 3. Hardware; 4. Database; 5. Policy, regulation, market; 6. Other);
- Input and output Technology Readiness Levels (TRL).

Categorization in clusters

The graphs below characterize the sample of achievements of non-European R&I projects for all clusters in distribution. A comparison with the achievements from R&I projects in Europe is provided.



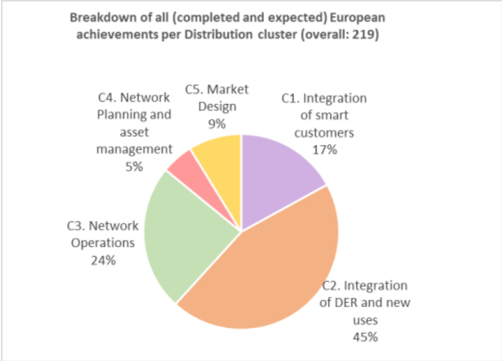


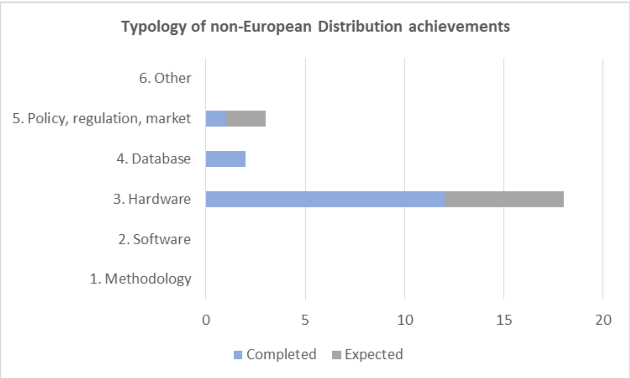
Figure 91: Achievements of non-European projects related in relation with each distribution cluster (left), compared to the achievements of R&I projects in Europe (right)

Highlights:

- Regarding non-European achievements per cluster on the left chart, it is noticed that the most addressed cluster of distribution activities is C2 (Integration of DER and new uses) with 90% of the monitored sample. In second place, C1 (Integration of smart customers) represents 12% and then, C5 (Market design) amounts hardly 2% of the achievements reviewed. Clusters C3 and C4 do not have any achievement among the sample.
- Most of the non-European projects reviewed are related to distributed storage and renewables integration at MV and LV levels: these activities are directly linked to cluster 2.
- For European achievements, C2 is also the most addressed cluster with 45%, followed by C3 with 24% and C1 with 17%.

Typology of achievements

The different types of achievements generated by the non-European and European projects are provided in the figures below.



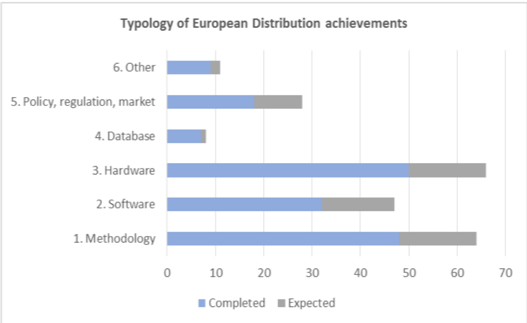


Figure 92: Typology of achievements from non-European R&I projects in distribution (left), compared to the achievements of R&I projects in Europe

Highlights:

- Non-European completed and expected achievements are principally related to hardware issues; then to policy, regulation and market topics, and finally to database aspects. Meanwhile, European projects address hardware and methodology subjects predominantly; and then, software issues come up to the third place.
- There was no reported results concerning neither methodology nor software topics in the non-European monitored achievements.

Evolution of the maturity of achievements

Innovations involved in the considered Distribution projects were characterized by their degree of maturity using the TRL metric as explained before in the previous homologue sections:

- Two levels of TRL were assessed: inputs before the project starts (in a clear colour code), and at the project end (darker colour). This is depicted in the figure below, with again a comparison with the achievements from R&I projects in Europe.

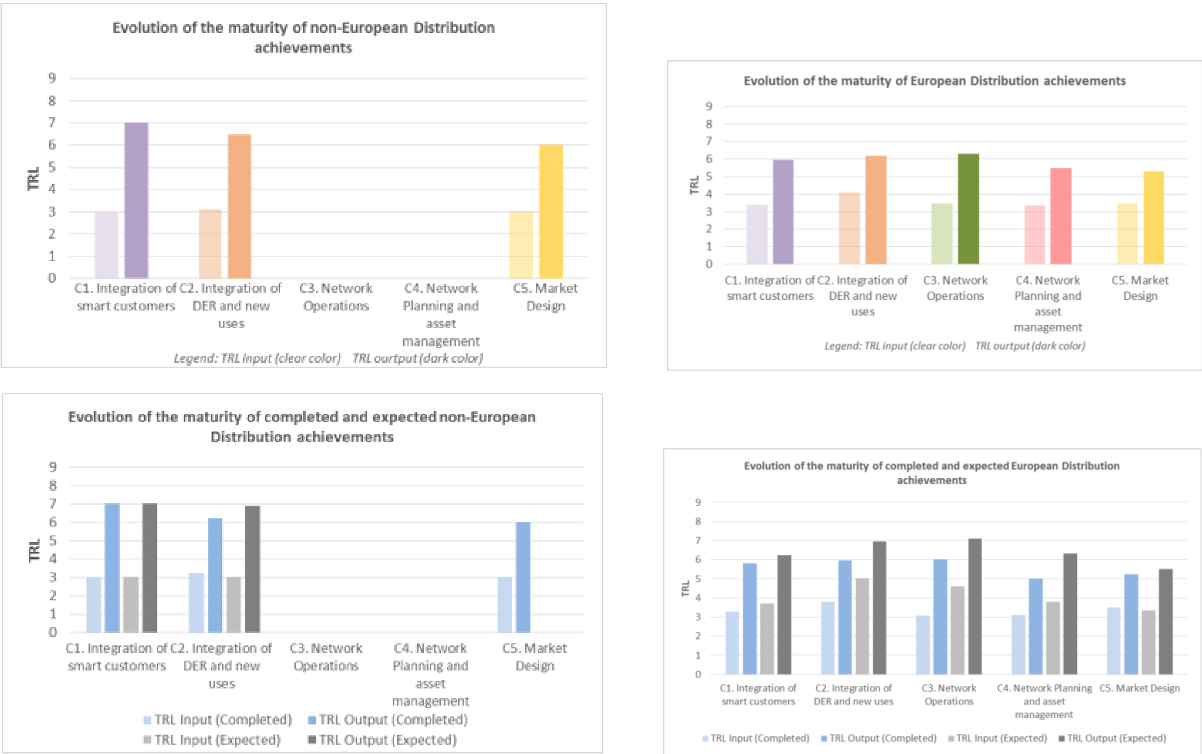


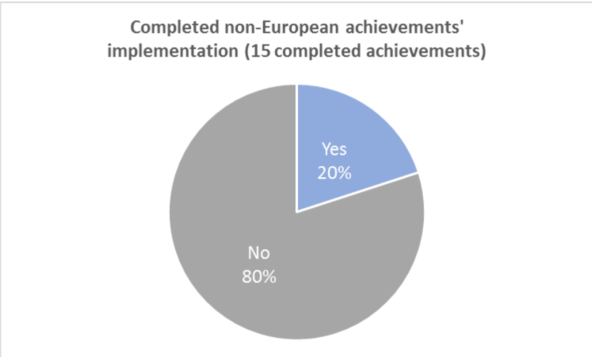
Figure 93: Evolution of the maturity of achievements from non-European projects related to distribution activities measured in TRL units (left), compared to the achievements of R&I projects in Europe (right)

Highlights:

- On average, for each addressed cluster of non-European projects, an increment of three to four units in the TRL scale is observed between the input and output TRL (left diagrams). The highest increment belongs to cluster C1 (Integration of smart customers) and cluster C3 with a TRL of 3 at the input up to a TRL of 7 at the output.
- The TRL levels of the three addressed clusters (C1, C2 and C5) of the non-European achievements are higher than their European homologues by one TRL unit.

23.1.1 Projective features of achievements

As explained previously, projective features of each achievement refer to possible implementations and next steps as considered by expert members of the Grid+Storage consortium. For non-European projects concerning distribution activities, VITO was the partner in charge of the analysis of non-European achievements' implementation and their further steps.



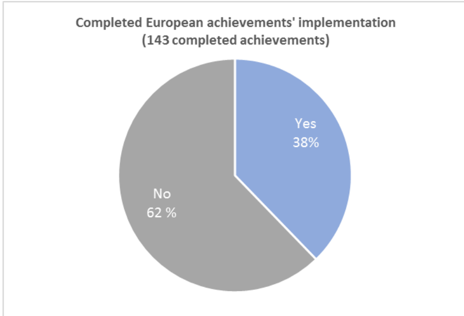


Figure 94: Implementation for non-European completed achievements in distribution (left), compared to completed achievements of R&I projects in Europe (right)

Highlights:

- It is shown that only 20% of the completed non-European achievements regarding distribution activities have been implemented versus a 38% of their European equivalent.
- It may occur that implementation actions of some achievements are foreseen but have not started yet: in such situations they are accounted for in the "next steps" diagrams.

The graphics below show the further steps of non-European and European achievements (either further research, further development, demonstration or deployment) in order to be implemented.

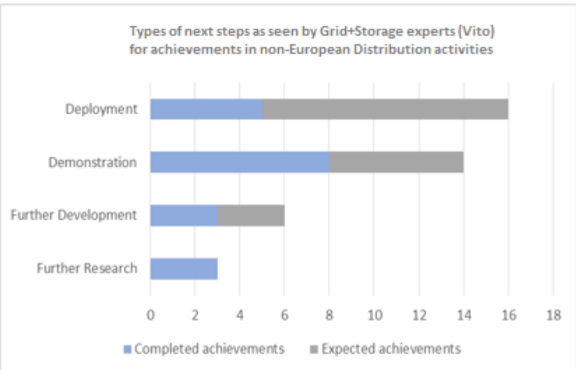


Figure 95: Implementation actions carried out for achievements from non-European R&I projects in distribution (left), compared to the achievements of R&I projects in Europe (right)

Highlights:

- For the majority of the non-European achievements, further project's steps were considered to be demonstration and deployment, principally. Only about 7 % of the non-European monitored sample was considered to require further research.

- In contrast, regarding the European achievements' next steps expressed by project coordinators; deployment (which is the step before implementation) obtained the lowest number of answers with 16% of the total monitored sample. In addition, further research for European achievements obtained a significant 20% of the answers. Most of the project coordinators' answers corresponded to further development and demonstration as next steps for their achievements.

23.2 Description of each project of the selected portfolio

23.2.1 From the USA

10 distribution projects from the USA have been monitored.

- **UCSD BMW second life EV energy storage system** (Privately funded-PG&E). A second life battery system has been installed at the BMW Technology Office (USA BMW) of North America in Mountain View. It consists of a 100 kW inverter and 8 used battery packs from former MINI E EVs, once driving on California roads; a total of 240kWh lithium iron phosphate battery housed in a shipping container. The system is used for multiple use cases, e.g. Demand Response programs, Peak Demand Shaving, and Photo-Voltaic Energy Storage, and Uninterruptable Power Supply for power outages. The system is fully integrated into an advanced building energy management system, and is connected to a 100 kW solar array as well as a network of EV charging stations, including several DC fast charging stations.
- **EnerVault Redox Flow Battery Demo Project** (Federal/National Office of Electricity and Reliability – RD&D). This project demonstrated an iron-chromium redox flow battery system in combination with an intermittent, renewable energy source (PV). The project used EnerVault's long duration system to reduce demand charges and enhance the performance of a 150 kWp AC dual-axis tracking photovoltaic system to power a large 260 kW irrigation pump.
- **DTE Community Energy Storage for Grid Support** (Federal/National American Recovery and Reinvestment Act of 2009 - RD&D). The project entails the implementation of 1-MW of distributed Li-ion energy storage on a distribution circuit in the DTE Energy service area. 18 S&C Electric (S&C) supplied 25kW/50kWh CES (community energy storage) units were installed, a 500kW Li-ion battery storage device was integrated with a 500 kW solar system together with two repurposed (secondary use) energy storage systems using Fiat Chrysler Automobile (FCA) 500e EV batteries. The first CES unit was installed at the DTE Energy Training and Development Center in Westland, MI for installation training, verification of work and operational procedures, and engineering design documentation. The remaining 17 CES units and the 500 kW battery are installed on a distribution circuit designated as TRINITY 9342 located near Monroe, MI. The repurposed batteries were installed at DTE Energy headquarter and at Next Energy Center in Detroit. This project successfully used DNP3 protocol through the DERMS (Distributed Energy Resource Management System) to test 23 use cases. These use cases range from testing communication to individual CES units to testing of aggregation of all batteries based on distribution circuit model commands and dispatching due to high locational marginal pricing (LMP).
- **Battelle Memorial Institute Pacific Northwest Smart Grid Demonstration** (Federal/National American Recovery and Reinvestment Act of 2009 – RD&D). PGE's Salem Smart Power Center (SSPC) is an Energy Storage Facility in Salem, Oregon. The project has a 5 MW, 1.25 MWh storage resource designed to increase distribution system reliability, aid renewable resource integration and decrease peak-price risk. The PGE's Salem Smart Power project is associated with the Pacific Northwest Smart Grid Demonstration Project test phase which began in September

2012. Portland General Electric (PGE) installed a microgrid that will allow about 500 business and retail customers to maintain power during blackouts. They employed energy storage as the backbone of the microgrid, with a 5-megawatt lithium-ion battery system installed at the PGE substation in Salem, Oregon. The energy storage is used as a way to transition to operation detached from the grid. The battery responds to an outage by supplying electricity to all residential, commercial, and industrial customers for 15–20 minutes — ample time to start standby power—six customer-owned distributed diesel generators—and synchronize them on the line. Once the feeder is isolated from the utility grid, the generators start up, and the circuit becomes an islanded microgrid.

- **NEDO New Mexico Smart Grid Demonstration Project**. Photovoltaic systems provide a significant portion of the power supply and account for up to 75% of the energy at the Los Alamos site. Because the output of photovoltaic systems vary with weather conditions, large-scale stationary batteries and demand response have been used to control the power flow of the distribution system and ensure quality. In Los Alamos County, a demonstration was conducted of a smart grid system to regulate the introduction of 1MW of solar power into a power distribution feeder system with a total demand of approximately 2-5MW. More specifically, this included testing the operation of a microgrid that can absorb fluctuations in solar power generation through a 1.8MW-level storage battery system; testing coordinated operations between HEMS and the power grid to absorb surplus solar power generation in residential-level storage batteries placed in prototype smart-houses; and testing residential demand-response with the participation of about 900 households. The project demonstrated technologies that successfully absorbed the variations in power output resulting from the massive introduction of renewable energy (PV) to deliver consistent power flow at the edges of the microgrid by using EMS in conjunction with NaS and lead storage batteries to control the fluctuations.
- **DOD Marine Corps Air Station Miramar Microgrid Energy Storage System** (Environmental Security Technology Certification Program [ESCTP]). Primus Power, was awarded a contract by Raytheon's Integrated Defense Systems (IDS) business to deliver and support an electrical energy storage system for a microgrid at the Marine Corps Air Station (MCAS) in Miramar, California. At MCAS Miramar a Primus Power 250 kW - 1 MWh Primus EnergyPodTM (a Zn/Br flow battery-based ESS) has been integrated with an existing 230 kW photovoltaic system. The combined microgrid system will demonstrate several capabilities including reducing peak electrical demand typically experienced in weekday afternoons and providing power to critical military systems when grid power is not available. Microgrid control technologies coupled with Miramar's infrastructure will provide energy security, islanding capability, and reduced costs. Success is being defined by the ability to peak shave and island a building circuit for 72 hours. Prior to installing the system, the National Renewable Energy Laboratory conducted testing of the power electronics and controls at the Energy Systems Integration Facility (ESIF) to characterize system behaviour and troubleshoot control settings. Performance data is currently being collected for total energy stored and peak power offset. The demonstration to "island" a building circuit is currently taking place (Spring/Summer of 2016).
- **UC San Diego CPV Firming** (California Energy Commission). Maxwell Technologies has collaborated on a California Energy Commission funded, two-phase program to demonstrate the cost and efficiency benefits of combining an energy storage system with Soitec's Concentrix™ CPV technology. Maxwell has been awarded a $1.39 million contract by the California Energy Commission's Research and Development program to fund design and integrate an ultracapacitor-based energy storage system with Soitec's CPV system located on the campus of UC San Diego and a

second commercial scale system at Soitec's solar power plant in Southern California. The integrated systems also take advantage of other technology advances, including solar forecasting and predictive energy control, to maximize the benefit of incorporating ultracapacitor energy storage. Ultracapacitors are energy storage devices that charge rapidly from any electrical energy source and discharge their stored energy on demand. In combination with a photovoltaic system, their function will be to act as a standby reservoir of electrical energy to mitigate the variability of solar energy generation. This "firming" of the output of a utility scale commercial CPV system is intended to reduce demand on the electric grid to fill in short-term solar "valleys" to maintain a facility's electricity output. In addition to reducing the variability of a solar power plant, integrated ultracapacitor-CPV systems will benefit public utility customers by reducing investment in utility generation capacity to meet transient peak power demand.

- **2 MW Potsdam, New York – Microgrid** (Federal/National Government – RD&D). Potsdam was the epicentre for a 1998 ice storm that left 130,000 people in the region without power. Now, National Grid (Potsdam's utility provider), General Electric, Clarkson University, and the National Renewable Energy Laboratory (NREL) are partnering to make sure severe weather events like the 1998 ice storm will not have such drastic effects again, by building what could be the nation's largest municipal microgrid. The microgrid will use local renewable resources as much as possible. The proposal calls for 3 MW of combined heat and power generators, 2 MW of solar PV, 2 MW of storage, and 900 kW or more of hydropower. A $1.2 million grant from the DOE's Office of Electricity Delivery and Energy Reliability and a $300,000 investment from GE will be used to develop an enhanced microgrid control system (eMCS). The control system will keep the town's electricity on for several days if the main power station goes down, and will also help National Grid better integrate distributed energy resources into the grid. The microgrid will normally operate in a grid-connected mode. The eMCS will also be used to maximize the operating revenue of any individuals who have their own distributed generation systems. While studies are still being conducted, the hope is that during an extreme event when the main grid goes down, the microgrid will operate in island mode and use energy storage to help power essential services for up to two weeks.
- **Hybrid Compressed Air Energy Storage and Thermal Energy Storage** (California Energy Commission). A team of engineers from the UCLA Henry Samueli School of Engineering and Applied Science, in partnership with Southern California Edison, has received a $1.62 million grant from the California Energy Commission to build a hybrid energy storage system that stores energy harvested from intermittently productive renewable sources such as solar panels and wind farms, then releases that energy into the grid when demand is high. The energy system under development is a hybrid of compressed air energy storage and thermal energy storage technologies. Although compressed air has long been used in energy storage, this system will use a state-of-the-art, high-temperature storage unit to enhance storage capacity and economic viability. This innovative technology offers the potential for a highly efficient, ultra-low-cost zero-carbon emission solution for storing intermittent renewables. Current estimated cost of energy for this unit is about $100 / kWh. The technology will be built on the Cal Poly Pomona campus and will be operated in conjunction with Southern California Edison.
- **Stapleton Neighborhood Energy Storage** (Colorado Public Utilities Commission [PUC]). Xcel Energy filed proposals on two solar-storage projects with regulators in Colorado. The two projects, one in the Stapleton neighbourhood in Denver and the other at the new Panasonic complex near Denver International Airport, will test the use of batteries as well as the operation of "microgrid" power systems. At the Panasonic test site, Xcel will install a utility-scale solar power system and one large

battery. The Panasonic project will have the capability to be operated as a microgrid, which can provide backup power in emergencies, as well as connected to the regional grid. At the second project, known as the Stapleton project, Xcel will install six batteries at customer's homes that already have rooftop solar power systems installed. Additional batteries will be installed on Xcel's feeder powerline in that area. This feeder line supports more than 330 rooftop solar installations which can supply up to 18.5 percent of the power line's capacity, one of the highest levels of solar penetration on Xcel's grid in the state. Up to six battery storage systems of multiple sizes will be deployed at strategic locations along the distribution feeder line.

23.2.2 From Canada

4 distribution projects from Canada have been monitored.

- **Wind R&D Park and Storage System for Innovation in Grid Integration** (Clean Energy Fund program [CEF]). The Wind Energy Institute of Canada has developed and operates a Wind Energy R&D Park and Storage System for Innovation in Grid Integration (Wind R&D Park), which consists of 10 MW of wind power and a 1 MW/2 MWh battery energy storage system (BESS). One of the objectives of the project is using electricity storage to optimize the benefit of wind power to the electrical grid system. Currently the storage system is being used to time-shift electricity. Possible future services for the battery are: Wind Prediction Firming; Voltage Support; Transmission loss reduction; Reduce Output Volatility; Demand Charge Management; Ancillary Services (including frequency regulation, load following, spinning reserve, supplemental –secondary- reserve, and/or backup supply). The Na-NiCl2 storage technology which was chosen has shown excellent charge/discharge cycles although it has just begun its operation and any results are only preliminary.
- **Cowessess First Nation High Wind and Storage Project** (Natural Resources Canada's Clean Energy Fund). This project involves installing an 800-kW wind turbine and 1000-kWh lithium-ion battery storage system on Cowessess First Nation (CFN) land 2-km southeast of Regina, Saskatchewan. The intent is to demonstrate a wind-storage system that can harness wind power and provide a more continuous and predictable output for on-grid and perhaps off-grid applications. The successful demonstration would prove this system as a model for other First Nation's communities across Canada. The wind-storage system could reduce wind volatility by as much as 70%, and the response to load changes would be very fast. Hence, the system could be used to control wind power ramping rates and add more predictability to the turbine's power output. If connected to the grid, the system could command a better electrical rate because the battery could be charged during off-peak periods and dispatched during the morning, noon, and evening peak times. Furthermore, the system could potentially act as a stand-alone unit to provide service to remote off-grid communities given sufficient storage.
- **Energy Storage and Demand Response for improved reliability in an outage-prone community** (Natural Resources Canada's Clean Energy Fund). BC Hydro's Golden substation (GDN) supplies power to the town of Golden and surrounding areas (including the community of Field) via four radial feeders. Field has 155 BC Hydro residential and commercial accounts. The electricity supply for Field is provided by a single 25 kV, 55 km long distribution feeder, which is prone to frequent power outages of significant duration. In order to mitigate reliability issues at Field, BC Hydro evaluated alternatives such as battery storage and diesel generation. Because the cleaner battery option was preferred, BC Hydro put forward the project for funding consideration through the Clean Energy Fund (CEF). The project was awarded $5.98M to install a 1 MW battery energy storage system (BESS) in order to provide clean back-up power and enhance customer supply

reliability for the community of Field. BC Hydro selected both the battery and system integrator through a Request for Proposal (RFP) process. NGK Insulators' sodium-sulphur (NaS) battery was selected because it met performance and cost criteria. S&C Electric was chosen because of its previous experience with sodium sulphur BESS installations. On July 11, 2013, the BESS became operational and started delivering clean, back-up power. The system has since been providing benefits by delivering a clean source of back-up electricity during power outages and reducing the overall demand of Golden substation during on-peak hours. As of January 2015, the BESS in Field has provided 76 hours of back-up power to the community of Field. This is equivalent to a reduction of 11,455 customer hours lost (CHL).

- **Utility Scale Electricity Storage Demonstration Using New and Re-purposed Lithium Ion Automotive Batteries** (Natural Resources Canada's Clean Energy Fund). During nights, a large amount of wind energy is generated in Ontario, but not used. The idea of a storage system is to stockpile the energy generated during off-peak, low-demand hours and delivering it to homes and buildings during peak, high-demand hours. As the province seeks to up its renewable energy production, the need for a large-scale energy storage system becomes urgent. Moreover, energy storage could provide a means of delaying substation upgrades and transmission line extensions, as well as reducing the need for building new generation. Electrovaya will be developing an energy storage system in partnership with Hydro One. The project will produce a state-of-the-art 1.1 MWh lithium-ion battery system. The new energy storage technology, Lithium Ion Super Polymer batteries, have a number of advantages including high energy density and the battery has a built-in converter. With Electrovaya, Hydro One, Toronto Hydro and a number of other companies sponsoring the project, Ryerson was enlisted to conduct the research on the battery for one year (currently ongoing). Once that year is over, that battery will be sent back to its manufacturers who can then decide to test it at other locations. The battery was delivered in early October 2015 and is the object of a research project aimed at correcting problems from the city's electricity grid. The 1.1 megawatt-hour battery is connected to the City of Toronto's electricity grid, and supplies stored energy to the building during peak hours. During off-peak hours, it will capture excess energy from the grid and store it for later use. The battery bank is also expected to power 200 houses in the area for five hours per day.

23.2.3 From Australia

2 distribution projects from Australia have been monitored.

- **Trialling a new residential solar PV and battery model** (ARENA [Australian Renewable Energy Agency]). This project involves Queensland energy provider Ergon Retail undertaking a pilot demonstration to test a commercial and operational model for providing grid-connected solar photovoltaic (PV) and battery storage systems to residential customers. The demonstration will involve installing and testing 33 systems in Cannonvale, Toowoomba and Townsville. Ergon Retail will be trialling a new business model for providing grid-connected PV and battery systems to residential customers which involves installing the system at the customer's premises but retaining ownership and charging the customer a fixed service fee. Ergon Retail will aim to optimise the different value streams available from the PV and battery system, such as minimisation of customers' electricity bills, reducing Ergon Retail's wholesale market risk, revenue from the provision of network demand side management services to the network business to reduce network peak demand, and any other possible revenue sources (e.g. related to grid support). The pilot demonstration will draw on real customer and operational experiences to provide a deeper understanding of the costs and benefits of the model. The systems, which will consist of a 4.9kW SunPower PV array and a 12kWh/5kW

Sunverge battery storage and control system, are expected to be installed and commissioned by the end of 2015. They will be operated and tested for a period of 12 months with the demonstration expected to be completed by the end of 2016.

- **Solar and storage trial at Alkimos Beach residential development** (ARENA [Australian Renewable Energy Agency]). This project involves developing, deploying and testing the commercial feasibility of a new energy retail model. It will combine community scale battery energy storage, high penetration solar photovoltaics (PV) and energy management within a new residential development at Alkimos Beach in Western Australia. There are currently no existing tariffs to allow community energy storage to discharge onto electricity networks. There is also a need to better understand the level of electricity supply reliability provided by a combination of renewable energy generation and enabling products when compared with traditional poles and wires. A centralised battery will provide customers with the benefits and incentives of stand-alone storage without requiring on-site installation and maintenance. The project will:
    - design, manufacture and install a fully contained lithium ion energy storage system of approximately 250 kilowatts peak / 1.1 megawatt-hours;
    - install an Energy Smart Home Package in at least 100 homes; and
    - develop and test at least three new electricity retail products.

  The central 1.1 megawatt-hour (MWh) of lithium ion battery storage has already been installed in two shipping containers in the suburb.

23.2.4 From Japan

1 distribution projects from Japan has been monitored.

- **Niijima Island Microgrid**[29]. Tokyo Electric Power Company (TEPCO) will conduct a microgrid demonstration project on a remote Japanese island, incorporating solar, storage, wind and diesel. Saft has been awarded its first energy storage system contract in Japan to supply a containerized 520 kWh/1 MW lithium-ion battery system for the Niijima Island Microgrid project conducted by Takaoka Toko Co., Ltd. – a subsidiary of Tokyo Electric Power Company (TEPCO). The demonstration project will comprise diesel generators, solar panels and wind power installations working in various combinations to optimize the usage of renewable energy resource. The battery will operate in combination with Takaoka-Toko's intelligent control system that enables large amounts of wind and other renewable energy based power to be integrated into diesel powered grids, ensuring system stability and smooth control of the gensets. The program will investigate the use of energy storage for various applications in the microgrid setting. The demonstration site is currently under construction.

23.2.5 From India

3 distribution projects from India have been monitored.

- **Sun-carrier Omega Net Zero Building in Bhopal**. India's rapid rate of growth in the recent past has resulted in a significant energy deficit. As a result, an increasing number of industries, commercial complexes, residential units, and agricultural facilities have had to resort to captive power generation. In this context, diesel generators have been the single largest source of captive power, as also the single largest source of green-house gases. Since buildings consume almost 29% of all energy consumed, investing in net-zero energy systems for buildings is an idea

[29] This microgrid project has also been reported in the non-European transmission projects since it is led by a transmission network operator. The small area and population of around 3,000 people of the Niijima Island make it the perfect location for such a demonstration project as a miniature model of Japan.

whose time has come. The SunCarrier Omega Net Zero Energy Building (NZEB), is an example of how organizations that can, to go beyond adopting the best in energy conservation technologies, and augmenting the energy supply by implementing 'green' energy systems that leverage nature's abundance of solar energy.
The project entailed the Integration of a large capacity energy storage system, the Cellcube FB 10-100. In addition to its ability to store up to 100 kWh of energy per unit, it also functions as an effective energy management system. Excess energy produced during the day by the SC 260 is stored in the Cellcube, which in turn supplies energy during the night hours, and during monsoon days when the sun does not shine.

- **Gram Power Khareda Lakshmipura Microgrid**. Gram Power's microgrid is powered by a centralized array of solar panels which collect the sun's energy and convert it to DC electricity. Surplus solar DC energy is stored in a battery array, providing users with energy even during peak usage times and night. DC electricity from the solar array and batteries is converted via an AC inverter. Gram Power sells electricity in units of rupees (Rs) an hour. Prices compare favourably with the government supply. The first microgrid installed was the Gram Power Khareda Lakshmipura Microgrid incorporating a 40 kW Lead-acid Battery. Currently at least 30 more villages have a Gram Power microgrid. In July 2012, India experienced the worst blackout in modern history. At least 20 states lost power in three huge grid failures covering an area home to more than 700 million people. In one tiny village in very rural Rajasthan, where the Gram Power Khareda Lakshmipura Microgrid is located, the lights stayed on.
- **India One Solar Thermal Plant** (Indian Ministry of New and Renewable Energy Sources [MNRE]/ the German Ministry for Environment, Nature Conservation and Nuclear Safety [BMU through GIZ]). In 2011 the World Renewal Spiritual Trust initiated the design, development and installation of “India One”, a 1 MW solar thermal power plant with 16 hours storage for continuous operation. This research project uses the in-house developed 60 m^2 parabolic dish and features an innovative thermal storage for night operation. The 60 m^2 dish is a proven technology and is based upon 15 years of experience with the parabolic concentrator with fixed focus. The concentrated solar power plant (CSP) generates heat and power for a campus of 25,000 people.

23.3 Recommendations and final remarks for R&I policy makers

In general, the analyses presented above show that R&I projects carried out outside Europe at distribution level have reached roughly the same TRL levels as in Europe, for similar R&I activities. As for non-European transmission projects, most of the funding seems to be dedicated to the deployment and market uptake of (new) technologies by the market makers (network operators) and the market players. However, the TRL level reached and the envisaged next steps for the projects show that more R&I projects are needed before industrial deployments can be envisaged.

For projects with a storage component, the following specific remarks can be made:

- There is a significant effort (especially in the US) to test and qualify the use of second life batteries (from EVs) for stationary applications in distribution networks;
- Ultracapacitor-based energy storage systems are being tested;
- Many of the projects (North-America, India, Australia) are relative to microgrids where the storage devices are used in islanding mode to help power essential services.

R&I activities in Europe relative to the integration of storage in distribution networks are at the state-of-the-art level. R&I policies in Europe should encourage the export of this know-how.

GENERAL CONCLUSION

The analyses presented in this monitoring report have allowed the specifications of the future R&I activities to be undertaken during 2016-2025.

Recommendations have been made for the structure of the new roadmap:

- ENTSO-E, with the support of the Grid+Storage partners, decided to modify the general organisation of the new R&I roadmap, going from a point of view driven by actions and R&I activities to a point of view driven by challenges for the transmission system at the pan-European level;
- The Grid+Storage partners decided to keep the structure of the previous roadmap with slight modifications mainly relative to the description of the functional objectives in terms of cross-cutting challenges (similar to the challenges for transmission);
- The joint TSO/DSO R&I activities were removed and integrated in the transmission and distribution activities, respectively, when relevant.

For international projects:

- for transmission R&I activities, the analyses showed that R&I projects carried out outside Europe have reached much higher TRL levels than in Europe, for similar R&I activities. This tends to suggest that the funding mechanisms and the associated policies are focused on the deployment and market uptake of new technologies by the market makers (network operators) and the market players.
- for distribution R&I activities, the analyses showed that, on the one hand, R&I projects carried out outside Europe level have reached roughly the same TRL levels as in Europe, for similar R&I activities, and on the other hand, R&I activities in Europe relative to the integration of storage in distribution networks are at the state-of-the-art level.

GLOSSARY

Generic terms related to the R&I roadmaps

EEGI European Electricity Grid Initiative

R&I Research and Innovation

EEGI roadmap 2013-2022

Current R&I roadmap, framework for the present monitoring report

R&I roadmap 2016-2025

This is the Grid+Storage roadmap, notably based on the recommendations provided by the present monitoring report.

DSO Distribution System operator

TSO Transmission System operator

FO Functional Objective

Cluster Set of Functional Objectives organizing the R&I Roadmap

T_i Identification of a Functional Objective in the transmission part of the roadmap, i is an index varying from 1 to 17.

D_j Identification of a Functional Objective in the distribution part of the roadmap, j is an index varying from 1 to 13

TD_k Identification of a Functional Objective in the joint TSO/DSO cluster in the roadmap, k is an index varying from 1 to 5

Specific terms adopted for this monitoring report

Achievement An output of a project that contributes to the R&I roadmap. Achievements are characterized by be either "completed" or "expected".

Achievements correspond to the lowest scale for our analysis generated by a completed (or on-going) project. They are typically either identically to one project deliverable, or a part of a project deliverable, or an aggregation of various project deliverables. The formulation of the appropriate level for each achievement was under the responsibility of the project coordinator who is in the best position to select a few (typically 3-5) achievements synthesizing the key project results.

Achievements are characterized by descriptive and projective features.

Descriptive feature

Descriptive features include information for achievement categorization (in Clusters, in Functional Objective, in typology of achievement) as well as an estimation of the maturity increment of each considered innovation (measured in TRL units). Typology of achievements include six predefined types: 1. Methodology, 2. Software, 3. Hardware, 4. Database, 5. Policy, regulation, market, 6. Other.

Projective feature

They include an information on status of implementation as of 2016 as well as a characterization of the next steps. Next steps could include further research (FRes), further development (FDev), demonstration (Dem), deployment (Depl) or a mix of these options

Implementation

	Characterization of an achievement. Either the achievement is already implemented or if it not the case, it refers to the plan for a future implementation of such achievement (next steps)
Res	Characterization of next steps: the implementation plan includes further research
Dev	Characterization of next steps: the implementation plan includes further development
Dem	Characterization of next steps: the implementation plan includes demonstration
Depl	Characterization of next steps: the implementation plan includes deployment.
TRL	Technology Readiness Level

24. R&I achievements' description of the reviewed projects

24.1 Transmission achievements

Table 11 below presents the list of analyzed R&I achievements related to transmission.

NB: As explained in the section 3.2, id codes were used to abbreviate projects' names all along the document.

The colour code for each project acronym corresponds to the source that has provided the filled-in questionnaires (**EU projects** are displayed in bold text while projects funded at national level are displayed in plain text):

EASE	ENTSO-E

Table 11: Detailed description of achievements related to transmission activities of each project reviewed as provided by project coordinators

Projects		Achievements			Achievement description
Name	Id code	Name	Id code	Name	
220 kV SSSC device for power flow control	SSSC	R1	Completed	3. Hardware	VSC + protection of power electronics (thyristor and breaker by-pass)
		R2	Completed	1. Methodology	Control system methodology
		R3	Completed	3. Hardware	Series coupling transformer
A complete and normalized 61850 substation	61850sub	A1	Completed	3. Hardware	Substation Automation System (SAS) multivendor interoperable laboratory test bench.
		A2	Completed	3. Hardware	Control and centralization (IEC61850) field box for the process bus.
		A3	Completed	3. Hardware	IEC61850 Remote Input Output (RIO) IEC61850 communications in EHV Substations. On site demonstration.
		A4	Completed	5. Policy, regulation, market	EPRI61850: Application Guides, Software Tools and Migration Strategies for the Implementation of the IEC 61850 Standard
AFTER	**AFTER**	**A1**	**Completed**	**2. Software**	**Method and tool for global vulnerability analysis and risk assessment of Power Systems**
		A2	**Completed**	**2. Software**	**Physical security improvement, by innovative techniques for early warning of substation intrusion events**
		A3	**Completed**	**1. Methodology**	**Advanced defence of power system operation following severe grid outages, by innovative defence plans techniques**

		A4	**Completed**	**2. Software**	**SW tool for system restoration after major disruptions, by adaptive and efficient restoration plans**
ANEMOS.PLUS	**ANEMOS**	**R1**	**Completed**	**2. Software**	**Methods & SW for definition of reserves requirements based on probabilistic forecasts for the current day and for day ahead.**
		R2	**Completed**	**2. Software**	**Methods & SW for the optimal scheduling of power systems with high penetration**
		R3	**Completed**	**2. Software**	**Methods & SW for short-term probabilistic forecasting of wind power.**
BEST PATHS	**BESTPATHS**	**E1**	**Expected**	**2. Software**	**Demo1: control strategies to manage the interactions between HVDC links and wind turbine generators**
		E2	**Expected**	**1. Methodology**	**Demo 2: interoperability standards of multi-terminal VSC HVDC**
		E3	**Expected**	**2. Software**	**Demo 2: Test methodology to measure the performance of coupled VSC units from different manufacturers**
		E4	**Expected**	**3. Hardware**	**Demo 3: new multilevel VSC converter and operations strategies integrating XLPE submarine and land cables, HTLS DC conductors, DC insulators and DC fault management systems**
		E5	**Expected**	**1. Methodology**	**Demo 3: Methodology for high performance upgrading of existing DC links**
		E6	**Expected**	**3. Hardware**	**Demo 4: innovative HTLS conductors for repowering existing AC OHL**
		E7	**Expected**	**2. Software**	**Demo 4: Insulated cross-arms for AC OHL**
		E8	**Expected**	**3. Hardware**	**Demo 4: innovative Dynamic Line Rating for repowering existing AC OHL**
		E9	**Expected**	**3. Hardware**	**Demo 4: innovative tower design and field work (live-line working) for repowering existing AC OHL**
		E10	**Expected**	**3. Hardware**	**Demo 5: Manufacturing of new (MgB2) superconducting cables**
		E11	**Expected**	**3. Hardware**	**Demo 5: Technology to integrate DC superconducting links within an AC meshed network (design, manufacturing and grid operations)**
BESTGRID	**BESTGRID**	**R1**	**Completed**	**1. Methodology**	**Handbook "Public Participation and Transparency in Power Grid Planning"**
		R2	**Completed**	**1. Methodology**	**Handbook "Protecting Nature in Power Grid Planning"**
		R3	**Completed**	**5. Policy, regulation, market**	**Final report of the project, summarizing experiences the consortium made and including overall recommendation and ten of the most valuable lessons learned**
Class project	Class_project	E1	Expected	1. Methodology	How to operate CAES/LAES in connection with conventional power plants
		E2	Expected	3. Hardware	Development of materials and components for CAES/LAES
Concept for Management of the Future Electricity System	Concept	R1	Completed	1. Methodology	Efficient power balancing
		R2	Completed	1. Methodology	Active power grid control
		R3	Completed	1. Methodology	Intelligent resource activation and control
Development of market	DevMarket	R1	Completed	1. Methodology	Methodology for increasing market modelling capacity

modelling capacity		R2	Completed	4. Database	Database and market models
DSR	DSR	A1	Completed	1. Methodology	Identification of DSR potential for Estonia. Opportunity to use the DSR as source for flexibility
		E1	Expected	5. Policy, regulation, market	Develop the market model for DSR
		E2	Expected	2. Software	Applications for DSR aggregation
eBADGE	**eBADGE**	**A1**	**Completed**	**2. Software**	**Transnational balancing market simulator**
		A2	**Completed**	**2. Software**	**eBADGE Message Bus enabling communications among all involved parties; home energy hubs (HEHs), VPPs, DSOs, TSOs and possibly others.**
		A3	**Completed**	**2. Software**	**Optimal planning of VPP resources activation for cyberGRIDs VPP, using evolutionally algorithm.**
EcoGRID EU	**EcoGRID**	**R1**	**Completed**	**1. Methodology**	**Real-time market concept**
		R2	**Completed**	**2. Software**	**Marketplace (based on cloud computing) -> control to field equipment, DLC, demand forecasting model for DR**
		R3	**Completed**	**4. Database**	**Field results**
e-Highway2050	**eHW**	**A1**	**Completed**	**1. Methodology**	**Top-down planning methodology organized in modular blocks**
		A2	**Completed**	**6. Other**	**The modular plan of pan-European grid architectures at 2050 (including data)**
		A3	**Completed**	**4. Database**	**A database of cost and performances of power system technologies**
		A4	**Completed**	**1. Methodology**	**Enhanced transmission expansion planning based on optimisation methods**
		E1	**Expected**	**2. Software**	**Enhanced transmission expansion planning based on optimisation methods**
		E2	**Expected**	**1. Methodology**	**Use of A1, A2 and A3 achievements in future TYNDP exercises**
EnergyLab Nordhavn	EnergyLab	E3	Expected	6. Other	Development of new business models for renewable energy integration
Estfeed	Estfeed	A1	Completed	2. Software	Data sharing platform designed for organisations and individuals to more efficiently organise their energy consumption
		A2	Completed	2. Software	Development of sample applications based on the data sharing platform
		E1	Expected	2. Software	Further development of data platform
EWIS	**EWIS**	**R1**	**Completed**	**1. Methodology**	**Methodological link between market-based simulations (zonal) and network simulations (nodal).**
		R2	**Completed**	**1. Methodology**	**Real time data exchange between network operators and day ahead data exchange concerning solar and wind production forecast**
		R3	**Completed**	**5. Policy, regulation, market**	**RES integration increases the costs for system balancing. These costs must be taken into account and must be transparent. RES producers shall be responsible for the unbalances caused by the RES.**
FutureFlow	**FutureFlow**	**E1**	**Expected**	**1. Methodology**	**Design of a cross-border cooperation scheme for procurement and activation of balancing reserves**
		E2	**Expected**	**2. Software**	**Prototype DR and DG flexibility aggregation platform for FRR**

		E3	**Expected**	**2. Software**	**Prototype Regional Balancing and Redispatching Platform**
GARPUR	**GARPUR**	**E1**	**Expected**	**1. Methodology**	**Development of new, probabilistic reliability approach and criteria (RMAC) encompassing the three key activities at different time scales (power system operation, asset management, system development)**
		E2	**Expected**	**2. Software**	**Development of a prototype quantification platform to evaluate the socio-economic impact of the new RMAC**
GREDOR	**GREDOR**	**A1**	**Completed**	**2. Software**	**Market design tool for modelling the interaction between the users of the grid and the DSO in presence of DER and DSR.**
		A2	**Completed**	**2. Software**	**Optimal investment strategies tool for distribution expansion planning in presence of increased flexibility needs**
		A3	**Completed**	**2. Software**	**Operational planning tool for distribution networks**
GridTech	**GridTech**	**R1**	**Completed**	**2. Software**	**Zonal tool and model (with 2020, 2030, 2050 data) for pan-European system planning studies**
		R2	**Completed**	**1. Methodology**	**Integrated top-down/bottom-up approach for transmission planning and grid-impacting technologies assessment**
		R3	**Completed**	**2. Software**	**Toolbox for transmission expansion planning with storage, DSM/DR, EV**
Humber Smartzone Pilot Project	Humber	A1	Completed	3. Hardware	Tools to monitor and predict thermal capacity of a circuit
		A2	Completed	2. Software	Application to estimate and predict thermal capacity margin in a region
		A3	Completed	2. Software	Decision support system to coordinate plant and equipment maximizing the utilization of the network
HyUNDER	**HyUNDER**	**A1**	**Completed**	**4. Database**	**Assessment of the potential, the actors and relevant business cases for large scale and seasonal storage of renewable electricity by hydrogen underground storage in Europe**
ICOEUR	**ICOEUR**	**R1**	**Completed**	**3. Hardware**	**Development and implementation of low voltage large-scale WAMS system**
		R2	**Completed**	**2. Software**	**Development of distributed coordination system for real-time power flow control**
		R3	**Completed**	**1. Methodology**	**Evaluation of interconnection concepts for system stability by the development of models and tool for large-scale power system inter-area oscillation analysis**
Impact of electric and gas vehicles	ImpactEV	A1	Completed	1. Methodology	Methodology to evaluate the impact of electric transport on grid operation and first analyses focused on the high speed railway.
		A2	Completed	5. Policy, regulation, market	Identification of requirements/principles for connecting the electric transport loads to the system
		E1	Expected	1. Methodology	Complete model for assessing the impact of electric vehicles and high speed railway on the grid.
		E2	Expected	5. Policy, regulation, market	Cost benefit analysis related to both gas and electric vehicles, considering also socio-economic aspects. Policy recommendations and suggestion to identify new environmental national targets.

INSPIRE-Grid	**INSPIRE**	**A1**	**Completed**	**4. Database**	**Stakeholders' map**
		A2	**Completed**	**1. Methodology**	**Assessment methodologies for stakeholder's' engagement (MCA, LCA, WebGIS)**
		A3	**Completed**	**2. Software**	**Participatory WebGIS**
		E1	**Expected**	**1. Methodology**	**Final Handbook**
		E2	**Expected**	**5. Policy, regulation, market**	**Synthesis and recommendations**
iTesla	**iTesla**	**A1**	**Completed**	**2. Software**	**The iTesla toolbox**
		A2	**Completed**	**2. Software**	**The iTesla platform**
		A3	**Completed**	**2. Software**	**The Rapid tool**
		A4	**Completed**	**2. Software**	**The iTesla Power Systems Library (iPSL)**
		E1	**Expected**	**2. Software**	**Validated iTesla toolbox**
KÄVA2	KÄVA2	R1	Completed	1. Methodology	Estimation of probability-based security levels
		R2	Completed	1. Methodology	Evaluation of components' failure rates for asset management
LIFE Elia	**LIFE**	**A1**	**Completed**	**1. Methodology**	**Guidelines on "vegetation mapping of powerline corridors in forests"**
		A2	**Completed**	**1. Methodology**	**CBA on alternative vegetation management in forest corridors**
		E1	**Expected**	**5. Policy, regulation, market**	**Integration of biodiversity preservation into the vegetation management**
Market4RES	**Market4RES**	**E1**	**Expected**	**5. Policy, regulation, market**	**Recommendations for the implementation of policy, legislation and regulation across the renewable energy sector, based on qualitative and quantitative analyses**
MERGE	**MERGE**	**A1**	**Completed**	**1. Methodology**	**Methodology to assess the variations in the load curve due to the EV development, considering different future scenarios and different users' behaviours in terms of charging (dumb Vs smart charging).**
		A2	**Completed**	**3. Hardware**	**Identification of a high level architecture that allows an effective connection of the vehicles to the grid and an effective communication among all the involved actors.**
		A3	**Completed**	**1. Methodology**	**Forecasts and scenarios on EV diffusion in different countries in 2020 and 2025.**
		R1	**Completed**	**1. Methodology**	**Integration of EV data (from results A1 and A3) in a tool used by the TSO to perform grid planning. Inclusion of EV impact on grid planning methodology.**
		R2	**Completed**	**5. Policy, regulation, market**	**Recommendations for needed changes in regulation activity in order to develop e-mobility with the identified architecture (result A2).**
MIGRATE	**MIGRATE**	**E1**	**Expected**	**1. Methodology**	**KPIs to measure the distance to instability under different PE scenarios**
		E2	**Expected**	**1. Methodology**	**New parameters (retuned controllers) for a few types of instabilities (generic test cases)**
		E3	**Expected**	**1. Methodology**	**Recommendations on network connection code**
		E4	**Expected**	**2. Software**	**Existing PMUs have been operated in real time to provide reliable stability KPIs**
		E5	**Expected**	**1. Methodology**	**New control strategies for transmission networks operated at 100% PE**

		E6	**Expected**	**2. Software**	**Adaptation of existing protection schemes with high PE penetration**
		E7	**Expected**	**3. Hardware**	**New protection schemes in transmission networks with high PE penetration**
		E8	**Expected**	**2. Software**	**Power quality analyses in transmission networks with high PE penetration**
OPTIMATE	**OPTIMATE**	**A1**	**Completed**	**2. Software**	**Prototype simulation tool able to simulate different market architecture options at the day-ahead stage**
		A2	**Completed**	**1. Methodology**	**Innovative approach consisting in modelling in a sequential manner different short-term electricity markets to compare different market architecture options**
		A3	**Completed**	**4. Database**	**Extensive database gathering information about technical and economic features of thermal plants, half-hourly forecasts of intermittent generation, PTDFs…**
		R1	**Completed**	**2. Software**	**Upgraded prototype tool: improved robustness and computation time, enlarged functional scope (real-time and intraday module)**
		E1	**Expected**	**2. Software**	**Industrial tool, with full functional scope and high robustness**
PoStaWind	PoStaWind	R1	Completed	1. Methodology	Study of wind power integration in the Nordic transmission system: inter-area power oscillation
		R2	Completed	1. Methodology	Study of wind power integration in the Nordic transmission system: synthetic inertia from wind farms
		R3	Completed	1. Methodology	Study of wind power integration in the Nordic transmission system: transient reactive power
Power to gas	P2G	A1	Completed	1. Methodology	Overview of technologies and potential solutions for power to gas
		E1	Expected	1. Methodology	Knowledge of power to gas technologies in the world and realization of a small scale demo plant
		E2	Expected	6. Other	Economic benefit analysis of the solution
Promotion	**Promotion**	**E1**	**Expected**	**1. Methodology**	**Offshore grid architecture for optimised wind resources facilitation and market extension in the north seas. Deployment plan for offshore grid development**
		E2	**Expected**	**3. Hardware**	**Demonstration of innovative offshore converter topology, development and demonstration of HVDC grid protection systems (software and hardware)**
		E3	**Expected**	**5. Policy, regulation, market**	**Development of policies and market mechanisms in order to boost investment in offshore HVDC systems**
REALSMART	**REALSMART**	**A1**	**Completed**	**1. Methodology**	**Methods for enhancing power transmission system security**
		A2	**Completed**	**1. Methodology**	**Analytical understanding of the interactions between industrial loads and the grid, and of the electrical interactions with industrial process systems**
		A3	**Completed**	**1. Methodology**	**Grid planning methods to take into account installed large-scale wind power**
SAFEWIND	**SAFEWIND**	**R1**	**Completed**	**2. Software**	**Methods & SW for probabilistic forecasting of wind power and for predicting "extreme" events (i.e. ramps).**

		R2	**Completed**	**2. Software**	**Methods & SW for predicting the level of predictability for the next hours and for warning and alarming in case of difficult extreme situations (high wind speeds, weather fronts, any situations producing large forecast errors, …) for producers or DSOs and TSOs**
		R3	**Completed**	**2. Software**	**Wind power predictability maps for spatial planning of wind energy at European scale**
SAMREL - Security of electricity supply - analysis tools	SAMREL	A1	Completed	1. Methodology	A methodology for the chain of analyses from power market analysis to reliability of supply analysis
		A2	Completed	2. Software	Prototype tool for security of supply and vulnerability analysis tested on a regional, national and Nordic level
		A3	Completed	6. Other	PhD in evaluation and grouping of power market scenarios
SECONOMICS	SECONOMICS	R1	Completed	5. Policy, regulation, market	Policy framework for comparing the effect of different security regulations
		R2	Completed	1. Methodology	Risk assessment methodology for security vulnerability
		R3	Completed	2. Software	Toolkit for simulating different security policy models
Smart Substation	SmartSub	E1	Expected	3. Hardware	Deployment of a smart HV substation
		E2	Expected	4. Database	Data management for asset management
SmartNet	**SmartNet**	**E1**	**Expected**	**2. Software**	**SW for optimized architecture(s) for TSO-DSO interaction to allow participation to ancillary services market by resources in distribution**
		E2	**Expected**	**1. Methodology**	**Analyses on optimized architecture(s) for TSO-DSO interaction to allow participation to ancillary services market by resources in distribution**
		E3	**Expected**	**3. Hardware**	**3 national pilots on monitoring and on flexibility resources in distribution**
SOSPO PMU/WAMS Early Warning Systems	SOSPO	A1	Completed	2. Software	Dynamic and static security assessment in real-time. Long-term Voltage Stability Assessment (VSA)
		A2	Completed	2. Software	Wide Area Prosumption Control: Modelling aggregated prosumption as a controllable reserve; Wide area prosumption control algorithms
		A3	Completed	2. Software	Wide Area Emergency Control: Adaptive control for small signal instability; state and parameter estimation; Transient Stability Emergency Control
		A4	Completed	2. Software	Dynamic voltage and rotor angle stability assessment
STORE	STORE	A1	Completed	1. Methodology	Provision of inertia and active power for primary regulation, validating technology's ability to prevent outages due to unforeseen faults in GENERATION UNITS, as well as assistance in continuously stabilise voltage
		A2	Completed	1. Methodology	Reinforcing the system and improving the quality of supply.
SUMO	SUMO	A1	Completed	2. Software	Development of methods and software for evaluating and forecasting Dynamic Line Ratings

		A2	Completed	2. Software	Development of fast methods to perform N-1 analyses
		A3	Completed	2. Software	Implementation of an alarm system for extreme weather conditions affecting transmission lines
TWENTIES	**TWENTIES**	**R1**	**Completed**	**2. Software**	**Tool/methodology to obtain system services used by TSOs from wind generation smart control**
		R2	**Completed**	**2. Software**	**Centralized control/co-optimization software across the value chain (wind, CHPs, local generation and load) to obtain cost efficient system services and wind balancing (inter- and intraday energy markets/ancillary services)**
		R3	**Completed**	**1. Methodology**	**Secure architecture and controls for meshed HDVC networks**
		R4	**Completed**	**3. Hardware**	**A Circuit breaker technology adapted to secure meshed HVDC offshore networks**
		R5	**Completed**	**2. Software**	**Storm controllers for offshore wind farms: operational and new version under development (TRL 9)**
		R6	**Completed**	**3. Hardware**	**Dynamic Line Rating**
		R7	**Completed**	**3. Hardware**	**Power Flow Controlling Devices**
		R8	**Completed**	**3. Hardware**	**Wide Area Monitoring Systems (WAMS)**
		R9	**Completed**	**3. Hardware**	**Dynamic line rating system**
		R10	**Completed**	**3. Hardware**	**Overhead line controller**
UMBRELLA	**UMBRELLA**	**A1**	**Completed**	**2. Software**	**Innovative toolbox prototype to support the decentralised grid security approach of TSOs**
		A2	**Completed**	**1. Methodology**	**Risk based security assessment methods, deterministic and probabilistic approaches. Operational planning methodology based on forecasting and optimization**
		A3	**Completed**	**5. Policy, regulation, market**	**Common recommendations to ENTSO-e regarding TSO and RSCI rules for business processes and data exchange**
VENTOTENE	VENTOTENE	E1	Expected	1. Methodology	How to operate batteries in parallel with diesel generators and renewables
WAMPAC_Elering	WAMPAC_Elering	A1	Completed	1. Methodology	PMU deployment algorithms for selection of PMUs optimal location and grid losses assessment
		A2	Completed	2. Software	Separate SW modules to improve network observability and to assess grid losses
WAMPAC_Eles	WAMPAC_Eles	A1	Completed	1. Methodology	Study on dynamic phenomena and their impact on Slovenian network
		A2	Completed	2. Software	Display voltage angles in continental EU
		E1	Expected	2. Software	Fault identification and localization
		E2	Expected	2. Software	Operator support tool for island management after severe fault in network leading to network separation

24.2 Distribution achievements

Table 12 below presents the list of analyzed R&I achievements related to distribution.

> NB: As explained in the section 3.2, id codes were used to abbreviate projects' names all along the document.
>
> The colour code for each project acronym corresponds to the source that has provided the filled-in questionnaires (**EU projects** are displayed in bold text while projects funded at national level are displayed in plain text):

EDSO	EASE

Table 12: Detailed description of achievements related to distribution activities of each project reviewed as provided by project coordinators

Projects		Achievements			Achievement description
Name	Id code	Code	Status	Typology	
ADDRESS	**ADDRESS**	**A1**	**Completed**	**5. Policy, regulation, market**	**Market design to facilitate demand-side management: market-based proposals and economic analysis**
		A2	**Completed**	**4. Database**	**Questionnaires to validate social acceptance and customers' commitment. Different questionnaires will be completed out during the field test period (pre/during/post trials).**
		A3	**Completed**	**2. Software**	**Aggregator toolbox. Full validation of aggregator's functionality and 'core business model' through the validation of the Aggregator Toolbox functionality.**
		A4	**Completed**	**3. Hardware**	**Technical validation of the proposed solutions and prototypes for the Home System. Validation of home system communication, Validation of equipment operation and the Collection and processing of metering information.**
ADVANCED	**ADVANCED**	**A1**	**Completed**	**1. Methodology**	**Target matrix to determine what the quantities to be measured**
		A2	**Completed**	**1. Methodology**	**Validated and operationalised KPIs both at pilot and household level**
		A3	**Completed**	**1. Methodology**	**Qualitative & Quantitative surveys**
		A4	**Completed**	**1. Methodology**	**Actionable framework**
		A6	**Completed**	**6. Other**	**AD Potential**
ALIADOS	Alia2	A1	Completed	3. Hardware	3 Building management systems (BMS): module, cabinet and container
		A2	Completed	2. Software	Black-start based on batteries for small-hydro plants.
		A3	Completed	1. Methodology	Work method for manufacturing of modules in Vitoria plant
		R1	Completed	3. Hardware	Improvements on the storage system. New generation with double power density and taking up less space.
		R2	Completed	3. Hardware	New cylindrical version of energy storage solution with reduced mobility and stationary (up to 400V) at home.

		E1	Expected	3. Hardware	Finish new product with 1MW capacity. Integrate in grids, generation plants (PV and wind), ramps in tropical countries
		E2	Expected	1. Methodology	Black-start to support DSOs and TSO to manage electricity. Service for small industries, neighbourhoods, EV recharging and induction furnaces.
Ampacity	Ampacity	A1	Completed	1. Methodology	Specification and requirements to the system; planning (civil works, primary and secondary technology); risk analysis
		A2	Completed	1. Methodology	Installation of the HTS cable and the superconducting fault current limiter, testing and commissioning of the system
		A3	Completed	3. Hardware	Field test in real grid operation and proof of reliable working, both in normal operation and also in fault cases
		R1	Completed	5. Policy, regulation, market	Cooperation RWE / Nexans with the goal to commercialize the technology
ATENEA Microgrid	ATENEA	A1	Completed	6. Other	Control & Energy Management Systems and SCADA
		A2	Completed	3. Hardware	Microgrid demonstration
		A3	Completed	2. Software	Micrograds & Energy Management Strategies Simulation Platform-CeMOS
BIENVENU	BIENVENU	E1	Expected	3. Hardware	To develop and test new solutions for EV charging devices connexion, management and services in residential collective housing
		E2	Expected	2. Software	Optimization of EV charging in collective housing, taking into account both EV needs and impact on the distribution network
CAES Larne	CAES_Larne	E1	Expected	3. Hardware	CAES plant
CHPCOM Combined Heat and Power Communication	CHPCOM	A1	Completed	2. Software	TSO/DSO system integration communications, including security keys, for CHP power plant management
Control and regulation of modern distribution system	Control	A1	Completed	2. Software	Normal Operation-Optimisation model
		A2	Completed	2. Software	Abnormal/Emergency Operations Control Strategies
CryoHub	**CryoHub**	**E1**	**Expected**	**3. Hardware**	**Demonstration of Cryogenic Energy Storage (CES) technology in a refrigerated food warehouse**
Dezentrale Netzintelligenz	Dezentrale	A1	Completed	1. Methodology	Using automated secondary substations to reduce/shorten outages in the grid
		E1	Expected	2. Software	Regional controller to monitor and control a part of the MV grid
		E2	Expected	3. Hardware	Line voltage regulators in MV network
DISCERN	**DISCERN**	**A1**	**Completed**	**2. Software**	**Development of novel tools and methodologies**
		A2	**Completed**	**4. Database**	**The facilitation of knowledge sharing on cost-effective technological solutions through field-tests and simulations**
		A3	**Completed**	**5. Policy, regulation, market**	**Contribution to standardization activities**

DRIP - Demand Response on Industrial Production	**DRIP**	**A1**	**Completed**	**1. Methodology**	**DRIP provides with a novel approach to the flexibility of industrial customers by means of an exhaustive analysis based on processes**
		A2	**Completed**	**5. Policy, regulation, market**	**New business opportunities arise for the adequate trading of Demand Response resources in the market**
		A3	**Completed**	**1. Methodology**	**New tools and techniques have been developed to determine, quantify and certify demand response resources in the industrial production**
		R1	**Completed**	**5. Policy, regulation, market**	**A roadmap for the implementation of Demand Response will be provided to industrial customers and policy makers to promote the active participation of DR resources into the European electricity market**
DSO challenges from introduction of heat pumps	Heat_Pumps	A1	Completed	1. Methodology	Model to forecast the impact of mass uptake of heat pumps on LV grids
		A2	Completed	2. Software	Power electronics algorithm to prevent overload of LV grid with many heat pumps
Dynamic Network Access tariffs	DNAT	A1	Completed	1. Methodology	An analysis of the periods of highest network congestion has been carried out.
		E1	Expected	1. Methodology	We expect to see how customers react to the dynamic pricing scheme
		E2	Expected	5. Policy, regulation, market	If the new scheme proves to provide more benefits than costs for the Electricity System, its implementation may be considered in the future.
		E3	Expected	5. Policy, regulation, market	The main expected achievement would be the decrease in peak hour consumption, in order to lower the need to invest in grid expansion.
E-DeMa	E-DeMa	A1	Completed	3. Hardware	Operational Platform and Marketplace
		A2	Completed	6. Other	Price benefits are only motiving few customers to adapt their behaviour
		A3	Completed	5. Policy, regulation, market	New/adopted business models for aggregators are very reasonable
		R1	Completed	2. Software	Software for the Market Place
Electrogas - The renewable e-power buffer	Electrogas	A1	Completed	3. Hardware	Hydrogen injector
		A2	Completed	1. Methodology	Microbial electrosynthesis cell
		R1	Completed	3. Hardware	Successful H2 addition up to 90% CH4
		R2	Completed	3. Hardware	Microbial electrosynthesis cell
		E1	Expected	1. Methodology	Hydrogen addition to anaerobic digester to form methane from CO2
		E2	Expected	1. Methodology	Microbial electrosynthesis using direct electron transfer to a biofilm on a biocathode to form methane, ideally inside an anaerobic digester
EnergyLab Nordhavn	EnergyLab	E1	Expected	1. Methodology	Experience on integration of different energy sectors (electricity, heat)
		E2	Expected	2. Software	IT solutions for optimal control of system operation
FINSENY (Future Internet for Smart Energy)	**FINSENY**	**A1**	**Completed**	**1. Methodology**	**Analysis of different scenarios**
		A2	**Completed**	**2. Software**	**Reference ICT architecture**
		A3	**Completed**	**3. Hardware**	**ICT requirements. Identification of generic ICT platform enablers.**
		A4	**Completed**	**1. Methodology**	**Preparation of pan-European use case trials**

		A5	**Completed**	**5. Policy, regulation, market**	**Cross-industry standardisation strategy**
FLEXe WP1	FLEXe	A1	Completed	3. Hardware	Optimal heat system component design in future scenarios with large shares of wind and solar energy
		A2	Completed	1. Methodology	Comparison of flexibility options, costs and benefits in future systems with high shares of variable generation
		E1	Expected	1. Methodology	Optimized and secured integration and operation of future energy networks
G4V - Grid for Vehicles	**G4V**	**A1**	**Completed**	**1. Methodology**	**3 scenario worlds have been developed to assess the project results in different future frameworks for EVs.**
		A2	**Completed**	**1. Methodology**	**Without control, the charge of EVs can have significant impacts on the use of generation plants and increase network constraints.**
		A3	**Completed**	**6. Other**	**Revenues from V2G (Ancillary services) with battery discharge are nowadays insignificant, but future market development may open new opportunities**
Gigha Wind Farm Battery Project	Gigha	E1	Expected	3. Hardware	Knowledge on how to operate a grid-connected VRB in conjunction with wind turbines in island mode
Gorona del Viento El Hierro	Gorona	A1	Completed	1. Methodology	Integrate great amount of wind energy in the system
		A2	Completed	2. Software	Simulation of the system. Stability studies and energy studies.
		R1	Completed	2. Software	AGC (automatic generation control) of the plant
HyUNDER	**HyUNDER**	**A1**	**Completed**	**4. Database**	**Assessment of the potential, the actors and relevant business cases for large scale and seasonal storage of renewable electricity by hydrogen underground storage in Europe**
IGREENGrid	**IGREENGrid**	**A1**	**Completed**	**5. Policy, regulation, market**	**Most promising solutions for DRES integration**
		A2	**Completed**	**1. Methodology**	**Hosting capacity study in European distribution grids and improvement using smart grid solutions.**
		A3	**Completed**	**1. Methodology**	**Scalability and Replicability**
		A4	**Completed**	**1. Methodology**	**Economic analysis of solutions for DRES integration**
		A5	**Completed**	**1. Methodology**	**KPI analysis**
		A6	**Completed**	**1. Methodology**	**Guidelines for future massive integration of DRES**
		A7	**Completed**	**4. Database**	**Repository to collect operating data from different sources in order to calculate KPIs**
		E1	**Expected**	**5. Policy, regulation, market**	**Improve current European regulation framework to foster DRES integration**
INCREASE	**INCREASE**	**A1**	**Completed**	**1. Methodology**	**Policy for ancillary services**
		A2	**Completed**	**3. Hardware**	**Three-phase grid-connected inverters**
INGRID - High-capacity hydrogen-	**INGRID**	**A1**	**Completed**	**3. Hardware**	**Improved electrolyser technology**
		A2	**Completed**	**3. Hardware**	**Improved solid state hydrogen storage devices and materials**

based green-energy storage solutions for grid balancing		**A3**	**Completed**	**1. Methodology**	**Experience on control of grid-connected electrolysers**
Isernia	Isernia	R1	Completed	3. Hardware	Demonstration of 'Customer Information' using Enel's 'Smart Info' devices
		R2	Completed	3. Hardware	Implementation of storage facility (Li-ion battery) on real network
		R3	Completed	3. Hardware	Demonstration of voltage regulation by remote control of DER and storage (Li-ion battery) using a centralised control system
		R4	Completed	2. Software	Implementation of network automation algorithm for DER integration
		R5	Completed	3. Hardware	Demonstration of island detection device
		R6	Completed	3. Hardware	Installing EV charging station
Life Factory Microgrid - Electric vehicles to grid, renewable generation and Zn-Br flow battery to storage in industry	**Life**	**A1**	**Completed**	**3. Hardware**	**Experience on operating Zn-Br flow battery technology**
		A2	**Completed**	**3. Hardware**	**V2G integration in microgrid**
		A3	**Completed**	**1. Methodology**	**Development of strategies for a microgrid with 3 storage technologies and V2G**
		E1	**Expected**	**1. Methodology**	**Validation of energy management strategies capable of using or storing all produced renewable energy**
LINKY	LINKY	A1	Completed	2. Software	Roll-out of smart meters
		A2	Completed	3. Hardware	Roll-out of smart meters
		E1	Expected	2. Software	Network operation advanced functions and assets management improvements enabled by the Linky system
		E2	Expected	3. Hardware	Network operation advanced functions and assets management improvements enabled by the Linky system
Local Energy Storage	Local	A1	Completed	2. Software	Hourly based economic model for PV/storage/usage/grid
		E1	Expected	3. Hardware	Development of new power conversion technology
		E2	Expected	1. Methodology	Control of storage strategy
LODIS (Czech abbreviation for Local Management of Distribution Grid)	LODIS	A1	Completed	2. Software	Software for intelligent data concentrator
		A2	Completed	3. Hardware	Intelligent data concentrator
		E1	Expected	5. Policy, regulation, market	Scheme allowing absorption of surplus (PV) generated energy at the local level through load management
MERGE (Mobile Energy Resources in Grids of Electricity)	MERGE	A4	Completed	2. Software	Adaptation of existing simulation tools with EV models to perform analytical studies
		A5	Completed	2. Software	Development of simulation tools that can be used by TSOs, DSOs and Market operators to assess the impact of increased EV penetration at distribution level, transmission level and also generation and market operation.
		A6	Completed	5. Policy, regulation, market	Regulatory proposals for market uptake (of EV) in Spain, Ireland, Greece, Germany, UK and Portugal.

		A7	Completed	1. Methodology	Develop a EU roadmap for EV's development (the same countries)
		R3	Completed	1. Methodology	Optimal EV charging management
		R4	Completed	3. Hardware	Development of EV charging stations and back-office management system
		R5	Completed	3. Hardware	(Fast in charge) Wireless charging infrastructure
		R6	Completed	3. Hardware	Pilot installation of EV charging stations and charging monitoring systems. (Green E-motion)
		E1	Expected	3. Hardware	Widespread Pilot installations of EV charging stations
MESHARTILITY	**MESHARTILITY**	**A1**	**Completed**	**1. Methodology**	**Open Data Platform for the Sustainable Energy Action Plans**
METAPV - Metamorphosis of Power Distribution: System Services from Photovoltaics	**METAPV**	**A1**	**Completed**	**1. Methodology**	**To develop - at strategic level - the methodology to increase the grid capacity with 50% against 10% of the costs. (done via distributed control of the PV-inverter)**
		A2	**Completed**	**2. Software**	**A software was developed to control the PV-inverter connected to the DNS-system of the DSO**
		A3	**Completed**	**3. Hardware**	**Development of remote controlled and monitored inverters.**
		A4	**Completed**	**4. Database**	**The available DNS and SCADA-systems of the DSO was used for the steering of the inverters**
		A5	**Completed**	**5. Policy, regulation, market**	**Proposal for new policy principles and technical rules for DSOs and PV owners. The flexibility we have today regarding the power factor is developed by this project. Nevertheless, standards, policies and regulations should be further improved.**
		E1	**Expected**	**6. Other**	**Other achievements in the project: understanding that in an early stage the ICT [especially the communicative technology] like (GPRS, glasvezel - internet), needs to be involved.C13**
METER - ON	**METER_ON**	**A1**	**Completed**	**5. Policy, regulation, market**	**Exchange and interaction among the most representative projects carried out within the smart metering field in Europe (21 EU projects analysed – 15 countries covered)**
		A2	**Completed**	**5. Policy, regulation, market**	**360 degree analysis covering all the relevant aspects of smart metering. A purely technical analysis was not sufficient**
		A3	**Completed**	**5. Policy, regulation, market**	**Analysis of viable business models for the implementation of smart metering roll-out**
		A4	**Completed**	**5. Policy, regulation, market**	**Adapt the project workflow based on the expectations of the stakeholder's community. Analysis of compliance to EU/148/2012 minimum functionalities Viable Business Models**
		R1	**Completed**	**5. Policy, regulation, market**	**Recommendations**
		R2	**Completed**	**2. Software**	**Toolkit**
Modeller i EU-projektet	stoRE	A1	Completed	2. Software	Modelling pumped hydro trading in day ahead market

stoRE af økonomien i ellagre		A2	Completed	2. Software	Developing modelling software to use pump hydro in the balancing market
Nice Grid	NiceGrid	A1	Completed	3. Hardware	Experiment local and temporary islanding and reconnexion of a subnetwork energised through storage and solar generation
		A2	Completed	3. Hardware	Optimize the operation of a network integrating a massive production of photovoltaic energy
		A3	Completed	4. Database	Involve the consumer in energy efficiency in order to solve local energy constraints
Northern Isles New Energy Solutions (NINES)	NINES	R1	Completed	1. Methodology	Active Network Management has pushed energy supply towards low carbon emissions by allowing the maximum possible amount of renewable generation to be connected thus reducing the amount of fossil fuel consumption
		R2	Completed	3. Hardware	Significant insight into the installation and operation of MW scale batteries and provision of high quality research data for SSE Future Networks
OPEN NODE	**OPEN_NODE**	**A1**	**Completed**	**3. Hardware**	**Prototype to concentrate measurements (smart metering) for the Secondary substation.**
		A2	**Completed**	**2. Software**	**MMC (Metering management collector)**
PlanGridEV	**PlanGridEV**	**A1**	**Completed**	**2. Software**	**Optimised and enhanced grid architecture for EVs in Europe; the developed architecture provides a useful framework which is applicable for different European DSOs**
		A2	**Completed**	**2. Software**	**Prototype tool for optimising existing assets and grid planning using controllable loads and to maximise integration of EVs and DER in distribution grids**
		A3	**Completed**	**1. Methodology**	**Novel planning rules for EVs in smart grids**
		R1	**Completed**	**5. Policy, regulation, market**	**Roadmap and recommendations for innovation, regulation and policies**
Power-to-Gas via Biological Catalysis (P2G-BioCat)	BioCat	A1	Completed	4. Database	Interactive pricing and planning model for project in DK
		R1	Completed	1. Methodology	Biological conversion of CO2 and hydrogen to methane
		R2	Completed	3. Hardware	Equipment for the method mentioned in R1
		R3	Completed	5. Policy, regulation, market	Market pricing required for cash flow positive operation of system integrated at WWTP
PRICE	PRICE	A1	Completed	2. Software	MV/LV dispatch prototype & Distribution Mgmt. System for DG
		A2	Completed	2. Software	Energy balance web
		A3	Completed	3. Hardware	Energy balance system & SCADA tool
		A4	Completed	3. Hardware	STATCOM MV
		A5	Completed	3. Hardware	STATCOM LV
		A6	Completed	3. Hardware	Scaled grid
		A7	Completed	6. Other	State Estimator algorithm & voltage control algorithm
		A8	Completed	2. Software	Remote Demand management System (Consumption viewer)
		A9	Completed	3. Hardware	Smart Household Appliances and loading manager

		A10	Completed	6. Other	Platform management and mobility applications
		A11	Completed	2. Software	Smart system for on demand-side management
Proaktives Verteilnetz	Proaktives	A1	Completed	1. Methodology	Definition of operation mode for "yellow traffic light-phase"
		A2	Completed	2. Software	Grid State estimation
		A3	Completed	6. Other	Market model for flexibilities in yellow light phase
Puglia Active Network	Puglia	E1	Expected	3. Hardware	Active management of MV network
		E2	Expected	3. Hardware	Deployment of 'Smart Info' devices to provide customer with information to enable demand response strategies
		E3	Expected	3. Hardware	Installing recharging infrastructure for Electric Vehicles
PV-KWK / Intelligent energy management solutions and photovoltaic combined systems for optimized electricity and heat generation in the house	PV-KWK	A1	Completed	1. Methodology	Expansion and optimisation of energy management solutions as well as drafting open interface standards
Smart Country	Smart_Country	A1	Completed	3. Hardware	Active voltage regulator for medium voltage
		A2	Completed	3. Hardware	Wide area control is implemented in further primary substations
		A3	Completed	3. Hardware	Effective biogas storage
Smart Grid Judenburg	Judenburg	A1	Completed	3. Hardware	Demonstration of voltage regulation by remote control of DG using centralised control system
Smart Grid Vendée	SGV	A1	Completed	2. Software	Implementation of consumptions and generation forecasting tool at primary substation scale
		E1	Expected	2. Software	Implementation of a Web portal for energy shaving purpose
		E2	Expected	2. Software	Tools devoted to technico-economic analysis in order to help decision making
Smart grids: Back End Systems	Smart_grids	A1	Completed	3. Hardware	Implementation of operating management systems. Full roll-out in our operating centres.
		A2	Completed	3. Hardware	Roll-out of the new operations to the field crew
		A3	Completed	6. Other	Automatic curtailment of wind and automatic load shedding
		E1	Expected	5. Policy, regulation, market	Integration of DSM as system reserve (DSO/TSO)
		E2	Expected	5. Policy, regulation, market	Integration of storage, including the ancillary services provided by storage solutions
		E3	Expected	6. Other	Integration of the outage management for LV networks
Smart LV Grid - Heimschuh	Heimschuh	R1	Completed	3. Hardware	Demonstration of voltage regulation using OLTC at secondary substation
Smart Operator	Smart_ Operator	A1	Completed	3. Hardware	Smart Operator concept validated
		E1	Expected	4. Database	Improved future grid planning
Smart Storage	Smart_	A1	Completed	3. Hardware	Development of storage system

	Storage	A2	Completed	1. Methodology	Experience on operation of LV grid-connected battery
Smart Toruń	Smart_ Toruń	A1	Completed	3. Hardware	PV installation (3,77 MW peak power)
		A2	Completed	3. Hardware	Smart meters installation (92 600)
		A3	Completed	3. Hardware	Automation of the power grid (56 MV with remote control, 86 radio-controlled switches)
SOGRID	SOGRID	E1	Expected	3. Hardware	To develop and test "full PLC" of “3D generation" on the LV and MV network (Cenelec-A band and FCC band)
SOLENN	SOLENN	A1	Completed	6. Other	First, roll-out of 10 000 smart meters and recruiting
		E1	Expected	2. Software	Develop solutions to provide volunteer customers with own and collective electric data in order to develop a new Energy Efficiency dynamics
		E2	Expected	2. Software	Provide local communities with an IT tool helping the definition and implementation of local energy politics
		E3	Expected	2. Software	Provide new tools using curtailments via smart meters avoiding load shedding near real time operations
Storage in Evora	Evora	A1	Completed	3. Hardware	MV Storage system demonstrator
		E1	Expected	2. Software	Automated support for grid management using specialized algorithms
		E2	Expected	1. Methodology	Explore islanding mode in grid operation
STORE	STORE	A3	Completed	1. Methodology	Cost reduction of electrical system in islands
STORY	**STORY**	**E1**	**Expected**	**1. Methodology**	**Demonstration and evaluation of a household/neighbourhood increased self-supply by using heat and electricity production and storage**
		E2	**Expected**	**3. Hardware**	**Medium scale battery system introduced in the distribution network and in industrial environments**
		E3	**Expected**	**3. Hardware**	**CAES unit**
TILOS	**TILOS**	**A1**	**Completed**	**2. Software**	**Forecasting of RES and load demand**
		A2	**Completed**	**5. Policy, regulation, market**	**Policy recommendations for the distinction of storage technologies in the Greek regulation and the permission to run islands diesel-free**
TRANSFORM	**TRANSFORM**	**R1**	**Completed**	**1. Methodology**	**Handbook to pave the way toward a Smart City**
UPGRID	**UPGRID**	**E1**	**Expected**	**1. Methodology**	**Increase the observability and control of LV grid.**
		E2	**Expected**	**1. Methodology**	**Functional specification of LV dispatch**
		E3	**Expected**	**2. Software**	**Deployment of tools to support LV operation of field crews**
		E4	**Expected**	**1. Methodology**	**Improvement in Operations and Maintenance of LV grid**
		E5	**Expected**	**1. Methodology**	**Improvement of QoS to customers**
		E6	**Expected**	**5. Policy, regulation, market**	**Evaluation of incentive and market framework in demo regions**
		E7	**Expected**	**5. Policy, regulation, market**	**Identification of investment alternatives for UPGRID innovative concepts**
		E8	**Expected**	**1. Methodology**	**Assessment of optimal business models for market participants**

		E9	**Expected**	**2. Software**	**Integration and processing of meter events in the OMS (Outage Management System). Within SCADA system**
		E10	**Expected**	**3. Hardware**	**Deployment of Multiservice PRIME subnetwork**
		E11	**Expected**	**2. Software**	**Development of LV grid remote control operation over Smart Metering PRIME infrastructure**
		E12	**Expected**	**2. Software**	**Improvement of customer capacity building web-based systems**
		E13	**Expected**	**5. Policy, regulation, market**	**Development of interactive communication campaigns**
		E14	**Expected**	**1. Methodology**	**Societal research on the socio-economic impact of Smart Grid solutions on the demo regions**
V/Q regulation	V/Q_regulatio n	A1	Completed	2. Software	Advanced SW allowing voltage regulation through reactive power
		E1	Expected	2. Software	Tested solution is relevant for deployment and is expected to meet its goal – enhance the capacity of the grid to integrate additional DER through voltage regulation via management of reactive power
VENTEEA	VENTEEA	A1	Completed	3. Hardware	New functions for a better management of the integration of the renewable energies on the MV network
		A2	Completed	1. Methodology	Assess the impact of the renewable energies on power quality, protection coordination, security of people
VENTOTENE	VENTOTENE	A1	Completed	2. Software	Co-designing of new power electronics control rules
		R1	Completed	1. Methodology	Methodology for designing new hybrid generation assets

24.3 Transmission/distribution achievements

Erreur ! Référence non valide pour un signet. below presents the list of analyzed R&I achievements related to both distribution and transmission.

> NB: As explained in the section 3.2, id codes were used to abbreviate projects' names all along the document.
>
> The colour code for each project acronym corresponds to the source that has provided the filled-in questionnaires (**EU projects** are displayed in bold text while projects funded at national level are displayed in plain text):

EDSO	EASE	ENTSO-E

Table 13: Detailed description of achievements related to transmission/distribution activities of each project reviewed as provided by project coordinators

Projects		Achievements			Achievement description
Name	Id code	Name	Id code	Name	
A complete and normalized 61850 substation	61850sub	A4	Completed	5. Policy, regulation, market	EPRI61850: Application Guides, Software Tools and Migration Strategies for the Implementation of the IEC 61850 Standard
ADVANCED	**ADVANCED**	**A5**	**Completed**	**1. Methodology**	**Communication umbrellas**
		A6	**Completed**	**6. Other**	**AD Potential**
AES Kilroot Battery Storage	AES-KBS	E1	Expected	1. Methodology	Practical experience on use of batteries for primary control and balancing in grids
		E2	Expected	6. Other	Experience on economy of using batteries for primary control and balancing in grids
AES Netherlands Advancion® Energy Storage	AES_Netherlands	R1	Completed	1. Methodology	Practical experience on use of batteries for primary control in grids
		R2	Completed	5. Policy, regulation, market	Commercial application of previously proven system
		R3	Completed	6. Other	Experience on economy of using batteries for primary control in grids
ALIADOS	Alia2	A1	Completed	3. Hardware	3 Building management systems (BMS): module, cabinet and container
		A2	Completed	2. Software	Black-start based on batteries for small-hydro plants.
ATENEA Microgrid	ATENEA	R1	Completed	1. Methodology	Microgrid design & deployment methodology
Belgium east loop active network management	Belgium East Loop	A1	Completed	1. Methodology	Development of a methodology to determine the theoretical maximum feasible capacity of new generation that could be connected to the East Loop, following different principle of access and different utilization factors.
		A2	Completed	6. Other	Technical specification for the deployment of an ANM scheme was delivered.
		R1	Completed	2. Software	Implementation of automatic centralized curtailment of generators in case of congestion in HV network
		R2	Completed	2. Software	Implementation of automatic centralized curtailment of generators in case of congestion in HV/MV transformers
		R3	Completed	3. Hardware	Implementation of automatic decentralized curtailment of generators in case of congestion in HV/MV transformers
BEST PATHS	**BESTPATHS**	**E4**	**Expected**	**3. Hardware**	**Demo 3: new multilevel VSC converter and operations strategies integrating XLPE submarine and land cables, HTLS DC conductors, DC insulators and DC fault management systems**
		E5	**Expected**	**1. Methodology**	**Demo 3: Methodology for high performance upgrading of existing DC links**
CHPCOM Combined Heat and Power	CHPCOM	A1	Completed	2. Software	TSO/DSO system integration communications, including security keys, for CHP power plant management

Communication					
DSR	DSR	A1	Completed	1. Methodology	Identification of DSR potential for Estonia. Opportunity to use the DSR as source for flexibility
		E2	Expected	2. Software	Applications for DSR aggregation
E-DeMa	E-DeMa	R2	Completed	1. Methodology	Methodology can be used for further projects
EnergyLab Nordhavn	EnergyLab	E2	Expected	2. Software	IT solutions for optimal control of system operation
Estfeed	Estfeed	A1	Completed	2. Software	Data sharing platform designed for organisations and individuals to organise more efficiently their energy consumption
		A2	Completed	2. Software	Development of sample applications based on the data sharing platform
		E1	Expected	2. Software	Further development of data platform
GREDOR	GREDOR	A1	Completed	2. Software	Market design tool for modelling the interaction between the users of the grid and the DSO in presence of DER and DSR.
		A2	Completed	2. Software	Optimal investment strategies tool for distribution expansion planning in presence of increased flexibility needs
		A3	Completed	2. Software	Operational planning tool for distribution networks
GridTech	**GridTech**	**R1**	**Completed**	**2. Software**	**Zonal tool and model (with 2020, 2030, 2050 data) for pan-European system planning studies**
		R3	**Completed**	**2. Software**	**Toolbox for transmission expansion planning with storage, DSM/DR, EV**
INCREASE	**INCREASE**	**E1**	**Expected**	**2. Software**	**Decision support model, based on probabilistic and stochastic analysis of (LV) distribution network operation**
		E2	**Expected**	**2. Software**	**Technological solutions to increase the RES penetration (PV as an example)**
		E3	**Expected**	**2. Software**	**Simulation tool that enables DSO to estimate the impact of the proposed solution as well as state-of-the-art solutions.**
INGRID - High-capacity hydrogen-based green-energy storage solutions for grid balancing	**INGRID**	**A1**	**Completed**	**3. Hardware**	**Improved electrolyser technology**
		A2	**Completed**	**3. Hardware**	**Improved solid state hydrogen storage devices and materials**
		A3	**Completed**	**1. Methodology**	**Experience on control of grid-connected electrolysers**
Nice Grid	NiceGrid	E1	Expected	5. Policy, regulation, market	How to use and to value flexibility coming from distributed energy resources (DER), including storage, RES production, and industrial and residential demand response
PROBA	PROBA	A1	Completed	1. Methodology	A probabilistic method based on a quasi-systematic search of the space of uncertainties, addressing correlations while managing computation time (use of importance sampling algorithm)

		A2	Completed	2. Software	A tool supporting the methodology was developed. This one allows to assess risk indices and thermal constraints on Elia grid and/or TSO/DSO interface due to the connection of a new DG unit on one hand and risk indices related to the produced power of the DG unit. The developed tool uses the Elia network calculations software (LF & OPF computations).
		R1	Completed	2. Software	SW for localization of congestions in HV/MV transformers
		R2	Completed	2. Software	SW for localization of congestions in HV grid
RealValue - Realising Value from Electricity Markets with Local Smart Electric Thermal Storage	**RealValue**	**A1**	**Completed**	**1. Methodology**	**Controlling many storage heaters to provide grid services**
SAFEWIND	**SAFEWIND**	**R2**	**Completed**	**2. Software**	**Methods & SW for predicting the level of predictability for the next hours and for warning and alarming in case of difficult extreme situations (high wind speeds, weather fronts, any situations producing large forecast errors, …) for producers or DSOs and TSOs**
SECONOMICS	**SECONOMICS**	**R2**	**Completed**	**1. Methodology**	**Risk assessment methodology for security vulnerability**
Smart Grid Vendée	SGV	E3	Expected	5. Policy, regulation, market	How to use and to value flexibility coming from distributed energy resources (DER), including storage, RES production, and industrial and residential demand response
Smart grids: Back End Systems	Smart_grids	A1	Completed	3. Hardware	Implementation of operating management systems. Full roll-out in our operating centres.
		A3	Completed	6. Other	Automatic curtailment of wind and automatic load shedding
		E1	Expected	5. Policy, regulation, market	Integration of DSM as system reserve (DSO/TSO)
		E2	Expected	5. Policy, regulation, market	Integration of storage, including the ancillary services provided by storage solutions
SmartNet	**SmartNet**	**E1**	**Expected**	**2. Software**	**SW for optimized architecture(s) for TSO-DSO interaction to allow participation to ancillary services market by resources in distribution**
		E2	**Expected**	**1. Methodology**	**Analyses on optimized architecture(s) for TSO-DSO interaction to allow participation to ancillary services market by resources in distribution**
		E3	**Expected**	**3. Hardware**	**3 national pilots on monitoring and flexibility resources in distribution**
The Cell Controller Pilot Project	Cell controller	A1	Completed	2. Software	On line field data monitoring system
		A2	Completed	2. Software	On line automatic grid controller

25. Description of projects' budgets

25.1 Projects' budgets related to transmission activities

Table 14 presents the budget of each project related to transmission, as communicated by the project coordinators.

> NB: As explained in the section 3.2, id codes were used to abbreviate projects' names all along the document.
>
> The colour code for each project acronym corresponds to the source that has provided the filled-in questionnaires (**EU projects** are displayed in bold text while projects funded at national level are displayed in plain text):
>
> | EASE | ENTSO-E |
> |---|---|

Table 14: Description of projects' budgets related to transmission activities

Projects		Budget		
Name	**Id code**	**Total (M€)**	**Public (M€)**	**Funding source**
220 kV SSSC device for power flow control	SSSC	5.50	5.50	Granted by PSE during 2009 – 2010 and INNPACTO during 2011 – 2014 (Spanish R&D Programs)
A complete and normalized 61850 substation	61850sub	0.80		REE
AFTER	**AFTER**	**5.05**	**3.47**	**FP7**
ANEMOS.PLUS	**ANEMOS**	**5.70**	**2.60**	**FP6**
BEST PATHS	**BESTPATHS**	**62.8**	**35.5**	**FP7**
BESTGRID	**BESTGRID**	**1.95**	**1.46**	**IEE**
Class project	Class_project	1.78		National Italian
Concept for Management of the Future Electricity System	Concept	0.50		-
Development of market modelling capacity	DevMarket	0.40		Internal Baltic TSOs (Elering, AST, Litgrid) funds
DSR	DSR	0.50		Elering
eBADGE	**eBADGE**	**4.98**	**3.19**	**FP7**
EcoGRID EU	**EcoGRID**	**20.64**	**12.65**	**FP7**
e-Highway2050	**eHW**	**13.05**	**8.99**	**FP7**
EnergyLab Nordhavn	EnergyLab	17.30	10.30	EUDP - Danish national
Estfeed	Estfeed	1.50	0.50	Norwegian Financial Mechanism, other partners 0.1 M€, Elering
EWIS	**EWIS**	**4.04**	**4.04**	**FP6**
FutureFlow	**FutureFlow**	**12.90**	**12.90**	**H2020**
GARPUR	**GARPUR**	**10.90**	**7.80**	**FP7**
GREDOR	**GREDOR**	**4.34**		**Wallonia Region - Belgium**
GridTech	**GridTech**	**1.96**	**1.47**	**IEE**
Humber Smartzone Pilot Project	Humber	1.49		IFI/NIA
HyUNDER	**HyUNDER**	**1.77**	**1.19**	**JU FHC FP7**

ICOEUR	**ICOEUR**	**4.80**	**2.00**	**EC FP7 and Russian FASI Agency / National institutions/ internal partners and TSO sources**
Impact of electric and gas vehicles	ImpactEV	0.30		Elering
INSPIRE-Grid	**INSPIRE**	**3.50**	**2.60**	**FP7**
iTesla	**iTesla**	**19.30**	**13.20**	**FP7**
KÄVA2	KÄVA2	0.44		Fingrid
LIFE Elia	**LIFE**	**3.00**	**1.95**	**EU LIFE program, Elia, RTE, Walloon Region**
Market4RES	**Market4RES**	**2.40**	**1.80**	**IEE**
MERGE	**MERGE**	**4.43**	**2.96**	**FP7**
MIGRATE	**MIGRATE**	**17.86**	**16.74**	**H2020**
OPTIMATE	**OPTIMATE**	**4.25**	**2.60**	**FP7**
PoStaWind	PoStaWind	0.19		Elforsk (Vindforsk III) with initial funding from TSOs Fingrid, Statnett and SvK and other stakeholders
Power to gas	P2G	0.05		Elering
Promotion	**Promotion**	**52.00**	**39.00**	**H2020**
REALSMART	**REALSMART**	**1.09**	**1.09**	**Marie Curie FP7 IAPP (Industry Academic Pathways and Partnerships)**
SAFEWIND	**SAFEWIND**	**5.60**	**4.00**	**FP7**
SAMREL - Security of electricity supply - analysis tools	SAMREL	2.00	1.60	Research Council of Norway
SECONOMICS	SECONOMICS	4.72	3.45	FP7
Smart Substation	SmartSub	32.00	9.70	National (France) - ADEME
SmartNet	**SmartNet**	**12.70**	**12.70**	**H2020**
SOSPO PMU/WAMS Early Warning Systems	SOSPO	4.00		The Danish Council for Strategic Research
STORE	STORE	11.00	N/A	National Spanish, CDTI
SUMO	SUMO	3.50		company
TWENTIES	**TWENTIES**	**56.70**	**31.70**	**FP7**
UMBRELLA	**UMBRELLA**	**5.00**	**3.86**	**FP7**
VENTOTENE	VENTOTENE	1.10		Private
WAMPAC_Elering	WAMPAC_Elering	0.60		ELERING
WAMPAC_Eles	WAMPAC_Eles	1.4		Eles

25.2 Projects' budgets related to distribution activities

Table 15 presents the budget of each project related to distribution, as communicated by the project coordinators.

> NB: As explained in the section 3.2, id codes were used to abbreviate projects' names all along the document.
>
> The colour code for each project acronym corresponds to the source that has provided the filled-in questionnaires (**EU projects** are displayed in bold text while projects funded at national level are displayed in plain text):
>
> | EDSO | EASE |
> |---|---|

Table 15: Description of projects' budgets related to distribution activities

Projects		Budget		
Name	**Id code**	**Total (M€)**	**Public (M€)**	**Funding source**
ADDRESS	**ADDRESS**	**16.00**	**9.00**	**FP7-ENERGY ENERGY-2007-7.1-01**
ADVANCED	**ADVANCED**	**4.10**	**2.72**	**FP7-ENERGY ENERGY 2012-7.1.3**
ALIADOS	ALIA2	4.60	1.86	ETORGAI Regional funding
Ampacity	Ampacity	15.50	6.70	National funding scheme (German BMWi)
ATENEA Microgrid	ATENEA	3.10	3.10	Regional Government/FEDER
BIENVENU	BIENVENU	10.00	4.00	ADEME
CAES Larne	CAES_Larne	12.93	6.47	PCI EU
CHPCOM Combined Heat and Power Communication	CHPCOM	2.04	1.48	ForskEL, Energinet.dk
Control and regulation of modern distribution system	Control	0.67	0.63	ForskEL, Energinet.dk
CryoHub	**CryoHub**	**8.33**	**7.05**	**H2020-LCE-2015-3**
Dezentrale Netzintelligenz	Dezentrale	1.00		
DISCERN	**DISCERN**	**7.90**	**4.70**	**FP7-ENERGY ENERGY**
DRIP - Demand Response on Industrial Production	**DRIP**	**0.99**	**0.49**	**EU (LIFE+ 2011)**
DSO challenges from introduction of heat pumps	Heat_Pumps	1.34	0.89	ForskEL, Energinet.dk
Dynamic Network Access tariffs	DNAT	N/A	1.00	The pilot costs are expected to be recovered through network tariffs
E-DeMa	E-DeMa	7.2	2.8	BMWi (German Minestry)
Electrogas - The renewable e-power buffer	Electrogas	3.50		National Danish
EnergyLab Nordhavn	EnergyLab	17.30	10.30	EUDP - Danish national
FINSENY (Future Internet for Smart Energy)	**FINSENY**	**9.13**	**5.18**	**FP7-2011-ICT-FI / FI.ICT-2011.1.8**
FLEXe WP1	FLEXe	3.00	1.65	TEKES national funding
G4V - Grid for Vehicles	**G4V**	**3.76**	**2.54**	**EU (FP7)**
Gigha Wind Farm Battery Project	Gigha		4.50	Department of Energy & Climate Change - UK

Gorona del Viento El Hierro	Gorona	71.00	35.00	Ministry of Industry, Energy and Tourism and IDAE
HyUNDER	**HyUNDER**	**1.77**	**1.19**	**JU FHC FP7**
IGREENGrid	**IGREENGrid**	**6.60**	**4.30**	**FP7-ENERGY ENERGY.2012.7.1.1**
INCREASE	**INCREASE**	**4.30**	**3.10**	**FP7-ENERGY ENERGY.2012.7.1.1**
INGRID - High-capacity hydrogen-based green-energy storage solutions for grid balancing	**INGRID**	**24.06**	**13.79**	**FP7 - Energy**
Isernia	Isernia	6.90	2% WACC	AEEGSI
Life Factory Microgrid - Electric vehicles to grid, renewable generation and Zn-Br flow battery to storage in industry	**Life**	**1.99**	**1.13**	**Life +**
LINKY	LINKY	-	-	
Local Energy Storage	Local	2.68	1.32	National Danish
LODIS (Czech abbreviation for Local Management of Distribution Grid)	LODIS	N/A	N/A	Internal sources
MERGE (Mobile Energy Resources in Grids of Electricity)	MERGE	4.40	2.96	FP7-ENERGY ENERGY.2009.7-1
MESHARTILITY	**MESHARTILITY**	**2.30**	**1.73**	**Intelligence Energy Europe Program**
METAPV - Metamorphosis of Power Distribution: System Services from Photovoltaics	**METAPV**	**9.38**	**5.52**	**FP7-ENERGY**
METER - ON	**METER_ON**	**1.50**	**N/A**	**FP7-ENERGY ENERGY.2012.7.3.1**
Modeller i EU-projektet stoRE af økonomien i ellagre	stoRE	0.18	0.11	ForskEL, Energinet.dk
Nice Grid	NiceGrid	30.00	4.00	ADEME
Northern Isles New Energy Solutions (NINES)	NINES	43.97		Ofgem, DECC and Hjaltland Housing Association
OPEN NODE	**OPEN_NODE**	**5.26**	**2.79**	**FP7**
PlanGridEV	**PlanGridEV**	**8.37**	**5.47**	**EU (FP7)**
Power-to-Gas via Biological Catalysis (P2G-BioCat)	BioCat	6.65	3.65	Danish - ForskEl
PRICE	PRICE	34.00	24.00	INNPACTO 2011 funding program, funded by the Spanish Ministry of Economy and Competitiveness and by FEDER funding
Proaktives Verteilnetz	Proaktives	6.50	3.74	natinal funding program: „Zukunftsfähige Stromnetze“ by Bundesministerium für Wirtschaft und Energie
Puglia Active Network	Puglia	170.00		NER 300
PV-KWK / Intelligent energy management solutions and photovoltaic combined systems for optimized electricity and heat generation in the house	PV-KWK	5.50	3.00	Bundesministerium für Bildung und Forschung
Smart Country	Smart_Country	7.20	3.00	Natinoal funding scheme (German BMWi)

Smart Grid Judenburg	Judenburg	N/A	N/A	N/A
Smart Grid Vendee	SGV	27.70	9.50	ADEME (French Agency)
Smart grids: Back End Systems	Smart_grids	15.00		
Smart LV Grid - Heimschuh	Heimschuh	N/A	N/A	N/A
Smart Operator	Smart_Operator	8		
Smart Storage	Smart_Storage	1.68		Ministry of Economic Affairs - Agriculture and Innovation (NL)
Smart Toruń	Smart_Toruń	17.35	4.02	National Fund for Environmental Protection and Water Management
SOGRID	SOGRID	27.00	0.20	ADEME
SOLENN	SOLENN	13.30	5.30	ADEME
Storage in Evora	Evora	1.20		EDP Distribuição, included in tarifary plan
STORE	STORE	11.00	N/A	National Spanish, CDTI
STORY	**STORY**	**15.50**	**12.50**	**Horizon 2020**
TILOS	**TILOS**	**14.00**	**11.00**	**H2020-LCE-2014-3**
TRANSFORM	**TRANSFORM**	**7.80**	**5.85**	**FP7_ENERGY.2012-8.8.1**
UPGRID	**UPGRID**	**15.70**	**11.70**	**H2020-LCE-2014-3**
V/Q regulation	V/Q_regulation	N/A	4.30	Internal sources
VENTEEA	VENTEEA	23.80	7.60	ADEME (French Agency)
VENTOTENE	VENTOTENE	1.10		Private

25.3 Projects' budgets related to transmission/distribution activities

Table 16 presents the budget of each project related to both transmission and distribution, as communicated by the project coordinators.

> NB: As explained in the section 3.2, id codes were used to abbreviate projects' names all along the document.
>
> The colour code for each project acronym corresponds to the source that has provided the filled-in questionnaires (**EU projects** are displayed in bold text while projects funded at national level are displayed in plain text):

EDSO	EASE	ENTSO-E

Table 16: Description of projects' budgets related to transmission/distribution activities

Projects		Budget		
Name	Id code	Total (M€)	Public (M€)	Funding source
A complete and normalized 61850 substation	61850sub	0.80		REE
ADVANCED	**ADVANCED**	**4.10**	**2.72**	**FP7-ENERGY ENERGY 2012-7.1.3**

AES Kilroot Battery Storage	AES-KBS	5.00		
AES Netherlands Advancion® Energy Storage	AES_Netherlands	N/A		
ALIADOS	Alia2	4.60	1.86	ETORGAI Regional funding
ATENEA Microgrid	ATENEA	3.10	3.10	Regional Government/FEDER
Belgium east loop active network management	Belgium East Loop	0.07		ELIA-ORES (DSO)
BEST PATHS	**BESTPATHS**	**62.80**	**35.50**	**FP7**
CHPCOM Combined Heat and Power Communication	CHPCOM	2.04	1.48	ForskEL, Energinet.dk
DSR	DSR	0.50		Elering
E-DeMa	E-DeMa	7.2	2.8	BMWi (German Minestry)
EnergyLab Nordhavn	EnergyLab	17.30	10.30	EUDP - Danish national
Estfeed	Estfeed	1.50	0.50	Norwegian Financial Mechanism, other partners 0.1 M€, Elering
GREDOR	GREDOR	4.34		Wallonia Region - Belgium
GridTech	**GridTech**	**1.96**	**1.47**	**IEE**
INCREASE	**INCREASE**	**4.33**	**3.11**	**FP7**
INGRID - High-capacity hydrogen-based green-energy storage solutions for grid balancing	**INGRID**	**24.06**	**13.79**	**FP7 - Energy**
Nice Grid	NiceGrid	30.00	4.00	ADEME
PROBA	PROBA	0.27		ELIA
RealValue - Realising Value from Electricity Markets with Local Smart Electric Thermal Storage	**RealValue**	**15.50**	**12.00**	**Horizon 2020**
SAFEWIND	**SAFEWIND**	**5.60**	**4.00**	**FP7**
SECONOMICS	**SECONOMICS**	**4.72**	**3.45**	**FP7**
Smart Grid Vendée	SGV	27.70	9.50	ADEME (French Agency)
Smart grids: Back End Systems	Smart_grids	15.00		
SmartNet	**SmartNet**	**12.70**	**12.70**	**H2020**
The Cell Controller Pilot Project	Cell controller	13.40		Energinet