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Smart grid projects outlook 2017

Facts, figures and trends in Europe

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Smart grid projects outlook 2017: facts, figures and trends in Europe

Abstract
The 2017 Outlook offers a snapshot of the state of play and of the latest developments in the field of smart grids in Europe. The analysis is based on a database of 950 R & D and demonstration projects, totalling around EUR 5 billion of investment. It aims to foster knowledge sharing and to inform future policymaking.

Smart grid projects outlook 2017

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Executive summary

Policy context

The power system and market are at the centre stage of the European Union's energy policies. The recent measures proposed by the European Commission with the 'Clean energy for all Europeans' package rely on smart technologies, solutions and concepts to accelerate, transform and consolidate the EU economy's clean energy transition. The deployment of smart grid solutions can help to make distribution grids more flexible and to cope with variable renewable energy sources and new loads. They can enable active consumers and energy communities, supporting their participation in the energy markets. Smart grid deployment will enable new services and create business opportunities for new and established actors.

Over the last few years, investment in smart grid research and development (R & D) and demonstration activities have grown considerably in Europe. A bird's eye view of what has already been achieved and of the latest developments in the field can help to understand the direction Europe is taking and to inform future support policies. In its role as an independent observer of the energy system, the JRC has made a strong effort to collect, process and analyse smart grid project data with the aim of providing different stakeholders with a tool to better understand the rapidly changing scene, enabling early identification of developments and opportunities and supporting evidence-based policymaking.

This report is intended to be a compendium of key facts and figures that can be used to inform and support further analysis. It also aims to collect and share success stories and best practices that can be used as a source of inspiration for similar initiatives. The analysis is based on a database of smart grid R & D and demonstration projects, a living compilation of facts and knowledge that is periodically updated to reflect the continuous developments in the field.

Main findings

Thanks to our renewed data collection efforts, the database of smart grid R & D and demonstration projects now includes 950 projects, totalling around EUR 5 billion of investment. The database focuses on the 28 EU Member States, but Switzerland and Norway are also covered to a good extent. Other non-EU countries appear only when they participate in projects together with EU Member States or Switzerland and Norway.

Strong differences exist between Member States in the number of projects and the overall level and pace of investment. Several country-specific circumstances have an influence on these figures and can contribute to explain differences among Member States. Our analysis identifies some of these factors and tries to explain the reasons behind the most interesting findings.

Private investment is clearly the most important source of financing of smart grid projects, but European and national funding play an important role in leveraging private finance and incentivising investment. Distribution system operators (DSOs) are the stakeholders with the highest investment, but non-traditional actors such as public institutions and other emerging stakeholders are steadily increasing their investment in the field.

The domains with highest investment are smart network management, demand-side management and integration of distributed generation and storage, together accounting for around 80 % of the total investment. Many projects however address several domains at the same time to investigate and test the systemic integration of different solutions.

Summary of the 2017 database

Related and future JRC work

The database represents a powerful tool to monitor and analyse smart grid developments and the JRC will therefore continue in its monitoring activity in order to inform policymaking and contribute to the dissemination of best practice and lessons learned. In the future we also intend to release dedicated insights into specific aspects of smart grids.

Quick guide

After a bird's eye view of the state of play of smart grid innovation effort in Europe (Chapter 2), the report addresses three main topics. Chapter 3 looks into the sources of investment to see how projects are financed. Smart grid R & D and demonstration projects require large investment, and uncertainties related to the maturity of the technology, the regulatory framework and the evolving business models can negatively affect investment decisions. In this context, public funding assumes a very important role to leverage private finance and incentivise investment. Our analysis looks into the private and public financing streams at European and national level in order to get an idea of what we can expect in the near future and to share best practices that can help support investment.

Chapter 4 looks at smart grid investors to see what kind of actors are actively involved in innovation projects, to identify emerging synergies and to investigate the positioning of European companies in the global smart grid marketplace. With the rise of new technologies and business models, old actors are repositioning themselves and new actors are emerging. Observing and understanding these trends can provide important clues on how to support and accelerate the deployment of smart grids.

Finally, in Chapter 5 we investigate smart grid project domains to identify the main areas of investment and to assess if and how they are changing. Such analysis contributes to better understanding the progress of different solutions on their path from demonstration to deployment. It also helps to identify emerging opportunities and new business models for European smart grid investors.

1 Introduction

The past few years have seen major transformation in all segments of the power industry, from generation to supply. Regulatory, technological and market structure changes have been spurred by the adoption by the European Union (EU) of ambitious policy objectives aimed at improving the competitiveness, security and sustainability of the EU's energy system.

The growing penetration of renewable and distributed energy resources and the increasing involvement of electricity consumers in the production and management of electricity, are acting as strong transformative forces in the power sector. These new developments are expected to radically change the local electricity industry and markets, especially at distribution level (Ruester, Perez-Arriaga, Schwenen, Batlle, & Glachant, 2013), creating opportunities but also posing challenges to the reliability and efficiency of system operation.

All segments of the power industry are affected by these changes. DSOs for example, have been put under increasing pressure to adopt a more active role for the development, management and operation of their networks and many of them have started testing smart grid solutions to improve network reliability, efficiency and security. Other organisations have also started showing growing interest for smart grid solutions, attracted by the opportunities offered by new technologies and emerging business models. Technology manufacturers, service providers and information and communications technology (ICT) developers for example, are increasingly eager to develop and test new solutions to gain technology leadership that can be exported globally.

Investment in smart grid R & D and demonstration activities has grown considerably in Europe. The number of initiatives and the level of investment in each Member State vary in relation to country-specific circumstances, e.g. national policies, the state of the electricity grids, the regulatory framework, the existence and scope of co-funding mechanisms at national and European level.

A global view of the R & D and demonstration efforts carried out in Europe so far can help to understand the direction Europe is taking and to inform future support policies. To this end, the 2017 Smart grid projects outlook aims to offer a snapshot of what has already been achieved and to provide a view of the latest developments in the field.

The report has been thought as a compendium of key facts and figures that can be used to inform and support further analysis. It also aims to collect and share success stories and best practices that can be used as a source of inspiration for similar initiatives. In the field of smart grids, knowledge sharing is indeed of fundamental importance to stimulate regulators to design tailored incentive schemes, to inspire public authorities to replicate initiatives successfully tested elsewhere and to inform companies' investment strategies.

1.1 The data collection process

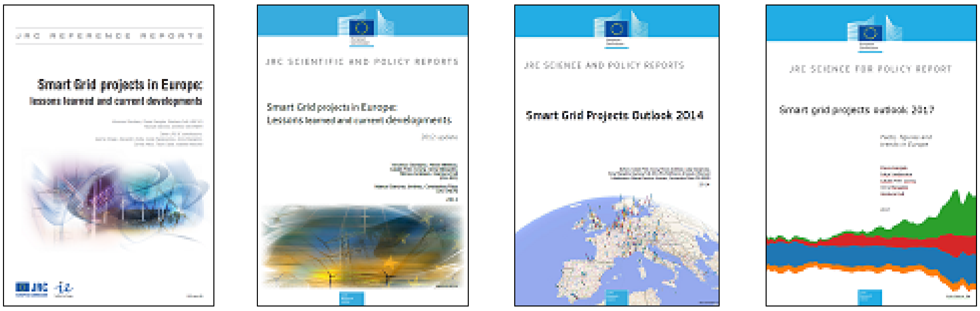
This report is based on the analysis of the projects included in the updated version of the JRC database of smart grid projects. The JRC started its data collection effort in 2010 with the launch of a survey that collected quantitative and qualitative data about smart grid projects in Europe. The first smart grid projects outlook was released in 2011 (Giordano, Gangale, Fulli, & Sanchez Jimenez, 2011) and updated twice, in 2013 (Giordano, et al., 2013) and 2014 (Covrig, et al., 2014) (Figure 1). In 2016 we started a new data collection exercise, with the launch of a revised online questionnaire. The new questionnaire simplifies the data-collection and processing phases, facilitating the standardised input of data by project coordinators.

Although the online survey is an important tool to get first-hand information directly from project partners, much of the information on the projects included in the 2017 database was retrieved through an active search by our multilingual team. The main sources of information were the websites of the projects (where they existed) and of the participating organisations. We also searched and analysed scientific articles and dissemination and communication material, and, when necessary, we contacted the leading project partners to verify the information collected. In some Member States, contacts with national authorities and funding institutions proved to be a very useful channel through which to collect data. Another important source of information for projects co-funded by the European Union was the Community Research and Development Information Service (CORDIS) website ([1]), the European Commission's primary portal for results of EU-funded R & D and demonstration projects. We also reviewed the information publicly available through two EU co-funded initiatives on smart grids, i.e. GRIDinnovation online ([2]) and ERA-Net smart grid plus ([3]).

Projects were included in the database only when, by comparing several sources of information, the retrieved data were deemed to be sufficient and reliable. The report only shows data up to the year 2015; the aggregations for 2016 were not included in the analysis as they cannot be considered final due to the delay with which smart grid project proponents tend to communicate the beginning of their R & D and demonstration activities. Projects not included in this edition of the report will be considered for inclusion in the next edition, provided that complete and reliable information is found.

The online questionnaire ([4]) remains open to collect information for the next edition of the Outlook. To further support knowledge sharing, we also created a visualisation platform, linked to the database and hosted on our website ([5]), which maps projects across Europe. In the report, as well as in the visualisation platform, all financial and economic information is treated confidentially and only aggregated data are published.

Figure 1. The JRC smart grid projects Outlook



2011 | 2013 | 2014 | 2017

([1]) http://cordis.europa.eu/home_en.html
([2]) GRID Innovation online was developed in the framework of the Grid+ project, a coordination and support action supported by the seventh framework programme (FP7). It aims to facilitate knowledge flows and exchanges among new, ongoing or completed research and innovation (R & I) projects contributing to the objectives of the European electricity grid initiative (EEGI) R & D roadmap. More information is available at: http://www.gridinnovation-on-line.eu/
([3]) ERA-Net smart grid plus is a network of programme owners and program managers of national and regional funding programs in the field of research, technical development and demonstration. It is supported by funding by the European Union's Horizon 2020 R & I programme. More information is available at: http://www.eranet-smartgridsplus.eu/
([4]) The online survey can be accessed at: http://ses.jrc.ec.europa.eu/survey-collection-european-smart-grid-projects.
([5]) http://ses.jrc.ec.europa.eu/

1.2 Boundaries and assumptions of the smart grid database

The JRC Smart grid projects outlook is a periodic publication whose main aim is to monitor the state of play of smart grids in Europe through the observation of the R & D and demonstration activities carried out by private and public stakeholders.

The report is based on a database that is periodically updated to include new projects, as well as older projects which were not detected in previous editions. In addition, from time to time, minor adjustments are made to the structure of the database to allow for more in-depth analysis and to reflect early findings of the updated data collection. For these reasons, the findings of this new report are not always directly comparable with the ones of the previous editions of the Outlook. The database should be considered as a *living compilation of facts and knowledge, periodically updated in an iterative process to reflect the continuous developments in the field.*

In the following sections, we will explain the boundaries and assumptions of the current database, highlighting, when necessary, the differences with the previous editions.

Scope of the data collection

In line with the definition of smart grids ([6]), the database includes projects focusing on the integration of new technologies, capabilities and resources into the grid, as well as those focusing on the promotion and integration of the behaviours and actions of all connected users. We only included projects aimed at making the grid smarter, while we did not include projects aimed at reinforcing the grid by using conventional approaches (e.g. through new lines, substations and power plants).

Many new projects were added, but despite our effort, the data collection cannot be considered exhaustive, especially for the more recent years (from 2012 onwards). For many projects, information becomes available only later in their lifetime or even after their completion. The decrease in the number of projects from 2012 onwards might be partially attributable to this circumstance, even though, as we will explain later, other factors also play a role.

Also, we tried to cover all Member States to the best of our ability. For some of them however, the lack of information publicly available in English made the data collection exercise more complicated. Despite the effort of our multilingual team, some projects might have escaped the radar.

Stages of the innovation cycle

The database includes projects belonging to the R & D and demonstration stages of the innovation cycle ([7]). In line with the Frascati manual, by R & D we mean 'creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications' (OECD, 2002). By demonstration, we mean the preview phase before marketing, during which a technology or solution is tested in different operational environments, through to full market trials in which the technology is used in customer installations (Brown & Hendry, 2009). In some cases the identification of the innovation cycle stage was not straightforward, as projects may include both R & D and demonstration activities. In these cases, we assigned the project to the stage that

([6]) According to the definition used by European Commission in the accompanying documents (European Commission, SEC(2011) 463 final), a Smart Grid is 'an electricity network that can cost efficiently integrate the behaviour and actions of all users connected to it — generators, consumers and those that do both — in order to ensure economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety'. The same definition was first used by the Council of European Energy Regulators (CEER) (European Regulators Group for Electricity and Gas, 2009).

([7]) In previous editions of the Report, we referred to the 'stages of the innovation cycle' as 'stages of development'.

seemed to best characterise it and to which most of the time and budget resources were allocated. Where available/relevant, also the technology readiness level (TRL) ([8]), as defined in the Horizon 2020 Framework Programme, was used to support the project classification exercise.

In this new edition of the Outlook, after careful reconsideration, we decided to remove those projects which we previously assigned to the deployment stage. Only a handful of projects could actually be considered as deployment projects and their inclusion in the database would have given a distorted picture of the level of commercial maturity of some technologies and solutions. Some smart grid solutions have indeed already reached or are close to reaching commercial maturity and are being implemented at a different pace in different Member States (e.g. smart meters, sensors, actuators, control systems). These initiatives however are not always announced and publicised by the investor, and their inclusion in the database would have resulted in an underrepresentation ([9]).

Project budget

Although we made a big effort to try to retrieve project financial information, this task was sometimes made difficult by the reluctance of project participants to share this type of information. Where all other fields were complete, projects lacking financial information (85 projects in total) were however included in the database, but they were not counted in any of the analysis involving investment.

For yearly aggregations of investment, the project budget was assigned to the starting year. In some figures however, in order to show a more realistic distribution of investment across the years, we evenly divided the project budget across the lifetime of the project.

Unless specific information was available, the project budget was equally divided between the different domains addressed by the project. Although sometimes this allocation does not reflect the real apportionment of financial resources within the project, such solution was made necessary by the lack of accurate information on the real distribution of funds among the different domains.

We followed the same approach also with participating organisations. Unless specific information was available, the project budget was equally distributed among the different partners, irrespective of their actual individual contribution to the project's financing.

Finally, for the allocation of budget to the project's demonstration/implementation sites, in cases where there is only one site, investment was allocated entirely to the country hosting the demonstration. In the case of projects with several implementation sites (in one or more countries) the budget was distributed evenly among the sites.

Source of financing

A strong effort was also made to identify the source of financing. For each project we tried to verify whether the project was financed by the organisation's own resources (own/private investment), by public funding (national and/or EU funding) or by a

([8]) Technology Readiness Levels (TRLs) are indicators of the maturity level of particular technologies. This measurement system provides a common understanding of technology status and addresses the entire innovation chain. There are nine technology readiness levels; TRL 1 being the lowest and TRL 9 the highest. Annex G of the General Annexes to the Work Programme 2016/17 provides a full description of TRLs.

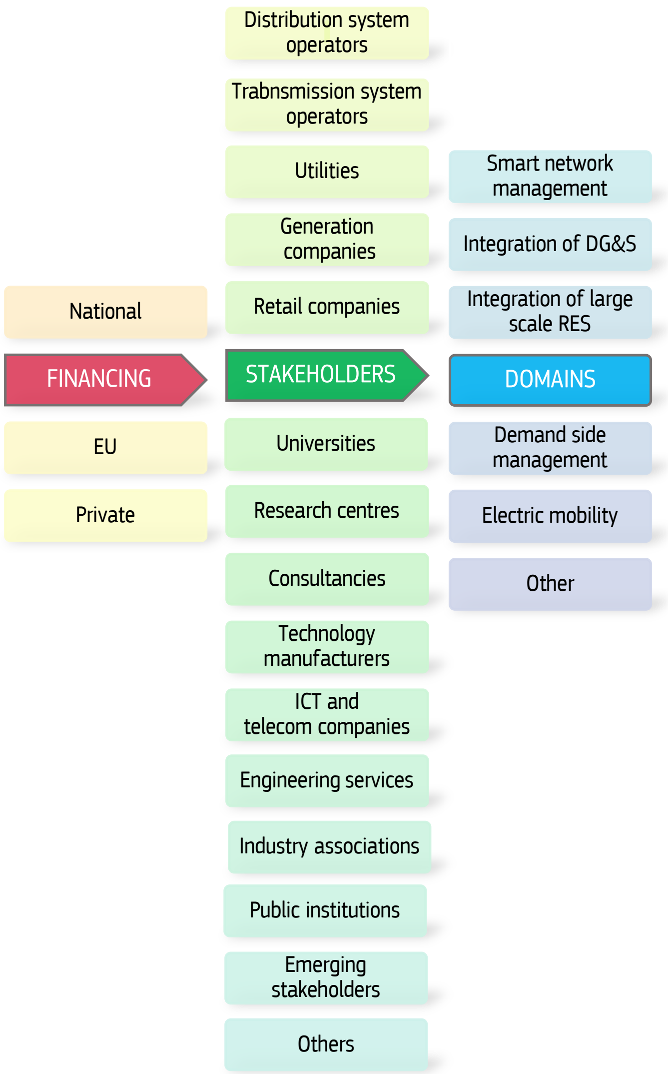
([9]) While this is true for several smart grid technologies, it is not the case for smart metering deployment projects which are actually usually well publicly announced. The decision to exclude them from the database was mainly influenced by the fact that in 2014 the Commission already published a Report to measure progress on the deployment of intelligent metering in EU Member States in line with the provisions of the third energy package (European Commission, 2014).

combination of the above. A more detailed explanation of each financing source is provided in Chapter 3.

Stakeholders

We grouped the main actors participating in smart grid projects in 15 different stakeholder categories: generation companies, utilities, transmission system operators (TSOs), DSOs, retail companies, ICT and telecom companies, technology manufacturers, industry associations, companies providing engineering services, universities, research centres, consultancies, public institutions, emerging stakeholders, other. Compared to previous editions of the Outlook, the organisation types have been slightly changed to provide more granularity and to better understand the links and relations between established and emerging actors. A detailed definition and explanation of each stakeholder categories is provided in Chapter 4.

Figure 2. Database categories: financing source, stakeholders, domains



Project domains

We identified six project domains, i.e. smart network management (SNM), demand-side management (DSM), integration of distributed generation and storage (DG&S), electric mobility (E-mobility), integration of large-scale renewable energy sources (L_RES) and other.

Compared to previous editions of the Outlook, the project domains have been slightly changed. The former domains aggregation and smart customer/smart home have been grouped into the DSM domain. The domain integration of distributed energy resources (DER) has been renamed integration of DG&S. The domain smart metering has been removed from the database as, in most countries, smart-metering projects have now reached the deployment stage. A detailed definition and explanation of the different domains is provided in Chapter 5.

We tried to assign the projects to the domain that best characterises them. In many cases however, projects address several domains without any of them prevailing. Indeed, a growing number of projects investigate and tests the systemic integration of different smart grid solutions. In these cases, the project is assigned to all relevant domains and, unless more precise information is retrieved, the budget is split equally among them. Figure 2 below presents the main categories of our database — financing sources, organisations and domains — and the subcategories in which they are organised.

2 Smart grid projects in Europe: a bird's eye view

Key messages

Strong differences exist between Member States in the number of projects, overall level and pace of investment. Several country-specific circumstances have an influence on these figures and can contribute to explain differences among Member States.

Promoting initiatives at national level, e.g. through favourable policy and regulatory frameworks, can support the growth of national organisations and accelerate smart grid investment. It also contributes to making a country attractive for foreign smart grid investment.

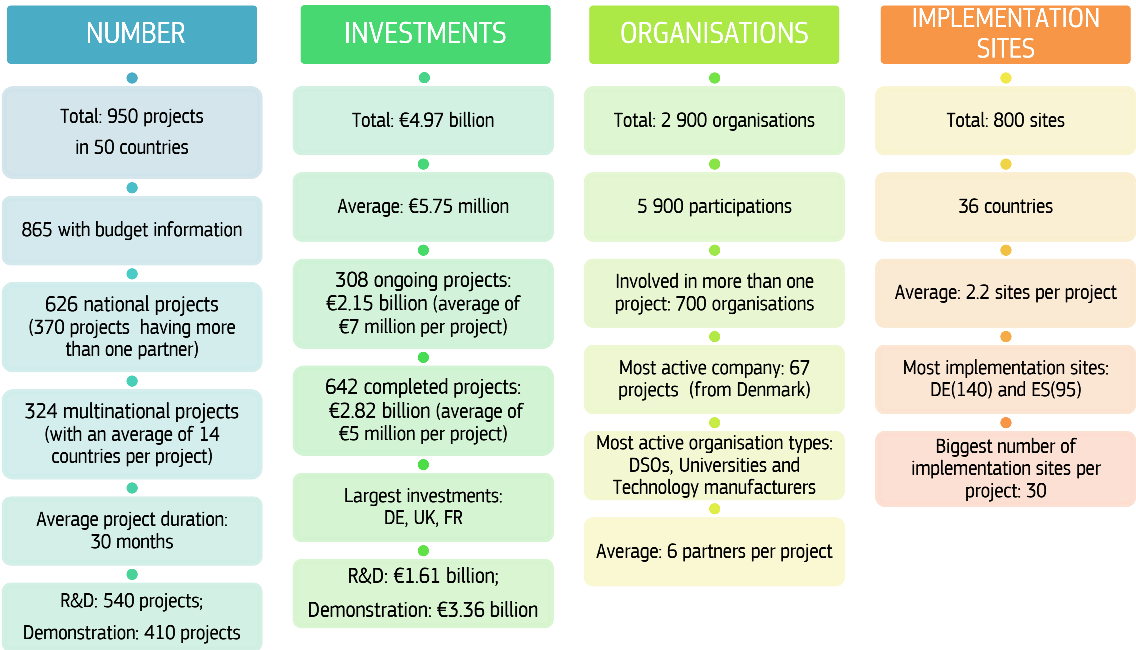
Also, the adoption of smart grid roadmaps can give a sign that smart grids are high on the national agenda, thus attracting foreign investors to seek partnerships with local stakeholders in order to enter the national market.

The amount of available national and European co-funding can influence the project scope, supporting the development of more ambitious and expensive projects, thus positively influencing the level of investment.

Investment decisions are closely linked to the perceived opportunities and risks associated with smart grid projects, and to the possibility of getting a fair return on investment. The reduction in the number of projects after 2012 seems to be partially attributable to the cautiousness of private investors to finance projects developing and testing more advanced solutions.

Even if some applications are getting closer to reaching commercial maturity, smart grid stakeholders still see the need and potential of investing in R & D and of more advanced, integrated and interoperable solutions.

Figure 3. Summary of the 2017 database



2.1 The big picture

Based on the analysis of the JRC database of R & D and demonstration projects, this chapter provides a bird's eye view of the main developments in the field of smart grids in Europe. Thanks to our renewed data collection effort, the database now includes 950 projects, totalling around EUR 5 billion of investment (10). The database focuses on the 28 EU Member States, but Switzerland and Norway are also covered to a good extent. Other non-EU countries appear only when they participate in projects together with EU Member States or Switzerland and Norway.

Figure 3 offers a quick summary of the main facts and figures of the 2017 database.

Time distribution

Figures 4 and 5 show the time distribution of projects and investment. The number of projects starting each year (orange bar in Figure 4) and the total investment (Figure 5) increase constantly until 2012, when they slowly start to decrease. As we will argue later, this reduction seems to be partially attributable to the cautiousness of private investors in financing projects which develop and test more advanced solutions. Investment decisions are closely linked with the perceived opportunities and risks associated with the project, and with the possibility of getting a fair return on investment. A supporting national and regulatory framework as well as the introduction of dedicated funding opportunities can positively influence investment decisions.

It needs to be noted however, that the results presented in Figures 4 and 5 might not be complete, as the data-collection effort for the most recent years is still ongoing.

Figure 4. Time distribution of projects

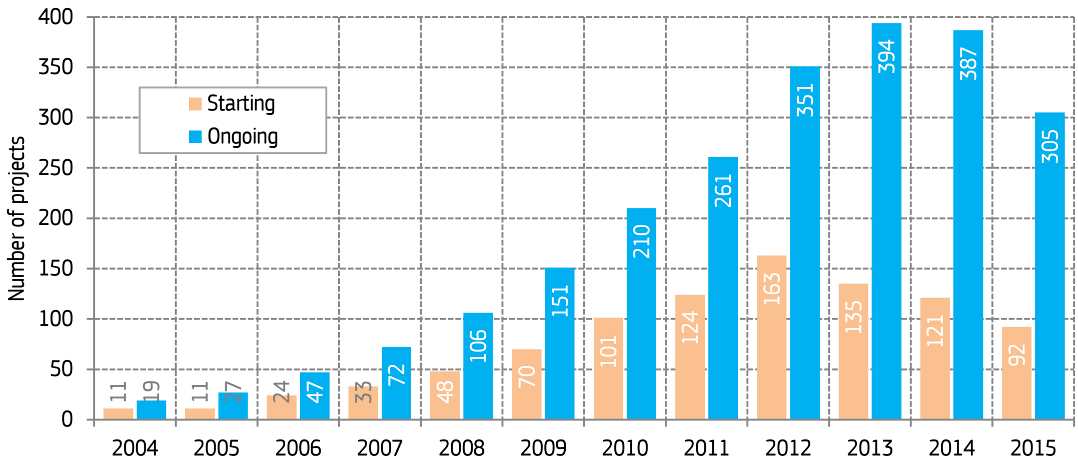
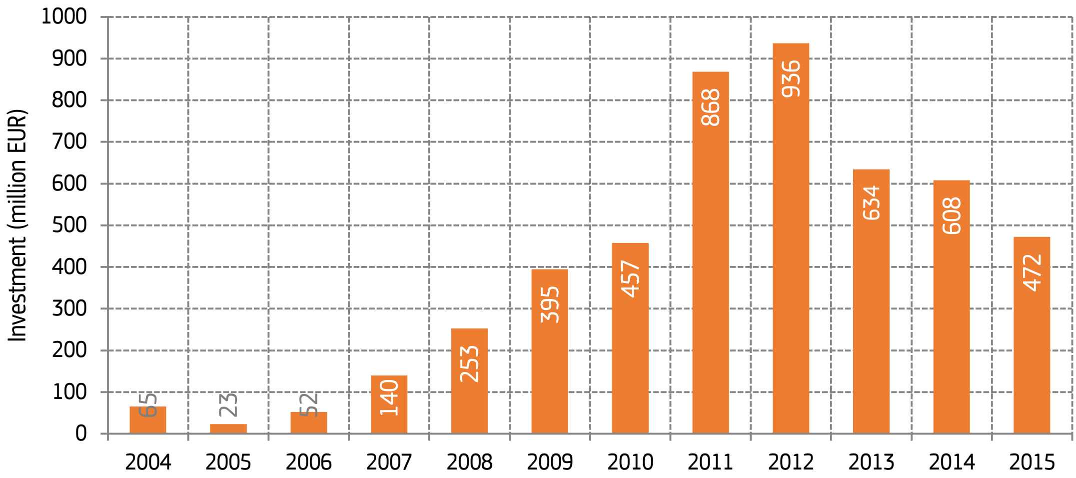


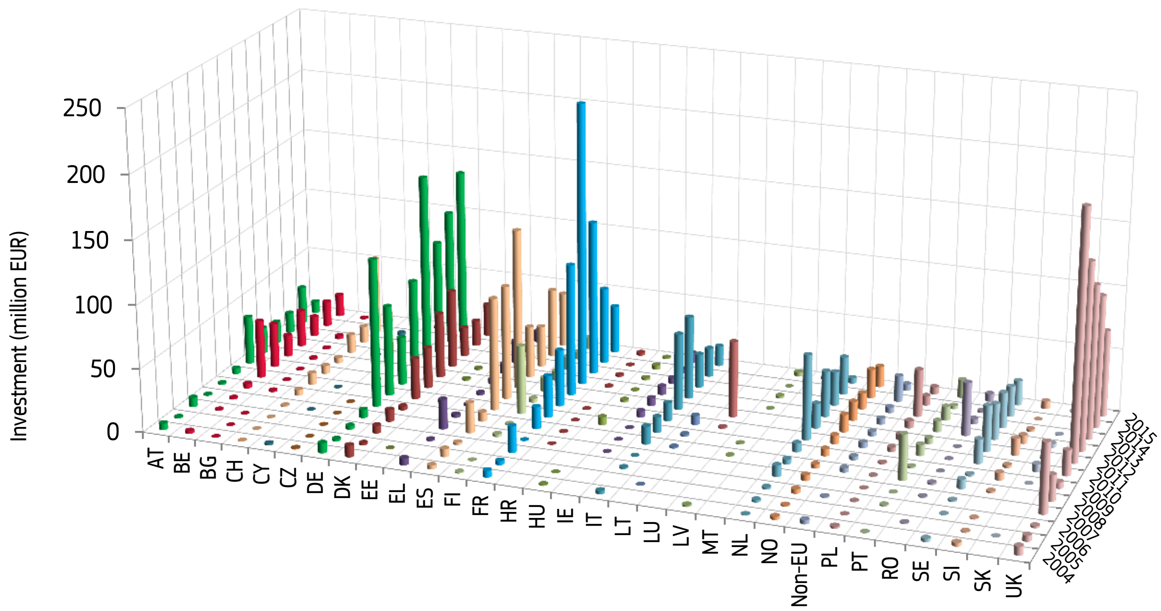
Figure 5. Time distribution of total investment



(10) For 85 projects however, financial data were not available: even though they were included in the database, they were not counted in any of the analysis involving investment.

Figure 6 shows the time distribution of investment per country. Investment is concentrated in a few countries (Denmark, Germany, Spain, France and the United Kingdom), with each country following its own pace. Some Member States pioneered large investments earlier than others (e.g. France, the United Kingdom), while other Member States started investing later (e.g. Belgium, Sweden). In the next section we will see how this finding relates to some specific national circumstances.

Figure 6. Time distribution of investment per country



Stages of the innovation cycle

R & D projects are more numerous than demonstration projects (57 % vs 43 %), but they account for a smaller share of the total investment (32 % vs 68 %) - Figures 7 and 8.

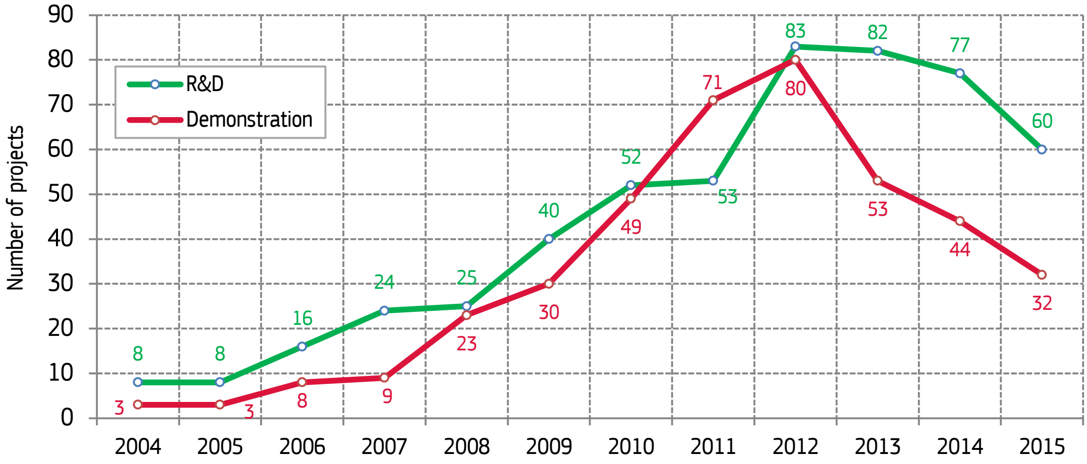
The high number of R & D projects suggests that even if some smart grid solutions are getting close to the commercialisation phase, R & D efforts are still required in many fields to investigate new options and features as well as their integration and interoperability within the grid.

The larger budget dedicated to demonstration projects points to the fact that demonstration projects involve higher investment than R & D projects. The average investment for R & D projects is EUR 3.3 million, while the average spending for demonstration projects is EUR 9 million.

The R & D projects in our database are less cost intensive as they usually do not include technology development as such — whose costs are typically very high — but they rather focus on the use of existing technologies in novel applications to support the development of new products and services. On the contrary, demonstration projects require large investments, which are needed to test the technical and market viability of new solutions in real life environments, often including large field testing with several user groups. Demonstration projects often require the involvement of a variety of actors and they frequently incur high running costs, e.g. customer service and technical assistance costs.

To better understand these results, we looked at the time distribution of projects and investment by stage of the innovation cycle. The time distribution of R & D projects appears more constant than that of demonstration projects. Their number increases steadily until 2012, when it starts to slowly decline with a curve that is less steep than that of demonstration projects (Figure 9). This observation seems to confirm that even if some applications are getting closer to reaching commercial maturity, smart grid stakeholders still see the need and potential of investing in the R & D of more advanced solutions. Again, caution is necessary in interpreting these findings, as the results shown might still not be complete.

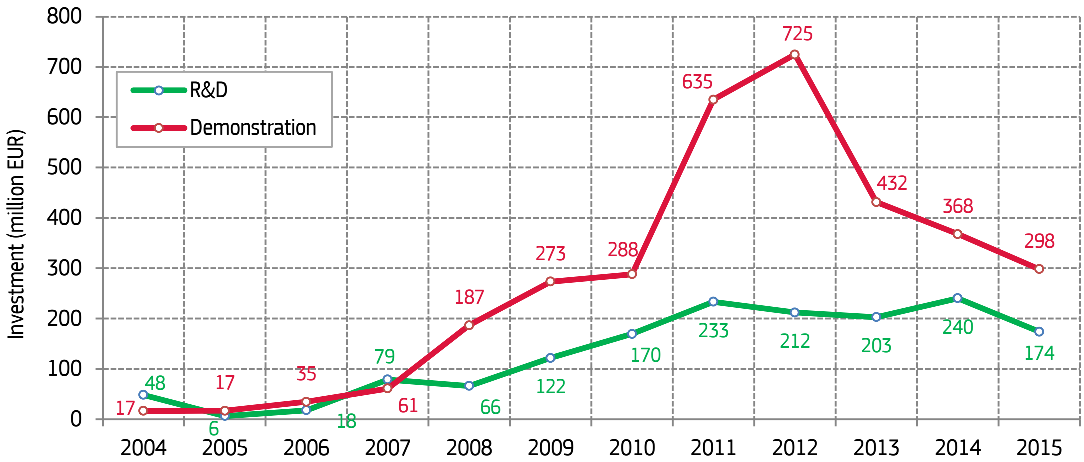
Figure 7. Time distribution of R & D and demonstration projects



When we look at the time distribution of investment, the situation changes only slightly (Figure 10). R & D and demonstration investment levels are very close until 2007, after which demonstration investment starts growing at a much quicker pace. While demonstration investment peaks in 2012 and then starts decreasing quite sharply, R & D investment increases constantly until 2011, experiences a minor decrease in 2012 and 2013, and reaches a new peak in 2014.

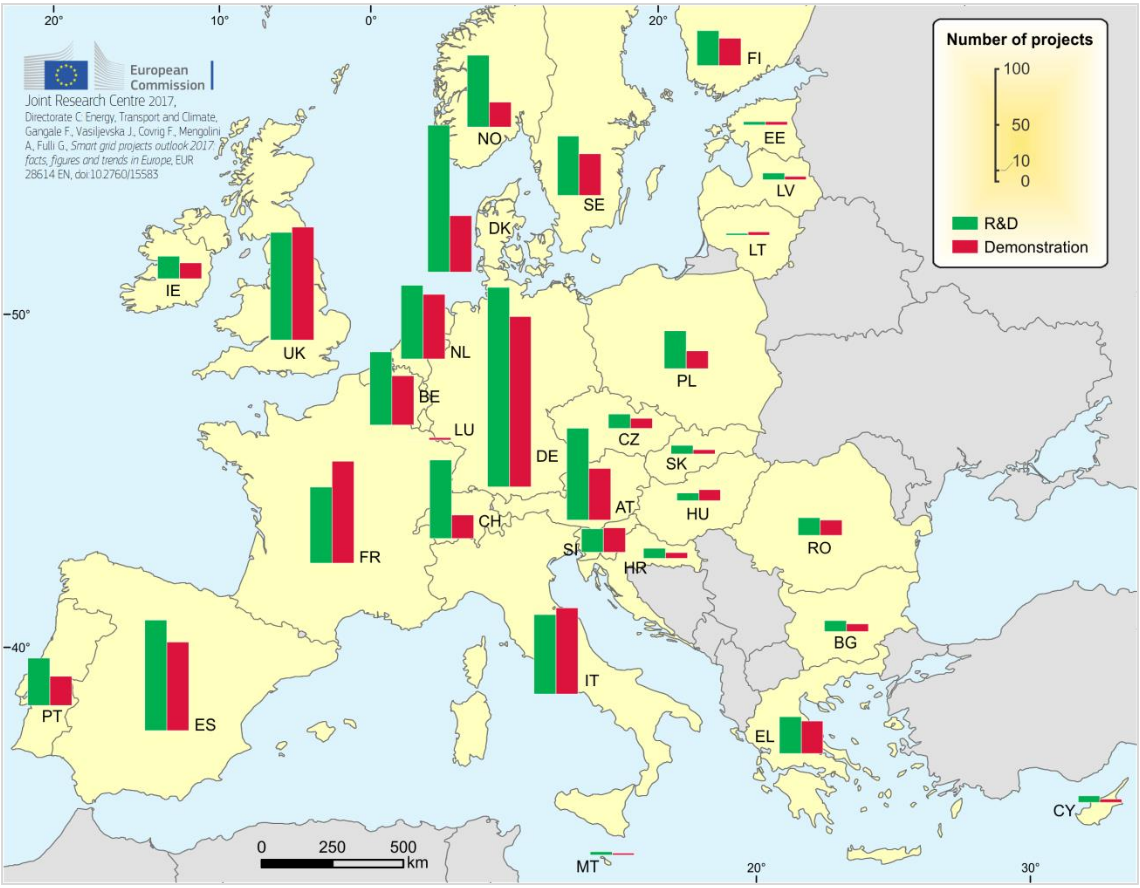
These different trends are the result of a complex interaction of factors, including the different mix of technologies investigated and tested each year, their respective costs and level of maturity, the changing investment priorities of the different Member States, the evolving focus of funding mechanisms, etc. In Chapters 3 and 5 we will present an analysis of some of these factors, trying to shed some light on the most interesting dynamics.

Figure 8. Time distribution of R & D and demonstration investment



Finally, Figures 8 and 9 show the different shares of R & D and demonstration initiatives and investment at Member State level. R & D projects are more numerous than demonstration projects in most countries, with the noteworthy exceptions of France, Italy, Luxembourg and the United Kingdom, (Figure 9). As we will see later, the high number of demonstration projects in these countries finds an explanation in the national policy priorities and regulatory framework which have incentivised the adoption of demonstration initiatives in different domains.

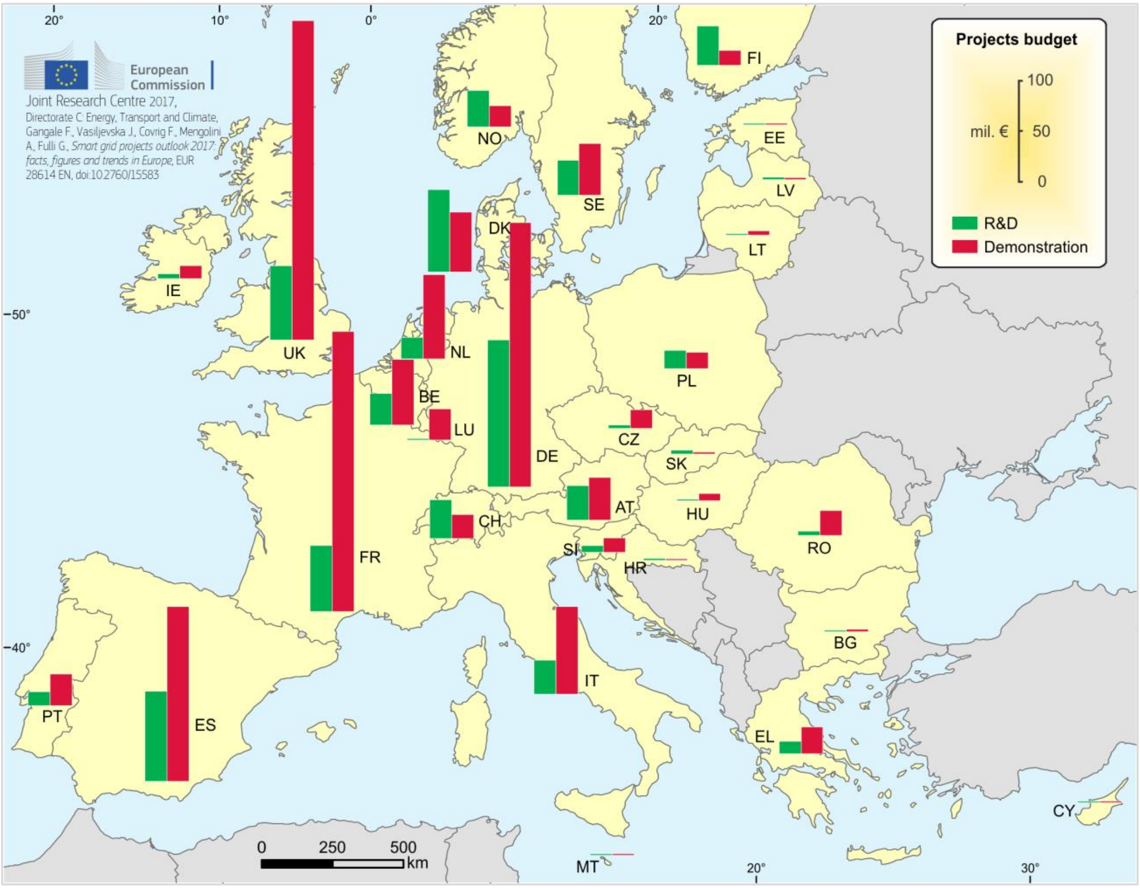
Figure 9. Number of R & D and demonstration projects in the EU



In line with the general remarks on the respective costs of R & D and demonstration projects in our database, when we look at investment we can observe that the majority of countries show a higher level of investment in demonstration activities (Figure 10). Noteworthy exceptions are Denmark, Finland, Norway and Switzerland, where R & D investment is remarkably high. Such a peculiarity is likely to be linked to the existence of dedicated research programmes and funding schemes ([11]), which also make the retrieval of project information easier.

([11]) As we will see later in Chapter 3, in these countries R & D programmes and funding schemes are well developed and information about projects easily accessible. In Denmark, the ForskEL programme grants funds for research, development and demonstration projects aiming at the development of an environmentally friendly and secure electricity system. Information on projects is available on http://www.energinet.dk. In Finland — still in 2014 the EU country with the highest gross domestic expenditure on R & D — funds for R & D on smart grid related topics are provided by the Academy of Finland (through the New Energy Programme and the Strategic Research Council) and by Tekes, the Finnish Funding Agency for Innovation. In Norway, the Research Council of Norway established dedicated R & D programs for smart grid R & D. Furthermore, a Smart Grid research strategy was prepared in 2015 by the Scientific Committee of the Norwegian Smart Grid Centre with the contribution of the main academic and research institutions active in the Smart Grid area. Finally, in Switzerland, the Swiss Federal Office of Energy (SFOE) launched the research programme 'Networks' to initiate, finance and coordinate corresponding projects at both the national and the international level. Network research focuses on the analysis and design of electrical and integrated energy systems, including their planning, development and operation.

Figure 10. R & D and demonstration investment in the EU



National vs multinational projects

Figure 11. Number of national and multinational projects and of R & D and demonstration projects

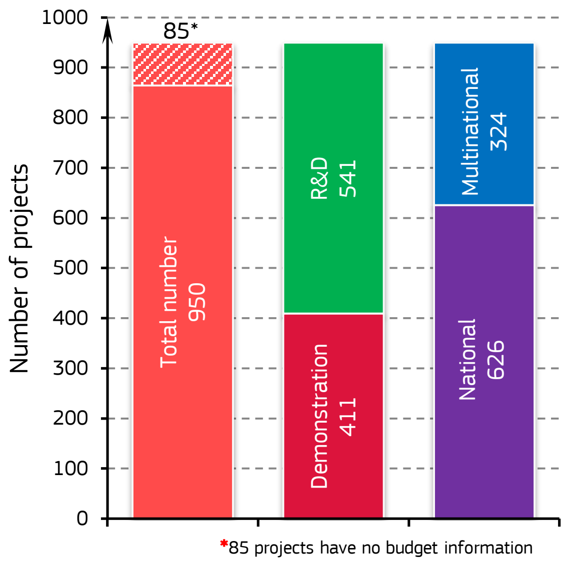
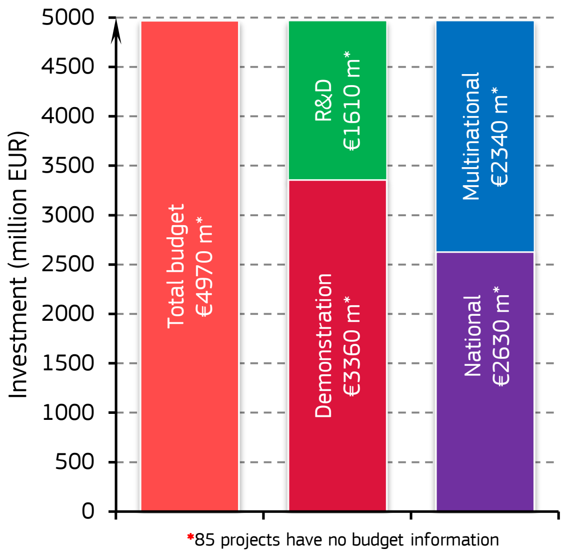


Figure 12. Investment in national and multinational projects and in R & D and demonstration projects



Most of the projects in the database are national projects (66 %), i.e. projects carried out in one country with the exclusive participation of organisations from that country (Figure 11). Multinational projects, i.e. projects that see the participation of organisations coming from different countries, are less numerous but larger in average investment size (EUR 7.5 million vs EUR 4.7 million of national projects).

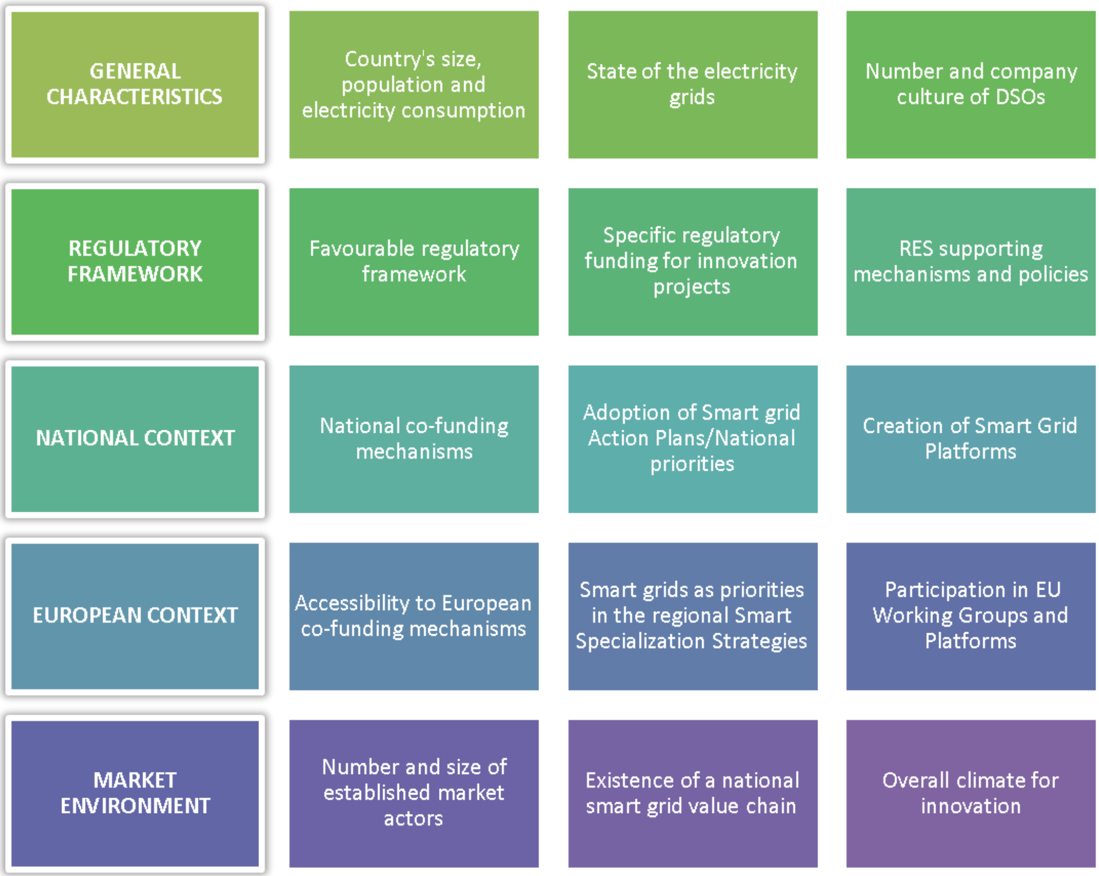
This difference can be explained by the fact that multinational projects typically involve a higher number of project participants (on average 12 vs 3), and therefore, normally, a higher budget. They also have access to multiple sources of funding, both at national and European level. As a result, although multinational projects represent only for 34 % of the projects, they account for 47 % of the total investment (Figures 11 and 12).

2.2 Geographical distribution of projects and investment

Strong differences exist between Member States in the number of projects, overall level and pace of investment. Several country-specific circumstances have an influence on these figures and can contribute to explain them.

Figure 13 highlights some of these factors as they have been identified during our analysis. Accounting for each one of them is out of the scope of this study, but in this chapter and throughout the report, we will try to explain the reasons behind the most interesting findings.

Figure 13. Main factors affecting the number of projects and the level of investment

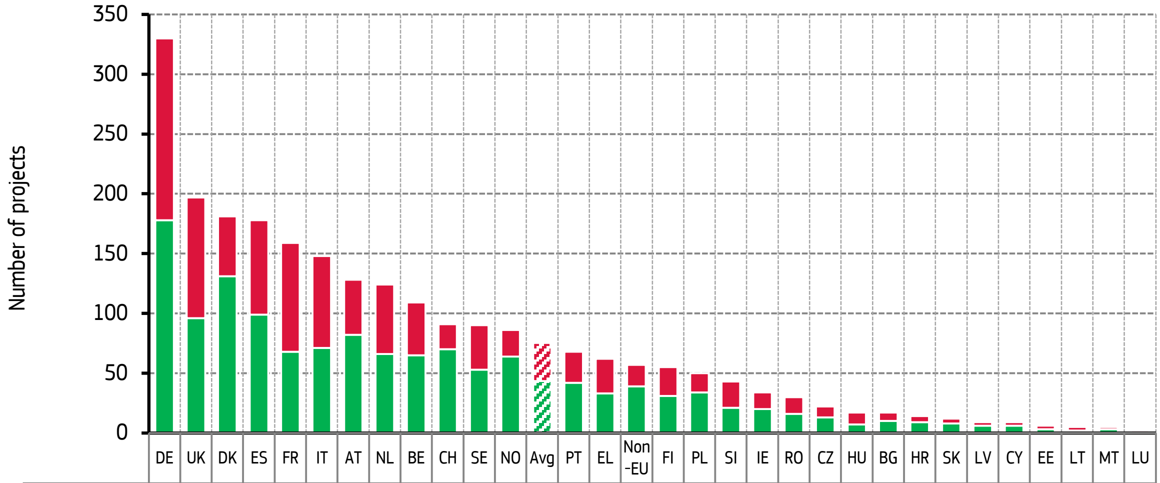


2.2.1 Differences among Member States in the number of projects

In this section we investigate the number of projects per country, which can be considered as an indication of the intention to invest in smart grid solutions in each country.

In absolute terms, projects are still concentrated in a group of Member States, with Germany towering over all the others (Figure 14). To better understand this result it is necessary to clarify the way the project count works. The project count assigns projects to the countries where the participating organisations are based. This means that in the case of multinational projects, a single project is counted more than once and therefore the sum of the number of projects per country as shown in Figure 14 is higher than the total number of projects in the database (950 projects). Even though this counting system might not be immediately intuitive, our experience shows it is the best way to count both projects carried out at national level and countries' participation in multinational projects.

Figure 14. Number of projects per country

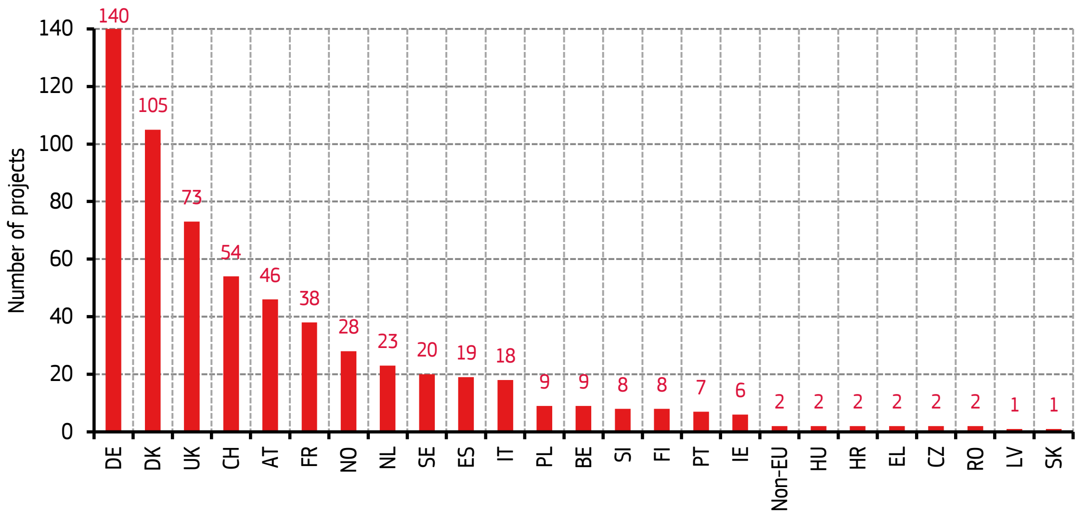


	DE	UK	DK	ES	FR	IT	AT	NL	BE	CH	SE	NO	Avg	PT	EL	Non-EU	FI	PL	SI	IE	RO	CZ	HU	BG	HR	SK	LV	CY	EE	LT	MT	LU
Demonstration	152	101	50	79	91	77	46	58	44	21	37	22	32	26	29	18	24	16	22	14	14	9	10	7	5	4	3	3	3	3	2	2
R&D	178	96	131	99	68	71	82	66	65	70	53	64	43	42	33	39	31	34	21	20	16	13	7	10	9	8	6	6	3	2	3	0

There are 10 Member States, along with Switzerland and Norway, which are over the EU average, with Germany, the United Kingdom, Denmark and Spain being the countries with the highest number of initiatives. This finding implies that organisations in these countries are very active, taking the decision to invest in a large number of initiatives within their country of establishment as well as in other Member States.

To get a clearer picture of how this finding relates to the overall level of activity of a country in the smart grid sector, it is useful to compare the information derived from Figure 14 with the count of national projects, i.e. projects carried out in one country with the exclusive participation of organisations from that country. Figure 15 shows the number of national projects.

Figure 15. Number of national projects per country



The correlation between a high total number of projects and a high number of national projects might be a sign of a mature smart grid environment, where different smart grid stakeholders have had the opportunity to test new technologies, opportunities and business models thanks to previous R & D and demonstration experiences and to the existence of a supporting national and regulatory framework.

Germany, Denmark and the United Kingdom all have a very high number of projects and a high share of national projects. As we will see later in Chapter 3, the same countries are indeed noteworthy for the **favourable national or regulatory environment** they have created for the development of smart grids. In the United Kingdom for example, the interaction between the national regulatory authority (Ofgem) and the DSOs has generated a drive and funding for innovation that lies at the heart of the smart grid developments in the United Kingdom. Acting as promoters of smart grid projects, DSOs have become the main source of technology pull and downstream funding for the development of an innovative supply chain (Owaineh, Leach, Guest, & Wehrmeyer, 2015), making it possible to test new business models and practices and creating opportunities for other organizations to learn and grow.

Promoting initiatives at national level can therefore support the growth of national organisations and accelerate smart grid investment. Companies that succeed in strengthening their expertise and experience at national level can start pursuing emerging business opportunities in other Member States and overseas. One interesting example of this dynamic is offered in our database by the ENR-Pool project. Here, a new company offering aggregation services, Energy Pool, has provided aggregation of 100 MW of demand response from industrial loads for participating in ancillary services. Building on the experience of this pilot project, Energy Pool ([12]), teaming up with an established company (Schneider Electric), has now developed a commercial portfolio of 1500 MW of industrial load flexibility, which is active in multiple markets in several countries.

Besides strengthening the national export potential, a favourable national policy and regulatory framework is also important to make the country attractive for foreign smart grid investment. In particular, the **adoption of smart grid roadmaps** is a clear sign that smart grids are high on the national agenda, thus attracting foreign investors to seek partnerships with local stakeholders to enter the national market. So far only a few Member States have adopted roadmaps for the swift development of smart grids (e.g. Denmark, Germany, Ireland, France, Austria, Slovenia, Sweden and the United Kingdom, see Box 1) and we can already notice a clear positive correlation with the number of smart grid projects in these countries.

To a lower extent, the creation of national and regional **smart grid platforms** can also promote the development of smart grid projects. Smart grid platforms are networks of different smart grid stakeholders who get together to foster the transition to smarter grids, to promote the development of joint initiatives, and to disseminate best practices and lessons learned. Smart grid platforms have been set up in several Member States (see Box 1), where they have contributed to the launch and success of several R & D and demonstration projects.

Finally, another factor which will have an increasing importance for the promotion of smart grid projects in the coming years is the adoption of **national and regional smart specialisation strategies**. More details on this topic can be found in Chapter 3.

If the factors that we mentioned above can contribute to explain the high number of projects in some Member States, their absence can conversely help to justify the lower number of projects in other Member States.

Other very relevant factors that we have not mentioned yet but that have a very strong impact on the overall level of activity of a country are its **size, population and electricity consumption**. It is no surprise that at the low end of the project count spectrum (Figure 14) we find countries characterised by having a smaller territory and

([12]) More information on the project is available at: http://www.en http://www.energy-pool.eu/en/ergy-pool.eu/en/

population and by lower overall electricity consumption. More analysis on these aspects will be presented in the following section dedicated to normalisation. In this section however, some clarification is necessary on the peculiarities of two Member States with a low project count, Estonia and Luxembourg.

Luxembourg is the Member State with the reported lowest number of projects. The JRC database includes only two projects from Luxembourg which, given the country's size and population and the generally good **state of the electricity grid**, is not surprising. What needs to be mentioned here is that one of the projects presented some problems for its inclusion in the database, as it did not entirely fit our project selection criteria. The Creos project, led by the transmission and distribution network operator Creos Luxembourg, along with other activities aimed at improving the observability and controllability of the networks, also included the national roll-out of smart meters. Although we did not include smart metering roll-outs in our database, we decided to keep the Creos project as we could not easily separate the budget lines dedicated to the different activities. On the other hand, given its very large budget, its inclusion in the database makes Luxembourg the EU country with the highest smart grid investment per capita and by electricity consumption.

Another country that deserves special consideration is Estonia, which figures in only six multinational projects and no national projects in our database. Even though Estonia is a relatively small country with a small population, the high level of digitalisation of the economy and the **overall positive climate for innovation**, would have suggested a higher number of smart grid projects. It needs to be noted however, that two notable initiatives were not included in the JRC database because they only partly fitted our definition of smart grid projects. The most relevant one is the Estfeed project ([13]), a data sharing platform that allows network companies, energy producers and consumers to interact more efficiently and makes the energy consumption data understandable and usable for end users. Estfeed was not included in the database because it cannot be considered as an R & D or demonstration project and because none of the other data exchange platforms in the EU were included. Another interesting project which could not be considered as an R & D or demonstration project and was therefore not included in our database is the Elmo project, the Estonian electromobility programme. The programme ran from 2011 to 2014 and required the purchase of 507 Mitsubishi iMiev electric cars by the ministry of social affairs, the set-up of a grant scheme for the purchase of 650 electric cars and the development of a quick-charging network. Even though these initiatives cannot be considered as smart grid projects within the criteria set for our database, they nonetheless testify to the strong interest of Estonia in the transition to a smarter energy system.

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([13]) More information on the Estfeed project is available on http://estfeed.ee/en/.

Box 1. National/regional smart grid roadmaps and platforms

Smart grid roadmaps have been adopted in several Member States under different names (roadmap, route map, strategy, etc.), mostly by the competent national authorities, but sometimes by private organisations.

In Germany a roadmap was drafted by the federal association of the energy and water industry, BDEW (BDEW Bundesverband der Energie- und Wasserwirtschaft e.V., 2013). In the United Kingdom, the smart grid vision and routemap was adopted in 2014 by the Department of Energy & Climate Change (Department of Energy & Climate Change, 2014). In Denmark, a smart grid strategy was adopted in 2013 by the Danish Ministry of Climate, Energy and Building (Danish Ministry of Climate, Energy and Building, 2013). In France, it was the environment and energy management agency which adopted a strategy in 2013 (French Environment & Energy Management Agency (ADEME), 2013). In Austria, a technology roadmap was developed during the Smart grids 2.0 strategy process on behalf of the federal ministry for transport, innovation and technology (Smart Grids Austria, 2015). In Sweden, an action plan was adopted in 2014 by the Swedish coordination council for smart grids, which was appointed by the Swedish government in 2012 (Coordination Council and National Knowledge Platform for Smart Grids, 2014). In Slovenia, a smart grid implementation plan has been proposed by the University of Ljubljana, in collaboration with SODO, the main DSO, which is 100 per cent owned by the state (University of Ljubljana, in collaboration with SODO d.o.o., 2012). Finally, in Ireland, a smart grid roadmap to 2050 was adopted by the Sustainable Energy Authority of Ireland in 2011 (Sustainable Energy Authority of Ireland, 2011).

Smart grid platforms have been set up in Spain (FutuRed, 2005), Slovenia (Tehnološka platforma za pametna omrežja, 2006), Austria (SmartGrid Austria, 2008), Czech Republic (Česká technologická platforma Smart Grid, 2009), Ireland (SmartGridIreland, 2009), Flanders region (Smart Grids Flanders, 2010), Norway (The Norwegian Smartgrid Centre, 2010), Poland (Smart Power Grids Poland Consortium, 2010), Switzerland (Smart Grid Switzerland Association, 2011), Netherlands (Topconsortia for Knowledge and Innovation (TKI) Switch2SmartGrids, 2012), Denmark (PowerLabDK, 2012 and SmartEnergy Networks RD&D, 2013) Baden-Württemberg Region (SmartGrids Baden-Württemberg, 2013), Italy (Smart Grids Italia, 2014), Greece, (Hellenic Technology Platform for Smart Grids, 2014), Cyprus (Cyprus Technology Platform for Smart Grids, 2014), Latvia, (Smart Grids Latvia, 2014), and France (Think Smartgrids, 2015).

2.2.2 Differences among Member States in the level of investment

When we move our attention from the number of projects to the overall level of investment (Figure 16), the country positioning follows a similar pattern with a slightly different order.

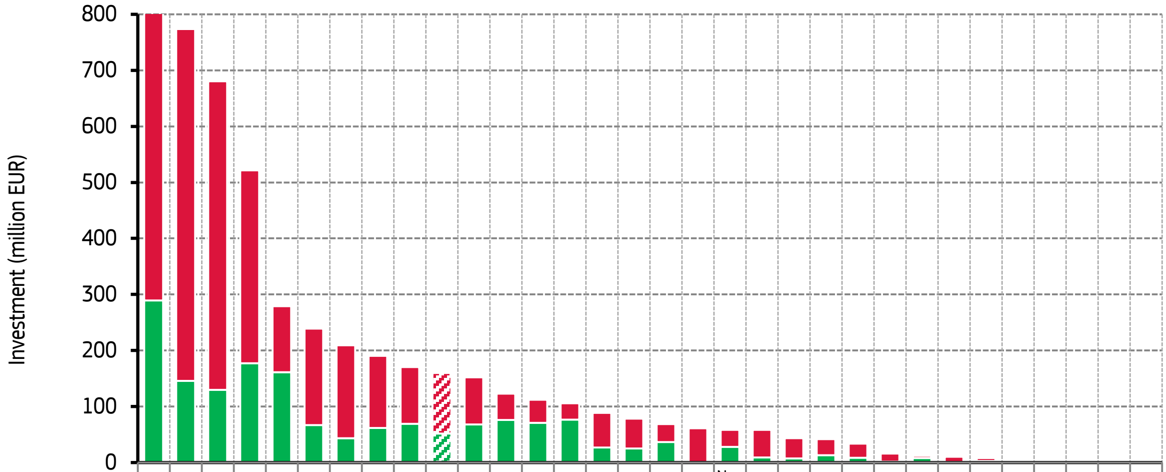
The investment count assigns the investment to the countries where the project partners are based. Unless more precise information is available, the project budget is split equally between the partners. This implies that the budget of multinational projects is spread across all the countries where the project partners are based.

The level of investment in each Member State is obviously strongly related to the number of projects per country, but other factors also have an influence.

One of the main factors seems to be the **share of R & D and demonstration projects**, with a higher share of demonstration projects having a positive influence on the level of investment. This correlation is justified by the fact that, as we mentioned above, the average investment for demonstration projects in our database is higher than the average investment for R & D projects (EUR 9 million compared to EUR 3.3 million, respectively).

In the light of this information, looking back at Figure 14 and Figure 16, we can see how the high share of demonstration projects in France and Italy makes them figure higher in the country ranking, surpassing Denmark which, in turn, shows a very high share of R & D projects.

Figure 16. Total investment (million EUR) per country



	DE	UK	FR	ES	DK	IT	NL	BE	SE	Avg	AT	CH	NO	FI	PT	EL	PL	LU	Non -EU	RO	CZ	SI	IE	HU	SK	LT	BG	LV	HR	CY	EE	MT
Demonstration	520	628	550	344	117	172	166	128	102	108	84	47	41	29	62	53	32	61	30	49	36	28	25	14	3.7	8.9	5.1	3.5	2.4	1	2.3	1.2
R&D	289	146	130	177	161	67	43	62	69	52	68	76	71	77	27	25	36	0	28	9.1	7.1	13	8.8	1.8	8.2	1.2	2.9	4.2	3.8	3.7	1	1

Other factors also have a strong influence on the level of investment. The **amount of available co-funding** can influence the project scope, supporting the development of more ambitious and expensive projects. In this respect, as we will see better in Chapter 3, countries with extensive supporting mechanisms in place, such as Germany and the United Kingdom, show a high level of investment. On the same note, a country's participation to EU co-funded projects can also positively influence the national level of investment, as EU co-funded projects show a higher average budget compared to projects receiving only national co-funding (EUR 7.21 million and EUR 4.72 million respectively). **Co-funding however, cannot substitute private financing;** countries with a lower share of private financing (i.e. under 30 %), e.g. Bulgaria and Slovakia, figure at the low end of the investment spectrum.

Other factors — such as the size of the participating market actors and the comparative share of investment in the different domains — have a less clear impact on the national level of investment. The **size of the market actors** operating at national level can influence the investment level, as smaller organisations usually have fewer financial resources to invest in innovation projects. The size factor can indeed affect the overall level of investment as many organisations increasingly active in the smart grid environment, such as ICT and energy-management service providers, are small and medium-sized enterprises (SMEs).

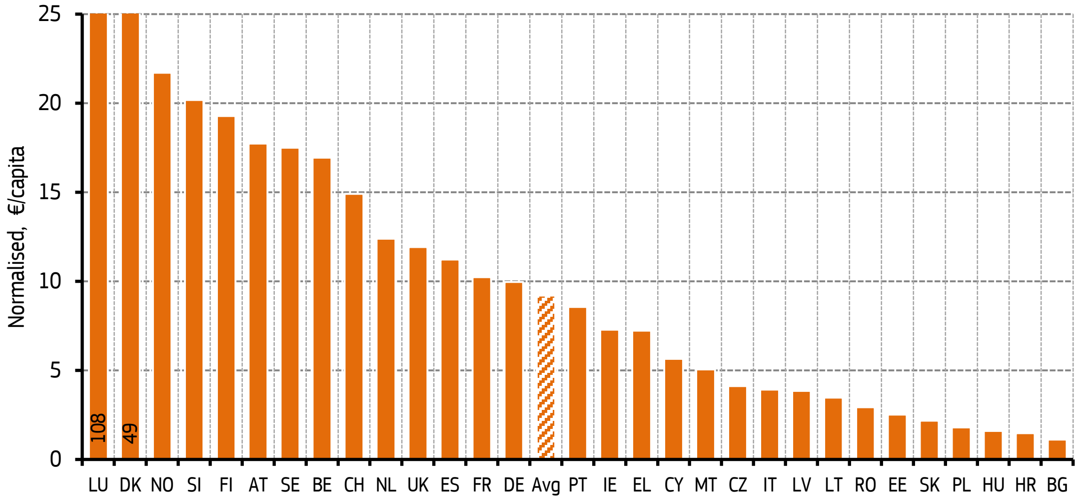
The **national investment priorities**, i.e. the shares of investment in the different project domains, could also affect the overall level of investment as a result of the different costs of the investigated solutions. As we will see in more detail in Chapter 5, on average, E-mobility projects show the highest average investment (EUR 8 million), followed by DSM projects (EUR 7.9 million) and L_RES projects (EUR 7.5 million). However, for these and other factors, more data and research is necessary to clarify their impact and their relation with other causes.

2.3 Data normalisation

As we have seen above, the decision to invest and the level of investment is influenced by a combination of different factors and country-specific circumstances. Figure 14 and Figure 16 show the level of activity per country, with reference to the number of projects and the level of investment, respectively. Although they show a country ranking, these aggregations are not meant to compare countries, but only to provide a snapshot of the level of activity in each Member State and of the main factors that may have an influence on it.

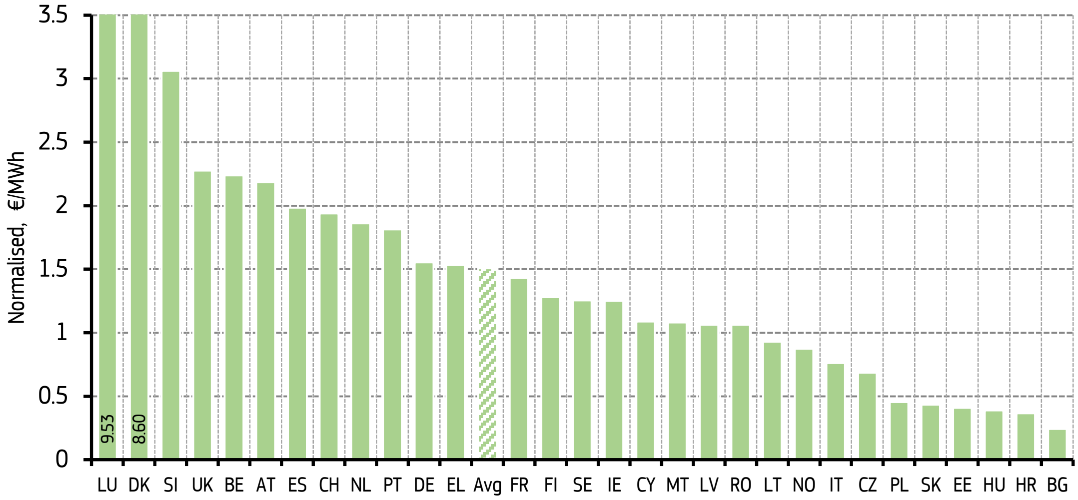
Comparing Member States with different characteristics — e.g. **size, population and electricity consumption** — would not be fair and it could be misleading. Countries with very different population sizes for example, can face very different challenges when it comes to ensuring the reliability and efficiency of power system operations. Just to give an indication of the influence of such country-specific circumstances, in this section we will present the results of two data normalisations, using population and electricity consumption as normalising denominators for the level of investment (Figures 17 and 18).

Figure 17. Total investment normalised per capita (*)



(*) *Source: Own elaboration based on Eurostat data (2015)*

Figure 18. Total investment normalised per electricity consumption (*)



(*) *Source: Own elaboration based on ENTSO-e 2015 data*

Comparing the figures above with the aggregations of Figure 16 clearly shows the impact of different normalisation factors on the country ranking. Generally speaking, providing an explanation for each country's new positioning would not be a useful exercise, as we made clear that the overall level of investment in a country is the result of the combination of a variety of different factors. In a few cases however, the magnitude of the observed repositioning deserves some further investigation.

We have already mentioned the case of Luxembourg which, after normalisation, moves from well below the average EU investment level to the first position for investment in Europe. As we already explained, such change is due to the inclusion in the database of a very large project, the Creos project, which, along with other activities aimed at improving the observability and controllability of the networks, also included the national roll-out of smart meters.

Another interesting case is that of Slovenia, which also moves from the low end of the investment level spectrum (Figure 16) to a very high position after normalisation. Slovenia is indeed a small country with a small population, which, given the peculiarities of its power networks, has invested in a timely manner and extensively in the modernisation of the grids. At transmission level, Slovenia is a regional crossroad, exposed to large transit power flows from neighbouring countries, with the consequent need to improve the observability and predictability of the power systems. Project SUMO, for example, was initiated by the national TSO, Eles, to improve system operation reliability and security, especially in cases of increased load flows through existing transmission network infrastructure. SUMO allows for the real-time identification of operation limits, considering the allowable current loadings of the lines and transformers; it also enables forecasts of up to 3 hours. At distribution level, many projects have addressed the need to enable the active participation of users and new market actors through the adoption of demand-response solutions. Projects such as ITI, KC-SURE and KIBERnet, all in our database, develop around the active network concepts.

This normalisation exercise is meant to help contextualise findings and provide additional insight on some Member States. Other normalising denominators are however possible and their use would bring different results.

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In conclusion, in sections 2.2 and 2.3, we tried to present the differences in the number of projects and overall level of investment between different Member States, accounting, when possible, for the country-specific circumstances influencing such differences. Not all of the factors identified in Figure 13 have been addressed in this exposition, but more of them will be addressed in the following chapters. In particular Chapter 3 will address the factors relating to the regulatory framework and the national and European contexts, e.g. the specific regulatory funding for innovation projects, the national and European co-funding mechanisms, and the creation of smart specialisation platforms. Chapter 4 will address the factors related to the market environment, especially on the role of established and emerging actors and on their evolving synergies. Finally Chapter 5 will use the smart grid domain assessment to detail the market analysis at domain's level and to provide more insight on national investment priorities.

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3 Sources of financing of smart grid innovation projects

Key messages

Even though private investment is the most important source of financing of smart grid projects, only 15 % of the projects in the database are financed exclusively by private resources. This observation confirms the importance of European and national funding to leverage private finance and incentivise investment. This is particularly true for R & D activities, where fewer than 10 % of projects are financed exclusively through private resources.

The reduction in private investment after the peak year 2011 has only partially been compensated by the rise in national and EU funding.

National regulatory reforms introducing specific incentives for innovation activities might encourage DSOs — the main investors in the smart grid environment — to invest more in innovation projects.

National funding schemes can be a powerful tool to encourage innovation and to support actors that normally have limited access to capital, such as SMEs. For network companies, access to national funding can be a valid alternative to regulatory funding to pursue innovation projects.

European funding seems to play a key role in supporting investment especially in those countries where smart grids are still not high on the national agenda.

3.1 Introduction

Smart grid R & D and demonstration projects require large investment and face great uncertainties. Developing and testing new processes, technologies and business models imply high risks involving, for instance, the performance, reliability and life span of the adopted technology, future government and regulatory support, project replicability and consumer response (Shomali & Pinkse, 2016; Eurelectric, 2014). These uncertainties can negatively affect investment decisions and ultimately result in a barrier to smart grid adoption.

External funding represents therefore a very important tool to reduce risks, thus leveraging private finance and incentivising investment. This chapter analyses the sources of financing of the projects in the JRC database to offer an overview of the main trends across Member States and domains and to provide an insight into possible future developments.

In the current report, we rationalised the categorisation introduced in previous editions and considered three main financing sources, i.e. own/private financing, national and EU.

Under this new classification, regulatory funding — i.e. funding made available to network operators by national regulatory authorities (NRAs) to give specific incentives to innovation activities — which was previously considered as a separate category, now falls within the category own/private financing. The main reason for such change is that most investment made by network operators is financed through tariffs, either through the general incentive mechanism for investment or through specific incentive schemes/programmes. Irrespective of the regulatory mechanism, once the DSO gets its revenues, they become part of its own/private resources. Examples of this type of financing are the call for smart grid demonstration projects launched by the Italian NRA ([14]) and the United Kingdom low carbon networks fund (LCNF) ([15]).

([14]) Call for smart grid demonstration pilot projects launched by AEEG with the Regulatory order ARG/elt 39/10.

([15]) The LCNF was introduced in 2010 to encourage network companies to sponsor projects, which trial innovative technological operating and commercial arrangements, to facilitate the transition to a low carbon future (Department of Energy & Climate Change, 2014).

Another minor change to the previous classification involves the repositioning of the funding granted through the Danish ForskEL programme ([16]), which — following the elimination of the regulatory funding category — was moved to the national funding category. This change was also suggested by the general scope of the programme which, although financed through tariffs, is not aimed solely at the promotion of projects run or sponsored by network operators. Public or private enterprises and knowledge institutions, including universities and approved technological service providers, can apply for funding from the ForskEL programme (Energinet.dk, 2015). Foreign participants can also apply for funding; emphasis is, however, on the results promoting the development of the Danish electricity system.

3.2 Own/private financing

Under this category we have included all investment made by private and public organisations to finance their own project or to participate in multi-partner projects. Different actors have different drivers for investing in smart grids; they face different barriers and bear different risks when timing and sizing their investment or when choosing their technology partners.

Network operators, for example, mainly invest in smart grid research and demonstration projects to develop and test new solutions in order to integrate larger shares of distributed energy resources into their networks and to improve the reliability and efficiency of system operation. This investment, however, is cost intensive and cannot always be recovered through the revenues allowed by national regulatory schemes. In most countries R & D and demonstration projects are treated like any other cost, without any specific compensation for the risks involved in testing new processes and technologies (Eurelectric, 2014).

Equipment, services and smart grid ICT developers invest in smart grid projects to develop and test their solutions in real life environments and gain technology leadership that can be exported globally. Their inclination to invest, however, can be affected by the low technological maturity of the proposed solutions, the lack of suitable business models and low consumer acceptance and engagement.

Public institutions are increasingly interested in participating in smart grid projects as a way to find solutions to improve the sustainability, affordability and security of local energy systems, thus addressing the concerns of a growing number of consumers and communities. Their participation in smart grid projects is nevertheless hindered by their lack of experience and resources.

Other actors also face specific barriers and risks when investing in smart grid innovation. Despite the different approaches in financing innovation investment, a barrier that seems to be encountered by all smart grid actors is the difficulty in finding sufficient resources to finance the projects exclusively by their own means.

This difficulty is reflected in our database, where only 15 % of the projects are financed exclusively by own/private resources (from now on, for the sake of simplicity, we will refer to this category as private), accounting for 18 % of the total investment. For the vast majority of projects, private investors have had the need to seek financial support from national and European funding schemes. This observation confirms the **importance of external funding to leverage private finance and incentivise investment**. This is particularly true for R & D activities, where fewer than 10 % of projects are financed exclusively through private resources.

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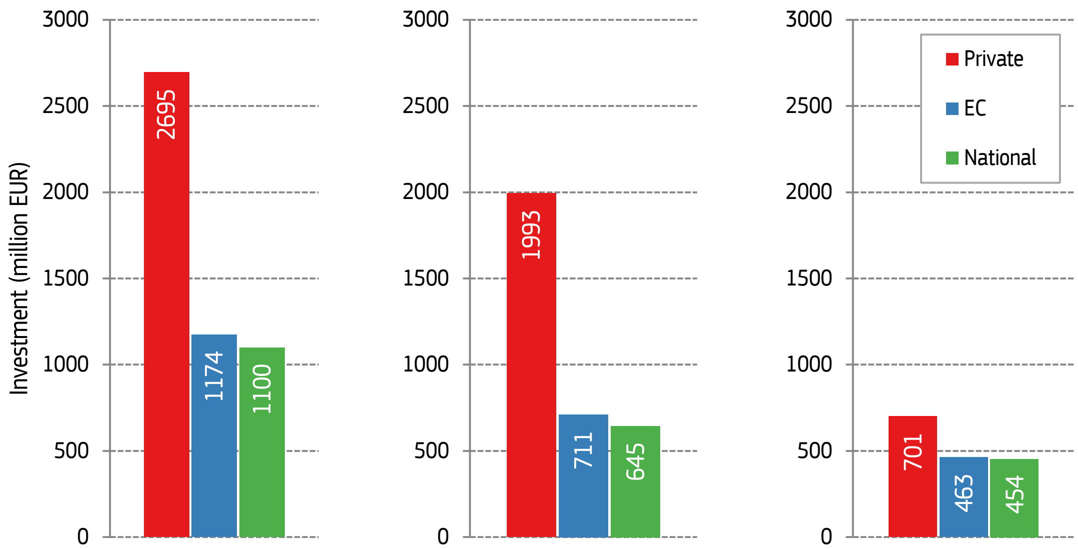
([16]) The ForskEL programme was launched in 1998 and it is administered by Energinet.dk, the national TSO for electricity and gas. The Programme is financed through a Public Service Obligation (PSO) tariff which all electricity consumers pay via their electricity bills. Its objective is 'to grant funding for research, development and demonstration projects needed to utilise environmentally friendly electricity generation technologies, including the development of an environmentally friendly and secure electricity system'.

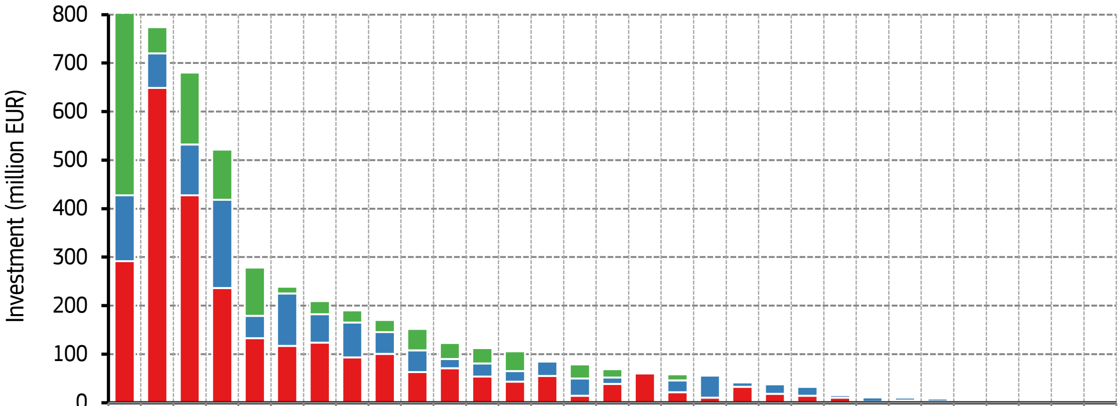
Even if external funding is of the outmost importance, **private investment still represents the highest share of resources for both R & D and demonstration projects**. Their relative importance is particularly significant for demonstration projects, where private investment represents about 60 % of the allocated resources. For R & D projects this share is about 40 % (Figure 19).

Figure 19. Investment in smart grid projects in Europe by source of financing: all projects (left), demonstration projects (centre), R & D projects (right)



Despite strong differences between Member States, private investment represents the main source of financing in most of the countries in Europe (Figure 20, 21, 22). The contribution of each financing source depends on several specific national circumstances, e.g. the existence of dedicated regulatory incentives for innovation activities, the existence of national funding schemes, the level of access to European funding by private companies and research and innovation (R & I) organisations, the presence of business angels and incubators. In the next section we will discuss in some more detail the role of regulatory incentives for the promotion of smart grid innovation.

Figure 20. Total investment per country by source of financing



	DE	UK	FR	ES	DK	IT	NL	BE	SE	AT	CH	NO	FI	PT	EL	PL	LU	Non-EU	RO	CZ	SI	IE	HU	SK	LT	BG	LV	HR	CY	EE	MT
Total	809	774	680	522	279	239	209	190	171	152	123	112	106	89	78	69	61	59	58	43	42	34	16	12	10	8	7.7	6.2	4.8	3.3	2.2
National	382	54	148	104	100	14	27	25	25	44	33	31	41	4.2	28	17	0.3	13	2.4	1.3	3.8	0.9		1			0.1		0.1	0.1	0
EC	136	71	105	182	46	108	58	71	45	45	19	27	22	30	36	14	0.5	24	45	9.7	20	19	5.8	8.8	6	5.7	3.4	3.3	3	2.1	1.6
Private	291	649	428	236	133	117	124	94	101	63	71	54	43	55	14	38	60	21	10	32	18	14	10	2	4.1	2.3	4.1	2.9	1.7	1.1	0.6

Figure 21. Geographical distribution of investment by source of financing

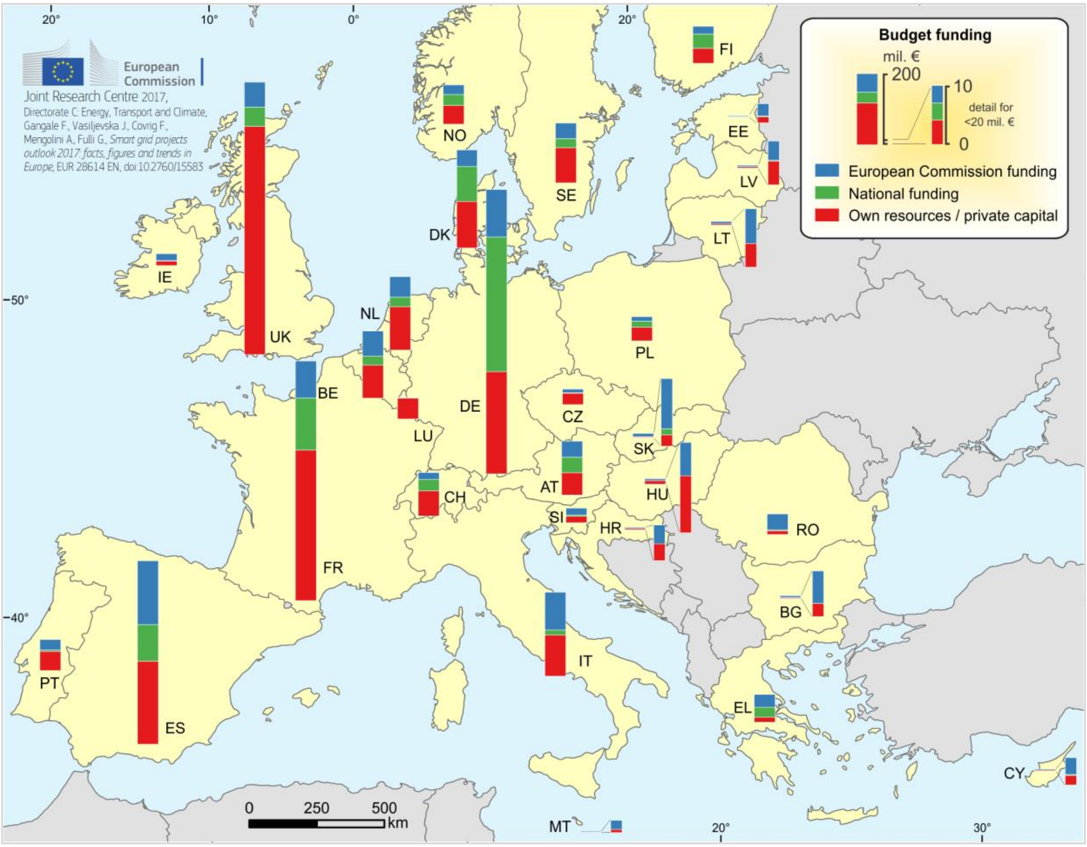
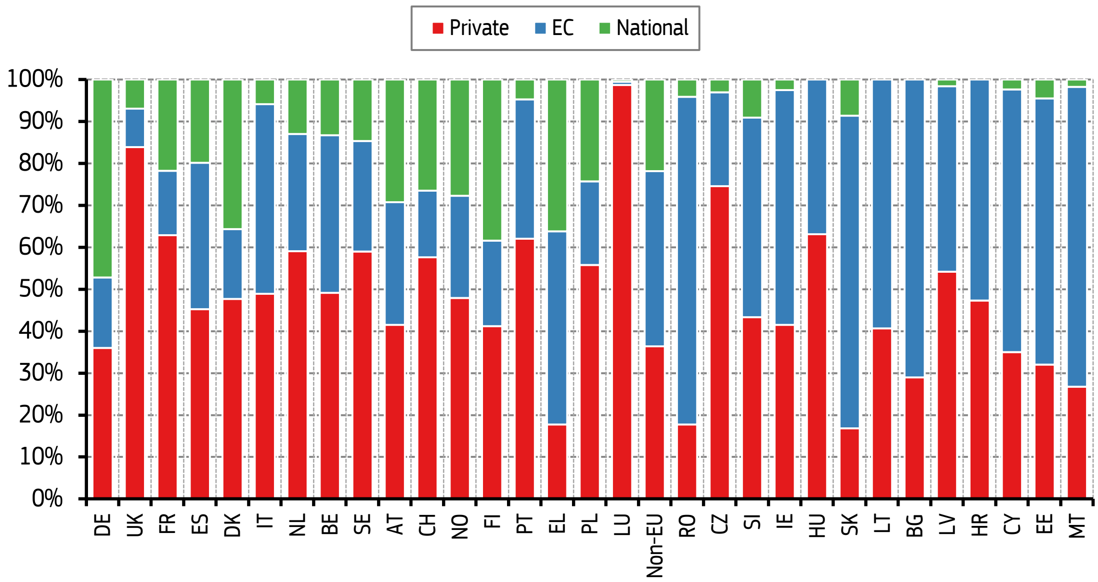


Figure 22. Share of overall investment by financing source per country



As shown in Figure 22, private investment is particularly high in the United Kingdom and in Luxembourg (83 % and 98 % of the total national investment respectively).

In the United Kingdom this observation can be explained by the fact that we considered the innovation incentives made available by NRAs as private financing. About 30 % the projects from the United Kingdom received such incentives, and this circumstance increased the share of total private investment.

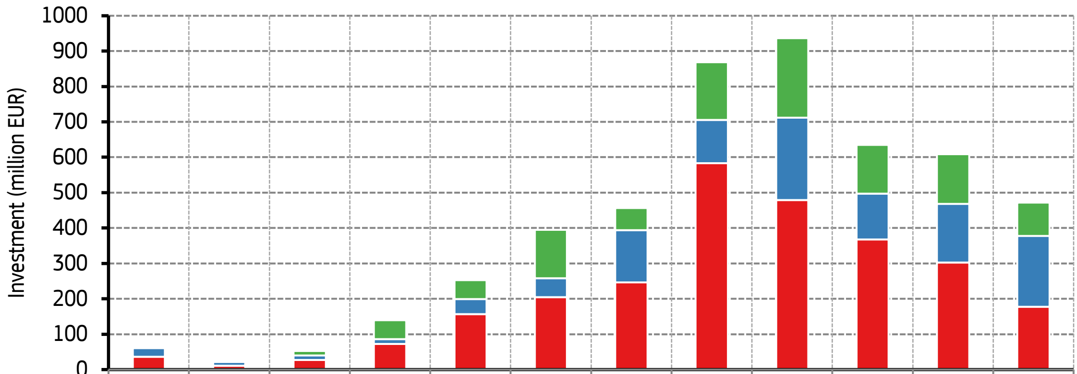
In Luxembourg the high percentage of private financing is attributable to one big project led by the transmission and distribution network operator, Creos Luxembourg, to improve the observability and controllability of the networks, which includes the roll-out of smart meters.

Private investment is also high in Belgium, Denmark (mostly the area around Copenhagen) Spain (particularly the Basque region area), France (mainly the area around Paris), Italy and the Netherlands. Figure 23 visualises the main hotspots for private investment in Europe.

Figure 23. Private investment hotspots in Europe

Figure 24 confirms the **reduction in private investment — after the peak year 2011 —** already identified in the last edition of the Outlook. In 2011 the peak in private investment is partially attributable to the high share of United Kingdom projects that received specific innovation incentives from the NRA (amounting to 21 % of the total investment for 2011). Even considering that the collected data might still be incomplete, especially for the more recent years, the observed reduction in private investment from 2012 might be an indication of the hesitancy of private investors to finance innovation projects which develop and test more advanced solutions. The uncertainties related to the regulatory environment and to the possibility of getting a fair return on investment might indeed slow down private investment in smart grids. As we will see later however, this reduction has been partially compensated by the rise in national and EU funding.

Figure 24. Time distribution of investment by source of financing



	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
National	4.64	1.14	11.96	53.23	53.54	137.13	63.01	163.25	224.74	137.54	139.68	94.16
EC	23.90	10.62	13.47	14.23	42.14	53.48	147.94	121.79	232.63	129.34	166.06	200.20
Private	36.51	11.43	26.90	72.31	157.11	204.50	245.96	583.26	479.09	367.61	302.39	177.68

3.2.1 Regulatory incentives to innovation activities

Only in a few Member States does the regulatory framework that governs network companies provide for specific compensation for innovation activities (Eurelectric, 2014) (Eurelectric, 2016) (Cambini, Meletiou, Bompard, & Masera, 2016). Specific incentives may encourage innovation projects, as they lower the financial risk for DSOs. DSOs are subject to economic regulation and are therefore exposed to the risk of not seeing the costs allowed by regulators if the innovation projects fail. This is particularly true for larger-scale demonstration projects that carry high risks and uncertainties and whose costs are usually quite high. Their importance to test new solutions and evolving business models however, is crucial for the fast development of smart grids and could justify their funding via special funding mechanisms and not exclusively through the ordinary regulatory framework. How to encourage innovation in network design and operation is, however, still an open question in distribution regulation and only few Member States are designing ad hoc regulatory schemes (Eurelectric, 2016).

In our database, about 18 % of the projects in which DSOs are involved received specific incentives for innovation, accounting for about 35 % of the total DSO investment. Most of these projects (88 %) are from the United Kingdom, and they received funding from different funding mechanisms.

The case of the United Kingdom: The most recurrent funding scheme in our database is the LCNF, which was established by the national regulatory agency, Ofgem, as part of the electricity distribution price control arrangements that ran from 1 April 2010 to 31 March 2015. Over this period, the LCNF has provided approximately 250 million GBP to the six DSOs of the United Kingdom. The objective of the fund was to help all DSOs understand what needs to be done to provide security of supply whilst achieving value for money and also what role the DSOs could play in facilitating low-carbon and energy-saving initiatives to tackle climate change. The fund aimed to support projects sponsored by the DSOs to try out new technology and new operating and commercial arrangements (Pöyry Management Consulting Ltd, 2016).

There were two tiers of funding available under the LCNF. The first tier was designed to enable DSOs to recover a proportion of expenditure incurred in small-scale projects (Tier 1 projects). The second tier was intended to help fund a small number of flagship projects, participating in an annual competition in which bids were submitted and decided upon by Ofgem (Tier 2 projects). These projects were meant to explore how networks can facilitate the take up of low-carbon and energy-saving initiatives such as electric vehicles, heat pumps, micro and local generation and DSM, as well as investigating the opportunities that smart meter roll-out provide to network companies. In April 2013 Ofgem replaced the LCNF with a more comprehensive innovation stimulus package.

Not all of the projects funded by the LCNF are yet included in our database. According to an independent review to Ofgem of the LCNF, there have been 42 Tier 1 ([17]) and 23 Tier 2 ([18]) projects (Pöyry Management Consulting Ltd, 2016). In our database we have included 11 Tier 1 and 22 Tier 2 projects. More research will be carried out in the next edition of the Outlook to validate and include more LCNF projects in the database, especially Tier 1 projects. It is worth taking note however that Tier 1 projects are smaller in budget size, and therefore the fact that many of them have until now been left out of our database does not have a very big impact on the overall United Kingdom investment.

The case of Italy: Another interesting example of regulatory incentives for innovation activities is offered by the initiative launched by the Italian NRA, AEEG, with regulatory decision ARG/elt/39/10 ([19]). The decision set up a competitive process to select a number

([17]) At the time of the independent review (May 2016) 31 had been completed, 8 were ongoing and 1 had halted during the programme.

([18]) At the time of the independent review (May 2016) 11 had been completed, 8 were well underway while 4 commenced in 2015.

([19]) Regulatory decision ARG/elt 39/10 'Procedura e criteri di selezione degli investimenti ammessi al trattamento incentivante di cui al comma 11.4 lettera d) dell'Allegato A alla deliberazione dell'Autorita' per of demonstration projects that would benefit from an extra remuneration of capital cost — 2 % extra weighted average cost of capital (WACC) in addition to the ordinary return — for a period of 12 years. The selection process identified seven projects, all included in our database.

Other countries have also introduced specific regulatory mechanisms to promote R & D and demonstration projects. According to Eurelectric (Eurelectric, 2016), 8 Member States ([20]), plus Norway, have recently adopted such mechanisms. Incentives by Portugal have already been detected by our analysis; more effort will be made in future editions of the Outlook to identify the projects that have received innovation incentives from their regulatory authorities.

3.3 National funding

We have included in this category all contributions given by national and regional institutions to support the development of smart grid projects: 49 % of projects received some sort of national funding, which accounts for about 22 % of the total investment. We are aware that in some cases there may be a close link between national funding and EU funding, as some national funding may come from EU sources, but we have put a lot of effort into assigning the funding to the right domain.

National funding schemes can be a powerful tool to encourage innovation and to support actors who normally have limited access to capital, such as SMEs. For network companies, access to national funding can be a valid alternative to regulatory funding in order to pursue innovation projects.

There are strong differences between Member States in the share of overall investment covered by national funding (Figure 22). Some Member States have set up extensive supporting schemes for smart grid innovation. Some of these cases are particularly interesting because of the high share of national funding in the overall level of investment. In the majority of Member States this percentage is under 10 %, while in seven countries it is over 20 % (Denmark, Germany, Greece, France, Austria, Poland and Finland).

In Germany for example, national funding accounts for 47 % of the total national investment. An interesting example of such funding comes from the 'E-Energy — ICT-based energy system of the future' initiative, a joint funding programme of the federal ministry of economics and technology (BMWi) and the federal ministry for the environment, nature conservation and nuclear safety (BMU). The 4-year initiative had a funding of about EUR 60 million and promoted the creation of six e-energy model regions where key technologies and business models for smart grid deployment were developed and tested (Federal Ministry of Economics and Technology, 2009). All the six e-energy projects are included in our database.

In Denmark, national funding accounts for 36 % of the total national investment. A relevant part of this funding comes from ForskEL, a funding programme launched in 1998 and administered by Energinet.dk, the national TSO for electricity and gas. The purpose of the programme is 'to grant funding for research, development and demonstration projects needed to utilise environmentally friendly electricity generation technologies, including the development of an environmentally friendly and secure electricity system' (Energinet.dk, 2016). On an annual basis, the minister for energy, utilities and climate determines the focus areas of the programme as well as the financial framework. In the last few years, the annual funding made available by ForskEL amounted to 130 million DKK, equivalent to about EUR 17.5 million.

Other countries have also adopted specific funding schemes to support smart grid innovation projects. In Finland, for example, smart grid innovation projects have received funding by Tekes, the Finnish funding agency for innovation. These funds have been

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l'energia elettrica e il gas del 29 dicembre 2007, n. 348/07.

([20]) These member States are: Finland, France, Ireland, Italy, the United Kingdom, Greece, Portugal, Slovenia.

channelled mostly through the smart grid energy market (SGEM) programme, a 5 year initiative that focuses on power distribution and interfaces. In France, several smart grid projects have been funded by the investment for the future programme (*programme d'investissements d'avenir* (PIA)).

Other countries also receive varying shares of national funding, often channelled through more general funding lines and programmes. As shown in Figure 25, other important hotspots for national funding in Europe are Austria (mostly the area around Vienna), Greece (mostly the area around Athens) and Spain (mainly the Basque region area).

Figure 25. Hotspots for national funding in Europe

3.4 EU funding

Under the category EU funding, we have included all EU funding instruments that offer financial support to promote the transition towards a smarter and more sustainable energy system. About 30 % of the projects in the database received EU funding; 55 % of them are R & D projects and 45 % are demonstration projects. When we look at the amount of funding allocated to the two stages of the innovation cycle however, 39 % of EU funding went to R & D projects and 61 % to demonstration projects. This finding is in line with the higher costs usually involved in demonstration projects, and the difficulties typically encountered for financing them.

The most recurring co-funding instruments in our database are the European research framework programmes, in their successive editions from the fifth framework programme (FP5, 1998-2002) to Horizon 2020 (which would be FP8 and covers the years 2014-2020).

As shown in Figure 24, it is only in 2007 (and therefore under FP7, 2007-2013) that EU funding started to play an important role. This evidence can be explained by the launch in 2007 of the EU strategic energy technology plan (SET plan) ([21]), which aimed to accelerate the development and deployment of cost-effective-low-carbon technologies to support the energy policy for Europe objectives, adopted by the European Council on 9 March 2007 ([22]). This new energy policy framework prompted the allocation of new resources to accelerate the development of sustainable energy and to work out ways to manage the energy grid more efficiently.

([21]) Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions — Towards a European strategic energy technology plan, COM(2006) 847

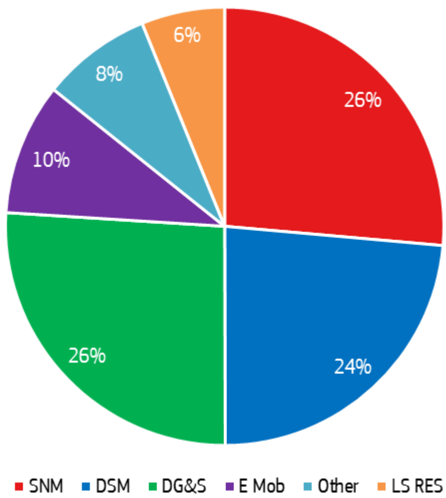
([22]) European Council conclusions adopted on the basis of the Commission's energy package, e.g. the Communications: 'An Energy Policy for Europe' COM(2007)1, 'Limiting global climate change to 2 degrees Celsius' COM(2007)2 and 'Towards a European Strategic Energy Technology Plan' COM(2006)847

European funding seems to play a crucial role in supporting investment in some Member States (e.g. Bulgaria, Cyprus, Malta, Romania and Slovakia), where it reaches over 60 % of the total investment (Figure 22). This observation, together with the fact that the same countries usually take part in projects as partners and rarely as leaders, might indicate that smart grids still do not figure high on the national agendas.

In other countries EU funding also plays an important role. Several hotspots for EU funding exist in Europe (e.g. in Belgium, Spain, France and the Netherlands), as shown in Figure 26.

Figure 26. Hotspots for EU funding in Europe

Figure 27. Share of EU funding (%) by smart grid domain



EU funding has grown quite steadily over the years (Figure 24). After a temporary drop in 2013, which coincides with the end of FP7, funding has started growing again with the start of the new framework programme, Horizon 2020 (H2020).

Until 2015 EU funding has been concentrated almost equally on three project domains: SNM, 26%; DSM, 24% and integration of DG&S, 26% (Figure 27). More information on investment and financing sources per domain can be found in Chapter 5.

This trend will most likely continue in the near future, as the same areas fit well under the focus areas identified by the Work Programme 2016-2017 of the 'Secure, clean and efficient energy' challenge of H2020 ([23]) (i.e. energy efficiency, competitive and low-carbon energy and smart cities and communities) and under the activities specifically targeting Fuel Cells and Hydrogen[24]. Under this challenge, which is specifically dedicated to supporting energy-related R & I activities, funds can be granted to projects supporting the transition to a reliable, sustainable and competitive energy system along the full innovation cycle, from proof of concept to applied research, pre-commercial demonstration and market uptake (Table 1 and Table 2).

([23]) More than EUR 1 billion has been made available by the work programme 2016-2017.

[24] Activities specifically targeting Fuel Cells and Hydrogen are not supported in the calls 'Energy Efficiency', 'Competitive Low-Carbon Energy' and 'Smart Cities and Communities', but through calls for proposals of the Fuel Cells and Hydrogen Joint Technology Initiative, still under the H2020 Framework Programme.

Table 1. H2020 funding for R & D activities for 2016-2017

Scope of the call	Million EUR per project	Total funding for 2016 (million EUR)	Total funding for 2017 (million EUR)
Next generation technologies and services enabling smart grids, storage and energy system integration with increasing share of renewables: distribution network (LCE-01-2016-2017)	2.0-4.0	20.0	19.0
Support to R & I strategy for smart grid and storage (LCE-03-2016)	4.0	4.0	0.0
To develop tools and technologies for coordination and integration of the European energy system (LCE-05-2017)	2.0-4.0	0.0	30.0
Establish testing protocols for electrolysers performing electricity grid services (FCH-02-1-2016)	2.0	2.0	0.0
Total		**26.0**	**49.0**

Source: Own elaboration. Last update: February 2017

Table 2. H2020 funding for demonstration activities 2016-2017

Scope of the call	Million EUR per project	Total funding for 2016 (million EUR)	Total funding for 2017 (million EUR)
To demonstrate smart grid, storage and system integration technologies with increasing shares of renewables: distribution system (LCE-02-2016)	12.0-15.0	73.7	0.0
Demonstration of smart transmission grids, storage and system integration technologies with increasing share of renewables (LCE-04-2017)	15.0-20.0	0.0	65.3
Demonstration of large-scale rapid response electrolysis to provide grid-balancing services and to supply hydrogen markets (FCH-02-7-2016)	2 projects (EUR 12.0 m illion and EUR 4.0 milli on)	16.0	0.0
Large scale demonstration of commercial fuel cells in the power range of 100-400 kW in different market applications (FCH-02-9-2016)	7.5	7.5	0.0
Demonstration of fuel-cell-based energy storage solutions for isolated micro-grid or off-grid remote areas (FCH-02-10-2016)	5.0	5.0	0.0
Integration of demand response in energy management systems while ensuring interoperability through public-private partnership (EE-12-2017)	3.0-4.0	0.0	8.0
Smart cities and communities lighthouse projects (SCC-1-2016-2017)	12.0-18.0	60.0	69.2
Total		**162.2**	**142.5**

Source: Own elaboration. Last update: February 2017

To have access to the European structural and investment funds (ERDF and CF), Member States and regions are required to adopt smart specialisation strategies (S3) ([25]), which provide the policy framework for strong R & I support, based on evidence and stakeholder involvement, building on regional strengths and following a common methodology. The European Commission has encouraged Member States to include smart grids in their plans for the 2014-2020 cycle, and some of them have indeed made this a priority.

Smart grids figure highly in many EU Member State and region strategies, but many of them still need support to identify their strengths and weaknesses and to position their strategies in the framework of the EU-wide policy and technological context. To support this process, the JRC is currently leading the set-up and operation of a smart grid partnership bringing together different EU regions to explore knowledge sharing and collaboration opportunities to develop new and ambitious R & D and demonstration projects ([26]).

Although not detected in our database, other important EU funding lines for smart grid projects are the European Fund for Strategic Investments (EFSI) ([27]) and the Connecting Europe facility (CEF) ([28]).

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([25]) According to Regulation (EU) 1301/2013 of the European Parliament and of the Council of 17 December 2013, 'Smart specialisation strategy' means the national or regional innovation strategies which set priorities in order to build competitive advantage by developing and matching R & I own strengths to business needs in order to address emerging opportunities and market developments in a coherent manner, while avoiding duplication and fragmentation of effort.

([26]) More information is available at: http://s3platform.jrc.ec.europa.eu/s3p-energhttp://s3platform.jrc.ec.europa.eu/s3p-energy

([27]) EFSI is an EU initiative launched jointly by the EIB Group and the European Commission to help overcome the investment gap in the European Union by mobilising private financing for strategic investment. It provides support for projects in several fields, among which 'Energy and digital infrastructure'. EFSI is demand driven and will provide support for projects everywhere in the EU, including cross-border projects. More information is available at http://www.eib.org/efsi/what-is-efsi/index.htm

([28]) The Connecting Europe Facility is a key EU funding instrument to promote growth, jobs and competitiveness through targeted infrastructure investment at European level. It supports the development of high performing, sustainable and efficiently interconnected trans-European networks in the fields of transport, energy and digital services. In the energy sector, a total budget of EUR 5.35 billion has been made available for the 2014-2020 period to upgrade and develop the European energy infrastructure. More information on CEF Energy is available at https://ec.europa.eu/inea/en/connecting-europe-facility/cef-energy

4 Who's investing?

Key messages

DSOs are the stakeholders with the highest investment, followed by universities and technology manufacturers.

Non-traditional actors such as public institutions, emerging stakeholders and organisations grouped under the category 'other', have entered the smart grid scene relatively later, but their investment has been growing steadily.

Emerging stakeholders, in particular, show a steady investment growth in the period 2009-2014, with investment peaking 2013-2014.

Emerging stakeholders mostly collaborate with universities, technology manufacturers, consultancies and public institutions. There is also a significant collaboration link with DSOs, where the focus is mainly on demand response and provision of flexibility services.

4.1 The big picture

The current smart grid project catalogue contains 950 projects with an average of 6 and a maximum of 76 participating organisations in a single project. These organisations have been classified under 15 different stakeholder categories, as indicated in Table 3.

Table 3. Classification of stakeholder categories

Generation companies	Organisations dedicated to the generation of electricity, including independent power producers (IPPs).
Transmission system operators (TSOs)	Organisations responsible for operating, maintenance and development of the transmission system in a given area and, where applicable, its interconnections with other systems, and for ensuring the long-term ability of the system to meet reasonable demands for the transmission of electricity.
Distribution system operators (DSOs)	Organisations responsible for the operation, management and planning of distribution electricity networks serving more than 100 000 connected customers, independently of their ownership structure.
Utilities	Organisations active in power generation, distribution and sale, serving fewer than 100 000 connected customers.
Retail companies	Organisations active in the sale, including resale, of electricity to customers.
ICT and telecom companies	Organisations active as software developers, system designers, system integrators and telecom companies.
Technology manufacturers	Organisations active in the design and production of smart grid solutions, particularly hardware solutions.
Industry associations	EU and national organisations supporting the rights and interests of different smart grid stakeholders.
Engineering services	Organisations active in engineering services, e.g. development and construction of low-energy buildings and other civil infrastructures, installation and management of smart metering infrastructure.
Universities	Public and private higher education institutions, e.g. universities, institutes of technologies and colleges.
Research centre	Public and private organisations dedicated to scientific research, both basic and applied.

Consultancies	Organisations providing professional expert advice to other public and private organisations.
Public institutions	Public entities, such as regions, municipalities, environmental and energy agencies and local authorities.
Emerging stakeholders	Organisations that offer novel solutions and services or that have more recently started to collaborate with traditional smart grid actors to implement smart solutions at local level (i.e. aggregators, energy-management service providers, housing associations/real estate developers, municipal utilities, transport solution providers, energy cooperatives).
Other	Organisations active in different sectors, that cannot be placed in any of the above mentioned categories, e.g. incubators, early investors, charities, funding institutions, networks of different organisations (public and private) promoting a common objective and power spot market exchange.

Organisations and participation: In total, 2 930 organisations, from 50 countries, participate in the smart grid projects in our database. As some of these organisations participate in more than one project, we also checked the number of participations and the total there was around 5 900.

Figure 28 depicts both the number of organisations and participations. Out of the 2 930 organisations, nearly 27 % participate in more than one project. The most active organisation is located in Denmark and participates in 67 projects.

Figure 28. Project organisations and participations

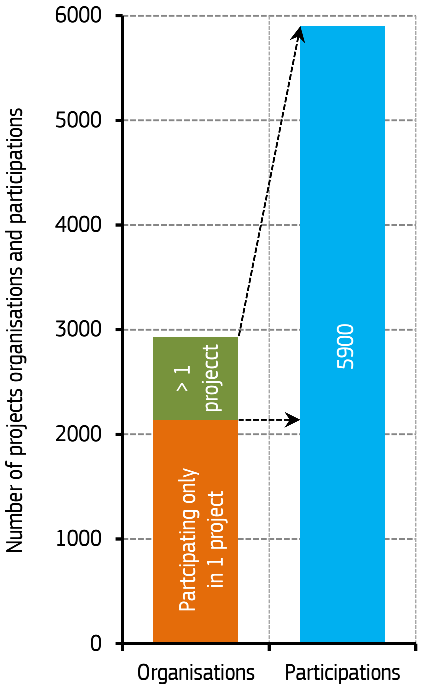


Figure 29. Project participations number and investment — share of R & D and demonstration

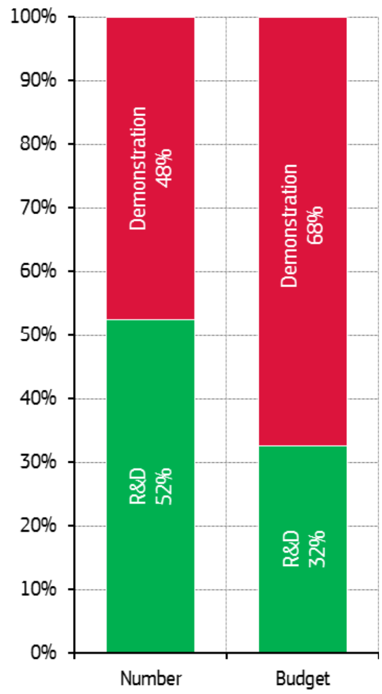
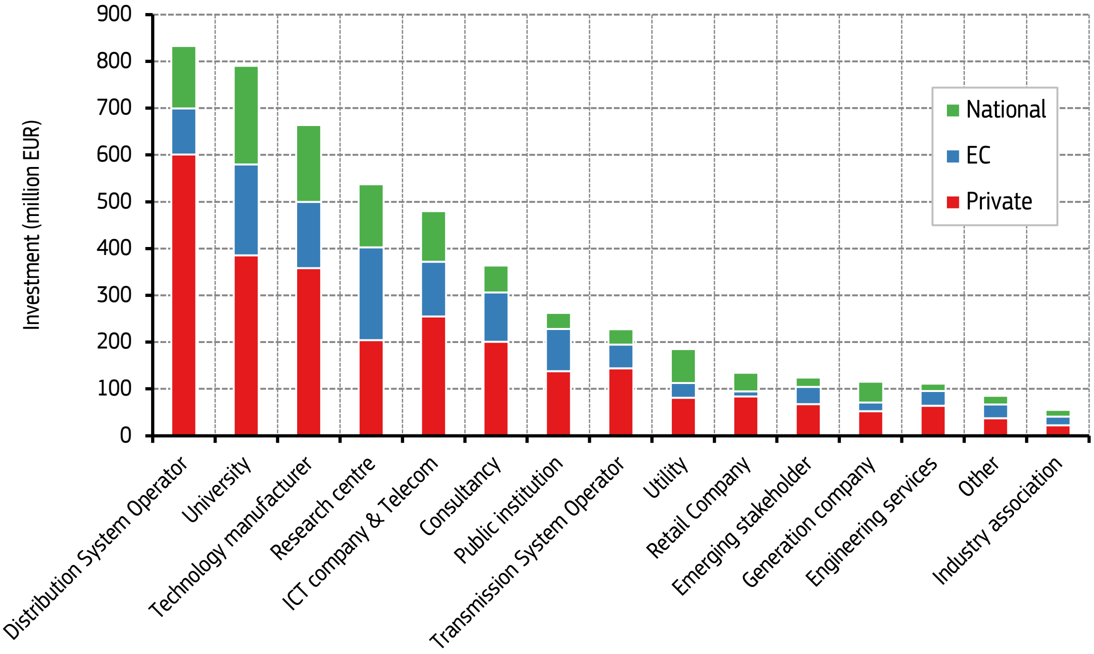


Figure 29 illustrates the percentage distribution between R & D and demonstration participations in terms of number of projects and investment. As for the number of projects, there is no major difference between R & D and demonstration projects (52 % and 48 % respectively). On the other hand, organisations invest mainly in demonstration projects (68 %), while investment in R & D projects accounts for 32 %.

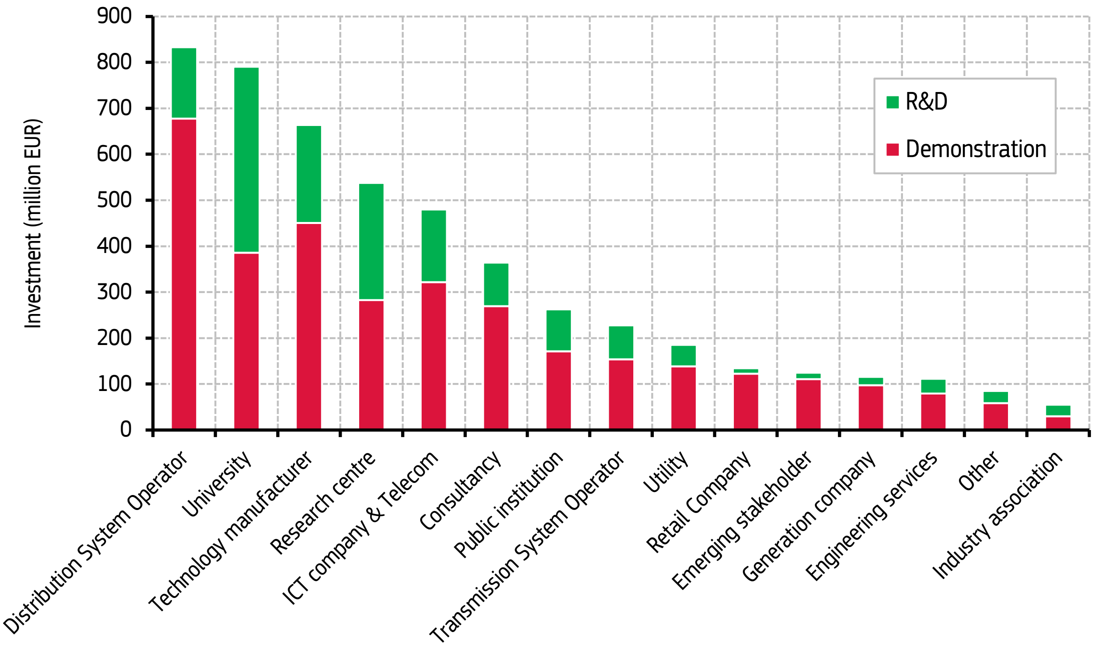
Financing: DSOs are the stakeholders with the highest investment, followed by universities and technology manufacturers. Figure 30 illustrates the source of financing for each stakeholder category. For most of the categories, private financing is the main source of project financing. For DSOs in particular, above 70 % of investment is private, which also includes funding allocated through regulatory incentive schemes (e.g. LCNF in the United Kingdom). At the other side of the spectrum, research centres are the stakeholders with the lowest share of private resources (38 %).

Figure 30. Investment by stakeholder category and source of financing



Stages of the innovation cycle: Figure 31 shows the share of R & D and demonstration investment per stakeholder category. Universities and research centres invest nearly equally in both R & D and demonstration projects, while all other stakeholders invest mostly in demonstration projects.

Figure 31. Total R & D and demonstration investment per stakeholder category



Geographical distribution: The area encompassed between Belgium, the south of the Netherlands and the west of Germany show the highest density of organisations involved in smart grid projects, both in terms of number and total investment (Figure 32). Other areas of organisation high density can be seen around some EU capitals, such as London, Copenhagen, Madrid, Rome and Paris, and regions such as eastern Denmark, the Basque country (Spain) and northern Italy.

Countries in south-east Europe, such as Bulgaria, Greece and Romania present a relatively high number of organisations compared to the deployed investment. This finding highlights an existing interest in smart grid solutions which is, however, not yet reflected in the level of investment.

Figure 32. Geographical distribution of the organisations involved in smart grid projects: number of organisations (left); total investment (right)

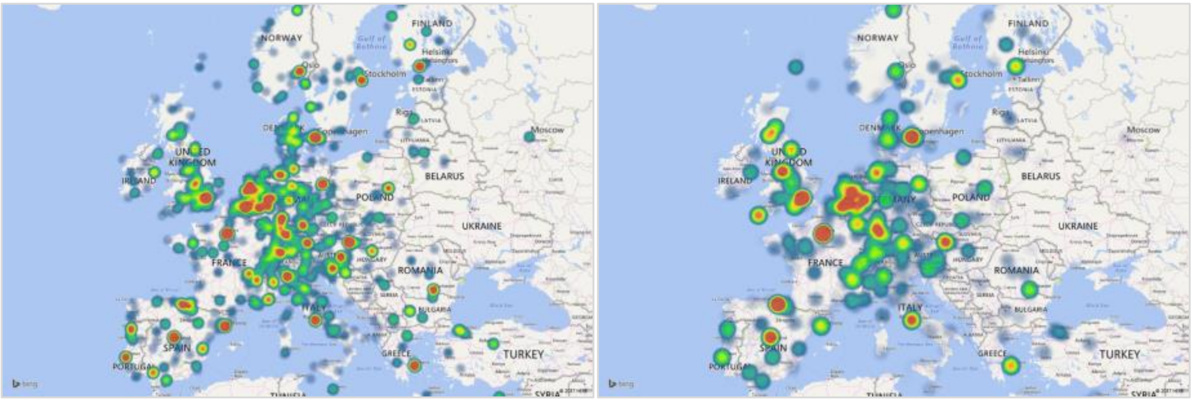
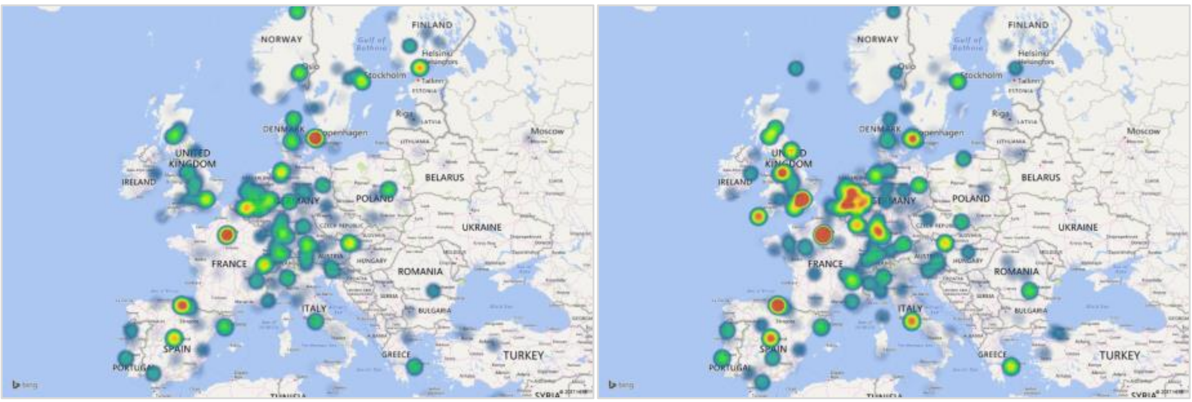


Figure 33 illustrates the distribution of the organisations weighted with the total investment for R & D and demonstration projects. In the area around Copenhagen, Paris and the Basque country, organisations involved in R & D projects show higher investment while, for demonstration projects, the organisations investing the most are mainly located in Belgium, the Netherlands and in the areas around some European capitals, e.g. London, Paris and Rome.

Figure 33. Geographical distribution of the organisations involved in smart grid projects (corrected by total investment): R & D projects (left); demonstration projects (right)



Time distribution: Figure 34 shows the evolution of the total investment per stakeholder category considering the lifetime of the projects. As one can observe, some stakeholder categories, such as emerging stakeholders, public institutions and organisations grouped under the category 'other', entered the smart grid scene relatively later, in comparison with the rest of the stakeholders, and remain active in the following years, thus showing the interest of non-traditional actors in investing in smart grid solutions.

Figure 34. Distribution of total investment over the project lifespan per organisation type

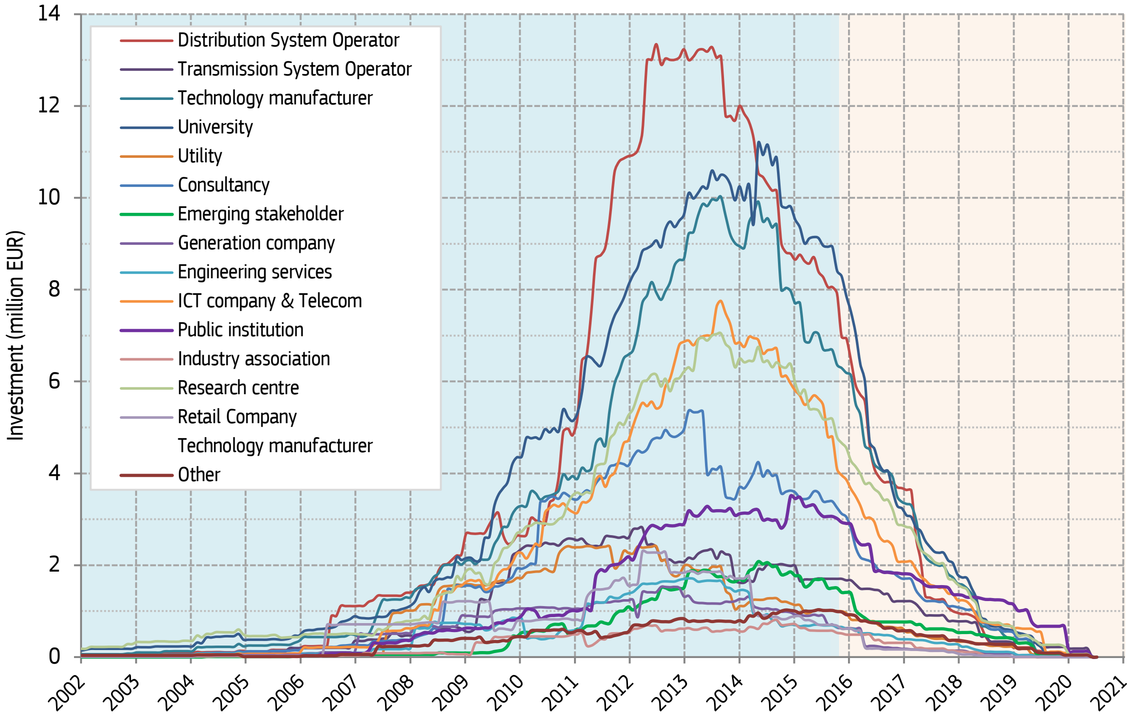
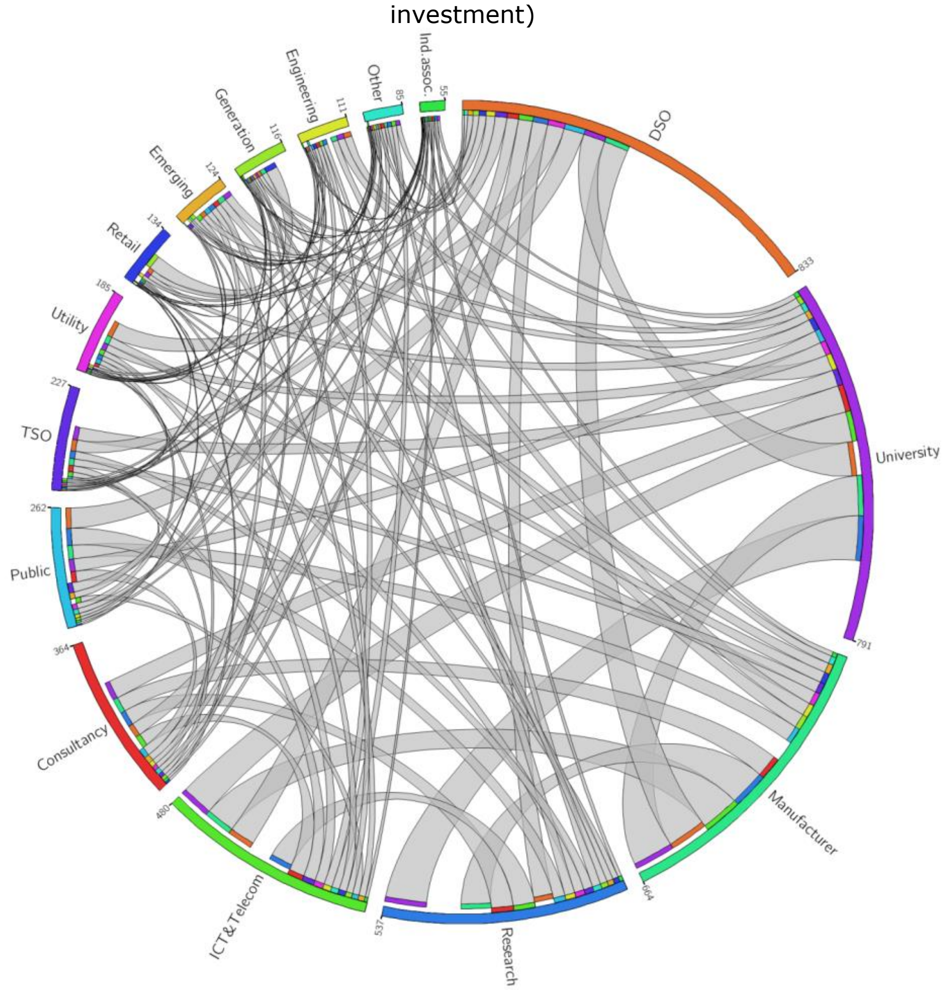


Figure 35. Collaboration links between different types of organisations (weighted by total investment)



Synergies and collaboration links: Figure 35 presents a circular representation of the weighted relationships among the 15 stakeholder categories. The perimeter of the circle is the total smart grid investment, divided into 15 unequal segments in accordance with the respective investment by each category. The chords connecting the different categories illustrate the collaboration level between stakeholders, where a thicker chord illustrates a stronger collaboration. In a project with several partners, there can be multiple organisations from the same category. For instance, a single project can include three DSOs and one technology manufacturer, each of them participating with a similar budget. However, in this case, DSOs would invest more in this collaboration; hence the thickness between the two ends of a chord in the chart. Nearly all of the 15 segments (stakeholder categories) have a portion that does not send/receive any chord. These portions show the budget related to the internal collaboration of these organisations (e.g. DSOs collaborating with other DSOs).

DSOs and universities are the most active players, collaborating significantly among themselves, but also with manufacturers, public institutions, and ICT and telecom companies.

A further insight that can be derived from the analysis of the projects in our database is that DSOs are still proceeding with R & D projects, mainly together with universities and research centres. These collaborations are mainly targeting tools and ICT services for the efficient integration of DG&S in distribution networks through the development of new operational and control strategies for management of an increasing RES penetration level and provision of ancillary services (e.g. voltage control).

Box 2. DSOs as the driving force behind smart grid investment in Europe

DSOs are the organisations with the highest investment in smart grid (mainly demonstration) projects. The strong DSOs interest in innovation projects is their way of responding to the rapid changes that are occurring in the distribution segment. Smart grid technologies and solutions are expected to radically change local electricity industry and markets at the distribution level (Ruester, Perez-Arriaga, Schwenen, Batlle, & Glachant, 2013), creating opportunities but also posing challenges to the reliability and efficiency of system operation. In most countries, DSOs are therefore proactively investigating and testing new solutions, as well as new roles and business models, in order to get ready to take up the new tasks, responsibilities and opportunities that are shaping up in the evolving power system.

With growing penetration levels of renewable and dispersed power resources, electric vehicles and active demand-side participation, DSOs play an increasingly important role in facilitating effective and well-functioning retail markets. Their traditional role is swiftly evolving towards neutral market facilitators or information hub providers, granting energy end-users with the possibility to opt for better energy contracts and allowing retail companies to offer options and services best tailored to customer needs.

In the future DSOs will also be increasingly required to perform more (pro-) active grid development, management and operation, as the ongoing changes in the distribution sector place new requirements on the networks in terms of operational security, while offering at the same time more options for the DSOs to manage their grids in a more flexible and efficient way (van den Oosterkamp, et al., 2014).

In this context, DSOs appear as one of the leading actors in smart grid projects in EU, particularly in domains such as SNM, DSM and integration of DG&S. Such projects explore the roles DSOs may play in data handling and provision and at the same time make use of flexibility services and performing local balancing activities to deliver better outcomes to the end-users. They also explore the synergies with other actors along the supply chain. Technology manufacturers, ICT and telecom companies, TSOs as well as public institutions (particularly in the DSM and integration of DG&S domain) appear as organisations the DSOs mostly collaborate with and these mutually beneficial relationships are central to the structuring of more valuable interaction with energy consumers and development of smart communities.

DSOs also show high interest in R & D projects, where together with universities and research centres, they work on developing new operational and market strategies for the integration and management of increasing RES penetration.

Their involvement in innovation projects varies largely from country to country, due to their heterogeneity and to differences in national regulation. Along with regulatory, technical and economic factors, the company culture also plays an important role.

4.2 Emerging stakeholders

The category 'emerging stakeholders' includes a wide range of organisations characterised by different core businesses, objectives, business models and market presence. For the sake of clarity, such organisations can be clustered under two main groups.

- Organisations that offer solutions and services related to energy generation, supply, distribution or other energy services (such as demand response and energy efficiency). These organisations can be new entrants on the smart grid scene or existing organisations that offer novel products or services and thereby engage with the energy market in a different way from traditional actors (DSOs, retailers, utilities, etc.). Organisations in this group include actors providing bundled services (e.g. energy-management service providers offering demand management as part of an energy service contract), or services enabling higher consumer participation (e.g. aggregators, energy-management service providers). These actors aim to promote and facilitate customer participation, thus allowing consumers to engage with energy in new ways (e.g. remotely operated and controlled energy-management platforms, smart appliances or peer-to-peer energy trading).
- Organisations that have more recently started to collaborate with traditional smart grid actors to implement smart solutions at local level, such as municipal utilities, housing associations, transport solution providers, energy cooperatives. Our database offers many examples of projects involving these organisations, mainly focusing on energy community initiatives. In these projects emerging stakeholders collaborate largely with public institutions to target multiple objectives, such as the increase of energy efficiency across different end-user segments (industrial, commercial, residential, including social housing), maximising the use of renewable energy sources (e.g. through community-run renewable power sources) and the development of innovative approaches for citizens' engagement to ensure long-term sustainable development.

Geographical distribution: Figures 36 and 37 depict the distribution of total investment associated with the emerging stakeholders per participating country (totalling EUR 124 million). France, the United Kingdom and Germany are the three Member States with the highest investment coming from emerging stakeholders. Most of these actors in France are energy-management service providers offering consumption monitoring and management solution for the benefit of both consumers and operators. In the United Kingdom, these organisations are mainly aggregators, housing associations and energy-management service providers taking part in energy community projects, whereas in Germany the focus is mainly on E-mobility projects.

Figure 36. Distribution of total investment of participating emerging stakeholders per country

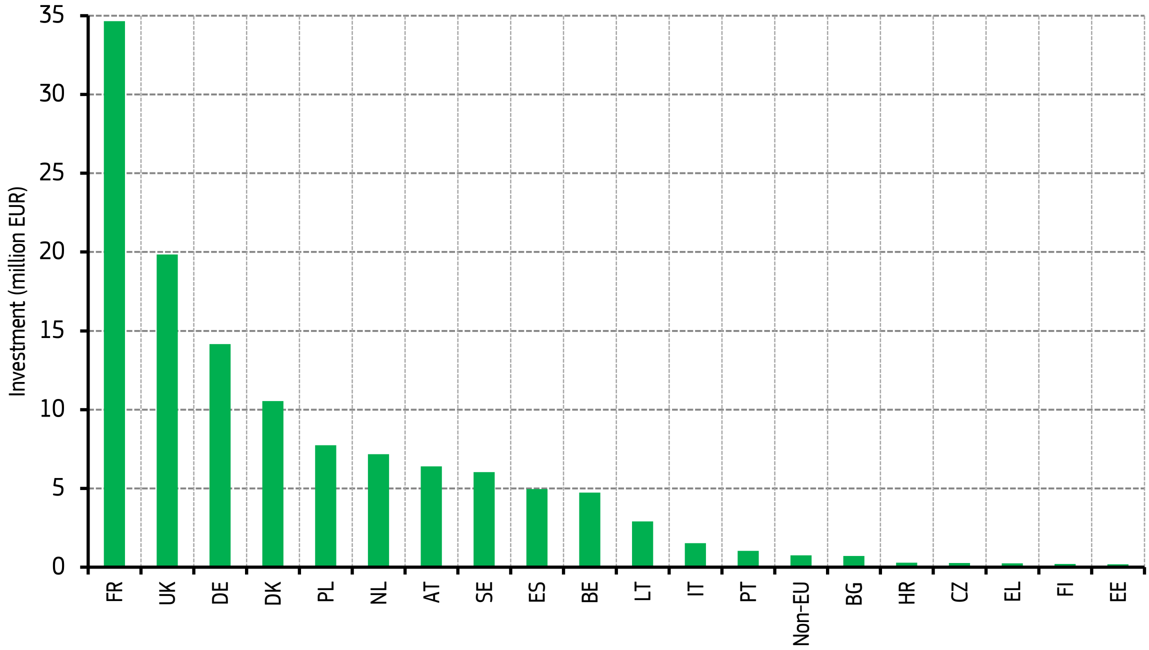
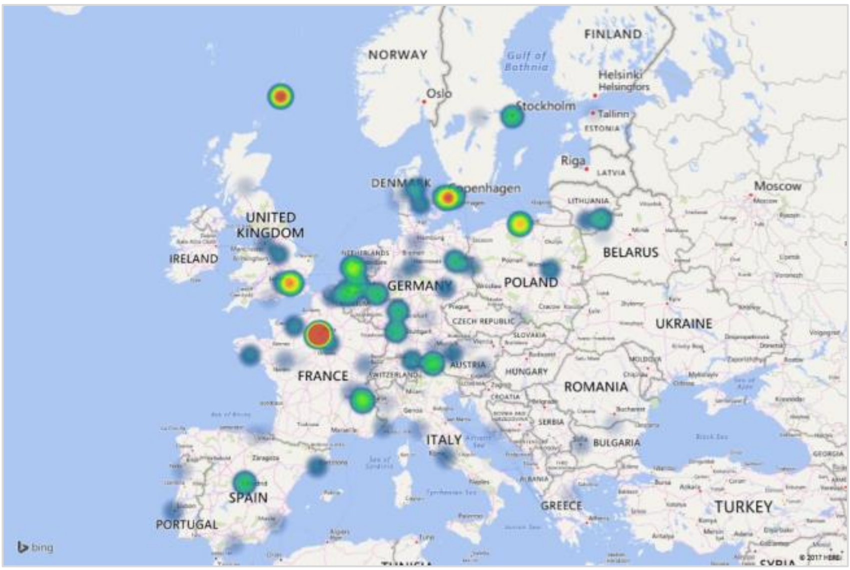


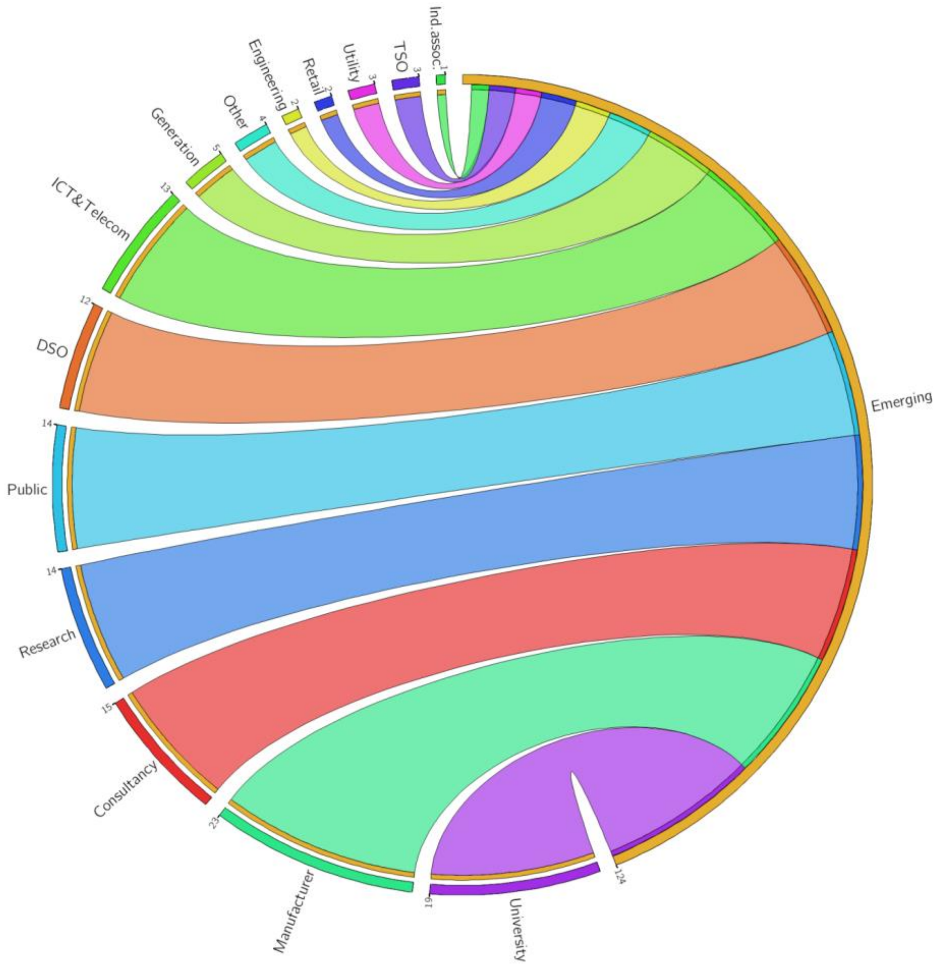
Figure 37. Geographical distribution of total investment of participating emerging stakeholders per country



Time distribution: As we already highlighted in Figure 34, there is a steady investment growth associated with emerging stakeholders in the period 2009-2014, with 2013-2014 being the period with highest investment.

Synergies and collaboration links: Figure 38 sheds some light on the synergies between emerging stakeholders and traditional actors by illustrating their collaboration links. The perimeter of the circle is divided into 15 unequal segments in accordance with the stakeholder categories and their respective total investment. The segments are connected with chords which illustrate the relationship between the different categories, where a thicker chord illustrates stronger collaboration. The right side of the circle represents the investment coming from the emerging stakeholders, whereas the right side of each chord stands for the budget allocated to the emerging stakeholders in the projects where they collaborate with the respective organisation types.

Figure 38. Collaboration links between emerging stakeholders and different types of organisations (weighted by total investment)



As one may observe from the chord thickness on the right side of the circle, the emerging stakeholders mostly collaborate with universities, followed by technology manufacturers, consultancies and public institutions. Also, there is a significant collaboration link with DSOs, where the focus is mainly on demand response and provision of flexibility services. An example of such a case is the Flexiciency project ([29]), where a DSO provides localised consumption load curves and an aggregator maps the current demand response. An energy-management service provider is responsible for development and installation of a gateway, which communicates with the smart meter and to a service platform. A technology manufacturer and an ICT provider are responsible for system development and integration.

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([29]) More information on the project is available at: http://www.flexiciency-h2020.eu/

5 Project domains

Key messages

Many projects in the database address several domains at the same time to investigate and test the systemic integration of different solutions.

The domains with highest investment in Europe are smart network management (34 %), demand-side management (25 %) and integration of DG&S (22 %), together accounting for around 80 % of the total investment.

5.1 The big picture

This chapter analyses the main domains covered by smart grid projects across Europe to provide further insight into the main areas of interest and into the collaboration links among smart grid stakeholders.

We have identified five main project domains, plus an additional one where we included applications that cannot be placed in any of the other domains. In many cases however, projects address several domains without any of them prevailing, as they investigate and test the systemic integration of different smart grid solutions. In these cases, the project is assigned to all relevant domains and, unless more precise information is retrieved, the budget is split equally among them.

Table 4 illustrates the identified domains and the most widespread applications under each one of them.

Table 4. Classification of project domains and applications

SNM: Projects in this domain focus on increasing the operational flexibility of the electricity grid through enhanced grid monitoring and control capabilities. Typically, this involves installation of network monitoring and control equipment and fast and real-time data communications.	
Key applications	Wide area monitoring systems (WAMS) at transmission network level. Fine-grained measuring devices and advanced prosumer grid interfaces at distribution network level to cope with volatile grid states. Tools for pan-European network observability. Tools for pan-European network reliability assessment. Advanced sensors on network equipment to identify anomalies and communicate with nearby devices when a fault or another issue occurs. Tools for self-controlling and healing grids i.e. the ability of a power system to automatically prevent, detect, counteract and repair itself. New capabilities for frequency control, reactive control and power-flow control. Controllable distribution substations, smart inverters, smart protection selectivity (smart relays). Dynamic line rating. Deployment of leading-edge transformers, capacitors, VAR-control devices for reduced losses and voltage control.
DSM: This domain includes both projects that aim to shift consumption to another point in time (demand response) and projects that aim to reduce the level of energy consumption while providing the same service and without affecting the level of comfort (energy conservation/efficiency).	

Key applications	Development of ICT solutions and services for demand response and energy efficiency. Implementation of initiatives and solutions to encourage residential, commercial and industrial consumers to modify their level and pattern of energy usage. Empowerment of energy consumers (including vulnerable consumers) through the implementation of smart metering enabled services and awareness-raising initiatives. Demand response and energy management within energy communities.
Integration of DG&S: This domain includes projects focusing on advanced-control schemes and new ICT solutions for integrating distributed generation (DG) and energy storage into the distribution network while ensuring system reliability and security.	
Key applications	Network planning and analysis tool for assessment of network capacity for DG connections. Active grid support (power-frequency control, voltage control) through smart inverters to facilitate DG connection. Centralised vs decentralised (e.g. agent-based) control architectures. Integration of storage systems as key enablers for future renewable energy supply. Integration of distributed energy storage to increase the distribution network operational flexibility. Development of open and interoperable information and automation solutions for integration of DG&S. Aggregation of controllable DG and storage into virtual power plants and microgrids.
E-mobility: Projects in this domain focus on the smart integration of electric vehicles (EVs) and plug-in hybrid vehicles (PHEV) into the electricity network.	
Key applications	Development of smart charging infrastructure and control strategies. Integration of EV for provision of ancillary services. Development and validation of vehicle-to-grid (V2G) interfaces, etc.
Integration of L_RES: Projects in this domain mainly aim to integrate RES at transmission or high-voltage distribution network	
Key applications	Development and testing of new grid technologies that will allow for increased grid capacity and flexibility at pan-European level while maintaining system reliability. Offshore networks for wind power integration. Development of numerical test platform for testing and validating new market designs for integration of massive flexible generation dispersed in several regional power markets. Development of novel technologies coupled with innovative system management approaches for provision of system services (voltage and frequency control) by aggregated wind farms. Forecasting tools for RES production. Integration of DSM for provision of ancillary services by DSOs to support TSO operation.
Other: The rest of the smart grid project applications not included in the above mentioned domains are included in this group	

Key applications	Market and regulation (e.g. identification of research and technology gaps for emerging and future roles of DSOs in the European electricity system). Cybersecurity (development of novel cybersecurity means for critical infrastructures), etc.

Financing Figure 39 depicts the total investment per smart grid domain. The most targeted domains in Europe are SNM (34 %), DSM (25 %) and integration of DG&S (22 %), together accounting for around 80 % of the total investment.

Figure 39. Total investment per smart grid domain

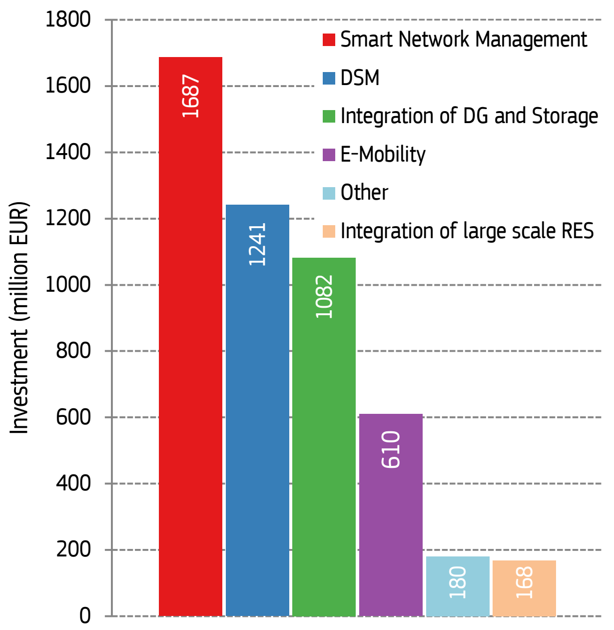
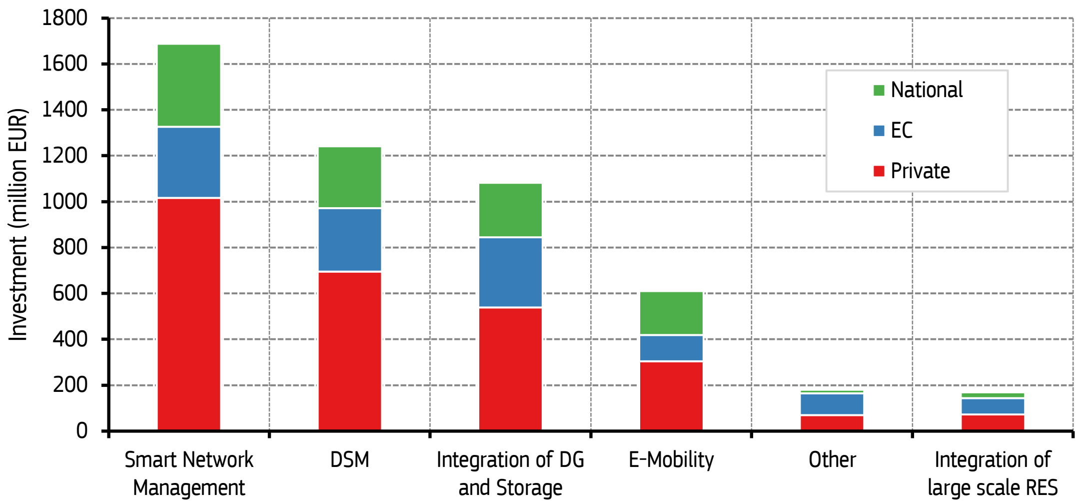


Figure 40 shows additional information on the source of financing per smart grid domain. In all project domains the highest investment comes from private resources (54 %), while the rest is divided between national (22 %) and EU funding (24 %). Further analysis has revealed that an important share of private investment comes from commercial parties — such as ICT companies and technology manufacturers — indicating significant private-sector interest in in smart grid solutions.

20 % of the total private investment is financed through specific regulatory incentives available to network operators for innovation activities (e.g. the calls for innovation projects by the Italian NRA and the United Kingdom LCNF).

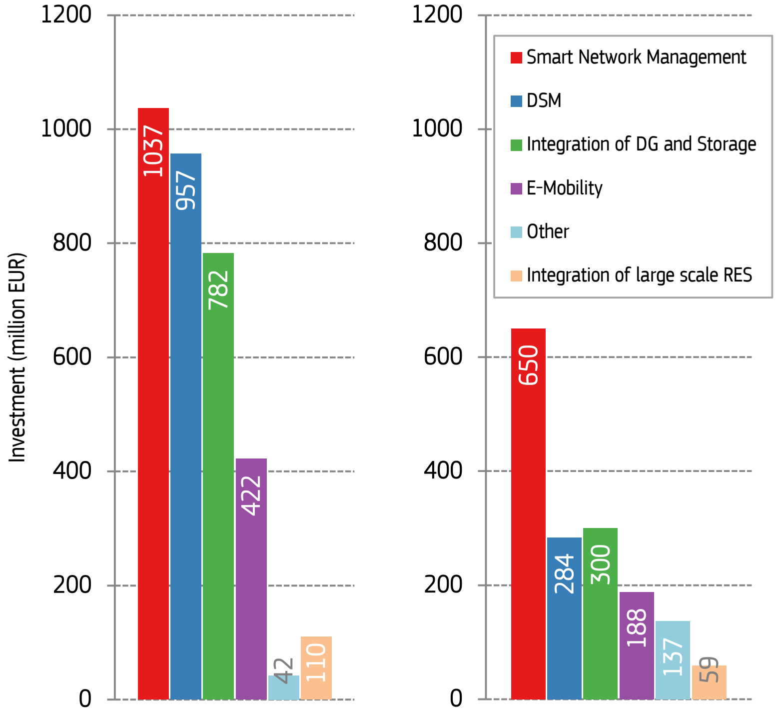
Figure 40. Total investment per smart grid domain and source of funding



Stages of the innovation cycle: Figure 41 shows that projects focusing on SNM attract the highest investment, both in demonstration and R & D activities, closely followed by DSM and integration of DG&S. In all domains, except 'other', demonstration projects account for the largest share of investment. The R & D projects in the domain 'other' mainly target integrated research programmes on smart grids to reinforce and accelerate

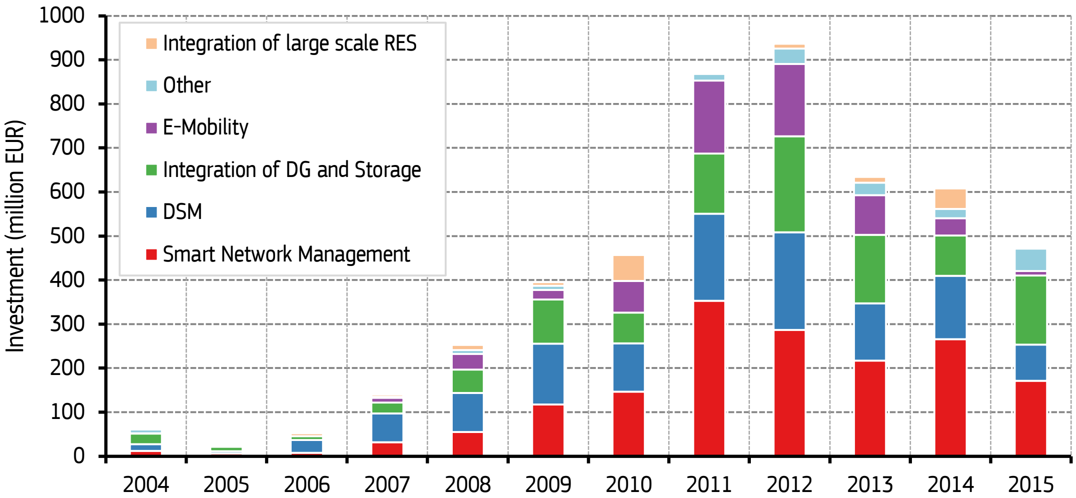
Europe's medium- to long-term research cooperation in this area. They aim to strengthen the collaboration links among the participating organisations and the integration of the related national programmes.

Figure 41. Total investment per smart grid domain and stage of development: Demonstration (left); R & D (right)



Time distribution: Investors have shown a relatively steady interest in projects focusing on SNM, DSM and integration of DG&S throughout the years, with investment peaking in 2011-2012 (Figure 42). As we can see in Figure 42, in 2010 and in 2014 there is an evident increase in the investment in integration of L_RES projects. This increase is due to the start of a few projects with a very high budget, focusing on novel network technologies aiming to increase the pan-European transmission network capacity and to enhance electricity system flexibility to accommodate growing RES penetration levels. As for E-mobility projects, investment grew quite steadily until the peak year 2011, after which they started decreasing very slowly until 2013 and quite sharply afterwards.

Figure 42. Distribution of total investment by application and starting year



5.2 Geographical distribution

Investment levels in the different domains differ from country to country due to a combination of various national-specific circumstances, including the state of the electricity grids, the level of RES penetration, the existence of a favourable national and regulatory environment, the company culture of the different stakeholders, etc.

Luxembourg shows the largest share of investment associated with the SNM domain; as we mentioned in Section 2.2.1, such investment is mainly attributable to one large-scale demonstration project, the Creos project, which focuses on increasing the observability and controllability of the distribution network. The United Kingdom also shows a large share of investment in this domain (mostly national projects supported by regulatory incentive mechanisms), together with some countries in eastern Europe (e.g. Czech Republic, Hungary and Poland) (Figure 45). Further analysis of the projects in the database has revealed that DSOs in the Czech Republic and Hungary and ICT companies in Poland are among the most active organisations investing in smart grid solutions.

Nearly one third of the investment associated with DSM is found in France and the United Kingdom, whereas Germany, France and the United Kingdom together account for nearly half of the investment in integration of DG&S.

Projects focusing on electric mobility are concentrated in a limited number of countries, with Germany, Spain, France and Austria accounting for about 40 % of the total investment in this domain.

As we noticed above, many projects in the database address several domains at the same time to investigate and test the systemic integration of different solutions. One interesting example of such integration is the Greenlys project, one of the largest national smart grid projects in France. The project addresses the whole value chain from generation to energy use, developing and testing innovative solutions for both network and energy consumer management, while integrating DG and EVs. At the end-user level, a cloud-based demand-side operation platform enables optimisation of the energy bills and encourages energy-efficient practices while offering flexibility services to the electricity network.

Figure 43. Distribution of investment per smart grid domain and country

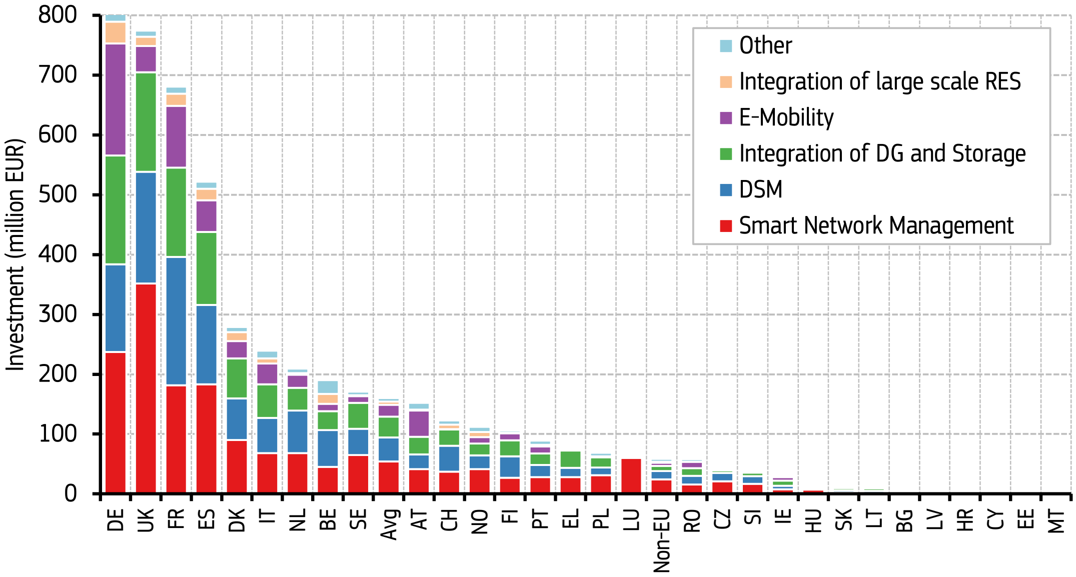


Figure 44. Distribution of investment per smart grid domain and country

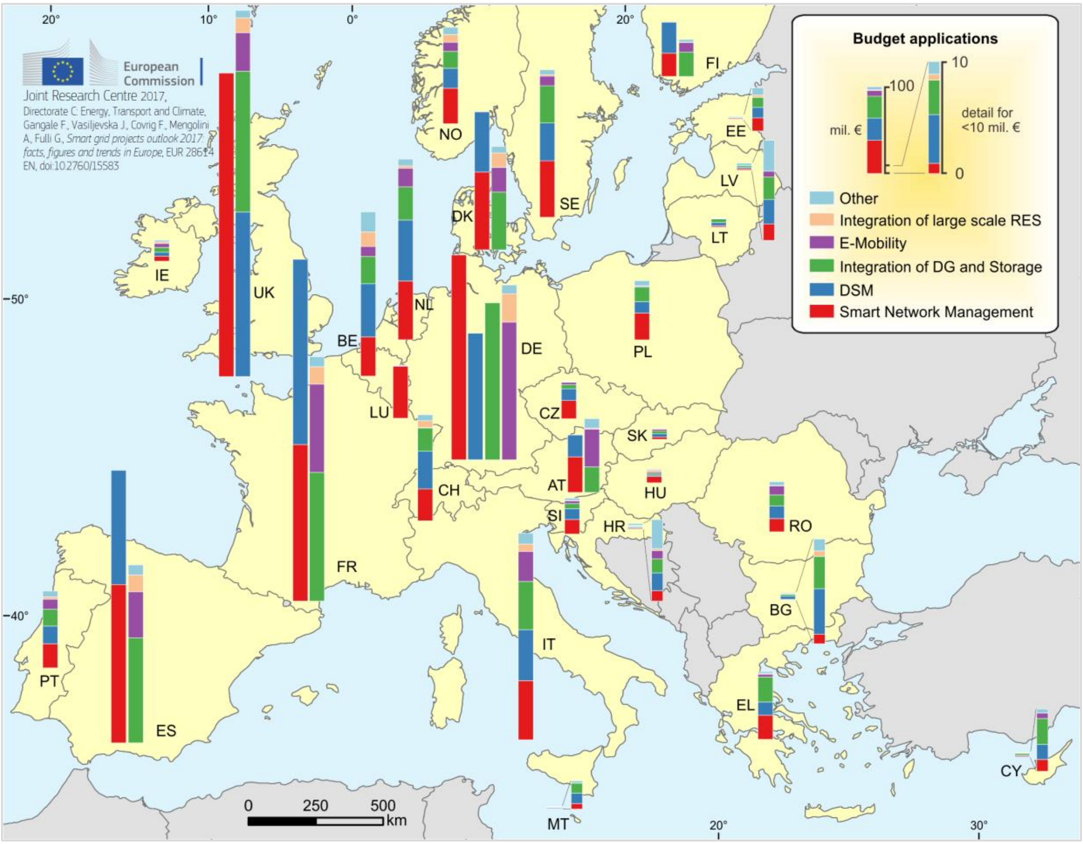


Figure 45. Percentage distribution of total investment per smart grid domain and country

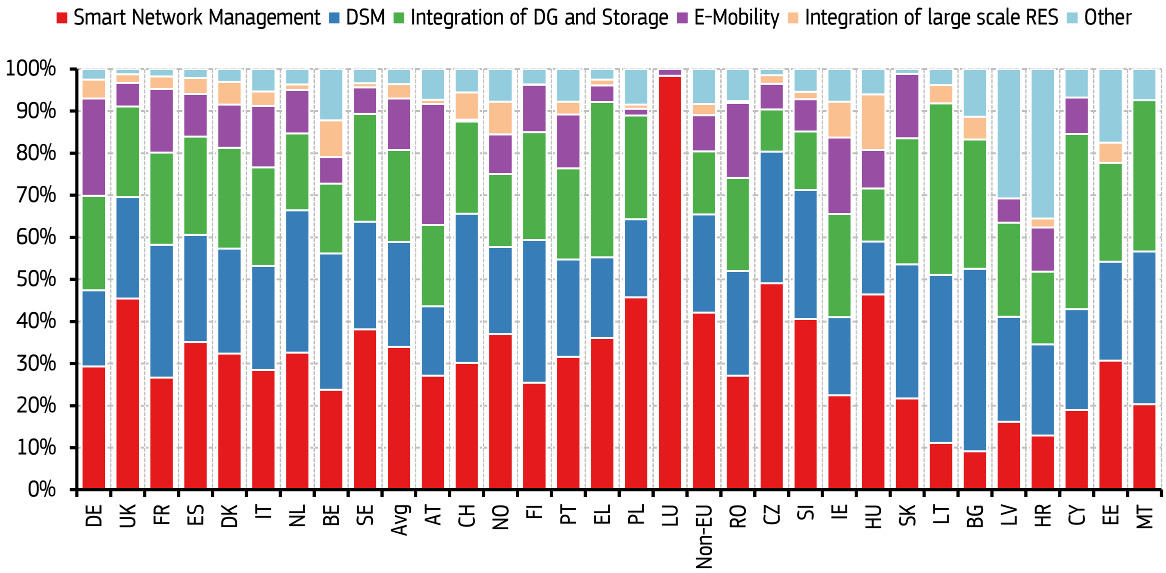


Figure 46 and Figure 47 depict the distribution of smart grid investment in the implementation sites in the EU. As mentioned earlier, implementation sites represent the geographical locations where demonstration projects take place, testing the technical and market viability of new solutions in real life environments. Their location can therefore shed some light on the national and regional interest for the development of specific smart grid solutions.

An example is offered by Germany, where an important share of investment in the implementation sites is dedicated to the integration of DG&S (Figure 46). Here, the rapidly growing distributed solar-photovoltaic (PV) generation, along with new regulatory schemes subsidising battery/PV systems, has spurred intense interest in behind-the-meter battery/PV systems. This solution, thanks also to the falling costs of battery-based energy storage systems, is gaining ground as a means to cost-effectively integrate solar PV into the German power distribution system. Thanks to these developments, Germany is becoming one of the leading emerging markets in the EU for residential DG (particularly PV) and storage (IRENA, 2015). Along with residential storage and peer-to-peer energy trading, developers (e.g. Sonnenbatterie) and traditional retailers in Germany (e.g. E.ON) have also started to invest in residential storage and offer decentralised energy solutions to end-users.

Figure 46. Geographical distribution of investment in the implementation sites

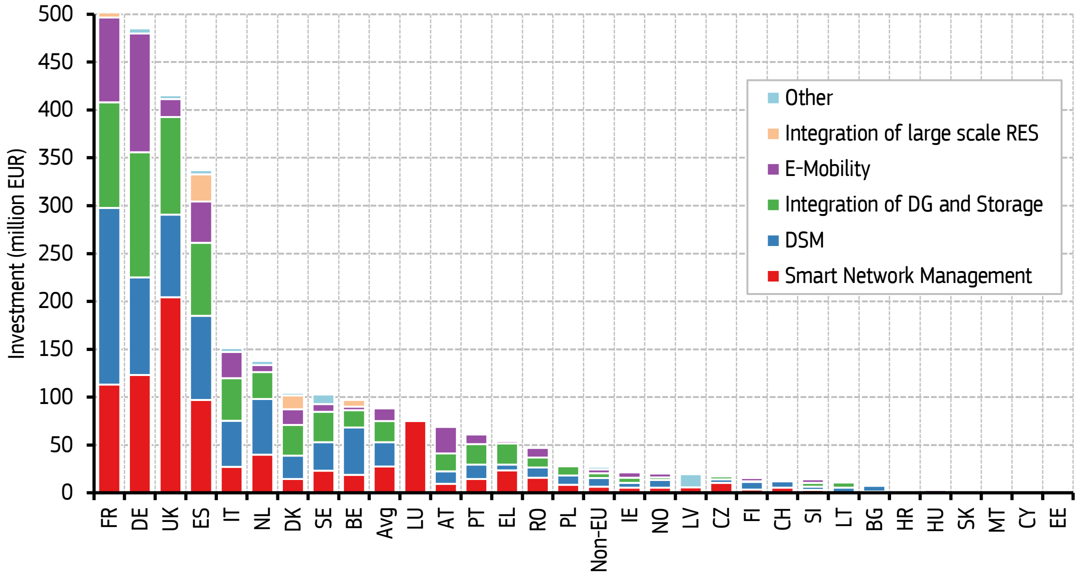


Figure 47. Geographical distribution of total implementation site investment

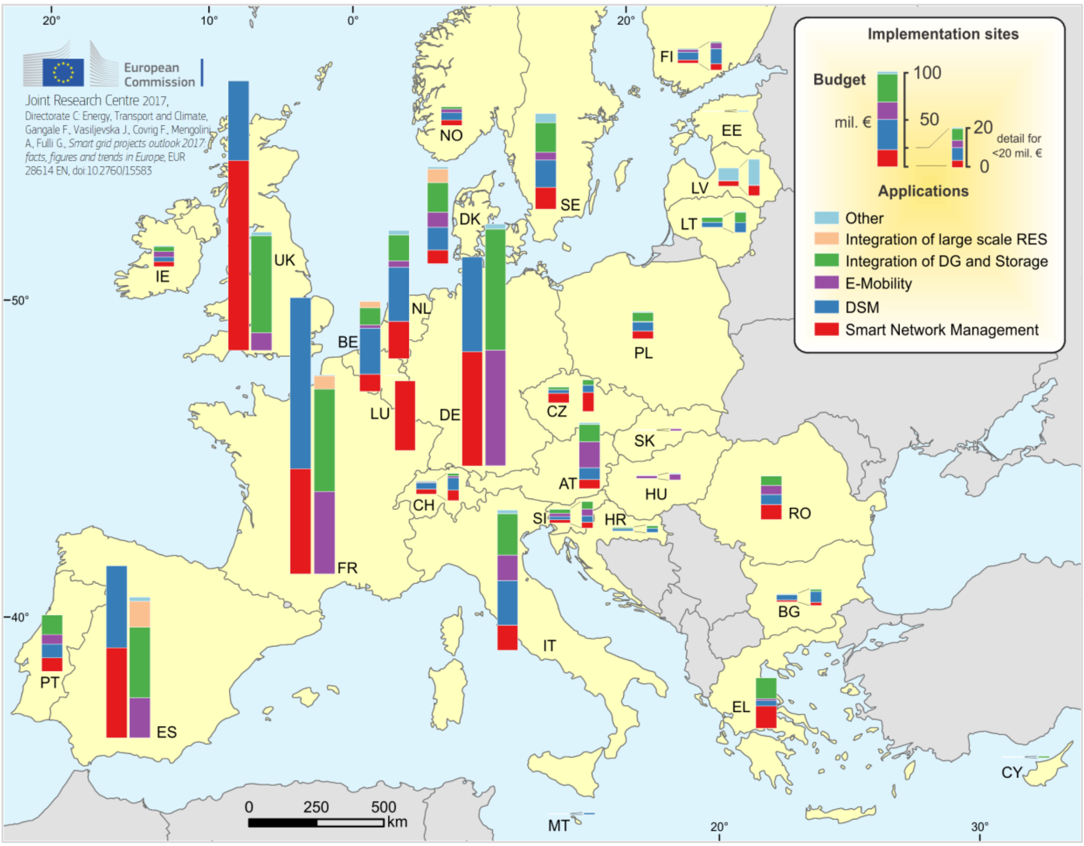
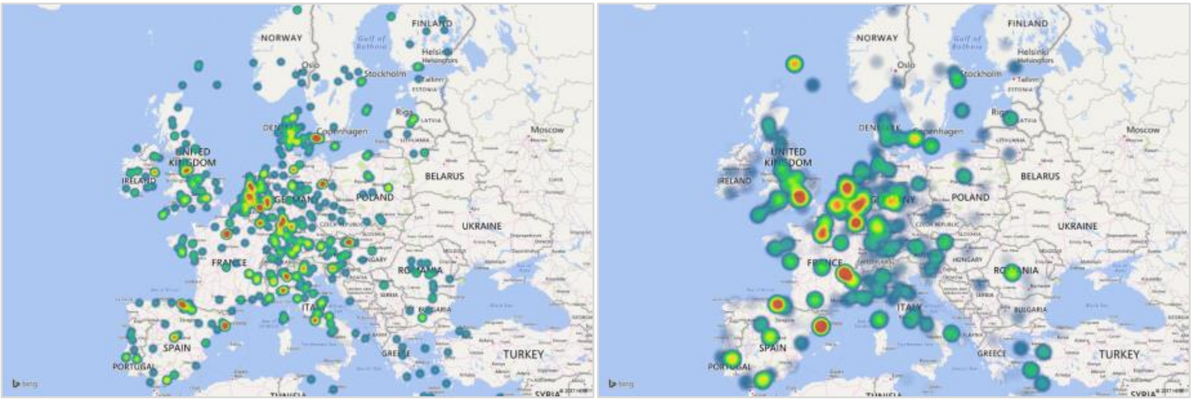


Figure 48 provides some insight into the distribution of implementation sites and associated investment. There is a quite dispersed distribution all over Europe, with the highest concentration evident in central Europe. However, the region of north France, Belgium, south Netherlands and west Germany, including the London area and the north of Spain still present the area with largest investment related to the implementation sites.

Figure 48. Geographical distribution of smart grid implementation sites: number of implementation sites (left); total investment (right)



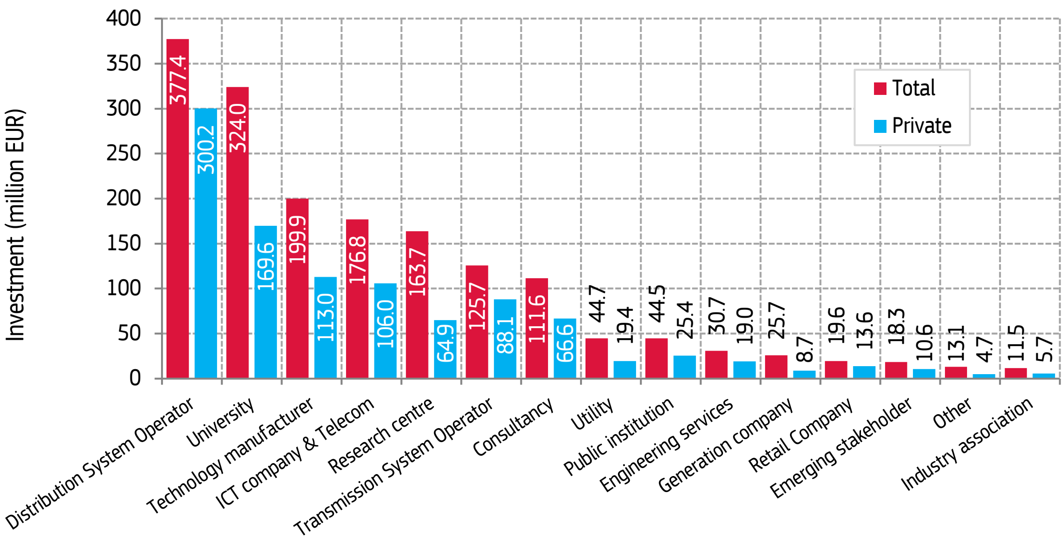
5.3 Analysis per smart grid domain

In this section we provide a more in-depth insight into each of the smart grid domains with the aim of shedding further light on the main areas of interest and on collaboration links among smart grid stakeholders.

5.3.1 Smart network management

The main focus of this domain is the development and implementation of smart grid assets/functionalities for minimising the operational and planning costs of DSOs, thus offering alternative solutions to the traditional grid investment and operational practices. This type of investment falls within the business practices of the DSOs, and an appropriate regulatory framework may play a significant role in incentivising them to opt for smart grids over traditional investment.

Figure 49. SNM total and private investment per stakeholder category

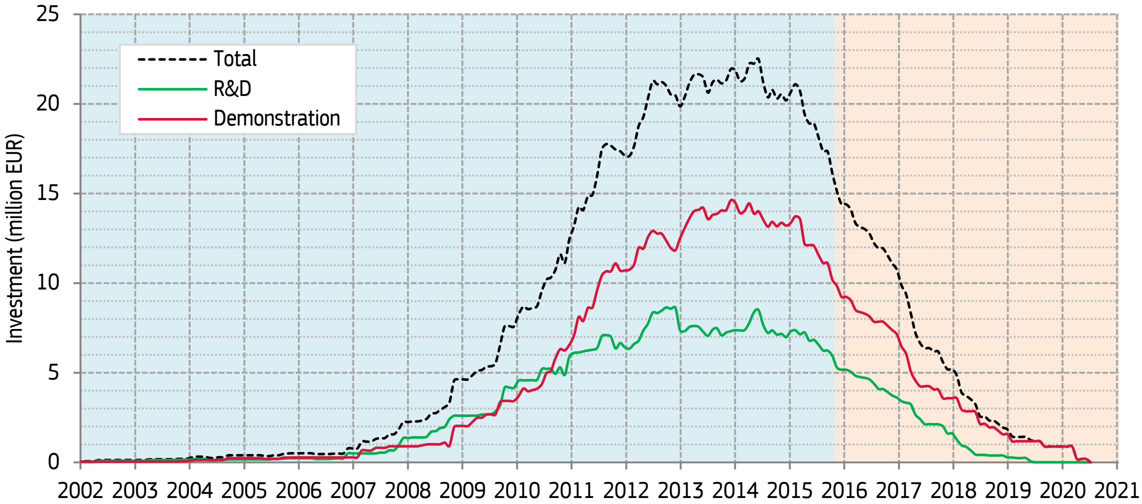


The traditional asset-based approach to the provision of additional demand or generation capacity may prove unable to facilitate the decarbonisation of energy and transport at an affordable cost and thus require innovative approaches for release of additional network capacity. In the C2C project, for instance, additional network capacity is released through a combination of innovative network management technologies in conjunction with new customer commercial arrangements. This allows the DSO to increase the loadings on a selection of trial circuits, representing approximately 10 % of the high-voltage (HV) network, without resorting to conventional network reinforcement.

Figure 49 illustrates the share of total and private investment for the different stakeholder categories targeting SNM applications. As already mentioned, DSOs are the stakeholders showing the highest interest in this domain, with nearly 80 % of their investment coming from private resources. Above one third of the total DSOs investment is attributable to the United Kingdom regulatory incentives; however also DSOs in Germany, Spain and France are particularly active in both national and multinational projects.

Stage of the innovation cycle: Figure 50 illustrates the share of the total investment associated with SNM per stage of the innovation cycle and over the project lifetime. We can see that in the course of 2011, the investment in demonstration projects surpassed the investment in R & D projects. Nevertheless, R & D SNM projects continue with a certain level of investment, particularly in area of developing technical- and market-based solutions for increased distributed network flexibility.

Figure 50. Distribution of SNM investment over the project lifespan per stage of development



Financing: Figure 51 provides insights into the type of financing supporting SNM projects. The peak in private investment occurs in the course of 2012, with around 20 % of the peak attributable to regulatory mechanisms in the United Kingdom, such as the LCNF.

National and EU investment in SNM projects are mostly aligned, with a peak occurring in 2014-2015.

A large part of the EU investment comes from the Horizon 2020 Framework Programme, which started in 2014 and addresses a wide range of topics targeting next generation technologies and services enabling smart grids.

The largest part of the national funding allocated to SNM projects comes from Germany (nearly 35 %) and it is linked to the implementation of the German energy transition programme — Energiewende. One of its funding initiatives, the Future-proof power grids, is funded by two German federal ministries, the ministry for economic affairs and energy and the ministry for education and research. Its goal is to enable technology for the development of intelligent distribution and transmission grids that are able to integrate large-scale renewables, while improving efficiency and security of supply. The Future-proof power grids funding initiative supports the cooperation between industry and academia throughout the value-added chain and facilitates international research collaborations, with first alliances starting their research projects in August 2014.

As elaborated in Chapter 3, there is also strong national support in Denmark, coming from the funding programme administered by Energinet.dk (Energinet.dk, 2016) and France, where several projects have been funded by the PIA programme.

Figure 51. Distribution of SNM investment over the project lifespan per type of financing

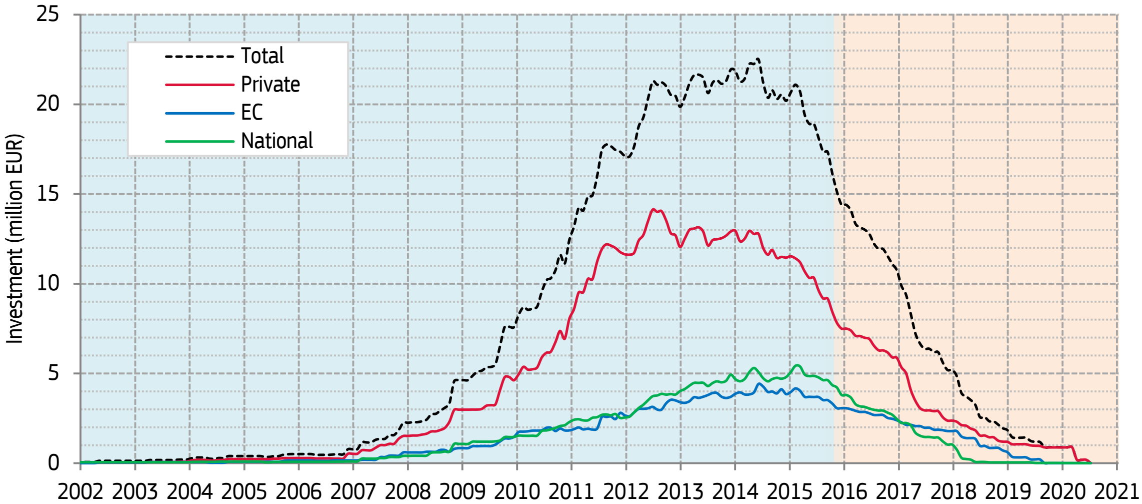
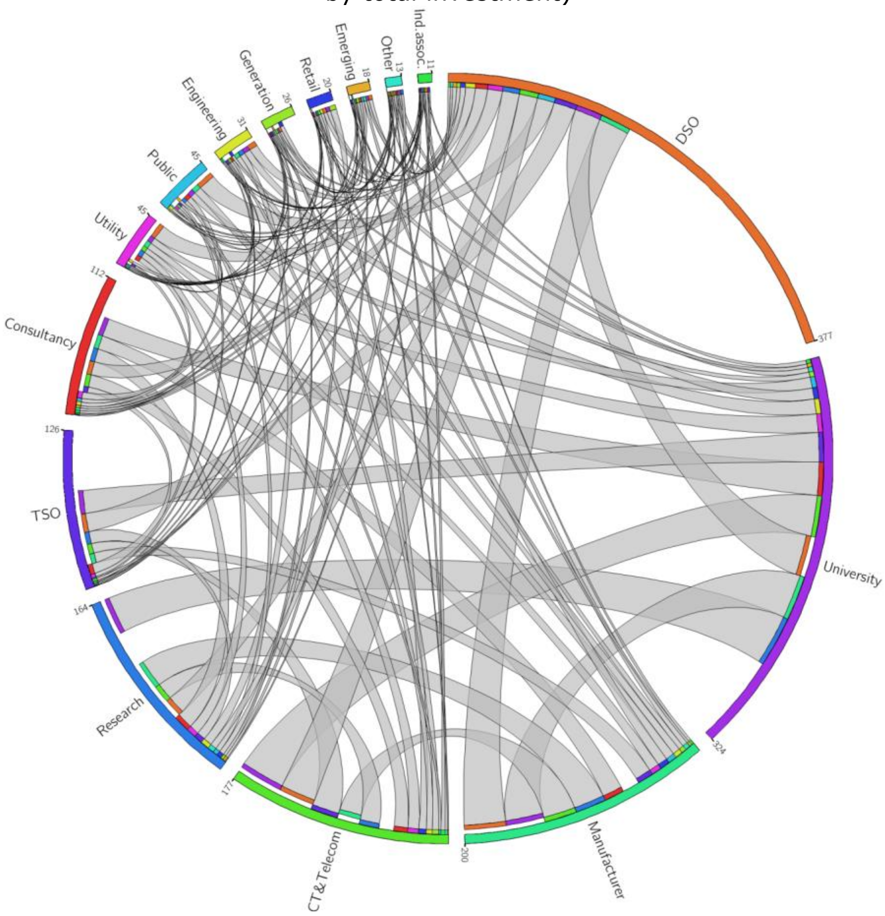


Figure 52. Collaboration links between different types of organisations investing in SNM (weighted by total investment)



Synergies and collaboration links: Figure 52 shows the collaboration links between different stakeholders targeting SNM projects. As mentioned before, DSOs are the stakeholders showing highest interest in the smart grid domain with more than half of their investment focusing on collaborations with other DSOs, but also collaborating great deal with manufacturers, universities and TSOs.

Nearly 30 % of the investment allocated to SNM projects includes TSO-DSO collaboration. Such collaboration includes exchange of necessary information and data with respect to daily operation of their networks and long-term planning of network investment, performance of generation assets and demand response, etc. This is in line with the increase in coordination activities between these two actors, particularly with integration of growing levels of renewable energy sources and the increasing need for ancillary service provision from DG connected at the distribution network to support TSO operation.

Figure 53 shows the geographical distribution of investment targeting SNM applications along with the investment associated with the implementation sites. Most of the investment comes from the United Kingdom (more than 20 %) and they are mainly national projects, followed by south-west Germany, north Spain and France. These outcomes are in line with current regulatory frameworks in the United Kingdom (e.g. LCNF) and national supporting schemes in Germany (e.g. E-energy) promoting smart grid investment. When it comes to implementation sites, the largest investment appear in the region of central and south-west Germany, south United Kingdom and south France. Also, the islands of south-east Greece and central Romania present larger investment associated with implementation sites.

Figure 53. Geographical distribution of SNM investment: total investment (left) and implementation site investment (right)

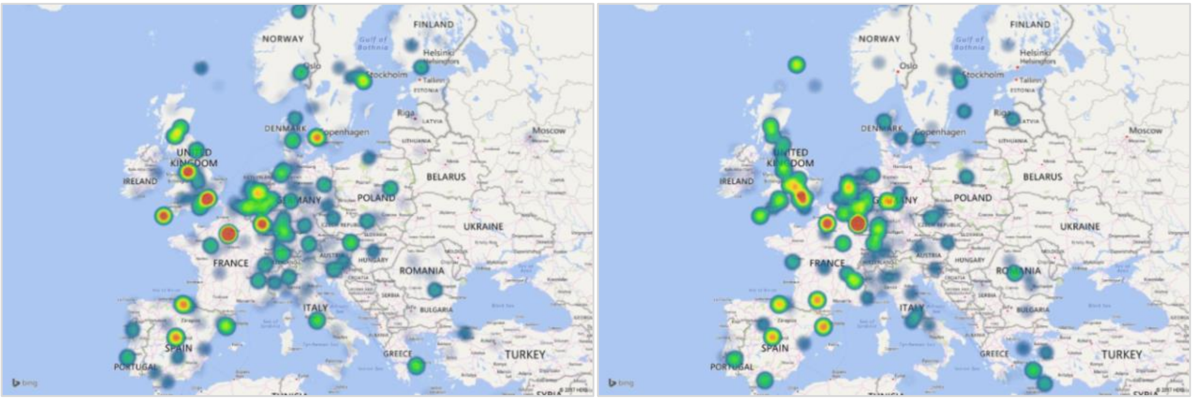
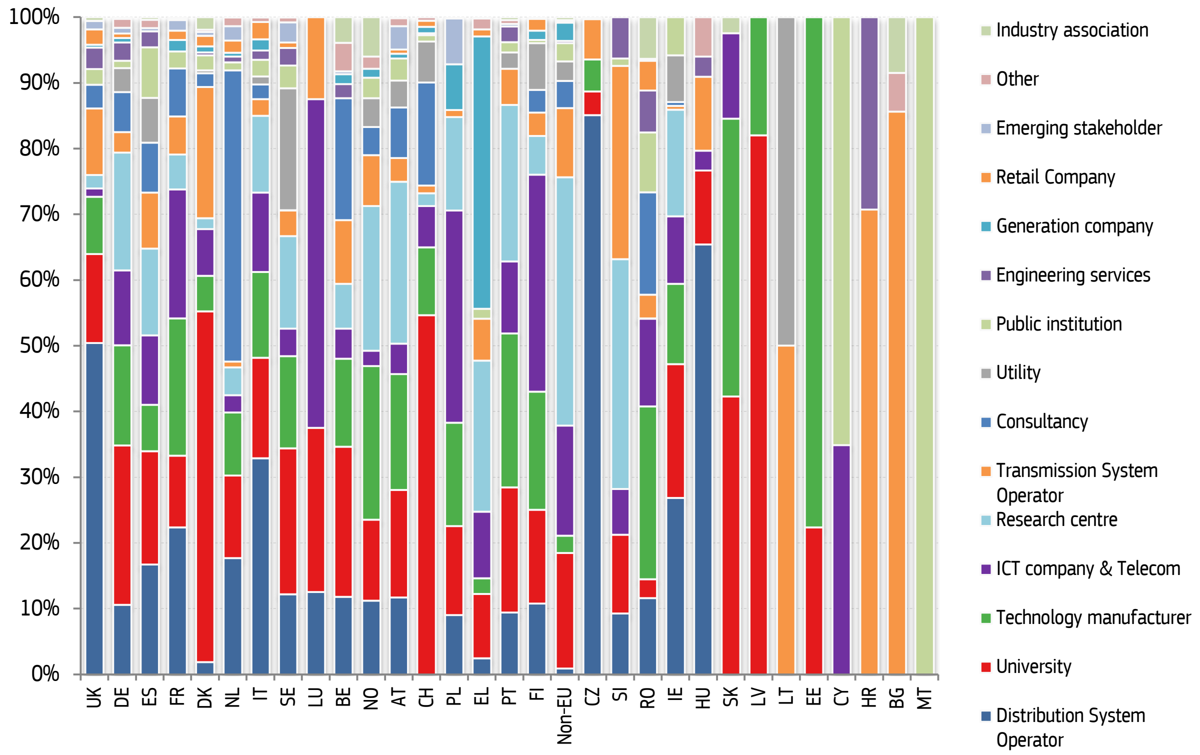


Figure 54 presents the percentage distribution of total investment associated with SNM per country. As expected, in countries such as Italy and the United Kingdom, the high interest of DSOs in this domain is evident due to the presence of regulatory incentives for innovation activities. In the Czech Republic and Hungary, DSOs are the main actors investing in this domain, and most of the projects target development of advanced tools for increasing the medium-voltage (MV) and HV distribution network observability and controllability.

Also, there is a widespread presence of technology manufacturers and ICT companies across the countries, particularly in east Europe (e.g. Estonia, Romania, Slovakia and Finland), placing the industry as one of the key actors in smart grid deployment.

Figure 54. Percentage distribution of investment associated with the SNM domain per country



5.3.2 Demand-side management

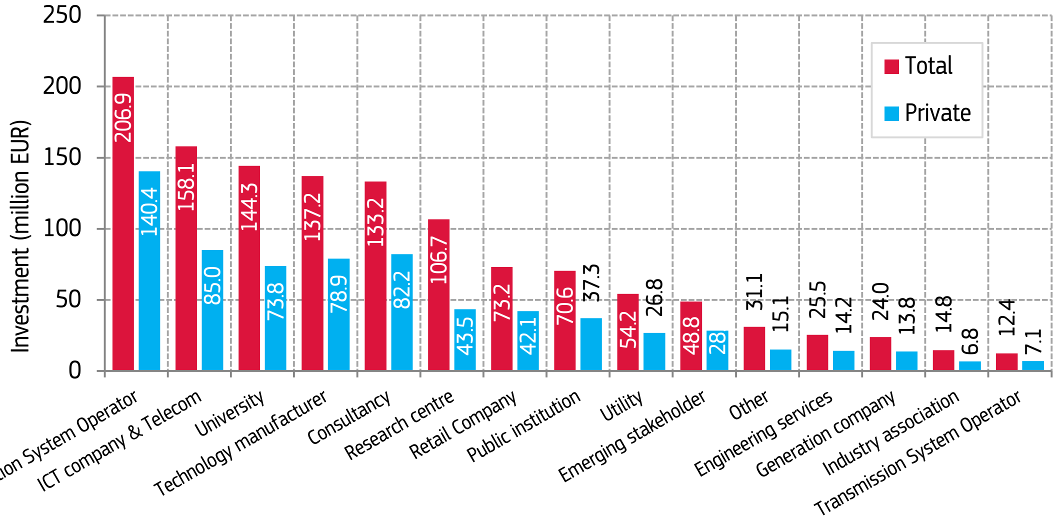
This domain addresses a wide range of applications targeted to smart grid projects and it evolves around the concept of active consumer and prosumer. The energy union (European Commission, 2015), since its inception, has given the customer a central role. Large penetration levels of renewables and growing need for network flexibility make customers the key enablers of the energy transition, where they play a more active role in the energy market, taking ownership of the way they use and consume their electricity, while benefiting from solutions to reduce energy bills, improve quality of service and protect vulnerable consumers.

Projects targeting this domain deal with energy efficiency, energy conservation and demand response at household, building and community level and across different consumers' segments (residential, commercial and industrial). These projects target applications enabling customers' active participation in the retail, but also balancing markets and provision of different ancillary services (e.g. voltage control).

Figure 55 illustrates the share of the total investment allocated to DSM projects by the different stakeholder categories involved. DSOs appear to be the actors with the highest investment in projects targeting DSM applications, closely followed by ICT companies, universities and technology manufacturers.

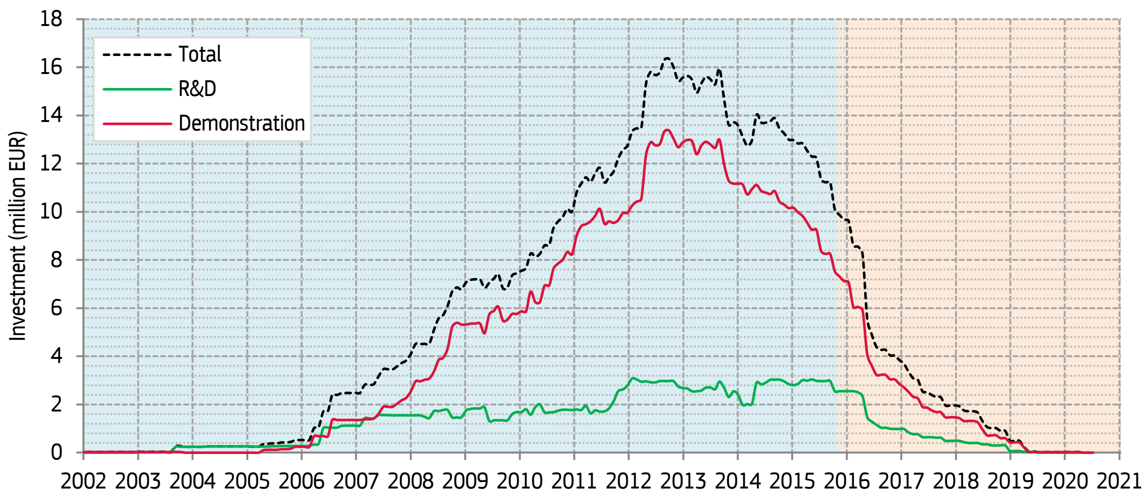
Such projects mainly aim to increase the efficiency of distribution network operation and planning by actively engaging customers in the management of their electricity use. Additionally, these projects explore the DSO role as data manager and neutral market facilitator in deployment of novel services in the electricity retail markets (ranging from advanced monitoring to local energy control and flexibility services).

Figure 55. Distribution of the DSM investment per organisation type



Stage of the innovation cycle: Figure 56 depicts the investment associated with DSM projects per stage of the innovation cycle and over the lifetime of the project. As of 2008, investment in DSM demonstration projects exceeded the R & D investment and since then they continued growing, with a peak in investment in 2013. Main applications in this regard include development of DSM platforms to allow end-user engagement in more effective management of their energy use (at household, building or district level), while enabling more efficient grid utilisation.

Figure 56. Distribution of DSM investment over the project lifespan per stage of development



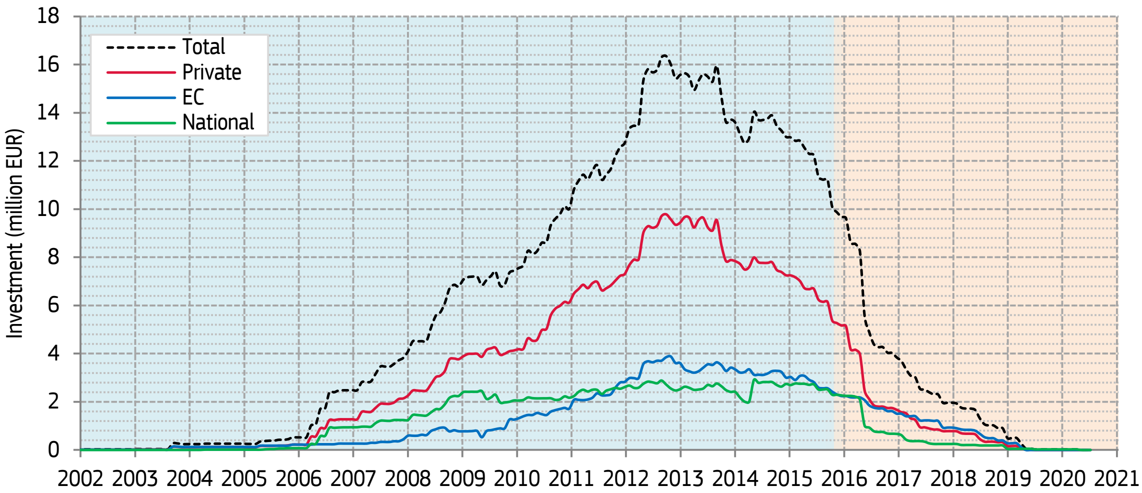
Financing: Regarding the type of financing, there is an evident peak in the private and national financing in 2013-2014 (Figure 57). National funding initiatives mainly support DSM applications within smart city/community initiatives (e.g. Austrian climate and energy fund and the Dutch ministry of infrastructure and the environment), where also private organisations are encouraged to take active part. Furthermore, there are several projects supported by public-private partnerships, such as the Cellular smart grids platform project supported by the Dutch TKI ([30]).

EU funding in this domain presents evident growth at the end of 2013 and at the beginning of 2015. Most of the projects within this domain evolve around the concept of

([30]) More information on TKI is available at http://tki-switch2smartgrids.nl/en/topconsortia-knowledge-innovation/

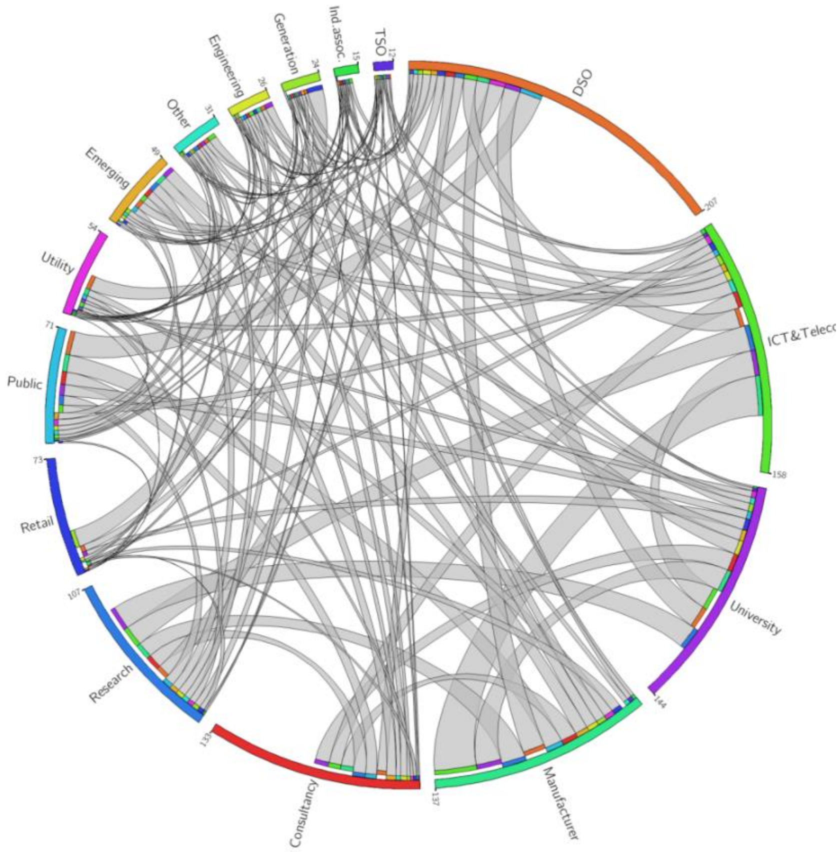
smart community/smart city and development of ICT-based energy services (particularly projects that have started in 2015).

Figure 57. Distribution of DSM investment over the project lifespan per type of financing



Synergies and collaboration links: Figure 58 depicts the synergies between the main actors active in this domain. As in the case of the SNM domain, more than half of the DSOs' investment target projects where DSOs collaborate with other DSOs.

Figure 58. Collaboration links between different types of organisations investing in DSM projects (weighted by total investment)



Such projects include development of innovative services in the area of advanced energy monitoring and local energy control (demand response). Here, the role of the DSO as a neutral market facilitator is further explored, where relevant meter data are made available by DSOs in a non-discriminatory way to third market players, under customer consent, through advanced interoperable platforms. In this context, for instance, the Flexiciency project (31) addresses the development of DSO platforms enabling: 1) provision of metering data close to real time to any interested stakeholder willing to provide services; 2) data storage (both historical, close to real time and/or forecasted data); 3) advanced functionalities, such as data analytic and forecasting and 4) technical validation of requested services, when impacting the network, by interfacing with the DSO's legacy systems. Similarly, the Flex4Grid project (32), aims to develop an open data and service framework for prosumer flexibility management, thus offering new services to DSOs, prosumers and third market players.

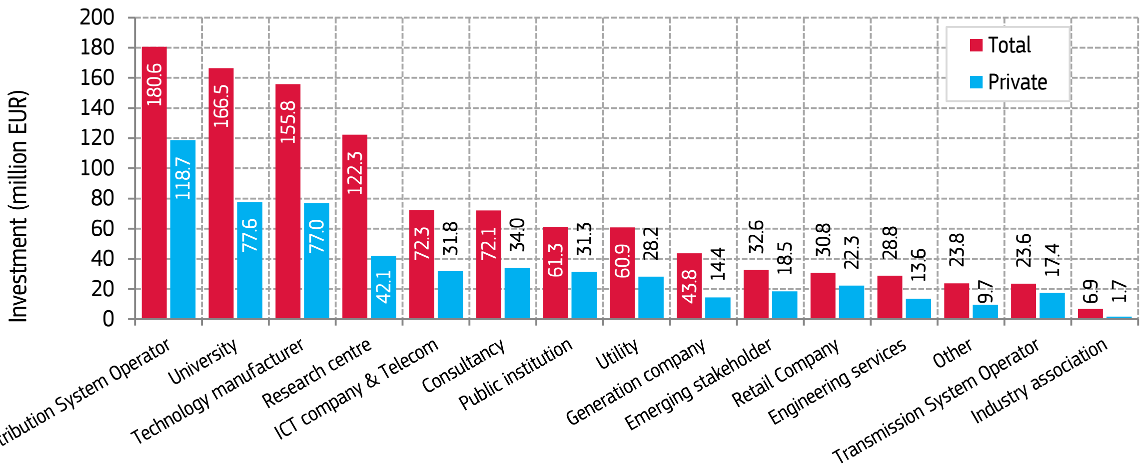
Nearly 75 % of the total DSO investment in this domain is allocated to national projects. This confirms the national interest of certain Member States (in particular, Germany, Spain, France, Italy and the United Kingdom) in DSM projects. It is also interesting to note that DSOs highly collaborate with public institutions, such as city/town halls, local energy agencies, etc., which again stresses out the relevant role of DSOs in the development of sustainable energy communities. Furthermore, there are strong collaboration links between ICT & telecom companies and technology manufacturers as two of the main actors enabling the digital transformation of the power industry.

5.3.3 Integration of distributed generation and storage

This domain includes the development of control and management strategies for enlarged and more effective integration of DG&S into the distribution networks. Typical applications in this regard include the development of flexible DG connections through innovative commercial arrangements that enable greater flexibility in accommodating cheaper and faster DG connections. In these projects, DG customers are connected to the distribution network on the basis that their generation output can be controlled by the DSO for operational purposes. Other projects focus on the development of business models to quantify the potential of small-scale storage as an aggregated controllable load.

Figure 59 illustrates the total and private investment in projects targeting the integration of DG&S per organisation type. As in the previous two domains, DSO continues to be the stakeholder with highest interest in this domain.

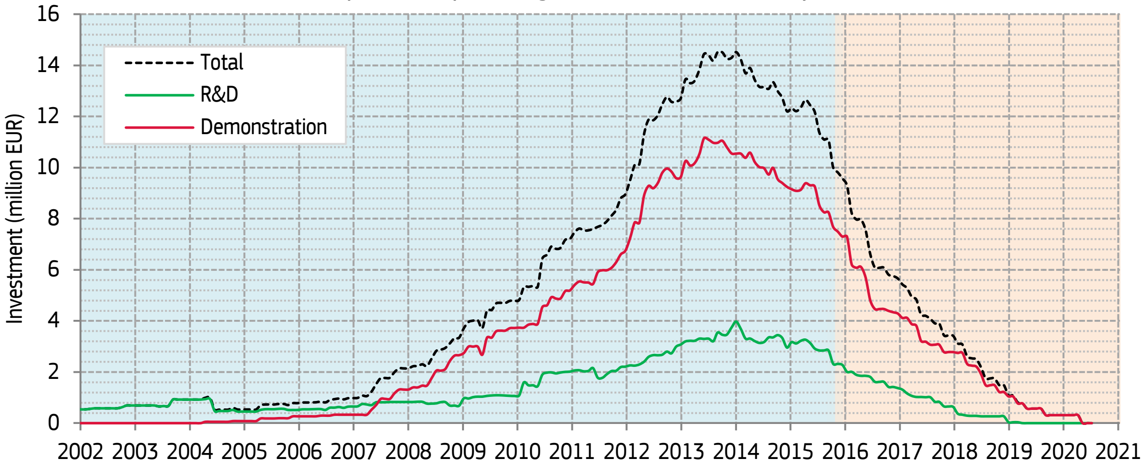
Figure 59. Total and private investment associated in the integration of DG & storage domain per organisation type



Stage of the innovation cycle: Figure 60 illustrates the distribution of total investment associated with this domain over the lifetime of the projects and per stage of the innovation cycle. Similar to the DSM domain, as of 2008 the investment allocated to demonstration projects surpassed the R & D investment. The peak in investment, both for R & D and demonstration projects is towards the end of 2013.

(31) More information on the project is available at: http://www.flexiciency-h2020.eu/
(32) More information on the project is available at: https://www.flex4grid.eu/

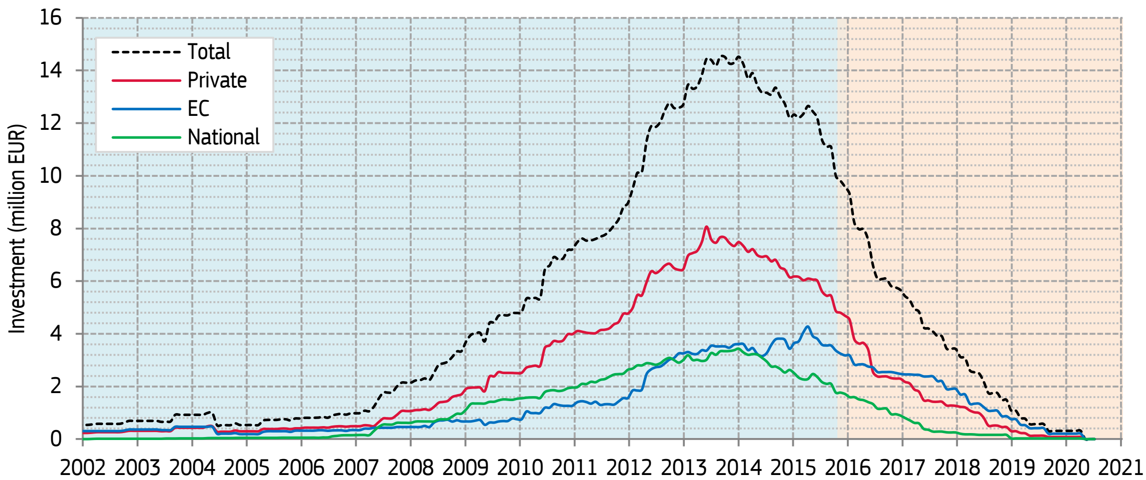
Figure 60. Distribution of investment associated with integration of DG & storage over the project lifespan and per stage of the innovation cycle



Financing: Figure 61 presents the investment in this domain per type of financing. Private financing and national funding reach their peak by 2014, whereas as of 2008 there is a relatively continuous growth of EU funding supporting integration of DG&S, with peak investment in the course of 2015.

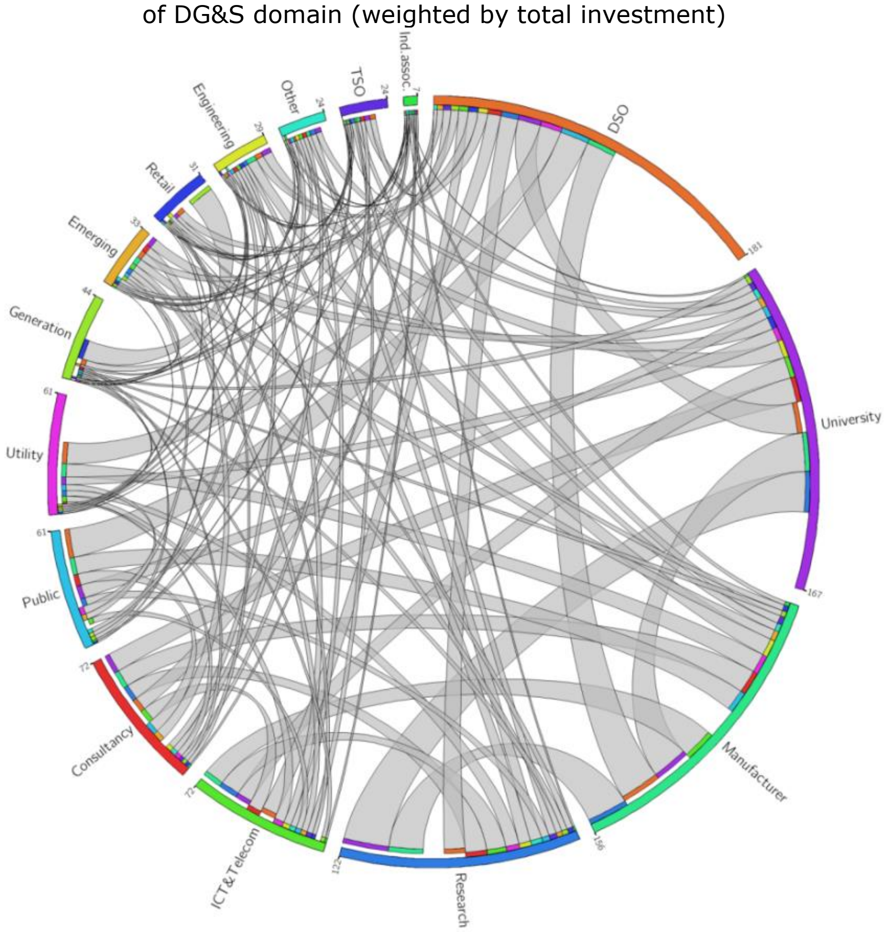
Most of these projects focus on increasing the distribution network hosting capacity for accommodating larger portion of distributed renewable energy sources without compromising the reliability and quality of supply. There is also significant number of EU co-funded projects targeting integration of large-scale DG and storage within the smart community/smart city concept (particularly in recent years). Such projects address more integrated approach for energy, ICT and transport infrastructure with the aim to explore opportunities for replication of such solutions in other districts/cities. In this context, for instance, the CITyFiED project aims to develop a systemic, integrated and replicable strategy to adapt European cities and urban ecosystems into the smart city of the future, focusing on reducing the energy demand and greenhouse gas (GHG) emissions and increasing the use of RES. The strategy relies upon development and implementation of innovative technologies for building renovation, smart grid and district heating networks and their interfaces with ICTs and mobility. Similarly, the SINFONIA project focuses on validation of a refurbished city-district model where the potential for scalability and replicability by middle-sized European cities is explored and validated during demonstration, based on energy technologies deployed by two pioneer cities (Bolzano and Innsbruck).

Figure 61. Distribution of total investment associated with integration of DG&S over the project lifespan and per type of financing



Synergies and collaboration links: Nearly half of the total investment in this domain allocated to DSOs is invested in projects where DSOs collaborate with other DSOs (Figure 62). Typical applications of such projects address the increase of the distribution network hosting capacity and the more efficient integration of DG through for instance, development of innovative voltage control algorithms, development of coordinating functions for aggregating multiple decentralised generating units and providing network services to the DSOs. Also, DSOs highly collaborate with technology manufacturers, public institutions and utilities, and this again confirms the relevant role of DSOs as neutral market enablers of innovative end-user services and facilitators in the development of more decentralised energy structures, such as energy community.

Figure 62. Collaboration links between different types of stakeholders investing in the integration of DG&S domain (weighted by total investment)

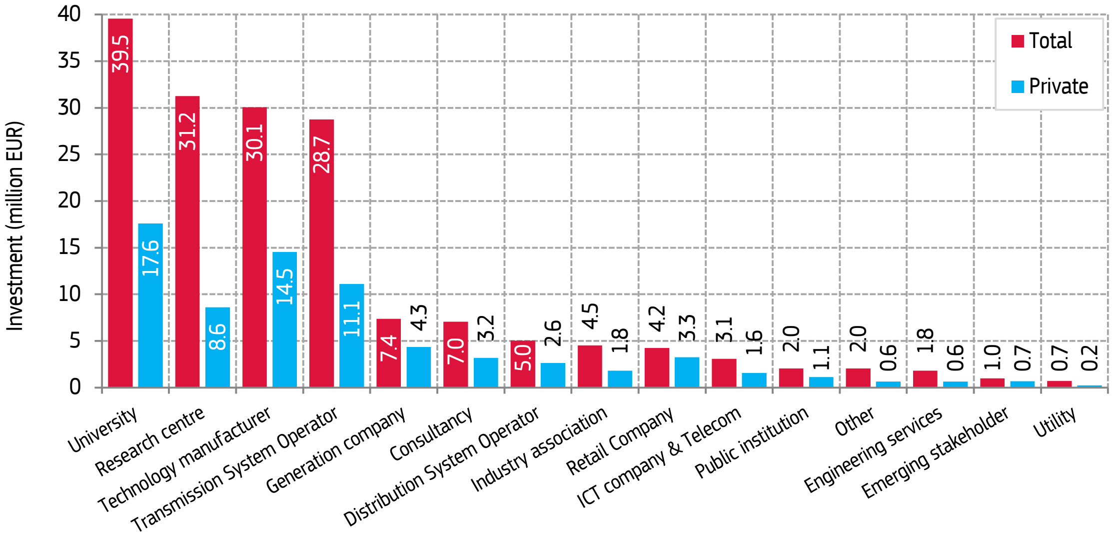


5.3.4 Integration of large-scale RES

This domain includes projects with a main focus on the integration of L_RES (principally wind energy) into the HV distribution and transmission networks. Typical applications in this domain include the development of new electricity market designs for more efficient integration of massive renewable generation dispersed over several regional markets; development of novel network technologies to increase the pan-European transmission network capacity and electricity system flexibility to accommodate higher penetration levels of RES, etc.

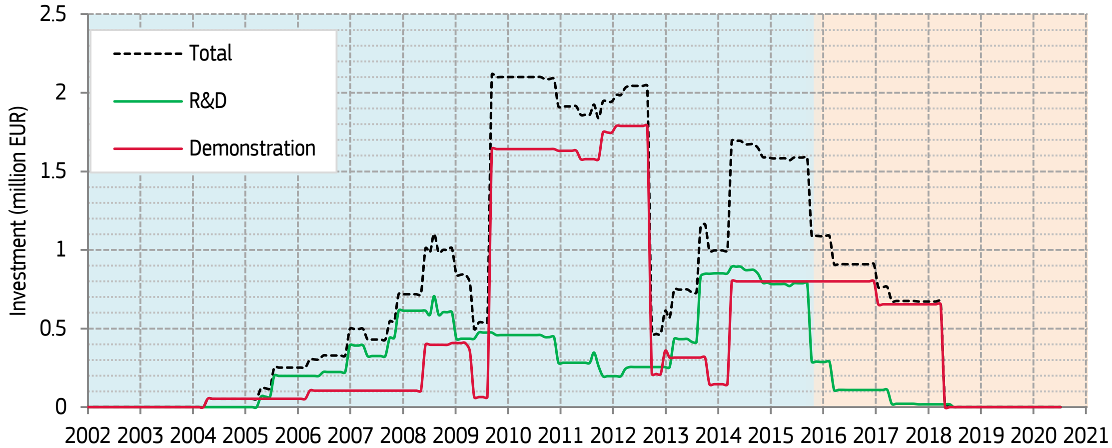
Universities and research centres show the highest interest in this domain, closely followed by technology manufacturers and TSOs (Figure 63). Nearly all the investment allocated to this domain come from multinational projects.

Figure 63. Distribution of total investment associated with integration of L_RES per organisation type



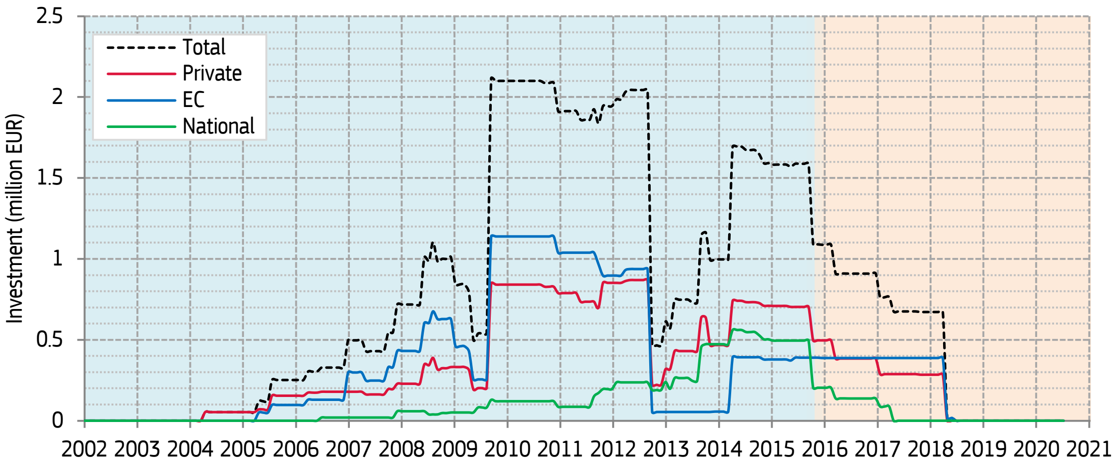
Stage of the innovation cycle: Figure 64 depicts the share of total investment in projects targeting integration of L_RES over the project lifetime and stage of the innovation cycle. Investment in demonstration projects in this domain exceed the R & D investment by 2010, whereas by 2014 the R & D investment rises above the demonstration project investment owing to innovative projects targeting for instance, wind and solar-based grid support services at EU level and development of a European market for ancillary services, development of ICT solutions for providing balancing power using virtual power plants with intermittent RES, etc. In this regard, for instance, the REserviceS project promotes efficient and economic deployment of large shares of renewable energy sources by exploring how wind and solar photovoltaic plants can provide such services in the future European power system.

Figure 64. Distribution of investment associated with integration of L_RES over the project lifespan and per stage of the innovation cycle



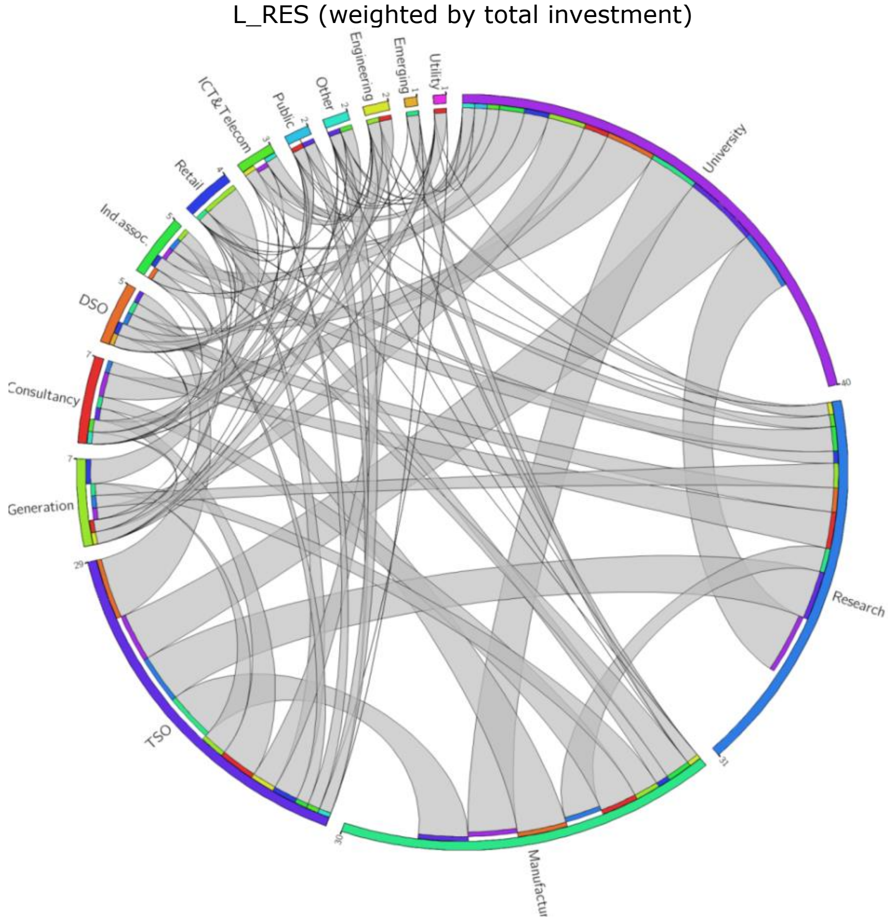
Financing: In what concerns the type of financing, in 2010 there was an evident increase of EU funding supporting this domain (Figure 65). This partly results from initiation of one of the largest renewable energy demonstration project in that year, the TWENTIES project, co-funded by EU under its FP7. Its aim was to advance the development and deployment of new technologies, which facilitate the widespread integration of more onshore and offshore wind power into the European electricity system by 2020 and beyond. Other projects in that period focus on the optimisation of RES infeed (primarily onshore- and offshore-wind energy) using pumped storage power plant and the development of market mechanisms for ensuring electricity system adequacy and efficiency while integrating large amounts of RES generation. Furthermore, a set of projects have started in 2014, mainly targeting novel technologies to increase the pan-European transmission network capacity and electricity system flexibility. Their aim is to accommodate growing RES penetration levels and deployment of wind and solar-based grid support services at EU level, thus contributing to the design of the EU market for ancillary services.

Figure 65. Distribution of total investment associated with integration of L_RES over the project lifespan and per type of financing



Synergies and collaboration links: Figure 66 shows the collaboration links among different stakeholders in this domain. We see that universities are the stakeholders showing the highest involvement, very closely followed by research centres, technology manufacturers and TSOs.

Figure 66. Collaboration links between different types of organisations investing in integration of L_RES (weighted by total investment)



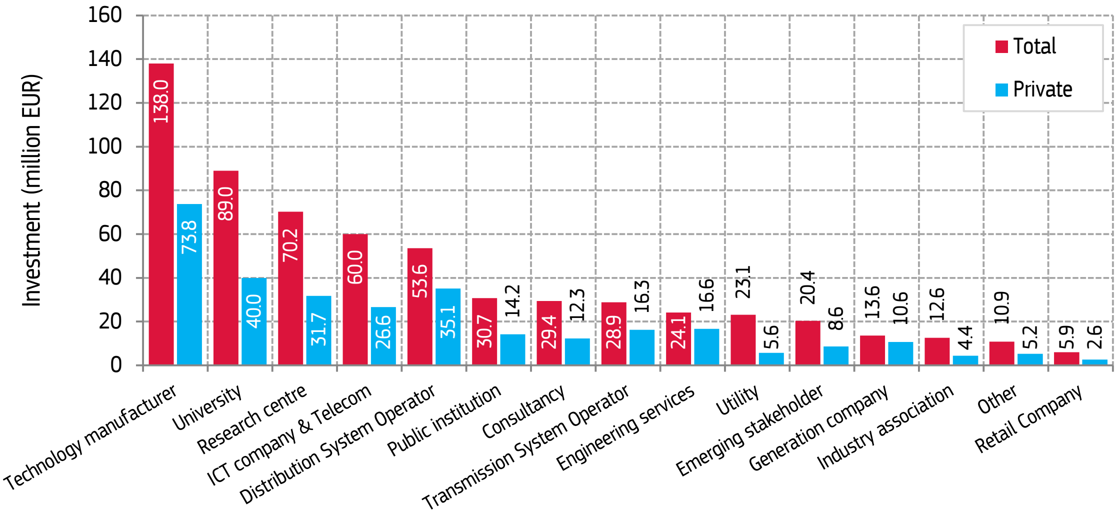
It is interesting to note that the highest TSOs investment is allocated to projects where they collaborate with DSOs, and this again shows the need for increased coordinating activities between these two actors, spanning the domains of energy markets, system operations, network planning and data handling.

5.3.5 Electric mobility

This domain addresses the integration of EVs and vehicle-to-grid applications, including the development and deployment of charging infrastructure, smart-charging strategies and ICT services for electric mobility.

Technology manufacturers are the stakeholders who most invest in this domain, which includes the automotive industry, providers of charging infrastructure, charging and drive systems, etc. (Figure 67). There is also an evident share of investment attributed to DSOs, with most of the DSOs located in the Germany, Spain, Italy, the Netherlands and the United Kingdom. Typical applications in this regard address the impact of EVs on the reinforcement costs of low-voltage (LV) networks, including smart charging strategies, new business models for public charging infrastructure and optimised integration of EVs into the grid, development of European wide market place for electric mobility and related services (e.g. roaming).

Figure 67. Distribution of investment associated with E-mobility per stakeholder category



Financing and stage of the innovation cycle: Figure 68 andFigure 69 illustrate the investment in this domain over the project lifetime per stage of development and type of financing, respectively. Most of the projects in this domain are demonstration projects, with highest investment in the course of 2013-2014. R & D applications cover testing the conformance, interoperability and performance of the different systems (electricity system, charging infrastructure, etc.) to be included in the infrastructure for smart charging of EVs.

Regarding the financial support, we observe a steep increase of national funding in 2012 and this is mainly attributed to the ICT for electric mobility II technology programme ([33]), by the German federal ministry for economic affairs and energy. This programme supports 18 projects (all included in our database) focusing on new ideas and technologies for interaction between smart vehicle systems in the electric car (Smart car), smart power supply (smart grid) and smart mobility concepts (Smart traffic). The largest R & D project in the context of this programme is the econnect Germany project,

([33]) More information on the programme is available at: https://www.bmwi.de/Redaktion/EN/Artikel/Industry/electric-mobility-r-d-funding.html which is a research alliance between industry partners, universities and municipalities with a main focus on sustainable mobility concepts within the communal area.

Figure 68. Investment associated with the E-mobility domain over the project lifespan and per stage of development

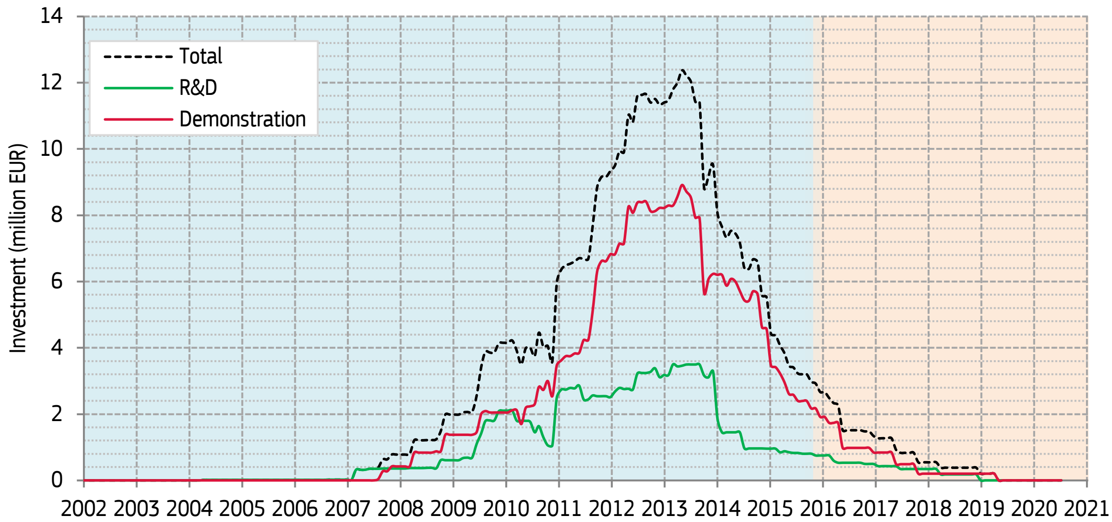
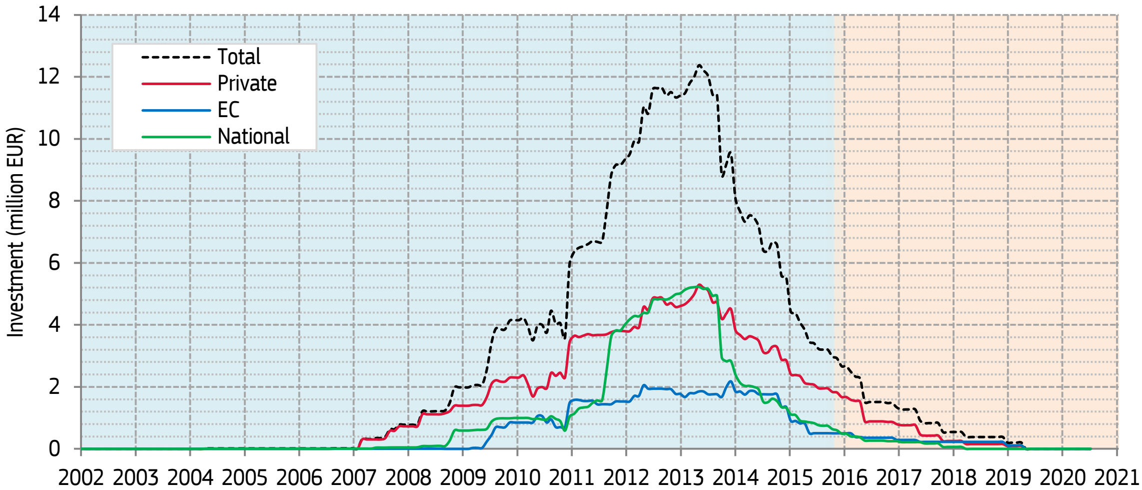


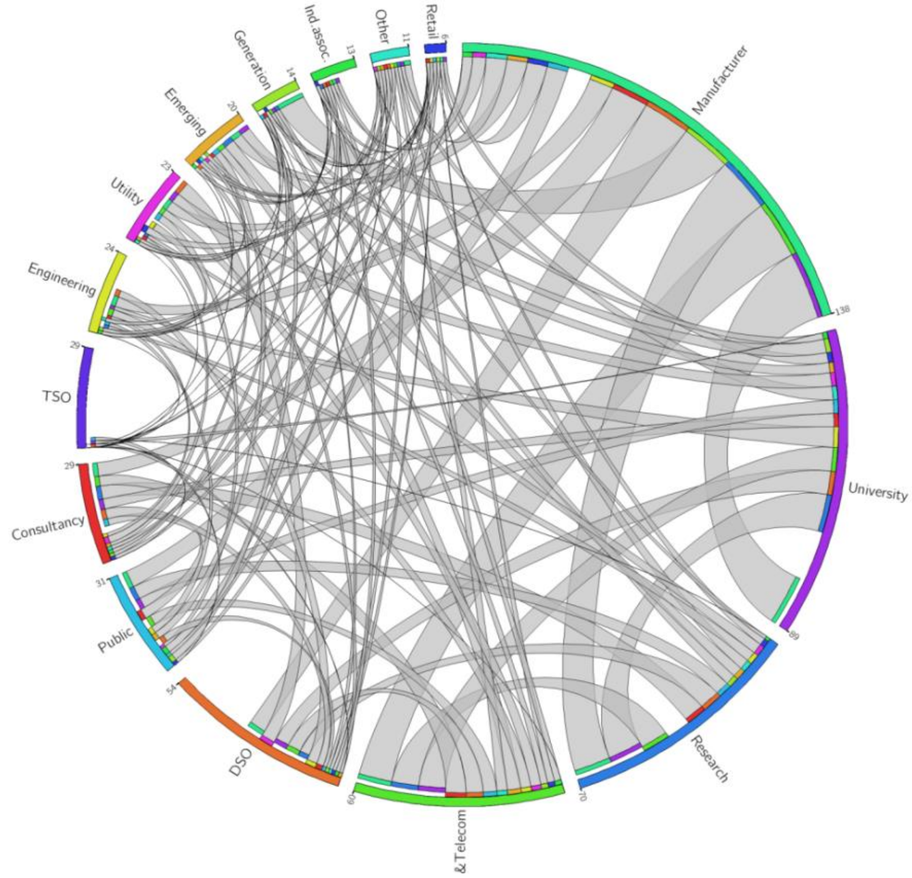
Figure 69. Investment associated with the E-mobility domain over the project lifespan and per type of financing



Synergies and collaboration links: Figure 70 depicts the collaboration links among different actors active in this domain. We see that the technology manufacturers, the stakeholders showing the highest investment, mostly collaborate with universities followed by ICT and telecom companies, research centres and generation companies. We also observe that nearly half of the investment allocated to DSOs is invested in collaboration with other DSOs. The main area of interest for DSOs in this domain is the development of smart/coordinated charging strategies, so that the impact of large-scale EV penetration on the grid is minimised, while at the same time having the distribution network benefiting from flexibility services provided by EV owners.

Furthermore, projects in this domain also address the potential role of the DSOs as owner and technical operator of the EV-charging infrastructure, as an extension of their regulated assets, while commercial operation of the charging posts could be handled by a market party. Nevertheless, project findings outline that the business models for electric mobility may only prove viable if combined with a multitude of basic and advanced services to the driver, thus placing the ICT sector and technology manufacturers as key actors in the large-scale deployment of electric mobility (e.g. Green eMotion project).

Figure 70. Collaboration links between different types of organisations investing in E-mobility (weighted by total investment)



5.3.6 Other

This domain includes projects focusing on topics which could not be grouped under any of the previous domains. Typical applications target areas such as market and regulation (e.g. identification of research and technology gaps for emerging and future roles of DSOs in the European electricity system), cybersecurity (development of novel cybersecurity means for critical infrastructures), development of energy infrastructure roadmaps in EU.

The stakeholders showing the highest interest in this domain are public institutions, that includes municipalities, energy agencies, ministries, chambers of commerce and industry, etc. Large investment in this domain goes to projects focusing on the definition of a conceptual framework for the energy transition of cities into smart cities and communities.

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6 Future work

The Report provides an overview of the main trends and developments in the field of smart grids in Europe. It offers policymakers and different stakeholders a tool to understand the rapidly changing scene and to anticipate the direction Europe is taking.

In its role as an independent observer of the energy system, the JRC will continue to collect and analyse smart grid project data and to monitor the innovation process in Europe. Special attention will be given to the identification of success stories and best practices that can be used as a source of inspiration for similar initiatives. In the field of smart grids, knowledge sharing is indeed of fundamental importance to stimulate regulators to design tailored incentive schemes, to inspire public authorities to replicate initiatives successfully tested elsewhere and to inform companies' investment strategies.

Work is also under way to expand to scope of the Outlook and to focus more on smart grid stakeholders and their interactions. The aim of this work is to support the mapping of national and regional capacities and the identification of smart grid value chains as a means to foster international and interregional collaboration in this field. Future work will also be devoted to perform focused analysis on specific themes, such as energy communities, energy poverty and vulnerable consumers, thus contributing to policy development towards a fair and more sustainable energy system.

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Country codes

EUROPEAN UNION			
EU 28 / EU27 / EU25 / EU15 / EU 12	BE	Belgium
	DE	Germany
	DK	Denmark
	EL	Greece
	ES	Spain
	FR	France
	IE	Ireland
	IT	Italy
	LU	Luxemburg
	NL	Netherlands
	PT	Portugal
	UK	United Kingdom
EU 28 / EU27 / EU25 / EU15	AT	Austria
	FI	Finland
	SE	Sweden
EU 28 / EU27 / EU25	CY	Cyprus
	CZ	Czech Republic
	EE	Estonia
	HU	Hungary
	LT	Lithuania
	LV	Latvia
	MT	Malta
	PL	Poland
	SI	Slovenia
	SK	Slovakia
EU 28 / EU27	BG	Bulgaria
	RO	Romania
EU 28	HR	Croatia

OTHER COUNTRIES	
AL	Albania
AU	Australia
AZ	Azerbaijan
BA	Bosnia and Herzegovina
BY	Belarus
CH	Switzerland
CN	People's Republic of China
IL	Israel
IN	India
IS	Iceland
KR	South Korea
LI	Liechtenstein
MC	Monaco
ME	Montenegro
MK	The former Yugoslav Republic of Macedonia
NO	Norway
RS	Serbia
RU	Russia
TR	Turkey
US	United States of America

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List of abbreviations and definitions

Aggregator	A legal entity that aggregates the load or generation of various demand and/or generation/production units. Aggregation can be a function that can be met by existing market actors, or can be carried out by a separate actor (Expert Group 3 - Smart Grid Task Force, 2015).	
Ancillary service	A service necessary for the operation of a transmission or distribution system (Directive 2009/72/EC).	
	Cohesion Fund	CF
	Competitiveness and innovation framework programme	CIP
Demonstration	A preview phase before marketing, during which a technology or solution is tested in different operational environments, through to full market trials in which the technology is used in customer installations (Brown & Hendry, 2009).	
Demand side management	A global or integrated approach aimed at influencing the amount and timing of electricity consumption in order to reduce primary energy consumption and peak loads (Directive 2009/72/EC).	
Distributed energy resources	Smaller power sources that can be aggregated to provide power necessary to meet regular demand.	DER
Distributed generation	Generation plants connected to the distribution system (Directive 2009/72/EC).	DG
Distribution system operators	A natural or legal person responsible for operating, ensuring the maintenance of and, if necessary, developing the distribution system in a given area and, where applicable, its interconnections with other systems and for ensuring the long-term ability of the system to meet reasonable demands for the distribution of electricity'. In this report, under the DSO category we included only those DSOs serving more than 100 000 connected customers, while those serving fewer than 100 000 connected customers are listed under the category utilities (Directive 2009/72/EC)	DSO
	European Regional Development Fund	ERDF
	Framework programme	FP
	National regulatory authority	NRA
Research and Development	In line with the Frascati manual, by R & D we intend any 'creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications' (OECD, 2002).	R & D

Renewable energy sources	Renewable non-fossil energy sources (wind, solar, geothermal, wave, tidal, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases) (Directive 2009/72/EC).	RES
Smart grid	'An electricity network that can cost efficiently integrate the behaviour and actions of all users connected to it — generators, consumers and those that do both — in order to ensure economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety' (European Commission, SEC(2011) 463 final).	
Technology readiness level	TRLs are indicators of the maturity level of particular technologies. This measurement system provides a common understanding of technology status and addresses the entire innovation chain. There are nine levels; TRL 1 being the lowest and TRL 9 the highest. Annex G of the general annexes to the Work Programme 2016/17 provides a full description of TRLs.	TRL
Transmission system operators	'A natural or legal person responsible for operating, ensuring the maintenance of and, if necessary, developing the transmission system in a given area and, where applicable, its interconnections with other systems, and for ensuring the long-term ability of the system to meet reasonable demands for the transmission of electricity' (Directive 2009/72/EC)	TSO

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Annexes

Annex 1. Other figures

Figure A1. Geographical distribution of total investment normalised per capita (*) and electricity consumption (**)

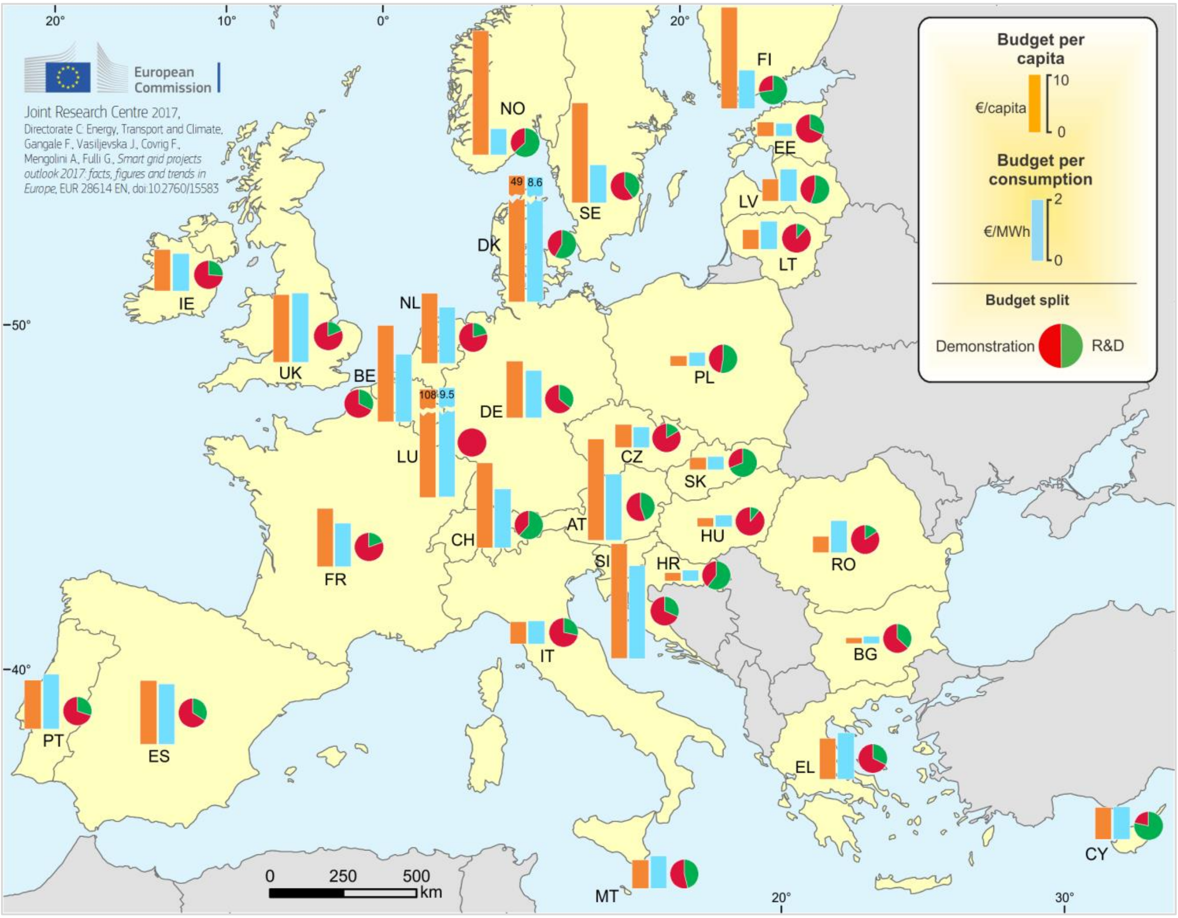
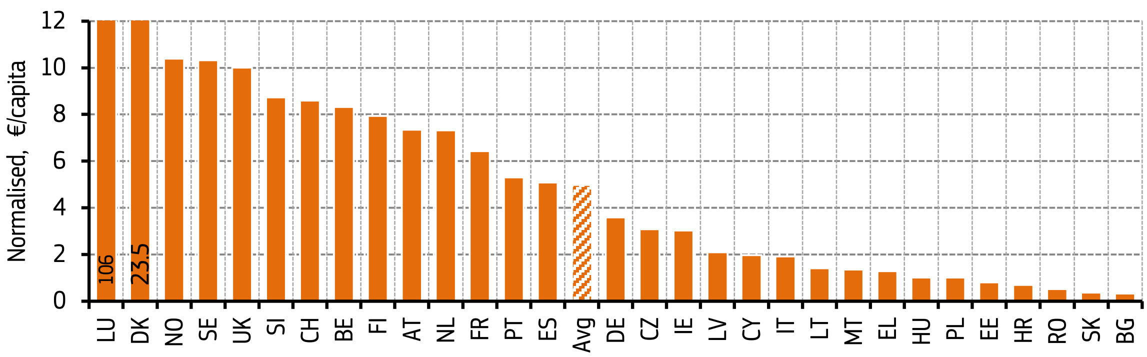
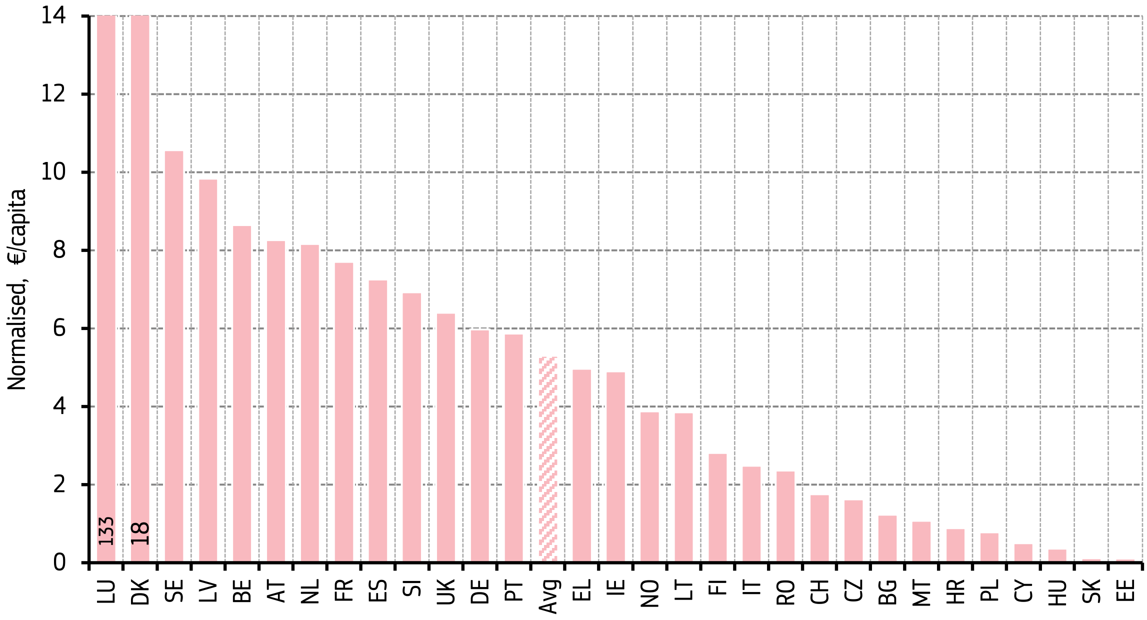


Figure A2. Private investment normalised per capita (*)



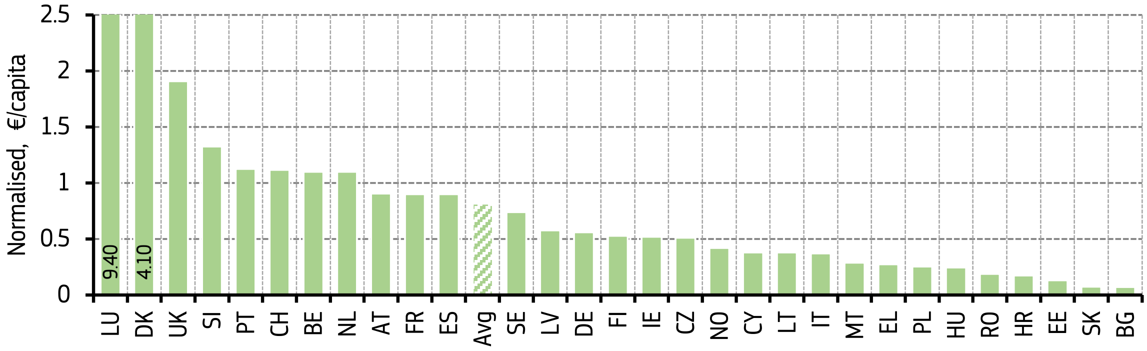
(*) *Source: Own elaboration based on Eurostat data (2015)*

Figure A3. Implementation site investment normalised per capita (*)



(*) *Source: Own elaboration based on Eurostat data (2015)*

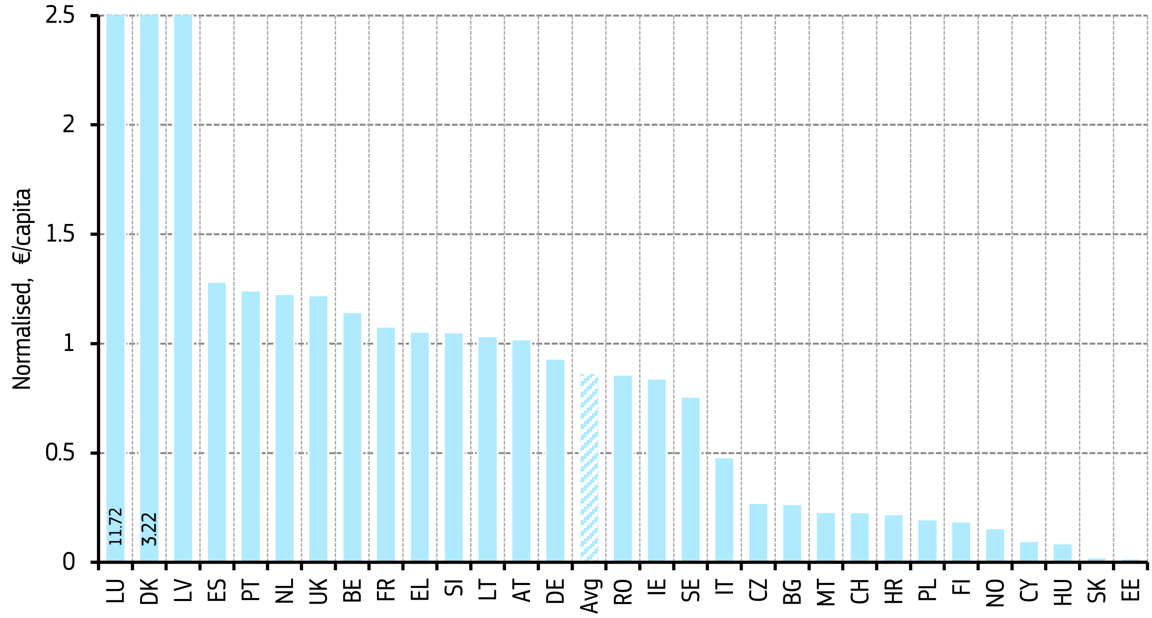
Figure A4. Private investment normalised per electricity consumption (**)



(*) *Source: Own elaboration based on Eurostat data (2015)*

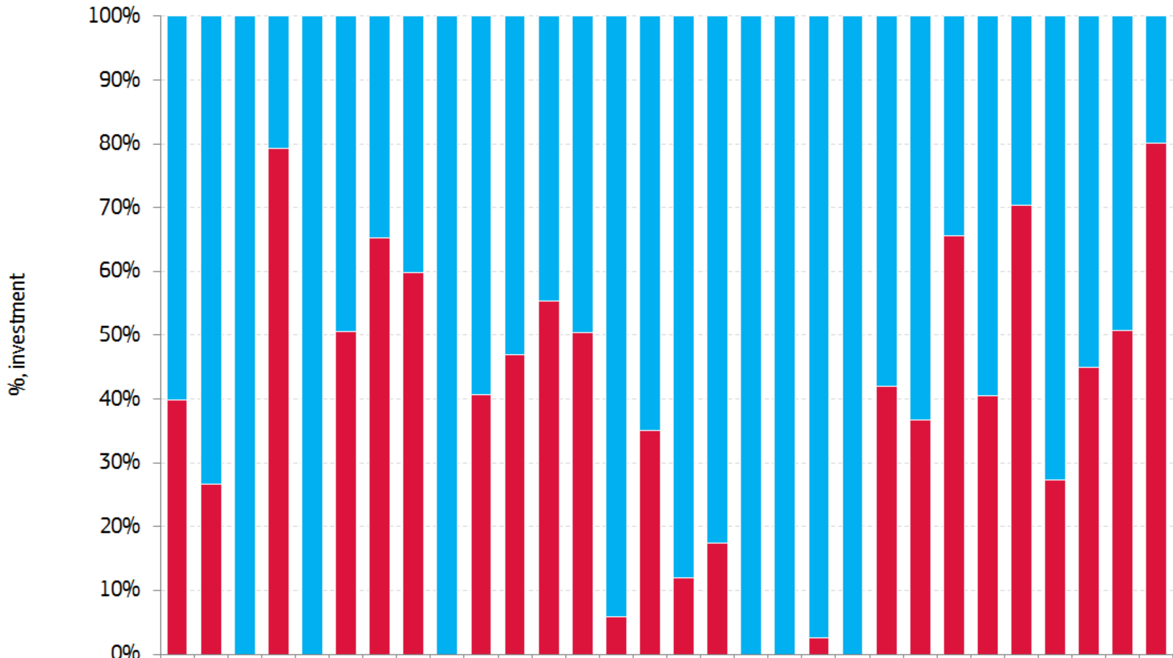
(**) *Source: Own elaboration based on ENTSO-e 2015 data*

Figure A5. Implementation site investment normalised per electricity consumption (**)



(**) *Source: Own elaboration based on ENTSO-e 2015 data*

Figure A6. Investment in national and multinational projects per country



	AT	BE	BG	CH	CY	CZ	DE	DK	EE	EL	ES	FI	FR	HR	HU	IE	IT	LT	LU	LV	MT	NL	NO	PL	PT	RO	SE	SI	SK	UK
Multinational	91	139	8	26	4.8	21	282	112	3.3	47	277	47	338	5.9	10	30	197	10	61	7.5	2.2	121	71	24	53	17	124	23	5.8	154
National	61	51		97		22	528	167		32	245	58	343	0.4	5.5	4.1	42			0.2		88	41	45	36	41	47	19	6	620

Figure A7. Distribution of projects per budget and number of partners

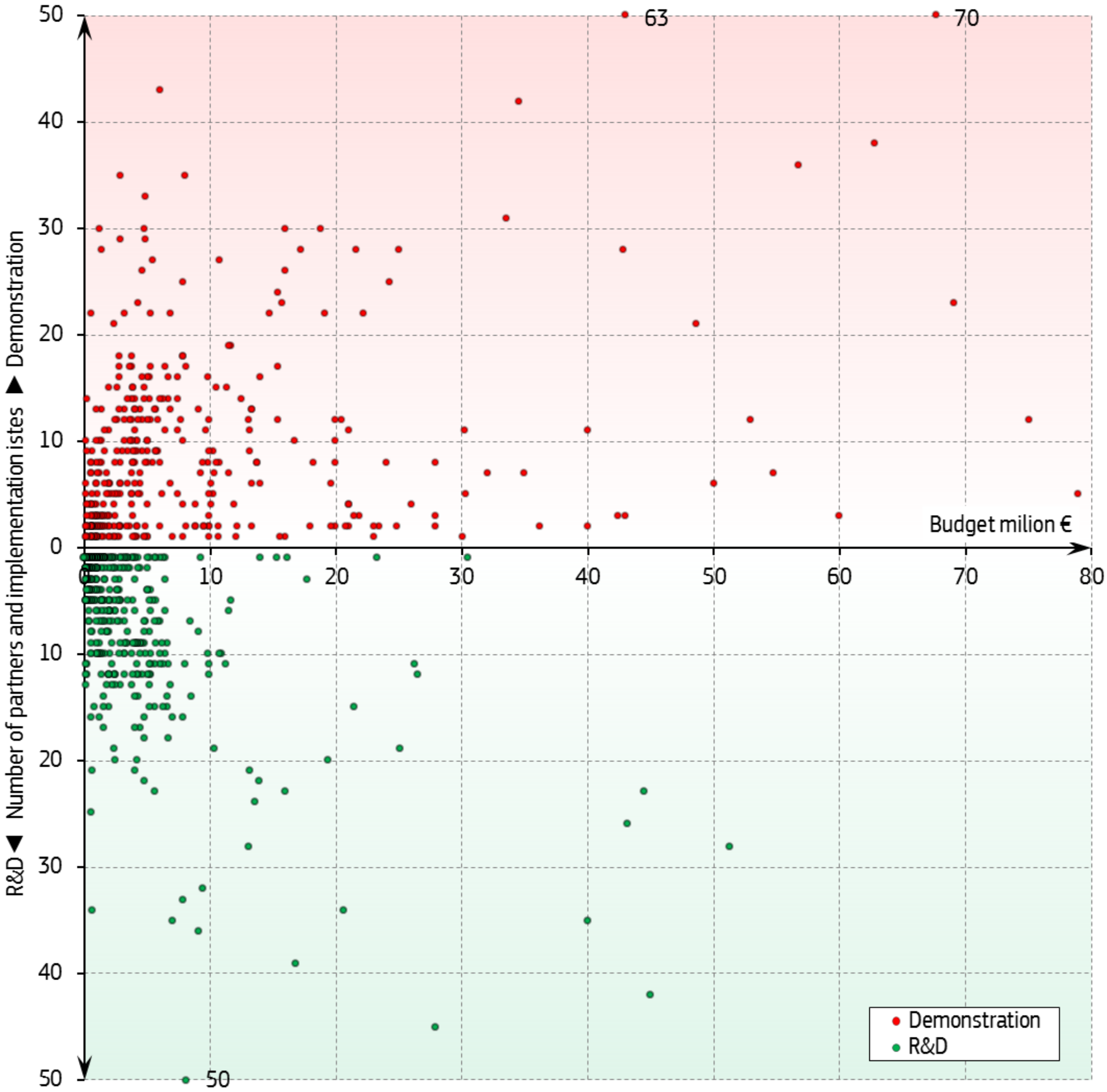


Figure A8. Private R & D and demonstration investment per stakeholder category

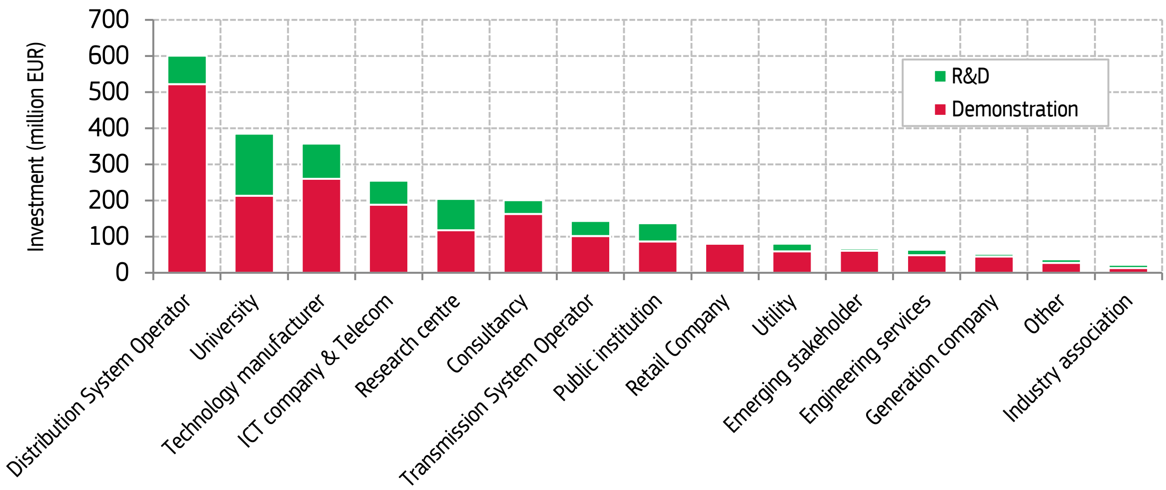


Figure A9. Geographical distribution of total investment per organization type

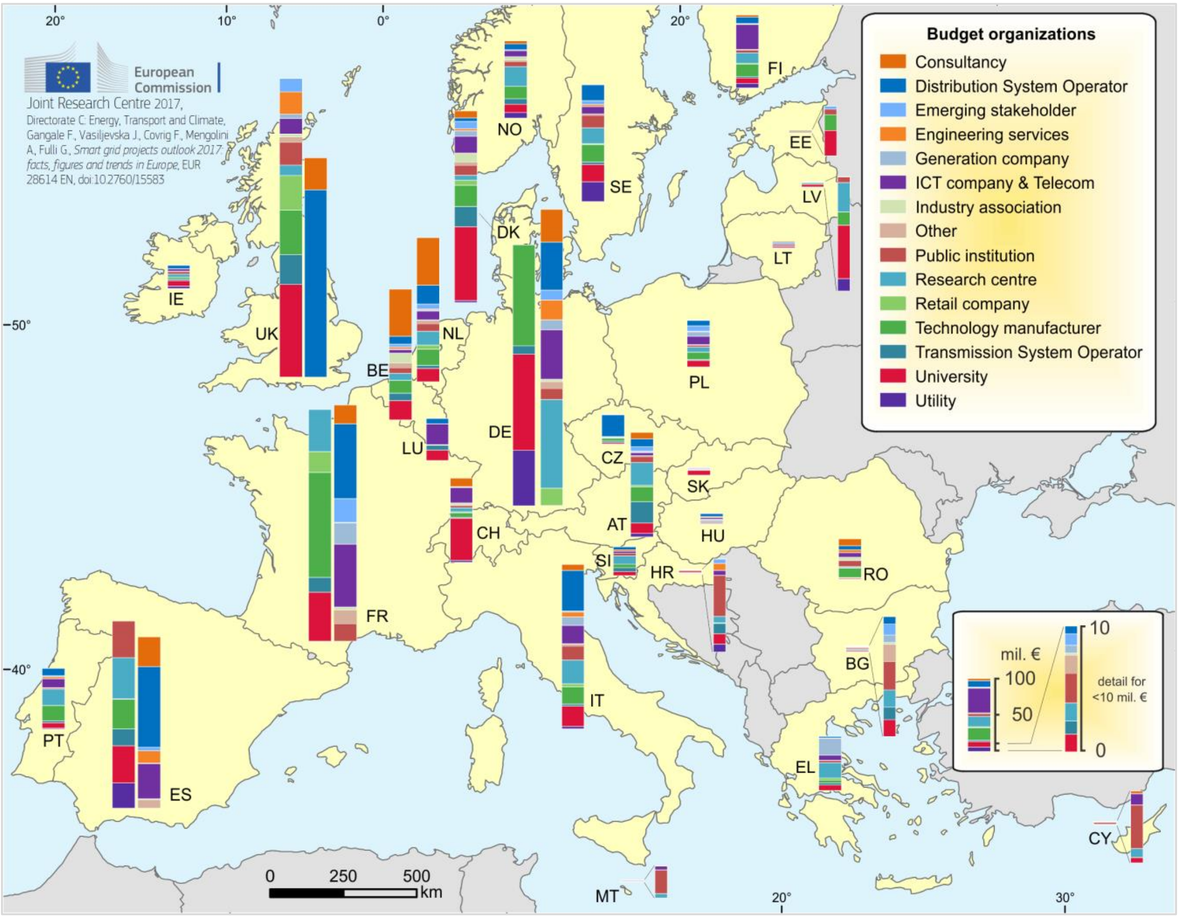


Figure A10. Number of new organizations per year (first time in a smart grid project)

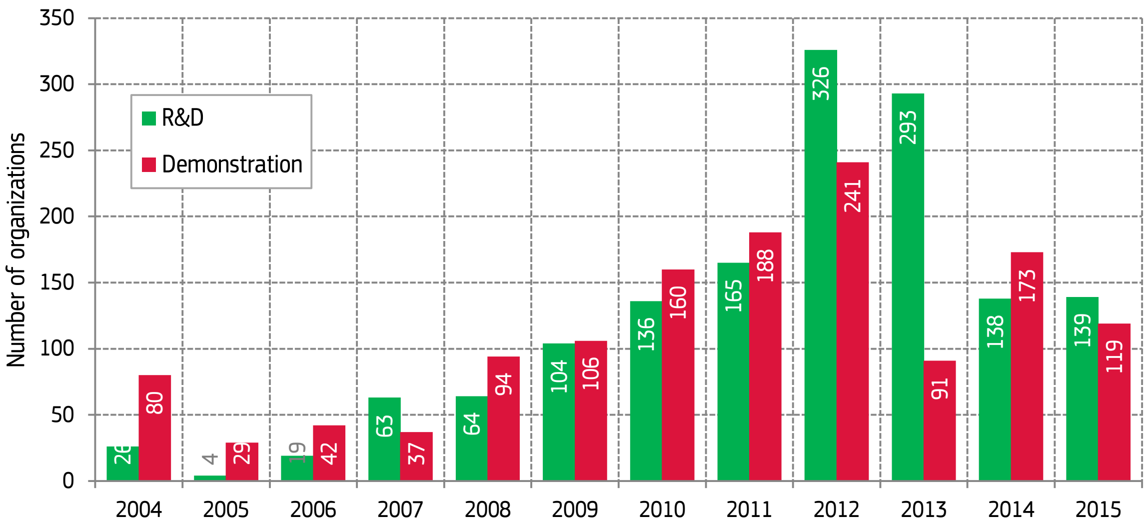


Figure A11. Investment by source of financing and stakeholder category

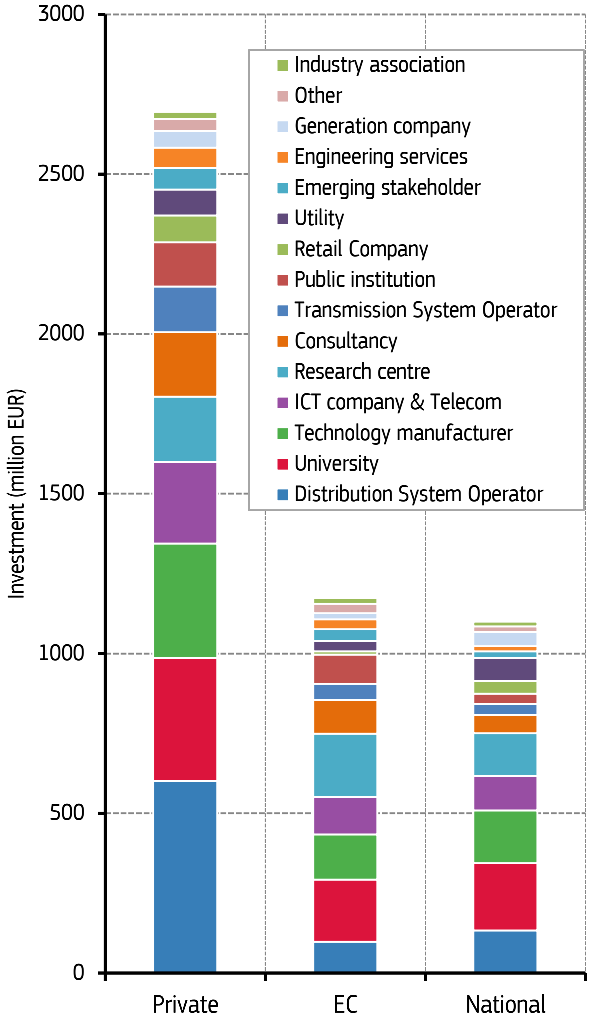


Figure A12. Investment by project domain and project domain

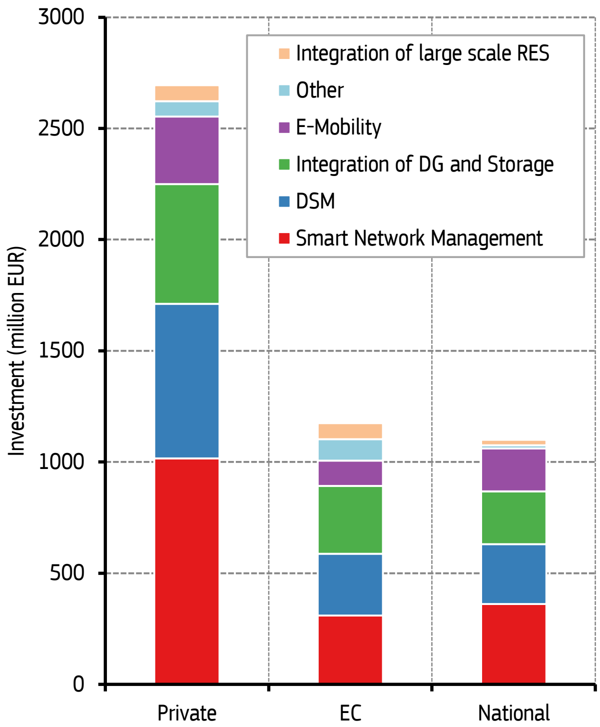


Figure A13. Investment by year and stakeholder category

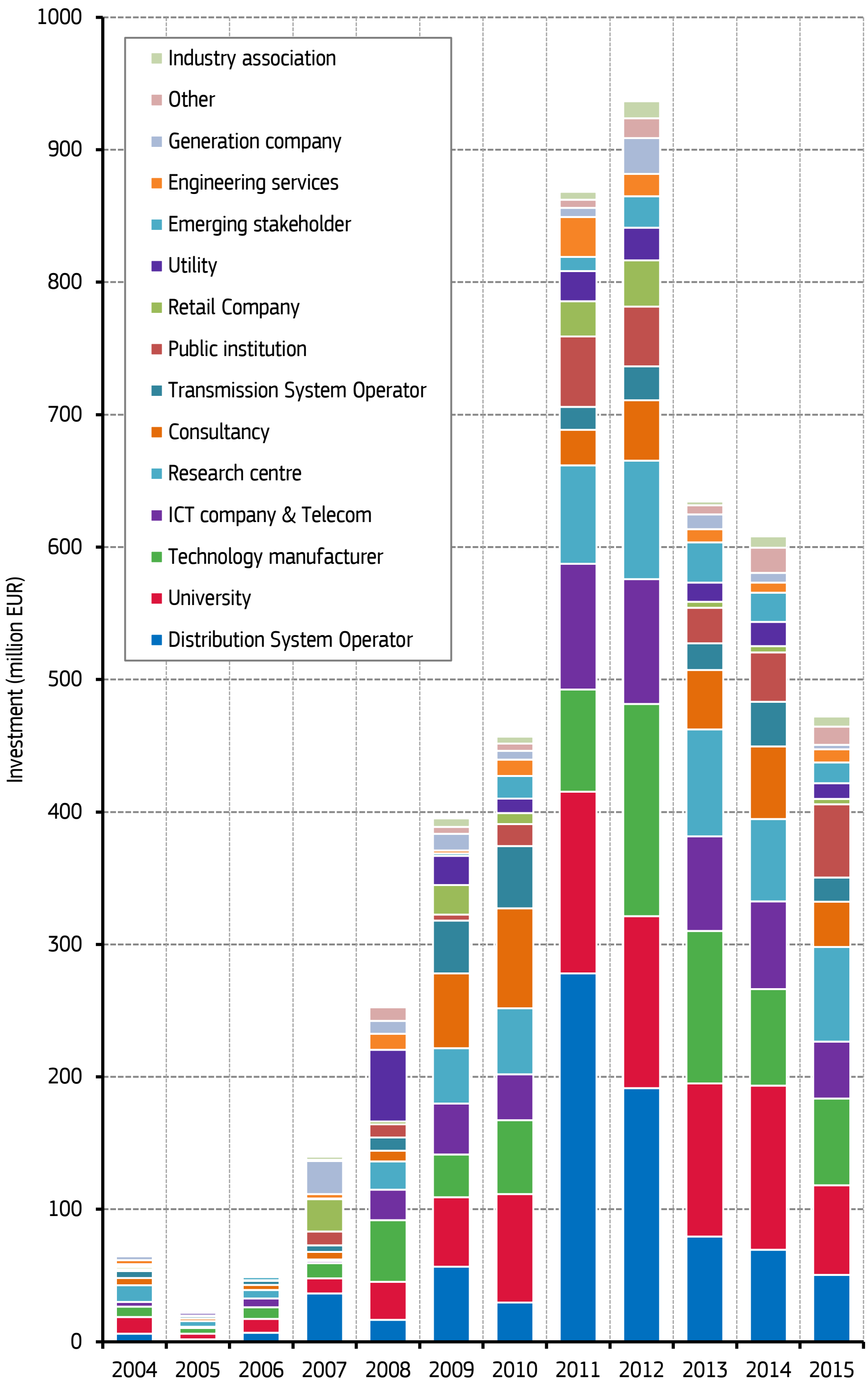


Figure A14. Total investment per smart grid domain and source of funding: Private (left); EU (Centre); National (right)

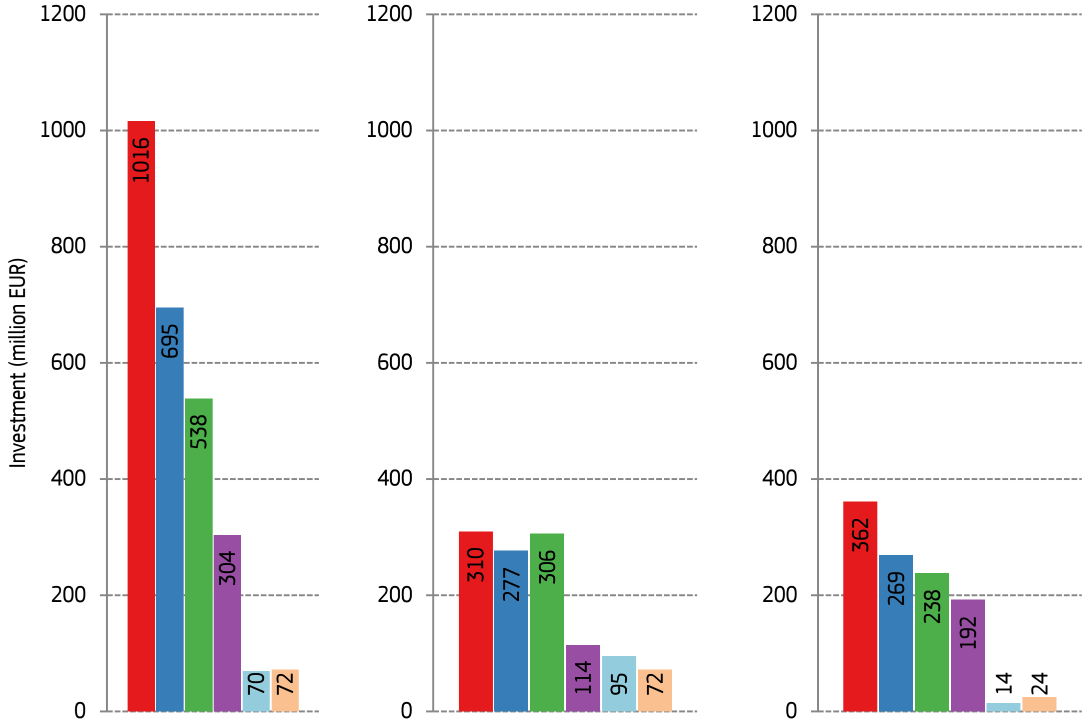


Figure A15. Distribution of total investment per smart grid domain and starting year

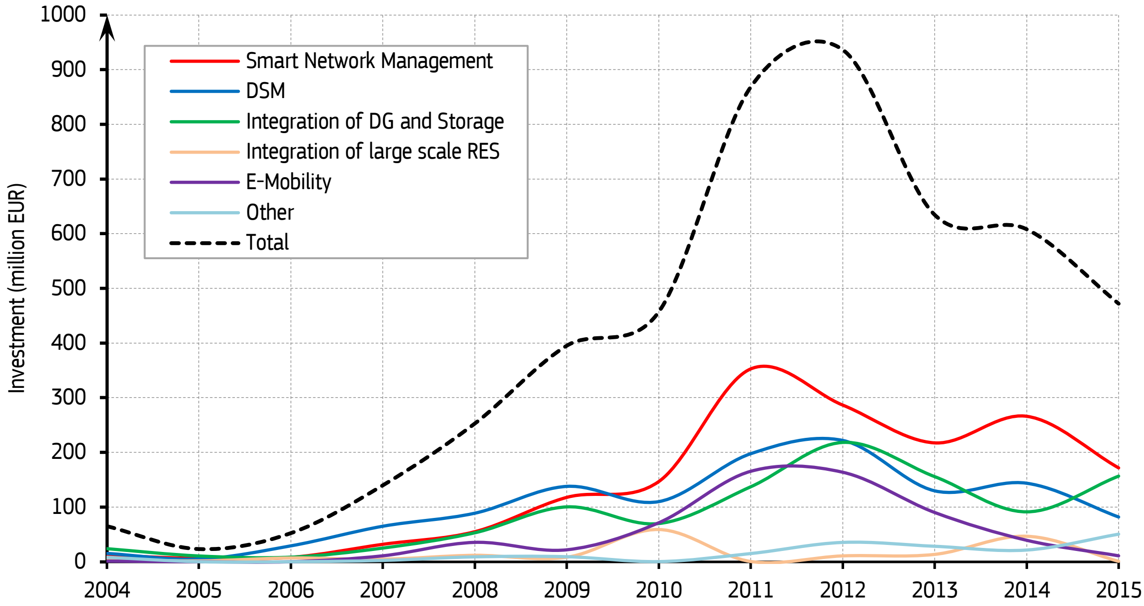


Figure A16. Distribution of average total investment by application and starting year

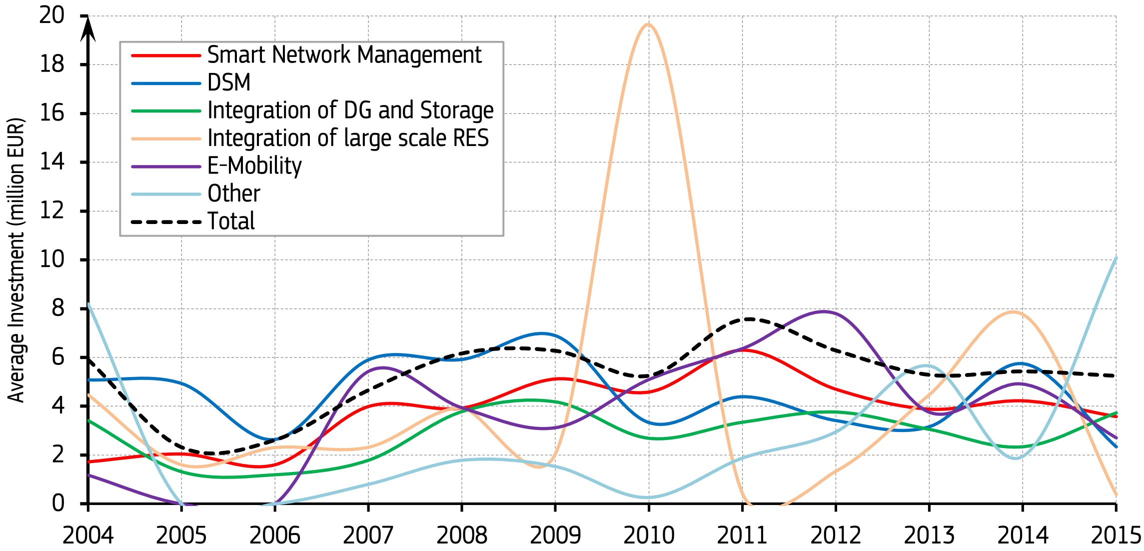


Figure A17. Number of implementation sites per smart grid domain and country

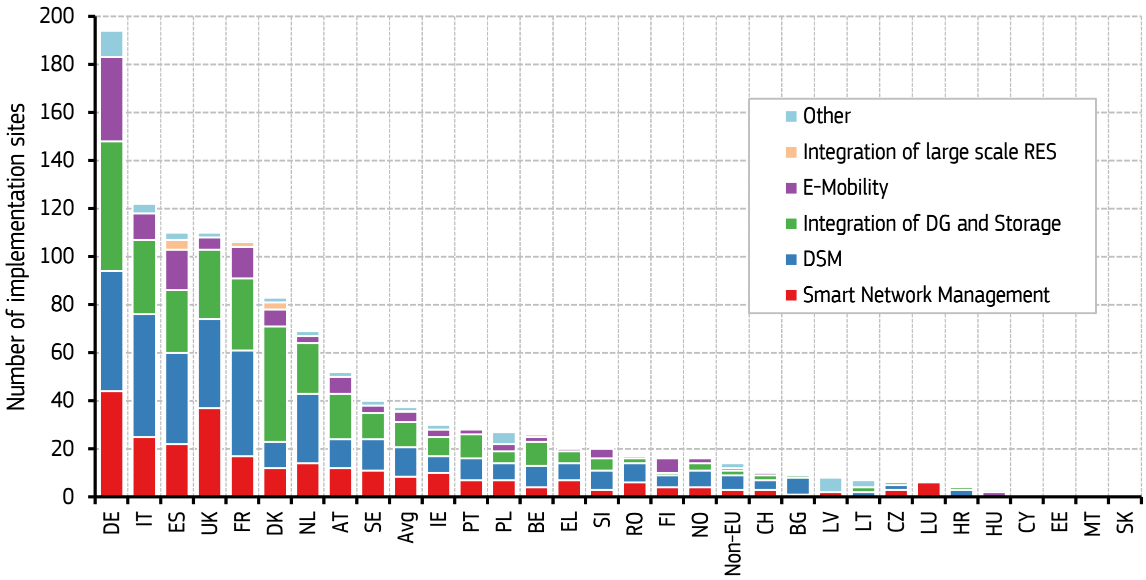
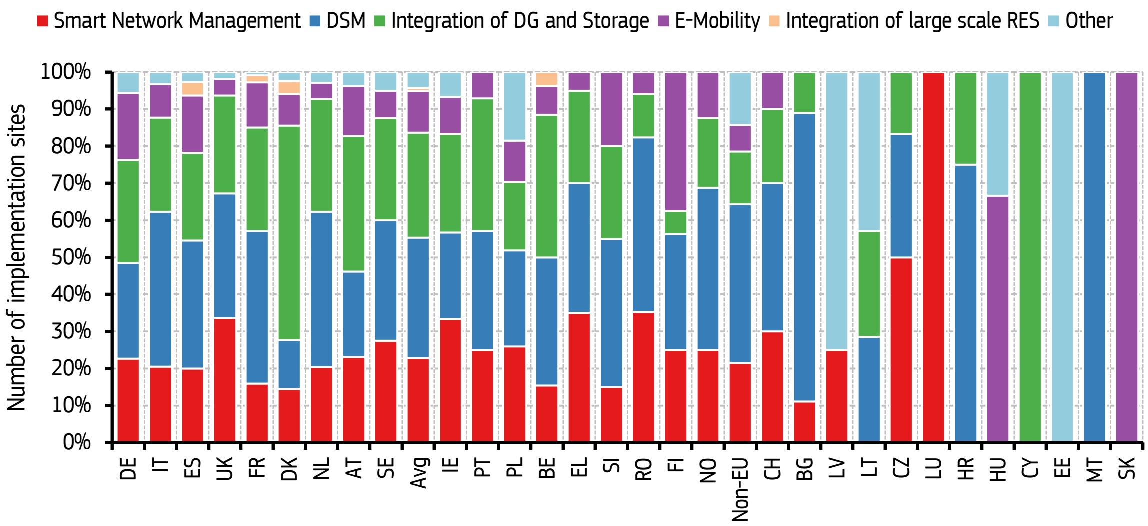


Figure A18. Number of implementation sites per smart grid domain and country



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