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Collective action in the energy sector: insights from EU research and innovation projects

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Abstract

This report analyses EU-funded collective action projects in the energy field. The objective is to provide an overview of the current state of play of relevant research and innovation activities in the EU and to identify the research gaps to be addressed in the future. The report focuses on collective action projects that combine the use of new technologies, business models and community engagement approaches to support consumers in changing the way they use electricity. The analysis is also supported by an overview of projects that address the social dimension of the energy transition and promote the development of collective action initiatives at policy, institutional and societal level.

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Executive summary

Policy context and scope of the report

In recent years, technological innovation and the decreasing cost of technology have made new forms of consumer participation in energy production and management more accessible. Consumers have started to produce, store and consume their own energy and are able to support the operation of power grids and energy market by changing their load patterns. New forms of collective energy action have also started to emerge, enabling a more active role of consumers in the energy system. In some Member States, local communities already get involved in initiatives to collectively reduce energy use, manage energy better, generate or purchase energy. Energy cooperatives, peer-to-peer (P2P) trading and collective self-consumption run within existing legal frameworks, under regulatory exemptions or in the framework of innovation projects.

This new activism by consumers, acting collectively to widen the reach of their endeavours, has been acknowledged by recent EU energy policy documents that address the collective dimension of energy use. The Clean Energy Package (CEP), for example, has elaborated on the central role that collectively acting consumers can play in the energy transition and have established a legislative framework where “jointly acting consumers” and “jointly acting renewable self-consumers” have more opportunities to get actively involved. The CEP also introduced the concepts of “citizen energy communities” and “renewable energy communities” as a way to engage consumers and increase the acceptance of renewables. Communities and individuals are given the right to produce, store, consume and sell their own energy and are recognized as key stakeholders in the new energy system.

The EU has also supported a variety of research and demonstration projects to test and validate innovative approaches of collective action in the energy field and to promote good practice at national, regional and local level.

The objective of this report is to analyse these projects, to provide an overview of the current state of play of relevant research and innovation (R&I) activities in the EU and to identify the research gaps to be addressed in the future. The report focuses on EU-funded **collective action projects** i.e. projects that combine the use of new technologies, business models and community engagement approaches to support a more active participation of consumers in the energy market. More specifically, it focuses on projects that research and test collective level solutions to increase the ability of consuming self-produced and locally generated electricity and to facilitate the uptake of energy efficiency and active demand services. The analysis is also supported by an overview of projects co-funded by the EU to address the social dimension of the energy transition and to promote the emergence and development of collective action initiatives at policy, institutional and societal level (i.e. **projects addressing non-technological challenges**).

By analysing these projects, the Joint Research Centre (JRC) aims to highlight emerging trends in collective energy use in the EU and to contribute to the sharing of knowledge and best practices. It also aims to contribute to the ongoing debate on how funding for research and innovation activities can support an inclusive energy transition.

Main findings

Overall, the report analyses 38 EU-funded projects: *22 collective action projects* and *16 projects addressing non-technological challenges* (i.e. policy, institutional and societal challenges).

Project number. Collective action projects in the energy field are not new in the EU R&I scene, with a pretty constant number of projects starting each year since 2011. Time trend data suggests that the growing attention that collective action grass-root initiatives have attracted at policy level in recent years has not yet been fully reflected in the research and innovation projects carried out to date with EU financial support. More funding is desirable in the future to investigate the technological, economic and social aspects of collective action in the energy sector. New projects are however expected in the framework of H2020 as, at the time of writing, funding is still available under topics that may award more collective action projects. The "Orientation towards the first Strategic Plan implementing the research and innovation framework programme Horizon Europe" also mentions energy communities as potential future research area.

Geographical coverage. Organization participating in *collective action projects* come from a small number of EU Member States, with most countries in central and Eastern Europe showing limited participation. Geographical differences in stakeholder participations depend on a variety of national circumstances. In particular, a supportive legislative and regulatory environment encourages the participation of institutional, commercial and non-governmental actors in innovation projects. Their participation, in turn, strengthens their capacities and expertise, and enables commercial actors to pursue emerging business opportunities at national and international level.

As for *projects addressing non-technological challenges*, the analysis shows a high level of activity in countries with a long tradition of local energy activism, such as Germany, Belgium, the Netherlands and the UK with participation by EU-13 countries in general higher than in collective action projects. This finding seems to suggest a growing interest in collective action initiatives in these countries, interest that research and public institutions, as well as civil society associations, are trying to capture, ahead of more technological stakeholders.

Future EU-funded projects should try to cover more geographical areas and to increase the participation of underrepresented countries. This would help them to strengthen the scientific and networking capabilities of national stakeholders and to bring about more widespread and quicker uptake of solutions and best practices for the active participation of consumers in the energy market.

Targeted sectors. The majority of *collective action projects* are targeted at the residential sector only, while some projects also involve the commercial and public sectors. The inclusion of other sectors in the scope of the projects is an interesting development, as it is in line with the idea of a multi-stakeholder, municipally-based partnership, which is at the core of an integrated community-oriented approach.

Key conclusions

Technologies tested. The *collective action projects* surveyed trial a variety of different technological solutions that revolve around collective energy demand side management as a means to improve local energy management, reduce energy consumption and costs for consumers, improve energy independency and support participation in local flexibility markets.

Projects combine the demonstration of innovative technological solutions, business models and community engagement approaches to support consumers in changing the way they use electricity. To effectively support the deployment of innovative technological solutions, future R&I projects should increasingly combine these three aspects.

Stakeholder's categories. Overall, *collective action projects* display a high participation of traditional stakeholders (e.g. universities and research centres, DSOs, technology manufacturers), and a moderate participation of emerging actors, newer in the energy research and innovation arena, such as public institutions, energy cooperatives and local/not-for-profit organisations.

Participation by a wide range of organisations, with different roles and expertise, should be encouraged as it helps to enrich the debate and add new perspectives, including from a geographical point of view.

Future R&I projects should promote wider participation by different stakeholder categories and encourage collaboration between existing and new players in flexibility services to test innovative business models.

Consumer engagement. The *collective action projects* surveyed reveal that engagement interventions based on community dynamics and on the sense of a community-based initiative can offer a valid support to promote behavioural change and reach the project goals. Although most projects emphasise the importance of the social context in which consumers live and operate and introduce the project goals as community's achievements, many of them still focus mostly on the technical level, giving only a theoretical relevance to the social dimension associated with energy practices. In the future, it is desirable that projects translate theory into practice and associate social science and humanities-related work more closely with the development of technological solutions.

A well-designed engagement strategy appears to be key to bringing participants together with a common purpose and achieve the project objectives. The engagement strategy should be constantly reviewed during the course of the project to transpose the interim results of the interventions deployed.

Future R&I should draw upon and add to the body of knowledge that has been developed by past EU-funded projects, adapting their findings to the local and specific circumstances. Efforts should be made to make the new knowledge developed within the projects available to a wide range of stakeholders, well beyond the project closing.

Related and future JRC work

The JRC continues to conduct research on sociotechnical aspects of the energy transition and on how the collective dimension of energy use can contribute to an inclusive energy transition. The JRC will carry on analysing research and innovation projects at national and European levels with the aim to support early identification of the challenges and opportunities that the use of digital technologies and other innovative solutions can present for EU consumers' living conditions.

1 Introduction

1.1 Policy context

The European Union's energy system is undergoing a profound transformation driven by the need to reach the EU climate objectives through further decarbonisation and to supply secure and affordable energy to consumers and businesses (European Commission, 2019) (IRENA, 2019).

The process of electrification of the energy system and its digitalisation is one of the key enablers of this transformation (IRENA, 2019). Developing a power sector that combines widespread electrification and digital technologies with renewable sources is considered crucial to achieve carbon neutrality by 2050 (European Commission, 2018). By linking different energy carriers, energy system integration will allow consumers to embrace cleaner energy alternatives.

In the last decade, the European power sector has seen a sharp increase in the share of distributed and renewable energy sources (RES). This shift from generation in large central installations towards decentralised production of electricity from renewable sources is challenging the technical and economic efficiency of incumbent network management arrangements, requiring the development of new strategies for handling a more decentralized system. A variety of supply and demand side solutions need to be developed and trialled in order to facilitate the transition to the new energy system, harnessing flexibility in all of its parts (IRENA, 2018).

According to the directive on common rules for the internal market for electricity*, "consumers have an essential role to play in achieving the flexibility necessary to adapt the electricity system to variable and distributed renewable electricity generation"* (The European Parliament and the Council of the European Union, 2019). Empowering and providing consumers with the tools to participate more in the energy market, will help to achieve the EU renewable energy targets and enable EU citizens to benefit from the internal market for electricity (The European Parliament and the Council of the European Union, 2019; European Commission, 2019).

New forms of consumer participation in energy production and management are becoming more accessible thanks to technological innovation and the decreasing cost of technology (Council of European Energy Regulators, 2019). Consumers have started to produce, store and consume their own energy and are able to support the operation of power grids and energy market by changing their load patterns. New forms of collective energy action have also started to emerge, enabling a more active role of consumers in the energy system. In some Member States, local communities already get involved in initiatives to collectively reduce energy use, manage energy better, generate or purchase energy (Council of European Energy Regulators, 2019). Energy cooperatives, peer-to-peer (P2P) trading and collective self-consumption run within existing legal frameworks, under regulatory exemptions or in the framework of innovation projects.

This new activism by consumers, acting collectively to widen the reach of their endeavours, has been acknowledged by recent EU energy policy documents that address the collective dimension of energy use (see Box 1). The Clean Energy Package (CEP), for example, has elaborated on the central role that collectively acting consumers can play in the energy transition and has established a legislative framework where "jointly acting consumers" and "jointly acting renewable self-consumers"[1] have more opportunities to get actively involved. Communities and individuals are given the right to produce, store, consume and sell their own energy and are recognized as key stakeholders in the new energy system. The CEP also provide the definitions of "citizen energy community" and "renewable energy community" which are both formulated as a particular way to organise collective actions around a specific energy-related activity, specifically through a legal entity (RESCoop, 2019). A recent study of the European Commission argues that energy communities represent an opportunity for the consumer to benefit of the digitalisation of the energy sector (European Commission, 2019). More recently, the European Green Deal communication has highlighted the need to further empower regional and local communities, including energy communities, thus acknowledging the collective dimension of energy use in the transition to a more sustainable energy future (European Commission, 2019).

In recent years, collective action initiatives, usually referred to as community energy initiatives (Walker & Devine-Wright, 2008) (Gregg, et al., 2020), have also been extensively investigated in the social sciences to understand their potential to influence the way energy is produced, distributed, consumed and stored. Recent studies show that in a collective action context, consumers are willing to sacrifice part of their comfort to reduce energy use, even in the absence of direct financial benefits (Kandul, Lang, & Lanz, 2020). Leveraging on communal motives appears to be a promising way to enhance involvement in community energy initiatives and foster sustainable behaviour among people who may not otherwise be interested in environmental protection (Sloot, Jans, & Steg, 2019). Community energy initiatives can also help to mitigate energy poverty (Hanke & Lowitzsch, 2020), thus contributing to a social and just energy transition.

In this report, we do not look specifically into energy communities, but we rather keep a wider focus and look into how collective action has been experimented in R&I projects in the EU to support the EU ambitious energy goals. By analysing the technological solutions tested and the engagement strategies deployed at collective level, the report aim is to provide insights on how collective action project can positively contribute to flourishing energy communities. In times when the implications of the COVID-19 crisis for energy systems and clean energy transition are still evolving, the report aims to highlight the current R&I efforts towards a more sustainable energy future with consumers and communities at its centre.

[1] As defined in the Electricity Directive and the Renewable Energy Directive respectively ((The European Parliament and the Council of the European Union, 2018) (The European Parliament and the Council of the European Union, 2019).

Box 1. From energy consumers to collectively acting energy citizens in EU energy policy

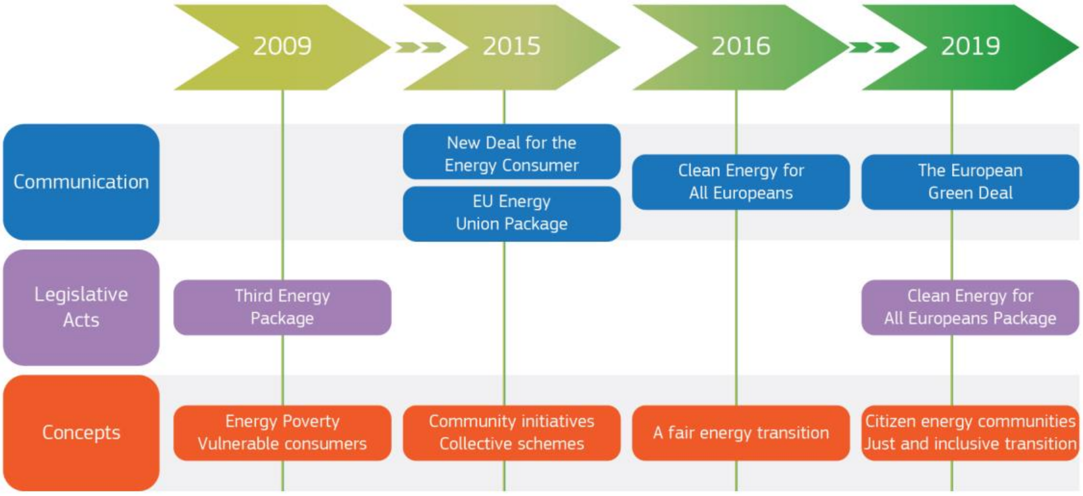
The energy consumer has been acquiring an increasing central role in EU energy policy documents (Figure 1). The 2015 **Energy Union strategy** (European Commission, 2015) places citizens at its core and recognizes that by taking ownership of the opportunities allowed by the energy transition, they can "*benefit from new technologies to reduce their bills, participate actively in the market*" and contribute to an energy transition *"where vulnerable consumers are protected*".

The communication "**Delivering a New Deal for Energy Consumers**" (European Commission, 2015) further clarifies the role of the consumer in the energy transition. It recognises that the combination of decentralized generation with storage options and demand side flexibility "*can further enable consumers to become their own suppliers and managers for (a part of) their energy needs, becoming producers and consumers and reduce their energy bills".*

While the New Deal recognizes that consumers increasingly participate in collective schemes and community initiatives, "*to better manage their energy consumption",* it is only with the **Clean Energy for All Europeans** (European Commission, 2016) that the collective dimension of energy use is fully acknowledged. The focus shifts from the individual consumer acting in isolation to the collective dimension of energy use and to how this can contribute to a more inclusive energy transition. Indeed, the communication highlights that community energy represents an inclusive option for all consumers "*to have a direct stake in producing, consuming and or sharing energy between each other*" and in fighting energy poverty through reduced consumption and lower supply tariffs. Community energy initiatives directly engage with consumers and therefore can be best suited "*in facilitating the up-take of new technologies and consumption patterns, including smart distribution grids and demand response, in an integrated manner*". It is recognized that "*where they have been successfully operated such initiatives have delivered economic, social and environmental value to the community that goes beyond the mere benefits derived from the provision of energy service*". The appropriate legal framework has been put in place with the adoption of the Electricity Directive and the Renewable Energy Directive.

The recent **European Green Deal** (European Commission, 2019) presents a forward-looking strategy where no one should be *left behind*. It emphasises the involvement of "*local communities in working towards a more sustainable future*" and the need to further "*empower regional and local communities, including energy communities".* It also advocates for a socially just transition where the risk of energy poverty must be addressed and citizens and workers most vulnerable to the energy transition must be protected.

Figure 1. Towards a more inclusive and collective EU energy policy



Source: JRC, (2020)

1.2 Scope of the report

Collective energy action initiatives have existed in the European energy system for a long time and under different forms, such as energy cooperatives, community energy groups, associations of consumers and collective purchasing groups. The recent developments in EU legislation discussed above – the recognition of jointly acting renewable self-consumers and active consumers as well as citizen and renewable energy communities– have paved the way for their widespread diffusion with a more formal role.

Collective action initiatives in the energy field are often hindered by technological, regulatory, economic and social challenges. R&I projects can play a pivotal role to address these challenges and speed up the transition to a new energy system with consumers and communities at its heart. In the last decade, several R&I projects have started to investigate new types of interactions between active consumers that allow them to capture the benefits of renewable energy generation and to participate in electricity markets by providing flexibility to the system.

> In this report, we use the expression *collective energy action initiatives* to refer to different forms of citizen participation around the issue of energy.
>
> By *collective action projects*, on the other hand, we refer to R&I activities that research and test collective-level technological solutions to enable a more active participation of consumers in the energy market. R&I projects need to have a start and an end date, to state clear research objectives and to provide for a monitoring and evaluation framework.

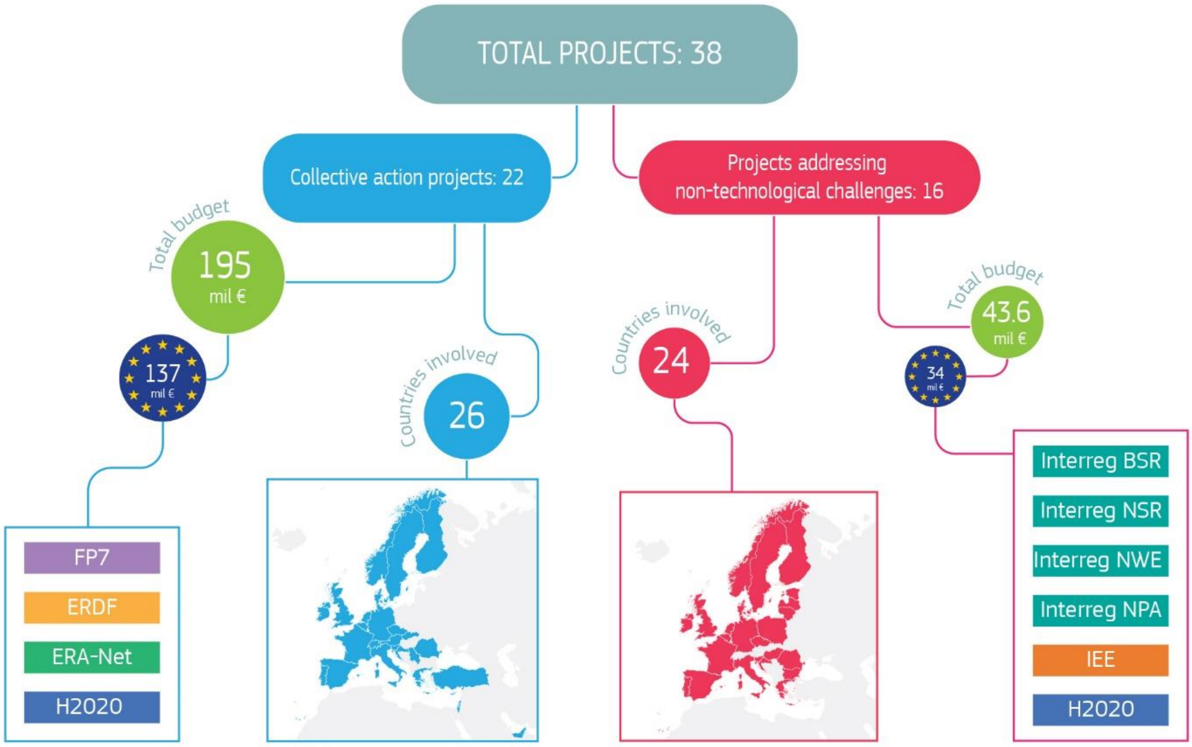
In many Member States, R&I projects have been carried out to investigate the feasibility of collective action initiatives, the challenges they have to face and the contribution they can offer to a more secure and sustainable energy system. In some Member States in particular, advanced legislation, regulatory exemptions and a well-established local energy activism (Wierling, et al., 2018) have favoured the flourishing of a variety of R&I projects (e.g. the Netherlands and Denmark).

The EU has also funded a number of R&I projects in this field. In this report, we focus on **EU-funded collective action projects** that combine the use of new technologies, business models and community engagement approaches to enable a more active participation of consumers in the energy market (abbreviated as 'CA projects' in the figures titles).

More specifically, we focus on **projects that research and test technological solutions at collective level to increase the ability of consuming self-produced and locally generated electricity and to facilitate the uptake of energy efficiency and active demand solutions and services.** We direct our analysis on projects funded under the Framework Programmes for Research and Innovation, the Intelligent Energy Europe (IEE) programme and the European Structural and Investment Funds (ESIF). These programmes have produced many examples of good practice at national, regional and local levels and can serve as blueprints for similar initiatives in other Member States, enabling a more systematic uptake of good practices across the EU (European Commission, 2016).

The analysis is also supported by a brief overview of projects co-funded by the EU to address the social dimension of the energy transition and to promote the emergence and development of collective action initiatives at policy, institutional and societal level (**projects addressing non-technological challenges**, abbreviated as 'NTC projects' in the figures titles) (Figure 2). These projects focus on the policy, institutional, economic and societal dimensions of collective energy action initiatives to boost citizen's participation and speed up the transition towards renewable energy. Their analysis is presented in a separate chapter at the end of the report.

Figure 2. Overview of projects suveyed



Source: JRC, (2020)

Overall, the report provides an overview of the current state of play in the EU to see what has already been done and to identify the research gaps to be addressed in the future. Its ambition is thus to share the body of knowledge and best practices that EU-funded collective action projects have developed and to provide actionable recommendations for future research programmes. The report is addressed to all stakeholders involved in setting up collective action initiatives at national, regional and local level, that may benefit from the experiences collected so far thanks to EU funding. It is also addressed to stakeholders interested in furthering research on this topic, who may find the analysis helpful in identifying research gaps.

The report complements previous works carried out by the Joint Research Centre (JRC) that have looked into sociotechnical aspects of collective energy use, such as: community engagement strategies, stakeholders' involvement, emerging technologies and social innovation in energy transition (Mengolini, Gangale, & Vasiljevska, 2016) (Marinopoulos, Vasiljevska, & Mengolini, 2018) (Kounelis, et al., 2017) (Caramizaru & Uihlein, 2020). It builds on the work carried out by the JRC as part of its smart grid projects outlook (Gangale, Vasiljevska, Covrig, Mengolini, & Fulli, 2017) and is part of the JRC efforts to provide updated topic-specific analyses (Gangale & Mengolini, 2019). It also acknowledges and contributes to the current research developments in the field (BRIDGE, 2019) (Tounquet, De Vos, Abada, Kielichowska, & Klessmann, 2019) (USERSTCP, 2020).

The report is driven by the following research questions:

- Is the growing attention that collective action initiatives have gained at policy level in recent years reflected in the research and innovation projects carried out to date with EU financial support?
- What kind of technologies and solutions have been trialled?
- What kind of community engagement strategies have been tested?
- What kind of stakeholders have been involved and what key partnerships have emerged?
- What are the research gaps and areas for future research?

The report is structured as follows. Chapter 2 introduces the collective energy action projects surveyed, providing an overview of their objectives and of their time and geographical distribution. It also analyses in more depth the technologies tested, the stakeholders involved and the community engagement strategies used in the projects. Chapter 3 provides a snapshot of the projects that address the policy, institutional, economic and societal challenges of collective energy action initiatives and of the activities they carry out. Finally, Chapter 4 provides a summary of the main findings and offers suggestions for future research.

2 Collective action projects

2.1 Projects identification and selection criteria

This chapter focuses on EU-funded collective action projects that research and test collective-level technological solutions to increase the ability of consuming self-produced and locally generated electricity and to facilitate the uptake of energy efficiency and active demand-side solutions and services.

The identification and documentation of projects involved a systematic search that used various combinations of the following keywords: innovation, collective, self-consumption, storage, peer to peer, energy trading, energy sharing, community, energy cooperative, neighbourhood, virtual power plant, microgrid, distributed generation, demand management, demand response, smart grids.

A main source of information was the JRC database of smart grid projects (the SG database)[2]. The SG database includes about 950 projects and can be searched for stage of development, project main application, funding source and stakeholder category. The SG database was an important starting point for projects identification, but further search was necessary to detect recent relevant projects. Other sources of information used in the search process were:

- The Community Research and Development Information Service (CORDIS). CORDIS is the European Commission's primary source of results for the projects funded by the EU's framework programmes for research and innovation (from FP1 to Horizon 2020). It has a rich and structured public repository with all project information held by the European Commission such as project factsheets, participants, reports, deliverables and links to open-access publications.
- The Intelligent Energy Europe (IEE) projects database. The online database provides a repository for projects funded under the IEE programme, launched by the European Commission in 2003 as a means of supporting energy efficiency and renewable energy policies and help bring the EU closer to its 2020 targets. The IEE ran until 2013, but some projects funded through the last calls for proposals started in 2014.
- The online databases of the INTERREG transnational cooperation programmes, key instruments of the European Union supporting cooperation and regional development within the EU through project funding by the European Regional Development Fund (ERDF).

The search in organized repositories was coupled with a wide internet search of different sources of information, such as project websites, academic articles, scientific reports and projects' dissemination and communication materials.

Projects emerging from the search were included in a dedicated database only if they met the following selection criteria:

- The project is co-funded by the EU.
- The project targets the residential sector, either exclusively or in combination with other sectors.
- The project actively involves consumers at collective level.

[2] The SG database was developed by the JRC to analyse the state of play of smart grid projects in the EU. A version of the database, not containing budget and personal data, can be found at: https://ses.jrc.ec.europa.eu/sites/ses.jrc.ec.europa.eu/files/u24/2017/jrc_smart_grid_projects_inventory_2017.xlsx

- There is enough information publicly available, e.g. in the form of deliverables, reports, research articles or a demonstrator description.

The cut-off date for projects' inclusion in the database was 31st March 2019.

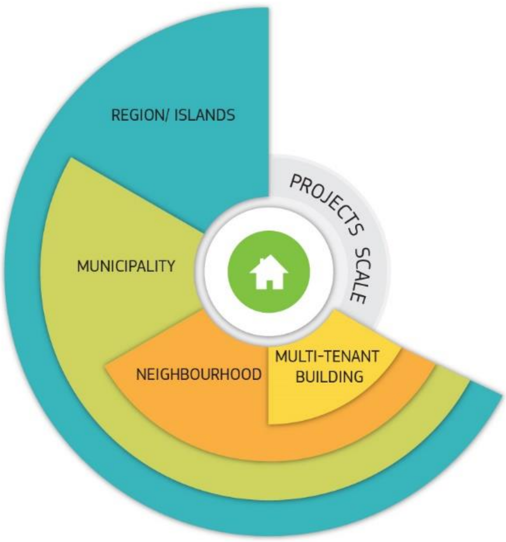
At the end of the identification and selection process, we retained 22 collective action projects in the database, involving 227 organizations from 26 EU countries and from some associated and enlargement countries, i.e. Switzerland, Israel, Iceland, Norway, Serbia and Turkey.

2.2 Project categories

Project documentation was scanned to retrieve a variety of information, using as much as possible the categorisation proposed in the JRC smart grid projects outlook 2017 (Gangale, Vasiljevska, Covrig, Mengolini, & Fulli, 2017). The categories used are listed below, and a brief explanation is provided in case of discrepancy with the above mentioned outlook 2017.

- **Start and end date**.
- **Demonstration site**.
- **Funding sources** (EU, own resources/national funding) and **budget**.
- **Scale**. This is a new field of the database, introduced to gather information on projects' spatial and relational dimension (Figure 3). The scale of a project refers to the spatial area where the project intends to demonstrate its solutions and where consumers are linked using the same enabling technology.
- **Sector**. The main focus of the report is on residential consumer participation in energy production, consumption and management. For this reason, the database only reports residential and mixed sector projects, i.e. projects targeting one or more sectors, along with the residential one. Projects targeted exclusively at the industrial, commercial and public sector were not taken into consideration.

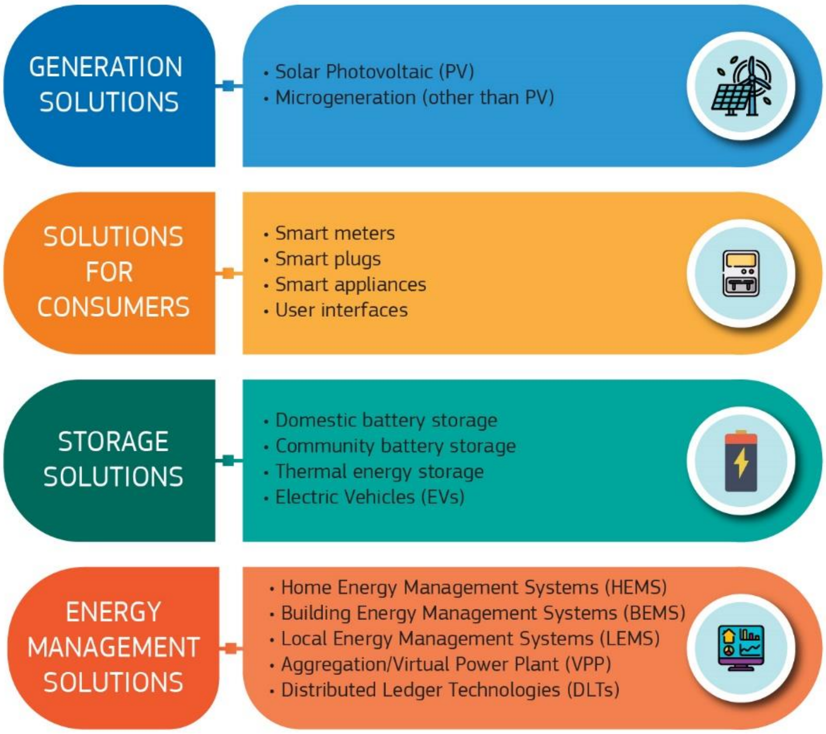
Figure 3. CA projects: scale



Source: JRC, (2020)

- **Technological solutions trialled**. This is a new field of the database, designed to monitor the technological solutions trialled in collective action projects. These solutions are grouped under four broad categories: generation solutions, solutions for consumers, storage solutions and energy management solutions. Figure 4 presents the four general categories that will be further elaborated in section 2.4.

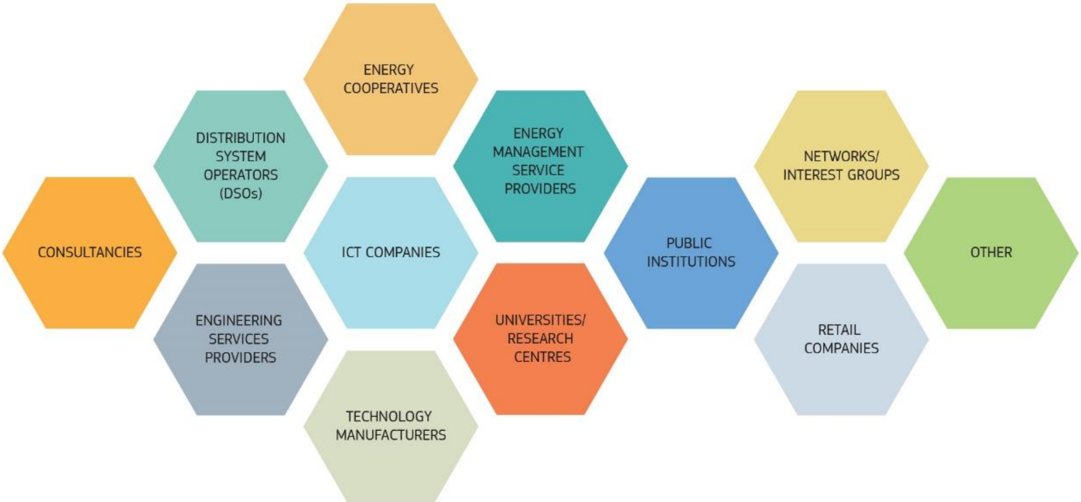
Figure 4. Technological solutions trialled in CA projects



Source: JRC, (2020)

- **Stakeholders involved**. The stakeholder categories proposed in the JRC smart grid projects outlook (Gangale, Vasiljevska, Covrig, Mengolini, & Fulli, 2017) were adapted to reflect more accurately the type of actors involved in collective action projects and to better understand the links and relations between them. Figure 5 below lists the stakeholders identified for this study that will be further investigated in section 2.5.

Figure 5. Stakeholders involved in CA projects



Source: JRC, (2020)

- **Consumer engagement interventions tested**. This is another new field of the database. Engaging consumers in a collective effort requires the implementation of a well-thought engagement strategy that builds on a sense of community and of shared values and goals. Figure 6 presents the main interventions used by the projects to actively involve consumers at collective level to reach a common objective. Section 2.6 will provide further analysis.

Figure 6. Consumer engagement interventions trialled in CA projects

Source: JRC, (2020)

2.3 Projects overview

2.3.1 Overarching and specific objectives

The analysis of the projects' description and goals revealed that all projects pursue one or more of the following overarching objectives, in line with the EU energy and climate policy goals:

- Reducing energy use and CO_2 emissions.

- Supporting the fast growth of renewable energy generation, particularly in constrained networks.
- Supporting distribution grids stability, alleviating network constraints and avoiding RES curtailment.

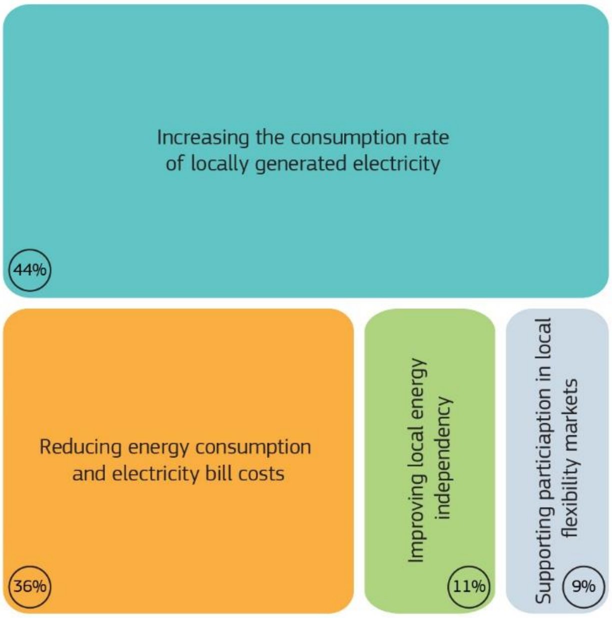
Besides these general objectives, that are common to many other EU-funded projects, the collective action projects analysed in this report typically pursue other - often intertwined - specific objectives (Figure 7), such as:

- Increasing the consumption rate of locally generated electricity.
- Improving local energy independency and self-sufficiency.
- Reducing energy consumption and electricity bill costs[3]; increasing consumers understanding and engagement in energy efficiency.
- Supporting collective action initiatives (e.g. energy cooperatives, local energy communities) to introduce themselves in local flexibility markets.

To achieve these objectives, the projects surveyed use different enabling technologies and engagement approaches that connect and unite consumers, widening the reach of their individual endeavours and supporting their role as active energy players.

In many projects, for example, collective flexibility is used to optimise local energy management (e.g.: *Compile, City-Zen Amsterdam)*, while some projects go further and explore the possibility of offering this collective flexibility to the market (e.g.: *Flexcoop, Merlon)*.

Figure 7. CA projects: specific objectives



Source: JRC, (2020)

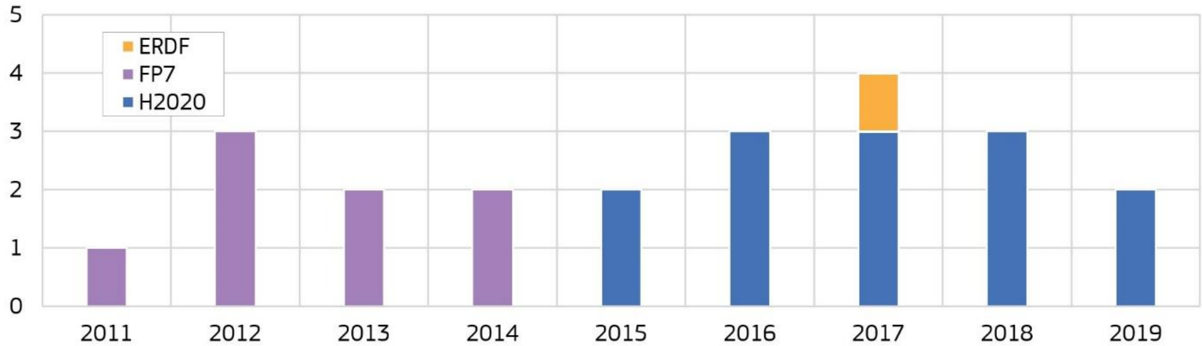
[3] It is also interesting to note that several projects also have the reduction of energy poverty among their project objectives (i.e.: *Compile*, *Energaware*, *Smart Energy Island*, *WiseGrid*).

The projects analysed in this report also differ from other EU-funded projects for their focus on consumers and the attention to the individual and social dimension of energy consumption[4]. The selected projects require the collective active participation of end consumers and the adoption of tailored strategies to ensure their engagement throughout the project activities and beyond. For this purpose, many projects consider social science and humanities disciplines as integral part of the project and include them from the beginning of the project and not just as an isolated task.

2.3.2 Time trend of projects and investment

The scanning of the selected projects revealed that collective action projects are not new in the EU R&I scene, with a pretty constant number of projects starting each year since 2011 (Figure 8 and Figure 9). Under FP7, projects were funded in 2011 (*Nice Grid*), 2012 (*Eepos*, *Origin* and *Ideas*), 2013 (*Civis* and *Cossmic*) and 2014 (*City-zen* and *CityOpt*). Since the start of H2020, 10 collective action projects were funded (*Energaware*, *Sensible*, *Shar-Q*, *WiseGrid*, *Compile*, *Flexcoop*, *Nice Smart Valley*, *Merlon*, *Muse Grid*, *React*). H2020 projects also includes projects funded under the ERA-Net Smart Grids Plus initiative in 2016 (*Grid-Friends*), 2017 (*Nemogrid*) and 2018 (*Smart-MLA*). Finally, the database also includes one project co-funded by the European Regional Development Fund (ERDF) in 2017 (*Smart Energy Island*). Data for 2019 is only partial, as the database includes projects that started up to 31 March 2019.

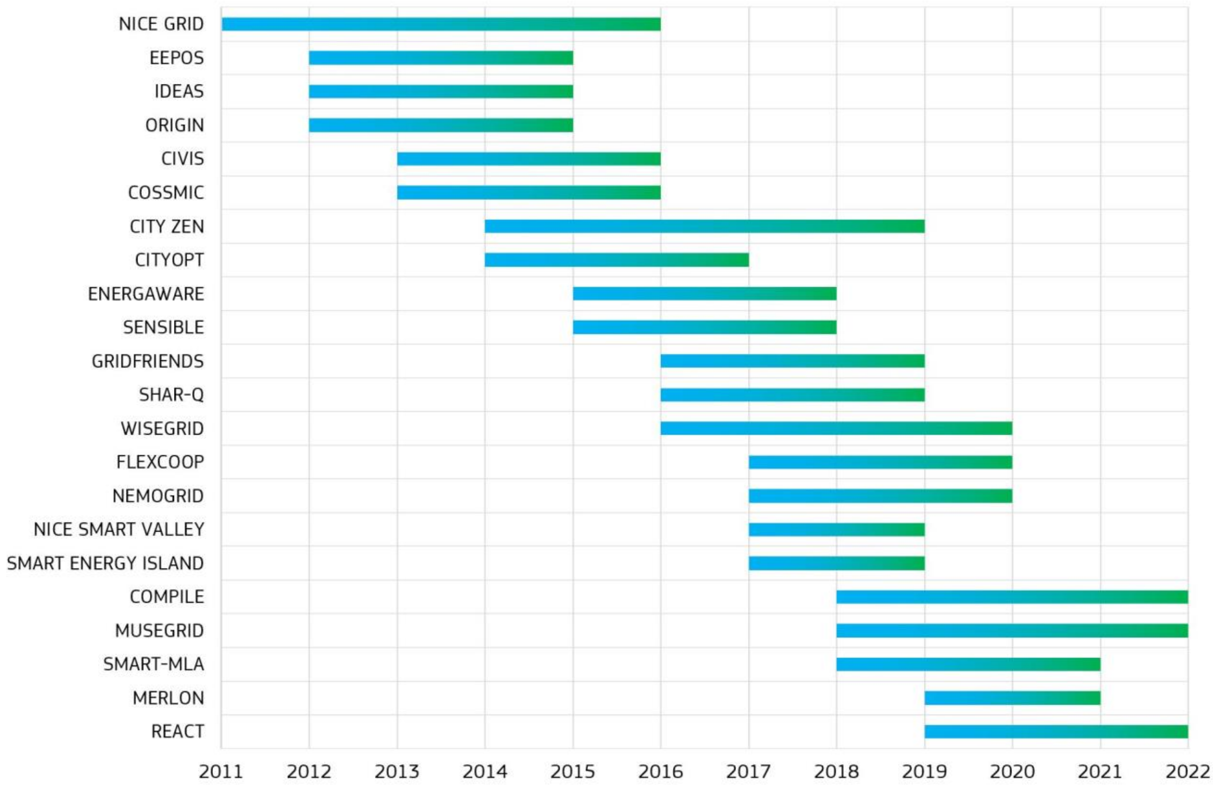
Figure 8. CA projects: start date by funding source



Source: JRC, (2020)

[4] Dozens of projects have been funded under the EU Research Framework Programmes where the same objectives were pursued but without the specific focus on collective actions and community approaches. Just to give a few examples of projects trialling similar solutions: *E-hub* (https://cordis.europa.eu/project/id/260165), *Sim4blocks* (https://www.sim4blocks.eu), *Singular* (https://cordis.europa.eu/project/id/309048), *Dimmer* (https://cordis.europa.eu/project/id/609084), *E-balance* (http://ebalance-project.eu)

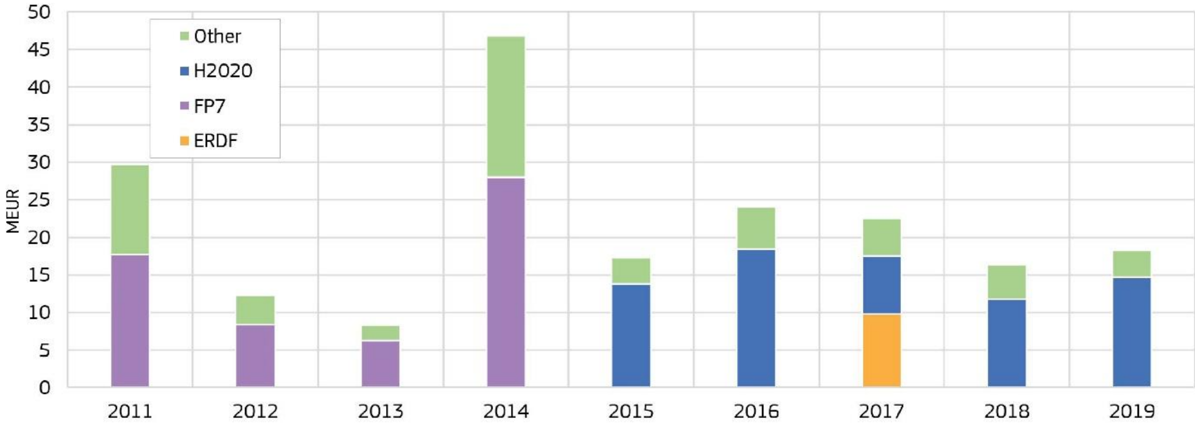
Figure 9. CA projects: start and end date



Source: JRC, (2020)

As for investment, its time distribution is not always in line with the number of projects starting each year (Figure 10). Several reasons may explain the differences in the volume of project funding, such as the size of the sample population of the demonstrators or the number of demonstrators carried out within the same project. Not all the project funding is always dedicated to testing collective action solutions. For several projects for example (9 out of 22), we considered the whole budget even if the project carries out several demonstrators and not all of them were considered relevant for our analysis. This approach implies that the whole project budget is taken into consideration even if only a fraction of it was spent on the relevant demonstrators. In most cases, we believe that this method does not affect the time trend soundness. Only in two cases, *City-zen* (Amsterdam, 2014) and *WiseGrid* (Ghent, 2016), the budget effectively allocated to the relevant demonstrator might have been sensibly lower than the overall project budget.

Figure 10. CA projects: time distribution of investment *

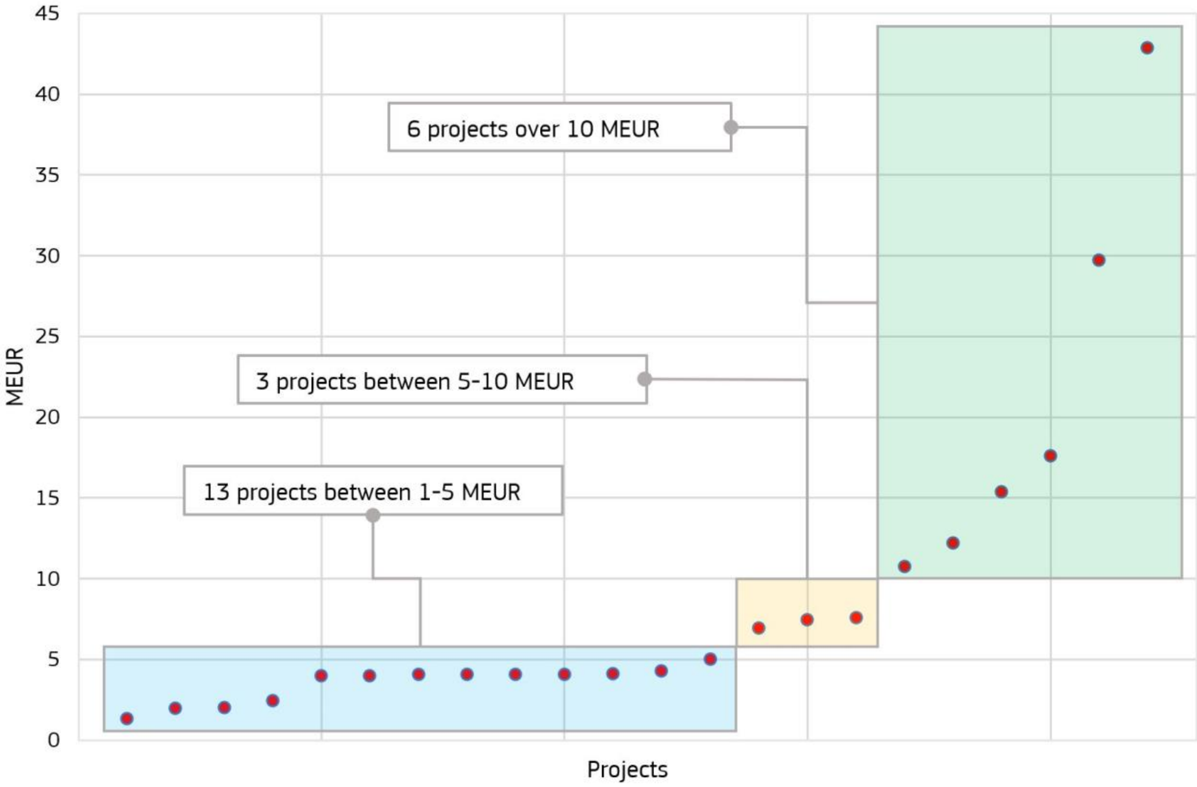


Source: JRC, (2020)

* For yearly aggregations of investment, the project budget was assigned to the starting year. The category 'Other' includes private financing and funding received by national sources.

Finally, Figure 11 shows that the most common project budget range is 1 to 5 M€ (13 out of 22 projects). 6 out of 22 projects have a budget over 10 M€ and only 3 projects a budget between 5 and 10 M€.

Figure 11. CA projects: budget ranges



Source: JRC, (2020)

Overall, time trend data suggests that the growing attention attracted by collective action initiatives at policy level in recent years has not yet been fully reflected in the research and innovation initiatives carried out to date with EU financial support. More funding is desirable in the future to investigate technological, economic and social aspects of collective action projects.

New projects are however expected in the framework of H2020 as, at the time of writing, funding is still available under topics that may award more collective action projects, e.g. LC-SC3-EC-1-2018-2019-2020 "The role of consumers in changing the market through informed decision and collective actions"[5], LC-SC3-EC-3-2020 "Consumer engagement and demand response"[6], LC-SC3-ES-3-2018-2020 "Integrated local energy systems (Energy islands)"[7], "LC-SC3-SCC-1-2018-2019-2020 - Smart Cities and Communities"[8] and LC-SC3-SCC-2-2020 "Positive Energy Districts and Neighbourhoods for urban energy transitions"[9]. Relevant projects have also been funded under the ERA-Net Smart Energy Systems, Joint Calls 2017 and 2018, but they were not included in the database as, being very recent, not enough information was yet available[10]. The "Orientations towards the first Strategic Plan implementing the research and innovation framework programme Horizon Europe" also mentions energy communities as potential future research area. [11]

2.3.3 Geographical distribution of demonstration sites

Most projects carry out several demonstrators across different climatic, cultural and regulatory conditions to validate the technical, regulatory and economic concepts associated with the innovative solutions trialled. We only considered the demonstration sites targeted at the residential sector (either exclusively or together with other sectors), where collective level technological solutions were trialled. After this screening we retained 38 out of the 51 demonstrators carried out within the projects. Figure 12 shows that demonstration sites are concentrated in a few countries (e.g. Italy, UK, France, Netherlands, Portugal, Spain), with most Member States in eastern Europe lacking any demonstrator.

[5] Submission deadline is 20 September 2020.

[6] Submission deadline is 29 January 2020.

[7] Since the end of March 2019, latest start date for the inclusion in our database, two more potentially relevant projects received funding under this call, i.e. *Ielectrix* (https://cordis.europa.eu/project/id/824392) and *Renaissance* (https://cordis.europa.eu/project/id/824342)

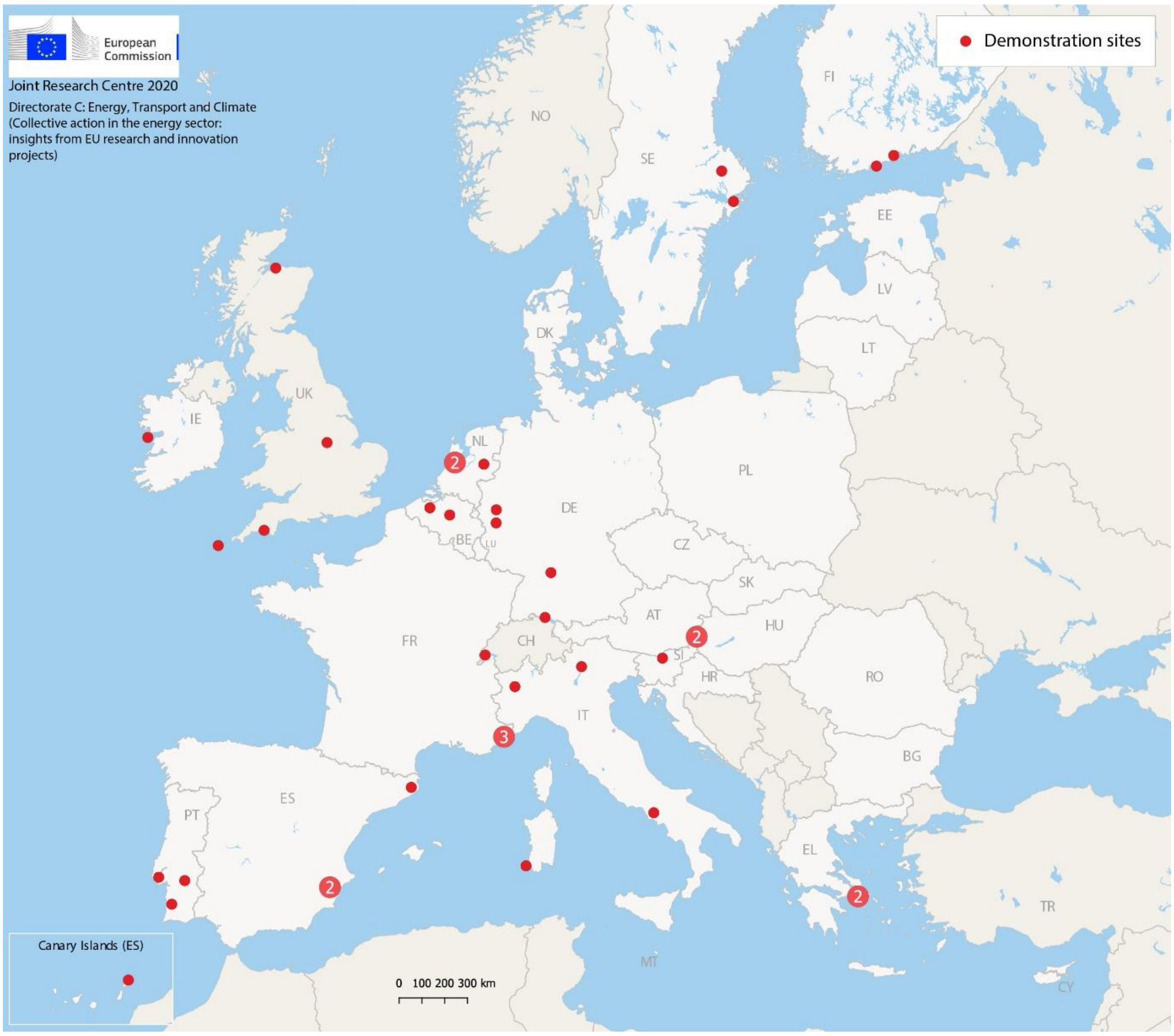
[8] Submission deadline is 29 January 2020. Since the end of March 2019, latest start date for the inclusion in our database, two more potentially relevant projects received funding under this call, i.e. *Atelier* (https://cordis.europa.eu/project/id/864374) and *Sparcs* (https://cordis.europa.eu/project/id/864242).

[9] Submission deadline is 29 January 2020.

[10] Relevant projects include *SONDER* - Service Optimization of Novel Distributed Energy Regions (01/09/2019 – 31/08/2022, joint call 2018) and *CLUE* - Concepts, planning, demonstration and replication of Local User-friendly Energy communities (01/10/2019 – 31/12/2022, joint call 2018)

[11] https://ec.europa.eu/research/pdf/horizon-europe/ec_rtd_orientations-towards-the-strategic-planning.pdf

Figure 12. CA projects: number and location of demonstration sites



Source: JRC, (2020)

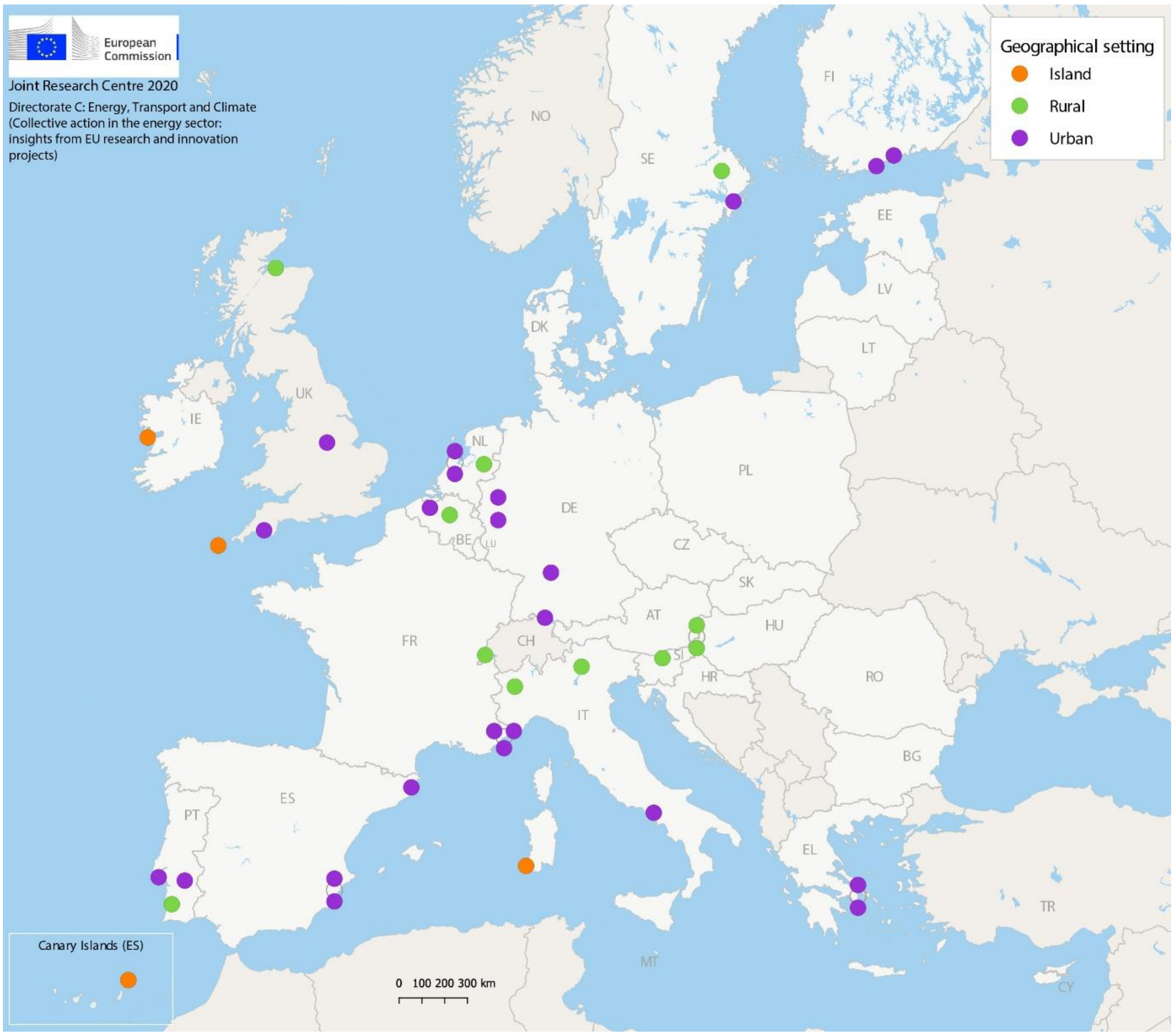
The map also shows that some municipalities have attracted more than one project (e.g. Nice (FR), Strem (AT), Rafina (EL), Amsterdam (NL)). This circumstance is likely due to favourable local conditions, such as the number of already existing prosumers and their interest in innovative energy initiatives, the presence of stakeholders active on these topics, and the solicitude of local authorities for the development of such projects. If on the one hand this practice allows to take advantage of existing relations among local stakeholders and to build on the results of previous research and innovation activities, on the other hand a greater geographical diversification would help testing solutions in a larger set of climatic, cultural and regulatory conditions. It would also help to showcase solutions and build capacities in a larger number of countries, raising interest among commercial and public stakeholders as well as citizens.

Figure 13 shows that the majority of projects are carried out in an urban setting, about one third are implemented in a rural environment[12] and four projects are carried out in geographical islands. Carrying out projects in different settings enables testing of technological solutions in different social and economic environments. Cities are major centres of energy consumption, as well as formidable breeding grounds for innovative and ambitious energy transition initiatives (International

[12] Following (EUROSTAT, 2017), by rural areas we mean thinly populated areas with less than 5000 inhabitants.

Energy Agency, 2016). Rural areas, on the other hand, seem to offer a particularly fertile ground for the development of a decentralised, community-based approach. As we will also see later, projects revealed that social fabric and community identity are important factors for the success of collective action projects. Small towns and villages appear to be more cohesive social clusters than city neighbourhoods (Abdurafikov, et al., 2014) while, in general, closer communities report higher engagement and satisfaction levels (CIVIS, 2016).

Figure 13. CA projects: geographical setting of the demonstration sites

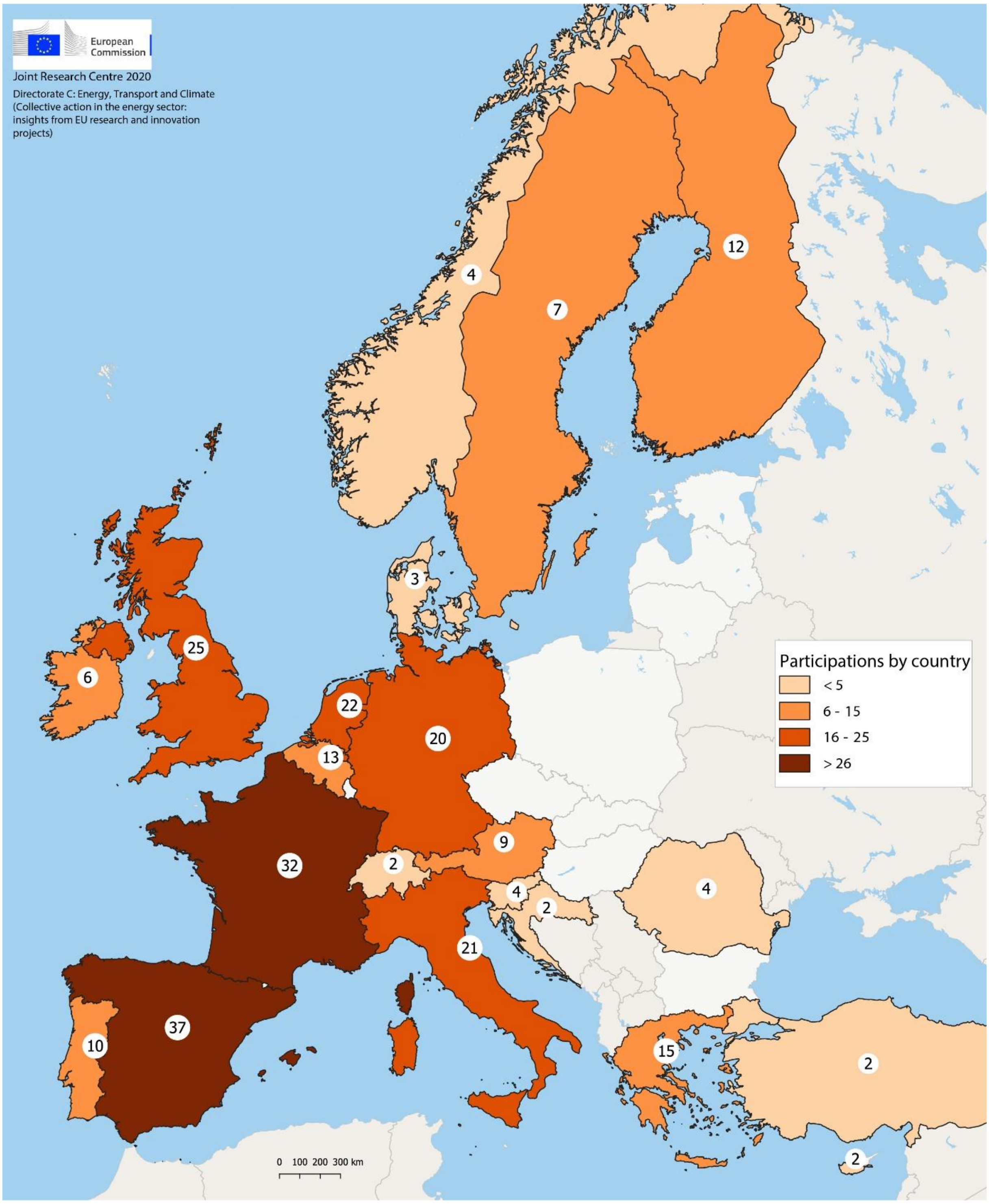


Source: JRC, (2020)

2.3.4 Geographical distribution of stakeholders

Looking at the geographical distribution of project stakeholders, it appears that participations are also concentrated in a small number of EU countries, with most countries in central and Eastern Europe showing limited participation (Figure 14).

Figure 14. CA projects: geographical distribution of participations



Source: JRC, (2020)

Besides the long-observed participation divide between EU-13 and EU-14[13] countries (European Commission, 2018), there may be other reasons for this concentration.

The countries with a higher number of participants are characterised by a well-established local energy activism and by supportive legislative and regulatory frameworks. Some countries have set

[13] EU13 Member States are meant as Bulgaria; Croatia; Cyprus; Czech Republic; Estonia; Hungary; Latvia; Lithuania; Malta; Poland; Romania; Slovakia; and Slovenia, whereas EU14 countries are the other 14 Member States of the European Union (not considering the UK that left the European Union on 31 January 2020.

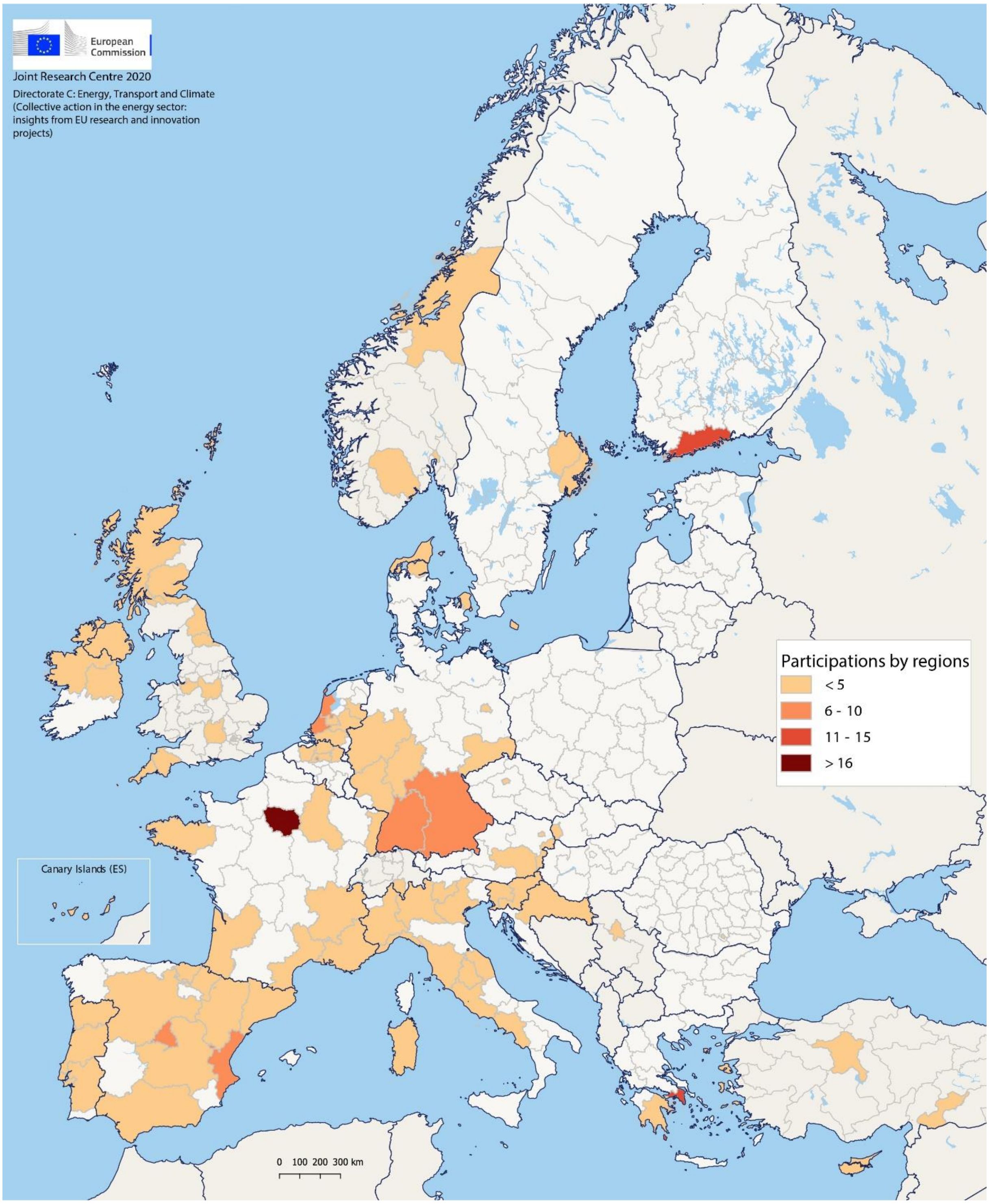
up sandbox programmes, i.e. experimental spaces in which innovators are allowed to trial new products, services and business models in a real-world environment without some of the usual rules and regulations applying (IEA ISGAN, 2019). Germany, Italy, the Netherlands and the United Kingdom have already implemented sandbox programmes, while other countries such as Denmark, Ireland, Spain, Austria France, Norway and Sweden are either discussing or already in the process of designing and proposing a sandbox programme for implementation (IEA ISGAN, 2019). The scope of such frameworks varies from country to country, but it often includes the integration of increasing shares of renewable generation, the development of flexibility services for grid stability, the integration of energy storage in the power sector and management of local energy communities (IEA ISGAN, 2019). The Netherlands for example, already in 2015 adopted an experimental derogation from specific provisions of the Dutch Electricity Act to test alternative ways to increase the use of renewable energy or combined heat and power at local level, to promote more efficient use of the available energy infrastructure and to support increased involvement of energy users in their own energy provision[14].

One of the projects in our database, *Grid-Friends*, is carried out in the demonstration site of one of the Dutch projects that benefited from the regulatory exemption. Other countries have adopted specific legal frameworks to support the development of energy communities, e.g. France, Germany, Belgium (Wallonia), Greece, Portugal, Slovenia (BRIDGE, 2019).

Regional differences in participation also exist within countries, with some regions leading investment in collective action projects. Figure 15 shows a higher concentration of participations around capital cities (e.g. Paris, Helsinki, Athens). This finding is in some cases justified by the location of the project demonstration sites, while in others it may more simply be attributed to the location of the participating organisations' headquarters.

[14] The experimental regime allows for associations to engage in collective generation, peer-to-peer supply, and in 'project grids' for system operations. These associations must be entirely controlled by their members who decide on the organisation, process and distribution of costs (Lammers & Diestelmeier, 2017). There are exemptions from the rules regarding the separation of regulated and market activities. Associations may operate microgrids and benefit from exemptions concerning supply license requirements under certain derogations.

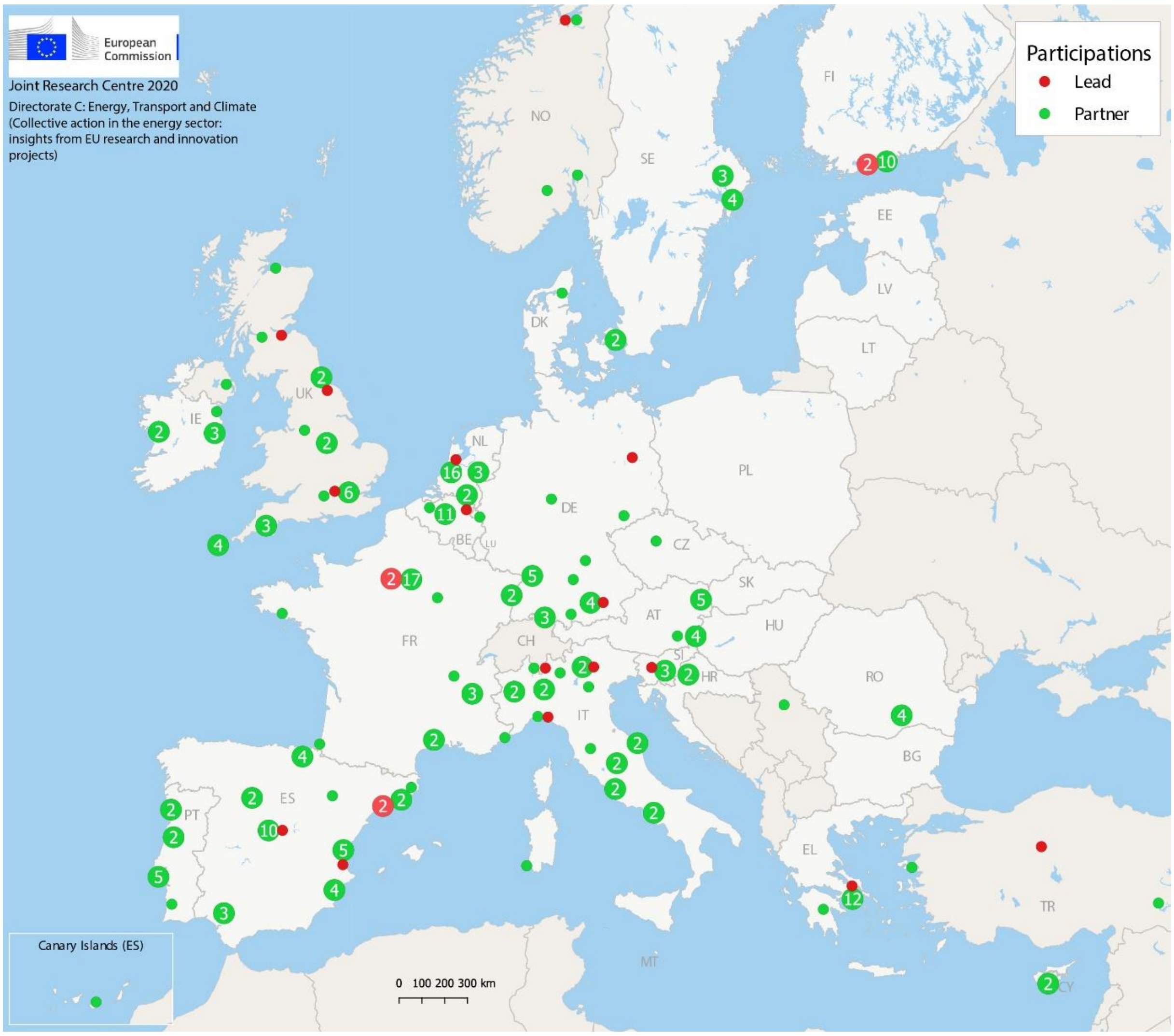
Figure 15. CA projects: geographical distribution of participations by regions



Source: JRC, (2020)

Finally, Figure 16 shows the geographical distribution of lead and partner organisations. As expected, the comparison with the map displaying the geographical distribution of participations (Figure 14), shows that the countries with a higher number of participations also show a higher number of lead organisations.

Figure 16. CA projects: geographical distribution of lead and partner organizations



Source: JRC, (2020)

In conclusion, the attention dedicated by some countries to the consumption of self-produced and locally generated energy and to the uptake of active demand solutions and services, might contribute to justify the high level of activism among national stakeholders. A supportive legislative and regulatory environment encourages the participation of institutional, commercial and non-governmental actors in innovation projects. Their participation, in turn, strengthens their capacities and expertise, and enables commercial actors to pursue emerging business opportunities at national and international level.

Future EU-funded projects should try to cover more geographical areas and to increase the participation of underrepresented countries. This would help them to strengthen the scientific and networking capabilities of national stakeholders and to bring about more widespread and quicker uptake of solutions and best practices for the active participation of consumers in the energy market.

2.3.5 Scale and sector

Projects are implemented at different scales, ranging from multi-tenant buildings to whole regions and islands. Table 1 below provides a brief description of the categories identified in the projects reviewed.

Table 1. CA project: scale categories

Scale	Description
Multi-tenant building	Research and testing localised at a single multi occupancy dwelling (e.g. a housing association complex).
Neighbourhood	Research and testing spread across a localised area, typically characterised by social interactions and networks.
Municipality	Research and testing spread across a village, town or part of a city.
Region	Research and testing spread across a wider local authority, network operator or energy retailer area.
Island	Research and testing spread across an entire island.

Source: JRC, (2020)

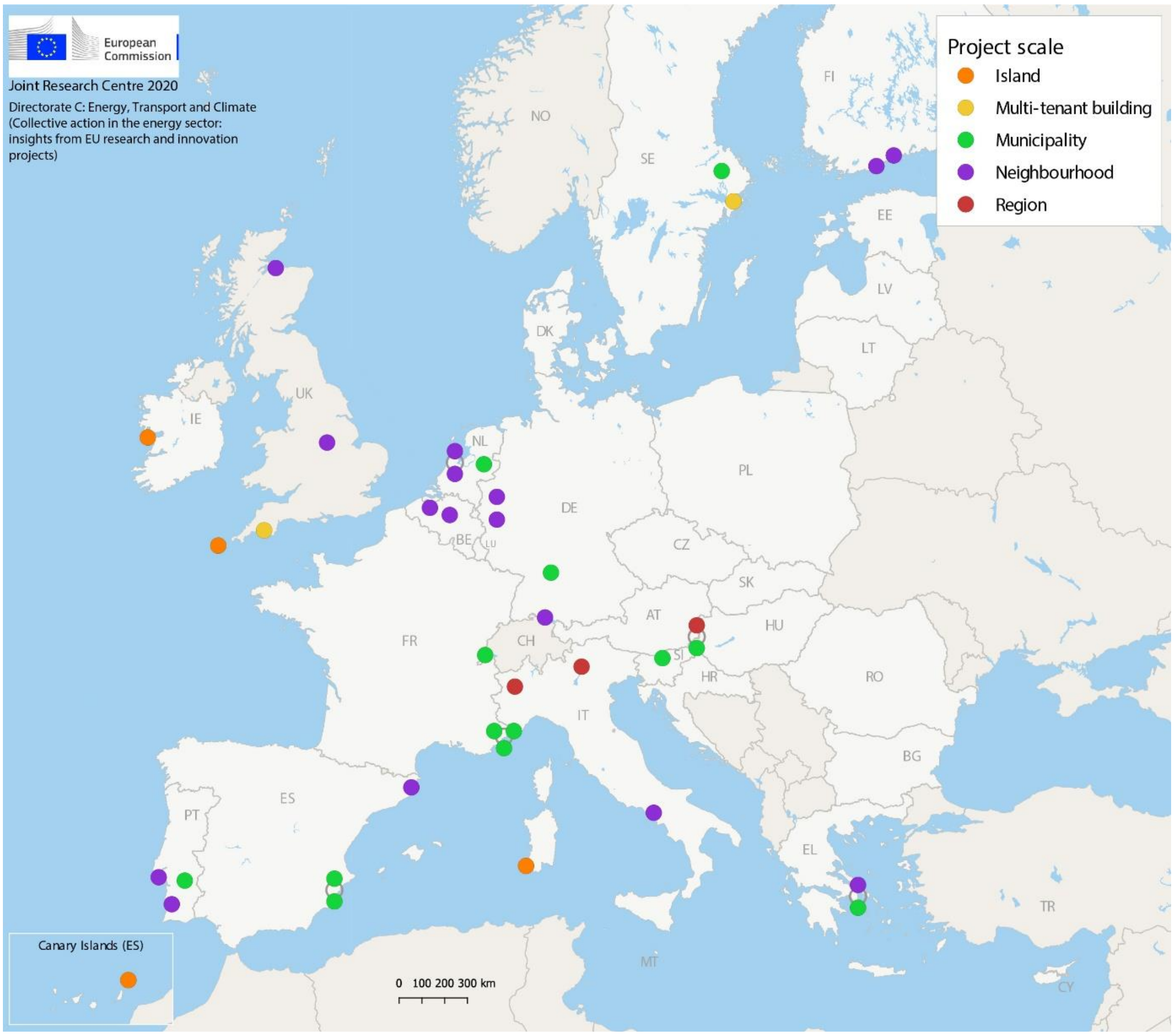
The majority of projects involve neighbourhoods (12 out of 22 projects, 16 demonstration sites) or are spread across a village, town or parts of a city (8 projects, 13 demonstration sites). Two projects (4 demonstration sites) are carried out at island scale, three at regional scale (3 demonstration sites) and two in multi-tenant buildings (2 demonstration sites). Figure 17 shows the geographical locations of demonstration sites by scale.

The two projects developed at multi-tenant building scale are carried out in social housing complexes in urban areas and have a strong focus on energy efficiency and demand side management. This area of research might reveal interesting insights especially for those Member States that have already introduced a regulatory framework allowing collective self-consumption in multi-apartment buildings. Focusing on social housing complexes offer also the possibility of addressing energy poverty (Gangale & Mengolini, 2019).

Neighbourhoods offer ideal conditions for the development of collective action projects, especially in new urban developments and renewals, where diverse enabling technologies can be installed as part of the initial investment. We only find two projects in new city developments in our database (*Grid-Friends* and *Eepos*), and not much information on their peculiarities is provided in the project documentation available.

Projects developed at municipality, region and island scale involve prosumers generally spread across a wider territory and are often motivated by the sense of identity and pride being attached to community and locality and by the objective of reaching increased local energy independence.

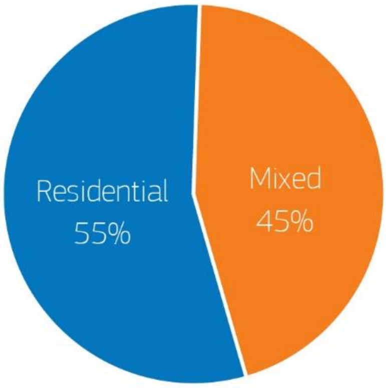
Figure 17. CA projects: geographical distribution of demonstration sites by scale



Source: JRC, (2020)

Figure 18 shows the share of projects by sector. The majority of projects still targets the residential sector exclusively, while some projects also involve the commercial and public sectors (mixed sector projects). The inclusion of other sectors in the scope of the project is an interesting development, as it is in line with the idea of a multi-stakeholder, municipally-based partnership, which is at the core of an integrated community-oriented approach. Such an approach can also help with maximising benefits and opportunities for consumers, thus contributing to technology acceptance and consumer engagement (Mengolini, Gangale, & Vasiljevska, 2016).

Figure 18. Share of CA projects by sector

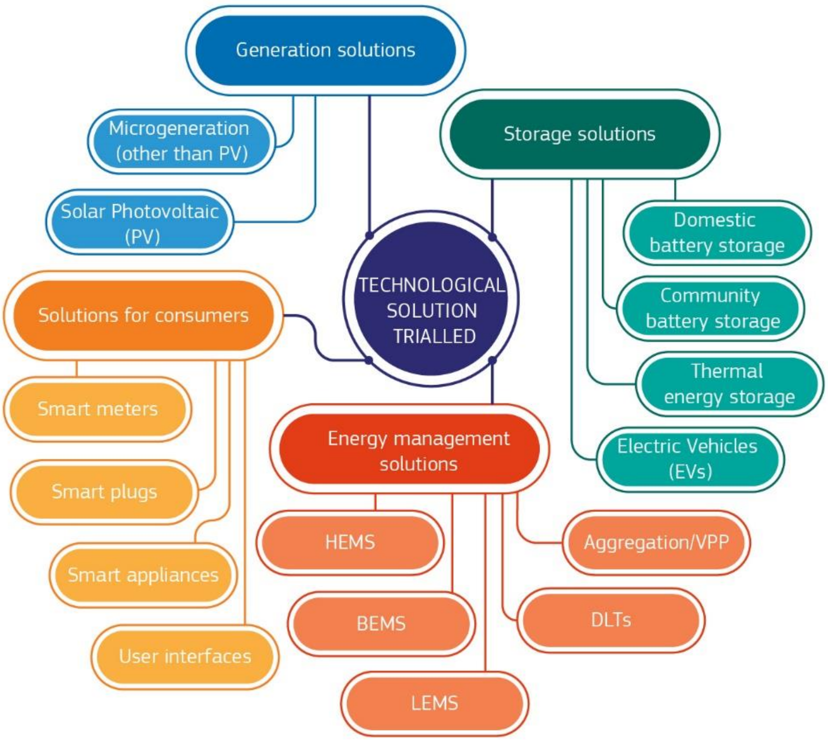


Source: JRC, (2020)

2.4 Technologies trialled

Collective action projects trial different technological solutions to achieve their objectives, typically to increase the ability of consuming self-produced and locally generated electricity and to facilitate the uptake of energy efficiency and active demand solutions and services. All solutions, however, revolve around collective demand side management, both implicit and explicit, as a means to improve local energy management and/or to reduce energy consumption and costs for consumers. The solutions trialled in the projects, grouped under four broad categories, are summarized in Figure 19.

Figure 19. CA projects: technological solutions categories



Source: JRC, (2020)

Collective demand response actions and other solutions building on community approaches are key to **optimising local energy** use on a collective level, thus supporting local consumption of renewable and locally generated electricity.

In some projects, collective approaches to demand side management and energy efficiency are only used as a means to **increase consumers understanding and engagement** in energy efficiency and reduce overall energy costs for consumers (e.g. *EnergAware*, *CityOpt Nice*). In these projects, the collective approach is meant to trigger behavioural change to cut local electricity demand and shift electricity demand peaks.

In other projects, ICT solutions based on accurate localised weather forecasting (e.g. *Origin*, *Civis*) are used to **improve the management of locally generated renewable energy** through demand side management of shiftable electrical loads. Demand management is used to provide flexibility and it is often paired with efficiency measures to reduce consumption overall.

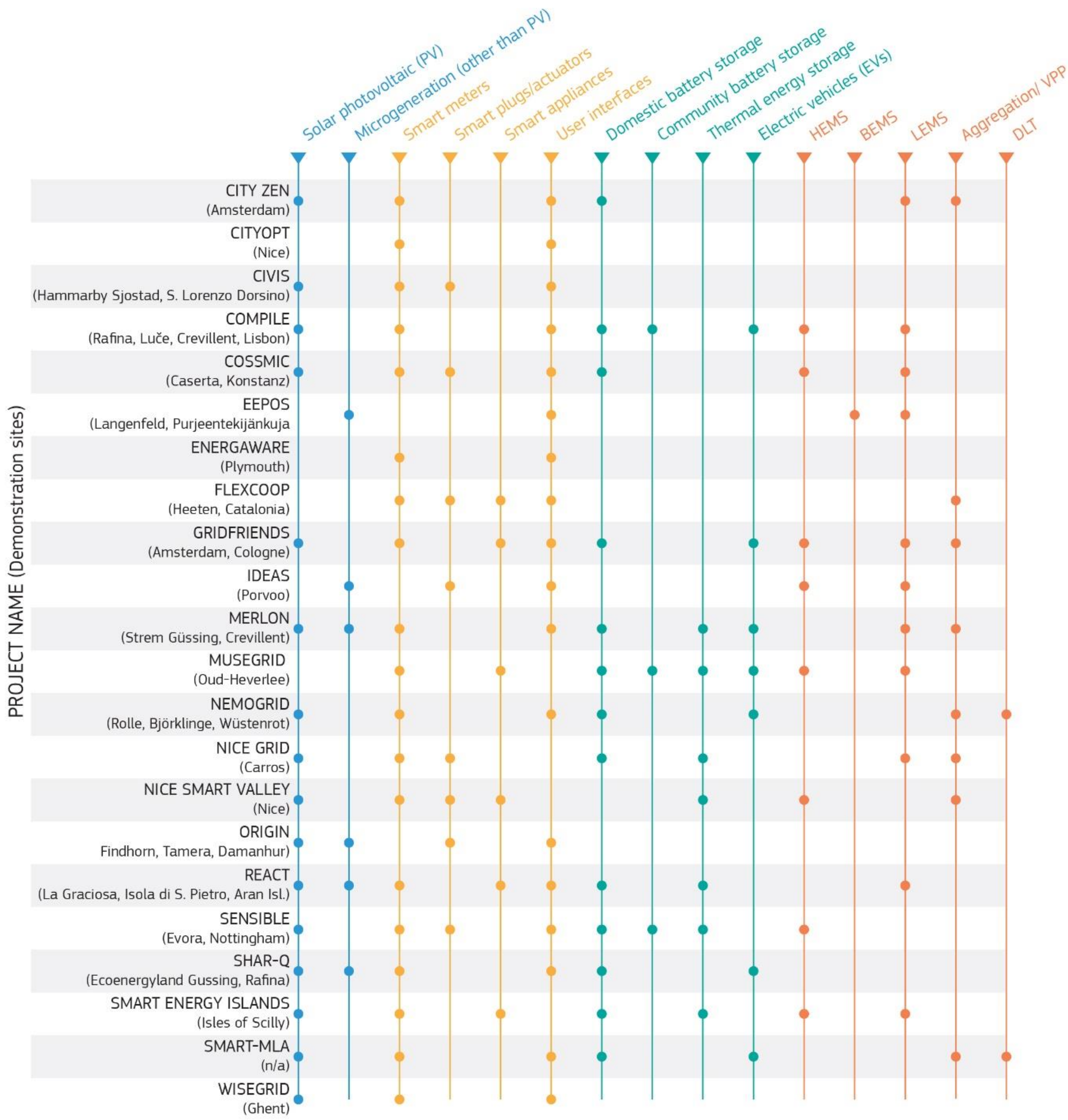
Furthermore, some other projects combine demand side management with the **use of storage** (e.g. *React*) and smart EV charging (e.g. *Compile*, *Grid-Friends*, *Merlon*), while in others, the matching of local load and generation is achieved through the resort to innovative community-based solutions, such as community-scale storage (e.g. *Smart Nice valley*, *Compile*), virtual power plants (VPP) (e.g. *City-Zen Amsterdam*) and P2P approaches (e.g. *Cossmic*, *Shar-Q*).

Finally, collective demand response and energy efficiency solutions are used also to provide **balancing and ancillary assets** towards grid stability and alleviation of network constraints, enabling energy communities (e.g. cooperatives) to introduce themselves in local flexibility markets (e.g. *Flexcoop*, *Merlon*).

In general, projects rely on different levels of automation and complexity, with advanced ICT tools and approaches (e.g. internet of things, big data, artificial intelligence, blockchain) used to different degrees. The optimisation and matching of local renewable electricity generation and consumption for example, can be achieved with different solutions ranging from ICT-enabled demand response schemes to more complex local energy management solutions, built on ICT platforms that enable the orchestration of decentralized energy supply, storage, transport, conversion and consumption within a given local geographical area.

In the next paragraphs, we will present an overview of the main technological solutions trialled in the projects. These solutions, as listed in Figure 19, are represented further in Figure 20, where each solution is associated to the project where it has been trialled. Besides these technologies, we have also identified the projects that implement a microgrid in their demonstration sites. However, since the term “microgrid” has been often misused, we did not include “microgrids” as a trialled technology. In Box 2 we provide a definition of “microgrids” and how this definition differs from the concept of energy communities; we further present how “microgrids” are implemented in some selected projects.

Figure 20. Technological solutions trialled in each CA project



Source: JRC, (2020)

Box 2. Microgrids

The definition of “microgrid” has been proposed as early as 2004 in the EU project “Large scale integration of micro-generation to low voltage grids (*MicroGrids*)” funded by the FP5 programme. It has been later complemented by the *More MicroGrids* project and in general terms, it can be formulated as follows: microgrids are electricity distribution systems containing loads and distributed energy resources, (such as distributed generators, storage devices, or controllable loads), that can be operated in a controlled, coordinated way, either while connected to the main power network and/or while islanded (Papadimitriou, Kleftakis, & Hatziargyriou, 2018). As mentioned by the EU Technology Platform on Smart Grids (currently ETIP-SNET), the unique feature of microgrids is that, although they operate most of the time connected to the distribution network, they can be automatically transferred to islanded mode and continue to operate, serving the loads of the microgrid in case of a fault in the upstream grid or for any other reason. They can also resynchronize automatically after the fault restoration.

Based on the above, the microgrid is a fully controlled entity that can operate autonomously and be seen by the main grid as a single aggregated load and/or generator. Thus, they should not be confused with the interconnection of distributed generation to a distribution line in the absence of loads or monitoring and control, or with the demand side integration in the absence of any generation (Hatziargyriou, 2014). Another common confusion regards the virtual power plant (VPP), which is also a cluster of distributed energy resources (and possibly loads) collectively operated by a control entity; these resources are not necessarily located together and can also refer to much bigger sizes. Finally, microgrids should not be confused with local energy communities, since the latter can be based on a microgrid structure or not.

As for the analysed collective action projects, six of them claim to implement a microgrid in their demonstration sites. In the Luče demonstration site of the *Compile* project, a microgrid is tested. A remote rural low voltage network with weak and unstable connection to the upstream grid is equipped with generation capacity (solar photovoltaic panels), community and residential battery energy storage systems (BESS), home energy management system (HEMS) and a microgrid controller to be able to operate autonomously and increase the security of supply. A similar concept is implemented in the Oud-Heverlee demonstration site in Belgium, part of the *Muse Grids* project, where the last dozen houses in a distribution line in a rural street will become a microgrid, being able to act as an energy island when needed. Although a “microgrid” is mentioned in the Schoonschip demonstration site of the *Grid-Friends* project in Amsterdam, this is not technically a microgrid. As the subtitle of the project also implies, it is about “demand response for grid-friendly quasi-autarkic energy cooperatives”, with the goal to maximise cost efficiency and use intelligent demand response to support the community and provide green energy and system services to the grid. Microgrids are also mentioned in the *Merlon* project, but only in the context of providing additional services to the distribution and transmission grid (microgrid-as-a-service). Finally, in the *Nice Grid* project a successful islanding part of the grid operating as a microgrid for a few hours has been tested, but full microgrid capability was not an objective of the demonstrator.

2.4.1 Generation solutions

In most of the projects (18 out of 22), generation technologies are part of the demonstration site, supporting the reduction of energy needs from the main electricity (or heat) network. Photovoltaic (**PV)** solar panels are used in the majority of these projects (16 out of 18). In some cases, ownership of solar panels is a pre-requisite for participation in the project (e.g. *City-zen*), while in others they are leased to project participants during the demonstration. There are also cases where PV generation comes from solar parks owned by the participating energy cooperative. Some projects use combined heat and power (**CHP)** plants, either exclusively (e.g. *Eepos*, *Ideas*) or complementary to PV (e.g. *Merlon*, *Origin*, *Shar-Q*). CHP plants generally use some kind of biofuel and are therefore considered as a form of renewable energy source. They are typically owned by the community and there is no need for micro-CHP installation in each house/building.

Below, we present **some examples** from representative projects.

In the Italian demonstration site of the *Origin* project a group of residential and commercial buildings forms the energy community under study. Residential buildings have approximately 20 to 25 residents each, and are heated using biomass boilers augmented with solar hot water systems; electrical demand is met by a combination of large solar-PV arrays and grid electricity (ORIGIN, 2015). Besides electrical storage and EV to enhance self-consumption of solar PV, solutions like addition of wind and/or hydro generation with pump storage were found attractive for the site. Another proposed solution included the expansion of the district heating to more than one residential buildings with *Origin* orchestrated biomass CHP / solar system with thermal storage. While for this community the addition of wind and hydro electricity generation in combination with electrical storage showed a good potential to provide a better year-round electricity supply, the biomass and CHP options needed careful consideration, due to the biomass supply chain and the need for a comparative lifecycle carbon and financial assessment. In general, the possibility to model and analyse possible scenarios was very beneficial for the community.

In the Finnish demonstration site of the *Idea* project, a district energy supplier generates, distributes and supplies heat and electricity from renewable resources (bio-fuelled CHP and wind turbines) in a predominantly residential area. It interacts with the energy market and has the means to control local energy production and distribution to increase profits. The district energy supplier can also provide services to its customers. According to the project, in the future district heating providers can profitably extend their energy service contract to their customers to include the generation, supply and distribution of locally produced renewable electricity.

2.4.2 Solutions for consumers

The projects surveyed test several technological solutions that enable demand response to support end-users to effectively manage their energy production and consumption.

In all except three of the projects, some kind of near real-time metering of consumption is used, either by a **smart meter** or by sub-metering. In some cases, smart meters were already in place in the houses/buildings participating in the projects, whereas in other cases commercial or prototype smart meters, often with some extended functionality, were installed as part of the demonstration.

Smart meters are key enablers for the involvement of consumers and communities. Their roll out at EU level has been going on since the Third Energy Package in 2009. Estimations from the Member States and the EC suggest that by 2030 more than 90 % of the electricity meters in EU will be smart; however according to a recent benchmarking[15] the penetration level in 2020 was still smaller than 50 %.

Other technologies tested in the projects surveyed include: **smart plugs** with remote monitoring and control capabilities to make a legacy device “smart”; **smart home appliances**, which include smart features and wireless connectivity and **user interfaces**, in most cases part of the related home management system (HEMS).

[15] Benchmarking smart metering deployment in the EU-28, https://op.europa.eu/s/n8i2

The projects surveyed involved the participants, either from the planning phase of the project or at least during the demonstration period. In this way they collected valuable feedback on how the consumers received the solutions, how they used them and how engaged they were during and after the demonstration phase.

Below, we present **some examples** from representative projects.

The *CIVIS* project highlights the important role of ICT solutions in the successful engagement with energy community. In particular, it proposes a triple-role for the future of ICT: as an engagement tool, as a research tool, and as a project design tool (CIVIS, 2016).

In the *City-zen* project, user interfaces (tied to solar panels, household batteries, or energy platforms) were designed to support consumers to become more conscious of how they consume energy. By monitoring their energy use, they experience and understand their relationship to energy and experience gratification upon seeing their energy savings and the respective monetary gains (Gerritse, van Loon, van der Eerden, Zweistra, & Eising, 2019).

In the *Origin* project, user interfaces played an important role. Feedback from participants highlights the wish to get the information from monitoring more accessible on phones and tablets, even mentioning a one-click approach. This would help elderly consumers and the busier ones and could open up new business models and increase the pool of potential participants (ORIGIN, 2015). Moreover, feedback on smart systems such as smart plugs and sensors suggested a plug-and-play approach, so that they can easily be retrofitted into existing dwellings, ideally without the need for specialist installers.

2.4.3 Storage solutions

In the majority of projects (15 out of 22) energy storage solutions are implemented in the demonstrator, mostly in the form of a battery energy storage system (BESS) and less frequently in the form of thermal energy storage, i.e. electric water heater and heat pumps for domestic hot water and/or heating purposes.

EV batteries can be also considered as a form of energy storage; they are used in several of the projects surveyed to increase self-consumption of energy produced on-site encouraging consumers to move their charging from times when local production is low to times when production is high (e.g. *Merlon*, *Smart-Mla*). Some projects also provide the installation of community EV charging points (e.g. *Compile*).

In recent years, the concept of V2G (Vehicle-to-Grid) has emerged; according to it batteries of an EV could be used to store excessive electric energy and give it back to the grid, i.e. using the EV battery as a buffer. Some of the projects surveyed tested the V2G concept (e.g. *City-zen*, *Shar*-Q), but not in combination with the collective action approach.

Regarding BESS, in most of the cases a domestic BESS is employed, which often operates in coordination with a solar PV system and an energy management system (EMS) in order to maximize self-consumption of PV produced electricity. Such residential battery storage systems have been commercialized since 2015 and the introduction of the well-known Tesla Powerwall. In four projects (*Compile*, *Muse Grids*, *Nice Grid, Sensible*) the concept of a community BESS is implemented. With such a system, the community members can benefit from a larger storage capacity compared to a household one, which can be sized in a more optimal way thanks to the aggregation of demand

and/or production from the whole community. The objectives of such a community BESS are multiple:

- In the *Compile* project, a BESS is installed in the demonstration site Luče in Slovenia. This is a rural low voltage network with a weak and unstable connection to the grid, resulting in frequent power failures and reduced capability to integrate renewables. Therefore, the goal of the community BESS, along with the rest of the system, will be to **ensure the security of supply** of the local energy system with high penetration of renewables.
- In the *Muse Grids* demonstration site of Oud-Heverlee in Belgium, the community BESS is combined with a number of existing heat pumps, roof-top solar PV installations, EV chargers, fuel cells, thermal storage, etc. all installed in the last dozen of houses of a rural street. The aim of this demonstrator is for these houses to become a **microgrid** at the end of the distribution line, with the ability to act as an energy island, being more autonomous and independent.
- In the *Nice Grid* project, four different types of BESS at different levels of the distribution grid of Carros (France) are installed. These four systems have demonstrated the wide range of flexibility capabilities that energy storage can offer. More specifically, two community BESS have been installed in residential solar districts offering **peak demand reduction** during cold days and **storing of excessive PV** generation during sunny days. The other three types of storage were: a) a large BESS connected at the primary substation for **peak demand reduction**, b) a large BESS connected at the secondary substation in an industrial area that could offer limited **islanding capability**, and c) 18 small residential BESS in combination with PV allowing prosumers to help **reduce winter consumption and summer injection peaks**.
- In the *Sensible* project, community BESS are implemented in two of the demonstration sites. In the Meadows community located on the south side of Nottingham city centre (UK), a community BESS operates along with residential BESS and monitoring and control installed in 40 selected houses. In the demonstration site of Evora (Portugal) a BESS is installed together with supercapacitors at the secondary substation, which is owned by the DSO (EDP Distribucao) and it is also complemented by additional BESS along the low voltage feeder and at household level. This solution represents a mixed concept where **multiple BESS** are installed and owned by different actors (both DSO and the community), operating in coordination for the optimized and safe operation of the distribution grid.

2.4.4 Energy management solutions

An important technology trialled in many projects is the energy management system (EMS). Even though there is no single definition, usually by EMS we refer to an integrated information and automation system of computer aided tools that collects measurement data and any other necessary piece of information, to monitor, control, and optimize the energy performance of a system. A secondary objective of an EMS can be to better visualize and share the above information not only with the operators but also with the end-users. Depending on the scale of the demonstration site (see Figure 3 and Figure 17), different energy management systems are implemented: HEMS and building energy management system (BEMS) for the home and building level and local energy management system (LEMS) for the local level. VPPs and Distributed Ledger Technology (DLT) are used for virtual communities[16] and special applications.

HEMS and BEMS are well-established energy management systems and the main challenge faced by the projects was to integrate new type of devices into such systems, as for example PV, batteries, EV charging stations, etc., as well as to make them interoperable with other applications or elements of the energy system. More relevant for collective action projects are LEMS that are found in 11 of the analysed projects. LEMS allow the coordination, consumption and storage of decentralized energy sources within a local geographical area, enabling the optimisation of demand and supply side management at community level. This optimisation can serve multiple purposes, such as the maximization of self-produced energy from the local energy community, the aggregation of energy consumption and/or production for participation in the energy market, or the improvement of security of supply in case of disruption in the main grid. At the core of a LEMS is an integrated ICT platform that process a large quantity and variety of data, including energy production and consumption data, weather forecast, devices status and hourly electricity tariffs. Similarly, the VPP technology aggregates the capacities of various distributed energy resources, which however can be located in a different geographical area. In this sense, it is more a cloud-based distributed power plant and its purposes are mainly trading or selling power.

In Figure 19, we have included DLT under the category of energy management solutions, although DLTs are not energy management systems per se. In fact, DLTs are "*particular types of databases in which data is recorded, shared and synchronised across a distributed network of computers or participants*" to enable "*parties with no particular trust in each other to exchange any type of digital data on a peer-to-peer basis with fewer or no third parties or intermediaries*" (Nascimento, et al., 2019). DLTs (e.g. blockchain) are currently been implemented in a number of demostration sites to facilitate various types of energy transactions. In the *Nemogrid* project, for example, a scenario of a peer-to-peer market based on blockchain for energy transactions is investigated with the objective to evaluate new sustainable business models. In the *Smart-Mla* project, blockchain is used for smart contracts that enable interactions between energy assets in a community and external flexibility markets.

Below we report **some examples** from representative projects. We focus on LEMS and the Aggregation/VPP concept, as they better exemplify the collective approach.

The *Idea* project tested an energy management tool at the neighbourhood level (LEMS) whose analytical functionality was based on simulation, prediction, and optimisation models. These models could accurately predict the energy supply and demand of the neighbourhood, could offer user-specific optimisation for the production, storage and sale of RES energy at neighbourhood level, and could simulate the effects of further RES investments to support investment decision-making process for the consumers and the neighbourhood as a whole. The objective of the optimisation algorithms was the energy cost and/or the CO_2 emissions. From the technical point of view, the main components of the developed LEMS were: a) an internet-based infrastructure to manage real-time information flows, b) an optimisation and decision support system for the management of energy production and consumption, and c) data management and storage services.

[16] Virtual communities are non-placed based communities. In these cases, 'the community need not to be an actual neighbourhood or physical community but a collection of participants or members who form a virtual community, typically through intermediaries (Sioshansi, 2019).

In the Austrian demonstration site of the *Merlon*[17] project an integrated LEMS optimising and managing electricity and heat is tested, which includes a large energy storage connecting PV, electric vehicle charging facilities, a large biogas CHP unit, and residential and public buildings, acting as prosumers. One of the goals is to enable aggregators and energy cooperatives to gain access to this wide variety of distributed energy resources assets through a properly configured open and fully transparent flexibility pooling and sharing marketplace. This will give the interested stakeholders the opportunity to optimally segment, classify and cluster/aggregate demand, storage, EV and CHP assets for the formulation of virtual power plants for the provision of flexibility services to the local DSO.

In the *City-Zen* project, a VPP of 50 households equipped with battery systems and solar panels was formed by connecting them to a central control system. Each household individually produces, consumes and stores energy. One use case of the VPP tested in the project is to allow trading in energy markets via an aggregator while another use case is using locally generated energy, i.e. expanding the notion of home self-consumption achieved with a HEMS to a broader area.

2.5 Stakeholders involved

In total, 227 organisations, grouped into 12 categories, participated in the projects. As some of these organizations participated in more than one project (about 12 % of them), we also checked the total number participations, totalling 257. Project consortia range from 4 to 23 partners and most of them (86 %) are multinational, that is, bringing together organisations from different countries. For such organisations, projects represent an opportunity to encounter partners from other countries and share knowledge and ideas with them, as well as to network and explore new market possibilities.

Unless the project documentation makes it clear that only some project partners participated in the relevant demonstrators, the database includes all the partners of the project consortium, regardless of their specific contribution to the development of collective action solutions. We based this decision on the consideration that project partners usually participate in all project tasks, even if only with an advisory role.

Table 2 presents a short description for each category, while Figure 21 shows the number of participations in the surveyed projects. Universities and research centres, technology manufacturers and ICT companies are the categories with the highest number of participations, but other stakeholder categories, such as DSOs, public institutions and energy cooperatives, also play an increasingly important role.

In the following paragraphs we provide some examples of the role taken by the participating organisations in the project surveyed.

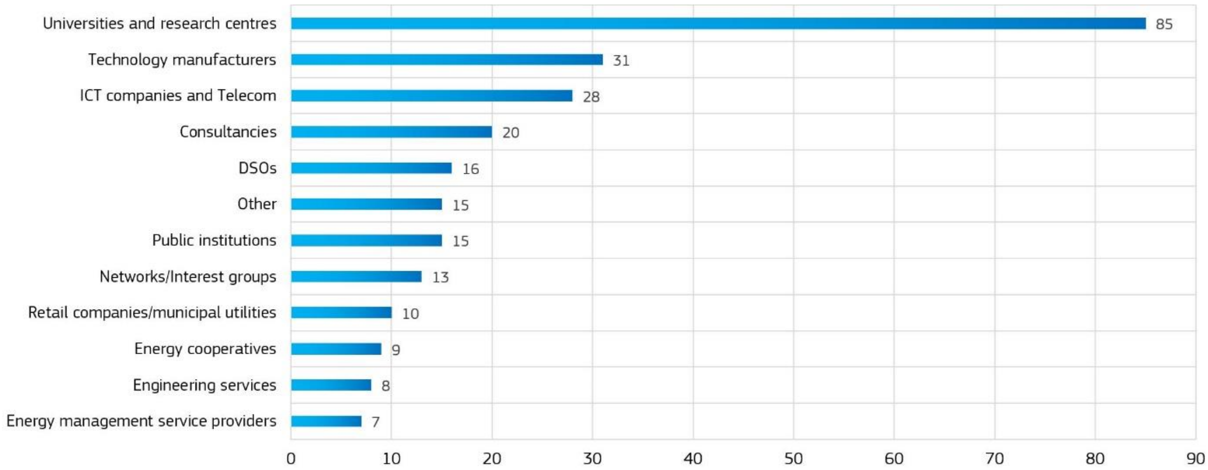
[17] www.merlon-project.eu/

Table 2. CA projects: stakeholder categories

Stakeholder category	Description
Consultancies	Organisations providing professional expert advice to other public and private organisations
Distribution system operators (DSO)	DSOs are organisations responsible for the operation, management and planning of distribution electricity networks
Energy cooperatives	Given the differences in country-specific definitions, the Report adopts a wide definition of energy cooperatives, as associations where citizens jointly own and participate in decentralised energy or energy efficiency projects, independently of their legal statute.
Energy management service providers	Organisations providing energy management solutions and services, typically enabling higher consumer participation
Engineering services providers	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.
ICT companies	Organisations active as smart energy software developers, system designers, system integrators.
Public institutions	Public entities, such as regions, municipalities, local authorities, environmental and energy agencies.
Retail companies/municipal utilities	Organisations active in the sale, including resale, of electricity to customers.
Technology manufacturers	Organisations active in the design and production of technological solutions, particularly hardware solutions.
Universities/research centres	Universities are public and private higher education institutions, e.g. universities, institutes of technologies and colleges. Research centres are public and private organisations dedicated to scientific research, both basic and applied.
Networks/Interest groups	Organizations whose scope is to represent and promote a common objective at national and international level.
Other	Organisations active in different sectors, that cannot be placed in any of the above-mentioned categories (e.g. innovation angels, district heating operators, real estate developers, housing associations, electric mobility providers).

Source: JRC, (2020)

Figure 21. CA projects: number of participations per stakeholder category



Source: JRC, (2020)

Universities and research centres is the category with the highest number of participations (33 %) and the category which figures more often with a project lead role (in 11 projects out of 22). This finding may suggest that research into technological and social aspects of collective action projects is still much needed. Besides conducting research, Universities and research centres also take up a consulting role, supporting other stakeholders in the implementation of projects through their knowledge and expertise. In the project *Nemogrid* for example, the Chemnitz University of Technology is responsible for the investigation of consumer and prosumer perspectives, their motivation, and acceptance. In the *Merlon* project, the Imperial College London leads the activities for the definition of new business models for local energy flexibility markets, while more on the technical side, in the project *Muse Grids* the Fundación CARDIF is involved in the design and development of the smart control for multiple energy grids.

Although their participation in collective action projects is surely beneficial, Universities and research centres should be aware of adopting a marked academic approach in collective action projects, as such an approach was reported by some participants as having a negative impact on engagement (CIVIS, 2016).

DSOs figure in 10 out of 22 projects and represent 6 % of all participations. Their participation in collective action projects represents an opportunity to trial new technological solutions in real life environments, as well as to explore new business models that create value for all the parties involved. In the *Merlon* project for example, the DSO is testing new solutions for the integration of distributed energy resources that help to avoid, or at least reduce to a minimum, the need for grid reinforcement. In the Italian demonstrator of the *WiseGrid* project, the local DSO is testing the possibility to use electric vehicles and battery storage along the low voltage branch of its smart grid, to mitigate and smooth the fluctuating power output generated by the nearby PV farm. The *Nice Smart Valley* project has investigated the set-up of a local flexibility market, operated by the DSO, as a means to value flexibility for the operation of the distribution grid. By participating in these projects, DSOs can also gain experience in aspects related to community development, such as social cohesion, citizen engagement activities and activation of end-users (e.g. in the *Compile* project).

The category **Other,** includes a variety of organisations that cannot be placed in any other category. An interesting type of organisation figuring in this category is 'Local not-for-profit organisations' (3 participations), stakeholders that are mainly acting as a contact point for project participants, facilitating their recruitment and engagement. An interesting example of their contribution is offered by the project *Sensible*, where the backing received by the project partner Mozes, a not-for-profit community energy group, meant that the project found it easier to gain trust and support from the local community members (Kiamba, Rodrigues, & Marsh, 2017). Mozes treated community engagement as a cumulative process that aimed to not only gauge the level of support for the scheme but also to prioritise local needs, strengthen the relationship with the community, and review and inform on the project (Kiamba, Rodrigues, & Marsh, 2017). Another interesting case is provided by the project *Smart Energy Island*, where a not-for-profit community interest company partnered with not-for-profit energy supplier to provide inhabitants with a competitive, local energy deal. This proposal helped the project in gaining participants support and engagement and contributed to reduce energy poverty in a location where the percentage of fuel poor is higher than in the rest of the country (i.e. 15.5 % fuel poor compared with English average 11.1 %).

The analysis of the projects surveyed shows that participation of local actors with strong roots within the community where the demonstration takes place is still very limited in collective action projects. On the other hand, we will later see how these organisations show a much higher participation rate in projects addressing non-technological challenges. This finding seems to highlight the difficulty still faced by most collective action projects to focus on the end users and to take into consideration the social dimensions of the energy transition. Which stakeholder is best placed to ensuring that the social dimension is taken in due consideration depends on a variety of local factors. In general, it can be said that organisations with strong local ties, who are already trusted to act in the interest of the local community are in a better position to trigger collaboration, engagement, knowledge-sharing and co-creation and that it would be desirable to see more of them in future project consortia.

Public institutions also represent only 6 % of participations and are present in 9 out of 22 projects, most of them being municipalities. Although they never hold a leading role, their participation in the projects is often crucial to help building the sense of a community effort and to facilitate project recruitment and engagement (Mengolini, Gangale, & Vasiljevska, 2016). In the project *CityOpt* for example, the metropolitan local authority Nice Côte d'Azur was widely involved in project recruitment, e.g. through sending the initial recruitment letter, the development of a registration online form on their website and the implementation of a participant hotline and web forum. The local authority marketed the project as an opportunity for citizens to participate in an innovative initiative that could improve the resilience of the local energy system and put the metropolitan area on the path towards the upcoming energy transition. Besides helping the recruitment and engagement processes, the participation of public institutions - in particular local authorities - in collective action projects could also help to build their capacity to take the lead or participate in future community energy projects. As land use planners, local authorities can take advantage of urban development plans, such as new eco-friendly neighbourhoods, to lead project developers towards community energy solutions, including collective self-consumption (Bolle, 2019). In our database, the only projects implemented in newly developed neighbourhoods (i.e. in *Eepos*, the housing area "Merenkulkijanranta" in Helsinki, and, in *Grid-Friends*, the new neighbourhood Schoonschip, in Amsterdam), do not list local authorities in the project consortium. In future research projects, it would be desirable to see more public institutions and local authorities taking the lead of collective action projects in the framework of their urban development and renewal plans, also in cooperation with local energy cooperatives and local associations.

Overall, the projects surveyed display a high participation of traditional stakeholders (e.g. universities and research centres, DSOs, technology manufacturers), and a moderate participation of emerging actors, newer in the energy research and innovation arena, such as public institutions, energy cooperatives and local not-for-profit organisations. Contrary to what one might have expected, other emerging stakeholders, such as for example aggregators, do not figure in the analysis. Their role is however sometimes fulfilled by other actors, such as traditional retailers (e.g. EDF in the *Nice Smart Valley* project, where EDF implemented a platform to indirectly control the flexibilities of its customers) or cooperatives (e.g. in the *Flexcoop* project, where energy cooperatives assumed also the role of aggregators to trial an innovative business model).

Future R&I projects should promote wider participation by different stakeholder categories and encourage collaboration between existing and new players in flexibility services to test innovative business models.

2.6 Community engagement strategies

Active participation of users is a distinctive characteristic of collective action projects in our database, where new technologies, business models and engagement approaches that build on the idea of a shared effort are combined to support consumers in changing the way they use energy.

Engagement strategies typically combine the use of a wide variety of targeted interventions that, in most cases, have the double objective to support the recruitment of project participants and to engage them in the project activities over the duration of the project and beyond. A well-designed engagement strategy that leverages on community-level dynamics is key to bringing people together with a common purpose and achieve the project objectives. Overall, engaged community members are less likely to perceive barriers to a local energy project, thereby enabling smother project implementation (Kiamba, Rodrigues, & Marsh, 2017).

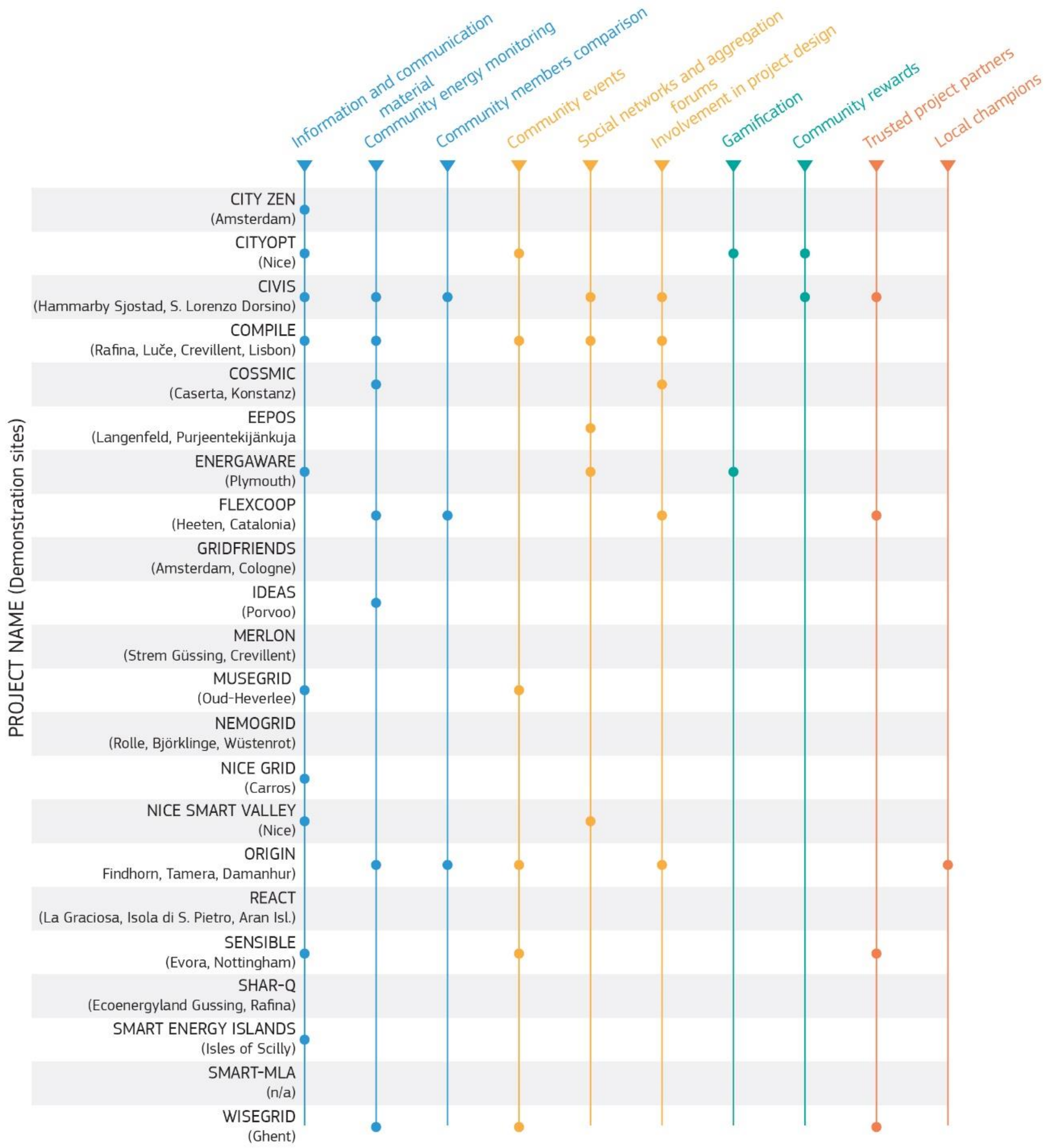
Our analysis presents the interventions that aim to develop the sense of a community-based initiative and use community dynamics to foster individual behavioural change towards sustainable energy practices. Projects reports were screened to identify the interventions used throughout the project, the challenges encountered, the outcomes achieved, and the lessons learned. For about 1/3 of the projects, however, especially the most recent, this analysis was not possible, as the project documentation does not contain any reference to the engagement strategy used. In most cases, given the importance (at least formally) attributed by the projects surveyed to social aspects, the lack of documentation is probably due to their recent start. In some cases, on the other hand, it might also be a sign of the difficulty faced by most projects to focus on the end users and integrate their social dimension since the early stages of project development. Table 3 below describes the main interventions used in the projects, aggregated according to the main lever used to engage participants, while Figure 22 lists the projects where the listed interventions where used.

Table 3. CA projects: consumer engagement interventions

Lever	Intervention	Description
Increased awareness	*Information and communication material*	A wide variety of means used to advertise the project, inform the participants about its objectives, achievements and benefits for the local community.
	Social comparison	Social comparison correlates a household's performance in the project to that of similar households in the community to provide a point of comparison for an individual's own behaviour.
	Community energy monitoring	Community-wide energy monitoring devices provide project participants with a collective overview of their consumption and of the level of renewable and locally generated electricity in the community.
Participatory approach	*Community events*	Community events are used to provide an opportunity for participants to come together within the context of the project and develop the sense of a community-based initiative. They can take different forms, e.g. thematic meetings, workshops, coffee mornings, open house days in the project show room.
	Social networks and aggregation forums	Social networks and dedicated virtual aggregation platforms can be used to provide a virtual place for participants to exchange their experiences, share data of their achievements, tips and best practices, and to offer energy advice to other participants. They can also be used by project partners to interact with participants and share information with them.
	Involvement in project design	Involvement in project design (co-design) refers to the active involvement of project participants in the creation and evaluation of the technologies, concepts and services that they will ultimately use.
Incentives & rewards	*Community rewards*	Community rewards are tangible (typically financial) outcomes linked to project participants' collective achievements. They are typically allocated to initiatives that benefit the community.
	Gamification	Gamification refers to the use of playful challenges and competitions with other project participants to enhance participation and engagement.
Community trusted actors	*Trusted project partners*	Trusted project partners are typically local organisations that are perceived by the project participants as acting in their interest and in the interest of the local community.
	Local champions	Local champions are members of the community where the demonstration takes place, who volunteer to spread the word on the project and its importance for the community, thus helping in the recruitment and engagement phases. They also act as a local point person for other participants who may have questions and concerns and as a liaison with the project partners.

Source: JRC, (2020)

Figure 22. Consumer engagement interventions trialled in each CA project



Source: JRC, (2020)

2.6.1 Increased awareness

Information and communication material is used by about half of the projects surveyed. Information material includes a wide range of means, e.g. leaflets, street posters, information brochures, press coverage, promotional videos, animations, graphic tutorials, comic strips and even the use of dedicated show rooms to explain the demonstration. In the project *Nice Smart Valley* for example, the show room was equipped with virtual and augmented reality technologies, to make visitors immerse themselves in the demonstrator's operation, discover the latest technologies and display the data platforms at the heart of the smart city. In the project *Nice Grid* on the other hand, the information and communication strategy also included a variety of less conventional means, e.g. an agreement with a local charity organization to contribute to the project by painting local LV/MV substations so that they are better integrated into the urban landscape, while at the same time enhancing local young people's awareness about smart grids and the creation of a storytelling containing explanations of vocabulary specific to the energy sector with simple words.

Social comparison is an engagement intervention that aims to influence participants' behaviour by comparing their performance to the performance of peer members of the community. Peer comparison activates social norms – descriptive and injunctive norms – that have an important influence on behaviour (Cialdini, Kallgren, & Reno, 1991) (Schultz, Nolan, Cialdini, Goldstein, & Griskevicius, 2007). Descriptive norms describe the prevalent behaviour in a particular situation, motivating action by informing people of what is generally seen as effective or adaptive behaviour in a given situation (Reno, Cialdini, & Kallgreen, 1993). Injunctive norms refer to perceptions of what is commonly approved or disapproved within the culture and motivate action by promising social sanctions for normative and counter normative conduct (Reno, Cialdini, & Kallgreen, 1993). Adding an injunctive norm that conveys the message that the energy practice is good for the community, for example through colour coding of the actual versus average energy profile, can support behavioural change and substantially reduce the risk of the boomerang effect (Allcot, 2011). The *Origin* project, for example, stressed the sense of a community achievement by using the energy monitor to map the buildings that participate in the project and by colour coding them to visualise those that consume more or less energy than the community average, using normalised indicators.

A large body of literature indicates that peer comparison interventions can cause households to reduce residential energy use (Kažukauskas, Broberg, & Jaraitė, 2017) (Schultz, Nolan, Cialdini, Goldstein, & Griskevicius, 2007) (Allcot, 2011). The surveyed projects do not provide an assessment of the intervention effectiveness but provide interesting observations regarding participants' preferences and the relevant peer group.

In the *Civis* project, for example, the user study revealed that people are willing to share publicly (or with a selected group of people) their energy conservation actions, and do not consider this a privacy issue. Besides getting information on the average energy use of other cooperatives and of the neighbourhood, participants in the Swedish demonstrator were also interested in getting information on building-level energy reduction actions taken by other cooperatives. Participants in the Italian test sites were very interested by the provision of daily consumption comparisons between different municipalities involved in the project (CIVIS, 2016).

The *Flexcoop* project revealed that interest for peer comparison is particularly strong in energy cooperatives, where comparison with similar peers acts as a motivation towards energy efficient behaviour. A recent research seems to confirm this finding. A survey conducted in two cooperatives in France and Belgium, reveals that length of membership and members having many peers who are (also) members are positive, significant predictors of reported energy savings and engaged energy-saving actions (Hoppe, Coenen, & Bekendam, 2019).

Community energy monitoring is a way to increase individual and collective awareness about local energy production and consumption patterns and about the status of the local energy grid. Increased awareness can support the establishment of a collaborative framework and enable individuals to contribute their share towards meeting the collective goal, triggering behavioural change. In case of excess or deficit of energy at local level, for example, participants can shift their demand or change their patterns of usage if they are timely informed of the event and of the actions they can take. In the *Origin* project, project participants received local renewables and demand forecasts coded into four colour levels, with dark red representing a clear deficit, and bright green representing a clear surplus. The colour codes invite participants to change their energy related behaviour, guided by textual suggestions. In the project *WiseGrid*, participants are given an individual and collective overview of their consumption, as well as of the production of renewable energy from the solar panels in the neighbourhood. In order to maintain a good net balance, project participants are encouraged to consume consciously when local solar energy is high.

Information about local energy production and consumption is generally conveyed through a user interface, installed in participants' premises or in communal areas, or even more accessibly on phones and tablets. The focus is typically on indicators and metrics related to the collective performance of project participants, e.g. self-consumption levels, demand flexibility potential, grid imports-exports. Besides the current situation, many projects display also historical data to see how local production and consumption patterns have changed with time (e.g. *Ideas* project).

2.6.2 Participatory approach

Knowledge acquisition and learning are greatly facilitated by interaction and collaboration with others (Lave & Wenger, 1991). Exchanging experiences and knowledge among peers can also facilitate engagement in the project and acceptance of the trialled technological solutions. Several projects highlighted participants desire for peer support and knowledge-sharing and implemented different forms of physical or virtual collaboration, including community events, social networks and dedicated aggregation forums, and co-design sessions. These interventions facilitated direct personal interaction and interpersonal trust and served to strengthen local ties and networks among participants.

Community events are used to provide an opportunity for participants to come together within the context of the project and develop the sense of community of the initiatives. They also create opportunities to make visible what people are doing individually, giving people a sense that 'things are happening' (Coxcoon, Sansom, McMullen, & Ballard, 2015). They can take different forms, e.g. information sessions, focus groups, thematic meetings, workshops, coffee mornings, open house days in the project show room.

Community events are typically organised to share information about the project objectives and initiatives, the state of progress of the project activities and the challenges that participants may face. They serve also as settings for people to meet and informally exchange personal experiences with the trialled technological solutions with their neighbours and give advices. In this way, community events contribute to informal knowledge sharing and shared learning within the local community, promoting engagement and behavioural change. The majority of projects surveyed resorts to one or more forms of community events (e.g. *CityOpt Nice*, *City-zen*, *Civis*, *Compile*, *Cossmic*, *Muse Grids*, *Nice Grid*, *Nice Smart Valley*, *Origin*, *Sensible*, *Smart Energy Island*, *WiseGrid*).

Social networks and aggregation forums represent a way to inform participants who have access to ICT about project developments, to make actions happening at the household level visible at the community level and to promote the creation of virtual communities of practice where participants can interact and collaborate online.

In the *Nice Smart Valley* project for example, a specific Twitter account for the community of prosumers was created to promote the project, solicit participation and engage participants. Through this account, the *Nice Smart Valley* community could regularly get information about the demonstrator, share publications and interact with the project team.

In the *Civis* project, the ICT platform provided information about how many participants have taken an action, and supported collaboration and sharing of experiences through a commenting function for each action added, where users can post questions and react to other participants' input. Participants can also sign up and log in with a Facebook account and 'share' their actions directly with other participants.

In the *Eepos* project, an end user collaboration tool was created that offered an interface between the ICT platform and social media, such as Facebook, LinkedIn and Google+. The tool allows users to publish their energy saving and to compare their performance with others.

These and other interventions trialled by the projects aim to support knowledge sharing between a community of users, reinforce the sense of participation in a community endeavour and enhance experiences of social gratification from collective activities. As noted by the project *Civis*, participants at the demonstration sites seemed to enjoy these features, supporting the notion that engagement can be driven not just by individuals' pre-existing motivations (e.g., financial or environmental) but by households' experiences and interactions once they start participating in the project and that ICT can help support these more community-based routes to engagement (CIVIS, 2016).

Involvement in project design (co-design). Early community involvement in project design can help to motivate participants, convey the idea of a community effort, build trust in the initiative and trigger a desire to cooperate. Several projects surveyed adopted some sort of community involvement in project design.

In the *Cossmic* project, co-design workshops and games were conducted with participants to develop the project concepts. Methods used included rough prototyping, experience prototype and product box. Workshops incorporated a number of communication tools to encourage ideas and discussion to flow, such as tomorrow headlines, storyboards, service images (COSSMIC, 2015).

In the *Origin* project, a participatory approach was used to produce community-led inputs for the design of the user interface and to assess its acceptance by the users. A similar approach was adopted in the project *Flexcoop*, where the elicitation of end user's requirements was done through a participatory process carried out in the two *Flexcoop* Living Labs.

In the project *Civis*, the co-design process informed the iterative design of interventions and apps and suggested possibilities for future projects (e.g., a focus on involving youth). Besides emphasising the many benefits associated with the resort to co-design approaches, the project also highlighted the potential challenge of generating unfulfilled expectations with the consequent negative impact on participation and engagement (CIVIS, 2016). In the Italian test sites, for example, the project reported a negative impact on some participants who, having actively participated in co-design activities, did not see realized in the ICT platform a dedicated tool-set for the optimization of private PV panels (CIVIS, 2016).

2.6.3 Incentives and rewards

Community rewards are used to support participants engagement by providing an incentive to reach common societal (e.g. energy saving) and community goals (e.g. avoiding blackouts, supporting local community projects) (Mengolini, Gangale, & Vasiljevska, 2016). They are typically financial outcomes linked to project participants' collective achievements and are usually allocated to initiatives that benefit the local community.

Two projects in the database trialled this intervention, reporting encouraging results. The *CityOpt* project designed an engagement strategy that revolved around the idea of engaging individuals as members of a community, rather than only as consumers of energy (Abdurafikov, et al., 2014). A community-based application was created where demand response solicitations based on real network peaks were sent to participants. By participating in the collective challenge of load shedding, participants gained points that could be invested in one or more project benefiting the local community. Schools and the education system in general were indicated as the ideal target for initiatives aimed at rewarding community-based efforts (Abdurafikov, et al., 2014). The project reported a strong commitment of the participants to reduce their consumption during the alerts. The average load shedding per participant was equivalent to that recorded by participants in the *Nice Grid* project, where participants were bigger consumers, using mostly electric heating[18]. Although such results cannot be credited to a single intervention, the idea of a community of people working together for the same objectives seemed to be effective in giving a collective dimension to individual action and in amplifying individual behaviours. In a survey run during the project, participants said that they felt 'actors' of the change and not simply observer, since the effect of their little action would affect their community on a very pragmatic level (Abdurafikov, et al., 2014).

The *Civis* project also reported positive participants' feedback from the provision of a community-level incentive. The project assigned savings achieved by participants through a more efficient use of energy to initiatives that benefit the local community. Participants stressed that the benefits should go to a local, tangible project clearly connected to their community's efforts (CIVIS, 2016). Participants would rather finance local associations than the public sector/social initiatives, as they feel associations are more worthwhile in their local context. They would rather save energy for a little project that is financed completely by *Civis*, rather than donate to an already existing initiative, covering just a percentage of the amount required (CIVIS, 2016). According to the *Civis* project, participants' response to the use of community-level rewards varies between test sites for different potential reasons, including the different community boundaries, which characterize the involved areas. Closer communities report higher engagement and satisfaction levels (CIVIS, 2016). A similar conclusion was also drawn by the *CityOpt* project, where small towns and villages appeared to be more cohesive social clusters than city neighbourhoods. Villagers are indeed more open to possibilities and more interested in rewards at the local community level (Abdurafikov, et al., 2014).

Gamification. Including playful challenges and competitions has been trialled in several national and EU funded projects as a way to enhance consumers' participation and engagement (S3C consortium, 2014) (Mengolini, Gangale, & Vasiljevska, 2016). The experiences with gaming interfaces and competitive elements are promising and inspiring, both in terms of engagement and in terms of outcomes. Gamification modifies consumer engagement into a function of both interest in the project scope and in gaming, with one potentially providing mutual support to the other (Davison, 2019). However, a challenge of gamification is to capture the interest and attention of end users in the long run (S3C consortium, 2014).

[18] In *CityOpt*, it was observed an average load shedding of 300 Wh per participant between 6 and 8 pm, the average annual consumption being 3,500 kWh (90 % of *CityOpt* customers contracted power is less than 6 kVA). While in the *Nice Grid* project, the average load shedding was 350 Wh per participant between 6 and 8 pm, the average annual consumption being 8,000 kWh (70 % of Nice Grid customers contracted power greater than 9 kVA) (Abdurafikov, et al., 2014).

Two projects in the database provide interesting insights into the use of gamification in collective action projects. In the *Energaware* project, a serious game was implemented to teach users, households from the social housing sector, about best practices for achieving energy savings at home. The project found evidence of improvement in engagement in certain specific energy saving behaviours. The intervention was, to some extent, effective in motivating positive behaviour change, but this effect were only found to prevail in the relative short-term, and did not persist to the final term stage (ENERGAWARE, 2018).

The project *CityOpt* on the other hand, offers interesting evidence of the benefits of combining gamification with community rewards. Participants could earn points corresponding to the estimated electricity saved during a load shedding request alert. As we already noted above, *CityOpt* points could then be used as a currency to invest in one or more community project, at neighbourhood, city or regional scale.

2.6.4 Community trusted actors

Several projects stressed that establishing a trusted relationship with the consumer is a crucial step to overcome resistance and fully engage the consumer. The project *Origin*, for example, highlighted that regardless of the type of demand response program deployed, participation is likely to be predicated on a consumer engagement strategy that encourages trust and provides clear information describing its aims and outcomes (ORIGIN, 2015). Recent studies on stakeholder's influence on the development of community renewable energy schemes (Ruggiero, Onkila, & Kuittinen, 2014) have highlighted the importance of two stakeholders: intermediary organizations acting as "trusted authorities" and local champions (Mengolini, Gangale, & Vasiljevska, 2016).

Trusted project partners are organisations involved in the project as project partners or as supporting organisations. They are typically existing local and community organisations with a good knowledge of the locality and of the social environment in which they operate. Organisations with strong local ties that adopt a community relationship approach are better placed than other actors to bring people together with a common purpose and their involvement in the project can often work as a door opener. In the project *Sensible*, for example, the backing received from a pre-existing not-for-profit energy community group has meant that the project has found it easier to gain trust and support from the local community members (Kiamba, Rodrigues, & Marsh, 2017).

In some of the projects surveyed, an important role in recruiting project participants and ensuring their active participation in project activities is played by energy cooperatives. Energy cooperatives are community-led energy initiatives trusted for being community partners and political advocates. In the EU, where overall trust in the electricity market is still problematic (European Commission, 2018), energy cooperatives can play an important role in gaining consumer trust and enabling a wider reach. A survey developed during the *Flexcoop* project, for example, revealed that the acceptance level to grant the management of home devices to cooperatives was 83 % in Spain and 60 % in the Netherlands. Many would not be willing to participate in the project if the managing company was a different one (FLEXCOOP, 2018).

Other stakeholders, such as public institutions and housing cooperatives, can also act as local trustworthy organisations. In the *Civis* project, for example, the region energy advice service, provided by the cities in the region, as well as housing companies, seem to be perceived as reliable sources of information (CIVIS, 2016), able to make participants understand the objectives and the challenges of the project.

Local champions are members of the local community where the demonstration takes place, who play a project marketing role and a participants' supporting role. They have a prominent role in starting, endorsing or carrying out a project thanks primarily to their individual values, skills and competencies (Ruggiero, Onkila, & Kuittinen, 2014). We could find evidence of resort to this engagement intervention only in the project *Origin*. The project sought to create local champions who then became trusted advocates of the project in each community. Their contribution to the project success was indeed relevant as evidence was found to suggest that the absence of this localism caused the notion of demand response to disappear from community consciousness. Energy practices quickly reverted back to their original state (ORIGIN, 2015). This finding underlines the importance of interpersonal relations to build the sense of a community achievement and the difficulty of achieving firm, long lasting changes through an engagement strategy based on a purely informational approach. The importance of trusted actors that participants can relate to is confirmed also by the findings of a survey carried out within the project *Civis*, where participants reported as reasons for decreasing engagement during the trial a perceived 'academic' approach to the project by the project team (CIVIS, 2016).

3 Projects addressing non-technological challenges

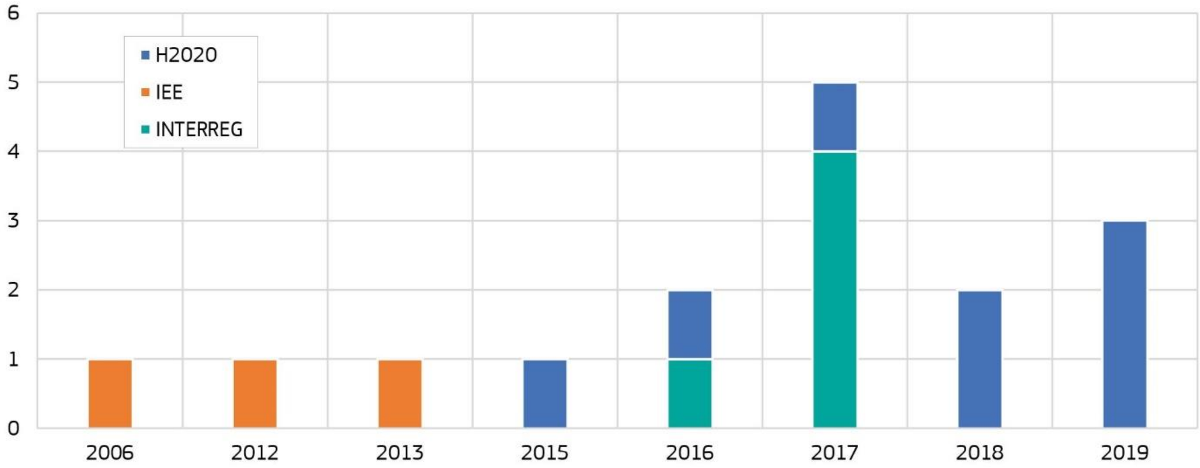
This section presents an overview of EU-funded projects that address the policy, institutional, economic and societal challenges of collective energy action initiatives. Rather than testing enabling technological solutions, these projects draw on social sciences and humanities to promote the emergence and development of collective energy action initiatives at local level. These initiatives are seen as a means to boost citizens' participation, to deliver environmental, social and economic value to the people and communities involved and to speed up the transition towards renewable energy.

To identify relevant projects, we searched internet sources and EU organised repositories using various combinations of the following keywords: community energy, collective action, energy cooperatives, community-owned, community-based, prosumers initiatives, shared-interest, citizen energy, local partnerships, Rescoops.

We identified 16 projects funded between 2006 and 2019 under different EU funding streams, such as the IEE, H2020 and the INTERREG transnational cooperation programmes[19] (Figure 23 and Figure 24). Figure 23 shows an increasing interest in projects supporting the emergence of collective action initiatives since 2016.

The projects share the ambition to support the development of local initiatives that increase the ability of consuming self-produced and locally generated electricity and that facilitate the uptake of energy efficiency and active demand solutions and services. They all put citizens at centre stage of the ongoing energy transition and leverage on the sense of a community effort towards a more sustainable and participatory energy future.

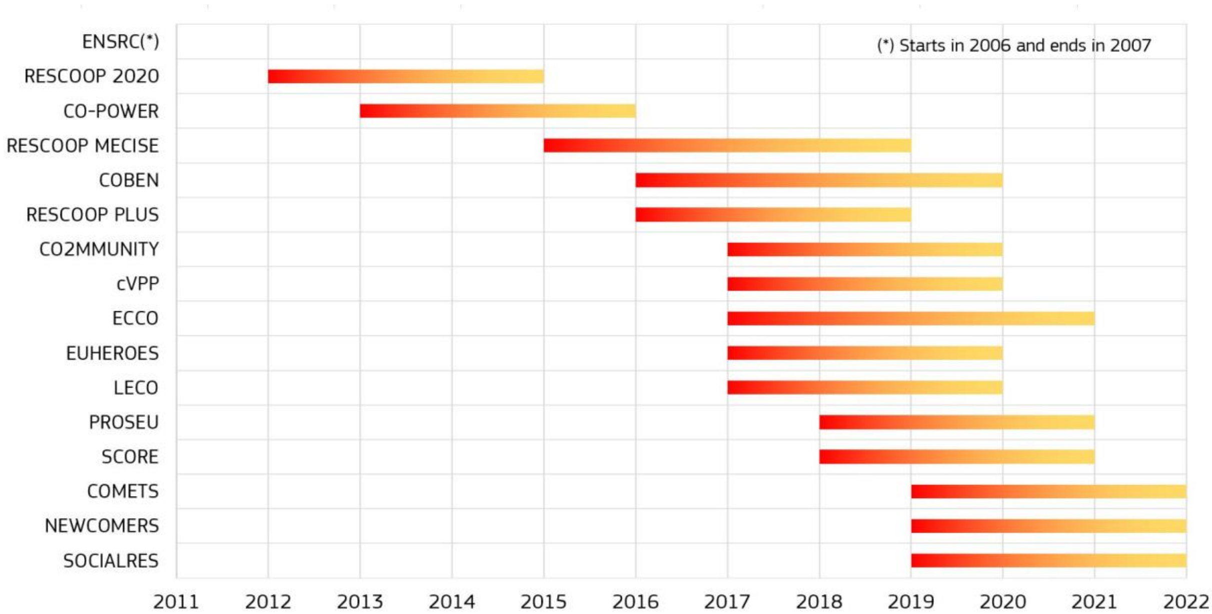
Figure 23. NTC projects: time distribution by funding source



Source: JRC, (2020)

[19] In particular we found projects funded under the following Interreg V cooperation programmes: Baltic Sea Region (BSR), North West Europe (NWE), North Sea region (NSR) and Northern Periphery and Artic (NPA).

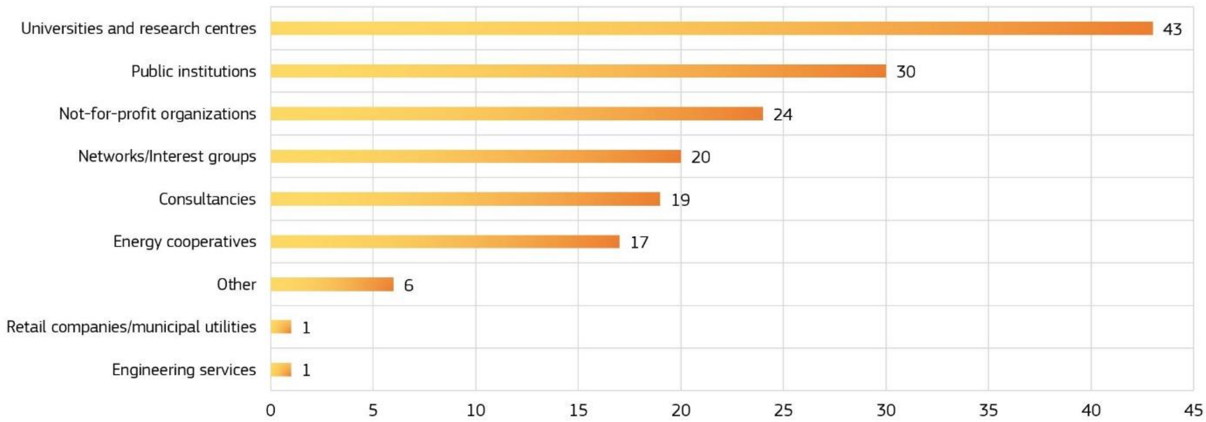
Figure 24. NTC projects: start and end date



Source: JRC, (2020)

161 organisations, grouped into 9 categories, participated in the projects (Figure 25). The categories are the same as those considered in the collective action project analysis, with the only difference that, given their large number, *Not-for-profit organisations* are counted as a separate category and not included in the category *Other* as it was the case for collective action projects.

Figure 25. NTC projects: number of participations per stakeholder category



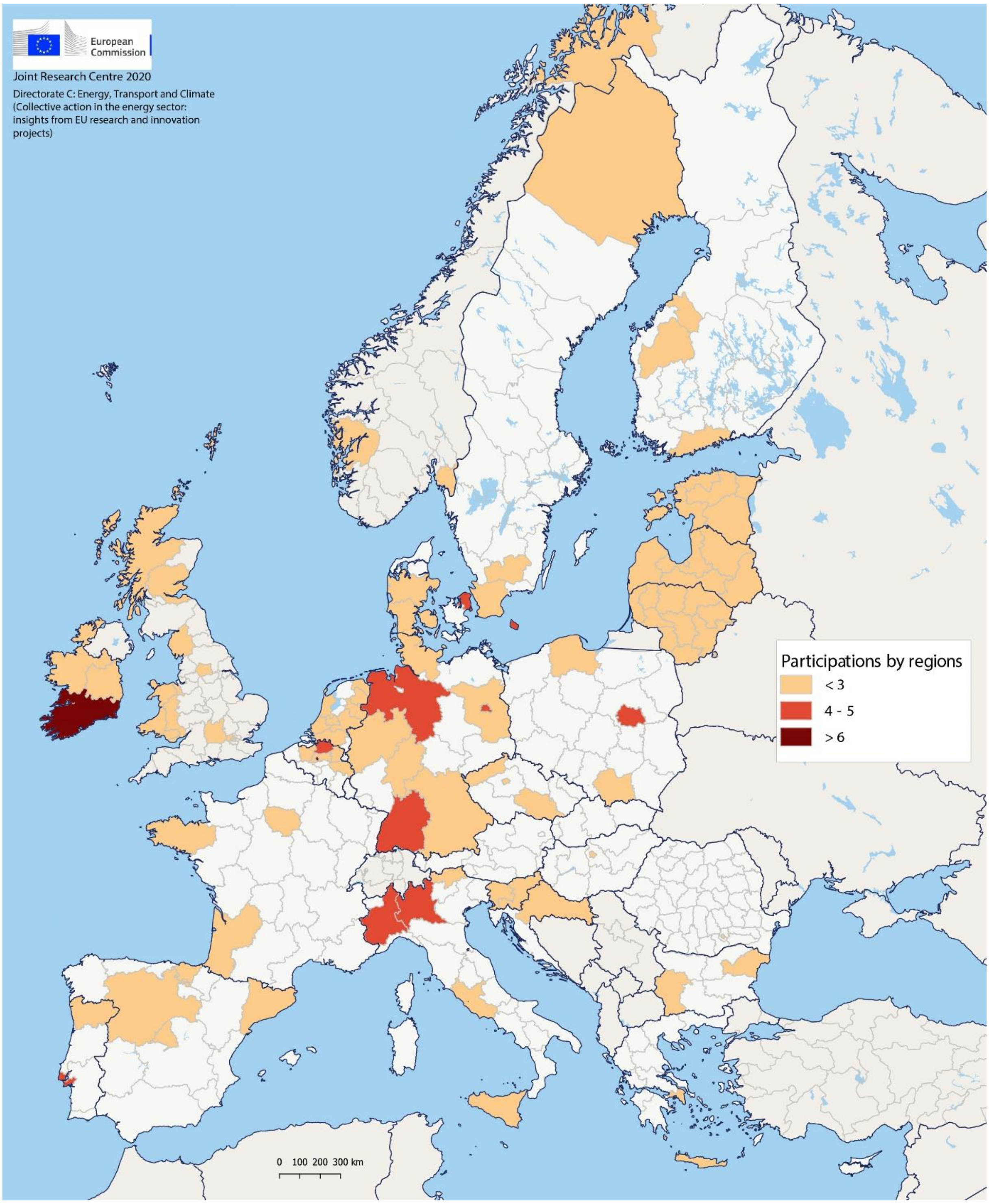
Source: JRC, (2020)

Universities and research centres play a leading role, showing that research in this sector is still much needed. *Public institutions* also show a high level of participation, as their involvement is often crucial to promote the emergence and development of collective action initiatives at local level. A very interesting role is played by *Not-for-profit organisations* that participate in 8 out of 16 projects. In this category we mainly find environmental organisations (such as Friends of the Earth and ClientEarth), acting as trusted actors to promote citizen engagement and project development. A similar role is also played by the category *Networks/Interest groups*, mainly listing associations of energy cooperatives (e.g. RESCoop, Energy4All, Ode Decentraal) and other associations lobbying to promote the development of local innovative projects and the development of collective action initiatives amongst their associates. A relevant role is finally played by *Energy cooperatives*, often acting as knowledge centres to develop and test methodologies based on best practices.

As for the geographical distribution of stakeholders, Figure 26 shows a high level of activity in countries with a long tradition of local energy activism, such as Germany, Belgium, the Netherlands and the UK. It is also interesting to note that participation by EU-13 countries is in general higher than in collective action projects. Countries like Bulgaria, Estonia, Hungary, Lithuania, Latvia and Poland, that did not have any participation in collective action projects, figure in several projects addressing non-technological challenges. This finding seems to suggest a growing interest in collective action initiatives in these countries, interest that research and public institutions, as well as civil society associations, are trying to capture, ahead of more technological stakeholders.

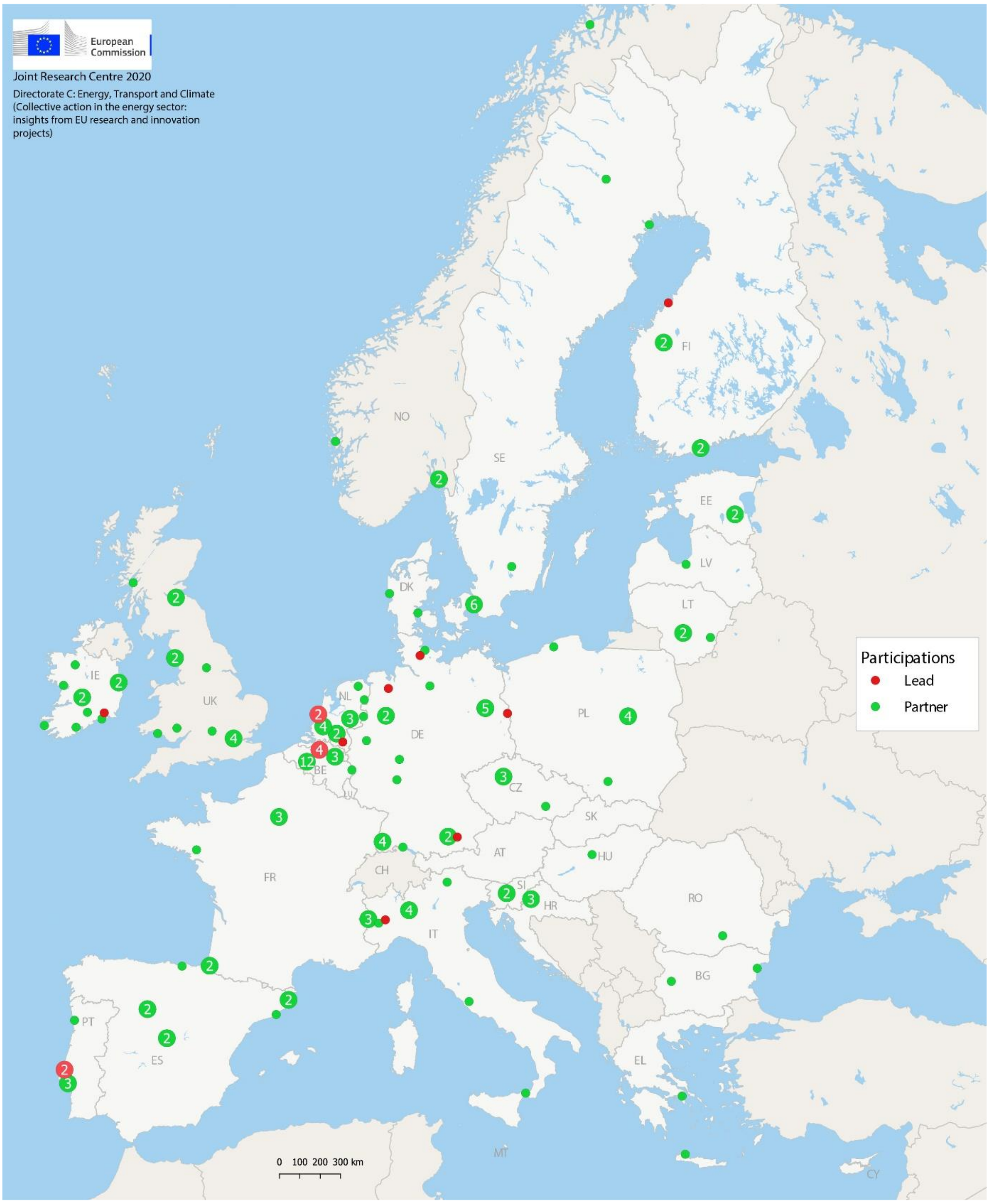
Finally, Figure 27 shows the geographical distribution of lead and partner organisations. As expected, the comparison with the map displaying the geographical distribution of participations (Figure 26) shows that the countries with a higher number of participations also show a higher number of lead organisations.

Figure 26. NTC projects: geographical distribution of stakeholders



Source: JRC, (2020)

Figure 27. NTC projects: geographical distribution of lead and partner organizations



Source: JRC, (2020)

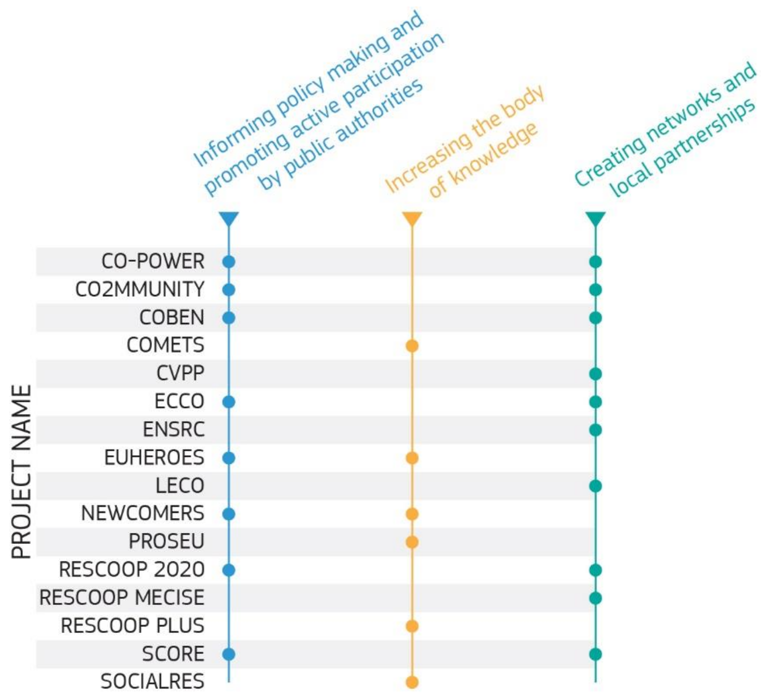
The activities adopted to promote the emergence and development of collective action initiatives can be grouped under the following three main categories (Figure 28):

Informing policy making and promoting active participation by public authorities. Several projects draft policy papers and country specific handbooks to inform and empower policy makers at EU and national level to put forward enabling legislative and regulatory frameworks for collective action initiatives. These outputs address a variety of topics, such as financial, legal, regulatory and governance aspects and make practical recommendations to enable legislative change. Some projects also carry out capacity building activities for local authorities, e.g. supporting them to include collective action initiatives into local energy action plans or to team up with other stakeholders to develop local initiatives.

Increasing the body of knowledge. Many projects aim to promote a better understanding of the factors that drive individual and collective energy choices and energy related behaviour. They investigate a wide spectrum of factors, including socioeconomic, gender, sociocultural, and socio-political issues and their interrelations with technological, regulatory, and investment-related aspects. Deeper knowledge in these fields can help in the identification of innovative and effective ways of involving local communities in collective action initiatives. Projects also investigate the changing roles of different stakeholders in the evolving energy system, new business models and innovative financing instruments for energy cooperatives and other community-based initiatives.

Creating networks and local partnerships to support the development of collective action initiatives. Partnerships bring together a diverse range of stakeholders, such as energy cooperatives, not-for-profit organisations, local authorities and technology providers, thus creating a forum to exchange experience and knowledge, develop and test methodologies based on best practices, create opportunities for investment. Projects often promote the exchange of best practices from different countries through manuals and studies, while supportive tools, such as feasibility studies, template contracts and financing and investments schemes, are shared to support the development, replication and upscaling of initiatives. Projects also adopt specific actions to inform citizens on the opportunities and benefits of becoming active consumers and on the opportunities to form collective consumer groups and consumer cooperatives.

Figure 28. NTC projects activities



Source: JRC, (2020)

4 Conclusions and suggestions for future research

This report reviews **collective action projects**, i.e. projects whose main focus is testing and demonstrating technological solutions at collective level to support a more active participation of consumers in the energy market. More specifically, it focuses on projects that research and test collective level solution to increase the ability of consuming self-produced and locally generated electricity and to facilitate the uptake of energy efficiency and active demand solutions and services.

The following considerations have emerged from these collective action projects.

Project number. Collective action projects are not new in the EU R&I scene, with a pretty constant number of projects starting each year since 2011. This time trend data suggests that the growing attention attracted by collective action initiatives at policy level in recent years has not yet been fully reflected in the research and innovation initiatives carried out to date with EU financial support. New projects are however expected in the framework of H2020 as, at the time of writing, funding is still available under topics that may award more collective action projects.

Geographical coverage. Demonstration sites are concentrated in a few countries (e.g. Italy, UK, France, Netherlands, Portugal, Spain), with most Member States in eastern Europe lacking any demonstrator. The majority of projects are carried out in an urban setting, while about one third of them are implemented in a rural environment.

Stakeholder participations are also concentrated in a small number of EU countries, with most countries in central and Eastern Europe showing limited participation. Regional differences in participation also exist within countries, with some regions leading investment in collective action projects. Geographical differences in participation depend on a variety of national circumstances. In particular, a supportive legislative and regulatory environment encourages the participation of institutional, commercial and non-governmental actors in innovation projects. Their participation, in turn, strengthens their capacities and expertise, and enables commercial actors to pursue emerging business opportunities at national and international level.

Future EU-funded projects should try to cover more geographical areas and to increase the participation of underrepresented countries. This would help them to strengthen the scientific and networking capabilities of national stakeholders and to bring about more widespread and quicker uptake of solutions and best practices for the active participation of consumers in the energy market.

Targeted sectors. The majority of projects still targets the residential sector exclusively, while some projects also involve the commercial and public sectors (mixed sector projects). The inclusion of other sectors in the scope of the project is an interesting development, as it is in line with the idea of a multi-stakeholder, municipally-based partnership, which is at the core of an integrated community-oriented approach.

Technologies tested. The projects surveyed trial a variety of different technological solutions that revolve around collective energy demand side management as a means to improve local energy management, reduce energy consumption and costs for consumers, improve energy independency and support participation in local flexibility markets. In general, projects rely on different levels of automation and complexity, with advanced ICT tools and approaches (e.g. internet of things, big data, artificial intelligence, blockchain) used to different degrees. The optimisation and matching of local renewable electricity generation and consumption for example, is achieved with different solutions ranging from ICT enabled demand response schemes to more complex local energy management solutions, built on ICT platforms that enable the orchestration of decentralized energy supply, storage, transport, conversion and consumption within a given local geographical area.

Projects often combine the demonstration of innovative technological solutions, business models and community engagement approaches to support consumers in changing the way they use electricity. To effectively support the deployment of innovative technological solutions, future R&I projects should increasingly combine these three aspects.

Stakeholders' categories. Some organizations (about 12 % of them) participate in more than one project. Although this enables organisations to deepen their expertise on technical and social sciences solutions, participation by a wide range of organisations should be encouraged as it helps to enrich the debate and add new perspectives, including from a geographical point of view.

'Universities and research centres' is the category with the highest number of participations (33 %). This finding may suggest that research into technological and social aspects of collective action projects is still much needed. Although their participation in collective action projects is surely beneficial, Universities and research centres should be aware of adopting a marked academic approach in collective action projects, as such an approach was reported by participants as having a negative impact on engagement.

The participation of DSOs in collective action projects (6 %) represents an opportunity to trial new technological solutions in real life environments, as well as to explore new business models that create value for all the parties involved.

The participation of public institutions, especially local authorities, in collective action projects is often crucial to help building the sense of a community effort and to facilitate project recruitment and engagement. Their participation in future EU-funded projects should be incentivised, as it also helps to build their capacity to participate in future community energy projects and initiatives. In future research projects, it would be desirable to see more public institutions and local authorities taking the lead of collective action projects in the framework of their urban development plans.

Several local factors influence the identification of the stakeholders that are best placed to ensure that the social dimension is taken in due consideration. In general, it can be said that organisations with strong local ties, who are already trusted to act in the interest of the local community are in a better position to trigger collaboration, engagement, knowledge-sharing and co-creation. Their participation in collective action projects is still quite limited, which may suggest the difficulty still faced by most projects to focus on the end users and to take into consideration the social dimensions of the energy transition.

Overall, the projects surveyed display a high participation of traditional stakeholders (e.g. universities and research centres, DSOs, technology manufacturers), and a moderate participation of emerging actors, newer in the energy research and innovation arena, such as public institutions, energy cooperatives and local/not-for-profit organisations.

Future R&I projects should promote wider participation by different stakeholder categories and encourage collaboration between existing and new players in flexibility services to test innovative business models.

Consumer engagement. The projects surveyed reveal that engagement interventions based on community dynamics and on the sense of a community-based initiative can offer a valid support to promote behavioural change and reach the project goals. Although most projects emphasise the importance of the social context in which consumers live and operate and introduce the project goals as community's achievements, many of them still focus mostly on the technical level, giving only a theoretical relevance to the social dimension associated with energy practices. In the future, it is desirable that projects translate theory into practice and associate social science and humanities-related work closely with the development of technological solutions.

A well-designed engagement strategy appears to be key to bringing participants together with a common purpose and achieve the project objectives. The engagement strategy should be constantly reviewed during the course of the project to transpose the interim results of the interventions deployed.

Future projects should draw upon and add to the body of knowledge that has been developed by past EU-funded projects, adapting their findings to the local and specific circumstances. Efforts should be made to make the new knowledge developed within the projects available to a wide range of stakeholders, well beyond the project closing.

The projects surveyed generally reported a widespread interest and positive participants' feedback in the engagement interventions trialled. Future research projects, however, should try to evaluate the effectiveness of specific engagement interventions, at least from a qualitative point of view. The analysis of the projects also suggests a number of aspects that would benefit from further investigation by future research projects, including:

- Personal motivations for joining a collective action project/initiative and invest in the enabling technologies. Some factors, such as the sense of identity and pride being attached to community and locality and by the objective of reaching increased local energy independence, should be given particular attention. Research should investigate different consumer segments, such as youth, women and vulnerable consumers.
- Comparative research could also investigate the different response of participants who are consumers of energy supplied by energy cooperatives and consumers who are supplied by traditional suppliers, in terms of engagement and behavioural change.
- Research in the effectiveness of specific interventions would also be beneficial, especially in the case of more complex interventions, such as community rewards.

This report also analyses projects that address **non-technological challenges of local collective energy action initiatives**. These projects put citizens at centre stage of the ongoing energy transition and leverage on the sense of a community effort towards a more sustainable and participatory energy future. They show a high participation of emerging actors, such as public institutions, local/not-for-profit organisations and energy cooperatives. Their inclusion in the project consortia is in line with the typical project objectives (i.e. informing policy making and promoting active participation by public authorities, increasing the body of knowledge and creating networks and local partnerships) and with the attention that these projects show for the social dimension of energy consumption.

As for the geographical distribution of stakeholders, the analysis shows a high level of activity in countries with a long tradition of local energy activism, such as Germany, Belgium, the Netherlands and the UK. It is also interesting to note that participation by EU-13 countries is in general higher than in collective action projects. This finding seems to suggest a growing interest in collective action initiatives in these countries, interest that research and public institutions, as well as civil society associations, are trying to capture, ahead of more technological stakeholders.

The JRC continues to conduct research on sociotechnical aspects of the energy transition and on how the collective dimension of energy use can contribute to an inclusive energy transition. The JRC will carry on analysing research and innovation projects at national and European levels with the aim to support early identification of the challenges and opportunities that the use of digital technologies and other innovative solutions can present for EU consumers' living conditions.

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List of abbreviations

BEMS	Building Energy Management System
BESS	Battery Energy Storage System
CA	Collective Action
CEP	Clean Energy for All Europeans Package
CHP	Combined Heat and Power
CORDIS	Community Research and Development Information Service
DLT	Distributed Ledger Technology
DSO	Distribution System Operator
EC	European Commission
EMS	Energy Management System
ERDF	European Regional Development Fund
ESIF	European Structural and Investment Funds
EU	European Union
EV	Electric Vehicle
HEMS	Home Energy Management System
ICT	Information and Communication Technology
IEE	Intelligent Energy Europe
JRC	Joint Research Centre
LEMS	Local Energy Management System
NTC	Non Technological Challenges
P2P	Peer to Peer
PV	Photovoltaic
R&I	Research and Innovation
RES	Renewable Energy Sources
SG	Smart Grid
TSO	Transmission System Operator

List of country codes

AT	Austria
BE	Belgium
BG	Bulgaria
CY	Cyprus
CZ	Czechia
DE	Germany
DK	Denmark
EE	Estonia
EL	Greece
ES	Spain
FI	Finland
FR	France
HR	Croatia
HU	Hungary
IE	Ireland
IT	Italy
LT	Lithuania
LU	Luxembourg
LV	Latvia
MK	North Macedonia
MT	Malta
NL	Netherlands
NO	Norway
PL	Poland
PT	Portugal
RO	Romania
RS	Serbia
SE	Sweden
SI	Slovenia
SK	Slovakia
UK	United Kingdom

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Annexes

Annex 1. Collective action projects - Key facts

Project name	Project duration	Total budget (M EUR)	Countries involved	Project coordinator
CITY-OPT	Feb 2014 – Jan 2017	3.96	AT, FI, FR, IT	VTT Technical Research Centre of Finland (FI)
CITY-ZEN AMSTERDAM	Mar 2014 – Feb 2019	42.9	BE, FR, NL, IT, UK	Vlaamse Instelling voor Technologisch Onderzoek NV (BE)
CIVIS	Oct 2013 – Sept 2016	4.07	DE, FI, IT, NL, PT, SE, UK	University of Trento (IT)
COMPILE	Nov 2018 – Apr 2022	6.93	AT, BE, EL, ES, HR, PT, SI,	University of Ljubljana (SI)
COSSMIC	Oct 2013 – Dec 2016	4.27	DE, IT, NL, NO	Sintef (NO)
EEPOS	Oct 2012 – Sept 2015	4.1	AT, DE, ES, FI	VTT Technical Research Centre of Finland (FI)
ENERGAWARE	Feb 2015 – Apr 2018	1.96	ES, FR, PT, UK	Universitat Politecnica de Catalunya (ES)
FLEXCOOP	Oct 2017 – Sept 2020	3.98	BE, CY, DE, DK, EL, ES, HR, NL, UK	Fraunhofer FOKUS (DE)
GRID-FRIENDS	May 2016 – Feb 2019	2.42	DE, NL	CWI - Stichting Centrum Wiskunde & Informatica (NL)
IDEAS	Nov 2012 – Oct 2015	4.08	FI, FR, IS, UK	Teesside University (UK)
MERLON	Jan 2019 – Dec 2021	7.55	AT, BE, CY, EL, ES, FR, UK	Hypertech EnergyLabs (EL)
MUSE GRIDS	Nov 2018 – Oct 2022	7.43	BE, DK, ES, IE, IL, IT, NL	Rina Consulting (IT)

NEMOGRID	Apr 2017 – March 2020	1.32	CH, DE, SE	SUPSI - University of Applied Sciences and Arts of Southern Switzerland (CH)
NICE GRID	Nov 2011 – Jan 2016	29.7	FR	Enedis (FR)
NICE SMART VALLEY	Jan 2017 – Dec 2019	5	FR	Enedis (FR)
ORIGIN	Nov 2012 – Oct 2015	4.08	DE, ES, IT, PT, UK	Heriot-Watt University (UK)
REACT	Jan 2019 – Dec 2022	10.76	AT, DE, ES, IE, IT, FR, NL, RS, SE, UK	VEOLIA Serveis Catalunya (ES)
SENSIBLE	Jan 2015 – Dec 2018	15.38	DE, ES, FI, FR, PT, UK	Siemens AG (DE)
SHAR-Q	Nov 2016 – Oct 2019	4.04	AT, CZ, DE, EL, ES, PT, SK	ATOS Spain (ES)
SMART ENERGY ISLAND	2017 - 2019	12.21	UK	Hitachi Europe Ltd (UK)
SMART-MLA	Nov 2018 -Oct 2021	2.02	DK, NO, RO, SE, TR	Engineering Procurement Research Analysis EPRA (TR)
WISEGRID	Nov 2016 – Apr 2020	17.60	BE, DE, EL, ES, FR, IT, RO, UK	Etra i+d (ES)

Annex 2. Projects addressing non-technological challenges – Key facts

Project name	Project duration	Total budget (M EUR)	Countries involved	Project coordinator
CO-POWER	Apr 2013 – Apr 2016	1.56	BE, CZ, DE, DK, ES, HU, IE, UK	Friends of the Earth Europe (BE)
CO2MMUNITY	Oct 2017 - Sept 2020	3.15	DE, DK, EE, FI, LT, LV, PL, SE	Christian-Albrechts University Kiel (DE)
COBEN		4.62	BE, DE, DK, NL, NO, UK	University of Oldenburg (DE)
COMETS	May 2019 – Apr 2022	3.00	BE, DK, EE, ES, IT, NO, NL, PL	University of Turin (IT)
CVPP	2017 - 2020	6.11	BE, IE, NL	TUE - Technische Universiteit Eindhoven (NL)
ECCO	2017 - 2021	5.39	BE, DE, FR, IE, NL, UK	Boerenbondvereniging voor Innovatieve Projecten vzw (BE)
ENSRC		0.37	BG, IE, PT, UK	Waterford County Council (IE)
EU HEROES	Sept 2017 – Aug 2020	1.23	DE, EL, ES, LT, NL, PL, UK	RVO- Ministerie Van Economische Zaken (NL)
LECO	Aug 2017 – July 2020	1.95	DE, FI, IE, NO, SE	CENTRIA University of Applied Sciences (FI)
NEWCOMERS	Jun 2019 – May 2022	2.98	DE, IT, NL, SE, SI, UK	VUA - Vrije Universiteit Amsterdam (NL)
PROSEU	Mar 2018 – Feb 2021	3.12	DE, ES, HR, NL, PT, UK	FC.ID – Associação para a Investigação e Desenvolvimento de Ciências (PT)
RESCOOP 2020	Apr 2012 – Mar 2015	1.96	BE, DE, DK, FR, IT, NL, UK	Ecopower Cvba (BE)

RESCOOP MECISE	Mar 2015 – Apr 2019	2.19	BE, ES, FR, UK	Ecopower Cvba (BE)
RESCOOP PLUS	Mar 2016 – Feb 2019	1.50	BE, DK, EL, ES, FR, IT, NL, PT	Levelcardinal Unipessoal LDA (PT)
SCORE	Apr 2018 – Mar 2021	1.99	BG, CZ, DE, IT, PL	European University Viadrina Frankfurt (DE)
SOCIAL RES	May 2019 – Aug 2022	2.44	DE, ES, FR, HR, IE, IT, PT, RO, UK	WIP Wirtschaft und Infrastruktur GmbH & Co Planungs-KG (DE)

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