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Energy poverty through the lens of EU research and innovation projects

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Executive summary

Policy context

In recent years, energy poverty has become a widely recognised challenge in the EU. Estimates indicate that more than 50 million people in the EU experienced energy poverty in 2018. The extent and seriousness of the problem have attracted a significant amount of scholarly attention and advocacy work, calling for urgent action at EU and Member State levels.

Although the EU has not adopted a definition of 'energy poverty' or of 'energy-vulnerable consumers', it has adopted a wide range of provisions to trigger and steer Member State action in this area. The EU approach requires Member States to adopt a comprehensive strategy, including energy and non-energy measures, to address the root causes of energy poverty and to alleviate the condition of energy-poor and vulnerable consumers.

The EU has also supported a variety of research and demonstration projects to test and validate innovative approaches to fighting energy poverty and to promoting good practice at national, regional and local levels. By analysing these projects, the Joint Research Centre (JRC) aims to highlight emerging trends in efforts to tackle energy poverty 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 the fight against energy poverty and improve the living conditions of vulnerable consumers.

Main findings

The study analysed 31 innovation projects, carried out by organisations headquartered in 30 countries. Projects were grouped into four categories, according to their scope.

Digital technologies projects use information and communication technology (ICT) to reduce energy consumption in social housing, thus helping vulnerable consumers to reduce their energy bills. Although the alleviation of energy poverty is not the primary objective of these projects, in many cases it is viewed as an important collateral impact of the project activities.

Overall, the projects surveyed helped to demonstrate that energy savings are possible even in vulnerable households and that smart metering can lead to lower energy bills, thus contributing to the alleviation of energy poverty. Energy consumption reductions were achieved at almost all pilot sites, and only in a few cases was an increase rather than a decrease in energy consumption observed. The large variation in the results obtained by the different demonstrators points to the importance of local circumstances. The effectiveness of the ICT solutions trialled depends on a variety of technical, geographical, social and cultural factors.

The low level of tenant engagement is reported in the majority of project outputs as one of the main challenges for the success of this kind of initiative. A lack of trust on the part of tenants, tenants' lack of experience in handling technology and low literacy rates, limited energy-saving opportunities and high percentages of immigrant residents are considered the main issues making it necessary to promote engagement and encourage residents' full participation in initiatives.

> 🔍 Future research initiatives and pilot projects could investigate the attitude of vulnerable consumers towards time-varying tariffs and their effects on energy bills. Another field of research could be testing a range of services for vulnerable

households, for example sending warnings if consumption patterns drastically change or consumption ceases altogether, and ensuring that room temperatures do not fall below a healthy level. Future research initiatives could also explore other approaches to engagement, particularly those based on co-designing solutions and building on vulnerable consumers' real needs and expectations.

Behavioural change projects provide low-income and vulnerable consumers with information and tailored advice to encourage behavioural change and help them reduce their energy consumption and bills. The alleviation of energy poverty is a primary objective of these projects.

The main tool used to induce behavioural change and reduce energy consumption is the energy adviser or ambassador, that is, an intermediary trained to provide tailored energy advice during home visits. Overall, most projects claimed to have achieved encouraging results, even though the estimates of those results are difficult to assess and compare.

One challenge often reported in the project outputs is difficulty in recruiting and engaging vulnerable consumers, mainly because of their uneasiness about acknowledging their disadvantages and owing to the limited possibilities for reducing their energy consumption and lowering their energy bills. The strategy that seemed to work best to improve engagement was collaboration with trusted interlocutors.

 Future research initiatives and pilot projects could investigate new and innovative ways of overcoming the lack of the financial resources needed to act on the energy advice received, such as efficient-appliance rental schemes or targeted collective purchasing schemes.

Financing projects address the legal and financial barriers to energy retrofit of low-income and social housing and test innovative financing solutions for energy efficiency investment. The main objective of the projects is to increase energy efficiency in social housing, in some cases explicitly as a means to address energy poverty.

The analysis of the projects surveyed highlighted that the renovation of a building was often not enough to reduce residents' energy consumption, as savings strongly depended on the occupants' behaviour and might not meet expectations. In projects financed through energy performance contracting (EPC) in particular, the uncertainty about actual savings represents a major barrier to investment and has a strong influence on risk allocation with regard to energy savings and on the related technical and financial arrangements.

The main social challenge is engaging residents in refurbishment works. The low level of energy awareness and limited interest in energy efficiency opportunities are also important issues that need to be tackled in the very early stages of the retrofit process through a tailored engagement strategy.

 Future research initiatives and pilot projects could delve into behavioural approaches to EPC in the social housing sector. New pilot projects could also investigate innovative approaches to dealing with the rebound effect, without penalising energy-poor tenants who increase their consumption to cover their basic energy needs.

Sharing of best practices projects aim to identify and promote tailored solutions to address the technological, social and financial barriers hindering energy retrofit of social housing in Europe.

Most projects in this category considered energy retrofit of social housing a means to increase the energy efficiency of the European social housing stock and to contribute to the European strategy to mitigate climate change. The alleviation of energy poverty was considered an additional societal benefit of the retrofit operations, resulting in lower energy bills and increased thermal comfort for social housing residents. Only some projects explicitly included the alleviation of energy poverty among their primary objectives.

Most project outputs reported residents' engagement as one of the main challenges for the implementation of energy retrofit projects in social housing. Some project outputs also emphasised the need to limit rent increases for low-income households and warned that, in situations of high energy poverty, cost recoupment could mean that retrofit does not lead to a reduction in energy poverty.

> 🔍 Future research initiatives and pilot projects could focus more on energy poverty and resident behaviour to provide all stakeholders involved with a clearer picture of the social dimension of energy retrofit operations in social housing complexes.

Key conclusions

The analysis shows an uneven geographical distribution of projects and investment. Several countries in central and eastern Europe had limited participation, despite the high prevalence of energy poverty in their jurisdictions. Future projects should try to cover more geographical areas and increase the participation of underrepresented countries.

Time-trend data suggest that the growing attention attracted by energy poverty at policy level in recent years has not yet been reflected in the research and innovation initiatives carried out to date with EU financial support. More projects specifically tailored to energy-poor consumers would help to improve understanding of this phenomenon. Furthermore, the targeting approach could be improved to enable fine-grained identification of consumers in real need, especially in those countries with a low level of social housing provision.

The participation of some key stakeholders (e.g. distribution system operators (DSOs) and utilities, technology manufacturers) in future innovation projects dealing with energy poverty should be encouraged. The participation of DSOs and utilities in particular would help them to gain experience in achieving energy savings in the framework of national energy efficiency obligation schemes.

Project outputs are not always available online and results are usually very difficult to compare. In addition, results calculated in terms of energy or cost savings are not always a good measure of the projects' success in tackling energy poverty. Other indicators, tailored to different segments of the population of vulnerable consumers, should be investigated.

Consumer motivation and engagement are often reduced by the limited margins for reducing energy consumption and achieving lower energy bills. Developing a consumer engagement strategy based on community dynamics can help to ensure consumer participation during and after the project activities.

Related and future JRC work

The JRC continues to conduct research on energy poverty in the EU by analysing research and innovation projects at national and European levels. The aim is to support early identification of the challenges and opportunities that the use of digital technologies and other innovative solutions can present for energy poverty and EU consumers' living conditions.

1. Introduction

In recent years, energy poverty has become a widely recognised challenge in the EU. Estimates indicate that more than 50 million people in the EU experienced energy poverty in 2018 (Thomson and Bouzarovski, 2018). The extent and seriousness of the problem have attracted a significant amount of scholarly attention and advocacy work, calling for urgent action at EU and Member State levels.

Despite the growing attention that the topic is gaining in Europe, there is still a lack of consistency in the terms used to discuss lack of energy services in the home. As highlighted by several authors (Bouzarovski and Petrova, 2015; Thomson et al., 2016), the expression 'energy poverty' has traditionally been used to refer to the condition of people in the developing world suffering from a lack of access to adequate facilities for cooking, lighting and electrical appliances but also to other services such as space cooling and heating. The expression 'fuel poverty', on the other hand, has traditionally been used to refer to people in developed countries suffering from inadequate heating in the home; in these countries, however, the importance of other services (particularly space cooling, lighting, appliances, IT) has increased substantially in recent years (Bouzarovski and Petrova, 2015).

In this study, we will use the expression 'energy poverty', as it is still the term most widely used at European level to refer to a situation where a household is unable to adequately meet its energy needs at an affordable cost. According to Thomson (2014), 'energy poverty' is preferred to 'fuel poverty', being used in the vast majority of EU policy documents since 2001 ([1]). The two terms, however, are also often used interchangeably in the same context, indicating a level of uncertainty among policy stakeholders (Thomson, 2014).

This terminological uncertainty is aggravated by the lack of a common definition of 'energy poverty' at EU level. Many academics have argued in favour of a common definition (Dobbins et al., 2019; Thomson et al., 2016). Thomson et al. (2016) highlighted that a common approach could increase recognition of the problem in Europe and help resolve the existing terminological confusion, paving the way for more detailed national definitions. It could also encourage synergies both between energy poverty policy and other policy domains and with regard to policy cooperation between Member States. Some authors argue that, given the diversity of European contexts, it is not easy to set an absolute threshold for energy poverty at European level; they favour a definition that takes into consideration the specificities of geographical circumstances (Grevisse et al., 2011). Others (see, for example, Deller, 2016) have argued that the significant differences between Member States make a common EU definition undesirable and that the choice of energy poverty definitions and policies should rest with Member States.

In the absence of a common EU definition, several Member States have adopted official definitions of energy poverty, relying on different criteria, such as a minimum income threshold or the proportion of household income consumed by paying for adequate fuel. Current EU legislation does not require Member States to adopt a definition of energy poverty, but it does require them to define the concept of 'vulnerable customers' — who may include individuals at risk of or in energy poverty — in order to comply with the requirements stemming from the third energy package (for

([1]) Thomson (2014) analysed the terminology used by legislative and consultative institutions and bodies of the European Union since 2001 and found that the expression 'energy poverty' has been used far more frequently than 'fuel poverty', with 132 out of 187 policy documents (70.6 %) using the term 'energy poverty.

further details, see Box 1). While there is a correlation between the notions of consumer vulnerability and energy poverty, the latter is a more specific concept, which refers to the relationship between limited household budget and the cost of adequate energy services (Vulnerable Consumer Working Group, 2016). In the rest of this study, we will use the two expressions interchangeably, as the projects surveyed do not differentiate between the two concepts and generally use the expressions as synonyms.

The aim of this report is to shed light on the efforts carried out through EU research and innovation initiatives to develop a better understanding of the types and needs of energy-poor households and to demonstrate innovative solutions to address energy poverty. Piloting innovative solutions on vulnerable consumers can help to anticipate problems and opportunities and to build an inclusive energy future. Projects carried out under the framework programmes for research and innovation, the Intelligent Energy Europe (IEE) programme and European Structural and Investment Funds (ESIF) programmes have produced many examples of good practice at national, regional and local levels. These examples can serve as blueprints for similar initiatives in other Member States, enabling a more systematic uptake of good practices across the EU (European Commission, 2016a).

The ambition of this report is thus to analyse the state of play of EU-funded innovation projects on energy poverty in Europe, to share the body of knowledge and best practices that they have developed and to provide actionable recommendations for future research programmes. The report is addressed to all stakeholders involved in setting up initiatives to alleviate energy poverty that may benefit from the experiences had 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 analysis builds on the work carried out by the Joint Research Centre (JRC) as part of its smart grid projects outlook ([2]), but — given the specificities of the topic — it expands its focus beyond technological innovation to include behavioural, financing and capacity-building solutions. Chapter 2 presents the project categories identified and provides a general analysis. Chapter 3 analyses the various project categories, setting out insights and lessons learned from the projects. Chapter 4 discusses the main conclusions and offers policy feedback for future research.

([2]) For an overview of the activities carried out by the JRC in the field of smart grids, visit the JRC website (https://ses.jrc.ec.europa.eu/scanning-smart-electricity-ecosystem).

Box 1. Energy poverty in EU legislation

Despite the lack of common definitions of 'energy poverty' and 'energy vulnerability' at European level, the two concepts appear in several EU legislative documents. **Directive 2009/72/EC** (European Parliament and the Council of the European Union, 2009a) and **Directive 2009/73/EC** (European Parliament and the Council of the European Union, 2009b) set out the key provisions that frame the concepts and steer Member States' actions. Article 3 of both directives requires Member States to 'ensure that there are adequate safeguards to protect vulnerable customers' and to define 'the concept of vulnerable customers, which may refer to energy poverty and, inter alia, to the prohibition of disconnection to such customers in critical times'. Member States 'shall ensure that rights and obligations linked to vulnerable customers are applied. In particular, they shall take measures to protect final customers in remote areas'.

The directives also require Member States to take 'appropriate' measures to tackle energy vulnerability and energy poverty, 'such as formulating national energy action plans, providing social security benefits to ensure the necessary [electricity and gas] supply to vulnerable customers, or providing for support for energy efficiency improvements, to address energy poverty where identified, including in the broader context of poverty'.

Energy efficiency improvements are also pinpointed in other directives as a means to tackle energy poverty. Article 7 of Directive 2012/27/EU (European Parliament and the Council of the European Union, 2012), as amended by **Directive (EU) 2018/2002** (European Parliament and the Council of the European Union, 2018a), requires Member States to take into account the need to alleviate energy poverty when designing policy measures to fulfil their obligations to achieve energy savings. In particular, Member States must require, 'to the extent appropriate, a share of energy efficiency measures under their national energy efficiency obligation schemes, alternative policy measures, or programmes or measures financed under an Energy Efficiency National Fund, to be implemented as a priority among vulnerable households, including those affected by energy poverty and, where appropriate, in social housing'. The new **energy performance in buildings directive** (European Parliament and the Council of the European Union, 2018b) requires Member States to include in their long-term renovation strategies 'an overview of policies and actions to target the worst performing segments of the national building stock, split-incentive dilemmas and market failures, and an outline of relevant national actions that contribute to the alleviation of energy poverty'. In addition, the **governance of the energy union regulation** (European Parliament and the Council of the European Union, 2018c) requires Member States to report on energy poverty and to set energy poverty reduction objectives in their national energy and climate plans.

Finally, the new **electricity directive** (European Parliament and the Council of the European Union, 2019) requires Member States to ensure the protection of energy-poor or vulnerable customers 'by social policy or by other means than public interventions in the price setting for the supply of electricity'. Under certain circumstances, however, such interventions may still be applied (see Article 5).

In conclusion, even though the EU has not adopted a definition of 'energy poverty' or of 'energy-vulnerable consumers', it has adopted a wide range of provisions to trigger and steer Member State actions in this area. The EU approach requires Member States to adopt a comprehensive strategy, including energy and non-energy measures, to address the root causes of energy poverty and to alleviate the condition of energy-poor and vulnerable consumers.

2. Energy poverty through the lens of EU innovation projects

A variety of projects has been carried out in the past few years to investigate energy poverty and to test and demonstrate innovative solutions that can help alleviate the condition of vulnerable consumers in Europe. Through desk research and expert knowledge, we identified a list of projects that target energy-poor/vulnerable households by implementing measures that address the root causes of energy poverty, poor home energy efficiency in particular. We looked into projects funded by the EU framework programmes for research and innovation and by other EU initiatives supporting research, innovation and technological development (e.g. the IEE programme and the European Regional Development Fund (ERDF)). We gathered information on ongoing and completed projects through the projects' websites, EU online databases (e.g. the Community Research and Development Information Service and the IEE websites), scientific articles and reports, and dissemination and communication materials.

In some cases, the projects explicitly recognise the alleviation of energy poverty as the main project objective, while, in other cases, energy poverty is only one of several objectives pursued (often alongside mitigating climate change and promoting energy efficiency). In almost all projects, the engagement of energy-poor/vulnerable households in the project activities is considered of outmost importance to achieve the project's objectives.

The list includes projects that aim to lower the energy bills of energy-poor households by implementing measures that increase their energy awareness and reduce their energy consumption. It also includes projects that adopt a wider approach and address external circumstances hindering the implementation of energy efficiency initiatives in vulnerable households. In particular, we looked at projects that test innovative financial mechanisms to finance energy retrofit operations in low-income and social housing complexes and at projects that involve key stakeholders in identifying, sharing and implementing solutions and best practices for social housing energy retrofit.

The project categories that emerged during the analysis are therefore the following:

- **digital technologies** — projects that use digital solutions to engage social housing residents and reduce their energy consumption;
- **behavioural change** — projects that address vulnerable consumers, providing them with tailored energy advice to support them in their efforts to reduce energy consumption and better satisfy their energy needs;
- **financing** — projects that investigate and test innovative financing models to encourage energy efficiency retrofit in social housing;
- **sharing of best practices** — projects that carry out knowledge-sharing and capacity-building activities to disseminate best practices and increase the rate of social housing retrofit in Europe ([3]).

Separately, we also analysed a number of EU-wide initiatives that have investigated the causes and consequences of energy poverty, its prevalence across the EU and the measures that have been adopted at European and national levels to alleviate it. Finally, we also took a look at social

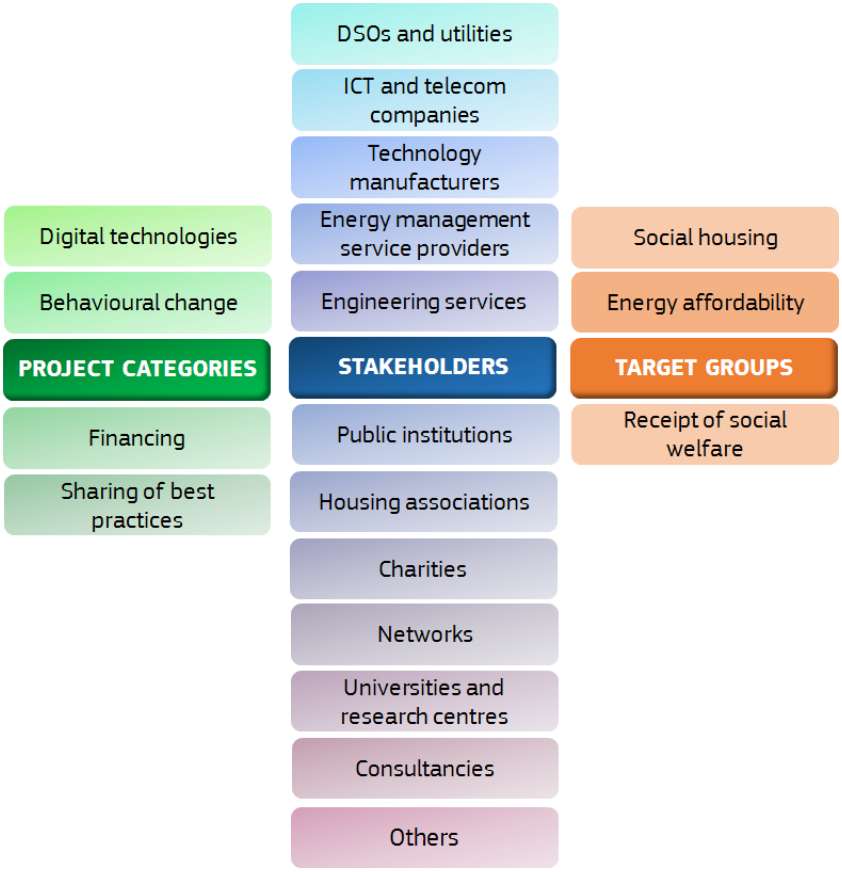
([3]) This category does not include projects focusing on the building renovation industry with the aim of accelerating the adoption of energy efficient materials and technologies and solutions for the energy retrofit of social housing. We excluded both projects aimed at supporting knowledge sharing and capacity building for various building industry stakeholders and projects aiming to develop, demonstrate and evaluate novel technologies and materials.

innovation initiatives in Member States to draw inspiration from the innovative approaches they have adopted to tackle energy poverty.

To identify the main trends and derive useful insights, data from EU-funded projects were collected in a database. The database contains 31 projects, carried out by organisations headquartered in 30 countries, namely the EU Member States (with the exception of Luxembourg) plus North Macedonia, Norway and Serbia.

Figure 1 presents the main categories of the database — project categories, stakeholders and target groups — and the subcategories in which they are organised.

Figure 1. Project categories, stakeholders and target groups



2.1. Project categories and funding sources

The number of projects per project category and the related investment are showed in Figure 1 and Figure 2. In the digital technologies category, we find the highest number of projects and the highest level of investment. The high level of investment is due to the cost of the technologies trialled in these projects (e.g. advanced metering, communication technology, energy management solutions). All the other categories either use more established and lower cost technologies or no technology at all. Clearly, in the deployment phase, higher investments need to be compensated for by better or longer-lasting results. Although comparing the costs and benefits of the project categories is outside the scope of this study, in the next chapter we present the available reported quantitative results of the actions implemented. In Box 2, we reflect on the difficulties related to measuring projects' expected results.

Figure 2. Number of projects per category

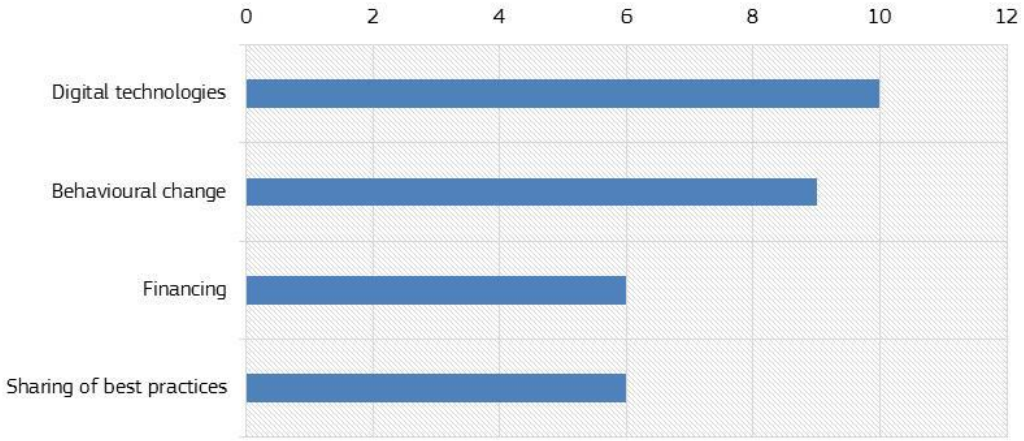
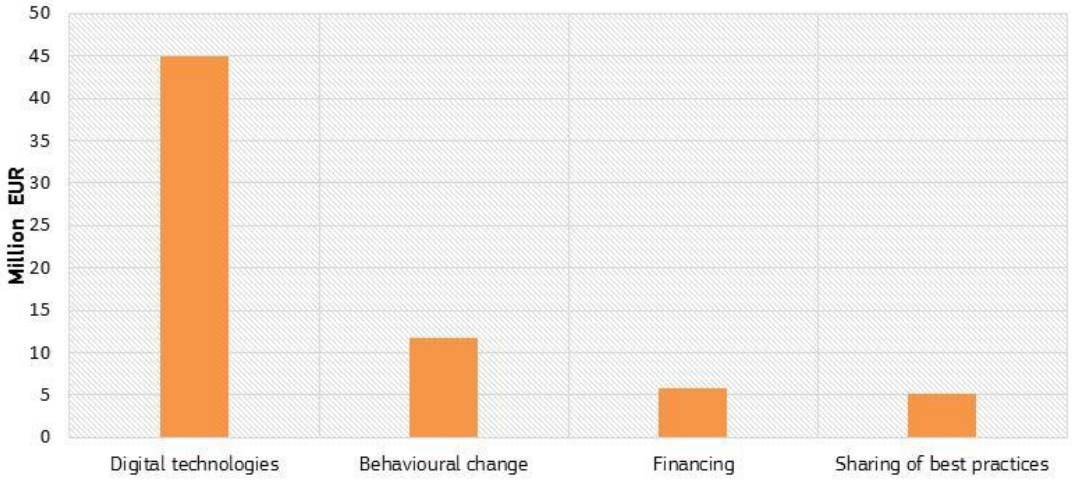


Figure 3. Investment per project category



Box 2. Projects' expected impact

The indicators used to assess the projects' expected impact vary according to the project category and the type of intervention involved. Most projects use the amount of energy savings (in energy and monetary terms) as the main indicator of success. Other indicators commonly used are the reduction in greenhouse gas emissions, the percentage of households following advice received to manage energy in the home and the number of energy audits performed.

The indicator 'primary energy savings triggered by the project' is used in the H2020 work programme 2018-2020 (European Commission, 2018) to assess the expected impact of the projects funded. For projects tackling energy poverty, however, results calculated in terms of energy or cost savings are not always a good measure of the success of the initiative. In local situations where there is high energy poverty, households can decide to reinvest part of the savings to achieve better living conditions. In those cases, the unchanged or even higher energy consumption reported after the implementation of the project activities, far from being an indicator of a project's failure, is a sign that the project was successful in mitigating energy poverty.

Future research should investigate other indicators to measure initiatives' success, tailored to different segments of the population of vulnerable consumers (e.g. greater comfort; health and well-being; market value added to the property).

The time trends with regard to number of projects and investment for the different categories since 2006 are shown in Figure 4 and Figure 5. The duration of the projects is generally between 24 months and 36 months, but for yearly aggregations of investment the project budget was assigned to the starting year. The time distribution of the number of projects in the various categories is strongly influenced by the availability of EU funding, the main financing source for the projects in the database.

Digital technologies projects are concentrated in the period 2010-2011, as most of them (7 out of 10) were funded through the ICT policy support programme (ICT PSP), which was the part of the EU's competitiveness and innovation framework programme (CIP) focusing on ICT. The ICT PSP work programme for 2009 and 2010 provided funding for ICT projects for energy efficiency in social housing with the aim of validating innovative solutions and demonstrating the energy efficiency benefits that ICT can bring to building owners and their inhabitants. Although the alleviation of energy poverty was not specifically mentioned in the calls for proposals, awarded projects were expected to empower end-users to play a central role in increasing energy efficiency, and most of the projects considered the reduction of energy poverty a project objective.

Behavioural change projects are more evenly distributed over time, as this kind of initiative has received a constant stream of funding since 2006. From 2006 to 2014, projects were financed through the IEE programme ([4]), a pillar of the EU's CIP. Launched in 2003, the programme supported EU energy efficiency and renewable energy policies, with a view to reaching the EU 2020 targets. Since 2014, this type of project has been supported by the 'Market uptake of energy innovation' topic of the Horizon 2020 (H2020) programme.

Financing projects and sharing of best practices projects received dedicated funding mainly between 2006 and 2010, with new projects being funded in 2016. For these project categories, the main funding sources have also been the IEE programme and H2020, with two projects being funded by the ERDF.

Overall, time-trend data for all project categories suggest that the growing attention attracted by energy poverty at policy level in recent years has not yet been reflected in the research and innovation initiatives carried out to date with EU financial support.

New projects are, however, expected in the coming years, as the H2020 work programme for the period 2018-2020 recognises the need to support targeted initiatives in this field. The proposed actions should contribute to actively alleviating energy poverty and developing a better understanding of the types and needs of energy-poor households and how to identify them. EU funding will support actions that aim to (i) facilitate behaviour change and the implementation of low-cost energy efficiency measures tailored for energy-poor households; (ii) promote the set-up of financial and non-financial support schemes for energy efficiency and/or small-scale renewable energy investments for energy-poor households; (iii) develop, test and disseminate innovative schemes for energy efficiency / renewable energy investments established by utilities or other obligated parties under Article 7 of the energy efficiency directive ([5]). Twenty project proposals were presented in response to the 2018 call; at the time of writing, the 2019 call is still open.

([4]) The IEE ran until 2013, but some projects funded through the last calls for proposals started in 2014.
([5]) https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/lc-sc3-ec-2-2018-2019-2020.

Figure 4. Time distribution of project categories

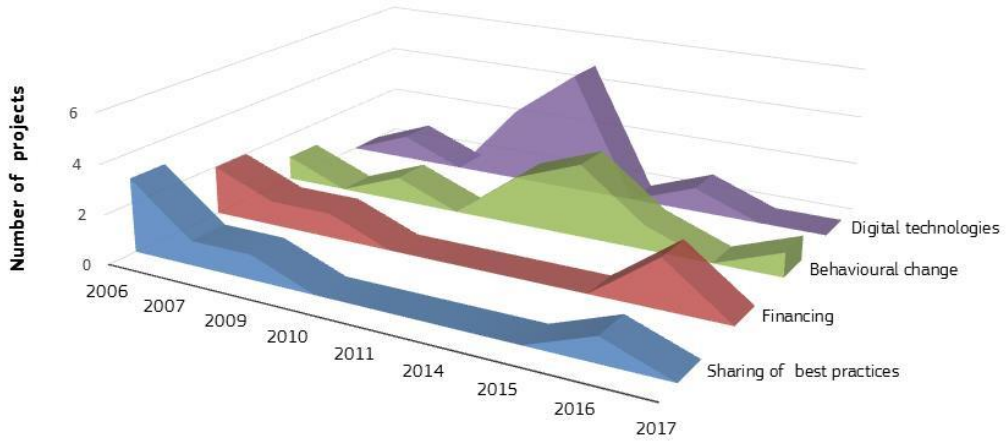
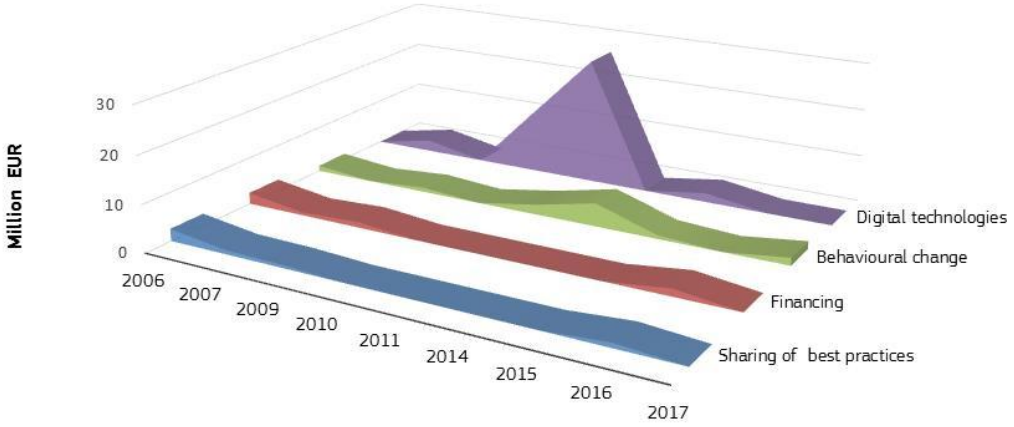


Figure 5. Time distribution of investment per project category



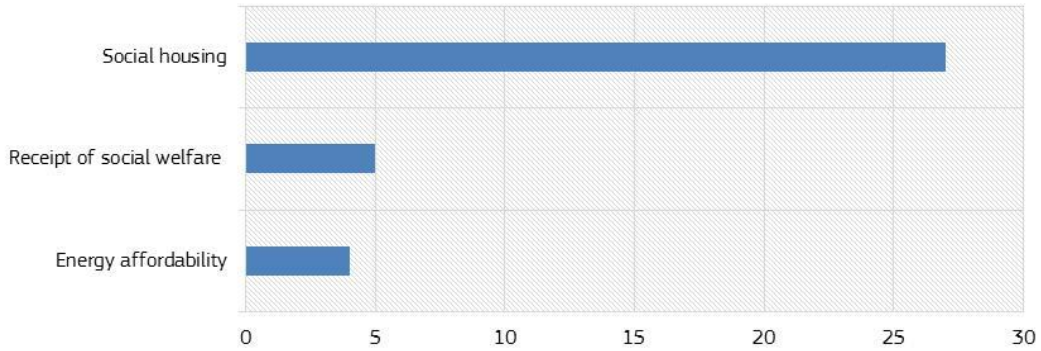
2.2. Target groups

The identification of the target group is a fundamental step for the implementation of project activities. For most projects in the database, this does not present particular problems, as the selection of the study population is inherent in the project's objectives. These projects typically target social housing complexes with the primary objective of decreasing energy consumption and emissions in social housing, while increasing tenants' understanding of and engagement with energy efficiency. For these projects, where the alleviation of energy poverty is generally a positive externality of the project action, the identification of the target group is ultimately linked to its housing situation. On the other hand, for projects where tackling energy poverty is the main project objective, the identification of households in real need of support is often carried out through the application of multiple selection criteria, enabling more fine-grained identification of the target group.

Overall, projects in the database have chosen their target group among consumers in specific conditions that typically suggest a particular vulnerability of a household to the risk of falling into a situation of energy poverty. The following categories emerged from the analysis of the projects:

- **consumers living in social housing** — includes projects targeting the social housing sector;
- **consumers in receipt of social welfare** — includes projects targeting recipients of social welfare benefits as well as people in the care of social workers;
- **consumers experiencing energy affordability issues** — includes projects that explicitly target households facing difficulties with affording their basic energy needs.

Figure 6. Number of projects per target group category



As illustrated by Figure 6, most projects in the database (24 out of 31 projects) used the criterion 'social housing' to recruit their study sample. As there is no common definition of the term 'social housing' across Europe (Braga and Palvarini, 2013; Granath Hansson and Lundgren, 2018) we have included in this category all projects carried out in 'self-defined' social housing complexes, regardless of the type of residents, form of tenure, type of provider and whether or not they are subsidised.

The use of the category 'social housing' to identify and recruit the study population presents several strengths. Energy poverty is a complex social problem touching on broad societal issues that cannot be captured by simple indicators or metrics. Social housing residents are typically exposed to the interaction of complementary factors that affect energy use. They are usually more likely to have a low income, to live in old and non-renovated houses with low energy efficiency and to belong to vulnerable groups. In this sense, they make a good target for energy poverty interventions, although the real conditions of the residents should always be examined individually, as the social housing sector includes a wide variety of people — in terms of age, income and needs — and buildings.

In addition, addressing social housing complexes also helps making energy poverty interventions easier and less expensive to carry out, as it makes it possible to target a large number of potential recipients in the same place. Since social housing, cooperative housing and public housing make up on average 11 % of the housing stock of the EU Member States (Pittini et al., 2017), targeted interventions could make a significant impact on energy poverty at European level.

A downside of this approach lies in the uneven distribution of social housing in Europe. Social renting is particularly strong in countries such as Denmark, France, the Netherlands, Austria, Sweden and the United Kingdom, and quite limited in eastern European and the Mediterranean countries (Pittini et al., 2017; Scanlon et al., 2015). According to recent estimates, on the other hand

(Thomson and Bouzarovski, 2018), eastern and southern Europe show a high prevalence of energy poverty. In these areas, using the 'social housing' criterion to identify energy-poor households would offer only limited help in reaching out to people in need.

Only a limited number of projects has used the other two criteria, 'receipt of social welfare' (5 out of 31 projects) and 'energy affordability' (4 out of 31 projects), either alone or in combination with one another. These two criteria usually link the identification of vulnerable consumers with the application of national social policy measures. In these cases, a partial overlap with the 'social housing' criterion is of course possible, because, as mentioned before, social housing residents are more likely to have a low income and to belong to vulnerable groups.

2.3. Stakeholders

The stakeholder categories were adapted from those used in the JRC smart grid projects outlook 2017 (Gangale et al., 2017). The list was, however, adapted to emphasise some categories (e.g. charities), merge others and remove stakeholders that did not figure in any of the projects analysed (e.g. transmission system operators, aggregators, energy cooperatives). Table 1 lists the stakeholders identified for this study and provides a brief explanation for each category.

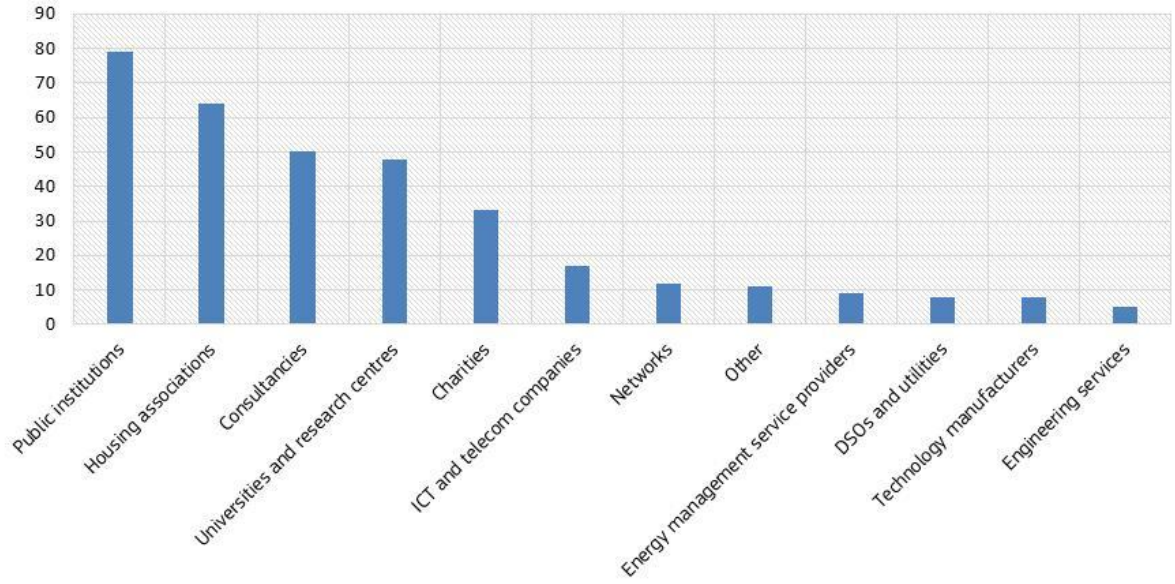
Table 1. List of stakeholder categories

Charities	Non-profit organisations whose primary objective is social well-being
Consultancies	Organisations providing professional expert advice to other public and private organisations
DSOs and utilities	DSOs are organisations responsible for the operation, management and planning of electricity distribution networks serving more than 100 000 connected customers, regardless of their ownership structure Utilities are organisations active in power generation, distribution and sale, serving fewer than 100 000 connected customers
Energy management service providers	Organisations providing energy management solutions and services, typically enabling greater consumer participation (e.g. energy services companies (ESCOs))
Engineering services	Organisations active in engineering services, e.g. development and construction of low-energy buildings and other civil infrastructures, installation and management of smart metering infrastructure
Housing associations	Organisations that provide affordable housing for rent or accession to ownership to specific target groups, typically defined in terms of socioeconomic status or the presence of vulnerabilities. This category includes a limited number of real estate developers that have got involved in social housing projects
ICT and telecom companies	Organisations active as software developers, system designers, system integrators and telecom companies
Networks	Organisations grouping various entities (public and private) whose scope is to represent and promote a common objective at national and international levels. They mostly operate in the social and energy sectors
Public institutions	Public entities, such as regions, municipalities, environmental and energy agencies, and local authorities
Technology manufacturers	Organisations active in the design and production of technological solutions, particularly hardware solutions
Universities and research centres	Universities are public and private higher education institutions, e.g. universities, institutes of technology and colleges. Research centres are public and private organisations dedicated to scientific research, both basic and applied
Other	Organisations active in various sectors that cannot be placed in any of the abovementioned categories, e.g. municipal utilities, metering companies, generation companies, incubators

In total, 293 organisations, grouped into 12 categories, participated in the projects in the database. As some of these organisations participated in more than one project (about 13 % of them), we also checked the number of individual participations, totalling 344. Figure 7 shows the number of participations per stakeholder category.

Project consortia range from 4 partners to 38 partners and most of them (93 %) 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.

Figure 7. Number of participations per stakeholder category



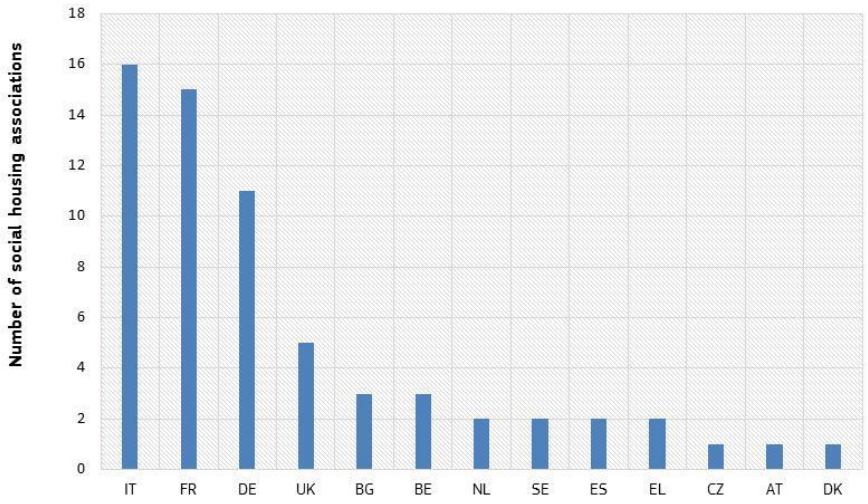
'Public institutions' is the category with the highest number of participations (23 %). About 52 % of them are counties and municipalities, 24 % are energy agencies, and the remaining 24 % includes local government departments, local development agencies and urban regeneration agencies. The high presence of public institutions indicates their interest in alleviating energy poverty in their jurisdictions, as well as their need to build the competences to replicate successful interventions at a wider scale.

The category 'Housing associations' also shows a high number of participations (19 %). This finding is in line with the fact that most projects target energy-poor households based on their specific housing situation, that is, their location in a social housing complex. Social housing operators are typically involved in the projects surveyed as managers of the demonstration sites; they have a lot to learn from the projects and can use this knowledge to ensure the continuity of the results after the projects have ended. Projects represent an opportunity to implement measures that can contribute to increasing the living standards of tenants while improving the state of the property and communicating a message of social responsibility. Their involvement in such projects could also help to increase access rates and assist with understanding the needs of vulnerable consumers.

Figure 8 shows the number of housing associations involved in the projects per country. Italy represents an interesting case. Although social rental housing represents only 4 % of the national housing stock (Czischke and van Bortel, 2018), Italian housing associations have been very active in

chasing the opportunities offered by European funding to address energy poverty and refurbish their properties. Besides Italy, among the other EU countries with a high incidence of energy poverty ([6]), we find that social housing providers from Bulgaria and Greece have also participated in several EU-funded energy poverty projects. Participating in demonstration projects helps social housing providers to build capacity, raise awareness, circulate new ideas and test new solutions to combat energy poverty.

Figure 8. Number of housing associations involved in the projects per country



The categories 'Universities and research centres' and 'Consultancies' (14 %) mainly have a consulting role, supporting other stakeholders in the implementation of projects through their technical knowledge and expertise.

Another widely represented category is 'Charities' (10 %), which includes a variety of non-profit organisations whose primary objective is social well-being. The majority of the charities participating in the projects surveyed are specialised in energy issues and aim to empower individuals and communities through innovation and social interventions. Their participation in the projects helps to recruit and engage vulnerable households, as they are seen as trustworthy organisations with a good knowledge of the social environment in which they operate. Their involvement in a project can also often work as a door opener. A similar role is played by the category 'Networks of different organisations' operating in the social and energy sectors. They usually aim to represent and promote a common objective at national and international levels.

All the other categories show a limited number of participations (less than 5 %). Among these, 'ICT and telecom companies', 'Energy management service providers', 'DSOs and utilities' and 'Technology manufacturers' have low participation rates, but in the future they could play an important role in designing solutions to address energy poverty.

The category 'DSOs and utilities' represents an interesting case. Although they currently account for only 2 % of participations, their contribution to projects linked to energy poverty is likely to increase

([6]) We refer to EU countries where both the indicators 'ability to keep the home adequately warm' and 'arrears on utility bills', as reported by Thomson and Bouzarovski (2018), are above the EU average.

in the coming years. By participating in these projects, DSOs and utilities can gain experience in achieving energy savings in the framework of national energy efficiency obligation schemes (EEOS) ([7]) (Fawcett et al., 2018), where these are in place in the Member State where they are established. Under Article 7 of Directive 2012/27/EU, as amended by Directive (EU) 2018/2002, Member States must require, 'a share of energy efficiency measures under their national energy efficiency obligation schemes … to be implemented as a priority among vulnerable households, including those affected by energy poverty and, where appropriate, in social housing'. This provision could unlock investments in energy efficiency for energy-poor households, as DSOs and retail companies (or utilities) have at their disposal the necessary data and means to identify energy poverty among their customers and effectively address it, fulfilling in this way the energy efficiency obligation. Acknowledging the need to build the capacity of the obligated parties, the H2020 work programme for 2018-2020 funds actions to 'develop, test and disseminate innovative schemes for energy efficiency/RES [renewable energy] investments established by utilities or other obligated parties under Article 7' ([8]).

2.4. Geographical distribution of projects and investment

Project participations and investment are concentrated in a small number of countries, namely France, Spain, Italy, Germany and the United Kingdom (Figure 9 and Figure 10). To better understand this result, it is necessary to clarify how participations and investment are counted. The participation count assigns projects to the countries where the participating organisations are based. This explains why the number of participations is higher than the number of projects surveyed. This counting system allows us to see the level of activity of a country; a high number of participations implies that organisations in a given country are very active, taking the decision to participate in a large number of initiatives within their country of establishment as well as in others.

The investment count, unless specific information is available, distributes the project budget equally among the different partners, irrespective of their actual individual contributions to the project's financing. This approach — necessitated by the difficulty of finding real investment data (on private and external funding) per project participant — simplifies the investment count without compromising the reliability of the overall data.

([7]) An EEOS requires obligated parties, generally energy utilities, to meet energy-saving targets by delivering or procuring energy savings at the customer end of the energy system (Fawcett et al., 2018). Within this general definition, individual EEOS look very different from each other, with obligations being variously placed on energy retailers, energy distributors or both; across different geographical scales; on a variety of energy types; with different levels of ambition and metrics; and across all sectors of the economy or just for particular customer groups (Fawcett et al., 2018).

([8]) https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/lc-sc3-ec-2-2018-2019-2020.

Figure 9. Number of participations per country

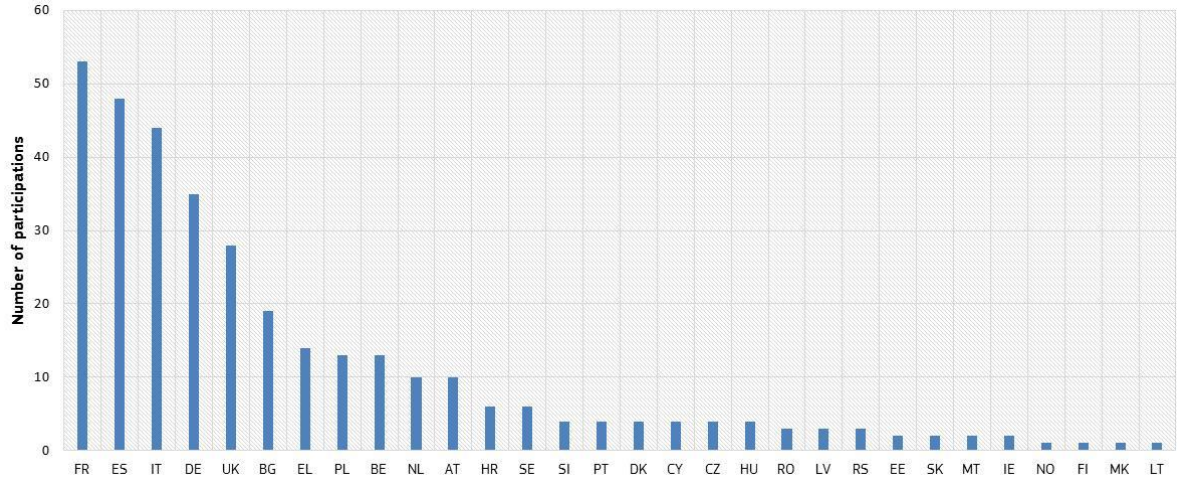


Figure 10. Investment per country

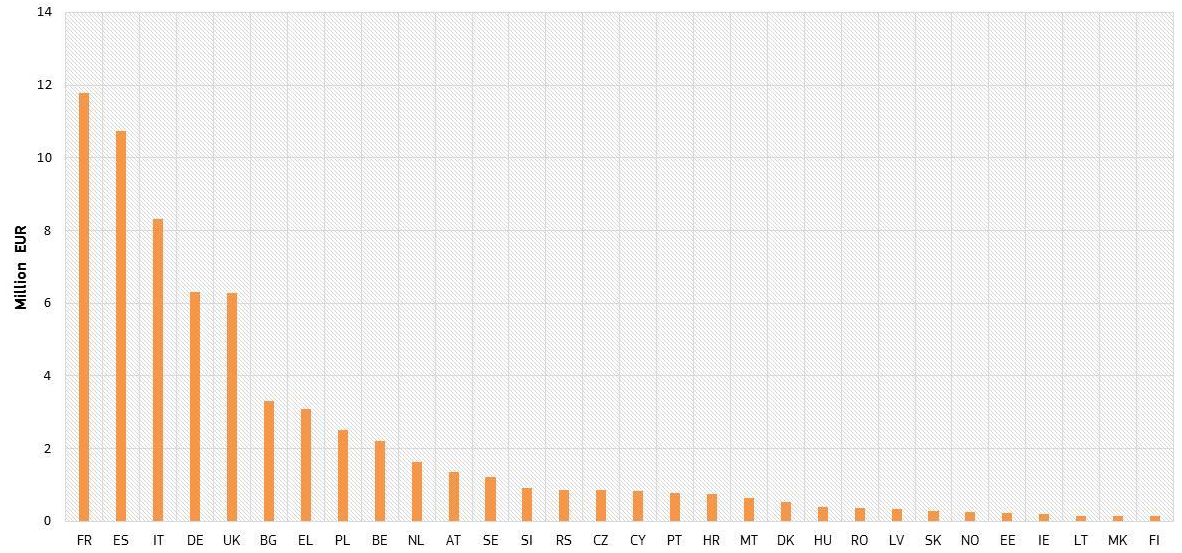


Figure 9 and Figure 10 are not intended to compare countries with different characteristics, as such an approach would not be fair and could be misleading. They are meant as a tool to identify current trends and to try to explain their causes. The differences between countries in the number of participations and level of investment in energy-related innovation projects are attributable to a combination of country-specific circumstances that shape national responses to energy poverty, such as the prevalence of energy poverty, the national policy framework, the company cultures of DSOs and retailers, and the number of social housing providers.

In France, for example, there are several favourable conditions for investment in innovation projects addressing energy poverty. Energy poverty has been on the national agenda for over a decade and several social and energy policy measures have already been adopted to alleviate it and to tackle its root causes (Legendre and Ricci, 2015; Schumacher et al., 2015). The social housing sector accounts for about 17 % of the building stock, and social housing providers are engaged in a plan to renovate 800 000 social housing units by 2020 in order to improve their energy efficiency ([9]).

([9]) With the Grenelle law, France committed EUR 320 million of ERDF funding to renovate 800 000 social housing dwellings with low energy performance by 2020.

Social housing providers, as well as other eligible operators, can also benefit from the national EEOS. In 2016, the law on energy transition for green growth created a new obligation specifically aimed at combating fuel poverty. Actions implemented among low-income households are now eligible for fuel poverty energy-saving certificates (French Ministry of the Environment, Energy and the Sea, 2017).

Similarly, in the United Kingdom, the debate on energy poverty is among the oldest in Europe and has given rise to a growing number of national policy frameworks to define, measure and alleviate this phenomenon. The steady attention dedicated to this topic over the years has generated a high level of awareness of the problem not only at policy and academic levels but also among other institutional, commercial and non-governmental actors. This environment has encouraged the participation of national stakeholders in EU-funded projects, as well as their participation in a number of innovation projects funded at national level.

Of the countries with a high prevalence of energy poverty ([10]), we find that Bulgaria, Greece and Italy have been quite active in investing in EU-funded innovation initiatives to address energy poverty, while other countries have benefited less from this investment opportunity. Some of them, however, have been quite active in seeking other sources of EU funding, such as the technical assistance programme ELENA ([11]) or the Jessica ([12]) initiative.

Figure 11 shows the distribution of project categories across countries. Behavioural change projects have attracted the highest country participation, with 80 % of countries having participated in at least one project. Sixty-seven per cent of countries have participated in at least one digital technologies project, 63 % in at least one sharing of best practices project, and 47 % in at least one financing project. Thirty per cent of countries have participated in all project categories.

([10]) Bulgaria, Greece, Croatia, Italy, Cyprus, Latvia, Lithuania, Hungary and Romania show values above the EU average for the energy poverty indicators 'inability to keep home adequately warm' and 'arrears on utility bills' (Thomson and Bouzarovski, 2018).

([11]) ELENA (European Local Energy Assistance Fund) is a joint initiative by the European Investment Bank (EIB) and the European Commission under the H2020 programme. It provides grants for technical assistance focused on the implementation of energy efficiency, distributed renewable energy and urban transport projects and programmes.

([12]) Jessica (Joint European Support for Sustainable Investment in City Areas) is a policy initiative of the European Commission developed jointly with the EIB and in collaboration with the Council of Europe Development Bank.

Figure 11. Distribution of project categories across countries

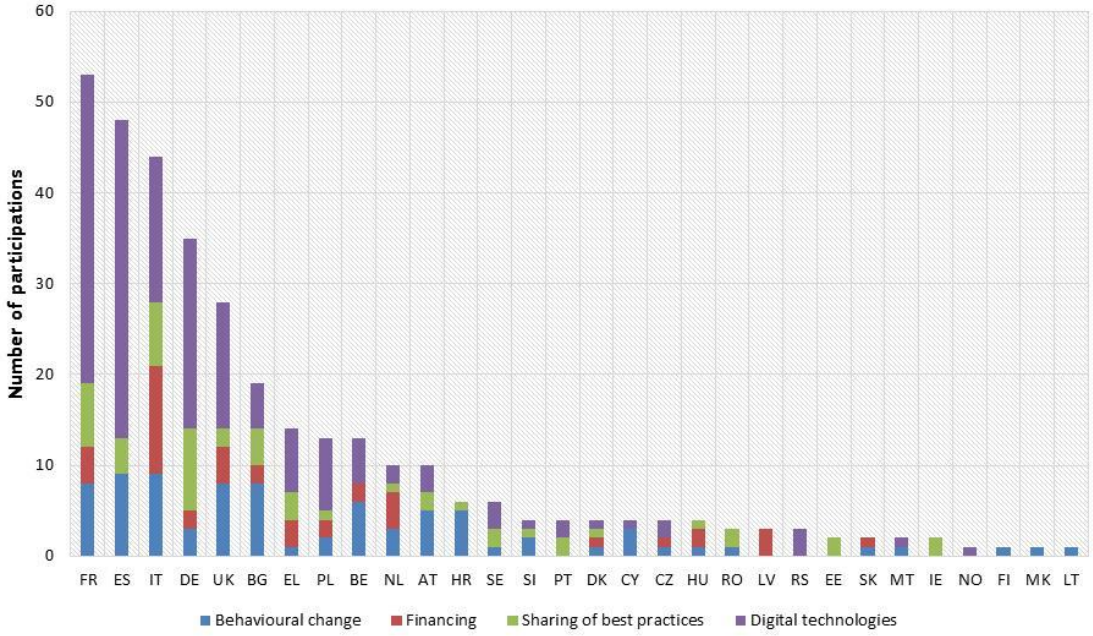
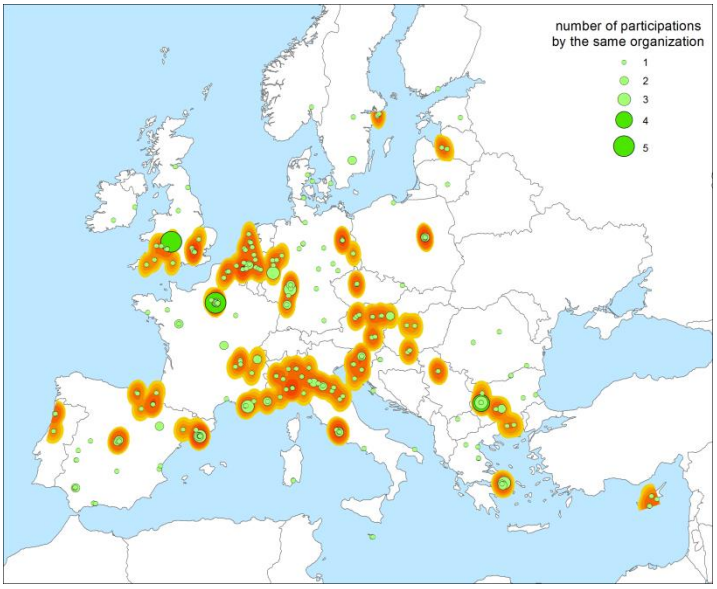


Figure 12. Geographical distribution of organisations within countries



Finally, Figure 12 shows the distribution of organisations within countries. The green circles represent the location of the participating organisations, with larger circles indicating the participation by the same organisation in different projects (up to five). In areas with a high density of organisations, the green circles overlap and fail to show the presence of different organisations in the same place. The organisation density in a given area is therefore indicated using orange shading. The darker the shading, the higher the number of participating organisations in that area.

The figure illustrates that, in most countries, organisations active in energy poverty projects are concentrated in a few areas, not always matching the areas most severely hit by energy poverty issues at national level. In Italy, for example, the participating organisations are concentrated in the north of the country (30 organisations) and in the area around Rome (9), while there are no organisations active in the south, despite tenants and residents in southern regions being

particularly vulnerable to energy poverty (Miniaci et al., 2014). Other countries also show significant differences at regional level and a high concentration of participating organisations around the main cities (e.g. Athens, 8; Barcelona, 14; London, 7; Paris, 23; Sofia, 9; Warsaw, 10).

Promoting the participation of organisations based in areas with high rates of energy poverty would help to bring about more widespread uptake of good practices and the use of EU funds where they are most needed. This approach would, however, require more research on harmonised regional energy poverty assessments, as suggested by the Engager Cooperation in Science and Technology (COST) action (Engager — Energy Poverty Action, 2018). The identification of regions with similar energy poverty features could also foster collaboration links between them, promote the exchange of best practices and provide opportunities for local stakeholders with successful solutions to pursue business opportunities in other Member States.

Summary

Time-trend data suggest that the growing attention attracted by energy poverty at policy level in recent years has not yet been reflected in the research and innovation initiatives carried out to date with EU financial support.

Four categories of projects emerged during the review of EU-funded projects that have addressed energy poverty since 2006: 'Digital technologies', 'Behavioural change', 'Financing' and 'Sharing of best practices'. 'Digital technologies' is the category with the highest number of projects and the highest level of investment. 'Behavioural change' projects have attracted participation from the most countries, with 80 % of countries having participated in at least one project. Thirty per cent of countries have participated in all project categories.

Most projects in the database (77 %) recruited their study sample from social housing.

A total of 293 organisations, grouped into 12 categories, participated in the projects in the database. 'Public institutions' is the category with the highest number of participations (23 %), followed by 'Housing associations' (19 %). 'ICT and telecom companies', 'Energy management service providers', 'DSOs and utilities' and 'Technology manufacturers' have low participation rates (less than 5 %), although they could play an important role in designing future solutions to address energy poverty.

The indicators used to assess the projects' expected impact vary according to the project category and the type of intervention involved. Most projects use the amount of energy savings (in energy and monetary terms) as the main indicator of success.

Project participations and investment are concentrated in a small number of countries, namely France, Spain, Italy, Germany and the United Kingdom. The differences between countries in the number of participations and in the level of investment in energy-related innovation projects are attributable to several country-specific circumstances that shape national responses to energy poverty.

In most countries, organisations active in energy poverty projects are concentrated in a few areas, not always matching the areas most severely hit by energy poverty issues at national level.

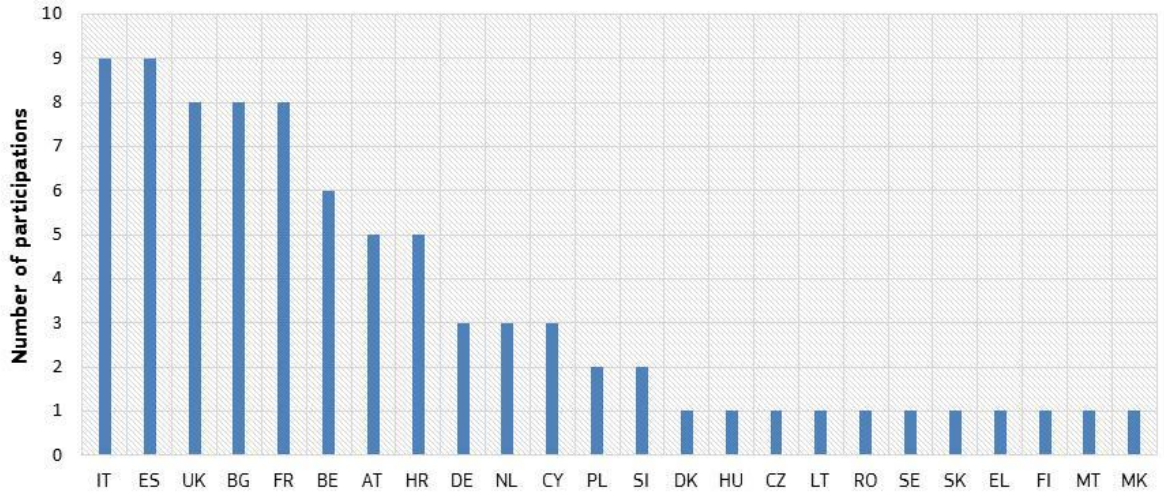
3. Insights and lessons learned from the projects

Having given an overview of the main trends regarding the project categories, target groups and stakeholders involved in EU-funded projects addressing energy poverty, we will now take a closer look at the projects in the database to analyse their scope, the challenges they had to confront, the results achieved and the recommendations that can be extrapolated from the experiences gained.

3.1. Digital technologies projects

Projects in this category use digital technologies to reduce energy consumption in social housing complexes, thus helping vulnerable consumers to reduce their energy bills. The projects had 165 participations and covered 20 countries, with the majority of partners coming from Spain (35), France (34) and Germany (21). This project category involved the largest partnerships, with consortia ranging from 7 partners to 38 partners, with an average of 16 (Figure 13).

Figure 13. Number of participations in digital technologies projects per country



The digital technologies projects are presented in Table 2.

The project Save@Work4Homes was funded by the IEE programme to help tenants improve their energy awareness by encouraging them to monitor their consumption and by providing them with information including heating data and data analyses.

Seven projects — 3e-Houses, eSESH, e3SoHo, ICEWish, BECA, SHOWE-IT and EnergyTIC — were funded through the ICT PSP with the aim of demonstrating that advanced ICT components and systems can contribute directly to reducing both peak consumption and annual energy use by more than 15 % under real conditions in European social housing. The technical actions piloted by these projects targeted both the building and the dwelling level through the adoption of building energy management systems ([13]) and energy awareness systems ([14]). The actions carried out at the dwelling level are the most interesting for our study, as they allow us to focus on the behaviour of vulnerable consumers and their responses to technological innovation.

([13]) These systems collect, analyse and deliver information about environmental and energy use, as well as the main technical parameters of the equipment. They help building managers to administer their buildings better, enabling more efficient energy management, fairer energy billing, the introduction of more powerful incentives for saving, and intelligent electricity peak savings (Jáñez Morán et al., 2015).

([14]) Systems that provide consumers with real-time data on their actual energy consumption to enable them to save energy by adapting their consumption behaviour.

Elih-Med was funded by the Interreg Med programme ([15]) and aimed to experiment with multi-energy smart meters in low-income dwellings to improve energy consumption habits and reduce energy bills. Finally, EnerGAware was funded under H2020 and aimed to demonstrate the effects of providing social housing tenants with a serious game linked to the actual energy consumption of their houses measured through smart meters.

Table 2. Digital technologies projects surveyed

Project name	Project duration	Countries involved
Save@Work4Homes	Jan 2007-Dec 2008	DE, FR, PL, UK
3e-Houses	Feb 2010-May 2013	BG, DE ES, UK
e3SoHo	Feb 2010-Sep 2013	BE, ES, FR, IT, NO, PL, PT
eSESH	Mar 2010-Feb 2013	AT, BE, DE, ES, FR, IT, PL
BECA	Jan 2011-Dec 2013	BG, CZ, DE, EL, ES, FR, IT, RS, SE
SHOWE-IT	Jan 2011-Dec 2014	DE, ES, FR, SE, UK
EnergyTIC	Mar 2011-Sep 2013	BE, ES, FR, UK
ICEWish	Mar 2011-Sep 2014	BE, BG, DE, DK, EL, ES, FR, IT, NL, PL, UK
Elih-Med	Apr 2011-Mar 2014	CY, EL, ES, FR, IT, MT, SI
EnerGAware	Feb 2015-Jan 2018	ES, FR, PT, UK

All the projects were implemented in social housing complexes across Europe, covering a variety of different climatic conditions, cultures and social housing ownership structures. They all monitored the energy consumption of social housing tenants, providing them with near real-time information on their actual consumption and with energy-saving feedback and rewards ([16]). Although the alleviation of energy poverty was not the primary objective of the projects, many of them considered it a relevant positive impact of the project activities (BECA, Elih-Med, eSESH, EnerGAware, SHOWE-IT). Providing tenants with the information necessary to control their consumption is seen as a way to reduce the risk of their falling into a state of energy poverty.

Stakeholders. This project category is also the one with the highest partner diversification, being the only one in which all the stakeholder categories are represented (Figure 14). The main actors are housing associations (24 %), public institutions (15 %) and ICT and telecom companies (10 %).

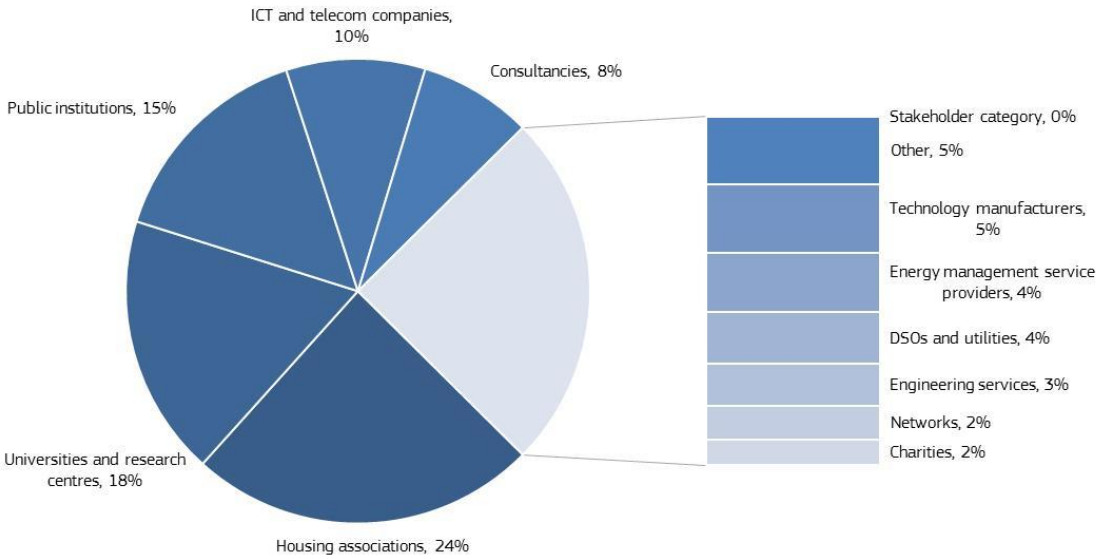
Housing associations have a strong incentive to invest in innovative solutions that lower the consumption costs of tenants, who then have more disposable income to pay rent. Such investment also pays back in terms of public image and reputation, as it improves the living standards of social housing residents (SHOWE-IT, 2015). ICT and telecom companies can also benefit from participating in these projects, as social housing complexes can serve as a living lab for testing ICT solutions on different consumer segments. Furthermore, the replication potential of successful initiatives makes these projects even more appealing, as social housing companies make up as much as 11 % of the European housing stock.

([15]) The Interreg Med programme is an EU transnational cooperation programme that gathers 13 European countries from the northern shore of the Mediterranean. They are working together for sustainable growth in the region. The programme supports projects developing innovative concepts and practices and promoting reasonable use of resources.

([16]) In particular, in the case of EnerGAware, rewards consisted in the possibility of unlocking features and content in the serious game.

Similarly, DSOs and utilities can profit from taking part in digital technologies projects, but their participation in the projects surveyed was quite low. Two project outputs (for BECA and eSESH) reported that some energy providers collaborated only tentatively with the project, as they did not anticipate significant benefits from their involvement (Korte et al., 2013; Vogt et al., 2014). This lack of interest may be because many utilities already offer individualised monitoring tools using real-time consumption data to all consumers. Pilot projects targeting vulnerable consumers, however, still offer room for testing remote metering and additional services tailored to this consumer segment. The experiences gained in these pilot initiatives could help DSOs and utilities to respond more promptly to future regulatory requirements.

Figure 14. Stakeholders involved in digital technologies projects



Innovative approach. The innovation potential of the projects in this category does not lie in the technologies trialled — already close to market maturity — but, rather, in the choice of the target population for the pilot projects. Many other EU-funded projects have demonstrated similar solutions, but they targeted the average consumer, if not early adopters. Their focus was more on the technology and on how it could contribute to energy efficiency gains, and — when the consumer and the dynamics influencing his or her choice were taken into consideration — the attention was on less vulnerable segments of the consumer population. The projects in this category, on the other hand, target social housing tenants, typically a category of consumers that is more exposed to energy poverty, as these consumers are usually more likely to have a low income and to belong to vulnerable groups.

Accessible, accurate and timely consumption data can help vulnerable consumers to understand and manage their energy use better, and can reduce the cost of achieving comfort (Csiba et al., 2016; Darby, 2012). Social housing tenants often have no idea of their actual household consumption or do not know how the final costs included in their rent are calculated. Even many of those who already have individual meters still receive estimated bills. Smart metering can therefore increase their energy awareness and enable them to gain control over their energy costs.

Challenges and results. Overall, the projects surveyed helped to demonstrate that energy savings are possible even in vulnerable households and that smart metering can lead to lower energy bills, thus contributing to the alleviation of energy poverty. Energy consumption reductions were achieved at almost all pilot sites ([17]), and only in a few cases was an increase rather than a decrease in energy consumption observed (Table 3).

Table 3. Digital technologies project results

Project	Quantitative results
Save@Work4Homes (Save@Work4Homes, 2009)	DE, heat, 9 %
3e-Houses	Average energy savings for all pilots: 9.6 % (*) (ES, 21.52 %; DE, –1.82 %; UK, 9.4 %; DE, replicator, 10 %)
e3SoHo	Average energy savings for all pilots: 7.5 % (*) (ES, heating, 10.4 %; ES, electricity, 7.8 %; PL, heating, 10 %; PL, electricity, 1.9 %)
eSESH (Korte et al., 2013)	Average energy savings for all pilots: electricity, 5.9 %; heating, 9 %
BECA	Average energy savings for all pilots: 8.9 % (*) (electricity, 2 %; heating, 15 %)
SHOWE-IT (SHOWE-IT, 2014)	FR, electricity, –4 %; FR, heating, 0 %; SE, electricity, 8 %; SE, heating, 15 %; UK, electricity, 12 %; UK, heating, –14 %.
ICEWish	Average energy savings for all pilots: 26.7 % (*)
EnergyTIC	n.a.
Elih-Med (Elih-Med, 2014)	Electricity savings: ES (1), 22.4 %; ES (2), 10.2 %; FR, 0 %; CY, 27.4 %; EL, 10 %.
EnerGAware	n.a.

(*) Unweighted average saving for all pilots reported through the eeMeasure website (http://eemeasure.smartspaces.eu/).

The large variation in the savings obtained by the different demonstrators (for electricity, from –4 % to more than 27 %), points to the importance of local circumstances. The effectiveness of the ICT solutions trialled depends on a variety of technical, geographical, social and cultural factors. The installation of a smart metering solution alone does not lead to energy savings unless consumers are involved from the early stages of the initiative through an engagement strategy that takes into consideration all of these factors. To actually trigger behavioural change it is necessary to build confidence and trust and to leverage consumers' motivations and values, putting them at the centre of the engagement strategy (Gangale et al., 2013). It is also important to address consumers' concerns and remove all obstacles to the acceptance of the new technological solution and to their full participation in the initiative.

([17]) The results of the seven ICT PSP projects include the energy reductions achieved through the implementation of energy management systems and are not entirely attributable to the increased energy awareness of social housing tenants. As reported by Korte et al. (2013), energy awareness systems and energy management systems sometimes compete for the same savings. For example, while optimising the operation of central heating systems, the energy management system limits the internal temperature and reduces or stops heating during the night, diminishing the chances that savings will result from similar energy awareness system functionalities and recommendations.

Several studies have analysed consumer engagement strategies in smart grid and smart metering projects in Europe and the impact of different interventions on consumer participation and energy savings (Gangale et al., 2013; Kessels et al., 2016; Mengolini et al., 2016; S3C Consortium, 2014). In this study, we will focus on the specific challenges that the projects had to address in relation to the specificities of the target group, for example their financial and social constraints.

Several project outputs (e.g. for eSESH, BECA and Elih-Med) reported that social housing tenants showed a lack of trust in social housing companies and in energy suppliers, resulting in low engagement levels. To gain their trust, projects trialled cooperating with social services (eSESH, BECA), in particular with social workers in touch with the tenants on a regular basis. Social housing tenants were found to welcome advice coming from individuals whom they trusted to operate in their interests (Korte et al., 2013; Vogt et al., 2014). To be able to support tenants effectively, however, social workers need to be provided with basic training on relevant topics, such as energy efficiency, energy poverty and end devices. Social workers could also work alongside 'champions', that is, tenants who show a strong interest in technical and energy-saving matters and who can act as multipliers by 'spreading the message' and helping neighbours who have questions. For energy suppliers in particular, distrust issues can be tackled by adopting a proactive approach in suggesting optimal contract options to their customers in low-income households. Reviewing utility contracts — for example by lowering the contracted power or changing tariff — can help tenants to quickly cut down on energy costs and can be used as an icebreaker to gain consumer trust (Elih-Med, 2014).

Projects also showed that ensuring engagement throughout the entire duration of the project and beyond can prove difficult, especially if the savings achieved are not high (3e-Houses, Elih-Med, e3SoHo, eSESH, BECA). The often low energy consumption of social housing tenants reduces motivation to save and makes further reductions difficult. In environments with already low consumption, it is advisable to adjust communication materials to focus on detecting waste, rather than on additional savings (3e-House, eSESH, BECA, Elih-Med, SHOWE-IT). Furthermore, involving tenants during service design and interacting with them from the very start of the installation process helps to keep them engaged during and after the project activities. Community involvement helps to motivate tenants and trigger a desire to cooperate. Selecting local representatives to coordinate early activities (e.g. the organisation of education and awareness sessions, the coordination of the installation process between installers and tenants), in particular, has helped to convey the idea of a community effort and to build trust in the initiative (Elih-Med, 2014).

Finally, project outputs highlighted that some categories of tenant are particularly hard to reach and motivate, notably those with low IT literacy, immigrants and the elderly. The low technological handling of many social housing tenants can represent a serious challenge for an ICT project. Training sessions for tenants lacking ICT knowledge should be organised to ensure that they can participate in the project and benefit from it. In any case, it is advisable to provide tenants with feedback in a paper-based format, possibly combined with the monthly bill, to make sure that all tenants are reached (3e-Houses, e3SoHo, eSESH, BECA, Elih-Med). In those social housing complexes with a large percentage of immigrant residents, resources should be allocated for translation and interpretation of bills, feedback and communication materials. Such materials should, however, be straightforward enough for all tenants to understand them, taking into consideration possible language barriers and lower literacy rates (3e-Houses, eSESH, BECA).

On a different note, another challenge strictly linked to the peculiarities of the target population of the trials is the cost of the technological solutions to be installed. According to Jáñez Morán et al. (2015), in the projects funded under the ICT PSP, the ICT system installation costs range from EUR 300 to EUR 1 000 per dwelling, depending on the number of installations monitored and the average country prices. The payback period depends on the average energy cost; therefore, in some countries current energy prices are too low to calculate a positive return on investment. Nevertheless, the financial pay-off is achieved by most social housing tenants during the first 5 years and by almost all after 10 years (Jáñez Morán et al., 2015).

To speed up the adoption of ICT-based energy awareness solutions among vulnerable consumers, it is necessary to find innovative ways of funding the additional services and equipment required. A possible solution would be rewarding the achieved energy savings and load shifted in the framework of EEOS under article 7 of the energy efficiency directive. As mentioned above, such a system was recently introduced in France, where in 2016 the law on energy transition for green growth created a new obligation specifically aimed at combating fuel poverty. Actions implemented in low-income households are now eligible for fuel poverty energy-saving certificates (French Ministry of the Environment, Energy and the Sea, 2017). Similar schemes are also in place in Ireland, Austria and the United Kingdom (Bertoldi et al., 2015). Rewarding the energy savings achieved in low-income households could make suppliers more interested in offering adapted energy efficiency programmes to this consumer segment. Other financing tools, which leverage private investment and do not require refinancing via surcharges on the energy bill, should, however, also be investigated.

Future research. The projects made an important contribution to understand the link between smart metering and vulnerable consumers, to identify the interventions that can help achieving energy savings and to address the main challenges deriving from the economic and social constraints of vulnerable consumers. On a less positive note, they all had a technical and economic focus that prioritised energy performance measures without specifically addressing the needs of vulnerable consumers. Future pilot projects should be tailored to the characteristics of this consumer segment and to the wider societal aspects of energy poverty. Given the difficulties in engaging project participants highlighted by many of the project outputs, future research initiatives could also explore other approaches to engagement. In particular, co-designing solutions, building on vulnerable consumers' real needs and expectations, should be investigated as a way to promote active participation and support long-lasting engagement.

Future research could also investigate other ways in which smart metering can affect energy-poor households, thus helping to shape future national- and European-level policies and measures. An interesting area to explore is the attitude of vulnerable consumers towards time-varying tariffs and their effects on energy bills. Time-varying tariffs are meant to encourage demand response, that is, the shifting of consumption to another point in time, typically in response to a price signal. Evidence on the impact of demand response initiatives on vulnerable consumers is limited and inconclusive, but there are several reasons to believe that low-income consumers may have different peak use reductions from average consumers. Owen (2012), for example, suggests that factors such as lower overall electricity use, flatter load shapes, different standards of housing and different appliance ownership patterns may all have an impact on the ability and willingness of low-income consumers to shift consumption. Rowlands and Stephen (2016) argue that vulnerable households have fewer

'discretionary' loads to shift and that, consequently, if they are not natural beneficiaries of the change in rates, they will not benefit at all from the introduction of time-varying tariffs. Given the lack of tailored studies and trials, projects piloting demand response mechanisms are needed to investigate the exposure of vulnerable consumers to price fluctuations and how they may be affected by the introduction of demand response measures. An interesting example of such a project is Energywise, a research study carried out in the United Kingdom to explore the opportunities for energy-poor consumers to participate in energy efficiency and demand response campaigns (see Box 3).

Box 3. The Energywise project

The Vulnerable Customers and Energy Efficiency project, also known as Energywise, is a project funded under the Low Carbon Networks Fund and led by UK Power Networks. The project, which ran from January 2014 to September 2018, involved undertaking a research study of 538 households that might be struggling with their energy bills in the London borough of Tower Hamlets. In a first trial, the project explored whether or not households benefited from smart metering solutions (a smart meter and smart energy display) and from energy efficiency technologies such as energy efficient light bulbs, an eco-kettle and standby shutdown.

In a second trial, the project aimed to evaluate households' eagerness to change their behaviour when on a time-of-use (ToU) tariff or critical peak rebate scheme. Prepayment customers were offered Bonus Time, a dynamic non-punitive critical peak rebate designed specifically for the project. Credit customers were offered HomeEnergy FreeTime (HEFT), a static free-time ToU tariff.

The results showed that the Bonus Time offering was associated with a 1.5 % reduction in average weekday evening peak demand for all households involved. The level of reduction observed in the households varied considerably, with the best-performing households (top 10 %) achieving average demand reductions of 18.7 % during Bonus Time events. Customers earned rebates ranging from GBP 3 to GBP 111 per year, with the average rebate comprising GBP 37 per year. HEFT participants on average shifted 0.92 kWh per week out of the paid time into the free time, saving GBP 0.12 per week. The highest amount shifted from the paid to the free time was 8 kWh per week. The HEFT tariff was associated with an average 2.2 % reduction in the weekday evening peak demand of the monitored households. However, this tariff was also associated with an average 22.2 % increase in the peak demand for the weekend day containing the HEFT free period (UK Power Networks, 2018). More information on this project is available at the UK Power Networks website (http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Energywise/).

Future pilot projects could also be used to test a range of services for vulnerable and energy-poor households, for example sending warnings if consumption patterns drastically change or consumption ceases altogether, ensuring that room temperatures do not fall below a healthy level, and accelerating the implementation of low-cost and discounted tariffs (Rowlands and Stephen, 2016; Mannion, 2012).

Piloting smart metering and other innovative solutions on vulnerable consumers can help to anticipate problems and opportunities and to build an inclusive energy future. If the perspective of vulnerable consumers is not taken into consideration at an early stage in the development of the relevant technology, they could miss out on the new opportunities and empowerment brought about by digitalisation and even be negatively affected by technological innovation.

Summary

Digital technologies projects use ICT to reduce energy consumption in social housing and help vulnerable consumers reduce their energy bills. This project category had the highest number of participations (165), with the majority of partners coming from Spain (35), France (34) and Germany (21). It also involved the largest partnerships and showed the highest partner diversification, being the only category in which all the stakeholder categories were represented.

All of the projects surveyed were implemented in social housing complexes across Europe. Although the alleviation of energy poverty was not the primary objective of the projects, many of them considered it an important collateral impact of the project activities. Providing tenants with the information necessary to control their energy consumption is seen as a way to reduce the risk of their falling into a state of energy poverty.

Overall, the projects surveyed helped to demonstrate that energy savings are possible even in vulnerable households and that smart metering can lead to lower energy bills. Energy consumption reductions were achieved at almost all pilot sites, and only in a few cases was an increase rather than a decrease in energy consumption observed.

The large variation in the energy savings obtained by the different demonstrators points to the importance of local circumstances. The effectiveness of the ICT solutions trialled depends on a variety of technical, geographical, social and cultural factors.

The low level of tenant engagement is reported in the majority of project outputs as one of the main challenges for the success of this kind of initiative. Lack of trust, the low technological handling and literacy rates of the tenants, low saving opportunities and large percentages of immigrant residents are considered the main issues making it necessary to promote acceptance of the new technological solutions and encourage residents' full participation in initiatives.

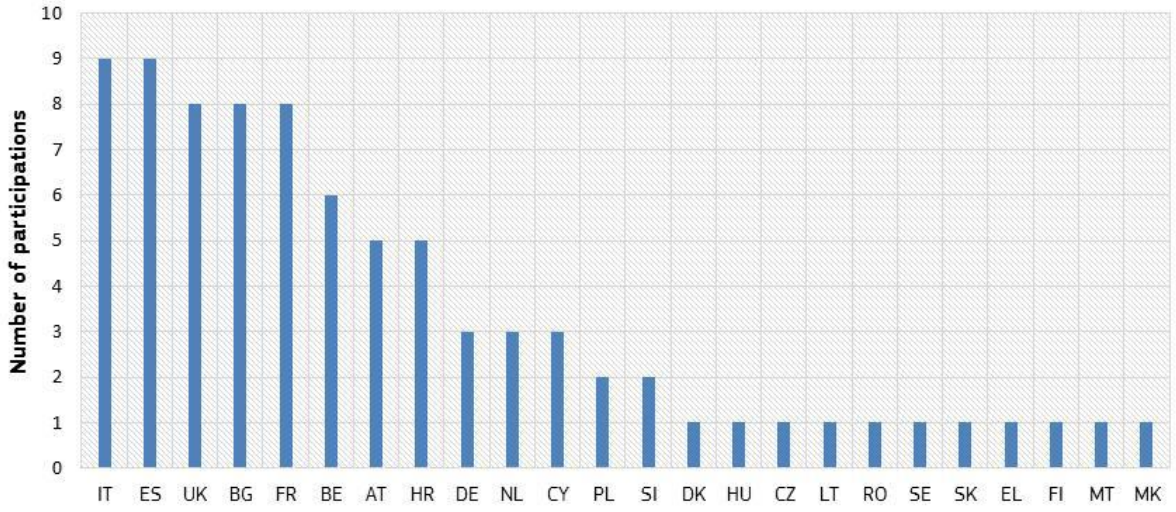
All the projects had a technical and economic focus that prioritised energy performance measures without specifically addressing the needs of vulnerable consumers. Future pilot projects should be tailored to the characteristics of this consumer segment and to the wider societal aspects of energy poverty. Other approaches to engagement that build on vulnerable consumers' real needs and expectations (e.g. solution co-design) should also be investigated.

Future pilot projects could also investigate the attitude of vulnerable consumers towards time-varying tariffs and their effects on energy bills. Another field of research could be testing a range of services for vulnerable households, such as sending warnings if consumption patterns drastically change or consumption ceases altogether, and ensuring that room temperatures do not fall below a healthy level.

3.2. Behavioural change projects

Projects in this category provide low-income and vulnerable consumers with information and tailored advice to encourage behavioural change and help them reduce their energy consumption and bills. The projects had 82 participations and covered 24 countries, with the majority of partners coming from Italy and Spain (both with 9 participations). Consortia ranged from 4 partners to 20 partners, with an average of 9 (Figure 15).

Figure 15. Number of participations in behavioural change projects per country



The behavioural change projects are presented in Table 4.

Table 4. Behavioural change projects surveyed

Project name	Project duration	Countries involved
ISEES	Jan 2006-Dec 2007	AT, BG, CZ, LT, SK, UK
Energy Ambassadors	May 2009-Oct 2011	BG, DK, EL, ES, FR, RO, SE, UK
EC-LINC	Mar 2011-Feb 2014	AT, BE, DE, HU, UK
Achieve	May 2011-Apr 2014	BG, DE, FR, SI, UK
REACH	Mar 2014-Feb 2017	BG, HR, MK, SI
TRIME	Sep 2014-Aug 2017	BE, ES, FR, NL, UK
Fiesta	Oct 2014-Sep 2017	BG, CY, ES, HR, IT
Smart-Up	Mar 2015-Jul 2018	ES, FR, IT, MT, UK
Assist2gether	May 2017-Apr 2020	BE, ES, FI, IT, PL, UK

Seven projects — ISEES, Energy Ambassadors, EC-LINC, Achieve, REACH, TRIME and Fiesta — were funded by the IEE programme between 2006 and 2014, while the more recent projects — Smart-Up and Assist2gether — were funded by H2020.

The projects experimented with different ways of providing energy advice to vulnerable consumers. The main tool tested was the figure of the energy adviser or ambassador (EA), used in all projects except ISEES ([18]). EAs are intermediaries trained to provide tailored energy advice during home visits. During a visit, the EAs analyses the energy efficiency performance of the property and the energy consumption behaviour of the householders with the aim of identifying strategies to reduce the household's vulnerability to energy poverty. Strategies can be financial (e.g. switching to a cheaper energy tariff), physical (e.g. installing energy efficiency measures) or behavioural (e.g.

([18]) The purpose of ISEES was to examine the rationality behind consumers' choices and the influence of individual user behaviour on energy demand in social housing. It developed solutions to integrate energy efficiency and renewable energy measures into social housing based on a concept using 'social dialogue'. ISEES investigated social dialogue with regard to the following activities in social housing: reducing household energy use (and improving thermal comfort conditions) through modifying user behaviour; maximising the benefits of building refurbishment; improving communal district heating services.

lowering thermostat set points, turning off unwanted lights) (Reeves, 2016). When necessary, EAs can also direct consumers in need to relevant support initiatives.

In the projects in the database, EAs mainly looked at everyday choices and practices to provide vulnerable households with face-to-face support to increase their energy awareness and promote behavioural change. Home visits provided EAs with an understanding of how people behaved in their homes and of the barriers to reducing their energy consumption and bills. Through the visits, EAs could understand each specific situation and tailor their advice to different vulnerable consumer groups. In one project, Smart-Up, EAs took on a more specific role, namely informing vulnerable consumers about the benefits of smart metering and advising them on how to get the most out of their smart meter and in-home display.

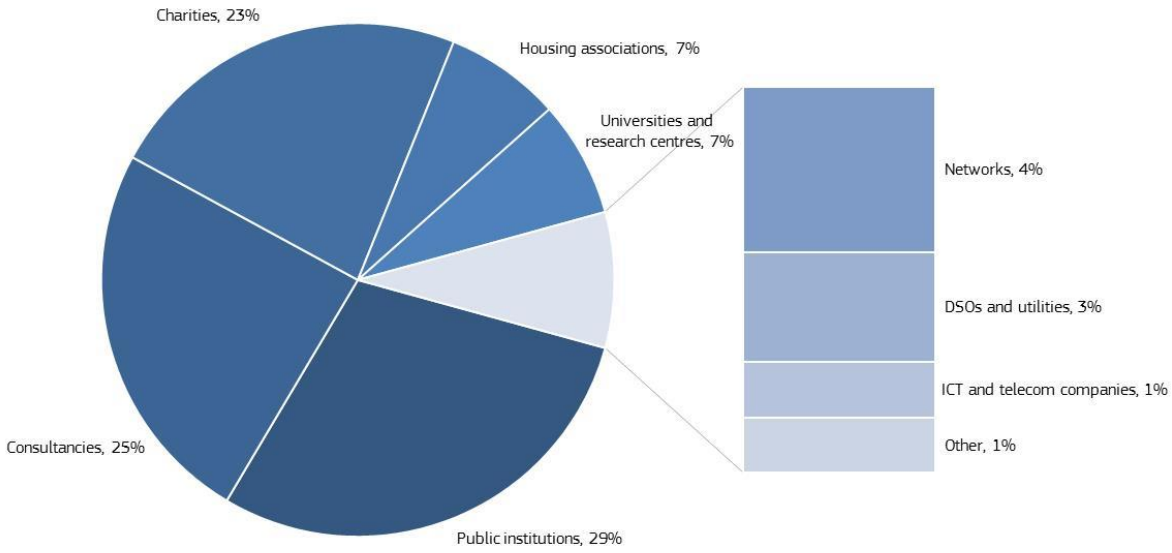
EAs also played a key role in the identification and recruitment of vulnerable consumers and in ensuring their engagement in project activities. Vulnerable consumers are usually more difficult to reach because of their uneasiness about acknowledging their disadvantages and economic situation. They are also more likely to welcome advice coming from individuals who can understand their situation and whom they trust to operate in their interests. To increase the reach of the project messages, some projects recruited EAs from health and social care professionals who were already in touch with the target population (e.g. Energy Ambassadors, Smart-Up). Others (e.g. TRIME) used peer social housing tenants, who were able to approach households in a friendly way and were trusted by their neighbours to provide advice. This approach also helped in building a sense of community and improving local relations. Some projects combined different social goals by recruiting EAs who were long-term unemployed, low-skilled people or students (e.g. Achieve, EC-LINC, REACH). Finally, the most recent project, Assist2gether, opted to professionalise the activity by developing a training and accreditation system in each participating country.

In all the projects, EAs received training and were equipped with information materials aimed at vulnerable consumers and focusing on simple and viable tips to save energy at home. Some projects also provided the households visited with free energy-saving devices, such as compact fluorescent lamps, switchable plug connectors and tap aerators (EC-LINC, Achieve, REACH) ([19]).

Stakeholders. Projects were implemented with the collaboration of various stakeholders, in particular public institutions, such as municipalities and energy agencies (29 %), social housing associations (7 %) and charities (23 %) (Figure 16).

([19]) The projects surveyed were inspired by forerunner initiatives developed at national level. In Belgium, for example, since 2007 the Energiesnoeiers project has provided vulnerable households with free energy scans, small energy-saving devices and insulation installation (https://energiesnoeiers.net/index.html). In Germany, the Stromspar Check started in 2008 to offer energy audits to vulnerable households, advising them on energy efficiency improvements and providing them with some basic energy-saving equipment (https://www.stromspar-check.de/). The EU-funded projects, in turn, helped to inspire and shape other initiatives, such as the Energiebox (https://www.energiebox.org/) and Energielegioen initiatives in the Netherlands, the Energieberatung in einkommensschwachen Haushalten project in Austria (https://www.ea-stmk.at/de_DE/endbericht-eshh) and the clevererKIEZ initiative in Germany. More recently, in France, the initiative Diagnostics énergétiques pour accompagner la rénovation was set up to identify households in energy poverty through postal workers, to provide them with advice on energy saving and to support them with refurbishment plans (https://www.soliha.fr).

Figure 16. Stakeholders involved in behavioural change projects



The importance of partnership and collaboration between stakeholders was acknowledged by several project outputs as a key factor in the success of the initiative (e.g. Achieve, EC-LINC, Energy Ambassadors, Fiesta). Public institutions' involvement in the projects helped to ensure political support, access to data on local households, and linkages with a variety of organisations. By participating in the projects, the public institutions were able to test and gain experience in the implementation of low-cost measures to tackle energy poverty in their jurisdictions. For those municipalities that are signatories to the Covenant of Mayors, the projects also offered the opportunity to develop and test an energy-saving action under their sustainable energy and climate action plans ([20]) (e.g. Energy Ambassadors).

As for housing associations, their participation in this kind of project helped to increase access rates and assisted with understanding the needs of vulnerable consumers. The implementation of a home energy advice project helped them to reduce the number of households in arrears and increase the living standards of tenants while improving their public image and reputation. Finally, the participation of charities was essential to reach and engage with vulnerable households. In their role as trusted intermediaries, they helped in the identification, recruitment and engagement stages of the projects; for them, the projects represented an opportunity to gain experience, build collaboration links with other stakeholders and expand their local social network.

Innovative approach. For this project category, as for digital technologies projects, the innovation potential lies in the choice of the target population for the pilots. Numerous EU-funded projects have looked at how to change consumers' behaviour to reduce their energy consumption, but only a few have focused on how to change the behaviour of vulnerable consumers. The comparatively limited number of projects targeting vulnerable consumers' behaviour is partly attributable to the

([20]) Sustainable energy and climate action plans are documents adopted by towns, cities and regions who have joined the Covenant of Mayors to define reduction measures to reach the local authority's voluntary CO_2 reduction target. The Covenant of Mayors is a European initiative through which local authorities voluntarily commit to reducing their CO_2 emissions beyond the 20 % target set at EU level.

fact that energy poverty and vulnerability are relatively new topics on the EU agenda. Another factor that might contribute to explaining this research gap is the questionability of promoting measures to reduce energy consumption in this consumer segment. If, on the one hand, increasing energy awareness and reducing energy use through behavioural changes and lifestyle adjustment could benefit energy-poor households, on the other hand initiatives intended to achieve this might also generate a state of frustration, as vulnerable consumers are less likely to be able to act on the information provided to cut their bills. EAs need to take into consideration factors such as available income, property type and quality, heating fuel, and tenure, as they can restrict the options for saving energy, and adapt the content of their advice to the consumer's situation. Tailored advice could indeed bring peace of mind for many vulnerable consumers, by providing reassurance, reducing the feeling of isolation or giving them access to targeted support (O'Connor and Johnston, 2014).

Challenges and results. Overall, most of the projects claimed to have achieved encouraging results (Table 5). Unfortunately, it is not possible to provide a comparative analysis to see what worked best to achieve behavioural change. The projects used different methodologies to estimate results and, in some cases, they reported only the financial savings resulting from the project interventions. In any case, even if the projects had used a standardised methodology, the results would still be hard to compare, as a household's response to energy advice is highly individual and dependent on a range of factors, including the consumer's own particular life circumstances, level of vulnerability and understanding of the advice received.

It might therefore be more useful to look at qualitative results than quantitative results, at the challenges that the projects had to face and at how they addressed them. A challenge reported by all the project outputs is initial difficulty in recruiting and engaging vulnerable consumers. This difficulty is attributable to several factors, such as vulnerable consumers' uneasiness about acknowledging their disadvantages and their low motivation owing to the limited possibilities for reducing their energy consumption and lowering their energy bills. The projects tried different strategies to improve engagement, and what seemed to work best was collaboration with trusted interlocutors, be they local social institutions, charity organisations or peer EAs. In projects implemented in social housing complexes in particular (e.g. TRIME), using peer tenants as EAs helped to improve local relations and help tenants feel more socially empowered. Another successful approach proved to be implementing community engagement strategies (e.g. neighbourhood events, social competitions and community rewards), which helped in involving harder-to-reach consumers by adopting a more participatory approach and in building a sense of community and of shared values and goals (Mengolini et al., 2016).

Table 5. Behavioural change project results

Project name	Quantitative results
ISEES	No quantitative results available. The project report's conclusions, however, find that the energy-saving potential associated with changes in user behaviour is limited for non-refurbished residential buildings
Energy Ambassadors	Estimated 4.5 GWh energy savings (over the whole project, 1 800 households, 51 % heat and 49 % electricity)
EC-LINC	Estimated average electricity savings of 284.81 kWh per household per year (PHPY) and 290 MWh over the whole project. Estimated heating energy savings of 1 021 kWh PHPY and 1 040 MWh over the whole project
Achieve	Estimated average savings of EUR 150 and 320 kg of CO_2 PHPY
REACH	Estimated average savings of 768 toe of energy (over the whole project, 1 600 households); average 10 % reduction in energy use
TRIME	Estimated average energy saving: 62 kWh of electricity and 116 m^3 of gas PHPY
Fiesta	Estimates of energy savings do not give separate values for interventions carried out in social housing units
Smart-Up	Final report still in progress
Assist2gether	Project still in progress

Another challenge reported in several project outputs was the lack of financial resources on the part of project participants to put some of the energy advice into action. In many cases, the most effective way to achieve meaningful electricity savings is to replace old electrical appliances with new and more efficient ones. Energy-poor households, however, often lack the means to buy new appliances and do not consider it useful to replace them when the old ones still work well (e.g. ISEES, Energy Ambassadors, EC-LINC).

Future research. Investigating new and innovative ways to provide energy-poor households with energy efficient appliances could be a topic for future pilot projects. Inspiration for possible initiatives can be drawn from social innovation experiences at national level. In Belgium, for example, the project Apparaat op maat, developed by the charity Samenlevingsopbouw, set up a system to rent energy efficient appliances to people who cannot afford to buy new ones. The system offers people suffering from energy poverty the possibility to replace their old appliances and save on their energy bills. Future research and innovation projects could also further test the set-up of targeted collective purchasing schemes to buy energy efficient solutions ([21]) and renewable technologies, thus helping vulnerable consumers to reduce their energy costs by getting a group deal.

Social innovation initiatives also provide inspiration for ways of financing energy awareness and advice projects at national/local level. An interesting example is provided by the project Énergie Solidaire, developed by the French charity Les amis d'enercoop. The project funds a variety of interventions (e.g. energy audits, help with completing applications for support measures, help with

([21]) Fiesta tried to set up local consumer purchasing groups as instruments to increase household investments in energy efficiency solutions, particularly high-efficiency heating and cooling devices. However, owing to different local contexts and to the lack of national pioneering experiences on the issues, a unique classic transnational consumer purchasing group model was hard to define.

minor refurbishment measures) through a solidarity fund. The fund raises money from micro-donations by consumers on their energy bills and from donations of excess renewable energy by renewable energy producers and individual prosumers. EU funds could help in investigating the effectiveness of innovative grassroots initiatives aimed at tackling energy poverty and in assessing their replicability and scalability potential.

Summary

Behavioural change projects provide low-income and vulnerable consumers with information and tailored advice to encourage behavioural change and help them reduce their energy consumption and bills. This project category attracted participation from the highest number of countries (24). The projects surveyed had 82 participations, with the majority of partners coming from Italy and Spain.

The alleviation of energy poverty is a primary objective of these projects. The main tool used to induce behavioural change and reduce energy consumption is the figure of the energy adviser or ambassador, that is, an intermediary trained to provide tailored energy advice during home visits.

Overall, most of the projects claimed to have achieved encouraging results; however, the results estimates were difficult to assess and compare.

One of the challenges most commonly reported in the project outputs is initial difficulty in recruiting and engaging vulnerable consumers, mainly because of their uneasiness about acknowledging their disadvantages and owing to the limited possibilities for reducing their energy consumption and lowering their energy bills. The strategy that seemed to work best to improve engagement was collaboration with trusted interlocutors. Another successful approach proved to be implementing community engagement strategies. These strategies helped in involving harder-to-reach consumers by adopting a more participatory approach and in building a sense of community and of shared values and goals.

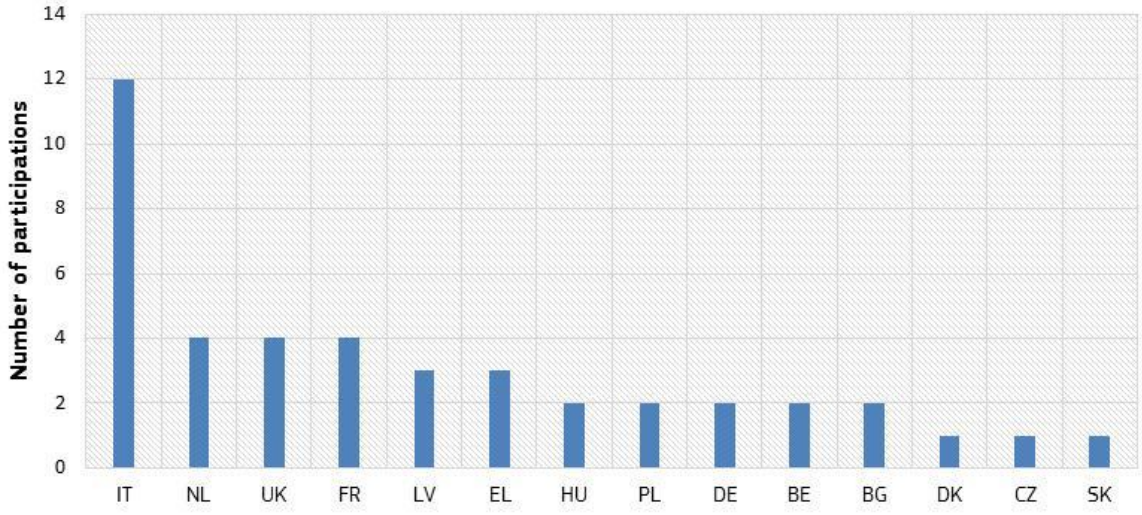
Another challenge reported in several project outputs was the lack of financial resources on the part of project participants to put some of the energy advice into action, especially as regards replacing old electrical appliances.

Future pilot projects could investigate new and innovative ways of overcoming the lack of the financial resources needed to act on the energy advice received, such as efficient-appliance rental schemes or targeted collective purchasing schemes.

3.3. Financing projects

Projects in this category aim to address the legal and financial barriers to energy retrofit of low-income and social housing, and to identify and test innovative financing solutions for energy efficiency investment. The projects had 43 participations and covered 14 countries, with the majority of partners coming from Italy (12 participations). Consortia ranged from 4 partners to 12 partners, with an average of 7 (Figure 17).

Figure 17. Number of participations in financing projects per country



The financing projects are presented in Table 6.

Table 6. Financing projects surveyed

Project name	Project duration	Countries involved
InoFin	Jan 2006-Dec 2008	BG, CZ, DE, DK, LV, NL, PL, SK
Ecolish	Dec 2006-Nov 2009	BE, EL, HU, LV, NL
FINSH	Dec 2007-May 2010	DE, FR, PL, UK
FRESH	Jun 2009-May 2012	BG, FR, IT, UK
EnerSHIFT	Feb 2016-Jan 2019	IT
LEMON	Feb 2016-May 2018	IT

Four projects — InoFin, Ecolish, FINSH and FRESH — were funded by the IEE programme between 2006 and 2009 ([22]), while the more recent projects — LEMON and EnerSHIFT — were funded by H2020 ([23]). They all aimed to increase energy efficiency in social housing, in some cases explicitly as a means to address energy poverty (e.g. Ecolish, FINSH, FRESH).

Poorly energy efficient homes are a major factor influencing energy costs and one of the root causes of energy poverty. Energy efficiency measures focusing on building retrofit offer an important opportunity to reduce household energy consumption and improve affordability and are therefore a key tool for tackling energy poverty in the longer term.

Targeting of such measures is still a topic under debate in many Member States; this goes hand in hand with discussions about the definition of energy-poor households. In several Member States (e.g. Denmark, France, the Netherlands and the United Kingdom), retrofit efforts have concentrated on improving energy efficiency in the social housing sector (Pye and Dobbins, 2015). This approach allows for a reduced targeting effort, as social housing accommodates a higher share of vulnerable

([22]) In the funding period 2003-2006, the work programme for IEE identified 'Retrofitting of social housing' as one of the key actions focusing on energy efficiency in buildings and industry. For this key action, 'social housing' was defined as single or multi-family houses built to provide affordable dwellings for low-income people.

([23]) EnerSHIFT and LEMON were funded under H2020 EE-20-2015, 'Project development assistance (PDA) for innovative bankable and aggregated sustainable energy investment schemes and projects'. PDA is a process supporting the preparation of and mobilisation of financing for bankable, sustainable energy projects, and which covers the costs of the technical support necessary to prepare, implement and finance the investment programme.

and lower-income households. It also allows for economies of scale that can be generated on large social housing estates and that can help to reduce overall construction costs. The availability of this option depends, however, on the size of the social housing segment in the country in question.

Despite the clear benefits that social housing retrofit initiatives can produce in terms of energy poverty alleviation, their implementation in the EU is still quite limited. Financial barriers represent one of the main obstacles to their implementation, as energy efficiency upgrades require high up-front costs and social housing organisations typically lack the financial means to implement them. In addition, housing associations cannot usually recover the costs of the investment, owing to the so-called split incentive dilemma ([24]). Furthermore, in many Member States, housing associations cannot recover retrofit costs by raising rents to balance their investments in energy savings, nor can they charge an additional fee for energy efficiency, even if the overall bill has been lowered after refurbishment (Milin et al., 2012) ([25]).

Financial institutions are often sceptical about financing energy retrofit measures in social housing, which are perceived as high-risk investments. Energy savings are not usually considered tangible by financial institutions, in particular because of the uncertainty about the actual savings, which may sometimes not be achieved owing to a range of circumstances, such as inappropriate design, implementation and/or operation of the building (Milin et al., 2012) or the post-retrofit consumption behaviour of the residents. As a result, public funds remain the main source of financing for energy retrofit initiatives in social housing. In the current climate of resource constraints, however, traditional public incentive mechanisms (e.g. grants, tax rebates, subsidised loans) are not sufficient to mobilise the amount of investment required at European level. Alternative financing mechanisms are needed to support sustained large-scale retrofit operations.

In this context, the projects surveyed provided an overview of the main existing financial instruments in Europe (see Box 4). They investigated the design and implementation of innovative financial solutions tailored for energy efficiency investment in social housing. They also investigated the social, legal and regulatory barriers to investment and put forward recommendations for different categories of stakeholders.

The most investigated financial solution (Ecolish, FRESH, LEMON and EnerSHIFT) was energy performance contracting (EPC), an innovative mechanism that makes it possible to fund energy upgrades from cost reductions. EPC has already been widely used for energy renovations in the residential, commercial and public sectors, but its implementation in the social housing sector continues to face scepticism and reluctance. The projects surveyed demonstrated its fruitful applicability to this sector and provided guidance on how to tackle the main barriers to its implementation.

([24]) Split incentives arise if the actor who invests in energy efficiency measures is not the same as the actor who reaps the subsequent financial benefits (Castellazzi, et al., 2017).

([25]) France provides an interesting example of cost recoupment. In 2009, a law was passed ('loi Molle') which allows social housing companies to recoup energy savings from tenants when they invest in the energy retrofit of the building, thus overcoming the split incentive. Through this mechanism, 50 % of the energy cost savings generated by the investments are invoiced to the tenant through what is called a 'third line of invoice' (on top of the rent and usual rental charges). This third line can be charged for 15 years but remains a fixed amount even if energy cost savings tend to increase over time (European Commission, 2016).

Box 4. Main financial solutions as identified by the projects surveyed

Public grants/subsidies. Public grant/subsidy programmes are used in many Member States to help overcome the financial barriers hindering the implementation of energy efficient retrofit projects. Although they represent an important tool to create economic stimulus for energy renovation projects, they are unlikely to form a major driver for large-scale investments, especially where fiscal budgets are limited (Economidou and Bertoldi, 2014).

Revolving funds. Revolving funds are self-sustaining financing schemes requiring a one-time initial investment that is replenished through savings from the energy retrofit projects funded.

Subsidised loans. Loan schemes for energy retrofit of social housing provide liquidity and direct access to capital while setting more generous repayment conditions than conventional bank loans (typically low or even zero interest rates).

Loan guarantees. These consist in a government offering a bank a guarantee to facilitate access to loans for energy retrofit projects.

Tax incentives. These reduce the tax paid by consumers or companies that undertake energy efficiency investments. They can take the form of accelerated depreciation for commercial companies, income tax credits or deductions for households or companies, and VAT reduction for consumers (Economidou and Bertoldi, 2014).

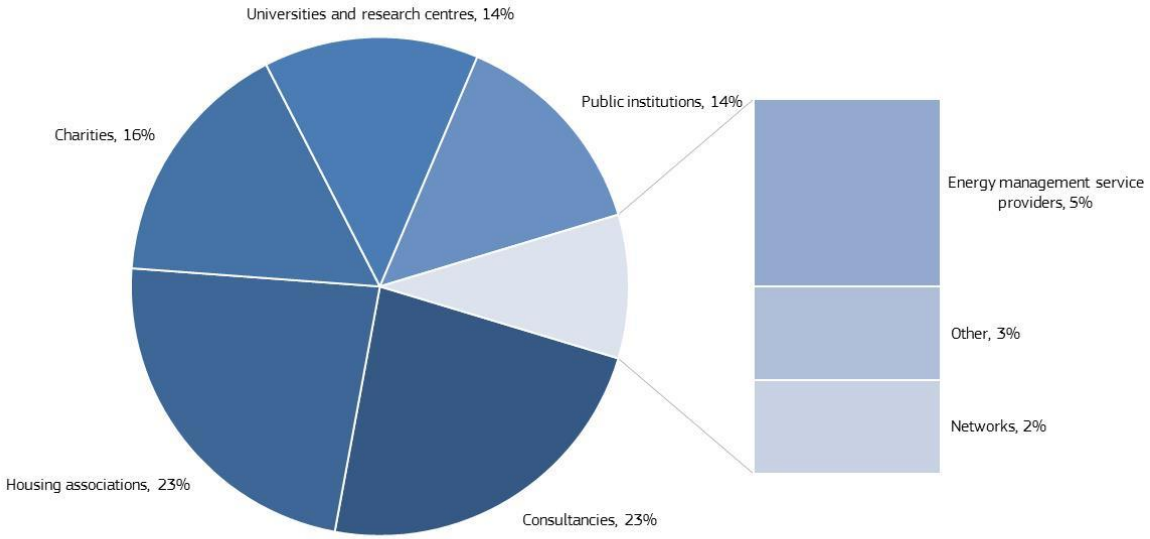
Energy efficiency obligation schemes. EEOS are schemes set up under Article 7 of the EU energy efficiency directive that require energy companies to achieve yearly energy savings in terms of annual sales to final consumers. To meet their targets, energy companies deliver or procure energy efficiency improvements in the premises of end-use customers.

Energy performance contracting. An energy performance contract is a contractual arrangement between the beneficiary and the provider (normally an ESCO) of an energy efficiency improvement project, where upfront investment costs are repaid through the energy cost savings generated by the project, in relation to a contractually agreed level of energy efficiency improvement. The contracts are designed so that the value of the energy savings is split between the beneficiary and the provider throughout the contract term (Economidou and Bertoldi, 2014). There are two main schemes for EPC, one involving 'shared savings' — where the cost savings are split for a predetermined period of time in accordance with a prearranged percentage — and the other involving 'guaranteed savings', where the ESCO guarantees a certain level of energy savings and shields the client from any performance risk. EPC helps to trigger private investments with a relatively small contribution from the public budget, typically in the form of a loan or a grant. The combination of different financing sources is, however, necessary to ensure the sustainability of most energy retrofit projects, with public funding usually backing capital-intensive measures with a longer payback time.

European Union funding. The EU supports energy efficiency renovation initiatives through various funds. Relevant programmes include ESIF, the European Fund for Strategic Investments, the ERDF, the Cohesion Fund, ELENA, Jessica and Joint Assistance to Support Projects in European Regions.

Stakeholders. Projects in the database saw the collaboration of a range of stakeholders (Figure 18), in particular housing associations (23 %), charities (16 %) and public institutions (14 %). An interesting role was also played by energy management service providers (5 %).

Figure 18. Stakeholders involved in financing projects



All the projects highlighted the need to adopt a multi-partner approach involving a wide range of stakeholders, including local authorities, housing and tenants' associations, energy suppliers and financial institutions. Their close collaboration throughout the project is of outmost importance for the success of the initiative.

Successful energy retrofit projects bring about a wide range of energy and non-energy benefits for all stakeholders involved. For public institutions, municipalities in particular, energy retrofit operations in social housing complexes are a key tool for addressing energy poverty and improving the quality of life and the economic resilience of the tenants, resulting in greater social inclusion and improved well-being for citizens. For those municipalities that have signed the Covenant of Mayors, such projects can also be adopted as energy-saving actions in their sustainable energy and climate action plans. The involvement of public institutions in energy renovation initiatives can contribute to the financial viability of the projects through the provision of complementary financial resources, such as revolving funds, grants, subsidies or loan guarantees. Their involvement can also help in the implementation of larger-scale projects, where economies of scale can help to reduce overall construction costs.

For housing associations, energy retrofit projects represent an opportunity to extend the lifetime of their buildings, resulting in a longer period of rent collection. They also improve the quality and environmental performance of the building stock, thus contributing to lower maintenance costs. Major energy efficiency enhancements (e.g. insulation, installation of high-efficiency glazing and replacement of boilers) lead to improved comfort and often also to a significant reduction in energy costs for tenants. Reducing tenants' energy bills is a way for housing associations to improve their financial situation, thus limiting the amount of unpaid rents and vacancy. In countries where the social housing sector is privatised, energy retrofit operations that lead to better housing quality (i.e.

healthy, comfortable houses with low energy bills) can also provide housing associations with a competitive advantage (Op 't Veld, 2009). Finally, by implementing retrofit projects, housing associations can gain an insight into their buildings' energy consumption and costs. This information can be used for other building complexes where the housing association plans to implement further energy-saving measures.

Charities play an important role in helping to organise the residents and engage them during all stages of the energy renovation works. Using their knowledge of the local and social environment, charities can help to include the residents' practices, behaviours, motivations and aspirations in the retrofit process. This can help to ensure the project's success, both in terms of residents' engagement with the retrofit initiative and in terms of actual energy-saving outcomes (Gram-Hanssen, 2014).

Finally, energy management service providers, ESCOs in particular, are a key partner in energy retrofit projects, especially those involving EPC. They can provide turn-key services, from the initial energy audit through long-term monitoring and verification of project savings. An ESCO's involvement in the project reduces the risks of the retrofit operation, as the ESCO takes on the risk of not achieving the prescribed savings. ESCOs' participation provides social housing associations with the technical, legal and financial competences needed to promote the implementation of successful energy retrofit projects in social housing.

Innovative approach. The innovativeness of the projects in this category lies in the type of buildings targeted by the actions funded. While the EU has funded a large variety of projects aiming to remove the financial barriers to energy retrofit of existing buildings in the public, commercial and residential sectors ([26]), the projects in this category focus on a very specific group of buildings, namely social housing complexes, with all their peculiarities and specificities.

Social housing is characterised by a diversity of national housing contexts, conceptions and policies that influence the applicability of most financial solutions. The projects surveyed addressed general and country-specific barriers to energy retrofit of social housing, identifying tailored financial solutions that could be replicated and scaled up at national level in all participating countries. EPC was the most investigated solution, with some 'first of its kind' contracts signed in various countries.

Challenges and results. For projects in this category, quantitative results in terms of energy savings achieved are not available. However, the projects achieved important results, contributing to the body of knowledge on energy retrofit of social housing and helping clear the way for the use of innovative financing solutions in this sector. They supported the implementation of real-life energy retrofit projects in several pilot sites ([27]), created a methodology for implementing EPCs in social housing, designed standard documents and contract templates, and issued recommendations for implementing successful retrofit operations and for their replication and scaling up. They also

([26]) Among others: CERtuS — cost efficient options and financing mechanisms for nearly zero energy renovation of existing buildings stock (2014-2016); InfiniteSolutions — financing energy transition in cities (2014-2015); Stepping — supporting the EPC public procurement in going-beyond (2016-2019); GuarantEE — energy efficiency with performance guarantees in private and public sector (2016-2019); Enerinvest — Spanish sustainable energy financing platform (2016-2019); BuildInterest — improving the attractiveness of investments in energy efficiency and sustainability in buildings (2016-2018); Sefipa — Sustainable energy financing platform in Austria (2016-2019); Trust EPC South — financing energy efficiency contracting in the tertiary sector (2015-2018); Finerpol — Financial instruments for energy renovation policies (2016-2018).

([27]) Projects with an implementation site set ambitious objectives. FRESH — minimum 35 % energy savings; LEMON — minimum 40 % energy savings; EnerSHIFT — minimum 53 % energy costs savings.

highlighted the importance of putting residents centre stage and involving them in all phases of the retrofit operation.

Engaging residents is indeed the main social challenge identified by the projects. As reported by Donkelaar et al. (2006), Op 't Veld (2009) and Milin et al. (2012), many residents, especially the older ones, are sceptical about new technologies (e.g. central heating boilers and solar collectors), question their technical validity and ease of use, are concerned about nuisance, and fear not being able to access their apartment during the refurbishment works. The projects surveyed addressed these issues in the planning phase through comprehensive strategies aimed at reducing tenants' discomfort and engaging them in the whole process, for example through information campaigns, regular meetings with tenants and involving tenants' unions in stakeholders' committee meetings.

The low level of energy awareness and limited interest in energy efficiency opportunities are also important issues that need to be tackled in the very early stages of the retrofit process through a tailored engagement strategy. Supporting residents' awareness and participation, and building confidence and trust, help in achieving the predicted savings, thus effectively contributing to the alleviation of energy poverty. Experiences gained in a variety of energy retrofit projects in the United Kingdom show that projected energy savings may not be achieved because of behavioural factors that mean social housing residents either do not adopt sustainable retrofit or, if they do, do not use the improvements effectively (Swan et al., 2013). In addition, the analysis of the projects highlighted that the renovation of a building was often not enough to reduce residents' energy consumption, as savings strongly depended on the occupants' behaviour and might not meet expectations (Op 't Veld, 2009).

In projects financed through EPC in particular, the uncertainty about actual savings represents a major barrier to investment and has a strong influence on risk allocation with regard to energy savings and on the related technical and financial arrangements. Given the uncertainties linked to tenants' behaviour, the costs associated with the energy performance guarantee usually increase accordingly (Milin et al., 2012). In addition, the ESCO is likely to focus on lower-cost measures with easy-to-predict savings in order to reduce its risk, without proposing solutions that provide greater savings but at a significantly higher cost (Milin et al., 2012).

A lower-than-expected reduction in energy consumption may be partly due to the so-called rebound effect that happens when, following an energy efficiency improvement that has made energy services cheaper, consumption of those services increases. In retrofit operations financed through EPC, such behaviour could be further encouraged by the fact that the extra consumption is to be paid for by the ESCO. If the emergence of the rebound effect is normally considered an unwanted consequence, in social housing complexes with a high number of energy-poor tenants, its occurrence may actually indicate that the households concerned have decided to reinvest part of the savings in greater comfort. In this sense, the rebound effect might be seen as a way of mitigating energy poverty (Galvin and Sunikka-Blank, 2016; Pollitt et al., 2017). When this is not the case and the increase in consumption after refurbishment is not the result of an abnormally low pre-retrofit level of spending on energy services, measures should be adopted to limit the rebound effect and its impact of on the ESCO's liability.

An interesting example of such measures is presented by the FRESH project, where the occurrence of the rebound effect was limited by the adoption of various strategies. At the French pilot site in Schiltigheim, tenants payed for their actual consumption even in the event of over-consumption.

Penalties for the ESCO were triggered only if the total consumption of all dwellings was above the target, so that over-consumption could be offset by under-consumption by other tenants. Penalties paid by the ESCO to the housing association in the event of global over-consumption were redistributed equally among all tenants, creating a system where the tenant who over-consumes receives back only a fraction of his extra consumption through the redistribution of penalties (Milin et al., 2012).

Over-consumption can also be reduced through post-retrofit training in energy use behaviour and targeted advice, which can help to realise the full benefits of the structural and technical improvements. The projects surveyed adopted different strategies to increase tenants' energy awareness and engagement with the retrofit initiative, including manuals and training courses on energy management in dwellings (e.g. LEMON), stakeholders' committee meetings including tenants' unions (FRESH), meetings, and events and other awareness-raising activities with tenants (FRESH, EnerSHIFT, Ecolish). In some cases, these actions were subcontracted to local associations, which helped in gaining vulnerable consumers' trust.

Future research. As suggested by one of the project outputs (Milin et al., 2012), energy retrofit initiatives in social housing could benefit from further research on behavioural approaches to EPC in the social housing sector. New pilot projects could also investigate innovative approaches to dealing with the rebound effect without penalising energy-poor tenants who increase their consumption to cover their basic energy needs. A variety of tools to increase tenants' energy awareness have already been piloted in social housing complexes (e.g. improved energy consumption monitoring, targeted energy advice, leveraging community dynamics) but need to be adapted to the specificities of an EPC retrofit.

Inspiration for further research can also be drawn from social innovation initiatives implemented in EU Member States. An interesting idea to finance energy retrofit initiatives in individual and owner-occupied houses comes from the project Tiers-payant rénovation ([28]), run by the French organisation CAMEL (Collectif pour l'amélioration énergétique du logement). The project idea starts from the assumption that the deferred payment of subsidies for energy renovation works from public institutions constitutes a major obstacle to the implementation of energy retrofits in households with limited financial resources. Lack of capital and lack of credit often prevent energy-poor consumers from taking advantage of low-income energy efficiency programmes. The project therefore aims to create a solidarity fund to prefinance renovation works, thus encouraging the uptake of energy efficiency improvements.

Summary

Financing projects address the legal and financial barriers to energy retrofit of low-income and social housing and test innovative financing solutions for energy efficiency investment. The projects had 43 participations and covered 14 countries, with the majority of partners coming from Italy.

The main objective of the projects is to increase energy efficiency in social housing, in some cases explicitly as a means to address energy poverty.

The analysis of the projects highlighted that the renovation of a building was often not enough to reduce residents' energy consumption, as savings strongly depended on the occupants' behaviour and might not meet expectations. In projects financed through EPC in particular, the uncertainty about actual savings

([28]) http://camel-habitat-energie.e-monsite.com/pages/tiers-payant-renovation/tiers.html

represents a major barrier to investment and has a strong influence on risk allocation with regard to energy savings and on the related technical and financial arrangements.

The main social challenge is engaging the residents in the refurbishment works. Many low-income and vulnerable consumers are sceptical about new technologies, question their technical validity and ease of use, and are concerned about nuisance and restricted access to their apartments. The low level of energy awareness and limited interest in energy efficiency opportunities are also important issues that need to be tackled in the very early stages of the retrofit process through a tailored engagement strategy.

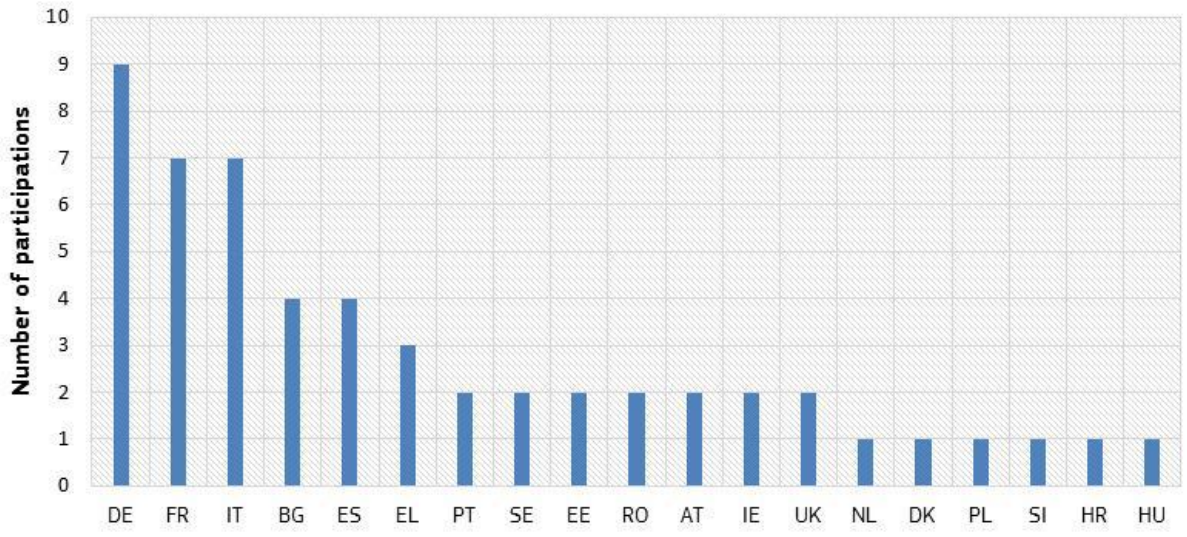
Post-retrofit training in energy use behaviour and targeted advice can help to realise the full benefits of the structural and technical improvements.

Energy retrofit initiatives in social housing could benefit from further research on behavioural approaches to EPC in the social housing sector. New pilot projects could investigate innovative approaches to dealing with the rebound effect without penalising energy-poor tenants who increase their consumption to cover their basic energy needs.

3.4. Sharing best practices projects

The projects in this category aim to identify and promote tailored solutions to address the technological, social and financial barriers hindering energy retrofit of social housing in Europe. The projects cover 19 European countries, with the majority of partners coming from Germany (9), France (7) and Italy (7). Consortia vary from 7 partners to 12 partners, with an average of 9 (Figure 19).

Figure 19. Number of participations in sharing of best practices projects per country



The projects included in this category are presented in Table 7.

Table 7. Sharing of best practices projects surveyed

Project name	Project duration	Countries involved
Nirsepes	Jan 2006-Dec 2007	DE, EL, ES, IT
ROSH	Jan 2006-Jun 2008	AT, BG, DE, IE, IT, PL
SHARE	Jan 2006-Jun 2008	BG, DE, EE, FR, IE, SE, SI, UK
Tackobst	Jan 2007-Dec 2008	BG, DE, FR, IT
CASH	Nov 2009-Jan 2013	BG, DE, DK, EL, FR, HU, IT, NL, UK
Social Green	Apr 2016-Sep 2020	EE, ES, HR, PT, RO, SE

Four projects were funded by the IEE programme ([29]) (SHARE, ROSH, Nirsepes and Tackobst) with the aim of improving the body of knowledge on social housing retrofit, thus supporting the uptake, implementation and replication of successful solutions tailored to this sector. The project CASH was funded by the Urbact programme ([30]), while the project Social Green was funded by the Interreg Europe programme ([31]).

Most projects in this category considered energy retrofit of social housing a means to increase the energy efficiency of the European social housing stock and to contribute to the European strategy to mitigate climate change. The alleviation of energy poverty was considered an additional societal benefit of the retrofit operations, resulting in lower energy bills and increased thermal comfort for social housing residents. Only some projects (SHARE, CASH and Social Green) explicitly includes the alleviation of energy poverty among their objectives.

The projects adopted an integrated approach that combines information, training and communication activities tailored to a variety of stakeholders, including public institutions, housing associations, social housing residents, energy providers, building and services contractors, and a variety of specialists working within the sector. These knowledge-sharing and capacity-building activities aim to disseminate best practices and raise awareness to stimulate the market and increase the rate of social housing retrofit.

The main tools used by the projects to engage the different stakeholders were local stakeholder forums that periodically met to discuss the possibilities with regard to energy-efficient retrofit of social housing. The engagement of social housing residents in particular was considered a pivotal element in all the projects to ensure the success of the retrofit initiative. Residents should be involved from the planning phase and during all stages of the renovation process for the co-conception of energy efficient renovation to ensure their engagement and the proper functioning of the renovated buildings (Moreau and Dictus, 2013). Forums were also used as an opportunity to increase the energy awareness of tenants, involving them in training sessions on topics they

([29]) The IEE programme funded many other projects dedicated to promoting the sharing of knowledge and best practices to support the energy retrofit of social housing (e.g. Power House Nearly Zero Energy Challenge, Transition Zero). These other projects were, however, not included in the project list because their main focus was on improving the energy efficiency of the social housing stock, with limited attention to energy poverty considerations.

([30]) The Urbact programme is the European territorial cooperation programme aiming to foster sustainable integrated urban development in cities across Europe. It is an instrument of the cohesion policy, co-financed by the ERDF, the 28 Member States, Norway and Switzerland. Urbact's mission is to enable cities to work together and develop integrated solutions to common urban challenges, by networking, learning from one another's experiences, drawing lessons and identifying good practices to improve urban policies.

([31]) The Interreg Europe programme provides funding for interregional cooperation to help regional and local governments across Europe to develop and deliver better policy. It is implemented under the EU's territorial cooperation objective and financed through the ERDF.

typically have problems with, including understanding energy bills, efficient use of electrical appliances, lighting, heating and hot water controls, and support with grants and assistance (e.g. SHARE). To further increase awareness and support residents' participation, some projects (e.g. Tackobst) highlighted the need to organise community-based training. The dissemination of the results from successfully renovated pilot buildings was also identified as an effective strategy.

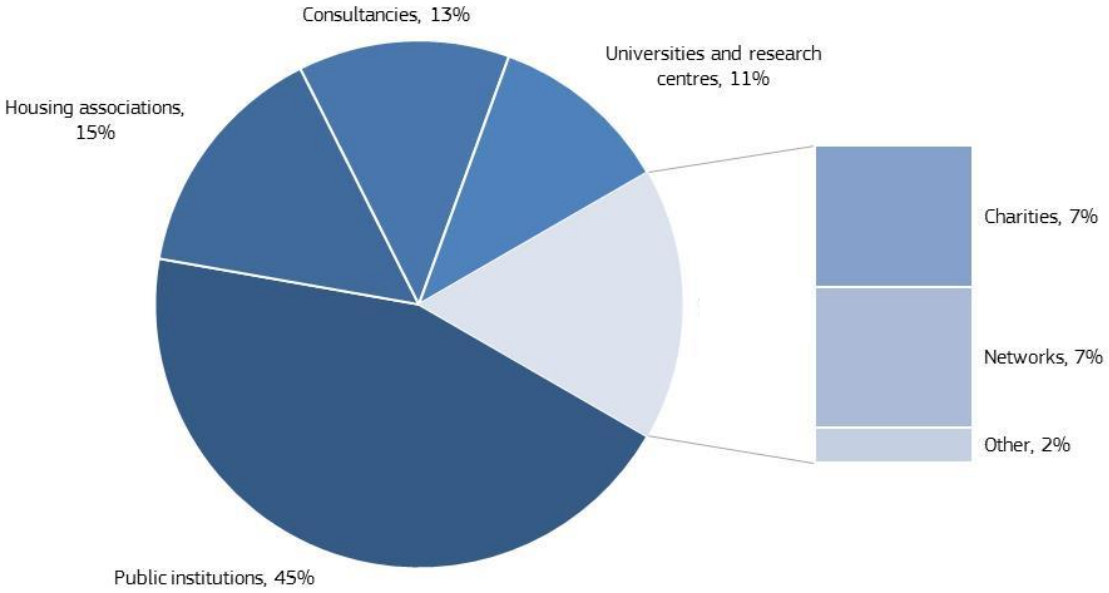
Another important tool used in the projects to disseminate best practices was the production and dissemination of guidebooks aimed at various stakeholders. Inventories of retrofit technologies and solutions, manuals on innovative financial schemes and guides on the legal framework for energy efficient renovations were produced by all the projects and disseminated among regional and local authorities, housing associations, and building and services specialists working in the retrofit sector.

Stakeholders. Public institutions, mainly municipalities and energy agencies, are the main stakeholders in this project category (45 %) (Figure 20).

Their participation in this group of projects testifies to their interest in overcoming the barriers that slow down the uptake of retrofit initiatives in the social housing sector. Retrofit initiatives in social housing are increasingly seen as a significant tool for contributing to several public policies, including the alleviation of energy poverty. In some EU countries, municipalities are directly involved, as they own part of the social housing stock, either directly or through companies in municipal ownership ([32]). Even when the ownership of the social housing stock belongs to housing associations, the sector is usually heavily regulated by national and local regulations. Municipalities often lack the experience, competence and resources to implement or support large retrofit operations of the social housing stock. The projects surveyed offered the opportunity to learn from other partners, getting useful advice from those who had already successfully dealt with a common challenge. Experiences gained by other initiatives provided municipalities with useful inspiration for adapting solutions successfully introduced elsewhere to the peculiarities of the local context, with its own set of rules and regulations.

([32]) Municipalities and housing associations are the typical types of owners of social rented housing in Europe. In some countries, such as Denmark, all the social stock is owned by housing associations; in others, such as Czechia, all social housing is municipal. Most countries have a mix, although the relative proportions of each type of ownership vary widely, partly for historical reasons (Scanlon et al., 2015).

Figure 20. Stakeholders involved in sharing of best practices projects



Housing associations (15 %) also benefited from increased knowledge sharing. Managers in social housing have many issues to cope with other than energy, such as anti-social behaviour, property issues and funding issues. Even when they are keen to do something about energy saving, they struggle to prioritise this area in the current climate of resource constraints. The forums promoted by the projects surveyed allowed social housing managers to share information, catch up with the latest technological updates, discuss problems, and reduce the risk and costs of procurement. The guidebooks also provided up-to-date information on best practices and case study experiences, technical reviews and practical recommendations.

Innovative approach. The innovativeness of the projects in this category lies in the ambition of bringing together several stakeholders, including social housing residents, to discuss improving the energy efficiency of social housing. Including different perspectives, meeting and discussing different options for the energy retrofit of the building, help to ensure the commitment and the engagement of all stakeholders during and after the renovation works.

Challenges and results. The main aim of the projects in this category was the development of an integrated strategy for the energy retrofit of social housing complexes, while the analysis of the social, environmental or monetary impact of the action adopted was not included in the project objectives. Only one project (i.e. ROSH), reported the quantitative results achieved in the demonstration projects supported by the strategy developed ([33]). In some cases (e.g. SHARE), the measure of the success of the project was the householders' and forum members' evaluation of the project. The positive feedback from the householders revealed the perception that the information provided was of consequence to their daily lives (Jensen et al., 2018).

During the implementation of the projects, common challenges for the success of energy retrofit projects in social housing were identified and knowledge about possible solutions disseminated.' Several project outputs reported residents' engagement as one of the main challenges (e.g. SHARE,

([33]) The demonstration projects implemented various technical solutions and achieved savings in energy consumption for space heating and domestic hot water (kWh/m^2/yr) ranging from 90 % to 18 %.

ROSH, CASH, Tackobst). The implementers of the project SHARE reported a lack of shared understanding between the project initiators and the householders and difficulty in keeping the focus of the forums on energy issues. The implementers reported that trying to focus specifically on energy in social housing presents a challenge, as people have lots of other issues in their lives that they need to deal with, and energy is not often a priority (Jensen et al., 2018). They also emphasised the need to adopt a more holistic approach to energy use that, besides environmental and economic concerns, also includes issues such as comfort, health and well-being (Jensen et al., 2018). The research carried out as part of the project ROSH highlighted a low level of awareness and knowledge about the proper use of heating, ventilation and electricity (particularly among less educated and migrant residents) and the need to provide tailored awareness raising and education and to stimulate active and informed involvement in retrofit operations.

As emphasised by the report on the project CASH, the development and implementation of a residents' engagement strategy is often hindered by a lack of appropriate funding for engagement activities and by the reluctance of major stakeholders (social landlords and designers) who fear that resident engagement will represent more work (Moreau and Dictus, 2013). Ensuring a dedicated budget for tenants' participation will help to increase acceptance and engagement and ensure the success of the retrofit operation.

Several projects also addressed the financial barrier represented by split incentives and cost recoupment (e.g. CASH, Tackobst, Social Green), and outputs described several approaches to the problem, including tenants covering some share of the renovation cost through transfer of the investment to the rent. Interestingly, projects with a stronger focus on energy poverty (e.g. CASH, Social Green) emphasised the need to limit rent increases for low-income households (Moreau and Dictus, 2013) and warned that, in situations of high energy poverty, cost recoupment could mean that retrofit does not lead to a reduction in energy poverty (Nordregio, 2017).

Project outputs also highlighted the need for better coordination between different administration levels (e.g. Tackobst, Social Green). According to Nordregio (2017), national legislation, regulations and policy rarely address retrofit of social housing explicitly. This implies the existence of a 'policy deficit' that hinders the implementation of retrofit operations and requires the development of a national strategy to coordinate efforts and funding among local, regional and national public administrations (Nordregio, 2017).

Finally, projects brought out the need for updated, reliable and accessible information on retrofit technologies and solutions, including financial options, to help social housing managers decide which route to follow and which case studies to rely on. This information needs to be transparent about methodology and the robustness of the data, and should offer guidance on materials, costs and impacts (Provan and Brady, 2015).

Future research. As mentioned above, energy poverty is still a collateral aspect of most projects in this category. Other policy objectives, such as increasing energy efficiency and reducing CO_2 emissions, predominantly drive the initiatives developed by the project partners. In the future, the EU could support initiatives with a stronger focus on energy poverty and resident behaviour to provide all stakeholders involved with a clearer picture of the social dimension of energy retrofit operations in social housing complexes.

As suggested by other studies (Provan and Brady, 2015), social housing landlords would also benefit from an information and case study hub that they could use to share their experiences and advice. Such a tool would help them navigate the considerable amount of information available, keep up to date with the latest retrofit solutions, and identify what works well and what does not work. Such a platform would need to ensure the robustness of the data and the transparency of the methodologies used to evaluate the costs and benefits of the planned interventions ([34]).

Summary

Sharing of best practices projects aim to identify and promote tailored solutions to address the technological, social and financial barriers hindering energy retrofit of social housing in Europe. The projects covered 19 European countries, with the majority of partners coming from Germany (9), France (7) and Italy (7).

Most projects in this category considered energy retrofit of social housing a means to increase the energy efficiency of the European social housing stock and to contribute to the European strategy to mitigate climate change. The alleviation of energy poverty was considered an additional societal benefit of the retrofit operations, resulting in lower energy bills and increased thermal comfort for social housing residents. Only some projects explicitly included the alleviation of energy poverty among their primary objectives.

The projects surveyed adopted an integrated approach that combines information, training and communication activities, tailored to a variety of stakeholders, to stimulate the market and increase the rate of social housing retrofit.

Most project outputs reported residents' engagement as one of the main challenges for the development of energy retrofit projects in social housing. Ensuring a dedicated budget for tenants' participation would help to increase acceptance and engagement and ensure the success of the retrofit operation. Some project outputs also emphasised the need to limit rent increases for low-income households and warned that, in situations of high energy poverty, cost recoupment could mean that retrofit does not lead to a reduction in energy poverty.

Future pilot project could focus more on energy poverty and resident behaviour to provide all stakeholders involved with a clearer picture of the social dimension of energy retrofit operations in social housing complexes.

([34]) Very interesting work in this respect has already been carried out by the Power House Nearly Zero Energy Challenge initiative, co-funded by the IEE. Among other activities, the project developed the Hive, a user-friendly tool that helps to map, monitor and understand actual energy consumption under real-use conditions in buildings. Around 30 test cases of low-energy and nearly zero-energy buildings in different climate zones and types of tenure were monitored to determine their real energy performance and cost-optimality. More information is available on the project website (http://www.powerhouseeurope.eu/home/).

4. EU-wide studies

The EU has also funded a number of EU initiatives to deepen knowledge about energy poverty in the EU and to identify the measures adopted at national level to tackle it. In this chapter, we will mention the most relevant initiatives, highlighting their contribution to knowledge about energy poverty in the EU and trying to identify possible areas for further research. The initiatives surveyed are presented in Table 8.

Three initiatives — EPEE, Insight_E and EPOV — produced an overview of the situation in the EU to improve understanding of energy poverty and to support the sharing of best practices among Member States. Evaluate focused its research activities on post-Communist states in eastern and central Europe, while Engager focuses on multidisciplinary research to generate a step change in how energy poverty is theorised, detected and addressed.

All the initiatives surveyed share an understanding of energy poverty as a situation where a household is not able to secure a socially and materially necessitated level of energy services in the home. In over a decade, they produced a vast body of knowledge on energy poverty, its causes and consequences, and its prevalence in the EU, laying the theoretical foundations for the adoption of tailored policies and measures at EU and national levels.

Further research on this topic would, however, be beneficial to provide Member States with more practical knowledge to tackle energy poverty. Member States could benefit from guidance on how to operationalise concepts and how to design effective policies and measures to address energy poverty and vulnerability in their jurisdictions. The involvement of relevant national authorities in research consortia could help in this regard. In the initiatives surveyed, the organisations involved were mainly universities and research centres, consultancies and charities, with some of the organisations involved in different initiatives at the same time (e.g. the University of Manchester). Widening and diversifying the research partners could enrich the debate and add new perspectives, including from a geographical point of view.

As pointed out by Thomson et al. (2017), knowledge about energy poverty and related concepts is primarily centred on the United Kingdom and Ireland, which have a long tradition of academic scholarship, practice-based responses and policy frameworks to address the issue. Taking a closer look at experiences in other Member States, including at grassroots level, would help to cover additional needs and geographical areas and to identify best practices and out-of-the-box solutions. Further research could also look at the experiences gained outside the EU, where research and practice on energy poverty can offer inspiration for new approaches and solutions.

Table 8. EU-wide research initiatives

Initiative's name and duration	Objectives	Partners
EPEE — European fuel poverty and energy efficiency (2006-2009)	EPEE is an IEE project that aimed to increase knowledge and understanding of fuel poverty, to quantify the households in this situation and to devise some effective operational mechanisms to tackle it. It produced (i) an analysis of the fuel poverty situation in the partners' countries (BE, ES, FR, IT, UK); (ii) an analysis of the current policies to address fuel poverty and to identify best practices; and (iii) some recommendations to decision-makers on legal, economic and administrative aspects to contribute to a better understanding of fuel poverty at national and European levels	Alphéeis, Ademe, Cestec, CLER, CUNIC, Ecoserveis, NEA
Evaluate — energy vulnerability and urban transitions in Europe (2013-2018)	Evaluate is a project funded by the European Research Council that aimed to investigate the manner in which urban institutional structures, built tissues and everyday practices shape energy poverty at a variety of geographical scales. The project used an energy vulnerability framework to explore fuel poverty and domestic energy deprivation in Europe	University of Manchester, University of Gdansk, Charles University, Central European University, University of Skopje
Insight_E — policy report *Energy poverty and vulnerable consumers in the energy sector: analysis of policies and measures* (Oct 2014-Apr 2015)	Insight_E is an energy think-tank that was set up with the support of the EU's 7th framework programme to run an energy observatory and deliver publications on energy policy. Its policy report *Energy poverty and vulnerable consumers in the energy sector: analysis of policies and measures* assessed how Member States define the issue of energy poverty and vulnerable consumers, and the measures that have been implemented to address these issues	University College London, USTUTT, KicInnoEnergy, EIHP, E4SMA, University College Cork
EPOV — the EU Energy Poverty Observatory (2016-2019)	EPOV is an initiative by the European Commission to help Member States in their efforts to combat energy poverty. It aims to improve the measuring, monitoring and sharing of knowledge and best practices on energy poverty	University of Manchester, Ecofys, European Policy Centre, Intrasoft International, National Energy Action, Wuppertal Institut
Engager — European energy poverty: agenda co-creation and knowledge innovation (2017-2022)	Engager is a research network funded via the European COST scheme. It aims to develop and grow an international community of researchers and practitioners focused on combating energy poverty. Its core aim is to transform the extent and depth of scientific knowledge about energy poverty in Europe by establishing multidisciplinary collaborations at the nexus of several domains in which energy poverty has been treated separately to date	University of Manchester (Grant Holder Institution) and a variety of partners representing academia, business, NGOs and advocates for vulnerable households

5. Conclusions

General and topic-specific considerations have emerged from the review of projects carried out with the financial contribution of the EU.

Project numbers. Overall, time-trend data suggest that the growing attention attracted by energy poverty at policy level in recent years has not yet been reflected in the research and innovation initiatives carried out to date with EU financial support.

Project objectives. The projects surveyed show a lack of specific focus on the needs of vulnerable consumers and on the wider societal aspects of energy poverty. Many projects pursue multiple objectives, such as contributing to the EU energy and climate targets and to the alleviation of energy poverty. Such objectives complement each other but often compete for priority and resources. More projects with a clearer focus on energy poverty and vulnerable consumers would help to improve understanding of this phenomenon and to identify effective solutions to address it.

Geographical coverage. Project participation and investment are concentrated in a small number of countries. Several countries in central and eastern Europe had limited participation, despite the high prevalence of energy poverty in their jurisdictions. Future projects should try to cover more geographical areas and increase the participation of underrepresented countries. In addition, in most countries, organisations active in energy poverty projects are concentrated in a few areas, not always matching the areas most severely hit by energy poverty issues at national level. Promoting the participation of organisations based in areas with high rates of energy poverty would help to bring about more widespread uptake of good practices and the use of EU funds where they are most needed.

Targeting process. Most projects in the database (over 70 %) address consumers living in social housing. This approach makes it possible to target a large number of potential recipients in the same place and thus makes the interventions easier and less expensive to carry out. On the other hand, however, the uncritical application of this approach does not allow fine-grained identification of consumers in real need, as the social housing sector includes a wide variety of people — in terms of age, income and needs — and buildings. To increase the effectiveness of the targeting process, the real conditions of the residents should always be examined individually. Another downside of this approach lies in the uneven distribution of social housing in Europe. Social renting is particularly strong in countries such as Denmark, France, the Netherlands, Austria, Sweden and the United Kingdom, and quite limited in eastern Europe and the Mediterranean countries, where high levels of energy poverty are reported. Future EU-funded initiatives could contribute to the sharpening of the targeting approach by researching other identification criteria and application methods.

Stakeholder categories. Project consortia include stakeholders from various sectors, but several stakeholder categories participate only in a limited number of projects. Stakeholders such as ICT and telecom companies, energy management service providers, DSOs and utilities, and technology manufacturers can play an important role in designing solutions to address energy poverty, and their participation in future innovation projects should be encouraged. The participation of DSOs and utilities in particular, would help them to gain experience in achieving energy savings in the framework of national energy efficiency obligation schemes.

Availability of project outputs. After the closing of the project website, information can usually be found on EU online databases, but project deliverables are not always available. A dedicated repository of all the main documents, with easy-to-search functionalities for different stakeholder categories, would help to circulate and extend the reach of best practices and success stories.

Comparability of results. Quantitative results are not always available and, when they are, they are usually difficult to compare. Besides the differences in the sample population and local circumstances, projects often use different methodologies to estimate or measure the results. Better and standardised monitoring, evaluation and reporting would help to identify what works and what does not, to provide evidence of successful solutions and to promote scaling up and replication.

Project success indicators. For projects tackling energy poverty, results calculated in terms of energy or cost savings are not always a good measure of the success of the initiative. In local situations of high energy poverty, households can decide to reinvest part of their savings into greater comfort. In these cases, the unchanged or even higher energy consumption reported after the implementation of the project activities is a sign that the project was successful in mitigating energy poverty. Future research should investigate other indicators to measure initiatives' success, tailored to different segments of the population of vulnerable consumers' (e.g. greater comfort; health and well-being; market value added to the property).

Motivation and engagement. Vulnerable consumers' motivation and engagement are often reduced by the limited margins for reducing energy consumption and lowering their energy bills. Developing a consumer engagement strategy can help to ensure consumer participation and involvement during and after the project activities. Strategies focusing on supporting consumer awareness and participation, building confidence and trust, and promoting a sense of community should be mainstreamed into measures aimed at tackling energy poverty. The development and implementation of a consumer engagement strategy is often hindered by a lack of appropriate funding for engagement activities and by the reluctance of other stakeholders, who fear project delays and extra work. Ensuring a dedicated budget for consumer engagement activities will help future projects to develop a tailored strategy and to implement it from the very early stages of the project activities. Future research should also promote and demonstrate the use of different methodologies for consumer engagement, in particular those using co-designing solutions, building on vulnerable consumers' real needs and expectations.

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Abbreviations

CIP	competitiveness and innovation framework programme
DSO	distribution system operator
EA	energy adviser or ambassador
EEOS	energy efficiency obligation scheme(s)
EIB	European Investment Bank
ELENA	European Local Energy Assistance Fund
EPC	energy performance contracting
ERDF	European Regional Development Fund
ESCO	energy services company
ESIF	European Structural and Investment Funds
EU	European Union
H2020	Horizon 2020
HEFT	HomeEnergy FreeTime
ICT	information and communication technology
ICT PSP	ICT policy support programme
IEE	Intelligent Energy Europe
Jaspers	Joint Assistance to Support Projects in European Regions
Jessica	Joint European Support for Sustainable Investment in City Areas
JRC	Joint Research Centre
PHPY	per household per year
ToU	time-of-use

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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Annex - List of projects surveyed

	Project name	Project duration	Countries involved	Funding source
Digital technologies	Save@Work4Homes — supporting European housing tenants in optimising resource consumption	Jan 2007-Dec 2008	DE, FR, PL, UK	IEE
	3e-Houses — energy efficient e-houses	Feb 2010-May 2013	BG, DE, ES, UK	CIP ICT PSP
	e3SoHo — Energy Efficiency in European Social Housing	Feb 2010-Sep 2013	BE, ES, FR, IT, NO, PL, PT	CIP ICT PSP
	eSESH — saving energy in social housing with ICT	Mar 2010-Feb 2013	AT, BE, DE, ES, FR, IT, PL	CIP ICT PSP
	BECA — Balanced European Conservation Approach	Jan 2011-Dec 2013	BG, CZ, DE, EL, ES, FR, IT, RS, SE	CIP ICT PSP
	SHOWE-IT — real-life trial in social housing of water and energy efficiency ICT services	Jan 2011-Dec 2014	DE, ES, FR, SE, UK	CIP ICT PSP
	EnergyTIC — technology, information and communication services for engaging social housing residents in energy and water efficiency	Mar 2011-Sep 2013	BE, ES, FR, UK	CIP ICT PSP
	ICEWish — demonstrating through intelligent control (smart metering, wireless technology, cloud computing and user-oriented display information) energy and water wastage reductions in European social housing	Mar 2011-Sep 2014	BE, BG, DE, DK, EL, ES, FR, IT, NL, PL, UK	CIP ICT PSP
	Elih-Med — energy efficiency in low-income housing in the Mediterranean	Apr 2011-Mar 2014	CY, EL, ES, FR, IT, MT, SI	Interreg Med
	EnerGAware — energy game for awareness of energy efficiency in social housing communities	Feb 2015-Jan 2018	ES, FR, PT, UK	H2020

	Project name	Project duration	Countries involved	Funding source
Behavioural change	ISEES — improving the social dialogue for energy efficient social housing	Jan 2006-Dec 2007	AT, BG, CZ, LT, SK, UK	IEE
	Energy Ambassadors — campaign to fight against fuel poverty and raise awareness on energy efficiency and energy savings	May 2009-Oct 2011	BG, DK, EL, ES, FR, RO, SE, UK	IEE
	EC-LINC — Energy Check for Low Income Households	Mar 2011-Feb 2014	AT, BE, DE, HU, UK	IEE
	Achieve — actions in low-income households to improve energy efficiency through visits and energy diagnosis	May 2011-Apr 2014	BG, DE, FR, SI, UK	IEE
	REACH — Reduce Energy Use and Change Habits	Mar 2014-Feb 2017	BG, HR, MK, SI	IEE
	TRIME — Trias Mores Energetica	Sep 2014-Aug 2017	BE, ES, FR, NL, UK	IEE
	Fiesta — Family Intelligent Energy Saving Targeted Action	Oct 2014-Sep 2017	BG, CY, ES, HR, IT	IEE
	Smart-Up — consumer empowerment in a smart meter world	Mar 2015-Jul 2018	ES, FR, IT, MT, UK	H2020
	Assist2gether — support network for household energy saving	May 2017-Apr 2020	BE, ES, FI, IT, PL, UK	H2020

	Project name	Project duration	Countries involved	Funding source
Financing	InoFin — innovative and tailored financing schemes for social housing refurbishment in enlarged Europe	Jan 2006-Dec 2008	BG, CZ, DE, DK, LV, NL, PL, SK	IEE
	Ecolish — energy exploitation and performance contracting for low-income and social housing	Dec 2006-Nov 2009	BE, EL, HU, LV, NL	IEE
	FINSH —financial and support instruments for fuel poverty in social housing	Dec 2007-May 2010	DE, FR, PL, UK	IEE
	FRESH — social housing comprehensive refurbishment through energy performance contracting	Jun 2009-May 2012	BG, FR, IT, UK	IEE
	EnerSHIFT — Energy Social Housing Innovative Financing Tender	Feb 2016-Jan 2019	IT	H2020
	LEMON — Less Energy More Opportunities	Feb 2016-May 2018	IT	H2020

Project name	Project duration	Countries involved	Funding source
Nirsepes — new integrated renovation strategy to improve energy performance of social housing	Jan 2006-Dec 2007	DE, EL, ES, IT	IEE
ROSH — development and marketing of integrated concepts for energy efficient and sustainable retrofitting of social housing	Jan 2006-Jun 2008	AT, BG, DE, IE, IT, PL	IEE
SHARE — Social Housing Action to Reduce Energy Consumption	Jan 2006-Jun 2008	BG, DE, EE, FR, IE, SE, SI, UK	IEE
Tackobst — tackling obstacles in social housing	Jan 2007-Dec 2008	BG, DE, FR, IT	IEE
CASH — Cities Action for Sustainable Housing	Nov 2009-Jan 2013	BG, DE, DK, EL, FR, HU, IT, NL, UK	ERDF
Social Green — regional policies towards greening the social housing sector	Apr 2016-Sep 2020	EE, ES, HR, PT, RO, SE	Interreg Europe and ERDF

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