EUFORIE
European Futures for Energy Efficiency

Identification of promising instruments and instrument mixes for energy efficiency

Deliverable 5.2

version 24.04.2019

This project is supported by the European Commission
Horizon2020 Research and Innovation Programme

www.euforie-h2020.eu

Please cite as

Spangenberg, Joachim H . (2019). Identification of promising instruments and instrument mixes for energy efficiency. *EUFORIE – European Futures for Energy Efficiency*

Key findings and summary for stakeholders

1. The issue to be explored

Households are one of the major energy consumers in the EU, and haves not yet exhausted their enormous potential in fulfilling the EU energy policy objectives. Within households, low temperature heat generation for room heating and warm water holds by far the largest share in energy consumption. The heat sources are varying between households and Member States; they include coal, oil, gas, wood and electricity. Electricity use for lighting and household appliances is much less important, but has received a disproportional share of public interest and support by the EU.

Analysing energy efficiency contributions of households requires taking system effects into account. For instance, replacing individual stoves by electric or district heating will have different effects depending on the energy provision system into which the house-hold is embedded, and recommendations for household choices must take those differences into account. Thus like for efficiency, the system matters for carbon intensity: the relation of final energy consumption to primary energy consumption is to a large degree determined by the system (see WP 4).

Acknowledging this diversity, we refrain from suggesting any best practice or standard policy measures but analyse which instruments have addressed which causal factors, and – as far as information is available – how effective they have been under specific circumstances. The recommendation is then not one of a specific policy mix across Europe, but of a policy toolbox.

2. What was done to investigate it

We classified policy strategies intentionally addressing a number of objectives described in the next section as 'promising'. Policies supporting technical innovations for energy efficiency of buildings are also considered as part of the 'promising' category. Finally the physical minimum demands of making buildings more energy efficient are also used as a yardstick to identify policies which are not promising, or even counterproductive, be it in a planning, economic/fiscal or other policy context.

Policy strategies supportive of enhancing the overall efficiency of household energy consumption are part and parcel of many but by far not all National Energy Action Plans. For national implementation a variety of means can be chosen as long as they pursue and reach the same ends. This rules out the existence of any 'silver bullet policy mix', and so does the diversity of climatic, building and institutional settings. If and how these conditions can be fulfilled in everyday life depends on a multitude of factors, such as the age and structure of dwellings, settlement structures, planning processes, income levels and human routines, habits, norms and preferences, but also external factors like climate and institutions/administrative traditions. Especially social norms are hard to influence by climate and energy related policies, and are thus hardly addressed in the context of energy efficient dwellings. This is easier in the case of buying household appliances influencing the household electricity use. Their assessment follows different but related rules to those for heat consumption and is discussed in a separate section of the report.

3. The method employed

To minimise energy consumption while maintaining a good supply of energy services, in particular in terms of low temperature heat, a household must confirm to a number of physical, social and behavioural conditions. In particular, a building must fulfil the condition to be

i. capable of keeping heat within the building envelope, by means of isolated walls and roofs, adequate windows, doors and shutters;
ii. built in a heat conservation and appropriation supporting way, based on local or regional planning (governance);

iii. equipped with service providing installations requiring only low inputs;

iv. offering energy security; as standard heat storage tanks offer supply for about 2 hours per m^3 of storage, external supply or in-house fuel storage must be available;

v. used accordingly, which required adequate behaviour based on relevant knowledge, motivation and skills (management);

vi. part of an efficiency enhancing energy supply system.

The first three criteria primarily address the physical characteristics of the building, and since based on physics, they are the same throughout the European Union. The fourth criterion, although formulated for reasons of service reliability, is similarly phrased in physical terms. Criterion five refers to the adequate use of the physical structures, and in our analysis on the information provision for this behalf. Finally, the sixth criterion addresses the overall energy supply system in which the households are embedded.

4. The data and sources

This report is based on different data and information sources, in particular on eight European country reports (Finland, Germany, Hungary, Italy, Latvia, Romania, Spain, and the United Kingdom) covering a wide range of policies and private initiatives addressing energy efficiency in the residential sector (see D5.1 and Annexes). The country reports have been compiled by national experts provided with the capabilities to analyse national language information material, but also the knowledge of where to find the appropriate information. In some cases the collection of information has been supported by interviewing external stakeholder. Main EU laws, policies, and related documents (e.g., the Energy Efficiency Directive 2012/27/EU) were taken from public sources, mainly the EU law database (URL: http://eur-lex.europa.eu/homepage.html) as the basis for assessing the policy impact role of EU regulations, the third National Energy Efficiency Action Plans (NEEAPs) and other national policy documents.

An extensive use was made of the ODYSSEE database which contains detailed data on energy consumption and related CO_2 emissions. ODYSSEE data on energy consumption are complemented with data on residential building stock taken from national statistics databases. This is because there exists a strong correlation between dwelling characteristics – age, tenure, type, size – and the energy consumption and thermal efficiency performance of buildings, in addition to household composition, income and behavioural traits.

5. The results

The achievable effect of energy efficiency policies depends not only on the local or national circumstances and the policy instruments chosen, but also on the design of the instrument and the process of developing, implementing and adapting it, to degrees varying with the situation.

Selected general success factors include

- Using an instrument mix with special emphasis on building energy codes. They include e.g. energy performance standards, minimum thermal insulation standards including glazing and airtightness, and standards for the efficiency of fixed building services such as heating, lighting and controls. Such regulatory policies have been found to have more impact than financial or informative instruments.
- Effective multi-level governance permitting lower levels to test means of implementation in a niche, with the perspective of scaling up. Scales reach from neighbourhood plan and local plans to reginal, provincial and national plans.
- Competitive markets as a condition for informal and fiscal/financial incentives to be effective; in oligopolic markets e.g. in the construction sector new buildings are rather are set up following established practice than making use of best available technologies BAT.
- A national space standard limiting continuous growth of flat sizes is a main tool for limiting the energy consumption per household and to avoid the overcompensation of efficiency gains by increased heated area. Building standards and fiscal measures might be used to implement it.

Furthermore, some success factors are instrument-specific, such as

Standards

Standards need to be monitored and updated regularly to remain in touch with technological developments. Emphasising the best available technology BAT or – even better – the state of science and technology in building standards can introduce an inherent dynamic, like the top- runner approach can do for electrical and other appliances.

Economic instruments

Economic incentives must be high enough to be effective, making investments into energy efficiency profitable. They should be targeted at actions which are cost effective from a collective point of view, e.g. avoiding externalised cost, but which would not otherwise have been undertaken by consumers. The level will be differing between countries, mainly according to disposable income levels, if households are the investors. Profitability can often not be achieved efficiently with one policy instrument but requires a combination of several tools such as grants, reduced interest (soft) loans and tariff reductions. Such packages can be effective incentives for measures to be taken by economic agents, beyond compliance. Subsidising energy audits and the purchase of highly efficient appliances can also be an incentive, but could also be offered by banks as soft loans, repayable from the energy savings. In order not to lose effectivity, fiscal incentives should be dynamic, linked to the overall income index and must be set in a socially responsible manner. Instead of lowering energy prices for social reasons, adapting transfers and maintaining the efficiency incentive seems to be more promising without reducing social security (a package concept).

Education and information

Consumer education should focus on making people familiar with energy sensitive behavioural routines and practices, in particular in the use of heat (for room heating and warm water). Communication linking efficiency to modernity or other fringe benefits might be more effective than emphasising energy saving potentials. Training measures should not only target households and their in-house energy management, but also enhance the qualification of local authorities supervising standard implementation, and the respective businesses.

As this overview of success factors has illustrated, energy efficiency improvements in the residential sector differ significantly between countries, be it EU Member States or beyond. No country can claim to "have it all got right" – there is ample opportunity for learning from each other.

6. Their significance for policy-makers, stakeholder, and/or other researchers

Using energy efficiency to enable lower energy prices for households and industry (Romania), pursuing the reduction of energy cost (Finland) and considering energy price a matter of competitiveness (Hungary) are counterproductive to reducing household energy consumption, contributing to falling short of implementing the EU targets. Economic considerations should not neglect the fact that instruments such as energy efficiency standards (e.g. EPBD) and energy pricing have been one of the main drivers of innovation. Most MS implement the directive and nothing but the directive, only few set a number of more ambitious targets (Hungary, Italy, Spain, Denmark). As the directives lag behind what is technically possible and environmentally desirable (in particular after the Paris agreements), sharpening the standards in the coming revision is advisable.

A serious obstacle to achieving improved energy efficiency in the residential sector is house owners' experience of excessive administration and procurement procedures, delays and cost. Reliance on informational methods seems to be insufficient – but can accompany other tools to enhance public acceptance. Economic incentives can be effective, but carry the risk of regressive effects. Enhancing social distribution problems can put energy efficiency policies at risk. In such cases, regional and social targeting may increase the standing of energy efficiency policies.

Other significant lessons refer to the process of policy development and implementation:

- Stakeholder participation in design and implementation of policy measures helps public acceptance and easy implementation.
- Continuous revision and improvement of an instrument during the implementation phase: Regulatory mechanisms need to be monitored, evaluated and updated regularly to remain in touch with societal trends and technical developments.
- Smart integration of policy instruments into effective policy packages: larger energy savings are potentially possible if measures aiming at technical, infrastructural and behavioural improvements are applied in combination, mutually reinforcing each other.
- A building code or other forms of rules signalling the future direction of building regulations in relation to carbon emissions from, and energy use in homes can provide more regulatory certainty for the homebuilding industry, investors and households.
- Easy procedures for changing energy suppliers can be an effective support in a competitive market, but need to be supported by information about both the possibilities and the performance of different sup-pliers. National regulation should make sure that efficiency- conscious package deals carry the best economic bargain.

Tasks of this deliverable related to WP 5

WP5 - Consumers and energy efficiency
Task 5.2. Identification of promising instruments and instrument mixes for energy efficiency.

Work package 5 of the EUFORIE project started with a stock taking of administrative, economic or informational instruments targeting energy consumption in households including the behavioural aspect the investment phase but also indirect influences changing the consumption environment. Countries' analysed were Germany, Finland, Hungary, Italy, Latvia, Romania, Spain and the UK. Next to public policies attention was given to the support coming from the private sector complementing public activities over the whole range of relevant activities from planning (architects, planners), financing (e.g. specific green loans from banks to private owners and other investors), consulting (in particular for modernisation) (see D 5.1).
In this deliverable we structured the earlier findings according to an overarching scheme of conditions for a building to minimise energy consumption while maintaining a good supply of energy services. Using the conditions as a selection criterion, we identified policies addressing them, which were consequently considered as promising instruments, and in combination as promising instrument mixes for energy efficiency in the residential sector.
The results of D5.2 will provide input to the subsequent WP 5 deliverables, as well as to outreach and policy recommendation formulation.

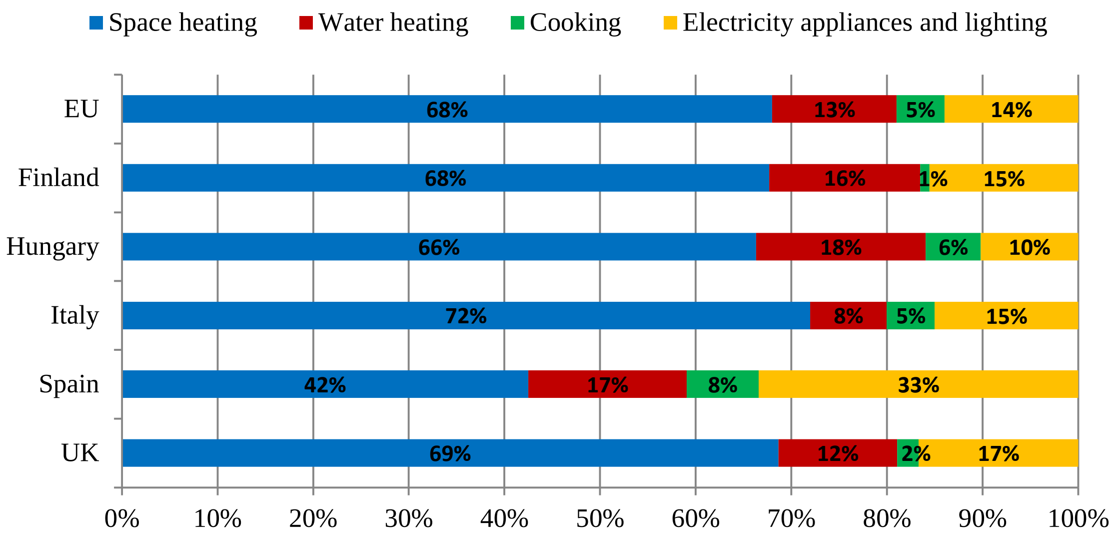
Table of Contents

1. Introduction: The context

Energy efficiency is one of the priorities of the European Union, as reflected in the various documents, which place it at the heart of the European corpus on energy and environment policy. Most of the texts on energy efficiency adopted by the EU since early 2000 were written in the context of the fight against climate change, as is the case in the Member States (European Commission 2002; 2010; 2012; 2015).

The overarching goals of European energy policy are reducing energy demand, increasing security of energy supply and enhancing competitiveness. By 2030, it aims at cutting greenhouse gas emissions by 40% compared to 1990 level, increasing the share of renewable energy to at least 27%, and continuing the improvements in energy efficiency (at least 27% energy savings compared with the business-as-usual scenario)(European Commission 2015). Little wonder then that most initiatives on the Member State level are not confined to energy efficiency improvements but combine them with measures to stimulate the generation of renewable energy and reduce carbon emissions in the same package (European Commission 2009). This holds true today for the housing sector as well, as our stocktaking has confirmed (EUFORIE D5.1).

Figure 1. Breakdown of residential energy consumption by end-use in 2013 for the European Union



*Source: Authors' elaboration based on Odyssee database (2017). *Data for Hungary are of 2010*

Households, the focus of this WP, are one of the major energy consumers in the EU, and one which has not yet exhausted its enormous potential in fulfilling the EU energy policy objectives (Jaffe, Stavins 1994; Allcott, Greenstone 2012; Kallbekken et al. 2013; Gillingham, Palmer 2014). Within households, low temperature heat generation for room heating (68%) and warm water (13%, 2013) holds by far the largest share in energy consumption (see figure 1)(Odyssee 2017). The heat sources are varying between households and Member States; they include coal, oil, gas, wood and electricity. Electricity use for lighting and household appliances is much less important (14%), but has received a disproportional share of public interest so far, plus the support by the EU.

Households as final consumers are part of the energy system. Their influence on the total energy consumption and the efficiency of transforming primary energy into energy services cannot be identified exclusively by focussing on what is happening inside the house. Analysing energy efficiency contributions of households requires taking system effects into account as well. For instance, replacing individual stoves by electric or district heating will have different effects depending on the energy provision system into which the household is embedded, and recommendations for household choices must take those differences into account.

For instance, the mandatory connection to district heating in dedicated zones practiced in Denmark will reduce the diversity of options together with the cost as compared to a voluntary connection regulation as practiced in Germany. If the district heating system is fed by coal fired power plants (examples exist in Poland and Germany), by gas turbines (as in Denmark) or from industrial surplus heat (as in the “industrial symbiosis” examples) will strongly affect the carbon intensity of low-temperature heat provision. Thus like for efficiency, the system matters for carbon intensity: the relation of final energy consumption to primary energy consumption is to a large degree determined by the system.

Financial support measures have to be shaped according to the prevailing institutional setting, and the level of incentives varies. To be effective it should correspond to local price levels. Acknowledging this diversity, we refrain from suggesting any best practice or standard policy measures (which overwhelmingly would be in fields of national competence anyway) but analyse which instruments have addressed which causal factors, and – as far as information is available – how effective they have been under specific circumstances. The recommendation is then not one of a specific policy mix across Europe, but of a policy toolbox.

2. Data sources and methodology

2.1. Data sources

This report is based on different data and information sources, in particular on eight European country reports covering a wide range of policies and private initiatives addressing energy efficiency in the residential sector (see EUFORIE Deliverable D5.1 and Annexes). Main EU laws, policies, and related documents (e.g., the Energy Efficiency Directive 2012/27/EU) were taken from public sources, mainly the EU law database (URL: http://eur-lex.europa.eu/homepage.html) as the basis for assessing the policy impact role of EU regulations. The in-depth analysis of the third National Energy Efficiency Action Plans (NEEAPs) and other national policy documents is taken from D 5.1 and based on the country reports from Finland, Germany, Hungary, Italy, Latvia, Romania, Spain, and the United Kingdom, and supported by literature sources (Bertoldi, Economidou 2016).

The country reports have been compiled with the help of national experts and based on their country analyses. They had not only the language capabilities to analyse national language information material, but also the knowledge of where to find the appropriate information. Additionally, in some cases the collection of information has been supported by interviewing external stakeholder with expertise in the residential energy sector and energy efficiency.

An extensive use was made of the Odyssee database which contains detailed data on energy consumption and related CO_2 emissions (Odyssee 2017). Odyssee data on energy consumption are complemented with data on residential building stock taken from national statistics databases. This is because there exists a strong correlation between dwelling characteristics – age, tenure, type, size – and the energy consumption and thermal efficiency performance of buildings, in addition to household composition, income and behavioural traits (Eakins 2013; Danlami et al. 2015).

2.2. Methodology

To minimise energy consumption while maintaining a good supply of energy services, in particular in terms of low temperature heat, a household must confirm to a number of physical, social and behavioural conditions. In particular, a building must fulfil the condition to be

vii. capable of keeping heat within the building envelope, by means of isolated walls and roofs, adequate windows, doors and shutters;

viii. built in a heat conservation and appropriation supporting way, based on local or regional planning (governance);

ix. equipped with service providing installations requiring only low inputs;

x. offering energy security; as standard heat storage tanks offer supply for about 2 hours per m^3 of storage, external supply or in-house fuel storage must be available;

xi. used accordingly, which required adequate behaviour based on relevant knowledge, motivation and skills (management);

xii. part of an efficiency enhancing energy supply system.

The first three criteria primarily address the physical characteristics of the building in question, and since based on physics, they are the same throughout the European Union. The fourth criterion, although formulated for reasons of service reliability, is similarly phrased in physical terms. Criterion five refers to the adequate use of the physical structures, and in our analysis on the information provision for this behalf. Finally, the sixth criterion addresses the overall energy supply system in which the households are embedded. The criteria are formulated on a level general enough to be applicable across the board in Europe.

The core method of analysis then consists of screening EUFORIE Deliverable D5.1 and its annexes for policy instruments addressing these criteria, considering those which do as promising instruments and, in combination, as promising instrument mixes.

In the reminder of this Deliverable, the policies explicitly addressing these criteria have been identified in D5.1, with two consequences: the analysis in this Deliverable is limited to the countries analysed in D5.1, and as no data about the effectiveness of certain instruments in specific contexts (legal, institutional, political majorities and traditions, or age, ownership and state of the building stock, etc.) are available, we classified policy strategies intentionally addressing these objectives as “promising”. Furthermore, policies supporting technical innovations favouring energy efficiency of buildings are also considered as part of the promising category (Noailly 2012). Finally the physical minimum demands of making buildings more energy efficient are also used as a yardstick to identify policies which are not promising, or even counterproductive, be it in a planning, economic/fiscal or other policy context.

Policy strategies supportive of enhancing the overall efficiency of household energy consumption are part and parcel of many but by far not all National Energy Action Plans (European Commission 2009; EUFORIE Deliverable D5.1 plus Annexes). As usual for the national implementation, a variety of means can be chosen as long as they pursue and reach the same ends. This very fact rules out any the very existence of any “silver bullet policy mix”, and so does the diversity of climatic, building and institutional settings. To the contrary: if and how these conditions can be fulfilled in everyday life depends on a multitude of factors, such as the age and structure of dwellings, settlement structures, planning processes, income levels and human routines, habits, norms and preferences (Ameli, Brandt 2014), but also external factors like climate and institutions/administrative traditions. Such variations cannot be covered in a study focussing on the national level. Social norms are hard to influence by climate and energy related policies, and are thus hardly addressed in the context of energy efficient dwellings (Allcott 2011). This is easier in the case of buying household appliances influencing the household electricity use. The assessment follows different but related rules to those for heat consumption and is discussed in a separate section (Mills, Schleich 2010).

The structure of the analysis (i.e. screening D5.1 and annexes using the criteria I to vi) is reflected in the results reported in section 3: in each subchapter we list policies identified as addressing the specific criterion dealt with in the subchapter, from the countries analysed in D5.1 (this also illustrates that the systematique suggested and applied here is capable of capturing the empirical findings and suitable to structure them). As most policies address several objectives, and frequently more than one of the six criteria chosen, some more comprehensive policies have to be mentioned more than once, although we tried to limit mentioning a policy again to those cases where there policy obliviously has two or more objectives on the same level of importance (as defined in the country of origin).

We have to highlight again that data on the effectiveness of individual policy strategies do not exist, and even if they did the different conditions of success would be prohibitive for any approach of standardisation or transferability: there are no “best solutions”. Instead the lists of instruments which have been promising under specific circumstances in the countries analysed can be read as a toolbox to get inspiration from for a suitable design of policies and policy mixes in the respective socio-political context.

3. Success factors for policy instruments

Concluding from the literature, the physical logic and confirmed by the empirical data gathered and the analysis conducted, success factors have been identified in section 2. As for all instruments not only the choice of instrument as such, but its design and application are decisive for the effect, we highlight not only generally, i.e. under all conceivable conditions applicable success factors, but also mention those which refer to the process of policy development and implementation. Where it is known that success may be conditional on external circumstances for to the kind of instrument under discussion, these conditionalities are listed as success factors which apply to specific instruments. In the analysis, we follow the order of the success conditions identified in section 2.

3.1. Capable of keeping heat within the building envelope, by means of isolated walls and roofs and adequate windows, doors and shutters

In implementing the EU regulations, almost all countries have set efficiency standards for new buildings. However, the housing stock remains unaddressed by such regulations.

- In many countries the legislation obliges all individuals undertaking a major renovation, alteration or system renovation to incorporate measures enhancing energy efficiency. The targets set, and the threshold above which such measures are mandatory varies between countries. In Finland, for instance, it refers to all projects requiring a permission and aims at cost-optimal levels of minimum energy performance. With cost as a (variable) basis, Finland lags behind other EU countries in terms of energy efficiency increases in the residential sector despite offering subsidies to stimulate renovation.
- The Aid Programme for the Energy Renovation of Existing Buildings, Spain, supports integrated energy efficiency approaches, including measures improving a building’s thermal insulation such as the renovation of windows and roofs.
- Thermal rehabilitation of apartment blocks and single-family residences is foreseen in Romania, reflecting the countries housing stock.
- Building renovation measures in Latvia cover residential, central government and municipal buildings. The scheme is being changed from a 50% grant to a 100% low-interest loan, with the money flowing back used for additional measures; 35% of the loan can be waived if high energy efficiency achievements can be proven and repayment only starts after the measures have been completed so that they can be financed from the energy savings. The intention is that no up-front cost emerge, enabling willing households with insufficient capital to start a renovation (even with 50% grants) to get going.

- Energy efficiency enhancing renovation projects in multi-apartment building enjoy a 20% public co-funding in Latvia. Beneficiaries have been individual flat owners until 2013.
- In Germany, programs for thermal modernisation (including standards, building renovation programs and subsidised credit from the KfW) have a long history, but progress of acceptance is slow in residential building with rented flats due to the diverging interests of landlords and tenants (the situation where the landlord invests and only the tenant reaps the benefits), as in many Central European countries.
- In the UK, the building renovations strategy aims at making building more thermally efficient through better isolation and improved air-tightness, stringent building regulations are a key element. The landlord-tenant tension was addressed by the Green Deal enabling private firms to offer consumers energy efficiency improvements to their homes at no upfront cost, and get back payments through instalments on the energy bill. An important side effect of this model is, that if tenants moved out and ceased to be the bill-payer at that property, the financial obligation didn't move with them but moved to the next bill payer. In this way, the Green Deal differed from existing lending – it was not a conventional loan since the bill-payer was not liable for the full capital cost of the measures, but only for the charges on the energy bill. The Green Deal was cancelled in 2015 due to lower-than-expected participation despite its interesting features. The additional tax relief system for landlords contributes to a situation where there is also no net or up-front cost to landlords.
- Hungary has a national target for efficiency increases in the building stock; priority is given to measures affecting the most common type of housing, single family homes built in the Communist regime time period.
- The Italian income tax deduction scheme aims at reducing heating demand by means of overall upgrading of the building's energy performance; it supports improvements of the building's thermal insulation (replacement of windows, including blinds or shutters, and insulation of roofs, walls and floors);

3.2. Equipped with low input service providing installations

- The Aid Programme for the Energy Renovation of Existing Buildings, Spain, supports incorporation of equipment to individually measure heating and domestic hot water consumption.
- The German approach is offering cheap credit and information to commercial house owners, hoping that market forces will promote energetic modernisation of installations, a strategy suffering from low energy prices. In some Federal States, in case of new buildings or major restorations, a fixed share of the buildings future energy consumption will have to come from renewable sources (regulations differ widely between Federal States and municipalities).

<u>Efficient heating systems like floor heating, boilers etc.</u>

- The Program of Building Rehabilitation, Spain, supports the renovation and maintenance of fixed installations and equipment of (mainly) residential buildings built before 1981 if the measures undertaken reduce the energy consumption be at least (certified) 30%. Main beneficiaries are property owners (individual or associations).
- The Aid Programme for the Energy Renovation of Existing Buildings, Spain, supports integrated energy efficiency approaches, including measures improving energy efficiency in thermal and lighting installations (including solar thermal) such as boilers, air conditioning equipment.
- In the UK, the building renovations strategy aims at improving the efficiency of heating systems through the use of more efficient boilers.
- In Germany, boilers older than 1978 have to be replaced by law, but there is no control or enforcement for this regulation.

Renewable solar energy providing systems (thermal and electric)

- Promoting the use of alternative heating systems based on solar, waste wood or geothermal energy to complement or replace traditional heating systems (Romania)
- The Italian income tax deduction scheme supports installing solar thermal panels;

Renewable geo-energy providing systems (heat pumps, geothermal energy)

- The Domestic Renewable Heat Incentive (domestic RHI), UK, is a Government financial incentive to promote the use of renewable heating system targeted at, but not limited to, homes off the gas grid. The scheme covers single domestic dwellings and is open to homeowners, private landlords, social landlords and self-builders It pays beneficiaries a fixed amount of money for heat generated according to the heat source, calculated based on the expected cost of renewable heat generation over the next 20 years.
- The Aid Programme for the Energy Renovation of Existing Buildings, Spain, supports integrated energy efficiency approaches, including replacement of conventional energy with geothermal energy in thermal installations.
- Romania promotes the use of alternative heating systems based on solar, waste wood or geothermal energy to complement or replace traditional heating systems.
- Heat pumps for detached and terraced houses are part of an energy efficiency obligation scheme in Finland.
- The Italian income tax deduction scheme supports replacing winter heating systems with condensing boilers or heat pumps, and replace electrical water heaters with heat pump water heaters.

Renewable bio-energy providing systems

Many of the national programs include support for biomass boilers, heaters and fireplaces as an incentive to make more use of renewable energies (although in fact – unlike legally – wood is not a CO_2 free energy source). However, this is not increasing energy efficiency, and can be detrimental to it. Before supporting such solutions a regional heat provision plan should be available, based on cost-effectiveness considerations, which identifies which areas are best supplied with external heat (municipal, district, settlement levels) and in which internal heating systems for all houses are preferable.

Even where this is the case, the balance of supply and demand needs to be managed: if due to subsidies biomass demand surpassed locally available biomass from sustainable production, either the impact becomes negative, or – if there are limits to harvest – the efficiency suffers from longer, energy consuming supply chains.

- Grants can be conditioned to generate co-benefits; in Romania a condition is that applicants have no duties to public authorities and have not violated environmental protection regulations.
- The Domestic Renewable Heat Incentive (domestic RHI), UK, pays beneficiaries such as biomass boiler owners a fixed amount of money for heat generated according to the heat source, calculated based on the expected cost of renewable heat generation over the next 20 years.
- The Renewable Energy for Heating and Cooling Support Scheme, Italy, supports (for private parties) the replacement of existing systems for winter heating with more efficient ones (condensing boilers), and the replacement and, in some cases, construction of new renewable- energy systems (heat pumps, biomass boilers, heaters and fireplaces, solar thermal systems, including those based on the solar cooling technology).
- Promoting the use of alternative heating systems based on solar, waste wood or geothermal energy to complement or replace traditional heating systems (Romania)

- The Aid Programme for the Energy Renovation of Existing Buildings, Spain, supports integrated energy efficiency approaches, including replacement of conventional energy for biomass in thermal installations, replacing conventional energy with biomass.

3.3. Offering energy security

As standard heat storage tanks offer supply for about 2 hours per m3 of storage, external supply or in-house fuel storage must be available. Examples are:

- Subsidies for district heating providers, Hungary
- Mandatory connection to local gas or district heat, Denmark
- Support for installing electricity storage (batteries) in private households in Germany, to be combined with self-generated solar electricity. Such installation can, if spread widely, help buffering demand peaks and smoothen the integration of renewables into the electricity grid. Since the feed-in tariff has been decreased so much that it is lower now than electricity bought from the grid, the economic incentive has stimulated in particular owners of detached houses to install such energy storage capacity (not available for heat yet). However, the German government plans to tax self-used electricity, making the subsidised trend economically unfeasible.

3.4. Used accordingly, which required adequate behaviour based on relevant knowledge, motivation and skills (Management)

Education

Information and education measures are used in all EU member states, as required by the EU directives. Different kinds of information can be distinguished: *pull information* requires end users to seek for information, pull them out from homepages, workshops, seminars, training courses, etc.: consumers have to become active first to get hold of the information. This kind of information provision regarding technology or funding is an excellent source for experts, but rarely used by households. If addressed to children e.g. in school, it may be helpful for awareness raising but will not influence household energy efficiency in the foreseeable time.

Push information is delivered by authorities, agencies and companies to household without prior demand articulation, e.g. by advertisements, TV shows, social platform network information or other campaign elements. It has a number of difficulties of its own: consumers can hardly distinguish reliable information from hidden advertising and from weird internet posting, and to reach all addressees, the information cannot be very specific.

A frequent argument for promoting energy saving (for labelling, eco-design, support for buying efficient equipment and renovating buildings) is the resulting cost saving, i.e. the rebound effect is used as an argument for the primary saving – maybe not the best possible and most logical argument. Overall, the hope that market mechanisms – information about cost saving guiding consumer behaviour – would be the most effective instrument have long been falsified by experience. This hope is one of the main reasons why a lot of information is intended to raise the environmental awareness in general but falls short on practical behavioural advice.

This points to another way of classifying information dissemination: what is the message conveyed? First of all, a more-than-proportional part of the information focusses on electricity as compared to heat generation and management. Secondly, most information accompanies or points to available technologies and financial incentives (and is indispensable for their success), i.e. they are not stand- alone energy efficiency education measures aimed at changing household energy management, but of a more explanatory and promotional role for other instruments.

However, there are limitations to this approach: if the matter to be explained is complex and dynamic, good didactics cannot make it easier than it is – for instance, the regular change within the set of about 15,000 funding opportunities in Germany (loans and grants, tax benefits and technical support, with differing conditionalities and different modes of calculation, to be obtained from the national, state or municipal level, which can be combined or not) makes transparency impossible and expert courses are outdated within a year. According to our interviews with installation firms and energy efficiency consultants, the online databases available to consumers to tailor-make a readout of the available support schemes at all governmental levels do not provide a legal planning and decision making base; they are neither always up-to-date nor indeed user-friendly. Consumers have to consult experts (and more expert involvement is foreseen by government in the process of receiving a grant or loan) at serious cost, denting deep into the support provided by the same government.

Finally, the educational programs aiming changing household management in favour of energy efficiency often do not reach their clients due to high cost (participation in courses, workshops, etc.), wrong timing (household members in paid and unpaid work have different, but always limited flexibility) or difficult language (technical, economic).

Information campaigns

- Information to consumers, house owners and rental flat management companies is a key pillar of all efforts for energy efficiency in Germany (together with subsidised loans).
- As energy efficiency and renewable energies are widely accepted in Germany, several leading companies in the household equipment, heating and sanitary installation sector offer training to their local contract companies, introducing new technologies and demonstrating upgrade potentials (B2B education & training).
- In Spain, the energy efficiency and renewable energy citizen information service provides sources of information, accompanied by public outreach through advertising and communication campaigns.
- The Latvian campaign “Let’s live warmer” is an integrated multi-media campaign, despite its title for energy saving, promoting the available information on housing insulation issues. It appeals to the quality of life in homes.
- In Hungary, the public awareness raising campaign goes under the title “the price of energy”, a mainly economic argumentation.

Energy audits

Voluntary energy efficiency agreements and audits have a long tradition and brought good results in Finland, but so far do not focus on households. In almost all countries they are foreseen, but do not necessarily play a central role.

- Energy audits in multi-apartment building receive a significant share of the annual energy efficiency support for households, which is more than 120 million € in Latvia.
- In Latvia as well, energy efficiency and traditional city competition have been brought together in the annual contest to identify the “Best Energy Efficiency” Building”

Efficiency labelling

Energy efficiency labelling applies almost exclusively to electricity consumption and thus plays a limited role in overall household energy efficiency, but receives a more than adequate attention. This success figures published are in so far questionable, as other reasons like modernity (would producers have offered outdated designs if they had not been discriminated by a low efficiency label?) are hard to disentangle from other motives. In particular the claim that lower bills have led to less consumption is implausible from an economic point of view.

In particular the fact that overall household electricity consumption for appliances has not been decreasing has a number of reasons (demography, technical progress), but the rebound effect from money saved by energy saving is certainly one of them as it allows households to replace durable consumer goods like TVs before the end of their technical life span, buy additional appliances and use the ones owned more intensively. As these effects are considered in none of the studies testifying for the effectiveness of ecolabelling (and for eco-design alike), the success figures should be taken with a grain of salt. Overall, promoting energy efficiency but highlighting rebounds (i.e. savings) seems to be an incoherent strategy if not combined with energy taxation which keeps the energy cost for users of efficient equipment rather constant and provides incentives for laggards to catch up in order to escape increasing prices.

Some of the least efficient products are off the market – it is an open question where this limit should be set, where the responsibility for environmentally benign behaviour of regulators and producers ends and that of consumers begins. For instance, if European minimum conditions would be set based on the best national average and deviations from the minimum efficiency standard were sanctioned, lagging countries might (correctly) feel pressurised, but could realise significant savings (for the resulting rebound effect see above).

Where labelling is used, some conditions should apply:

- Besides labels informing consumers on the electricity efficiency of appliances, boilers and heating systems could also be classified (although this may be more of an information for architects, installation firms etc. they share with consumers).
- As an "A" label plus different numbers of "plusses" has turned out to be less effective, an overhaul of the labelling system seems advisable; a ban on all products below class A would clear the ground for doing so.

3.5. Built or renovated in a heat conservation and appropriation supporting way, based on local or regional planning (governance)

Energy certificates

- In Germany, energy certification is part of a "Housing Pass" and must be presented to all potential clients by the landlord when a flat is rented out, i.e. with any change of tenants.
- In Finland, testified energy certificates have been one important item of governmental consumer information campaigns.

Technical inspections

- Technical inspections in multi-apartment buildings is a second field supported by the annual energy efficiency support for households, which is more than 120 million € in Latvia.
- In Germany technical inspections have been mandatory for a long time – done by installation firms, they check the overall heating system efficiency once a year, and have significantly contributed to avoiding accidents. In addition, emissions are controlled by a chimney sweeper every second year.

Land use planning

Planning for new settlements, with roads and thus houses laid out to enhance heat conservation and appropriation supporting way, for instance with large windows oriented southwards to capture solar warmth, or northwards to avoid this effect, depending on the local climate conditions.

While optimising spatial planning has long been an issue in urban planning and played a role in setting up energy-efficient and renewable energy supplied settlements, it seems to play no role in the energy efficiency policies of member states.

3.6. Part of an efficiency enhancing energy supply system

An energy system within which significant amounts of heat escape unused into the atmosphere while nearby energy carriers are used to produce fresh heat is easily energy inefficient (depending on distances, transport modes and external circumstances). Making use of nearby heat sources is the probably most efficient way of providing heat to households. District heating (like in DK) offers even the possibility to completely phase out fossil fuels from household heat generation – a much more efficient solution than electric heating as it was promoted in some new Member States when they were still part of the Soviet Union.

- Community Energy Saving Program, UK
- Support for co-generation (combined heat and power CHP) is one element in the effort to reduce fossil fuel use in Germany, albeit so far underexploited. Such installation can cater for one residential building or for a block of such houses.
- The Danish approach seems to be quite unique in the EU. Under the current legislative system, households have to connect either to a district heating or a gas supply net – connection is mandatory, and thus the choice of the heating system is predetermined. The basic idea is to assess if enough heat sources are available at suitable distance, and then go for a distant heating network, and otherwise enforce the use of efficient and low-emission natural gas. This is probably the most effective system for enhancing system efficiency rather than efficiency at household level which can still lead to inefficiencies at a larger scale.

<u>Standards</u>

Building standards should not be set in stone, but be flexible enough to evolve with conceptual and technological developments. Legislation requiring an advanced state of the art, or even better the state of science and technology is open to such improvements, and what is the state can be pushed forwards by economic incentives.

In all EU countries standards are set, implementing the EU directives and demanding that new buildings have to require near-zero energy standards.

<u>Economic instruments</u>

Financial support measures should be focussed on cost-effective, long-term sustainable solutions to urgent problems (i.e. neither focus on fringe problems not support solutions which will have to be dismantled with future sustainability-enhancing system changes). They have to be regionally differentiated, shaped according to the prevailing institutional setting, and the level of incentives must be oriented by the local price levels to be effective. Energy efficiency criteria to be applied are:

- Incentive effect
- Affordability effect
- Time horizon (for investments beyond the usual household calculation time horizon)

In general, the public preference is for grants and subsidies, rather than for subsidised soft loans. Government policies set different priorities, preferring loans to grants, for more or less convincing reasons, like the ease of implementation by the banking sector (not really convincing), the limited funds available (more a matter of political prioritising), the possibility of creating a rolling fund which lends out all interest and payment for new energy efficiency programs (a point to consider) and the possibility for low-budget households to start energy renovation programs without up-front cost (a good argument).

Tax modifications (income tax, VAT) are also potential economic instruments, but so far rather unused. VAT changes would have to be agreed on the EU level (legally and to avoid distortions of the EU's internal market), and reducing VAT would dent on the EU budget. Similarly, income tax modifications rewarding energy efficiency investments remain hypothetical in most member states, but Italy, Spain and Finland have some experience to provide.

- In Finland, taxpayers can currently deduct from their taxes 45% of the value of household service or maintenance work conducted at the taxpayer's or his/her parent's home, up to a maximum value of €2,000 per year (€4,000 for a couple). However, due to overcapacities in electricity generation, the electricity price is very low, and drags down the price of heating energy as district heating holds a high share in apartment blocks and it is argued that the heat is available anyway as a co-product from electricity production.
- In Italy, tax deductions for the energy upgrading of buildings have been key drivers of energy efficiency improvements in the housing sector over the last ten years. Tax deductions can be claimed by all taxpayers, including natural persons, professionals, companies family members living with the owner or possessor of the property and tenants holding a regular letting agreement. They reduce the personal or corporate income tax with respect to measures taken improving the energy efficiency of existing buildings. Eligible measures include improving a building's thermal insulation (replacement of windows, including blinds or shutters, and insulation of roofs, walls and floors), installing solar thermal panels and replacing heating systems (winter heating with condensing boilers or heat pumps, electrical water heaters with heat pump water heaters).

  Although the system is comprehensive and effective (it has been identified as best practice by the IEA), it has three downsides (1) the income tax base causes regressive effects (the higher the income and thus the tax rate the higher the tax savings), (2) the income tax is national and permits no regional differentiation, and (3) it is expensive, so that the government plans changes to rationalise cost (which undermines the longer-term reliability criterion).
- When discussing financial instruments, one prominent consideration has been how to avoid free riding effects. Doing so requires knowledge about not yet realised intention, which is hard to get and even harder to administer. From our point of view, this demand from economic theory is not necessary, even dangerous or at least counterproductive: whoever takes the financial support to implement efficiency enhancing measures does what was the intention of providing the incentive, regardless of her earlier intentions – the direct link of investment and efficiency effect is unchallenged. Furthermore, making support conditional on earlier unwillingness to go beyond compliance is discriminating those who as first movers have been or would be willing to take initiatives which – in the interest of energy efficiency – have the potential to transform the market. Dropping this consideration will also help to minimise the administrative burden, thus reducing the cost of the overall programs. Tariff modification that worked are for instance:
- The feed-in-tariff scheme for electricity from renewable sources in Germany is the oldest one in Europe and currently being dismantled to slow down renewable energy generation growth. Similar schemes are now implemented in most EU member states.
- The progressive cost structure for household electricity consumption in some regions of Italy has led to substantive savings there.

Overall, economic instruments play an important role in the political and scientific discourse, as for instance demonstrated by the EU-funded energy efficiency policy project CECILIA (2015) which strongly focussed on economic instruments (albeit without ignoring others). For the residential sector the main suggestion is the activation of market forces, with limited descriptions of the institutional settings required for the market forces to act as expected and hoped for.

Cost transparency

Individual metering is a preferred measure and made compulsory by European legislation. Giving consumers information about their actual energy consumption, even in real-time, was expected to motivate energy saving behaviour. However, it seems to have the highest impact amongst owners of detached houses, while the savings amongst tenants of multi-resident houses are rather small –the structure of the housing stock is decisive for the obtainable impact. So far, experiences are mainly from electricity metering, individual gas metering is spreading slowly.

The reasons are easy to understand: smart meters that facilitate real time and tailored monitoring and feedback provide many advantages for energy companies and Distribution System Operators (DSOs) in terms of operation cost reductions; they rolled them out enthusiastically. The impacts on the household side are less clear: while real-time information about load dependent electricity prices can lead to time shifts in electricity consumption to save cost, it does not reduce energy consumption, on the contrary: saved money causes a rebound effect of additional energy consumption, which makes the net balance negative.

Furthermore, the situation is different between electricity and gas consumption: while the elasticity of electricity consumption is limited by household convenience (cooking will not be shifted to low price periods in the night), but significant potentials exist to use electricity consuming appliances like washing machines in the night with automatic timers, the elasticity of heat demand is almost zero: neither room temperature nor showering will be adjusted to price fluctuations.

Prominent programs include:

- The Aid Programme for the Energy Renovation of Existing Buildings, Spain, supports integrated energy efficiency approaches, including incorporation of equipment to individually measure heating and domestic hot water consumption. For central heating serving more than one household, and for district heating, individual metering has been made compulsory.
- To improve performance, households installing metering and monitoring packages get an extra 230 £ for heat pump users and 200 £ for biomass boiler owners under the Domestic Renewable Heat Incentive, UK. By 2020, 53 million gas and electricity meters in 30 million households will be replaced.
- Individual metering of electricity consumption is the norm in Germany, but not (yet) of gas or district heat consumption; cost transparency regulation obliges owners of rental flat to detail the information provided to clients. Utilities offer extra services like distant metering or account management. Reverse metering is spreading with local renewable energy generation to assess the feed-in tariff entitlement.
- In Italy, the replacement of traditional by smart electricity meters started as a voluntary initiative, but has become compulsory in 2006. As gas meters are also smartening up following the regulatory framework, Italy is ahead of the European average in this field.

Social and distributional aspects

Economic incentives can have regressive effects which might undermine the acceptability of efficiency policy as such. Thus social concerns are not only an important issue in itself, but can also be decisive for the program implementation success.

- The Spanish PAREER-CRECE Programme offers a money allowance, composed of a Base Aid and an Extra Aid, the latter for public housing, housing subsidised for social reasons and urban regeneration areas, i.e. targeted at socially deprivileged housing conditions (for ambitious energy efficiency upgrades and comprehensive approaches).

- To design effective policies, the difference between energy-supply affecting income poverty (not enough income to pay for energy supply) has to be distinguished from energy poverty (a too high share of energy in household expenditure), as for both situations the remedies are different. Where both overlap, both kinds of measures are needed to overcome the problem.

- Both forms of energy poverty have been an issue long discussed in the UK. Recent measures like the Warm Home Discount aim at the second form, by specifically reducing the electricity bill by a one-off discount of £ 140 during the winter heating period. Some suppliers offer reduced rates for low income households (in particular to those with a small child).
- The second form of energy poverty is addressed by the UK Green Deal Home Improvement Fund, enabling private firms to offer consumers energy efficiency improvements to their homes, community spaces and businesses at no upfront cost, and get back payments through instalments on the energy bill.
- Regional distribution plays a role for social and for climate reasons; in Spain and Italy special programs, partly financed by the European Investment bank, apply to provinces most in need of support.
- In Romania, a project funded by UNDP-GEF offers specialisation of architects, building engineers, qualified auditors through training and postgraduate courses in energy efficiency of buildings to address energy efficiency in low-income household and communities.
- Tax incentives, i.e. income tax reductions for efficiency increasing investments have a regressive effect wherever progressive taxation is in place; in Finland (unlike in Italy) the effect is limited by an annual cap per person. Compensatory measures are not foreseen.

<u>Housing structures</u>

Housing structures have predominant impact on the energy consumption during the use phase of 50,100 or more years. So far, many EU member States subsidise detached house construction; in most Member States house ownership is a widely spread social demand (however receding in the younger generation, and often specific to a house designed to meet one's personal need and taste. Inherited houses are often not seen as realising this ambition).

In some countries, user-owned flats in the city play an important role, causing problems in energy efficiency improvements in particular in those cases, when installations in multi-flat buildings are shared and can only be upgraded by joint decision (often, but not exclusively in cases where former rental flats were privatised).

To limit energy consumption per household, subsidies for detached and semi-detached houses should be phased out, and those for terrace house in urban areas should be limited (a beneficial side effect would be less support to transport provoking settlement structures). This would also limit the living space per capita which through its permanent increase has massively reduced the absolute gains from reducing heating energy demand per square meter. Alternatively or complementary – but without the positive side effects – strict standards could be set for such dwellings, beyond the "almost zero" required by the EU.

4. Conclusions

The achievable effect of energy efficiency policies depends not only on the local or national circumstances and the policy instruments chosen, but also on the design of the instrument and the process of developing, implementing and adapting it, to degrees varying with the situation.

Promising instruments and instrument mixes must fulfil the condition to be (1) capable of keeping heat within the building envelope; (2) built in a heat conservation and appropriation supporting way, based on local or regional planning (governance); (3) equipped with service providing installations requiring only low inputs; (4) offering energy security; (5) used accordingly, which required adequate behaviour based on relevant knowledge, motivation and skills (management); and (6) part of an efficiency enhancing energy supply system.

<u>Success factors</u>

General success factors include

- A motivated government not ideologically biased against specific instruments such as plans or standards, dedicated to respecting EU standards and going beyond to meet the Paris targets.
- Using an instrument mix with special emphasis on building energy codes which have been demonstrated to have a significant effect on the improvement of residential space heating energy efficiency. They include e.g. energy performance standards, minimum thermal insulation standards including glazing and airtightness, and standards for the efficiency of fixed building services such as heating, lighting and controls. Such regulatory policies have been found to have more impact than financial or informative instruments. One reason probably is that they ensure that the desirable energy performance of e.g. building components and (especially) heating equipment is achieved even when its purchaser has no manifest interest in obtaining particularly efficient products (due to either behavioural failure or lack of incentives).
- Effective multi-level governance permitting lower levels to test means of implementation in a niche, with the perspective of scaling up (in line with the subsidiarity principle, realised for instance in Sweden and recently abolished in the UK). Scales reach from neighbourhood plan and local plans to reginal, provincial and national plans.
- Sufficiently high energy prices (by government intervention in case of collapsing world market prices) to allow for a decent return on energy efficiency investment (social vulnerabilities need to be taken into account).
- Competitive markets as a condition for informal and fiscal/financial incentives to be effective; in oligopolic markets e.g. in the construction sector new buildings are rather are set up following established practice than making use of best available technologies BAT (housing construction in the UK was mentioned as one example in our interviews).
- A national space standard limiting continuous growth of flat sizes is a main tool for limiting the energy consumption per household and to avoid the overcompensation of efficiency gains by increased heated area. Building standards and fiscal measures might be used to implement it.

Other success factors refer to the process of policy development and implementation:

- Stakeholder participation in design and implementation of policy measures helps public acceptance and easy implementation.
- Continuous revision and improvement of an instrument during the implementation phase: Regulatory mechanisms need to be monitored, evaluated and updated regularly to remain in touch with societal trends and technical developments.
- Smart integration of policy instruments into effective policy packages: larger energy savings are potentially possible if measures aiming at technical, infrastructural and behavioural improvements are applied in combination, mutually reinforcing each other.
- A building code or other forms of rules signalling the future direction of building regulations in relation to carbon emissions from, and energy use in homes can provide more regulatory certainty for the homebuilding industry, investors and households.
- Easy procedures for changing energy suppliers can be an effective support in a competitive market, but need to be supported by information about both the possibilities and the performance of different suppliers. National regulation should make sure that efficiency- conscious package deals carry the best economic bargain.

Finally, some success factors are instrument-specific, such as

<u>Standards</u>

Standards need to be monitored and updated regularly to remain in touch with technological developments. Emphasising the best available technology BAT or – even better – the state of science and technology in building standards can introduce an inherent dynamic, like the top- runner approach can do for electrical and other appliances (the eco-design directive does not fully exploit this potential so far). Standards supporting the use of renewable energy include

- Minimum solar contribution rules for hot water supply in new and renovated buildings
- Minimum photovoltaic contribution standards to electricity supply
- Product related rules and standards have individual problems to deal with, such as
- Minimum efficiency standards for boilers: the wide variation across EU Member States would imply that all boilers usually built in had to be taken off the market in some MS. An EU-wide Top Runner approach in the Ecodesign Directive could implement that.
- Compulsory replacement of old boilers above a certain age: This is long mandatory in a number of member states including Germany, but there is no monitoring and enforcement which makes the regulation rather ineffective.
- Periodic mandatory inspection of boilers: Implemented in a number of MS, with positive impacts on accident risks. Again, enforcement is the challenge, and matters of responsibility and liability are important.
- Periodic mandatory inspection of Heating/Ventilation/AC (HVAC): see above
- Mandatory heating pipe insulation: for obvious reasons, every cost-saving household and every installation form will take care of this. The only relevant case will be old houses not undergoing renovation. While probably feasible for multi-flat buildings, enforcement for single family houses is almost impossible.
- Mandatory use of solar thermal energy in buildings: This is already the case in some Mediterranean countries and (for all kinds of renewables) in some German Federal States. Problems arising in multi-owner buildings require an adequate legal basis for problem solving.

<u>Economic instruments</u>

- Economic incentives must be high enough to be effective, making investments into energy efficiency (for new buildings beyond standards, for renovations, CHP, or renewables) profitable. They should be targeted at actions which are cost effective from a collective point of view (e.g. avoiding externalised cost), but which would not otherwise have been undertaken by consumers (no free riding, no crowding out – but effects last only as long as payments are made and budgets should be sufficient to deal with higher-than-expected demand to avoid frustrations). The level will be differing between countries, mainly according to disposable income levels– not GDP/cap, if households are the investors. Profitability can often not be achieved efficiently with one policy instrument but requires a combination of several tools such as grants, reduced interest (soft) loans and tariff reductions. Such packages can be effective incentives for measures to be taken by economic agents, beyond compliance. Subsidising energy audits and the purchase of highly efficient appliances can also be an incentive, but could also be offered by banks as soft loans, repayable from the energy savings.
- In order not to lose effectivity, fiscal incentives should be dynamic, linked to the overall income index (otherwise the incentive declines with raising income). Individual billing in multi-household buildings for instance is only an effective incentive if energy process are high enough.
- Economic incentives must be set in a socially responsible manner. Instead of lowering energy prices for social reasons, adapting transfers and maintaining the efficiency incentive seems to be more promising without reducing social security (a package concept).
- If energy efficiency gains lead to decreasing energy expenditure and thus to increasing rebounds, they

should be coupled with energy taxation which makes sure that the average energy cost is at least not sinking, and increasing for the laggards not making use of energy efficiency improvement opportunities.

Education and information

- Consumer education should focus on making people familiar with energy sensitive behavioural routines, in particular in the use of heat (for room heating and warm water). For this behalf, all members of a family could be addressed (parents most effectively learn from their children), like in the case of "stop stand-by" information. Product design plays a major role in this case.
- Regarding information relevant for purchasing decisions, the target group should be analysed and the information specified. For instance, for durable consumer goods it is adults taking the decision, and for white goods women dominate while for technical equipment like TVs males have a higher influence (and are less energy efficiency sensitive). Communication linking efficiency to modernity might be more effective than emphasising energy saving potentials.
- Training measures should not only target households and their in-house energy management, but also enhance the qualification of local authorities supervising standard implementation, and the respective businesses.

As this overview of success factors has illustrated, energy efficiency improvements in the residential sector differ significantly between countries, be it EU Member States or beyond. No country can claim to "have it all got right" – there is ample opportunity for learning from each other. That is why exchanging experience and good practice, such as analysed in this report, is crucial. For instance the BigEE web portal ("BigEE – Your Guide to Energy Efficiency in Buildings") is such a sharing tool, comprising an information instrument about design and technologies (how to upgrade to ultra-low-energy buildings, making them the standard), a policy guide (learning from advanced countries how to assist markets in becoming energy-efficient) and an appliances guide (how to get super-efficient appliances). While EUFORIE does not contribute to the third module, it offers elements for the first and a complement for the second, adding the policy framing, norms and standards, regulations and planning to the market focus of the BigEE policy guidance. Integrating both administrative and market-oriented approaches offers an opportunity to strengthen and accelerate the transition towards low energy, low carbon household performances throughout the Union.

5. Counterproductive Factors

- Falling short of implementing the EU targets like Finland, Romania, Croatia, Cyprus, Greece, and Portugal. Most MS implement the Directive and nothing but the directive, only few make use of the possibility to set a number of more ambitious targets (Hungary, Italy, Spain, Denmark). As the directives lag behind what is technically possible and environmentally desirable (in particular after the Paris agreements), sharpening the standards in the coming revision is advisable.
- Applying energy efficiency measures (standards, guidelines, financial incentives) to new constructions, or to major renovations (size matters – the UK took steps to exempt smaller renovations from efficiency standard application) without a clear program addressing the building stock. Spain sets such targets for the building stock and is among the MS with the lowest household energy consumption.
- Using energy efficiency to enable lower energy prices for households and industry (Romania), pursuing the reduction of energy cost (Finland) and considering energy price a matter of competitiveness (Hungary). Economic considerations should not neglect the fact that instruments such as energy efficiency standards (e.g. Energy Performance of Buildings Directive) and energy pricing have been one of the main drivers of innovation.
- Building sustainability indices aggregating energy, water and waste issues pose the risk of camouflage – progress in one field can cover-up deficits in another. A certified Building Pass with standardised catego-

ries similarly informs households before renting or buying, but leaves less room for misinterpretations; it can be combined with ratings to allow for easy comparison, but should also include absolute figures.

- A serious obstacle to achieving improved energy efficiency in the residential sector, not only to privately owned housing, is if house owners experience excessive administration and procurement procedures, delays and cost, as reported from Latvia.
- Reliance on informational methods seems to be a safe receipt for failure – they can accompany other tools to enhance public acceptance but were found to be ineffective on themselves.
- Economic incentives can be effective, but carry the risk of regressive effects. Enhancing social distribution problems can put energy efficiency policies at risk. On the other hand, regional and social targeting (overcoming energy poverty) may increase the standing of energy efficiency policies.

6. One research suggestion

Already two decades ago a Dutch study found that energy saving – energy costing about 2% of business expenditure – was not a paying investment, but if combined with resource efficiency, the balance was attractive (Gielen et al. 1996). Not narrowing down the horizon in case of cost problems but widening the perspective and increasing the ambition turned out to be the economically most promising solution. No such studies are available for the household sector; further research on this aspect is warranted.

This refers in particular to studies not analysing changes in single behavioural traits but the transformation of complex household consumption habits which are not necessarily focussed on energy but in the course of transition will affect the energy consumption significantly. For instance, giving up auto-mobility leads to changing time schedules, mobility planning, meeting arrangements and the like – a social process as much as an individual decision.

While the research deriving its hypotheses from the Theory of Rational Behaviour has often produced prescriptions failing its intention, the Social Practice Theory can accommodate the complex social contexts of consumption decisions, but hardly leans itself to providing policy tools for change.

The weakness of both bodies of theory and the need for a synthesis will be analysed and discussed, first elements presented and conclusions for policy instrument selection drawn in D5.3.

7. References

Allcott, H. (2011). Social norms and energy conservation. Journal of Public Economics 95(9): 1082-1095.

Allcott, H., Greenstone, M. (2012). Is there an energy efficiency gap? The Journal of Economic Perspectives 26(1): 3-28.

Ameli N., Brandt, N. (2014). Determinants of households' investment in energy efficiency and renewables – evidence from the OECD survey on household environmental behaviour and attitudes. OECD Economics Department Working paper series 1165.

Bertoldi, P., Economidou, M. (2016). The assessment of the Member States National Energy Efficiency Action plans: will the EU reach the 2020 target? International Energy Policy and Programme Evaluation Conference 2016. http://www.ieppec.org/wp-content/uploads/2016/05/Paper-Bertoldi-2.pdf.

BigEE – Your Guide to Energy Efficiency in Buildings, accessible at URL: http://www.bigee.net/

CECILIA 2015. Final Project Report. Accessible for download at http://cecilia2050.eu/system/files/Huppes%20and%20G%C3%B6rlach%20%282015%29_Towards%20optimal%20short%2C%20medium%20and%20long%20term%20climate%20policy%20instrumentation_0.pdf

Danlami, A.H., Rabiul, I., Dewi Applanaidu, S. (2015). An Analysis of the Determinants of Households' Energy Choice: A Search for Conceptual Framework. International Journal of Energy Economics and Policy 5(1): 197-205.

Eakins, John (2013). An Analysis of the Determinants of Household Energy Expenditures: Empirical Evidence from the Irish Household Budget Survey. PhD thesis, University of Surrey

European Commission (2002). Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings, OJ L1, 4.01.2013.

European Commission (2009). Synthesis of the complete assessment of all 27 National Energy Efficiency Action Plans as required by Directive 2006/32/EC on energy end-use efficiency and energy services. http://www.uni-mannheim.de/edz/pdf/sek/2009/sek-2009-0889-en.pdf

European Commission (2010). Directive 2010/31/EU of the European Parliament and of the Council of 19 May on the energy performance of buildings.

European Commission (2012). Directive 2012/27/EU on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC. OJ L315, 14 November 2012.

European Commission (2015). Energy Union Package COM(2015) 80 final. http://eur-lex.europa.eu/resource.html?uri=cellar:1bd46c90-bdd4-11e4-bbe1-01aa75ed71a1.0001.03/DOC_2&format=PDF

Gielen, D., Kram, T., Ybema, R. (1996). Integrating energy and materials strategies for greenhouse gas reduction: a promising challenge. CHANGE(30): 10-12.

Gillingham, K., Palmer, K. (2014). Bridging the energy efficiency gap: Policy insights from economic theory and empirical evidence. Review of Environmental Economics and Policy 8(1): 18-38.

Jaffe, A.B., Stavins, R.N. (1994). The energy-efficiency gap What does it mean? Energy policy 22(10): 804-810.

Kallbekken, S., Sælen, H., Hermansen, E.A. (2013). Bridging the energy efficiency gap: A field experiment on lifetime energy costs and household appliances. Journal of Consumer Policy 36(1): 1-16.

Mills, B. Schleich, J. (2010). What's driving energy efficient appliance label awareness and purchase propensity? Energy Policy 38(2): 814-825.

Noailly, J. (2012). Improving the energy efficiency of buildings: The impact of environmental policy on technological innovation. Energy Economics 34: 795-806.

Odyssee database, URL: http://www.indicators.odyssee-mure.eu/energy-efficiency-database.html , accessed June 1st, 2017.

Annex: Energy efficiency in the residential sector: identification of promising policy instruments and private initiatives among selected European countries. *Energy Efficiency 11*, 2111–2135. Trotta, Gianluca, Joachim Spangenberg and Sylvia Lorek (2018).

Energy Efficiency (2018) 11:2111–2135
https://doi.org/10.1007/s12053-018-9739-0

ORIGINAL ARTICLE

Energy efficiency in the residential sector: identification of promising policy instruments and private initiatives among selected European countries

Gianluca Trotta · Joachim Spangenberg · Sylvia Lorek

Received: 21 April 2017 / Accepted: 25 September 2018 / Published online: 5 October 2018

Abstract Improving residential energy efficiency is widely recognised as one of the best strategies for reducing energy demand, combating climate change, and increasing security of energy supply. However, progress has been slow to date due to a number of market and behavioural barriers that have not been adequately addressed by energy efficiency policies and programmes. This study is based on updated findings of the European Futures for Energy Efficiency Project that responds to the EU Horizon 2020 Work Programme 2014–2015 theme 'Secure, clean and efficient energy'. This article draws on five case studies from selected European countries—Finland, Italy, Hungary, Spain, and the UK—and evaluates recent energy efficiency developments in terms of indicators, private initiatives, and policy measures in the residential sector. Our analysis shows that the UK government has implemented a better range of policies, coupled with initiatives from the private sector, aimed at improving energy efficiency. However, its existing conditions appear to be more problematic than the other countries. On the other hand, the lack of effective and targeted policies in Finland resulted in increased energy consumption, while in Hungary, Spain and Italy some interesting initiatives, especially in terms of financial and fiscal incentives, have been found.

Keywords Energy efficiency policy · Residential sector · European Union · NEEAPs · ESCOs

Introduction

Energy efficiency is widely considered as the most cost-effective way to enhance the security of energy supply and to reduce the emissions of greenhouse gases. In fact, the cheapest energy, the cleanest energy, the most secure energy is the energy that is not consumed at all (EC 2016a). Furthermore, energy efficiency improvements are thought to have the potential to support economic

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s12053-018-9739-0) contains supplementary material, which is available to authorized users.

G. Trotta (✉)
School of Accounting and Finance, Economics, University of Vaasa, Wolffintie 34, 65200 Vaasa, Finland
e-mail: Gianluca.Trotta@seri.de

G. Trotta · J. Spangenberg · S. Lorek
Sustainable Europe Research Institute, Vorsterstr. 97-99, D-51103 Cologne, Germany

J. Spangenberg
e-mail: Joachim.Spangenberg@seri.de

S. Lorek
e-mail: Sylvia.Lorek@seri.de

growth and social development, to improve occupant health and well-being, and to enhance competitiveness and investment opportunities (IEA 2014a).

In the last years, the European Commission has acknowledged these benefits in a series of directives and long-term strategy documents—such as the Energy Performance of Buildings Directive 2010/31/EU, the Energy Efficiency Directive 2012/27/EU, the Energy Roadmap 2050, etc.—by establishing a set of measures for improving the existing policy framework of measures and promoting energy efficiency within EU. In addition, the new 32.5% energy efficiency target for 2030 (with an upwards revision clause by 2023) agreed on 14 June 2018 by negotiators from the Commission, the European Parliament, and the Council[1] put the level of ambition of European energy efficiency policies into sharp focus. These regulations and policy documents have been mainly designed to meet the EU climate policy goals, i.e. an 80% reduction of CO_2 emissions by 2050, but they are still not in line with the commitments under the Paris climate treaty which would require even more efforts—so for the future stricter rather than relaxed regulations can be expected.

The residential sector is one of the most significant single sectors for energy consumption presenting high cost-efficient potentials for mitigation, and it is consequently vital to meeting the EU objectives towards a low-carbon economy and energy system. Nevertheless, recent years' experience has shown that there are considerable barriers to fully realise economically effective and technically feasible energy savings opportunities (Gillingham and Palmer 2014; Frederiks et al. 2015a; EC 2016b; Knoop and Lechtenböhmer 2017).

In compliance with the Energy End-Use Efficiency and Energy Services Directive 2006/32/EC (ESD) and Energy Efficiency Directive 2012/27/EU (EED), Member States are required to translate the energy savings objectives into domestic and effective measures in their National Energy Efficiency Action Plans (NEEAPs). But there exists a wide disparity in terms of content, level of detail in describing, and the level of ambition about the energy efficiency instruments in place and planned for the next years between Member States. At the same time, the energy share of residential sector strongly varies among countries due to different energy infrastructures, climate conditions, energy resource availability, income, economic structure (IEA 2014b), dwellings' characteristics, household characteristics (Mills and Schleich 2012), lifestyles (Lorenzen 2012; Thøgersen 2017), household behaviour (Lopes et al. 2012; Frederiks et al. 2015a), and other country-specific conditions.

Therefore, the type of policy instrument suitable for driving energy efficiency depends on many country and sector specifics, and the circumstances determine which policy instruments are more appropriate than others.

Although policy makers have a decisive role to play in reducing energy consumption in the residential sector, there are many other players that can stimulate energy efficiency improvements:

- Energy utilities could provide advice and assistance to energy consumers, technology development, on-bill financing, etc.;
- Energy Service Companies (ESCOs), under an Energy Performance Contracting (EPC) arrangement, implement an energy efficiency project and use the stream of income from the cost savings to repay the costs of the project;
- National or local energy agencies promote training and information campaigns to help people to save energy and provide support to public administrations in the preparation, implementation, and control of energy efficiency policies;
- National or regional banks, public or private, might develop specific packages for households to support energy efficiency improvements, renewable energy and broader green investments.
- Non-Governmental Organisations (NGOs) and consumer organisations promote energy efficiency through advice to and training of citizens, and by acting as political pressure groups.

A comprehensive review of all energy efficiency policies and private initiatives in the residential sector of the European Union is beyond the scope of this (and any other) paper, and given the diversity of local circumstances influencing the success of policy measures, the authors do not try to identify a 'best practice', let alone search for silver bullets or no one-size-fits-all approach solutions. Nonetheless, the authors assume that policy design matters, and try to identify some meta-level characteristics found by comparing promising recent residential energy efficiency policies and private initiatives in five case countries—Finland, Hungary, Italy, Spain, and the UK.

[1] http://europa.eu/rapid/press-release_STATEMENT-18-3997_en.htm

Most of the literature focuses on the analysis of the energy efficiency policies by the type of instrument (regulatory, economic, informational, etc.) without considering (i) the underlying determinants driving the design of a specific policy and (ii) the coherence among policies creating synergies towards the achievement of higher levels of energy efficiency. A recent review within the context of energy efficiency policies mix in buildings (Rosenow et al. 2016) supports this view. In addition, to the best of the authors' knowledge, the analysis of the role of the private sector in supporting the national government in stimulating energy efficiency investments in the residential sector has received little attention.

The remainder of the paper is organised as follows. Section 2 provides a brief literature review about energy efficiency policies and barriers; the identified barriers are used as basis for the subsequent analysis of policies. Section 3 describes the data and method used in this study; Section 4 illustrates data and information about the residential energy sector with indicators of energy efficiency; Section 5 analyses the main policy initiatives implemented in the European countries under investigation addressing the barrier identified in Section 2; Section 6 investigates the private initiatives that stimulate energy efficiency improvements; Section 7 offers some hints regarding the effectiveness of the policy packages implemented by presenting a cross-country comparison of energy efficiency progress; and Section 8 concludes by offering some explanations for obvious policy failures on the national level, and by deriving some meta-level success criteria for future European residential sector energy efficiency policy.

A brief literature overview

Despite the proven cost-effective energy efficiency opportunities for reducing energy consumption and related emissions in the residential sector, several studies consistently indicate that a large potential for the existing building stock remains untapped (see Gillingham and Palmer 2014 for an overview). In addition, improvements in energy efficiency do not regularly lead to one-to-one reductions in energy consumption (Galvin 2014), as energy efficiency gains alter the perceived cost of comfort and may thereby generate shifts in consumption patterns—a 'rebound effect' (Aydin et al. 2017). This discrepancy between the expected/realised energy savings and the optimal/actual investments in energy-efficient technologies is often referred to as the 'energy efficiency gap' or 'energy efficiency paradox', which has been illustrated and examined in multiple articles (York 1978; Stern 1992; Jaffe and Stavins 1994; Schleich and Gruber 2008; Chai and Yeo 2012; Allcott and Greenstone 2012; Kallbekken et al. 2013; Ameli and Brandt 2015; Brown and Wang 2017; Gerarden et al. 2017). There is a substantial literature on the barriers to energy efficiency and on the importance of appropriate policy responses and actions in overcoming these impediments and stimulating investments (see Gillingham et al. 2009 for an overview). Low levels of investments in energy efficiency have long been associated with market failures, which are considered to be among the most important barriers to energy efficiency in the residential sector, assuming 'rational' (i.e. utility maximising) behaviour. Commonly cited market failures include the following: (i) 'credit constraints' that prevent consumers from investing in energy efficiency solutions; (ii) 'imperfect information for consumers' about the energy savings from purchasing more energy efficient products, thus undermining incentives to invest in them; and (iii) 'landlord-tenant problem', that is when landlords have little incentive to invest in the energy efficiency of their properties, given that it is the tenant who benefits from lower energy bills (Allcott and Greenstone 2012). Thus, we analyse measures offering financial facilities to encourage private capital investments and fiscal incentives indirectly reducing the cost of investments, increasing consumer information, and measures addressing the landlord-tenant problem.

However, there can also be a state or policy failure in that plans, standards, and regulations are either not ambitious enough or the enforcement is missing. To cover this aspect, we address the energy performance standards of new and existing buildings as a potential obstacle and their improvement as an efficiency opportunity.

More recently, several authors have supplemented the state and market failure approach with insights from behavioural economics and psychology. Behavioural barriers such as heuristic-decision making, status quo bias, loss and risk aversion, endowment effects, temporal and spatial discounting, and normative social influence offer a more realistic view of the consumer decision-making process (Pollitt and Shaorshadze 2011; Gillingham and Palmer 2014; Sallee 2014; Frederiks et al. 2015a). They are addressed by information promoting behavioural change, energy performance standards, and specific measures for vulnerable consumers and against fuel poverty.

Methodological approach

Data sources

This paper draws on research undertaken for the EU H2020 project EUFORIE (European Futures for Energy Efficiency), in particular on seven European country reports (Finland, Hungary, Italy, Latvia, Romania, Spain, and the UK)[2] covering a wide range of policies and private initiatives addressing energy efficiency in the residential sector (D5.1)[3] and their analysis (D5.2).[4] Main EU laws, policies, and related documents (e.g. the Energy Efficiency Directive 2012/27/EU) were taken from public sources, mainly the EU law database.[5] The in-depth analysis of the third NEEAPs and other national policy documents is also based on D5.1 and supported by literature sources (Bertoldi and Economidou 2016; Economidou and Bertoldi 2018).

The country reports have been compiled with the help of national experts and are based on their country analyses. They had not only the language capabilities to analyse national language information material, but also the knowledge of where to find the appropriate information. Additionally, in some cases, the collection of information has been supported by interviewing external stakeholder with expertise in the residential energy sector and energy efficiency.

An extensive use was made of the Odyssee database, which contains detailed data on energy consumption and related CO_2 emissions (Odyssee database 2017). Odyssee data on energy consumption are complemented with data on residential building stock taken from national statistics databases. This is because there exists a strong correlation between dwelling characteristics—age, tenure, type, size—and the energy consumption and thermal efficiency performance of buildings (Huebner et al. 2015; Trotta 2018a), in addition to household composition, income, and behavioural traits (Danlami et al. 2015; Frederiks et al. 2015b; Trotta 2018b). To keep the sample size manageable, while ensuring a broad coverage of the European countries, in this study we focus our analysis on five countries: Finland, Hungary, Italy, Spain, and the UK.

Methodology

In order to provide a picture of the European Union and the countries under investigation, we first introduce a broadly accepted set of energy efficiency indicators used by the International Energy Agency (IEA 2014b; IEA 2014c). Then, we examine the residential energy efficiency policies in force by providing relevant information about the promising strategies adopted by the countries under investigation.

The promising strategies were selected from the country studies based on assessment if they addressed the key physical, social, and behavioural obstacles to increasing domestic energy consumption known from the literature. As no detailed data about the effectiveness of certain instruments in specific contexts (legal, institutional, political majorities and traditions, or age, ownership and state of the building stock, etc.) are available, policy strategies intentionally addressing these objectives have been classified as ‘promising’ (see EUFORIE Deliverable D5.2).

Since this paper is based on country data, we do not discuss *which obstacles should have been addressed by what means*, but describe *which obstacles have been addressed by which measures*. Moreover, we analyse the role of the private sector in stimulating the investments in energy efficiency and complementing European and national public policies. In conclusion, we offer some hypotheses explaining obvious policy failures on the national level, indicating where there is room for improvement, and draw some conclusions—albeit on a meta-level—for EU residential energy policies.

The EU residential energy sector

The residential sector accounted for about a quarter of the total final energy consumption in Europe in 2015. This is only an EU average, and there exists a wide disparity of the share of the residential energy sector among countries due to climate condition, resource

[2] http://www.utu.fi/en/units/euforie/Research/deliverables/country-reports/Pages/home.aspx
[3] Trotta, Gianluca and Lorek, Sylvia (2018). D5.1. http://www.utu.fi/en/units/euforie/Research/deliverables/PublishingImages/Pages/home/D%205%201%20_Stocktaking_of_instruments_targetting_household_energy_efficiency.pdf
[4] Spangenberg, Joachim (2018). D5.2. http://www.utu.fi/en/units/euforie/Research/deliverables/Documents/D5%202%20Identification%20of%20promising%20instruments%20and%20instrument%20mixes%20for%20energy%20efficiency.pdf
[5] http://eur-lex.europa.eu/homepage.html

availability, energy infrastructure, economic structure, and other country-specific conditions. For example, among the countries under investigation, in Spain the residential sector represented only 18.5% of the total energy consumption in 2015, while in Hungary and the UK it was 34.9 and 28.6%, respectively; in Finland it represented 20%, while in Italy it was 27.9% (Odyssee database 2017).

At EU level, the space heating consumption is assumed to hold the largest portion of households energy use representing 65% in 2015 (Odyssee database 2017), followed by the electricity consumption for electrical appliances and lighting (15.9%), water heating (13.7%), and cooking (5.4%). A similar composition of the energy consumption by end-use is found in Finland, Hungary, Italy, the UK, but not in Spain where the portion of space heating is lower and electricity consumption is higher than the other European countries.

For each end-use, we selected the indicators of energy efficiency suggested by the International Energy Agency (IEA 2014b; IEA 2014c), namely the final residential energy consumption per stock of permanently occupied dwellings (at normal climate),[6] the final residential space heating consumption per floor area 1990–2015 (at normal climate), and the final water heating, cooking, electrical appliances, and lighting consumption per stock of permanently occupied dwellings.

While these detailed indicators do not fully explain what is driving the changes in observed energy consumption, they provide indications about recent trends, and combined with implemented European and national policy and private instruments aimed at reducing energy consumption and CO_2 emissions, they can provide some guidance on the efficiency improvements achieved in the residential sector and allow for cross-country comparisons.

In order to compare the residential energy building performance of the European countries under investigation, we use the final residential energy consumption per stock of permanently occupied dwellings 1990–2015 (at normal climate) as indicator (Fig. 1).

Finland had the highest residential energy consumption per stock of permanently occupied dwellings in 2015 followed by Hungary, Italy, the UK, and Spain. Although Finland, Italy, and Spain did not decrease their consumption, in the European Union the final residential energy consumption per stock of permanently occupied dwellings decreased by 21.8% between 1990 and 2015.

To build more detailed indicators of energy efficiency, it is necessary to disaggregate data further, and to understand which end-use has driven energy consumption in the last years. The energy end-use consumption data (e.g. space heating, lighting) are based on modelling or estimates (e.g. national surveys) as in large-scale assessment it is not possible to measure the distribution of residential energy consumption by end-use directly.

Figure 2 shows the final residential space heating consumption per floor area 1990–2015 (at normal climate) for the European Union and selected countries (kgoe/m^2).

Space heating consumption per floor area decreased in all Member States (on average) between 1990 and 2015 (Odyssee database 2017). The lower space heating consumption per floor area could be explained by more stringent energy efficiency requirements for buildings, appliances, and heating technologies, partly due to the progressive implementation of the Energy Performance of Buildings Directive in 2002 (2002/91/EC) and 2010 (2010/31/EU). With the exception of the UK where high potential for reducing space heating consumption exists, no or small improvements have been found in the other countries during the period under consideration.

However, it is important to note that this indicator of energy efficiency for space heating do not provide any information about the infrastructural components of energy consumption, such as for instance the construction year of the dwellings. In fact, the age of a dwelling usually affects its energy efficiency, and older homes typically have poorer insulation than modern homes. For example, as shown in Fig. 3, in the UK approximately 70% of the existing residential dwelling stock was built before the first national Building regulations in 1965 that set up minimum standard for insulation entered in force. Before this time, solid walls, un-filled cavity walls, single glazing, un-insulated roofs, and uninsulated floors were common construction features (Dowson et al. 2012). On the other hand, Spain has experienced a strong boom in construction in the last years: approximately 30% of the existing dwelling stock was built after 2000.

With regard to the others residential end-use efficiency, on average the combined final energy consumption

[6] 'Normal climate' or 'climate correction' is an adjustment to space heating and cooling energy consumption to normalise the consumption pattern over time by removing the impact of year-to-year temperature variations (IEA 2014b; IEA 2014c; Odyssee database 2017).

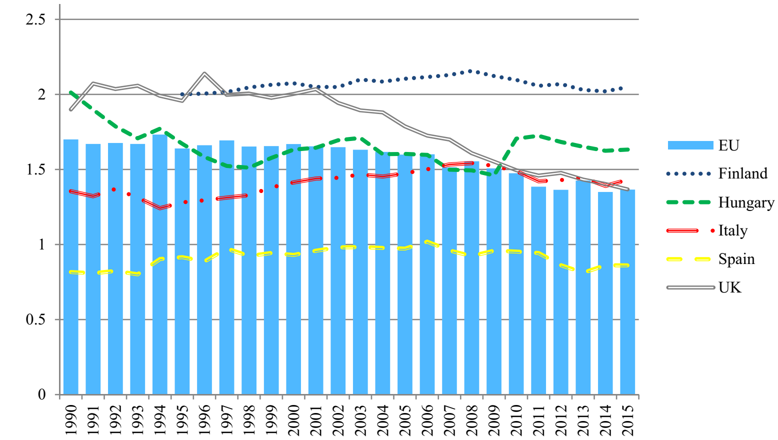


Fig. 1 Final residential energy consumption per stock of dwelling permanently occupied 1990–2015 (at normal climate) for the European Union and selected countries (toe/dwellings)

of water heating and cooking (per stock of permanently occupied dwellings) decreased in the European Union, Italy, Spain, the UK, and Hungary between 1990 and 2015 (Fig. 4), while the electricity consumption for household appliances (and lighting) increased in the European Union on average, in Hungary and Spain.

Policies and measures to remove energy efficiency barriers in the residential sector

In the next paragraphs, we analyse the energy efficiency policies that have been recently implemented in the residential sector of Finland, Hungary, Italy, Spain, and the UK, with reference to the barrier and/or specific target addressed, as follows:

- Improving the energy performance standards of buildings and energy-related products;
- Financial facilities to encourage private capital investments;
- Fiscal incentives that indirectly reduce the cost of investments;
- Measures addressing vulnerable consumers and fuel poverty;
- Measures addressing the landlord-tenant problem;
- Increasing consumer information and promoting behavioural change.

The chapter shows that whereas there are quite a number of informational efforts (5.6) and incentives for energy efficiency (5.2, 5.3), hardly any country has thoroughly analysed the obstacles and none had comprehensive policies to overcome them. To the contrary: often other public policies are directly counterproductive to residential housing efficiency improvements (e.g. policies to keep energy prices as low as possible to stimulate economic growth). While standard setting dominates (5.1), social aspects play a minor role (5.4).

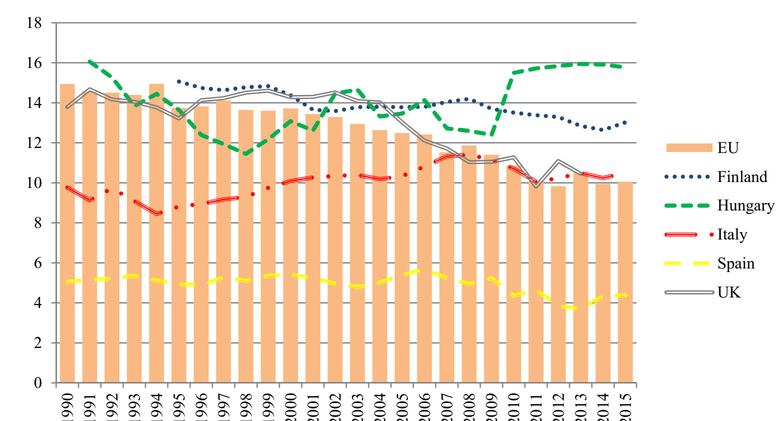
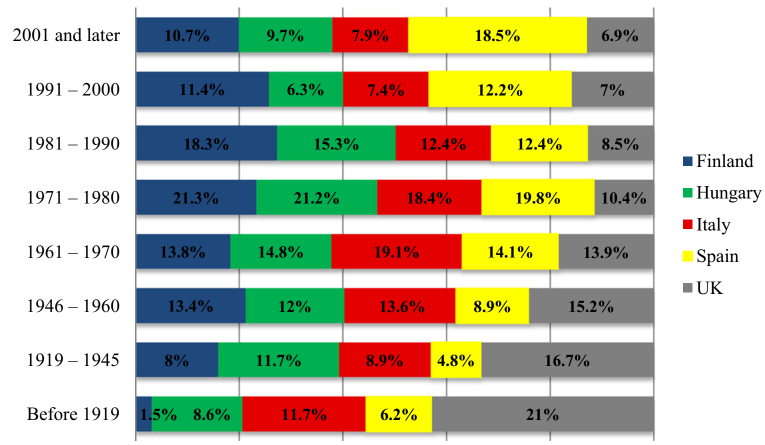


Fig. 2 Final residential space heating consumption per floor area 1990–2015 (at normal climate) for the European Union and selected countries (kgoe/m^2)

Fig. 3 Percentage of the dwelling stock by period of construction in selected countries



This chapter addresses the policy initiatives as identified in the country studies directed at the obstacles identified in the literature analysis, but does not discuss the missing policies that should be in place to eliminate these hindrances. An overview of the policies discussed in the next sections is provided in Table 1.

Improving the energy performance standards of buildings and energy-related products

Standards for buildings and energy-related products ensure that the desirable energy performance of e.g. building components and (especially) heating equipment is achieved even when its purchaser does not show interest in obtaining more efficient products due to either credit constraints or lack of incentives (IEA 2011).

Reviews of the literature on energy efficiency policy shows that instruments such as energy efficiency standards have been one of the main drivers of innovation (Noailly 2012), and the preferred policy option in the European Union to address barriers to energy efficiency (Bleischwitz et al. 2009). Broin et al. (2015) by using a panel of 14 EU countries to estimate the impact of efficiency policies affecting space heating demand in the residential sector have found that regulatory policies had a greater success than financial or informative instruments in the period 1990–2010. These findings are in line with results from previous studies of Saussay et al. (2012) and Filippini et al. (2014).

The Ecodesign Directive 2009/125/EC for Energy Related Products (ErP) and the 2010 recast Directive on Energy Performance of Buildings (recast EPBD, 2010/31/EU) are the main legislative instruments affecting energy use and efficiency of energy-related products and buildings in the EU, respectively. Both looked at energy efficiency beyond the immediate point of consumption, and entered into the design and lifelong energy use of household appliances, equipment, and new buildings. As integral part of the EPBD, the Energy Performance Certificates (EPCs) are an important tool

Fig. 4 Final water heating, cooking, electrical appliances, and lighting consumption per stock of dwelling permanently occupied in 1990 and 2015 for the European Union and selected countries (toe/dwellings)

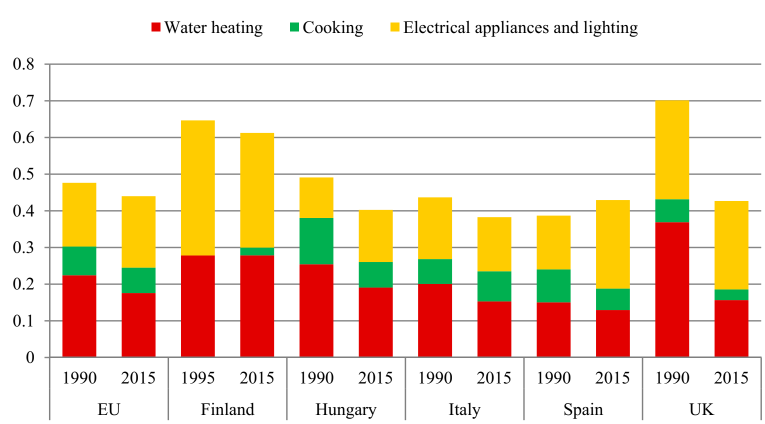


Table 1 Overview of the energy efficiency policies in the residential sector

	Finland	Hungary	Italy	Spain	UK
Improving the energy performance standards of buildings and energy-related products	• EPBD • ErP	• EPBD • ErP	• EPBD • ErP	• EPBD • ErP	•EPBD •ErP
Financial facilities to encourage private capital investments		• The Warmth of the Home Programme	• Thermal Account • Thermal Account 2.0	• State Housing Plan • PAREER-CRECE Programme	
Fiscal incentives that indirectly reduce the cost of investments	• A general tax reduction for any household services		• Tax deductions for the energy upgrading of buildings		
Measures addressing vulnerable consumers and fuel poverty			• (Social bonus)	• (Social bonus)	• Energy Company Obligation • Warm Home Discount
Measures addressing the landlord-tenant problem			• Regional Law 13/12/2013		• Landlord's Energy Saving Allowance • Green Deal • New Minimum energy efficiency standards
Increasing consumer information and promoting behavioural change	• Completed roll out of smart meters • Motiva	• Energy and Climate Awareness-Raising Action Plan • No smart meters • Energy Saving Trust	• Completed roll out of smart meters • Italian National Agency for New Technologies, Energy and Sustainable Economic Development	• Roll out of Smart meters by 2018 • Institute for the Diversification and Saving of Energy	• Roll out of Smart meters by 2020 • National Environmental Protection and Energy Center Nonprofit

to enhance the energy performance of buildings. They include a report that assesses the energy efficiency of a property and recommendations for cost-effective improvements. These certificates enable consumers to obtain information about the energy consumption of the dwelling they are going to buy or rent and are mandatory in EU countries each time there is a change of occupant or a sale. While new buildings can be constructed to be very efficient, the existing stock is predominantly of poor energy performance, having mostly been built before legal requirements concerning the use of energy were introduced and when there were very different expectations of thermal comfort. Furthermore, building components and technical systems are subject to deterioration over time, resulting in increased energy use to provide the same level of energy service.

By law, EPCs can only be produced by an accredited Energy Assessor. The accreditation schemes protect builders, owners, landlords, and tenants by making sure Energy Assessors have the appropriate skills to carry out energy assessments, and that EPCs are always of the same high quality. Nevertheless, the EPC schemes are not yet fully implemented in all Member States nor sufficiently enforced. Therefore, the EPCs' quality, credibility, and usefulness vary largely among Member States, and there is still a need to further support and set guidelines for the implementation of the EPC schemes at national level (Arcipowska et al. 2014). Today, performance certificates may be understood in different ways from one European country to the next, and definitions and certificate types can vary widely even within countries.

In a recent study commissioned by the DG Energy, the ICF Consulting Group analysed the national frameworks and systems put in place by Member States to help deliver and achieve compliance with the Energy Performance of Buildings Directive (EPBD) in relation to the EPCs and the minimum energy performance (MEP) requirements for buildings, building elements, and technical building systems (EC 2015). Among the countries under investigation, Italy received a higher score in terms of compliance rate with the application of MEP requirements and production and use of EPCs placing fifth in the EU Member States' ranking, followed by the UK (seventh position), Finland (tenth position), Spain (13th position), and Hungary (15th position).

Most of the Member States reported a high compliance rate for MEP requirements. Spain and Hungary failed to comply with the production of EPCs in rented buildings, while Italy has not produced EPCs for public buildings.

Financial facilities to encourage private capital investments

Financial incentives can take many forms—grants, subsidies, soft loan, etc.—and are commonly used to encourage energy efficiency improvements by lowering inhibitive upfront costs faced by households.

In Hungary, the main financial instrument managed by the central government to promote investments aimed at furthering energy efficiency in households is a grant scheme called the 'Warmth of the Home Programme'. The Warmth of the Home Programme was launched in September 2014 and till date there have been five sub-programmes implemented focusing on the following aspects: (1) the modernisation of heating systems (replacement of inefficient heating boilers)—HUF 1.2 billion (c.a. € 3.85 million); (2) support to the complex energetic refurbishment of blocks of flats 2015—HUF 11.8 billion (c.a. € 37.9 million); (3) the replacement of energetically obsolete facade doors and windows 2014—HUF 876 million (c.a. € 2.8 million); (4) the replacement of inefficient refrigerators and freezers with new efficient ones 2014—HUF 780 million (c.a. € 2.5 million), and 2016—HUF 1.5 billion (c.a. € 4.8 million); (5) the replacement of inefficient washing machines with new efficient ones—HUF 1.2 billion (c.a. € 3.85 million). All of them provided co-financing up to a maximum of 40 or 50% of the total expenses incurred by the households (Hungary's NEEAP 2014; UNFCCC 2016).

Due to overwhelming interest on the part of households, the sub-programme funds have been sourced out fully after announcement, either within hours, or after a few days the latest (Slezák et al. 2015). Over 85,000 households benefitted from these programmes, but the allocated government budget (HUF 17.3 billion, c.a. € 55.7 million) did not satisfy all the requests from households. To meet the high demand, the Hungarian government has recently announced that from the spring of 2018 the Warmth of the Home Programme will be refinanced. Households can receive a reimbursement of up to 40 or 90% of the total expenses incurred, and in some cases (e.g. vulnerable households) they can claim a reimbursement of up to 100%.

The Thermal Account, introduced by the Ministerial Decree of 28 December 2012 'Renewable Energy for Heating & Cooling Supporting Scheme' (Legislative Decree No 28/2011), is the first nationwide and the youngest direct incentive scheme in Italy for projects of energy efficiency improvements and the generation of small-scale renewable thermal energy in buildings. The Thermal Account supports the following projects:

- Energy efficiency improvements in existing building envelopes (thermal insulation of walls, roofs, and floors; replacement of doors, windows, and shutters; installation of solar screens);
- Replacement of existing systems for winter heating with more efficient ones (condensing boilers);
- Replacement and, in some cases, construction of new renewable energy systems (heat pumps, biomass boilers, heaters and fireplaces, solar thermal systems, including those based on the solar cooling technology).

The scheme is addressed to both public administrations and private parties (i.e. individuals, apartment block owners, and parties with business or agricultural income). The incentive covers part of the costs incurred and is paid out in annual instalments for a period from 2 to 5 years according to the actions implemented. Since its implementation in July 2013 until December 2015, eligible private beneficiaries submitted around 17,407 applications, among which approximately 8000 in 2015 (GSE 2015; GSE 2016). Approximately 0.54 Mtoe/y savings by 2020 are expected to come from the implementation of the Thermal Account in the residential sector (Italy's NEEAP 2014).

With the Ministerial Decree of 16 February 2016, the new Thermal Account 2.0 entered into force the 31st of May 2016. It provides incentives for € 900 million per year, of which 700 for private sector and 200 for public entities, over the next 5 years. The new Thermal Account 2.0 introduced simplified access mechanisms, included the housing cooperatives in the list of private eligible beneficiaries, introduced new types of improvements subject to the incentives, and increased the reimbursement limits of the projects (65% of the total expense incurred). In addition, it states that private entities should receive reimbursement of up to € 5000 (instead of € 600) in one single instalment within 2 months from the request submission.

In Spain, the Royal Decree 233/2013 of 5 April 2013 of the Ministry of Development approved the State Housing Plan aimed at promoting the energy renovation of residential buildings. The main functions of the State Plan 2013–2016 were underlined in its preamble: 'to adapt the aid system to the current social needs and to the scarcity of resources available, concentrating them on two issues: the promotion of tenancy and the promotion of rehabilitation and urban regeneration and renewal.' The plan was funded by the Directorate General of Architecture, Housing and Land (€ 2.311 million) and the Autonomous Regions (€ 216 million). Measures eligible for subsidy include the following: improving the thermal envelope of buildings to reduce energy demand for heating and cooling; installing heating, cooling, domestic hot water and ventilation systems and common building facilities such as lifts and lighting. To qualify for subsidies, the building's total annual energy demand in terms of heating and cooling must be reduced by at least 30% compared to the levels taken before implementation of the measures, as demonstrated by the energy certificate. Up to 35 or 50% of the eligible costs of the action, with a maximum of up to € 11,000 per house or 100 m^2 of the premises useful surface could be claimed. Beneficiaries of assistance from this programme include owners' associations, groups of owners' associations, or individual owners of residential buildings as well as public administrations and public-law entities.

Despite a general positive valuation of the government about the results obtained by the State Plan in driving efficient renovation in buildings, many points of criticism have been raised by different stakeholders. In particular, a slow implementation of the Plan combined with problems of communication and the lack of widespread publicity dissuaded many potential applicants from applying.

In combination with the State Plan, but more specifically targeted to energy efficient retrofit measures in the residential sector, the Ministry of Industry, Energy and Tourism through the Institute for Energy Diversification and Saving (IDAE) has recently launched the PAREER-CRECE Programme 'Aid programme for integral energy efficiency and saving projects in residential buildings'. It is a specific aid and financing programme amounting to € 207 million that encouraged and promoted the (i) upgrade of the energy efficiency in the thermal envelope, (ii) upgrade of energy efficiency in thermal and lighting installations, and (iii) replacement of conventional energy by thermal biomass or geothermal energy in building thermal installations. Eligible beneficiaries of the aids from this Programme are natural and legal persons, owners of residential and hotel buildings, owners of single-family houses or sole owners of residential buildings, associations of property owners or associations of residential-building property owners, and ESCOs. All types and beneficiaries were entitled to receive a money allowance without consideration, supplemented with a refundable loan, varying from 20 to 30% of the total investment costs. Aid could be requested from the 5th of May 2015 to the 31st of December 2016.

Fiscal incentives that indirectly reduce the cost of investments

Fiscal incentives for the energy efficiency in buildings include several measures to lower the taxes paid by consumers and are one of the instruments that can be used by Member States to promote and facilitate efficient use of energy among domestic costumers (EED, article 12 (2a)).

Fiscal incentives have been traditionally common in Italy and Finland. Tax deductions for the energy upgrading of buildings were introduced in Italy by the Budget Law 2007 and are still in force. They consist of reductions of IRPEF (personal income tax) and IRES (corporate income tax) in respect of actions to improve the energy efficiency of existing buildings, in particular for expenses incurred to:

- Reduce heating demand by means of overall upgrading of the building's energy performance;

- Improve the building's thermal insulation (replacement of windows, including blinds and fittings, and insulation of roofs, walls, and floors);
- Install solar thermal panels;
- Replace winter heating systems (with condensing boilers or heat pumps);
- Replace electrical water heaters with heat pump water heaters.

The total deductible amount is then distributed over a period of 10 years. These deductions have been key drivers of energy efficiency improvements in the housing sector helping to achieve final energy savings of 1.066 Mtoe between 2011 and 2015 and are expected to be the largest contributor of the final residential energy savings in 2020 (Italy's NEEAP 2014). In total, from 2007 to 2013, the intervention that benefited more from tax deductions has been the replacement of windows (including blinds and fittings), representing 56.2% of the total incentive; it was followed by intervention for efficient heating system (27.4%), replacement water boiler (12.2%), multiple selection (2.6%), and overall renovation (1.3%).

The tax deduction scheme has been renewed on a yearly basis. Also, the Decree Law No 63/2013 (converted by Law No 90/2013) increased the tax deduction rate from 55 to 65%. This led to an increase of more than one third of requests of tax deductions compared to the year 2012 (when the rate was 55%).

The International Energy Agency mentioned this measure as a best practice at international level (IEA 2014c), with specific reference to its role in spreading energy efficiency culture at local level. Indeed, between 2007 and 2014, more than 2 million of interventions have been realised, and in 2013 households had invested € 22 billion, with a cost of € 13 billion in terms of foregone fiscal revenue (Concerted Action Energy Efficiency Directive 2016).

A tax deduction for the labour costs incurred in replacing, upgrading, and repairing the heating and electricity systems of residential houses has been available in Finland since 2000. The maximum amount of household deduction varied according to the year it has been claimed. The house owner bears the first €100 of the labour costs and the deduction is available for the taxation of both spouses. In 2017, the maximum credit that can be deducted is € 2400 per person, and it is available during the year when the claimer has to pay an invoice to a service-provider company or to pay wages to someone he employs.

Measures addressing vulnerable consumers and fuel poverty

The EED article 7 (7a) allows EU Member States to include requirements with social aims in their Energy Efficiency Obligation Schemes,[7] as for example to prioritise households in energy poverty or social housing. However, most of the Member States have not translated this requirement into national legislation, if not through one-off measures. The UK is one of the few EU Member States where this problem is both recognised and systematically addressed by means of household support policies and energy efficiency investments (Bouzarovski 2014). The Energy Company Obligation (ECO), which started in 2013, is a government scheme for Great Britain that placed legal obligations on larger energy companies to deliver energy efficiency measures to domestic premises targeted at low-income and vulnerable households, and homes in low-income areas. In particular, ECO has three distinct targets:

- The Carbon Emissions Reduction Obligation (CERO) which focuses primarily on the installation of insulation measures in hard-to-treat properties;
- The Carbon Saving Community Obligation (CSCO) which focuses on the provision of insulation measures and connections to district heating systems to domestic energy users that live within an area of low-income;
- The Home Heating Cost Reduction Obligation (HHCRO)—'Affordable Warmth Group'—under which suppliers provide measures that improve the ability of low-income and vulnerable households to affordably heat their homes.

The first phase of ECO, known as ECO1, ran from January 2013 to March 2015, and the second (ECO2) from April 2015 until March 2017; recently, the government announced that from the first of April 2017 the scheme will be replaced with a new supplier obligation (ECO3) that will run for 5 years.

Before the ECO scheme, several others obligation schemes such as the Energy Efficiency Standards of Performance in 1994 (for a review see OFGEM & Energy Saving Trust 2003), the Energy Efficiency

[7] Under the Energy Efficiency Directive, EU countries should set up an energy efficiency obligation scheme. This scheme requires energy companies to achieve yearly energy savings of 1.5% of annual sales to final consumers.

Commitment in 2002 (OFGEM 2002), the Carbon Emissions Reduction Target in 2008 (OFGEM 2008), and the Community Energy Saving Programme in 2009 (OFGEM 2009) were implemented in the UK for tackling fuel poverty and lowering the pressure placed by energy prices on low-income households (Rosenow 2012; Rosenow et al. 2013). Alongside the obligation scheme, the UK government introduced in 2011 the 'Warm Home Discount' programme. It is a 5-year scheme, in which the government, in collaboration with the electricity suppliers, offers a one-off discount of £ 140 on the electricity bill, usually between September and March, to private eligible customers (low-income and vulnerable customers who met their individual eligibility criteria and successfully applied, and people in receipt of Pension Credit Guarantee Credit). Since 2011, the Warm Home Discount has helped around 2 million low-income and vulnerable households (Department of Energy and Climate Change 2016a). That is why the UK government has committed to continuing this scheme until 2021 at current levels of spending—£ 320 million per year rising with inflation.

Similarly to the Warm Home Discount, a 'social bonus'—that is a discount of the electricity bill each year, dependent upon the use and number of people in the family—is offered by the governments of Italy and Spain to help people struggling to pay their energy bills.

Measures addressing the landlord-tenant problem

According to the article 19 of the EED, Member States should take appropriate measures to overcome misaligned incentives between landlords and tenants. The landlord-tenant problem occurs when landlords have little incentive to invest in the energy efficiency of their properties, given that it is the tenant who benefits from lower energy bills (Allcott and Greenstone 2012). As a consequence, rental properties tend to be less energy efficient than owner-occupied houses. This split incentive between owners and renters is one of the greatest barriers hindering the development of sustainable renovation of residential buildings in Europe, but it has hardly been an objective of policy-making. In 2015, on average in the European Union, 69.5% of the dwellings were owner-occupied (own it outright and mortgagors), while the remaining were privately or social rented (Eurostat 2017). Significant differences exist among Member States: for example, in Hungary 86.3% of the dwellings, while in the UK only 63.5%, were owner occupied in 2015. In particular, the private rented sector has been growing in recent years in the UK, and is at its highest level since the early 1990s. In 2014–2015, 19% (4.3 million) of households were renting privately, while 17% (3.9 million) of households lived in the social rented sector (Department for Communities and Local Government 2015). Thus, a significant portion of rented properties in the UK leaves a considerable room for energy efficiency policies to addressing the split incentive barrier. As result, in the UK a combination of regulatory and economic instruments has been established to tackle this issue.

In particular, the Landlord's Energy Saving Allowance (LESA) was a tax allowance introduced in 2004, which let landlords claim on their tax return against the cost of buying and installing energy efficient retrofit measures such as cavity wall and loft insulation, solid insulation, draught-proofing, hot water system insulation, and floor insulation. Tax relief was for a maximum of £ 1500 per property. This aid scheme applied until the first of April 2015.

With the Green Deal (GD), the UK has been the first European country that adopted an on-bill finance scheme, designed to address, interalia, the split incentive barrier. The GD, which came into force in the beginning of 2013, allowed owners to install energy-efficient retrofits at no upfront costs and enabled repayments to be made through a charge on the occupants' utility bills—'Golden rule' (Economidou 2014). However, due to low take up and concerns over industry standards, the government announced the end of funding for the GD in June 2015.

On the other hand, the first of April 2016 the new 'Tenant's Energy Efficiency Improvement Regulations' entered into force. While it is still the responsibility of the tenant to ensure that the energy efficiency improvements are funded and that no upfront costs should fall on the landlord (unless he agrees to contribute), now the landlord cannot simply refuse the permission for any energy efficiency improvements requested by the tenant without motivating its decision.

However, the situations in which a landlord can reasonable refuse the consent to the proposed interventions are many (Department of Energy and Climate Change 2016b); initial evidence suggests that 58% of tenants surveyed by letting agent PropertyLetByUs have had requests for energy efficiency improvements refused (Climate Change Committee 2016).

Starting from the first of April 2018, the new Minimum energy efficiency standards (MEES) makes unlawful to let buildings (both commercial and domestic) in England and Wales which do not achieve a minimum Energy Performance Certificate (EPC) rating of 'E'. The landlord will need to ensure a property complies with MEES before the lease is granted. But in certain circumstances the landlord will have 6 months after the lease is granted to comply. From 1 April 2023, MEES will be extended to cover all leases, including existing leases but only if the property has a valid EPC on the relevant date.

In Italy, an interesting policy measure similar to the UK GD has been implemented at regional level. The Emilia Romagna region approved a legislative reform in 2013 (Regional Law 13/12/2013) that promotes energy efficiency improvements in the social housing sector and provides savings to the tenants at no upfront cost. This policy has the double objective to both address the split incentive problem and to help households living in fuel poverty. The tenants renounce to part of the savings to pay back the energy efficiency investment and the ESCO (not a bank) is responsible for the energy efficiency improvements. In this way, the energy efficiency measures become economically sustainable and it is possible to involve private investors. The contract between the company social housing and the ESCO lasts 12 years and it is renegotiable in case of further improvement interventions. The ESCO guarantees minimum results and provides the report to the monitoring of individual consumptions.

Increasing consumer information and promoting behavioural change

Information and educational programmes typically aim to induce change of the consumer's behaviour by providing information about potential energy savings from energy-efficient products or investments and by including programmes to give feedback to consumers about their energy consumption. The intention is that through the provision of greater and more reliable information, issues of uncertain future returns and asymmetric information may be lessened (Gillingham et al. 2009). However, this reliance on the concept of 'rational decisions', considering negative responses as irrational and interpreting them as a result of information deficits, leads to neglect other factors such as habits, routines, social constrains, etc., and thus minimises the impact of information provision by misguiding its focus.

According to articles 12 and 17 of the EED, Member States shall take appropriate measures to promote and facilitate an efficient use of energy by small energy customers, including domestic customers. Furthermore, Member States shall, with the participation of stakeholders, including local and regional authorities, promote suitable information, awareness-raising and training initiatives to inform citizens of the benefits and practicalities of taking on energy efficiency improvement measures (Concerted Action Energy Efficiency Directive 2014).

With the aim of guiding consumers to be more concerned of energy efficiency in their purchasing decisions, governments and energy agencies[8] have introduced in the last years a number of different mechanisms, ranging from energy labels and energy performance certificates to pure publication of information in brochures and mass media campaigns via internet or TV, respectively. Their effectiveness vary depending on the objective pursued, the obstacles present, and the way they are integrated with measures addressing routines, social norms and values, etc., and of course the technical feasibility.

Of particular importance is the Energy and Climate Awareness-Raising Action Plan (ECARAP) endorsed by the Hungarian government in September 2015. The plan identifies the main areas of action for the government in the short term to foster a major change in the awareness, attitudes, and values of stakeholders concerning the use of energy and related to climate change, as well as towards the necessary change of related consumption patterns. The ones with the most relevance to the household sector are (i) the promotion of energy efficiency and energy conservation and (ii) the realisation of new social and economic structures according to the principles of resource efficiency and low-carbon intensity. The intended main 'messages' of the ECARAP are differentiated according to specific target group based on age and level of income. Target groups are selected so that activities can be specifically set for the behavioural changes that are requested for a specific group, rather than following a scattergun approach.

The shift in consumer behaviour towards energy conservation measures can be also supported by the

[8] Motiva in Finland, Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) in Italy, the National Environmental Protection and Energy Center Nonprofit (NKEK) in Hungary, Institute for the Diversification and Saving of Energy (IDEA) in Spain, the Energy Saving Trust (EST) in the UK.

installation of smart meters and more accurate billing information (articles 9, 10, and 11 of the EED). By providing real-time feedback, smart meters allow consumers to take control of the energy bill, and to become more aware of their actual energy consumption. Consumers are then able to compare this feedback to previous consumption periods or benchmark values to detect and implement energy efficiency options. The early actor of the smart meters roll out has been Italy (completed in 2011), followed by Finland (completed in 2013); in Spain and in the UK the complete roll out of the smart meters is expected to be by the end of 2018 and 2020, respectively, while in Hungary pilot projects are still ongoing.

Private initiatives supporting public activities towards energy efficiency

Beyond public programmes and policy instruments, energy efficiency improvements in the residential sector are supported by the private sector in a variety of ways:

- Initiating and implementing concrete actions, e.g. through providing loans, investment and implementing demonstration programmes, alternative solutions to low-energy buildings;
- Organising awareness-raising and information exchange programmes;
- Providing input to policies, analysing policies, and initiating discussion.

Mobilising investments and actions from the private sector is therefore essential to complement public activities and to contribute meeting the energy efficiency and climate change goals. What motivates the private sector is the possibility for profit. Shareholders tend to request maximal dividends (institutional shareholders all the more), and tend to reject 'climate motivated' actions. Politics must make sure that the environmentally necessary is also the economically desirable—that is the justification for economic instruments and should be our yardstick for their efficacy.

Energy service companies

Traditional utilities, start-ups, or cooperatives can all become ESCOs, be it as the business model of a new market agent or the new business model of an old market agent. They all face certain obstacles, but different ones due to their size, history, and corporate structure. The task of politics is to remove such obstacles, even grant 'launch platforms' supporting the start into unchartered territory during the pre-competitive phase.

The ESCO can be a natural or legal person that delivers energy services and/or other energy efficiency improvement measures in a user's facility or premises—such as project finance, engineering, project management, equipment maintenance, monitoring, and evaluation—and accepts some degree of financial risk in so doing (ESD). These are usually made through Energy Performance Contracts (EPCs), which are self-reimbursing loans (i.e. that are repaid through savings). The EPC is a contractual arrangement between the beneficiary and the provider of an energy efficiency improvement measure, where investments are paid for in relation to a contractually agreed level of energy efficiency improvement. Energy performance contracting takes several different forms but all such projects share the characteristic that the technical risk is transferred from the client to the ESCO and that the ESCO will not receive its payment unless the project delivers energy savings as expected.

Despite the large economic energy saving potential, the ESCO market in the residential sector is much less developed compared to the industry, tertiary and public sectors in the European Union, as indicated in several reports and studies (e.g. Marino et al. 2011; Bertoldi et al. 2014; Bertoldi and Boza-Kiss 2017).

Irrek et al. (2013) and Labanca et al. (2015) provide a comprehensive overview of the barriers preventing a large-scale application of the ESCO concept in the residential sector: (i) the particularly high transaction costs for ESCOs relative to the small amount of energy costs and thus potential cost savings per single energy efficiency service supplied; (ii) the landlord/tenant problem and the decision-making processes existing in multi-apartment buildings; (iii) the perception of the ESCO as not a trustworthy organisation and the fear of households to become too much dependent on the ESCO; and (iv) the difficulties for residential customers to understand the ESCO model and the EPC financing and contract and lack of information on the availability of ESCO services.

The number of ESCOs, their market size, and the type of services provided varies a lot among Member States. Recently, Bertoldi and Boza-Kiss (2017) have analysed the market development of the ESCO industry in EU Member States and neighbouring countries between 2010 and 2013. From their analysis, it emerged that with the exception of Hungary (and according to some experts also Sweden and the Netherlands), all the EU MSs' market grew during the period under investigation, or remained stable as in the case of Finland. Although the residential buildings were still not very attractive for ESCOs, compared to 2010 more activities were targeted to this sector.

In Italy, there were about 272 ESCOs in 2016, with a market size of € 836 million, corresponding to approximately 14% market share of the total energy efficiency investments (Polytechnic University of Milan 2017). Here, not many ESCOs couple energy services with other functions. Within the 'energy services' area, the most commonly offered service is the energy audit, followed by concluded EPC contracts. Excluding energy services, the three principal functions of Italian ESCOs are technologies for the generation and use of thermal energy, CHP and CCHP systems, and efficient buildings. The sectors covered by these businesses are commercial, services, and partially residential, which generate together the 76.7% of their total turnover; the remaining share comes from the industrial sector (23.2%), and a negligible portion from the agricultural sector (Italy's NEEAP 2014). According to the latest Energy Efficiency Report of the Polytechnic University of Milan (2017), although the total energy efficiency investments in 2016 have been driven by the residential sector (53%), the support of the ESCOs has been marginal. In fact, only 3.4% of the total energy efficiency investments in the residential sector have been financed by ESCOs. This means that the residential sector covered by ESCOs accounted for € 110 million, representing 13.4% of the total investments made by ESCOs in 2016.

In the UK, despite the fact that the ESCO market is one of the most developed in Europe, ESCOs activities have been mostly concentrated in the commercial and industrial sector (Labanca et al. 2015; ENSPOL 2015a). There are about 30–50 ESCOs active on the UK market with an estimated market size of more than € 400 million: the major players are large international manufacturers of building automation and control systems but a growing number of construction and property companies, smaller consultancies, and dedicated ESCO firms started to populate the market in recent years. New ESCO entrants and in particular utilities see it reasonable to engage in the field of energy savings as they see a serious national commitment to a low-carbon transition (Hannon et al. 2013)—framed by the Climate Change Act 2008—and an increased attention towards energy efficiency in the residential sector. Alongside ECO, which encouraged large energy suppliers to team up with ESCOs in order to deliver energy efficiency measures to vulnerable households, the GD was expected to set the necessary framework to open up the residential market to ESCOs, but failed to achieve its purpose.

In Spain, the profile of the ESCOs is essentially that of engineering, installation, and assembly companies, some of which are associated with building heating system maintenance companies, as well as with subsidiaries of building companies and electricity suppliers, primarily. There is no agreement about the number of ESCOs in Spain among local experts. The most likely range of available companies is 20–60 with a market size of over € 300 million (Bertoldi and Boza-Kiss 2017). About 80% of the registered companies provide services in industrial activities and service buildings, 70% in residential sector, 65% in outdoor lighting, and just 50% in cogeneration. Ninety-three percent of these companies are SMEs, that is, they have fewer than 250 employees and annual revenue of less than € 50 million, while 7% are large enterprises (Spain's NEEAP 2014). In the last years, the ESCO market for the residential sector has benefited from the support of the IDAE-managed programmes, BIOMCASA II, GEOTCASA, SOLCASA, and GIT. However, the main aim of these programmes is to promote renewable energy investments such as heating and cooling systems powered by biomass, solar power, or geothermal energy, and only to limited extent energy efficiency investments.

In Hungary, the complex refurbishment of residential block houses has been a fast emerging market area for ESCOs mainly due to state and municipal grants available for panel blockhouse refurbishment (Irrek et al. 2013). More recently, the market has experienced a strong decline due to the instability of funding programmes, financial crisis, and the collapse of the construction sector. As a result, the 20–30 active companies were reduced to 6 in 2013. Some ESCOs disappeared because of lack of business or decline of profits, while other firms that had been active in construction or consultancy before entered the market and succeeded with providing new products in the form of ESCO projects (Bertoldi et al. 2014).

In Finland, only five to eight are actually active companies, with a market size of € 10 million. Pätäri and Sinkkonen (2014), by following a two-round Delphi study, analysed the reasons for the limited ESCO market in Finland. The findings of this study indicate that the generally weak knowledge about ESCOs and their offerings is among the key reasons for the immaterialised volume of activity in Finland. Like other countries, the residential sector constitutes a minor share of ESCO operations. Customers may regard ESCO projects as complicated and time-consuming, and potentially not 'worth the trouble'.

Energy providers

The principal driver of the energy providers to deliver energy saving activities is induced by regulatory mechanisms created by the 'Energy Efficiency Obligation Scheme' (EEOS, article 7, EED) which calls on each Member State to ensure that energy providers achieve new savings each year from 1 January 2014 to 31 December 2020 of 1.5% of the annual energy sales to final customers of all energy distributors. In the transposition of the EEOS into national law, the government of Finland decided to adopt the 'alternative approach', meaning that it opted to take other policy measures such as energy or CO_2 taxes, financing schemes and fiscal incentives, voluntary agreements, etc., in order to achieve an equivalent energy saving target, while Italy, Spain, and the UK adopted a combination of both EEOS and alternative measures (Bertoldi et al. 2015). In Hungary, the EEOS was initially planned but then it has been withdrawn (Fawcett et al. 2018).

Differently from Spain, the Italian and the UK governments placed legal obligation on larger energy suppliers or distributors to deliver energy efficiency measures before the ones set by the EEOS. In the UK, the Energy Company Obligation that ran from 2013 (see "Measures addressing vulnerable consumers and fuel poverty" section) was introduced as a successor to the Carbon Emissions Reduction Target (CERT) and Community Energy Savings Programme (CESP) schemes which ran from April 2008 to December 2012 and October 2009 to December 2012, respectively. Within the CERT, energy suppliers were required to achieve an overall target of 293 million lifetime tonnes of carbon dioxide ($MtCO_2$) by 31 December 2012, while the CESP required gas and electricity suppliers and electricity generators to deliver energy saving measures to domestic consumers in specific low-income areas of Britain (for a comprehensive overview, please see Rosenow 2012; Rosenow and Eyre 2013; Rosenow et al. 2013; Rosenow and Eyre 2015). In Italy, the White Certificate scheme entered into force in 2005 and was imposed on electricity and gas distributors (DSOs) with more than 100,000 users connected to their grid (from 2008, the obligated parties' threshold was 50,000 users). These parties are required to deliver yearly quantitative primary energy-saving targets through the White Certificates attesting the energy savings claims of market actors as a consequence of energy efficiency measures. All type of energy efficiency measures, apart from the improvement of energy efficiency in power plants, and all sectors are covered (ENSPOL 2015b). From 2005 to 2015, the White Certificates contributed to save 1.7 Mtoe in the residential sector, corresponding to 38.8% of the total final energy saved through this scheme (ENEA 2016).

Compliance with European or national regulations is not the only way to mobilise energy providers to take on energy saving activities: market mechanisms, financial incentives, funding opportunities, business retention and development, and voluntary agreements are also needed to stimulate energy providers to delivery energy efficiency investments in the residential sector. Governments turn to energy providers to deliver energy efficiency for several reasons. Energy providers have longstanding commercial relationships with the end-use customers, allowing them to influence energy saving activities in diffuse markets; they have the technical capacity and infrastructure for delivering services in their area of operations and they possess detailed information on the energy consumption habits of their energy consumers. However, revenues and profits of the energy providers are directly linked to the volume of energy they sell: this creates a powerful disincentive to deliver energy efficiency solutions.

Even though in almost all jurisdictions we find energy providers active in some form of demand-side management or other types of programmes, this energy efficiency activity seems to be only a window dressing or driven by legal requirements. On the other hand, in some cases, energy suppliers seem to be genuinely attempting to develop and implement new business models that incorporate energy efficiency, driven by a non-traditional profit motive and a belief that it is the right thing to do (Fawkes 2016).

In a study carried out in 2013, the International Energy Agency identified several distinct types of energy saving activities that energy providers engaged in (42 case studies in 19 countries). While advice and assistance to energy consumers was the most common energy saving activity, in about one third of the case studies energy providers offered or helped access financial incentives and in almost half of the case studies energy providers disseminated information, educated consumers, and promoted energy saving measures. Other energy saving activities included comprehensive implementation, direct installations, replacing equipment, on-bill financing, and technology development. For example, in Spain, the Iberdrola's Integrated Energy Management initiative utilises an ESCO model to upgrade and manage centralised heating and hot water systems in residential apartment buildings. Through this activity, Iberdrola finds and replaces older fuel-oil or coal-burning boilers with more efficient natural gas installations, facilitating financing and then maintenance over a 10-year contract period.

In Italy, the Energy@home association funded by Enel Energia (the biggest national electricity provider), in collaboration with Electrolux, Indesit Company, and Telecom Italia, has the mission of developing and promoting technologies and services for energy efficiency in smart homes based upon the interaction between user devices and the energy infrastructure. Its goal is to promote the development and widespread of products and services based on the interoperability and collaboration of the appliances within the household.

In Hungary, E.ON Hungária organised in 2015 for the second time the 'Energy Experience' that is a large-scale educational programme aimed at increasing energy awareness and knowledge of citizens with a special focus to children and young people. Similarly, the provider ELMÜ-ÉMÁSZ offers two incentives and programmes, namely 'Energiapersely' and 'GREEN and GEO tariffs', both intended to increase household energy efficiency and awareness. The former provides tips and advice for daily energy-saving behaviours and allows households to borrow energy meters; the latter offers interest-free loans to households for installation of solar energy systems.

Cross-country comparison of energy efficiency progress

Figure 5 illustrates the energy efficiency trends in the residential sector of Finland, Hungary, Italy, Spain, the UK, and European Union over the period 1990–2015. Energy efficiency is calculated as the ratio of final residential energy consumption and the stock of permanently occupied dwellings. Differently from Fig. 1 ("The EU residential energy sector" section), the cumulative percentage variation from 1990 to 2015 and year-to-year percentage changes are represented. The cumulative percentage variation is the sum of the positive and negative percentage changes of energy efficiency improvements from 1990 to 2015 using 1990 as the baseline year (with the exception of Finland that is from 1995 to 2015), while the year-to-year percentage changes represent the positive or negative percentage variation of energy efficiency in comparison to the previous year.

In order to improve the readability of the graph, we converted positive values to negative values and vice versa. In this way, an upward trend represents an increase in energy efficiency (otherwise, a negative value would indicate an increase in energy efficiency).

The implementation of policies and other measures to improve energy efficiency in the residential sector does not happen into an 'empty' economic, political, and social context. In addition, several other factors can affect energy efficiency variations over time such as energy prices, climate conditions, changing household composition, behaviours, and lifestyles, larger homes (average), more people living in urban areas, and rebound effects (e.g. Sudarshan 2013; Filippini et al. 2014; Ameli and Brandt 2014). Therefore, measuring the direct causal effect of a policy or a range of policies on energy efficiency improvements and what the outcome would have been in the absence of interventions can be very challenging (Ferraro 2009; Rosenow et al. 2016) and not accurate (Sorrell 2015). Thus, we simply provide some indication of energy efficiency trends in relation to the measures previously analysed. It is important to interpret these results with caution, given the reliance on a macro energy efficiency indicator.

It can be noted from Fig. 5 that the energy efficiency trends of the residential sector among countries are very diverse. While some countries show an upward and quite linear trend (the UK, and the EU as a whole), others show variable results (Finland, Italy, Spain, and Hungary).

In the UK from 1990 to 2015, energy efficiency in the residential sector improved by 31%, in total. In other words, from 1990 to 2015 energy efficiency improvements produced energy savings of 1.19% on average per year. While from 1990 to 2001 energy efficiency improvements have not been able to offset increasing

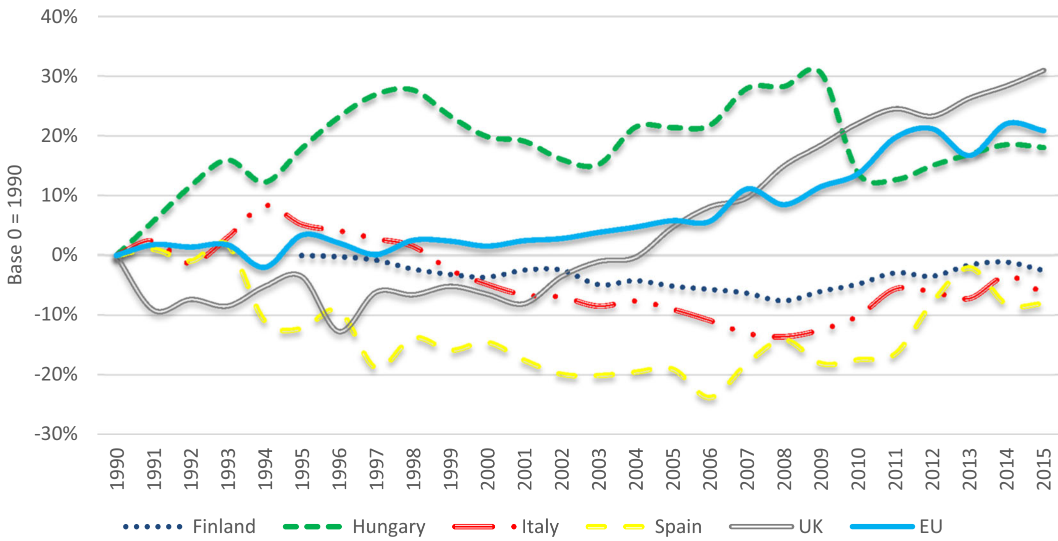


Fig. 5 Cumulative and year-to-year % variation of energy efficiency trends 1990–2015

demand of energy, from 2001 to 2015 there has been significant progress. The Energy Company Obligation that ran from 2013 and some of its predecessors—the Carbon Emissions Reduction Target (2008) and the Community Energy Savings Programme schemes (2009)—combined with measures addressing the landlord-tenant problem and fuel poverty, certainly contributed to this positive trend. In fact, half of the total energy efficiency improvements have been achieved from 2008 to 2015. Compared to the period 1990–2007, from 2008 to 2015 households in the UK consumed in total 16% less energy for satisfying their needs for energy services, such as electrical appliances, lighting, water heating, cooking, and space heating.

Finland, Italy, and Spain show a non-linear but similar trend. Whereas a downward trend is observed before 2006–2007, a slightly positive trend is observed after 2006–2007. This result may reflect the increasing efforts of Member States to translate EU requirements (e.g. Directive 2006/32/EC) into national energy efficiency policies and investment opportunities for households. In absolute values, compared to Finland and Spain, the energy efficiency improvements in Italy contributed to higher savings; tax deductions (since 2007), financial incentives (Thermal Account of 2012), compliance rate with the application of MEP requirements, and ESCOs activities might have influenced this result. Despite progress in the last years, the total effect of energy savings provided by energy efficiency improvements on energy consumption is still negative and far from the EU average.

In Hungary, from 1990 to 2015 the final household energy consumption per dwelling varied from 2.01 (toe/dwellings) to 1.63 (toe/dwellings). The policies and measures analysed that have been implemented in the last years do not support any conclusion in this regard. However, the intuition here is that reduction of energy consumption might have mainly been driven by other factors rather than actual energy efficiency investments. Energy bills are a fundamental component of personal finance of Hungarian households and a considerable number of the population live in a fuel poverty condition—and thus being unable to finance energy efficiency investments (Fellegi and Fülöp 2012; Team and Baffer Team and Baffert 2015). In addition, one fourth of households accumulated debt towards energy utility companies due to steadily increasing price of imported natural gas (Fülöp and Kun 2014; Slezák et al. 2015). On the other hand, there is also evidence suggesting an increasing attention of households to energy efficiency solutions. For example, the 2014 edition of the Energy efficiency barometer (Fülöp and Kun 2014) found that from 2004 to 2014 about 64% of the households performed some kind of energy efficiency investment such as insulation, update of the heating system, and replacement of windows. Also, the rapid end of funds allocated by the Warmth of the Home Programme confirms the willingness of households to improve their energy use and living standards.

At EU level, the trend is linear and positive. Most of the energy efficiency progress have been achieved after

2006. One explanation for this positive trend is the increasing role of energy efficiency in shaping the EU strategic objectives and policy agenda. It was in 2006 that the European Union implemented the first major wide-reaching piece of legislation on energy efficiency, commonly referred to as the Energy Services Directive (Directive 2006/32/EC). This directive was followed by the Ecodesign Directive in 2009, the Energy Labelling Directive in 2010, the recast Energy Performance of Building Directive in 2010, and the new Energy Efficiency Directive of 2012 that is still the most important legislation currently in force establishing a common framework of measures for the promotion of energy efficiency within the European Union.

Conclusion and implications for energy policy

This study builds on the EU Horizon 2020 project 'European Futures for Energy Efficiency' and provides insights on the different energy efficiency strategies adopted by some EU Member States to remove barriers and stimulate energy efficiency investments in the residential sector.

In particular, we analysed private initiatives and policies implemented in the residential sector over the last years in Finland, Hungary, Italy, Spain, and the UK. Since it is not possible to show a causal relation between energy efficiency trends and differences on the basis of indicators (our means of assessment), we conducted an analysis of the policies implemented, combined with private measures targeting energy efficiency in the residential sector. While not indicating mechanical causalities, this analysis further improves the understanding of the country-specific conditions and actions. With the development of a framework taking into account multiple actors and both quantitative and qualitative information in the evaluation process, we contribute to a comprehensive analysis and enhanced comparability among case studies.

Country level insights

When compared to what has been achieved in the last years in Finland, Spain, Italy, and Hungary, the UK government's set of energy efficiency policies targeted at the residential sector appears to be more effective. We argue that its more balanced character, together with the participation of and obligations for private actors have been decisive for this relative success. In particular, the legal obligations placed on energy suppliers to deliver domestic energy efficiency programmes are part of a holistic policy package with a medium-term framework addressing many aspects of energy efficiency in the residential sector. The motivation for this rather ambitious approach appears to be a domestic one: the UK residential energy sector is more problematic than the European average. In particular, the prevalence of older dwellings in the national stock, built to lower standards of energy efficiency, combined with a high share house ownership among the less affluent sectors of society and the dominant role of the private sector in the housing rental market leaves larger untapped potential for improvements than in the other countries under investigation. Due to the significant energy efficiency improvements at a faster pace than the EU average since 2007, in 2015 the energy use by households in the UK was in line with the EU average.

It is currently unclear how Brexit will influence future energy efficiency policies in the UK. The importance of energy efficiency improvements in the residential sector will probably prevail, as reducing household emissions is an important means contributing to meeting the national emission reduction targets codified in the 2008 Climate Change Act. On the other hand, assuming that the UK leaves the common market after Brexit, the UK will not be obliged to transpose the EU Winter Package into national legislation, in particular not the extension for the period 2021–2030 in article 7 of the proposed new Energy Efficiency Directive. This means that progress will slow unless a strong national energy efficiency strategy replaces the EU legislation as a driver of efficiency improvements.

In Finland, improvements of energy efficiency in the residential sector seem not to have been a priority for policymakers, although Finland has the highest energy consumption per capita and the highest space heating demand per dwelling in Europe. Beyond a general tax reduction for any household services, no real economic incentives have been provided to stimulate energy efficiency investments in the last years. Issues like fuel poverty and the landlord-tenant problem have not been taken into account in the national energy efficiency strategy, and the private sector remains a marginal player. Therefore, it comes as no surprise that the residential energy consumption per stock of permanently occupied dwellings did not decrease within the period 1995–2015. One possible explanation for the lack of political commitment is the policy makers' focus on the energy-intensive industries representing almost half of the energy consumed in the national energy sector.

Also in Spain, the residential energy sector seems not to have been at the top of the energy saving agenda; instead, the attention has been focused on the transport sector representing about 40% of the energy consumption. But as opposed to Finland, in Spain the residential energy sector is one of the most efficient in Europe, mainly because of the modern building stock and the low level of space heating demand (however, due to the economic crisis, a significant share of the modern buildings is standing idle). In addition, with the State Housing Plan 2013–2016 and the PAREER-CRECE Programme, both the national and local governments have recently allocated a significant share of the budget for energy efficiency and saving projects to inhabited residential buildings.

In Hungary, with the Warmth of the Home Programme, the government provided financial incentives to households ranging from the replacement of inefficient appliances or obsolete facade doors and windows, to complex energetic refurbishment of blocks of flats. The success of this policy measure has been witnessed by the rapid exhaustion of funds allocated (in other words: the programme was underfunded as compared to demand). In order to increase energy awareness, large-scale educational programmes targeted to specific groups have been provided by both the government (ECARAP) and the energy providers E.ON and ELMÜ-ÉMÁSZ. However, there is still room for improvement: implementing policies incentivising energy efficiency investments could reduce domestic energy consumption, alleviate fuel poverty, and improve health and thermal comfort (Poortinga et al. 2017), while reducing the dependence on Russian gas.

Italy offers some interesting policy initiatives in terms of fiscal and financial incentives. The tax deduction scheme (in force since 2007) has proven to be very effective in attracting more investments than what it actually cost in terms of foregone fiscal revenue. In addition, since 2012, the Thermal Account has provided substantial incentives for energy efficiency (and also renewable energy) investments. Subsidies covering part of the expenses for renovation will be available until 2021. Benefits from these policy measures are partially exploited by ESCOs. These measures and activities, and the resulting energy efficiency improvements since 2007–2008 may have contributed to curb the negative trend of energy savings. However, these measures have not been developed into a comprehensive policy package addressing all the aspects of the residential energy sector.

European perspectives

It may be surprising that the EU member states analysed, despite a shared ambitious EU residential energy policy, have highly different levels of per capita or per dwelling household energy consumption. The reasons revealed by our study show that this is to a large degree influenced by policies of the last decades, as the housing stock is a lasting legacy of such decisions. For instance, governmental preferences for large uniform housing blocks in the socialist countries led to settlement structures different from e.g. the UK where the 1980s policies supporting house ownership still shape the dwelling landscape and the occurrence of energy poverty to a significant degree. More recent policies were found in Spain and Finland—in both countries governments focussed their climate mitigation efforts on other, more dominant sectors, transport in Spain and industry in Finland. Furthermore, economic dynamics play a role: the recent construction boom in Spain led to a significant share of the housing stock built according to advanced energy standards, unlike in the UK or in Finland.

Finally, answering our research question, policy design matters, if only in terms of meta-level criteria: an optimal policy strategy aiming at improving energy efficiency in the residential sector should seek to impact different barriers and target segments through a holistic approach pursuing multiple goals coherently, mutually supporting each other. However, as the barriers are diffuse and policy mechanisms rarely operate effectively in isolation (Sovacool 2009), a holistic approach must be based on a thorough analysis of the local and national situation. Only then the hope for synergies (IEA 2005), making the combined impact larger than the sum of isolated effects, may be realised. This implies that a comprehensive energy efficiency policy strategy is determined by the degree to which the design of policy mixes address the barriers identified. Our study has provided some examples for such relatively successful strategies. We could also illustrate that an energy efficiency policy package tends to be more effective if it is maintained over the long-term. Therefore, the 2021–2030 Integrated

National Energy and Climate Plans (EC 2016c) which will replace the NEEAPs and the National Renewable Energy Action Plans (NREAPs) provide an opportunity for Member States to think up new energy efficiency policies with a longer perspective.

In addition to policy packages, engaging the private sector is acknowledged as being central to ensuring long-lasting impact. As such, private initiatives do not duplicate governmental energy efficiency measures in the residential sector, but rather augment and strengthen them (Haney et al. 2010). A long-term policy horizon is a necessary, but not sufficient condition for mobilising private investments in energy efficiency in the residential sector. While it could strengthen the confidence that there will be money to be made through efficiency in the longer run, justifying investments and a rethinking of business models, the latter is still challenging. The cliché 'the cheapest energy is the energy not consumed at all' may be attractive to residents, but is a deterrence to business: there appears to be nothing to sell, and thus no profit to make (Fawkes 2016). In their current business model, energy providers cannot decouple utility profits from energy volumes and energy service companies do benefit from economies of scale when selling energy efficiency solutions to households.

While coherent public policies and business investment are indispensable, the reductions in household energy consumption needed to reach the Paris climate goals are unlikely to be achieved from interventions designed to retrofit buildings alone. Studies on household energy use have found a high variability in energy consumption across identical houses, implying that the occupants are the third decisive agent and their behaviour can be as important as building physics (Santin et al. 2009). Beyond efficiency, including sufficiency principles into policy design for a good quality of life could contribute to reducing energy consumption: energy efficiency and energy sufficiency are complementary approaches to energy saving (Thomas et al. 2015; Bertoldi 2017; Samadi et al. 2017). Given the different obstacles in different circumstances, any approach of standardisation or transferability of approaches would be futile: there are no 'best solutions'. Instead, the lists of instruments and their design which have been promising under specific circumstances in the countries analysed can be read as a toolbox to get inspiration from for a suitable design of policies and policy mixes in the respective socio-political context.

Acknowledgements The authors would like to thank József Slezák and Edina Vadovics for the information provided about Hungary, and the participants of the '3rd RSEP Multidisciplinary Conference' (April 5–7, 2017) in Vienna and the 'Biennial International Workshop Advances in Energy Studies' (September 25–28, 2017) in Naples for their comments. We are also thankful to the anonymous reviewers for their valuable comments on the earlier version of this paper.

Funding information This work has been supported by the European Commission under the project grant EUFORIE/H2020-EE-2014-2015-RIA/649342.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

Allcott, H., & Greenstone, M. (2012). Is there an energy efficiency gap? *The Journal of Economic Perspectives, 26*(1), 3–28.

Ameli N. and Brandt, N. (2014). Determinants of households' investment in energy efficiency and renewables—evidence from the OECD survey on household environmental behaviour and attitudes. OECD Economics Department Working Paper No. 1165, OECD Publishing, Paris. http://www.oecd-ilibrary.org/determinants-of-households-investment-in-energy-efficiency-and-renewables_5jxwtlchggzn.pdf;jsessionid=8eo8i8um6mhl2.x-oecd-live-02?contentType=%2fns%2fWorkingPaper&itemId=%2fcontent%2fworkingpaper%2f5jxwtlchggzn-en&mimeType=application%2fpdf&containerItemId=%2fcontent%2fworkingpaperseries%2f18151973&accessItemIds=&option6=imprint&value6=http%3a%2f%2foecd.metastore.ingenta.com%2fcontent%2fimprint%2foecd

Ameli, N. and Brandt, N. (2015). What impedes household investment in energy efficiency and renewable energy? OECD Economics Department Working Paper No. 1222, OECD Publishing, Paris. http://www.oecd-ilibrary.org/docserver/download/5js1j15g2f8n-en.pdf?expires=1521128385&id=id&accname=guest&checksum=1A458058622727DC56A6CCA315363A1C

Arcipowska, A., Anagnostopoulos, F., Mariottini, F. and Kunkel, S. (2014). Energy performance certificates across the EU. A mapping of national approaches, The Buildings Performance Institute Europe (BPIE). http://bpie.eu/wp-content/uploads/2015/10/Energy-Performance-Certificates-EPC-across-the-EU.-A-mapping-of-national-approaches-2014.pdf

Aydin, E., Kok, N., & Brounen, D. (2017). Energy efficiency and household behavior: the rebound effect in the residential sector. *The Rand Journal of Economics, 48*(3), 749–782.

Bertoldi, P. (2017). Are current policies promoting a change in behaviour, conservation and sufficiency? An analysis of existing policies and recommendations for new and effective policies. In ECEEE Summer Study (pp. 201–211). Toulon: ECEEE. https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2017/1-foundations-of-future-energy-policy/are-current-policies-promoting-a-change-in-behaviour-conservation-and-sufficiency-an-analysis-of-existing-policies-and-recommendations-for-new-and-effective-policies/2017/1-362-17_Bertoldi.pdf/

Bertoldi, P., & Boza-Kiss, B. (2017). Analysis of barriers and drivers for the development of the ESCO markets in Europe. *Energy Policy, 107*, 345–355.

Bertoldi, P. and Economidou, M. (2016). The assessment of the Member States National Energy Efficiency Action plans: will the EU reach the 2020 target? International Energy Policy and Programme Evaluation Conference 2016. http://www.ieppec.org/wp-content/uploads/2016/05/Paper-Bertoldi-2.pdf

Bertoldi, P., Boza-Kiss, B., Panev, S. and Labanca, N. (2014). ESCO Market Report 2013. http://publications.jrc.ec.europa.eu/repository/bitstream/JRC89550/jrc_89550_the%20european%20esco%20market%20report%202013_online.pdf

Bertoldi, P., Castellazzi, L., Spyridaki, N. A. and Fawcett, T. (2015). How is Article 7 of the Energy Efficiency Directive being implemented? An analysis of national energy efficiency obligation schemes. ECEEE 2015 Summer Study proceedings, 455–465. https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2015/2-energy-efficiency-policies-8211-how-do-we-get-it-right/how-is-article-7-of-the-energy-efficiency-directive-being-implemented-an-analysis-of-national-energy-efficiency-obligations-schemes/2015/2-380-15_Bertoldi.pdf/

Bleischwitz, R., Bahn-Walkowiak, B., Irrek, W., Schepelmann, P., Schmidt-Bleek, F., Giljum, S Lutter, S., Bohunovski, L., Hinterberger, F., Hawkins, E., Kuhndt, M. and Pratt, N. (2009). Eco-innovation-putting the EU on the path to a resource and energy efficient economy. Wuppertal Spezial No. 38, Wuppertal Institut für Klima, Umwelt und Energie, Wuppertal. https://epub.wupperinst.org/frontdoor/deliver/index/docId/3433/file/WS38.pdf

Bouzarovski, S. (2014). Energy poverty in the European Union: landscapes of vulnerability. *Wiley Interdisciplinary Reviews: Energy and Environment, 3*(3), 276–289.

Broin, E. Ó., Nässén, J., & Johnsson, F. (2015). Energy efficiency policies for space heating in EU countries: a panel data analysis for the period 1990-2010. *Applied Energy, 150*, 211–223.

Brown, M. A., & Wang, Y. (2017). Energy-efficiency skeptics and advocates: the debate heats up as the stakes rise. *Energy Efficiency, 10*(5), 1155–1173.

Chai, K. H., & Yeo, C. (2012). Overcoming energy efficiency barriers through systems approach—a conceptual framework. *Energy Policy, 46*, 460–472.

Climate Change Committee (2016). Next steps for UK heat policy. London, Climate Change Committee. https://www.theccc.org.uk/wp-content/uploads/2016/10/Next-steps-for-UK-heat-policy-Committee-on-Climate-Change-October-2016.pdf

Concerted Action Energy Efficiency Directive (2014). Designing measures for behavioural change. http://www.ca-eed.eu/private-area/themes/consumer-information-ct6/Executive-Summary-6.3-Designing-measures-for-behavioural-change

Concerted Action Energy Efficiency Directive (2016). National EED Implementation Reports (NIR). http://www.ca-eed.eu/private-area/outcomes/national-eed-implementation-reports/national-implementation-report-2016-consolidated-document

Danlami, A. H., Islam, R., & Applanaidu, S. D. (2015). An analysis of the determinants of households' energy choice: a search for conceptual framework. *International Journal of Energy Economics and Policy, 5*(1), 197.

Department for Communities and Local Government (2015). English Housing Survey Headline Report 2014–15. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/501065/EHS_Headline_report_2014-15.pdf

Department of Energy and Climate Change (2016a). Warm Home Discount Scheme. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/514324/Final_Warm_Home_Discount_consultation_for_publication.pdf

Department of Energy and Climate Change (2016b). Private rented sector tenants' energy efficiency improvements provisions. Guidance for landlords and tenants of domestic property on Part Two of the Energy Efficiency (Private Rented Property) (England and Wales) Regulations 2015. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/508180/2016_01_19__PRS_tenants__energy_efficiency_improvements_guidance.pdf

Dowson, M., Poole, A., Harrison, D., & Susman, G. (2012). Domestic UK retrofit challenge: Barriers, incentives and current performance leading into the Green Deal. *Energy Policy, 50*, 294–305.

EC (2015). Energy Performance of Buildings Directive (EPBD) Compliance Study. https://ec.europa.eu/energy/sites/ener/files/documents/MJ-04-15-968-EN-N.pdf

EC (2016a). Proposal for a Directive of the European Parliament and of the Council amending Directive 2012/27/EU on Energy Efficiency. http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52016SC0405R(01)&from=EN

EC (2016b). Good practice in energy efficiency COM(2016) 761 final. http://ec.europa.eu/energy/sites/ener/files/documents/5_en_autre_document_travail_service_part1_v4.pdf

EC (2016c). Regulation of the European Parliament and of the Council on the Governance of the Energy Union. http://ec.europa.eu/energy/sites/ener/files/documents/1_en_act_part1_v9_759.pdf

Economidou, M. (2014). Overcoming the split incentive barrier in the building sector. In Workshop summary. Institute for environment and sustainability, European Commission DG Joint Research Centre, Ispra, Italy. http://publications.jrc.ec.europa.eu/repository/bitstream/JRC90407/2014_jrc_sci_pol_rep_cov_template_online_final.pdf

Economidou, M., Bertoldi, P. (2018). Assessment of the National Energy Efficiency Action Plans 2017 under the Energy Efficiency Directive. 2018 International Energy Policy & Programme Evaluation Conference, 25–27 June, Vienna, Austria. http://www.ieppec.org/wp-content/uploads/2018/06/Bertoldi_paper_vienna.pdf

ENEA (2016). Italy's energy efficiency annual report. http://www.enea.it/it/seguici/pubblicazioni/pdf-volumi/executive-summary-2016-eng.pdf

ENSPOL (2015a). Energy Saving Policies and Energy Efficiency Obligation Scheme. D2.1.2: Report on Context Profiles of EU MS countries—Part III: Context analysis of countries with existing/planned EEOs. http://enspol.eu/sites/default/files/results/D2.1.2%20Report%20on%20Context%20Profiles%20of%20EU%20MS%20countries%20-%20Part%20III%20Context%20analysis%20of%20countries%20with%20EEOs.pdf?v=2

ENSPOL (2015b). Energy Saving Policies and Energy Efficiency Obligation Scheme. D2.1.1: Report on existing and planned EEOs in the EU—Part I: Evaluation of existing schemes. Italy. http://www.article7eed.eu/images/pdf/Existing%20and%20planned%20EEOs%20in%20Italy%20_%20Part%20I%20Evaluation%20of%20existing%20schemes.pdf

Eurostat (2017). Distribution of population by tenure status, type of household and income group. http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ilc_lvho02&lang=en

Fawcett, T., Rosenow, J., & Bertoldi, P. (2018). Energy efficiency obligation schemes: their future in the EU. *Energy Efficiency*, 1–15.

Fawkes, S. (2016). *Energy efficiency: the definitive guide to the cheapest, cleanest, fastest source of energy*. Routledge.

Fellegi, D., Fülöp, O. (2012). Szegénység vagy energiaszegénység? Az energiaszegénység definiálása Európában és Magyarországon. ENERGIAKLUB Szakpolitikai Intézet és Módszertani Központ, Budapest, Hungary. pp. 26. [Poverty or energy poverty? Defining energy poverty in Europe and Hungary] https://energiaklub.hu/sites/default/files/energiaklub_szegenyseg_vagy_energiaszegenyseg.pdf

Ferraro, P. J. (2009). Counterfactual thinking and impact evaluation in environmental policy. *New Directions for Evaluation, 2009*(122), 75–84.

Filippini, M., Hunt, L. C., & Zorić, J. (2014). Impact of energy policy instruments on the estimated level of underlying energy efficiency in the EU residential sector. *Energy Policy, 69*, 73–81.

Frederiks, E. R., Stenner, K., & Hobman, E. V. (2015a). Household energy use: applying behavioural economics to understand consumer decision-making and behaviour. *Renewable and Sustainable Energy Reviews, 41*, 1385–1394.

Frederiks, E. R., Stenner, K., & Hobman, E. V. (2015b). The socio-demographic and psychological predictors of residential energy consumption: a comprehensive review. *Energies, 8*(1), 573–609.

Fülöp, O., & Kun, Z. (2014). *Lakossági Energiahatékonysági Barométer 2014*. Budapest, Hungary: ENERGIAKLUB Szakpolitikai Intézet és Módszertani Központ https://energiaklub.hu/sites/default/files/lakossag_energiahatekonysagi_barometer_2014_energiaklub.pdf.

Galvin, R. (2014). Estimating broad-brush rebound effects for household energy consumption in the EU 28 countries and Norway: some policy implications of Odyssee data. *Energy Policy, 73*, 323–332.

Gerarden, T. D., Newell, R. G., & Stavins, R. N. (2017). Assessing the energy-efficiency gap. *Journal of Economic Literature, 55*(4), 1486–1525.

Gillingham, K., & Palmer, K. (2014). Bridging the energy efficiency gap: policy insights from economic theory and empirical evidence. *Review of Environmental Economics and Policy, 8*(1), 18–38.

Gillingham, K., Newell, R. G., & Palmer, K. (2009). Energy efficiency economics and policy. *Annu. Rev. Resour. Econ., 1*(1), 597–620.

GSE (2015). Relazione sul funzionamento del Conto Termico giugno 2013 - dicembre 2014. http://www.gse.it/it/Conto%20Termico/GSE_Documenti/Relazione%20Conto%20Termico_2013-2014.pdf

GSE (2016). Relazione sul funzionamento del Conto Termico gennaio - dicembre 2015. http://www.gse.it/it/Conto%20Termico/GSE_Documenti/Relazione%20Conto%20Termico_2015.pdf

Haney, A. B., Jamasb, T., Platchkov, L. M., & Pollitt, M. G. (2010). Demand-side management strategies and the residential sector: lessons from international experience. http://www.econ.cam.ac.uk/research-files/repec/cam/pdf/cwpe1060.pdf

Hannon, M. J., Foxon, T. J., & Gale, W. F. (2013). The co-evolutionary relationship between Energy Service Companies and the UK energy system: implications for a low-carbon transition. *Energy Policy, 61*, 1031–1045.

Huebner, G. M., Hamilton, I., Chalabi, Z., Shipworth, D., & Oreszczyn, T. (2015). Explaining domestic energy consumption—the comparative contribution of building factors, socio-demographics, behaviours and attitudes. *Applied Energy, 159*, 589–600.

Hungary's National Energy Efficiency Action Plan until 2020 (2014). https://ec.europa.eu/energy/sites/ener/files/documents/hungaryActionPlan2014_en.pdf

IEA (2005). Evaluating energy efficiency policy measures & DSM programmes Volume I Evaluation Guidebook.OECD/IEA, Paris. http://www.ieadsm.org/wp/files/Exco%20File%20Library/Key%20Publications/Volume1Total.pdf

IEA (2011). Energy efficiency policy and carbon pricing. OECD/IEA, Paris. https://www.iea.org/publications/freepublications/publication/EE_Carbon_Pricing.pdf

IEA (2014a) Capturing the multiple benefits of energy efficiency. OECD/IEA, Paris. http://www.iea.org/publications/freepublications/publication/Captur_the_MultiplBenef_ofEnergyEficiency.pdf

IEA (2014b). Energy efficiency indicators: fundamentals on statistics. OECD/IEA, Paris. https://www.iea.org/publications/freepublications/publication/IEA_EnergyEfficiencyIndicatorsFundamentalsonStatistics.pdf

IEA (2014c). Energy efficiency indicators: essentials for policy making. OECD/IEA, Paris. https://www.iea.org/publications/freepublications/publication/IEA_EnergyEfficiencyIndicators_EssentialsforPolicyMaking.pdf

Irrek, W., Bertoldi, P., Labanca, N., & Suerkemper, F. (2013). ESCOs for residential buildings: market situation in the European Union and policy recommendations. https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2013/5a-cutting-the-energy-use-of-buildings-projects-and-technologies/escos-for-residential-buildings-market-situation-in-the-european-union-and-policy-recommendations/2013/5A-524-13_Irrek.pdf/

Italy's National Energy Efficiency Action Plan (2014). https://ec.europa.eu/energy/sites/ener/files/documents/2014_neeap_en_italy.pdf

Jaffe, A. B., & Stavins, R. N. (1994). The energy-efficiency gap: what does it mean? *Energy Policy, 22*(10), 804–810.

Kallbekken, S., Sælen, H., & Hermansen, E. A. (2013). Bridging the energy efficiency gap: a field experiment on lifetime energy costs and household appliances. *Journal of Consumer Policy, 36*(1), 1–16.

Knoop, K., & Lechtenböhmer, S. (2017). The potential for energy efficiency in the EU Member States—a comparison of studies. *Renewable and Sustainable Energy Reviews, 68*, 1097–1105.

Labanca, N., Suerkemper, F., Bertoldi, P., Irrek, W., & Duplessis, B. (2015). Energy efficiency services for residential buildings: market situation and existing potentials in the European Union. *Journal of Cleaner Production, 109*, 284–295.

Lopes, M. A. R., Antunes, C. H., & Martins, N. (2012). Energy behaviours as promoters of energy efficiency: a 21st century review. *Renewable and Sustainable Energy Reviews, 16*(6), 4095–4104.

Lorenzen, J. A. (2012). Going green: the process of lifestyle change. In Sociological Forum (Vol. 27, No. 1, pp. 94–116). Blackwell Publishing Ltd,.

Marino, A., Bertoldi, P., Rezessy, S., & Boza-Kiss, B. (2011). A snapshot of the European energy service market in 2010 and policy recommendations to foster a further market development. *Energy Policy, 39*(10), 6190–6198.

Mills, B., & Schleich, J. (2012). Residential energy-efficient technology adoption, energy conservation, knowledge, and attitudes: an analysis of European countries. *Energy Policy, 49*, 616–628.

Noailly, J. (2012). Improving the energy efficiency of buildings: The impact of environmental policy on technological innovation. *Energy Economics, 34*, 795–806.

OFGEM. (2002). Energy Efficiency Commitment 2002-2005 Technical Guidance Manual. London, UK: Office of the Gas and Electricity Markets. https://www.ofgem.gov.uk/ofgem-publications/58659/135-oct2002pdf. Accessed 9 Jan 2017.

OFGEM. (2008). Carbon Emissions Reduction Target (CERT) 2008-2011 Technical Guidance Manual. London, UK: Office of the Gas and Electricity Markets. https://www.ofgem.gov.uk/ofgem-publications/58721/tm-guidancepdf. Accessed 9 Jan 2017.

OFGEM. (2009). Community Energy Saving Programme 2009 - 2012 Generator and Supplier Guidance. London, UK: Office of the Gas and Electricity Markets. https://www.ofgem.gov.uk/sites/default/files/docs/2009/11/cesp-generator-and-supplier-guidance.pdf. Accessed 9 Jan 2017.

OFGEM, & Energy Saving Trust. (2003). A review of the energy efficiency standards of performance 1994–2002. London, UK: Office of the Gas and Electricity Markets. https://www.ofgem.gov.uk/ofgem-publications/58653/4211-eesopreportjuly03pdf. Accessed 9 Jan 2017.

Odyssee database, (2017). Database on the energy consumption drivers by end-use, energy efficiency and CO_2 related indicators. http://www.odyssee-indicators.org/database/database.php (subscription-based).

Pätäri, S., & Sinkkonen, K. (2014). Energy Service Companies and Energy Performance Contracting: is there a need to renew the business model? Insights from a Delphi study. *Journal of Cleaner Production, 66*, 264–271.

Pollitt, M. G., & Shaorshadze, I. (2011). The role of behavioural economics in energy and climate policy. https://www.repository.cam.ac.uk/bitstream/handle/1810/257212/cwpe1165.pdf?sequence=1&isAllowed=y

Polytechnic University of Milan (2017). Energy Efficiency Report. La filiera dell'Efficienza Energetica in Italia. Energy & Strategy Group. http://www.energystrategy.it/assets/files/EER_17_conCover_alta.pdf

Poortinga, W., Jiang, S., Grey, C., & Tweed, C. (2017). Impacts of energy-efficiency investments on internal conditions in low-income households. Building Research & Information, 1–15.

Rosenow, J. (2012). Energy savings obligations in the UK—a history of change. *Energy Policy, 49*, 373–382.

Rosenow, J., & Eyre, N. (2013). The green deal and the energy company obligation. *Proceedings of the Institution of Civil Engineers-Energy, 166*(3), 127–136.

Rosenow, J., & Eyre, N. (2015). Re-energising the UK's approach to domestic energy efficiency. In Proceedings of ECEEE Summer Study (pp. 281–289). http://eng.janrosenow.com/uploads/4/7/1/2/4712328/2-001-15_rosenow.pdf

Rosenow, J., Platt, R., & Flanagan, B. (2013). Fuel poverty and energy efficiency obligations—a critical assessment of the supplier obligation in the UK. *Energy Policy, 62*, 1194–1203.

Rosenow, J., Fawcett, T., Eyre, N., & Oikonomou, V. (2016). Energy efficiency and the policy mix. *Building Research & Information, 44*(5–6), 562–574.

Sallee, J. M. (2014). Rational Inattention and Energy Efficiency. The Journal of Law and Economics 57 (3):781–820.

Samadi, S., Gröne, M. C., Schneidewind, U., Luhmann, H. J., Venjakob, J., & Best, B. (2017). Sufficiency in energy scenario studies: taking the potential benefits of lifestyle changes into account. *Technological Forecasting and Social Change, 124*, 126–134.

Santin, O. G., Itard, L., & Visscher, H. (2009). The effect of occupancy and building characteristics on energy use for space and water heating in Dutch residential stock. *Energy and Buildings, 41*(11), 1223–1232.

Saussay, A., Saheb, Y., & Quirion, P. (2012). The impact of building energy codes on the energy efficiency of residential space heating in European countries—a stochastic frontier approach. In International Energy Program Evaluation Conference. Rome. http://www.iepec.org//conf-docs/papers/2012PapersTOC/papers/053.pdf#page=1

Schleich, J., & Gruber, E. (2008). Beyond case studies: barriers to energy efficiency in commerce and the services sector. *Energy Economics, 30*(2), 449–464.

Slezák, J., Vadovics, E., Trotta, G., Lorek, S. (2015). Consumers and energy efficiency—country Report for Hungary. An inventory of policies, business and civil initiatives at the national level, focusing on heating, hot water and the use of electricity. December, 2015. EUFORIE - European Futures for Energy Efficiency. http://www.utu.fi/en/units/euforie/Research/deliverables/country-reports/PublishingImages/Pages/home/EUFORIE%20D%205%201%20%20Country%20Report%20Hungary.pdf

Sorrell, S. (2015). Reducing energy demand: a review of issues, challenges and approaches. *Renewable and Sustainable Energy Reviews, 47*, 74–82.

Sovacool, B. K. (2009). The importance of comprehensiveness in renewable electricity and energy-efficiency policy. *Energy Policy, 37*(4), 1529–1541.

Spain's National Energy Efficiency Action Plan (2014). https://ec.europa.eu/energy/sites/ener/files/documents/2014_neeap_en_spain.pdf

Spangenberg, Joachim (2018). D5.2—Identification of promising instruments and instrument mixes for energy efficiency. EUFORIE—European Futures for Energy Efficiency. http://www.utu.fi/en/units/euforie/Research/deliverables/Documents/D5%202%20Identification%20of%20promising%20instruments%20and%20instrument%20mixes%20for%20energy%20efficiency.pdf

Stern, P. C. (1992). What psychology knows about energy conservation. *American Psychologist, 47*(10), 1224–1232.

Sudarshan, A. (2013). Deconstructing the Rosenfeld curve: making sense of California's low electricity intensity. *Energy Economics, 39*, 197–207.

Team, A., & Baffert, C. (2015). Energy poverty and vulnerable consumers in the energy sector across the EU: analysis of policies and measures. Policy, 2.

Thøgersen, J. (2017). Housing-related lifestyle and energy saving: a multi-level approach. *Energy Policy, 102*, 73–87.

Thomas, S., Brischke, L. A., Thema, J., & Kopatz, M. (2015). Energy sufficiency policy: an evolution of energy efficiency policy or radically new approaches?. Wuppertal Institut für Klima, Umwelt, Energie. https://epub.wupperinst.org/frontdoor/deliver/index/docId/5922/file/5922_Thomas.pdf

Trotta, G. (2018a). The determinants of energy efficient retrofit investments in the English residential sector. *Energy Policy, 120*, 175–182.

Trotta, G. (2018b). Factors affecting energy-saving behaviours and energy efficiency investments in British households. *Energy Policy, 114*, 529–539.

Trotta, Gianluca and Lorek, Sylvia (2018). D5.1—Consumers and Energy Efficiency—stock taking of policy instruments targeting household energy efficiency. EUFORIE—European Futures For Energy Efficiency. http://www.utu.fi/en/units/euforie/Research/deliverables/PublishingImages/Pages/home/D%205%201%20_Stocktaking_of_instruments_targetting_household_energy_efficiency.pdf.

UNFCCC (2016). Techincal expert meeting. Session SBI45 (2016). https://unfccc.int/files/focus/mitigation/the_multilateral_assessment_process_under_the_iar/application/pdf/sbi45_hun_session_final_result.pdf

York, C. M. (1978). Bibliography on institutional barriers to energy conservation. Lawrence Berkeley National Laboratory. https://cloudfront.escholarship.org/dist/prd/content/qt5vh2f55z/qt5vh2f55z.pdf