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ADVANCED REVIEW

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How to finance energy renovation of residential buildings: Review of current and emerging financing instruments in the EU

Paolo Bertoldi[1] | **Marina Economidou**[1] | **Valentina Palermo**[1] | **Benigna Boza-Kiss**[2,3] | **Valeria Todeschi**[4]

[1]Joint Research Centre, Ispra, Italy

[2]Central European University, Nador utca 9, Budapest, 1051, Hungary

[3]International Institute for Applied Systems Analysis, Schlossplatz 1, Laxenburg, 2361, Austria

[4]Energy Department (DENERG), Politecnico di Torino, Torino, Italy

Correspondence
Paolo Bertoldi, Joint Research Centre, Ispra, Italy.
Email: paolo.bertoldi@ec.europa.eu

Abstract

The Paris Agreement goals require net-zero CO_2 emissions by mid-century. The European Commission in its recent proposal for climate and energy strategy for 2050 indicated the need for more intensified actions to substantially improve the energy performances of buildings. With the rate of new construction in Europe, the challenge is to increase both the pace and depth of building energy renovations. Several barriers inhibit the wide uptake of comprehensive energy renovations, including the inability or inertia to finance upfront costs of energy renovations. Despite various policies implemented to address some of these barriers, current investments in buildings remain at suboptimal levels. The paper reviews current financing practices for energy renovations and investigates some innovative instruments with a special focus on their applicability to residential buildings. In addition to "traditional" financial schemes such as subsidies, tax incentives, and loans, the paper assesses innovative financing schemes: On property tax and on-bill financing, energy efficiency mortgages, and energy efficiency feed-in tariffs. The paper also investigates the concept of one-stop shops for building renovations and crowdfunding. The paper offers an assessment of the characteristics, benefits, and challenges of each analyzed financing instrument and provides policy recommendations for their successful implementation. In general, as financing instruments involve different stakeholders and due to complex nature of the sector, there is no single solution to accelerate energy renovation investment in buildings. The emerging financial models offer the potential to address the long-standing barriers to investment in energy efficiency.

This article is categorized under:

Energy Efficiency > Economics and Policy
Energy Efficiency > Climate and Environment
Energy and Climate > Economics and Policy

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KEYWORDS

building renovations, energy efficiency, energy service companies, one-stop shops, sustainable energy financing

1 | INTRODUCTION

The adoption of the Paris Agreement at COP 21, an important milestone in climate change policy, defines a worldwide action plan to alleviate catastrophic climate change impacts by keeping global warming to well below 2°C and pursuing efforts to limit it to 1.5°C. The IPCC Special Report on 1.5°C (IPCC, 2018) confirms that due to the large energy efficiency (EE) potential of the current building stock, energy renovations are considered to be pivotal toward carbon neutrality (He, Liao, Bi, & Guo, 2019). In addition, energy renovation of buildings brings a number of important additional benefits (Kerr, Gouldson, & Barrett, 2017), including lower emissions, reduced pollution, and other co-benefits (Fawcett & Killip, 2019). For households, it results in reduced energy bills, increased disposable income, reduction of energy poverty, improved indoor comfort levels, health, and environment (Boemi & Papadopoulos, 2019; Ortiz, Casquero-Modrego, & Salom, 2019, Ürge-Vorsatz et al. (2016) and as investigated in the COMBI project, Thema, Rasch, Suerkemper, & Thomas, 2018). For governments, improved EE translates in more jobs, higher energy supply security and reduced local pollutions and lower GHG emissions (Ryan & Campbell, 2012).

The adopted 2030 EU targets comprise a 40% GHG emissions reduction compared to 1990 levels, a minimum 32% of renewable energy consumption share in the energy mix and a minimum 32.5% of energy savings. To achieve highly energy-efficient and decarbonized economies, Member States (MSs) must set a strategic vision and ambitious energy and climate targets for 2030 (European Union, 2018/1999). The EU has recently called for carbon neutrality by 2050 in its Communication on the Long Term 2050 climate action strategy (EU COM, 2018). The strategy emphasizes the importance of EE in the decarbonization efforts undertaken by the EU by outlining a 50% final energy consumption reduction compared to 2005 (given the gross inland consumption of 1,639 Mtoe in 2016, the goal is to reduce consumption to 1,255 Mtoe for 2050). This reduction is primarily expected to be, inter-alia, achieved in the building sector. Buildings are responsible for 40% of the total EU final energy consumption, with residential buildings accounting for 25% of the total consumption (Tsemekidi Tzeiranaki et al., 2019). Given the low rate of new constructions and the long lifetime of buildings, with estimates showing that at least 75% of the current EU building stock will be still standing in 2050, existing buildings represent the biggest challenge and opportunity (Urge-Vorsatz et al., 2012). The renovation of existing buildings to nearly-zero energy levels is a political priority for the EU. To promote building renovations, the updated Energy Performance of Buildings Directive (EU) 2018/844 (Directive (EU), 2018b) and revised Energy Efficiency Directive (EU) 2018/2002 (Directive (EU), 2018a) call for several actions to stimulate new investments in energy efficiency. The improvement of financial instruments is necessary, including the reinforcement of existing ones, the set-up of new financial models, the development of supporting mechanisms, and a more active and proactive engagement of financial institutions. The EU Structural and Investment Funds, such as the European Regional Development Fund (ERDF), European Social Fund (ESF) and Cohesion Fund (CF) have a history to promote sustainable energy projects as part of their activity in the economic and social development in EU member states (Štreimikienė, 2016).

Although there is an opportunity to incorporate EE measures when general building renovations take place, current energy efficiency renovations are rare and not in par with their overall potential (Baek & Park, 2012; Rosenow, 2017). At least half of existing residential and commercial buildings are in need of deep, comprehensive renovations (Femenías, Mjörnell, & Thuvander, 2018; Jensen, Maslesa, Berg, & Thuesen, 2018). While some national building renovation programs and policies in France and Germany (such as the "Building" and "heating check" program[1]) have made substantial strides in supporting energy efficiency renovations, more efforts are necessary, to both increase the number of renovations taking place and to shift from a single-measure approach to comprehensive renovations comprising a package of multiple measures (Sebi, Nadel, Schlomann, & Steinbach, 2019).

Several well-investigated barriers are responsible for the suboptimal level of renovation processes, including split incentives, lack or inadequate information about costs and (co-) benefits, high upfront investment costs, decision-making process (van Oorschot, Hofman, & Halman, 2016), lack of access to finance (Bertone et al., 2018), and scarcity of available private capital (Vogel, Lundqvist, & Arias, 2015). From the viewpoint of financial institutions, high transaction costs, small project sizes and perceived risks associated with credit or estimated energy savings are among the most commonly cited barriers (Cooremans & Schönenberger, 2019). The duration of the financing may also not suit the long pay-back of energy renovation projects in buildings. Moreover, limited underwriting EE loan practices and lack of standardization of energy savings measurement and verification methods are also important inhibiting factors (Bertoldi & Kromer, 2006). High interest rates often attached to financial EE products can be explained in part by the lack of liquidity and exit opportunities for investors through secondary markets (Zabaloy, Recalde, & Guzowski, 2019).

By adopting appropriate sets of policy tools, governments can support the uptake of building renovations and development of EE market (Baek & Park, 2012; Brown, 2001). Financial and fiscal instruments have a prominent role in the policy framework adopted by many countries, as they can tackle numerous EE barriers (Zimring, Borgeson, Todd, & Goldman, 2014) by lowering payback times and removing upfront cost barriers (Brown, Sorrell, & Kivimaa, 2019). Depending on the stage of market development, governments can support different project phases, technologies, building types, and occupants with the ultimate goal to increase the leverage of private financing (Sorrell et al., 2000). Indeed, enhanced private sector involvement is a prerequisite for a sustainable market activation (Maio, Zinetti, & Rod, 2012).

Financial instruments for energy efficiency can take the form of debt or equity financing. In the EU, they typically range from conventional instruments such as subsidized loans to new or emerging models in the European market such as energy efficiency mortgages, crowdfunding, dedicated renovation saving accounts,[2] and so on. As shown in Figure 1, these can be classified according to type (non-repayable rewards, debt financing or equity financing) and level of market saturation (traditional/well established, tested and emerging, and new and innovative).

The focus of the paper is to provide an EU-wide review and assessment of various financial instruments, discussing their uptake, characteristics, benefits, and challenges as well as applicability for various segments of the residential building stock. Traditional financial instruments are defined as financial instruments that have been already operating for several decades across many EU Member States, while innovative instruments are instruments which are either in pilot phase or yet under consideration in the EU Member States, but often already implemented in other regions (e.g., PACE financing in the US). Tested and growing instruments represent instruments that have been proven to work in several EU Member States, and are increasingly significant in scale, thus have a potential for a more widespread application. The paper focuses on financial schemes only for direct interventions in buildings, that is, excluding any programs that are R&D oriented or solely have an advisory, motivational, or informational role. In addition, we only considered instruments designed to improve primarily energy efficiency.[3] In other words, general renovation programs, which are directed at general restoration and maintenance with no particular focus on energy efficiency, are excluded.

This article is structured as follows. Section 2 introduces the concept of energy renovations and key features of financial instruments covered in this study. Traditional and well-established instruments (in particular, grants and subsidies, tax incentives, and loans) identified in the EU are discussed in detail in Section 3. Tested and growing

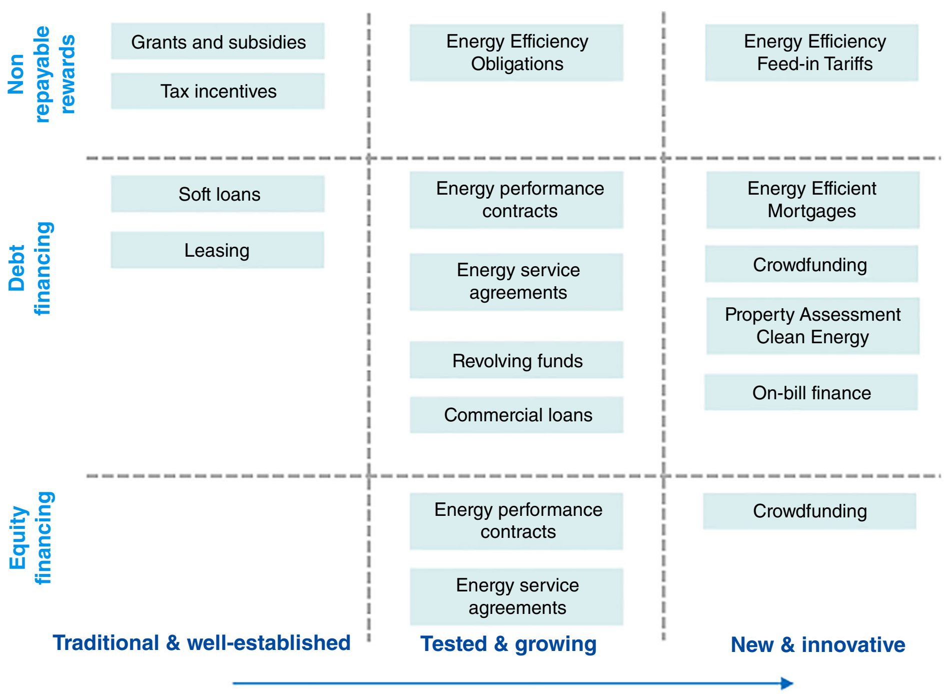

FIGURE 1 Overview of current financial instruments supporting energy renovations in the EU classified according to market saturation (traditional, growing and new) and type (non-repayable reward, debt financing, and equity financing)

instruments (in particular, energy efficiency obligations, energy service companies, energy performance contracts [EPCs], and energy service agreements) are covered in Section 4, while new and innovative schemes that can help unlock energy efficiency upgrades are described in Section 5. The latter are on-bill finance, property assessed clean energy (PACE) financing, energy-efficient mortgages, energy efficiency feed-in tariffs, incremental property taxation, one-stop shops, and crowdfunding. Section 6 gives a critical review of the application of the described instrument in different segments of the residential sector in the EU. The section also provides recommendations on how to fill the remaining financing gap in energy efficiency with the view of achieving the energy transition that would lead to the 2050 carbon neutrality objective envisioned by the EU.

2 | BACKGROUND AND METHODOLOGY

Renovation is often used to describe various interventions in a building. It can refer to maintenance or repair works to general modernizations, restorations, or upgrades. An energy efficiency upgrade or energy renovation is often "behind the scenes" of several of these interventions, generating different levels of energy savings. While there is no clear definition of an energy renovation in the literature, one may describe it in terms of installed intervention measures or targeted energy performance improvement. There are only a few studies in the literature that link the depth or ambition of an energy renovation with relative energy savings or energy performance generated once the renovation is completed (Economidou, Laustsen, Ruyssevelt, Staniaszek, & Strong, 2011; Shnapp, Sitjà, & Laustsen, 2013). For example, some of these draw a link between "deep renovation" and a relative energy consumption drop of at least 60%. Due to the lack of official or widely accepted definition of energy renovation, herein we related energy renovation with any intervention measure on the building envelope or the building technical systems, which result in quantifiable improvements in energy performance. These improvements primarily stem from energy efficiency interventions, but may also include installations of renewable heat/cooling generation and electricity systems as well as energy management systems.

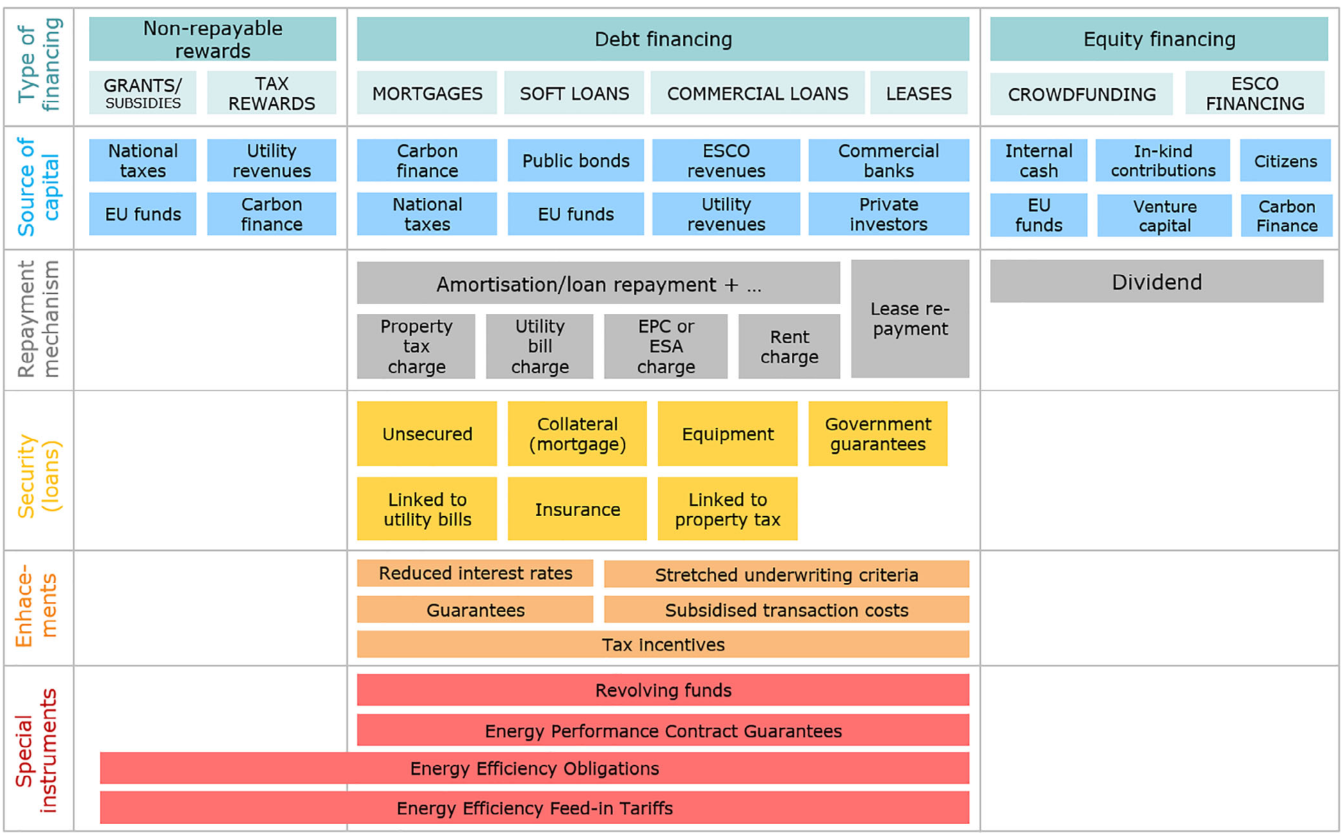

FIGURE 2 Summary of key characteristics of financial instruments for energy renovations in buildings

The financial instruments covered in this article have fundamental differences in how they work in practice. Figure 2 summarizes the various design and implementation elements of the instruments discussed herein such as source of capital, repayment mechanism, types of enhancements, and so on. Debt financing is typically linked to traditional amortization arrangements, but given the nature of energy efficiency investments, more innovative repayment channels can be available, including property tax, utility bills, and so on. Another important element to consider in their design is the capital structure which may stem from public and/or private sources and cover venture capital and equity investments, mezzanine finance (Bertoldi, 2009; Bertoldi & Rezessy, 2010). For debt financing, security options may include the property itself in case of mortgage, utility bills in case of on-bill models, property tax, or in some cases special government guarantees.[4] The latter are put in place to reduce financial institutions' perceived risks, in particular, with regards to delayed payments or defaults from clients. In public-private partnerships, governments can also choose to subsidize interest rates so that banks can offer a preferential interest rates in their loan financing products offered to their customers. Reduced interest rates may also be directly considered by banks as it becomes more and more evident that these energy efficiency investments enhance the purchasing power of consumers by increasing disposable income due to lower energy bills. Tax credits and deductions for the acquisition/installation of energy-efficient products, building components, or whole renovations can also be offered as stand-alone incentives or combination features alongside other financial products. Other enhancements include stretched underwriting criteria, subsidized transaction costs, and so on. Finally, these instruments can be used in conjunction with other instruments, including revolving funds, whereby loan funds are recycled and re-lent for more energy efficiency investments. Energy efficiency obligations (EEO) can be placed by governments on energy companies in the form of specific energy savings targets such as the energy savings of 1.5% of annual sales to final consumers stipulated by Article 7 of Directive 2012/27/EU (Fawcett, Rosenow, & Bertoldi, 2019).

Energy companies then apply their technical know-how to deliver or procure energy savings for their customers, thus providing some financing. An opposite instrument applies in energy efficiency feed-in tariffs where incentivized end-users are encouraged to save energy through the provision of a financial incentive based on the kWh saved.

To offer an overview of traditional and innovative financial instruments, a comprehensive literature review was performed to analyze each instrument in detail (databases: Web of Science, Scopus, and Google Scholar). The review covers definitions/descriptions, impacts on effectiveness, and notable examples in Europe. In the study, 13 financial instruments were identified, of which three were classified as "traditional," three as "growing", and seven as

TABLE 1 Literature review of energy efficiency policies and impact assessment in buildings

Category	No. of papers	Source
Traditional and well-established	14	Bertoldi & Rezessy, 2010; Olmos, Ruester, & Liong, 2012; Ruijs & Vollebergh, 2013; Economidou & Bertoldi, 2014; Mir-Artigues & del Río, 2014; Rosenow, Platt, & Demurtas, 2014; Gutierrez, 2016; Kuusk & Kalamees, 2016; Economidou et al., 2018; McInerney & Bunn, 2019; Newell, Pizer, & Raimi, 2019; Polzin, Egli, Steffen, & Schmidt, 2019; Villca-Pozoa & Gonzales-Bustos, 2019; IEA-RETD, 2012, Economidou, Todeschi, & Bertoldi, 2019.
Tested and growing	12	Bertoldi, Rezessy, & Vine, 2006; Bertoldi & Rezessy, 2008; Robinson, Varga, & Allen, 2015; Nolden & Sorrell, 2016; Bertoldi & Boza-Kiss, 2017; Boza-Kiss, Bertoldi, & Economidou, 2017; Rosenow & Bayer, 2017; Tsoutsos et al., 2017; Augustins, Jaunzems, Rochas, & Kamenders, 2018; Frangou, Aryblia, Tournaki, & Tsoutsos, 2018; Tupikina & Rozhkova, 2018; Fawcett et al., 2019.
New and innovative	34	Brown, 2009; Bell, Nadel, & Hayes, 2011; Headen, Bloomfield, Warnock, & Bell, 2011; Henderson, 2012; Neme & Cowart, 2012; Bertoldi, Rezessy, & Oikonomou, 2013; Bürger, 2013; Eyre, 2013; Eadson, Gilbertson, & Walshaw, 2013; Ingram & Jenkins, 2013; Mahapatra et al., 2013; Mahapatra, Mainali, & Pardalis, 2019; Kirkpatrick & Bennear, 2014; Oxera, 2015; Balson, Moreira, & Simkovicova, 2016; Mills, 2016; Lam & Law, 2016; Shazmin, Sipan, & Sapri, 2016; Dilger, Jovanovi, & Voigt, 2017; Grøn Bjørneboe, Svendsen, & Heller, 2017; Shazmin, Sipan, Sapri, Ali, & Raji, 2017; Boza-Kiss & Bertoldi, 2018; Miller & Carriveau, 2018; Miu, Wisniewska, Mazur, Hardy, & Hawkes, 2018; Bento, Gianfrate, & Groppo, 2019; Brown et al., 2019; McInerney & Bunn, 2019; Polzin et al., 2019; Mundaca & Kloke, 2018, McGovern, 2019; Ameli & Kammen, 2012; Ameli & Kammen, 2014, IEA-RETD, 2012, Speer, 2014; Johnson, Willoughby, Shimoda, & Volker, 2012; Jewell, 2009; Jewell, 2010.

"innovative". For each of them, general information was collected: How the instrument works, good EU practices, the source of finance, main barriers addressed (i.e., upfront cost, cost of finance), advantages and challenges, stakeholders involved. Table 1 shows the main published articles for each category.

In particular, this work analyses the following financial instruments for energy renovations in buildings:

Traditional and well-established (Section 3):

- Grants and subsidies
- Tax incentives
- Loans

Tested and growing (Section 4):

- Energy Efficiency Obligations
- Energy Services Companies (ESCO) and Energy Performance Contracting
- Energy Services Agreement (ESA)

New and innovative (Section 5):

- On-bill finance (OBF)
- Property Assessed Clean Energy (PACE) financing
- Energy Efficient Mortgages
- Energy Efficiency Feed In Tariffs
- Incremental property taxation
- One-stop Shops
- Crowdfunding

3 | TRADITIONAL AND WELL-ESTABLISHED FINANCIAL INSTRUMENTS

This section discusses traditional financing instruments, which are already in place and implemented in many of the EU MSs. These "traditional" instruments—grants and subsidies, tax incentives, loans—can support the establishment of a new market at its initial stages and provide liquidity and direct access to capital. Although they can be specifically designed to provide assistance to vulnerable groups and can be used in conjunction with other mechanisms, they typically focus on individual interventions and small projects. In specific cases when the intensity of the instrument is high, they can support deep renovations. The main aspects, strengths, and limits of these financial instruments together with examples in different MSs are described in detail below.

3.1 | Grants and subsidies

Grants and subsidies, such as direct investment subsidies, are used by governments when optimal levels of investments cannot be fully provided by the market alone. They can partly contribute to overcoming the upfront cost barrier since they directly fill an immediate financial gap and, hence, enable a temporary shift in the market (Newell et al., 2019). For energy efficiency, grants and subsidies can also raise awareness and trust in EE projects, improve cash flow, and increase investors' access to debt finance (Bertoldi & Rezessy, 2010). These forms of support are usually included in policy mixes covering further fiscal and financial instruments such as feed-in tariffs and tax breaks (Polzin et al., 2019). Their main limitation, however, is budget restrictions as they are typically linked to public resources and can thus neither offer a sustainable solution nor support massive market uptake programs. Moreover, the effectiveness of a subsidy program can be difficult to assess because of rare monitoring processes of the share of free riders—beneficiaries that would have implemented their economically sound projects even without access to subsidies (Bertoldi & Rezessy, 2010). Another barrier is that subsidies for small projects may hinder more ambitious projects achieving higher energy savings goals. Ideally, comprehensive packages are needed in cases where public grants are combined with other financing schemes deployed by public and commercial financial institutions with the aim of boosting the investment volume and support renovation work that focuses on extensive renovation work (Kuusk & Kalamees, 2016).

Public grant programs are used in almost all MSs to support EE projects (Economidou et al., 2018; Economidou & Bertoldi, 2014). In the EU, these are mostly used to reduce initial costs for the purchase and the installation of equipment, as well as provision of advice and certification services. More and more these schemes however, support comprehensive renovations with energy performance criteria attached to them, rather than individual interventions. Examples include the Estonian energy renovation subsidy program supported through carbon emission trading funds between 2010 and 2014. This program was based on three main innovative pillars: The introduction of technical consultants for apartment associations to help make the correct decisions and steer a rather complex renovation process; the process review for a developed design by third-party experts to ensure the fulfillment of all technical requirements and the adequate quality of design documents; and the commissioning of ventilation requirements using measuring protocol (Kuusk & Kalamees, 2016). In the Czech Republic, the "New Green Savings Programme" supports the renovation and construction of residential buildings with up to 50% of the total eligible expenses and it is funded by revenues from the sale of EUA (European Union Allowance) and EUAA (European Union Aviation Allowance) units.[5] Other examples include the "Saving Energy at Home" Program in Greece, the "Save & Upgrade" in Cyprus, the "Environment Operational Programme" in the Czech Republic, the "Operational Programme Infrastructure and Environment" for the residential and public sectors in Poland, the "National Programme for Renovation of Residential Buildings" for multifamily buildings in Bulgaria and the regional subsidies for energy efficiency in residential buildings in Austria.

Rosenow et al. (2014) proposed an indicative and illustrative model to assess the impact on the UK Exchequer of a subsidy scheme to support the uptake of solid wall insulation measures across the UK's residential building stock. Three distinct subsidy options were designed and modeled: Private householder scheme, social housing scheme, and loan scheme. Their analysis shows that a significant amount of the cost of a scheme funding solid wall insulation would be offset by increased revenues and savings.

3.2 | Tax incentives

Taxation can be also a powerful tool to stimulate EE by giving incentives through tax exemptions, allowances or benefits, and through incentive regimes related to, for example, capital gain tax, property tax, VAT, and accelerated or free depreciation. Tax benefits may be more effective than subsidies (McInerney & Bunn, 2019). Tax schemes directed toward energy renovations of buildings have been used in Belgium, Denmark, Netherlands, France, Italy, and Greece. Eligible measures cover all intervention types in buildings: Envelope improvements, building technical systems, connection to district heating, renewable heat, and electricity generation systems.

Another form of tax allowance is the tax credit, whereby a percentage of the investment cost of approved technologies can be used to offset taxes. France and Italy have established tax credits as a policy to promote EE. Although being administered via income tax declaration, these have the effect of a direct grant. Tax schemes can have a positive impact on new, innovative technologies. By allowing for frequent updates of the eligible measure list, the schemes can promote the market introduction phase of new technologies if the innovative technologies are considered in the list (Ruijs & Vollebergh, 2013).

Differentiated VAT may encourage efficiency improvements, for example, it can be reduced on efficiency equipment and/or services. While, in certain circumstances, the owners might not be stimulated in refurbishing their homes because of property tax regimes. Swedish property tax is calculated upon five categories, including Energy Efficiency. Therefore, the property tax is higher for good performances of the property. In France, the calculation of the tax is based on the potential revenue in case the property is rented. On the contrary, in the Czech Republic, a real estate tax relief is ensured for 5 years to owners who modernize the heating system of their property and a temporary exemption from property tax is given for high-efficiency residential buildings in Bulgaria (Bertoldi & Rezessy, 2010). In Italy, the "Ecobonus" scheme (Law no. 145 of December 31, 2018) allows a tax deduction up to 85% of the sustained EE costs (to be received in 10 years; Formisano, Vaiano, & Fabbrocino, 2019). In Spain fiscal policy has not significantly advanced toward encouraging improvements in energy efficiency in residential buildings. Suggestion to include the EE in the fiscal policy are provided by several studies, as the one of Villca-Pozoa and Gonzales-Bustos (2019), who proposed two measures focused on a Personal Income Tax (PIT) linked to improve energy rating of housing and on improved regulations for Real Estate Tax (RET) and Tax on Building.

3.3 | Loans

Loans are form of debt financing that provides liquidity and direct access to capital, which can be more relevant for EE measures attached to high upfront costs, especially in deep renovation projects. A loan scheme increases the leverage of government subsidies and, if accessible to private households and social housing providers, it allows additional revenue for the Exchequer in addition to budget neutrality (Rosenow et al., 2014).

However, private debt finance supporting energy renovations is limited as financial institutions are not familiar with these investments and perceive EE loans as high-risk investments. Factors that hinder market uptake include high transaction costs for relatively small projects and failure to offer financing to support deeper measures for the necessary period. To address some of these issues, international financing institutions and national governments have intervened with the aim to provide subsidies in public–private partnerships so that financial institutions can offer customers loans with attractive terms (Olmos et al., 2012). Techniques for securing EE equipment and project loans to end-users include preferred drawing rights and special escrow accounts, reserve funds, security interest in equipment and project, collections via utility bills or property taxes, extra collateral from the borrower, guarantees and credit enhancement programs.

Soft loan schemes involve favorable conditions for borrowers (Mir-Artigues & del Río, 2014) and are commonly used for EE measures. Below-average market rates, longer payback periods, and loan guarantees, which provides buffer by first losses of nonpayment, are mechanisms whereby public funding promotes and prompts investments in EE. Loan conditions include: Extended payback periods, low or zero interest rates, short-term interest deferral periods, and/or inclusion of payback grace periods. For example, the “KredEx Renovation loan for apartment buildings” in Estonia gives the possibility to obtain long-term low-interest rate renovation loans for improving energy efficiency of apartment buildings constructed before 1993.

Some governments have appointed State Investment Banks (SIBs) to close the financing gap and support the greening of their economies. SIBs can be decisive in leveraging additional private finance, including enabling financial sector learning, creating trust for projects, and taking an early mover role to help projects gain a track record. SIBs are considered by policymakers as a key component within a country's overall energy policy mix. Two examples of activities and financial institutions are the Green Investment Bank (GIB) in the UK, founded in 2012 with government funding, and the Kreditanstalt fuer Wiederaufbau (KfW) in Germany (Geddes, Schmidt, & Steffen, 2018). KfW, while originally established as the country's development bank, is the most well-known scheme in Germany, which has supported building energy renovations for several years. The German case indicates that KfW's widespread financing, in conjunction with policy support, influenced the country's advanced stage of low-carbon sector development.

Therefore, in this context, banks play an essential role as an intermediary between economic development and environmental protection, for promoting sustainable investment. Gutierrez (2016) proposed a green housing loan model for banks to save the environment with a proactive contribution. The model supports the promotion of green loans and in encouraging possible lenders to avail of environmental friendly bank products. However, there is neither a wide offer of green loans and green deposits nor a clear cut policy that pertains to green banking (Gutierrez, 2016).

4 | TESTED AND GROWING FINANCIAL INSTRUMENTS AND TOOLS

In this section, financing instruments tested and growing in EU MSs are presented. As mentioned before these include Energy Efficiency Obligations (EEOs), Energy Service Companies and Energy Performance Contracts (ESCO and EPCs), and Energy Service Agreements (ESAs). Advantages and barriers are illustrated in the discussion below.

4.1 | Energy efficiency obligations

The principle behind EEOs is that the obliged energy companies are required to prove that they have achieved energy savings with activities that promote or fund EE improvements in the premises of end-users. In 2017 the number of EEOs grown from five schemes to 16, as a consequence of the introduction of the EU Energy Efficiency Directive (EED) in 2012 (Rosenow & Bayer, 2017). EEOs mandated to different energy market actors have been used until today in Denmark, Flanders, France, Italy, and United Kingdom (Rosenow, 2012) and recently, according to Article 7 of the EED (Directive 2012/27/EU), in other MSs (Fawcett et al., 2019). After some unsuccessful trials, an EEO was also put in place in Poland (Fawcett et al., 2019). In some MSs such as Italy and France, since energy-saving obligations are combined with tradable white certificates (WCs), the accredited parties (not just the obliged energy providers) can earn WCs which can be subsequently traded (Bertoldi et al., 2010; Bertoldi & Rezessy, 2008). EEOs deliver several economic, energy, environmental, and social benefits, such as reduction of energy consumptions and GHG emissions, improvement of thermal comfort conditions, and air quality of indoor and outdoor spaces, bill savings, and reduction costs in transmission and distribution. Since EEOs schemes may often overestimate actual energy savings achieved (Moser, 2017), it is very difficult to estimate accurately cost and savings of EEOs in Europe (Rosenow & Bayer, 2017; Rosenow & Galvin, 2013).

Under an EEO, eligible measures for the building sector may cover the building envelope, technical building systems, renewable heat, and electricity generation systems. For example, in the UK, the most common measures include insulation and energy-efficient lighting, while in France condensing boilers (IEA-RETD, 2012). The list of eligible sectors and measures is usually defined in advance by the monitoring and verifying authorities.

To deliver their obligations, energy companies mainly establish contracts with third parties within the EE market such as insulation companies, retailers of appliances, manufacturers, and heating installers. Implementing an obligation on energy suppliers has the advantage of not placing a burden on the national budget as the obliged bodies can recover their costs via the consumers' energy bills or through regulated tariffs in the case of regulated distribution companies. As funding is not dependent on public expenditure, the schemes are not affected by any budget cuts.

4.2 | Energy services companies and energy performance contracting

ESCOs finance the up-front costs of an energy performance improvement project from the energy cost savings during operation. An ESCO may substitute the traditional utility provider, or contract the client only for the implementation of a set of EE measures agreed together. An ESCO-implemented investment helps the end-user investment without major risks in an unknown field, because the ESCO takes on performance and sometimes credit risks. After the ESCO contract, the end-user is left with a building or site that has an increased energy performance than before, and that has lower energy costs (Robinson et al., 2015).

An EPC is a guarantee-based agreement between the client and the ESCO, often with the participation of third-party, such as a bank, whereas the ESCO issues a performance guarantee, and their remuneration is directly linked to the savings achieved (Bertoldi & Boza-Kiss, 2017; Pätäri & Sinkkonen, 2014). In case of no or lower performance, the ESCO has to financially compensate the client (Bertoldi et al., 2006; Tsoutsos et al., 2017). Normally, an ESCO implements the agreed energy improvement measures using its technical and organizational know-how during the project. Often, the ESCO is also responsible for monitoring the energy savings. The financing for the investment may come from the client (e.g., in Denmark), the ESCOs own funds (in case of large ESCOs usually, typical for example, in Italy, France), or from a third-party using the EPC guarantee as a credit basis (as common in the Czech Republic and Germany) (Boza-Kiss et al., 2017). In an EPC, the ESCO provides a performance guarantee which guarantees the flow of energy savings from a retrofit project. Alternatively, the guarantee ensures that the energy savings resulting from the investment will be sufficient to repay monthly debt service costs. ESCOs use various financing structures, such as limited recourse debt, usually with additional collateral or credit support needed, and an important role is played by the economic evaluation of the contract implementation (Tupikina & Rozhkova, 2018).

Transaction costs of a typical ESCO project are high in comparison with other financial solutions (Nolden & Sorrell, 2016), partly because they assume the technical, and sometimes even the financial risks that normally an end-user would have to bare. Therefore, ESCO projects are usually undertaken by large energy-consuming end-users (such as industrial sites or large commercial buildings). There are a few special examples of ESCO projects in large multifamily and social housing residential buildings in Italy, France, Germany, Latvia, Romania, Slovakia, Hungary, and Bulgaria (Boza-Kiss et al., 2017). EPC can also be provided by Public-Private Partnerships to deliver energy efficiency projects in the public sector (Carbonara & Pellegrino, 2018), where trust in these structures exists (Boza-Kiss et al., 2017). An interesting combination is the LEMON[6] project in Italy that promotes new contracting models including EPCs for social housing retrofit. It provides technical assistance to public and private entities for the preparation of tenders for the energy retrofitting of social housing units in the provinces of Reggio Emilia and Parma. In Latvia, the LABEEF program[7] was introduced to repurchase the long-term investments necessary for multifamily building renovation. The Latvian experience proved that ESCOs can solve and eliminate many of the previously hindering technical and financial barriers of projects even in sectors previously considered difficult (Augustins et al., 2018). The tertiary sector holds a huge potential of energy savings through EPC, and the Trust EPC South[8] project implemented in the southern EU countries (improves the financing access and conditions of sustainable energy solutions in this sector, by improving trust and confidence in the financing parties (Frangou et al., 2018).

4.3 | Energy services agreement

Similar to EPC, an ESA is a contract able to combine different EE measures giving a service to building owners that pay for through a charge based on realized energy savings without having to provide the upfront cost (Figure 3; Kim et al., 2012). Since, in the ESA model, payments are based on actual energy units saved, ESA providers give performance guarantees assuming the risk that expected savings will occur. The project developer then operates and maintains the EE measures during the term of the ESA, while the customer pays for the energy saved as a service. When the ESA contract ended, the project costs have been paid, the building owners continue to pay reduced bills and energy saving become their profits. Sometimes, when the ESA provider pays a facility's energy bill and in turn bills the customer for the energy efficiency services this is known as “managed energy services agreement” or MESA. The advantage of ESAs is that they allow customers to finance these improvements “off-balance sheet” which can be useful for tax purposes or in cases where existing mortgage are attached to restrictive terms.

In the past few years, a growing number of ESA projects has been implemented in the US, mainly targeting large buildings, such as Metrus Energy, mostly involving the installation of LED lighting. More recently, ESAs are also available to single-family housing and are offered by several EE service providers and financial organizations. For example, in New York, there is the Home Advance financing program for single-family homes that offers energy efficiency retrofit packages, with a reduction in electricity use up to 5% and in heating fuel use up to 20–25%. To date, ESAs have not been used for deep retrofits that save at least 30%. The execution of larger projects with larger savings could be addressed by combining ESA financing with utility incentives (ACEEE[9]).

5 | NEW AND INNOVATIVE FINANCIAL INSTRUMENTS AND TOOLS

In this section, some of the “innovative” mechanisms on how to overcome some of the key barriers associated with EE financing in the EU are presented. These “innovative” mechanisms may be based on funding structures permitting a loan to be repaid from energy savings, similarly to EPC, but through other actors (e.g., utilities or local authorities) and

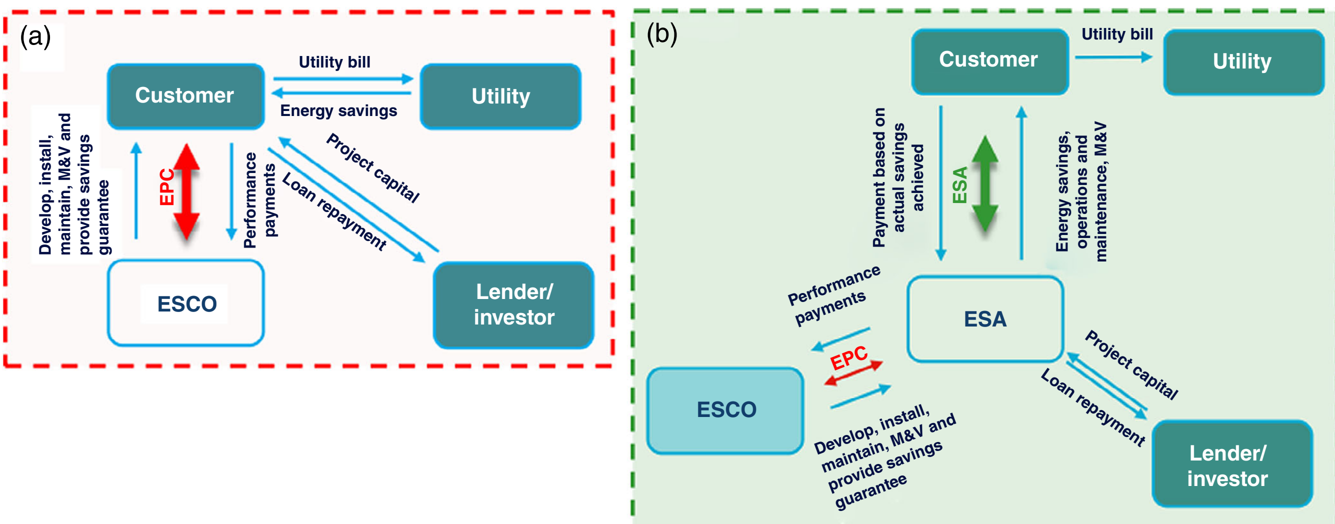

FIGURE 3 Schematic diagram illustrating the underlying principles of (a) EPC and (b) ESA models (Economidou & Bertoldi, 2014)

thus eliminating the need for upfront capital. They can take the form of property assessment clean energy or on-bill finance. As debt financing typically needs to be compatible with restrictions associated with existing mortgages, energy mortgages can also offer an attractive option. The cost of capital, the reduction of complexity, and the possibility to enable also non-energy measures, such as general improvement works, affect the success of these financing instruments (Brown et al., 2019).

5.1 | On-bill finance

OBF lowers first-cost barriers by linking repayment of EE investments to the utility bill. Therefore, customers are able to pay back part or all costs of EE investments over time (Brown, 2009). It is an effective approach to address the split incentives barrier and can be, therefore, suitable for EE investments in multi-family or rented properties. The funds used to support these investments can originate from utilities, the state, or third parties including commercial banks. Energy savings accruing from the installed EE measures, must be large enough, so that the total post-renovation utility bill does not exceed the pre-renovation bill (Henderson, 2012). Given possible challenges that this type of instrument may pose on utility core business models as well as complex tendencies of energy efficiency markets, other policies need to complement this innovative financing mechanism (Mundaca & Kloke, 2018).

On-bill loans and *on-bill tariffs* are the two categories on-bill finance programs can be categorized in. With lower interest rates than market-rate lending options, on-bill loans mainly differ from on-bill tariffs in the fact that the former must be paid off in case of ownership transfer, on-bill tariffs assign the obligation to the property/meter, hence, they allow for a transfer of the repayments to the next tenant or buyer and the treatment of the charge as part of the utility bill (Jewell, 2009).

Utility OBF programs have been used in the US for many years (Bell et al., 2011). The capital in these cases can be used to create loan loss reserves and guarantees to hedge against default risk or to buy down interest rates to make these programs more attractive, thereby reducing risk. Other capital sources may include bond issues, public loan funds, revenue from cap, and trade programs, banks, credit unions, and capital markets (Bell et al., 2011). They can be administrated by utilities although in certain cases, other actors (such as government, energy agency, nonprofit, or service companies) can assume this responsibility. The US experience demonstrates that although OBF is associated with elements that can overcome upfront cost and split incentives, important concerns need to be addressed. These include the need to modify billing systems, the definition of the role of utilities as financial institutions, the identification risks of no payment cases, management of handling issues related to property transfer, diversification of capital sources, and consideration of nonutility and fuel diversity. Numerous US utilities have long used the utility bill approach as the mechanism for repayment in the business sector. The Southern California Edison (SCE) offers to business, government and institutional customers a no-fee, interest-free loan paid back through the SCE electricity bill which is based on the estimated energy savings (Jewell, 2010).

On-bill tariff programs are based on a concept similar to PAYS® model which was first introduced as a pilot program in New Hampshire in 1999 in response to diminishing national funding, while programs were later introduced in five states (EEI, 2013). The US successful implementation of HELP PAYS program has been approached in rural cooperatives who leveraged on-bill approaches to provide their members with guaranteed bill savings from energy efficiency improvements (ACEEE[10]).

OBF has also advanced in the residential sector. By comparing the on-bill programs developed by two utilities, Midwest Energy and Hawaiian Electric Company, Johnson et al. (2012) highlighted the key aspects for a successful implementation of OBF in residential buildings. Among these, a simple application process, a good relationship with the contractors, common benefits to all involved actors, and flexibility in terms and conditions play a significant role.

The first PAYS®-inspired scheme in Europe was implemented in the UK in 2013 with the Green Deal, which enabled owners and occupants to install EE improvements at no up-front cost. However, the performance of this scheme was not as originally foreseen, with several factors contributing to its failure (Mundaca & Kloke, 2018). A detrimental factor was the high (7–8%) interest rate attached to the Green Deal loan which was considered uncompetitive in comparison with general home improvement loans.[11] The attachment of the loan with the property rather than the occupant—a recent concept that could help facilitate energy renovations—was perceived as a disincentive by several building owners as it was argued that this could make a property less attractive to prospective tenants or buyers (Eadson et al., 2013). Finally, the loan repayments were based on average estimated figures rather than figures tailored to the occupant's energy usage. While an updated version of the RdSAP[12] tool was planned to be used (incorporating occupancy-related "in-use" factors), there was no guarantee that the estimated bill savings and thus monthly loan repayments were less than real savings (Ingram & Jenkins, 2013).

Another European initiative was the "Better Energy Finance" scheme launched in 2015 in Ireland by the Irish government and industries and based on the idea of a market-based PAYS® residential retrofit scheme. Despite some design differences with the UK Green Deal, the Irish scheme did not gain momentum. Some of the challenges that can explain why OBF instruments, in general, have not yet had success in the EU include complex design features, the need for additional regulation to enable repayment charges on the utility bill and the establishment of fully liberalized EU energy markets with several suppliers being reluctant to participate. It is also worth noting that OBF instruments have to compete with various other EU financing instruments—with often more attractive terms than OBFs—such as low-interest loans, tax incentives, and grants.

5.2 | Property assessed clean energy financing

PACE is a means of financing energy renovations and renewable energy improvements using specific bonds offered by municipal governments to investors (Mills, 2016). The funds raised by these bonds are used to loan money toward energy renovations in residential or commercial buildings. An annual assessment of the property tax bill is used to repay the loan over the long-term period of 15 or 20 years (Kirkpatrick & Bennear, 2014). Since PACE assessments are transferable, the investments can be recouped upon sale, therefore, the concern investment recovery during sale transactions is reduced. Moreover, PACE programs are secured by a senior lien on the owner's property, thereby detaching repayment security to the borrower's creditworthiness and being more attractive to financiers (Headen et al., 2011). What is innovative in this mechanism is that the collection of the repayment is done via taxation by a public (local) authority. Commercial (C-PACE) and Residential (R-PACE) PACEs are very different, with C-PACES more sophisticated but in a process of growing, thanks also to new simpler models (McGovern, 2019) as reported in a study by the US Department of Energy's Lawrence Berkeley National Lab.[13]

PACE programs were mainly implemented in the United States with an initial allocation of $150 in federal grant funds (LBNL, 2011). According to the latest market data of 2019 of PACENation, a movement for supporting PACE financing, in the last 10 years about 5,600 million dollars have been invested in residential PACE and more than 200 000 buildings renovated with a boost in the last 2 years (https://pacenation.org/pace-market-data/). A PACE enabling legislation is available in 36 US states, 12 states have active programs while others are in the process of program development. Despite a suspension in 2010, there is still growing interested around the PACE mechanism in the US. The California Statewide Communities Development Authority (CSCDA) announced that a PACE program (the so-called CaliforniaFIRST) was launched in 17 California counties and 167 cities in the second half of 2014. Key actions have also been taken to create a PACE mortgage loss reserve program, aimed at refunding mortgage holders from losses associated with a PACE lien on the property, thereby addressing concerns raised by mortgage providers. The program is administered by the California Alternative Energy and Advanced Transportation Financing Authority (CAEATFA). The recent PACE study also showed that most jurisdictions adopting PACE programs are using a model like the one adopted in Wisconsin, due to its simplicity. In Michigan (Mills, 2016) the PACE approach has been successfully combined with a more traditional instrument, the ESPC, providing a win-win solution for upgrading office-buildings.

PACE financing is not yet available in the EU. Some impeding factors include complex legal processes and first-lien complications which must be best addressed at the EU level. In addition, PACE is normally based on bond issued by cities, which is not common in EU cities, especially small ones. However, the pilot project, EuroPACE[14] is testing the concept in a municipality in Spain. EuroPACE adopts best practices from the US PACE market and intends to further enhance its impact. The project aims at addressing several fundamental challenges to EE investment. The first ambition is to deploy private capital as up-front financing to homeowners (IEA-RETD), that is, reduce reliance on grants and subsidies; a de-risk approach to EE investments is the second aim. To optimize the decision-making processes for homeowners, the project includes the training of energy service contractors (technical assistance) and finally, it provides design standard underwriting requirements and project performance guidelines to facilitate the project aggregation and the issuance of Green Bonds. In addition, the PACE model has been considered as an innovative effective tool that may support the financing of solar energy generation (Speer, 2014), as it allows reducing the initial costs of PV installation and dealing with the change of ownership (Ameli & Kammen, 2012, 2014).

5.3 | Energy-efficient mortgages

Preferential terms for energy efficiency can also be delivered through mortgages. Energy mortgages can be categorized in (a) the Energy Efficient Mortgages (EEMs) and (b) the Energy Improvement Mortgages (EIMs). Essentially, an EEM is a loan with reduced interest that credits the EE of the building in the mortgage itself and thereby increases the home buying power of consumers and capitalizes the energy savings in the appraisal. In the United States, EEMs are typically used to purchase a new home that is already energy efficient, such as Energy Star qualified one.

An EIM is used to purchase existing buildings that will be subjected to an EE improvement. Through EIMs borrowers can include the cost of EE improvement in the mortgage without increasing the down payment. The money saved in utility bills are used to finance energy improvements. A building certification is a requirement for the two categories of energy mortgages in US since the energy rating discloses estimated monthly energy savings and the value of the EE measures. In the EU, there is a pilot project (EeMAP[15]) aiming at creating a standardized "*energy efficient mortgage*". Attention should be paid to the fact that mortgages entail high transaction cost (e.g., notary costs) and therefore may not suitable for low-cost EE investments. The success of the EEM depends on the improvement of the energy efficiency of a property with a positive impact on property value, reduction of energy bills, and the increase of the income in the household reducing a bank's credit risk. In the UK a Green Mortgage shows remarkable potential to address the main barriers to retrofit policies. This scheme supports the offering of re-mortgage products which cover the financing of EE measures, while maintaining economic viability and contributing to high-level UK targets (Miu et al., 2018).

5.4 | Energy efficiency feed-in tariffs

Energy efficiency feed-in tariffs (EE FITs) represent a new instrument based on the concept of Feed in Tariffs for renewable energy (RE FITs), namely, that the participant is rewarded for the operational performance of their investment (Krupa & Harvey, 2017). While the reward for RE FITs is in the form of a payment for energy produced from renewable sources, EE FITs is a reward for the energy savings delivered by EE investments.[16] Consumers under an EE FIT are encouraged in the reduction of energy use through an additional financial incentive besides the monetary savings from reduced energy bills. The additional financial incentive is related to the actual performance of the investment.

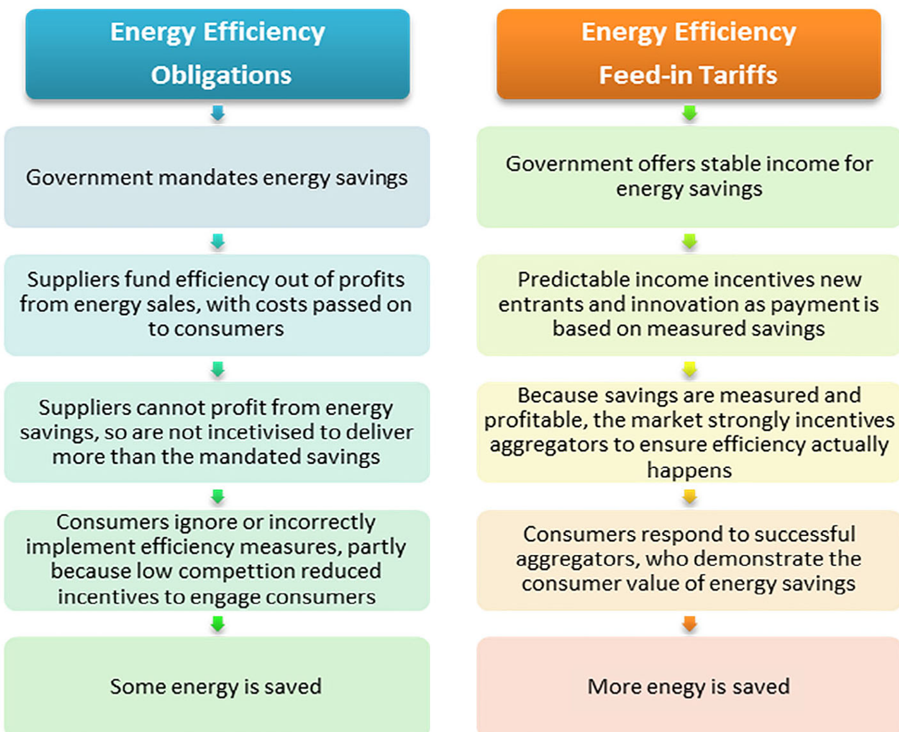

FIGURE 4 Conceptual differences between Energy Efficiency Obligation and Feed-In Tariff schemes (Green Alliance: Benton, 2011)

EE FITs work in a reverse mechanism compared to EEO/WC (Figure 4). In EE FIT, the price for a kWh of energy saved is defined and the market can determine the quantity of energy savings to be delivered (*price-based* mechanism). Conversely, the quantity of savings is established under the EEO with the target, and the market then determines via the obliged energy companies the price of achieving them (*quantity-based* mechanism).

While the concept of EE FITs is relatively simple, it is necessary to take into account policy design issues (Bertoldi et al., 2013; Eyre, 2013; Neme & Cowart, 2012). Neme and Cowart (2012) proposed that payments under an EE FIT should be allowed for verified savings arising from both individual projects as well as mass market programs.

One problem with this new instrument is that there are no practical examples from which experiences can be drawn. The price of energy savings (€ per kWh) is a critical element of the design process. While a fixed price system will generally favor cheap EE measures, price variations which can encourage more difficult or expensive savings to be realized, as proposed by Neme and Cowart (2012). For example, rewards can increase with the depth of measures where deeper or more advanced measures with low market penetration are offered a bonus. The price of energy savings is also suggested to vary depending on end use as well as different market segments (e.g., residential, low-income households, small commercial customers). Debates on whether the reward should be based on monitored savings as well as the approach to be used for evaluation, measurement, and verification need to be carefully examined (Bertoldi et al., 2013). Another key element is the number of years for which savings are to be paid, where the savings produced over their entire lifetime should be ideally recognized (Polzin et al., 2019). Finally, payment options can range from a full up-front payment immediately after the measures are installed to yearly payment according to each year's savings, where the former effectively works as an installation grant, while the latter as stream of annual payments.

5.5 | Incremental property taxation

Property taxes are imposed in most of EU MSs, which can be distinguished in recurrent taxes on immovable property and other taxes such as taxes imposed on purchase transactions. These taxes mostly depend on the real estate value of each building. A modification, however, could be introduced to include the building efficiency level in the property tax paid by the owner (e.g., based on building's Energy Performance Certificate). By doing so, an incentive is given to the property owners to invest in energy renovation measures in buildings to reduce their tax relief. According to Bürger (2013), since taxes are increased for inefficient buildings only, the adjustment can be revenue-neutral. The generated revenue of the inefficient buildings could feed a public support fund for vulnerable groups such as low-income households or SMEs. This efficiency adjustment could apply to both annual property taxes paid by the building owners and taxes paid in property purchases. In case of a property purchase, the new owner could be given a certain grace period (e.g., 2 years after the transaction) before the extra tax charge attached to the building's efficiency is due. This would give the opportunity to new owners to carry out renovation work and improve their building energy label in the meantime. Several countries have adopted property tax incentives on green building. Some countries in Europe, Canada, and the US provide reductions on property tax assessment as incentives; India, Malaysia, and the US provide rebates on property tax assessments as an incentive for green building (Shazmin et al., 2016). Through exemption, incentive model provides no increment on existing property tax revenue, and taxpayers obtain benefits from saving in energy bills. The reduction incentive model provides for an increased in taxes offset by annual energy savings (Shazmin et al., 2017).

5.6 | One-stop shops

One-stop shops (OSS) are independent, government-led, or industry-linked advisors that offer services that cover the whole or at least most of the renovation value chain. The specific mixture of their offer may change, but these include general awareness raising, assessment of the energy performance, organization of the renovation project, technical assistance, or even implementation, structuring and provision of financial support (often from a third party), and the monitoring of savings (Boza-Kiss & Bertoldi, 2018).

The key benefit of working with OSSs is that through their services, they overcome many barriers related to residential building renovation. On one hand the OSS acts as an intermediary that simplifies the fragmented offer of renovation suppliers, for example, designers, suppliers, installers, financiers into a single offer to the homeowners (Balson et al., 2016). At the same time, an OSS helps the supply side of building renovation by mediating with the potential clients (Boza-Kiss & Bertoldi, 2018) using techniques such as organizing offer packages, pooling the projects, organizing the project, and so on. OSSs are well-placed to facilitate the implementation of locally developed projects and strong and trustworthy partnerships between homeowners, local actors (e.g., SMEs, financial institutions, energy agencies), and even local governments.

Among their services, OSSs sometimes deliver financing of various kinds to the final users. Many of them also established partnerships with banks, in particular with local banks. In a recent survey by the Joint Research Center, 15 out of 60 OSS offer a financing plan as part of their services. This means that they assess the technical feasibility and alternatives of the home for renovation, and they attach recommendations on the sources to be used to cover the costs in the most economical way. The OSS has an overview of the locally relevant funding sources and their combinations. These include most of the financing instruments discussed in this paper, such as national and local grants, commercial and preferential loans, EPC or EEO sources, and so on. The EuroPACE project under H2020 is testing property-tax based financing, too. A few OSS may be able to offer their own resources, too. Five out of 60 OSS around Europe offer their own financing for all or most projects, while four only sometimes. These OSSs employ EPC for homeowners, that is, provide a guarantee, linking their remuneration to the savings, and working together on the implementation of the project, too (Boza-Kiss & Bertoldi, 2018).

To boost the usage of OSS for home energy renovation, it is necessary to show its benefits of high-quality outcomes and cost-efficiency (Mahapatra et al., 2019). Moreover, since the projects include significant trust, one of the decision success factors is the reliability of the stakeholders involved (Mahapatra et al., 2013). The European Commission has increased its interest in the OSS business model for residential buildings renovation, with OSS becoming a critical element of the "Smart financing for smart buildings" initiative (EU COM, 2016). The Directive 2018/844/EU, which amends the Directive 2010/31/EU on the energy performance of buildings (EPBD) and Directive 2012/27/EU on Energy Efficiency (EED) also calls for OSSs as an element toward increased renovation of the European building sector. OSS services are effective because they typically have the following characteristics: OSSs are local; increase the rate of building refurbishment by informing, motivating, and guiding building owners to implement EE investments. They stand beside homeowners from the start of the project to the end; in particular, they can build on the interest of motivated but not yet committed energy users/asset owners to actually implement an energy saving or other type of sustainable project. Furthermore, OSSs ease access to financing and may offer the same services for lower costs. In certain cases, for example, in combination with industrialized renovation packages, OSS can also improve the average renovation depth in terms of energy performance.

BetterHome is a successful OSS in Denmark that offers predefined renovation packages to private homeowners. They rely partially on automated and customized services, allowing the future client to pre-inform the installers and pre-select the measures via the website and app. However, as a next step, the homeowner is in direct and responsive relationship with the technical team. This allows tailoring of the exact package—as much the technical, as the financial terms—to the exact needs of the homeowner. BetterHome has local craftsmen that carry out the actual work, who get training and tools to ensure quality services, and BetterHome carries out promotion, quality assurance, monitoring, and in general, all customer care tasks. Over 200 projects were completed in 2016 and have been expanding since then (Boza-Kiss & Bertoldi, 2018). A different scheme is implemented in France by the Région Ile de France, where the regional government organizes the OSS. A new Semi-Public Company was established and ESCO was developed to offer a whole value chain of building renovation to residential homeowners (Boza-Kiss & Bertoldi, 2018). HolaDomus is an integrated home renovation program based on the One-Stop-Shop (OSS) model, recently launched in Spain. Despite not having yet the necessary experience to determine the specific level of renovation achievable, it has been confirmed that a more extensive renovation is feasible with the support of OSS (Grøn Bjørneboe et al., 2017).

5.7 | Crowdfunding

A new form of financing that, using internet-based platforms, connects investors directly with borrowers (without involving other traditional financial organizations) is crowdfunding (Miller & Carriveau, 2018; Oxera, 2015). In the last few years, crowdfunding has become an alternative means of financing renewable energy projects (Dilger et al., 2017), playing a key role to finance the early stages of projects (Lam & Law, 2016).

Crowdfunding can be categorized in four types depending on the funding purpose and investment method: (a) donation-based, (b) reward-based, that can be collectively referred as "community crowdfunding", (c) equity-based, or (d) lending-based, that can be defined as financial return crowdfunding or investment crowdfunding. Below some examples of crowdfunding are indicated: “efficient stoves to protect pandas” in China with the construction of 100 highly energy-efficient cook stoves for residential buildings (reward-based); “A Flame Called Hope” in Nepal with the exploitation of biogas energy (donation-based); “Pay-As-You-Go” in Tanzania with the production and sale of 1,000 solar home systems (lending-based); “Solar Green Point” in the Netherland with the installation of 1,000 solar panels on the roof of the Caballero Fabriek (equity-based).

The main benefits of this financing instrument are flexibility and reduction in transition costs, competing with traditional channels of financial intermediation (Oxera, 2015). Potential problems with this type of instrument are for example that the funds are often insufficient compared to the demand from entrepreneurs; or else the possibility of online fraud due to the unproven technology (Bento et al., 2019). In general, the returns are not enough compared to the risks related to the technology adopted, in fact, projects offering better risk-adjusted returns attract relatively larger contributions. Tax reliefs could be an important element to improve crowdfunding model. For example, in the UK, stakeholders can invest through a tax-efficient Individual Savings Account (McInerney & Bunn, 2019).

In the European context, the CrowdFundRES[17] project promotes the use of crowdfunding for financing the acceleration of renewable energy growth. The CrowdFundRES project involves three main actors: renewable energy project developers, public actors interested in investing in projects, and crowdfunding platforms to link public and project developers (facilitating the financial transaction). In Croatia, a crowdfunding platform project for energy efficiency has been put in place with the aim of funding public buildings and infrastructures benefitting the community. The projects has seen the collaboration of North-West Croatia Regional Energy Agency (REGEA), the Centre for Social Innovations and Sustainable Development (CEDIOR), and the University of Zagreb and the first pilot project focused on the complete renovation of a kindergarten, paving the way for future application of the funding scheme.

6 | DISCUSSION

An assessment of the main financial instruments available for energy renovations of residential buildings, including adoption EU rates, main advantages, and implementation challenges is outlined in Table 2. Some of the main factors that would affect the selection and adoption of financing instruments at the national level include prior experience, political acceptance, stakeholder engagement, public opinion, economic conditions, and so on. Often, a combination of different instruments is preferred by countries to enhance attractiveness and success of a certain instrument as well as ensure wide coverage of building types, users, and needs. Possible combinations can be in the form of guarantees with loans, EPCs with subsidies, and so on.

Public subsidies provided by EU governments have created an early economic stimulus toward energy renovation projects. Even though they currently form the most popular instrument type provided in the EU, they are unlikely to form a major driver for large-scale investments. Given that subsidies can place a burden on public finances and may be associated with free ridership issues, governments may choose to limit their access to specific target groups, for example, low-income households as well as micro, small and medium enterprises. Moreover, well-designed grants and subsidies can be geared toward new emerging technologies and difficult-to-reach segments in the building sector such as rental properties. Despite this, even the most prominent grants and subsidies cannot offer a real widespread solution.

Debt financing in the form of loans has proven to be a successful way of scaling up energy efficiency investments through more liquidity and direct access to capital. New credit lines tailored toward energy efficiency improvements have been identified in several EU countries (i.e., “Residential Energy Efficiency Credit Line” in Bulgaria, “Public financing” in Estonia, and “Zero-rated eco-loan” in France), reflecting their increasing popularity in the region. Preferential loans, such as the ones administered by the KfW bank in Germany, provide support to more ambitious renovations, while at the same time offer competitive interest rates and long repayment periods. If debt financing instruments are attached to long repayment conditions, deeper renovations can often be targeted. One of the reasons behind the popularity of this type of instrument is that green credit lines can often be coupled with enhancements to increase their attractiveness to customers. They can be combined with subsidies to help alleviate the upfront cost barrier and can be offered alongside guarantees, such as loan loss reserves, to decrease the risk of client defaults to lenders and support more clients to access them. The main limitation of debt financing is, however, reluctance from risk-averse consumers who may not be willing to take on additional debt. In addition, access to households with insufficiently high credit score such as low-income households or vulnerable groups is difficult.

TABLE 2 Summary review of financial instruments in the residential sector across the EU

Financial instrument	Adoption rate	Good EU practices	Source of finance	Main barriers addressed: Upfront cost	Main barriers addressed: Cost of finance	Main barriers addressed: Split incentive	Advantages	Challenges	Buildings/ households best suited
Grants & subsidies	High	Better energy homes scheme (IE)	Taxpayer & Subsidy recipient	X			Support of new emerging technologies; help to kick start market; can be combined with other types of instruments	Public budget restrictions; free riders; mostly shallow measure support	Vulnerable/low income households; hard to reach properties (e.g., rented properties)
Energy efficiency obligations	Medium/ high	Energy savings agreement (DK)	Energy consumers	X		X	No public budget burden; wide range skills offered by energy suppliers; third party involvement	Energy bill surcharge; low consumer trust to energy suppliers; mostly shallow measure support	All
Tax incentives	Low/ Medium	Eco-bonus (IT)	Taxpayer				Useful at promoting new technologies; lower burden to public resources than subsidies	Reduced tax revenue to government; success depends on tax collection rate; less beneficial to low-income households	All
Preferential loans	Medium	KfW (DE)	Government/ private investors	X	X		Less burden on public resources than grants; support to deeper renovations	Upfront cost barrier due to down-payment; reluctance to take on additional debt; large transaction costs in small projects	Households with sufficiently high credit score
Revolving funds	Medium	KredEx (EE)	Government/ private investor/ repayments	X			Repayments cycled back into fund for future projects	Fund may "revolve" quite slowly; limited short-term impact of public funds	Depends on financial product supported by fund
Energy performance contracts	Medium	Renesco (LV); lemon (IT)	ESCO/client	X			No upfront costs for consumers; know-how of ESCOs	Performance risk; high fees charged by ESCOs	Large condominiums
Energy service agreements	Low	N/A	ESCO/client	X		X	Finance improvements "off-balance sheet"	Not adapted for deep renovations	Large condominiums
Energy efficient mortgages	Low	Raifaissen; Nordea; Muenchener Hyp	Lender	X	X		Easy access to capital (low cost); increase in ability to pay monthly installments; long repayment period; support to deeper renovations	Large transaction costs in small projects; strict collateral requirements	Creditworthy homeowners;

(Continues)

TABLE 2 (Continued)

				Main barriers addressed					
Financial instrument	**Adoption rate**	**Good EU practices**	**Source of finance**	**Upfront cost**	**Cost of finance**	**Split incentive**	**Advantages**	**Challenges**	**Buildings/ households best suited**
Property assessment clean energy	N/A	EuroPACE (ES)	Municipal bonds	X	X		Long repayment period; lower transaction costs by streamlining application processes; support to deeper renovations	Available only to homeowners; not available for small investments; high set up costs for municipalities	Property owners only
On-bill finance	Low	Green Deal (UK)	Utility or third party	X		X	Attractive option for leased properties; no upfront cost to consumer; easy repayment	Potentially high-interest rate attached to on-bill loans; not suited for very large projects	Rented properties
Crowd-funding	Low	Bettervest (DE)	Individuals	X			Access to finance for consumers not eligible for conventional financing products	Difficulty to reach funding target; risky investments; weak regulatory framework	Communal projects
Feed in tariffs	N/A	N/A	Consumer			X	Incentive to maximize savings given they are output-based	Complex design issues; budget restrictions	All

Tax incentives, either as standalone policy or as an enhancement feature with debt financing, are considered a major instrument in supporting energy efficiency investments in certain EU countries such as Italy, France, Belgium, and Denmark. Considered to be less costly than grants and subsidies, they can support the uptake of energy renovations by lowering their cost through reduced taxes for households and businesses. The Ecobonus tax incentive in Italy, which can now be transferred to the supplier of the service in exchange for a discount thereby enabling a more widespread use, has had a significant impact on the Italian market. Tax incentive schemes can take the form of income tax credits/deduction, accelerated depreciation, tax exemptions, or VAT reduction. They may work well in cases where resulting tax loss incurred by the public authorities as a result of this type of financial instrument can be compensated by other streams of tax revenues such as taxation of energy intensive industries. Their success largely depends on the effectiveness of tax collection system.

Following the adoption of the Energy Efficiency Directive, energy efficiency obligations, which have the advantage of placing no burden on the national budget and are therefore independent of budgetary changes, has become a more widely used instrument in Europe. They are some of the most long-standing and successful schemes supporting energy efficiency upgrades in Italy, France, Denmark, and the UK. They, however, require political support for their continuation, as confirmed by the recent extension of the EED Article 7 till 2030. While they offer the possibility to engage third parties with a wide range of skills, they may often be faced with reluctance due to possible energy bill surcharges and low consumer trust to energy suppliers. They are usually more suitable to “low-hanging” fruit investments, focusing mainly on measures that yield the cheapest savings, such as boiler replacement.

Energy performance contracts have also gained popularity in many EU Member States in the last few years, even though they cover a fraction of residential buildings (and only large multifamily or social housing). EPCs offer the option of performance guarantees which can reduce risks associated with complex projects. Given that they enable funding of energy renovations from energy cost savings, they are successful at tackling upfront cost barriers for consumers. ESCOs are equipped with advanced technical and operational know-how, allowing them to offer state-of-the-art solutions, optimize operations, and generate high energy savings to customers. Key issues with this type of model include high transaction costs as EPCs cannot offer a realistic framework for smaller projects. Large condominiums or apartment blocks are therefore more appropriate target for this type of model than single-family houses or small residential buildings. As customers may bear the responsibility of securing the financing part for EPCs, energy service agreements can offer an alternative solution by allowing customers to finance these improvements “off-balance sheet”, while they pay only for actual savings realized. The challenge with EPCs, however, is that they are typically not adapted for deep renovations. Despite this, there are some interesting projects where EPCs are used in conjunction with forfeiting (selling of the receivable) to support deep renovations (e.g., Latvia).

Our analysis has demonstrated that the energy renovation market is complex and many players such as multi-family building owners, tenants, or other actors who may not be eligible for credit are not always served by traditional instruments. While grants and subsidies can provide additional incentives, they may not be enough to completely alleviate first-cost barriers. Moreover, it may not always possible to offer attractive loan terms for deep renovations. Conventional mortgage underwriting processes by commercial banks do not take into consideration EE parameters and energy costs. The difficulty of forecasting energy savings leads to uncertainty over return which can act as hurdle for diversifying existing capital sources and attracting private interest.

Some of the innovative instruments and measures that have been examined in this article are designed to overcome some of these hurdles. For example, OBF reduces upfront cost barriers by incorporating EE investment repayments in the utility bill. It can be tied to the property, making the obligation of repayment transferable to the next occupant or building owner. It can be therefore used to overcome the split incentive barrier in rented properties. Some of the barriers related to on-bill programs include high administrative costs (due to the need for individual energy audits and new billing structures), allocation of risk in the event of default, transferability of obligations in the event of property sale in practice, and ways to ensure energy savings exceed loan or tariff payments. Given that the utility bill after the renovation (i.e., energy costs plus investment repayment charge) must in general not exceed the utility bill prior to the renovation, shallow renovations or small efficiency improvements will be in general favored by this type of instrument.

The PACE model is another promising means of scaling up EE investments in the building sector, by leveraging specific bonds offered by municipal governments and tax assessments against the properties benefitted by such improvements. PACE overcomes the barrier of access to long-term financing—with terms typically ranging from 15 to 20 years—and often offers more attractive interest rates than standard bank loans. With these design features, it has the potential to support more comprehensive measures and deeper renovations. It can also be associated with lower transaction costs as a result of streamlined application processes. They are only available to homeowners and are usually not suitable for small investments. High set-up costs for municipalities and legal complications related to the lien priority, however, need to be addressed.

Mortgage lending can play an important role in promoting EE by making it more mainstreamed and addressing some of persistent problems associated with EE financing. As debt financing typically needs to be compatible with restrictions associated with existing mortgage on the properties, EE can offer an alternative option. By recognizing the savings accrued through energy efficiency upgrades, banks can add the potential cost of energy renovations to the mortgage and offer preferential terms through energy-efficient mortgages. Energy efficiency mortgages have the potential of unlocking additional finance for renovation from the private sector, while reducing the need for governmental energy subsidies. With design features such as low-interest rate and long repayment period, energy efficiency mortgages have the potential to support deep renovations. The main challenges are associated with high transaction costs for small projects and strict collateral requirements.

The feed-in tariff, a market-based mechanism that can reward real energy savings rather than the investments themselves, offers a promising solution to consumers who are not eligible for conventional financing products. While the concept is not new as renewable energy feed-in tariffs have been extensively used in the past, the model has not yet been tested for energy efficiency. Complex design issues and budget restrictions may be some of the main challenges that must be considered by policymakers. Their design may also mean that moderate energy savings are only captured as the focus is mainly on behavioral change measures. Crowdfunding is also an innovative way to collect funds through contributions from groups that share a common interest through internet-based platform, without involving traditional organizations. As in the case of feed in tariffs, it is often used to finance renewable energy projects and innovative green technology start-ups. It blends new funding sources from many small investors, thus empowering them to seek control over their investments. The main challenges are linked to higher risk investments and weak regulatory framework offering protection in case of defaults.

7 | CONCLUSIONS

It is widely recognized that new models and sources of finance are necessary to deliver the untapped energy efficiency potential of buildings. As the EE finance market grows, tested concepts will evolve into more well-established schemes, while new ones will develop. The emerging financial models discussed in this paper offer the potential to remove some of the long-standing barriers to energy efficiency (such as upfront costs, split incentives, and cost of finance), which most conventional solutions have failed to successfully tackle. While the present assessment focuses on financial instruments in the EU (with some examples of their application in some Member States), this is not a comprehensive review of all the instruments currently available in Member States. It is recommended that a follow-up study would address this point. The current research shows that no single “silver bullet” for EE finance solutions exists due to complex nature of the sector and long-chain of actors involved in the building sector and their diverse interests. The financial instruments reviewed in this article are therefore suitable for different national and local situations as well as different types of residential buildings: Single family, multifamily, social housing, and rented properties.

Moreover, the frequent interactions between financial instruments and various policy measures must be stressed. For example, financial instruments are often linked with energy building codes, where incentives are awarded to projects achieving energy performance levels beyond current code levels, or a certain energy class under the national energy performance certification scheme. The importance of the latter as a tool to determine the EE criteria of planned renovations and/or as a tool for compliance checks has been underlined in discussions on efforts made by stakeholders to standardize energy efficient mortgages (EeMAP). This highlights the need of a more direct dialogue between financiers, policy makers, and other stakeholders. Feedback between financiers and policy makers can enable energy performance certificates become truly useful policy tools. The recently established Energy Efficiency Financial Institutions Group by the EU[18] is a positive step toward establishing this dialogue and increasing awareness among financial institutions and other intermediaries such as providers of energy and technical services, local energy agencies, and aggregators.

For now, these financial instruments remain an integral part of any comprehensive energy efficiency policy framework due to their ability to incentivize stakeholders, balance risks, and provide direct support to investments that generate significant and long-lasting energy savings. In the future, research, however, must focus on how financial models can be better integrated with new and emerging practices in the field. For instance, one stop shops, a concept that has recently gained popularity, offer a single entry to customers which can guide them through all aspects of the complex renovation value chain, including support on how to access finance. Beyond this, financial models can only be successful if solutions on how to aggregate small projects are found as well as ways to address split incentives. Moreover, financial instruments cannot resolve performance risks and issues related to uncertainties in estimating future energy savings, a key area where further research is needed. Further studies on methodological approaches on how to estimate non-energy benefits of energy efficiency investments (e.g., increased property value or improved thermal comfort) are also needed (Zancanella, Bertoldi, & Boza-Kiss, 2018). All these issues, alongside new financial models and solutions, must be investigated in more detail to offer true market transformation and ensure a successful energy transition in the coming decades.

CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

DISCLAIMER

The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.

AUTHOR CONTRIBUTIONS

Paolo Bertoldi: Conceptualization; investigation; methodology; supervision; writing-original draft; writing-review and editing. **Marina Economidou:** Investigation; methodology; writing-original draft; writing-review and editing. **Valentina Palermo:** Investigation; methodology; writing-original draft; writing-review and editing. **Benigna Boza-kiss:** Investigation; methodology; writing-original draft; writing-review and editing. **Valeria Todeschi:** Investigation; methodology; writing-original draft; writing-review and editing.

ORCID

Paolo Bertoldi https://orcid.org/0000-0002-2797-7941
Valentina Palermo https://orcid.org/0000-0002-5676-3272
Benigna Boza-Kiss https://orcid.org/0000-0003-4005-2481
Valeria Todeschi https://orcid.org/0000-0002-4080-1692

ENDNOTES

[1]An advisory service put in place and co-financed by the Federal Ministry for Economic Affairs and Energy in Germany (https://www.bmwi.de/Redaktion/EN/Dossier/enhancing-energy-efficiency-in-buildings.html).

[2]Obligatory in a number of Central European and Eastern countries for multi-apartment buildings (including Italy). These are usually used for general maintenance, but can be a good source of financing for EE.

[3]This study covers financing instruments that are also including on-site renewable generation, but does not take into consideration renewable generation only financing. Moreover, the focus of the instruments included in this paper is on buildings and building technical equipment, neglecting appliances.

[4]Governments are intended to be at different levels from national to municipal. Guarantees, mainly for nonresidential buildings can often also come from international financiers, such as the EIB, which have special program for this, and national ones, such as the national Development Banks.

[5]State Environmental Fund of the Czech Republic. https://www.sfzp.cz/en/administered-programmes/new-green-savings-programme/.

[6]LEMON project: http://www.lemon-project.eu/.

[7]SUNShINE project: http://citynvest.eu/content/sunshine.

[8]Trust EPC South project: http://www.trustepc.eu/en.

[9]American Council for an Energy-Efficient Economy: https://aceee.org/blog/2019/02/energy-service-agreements-potential.

[10]American Council for an Energy-Efficient Economy: https://aceee.org/blog/2019/04/bill-financing-gains-ground-faces.

[11]Loans for home improvements can be as low as 5% although in certain cases they can be much higher than 7% (Guertler, Royston, & Robson, 2013).

[12]RdSAP stands for Reduced Data Standard Assessment Procedure is a steady state model used to assess and compare the energy and environmental performance of dwellings.

[13]Leventis, G. & Schwartz, L. Commercial PACE Financing and the Special Assessment Process: Understanding Roles and Managing Risks for Local Governments. Available at http://eta-publications.lbl.gov/sites/default/files/final_cpace_brief_1_112308-74205-eere-c-pace-report-arevalo-fz.pdf.

[14]http://www.europace2020.eu/. The pilot programme, entitled HolaDomus, is an integrated home renovation programme designed to make home renovation easier, faster, more reliable and affordable.

[15]https://eedapp.energyefficientmortgages.eu/.

[16]Bertoldi et al. (2013) suggest that savings delivered through behavioral actions can also be awarded under the EE FIT.

[17]http://www.crowdfundres.eu/index.html.

[18]http://www.eefig.com/.

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