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Supporting energy efficiency measures in the residential sector. The case of on-bill schemes

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A B S T R A C T

Implementation of energy efficiency interventions in the residential sector is pivotal to drive the energy transition and achieve energy policy targets. For such a reason, public programs supporting the renovation of residential buildings are available globally, but public incentives are not enough to address all the potential and it is necessary to attract private investments. An innovative approach to consider is represented by on-bill schemes, which foresee investments by energy utilities with possible cooperation of financial institutions. The present contribution proposes an in-depth description of on-bill mechanisms, their possible frameworks, the barriers to their implementation as well as the impact they may have on the core business of utilities. The study is based on a review of the existing literature integrated with the results of on-field interviews and discussions with the aim to obtain a full picture of on-bill schemes in a European replication perspective. Methodologically, the paper is based on structured desk research and on-field feedback obtained from selected stakeholders. Additionally, a SWOT analysis is developed highlighting that on-bill schemes may result very convenient for power utilities and energy retailers. Furthermore, on-bill schemes can help to address the issue of the split incentives. In conclusion, on-bill schemes can be considered a valid tool to support energy renovation in the residential sector, but they do not represent a global solution since their application is not tailored for all the contexts. The analysis highlights that power utilities are in a strong position since they can use on-bill schemes to switch part of the demand from fossil fuels , e.g., natural gas, to electrical power. Similarly, energy retailers are in a good position since they can enlarge their business by selling energy efficiency as a service through on-bill schemes.

1. Introduction

Heating and cooling of buildings is responsible for approximately 50% of energy consumption (European Parliament, 2018) in EU, therefore the implementation of energy efficiency measures is considered of paramount importance to sustain the energy transition and to pursue the decarbonization, as envisaged by different energy and climate policy initiatives (European Commission, 2019).

Within the building sector, residential buildings have a prominent role by accounting for 75% of the total building stock (Pohoryles et al., 2020), thus it is fundamental to promote energy efficiency measures in this sector.

The barriers hampering the implementation of energy efficiency measures, which often are profitable by themselves, are of different typology. In accordance with Amoruso et al. (2018), the barriers can be categorized according to the following dimensions: institutional barriers, misplaced incentives, lack of awareness and information, market-related barriers, and financial barriers.

Among these, as illustrated by Bertoldi et al. (2021), a relevant barrier is represented by the upfront costs necessary to implement appropriate building retrofitting interventions. In fact, energy policies often focus on the implementation of financial supporting mechanisms to stimulate the necessary investments. The importance of the financial barriers is also highlighted by Xiatong et al. (2015) and Forrester and Reames (2020), who examined the Chinese and USA context, respectively. More specifically, Xiatong et al. (2015) proposed a methodology for a more precise evaluation of cost and benefits in the implementation of energy efficiency measures. According to their view, a correct estimation of the convenience represents an incentive for both private citizens and public authority in co-investing for improving energy efficiency. The same concept was remarked by Belaid et al. (2021), who developed an analysis on the cost-effectiveness of energy efficiency measures in the French residential building

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stock. They identified the most profitable measures according to the climatic conditions and building typology. A focus on the estimation of the coverage gap of programs designed for supporting the renovation of low-income households was proposed by Forrester and Reames (2020). They argue that these programs left uncovered a relevant number of households which have a high income to enter the program, but, on the other hand, their income is not enough for qualifying for traditional financing sources. They developed a quantitative methodology to estimate the gap.

Due to the long operating life of buildings and a very low demolition rate in EU, it is estimated that in 2050 at least the 75% of the current building stock will be operating (Urge-Vorsatz et al., 2012). Therefore, it is mandatory to develop large scale retrofitting programs to fulfill EU targets, e.g., 2030 and 2050 objectives. Furthermore, as highlighted by Giraudet (2020), informational barriers play a relevant role in hampering and discouraging the implementation of energy efficiency measures. The valuation and implementation of energy efficiency measures involve complicated analyses, e.g., the NPV is stochastic in its nature (e.g., random weather conditions, uncertainty on future energy prices, etc.), a relevant number of stakeholders to implement the interventions (e.g., designers, installers, etc.) and final users' behaviors (e.g., tenants behaving differently from the past, etc.). In case of under-performance, it is extremely complicated to understand the origin of the problem. This is acknowledged in the literature. In fact, as demonstrated by Belaid and Joumni (2020) in the French context, subjective factors, namely the behavior of the occupants, are relevant, but also geographic location plays a fundamental role (Belaid et al., 2019). All this discourages the interventions.

To stimulate virtuous behaviors, EU issued different directives, e.g., Energy Performance Building Directive and Energy Efficiency Directive, aiming at implementing energy efficiency measures on the building stock (Economidou et al., 2020).

Due to the prominence of the topic, many researchers tried to investigate and scrutinize the optimal supporting mechanisms to develop energy efficiency measures in residential buildings.

According to this, Brown et al. (2019) evaluate alternative financing mechanisms for supporting energy retrofitting in residential buildings. They highlight a set of key features which are to be considered while designing a financing mechanism for the residential market. They mention that the cost of capital is a critical factor to ensure the success of a possible program together with its simplicity.

The effectiveness of the Irish Better Energy Homes scheme is analyzed by Collins and Curtis (2018). They estimate the households' willingness to pay for energy efficiency improvements and subsequently determine the number of retrofits that would have occurred in the absence of grant aid, i.e., the so-called *free riders*. According to their calculation, the number of free riders is equal to 7%, which is a low number. Therefore, the scheme demonstrated to be effective, since without it most of the houses would not have been refurbished. Similarly, Weber and Wolff (2018) investigate the obstacles to energy retrofitting in the German residential market. They highlight that most of the housing stock is rented, therefore the issue of split incentives arises. According to the German law, landlords can charge up to the 11% of the energy renovation cost on the annual rent. On the other hand, even in presence of substantial savings on the energy bills, the system is not convenient for the tenants who experience a higher rent than before the retrofitting. The authors conclude that new financial models are necessary to support the implementation of energy efficiency measures.

Energy efficiency programs launched by private companies are investigated by Alberini and Towe (2015), who estimate the impact of two energy efficiency programs proposed by utilities for residential customers in Maryland (USA). One is focused on energy audits and the other on rebates for the installation of heat pumps. Both the programs lead to a 5% energy savings. The effects are similar in winter and summer for the energy audit-based program, whereas they appear stronger in winter for the heat pump rebate group. They also notice that house characteristics and previous consumption patterns have a limited influence on the level of savings. Hyland et al. (2013) propose an analysis of the impact that energy efficiency certification introduced by the Energy Performance Building Directive had on the Irish market in terms of increased value of the property. They found that a positive rating has positive effects on both sale and rental price of the property, but the effect on the sale price is stronger. These results were confirmed also by the work of Caroll et al. (2016), who analyzed the willingness to pay for residential rentals in Ireland. They detect that tenants attribute an extra value to dwellings with an energy class higher than the worst level. However, the higher is the energy class and the lower is the incremental value of the rent.

The Property Assessed Clean Energy (PACE) program is studied by Rose and Wei (2020) and by Headen et al. (2011). PACE is an innovative financing program for energy efficiency linked to the property tax. Rose and Wei (2020) estimate the global economic impact of the PACE implementation in California by also including general equilibrium effects, e.g., new job places, etc. Similarly, Headen et al. (2011) discussed the application of PACE in Ohio by scrutinizing the possible interventions to develop and the pros and cons of the program. PACE is the scheme which has more conceptual analogies with OBS, namely, it is attached to the property (i.e., object-based financing), there are no upfront costs for the users, and its payments are identified as an additional item in the tax breakdown. A detailed review of the most relevant energy efficiency financing schemes can be found in Bertoldi et al. (2021).

The financial supporting mechanisms available in Malaysia are discussed by Hor and Rahmat (2018). They review a set of available schemes based on tax incentives, investment incentives, etc. for both companies and residential sector. Similarly, Sebi et al. (2019) examined buildings energy retrofitting policies in Germany, France, and USA. They focused on the three different approaches considered in these countries, namely the promotion of grants and loans in Germany through the KfW program, increase of energy class of properties for any transaction in France and a mix of rating, innovative financing mechanisms and technical assistance in USA.

An innovative financial mechanism to support the implementation of energy efficiency interventions in residential buildings is represented by on-bill programs. These programs aim to remove the barrier represented by the upfront cost of energy efficiency interventions. The capital to implement the interventions is provided by the energy utility itself or in cooperation with financial institutions, and the users repay the investment with installments on the energy bill for a certain period.

This scheme is very attractive since it allows the cooperation between energy utilities and financial institutions. Despite the relevant investment potential, financial institutions encounter difficulties in approaching the energy renovation market. In particular, the main issues are related to the fragmentation of the investments, lack of project standardization and unfamiliarity with the valuation of energy efficiency projects. Partnerships with energy utilities may allow to overcome these problems. Correspondingly, energy utilities can benefit from the cooperation with financial institutions since they can have access to capital to set-up ambitious programs. On-bill programs are based on private initiatives and they do not require public funding, therefore they represent an interesting option for attracting private investments in the energy renovation market.

Table 1
Summary of the reviewed literature about on-bill programs.

Paper	Issues addressed
Bertoldi et al. (2021)	Review of the main energy efficiency financing mechanisms. The authors dedicated a small sub-chapter to on bill mechanisms just to make a brief introduction and overview.
Hor and Rahmat (2018)	Analysis of the possible energy efficiency financing scheme to be considered in Malaysia. Among the others a brief discussion is dedicated to on-bill mechanisms.
Johnson et al. (2012)	Development of a case study related to two companies, namely HECO and Midwest Energy. The analysis is focused on the implementation strategies that these two companies adopted for their on-bill schemes
Mundaca and Kloke (2018)	Comparison of two on-bill programs, namely HowSmart active in Kansas and Green Deal in UK. They provided a comparison between a success story, i.e., HowSmart, and a failure, i.e., Green Deal.
Bird and Hernandez (2012)	Paper focused on the problem of the split incentives in energy renovation. A focus is given on the possible role played by on-bill schemes in addressing this issue.
Rosenow et al. (2013)	Analysis of the main features of the Green Deal program. The mechanisms and organization of the program are illustrated and discussed.
Rosenow and Eyre (2016)	Analysis of the main causes of the failure of the Green Deal program. The failures in terms of policy design and administration of the program are highlighted and discussed.

Despite the high innovation level of these programs, contributions providing a deep insight are scarce in the literature.

Bertoldi et al. (2021) devote a brief sub-chapter of their paper to them, whereas Johnson et al. (2012) develop a case study focused on the on-bill programs promoted by two utilities in USA. A deep analysis of two schemes, namely HowSmart in USA and the Green Deal in UK is proposed by Mundaca and Kloke (2018). They developed a comparative analysis by highlighting the drivers for the success of HowSmart and the causes for the failure of the Green Deal. Further works are proposed by Rosenow et al. (2013) and by Rosenow and Eyre (2016).

Rosenow et al. (2013) propose a comparison between the German KfW scheme and the UK Green Deal. They discussed the two different approaches considered in the two programs for overcoming the upfront investment barriers in implementing energy efficiency interventions. Whereas Rosenow and Eyre (2016) analyze the reasons for the failure of the Green Deal program. The issue of the split incentives is addressed by Bird and Hernandez (2012), who discuss, among the others, the possible role that on-bill programs can have in softening this barrier for the investment in energy efficiency.

The reviewed literature highlights a limited analysis of on-bill schemes. Table 1 provides a summary of the reviewed literature which mentions on-bill programs. It highlights that most of the available works are focused on case studies or on-bill schemes are only mentioned as one of the possible innovative financing programs without a deep and structured analysis of the mechanism.

The main research object of this paper is to offer a systematic work which provides an insight analysis of on-bill schemes by highlighting their advantages and limitations.

The present contribution differs from previously published papers, since it addresses the potential of on-bill schemes without focusing on a specific program linked to a narrow context.

This paper proposes a deep analysis of on-bill programs by discussing the structure of these schemes, the possible variants, and the barriers to their implementation. Furthermore, the impact of on-bill programs on the core business of the different typologies of utilities is discussed.

The present paper aims to address the following research questions, which were not previously addressed in the literature:

– Which are the main typologies of on-bill schemes and the main features to consider for their implementation?
– Which are the barriers that hamper the diffusion of on-bill schemes?
– Which is the impact that on-bill programs may have on the utilities' core business?

By answering to these three research questions, the paper offers a novel contribution to the energy efficiency financing literature. In particular, by answering to the first question OBS are clearly categorized and precise indications to define the optimal scheme are given. The answer to the second question provides a detailed context analysis which illustrates the main difficulties for the development of OBS. Finally, the answer to the third question provides insights on the impact that OBS can have on utilities business, also depending on the typology of the utility itself (i.e., power utility, natural gas utility, energy retailer, etc.). This last aspect is relevant for determining the success of the schemes which necessitate a strong company support.

Despite their relevance, these aspects were not considered in the existing literature thus it is of fundamental importance to offer an in-depth discussion based on the results achieved by the Horizon 2020 funded project RenOnBill. The research project offered to the authors the possibility to meet a variety of stakeholders, e.g., utilities, financial institutions, local authorities, etc., for discussing many aspects of OBS.

The paper fills an important gap in the literature, and it is believed to be an important reference for utilities managers and policy makers working on energy efficiency issues. Although most of the considerations reported in the present paper can be applied to a variety of situations, the focus of the present work is the European Union context.

2. Overview of on-bill schemes

On-bill programs are innovative schemes for financing energy efficiency renovation which use the utility bill as repayment vehicle. Often these schemes are grouped under the umbrella term *on-bill financing* (OBF), even if OBF refers to a specific scheme as discussed in the following. These programs attracted the interest of many researchers, companies, and policy makers since they allow to overcome some of the typical barriers hampering energy efficiency renovation in the residential market, namely: the high upfront investment costs, the increase of the households' debt level , the relationship between households and financial institutions for accessing traditional financing instruments and the owner-tenant dilemma.

A schematic sketch of an on-bill program is depicted in Fig. 1.

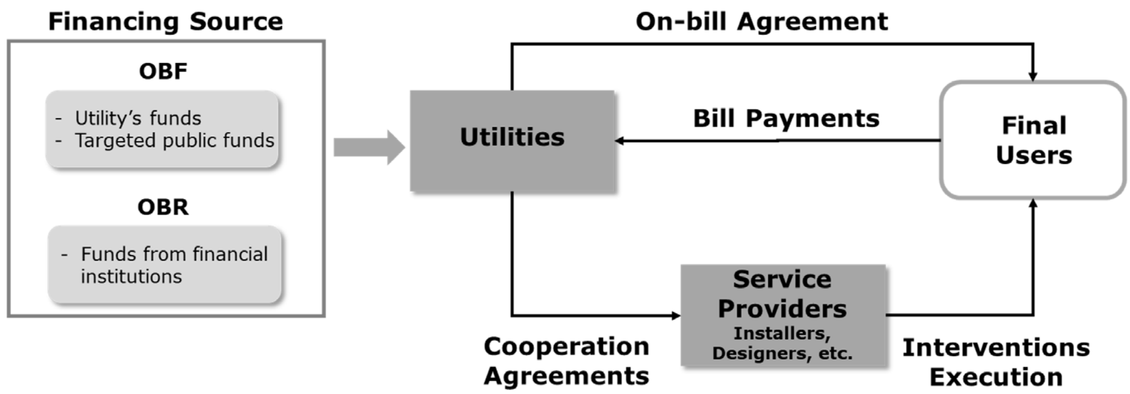

Fig. 1. Basic sketch of an on-bill program.

2.1. Frameworks for on-bill schemes

If the source of financing is considered as classification element, two variants of on-bill schemes can be identified, namely *on-bill financing* (OBF) and *on-bill repayment* (OBR) programs.

OBF schemes are financed by energy utilities by using own sources or targeted public funds. Usually, the utility manages all the process, from the acquisition of the client to the monitoring of the performance of the energy efficiency interventions. Energy audits are developed by the utility promoting the program to identify the most suitable interventions. The end user repays the cost associated with the renovation through the utility bill in a number of years according to the program rules.

OBR schemes are financed with third party capital, e.g., from financial institutions, and energy utilities act as repayment intermediary, since they collect the installments on the bill. OBR can be organized in different ways; the three most common frameworks are the following (SEE Action, 2014):

- *Program administrator acting as warehousing entity*. In the first phase the program administrator, usually an energy utility, uses its own financial resources to initiate the program. In the second phase, the administrator aggregates the credits and sells them to a financial institution based on specific agreements. The financial institution usually develops specific financial products to sell these credits on the financial market. Alternatively, these credits can be embedded in existing investment products already available for the partnering financial institution. Finally, on-bill repayments are collected by the utility and transferred to the investors.
- *Program administrator raising capital upfront*. In this framework the program administrator involves the partner financial institution from the onset without using own funds. The program administrator bundles the clients request for OBR schemes and the investor provides the capital to implement the corresponding energy efficiency measures. Then the repayments are collected by the utility on the bill and transferred to the investor. Thus, the utility plays the role of a demand aggregator and of an intermediary between the investor and the final user.
- *Open market*. In this framework, financial institutions directly interact with final users and utility bills are used as repayment vehicle. The utility only acts as repayment agent by collecting money from the bill and transferring to the investor. The process is coordinated by a master servicer managing the workflow between utilities and financial institutions.

OBR schemes allow to deeply involve financial institutions in the financing of residential energy efficiency renovations, and they can be regarded as an effective market-based approach to attract private capitals in the energy renovation market. Fur such reasons they are taken in careful consideration by policy makers.

In general, on-bill schemes can be associated to the property meter, i.e., *attached to the meter*, or to the user (traditional arrangement), i.e., *tied to the user*. These two possibilities are also respectively indicated as *tariffed on-bill* and *on-bill loan* (SEE Action, 2014).

The possibility of the meter attachment offers a higher degree of flexibility, since the payments can be transferred among the property owners or tenants (e.g., if the previous owner or tenant leaves the property, the next occupant can continue to pay for the active on-bill scheme). This system works in areas where there is a dynamic real estate market and vacancies are unlikely to happen, e.g., large urban areas. On the other hand, the risk profile of the meter attachment framework can be higher since the reliability of more users is to be considered. Another possible drawback of meter attachment could be represented by a lower attractiveness of the property on the market, both for selling or renting, since it has an attached "debt". Anyway, a rational choice should not be affected by this, because if the benefits of "stepping-in" a previous OBS are higher than installments to pay, there is no economic or financial reason for rejecting this option.

Another possible tag for on-bill schemes is represented by the *disconnection for non-payment*, namely the possibility to interrupt the energy supply for users who do not pay the on-bill installments. In many European countries this possibility is strictly regulated since energy is seen as a primary good. For such a reason the disconnection can be also perceived as a non-ethical action. The possibility of disconnection is an option to prevent unfair behaviors of the users, in fact on-bill schemes in USA are characterized by very low default rates (SEE Action, 2014).

On the other hand, the low default rates can be also ascribed to the fact that to be admitted in on-bill schemes (OBSs), clients are usually ranked according to their bill payments history. Generally, only users with a regular paying track-record are admitted in the OBSs and this minimizes the default rate. The payment history can be used for OBSs in the same way of credit scoring for usual bank loans.

Conceptually, OBSs can be organized to guarantee the *bill neutrality*, also known as the *Golden Rule*, namely the offsetting of the on-bill installment with the obtained energy savings. With this mechanism, final users do not pay higher bills than before the interventions and after the repayment of the investment for the energy efficiency interventions, they start saving. On the contrary, bill neutrality determines a longer pay-back period for the utilities. Usually, bill neutrality is considered for small interventions which have limited effect on the pay-back periods of the investments. Also, to conceive mechanisms based on bill neutrality implies to have a clear view on future energy prices, which are affected by large uncertainty in the long term, therefore bill neutrality is considered a high-risk approach.

2.2. Development of on-bill schemes

OBSs can result of interest for financial institutions aiming to invest in energy efficiency, since they can cooperate with utilities. Partner utilities can bundle a significant amount of energy efficiency investment, since they already have a customer basis, and they are structured and used to manage the relationship with them. Therefore, financial institutions (e.g., banks, private equity funds, etc.) can establish a relation of *B2B* nature with utilities, without the necessity and the cost to manage many counterparties (e.g., final users), which are handled by utilities in the framework of their daily core-business.

Oppositely, final users by opting for OBSs simply buy an energy service, without acquiring any debt, which can influence their access to credit for other needs.

This configures a *win–win* situation for final users, who can obtain new energy efficiency services, financial institutions, which can enter the energy efficiency market, and for utilities, which can offer new energy efficiency services, but some specific categories of utilities may see affected their core business, i.e., the sales of energy, as discussed in the following. On the other hand, during the last years, radical changes occurred in the utilities sector (Bianco, 2018), therefore, innovative financing models for energy efficiency can be considered an opportunity for the most dynamic companies.

Moreover, the development of energy efficiency initiatives represents an irreversible trend in place all over the world. Thus, from a strategic point of view, it is more significant for the utilities to lead this process trying to extract value from it, rather than to undergo this transformation passively.

Fig. 2 illustrates the key-points to evaluate when designing OBSs. Four areas are highlighted, namely:

- Goals and Objectives: it refers to the segment of clients to reach, the interventions to promote and the profitability to obtain;
- Regulatory and Legal Issues: it means to the definition of regulatory and legal perimeter to work with;
- Programs structure and financing: it focuses on the financial structure and typology of the program, i.e., OBF vs. OBR;
- Program management: it implies the integration of OBSs processes in the daily business of the energy utilities.

From the operational point of view, it is simpler to promote small interventions (e.g., boiler replacement, installation of efficient air-conditioning units, etc.) through OBS rather than to target deep-renovation of buildings. Pay-back period of small interventions is noticeably shorter than deep-renovations. On the other hand, this is not true in absolute terms and it is necessary to analyze all the relevant boundary conditions (e.g., climate, availability of public guarantees, companies' strategy, possible matching with other schemes, etc.) to check which interventions are convenient and feasible within an OBS.

Another relevant issue in developing OBS is the sharing of the financial risk among the actors involved in the process. Usually, most of the risk is taken by utilities and financial institutions which are the financers of the program. The difficulty in managing risk is also due to the absence of warranties, also because it is difficult to take back the installed devices or measures (e.g., insulation, windows, etc.) in case of insolvency. The risk is usually managed from a commercial point of view, namely an accurate segmentation of clients eligible for OBS is developed according to the bill payment history. Results from USA demonstrate that the insolvency rate is quite low (SEE Action, 2014).

2.3. Barriers to the implementation of on-bill schemes

OBSs can be a possible solution to overcome the financing barrier hampering energy efficiency in residential sector, since they can support final users in managing the high upfront capital cost of the renovation on one side, on the other side they can help in reducing the fragmentation of the investments because the utility can bundle a relevant amount of investments and attract capital from financial institutions.

On the other hand, there are barriers to the diffusions of OBSs as well, and they can be categorized in three different typologies, namely regulatory, customers and utilities related barriers.

As for regulatory barriers the main impediment can be represented by possible obstacles with the financial institution regulations, as also highlighted by ACEEE (2020). OBSs comprise the collection of payments, which is a core competence of utilities, but they also include money lending activity, which is the core business of financial institutions. This can hamper the diffusions of OBF, which do not foresee the presence of financial institutions. The regulations are largely variable depending on the country and a deep analysis of the legal framework is necessary to understand the possible degrees of freedom in the design of OBF. OBR are less problematic, since they include the presence of a financial institution, which can perform money lending activities.

Customers barriers are mainly linked to the problem of the split incentives between tenants and owners. Split incentives are linked to the sharing of benefits deriving from the implementation of energy efficiency interventions. When the sharing is unbalanced one of the two parties is pushed to inaction (Charlier, 2015). In fact, owners are not interested in investing in energy savings measures which will be exploited by tenants and tenants are not willing to make investments in units they do not own.

The argument that the implementation of energy efficiency will increase the value of the property is effective to a certain extent, since the owner will appreciate it only if there is an immediate increase of the rent or if the property is sold and extra-value ascribed to the energy renovation is extracted. On the contrary, the benefit for the owner is only theoretical.

Energy and temporal split incentives are the most relevant for OBSs. In energy split incentives, the tenants pay the bills therefore the landlord is not interested in performing energy efficiency investment. Whereas temporal split incentives refer to the situation where the energy efficiency investment will not be profitable before the owner or tenant leave the property.

Energy split incentives can be solved by OBSs, since no upfront cost is required for the landlord, who can simply authorize the tenant to enter the program.

Temporal split incentives can be divided in two sub-cases, namely OBS subscribed by a tenant paying the rent and OBS subscribed by the owner. The first case can be solved with the meter attachment and the next tenant will continue to pay for the OBS. Anyway, this mechanism works only in dynamic real estate markets, where the unoccupied period of the property is minimal. This system is not easy to implement, because the next tenant has not the possibility to choose its energy suppliers and in some areas, e.g., European Union, this violates local directives. When the property is occupied by the owner, the meter attachment mechanism can be used again, and the next owner can continue to pay for the OBS. Alternatively, the leaving owner must pay the remaining installments to the utility in one solution and reflect this amount in the property sale price. This last option discourages the adoption of OBS, since there is a risk of losing part of the invested capital.

Therefore, it is relevant to identify possible solutions to guarantee a smooth transfer of OBS to next tenants/owners.

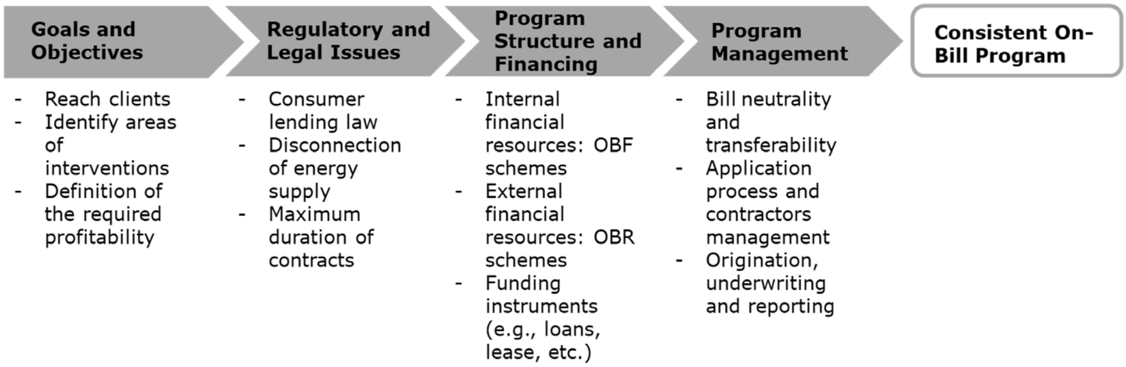

Fig. 2. Key-points to consider in the development of on-bill schemes.

Table 2
Overview of program operation barriers.

Barrier	Business Area	Description
Billing process	Administration	Modification of the billing process for adding a line dedicated to OBS in the bill. The financial and accounting management of this money is not necessarily simple and ad-hoc processes are to be set up.
Market segmentation	Sales &Marketing	Selection of targeted customers for offering on-bill services. It is necessary to process a large amount of data to identify optimal clusters of customers to be matched with corresponding services. Relevant skills are necessary to develop this activity.
Management of suppliers and installers	Operations	Management of a large network of suppliers and installers to implement the interventions. The activity is very time and resource intensive, since it requires the control and support of a large amount of third parties.

The last category of barrier is linked to the utilities. In particular, two typologies of barriers can be identified, namely *corporate strategy* and *program operation* barriers.

Corporate strategy barriers relate to the fact that the implementation of energy efficiency services affects the core business of the utilities, namely energy sales. This is especially true for vertically integrated companies which performed relevant investments in extraction of primary energy, energy generation, etc. They need to carefully assess the cost and benefits of OBSs or similar programs. Instead, program operation barriers attain the added complexity deriving from the implementation of OBSs. Three main areas of complexity are identified, namely market segmentation, billing process and management of suppliers, as highlighted in Table 2. Companies need to assess the investments necessary to manage the increased level of complexity in their organizations before launching on-bill initiatives.

3. Utilities' perspective

On-bill programs have a different impact on the utilities business according to their typology. Before considering the setting up of OBSs, it is fundamental to evaluate the degree of complementarity with the existent business and to estimate the possible level of cannibalization (e.g., the possible reduction in energy sales due to the promotion of energy efficiency actions). In the present work four typologies of energy utilities are identified and analyzed, namely power utilities, natural gas utilities, district heating utilities, retailers, and distribution system operators (DSOs).

Power utilities are represented by companies which are integrated in the electricity value chain and cover from the generation to sales to final customers. These companies have assets on the generation side, and they are interested in pushing the electricity demand, in order to guarantee adequate load factors for their power plants and increase the electricity sales. These companies

Table 3
Most convenient interventions to promote through on-bill schemes according to the typology of utility.

Power utilities	Natural gas utilities	District heating utilities	Retailers and DSOs
– Installation of heat pumps – Envelope insulation – Windows substitution – Air sealing	– Lamps substitution – Installation of efficient electrical devices (e.g., refrigerators)	– Envelope insulation – Windows substitution – Installation of efficient electrical appliances	– All measures

can use OBSs to promote energy efficiency actions that, in general, aim at reducing the consumption of fossil fuel, e.g., insulation of the building envelop to reduce natural gas consumption for heating, etc. Apart from the implementation of energy efficiency measures, OBS can also support the offering of other services such as maintenance, monitoring, providing tips for behavioral changes, etc.

In general, the promotion of OBSs may affect only marginally the electricity sales and, on the contrary, new technologies, such as electrical heat pumps, can be promoted to support the switch of the heating demand from the fossil fuel market to the electricity one. Table 3 provides a summary of the energy efficiency actions which are more convenient to implement according to the typology of utility.

Power utilities are now in a *win–win* position and can be aggressive on the market by exploiting the positive political and public opinion support.

Natural gas utilities are companies which are integrated along the natural gas value chain from the upstream to the sales to final customers. Usually, they are very large companies with a substantial amount of assets (e.g., exploration facilities, pipelines, LNG facilities, etc.). Currently, they are in a difficult position since energy efficiency actions reduce the sales of natural gas, therefore their core business is directly affected. They are also under the aggressive concurrency of power utilities which push the electrification of heating demand. The implementation of OBSs would represent a defensive action to reduce the losses on the natural gas sales, since for large companies it is extremely complicated to offset natural gas sales with margins deriving from energy efficiency interventions.

District heating utilities are companies managing a district heating network. Therefore, they supply heat and sanitary hot water to an urban area by operating a large network of pipes. The implementation of OBSs can be a relevant option for these utilities, since from one side they can offer new services for energy efficiency and, from the other side, a reduced demand for heat would allow to connect more users to the network without revamping the power plants. Therefore, they can experience some operational benefits.

Retailers are companies which develop trading activities, namely they buy energy, i.e., electricity and natural gas, on the wholesale market and then they resell to final customers. They do not have fixed assets, e.g., power plants, LNG facilities, etc. From their point of view the implementation of OBSs represents a further opportunity to enlarge their business. OBSs can be seen an instrument to sell ''energy efficiency services''.

If profitable, the switching from natural and power sales to energy efficiency sales through OBSs is not dramatic since they have no fixed assets. They are very flexible in selling the more convenient energy product. The only necessary action on their side is the re-organization of their commercial units.

Finally, DSOs are usually operated on the base of state concessions and they represent a zonal monopoly, i.e., in an area there is one DSO. DSOs manage and provide services to the distribution grid; therefore, they can be regarded as an institutional party, unlikely to participate in a free market competition. On the other hand, the role of DSOs could be pivotal to solve some complexities such as the meter attachment or the transfer of an existing OBS to the next owner/tenant. They may provide services for facilitating the implementation of OBS.

To summarize the discussion related to the impact that OBS have on different typologies of utilities, a SWOT analysis is performed as shown in Table 4. It emerges that power utilities and retailers can better exploit OBS, district heating utilities can experience some operational advantages, whereas natural gas utilities need to reposition themselves and develop new strategies.

Another important aspect of OBS is that they could be considered as a mean to comply with the energy efficiency obligations established by the Energy Efficiency Directive (EED). According to the revised EED Article 7 and 7a, in Member States that chose to implement an energy efficiency obligations scheme, energy companies may be obliged to reduce the supply of primary energy to final customers. In these cases, OBS can be a valid instrument to satisfy this commitment by obliged energy companies also originating new business opportunities. An in-depth discussion on energy efficiency obligations scheme is provided by Fawcett et al. (2019).

4. Discussion

Current scientific literature offers a limited coverage of OBS, which are often mentioned within larger contexts, therefore only very general analyses of on-bill mechanisms are provided. Oppositely, other contributions focus on very specific case studies reporting success or failure experiences, as summarized in Table 1. The discussion developed in this section aims to go deeper and focus on more specific aspects of OBS, which need careful evaluation for the development and implementations of these programs with reference to the EU context.

Previous sections of this paper illustrated the structure of on-bill programs and their possible impact on different typologies of utilities. As previously highlighted, a fundamental difference in OBS is represented by the source of financing. Namely, on-bill financing programs are based on own sources of utilities or by using targeted public funds, whereas on-bill repayment programs are organized based on a cooperation between utilities and financial institutions.

In general, it can be said that OBF is more convenient for utilities, since it determines a less complex value chain, i.e., financial institutions are not present, and they do not need to be remunerated. On the contrary, this solution is complicated for small utilities which have not adequate resources to invest. Furthermore, a high volume of capital invested in OBF determines a substantial growth of the utility's credit. This in turn provokes a low solvency rating due to the risk to collect these credits, which will result in a higher cost of capital. Thus, it is fundamental for utilities to carefully assess their financial exposition and opportunity costs while defining OBF.

Partnership with financial institutions allows to solve the credit exposition issues, to share the risks of clients' solvency and to use more capital for other initiatives. Oppositely, OBR programs might generally be less profitable due to the more complex value chain. The presence of another actor in the value chain may also provoke a substantial increase of the transaction costs by making the scheme much less attractive or feasible only for larger investments. In particular, if the financing is provided to the utility the impact of transaction costs could be limited. On the contrary, if the financial institution has the relationship with all the final users, transaction costs could have a higher impact.

An important selling point of energy renovation programs, including OBS, is the increase of non-energy benefits. These benefits, e.g., increased comfort, lead to an increased value of the property. In case of owned occupied dwelling the increased value is only theoretical, and it can be appreciated only if the properties are sold or rent and if real estate market appreciates high energy performances.

In case of rented properties, non-energy benefits should lead to a higher rent, but this often discourages the tenants. In an analysis of the Irish residential market, (Caroll et al., 2016) observed that tenants give a substantial appreciation to energy classes a little bit better than the worst case. On the contrary, higher energy performances receive a lower incremental appreciation. A comparable situation is observed in the Dutch market, where a market premium between 2% and 6% on the selling price of houses is detected, when energy performance certificates (EPC) in high classes are available (Chegut et al., 2016). Fuerst et al. (2015) also detect a positive correlation between EPC rating and selling prices for houses in UK. However, there is not a full consensus in the literature regarding the positive impact of non-energy benefits on real estate transactions (i.e., selling price or rent). For example, Gabe and Rehm (2014) tested that tenants are not willing to pay a higher rent for space in high energy efficient office properties.

Furthermore, there is not a univocal methodology to estimate non-energy benefits, which are complicated to be reflected in the property value (Popescu et al., 2012).

Differently from other financing mechanisms, OBS allow to exploit energy and non-energy benefits proportionally to their payment, since there is not an upfront investment for the energy efficiency interventions. Furthermore, in case of meter attachment, the remaining benefits can be transferred to the next tenant or owner, who can pay for them. This is of relevant

Table 4
SWOT analysis for the implementation of OBS depending on the utility typology.

	S	W	O	T
Power utilities	– Possibility to enlarge the business to propose a large range of measures – Limited or positive impact on the core business – Pivotal role in the energy efficiency "game" – To leverage on the existing customer basis	– Necessity to invest for acquiring adequate know-how in EE	– To improve the revenue stream – To increase client loyalty – To act as leaders in supporting energy efficiency – To offer an integrated smart energy package (e.g., e-mobility, domotic, energy efficiency) – Get new clients	– Necessary organizational change more tough than expected – Other competitors can arise (e.g., ESCOs) – Low level of engagement from the customer basis
Natural gas utilities	– To leverage on the existing customer basis	– Necessity to invest for acquiring adequate know-how in EE – Reduction of natural gas sales	– To increase client loyalty – To limit losses deriving by energy efficiency measures promoted by competitors – Get new clients	– Decrease of gas demand due to EE improvements – Low level of engagement from the customer basis – Financial issues for the repayment of previous infrastructural investments
District heating utilities	– Reduction of re-powering costs – To leverage on the existing customer basis	– Necessity to invest for acquiring adequate know-how in EE	– To increase client loyalty – To connect more users to the heat supply network	– Reduction of revenues from heat supply not compensated by new customers – Low level of engagement from the customer basis
Retailers	– To leverage on the existing customer basis – smaller utilities can take the risk of entering into new markets – They are usually more dynamic when it comes to enter into new business	– Necessity to invest for acquiring adequate know-how in EE – Lack of financial muscle to put the schemes in place (for the cases when utilities make the up-front investment) – They may lack of resources (marketing staff or IT systems or administrative support) to offer on-bill renovation	– To increase client loyalty – Get new clients – Possibility to enter into new market niches – It can constitute a way to differential themselves from others – The name of the retailer can benefit from undertaking "sustainable projects"	– New competitors (e.g. large white goods retailers, ESCO, etc.) could appear – Necessity to manage more complex processes – They may not have the purchase power of bigger agents, which mean less bargaining power when negotiating with banks (in case of third-party financing) and with renovating services providers
DSOs	– Possibility to enlarge the business as an active or passive player – Possibility to leverage on an extensive customer basis	– Necessity to acquire appropriate know-how in EE	– To increase the influence on the business	– Compliance to regulations to be carefully assessed

importance since, as observed by Caroll et al. (2016), some interventions, such as wall insulation, have a too long pay-back time to be implemented and there is not the willing to invest, since investors are not sure to be able to exploit their investment. This situation is defined as "Temporal Split Incentive".

The meter attachment mechanism allows to mitigate the Temporal Split Incentive issue, but not to solve it. Meter attachment works well only in dynamic real estate market, e.g., important urban areas, where it is unlikely that a property remains vacant for long time and the next tenant/owner can step in the OBS and continue to pay the bill. If this does not happen, it is likely that the owner should continue paying for OBS, therefore the owner-tenant dilemma is reproposed, since such a situation discourages owners in authorizing tenants to join OBSs. Also, the next tenants would be obliged to subscribe the energy supply agreement with the utility chosen by the previous tenant/owner, and this could limit the freedom to choose the energy suppliers. In EU this could be a legal issue since EU directives guarantee the freedom for customers to choose their energy suppliers (Bianco et al., 2014).

To solve this problem innovative solutions should be found. A possible approach to overcome this issue could be to involve DSOs in OBS. DSOs could provide services to the whole system to support the development of flexible OBS. In particular, the OBS charge paid on the utility bill could be collected by the DSO, as it currently happens in EU with the taxes to pay renewable energy incentive. The DSO, in turn, diverts the OBS charge to the utility which promoted the scheme against a management fee for the service. A conceptual schematic of this framework is reported in Fig. 3. This mechanism would allow to decouple the energy supply from the OBS and could make the market more dynamic.

Finally, OBSs are also implemented in developing countries. There are schemes in Tunisia, Sri Lanka, India, and Mexico. The primary aim of these programs is not the promotion of energy efficiency, rather than they are used to reduce energy poverty and to promote the use of local resources, e.g., in Tunisia, or to implement demand-side management strategies, e.g., in Sri Lanka, India and Mexico. In these countries the relation between electricity supply and demand is unbalanced. There is a shortage of supply facilities, therefore the risk of black-out is relevant. Therefore, it is necessary to limit the demand. To support the demand reduction, power companies promote on-bill schemes to help final users in substituting simple inefficient devices (e.g., lamps, air conditioners, etc.) with more efficient appliances. Due to the poor economic conditions, users have not the possibility to buy new lamps, air conditioners, etc. on their own and they need a support for the upfront cost. Usually, users have a net benefit on the energy bills due to the higher efficiency of the new devices. These programs allow to obtain a threefold objective, namely, to manage the supply and demand balance, to reduce the energy poverty and to promote energy efficiency.

5. Conclusions and policy implications

On-bill schemes are innovative financing mechanisms for supporting energy efficiency renovations by using the utility bills as repayment vehicle. This paper attempted to provide an overall analysis of OBSs with the aim to highlight the main frameworks, the process for their development, the main barriers which hamper their diffusion and their possible impact on energy utilities business.

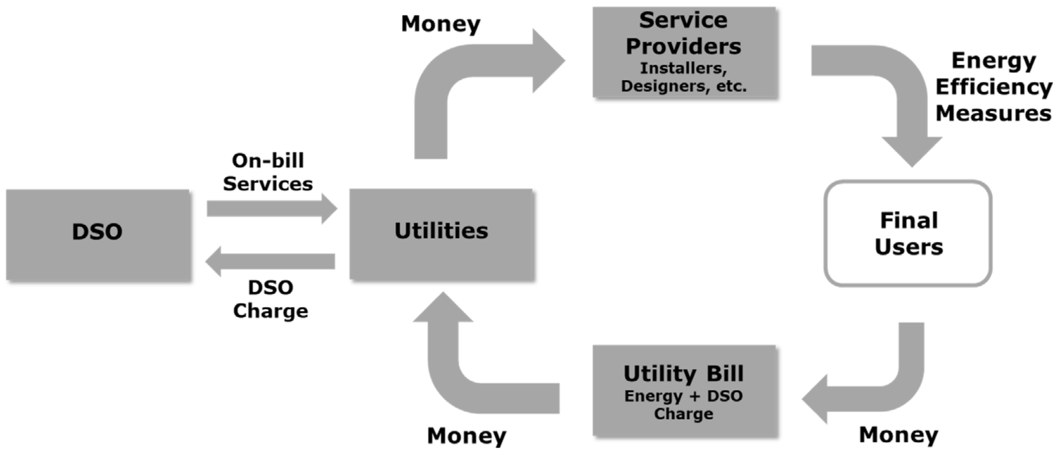

Fig. 3. Conceptual scheme of DSO supporting the implementation of on-bill schemes.

It is shown that on-bill programs have a relevant potential in financing energy efficiency interventions in the residential market, since they can leverage on the large customer basis of the utilities. Utilities can be seen as investment aggregators, therefore the fragmentation of investments in energy efficiency, which is often indicated as one of the main limiting factors for attracting large private capitals, is overcame.

The most relevant policy implications deriving from the promotion and implementation of on-bill schemes can summarized as follows:

- To activate a market-based mechanism to push energy efficiency interventions and to progress towards the energy transition;
- To exploit utilities customer base to aggregate a substantial amount of energy efficiency investments to overcome the typical fragmentation in the sector in order to arrange attractive investments for utilities and financial institutions;
- To attract private capital from financial institutions/utilities for extensive energy efficiency renovation of residential buildings;
- To solve issues related to the spit incentives at some extent, with particular reference to the owner-tenant split incentives and temporal split incentives.

On-bill schemes cannot be regarded as a global solution to the issue of supporting energy efficiency investments in the residential sector, but they represent a valid instrument to reach and support a substantial share of final users through private capitals. They are flexible since both small, i.e., appliances substitution, and larger investments, i.e., insulation of the envelope, can be supported. For some categories of utilities, e.g., power utilities and retailers, they represent an optimal opportunity to enlarge the traditional businesses and to find convergence with other initiatives which are under development, such as the promotion of e-mobility services. Integrated offers including residential energy efficiency and e-mobility could be conceived to offer *Value Added Energy Services*.

It can be concluded that on-bill schemes are flexible financial mechanisms for utilities to be used

to develop energy efficiency renovation in the residential sector and to promote innovative energy services. Their flexibility makes them applicable to a large range of interventions and services and the possibility to cooperate with financial institutions allow to scale-up the program and to develop many interventions.

CRediT authorship contribution statement

Vincenzo Bianco: Conceptualization, Methodology, Writing - original draft, Writing - review & editing. **Paolo Michele Sonvilla:** Conceptualization, Methodology, Writing - original draft, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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