economics for energy

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Climate Change, Buildings and Energy Prices

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Climate Change, Buildings and Energy Prices

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Abstract

Buildings are crucial to control present and future energy demand and, therefore, greenhouse gas concentrations in the atmosphere. In this chapter we suggest that, due to a number of general and specific barriers to the implementation of energy efficiency in buildings, energy prices and conventional energy and environmental policy instruments may not achieve the desired outcomes. Instead, we suggest a novel package of complementary measures that can simultaneously tackle the problems of imperfect information, split incentives among agents, uncertainty about cost and limited access to capital. The proposed policy package is defined around energy certification of buildings, uses flexible building codes, smart metering and employs a new tax on energy inefficiency to foster continuous incentives towards energy efficiency improvements and to provide revenues for an energy efficiency fund that provides capital to firms and poor households.

1. Introduction

Buildings are a crucial sector for controlling energy demand and, therefore, greenhouse gas (GHG) emissions. Buildings currently account for around 40% of the final energy use in the world (IEA, 2008; IPCC, 2007) and, as indicated by Figure 1, in developed countries such as the US they are responsible for 30% of total energy consumption and for around 20% of carbon dioxide (CO_2) emissions. The importance of buildings for energy and environmental policies also arises from the fact that they constitute a 'stock' of future energy consumption and emissions. For example, around 60% of the existing buildings in the UK, US, or Spain were built before 1980 (Sweatman and Managan, 2010) and therefore are likely to have lower energy efficiency and higher GHG emissions than modern buildings. Thus, failing to retrofit old buildings to improve their energy and environmental performances, or an inadequate construction of new buildings, may endanger GHG mitigation.

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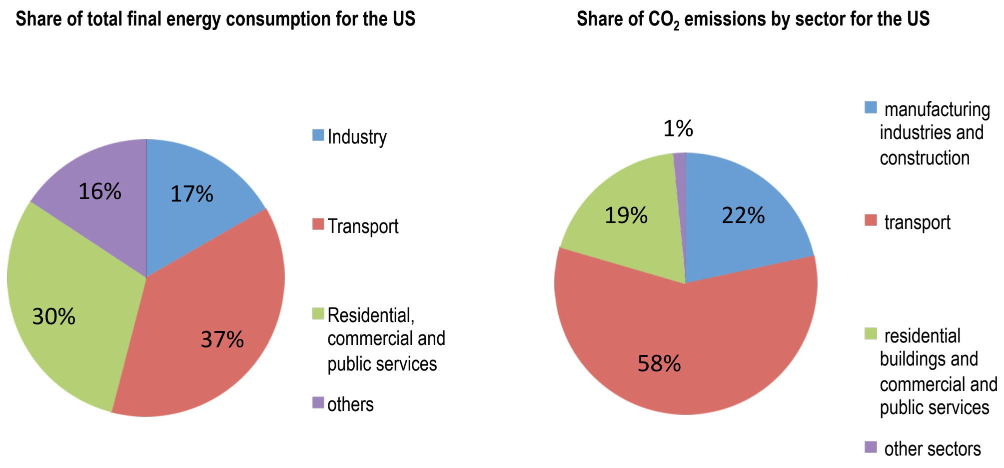
Figure 1. Main sources of US energy consumption and CO_2 emissions (2009)



Source: IEA (2012) and World Bank (2012)

In this sense, there is a particular concern with emerging economies where increasing population and economic growth may lead to a renewed activity in building construction that could considerably expand future energy consumption and its associated GHG emissions. Higher consumption and emissions would be brought about by a combination of more energy-inefficient buildings (stock) and the increasing flow demanded by households with rising incomes[1]. If this is the case, future energy systems may be clearly unable to comply with the current objectives to reduce greenhouse gas emissions because they actually rest on significant energy savings from this sector: up to 30% of the baseline emissions by 2030 (IPCC, 2007). In fact, the last *World Energy Outlook* of the IEA (2011a) emphasizes the critical importance of energy efficiency to overcome the rising GHG emissions trend and indicates that the stock component of such emissions, together with a lack of significant action, is already closing the window of opportunity to avoid large increases in GHG atmospheric concentrations.

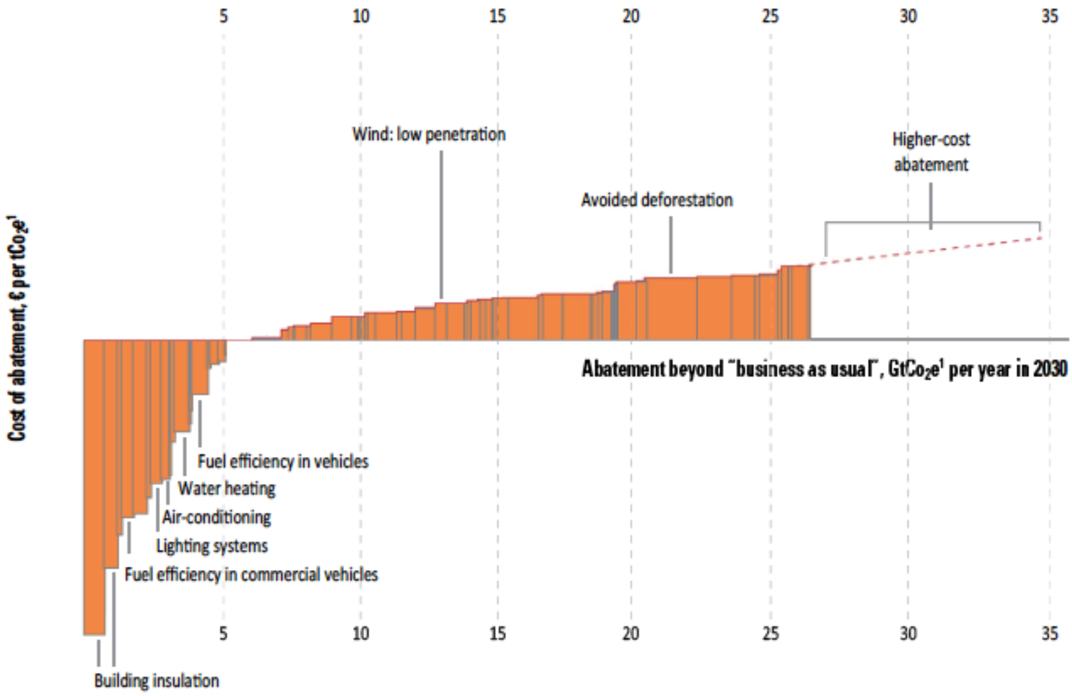
The building sector presents not only a challenge but also an opportunity, because of the apparent cost-effectiveness of energy efficiency measures in buildings. Expert engineers indicate the existence of a large potential to reduce energy consumption in new facilities, through proper design and construction, and in existing buildings through retrofitting. Some studies suggest energy abatement possibilities of up to 75% in new buildings and of 20-50% through retrofitting old facilities (IPCC, 2007; European Commission, 2011). Not only there is large potential for energy savings in the building domain: these measures, especially those applied on new buildings, are usually ranked among the most cost-effective alternatives to reduce energy consumption. This is depicted in Figure 2, where some energy-saving measures in the building sector show even negative costs ('win-win' options) in the global abatement cost curve for greenhouse gases in 2030. While this information should be treated with care, given the several

[1] The current breakdown of household and commercial energy demand in emerging economies reveals a heterogeneous pattern. For instance, the Chinese distribution of energy use in residential and commercial buildings is close to the observed in developed countries; however other emerging societies, such as Mexico, show remarkable differences (IPCC, 2007; Rosas-Flores et al., 2011). This variation is probably due to specific climatic and cultural conditions that will obviously affect the potential evolution (and savings) of energy uses in buildings within the developing world.

methodological and empirical shortcomings of GHG abatement cost curves such as this (Linares et al., 2012), it identifies promising possibilities in this area.

Indeed, from a technical point of view, most of the energy-efficiency measures in buildings are already mature as they have been widely studied and applied since the energy crisis of the 1970s. For instance, Laquatra (1986) and Gilmer (1988) analyze the market effects of energy efficiency investments for units constructed through the *Energy Efficiency Housing Demonstration Program* carried out by a Minnesota Agency in the 1970s. Nowadays, many possibilities are already available in the market, mostly related to the general lighting and heating/cooling facilities, insulation techniques (envelope and windows) and de-centralized renewables. For instance, improvements in space heating, which are very important because this end use is responsible for around 30% of energy use in residential buildings (IEA, 2008), may be achieved through a combination of insulation, improved heating/cooling methods and the use of different types of renewables. This chapter is interested in this type of combination of alternatives because, although we recognize the importance of energy consumption and emissions from other household appliances, their characteristics and regulation raise different issues from those associated with buildings and discussed in this paper.

Figure 2. Global GHG abatement cost curve beyond business-as-usual-2030



Source: McKinsey (2009)

Given the focus of this book, we have emphasized the close relationship between energy consumption by buildings and GHG emissions. However, energy efficiency in buildings would bring about a richer array of benefits. It would definitely reduce other types of pollutants in urban areas, an increasing problem in many emerging economies (those, as indicated before, that may see a larger expansion of their building stock), thus improving health conditions for the population and reducing social damages. Reducing energy use in buildings may also contribute to reducing dependence on foreign supplies of energy, having a positive effect on the so-called energy security of countries. Moreover, energy conservation may result in net savings for households and firms, thus increasing their disposable income and profits. Energy efficiency measures in buildings may not only reduce energy expenditures but also may improve living conditions and indoor air quality (for instance through substitution of inefficient wood or coal usage) can also be achieved through energy-efficiency measures in homes and buildings. In the commercial sector there is evidence of the positive influence of more energy efficient buildings on indoor air quality and eventually on worker productivity (Leaman and Bordass, 1999). There is abundant evidence that firms can achieve positive reputational effects through eco-friendly behavior. Furthermore, energy efficiency in buildings offers large possibilities for new businesses such as ESCOs[2] and for owners and real estate investors due to its positive effect on property prices (Eichholtz et al., 2010a; Fuerst and McAllister, 2011). Lastly, the economy as a whole may benefit from the creation of jobs that are related to the implementation of energy-efficiency measures in buildings[3].

Last but not least, a widespread introduction of energy efficiency improvements in buildings can generate significant distributional benefits. They may be related to those households with a limited access to basic energy sources and services, quite common in emerging or developing countries. But they may be also linked to overcoming energy poverty in developed countries by allowing households to live in comfortable temperature conditions at affordable costs (UKDECC, 2011a).

Despite the socio-economic and environmental importance of these matters, in practice energy efficiency measures and techniques have been barely introduced in commercial or residential buildings. A number of factors explain the real-world barriers to energy efficiency improvements, in buildings and elsewhere, which are actually the reason for persistent public intervention in this area. However, buildings and dwellings have particular characteristics that differentiate them from other products and sectors: they are long-lived and costly assets and many agents are usually involved in this market. These particularities must be taken into account for a proper understanding of this sector, a necessary condition for the design of effective energy-efficiency policies. This is the setting for the chapter, which will first provide a general description and discussion on the barriers to energy efficiency in buildings (Section 2.1) and then present the main policy tools available to tackle this problem (Section 2.2). With that information, in Section 3 we will propose a policy package that can simultaneously overcome most of the preceding barriers and provide incentives for a cost-effective implementation of energy efficiency measures in this important sector. Section 4 concludes with a summary of the main implications of our findings and policy proposal.

But before further discussing strategies and policies, it is necessary to emphasize the significant heterogeneity within this sector. First, as indicated before, there is a crucial distinction between new buildings and existing buildings: this difference is very relevant for the design and implementation of energy efficiency measures. For instance, measures are likely to be cheaper and with a higher savings potential if introduced in new buildings. Moreover, some measures are only applicable to new buildings, such as construction or planning codes. Finally, the agents involved in decisions vary in new and existing facilities: in new buildings decisions on energy efficiency are largely in the hands of builders and investors, whereas in existing buildings energy efficiency measures may involve owners and tenants. A second characteristic of buildings is the heterogeneity of users, including both residential and commercial (which

[2] An ESCO is a company that offers energy services, such as analysis, audits, management, implementation or maintenance. In contrast to other firms or institutions, ESCOs also offer guaranteed energy savings (see Section 3.4).
[3] The European Commission (2005) estimates that a 20% reduction in EU energy consumption may directly and indirectly create one million new jobs in the EU.

may also involve public and governmental, and sometimes industrial); this heterogeneity has important implications for the design and application of energy efficiency policies. Lastly, even residential or commercial buildings (whether new or old) may have plenty of internal heterogeneity: single-unit residences, multi-property houses with common areas or services, different uses in the so-called commercial sector, etc. But complexity does not end there because the heterogeneity also interacts with geographic and climatic variation. Essential factors for energy efficiency such as the ownership turnover period, occupancy rates or the stock of existing buildings are clearly dependent on climate and country/region.

2. Economics of Energy in Buildings

2.1. Market failures and barriers

If there is a limited implementation of energy-efficiency measures in buildings, as suggested in the previous section, the negative cost figures in Figure 2 would clearly reflect the so-called 'energy efficiency paradox' (Jaffe and Stavins, 1994). Why are agents reluctant to invest in energy efficiency measures in buildings despite their negative costs? One possibility is that the net costs are not negative: either the outlays are understated or the energy-savings benefits are overstated, or perhaps some of the benefits do not accrue to those who must make the outlays (Figure 2 fails to consider the *distribution* of benefits and costs). But it is also possible that the net costs are negative but that barriers exist in the real estate sector that strongly affect investment decisions on energy efficiency. These barriers have been generally identified as absence of information, the conflict of interest between principal and agent, the difficulty to financing a high up-front cost, and uncertainty about the reliability of the energy efficiency device. We now elaborate on these explanations for the sub-optimal allocation of resources to energy efficiency before proceeding to identify some possible corrective measures.

Generally, agents have substantial lack of information on future energy consumption at the moment of purchasing or renting a commercial or residential building. This is not something that is easily measured. Future energy use depends partly on the behavior of future occupants and on investments they might make in energy efficiency; it also depends on the aging of the building and the energy-using equipment within it. Another fact is that building owners and occupants may not have the same economic interests and thus problems of asymmetric information and lack of trust could arise. As a consequence, agents may give less consideration to expenditures for energy efficiency, and be less inclined to value the implementation of such measures.

The conflict in interests among the agents that operate in the building sector pertains not only to information. In addition, there is the well-known principal/agent problem where the party that takes the investment decisions on energy efficiency would not benefit from their returns. In new buildings, for example, the builder may be interested in achieving the highest revenues at the lowest costs without paying attention to the effects on the stream of future energy expenditures and associated pollution emissions. In existing buildings the principal/agent problem is also present in the owner/tenant relationship: tenants may have incentives to promote energy efficiency to reduce their bills but they are unlikely to invest in items that become permanent fixtures in buildings they do not own and may occupy for only a limited period of time, leaving these fixtures for the owners once they quit the building. If the owners do not pay their tenants' energy bills they themselves have little incentive to invest in energy-savings fixtures, except to the extent this would enable them to charge sufficiently higher rents to recoup their investment. This problem also arises in commercial buildings and it becomes even more important in multi-unit residences because the number of actors increases.

There are several other barriers that, while not necessarily market failures, could be mitigated by public actions. First, the large up-front capital cost often required for energy-efficiency investments in existing residential and commercial buildings to pay for things like replacing heating systems, installing new windows, better insulation or renewable energy, discourages these investments, since it may be difficult to find a way of financing the capital outlay. Second, the so-called bounded rationality that potentially affects all agents participating in this sector, in new and existing buildings or in commercial and residential units. Bounded rationality is partially due to the above-mentioned lack of information but it is also affected by cultural or idiosyncratic habits that make consumers unaware of their energy use and associated emissions (Brounen et al., 2012; Palmer et al., 2011). Moreover, uncertainty also prevents agents from investing either because of changing legislation or because first movers cannot benefit from lower prices resulting from learning-by-doing effects or economies of scale (NRTE, 2009). On top of this, there might be significant hidden costs that affect the adoption of energy efficiency measures in existing buildings: transaction costs and the inconvenience and nuisance associated with retrofitting (and the possible need for another temporary dwelling). Finally, the literature has also mentioned long payback periods and high discount rates as other barriers to the adoption of energy efficiency in buildings.

It should be emphasized that whether or not these factors are considered market failures is immaterial. What is important is that they are potentially amenable to policy action. Market failure signifies a violation of economic efficiency (typically based on the Kaldor-Hicks criterion of a potential Pareto improvement). But economic efficiency is defined by reference an existing set of actors, with existing choice sets, existing preferences, existing production technologies, existing constraints, existing information sets, and existing behavioral rules for the economic actors. If one can change some of these components of the existing economic system, there will be a different outcome that may be judged superior ex post, but this does not make the prior outcome inefficient relative to the economic system that applied then. Thus, creating a new financing mechanism (for example, local government financing of energy-efficiency retrofits of buildings repayable through a supplement to property taxes), providing new and more transparent measurement of energy use, providing information/advertising that makes energy use more salient to economic actors and similar interventions change the economy in such a way as to generate a different economic outcome, one not attainable prior to the intervention.

2.2. Policy instruments

The preceding market barriers and market failures just described, together with the growing importance of energy efficiency in environmental and energy policies provide a clear justification for public intervention. The catalogue of policy instruments to promote energy efficiency is well known in the economic literature (Linares and Labandeira, 2010), but the applications of these instruments to the buildings sectors are surprisingly scarce. This may be related to the fact that, for some economists, proper energy prices should do the job. In this sense, sub-optimal energy-efficiency efforts in buildings may be related to artificially low energy prices (either because of subsidies or due to partial coverage of external costs) and, as a corollary, getting the prices 'right' would solve the problem.

Although we agree that a proper level of energy prices is a necessary condition for successful implementation of energy efficiency policies throughout the economy, the complexities associated with buildings (heterogeneity, market failures and barriers, stock consumption and emissions, etc.) make it hardly a sufficient condition in this sector. This is a key argument of the chapter, which is also related to the usually low elasticities of household energy demand reported by the literature and to the possible exacerbation of energy poverty through higher prices (Gillingham et al., 2012; Ürge-Vorsatz and Herrero, 2012).

Given this general setting, we next provide a brief review of the three main regulatory alternatives to promote energy efficiency in buildings, with an evaluation of their effects as available in the literature. This will serve as a basis for the definition of a policy proposal that, unlike these partial approaches, can tackle the multiple challenges and problems that exist in this complex sector.

2.2.1. Command and control

As in other energy and environmental areas, command and control approaches have been widely used by many governments, with a varying level of stringency, to promote energy efficiency in the building sector. These usually take the form of building and/or planning codes that, therefore, are usually restricted to new buildings. Sometimes there are requirements that have to be satisfied when buildings are resold. However, some standards can be introduced on the heating/air conditioning systems of buildings and thus can be effective in fostering improvements both in new and existing units.

The effectiveness of these building codes depends on how they are designed and also on the relative importance of new buildings in the overall stock. For instance, building codes with minimum energy performance standards have bigger impact in emerging countries, like China and India, where there is rapid construction of new structures in parallel with economic and population growth. This phenomenon was confirmed by Chan and Yeung (2005), who report a significant decrease in commercial electricity consumption after the introduction of building codes in Hong Kong. Yet building codes in developing countries, although increasing in number, are considerably more lenient than in the developed world (Iwaro and Mwasha, 2010). Precisely, these instruments have a more limited effectiveness in industrialized countries where old and inefficient buildings are a majority. For instance, Aroonruengsawat et al. (2009) analyze the effects of building codes for 48 US states on per capita electricity consumption in residential units between 1997-2006 and find only modest reductions in energy use in the range of 3-5%.

Command and control approaches have usually been considered inefficient or cost-ineffective in energy and environmental policies, due to the tendency to make the regulation a uniform requirement (as a consequence of asymmetric information between the regulator and the regulated). In the case of buildings, the remarkable heterogeneity would intensify this problem and demands flexible or differentiated codes and standards (Galvin, 2010). This is particularly important regarding climatic variations and their interactions with the different nature and use of buildings.

2.2.2. Taxes, permits, white certificates and subsidies

Energy and environmental taxes (or equivalent tradable emissions permit systems) would contribute to higher energy prices and thereby stimulate the adoption of energy efficiency devices in a cost-effective (flexible) way. In practice, however, fiscal instruments designed to enhance energy efficiency in buildings have tended to take the form of tax deductions for investments. This may be related to the fact that, although energy taxes and tradable permits have been widely applied in a number of countries for many years they have usually been targeted at the transport sector and energy-intensive users. Sometimes this has led to the application of complementary instruments that attempt to reach sectors that are not covered (or just partially covered) by energy and environmental taxes or tradable permits, such as the British climate change levy (a tax on energy usage for industrial, commercial and public sectors) or the carbon reduction commitment (tradable permits on non-energy intensive sectors such as hotels, supermarkets, etc.). Even though these complementary approaches may foster the adoption of energy efficiency measures in buildings, as they usually take place in commercial or residential domains that are hardly affected by general pricing instruments (such as the European emissions trading scheme), there is an obvious risk of negative interactions with other policy tools being applied at the same time (Labandeira and Linares, 2011).

Some examples of significant tax deductions to promote energy efficiency in buildings can be found in the US 2009 Recovery Act. On the one hand, the *Non-Business Energy Property Tax Credit* applies when space heating and air conditioning devices, biomass heating systems or other insulation measures with efficient properties, are purchased. On the other hand, the *Energy Efficiency Property Tax Credit* offers deductions on the installation costs of solar panels, wind or geothermal systems of renewable energy. Gillingham et al. (2006) survey the literature on tax deductions to promote energy efficiency, finding mixed empirical evidence. More recently, McKibbin et al. (2011) compare household tax credits aimed at promoting energy efficiency purposes with carbon taxation, and demonstrate that the latter has greater environmental effectiveness and lower economic costs of the former.

Another market-based instrument that can be applied in this area is the so-called white certificate scheme, already implemented in several developed countries such as France, Italy, Denmark or the UK during the last few years (Bertoldi et al., 2010). This consists of obligations on energy producers or sellers to foster cost-effective energy-efficiency improvements in commercial and residential consumers that are tradable. Mundaca and Neij (2009) provide an assessment of the effectiveness of the British Energy Efficiency Commitment, a white certificate scheme that focuses on buildings; they find a significant increase in certified energy savings during its life span (although they are unable to identify what share of the energy savings was due to a business-as-usual trend for improvements).

Tax deductions are not dissimilar from direct subsidies for energy-efficiency measures in buildings, or from preferential interest rates (i.e. partly funded by the public sector) for energy efficiency investments. In all of these cases, the effects on long-run investment will depend on the perceived continuity of the subsidy over the usually long payback period involved. Moreover, as with building codes, subsidy programs policies should be adjusted to fit the climate variability within the country to achieve cost effective outcomes. For example, using uniform grants or tax deductions across the country to promote more-efficient air conditioning would not allow for different levels and intensities of use in different climatic regions, and would therefore probably be cost-ineffective. Finally, fiscal deductions may bring about problems of free riding when they are applied indiscriminately because some agents would have taken the energy-efficient alternative without the tax incentive (NRTE, 2009). Linking an indicator of economic capacity, or in some cases of geographical/climatic variation, to the definition of the fiscal deduction could overcome this problem, although probably at higher administration and compliance costs. The empirical evidence on the effectiveness of subsidies for energy efficiency finds mixed results: Nair et al. (2010) found that the initial investment cost was quite important for the decisions of Swedish consumers and thus energy efficiency subsidies could play an important role (although necessarily complemented by campaigns that provide information on energy savings and available financial facilities), whereas Kemp (1997) found limited effects of subsidies for energy efficiency in the Netherlands during the 1970s and 1980s.

2.2.3. Energy performance certificates

In the last few years the use of certificates or labeling systems for many products (such as renewable energy, ecological food, household appliances or buildings) has seen a remarkable expansion with the objective of providing consumers with environmental and energy information that is not easily available in the market. In the case of buildings, where such informational problems certainly exist and constitute one of the main barriers for energy efficiency (Section 2.1), energy performance certificates offer detailed information about the future demand of energy that would be necessary to maintain a standard comfortable level of temperature within the unit. Consumers would then have direct access to reliable energy information of the building that can be added to their preferences and thus are likely be more energy conscious when taking decisions.

Although energy certification systems for buildings may be voluntary or mandatory, depending on the country and/or type of building, they always follow the same basic methodology. First, some private or public experts compute the energy consumption of the building, taking into account factors such as the level of insulation, air conditioning, heating and lighting systems, and the presence of any source of renewable energy. Later, an energy index (usually ranking facilities from A/platinum –most efficient- to G/certified -less efficient[4]) is used for rating the building while controlling for geographic and other structural factors that allow for a consistent comparison with other units (CEN, 2005).

So far energy performance certificates have been widely used in the case of US commercial buildings through two voluntary rating systems: the *Leadership in Environmental and Energy Design* (LEED), created in 1998 by the US Green Building Council, and the *EnergyStat Program*, developed in 1995 by the US Environmental Protection Agency and the Department of Energy. But other countries, such as Australia, Canada or the European Union, have also introduced labeling systems for buildings (Laustsen, 2008). The European Commission moved a step further by promoting the 2002 *Energy Performance of Buildings Directive* (EPBD) that demands member states to require a certificate of energy performance to all commercial and residential buildings when sold or rented out.

In addition to the information function, energy performance certificates also generate incentives for investing in energy efficiency because it is reasonable to expect price increases in those buildings with better certifications (linked to a lower flow of future energy expenses). If this is the case, energy efficiency investments in buildings may become more attractive both to real estate investors and to property owners who would get higher sale or rental prices. Although there are important data limitations to evaluate the effects of certificates on selling and rental prices, there is a growing literature computing the price premium

[4] Following the grades awarded by the EU EPBD and the US LEED programs (see below).

associated with more efficient buildings. Using hedonic prices, Eichholtz et al. (2010a), Kok et al. (2011b) and Fuerst and McAllister (2011) reported the existence of a price increase of around 2-6% in effective rents and of 13-16% in selling prices for US commercial buildings. After the introduction of the EPBD in Europe, Brounen and Kok (2011) found that the residential Dutch housing market has capitalized the information of the certificates into the prices of houses. Other authors such as Banfi et al. (2008), Kwak et al. (2010) and Leung et al. (2005) used contingent valuation methods to analyze the willingness to pay for energy-efficiency retrofits revealing positive figures for the replacement of old air conditioning or heating systems by residential and commercial consumers.

The power of this instrument to overcome several of the problems advanced in Section 2.1 is thus evident. It would, first of all, mitigate the informational problem and, by doing so, would reduce the asymmetric information that is present in the sector. Moreover, this instrument seems to generate incentives to investment by tackling some of the principal/agent problems. It is therefore an essential policy instrument to promote energy efficiency in buildings, although it is still unable to solve some of the problems identified in 2.1 such as access to capital or fragmented property, and their effectiveness may be affected by voluntary schemes or restricted to singular purchases/rentals. A coordinated combination of this instrument with other policy alternatives could produce a successful policy package, as we will show in the next section.

3. A new policy package

As explained above, the design and implementation of energy efficiency policies in buildings is a rather difficult but important task, which probably explains the limited and often ineffective experience seen so far. Market failures and barriers, huge heterogeneity within this sector that interacts with climatic and geographical variations, efficiency and distributional concerns, are all factors that undermine conventional and piecemeal regulation in this area. The application of isolated policy instruments, such as those described in Section 2.2, to foster energy efficiency in such a complex and difficult context is likely to fail or to produce sub-optimal results.

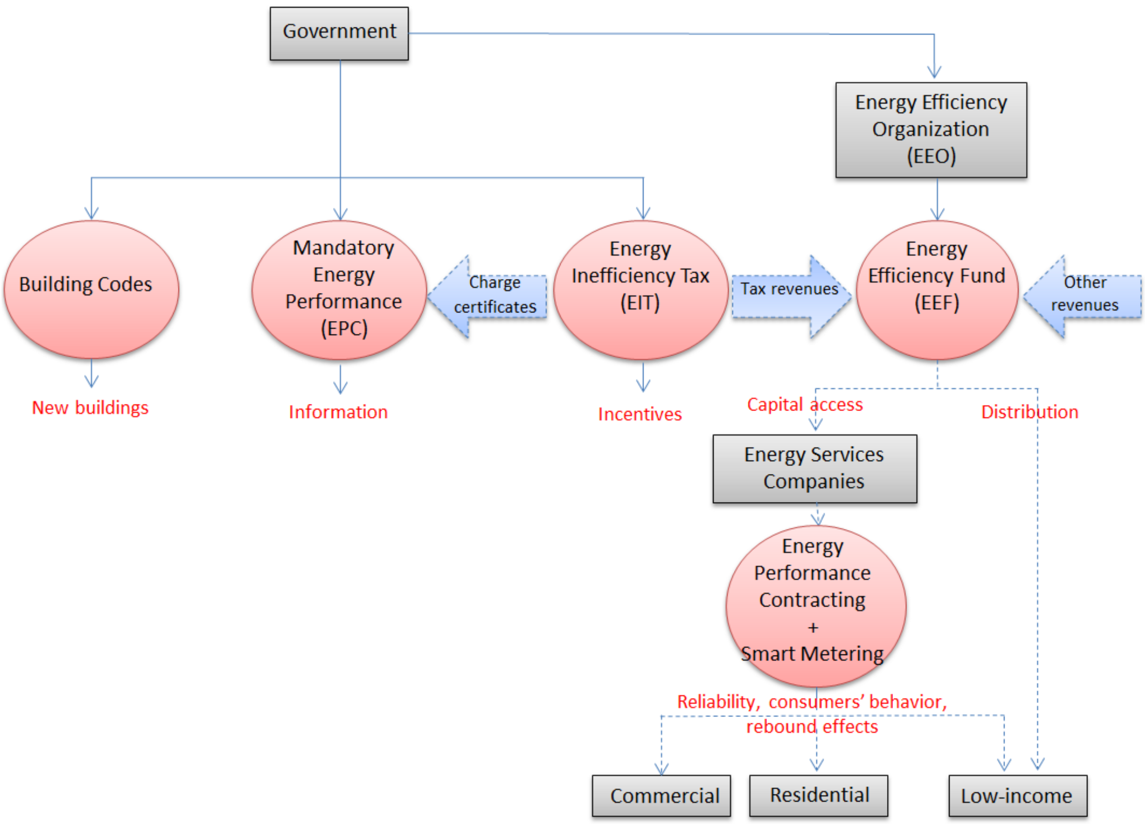
In this section we propose a policy package that aims to tackle the main obstacles for the adoption of energy efficiency measures in buildings, namely problems of information, incentives, reliability and access to capital. The proposed policy package offers the simultaneous and coordinated application of several instruments: a mandatory energy performance certificate for all buildings (EPC), a new energy inefficiency tax (EIT), a fund to provide capital for energy efficiency measures (EEF), and other complementary tools (smart metering, building codes, etc.). The package is not just a combination of instruments to avoid negative interactions and to promote positive synergies towards a cost-effective promotion of energy efficiency but also an institutional device, built around an energy efficiency organization (EEO) and firms providing energy services, that attempts to respond both to efficiency and distributional concerns. Before describing them in detail, Table 3 depicts the main components of the scheme, with their linkages and expected outcomes.

3.1. Energy performance certificate system

The EPC system is a central piece of the policy package as, besides its important specific roles, it works as a kind of linking mechanism to other instruments (see below). As explained in section 2.2.3, EPC systems provide the essential information for consumers on energy efficiency characteristics of buildings and, indirectly, they create incentives for agents to invest in it as long as real estate markets capitalize their information. EPC systems are also flexible tools, able to adapt to heterogeneous geographical and climatic conditions, because ratings explicitly take account of unit-specific factors to allow for comparability.

In this proposed policy package the EPC system should be mandatory to promote behavioral change among consumers due to improved information and better incentives. Voluntary EPC systems do not work properly when a significant proportion of agents do not expect to be selling or renting their properties in the short or medium run. Voluntary EPC systems would also prevent the general application of other instruments of the policy package that depend on their existence, as seen below. Moreover, voluntary EPCs could bring about undesirable distributional effects if only high-income individuals can take advantage of the system because only they are able to invest in high-efficiency buildings and thereby obtain better ratings with higher associated prices/rentals. The system should be, moreover, applied to all types of buildings for the same reasons that merit a compulsory application of the scheme. Finally, it would be desirable to have a periodic review and update of the building EPCs in order to provide updated information and promote continuous efficiency improvement.

Figure 3. The policy package to promote energy efficiency in buildings



Source: the authors

3.2. Energy inefficiency tax

Even mandatory EPCs do not provide meaningful incentives for energy-efficiency improvements to agents who have only a limited involvement in transactions related to buildings (purchases or rentals). To solve this problem we propose a new recurrent tax on energy inefficiency in buildings (EIT), also able to generate revenues for a partial or full funding of the package through the energy efficiency fund (EEF). This tax is closely related to the mandatory EPC, which is used for the definition of a unit-specific tax rate, thus contributing to the central importance of that instrument within the package.

As any tax, the EIT applies a tax rate on tax base. To avoid legal challenges and to send the proper economic incentives, we propose a scheme with a progressive rate that depends on the grade of energy inefficiency of the building and is also related to a general energy tax that is supposed to attain an exogenously determined level of energy demand. Figure 4 depicts the tax rate of the general energy tax (t_e) and of the energy inefficiency tax (t_c) on buildings. The general energy tax is designed to move energy consumption from an unrestricted level, where the existence of some win-win options is reflected in the chosen shape of the marginal abatement cost curve, to the exogenously defined level (e^o). As indicated in Section 2, if energy prices alone would provide the incentives for a successful adoption of energy efficiency, no other instruments would be necessary. However, the already mentioned presence of several barriers to the adoption of energy efficiency measures justifies the EIT within a broader package. Yet by linking this new tax to a general energy tax, we use a non-discretionary tax rate that can be related to energy/environmental objectives elsewhere and reduces the possibility of promoting too-high or too-low energy efficiency efforts in the building sector[5]. Expression (1) shows the linkages between the tax rates of the general energy tax and the EIT.

$$t_c = (C_x - C_A)\, t_e \qquad (1)$$

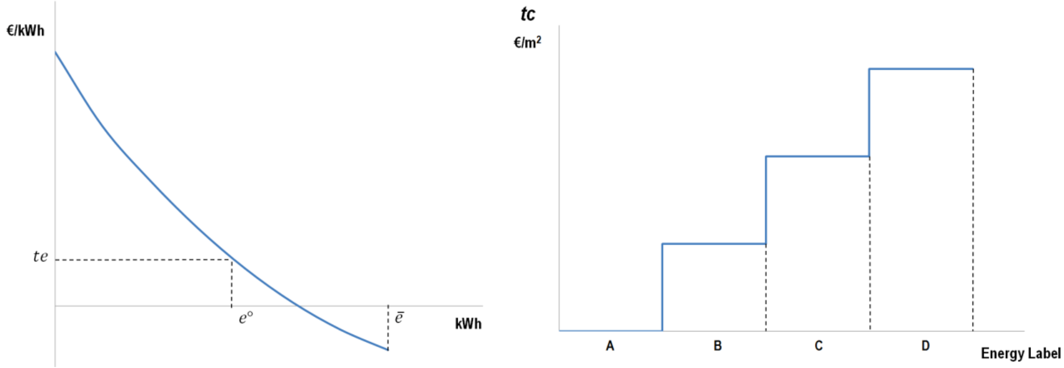
where C_X and C_A are respectively the estimated energy consumption provided by the EPC (used as the basis for grading), per square meter, of a building unit awarded with certificate X and A (the most efficient). This means that, as shown in Figure 4, t_c would increase with the level of inefficiency of labels, with a zero value when the unit has the highest energy efficiency rating.

Once the tax rate of the EIT is defined, in Euros per square meter, its application is straightforward as the tax base should be the built area (S, in square meters) to provide the adequate level of incentives. This would lead to tax revenues of T_c for a unit with a label X, as shown in equation (2).

$$T_c = t_c S \qquad (2)$$

[5] It can be argued that a simultaneous presence of both taxes may cause negative interactions and efficiency losses through a sort of double taxation. However, the EIT is just a tax to promote the highest level of energy efficiency whereas the general energy tax is levied on consumption. Actually, the presence of the general energy tax could contribute to the limitation of the rebound effect that could be generated by higher levels of energy efficiency (see note 7).

Figure 4. Energy inefficiency tax rate and base



Source: The authors

It should be stressed that the actual application of the EIT would not be burdensome from administrative or compliance perspectives. As long as the EPC is mandatory, the information on the ratings and associated energy consumption would be available for every building unit. Moreover, information on built areas should be easily retrieved from the property taxes on buildings that are common elsewhere and generally use them as indicators of property value. Indeed, although EIT could be implemented by almost any jurisdiction given its reduced administration costs, it would be probably recommendable to allocate them to the government level that manages taxes on building properties (in many cases local authorities). Of course, the preceding does not preclude the likely existence of political and social opposition to the introduction of a new tax.

Although this tax would provide revenues that are earmarked for the EEF, another essential instrument within the policy package, its main objective should be the continuous promotion of energy efficiency. As long as building codes are properly implemented and lead to good energy efficiency ratings, the EIT will be especially useful to promote retrofitting of old units. Given that old buildings are prevalent in many advanced countries, EIT may have a particularly important role there. However, building ratings are not static because they usually get more stringent due to technological advances and stricter regulations or because the energy properties of buildings are subject to obsolescence, which is why we proposed a periodic reassessment of EPCs in the previous section. In this setting, the EIT works even better because it provides continuous incentives to improvement and may also promote voluntary reevaluations of energy grades to avoid tax payments. Indeed, the EIT has the advantages and flexibility of pricing mechanisms as agents would only pay the tax when its costs are lower than the difference between benefits (reduced consumption) and costs (investments associated to a higher grade) of energy efficiency improvements: hence the economic importance of a non-discretionary approach to tax rate setting.

3.3. Complementary tools: building codes, smart metering and energy performance contracting

Although the preceding instruments constitute the core of our proposal, other policy alternatives are also necessary to guarantee the effectiveness and good performance of the package. As indicated by Figure 3, a coordinated use of three other tools is particularly necessary: building codes with minimum energy performance standards, smart metering for residential and commercial buildings and energy performance contracting.

As shown in Section 2.2.1, building codes should play an important role in fostering more energy-efficient new buildings as energy-efficiency measures introduced at this stage are usually cheaper and they also prevent the increase of the stock of inefficient buildings. Their main problem is related to the command-and-control nature, which may lead them to obtain the desired objectives without cost minimization due to uniform approaches in a very heterogeneous setting. In our policy package, however, building codes should only provide some minimum level of energy efficiency because the existence of the other policy instruments would provide incentives, even at the moment of construction, to improve the standard if deemed necessary. Therefore, flexible building codes may increase the level of energy efficiency in new buildings without compelling investments that are over or under the socially desirable outcome.

Smart metering is a useful complement for two reasons. First, it improves consumers' awareness and may make energy use more salient to them[6]. Once consumers know their energy consumption at each point in time, they can make adjustments if they wish to lower their energy use. Behavioral adjustment would be reinforced if there were some form of time-differentiated pricing, which is hardly worthwhile in the absence of real-time metering. The combination of smart metering and time-varying pricing has the potential to overcome bounded rationality barriers (see Section 2.1). Second, smart metering makes it easier for building managers or ESCOs to manage energy use in retrofitted buildings[7]. A possible way to introduce this technology in buildings is by adding an obligatory clause in the retrofitting contract that requires the installation of a smart metering system.

Finally, many governments and institutions are promoting the diffusion of energy performance contracting as a way to facilitate efficient investment (IPCC, 2007; European Commission, 2011). These contracts determine that payments for the services provided by energy services companies (see below) are subject to the performance of the new installation and to the expected energy savings. Using this performance-based form of acquisition, improvements in energy efficiency are paid through the energy savings derived from the investment. Energy performance contracting is also included in this policy package to provide confidence for those doubtful consumers who do not believe in the potential to reduce energy consumption. Indeed, the incorporation of such contracts contributes to overcome another major barrier for energy efficiency: lack of reliability.

3.4. Energy efficiency fund and institutional arrangements

Another important component of the policy package, and certainly related to some of the preceding instruments, is the energy efficiency fund (EEF). Given their partial or total funding through the energy inefficiency tax[8], the EEF should have clear links with the government, ideally through a public or semi-public non-profit energy efficiency organization (EEO). The fund must provide access to capital, another of the main barriers to energy efficiency indicated by Section 2.1, to low-income households and to the previously mentioned energy services companies (including ESCOs) whose role in the policy package will be described below.

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[6] This is confirmed by an OECD (2011) survey that shows that consumers who are charged differentially for their electricity consumption based on the time of use (peak versus off-peak) exhibit more responsible behavior with regard to energy use.

[7] This is also likely to mitigate any rebound effect, whereby higher efficiency energy-using appliances lower the real cost of energy services and stimulate an increase in their demand.

[8] The EEF may obtain further funds from the government or from energy utilities or companies that may be compelled to use part of their revenues to foster energy efficiency.

The EEF is thus the tool that should take care of the distributional concerns and objectives associated to energy-efficiency policies. As stated before, energy efficiency is not just concerned with economic efficiency because it can considerably improve the economic conditions and quality of life of the so-called energy poor (see Section 1). Moreover a policy package without the EEF would lead to undesirable distributional and efficiency effects from the EIT because, given the particularly limited access of poor households to capital for energy-efficiency investments in their dwellings, they would keep paying the burdens of the tax without simultaneous energy-efficiency gains.

In addition, the EEF can provide financial resources to companies that manage energy efficiency retrofits in buildings. Energy services companies would need a sizable initial capital to start the operation of such a system. This is the particular case of ESCOs, with an increasing importance in countries such as the US or Germany (IPCC, 2007), which guarantees energy savings (reliability) through the above-mentioned energy performance contracts. The links of energy services companies with the EEF explains the compulsory introduction of smart metering and use of energy performance contracts for those households and businesses that benefit from the EEF.

Although, given their regulatory characteristics, the EPC system and the EIT should be logically implemented by the government (at national, state or local level), an EEO with public or semi-public nature should be in charge of the EEF. There might be reasons for private involvement in the EEO, such as the possibility to attract external contributions to the resources of the EEF, although its central role in the policy package (full right hand side of Figure 3) certainly demands public involvement[9]. Actually, the EEO should define the characteristics that make households and companies eligible for funds of the EEF and should play the role of information provider on energy efficiency for all sectors of the economy. Although the EEO does not itself conduct retrofitting operations, it should maintain an official list of energy services companies that are judged to have done successful retrofits. In this way, the EEO is a matchmaker between energy services companies and consumers. Furthermore, the EEO should oversee and guarantee a proper functioning of the energy performance contracts and, in general, of the liaisons between energy services companies and final energy consumers.

In closing this section we should note that, although we have presented a novel and comprehensive policy proposal that has not been tested in reality, some of the components are related to a successful package applied in the American state of Vermont with the same objectives. The scheme is based on a volumetric *Energy Efficiency Charge* paid by all retail electric consumers and that fund *Efficiency Vermont*, an entrepreneurial NGO selected through an auction by the state administration with a performance-based contract. The main objective of *Efficiency Vermont* is to influence energy-related decisions through the most cost-effective strategies that can be devised and implemented. All utility customers should have the opportunity to participate and benefit from the energy-efficiency programs, especially those with high barriers, as low income, seniors or small businesses (Hamilton, 2010). Moreover, in mid 2011 the European Commission launched the European Energy Efficiency Fund, which also has similarities with our proposed EEF[10]. Finally, the so-called *Green Deal*, a funding scheme for residential and commercial energy consumers that should be implemented during 2012 in Britain, attempts to promote cost-effective

[9] This fund is partially funded by the EU and several financial institutions to back projects in the field of energy efficiency and renewable energy.

[10] This is also likely to mitigate any rebound effect, whereby higher efficiency energy-using appliances lower the real cost of energy services and stimulate an increase in their demand.

improvements in energy consumption in buildings through expert assessment and compulsory funding (UKDECC, 2011b). However, all the preceding schemes lack the comprehensive and coordinated use of several policy instruments of our policy proposal, which tackles all the market barriers and market failures associated to energy efficiency in buildings.

4. Conclusions

Buildings are crucial to control present and future energy demand, and therefore GHG concentrations in the atmosphere, as they are responsible for a sizeable share of global energy consumption and GHG emissions and are associated to an important 'stock' of future energy consumption and emissions. This phenomenon is likely to worsen due to the irruption of emerging economies whose where increasing population and economic growth will lead to a renewed activity in building construction and use. Enhanced energy efficiency in buildings will thus bring about environmental (less emissions and damages) and economic (savings to households and firms) benefits, but also improvements in energy security and positive distributional effects (a mitigation of energy poverty).

However, despite the socio-economic and environmental importance of these matters, in practice energy efficiency measures and techniques have been hardly introduced in commercial or residential buildings. This is somehow surprising because, from a technical point of view, most of the energy-efficiency measures in buildings are already technologically and economically mature. Indeed, many of the measures applicable to buildings are apparently among the most cost-effective within the energy efficiency domain.

A number of issues explain the real-world barriers to energy efficiency improvements, which are not restricted to this sector and are actually the reason for persistent public intervention in this area. However, buildings and dwellings have particular characteristics that differentiate them from other products and sectors: they are long-lived and costly assets and many agents are usually involved in this market. Indeed, absence of information, high financial requirements and lack of reliability, have been identified as the major barriers for the adoption of energy-efficiency measures in buildings.

In this chapter we suggest that, due to a number of general and specific barriers to energy efficiency policies in this area, energy prices and conventional energy and environmental policy instruments may not achieve the desired outcomes unless they are introduced in a comprehensive and coordinated package of instruments that can simultaneously tackle the existing problems of information, split incentives among agents, uncertainty or access to capital. The proposed policy package is defined around energy certification of buildings, uses flexible building codes, smart metering and employs a new tax on energy inefficiency to foster continuous incentives towards energy efficiency improvements and to provide revenues for an energy efficiency fund that provides capital to firms and poor households.

We feel that the proposed policy package is, first of all, of easy application: most of the instruments already exist and the novel tax on energy inefficiency would have low administration and compliance costs due to its easy integration within existing tax systems. Second, and more importantly, the package can be defined as long, loud and legal because it provides a set of legally feasible instruments that generate reliability and strong incentives on agents for the adoption of energy efficiency measures. This is especially needed, given the size and likely evolution of the problems associated to energy consumption and emissions from buildings.

One can think of the policy package that we have proposed as a means of *commodifying* energy efficiency. While energy is clearly a recognized commodity that is sold in existing markets, as are the individual pieces of equipment that contribute to energy efficiency, for the typical residential consumer, or the typical small business owner, energy efficiency is not something he sees as amenable to his control. It is not an item that he can simply go out and purchase, the way he can purchase a light bulb or a gallon of gasoline. He would not know how to transform his home, or his office, to make it use less energy, how much it would cost him to do this, how much money it would save him. He does not know how to make the transformation happen, or even where to acquire that information. The portfolio of measures that we propose makes the energy efficiency transformation accessible, visible and affordable to these consumers. By certifying the energy efficiency of buildings, and taxing the energy efficiency gap relative to a high-efficiency building, our package makes the lack of energy efficiency very visible and highly salient. This is the precondition for energy efficiency to become a marketable commodity. The other measures in our package lower the cost and ease other barriers to the purchase of energy efficiency as a commodity. In the successful Vermont experience, for instance, homeowners do not have to leave their home: representatives of *Efficiency Vermont* come to their door with the offer of analyzing their energy use, identifying solutions that conserve energy, bringing in architects, engineers and contractors to implement these solutions, and offering a financing package that eliminates any large up-front cost and makes it affordable. This goes beyond lowering the cost of energy efficiency to the individual energy user: it makes energy efficiency a commodity that is accessible as well as affordable.

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