Market-based instruments for energy efficiency: a global review

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Abstract

Across the world, an increased uptake of so-called market-based instruments (MBIs) for energy efficiency such as energy efficiency obligations and auctions can be witnessed. So far, a global assessment of those instruments is absent. In this paper, we analyse the most recent data across the world for all MBIs for energy efficiency. Whilst most of the 52 instruments identified can be found in the US and in Europe, they are now operational on all continents. We estimate that globally around $26 billion of investment in energy efficiency is delivered through these instruments - this equates to more than 10% of the global annual investment in energy efficiency. There is considerable variation in costs among programmes. The available data show that expenditure by obligated parties and payments to auctions winners (programme costs") average around 0.013 USD/kW and are below the typical costs of producing a kWh in most sectors and locations.

Keywords: market-based instruments; energy efficiency; auctions; energy efficiency obligations; white certificates

1 Introduction

There is an increasing interest in the role so-called market-based instruments (MBIs) can play to deliver energy efficiency across the world, although the use of the term MBIs for delivering energy efficiency is ambiguous. Recent policy initiatives have given a boost to MBIs. For example, in Europe, the introduction of the Energy Efficiency Directive in 2012 set EU Member States targets for energy savings from obligations or alternative measures, leading to an increase in the number of both obligations and auctions (Rosenow et al. 2016a), with 16 Member States now using different types of MBIs (Fawcett et al. 2018). In the United States, an increasing number of States are employing MBIs with many increasing their level of ambition. Countries in Asia and Latin America also show increased interest in MBIs and there are long-standing programmes in place in Australia, Brazil, China, Korea and South Africa.

The rising popularity of MBIs among policy makers is in part owing to their characteristics. They tend to be less prescriptive than traditional regulations and grants as they focus on outcomes (e.g. energy savings) as opposed to the means of delivery (e.g. technology, sector, fuel or delivery method i.e. who provides the energy efficiency measures to end-users). And through the direct involvement of profit-maximising companies, either as obligated parties or auction bidders, policy makers' objectives can potentially be met more cost-effectively. In addition, in the case of obligations, the costs to utilities do not appear on government balance sheets (with utilities passing on their costs to consumers through energy prices).

These characteristics can also create some challenges for policy makers, although so far these have not resulted in a slowdown of the uptake of MBIs. The freedom given to private sector actors to discover the most cost-effective means of generating energy savings can lead to the concentration of delivery in particular technology types, particularly if their costs decline quickly. This puts a premium on good programme design with regular evidence-based reviews and in many cases limits on the amount of energy savings that can be claimed by individual technologies. Another issue facing obligations, is that instruments that are funded through energy prices are potentially more regressive than those funded through general taxation, given that poorer households tend to consume more energy as a proportion of their incomes. A number of programmes have elements targeted at fuel poor households, while other policy makers have employed explicit redistribution policies aimed at lowering the energy bills paid by poorer households.

For the first time, this paper provides a global assessment of the impact of MBIs for energy efficiency both in terms of investment, energy savings and cost-effectiveness. We analyse 52 different instruments from across the world. The analysis shows that MBIs are becoming increasingly important in terms of their number, global coverage, energy savings and investment triggered.

First, a background section including a definition of MBIs for energy efficiency and the current level of their deployment across the world is provided. Second, we provide a detailed methodology with all the data sources used for the analysis. This is followed by an analysis of the global investment triggered by MBIs and a comparative assessment of their cost-effectiveness. Finally, we provide a future outlook for MBIs before we conclude.

2 Background

2.1 Defining market-based instruments for energy efficiency

The term MBIs originates from the environmental economics literature (Stavins 2003) and is describing policies that are 'harnessing market forces' to achieve environmental goals. In its broadest sense, MBIs for energy efficiency 'use market forces to minimise the cost of saving energy' (Farinelli et al. 2005).

We follow the definition used in a report by the International Partnership for Energy Efficiency Cooperation (IPEEC 2016) in response to the mandate from G7 Members following the G7 Energy Ministerial in May 2015 and by the World Bank (Sinton and de Wit 2014). We define MBIs for energy efficiency as:

"instruments that set a policy framework specifying the outcome (e.g. energy savings, cost-effectiveness) to be delivered by market actors, without prescribing the delivery mechanisms and the measures to be used."

Following this definition, MBIs are distinct from other energy efficiency programmes which typically prescribe the *means* for delivering savings i.e. the types of technologies or interventions that are supported as well as the levels of support provided (Bertoldi et al. 2013). MBIs as defined here specify the *outcome* that has to be achieved (energy savings) without prescribing the means through which this is achieved (as long as those means meet the eligibility criteria for the programme).

Two types of programmes fit well with this definition:

1) Energy Efficiency Obligations (EEOs - also known as Energy Saving Obligations, Energy Efficiency Resource Standards, Energy Efficiency Performance Standards or White Certificates) which require utilities to carry out a defined level of activity delivering energy savings but leave it to the utilities to find the best delivery routes for doing so.

2) Auction mechanisms allow market actors to put forward bids either in competitive tenders where the lowest bid wins or within a framework that sets the price per unit of energy savings invited market actors to put forward proposal to deliver savings at that price.

It is common for MBIs to use a range of criteria when selecting energy efficiency projects (quality, technology, location, etc.). For example, the Portuguese tendering mechanism uses several criteria for ranking bids, with the main difference compared to standard public tendering procedures being the explicit use of the metric cost / kWh as a key criterion.

Other common energy efficiency policy instruments fail to meet the above definition. A standard public subsidy programme (e.g. grants, loans, tax rebates) would not satisfy the definition because a) the levels of financial support are typically predetermined as a fixed payment or percentage of the overall cost of the technologies supported and b) the metric money spent per kWh is usually not used explicitly when assessing bids. Codes and standards likewise do not fit the definition, although they are usually evaluated in cost-effectiveness terms. Whilst MBIs focusing on carbon abatement can result in energy efficiency improvements, they do not explicitly target energy efficiency and efficiency is just one of many technologies to deliver carbon savings.

However, the term MBIs is not as clear-cut. For example, one might argue that obligations on energy utilities are in fact regulatory instruments rather than market-based. Also, there are other types of programmes that might be classified as market-based if a somewhat different interpretation is applied. For the purpose of this paper, we use the term MBIs to describe obligations and auctions as explained above.

The term ‘white certificates’ is sometimes used with different meanings. In this paper, we refer to white certificates as tradable certificates declaring that a certain reduction of energy consumption has been attained in accordance with the rules of an EEO. Most EEOs do not include this feature but some in Europe and Australia do.

2.2 Key differences between different types of MBIs

An important issue is how different types of MBI are funded (Figure 1). Obligations are funded through energy tariffs, either as a surcharge (regulated or unregulated) on energy bills, or simply as a cost of doing business, and paid for by all consumers or a segment of consumers (e.g. only residential customers). Auctions can be funded through a variety of funding streams, the most typical being funds from general taxation as in the United Kingdom, a levy on energy bills allocated to the auction as in Portugal (Sousa et al., 2015) and a levy on the electricity transmission grid as in Switzerland (Radgen et al. 2016). Other funding mechanisms are possible as well, for example ringfencing revenues from auctioning CO_2 allowances and using them to fund auctions.[1] In some US markets, capacity auctions pay for efficiency via capacity charges paid by all retailers and thus the costs are included in the retail electricity prices along with capacity charges for generators, transmission charges and other costs of doing business (Liu 2017).

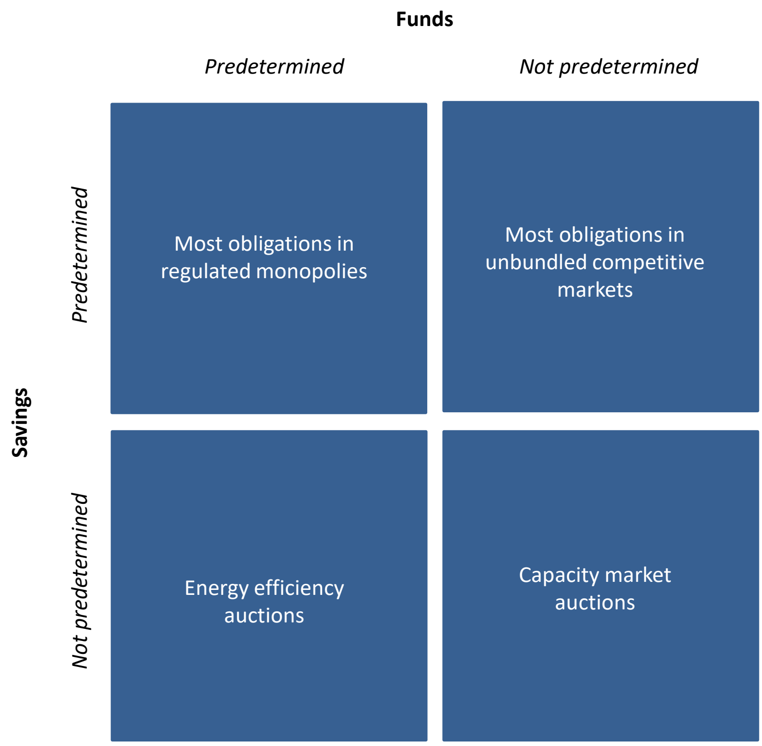
[1] Germany has an energy and climate fund part-funded by revenues from the EU Emissions Trading System. This is used to finance the auction mechanism (BMWI, n.d.a).

How an MBI is funded may not have a major impact on how it is delivered but has important social equity implications. Raising funds through energy bills is more regressive than doing so through general taxation (provided taxation is progressive). While regressive impacts on the cost side may be offset by broader cost reductions,[2] and can also be offset through progressive delivery of energy savings, this may be a concern. Policy changes in the United Kingdom, for example, have been driven partly by a debate around the impacts of obligations on energy bills.

In addition to the funding question, the degree of control over the outcome (in terms of energy savings) varies between the different types of MBIs. Obligations set a firm target for energy savings to be delivered and historical experience shows that the target is usually achieved, with some exceptions (Lees and Bayer, 2016). While auctions specify the outcome (energy savings), they do not predetermine the total quantity of savings being delivered. Instead, efficiency-only auctions typically have a defined budget used to deliver the outcome. Programme administrators may carry out an ex-ante analysis around expected savings and ex-post evaluations of achieved savings but they are not able to specify the total amount of savings possible for obligations.

[2] For example, by avoiding the cost of transmission and distribution upgrades that would be paid for by all consumers, or by lowering the cost of capacity payments and other reliability services, which are also rolled into the power costs that all customers, including low-income customers, must pay.

Figure 1: Differences between MBIs regarding predetermination of funds and savings



Obligations operating in unbundled, competitive markets often estimate the amount of funding required to deliver the outcome (they may even require obligated parties to report on this for transparency reasons). However, unless the cost-pass through to consumers is regulated, as is the case for most obligations operating in vertically integrated markets, the amount of funds required in order to deliver the savings cannot be predetermined. In contrast, in vertically integrated markets with regulated monopolies, the utility must have the regulator approve the cost passed to the consumer; the savings required are predetermined and then the utility must determine the funds needed to meet that savings levels and request the regulator approve it. Once agreement has been reached, both the savings and the costs passed through are predetermined.

Capacity market auctions are different altogether as it is not clear how many energy efficiency resources will clear the auction nor is the clearing price known prior to a capacity market auction. The way they are designed, there is no mechanism to predetermine either savings or funds.

In addition to funding, decision-makers often wonder whether MBIs are better suited or more successful in traditional, vertically-integrated power and natural gas markets, or in unbundled, competitive environments. The studied sample reveals that they can work well in any of the usual market structures operating in power and gas markets today.

2.3 Status and evolution of MBIs for energy efficiency

There has been significant growth in the number of MBIs to deliver energy efficiency. In total, there are now around 46 EEOs across the globe - 24 in the US (Downs and Cui 2014), 14 in Europe (Austria, Bulgaria, Denmark, France, Greece, Ireland, Italy, Latvia, Luxembourg, Malta, Poland, Slovenia, Spain, UK) with another due to start shortly (Croatia) (ATEE 2017; Rosenow et al. 2016b) and 2 further countries considering their introduction (Greece, Netherlands), 4 in Australia (Energy Efficiency Exchange 2016), 1 in Canada (IESO 2016), 1 in China (Crossley and Xuan 2015), 1 in Brazil (ANEEL 2016a), 1 in Uruguay (Lees 2010), 1 in South Korea (Crossley et al. 2012), and 1 in South Africa (BIGEE 2016).

In addition, there are 6 auction mechanisms of which there are 2 in the US (Neme and Cowart 2014), 1 in Switzerland (BfE 2014, Radgen et al. 2016), 1 in the UK (DECC 2015), 1 in Portugal (Sousa et al. 2015), and one in Germany (BMWi 2016). Note that some EEOs use auctions as a procurement mechanism at the level of the obligated party (e.g. South Africa, Texas). In this paper, those mechanisms are treated as obligations, given the focus on decisions taken by government policy makers.

The number of obligations and auctions has quadrupled over the last decade. Ten years ago there were no auctions and only 13 obligations in place, of which there were seven in the US (Downs and Cui 2014), four in Europe (ENSPOL 2015), and one each in Brazil (Broc et al. 2015) and South Korea (Crossley et al. 2012).

In the European Union, the Energy Efficiency Directive has triggered several new obligations. Before the Directive, only five obligation programmes existed in the European Union, whereas 14 were operational in 2015 and another EEO is about to start (Fawcett and Rosenow 2016).

Figure 2: Global coverage of MBIs for energy efficiency

Source: International Energy Agency (2017)

3 Methodology

This section sets out the overall approach taken, the key data sources for each of the MBIs analysed and the leverage factors used to estimate total global investment triggered through MBIs.

3.1 Approach

It is not surprising that the available data on both the costs and the savings associated with MBIs are heterogenous given the diversity of national and regional contexts in which MBIs operate. Hence, drawing conclusions as to the cost-effectiveness of different instruments is challenging. The main reason for this heterogeneity are the methodologies used by countries to estimate and report costs and savings which are not consistent:

- Some countries discount energy savings whereas others do not.
- Estimates for free-ridership vary across countries with some assuming higher free-ridership than others.

- Rebound effects are taken into account to different degrees.
- Some countries report lifetime savings whereas other only report first-year savings.
- Lifetimes of measures are not consistent even for the same intervention.
- Some evaluations are ex-ante, others ex-post. The rigor is not the same across all countries.
- Some estimates are based on metering whereas others solely rely on standardized methods or bespoke engineering models.
- Units of savings are derived from different mixes of fuels and conversions are required to arrive at kWh equivalents.

The list above is not exhaustive and other factors can also have an impact on the differences observed. Consequently, a number of assumptions such as average lifetime[3] of energy efficiency measures and unit conversion factors[4] had to be made when calculating the savings from specific MBIs. We have provided estimates of savings and costs for most instruments in the same units but it is not possible to meaningfully adjust the reported energy savings in such a way that they are fully harmonized. This complexity is also described in Moser et al. (2012) and it would require access to the models used to calculate savings for each technology promoted under the schemes analysed. This is because for each technology supported by MBIs (and there are several hundred in some countries) the assumptions used for estimating the savings would need to be reviewed. Such an approach could potentially provide more homogenous and reliable data but is not feasible without committing significant resources to it. The results of our analysis therefore need to be treated with some caution. We report the energy savings in annual incremental terms (GWh/year) which means the additional energy demand reduction achieved in a given year and is different to cumulative or lifetime savings which are sometimes used to express the savings achieved.

Cost data have been reported purely as programme costs i.e. only the expenditure by obligated parties as part of an EEO and payments to auction winners. We use US $ as the currency and have obtained exchange rates from Google Finance for the purpose of converting cost figures.

[3] We considered the technologies promoted by a specific instrument and used standardised lifetimes from CEN (2007) for deriving an average lifetime. This is the case for China (10 years), Portugal (10 years) and South Africa (8 years).
[4] We used the IEA unit converter (https://www.iea.org/statistics/resources/unitconverter/).

3.2 Data sources

For each programme analysed in this study the main data and data sources used are listed in the detailed details in the Appendix to this paper. The following sections provide a brief overview of the key sources used.

3.2.1 United States

There is detailed data on both the costs of and the savings delivered by MBIs in the United States. The American Council for an Energy Efficiency Economy (ACEEE) provides such data annually for all states with an EEO through its State Energy Efficiency Scorecard (http://aceee.org/state-policy/scorecard), a benchmarking framework for measuring the progress of state policies and programmes that save energy which has been in existence for more than 10 years (Berg et al. 2016). The data used by ACEEE are vetted by state energy officials. Lifetime savings are not reported but data on the cost-effectiveness are provided by ACEEE in a separate publication (Molina 2014).

Other key data sources are provided by Lawrence Berkeley National Laboratory (LBNL) which tracks and analyses energy efficiency policies and programmes including MBIs. LBNL analyses data that efficiency program administrators report to state regulators (Hoffman et al. 2017). Published data from LBNL provides estimates of the cost of electricity savings achieved through EEOs but not for gas savings. Data on the total savings and expenditures by state are not publicly available, although LBNL tracks those in its database of energy efficiency programmes.

For capacity market auctions (PJM and ISO New England), figures on the total annual energy efficiency spending can be derived by multiplying the clearing price with the amount of cleared energy efficiency resources. However, there are difficulties of determining the savings provided by energy efficiency measures receiving capacity payments. This is because there is overlap of energy efficiency improvements funded through capacity market auction payments and EEOs. Data from New England shows that 99% of capacity from energy efficiency is allocated to utilities with an obligation, suggesting that without obligations energy efficiency would not be able to compete in the current capacity market (ISO-NE 2015). It can therefore be assumed that the amount of energy savings delivered by capacity market auctions additional to EEOs is relatively small, although precise data is missing.

3.2.2 Europe

There is currently no database in Europe similar to the ACEEE and LBNL evidence discussed above. Data on the costs of MBIs in Europe is scarce and there are few academic assessments (Bertoldi et al. 2010; Eyre et al. 2009; Giraudet et al. 2012). The most recent study (Rosenow and Bayer 2017) provides data on the savings, costs and cost-effectiveness for EEOs in Austria, Denmark, France, Italy and the United Kingdom. This data has been complemented using additional sources and estimating savings and costs based on the energy saving targets notified to the European Commission.

3.2.3 Australia

The main objective of all four Australian EEO schemes is to reduce greenhouse gas emissions. Therefore, all Australian schemes initially denominated and reported savings in terms of emissions abated, usually expressed as tonnes of carbon dioxide equivalent (tCO2-e). From 1 January 2015, the South Australian scheme denominated and reported savings in energy terms (GJ).[5] The energy savings corresponding to emissions abated can be calculated using emissions factors. Savings are reported on a cumulative (New South Wales, Victoria) and/or a lifetime basis (Australian Capital Territory, South Australia). Cumulative savings refer to the total accrued energy savings over a certain time frame. Lifetime savings refer to the expected energy savings over the lifetime of the energy efficiency measures delivered.

It is difficult to calculate the costs of energy savings in the four Australian EEO schemes. Third parties and obligated energy retailers are not required to disclose their costs to acquire energy savings, so there is no information publicly available about these costs. It is possible to make estimates of the costs by using a proxy. In white certificate schemes (in place in New South Wales and Victoria), the proxy can be the average certificate spot price; however, the majority of certificate sales to obligated

[5] South Australia is the State with the highest renewable energy share in the electricity production and keeping the measurement in CO2 savings would not fully reflect the energy savings.

parties are private bilateral transactions, presumably at lower prices than in the public spot market. In schemes without white certificates, the proxy can be the value of the penalties payable by obligated energy retailers who fail to achieve their energy saving (or emissions abatement) targets. Obligated parties will not pay more for energy savings than they would have to pay in penalties, so the value of the penalty represents a theoretical maximum cost per unit of energy savings. Calculations using either the certificate spot price or the penalty as a proxy will necessarily overestimate the actual costs of acquiring energy savings.

3.2.4 Rest of the World

Outside of the United States, Europe and Australia we identified a further six MBIs in operation at the time of writing including in Ontario (Canada), Brasil, Uruguay, China, South Korea, and South Africa.

For Brasil, the Agência Nacional de Energia Elétrica provides detailed savings and cost data on its website (ANEEL 2016b). We assumed a 10-year lifetime to calculate the costs per unit of energy saved.

The EEO in Ontario (Canada) has been evaluated regarding its cost-effectiveness for the years 2011-2014 (IESO 2015) and based on the reported savings for 2015 (ISOE 2016) and cost per unit of energy saved we estimated expenditure in 2015.

Expenditure and cost data for the EEO in China is reported by State Grid (2016) and China Southern Power Grid Company (2015). Assuming a 10-year lifetime we estimated the lifetime savings and cost-effectiveness.

No published data for the EEO in Southern Africa was identified. However, the obligated utility, Eskom, shared an unpublished report with us that includes both cost and savings data for 2013 (ESKOM 2015). Based on the technologies supported we assumed a lifetime of 8 years and calculated the cost-effectiveness of the programme.

No reported data on the costs and energy savings could be identified for the EEO in Uruguay. However, a figure on the costs per unit of savings has been published (Ministerio de Industria, Energía y Minería (2016). Cost and savings data was obtained directly from the Ministerio de Industria, Energía y Minería (2017).

Data for South Korea was obtained through the International Energy Agency.

4 Results and discussion

4.1 Current investment through market-based instruments for energy efficiency

4.1.1 Programme expenditure

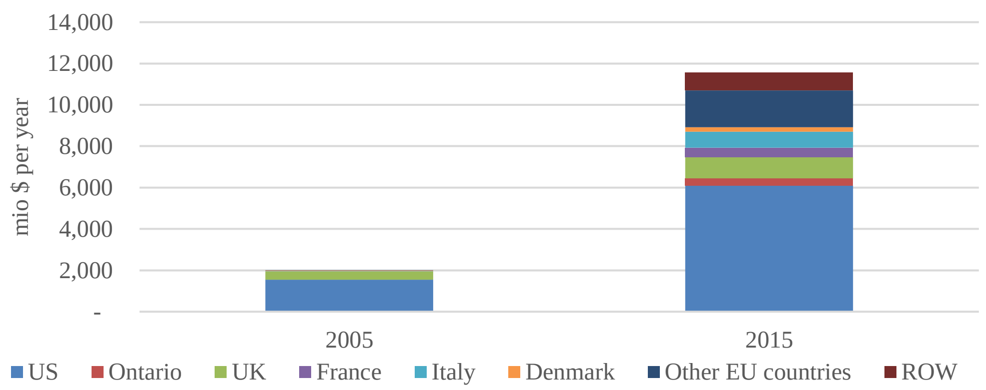
As a result of the growing number of instruments and the increasing ambition of their targets, expenditure through MBIs for energy efficiency has increased by a factor of close to six over the last decade (Figure 3). Approximately 4% of programme expenditure can be attributed to auctions, with the remaining 96% coming through EEOs. Programme expenditure represents the cost to the public through surcharges on energy bills or funding derived from general taxation. The amounts do not include the investment made by programme participants (e.g. the beneficiaries that retrofit their building and receive a partial contribution from a programme). For an EEO, programme expenditure represents the incentives paid to beneficiaries by the obligated parties. For an auction scheme, programme expenditure relates also to incentives paid to beneficiaries allocated through the successful bidders in an auction.

Figure 3 shows the programme costs of both obligations and auctions in 2005 and 2015. Also, the administrative costs to the public agency responsible for implementation of a programme are not included in the data presented. For most obligations, the administrative costs constitute a small fraction- less than one percent - of the total costs to the obligated parties. Analysis of European obligations suggests administrative costs of 0.2-1.4% of programme costs (Rosenow and Bayer 2017). In general, administrative costs include the following:

- for EEOs only: allocating the government-set energy savings target between obligated energy companies;

- determining accreditation process for energy savings;
- issuing technical guidance on eligible measures;
- accrediting energy savings;
- for EEOs only: putting in place mechanisms to track any transfer or trade of savings; and
- monitoring and verification.

Figure 3: Programme cost of MBIs for energy efficiency



Note: Figures are nominal. "Other EU countries" includes Bulgaria, Ireland, Lithuania, Luxembourg, Malta, Poland, Slovenia and Spain. ROW refers to "Rest of the World and includes Ontario (Canada), Brazil, Uruguay, China, South Korea, South Africa

4.1.2 Total investment

Data on the total investment triggered by obligations and auctions (defined as the sum of programme expenditure and the cost to the participants) are not readily available and would require detailed surveys on the cost to the participants. Instead, total investment can be estimated by applying leverage factors. Such leverage factors are, however, not available for many of the MBIs we analysed. A study of several EEOs in the United States estimates the total investment at 241% on average of the programme expenditure. This means that, on average, a programme costing utilities USD 1 billion per year results in an additional investment of 1.4 billion by consumers and total investment by society of USD 2.4 billion per year (Molina 2014). Another assessment for the United States suggests that total investment is twice programme expenditure (Hoffman et al. 2017). An investigation in Europe (Rohde et al. 2015) found the following leverage effects (total investment as a percentage of programme expenditure):

- United Kingdom: 187% of obligated parties' cost (2002-05), 144% (2005-08, residential sector only)
- France: 137% (programme expenditure includes expenditure by Government on tax credit)
- Denmark: 300% of obligated parties' costs (industry sector only).

In the United Kingdom, leverage ratios are also available for able-to-pay and low-income households. In the period 2005-08, total investment was 190% for able-to-pay households and 120% for low-income households. The data for the able-to-pay sector are similar to the results for the United States cited above. This data above suggests that one dollar of public investment triggers around one to two dollars of private investment.

In reality, the leverage factors vary between the different instruments, geographies, technologies, and customer segments. The leverage ratio depends on a number of factors (Table 1). The more aggressive the target and level of ambition, the more difficult it becomes to persuade additional beneficiaries to contribute private capital. Focusing on low-income customers increases the monetary contribution made by the programme. There is an inherent tension between delivering energy efficiency to low-income customers and the objective of MBIs to deliver energy savings at least cost. If focused on minimising the cost of delivering energy savings there is a disincentive to deliver energy efficiency to those on low incomes. In contrast, if the focus lies on providing mainly or exclusively for low-income households programme costs need are higher to achieve the same amount of savings or if costs are kept at the same level the amount of savings will be lower compared to a programme open to a wider range of participants (Rosenow et al. 2013). Recent experience in the UK suggests that reorienting MBIs exclusively towards fuel poverty alleviation risks losing vital support for the able-to-pay sector. It therefore seems sensible to design an MBI in such a way that all end-users can benefit from the programme if they want to rather than focusing exclusively on one sub-sector. To ensure that also low-income consumers benefit an allocation of a percentage share of all savings can and often is made to benefit disadvantaged end-users.

If the additionality requirements are relaxed, it is possible to count savings even from beneficiaries who would have made the investment anyway; this may result in a high calculated leverage ratio but there is a clear trade-off. Finally, the available data indicates that the highest leverage ratios are achieved in the industrial and commercial sectors: Hoffman et al. (2017) calculate leverage ratios of 174% in the residential sector, 217% in the commercial, industrial and agricultural sector, and only 106% in the low-income residential sector.

Table 1: Factors affecting leverage of MBIs

	Leverage ratio low	Leverage ratio high
Aggressiveness of target or ambition level	High	Low
Focus on low-income beneficiaries	Yes	No
Approach to additionality	Stringent	Relaxed
Sectors	Low-income residential sector	Commercial, public and industrial sector

As shown above, typically, the total investment is two to three times the programme expenditure, because programmes leverage additional investments by consumers (Molina 2014; Rohde et al. 2015). Applying these leverage factors to the programme costs of all MBIs operational in 2015, suggests that total investment through MBIs was between USD 23 billion and USD 30 billion, with a central estimate of around USD 26 billion per year.

As discussed in the methodology section, the leverage factors vary by instrument, technology, market segment and geography. A more granular estimation is not possible due to scarce data. Furthermore, no leverage factors for auction mechanisms could be found. It is likely for those to be within a similar range as the beneficiary is presented with a financial incentive sufficient to trigger the investment and is often not aware of the funding mechanism operating in the background. Thus, it should make no difference to the beneficiary whether the financial incentive is provided through an obligation or auction mechanism. However, in reality beneficiaries are responding differently to different actors and it makes an important difference which actor is seen as the primary delivery agent. Utilities may face trust issues and working in tandem with a trusted intermediary can help mitigate against this. Furthermore, it also makes a difference whether or not the financial contribution is paid upfront or after the intervention. EEOs and auctions can differ with regard to both elements, intermediaries and payment terms, but in principle they can look very similar from the perspective of the beneficiary.

The question remains why EEOs are so much more popular compared to auction mechanisms. One explanation is that auctions are a fairly new instrument whereas EEOs have been in existence since the 1970s. A second reason might be that auction schemes are potentially more complex to run or at least being perceived in this way by policy makers.

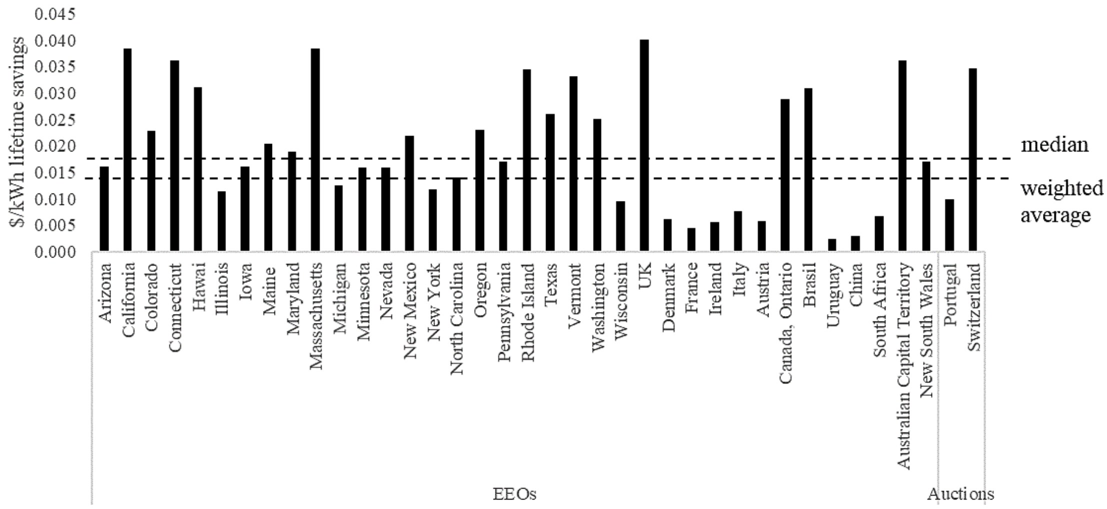
4.2 Cost-effectiveness

4.2.1 Results

We use negawatt hour costs in money spent per kWh saved as a result of obligations and auctions as this metric is particularly useful for comparing such programmes (Gillingham et al. 2006) and commonly used across the world when assessing the costs and benefits of energy efficiency schemes. Negawatt costs can be compared to the cost of energy supplied to final customers (or megawatt costs) to establish if the programmes are cost-effective.

Programme expenditure (costs) and savings data for 37 MBIs around the world have been identified (Figure 4). The median programme cost is \$0.017/kWh lifetime savings and the average weighted by the reported energy saved is \$0.013/kWh.

Figure 4: Programme costs of MBIs for energy efficiency per unit of saved energy (years vary)



Reliable data on the societal costs of programmes does not exist for schemes outside of the US and a small number in Europe. Applying the leverage factor of two to three to the programme costs suggests median total costs of between $0.034 and $0.051/kWh lifetime savings and a weighted average of between $0.026 and $0.039/kWh lifetime savings.

This is well below the typical costs of energy supplied in most sectors and most locations. For example, in the United States average electricity prices in June 2018 ranged from about $0.07/kWh in the industrial sector to $0.13/kWh in the residential sector. In individual states prices can be lower but typically they are well above $0.05 (EIA 2018a). Natural gas prices range from $0.03/kWh in the industrial and commercial sectors to $0.04/kWh (EIA 2018b; used conversion factor of 0.29 to convert cubic feet to kWh). The picture for electricity is similar in Europe: residential electricity prices in 2017 ranged from $0.16/kWh in Bulgaria to $.035/kWh in Denmark. Non-residential (industry and commercial) prices ranged from $0.08 in Sweden to $0.17 cents in Germany (Eurostat 2018b). Natural gas prices for residential customers are lower and ranged from $0.04/kWh in Romania to $0.13/kWh in Sweden. For non-residential customers gas prices ranged from $0.03/kWh in the United Kingdom to $0.06/kWh in Finland (Eurostat 2018c). It is important to consider that electricity prices may not always reflect the true costs of generating and supplying electricity as prices are regulated in some markets but not in others.

4.2.2 Discussion

Looking purely at the cost per kWh compared to the cost of supplied energy is misleading for assessing the economics of MBIs as this does not factor in all of the multiple benefits that efficiency can provide (see for example Persson and Landfors 2017). Multiple benefits include for example health benefits (such as reduced respiratory disease symptoms and lower rates of excess winter mortality), avoided or deferred investments in generation, transmission and distribution capacity, risk mitigation in terms of resource diversification and hedging for fuel price volatility, and avoided CO_2 permit costs for power generating facilities that are within a carbon tax or cap-and-trade regime. A more comprehensive quantitative analysis is complex, although there are now some examples of the partial quantifications of those multiple benefits (see for example Rosenow et al. (2018) for the UK).

Furthermore, the extent to which factors including the rebound effect and free-ridership reduce energy savings and thus result in higher costs per kWh figures is uncertain and cannot be resolved easily. However, the upper end of the range provided is associated with programmes that can be characterized by the most sophisticated evaluation techniques and the above statement still holds even if the true costs per unit of energy saved are higher than is the case for some of the programmes analysed here.

The differences in cost-effectiveness are explained by several factors including but not limited to:

- Depending on how the programmes are designed they deliver energy efficiency measures with different cost profiles (e.g., low-income programs have higher costs or considering the magnitude of the non-energy benefits).
- More robust monitoring, verification and evaluation is likely to result in lower estimates of delivered energy savings, which in turn results in higher cost per kWh estimates.
- The ‘aggressiveness’ of the savings target / level has an impact on the cost per kWh saved.

- Programmes offer different levels of support to beneficiaries, ranging from only a small contribution to close to full funding of the investment.

Future research would be well-advised to look into more detail into a) how energy savings are modelled in the various schemes assessing the various assumptions going into the estimates and b) how calculation methodology harmonisation could be achieved between programmes more easily.

This study has shown that at the moment there is substantial heterogeneity across the world when it comes to evaluating energy efficiency programmes, this is supported by previous research (e.g. Wade & Eyre, 2015). For example, in the United States about 3-6% of programme costs are spent on evaluation, monitoring and verification (State and Local Energy Efficiency Action Network, 2012). In European countries with MBIs the evaluation budget is significantly smaller. There are no EU-wide estimates but we can draw on examples where data on the budget allocated to evaluation has been made public. For example, the obligation operating in the United Kingdom from 2008 to 2012 was evaluated with a budget of around USD 630 000 compared to programme costs of around USD 4.5 billion. This equates to just 0.02% of the programme costs (Ipsos MORI et al., 2014). However, some of the costs are borne by the obligated parties. In the United Kingdom, this cost is estimated to be around 1%. This is based on the requirement that approximately 5% of all measures have to be audited at a cost of approximately 10% of the measure cost. This equates to 0.5% of the total programme cost. In addition, there is a cost to the obligated parties of employing a compliance team of up to 0.5% of programme costs.

The inconsistent approach to measuring energy savings and monitoring and verification leads to considerable uncertainties as to whether the benefits of energy efficiency policies will materialize to the extent anticipated by policy-makers.

There are detailed global standards for monitoring and verification such as the International Performance Measurement and Verification Protocol (IPMVP) (EVO, 2014) that address some of those issues, but those standards are mainly being used for larger projects rather than in the residential sector where many of the savings are currently achieved and will need to be achieved going forward.

In California in the United States there is a common approach to evaluation, monitoring and verification (e.g. TecMarket Works Framework Team, 2004) that covers a broader range of energy efficiency interventions. In Europe, such frameworks do not exist yet. Recent analysis by Schlomann et al. (2015) illustrates that this is largely a result of the lack of binding rules for monitoring and verification at the EU level that provide sufficient detail and clarity to Member States. It appears sensible to a) develop guidelines for sound evaluations, monitoring and verification covering a broader range of energy efficiency measures and b) allocating a higher share of programme cost to evaluation, monitoring and verification. Future research should investigate the potential for increasing the reliability of the estimates of the impacts of energy efficiency programmes and harmonising methodologies.

5 Future prospects for MBIs

Future investment is difficult to predict because it depends heavily on the policies in place and the calibration of the different obligations and auctions. However, it is likely that the investment levels triggered through MBIs will increase further over the next 5-10 years.

Expenditure by utilities driven by obligations in the United States has been projected to rise to USD 15.6 billion by 2025, an increase by a factor of more than 2.5 compared to 2015 (Barbose et al. 2013). A key driver is States that have only recently adopted obligation programmes and are likely to expand the energy savings targets over time, now that the regulatory framework has been established (as other US States have done in the past). Also, the development of statutory or regulatory requirements that utilities acquire “all cost-effective” energy efficiency are likely to drive an increase in spending. Such requirements require utilities and programme administrators “to define and invest in the highest level of efficiency determined to be cost-effective” (Gilleo 2014) and obligations and auctions seem to match this definition perfectly.

As discussed previously, the Energy Efficiency Directive means that both EU Member States and members of the Energy Community are likely to introduce new MBIs (mainly obligations but also auctioning mechanisms). Assuming similar levels of programme expenditure to existing obligations, close to USD 100 million will be added by 2020 (Rosenow et al. 2016b). The Clean Energy for All Europeans package, the proposed energy and climate policy framework for post-2020 published in November 2016 suggested that the targets of the Directive (Article 7) remain at similar levels post-2020 (European Commission (2016) and which would have meant that investment levels would have needed to be maintained in order to achieve those targets. However, the final negotiated targets for 2030 have been tightened beyond the status quo and additional energy savings will have to be achieved by Member States after 2020. This means that the level of investment may have to increase beyond current levels. The Directive's policy framework provides certainty in the medium term that energy efficiency spending will remain stable or increase further.

Utility spending on energy efficiency in China could potentially increase in the coming years. In the future, grid companies may be able to access new funding sources for demand side management and energy efficiency, particularly if such expenses are generally approved as allowed costs in setting retail prices for transmission and distribution. Depending on implementation details, the kind of pricing reform implemented in the pricing pilots may open up greater opportunities for grid companies to support energy efficiency and demand side management by breaking the regulatory link between electricity sales and grid company revenues (Central Committee of the Communist Party and State Council of China 2015).

6 Conclusion and Policy Implications

MBIs for energy efficiency are becoming increasingly popular and our analysis has identified 52 such schemes across the world, four times more than 10 years ago. Whilst most of the MBIs can be found in the US and in Europe, they are now operational on all continents. We estimate that globally around $26 billion of investment in energy efficiency is delivered by MBIs - this equates to more than 10% of the $221 billion per annum of global investment in energy efficiency (IEA 2016).

The evidence base on the costs and energy savings of MBIs is still emerging and the quality of the data varies significantly with the most robust data being available for schemes in the US. A preliminary assessment of the costs per unit of saved energy suggests total costs of around $0.026/

kWh lifetime savings (weighted average based on reported savings). There are considerable uncertainties associated with this estimate resulting from the different approaches used across the world when calculating energy savings and costs of obligations and auctions. However, the evidence that exists suggests that obligations and auctions deliver savings at a cost below the costs of supplied energy.

Our analysis also revealed that the available evidence and the quality of that evidence on MBIs is not consistent across the world. The US programmes have been subjected to extensive evaluations in the past and considerable resources have been dedicated to developing evaluation protocols and carrying out detailed evaluations. This is not the case in many other programmes. For example, in the EU previous work has identified poor evaluation practices as a major issue (Rosenow et al. 2016). It is therefore important that EU and other countries invest more in evaluating the schemes providing more robust data which also includes quantifications of free-ridership, the rebound effect, and the performance gap since all of those factors may be substantial. This is needed in order to be able to make better comparisons between countries in the future.

Future research should also analyse in more depth the differences in costs and cost-effectiveness of auctions and obligation schemes. Whilst in theory they should be similar there may be differences due to the different programme architecture and delivery approach of energy efficiency measures.

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Appendix

Table 2: Data used for the United States

Type of MBI	State	Year spending and energy savings data obtained for	Costs per year ($million)	Cost-effectiveness ($/kWh lifetime, 4-year average 2009-2012)	annual incremental energy savings (GWh / year)	Incremental energy savings compared to Total Fuel Consumption according to EIA (2016)	Sources
EEO	Arizona	2015	117	0.016	1,084	0.3%	Berg et al. 2016; Molina 2014
EEO	Arkansas	2015	413	n/a	423	0.1%	Berg et al. 2016;
EEO	California	2015	1,393	0.038	6,485	0.3%	Berg et al. 2016; Molina 2014
EEO	Colorado	2015	125	0.023	682	0.2%	ibid
EEO	Connecticut	2015	174	0.036	603	0.3%	ibid
EEO	Hawaii	2015	113	0.031	144	0.2%	ibid
EEO	Illinois	2015	341	0.011	2,591	0.1%	ibid
EEO	Iowa	2015	114	0.016	774	0.2%	ibid
EEO	Maine	2015	58	0.020	188	0.1%	ibid
EEO	Maryland	2015	462	0.019	621	0.2%	ibid
EEO	Massachusetts	2015	633	0.038	2,242	0.5%	ibid
EEO	Michigan	2015	239	0.012	2,520	0.3%	ibid
EEO	Minnesota	2015	156	0.016	1,598	0.3%	ibid
EEO	Nevada	2015	49	0.016	257	0.1%	ibid
EEO	New Mexico	2015	230	0.022	129	0.1%	ibid
EEO	New York	2015	378	0.012	2,641	0.1%	ibid
EEO	North Carolina	2015	136	0.014	828	0.1%	ibid

EEO	Oregon	2015	156	0.023	704	0.3%	ibid
EEO	Pennsylvania	2015	237	0.017	904	0.1%	ibid
EEO	Rhode Island	2015	86	0.034	346	0.6%	ibid
EEO	Texas	2015	184	0.026	699	0.0%	ibid
EEO	Vermont	2015	76	0.033	137	0.3%	ibid
EEO	Washington	2015	277	0.025	1,275	0.2%	ibid
EEO	Wisconsin	2015	80	0.009	1,380	0.2%	ibid
Capacity market auction	PJM (all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, and the District of Columbia.)	2015	55	n/a	n/a	n/a	PJM 2016
Capacity market auction	ISO New England (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont)	2015	247	n/a	n/a	n/a	ISO-NE 2015

Table 3: Data used for Europe

Type of MBI	**Country**	**Year spending and energy savings data obtained for**	**Year cost-effectiveness data obtained for**	**Costs per year ($million)**	**Cost-effectiveness ($/kWh lifetime)**	**annual incremental energy savings (GWh / year)**	**incremental energy savings compared to Total Fuel Consumption according to Eurostat (2018)**	**Sources**
EEO	Austria	2015	2015	106	0.006	1,578	0.5%	Rosenow and Bayer 2017
EEO	Bulgaria	2015	2015	283	n/a	807	0.8%	Kulevska 2017 and Ministry of Economy and Energy 2014
EEO	Denmark	2015	2015	207	0.006	3,384	2.2%	Rosenow and Bayer 2017
EEO	France	2015	2011-2013	437	0.005	12,210	0.7%	Rosenow and Bayer 2017
EEO	Ireland	2015	2015	48	0.006	449	0.4%	Commission for Regulation of Utilities 2017 and Durkan 2018

EEO	Italy	2015	2014	784	0.008	5,815	0.4%	Rosenow and Bayer 2017
EEO	Luxembourg	2015	n/a	28	n/a	214	0.5%	based on average cost per kWh of annual savings in other EU countries and Ministère de l'Économie 2014
EEO	Malta	2015	n/a	1	n/a	4	0.1%	based on average cost per kWh of annual savings in other EU countries and Ministry for Energy and Health (2014)
EEO	Poland	2015	n/a	808	n/a	6,155	0.9%	based on average cost per kWh of annual savings in other EU countries and Ministry of Economy 2014
EEO	Slovenia	2015	n/a	13	n/a	131	0.2%	based on Vendramin, 2016 and Ministry of Infrastructure 2015
EEO	Spain	2015	n/a	346	n/a	2,640	0.3%	based on average cost per kWh of annual savings in other EU countries and Ministry of Industry, Energy and Tourism 2014
EEO	UK	2015	2015	1,035	0.04	922	0.1%	DECC 2016a and 2016b
Energy efficiency auction	Portugal	2014	2014	13	0.010	117	0.5%	Sousa et al. 2015
Energy efficiency auction	Switzerland	2014	2014	23	0.035	50	0.8%	BfE 2014

Energy efficiency auction	Germany	2015	n/a	111	n/a	n/a	2.2%	BMWi 2016
Energy efficiency auction	UK	2015	n/a	6	n/a	n/a	0.7%	DECC 2015

Table 4: Data used for Australia

Type of MBI	Region	Year spending and energy savings data obtained for	Year cost-effectiveness data obtained for	Costs per year ($million)	Cost-effectiveness ($/kWh lifetime)	annual incremental energy savings (GWh / year)	incremental energy savings compared to Total Fuel Consumption according to Office of the Chief Economist (2016)	Sources
EEO	Australian Capital Territory (ACT)	2015		8.9	0.036	19	included in NSW	Wild-River 2016
EEO	New South Wales	2015		52	0.017	237	0.1%	New South Wales Office of Environment and Heritage 2016
EEO	South Australia	n/a		11*	n/a	24	0.03%	Essential Services Commission of Victoria. 2016
EEO	Victoria	n/a		71**	n/a	324	0.1%	Brazzale 2016

* based on ACT cost per kWh lifetime

** based on New South Wales cost per kWh annual incremental

Table 5: Data used for rest of the world

Type of MBI	Country/ Region	Year spending and energy savings data obtained for	Year cost-effectiveness data obtained for	Costs per year ($million)	Cost-effectiveness ($/kWh lifetime)	annual incremental energy savings (GWh / year) according to IEA (2018)	Sources
EEO	Ontario (Canada)	2015	2011-2014	364	0.029	1,231	IESO 2015, 2016; Statistics Canada 2018

EEO	Brasil	2015	2015	191	0.031	620	ANEEL 2016b
EEO	Uruguay	2015	2015	2	0.002	437	Ministerio de Industria, Energía y Minería 2016, 2017
EEO	China	2015	2015	448	0.003	14578	State Grid 2016 and China Southern Power Grid Company 2015
EEO	South Korea	2015	n/a	128	n/a	331	IEA 2017
EEO	South Africa	2015	2015	44	0.007	816	ESKOM 2015