Addendum to:-
IRELAND
Long Term Renovation Strategy
2017 - 2020

Extracts from:-

Unlocking the Energy Efficiency Opportunity

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With thanks to

The Research Perspective

NOTE:

This is an extract from 'Unlocking the Energy Efficiency Opportunity (Main Report) June 2015' to provide an overview of the cost effective analysis for renovation options.

All references to the 'Main Report' are to 'Unlocking the Energy Efficiency Opportunity (Main Report) June 2015'. This Main Report can be found on the Sustainable Authority of Ireland (SEAI) website;

https://www.seai.ie/resources/publications/Unlocking-the-Energy-Efficiency-Opportunity-Main-Report.pdf

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1 Energy savings potential by sector

1.1 Energy efficiency cost curves

In this section, we present the energy efficiency cost curves derived for each of the sectors modelled. For details on the methodology behind the construction of the cost curves, the reader is referred to the box, 'Methodology behind energy efficiency cost curves.'

Cost curves are presented for individual energy efficiency measures and for 'packages' of measures (described below). The cost curves will be used to highlight measures offering the most significant opportunity for energy savings, and to indicate whether the savings are economic without intervention, or whether intervention is required to render them economic (for the definition of 'economic', see the box, 'Methodology behind energy efficiency cost curves'). As explained below, we will also highlight the cases where promoting the uptake of packages of measures could be a useful mechanism by which to increase, in effect, the economic energy saving potential.

For all cost curves shown here, it should be noted that the actual uptake of measures or packages by 2020 will be lower due to the factors such as decision-making frequency, awareness and engagement, budget limits and willingness to pay. These factors are explained and accounted for in Section 3 of the Main Report where the link is made between the potential for energy savings in the context of Government energy efficiency policy.

Methodology behind energy efficiency cost curves

Energy savings potential shown accounts for the 'suitability' of measures

- *The cost curves present all measures modelled for each sector.*
- *The horizontal axis shows the full technical savings potential in 2020 in units of TWh primary energy, and the individual contribution of each measure.*
- *The technical savings potential of measures was derived using detailed bottom-up stock modelling with archetypes, as described in the accompanying Technical Appendix (Methodology and technical assumptions).*
- *For all measures, the savings potential shown incorporates the 'suitability' of the measure across the stock. For example, the savings potential shown for 'cavity wall insulation' accounts for the fact that the majority of cavity walls in Ireland have already been filled.*
- *For details on the methodology in the Transport sector, please refer to the box 'Methodology behind energy efficiency cost curves for the transport sector'.*

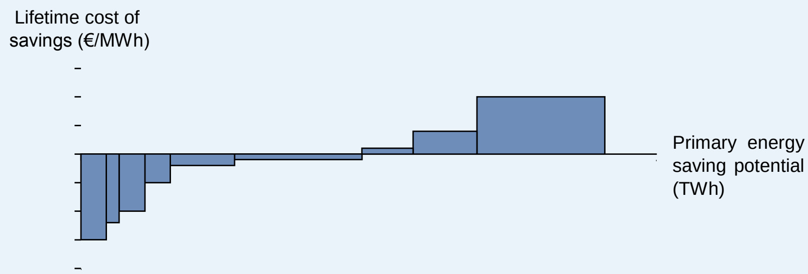

Figure 1-1: Illustrative energy efficiency cost curve

We present cost curves from a 'private' perspective

- *The lifetime cost of the savings attributed to each individual measure is shown on the vertical axis, in units of €/MWh primary energy.*
- *The lifetime cost of measures was calculated against the appropriate counterfactual, including technical capital and operating costs, ongoing fuel and carbon costs, and **'hidden' costs** (which are included to give a fuller representation of costs associated with deploying each individual measure).*
- *In this section, we present cost curves calculated using a 10% discount rate, reflecting a 'private' perspective. To offer a full Exchequer perspective or societal perspective, wider economic issues such as tax transfers from the purchaser of the fuel to the Government and policy intervention costs should be considered. In Section 4 of the Main Report, we consider the full 'Exchequer perspective', and use a public sector discount rate of 5%.*
- *A negative lifetime cost corresponds to economic savings over the lifetime of the measure; measures with a negative lifetime cost are here termed 'economic' or 'cost-effective' (used interchangeably). Measures with positive lifetime cost are termed 'uneconomic'.*

Uneconomic measures may present a significant opportunity for additional savings

- *It is important to note that uneconomic measures should not be deemed unachievable and therefore unimportant. Measures that are uneconomic using a 10% discount rate are likely to be difficult to achieve without additional intervention but could be unlocked with well-targeted support and/or financial incentives.*
- *It should also be noted that implementation of 'packages' (i.e. installing uneconomic measures at the same time as the economic measures) could make the overall investment economic.*

1.2 Energy efficiency measures

We have modelled both ‘technical’ measures and ‘behavioural’ measures. Technical measures include building insulation retrofits (wall and roof insulation, high efficiency glazing, draught proofing), heating/cooling system replacements (more efficient boiler, heating controls, more efficient air conditioning, heat pump), more efficient lighting and more efficient office appliances and refrigeration. Behavioural measures include turning off unnecessary lighting (i.e. turning off lights for extra hours), reducing the target room temperature by 1 degree Celsius and reducing unnecessary hot water use. The two types of measure are distinguished on each cost curve.

Note on interaction of measures shown in energy efficiency cost curves

Energy efficiency measures typically ‘interact’ with each other, and so the order in which measures are applied influences the savings achieved by each individual measure. For example, consider the purchase of a more efficient boiler, which reduces a building’s energy consumption by 10%, from 10 MWh per year to 9 MWh per year. The savings potential of the boiler is 1 MWh per year If insulation was installed in the same building, reducing its energy consumption to 8 MWh per year, the boiler would only save 0.8 MWh per year.

There are similar interactions between many other measures in all sectors. It is important that this interaction between measures is captured in the cost curves in order that the savings potential is not overestimated. In the cost curves shown, all interactions are accounted for. It can also be seen that the order in which the measures are applied affects the savings potential attributed to each individual measure. It should be noted that, in the cost curves shown in this section, all technical measures are applied before all behavioural measures. Within each category, measures are applied in order of cost-effectiveness. Applying measures in a different order would yield different results on a per measure basis.

1.3 Energy efficiency packages

In many situations, such as when a building is undergoing a major renovation or when an industrial facility is undergoing a shut-down for maintenance, it may be the case that a ‘package’ of several energy efficiency measures is implemented at the same time. In order to reflect this, we show cost curves in terms of packages as well as in terms of individual measures. An important finding described in this report, is that promoting the implementation of packages of measures could be a useful mechanism by which to increase, in effect, the economic energy saving potential.

For the commercial, public and residential buildings sectors, and for the industry sector, we have constructed three packages of measures, namely ‘Shallow’, ‘Medium’ and ‘Deep'. To best reflect reality, packages are defined to group measures on the basis of associated ‘decision frequency’ and upfront cost. The decision frequency, which is explained in greater detail in Section 3.1 of the Main Report, places a limit on the rate at which energy efficiency measures can be taken up. In some cases, such as for heating, lighting or motor systems, this is related to the lifetime of the equipment in question. In other cases, such as for insulation measures, this reflects the frequency with which consumers undertake building renovation or maintenance with a comparable level of disruption. In simple terms, the Shallow package contains measures which are relatively easy to install and have a low upfront cost, and the Deep package contains all measures including the ones which are more difficult to implement and/or have a high upfront cost.

The energy efficiency measures contained within the packages will be described for each sector in turn. We note that behavioural measures are not included in the packages and we do not construct packages for the transport and public utilities sectors.

1.4 Energy efficiency cost curve: Commercial buildings

Figure 1-2 shows the energy efficiency cost curve for the commercial buildings sector. The modelling suggests that, for the technologies considered, total primary energy savings potential in the sector is 6.0 TWh, corresponding to around 35 % of the primary energy demand in this sector in 2013, which is estimated to be 17 TWh.[4] The largest savings potential among the technical measures in the commercial buildings sector relates to the installation of energy efficient lighting with lighting controls (1.1 TWh) and heat pumps (0.8 TWh), retrofit with roof insulation (0.7 TWh) and energy efficient glazing (0.7 TWh), and installation of more efficient air-conditioning (0.5 TWh). Of the behavioural measures, reducing the room temperature by 1 degree Celsius has the largest potential of 0.5 TWh.

Behavioural measures are the most cost-effective in this sector.[5] However, all of the savings potential in the commercial buildings sector is cost-effective – that is, all savings carry a negative lifetime cost. The main reason for this is that there is a high fraction of electrical heating in the commercial sector – around two thirds of commercial buildings have an electrical main (primary) heating system. Since electricity is relatively expensive – typically €0.21/kWh for non-domestic consumers[6] – saving energy results in a large economic benefit.

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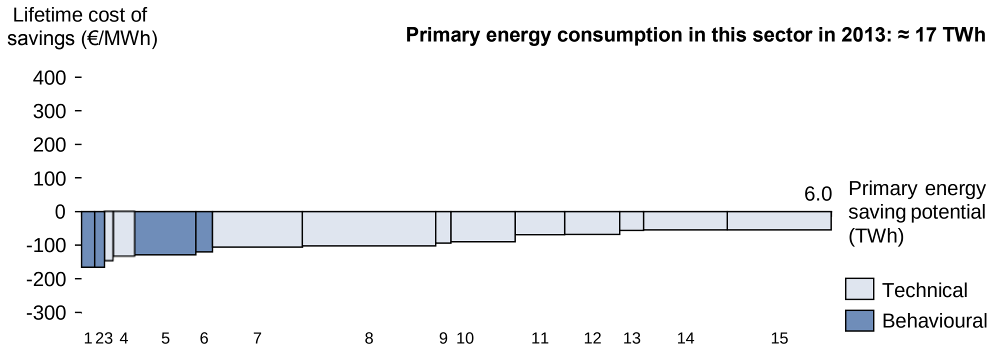
[4] Element Energy and The Research Perspective, 2014, *'Extensive survey of the commercial buildings stock in the Republic of Ireland.'*

[5] We note that in the cost curves shown in this section, we have assumed no cost for the implementation of behavioural measures. In the Exchequer analysis in Section 5, of the Main Report http://www.element-energy.co.uk/wordpress/wp-content/uploads/2015/06/Unlocking-the-Energy-Efficiency-Opportunity-Main-Report-.pdf ,we include a cost for the delivery of behavioural measures.

[6] See the latest commercial fuel cost comparison here: http://www.seai.ie/Publications/Statistics_Publications/Fuel_Cost_Comparison/



Measure	PE saving (TWh)	Measure	PE saving (TWh)
Total technical measures	**5.15**	14. Energy efficient glazing	0.67
3. Energy efficient appliances - Refrigeration	0.07	15. Heat pump	0.82
4. Draught proofing	0.17		
7. Roof insulation	0.71	**Total behavioural measures**	**0.80**
8. Energy efficient lighting with lighting control	1.11	1. Turn off lights for extra hours	0.10
9. Cavity wall insulation	0.12	2. Enable standby features on all PCs and monitors	0.08
10. More efficient air conditioning	0.51	5. Reducing room temperature	0.49
11. More efficient boiler with heating control	0.39	6. Reducing hot water use	0.13
12. Solid wall insulation	0.44		
13. Energy efficient appliances - Office equipment	0.19	**Total**	**5.95**

Figure 1-2: Energy efficiency cost curve for the Commercial sector

The measures contained in the Shallow, Medium and Deep packages for the commercial and public sectors are shown in Table 1-1. Figure 1-3 shows the energy efficiency cost curve for packages for the commercial buildings sector (we note that behavioural measures are not included in the packages). It can be seen that all packages in the commercial buildings sector are cost-effective.

Table 1-1: Measures contained in packages for the commercial and public buildings sectors

Sector	Shallow	Medium	Deep
Commercial and Public	• Cavity wall insulation • Draught proofing • Energy efficient lighting • Heating controls	• **All Shallow measures** • Roof insulation • Energy efficient office equipment • Energy efficient refrigeration • More efficient boiler[7]	• **All Medium measures** • Solid wall insulation • More efficient air conditioning • Energy efficient glazing • Heat pump • Lighting controls

[7] Installation of more efficient boilers is included in the Medium package in the Commercial and Public sectors. Only the archetypes with old boilers (e.g. older than 5 years) were assumed to replace boilers.

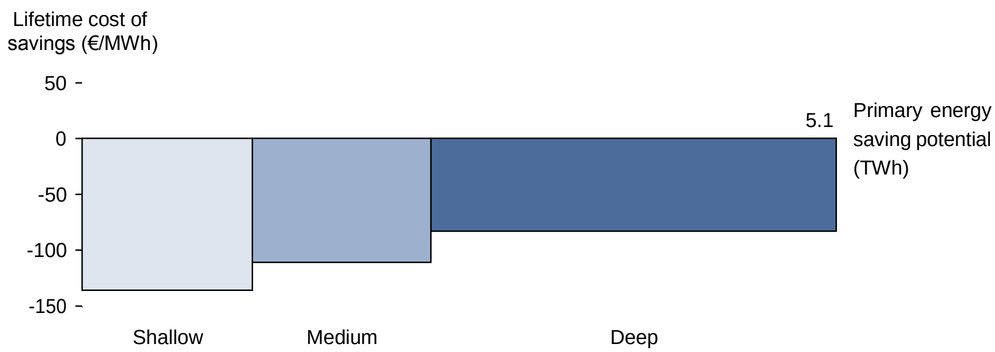
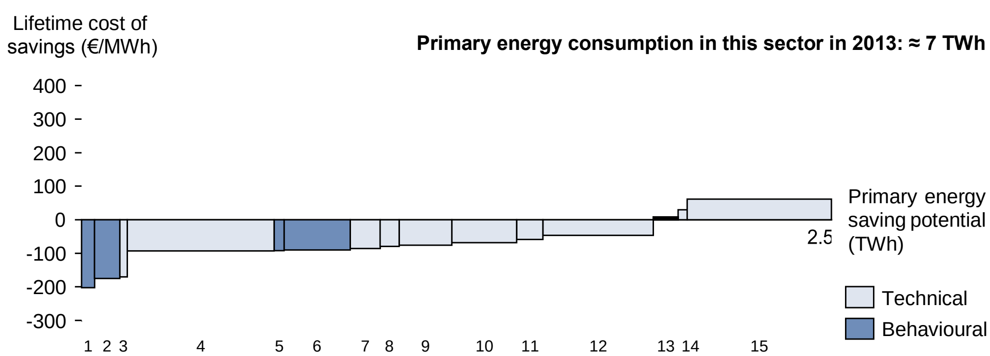


Figure 1-3: Energy efficiency cost curve for the Commercial sector (packages)

1.5 Energy efficiency cost curve: Public buildings

Figure 1-4 shows the energy efficiency cost curve for the public buildings sector. The total primary energy savings potential in the sector is 2.5 TWh, corresponding to around 35 % of the total energy demand in the public buildings sector in 2013 (ca. 7 TWh). The largest technical savings potential in the public buildings sector is available through the installation of energy efficient lighting with lighting controls (0.5 TWh), retrofit with roof insulation (0.2 TWh) and energy efficient glazing (0.5 TWh) and the installation of more efficient boilers (0.4 TWh) and more efficient office appliances (0.2 TWh). Reducing the room temperature by 1 degree Celsius is, as for commercial buildings, the behavioural measure with the largest savings potential (0.2 TWh).



Measure	PE saving (TWh)	Measure	PE saving (TWh)
Total technical measures	**2.09**	14. Heat pump	0.03
3. Energy efficient appliances - Refrigeration	0.03	15. Energy efficient glazing	0.47
4. Energy efficient lighting with lighting control	0.48		
7. Draught proofing	0.10	**Total behavioural measures**	**0.38**
8. Cavity wall insulation	0.06	1. Turn off lights for extra hours	0.04
9. Energy efficient office equipment	0.17	2. Enable standby features on all PCs and monitors	0.08
10. Roof insulation	0.21	5. Reducing hot water use	0.03
11. More efficient air conditioning	0.09	6. Reducing room temperature	0.22
12. More efficient boiler with heating control	0.36		
13. Solid wall insulation	0.08	**Total**	**2.47**

Figure 1-4: Energy efficiency cost curve for the Public buildings sector

The greater prominence of more efficient boiler replacement, as compared with the commercial buildings sector, is due to the higher fraction of oil and gas heating in the public sector. More efficient office appliances are also relatively more important in public buildings, due to the more widespread use of IT equipment in public buildings than in many commercial buildings, such as retail and hospitality buildings.

The majority of the energy saving potential in public buildings is cost-effective. However, it can be seen that savings related to space heating (such as insulation and energy efficient glazing) are rather less cost-effective than in the commercial sector, due to the greater prevalence of oil and gas heating in the public sector. Oil and gas are the main heating fuel for 50 % and 23 % of public buildings respectively, compared with 26 % and 8 % respectively for commercial buildings. Since oil and gas heating are less expensive than direct electrical heating, the economic benefit of energy saving is smaller in the public sector than in the commercial sector.

Figure 1-5 below shows the energy efficiency cost curve for packages for the public buildings sector.[8] It can be seen that all packages in the public buildings sector are cost-effective. It is notable that the Deep package is cost-effective even though it contains a number of measures, including energy efficient glazing, heat pumps and solid wall insulation, which are not cost-effective when installed as individual measures. This demonstrates the utility of promoting the uptake of energy efficiency packages rather than individual measures: if uneconomic measures are installed at the same time as the economic measures, the overall investment may be economic. In some cases – for some consumers – this may increase the uptake of the uneconomic, 'harder-to-get' measures without decreasing the uptake of the economic 'low hanging fruit'.

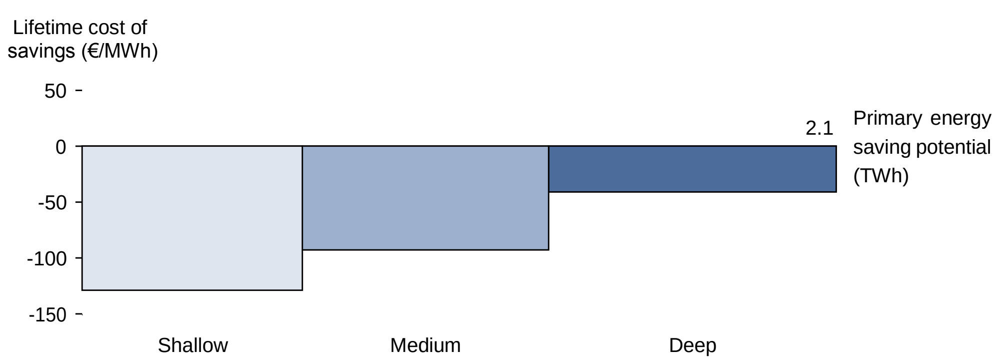


Figure 1-5: Energy efficiency cost curve for the Public buildings sector (packages)

1.6 Energy efficiency cost curve: Public utilities

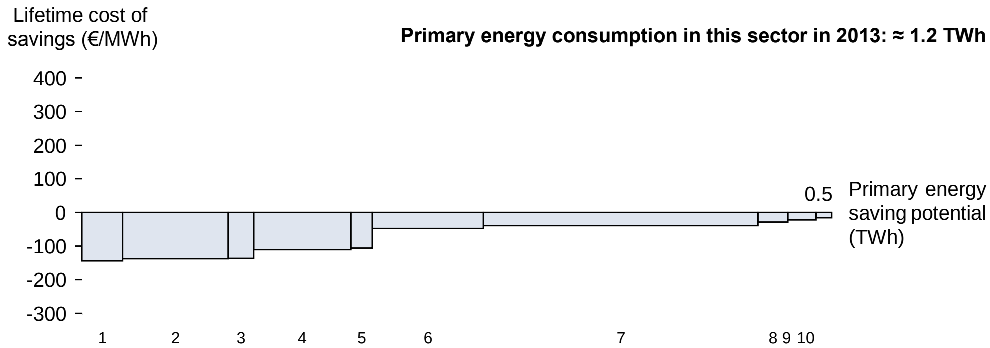
Figure 1-6 shows the energy efficiency cost curve for the public utilities sector (i.e. street lighting and water services). The total primary energy savings potential in the sector is around 0.5 TWh, corresponding to around 40 % of the 1.2 TWh[9] total primary energy demand in the sector in 2013.

We have considered energy savings in public lighting, water supply and wastewater treatment. In public lighting, replacement of lanterns with LEDs and optimised control by a central management system could lead to savings of 0.2 TWh. The measures with the largest potential in the water and wastewater sub-sector include elimination of excess air and retrofit of fine bubble diffused air systems in wastewater treatments plants (0.1 TWh each) and higher efficiency pump retrofit at water supply stations (0.1 TWh). It should be noted that water conservation could have an impact beyond these estimates.

All energy saving measures considered for public utilities are cost-effective.

[8] The measures contained in the Shallow, Medium and Deep packages for the public sectors are shown in Table 1-1 in the previous section. We note that behavioural measures are not included in the packages.

[9] SEAI, 2012, 'Energy Efficiency & Public Lighting Overview' and 'Energy Efficiency & Water Services', overview reports.



Measure	PE saving (TWh)	Measure	PE saving (TWh)
1. Elimination of parasitic loads in pump house (e.g. heaters)	0.03	7. Replace street lighting by LEDs (including central management system e.g. dimming and trimming)	0.20
2. Elimination of excess air to a level appropriate for plant requirements	0.08	8. Dissolved oxygen control of aeration systems	0.02
3. Optimising operation to best efficiency point through duty & assist control	0.02	9. Retrofit of blowers with VSD	0.02
4. Higher efficiency pump retrofit	0.07	10. Retrofit of high efficiency motors in aeration systems	0.01
5. Install Variable Speed Drive (VSD) instead of throttling	0.02	**Total**	**0.53**
6. Retrofit of fine bubble diffused air systems	0.08		

Figure 1-6: Energy efficiency cost curve for the Public utilities sector

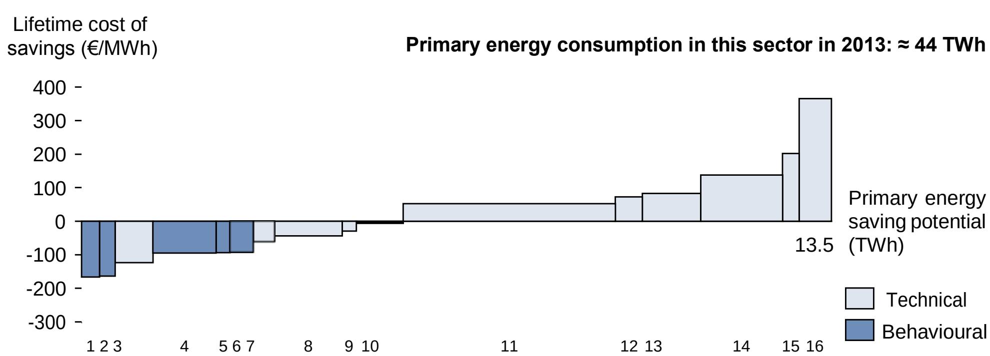
1.7 Energy efficiency cost curve: Residential buildings

Figure 1-7 shows the energy efficiency cost curve for the residential buildings sector. The total primary energy savings potential (for the technologies considered) in the sector is 13.5 TWh, corresponding to 30 % of the 44 TWh total demand in the sector in 2013.

Technical measures include building insulation retrofits (wall, roof and floor insulation, energy efficient glazing, draught proofing), heating/cooling system replacements (more efficient boilers, heating controls, heat pumps, solar water heating), energy efficient lighting and more efficient household appliances and electronics. Behavioural measures include reducing the target temperature by 1 degree Celsius, turning off heating in unused rooms, turning off lights when not in use, installing a low-flow shower head and air-drying rather than tumble-drying clothes.

The largest savings potential among the technical measures in the residential buildings sector relates to the installation of more efficient boilers with heating controls (3.8 TWh) and retrofit with solid wall insulation (1.5 TWh), roof insulation (1.2 TWh) and floor insulation (1.0 TWh). Reducing the target temperature by 1 degree Celsius has the potential to save 1.1 TWh of primary energy.

According to this study's methodology, approximately half of the technical savings potential in the residential buildings sector is cost effective using a 10 % discount rate. The lower proportion of cost-effective savings compared with the commercial sector is primarily due to 'comfort taking', which is explained in the box 'Comparison of internal and external solid wall insulation' and the higher prevalence of gas and oil heating in residential buildings, and hence the lower value of energy savings. Key opportunities for large and/or cost-effective savings in the residential sector include the installation of roof insulation and cavity wall insulation, more efficient boilers with heating controls and appliances with higher energy efficiency performance.



Measure	PE saving (TWh)	Measure	PE saving (TWh)
Total technical measures	**11.05**	15. Heat pump	0.30
3. Energy efficient appliances -"Cold" and "Electrical cooking"	0.67	16. Energy efficient glazing	0.57
7. Draught proofing	0.38		
8. Roof insulation	1.21	**Total behavioural measures**	**2.41**
9. Energy efficient lighting	0.26	1. Air dry instead of tumble dry	0.32
10. Cavity wall insulation	0.84	2. Turn off lights when not in use	0.29
11. More efficient boiler with heating control	3.81	4. Reduce room temperature by 1C	1.14
12. Energy efficient appliances - "Wet" and "Consumer electronics"	0.48	5. Turn off heating in unused rooms	0.25
13. Floor insulation	1.05	6. Use efficient shower head	0.42
14. Solid wall insulation	1.47	**Total**	**13.46**

Figure 1-7: Energy efficiency cost curve for the Residential buildings sector

Comfort taking in the Residential sector

'Comfort taking' is an example of the 'rebound effect' in the Residential building sector. It has been shown that the energy savings expected from energy efficiency measures applied in a domestic context are not achieved in full, and that this is due, at least in part, to a change in behaviour of the building occupier. For example, after the installation of insulation measures, the occupier may become accustomed to greater comfort, resulting in them raising the thermostat or heating previously unheated rooms.

We have accounted for comfort taking in the results shown in the residential sector. We apply a fixed factor of 64% in the Residential sector, which corresponds to 36% of the savings being taken in comfort. This estimate is based on a study by Scheer et al., in which the ex-post measured savings achieved through SEAI's Home Energy Saving residential retrofit scheme were compared against ex-ante engineering-type estimates of the savings potential of the measures installed. The total technical potential before applying the effect of comfort taking is therefore 21 TWh, corresponding to nearly 50% savings versus the baseline.

It should be noted that economy-wide rebound effects might also arise from increased economic activity (spending) resulting from increased disposable income resulting from energy savings, which in turn leads to increased demand for energy to service the aggregate demand for goods and services. This could arise outside of Ireland's economy in the form of the embodied energy in imports. Economy-wide rebound effects are not within the scope of this study.

To some extent, rebound effects can be seen as part of the wider benefits of energy efficiency programmes, as set out in the recent report 'Capturing the Multiple Benefits of Energy Efficiency' from the IEA. Direct rebound effects in the form of comfort taking, while offsetting the energy savings, reflect an increase in the welfare of households which can now afford to heat their homes to the desired standards. Where previously under-heated homes are made warmer, physical health benefits also arise.

Performance Gap

Finally, we note that there is an increasing body of work dedicated to understanding the so-called 'performance gap', or the difference between the theoretical thermal performance of a building and the measured performance. We note that the performance gap is, in general, related to issues at all stages of the building life, including imperfect design, construction and handover as well as variations in post-occupancy use (to which the rebound effect typically refers).

The performance gap presents an additional reason to promote deep rather than shallow retrofits. As building thermal efficiency increases (i.e. depth of retrofit increases), energy use in absolute terms becomes less sensitive to variation in internal temperature, as has been shown in Love's 2012 paper 'Mapping the impact of changes in occupant heating behaviour'. In other words, as buildings become better insulated and more efficient, occupant behaviour matters less, and comfort taking is less of a concern. Any strategy aiming to achieve a fixed and low level of energy consumption should account for this observation.

Comparison of internal and external solid wall insulation

The cost curve in this section shows the savings potential of solid wall insulation. Solid walls may be insulated using internal or external insulation. Here, we describe some of the differences between the two categories of solid wall insulation.

Based on fabric costs (per unit area) published by AECOM [AECOM, 2013], the average installation cost of solid wall insulation for a typical terraced house, including materials and labour, is approximately €4,000 for internal wall insulation and €6,000 for external wall insulation. However, these figures exclude the additional or 'hidden' costs associated with installation. Hidden costs associated with internal wall insulation relate to the loss of internal floor area, the need to store room contents elsewhere during the work, to remove and re-install radiators, pipework and sockets, to re-cut carpets, to replace the kitchen fittings (where relevant) and to redecorate the affected rooms. For external wall insulation, possible hidden costs relate to the need to erect scaffolding, to remove and re-install drainpipes and cabling, to protect the garden, to extend the existing boiler flue, to adjust the door canopy and windows and, where relevant, to create a larger roof overhang [AEA/Ecofys for the CCC, 2008 and Ecofys, 2009].

In both cases, hidden costs can therefore be estimated to be in the range of €5,000-20,000, depending strongly on individual circumstances. For example, if major re-decoration work is already planned, internal insulation may be a more attractive option. Conversely, in a small dwelling where space is at a premium, the loss of internal floor area with internal insulation may be priced very highly.

There are also non-economic advantages and disadvantages to the two options. Internal wall insulation can be attempted one wall at a time, which may make the project more manageable. However, internal insulation is likely more disruptive for the occupier. In addition, internal insulation results in the loss of the thermal mass of the wall, meaning the internal temperature may fall more quickly than before when the heating is off. Since the temperature of the wall fabric will be lower after it has been internally insulated, it may also become prone to problems of damp unless expertly installed.

External insulation brings a number of non-economic advantages such as noise reduction and improved weather protection. It is less disruptive than internal insulation, and also preserves the thermal mass of the wall. Further, as may be relevant for local authorities or housing associations, all dwellings in a terrace or block may be insulated simultaneously. The disadvantages of solid wall insulation are largely economic.

Figure 1-8 shows the energy efficiency cost curve for packages for the residential buildings sector (we note that behavioural measures are not included in the packages). It can be seen that both the Shallow and Medium packages are cost-effective (shown here, as for the other sectors, using the 10 % discount rate) although the Medium package includes a number of measures, which are not cost-effective when installed individually. Cost-effective/economic energy savings potential for technical measures therefore increased from 3.4 TWh to 5.3 TWh.

On the other hand, the Deep package is not cost-effective at a 10 % discount rate. As explained previously, uneconomic measures/packages should not be deemed unachievable as these measures could be unlocked with Government interventions, which will be examined in more detail in Section 3.2.4 of the Main Report. The box, 'Making deep retrofit options cost-effective', also explains a number of ways to make the Deep package cost-effective.

Table 1-2: Measures contained in packages for the Residential buildings sector

Sector	Shallow	Medium	Deep
Residential	• Cavity wall insulation • Roof insulation • Draught proofing • Energy efficient lighting	• **All Shallow measures** • Energy efficient appliances (Wet and Consumer electronics) • Heating controls	• **All Medium measures** • Solid wall insulation • Energy efficient glazing • Energy efficient appliances (Cold and Electrical cooking) • More efficient boiler[10] • Heat pump • Floor insulation

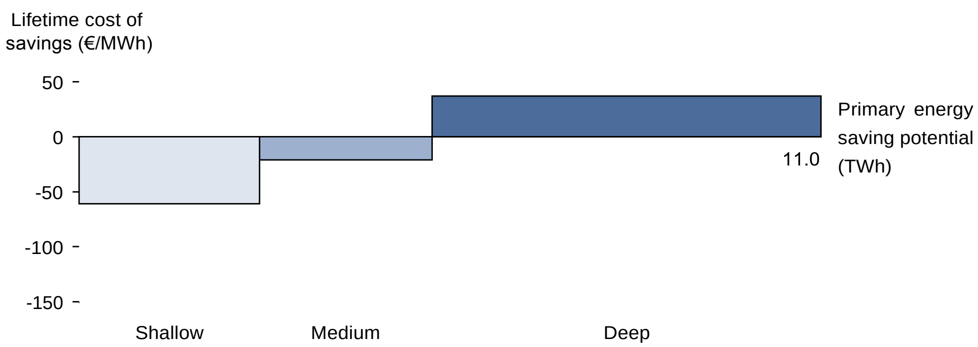


Figure 1-8: Energy efficiency cost curve for the Residential sector (packages)

Making deep retrofit options cost-effective

The Deep package in the residential sector includes several energy efficiency measures with significant savings potential such as solid wall insulation, more efficient boiler and energy efficient glazing. However, the uptake of the Deep package, which is estimated to be 'uneconomic' using a 10% discount rate, is likely to be low without additional intervention. Uptake of energy efficiency in the residential sector will therefore require intervention, even more than in other sectors. We have identified a number of potential and existing interventions including regulation, Pay-As-You-Save (PAYS), information campaigns and direct financial support. The potential impact of these interventions will be explained in more detail in Section 3.2.4 of the Main Report.

The deep package in the residential sector also becomes cost-effective when a lower discount rate (i.e. 5%) is used. This suggests that investment in the Deep package using a commercial loan (i.e. with interest rates of 8%–10%) may not be cost-effective; however, the Deep package can be made cost-effective if low interest rate loans are available for the consumers in the residential sector such as PAYS with lower interest rates.

[10] Both heat pumps and boilers are included in the packages as it was assumed that heat pumps replace direct electric heating whereas energy efficient boilers replace old oil and gas boilers.

1.8 Energy efficiency cost curve: Transport

Figure 1-9 shows the energy efficiency cost curve for the transport sector. Further details on the transport cost curve calculations are given in the box, 'Methodology behind energy efficiency cost curves for the transport sector'. The total primary energy savings potential in the transport sector to 2020 is around 7.4 TWh, corresponding to around 17 % of the 43 TWh total demand in the sector in 2013.[11]

Technical measures include the use of more efficient internal combustion engine (ICE) vehicles, the uptake of alternative fuel vehicles (AFVs) – that is, hybrid and electric vehicles – and a shift in the weight class of heavy goods vehicles (HGVs). We note that in terms of the measures in Figure 1-9, the use of more efficient ICE vehicles corresponds to 'EU regulation' and 'VRT rebalancing'. 'EU regulation' refers to EU regulation 443/2009, the mandatory emissions standards imposed upon manufacturers of cars and light-duty vans. 'VRT rebalancing' refers to Ireland's 2008 shift to a Vehicle Registration Tax and Annual Motor Tax system based on carbon emissions rather than on engine size. Behavioural measures include 'eco-driving', a modal shift to public transport, cycling or walking and smaller vehicles.

Measures relating to private cars dominate the transport sector savings potential. The largest potential for savings relates to the use of more efficient combustion-engine cars resulting from EU regulation and VRT rebalancing (3.4 TWh) – measures already in place. Large savings potential is also available through modal shift (1.5 TWh) and a shift to smaller vehicles (0.6 TWh). Across all forms of road transport, eco-driving could save up to 0.8 TWh.

The cost-effectiveness of measures in the transport sector has also been considered (also see the box, 'Methodology behind energy efficiency cost curves for the transport sector' for notes on key assumptions made and data used). It is important to emphasise at this point that, although we find that many of the measures in the transport sector are cost- effective (from the private/consumer perspective), this does not mean that they are easy to achieve. As will be described in Section 3.2.5 of the Main Report, many of the measures shown here are deemed unlikely to be achieved by 2020; this includes modal shift, a shift to smaller vehicles and a weight class shift for HGVs.

[11] This figure is based on Energy Balance 2013 estimates, excluding rail, aviation and fuel tourism.

Methodology behind energy efficiency cost curves for the transport sector

Overall approach

- *The technical savings potential of measures was derived through a combination of bespoke analysis and detailed literature review. The detailed assumptions are given in the accompanying Technical Appendix (Methodology and technical assumptions).*
- *For the private car sub-sector, the analysis is based on a detailed stock model including 9 vehicle types.*
- *The lifetime cost of each measure was derived by considering the marginal costs and benefits relative to an appropriately-defined counterfactual.*
- *Operating costs of vehicles are discounted over the vehicle lifetime. For private cars, retirement is based on a scrappage curve from ESRI (Hennessy and Tol, The Economic and Social Review 42, 135, 2011); for HGVs, the lifetime is taken as 12 years; for LDVs, the lifetime is taken as 8 years; for public buses, the lifetime is taken as 12 years.*
- *Fuel prices forecasts were provided by SEAI; petrol prices vary from €0.046/MJ in 2013 to €0.049/MJ in 2030; diesel prices vary from €0.040/MJ in 2013 to €0.042/MJ in 2030.*
- *In the cost curves shown here, a discount rate of 10% is used, reflecting a 'private' consumer perspective.*

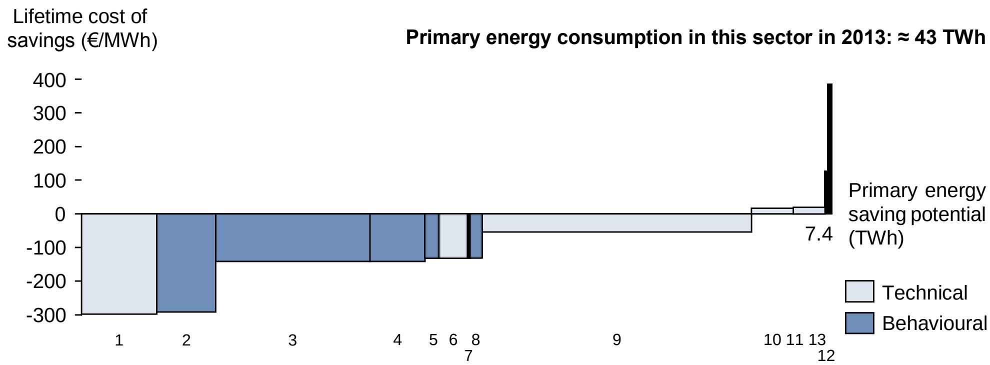
Notes for specific measures

- *Full details of the assumptions for each measure are given in the accompanying Technical Appendix (Methodology and technical assumptions).We also note here a number of important clarifications and key assumptions.*
- *'Modal shift' is treated as a voluntary and unincentivised behavioural measure; we do not include here, for example, the cost to the Exchequer of improved public transport infrastructure. Where this measure is applied, we model a decrease in annual mileage but no decrease in the number or type of vehicles purchased.*
- *'Shift to smaller vehicles' is also treated as a voluntary and unincentivised behavioural measure. This measure does not imply the reversion of a vehicle tax system based on engine size (as was the case before the current emission-based system was implemented).*
- *The cost premium for vehicles due to EU regulation on mandatory emissions standards (versus a pre-2008 efficiency improvement trend) was based on AEA's 2012 report 'A review of the efficiency and cost assumptions for road transport vehicles to 2050'.*
- *We note that the cost to the Exchequer of a national eco-driving scheme is not included in the cost curve, but is included in the later analysis of Exchequer perspective.*

The use of more efficient ICE cars resulting from the VRT rebalancing is found to be highly cost-effective. The dominant effect of the rebalancing was a shift from petrol to diesel cars, due to the higher efficiency of diesel vehicles.[12] In Ireland, diesel is also cheaper than

[12] Rogan et al., 'Impacts of an emission based private car taxation policy – First year ex-post analysis', *Transportation Research Part A,* 2011.

petrol on a per litre basis; this means that the measure has a large, negative associated cost. We note that the strong shift towards diesel may have an impact on the balance between diesel and petrol prices; an analysis of this is not included here.



Measure	PE saving (TWh)	Measure	PE saving (TWh)
Total technical measures	4.45	**Total behavioural measures**	**2.92**
1. Private cars - VRT re-balancing	0.74	2. Private cars - Shift to smaller vehicles	0.58
6. HGVs - Weight class shift	0.28	3. Private cars - Modal shift	1.52
9. Private cars - EU regulation	2.65	4. Private cars - Eco-driving	0.55
10. LDVs - EU regulation	0.41	5. HGVs - Eco-driving	0.13
11. HGVs - Increasing ICE efficiency	0.31	7. Public passenger - Eco-driving	0.03
12. Public passenger - increasing ICE efficiency	0.03	8. LDVs - Eco-driving	0.12
13. Private cars - AFV incentive	0.03	**Total**	**7.38**

Figure 1-9: Energy efficiency cost curve for the Transport sector

Other cost-effective measures include a shift to smaller vehicles (where both capital cost and running costs are reduced), modal shift (where it has been assumed that cars are used less, but still purchased) and eco-driving. We note that the promotional and training cost to the Exchequer of an eco-driving scheme is not included in the cost curves, which reflect the private perspective. The cost to the Exchequer of the eco-driving scheme is included in the analysis of the Exchequer perspective in Section 4 of the Main Report. We emphasise that the shift to smaller vehicles and modal shift behavioural measures have been treated as voluntary and un-incentivised; we do not include here, for example, the cost to the Exchequer of improved public transport infrastructure. The use of more efficient ICE cars resulting from EU regulation is cost-effective, albeit less so than the measures listed above. The cost premium on the more efficient vehicles meeting the EU regulation in 2020, amounting to approximately 7 – 10 %, is more than compensated for by the reduced running costs.

Less cost-effective measures in 2020 include the EU regulation for light-duty vehicles (LDVs), where the cost premium for efficient vehicles in 2020 is also around 10 % but the energy efficiency gain is smaller than for cars (and is not compensated for by the higher mileage of LDVs); and higher efficiency HGVs, where the efficiency increase carries a larger cost premium of up to 20 % (also not compensated for by the higher mileage of HGVs).

Primary energy savings due to the uptake of AFVs, which currently carry a high cost premium relative to ICE vehicles, are also less cost effective. However, we emphasise that there is considerable uncertainty around the cost and performance improvements of EVs to 2020, and hence the uptake shown here may be a significant underestimate. In the scenario shown in the cost curve, there are around 25,000 AFVs in the stock by 2020 (the majority being plug-in hybrids, with around 1,500 full battery electric vehicles). The reader is referred to the box, ‘Comfort taking in the Residential sector for further discussion of the scenarios considered and comparison with current targets. We also note that EVs bring additional and highly significant benefits to the energy system other than primary energy savings; they also reduce dependence on fossil fuels, are compatible with a zero carbon energy system and offer the potential for grid-balancing services.

Key opportunities in the transport sector, excluding those which have already been implemented (namely EU regulation and VRT rebalancing), include modal shift to public transport, walking and cycling; a shift to the purchase of smaller vehicles; and eco-driving.

Savings potential of electric vehicles to 2020

The Irish Government previously stated a target for 10% of the road vehicle fleet to be electric by 2020. This was recently revised down to 2.5% of the stock, which corresponds to ~50,000 vehicles. The uptake of AFVs was predicted using the ECCo consumer choice model developed by Element Energy for the Energy Technologies Institute, which is based on consumer preference data from a survey of 2,700 new car buyers. ECCo is described in more detail in the accompanying Technical Appendix (Methodology and technical assumptions).

Applying SEAI’s existing incentive for AFVs, ECCo predicts the uptake of around 25,000 AFVs in the stock by 2020. Due to the high cost premium of full battery electric vehicles (BEVs) within the model, the great majority of the 25,000 are predicted to be plug-in hybrids (PHEVs), with around 1,500 BEVs. However, there is considerable uncertainty around the cost trajectory of AFVs and therefore around the number of vehicles which will be deployed to 2020. As a result of falling prices and the availability of a wider range of electric options, there has recently been a significant upturn in the number of new BEVs registered in Ireland. Between January and August 2014, 215 new BEVs were registered, compared with 54 in the whole of 2013. With continuing reductions in price and changing public opinion, it may be expected that the uptake of BEVs will accelerate in the years to 2020.

We can estimate the additional savings potential which would be achieved if the revised Government target is met – that is, if there are 50,000 BEVs on the road in 2020. For the purposes of this illustration, we consider the potential savings if (i) the predicted relative share of PHEVs and BEVs remains the same as in the case shown in the cost curve and if (ii) these vehicles are all BEVs. On top of the 30 GWh savings shown in the cost curve, achieving the target of 50,000 AFVs on the road in 2020 would bring an additional primary energy savings of 40 GWh for case (i), and 110 GWh for case (ii).

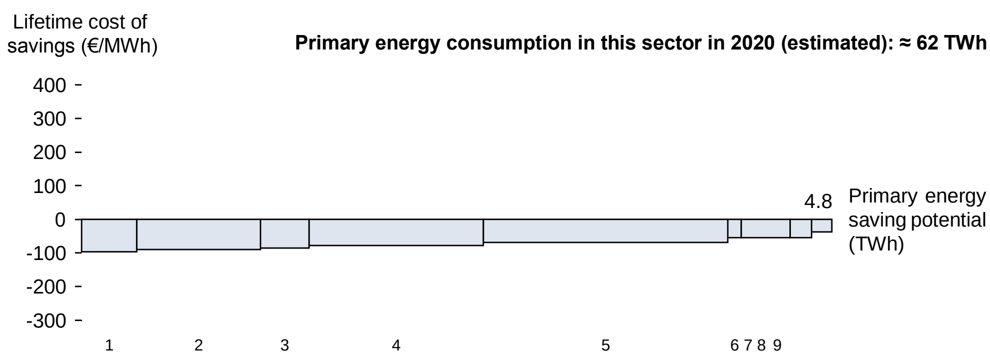
It can be seen that the primary energy savings potential to 2020 of a shift to AFVs is not large compared with the potential of many of the other measures shown. In part, this reflects the modest uptake to 2020 presented above. However, considering only primary energy savings, which is the focus of this analysis, also misses a very important advantage of EVs. EVs offer a pathway to zero emission mobility and are compatible with a low or zero carbon energy system. Provided technology developments and cost reductions for EVs continue, their uptake may accelerate in the period after 2020 making them an increasingly important part of the policy mix in the context of reducing emissions from the transport sector.

1.9 Energy efficiency cost curve: Industry

Figure 1-10 shows the energy efficiency cost curve for the industry sector. The total primary energy savings potential in this sector to 2020 is around 4.8 TWh, corresponding to around 8 % of the 62 TWh total estimated energy demand in the sector in 2020. The fractional savings potential in the industry sector is low compared with the other sectors. This can largely be explained by the fact that by 2020 nearly 60 % of industry final energy consumption is expected to be related to high or low temperature processes, the majority of this in the food and drink, basic metals and non-metallic minerals sub-sectors. Compared with end-use processes such as lighting, refrigeration and motor systems, the savings potential from heating processes, particularly in the basic metals and non-metallic minerals sub-sectors, is relatively small.

We note that Ireland's highly successful energy efficiency programme for large industry, the LIEN[13], which now covers more than half the total industry primary energy demand, claimed nearly 580 GWh in primary energy savings in 2012. As a result, the remaining potential for LIEN members is lower than for non-LIEN members; 'suitability factors' have been developed and applied accordingly.

Technical measures[14] in the industry sector include more efficient motors, refrigeration, compressed air and steam systems, process integration and heat recovery[15], more efficient HVAC (heating, ventilating, and air conditioning) and lighting, and CHP (combined heat and power). The largest savings potential is available through process integration and heat recovery for low temperature processes (1.6 TWh), CHP (0.8 TWh) and more efficient motor systems (1.1 TWh). The remaining measures offer further potential savings of 1.3 TWh.



Measure	PE saving (TWh)	Measure	PE saving (TWh)
1. More efficient refrigeration	0.35	6. More energy-efficient lighting	0.09
2. CHP	0.79	7. Process integration & heat recovery - high T processes	0.31
3. More efficient compressed air systems	0.31	8. More energy efficient steam system	0.14
4. Motor efficiency	1.10	9. More efficient HVAC and ventilation	0.13
5. Process integration & heat recovery - low T processes	1.55	**Total**	**4.76**

Figure 1-10: Energy efficiency cost curve for the Industry sector

[13] http://www.seai.ie/Your_Business/Large_Energy_Users/LIEN/

[14] We note that no behavioural measures have been included in the industry sector, as energy consumption in the sector is dominated by energy-intensive processes.

[15] 'Process integration and heat recovery' refers to the use of design principles and/or technologies enabling previously 'wasted' heat resulting from a certain process to be captured and used as an input to a second process.

We note that no behavioural measures have been included in the industry sector, as there is a dearth of evidence on the potential for such energy savings (although we note that, to the extent that it involves a change in the way systems are designed and operated, ‘process integration and heat recovery’ can be seen partly as a behavioural measure).

All measures modelled in the industry sector are found to be cost-effective. This reflects the fact that the utilisation of equipment in industry is typically high, meaning that the premium for high efficiency equipment is paid off over a much shorter period than the lifetime of the equipment.

The measures contained in the Shallow, Medium and Deep packages for the public sectors are shown in Table 1-3. Figure 1-11 shows the energy efficiency cost curve for packages for the industry sector. It can be seen that all packages for the industry sector are cost-effective and the lifetime cost of the Deep package is more negative than that of the Medium and Shallow packages. It is worth remembering here that the measures in the Deep package are in the Deep package due to either a high capital cost or a low decision frequency or both; this is not inconsistent with the very negative lifetime cost of savings.

Table 1-3: Measures contained in packages for the industry sector

Sector	Shallow	Medium	Deep
Industry	• Energy efficient lighting	• **All Shallow measures** • More efficient compressed air systems • Process integration and heat recovery – high and low temp. processes • More energy efficient steam system	• **All Medium measures** • More efficient HVAC and ventilation • CHP • More efficient refrigeration • Motor efficiency

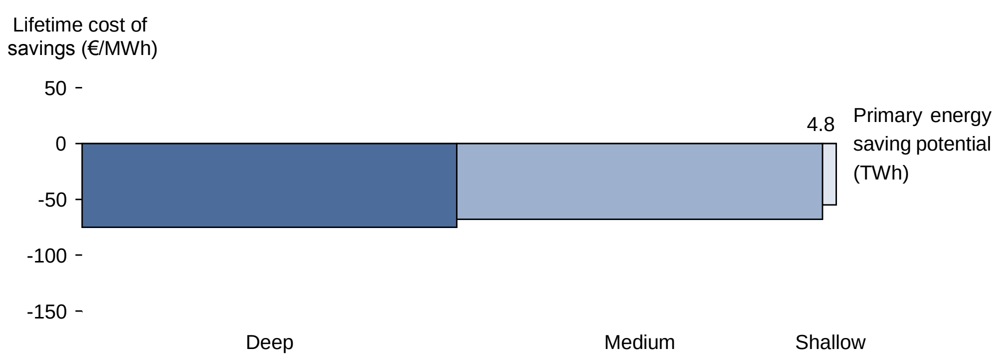


Figure 1-11: Energy efficiency cost curve for the Industry sector (packages)

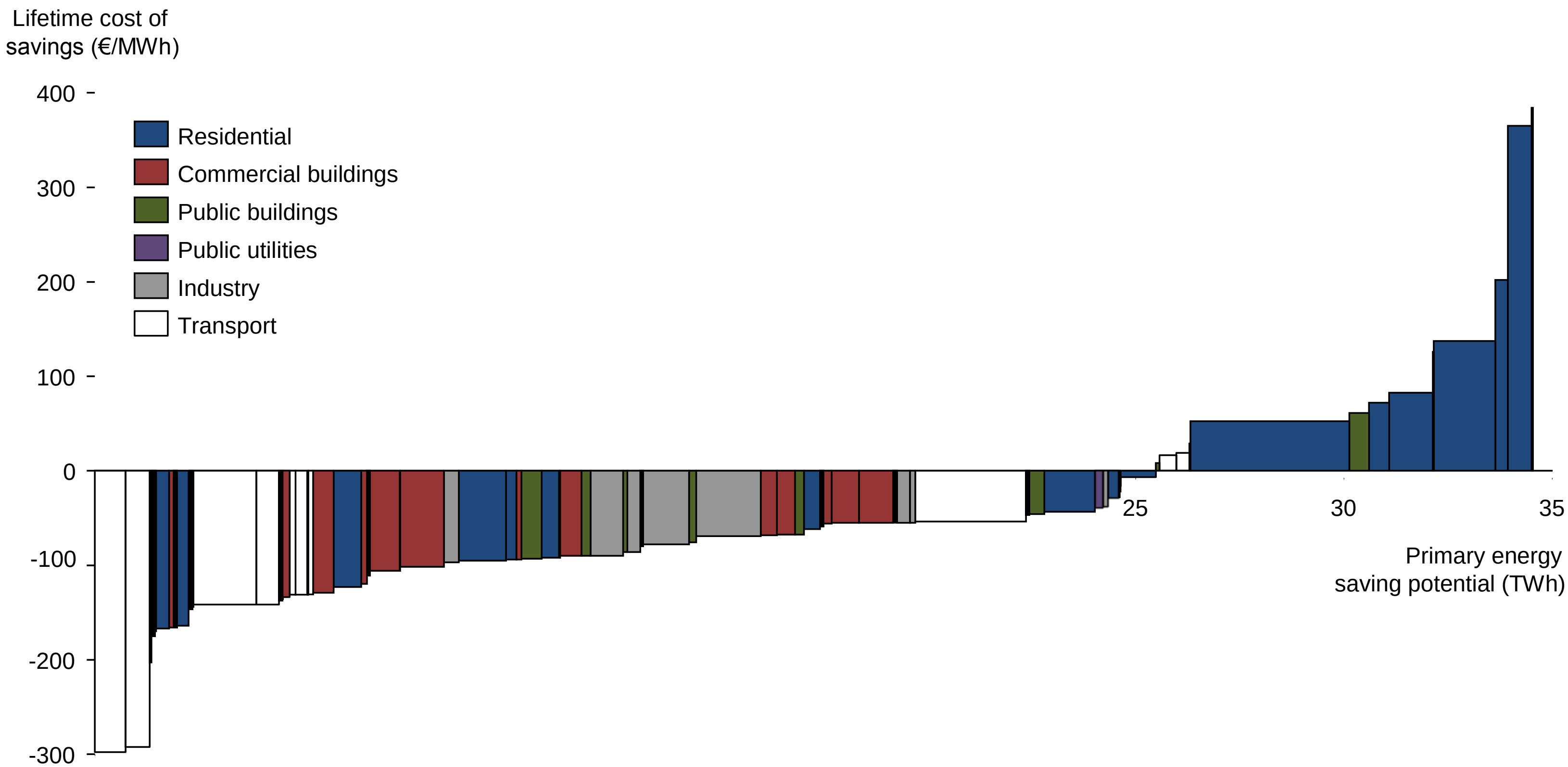
1.10 Energy efficiency cost curve: all sectors

Figure 1-12 presents the energy efficiency cost curve for individual measures across all demand-side sectors in Ireland and Table 1-4 summarises the technical and economic potential[16] in each sector both in absolute terms and as a percentage of the total demand in 2013. Across all sectors studied there remains nearly 35 TWh of technical savings potential to 2020, representing 19 % of the total primary energy demand in 2013.[17] More than 26 TWh of this, corresponding to 15 % of the total demand in 2013, is economic (i.e. below the x-axis).

We emphasise that measures that are uneconomic (i.e. above the x-axis) using a 10 % discount rate are likely to be difficult to achieve without additional intervention, but could be unlocked with well-targeted support and/or financial incentives. Potential Government interventions are examined in detail in the next section. Furthermore, as shown in the above sections, the application of packages rather than individual measures is a powerful way of increasing the fraction of the overall potential which is economic without requiring further support or financial incentive.

The reader is referred to the Appendix, Section 7.1 of the Main Report for a version of the economy-wide cost curve labelled with all measures contained and the associated savings potential.

[16] We define 'economic' to mean a negative lifetime cost at stated the discount rate (in this section, the discount rate used is 10%).
[17] We emphasise that this does not include savings achieved between 2007 and 2012 (amounting to around 12 TWh), and so does not suggest that the 20% target for 2020 cannot be met.



Note: All Energy Efficiency cost curves included in this chapter show measures applied cumulatively in order of cost-effectiveness. In the buildings sectors, behavioural measures are always applied after all non-behavioural measures.

Figure 1-12: Energy efficiency cost curve for Ireland

Table 1-4: Summary of Technical and Economic potential for all sectors[18]

Sector	Measure type	Energy savings potential
Commercial	Technical measures	5.15
	Behavioural measures	0.80
	Total	**5.95**
	As % of Baseline	**35%**
Public buildings, transport and utilities	Technical measures	2.65
	Behavioural measures	0.40
	Total	**3.05**
	As % of Baseline	**30%**
Residential	Technical measures	11.05
	Behavioural measures	2.41
	Total	**13.46**
	As % of Baseline	**30%**
Transport (excl. public transport)	Technical measures	4.43
	Behavioural measures	2.90
	Total	**7.32**
	As % of Baseline	**17%**
Industry	Technical measures	4.76
	Total	**4.76**
	As % of estimated Baseline (2020)	**8%**
All sectors	Technical measures	28.03
	Behavioural measures	6.51
	Total	**34.55**
	As % of Baseline	**19%**

[18] Primary energy savings in 2020 (TWh).