Energy efficiency investment pathways in Ireland

for

Sustainable Energy Authority of Ireland

Appendix: Methodology and technical assumptions

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Purpose of this document

- SEAI commissioned Element Energy to undertake a detailed analysis of the potential for energy efficiency improvements across all major energy-consuming sectors in Ireland to 2020. This work forms a key evidence base to inform Ireland's national strategy to meet its on-going obligations with respect to the Re-cast Energy Performance in Buildings Directive (2010) and Energy Efficiency Directive (2012).

- This study provides valuable new information for Ireland as it continues to develop its energy efficiency strategy, offering a detailed analysis of the range of measures which could contribute to the target and the variety of policy interventions which could ensure the target is met most cost-effectively.

- This document is the Final Appendix and accompanies the Final Report on the energy efficiency investment pathways in Ireland. This Final Appendix provides further details on the methodology and key technical assumptions.

- In addition to the Final Report and Final Appendix, we have published two reports describing a series of surveys carried out in the commercial building sector as part of this study.

- Please send comments to:
  - Emrah.Durusut@element-energy.co.uk, or
  - Sam.Foster@element-energy.co.uk

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Technical potential for commercial buildings is estimated using the outputs of the SBEM model based on the data collected in site visits and data from ND-BER database

Process

1. Survey statistically representative sample of commercial buildings
2. Link survey database with detailed ND-BER and NCM databases
3. Select archetypes for use in national stock model based on coverage of final energy
4. Construct national stock model using outputs from Element Energy SBEM model
5. Estimate technical potential energy savings using outputs from EE SBEM model

Key aspects of methodology

- **1,500 site visits** completed on time
- Information collected for a variety of commercial building types on building fabric, building type/shape, size, activity, HVAC and fuel type, lighting, heating and lighting controls
- See the report for "Extensive survey of commercial buildings in Ireland" for further details

Characterise commercial buildings by sub-sector using **GeoBusiness***

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Statistically robust sampling ensuring sufficient data points for all sub-sectors identified

Survey design maximising the value out of the survey, and considering data requirements for energy modelling and other data sources available

↓

1,500 site visits completed on-time

↓

Dataset of the Irish commercial buildings stock

Source: Element Energy analysis for SEAI

* GeoBusiness, an electronic register of every business address in the State, provides a complete geographical database covering close to 200,000 businesses across the Republic of Ireland.

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Key aspects of methodology

- It was possible to collect a wide range of useful data to use as inputs to the energy modelling. However, to collect all required inputs for the modelling, additional data sources were required.
- **Filtered ND-BER database,** which provides detailed data such as **U values** of the building elements for over 10,000 commercial buildings in Ireland, **linked with survey results**
- **Detailed activity data** gathered by linking the ND-BER with **NCM activity database*** using activity IDs and areas of individual zones for all buildings

Data source	Data gathered
Survey results	Building activity (sub-sector), Size (floor area), HVAC type, Heating fuel, Fraction of double glazing, Wall type, Commercial only or commercial/residential, Building type, Number of storeys, Building height, Listed/heritage status, Existence of heat pump, Fraction of low energy lighting, Lighting and heating controls
ND-BER database	Building activity (sub-sector), Size (floor area), HVAC type, Heating fuel, Wall, window, roof, floor, door U values, Infiltration rate, Heating seasonal efficiency, Cooling seasonal efficiency
NCM activity database	Peak occupancy density (person/m^2), Hot water (l/day/m^2), Illuminance (lux), Display lighting (W/m^2), Heating schedules (hourly), Cooling set point, Cooling schedules (hourly), Occupancy schedules (hourly), Metabolic rate (W/person), Ventilation requirement (l/sm^2), Equipment (W/m^2), Equipment schedules (hourly)

Source: Element Energy analysis for SEAI

* National Calculation Methodology (NCM) activity database is available at:
http://www.seai.ie/Your_Building/BER/Non_Domestic_buildings/Download_SBEM_Software/Download_SBEM_Software.html

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Key aspects of methodology

- Buildings in the survey categorised based on building activity, size (floor area), HVAC type, heating fuel, wall type/condition, window condition, building type (detached or mid-terrace) and whether the building is commercial only or commercial and residential.
- In order to select the final archetypes, the energy consumption of each possible archetype was estimated based on the floor area from survey and the kWh/m2 value from ND-BER. Out of ~340 possible archetypes, **115 commercial** building archetypes are selected based on total final energy covering **more than 80% of final energy and floor area** for each sub-sector. Detailed energy consumption of the final archetypes was calculated using the SBEM model, as shown in the next slide.
- In order to achieve a reasonable number of archetypes, a limited number of options are included for each category:

Category	Options for category
Building activity	"Office", "Retail", "Hotel", "Restaurant/public house" or "Warehouse/storage"
Size	"Large" (>=1,000 m^2) or "Small" (<1,000 m^2) based on gross floor area
HVAC type	"Heating only, natural ventilation", "Heating only, mechanical ventilation" or "Heating and cooling, mechanical ventilation"
Heating fuel	"Grid supplied electricity", "Natural gas" or "Oil"
Wall condition	"Poor" (>=0.6 W/m^2K) or "Good" (<0.6 W/m^2K) using ND-BER database
Window condition	"Poor" (single glazing) or "Good" (double/triple glazing)
Building type	"Mid-terrace" or "Detached" (includes all other building types)
Purpose	"Commercial only" or "Commercial and residential"

Source: Element Energy analysis for SEAI

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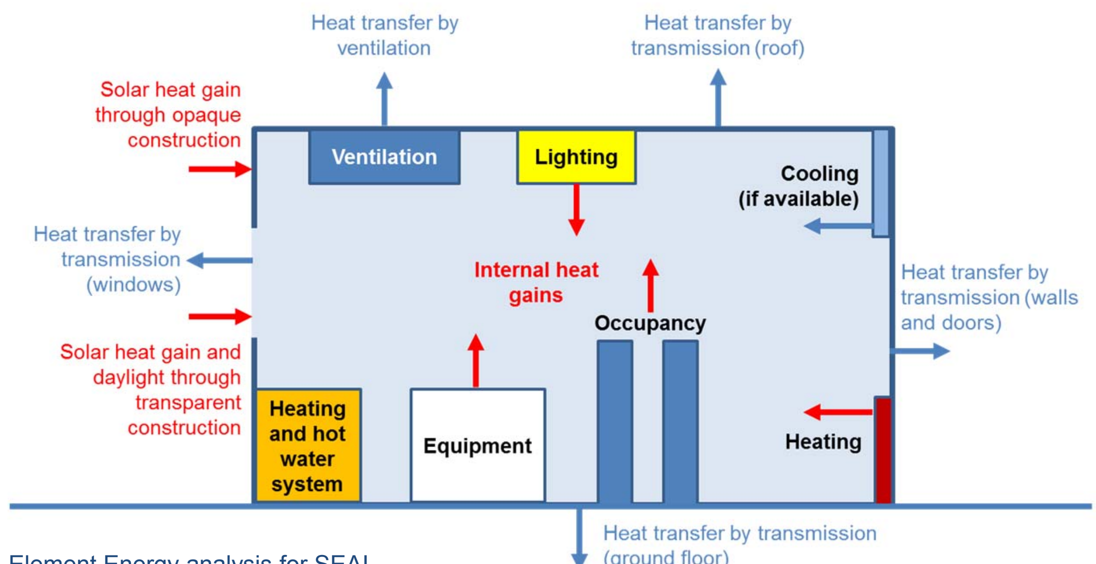
Key aspects of methodology

- All the data collected for all of our archetypes are then used as model inputs for Element Energy’s SBEM-based energy model. SBEM is a model that provides an analysis of a building’s energy consumption and is also used for the ND-BER assessments in Ireland.
- The calculation is based on the building fabric properties, geometry, activity, HVAC system, lighting systems, space heating, cooling, ventilation, lighting, equipment, hot water and auxiliary energy demand, solar irradiance and weather data in Ireland, etc. The diagram below illustrates the calculation process in the model.
- EE SBEM model tested for a number of building types in each sub-sector and model outputs for baseline consumption are **consistent with estimates in ND-BER database.**



Source: Element Energy analysis for SEAI

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Key aspects of methodology

- Impacts of **a variety of energy efficiency measures** as identified in the project inception report modelled using EE SBEM model
- Detailed results such as savings **per archetype, sector, technology and fuel type** are available in the model
- See "Energy efficiency measures" slides for the technical assumptions on target values and suitability factors

Measures included in the analysis

Fabric	Wall insulation	**HVAC**	More efficient boiler replacement
	Roof insulation		Air source heat pump
	Glazing		Heating controls
	Draught proofing		More efficient air conditioning
Lighting	Energy efficient lighting	**Behavioural**	Reducing room temperature
	Lighting control		Turn off lights for extra hours
Appliances	Energy efficient appliances		Reducing hot water use

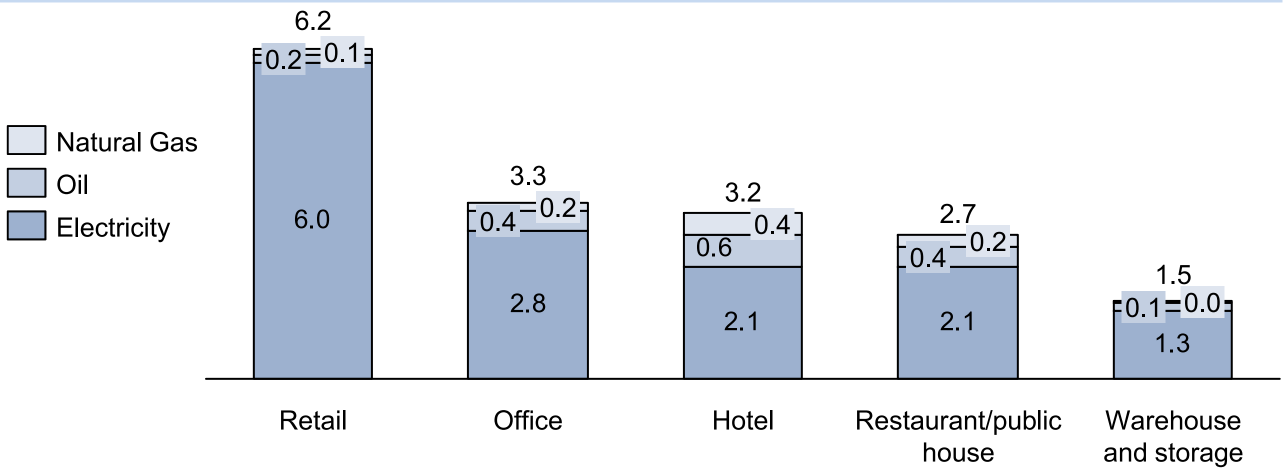
Source: Element Energy analysis for SEAI

Commercial buildings stock

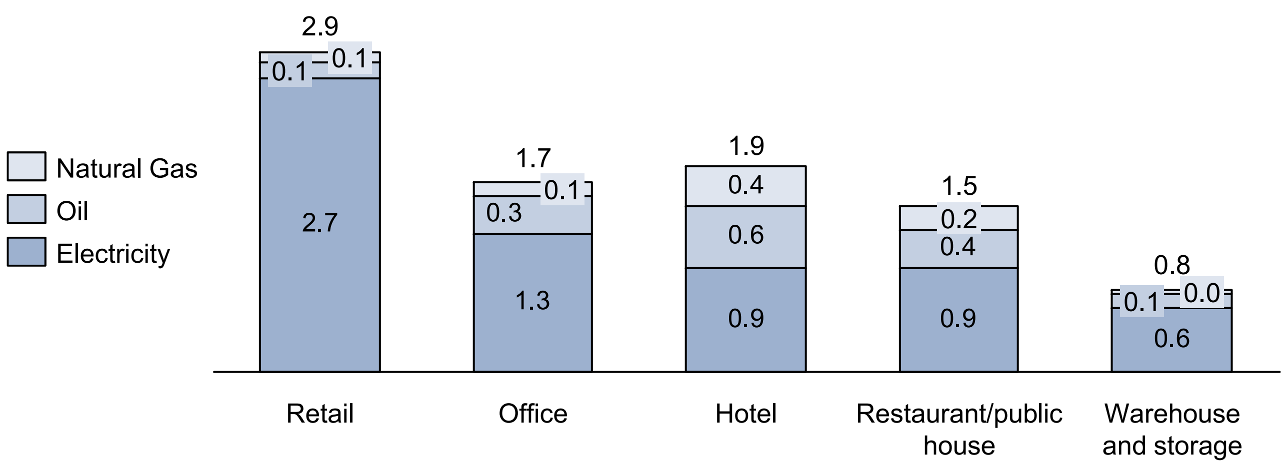
Commercial building stock (total ~ 109,000)

Baseline energy consumption – Commercial buildings

Primary energy demand by fuel type in the commercial buildings sector (Total = ~17 TWh)



Final energy demand by fuel type in the commercial buildings sector (Total = ~9 TWh)



Technical potential for public buildings is estimated using the SBEM model outputs based on the data from ND-BER and DEC databases

Process

1. Estimate total number of public buildings based on GeoBusiness and literature
2. Obtain detailed data from DEC, ND-BER and NCM databases
3. Select archetypes for use in national stock model based on coverage of final energy
4. Construct national stock model using outputs from Element Energy SBEM model
5. Estimate technical potential energy savings using outputs from EE SBEM model

Key aspects of methodology

- DEC database, which includes data for more than 2,000 public buildings in Ireland, suggests energy usage in public buildings dominated by “Offices”, “Education” and “Healthcare”.
- Based on the previous Byrne Ó Cleirigh estimation, there are around 2,000 healthcare buildings and the total number of Public buildings is 10,000* in Ireland*.
- This also suggests that there are in total around 8,000 buildings in “Education” and “Public office” sub-sectors.
- 8,000 buildings are allocated into “Education” and “Public offices” proportional to their number of addresses in the GeoBusiness database (Using GeoBusiness, around 4,500 and 2,400 addresses are identified as “Education” and “Public Office”, respectively. However, the total number of public buildings could in reality be higher as there might be more than one building with the same address).
- Estimates **consistent with** previous BOC and SEAI publications*
- The fraction of small/large public buildings is based on their fraction in the ND-BER database. It is estimated that there are more than 3,000 public buildings with floor area above 1,000 m^2 in Ireland, which is also consistent with previous SEAI estimates*.

Public building sub-sector	Number of public buildings estimated	Number of large public buildings (>=1000m^2)	Number of small public buildings (<1000m^2)
Education	5,200	2,200	3,000
Healthcare	2,000	500	1,500
Office	2,800	500	2,300
	10,000	**3,200**	**6,800**

Source: Element Energy analysis for SEAI

* Public Sector Energy Consumption (SEAI, BÓC, 2010), Scope of EED Public Sector Building Renovation Target (SEAI, BÓC, 2013)
Education buildings: third level institutions (M&R TUFA = 2,000,000 m2) and schools (>4,000 buildings)
Public office buildings: More than 1,000 justice & defence buildings. OPW manages more than 2,000 public buildings (mainly offices)

Technical potential for public buildings is estimated using the SBEM model outputs based on the data from ND-BER and DEC databases

Process

1. Estimate total number of public buildings based on GeoBusiness and literature
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3. Select archetypes for use in national stock model based on coverage of final energy
4. Construct national stock model using outputs from Element Energy SBEM model
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Key aspects of methodology

- **ND-BER database** and **DEC database**, which includes data for more than 2,000 public buildings in Ireland, filtered and linked using sub-sector, size, HVAC and fuel type
- **Detailed activity data** gathered by linking the ND-BER with **NCM activity database*** using activity IDs and areas of individual zones for all buildings

Data source	Data gathered
DEC database	Building activity (sub-sector), Size (floor area), HVAC type, Heating fuel
ND-BER database	Building activity (sub-sector), Size (floor area), HVAC type, Heating fuel, Wall, window, roof, floor, door U values, Infiltration rate, Heating seasonal efficiency, Cooling seasonal efficiency
NCM activity database	Peak occupancy density (person/m^2), Hot water (l/day/m^2), Illuminance (lux), Display lighting (W/m^2), Heating schedules (hourly), Cooling set point, Cooling schedules (hourly), Occupancy schedules (hourly), Metabolic rate (W/person), Ventilation requirement (l/sm^2), Equipment (W/m^2), Equipment schedules (hourly)

Source: Element Energy analysis for SEAI

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Key aspects of methodology

- The coverage of large public buildings and small education buildings is high in the DEC database; however, small office and healthcare buildings are not well represented.
- ND-BER database is used to develop the archetypes for small office and small healthcare as ND-BER has higher coverage for these building categories (see the table below)
- Public buildings in the ND-BER and DEC databases categorised based on sub-sector, size, HVAC type, heating fuel, wall condition and window condition
- In order to achieve a reasonable number of archetypes, a limited number of options are included for each category (similar to the commercial buildings)
- Overall, 46 public building archetypes are selected based on total final energy covering at least 80% of final energy for each sub-sector and size.

Public building sub-sector	Coverage in DEC database (based on number of buildings)		Database used to develop archetypes	
	Large public buildings (>=1000m²)	Small public buildings (<1000m²)	Large public buildings (>=1000m²)	Small public buildings (<1000m²)
Education	43%	36%	DEC	DEC
Healthcare	28%	**1%**	DEC	**ND-BER**
Office	54%	**2%**	DEC	**ND-BER***

Source: Element Energy analysis for SEAI

* Small office buildings in the ND-BER include both commercial and public buildings.

Technical potential for public buildings is estimated using the SBEM model outputs based on the data from ND-BER and DEC databases

Process

1. Estimate total number of public buildings based on GeoBusiness and literature
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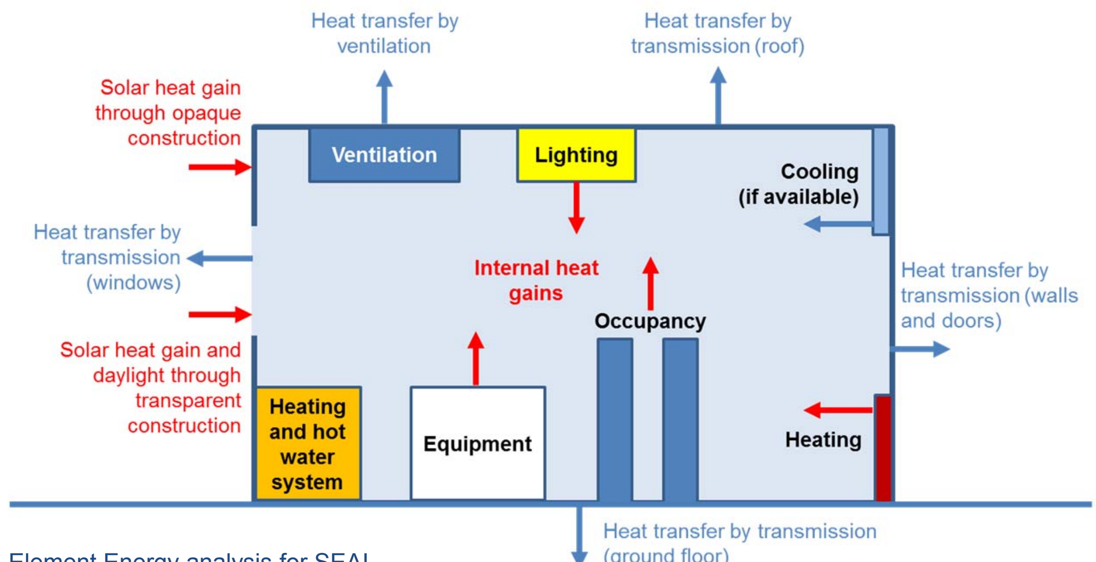
Key aspects of methodology

- All the data collected for all of our archetypes are then used as model inputs for Element Energy's SBEM-based energy model. SBEM is a model that provides an analysis of a building's energy consumption and is also used for the ND-BER assessments in Ireland.
- The calculation is based on the building fabric properties, geometry, activity, HVAC system, lighting systems, space heating, cooling, ventilation, lighting, equipment, hot water and auxiliary energy demand, solar irradiance and weather data in Ireland, etc. The diagram below illustrates the calculation process in the model.
- EE SBEM model is tested for a number of building types in each sub-sector and model outputs for baseline consumption are **consistent with estimates in ND-BER database.**



Source: Element Energy analysis for SEAI

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Key aspects of methodology

- Impacts of **a variety of energy efficiency measures** as identified in the project inception report modelled using EE SBEM model
- Detailed results such as savings **per archetype, sector, technology and fuel type** are available in the model
- See "Energy efficiency measures" section for the technical assumptions on target values and suitability factors

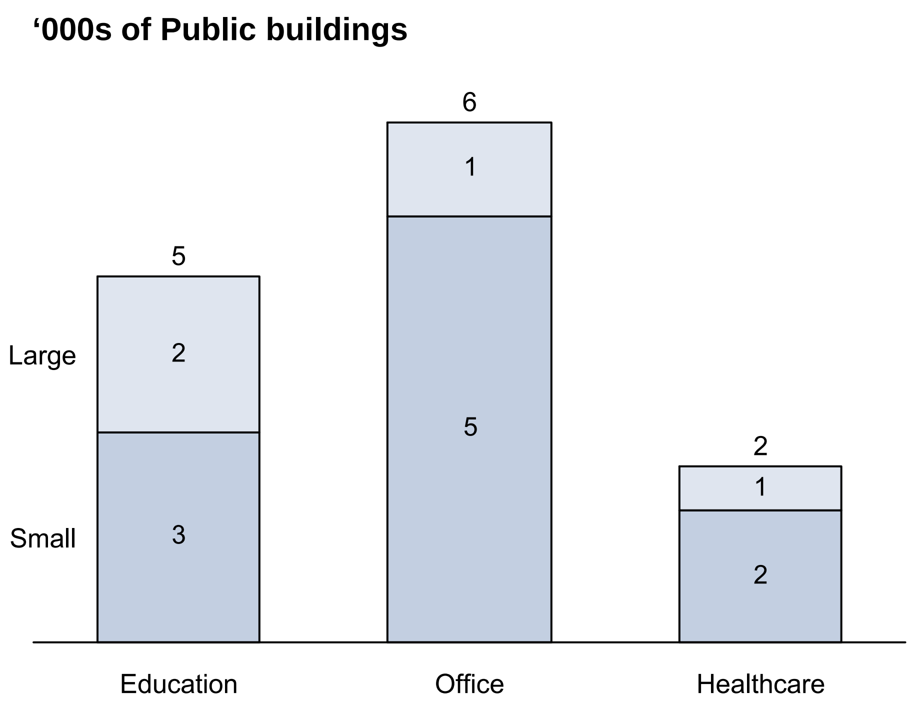
Measures included in the analysis

Fabric	Wall insulation Roof insulation Glazing Draught proofing	**HVAC**	More efficient boiler replacement Air source heat pump Heating controls More efficient air conditioning
Lighting	Energy efficient lighting Lighting control	**Behavioural**	Reducing room temperature Turn off lights for extra hours Reducing hot water use
Appliances	Energy efficient appliances		

Source: Element Energy analysis for SEAI

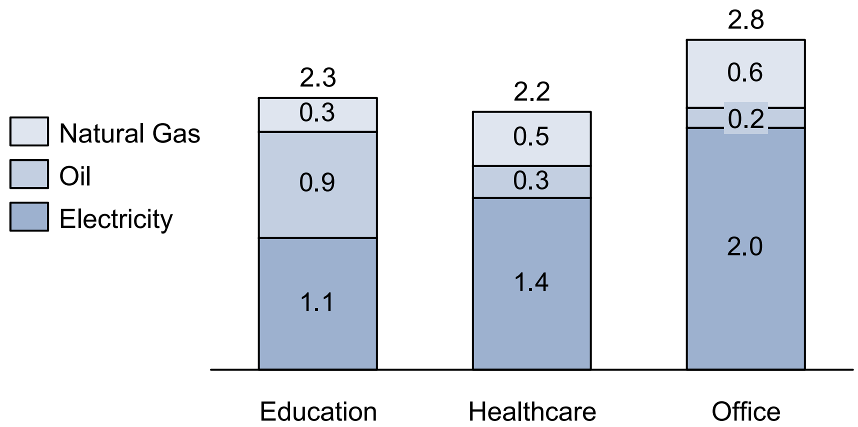
Public buildings stock

Public building stock (total ~ 13,000)



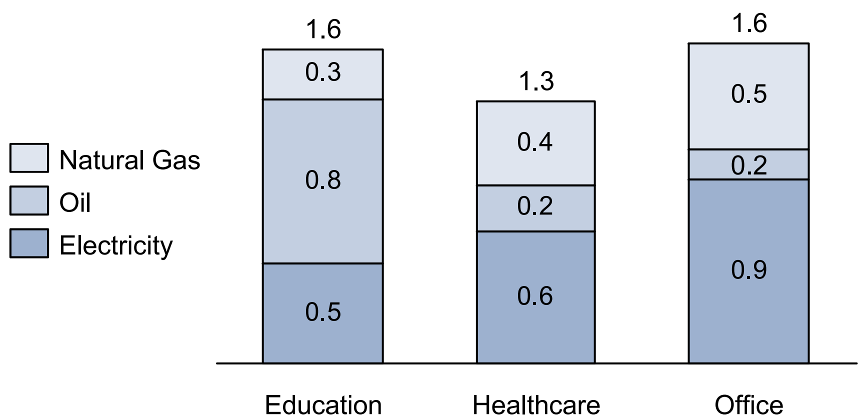
Baseline energy consumption – Public buildings

Primary energy demand by fuel type in the public buildings sector (Total = ~7 TWh)



- Total final energy consumption of public buildings estimated based on bottom-up modelling has been calibrated using the confidential SEAI data submitted by large public sector organisations.
- Bottom-up estimate of baseline energy consumption is consistent with the total primary energy demand in Energy Demand 2012 and 2013; however, fuel shares are different.

Final energy demand by fuel type in the public buildings sector (Total = ~4 TWh)



Source: Element Energy analysis for SEAI

Energy efficiency measures for commercial and public buildings (1)

	Cavity wall insulation	Solid wall insulation	Energy efficient glazing	Roof insulation	Draught proofing	Energy efficient lighting	Energy efficient appliances	More efficient boiler replacement (gas, oil)
Variable	Wall U-value	Wall U-value	Window U-value	Roof U-value	Infiltration rate	Fraction of energy efficient lighting	Equipment (W/m^2)	Seasonal efficiency of boiler
Target value	0.55	0.35	1.5	0.25	Reduction in infiltration by 1/3 or infiltration rate of 10 m^3/m^2hr , whichever is larger	100% energy efficient lighting (replace incandescent with LED lighting)	Depending on sector (see separate slide)	92%
Source for target value	Ireland Part L* Table 5	Ireland Part L* Table 5	Ireland Part L* Table 5 - double-glazed, air filled (low-E, Ân = 0.05, soft coat) 12 mm gap	Ireland Part L* Table 5 for flat roof	Ireland Part L*	Element Energy assumption	See separate slide	HARP database
Suitable commercial buildings	"Poor" cavity walls	"Poor" non-cavity walls excluding curtain wall and heritage buildings	"Poor" windows	U value higher than 0.3 W/m^2K	"Poor" windows	All buildings except buildings with 100% energy efficient lighting based on survey	All buildings are suitable	Gas, oil boilers with efficiencies less than 90%
Suitable public buildings	"Poor" cavity walls	"Poor" non-cavity walls (solid and concrete)	"Poor" windows	U value higher than 0.3 W/m^2K	"Poor" windows	Suitability is assumed to be 50% for public buildings (based on the survey average for commercial buildings)	All buildings are suitable	Gas, oil boilers with efficiencies less than 90%

Source: Element Energy analysis for SEAI

* Ireland Building Regulations 2011, Technical Guidance Document L, available at: http://www.environ.ie/en/Publications/DevelopmentandHousing/BuildingStandards/FileDownLoad,27316,en.pdf

Energy efficiency measures for commercial and public buildings (2)

	Heat pump	Heating controls (room-by-room time and temperature control)	Lighting control	More efficient air conditioning	Reducing room temperature	Turn off lights for extra hours	Reducing hot water use	Enable standby features on all PCs and monitors
Variable	Seasonal efficiency of heat pump	Seasonal efficiency of heating system	Occupancy sensing	Seasonal efficiency of air conditioning (SEER)	Internal temperature set point for heating (ºC)	Lighting consumption (W/m^2)	Hot water ($l/day/m^2$)	Equipment (W/m^2)
Target value	2.7 for heating (all buildings) 1.0 for hot water***** (small buildings)	3% increase	22% reduction in lighting demand	4.5	1ºC reduction	10% reduction	10% reduction	30% reduction in PC and monitor energy use
Source for target value	European Commission guidance*	SBEM technical manual**	LBNL, 2012******	AECOM zero carbon non-domestic buildings***	Element Energy assumption	Carbon Trust guidance for retail****	Element Energy assumption	Carbon Trust Technology Overview CTV005
Suitable commercial buildings	(i) Buildings with both “poor “walls and “poor” windows, (ii) premises without roof (iii) heritage buildings and (iv) buildings with heat pumps are not suitable	Based on the survey results	All buildings are suitable	Buildings with cooling and SEER less than 3.5	All buildings are suitable	All buildings are suitable	All buildings are suitable	All buildings are suitable
Suitable public buildings	Buildings with both “poor” walls and “poor” windows are not suitable	All public buildings are assumed to be suitable	All buildings are suitable	Buildings with cooling and SEER less than 3.5	All buildings are suitable	All buildings are suitable	All buildings are suitable	All buildings are suitable

Source: Element Energy analysis for SEAI

* European Commission Guidelines, C(2013) 1082, 2013/114/EU, available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:062:0027:0035:EN:PDF

** SBEM technical manual v3.5.a for SEAI, available at: http://www.seai.ie/Your_Building/BER/Non_Domestic_buildings/Download_SBEM_Software/SBEM%20Technical%20Manual%20V3-4a%20Oct%202009.pdf

***AECOM, 2011, Zero carbon non-domestic buildings, Phase 3 final report, available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/6329/1940106.pdf

**** Carbon Trust, Retail overview, available at: http://www.carbontrust.com/media/39228/ctv001_retail.pdf

***** AEA, 2012, RHI Phase II – Technology Assumptions

******LBNL, 2012, “Quantifying National Energy Savings Potential of Lighting Controls in Commercial Buildings”

Savings potential due to upgrade to energy efficient appliances in commercial and public buildings is included in the analysis

Key aspects of methodology

- Savings potential in appliances considered for all public and commercial buildings
- Efficiency improvements in office equipment and electronics, and in refrigeration considered
- Office equipment and electronics: measures include greater use of standby features for PCs and monitors, 7-day time controls for printers and photocopiers, use of low-energy printers and high efficiency charging devices for consumer electronics
- Share of appliance energy use in each category estimated per sector using literature sources

Technical assumptions

Appliance category	Technical savings potential	Source
Office equipment and electronics	33%	• "CTV005 Technology Overview: Office equipment", Carbon Trust • "Ireland's Low Carbon Opportunity", SEI/McKinsey (2009)
Refrigeration	20%	• "CTG046 Technology Guide: Refrigeration systems", Carbon Trust • "Energy Star Guide for Restaurants: Putting Energy into Profit", EPA (2012)
Other	0%	

Sector	Share of final energy			Overall potential	Source
	Office equip.	Refrigeration	Other		
Office	100%	0%	0%	34%	• "CTV005 – Technology Overview: Office equipment", Carbon Trust
Retail	24%	23%	53%	13%	• "CTV007 – Sector Overview: Office-based companies", Carbon Trust
Hotel	20%	18%	62%	10%	• "CTV001 – Sector Overview: Retail", Carbon Trust
Restaurant/pub	0%	58%	42%	12%	• "CTV013 – Sector Overview: Hospitality", Carbon Trust
Education	14%	23%	63%	9%	• "Energy Smart Tips for Restaurants", SEDAC (2011)
Healthcare (Large)	15%	17%	68%	9%	• "CTV019 – Sector Overview: Schools", Carbon Trust • "CTV024 – Sector Overview: Hospitals", Carbon Trust
Healthcare (Small)	29%	6%	35%	11%	• "CTV025 – Sector Overview: Primary Healthcare", Carbon Trust

Source: Element Energy analysis for SEAI

Contents

Technical potential for public utilities estimated by applying a set of efficiency measures as identified in the SEAI Working Group reports

Process	Key aspects of methodology
Derive baseline energy consumption for public lighting and water services	• Existing number of public lighting and energy demand identified in the SEAI Public Lighting Overview Report • Baseline energy consumption in the water services covers pumping and waste water treatment plants
Determine energy saving potential of a set of measures for public lighting and water services	• Existing street lighting is assumed to be replaced by LEDs (including central management system e.g. dimming and trimming) • Nine energy efficiency measures chosen for water services having immediate, short and medium payback times based on SEAI Water Services Overview report
Estimate technical potential energy savings	• Incremental energy savings potential for public lighting estimated compared to incandescent (see the slide for street lighting in the "Energy efficiency cost curves" section) • Rules-of-thumb estimations of energy efficiency measures for water services are based on the SEAI Working Group reports (see next slide for further information)

Source: Element Energy analysis for SEAI

Estimations of energy efficiency measures for water services are based on the SEAI Working Group reports

Water services

Measures		**Fraction of stock suitable for measure**	**Typical energy saving (single unit)**	**Payback time***
Pumping optimisation	Higher efficiency pump retrofit	40%	30%	Short
	Elimination of parasitic loads in pump house	80%	10%	N/A
	Optimising operation through duty & assist control	20%	15%	Immediate
	Install Variable Speed Drive (VSD) instead of throttling	20%	15%	Short
Wastewater treatment plant	Retrofit of fine bubble diffused air systems	40%	40%	Medium
	Elimination of excess air to an appropriate level	75%	15%	Immediate
	Dissolved oxygen control of aeration systems	20%	25%	Medium
	Retrofit of blowers with VSD	25%	20%	Medium
	Retrofit of high efficiency motors in aeration systems	60%	5%	Medium

Source: Element Energy analysis for SEAI

* Energy efficiency measures having long payback periods are not included in the analysis

Contents

SEAI Residential model has been reviewed and measures added for energy-efficient appliances and behaviour change

Process	Key aspects of methodology
Review SEAI Residential model	• Residential model recently upgraded by SEAI and external consultants • Model estimates technical (and economic) energy savings potential of 12 energy efficiency measures and several packages of measures across the Irish housing stock • **As requested by SEAI, model reviewed and initial quality control undertaken**
Add energy-efficient appliances measure	• Baseline appliance energy consumption based on the energy consumption patterns of Irish households* • Technical savings potential of upgrading current stock of appliances to best-in-class based on UK data (see next slide for further information)
Add behavioural measures	• Energy consumption by end-use category available in the SEAI Residential model • Technical savings potential of behavioural measures applied to appropriate end-use categories based on a study for DECC in the UK (see later slide for further information)
Estimate technical potential energy savings	• Primary energy consumption of measures and packages derived

Source: Element Energy analysis for SEAI

* SERVE Energy Monitoring Project – Report on Implementation and Analysis (Tipperary Rural and Business Development Institute)

Savings potential due to upgrade to energy efficient appliances in residential buildings is included in the analysis

Sector and measure

Residential buildings: Efficient appliances

Key aspects of methodology

- Fractional savings potential due to upgrading from current appliance stock to best-in-class appliances derived using UK data
- Appliance energy consumption in Ireland based on ESRI data
- Electricity consumption disaggregated by end-use to allow integration with UK data

Technical assumptions

Appliance segment	Appliance	Appliance share of segment	Technical savings potential	Source
Cold	Refrigerator	13%	60%	• "Household Electricity Survey: A study of domestic electrical product usage", Intertek, Final Report Issue 4 for AEA (2012) • Haines et al., "How Trends in Appliances Affect Domestic CO2 Emissions: A Review of Home and Garden Appliances – Technical Annex". Report prepared for DECC (2010)
	Freezer	26%	59%	
	Fridge-freezer	61%	62%	
Wet	Tumbledrier	33%	22%	
	Dishwasher	17%	20%	
	Washer-drier	17%	0%	
	Washing machine	33%	33%	
Consumer electronics	TV	32%	88%	
	Other	68%	0%	
Cooking	Electric hob	50%	0%	
	Electric oven	50%	30%	

Parameter	Appliance segment	Baseline	Technical potential	Source
Appliance consumption (kWh p.a.)	Cold	473	287	• Baseline taken from "Electrical Appliance Ownership and Usage in Ireland", Working Paper No. 421, ESRI, 2012 • Technical potential calculated using data in above table
	Wet	387	84	
	Consumer electronics	559	156	
	Cooking	516	77	
	Total	**1,935**	**604**	

Source: Element Energy analysis for SEAI

Savings potential due to a range of behavioural measures is included in the analysis

Sector and measure

Residential buildings:
Behavioural measures

Key aspects of methodology

- Savings potential of six behavioural measures is included
- Data for the energy consumption across four end-use categories (space heating, hot water, lighting, pumps and fans) is available for dwellings in the Residential model provided by SEAI
- Energy consumption of appliances (including tumble drier) added by Element Energy
- Savings potential of the measures is estimated by applying percentage reductions in the appropriate end-use category based on a UK study for DECC

Technical assumptions

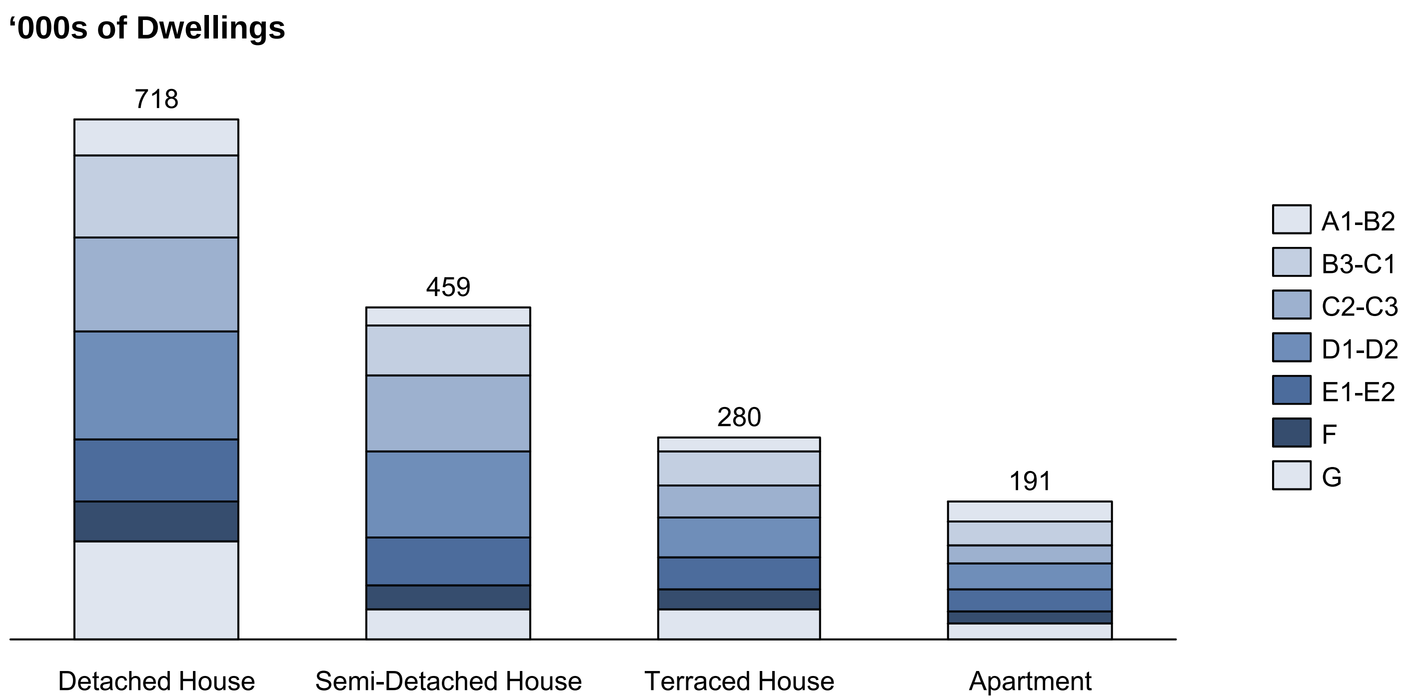
Behavioural measure	End-use category addressed	Technical potential reduction in end-use category (%)	Additional assumption	Source
Reduce thermostat by 1ºC	Space heating	13%		• Cambridge Architectural Research, "How much energy could be saved by making small changes to everyday household behaviours?“. Report for DECC (2012) • Haines et al., “How Trends in Appliances Affect Domestic CO2 Emissions: A Review of Home and Garden Appliances – Technical Annex”. Report prepared for DECC (2010)
Delay start of heating from Oct to Nov	Space heating	5%		
Turn off heating in unused rooms	Space heating	4%	Apartments not suitable	
Install low-flow shower head	Hot water	12%		
Air dry instead of using tumble drier	Appliances	Varies*		
Turn of unnecessary lights	Lighting	25%		

Source: Element Energy analysis for SEAI

*Average Baseline consumption due to tumble drier 126 kWh per household per annum – reduces to zero with air dry

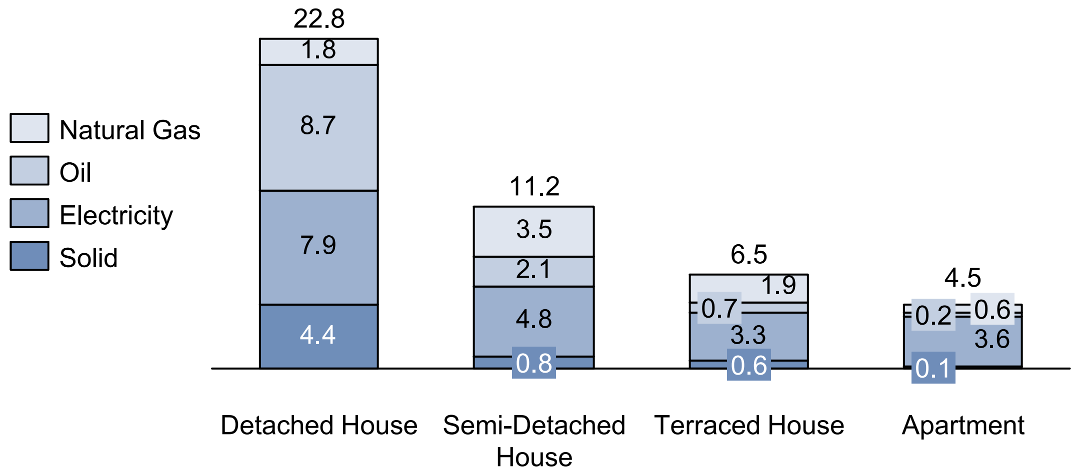
Residential buildings stock

Residential stock (total ~ 1,649,000)

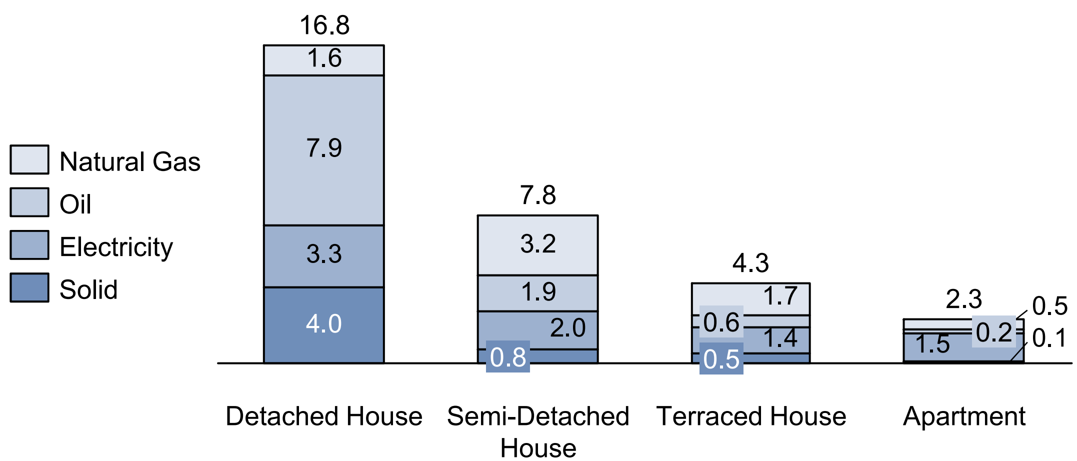


Baseline energy consumption – Residential buildings

Primary energy demand by fuel type in the residential sector (Total = ~45 TWh)



Final energy demand by fuel type in the residential sector (Total = ~31 TWh)



- Total energy consumption of residential buildings estimated based on bottom-up modelling has been calibrated to Energy Demand 2012.

Source: Element Energy analysis for SEAI

Contents

Technical potential for private cars is based on a bottom-up stock model, developing scenarios using the ECCo powertrain uptake model, published literature and Element Energy analysis

Process	Key aspects of methodology
Construct bottom-up car stock model disaggregated by powertrain, fuel and segment	• **Stock, activity and MJ/km disaggregated by powertrain, fuel and segment** up to 2020 • **Final energy in 2008 consistent** to within 6% of value in SEAI National Energy Balances[1]
Develop set of scenarios incorporating recent policy and potential additional measures	• Effect of policy measures including EU regulation and VRT re-balancing determined in detail • Potential effect of a range of additional measures, including modal shift to public transport or walking/cycling, eco-driving and segment shift, quantified in a series of 'what if?' scenarios
Model uptake of alternative powertrain technologies in each scenario using ECCo	• ECCo powertrain uptake model[2] includes **Willingness to Pay data derived from a quantitative survey of over 2,700 new car buyers** in the UK in 2010 • **Updated for Ireland** for tax policy, grant schemes, EV charging point roll out and fuel prices • Model outputs 2010-2013 **consistent with real-world EV market shares** in Ireland
Apply segment and fuel shares for each scenario using literature and own analysis	• Range of academic papers and other published literature used alongside Element Energy analysis • Market share, stock, activity and MJ/km determined for each vehicle type in each scenario
Estimate technical potential energy savings	• Technical potential final and primary energy savings derived for each year up to 2020 • **Individual and cumulative effect of measures** can be determined

Source: Element Energy analysis for SEAI

[1]Without calibration of bottom-up parameters; due predominantly to (i) differences in vehicle segmentation used in the Element Energy model and in the Energy Balances calculation, leading to small discrepancies in average MJ/km and mileage, and (ii) use of different 'real-world' factors from the literature; [2]ECCo model, Element Energy (2013)

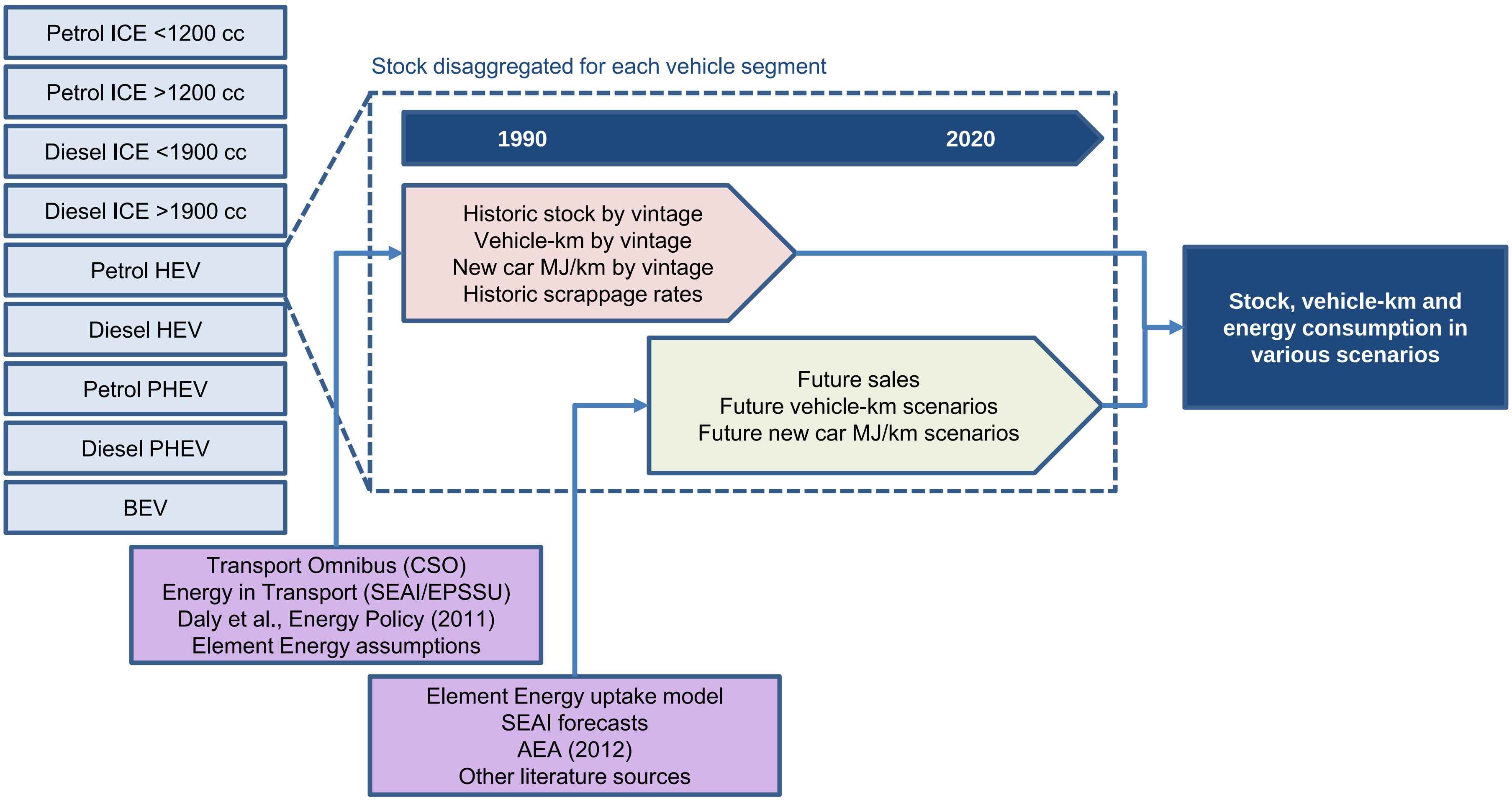
A bottom-up private car stock model has been developed

Sector

Private cars

Description of methodology

- Stock, activity and MJ/km disaggregated across nine vehicle types by powertrain, fuel and segment up to 2020



Bottom-up private car stock model is constructed using CSO and SEAI data

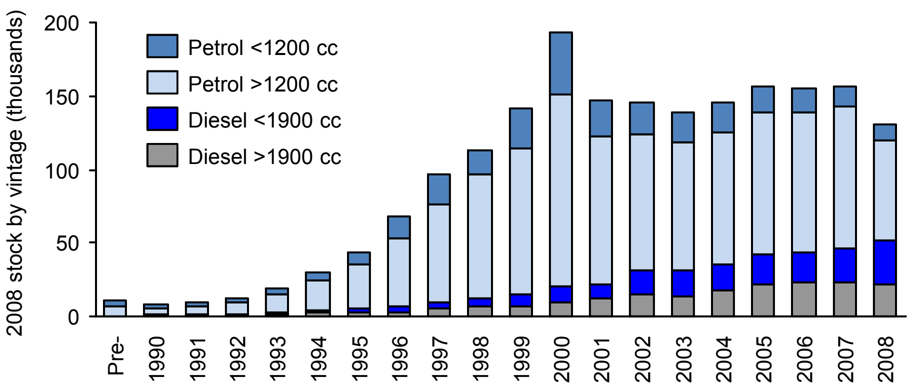
Sector

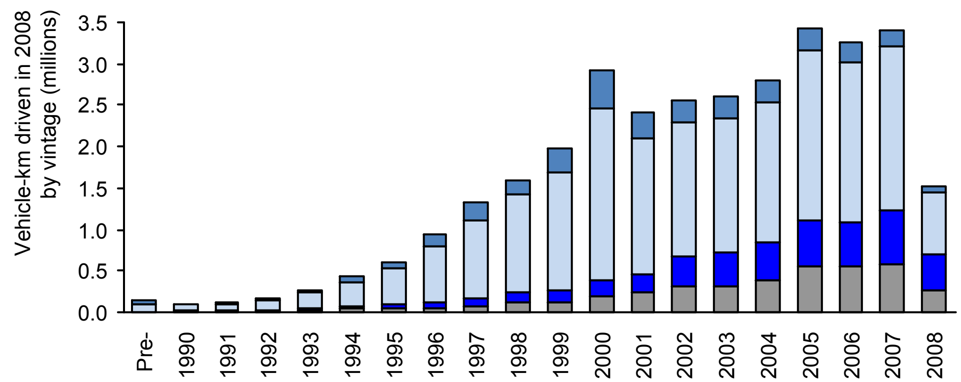
Private cars

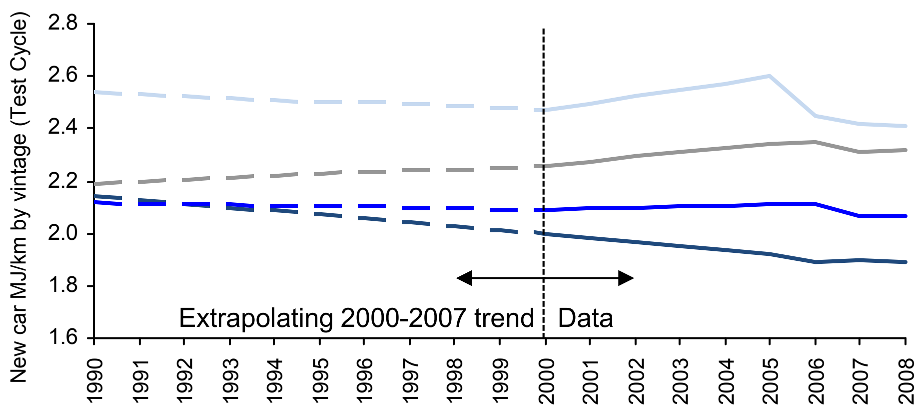
Description of methodology

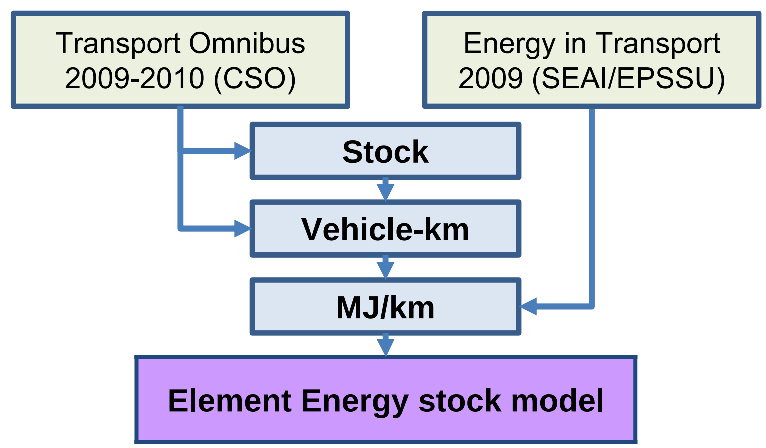
- Stock model constructed with base year 2008 using CSO and SEAI/EPSSU data
- 2008 stock disaggregated into the four internal combustion engine (ICE) vehicle types
- First sales of the five further vehicle types (HEVs, PHEVs and BEVs) assumed in 2008

Stock model for private cars









Source: Element Energy analysis for SEAI

“Transport Omnibus”, CSO (2010); Howley et al., “Energy in Transport”, SEAI/EPSSU (2009); Daly et al., Energy Policy (2011)

Stock modelling to 2020 based on SEAI projections of car sales and car stock projections from the HERMES model, with Baseline activity derived using an econometric analysis

Sector	Description of methodology
Private cars	• Private car sales to 2020 based on SEAI projections • Car stock to 2020 derived using historic retirement rates per vehicle type calibrated to be consistent with the HERMES car stock projection • Activity (vehicle-km) to 2020 derived using an econometric analysis following the study of Daly et al.

Private car sales, stock and vehicle-km assumptions

Case	Parameter	Values			Source
		2008	2015	2020	
All	Private car sales (thousands)	147	90	100	• SEAI projection
	Private car stock (millions)	1.92	1.93	2.08	• Historic retirement rates from Hennessy and Tol, Economic and Social Review (2011) • Calibrated for consistency with HERMES “Medium Term Recovery” scenario
All except Modal shift	Private car vehicle-km (billion km)	32.6	29.5	32.4	• Derived using econometric equation following Daly et al., Energy Policy (2011) • Economic growth assumptions provided by SEAI (HERMES “Medium Term Recovery” scenario) • Fuel price assumptions provided by SEAI (PROMETHEUS scenario)

Underlying reduction in energy intensity of new ICE vehicles is driven by EU regulation

Sector and measure

Private cars: EU regulation

Description of methodology

- EU regulation 443/2009 imposes a mandatory emissions target for manufacturers for the new car fleet in 2015 and 2021 (compliance date recently amended from 2020 to 2021)
- Ricardo-AEA has developed a database of future vehicle characteristics consistent with this regulation up to 2020 for mid-segment vehicles
- 'Pre-2008 trend' models a continuation of the weak trend of improvement in new car energy intensity before 2008; 'EU regulation' incorporates the Ricardo-AEA pathway up to 2020
- Vehicle efficiencies scaled across engine size segments according to SEAI/EPSSU data

Private car ICE efficiency assumptions

Measure	Parameter	Segment	Case	Values			Source
				2008	2015	2020	
EU regulation	New car MJ/km (Test Cycle)	Petrol <1200cc	Pre-2008 trend	1.89	1.80	1.73	• Howley et al., "Energy in Transport", SEAI/EPSSU (2009) • AEA (2012)
			EU regulation	1.89	1.67	1.42	
		Petrol 1200-1900cc	Pre-2008 trend	2.41	2.36	2.33	
			EU regulation	2.39	2.02	1.71	
		Diesel 1200-1900cc	Pre-2008 trend	2.07	2.05	2.04	
			EU regulation	2.08	1.66	1.46	
		Diesel >1900cc	Pre-2008 trend	2.32	2.37	2.40	
			EU regulation	2.19	1.91	1.68	
		Petrol HEV	All	1.74	1.56	1.37	• AEA (2012)
		Diesel HEV	All	1.45	1.34	1.22	
		Petrol PHEV	All	1.37	1.20	1.02	
		Diesel PHEV	All	1.18	1.05	0.93	
		BEV	All	0.56	0.53	0.50	

Source: Element Energy analysis for SEAI

Re-balancing of the VRT has led to a strong and enduring shift towards the purchase of diesel cars

Sector and measure

Private cars:
VRT/AMT re-balancing

Description of methodology

- Re-balancing of the Vehicle Registration Tax (VRT) in July 2008 has already led to a strong improvement in the average energy efficiency of new vehicles purchased
- VRT re-balancing led to a clear shift in purchasing from petrol to diesel, strongly accelerating an existing trend
- No systematic shift in engine size has been observed as a result of the change
- ‘Pre-2008 trend’ models a continuation of the existing trend in ICE market share; ‘VRT/AMT’ models an enduring shift towards the purchase of diesel cars to 2020

ICE petrol and diesel share assumptions

Measure	Parameter	Segment	Case	Values			Source
				2008	2015	2020	
VRT/AMT re-balancing	New ICE vehicle petrol-diesel share	Petrol	Pre-2008 trend	70%	58%	49%	• CSO data • Rogan et al., Transportation Research Part A (2011) • Leinert et al., Energy Policy (2013)
			Shift to diesel	65%	25%	25%	
		Diesel	Pre-2008 trend	30%	42%	51%	
			Shift to diesel	35%	75%	75%	

Market share of ICE and ‘alternative fuel’ vehicles up to 2020 has been derived using Element Energy’s ECCo uptake model

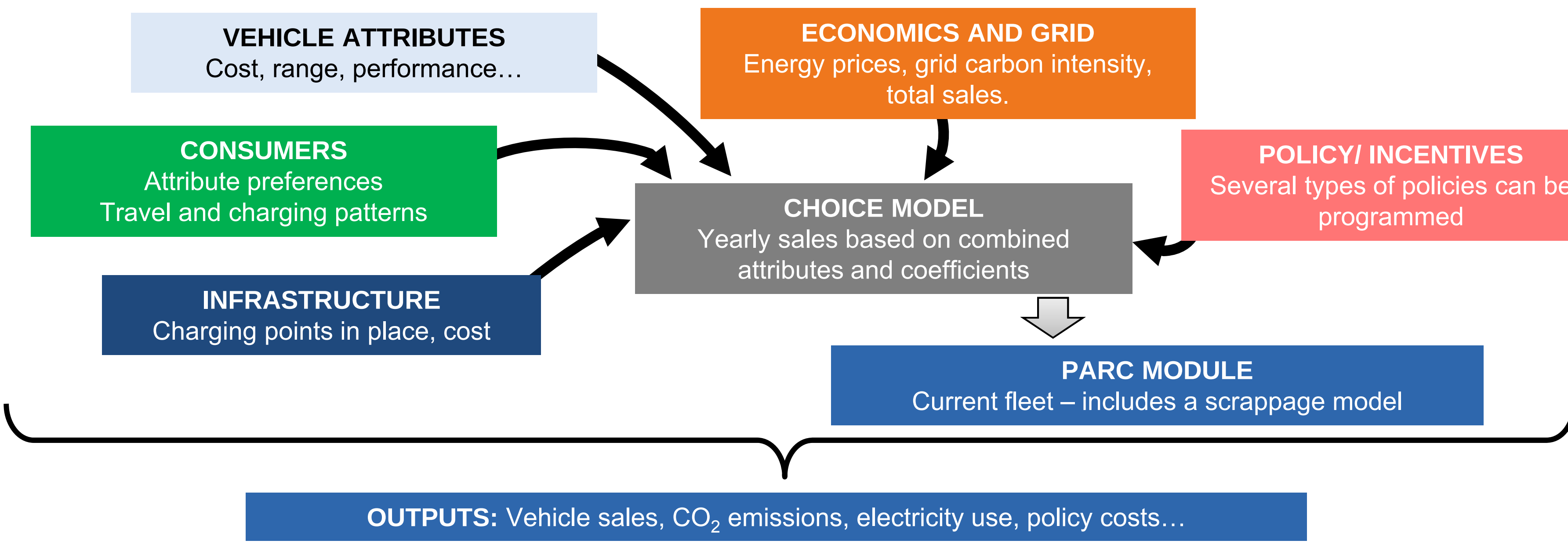
Sector and measure

Private cars: High AFV support

Description of methodology

- ECCo is a consumer choice model developed for Energy Technologies Institute in 2010-11, extended and updated for the UK Department for Transport in 2012
- It incorporates the Ricardo-AEA vehicle cost and performance data for a range of vehicles
- Uses consumer preference data from a survey of 2,700 UK new car buyers
- Powertrains included: ICE (conventional, stop-start, pure hybrid) and plug-in hybrid (PHEV, RE-EV) for both petrol and diesel, and BEV
- Prediction of the market share of each vehicle type is based on a multinomial logit model

Overview of ECCo (Electric Car Consumer Model)



ECCo has been updated with data on Irish taxation policy, grant schemes, electric vehicle charging point roll-out and fuel prices

Sector and measure

Private cars: High AFV support

Description of methodology

- ECCo updated extensively with data for the Irish case
- Updated with battery costs from recent Element Energy analysis

Key input data for ECCo

Key inputs based on Irish data

Policy levers
- Vehicle Registration Tax and Annual Motor Tax based on CO_2 emissions
- SEAI Electric Vehicle Grant scheme
- VAT and fuel duty

Charging infrastructure cost and roll-out
- Electric vehicle charging point roll-out in Ireland based on ESB[1] data and targets
- Consumer access to off-road parking at home and work in Ireland[2]

Fuel prices
- Fossil fuel price projections from SEAI

Other key inputs

Cost and performance of powertrain technologies
- Detailed database based on dataset compiled by Ricardo-AEA up to 2050[3]
- Battery costs updated for recent Element Energy analysis (2012)

Consumer behaviour
- Quantitative survey of 2,700 new car buyers in the UK

ECCo CHOICE MODEL

Technology uptake: market share of ICE, hybrid and electric vehicles

Source: Element Energy analysis for SEAI

[1]www.esb.ie/electric-cars (accessed 22/01/2014); [2]National Travel Survey, CSO (2009); [3]AEA (2012)

Choice model is based on Willingness to Pay data and consumer preferences derived from a survey of UK consumers

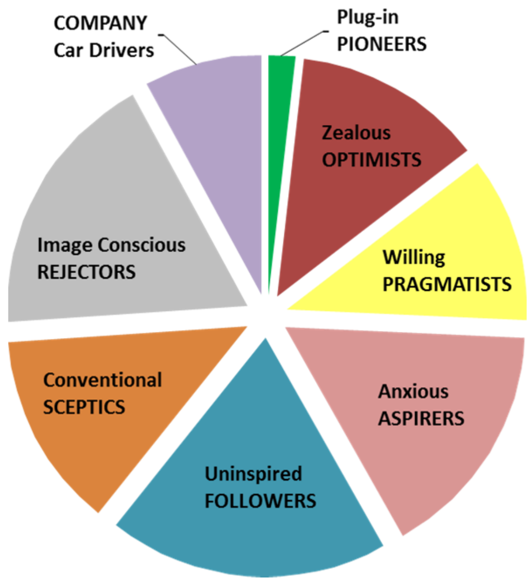
Sector and measure

Private cars: High AFV support

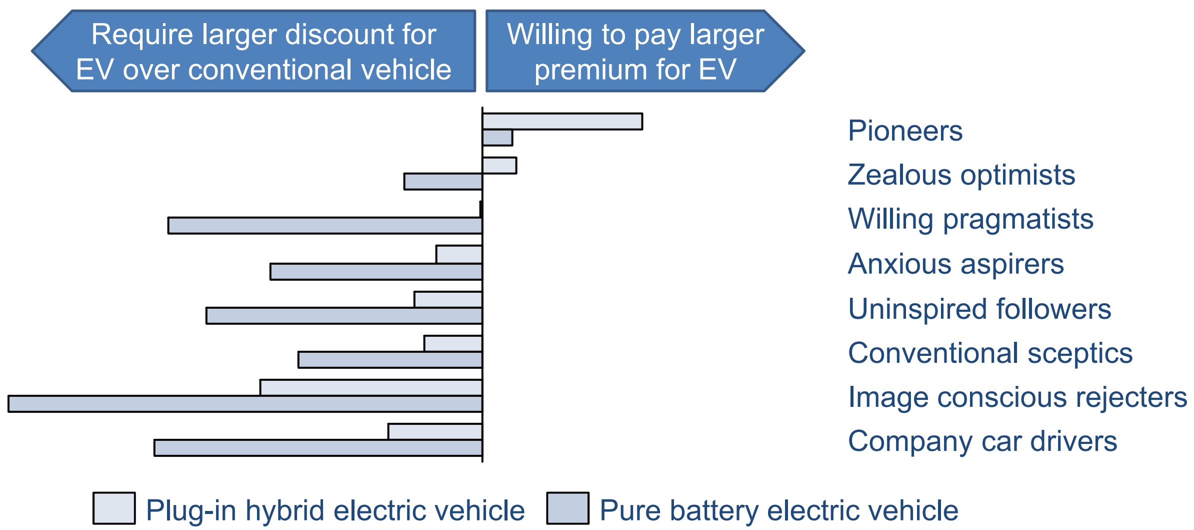
Description of methodology

- Survey found Willingness to Pay for vehicle attributes: price, running costs, electric range, acceleration and charging time, as well as 'symbolic' factors such as status, novelty and environmental impact)
- Most consumer segments have a bias <u>against</u> electric vehicles (EVs), particularly pure battery EVs, citing concerns such as limited range, practicality of re-charging and an 'embarrassment' factor
- A small fraction of consumers, 'Pioneers' and 'Optimists', are willing to pay a premium for a plug-in EV with the same key attributes as a conventional vehicle

Consumer segmentation for EV market



Willingness to Pay for EV versus conventional vehicle



Source: Element Energy analysis for SEAI

Effect on uptake of purchase grants and tax exemptions for PHEVs and BEVs is modelled in ECCo

Sector and measure

Private cars: High AFV support

Description of methodology

- In the 'Baseline AFV support' case, effect of the existing SEAI Electric Vehicle Grant for PHEVs and BEVs is modelled
- In the 'High AFV support' case, strong support for EVs remains in place up to 2020
- A scenario with no AFV incentive, 'No AFV support', is modelled for comparison

Scenarios for EV support

Measure	Case	Segment	Description 2011-2014	Description 2015-2020
High AFV	No AFV support	BEV	No support	No support
		PHEV	No support	No support
	Baseline AFV support	BEV	20% of purchase price, capped at €10,000*	No support
		PHEV	22% of purchase price, capped at €7,500*	No support
	High AFV support	BEV	20% of purchase price, capped at €10,000	24% of purchase price, capped at €10,000
		PHEV	22% of purchase price, capped at €7,500	25% of purchase price, capped at €7,500

Source: Element Energy analysis for SEAI

* Based on purchase of typical BEV or PHEV costing €49k and €33k respectively in 2013

Effect on uptake of purchase grants and tax exemptions for PHEVs and BEVs is modelled in ECCo

Sector and measure

Private cars: High AFV support

Description of methodology

- In the 'Baseline AFV support' case, effect of the existing SEAI Electric Vehicle Grant for PHEVs and BEVs is modelled
- In the 'High AFV support' case, strong support for EVs remains in place up to 2020
- A scenario with no AFV incentive, 'No AFV support', is modelled for comparison

ECCo model outputs: market share for EVs in the various support scenarios

Measure	Parameter	Segment	Case	Values			Source
				2008	2015	2020	
High AFV	Market share of new vehicles	PHEV	No AFV support	0.0%	0.7%	3.8%	• ECCo powertrain uptake model, Element Energy (2013)
			Baseline AFV support	0.0%	0.7%	3.9%	
			High AFV support	0.0%	2.1%	9.6%	
		BEV	No AFV support	0.0%	0.0%	0.1%	
			Baseline AFV support	0.0%	0.0%	0.1%	
			High AFV support	0.0%	0.2%	0.3%	

Source: Element Energy analysis for SEAI

Potential savings of modal shift from private cars to walking, cycling and public transport are estimated

Sector and measure

Transport: Modal shift

Description of methodology

- National Travel Survey (CSO, 2009) used to disaggregate passenger-km by mode, distance and purpose
- Modal shift from private car to walking and cycling: fraction of all driven/walked/cycled journeys (all purposes) less than 4 km undertaken by walking increases to 12.5%, and fraction of all driven/walked/cycled journeys less than 6 km undertaken by cycling increases to 12.5%
- Modal shift to public transport: decrease in the modal share of private car driving for commuting (to work and education) from 66% to 55% of journeys by 2020 (corresponding to achieving half the shift targeted in the "Smarter Travel" policy document)

Scenarios for modal shift

Measure	Parameter	Case	Mode	Values			Source
				2008	2015	2020	
Modal shift	Modal share of all journeys	Baseline	Private car driver	64%	64%	64%	• "National Travel Survey", CSO (2009) • "Smarter Travel: A Sustainable Transport Future", Department of Transport (2009) • Element Energy analysis
			Walk	15%	15%	15%	
			Cycle	1%	1%	1%	
			Public bus	4%	4%	4%	
			Other	16%	16%	16%	
		Modal shift*	Private car driver	64%	61%	58%	
			Walk	15%	16%	17%	
			Cycle	1%	3%	5%	
			Public bus	4%	4%	4%	
			Other	16%	15%	15%	

Source: Element Energy analysis for SEAI

*N.B. this corresponds to the "Modal shift (Moderate)" option in the accompanying model

Potential savings of an eco-driving scheme estimated using sources including real-world data from the Dutch scheme

Sector and measure

Private cars: Eco-driving

Description of methodology

- Effect of an Eco-driving scheme modelled through improvements in the ‘Real-World’ (RW) factor (the correction factor between Test Cycle MJ/km values and the MJ/km typically achieved on the road)
- Base case RW factors for each car segment are taken from AEA/CCC (2012)
- Based on the literature, a reduction of up to 5% in RW factor is possible including the effects of driving school curricula, re-education of licensed drivers, promotion of fuel-saving in-car devices (incl. on-board computers, gear shift indicators) and education regarding optimal tyre pressure
- The eco-driving measure here entails a reduction in RW factor of 2%*. We note that this still entails widespread uptake of eco-driving behaviour.

Eco-driving assumptions

Measure	Parameter	Segment (selected examples)	Case	Values			Source
				2008	2015	2020	
Eco-driving	Real-World (RW) factor	Petrol 1200-1900cc	Baseline	1.20	1.20	1.20	• AEA (2012) • Wilbers et al., “The Dutch national eco-driving programme Het Nieuwe Rijden: A success story” (2007) • Smokers et al., “Review and analysis of the reduction potential and costs of technological and other measures to reduce CO_2-emissions from passenger cars” (2006) • Barkenbus, Energy Policy (2010) • “Easy on the Gas – The effectiveness of eco-driving”, RAC (2012)
			Eco-driving	1.20	1.19	1.18	
		Diesel 1200-1900cc	Baseline	1.22	1.22	1.23	
			Eco-driving	1.22	1.22	1.21	
		BEV	Baseline	1.25	1.25	1.25	
			Eco-driving	1.25	1.24	1.23	

Source: Element Energy analysis for SEAI

*N.B. this corresponds to the “Eco-driving (Moderate)” option in the accompanying model

Potential savings due to a behavioural change involving a shift towards the use of smaller vehicles is quantified

Sector and measure

Private cars: Shift to smaller vehicle segment

Description of methodology

- Consider effect of a shift in market share from larger vehicle segments to smaller vehicle segments (as a behaviour change)
- Potential shift based on historical market shares and market shares of proxy countries

Scenarios for segment share of ICE vehicles

Measure	Parameter	Segment	Case	Values			Source
				2008	2015	2020	
Shift to smaller vehicle segment	Market share of new ICE vehicles	<1200 cc	Baseline	8%	10%	10%	• CSO data • Daly et al., Energy Policy (2011) • "European Vehicle Market Statistics", ICCT (2011)
			Shift to smaller segment	8%	13%	17%	
		1200-1900 cc	Baseline	74%	70%	70%	
			Shift to smaller segment	74%	70%	69%	
		>1900 cc	Baseline	19%	20%	20%	
			Shift to smaller segment	19%	17%	14%	

Analysis of savings potential in public and freight transport is based on an energy intensity model

Sub-sector	Key aspects of methodology
Public passenger: buses	• High-level analysis combining data from CSO National Travel Survey 2009, CSO Transport Omnibus, SEAI/EPSSU Energy in Transport and AEA/CCC vehicle database* • In addition to **modal shift**, effect of **improvement in bus efficiency** and of **eco-driving** modelled using literature sources
Road freight: HGVs	• **HGV freight baseline** projection of activity and energy based on academic literature** and is **consistent with our economic growth assumptions** • Potential **improvement in HGV efficiency** based on UK DfT National Transport Model • Potential effect of a **shift to larger weight class HGVs** and **eco-driving** quantified in ‘what if?’ scenarios
Road freight: LDVs	• **Particular absence of detailed and reliable data** on LDVs • High-level analysis estimating LDV activity using CSO data and combining with AEA/CCC data, linking future activity projection to GDP • Effects of **EU regulation** for LDV efficiency and of **eco-driving** are modelled

Source: Element Energy analysis for SEAI

* A review of the efficiency and cost assumptions for road transport vehicles to 2050”, AEA/CCC (2012)
** Whyte et al., Energy 50 (2013)

Baseline public transport activity derived using CSO and SEAI data

Sector	Description of methodology
Public transport	• Public transport analysis based on energy intensity model (with activity metric MJ/vehicle-km), not a stock model as for private cars • Baseline vehicle-km derived from SEAI/EPSSU and CSO data • Passenger-km derived from the analysis of the CSO National Travel Survey and private car sector analysis • Growth in passenger-km assumed to be small enough in all cases that vehicle-km can be assumed fixed

Public passenger vehicle-km and passenger-km assumptions

Case	Parameter	Values			Source
		2008	2015	2020	
Baseline	Vehicle-km (million km)	311	311	311	• "Energy in Transport", SEAI/EPSSU (2009) • "Transport Omnibus", CSO (2011) • Vehicle-km assumed fixed up to 2020
	Passenger-km (million km)	2,244	2,460	2,640	• "National Travel Survey", CSO (2009); passenger-km based on analysis of NTS such that modal share is consistent with private car sector analysis

Source: Element Energy analysis for SEAI

Baseline freight activity derived using CSO, SEAI and literature data

Sector	Description of methodology
Freight	• Analysis of freight (HGV and LDV) based on energy intensity model (with activity metric tonne-km for HGVs and vehicle-km for LDVs) • HGVs: total tonne-km and Baseline shares by weight class to 2020 based on a study by Whyte et al. in which HGV tonne-km linked in detail with economic activity • LDVs: total vehicle-km in 2008 estimated using CSO data; activity to 2020 linked to economic growth projections

Freight activity assumptions

	Parameter	Weight class	Values 2008	2015	2020	Source
HGVs	Total tonne-km (million)	All (> 2 t)	17,314	14,654	17,314	• Whyte et al., Energy (2013) • “Traffic emissions – unit emissions of vehicles in Finland”, VVT, LIPASTO (2007)
	Weight class tonne-km shares	2–5 t	3%	Varies by scenario		
		5–7.5 t	4%			
		7.5–10 t	8%			
		10–12.5 t	29%			
		> 12.5 t	57%			
LDVs	Total vehicle-km (million)	All (< 2 t)	5,751	5,659	6,737	• “Transport Omnibus 2011”, CSO (2011); vehicle-km travelled by LDVs estimated as difference between vehicle-km travelled by ‘Goods vehicles’ (p.66) and ‘Road freight’ (p.79) • “Energy in Transport”, SEAI/EPSSU (2009); vehicle-km to 2020 estimated by scaling with economic growth

Source: Element Energy analysis for SEAI

Potential savings due to an improvement in bus efficiency and bus eco-driving are quantified

Sector and measure

Public transport: Improved bus efficiency and eco-driving

Description of measure and methodology

- Public transport analysis based on energy intensity model (with activity metric MJ/vehicle-km), not a stock model as for private cars
- Potential for technological improvement in bus efficiency taken from AEA/CCC (2012)
- Fleet average efficiency estimated assuming a stock turnover of 12 years
- Potential for eco-driving based on literature and SEAI case studies, and modelled using a Real-World factor as for private cars

Public transport efficiency and eco-driving scenarios

Measure	Parameter	Case	Values 2008	2015	2020	Source
Improved bus efficiency	Fleet average MJ/km (Test Cycle)	Baseline	12.86	12.86	12.86	• AEA (2012)
		Improved bus efficiency	12.86	12.77	12.59	
Eco-driving (bus)*	Real-World (RW) factor	Baseline	1.09	1.09	1.09	• AEA (2012) • SEAI case studies
		Eco-driving	1.09	1.08	1.07	

Source: Element Energy analysis for SEAI

*N.B. this corresponds to the "Eco-driving (Moderate)" option in the accompanying model

Improvements in HGV efficiency, eco-driving and a shift to higher weight class HGVs are included in the analysis

Sector and measure

HGVs: Improved efficiency, shift to higher weight class, eco-driving

Description of measure and methodology

- HGV analysis based on energy intensity model (with activity metric tonne-km)
- HGVs disaggregated into five weight classes (only two shown below for brevity)
- MJ/tonne-km values for the weight classes taken from Whyte et al. (2013), and the potential for efficiency improvements based on data from the UK National Transport Model
- Effect of a shift in freight towards higher weight class HGVs quantified
- Potential for eco-driving based on literature and SEAI case studies

HGV efficiency, weight class shift and eco-driving scenarios

Measure	Parameter	Case	Weight class	Values 2008	2015	2020	Source
Improved HGV efficiency	Fleet average MJ/tonne-km	Baseline	<12.5 t	1.42	1.42	1.42	• Whyte et al., Energy 50 (2013) • "Road Transport Forecasts 2013", Department for Transport (2013)
			>12.5 t	1.13	1.13	1.13	
		Improved efficiency	<12.5 t	1.42	1.39	1.35	
			>12.5 t	1.13	1.11	1.07	
Shift to higher weight class*	Tonne-km shares	Baseline	<12.5 t	43%	43%	43%	• Whyte et al., Energy 50 (2013) • "Road Transport Forecasts 2013", Department for Transport (2013) • "Energy Efficiency Trends in the Transport sector in the EU: Lessons from the ODYSSEE MURE project", Enerdata (2012)
			>12.5 t	57%	57%	57%	
		Shift to higher weight class	<12.5 t	43%	37%	25%	
			>12.5 t	57%	63%	75%	
Eco-driving (HGV)**	Reduction in MJ/km	Baseline	All	0%	0%	0%	• SEAI case studies • Barkenbus, Energy Policy (2010)
		Eco-driving	All	0%	1%	2%	

Source: Element Energy analysis for SEAI

*N.B. this corresponds to the "Weight class shift (Moderate)" option in the accompanying model

**N.B. this corresponds to the "Eco-driving (Moderate)" option in the accompanying model

Improvements in LDV efficiency and eco-driving are included in the analysis

Sector and measure

LDVs: EU regulation, eco-driving

Description of measure and methodology

- LDV analysis based on energy intensity model (with activity metric vehicle-km)
- LDVs, unlike HGVs, are covered by EU regulation 443/2009
- New LDV MJ/km based on AEA/CCC (2012), and fleet average MJ/km estimated assuming a stock turnover of 8 years
- Potential for eco-driving based on literature and modelled using a Real-World factor

LDV efficiency and eco-driving scenarios

Measure	Parameter	Case	Values			Source
			2008	2015	2020	
EU regulation	Fleet average MJ/km (Test Cycle)	Pre-2008 trend	2.43	2.43	2.43	• AEA (2012)
		EU regulation	2.43	2.35	2.26	
Eco-driving (LDV)*	Real-World (RW) factor	Baseline	1.20	1.20	1.20	• AEA (2012) • SEAI case studies
		Eco-driving	1.20	1.19	1.18	

Source: Element Energy analysis for SEAI

*N.B. this corresponds to the "Eco-driving (Moderate)" option in the accompanying model

Contents

Technical potential in industry derived by applying a set of efficiency measures to sub-sector archetypes profiled by energy end-use

Process	Key aspects of methodology
Derive Baseline energy consumption in industry by sub-sector and fuel up to 2020	• 12 industry sub-sector groups modelled, **covering all industrial energy consumption** • **Growth of each industry sub-sector to 2020** taken from SEAI forecasts (LEAP modelling) to account for structural changes
Develop industry sub-sector 'archetypes' defined by split in energy end-use	• Archetypes developed with UK data (as a close proxy in the absence of corresponding data for Ireland) to estimate how energy is typically used in each sub-sector • **Nine energy end-use categories** considered, including low and high temperature process heat, motors, lighting, HVAC, refrigeration and others
Determine energy saving potential of a set of measures for each end-use category	• **Nine energy efficiency measures chosen** based on savings potential in previous published studies, covering all end-use categories • Savings potential estimated using a range of published literature including SEAI Working Group reports, academic studies and Element Energy analysis
Estimate technical potential energy savings	• Final and primary energy savings potential estimated for each measure and each sub-sector

Source: Element Energy analysis for SEAI

Industry Baseline final energy consumption is based on SEAI projections

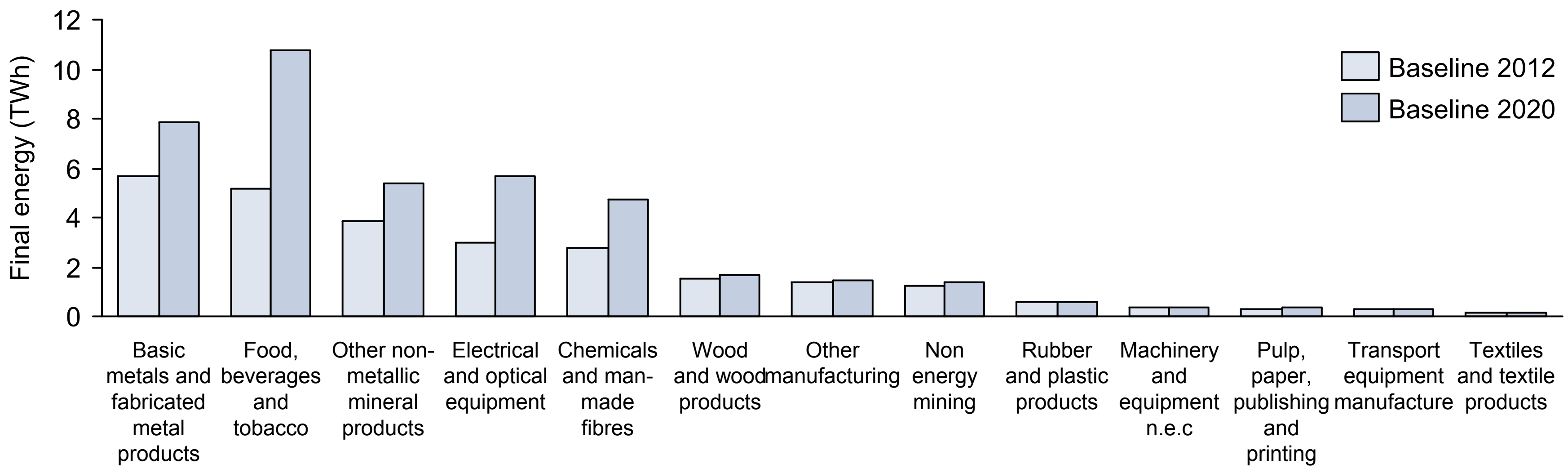
Sector

Industry

Description of methodology

- SEAI Energy Statistics Databank includes final energy consumption of Irish industry divided into 13 NACE groups, here referred to as 'sub-sectors'
- All 13 NACE groups are included in this analysis
- Industrial activity in 2020 is taken from the SEAI forecast developed using the LEAP model

Baseline industry final energy consumption



Energy end-use profiles for each industry sub-sector are derived

Sector

Industry

Description of methodology

- Using UK data, energy consumption in each industry sub-sector profiled by end-use
- Nine end-use categories are considered, including high and low temperature heating processes, motor processes, refrigeration, lighting and compressed air systems
- End-use profiles of each sub-sector assumed fixed over the modelling time period

End-use fractions for each sub-sector

Sub-sector	High T process	Low T process	Drying & separation	Motors	Compressed air	Lighting	Refrigeration	Space heating	Other
Basic metals and metal products	63%	14%	0%	4%	1%	1%	0%	8%	8%
Food, beverages and tobacco	0%	63%	7%	8%	0%	0%	8%	0%	14%
Other non-metallic mineral products	73%	5%	5%	7%	0%	0%	0%	1%	8%
Electrical and optical equipment	3%	29%	0%	2%	5%	16%	0%	39%	6%
Chemicals and man-made fibres	10%	28%	16%	21%	5%	0%	6%	2%	11%
Wood and wood products	0%	25%	14%	39%	9%	0%	0%	7%	7%
Other manufacturing	0%	24%	14%	39%	9%	0%	0%	7%	7%
Non energy mining	65%	5%	5%	17%	0%	0%	0%	1%	7%
Rubber and plastic products	0%	22%	12%	44%	10%	0%	0%	6%	6%
Machinery and equipment n.e.c	6%	51%	0%	1%	4%	5%	0%	29%	3%
Pulp, paper, publishing and printing	0%	27%	42%	6%	8%	0%	0%	7%	10%
Transport equipment manufacture	3%	38%	0%	1%	4%	4%	0%	43%	7%
Textiles and textile products	0%	36%	10%	15%	0%	0%	0%	39%	0%

Source: Element Energy analysis for SEAI

"Energy Consumption in the UK" (DECC, 2013)

Energy efficiency measures are applied to individual energy end-use categories

Sector

Industry

Description of methodology

- Energy efficiency measures are then applied to individual energy end-use categories as shown in the table below

Applicability of efficiency measures to end-use categories

Measure	High T process	Low T process	Drying & separation	Motors	Compressed air	Lighting	Refrigeration	Space heating
Process integration and heat recovery - high T processes	•							
Process integration and heat recovery - low T processes		•	•					
Steam system efficiency		•						
Motor efficiency				•				
Compressed air systems efficiency					•			
Lighting efficiency						•		
Refrigeration efficiency							•	
HVAC and ventilation efficiency								•
CHP	Savings applied to primary energy							

Source: Element Energy analysis for SEAI

Technical savings potential of measures estimated using SEAI sources, third-party literature sources and Element Energy analysis

Sector	Description of methodology
Industry	• Savings potential of each measure, as a fraction of the end-use category consumption, derived from sources as described below

Technical savings potential of measures

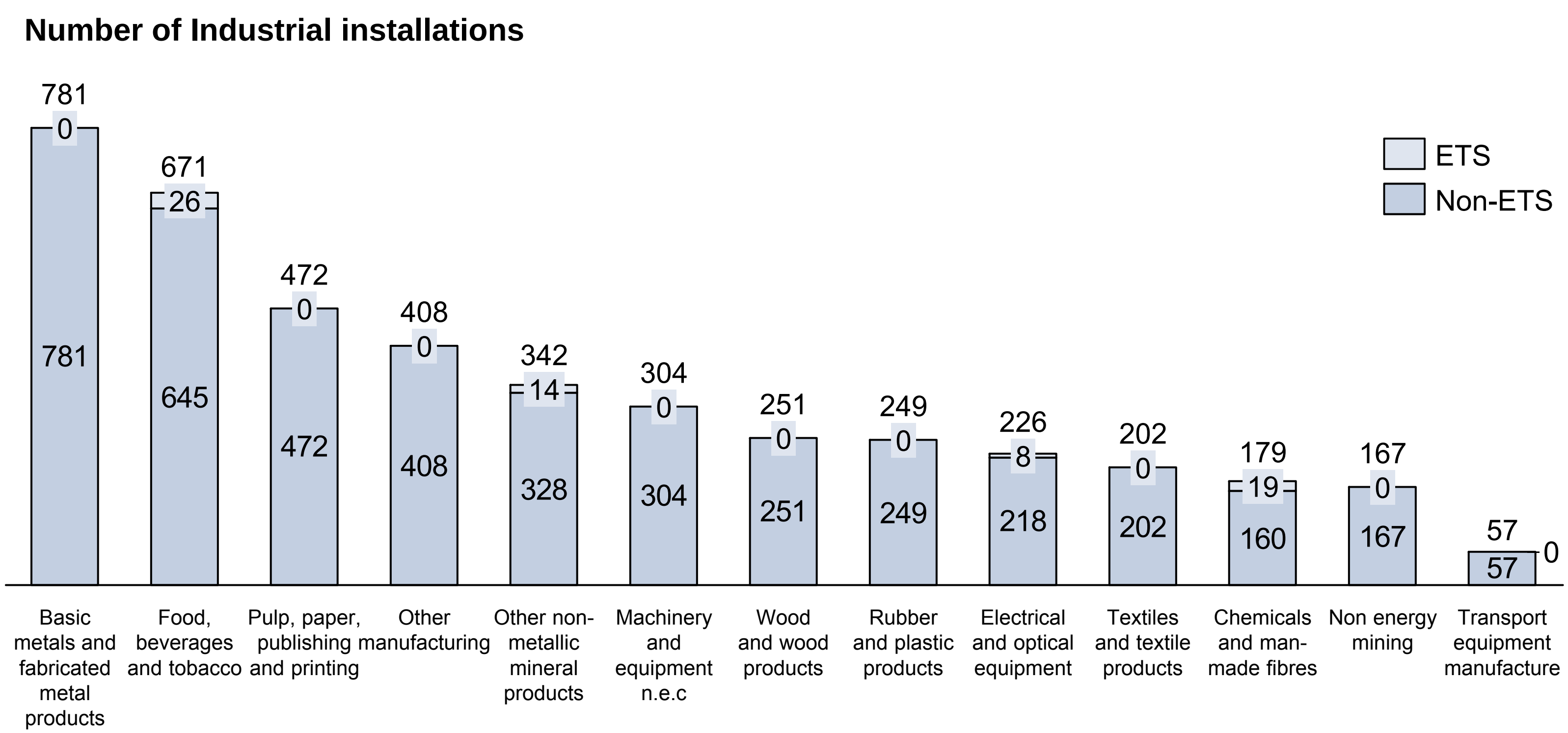
Measure	Technical potential (% of applicable end-use category)	Source
Process integration and heat recovery - high T processes	0-20%	• Varying by sub-sector • Element Energy analysis • McKenna & Norman, Energy Policy 38 (2010) • "Ireland's Low Carbon Opportunity", SEI/McKinsey (2009)
Process integration and heat recovery - low T processes	0-20%	• Element Energy analysis • McKenna & Norman, Energy Policy 38 (2010) • Law et al., Applied Thermal Engineering 53 (2013) • "Ireland's Low Carbon Opportunity", SEI/McKinsey (2009)
Steam system efficiency	0-15%	• Varying by sub-sector • Steam systems assumed to account for 10% of low T processes • "Tracking Industrial Energy Efficiency and CO2 Emissions", IEA (2007)
Motor efficiency	20%	• "Tracking Industrial Energy Efficiency and CO2 Emissions", IEA (2007) • "Energy-Efficiency Policy Opportunities for Electric Motor-Driven Systems", IEA (2011)
Compressed air systems efficiency	30%	• "Tracking Industrial Energy Efficiency and CO2 Emissions", IEA (2007) • Dyer et al., Energy Policy 36 (2008)
Lighting efficiency	19%	• Element Energy analysis (based on the survey of commercial buildings in Ireland)
Refrigeration efficiency	24%	• "Refrigeration Special Working Group Project Report 2008", SEI (2009) • "CTG046 Technology Guide: Refrigeration Systems", Carbon Trust (2011)
HVAC and ventilation efficiency	14%*	• HVAC Working Group Special Spin II Report 2008 (SEI, 2009)
CHP	Varies	• Assume for suitable installations that all electricity demand on-site is met by CHP; non-electrical fuel consumption increases according to the reduced thermal efficiency • Implemented in 15% of sites by 2020 • "Combined Heat and Power in Ireland: 2012 update", SEAI (2012) • "Ireland's Low Carbon Opportunity", SEI/McKinsey (2009)

Source: Element Energy analysis for SEAI

*Only applied to non-electrical fraction of space heating energy use

Industrial installations stock

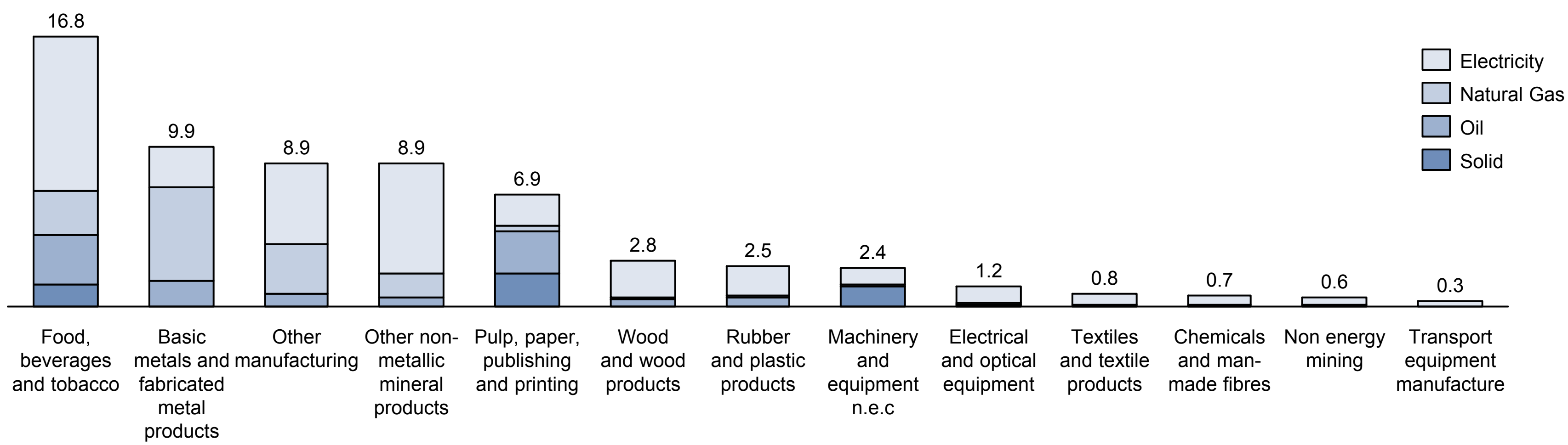
Industrial installations stock (total ~4,300)



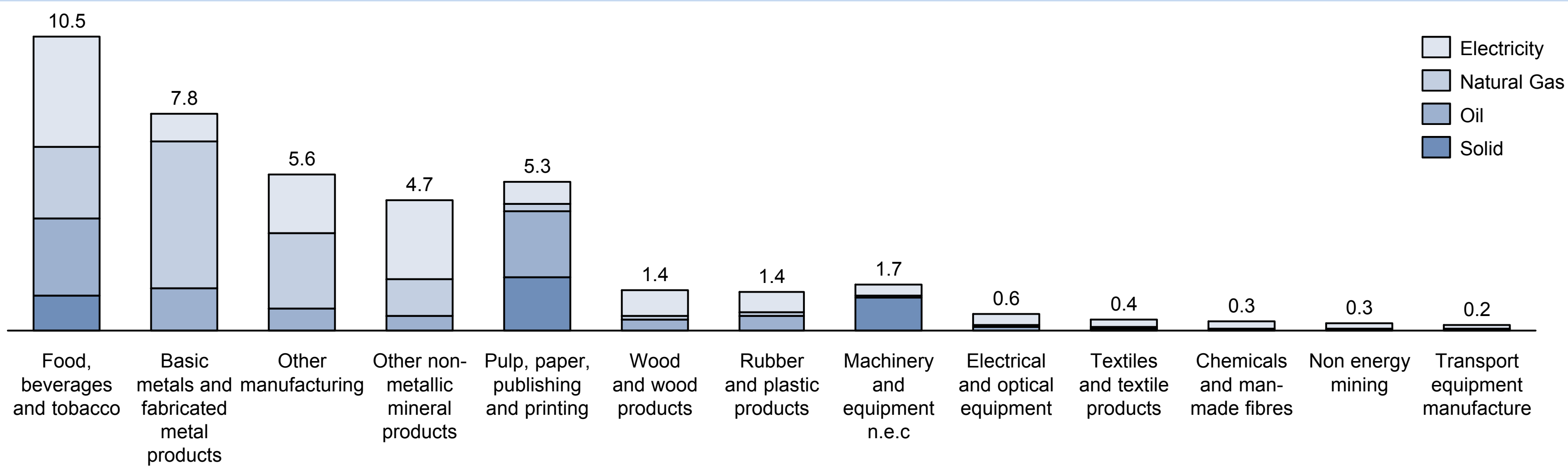
Source: Element Energy analysis for SEAI

Baseline energy consumption – Industry

Primary energy demand by fuel type in the industry sector – 2020 forecast (Total = ~63 TWh)



Final energy demand by fuel type in the industry sector – 2020 forecast (Total = ~42 TWh)



Source: Element Energy analysis for SEAI

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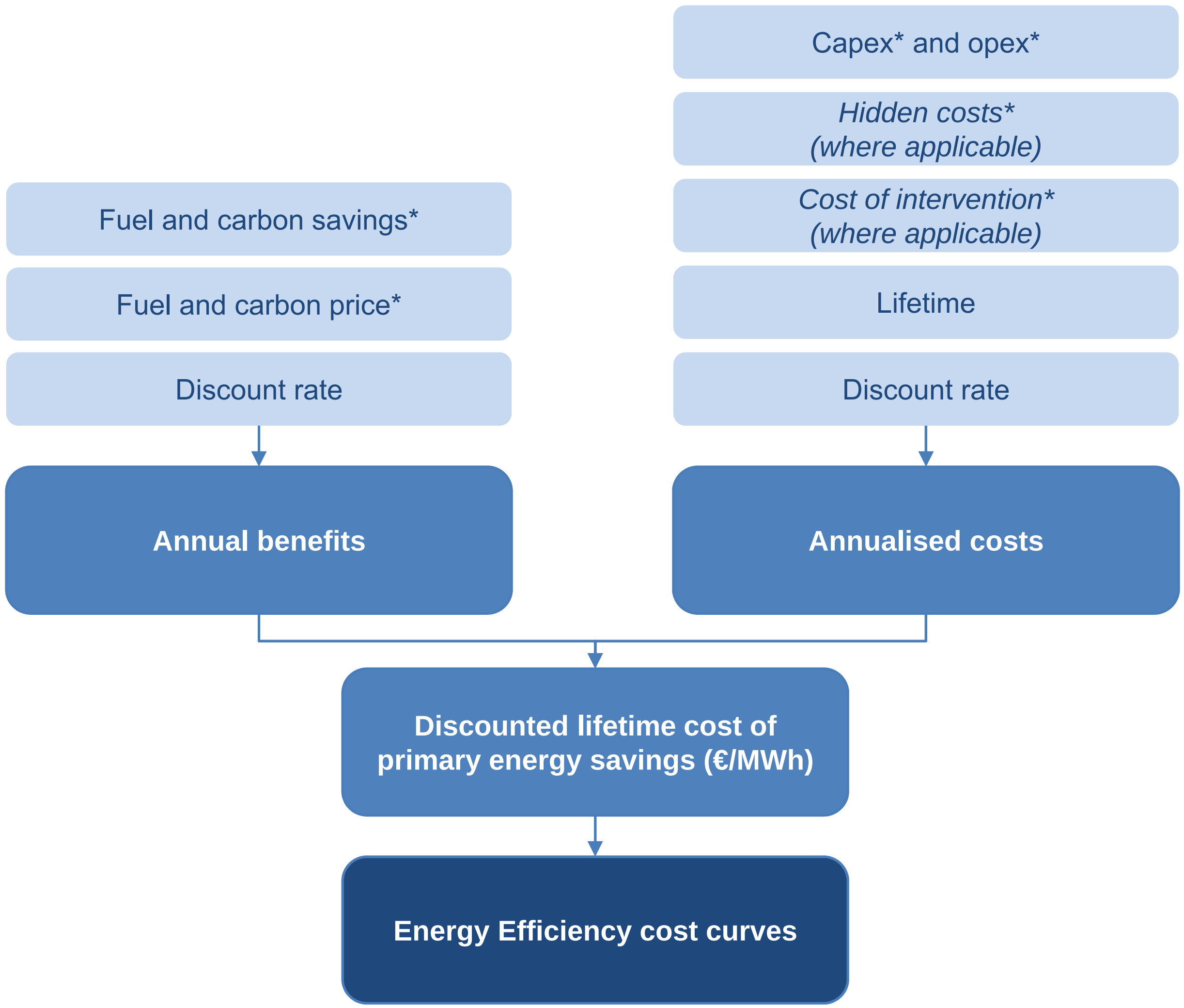
Energy Efficiency cost curves of each measure and package have been derived using literature cost and lifetime data and suitable discount rates



Source: Element Energy analysis for SEAI

*All costs and prices are inflated to 2013 prices

Energy Efficiency cost curves of each measure and package have been derived using literature cost and lifetime data and suitable discount rates

Annualised cost

$$Annualised\ cost = \frac{i\ \times Present\ value\ of\ capital\ cost}{1 - \frac{1}{(1+i)^n}} + Annual\ operating\ cost$$

n = lifetime of measure (in years) *

i = discount rate

Annual benefit

$$Annual\ benefit = Value\ of\ annual\ fuel\ and\ carbon\ savings$$

(Note: this changes over time with the fuel and carbon price)

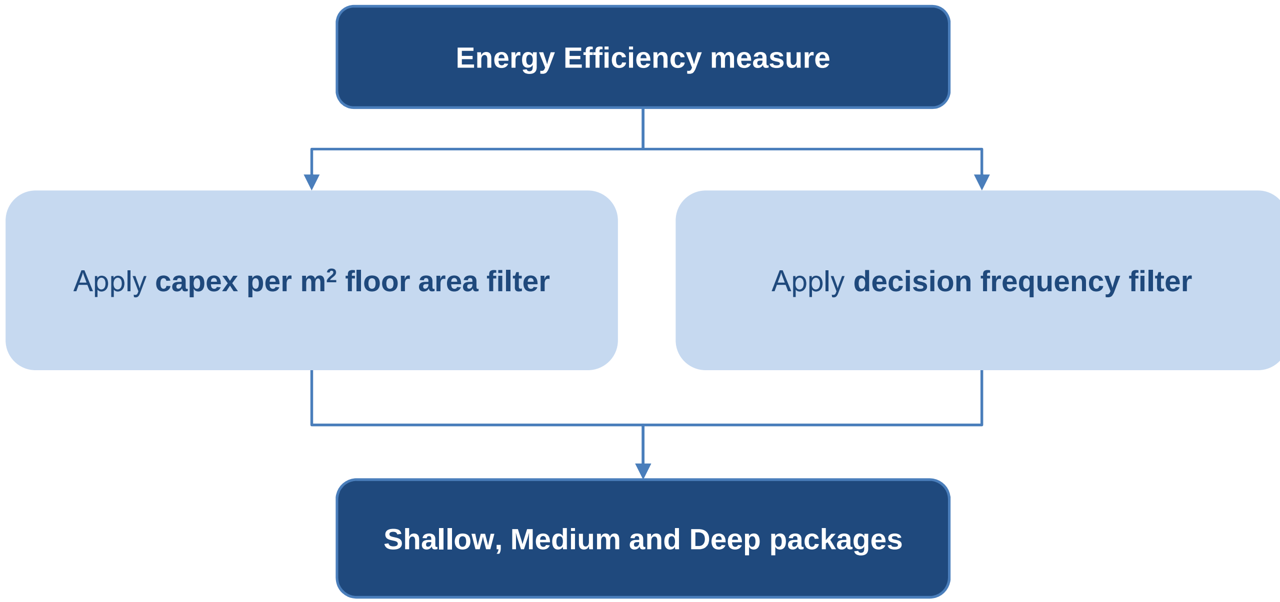
Discounted lifetime cost of primary energy savings (€/MWh)

$$Discounted\ lifetime\ cost\ of\ primary\ energy\ savings = \sum_{Start\ Year}^{Start\ Year\ +39*} \frac{Discounted\ annualised\ cost - Discounted\ annual\ benefit}{Discounted\ annual\ primary\ energy\ saving}$$

Source: Element Energy analysis for SEAI

*The lifetime of each individual measure is used for the annualised cost calculation. However, for the calculation of discounted lifetime cost of energy savings, annual costs (including annualised CAPEX) and benefits over a 40-year period are included in the analysis for all measures.

For all buildings sectors, packages of measures were formed based on the corresponding capex requirement and decision frequency



Contents

Cost table: Commercial and Public buildings

Measure	Cost unit	Cost	Source	Comment
Cavity wall insulation	€/m2 fabric capex (2013€)	5.6	Cost Optimal Calculations and Gap Analysis for recast EPBD for Non-residential Buildings	Cost available for U=0.3
Solid wall insulation	€/m2 fabric capex (2013€)	36.9	Cost Optimal Calculations and Gap Analysis for recast EPBD for Non-residential Buildings	Value for external solid wall insulation. Cost available for U=0.36
Energy efficient glazing	€/m2 fabric capex (2013€)	265	Cost Optimal Calculations and Gap Analysis for recast EPBD for Non-residential Buildings	Cost available for U=1.8
Roof insulation	€/m2 fabric capex (2013€)	20.3	Cost Optimal Calculations and Gap Analysis for recast EPBD for Non-residential Buildings	Cost available for U=0.25
Draught proofing	€/m per circumference of windows and doors capex (2013€)	1.7	Carbon Trust guide CTL063	Based on the cost of rubber sealing strip
Energy efficient lighting	€/m2 capex for LED lighting (2013€)	4.5-18.7	McKinsey, 2012; Ramroth et al., 2008.; Energy Star "Light Bulb Calculator"	Depending on the lighting usage hours and illuminance requirements of the building.
Energy efficient lighting	€/m2 annual capex for incandescent lighting (2013€)	0.3-0.9	McKinsey, 2012; Ramroth et al., 2008.; Energy Star "Light Bulb Calculator"	Depending on the lighting usage hours and illuminance requirements of the building.
Energy efficient office equipment	€ capex premium per MWh annual consumption (2013€)	268	SEI/McKinsey, 2009; Element Energy analysis	Capex for typical stock of office appliances based on Element Energy analysis; premium on capex for high efficiency office equipment is 12% based on SEI/McKinsey report
Energy efficient refrigeration	€ capex premium per MWh annual consumption (2013€)	8.7	Stanford University Energy Modelling Forum, 2011; Carbon Trust guide CTG046	Capex for typical refrigeration display case from Stanford Energy Modelling Forum; premium on capex for high efficiency refrigeration is 10% based on Carbon Trust CTG046
More efficient boiler replacement (gas, oil)	€ capex per kW (2013€) of more efficient boiler	89-127	NERA/AEA, 2009	Depending on the boiler size; 92% efficiency
More efficient boiler replacement (gas, oil)	% capex premium vs counterfactual 86% boiler	50%	"Zero carbon non-domestic buildings: Phase 3 final report", AECOM, 2011	In cost curves, measure applied to all buildings in single year; hence, we take the average of the premium and the full cost.
More efficient boiler replacement (gas, oil)	Annual opex (% of capex)	3.0%	NERA/AEA, 2009	
Heat pump	€ capex per kW (2013€)	745	NERA/AEA, 2009	Air-source heat pump; SEEF=2.7
Heat pump	Annual opex (% of capex)	1.0%	NERA/AEA, 2009	
Heating controls	€/m2 floor area capex (2013€)	0.65	Enviros, 2006; Element Energy analysis	Capex of thermostatic radiator vales from Enviros; capex of programmable room thermostat and heating control requirement per floor area based on Element Energy analysis
Lighting controls	€/m2 floor area capex (2013€)	16.5	"Zero carbon non-domestic buildings: Phase 3 final report", AECOM, 2011	
More efficient air conditioning	€/m2 floor area capex (2013€) of more efficient chiller	26.1	Cost Optimal Calculations and Gap Analysis for recast EPBD for Non-residential Buildings	SEER=4.5; costs for three buildings are given, from which a cost per floor area is derived
More efficient air conditioning	% capex premium vs counterfactual SEER=3.5 chiller	8.0%	Cost Optimal Calculations and Gap Analysis for recast EPBD for Non-residential Buildings	
More efficient air conditioning	Annual opex (% of capex)	7.5%	Cost Optimal Calculations and Gap Analysis for recast EPBD for Non-residential Buildings	

Lifetime table: Commercial and Public buildings

Measure	Lifetime (years)	Source
Cavity wall insulation	40	Element Energy "Uptake of Energy Efficiency in Buildings", Report for CCC (2009)
Solid wall insulation	40	Element Energy "Uptake of Energy Efficiency in Buildings", Report for CCC (2009)
Energy efficient glazing	25	Element Energy "Uptake of Energy Efficiency in Buildings", Report for CCC (2009)
Roof insulation	40	Element Energy "Uptake of Energy Efficiency in Buildings", Report for CCC (2009)
Draught proofing	25	Element Energy "Uptake of Energy Efficiency in Buildings", Report for CCC (2009)
Energy efficient lighting	50,000 (LED); 2,000 hours (incandescent)	U.S. Department of Energy, Buildings Energy Data Book 2011
Energy efficient office equipment	8	Element Energy "Uptake of Energy Efficiency in Buildings", Report for CCC (2009)
Energy efficient refrigeration	10	Carbon Trust guide CTG046
More efficient boiler replacement (gas, oil)	15	CIBSE Lifetimes of Building Energy Services
Heat pump	15	CIBSE Lifetimes of Building Energy Services
Heating controls	15	Element Energy "Uptake of Energy Efficiency in Buildings", Report for CCC (2009)
Lighting controls	20	CIBSE Lifetimes of Building Energy Services
More efficient air conditioning	15	CIBSE Lifetimes of Building Energy Services

Source: Element Energy analysis for SEAI

Cost and lifetime table: Public utilities (Street lighting)

Cost data			**Source**
Average LED lighting capital	£505 (€610)	per unit	Green Investment Bank, 2014, Low energy street lighting: making the switch
Existing incandescent cost	£50 (60)	per unit	Scottish Futures Trust, 2013, Street Lighting Toolkit
Technical data			
Total electricity consumption per annum	205	GWh/year final energy	SEAI, 2012, Energy Efficiency & Public Lighting Overview Report
Number of public lighting	420,000	Units	SEAI, 2012, Energy Efficiency & Public Lighting Overview Report
Column lifetime	40	years	CSS Street lighting project, 2007, Invest to save, sustainable street lighting
Lantern lifetime	20	years	
Annual operating hours per lighting	4,150	hours	SEAI, 2012, Energy Efficiency & Public Lighting Overview Report
LED lifetime	100,000	hours	Green Investment Bank, 2014, Low energy street lighting: making the switch
Standard streetlight lifetime	15,000	hours	
LED street lighting energy savings	50%	of energy saving	The Climate Group, 2013, Lighting the Clean Revolution
	50%	of energy saving	Green Investment Bank, 2014, Low energy street lighting: making the switch

Source: Element Energy analysis for SEAI

*Energy savings and payback requirements for water services are based on the SEAI Working Group reports.

Cost table: Residential buildings

Measure	Cost unit	Cost	Source	Comment
Roof insulation	€/m2 fabric capex (2013€)	7.0	"Report on the Development of Cost Optimal Calculations and Gap Analysis for Buildings in Ireland Under Directive 2010/31/EU on the Energy Performance of Buildings (Recast): Section 1 - Residential Buildings", AECOM, 2013.	Cost available for U=0.13
Cavity wall insulation	€/m2 fabric capex (2013€)	7.1	"Report on the Development of Cost Optimal Calculations and Gap Analysis for Buildings in Ireland Under Directive 2010/31/EU on the Energy Performance of Buildings (Recast): Section 1 - Residential Buildings", AECOM, 2013.	Cost available for U=0.31
Solid wall insulation	€/m2 fabric capex (2013€)	106	"Report on the Development of Cost Optimal Calculations and Gap Analysis for Buildings in Ireland Under Directive 2010/31/EU on the Energy Performance of Buildings (Recast): Section 1 - Residential Buildings", AECOM, 2013.	Cost available for U=0.28
Floor insulation	€/m2 fabric capex (2013€)	27.0	"Report on the Development of Cost Optimal Calculations and Gap Analysis for Buildings in Ireland Under Directive 2010/31/EU on the Energy Performance of Buildings (Recast): Section 1 - Residential Buildings", AECOM, 2013.	Cost available for U=0.24
Energy efficient glazing	€/m2 fabric capex (2013€)	328	"Report on the Development of Cost Optimal Calculations and Gap Analysis for Buildings in Ireland Under Directive 2010/31/EU on the Energy Performance of Buildings (Recast): Section 1 - Residential Buildings", AECOM, 2013.	Cost available for U=1.6
Heating controls	€ per dwelling (2013€)	1,067 - 1,345	SEAI residential model	Depending on dwelling type
More efficient boiler	€ per dwelling (2013€)	1,882 - 2,049	"Report on the Development of Cost Optimal Calculations and Gap Analysis for Buildings in Ireland Under Directive 2010/31/EU on the Energy Performance of Buildings (Recast): Section 1 - Residential Buildings", AECOM, 2013.	Depending on dwelling type
Energy efficient lighting	€/m2 capex for LED lighting (2013€)	5.9	"Lighting the Way: Perspectives on the global lighting market", McKinsey & Co., 2012; "Comparison of Life-Cycle Analyses ofCompact Fluorescent and Incandescent Lamps Based on Rated Life ofCompact Fluorescent Lamp", Rocky Mountain Institute, 2008; Energy Star "Light Bulb Calculator"	
Energy efficient lighting	€/m2 annual capex for incandescent lighting (2013€)	0.15	"Lighting the Way: Perspectives on the global lighting market", McKinsey & Co., 2012; "Comparison of Life-Cycle Analyses ofCompact Fluorescent and Incandescent Lamps Based on Rated Life ofCompact Fluorescent Lamp", Rocky Mountain Institute, 2008; Energy Star "Light Bulb Calculator"	
Draught proofing	€/m2 total floor area capex (2013€)	3.0	SEAI residential model	"Basic ventilation" cost derived from 135m2 average dwelling
Heat pump	€ per dwelling (2013€)	15,462 - 18,020	"Report on the Development of Cost Optimal Calculations and Gap Analysis for Buildings in Ireland Under Directive 2010/31/EU on the Energy Performance of Buildings (Recast): Section 1 - Residential Buildings", AECOM, 2013.	Depending on dwelling type (assuming flats are not suitable)
Energy efficient appliances (Cold and Electrical cooking)	Premium capex for high efficiency appliances (2013€)	122	"How Trends in Appliances Affect Domestic CO2 Emissions: A Review of Home and Garde	Capex based on Element Energy data; ownership based on Haines et al., premium on capex for high efficiency appliances is 12% (based on SEI/McKinsey report)
Energy efficient appliances (Wet and Consumer electronics)	Premium capex for high efficiency appliances (2013€)	364	"How Trends in Appliances Affect Domestic CO2 Emissions: A Review of Home and Garde	Capex based on Element Energy data; ownership based on Haines et al., premium on capex for high efficiency appliances is 12% (based on SEI/McKinsey report)

Source: Element Energy analysis for SEAI

Lifetime table: Residential buildings

Measure	Lifetime (years)	Source
Roof insulation	40	Element Energy "Uptake of Energy Efficiency in Buildings", Report for CCC (2009)
Cavity wall insulation	40	Element Energy "Uptake of Energy Efficiency in Buildings", Report for CCC (2009)
Solid wall insulation	40	Element Energy "Uptake of Energy Efficiency in Buildings", Report for CCC (2009)
Floor insulation	40	Element Energy "Uptake of Energy Efficiency in Buildings", Report for CCC (2009)
Energy efficient glazing	25	Element Energy "Uptake of Energy Efficiency in Buildings", Report for CCC (2009)
Heating controls	10	SEAI Residential model
More efficient boiler	15	CIBSE building services technology lifetimes
Energy efficient lighting	50,000 (LED); 2,000 hours (incandescent)	U.S. Department of Energy, Buildings Energy Data Book 2011
Draught proofing	17	SEAI Residential model
Heat pump	15	CIBSE building services technology lifetimes
Energy efficient appliances (Cold and Electrical cooking)	15	Element Energy "Uptake of Energy Efficiency in Buildings", Report for CCC (2009)
Energy efficient appliances (Wet and Consumer electronics)	7-8	Element Energy "Uptake of Energy Efficiency in Buildings", Report for CCC (2009)

Source: Element Energy analysis for SEAI

Cost and lifetime table: Transport sector

Item	Cost unit	Cost (2013)	Cost (2020 Baseline efficiency case)	Cost (2020 high efficiency case)	Source	Comment	Lifetime (years)	Source
Petrol (<1200 cc)	Per vehicle (2013€)	9,600	9,600	9,887	"A review of the efficiency and cost assumptions for road transport vehicles to 2050", AEA (2012); "Influences on the Low Carbon Car Market from 2020–2030", Element Energy (2011).	Petrol <1200 cc cost relative to Petrol 1200-1900 cc cost based on scaling factor from "Influences on the Low Carbon Car Market from 2020–2030", Element Energy (2011)	Detailed retirement curve	Retirement curves for private cars based on Daly et al., Energy Policy (2011), calibrated for consistency with car stock in HERMES "Medium Term Recovery" scenario
Petrol (>1200 cc)	Per vehicle (2013€)	22,482	22,482	23,156	A review of the efficiency and cost assumptions for road transport vehicles to 2050, AEA (2012).		Detailed retirement curve	Retirement curves for private cars based on Daly et al., Energy Policy (2011), calibrated for consistency with car stock in HERMES "Medium Term Recovery" scenario
Diesel (<1900 cc)	Per vehicle (2013€)	23,371	23,371	24,229	A review of the efficiency and cost assumptions for road transport vehicles to 2050, AEA (2012).		Detailed retirement curve	Retirement curves for private cars based on Daly et al., Energy Policy (2011), calibrated for consistency with car stock in HERMES "Medium Term Recovery" scenario
Diesel (>1900 cc)	Per vehicle (2013€)	30,453	30,453	31,571	"A review of the efficiency and cost assumptions for road transport vehicles to 2050", AEA (2012); "Influences on the Low Carbon Car Market from 2020–2030", Element Energy (2011).	Diesel >1900 cc relative to Diesel 1200-1900 cc cost based on scaling factor from "Influences on the Low Carbon Car Market from 2020–2030", Element Energy (2011)	Detailed retirement curve	Retirement curves for private cars based on Daly et al., Energy Policy (2011), calibrated for consistency with car stock in HERMES "Medium Term Recovery" scenario
Petrol HEV	Per vehicle (2013€)	25,920	25,008	25,008	"A review of the efficiency and cost assumptions for road transport vehicles to 2050", AEA (2012); "Influences on the Low Carbon Car Market from 2020–2030", Element Energy (2011).	EV costs include Element Energy's updated battery costs	Detailed retirement curve	Retirement curves for private cars based on Daly et al., Energy Policy (2011), calibrated for consistency with car stock in HERMES "Medium Term Recovery" scenario
Diesel HEV	Per vehicle (2013€)	26,339	25,774	25,774	"A review of the efficiency and cost assumptions for road transport vehicles to 2050", AEA (2012); "Influences on the Low Carbon Car Market from 2020–2030", Element Energy (2011).	EV costs include Element Energy's updated battery costs	Detailed retirement curve	Retirement curves for private cars based on Daly et al., Energy Policy (2011), calibrated for consistency with car stock in HERMES "Medium Term Recovery" scenario
Petrol PHEV	Per vehicle (2013€)	32,136	28,533	28,533	"A review of the efficiency and cost assumptions for road transport vehicles to 2050", AEA (2012); "Influences on the Low Carbon Car Market from 2020–2030", Element Energy (2011).	EV costs include Element Energy's updated battery costs	Detailed retirement curve	Retirement curves for private cars based on Daly et al., Energy Policy (2011), calibrated for consistency with car stock in HERMES "Medium Term Recovery" scenario
Diesel PHEV	Per vehicle (2013€)	32,775	29,381	29,381	"A review of the efficiency and cost assumptions for road transport vehicles to 2050", AEA (2012); "Influences on the Low Carbon Car Market from 2020–2030", Element Energy (2011).	EV costs include Element Energy's updated battery costs	Detailed retirement curve	Retirement curves for private cars based on Daly et al., Energy Policy (2011), calibrated for consistency with car stock in HERMES "Medium Term Recovery" scenario
BEV	Per vehicle (2013€)	46,553	37,295	37,295	"A review of the efficiency and cost assumptions for road transport vehicles to 2050", AEA (2012); "Influences on the Low Carbon Car Market from 2020–2030", Element Energy (2011).	EV costs include Element Energy's updated battery costs	Detailed retirement curve	Retirement curves for private cars based on Daly et al., Energy Policy (2011), calibrated for consistency with car stock in HERMES "Medium Term Recovery" scenario
Public bus	Per vehicle (2013€)	166,544	166,544	170,071	A review of the efficiency and cost assumptions for road transport vehicles to 2050, AEA (2012).		12	Element Energy analysis
Light-duty freight vehicle (LDV)	Per vehicle (2013€)	19,427	19,427	20,037	A review of the efficiency and cost assumptions for road transport vehicles to 2050, AEA (2012).		8	Element Energy analysis
Heavy goods vehicle (HGV)	Annual cost of replacing retired stock per million tonne-km (2013€)	24,310	24,310	29,172		Cost based on small rigid HGV. Number of vehicles in Irish stock and typical annual tonne-km per vehicle based on CSO Transport Omnibus data. Assumed vehicle lifetime of 12 years. 20% premium for high efficiency HGVs based on AEA (2012) data.	12	Element Energy analysis
Eco-driving scheme (all vehicle types)	Cost of 7 year scheme (2013€)	7 million (1 million per year)	N/A	N/A	"The Dutch national eco-driving programme Het Nieuwe Rijden: A success story", Wilbers et al., 2007	Based on the cost of the Dutch Eco-driving scheme, scaled according to the number of licensed drivers in the two countries	N/A	
Modal shift to public transport, cycling and walking		No cost modelled - assumed to be a behavioural change						
Shift to purchase of smaller segment vehicles		No cost modelled - assumed to be a behavioural change						

Cost table: Industry sector

Measure	Cost unit	Cost	Source	Comment	Lifetime (years)	Source
More efficient HVAC and ventilation - more efficient boiler replacement	€/m2 floor area capex (2013€)	2.7	"The UK Supply Curve for Renewable Heat", NERA/AEA for DECC, 2009; CIBSE Energy Efficiency Best Practice Programme	Average industry heating demand 180 kWh/m2 (CIBSE); boiler capex 65 €/kW (NERA/AEA); peak heating requirement approximately 200% of annual average (based on Commercial sector analysis within SBEM)	15	CIBSE Lifetimes of Building Energy Services
More efficient HVAC and ventilation - heating controls	€/m2 floor area capex (2013€)	0.7	"Review and development of carbon dioxide abatement curves for available technologies as part of the Energy Efficiency Innovation Review", Final report by Enviros Consulting Ltd, 2006; Element Energy analysis	Capex of thermostatic radiator vales from Enviros; capex of programmable room thermostat and heating control requirement per floor area based on Element Energy analysis	15	Element Energy "Uptake of Energy Efficiency in Buildings", Report for CCC (2009)
More efficient refrigeration	€ capex premium per MWh annual energy consumption (2013€)	9.2	"Energy Efficiency and Climate Change Mitigation", Stanford University Energy Modelling Forum Report 25 Volume 1, 2011; "Refrigeration systems", Carbon Trust Guide CTG046.	Capex for typical refrigeration display case from Stanford Energy Modelling Forum; premium on capex for high efficiency refrigeration is 10% based on Carbon Trust CTG046	10	Carbon Trust guide CTG046
Motor efficiency	€ capex per MWh annual energy consumption (2013€)	52.0	"Ireland's Low-Carbon Opportunity: an analysis of the costs and benefits of reducing greenhouse gas emissions, Technical Appendix", SEI/McKinsey, 2009.	Cost of high efficiency motor replacement	15	CIBSE Lifetimes of Building Energy Services
More efficient compressed air systems	€ capex per MWh annual savings (2013€)	219	"Compressed Air Special Working Group Report 2007", SEAI, 2007.	Including all measures with known capex given in Table 2 of the report	15	Element Energy analysis
More efficient lighting	€/m2 capex for LED lighting (2013€)	8.8	"Lighting the Way: Perspectives on the global lighting market", McKinsey & Co., 2012; "Comparison of Life-Cycle Analyses ofCompact Fluorescent and Incandescent Lamps Based on Rated Life ofCompact Fluorescent Lamp", Rocky Mountain Institute, 2008; Energy Star "Light Bulb Calculator"		50,000 (LED); 2,000 hours (incandescent)	U.S. Department of Energy, Buildings Energy Data Book 2011
More efficient lighting	€/m2 annual capex for incandescent lighting (2013€)	0.4	"Lighting the Way: Perspectives on the global lighting market", McKinsey & Co., 2012; "Comparison of Life-Cycle Analyses ofCompact Fluorescent and Incandescent Lamps Based on Rated Life ofCompact Fluorescent Lamp", Rocky Mountain Institute, 2008; Energy Star "Light Bulb Calculator"		50,000 (LED); 2,000 hours (incandescent)	U.S. Department of Energy, Buildings Energy Data Book 2011
Process integration and heat recovery - high temperature processes	€ capex per MWh annual savings (2013€)	39-159	Element Energy (2014)	Depending on sector. Based on techno-economic model developed in 2013 to model the potential for heat recovery in UK industry	20	Element Energy analysis
Process integration and heat recovery - low temperature processes	€ capex per MWh annual savings (2013€)	39-159	Element Energy (2014)	Depending on sector. Based on techno-economic model developed in 2013 to model the potential for heat recovery in UK industry	20	Element Energy analysis
Process integration and heat recovery - high and low temperature processes	Annual opex (% of capex)	2.5%	Element Energy (2014)			
More energy efficient steam system	€ capex per MWh annual savings (2013€)	204	"Tracking Industrial Energy Efficiency and CO2 Emissions", IEA, 2007	Most cost effective improvements to achieve 15% savings included	20	Element Energy analysis
CHP	€ capex per MWh annual electricity savings (2013€)	134	"Combined Heat and Power", IEA ETSAP, 2010	Typical investment cost of 2008$ 1150/kW$_e$ for gas-fired ICE CHP	20	IEA ETSAP, "Combined Heat and Power", 2010
CHP	Annual opex (% of capex)	20%	"Combined Heat and Power", IEA ETSAP, 2010			

Lifetime table: Industry sector

Measure	Lifetime (years)	Source
More efficient HVAC and ventilation - more efficient boiler replacement	15	CIBSE Lifetimes of Building Energy Services
More efficient HVAC and ventilation - heating controls	15	Element Energy "Uptake of Energy Efficiency in Buildings", Report for CCC (2009)
More efficient refrigeration	10	Carbon Trust guide CTG046
Motor efficiency	15	CIBSE Lifetimes of Building Energy Services
More efficient compressed air systems	15	Element Energy analysis
More efficient lighting	50,000 (LED); 2,000 hours (incandescent)	U.S. Department of Energy, Buildings Energy Data Book 2011
Process integration and heat recovery - high temperature processes	20	Element Energy analysis
Process integration and heat recovery - low temperature processes	20	Element Energy analysis
More energy efficient steam system	20	Element Energy analysis
CHP	20	IEA ETSAP, "Combined Heat and Power", 2010

Source: Element Energy analysis for SEAI

Cost table: Hidden costs

Sector	Measure type	Project administration (hrs)		Project disruption and additional engineering (% of capex)	
		Central	High	Central	High
Residential	Non-Behavioural (low cost)	2.8	7.3	5.0%	10.0%
	Non-Behavioural (high cost)	9.8	19.3	5.0%	10.0%
	Behavioural	0.5	2.0	0.0%	0.0%
Commercial	Non-Behavioural (low cost)	3.5	12.0	2.0%	7.5%
	Non-Behavioural (high cost)	3.5	12.0	2.0%	7.5%
	Behavioural	1.5	3.0	0.0%	0.0%
Public	Non-Behavioural (low cost)	6.5	17.0	2.0%	7.5%
	Non-Behavioural (high cost)	6.5	17.0	2.0%	7.5%
	Behavioural	3.5	8.0	0.0%	0.0%
Industry	Non-Behavioural	53.0	105.0	6.0%	15.0%

Source: Element Energy analysis for SEAI

For Residential, Commercial and Public, "low cost" refers to measures with capital cost <5 EUR/m² and "high cost" to measures with capital cost >5 EUR/m²

Cost table: Value of time

Sector	Value of time (2013€/hr)	Source
Residential	10.82	Project Appraisal Guidelines, National Roads Authority, 2011 (value for 'Other' i.e. non-working time)
Commercial	30.15	Project Appraisal Guidelines, National Roads Authority, 2011 (value for 'Working' time)
Public		
Industry		

Source: Element Energy analysis for SEAI

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Fuel price forecasts (2013€/kWh)

Sector	Fuel	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2025	2030
Residential	Electricity	0.248	0.248	0.230	0.236	0.250	0.271	0.283	0.287	0.294	0.301	0.301	0.301	0.329	0.356
	Electricity (Night Saver)	0.09	0.09	0.09	0.09	0.09	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.12	0.14
	Gas	0.060	0.065	0.065	0.071	0.078	0.084	0.088	0.091	0.090	0.092	0.092	0.092	0.092	0.092
	Oil	0.082	0.101	0.107	0.117	0.114	0.116	0.116	0.120	0.120	0.121	0.121	0.122	0.125	0.128
	Solid	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064
Commercial	Electricity	0.216	0.197	0.190	0.207	0.212	0.231	0.241	0.244	0.250	0.256	0.256	0.257	0.284	0.311
	Gas	0.065	0.052	0.051	0.057	0.062	0.067	0.070	0.073	0.075	0.076	0.076	0.076	0.076	0.076
	Oil	0.076	0.096	0.104	0.118	0.117	0.118	0.118	0.122	0.123	0.123	0.124	0.124	0.127	0.130
Public	Electricity	0.216	0.197	0.190	0.207	0.212	0.231	0.241	0.244	0.250	0.256	0.256	0.257	0.284	0.311
	Gas	0.065	0.052	0.051	0.057	0.062	0.067	0.070	0.073	0.075	0.076	0.076	0.076	0.076	0.076
	Oil	0.076	0.096	0.104	0.118	0.117	0.118	0.118	0.122	0.123	0.123	0.124	0.124	0.127	0.130
Industry	Electricity	0.142	0.110	0.104	0.118	0.134	0.145	0.152	0.154	0.158	0.161	0.162	0.162	0.189	0.217
	Gas	0.044	0.036	0.040	0.043	0.046	0.050	0.052	0.053	0.054	0.055	0.055	0.055	0.062	0.068
	Oil	0.065	0.084	0.092	0.104	0.104	0.105	0.105	0.106	0.106	0.106	0.106	0.107	0.116	0.125
	Solid	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
Transport	Petrol	0.118	0.139	0.158	0.172	0.166	0.167	0.167	0.170	0.171	0.171	0.172	0.172	0.175	0.178
	Diesel	0.098	0.117	0.136	0.148	0.141	0.141	0.142	0.142	0.143	0.143	0.144	0.144	0.147	0.149
	Electricity	0.248	0.248	0.230	0.236	0.250	0.271	0.283	0.287	0.294	0.301	0.301	0.301	0.329	0.356

Source: Element Energy analysis for SEAI

Consumer prices (i.e. including VAT and carbon tax). Source: provided by SEAI, except solid fuel prices, which are taken from SEAI Fuel Cost Comparison (Jan 2014). For Residential, price of solid fuel is taken as price of peat; for Industry, price of solid fuel is taken as price of coal.

Carbon price forecast (2013€/tCO2)

Category	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2025	2030
Carbon price (ETS)	2013€/tCO2	7	7	8	8	8	9	9	10	50	89
Carbon tax	2013€/tCO2	20	20	20	30	30	30	30	30	30	30
Social cost of carbon	2013€/tCO2	17	18	39	39	39	39	39	39	39	39

Source: Element Energy analysis for SEAI

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Three economy-wide scenarios have been constructed to meet the 2020 target for primary energy savings

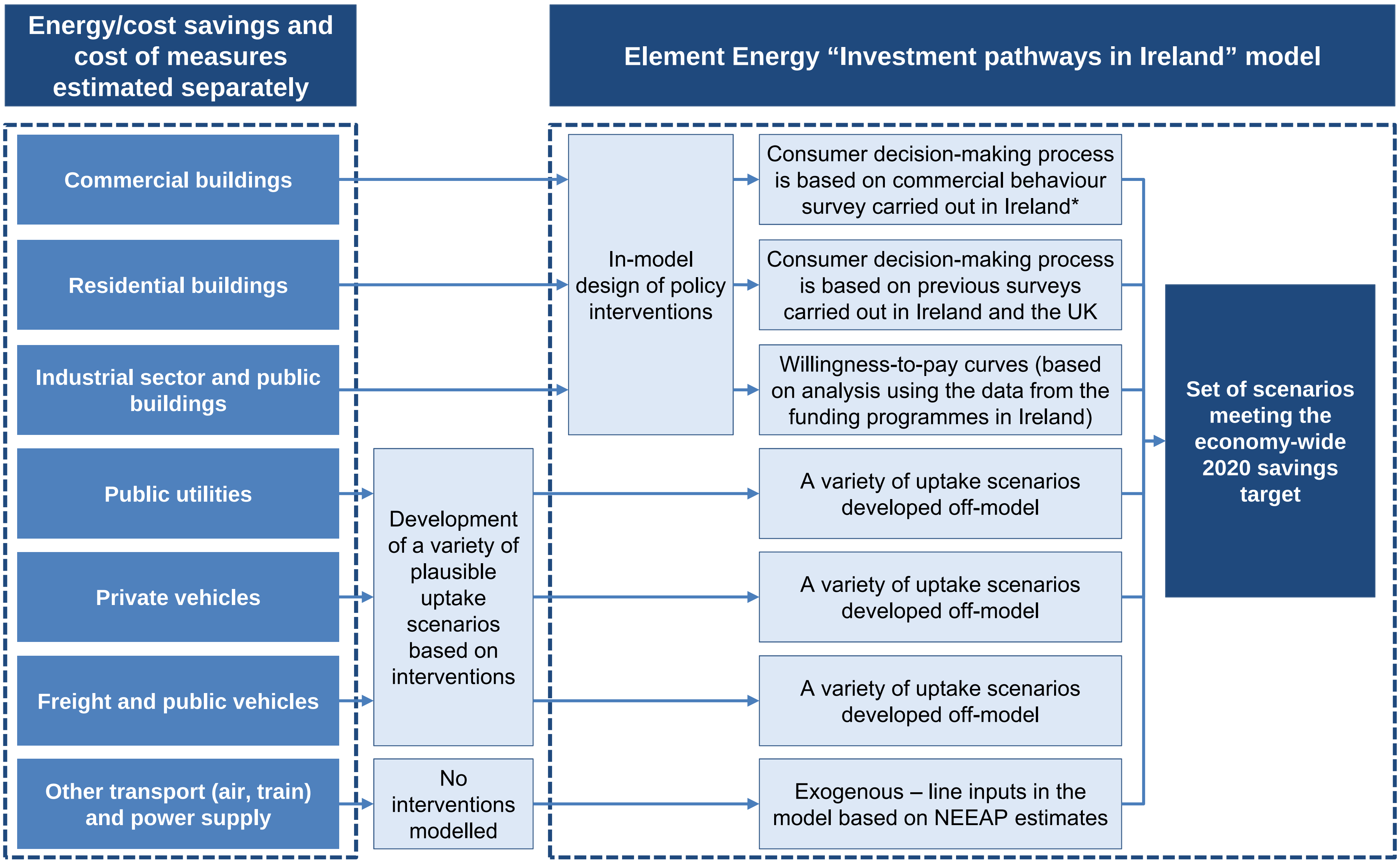
Process	Description
Energy/cost savings and cost of measures/packages collected in WP1-4	• Shallow, Medium and Deep packages formed for 'Residential', 'Commercial', 'Public' and 'Industry' sectors • Savings and costs for all packages and behavioural measures as explained in the previous sections
Element Energy "Investment pathways in Ireland" model developed	• 'Decision-making processes' designed for 'Residential', 'Commercial', 'Public' and 'Industry' sectors based on surveys deployed in Ireland and data available both in the UK and Ireland • Existing 'building archetypes' have been disaggregated into a number of 'consumer archetypes' to better represent the decision-making process of different consumer types**
Scenarios defined for **all sectors**	• 'Central', 'High' and (where appropriate) 'Very high' scenarios have been defined for 'Commercial buildings', 'Public buildings', 'Industry' and 'Residential' sectors with different levels of interventions using the uptake model • 'Transport', 'Public utilities' and 'Public transport' scenarios developed off-model
Economy-wide scenarios constructed using sector-level scenarios	• With the combination of sector-level scenarios, economy-wide scenarios constructed, all meeting the 2020 energy savings target
3 scenarios meeting the 2020 savings target compared against key parameters	• Three scenarios meeting the economy-wide energy savings target have been compared • "Cost/benefit to the exchequer" and macro-economic impacts have also be examined

Source: Element Energy analysis for SEAI

*Discounted lifetime cost of primary energy savings (€/MWh)

**E.g. 374 commercial and 336 residential archetypes in total

Policy interventions towards achieving the 2020 target have been studied using uptake modelling and off-model scenario development



NEEAP estimates of energy savings to 2020 have been used for the minority of items excluded from our detailed analysis (1)

NEEAP sector	NEEAP measure	Modelled?	Sector/sub-sector in which measure included
Public Sector	Public Sector Retrofit (Including Public Sector Programme)	Modelled	Public buildings
	Green Public Procurement (via ACA)	Modelled	Public buildings
	SEEEP and EERF (public sector)	Modelled	Public buildings (no longer active)
	Public Sector Building Demonstration Programme (retrofits)	Modelled	Public buildings (no longer active)
	Public Sector Building Demonstration Programme (new buildings)	-	N/A
	CHP (public sector)	-	N/A
	ReHeat (public sector)	Modelled	Public buildings (no longer active)
	Public transport efficiency (Dublin Bus eco-driving, Dublin Bus fleet replacement)	Modelled	Public passenger transport
	Public transport efficiency (Rail, Dublin Bus congestion reduction and technical measures; Dublin Bus Network direct programme)	-	N/A
	Better Energy (public sector)	Modelled	Public buildings (no longer active)
Business	SEAI Large Industry Programmes	Modelled	Industry
	SEAI SME Programme	Modelled	Commercial buildings
	ACA (private sector)	Modelled	Industry and commercial buildings
	SEEEP and EERF (private sector)	Modelled	Industry and commercial buildings (no longer active)
	CHP (private sector)	Modelled	Industry
	ReHeat (private sector)	Modelled	Industry and commercial buildings (no longer active)
	Better Energy (Commercial sector)	Modelled	Industry and commercial buildings (no longer active)
	Commercial/Industry Sector Retrofit	Modelled	Industry and commercial buildings

Source: Element Energy analysis for SEAI

If a NEEAP measure is included, Element Energy “Investment pathways in Ireland” model has been used to calculate the energy savings to 2020. Otherwise, NEEAP estimates of energy savings to 2020 have been used.

NEEAP estimates of energy savings to 2020 have been used for the minority of items excluded from our detailed analysis (2)

NEEAP sector	NEEAP measure	Modelled?	Sector/sub-sector in which measure included
Buildings	2002 Building Regulations -Dwellings	-	N/A
	2008 Building Regulations -Dwellings	-	N/A
	2011 Building Regulations -Dwellings	-	N/A
	Building Regulations - Nearly Zero Energy Dwellings	-	N/A
	2005 Building Regulations - Buildings other than dwellings	-	N/A
	2012 Building Regulations - Buildings other than dwellings	-	N/A
	Energy efficient boiler regulation	Modelled	Residential, commercial and public buildings
	Domestic Lighting (Eco-Design Directive)	Modelled	Residential buildings
	Greener Homes Scheme (GHS)	Modelled	Residential buildings (no longer active)
	Warmer Homes Scheme (WHS)	Modelled	Residential buildings (no longer active)
	Home Energy Saving (HES) scheme	Modelled	Residential buildings (no longer active)
	Smart Meter roll-out	Modelled	Residential buildings (behavioural measures)
	Residential retrofit	Modelled	Residential buildings
Mobility-Transport	Electric vehicle deployment	Modelled	Private cars
	Vehicle registration tax (VRT) and annual motor tax (AMT) rebalancing	Modelled	Private cars
	Improved fuel economy of private car fleet (EU Regulation)	Modelled	Private cars and LDVs
	More efficient road traffic movements (efficient driving)	Modelled	Private cars
	Aviation efficiency	-	N/A
Energy Supply	Electricity generation efficiency improvements	-	N/A
	Transmission and distribution upgrades	-	N/A
Cross Sectoral	Carbon Tax	-	N/A

Source: Element Energy analysis for SEAI

If a NEEAP measure is included, Element Energy “Investment pathways in Ireland” model has been used to calculate the energy savings to 2020. Otherwise, NEEAP estimates of energy savings to 2020 have been used.

Industry shares of the ‘Business’ sector savings in NEEAP by 2012 have been estimated based on the technical potential available in those sectors and the share of savings in the Better Energy Workplaces programme

Estimate of industry shares of the ‘Business’ sector savings in NEEAP*: savings already achieved to 2012

NEEAP measure	NEEAP savings already achieved to 2012 (GWh)	Estimated industry share (GWh)	LIEN/ETS (GWh)	LIEN/Non-ETS (GWh)	Non-LIEN/Non-ETS (GWh)	Assumption/Source
SEAI Large Industry Programmes	1,802	1,802	1,297	505	0	• Assume Large Industry Programme includes LIEN only; shares estimated based on the technical potential savings for each group.
SEAI SME Programme	270	0	0	0	0	• Assume Commercial buildings only.
ACA (private sector)	137	106	39	15	52	• Of the ACA measures included in the NEEAP estimate, motors and VSDs assigned to industry only. Industry and Commercial buildings shares of BEMS, lighting and lighting controls estimated based on the technical potential savings for each group.
SEEEP and EERF (private sector)	177	108	40	15	53	• Industry and Commercial buildings shares estimated based on the technical potential savings for each group.
CHP (private sector)	309	289	289	0	0	• Based on CHP installed capacity shares from “Combined Heat and Power in Ireland: 2012 update”, SEAI (2012), excluding installations in the public sector. Assume all industrial installations are those of LIEN/ETS members.
ReHeat (private sector)	288	176	65	25	87	• Industry and Commercial buildings shares estimated based on the technical potential savings for each group.
Better Energy (private sector) BEW	274	209	49	122	37	• Industry and Commercial buildings shares estimated based on the shares of savings from the Better Energy Workplaces programme
TOTAL	**3,256**	**2,691**	**1,778**	**683**	**230**	

Source: Element Energy analysis for SEAI

*Industry shares based on technical potential and Better Energy Workplaces – see later slide

Industry shares of the ‘Business’ sector savings in NEEAP by 2020 have been estimated based on the technical potential available in those sectors and the share of savings in the Better Energy Workplaces programme

Estimate of industry shares of the ‘Business’ sector savings in NEEAP*: target for 2020

NEEAP measure	NEEAP target 2020 (GWh)	Estimated industry share (GWh)	LIEN/ETS (GWh)	LIEN/Non-ETS (GWh)	Non-LIEN/Non-ETS (GWh)	Assumption/Source
SEAI Large Industry Programmes	2,728	2,728	1,963	765	0	• Assume Large Industry Programme includes LIEN only; shares estimated based on the technical potential savings for each group.
SEAI SME Programme	511	0	0	0	0	• Assume Commercial buildings only.
ACA (private sector)	688	534	195	76	263	• Of the ACA measures included in the NEEAP estimate, motors and VSDs assigned to industry only. Industry and Commercial buildings shares of BEMS, lighting and lighting controls estimated based on the technical potential savings for each group.
SEEEP and EERF (private sector)	177	108	40	15	53	• Industry and Commercial buildings shares estimated based on the technical potential savings for each group.
CHP (private sector)	428	400	400	0	0	• Based on CHP installed capacity shares from “Combined Heat and Power in Ireland: 2012 update”, SEAI (2012), excluding installations in the public sector. Assume all industrial installations are those of LIEN/ETS members.
ReHeat (private sector)	288	176	65	25	87	• Industry and Commercial buildings shares estimated based on the technical potential savings for each group.
Better Energy (private sector) BEW	274	209	49	122	37	• Industry and Commercial buildings shares estimated based on the shares of savings from the Better Energy Workplaces programme
Commercial/Industry sector retrofit	2,500	1,093	0	0	1,093	• Assume this includes only Non-LIEN industry (LIEN companies accounted for in LIEN programme and above measures). Commercial/industry shares then based on the technical potential savings for each group
TOTAL	**7,594**	**5,249**	**2,712**	**1,004**	**1,533**	

Source: Element Energy analysis for SEAI

*Industry shares based on technical potential and Better Energy Workplaces – see later slide

Technical potential and share of savings in the Better Energy Workplaces programme – data used to estimate the shares of savings attributed to industry

Technical potential in industry and commercial buildings (assuming 100% suitability)

Sector	Technical potential (TWh)	Source
Industry	9.5	Element Energy industry model
Of which LIEN/ETS	*3.5*	
Of which LIEN/Non-ETS	*1.4*	
Of which Non-LIEN/Non-ETS	*4.7*	
Commercial buildings	6.0	Element Energy commercial buildings model (excluding behavioural measures)

Energy savings in the Better Energy Workplaces (BEW) programme 2011-2012

	LIEN/ETS	LIEN/Non-ETS	Non-LIEN/Non-ETS	Commercial including SME[1]	Source
Primary energy savings 2011-2012 (GWh)	71	178	54	194	Better Energy Workplaces (BEW) project database (provided by SEAI)
Share of total	14%	36%	11%	39%	

Source: Element Energy analysis for SEAI

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Existing 'building archetypes' have been disaggregated into a number of 'consumer archetypes' to better represent the decision-making process of different consumer types

Sector	Consumer archetype parameters	Total archetypes	Notes	Source
Commercial	**Company size (x2)** • Large company • Small company **Tenancy/decision-making (x3)** • Owner/Decision-maker • Tenant/Decision-maker • Tenant/Not decision-maker	374	• For each building archetype, the share of each consumer archetype was derived using the results of the survey of consumer behaviour in the commercial sector (see survey results for details) • A "Large company" is one with more than 10 employees	• Survey of consumer behaviour in the commercial sector in Ireland deployed for this study
Public	Public buildings not further disaggregated into consumer archetypes	46		
Residential	**Tenancy (x3)** • Owner with mortgage • Owner outright • Tenant	336	• Owner with mortgage: 36% • Owner outright: 35% • Tenant: 29% • Shares of each consumer archetype applied uniformly across all building archetypes	• Census 2011 (CSO) • "Not stated" tenancies assigned proportionately across the three categories
Industry	**LIEN membership (x2)** • LIEN • Non-LIEN **ETS membership (x2)** • ETS • Non-ETS	52	• Number of companies for each archetype derived using CSO data, LIEN Annual Reports and the ETS database • Primary energy shares of each consumer archetype estimated using data provided by SEAI on the primary energy consumption of LIEN companies in 2008 (latest year available), the Energy Balance 2008 and 2008 ETS data • No primary energy consumption was identified for "Non-LIEN/ETS" archetypes, so the number of these archetypes set to zero	• Census of Industrial Production (CSO) • LIEN Annual Report 2008 (SEAI) • LIEN Annual Report 2012 (SEAI) • ETS database (2008 verified data) • SEAI data on LIEN primary energy consumption 2008 (Caiman Cahill and SEAI) • Energy Statistics Databank (2008 industry energy consumption data)

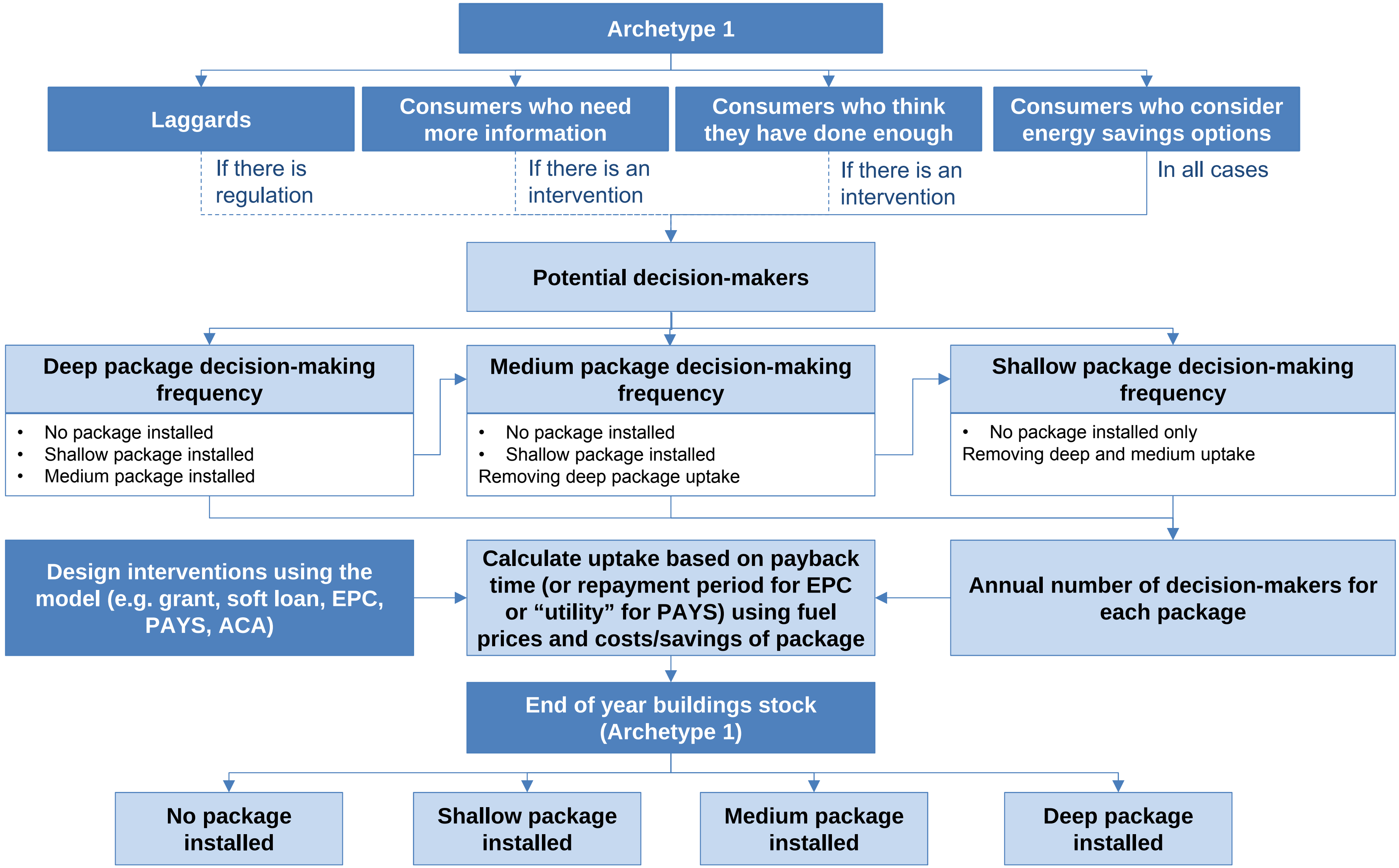
Source: Element Energy analysis for SEAI

More than 10 interventions can be designed in the model for different consumer types within specific sectors

Interventions	Modelled in sectors	In-model/off-model design
Capital grant for specific packages/consumers	Residential, Commercial, Public and Industrial	In-model
Tax incentives (e.g. ACA)	Commercial, Public and Industrial	In-model
Loans/soft loans	Residential, Commercial, Public and Industrial	In-model
Pay-As-You-Save (PAYS)	Residential	In-model
Energy Performance Contract	Commercial, Public and Industrial	In-model
Information campaign for non-behavioural measures	Residential, Commercial and Public	In-model
Active promotion of PAYS	Residential	In-model
Active promotion of ESCOs	Commercial, Public and Industrial	In-model
Regulation to include laggards/Mandatory audits	Commercial, Public and Industrial (large companies)	In-model
Regulation to increase decision-making frequency	Residential, Commercial and Public	In-model
Information campaign for behavioural measures	Residential, Commercial and Public	In-model
Boiler regulation	Residential, Commercial and Public	In-model
Domestic Lighting (Eco-Design Directive)	Residential, Commercial and Public	In-model
EU regulation 443/2009	Private cars and LDV freight	Off-model
VRT/AMT re-balancing	Private cars	Off-model
High AFV incentive	Private cars	Off-model
Eco-driving	Private cars, HGV freight, LDV freight, Public buses	Off-model
Moderate Modal shift	Private cars	Off-model
Increasing HGV ICE efficiency	Private cars	Off-model

Source: Element Energy analysis for SEAI

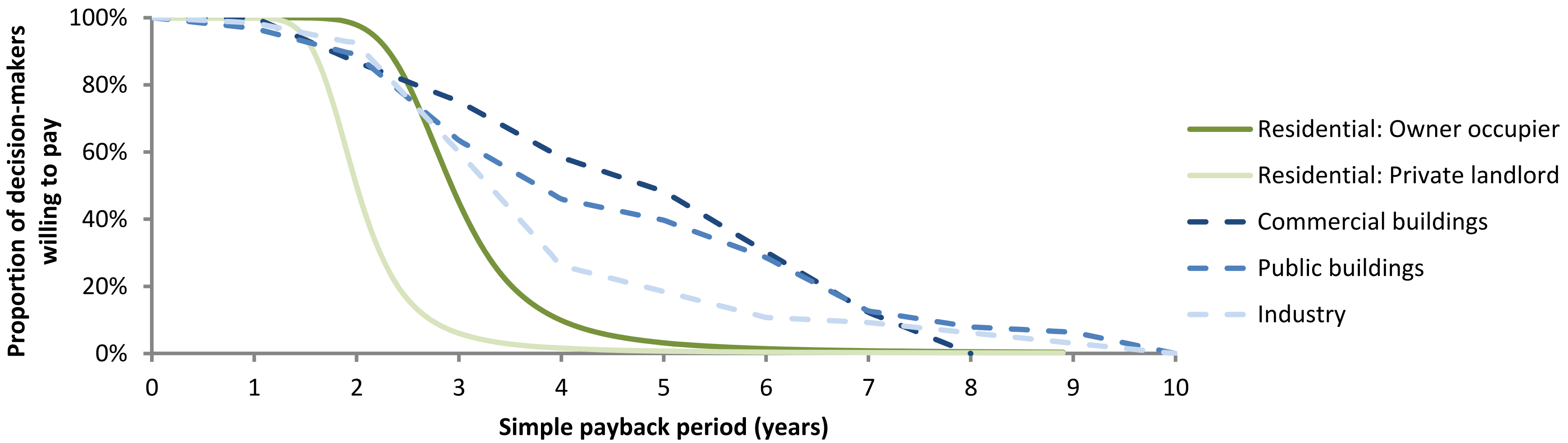
Flow diagram for annual uptake calculation: this process is repeated annually for each archetype in the residential, commercial, public and industrial sectors



Source: Element Energy analysis for SEAI

Uptake of energy efficiency packages are calculated using the willingness-to-pay curves derived for each sector

Willingness-to-pay curves used in the uptake model

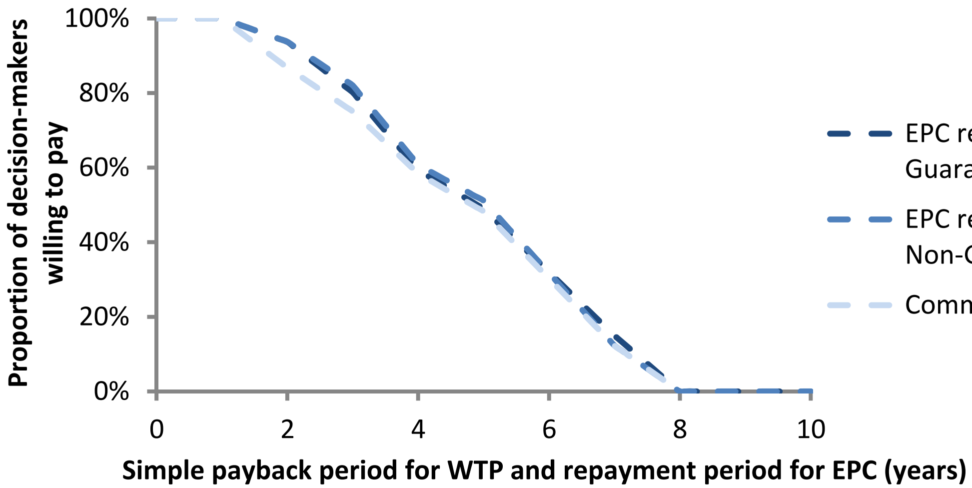


Data sources

Willingness-to-pay curve	Source
Residential: Owner-occupier	WTP curve derived using the coefficients from the Element Energy study, "Uptake of energy efficiency in buildings" (2009) for the Committee of Climate Change
Residential: Private landlord	WTP curve derived using the coefficients from the Element Energy study, "The growth potential for Micro-generation in England, Wales and Scotland" (2008) for BERR UK
Commercial buildings	Derived using the survey of consumer behaviour in the commercial sector in Ireland deployed for this study
Public buildings	Derived using cost and savings data from around 200 energy saving projects funded by the "Better Energy 2011 and 2012" programmes.
Industrial organisations	Derived using cost and savings data from around 200 energy saving projects funded by the "Better Energy 2011 and 2012" programmes.

Uptake under EPC and PAYS schemes is calculated with a different approach as it is not possible to calculate simple payback period

Uptake under EPC



- Repayment requirements* derived from the survey for 'guaranteed' and 'non-guaranteed' ESCO schemes are very similar to the simple payback requirements in the commercial buildings sector.

- Industrial WTP curve is therefore used for calculation of uptake under EPC in the industrial sector.

Uptake under PAYS

Design aspects of PAYS	Perceived cost value**
1% increase in loan interest rate	€ 250
1 year increase in loan length	€ 322
€1 increase in annual repayments	€ 3.1
Bonus dependent upon source of loan	
• Mortgage extension	-€ 906
• Bank loan	-€ 2,453
• Energy supplier loan	-€ 2,640
• Government loan	-€ 2,916

- Using the Logit coefficients shown on the left, the model calculates an overall 'utility' under the designed PAYS scheme for each energy efficiency package and archetype, in each year
- Annual uptake is then calculated using the Logit equation.

Source: Element Energy analysis for SEAI

*Source: survey of consumer behaviour in the commercial sector deployed in Ireland

**Source: Element Energy, 2009, Energy Efficiency Measures Willingness to Pay for the Energy Saving Trust

Decision-making process data sources in the commercial sector (1)

Decision-making process		Values used	Notes	Survey question/answer	Data sources
Awareness and engagement – Fabric measures	Fraction of laggards	Varies between 18% and 59%	Depending on sub-sector, company size (small/large) and decision-making attribute (Owner/Decision-maker, Tenant/Decision-maker, or Tenant/Not decision-maker)	The organisation has not investigated ways to reduce energy use through improving the building fabric as energy is not a top priority and they do not think there are ways to reduce energy use	Derived using the results of the survey of consumer behaviour in the commercial sector in Ireland deployed for this study
	Fraction of consumers who think they have done enough	Varies between 0% and 45%		The organisation has already put in place all the possible measures to reduce energy use through improving the building fabric	
	Fraction of consumers who need more information	Varies between 0% and 11%		They think there may be ways to reduce energy use through improving the building fabric, but they need more information	
Awareness and engagement – Behavioural measures	Fraction of laggards	Varies between 13% and 54%		The organisation has not investigated ways to reduce energy use through behaviour change as energy is not a top priority and they do not think there are ways to reduce energy use OR the organisation has investigated but thought it would not work	
	Fraction of consumers who think they have done enough	Varies between 8% and 49%		The organisation has already put in place all the possible measures to reduce energy use through behaviour change	
	Fraction of consumers who need more information	Varies between 0% and 11%		They think there may be ways to reduce energy use through behaviour change, but they need more information	
Decision-making frequency	Shallow package	Varies between 3 years and 8 years	Depending on sub-sector, company size (small/large) and decision-making attribute (Owner/Decision-maker, Tenant/Decision-maker, or Tenant/Not decision-maker)	How recently action undertaken in building organisation occupies: • Maintenance\repairs on the building fabric (Shallow) • New fit-out of a room or space (Shallow) • Lighting system re-fit\upgrade (Shallow) • Re-wiring a room or space (Medium) • Replacing windows and\or doors (Medium) • Renovation\Replacement of the heating system (Medium) • Major internal renovation work such as installing a new wall or floor) (Deep) • Major external renovation work such as changing the external appearance of the building (Deep)	
	Medium package	Varies between 4 years and 10 years			
	Deep package	Varies between 6 years and 13 years			
	Behavioural measures	Linked to uptake of medium/deep packages with or without EPC			

Decision-making process data sources in the commercial sector (2)

Decision-making process		Values used	Notes	Survey question/answer	Data sources
Budget limit	Budget limit per consumer	Varies between €5,500 and €33,500	Depending on sub-sector, company size (small/large) and decision-making attribute (Owner/Decision-maker, Tenant/Decision-maker, or Tenant/Not decision-maker)	What is the maximum amount organisation could conceive spending on the measure which met the payback period requirements?	Derived using the results of the survey of consumer behaviour in the commercial sector in Ireland deployed for this study
	Fraction of consumers with no budget limit	Varies between 24% and 63%		Consumers who stated there is no fixed budget and their energy efficiency budget is more than €100,000	
	Fraction of consumers without any budget for energy efficiency	Varies between 7% and 12%	Depending on sub-sector	Consumers who stated their energy efficiency budget is less than €500	
Attitude towards interventions	Fraction not willing to avail of EPC scheme	Varies between 18% and 65% for “Guaranteed” EPC scheme, and between 21% and 62% for “Non-Guaranteed” EPC scheme.	Depending on sub-sector, company size (small/large) and decision-making attribute (Owner/Decision-maker, Tenant/Decision-maker, or Tenant/Not decision-maker)	Consumers who, having been read a description of the EPC scheme, stated that they would not accept such an offer for any repayment period	

Source: Element Energy analysis for SEAI

Decision-making process data sources in the public buildings sector

Decision-making process		Values used	Notes	Data sources
Awareness and engagement – Fabric measures	Fraction of laggards	0%	Fraction of laggards is assumed to be 0% for the public sector	
	Fraction of consumers who think they have done enough	Varies between 26% and 31%	Based on the survey results for commercial buildings Large public buildings: average of large commercial buildings Small public buildings: average of small commercial buildings	Derived using the results of the survey of consumer behaviour in the commercial sector in Ireland deployed for this study
	Fraction of consumers who need more information	Varies between 2% and 3%		
Awareness and engagement – Behavioural measures	Fraction of laggards	0%	Fraction of laggards is assumed to be 0% for the public sector	
	Fraction of consumers who think they have done enough	Varies between 25% and 27%	Based on the survey results for commercial buildings Large public buildings: average of large commercial buildings Small public buildings: average of small commercial buildings	
	Fraction of consumers who need more information	Varies between 4% and 5%		
Decision-making frequency	Shallow package	Around 6 years	Based on the survey results for commercial buildings Large public buildings: average of large commercial buildings Small public buildings: average of small commercial buildings	Derived using the results of the survey of consumer behaviour in the commercial sector in Ireland deployed for this study
	Medium package	Around 8 years		
	Deep package	Around 11 years		
	Behavioural measures	Linked to Smart-meter rollout or uptake of medium/deep packages		
Budget limit	Budget limit per consumer	Varies between €7,500 and €16,000	Based on the survey results for commercial buildings Large public buildings: average of large commercial buildings Small public buildings: average of small commercial buildings	Derived using the results of the survey of consumer behaviour in the commercial sector in Ireland deployed for this study
	Fraction of consumers with no budget limit	Varies between 46% and 49%		
	Fraction of consumers without any budget for energy efficiency	0%	Fraction of consumers without budget is assumed to be 0%	
Attitude towards interventions	Fraction not willing to avail of EPC scheme	0%	Fraction of consumers not willing to avail of EPC scheme is assumed to be 0%	

Source: Element Energy analysis for SEAI

Decision-making process data sources in the residential sector (1)

Decision-making process		Values used	Notes	Data sources
Awareness and engagement – Fabric measures	Fraction of laggards	32.2% for the 'Private landlords' 23.4% for 'Owner outright' and 'Owned with mortgage'	32.2% of the private landlords stated that they will never install an energy efficiency measure 26% of households see no benefit in energy efficiency (including 32.2% of private landlords)	Retrofit Research: Qualitative & Quantitative Report, 2013, Behaviour & Attitudes for SEAI Private Landlord Survey, 2013, Behaviour & Attitudes for SEAI
	Fraction of consumers who think they have done enough	9.4%	Of the households who see a benefit in improving one of the energy efficiency aspects of their home (74%), Around 13% (average) cited that these measures are not necessary/home is already of sufficient standard. These do not include the consumers who have actually installed these measures.	Retrofit Research: Qualitative & Quantitative Report, 2013, Behaviour & Attitudes for SEAI
	Fraction of consumers who need more information	4.4%	Of the households who see a benefit in improving one of the energy efficiency aspects of their home (74%), Around 6% cited (first and second mention) that they do not know enough about these measures.	Retrofit Research: Qualitative & Quantitative Report, 2013, Behaviour & Attitudes for SEAI
Behavioural measures	Fraction of laggards, consumers who think they have done enough or need more information	Same as above		
Decision-making frequency	Shallow package	5.6 years	54% of all households have undertaken home improvement in the last 3 years (18% annually)	Retrofit Research: Qualitative & Quantitative Report, 2013, Behaviour & Attitudes for SEAI
	Medium package	8.7 years	34% of household have undertaken improvements excluding shallow (i.e. redecoration) in the last 3 years (11.5% annually)	
	Deep package	14.5 years	21% of households have undertaken deeper home improvements (i.e. extensive work on garden, extending home, etc.) in the last 3 years (6.9% annually)	
	Behavioural measures	Linked to Smart-meter rollout or uptake of medium/deep packages		

Decision-making process data sources in the residential sector (2)

Decision-making process		Values used	Notes	Data sources
Budget limit	Budget limit per consumer	Central budget limit is €3,400 for 'Owned with mortgage' and €6,000 for other consumers	From the "Thinking Deeper" report, most consumers prefer to use their own funds or savings for energy efficiency investments. Savings are calculated for 6 months (Low), 1 year (Central) and 2 years (High)	Household Budget Survey, 2009-2010
	Fraction of consumers with no budget limit	10.2%	Around 10% of the households stated that "lack of own funds" is not an important barrier	Thinking Deeper: Financing options for home retrofit, 2011, IIEA
	Fraction of consumers without any budget for energy efficiency	Varies between 5.7% and 9.4% depending on house type and whether owner has a mortgage	Based on unemployment rates for different house types and whether owner has a mortgage or not	SEAI data
Attitude towards interventions	Fraction not willing to avail of PAYS scheme	41%	41% of all respondents answered "Strongly disagree" to the question: "To what extent do you agree or disagree with the following statement – I would like to have the option of repaying smaller amounts spent on energy efficiency measures (e.g. up to €1,000) on my electricity bill over time."	Retrofit Research: Qualitative & Quantitative Report, 2013, Behaviour & Attitudes for SEAI

Source: Element Energy analysis for SEAI

Decision-making process data sources in the industry sector

Decision-making process		Values used	Notes	Data sources
Awareness and engagement – Fabric measures	Fraction of laggards	0% for LIEN companies 33% for Non-LIEN companies	Assume that due to the LIEN programme, LIEN members are all aware and engaged in energy efficiency. For Non-LIEN companies, the average value of Large Commercial buildings has been used.	Survey of consumer behaviour in the commercial sector in Ireland deployed for this study
	Fraction of consumers who think they have done enough	0% for LIEN companies 35% for Non-LIEN companies	Assume that due to the LIEN programme, LIEN members are all aware and engaged in energy efficiency. For Non-LIEN companies, the average value of Large Commercial buildings has been used.	
	Fraction of consumers who need more information	0% for LIEN companies 4% for Non-LIEN companies	Assume that due to the LIEN programme, LIEN members are all aware and engaged in energy efficiency. For Non-LIEN companies, the average value of Large Commercial buildings has been used.	
Behavioural measures	Fraction of laggards, consumers who think they have done enough or need more information	No behavioural measures modelled in industry		
Decision-making frequency	Shallow package	1 year	Shallow package includes energy efficient lighting only – assume that this decision can be made each year.	
	Medium package	5-10 years, varying by sub-sector	Medium package includes retrofit measures which would require a plant shut-down, and is therefore assumed to be implemented only when the plant closes for maintenance. AEA has estimated the period between such closures as 5-10 years depending on the sub-sector.	Review and update of UK abatement costs curves for the industrial, domestic and non-domestic sectors: RM 4851, AEA/Ecofys Final Report to the Committee on Climate Change, 2008
	Deep package	15 years	Deep package includes end-of-life replacement measures such as boiler and motor system replacement, and is therefore assumed to be implemented only after the natural lifetime of that equipment, typically 15 years.	Lifetimes of building services, CIBSE
Budget limit	Budget limit per consumer	No budget limit assumed in industry		
Attitude towards interventions	Fraction not willing to avail of EPC scheme	35% for “Guaranteed” EPC scheme, and 39% for “Non-Guaranteed” EPC scheme.	For all companies, the average value of Large Commercial buildings has been used.	Survey of consumer behaviour in the commercial sector in Ireland deployed for this study

Source: Element Energy analysis for SEAI

Contents

Cost to Exchequer: Cost assumptions

Item	Assumption	Notes/Source
Administration costs	€150 per end-user	• Applies to Active promotion, PAYS, loan scheme and Grant scheme only • Based on an analysis of: Scheer et al., Economic Analysis of Residential and Small-Business Energy Efficiency Improvements, SEAI (2011)
Information campaign fixed cost	Fixed cost of €5 million per year	• Power of One campaign cost approximately €3 million • Diffney et al., Advertising to boost energy efficiency: the Power of One campaign and natural gas consumption, ESRI Working Paper 280 (2009)
Cost of information campaign for behavioural measures	€0.025/kWh primary savings	• RAND, What works in changing energy using behaviours in the home? (2011) • Wortmann et al., Off. Really Off? (2003) • Ward et al., Transition Streets (2011)
Direct grant support	Endogenous within uptake model	
Excise duty on fuel foregone	Based on excise duty by fuel and sector	
Carbon tax foregone	Based on carbon tax	
Corporation tax resulting from fuel savings	12.5% of savings from fuel and carbon	• Assumes all savings taken in profit • Applies to commercial and industry sectors only
Reduction in net taxes from social security, VAT and income tax	Calculated by E3ME	
Value of energy savings to public sector	Endogenous within uptake model	

Source: Element Energy analysis for SEAI