

# Renewable Heat in Ireland to 2020

Achieving Ireland's 2020 renewable heat target: Analysis of policy options



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## ***Sustainable Energy Authority of Ireland***

The Sustainable Energy Authority of Ireland (SEAI) was established as Ireland's national energy authority under the Sustainable Energy Act 2002. SEAI's mission is to play a leading role in transforming Ireland into a society based on sustainable energy structures, technologies and practices. To fulfil this mission SEAI aims to provide well-timed and informed advice to Government, and deliver a range of programmes efficiently and effectively, while engaging and motivating a wide range of stakeholders and showing continuing flexibility and innovation in all activities. SEAI's actions will help advance Ireland to the vanguard of the global green technology movement, so that Ireland is recognised as a pioneer in the move to decarbonised energy systems.

SEAI's key strategic objectives are:

- Energy efficiency first – implementing strong energy efficiency actions that radically reduce energy intensity and usage;
- Low-carbon energy sources – accelerating the development and adoption of technologies to exploit renewable energy sources;
- Innovation and integration – supporting evidence-based responses that engage all actors, supporting innovation and enterprise for our low-carbon future.

The Sustainable Energy Authority of Ireland is financed by Ireland's EU Structural Funds Programme co-funded by the Irish Government and the European Union.

## Summary

### *Introduction*

Ireland has set a target to deliver 12% of final heat demand from renewable energy sources by 2020. Achievement of the heat target would contribute about 20% of Ireland's overall binding renewable energy target, and is a key means of reducing CO<sub>2</sub> emissions that count towards Ireland's binding greenhouse gas emission target in 2020. While progress has been made on deployment of renewable heat technologies in recent years, energy forecast projections show that Ireland is likely to fall short of the RES-H 12% target, even under optimistic assumptions about what current policy can deliver. Additional policy action is required to meet the RES-H target and reduce the risk of the potential exchequer costs associated with compliance purchasing and fines.

The Government's Draft Bioenergy Plan (October 2014) recognises the challenges associated with meeting the 2020 renewable targets including the renewable heat target.<sup>1</sup> The draft Plan proposes measures to stimulate demand and supply, as well as research, development and demonstration. The purpose of the report is to inform policy development in this area by evaluating the magnitude of the gap to the achievement of the RES-H target and by examining the costs and impacts of policy options available to achieve the RES-H target by 2020.

The analysis simulates how different categories of consumers, representing distinct sections of the heat sector, respond to the various technology attributes when choosing a heat technology. The attributes include the upfront installation costs, ongoing fuel and maintenance costs and any hassle costs associated with the installation of a heat technology. Biomass resource (fuel) cost is an important factor in determining the ongoing costs of bioenergy technologies, and the availability, cost and demand for biomass resources across all sectors is accounted for in the modelling methodology. The potential contribution of renewable heat technologies over the period to 2020 is assessed across scenarios which examine changes in fossil fuel costs, biomass resource availability, heat demand growth and renewable policy measures.

The experience from other EU countries is examined and the costs of three of the more common financial policy instruments – FiT/bonus schemes, upfront grants and CO<sub>2</sub> tax increases – implemented in the EU are assessed in the Irish context.

### *Heat energy use in Ireland*

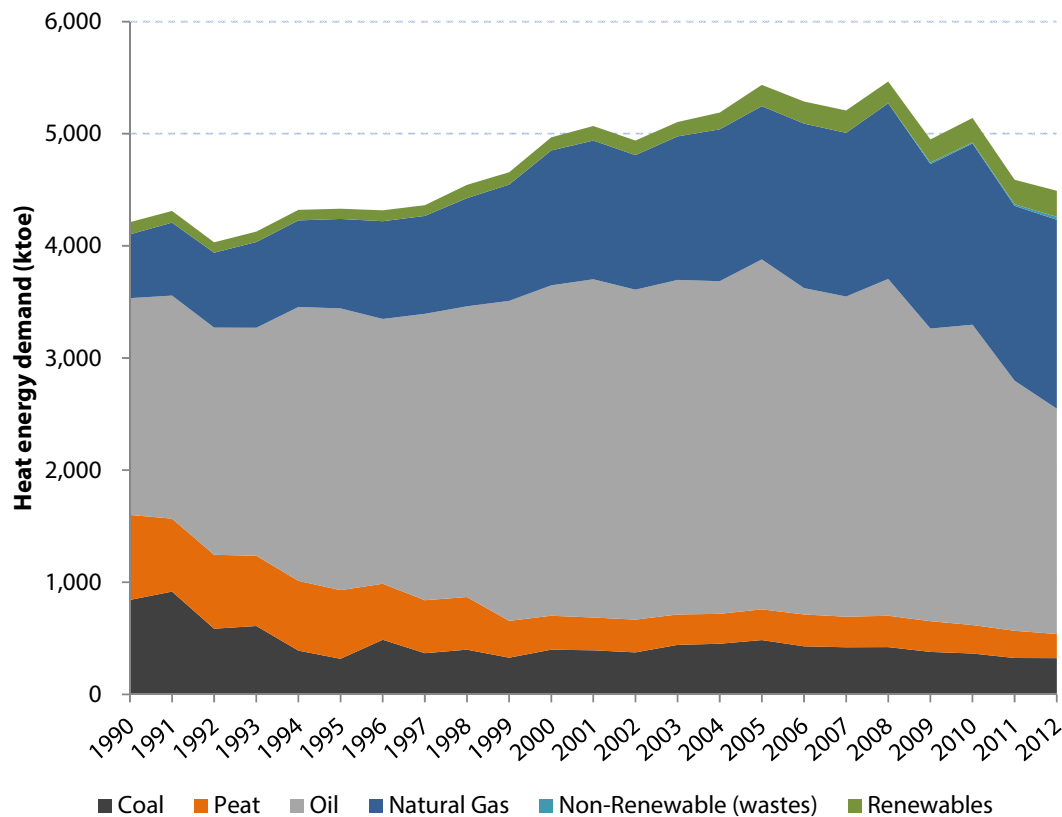
The demand for heat energy was the largest source of energy use in 2012, accounting for 45% of all primary energy and 33% of CO<sub>2</sub> emissions. Space and water heating in residential dwellings and the services sector account for over 60% of heat demand, with process heat in the industrial sector accounting for over 30% of such demand.

As Figure i shows, the majority of fuel used in the production of heat energy comes from oil – 54% in 2012. Natural gas use has grown in line with the expansion of the gas grid infrastructure, and currently accounts for 38% of heat energy fuel inputs. Solid fuels – peat and coal – have seen a gradual decline since 1990 and accounted for 12% of primary fuel use in 2012.

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<sup>1</sup> Department of Communications, Energy and Natural Resources (2014), Draft Bioenergy Plan. Available at: <http://www.dcenr.gov.ie/Energy/Sustainable+and+Renewable+Energy+Division/Draft+Bioenergy+Plan.htm>

Figure i: Fuel used in the generation of heat energy 1990-2012<sup>2</sup>



Renewable energy use has increased in recent years, contributing just over 5% of heat energy in 2012. Biomass combustion in the industrial sector accounts for the majority of renewable heat use, with biomass accounting for 84% of total renewable energy consumption of 218 ktoe (2,535 GWh) in 2012. Geothermal energy from heat pumps (8%), biogas combustion (4%) and solar thermal (4%) accounted for all remaining renewable heat energy use in 2012.

### Approach to modelling the heat sector

Heat energy is difficult to transport over a significant distance in an efficient way. As a result, heat energy tends to be generated from a diverse range of technologies, using a diverse range of fuels, installed close to each individual demand site. Each site has its own unique set of physical circumstances and, at a small scale, each customer has a unique set of preferences and barriers, all of which influence the costs and choice of heat-producing technologies.

To capture the detailed nature of heat technology choice, a consumer choice model of the heat sector in Ireland was built. This model is based on data that describes the Irish building stock, heat requirements in each sector, and information on how various consumer types respond to the attributes of individual heat technologies. The heat sector is divided into 35 different consumer types, based on sector, building type, annual heat demand and existing primary fossil fuel source.

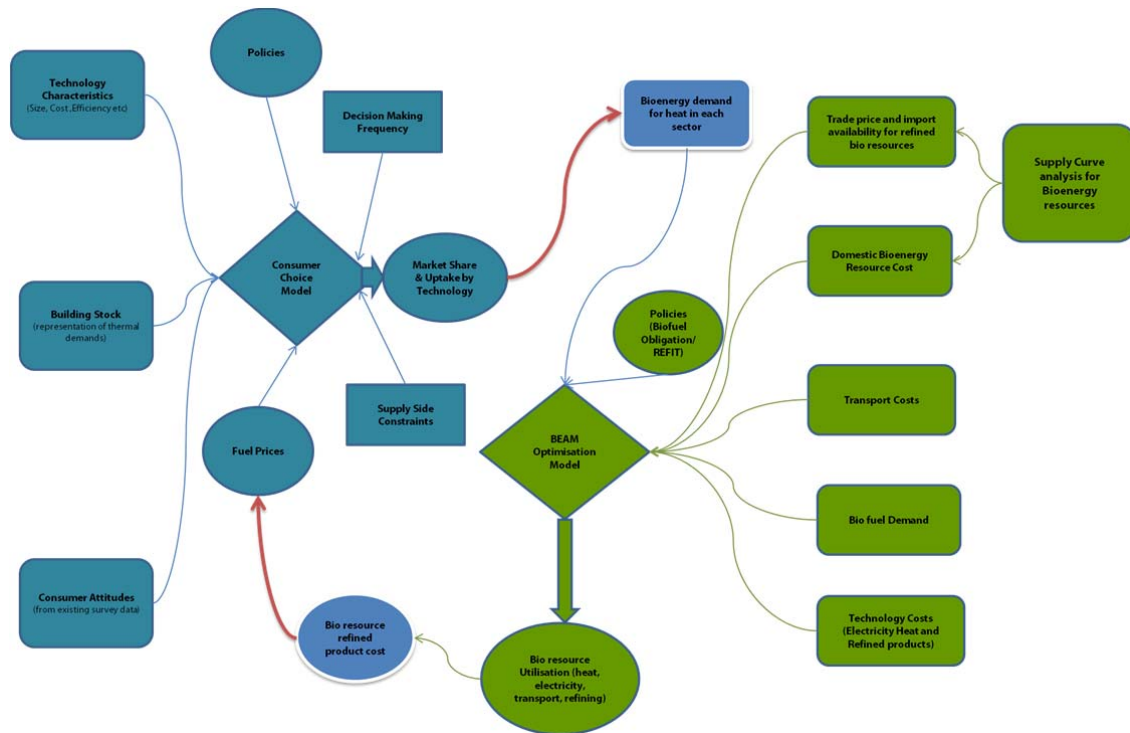
<sup>2</sup> EPSSU (2013). *Energy in Ireland 1990 – 2012. 2013 Report*. Available at: [http://www.seai.ie/Publications/Statistics/Publications/Energy\\_in\\_Ireland/Energy\\_in\\_Ireland\\_1990\\_-\\_2012\\_Report.pdf](http://www.seai.ie/Publications/Statistics/Publications/Energy_in_Ireland/Energy_in_Ireland_1990_-_2012_Report.pdf)

Consumer responses to technology attributes such as upfront capital costs, fuel and maintenance costs and the hassle costs associated with installing a new technology are represented for each consumer category. A combination of all these attributes determines the total attractiveness of a technology to a consumer. The technology that provides the highest utility to each consumer group gains the largest market share of new installations for that group. The number of potential installations of new renewable heat technologies is limited (constrained) by the natural retirement rate of fossil fuel technologies, the suitability of renewable technologies in a given setting and any supply-side constraints (such as lack of trained installers).

The relative costs of fuels are an important attribute in the choice of a heat technology. Renewable heat technologies tend to reduce ongoing fuel costs, due to either efficiency improvements (heat pumps) or lower fuel costs (biomass). If the cost reductions cover the higher installation costs of these technologies in a period of time that is agreeable to the individual heat consumers, then the renewable options are favoured. Biomass technologies in industrial or large commercial settings are currently most competitive with the fossil fuel alternatives, as fuel costs tend to be the largest component of the cost of generating heat in these settings. The ongoing cost of biomass resources relative to fossil fuels is therefore a significant determinant of the likelihood of uptake of biomass technologies. Given biomass resources can be used to produce electricity, transport and heat energy, changes in demand for biomass inputs in any of these energy end-uses can impact on the price of the resources in all end-use sectors.

To capture this influential aspect of the heat technology uptake, the SEAI BioEnergy Analysis Model (BEAM) was used in conjunction with the Consumer Choice heat model to establish the price impacts of any change in bioenergy demand. The BEAM model is a least-cost linear optimisation model that uses data on the available resources at different market prices, refining costs for raw biomass resources, resource transportation costs, conversion and refining technology costs and government policy impacts to meet demand for bioenergy in the transport, electricity and heat energy end-use sectors at the lowest overall cost. Higher demand for biomass resources across the heat, electricity and transport sectors means that more expensive biomass resources must be harvested to meet this demand, which raise the market price for the various refined biomass products (i.e. biofuels, wood chips and pellets, biogas) that are used to meet the demand. These prices are inputted into the heat model to estimate a bioenergy demand in the heat sector, and the process is repeated until stable market equilibrium is reached. Data from the SEAI publication *BioEnergy Supply Curves for Ireland 2010 – 2030* are used to represent the cost of harvesting raw biomass resources. The cost implications of the various supply-side barriers to resource extraction, such as the willingness of farmers to grow energy crops at various price levels, are accounted for within this analysis. Figure ii shows a representation of the input variables and linking of the heat model with BEAM.

Figure ii: Schematic representation of heat model, BEAM linking and data inputs



### Scenarios examined

Three scenarios are presented to examine the impact of variations in fossil fuel prices, bioenergy availability and energy demand that may arise in the period leading up to 2020. These factors influence the heat technology choices that consumers make, and could potentially vary quite substantially over this period. Table i summarises the scenarios examined.

Table i: Summary of scenarios modelled

Scenario	Fossil fuel prices	Bioenergy availability	Energy demand
<b>High</b>	Central scenario +10% by 2020	Some wood chips and wood pellets imported (cheaper than available domestic resources).	All energy efficiency measures targeted by policy are implemented.
<b>Central</b>	IEA 'current policies' scenario outlined in <i>World Energy Outlook 2012</i>	All domestic biomass resources used to meet demand before higher-cost resources are imported.	All energy efficiency measures targeted by policy are implemented.
<b>Low</b>	IEA 'new policies' scenario (prices 10% less than 'current policies' scenario by 2020).	All domestic biomass resources used to meet demand before higher-cost resources are imported.	Shortfall in the energy efficiency targets

The scenarios define a range of possible RES-H outcomes under the current policy environment. The existing policy measures include:

- the anticipated impact of energy efficiency policies as outlined in the *National Energy Efficiency Action Plan* (NEEAP);<sup>3</sup>
- the renewable energy feed-in tariff (REFIT) for bioenergy technologies that produce electricity;<sup>4</sup>
- Part L of the 2008 Building Regulations requiring 10/kWh/m<sup>2</sup> of renewable heat to be installed in new dwellings;<sup>5</sup>
- a grant of €800 for solar thermal installations until the end of 2014<sup>6</sup>;
- the carbon tax, remaining at current levels.<sup>7</sup>

**Central scenario:** *An improving environment for renewable heat technologies*

SEAI's energy price comparison publication contains information on retail prices for oil, gas and electricity in the residential, services and industrial sectors. These prices are used as the starting point for fuel price growth in each sector,<sup>8</sup> which are grown in-line with fossil fuel price projections in the 'current policies' scenario from the International Energy Agency publication *World Energy Outlook 2012*.<sup>9</sup> Due to the high share of natural gas consumption in the electric power sector in Ireland, retail electricity prices are assumed to grow at the same rate as natural gas.

Energy demand projections are consistent with the 'NEEAP/NREAP'<sup>10</sup> scenario as published in the 2012 national energy forecasts.<sup>11</sup> The 'NEEAP/NREAP' scenario assumes that the 2020 targets for energy efficiency are met in full and the renewable energy targets, as detailed in the *National Renewable Energy Action Plan* (NREAP), are achieved. As the majority of savings identified in the *National Energy Efficiency Action Plan* (NEEAP) are aimed at reducing heat usage, this assumption means that less energy output is required for renewable heat technologies in order to achieve the RES-H 12% target.<sup>12</sup>

Imports of biomass products are restricted and are only available for import when all domestic resources have been brought into production.

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<sup>3</sup> Department of Communications, Energy and Natural Resources (2014). *National Energy Efficiency Action Plan 2014*. Available at: <http://www.dcenr.gov.ie/NR/rdonlyres/20F27340-A720-492C-8340-6E3E4B7DE85D/0/DCENRNEEAP2014publishedversion.pdf>

<sup>4</sup> Department of Communications Energy and Natural Resources (2013). *Renewable Energy Feed in Tariff A Competition for Electricity Generation – from Biomass Technologies 2010-2015*. Available at: <http://www.dcenr.gov.ie/NR/rdonlyres/05441877-FC28-4A6C-8F5F-0EEAC8271DDF/0/REFIT3TermsandConditionsJuly2013.pdf>

<sup>5</sup> Department of Environment, Heritage and Local Government (2011). Technical Guidance Document, Part L Building Regulations 2011. *Conservation of Fuel and Energy – Dwellings*. Available at: <http://www.envron.ie/en/Publications/DevelopmentandHousing/BuildingStandards/FileDownload,27316,en.pdf>

<sup>6</sup> Via the Sustainable Energy Authority of Ireland, 2013, Better Energy Homes scheme. See: [http://www.seai.ie/Grants/Better\\_energy\\_homes/About\\_the\\_Scheme/](http://www.seai.ie/Grants/Better_energy_homes/About_the_Scheme/)

<sup>7</sup> Finance Bill 2013. Available at: <http://www.finance.gov.ie/sites/default/files/financebill2013.pdf>

<sup>8</sup> EPSSU Fuel Cost Comparison sheets. Available at: [http://www.seai.ie/Publications/Statistics\\_Publications/Fuel\\_Cost\\_Comparison/](http://www.seai.ie/Publications/Statistics_Publications/Fuel_Cost_Comparison/)

<sup>9</sup> International Energy Agency (2012). *World Energy Outlook 2012*. Available at: <http://www.worldenergyoutlook.org/publications/weo-2012/>

<sup>10</sup> Department of Communications, Energy and Natural Resources (2014). *National Energy Efficiency Action Plan 2014/National Renewable Energy Action Plan* (NREAP).

<sup>11</sup> SEAI (2011). *Energy Forecasts for Ireland to 2020*. 2011 Report. Available at: [http://www.seai.ie/Publications/Statistics\\_Publications/EPSSU\\_Publications/Energy\\_Forecasts\\_for\\_Ireland\\_for\\_2020-2011\\_Report.pdf](http://www.seai.ie/Publications/Statistics_Publications/EPSSU_Publications/Energy_Forecasts_for_Ireland_for_2020-2011_Report.pdf)

<sup>12</sup> As the renewable energy targets are set as a ratio of demand, lower demand results in a lower requirement for renewable energy output to meet the target.



**High scenario:** *A more favourable environment for renewable heat technologies*

Fossil fuel prices are assumed to be 10% higher in 2020 than the International Energy Agency (IEA) projections – making renewable heat technologies more competitive. Demand projections are based on the same assumptions as the *Central scenario*. Some bioenergy resources – wood chips and wood pellets – are available for import from 2015 at prices lower than the majority of domestic resources.

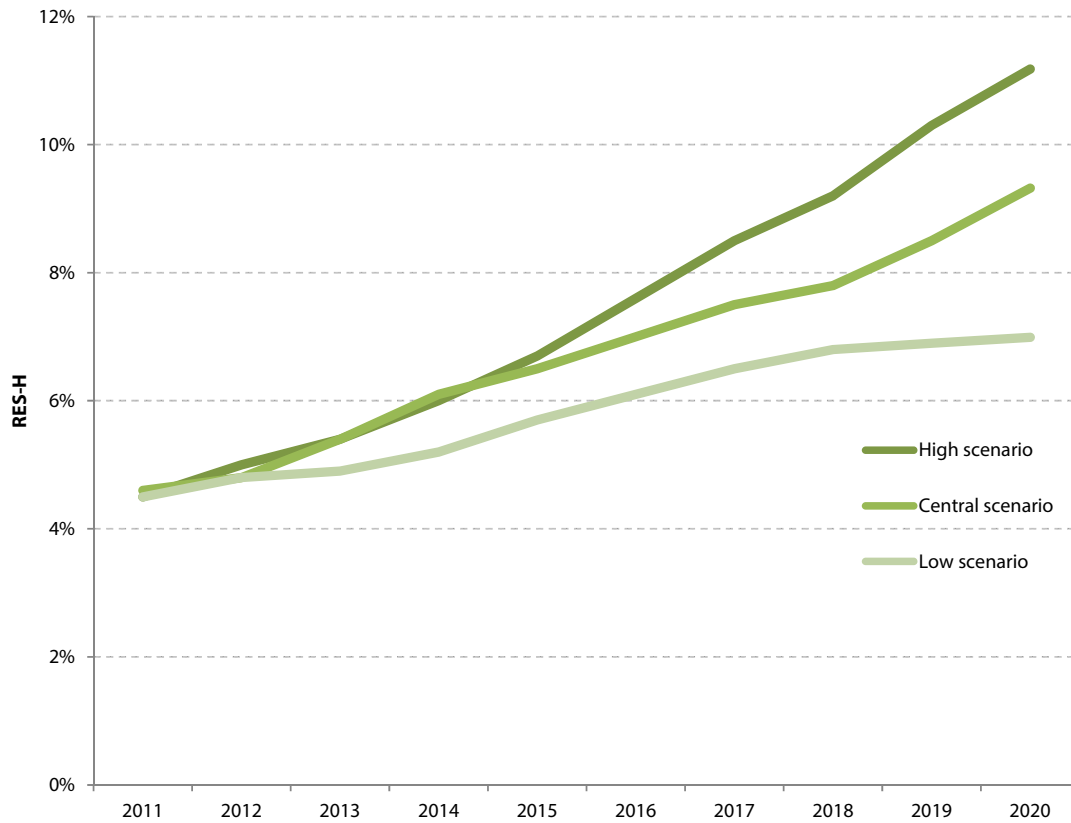
**Low scenario:** *A less favourable environment for renewable heat technologies*

Fossil fuel projections are ~10% lower than in the *Central scenario* based on the ‘new policies’ scenario in the IEA publication *World Energy Outlook 2012*. The baseline demand assumptions for the 2012 energy forecast are used to model a low uptake of energy efficiency measures. Imports of biomass products are restricted and are only available for import when all domestic resources have been brought into production.

*Gap to RES-H target 2020 under current policy*

In order to ensure that 12% of total heat demand is supplied by renewable energy, a total renewable heat output of 455 ktoe (5,292 GWh) is required in both the *Central scenario* and the *High scenario*. Both scenarios assume full implementation of the energy efficiency measures outlined in the *National Energy Efficiency Action Plan NEEAP*, and therefore are based on the same heat demand projection. A higher energy demand is modelled in the *Low scenario*, given the assumption that no new energy efficiency measures are implemented post 2012. As a result, the *Low scenario* requires a total renewable heat output of almost 550 ktoe (6,397 GWh) to meet the RES-H target. Figure iii shows the modelled trajectory of each scenario to 2020.

Figure iii: RES-H share projected for each scenario to 2020



In all three scenarios the RES-H 12% target is not reached. The *High scenario* shows the strongest growth in renewable heat. This is driven by higher fossil fuel prices, making renewable heat technologies more cost competitive. In this scenario, RES-H of 11% is reached by 2020 – 30 ktoe (349 GWh) short of the required output.

In the *Central scenario*, less expensive fossil fuels reduce the cost competitiveness of renewable heat technologies, resulting in fewer consumers choosing to install such technologies. The RES-H of 9% equates to a 110 ktoe (1,279 GWh) shortfall.

The *Low scenario* assumptions result in a renewable heat output of 230 ktoe (2,675 GWh) by 2020. Due to higher demand as a result of the modelled shortfall on energy efficiency and the lower cost of fossil fuel options, a RES-H of just 7% is reached, leaving a gap of 255 ktoe in 2020. Table ii summarises the high-level results from each scenario.

Table ii: Projected scenario outcomes in 2020

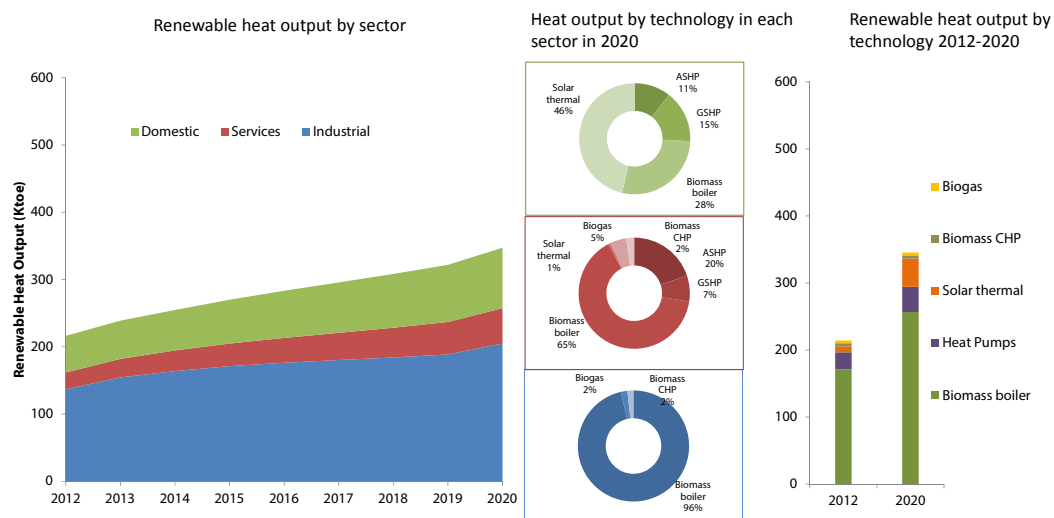
Scenario	Renewable heat output in 2020 (ktoe)	Required output to meet RES-H 12% (ktoe)	Projected RES-H in 2020
<i>High scenario</i>	420 / (4,885)	455 / (5,292)	11%
<i>Central scenario</i>	350 / (4,071)	455 / (5,292)	9%
<i>Low scenario</i>	325 / (3,780)	550 / (6,397)	7%

In order to bridge the estimated gap to target in the *Central scenario*, an additional 300,000 homes, 3,000 service sector<sup>13</sup> buildings or 200 large industrial sites (or a combination of all three) must install a renewable heat technology before 2020.

Figure iv shows a breakdown of renewable heat output to 2020 for the *Central scenario*. Most of the increase in renewable heat output is in the industrial sector; this is because more large industrial sites choose to replace oil boilers with biomass boilers as oil prices increase to 2020. Increased output is also observed from biomass boilers and heat pump installations in the commercial sector.

A steady increase in renewable heat output is observed in the residential sector. This is driven by Part L of the Building Regulations, which requires new residential buildings to install a renewable energy source, and on the assumption of an expected increase of the build rate of new dwellings to over 20,000 per year. Biomass CHP uptake in the services and industrial sectors does not increase markedly, despite investment signals from the REFIT 3 scheme. The rising demand for biomass in the heat sector leads to higher biomass fuel prices over the horizon and reduces the investment return from CHP investments as their fuel input costs rise.

*Figure iv: Renewable heat technology output 2012-2020 – no further policies (Central scenario)*



### *Policy options to bridge gap to target*

Renewable energy policy in EU member states has been focused on the deployment of renewable technologies in electricity and transport. Policy concentrating on renewable heat is less well developed across the EU, but some countries have achieved high levels of renewable heat use through effective policy intervention. These countries have used a combination of financial instruments, regulations and enabling measures over a period of time to maximise the use of their available biomass, increase the use of heat pumps and offset the use of oil for heat. Energy efficiency policies focused on reducing heat energy requirements have also played a significant role.

<sup>13</sup> The services sector encompasses both the public and commercial sectors.

Regulations for building and technology standards are in use in 13 EU member states, including Ireland. Enabling measures such as installer training, fuel quality certification and ongoing information campaigns are also common in those countries with high levels of renewable heat generation. Increases in renewable energy output due to regulations is limited in the short term, with the rate of growth tied to new building construction or, in cases where regulations apply to retrofits, at the replacement rate of existing technology. Enabling measures can help to drive the uptake rate of cost-competitive technologies, but can do little to remove financial barriers to renewable heat technology uptake.

The most frequently implemented forms of financial instrument across the EU have been investment grants and taxation measures. However, schemes based on feed-in-tariffs have more recently gained prominence, with the UK's Renewable Heat Incentive (RHI) being a notable example. Similarly in Ireland, the Government has proposed in its draft Bioenergy Strategy (2014) that it will introduce an Exchequer-funded incentive scheme from 2016 to reward users of each unit of renewable heat used from sustainable biomass.

The main advantages and disadvantages of the various policy options are summarised in Table iii under the categories of upfront funding measures, operational support schemes and taxation measures.

*Table iii: Advantages and disadvantages of policy options<sup>14, 15</sup>*

	Advantages	Disadvantages
	<b>Upfront funding</b>	
<b>Capital grants</b>	<ul style="list-style-type: none"> <li>• Little interaction between administrator and grant recipient.</li> <li>• Low transaction costs – public bodies have experience with grant distribution.</li> <li>• Positive consumer perception.</li> <li>• Grant schemes can support diversification of technologies by tailoring support levels to individual technologies.</li> </ul>	<ul style="list-style-type: none"> <li>• Low operational oversight means no guarantee that the installed capacity will generate the expected amount of energy.</li> <li>• Requires exchequer funding.</li> <li>• Stop-start nature of funding for grant schemes can give rise to market instability.</li> <li>• The need to select the technologies means that the government must decide which technologies to support</li> </ul>
<b>Public procurement programmes</b>	<ul style="list-style-type: none"> <li>• Useful in the development of markets for immature technologies.</li> <li>• Can help increase public awareness of renewable technologies through demonstration.</li> <li>• Can help develop supply chains in immature markets.</li> </ul>	<ul style="list-style-type: none"> <li>• Technology uptake is limited to buildings in public ownership, thus making these schemes unsuitable for wide-scale development.</li> <li>• Funding immature technologies exposes public organisations to the risks associated with less mature markets and technologies.</li> </ul>

<sup>14</sup> Connor, P., Bürger, V., Beurskens, L., Ericsson, K. and Egger, C. (2013) 'Devising renewable heat policy: Overview of support options', *Energy Policy*, volume 59, pp. 3-16.

<sup>15</sup> Intelligent Energy – Europe Consortium (2012). *D23 Final Report: RE-Shaping: Shaping an effective and efficient European renewable energy market*, Karlsruhe. Available at: [http://www.resaping-res-policy.eu/downloads/Final%20report%20RE-Shaping\\_Druck\\_D23.pdf](http://www.resaping-res-policy.eu/downloads/Final%20report%20RE-Shaping_Druck_D23.pdf)

Soft loans <sup>16</sup>	<ul style="list-style-type: none"> <li>• Can be more attractive to governments, given reduced impact on the exchequer budget.</li> <li>• Allows consumers the flexibility to choose the most suitable technology for their individual circumstance</li> </ul>	<ul style="list-style-type: none"> <li>• Resistance to taking on debt in the household sector can be high, which could limit uptake.</li> <li>• Default contingency can add to the total cost of the schemes.</li> <li>• Transaction costs can be large for a policy that deliverers uptake of many small-scale technologies in the heat sector, highlighting the suitability of the scheme for larger projects.</li> <li>• May be difficult to support in some financial/institutional frameworks.</li> </ul>
<b>Operating support</b>		
Feed in tariffs/bonus mechanisms	<ul style="list-style-type: none"> <li>• High level of certainty for investors, which promotes lower financing costs.</li> <li>• As technology costs evolve, support levels for new installations can be adjusted in line with cost changes.</li> <li>• Bonus payments can be tailored to individual technologies offering greater diversity.</li> </ul>	<ul style="list-style-type: none"> <li>• Total policy costs can be uncertain if caps are not placed on the quantity of renewable energy that will be supported.</li> <li>• It can be difficult to assess the costs for immature technologies accurately, and therefore to set the feed-in tariff price level accurately.</li> <li>• The need to select the technologies means that the government must decide on the size and type of technologies to support.</li> <li>• Administration of a feed-in tariff scheme for smaller-sized technologies can be difficult, leading to high transaction costs.</li> <li>• The dispersed nature of the heat market means that it can be difficult to confirm actual heat output from supported installations.</li> <li>• Possibility for misalignment with the goals of energy efficiency – users of renewable heat may have an incentive to use as much renewable energy as possible in order to maximise return from the scheme.</li> </ul>
Quota mechanisms/supplier obligations	<ul style="list-style-type: none"> <li>• Theory suggests that the costs to society are minimised as the renewable energy technologies must compete on cost in order to deliver quotas.</li> <li>• Market forces dictate which technologies are successful.</li> <li>• Predictable costs of support.</li> </ul>	<ul style="list-style-type: none"> <li>• Investor risk may be increased, as the price for renewable energy output is uncertain. This means that investors will need a higher return on investment, which can offset the cost savings predicted in theory.</li> <li>• Quota mechanisms can force different technologies to compete against each other on current cost, which disadvantages less mature technologies. This may not provide a least-cost solution over the long term.</li> <li>• Tends to favour a small number of technologies, which is unlikely to provide a diverse generation mix.</li> <li>• Oversight and licensing of heat suppliers is far more complex than for electricity suppliers. This can introduce significant transaction and administration costs.</li> <li>• Possibility for misalignment with the goals of energy efficiency – users of renewable heat may have an incentive to use as much renewable energy as possible in order to maximise return from the scheme.</li> </ul>

<sup>16</sup> A loan with an interest rate below market rates and other borrower concessions, such as long repayment periods, interest holidays etc.

Tendering mechanism	<ul style="list-style-type: none"> <li>• Cost competition is central to the mechanism, thus providing an incentive to reduce prices and the costs of supporting the scheme.</li> </ul>	<ul style="list-style-type: none"> <li>• Bidders may lower prices to unrealistic levels, thus making project unviable – although safeguards can be put in place to reduce this risk.</li> <li>• Not suitable for large uptake of renewable heat, as bidding rounds can lead to a start-stop development rather than stable growth.</li> <li>• Not suitable for small-scale projects.</li> <li>• The dispersed nature of the heat market means that it can be difficult to confirm actual heat output from supported installations.</li> <li>• Possibility for misalignment with the goals of energy efficiency – users of renewable heat may have an incentive to use as much renewable energy as possible in order to maximise return from the scheme.</li> </ul>
Taxation measures		
Tax incentives and levies	<ul style="list-style-type: none"> <li>• Funding of tax breaks from exchequer (incentives) must compete with other priority areas of public funding.</li> <li>• Taxation relief may not be sufficient to cover the cost differential between fossil fuels and renewable options. (incentives).</li> <li>• Taxation levies on fossil fuels will reduce the cost competitiveness of sites that do not switch to renewable technologies. (levies)</li> </ul>	<ul style="list-style-type: none"> <li>• Increased taxation of fossil fuels or CO<sub>2</sub> benefits the exchequer (levies).</li> <li>• Technology choices are made by the heat consumer (incentives and levies).</li> </ul>

### *Policy Options in the Irish context*

In order to estimate a range of possible policy costs, and thus ensure that the renewable heat target is met, one policy option from each category of financial instrument type was modelled using the Consumer Choice/BEAM model. A feed-in tariff (FiT)/bonus scheme, grant scheme, and a carbon tax increase were considered as mechanisms to incentivise the uptake of renewable heat technologies. Policy support levels were calibrated to ensure that the renewable heat output in each scenario is sufficient to achieve a RES-H of 12% by 2020. The policy support levels help heat consumers recover the cost differential between the marginal renewable technology required to meet the target and the fossil fuel alternative.

#### **FiT/bonus scheme**

The FiT/bonus scheme provides guaranteed price support for each unit of output from a renewable heat technology. Several price support levels can be defined on the basis of technology type, size and sector. Any detailed policy design could potentially include several tariff bands but, for simplicity, a single tariff paid by the exchequer to an installation for a 15-year period was modelled as part of this analysis.

Results modelled indicate that a tariff of 8 €/MWh for each unit of heat output could be required in the *Central scenario* in order to reach the RES-H target, with tariffs of 3 €/MWh and 12 €/MWh required in the *High scenario* and the *Low scenario* respectively.

#### **Grant supports**

Upfront grant supports are typically offered as a percentage of the total installation costs of a technology. Previous grant schemes for energy efficiency and renewable technologies in Ireland have offered support in the order of 30% of technology installation costs. The size of renewable heat installations varies across sectors and consumer types, and installation costs are higher per unit capacity at smaller scales. Grant amounts were applied in the model based on the installation

costs in individual size bands, and also based on a typical installation size and cost in band. The grant proportion offered in each scenario is sufficient to achieve uptake of renewable technologies to meet the RES-H 12% by 2020.

Results indicate that grants covering 35% of the capital costs are required to reach the 2020 RES-H target in the *Central scenario*, with a 15% grant delivering the required uptake in the *High scenario* and a 43% grant required in the conditions of the *Low scenario*.

### **CO<sub>2</sub> tax increase**

Increasing the CO<sub>2</sub> tax makes the use of fossil fuel technologies more expensive, thereby increasing the competitiveness of renewable energy technologies. Costs for this policy measure fall to private sector investors and proceeds go to the exchequer. In order to provide a consistent basis for comparison with the costs of other policy options, the analysis of carbon tax impacts is assessed for new fossil fuel heating technologies installed in the period 2015-2020 – i.e. the tax increase does not apply to pre-existing fossil fuel technologies. A more extensive application of a CO<sub>2</sub> tax increases to existing fossil fuel heat production and the transport sector would increase the private costs of the tax considerably without achieving any additional uptake of renewable heat technologies. In addition, by limiting the impact to new installations only, the wider economic impact of a carbon tax on the economy and energy demand can be said to be minimised. At present, a carbon tax of 20 €/tCO<sub>2</sub> is levied on fossil fuels and this is incorporated into the underlying fuel price assumptions.

In order to achieve the uptake required to reach the 2020 target for renewable heat, the modelling suggests that CO<sub>2</sub> tax increases to 29 €/tCO<sub>2</sub> in the *High scenario* and 38 €/tCO<sub>2</sub> in the *Central scenario* from 2015 for new fossil fuel installations would be required. The *Low scenario* conditions would require a CO<sub>2</sub> tax increase to over 80 €/tCO<sub>2</sub> and, given the likely severe wider economic impacts, it is not considered a realistic option.

### *Policy cost, technology deployment and benefits*

The impacts of these policy options in terms of technology uptake in each of the residential, services and industrial sectors are considered. The uptake levels drive the overall cost of the different policy options. The estimated policy funding costs are broadly indicative of what the various costs may be for financial instruments. More detailed policy design that includes a more sophisticated banding approach to tariff or grant development is likely to depart from the costs presented here. This analysis is useful to understand how the policies may influence funding costs under different fossil fuel price and biomass availability scenarios.

The total lifetime costs as well as the peak annual costs are presented for each policy in Table iv, and the cost profile for each policy in each scenario is shown in Figure v.

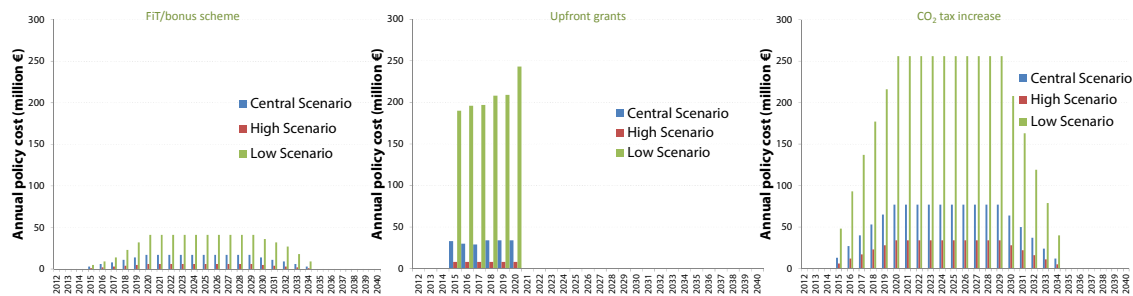
Table iv: Summary of policy cost evaluation

Policy option	Peak annual cost (€ million)			Total cost to 2035 (undiscounted) (€ million)			Total discounted cost <sup>17</sup> to 2035 (€ million)		
	High scenario	Central scenario	Low scenario	High scenario	Central scenario	Low scenario	High scenario	Central scenario	Low scenario
FiT/bonus	€6	€17	€41	€90	€255	€615	€54	€153	€361
capital grant	€9	€34	€243	€42	€194	€1,243	€28	€131	€836
CO <sub>2</sub> tax increase	€34	€77	€256	€508	€1,155	€3,840	€330	€750	€2,499

The funding cost between the FiT/bonus and capital grant scheme are considered negligible and within the uncertainties of the model.

The funding cost of the CO<sub>2</sub> tax increase is an order of magnitude greater than the cost of the other options examined. This arises because the cost of fossil fuels is still competitive for many sites, particularly those with access to the natural gas grid in spite of the CO<sub>2</sub> tax increase. The energy costs of these heat consumers are increased as a result of the tax, but not sufficiently to induce a decision to install a renewable heat technology.

Figure v: Annual cost of policy measures over life of the schemes (all scenarios)



In the FiT/bonus scheme one single marginal tariff dictates the cost. This marginal tariff level is set by the cost differential between bioenergy and oil in large commercial applications. However, this sector delivers a minority of the supported output towards the renewable heat target with large industrial applications taking up most of the demand. By introducing separate tariffs to cover the separate cost differentials in both the industry and the commercial sector, the overall cost could be reduced further. Conversely, expansion of the tariff bands to focus on individual technologies and/or smaller-scale technologies would lead to a more expensive policy funding cost.

The variation of costs in the grant scheme across scenarios is the largest of all the policy instruments examined. Grants fund a proportion of upfront installation costs unrelated to the energy output of a technology. Upfront costs are one component of the total costs of technologies and changes in these more variable cost components can result in a wide variation in the type and setting of renewable heat technology uptake. As a result, the energy output arising from a grant scheme can vary and greater number of individual installations maybe required to meet the RES-H target in 2020. The limitations of the grant scheme are highlighted in the *Low scenario*. It shows

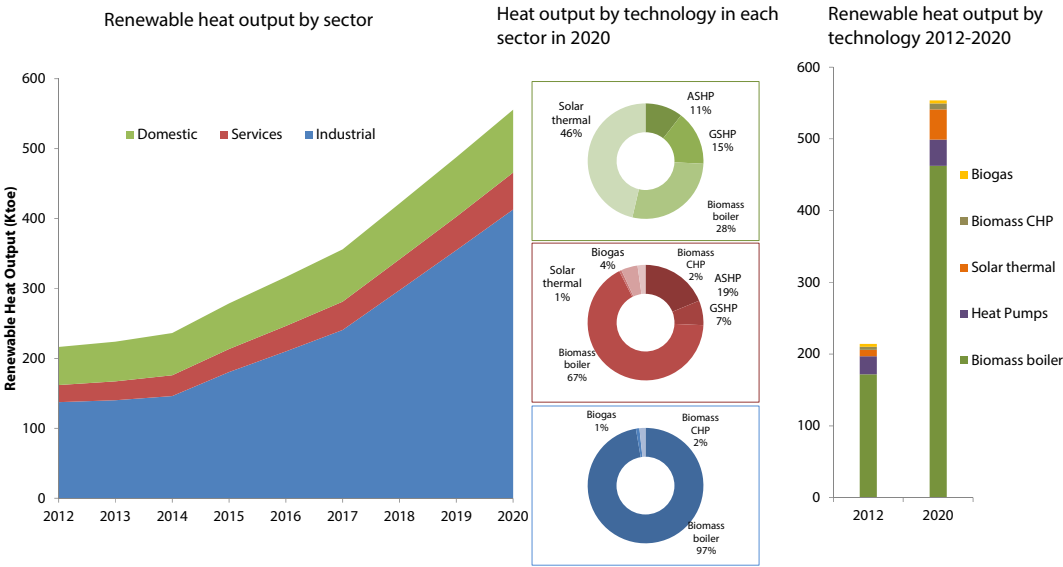
<sup>17</sup> A discount rate of 4% is used as per Department of Finance guidelines. See <http://publicspendingcode.per.gov.ie/wp-content/uploads/2012/08/D03-Guide-to-economic-appraisal-CBA-16-July.pdf>



that if there is shortfall on energy efficiency targets (i.e. higher overall energy demand) it could result in a significantly higher policy cost. As grant proportions were modelled at approximately 50% of the installation costs of a heat technology, more installations from the smaller size/higher cost bands are incentivised to meet the renewable heat target. As well as being costly, the numbers of individual installations could exceed 15,000 a year, indicating an increasing administrative burden in delivering such a scheme. In the event of future high fossil fuel prices, as modelled in the *High scenario*, the grant scheme could potentially provide the lowest cost route to the renewable heat target; this is because a 15% grant could prompt many of the larger industrial and commercial sites to switch from oil. Larger sites tend to have a higher year-round heat requirement, which means that the investment incentives deliver a large amount of renewable heat from each installation supported.

The technology uptake response is similar across all policy options. Figure vi shows the renewable heat output by renewable technology incentivised by the FiT/bonus scheme in the *Central scenario*. Biomass boilers replacing oil in large industrial and commercial sites account for the majority of the increased uptake due to policy intervention in all scenarios. Large biomass boilers on sites with reasonably constant year-round heat demand are the most cost competitive of the renewable heat technologies. Additional uptake of heat pumps in the commercial sector also occurs in the model. Biomass and AD CHP uptake rates remain at the low levels seen under the current policy scenarios.

Figure vi: Renewable heat technology output with FiT/bonus scheme 2012-2020 (Central scenario)



Fossil fuel savings to the heat user, and CO<sub>2</sub> reductions due to the various policies, are of a similar magnitude under all policy options. Table v shows the value of fossil fuel savings from the heat consumer's perspective, and the amount of CO<sub>2</sub> displaced across each scenario under each policy.

Table v: Fossil fuel and CO<sub>2</sub> savings to 2035 (all scenarios)

Scenario	Fossil fuel savings (€ million)			CO <sub>2</sub> savings (MtCO <sub>2</sub> )		
	Total savings (2015-2035)	discounted (2015-2035)	Peak savings	annual	Total savings (2015-2035)	Peak savings
<b>FiT/bonus</b>						
High scenario	464		48		3.9	0.3
Central scenario	865		89		5.8	0.4
Low scenario	1,648		173		9.4	0.7
<b>Upfront grant</b>						
High scenario	422		43		3.8	0.3
Central scenario	936		98		5.8	0.4
Low scenario	2,596		271		10.5	0.8
<b>CO<sub>2</sub> tax</b>						
High scenario	464		48		3.6	0.3
Central scenario	868		90		6.2	0.4
Low scenario	1,630		171		9.4	0.7

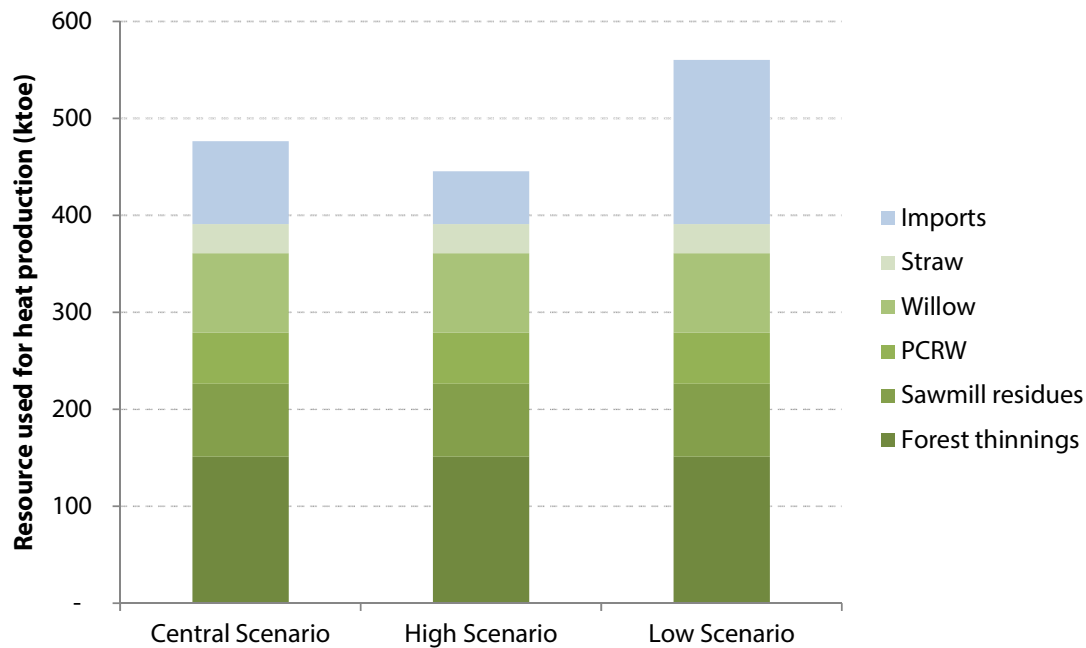
Oil displacement accounts for over 90% of the savings in all cases. Some differences in the amount saved under different policies are evident. This is due to the higher value of fossil fuels in smaller-scale applications – fuels are generally more costly per unit for consumers who use less energy across the year. Consumer savings include some loss of tax revenue for the exchequer.

In the *Central scenario*, the discounted value of fossil fuel savings over the lifetime of the scheme are estimated as being close to €900 million, peaking at over €90 million per year – or 1.5% of the 2012 import bill. The associated CO<sub>2</sub> savings are estimated as 6 MtCO<sub>2</sub> over the lifetime of the scheme to 2035; of these savings, 1.2 MtCO<sub>2</sub> is banked towards Ireland's non-ETS target in 2020.

### Impact of RES-H achievement on Bioenergy use

In achieving the 2020 renewable heat target in the policy scenarios, extensive use of the available domestic biomass sources is made due to cost competitiveness of bioenergy technologies. Figure vii shows the domestic resources selected by the model for the production of heat, and the level of imports required to meet the 2020 renewable heat target in each case.

Figure vii: Domestic and imported biomass resources used to meet RES-H 12% (all scenarios)



Imports have a role to play in all scenarios. There are a wide range of scenarios for the potential availability of imports; these scenarios are dependent on international factors which influence both the available supply and demand for resources in other jurisdictions. The use of the available domestic resource is influenced by the availability and harvesting cost of these resources. The bioenergy supply curves analysis, published by SEAI and used as an input to the modelling process, contains an in-depth examination of the biomass resource availability at various market prices for bioenergy. The harvesting costs of the resources include consideration of the supply-side barriers faced by producers of biomass material for energy, and these resources are only deployed in the model if the market price is sufficiently high to cover the harvesting costs. Several scenarios for the potential for international trade of biomass resources are also examined.

The costs associated with generating this increase in production are captured in the modelling, i.e. use of more expensive resources in BEAM result in a higher cost of biomass fuel in the Consumer Choice heat model, by including estimations of the price increases per fuel that are required to expand the bioenergy resource. Increases in biomass demand in the electricity sector will increase the competition for limited domestic resources; such increases are likely to lead to additional policy costs, in order to achieve the renewable heat target. Table vi shows the quantities of domestic resources used by the model in all scenarios in 2020.

Table vi: Resource requirement to produce required heat output in 2020 (all scenarios)

Resource requirement (common units)	Requirement in 2020
Forest thinnings (000 m <sup>3</sup> )	917
Sawmill residues (000 m <sup>3</sup> )	455
Post-consumer recycled wood (PCRW) (000 tonnes)	138
Short rotation coppice willow (000 ha)	17
Straw (000 tonnes)	88
Imported wood products (000 tonnes)	135-418

The quantities shown for domestic resources in 2020 represent a significant increase on current usage for most resources. For example, at present, there are 830 ha of willow<sup>18</sup> planted in Ireland and 17,000 ha are needed to meet the scenario demand modelled. Other resources have similar challenges. At present, about 500,000 m<sup>3</sup> of forest material<sup>19</sup> is used for energy purposes. More than double this amount needs to be brought into production in order to meet the portion of renewable heat demand for domestic forestry sources. The bioenergy supply curves analysis accounts for limits on resource deployment and shows that these uptake levels maybe possible with higher market prices for biomass resources. The policy costs estimated in this analysis include the price increases required to stimulate this increase in biomass resources deployment.

### Conclusion:

This analysis examined the possible future trends for renewable heat use in Ireland. A Consumer Choice heat model was employed to determine the potential uptake of renewable heat technology over the period to 2020. The modelling tools used account for assessments of the potential availability of raw biomass resources at various market prices for bioenergy out to 2020 and the demand for bioenergy in the heat, electricity and transport sectors over the same period. The optimisation model meets demand for bioenergy in each of the sectors at lowest cost by deciding where the most economic use of the available resource lies.

Three scenarios are presented to examine the impact of variations in fossil fuel prices, bioenergy availability and energy demand that may arise in the period leading up to 2020. These factors determine the likelihood of consumers switching from fossil-fuel to a renewable technology to provide their heat requirements and determine how much policy effort may be required to meet the RES-H target in 2020.

The analysis shows that, under current legislated policy, a gap to the RES-H 12% target of between 1-5 percentage points may arise. This implies that policy action is required to close the gap and achieve the 2020 target. A range of policy options are available that fall into the three broad categories of ongoing support, upfront support and taxation measures. Policy instruments within these categories each have advantages and drawback. Factors like the ease of implementation, the certainty that they will deliver the required uptake and administrative burden must be considered along with the funding cost of a policy instrument.

The analysis looked at the cost of representative policy instruments from each of the three broad categories. The cost differences between the FiT/Bonus scheme and the grant scheme are considered negligible and within the uncertainties of the model. The funding cost of carbon tax falls on fossil fuel consumers and is an order of magnitude higher than the other options.

Ongoing support in the form of a FiT/bonus (RHI) could deliver the gap to target at an annual cost of between €4.5 in a scenario with more favourable conditions for renewable heat technologies to

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<sup>18</sup> Tillage Sectoral Energy Crop Development Group (2014). *Achieving the Potential for Growing Energy Crops on Irish Farms*. Available at: [http://www.teagasc.ie/publications/2014/3130/Tillage\\_Sectoral\\_Energy\\_Crop\\_Development\\_GroupPlan2014.pdf](http://www.teagasc.ie/publications/2014/3130/Tillage_Sectoral_Energy_Crop_Development_GroupPlan2014.pdf)

<sup>19</sup> Phillips, H., Redmond, J., Mac Siúrtáin, M. and Nemesova, A. for COFORD, National Council for Forest Research and Development (2009). *Roundwood production from private sector forests 2009-2028 – A geospatial forecast*. Available at: <http://www.coford.ie/media/coford/content/researchprogramme/thematicareaeestablishingandgrowingforests/Roundwood%20production%20from%20private%20sector%20forests%202009-2028%20-%20A%20geospatial%20forecast.pdf>

€31 million in a less favourable scenario for renewable heat technologies. The total discounted lifetime cost for ongoing support is estimated at between €54 million and €361 million. In this analysis, a single tariff level is modelled and is determined by the most expensive technology required to meet the RES-H target. Further policy design can develop tariff levels for individual technology size bands, with lower cost bands (e.g. sites with large heat demands currently provided by oil switching to biomass) receiving a lower tariff level than the smaller more expensive marginal sites that set the tariff level for all technologies in this analysis. By introducing separate tariffs to cover the different cost differentials in the industry and the commercial sector, the overall cost could be reduced further. Conversely, expansion of the tariff bands to focus on more expensive technologies and/or smaller-scale technologies would lead to a more expensive policy funding cost.

The Government has proposed in its draft Bioenergy Strategy (2014) that it will introduce an Exchequer-funded incentive scheme from 2016 to reward users of each unit of renewable heat used from sustainable biomass. The analysis in this report supports the design and implementation of this scheme.

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## 1. Introduction

Ireland has set a target to deliver 12% of final heat demand from renewable energy sources by 2020. Achievement of the heat target would contribute about 20% of Ireland's overall binding renewable energy target, and it is one of the most important measures aimed at reducing the CO<sub>2</sub> emissions that count towards Ireland's target in 2020. While progress has been made on deployment of renewable heat technologies in recent years, energy forecast projections show that Ireland is likely to fall short of the RES-H 12% target, even under optimistic assumptions about what current policy can deliver. Additional policy action is required to meet the RES-H target and reduce the risk of the potential exchequer costs associated with compliance purchasing and fines. The analysis presented in this report supported the policy recommendations in the Draft Bioenergy Plan aimed at closing the gap to the renewable heat target.<sup>20</sup>

The purpose of the report is to evaluate the magnitude of the gap to the achievement of the RES-H target, and to examine the costs and impacts of policy options available to achieve the RES-H target by 2020. The analysis simulates how different categories of consumers, representing distinct sections of the heat sector, respond to the various technology attributes when choosing a heat technology. The attributes include the upfront installation costs, ongoing fuel and maintenance costs and any hassle costs associated with a heat technology. Biomass resource cost is an important factor in determining the ongoing costs of bioenergy technologies, and the availability, cost and demand for biomass resources across all sectors is accounted for in the modelling methodology. The potential contribution of renewable heat technologies over the period to 2020 is assessed across scenarios for changes in fossil fuel costs, biomass resource availability, heat demand growth and renewable policy measures.

Part 1 of the report provides details on the policy context for renewable heat use, a description of the heat sector in Ireland, the factors influencing consumer choice of a heat technology and the factors that determine the operational cost of individual technologies types. Part 2 describes the modelling method and scenarios examined. Part 3 shows the results for future renewable heat use under existing policy, including the impact on bioenergy use. Part 4 details some relevant international policy experience with policy interventions in the heat sector, and describes the main advantages and disadvantages associated with various policy options. Part 5 examines the costs and impacts associated with three policy interventions, including the impact on bioenergy use. Annex 1 and Annex 2 contain the detail of the modelling approach, data and assumptions.

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<sup>20</sup> Department of Communications, Energy and Natural Resources (2014), Draft Bioenergy Plan. Available at: <http://www.dcenr.gov.ie/Energy/Sustainable+and+Renewable+Energy+Division/Draft+Bioenergy+Plan.htm>

## **Part 1: The heat sector in Ireland – policy context, heat use and consumer technology decisions**

## 2. Renewable energy for heat – the policy context

The 2009 EU Renewable Energy Directive (2009/28/EC)<sup>21</sup> sets out the legal framework for binding renewable energy targets for each member state. Ireland's renewable energy target requires 16% of gross final energy consumption to come from renewable sources by 2020 (RES 16%).<sup>22</sup> National sub-targets in each of the energy end-use modes of electricity, transport and heat have been set by Ireland to achieve this overall target. These are a 40% penetration of renewable electricity in gross electricity consumption (RES-E 40%), a 10% penetration of renewable transport fuels in transport consumption (RES-T 10%) and a 12% penetration of renewable energy consumption in the heat sector (RES-H 12%). A shortfall in any of these targets will require Ireland to purchase renewable energy compliance from other member states that exceed their targets.

Policies and measures are in place to deliver on the transport and electricity goals. Heat policy is less developed, and projections from the latest SEAI energy forecast for the 2020 energy system show that, even under optimistic assumptions about the impact of current heat policies and measures, the RES-H 12% target is unlikely to be delivered.<sup>23</sup> Development of renewable heat policy will be strongly influenced by policy objectives for energy efficiency, greenhouse gas emissions outside of the Emissions Trading Scheme (non-ETS) and bioenergy.

Energy efficiency policy has a significant role in helping to achieve the RES targets. As the renewable energy targets are ratios measured against energy consumption, any lowering of energy consumption through efficiency improvements reduces the overall requirement for renewable energy deployment. The energy efficiency measures planned by the Irish government to deliver 20% energy efficiency savings are weighted towards the heat sector – (up to 50% of the targeted savings accrue through improvements in the thermal performance of the building stock).<sup>24</sup> Any shortfall in these efforts will mean an even larger requirement for renewable energy production.

In addition, a separate binding target, aiming for a 20% reduction by 2020 in those CO<sub>2</sub> emissions not covered by the EU Emissions Trading Scheme (ETS), is in place.<sup>25</sup> Current projections that assume full achievement of the targets in the energy sector – including the RES-H 12% target – show that non-ETS emissions are still likely to be in excess of the targeted reduction.<sup>26</sup> This optimistic scenario still shows a shortfall in the non-ETS emissions target. The current uptake trajectory of renewable heat will see Ireland fall further below this optimistic scenario outcome.

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<sup>21</sup> EU Renewable Energy Directive 2009/28/EC. Available at:

<http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0028&from=EN>

<sup>22</sup> RES is the acronym for Renewable Energy Share in gross final energy consumption.

<sup>23</sup> SEAI (2011). *Energy Forecasts for Ireland to 2020*. 2011 Report. Available at: <http://forecasts.seai.ie/>

<sup>24</sup> Ireland has set out plans to reduce energy demand by 20% in 2020 compared to the average consumption between 2001 and 2005. Department of Communications, Energy and Natural Resources (2014). *National Energy Efficiency Action Plan 2014*. Available at: <http://www.dcenr.gov.ie/NR/rdonlyres/20F27340-A720-492C-8340-6E3E4B7DE85D/0/DCENRNEEAP2014publishedversion.pdf>

<sup>25</sup> DECISION No 406/2009/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL, 23<sup>rd</sup> April 2009, on the effort of Member States to reduce their greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments up to 2020. Available at: <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009D0406&from=EN>

<sup>26</sup> EPA (2014). *Ireland's Greenhouse Gas Emission Projections 2013-2030*. Available at: [http://www.epa.ie/pubs/reports/air/airemissions/GHG\\_report2014.pdf](http://www.epa.ie/pubs/reports/air/airemissions/GHG_report2014.pdf)

### 3. The heat sector in Ireland

Thermal uses of energy account for 45% of all primary energy use in Ireland. The majority of heat energy is generated through the combustion of fossil fuels, with a significant minority coming from renewable sources. Electricity is also commonly used as a heating source, with the use of electricity for heat recorded as part of the overall electricity demand. The EU renewable energy directive details the method for calculating the renewable energy shares across the end-use sectors. The fossil fuels and renewable energy used for heat constitute the heat demand for the purposes of the calculation of RES-H. Electricity used for heat is captured in the demand used in the calculation of RES-E. This section deals with the heat demand included in the RES-H calculation.

Figure 1 shows the historical trends of heat use in Ireland since 1990.<sup>27</sup> The industrial and residential sectors account for the majority of heat demand, with the services and agricultural sectors accounting for the remainder. The demand from industry and the domestic sector are similar in magnitude, but very different in terms of how the heat energy is used. Industry tends to use heat as part of manufacturing processes, while domestic and commercial buildings use energy for space and water heating. A close look at the demand profile of industry in Figure 1 shows less variability between years, whereas the residential and services sectors should show a much higher variability. This points to the prominence of space and water heating in these sectors and the impact that climatic changes between years has on the heat energy use. In contrast, heat used for industrial processes is not influenced by these climatic changes, with heat demand being dictated by the requirements of production output.

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<sup>27</sup> Energy Policy Statistical Support Unit (2012). *Energy in Ireland 1990-2011*. Available at [http://www.seai.ie/Publications/Statistics\\_Publications/Energy\\_in\\_Ireland/Energy\\_in\\_Ireland\\_1990\\_-\\_2012\\_Report.pdf](http://www.seai.ie/Publications/Statistics_Publications/Energy_in_Ireland/Energy_in_Ireland_1990_-_2012_Report.pdf)

Figure 1: Energy use in the generation of heat by sector 1990-2012

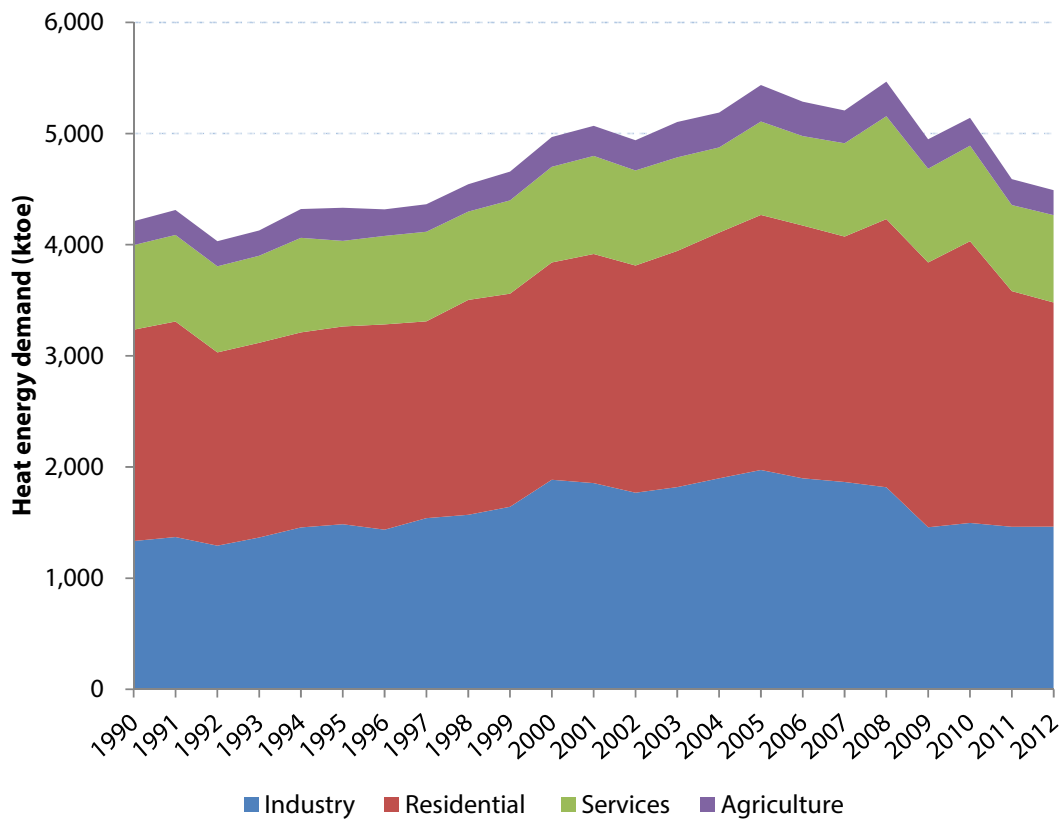


Figure 2 shows the fuels used to produce heat energy. Oil is the dominant fuel, accounting for almost 45% of the total in 2012, with natural gas the next largest, accounting for 38%.<sup>28</sup> The share of solid fuels – peat and coal – has seen a gradual decline over the period 1990-2012, accounting for 12% of final consumption in 2012. Renewable energy use has grown in recent years, contributing 5% of total final consumption of heat in 2012.

<sup>28</sup> Analysis by the Academy of Engineering suggests that up to 100,000 dwellings within 20m of the gas grid are currently using oil-fired central heating. This suggests that there is scope to increase the share of gas and reduce CO<sub>2</sub> emissions in the residential sector. See Irish Academy of Engineering (2013). *Policy Advisory – The Future of Oil and Gas in Ireland*, Section 6. Available at: [http://www.iae.ie/site\\_media/pressroom/documents/2013/Feb/26/IAE\\_-\\_Policy\\_Advisory\\_on\\_Oil\\_and\\_Gas\\_February\\_2013.pdf](http://www.iae.ie/site_media/pressroom/documents/2013/Feb/26/IAE_-_Policy_Advisory_on_Oil_and_Gas_February_2013.pdf)

Figure 2: Fuel used in the generation of heat energy 1990-2012

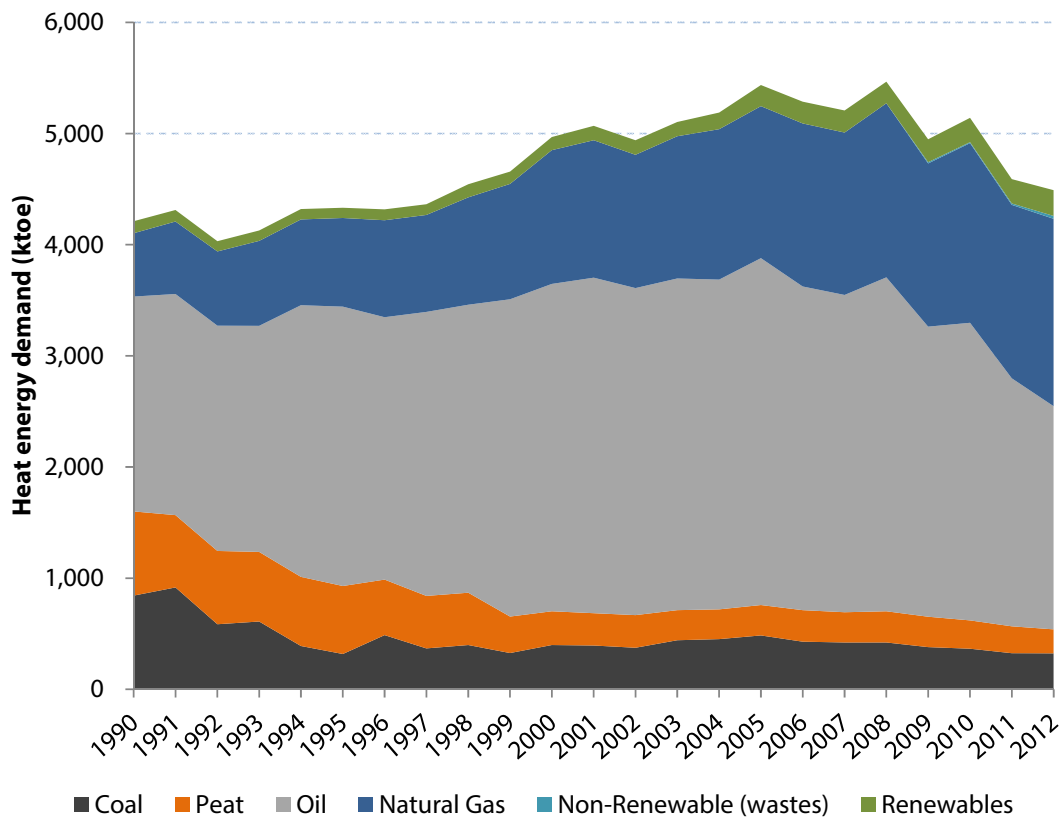
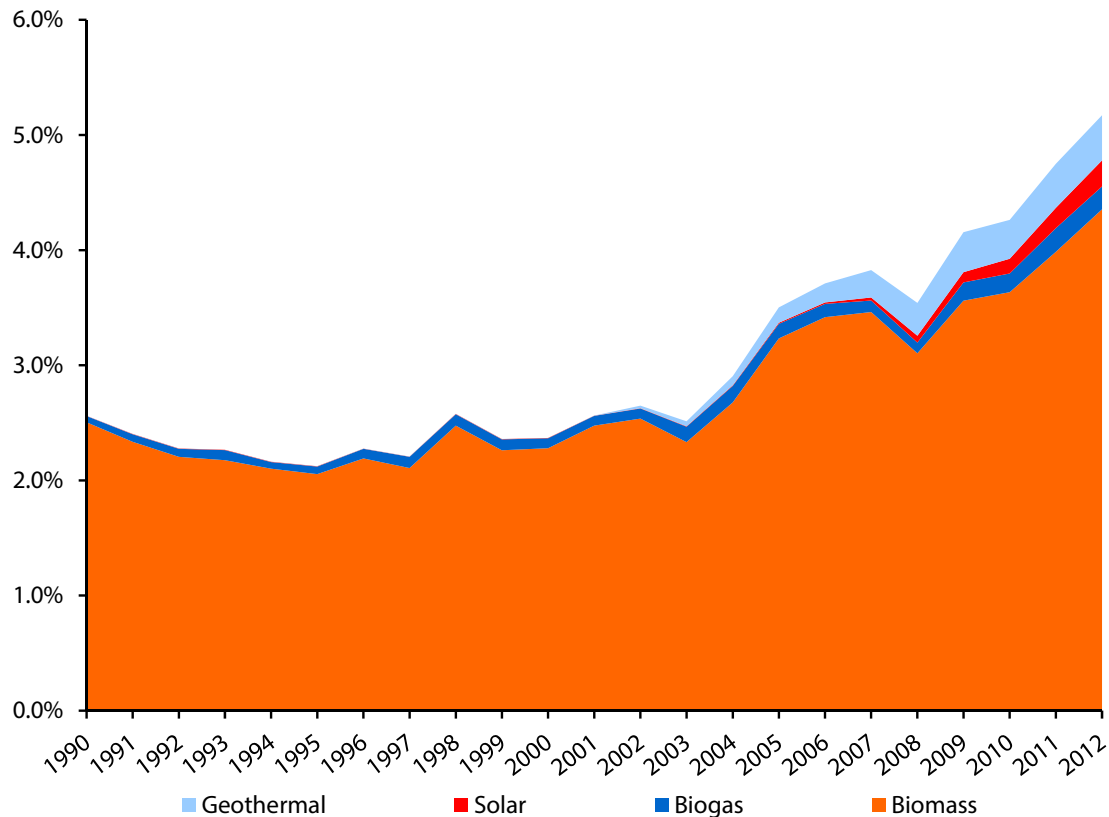


Figure 3 shows the historical breakdown of renewable heat usage as a proportion of total final consumption of heat by fuel type. Biomass has been the largest contributor over the period, with solar and geothermal<sup>29</sup> showing significant growth from 2006. Much of the current renewable energy usage occurs in the industrial sector through the combustion of biomass. In the services and residential sector there is much more diversity in the type of renewable fuels used, with solar and geothermal having a much larger role. The most recent energy balance showed an aggregate share of renewable heat in total final consumption of 5.1%.<sup>30</sup> This compares to a pre-policy level that has averaged around 3% since 1990. The policy interventions through the Greener Homes and ReHeat schemes, the REFIT tariffs for Biomass CHP and the Building Regulations requirement coincided with an increase in renewable heat usage. Rising fossil fuel prices in this period, energy efficiency measures and the economic recession also have had an influence on this trend.

<sup>29</sup> The amount of renewable energy from heat pumps is related to the amount the average Coefficient of Performance (COP) of heat pumps is greater than the conversion efficiency of the entire electricity system. Heat pumps can have COPs in the range of 3-6 and the conversion efficiency of the electricity system in 2012 was 2.18. The energy counted as renewable is determined by the difference between these metrics.

<sup>30</sup> Recent analysis by the Energy Policy Statistical Support Unit (EPSSU) has looked at accounting methodology for non-traded wood, which suggests that more biomass is currently being used in the residential sector. Should this extra quantity qualify under any sustainable criteria set at an EU level, then REH-H for 2011 could rise to 6.1%. The EPSSU has recommended that the current method should remain, due to difficulties with data collection and continuance of a consistent retrospective time series. For further information, see Annex 1 of EPSSU (2013) *Residential Energy in Ireland 1990-2011*. Available at: [http://www.seai.ie/Publications/Statistics\\_Publications/Energy-in-the-Residential-Sector/Energy-in-the-Residential-Sector-2013.pdf](http://www.seai.ie/Publications/Statistics_Publications/Energy-in-the-Residential-Sector/Energy-in-the-Residential-Sector-2013.pdf)

Figure 3: Renewable energy share of final consumption 1990-2012



#### 4. Factors that impact the choice of a heat technology

Policy intervention to overcome the barriers to renewable energy uptake in the heat sector has proven more difficult than in other areas. Heating demand in Europe is estimated to account for as much as 48% of all final energy demand, but the heat sector has seen much less activity to support renewable technology when compared with the transport and electricity sectors.<sup>31</sup> This points to the fragmented nature of the heat market, the difficulties of retrofitting buildings with new heat technology, the complexities of using biomass fuel supply, and the administrative difficulties of implementing policy support for renewable heat.

The generation and use of heat energy is shaped by the complexity in the interactions between generation, supply and end-use arising from the physical characteristics of heat energy. Heat energy is difficult to transport over significant distance in an efficient way. This means that the economies of scale that are available in the electricity sector, due to the relative ease of transportation from a few large generation sites through a common network, are unavailable. As a result, heat use tends not to be metered, and a diverse range of technologies – using a range of

<sup>31</sup> Intelligent Energy – Europe Consortium (2012). *D23 Final Report: RE-Shaping: Shaping an effective and efficient European renewable energy market*, Karlsruhe. Available at: [http://www.resaping-res-policy.eu/downloads/Final%20report%20RE-Shaping\\_Druck\\_D23.pdf](http://www.resaping-res-policy.eu/downloads/Final%20report%20RE-Shaping_Druck_D23.pdf)



fuels – are installed close to each individual demand site. As a result, heat is generally not traded as a commodity and typically does not have a market price.<sup>32</sup>

Existing households and businesses tend to change their heating system every 15 years. This means that in any one year about 6% of the heat technology stock is upgraded, with approximately 60,000 oil boilers, 40,000 gas boilers and 8,000 direct electric heaters being upgraded or replaced each year in Ireland. Additions to the building stock are closely related to economic growth, with about 25,000 new dwellings a year expected to be added to the housing stock each year to 2020.

Each site has its own unique set of physical circumstances and, at a small scale, each customer has a unique set of behavioural characteristics and market barriers, all of which influence the choice of heat-producing technologies. Large industry, commercial businesses and households tend to use heat in very different ways.

Process heat in industry often requires the generation of steam for use in applications such as medical device sterilisation and the drying of powdered milk in the food industry. These installations typically operate for a substantial number of hours during the year, producing heat at higher temperatures. This makes the fuel cost, security of supply of the input fuel and the availability of specialised maintenance essential considerations in cost minimisation efforts, and limits the technology choice to those capable of producing high-grade heat.

In contrast, space and water heating in offices and homes typically occurs over the winter months, with a residual demand for water heating over the summer months. This reduces the relative importance of fuel consumption and ongoing maintenance costs, and increases the relative importance of upfront installation costs in heat technology choice. The available technology choice is more diverse due to the lower temperature requirements of space and water heating. The hassle cost involved in researching the technology options, and the extra disruption involved in retrofitting new technology, discourages some consumers from upgrading to a less costly option. Tenants and landlords may have divergent incentives, with landlords' choice of heat technology dependent predominantly on the installation cost, while tenants are more concerned with the ongoing running costs. This can result in a technology with a higher overall lifetime cost being chosen.<sup>33</sup>

The suitability of a building for a technology type, and consumer attitudes towards changing technology, are also important determinants of which technology is chosen when replacing an old gas or oil central heating system. Factors such as the proximity to the gas grid and available space for fuel storage can also strongly influence the decision.<sup>34</sup> Biomass resources have lower energy densities than fossil fuels, making them more expensive to transport; in addition, they require larger amounts of storage space.

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<sup>32</sup> Suppliers of heat through district heating (DH) networks offer a market price for heat to consumers, but make up a minority of heat supplied internationally.

<sup>33</sup> Howarth, R.B. and Sanstad, A.H. (1995) 'Discount rates and energy efficiency'. *Contemporary Economic Policy*, 13(3), pp. 101-109.

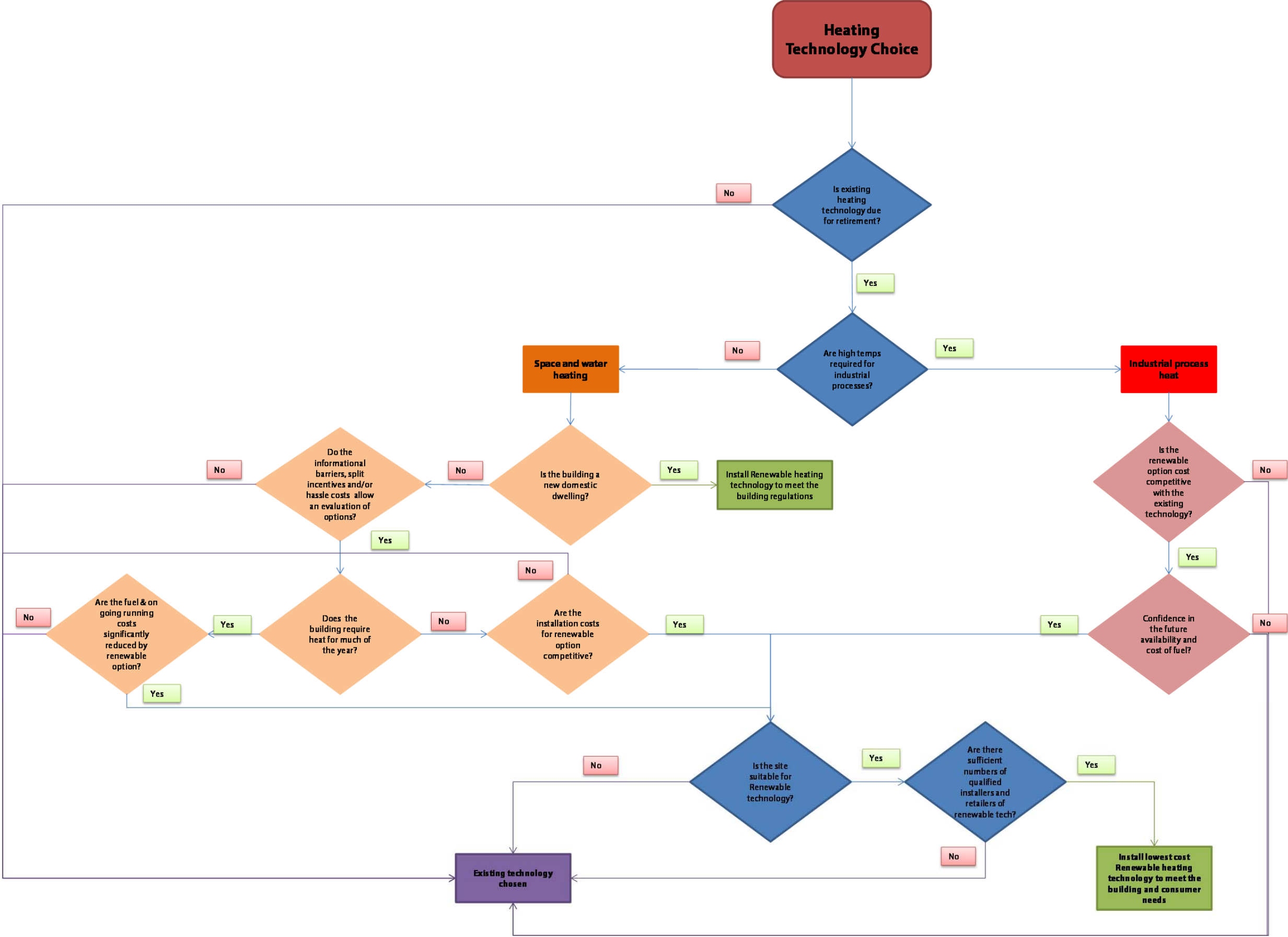
<sup>34</sup> Element Energy and NERA Economic Consulting for the Committee on Climate Change (2011). *Achieving deployment of renewable heat – Final report*, section 4. Available at: [http://www.element-energy.co.uk/wordpress/wp-content/uploads/2012/05/CCC-Renewable-Heat-final-report\\_06.05.11.pdf](http://www.element-energy.co.uk/wordpress/wp-content/uploads/2012/05/CCC-Renewable-Heat-final-report_06.05.11.pdf)

Renewable energy technologies such as solar thermal, biomass combustion, heat pumps and anaerobic digestion (AD) currently represent a specialised segment of heat supply. Limits on the available workforce skills and expertise, as well as the lack of demonstration of the more specialised technologies, can influence installation decisions. Furthermore, the availability of a secure fuel supply is an important factor for AD and for some biomass combustion technologies. Anecdotal evidence from SEAI's interaction with industry through the Large Industry Energy Network scheme suggests that concerns such as these may be holding back uptake of biomass, which otherwise makes economic sense. Analysis of the available biomass resource by SEAI<sup>35</sup> shows that while domestic resources are potentially available to contribute to the heat targets, these will only be developed if the market price of these resources increases significantly. International trade in bioenergy commodities such as wood pellets and wood chips could see adequate quantities of these commodities available to import into Ireland at a lower price, if global development of these markets materialises. The scenarios modelled account for the availability and cost of domestic resources and the interaction with imports of bioenergy commodities. Figure 4 shows a stylised flow chart representation of consumer choice.

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<sup>35</sup> SEAI and AEA (2013) *BioEnergy Supply Curves for Ireland 2010-2030*. Available at <http://www.teagasc.ie/energy/policies/BioenergySupplyCurvesForIreland2010-2030.pdf>

Figure 4: Stylised flow chart of consumer heat technology decision-making process



## 5. What are the costs of the different heat technology options?

Technology costs are influenced by a number of factors. The installation cost, ongoing maintenance costs and the fuel costs, along with the consumer's payback requirement and the technology life, determine the overall cost. This total lifetime cost is often expressed as the levelised cost of energy or LCOE. The setting and purpose of heat technology is key in determining the overall cost, with capital cost being a more influential component of cost in residential and small services sector buildings, and ongoing fuel and maintenance being more important in industry and large commercial settings. LCOE for technologies varies across sectors, due to the differing requirements for space heating and process heating. Consumer behaviour also has a bearing, with this variation being more pronounced in the residential sector, due to many combinations of consumers and building types; it is less pronounced in the industry sector, due to the greater homogeneity of that sector.

Figure 5 shows the detail of how heat technology LCOE varies across the fuel types, scale and applications, based on current fuel and technology prices and on expectations of how these prices may evolve to 2020. Technology installation costs and efficiencies are not expected to change significantly, with changes in fuel price exerting the greatest influence on changes in technology cost over the period to 2020. The height of the bars illustrates the range of costs a particular technology has across the various applications in each sector.

Some technologies may appear to be competitive with each other, based on a comparison of the height of the bars in Figure 5. However, in reality, they may have a much lower current market share of heat output – for example, oil heating has a much higher share of heating demand than direct electric heating in the residential sector. This can be explained in terms of the suitability of these technologies to meet the demand requirements of the buildings in which they are installed. The owners of apartments with modest heating requirements may opt for the low installation costs of direct electric heating, whereas the owners of larger homes with higher heat demand tend to opt for the lower running costs of an oil or gas central heating system. Buildings using oil or gas boilers typically have a much higher floor area – and heat demand – than buildings with direct electric heating. Because there are more of the former type of dwellings than the latter, oil has a greater share of the heat market.

Figure 5: Indicative cost of heat technology options 2012-2020 in each sector

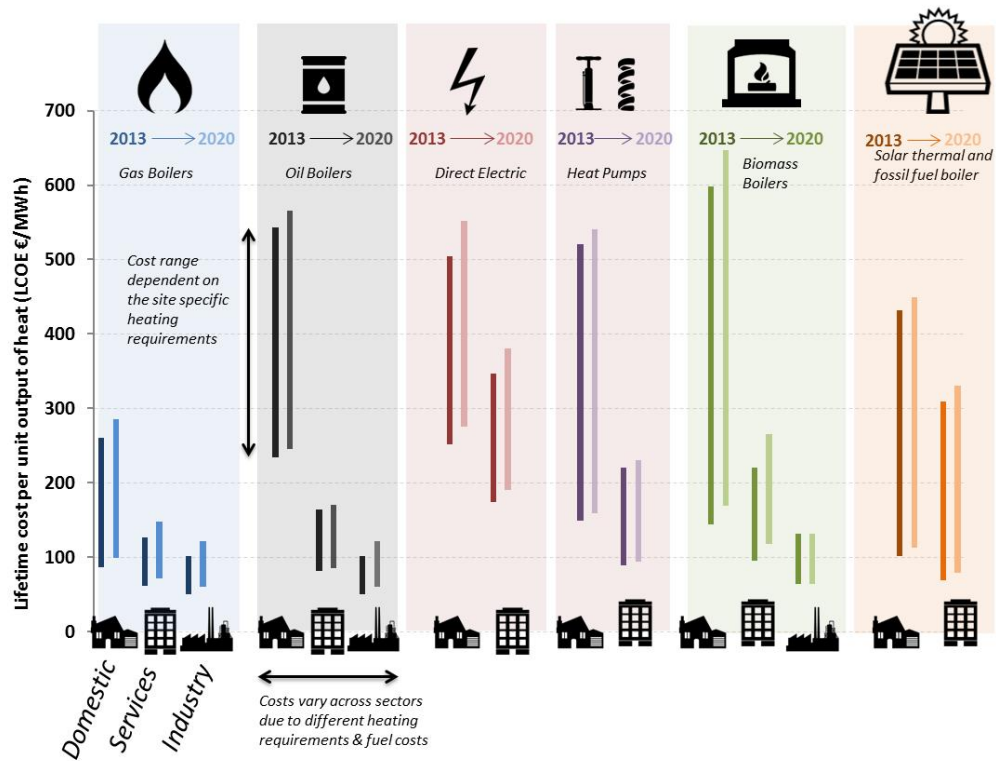


Figure 5 shows that biomass boilers in the industrial sector, heat pumps in the commercial sector and solar thermal in the residential sector are the most competitive with oil, gas and direct electric heating options. Annex 1 contains a detailed breakdown of the heat technology costs.

## **Part 2: Modelling the heat sector**

## 6. Approach to modelling the heat sector to 2020

The 2011 national energy forecast<sup>36</sup> identified a gap to the achievement of the RES-H target even under optimistic assumptions about what current policy may achieve by 2020. In order to achieve the target, further policy intervention is required. Analytical tools capable of characterising the intricacies of heat energy use were developed to evaluate the gap, and to examine the costs and impacts of potential policy options. SEAI commissioned Element Energy<sup>37</sup> to develop a consumer choice model of the heat sector in Ireland, using data on the Irish building stock supplemented by a representation of how different categories of heat consumers come to choose heat technology.

The heat sector is divided into 35 different consumer types, based on sector, building type, annual heat demand and existing primary fossil fuel source. Consumer responses to technology attributes, such as upfront capital costs, fuel and maintenance costs and the hassle costs associated with installing a new technology, are represented for each consumer category. A combination of all of these attributes determines the total attractiveness of a technology to a consumer. The technology that provides the highest utility to each consumer group gains the largest market share of new installations for that group. The number of potential installations of new renewable heat technologies is limited (constrained) by the natural retirement rate of fossil fuel technologies, the suitability of renewable technologies in a given setting and any supply-side constraints (such as lack of trained installers).

The relative costs of fuels are an important attribute in the choice of a heat technology. Renewable heat technologies tend to reduce ongoing fuel costs, due to either efficiency improvements (heat pumps) or lower fuel costs (biomass). If these reductions cover the higher installation costs of these technologies in a period of time that is agreeable to the individual heat consumers, then these renewable options are favoured. Biomass technologies in industrial or large commercial settings are currently most competitive with the fossil fuel alternatives, as fuel costs tend to be the largest component of the cost of generating heat in these settings. The ongoing cost of biomass resources relative to fossil fuels is therefore a significant determinant of the likelihood of uptake of biomass technologies. Given biomass resources can be used to produce electricity, transport and heat energy, and changes in demand for biomass inputs in any of these energy end-uses can impact on the price of the resources in all end-use sectors.

To capture this influential aspect of the heat technology uptake, the SEAI Bioenergy Analysis Model (BEAM) was used in conjunction with the Consumer Choice heat model to establish the price impacts of any change in bioenergy demand. The BEAM model is a least-cost linear optimisation model that uses data on the available resources at different market prices, refining costs for raw biomass resources, resource transportation costs, conversion and refining technology costs and government policy impacts to meet demand for bioenergy in the transport, electricity and heat energy end-use sectors at the lowest overall cost. Higher demand for biomass resources across the heat electricity and transport sectors means that more expensive biomass resources must be harvested to meet this demand, thereby raising the market price for the various refined

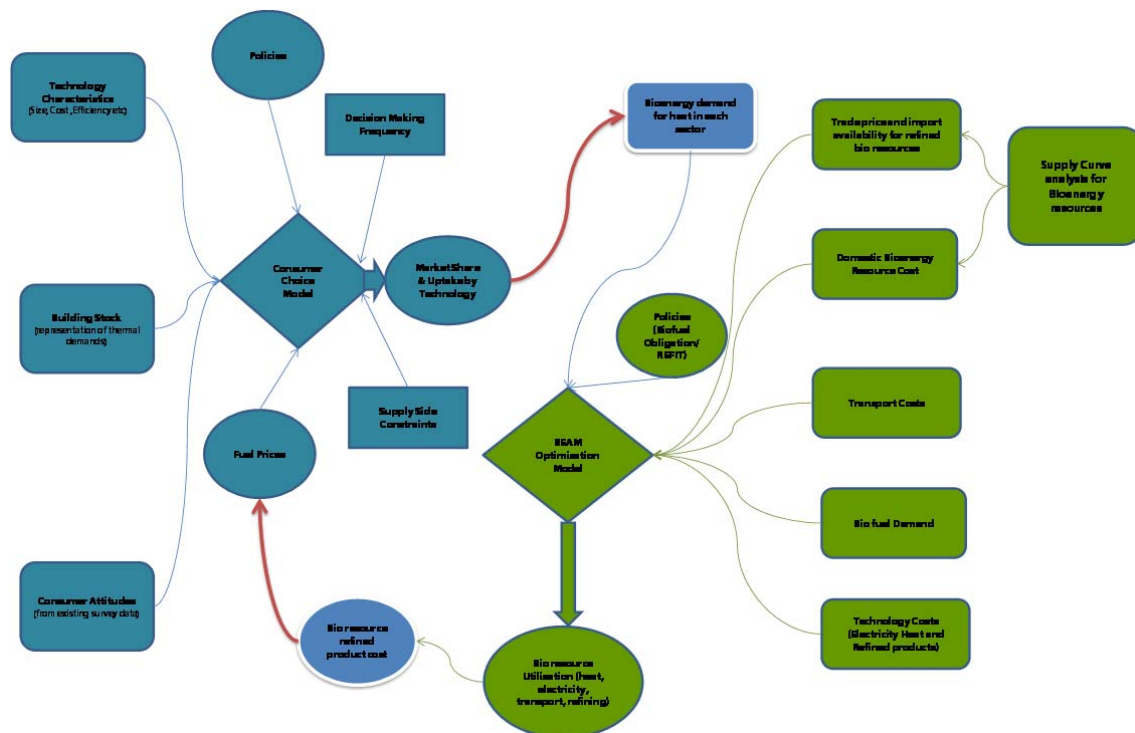
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<sup>36</sup> SEAI (2011) *Energy Forecasts for Ireland to 2020. 2011 Report*. Available at: [http://www.seai.ie/Publications/Statistics\\_Publications/EPSSU\\_Publications/Energy\\_Forecasts\\_for\\_Ireland\\_for\\_2020\\_2011\\_Report.pdf](http://www.seai.ie/Publications/Statistics_Publications/EPSSU_Publications/Energy_Forecasts_for_Ireland_for_2020_2011_Report.pdf)

<sup>37</sup> Element Energy, Terrington House, 13-15 Hills Road, Cambridge, CB2 1NL. See <http://www.element-energy.co.uk/>

biomass products (i.e. biofuels, wood chips and pellets, biogas) that are used to meet the demand in these sectors. These prices are inputted into the heat model to estimate a bioenergy demand in the heat sector, and the process is repeated until stable market equilibrium is reached. Data from the SEAI *Bioenergy Supply Curves for Ireland 2010 – 2030* publication are used to represent the cost of harvesting raw biomass resources. The cost implications of the various supply-side barriers to resource extraction, such as the willingness of farmers to grow energy crops at various price levels, are accounted for within this analysis. Figure ii shows a representation of the input variables and linking of the heat model with BEAM.

Figure 6: Schematic representation of modelling process and data inputs



### 6.1. Scenarios examined

Three baseline scenarios are examined to assess the impact of variations in the underlying assumptions on 1) fossil fuel price, 2) bioenergy availability and 3) energy demand scenarios that may arise over the period to 2020. The scenarios define a range of possible outcomes under the current policy environment. The existing policy measures included in the modelling are:

- The impact of energy efficiency policies as outlined in the *National Energy Efficiency Action Plan* (NEEAP).<sup>38</sup>
- The Electricity REFIT for bioenergy technologies.<sup>39</sup>

<sup>38</sup> Department of Communications, Energy and Natural Resources (2014) *National Energy Efficiency Action Plan 2014*. Available at: [http://www.dcenr.gov.ie/NR/rdonlyres/20F27340-A720-492C-8340-6E3E4B7DE85D/0/DCEN\\_RNEEAP2014publishedversion.pdf](http://www.dcenr.gov.ie/NR/rdonlyres/20F27340-A720-492C-8340-6E3E4B7DE85D/0/DCEN_RNEEAP2014publishedversion.pdf)



- Part L of the 2008 Building Regulations requires 10/kWh/m<sup>2</sup> of renewable heat to be installed in new dwellings.<sup>40</sup>
- A grant of €800 for solar thermal installations until the end of 2014.<sup>41</sup>
- Carbon tax remaining at current levels.<sup>42</sup>

*Table 1: Summary of scenarios modelled*

Scenario	Fossil fuel prices	Bioenergy availability	Energy demand
<b>High</b>	Central scenario + 10% by 2020	Some wood chips and wood pellets imported (cheaper than available domestic resources).	All energy efficiency measures targeted by policy are implemented.
<b>Central</b>	International Energy Agency (IEA) 'current policies' scenario as outlined in the IEA publication <i>World Energy Outlook 2012</i> .	All domestic biomass resources used to meet demand before higher cost resources are imported.	All energy efficiency measures targeted by policy are implemented.
<b>Low</b>	IEA 'new policies' scenario (prices 10% less than 'current policies' scenario by 2020).	All domestic biomass resources used to meet demand before higher cost resources are imported.	Shortfall in the energy efficiency targets.

**Central scenario:** *An improving environment for renewable heat technologies*

The EPSSU energy price comparison publication, which outlines retail prices for oil, gas and electricity in the residential, services and industrial sector, is used as the starting point for data on the fuel price growth rate in each sector.<sup>43</sup> The growth rate of fossil fuel prices is based on the 'current policies' projections outlined in the International Energy Agency (IEA) publication *World Energy Outlook 2012*.<sup>44</sup> Due to the high market share of natural gas in the power sector in Ireland, retail electricity prices are assumed to grow at the same rate as natural gas.

Energy demand projections are consistent with the 'NEEAP/NREAP'<sup>45</sup> scenario as published in the 2012 national energy forecasts.<sup>46</sup> The 'NEEAP/NREAP' scenario assumes that the 2020 targets for energy efficiency are met in full and that the renewable energy targets, as detailed in the National Renewable Energy Action Plan (NREAP), are achieved. As the majority of savings identified in the *National Energy Efficiency Action Plan* (NEEAP) are targeted to reduce heat usage, this assumption

<sup>39</sup> Department of Communications Energy and Natural Resources (2013) *Renewable Energy Feed in Tariff A Competition for Electricity Generation – from Biomass Technologies 2010-2015*. Available at: <http://www.dcenr.gov.ie/NR/rdonlyres/05441877-FC28-4A6C-8F5F-0EEAC8271DDF/0/REFIT3TermsandConditionsJuly2013.pdf>

<sup>40</sup> Department of Environment, Heritage and Local Government (2011) Technical Guidance Document, Part L Building Regulations 2011 - *Conservation of Fuel and Energy – Dwellings*. Available at: <http://www.environ.ie/en/Publications/DevelopmentandHousing/BuildingStandards/FileDownload,27316,en.pdf>

<sup>41</sup> Sustainable Energy Authority of Ireland, 2013, Better Energy Homes scheme. See [http://www.seai.ie/Grants/Better\\_energy\\_homes/About\\_the\\_Scheme/](http://www.seai.ie/Grants/Better_energy_homes/About_the_Scheme/)

<sup>42</sup> Finance Bill 2013. See <http://www.finance.gov.ie/sites/default/files/financebill2013.pdf>

<sup>43</sup> EPSSU Fuel Cost Comparison sheets. Available at: [http://www.seai.ie/Publications/Statistics\\_Publications/Fuel\\_Cost\\_Comparison/](http://www.seai.ie/Publications/Statistics_Publications/Fuel_Cost_Comparison/)

<sup>44</sup> International Energy Agency (2012) *World Energy Outlook 2012*. Available at: <http://www.worldenergyoutlook.org/publications/weo-2012/>

<sup>45</sup> Department of Communications, Energy and Natural Resources (2014) *National Energy Efficiency Action Plan 2014 (NEEAP)/National Renewable Energy Action Plan (NREAP)* <http://www.dcenr.gov.ie/Energy/Energy+Efficiency+and+Affordability+Division/National+Energy+Efficiency+Action+Plan.htm>

<sup>46</sup> SEAI (2011) *Energy Forecasts for Ireland to 2020*. 2011 Report. Available at [http://www.seai.ie/Publications/Statistics\\_Publications/EPSSU\\_Publications/Energy\\_Forecasts\\_for\\_Ireland\\_for\\_2020\\_-2011\\_Report.pdf](http://www.seai.ie/Publications/Statistics_Publications/EPSSU_Publications/Energy_Forecasts_for_Ireland_for_2020_-2011_Report.pdf)

means that less energy output is required for renewable heat technologies to achieve the RES-H 12% target.<sup>47</sup>

Imports of biomass products are restricted and are only available for import when all domestic resources have been brought into production.

**High scenario:** *A more favourable environment for renewable heat technologies*

Fossil fuel prices are assumed to be 10% higher in 2020 than the IEA projections – making renewable heat technologies more competitive. Demand projections are based on the same assumptions as the *Central scenario*. Some bioenergy resources – wood chips and wood pellets – will be available for import from 2015 at prices lower than the majority of domestic resources.

**Low scenario:** *A less favourable environment for renewable heat technologies*

Fossil fuel projections are based on the ‘new policies’ scenario outlined in the IEA publication *World Energy Outlook 2012* (10% less than the ‘current policies’ scenario). The baseline demand assumptions for the 2012 energy forecast are used to model a low uptake of energy efficiency measures. Imports of biomass products are restricted and are only available for import when all domestic resources have been brought into production.

*Table 2: Modelling input assumptions*

		<b>High scenario</b>	<b>Central scenario</b>	<b>Low scenario</b>
	2011	2020	2020	2020
<b>Fossil fuel</b>				
<b>Crude oil (\$/barrel)</b>	105	129	118	108
Retail oil prices: (€/MWh)				
Industrial	54	64	61	57
Services	65	78	74	70
Domestic	85	104	99	92
<b>Natural gas (Europe imports) (\$/ Mbtu)</b>	9.6	12.1	11	10.4
Retail natural gas prices(€/MWh):				
Industrial	54	49	47	45
Services	49	61	59	56
Domestic	60	74	71	67
Retail electricity prices(€/MWh):				
Industrial	129	153	146	140
Services	180	215	205	196
Domestic	200	238	227	217
<b>Heat demand (ktoe)</b>				
Industrial	1,441	1,327	1,327	1,330
Services (incl agri)	986	799	799	1,179
Domestic	2,124	1,672	1,672	2,417
<b>Available low-cost bioenergy imports (ktoe)</b>				
Wood chips	13	24	0	0
Wood pellets		73	0	0

<sup>47</sup> As the renewable energy targets are set as a ratio of demand, lower demand results in a lower requirement for renewable energy output to meet the target.

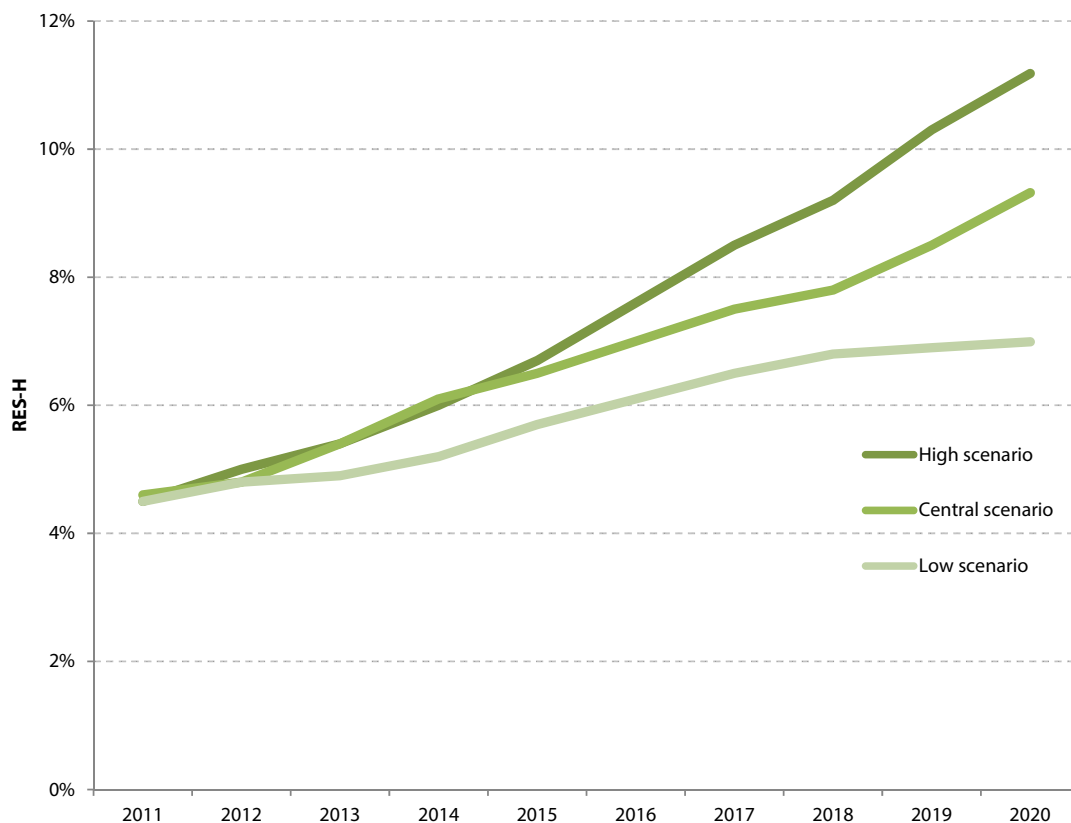
### **Part 3: Renewable heat uptake and bioenergy use under current policy**

## 7. What could current policy deliver towards RES-H?

Projections of future scenarios are inherently uncertain, as they rely on assumptions of the direction of key influencing factors such as fossil fuel prices and technology development. The outputs from the model can give insights which should be interpreted in the context of the wider issues pertaining to the heat market.

Figure 7 shows the trajectory of each scenario towards meeting the RES-H target of 12% by 2020. Based on the demand assumptions shown in Table 2, a total renewable heat output of 455 ktoe (5,292 GWh) is required to reach RES-H 12% in the *High scenario* and the *Central scenario*. Both scenarios assume full implementation of the energy efficiency measures outlined in the NEEAP. The *Low scenario* assumes that no new energy efficiency measures are implemented after 2012. As a result, the *Low scenario* requires a total renewable heat output of close to 550 ktoe (6,397 GWh) to meet the RES-H target.

Figure 7: RES-H share projected for each scenario to 2020



All three scenarios fall short of the 2020 target. The *High scenario* shows the strongest growth in renewable heat, driven by the cost competitiveness of renewable heat technology and with fossil fuel options reaching a RES-H of 11% by 2020 or 30 ktoe (349 GWh) short of the required output.

Less expensive fossil fuels in the *Central scenario* reduce the cost competitiveness of the renewable heat technologies, resulting in fewer consumers choosing to install these technology options. The RES-H of 9% equates to a 110 ktoe (1,279 GWh) shortfall.

The *Low scenario* results in a renewable heat output of just 230 ktoe (2,675 GWh) by 2020. Due to the higher demand as a result of the shortfall on energy efficiency and the lower cost of fossil fuel options, a RES-H of 7% is reached, leaving a gap of 255 ktoe (2,966 GWh) in 2020. Table 3 summarises the high-level results from each scenario.

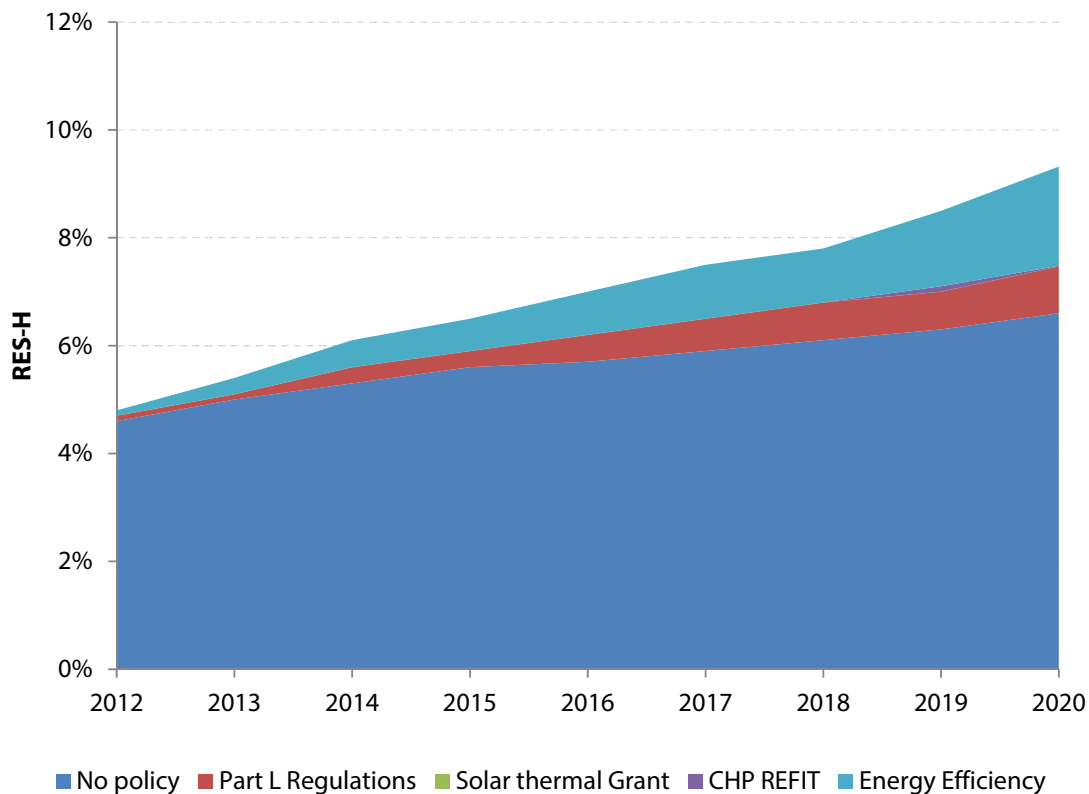
*Table 3: Projected scenario outcomes in 2020*

Scenario	Renewable heat output in 2020 ktoe /((GWh))	Required output to meet RES-H 12%( ktoe) /((GWh))	Projected RES-H% in 2020
<b>High scenario</b>	420 / (4,885)	455 / (5,292)	11%
<b>Central scenario</b>	350 / (4,071)	455 / (5,292)	9%
<b>Low scenario</b>	325 / (3,780)	550 / (6,397)	7%

### 7.1. Current policy impacts

Figure 8 shows how existing policies are influencing growth in the *Central scenario*. A baseline uptake of renewable energy technologies is driven by the impact of the relative economics of the available heating technologies on consumer choice. As fossil fuel costs rise relative to other technologies, more consumers may decide to replace fossil fuel heating sources with renewable alternatives. The modelling suggests that this effect could contribute up to 6.6% of the total RES-H by 2020 under the assumptions of the *Central scenario*.

*Figure 8: Impact of existing policy towards RES-H (Central scenario)*



Part L of the Building Regulations requires new residential buildings to have a renewable energy source installed. This policy will result in a steady increase in renewable heat output linked to an

expected increase in the build rate of new dwellings (i.e. reaching over 20,000 units per year), thus accounting for almost 1% of the total RES-H by 2020.<sup>48</sup>

The energy efficiency measures targeted in the NEEAP are focused on reducing the heat demand of buildings. The implementation of measures in the residential, public services and services sectors can result in a significant reduction in heat demand, estimated to be over 770 ktoe (9,000 GWh)<sup>49</sup> over the years to 2020. Much of the uptake of renewable heat technologies in the model is in the industrial sector. As renewable energy targets are expressed as a percentage of demand, energy efficiency measures act to support RES-H by proportionally reducing the total energy demand. A reduction in heat demand results in an additional 1.8% contribution towards RES-H from the output of the renewable heat technologies. The scenario sees little uptake of CHP across the time horizon.

Box 1 explains the underlying reasons for this low uptake in the model.

Figure 9 shows how the policies impact on the *High* and *Low* scenarios. The change in fossil fuel price assumptions results in a change in renewable energy output, assuming no further policies beyond those currently in existence. A higher fossil fuel price in the *High scenario* results in a stronger uptake of the cost-competitive renewable heat technologies. Similarly, the *Low scenario* results in a reduced uptake in renewable heat technologies, due to the lower fossil fuel price assumption.

The impact of the Building Regulations requirements is the same across the three scenarios, as uptake is linked to the number of new dwellings constructed.

Energy efficiency measures contribute a higher share in the *High scenario* than in the *Central scenario*. The RES-H level in the *High scenario* is helped further by the reduction in heat demand from the energy efficiency measures, which adds a further 2% to the RES-H share.

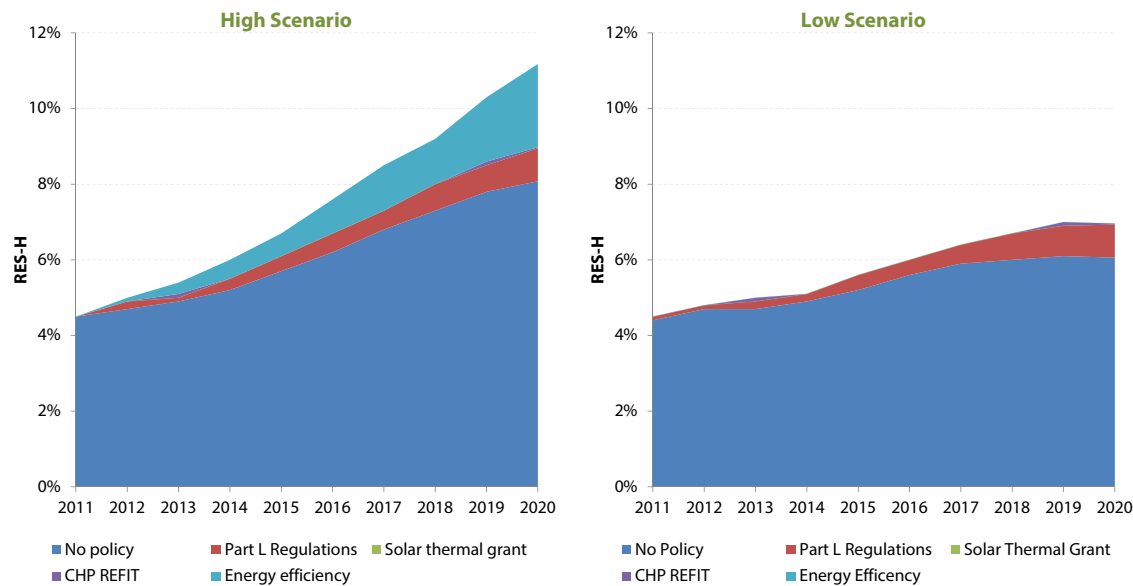
The *Low scenario* assumes that no further energy efficiency measures are implemented to 2020. The negative impact of a shortfall on energy efficiency ambition is shown by comparing the *Low scenario* with the impact of energy efficiency measures against the *Low scenario* without the heat demand reductions. The shortfall on energy efficiency results in a 1.4% reduction in RES-H by 2020 than would otherwise have been the case.

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<sup>48</sup> Bergin, A., Conefrey, T., Duffy, D., FitzGerald, J., Kearney, I., Timoney, K. and Znuderl, N. (2013) *Medium-Term Review: 2013-2020*, Number 12. Economic and Social Research Institute (ESRI).

<sup>49</sup> Department of Communications, Energy and Natural Resources (2014) *National Energy Efficiency Action Plan 2014*. Available at: <http://www.dcenr.gov.ie/NR/rdonlyres/20F27340-A720-492C-8340-6E3E4B7DE85D/0/DCENRNEEAP2014publishedversion.pdf>

Figure 9: Impact of existing policy towards RES-H (High scenario and Low scenario)



### Box 1: Biomass and anaerobic digestion (AD) CHP in the heat sector

The REFIT 3 scheme allows for 150 MW<sub>e</sub> of CHP to be connected into the electricity system – 100 MW<sub>e</sub> from solid biomass CHP, with the remaining 50 MW<sub>e</sub> to come from an anaerobic digestion (AD) CHP. A typical CHP unit produces 1.7 units of heat for each unit of electricity generated.<sup>50</sup> This suggests that the capacity available in the REFIT scheme could deliver as much as 100 ktoe (1,163 GWh) of renewable heat by 2020.

The modelling estimates that the uptake of CHP is limited in all scenarios. In contrast to this modelled outcome, a number of large solid biomass CHP projects have applied to the REFIT 3 scheme. The sizes of these projects are much larger than the 1.5 MW assumed under the REFIT tariff calculation. This increase in size can leverage large economy of scale savings – especially on the capital costs incurred – making these sites more economically viable. In addition, several of these sites may provide their own fuel or enter into long-term contracts for fuel at prices less than the prevailing market spot price.

Table 4 shows the cost assumptions that underpin the construction of the REFIT tariff and how they compare to international estimates for the costs of these technologies.

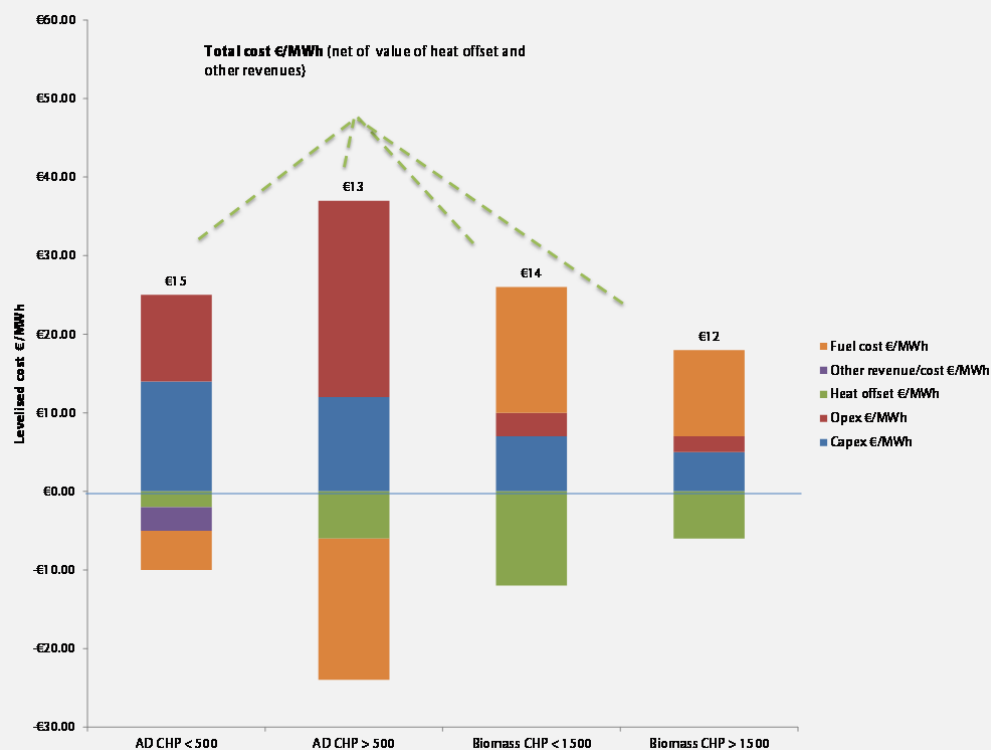
<sup>50</sup> EPSSU (2012) *Combined Heat and Power in Ireland*. SEAI. Available at: [http://www.seai.ie/Publications/Statistics\\_Publications/EPSSU\\_Publications/CHP\\_in\\_Ireland\\_2012\\_Report.pdf](http://www.seai.ie/Publications/Statistics_Publications/EPSSU_Publications/CHP_in_Ireland_2012_Report.pdf)

Table 4: Comparison of REFIT 3 cost assumptions with international sources<sup>51</sup>

	Capex €/kW		Opex €/kW		Fuel input Cost €/kWh	
	REFIT	Other sources	REFIT	Other sources	REFIT	Other sources
<b>AD CHP &lt; 500</b>	6,500	2,600 – 9,000	714	55 -220	-1.67	-
<b>AD CHP &gt; 500</b>	6,000	2,600-9,000	1,175	55 -220	-6.50	-
<b>Biomass CHP &lt; 1500</b>	3,700	2,000-3,700	205	60 - 220	2.30	1.8-5.0
<b>Biomass CHP &gt; 1500</b>	2,500	2,000-3,700	170	60 - 220	2.48	1.8-5.0

The state aid rules stipulate that the value of heat displaced and any other revenues arising from the sale of by-products should be taken into account in the calibration of the tariff. The value of heat displaced is determined from the cost of producing heat from an oil boiler, and the revenues available to AD units for the sale of digestate are also considered. The net levelised costs are shown in Figure 10 along with the other assumptions on amortised capital costs and fuel costs.

Figure 10: Cost assumptions underpinning REFIT tariff levels



<sup>51</sup> Mott MacDonald (2011) 'Costs of low-carbon generation technologies', *The Renewable Energy Review*, May 2011. London. Committee on Climate Change.

<sup>51</sup> SKM ENVIROS (2011) *Analysis of characteristics and growth assumptions regarding AD biogas combustion for heat, electricity and transport and biomethane production and injection to the grid*. Department of Energy and Climate Change.

<sup>51</sup> IRENA (2012) *Biomass for Power Generation*. Volume 1, Power Sector, Issue 1/5, Renewable Energy Technologies: Cost Analysis Series.

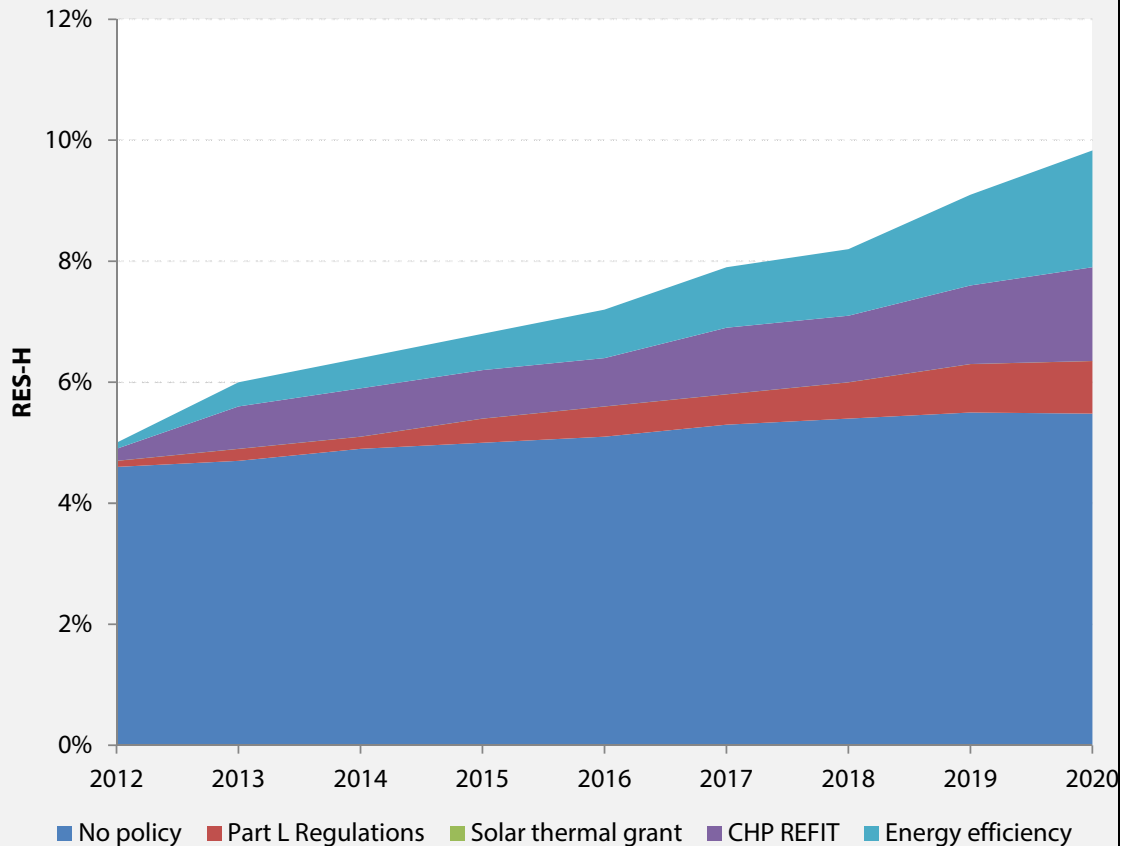


The fuel price assumptions underpinning the calculation of the REFIT tariff are substantially lower for solid biomass CHP than the modelled outcome. This challenges the economic viability of these units, resulting in the low uptake. AD CHP uptake is limited by the availability of fuel with sufficiently high gate fees.

The cost competitiveness of other renewable energy technologies at the CHP scale means that, in order to be constructed, a CHP unit must beat the fossil fuel alternative on cost by more than biomass or other renewable energy technologies. The scenario modelling shows that, at the large scale, biomass boilers are competitive with oil boilers under the *Central scenario* and the high fossil fuel price scenario.

A scenario where lower installation and ongoing costs prevail could see more CHP units being constructed. Figure 11 illustrates the impact that lower installation and ongoing costs could have on the CHP contribution towards the RES-H target in the *Central scenario*. The resultant RES-H in 2020 is 9.8% compared to a RES-H of 9% in the *Central scenario* based on current REFIT tariffs.

Figure 11: Impact of increased REFIT tariff for bioenergy CHP on RES-H (Central scenario)

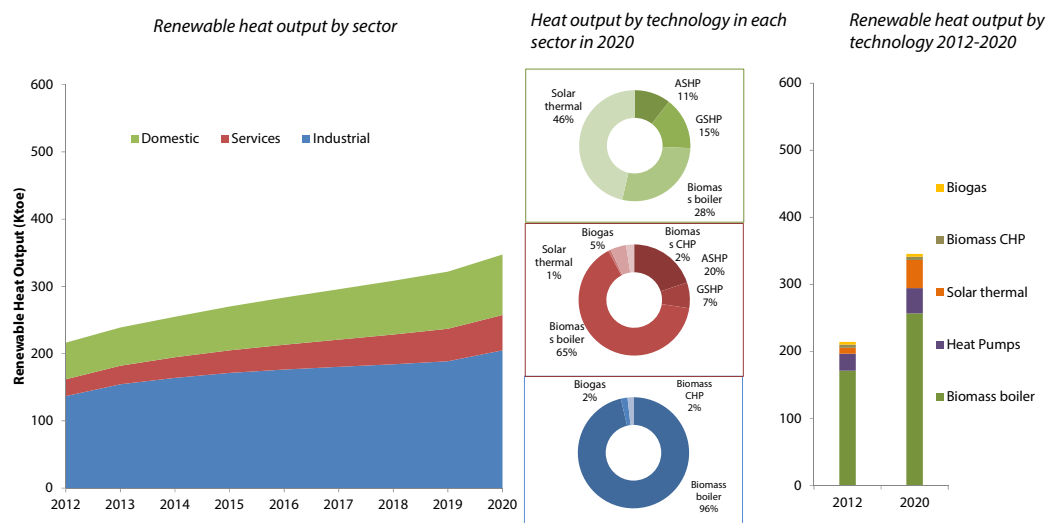


The additional increase in RES-H is due to the uptake of both AD CHP and solid biomass CHP. The increase in renewable heat output from CHP units increases RES-H but not by as much as the additional output of the CHP units might imply. The increased uptake in CHP increases competition for biomass resources and raises the price of the available resources. This displaces some of the underlying uptake of biomass boilers. With lower installation and ongoing costs, solid biomass CHP units can afford to pay a higher premium for input fuels than can operators of biomass boilers.

## 8. Which technologies are consumers choosing in the model?

Figure 12 shows which technologies deliver renewable heat and how this impacts on renewable heat output in each sector in the *Central scenario*. The various heating requirements and preferences of heat consumers across sectors are shown by differences in technology choice in the industrial, services and residential sectors. Uptake of biomass boilers is highest in the industrial sector, due to the favourable economics of biomass boilers in larger industrial applications with constant heat requirements for much of the year. Larger buildings in the services sector, out of reach of the gas grid, also see increased use of biomass. Heat pumps and solar are chosen by consumers in the services and residential sectors where space heating is required for part of the year and water heating is required all year round. The relative economics of each technology, and how these change across the time horizon, determine to a large extent the technology that is chosen for delivering the required heat. Other factors such as the suitability of the building for a heat technology and consumer preferences are also important in determining which technology is chosen.

Figure 12: Renewable heat technology output 2012-2020 (*Central scenario*)



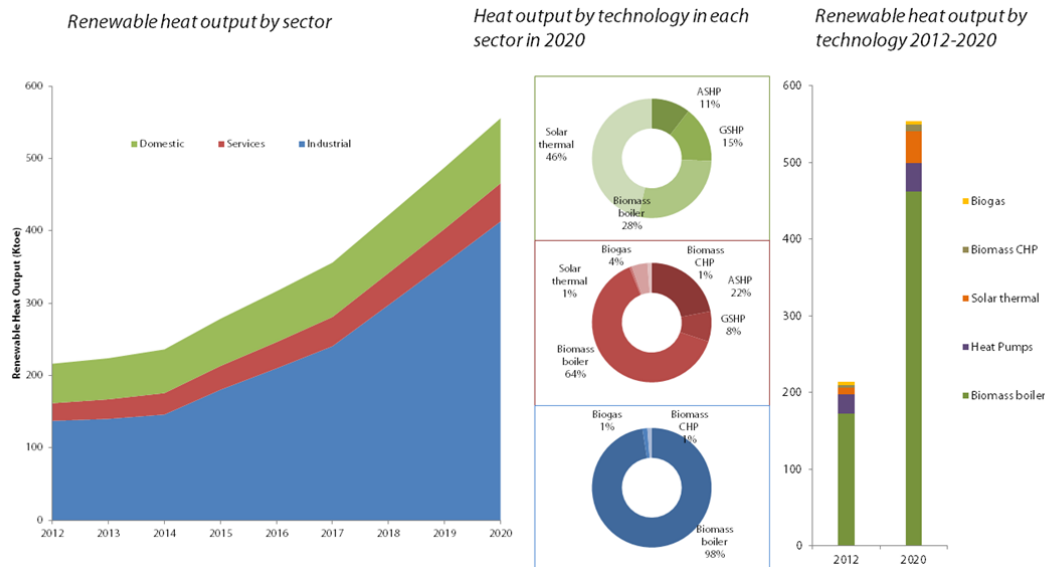
Renewable heat output grows by 61% to reach 350 ktoe (4,071 GWh) by 2020. Biomass boilers contribute over 74% of the total renewable heat output by 2020, with solar thermal delivering the next largest contribution at 12%. Air source and ground source heat pumps deliver a further 11%, with the remaining 3% coming from bioenergy CHP and biogas.

The industrial sector accounts for 59% of renewable heat use by 2020, predominantly from solid biomass combustion. The commercial sector sees an increase of 110% in renewable heat output, thus contributing 15% of renewable heat output by 2020. This is driven largely by uptake of heat pumps and increases in biomass use. The residential sector contributes the remaining 26% of output, predominantly through increased output from solar thermal and heat pumps in new dwellings.

Changing the fossil fuel price assumptions and the quantity of imports available at low cost alters the relative economics of renewable heat technologies and fossil fuel heating technologies. In the

*High scenario*, this results in some renewable technologies becoming more competitive, leading to a renewable heat output of 420 ktoe (4,885 GWh) in 2020. Figure 13 shows that biomass boilers in the industrial sector drive the 88% increase in renewable heat output from 2012 to 2020, with heat pumps in the services sector and solar thermal installations in the residential sector (due to Part L of the Building Regulations) contributing the remainder.

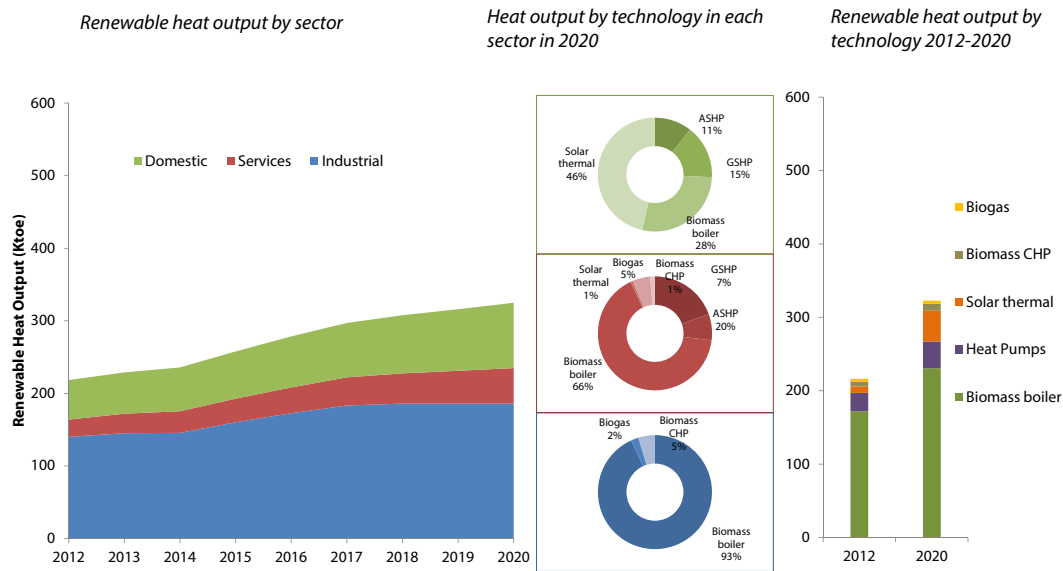
*Figure 13: Renewable heat technology output 2012-2020 (High scenario)*



The *Low scenario* shows a much lower growth in renewable heat output. With oil prices growing more slowly to 2020, renewable energy technologies are less competitive than in the scenarios set out above. Growth in renewable heat output is driven by solar thermal installations in the residential sector, with some small increases in industrial biomass use. Solar thermal continues to increase as a consumer response to the requirements under Part L of the Building Regulations.<sup>52</sup> Figure 14 shows how the uptake of renewable heat technology is impacted by the low fossil fuel prices in the *Low scenario*.

<sup>52</sup> Solar thermal installations are the least-cost option available to most consumers to meet the 10 kWh/m<sup>2</sup>/y obligation, with solar panels being installed along with a fossil fuel heating source. Should the obligation be increased beyond a certain critical point, the economics of the choice may lead consumers to choose a renewable heat technology capable of heating the entire building.

Figure 14: Renewable heat technology output 2012-2020 (Low scenario)



## 9. Biomass resources and bioenergy costs

Bioenergy is the largest contributor to renewable heat output in all scenarios. The evolution of the price differential between heat energy from oil and from biomass out to 2020 is the primary influence on the uptake of biomass boilers. In the *High scenario*, with high oil prices and availability of low-cost imports, biomass boilers are chosen more often by heat consumers to replace oil. The *Low scenario*, with low oil price growth and no low-cost imports, shows a much lower uptake of biomass.

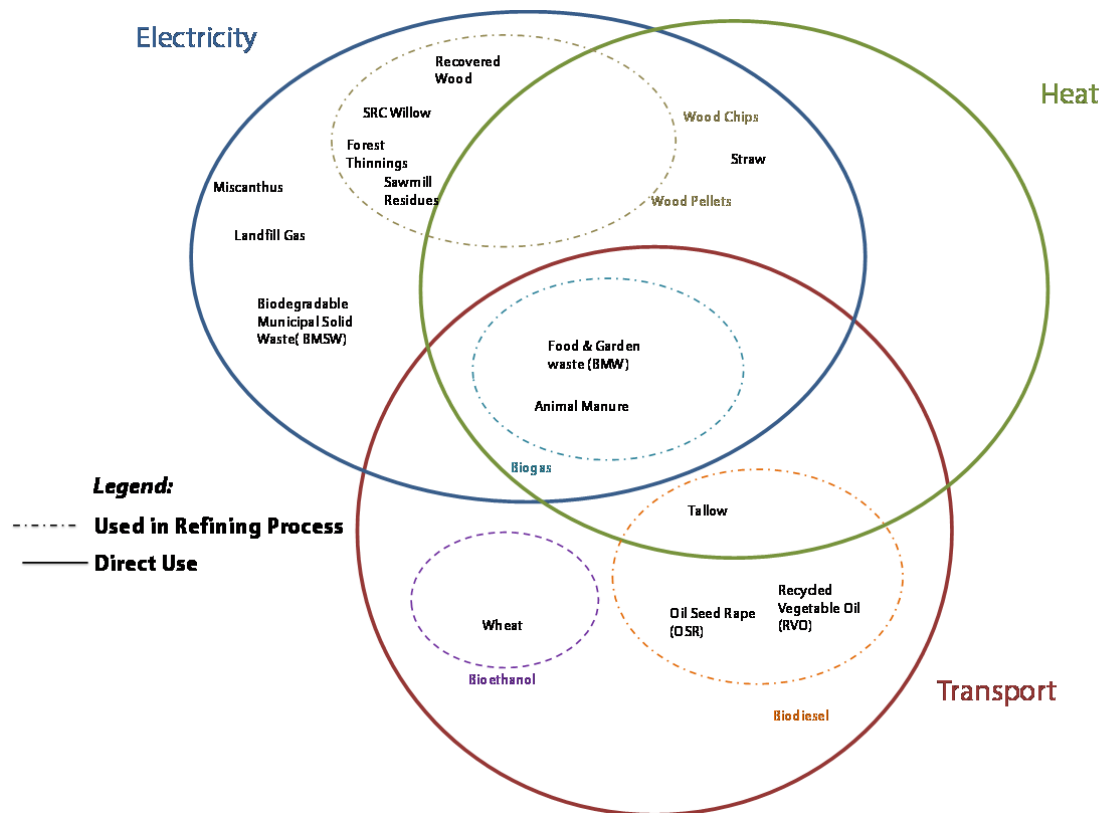
The cost of the biomass fuel used in heat-generating biomass boilers is a key determinant of demand for bioenergy in the heat sector. As bioenergy demand increases, less accessible and more expensive resources are required. Biomass resources are used in the production of heat, electricity and transport, with some resources capable of being transformed into any of the three energy end-use modes. An increase in demand for one type of bioenergy could raise the price of the biomass resources, making bioenergy more expensive to produce in the other end-use modes. This acts to reduce demand for bioenergy in other energy modes. As described in section 6, demand and supply of heat, electricity and transport are included within the BEAM model along with the costs and availability of biomass resources to capture this interaction.

### 9.1. Bioenergy production pathways

Figure 15 shows what resources can produce heat, transport and electricity within the model.<sup>53</sup> Some resources go through an intermediate refining step before energy transformation. These resource sub-sets are captured within the dashed ellipses. Resources and refined resources are transformed into heat, and electricity and transport are captured within the solid ellipses.

<sup>53</sup> This resource classification relates to current typical transformation routes. Future technology developments may increase the number of transformation paths (e.g. gasification of woody biomass) as well as increasing the number of resources available for conversion. The set of possible conversion routes was minimised to make the optimisation problem manageable within BEAM.

Figure 15: Venn diagram of resource classification in the BEAM model



Heat and electricity production in particular have significant resource overlap. Wood chips and wood pellets can be combusted to produce heat, electricity or both in CHP applications. Woody biomass resources that are commonly used to manufacture refined wood chips and pellets can be used in larger-scale electricity generation applications without being processed into these forms. Similarly, biogas from AD processes can be used to produce heat, electricity and transport energy. Landfill gas (LFG) and biodegradable municipal solid waste (BMSW) are used exclusively for electricity generation. Miscanthus is difficult to process for combustion, making it potentially more suitable for the boiler technology present in electricity generation than the boiler technology commonly used to produce heat.<sup>54</sup> Methods to refine miscanthus and straw into wood pellets that can accommodate the characteristics of these resources in the future are being trailed.<sup>55</sup>

## 9.2. Resource use to 2020 with current policies

In general, heat generation technologies have thermal efficiencies in the region of 75% to 90%, while electricity generators have lower efficiencies, ranging from 20% to 40%. CHP units typically have efficiencies upwards of 75%. As more resources are required by electricity-generating

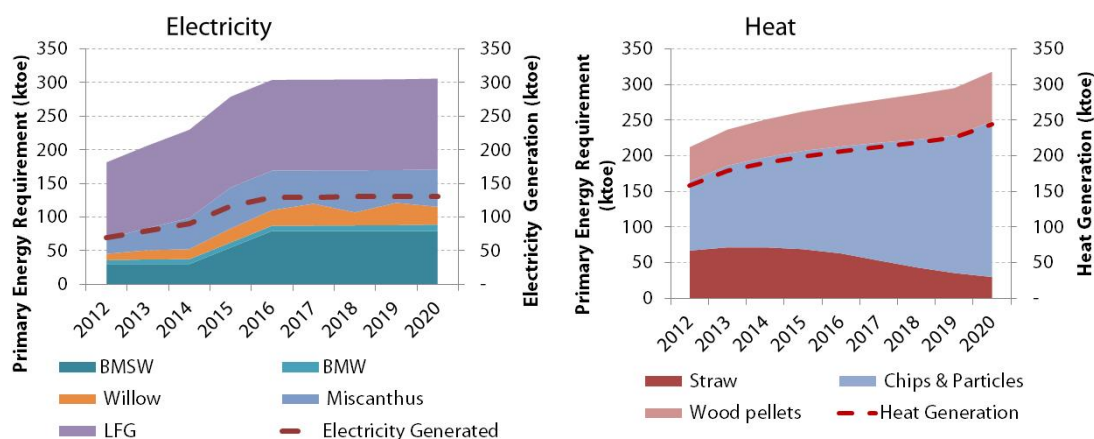
<sup>54</sup> Finnan, J. (2013) 'Feasibility of production and combustion of pellets from straw and energy crops', *Teagasc Technology Updates: Crops, Environment and Land Use*. Available at: [http://www.teagasc.ie/publications/2009/1320/Pelleting\\_5613.pdf](http://www.teagasc.ie/publications/2009/1320/Pelleting_5613.pdf)

<sup>55</sup> Murphy, F., Devlin, G. and McDonnell, K. (2013) 'Miscanthus production and processing in Ireland: An analysis of energy requirements and environmental impacts', *Renewable and Sustainable Energy Reviews*, 23: pp. 412-420.

technologies to produce a unit of energy, an increase in bioenergy demand in this sector will have a greater impact on resource price, all else being equal.

To illustrate this, Figure 16 shows the quantities and source of primary energy used in heat and electricity along with the amount of useful energy generated in the *Central scenario*.

Figure 16 : Primary energy requirement by resource use and final energy generation (Central scenario)



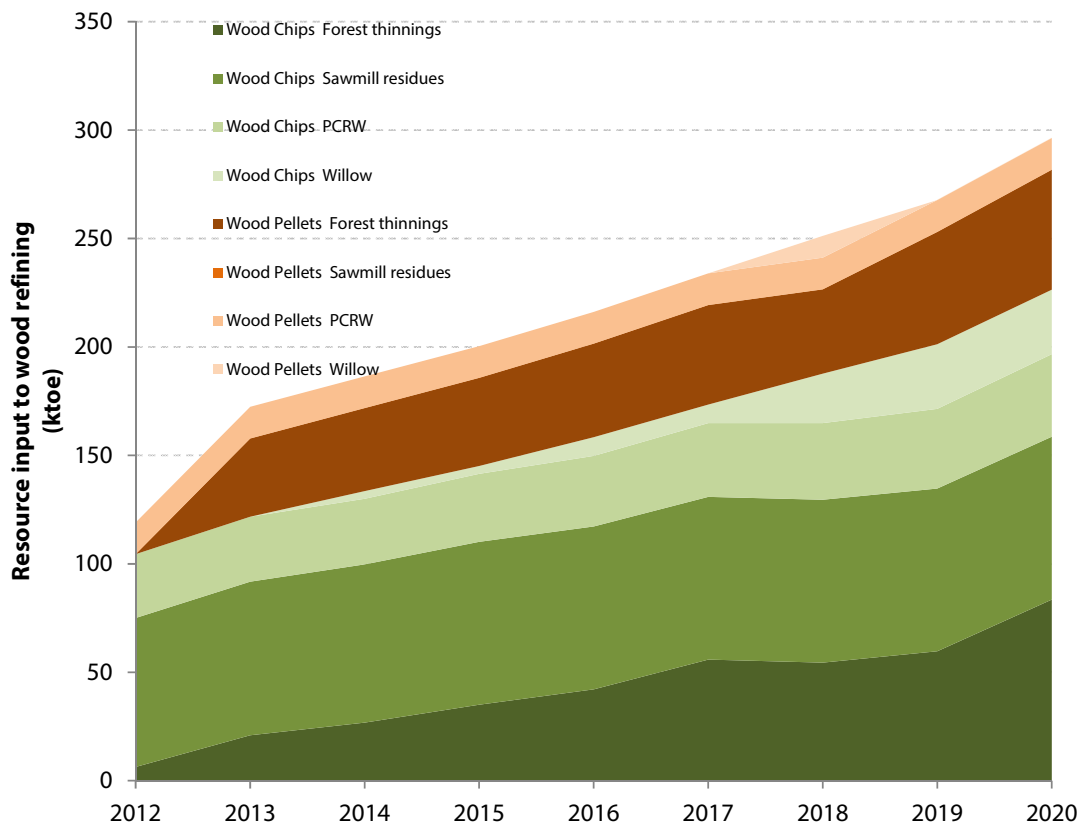
In total, close to 600 ktoe (6,975 GWh) of primary energy is required in 2020, split between heat and electricity at close to 300 ktoe (3,489 GWh) each. Due to the higher conversion efficiencies of heat boilers, the useful energy output from resources used to produce heat is more than double that of electricity. Electricity generators can handle a more diverse range of feedstock, with the ability to process a range of fuels of varying moisture content and chemical composition. Refined wood products such as wood chips and wood pellets are typically used in the heat sector as the fuel source. Electricity generation from biomass is supported through REFIT tariffs that offer individual tariffs for different technologies, with the tariffs for co-firing offering a higher tariff for the use of energy crops. The impact of this is to draw resources from energy crops into co-firing.

Refined wood products are processed from the available raw resources to produce fuels with more consistent energy content and chemical composition.<sup>56</sup> The typical heat-generating boiler is designed for combusting a refined wood fuel source. Smaller boilers tend to use wood pellets, with the higher energy density of wood pellets requiring less fuel storage space and more convenient fuel handling. Larger boilers tend to use wood chips, with storage and fuel handling issues being less significant at larger scale.

Figure 17 shows the resources used for the production of the refined wood products used in the *Central scenario*.

<sup>56</sup> Kofman, P.D. for COFORD (2010) 'Preview of European standards for solid biofuels', *Processing/ Products No. 23*. Available at: <http://www.woodenergy.ie/media/woodenergy/content/standardsand specifications/COFORD%20Connects%20Note%20on%20standards.pdf>

Figure 17: Refined wood product production resource uses (Central scenario)



While any of the resources used for producing wood chips and wood pellets could also be used in electricity generation, only willow is used in both applications, with the model deciding to use all refined wood products to produce heat. Competition for resources between electricity generation, CHP and heat technologies will manifest in the market price for wood chips and wood pellets. The market price for these refined wood products is determined by what resources are used, the cost of transporting these to the processing facility, and the cost of processing the resources into the final product. Higher supports for biomass in the electricity sector will tend to reduce uptake in the heat sector, all else being equal and vice-versa.

#### Box 2: The impact of co-firing on renewable heat use

Electricity generation through the co-firing of solid biomass resources has the potential to impact on the price of refined wood resources, and consequently on the use of these resources in heat generation. The REFIT 3 scheme allows for 115 MW of hybrid electricity generation. Modelling assumptions as part of the national energy forecast expect 30% co-firing, totalling 30 MW, to be achieved in Edenderry Power Plant by 2015. No further expansion of co-firing is expected to 2020.

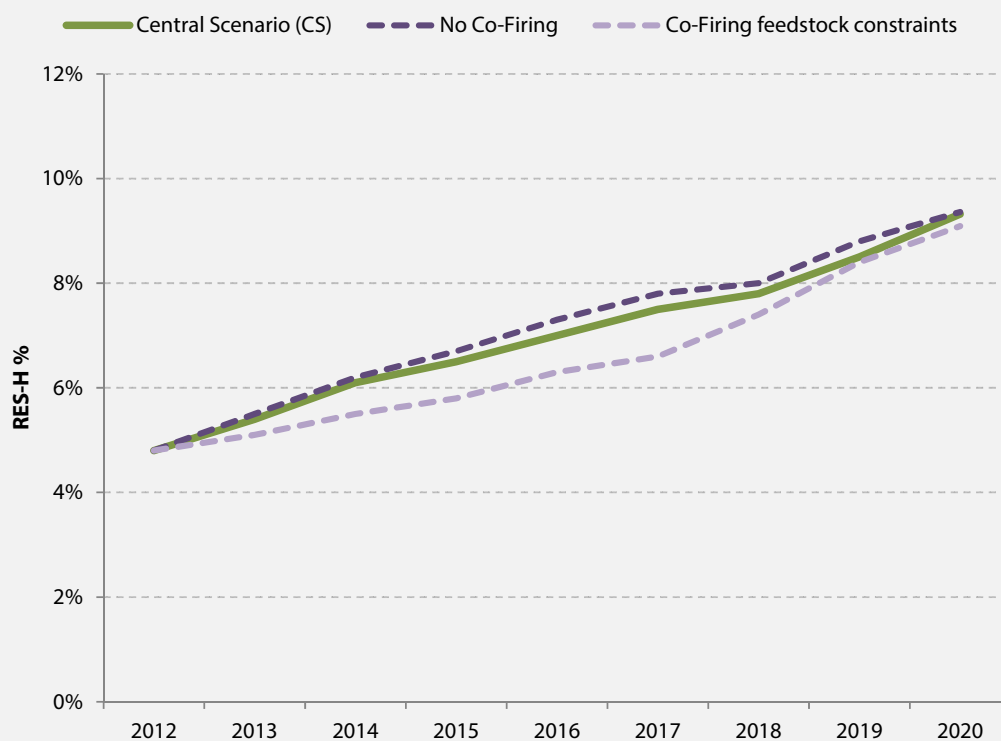
The scenarios described above include the assumption that Edenderry Power Plant will achieve an average annual co-firing rate of 30% by 2015 and will remain in operation until at least 2020. The modelling assumes that the both raw resources and refined resources can be used to produce electricity as described in Figure 15.

The REFIT scheme offers a higher tariff for energy crops to incentivise the development of energy crop supply chains. At present, the indications from the market are that co-firing units are opting to use materials other than energy crops for the majority of the feedstock used. The Edenderry plant is eligible for support for burning peat to 2015, and has not as yet joined the REFIT.

This box examines the high-level impact of two sensitivities on the co-firing assumptions. Firstly, what is the impact on the heat market if no co-firing takes place? Secondly, what is the outcome if co-firing requires more of the resources that can be used in the production of refined wood products? These outcomes are compared to the outcome of the *Central scenario* using the same assumptions for fuel price and bioenergy import availability.

Figure 18 shows the impact on RES-H of the three co-firing sensitivities.

*Figure 18: Sensitivity analysis of co-firing assumptions*



Overall, the sensitivities examined show little long-term impact on the uptake of biomass use in the heat sector. In the constrained feedstock scenario, the impact of the increased competition for resources between co-firing and heat is shared between a slight reduction in bioenergy use for heat and a reduction in the output from co-firing.

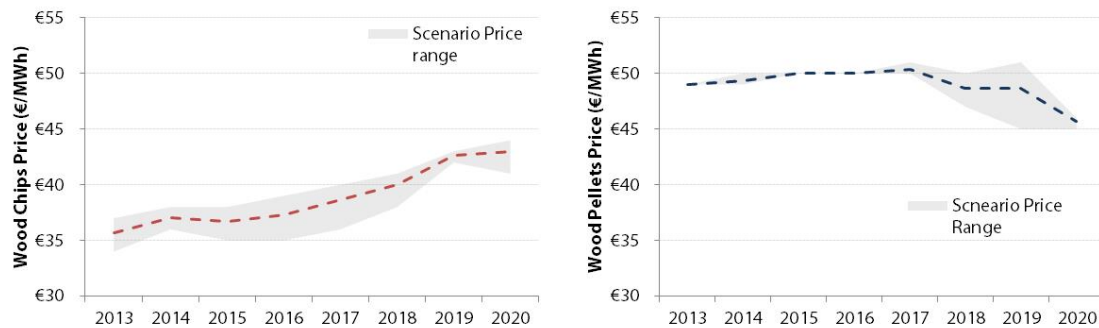
The addition of further biomass electricity generators would begin to impact more strongly on the RES-H uptake, particularly where imports of wood fuels were limited. For example, a conversion of all three existing peat stations in Ireland and the conversion of Moneypoint coal-fired station at the current rated capacities could require over 2,600 ktoe of primary biomass input in 2020. The most optimistic estimate for the available imports in the bioenergy supply curves suggests that up to 900 ktoe could be available for import, along with a further 700 ktoe of domestic biomass.



### 9.3. Wood product price

The most expensive resource required to meet the demand sets the resource input price to the refining process. Figure 19 shows the marginal price and the price range for wood chips and wood pellets to 2020 in the scenarios. The available resource increases over the time horizon, but demand for wood chips outpaces this growth, resulting in a rise in the price of refined wood product. Demand for wood pellets is more static over the period and leads to price swings in individual years as resource availability increases.

Figure 19: Marginal cost of resources used in wood fuel processing (All scenarios)



The cost of transporting resources to a central location for refining can be significant. The weighted average of these costs in the *Central scenario* is approximately 1 €/MWh for both chips and pellets based on the transport costs outlined in Annex 2.

Processing of raw resources requires drying, chipping and, in some cases, packaging. Overall, this cost can be in excess of 20 €/MWh for wood chips and 25 €/MWh for wood pellets. Bulk delivery of wood chips and pellets is less costly, and this is reflected in an additional 12% premium for wood product delivered to residential dwellings.<sup>57</sup> Annex 2 contains more detail on the costs of wood processing.

Figure 20 shows how the price of wood chips and wood pellets develops in each scenario. The dashed line shows the average price of wood fuels across scenarios, while the shaded area shows the range of prices.

<sup>57</sup> Based on difference between bulk and bagged wood products in EPSSU Fuel Cost Comparison. See: [http://www.seai.ie/Publications/Statistics/Publications/Fuel\\_Cost\\_Comparison/](http://www.seai.ie/Publications/Statistics/Publications/Fuel_Cost_Comparison/)

Figure 20: Wood chip and wood pellet prices (all scenarios)



The price of wood chips and pellets tends towards convergence over the time horizon, as both sources can be used in larger boilers and CHP units as substitutes. Wood chips see the largest increase in use, as more large-scale biomass boilers are built to replace oil boilers in response to rising oil prices to 2020. Some increase in wood pellet use occurs as prices fall due to increasing availability of biomass resources.

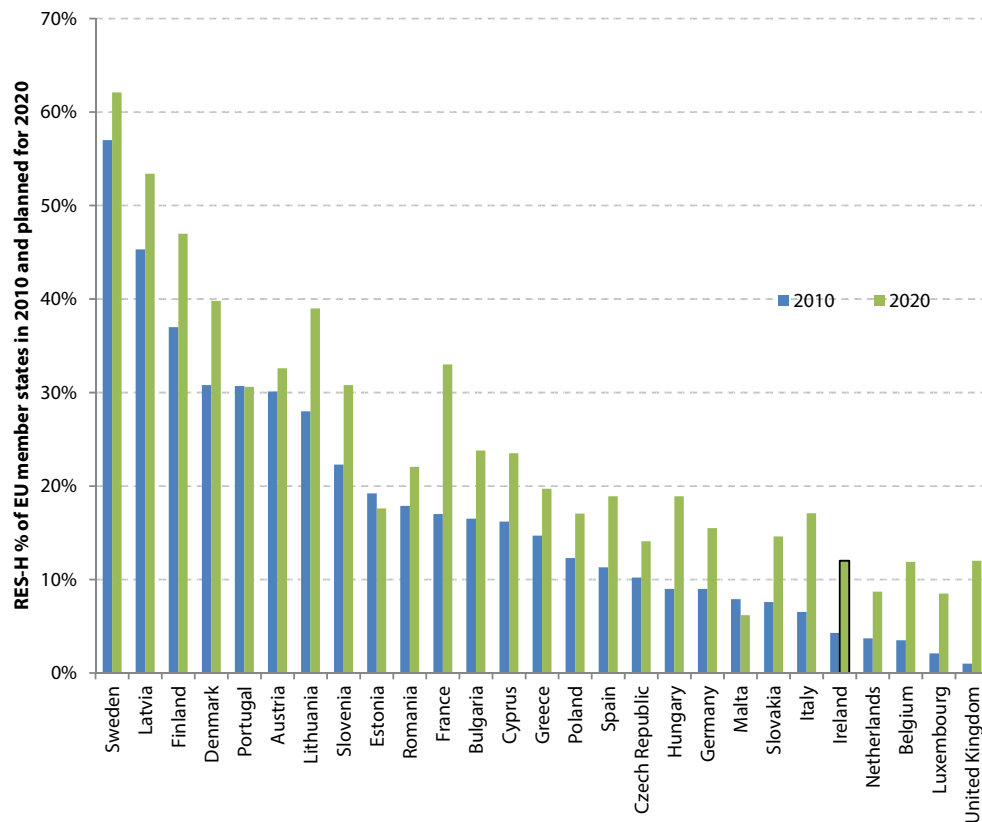
## **Part 4: Policy measures to encourage renewable heat uptake**

## 10. What can Ireland learn from international experience with RES-H policy?

Figure 21 shows how renewable heat contributed to overall heat consumption in EU countries in 2010, and the plans these countries have to expand renewable heat by 2020. Sweden, Denmark and Austria have large shares of renewable energy in thermal consumption. These countries have a long history of policy support for renewable heating and cooling. Ireland must increase RES-H by 179% by 2020 in order to reach the RES-H 12% target. Only Belgium, Luxembourg and the UK have targeted larger increases. Policy action in the UK has developed apace and many of the prevailing challenges are common to Ireland.

Sweden has a long history of supporting renewable heat in response to an over-reliance on imported oil and modest native natural gas supplies. The strategy to develop district heating (DH) that utilised the large indigenous biomass resource has embedded high biomass usage in the Swedish energy system. In addition, over-supply of electricity in the 1980s led to low electricity prices and a high incidence of direct electricity heating. Heat pumps subsequently look attractive as electricity prices rise. Sweden has had a carbon tax on fossil fuels since the early 1990s, which further contributed to increased use of biomass for heating.

Figure 21: RES-H contribution in 2010 and planned for 2020<sup>58</sup>



Similarly, Denmark has a long history of energy policies that promote secure, diverse and efficient energy systems. Throughout the 1960s, extensive development of DH networks with a focus on the use of CHP took place. Ongoing development of renewable heat focuses on using biomass – biodegradable waste, biogas and straw – as a fuel for the DH networks. The Danish Government has applied support policies ranging from subsidies and tax exemptions to information campaigns. The Biomass Agreement in 1993 was aimed at increasing the use of biomass by obligating power stations to use biomass as fuel.

Austria is endowed with a large forestry resource – over 40% of its land is under forest cover. There is a long history of using this resource for generating heat energy, with technological advances and efficiency improvements in biomass boilers arising from government-supported R&D programmes in the 1980s and 1990s. Support in the form of information campaigns, installer training, certification, specific targets and financial incentives have stimulated the growth of renewable heating.

Countries with substantial amounts of renewable heat resources have a long history of supporting renewable heat. Access to relatively cheap gas in these countries has been limited, forcing the choice between the historically less secure sources of imported oil and more secure domestically sourced biomass. The climate and the more concentrated spatial distribution of buildings in these

<sup>58</sup> ECN (2013) NREAP database. See: <https://www.ecn.nl/projects/nreap/2010/data/>

countries also means that DH schemes are attractive, due to the longer heating season and more highly concentrated building patterns.

While Ireland does not have high forest cover, 54% of heat demand came from relatively high-cost oil in 2012. The lack of fuel diversity, and the security of supply imperative that spurred government support for renewable heat in these exemplar countries, also applies to Ireland.

## 11. Policy Options for RES-H expansion in Ireland – advantages and disadvantages

Renewable energy policy instruments can be broadly classified into three categories: market regulation, financial incentives and soft measures. Regulations include options such as minimum building standards and minimum performance standards for technologies. Incentives give support to investors to invest in and operate renewable technologies. Investment support typically takes the form of direct grants, tax exemptions, payment for renewable output and/or taxation measures. Soft measures are targeted towards alleviating market barriers such as the education of consumers, legislators and installers, awareness-raising campaigns, access to expert impartial advice and enhancement of skills and training.

Support schemes and regulations for renewable electricity and transport support policies are common within the EU, and policy-makers have significant experience of implementing policy in these areas. Due to the fragmented nature of the heat sector and issues such as the difficulties in metering heat output, scheme compliance monitoring and the availability of fuel supply, the renewable heat sector has seen comparatively less policy intervention. In Ireland, regulation through the biofuels supplier obligation<sup>59</sup> is driving the increase in biofuels usage in transport which replaced a previous scheme that used tax exemptions to promote biofuels.<sup>60</sup> Operating support, firstly through a tendering system<sup>61</sup> and then through a feed-in tariff,<sup>62</sup> helped the development of renewable electricity. Grants for renewable heat technologies in dwellings<sup>63</sup> and services buildings<sup>64</sup> have been in place previously, with the aim of developing a renewable heat market in Ireland.

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<sup>59</sup> National Oil Reserves Agency, Biofuels Obligation Scheme (2012). See: <http://www.dcenr.gov.ie/NR/ronlyres/DC3F11A0-A1DF-48FB-ABFC-D6C1DEC68E34/0/B296264dilly.pdf>

<sup>60</sup> State aid N 473/2006 Ireland Biofuel Mineral Oil Tax Relief Scheme II. See: [http://ec.europa.eu/eu\\_law/state\\_aids/comp-2006/n473-06.pdf](http://ec.europa.eu/eu_law/state_aids/comp-2006/n473-06.pdf)

<sup>61</sup> Department of Communications, Energy and Natural Resources (2003) *Alternative Energy Requirement (AER VI - 2003) A competition for Electricity Generation from Biomass, Hydro and Wind*. See: <http://www.dcenr.gov.ie/NR/ronlyres/F070739C-0716-41AF-8A4E-DEBC1F8A99F5/0/AERVIIdraft9dcmnrPrintersFinalVersion.pdf>

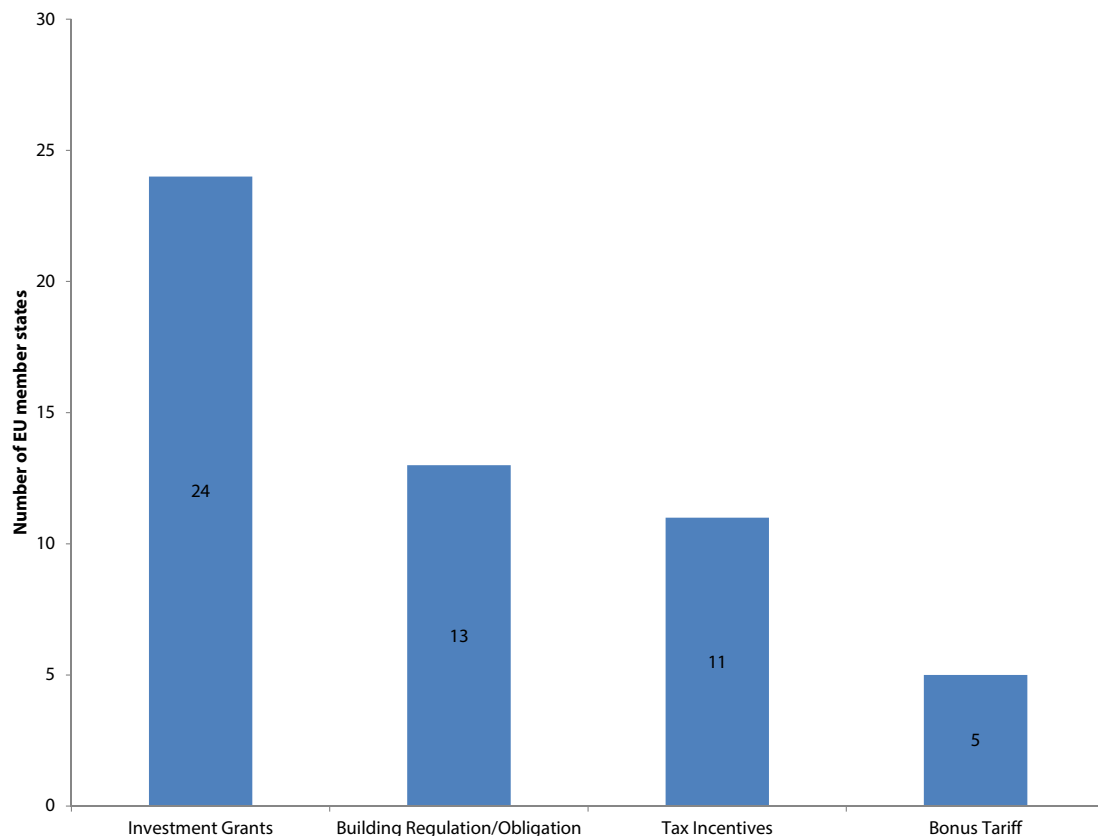
<sup>62</sup> Department of Communications, Energy and Natural Resources (2012) *Renewable Energy Feed in Tariff 2012. A competition for Electricity Generation from Onshore Wind, Hydro and Biomass Landfill Gas Technologies 2010-2017*. See: <http://www.dcenr.gov.ie/NR/ronlyres/693BB376-87AF-4E57-990F-64AD6286C8CB/0/REFIT2TermsandConditionsJune2013.pdf>

<sup>63</sup> SEAI (2010) *Greener Homes Scheme Phase III (Existing Dwellings Only) Application Guide Version 3.4*. Available at: [http://www.seai.ie/Grants/GreenerHomes/Homeowners/How\\_to\\_Apply/Greener\\_Homes\\_Application\\_Guide.pdf](http://www.seai.ie/Grants/GreenerHomes/Homeowners/How_to_Apply/Greener_Homes_Application_Guide.pdf)

<sup>64</sup> SEAI (2009), *Renewable Heat Deployment Programme Ver 1.6*. Available at: [http://www.seai.ie/Grants/Renewable\\_Heat\\_Deployment\\_Programme/ReHeat%20Application%20Guide%20Ver1\\_5.pdf](http://www.seai.ie/Grants/Renewable_Heat_Deployment_Programme/ReHeat%20Application%20Guide%20Ver1_5.pdf)

Figure 22 shows the type of schemes that EU member states tend to favour.<sup>65</sup> Capital investment grants were implemented in 24 out of 27 member states in 2012, but there are wide variations in funding levels and periods of support available by country. Building regulations or obligations have also been widely used and adopted by 13 EU member states. These require that renewable heat options be installed or at least considered as a heating source. Tax incentives, including tax exemptions, VAT reductions and tax credits, have been adopted by 11 EU countries. Tariff/bonus schemes, such as feed-in tariffs, have more recently gained prominence with the UK's Renewable Heat Incentive (RHI) being a notable example. Similarly in Ireland, the Government has proposed in its draft Bioenergy Strategy (2014) that it will introduce an Exchequer-funded incentive scheme from 2016 to reward users of each unit of renewable heat used from sustainable biomass.

*Figure 22 : Summary of European RES-H support schemes*



The following sub-sections outline the essential components of a number of the more widely used policy schemes for increasing renewable energy deployment. The advantages and disadvantages,

<sup>65</sup> Intelligent Energy – Europe Consortium (2012) *D23 Final Report: RE-Shaping: Shaping an effective and efficient European renewable energy market*. Karlsruhe. Available at: [http://www.reshaping-res-policy.eu/downloads/Final%20report%20RE-Shaping\\_Druck\\_D23.pdf](http://www.reshaping-res-policy.eu/downloads/Final%20report%20RE-Shaping_Druck_D23.pdf)

as well as selected examples from countries that implement these schemes, are discussed based on evidence from the literature.<sup>66</sup>

11.1. Financial incentives

Capital grants

Capital grants are designed to increase the relative attractiveness of a technology by subsidising part of the upfront capital cost. These supports are typically applied in the early stages of technology development. At this stage new technologies can be more expensive, due to a lack of economies of scale and investor uncertainties about the cost of investing in the technology over its lifetime. Grant schemes have several advantages for government. They are relatively simple to administer, with little interaction between the administrator and the recipient; they have low transaction costs; the total cost to the government is known in advance, and it can be allocated on a first come, first served basis. Nevertheless, grant schemes have some limiting drawbacks. The lack of operational oversight means the amount of renewable energy produced from the supported technologies is not guaranteed, there is a high burden on state budgets, and the transience of grants can create unstable markets based on subsidies.

Advantages	Disadvantages
<ul style="list-style-type: none"><li>• Little interaction between administrator and grant recipient.</li><li>• Low transaction costs – public bodies have experience with grant distribution.</li><li>• Positive consumer perception.</li><li>• Grant schemes can support diversification of technologies by tailoring support levels to individual technologies.</li></ul>	<ul style="list-style-type: none"><li>• Low operational oversight means no guarantee that the installed capacity will generate the expected amount of energy.</li><li>• Requires exchequer funding.</li><li>• Stop-start nature of funding for grant schemes can give rise to market instability.</li><li>• The need to select the technologies means that the government must decide which technologies to support</li></ul>

Public procurement programmes

Public procurement programmes encourage the uptake of renewable heat technologies in public buildings. They have generally been employed to move pre-commercial technologies through the demonstration phase. The quality of the supported technology can be ensured with reference to some form of accreditation or standards.

Public procurement can be a useful tool to create an initial market, but is unlikely to result in a large uptake of new technologies, due to the small market share of heating in public buildings. The impact on public confidence through the demonstration of technology in high-profile public buildings can be effective in increasing the confidence of the public in the technology and in developing immature supply chains. In the context of developing a robust biomass market, public procurement has the potential to help develop the market structures necessary to help a wider development of bioenergy use.

<sup>66</sup> Connor, P., Bürger, V., Beurskens, L., Ericsson, K. and Egger, C. (2013). 'Devising renewable heat policy: Overview of support options', *Energy Policy*, 59, pp. 3-16.



Advantages	Disadvantages
<ul style="list-style-type: none"> <li>• Useful in the development of markets for immature technologies.</li> <li>• Can help increase public awareness of renewable technologies through demonstration.</li> <li>• Can help develop supply chains in immature markets.</li> </ul>	<ul style="list-style-type: none"> <li>• Technology uptake is limited to buildings in public ownership, thus making these schemes unsuitable for wide-scale development.</li> <li>• Funding immature technologies exposes public organisations to the risks associated with less mature markets and technologies.</li> </ul>

### 11.2. *Soft loans*

The use of soft loans can help overcome the barrier of high capital costs. Providing loans below the market rate for finance associated with a specific purpose can provide a means of overcoming the barrier by spreading the total cost of the technology over a longer period. Germany employed soft loan mechanisms in the 1990s in conjunction with a feed-in tariff to support the deployment of wind energy installations and, more recently, this mechanism is being used as a tool to aid the uptake of energy efficiency measures. Soft loans require a framework to be developed with financial institutions. Where these frameworks already exist, adapting the scheme to incorporate support for renewable heat will require less administrative difficulty. Building a new loan scheme will require engagement with financial institutions and with legislative and regulatory systems.

Soft loans are attractive to governments because, compared with capital grants, they have less impact on exchequer budgets. Social resistance to loans is higher at the household level, which is also the sector where the impact of high capital cost barriers is most pronounced. Contingency to allow for defaulters can add to the cost of soft loan schemes.

Advantages	Disadvantages
<ul style="list-style-type: none"> <li>• Can be more attractive to governments, given reduced impact on the exchequer budget.</li> <li>• Allows consumers the flexibility to choose the most suitable technology for their individual circumstance</li> </ul>	<ul style="list-style-type: none"> <li>• Resistance to taking on debt in the household sector can be high, which could limit uptake.</li> <li>• Default contingency can add to the total cost of the schemes.</li> <li>• Transaction costs can be large for a policy that delivers uptake of many small-scale technologies in the heat sector, highlighting the suitability of the scheme for larger projects.</li> <li>• May be difficult to support in some financial/institutional frameworks.</li> </ul>

### 11.3. *Feed-in tariffs/bonus mechanisms*

Tariff/bonus mechanisms provide support to a renewable technology based on the amount of energy actually generated. The tariff level is calculated based on the lifetime costs – including the cost of capital – of producing energy from a renewable technology. Under feed-in tariff schemes that operate in the electricity system the grid operator must accept the output from a renewable installation, and the support scheme pays a set tariff for the electricity supplied. Where the generator receives the market price for electricity, the support scheme will pay a bonus equal to the difference between the market price and the tariff level. The revenue for the support can be levied from consumers or funded through direct taxation. Tariff levels can be tailored to the costs of individual technologies to promote a diverse portfolio and greater security of supply. Investors see high levels of certainty, with revenue streams assured for the eligible output for a number of years. This decreases the hurdle rates and results in less costly deployment of these technologies. Support levels can be adjusted over time as technology costs decrease.

As a heat market does not exist in the same way as the electricity market, these schemes can be more administratively challenging in the heat sector, making it is difficult to raise funds from heat consumers. This means that funding is likely to come from public/exchequer funding.

While the governing authority can set limits on maximum levels of renewable energy, there are uncertainties about total policy costs due to changing market prices. Support levels are set based on data of the costs of various technologies. Support levels can be difficult to estimate accurately for nascent technologies with low levels of deployment. Tariffs set too low will not induce renewable energy usage, while tariffs set too high can induce high uptake of renewable technologies, thereby resulting in high policy costs and excess rents accruing to heat generators. Adjusting tariff levels in response to these issues can impact on investor certainty and impact of renewable deployment. In the case of renewable heat, the absence of widespread metering creates difficulties for verifying output. Ensuring that the input to biomass combustion technologies is renewable is also a difficult administrative task. For these reasons the design of a Renewable Incentive Scheme is critical to ensure optimal uptake of the Scheme.

The Renewable Heat Incentive (RHI) implemented in the UK is the largest-scale example of a scheme of this type in the heat sector. In Ireland, a Draft Bioenergy Plan (October 2014) has been published and proposes, subject to State Aid clearance from the European Commission and further Government approval once the scheme is designed, to introduce from 2016 an Exchequer-funded incentive scheme to reward users for each unit of renewable heat used from sustainable biomass.

Advantages	Disadvantages
<ul style="list-style-type: none"> <li>• Theory suggests that the costs to society are minimised as the renewable energy technologies must compete on cost in order to deliver quotas.</li> <li>• Market forces dictate which technologies are successful.</li> <li>• Predictable costs of support.</li> </ul>	<ul style="list-style-type: none"> <li>• Investor risk may be increased, as the price for renewable energy output is uncertain. This means that investors will need a higher return on investment, which can offset the cost savings predicted in theory.</li> <li>• Quota mechanisms can force different technologies to compete against each other on current cost, which disadvantages less mature technologies. This may not provide a least-cost solution over the long term.</li> <li>• Tends to favour a small number of technologies, which is unlikely to provide a diverse generation mix.</li> <li>• Oversight and licensing of heat suppliers is far more complex than for electricity suppliers. This can introduce significant transaction and administration costs.</li> <li>• Possibility for misalignment with the goals of energy efficiency – users of renewable heat may have an incentive to use as much renewable energy as possible in order to maximise return from the scheme.</li> </ul>

#### 11.4. Quota mechanisms/supplier obligations

Quotas are legal obligations imposed by government, typically on energy suppliers, for the purchase of a specified amount of renewable energy. Government monitors the participants for compliance, and fines are payable for any shortfall against an obligation in a period. Obligations create a market for ‘green certificates’ or ‘renewable credits’ with suppliers trading compliance in a compliance market. Those suppliers who can produce renewable energy at lower cost can sell to suppliers whose costs of compliance are higher. Economic theory says that this will minimise, through competition, the cost of deploying renewable energy. Market forces will choose the portfolio of technologies. In practice, this can result in low diversity of technologies, as the scheme will tend to incentivise uptake of the cheapest technology at a given time. Experience with these

schemes has shown that support levels require substantial adjustments post introduction, leading to high transaction and administrative costs for government and heightened risk for investors.

Quota mechanisms are widely used to support RES-E, including the Renewables Obligation in the UK and Green Certificates in Belgium and Poland. Some countries have introduced quota schemes in the transport sector, which obligate fuel suppliers to produce renewable fuels. While there are no examples of quota schemes operating in the EU for RES-H, they may be possible to implement in theory. Administrative difficulties have contributed to the absence of these schemes in the heat sector. The lack of metered output from heat-producing installations means that it is difficult to verify the actual heat consumption. In addition, ensuring that generated heat is used productively could be costly. The complexity of engaging with many small-scale generators means that they are inappropriate at this scale. Extending the model from the transport quota schemes – blending renewable fuels with fossil fuels – has possibilities for home heating oil and natural gas used for heating. This avoids some of the administrative difficulties described, but may be limited by the availability of sustainable biofuels.

Advantages	Disadvantages
<ul style="list-style-type: none"> <li>• High level of certainty for investors, which promotes lower financing costs.</li> <li>• As technology costs evolve, support levels for new installations can be adjusted in line with cost changes.</li> <li>• Bonus payments can be tailored to individual technologies offering greater diversity.</li> </ul>	<ul style="list-style-type: none"> <li>• Total policy costs can be uncertain if caps are not placed on the quantity of renewable energy that will be supported.</li> <li>• It can be difficult to assess the costs for immature technologies accurately, and therefore to set the feed-in tariff price level accurately.</li> <li>• The need to select the technologies means that the government must decide on the size and type of technologies to support.</li> <li>• Administration of a feed-in tariff scheme for smaller-sized technologies can be difficult, leading to high transaction costs.</li> <li>• The dispersed nature of the heat market means that it can be difficult to confirm actual heat output from supported installations.</li> <li>• Possibility for misalignment with the goals of energy efficiency – users of renewable heat may have an incentive to use as much renewable energy as possible in order to maximise return from the scheme.</li> </ul>

### 11.5. *Tendering mechanism*

Under a tendering scheme, the government sets a quantity target for the desired amount of renewable energy. Prospective projects bid for government support to supply this capacity with the lowest-priced viable project(s) winning the tender competition. The subsidy is set at this price for the duration of the contract. Bidding rounds are typically targeted at specific technologies. These schemes favour the lowest cost. Experience shows that some winning projects do not get built as bidders may submit bids to overly ambitiously low levels in order to win the competitive tender. Bidding rounds also lead to start/stop type development, rather than stable growth. Due to the administrative burden of preparing and accessing project bids, tendering schemes are generally suited to large projects only. These schemes suffer from the same compliance policing burden that quota mechanisms and feed-in tariff schemes must deal with.

These schemes have being used in several countries to promote RES-E development. Denmark operates a tendering scheme for the development of offshore wind parks. An area of ocean is zoned for this purpose and prospective wind farm developers bid for the right to develop the area. France operates a tendering scheme for large-scale renewable electricity projects in specified

development zones. Lithuania uses tender rounds to support RES-E installations and support projects for 12 years. There are no international examples of tendering schemes directly supporting renewable heat.

Advantages	Disadvantages
<ul style="list-style-type: none"> <li>Cost competition is central to the mechanism, thus providing an incentive to reduce prices and the costs of supporting the scheme.</li> </ul>	<ul style="list-style-type: none"> <li>Bidders may lower prices to unrealistic levels, thus making project unviable – although safeguards can be put in place to reduce this risk.</li> <li>Not suitable for large uptake of renewable heat, as bidding rounds can lead to a start-stop development rather than stable growth.</li> <li>Not suitable for small-scale projects.</li> <li>The dispersed nature of the heat market means that it can be difficult to confirm actual heat output from supported installations.</li> <li>Possibility for misalignment with the goals of energy efficiency – users of renewable heat may have an incentive to use as much renewable energy as possible in order to maximise return from the scheme.</li> </ul>

### 11.6. *Tax incentives and levies*

Various forms of tax-based instruments have been used to support renewable energy and energy-efficient technologies. These include VAT exemptions on the purchase of equipment, offsetting energy system costs against personal income and tax credits to reduce companies' tax bills. Tax incentive schemes help renewable technologies whose costs are close to alternative heat-generating options, but have not been taken up due to other market barriers. Their effectiveness depends on the cost differential between the renewable technology option and a conventional option as well as on the tax rate – countries with higher tax rates provide more implicit support through these schemes. Well-designed schemes are administratively straightforward to implement and can target specific technologies with a minimum level of performance. The ultimate loss of revenue for the government can be difficult to anticipate in advance and these schemes must remain in place for significant periods of time in order to provide market certainty for investors in supported technologies.

Taxes on carbon emissions and levies on fossil fuels serve to increase the relative economic attractiveness of renewable energy technology. Levies and taxes can be used to raise funds to finance other support mechanisms, although hypothecation on exchequer funds is discouraged in many countries. A total of 11 EU countries have tax incentives in place for RES-H support, in the form of a carbon tax or fossil fuel levy. Using a tax as an instrument to drive uptake of renewable technologies can be costly; it can also impact on economic competitiveness and impact lower income groups disproportionately.

Advantages	Disadvantages
<ul style="list-style-type: none"> <li>Funding of tax breaks from exchequer (incentives) must compete with other priority areas of public funding.</li> <li>Taxation relief may not be sufficient to cover the cost differential between fossil fuels and renewable options. (incentives).</li> <li>Taxation levies on fossil fuels will reduce the cost competitiveness of sites that do not switch to renewable technologies. (levies)</li> </ul>	<ul style="list-style-type: none"> <li>Increased taxation of fossil fuels or CO<sub>2</sub> benefits the exchequer (levies).</li> <li>Technology choices are made by the heat consumer (incentives and levies).</li> </ul>

### *11.7. Building regulations and obligations*

Obligations set a minimum requirement for renewable energy use. Building regulations are the most common use of obligations for the promotion of renewable heat; they set minimum levels for renewable heat usage in buildings. These regulations typically apply to new buildings and stipulate that a specific type of technology must be installed, or that a quantity of renewable energy must be produced each year. The household or business then chooses the most suitable technology to meet the requirement. These types of schemes are attractive to government as they require no direct exchequer financing. Ensuring compliance with the obligation can place a large administrative cost on government. In addition, renewable energy output through these schemes will only grow at the rate of new building construction rates or, in a case where regulations apply to retrofits, at the replacement rate of technology. This means the scope for large-scale increases in renewable energy output is limited over the short term.

A total of 13 EU countries implement obligation schemes for renewable heat requirements in buildings. Denmark requires each local authority to conduct a feasibility study and outline a heat plan for an area. The heat supply of a new building is then chosen based on this plan. The rules relating to the feasibility underpinning the heat plan contain specifications directly relating to RES-H. Germany has enacted a law that requires each new building greater than 50 m<sup>2</sup> in floor area to install a renewable heat technology. The amount of energy required differs for each technology, ranging from 15% for solar thermal to 30% for heat pumps, biomass boilers and biogas. Ireland currently requires new buildings to produce 10 kWh/m<sup>2</sup>/yr of their energy from renewable sources.

## **Part 5: Achieving the REH-H target – policy costs and impacts**

## 12. Policy costs and impacts

As shown by the scenarios developed in section 4, further policy effort is required in order to meet the 2020 target of 12% renewable energy in heat use. Section 9 describes a range of other significant factors to consider in the choice of a policy instrument(s) to bridge this gap. The potential set of policy considerations is large. Ease of policy implementation and administration, total cost and annual costs, who pays, and coherence with other policy goals are important considerations in the decision. The total funding costs of the policy options are a primary criterion for in the choice of policy instrument. This section details the costs for the three types of financial instruments that can be used to induce uptake of renewable heat technologies.

- 1) Ongoing payments for renewable energy output (FiT/bonus, quota mechanism, tendering process)
- 2) Once-off upfront capital funding for installations (grants, loans)
- 3) Tax increases on competing technologies (CO<sub>2</sub> tax, fossil fuel levies)

Ongoing payments arise from policy schemes such as quota mechanisms, supplier obligations, tendering schemes and feed-in tariffs or bonus mechanisms. There are differences in how these schemes are funded and administered, but all renewable heat installations are funded on the basis of their renewable output. To represent the possible magnitude of costs for an ongoing payment-type scheme, a renewable heat feed-in tariff (FiT/bonus) is modelled.

Schemes that fund upfront capital costs are typically in the form of grants, tax reliefs or soft loans. All of these interventions directly fund some of the upfront capital costs of renewable heat technologies. In order to represent the direct funding costs of such schemes to deliver the RES-H target, a notional grant scheme is modelled.

Taxes on carbon or increased duties on fossil fuels used are fiscal tools sometimes employed to incentivise uptake of technology by increasing the cost of competing technology options. In order to represent the cost of such options to achieve the RES-H 2020 target, a carbon tax is modelled. The wider economic implications and feedbacks from implementing a carbon tax are not considered.

Implementation of an ongoing payment policy or a capital support policy will require funding from either the exchequer or from heat consumers. In contrast to the other policies examined, the implantation of a tax will benefit the exchequer at the cost to fossil fuel users.

### 12.1. *Feed-in tariff (FiT)/bonus scheme*

The FiT /bonus scheme provides a renewable technology installation with a payment for each unit of output delivered over a 15-year period. The tariff/bonus is calibrated against the market price for delivering energy from an oil boiler, and acts to pay the difference in cost between the market price and the cost of the marginal technology required to meet the RES-H target. A single tariff price is modelled for all technology types, with no differentiation based on size. The rates shown in Table 5 are at the levels required to incentivise enough consumers to switch to renewable heat technologies, in order to meet RES-H 12% by 2020 in all scenarios.

Table 5: Bonus payment level by scenario for FiT/bonus scheme

Scenario	Tariff level (€/MWh)
High scenario	€3
Central scenario	€8
Low scenario	€12

As described in Section 3, the size and type of heat technology impacts on the economics of the technology choice. The customer responses to the various components of the total cost, to being positively disposed to a support scheme, and the hassle factors of installing a new technology vary across consumer type. In general, larger sites with high ongoing fuel costs with lack of access to the gas grid require the least amount of support to change to a new technology. As such, biomass boilers in the industrial sector respond strongly to the incentives provided by the scheme. The tariff also induces some additional uptake of heat pumps in the commercial sector. Figure 23 shows the impact of a FiT/bonus scheme on renewable heat output in the *Central scenario*.

Figure 23: Renewable heat technology output for FiT/bonus scheme 2012-2020 (*Central scenario*)

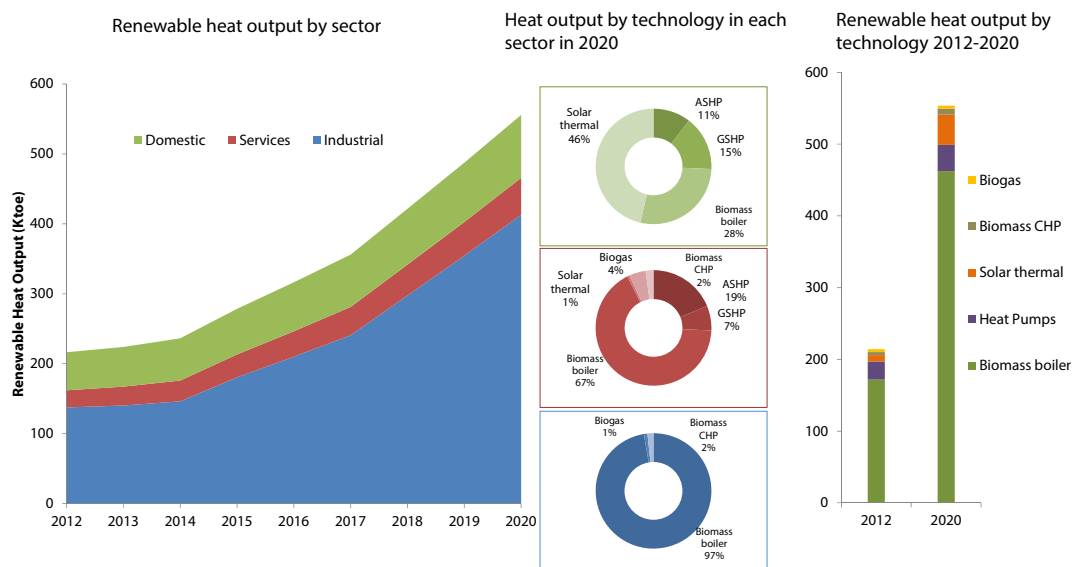
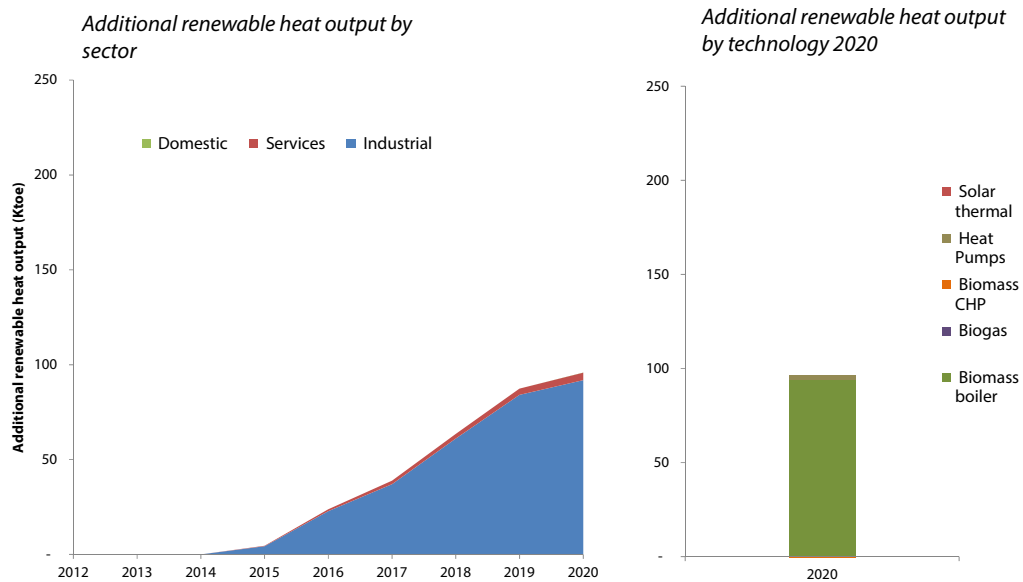


Figure 24 shows the technologies incentivised by the FiT/bonus scheme in the *Central Scenario*. Installations of biomass boilers increase by 8% in the commercial and industrial sectors and installations of heat pumps increase by 3%, leading to an additional renewable heat output of 100 ktoe (1,163 GWh) by 2020.

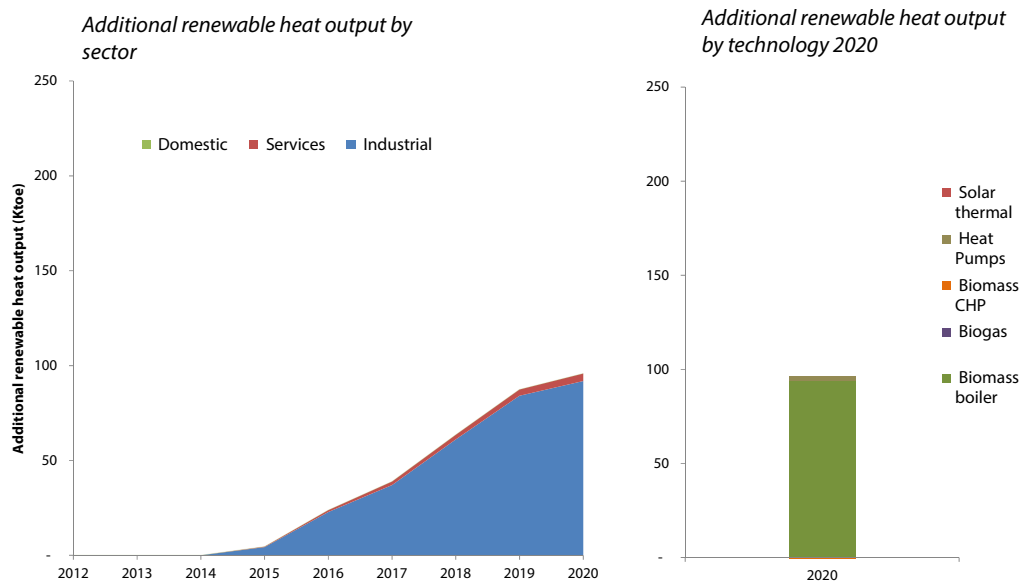


Figure 24: Additional renewable heat output due to FiT/bonus scheme 2012-2020 (Central scenario)



In the *High scenario*, the additional 70 ktoe (814 GWh) of renewable heat output required to meet the RES-H 12% is also primarily delivered from biomass in the industrial sector. Figure 25 shows the additional heat output in the *High scenario*.

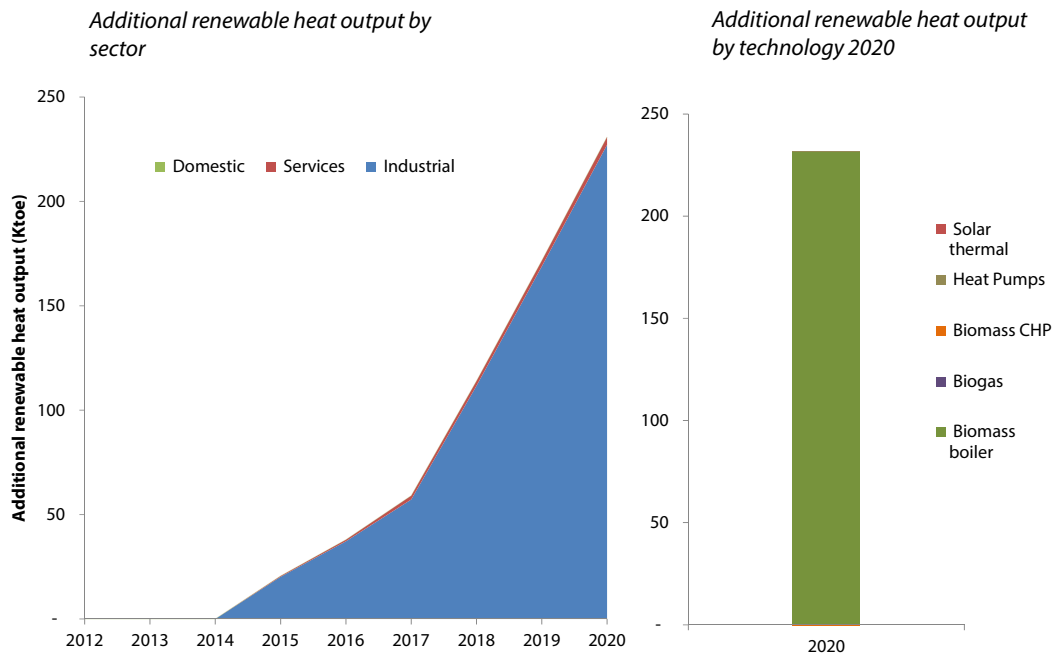
Figure 25: Additional renewable heat output due to FiT/bonus scheme 2012-2020 (High scenario)



In the *Low scenario*, the 12% increase in biomass boiler sales drives an increase of 231 ktoe (2,687 GWh) in renewable heat output. This number is substantially higher than the other scenarios for two reasons. First, the uptake of renewable heat technology under current policies is low, due to the lower fossil fuel prices, thus leading to a higher cost differential between renewable heat technology and the fossil fuel option. Second, the higher energy demand evident as a result of a

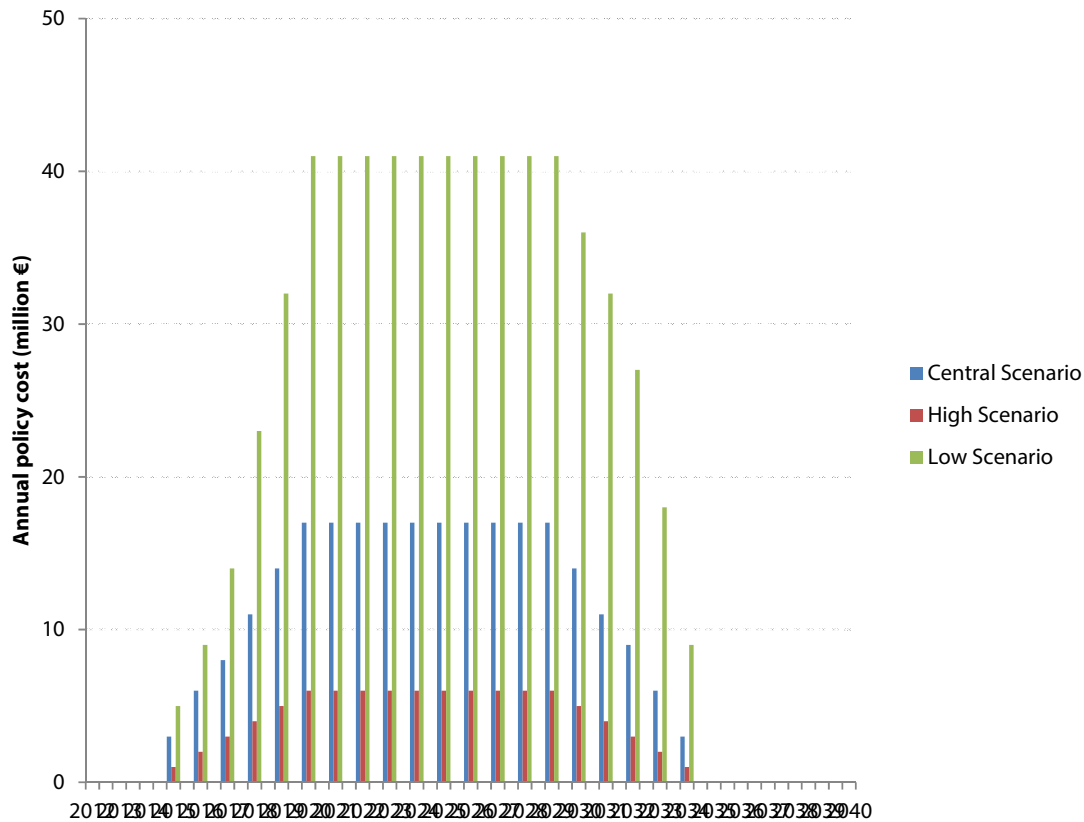
shortfall on energy efficiency policy means that more renewable energy is required in order to meet the RES-H 12% target.

Figure 26: Additional renewable heat output due to FiT/bonus scheme 2012-2020 (Low scenario)



The cost profile of the policy under each scenario is shown in Figure 27. The total discounted policy costs range from €58 million in the *High scenario* to €391 million in the *Low scenario*, with the peak annual cost ranging from €6 million to €41 million. The wide range in policy costs reflects the sensitivity of the uptake to changes in the relative cost of fossil fuels and renewable heat technologies across the scenarios and, in the *Low scenario*, the additional cost imposed due to a shortfall in energy efficiency policy and the additional uptake of renewable heat technologies required in order to meet the RES-H target. The policy is offered until 2020 and continues to require funding until 2035, when the last installations supported under the scheme retire.

Figure 27: FiT/bonus scheme annual policy cost over life of the scheme (all scenarios)



## 12.2. Upfront capital grant

Upfront grant supports are typically offered as a percentage of the total installation costs of a technology. Previous grant schemes in Ireland have offered support in the region of 30% of technology installation costs. The size of renewable heat installations varies across sectors and consumer types, and installation costs are higher per unit capacity at smaller scales. Grant amounts were applied in the model based on the installation costs in individual size bands, and also based on a typical installation size and cost in that band. The grant proportion offered in each scenario is sufficient to achieve uptake of renewable technologies to meet the RES-H 12% by 2020.

Results indicate that grants covering 35% of the capital cost are required to reach the 2020 RES-H target in the *Central scenario*, with a 15% grant delivering the required uptake in the *High scenario* and a 43% grant required in the *Low scenario*. The grant proportion and technology bands were modelled across a number of technology sizes, as shown in Table 6.

Table 6: Grant % modelled in each scenario<sup>67</sup>

Size (kW)	High scenario	Central scenario	Low scenario
	15% grant	35% grant	43% grant

<sup>67</sup> Solar thermal installations are currently eligible for a grant under the better energy homes scheme

Figure 28 shows the uptake of technologies in the *Central scenario* with grant support. As with the FiT/bonus scheme, biomass boilers account for increases in renewable heat output to meet the target. Under the grant scheme, uptake of biomass boilers is more pronounced in the services sector and less so in the industrial sector.

Figure 28: Renewable heat technology output for grant scheme 2012-2020 (Central scenario)

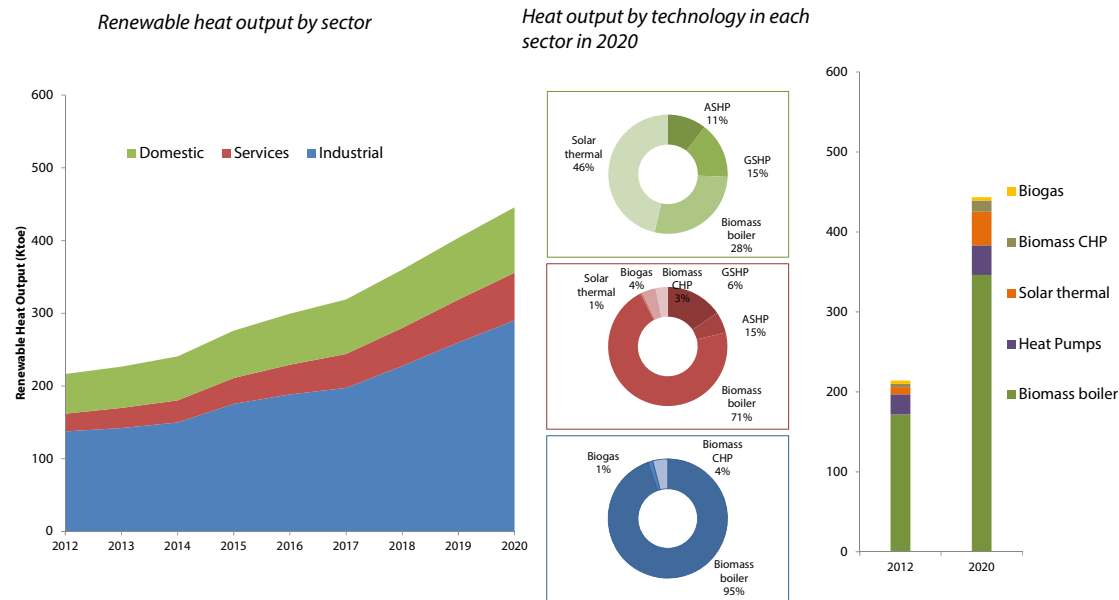


Figure 29 shows the additional energy output for renewable energy technologies as a result of a grant scheme. As with the FiT/bonus scheme, much of the additional renewable energy is due to the uptake of biomass boilers in the industrial sector; however, biomass boilers also see some additional uptake in the commercial sector. Overall, an additional 100 large biomass boilers a year are installed from 2015 onwards in the industrial sector, with an additional 450 units a year installed in the commercial sector.

Figure 29: Additional renewable heat output due to grant scheme 2012-2020 (Central scenario)

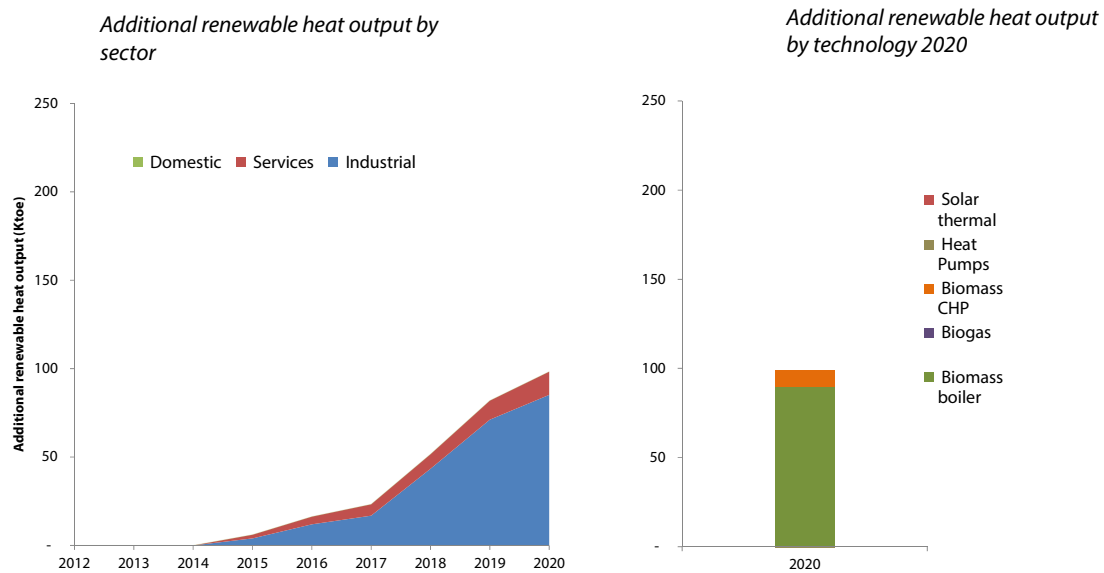


Figure 30 shows additional uptake of biomass boilers in the industrial sector to meet the RES-H target. The 15% grant required to deliver the RES-H target in the *High scenario* is too low to incentivise uptake of the more expensive, smaller scale technologies in other sectors. With higher oil prices and greater availability of biomass imports in the *High scenario*, the difference in cost to be bridged by a grant is smaller. A 15% grant for large installations is sufficient to get the additional uptake to achieve the renewable heat target, with an average of six additional large biomass boilers per year being installed, as compared to the current policy uptake trajectory.

Figure 30: Additional renewable heat output due to grant scheme 2012-2020 (High scenario)

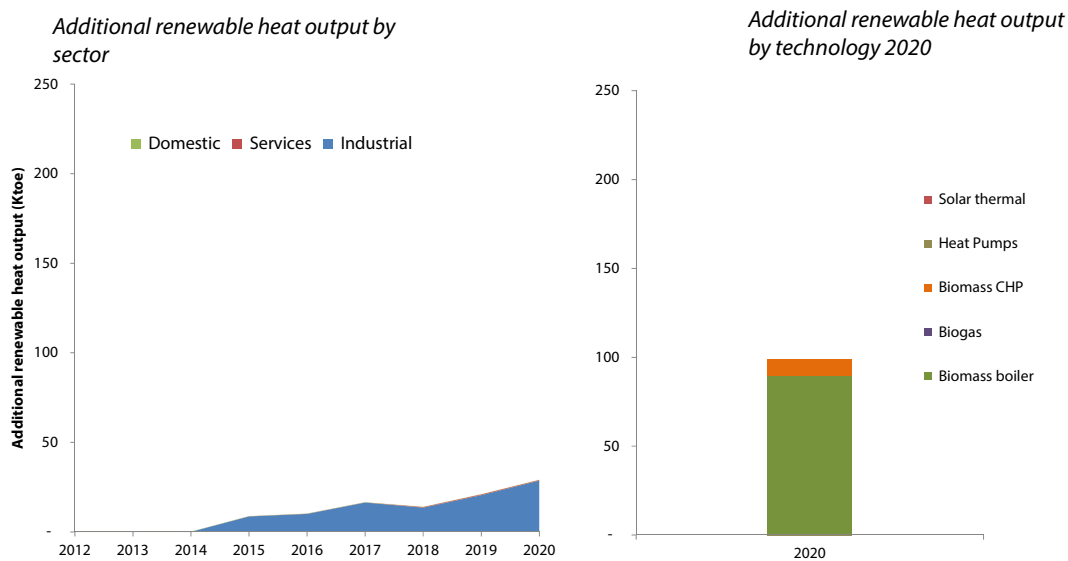


Figure 31 shows the additional uptake of renewable heat technologies in the *Low scenario*. The grants offered to technologies with lower peak outputs in the domestic and commercial sectors

result in a large additional uptake of technologies in these sectors. Biomass boilers constitute the majority of the uptake, but more heat pumps are also installed in the commercial sector. The administrative difficulty of this scenario is highlighted by the numbers of installations that are grant aided. An additional 15,000 biomass boilers per year and 500 heat pump installations per year are required in order to meet the renewable heat target. Much of this uptake is of smaller boilers in domestic and commercial space heating applications.

*Figure 31: Additional renewable heat output due to grant scheme 2012-2020 (Low scenario)*

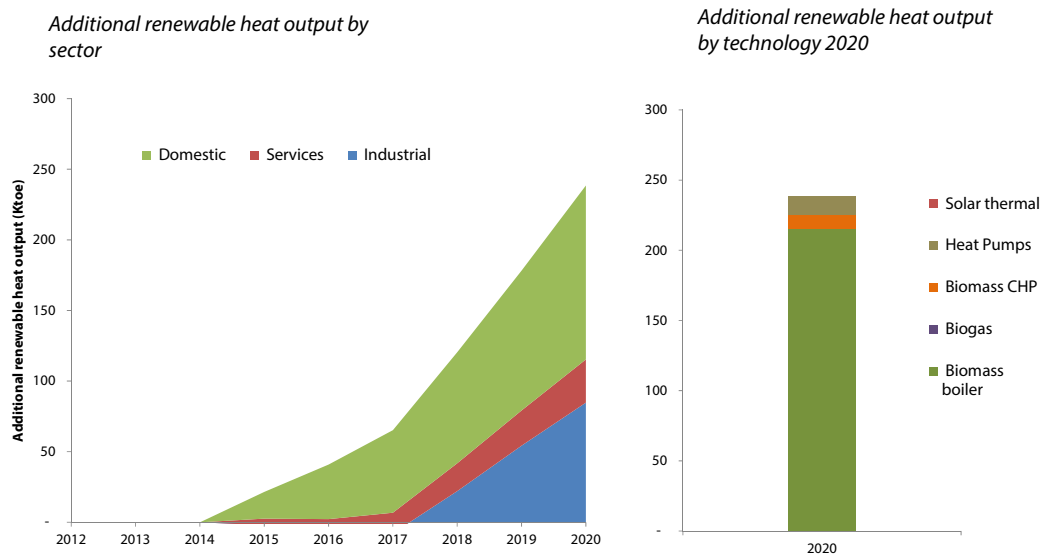
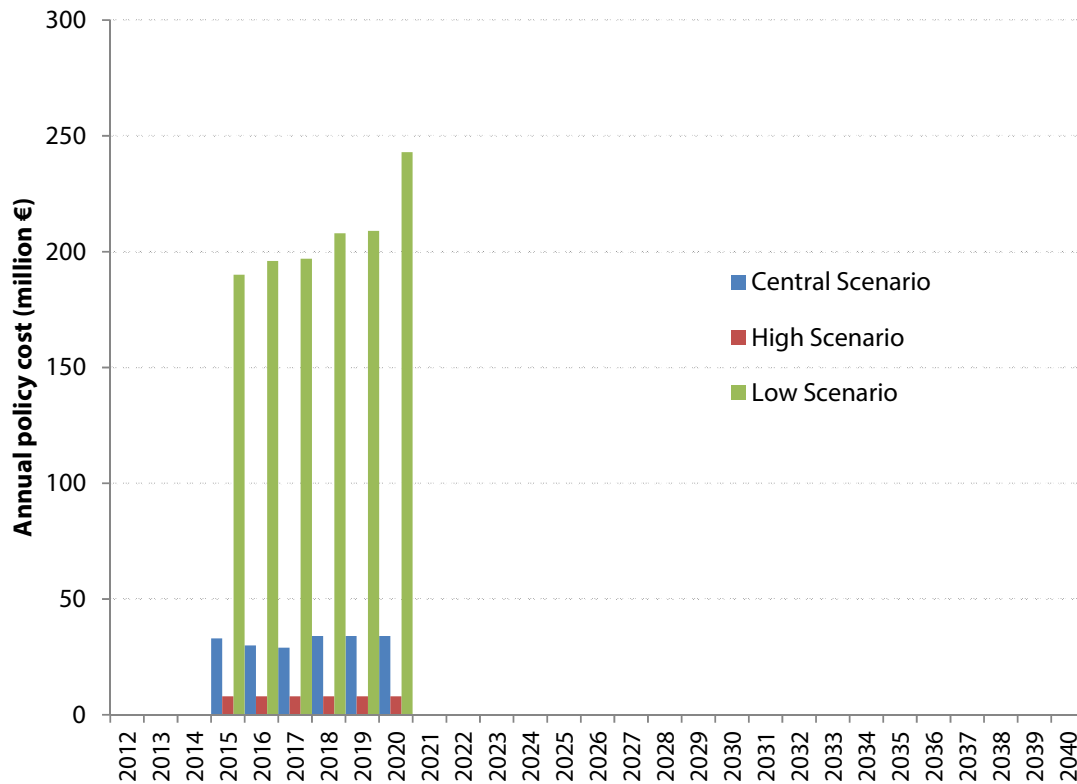


Figure 32 shows the cost profile of the grant scheme across all scenarios. The total discounted lifetime costs are €8 million in the *High scenario*, €131 million in the *Central scenario* and €836 million in the *Low scenario*. The large variation in costs between the *High scenario* and the *Low scenario* reflects the need to provide a higher proportion of grant support in the *Low scenario* in order to meet the renewable heat target.

Figure 32: Grant scheme annual policy cost over life of the scheme (all scenarios)



### 12.3. CO<sub>2</sub> tax increase

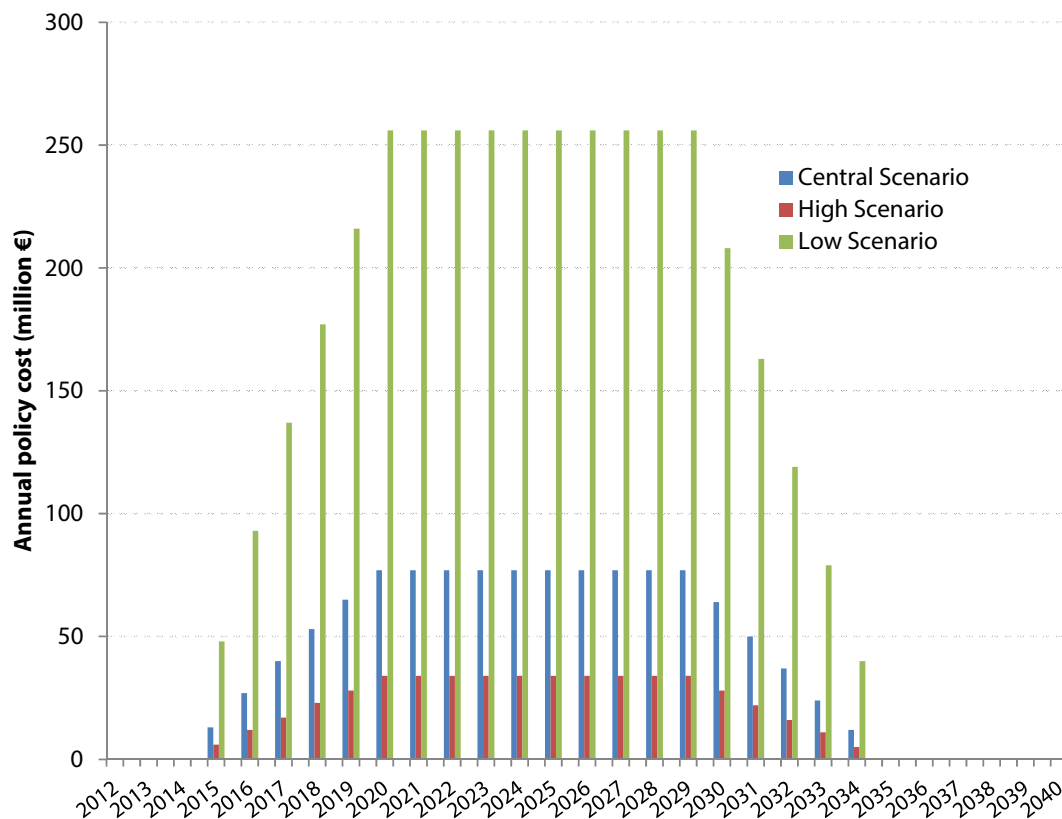
Increasing the CO<sub>2</sub> tax makes fossil fuel technologies more expensive and increases the competitiveness of renewable technologies. In order to provide a consistent basis for comparison with the costs of other policy options, the analysis of carbon tax impacts is assessed for new fossil fuel heating technologies installed in the period 2015-2020 – the tax increase does not apply to pre-existing fossil fuel technologies. A more extensive application of a CO<sub>2</sub> tax increase to existing fossil fuel heat production and the transport sector will increase the cost of the tax considerably without achieving any additional uptake of renewable heat technologies.

At present, a carbon tax of 20 €/tCO<sub>2</sub> is levied on fossil fuels and this is incorporated into the underlying fuel price assumptions. In order to achieve the uptake required to reach the 2020 target for renewable heat, CO<sub>2</sub> tax increases of between 29 €/tCO<sub>2</sub> in the *High scenario* and 38 €/tCO<sub>2</sub> in the *Central scenario*, would be levied on new fossil fuel installations from 2015 onwards. The *Low scenario* conditions would require a CO<sub>2</sub> tax increase to over 80 €/tCO<sub>2</sub> and, given the likely severe wider economic impacts that would ensue, it is not considered a realistic option.

As with the FiT/bonus scheme and the upfront grant, the carbon tax increase results in an increased uptake of biomass boilers in the industrial sector, with some additional uptake of biomass boilers and heat pumps in larger commercial applications. Unlike the previous policies, the cost of the carbon tax falls on consumers who source heat energy from fossil fuels, with the revenue raised flowing to the exchequer. The costs of the CO<sub>2</sub> tax increase are an order of

magnitude higher than the other policies, as the tax cannot discriminate between sectors, thus resulting in increased costs for consumers across residential, services and industry who install new fossil fuel technologies. Figure 33 shows the annual cost profile for the CO<sub>2</sub> tax increases for the *Central scenario* and the *High scenario*.

Figure 33: CO<sub>2</sub> tax cost to new fossil fuel consumers (all scenarios)



The cost of using a tax as the sole instrument to achieve the RES-H target is the most expensive of the policies examined. For sites that install fossil fuel-procuring heat technologies post 2015, the total cost is estimated to range from €330 to €750 million. Figure 33 shows the cost trajectory across the scenarios for the CO<sub>2</sub> tax increase for heat users only.

CO<sub>2</sub> tax could have a role in combination with other policy instruments. It can reduce the overall cost of the other policy instruments by reducing the relative cost of renewable energy technologies, thereby reducing the funding requirement for a support scheme. In addition, the revenue from a tax increase can provide a source of funding for the scheme through hypothecation of tax revenue raised from the carbon tax.

#### 12.4. Policy cost summary

The impacts of these policy options in terms of technology uptake in each of the residential, services and industrial sectors are considered. These uptake levels drive the overall cost of the different policy options. The estimated policy funding costs are broadly indicative of what the various costs may be for financial instruments. More detailed policy design that includes a more



sophisticated banding approach to tariff or grant development is likely to depart from the costs presented here. This analysis is useful to understand how the policies may influence funding costs under different fossil fuel price and biomass availability scenarios and, along with the wider policy implementation considerations presented, it helps to inform a policy decision as to the appropriate instruments to be put in place in order to close the gap to the RES-H target. The total lifetime costs as well as the peak annual costs are presented for each policy in Table 7.

*Table 7: Summary of policy cost evaluation*

Policy option	Peak annual cost (€ million)			Total cost to 2035 (undiscounted) (€ million)			Total discounted cost <sup>68</sup> to 2035 (€ million)		
	High scenario	Central scenario	Low scenario	High scenario	Central scenario	Low scenario	High scenario	Central scenario	Low scenario
<b>FiT/bonus</b>	€6	€17	€41	€90	€255	€615	€54	€153	€361
<b>capital grant</b>	€9	€34	€243	€42	€194	€1,243	€28	€131	€836
<b>CO<sub>2</sub> tax increase</b>	€34	€77	€256	€508	€1,155	€3,840	€330	€750	€2,499

The cost of the CO<sub>2</sub> tax increase is greater than the cost of the other options examined. The cost of fossil fuels is still competitive for many fossil fuel sites, particularly those with access to the natural gas grid. Moreover since the CO<sub>2</sub> tax mechanism cannot discriminate for these sites, their energy costs are increased as a result of the tax, but not sufficiently to induce a decision to install a renewable heat technology. The total cost is an order of magnitude less than for the other policies examined, as the support is focused on those sites that will install renewable heat technologies over the period to 2020 only.

The variation in costs in the grant scheme across scenarios is the largest of all the policy instruments examined. The nature of grants means that the funding of the installation is based on upfront costs and is unrelated to the amount of energy the installation produces. As a result, grants tend to support greater numbers of individual installations in order to produce the required amount of heat to meet the 2020 RES-H target. In the event of future high fossil fuel prices as modelled in the *High scenario*, the grant scheme could potentially provide the lowest cost route to the renewable heat target, as a 15% grant is likely to prompt many of the larger industrial and commercial sites to switch from oil. Larger sites tend to have a higher year-round heat requirement, which means that the investment incentives deliver a large amount of renewable heat from each installation supported. However, the limitations of the grant scheme are highlighted in the *Low scenario*, which could result if there is a shortfall on energy efficiency targets (i.e. higher overall energy demand) leading to the need for greater levels of renewable heat technology uptake and therefore a significantly higher policy cost. As grant proportions were modelled not to exceed 50% of the installation costs of a heat technology, more installations from the smaller size/higher cost bands are incentivised to meet the renewable heat target. As well as being costly, the number of individual installations could exceed 15,000 a year, indicating an increasing administrative burden in delivering such a scheme.

For the FiT/bonus scheme, a single tariff level is modelled and is determined by the most expensive technology required to meet the RES-H target. Further policy design can develop tariff

<sup>68</sup> A discount rate of 4% is used as per Department of Finance guidelines. See <http://publicspendingcode.per.gov.ie/wp-content/uploads/2012/08/D03-Guide-to-economic-appraisal-CBA-16-July.pdf>

levels for individual technology size bands, with lower cost bands (e.g. sites with large heat demands currently provided by oil switching to biomass) receiving a lower tariff level than the smaller more expensive marginal sites that set the tariff level for all technologies in this analysis. By introducing separate tariffs to cover the different cost differentials in the industry and the commercial sector, the overall cost could be reduced further. Conversely, expansion of the tariff bands to focus on more expensive technologies and/or smaller-scale technologies would lead to a more expensive policy funding cost. Fossil fuel savings to the heat user, and CO<sub>2</sub> reductions due to the various policies, are of a similar magnitude under all policy options. Table 7 shows the value of fossil fuel savings from the heat consumer's perspective, and the amount of CO<sub>2</sub> displaced across each scenario under each policy. Oil displacement accounts for over 90% of the savings in all cases. Some differences in the amount saved under different policies are evident. This is due to the higher value of fossil fuels in the smaller-scale applications in the services and household sectors – fuels are generally more costly per unit for consumers who use less energy across the year. Consumer savings include some loss of tax revenue for the exchequer.

In the *Central Scenario*, the discounted value of fossil fuel savings over the lifetime of the scheme are estimated as being close to €900 million, peaking at over €90 million per annum. The associated CO<sub>2</sub> savings are estimated as 6 MtCO<sub>2</sub> over the lifetime of the scheme to 2035; 1.2 MtCO<sub>2</sub> is banked towards Ireland's non-ETS target in 2020.

*Table 8: Fossil fuel and CO<sub>2</sub> savings to 2035 (all scenarios)*

	Scenario	Fossil fuel savings (€ million)			CO <sub>2</sub> savings (MtCO <sub>2</sub> )			
		Total savings to 2035	discounted savings	Peak annual savings	Total savings to 2035	savings to 2035	Peak annual savings	annual savings
<i>FiT/bonus</i>	<i>Central scenario</i>	865		89	5.8		0.4	
	<i>High scenario</i>	464		48	3.9		0.3	
	<i>Low scenario</i>	1,648		173	9.4		0.7	
<i>Upfront grant</i>	<i>Central scenario</i>	936		98	5.8		0.4	
	<i>High scenario</i>	422		43	3.8		0.3	
	<i>Low scenario</i>	2,596		271	10.5		0.8	
<i>CO<sub>2</sub> tax</i>	<i>Central scenario</i>	868		90	6.2		0.4	
	<i>High scenario</i>	464		48	3.6		0.3	
	<i>Low scenario</i>	1,630		171	9.4		0.7	

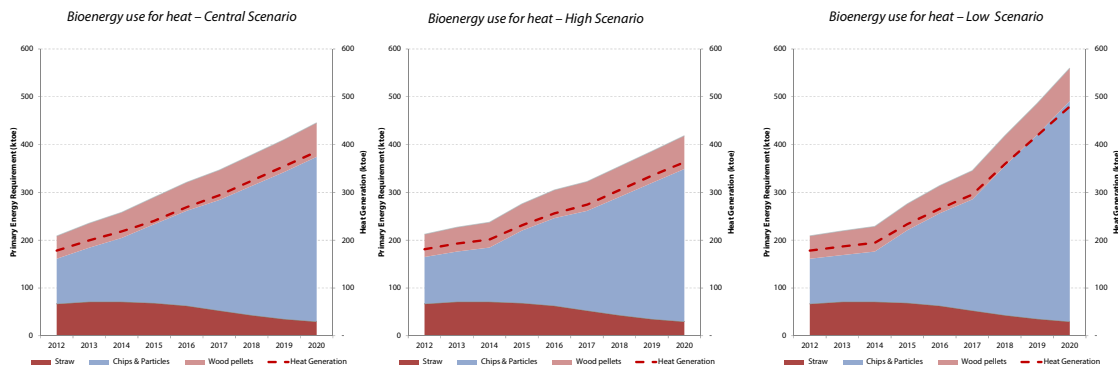
These policy costs are broadly indicative of what the various policy costs are for financial instruments. More detailed policy design that includes a more sophisticated banding approach to tariff or grant development is likely to depart from the costs presented here and even reduce the costs for the FiT/bonus scheme. This analysis is useful to understand how the policies may influence funding costs under different fossil fuel price and biomass availability scenarios and, together with the wider considerations presented in section 9, can help inform a policy decision as to the appropriate instruments to put in place to close the gap to the RES-H target.

### 13. The role of bioenergy in achieving the RES-H target

The modelling shows that bioenergy for heat in larger industrial-sized installations responds strongly to policy incentives. This section looks at the implications for bioenergy supply and the requirements for raw resources. All policy options examined result in similar uptake of bioenergy

technologies, and the results of the FiT/bonus scheme are presented here. Figure 34 shows the bioenergy used and the heat output from these sources in the model.

Figure 34: Bioenergy required for renewable heat production in FiT/bonus scheme (all scenarios)



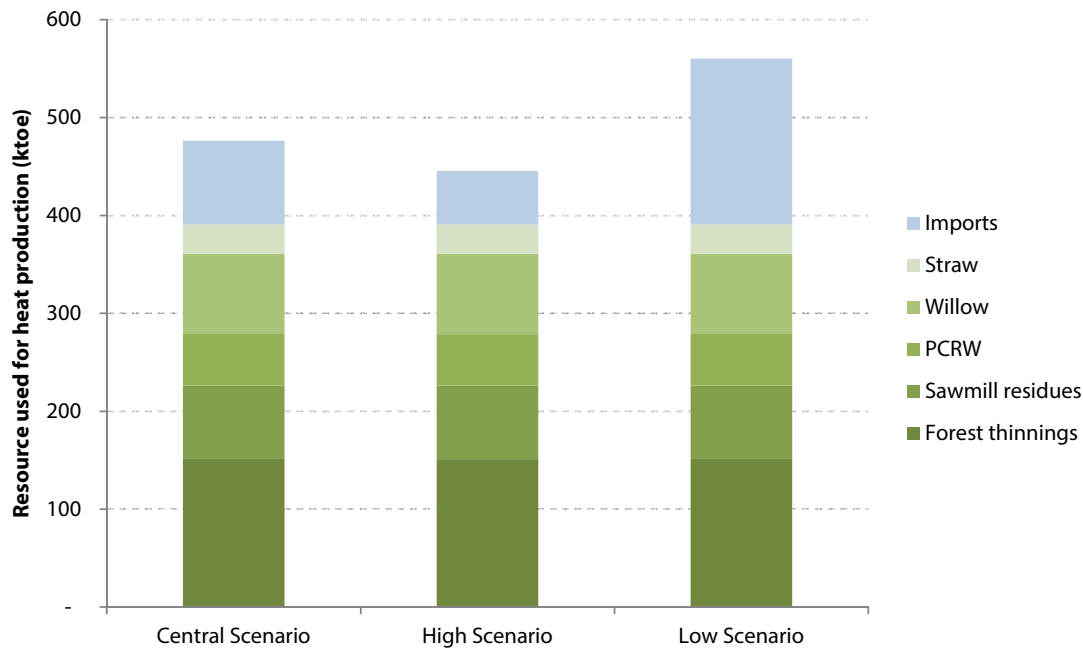
The combustion of wood chip and straw in boilers in the industrial sector is responsible for the majority of the growth in renewable heat output. Wood pellet combustion in the commercial and domestic sectors also contributes some of the heat output. Bioenergy resource requirements in the *Central scenario* and the *High scenario* are similar, as the total bioenergy required to meet the RES-H target is comparable in both of these scenarios. Due to the lower impact of energy efficiency policy assumed in the *Low scenario*, more output from renewable heat installations is required in order to meet the RES-H 12% target; most of this output comes from bioenergy as the most competitive energy source.

Wood chips and pellets are either produced from the available domestic raw biomass resources or imported in refined form. The availability of domestic resources is the same for all scenarios and reflects the analysis contained in SEAI's BioEnergy Supply Curves for Ireland 2010-2030 publication.<sup>69</sup> The cost and availability of imports differ. In the *Central scenario* and the *Low scenario* refined wood products are available for import, but at a higher cost than the refined cost of domestic resources. In the *High scenario* imports are based on the *Restricted supply/Reference demand scenario* analysis of global bioenergy supply contained in bioenergy supply curves publication, with any additional imports valued as in the other scenarios.

To achieve the 2020 renewable heat target, the model makes extensive use of the available domestic biomass sources. Figure 35 shows the domestic resources used in the production of heat and the scale of imports that maybe required to meet the 2020 renewable heat target.

<sup>69</sup> SEAI (2013) BioEnergy supply curves for Ireland 2010-2030. Available at [http://www.seai.ie/Publications/Energy\\_Modelling\\_Group/Energy\\_Modelling\\_Group\\_Publications/BioEnergy\\_Supply\\_Curves\\_for\\_Ireland\\_2010\\_-\\_2030.pdf](http://www.seai.ie/Publications/Energy_Modelling_Group/Energy_Modelling_Group_Publications/BioEnergy_Supply_Curves_for_Ireland_2010_-_2030.pdf)

Figure 35: Domestic and imported biomass resources used to meet RES-H 12% (all scenarios)



Imports have a role to play in all scenarios. There are a wide range of scenarios for the potential availability of imports, and these scenarios are dependent on international factors which influence both the available supply and the demand for resources in other jurisdictions. The use of the available domestic resource is influenced by the availability and harvesting cost of these resources. The BioEnergy Supply Curves for Ireland 2010-2030 analysis, published by SEAI and used as an input to the modelling process, contains an in-depth examination of the biomass resource availability at various market prices for bioenergy. The harvesting costs of the resources include consideration of the supply-side barriers faced by producers of biomass material for energy, and these resources are only deployed in the model if the market price is sufficiently high to cover the harvesting costs. Several scenarios for the potential for international trade of biomass resources are also examined.

The costs associated with generating this increase in production are captured in the modelling, i.e. use of more expensive resources in BEAM results in a higher cost of biomass fuel in the Consumer Choice heat model. By including estimations of the price increases per fuel that are required to expand the bioenergy resource. Increases in biomass demand in the electricity sector for the resources will increase the competition for limited domestic resources and is likely to lead to additional policy costs, in order to achieve the renewable heat target.

Table 9 shows the quantities of domestic resources used by the model in all scenarios in 2020.

Table 9: Resource requirement to produce required heat output in 2020 (all scenarios)

Resource requirement (common units)	Requirement in 2020
Forest thinnings (000 m <sup>3</sup> )	917

Sawmill residues (000 m <sup>3</sup> )	455
Post-consumer recycled wood (PCRW) (000 tonnes)	138
Short rotation coppice willow (000 ha)	17
Straw (000 tonnes)	88
Imported wood products (000 tonnes)	135 - 418

The quantities shown for domestic resources in 2020 represent a significant increase on current usage for most resources. For example, at present, there are 830 ha of willow<sup>70</sup> planted in Ireland and 17,000 ha are needed to meet the scenario demand modelled. Other resources have similar challenges. At present, about 500,000 m<sup>3</sup> of forest material<sup>71</sup> is used for energy purposes. More than double this amount needs to be brought into production to meet the portion of renewable heat demand for domestic forestry sources. The SEAI BioEnergy Supply Curves analysis accounts for limits on resource deployment, and shows that these uptake levels are possible at higher market prices for biomass resources. The policy costs estimated in this analysis include the price increases required to stimulate this increase in biomass resources deployment.

## 14. Conclusion

This analysis examined the possible future trends for renewable heat use in Ireland. A Consumer Choice heat model was employed to determine the potential uptake of renewable heat technology over the period to 2020. The modelling tools used account for assessments of the potential availability of raw biomass resources at various market prices for bioenergy out to 2020 and the demand for bioenergy in the heat, electricity and transport sectors over the same period. The optimisation model meets demand for bioenergy in each of the sectors at lowest cost by deciding where the most economic use of the available resource lies.

Three scenarios are presented to examine the impact of variations in fossil fuel prices, bioenergy availability and energy demand that may arise in the period leading up to 2020. These factors determine the likelihood of consumers switching from fossil-fuel to a renewable technology to provide their heat requirements and determine how much policy effort may be required to meet the RES-H target in 2020.

The analysis shows that, under current legislated policy, a gap to the RES-H 12% target of between 1-5 percentage points may arise. This implies that policy action is required to close the gap and achieve the 2020 target. A range of policy options are available that fall into the three broad categories of ongoing support, upfront support and taxation measures. Policy instruments within these categories each have advantages and drawback. Factors like the ease of implementation, the certainty that they will deliver the required uptake and administrative burden must be considered along with the funding cost of a policy instrument.

The analysis looked at the cost of representative policy instruments from each of the three broad categories. The cost differences between the FiT/Bonus scheme and the grant scheme are

<sup>70</sup> Tillage Sectoral Energy Crop Development Group (2014) *Achieving the Potential for Growing Energy Crops on Irish Farms*. Available at: [http://www.teagasc.ie/publications/2014/3130/Tillage\\_Sectoral\\_Energy\\_Crop\\_Development\\_GroupPlan2014.pdf](http://www.teagasc.ie/publications/2014/3130/Tillage_Sectoral_Energy_Crop_Development_GroupPlan2014.pdf)

<sup>71</sup> Phillips, H., Redmond, J., Mac Siúrtáin, M. and Nemesova, A. for COFORD, National Council for Forest Research and Development (2009). *Roundwood production from private sector forests 2009-2028 – A geospatial forecast*. Available at: <http://www.coford.ie/media/coford/content/researchprogramme/thematicareaestablishingandgrowingforests/Roundwood%20production%20from%20private%20sector%20forests%202009-2028%20-%20A%20geospatial%20forecast.pdf>

considered negligible and within the uncertainties of the model. The funding cost of carbon tax falls on fossil fuel consumers and is an order of magnitude higher than the other options.

Ongoing support in the form of a FiT/bonus (RHI) could deliver the gap to target at an annual cost of between €4.5 in a scenario with more favourable conditions for renewable heat technologies to €31 million in a less favourable scenario for renewable heat technologies. The total discounted lifetime cost for ongoing support is estimated at between €54 million and €361 million. In this analysis, a single tariff level is modelled and is determined by the most expensive technology required to meet the RES-H target. Further policy design can develop tariff levels for individual technology size bands, with lower cost bands (e.g. sites with large heat demands currently provided by oil switching to biomass) receiving a lower tariff level than the smaller more expensive marginal sites that set the tariff level for all technologies in this analysis. By introducing separate tariffs to cover the different cost differentials in the industry and the commercial sector, the overall cost could be reduced further. Conversely, expansion of the tariff bands to focus on more expensive technologies and/or smaller-scale technologies would lead to a more expensive policy funding cost.

The Government has proposed in its draft Bioenergy Strategy (2014) that it will introduce an Exchequer-funded incentive scheme from 2016 to reward users of each unit of renewable heat used from sustainable biomass. The analysis in this report supports the design and implementation of this scheme.

## Annex 1. Consumer Choice Heat Model detail

The model of the heat sector assesses how the market shares of renewable heat technologies may change under different policies, fuel price and technology scenarios between 2012 and 2020. The complexities of the heat sector mean that different types of consumers will respond in different ways to the various economic signals. Choice modelling allows these subtleties to be captured.

The modelling methodology implemented is based on an understanding of how consumers respond to attributes of each technology, and how these attributes determine the overall attractiveness of a technology to individual consumers. Choice modelling allows the relative importance of factors such as upfront expenditure, ongoing fuel savings and the hassle costs associated with changing technology to be captured for different consumer types. This allows for a more complete representation of competition between technologies, and can provide a more realistic representation of predicted uptake than is provided by models that are based on the total lifetime cost of technologies.

### A 1.1. Choice model

The consumer choice model calculates the number of installations of each technology for each consumer type. The primary function of the consumer choice model is to calculate the market shares for each technology type for each year in the model by following two steps. First, the total utility (attractiveness) of each technology type by combining the characteristics of each technology with the consumer preferences from the choice data. Second, the market share for each technology based on its utility.

The technology attributes are combined with the consumer preference data to calculate the overall utility of each technology. Each attribute is multiplied by its respective coefficient and summed. The following equation details the interaction:

$$U_n = \beta_0 Capex_n + \beta_1 fuel\ cost_n + \beta_2 Maintenance_n + \beta_3 Ongoing\ Policy\ Support_n + \beta_4 Hidden\ Cost_n$$

where  $U_n$  is the total utility of the specified technology  $n$ , and  $\beta_0, \beta_1, \beta_2, \beta_3, \beta_4$  are the consumer coefficients for the different attributes.

The coefficients vary between the different consumer groups (domestic, commercial and industrial) and influence the variations in uptake seen in different consumer groups. Residential consumers' weighting reflects their preference for lower payback periods than those favoured by industrial consumers. Compared with residential consumers, industrial consumers have a higher weighting factor for ongoing fuel savings, thus causing them to respond more favourably to technologies with lower fuel costs.

The technology utilities calculated for each attribute are used in a logit model to derive the market shares for each technology. A logit model allocates market share to each technology in proportion to its utility. A step-by-step derivation is shown in Train (2009).<sup>72</sup> The market shares of different technologies can be calculated by using the following logit formula:

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<sup>72</sup> Train, K.E. (2009) *Discrete Choice Methods with Simulation*. Cambridge University Press.

$$\text{Market share of technology}_n = \frac{\exp(U_n)}{\sum_n^N \exp(U_n)}$$

The market share of technology is expressed as a percentage of the total utility available across all technology choices. As existing heating technologies reach the end of their useful life, consumers have the choice to replace the technology with the same technology type or move to a new option. The decision-making frequency is based on an average boiler lifetime of 15 years. This corresponds to a turnover rate of 6.67% – each year 6.67% of the heating technology stock is replaced. This decision-making frequency represents a limit to the amount of new technology that may be installed each year in the existing building stock. In addition to the decision-makers who have replace retired boilers, the number of new buildings in a given year is added in order to calculate the total number of decision-makers in each year for each consumer group. Only oil, gas or direct electric heating are retired each year in the model. The new renewable technologies installed in recent years will still be within their useful life by 2020, and it is assumed that these will not be retired ahead of time.

While calculating the market shares, suitability factors are also taken into account, in order to describe the appropriateness of a given technology in a particular application. If a given technology is not suitable for a proportion of a given consumer group, the number of decision-makers who cannot install boilers is calculated. This option is then excluded from the logit calculation represented in the market share equation shown above. For example, a biomass boiler may not be suitable for an apartment, due to lack of fuel storage space.

In some cases, the uptake of a given technology can be limited by supply-side constraints such as the lack of trained installers or available materials. The model includes a facility to incorporate this aspect, where evidence of supply-side constraints exist for a given technology type. If the total demand for a constrained technology is greater than the maximum number of sales allowed, then total sales are adjusted such that the actual number of installations never exceeds the maximum number of sales allowed.

### A 1.2. Consumer coefficients

Consumer coefficients are a central input in the choice calculation performed by the model. Coefficients applied to consumers in the residential sector are based on UK survey data collected as part of a study entitled 'The Growth Potential for Microgeneration in England, Wales and Scotland'.<sup>73</sup> For the non-domestic sector, the key coefficients were derived from willingness to pay curves also used in previous studies for renewable heat uptake.<sup>74</sup> Willingness to pay contains similar information on the relative value placed by consumers on upfront costs versus ongoing savings.

These coefficients are a central assumption in forecasting the uptake of renewable heat under alternative policies. There is a level of uncertainty in setting appropriate values to best represent the attitudes and decision-making processes of consumers in Ireland. The unavailability of similar

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<sup>73</sup> Element Energy (2008) *The Growth Potential for Microgeneration in England, Wales and Scotland*.

<sup>74</sup> Element Energy and NERA Economic Consulting for the Committee on Climate Change (2011) *Achieving deployment of renewable heat*, section 4.2, pp.23-24.

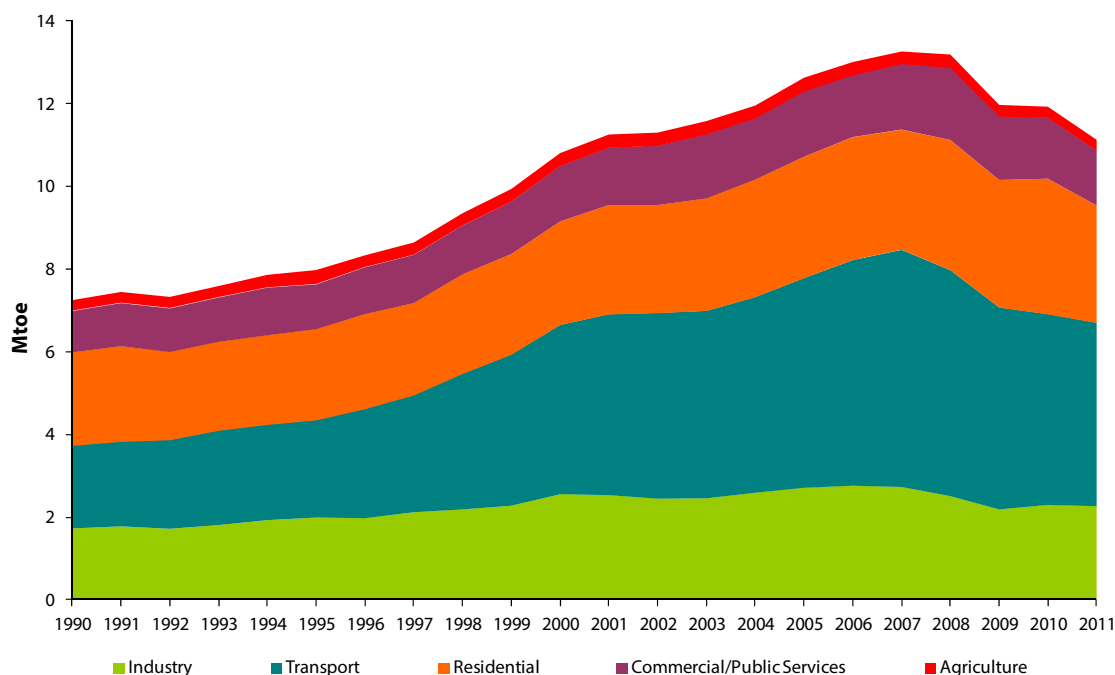


consumer attitude survey data in Ireland means the underlying assumption is that Irish consumers have similar attitudes to their UK counterparts. SEAI is currently undertaking a detailed survey of energy use in buildings in Ireland and the results of this analysis are expected to be available for any detailed policy design.

### A 1.3. Consumer types

Ireland's heat demand is approximately 60 TWh annually. Figure A. 1 shows the trend of energy demand across the economic sectors from 1990 to 2011.

*Figure A. 1: Heat demand by sector 1990-2011*



The demand across each sector is met by heat generated from a number of fuel sources. The model uses various data sources to describe the nature of the heat demand across each sector by dividing the heat market into the various consumer types. Based on the 2011 census of population, the number of residential dwellings in Ireland is around 2 million. 294,202 of these are vacant, meaning that the number of occupied dwellings that require heating is around 1.7 million. The GeoDirectory states that the total number of buildings stands at 1,889,143, of which 96,445 buildings are for commercial use only. The total number of industrial enterprises in Ireland is 5,028. This number does not necessarily correspond to a number of buildings, as one enterprise of industrial scale may include several buildings. In order to develop a detailed picture of the nature of this demand, a survey of the sector to elicit the detailed data is required.<sup>75</sup> The simplifying assumption made is that each large industrial site has one large heating boiler to heat all buildings within the site. This could overstate economies of scale in some cases.

<sup>75</sup> SEAI is currently undertaking a detailed survey of heat use in buildings as part of the energy efficiency cost curve project, covering residential, commercial and industry.

A distinct number of consumer types are modelled to represent the building stock. The computational limits of an Excel model sets a ceiling on the number of consumer types that can be included in the uptake modelling. The need to define the detail of the heat market must be balanced with these computational practicalities. The detail within the available datasets also places limits on the market resolution that can be modelled.

#### *A 1.4. Residential sector*

The Building Energy Rating (BER) database includes over 250,000 records of energy rating surveys carried out on residential properties in Ireland. This dataset includes details of the age, type, floor area and energy performance asset rating of the building as well as information on the fuel types used for supplying the heating demand. The BER sample set was scaled to the population level using data available from the Central Statistics Office. Average floor areas for each dwelling type and age are based on analysis of the BER database.

By combining the floor area and the BER data, estimates of the total primary energy demand were obtained. Non-thermal demands were removed from the total, based on estimated electricity consumption per dwelling for lighting and ventilation, as outlined in the SEAI 2008 publication *Energy in the Residential Sector*. A scaling factor based on data from an SEAI analysis of before and after energy efficiency upgrades, and how actual consumption related to the BER rating was used to calibrate the demands for energy rating categories that tend to deviate from the BER and floor area energy consumption prediction. The primary energy is transformed into final thermal demand based on the assumption that the average efficiency of oil and gas boilers is 80%.

On the basis of the magnitude of the estimated thermal demand per dwelling, the dwellings were classified as follows:

- Small – Flat/apartment
- Medium – Terraced house
- Large – Semi-detached/Detached house

In addition, the following energy demand categories were defined based on the outcome of the BER profiling:

- Low – BER B classes and above
- Moderate – BER C and D classes
- High – BER E,F and G classes

The BER data allowed an estimation of the proportion of dwellings within each size category that use a particular fuel type. In order to limit the number of consumers, it was assumed that consumers in each size category are represented by two of the three available fuel options: oil, gas and electricity. The table below shows the breakdown of dwellings by counterfactual fuel type and building size.

*Table A 1: Residential consumer types – existing buildings*

Consumer number	Building type	Demand band	Counter-factual fuel	Thermal demand per building (MWh/yr)	Number of buildings in ROI	Total thermal demand (GWh/yr)	Total fuel demand (GWh/yr)
1	Small	Low	Natural gas	3.5	10,222	35.8	45
2	Small	Low	Electricity	3.5	13,520	47.3	48
3	Large	Low	Natural gas	7.1	37,175	264.4	330
4	Large	Low	Oil	7.1	88,358	628.4	786
5	Medium	Low	Natural gas	4.6	17,243	79.2	99
6	Medium	Low	Oil	4.6	10,902	50.1	63
7	Small	Moderate	Natural gas	7.3	39,973	293.2	367
8	Small	Moderate	Electricity	7.3	52,872	387.9	396
9	Large	Moderate	Natural gas	14.5	229,391	3,320.7	4,151
10	Large	Moderate	Oil	14.5	545,219	7,892.6	9,866
11	Medium	Moderate	Natural gas	9.7	104,637	1,010.8	1,263
12	Medium	Moderate	Oil	9.7	66,157	639.1	799
13	Small	High	Natural gas	12.3	28,842	353.7	442
14	Small	High	Electricity	12.3	38,149	467.9	477
15	Large	High	Natural gas	26.3	95,718	2,513.9	3,142
16	Large	High	Oil	26.3	227,504	5,975.2	7,469
17	Medium	High	Natural gas	18.8	63,771	1,196.3	1,495
18	Medium	High	Oil	18.8	40,320	756.4	945
<b>Total:</b>					<b>1,709,973</b>	<b>25,913</b>	<b>32,184</b>

These counterfactual fuels are adjusted to account for other fuel sources to match the energy use recorded in the 2011 energy balance. This provides a starting point for 2012 and, as counterfactual technologies are retired in the model, consumers can choose to replace them with new renewable technologies, or reinstate the counterfactual option.

### *Residential new builds*

In addition to existing consumer types in domestic, commercial and industrial sectors, three consumer types were defined to represent new dwellings in the small, medium and large categories. These have relatively low thermal demand due to the strict requirements on thermal integrity contained in the 2008 Building Regulations. Part L of the regulations requires these new dwellings to have a source of renewable heating or electricity generation. In the case of heating, the requirement is 10 kWh/m<sup>2</sup>/y and this model assumes that all new dwellings choose the renewable heat option. Projections for new builds are based on the output of the 2012 national energy forecasts, rising from the current low rate of less than 10,000 units per year to over 30,000 units per year by 2020.

### A 1.5. Commercial sector

Compared to the residential sector, the commercial sector building stock has much less available data. The building stock analysis used in the model draws on a number of sources to construct a profile of the sector. SEAI data from grant schemes, public sector programmes and the Large Industry Energy Network were examined. Based on the GeoDirectory data, there are 96,445 commercial only buildings in Ireland. The available commercial heat databases cover only 1% of the entire sector. The energy end-use database provides energy demands in the commercial sector by fuel type and sub-sector, but is limited to information at entity-level only. This information was supplemented with data from the UK on typical building sizes, and fossil fuel demand per building type was collected. Based on these typical building sizes, sub-sectors in the commercial sector were allocated to three building size groups.

*Table A 2: Building size allocation based on activity*

	<b>Small</b>	<b>Medium</b>	<b>Large</b>
Sub-sectors	Offices	Wholesale	Hotels/catering
	Retail	Public administration	Health/social
		Education	
		Sport/culture	
		Transport support	

By combining building size and fuel demand per m<sup>2</sup> values, thresholds were defined for sub-sectors. It is assumed that for a building defined as 'small' the maximum fuel demand is 52 MWh/year. For example, if fuel demand for a retail company exceeds 52 MWh/year, it is assumed that the company owns more than one retail space.

*Table A 3: Energy thresholds for sub-sectors*

<b>Building type</b>	<b>Fuel demand per m<sup>2</sup> (kWh/m<sup>2</sup>)</b>	<b>Maximum floor space per building (m<sup>2</sup>)</b>	<b>Maximum fuel demand per building (MWh/year)</b>
Small	174	300	52
Medium	386	1,000	386
Large	386	3,000	1,157

These values were then used as thresholds for specific sub-sectors, in order to convert enterprise-level data from the commercial heat databases into building-level data. Building-specific data from SEAI programmes in Ireland were used to calibrate the demand thresholds. A total of six consumer types were defined.

*Table A 4: Commercial consumer types*

<b>Consumer number</b>	<b>Building type</b>	<b>Counterfactual fuel</b>	<b>Thermal demand per building (MWh/year)</b>	<b>Number of buildings in ROI</b>	<b>Total thermal demand (GWh/year)</b>	<b>Total fuel demand (GWh/year)</b>
19	Small	Natural gas	41.1	41.1	1,467.6	1,834
20	Small	Electricity	50.3	50.3	2,245.8	2,292
21	Medium	Natural gas	286.9	286.9	1,942.7	2,428
22	Medium	Oil	286.9	286.9	891.9	1,115
23	Large	Natural gas	774.2	774.2	1,365.8	1,708
24	Large	Oil	774.2	774.2	1,337.9	1,672
<b>Total:</b>				<b>93,719</b>	<b>9,251</b>	<b>11,049</b>

### A 1.6. Industrial sector

The Central Statistics Office (CSO) data show that there are around 5,000 industrial enterprises in Ireland. The majority of these sites are in the manufacturing sector and the SEAI SME database provides energy consumption data for over 400 sites in the manufacturing sector. In addition, the Large Industry Energy Network (LIEN) database contains details of energy consumption for 120 very large industrial sites. The data from the SME database were assumed to be representative of the industrial sector as a whole. Buildings were divided into four categories, based on their thermal demands. Average thermal demands for each building were then estimated. The assumption that industrial consumers making decisions on heating systems have a choice of one of two options – oil or gas – was imposed to limit the number of consumers in the model. Oil and gas accounted for 82% of fuel use for heat in 2012. Overall, eight industrial consumer types were identified to represent the sector.

Table A 5: Industrial consumer types

Consumer number	Building type	Counter-factual fuel	Thermal demand per building (MWh/year)	Number of buildings in ROI	Total thermal demand (GWh/year)	Total fuel demand (GWh/year)
25	Small	Natural gas	288.0	1,034	297.8	372
26	Small	Oil	288.0	1,920	553.0	691
27	Medium	Natural gas	2,000.0	621	1,242.0	1,552
28	Medium	Oil	2,000.0	809	1,618.0	2,022
29	Large	Natural gas	12,000.0	396	4,752.0	5,940
30	Large	Oil	12,000.0	226	2,712.0	3,390
31	Very large	Natural gas	120,000.0	11	1,320.0	1,650
32	Very large	Oil	120,000.0	12	1,440.0	1,800
<b>Total:</b>				5,029	13,935	17,418

### A 1.7. Technology

Technology cost and performance data are based on a number of data sources. SEAI grant schemes contain details on the costs of domestic-level technologies, and these sources are also supplemented by UK and international data, including the *Review of technical information on renewable heat technologies* (AEA for DECC (2011)),<sup>76</sup> *The potential and costs of district heating networks* (Pöyry for DECC (2009))<sup>77</sup> and *Achieving deployment of renewable heat* (Element Energy and NERA for the Committee on Climate Change (2011)).<sup>78</sup>

Table A 6 shows the summary detail of the technology costs, including the estimates for hidden and missing costs. Hidden and missing costs represent additional real and perceived costs to consumers who are installing heating systems. These costs dependent on consumer preferences

<sup>76</sup> AEA for Department of Energy and Climate Change (2011). *Review of technical information on renewable heat technologies*. Available at: [http://www.rhincentive.co.uk/library/regulation/1103AEA\\_Update.pdf](http://www.rhincentive.co.uk/library/regulation/1103AEA_Update.pdf)

<sup>77</sup> Pöyry for Department of Energy and Climate Change (2009). *The potential and costs of district heating networks*. Available at: <http://www.ecolateral.org/distributedheatpoyre0409.pdf>

<sup>78</sup> Element Energy and NERA Economic Consulting for the Committee on Climate Change (2011). *Achieving deployment of renewable heat*. Available at: [http://www.element-energy.co.uk/wordpress/wp-content/uploads/2012/05/CCC-Renewable-Heat-final-report\\_06.05.11.pdf](http://www.element-energy.co.uk/wordpress/wp-content/uploads/2012/05/CCC-Renewable-Heat-final-report_06.05.11.pdf)

and technology characteristics and are taken from previous research for SEAI carried out by Element Energy. Costs include project identification, research, scoping and negotiating, obtaining planning permission, construction management, cost of disruption, hassle cost of fuel deliveries and hassle costs of additional works. Upper and lower limits are estimated for these, thus allowing some sensitivity analysis in the modelling.

Table A 6: Summary of technology costs used in the modelling

Sector	Size	Fuel	Average thermal demands per building (MWh/year)	Total number of buildings in Ireland	Capex (€/kW)	Opex excluding fuel (€/kW)	Efficiency	Load factor	Indicative size (kWth)	Lifetime (years)	CF hidden cost: low (€/installation)	CF hidden cost: high (€/installation)
Domestic	Small	Oil	7.96	165,417	327.27	9.00	90%	8%	11	15	43	132
		Gas	8.04	209,250	272.73	9.00	90%	8%	11	15	43	132
		Electricity	6.55	66,392	220.00	2.20	100%	9%	8	15	0	0
		Biomass	8.04	-	1,090.91	13.64	85%	8%	11	20	60	1,849
		Solar	1.82	-	1,800.00	21.00	-	8%	3	20	60	212
		AS & GS HP <sup>79</sup>	8.04	-	1,500.00	8.33	250%	10%	9	20	60	212
	Large	Oil	17.99	813,043	225.00	9.00	90%	13%	16	15	43	132
		Gas	17.68	417,722	187.50	9.00	90%	13%	16	15	43	132
		Electricity	12.26	38,149	220.00	2.20	100%	10%	14	15	0	0
		Biomass	17.68	-	800.00	9.38	85%	13%	16	20	60	1,849
		Solar	1.82	-	1,800.00	21.00	-	8%	3	20	60	212
		AS & GS HP <sup>79</sup>	17.68	-	1,071.43	5.36	250%	14%	14	20	60	212
Commercial	Small	Oil	286.87	3,109	86.40	3.00	91%	22%	150	15	456	1,175
		Gas	80.25	42,494	72.00	3.00	91%	22%	42	15	456	1,175
		Electricity	50.33	44,625	235.00	1.70	100%	19%	30	15	0	0
		Biomass	80.25	-	450.00	18.00	81%	22%	42	15	1,247	4,870
		Solar	19.62	-	1,650.00	9.00	-	7%	32	15	687	1,870
		AS & GS HP <sup>79</sup>	80.25	-	600.00	15.12	350%	22%	42	15	447	1,270
	Large	Oil	774.24	1,728	86.40	3.00	91%	20%	450	15	456	1,175
		Gas	774.24	1,764	72.00	3.00	91%	20%	450	15	456	1,175
		Electricity	-	-	-	-	-	-	-	-	-	-
		Biomass	774.24	-	450.00	18.00	81%	20%	450	15	1,247	4,870
		Solar	19.62	-	1,650.00	9.00	-	7%	32	15	687	1,870
		AS & GS HP <sup>79</sup>	774.24	-	600.00	15.12	350%	21%	420	15	447	1,270
Industrial	Small	Oil	795.51	2,729	86.40	0.50	90%	65%	140	15	1,690	8,588
		Gas	930.39	1,655	72.00	0.50	90%	66%	160	15	1,840	10,388
		Biomass	930.39	-	450.00	35.00	81%	66%	160	15	1,247	4,870
	Large	Oil	17,445.38	238	50.00	0.50	90%	66%	3,000	15	1,690	8,588
		Gas	14,918.92	407	65.00	0.50	90%	68%	2,500	15	1,840	10,388
		Biomass	14,918.92	-	425.00	35.00	81%	68%	2,500	15	12,743	125,693

<sup>79</sup> Separate costs are included in the modelling for AS and GS heat pumps.

## Annex 2. Bioenergy Analysis Model (BEAM)

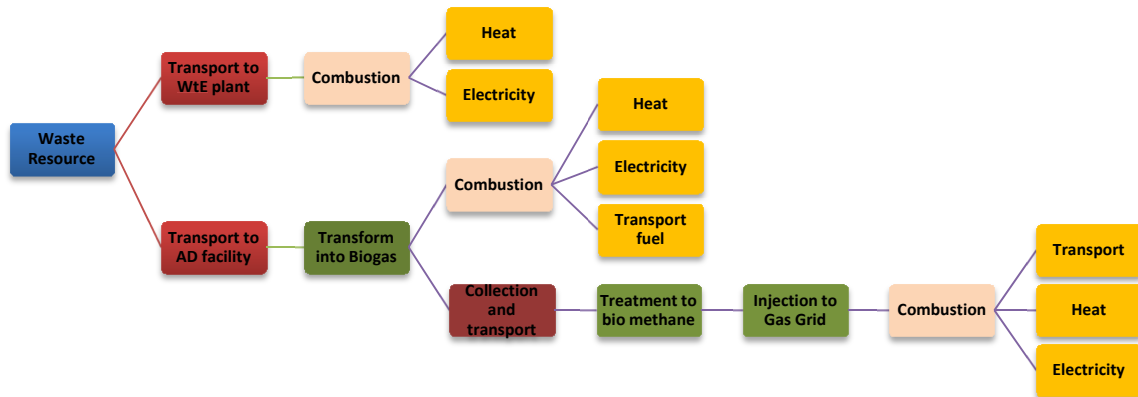
Biomass resources are used to produce energy for heating, electricity and transportation. Many individual biomass resources can be used to produce end-use energy in all three end-use sectors. The relative costs of generating energy from biomass resources to supply demand for a given end-use shapes how much of a resource is likely to be deployed to generate energy for heating, electricity and transportation. The delivered cost of bioenergy in each of the sectors reflects the cost of harvesting the resource, the cost of refining, any transportation costs, the cost of converting to final energy and the total demand for bioenergy across heat, transport and electricity. The demand for bioenergy reflects how competitive the costs of delivered bioenergy are with other alternatives. The Bioenergy Analysis Model (BEAM) captures the economics of the entire biomass resource to the bioenergy supply chain and allows estimation of the quantities of the various resources that may be deployed to meet demand in each end-use sector under various policy conditions.

Demand for bioenergy in each end-use sector within BEAM can be linked to outputs of other models dealing exclusively with the heat, electricity or transport end-use sectors, or is determined endogenously based on the economics of producing energy from biomass sources for sale into energy markets. The type and cost of biomass resources supplied within the BEAM model to meet the demand determines the market price for biomass resources. Market prices can in turn be used as an input to external energy models to determine the impact on demand in these sectors – an iterative process that continues until the models converge on market equilibrium between biomass supply and demand.

Technology usage is an important driver of resource use, intermediate product production and bioenergy output. Several pathways are available within the model to produce bioenergy to satisfy demand in the three end-use sectors. Some resources can be converted directly into energy; others must first be refined, and some can either be refined into intermediate product or directly converted to bioenergy. The physical characteristics of individual resources determine the extent of these pathways. Figure A. 2 shows an example of possible conversion pathways available for biodegradable waste.



Figure A. 2: Example of conversion pathway for waste



In addition, refined biomass products such as biofuels and wood pellets are traded internationally. BEAM allows for international trade of these products based on differences in domestic production costs and the international trade price. The model chooses the lowest-cost resources and conversion pathways to meet the end-use demands. Lower-cost technologies that use lower-cost resources and or refined products will tend to incur a higher utilisation rate and produce the most energy within the model.

The following sections describe the BEAM model in detail and outline the cost assumptions within the model.

### A 2.1. Description of BEAM

At its core, BEAM is a least-cost linear programming tool. Cost data about the various biomass streams, refining technologies, resource transportation and energy conversion technologies are optimised to produce a least-cost energy output to meet demand for bioenergy in the heat, electricity and transport end-use sectors, subject to a range of constraints and policy impacts, and incorporating the international trade of biomass resources.

#### Objective function

The objective of this model is to minimise total cost by making decisions on the type of technologies deployed, the utilisation rate of technologies, the quantity of resources used, how much and how far resources are transported and the quantities of refined products bought and sold on international markets in order to satisfy the demand for bioenergy in each year. This minimisation is subject to the demand for bioenergy output being met. A number of energy balance and other constraints for resource use, refined product use and transported resources also apply.

The optimisation decides usage in each year for individual technologies, resources, refined products and resource transportation. The various decision variables that drive the costs in the

optimisation function are aligned through a series of energy balance constraints. Demand for bioenergy can be specified as an exogenous input for heat electricity and transport; it can be determined based on the economic viability of production relative to a market price for energy, and/or imposed as a requirement for output from a refining technology or energy-producing technology.

The mathematical expression of the objective function is shown below.

$$\text{Min } C_y^{\text{total}} = \sum_i T_{i,y}^c + \sum_j R_{j,y}^c + \sum_k P_{k,y}^c + \sum_i D_{i,y}^c - \sum_u S_{u,y}^c$$

The objective of this model is to minimise total cost in each year,  $y$ ,  $\text{Min } C_y^{\text{total}}$  across each cost component,  $c$ , as follows: technology costs,  $T_{i,y}^c$ , resource costs,  $R_{j,y}^c$ , refining/energy production costs,  $P_{k,y}^c$ , transportation costs,  $D_{i,y}^c$ , less the cost of subsidies,  $S_{u,y}^c$ .

### *Technology utilisation and constraints*

Technology use is a primary driver of cost decisions in BEAM. Individual technologies,  $T_i$ , choose from the resources,  $R_j$ , available for use in that technology, to produce refined products,  $P_{k,i,y}^O$ . Each technology has an exogenously determined set of biomass resources available for conversion to refined products,  $P_k^O$ , that depends on the technical characteristics of individual technologies. Some technologies use the refined product output from other technologies as an input,  $P_k$ . For example, biomass boilers use the wood chips and wood pellets output from refining mills to produce energy. The resources and refined products available for use by an individual technology  $i$  in year  $y$  is given by

$$T_{i,y}^I = \sum_j R_{j,i,y} + \sum_k P_{k,i,y}$$

where  $T_{i,y}^I$  is the input for technology  $i$  in a year  $y$  and is determined by the sum of all resources,  $j$ , and refined products,  $k$ , available for use in technology  $i$ .

Conversion occurs at a specified efficiency  $\eta$  for each type of conversion technology. Some technologies, such as combined heat and power (CHP), are capable of outputting more than one refined product. The efficiency of conversion can vary within individual technologies,  $i$ , depending on the resource type or refined product, and can also vary across years,  $y$ . The total output of all refined products,  $P_{k,i,y}^O$ , from this technology is given by

$$\sum_k P_{k,i,y}^O = \sum_j (R_{j,i,y} * \eta_{j,i,y}) + \sum_k (P_{k,i,y} * \eta_{k,i,y})$$

The model decides the utilisation rate,  $T_{i,y}^U$ , of technology type  $i$  in year  $y$  to optimise the objective function to produce enough output,  $P_{i,y}^O$ , to meet demand.

$$T_{i,y}^U * T_{i,y}^I = \sum_j (T_{i,j,y}^U * R_{j,i,y}) + \sum_k (T_{i,k,y}^U * P_{k,i,y})$$

$$T_{i,y}^U * P_{i,y}^O = \sum_j (T_{i,j,y}^U * R_{j,i,y} * \eta_{i,j,y}) + \sum_k (T_{i,k,y}^U * P_{i,k,y} * \eta_{i,k,y})$$

The total consumption by a technology is equal to the total utilisation rate multiplied by the total inputs. The utilisation rate can vary for each refined product and resource input option available to a technology.

The total resource of type j used by all technologies in year y is given by

$$\sum_i (T_{i,j,y}^U * R_{j,y}) = \sum_i R_{i,j,y}^{Cons}$$

The total refined product of type k consumed by all technologies in year y is given by

$$\sum_i (T_{i,k,y}^U * P_{k,i,y}) = \sum_i P_{i,k,y}^{Cons}$$

Technology utilisation is limited directly by a number of constraints that specify the maximum build rate and the maximum retirement rate. Constraints on the utilisation rate recognise supply-side limits for maximum annual build rates,  $T_y^{MaxB}$ , and total build across the entire horizon of the model,  $T^{Max}$ , as follows:

$$0 \leq T_{i,y}^U \leq \text{Min} \{T_i^{Max} - T_{i,y}^E | T_{i,y}^{MaxB}\}$$

The number of existing technology units,  $T_{i,y=0}^E$ , is an input to the model. The capacity that the model chooses to build in subsequent years is added to this, while the user-defined retirement rate,  $T^R$ , for each year is subtracted from this number. The existing technology in each year, y, is given by

$$T_{i,y}^E = T_{i,y=0}^E + T_{i,y-1}^B - T_{i,y}^R$$

The consumption of resources and refined products by technologies must balance with available sources.

### *Resource utilisation and balance constraint*

The total resources used by all technologies must equal the total resource utilisation. The resource balance constraint within the BEAM model is expressed as:

$$R_{j,y}^U + R_{j,y}^I = \sum_i R_{j,y}^{Cons} + R_{j,y}^E$$

The model decides the level of technology utilisation required to meet bioenergy demand, which in turn determines the amount of resource j consumed by all technologies,  $R_{j,y}^{Cons}$ , in year y. Domestic resources are available for export,  $R_{j,y}^E$ , and will be traded if the cost of producing the domestic resource is less than the international market price. The sum of these terms must balance with domestic resource utilisation,  $R_j^U$ , and imported resources,  $R_j^I$ , for use by technologies to produce refined products. The follow constraints apply:

$$0 \leq R_{j,y}^{UMin} \leq R_{j,y}^U \leq R_{j,y}^{UMax}$$

$$0 \leq R_{j,y}^{IMin} \leq R_{j,y}^I \leq R_{j,y}^{IMax}$$

$$0 \leq R_{j,y}^{EMin} \leq R_{j,y}^E \leq R_{j,y}^{EMax}$$

$$0 \leq R_{j,y}^{AMin} \leq R_{j,y}^A \leq R_{j,y}^{AMax}$$

### *Refined products and balance constraint*

Technologies within the model produce two categories of refined products 1) energy for heating, transportation or electricity generation or 2) intermediate products, such as a wood pellet mill producing wood pellets. Intermediate products are available for consumption by energy-producing technologies or for export. Intermediate refined products can also be imported from outside the Irish energy system.

The refined product balance constraint allows demands for bioenergy in heat, electricity and transport to be inputted exogenously. Within this, individual sector demands can be specified – for example, heating demand in the residential, commercial and industrial sectors.

The refined product balance is given by

$$\sum_i P_{i,k,y}^{Cons} + P_{k,y}^E \leq P_{k,y}^I + P_{k,y}^O + P_{k,y}^D$$

where  $P_{k,y}^{Cons}$  is the consumption of refined product of type k, produced from all technologies in year y, and  $P_{k,y}^O$  is the total output of refined product by technologies. Inputs for bioenergy demand in heat, electricity and transport are captured through the term  $P_{k,y}^D$ . This term allows the demands for individual sectors or fuel types to be inputted e.g. heat demand in residential, commercial and industrial sectors.  $P_{k,y}^I$  is the total imports of refined product k in year y. Exports are captured by the term  $P_{k,y}^E$ .

$$0 \leq P_{k,y}^I \leq P_{k,y}^{Imax}$$

$$0 \leq P_{k,y}^E \leq P_{k,y}^{Emax}$$

### *Resource transportation and balance constraint*

The transport balance constraint within the model ensures that the quantity of resources used by a technology does not exceed the quantity of available resources from within each transport distance tranche.

The proportion of total technology requirement available within each distance is an exogenous input, and varies depending on the size of a technology and the resource used. Large technologies will most likely have to source much of the resource requirement from further away, while smaller technologies are likely to source much of the resource requirement from closer to the site. The exogenous inputs  $\delta^T$  determine the proportions of each refined product and resource consumed by the technology i over the three transport tranches T; short, S; medium, M; and long, L, distances from the technology location.

$$\delta_{j;k,i,y}^S + \delta_{j;k,i,y}^M + \delta_{j;k,i,y}^L = 1$$

The model decides the quantity of resource,  $D_{j,i,y}^R$ , and or refined product to be transported from each tranche to minimise the cost within the following constraints. The maximum amount of resource available for transport within each tranche is based on the specified availability of resources within each of the transport distances. The maximum constraint for resources  $j$  transported from distance  $D$  for technology  $i$  in year  $y$  is given by

$$0 \leq D_{T,j,i,y}^R \leq R_{j,i,y}^{Cons} * \delta^T$$

$$0 \leq D_{T,k,i,y}^R \leq P_{k,i,y}^{Cons} * \delta^T$$

The amount of resources and refined products from each transport distance tranche consumed by technologies must be less than the total consumption.

$$0 \leq \sum_T D_{T,j,i,y}^R \leq \sum_i R_{i,j,y}^{Cons}$$

$$0 \leq \sum_T D_{T,k,i,y}^R \leq P_{i,k,y}^{Cons}$$

### Technology costs

Technology costs relate to non-fuel annual running costs and any additional investment required in a year in order to meet additional demand. Total technology investment cost is determined by the individual investment cost,  $T_{i,y}^I$ , and the number of new installations built in year  $y$ ,  $T_{i,y}^B$ . Ongoing fixed costs,  $T_{i,y}^F$ , are related to the total number of installations,  $T_{i,y}^E$ , and ongoing variable costs,  $T_{i,y}^V$ , depend on the utilisation rate of technologies.

$$\sum_i T_{i,y}^C = \sum_i (T_{i,y}^M * T_{i,y}^B) + \sum_i (T_{i,y}^F * T_{i,y}^E) + \sum_i (T_{i,y}^V * T_{i,y}^U)$$

Annual investment costs of an individual technology  $i$  in year  $y$  are derived from the total installation cost,  $T^N$ , in year 0 amortised over the economic life,  $n_i$ , of that technology at the sector-specific discount rate,  $r_i^s$ . This rate may change in each year over the modelling horizon as risk perceptions change.

$$T_{i,y}^M = T_{i,y}^N * \frac{r_{i,y}^s (1 + r_{i,y}^s)^{n_i}}{(1 + r_{i,y}^s)^{n_i - 1}}$$

### Resource costs:

Each individual resource,  $j$ , has an input resource cost,  $R^C$ . Each resource type has an associated energy price,  $R^{PE}$ , which allows the model to determine the utilisation rate,  $R^U$ , of that resource in that year for energy production. Similarly, the import utilisation,  $R^I$ , and the export utilisation,  $R^E$ , has an associated trade price,  $R^{PT}$ .

$$\sum_j R_{j,y}^C = \sum_j (R_{j,y}^{PE} * R_{j,y}^U) + \sum_j (R_{j,y}^{PT} * R_{j,y}^I) - \sum_j (R_{j,y}^{PT} * R_{j,y}^E)$$

## Refined product costs

Technologies produce refined products within the model, with these costs captured within the technology cost term. Some refined products, such as wood pellets and biofuels, can be exported and imported. Where markets for a refined product exist, for example, the electricity market, the model can choose to sell refined product into the market. Refined product costs are:

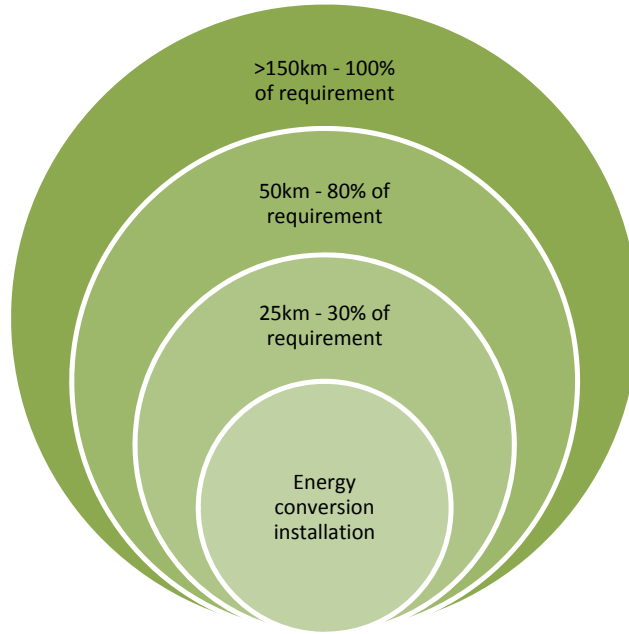
$$\sum_k P_{k,y}^c = \sum_k (P_{k,y}^I * P_{k,y}^T) - \sum_k (P_{k,y}^E * P_{k,y}^T) - \sum_k (P_{k,y}^M * P_{k,y}^P)$$

The term  $P_{k,y}^T$  is the trade price of a refined product  $k$  in year  $y$ .  $P_{k,y}^M$  is the quantity of refined product  $k$  sold at market price  $P_{k,y}^P$  in year  $y$ . Quantities of refined products sold for export  $P_{k,y}^E$ , or quantities,  $P_{k,y}^M$ , sold into energy markets with a market price for the refined commodity are represented as a negative cost based on the trade price  $P_{k,y}^T$ , and the commodity price  $P_{k,y}^P$ . Refined product imports,  $P_{k,y}^I$ , purchased into the system are captured as cost based on the trade price  $P_{k,y}^T$ .

## Transport costs

Many of the biomass streams have a low energy density when compared to fossil fuels. This means that it can be significantly more costly to transport biomass. Within the biomass categories themselves the energy density of the various biomass types displays a wide variation – wood energy typically has a high energy density, whereas waste streams have much lower values. This makes transport costs an important determinant in the viability of these resources, with the different resource types having widely different transport cost profiles. The length of the distance between an energy conversion installation and the requisite amount of biomass fuel impacts on the economic viability of the installation. The model represents this detail by assigning transport costs to three transport tranches within which there is a specified availability of the resource.

Figure A. 3: Transport of resources in BEAM model – illustrative example



The quantity of biomass transported in a single load is determined by either the maximum weight or the maximum volume that a resource transport mode can carry. For some of the lower energy density resources, the maximum volume is the limiting factor. The unit volume per unit weight is  $V^w$  for each resource, with the maximum weight of a resource transport mode given by  $W^{Max}$  and the maximum volume given by  $V^{Max}$ . The impact of these relative limits on resource transport is given by

$$W_{j;k,q} = \text{Min} \{ W^{Max}, V^{Max} / V^w \}$$

where  $W_{j,q}$  denotes the weight of a resource, j, or refined product, q, carried in a single transport. The energy density per unit weight of a resource or refined product is given by  $ED_{j;q}$  and the energy density of a single transport is then

$$ED_{j;k;q}^{Transport} = W_{j;k,q} * D_{j;k;q}$$

The cost of the transport is dependent on the efficiency of the transport mode. The distance travelled per unit of fuel consumption,  $\eta^{Transport}$ , the distance travelled,  $D_T$ , and the price of the fuel,  $F^p$ , are used to establish the transport cost. The efficiency of transport is dependent on the mode of transport and on the type of quality of roads over which a resource is transported. The distance travelled is broken down into three tranches, as shown in Figure A.3 above. Transport cost is given by

$$T_{j,q}^c = D_T / \eta^{Transport} * F^p$$

The cost per unit energy of transporting resource j or refined product q over a distance s is given by

$$TE_{j;q,s}^c = T_{j,q,s}^c / ED_{j;q}^{Transport}$$

The total cost of transporting resources and refined products to technology i is given by

$$D_i^c = \sum_j \sum_{s=1}^3 (TE_{i,j,s}^c * Q_{i,j,s}) + \sum_q \sum_{s=1}^3 (TE_{i,q,s}^c * Q_{i,q,s})$$

where  $Q_{i,j,q,s}$  is the quantity of resource j or refined product q transported to technology i from distance s. The sum across all technologies i gives the total transport cost for year y.

$$\sum_{i,y} D_{i,y}^c = \sum_i \left[ \sum_j \sum_{s=1}^3 (TE_{i,j,s}^c * Q_{i,j,s}) + \sum_q \sum_{s=1}^3 (TE_{i,q,s}^c * Q_{i,q,s}) \right]$$

### Subsidies

Subsidies apply to outputs of refined products from technologies. Subsidies apply to each unit of output for a given resource input to a specified technology. Feed-in tariffs can discriminate between levels of support for different resource inputs. For individual technology i, this is

$$S_{i,y}^c = \sum_j (T_{i,j,y}^U * R_{j,i,y} * \eta_{i,j,y} * S_{j,i,y}) + \sum_k (T_{i,k,y}^U * P_{k,i,y} * \eta_{i,k,y} * S_{j,i,y})$$

where  $S_{j,k,i,y}$  is the output subsidy for refined product k or resource j in year y for technology i. The model allows different output tariffs to apply for individual technologies, depending on the type of resource used. This accommodates policies that give higher tariffs for specific inputs.

### A2.2. Data inputs

The BEAM model uses input data for the costs and availability of resources, costs and performance characteristics of technologies, costs of transportation, demand for biofuels, and policy supports available through feed-in tariffs.

The costs of extracting resources will tend to rise as more resources are brought into production. This reflects the additional costs associated with extracting less accessible materials for use as bioenergy. The SEAI publication *BioEnergy Supply Curves for Ireland 2010-2030*<sup>80</sup> estimates the potential supply of 13 resources at various market price points for each year to 2030, as well as the potential availability and price of imports. The costs and availability of resources, as described in this publication, are used as an input to BEAM for resource cost and availability.

Technologies in the model produce either energy or an intermediate refined product that can be transformed into energy. The typical size and the number of existing technologies are based on

<sup>80</sup> SEAI (2013) *BioEnergy Supply Curves for Ireland 2010-2030*. Available at: [http://www.seai.ie/Publications/Energy\\_Modelling\\_Group/\\_Energy\\_Modelling\\_Group\\_Publications/BioEnergy\\_Supply\\_Curves\\_for\\_Ireland\\_2010\\_-\\_2030.pdf](http://www.seai.ie/Publications/Energy_Modelling_Group/_Energy_Modelling_Group_Publications/BioEnergy_Supply_Curves_for_Ireland_2010_-_2030.pdf)



data from EPSSU.<sup>81</sup> The total maximum number of installed technologies is specified for the limits stipulated in the REFIT support schemes that provide support for electricity producing technologies that use biomass as an input fuel. Maximum annual build is specified for technologies in the electricity sector, so as to ensure even distribution of deployment across the modelled horizon.

Performance characteristics and technology costs are derived from a number of sources. The cost and performance of the electricity-producing technologies are based on information submitted from Ireland as part of the state aid approval for the REFIT schemes.<sup>82</sup> Heat technology costs are based on a representative technology for the residential, commercial and industrial sectors, and are also based on the information shown in table A.6. Refining technology costs are based on information from published sources. Biomethane injection and the production of biogas for use in on-site combustion for heat or transport is based on a study for the Department of Energy and Climate Change in the UK.<sup>83</sup> Wood refining costs are based on a number of studies on the costs of wood refining, including a wood chip and wood pellet feasibility study in Nova Scotia<sup>84</sup>, a study of wood pellet production costs in Austria<sup>85</sup> and a study on the costs of developing a wood pellet sector in South Yorkshire.<sup>86</sup> Information on the costs of refining biofuels aligns with the IRENA publication on the costs of renewable road transport.<sup>87</sup>

Table A. 1 shows the cost data and other information for technologies in the BEAM model.

*Table A. 1: Refining technology cost and performance details*

	<b>Annual output (million litres of output)</b>	<b>Total capital cost (€ million)</b>	<b>Operation costs (€ 000 per annum)</b>	<b>Discount rate (%)</b>	<b>Economic life (years)</b>
Bioethanol refinery	2	23	260	12%	20
Biodiesel refinery	2	21	150	12%	20
	<b>Annual output (tonnes)</b>	<b>Total capital costs (€ million)</b>	<b>Operation costs (€ 000 per annum)</b>	<b>Discount rate (%)</b>	<b>Economic life (years)</b>
Wood pellets	30,000	2.5	625	12%	15
Wood chips	10,000	0.5	152	12%	15

<sup>81</sup> EPSSU (2012) *Combined Heat and Power in Ireland*. SEAI. Available at: [http://www.seai.ie/Publications/Statistics\\_Publications/EPSSU\\_Publications/CHP\\_in\\_Ireland\\_2012\\_Report.pdf](http://www.seai.ie/Publications/Statistics_Publications/EPSSU_Publications/CHP_in_Ireland_2012_Report.pdf)

<sup>82</sup> European Commission (2011) State aid SA.31861 (2011/N) – Ireland Biomass electricity generation. Available at: [http://ec.europa.eu/competition/state\\_aid/cases/241164/241164\\_1267430\\_98\\_2.pdf](http://ec.europa.eu/competition/state_aid/cases/241164/241164_1267430_98_2.pdf)

<sup>83</sup> SKM Enviros for Department of Energy and Climate Change (2011) *Analysis of characteristics and growth assumptions regarding AD biogas combustion for heat, electricity and transport and biomethane production and injection to the grid*. Available at: [https://www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/48166/2711-SKM-enviros-report-rhi.pdf](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48166/2711-SKM-enviros-report-rhi.pdf)

<sup>84</sup> CBCL Consulting Engineers for Annapolis Digby Economic Development Agency (2008). *Wood Chip and Wood Pellet Plant Feasibility Study*. Available at: [http://www.annapolisroyal.com/energy/Tab%2017%20-%20087563%20RE001%20\(Draft%20Final%20Report%20-%2012-Sep-08\).pdf](http://www.annapolisroyal.com/energy/Tab%2017%20-%20087563%20RE001%20(Draft%20Final%20Report%20-%2012-Sep-08).pdf)

<sup>85</sup> Thek, G. and Obernberger, I. 'Wood pellet production costs under Austrian and in comparison to Swedish framework conditions', *Biomass and Bioenergy*, Volume 27, Issue 6, December 2004, pp. 671-693.

<sup>86</sup> Schuller, A.L. for CONNESS GmbH, Austria; ECONERGY Ltd, Great Britain and SOUTH YORKSHIRE FOREST Partnership, Great Britain (2004) *Developing a wood pellet fuel sector in South Yorkshire*. Available at: [http://www.wood-fuel.org.uk/resources/developing\\_wood\\_pellet\\_sector\\_study\\_south\\_yorkshire.pdf](http://www.wood-fuel.org.uk/resources/developing_wood_pellet_sector_study_south_yorkshire.pdf)

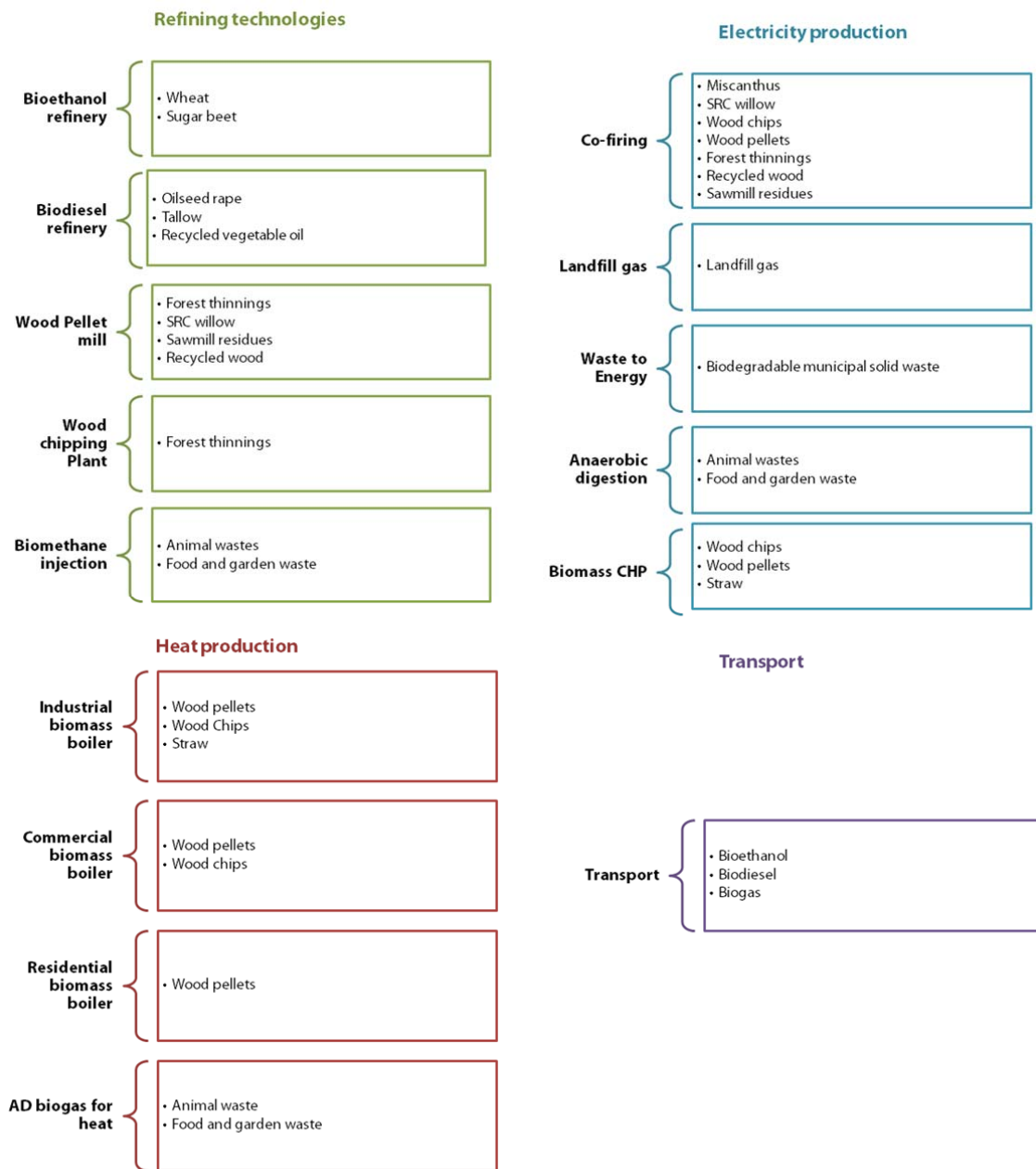
<sup>87</sup> IRENA (2013) *Road transport: The cost of renewable solutions – preliminary findings*. Available at: [http://www.irena.org/DocumentDownloads/Publications/Road\\_Transport.pdf](http://www.irena.org/DocumentDownloads/Publications/Road_Transport.pdf)

*Table A. 2: Energy-producing technology costs and performance details*

	<b>Typical size (kW)</b>	<b>Capex (€/kW)</b>	<b>Opex (€/kW)</b>	<b>Discount rate (%)</b>	<b>Economic life (%)</b>	<b>Load factor (%)</b>	<b>Thermal conversion efficiency (%)</b>
Peat co-firing	38,000	1,450	66	7%	15	80%	30%
Waste to energy	72,000	5,600	375	12%	15	70%	35%
AD electricity generation – large	1,000	5,156	375	12%	15	80%	33%
AD electricity generation – small	250	5,625	190	12%	15	73%	33%
AD CHP – large	800	5,625	180	12%	15	80%	71%
AD CHP – small	200	5,625	206	12%	15	71%	73%
Solid biomass CHP – large	3,000	2,500	170	12%	15	80%	78%
Solid biomass CHP – small	800	3,469	138	12%	15	80%	71%
Biomethane injection	3,000	1,791	190	12%	15	-	-
Biogas combustion for on-site heat	300	3,115	159	12%	15	70%	85%
Industrial biomass boiler	2,000	426	35	12%	15	68%	85%
Commercial biomass boiler	400	450	18	12%	15	20%	85%
Residential biomass boiler	14	890	10	12%	15	11%	85%

The characteristics of a technology determine what resources or refined products can be used to produce energy. Figure A. 4 shows the resource choice specified for each technology. To make the problem tractable, resource options are limited to those resources that have significant quantities of materials available and are available at reasonable cost.

Figure A. 4: Resource options for technology inputs



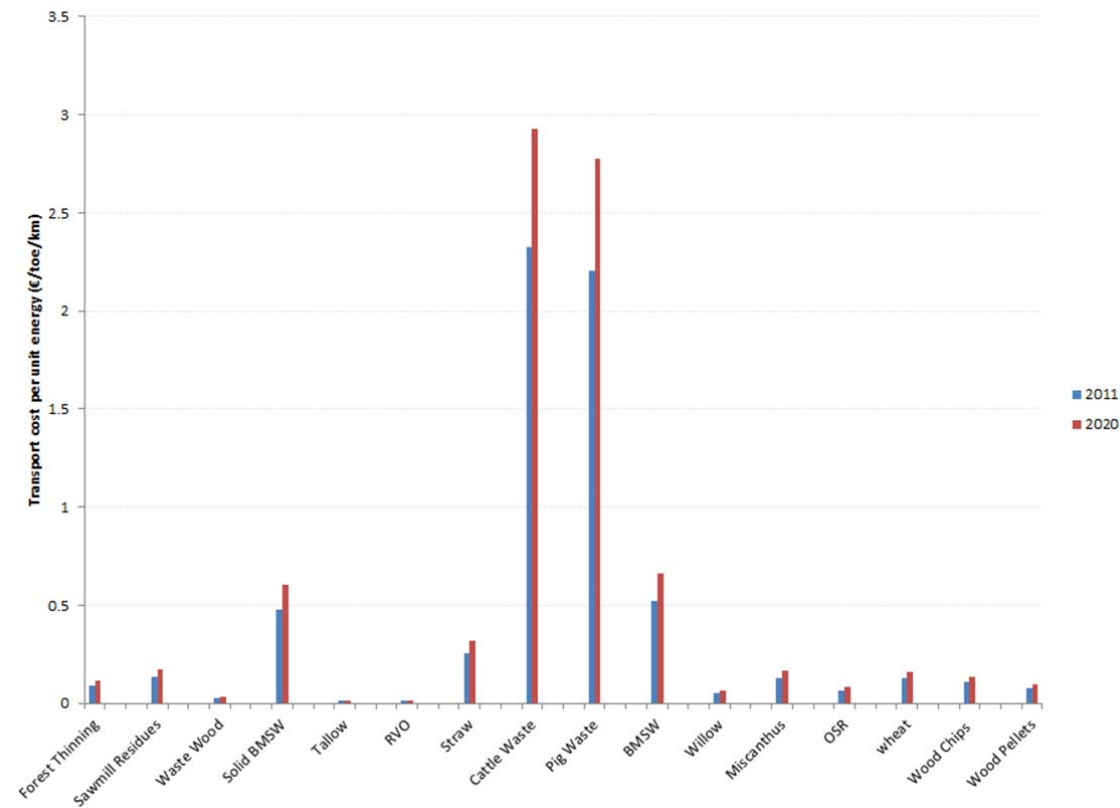
The estimated cost of transporting resources and refined products is based on the parameters evaluated by COFORD for the transportation of timber products<sup>88</sup>, and by Teagasc<sup>89</sup> for the transportation of slurry. The efficiency of transportation of timber is estimated in the range 1.24 to 2.23 km/litre of fuel use, and as 2.16 to 4.53 km/litre for general haulage. The maximum weight carried is between 42 and 44 tonnes, with the maximum volume of 120 m<sup>3</sup> of material. Fuel costs

<sup>88</sup> Devlin, G. for COFORD (2010) 'Fuel consumption of timber haulage versus general haulage', *Harvesting/Transportation*, 22.

<sup>89</sup> Fealy, R., O'Donoghue, C., Hanrahan, K., Martin, M., and Shulte, R.P. (2012) 'Modelling the Gross Cost of Transporting Pig Slurry to Tillage Spread Lands in a Post Transition Arrangement within the Nitrates Directive', *REDP Working Paper Series 12-WP-RE-04*, Teagasc.

are assumed to be as 150 c/litre of diesel in 2012 and are assumed to grow in line with crude oil price projections to 2020. For slurry, the maximum volume of transportation is 26 m<sup>3</sup> by truck and 12 m<sup>3</sup> for tractor and trailer – an average of 19 m<sup>3</sup> was used in the transport cost estimates. Figure A. 1 shows the per kilometre cost of transporting the various resources within the model.

Figure A. 5: Cost of transporting resources per unit of energy content per kilometre



The cost of transportation for each technology is evaluated at 20km, 50km and 120km. Technologies that use less resources can source more of their requirements from within the 20km band, with larger technologies required to source more of the resource requirement from further away.

The REFIT policy tariffs and the biofuels obligation are the main policy instruments impacting on the baseline model. The REFIT tariffs are applied as outline in the terms and conditions of the scheme.<sup>90</sup> The biofuels obligation requirements are estimated as part of the national energy forecast and are inputted as a demand that the model must meet from the available resources. Heat demand is based on the estimated requirements from the heat model described in Annex 1.

<sup>90</sup> Department of Communications, Energy and Natural Resources (2014). *National Energy Efficiency Action Plan 2014*. Available at: <http://www.dcenr.gov.ie/NR/rdonlyres/20F27340-A720-492C-8340-6E3E4B7DE85D/0/DCENRNEEAP2014publishedversion.pdf>



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