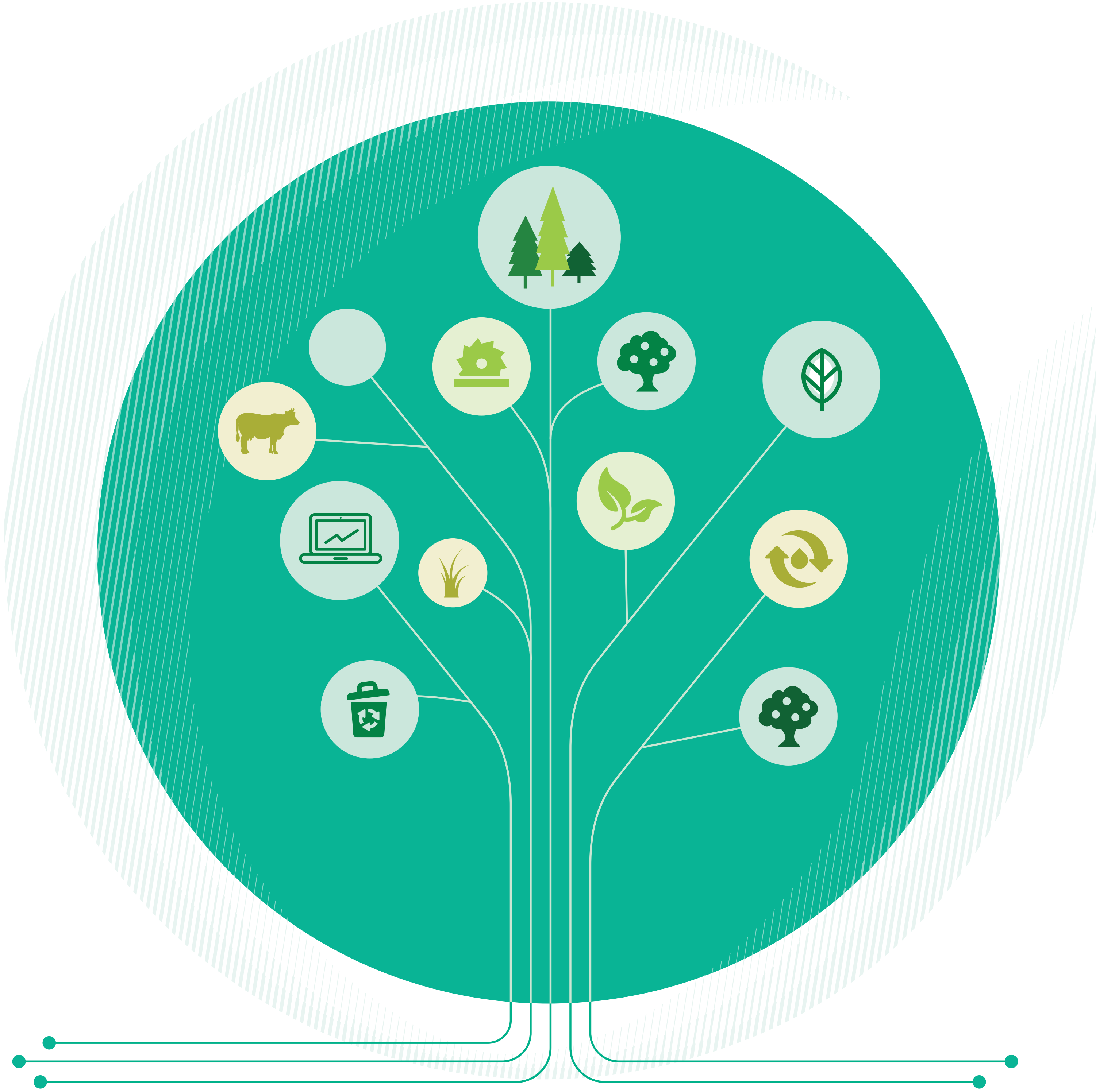
Bioenergy Supply in Ireland 2015 - 2035



Bioenergy Supply in Ireland 2015 – 2035

An update of potential resource quantities and costs

Ver 1.2 10.17

The Sustainable Energy Authority of Ireland

The Sustainable Energy Authority of Ireland (SEAI) was established as Ireland's national energy authority. SEAI's mission is to play a leading role in the transformation of Ireland to 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 clean 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 Ireland's low-carbon future

Acknowledgements

A large number of bioenergy experts in Ireland were contacted during the course of the study and their valuable inputs are gratefully acknowledged (see Appendix 1 for more details).

Highlights

- Under favourable conditions – high market prices for bioenergy resources and mitigation of supply-side barriers – the total amount of solid, liquid and gaseous bioenergy produced in Ireland could reach 3,290 ktoe (138 PJ) by 2035. This compares to total primary energy demand of bioenergy, including imports, of 468 ktoe (19.6 PJ) in 2014.

- This potential domestic bioenergy production in 2035 would be equivalent to 10% of Irelands 2014 energy needs if it were used to produce electricity, or almost 30% if it were used to produce heat.

- The majority of resource potential is available at a roadside/farm gate price above current market prices for bioenergy. This suggests that increased bioenergy demand, leading to sustained increases in the market price for bioenergy, is required to deliver an expansion in domestic bioenergy resources. In addition to stimulating increased demand, further supply-side interventions to remove identified barriers can lower production costs and further help the financial viability of resources at lower prices.

- At current market prices for bioenergy, the forestry resource has the largest available potential to 2035.

- The supply curves show that much of the potential for domestic resource expansion is available between 200 €/toe (4.7 €/GJ) and 600 €/toe (14.3 €/GJ). At this market price range, investment in harvesting equipment or management practices become economically viable. Willow and miscanthus have a large additional potential in this price range. Grass silage used for the production of biogas also has significant additional potential in the upper end of the price range.

- Agricultural and municipal wastes, along with other by-products, are typically available at low or even negative cost where disposal in landfill is avoided. The bioenergy potential for these resources represents 20% of the total potential estimated in 2035

- The energy crop potential has implications for land use. Based on forecasts of the land that could be available, the overall limit on conversion of pasture land imposed by the Common Agricultural Policy, and giving priority to additional land for annual crops, it is estimated that in total 203,000 ha could be available to grow willow and miscanthus.

- Resources typically used as solid fuel to produce heat and electricity (e.g. forest thinnings and residues; sawmill residues and energy crops) represent the majority of potential in all price bands. At low market prices, solid fuel represents 90% of the available potential. At high prices the share falls to 67% as more biogas resource potential becomes available.

- The potential availability of energy crops used for liquid biofuel production is limited and requires high market prices (>1,000 €/toe or 24 €/GJ) to be financially viable.

- Under favourable conditions – high market prices for bioenergy resources and mitigation of supply-side barriers – resources typically used to produce biogas represent 29% of the available potential estimated in 2035. Under less favourable conditions, the available potential in 2035 reduces to 10% of the total in line with the reduced availability of grass silage.

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1. Introduction

1.1 Background

The long term Government vision for Ireland's energy system is to reduce greenhouse gas emissions (GHG) from the energy sector by between 80% and 95% compared with 1990 levels by 2050.[1] How much renewable energy and energy efficiency potential exists, and at what cost, are key pieces of evidence for the Government in developing policy actions to deliver on this ambition.

The Irish Government published a draft Bioenergy Action Plan[2] in 2015 that sets out a number of actions to enhance the use of bioenergy in Ireland. In order to support the development of this plan, the Sustainable Energy Authority Ireland (SEAI) commissioned this study to update and expand a previous study entitled *Bioenergy supply curves for Ireland 2010 - 2030*. The previous study, completed in 2012, provided a set of bioenergy supply curves which detailed the quantity of bioenergy resources available and their prices out to 2030. This current study updates that work, increasing the number of resources examined and extending the timeframe for analysis to 2035.

1.2 Overview of Report

Fourteen market-ready bioenergy resources were examined in detail, with a further five less-market-ready resources examined for potential future availability. Table 1.1 shows the market-ready resources examined, the category of resource it falls under and the type of fuel typically produced from the resource.

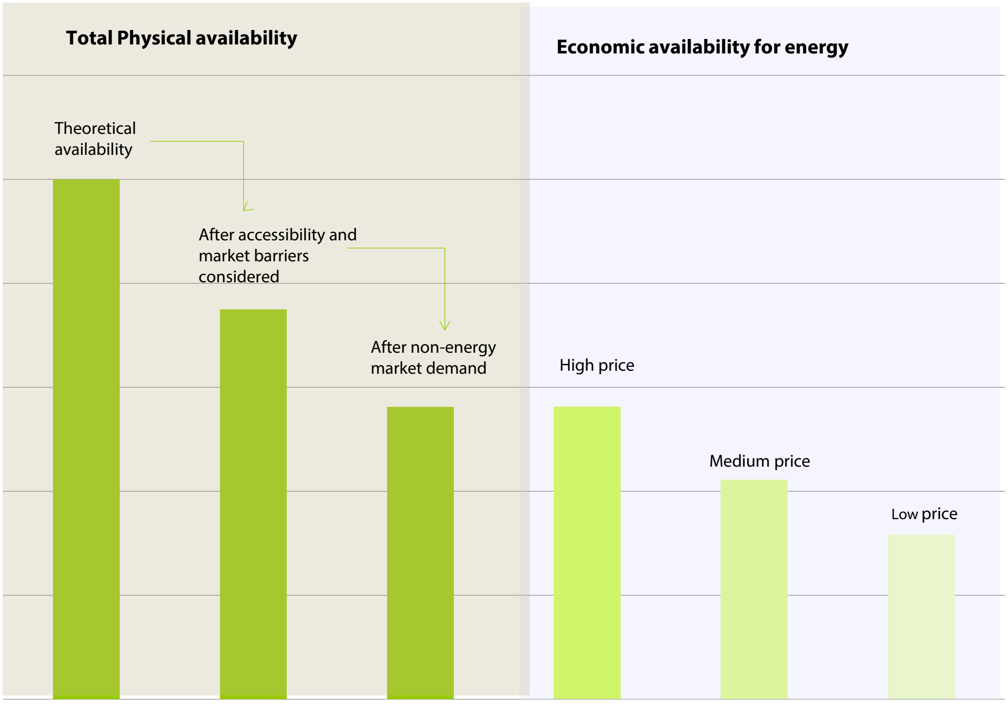
Table 1.1: Resources examined in detail in this report.

Resource	Resource category	Type of fuel available from resource
Forest thinnings and residues	Forestry	Solid fuel
Sawmill residues	Other by-products and waste	Solid fuel
Waste wood	Other by-products and waste	Sold fuel
Annual crops for biofuels – wheat and oil seed rape (OSR)	Energy crops	Biofuel
Perennial energy crops – Short rotation coppice (SRC) willow and miscanthus	Energy crops	Solid fuels
Grass silage	Energy crops	Biogas
Straw	Agricultural waste and residues	Solid fuel
Pig and cattle manure	Agricultural waste and residues	Solid fuel
Tallow	Other by-products and waste	Biofuel/bioliquid
Used cooking oil (UCO)	Other by-products and waste	Biofuel
Food waste	Other by-products and waste	Biogas
Residual Municipal Solid Waste (MSW)	Other by-products and waste	Solid fuel

[1] Department of Communications Energy and Natural Resources, (2015), Ireland's Transition to a Low Carbon Energy Future 2015-2030. Available at http://www.dcenr.gov.ie/energy/SiteCollectionDocuments/Energy-Initiatives/Energy%20White%20Paper%20-%20Dec%202015.pdf
[2] Department of Communications, Energy and Natural Resources (2014). Draft Bioenergy Plan.

The availability of each resource is determined individually. Resources that are by-products of some other commercial activity are assessed based on future requirements or production for that activity. The amounts of by-product that can be potentially recovered from the main activity are estimated as well as the quantities of by-product material likely to go to non-energy markets. The costs associated with the various recovery options are then included to produce an estimate of the resource availability at three market prices. Figure 1.1 illustrates how resource potential is estimated for each individual year.

Figure 1.1: Illustration of Resource assessment method



The estimates for dedicated energy crops grown for bioenergy production are based on the availability of land after the projections for food production are incorporated, the margin farmers can make from various land types and the annual planting rate possible based on assessments of supply chain maturity.

The analysis presented in this report uses up-to-date published information supported by direct communications with sectoral experts to develop estimates for the potential bioenergy resource in Ireland. Key plans and data from other sectors such as the Food Wise 2025 plan,[3] COFORD's All Ireland Roundwood Production Forecast 2016 – 2035[4] and the EPA's National Waste Report 2012[5] frame the estimates for bioenergy availability. The main supply-side barriers hampering the development of bioenergy resources are identified, as well as the impact of overcoming these on resource availability.

The study goes beyond a straightforward estimate of how much of each resource might be available to incorporate the crucial impact of the market price for bioenergy on the potential availability of bioenergy resources. The resulting supply curves, therefore, provide cost and availability information for each resource on a consistent basis and show the price ranges where expansion of resource potentials is likely to occur. This provides a foundation for analysis of the entire bioenergy supply chain that captures the market

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[3] Department of Agriculture Food and the Marine, (2015), Food Wise 2025 – Local roots Global reach – a 10 year vision for the Irish agri-food industry. Available at: https://www.agriculture.gov.ie/foodwise2025/

[4] Henry Phillips et al, (2016), All Ireland Roundwood Production Forecast 2016-2035, COFORD. Available at: http://www.coford.ie/media/coford/content/publications/2016/00663CofordRoundwoodProduction2016-2035WebVersion.pdf

[5] EPA (2012). National Waste Report. Available at: http://www.epa.ie/pubs/reports/waste/stats/EPA_NWR12_Complete_to_web_5Aug14.pdf

price/cost impacts of increasing the use of available bioenergy resources. The findings also offer insights into the long-term actions required to develop the resources for future energy use.

The remainder of this Section 1 outlines the key findings of the report. Sections 2 to 14 examine in detail each of the resources outlined in Table 1.1. For each resource, the potential quantity that might be available up to 2035 is estimated under two scenarios:

1) A Business As Usual (BAU) scenario where current policy actions continue into the future
2) An Enhanced Supply (ES) scenario that assesses the resource availability if all supply-side barriers were to be addressed

As the study is only concerned with supply-side issues, it was assumed in both cases that there was a potential demand for the resource, and any restrictions that demand side issues might have on supply were not considered. There is a short discussion, for each resource, of the main supply-side barriers to fully developing and utilising the resource.

As well as estimating the primary energy available from the resource, the study estimates the final delivered energy that might be available if it was used to generate electricity and/or heat or, where appropriate, used as a transport fuel. This allows the contribution of each resource to current gross final energy use to be assessed based on a set of assumptions (see Appendix 2). Finally, the price at which each resource might be available is considered.

The study also provides analysis, although less detailed, on five resources that are considered to be less market ready:

- Chicken litter
- Sewage sludge
- Fats, oils and greases
- Macroalgae
- Microalgae

This analysis is presented in Section 15. Section 16 contains a discussion of the quantity of bioenergy which might be available for import into Ireland.

1.3 Key findings

The bioenergy resource in Ireland has significant potential to expand between now and 2035. Realisation of this potential is dependent on higher market prices than currently prevail for most resource types for bioenergy as well as mitigation of the supply-side barriers to resource development. Under favourable conditions with high market prices for bioenergy resources and mitigation of supply-side barriers, the total amount of solid, liquid and gaseous bioenergy produced in Ireland could reach 3,290 ktoe (138 PJ) by 2035[6]. This compares to total primary energy demand of bioenergy, including imports, of 468 ktoe (19.6 PJ) in 2014.

Using the current total energy demand in Ireland as a benchmark, this potential is equivalent to 10% of our energy needs, if the available bioenergy resource is used to produce electricity, or almost 30% if used to produce heat.

Figure 1.2 shows the trajectory of potential by type of resource to 2035 for the BAU and ES scenarios. Bioenergy producers seeking to increase the utilisation of biomass resources for energy require higher market prices in many cases to make investment in harvesting equipment or management practices economically viable. For example, the cost of forestry management choices influences the volume available from thinning and residues for energy. Management practices that gather more of the residues left behind

[6] For an overview of commonly used units of energy measurement such as Joule, toe, please refer to Appendix 7

after the felling of forests for wood products can require specialised machinery and more personnel. The cost of producing energy crops includes the foregone margin a farmer would have received for agricultural produce as well as the establishment, management and harvesting costs. Land that produces high margins for farmers will require a higher market price for bioenergy to make it viable. Market prices refer to the road side or farm gate prices before the cost of transport, refining and energy conversion are included.

At current prices (~200 €/toe or ~5 €/GJ) the forestry resource offers the largest source of potential expansion to 2035.

Figure 1.2 shows that there is strong potential for increase in biomass resource coming from energy crops, particularly through tackling of supply-side barriers. A doubling of current energy price to 400 €/toe would also help the financial case for energy crops and thus the available bioenergy potential. Grass silage, in particular, sees a large increase in potential at prices above 400 €/toe (9.5 €/GJ). As food and animal wastes are available at negative or zero cost the full potential is available at all price levels examined. Together, mitigation of supply-side barriers faced by farmers, along with a doubling of price could lead to an increase in energy crop production in 2035 from 433 ktoe in the 200 €/toe BAU scenario to 1,536 ktoe in the 400 €/toe ES scenario. In the latter scenario energy crops account for 57% of the total estimated bioenergy potential in 2035.

Figure 1.2: Potential Bioenergy Resource by Type of Resource

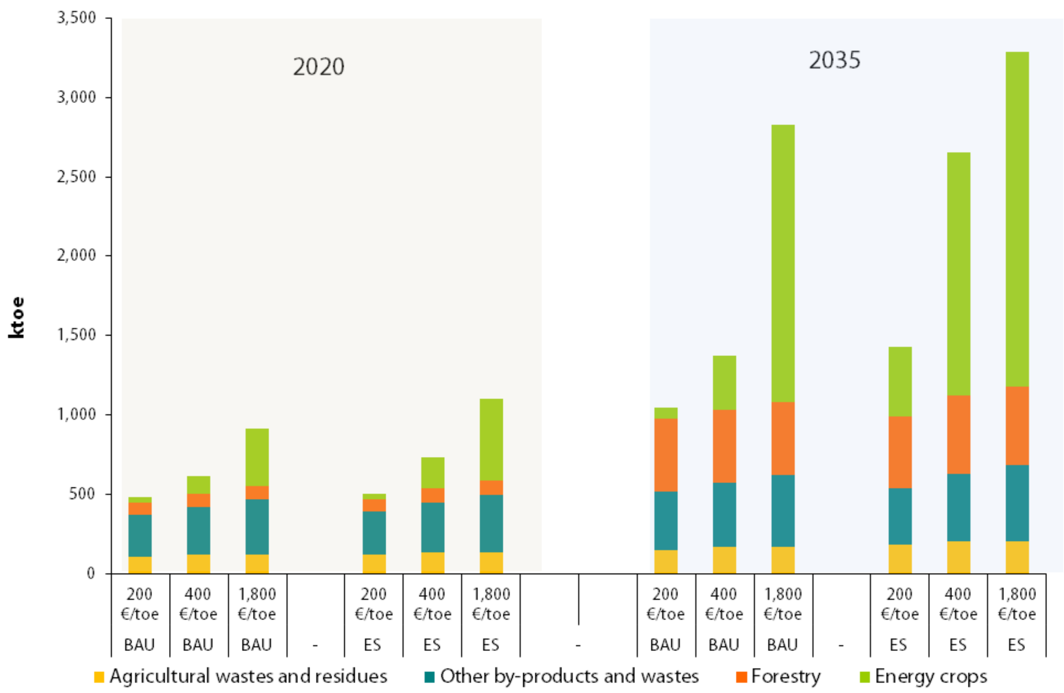
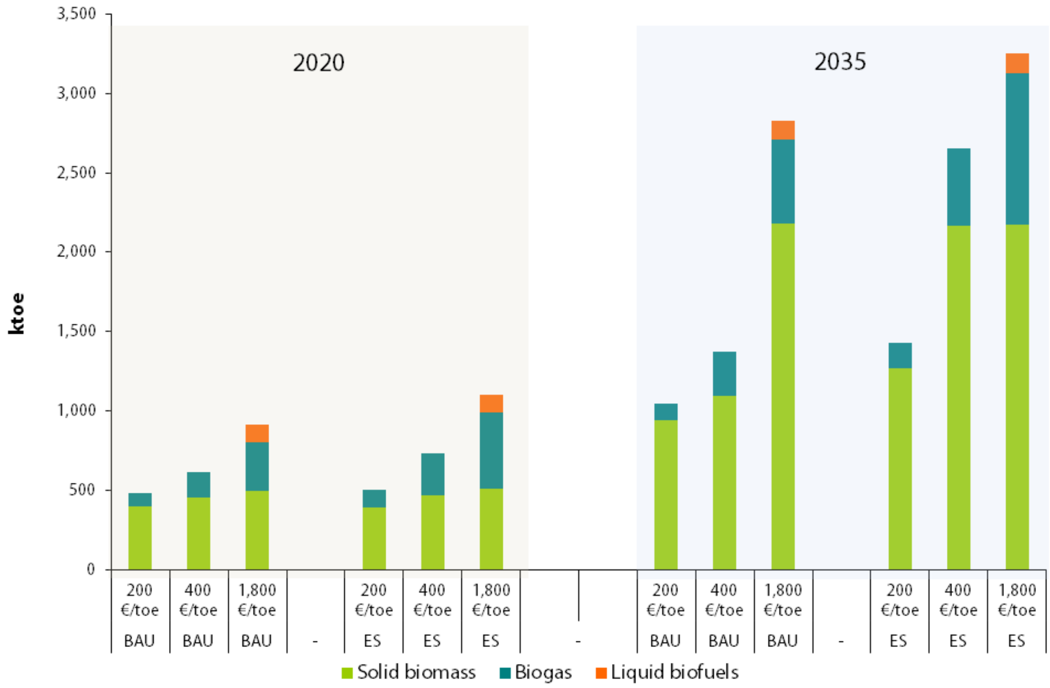


Figure 1.3 summarises the potential for each resource categorised by the type of fuel typically produced – solid, liquid or gas – in both scenarios across the three price scenarios. In all price bands, resources that provide solid biomass – typically used to produce heat and electricity – represent the majority of the domestic bioenergy potential. Under favourable conditions – high prices and mitigation of supply-side barriers – solid biomass represents 67% of the total potential resource in 2035. Under similar conditions, grass silage, animal wastes and food wastes, used to produce biogas, represent 29% of the estimated total bioenergy potential by 2035.

Resources that are typically used to produce liquid biofuels are only financially viable at high market prices (>1,000 €/toe or 24 €/GJ). In the highest market price scenarios assessed in this report these resources account for at most 4% of the total potential bioenergy resource or 128 ktoe (5 PJ). Should current low market prices continue to prevail and supply-side barriers remain, the potential in 2035 is estimated to be over two-thirds lower at 1,000 ktoe (41 PJ).

Figure 1.3: Potential Bioenergy Resource by Type of Fuel



1.3.1 Supply curves

The supply curves capture the cost and availability relationship across all bioenergy resources for each year to 2035. This enables analysis of energy system impacts and policy costs to take account of the cost structure. Figure 1.4 and Figure 1.5 show the full supply curve for 2020 and 2035 under the BAU scenario. The supply curves show that much of the potential for domestic resource expansion is available between 200 €/toe (4.7 €/GJ) and 600 €/toe (14.3 €/GJ). Willow and miscanthus have a large additional potential in this price range. Grass silage for biogas also has significant additional potential in this price range.

Energy crops used for biofuel production require high market prices to make financially viable and lie at the right of the supply curves. At the other end of the scale, energy-producing facilities that use biodegradable municipal waste or food waste as fuel get paid to take the waste from waste collectors seeking to minimise the disposal costs. This results in a negative cost for these resources.

Figure 1.4: Supply curves for all resources in 2020 BAU scenario

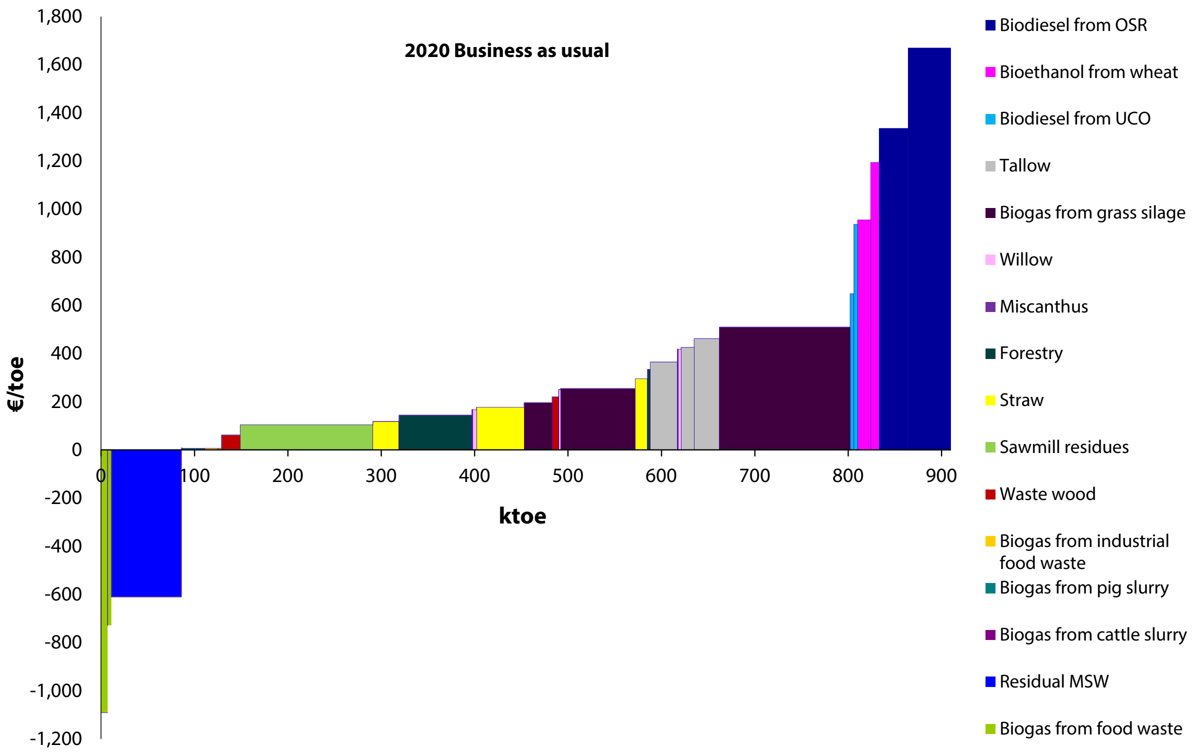
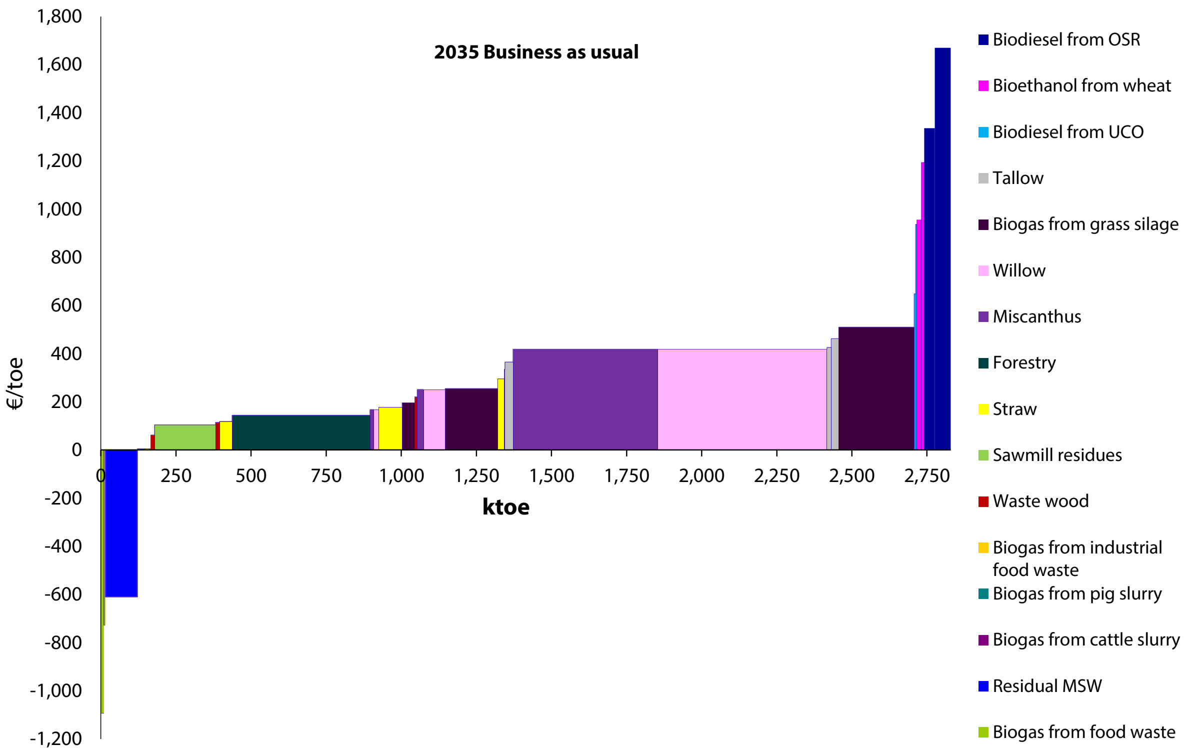


Figure 1.5: Supply curves for all resources in 2035 BAU scenario



1.3.2 Resource potential

The full potential for each individual resource under favourable conditions – high market prices and mitigation of market barriers – is shown in Figure 1.6. The large potential available from willow, miscanthus and grass silage is notable and points to the importance of the agricultural sector and farmers in realising the bioenergy resource potential. Residues for forestry activities are also a key resource and, as noted above, are available at lower market prices.

Figure 1.6: Total Potential Bioenergy Resource by Individual Feedstocks

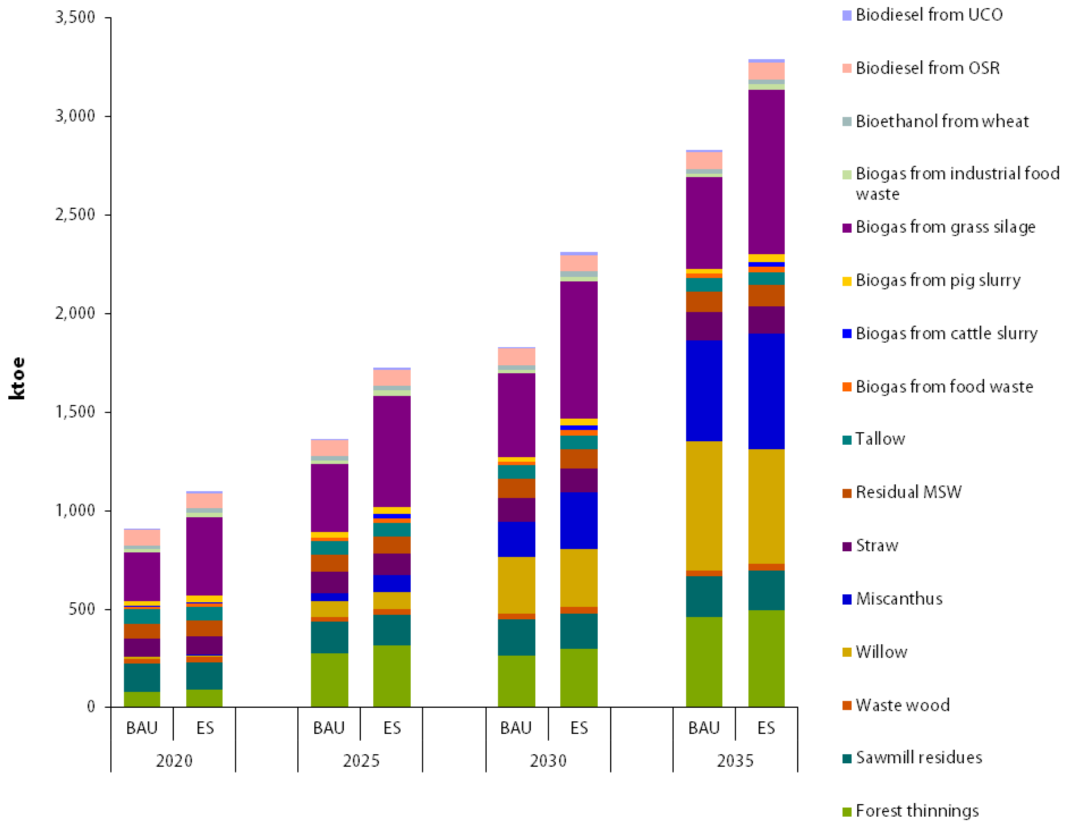


Table 1.2 expresses the information shown in Figure 1.6 in natural units typically used to quantify these resources for the BAU and ES scenarios.

Table 1.2: Available potential expressed in 'natural units'

Business as Usual	Units	2020	2025	2030	2035
Solid biomass					
Forest thinnings	000m3[7]	491	1,661	1,621	2,794
Sawmill residues	000m3	862	974	1,098	1,237
Waste wood	tonnes	75,127	81,153	87,662	94,693
Willow	odt[8]	18,491	171,827	626,344	1,435,424
Miscanthus	odt	7,339	84,664	391,831	1,135,909
Straw	tonnes	268,996	327,587	358,858	413,929
Residual MSW	tonnes	348,030	394,633	444,601	498,092
Tallow	tonnes	84,807	85,597	83,626	80,653
Feedstocks for anaerobic digestion (AD)					
Food waste for AD	tonnes	289,405	313,996	340,639	369,521
Cattle slurry for AD	tonnes	100,007	108,787	112,568	113,269
Pig slurry for AD	tonnes	2,252,814	2,257,514	2,252,649	2,253,592
Grass silage for AD	odt	637,442	891,561	1,087,284	1,195,600
Industrial food waste for AD	tonnes	148,634	150,483	150,928	150,621
Liquid biofuels					
Wheat for bioethanol	tonnes	118,969	123,175	127,381	131,587
Oilseed rape for biodiesel	tonnes	233,526	243,017	252,895	262,930
Used cooking oil for biodiesel	tonnes	9,673	10,023	10,316	10,614
Enhanced Supply	**Units**	**2020**	**2025**	**2030**	**2035**
Solid biomass					
Forest thinnings	000m3	541	1,905	1,811	2,988
Sawmill residues	000m3	862	974	1,098	1,237
Waste wood	tonnes	75,127	81,153	87,662	94,693
Willow	odt	18,491	188,323	643,810	1,280,772
Miscanthus	odt	14,005	183,557	638,764	1,290,562
Straw	tonnes	268,996	327,587	358,858	413,929
Residual MSW	tonnes	355,883	385,549	453,294	492,298
Tallow	tonnes	84,807	85,597	83,626	80,653
Biogas from anaerobic digestion					
Food waste for AD	tonnes	321,987	408,954	470,314	511,157
Cattle slurry for AD	tonnes	783,765	2,099,171	2,179,047	2,198,212
Pig slurry for AD	tonnes	3,234,785	3,487,539	3,480,023	3,481,479
Grass silage for AD	odt	1,010,579	1,435,987	1,768,224	2,135,000
Industrial food waste for AD	tonnes	238,666	302,042	302,937	302,321
Liquid biofuels					
Wheat for bioethanol	tonnes	118,969	123,175	127,381	131,587
Oilseed rape for biodiesel	tonnes	233,526	243,017	252,895	262,930
Used cooking oil for biodiesel	tonnes	11,023	14,482	18,054	18,574

[7] $000m^3$ is thousands of meters cubed.
[8] Odt is oven dry tonnes

1.3.3 Land use

The energy crop potential has implications for land use. The majority of grassland is currently used for livestock production in Ireland. However, Food Wise 2025 suggests that improved utilisation of grassland could support increased livestock production which could make substantial areas of pasture land available for conversion to arable land. Some of this converted pasture land could be used for growing energy crops.

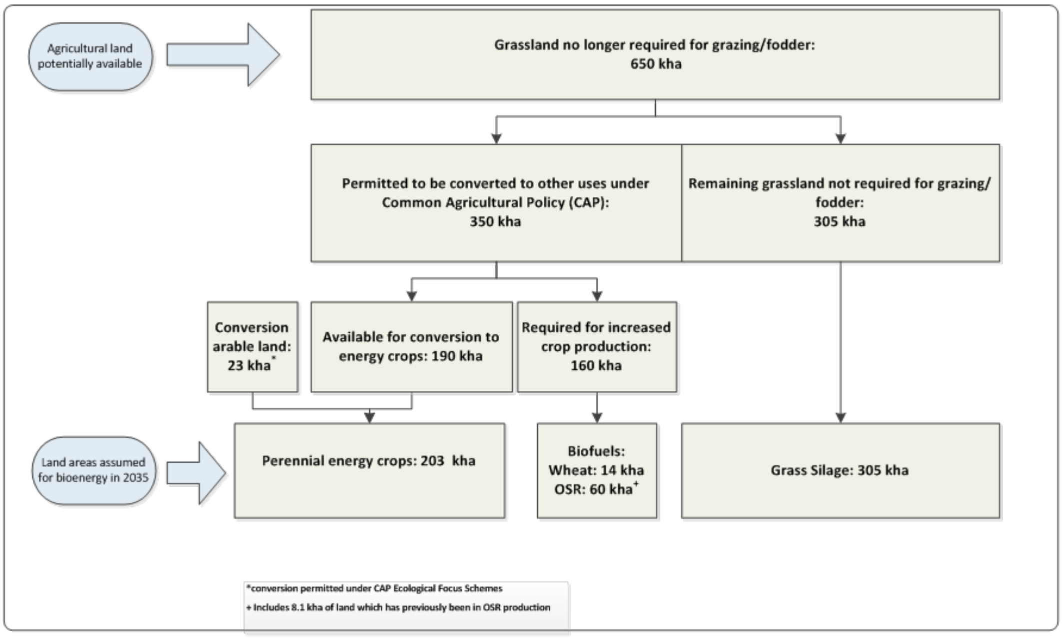
Based on forecasts of the land that could be available, the overall limit on conversion of pasture land imposed by the Common Agricultural Policy, and giving priority to additional land for annual crops, it is estimated that in total 203,000 ha could be available to grow Short Rotation Coppice (SRC) willow and miscanthus. It will take time for the immature and specialised supply chain to develop, so it would require several years to plant such an area. By 2020, it is estimated that energy crops could produce approximately 12 ktoe (490 TJ) of SRC and miscanthus in the BAU scenario. Under an Enhanced Scenario, where planting expands at a faster rate because of the removal of supply-side barriers, 15 ktoe (617 TJ) could be available. By 2035, if actions were taken to encourage the development of energy crops, it is considered that all of the available 203,000 ha could be utilised and 1,167 ktoe (48,855 TJ) of SRC willow and miscanthus could potentially be available.

The potential for grass silage to be used as a bioenergy resource is based upon an assumption (from recent work by Teagasc)[9] that much grassland used for grazing is currently under-utilised and, through improved management of livestock, additional land could be freed from grazing and made available for additional silage production or for other enterprises. To produce the quantities of grass silage estimated in the BAU Scenario will require this improved management as well as subsequent release of land from grazing to be achieved. In addition, farmers will have to use that released land for the production of grass silage for bioenergy.

Assumptions about land availability for bioenergy crops are summarised in Figure 1.7. The forestry resource that is estimated here is based on existing forest areas and assumes that no material from additional afforestation becomes available in the timeframe.

[9] McEniry et al (2013). 'How much grassland biomass is available in Ireland in excess of livestock requirements?' Irish Journal of Agricultural and Food Research 52, 2013.

Figure 1.7: Land Availability Assumptions in Study



1.3.4 Key barriers

The report identified a number of supply-side barriers that are hampering the development of biomass resources. Several policies are in place aimed at mitigating these and are accounted for in the BAU scenario. Further supply-side actions aimed at addressing the remaining barriers can enhance the supply available from the bioenergy resource.

Table 1.3 highlights some of the barriers identified for the largest resources that offer the largest potential for energy production.

Table 1.3: Supply-side barriers identified for resources with large bioenergy potential

Resource	Policy/regulatory barriers	Technical barriers	Infrastructural barriers	Market barriers
Forestry	Farmer reluctance to commit to afforestation because of the obligation to replant land after felling.	Lack of expertise and experience of planting, managing and harvesting forests in the private sector.	Some forests are remote and difficult to harvest. Supply chain development is still in its early stages, limiting access to markets and facilities (e.g. storage or drying, chipping).	Lack of market data, particularly on costs and biomass prices. Lack of transparent price platform for biomass trade in Ireland.
Perennial energy crops	Long-term policy uncertainty. Mismatch with incentives for competing land uses.	Immature supply chain for equipment and planting material. Lack of experience with crops.	Lack of local collection and distribution facilities.	Perception of risk and uncertainty. Requirements for up-front investment and cash flow issues in early years.
Grass silage	Lack of sustainability requirements for grassland improvement measures.	Quality of silage. Suitability of silage as a sole feedstock for AD.		Perception of risk and uncertainty in production of silage for energy. Variability in silage price. High transport costs.

1.3.5 Less market ready resources

A number of other potential bioenergy resources that are considered less market ready have been assessed to examine the potential scale of resource, the timescale over which it could become available and key barriers to utilisation. Five resources were examined for potential future availability: chicken litter, sewage sludge, fats/oils/greases, macroalgae, microalgae. Table 1.4 shows the current and future potential of these resources.

Table 1.4: Less market ready bioenergy resources

Resource	Current (ktoe)	Future (ktoe)
Chicken litter	4.6 to 7.4	5.8 to 9.2
Biogas from sewage sludge	8.0 to 8.7	10.8
Biogas from fats, oils and greases	<0.1	<0.1
Macroalgae	0.0	10.7
Microalgae	0.0	1.9
Total	**12.6 to 16.1**	**29.3 to 32.7**

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2. Forest Thinnings and Residues

2.1 Overview

2.1.1 What is the resource and how can it be used?

Forestry management involves a number of stages and produces forestry products that are of different quality, composition and value (e.g. sawlogs, pulpwood for use in panel board mills and paper mills, stakewood). Wood suitable for use as a fuel includes:

- Small roundwood, which is removed from the forest to thin plantations, and allow larger diameter trees to flourish (i.e. thinnings)
- Smaller size material, which is produced when the forest is finally harvested and is unsuitable for use as sawlogs
- Residues from final harvest operations (excluding those that must remain in the forest for environmental reasons)

To be suitable for use as a fuel, some drying or processing is likely to be necessary and most wood is left in the forest to dry ('season') for up to 12 months prior to use. Wood may be used as logs in domestic boilers and stoves, or may be processed into chips or pellets. These may be: co-fired in power stations, used in dedicated biomass power stations, in industrial CHP plants and in biomass boiler to produce electricity and heat. In the future, wood may also be converted into renewable transport fuels by using advanced techniques that are currently at the demonstration stage in Europe and the USA.

Chipping of wood may occur at the forest roadside or at a processing plant. Pelletising wood involves further drying and processing, but has the advantage that pellets are a more energy dense form of fuel, and are easier to handle and transport. In the future other techniques such as torrefaction or steam explosion could be used to pre-process wood and improve handling and transport.

2.1.2 How much resource could be available?

Forecasts of wood and residues that can be harvested to 2035 have been made by the Council for Forest Research and Development (COFORD),[10] based on current areas of forest, forecast increases in areas, and wood that may be harvested during thinning operations as well as at final harvest. An estimate is also made of residues that can be removed. These estimates have been combined with estimates of demand for pulpwood for non-energy purposes (e.g. panel board, stakewood, and other uses such as animal bedding) and demand for sawlogs, to estimate how much pulpwood could be available for bioenergy purposes. Under a BAU scenario it is assumed that only some thinning operations are carried out, and that residues are not extracted. Under an Enhanced Supply scenario, it is assumed that supply-side barriers (see below) are overcome, and all thinning operations assumed in the COFORD forecast are carried out by 2030, and all of the residues identified as available are extracted as well.

In the BAU scenario, supply rises from 81 ktoe (3,338 TJ) in 2020 to 460 ktoe (19,275 TJ) in 2035. Under an Enhanced Supply scenario, supply is about 7% higher in 2035, at 492 ktoe (20,614 TJ) (Table 2.1 and Figure 2.1). This is mainly due to the increasing volume of downgrades (large diameter timber not suitable for use as sawlogs) that become available in the future.

2.1.3 Supply-side barriers

Key supply-side barriers are summarised in Table 2.2, and are based on a wide variety of sources, and discussions with forestry experts and trade associations. The table also suggests examples of potential actions that could address these barriers; these are not intended as policy recommendations, but rather as illustrations of how the types of actions typically used to tackle barriers of these types could be implemented in Ireland. There is good awareness already of many of the barriers identified in Table 2.2, and, as described in the table, actions are already being undertaken to tackle some of them. For example, funding for access roads, the establishment of Bioenergy Ireland (a joint venture between Bord na Móna and Coillte), and development of the CLIMADAPT tool by COFORD. Information for the table has been obtained from a variety of sources (see Box 2.1).

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[10] Phillips, H. et al (2016).'All-Ireland Roundwood Production Forecast 2016-2035'.

Table 2.1: Potential forestry resource

	Unit	2020	2025	2030	2035
Business as usual scenario					
Forestry	'000 m^3	491	1,661	1,621	2,794
Forestry	ktoe	81	274	267	460
Final (delivered) energy					
Electricity only	ktoe	24 - 29	82 - 99	80 - 96	138 - 166
CHP	ktoe	57 - 65	192 - 219	187 - 214	322 - 368
Heat only	ktoe	61 - 69	205 - 233	200 - 227	345 - 391
Percentage of current gross final energy use[(a)]					
Electricity only	%	0.2 - 0.3%	0.7 - 0.9%	0.7 - 0.9%	1.2 - 1.5%
CHP	%	0.5 - 0.6%	1.7 - 1.9%	1.7 - 1.9%	2.9 - 3.3%
Heat only	%	0.5 - 0.6%	1.8 - 2.1%	1.8 - 2%	3.1 - 3.5%
Enhanced supply scenario					
Forestry	'000 m^3	541	1,905	1,811	2,988
Forestry	ktoe	89	314	298	492
Final (delivered) energy					
Electricity only	ktoe	27 - 32	94 - 113	90 - 107	148 - 177
CHP	ktoe	62 - 71	220 - 251	209 - 239	345 - 394
Heat only	ktoe	67 - 76	235 - 267	224 - 254	369 - 419
Percentage of current gross final energy use[(a)]					
Electricity only	%	0.2 - 0.3%	0.8 - 1%	0.8 - 1%	1.3 - 1.6%
CHP	%	0.6%	2 - 2.2%	1.9 - 2.1%	3.1 - 3.5%
Heat only	%	0.6 - 0.7%	2.1 - 2.4%	2 - 2.3%	3.3 - 3.7%

Notes (a) Gross final energy use in 2014 was 11,243 ktoe

Box 2.1: Sources used in identifying supply-side barriers for forest bioenergy resource

DAFM (2014). 'Forests, products and people. Ireland's forest policy – a renewed vision'
COFORD (2015). Mobilising Ireland's Forest Resource
DAFM (2015). Afforestation Grant and Premium Scheme 2014 – 2020 Edition 2/2015
DAFM (2015). Forestry Programme 2014 – 2020: Ireland IRL-DAFM-FS.023
https://www.agriculture.gov.ie/media/migration/forestry/publicconsultation/newforestryprogramme2014-2020/forestryprogramme2014-2020/DraftForestryProgramme20142020PubCon.pdf
DCENR (2014). Draft Bioenergy Plan
P. Howley (2013). 'Examining farm forest owners' forest management in Ireland: The role of economic, lifestyle and multifunctional ownership objectives'. Journal of Environmental Management 123, p. 105 – 112
Teagasc (2016). www.teagasc.ie/forestry (accessed December 2015 and January 2016)
H. Philips (COFORD). Personal Communications, November 2015 to February 2016
M. Fleming (Irish Farmers' Association). Personal Communication, 18 January 2016

Figure 2.1: Potential bioenergy resource from forestry

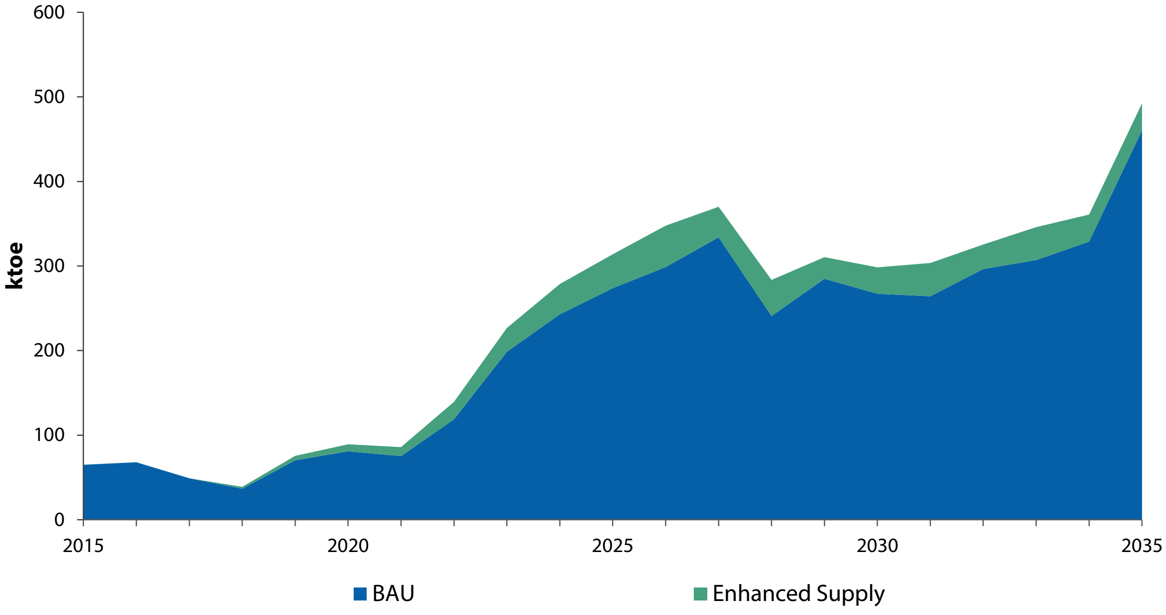


Table 2.2: Key supply-side barriers to development of forestry bioenergy resource

Supply-side barrier	Examples of potential measures to address barriers
Policy/regulatory barriers	
DAFM are aware that little or no afforestation will occur without grants and DAFM is supporting afforestation grants to 2020.[11] It is useful to understand land owner experience of these grants, where they are most effective, and factors that prevent their uptake. For example, trade associations have reported a lack of consistency in the application of environmental compliance requirements for afforestation grants across the country. They report that this significantly restricts afforestation rates in some regions.[12]	Investigate the administration of environmental guidance pre-grant, and whether or not there are reasons for different requirements or applications at regional level. Assess the necessity of the application of all of the environmental or social requirements for all of the afforestation applications; or if there is a potential for a two tier system of requirements depending on the objective of afforestation. If sustainability certification is required, ensure that forest owners understand what value this adds. Examine ways to rationalise/streamline the administration process. Assess the assistance land owners need to enable them to comply with these requirements; and provide an explanation of regional differences if necessary.
Farmer reluctance to commit to afforestation because of the obligation to replant land after felling.[13]	Examine the impact of this obligation on afforestation rates. Support work to understand why some landowners are not happy about the obligation and investigate alternative strategies that could provide resolution.

[11] Department of Agriculture Food and the Marine (2014). 'Forests, products and people. Ireland's forest policy – a renewed vision'.

[12] This refers to the requirement that forests are managed not only in accordance with the principles of sustainable forest management, but also with environmental guidance required at national and EU level. Trade associations report inconsistency in the environmental requirements between regions, resulting in additional administration burdens.

[13] See for example: Breem, J., Clancy D., Ryan M., Wallace M. 'Can't see the wood for the trees: the returns to farm forestry in Ireland' Working Paper 10-WP-RE-03; Breem, J., Clancy, D., Ryan M and Wallace M (2010) 'Irish land use change and the decision to afforest: an economic analysis' J. Soc, Irish Forestry 6-20 and O'Donoghue, C. and Upton, V. (2015) 'Land use change from agriculture to forestry: a structural model of the income and leisure choices of farmers.'

Supply-side barrier	Examples of potential measures to address barriers
Technical barriers	
Lack of expertise and experience of planting, managing and harvesting forests in the private sector. This prevents the full potential of mobilisation of biomass from being achieved and this situation is likely to continue in the future. For example, according to DAFM:[14] • 23% of the national estate had reached thinning stage but had not been thinned. This represents 164,000 ha of forests that have reached first-thinnings age have not been thinned. • approximately 8,000 forest owners have plantations of 12 – 22 years old that are approaching, or have already reached, thinning stage. The majority of these forest owners have no ongoing forest management or planning regimes in place.	Understand the knowledge gaps in the private sector. Provide access to knowledge to help private land owners improve management of forests. Trade organisations have said that training needs be targeted at the key issues where lack of knowledge will result in poor returns, in particular how to establish a forest and how to evaluate the 'crop' (including help in evaluating financial return). Targeted training can be provided through the internet, demonstrations, site visits, publicising success stories locally, advisory centres, and one-to-one meetings to provide tailored support for specific issues. Information should be targeted at non-forestry and non-farmer investors as well as farmers. Continued targeted support for the Thinning and Tending scheme[15] would also help.
Across the whole forest sector there is a lack of experience in the removal of residues for biomass and a need to understand optimal removal in terms of cost, ecological impact and efficiency of forestry operation.	Improved understanding is needed on: • the best methods for residue removal in different forest types and terrains; • investment in equipment; • terrain, ecological and hydrological restrictions. This could be gained through financial support for new technologies, or by developing a track record for residue removal and publishing its findings.
Trade associations have said that restrictions on the use of productive land for forest means that forests are less productive than they could be. DAFM state that, 'While 4.65 million ha are considered as having good production potential for forestry, the availability of land for forestry is constrained by land already in agricultural production or land with environmental constraints for afforestation.'	Examine the need to restrict afforestation to marginal land, including the potential alternative uses of higher quality land. This should include assessment of the best use of land to meet all Irish needs.

[14] DAFM (2015). Afforestation Grant and Premium Scheme 2014 – 2020 Edition 2/2015.
[15] http://www.teagasc.ie/forestry/grants/thinning_broadleaves_grant.asp and http://www.teagasc.ie/forestry/docs/grants/Woodland_Improvement_Scheme.pdf

Supply-side barrier	Examples of potential measures to address barriers
Climate change impacts on forest-resource markets are not well understood. Increased storms are already affecting Irish forests and distorting market prices for wood. However, the long-term effects of climate change are not understood and mitigation/adaptation strategies are not available.	Assess long term climate change impacts and the way in which they may influence the Irish market for wood. Develop adaptation strategies to overcome market distortions.[16]
Infrastructural barriers	
Some forests are remote and difficult to forest. This affects an estimated 200,000m^3/annum on Coillte land alone.[17]	Accessibility is an important issue for forests and is being addressed through funding for access roads.[18] The need for accessibility should be emphasised at afforestation grant stage.
Supply chain development is still in its early stages, limiting access to markets and facilities (e.g. storage or drying, chipping, etc.).	Improve information on market access, market requirements (e.g. specifications) and market facilities. This can be through mechanisms such as databases of suppliers and users or virtual 'exchanges' for supply and investment grants for facilities such as drying and storage.
Market challenges	
Lack of market data, particularly on costs and biomass prices. This means that private forest owners may not be achieving optimum return from thinning and final harvest. There is no transparent price platform for biomass trade in Ireland. This means that forest owners do not understand the value of their forests (in terms of all markets for their roundwood).	Provide information to enable forest owners to understand the value of their resource. Provide improved access to market information, e.g. published price data for the spot market, market indices, etc. Provide information on market conditions that allow forest owners to understand the value of their resource and how markets change with time. Trade organisations have begun to publish price data, but this could be augmented with monthly updates (perhaps also including regional differences). Understanding how other similar markets work across Europe may help forest owners understand the Irish market.

[16] For example COFORD has produced a web based GIS tool CLIMADAPT to assess changes in species suitability under different climate change projections (http://www.coford.ie/researchprogramme/thematicareapolicyandpublicgoods/forestsandclimatechange/climadapt/).

[17] H. Philips. Personal communication, Jan. 2016.

[18] Priority Roads Programme (PRP) (DAFM, 2014).

Supply-side barrier	Examples of potential measures to address barriers
The long-term impact of international competition and international prices.	The market in industrial wood pellets is becoming increasingly international. This feeds markets such as co-firing in coastal regions. Other wood biomass fuels (e.g. chips) are also traded across Europe. The long-term impact of these markets on Irish wood biomass markets needs to be understood to provide confidence for afforestation now.
Inefficiencies resulting from fragmentation of the private sector forest resource. There are currently an estimated 18 to 19,000 forestry holdings, with an average size of 8 ha.[19] Consolidation of these resources would enable efficiencies of scale, particularly at establishment, harvest, and for issues such as access.	Encourage private forest owners to think in terms of co-operatives or producer groups, aiming at optimising resources and combining expertise (e.g. to improve the efficiency of planting, care and harvesting of their forests). Examine the cost effectiveness of pooling resources for development of access roads or the use of contractors. Demonstrate mechanisms that enable this. Encourage the establishment of Bioenergy Ireland,[20] as a means of mobilising supply. Monitor its effectiveness in this role.
Lack of understanding of the objectives of private forest land owners. Landowners invest in forestry for a variety of reasons, not always related to optimising final yield (financial or crop yield). For example Howley (2013) examined farm forest owners' ownership objectives and concluded that, for some forest owners, lifestyle and multifunctional benefits are as important as economic benefits.	Understanding the multiple motivations for planting forests, the multiple objectives of forest management, would help inform policies aimed at increasing timber supply. It would also provide insight on how different objectives affect resource availability, which would not only help plan supply, but also inform training needs, particularly to improve thinning.
Currently much of the inventory that is ready for harvesting is Coillte forest. Coillte own panel board mills and send sawlogs to saw mills. In the longer term a large proportion of Irish forest supply will be made available from private sector forest owners. This change may have an impact on traditional wood and biomass supply chains and prices.	Examine the impact of the change in inventory with time on supply availability and competition for supply.

[19] Forest Industry Transport Group (undated). Managing Timber Transport. Available at http://www.teagasc.ie/forestry/docs/advice/Managing%20Timber%20Transport%20-%20Good%20Practice%20Guide%20Volume%201%202014-1.pdf and COFORD (2015). Mobilising Ireland's forest resource.

[20] One of the decisions set out in the Draft Bioenergy Plan (DCENR, 2014) is the establishment of BioEnergy Ireland as a biomass joint venture between Bord na Móna and Coillte to procure biomass at market rates.

2.2 Methodology used to estimate resource availability

Ireland's forest resource is widely spread across the country,[21] and is split between Coillte-managed State forest resources and privately owned forest. The latter is increasing due to Government policies, including grants to support afforestation.[22] The long-term target is to have 18% of land cover as forest by 2050, and to support a long-term sustainable roundwood supply of 7 – 8 million cubic metres per annum (m^3/a).

The basis of the resource estimate is the estimate of net realisable volume that can be harvested developed by COFORD.[23] This estimates the potential harvest by size class based on:

- The known inventory and accessibility of Coillte forest.
- An estimated maximum volume from private sector forest, subject to sustainability and commercial constraints, taking the increase in private forest into account. Sustainability constraints relate to the need to keep inventory volume the same year on year. Commercial constraints relate to the need for the trees to grow to a certain diameter before they can be clear felled. These constraints apply to Coillte and private forest.
- The potential for thinnings from both Coillte and private sector land. This takes into account experience to date of private sector thinning operations.
- The amount of residues that could be obtained from the forest (taking the topography into account, particularly the need to leave residues on peat land forests).

Other non-energy uses of wood are then subtracted from the estimate of the net realisable volume. These are:

- Sawlogs: timber of a quality to be used as sawlogs is not currently used for energy and is unlikely to be in the future due to the high price it commands. Sawlog demand in 2020 is taken from the COFORD report on wood mobilisation.[24] Demand from 2020 to 2035 is extrapolated, assuming that the rate of growth per annum is half the rate of growth per annum assumed in the COFORD report. The growth rate was reduced on the basis that the growth rate from 2014 to 2020 will be higher, as this constitutes a recovery period for the economy. Large diameter timber not used for sawlogs ('downgrades') is considered to be available for other uses normally satisfied by smaller diameter timber (i.e. pulpwood).
- Pulpwood: other non-energy uses are pulp for panel board and stakewood. As with sawlogs, demand in 2020 for these uses is taken from the COFORD report on wood mobilisation, and demand from 2020 to 2035 is extrapolated assuming that the rate of growth per annum is half the rate of growth per annum assumed in the COFORD report.

2.3 Price

The cost of forestry can vary significantly; key variables that influence the cost of operations are, the scale of the operation, and the approach taken to harvesting, which influences the machinery used. For example, at a small scale, where individual trees are felled by chainsaw, manual labour will be higher. At a larger commercial scale, advanced forestry harvesting equipment can be utilised to fell, trim off branches, and load directly onto a forwarder that can transport timber to roadside lorries. The above factors are also all influenced by proximity to forest roads and the overall terrain of the forest.

For pulpwood/small roundwood, which is the category of wood that would be used for bioenergy, little published data on current prices could be found. Available data for pulpwood at the roadside are summarised in Table 2.3, and range from 2.6 to 4.3 €/GJ. For comparison the Biomass Trade Centre project quotes a price for bulk purchases of wood chips in Ireland in 2014 of €136/t, which is equivalent to €9.3/GJ.[25] It is not clear if this is a delivered price, but assuming that it is, and assuming

[21] ADAS (2014). Ireland's Forestry Programme 2014 – 2020: Appropriate Assessment, Natural Impact Statement.

[22] DAFM (Department of Agriculture Food and the Marine) (2014). 'Forests, products and people. Ireland's forest policy – a renewed vision'.

[23] Phillips, H. et al (2016). 'All-Ireland Roundwood Production Forecast 2016 – 2035'.

[24] COFORD Wood Mobilisation Group (2015). 'Mobilising Ireland's forest resource'.

[25] Quoted moisture content for wood chips at this price is 20% moisture. Biomass Trade Centre. Wood fuel prices – Report no. 6, March 2014.

that transport costs would be about 1.5 to 1.75 €/GJ,[26] this would give a roadside cost of 7.5 to 7.8 €/GJ, considerably higher than the values shown in Table 2.3.

An overview of the potential costs of extracting first thinnings from private forests is available from a COFORD report, which estimated costs based on trials of a variety of forestry harvesting techniques across a range of woodlands. Current operations in Ireland follow the shortwood harvesting approach, which was assessed as having costs in the 6 – 8 €/GJ range. Costs could be reduced down to less than 5 €/GJ by using the whole tree harvesting method, but this would require investment in advanced forestry equipment. Whole tree harvesting does not produce a brash mat for machinery to operate on, and while the trials conducted for the study found that this would be possible for most sites, the method would require acceptance by foresters who are sceptical about not utilising a brash mat.

On the basis of the costs discussed above, it is assumed that pulpwood of diameter > 7cm is typically available at 3.45 €/GJ, a mid-range price from the table above. Forest thinnings and forestry residues are assumed to be available in the short term at a price of 8 €/GJ (the higher price indicated from the COFORD trial) but over time this price will fall as investments are made in equipment for whole tree harvesting, so that by 2030, half of this resource is available at a lower price of 5 €/GJ.

Table 2.3: Reported prices for wood pulp or chips at roadside

Wood resource	Date	Price €/m3	Price €/GJ[a]	Source
Conifer pulp (<7cm)	2015	18-28	2.6-4.1	IFA[27]
Pulpwood roadside	2014	25	3.6	IHB[28]
Thinnings, roadside	2014	18-30	2.6-4.3	IHB[28]
Woodchips and pulpwood (private sector)	Dec. 2012	24-30	3.5 -4.3	Teagasc[29]

Notes: (a) Prices converted from m3 using an energy content of 6.9 GJ/m^3 [30]

The quantities available at different price levels in 2035 under the BAU scenario are shown in Figure 2.2.

[26] Based on transport contribution offered by Bord na Móna for energy crops of Transport of €1.50/GJ up to 25km from the power plant and €1.75/GJ for distances greater than 25km. As quoted in Rokwood (2015), 'Energy crops in Europe: Best practice in SRP biomass from Germany, Ireland, Poland, Spain, Sweden & UK'.

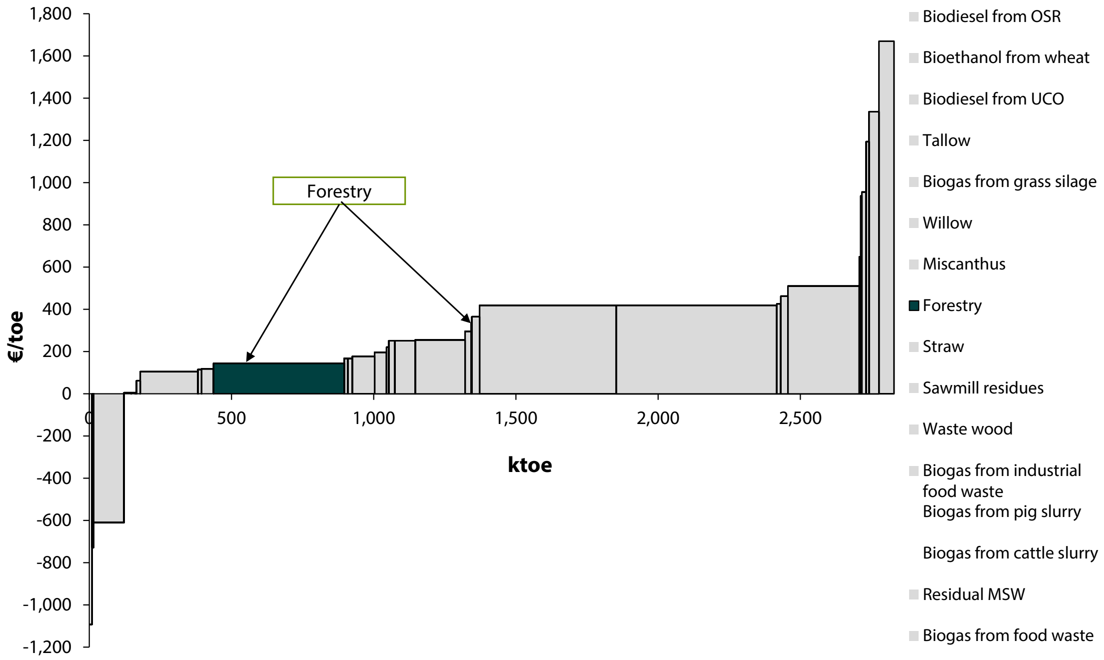
[27] IFA Farm Forestry Timber Market Report 2015 (IFA), see, for example: http://www.ifa.ie/market_reports/farm-forestry-timber-market-report/#.VpQQDfmLTrc

[28] http://www.ihb.de/wood/news/UK_Ireland_timber_prices_rise_37269.html

[29] Teagasc (2013). Forestry Economic Review 2012/2013.

[30] Derived from COFORD advice to H. Phillips as used in Phillips, H. (2011). 'All-Ireland Roundwood Production Forecast 2011 – 2028'.

Figure 2.2: Forestry in the bioenergy cost curve for 2035 (business as usual scenario)



3. Sawmill Residues

3.1 Overview

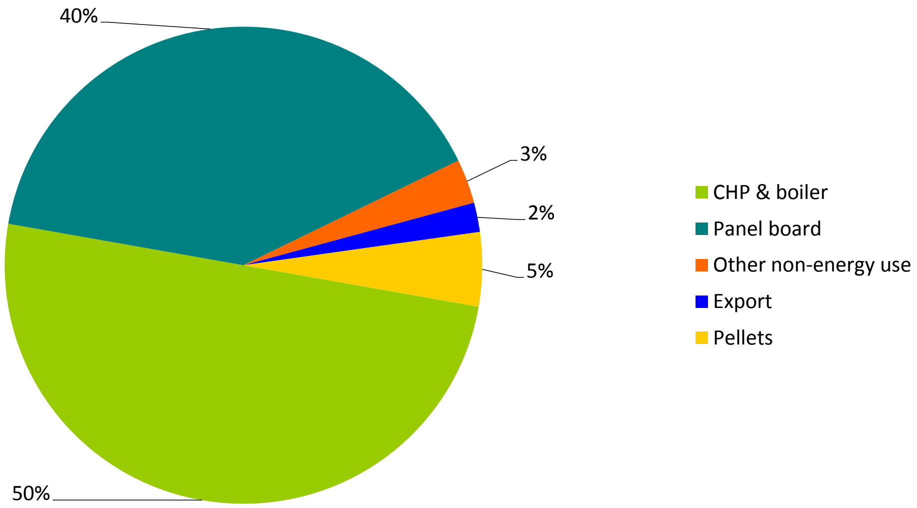
3.1.1 What is the resource and how can it be used?

When harvested timber is processed in a sawmill, wood chips, sawdust and bark are produced as well as the sawn timber. These wood chips, sawdust and bark are known collectively as sawmill residues. Panel board mills, if they debark small roundwood to produce wood chips for manufacture of the panel board on site, also produce bark and sawdust residues.

The residues can be used for energy, by combusting them in an appropriate plant to produce heat and/or power. In the case of wood chips and sawdust, they can also be processed into wood pellets, a fuel form which is more easily handled and transported, or briquettes.

There are a number of competing uses for sawmill residues: the largest is the use of woodchips for the production of panel board, but some is also used for animal bedding and, in the case of bark, as mulch. In 2014, of the 1,388,000 m^3 produced, 44% (595,000 m^3) went into non-energy uses – predominantly panel board manufacture.[31] Of the remaining 793,000m^3 (131 ktoe or 5,472 TJ), 88% (115 ktoe or 4,830 TJ) was directly used as a fuel for boilers or CHP plants, much of it within the timber and panel board industry and 9%, 12 ktoe (483 TJ), was used to produce wood pellets for combustion as a boiler fuel. The remaining 3% (4 ktoe or 159 TJ) was exported.

Figure 3.1: Use of sawmill and board-mill residues in 2014



Note: Total residues in 2014 were 1,388,000m³

3.1.2 How much resource could be available?

The quantity of sawmill residues produced depends on the throughput at sawmills. The quantity of board mill residues produced depends on the quantities of pulpwood debarked at the mill. The quantity available for energy purposes also depends on the size of competing markets.

COFORD[32] have estimated that throughput at sawmills and pulpwood debarking at board mills are likely to rise significantly by (27% and 20% respectively) between 2014 and 2020, as the economic recovery continues. As no projections were available post 2020, it was assumed that growth would continue, but at only half the rate forecast between 2014 and 2020, as the high growth rates seen in the recovery period would not be sustained in the longer term.[33] Quantities of sawmill residues

[31] COFORD Connect. 'Woodflow and forest-based biomass energy use on the island of Ireland' (2014), Gordon Knaggs and Eoin O'Driscoll.
[32] COFORD Wood Mobilisation Group (2015). 'Mobilising Ireland's forest resource'.
[33] The slower growth rate post 2002 (of 1.2%) is very close to the average growth forecast in the COFORD demand forecast made in 2011 for growth between 2011 and 2020, suggesting that this is a reasonable assumption for longer term growth rates.

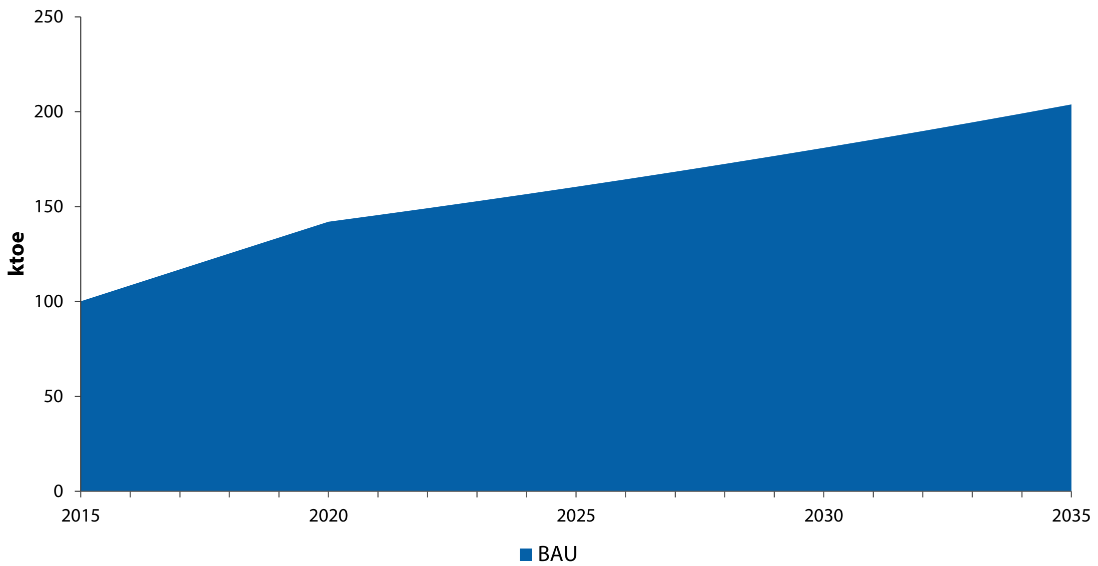
therefore rise significantly, and could provide 142 ktoe (5,947 TJ) by 2020, and 204 ktoe (8,535 TJ) by 2035 (Figure 3.2 and Table 3.1).

Table 3.1: Potential bioenergy resource from sawmill residues

	Unit	2020	2025	2030	2035
Business as usual scenario					
Sawmill residues	'000 m^3	862	974	1,098	1,237
Sawmill residues	ktoe	142	160	181	204
Final (delivered) energy					
Electricity only	ktoe	42.6 - 51.1	48.1 - 57.8	54.3 - 65.2	61.2 - 73.4
CHP	ktoe	42.6 - 56.8	48.1 - 64.2	54.3 - 72.4	61.2 - 81.5
Heat only	ktoe	56.8 - 56.8	64.2 - 64.2	72.4 - 72.4	81.5 - 81.5
Percentage of current gross final energy use[(a)]					
Electricity only	%	0.4 - 0.5%	0.4 - 0.5%	0.5 - 0.6%	0.5 - 0.7%
CHP	%	0.9 - 1%	1 - 1.1%	1.1 - 1.3%	1.3 - 1.5%
Heat only	%	0.9 - 1.1%	1.1 - 1.2%	1.2 - 1.4%	1.4 - 1.5%

Notes (a) Gross final energy use in 2014 was 11,243 ktoe

Figure 3.2: Potential bioenergy resource from sawmill residues



3.1.3 Supply-side barriers

As discussed above, all sawmill and board mill residues currently go to productive uses, with a substantial proportion already being used as a fuel. The resource that is available for energy use could potentially be increased if uses for non-energy markets were reduced. However for the main non-energy market (panel board manufacture) residues are an important feedstock, and it may not be desirable to divert this feedstock away from manufacture – particularly as the main substitute is likely to be pulpwood, which could itself form a useful bioenergy resource (see Section 2). In the estimates made above, it has therefore been assumed that demand from non-energy markets will be met.

3.2 Methodology used to estimate resource availability

The projection of the sawmill residue forecast is based on estimates made by COFORD[34] of future throughput at sawmills in Ireland and pulpwood used by panel board manufacturers. These are combined with values for the average ratio of residues generated to wood processed from 2010 to 2014, extracted from information on wood flows in Ireland.[35] The COFORD forecast was extended from 2020 to 2035, assuming the same per annum growth as contained in the forecast for 2014 to 2020.

Current non-energy uses of sawmill residues are bark mulch, animal bedding, and the panel board sectors. Levels of demand are assumed to remain constant for bark mulch and animal bedding at the average levels seen between 2010 and 2014. Demand in the panel board sector is assumed to rise as forecast by COFORD to 2020, with the same per annum growth as contained in the forecast for 2014 to 2020, assumed for the period 2020 – 2035.

3.3 Price

The current wide-scale usage of residues as a fuel (Section 2.3) indicates that they are likely to have a lower market price than wood chips produced from small roundwood. As much of the residue is used directly by sawmills and panel board mills to produce heat for the production processes, prices for residue are not reported. However, as the residues are essentially a by-product of the main production process, the prices are believed to be relatively low. A value of €2.5/GJ (€105/toe) is therefore assumed for all sawmill residues to reflect the lower price of residues compared to forestry wood chip. For reference, as discussed in Section 2.3, it is known that forestry woodchips are traded at between €6/GJ and €9/GJ.

[34] COFORD Wood Mobilisation Group (2015). 'Mobilising Ireland's forest resource'.
[35] COFORD Connect (2010 – 2014). 'Versions of woodflow and forest-based biomass energy use on the island of Ireland', Gordon Knaggs and Eoin O'Driscoll.

4. Waste Wood

4.1 Overview

4.1.1 What is the resource and how can it be used?

Waste wood (sometimes referred to as post-consumer recycled wood or PCRW) arises from a number of different sources and, importantly, is of differing quality. The quality of the wood determines the application it can be used for, which in turn influences its price. Four types of waste wood are potentially available for use for bioenergy.

- **Commercial packaging**: arising from any commercial sector where wooden protective packaging, or pallets, are used. This waste wood is generally clean and, as well as being used for bioenergy, is suitable for other uses such as producing animal bedding and mulches, or for producing panel board.
- **Wood recovered from kerbside collections of waste from households**: mixture of wood that is generally domestic packaging of mixed quality.
- **Civic amenity collection**: waste wood that is collected from household waste collection centres. Typical sources would be old wooden furniture. Most of this resource has been treated with paints or preservatives at some point.
- **Construction and demolition**: typically offcuts from wooden beams, doors or temporary wooden boarding. This wood is often a mixed combination of clean waste wood, waste wood that has been treated with paints or preservatives and MDF, which contains solvents.

Waste wood that is contaminated with, for example, paints or preservatives will need to be burnt in plants that have advanced emission scrubbing equipment and comply with the Industrial Emissions Directive (2010/75/EU). This emission abatement equipment is essentially an add-on to a combustion plant where the exhaust (flue) gases are filtered to remove harmful particulates. The equipment is expensive to install and operate and is normally associated with more stringent licensing requirements to ensure air quality targets are met. This equipment and licensing requirement results in additional costs to the plant operator, and mean that the price for contaminated wood is lower than for cleaner packaging wood waste.

4.1.2 How much resource could be available?

Information from the National Waste Report[36] on the amount of waste wood in each of the categories above was combined with trends in the production of waste to forecast future quantities of wood waste. Quantities of packaging wood that are currently recycled for other non-energy uses were then removed, giving an estimate of waste wood available for bioenergy. This rises from 26.4 ktoe (1,104 TJ), in 2020, to 33.2 ktoe (1,292 TJ in 2035).

4.1.3 Supply-side barriers

The main supply-side barriers to utilisation of this resource are:

Market related: competing demands from other non-energy sectors.

Infrastructure: lack of re-processing capability – the infrastructure required to enable waste wood to be separated from mixed waste. For many sectors this is simply a case of separation at source, followed by processing to an appropriate form for bioenergy. For other sectors, such as the municipal sector, a new collection and processing sector will need to be developed if all suitable wood from municipal waste is to be obtained.

[36] EPA (2014). National Waste Report 2012.

Figure 4.1: Potential bioenergy resource from waste wood

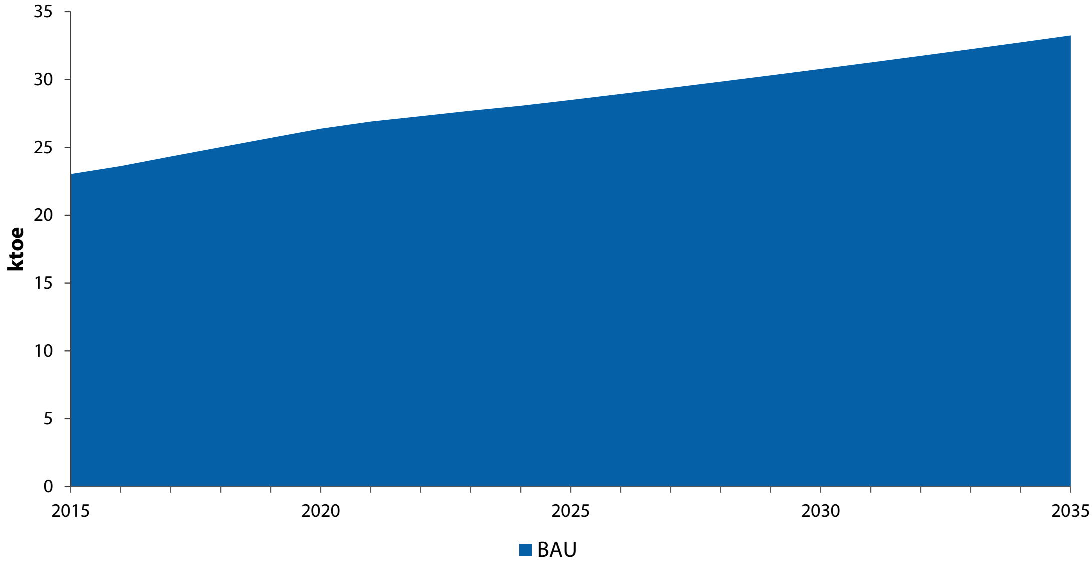


Table 4.1: Potential bioenergy resource from waste wood

	Unit	2020	2025	2030	2035
Business as usual scenario					
Waste wood	kt	75.1	81.2	87.7	94.7
Waste wood	ktoe	26.4	28.5	30.8	33.2
Final (delivered energy)					
Electricity only	ktoe	7.9 - 9.5	8.5 - 10.3	9.2 - 11.1	10 - 12
CHP	ktoe	7.9 - 10.6	8.5 - 11.4	9.2 - 12.3	10 - 13.3
Heat only	ktoe	10.6 - 10.6	11.4 - 11.4	12.3 - 12.3	13.3 - 13.3
Percentage of current gross final energy use[(a)]					
Electricity only	%	0.1%	0.1%	0.1%	0.1%
CHP	%	0.2%	0.2%	0.2%	0.2%
Heat only	%	0.2%	0.2%	0.2%	0.2 - 0.3%

Notes (a) Gross final energy use in 2014 was 11,243 ktoe

4.2 Methodology used to estimate resource availability

Quantities of waste wood in municipal solid waste (MSW) – the waste collected from households and some commercial premises – were calculated for 2012 from the quantity of MSW and composition of waste given in National Waste Report 2012.[37] Projections of the total quantity of municipal waste generated are taken from the Economic and Social Research Institute's Sustainable Development Model for Ireland (ISus) as reported in the Environmental Protection Agency's National Waste Report.[38] The forecast was extended from 2025 to 2035 based on the growth rate from 2025 to 2030. It was assumed that 50% of the waste wood in the MSW stream might be made available from energy use (e.g. through encouraging householders to separate out wood waste and take it to civic amenity sites, or through separation and recovery of the wood at MRF plants).

Waste wood collected at civic amenity sites in 2012 and packaging wood waste are taken from the National Waste Report 2012, and wood in construction and demolition waste from the National Waste Report 2011. All three waste streams are assumed to grow at the same rate as MSW. Quantities of packaging wood, which are recycled for non-energy use, are subtracted from the total quantity of

[37] EPA (2014). National Waste Report 2012.
[38] EPA (2012). National Waste Report 2010.

waste wood to give the available resource. Quantities for non-energy uses in 2012 are reported in the National Waste Report and it is assumed that the same percentage (82%) of packaging wood goes to non-energy uses in the future.

4.3 Price

Wood recyclers generally charge a gate fee for accepting low grade waste wood. No data could be found on these gate free prices in Ireland but for the UK a typical gate fee might be €18/t (1.2 €/GJ),[39] i.e. those wishing to dispose of low grade wood to the wood recycler would have to pay this fee for the recycler to accept the wood. In contrast, suppliers of higher grade clean wood could expect to receive a price from the recycler of €18/t (1.2 €/GJ). Prices that the wood recycler will charge for then supplying the wood to an energy user will be higher than these gate fees. Again no data could be found for the Irish situation so prices from the UK have been used as a proxy. Recent data from wood recyclers in the UK suggests they are receiving 22 to 40 €/t (1.5 to 2.7 €/GJ) for low grade wood and 78€/t (5.3 €/G) for high grade wood.

[39] WRAP (2011). 'Realising the value of recovered wood'.

5. Annual Crops for Biofuels – Wheat and Oil Seed Rape

5.1 Overview

5.1.1 What is the resource and how can it be used?

Conventional arable crops can be used as feedstocks for biofuels. Starch crops such as wheat can be fermented to produce bioethanol (a substitute for petrol), and oil from oil seed rape (OSR) can be converted to biodiesel. Both wheat and OSR are currently grown in Ireland, but are used for food and fodder or exported; none is used for biofuels production domestically.[40] No crushing facilities for OSR for bioenergy production are currently operating in Ireland. Additional production of these crops for the energy market can be done using the equipment, techniques and expertise already available on arable farms, but depend on the availability of suitable land, possible competition with food uses of the crops, and the security and profitability of the energy market for these crops.

5.1.2 How much resource could be available?

The Food Wise 2025 strategy and Teagasc's Tillage Sector Development Plan[41] (Teagasc, 2012) both assume a substantial increase in the arable area (of between 170,000 to 200,000 ha) through the conversion of grassland, much of which is currently under-utilised. Assuming that the projected increase in the wheat area (14,000 ha) in the tillage development plant will be surplus to food and feed requirements, 22.4 ktoe (938 TJ) of bioethanol could be produced by 2020 if processing facilities were available. However these quantities are insufficient to support a viable standard bioethanol plant, and any such plant located in Ireland would therefore have to import a proportion of the feedstock to meet feedstock volume requirements.[42] Advanced biofuels plants are under development which can use lignocellulosic materials in the ethanol fermentation process by pre-processing them. Some existing bioethanol plants are expanding to include a capability to pre-process lignocellulosic material and utilise it within the existing grain fermentation process. However it is unlikely, given sustainability concerns about using food crops for biofuels, and the increasing emphasis on using waste and residues for biofuels production, that any **new** advanced biofuels plants would be based on the combined use of grains and residues.[43]

Table 5.1: Potential biofuels resource from wheat and oil seed rape

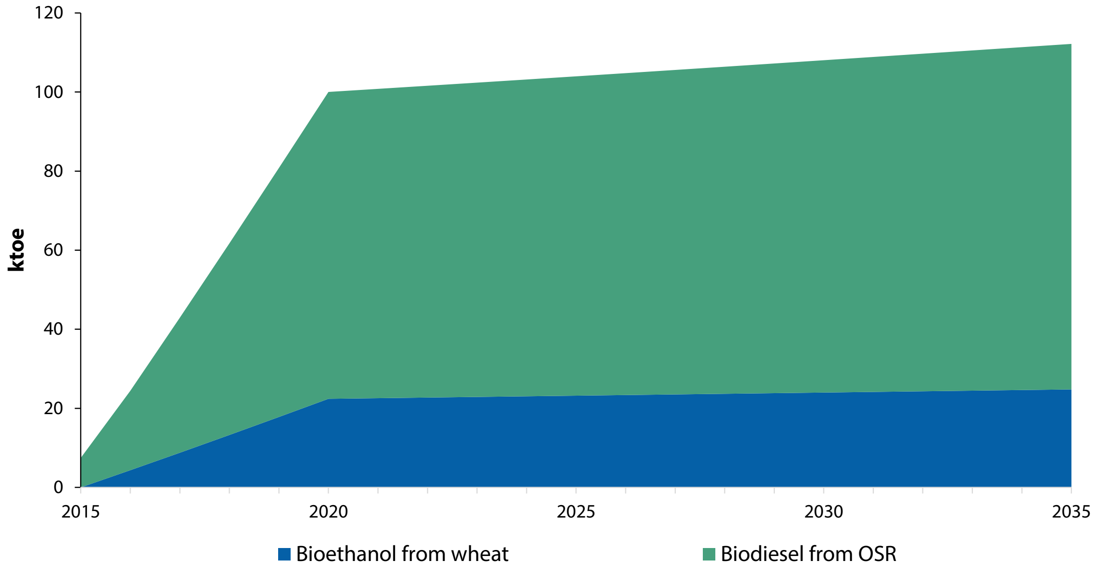
	Unit	2020	2025	2030	2035
Wheat	kha	14.0	14.0	14.0	14.0
OSR	kha	59.9	59.9	59.9	59.9
Wheat	kt	119.0	123.2	127.4	131.6
OSR	kt	233.5	243.0	252.9	262.9
Final (delivered) energy					
Bioethanol from wheat	ktoe	22.4	23.2	24.0	24.8
Biodiesel from OSR	ktoe	77.6	80.8	84.0	87.4
Total biofuels	ktoe	100.0	104.0	108.0	112.2
Percentage of current gross final energy use[(a)]					
Bioethanol from wheat	%	0.2%	0.2%	0.2%	0.2%
Biodiesel from OSR	%	0.7%	0.7%	0.8%	0.8%
Total biofuels	%	0.9%	1.0%	1.0%	1.0%

Note: Gross final energy use in 2014 was 11,243 ktoe

[40] Barry Caslin (Teagasc), 28 October 2015.
[41] Teagasc (2012). Tillage Sector Development Plan: A Plan for the Development of the Irish Tillage Crop Sector.
[42] Bioethanol plants are typically large to take advantage of economy of scales. European plants using wheat or sugar beet as feedstock are most relevant to Ireland, and typical plants in Europe have capacities in the range of 100,000 to 300,000 tonnes ethanol per annum. Factbox: Bioethanol plants across Europe, http://www.reuters.com/article/us-biofuels-europe-bioethanol-idUSTRE6172JX20100208. Identification and mapping of existing fuel producing industrial complexes in Europe. http://www.bioref-integ.eu/fileadmin/bioref-integ/user/documents/D1total.pdf
[43] Advanced biofuels also rely on economies of scale for viability and even a small 75,000 tpa plant would require about 320,000 tpa of straw, which is more than the current straw resource in Ireland.

If production from all of the area assumed to be growing OSR by 2020 (59,900 ha) could be processed into biodiesel, this would allow the production of 77.6 ktoe (3,249 TJ) of biodiesel.

Figure 5.1 Potential biofuels resource from wheat and oil seed rape



5.1.3 Supply-side barriers

While OSR is a useful break crop in Ireland, its current price (as determined by the international market) is too low to make it an attractive crop. The lack of an operational crushing facility in Ireland, means that what OSR is grown has to be exported for processing. The quantities of OSR that could be produced in Ireland would be enough to support a medium scale biodiesel plant or a number of small scale plants. However the current market prices for biodiesel are not high enough to make such investments attractive.

5.2 Methodology used to estimate resource availability

5.2.1 Theoretical resource estimate for OSR and wheat

A small amount of OSR is currently grown in Ireland (9,400 ha in 2014), although previous years have seen slightly higher levels (e.g. 17,500 ha in 2012). Expansion of OSR areas beyond these levels has not occurred largely due to economic reasons; production costs of OSR in Ireland are higher than the market price that prevails elsewhere so that cultivation is not competitive internationally. However, there is considerable theoretical potential for OSR as about 1.8 million ha[44] in the arable area of Ireland is suitable for production of OSR at acceptable yields (of at least 4.5 t/ha).

OSR is typically planted for one year after three successive years of cereal sowings in order to minimise pest and disease pressure and to maximise yields. This means that the current OSR area could be increased to an area that is 25% of the current cereal area; but that any subsequent increases in area must be accompanied by increases in the cereal area.

As discussed in 6.2.1, an additional 350,000 ha of land has been identified as potentially available from the conversion of permanent pasture. The maximum amount of land which could be converted to OSR as a break crop is therefore 25% of the existing cereal area of 300,000 ha (i.e. 60,000 ha), plus 25% of the additional 350,000 ha (i.e. 88,000 ha), giving a total maximum potential of 148,000 ha. This amount of production would imply an additional cereal (wheat) production on 262,000 ha, which could be used for bioethanol.

5.2.2 Accessible resource estimate for OSR and wheat

The estimate of the theoretical resource above would require a doubling of the tillage area in Ireland. The estimate of the accessible resource to 2035 is based on the more conservative estimates of the

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[44] Based on data from http://www.seai.ie/Renewables/Bioenergy/Information_and_Resources/Bioenergy_Mapping_System/

expansion of crop areas that are contained in the tillage sector development plan[45] (Teagasc, 2012). This suggests that, in total, the tillage area for arable crops could be increased by 160,000 ha, from 2008/11 levels, by 2020. This is consistent with work done for Food Wise 2025, which estimated an increase in tillage area of 170,000 ha by 2025. The tillage sector plan suggests increases, from 2008/11 areas, of 14,000 ha for wheat and 51,800 ha for OSR are possible by 2020, although notes that profitable markets will be required, together with technical support across the value chain and in some cases political support at the national or international level, in order to realise these potentials.

OSR and wheat produced on these areas are estimated using yields assumed in forecasts made using the FAPRI model for the Food Harvest 2020 strategy[46], and biofuels production is estimated using typical conversion efficiencies.[47] It is assumed sufficient machinery, seed and labour are available to achieve the above levels of planting of OSR or wheat since there is a mature international market in these commodities.

5.2.3 Other potential arable crops for energy

Other arable crops that could be used for bioenergy are sugar beet and maize. Both can be anaerobically digested, to produce biogas; sugar beet can also be used as a feedstock for bioethanol. Beet is well suited to the Irish climate, and farmers have substantial experience in growing it, but since the removal of the sugar quota, only small quantities of beet are grown for fodder. Producing enough sugar beet to support a bioethanol plant would require restarting a large scale sugar beet industry in Ireland, but smaller quantities could be co-digested (e.g. with slurry) in anaerobic digestion plants, if this was financially viable. The tillage sector development plan estimated that beet areas could be almost quadrupled from 2008/11 production levels to 1.8 Mt by 2020.

Current varieties of maize can be difficult to grow successfully in the Irish climate, although the tillage sector development plan foresees a 50% increase in maize production by 2020. If this additional maize were not required for fodder, then it could be used in AD plants if this was financially viable.

5.3 Price

To achieve the planting areas discussed above would require substantial and sustained price increases from current levels. Table 5.2 shows the range of prices that could prevail for wheat and OSR. The low price is typical of the current market price for the crop in Ireland [48] and the two higher price levels are based on the range of prices achieved for EU crops over the past two years.[49] The first column shows the farm gate price of the crops, and the second column the contribution of feedstock price to the price of the biofuel, based on the quantity of crop required to produce a tonne of oil equivalent (toe) of biofuel. For both bioethanol and biodiesel the feedstock price is the dominant component of the biofuel price, so the plant profitability is vulnerable to fluctuations in the market price of feedstocks. Plant operators will therefore aim at securing a proportion of their feedstock from supply contracts that provide price visibility in the medium term. Table 5.2 also shows the percentage of the accessible resource that Ricardo Energy & Environment estimate would be available for energy use if the energy plant operators were prepared to pay the low, medium and high feedstock prices respectively. These estimates are based on recent behaviour of current operating bioethanol and biodiesel plants as international feedstock prices fluctuate. In particular, if bioenergy plants are only prepared to pay a low price for the feedstock, they will not be able to secure a supply with sufficient reliability to make them viable.

[45] Teagasc (2012). Tillage Sector Development Plan: A Plan for the Development of the Irish Tillage Crop Sector.
[46] FAPRI (2011) data provided by Teagasc for Food Harvest 2020 Scenario.
[47] Biofuels yields taken from UK and Ireland Carbon Calculator 7.00 (build 118).
[48] 'Crops costs and returns 2014', Teagasc and 'Area under oil seed rape falls by more than half in 3 years', Agriland, June 27, 2015.
[49] FPMA bulletin, monthly report on food price trends, Dec. 15; 'Short term outlook for EU arable crops, dairy and meat markets in 2015 and 2016', EC, Winter 2015. 'Outlook for global oilseed prices this season'. 4 September 2014, AHDB.

Table 5.2: Price assumed for biofuels resource

Crop	Price €/t of crop	Equivalent price €/toe of biofuel*	Equivalent price €/GJ of biofuel*	% of accessible resource available at price (all years)
Wheat	150	796	19	0%
	180	955	23	60%
	225	1194	29	100%
OSR	300	903	22	0%
	444	1336	32	40%
	555	1670	40	100%

For feedstock element only i.e. not including conversion costs

6. Perennial Energy Crops

6.1 Overview

6.1.1 What is the resource and how can it be used?

Perennial energy crops suitable for cultivation in Ireland are miscanthus (a woody rhizomatous grass) and willow grown using a short rotation coppice (SRC) technique. These crops can be grown on arable land or reasonable quality permanent pasture. The planting, cultivation and harvesting of these crops requires specialised equipment, techniques and planting material. Establishment requires intensive effort and agrochemical input, but thereafter perennial crops require less input in agrochemicals and labour than annual crops. Once planted they take up to four years to reach maturity, after which they are harvested at regular intervals – typically every year for miscanthus and every four years for willow SRC. After about 20 to 25 years the crop is removed and replanted, and then the harvesting cycle begins again.

Wood from SRC is suitable for use in boilers to produce space, water and process heat SRC can also be combusted to produce electricity in a purpose built plant, or can be used in a combined heat and power (CHP) unit to produce both heat and electricity. SRC can also be co-fired in existing power plant in Ireland. Miscanthus however, while suitable for combustion in purpose designed plants, cannot be co-fired in the existing peat fired power plant in Ireland due to its chlorine content.[50] Wood and miscanthus may also be converted into renewable transport fuels by using advanced techniques that are currently at the demonstration stage in Europe and the USA.

Only small areas of energy crops have been planted to date, about 939 ha of SRC and 2,414 ha of miscanthus.[51] Although willow is only harvested every four years, when the quantities harvested are averaged out over this four-year period, it typically delivers the same yield as miscanthus, which is harvested every year. Both crops are capable of yielding about 10 oven dried tonnes per ha per year (odt/ha/y) [52] [53] so the quantities currently planted could produce about 33,000 odt annually, equivalent to 15 ktoe (617 TJ).

6.1.2 How much resource could be available?

The theoretical potential for perennial energy crops is high, with at least two million ha of land suitable for SRC and miscanthus production across Ireland. The majority of grassland is currently used for livestock production in Ireland, but Food Wise 2025 suggests that improved utilisation of grassland could support increased livestock production and also make substantial areas of pasture land available for conversion to arable land. Some of this converted pasture land could be used for growing energy crops. Based on forecasts of the land that could be available, the overall limit on conversion of pasture land imposed by the Common Agricultural Policy, and giving priority to additional land for annual crops, it is estimated that in total 203,000 ha could be available to grow SRC willow and miscanthus. It will take time for the immature and specialised supply chain to develop, so it would require several years to plant such an area. By 2020, it is estimated that energy crops could produce approximately 12 ktoe (490 TJ) of SRC and miscanthus under a business-as-usual scenario; under an enhanced scenario, where planting expands at a faster rate, 15 ktoe (617 TJ) could be available. By 2035, if actions were taken to encourage the development of energy crops, it is considered that all of the available 203,000 ha could be utilised, and 1,167 ktoe (48.855 TJ) of SRC and miscanthus could potentially be available (Figure 6.1 and Table 6.1).

[50] Personal communication. John Halloran (Bord na Móna). 9 December 2015.
[51] Personal communication. Barry Caslin (Teagasc). 20 October 2015. About 1,000ha of miscanthus has been removed in 2013/2014.
[52] The mass and energy content of woody energy crops depends on their moisture content. Yield and energy content are therefore expressed using odt, the mass at zero moisture content.
[53] John Finnan. Personal communication. SEAI bioenergy GIS tool: http://www.seai.ie/Renewables/Bioenergy/Information_and_Resources/Bioenergy_Mapping_System

Figure 6.1: Potential energy crops resource

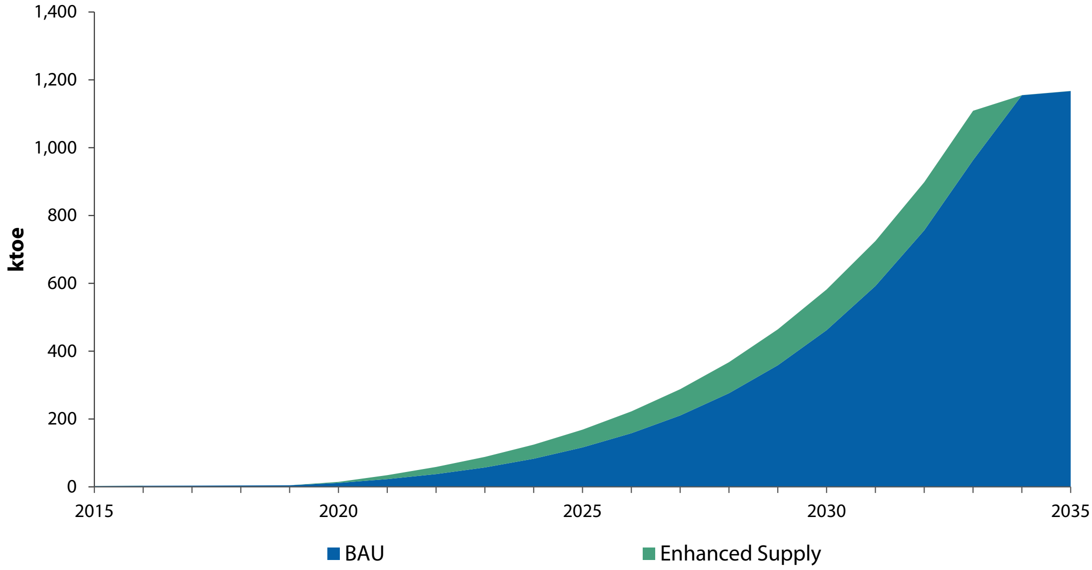


Table 6.1: Potential energy crops resource

	Unit	2020	2025	2030	2035
Business as usual scenario					
Energy crops	'000 odt	26	256	1,018	2,571
Energy crops	ktoe	12	116	462	1,167
Final (delivered) energy					
Electricity only	ktoe	4 - 4	35 - 42	139 - 166	350 - 420
CHP	ktoe	8 - 9	81 - 93	323 - 370	817 - 934
Heat only	ktoe	9 - 10	87 - 99	347 - 393	875 - 992
Percentage of current gross final energy use[(a)]					
Electricity only	%	0%	0.3 - 0.4%	1.2 - 1.5%	3.1 - 3.7%
CHP	%	0.1%	0.7 - 0.8%	2.9 - 3.3%	7.3 - 8.3%
Heat only	%	0.1%	0.8 - 0.9%	3.1 - 3.5%	7.8 - 8.8%
Enhanced supply scenario					
Energy crops	'000 odt	32	372	1,283	2,571
Energy crops	Ktoe	15	169	582	1,167
Final (delivered) energy					
Electricity only	ktoe	4 - 5	51 – 61	175 – 210	350 - 420
CHP	ktoe	10 - 12	118 – 135	407 – 466	817 - 934
Heat only	ktoe	11 - 13	127 – 143	437 – 495	875 - 992
Percentage of current gross final energy use[(a)]					
Electricity only	%	0%	0.5%	1.6 - 1.9%	3.1 - 3.7%
CHP	%	0.1%	1.1 - 1.2%	3.6 - 4.1%	7.3 - 8.3%
Heat only	%	0.1%	1.1 - 1.3%	3.9 - 4.4%	7.8 - 8.8%

Notes: (a) Gross final energy use in 2014 was 11,243 ktoe

6.1.3 Supply-side barriers

In current conditions, support will be required on both the supply and demand side to establish a perennial crop production industry in Ireland. This study investigates the bioenergy supply that might be achieved in the context of a robust bioenergy market in Ireland. Table 6.2 below highlights the main supply-side barriers and possible areas where intervention may be helpful. Organisations such as Teagasc are already aware of many of these barriers and have taken steps to provide information and training, for example producing best practice guidelines for both SRC and miscanthus.[54]

Table 6.2: Potential supply-side barriers for energy crops

Barrier type	Main barriers	Examples of types of interventions which could address barrier
Market/ Financial	Perception of risk and uncertainty. Requirements for up-front investment and cash flow issues in early years.	Good practice case studies. Financial instruments.
Policy/ Regulation	Long-term policy uncertainty. Mismatch with incentives for competing land uses.[55]	Review incentives for bioenergy in context of incentives for forestry and land rental sectors.
Technical	Immature supply chain for equipment and planting material. Lack of experience with crops.	Training and good practice dissemination. Clear quality standards for crops.
Infrastructure	Lack of local collection and distribution facilities	Support for expansion of local trading centres.

6.2 Methodology used to estimate resource availability

6.2.1 Availability of land

The SEAI suitability mapping tool[56] shows that large areas of land across the whole of Ireland have high or medium suitability for growing perennial energy crops. Just drawing on the pool of land for medium suitability land (assuming that high suitability land would be preferentially used for arable crops) gives an estimate of about two million ha grassland suitable for perennial crops. The majority of grassland in Ireland is currently used for livestock production, but studies have shown that the grassland could be used more efficiently by increasing utilisation and increasing grass productivity.[57] This would allow substantial areas to be released for conversion to other uses, even with the increase in herd numbers forecast in Food Wise 2025. The areas potentially available are discussed in detail in Section 7.2. Under the Common Agricultural Policy (CAP), a maximum of 10% of existing permanent grassland (about 350,000ha in Ireland) could be converted to tillage. Of the 350,000ha new tillage area potentially available, about 160,000 ha is required to meet the desired expansion in arable crops set out in the Tillage Sector Development Plan and Food Wise 2050, leaving 190,000 ha for growing perennial energy crops. It is also possible that up to 5% of existing arable land could be converted to energy crops as part of the CAP Ecological Focus Areas (EFA) scheme. This could provide an additional 23,000 ha by 2020, giving a total potential land area for energy crops of 203,000 ha by 2020. This potential will not increase to 2035 unless future negotiations under CAP allow more conversion of grassland to tillage after 2020.

[54] Teagasc (2015). Short Rotation Coppice Willow: Best Practice Guidelines and Miscanthus: Best Practice Guidelines. Available at http://www.teagasc.ie/publications/

[55] Current regulation makes use of sewage sludge as fertiliser for energy crops very difficult. Details given in Appendix 3.

[56] http://www.seai.ie/Renewables/Bioenergy/Information_and_Resources/Bioenergy_Mapping_System

[57] McEniry et al. (2103) 'How much grassland biomass is available in Ireland in excess of livestock requirements?' Irish Journal of Agriculture and Food Research 52.

6.2.2 Supply-side constraints to development

Planting rates of perennial crops in Ireland have been very low over the period 2007 – 2014 showing a maximum of about 185 ha/y for willow and 775 ha/y for miscanthus in this period. Low planting rates have also been seen in the UK over the same period.

Perennial crops are known to have high establishment costs, and do not provide an income for the first three to four years while they are maturing. The initial costs and poor cash flow in early years are therefore a barrier to perennial crop supply. However, a planting grant has been available for SRC and miscanthus, which is designed to help overcome the high establishment costs of these crops. The low planting rates cannot therefore be attributed solely to this issue.

Teagasc have identified a number of non-financial issues that currently constrain energy crops development in Ireland.[58] These include both supply and demand side constraints. The main demand side constraint is the lack of an established/ secure/ long-term market**.** Due to the long-term nature of the commitment to SRC/miscanthus it is crucial for farmers to see a profitable long-term market. A robust and diverse market would also reduce the risk in supplying these crops. This study is focussed on bioenergy supply and supply-side constraints, so we do not consider demand side constraints further.

The supply-side constraints identified were summarised above, in Table 6.2, together with examples of the types of interventions that could help to address the barriers. There are some differences for constraints between SRC and miscanthus. For miscanthus farmers have lost confidence in the crop due to expected yields not being achieved in some cases, and miscanthus not being a suitable feedstock for co-firing in the existing peat power stations in Ireland, which has meant lack of a current market for the crop.

The main constraints for SRC are the lack of attractiveness to Irish landowners of the crop compared to alternative enterprises,[59] the lack of infrastructure for trade of biomass crops and concerns about the long-term nature of the crop leading to a loss of alternative opportunities.

6.2.3 Planting rate constraints

As discussed above the planting rates of miscanthus and SRC have been very low to date, so have not been constrained by the immature production services industry (specialist equipment, planting material and specialist contractors) in the UK and Ireland. However, it is expected that if farmer interest were high, the planting rate would be constrained by the availability of these services. It is assumed that in the case of high farmer interest and strong crop demand the planting rate would be constrained, by the availability of specialist equipment and services, to 2,500 ha/y each for SRC and miscanthus in 2017, and that this could rise by a maximum of 20% per year. These maximum rates are based on a consideration of the current state of development of the industry and the proportion of this capacity that may be available for planting in Ireland. This planting rate constraint is applied in all scenarios, and effectively caps the growth of energy crops in some of the higher price scenarios.

6.2.4 Yields

The quantity of energy crops which would be available is estimated from the cumulative area planted in each scenario at each price point and the yield of the crop. This is taken as 10 odt/ha, currently rising linearly to 12 odt/ha y by 2030, with the rate of increase maintained to 2035. Quantities produced are based on the cumulative area planted four years previously to take account of the time needed for the crop to become productive.

6.3 Price

An important consideration in the production of energy crops is whether they are more profitable for farmers than existing enterprises. The modelling considers the quantity of energy crops which could be available at three price points: €4/GJ, €6/GJ and €10/GJ (about €75/odt, €110/odt and €180/odt,

[58] Energy Crops in Ireland, Teagasc.
[59] Mismatch of incentives for alternative land uses include tax incentives for forestry, land rental and bioenergy production. Details given in Appendix 4.

respectively for both SRC and miscanthus).[60] These price levels have been chosen based on work which suggests (see Box 6.1) that:

- At €4/GJ (€75/odt) energy crops give returns superior to low profitability enterprises, such as beef production, and are similar to returns from renting out grassland.
- At €6/GJ (€110/odt) returns will be comparable to those from winter wheat.
- At €10/GJ (€180/odt) returns will be comparable to the most profitable enterprise, dairy production.

Box 6.1: Profitability of perennial energy crops

One measure farmers use to compare profitability is annual gross margin per hectare of land, where gross margin is defined as the sale price of the crop minus the variable costs, such as sprays, fertiliser, and seed used in production. Since perennial crops take up to four years to become established and produce a harvestable crop, and may not be harvested every year throughout their lifetime, an annualised discounted gross margin is calculated based on the returns from the crop over the whole lifetime of the plantation. This annual equivalent is compared with competing annual crops.

A recent comparison of profitability of crops at the current prices by Teagasc (Thorne, 2011),[61] reflects the situation at prices of about €4/GJ, when an establishment grant of €1300/ha is included. Assuming yields of 10 odt/ha/y for SRC and miscanthus from the second harvest onwards, the annualised discounted gross margin[62] (the difference between income received for the crop and the variable costs of growing the crop) for miscanthus is estimated to be €370/ha and for SRC to be €300/ha. The paper shows that, at these prices, gross margins for SRC and miscanthus are superior to low profitability enterprises such as beef production (about €200/ha/y more), similar to renting out grassland, and less than cereal production (about €200/ha/y less for winter wheat). The paper estimates that even with a 10% increase in beef prices, biomass looks attractive and concludes that on the basis of profitability alone, beef farmers should seriously consider converting some of their land to energy crops.

Based on work produced by Trinity College (Styles 2007),[63] it is estimated that at €6/GJ biomass returns will be comparable to those from winter wheat, and that at €10/GJ returns will be comparable to the most profitable enterprise, dairy production. This agrees with analysis by Teagasc that biomass prices would need to reach at least €130/t at 20% moisture (about €9/GJ) before farmers would consider switching land from cereals to biomass.

In addition to gross margin considerations, the impact of tax incentives for different enterprises should be taken into account. Although energy crops and renting out land are comparable on a gross margin basis, tax breaks are available for long-term land rental agreements that make these more attractive to farmers, particularly the large number of older farmers. The tax situation for energy crops also compares unfavourably with forestry.[64] Details of the tax comparison are shown in Appendix 4.

Although grants have been available for the establishment of energy crops, the scheme is under review and not currently available.[65] In addition, there is a gap of up to three years between establishment and first harvest, during which there is no income from the crop. A support scheme to cover establishment, and to guarantee annual income, would overcome this issue.

Current farm gate prices available in Ireland for SRC (Bord na Móna)[66] are €38/tonne at 55% moisture (equivalent to €84/odt) for SRC chips. There is currently no market for miscanthus in Ireland. However,

[60] For SRC and miscanthus the price is often expressed as €/oven dry tonne (odt), which is the price of a tonne of biomass at zero moisture content. This convention is used because the moisture content of SRC and miscanthus and can vary markedly, from up to 55% moisture for freshly harvested green biomass down to 10% moisture in processed biomass. One odt has an energy content of 19 GJ.
[61] Thorne, 2011. 'Financial returns from biomass crops: A comparison with Conventional agricultural systems'. Bord Na Móna meeting Sept. 2011.
[62] Farm Gross Margins provide a simple method for comparing the performance of enterprises that have similar requirements for capital and labour. A gross margin refers to the total income derived from an enterprise less the variable costs incurred in the enterprise.
[63] Styles et al (2007). 'Energy crops in Ireland: An economic comparison of willow and miscanthus production with conventional farming systems'.
[64] Personal communication. Barry Caslin (Teagasc), 20 October 2015.
[65] Personal communication, Mary McMahon (DAFM), 21 October 2015.
[66] http://www.bordnamona.ie/our-company/our-businesses/feedstock/biomass-growers/

it is assumed that miscanthus would fetch a similar price to straw. This is estimated to be €60/tonne at 20% moisture, equivalent to €75/odt.[67] Current prices available are therefore at the lower end of the prices considered for the model.

6.4 Estimating uptake of energy crops

Studies to date show that perennial energy crops are potentially more profitable than current enterprises at a price of €4/GJ when the establishment grant is taken into account. However, to date, uptake has been low because of the highly significant demand and supply-side constraints (see Section 6.2 above). This study reviews the impact of supply-side constraints on the availability of bioenergy feedstock supply in the context of a robust bioenergy market.

The importance of each of the main types of supply-side barrier is shown in Table 6.3 as a function of the price paid for the feedstock. For most barriers their impact is reduced as the price increases. However, some barriers are not as sensitive to price and, to overcome these, additional measures will be required. This applies in particular to grower attitudes (which is categorised below as a market barrier).

Table 6.3: Importance of each type of supply-side barrier at the three farm gate price points

	SRC			Miscanthus		
	€4/GJ	€6/GJ	€10/GJ	€4/GJ	€6/GJ	€10/GJ
Market	High	Med	Low	High	High	Med
Financial	High	Med	Low	High	Med	Low
Policy/ regulation	High	Med	Low	High	Med	Low
Technical	High	High	Low	Med	Low	Low
Infrastructure	High	Low	Low	High	Low	Low

An estimate of the increase in planting that might be achieved in the future is shown in Table 6.4 below. Two scenarios are considered, a BAU scenario, and an Enhanced Supply scenario where the supply-side barriers identified are eased through the implementation of appropriate policies and measures targeted at the most significant barriers.

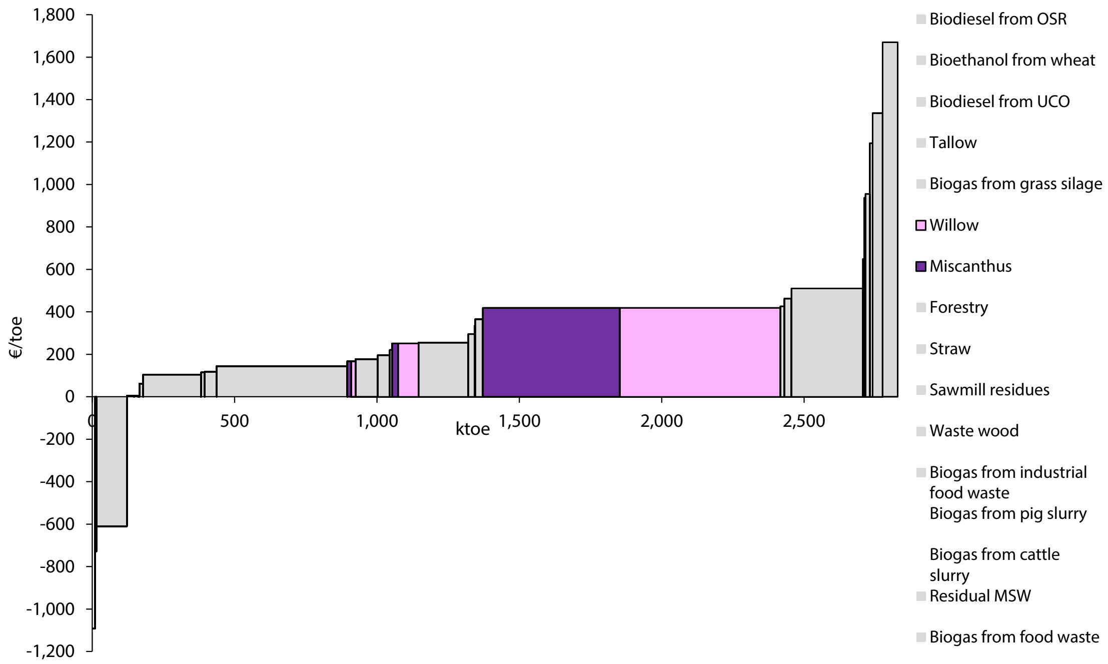
Table 6.4: Potential Increase in energy crops planting

Farm gate price	New area planted in 2017 (ha)		Potential growth in new area planted each year	
	Business as usual	Enhanced supply	Business as usual	Enhanced supply
SRC				
€4/GJ (€75/odt)	100	500	5%	20%
€6/GJ (€110/odt)	500	2000	10%	40%
€10/GJ (€180/odt)	1500	2500	30%	40%
Miscanthus				
€4/GJ (€75/odt)	100	750	5%	20%
€6/GJ (€110/odt)	200	2000	10%	40%
€10/GJ (€180/odt)	750	2500	30%	40%

[67] Personal communication. Barry Caslin (Teagasc), 20 October 2015.

. The quantities available at different price levels in 2035 under the BAU scenario are shown in Figure 6.2

Figure 6.2: Perennial energy crops in the bioenergy cost curve for 2035 (business as usual scenario)



7. Grass Silage

7.1 Overview

7.1.1 What is the resource and how can it be used?

Some permanent pasture in Ireland is currently under-utilised,[68] and it is suggested that by intensifying utilisation of grass by cattle, and by improving grass yields by better management and additional fertiliser application, substantial grass silage could be available for energy purposes without adversely affecting cattle production in Ireland.

Grass silage has a high moisture content and so is best suited to energy production by using Anaerobic Digestion (AD) to produce biogas. Biogas is a mixture of methane and carbon dioxide which can either be combusted in a boiler to supply heat, or in a gas engine to produce electricity and heat. Alternatively the biogas can be upgraded to pure biomethane (by removing the CO_2 and other impurities), which can then either be injected into the natural gas grid, or used directly as a vehicle fuel.

The grass silage could be co-digested with other feedstocks, such as cattle or pig slurries or food waste, in an AD plant, ranging from small scale on-farm systems to larger centralised AD systems shared between several farms. A small scale plant (e.g. a 100 kWe AD plant) would require silage from about 78 ha of land. This could be distributed over a number of farms, for example, if the silage came from five farms, about 16 ha would be needed on each farm for silage production. The farms would need to be located relatively locally, as due to the relatively low energy density of grass silage, it is not economically viable to transport it long distances – typically it would be used within about 10 km of where it is produced[69]. These estimates assume that a hectare of grass yields 7 tonnes of dry matter per year (tDM/yr). Teagasc launched a four year programme in January 2017, called Grass10, that aims to increase usable grass yields to 10 tDM per ha per year[70]. This would reduce the 78 ha for a 100 kWe AD plant to 55 ha, or 11 ha per farm if spread over 5 farms.

At present grass silage is only produced for animal feed and is not used in AD plants in Ireland. Bioenergy AD plants would aim to utilise silage that could be produced in excess of current and future livestock requirements. The AD plants envisaged would be managed by individual farmers or groups of farmers, who would control the production and utilisation of the silage, ensuring that livestock requirements are met first.

7.1.2 How much resource could be available?

Teagasc[68] has estimated the grassland biomass that might be available in Ireland in excess of livestock requirements if grassland is better utilised. Based on these estimates, and allowing for land needed to grow other proposed biofuels crops (wheat and OSR) and woody energy crops (miscanthus and SRC), it is considered that 200,000 ha could be available for silage production for energy use in 2016 rising to 305,000 ha in 2035.[71] Of this it is considered that 50,000 ha (25%) could be utilised from 2016, rising to 170,800 ha (55%) by 2035 under a BAU scenario; under an Enhanced Supply scenario, all of the potential area identified is utilised by 2035.

By 2020, it is estimated that grass silage could produce about 250 ktoe (10.5 PJ), almost doubling to 469 ktoe (19.6 PJ) by 2035 under a BAU scenario, and more than tripling to 837 ktoe (35 PJ) under the Enhanced Supply scenario. Table 7.1 and Figure 7.1.

These values represent the maximum resource it is considered could be available under the two scenarios, and is predicated on the improvement in grassland utilisation being achieved. As discussed above, due to its high moisture content/low energy density it is not economically viable to transport silage long distances.

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[68] McEniry et al (2013). 'How much grassland biomass is available in Ireland in excess of livestock requirements?' Irish Journal of Agricultural and Food Research 52, 2013.

[69] Smyth, B., Smyth, H., Murphy, J. (2010). 'Can grass biomethane be an economically viable biofuel for the farmer and consumer?' 10.1002/bbb.238 Biofuels, Bioproducts and Biorefining.

[70] https://www.teagasc.ie/news--events/news/2017/teagasc-grass10-campaign.php

[71] The total area of grassland available is 655,000ha. Assuming 350,000ha (the limit under CAP for grassland conversion) is used for annual biofuels crops and woody energy crops, this leaves about 305,000 ha for grass silage by 2035.

Table 7.1: Potential grass silage bioenergy resource

	Unit	2020	2025	2030	2035
Business as usual scenario					
Grass silage (for energy purposes)	kha	91	127	155	171
Grass silage (for energy purposes)	Mt	0.6	0.9	1.1	1.2
Biogas produced from silage	ktoe	250	349	426	469
Final (delivered) energy					
Electricity only	ktoe	75 - 100	105 - 140	128 - 170	141 - 187
CHP	ktoe	175 - 200	245 - 280	298 - 341	328 - 375
Heat only	ktoe	187 - 212	262 - 297	320 - 362	351 - 398
Transport	ktoe	250	349	426	469
Percentage of current gross final energy use[(a)]					
Electricity only	%	0.7 - 0.9%	1 - 1.3%	1.2 - 1.6%	1.3 - 1.7%
CHP	%	1.6 - 1.8%	2.3 - 2.6%	2.8 - 3.1%	3 - 3.5%
Heat only	%	1.7 - 2%	2.4 - 2.7%	3 - 3.3%	3.2 - 3.7%
Transport	%	2.2%	3.1%	3.8%	4.2%
Enhanced supply scenario					
Grass silage (for energy purposes)	kha	144	205	253	305
Grass silage (for energy purposes)	Mt	1.0	1.4	1.8	2.1
Biogas produced from silage	ktoe	396	563	693	837
Final (delivered) energy					
Electricity only	ktoe	119 - 158	169 - 225	208 - 277	251 – 335
CHP	ktoe	277 - 317	394 - 450	485 - 554	586 – 669
Heat only	ktoe	297 - 337	422 - 478	520 - 589	628 - 711
Transport	ktoe	396	563	693	837
Percentage of current gross final energy use[(a)]					
Electricity only	%	1.1 - 1.5%	1.6 - 2.1%	1.9 - 2.6%	2.3 - 3.1%
CHP	%	2.6 - 2.9%	3.6 - 4.2%	4.5 - 5.1%	5.4 - 6.2%
Heat only	%	2.7 - 3.1%	3.9 - 4.4%	4.8 - 5.4%	5.8 - 6.6%
Transport	%	3.5%	5.0%	6.2%	7.4%

Notes (a) Gross final energy use in 2014 was 11,243 ktoe

An estimate of the accessible resource that can be realised for energy would require spatially explicit assessments to identify 10 km radius catchments with potential for silage production in excess of fodder requirements.[72] This would need to be coupled with an assessment of the location of other bioenergy resources such as slurry which could be used for co-digestion.

7.1.3 Supply-side barriers

Grass grows well in Ireland and grass silage is already produced extensively for animal feed. Farmers have all the skills, technology and infrastructure for production, storage already exists, and there are few technical barriers to producing silage for AD. The main supply-side barriers (summarised in Table 7.2 below) relate to farmer perceptions of risk and uncertainty in producing energy crops, the year-to- year variation in silage yields (and hence prices), and the challenges in implementing large scale grassland improvement in a sustainable manner. For example, if productivity is increased by reseeding with more productive varieties of grass and combined with more frequent cutting, then this may have biodiversity impacts if the grassland was previously managed more extensively.

[72] As a guide, about 40% of the area under grass in 2010 is estimated to be in farms where the area of silage was greater than 20 ha (based on data from the Census of Agriculture) suggesting that quite a large number of farms might be of a size suitable to support AD plants.

Figure 7.1: Potential biogas production from grass silage

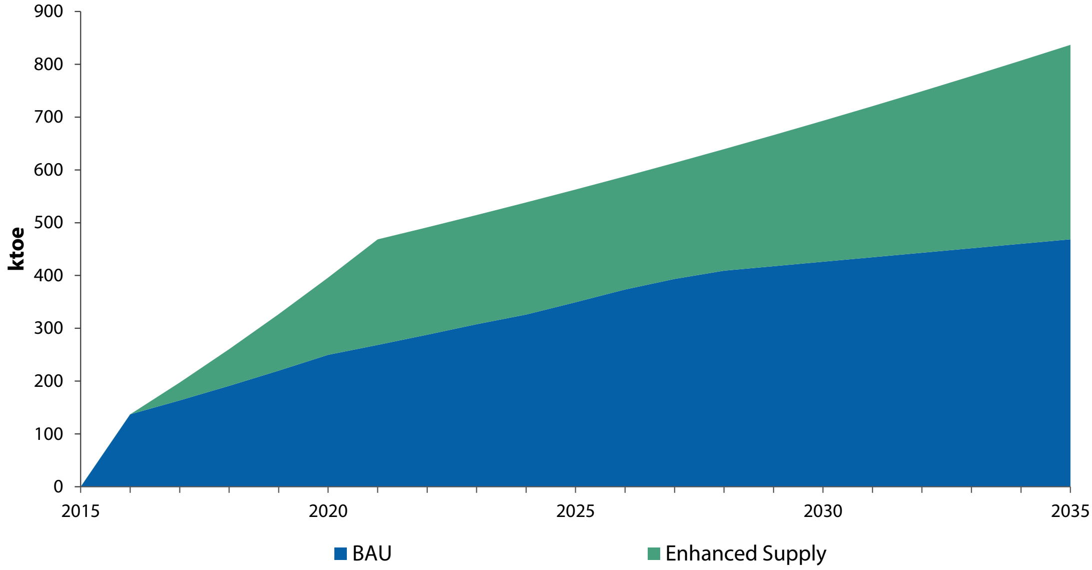

Table 7.2: Main supply-side barriers for grass silage

Type of barrier	Main Barriers	Examples of types of interventions which could address barrier
Market	Perception of risk and uncertainty in production of silage for energy.	Information dissemination on how AD complements and extends existing operations.
Financial	Variability in silage price. High transport costs.	Support geared to farm scale AD with local supply. Co-digest with other farm feedstocks.
Policy/ Regulation	Sustainability requirements for grassland improvement measures.	Policy guidelines. Priority given to silage as livestock feed in times of shortage.
Technical	Quality of silage Suitability of silage as a sole feedstock for AD.	Specifications for silage for AD developed and published.

7.2 Methodology used to estimate resource availability

There are about 3.9 million ha of grassland in Ireland, of which about 1 million ha is used to produce silage for livestock feed. Grassland used for grazing is currently under-utilised, and by improved management of livestock, additional land could be freed from grazing and be available for additional silage production or for other enterprises. Teagasc[68] has estimated the grassland biomass that might be available in Ireland in excess of livestock requirements, under different assumptions about future livestock numbers, rates of grassland utilisation and levels of nitrogen fertilisation. This estimates that under current conditions about 243,000 ha of grassland could become available for energy, but that in the future, even with significant increases in livestock, improved utilisation and increasing nitrogen fertilisation could lead to significant areas of land being available for the production of silage – up to 1.1 million ha (Table 7.3).

Table 7.3: Potential additional grassland resource available

Scenario description	Available grassland resource (million t DM)	Equivalent land available for bioenergy use (kha)[1]
Current estimated grassland supply, current national cattle herd and sheep flock.	1.7	243
Grassland supply estimated based on maximum annual rate of N fertiliser application allowed under statutory limits. Current national cattle herd and sheep flock.	9.3	846
Increased grass utilisation rate of cattle. Current N fertilisation. Current cattle herd and sheep flock.	5.6	800
Maximum N fertiliser application. Increased grass utilisation. Current cattle herd and sheep flock.	13.2	1,200
Current grassland management and N fertilisation. Increased dairy output by 50%, beef output of 40% and sheep output of 20%.	0.4	57
Maximum N fertiliser application. Increased grass utilisation. Increased dairy output by 50%, beef output of 40% and sheep output of 20%.	12.2	1,109

Notes: 1: Calculated from tDM assuming the current average yield of 7tDM/ha for scenarios with current N fertilisation and 11tDM/ha under high N fertilisation scenarios. This land available for all bioenergy uses including annual and woody perennial crops and silage for AD.

Source: based on McEniry (2013): Table 3 Annual available grassland resource in excess of livestock requirements.

However, it is possible that the application of additional nitrogen fertiliser may be constrained, due to obligations under the Water Framework and Nitrates Directives and requirements to control ammonia and nitrogen oxides emissions.[73] Estimates from McEniry (2013) have therefore been adapted to reflect the likely additional availability of pasture land for the situation where livestock numbers increase (as is the aspiration in Food Wise 2025) and grass management improves, but nitrogen applications and grass silage yields remain broadly at current levels. Based on the data in Table 7.3, and additional data from McEniry (2013) on the demand for silage for livestock fodder under various scenarios, this gives an estimate of 243,000 ha of pasture land being available for energy uses in 2016, rising to 655,000 ha in 2035. After allowing for the land assumed to be converted to arable land for other energy crops in 2016 (wheat, OSR, SRC and miscanthus) this gives 200,000 ha for grass silage production for energy purposes in 2016 and 305,000 ha in 2035.

The national average yield of grass silage under current management practices is 7t dry matter (DM) per ha per year. Increasing nitrogen fertiliser input to the maximum allowed under statutory limits, could increase yields to an average of 11tDM/ha/y.[74] However as discussed above, increases in nitrogen application may not be possible or desirable, so it is assumed that yields remain at 7 tDM per ha per year. From the perspective of energy balance from AD using silage, recent assessments showing good energy balance are based on current management practices and fertiliser inputs (Smyth, 2009):[75] it is not clear that any increase in yield due to additional nitrogen application would offset the increased energy requirements from the production of the additional nitrogen fertiliser.

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[73] Personal communication. Ronan Gleeson (DAFM), 30 November 2012.
[74] Padraig O'Kiely ([Teagasc). Personal communication, 28 October 2015.
[75] Smyth et al (2009). 'What is the energy balance of grass biomethane in Ireland and other temperate northern European climates?' Renewable and Sustainable Energy Reviews 13.

Increased land availability from better grass utilisation is likely to take some time to achieve, as it will require optimising soil fertility, improving drainage, implementing grassland management throughout the seasons, and an active re-seeding programme. Pasture land availability for silage is therefore assumed to rise from 200 kha in 2016, to about 250 kha in 2025, reaching 305 kha in 2035. Of this potentially available land, it is considered that under a BAU scenario 50,000 ha (25%) could be utilised from 2016, rising to 170,800 ha (55%) by 2035. Under an Enhanced Supply scenario, it is considered that all of the potential area identified could be utilised for silage production for energy purposes by 2035. Under the Enhanced Supply scenario it is assumed that any cultural barriers to producing silage for energy are overcome and that additional support is provided to enable earlier implementation of improved pasture management than might be required to meet the envisaged increase in livestock output.

7.3 Price

Silage is usually used on farm and the cost of production is estimated to be about €20/t (for a dry matter content of 23%) (€255/toe or €6.1/GJ). Under typical conditions the estimated range in production costs is estimated to be -30% to +100% , giving low and high prices of €15.4/t and €40/t (€196/toe and €510/toe or €4.7/GJ and €12.2/GJ) respectively.[76]

Grass silage for fodder is traded informally, and prices fluctuate depending on levels of demand and supply, both of which are likely to vary across Ireland, and from year to year depending on weather. Prices from recent years are shown in Table 7.4 and range from 14 to 56 €/t, broadly within the range of the production costs estimated above. It is should be noted that the highest prices were seen in some regions only and do not represent a national average. The productions costs are therefore taken as the low, medium and high farm gate prices, with the majority of the resource assumed to be available at the medium and high price. This does not take into account the high prices that may be seen in extreme conditions such as the fodder crisis of 2013. The quantities available at different price levels in 2035 under the BAU scenario are shown in Figure 7.2.

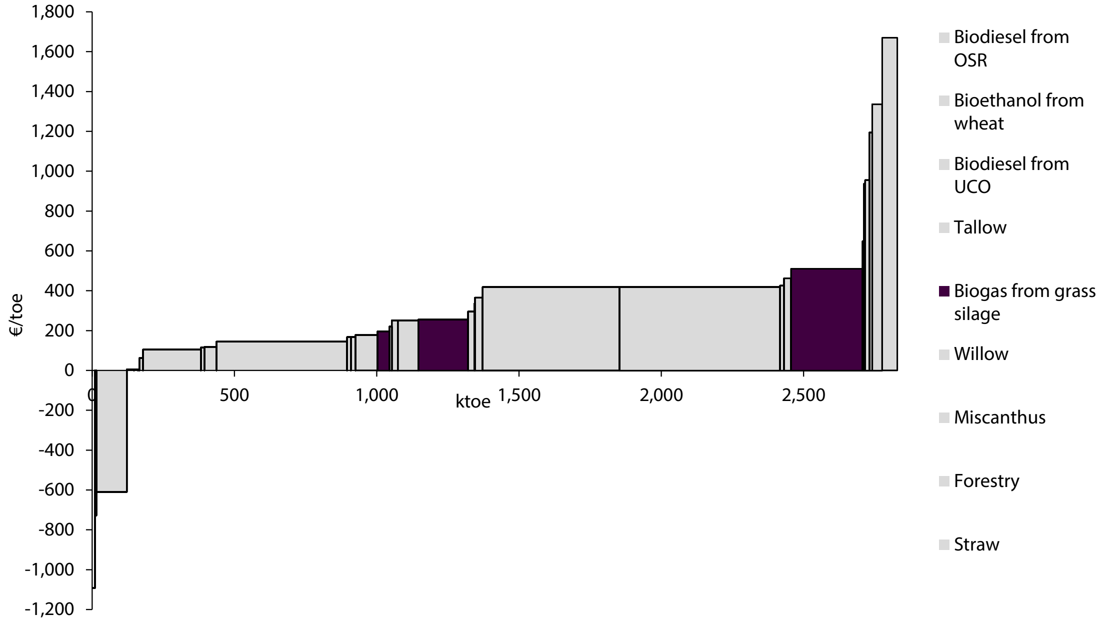
Table 7.4: Prices for silage fodder

Date	€/bale	€/t[(a)]	Source
Mar-13	20 to 40	28 to 56	www.independent.ie/business/farming/silage-hits-40bale-in-the-southwest-29153276.html
Nov-14	18 to 23	25 to 32	www.agriland.ie/farming-news/latest-fodder-prices-done-deal/
Jan-16	10 to 30	14 to 42	DoneDeals.co.uk. prices for silage bales accessed 13 Jan 2016
Apr-16		22 to 28	Irish Farmers Journal, 7 April 2016

Notes: (a) Based on a weight of 0.72 t for a chopped silage bale at 25% dry matter, from Teagasc advice note at www.teagasc.ie/dairy/grass-based-nutrition/docs/Bale_size.pdf

[76] Padraig O'Kiely (Teagasc). Personal communication, 28 October 2015.

Figure 7.2: Biogas from grass silage in the bioenergy cost curve for 2035 (business as usual scenario)



7.4 Potential supply-side barriers

As discussed above, there are few technical barriers to producing silage for AD, and the main supply-side barriers relate to farmer perceptions of risk and uncertainty in producing energy crops, the year-to-year variation in silage yields (and hence prices) and the challenges in implementing large scale grassland improvement in a sustainable manner. These are discussed in more detail in Box 7.1.

Realising the silage resource requires a wide-scale deployment of AD plants. A consideration of demand side issues, including deployment of conversion technologies such as AD, is outside the scope of this study (which is focussed on supply-side issues), but it is noted that there are several barriers which would need to be overcome. Potential issues include the high cost of small scale plants, lack of experience running plants, lack of finance to invest in farm scale AD plants, and the lack of biogas collection infrastructure if the energy is to be exported.

Box 7.1: Main supply-side barriers for use of grass silage in anaerobic digestion

Market barriers:

- **Perception of risk and uncertainty.** At present farmers produce silage for feed, and may be reluctant to produce it for energy purposes, and cautious about whether there would be a long term, stable market for silage for energy purposes.[77]

Financial barriers:

- **High transport costs.** Silage is a wet feedstock (about 23% DM content), which means that transport over long distances is not commercially feasible and it needs to be utilised locally. This in turn means that the scale of the AD system needs to be small, so that sufficient feedstock is available locally, or alternatively additional feedstocks need to be transported to the plant.
- **Variability of price and availability of silage.** Annual variation in silage production may impact on availability for AD use in some years. The yield of silage can vary markedly from year to year (up to about 17% differences observed in trials). Since the primary use for silage is as livestock feed, there is the danger that there will be insufficient silage available to meet supply obligations to the AD systems in years of poor yields. This risk needs to be managed at the AD plant by keeping a store of silage, using alternative feedstocks, or accepting a lower load factor for the AD plant. In particular in years of extremely low yields, such as the fodder crisis of 2013,[78] there may be insufficient silage even for fodder requirements. It would be worth considering a bioenergy policy that formally gives priority to feeding livestock in these circumstances.

Policy/regulatory barriers:

- **Grassland improvement measures.** The availability of land for additional silage production for energy purposes in the medium term requires that the improved utilisation of grasslands assumed in the Food Wise 2025 strategy is achieved. This in turn will require considerable changes in practices by farmers and is likely to take some time to achieve. It will require optimising soil fertility, improving drainage, implementing grassland management throughout the seasons, and an active re-seeding programme. All these measures will need to be undertaken with regard to sustainability legislation.

Technical barriers:

- **Quality of silage.** The production of biogas is dependent on the content of digestible material in the feedstock. Developing quality standards for the silage feedstock can help to ensure that farmers produce silage with the correct characteristics to ensure that expected biogas yields are achieved.
- **Suitability for AD process.** Grass silage has been reported to be deficient in some essential trace elements for long term mono-digestion. It may therefore be better to use it in systems where it is co-digested with other feedstocks.

[77] Tom Kent, (Waterford Institute of Technology). Personal communication, 2 December 2015. It has been suggested that under current conditions only about 5% to 10% of farmers are likely to be willing to grow silage for AD.
[78] http://www.irishexaminer.com/viewpoints/columnists/victoria-white/farm-fodder-crisis-will-continue-unless-we-confront-climate-change-230716.html

8. Straw

8.1 Overview

8.1.1 What is the resource and how can it be used?

Straw is a by-product resulting from growing commercial crops such as wheat, barley and oats, and can be combusted to produce electricity and/ or heat. Straw bales can be burnt whole, but are best opened and either chopped or shredded, or fed in sections into the combustion plant; straw can also be pelletised. In the future, the development of gasification and pyrolysis techniques could allow more efficient combustion, and advanced biofuel conversion technologies could allow the production of bioethanol from straw.

The density of straw is not high (about 0.46 t/m^3 for baled straw), which means it has only a moderate energy density (6.7 GJ/m^3). It is relatively bulky to transport, and significant travel distances can add substantially to the cost. It is therefore typically used locally.

8.1.2 How much resource could be available?

The straw resource is estimated based on projections of the cereal crop areas prepared by Teagasc for the strategy Food Wise 2025, and straw yields per ha. There are already a number of uses for straw, such as animal bedding, animal feed and mushroom compost, and the quantity of straw used for each of these purposes currently and in the future was estimated and subtracted from the straw resource. It is estimated that the available resource in 2020 could be 92 ktoe (3,865 TJ), rising to 142 ktoe (5,947 TJ) in 2035 (Figure 8.1 and Table 8.1).

Table 8.1: Potential straw bioenergy resource

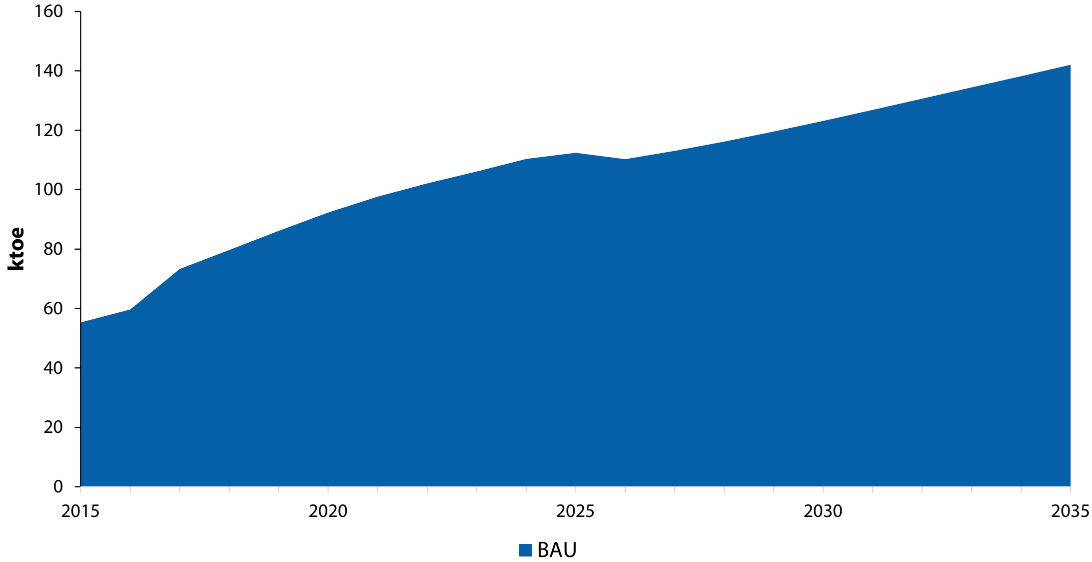
	Unit	2020	2025	2030	2035
Business As Usual Scenario					
Straw	kt	272	330	362	417
Straw	ktoe	92	112	123	142
Final (delivered) energy					
Electricity only	ktoe	27.7 - 33.2	33.7 - 40.5	36.9 - 44.3	42.6 - 51.1
CHP	ktoe	27.7 - 36.9	33.7 - 45	36.9 - 49.3	42.6 - 56.8
Heat only	ktoe	36.9 - 36.9	45 - 45	49.3 - 49.3	56.8 - 56.8
Percentage of current gross final energy use[(a)]					
Electricity only	ktoe	0.3%	0.3 - 0.4%	0.3 - 0.4%	0.4 - 0.5%
CHP	ktoe	0.6 - 0.7%	0.7 - 0.8%	0.8 - 0.9%	0.9 - 1%
Heat only	ktoe	0.6 - 0.7%	0.8 - 0.9%	0.9 - 1%	1 - 1.1%

Notes (a) Gross final energy use in 2014 was 11,243 ktoe

8.1.3 Supply-side barriers

The main barriers to utilising straw are its bulky nature and low energy density, which mean it is costly to transport. The supply may fluctuate from year to year depending on the weather, and the yields obtained, which leads to uncertainty over the quantities that may be available for users.

Figure 8.1: Potential straw bioenergy resource



8.2 Methodology used to estimate resource availability

Total straw production is estimated based on projected crop areas for winter and spring varieties of wheat, barley and oats as provided by Teagasc,[79] and as used for the strategy Food Wise 2025. These forecast that, overall, the cereals will increase by about 13% between 2015 and 2025. As no projections were available for the period 2025 – 2035, areas for this period were set to the average of 2021 – 2025 areas. Crop areas are multiplied by typical yields for the various types of straw (at 15% moisture content), as provided in the Teagasc Fact Sheet on Straw for Energy.[80] Total straw production in 2015 was estimated as 1.2 Mt rising to 1.3 Mt in 2035. Straw from OSR production is excluded from this analysis, as it is difficult to harvest, and data on its combustion characteristics indicate that it is not a good fuel for combustion.

Straw is often ploughed into fields where it is grown. This recovers its intrinsic fertiliser value and can be achieved at relatively low cost. The quantity of straw that is ploughed in will depend on the market for straw, as well as practical considerations such as the weather, ground conditions, and availability of storage space. Some farmers will choose to chop straw while harvesting for ploughing in later. A decision at harvest time carries a relatively low cost since the harvesting machinery is generally equipped to chop as it goes, while a decision by a farmer to chop later or bale will carry a significant cost. It was assumed that at least 2% of the straw production estimated will be ploughed in whatever the market conditions for straw.

The main competing demands for straw are animal bedding (all types of straw), animal feed (barley straw), and mushroom compost (wheat straw).

The use of straw for bedding is based on requirements for straw for bedding in a 2003 report, adjusted (as advised by Teagasc) to account for changes in cattle management and herd size. This estimate was combined with the herd size projections used to estimate the manure resource (see Section 9.2), which take into account the Food Harvest 2020 targets.[81]

Recent data on mushroom compost production provided in the Census of Mushroom Production in the Republic of Ireland 2011[82] indicate that mushroom compost production in 2011 was 183,948 tonnes. Teagasc have advised that straw comprises about 39% (DM) of the mushroom compost, and this has been used to calculate the current straw use for mushroom compost. No projections for mushroom compost production were available, therefore it was assumed that mushroom compost production and associated straw requirements remain constant from 2011 onwards.

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[79] Personal communication from Barry Caslin – data used for Food Wise 2025 analysis.
[80] Teagasc (2010). Fact Sheet, Tillage No. 12: Straw for Energy, Tillage Specialists 2010.
[81] http://cdr.eionet.europa.eu/ie/eu/mmr/art04-13-14_lcds_pams_projections/envvt4x3a/MMR_IRArticle23_table3_IE.xlsx/manage_document
[82] Teagasc (2012). Census of Mushroom Production in the Republic of Ireland 2011. Published in Mushrooms – A Teagasc Advisory Newsletter. Issue 37, April 2012.

In total, competing (non-energy) demands for straw accounted for about 86% of the potential straw resource in 2015, 78% in 2020, and 67% in 2035.

Key data sources used in the resource assessment are summarised in Table 8.2.

Table 8.2: Data sources used in modelling the straw resource

Data	Source
Projections for cereal crop areas harvested	Estimates from Teagasc for Food Wise 2025
Straw yields	Teagasc (2010) Fact Sheet, Tillage No. 12: Straw for Energy
Estimate of quantity of straw used for livestock bedding and mushroom production	Barry Caslin, personal communication
Projections for cattle numbers (used to update estimates of straw use for bedding)	Estimates from Ireland GHG emissions projections, file available at http://cdr.eionet.europa.eu/ie/eu/mmr/art04-13-14_lcds_pams_projections/envvt4x3a/MMR_IRArticle23_table3_IE.xlsx/manage_document
Price data	Current market data on straw prices from Teagasc analysis

8.3 Price

The price of straw was estimated based on a recent analysis performed by Teagasc of average prices for straw in Ireland over the period 2007 – 2012.[83] The following prices were assumed to be representative of prices for baled and stored straw, at the farm gate:

- Low €40/tonne (€118/toe or €2.8/GJ)
- Medium €60/tonne (€177/toe or €4.2/GJ)
- High €80/tonne (€296/toe or €7.1/GJ)

It was assumed that the low price of €40/tonne will bring 30% of the available straw resource (after competing demands have been removed) to the market, €60/tonne will bring 85% of the available straw resource to market, and €80/tonne will bring 100% of the available straw resource to market.

[83] Envest Environmental (2013). Biotricity: Analysis of the Use of Straw as a Fuel in Ireland.

9. Pig and Cattle Manure

9.1 Overview

9.1.1 What is the resource and how can it be used?

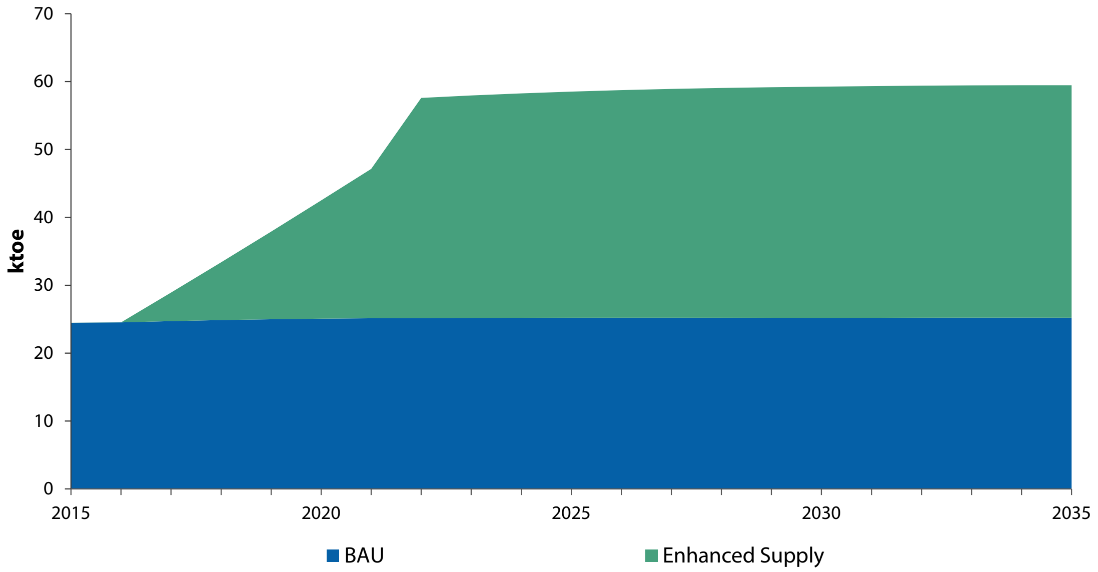
Slurry and manures from cattle and pigs can be processed in an AD plant to produce biogas, a mixture of methane and carbon dioxide. The biogas can then be used in a boiler to produce heat, burnt in a CHP unit to generate heat and/or power, or it can be upgraded to biomethane by removing the carbon dioxide. The biomethane can then be injected into the natural gas grid or used directly as fuel. An AD plant can range widely in size. Historically, a typical small scale plant that could be located on a farm would be about 100 kWe upwards, but very small 'micro scale' plants – from 10 kWe upwards – are available and in use in several European countries.[84] It is also possible to have much larger centralised plants (CAD) that can take waste from a number of farms, and potentially other types of waste too as AD plants can also 'co-digest' the slurries with other organic material e.g. grass silage or food waste (see Sections 7 and 12). Larger plants display the advantages of economies of scale, and capital costs are typically lower on a per kWe of installed capacity basis than smaller scale plants. Even a small scale plant requires slurry from a large number of animals (e.g. a 100 kWe AD plant could require slurry from about 1,000 dairy cows or over 6,000 pigs) so using other feedstocks in addition to slurries, or combining slurries from a number of farms in a co-operative venture can increase the number of farms where AD is applicable and increase the amount of resources that can be used.

9.1.2 How much resource could be available?

The potential quantities of cattle and pig slurries that could be available and the biogas that could be produced are shown in Table 9.1 and Figure 9.1. The quantity has been estimated based on the number of cattle and pigs that are kept in larger farms, and the quantities of slurry they produce. Only livestock that are on wet liquid slurry systems are included in the estimate, as this means the slurry is centrally collected, and can be transferred easily to an AD plant.

The average herd size for cows in Ireland is relatively small and, under the BAU scenario, it is assumed that less than 1% of liquid slurry is available for use. The main contribution comes from pig slurry, as the average size of pig farms is much larger, and about 46% of the slurry produced is therefore considered available. Under the Enhanced Supply scenario, it is considered that more co-operative ventures between farmers and more centralised plants are built, and co-digestion of feedstocks is encouraged, allowing more slurry from smaller farms to be used. Use of pig slurries, rises to 71% of waste collected as slurry, and use of cattle slurries to 8%.

Figure 9.1: Potential biogas production from cattle and pig slurries



[84] K. Hjort-Gregersen (2015). 'Market overview micro-scale digesters'. BioEnergy Farm II publication.

Table 9.1: Potential slurry bioenergy resource

	Unit	2020	2025	2030	2035
Business as usual scenario					
Cattle and pig slurries	Mt	2.4	2.4	2.4	2.4
Biogas produced from slurries	ktoe	25.1	25.2	25.2	25.2
Final (delivered) energy					
Electricity only	ktoe	7.5 - 10	7.6 - 10.1	7.6 - 10.1	7.6 - 10.1
CHP	ktoe	17.6 - 20.1	17.7 - 20.2	17.6 - 20.2	17.7 - 20.2
Heat only	ktoe	18.8 - 21.3	18.9 - 21.4	18.9 - 21.4	18.9 - 21.4
Transport	ktoe	25.1	25.2	25.2	25.2
Percentage of current gross final energy use[(a)]					
Electricity only	%	0.1%	0.1%	0.1%	0.1%
CHP	%	0.2%	0.2%	0.2%	0.2%
Heat only	%	0.2%	0.2%	0.2%	0.2%
Transport	%	0.2%	0.2%	0.2%	0.2%
Enhanced supply scenario					
Cattle and pig slurries	Mt	4.0	5.6	5.7	5.7
Biogas produced from slurries	ktoe	42.5	58.5	59.2	59.5
Final (delivered) energy					
Electricity only	ktoe	12.7 - 17	17.6 - 23.4	17.8 - 23.7	17.8 - 23.8
CHP	ktoe	29.7 - 34	41 - 46.8	41.5 - 47.4	41.6 - 47.6
Heat only	ktoe	31.9 - 36.1	43.9 - 49.7	44.4 - 50.4	44.6 - 50.5
Transport	ktoe	42.5	58.5	59.2	59.5
Percentage of current gross final energy use[(a)]					
Electricity only	%	0.1 - 0.2%	0.2%	0.2%	0.2%
CHP	%	0.3%	0.4%	0.4%	0.4%
Heat only	%	0.3%	0.4 - 0.5%	0.4 - 0.5%	0.4- 0.5%
Transport	%	0.4%	0.5%	0.5%	0.5%

Notes (a) Gross final energy use in 2014 was 11,243 ktoe

9.1.3 Supply-side barriers

As the resource is a waste, overall quantities are determined by livestock numbers and cannot be increased independently. Manures have a low energy density due to their high liquid content, and this means that it is not economic to transport them over long distances – typically not much more than 10 km from the farm of origin. The main supply-side barrier to utilising slurries is therefore the dispersed locations of the resource, with many farms having relatively small quantities of slurry. Ensuring full use of the resource will therefore require co-operative ventures between farms, or possibly lager centralised plants owned by third parties in areas with a high density of farms. Combining slurry with other feedstocks that have higher methane generation potentials, such as food waste or grass silage or other purpose grown crops, can also help to improve the economics of slurry-based AD as well as smoothing out seasonal variations in the availability of slurry.

Realising the slurry resource requires a wide-scale deployment of AD plants. A consideration of demand side issues, including deployment of conversion technologies such as AD, is outside the scope of this study (which is focussed on supply-side issues), but it is noted that there are several barriers that would need to be overcome. Potential issues include: lack of experience running plants, low rate of introduction to date, the lack of finance to invest in farm scale AD plants, and obtaining grid connections.

Animal manures and slurries have a value to the farmer because of the nutrients (e.g. nitrogen) contained in them, and there is a benefit to the farmer from spreading them on arable land or grassland. However the nutrients in the slurries are retained in the digestate produced by the AD plant, and so long as this can still be spread to land there is no loss to the farmer. For a farm scale plant treating only their own manure, this is the case. However if they are importing manure, then digestate can only go for landspread locally, i.e. it cannot be returned to the farm from where it was imported, unless all feedstocks to the plant are pasteurised before being anaerobically digested.[85] Pasteurisation of **all** feedstocks is required for all AD plants that import more 5,000 tonnes of feedstock from other farms, so such plants could return digestate to the farms where the manures originate. However for plants importing less than 5,000 tonnes per year of feedstocks, pasteurisation is only required for the imported manures, so digestate could not be returned. The requirement for this additional pasteurisation step could be a barrier to developing schemes taking feedstocks from more than one farm.

9.2 Methodology used to estimate the resource

9.2.1 Theoretical resource estimate

The total amount of manures produced by cattle and pigs was based on data from the EPA on current and projected livestock numbers (see Table 9.2), which was combined with an estimate of the quantity of manure excreted each day by each type of animal. This was then combined with an assessment of the proportion of animal waste managed using liquid (slurry) systems,[86] which are potentially suited to AD, to give an estimate of the theoretical manure resource.

Table 9.2: Data sources used in modelling the manure resource

Data	Source
Cattle and pig numbers from 2010 to 2012	EPA (2014) Ireland National Inventory Report 2014[87]
Projections for cattle and pig numbers (2015 to 2035)	EPA (2015) [88]
Quantity of volatile solids produced per animal	EPA (2014) Ireland's GHG Inventory – CRF[86]
Typical dry matter and volatile solids content of cattle and pig slurries	SEAI Gas Yields Table[89]
Proportion of animal waste managed using liquid (slurry) systems	EPA (2014) Ireland's GHG Inventory – CRF[86]
Size distribution of cattle and pig farms	CSO (2012) Census of Agriculture Structure Survey 2010[90]

The most recent projections of livestock numbers that are available are shown in Figure 9.2 and included as Appendix 5. They reflect the aspirations set out in Food Harvest 2020[91] for the development of the Irish agri-food and fisheries sector, but have not yet been updated to reflect further developments included in the subsequent Food Wise 2025 paper.[92] The beef herd is projected to decline (by 24%) between 2015 and 2035 whereas the number of dairy cows is forecast to rise by 35% by 2035.

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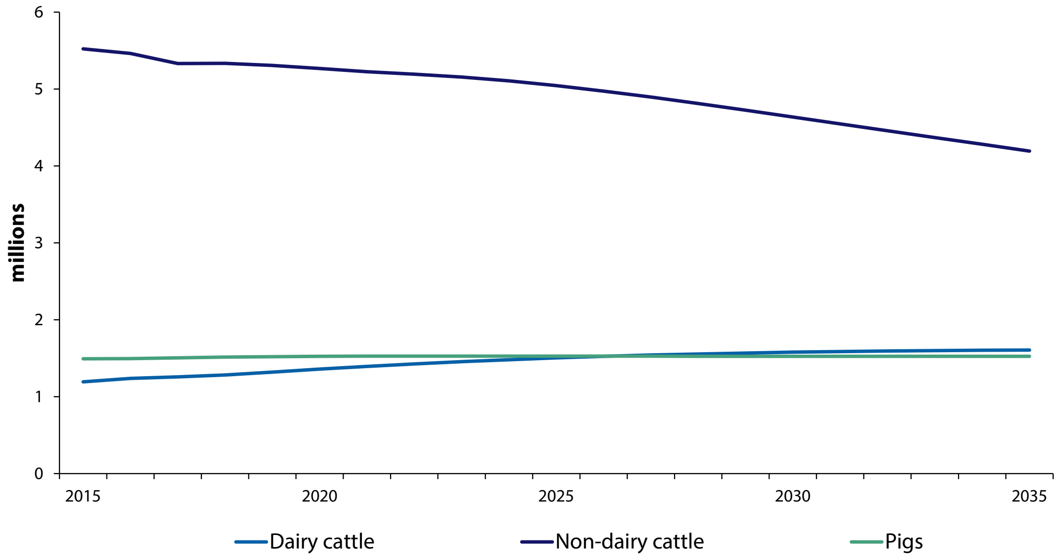
[85] DAFF (2009). 'Conditions for approval and operation of biogas plants treating ABP in Ireland'.
[86] Environmental Protection Agency (2014). Ireland's GHG Inventory – CRF Downloads. IRL-2014-2012-v1.4.xls. TABLE 4B(a) (Sheet 1 of 2) SECTORAL BACKGROUND DATA FOR AGRICULTURE. CH4 Emissions from Manure Management (Sheet 1 of 2).
[87] EPA (2014). Ireland National Inventory Report and Ireland's CRF tables. Available at http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/8108.php
[88]Data used by EPA to compile Irish GHG Projections. Available at http://cdr.eionet.europa.eu/ie/eu/mmr/art04-13-14_lcds_pams_projections/envvt4x3a/MMR_IRArticle23_table3_IE.xlsx/manage_document. 2013 and 2014 interpolated
[89] SEAI Gas Yields Table: http://www.seai.ie/Renewables/Bioenergy/Bioenergy_Technologies/Anaerobic_Digestion/The_Process_and_Techniques_of_Anaerobic_Digestion/Gas_Yields_Table.pdf
[90] CSO (2012). Farm Final Results, http://www.cso.ie/en/media/csoie/releasespublications/documents/agriculture/2010/full2010.pdf
[91] Department of Agriculture Fisheries and Food. Food Harvest 2020: 'A vision for Irish agri-food and fisheries'.
[92] Department of Agriculture Fisheries and Food. Food Wise 2025: 'A 10-year vision for the Irish agri-food industry'.

Figure 9.2: Projected livestock numbers



9.2.2 Accessible resource estimate

As discussed above, the high moisture content of slurry means that transport can significantly add to costs, and is typically restricted to less than 10 km[93] from the plant.

Farm census data for 2010 (the latest year for which data is available) gives the average dairy herd size in Ireland (in specialist dairy farms) as 63, although there are about 2,000 farms with over 100 cows, mainly concentrated in the south and southeast (Figure 9.3). Farms specialising in pigs tend to be much larger, with an average of 3,000 animals per farm.[94] However, even an AD plant as small as 100 kWe would require slurry from about 1,000 dairy cows or over 6,000 pigs. Therefore for widespread uptake of farm based AD, small plants – below 150 kWe, perhaps even down to 75 kWe – may be required.

The farm census data was used to generate an estimate of the quantities of slurry arising in farms of different types and sizes. It was then assumed that, under the BAU scenario, perhaps 5% of the slurry resource in farms where the herd size was greater than 100 could be used in AD plants, as well as the slurry in all pig farms where the herd size was greater than 10,000. For the Enhanced Supply scenario, it was assumed that more co-operative ventures between farmers and more centralised plants are built, and co-digestion of feedstocks is encouraged, allowing more slurry from smaller farms to be used. It was assumed that for cattle, 50% of slurry from all farms with herd sizes greater than 100 could be utilised, and for pigs, two-thirds of the resource in farms with herd sizes between 3,000 and 10,000 could be utilised in addition to that utilised in the BAU scenario.[95] It was assumed that policies to encourage the use of these slurries could start to take effect from 2017 onwards, with supply rising linearly to these values by 2021.

Finally the biogas that can be produced from the slurry is estimated, based on a biogas production of 424 MJ biogas per tonne of cattle slurry, and 447 MJ biogas per tonne of pig slurry. [96] Results for the two scenarios are shown in Table 9.1. In total about 25 ktoe (1,049 TJ) of biogas could be produced from slurries under the BAU supply scenario in 2020, mainly from pig slurries, with an additional 10.5 ktoe (439 TJ) available in the Enhanced Supply scenario, mainly from the additional utilisation of cattle slurries. Resource availability increases very slightly (by 1%) by 2035 in the BAU scenario due to the increase in the number of dairy cows.

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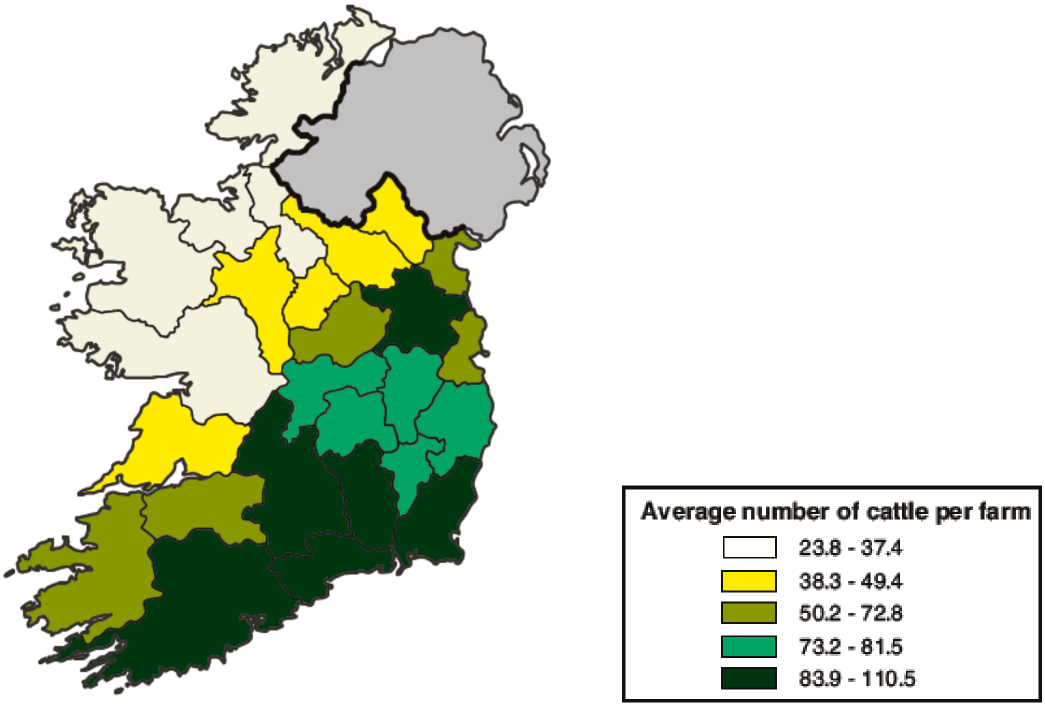
[93] M Poliafico (2007). Anaerobic Digestion: Decision Support Software. Available from http://erc.epa.ie/safer/iso19115/displayISO19115.jsp?isoID=38

[94] Census of Agriculture 2010 – Final Results http://www.cso.ie/en/media/csoie/releasespublications/documents/agriculture/2010/full2010.pdf

[95] These size classes are those used in the Census of Agriculture, and are the only ones for which data was available.

[96] Based on data from Ireland's GHG inventory (EPA, 2014) on methane producing potential of slurries.

Figure 9.3: Average number of cattle per farm, 2010



9.2.3 Competing demands for resource

The principal use for slurry is land spreading as a natural fertiliser and soil improver. Digestate produced by AD plants retains the vast majority of the nutrient content of the original input material and can be returned to agricultural land in a similar manner to slurry, so land spreading should not, in theory, present a competing demand for slurry. However, in cases where slurry is sent to an AD plant on another farm, then regulations can prevent its return to the farm of origin for land spreading (as discussed in 9.1.3) and this could be a potential barrier to the utilisation of the resource.

9.3 Price

For a farmer processing slurry produced on his own farm through an AD plant, the price for slurry could be zero. Where slurry is sourced as a feedstock for a third-party AD plant, farmers may charge for it, however the bulk of the price charged is likely to be made up of the transport cost, and, as slurry has a relatively low energy value, it is unlikely that it would be transported much more than 10 km from the farm of origin.[97] Costs of transporting liquid manure to and from a theoretical CAD plant in Ireland, with an average distance of 4 km from farms to plant, were estimated in the PROBIOGAS project[98] as
1.85 €/tonne of slurry[99] (equivalent to a contribution to biogas costs of about 4 €/GJ).

In the BAU scenario, we have assumed that all of the slurry resources considered available have a price of €0/tonne as it is predominantly used on farms. In the Enhanced Supply scenario, it is considered that slurry may have to be transported in order for it to be utilised, so the additional supply is assumed to have a cost of €1.85/tonne. This is equivalent to a contribution to biogas costs from the cost of the slurry of 183 €/toe for cattle slurry and 173 €/toe for pig slurry (equivalent to a contribution to biogas costs of about 4.4 €/GJ for cattle slurry and 4.1 €/GJ for pig slurry).

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[97] M. Poliafico (2007). Anaerobic Digestion: Decision Support Software. Available from http://erc.epa.ie/safer/iso19115/displayISO19115.jsp?isoID=38

[98] PROBIOGAS (2007). Assessment of a centralised co-digestion plant hypothetically sited in North Kilkenny, Ballyragget, Ireland. An EIE/Alterner project co-funded by the EU Commission. National Assessment Report. Available at https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/probiogas_national_report_ireland.pdf

[99] 1.7 €/t in 2007 prices, converted to 2014 prices using Consumer Price Index for Ireland for Transport Sector. Data from CSO, Consumer Price Index by Commodity Group and Year: Annual Figures 2007 to 2013.

10. Tallow

10.1 Overview

10.1.1 What is the resource and how can it be used?

Tallow is a by-product of meat processing, produced when offal and carcass/butchers' wastes are processed at rendering plants. Depending on the production method, it is classified into three categories, dictated by the Animal By-products Regulations:[100]

- Category 1 can only be used for burning or fuel production;
- Category 2 can be used for industrial applications;
- Category 3 can be used for human contact (e.g. in soaps and cosmetics).

Irish rendering plants produce Category 1 and Category 3 tallow.

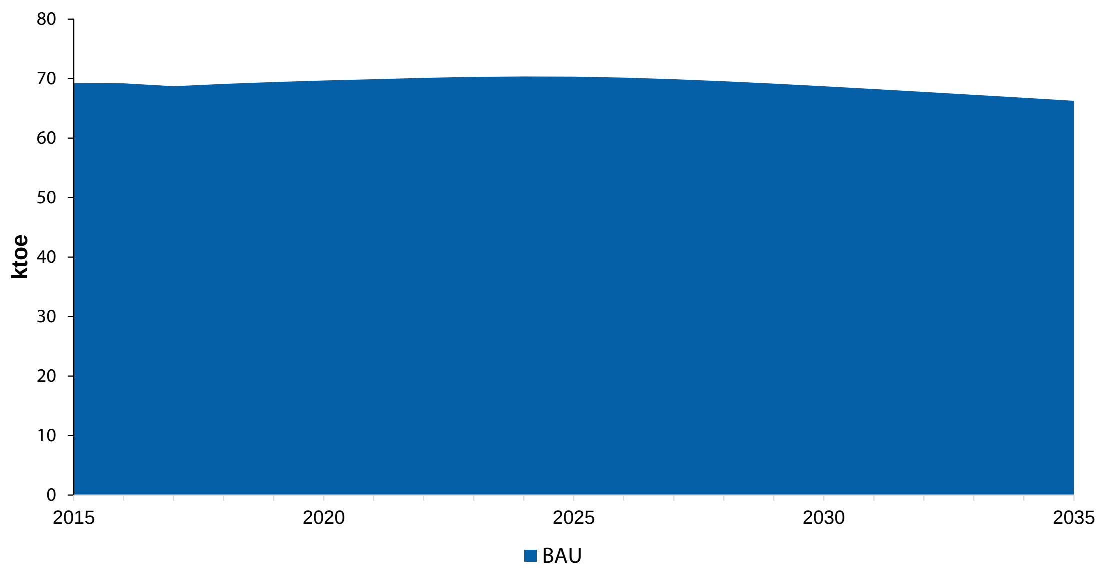
The most common energy uses of tallow are as a heating fuel, often within the rendering industry itself, or for processing into biodiesel. The rendering industry has, to date, made considerable use of tallow as a fuel within the industry, with use varying depending on the difference between the value of the tallow as sold into other industries and the price of mineral oil for heating. Data provided by the Department of Agriculture, Food and the Marine (DAFM) indicates that 103.5 kt of tallow were produced in 2014, of which 18.7 kt went to non-energy uses, leaving 84.7kt (70 ktoe or 2,914 TJ) available for energy use. Of this 49 kt were used within Ireland and 35 kt were exported.

10.1.2 How much resource could be available?

Based on forecasts of the number of animals sent for slaughter, the amount of tallow available for energy use is forecast to be at about current levels i.e. 69.7 ktoe (2,917 TJ) in 2030, but declines by about 5%, to 66 ktoe (2,773 TJ) by 2035 (Figure 10.1 and

Table 10.1). This is mainly due to a forecast decline in the number of cattle sent for slaughter, which is a result of the forecast decline in the cattle population[101] (see Section 9.2.1). No Enhanced Supply scenario is considered as all tallow currently produced is considered to have a market, so supply cannot be increased.

Figure 10.1: Tallow bioenergy resource



[100] Regulation (EC) No. 1774/2002 and more recently Regulation 1069/2009.
[101] Data used by EPA to compile Irish GHG Projections, available at http://cdr.eionet.europa.eu/ie/eu/mmr/art04-13-14_lcds_pams_projections/envvt4x3a/MMR_IRArticle23_table3_IE.xlsx/manage_document. 2013 and 2014 interpolated. This takes account of trends identified in Food Harvest 2020.

Table 10.1: Tallow bioenergy resource

	Unit	2020	2025	2030	2035
Tallow	Mt	84.8	85.6	83.6	80.7
Primary energy	ktoe	69.7	70.3	68.7	66.3
Final (delivered) energy					
if used to produce heat or biofuel	ktoe	84.8	85.6	83.6	80.7
Percentage of current gross final energy use[(a)]					
if used to produce heat or biofuel	ktoe	0.6%	0.6%	0.6%	0.6%

Notes (a) Gross final energy use in 2014 was 11,243 ktoe

10.1.3 Supply-side barriers

As tallow is a by-product of the meat processing industry, overall quantities are determined by livestock slaughtered and cannot be increased independently. No supply-side barriers were identified that restrict the amount of tallow available for use for bioenergy. Non-energy uses, e.g. for pharmaceuticals and soaps, do reduce the amount available for energy use, but overall account for only about 37% of Category 3 tallow or 18% of the total amount of tallow produced.[102]

10.2 Methodology used to estimate the resource

10.2.1 Theoretical resource estimate

The resource was estimated using the methodology set out in a previous detailed study from 2003 of the tallow resource,[103] with key assumptions updated wherever possible. The methodology estimates the amount of tallow production based on the herd size in Ireland, carcass weight, post processing carcass material reaching the renderers, and amount of tallow produced per tonne of carcass weight. Sources for the data and assumptions in the methodology are given in Table 10.2. This theoretical estimate of tallow production was then adjusted, using a comparison between the tallow production in 2014 as predicted by the model and the actual tallow production in 2014 as reported to DAFM. Forecasts of herd size, which are given in Appendix 5, reflect, as in the assessments of the cattle and pig slurry resource, the aspirations set out in Food Harvest 2020 for the Irish agri-food sector.

10.2.2 Competing demands for resource

About half of the tallow produced in Irish rendering plants is Category 1 tallow, which is high risk, and can only be used as a fuel or for biodiesel production, and half is Category 3 tallow. This is fit for human consumption and, in addition, to use for energy purposes, can be used for the production of tallow derivatives (including oleochemicals) and for pet food production. Data from DAFM showed that, in 2014, about 38% of Category 3 production was used in the pharmaceuticals/soap industry, for animal feed, or for technical use. It is assumed that a similar proportion goes to non-energy uses in future years.

10.3 Price

Data on tallow prices is difficult to acquire as tallow is not generally traded on the open market but as direct contracts between companies. A 2008 report[104] on UK tallow found that in the absence of subsidies the price of Category 1 tallow is linked to fuel oil prices. Category 2 and 3 tallow prices reflect the trends in Category 1 tallow, plus the additional cost of segregation and processing. The

[102] Data provided by DAFM on uses of tallow in 2014.
[103] Clearpower Ltd (2003). A Resource Study on Recovered Vegetable Oil and Animal Fats. Sustainable Energy Ireland.
[104] AEA (2008). Advice on the Economic and Environmental Impacts of Government Support for Biodiesel Production from Tallow, a Report to Department of Transport.
[104] AEA et al (2010). UK and Global Bioenergy Resource – Annex 1 report: details of analysis.

upper price of Category 3 tallow was thought to be linked to the lowest equivalent virgin plant oil, minus the transport costs and any import or export tariffs. Although data on prices was difficult to acquire, the study estimated that the price of Category 1 tallow was about €177/t. No information was available on the price of Category 3 tallow.

Table 10.2: Data sources used in modelling the tallow resource

Data	Source
Livestock number from 2010 to 2012	EPA (2014) Ireland National Inventory Report 2014[105]
Projections for livestock numbers	EPA (2015) [106]
Tallow production per head livestock and competing uses	Clearpower Ltd (2003) A Resource Study on Recovered Vegetable Oil and Animal Fats[103] AHDB (2012) Understanding lambs & carcases for better returns[107] AHDB (2015) GB Average Pig Carcase Weight[108] Teagasc (2010) What is the optimum slaughter weight for pigs?[109]

A 2013 report on the status of the tallow market for the UK's Department for Transport,[110] which contains quarterly price data, found that prices of Category 3 tallow had fluctuated between about €560/t and €870/t between 2010 and midway through 2013, broadly following trends in crude palm oil (a potential substitute for tallow). No market data could be obtained for Category 1 tallow, but it was the authors' understanding that Category 1 tallow had been trading in the range of €355 to €380/t) in the UK in 2013, and that it consistently trades at below the price of Category 3 tallow.

In Ireland DAFM reports that, although specific price data is not available, it believes Category 1 tallow is currently trading at between €300 and €350/t, and Category 3 tallow at about €380/t.

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[105]EPA (2014). Ireland National Inventory Report and Ireland's CRF tables can be downloaded from the following site: http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/8108.php

[106]Data used by EPA to compile Irish GHG Projections, available at http://cdr.eionet.europa.eu/ie/eu/mmr/art04-13-14_lcds_pams_projections/envvt4x3a/MMR_IRArticle23_table3_IE.xlsx/manage_document. 2013 and 2014 interpolated

[107] AHDB (2012). 'Understanding lambs & carcases for better returns', http://beefandlamb.ahdb.org.uk/wp/wp-content/uploads/2013/07/brp_l_Understanding_lamb_carcases250713.pdf

[108] AHDB (2015). GB Average Pig Carcase Weight, http://pork.ahdb.org.uk/prices-stats/production/gb-average-pig-carcase-weight/

[109] Teagasc (2010). http://www.teagasc.ie/pigs/articles/farming_independent/2010/Optimum_slaughter_weights_May2010.pdf

[110] Ecofys (2013). 'Status of the tallow (animal fat) market: 2013 update'. Report for Department of Transport.

11. Used Cooking Oil

11.1 Overview

11.1.1 What is the resource and how can it be used?

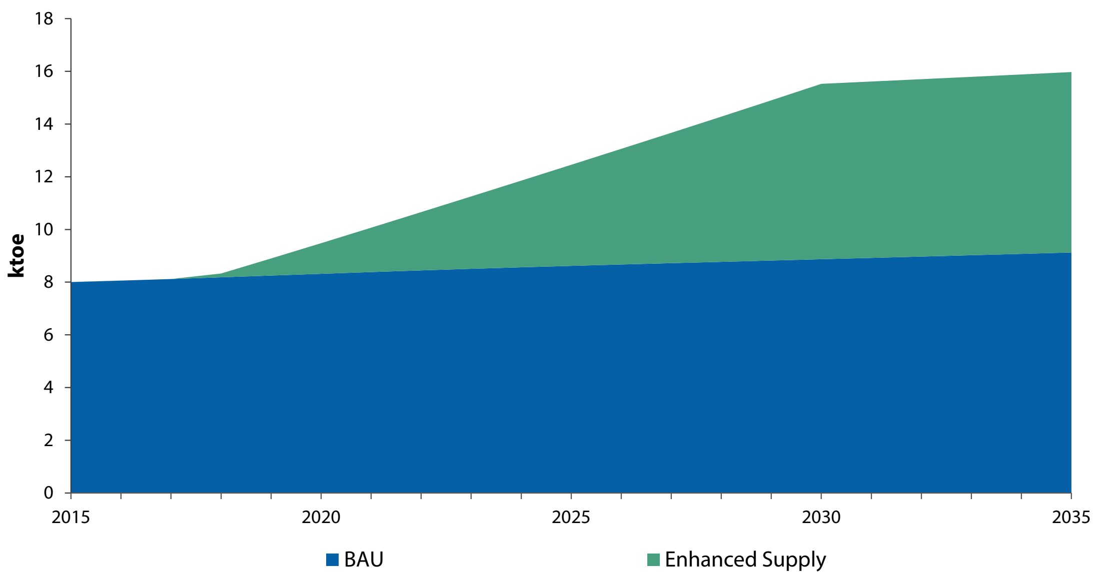
Used cooking oil (UCO) also referred to as recovered vegetable oil (RVO), or simply waste vegetable oil, can be collected, filtered and used as a feedstock in the production of biodiesel. The main sources of UCO are catering premises, food factories and households. There are commercial services which will collect UCO from catering premises and food factories, and some companies supplying oil to catering companies offer an integrated service that includes the free collection of used oil. There is currently no collection of UCO from households in Ireland.

A large biodiesel plant which uses a variety of feedstocks including UCO, tallow and plant oils began operation in Wexford in 2008. In 2014 3.6 kt of UCO were used to produce biodiesel or other renewable transport fuels in Ireland,[111] and a further 2.1 kt were exported to the UK for biodiesel production.[112]

11.1.2 How much resource could be available?

The amount of UCO that is potentially available for collection is estimated based on a consumption per head, the fraction of this oil that could be recovered, and forecasts of the Irish population. In the BAU scenario, it is assumed that only oil from catering premises and food factories is collected. This gives a potential resource of 8.3 ktoe (348 TJ) of UCO by 2020, rising slightly, as the population increases, to 9.1 ktoe (382 TJ) by 2035. Under an Enhanced Supply scenario it is assumed that policies and measures are put in place to allow recovery of UCO from households as well, so that 16 ktoe (669 TJ) of UCO could potentially be available by 2035.

Figure 11.1: Potential used cooking oil bioenergy resource



[111] Based on data from Biofuels Obligation Scheme Sustainability Statements for 2014, which show 3.72 million litres of biofuels were produced from UCO, and assuming a density for biodiesel of 1,124l/t, and that 0.91 t of biodiesel are produced from a tonne of UCO (based on data from UK and Ireland Carbon Calculator 7.00 (build 118)).

[112] Based on data from RTFO 'Year 7 Report 5: carbon and sustainability data of renewable transport fuel in UK 15 April 2014 to 14 April 2015', which shows 2.11 million litres of biofuels produced from Irish UCO in 2014/15.

Table 11.1: Potential used cooking oil bioenergy resource

	Unit	2020	2025	2030	2035
Business As Usual Scenario					
UCO	kt	9.7	10.0	10.3	10.6
Primary energy	ktoe	8.3	8.6	8.9	9.1
Final (delivered) energy					
if used to produce heat or biofuel	ktoe	7.6	7.8	8.1	8.3
Percentage of current gross final energy use[(a)]					
if used to produce heat or biofuel	ktoe	0.1%	0.1%	0.1%	0.1%
Enhanced Supply Scenario					
UCO	kt	11.0	14.5	18.1	18.6
Primary energy	ktoe	9.5	12.5	15.5	16.0
Final (delivered) energy					
if used to produce biofuel	ktoe	8.6	11.3	14.1	14.5
Percentage of current gross final energy use[(a)]					
if used to produce biofuel	ktoe	0.1%	0.1%	0.1%	0.1%

Notes (a) Gross final energy use in 2014 was 11,243 ktoe

11.2 Methodology used to estimate the resource

The quantity of cooking oil consumed was calculated based on the amount of waste oil generated per capita and population statistics, and it was then assumed that 70% of this is recoverable.[113] This gives a value of 3.8 kg per capita of oil that could be recovered. A 2009 study[114] on the potential UCO resource available for biodiesel production, suggested that collection from the catering, food processing and household sector could potentially yield (on average across Europe) about 5.8 kg per capita. A more recent study (2013)[115] considered that, from the catering sector only, amounts collected would be equivalent to about 2 kg per capita.

While oil collection from catering premises and food factories is well established, the recovery of oil from use in households is less developed, and is not widespread across Europe. In the BAU scenario, it is assumed that only UCO from the catering sector is available, and in the Enhanced Supply scenarios policies and measures are put in place to allow, in addition, the recovery of oil from households.

Legislation prevents UCO from being used in animal feed, and, although a small proportion is used in the oleochemical industry, it is assumed here that all UCO collected is potentially available for energy purposes.

11.3 Price

A study in 2003 estimated the price of bulk filtered UCO to be €179/t; no publicly available data on current prices paid for UCO in Ireland could be found to update this data. A recent UK study[116] found that the price paid for UCO in the UK had changed dramatically over the past few years, although the market was still relatively immature and not transparent. Prices paid for UCO to UCO collectors by biodiesel producers varied, and were affected by factors such as the time of year. Prices quoted were around €496 to €620 per tonne in winter months and €744 to €868 in summer months. These are similar to prices quoted in a European study for UCO in the German market.[115] This suggested that

[113] Population projections are the M2F2 projection from CSO (2013). Population and Labour Force Projections 2016 – 2046. Quantities of recoverable oil per capita from Clearpower Ltd (2003). A Resource Study on Recovered Vegetable Oil and Animal Fats. Sustainable Energy Ireland.
[114] BioDieNet (2009). El Libro, The Handbook for Local Initiatives for Biodiesel from Recycled Oil, quoted in Ecofys (2013). 'Low ILUC potential of wastes and residues for biofuels: straw forestry residues, UCO, Corn Cobs'.
[115] Ecofys (2013). 'Low ILUC potential of wastes and residues for biofuels: straw forestry residues, UCO, corn cobs'.
[116] Ecofys (2013). 'Trends in the used cooking oil market'.

small UCO collectors might sell filtered UCO at up to €550/t and large collectors sell purified UCO for €800 to €880/tonne.

Assuming that prices for UCO in Ireland would follow a similar trend to those in the UK, a low price of €558/tonne (€649/toe) and medium price of €806/tonne (€937/toe) are modelled. It is assumed that UCO from catering premises would be available at these prices, with 50% of the resource available at each price. In the Enhanced Supply scenario, it is assumed that there would be an additional cost to collect UCO from households, and the price for the additional resource is therefore set at €1,000/t (€1,163/toe).

12. Food Waste

12.1 Overview

12.1.1 What is the resource and how can it be used?

Food waste, if it is separately collected, can be processed in an AD plant to produce biogas, a mixture of methane and carbon dioxide. The biogas can then be used in a boiler to produce heat, burnt in a CHP unit to generate heat and/or power, or it can be upgraded to biomethane by removing the carbon dioxide. The biomethane can then be injected into the natural gas grid or used as a vehicle fuel.

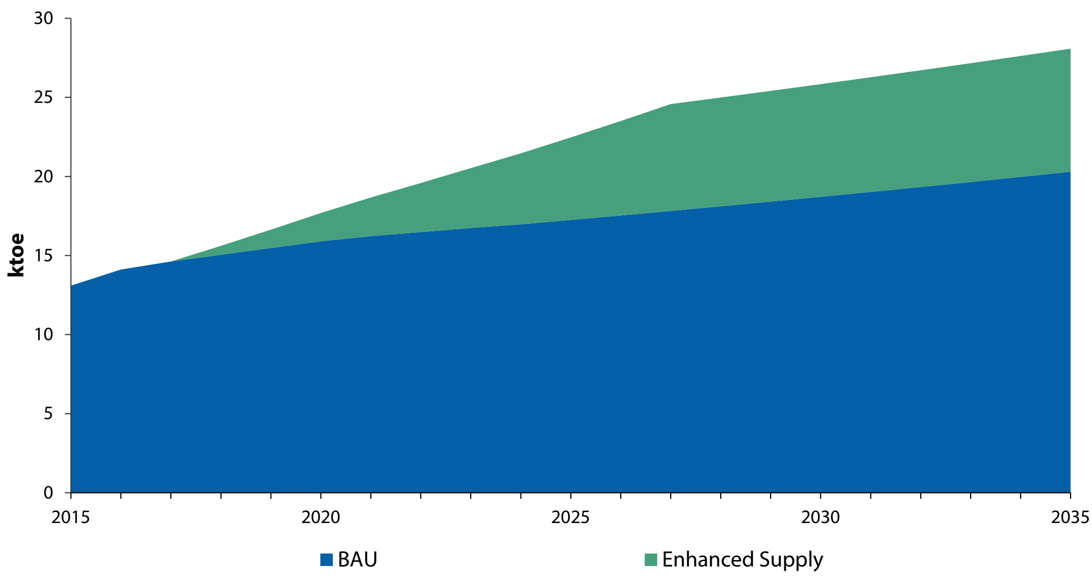
Waste regulations in Ireland require the provision of a 'brown bin' to households to collect organic waste (food waste and garden waste) and, in 2012, 80 kt of organic waste were collected via these types of collection,[117] almost all of which went to composting plants.[118] Similarly, commercial premises are also required to separate out their food waste, which is collected separately.

12.1.2 How much resource could be available?

The quantity of food waste that could be collected from households and commercial premises has been estimated based on the roll out of food waste collections to households, and assuming that all commercial premises have separate food waste collection. Under the BAU scenario, separation of food waste for disposal in the separate organic waste bin is assumed to be at current levels; in an Enhanced Supply scenario, it is assumed that greater efforts are made to separate out food waste and that 70% of food waste generated is collected separately.

The amount of biogas that could be generated from this food waste if it was then sent to an AD plant rises from 16 ktoe (666 TJ) in 2020 to 20 ktoe (850 TJ) in 2035 in the BAU scenario and, under an Enhanced Supply scenario, to 28 ktoe (1,175 TJ).

Figure 12.1: Potential biogas from food waste resource



[117] EPA (2012). National Waste Report.
[118] Rx3 (2012). Market Report on Irish Organic Waste Management and Compost Use.

Table 12.1: Potential biogas from food waste resource

	Unit	2020	2025	2030	2035
Business as usual scenario					
Food waste	kt	289	314	341	370
Biogas produced from food waste	ktoe	16	17	19	20
Final (delivered energy)					
Electricity only	ktoe	5 - 6	5 - 7	6 - 7	6 - 8
CHP	ktoe	11 - 13	12 - 14	13 - 15	14 - 16
Heat only	ktoe	12 - 14	13 - 15	14 - 16	15 - 17
Transport fuel	ktoe	16	17	19	20
Percentage of current gross final energy use[a]					
Electricity only	%	0 - 0.1%	0 - 0.1%	0 - 0.1%	0.1%
CHP	%	0.1%	0.1%	0.1%	0.1%
Heat only	%	0.1%	0.1%	0.1%	0.1 - 0.2%
Transport fuel	%	0.1%	0.2%	0.2%	0.2%
Enhanced supply scenario					
Food waste	kt	322	409	470	511
Biogas produced from food waste	ktoe	18	22	26	28
Final (delivered energy)					
Electricity only	ktoe	5 - 7	7 - 9	8 - 10	8 – 11
CHP	ktoe	12 - 14	16 - 18	18 - 21	20 – 22
Heat only	ktoe	13 - 15	17 - 19	19 - 22	21 – 24
Transport fuel	ktoe	18	22	26	28
Percentage of current gross final energy use[a]					
Electricity only	%	0 - 0.1%	0.1%	0.1%	0.1%
CHP	%	0.1%	0.1 - 0.2%	0.2%	0.2%
Heat only	%	0.1%	0.1 - 0.2%	0.2%	0.2%
Transport fuel	%	0.2%	0.2%	0.2%	0.2%

Notes (a) Gross final energy use in 2014 was 11,243 ktoe

12.1.3 Supply-side barriers

The main supply-side barrier to overcome is the under-utilisation of food waste collection systems, i.e. increasing the quantity of food waste separated by householders and businesses for disposal in brown bins. In addition, reducing the level of contaminants in the food waste though better separation would improve the quality and usability of the resource. This can be tackled through education. For example, a pilot project in Sligo[119] that carried out an awareness campaign on the correct use of the brown bin was successful in increasing the quantity of organic waste going into the brown bin and reducing the level of contaminants in the brown bin (from 45% to 1% in the best case). The introduction of 'pay by weight' charges for domestic waste in July 2016, where charges for brown bin waste may be lower than for residual waste, should also encourage the diversion of food waste to the brown bin.

Realising the food waste slurry resource requires a wide-scale deployment of AD plants. A consideration of demand side issues, including deployment of conversion technologies such as AD, is outside the scope of this study (which is focussed on supply-side issues), but it is noted that there

[119] http://www.sligococo.ie/News/Name,35754,en.html

may be barriers that would need to be overcome. Potential issues include lack of experience running plants, low rate of introduction to date, and obtaining grid connections.

It is worth noting that the higher energy density of food waste means that it is more cost-effective to transport food waste than other AD feedstocks with a lower energy density (e.g. slurries and grass silage), giving greater flexibility in the location and size of plants than for other resources.

12.2 Methodology used to estimate the resource

The total quantity of municipal waste generated is based on projections from ISus as reported in the Environmental Protection Agency's National Waste Report.[120] The forecast was extended from 2025 to 2035 based on the growth rate for waste estimated by the model from 2025 to 2030. The ISus model contains no forecast for commercial waste arisings. As the 2010 National Waste Report shows, historically both municipal and commercial waste arisings follow similar trends to those in Gross National Product (GNP), and, as the ISus model is itself based on models of growth in the economy, the same growth rate is assumed for commercial waste arisings as for municipal waste.

The quantity of food waste that could be collected from households has been estimated based on the fraction of households that will be required to have separate collection of their food waste (via a brown bin) under the European Union Household Food Waste and Bio-Waste Regulations,[121] and typical quantities of food waste collected per bin. By 2017, when the regulations are fully implemented, an estimated 67%[122] of households will be supplied with a brown bin. The Waste Management (Food Waste) Regulations 2009[123] require the source-separate collection of food waste from commercial premises, and it is assumed that by 2015 all commercial premises have this.

In the BAU Scenario, the quantity of food waste in the organic bin is assumed to be 35% of food waste generated in the household.[124] This estimate is based on data on the composition and quantity of waste in the brown bin. Commercial premises are assumed to separate out for collection 50% of their food waste.

In the Enhanced Supply scenario, it is assumed that policies and measures are put in place to encourage householders to separate out more food waste so that, over time, 70% of food waste generated in the household is put into the organics bin for collection.[125] It is assumed that separation in commercial premises also rises to this level. Similarly, better separation is assumed to occur in commercial premises.

12.3 Price

The main current route for management of food waste is composting. Price data for composting is available from a 2012 market report by RX3,[126] which gives the gate fee for bio-waste from brown bins at composting sites as €80/t in 2010. Gas Networks Ireland report that a typical gate fee from a composting plant in Ireland would be about €70/t and that the two AD plants that are accepting food waste are achieving a gate fee of €60 to €70/t.[127] For comparison, gate fees for in-vessel composting (which can be used to treat food waste) in the UK are €30 to €93/t with a median of €57/t. Gate fees for AD in the UK vary significantly, ranging from €14 to €74/t with a median of €50/t. [128] In the UK the gate fee is influenced by supply and demand, and the capacity in the region. In the UK some regions are currently facing overcapacity, as although there is increased collection of food waste, due to the general recession, less food waste is being produced. As a result gate fees are dropping in some regions.

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[120] EPA (2012). National Waste Report 2010.

[121] S.I. No. 71 of 2013. The regulations require progressive phasing in of separate collection of food waste and, by 1 July 2015, separate food waste collection must be provided for all population centres greater than 1,500 persons and, by 1 July 2016, for all population centres greater than 500 persons.

[122] Based on the requirement that by 1 July 2016 all population centres greater than 500 persons are provided with an organic bin, and data from the Central Statistics Office on population by town size in 2011 (Table CD116).

[123] http://www.environ.ie/en/Legislation/Environment/Waste/WasteManagement/FileDownLoad,21970,en.pdf

[124] Based on data from waste characterisation of the contents of the organic bin and composition of household waste in EPA, 2008. Municipal Waste Characterisation Report 2008.

[125] This increased rate of separation is based on evidence on separation rates achieved in trials in the UK, which found that recovery rates of up to 77% could be achieved. WRAP (2009) Evaluation of the WRAP Separate Food Waste Collection Trials.

[126] Rx3 (2012). Market Report on Irish Organic Waste Management and Compost Use.

[127] Personal communication. James Brown (Gas Networks Ireland), 21 January 2016.

[128] WRAP (2015). 'Comparing the cost of alternative waste treatment options'. Gate Fees Report 2015. Available at http://www.wrap.org.uk/content/comparing-cost-alternative-waste-treatment-options-gate-fees-report-2015#sthash.iOKWig9R.dpuf

It is assumed that in Ireland gate fees at AD plants would (as in the UK) need to be as low, or lower, than composting plants to attract the food waste resource. It is therefore assumed that at a gate fee of €60/t, 50% of the resource would be available, at €40/t a further 25% would be available, and at €0/t the remaining 25% of the resource would be available. These gate fees are equivalent to prices for the feedstock component of biogas costs: -€1,274/toe (€29-.8/GJ); -€728/toe (-€17.4/GJ), and; €0/toe (€0/GJ) respectively.

13. Residual Waste

13.1 Overview

13.1.1 What is the resource and how can it be used?

In 2012, Ireland produced approximately 2.69 million tonnes (Mt) of municipal solid waste (MSW), of which 1.75 Mt was biodegradable municipal solid waste (BMSW): paper, card, textiles, timber, food waste, as well as parks and garden waste.[129] Some of this waste is recycled (e.g. some paper, card, timber) and some is composted (e.g. food waste, parks and garden waste). The remainder was historically sent to landfill, but this is changing as the EU Landfill Directive (1999/31/EC) has required Member States to progressively reduce the amount of BMSW sent to landfill,[130] encouraging the use of other waste management routes.

The residual part of MSW (i.e. the part of the MSW left after materials have been recovered for recycling) can either be burnt directly in a waste to energy (WtE) plant to produce heat and/or electricity, or first processed into a refuse derived fuel (RDF), which, again, can be burnt in a dedicated WtE plant, or used as a fuel in other combustion plants such as cement kilns. In the future, residual MSW may also be converted into renewable transport fuels by using advanced techniques that are currently at the demonstration stage in Europe and the USA. A 200,000 t/year WtE plant burning residual MSW is now in operation in Meath, and plants in Cork and Dublin have been licensed but are not yet operational. An estimated 230 kt of RDF and 244 kt of waste including MSW were combusted with energy recovery in 2012.

13.1.2 How much resource could be available?

One of the underlying principles of waste policy in Ireland is compliance with the waste hierarchy.[131] Under this, the highest priorities are firstly to prevent the generation of waste and secondly, wherever possible, to reuse products. Third in the priority order is recycling, then other recovery, including the recovery of energy from waste and finally disposal, which in the case of Ireland, generally involves sending waste to landfill. The estimate of the quantity of residual waste from which energy could be recovered is consistent with this hierarchy, as wastes that can be recycled are not included in the resource estimate. Similarly, care is taken to avoid any double counting of the resource by not including food waste that can be anaerobically digested to produce biogas and is estimated as a separate resource (see Section 12).

The quantity of residual waste that could be collected from households and commercial premises has been estimated based on the growth in MSW, and allowing for the amount of recyclables and food waste that are collected separately. An estimate is then made of the 'biodegradable' proportion of this i.e. material which is of organic origin such as food, paper, wood and card. It is assumed in the BAU scenario that the quantity of waste landfilled is 427 kt in 2016, which is the maximum quantity permitted under Landfill Directives, and that this stays constant from 2016 onwards. In the Enhanced Supply scenario, it is assumed that additional efforts are made to divert waste away from landfill and utilise waste as an energy resource, so that the quantities landfilled fall to 257kt by 2030. Under the BAU scenario, the potential resource rises from 73 ktoe (3,071 TJ) in 2020 to 103 ktoe (4,324 TJ) in 2035 as the quantities of waste produced increase. In the Enhanced Supply scenario, an additional 37 ktoe could be available in 2035 compared with the BAU scenario, giving a total potential resource of 140 ktoe (5,853 TJ).

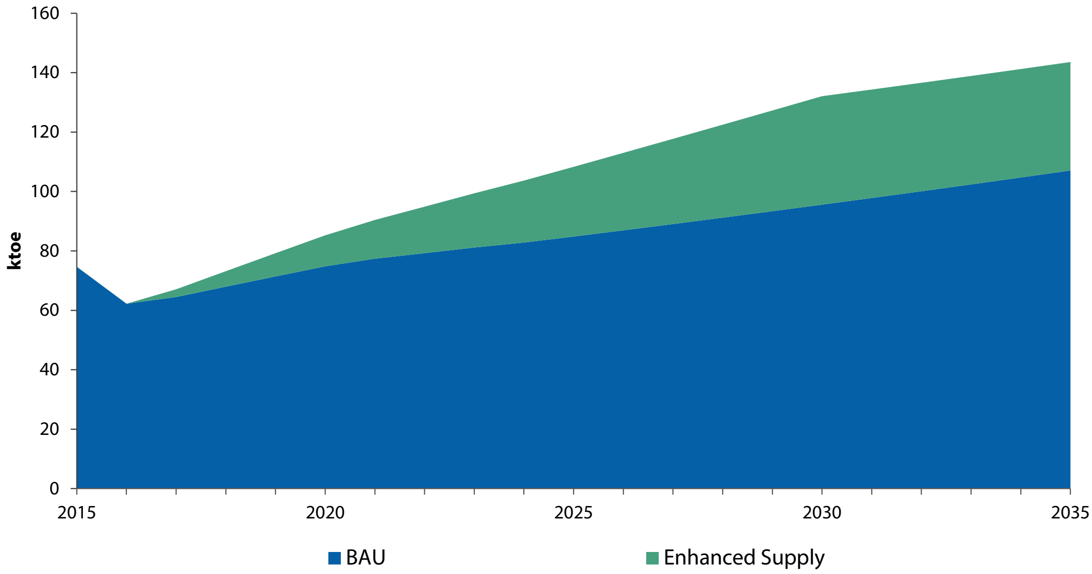
[129] EPA (2014). National Waste Report 2012.
[130] To 50% of 1995 levels by July 2013 and 35% of 1995 levels by July 2016.
[131] As stated in DECLG (2012). A Resource Opportunity: Waste Management Policy in Ireland. The waste hierarchy is set out in the Waste Framework Directive (2008/98/EC) and is enshrined in Irish Law by the Waste Management Act 1996 and the European Communities (waste Directive) Regulations 2011.

Table 13.1: Potential biodegradable residual waste resource

	Unit	2020	2025	2030	2035
Business as usual scenario					
Biodegradable Residual Waste	kt	348	395	445	498
Biodegradable Residual Waste	ktoe	75	85	96	107
Final (delivered) energy					
Electricity only	ktoe	22 - 27	25 - 31	29 - 34	32 - 39
CHP	ktoe	52 - 60	59 - 68	67 - 76	75 - 86
Heat only	ktoe	56 - 64	64 - 72	72 - 81	80 - 91
Percentage of current gross final energy use[a]					
Electricity only	%	0.2%	0.2 - 0.3%	0.3%	0.3%
CHP	%	0.5%	0.5 - 0.6%	0.6 - 0.7%	0.7 - 0.8%
Heat only	%	0.5 - 0.6%	0.6%	0.6 - 0.7%	0.7 - 0.8%
Enhanced supply scenario					
BMSW	kt	397	504	614	668
BMSW	ktoe	85	108	132	144
Final (delivered) energy					
Electricity only	ktoe	26 - 31	32 - 39	40 - 48	43 - 52
CHP	ktoe	60 - 68	76 - 87	92 - 106	101 - 115
Heat only	ktoe	64 - 72	81 - 92	99 - 112	108 - 122
Percentage of current gross final energy use[a]					
Electricity only	%	0.2 - 0.3%	0.3%	0.4%	0.4 - 0.5%
CHP	%	0.5 - 0.6%	0.7 - 0.8%	0.8 - 0.9%	0.9 - 1%
Heat only	%	0.6%	0.7 - 0.8%	0.9 - 1%	1 - 1.1%

Notes (a) Gross final energy use in 2014 was 11,243 ktoe

Figure 13.1: Potential biodegradable residual waste resource[132]



[132] The quantity of residual waste falls between 2015 and 2020 because the collection of food waste is expected to increase significantly in 2016 due to regulations extending the number of households that must be collected from. This outstrips the growth in waste generated and reduces the residual waste resource.

13.2 Methodology used to estimate the resource

The total quantity of municipal waste generated is based on projections from ISus as reported in the Environmental Protection Agency's National Waste Report.[133] The forecast was extended from 2025 to 2035 based on the growth rate from 2020 to 2025. The ISus model contains no forecast for commercial waste arisings. As the 2010 National Waste Report shows, historically both municipal and commercial waste arisings follow similar trends to those in Gross National Product (GNP), and as the ISus model is itself based on models of growth in the economy, the same growth rate is assumed for commercial waste arisings as for municipal waste. All households are assumed to have separate collection of recyclables from 2014 onwards and assumptions about the separate collection of food waste are the same as in the BAU food waste scenario (see Section 12.2).

In the BAU scenario, waste up to the limit specified by the EU Landfill Directive target is landfilled from 2016 onwards (and is thus unavailable for energy use). In the Enhanced Supply scenario, a target of 10% of BMSW generated is set for landfill in 2030 (loosely based on targets proposed by the EU in proposals for moving towards a circular economy).[134] This equates to 257 kt – a 40% reduction from the quantity permitted by the current EU Landfill Directive target in 2016.

In the Enhanced Supply scenario, it is assumed that separate food waste collection remains at the levels assumed in the BAU food waste scenario. If source-separate food waste collection was more successful, as assumed in the food waste Enhanced Supply scenario, then the solid BMSW resource would be at about the same level as in the BAU scenario by 2030, as the bioenergy potential is moved from this resource to the food waste resource.

13.3 Price

As discussed in Section 13.1.2, waste policy would seek to encourage the recovery of energy from waste, rather than its disposal to landfill, and as such the gate fee set by WtE plants would need to be lower, i.e. more attractive than that for landfill.

The price for residual BMSW is assumed to be set by the alternative disposal route, landfilling. Landfill disposal charges are composed of a gate fee, to cover the cost of operating the landfill, and a landfill levy, which is currently €75/t.[135] The gate fee is estimated to be €70/t based on information from Browne et al (2011),[136] and a 2012 study of landfill gate fees in Europe,[137] which reported that landfill gate fees in Ireland ranged from about €56 to €81 with a mean of €70/t. This gives a total cost of €145/t.

It is assumed that, to attract residual waste from landfill, gate fees at WtE plants would have to be more attractive, and they are therefore set at 90% of the landfill gate fees, i.e. €131/t. This gives a cost for the resource of -€610/toe (-€15/GJ).

[133] EPA (2012). National Waste Report 2010.
[134] See, for example, http://ec.europa.eu/environment/waste/target_review.htm, which summarises the Circular Economy Package and revised legislative proposals on waste, which include a binding landfill target to **reduce landfill to maximum of 10%** of all waste by 2030.
[135] Waste Management (Landfill Levy) (Amendment) Regulations 2013 (S.I. No. 194 of 2013).
[136] Browne et al (2011). 'Assessing the cost of biofuel production with increasing penetration of the transport fuel market: a case study of gaseous biomethane in Ireland', Renewable and Sustainable Energy Reviews, Volume 15, Issue 9, December 2011, pages 4537–47. Available at http://www.sciencedirect.com/science/article/pii/S1364032111003431)
[137] Bio Intelligence Service (2012). Use of Economic Instruments and Waste Management Performances.

14. Industrial Food Processing Wastes

14.1 Overview

14.1.1 What is the resource and how can it be used?

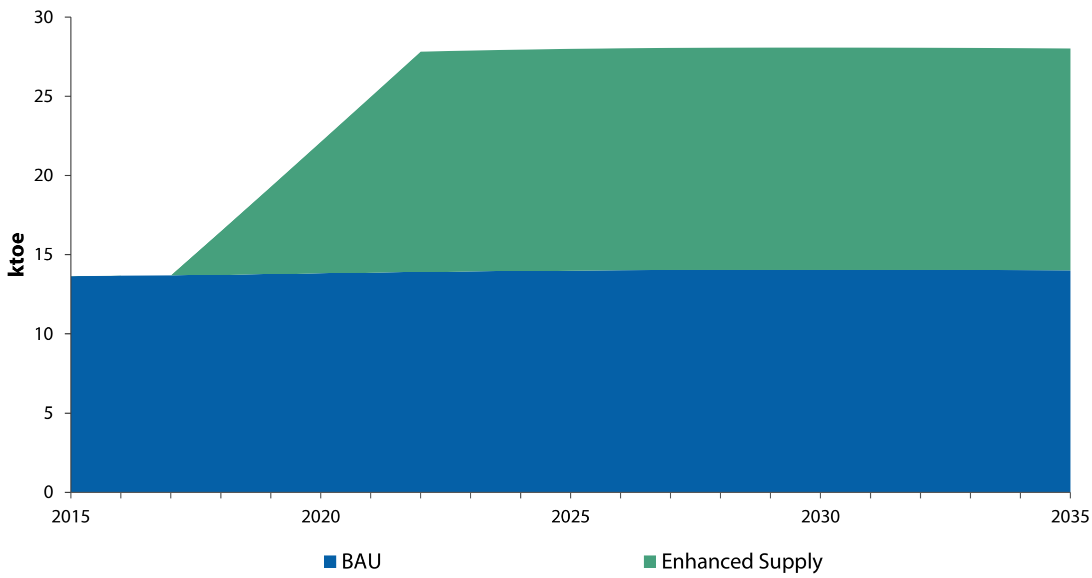
Wastes and liquid effluents with a high organic content, which arise from processing of foods, can be processed in an AD plant to produce biogas, a mixture of methane and carbon dioxide. The biogas can then be used in a boiler to produce heat, burnt in a CHP unit to generate heat and/or power, or it can be upgraded to biomethane by removing the carbon dioxide. The biomethane can then be injected into the natural gas grid or used as a vehicle fuel.

Food processing industries producing wastes that have been identified as suitable for anaerobic digestion include milk processing waste, slaughter house waste and fish processing waste. Much of this waste is currently disposed of by land spreading.

14.1.2 How much resource could be available?

The current resource has been estimated based on data provided from Gas Networks Ireland on the quantity of milk processing waste, slaughter house waste and fish processing waste that might be available.[138] As the resource is not yet that well characterised, the quantity that might be available and suitable for AD is still uncertain. In the BAU scenario, it is assumed that a third of the resource might be, and in the Enhanced Supply scenario, that this can be increased to two-thirds of the resource. This gives a resource of 14 ktoe (579 TJ) in 2020 in the BAU scenario, and 22 ktoe (926 TJ) in the Enhanced Supply scenario, rising to 28 ktoe (1,173 TJ) by 2035.

Figure 14.1: Potential biogas from industrial food processing wastes



Note: The quantity of residual waste falls between 2015 and 2020 because collection of food waste is expected to increase significantly in 2016 due to regulations extending the number of households which must be collected from. This outstrips the growth in waste generated and reduces the residual waste resource.

14.2 Supply-side barriers

As with other AD resources, a minimum quantity of resource is required to ensure the AD plant is of a viable scale, although co-digesting this with other AD feedstocks, such as animal manures or food waste from MSW, can increase the feedstock available to a plant. For milk processing and slaughter house waste there are a limited number of facilities where the waste is produced, so this may be less of an issue than for other feedstocks.

[138] James Brown (Gas Networks Ireland). Personal communication, 15 Dec. 2015. Data based on work by GNI and University College Cork, and data from Allen et al (2015). 'A detailed assessment of resource of biomethane from first, second and third generation substrates', Renewable Energy, Volume 87, pages 656–65.

Table 14.1: Potential biogas from industrial food processing wastes

	Unit	2020	2025	2030	2035
Business as usual scenario					
Industrial food waste	kt	147	152	153	153
Biogas produced	ktoe	14	14	14	14
Final (delivered) energy					
Electricity only	ktoe	4 - 6	4 - 6	4 - 6	4 - 6
CHP	ktoe	10 - 11	10 - 11	10 - 11	10 - 11
Heat only	ktoe	10 - 12	10 - 12	11 - 12	11 - 12
Transport fuel	ktoe	14	14	14	14
Percentage of current gross final energy use[a]					
Electricity only	%	0.04 - 0.05%	0.04 - 0.05%	0.04 - 0.05%	0.04 - 0.05%
CHP	%	0.1%	0.1%	0.1%	0.1%
Heat only	%	0.1%	0.1%	0.1%	0.1 - 0.2%
Transport fuel	%	0.1%	0.1%	0.1%	0.1%
Enhanced supply scenario					
Industrial food waste	kt	235	304	306	305
Biogas produced	ktoe	22	28	28	28
Final (delivered) energy					
Electricity only	ktoe	7 - 9	8 - 11	8 - 11	8 - 11
CHP	ktoe	15 - 18	20 - 22	20 - 22	20 - 22
Heat only	ktoe	17 - 19	21 - 24	21 - 24	21 - 24
Transport fuel	ktoe	22	28	28	28
Percentage of current gross final energy use[a]					
Electricity only	%	0.1%	0.1%	0.1%	0.1%
CHP	%	0.1 - 0.2%	0.2%	0.2%	0.2%
Heat only	%	0.1 - 0.2%	0.2%	0.2%	0.2%
Transport fuel	%	0.2%	0.2%	0.2%	0.2%

Notes (a) Gross final energy use in 2014 was 11,243 ktoe

14.3 Methodology used to estimate the resource

Estimates for the current quantities of waste and methane yields are based on data provided by Gas Networks Ireland. Milk processing waste is assumed to increase in line with growth in the dairy herd (see Section 9.2). Quantities of slaughter house waste are assumed to follow the same trend as quantities of tallow (see Section 10.2) and decline slightly. Fish processing waste is assumed to remain at current levels. Only slaughterhouse waste, which is classified as Category 2 and 3, is included in the estimates.

14.4 Price

These wastes will typically require disposal, often through land spreading or, for liquid effluents, treatment in a wastewater treatment plant, before discharge to sewer. The costs of these alternative waste management options will vary by type of waste, proximity to suitable areas of land for spreading, and level of wastewater treatment required. It is possible that facilities might be able to charge a gate fee and levels of €20/t have been suggested, but due to the lack of information in this area, a more conservative assumption is made here, that the resource is available at zero cost i.e. €0/t.

15. Other Potential Bioenergy Resources

A number of other potential bioenergy resources that are considered less market ready have been assessed to examine the potential scale of resource, the timescale over which it could become available and key barriers to utilisation.

15.1 Chicken litter

15.1.1 What is the resource and how can it be used?

Poultry litter consists of wood shavings or straw that has been used in poultry houses where chickens or turkeys are fattened, mixed with poultry dung, urine, feathers and food particles. The litter must be changed each time a flock of birds is reared and sent to the processors, so, in the case of chickens, litter is available every 6 – 8 weeks. The litter can be handled as a bulk solid like wood chips and transported in lorries. Laying hens generally produce a wet agricultural residue more suitable for anaerobic digestion and that resource is not considered here.

Poultry litter can either be transported off farm to be combusted in large centralised fluidised bed plants to produce electricity, or stored on farm and then used in smaller scale fluidised bed units on the farm to produce heat and power, with the heat used in the poultry houses.[139]

Currently poultry litter is either disposed of as mushroom compost, or disposed of by land spreading. The high nutrient content of chicken litter means that, when land spread, it has some value as a fertiliser. However, the quantities which can be land spread are limited by compliance with the Nitrates Directive.

15.1.2 How much resource could be available and when?

A 2003 study for SEAI[140] estimated that about 140 kt of chicken litter was produced per year from a population of about 13 million birds. Between 60 to 100 kt of the litter were used as mushroom compost with the remaining 50 to 80 kt land spread. Of the litter spread to land, the study considered that about 50%, i.e. 25 to 40 kt, could be collected and used as an energy resource. The energy content of this litter would be about 5.3 to 8.5 ktoe (225 to 360 TJ). The number of poultry fell by about 14% between 2002 and 2010[141] (the latest year for which agricultural census data is available). Forecasts of livestock numbers, which are consistent with plans for the agricultural sector, indicate poultry numbers remaining at about 2010 levels until 2019 after which they begin to steadily increase.[142] In summary therefore, assuming that the same percentage of litter is utilised by the mushroom compost industry, the current resource is estimated at about 4.6 to 7.4 ktoe (193 to 309 TJ) potential, rising by about 25% by 2035 to 5.8 to 9.2 ktoe (242 to 387 TJ) by 2035.

15.1.3 Price

Poultry litter is essentially a waste, so will have a low cost. The 2003 study reported that the mushroom industry paid up to 24.3 €/t (in 2015 prices) (€2.7/GJ) for chicken litter, mainly reflecting collection and haulage costs. While a centralised plant might need to pay similar prices, small scale on-farm use would be able to acquire the resource at a much lower cost.

Chicken litter that is land spread does have some value to the farmer because of its nutrient levels (estimated by the 2003 study to be 21 to 30 €/t, or 2.4 to 3.4 €/GJ), although the fertiliser value is not fully realised for a number of reasons. However the study also suggested that arrangements were usually informal and that no money generally changes hands, suggesting that the resource could be available at zero or low cost for on-farm use.

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[139] See for example the plant described on this website: http://www.bhsl.com/poultry-home-page/how-fbc-works/
[140] RPS MCOS (2003). An Assessment of the Renewable Energy Resource Potential of Dry Agricultural Residues in Ireland. Report for SEAI.
[141] CSO (2012). Census of Agriculture 2010. Final Results.
[142] Data used by EPA to compile Irish GHG Projections, available at http://cdr.eionet.europa.eu/ie/eu/mmr/art04-13-. These reflect the aspirations set out in Food Harvest 2020.

15.2 Sewage sludge

15.2.1 What is the resource and how can it be used?

Sewage sludge from wastewater treatment can be processed in an AD plant to produce biogas, a mixture of methane and carbon dioxide. The biogas can then be used in a boiler to produce heat, burnt in a CHP unit to generate heat and/or power, or it can be upgraded to biomethane by removing the carbon dioxide. The biomethane can then be injected into the natural gas grid or used as a vehicle fuel.

Irish Water are currently working to establish accurate information on routes for sewage sludge treatment, the number of AD plants, and their operational status.[143] Information collected to date suggests that AD plants are currently installed at 18 wastewater plants (Table 15.1), but that five of these do not have a CHP plant installed, with any biogas not used for heating the AD plant or the thermal drying of the sludge being flared. Of the other 13, the AD plant is not in operation at four, leaving nine plants capable of generating and utilising biogas. Three of these are currently being upgraded, so the CHP plant is not currently operational. Where sewage sludge is not treated via anaerobic digestion, it is either treated by thermal drying, lime stabilisation, or composting.

Table 15.1: Status of sites with anaerobic digestion plants

Status of sites with AD plant	Sites
Sites with AD but no CHP plant	5
Sites with AD and with CHP plant	13
of which	
Digester not in use - no plans currently to recommission	4
Digester in use and currently operating CHP plant	6
Digester in use and CHP plant will be operational once upgrading complete	3

15.2.2 How much resource could be available and when?

Irish Water estimated that in 2014, 70,420 tonnes of dry solids (tds) of sewage sludge were produced from primary and secondary treatment at wastewater plants. Of these about 42,000 tds were anaerobically digested in 2014, and this should rise to about 46,000 tds (65% of sewage sludge produced) when current upgrades are completed. This could produce about 8 ktoe (336 TJ) of biogas, rising to 8.7 ktoe (353 TJ) of biogas after upgrades are complete.[144] If all of the sites with AD plants were equipped with CHP plants and bought into operation, then about 57,000 tds could be treated, which would generate about 10.8 ktoe (452 TJ) of biogas.

15.2.3 Supply-side barriers and constraints

The strategic plan for Irish Water requires them to develop a National Wastewater Sludge Management Plan, which will include the use of AD plants where feasible and economically viable. This plan is currently being developed by Irish Water, but will require capital investments, e.g. to bring unused plants back into operation, add CHP plants at some sites with AD, and potentially build new plants. While projects to increase the AD capacity will be included in the new investment plan, which will go for approval at the end of 2016, other higher priority investment needs may mean that they will not be funded.

15.2.4 Price

As a waste which requires treatment before disposal, sewage sludge can be regarded as having a 'zero' cost as a feedstock.

[143] Fiona Lane. Irish Water. Personal communication, 10 Nov. 2015.
[144] Based on a biogas yield of 490 m3 biogas per tonne of volatiles solids and 0.8 tonne of volatile solids per tds, from SEAI Gas Yields Table: http://www.seai.ie/Renewables/Bioenergy/Bioenergy_Technologies/Anaerobic_Digestion/The_Process_and_Techniques_of_Anaerobic_Digestion

15.3 Fats, oils and greases

15.3.1 What is the resource and how can it be used?

Fats oils and greases (FOGs) from food service outlets (restaurants, etc.) and domestic households typically enter the sewer network, where they accumulate and form a hardened solid. These 'fatbergs' reduce the capacity of the sewerage system and are a contributing factor in an estimated 50 – 75% of sewerage blockages, increasing the risk of overflow.[145] If FOGs are intercepted at source by installing grease interceptors or grease recovery units, then they can be collected and processed in an AD plant to produce biogas, or potentially processed (like tallow and used cooking oils) to produce biodiesel.

15.3.2 How much resource could be available?

Since 2008, in an attempt to reduce operation problems in the sewerage system, food service outlets in Dublin have been required to apply for a trade effluent discharge license, which has required that they take actions to minimise the disposal of FOGs to sewer, including the separation of FOGs using grease traps. The recovered FOGs must then be disposed of separately as waste.

In 2015, there were over 2,200 licensed food service outlets in Dublin. Case study data from a sample group suggests that, on average, about 700 litres of grease trap waste was recovered annually from each premises, suggesting that, in total, about 1.4 kt of grease might be available.[146] If this was to be anaerobically digested then about 0.1 ktoe (2.8 TJ) of biogas could be produced.[147] Utilising the grease as a feedstock for biodiesel could recover more of the energy in the feedstock but is dependent on the grease being of a suitable quality.

Expanding the scheme to other cities could also increase the potential resource available, e.g. expanding to Cork, Limerick, Galway and Waterford would increase the potential resource by 38% (assuming the same ratio of food service outlets to population as in Dublin).

15.3.3 Supply-side barriers and constraints

Caustic contamination from cleaning chemicals can affect the viability of utilising recovered FOGs for energy purposes. Grease trap waste can also become contaminated with hydrocarbons and domestic sewerage where transporters use the same vehicle when pumping out grease traps, triple interceptor traps and septic tanks.

15.3.4 Price

As FOGs are a waste they can be regarded as having a 'zero' cost as a feedstock.

15.4 Macroalgae

15.4.1 Description

Macroalgae, or seaweeds, are multi-cellular photosynthetic plants that grow in aquatic environments (salt or freshwater). They are typically classified into three different groups, which can be distinguished based on their pigment – brown algae, red algae and green algae. Red and brown algae are almost exclusively marine, whilst green algae are also common in freshwater (rivers and lakes) and damp terrestrial locations.[148]

Currently, seaweed is typically harvested as a food source and to produce hydrocolloids for use as gelation and thickening agents in different food, pharmaceutical, and biotechnological applications.[149] These traditional markets currently sustain a higher price for raw material than that likely for biofuel production.

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145 Curran, T. (2015). Extracting Value from Fat, Oil and Grease (FOG) Waste.

146 Based on data from Gibbons, D. (2015). Dublin City Council's Fats, Oils and Grease Programme. Presentation to Water innovation Forum 2015, 28 May 2015. Available at http://www.futurewaterassociation.com/sites/default/files/public/event_documentation/10%20-%20David%20Gibbons%20-%20Presentation.pdf

147 Based on a biogas yield of 800 m3 biogas per tonne of volatiles solids and 0.12 tonne of volatile solids per tonne grease, from SEAI Gas Yields Table: http://www.seai.ie/Renewables/Bioenergy/Bioenergy_Technologies/Anaerobic_Digestion/The_Process_and_Techniques_of_Anaerobic_Digestion

148 Website: The Seaweed Site: information on marine algae (http://www.seaweed.ie/algae/seaweeds.php) accessed 14/01/2016

149 Rhein-Knudsen, N., Ale MT, Meyer, AS (2015).'Seaweed hydrocolloid production: an update on enzyme assisted extraction and modification technologies'. Mar Drugs. 2015 May 27; 13(6):3340-59, available at http://www.ncbi.nlm.nih.gov/pubmed/26023840

Macroalgae can be anaerobically digested to produce methane/biogas and/or fermented to ethanol.[150] Biogas production is a long-established technology and trials have shown that anaerobic digestion of seaweed is technically viable and that it should be possible to incorporate seaweed resources into existing AD plants.[151] In the case of fermentation, management of the presence of salt, polyphenols, and sulphated polysaccharides is required to avoid inhibition of the fermentation process.

There are five kelp species which are native to Ireland: *Laminaria digitata*; *L. hyperborean*; *Saccharina latissima*; Saccorhiza polyschides and *Alaria esculenta*; of these *Laminaria* (kelp) is considered to have the best prospects as a bioenergy feedstock.

Seaweed exploitation in Europe is currently restricted to the manual and mechanised harvesting of natural stocks. By comparison, the majority of Asian seaweed resources are cultivated. When harvesting natural stocks, the sustainability of this harvesting needs to be considered. In Ireland the access to wild stocks is controlled by the state. While harvesting of natural stocks is most prevalent in Europe, from a sustainability viewpoint it is preferable to cultivate seaweed and leave natural resources as they are. One possibility to achieve this is to align seaweed farms with salmon farms. The farmed seaweed will extract nutrients from the water released by the farmed salmon and the presence of seaweed can help to ameliorate the negative impacts of salmon farming.[152]

15.4.2 Resource availability

Ireland has 7,500 km of coastline at low tide. Excluding parts of the coastline that do not have suitable seabed or which comprise of sandy beaches and estuaries, it is estimated that kelp forests can be found on around 3,920 km of coastline (52% of total low tide coastline). The estimated resource from this is around 3,000,000 tonnes of kelp (wet weight).[153] Assuming that the dry weight of this material is 15% of the wet weight, this equates to a kelp resource of 450,000 tonnes dry weight per annum.[154] Cultivation of seaweed could increase this resource, although the costs of the cultivation of seaweed in Ireland and Europe are not currently well understood.

A 2009 study by Sustainable Energy Ireland outlines a number of scenarios for the exploitation of macroalgae for biofuel in Ireland. In terms of the contribution of biofuels from macroalgae by 2020, the most optimistic scenario estimates 447 TJ, which is around 0.2% of Ireland's 2009 national road-fuel demands.

15.4.3 Key barriers and constraints

There are clearly a number of key barriers and constraints that will need to be overcome in order to achieve a significant contribution from macroalgae.

Firstly, the impact of the harvesting of wild seaweeds on natural ecosystems needs to be better understood, particularly as macroalgae are recognised as having a role in supporting marine biodiversity. The potential for a negative impact on ecosystems means that the preferred supply option of seaweeds for biofuels is likely to be cultivation.

As discussed, macroalgae are currently used mainly as a food source and for hydrocolloid production. There is global interest in the cultivation of seaweeds for biofuels. Bioethanol and biogas are being explored in Asia, Europe and South America, while biobutanol from macroalgae are attracting research interest and investment in the USA. However, the cost of production is high, with estimates suggesting that biogas from seaweed could be 7 – 15 times more expensive than natural gas.[155] Reducing raw material costs to a competitive level is a significant economic challenge that needs to be overcome. There may be potential to learn lessons from the cultivation of seaweed in China.[156]

While there are potential synergies between seaweed cultivation and other sea uses, such as salmon farms, there are also potential conflicts with other sea uses (such as fishing and navigation). In

[150] Milledge, J. et al (2014). Macroalgae-Derived Biofuel: A Review of Methods of Energy Extraction from Seaweed Biomass. Energies 2014, 7, 7194-7222.
[151] Sustainable Energy Ireland (2009). A Review of the Potential of Marine Algae as a Source of Biofuel in Ireland.
[152] Murphy, JD (2015). 'A bioenergy model for Ireland: greening the gas grid'; Engineers Journal; 7 April 2015 (http://www.engineersjournal.ie/2015/04/07/bioenergy-model-ireland-greening-gas-grid/) accessed 14 Jan. 2016.
[153] Website: Kerry Healthcare: Seaweed in Ireland (http://kerryhealthcare.com/seaweed-in-ireland/) accessed 14 Jan. 2016.
[154] Xia, A., Herrmann, C., Murphy, JD (2015), 'How do we optimize third-generation algal biofuels?' University College Cork, Ireland, 2015 Society of Chemical Industry and John Wiley & Sons, Ltd.
[155] Ricardo-AEA (2013). 'Biofuels: Scottish feedstock summary and potential biofuel opportunities for Scotland'.
[156] Further information on the cultivation of seaweed (kelp) in China can be found at http://www.seaweed.ie/aquaculture/kelp_china.php

addition, the seasonality of supply could pose some operational challenges in delivering energy to markets.

There are a range of economic, technological and environmental challenges that need to be overcome to make the supply of macroalgae as a feedstock economically viable within Ireland. However, Ireland already has a long track-record in macroalgae research. Ireland is home to the Science Foundation Ireland (SFI) Marine Renewable Energy Ireland (MaREI) Centre,[157] which is a cluster of key university and industrial partners dedicated to solving the main scientific, technological and socio-economic challenges related to marine renewable energy. The centre looks to develop innovative solutions to overcome the challenges, reducing the time to market and reducing the costs to a competitive level. Within SFI MaREI, there are currently 11 researchers from the Environmental Research (ERI), University College Cork (UCC) who are investigating 'Smart Marine Energy: Marine Renewable Gas and Energy Storage.' The objectives of this research include:[158]

- The biomethane potential from various types of macroalgae harvested at different times of year.
- Optimum methods of generating biomethane from macroalgae including co-digestion with suitable substrates.
- Co-generation of hydrogen and methane from both macroalgae and microalgae.
- Investigation of microbial ecology of algae digesters.
- Design and fabrication of 'in-situ' and 'ex-situ' biomethanation processes.
- Optimal applications of Power to Gas systems.

While there is significant research being carried out in Ireland to help overcome the various challenges to macroalgae use, it is not yet clear the timescales over which this could become a viable feedstock.

15.5 Microalgae

15.5.1 Description

Microalgae are microscopic organisms that grow in aquatic environments (salt or freshwater). They are photosynthetic cells that are mostly unicellular. There are vast number of microalgae species (with over 30,000 known species), but only a small number are currently considered to have commercial significance. These include *Chlorella*, *Spirulina*, *Dunaliella* and *Haematococcus*.

Microalgae receive interest as a potential feedstock for biofuel production as, depending on the species and cultivation conditions, they can produce useful quantities of the raw materials (particular sugars and fats) required for producing bioethanol and biodiesel transport fuels. Microalgae also produce proteins that could be used as a source of animal feed. There are also species which produce compounds that have commercial value as pigments and pharmaceuticals.[159]

As with macroalgae, microalgae have a number of advantages over first-generation biofuel crops. Such advantages include higher yields, faster growth, and lower requirements for land. While there has been some significant investment in the development of algal biofuels within the energy and aviation sectors (examples include Airbus, ExxonMobil), to date algae-based biofuels have been demonstrated only on a very small scale. There are no suppliers currently operating on a full commercial basis.

15.5.2 Resource availability

A 2009 study by Sustainable Energy Ireland, looking at the exploitation of algae (both macro and micro) for biofuel in Ireland developed a number of scenarios looking at the potential microalgae contribution to biofuel by 2020. The most optimistic scenario stated that around 79 TJ could come

[157] Website: Centre for Marine and Renewable Energy (http://marei.ie)
[158] IEA (2014). IEA Bioenergy Task 37: Country Reports Summary 2014. (http://www.nachhaltigwirtschaften.at/iea_pdf/reports/iea_bioenergy_task37_country_report_summary_2014.pdf) accessed 14 Jan. 2016.
[159] Slade, R., Bauen, A. (2013). 'Micro-algae cultivation for biofuels: Cost, energy balance, environmental impacts and future prospects'; https://spiral.imperial.ac.uk/bitstream/10044/1/11762/2/Micro-algae%20cultivation%20for%20biofuels_Slade_2013.pdf

from microalgae resources by 2020. While this is a small proportion of the 2020 Irish biofuel target of 22,000 TJ, the report notes that there could be greater opportunities as a result of further research.

A research paper by UCC, published in 2014, looked at an optimal system combining dark fermentation, anaerobic digestion and carbon dioxide biofixation to produce biofuel from microalgae. This study suggested that, using the proposed process, 64% of total transport energy demand in Ireland in 2020 could be achieved from biomass. This is significantly higher than the estimates in the earlier 2009 study.

This demonstrates that microalgae could have potential in Ireland, but that further research is required in order to determine the optimal processes for obtaining a supply of biofuel from microalgae.

15.5.3 Key barriers and constraints

The high cost of growing, harvesting and processing microalgae presents a large barrier to commercialisation. The technology for the low cost harvesting of microalgae has not yet been demonstrated at a commercial scale. This still needs to be demonstrated at a significant scale to show that algae oil can become a viable future energy source.[160] There may also be potential to apply biorefinery-type processes to extract and separate several commercial products from microalgae, in addition to the biofuel resource. This could be a research area that would improve the economic viability of the technology.

In existing commercial applications, which are small scale and high value product manufacture, artificial light and sometimes heat are used for growing microalgae. However, this can be justified due to the high value nature of the products. Use of heat and light is unlikely to be applicable for the growth of microalgae for energy purposes and, therefore, only natural light (and possibly waste heat) should be considered. This means that there is uncertainty on the achievable productivity levels in view of the Irish climate and its prevailing natural light and temperatures. To overcome this potential barrier, the identification and demonstration of local strains, requiring low light intensities and lower water temperatures, but giving satisfactory growth rates and yields, would be required.

While there appears to be potential for microalgae use as a biofuel feedstock, further demonstration and research is required to help overcome the key barriers and constraints. It is not yet clear the timescales over which this could become a viable feedstock.

[160] IEA (2011). Algae as a Feedstock for Biofuels: An Assessment of the Current Status and Potential for Algal Biofuels Production, July 2011. (http://task39.org/files/2013/05/Algal-Biofuels-IEA-Task-39-and-AMF-Joint-Summary.pdf) Accessed 14 Jan. 2016.

16. Imports of Bioenergy

16.1 Current imports of bioenergy

In the case of liquid biofuels used in the transport sector a substantial proportion is met from imports: 91 ktoe of bioethanol and biodiesel were imported, compared to 24 ktoe (of biodiesel) produced in Ireland. In the case of solid biomass for combustion, 42 ktoe of biomass and renewable waste were imported in 2014, compared to 262 ktoe produced in Ireland.[161]

16.2 Potential availability of bioenergy for imports in the future

The quantities of biomass that are traded globally are likely to rise substantially in the future as countries increase their use of biomass. According to the IEA World Energy Outlook 2014, global primary energy demand for bioenergy could more than double between 2020 and 2035, rising from 905 Mtoe to 1911 Mtoe. A study completed for IEA Bioenergy Task 40 on Sustainable Bioenergy Trade,[162] examined the results from a number of global energy models for their impact on the global trade of bioenergy. It found that trade in solid biomass could increase by a factor of about 80 by 2030 (from 2010 levels), and liquid biofuels by a factor of about 70. This would give trade of about 24,000 PJ (about 570 Mtoe) of solid biomass and about 9,100 PJ (about 229 Mtoe) of liquid biofuels. It is likely that Europe would be a net importer, drawing on exports from North and South America, Russia and the former USSR and parts of Africa.

Ireland has deep water ports capable of receiving the large ships in which biomass is typically transported, but might need to develop other the infrastructure necessary to deal with large quantities of imported biomass (e.g. bulk handling facilities at ports). The fraction of the large forecast global trade that is captured by Ireland in the future is therefore likely to mainly depend on its willingness to pay for biomass compared to other countries wishing to import biomass, and, in the shorter term (see below), establishing supply contracts for the biomass.

One potential sustainability consideration in considering the use of imported bioenergy (particularly solid biomass) is the additional greenhouse gas emissions associated with these sources compared to domestic production. Both the energy used to pelletise biomass to make it suitable for long distance transportation, and the energy used in transport, will lead to additional greenhouse gas emissions.

16.3 Price

There is an emerging international trade in wood chips and wood pellets, and a relatively established market in biodiesel and bioethanol. It seems likely that, as trade of bioenergy becomes more common in the future, these markets will develop into commodity markets with prices set internationally. While some trade is likely to be under bilateral long-term contracts, these are likely to be informed by prices determined on the commodity market. As a relatively small consumer of biomass, it seems likely that Ireland will be a price taker, and will not influence the setting of prices.

A recent study looking at the supply of pellets from North America,[163] which is likely to be a key potential source of imports for Ireland, found that the price pellet mills have charged UK pellet users over the past year is CA$190 – 210/tonne for Canadian mills and US$ 160 – 210/tonne for US mills at UK ports.[164] This is equivalent to €7.8 to 10.2/GJ (€327 to 427/toe). Data from the Netherlands on the CIF price at Amsterdam-Rotterdam-Antwerp also shows prices of between €8 and 10/GJ (€225 to 419/toe) in 2015.[165] Prior to this, the pellet price is reported as stable between 2009 to 2014 (at an average price of €7.5/GJ (€314/toe) ± 10 %,) with the recent increases in early 2015 mainly due to the US dollar gaining against the euro from about 1.3 sto about 1.1.

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[161] 2014 Energy Balance, available at http://www.seai.ie/Publications/Statistics_Publications/Energy_Balance/Previous_Energy_Balances/

[162] Matzenberger, J., Daioglou, V., Junginger, M., Keramidas, K., Kranzl, L., Tromborg, E. (2013). 'Future perspectives of international bioenergy trade'. IEA Bioenergy Task 40.

[163] Ricardo Energy & Environment (to be published). 'Use of North American woody biomass in UK electricity generation: Assessment of high carbon biomass fuel sourcing scenarios'. Report to DECC.

[164] This is a CIF (Cost, Insurance and Freight) price and includes the cost of transport to the port.

[165] Utrecht University (2015). 'Sustainable biomass and bioenergy in the Netherlands: Report 2014'. Available at http://www.bioenergytrade.org/downloads/iea-task-40-country-report-2014-the-netherlands.pdf

As these are prices for pellets at the port, there will be additional costs for delivery to the user – typically in the order of €1.5/GJ, giving a total price (for bulk deliveries) of €9.3 to 11.7/GJ (€389 to 490/toe).

The price of biodiesel and bioethanol traded internationally were estimated, in a previous 2012 study on the potential global biomass resource available to the UK,[166] as €30.4/GJ (€1273/toe) and €19.6/GJ (€821/toe) respectively.

[166] AEA (2011). UK and Global Bioenergy Resource, A report to DECC by AEA, Oxford Economics, Biomass Energy Centre and Forest Research.

Appendices

Appendix 1: Acknowledgements

The following experts were consulted during this study and SEAI and Ricardo Energy & Environment would like to thank those listed for information and views provided.

Expert	Organisation
Barry Caslin	Teagasc
Bernard Hyde	EPA
Charles Shier	Bord na Móna
Danielle Coll	DAFM
David Moloney	DAFM
Des Byrne	DCENR
Eugene Hendrick	DAFM
Evelyn Wright	Dublin City Council
Fiona Lane	Irish Water
Helen Searson	EPA
Henry Phillips	Consultant to COFORD
Ian Kilgallon	Gas Networks Ireland
James Brown	Gas Networks Ireland
Jerry Murphy	University College Cork
John Muldowney	DAFM
John O' Halloran	Bord na Móna
John Paul Corkery	NTMA
Kevin Hanrahan	Teagasc
Mairéad Broderick	DAFM
Martin Hogan	Irish Water
Martyn Byrne	NTMA
Mary McMahon	DAFM
Michael Fleming	Irish Famers Association
Niall Mcloughlin	DECLG
Padraig O'Kiely	Teagasc
Peter Kelly	DAFM
Ronan Gleeson	DAFM
Shirley Boyce	DAFM
Sorcha Byrne	DECLG
Tom Kent	Waterford Institute of Technology
Tony Quinn	DAFM

Appendix 2: Assumptions used to calculate delivered energy

The final delivered energy that could be produced from the feedstock resources identified in the study (as shown in the tables in the overview section of each chapter) were estimated using the assumptions shown below. The final delivered energy is indicative only, and is based on the range of conversion efficiencies that might be expected to be seen in technologies used to convert feedstocks to heat and power.

The efficiencies shown below are based on a range of sources, including Ricardo Energy & Environment expert judgement.

Conversion	Typical range of conversion efficiencies
Conversion of biogas to heat and power	
Electricity (gas engine)	30% to 40%
CHP (gas engine)	
- overall	70% to 80%
- electricity	30% to 40%
- heat	40%
Heat (boiler)	75% to 85%
Conversion of solid fuels to heat and power	
Electricity (co-firing, dedicated plant)	30% to 36%
CHP (gas engine)	
- overall	70% to 80%
- electricity	30% to 40%
- heat	40% to 40%
Heat (boiler)	75% to 85%

Appendix 3: Sewage sludge applications to SRC willow

Spreading of sewage sludge on agricultural land is controlled by the 'The Waste Management (Use of Sewage Sludge in Agriculture) Regulations, 1998' (S.I. 148/1998). Under this, sewage sludge can be recycled to agriculture on approval of a nutrient management plan by the local authority (in conjunction with the Nitrates Directive and the code of good practice for agricultural use of sewage sludge, code of good agricultural practice for the protection of soil and water, etc. However, the definition of agriculture stated in S.I. 148/1998 does not include SRC willow as agriculture. This is because it is based on an older EU Instrument which was defined long before the current interest in Energy Crops. Application of sewage sludge to SRC therefore requires a 'Certificate of Registration' permit. This can be a significant barrier, as the application form for the certificates is lengthy (about 50 pages), requires a substantial amount of time and effort to complete, and there is an application fee of €300.[167] In addition, unless fields where the sewage sludge is being applied are contiguous, then they will require separate permits. This barrier could be removed by updating the definition of Agriculture to include cultivation of energy crops.

[167] Barry Caslin (Teagasc). Personal communication, 20 October 2015.

Appendix 4:Tax system and energy crops

Tax breaks are currently available for two competing land uses; renting out pasture and forestry. Although gross margins from renting out land and growing energy crops are similar, tax relief is available on income from long-term land rental, but not on energy crops production. This makes long-term land rental attractive, especially to the large number of older farmers in Ireland.

A comparison of the tax breaks available for energy crops and commercial forestry shows a number of differences, and a number of areas where clarification is needed as to whether concessions for forestry would also apply to energy crops. This is summarised in the table below.

Tax Break	Commercial Forestry	Energy Crops
Income Tax	The occupation of woodlands managed on a commercial basis is exempt from income taxes for individuals or corporations. Since 2007 the exemption has been restricted for individuals. It is now limited to €80,000 per person per annum assuming total income exceeds €125,000 for that person.	The revenue from energy crops is subject to income tax at either 20% or 41% whichever is relevant.
Universal Social Charge (USC)	Income from commercial woodlands including the forest premium scheme is not liable to USC.	Energy crops are liable to USC payments.
Annual premium	The annual premium received by farmers is exempt from income tax.	There is no annual premium with energy crops.
Capital Gains Tax (CGT)	Commercial woodlands occupied by individuals are exempt from CGT on the growing of timber. The underlying land is not exempt but chargeable gains are restricted to the surplus over inflation adjusted costs. CGT is not applicable to a disposal upon death. If land is sold you would pay tax on the value of the trees that were sold with the land. This exemption does not apply to companies.	Energy crops do not receive such recognition.
VAT	Similarly to all agri outputs such as milk, cattle, grain, etc., a farmer doesn't have to register for VAT. Similar to other agri outputs, a farmer (forestry included) is entitled to charge the farmer-VAT rate (currently 5.2%) and retain this.	This concession needs clarification for energy crops.
Stamp Duty	Growing timber in commercial woodlands is exempt from stamp duty but the underlying land is not. If you sell your forest the value received for the trees sold will have no stamp duty charged against it.	Clarification is needed for energy crops.
Capital Acquisition Tax (CAT), Inheritance Tax	Commercial woodlands are subject to CAT on gifts or inheritance by individuals regardless of the residence or domicile of the disposer and beneficiary. Relief is available to commercial woodlands as an agricultural property. As from 23 January 1997 the relief as a reduction in market value is as follows: a flat rate reduction of 90% applied to both gifts and inheritance of commercial woodlands.	Clarification needed for energy crops.

Information provided by Barry Caslin, Teagasc.

Appendix 5: Projections of livestock numbers

Projections of livestock numbers ('000 head)

	Dairy cattle	Non-dairy cattle	Pigs	Sheep	Poultry
2015	1,193	5,523	1,494	4,548	14,452
2016	1,239	5,465	1,496	4,566	14,451
2017	1,258	5,334	1,507	4,615	14,548
2018	1,284	5,335	1,516	4,666	14,709
2019	1,320	5,309	1,522	4,720	14,920
2020	1,359	5,268	1,526	4,781	15,168
2021	1,396	5,226	1,528	4,811	15,451
2022	1,428	5,194	1,529	4,818	15,771
2023	1,457	5,157	1,529	4,809	16,114
2024	1,482	5,108	1,529	4,788	16,475
2025	1,505	5,047	1,529	4,758	16,851
2026	1,525	4,975	1,528	4,722	17,153
2027	1,542	4,897	1,528	4,682	17,402
2028	1,557	4,814	1,527	4,637	17,612
2029	1,569	4,727	1,526	4,590	17,795
2030	1,579	4,638	1,525	4,541	17,959
2031	1,588	4,548	1,526	4,490	18,108
2032	1,595	4,458	1,526	4,438	18,248
2033	1,600	4,369	1,527	4,384	18,381
2034	1,604	4,283	1,526	4,329	18,513
2035	1,607	4,195	1,526	4,272	18,643

Source: Data used by EPA to compile Irish GHG Projections, available at http://cdr.eionet.europa.eu/ie/eu/mmr/art04-13-

Appendix 6 :Full results tables

Business as Usual	Units	2020	2025	2030	2035	Units	2020	2025	2030	2035
Solid biomass										
Forest thinnings	000m3	491	1,661	1,621	2,794	ktoe	80.9	274	267.2	460.4
Sawmill residues	000m3	862	974	1,098	1,237	ktoe	142.0	160	181.0	203.9
Waste wood	tonnes	75,127	81,153	87,662	94,693	ktoe	26.4	28	30.8	33.2
Willow	odt	18,491	171,827	626,344	1,435,424	ktoe	8.4	78	284.2	651.4
Miscanthus	odt	7,339	84,664	391,831	1,135,909	ktoe	3.3	38	177.8	515.5
Straw	tonnes	268,996	327,587	358,858	413,929	ktoe	92.3	112	123.1	142.0
Residual MSW	tonnes	348,030	394,633	444,601	498,092	ktoe	74.8	85	95.6	107.1
Tallow	tonnes	84,807	85,597	83,626	80,653	ktoe	69.7	70	68.7	66.3
Biogas from anaerobic digestion										
Biogas from food waste	tonnes	289,405	313,996	340,639	369,521	ktoe	15.9	17	18.7	20.3
Biogas from cattle slurry	tonnes	100,007	108,787	112,568	113,269	ktoe	1.0	1	1.1	1.1
Biogas from pig slurry	tonnes	2,252,814	2,257,514	2,252,649	2,253,592	ktoe	24.1	24	24.1	24.1
Biogas from grass silage	odt	637,442	891,561	1,087,284	1,195,600	ktoe	249.8	349	426.1	468.6
Biogas from industrial food waste	tonnes	148,634	150,483	150,928	150,621	ktoe	13.8	14	14.0	14.0
Liquid biofuels										
Bioethanol from wheat	tonnes	118,969	123,175	127,381	131,587	ktoe	22.4	23	24.0	24.8
Biodiesel from OSR	tonnes	233,526	243,017	252,895	262,930	ktoe	77.6	81	84.0	87.4
Biodiesel from UCO	tonnes	9,673	10,023	10,316	10,614	ktoe	8.3	9	8.9	9.1
Totals										
Solid biomass						ktoe	497.9	846.7	1,228.4	2,179.8
Biogas						ktoe	304.6	405.9	484.1	528.1
Liquid biofuels						ktoe	108.3	112.6	116.9	121.3
Grand total						ktoe	910.8	1,365.1	1,829.4	2,829.1

Enhanced Supply	Units	2020	2025	2030	2035	Units	2020	2025	2030	2035
Solid biomass										
Forest thinnings	000m3	541	1,905	1,811	2,988	ktoe	89.2	314	298.4	492.4
Sawmill residues	000m3	862	974	1,098	1,237	ktoe	142.0	160	181.0	203.9
Waste wood	tonnes	75,127	81,153	87,662	94,693	ktoe	26.4	28	30.8	33.2
Willow	odt	18,491	188,323	643,810	1,280,772	ktoe	8.4	85	292.2	581.2
Miscanthus	odt	14,005	183,557	638,764	1,290,562	ktoe	6.4	83	289.9	585.7
Straw	tonnes	268,996	327,587	358,858	413,929	ktoe	92.3	112	123.1	142.0
Residual MSW	tonnes	355,883	385,549	453,294	492,298	ktoe	76.5	83	97.4	105.8
Tallow	tonnes	84,807	85,597	83,626	80,653	ktoe	69.7	70	68.7	66.3
Biogas from anaerobic digestion										
Biogas from food waste	tonnes	321,987	408,954	470,314	511,157	ktoe	17.7	22	25.8	28.1
Biogas from cattle slurry	tonnes	783,765	2,099,171	2,179,047	2,198,212	ktoe	7.9	21	22.1	22.3
Biogas from pig slurry	tonnes	3,234,785	3,487,539	3,480,023	3,481,479	ktoe	34.5	37	37.2	37.2
Biogas from grass silage	odt	1,010,579	1,435,987	1,768,224	2,135,000	ktoe	396.1	563	693.0	836.7
Biogas from industrial food waste	tonnes	238,666	302,042	302,937	302,321	ktoe	22.1	28	28.1	28.0
Liquid biofuels										
Bioethanol from wheat	tonnes	118,969	123,175	127,381	131,587	ktoe	22.4	23	24.0	24.8
Biodiesel from OSR	tonnes	233,526	243,017	252,895	262,930	ktoe	77.6	81	84.0	87.4
Biodiesel from UCO	tonnes	11,023	14,482	18,054	18,574	ktoe	9.5	12	15.5	16.0
Totals										
Solid biomass						ktoe	510.9	937.2	1,381.5	2,210.5
Biogas						ktoe	478.3	671.7	806.1	952.3
Liquid biofuels						ktoe	109.5	116.4	123.6	128.1
Grand total						ktoe	1,098.7	1,725.4	2,311.2	3,290.9

Appendix 7 :Energy Units

Energy Units

joule (J): Joule is the international (S.I.) unit of energy.

kilowatt hour (kWh): The conventional unit of energy that electricity is measured by and charged for commercially.

tonne of oil equivalent (toe): This is a conventional standardised unit of energy and is defined on the basis of a tonne of oil having a net calorific value of 41686 kJ/kg. A related unit is the kilogram of oil equivalent (kgoe), where 1 kgoe = 10-3 toe.

Decimal Prefixes

deca (da) 10^{1}	deci (d) 10^{-1}
hecto (h) 10^{2}	centi (c) 10^{-2}
kilo (k) 10^{3}	milli (m) 10^{-3}
mega (M) 10^{6}	micro (µ) 10^{-6}
giga (G) 10^{9}	nano (n) 10^{-9}
tera (T) 10^{12}	pico (p) 10^{-12}
peta (P) 10^{15}	femto (f) 10^{-15}
exa (E) 10^{18}	atto (a) 10^{-18}

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