SUSTAINABLE ENERGY AUTHORITY OF IRELAND

Bioenergy Supply in Ireland 2015 - 2035

Report Summary and Key Findings

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An update of potential resource quantities and costs

Report Summary and Key Findings

September 2016

SEAI Sustainable Energy Authority of Ireland

Ricardo Energy & Environment

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.

Report Summary and Key Findings

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.

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 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: Resources examined in detail in this report.

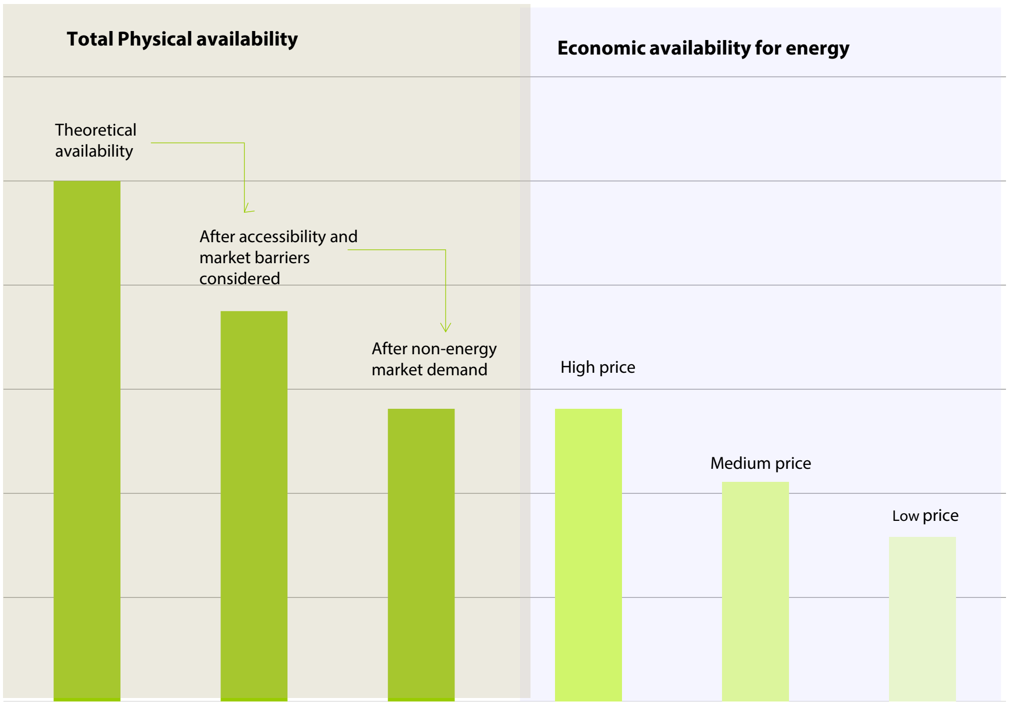
Resource	Resource category	Type of fuel available from resource
Forest thinnings and residues	Forestry	Solid fuel
Sawmill residues	Other by-products and waste	Solid fuel
Waste wood	Other by-products and waste	Sold fuel
Annual crops for biofuels – wheat and oil seed rape (OSR)	Energy crops	Biofuel
Perennial 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 illustrates how resource potential is estimated for each individual year.

Figure 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

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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

chain that captures the market 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.

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

Finally the report also contains a brief discussion of the quantity of bioenergy which might be available for import into Ireland.

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 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

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

volume available from thinning and residues for energy. Management practices that gather more of the residues left behind 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 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 2: Potential Bioenergy Resource by Type of Resource

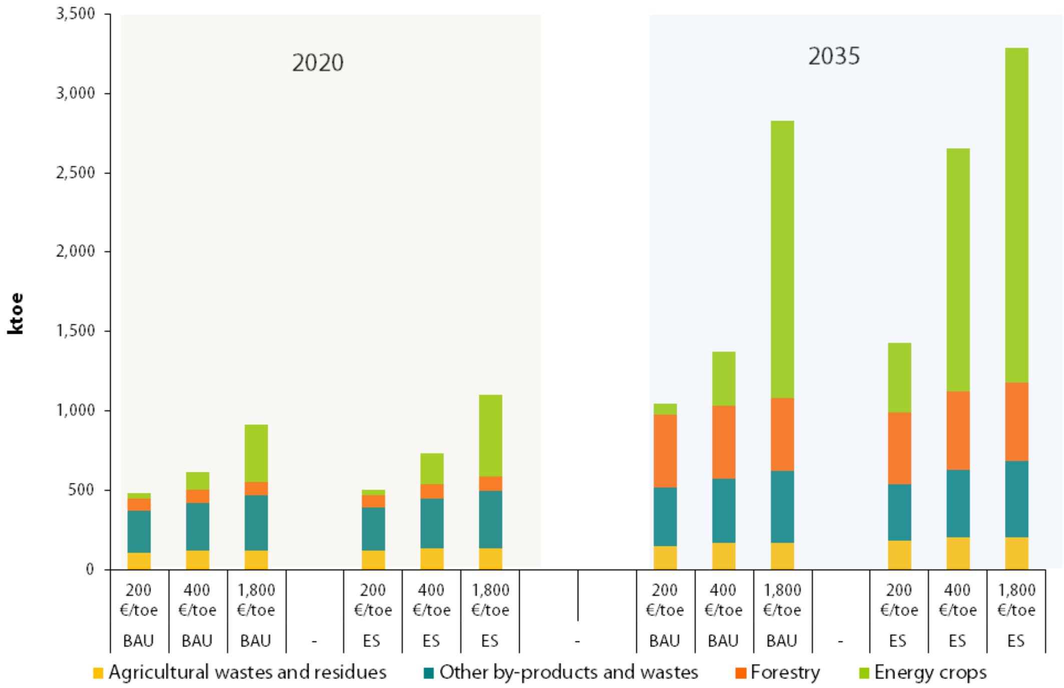
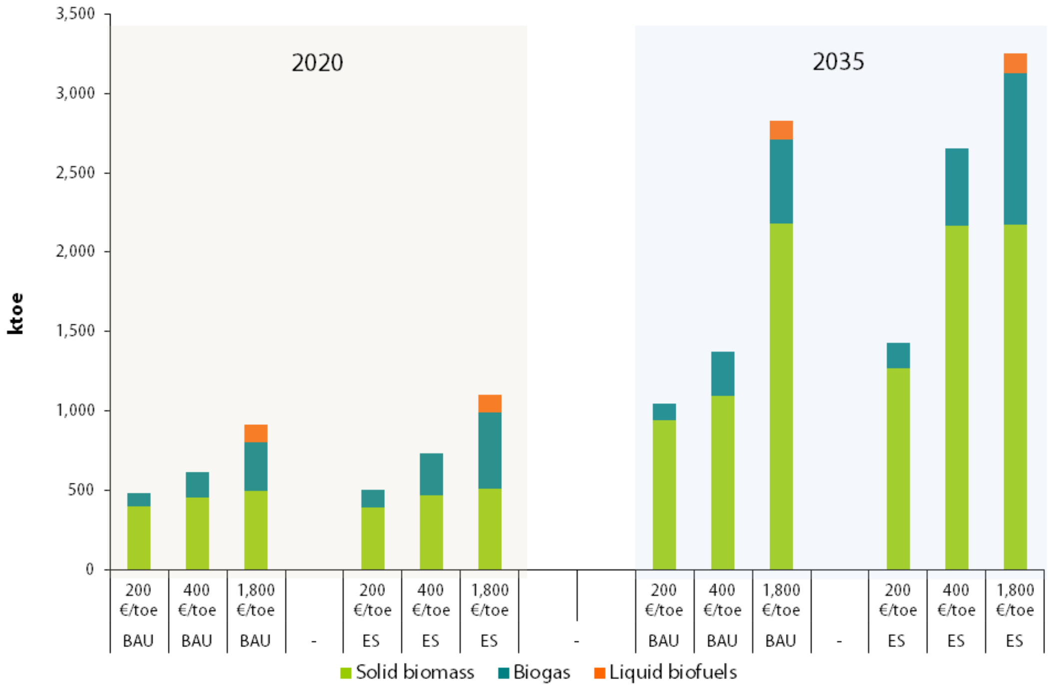


Figure 3 summarises the potential for each resource categorised by the type of fuel typically produced – solid, liquid or gas – in both scenarios across the three price scenarios. In all price bands, resources that provide solid biomass – typically used to produce heat and electricity – represent the 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 3: Potential Bioenergy Resource by Type of Fuel



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 4 and Figure 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 4: Supply curves for all resources in 2020 BAU scenario

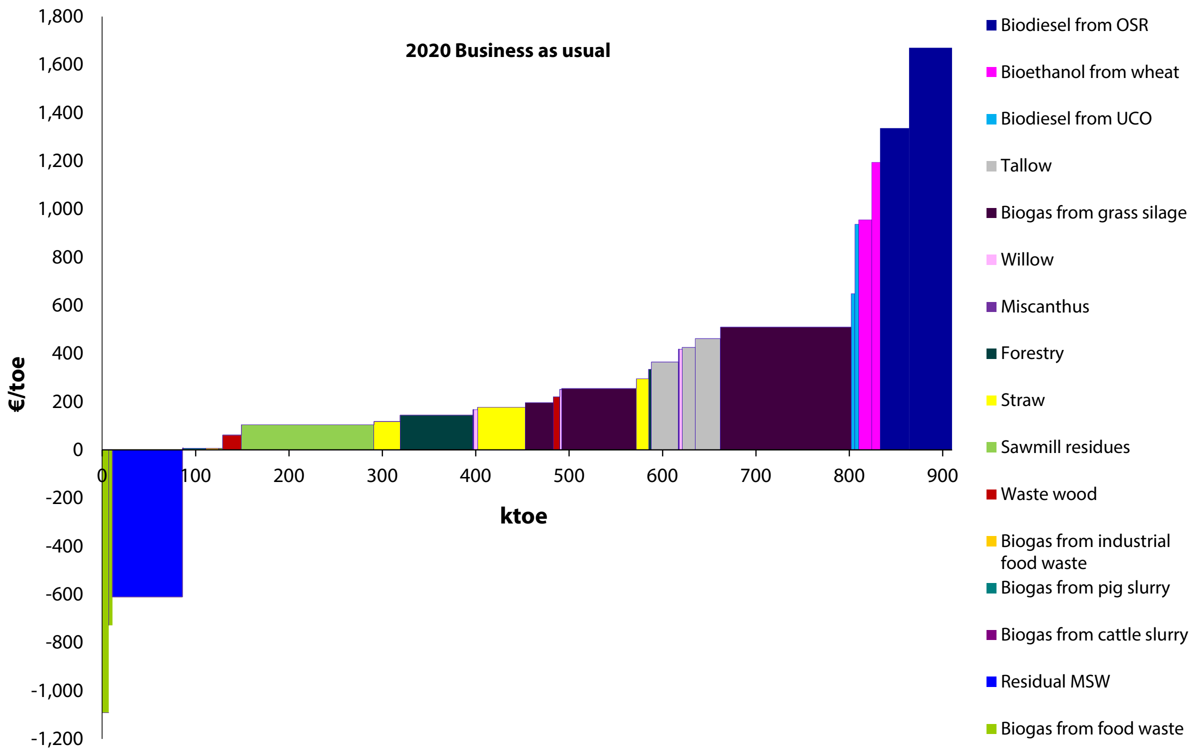
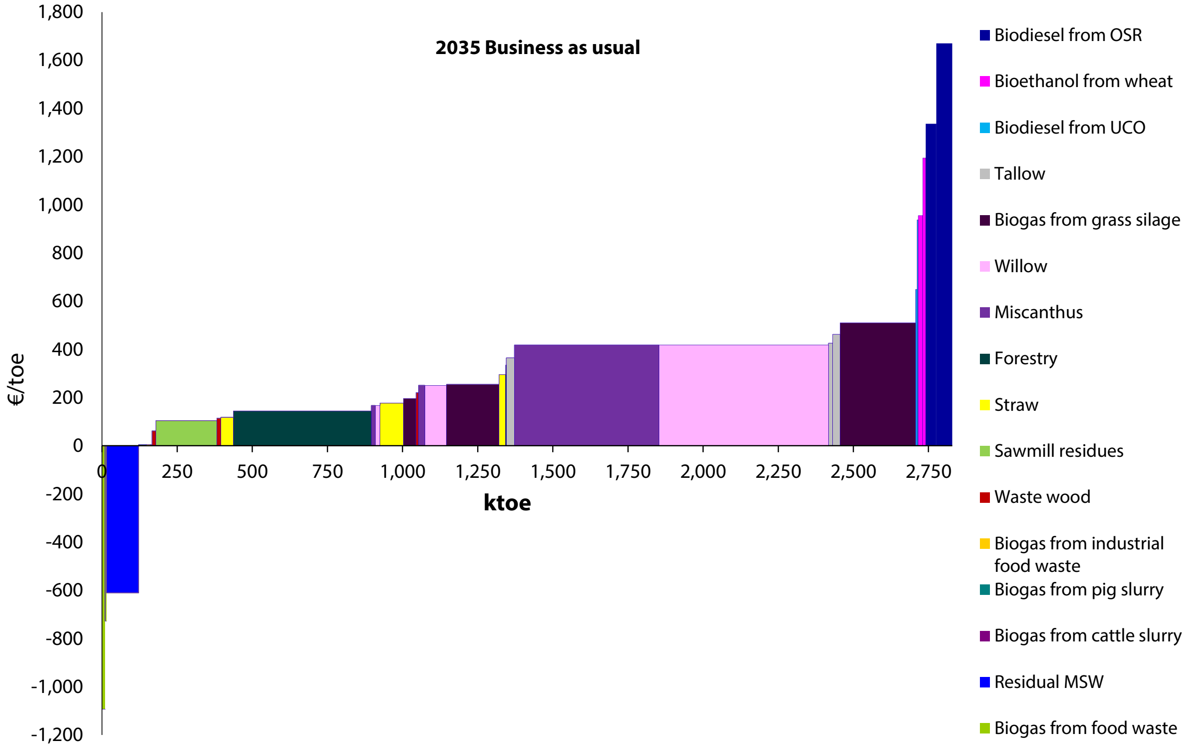


Figure 5: Supply curves for all resources in 2035 BAU scenario



Resource potential

The full potential for each individual resource under favourable conditions – high market prices and mitigation of market barriers – is shown in Figure 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 6: Total Potential Bioenergy Resource by Individual Feedstocks

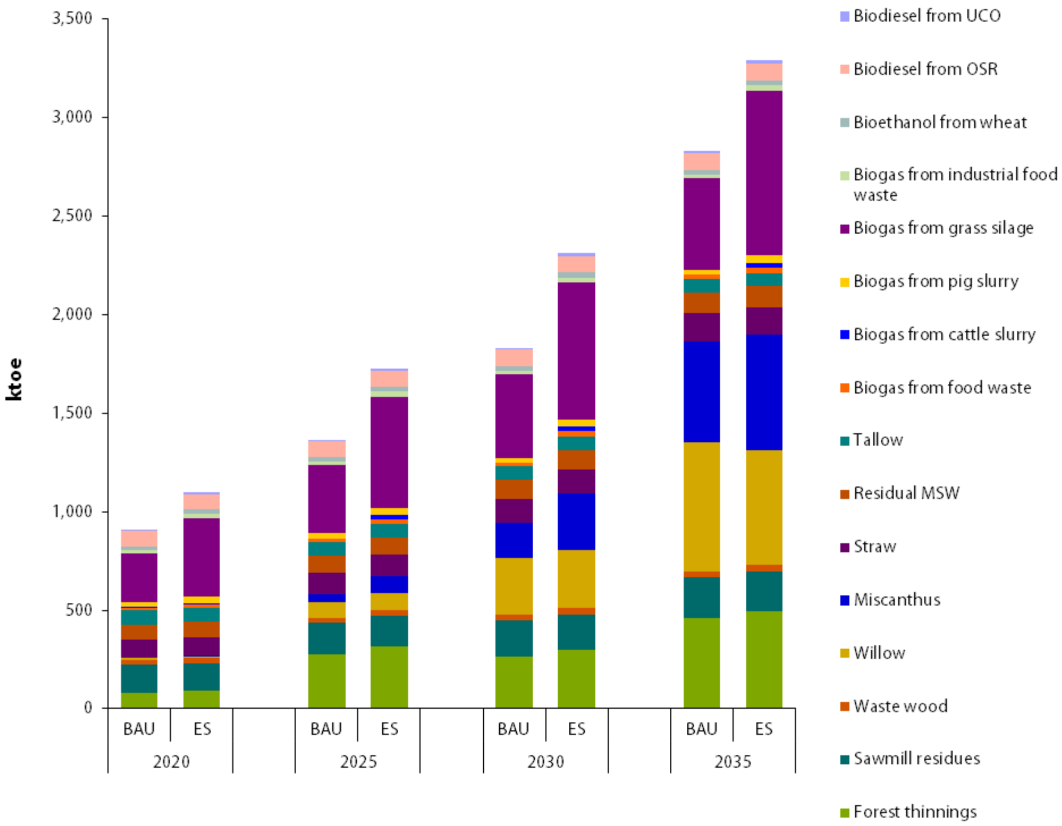


Table 2 expresses the information shown in Figure 6 in natural units typically used to quantify these resources for the BAU and ES scenarios.

Table 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

Land use

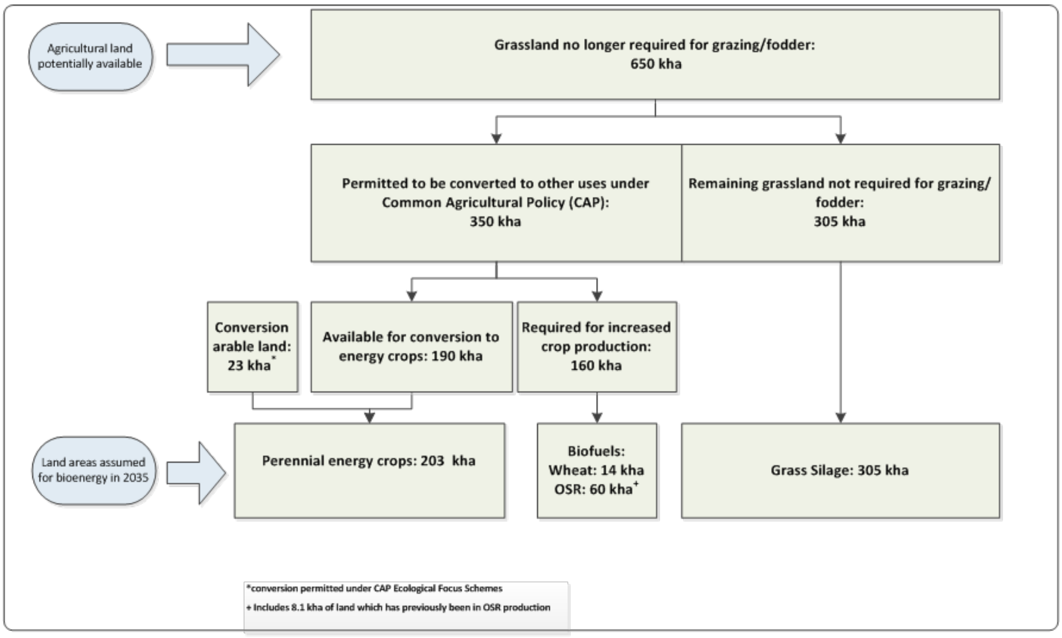
The energy crop potential has implications for land use. The majority of grassland is currently used for livestock production in Ireland. However, Food Wise 2025 suggests that improved utilisation of grassland could support increased livestock production which could make substantial areas of pasture 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 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.

Figure 7: Land Availability Assumptions in Study



[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.

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

Table 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.

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 4 shows the current and future potential of these resources.

Table 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**