BioEnergy Supply Curves for Ireland

2010 - 2030

seai
SUSTAINABLE
ENERGY AUTHORITY
OF IRELAND

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Repak




THE SUSTAINABLE ENERGY AUTHORITY OF IRELAND

The Sustainable Energy Authority of Ireland (SEAI) was established as Ireland's national energy authority under the Sustainable Energy Act 2002. SEAI's mission is to play a leading role in transformation of Ireland into a society based on sustainable energy structures, technologies and practices. To fulfil this mission, SEAI aims to provide well-timed and informed advice to Government and deliver a range of programmes efficiently and effectively, while engaging and motivating a wide range of stakeholders and showing continuing flexibility and innovation in all activities. SEAI's actions will help to 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 our low-carbon future

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

Energy Modelling Group

SEAI's Energy Modelling Group (EMG), established in 2009 to support evidence-based policy formation in the area of energy efficiency and renewable energy, provides analysis and policy advice on a range of sustainable energy issues at the national and European level. Along with SEAI's Energy Policy Statistical Support Unit (EPSSU), it operates within SEAI's Low Carbon Technologies Development division.

EXECUTIVE SUMMARY

Ireland's National Renewable Energy Action Plan (NREAP) identifies bioenergy as having a significant role in Ireland's energy future in the production of renewable heat, transport and electricity. Bioenergy can be produced from a range of biomass resources each with their own resource availability, production costs, and energy conversion methods. Understanding the detail of these complex interactions can aid the development of targeted policy measures to support the use of bioenergy. Previous studies have largely focused on the potential resource availability in Ireland of a range of resources, while EU-wide studies have estimated the impact of bioenergy policy on the international trade of biomass. The analysis in this report builds on these studies and incorporates the costs of harvesting Irish resources to determine the economically available supply in Ireland and looks at how these costs compare to a range of possible future scenarios for international bioenergy prices.

The availability of biomass for energy production depends on several interacting factors. The physically available resource is often driven by the anticipated demand for products for use in non-energy applications. Biomass used for bioenergy is typically sourced from the by-products of these non-energy activities or from the waste arising from the activities of households, businesses and farms. Energy crop cultivation is attracting interest from the agricultural sector and has the potential to add to the bioenergy resource. The quantities of these resources used for bioenergy depend on complex interactions between the cost of production, the demand in alternative non-energy markets and the prevailing price for bioenergy. The domestic price for bioenergy is in turn influenced by the prevailing international trade price and the availability of imports.

This report focuses on important factors that influence the supply of bioenergy resources in Ireland, namely the cost of producing domestic resources and possible scenarios for the development of international trade in bioenergy commodities. Supply curves for the raw cost and availability of 13 domestic bioenergy resources are estimated over the period to 2030. Identifying the raw cost allows a consistent comparison across the resources examined by focusing on the cost of harvesting at the resource location and excluding the costs associated with processing these resources into biofuels, biogas or wood pellets, or the cost of transporting them to bioenergy customers. Possible future scenarios for the development of international commodity markets are also examined to provide a perspective on possible interaction that trade may have with the development of domestic resources.

A consideration of these national and international aspects together enable an assessment of how much bioenergy may be available for use in Ireland at various market prices to 2030. They also provide detailed information for incorporation into future analysis that will examine the other factors that influence bioenergy use including the interaction between the market price for bioenergy and the demand for bioenergy resources.

Key Insights

- The physically available biomass resource has the potential to expand into the future but the use of this potential for bioenergy production will depend on the energy market price. Higher market prices are likely to stimulate more development of the physically available resources in Ireland. The market price is influenced in Ireland by international trade. The development of an international market for biomass commodities has the potential to alter the dynamics of the domestic markets - wide availability of biomass for import into Ireland is likely to lower the price for domestic bioenergy.
- The current market price for biomass resources is often specific to an individual resource. The analysis shows current market prices range between about -€1,200 €/toe and 250 €/toe depending on the resource.
- A market price of 420 €/toe [1] could bring 850 ktoe of domestically sourced bioenergy into use by 2020. The vast majority of this consists of resources suitable for heat and electricity generation. The domestic resources available for conversion into biofuel could be brought into production at prices between 500 €/toe and 1,570 €/toe.
- An increase in the market price for bioenergy to the highest price examined for each resource could see the available resource increase from 500 ktoe in 2012 to over 1,000 ktoe in 2020 and 3,000 ktoe in 2030. Most of the growth in potential is available from SRC willow and miscanthus.

[1] 420 €/toe is approx 36 €/MWh or 10 €/GJ (1 toe = 11.63MWh = 41.868 GJ)

- At current market prices, up to 6,000 ha of energy crops could be planted by 2020 and 9,000 ha by 2030. A 250% increase of the current price could see 60,000 ha planted by 2020 and 428,000 ha by 2030.
- A significant expansion of international supply and demand may see woody biomass available for import to Ireland at 300 €/toe to 500 €/toe. This suggests that quantities of wood chips and pellets may be available to import at price that is cheaper than the cost of using many of the domestic resources. On the other hand, a lower l demand and a restricted supply internationally show, that much less woody biomass may be available for import to Ireland.
- The available domestic resources for biofuels in 2020 are insufficient to meet the estimated requirements of the target for the transport sector of 10% of transport energy use to come from renewable sources by 2020.
- Imports of bioethanol are available in all scenarios examined at prices between 600 €/toe and 1,000 €/toe. The availability of biodiesel imports is limited in all scenarios in the period to 2020. The EU sustainability requirements for biofuels mean that available biodiesel imports could decrease to zero by 2020. Improvements in production methods are assumed to reduce the greenhouse gas (GHG) balance of these crops and improve their sustainability in the longer term. By 2030 it is estimated that up to 200 ktoe of biodiesel could be available at a price of 2,000 €/toe.

Context and Influences

The availability of biomass resources for energy production is influenced by interactions between physical availability, cost of production and demand for the resources in alternative non-energy applications. Much work has been conducted in Ireland on the physical availability of domestic biomass resources, such as the by-products of the wood and forest industries and the growing of energy crops. Such physical availability determines how much resource could be potentially used to produce bioenergy but does not account for other important factors that influence resource demand. Factors such as the location of the biomass resource, market confidence in the future development of the resource for energy and expectations about future costs for biomass fuel sources all influence the quantity of resource that will be used.

Biomass resources can be used to increase the amount of renewable energy used for heat, electricity and transport. At present, approx. 2.6% of Ireland's primary energy demand is met from the conversion of biomass into bioenergy.[1] The production of heat from native resources is the largest contributor, at 1.4% of primary energy use. This heat is used in the residential and commercial sectors for space and water heating and in the industrial sector for process heat.

Biofuel use in transport – as a result of the Biofuel Obligation[2] – accounts for 0.7%, with the majority coming from imports. Biomass use in electricity generation and in combined heat and power (CHP) installations currently stands at 0.5% of primary energy consumption.

The market demand for bioenergy depends to a large extent on the relative cost of using bioenergy when compared to fossil fuels or other renewable energies. Supply curves can help in establishing what the market price for bioenergy resources may be in the future by representing the cost increases associated with the harvesting of progressively less accessible tranches of resource to meet higher demand. Higher demand may arise from rising fossil-fuel prices, policy support for bioenergy or falling bioenergy prices. Bioenergy prices may fall due to increases in domestic availability, reductions in harvesting costs or increased availability of lower-priced imports of biomass resources such as wood chips and pellets or biofuels.

The extent to which an international commodity market develops for bioenergy resources will have implications for the market price for bioenergy in Ireland and determine the level of consumption of Ireland's domestic resources. A mature international commodity market for bioenergy resources can allow Irish producers to export lower-cost domestic biomass resources and enable imports of bioenergy to compete for a share of the domestic market. The EU Renewable Energy Directive target for the share of renewable energy in gross final consumption (RES) is 20% for the EU as a whole and 16% for Ireland by year 2020. Bioenergy has been identified by Ireland and the EU as having

1 EPSSU, Energy in Ireland 1990-2011 2012 Report, SEAI

2 See:http://www.dcenr.gov.ie/Energy/Sustainable+and+Renewable+Energy+Division/Biofuels/

3 IntelligentEnergyEurope(2012)."Re-Shaping,Shapinganeffective and efficient European renewable energy market – Final Report D13",Karlsruhe.Availableathttp://www.reshaping-res-policy.eu/

4 International Energy Agency (IEA) (2011), World Energy Outlook 2011, Paris

a significant role to play in achieving these targets. The National Renewable Action Plans (NREAP) of EU member states points to an increase of over 60% in bioenergy usage across EU member states in that period. EU-wide analysis indicates that a large proportion of this growth will most likely be met by imports from outside the EU.[3] Wider international efforts on climate change will influence the extent to which bioenergy resources are developed and used in other regions.[4]

Supply Curve Methodology

The interactions between the quantity of available biomass and the market price for these resources are represented in a supply curve. This supply curve indicates how much biomass could be available for bioenergy production at a particular market price. This estimate uses existing data to analyse the potential physical resource and subtracts the current and projected use of biomass for non-energy purposes.

Cost estimates for harvesting biomass resources are used as a basis to establish how much biomass might be available for energy purposes at various market prices in each year to 2030. This determines the economically available biomass resource at the resource location. Due to the low energy density of several of the biomass resources, large volumes are required to supply energy-producing installations with adequate resources,[5] so the need for transportation can significantly increase their cost. These transport costs are not included in the analysis as they will vary substantially based on the physical location of the bioenergy demand. The exclusion of the transport costs allows consistent comparison of the costs of each resource based on their physical availability and harvesting costs.

FIGURE 1: SCHEMATIC APPROACH TO DETERMINING THE AVAILABLE BIOMASS RESOURCE FOR BIOENERGY

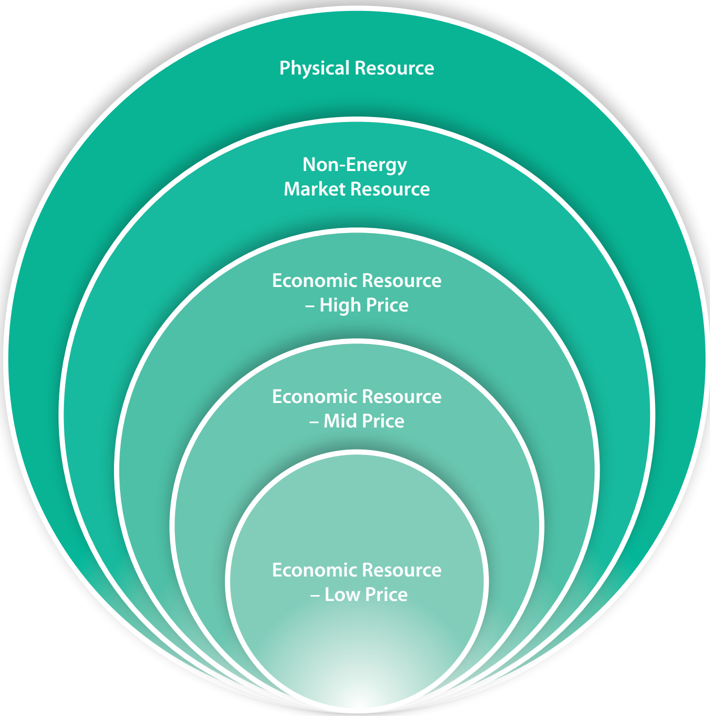


Figure 1 illustrates the steps in establishing the supply curves. The physical resource is determined based on factors

[5] For example, 1kg of straw contains less than 50% of the energy of 1kg of coal, so twice as much weight is required to supply an equivalent amount of energy.

such as the total area of forest or the area of land available for energy crops in each year to 2030. The quantities of biomass used for non-energy purposes – such as straw for animal bedding or the use of sawmill residues in fibre board mills – are then estimated and subtracted from the physical resource. The remainder represents the potential biomass available for bioenergy purposes. Cost estimates for harvesting these resources are then used as a basis to establish how much biomass might be available for energy purposes at various market prices in each year to 2030. The resultant quantities represent estimates of the economically available biomass resource at three different price points and provide a direct input to the cost curves.

Supply curves have been estimated for 13 biomass resources. These resources can be aggregated into three broad categories, based on the processes by which they are typically transformed into bioenergy.[6] Table 1 lists the resources examined, based on how they are typically transformed into bioenergy – through direct combustion, conversion into biofuels or processing into biogas.

TABLE 1: RESOURCE CATEGORIES AND END-USE MODE

END USE CATEGORY	RESOURCE FORM	DESCRIPTION	RESOURCE CATEGORY
Direct Combustion	Forest thinning	Byproduct of forest management and harvesting	Byproduct material
	Waste wood	Waste from construction and demolition	Waste material
	Sawmill residues	Byproduct of processing timber	Byproduct material
	Straw	Byproduct of cereal production	Byproduct material
	Miscanthus	Woody crop	Dedicated energy crop
	Biodegradable Municipal Solid Waste	Municipal Waste	Waste Material
Biogas	Pig manure	Animal waste	Waste material
	Cattle manure	Animal waste	Waste material
	Food and garden waste	Municipal waste	Waste material
Biofuel	Wheat	Arable crop	Dedicated energy crop
	Oil seed rape (OSR)	Arable crop	Dedicated energy crop
	Tallow	Meat processing byproduct	Byproduct material
	Recycled vegetable oil (RVO)	Used cooking oil	Waste material

[6] This list is not exhaustive; several other biomass resources can be used for bioenergy production but were excluded due to the relative cost of production. These resources are categorised based on the most common methods of transforming the resource
into bioenergy. Other methods are possible for some

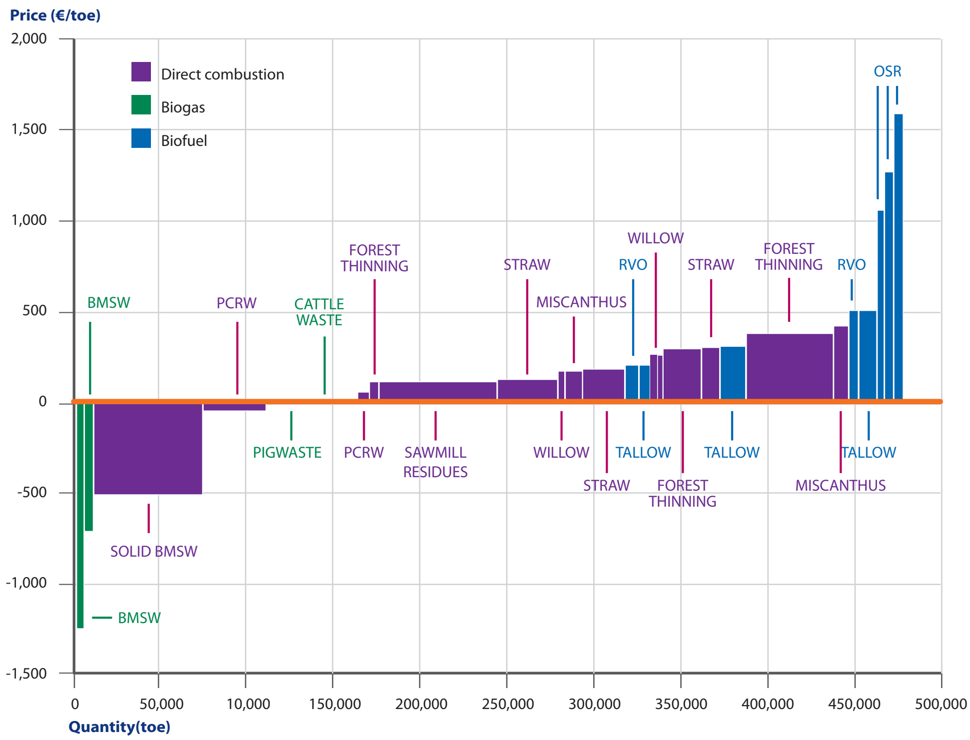
The supply curves of economically available bioenergy resource are developed by establishing the quantity of resource that would be available at three price points for each resource examined. The quantities estimated are the amounts of resource that might be available to the bioenergy market at a particular price; they are not a forecast of the amount of bioenergy which may be used in Ireland in the future. The actual use will depend on a number of factors, including the market price for bioenergy. These supply curves are intended for use in further analysis that captures the wider interactions that influence bioenergy demand.

Domestic Supply Curves

Figure 2 shows the supply-curve characteristics for all assessed domestic resources for year 2012. They show the quantity of the resource that could be available (the width in each step of the graph) and the price at which it is available (the height of the bar). Prices are derived on the basis of production costs of each biomass resource. The resource availability is estimated at three ascending price points, and three available quantities are estimated for each resource at these price points.

While the price points are fixed for the time horizon modelled, overall resource availability can increase over time. The higher prices are assumed to raise the incentive for resource suppliers to invest in measures to overcome existing barriers, such as new harvesting equipment or implementation of new harvesting techniques. For example, higher prices for forest thinning can provide a return in investment on new specialised harvesting equipment. Low prices at or close to current levels will not induce this investment. Increases in availability are limited by the physical availability of the resource.

FIGURE 2: DOMESTIC BIOENERGY RESOURCE SUPPLY CURVE FOR IRELAND, 2012



The disposal costs associated with waste mean these resources are typically available to bioenergy installations at a negative/zero price and appear on or below the zero price line. Materials such as Biodegradable Municipal Solid Waste

[7] Note this price does not include the cost of processing these resources into wood pellets/chips, biogas or biofuels.

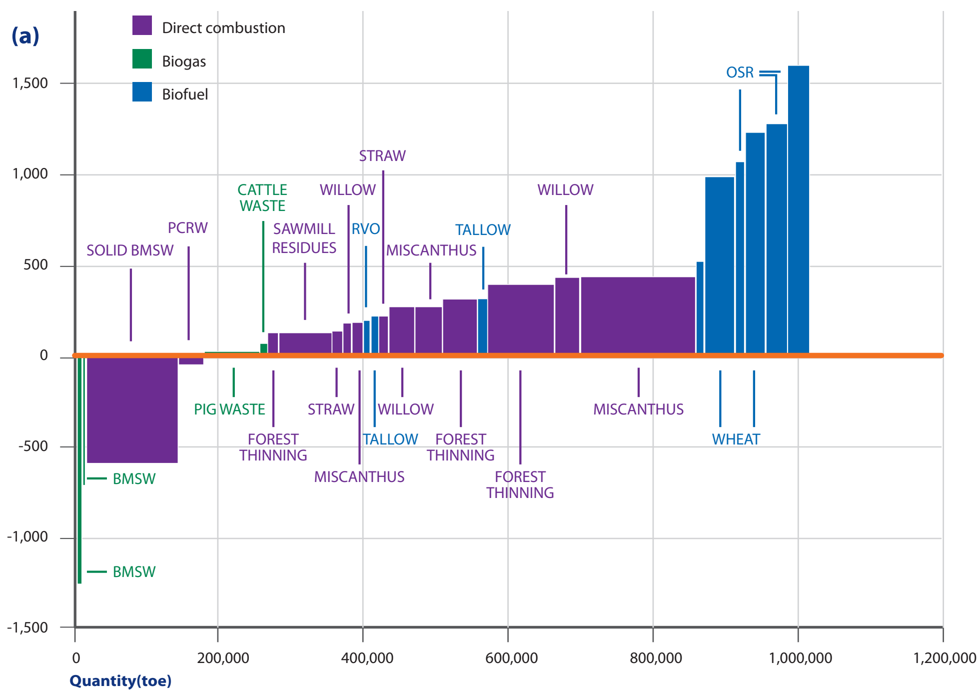
[8] For comparison, the current Brent crude oil price of 110 $/bbl is equivalent to 570 €/toe. It should be noted that the costs of processing and using biomass resources for energy can deviate substantially from the costs of processing oil and using oil for energy production. These supply curves are the raw unprocessed cost of the biomass resources at the resource location.

(BMSW) and animal waste are typically used in Anaerobic Digestion (AD) installations to produce biogas; Post Consumer Recovered Wood (PCRW) is used in combustion processes, and Recycled Vegetable Oil (RVO) is used to produce biofuel. By-product materials have costs associated with processing for bioenergy and appear above the line. Woody biomass, straw and by-products of the meat industry require further processing to bring the potential supply to the bioenergy market. This analysis shows that a market price of 450 €/toe[7,8], at the resource location could see all the available potential used. Woody biomass and straw are typically combusted to generate heat and/or electricity. Tallow is used to make biofuels for transport. Energy crops such as miscanthus and Short Rotation Coppice (SRC) willow are used for combustion. Wheat and Oil Seed Rape (OSR) are used in the production of biofuels. For these crops to be attractive to farmers, the market price must provide a return that is greater than the other conventional agricultural practices available on a farm. As a result, energy crops make up most of the higher end of the supply curve above the 420 €/toe price point. Crops used for the production of bioethanol and biodiesel require prices in excess of 1,000 €/toe to bring the potential into production.

Figure 3 (a) shows the estimated supply curve for 2020. The results can be compared with the level of bioenergy required to meet domestic targets for renewable energy in 2020 as modelled in SEAI's energy forecast.[9] The 2011 forecast shows that about 1,000 ktoe of bioenergy is required to meet domestic targets for renewable energy in 2020. This is made up of 370 ktoe for transport, 475 ktoe for heat and 155 ktoe for electricity, and contributes to the individual RES-T (10%), RES-H (12%) and RES-E (40%) targets (RES-E, RES-H and RES-T refer to electricity, heat and transport fuels derived from renewable energy sources). The analysis suggests that a price of 380 €/toe could bring enough domestic biomass into production to satisfy the heat and electricity demand. A potential domestic resource of about 180 ktoe could be made available for the production of biofuels, but even at the highest price point of 1,590 €/toe this would not bring enough domestic resources into production to meet the RES-T target.

By 2030 – as shown Figure 3 – the estimated domestic potential is estimated to be 3,000 ktoe – a threefold increase from 2020. This is driven by a large increase in the expected availability of energy crops, particularity SRC willow and miscanthus at higher market prices. These higher prices provide more farmers with the incentive to invest in the equipment and expertise required to grow the crops over the time horizon. A market price of 420 €/toe could see the potential from both of these crops brought into production. The quantities of energy crops available for biofuel production remain close to the 2020 levels. Other resources see smaller changes in the potential availability out to year 2030, even at the high prices.

FIGURE 3: (A) DOMESTIC RESOURCE SUPPLY CURVE FOR IRELAND 2020; (B) DOMESTIC RESOURCE SUPPLY CURVE FOR IRELAND 2030



9 SEAI (2011), "Energy Forecast for Ireland to 2020 – 2011 report", SEAI Dublin

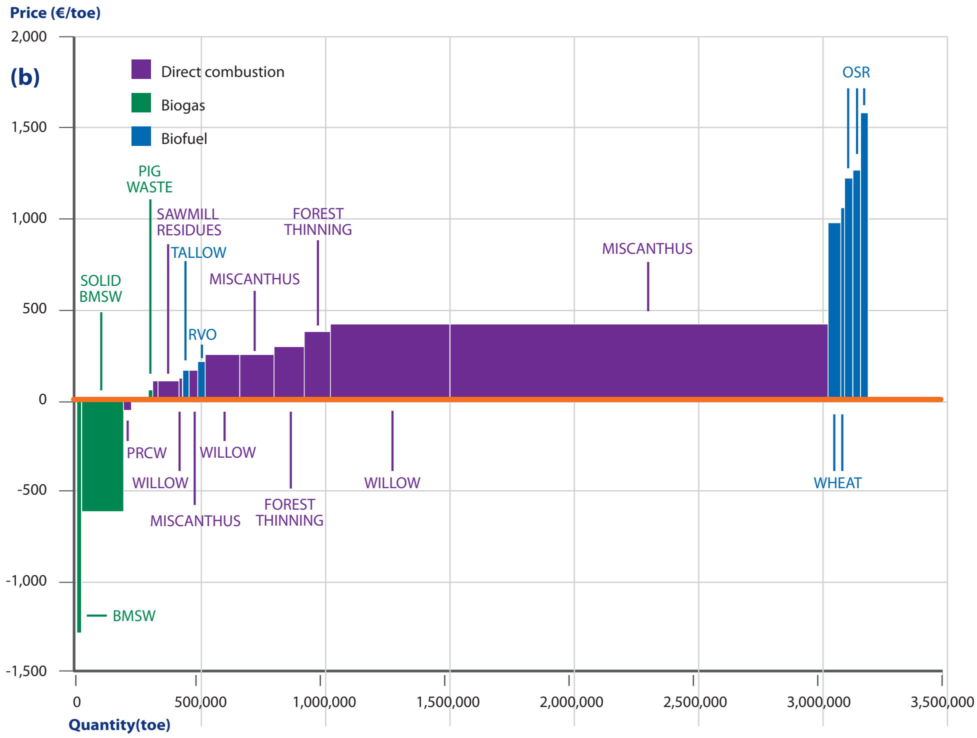
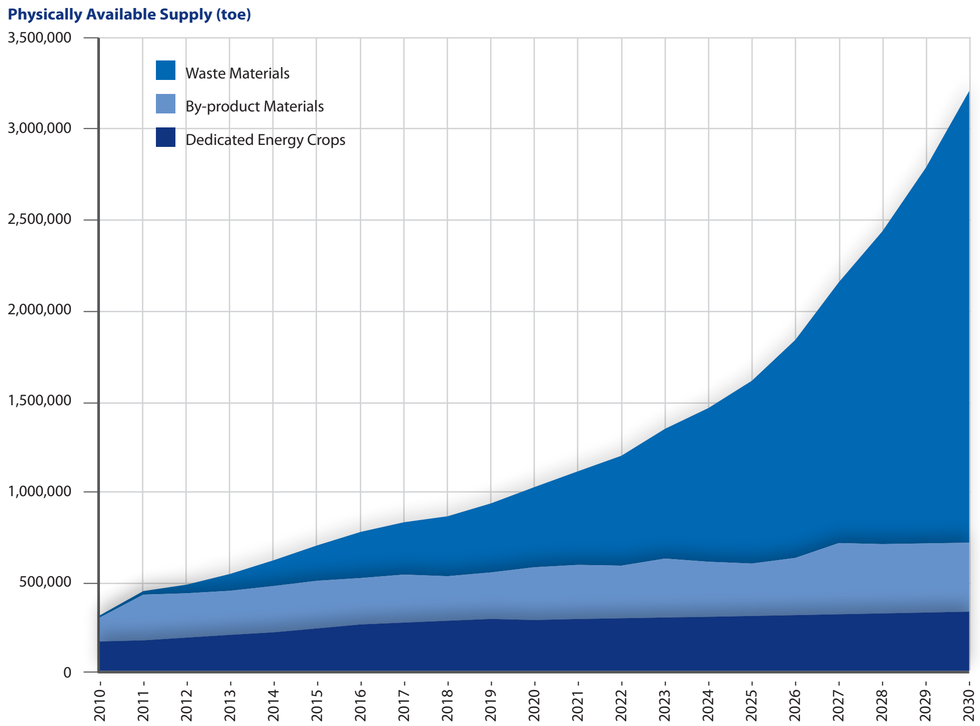


Figure 4 shows the potential biomass available at the highest price point on the supply curves for each resource in each year to 2030.[10] At this market price, all economically available biomass is used for bioenergy. By 2030 this theoretically available resource is estimated to increase tenfold, driven by the potential for a substantial increase in the availability of energy crops. The market price for these resources will determine how much of this potential is actually consumed. International trade will have a large impact on the market price that prevails in Ireland, which in turn will influence the quantity of domestic resources that will be used to meet bioenergy demand. A well-developed international trade could see lower-cost domestic resources exported and lower-cost imports displacing domestic resources.

10 To compare all the resources on an equivalent basis, the quantities of the resources have been converted into the primary energy they could supply, measured in ktoe.

FIGURE 4: POTENTIAL PHYSICALLY AVAILABLE DOMESTIC BIOMASS RESOURCE 2010-2030



International Trade

The plans for increased biomass usage in energy systems across the EU are likely to lead to trade development on internationally commodity markets. The trade in biodiesel and bioethanol is a relatively well-established market and the trade of wood chips and wood pellets is also likely to increase. Ireland, due to the relatively small size of the biomass market, will be a price taker; the domestic prices will be set by the import and export price.

The potential international supply and price of biomass resources has previously been estimated in work for the UK Department of Energy and Climate Change (DEEC).[11] The approach in that study has been adapted in this report to develop a methodology appropriate for Ireland. These estimates draw from a range of possible scenarios for world bioenergy supply and demand, based on sets of assumptions about general future development, the amount of land available for energy crops, and the level of demand for bioenergy in potential supply regions of the world. This analysis confirms that the amount of biomass that might be available to import is dependent on the progress of the development of biomass internationally.

Future demand estimates are based on scenarios established by the International Energy Agency (IEA). The IEA[12] has shown that significant additional international policy effort is required if climate-change impacts are to be contained. It highlights that this will include an expanded role for bioenergy and increased use of biomass in all global regions. Based on the same analysis, the IEA has shown that the current international policy trajectory will fall short of delivering on these goals, and implies a lower worldwide demand for bioenergy as a result. These demand projections have been combined with considerations on the potential for biomass supply to develop in several regions across the world. Five scenarios for international biomass supply and demand were developed by DECC, covering a range of possible futures based on this information. Two scenarios at either end of the range have been highlighted here.

The ambitious supply/high-demand scenario assumes significant development in the sustainable harvesting of biomass in developing nations. Internationally recognised fuel-quality standards allow for the reliable trade of biomass as a

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

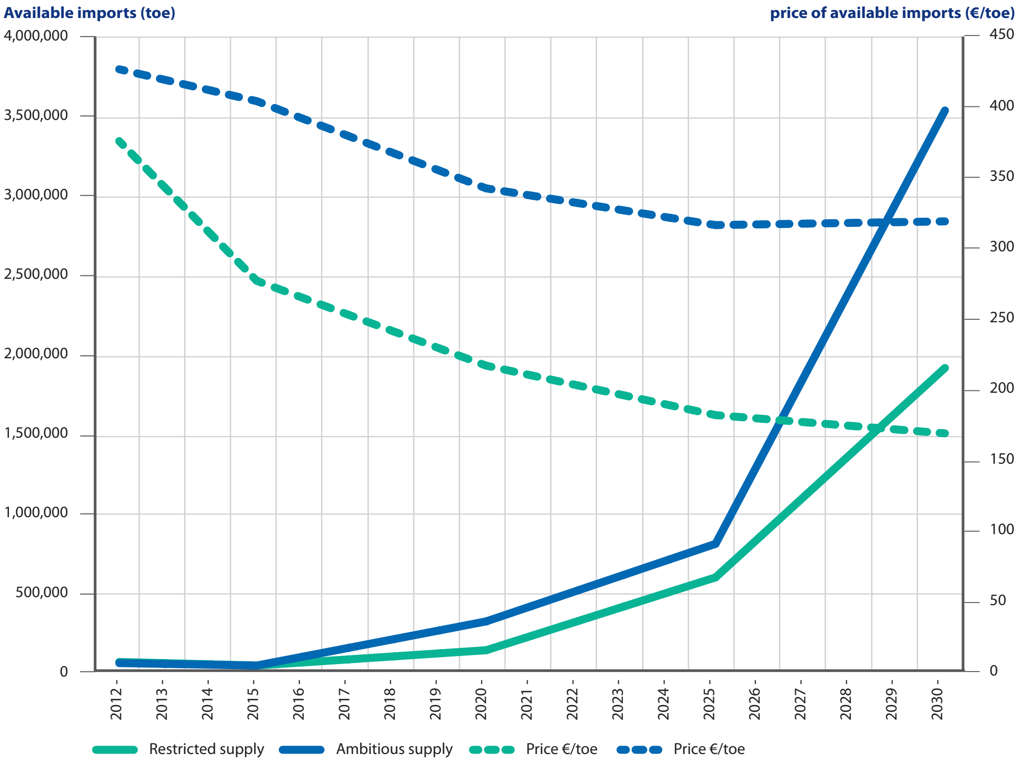
[12] The IEA World Energy Outlook 2009 outlines two scenarios: (1) The reference scenario based on current policy efforts and (2) the 450 scenario, where worldwide energy-related GHG emissions are limited to 450 parts per million (ppm) of CO_2 equivalent.

commodity. International demand is assumed to increase as policymakers extend measures to reduce GHG emissions. The price of imports is higher in this scenario as the quantities of resources required to meet demand are more costly to bring to market.

In contrast, the restricted supply/reference demand scenario assumes little technology transfer to developing nations, with little intensification of agriculture and a lower increase in yields. More land is needed for food production, thus reducing the land availability for bioenergy crops. In addition, there is less infrastructure development and international trade is limited due to the lower international demand associated with the lower reference scenario demand.

Figure 5 shows, for these two bounding scenarios, the potential amount of woody biomass that may be available for import to Ireland, and the associated projected price. Figure 6 shows the amount of bioethanol and biodiesel available for import. Section 11 (international trade) describes these and the other scenarios in more detail.

FIGURE 5: AVAILABLE IMPORTS OF WOODY BIOMASS AND INTERNATIONAL TRADE PRICE TO 2030



The available woody biomass supply is estimated to increase in both scenarios. Both scenarios see a decrease in price over the horizon as international trade develops and more supply becomes available. The price in each scenario depends on the interaction between the available supply and the demand assumptions. The higher price in the ambitious supply/ high-demand scenario is a result of high international demand for biomass. This occurs in spite of the increase in available supply. The price is lower in the restricted supply/reference demand scenario due to the lower demand.

The projections show that quantities of wood chips and pellets will be available for import to Ireland at prices between 200 €/toe and 350 €/toe in 2020. These prices are less than the price required to bring most of the domestic resources to market. The actual quantity of biomass imports available and the demand for bioenergy will determine how much domestic resource is consumed.

Figure 6 (a) and (b) indicate that the availability of sustainable biofuels may be limited in the short term. The EU requirement that biofuels must have a 50%[13] GHG saving as compared to fossil fuels is likely to impact on the amount of biofuel that may be available to import into Ireland. Biodiesel is especially limited; the modelling shows that almost no imports will be available in the short term.

FIGURE 6: (A) AVAILABLE IMPORTS OF BIOETHANOL AND INTERNATIONAL TRADE PRICE TO 2030; (B) AVAILABLE IMPORTS OF BIODIESEL AND INTERNATIONAL TRADE PRICE TO 2030

[10] To compare all the resources on an equivalent basis, the quantities of the resources have been converted into the primary energy they could supply, measured in ktoe.

Summary

The analysis shows that the physical potential of domestic biomass resources available for bioenergy has the capability to grow in the years ahead. How much of the potential is actually used to produce bioenergy will depend on the future price of these resources in the energy market. The price of competing energy sources (fossil and renewable) the demand for bioenergy resources, the supporting policies and the price and availability of bioenergy in the international market will all impact on the actual future market price for bioenergy in Ireland.

Should current prices levels for bioenergy resources prevail into the future, it is likely that much of the available domestic potential will not be developed. A 50% increase in price, particularly for woody biomass resources, could see a significant increase in the quantity of domestic bioenergy resources consumed. For the resources examined, a 250% increase could see almost all of the available domestic resource potential being brought into production with the large potential for the expansion of SRC willow and miscanthus contributing most.

The majority of the available domestic resources are suitable for use in heat and electricity generation. A 50% increase in the market price is likely to bring enough resource into production to cover the requirements of the renewable energy targets in heat and electricity as estimated in the 2011 National Energy Forecast to 2020.

The availability of potential resources for transport energy is much more restricted. Even at the highest price examined, the biofuel requirements for the 2020 renewable transport target are unlikely to be met from domestic sources alone. The scenarios for the availability of biofuels in international markets show that while there is likely to be adequate quantities of bioethanol available, biodiesel supply looks set to shrink out to 2020. This is as a result of the EU sustainability criteria for biofuels which requires a reduction total life cycle emissions from biofuels of 50% when the impact of land use change, harvesting and transportation, among other factors, are considered. The trend in Ireland towards diesel use in transport means that this may have implications for how the 2020 renewable transport target is achieved.

International markets for bioenergy resources are likely to strongly influence the bioenegry market in Ireland. The analysis shows that the range of market prices for internationally traded bioenergy commodities in a number of scenarios are below the cost of production for many of the domestic resources. The quantity of these internationally traded commodities for import are limited in several scenarios. Should these scenarios arise in the future, the lower volume of imports would limit the impact of international price on the domestic market.

This analysis focuses on the supply of bioenergy resources. Further modelling that incorporates the analysis from this report with deatial on the technology costs and energy demand can help identify the most cost effective use of the available bioenergy resources across heat, electricity and transport and incorporate the impact of factors such as increasing fossil fuel prices, policy support and transport costs on bioenergy demand.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

Ireland and the EU plan to increase the use of bioenergy as part of the pathway to reaching the 2020 targets set out in the Renewable Energy directive.[14] Previous studies have examined the potential resource availability in Ireland of a range of resources, while EU-wide studies have estimated the impact of bioenergy policy on the international trade of biomass. This analysis builds on these studies and incorporates the costs of harvesting Irish resources to determine the economically available supply in Ireland.

The availability of biomass for energy production depends on several interacting factors. The physically available resource is often driven by the anticipated demand for products for use in non-energy applications. Biomass used for bioenergy is typically sourced from the by-products of these non-energy activities or from the waste arising from the activities of households, businesses and farms. Energy crop cultivation is attracting interest from the agricultural sector and has the potential to add to the bioenergy resource. The quantities of these resources used for bioenergy depend on complex interactions between the cost of production, the demand in alternative non-energy markets and the prevailing price for bioenergy. The domestic price for bioenergy is in turn influenced by the prevailing international trade price and the availability of imports.

This report examines the factors that influence the quantity of biomass that could be provided at various market prices. Consideration is also given to the possible development of international trade as an important factor in developing domestic resources. This information is intended for use in SEAI's Bioenergy Analysis Model (BEAM)[15] and other similar models that use this supply-side data to investigate the impact of policy on actual bioenergy use.

As part of this process, SEAI contracted AEA to update and consolidate estimates of the quantity of bioenergy resources available in Ireland from 2010 to 2030, taking into account other competing demands for the resources, and any other constraints on development of the resource, and finally identifying how available quantities of the resource might vary with the price paid for the resource. The market price is defined as the price paid for a resource at the location of the resource. Transport costs are an important consideration in biomass resource cost and should be included in further modelling using this information.[16] The supply curves do not account for the cost of transporting the resources to bioenergy demand. This allows the resources to be compared on the basis of economic availability on a consistent basis and enables a high-level view of the possible impact of international trade.[17]

Each resource has individual characteristics that determine the quantity available at a given market price. The resources examined are shown in Table 2 along with a description of their source and how they are converted into bioenergy. This does not represent an exhaustive list of available biomass resources; they were chosen based on the availability of data and the current availability of demand-side infrastructure, and to limit the complexity of the analysis. The methodology outlined here may be applied to additional resources in the future.[18] Appendix 1 contains a table with more detailed descriptions of each resource.

The quantities estimated are the amounts of resource that might be available to the bioenergy market at a particular price; they are not a forecast of the amount of bioenergy that might be used in Ireland in the future. The actual quantity that will be used in the future depends on the market price for bioenergy, the market demand for bioenergy and the available import quantities and trade price. The report examines each resource individually to determine a supply curve specific to each resource.

14 Council Directive 2009/28/EC of 23rd April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

15 BEAM is a least-cost techno-economic model that optimises bioenergy usage in the heat, transport and electricity sectors.

16 The BEAM model includes the transport costs for each of the resources.

17 Transport costs are incorporated in the BEAM model and are not dealt with here.

18 E.g. grass has high potential to contribute to bioenergy but biogas injection to the gas grid and biogas use in transport require demand-side infrastructural changes.

TABLE 2: RESOURCE CATEGORIES AND END USE MODE

END USE CATEGORY	RESOURCE FORM	DESCRIPTION	RESOURCE CATEGORY
Direct Combustion	Forest thinning	Byproduct of forest management and harvesting	Byproduct material
	Waste wood	Waste from construction and demolition	Waste material
	Sawmill residues	Byproduct of processing timber	Byproduct material
	Straw	Byproduct of cereal production	Byproduct material
	Miscanthus	Woody crop	Dedicated energy crop
	Biodegradable Municipal Solid Waste	Municipal Waste	Waste Material
Biogas	Pig manure	Animal waste	Waste material
	Cattle manure	Animal waste	Waste material
	Food and garden waste	Municipal waste	Waste material
Biofuel	Wheat	Arable crop	Dedicated energy crop
	Oil seed rape (OSR)	Arable crop	Dedicated energy crop
	Tallow	Meat processing byproduct	Byproduct material
	Recycled vegetable oil (RVO)	Used cooking oil	Waste material

The content of the following sections is as follows:

- Sections 2 to 10 detail the methodology used to establish the supply curves for each individual resource.
- Section 11, on international trade, details the modelling assumptions and the results across a range of scenarios.
- Section 12 details the supply curves in selected years and for the resources used for direct combustion, biogas and biofuels.
- The concluding section highlights some important considerations arising from the analysis and how these interact with the international trade scenarios.

2 FORESTRY THINNINGS

2.1 OVERVIEW

Forestry management involves a number of stages and produces forestry products that are of different quality, composition and value. The primary and most lucrative of forestry markets is the production of sawlogs, which can be sawn into good-quality planks or boards that can be sold into markets such as the construction sector. Sawlogs need to come from larger, straight-growing trees, with a diameter of at least 14cm, although specifications for some uses may be higher (e.g. a diameter of greater than 20cm and length of at least 4.9m). To help establish straight-growing larger trees that will meet these specifications, thinning of the forest must take place periodically. During thinning, smaller non-sawlog-grade trees (typically less than 14cm diameter), known as pulpwood or small roundwood, are removed from the forest and sent into other markets such as paper and pulp manufacture, or the production of panelboard (e.g. plywood or chipboard). Any larger trees removed during thinning (e.g. in the 14 to 20cm diameter category) may be suitable for use as sawlogs, or to produce pallets.

Harvesting of timber once a section of forest is mature is typically done by clearfelling, where all trees within a certain area are felled regardless of size. This occurs because harvesting individual trees on a commercial basis is extremely labour-intensive and does not maximise the use of expensive forestry equipment. The use of clearfelling means that not all trees harvested will meet the specifications for sawlogs, while the harvested wood also includes smaller-diameter trees suitable for lesser-value markets such as pulpwood. In addition, parts of the tree that are mainly of sawlog quality (e.g. the thinner top of the tree) will only be suitable for other markets.

The lower-value, small roundwood, which typically goes to the pulp and paper mills and to panelboard mills, can also be used for bioenergy. Wood chips or wood pellets produced from the roundwood can be used as a fuel in biomass power stations to produce electricity or electricity and heat, or in boilers ranging in size from those suitable for the domestic market to larger plant heating public or commercial buildings.

The amount of small roundwood available for bioenergy use depends on the amount of wood produced from forest thinning, clearfell harvesting and competing demand from other industries. An increase in demand for bioenergy in Ireland along with an increase in the price of bioenergy could result in more small roundwood being extracted from forests.

The processing costs of this timber not suitable for sawlogs prices mean that this resource is not harvested at present. An increase in price can increase the profitability of this timber. An additional source of material is potentially available through the harvesting of tree tips and the collection of harvesting residues (e.g. side branches) and some harvest loss material on suitable sites. This resource, typically known as forestry residues, is collected and used for bioenergy in some other countries with forestry industries e.g. in Scandinavia, and could also be used in Ireland.

The small roundwood resource available for bioenergy has been estimated based on a forecast produced for the COFORD Council for Forest Research and Development of how much wood (of all classes) is available for harvest from both state and privately owned forests. The proportion of wood harvested that would be suitable for high-value sawlogs is estimated and is considered unavailable for bioenergy. From the lower-value resources that are left, demand for other uses is subtracted. Demand for pulpwood for panelboard production is taken from a forecast produced for COFORD, and demand for other markets (e.g. pallet production, fencing) is based on current use in these market as identified by COFORD in its analysis of wood flows in Ireland in 2010. In addition to this resource, forestry residues that may be available are estimated based on the COFORD forecast, and the assumption made in the COFORD forecast that 35% of the resources can actually be used. The key data sources used are summarised in Table 3.

TABLE 3: DATA SOURCES USED IN MODELLING THE FORESTRY RESOURCE

DATA	SOURCE
Projections for production of roundwood and forestry residues	Phillips H (2011). All-Ireland Roundwood Production Forecast 2011-2028, Report for COFORD.
Forecast of demand for panelboard industry	COFORD (2011). All-Ireland Roundwood Demand Forecast 2011-2020.
Demand for other markets	Knaggs G and O'Driscoll E (2012). Woodflow and forest based biomass energy use on the island of Ireland (2010), COFORD Connects Note.

The key report used to forecast the potential resource is the All-Ireland Roundwood Production Forecast 2011-2028 by Phillips (2011).[19] This forecast first estimates the standing volume of wood in both state and privately owned forests, i.e. the total volume of wood in trees in the forest, based on forecasts of areas of woodland, and age and type of species in woodland. It then estimates the expected volume that can be harvested from this standing volume, by making an allowance for harvesting losses. Finally, using geospatial analysis, constraints on accessibility, due for example to potential uneconomic forest-road requirements and management of small plots, were taken into account to reach a forecast of the net realisable volume, i.e. the estimated roundwood volume that is potentially available to the end user. The forecast specifies the volumes available by four size categories (diameter of <7cm, 7 to 13cm, 14 to 19cm and 20cm or above).

The first step in deriving an estimate of the wood potentially available for bioenergy uses is to subtract the fraction of the net realisable volume of wood that is suitable for use as sawlogs. Timber of a quality to be used as sawlog is not currently used for energy and is unlikely to be in the future due to the high price it commands. For example, Teagasc (2012)[20] reports a roadside price of €55-€64/m^3 for sawlogs, which is over twice that of woodchip and pulpwood, which are both reported at €26-€28/m^3. To calculate the proportion of roundwood that is suitable for sawlogs (i.e. is of a sufficient size and quality to be processed into planks and boards) information from Phillips (2011) – that historically 65-70% of the larger (greater than 14cm diameter) roundwood goes for sawlogs – is used. This leaves (excluding the forestry residue material smaller than 7cm in diameter), 1.5 million m3 of wood in 2010, rising to 2.6 million m^3 in 2030, as harvesting levels rise.

Other less significant competing demands identified in the wood flow analysis are for stakewood,[21] (about 0.1 million m^3) and 'other' markets[22] (0.06 million m^3); these are also taken into account in the resource estimate by assuming these volumes are not available for energy. By 2030, about 1.3 million m^3 of wood is available for bioenergy use. This is equivalent to about 221 ktoe.[23]

19 Phillips H (2011). All-Ireland Roundwood Production Forecast 2011-2028.

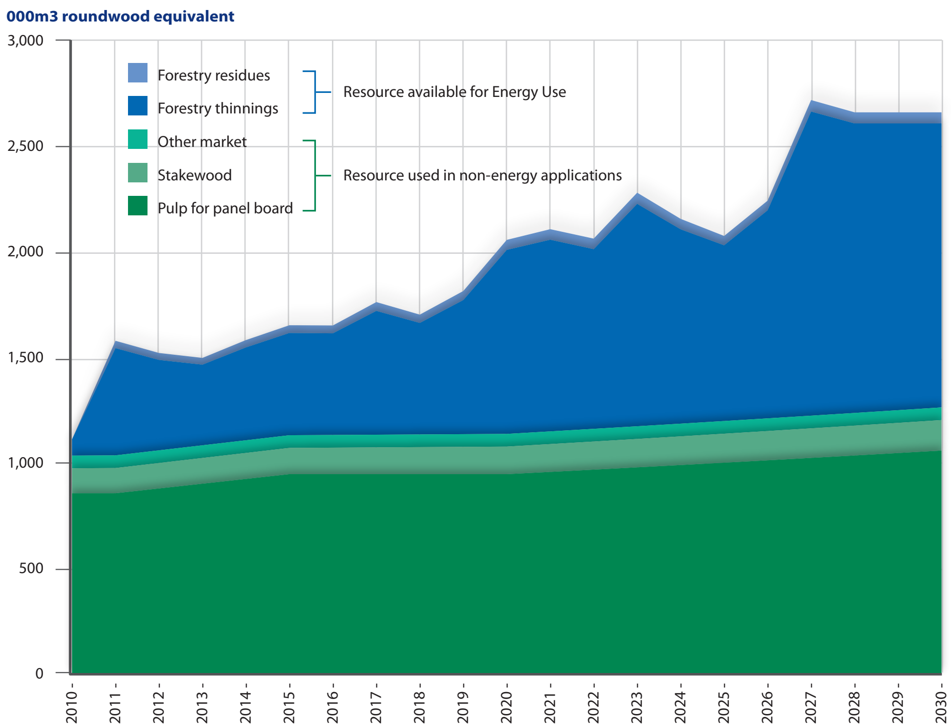
20 Teagasc (2012). Situation and outlook for Forestry 2011/12.

21 Stakewood markets include timber pallets and gate-posts.

22 'Other markets' are not defined by COFORD, but are likely to include markets such as animal bedding.

23 The energy content (in terms of GJ/m^3) of wood varies substantially with moisture content, rising as moisture content falls. Woodflows are typically reported in volumetric terms. The volumes quoted here are in m^3 overbark, the same unit as used in the COFORD reports, and are converted to energy content using the same value as in the COFORD reports, i.e. 6.90 GJ/m^3.

FIGURE 7: FORECAST OF POTENTIAL FORESTRY RESOURCE TO 2030



Note: 2010 values are based on actual values as reported in Knaggs and O'Driscoll (2012)

2.2 PRICE

The price at which this resource might be available is informed by detailed forestry trials undertaken in Ireland by COFORD. The cost of forestry varies; key variables that influence the cost of operations are the scale, machinery used and overall approach, which is in part influenced by the scale and machinery. 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 used to fell, trim branches and load directly onto a forwarder that can transport timber to roadside transportation. The above factors are also again all influenced by proximity to forest roads and the overall terrain of the forest. An overview of the potential costs of wood-fuel supply in Ireland is available from the COFORD report, 'Cost-effective woodfuel supply chains in Irish forestry'.[24] This examined the cost of extracting first thinnings from private forest, based on trials of a variety of forestry harvesting techniques across a range of woodlands in Ireland. The methods and costs examined included harvesting and chipping, or processing to firewood.

Out of the six methodologies trialled and reported, the three considered most relevant to the extraction of thinnings for bioenergy are:

- ***Mechanical harvesting of shortwood with forwarding to roadside for chipping.*** This approach is the most commonly used approach to thinning at present. It uses wood with a minimum diameter of 7cm and 3m in length; any thinner pieces of wood are discarded. The discarded material creates a 'brash mat' on which the machinery operates. The biomass extracted is typically termed 'pulp' and sold to panelboard, and increasingly to wood-fuel suppliers, but the approach may also produce sawlog and stakewood assortments. Costs for this method in the trials ranged from 245-362 €/toe.

24 Kent, T., Kofman, P.D. and Coates, E. (2011). Harvesting wood for energy. Cost effective woodfuel supply chains in Irish forestry. COFORD, Dublin.

- ***Whole tree chipping.*** The trees are felled by chainsaw, left whole to season on the forest floor for one year (which allows all needles to fall off) and then chipped in the stand with a terrain chipper. This option is more cost-effective, partly as it enables greater biomass extraction, with production costs in the trials ranging from 93-183 €/toe.
- ***Small scale operations.*** Prices are provided for small-scale wood-chip supply chains, where smaller, weaker trees are individually felled, left to season in situ and then chipped, of 271-427 €/toe. Firewood (small logs) production costs were much higher at 726 to 1,412 €/toe. The reasons for the higher costs are the high manual input and smaller volumes handled. The report, however, acknowledges that this represents an opportunity, as expensive capital equipment is not required and the requirement for labour could be used as diversification of revenue for a farmer.

Current operations in Ireland follow the shortwood harvesting approach, so current costs are in the 251 to 335 €/toe range. Foresters are sceptical about not using a brash mat for the machinery to operate on, but the trials demonstrated that the wholetree harvesting method, which does not produce a brash mat, would be possible for most sites. It could reduce costs to less than 209 €/toe, but would require investment in advanced forestry equipment.

Additional evidence on prices from Teagasc was considered, which gives private timber sale prices of woodchip at roadside that equate to around 377 €/toe. This is at the high end of the costs discussed above and indicates that there is scope for cost reductions if the harvesting approaches trialled in the COFORD report were to be implemented. If demand for forestry products were to increase in Ireland, foresters would have more of an incentive to invest in expensive forestry equipment, and also to fully exploit the value of all forest products.

It is assumed that over time new investments in forestry infrastructure are made, that enable some of the thinnings to be extracted by the cheapest method, wholetree chipping. More significantly, it is assumed that annual improvements are made in driving down the cost of thinning extraction, which will become an increasingly important revenue stream for forestry operators. The resource has been grouped into the price brackets shown in Table 4. Based on the potential to move to the lower-cost harvesting approaches reported by COFORD and economies of scale as demand increases, then reductions in the price of biomass should be achievable.

TABLE 4: FORESTRY RESOURCE BY PRICE CATEGORY IN 2012 AND 2030

BAND	FORESTRY TYPE	PRICE (€/toe)	% OF TOTAL IN 2012	% OF TOTAL IN 2030
A	Forestry residues	105	6	8
B	Downgrades	315	29	51
C	Thinnings	377	65	41

Potential barriers identified to extraction of the resource are:

- ***Machinery:*** The forestry trials conducted in Ireland were undertaken in conjunction with specialists from Denmark. In some areas there is not the same machinery infrastructure available as in Denmark. For example, the trials contracted in a wholetree chipper from Denmark as such machinery had not been used in Ireland previously. Therefore, to reach the lower-cost levels discussed above, some investment by the forestry sector will need to be made.
- ***Experience:*** As previously mentioned, foresters currently believe that brash mats are necessary for machinery to operate on; this reduces the volume of biomass that can be extracted.

As discussed above, it is assumed that, as the domestic demand for biomass develops and dissemination of best practice takes place, these forestry barriers can be overcome.

2.3 FORESTRY SUMMARY

A dedicated supply of biomass to the bioenergy sector in Ireland is developing. Private forest plantations are forecast to lead to an increasing output of roundwood through to 2030. As the volume of roundwood harvested increases, an increasing volume of downgrades from the sawlog sector will become available for bioenergy. Independent of this, forestry trials have shown that, with modified forestry practices, a greater volume of roundwood downgrades and thinnings can be made available to the bioenergy sector at a lower cost than at present. An increasing demand for biomass could also help drive this change as foresters see that a market exists that is willing to pay a price that makes such operations economical. Following analysis of competing demands for sawlogs and panelboard, it has been estimated that the volume of wood from forestry thinnings and forestry residues available for bioenergy will increase from approx. 0.5 million m^3 in 2011 to 1.25 m^3 in 2030. This is equivalent in energy terms to 89 ktoe (thousand tonnes of oil equivalent) in 2011, rising to 230 ktoe in 2030.

3 SAWMILL RESIDUES

3.1 OVERVIEW

Sawmill residues arise from the processing of timber (sawlogs) at sawmills. As the sawlogs are processed into timber of specific size, a large amount of residues is produced in the form of bark, wood chips and saw dust. These by-products are considered as clean wood, as the timber will not have been treated and so contains no preservatives or paint (unlike, for example, waste wood extracted from the municipal waste stream). The residues generally have a lower moisture content than wood when it is initially extracted from the forest, as there is some drying of the wood before it is processed at the sawmill. The residues can be used for energy, either by combusting directly in an appropriate plant to produce heat and/or power, or by being processed into wood pellets, a fuel form that is more easily handled and transported, which can then be combusted. There are a number of other uses for sawmill residues, e.g. in panelboard mills, as animal bedding and as mulch.

In addition to residues from sawmills, more residual material is generated at those panelboard mills that debark small roundwood to produce wood chips for the panelboard they produce.

The quantity of sawmill residues produced is directly related to the throughput of sawlogs at sawmills, and this together with information on the fraction of incoming timber which ends up as sawn timber, bark, wood chips or sawdust, is used to generate estimates of quantities of sawmill residues available. Future demand for sawlogs is used to project forward the quantity of sawlogs processed. Demand for sawlogs is driven by demand in the domestic market, but also internationally, as most sawn timber is exported. Competing uses – i.e. for panelboard, animal bedding and bark mulch – are based on existing demand for these markets; levels of demand are assumed to remain constant for bark mulch and animal bedding but that from the panelboard sector rises in line with the demand for pulpwood (as set out in Section 2).

The generation of residues from the panelboard mills is forecast forward based on the relationship between the residues generated and pulpwood use in 2010, and forecasts of demand for pulpwood in panelboard mills.

The main data sources used in producing the forecast are shown in Table 5.

TABLE 5: DATA SOURCES USED IN MODELLING THE SAWMILLS RESIDUE RESOURCE

DATA	SOURCE
Forecast of demand for panelboard industry and sawlogs	COFORD (2011). All-Ireland Roundwood Demand Forecast 2011-2020
Demand for other markets and ratio of sawmill residues to sawlogs	Knaggs G and O'Driscoll E (2012). Woodflow and forest based biomass energy use on the island of Ireland (2010), COFORD Connects Note

3.2 RESOURCE

The volume of sawmill residues is directly dependent on the amount of sawlogs processed in Ireland. Based on the COFORD report 'Woodflow for the Republic of Ireland in 2010', of the sawlogs processed in 2010, the split between sawn timber and residues was as shown in Table 6. It is worth noting that in 2010 only 48.2% of sawlog volume actually ended up as sawn timber; the remainder (51.8%) ended up as sawmill residues.

TABLE 6: RESIDUE RATIOS IN 2010

PRODUCT	VOLUME 000M³ob	% OF SAWLOGS PROCESSED
Sawn timber	772	48.2%
Wood chips	517	32.3%
Sawdust	168	10.5%
Bark	157	9.8%

As in the forecast of the forestry thinnings resource, the COFORD 'All-Ireland Roundwood Demand Forecast' is used as the basis of the demand for sawlogs in the ROI to 2020. COFORD assumes that:

- All sawmills and boardmills currently in operation on the island of Ireland will continue to upgrade their facilities to meet market demand.
- Normal market conditions will return from 2015 onwards.
- Conventional demand will grow on a linear basis from 2010 to 2015, and remain constant over the period 2015 to 2020.

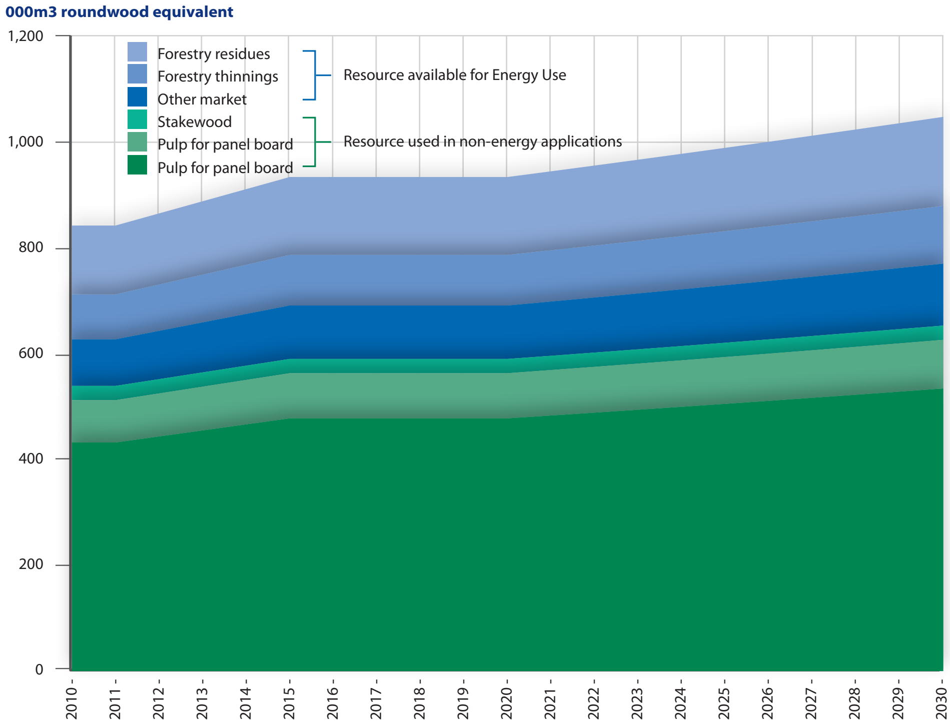
Demand is forecast to increase from 2,552m^3 in 2011 to 2,830m^3 in 2020. To extrapolate demand to 2030, the average growth rate between 2011 and 2020 is used for the period 2020 to 2030. This results in an increase in demand for sawlogs by about 25% over the period 2010 to 2030, leading to a similar increase in the amount of sawmill residues generated.

Residues are also generated at the panelboard mills from the pulpwood debarked and chipped there. Projections for these residues are forecast forward based on the current relationship between the residues generated and pulpwood use in panelboard mills in 2010, and forecasts of demand for pulpwood in panelboard mills. It should be noted that the panel board sector uses a large proportion of these residues for the production of heat required in the panelboard production process.[25]

Current non-energy uses of sawmill residues are bark mulch, animal bedding and panelboard. Levels of demand are assumed to remain constant for bark mulch and animal bedding, but demand from the panelboard sector rises in line with the demand for pulpwood in the panelboard sector – i.e. sawmill residues provide a constant proportion of the total supply to the panelboard sector. The resource available for energy use is shown in Figure 8.

[25] Irish Forestry and Forest Products Association: An overview of the Irish forestry and forest products sector, 2011

FIGURE 8: FORECAST OF POTENTIAL SAWMILL RESIDUE RESOURCE AVAILABILITY TO 2030



Note: includes residues (bark and sawdust) generated at panelboard mills

3.3 PRICE

Of the sawmill and panelboard residues available (i.e. not used to meet non-energy demands), a large proportion (87%) is already used for energy, much of it within the industry itself.26 The remainder is currently exported[26] although the market destination is not reported.[26] The high usage rate for sawmill residues 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 panelboard mills to produce heat for the production processes, the prices are not reported, but as the residues are essentially a by-product of the main production process, the prices are believed to be relatively low. A value of 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, it is known that forestry woodchips are traded at between 250 €/toe and 375 €/toe.

[26] COFORD (2012). Woodflow and forest-based biomass energy use on the island of Ireland (2010).

4 WASTE WOOD

4.1 OVERVIEW

Waste wood arises from a number of different sources and, importantly, varies in 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:

- Wood recovered from MSW kerbside collections: mixture of wood that is generally domestic packaging of mixed quality.
- Civic amenity collection: waste wood 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.
- Commercial packaging: arising from any commercial sector where wooden protective packaging is used, or pallets. This waste wood is often clean.
- 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 treated with paints or preservatives, and MDF which contains solvents.

A system for grading waste wood has been developed in the UK in recent years by the Wood Recyclers Association (see Box 4.1). For the lower-grade waste woods (C/D), high levels of contaminants are typically present in the wood, and any combustion facility taking this wood may need to have advanced emission scrubbing equipment. 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. Generally, all plants burning contaminated wood must comply with the Waste Incineration Directive. This equipment and licensing requirement results in additional costs to the plant operator. Thus a limited number of sites are willing to accept contaminated waste wood which means there is a lower demand and price as it cannot be used in most other markets.

BOX 1: WASTE WOOD GRADES

Grade A:	'Clean' recycled wood – material produced from pallets and secondary manufacture, etc., and suitable for producing animal bedding and mulches.
Grade B:	Industrial feedstock grade – including grade A material plus construction and demolition waste; suitable for making panelboard.
Grade C:	Fuel grade – made from all of the above material plus that from municipal collections and civic amenity sites; can be used for biomass fuel.
Grade D:	Hazardous waste – includes all grades of wood including treated material such as fencing and track work; requires disposal at special facilities.

Source http://www.defra.gov.uk/consult/files/consult-wood-waste-document-20120808.pdf

Information on the amount of wood recovered in 2010 is available from the EPA's National Waste Report. Forecasts of future amounts were produced using the overall growth trend predicted for municipal waste arisings in Ireland, as described in Section 8. Key data sources used are given in Table 7.

TABLE 7: DATA SOURCES USED IN MODELLING THE WASTE WOOD RESOURCE

DATA	SOURCE
Quantities of waste wood recovered currently from waste streams	EPA (2012). National Waste Report 2010
Projections for MSW generated	ISus model (Irish Sustainable Development Model) from the Economic and Social Research Institute

4.2 RESOURCE

The EPA's National Waste Report 2010 indicates that in total about 200,000 tonnes of waste wood were recovered from the waste stream in 2010, as shown in Table 8. About half of this is packaging waste, much of which is recycled for non-energy uses.

TABLE 8: WASTE WOOD RECOVERED IN 2010

WASTE WOOD TYPE	RESOURCE COLLECTED 2010 (tonnes)	RECYCLED FOR NON-ENERGY USES (tonnes)
Wood recovered from MSW	43,819	
Civic amenity collection	10,156	
Packaging	100,639	84,440
Construction and demolition	45,222	

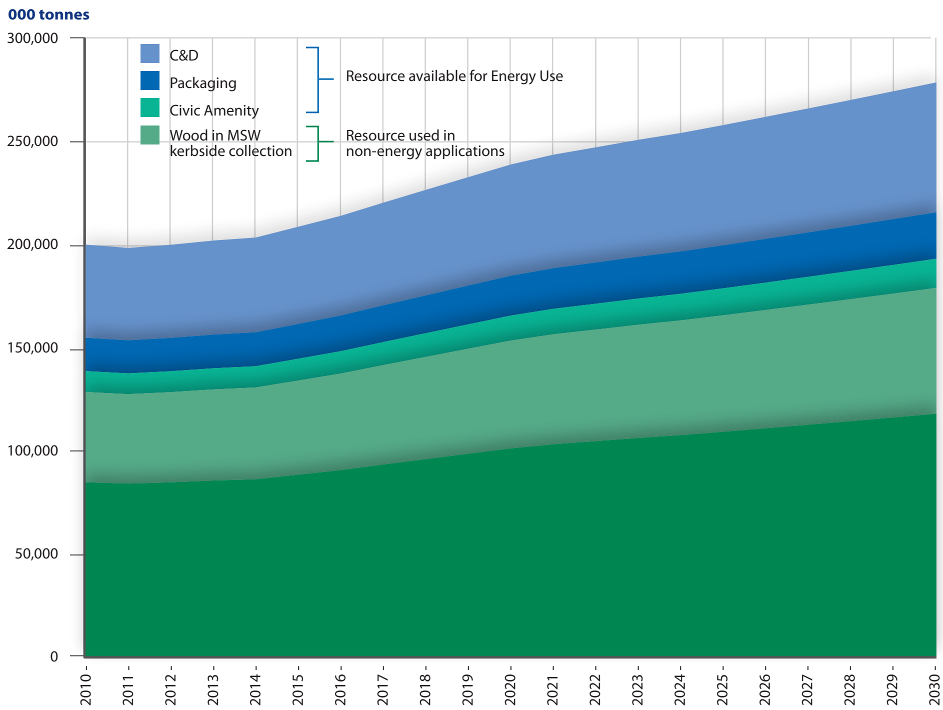
Source: EPA (2012). National Waste Report 2010

No specific forecasts of waste wood arisings exist, so the EPA's forecast growth in overall waste arisings, which is linked to the overall growth forecast for the economy, was used to forecast growth in all four streams. More details of the waste forecast are given in Section 8. For construction and demolition (C&D) waste, estimates may be conservative as the National Waste Report states that there are significant anomalies in the data collection for C&D waste, with not all waste data reported.

A high proportion (74%) of packaging waste wood was recycled in 2010. This was driven by the Packaging Directive under which Ireland had a target to recycle 60% of packaging waste in 2010. The fraction of packaging waste recovered for non-energy uses is assumed to remain constant at 74% in the future. Figure 4.1 shows the forecast of the waste wood resource; the recycling of packaging waste equates to the 'non-energy use' illustrated in Figure 8.

[27] EPA National Waste Review 2010, p.47.

FIGURE 9: FORECAST OF POTENTIAL WASTE WOOD RESOURCE 2010 - 2030



4.3 PRICE

Based on the typical characteristics of each waste stream, Table 9 shows generic grades reflecting the quality of the waste wood each waste stream is likely to provide. Box 1 (above) gives a definition of each grade. Typically a gate fee – a fee the waste producer pays the waste collector – is paid for disposal of low-grade waste wood. In the absence of information on formal waste wood prices in Ireland, UK prices have been used as a basis. A typical gate fee is assumed to be -€18/t (-45 €/toe). In contrast, suppliers of higher-grade clean wood could expect to receive a price of €18/t (45 €/toe). It is important to note that the price of waste wood fluctuates dramatically and it can generally be regarded as an immature market. Handling mixed waste wood requires specialist sorting facilities and specialist equipment for combustion plants. Historically, much of this waste has been landfilled and therefore can be classed as an emerging market that has yet to establish a stable baseline price. As producers and processors gain experience in dealing with the biomass energy market, it can be expected that a more stable future price will emerge.

TABLE 9: GRADE AND PRICE FOR EACH WASTE WOOD STREAM

WASTE WOOD TYPE	GRADE	€/toe
Wood recovered from MSW	C/D	-45
Civic amenity collection	C/D	-45
Packaging	A/B	45
Construction and demolition	C/D	-45

In the future as wood-waste processing facilities become more advanced, it is expected that increasing levels of sorting will take place to split the treated wood streams into more specific quality classes. This should allow a higher price to be gained for some of the wood currently classed as 'dirty' wood. The proportion of the overall waste-wood resource assumed to fall into each price band is summarised in Table 10. It is important to note that in order to use all of the waste wood, combustion plants that can handle treated waste wood will need to be constructed; without these, most of the wood that has contaminants (i.e. non-packaging) cannot be handled.

TABLE 10: FRACTION OF WASTE WOOD IN EACH PRICE BAND

BAND	Price €/gj	WASTE WOOD TYPE	% OF TOTAL IN 2012	% OF TOTAL IN 2030
Clean wood	1.1	Packaging	15	15
Wood with low levels of contaminants	0	Non-packaging	0	42.5
Contaminated wood	-1.1	Non-packaging	85	42.5

5 ENERGY CROPS

5.1 OVERVIEW

Energy crop is a general term applied to crops that are grown specifically for production of heat, electricity or transport fuels. Conventional arable crops such as wheat, oil seed rape (OSR) and sugar beet are grown for their starch, oil and sugar content respectively; these are converted to renewable transport fuels such as bioethanol and biodiesel. The woody material produced from dedicated perennial crops – such as miscanthus (a woody rhizomatous grass) and willow grown using short-rotation coppice (SRC) techniques – is combusted to produce heat and/or power.

The conventional annual crops can be grown on suitable arable land, using the equipment, techniques and expertise already available on arable farms. They are familiar to farmers, and the issues in expanding their production relate to 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.

Perennial energy crops can generally be grown on arable land or reasonably good permanent pasture. They are new to farmers, and their planting, agronomy and harvesting require specialised equipment, techniques and planting material. In contrast to annual crops, which are replanted each year, perennial crops take up to four years from planting to reach maturity, after which they are harvested at regular intervals of 1 to 4 years depending on species. Typically miscanthus is harvested annually and willow SRC every four years. In total, the crop will be in the ground for about 25 years before it is removed and replanted. Perennial crops require considerable initial investment, and do not start to generate income until the third or fourth year after planting. However, once productive they require less input in agrochemicals and labour, and produce a high yield of biomass for use in energy production. Large areas of land are suitable for production of perennial energy crops in Ireland, so there is a good potential for biomass production. Establishment grants are available in Ireland to help with the initial cost of establishing energy crops.

The wood from SRC and the biomass from miscanthus is commonly used in thermochemical conversion processes such as combustion and gasification to produce heat, electricity or both (CHP). Wood has more suitable combustion characteristics for small-scale heating plants and CHP and for existing power plant in Ireland. Miscanthus is suitable for combustion in purpose-designed plant. Wood can also be converted into renewable transport fuels by advanced techniques that are currently at the demonstration stage in Europe.

This section concentrates on the quantities of the annual crops, wheat and oil seed rape and the perennial crops willow SRC and miscanthus that it may be possible to produce in Ireland up to 2030. It does not consider what bioenergy-producing technology mix is likely to be developed in Ireland, and therefore what energy crops may be preferred. In the case of arable crops for producing biofuels, it makes no judgement on the potential availability of biofuels internationally, and the impact this might have on the choice to plant biofuels crops in Ireland. Instead it provides an estimate of the potential quantities of crops that could be grown domestically if there was a demand for the crops.[28]

The estimates are built up by looking first at the total farm land in Ireland, assessing the area suitable for energy crops, and estimating how much of this would be available for energy crops, while maintaining current food and feed outputs and taking sustainability concerns and current EU legislation into account. For the suitable and available land, the area that might be converted at different price levels for the crops is estimated, taking into account the profitability of the energy crops compared with other farm enterprises, farmer attitudes and other important constraints such as the early stage of development of the bioenergy market and uncertainty as to how the market might develop. The last is of particular importance for perennial crops, which have a lifetime of up to 25 years. In addition, for perennial energy crops where rhizomes (for miscanthus) or stools (for SRC) must be sourced from specialist suppliers, and specialist planting and harvesting equipment is required, the maximum rate at which the area planted could expand is considered. The overall approach taken to estimating the resource is summarised, together with key data sources used, in Figure 10.

FIGURE 10: FLOWCHART OF STAGES IN ASSESSMENT OF ENERGY CROP AREAS IN IRELAND

Total agricultural land	Agricultural land area in Ireland
	FAPRI 2011 forecasts in Food Harvest 2020, CSO, Teagasc
Suitable land	Identify land suitable for energy crops (SEAI land suitability GIS tool)
	Check conversion meets sustainability criteria in EC's Renewable Energy Directive.
Land profitable for energy crops	Land that would be profitable to convert at current biomass prices in Ireland
	Based on economic comparison of biomass vs other crops (Thorne, 2011)
Price required for conversion	Proportion of land converted at each price. Dependent on major constraints identified and the extent to which these are overcome at each price level
	Based on data on farmer attitudes (Clancy, 2007) and study on bioenergy targets (Caslin 2011)
Planting rate constraint	Maximum rate at which planting can be expanded given the stage of development of the energy crop industry (price-dependent)
	Estimated from recent maximum planting rates in Ireland and UK and expert opinion on state of industry and rate at which it can develop.
Land conversion constraints	Check that overall land converted is no more than the 10% grassland conversion allowed by CAP.

5.2 LAND AVAILABILITY

About 4.2 million hectares (ha) of land is used for agriculture and 730,000 ha for forestry in Ireland. Over 90% of the agricultural area is devoted to pasture and less than 10% to tillage crops. The tillage area, predominantly located in the south and east of Ireland,[29] has varied over the past 25 years, but is typically about 300,000 ha, with a range of 250,000 ha to 400,000 ha. High yields are achieved in spite of the challenges of the Irish climate.

Forecasts made using the FAPRI Food Harvest 2020 Strategy assume that cereal and overall crop production will remain fairly constant to 2020, at around the current level of about 300,000 ha. Teagasc believes the current area should be maintained for food/feed, but notes that the areas for OSR can be increased as it can be used as a break crop.[30] For the estimate of energy crop resource, it is assumed that a tillage area of 300,000 ha is maintained for crop production for food and feed.

29 Based on SEAI, FAPRI and CSO data, and the Food and Farming 2020 reports

30 A break crop is a secondary crop grown to interrupt the repeated sowing of cereals as part of a crop rotation. For example, in the case of OSR, it is grown every fourth year after three sowings of wheat.

The Common Agricultural Policy (CAP) allows for the conversion of up to 10% of permanent grassland to tillage by 2020, and it is this converted land (350,000 ha) that is assumed could be used for conventional arable crops (wheat and OSR) suitable for biofuels or for perennial energy crops (miscanthus or willow), should a suitable and profitable market emerge for the crops. In addition it is assumed that no rough grazing is converted to energy crops, as it is not assumed to be suitable, and that any new forestry area will be in addition to the area available for conversion to energy crops. At present the further conversion of pasture land post 2020 has not been considered under CAP. Pasture land in Ireland is currently under-used; to look at the maximum resource which might be available, it has been assumed that a further 200,000 ha (about 6%) of pasture land is available for conversion to energy crops post 2020. Use of this additional land would depend on suitable agreements being reached under CAP.

5.3 BIOFUEL ARABLE CROP RESOURCE

Currently 12,300 ha are given to OSR production, but a much larger area (about 1.8 million ha[31]) in the arable area of Ireland is suitable for production of OSR at acceptable yields (of at least 4.5 t/ha), so that availability of suitable land is not a constraint to increased OSR production. This is confirmed in a background paper for Food Harvest 2020,[32] on non-food crops in Ireland, which confirms the suitability of land in the existing arable area for expansion of tillage crops, and further states that this could be done without affecting existing farm enterprises to any great extent. To date, an expansion of OSR areas has not occurred largely because of economic reasons; farmers have not been assured of a market for the crop at a price that would make cultivation profitable or be competitive internationally. However, the purpose of this study is to consider the potential resource which could be available if more favourable market conditions prevailed. The sections below therefore consider, first, the maximum theoretical resource potential, assuming that all of the additional land potentially available from conversion of permanent pasture is used for biofuels arable crops rather than perennial woody energy crops, and then make a more realistic estimate of the achievable resource potential, based on the maximum levels of tillage in Ireland that have been achieved historically.

Theoretical resource estimate

OSR needs to be part of a four-year rotation of crops of different plant types to minimise pest and disease pressure and to maximise yields. It is typically planted for one year after three successive years of cereal sowings. This means that the current OSR area could be increased to an area that is 25% of the current cereal area; any subsequent increases in area must be accompanied by increases in the cereal area. It is assumed that, for OSR, production for biofuel use would be based in existing arable areas, to enable use of existing expertise and equipment, allow integration with cereal crops, and enable geographic proximity to a single processing plant.

The maximum amount of land which could be converted to OSR as a break crop in the existing tillage area is 25% of the existing cereal area (i.e. 60,000 ha). In addition, 25% of the additional 350,000 ha of land identified as potentially available from the conversion of permanent pasture could be dedicated to OSR – i.e. 88,000 ha. This total of 148,000 ha is a 12-fold increase from the current production of 12,300 ha, and would imply additional wheat production of 200,000 ha.

Accessible resource estimate

The estimate above suggests that theoretically there is substantial potential to increase production of wheat and OSR in Ireland for bioenergy purposes. However, this will only be realised if favourable circumstances prevail, including a profitable and stable domestic bioenergy market. The constraints to developing bioenergy are mainly the willingness/ability of farmers to adopt bioenergy crops, and the economic returns that can be achieved. In particular, there is need to establish confidence that a profitable and long-term bioenergy market would exist.

The estimate of theoretical resource potential above would require a doubling of the tillage area in Ireland, which is considered unlikely in the short to medium term, even if the required market conditions for production of biofuels exists. A more realistic estimate of the potential resource is therefore made, by assuming that only 100,000 ha of the 350,000 ha

31 Based on data from http://www.seai.ie/Renewables/Bioenergy/Information_and_Resources/Bioenergy_Mapping_System/

32 Non-food crops in Ireland (background paper for Food Harvest 2020). Available from http://www.agriculture.gov.ie/agri-foodindustry/foodharvest2020/backgroundpapers/

potentially available are converted to tillage; this limit is based on the maximum levels of tillage that have existed historically. Once again, this assumes that a profitable and stable bioenergy market develops. Assuming this 100,000 ha went into wheat/OSR production, there would be an additional 25,000 ha of OSR production and 75,000 ha of wheat production. In combination with an additional 30,000 ha of OSR that could be grown in existing tillage area as a break crop to replace cereals, this would give a total of 55,000 ha OSR and an additional 45,000 ha wheat, while maintaining current food and feed output.[33]

There is assumed to be sufficient machinery, seed and labour available to achieve the above levels of planting of OSR or wheat, and that these additional areas could be planted by 2016. Current and future yields for OSR are based on the yields assumed in forecasts made using the FAPRI model for the Food Harvest 2020 report.

Biofuel arable crop price

To achieve the planting areas discussed above would require substantial price increases from current levels and long-term supply contracts. Table 11 shows the percentage of the accessible resource it is considered would be available at a low price (typical of the current market price for the crop) and at two higher price levels.

The initial column shows the farm-gate price of the crops; the second column shows 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 part of the biofuel price, so agreeing a long-term supply contract can provide security of income to both the feedstock supplier and plant operator. The international price for biofuels would also influence decisions to develop wheat or OSR biofuel production in Ireland.

TABLE 11: PRICE ASSUMPTIONS FOR BIOFUELS RESOURCE

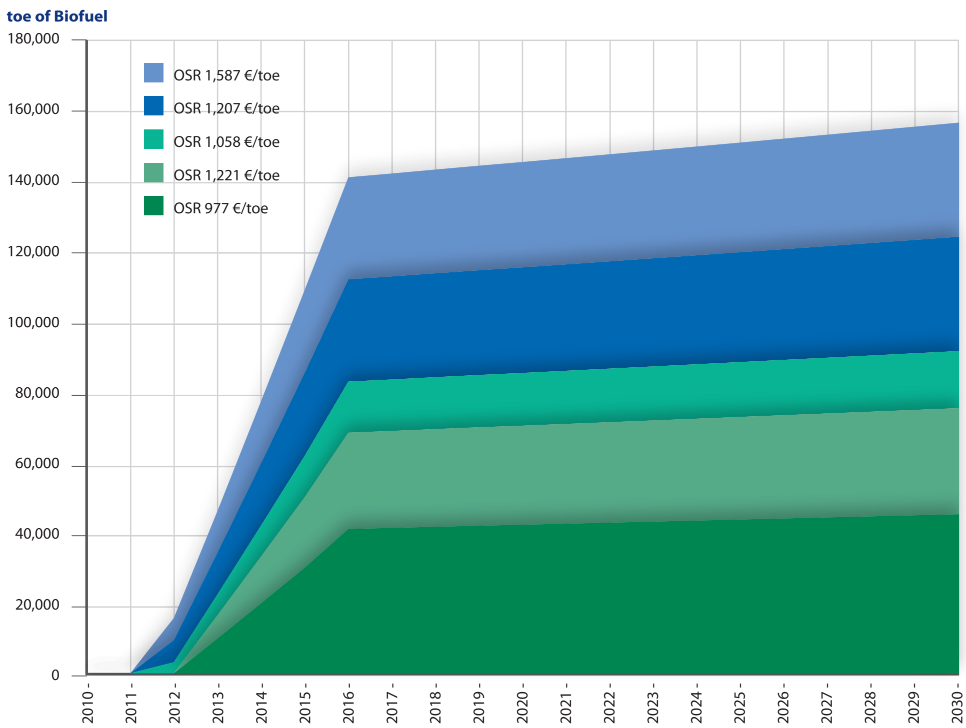
CROP	PRICE €/t OF CROP	EQUIVALENT PRICE €/toe OF BIOFUEL*	% OF RESOURCE AVAILABLE
Wheat	150	814	0%
	180	977	60%
	225	1,221	100%
OSR	370	1,058	20%
	444	1,270	60%
	555	1,587	100%

* For feedstock element only – i.e. does not include conversion costs

Figure 11 shows the forecast availability of energy crops used in the production of biofuels at each price level. With sufficiently high prices, these crops could see a large increase in production to 2020. After this point the physical constraints become the binding factor. The result is a smaller increase to 2030, even at high prices.

33 These assumptions have been sense-checked with experts in Teagasc (Barry Caslin, personal communication).

FIGURE 11: FORECAST POTENTIAL FOR BIOFUEL ENERGY CROPS 2010-2030



5.4 PERENNIAL ENERGY CROPS RESOURCE AND POTENTIAL

The production of perennial energy crops in Ireland is currently low, with about 900 ha of SRC and 2,400 ha of miscanthus planted up to July 2012.[34] Yields achieved to date are similar to those achieved in the UK, typically 10 oven-dried tonnes per ha per year (odt/ha/y).[35,36] The energy crop resource in Ireland is currently low, at about 33,000 odt/y. This resource is likely to be available over the lifetime of the plantations, i.e. about the next 20 years. There is significant technical potential for perennial energy crops in Ireland but this will only be realised if the demand develops and the constraints identified can be addressed.

The SEAI suitability mapping tool[37] shows that the climate in Ireland is suitable for lignocellulosic crops, with large areas of land across the whole of Ireland having high or medium suitability for energy crops. Assuming that medium-suitability land only is available for energy crop production, SEAI estimates that about 2 million ha of land are suitable for perennial energy crops across the island of Ireland. Suitability is therefore not a constraint for development of perennial energy crops, and these crops could be produced outside the current arable areas of Ireland.

Based on the maximum amount of permanent grassland Ireland is allowed to convert to tillage under CAP, it is assumed that 10% of existing permanent grassland could be converted to energy crops by 2020. Assuming no arable land will be converted to energy crops, then a maximum of 350,000 ha could be used for energy crops at acceptable yields. In particular, up to 10% of the 2.5 million ha used for beef farming could be converted to perennial energy crops without significant impact on current enterprises, due to current under-use of the pasture land.[34]

The lack of a secure market for the biomass produced for both SRC and miscanthus, farmer attitudes to changing farming systems, profitability of crop and availability of planting material/machinery represent limiting constraints on the technical

34 Barry Caslin (Teagasc), personal communication

35 The mass and energy content of woody energy crops depends on their moisture content. Yield and energy content are therefore expressed using oven-dried tonne, the mass at zero moisture content.

36 John Finnan, pers comm, SEAI bioenergy GIS tool: http://www.seai.ie/Renewables/Bioenergy/Information_and_Resources/Bioenergy_Mapping_System

37 http://www.seai.ie/Renewables/Bioenergy/Information_and_Resources/Bioenergy_Mapping_System

potential. The experience to date, as evidenced by planting rates of miscanthus, is that farmers are more inclined to plant miscanthus. Miscanthus is more difficult to process, handle and combust than SRC willow. The current energy conversion technology has limited the demand for the crop to date. SRC willow has not experienced these demand-side barriers but is limited by supply-side barriers such as the requirement for specialised harvesting machinery. SRC has more supply constraints, but a stronger current market; whereas for miscanthus there are fewer supply constraints, but a weaker current market demand. As this study is concerned with the potential supply of biomass only, to identify the potential resource which could be available if a suitable market existed, it is focused on supply-side constraints. Teagasc has identified a range of issues that currently constrain energy crops development in Ireland,[38] as listed in Box 2.

These fall into four main categories:

1. Constraints on the maximum rate at which planting may be expanded due to immature infrastructure
2. Profitability of the crop – farmers are most likely to consider energy crops if they offer a better return than current enterprises
3. Long-term commitment required for perennial crops, and lack of established/secure market
4. Experimental stage of current crops and lack of experience in crop production

Planting rate constraints

Planting rates of perennial crops in Ireland have been very low over the period 2005-2012, showing a maximum of about 190 ha/y for willow and 720 ha/y for miscanthus in this period. These low figures are despite the availability of a planting grant for SRC and miscanthus which is designed to help overcome the high establishment costs of these crops. For comparison, the maximum planting rates seen in the UK in the last 10 years have been 1,500 ha/y for SRC and 4,400 ha/y for miscanthus.

At the moment the major constraint on planting is farmer attitudes to the crops and the weak market for the crops. However, the production services industry for SRC and miscanthus (specialist equipment, planting material and specialist contractors) is also immature in both UK and Ireland. It is therefore expected that, even if farmer interest were high, the planting rate would be constrained by 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 availability of specialist equipment and services to 750 ha/y SRC and 2,000 ha/y miscanthus in 2012, 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 in Europe and the proportion of this capacity that may be available for planting in Ireland.

Profitability of perennial energy crops

An important consideration in the production of energy crops is whether they are more profitable for farmers than existing enterprises. Farmers usually compare profitability on the basis of 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.

Each biomass crop has a specific energy content per tonne (toe/t) based on the type of biomass and its moisture content. 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 miscanthus and SRC can vary markedly from up to 55% moisture for freshly harvested green biomass down to 10% moisture in processed biomass. In this analysis the primary unit of price is €/toe.[39]

38 Energy Crops in Ireland, Teagasc

39 One odt has an energy content of 0.45 toe

BOX 2: CONSTRAINTS TO ENERGY CROP DEVELOPMENT IDENTIFIED BY TEAGASC

FARMING REASONS
• High price for food crops makes energy crops less economic.
• The long-term investment makes the crop less attractive to farmers. The demographic profile of the farming population exacerbates this.
• The activity ties up land for long periods and it can be expensive to retire the land ahead of time. This means farmers lose the option of change practice in response to market profitability for traditional farming practices.
• There are comparatively high upfront costs to establish the crop.
• Cash-flow from the crops is different to familiar practices, generally involving harvested and sales each year. Perennial energy crops must be in the ground a number of years before the first harvest and can take a number of harvests before the investment is recovered.
• A lack of confidence that there will be an adequate demand for bioenergy for the crops in the future and expectations that future demand for food will increase prices for traditional produce.
• There is a perception that there is plenty of better-quality wood fuels available so there is no point in trying to compete.
• Farmers worry that planting energy crops will affect land values and land drainage and that the crops will be difficult to get rid of when their lifetime has expired.
• Once established, the crops require very little farmer input so they are off-putting to farmers who still want to farm their land.
• There is a lack of infrastructure – especially machinery for planting and harvesting SRC willow and processing miscanthus.

Source: Adapted from Energy Crops in Ireland, provided by Barry Caslin at Teagasc

Three farm-gate price levels are considered for bioenergy crops in our modelling: 170 €/toe, 250 €/toe and 420 €/toe. These are approx. equivalent to €75/odt, €110/odt and €180/odt, respectively, for both SRC and miscanthus. Current farm-gate prices available in Ireland are:

- €60/tonne at 20% moisture (equivalent to €75/odt) for miscanthus
- €38/tonne at 55% moisture (equivalent to €84/odt) for SRC chips

Current prices available are therefore at the lower end of the prices considered for the model.

A recent comparison of profitability of crops at the current prices available in Ireland is published by Teagasc.[40] This reflects the situation at prices of about €170 €/toe, when an establishment grant of €1,300/ha is included. Assuming yields of 10 odt/ha/y for SRC and miscanthus from the second harvest onwards, the annualised discounted gross margin[41] (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-profit 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 economically attractive to some farmers.

40 Clancy, D., Breen, J, Butler, A.M and Thorne, F. (2009). A Discounted Cash Flow Analysis of Financial Returns from Biomass Crops in Ireland. Journal of Farm Management, Volume 13, No. 9, pp. 595 -611.

41 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.

Styles et al[42] estimate that a price of 250 €/toe would see energy crops have a comparable returns to winter wheat. A price of 420 €/toe could see energy crops compete with profits from dairy. Dairy enterprises currently see the highest profit margin from their land. This agrees with analysis by Teagasc that biomass prices would need to reach at least €130/t at 20% moisture (about 290 €/toe) before farmers consider switching land out of cereals to biomass.

These analyses show that energy crops at current prices are a more profitable activity than beef farming. The National Farm Survey shows that most beef farms in Ireland are loss-making.[43] The fact that to date little land has been converted to perennial energy crops suggests that other constraints are holding back energy-crop development.

Other constraints

A previous study[44] modelled expected uptake of biomass in Ireland based on a combination of estimating land area where it would be profitable to switch to biomass crops, and the probability that farmers would consider such a switch, based on a survey of farmers' attitudes to energy crops. The model confirmed that it would be profitable for significant amounts of land to be converted to energy crops, but found that this switch would be extremely constrained by farmer attitudes. It was estimated that, with current attitudes, a maximum of about 72,000 ha land would be converted to energy crops. It was also noted that at €50/t (about 330 €/toe) the model predicted that farmers would be better off converting about 21,000 ha of land to willow. However, uptake to date has been much lower than 21,000 ha, even though current prices offered are higher than this assumed price. This confirms previous research that Irish farmers are reluctant to switch enterprise. This is thought to be a combination of a reluctance to move away from traditional enterprises, bad experiences of biomass production (in terms of examples of poor crop performance) and a reluctance to commit to a long-term enterprise when there are few customers in the marketplace and no guarantees of long-term market security.

Estimating uptake of energy crops

The studies to date show that perennial energy crops are potentially more profitable than current enterprises at a price of 170 € /toe and including establishment grant, but that to date uptake has been low because there are strong non-price constraints.

The modelling in this study assumes that, at the lowest price of 170 €/toe and with the current market and incentives in Ireland, planting of energy crops will continue at similar rates to those seen over the past two years. This means that, although energy crops are potentially more profitable than current beef enterprises, the other risks perceived in energy crops mean that there is minimal uptake of the new enterprise.

At the central price of 250 €/toe, energy crops offer a considerably higher margin than beef enterprises, probably similar to winter wheat. However, the lack of a secure long-term market is still seen as an important constraint at this price level. It is therefore assumed that the planting rate for both SRC and miscanthus will be 750 ha/y in 2012, similar to the maximum annual rate seen for either energy crop in Ireland over the past 10 years.

At the high price of 420 €/toe, it is assumed that the constraints imposed by farmer attitudes will be overcome for at least 10% of beef farm land, making about 250,000 ha available for energy crops by 2020. In this scenario planting rates are the constraint in early years. However, to continue the predicted rate of planting, it will be necessary to achieve the predicted yields and to maintain a secure long-term market, so that more conservative farmers can see that producing energy crops is a successful and profitable enterprise and will be prepared to enter the market. The assumptions made at each price level are summarised in Table 12.

These planting rates for SRC and miscanthus assume that there is no preference in the market for either SRC or miscanthus. From a demand perspective, there will be a preference for SRC or miscanthus depending on the energy production technology employed.

42 David Styles, Fiona Thorne and Michael B. Jones, Energy crops in Ireland: An economic comparison of willow and miscanthus production with conventional farming systems, Biomass and Bioenergy, 32, 5, 2008, 407, 421.

43 Thia Hennessy, Anne Kinsella, Brian Moran and Gerry Quinlan, National Farm Survey 2011, Teagasc 2011.

44 Clancy, D., Breen, J, Thorne, F. and Wallace (2011). The Influence of a Renewable Energy Feed-in Tariff on the Decision to Produce Biomass Crops in Ireland. Energy Policy, in press

TABLE 12: SUMMARY OF IMPACT OF MAJOR BARRIERS AT ASSUMED BIOMASS PRICES

	170 €/toe	250 €/toe	420 €/toe
Lack of secure long-term market	High	High	Medium
Poor cash-flow in early years	High	Medium	Low
Issues with successful cultivation	High	Low	Low
Estimated maximum % beef farm pasture converted to energy crops by 2020	0.2%	0.8%	2.5%
Planting rate assumed achievable in 2012 for miscanthus (ha/yr)	120	750	2000
Planting rate assumed achievable in 2012 for SRC willow (ha/yr)	200	750	750
Annual rate of increase in planting rate assumed	0%	7%	20%
Total area converted by 2020 (000 ha)	6.0	21.1	60.4
Total area converted by 2030 (000 ha)	9.2	59.2	428.7*

* Assumes that an additional 200,000 ha is available for conversion between 2020 and 2030, that this additional land conversion after 2020 can be agreed within CAP, and that such land meets any sustainability requirements brought in under RED for solid biomass.

The modelling shows that at the €170 €/toe and 250 €/toe prices there is sufficient land available to grow the maximum predicted areas of both SRC and miscanthus. Competition between SRC and miscanthus for land may only be an issue after 2020 at a price of 420 €/toe if no additional land is available for conversion from permanent pasture above the current 10% CAP limit.

5.5 SUMMARY OF PERENNIAL ENERGY CROPS POTENTIAL

The capacity to grow the perennial energy crops willow SRC and miscanthus on land in Ireland currently in grassland is substantial. Up to 250,000 ha of grassland could be converted to produce energy crops at acceptable yields without significant impact on existing farm enterprises or food and feed production.

Potentially, energy crop production is more profitable than beef farming at the lowest price level considered for energy crops (170 €/toe). However, to date, uptake of energy crop production has been very low, with plantings from 2005 to date estimated to be about 900 ha for SRC and 2400 ha for miscanthus, despite planting grants being available and prices being offered that are similar to the lowest price level modelled.

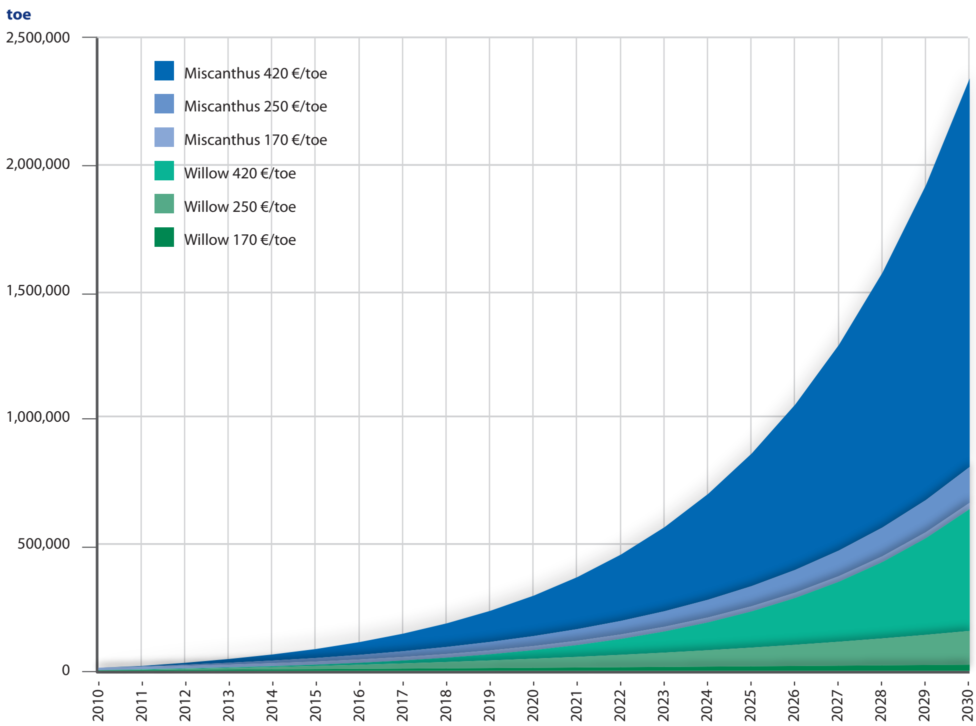
The low uptake to date can be explained by a number of important non-price constraints that have been identified in recent studies. The most important of these are the absence of a secure long-term market for perennial energy crops and the reluctance of farmers to move away from established enterprises to unfamiliar crops. These issues are exacerbated by previous examples of poor yields of perennial crops and experience of being unable to secure long-term markets for the crops. If these constraints can be overcome, the rate of planting of the energy crops will be constrained by the immature state of the energy crop production infrastructure. In particular, specialist planting material, equipment and expertise will not initially be available in the quantities required.

This modelling shows that, at the current price level and incentives, uptake of energy crops will remain at a low level, with 6,000 ha planted by 2020 and 9000 ha by 2030. A 50% increase in price could see the planting rate increase, starting at the maximum seen in Ireland over the past 10 years and increasing by 7% per year, to give 21,000 ha by 2020 and 59,000 ha by 2030. A doubling of price could see the planting rate being affected by the immature state of the energy-crop production industry, which constrains both the initial planting rate and the rate of growth of the industry. These assumptions restrict potential for planting to 60,000 ha by 2020 and 428,000 ha by 2030.

This is the only price level where the area that could be planted by 2020 would approach the area required to meet the contribution to 2020 renewable energy targets required from bioenergy. It is also the only case where more than 250,000 ha of land is required before 2030, leading potentially to competition for land between SRC and miscanthus, if further conversion of pasture land (above the 10% agreed in CAP) was not possible.

The potential energy crop resource at each price level is shown in Figure 12. Yields for energy crops are assumed to average 10 odt/ha over all areas planted until 2015 and then rise linearly to reach an average of 12 odt/ha for all areas planted in 2030. As discussed above, the modelling estimates the areas of SRC and miscanthus that could be produced, taking into account both the price offered for the crops and the non-price constraints on crop production. It does not consider the influence of demand for the two different crops on the area of each crop that might be planted. As both energy crops have a similar yield and energy content, the estimate of the overall resource would be unaffected by the proportion of land assumed to be dedicated to each crop, as long as the overall area planted with energy crops remains the same. However, it is unlikely that areas planted with SRC would increase above those estimated, even if a reduced amount of miscanthus was planted, as the estimate of the SRC resource is constrained by the rate at which it can be planted rather than land availability.

FIGURE 12: FORECAST OF POTENTIAL PERENNIAL ENERGY CROP RESOURCE 2010-2030



6 STRAW

6.1 OVERVIEW

Straw is a by-product resulting from growing commercial crops. The key crops for straw production in Ireland are wheat, barley and oats.[45] Currently the main conversion technology for straw is combustion to produce electricity and/or heat, but gasification and pyrolysis (thermochemical decomposition of organic material), although less developed, are also options. In the future, advanced conversion technologies may allow bioethanol production from straw. The heating value of straw depends on its moisture content and varies slightly between different types of straw, as shown in Table 13. As the density of straw is not high (about 0.46 t/m^3 for baled straw), however, it has only a moderate energy density (6.7 GJ/m^3) and is relatively bulky to transport; significant travel distances can thus add substantially to the cost of straw. 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.

TABLE 13: HEATING VALUE OF STRAW[46]

TYPE	NET CALORIFIC VALUE (NCV) (MJ/kg)
Wheaten straw	14.6
Barley straw	14.37
Oaten straw	13.4

The straw resource was estimated based on projections of the cereal crop areas which will be harvested to 2020 that were prepared by Teagasc for the strategy document 'Food Harvest 2020: A vision for Irish agri-food and fisheries', and straw yields per ha. There are already a number of uses for straw such as animal bedding, animal feed and mushroom compost; the quantity of straw used for each of these purposes currently and in the future was estimated and subtracted from the straw resource. Key data sources used in the resource assessment are listed in Table 14.

TABLE 14: DATA SOURCES USED IN MODELLING THE STRAW RESOURCE

DATA	SOURCE
Projections for cereal crop areas harvested	FAPRI (2011) data provided by Teagasc for Food Harvest 2020 Scenario
Straw yields	Teagasc (2010). Fact Sheet, Tillage No. 12: Straw for Energy
Estimate of quantity of straw used for alternative uses	SEI (2003). An Assessment of the Renewable Energy Resource Potential of Dry Agricultural Residues in Ireland
Projections for cattle numbers (used to update estimates of straw use for bedding)	FAPRI (2011) data provided by Teagasc for Food Harvest 2020 Scenario
Data for mushroom production	Teagasc (2012). Census of Mushroom Production in the Republic of Ireland 2011
Price data	Current market data on straw prices

45 Straw from oilseed rape (OSR) production has been excluded from our analysis because, although production is increasing in Ireland, quantities are still relatively small.

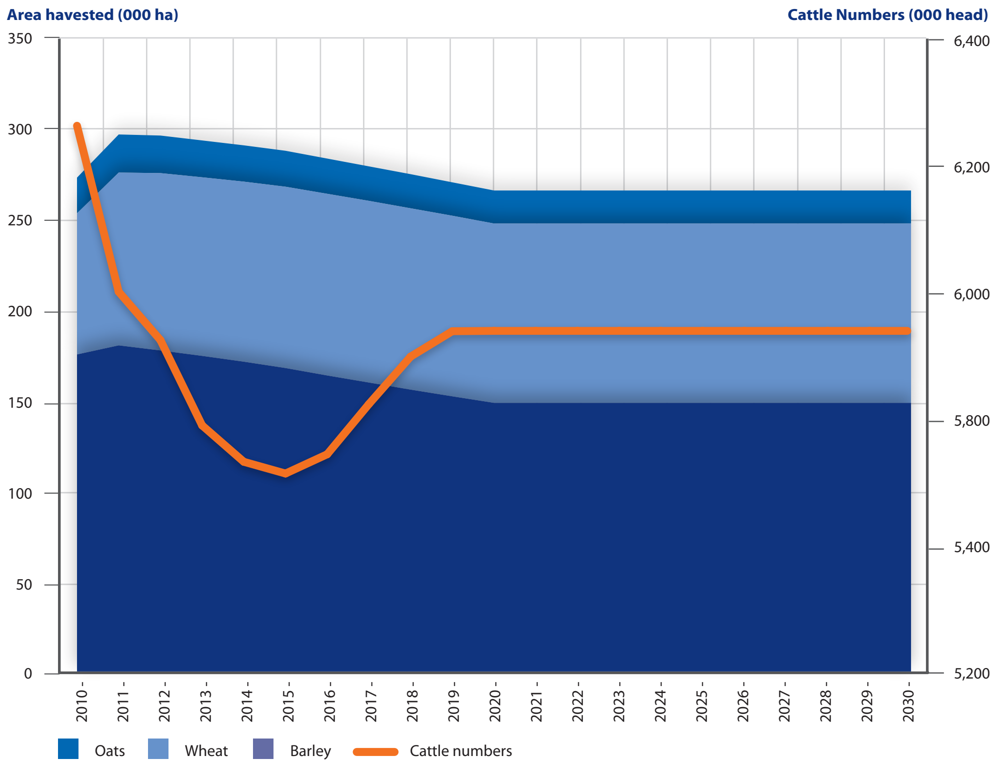
46 The net calorific value (NCV) of wheat and barley straw was provided by Barry Caslin (Teagasc). NCV of oaten straw assumed to be same as the value for generic straw provided in DECC Digest of UK energy statistics. A.1 Estimated average calorific values of fuels, 2010.

6.2 RESOURCE

Theoretical resource estimate

The underlying activity data for the estimate of the theoretical straw resource (i.e. total straw production) consisted of historical and projected crop areas for winter and spring varieties of wheat, barley and oats. Annual crop area projections for 2010 to 2020 were provided by Teagasc[47] and are those used for the strategy document 'Food Harvest 2020'. The projections, shown in Figure 13, forecast that the area of barley harvested will decrease by about 15% between 2010 and 2020, whereas the areas of wheat will increase by about 27%. As no projections were available for 2020 to 2030, it was assumed that crop areas would remain constant over this period.

FIGURE 13: FORECAST OF CROP AREAS HARVESTED AND CATTLE NUMBERS 2010-2030



Typical yields for the various types of straw at 15% moisture content, as provided in the Teagasc (2010) Fact Sheet on Straw for Energy, were applied to the crop area data to give the theoretical straw resource.

Actual straw yields are highly variable and depend (among other things), on the level at which the crop is cut. However, the straw yield estimates used were relatively low compared with estimates provided in other sources, as shown in Table 15 below. Therefore the estimate of the theoretical resource is thought to be relatively conservative.

[47] FAPRI (2011). Scenario 2: Food Harvest 2020 Scenario.
Table A12: Scenario 2 Activity Levels for Irish Agriculture (PART II).
Data provided by Kevin Hanrahan, Teagasc.

TABLE 15: COMPARISON OF STRAW YIELDS PROVIDED IN VARIOUS SOURCES (T STRAW/HA)

	TEAGASC (2010)[48] (t STRAW/ha)	SEI (2003 [49] (t STRAW/ha)	RULE OF THUMB: STRAW PRODUCTION = 2/3 CROP PRODUCTION APPLIED TO 2011 DATA (t STRAW/ha) [49]
Spring Wheat	3.0	6.0	5.6
Winter Wheat	4.2	8.0	
Spring Barley	3.6	4.0	4.6
Winter Barley	4.2	5.0	
Spring Oats	3.9	5.6	5.2
Winter Oats	4.7	7.0	

Accessible resource estimate

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.

As a general rule, if the straw price is less than €86/ha for straw cut and unbaled, it is more cost-effective for farmers to return this straw to the ground. This equates to approx. €20/tonne for unbaled wheaten straw (using a straw yield of 4.2 t straw/ha). If the straw is be baled for sale, there are additional costs for baling (of around €13/tonne) and handling (of around €4/tonne), bringing the minimum price for baled wheaten straw to approx. €37/tonne (or 105 €/toe). Where straw prices are close to or below this value, farmers may decide to chop and plough in straw rather than bale and sell it.

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 theoretical straw resource will be ploughed in whatever the market conditions for straw. This leaves a resource of about 1 million tonnes of straw.

Available resource estimate

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

It was assumed that the total quantity of straw of all types used for animal bedding is in line with the estimate provided in SEAI's 2003 publication; this estimated that the (then) Irish herd of around 7 million head of cattle had a straw requirement of approx. 1 Mt. The herd size is currently lower than this (around 5.9 million head in 2011)[50] so the amount of straw currently going to this use was adjusted pro rata. Barley and oaten straw are preferred for animal bedding over wheaten straw; therefore it was assumed that all of the available barley and oaten straw will be used up for animal bedding, with the balance of straw bedding requirements being made up by wheaten straw. In effect, this means that no barley or oaten straw will be available for bioenergy production.

48 Teagasc (2010). Fact Sheet, Tillage No. 12: Straw for Energy, Tillage Specialists, 2010

49 SEI (2003). An Assessment of the Renewable Energy Resource Potential of Dry Agricultural Residues in Ireland.

50 FAPRI (2011). Scenario 2: Food Harvest 2020 Scenario. Table A9: Scenario 2 Activity Levels for Irish Agriculture – Housing Period. Data provided by Kevin Hanrahan, Teagasc.

Future use of straw for bedding was based on the herd size projections produced by Teagasc,[51] which underpin the Food Harvest 2020 targets. These projections, shown in Figure 13 above, indicate that cattle numbers will decline until 2015, before recovering slightly to 2020. For the period 2020 to 2030, for which no projections were available, it was assumed that cattle numbers remain constant.

It was assumed that the quantity of straw required for mushroom compost is in line with the previous estimate provided by SEAI – i.e. some 100,000 – 120,000 tonnes of wheaten straw were used in 2002 to produce 289,236 tonnes of mushroom compost. Recent data on mushroom compost production, provided in the Census of Mushroom Production in the Republic of Ireland 2011,[52] indicate that mushroom compost production in 2011 was 183,948 tonnes, and the straw requirement for mushroom compost has been adjusted pro rata for the more recent data. No projections for mushroom compost production were available, so it was assumed that mushroom compost production and associated straw requirements remain constant from 2011 onwards.

In total, competing (non-energy) demands for straw accounted for about 95% of the potential straw resource in 2010.

6.3 PRICE

The price of straw was estimated based on advertised prices for baled straw in Ireland in 2012.[53] Straw is offered for sale at a price per bale, so the estimated weight of different-sized straw bales, as reported in Teagasc (2010)[54] and shown in Table 16, were used to convert price per bale to price per tonne.

TABLE 16: ASSUMED WEIGHT OF STRAW BALES

BALE SIZE/SHAPE	WEIGHT (kg)
Small square bale	15
4 x 4 round bale	150
5 x 4 round bale	240
8 x 3 x 2 (square)	150
8 x 3 x 3 (square)	450
8 x 4 x 4 (square)	625

A 4x4 round bale was the most common bale size offered for sale, with average price around €9/bale, equating to €63/tonne. Minimum and maximum prices observed for the period analysed were €4/bale (€27/tonne) and €15/bale (€100/tonne). Overall, the following prices were assumed to be representative of prices for baled and stored straw:

- Low €40/tonne
- Medium €60/tonne
- High €100/tonne

It was assumed that the low price of €40/tonne will bring 50% of the available straw resource (after competing demands have been removed) to the market, €60/tonne will bring 85% to market and €100/tonne 100% to market. The total resource is shown in Figure 14.

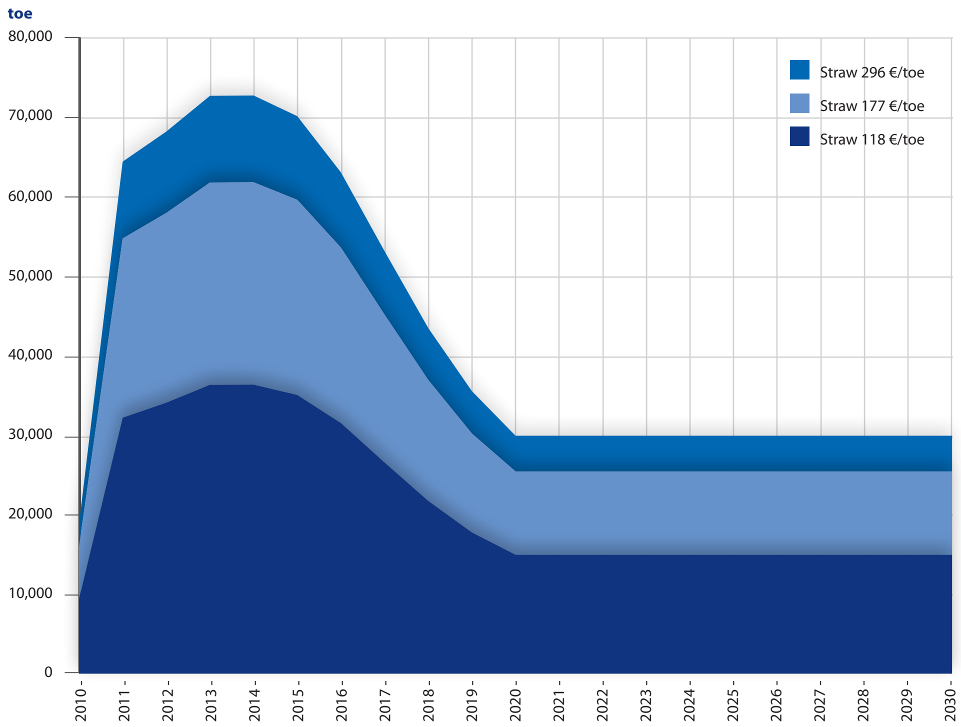
51 FAPRI (2011). Scenario 2: Food Harvest 2020 Scenario. Table A9: Scenario 2 Activity Levels for Irish Agriculture – Housing Period. Data provided by Kevin Hanrahan, Teagasc.

52 Teagasc (2012). Census of Mushroom Production in the Republic of Ireland 2011. Published in Mushrooms – A Teagasc Advisory Newsletter. Issue 37, April 2012.

53 www.donedeal.co.uk (accessed 22/06/12) and www.farmersjournal.ie (03/03/12)

54 Teagasc (2010). Fact Sheet, Tillage No. 12: Straw for Energy, Tillage Specialists 2010.

FIGURE 14: FORECAST OF POTENTIAL STRAW RESOURCE AVAILABLE FOR ENERGY 2010-2030



The rise to 2015 and subsequent decline is a consequence of the interplay between the projected crop areas for different cereals and the competing demand for straw for cattle bedding and feed. Cattle, which account for the main competing demand for straw, are projected to decrease in numbers to 2015, before recovering slightly to 2020, whereas the area of barley harvested is projected to decline between 2010 and 2020. As the quantity of barley straw declines, more wheaten straw will be required in its place for animal bedding and feed, amplifying the effect of changes in cattle numbers on the availability of wheaten straw for bioenergy.

7 PIG AND CATTLE MANURE

7.1 OVERVIEW

Slurry from cattle and pigs can be processed through an anaerobic digestion (AD) plant to produce a methane-rich biogas. The biogas can be used to generate heat and/or power or upgraded to biomethane for use as vehicle fuel or injection to the gas grid.

The amount of slurry produced in Ireland currently and in the future was estimated based on the projections of cattle and pig populations prepared by Teagasc for the strategy document 'Food Harvest 2020'. These were combined with an estimate of the quantity of manure produced per animal and the proportion of this managed using wet (slurry) systems which are potentially suited to AD, to give an estimate of the theoretical manure resource. As slurries produced in small quantities or remote areas will be much more difficult to access for AD, data on farm size were used to estimate how much of this theoretical resource is actually accessible.

Biogas is produced when anaerobic bacteria break down the digestible organic matter in slurry; the following characteristics determine how much biogas will be produced from a given volume of slurry:

- How much digestible organic matter is present – usually expressed as quantity of volatile solids (VS)
- How much of the slurry is made up of water – usually expressed in terms of dry matter (DM)
- The methane potential of the of the organic material being digested – usually expressed as m3 CH4/kg VS

The amount of biogas that could be produced from the accessible manure resource was therefore calculated on the basis of the relevant values for these parameters for cattle and pig slurry.

A list of the key data sources used to develop the resource estimate is given in Table 17.

TABLE 17: DATA SOURCES USED IN MODELLING THE MANURE RESOURCE

DATA	SOURCE
Projections for cattle and pig numbers	FAPRI (2011) data provided by Teagasc for Food Harvest 2020 Scenario
Quantity of volatile solids produced per animal	EPA (2012). Ireland's GHG Inventory
Typical dry matter and volatile solids content of cattle and pig slurries	SEAI Gas Yields Table
Proportion of animal waste managed using liquid (slurry) systems	EPA (2012). Ireland's GHG Inventory
Size distribution of cattle and pig farms	CSO (2008). Farm Structure Survey 2007. Data from CSO Farm Analysis by Size of Herd

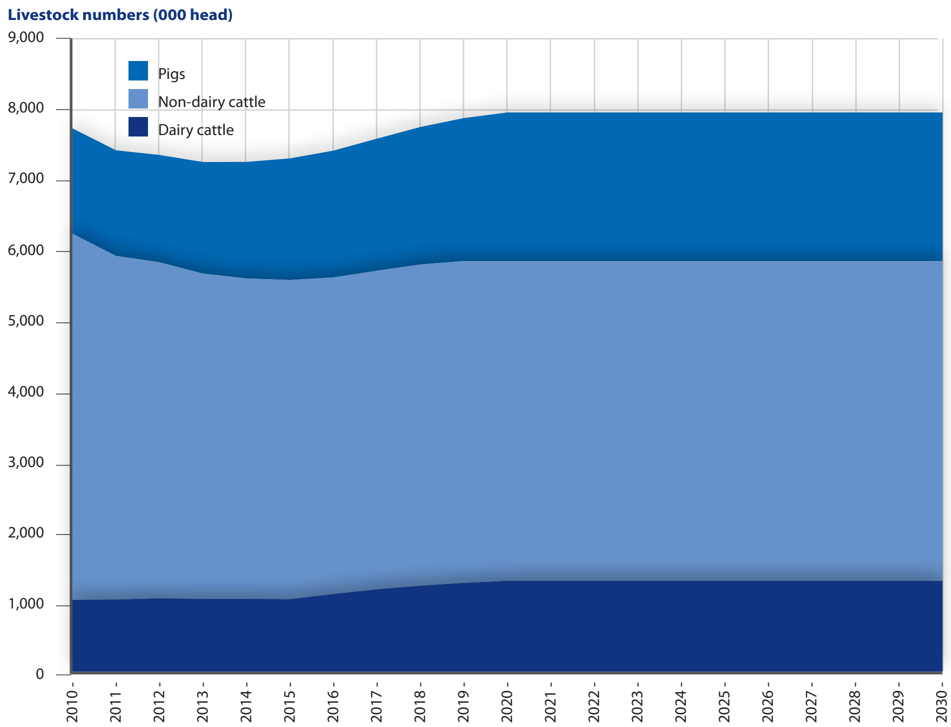
7.2 RESOURCE

Theoretical resource estimate

The underlying activity data used to estimate the theoretical slurry resource was historical and projected livestock numbers for cattle and pigs. Annual livestock numbers for 2010 to 2020 were provided by Teagasc, and are those produced by Teagasc using the FAPRI model which underpins the Food Harvest 2020 targets.[55] The projections shown in Figure 15 estimate that dairy cattle numbers remain roughly constant to 2015 and then increase to 2020, as a result of the abolition of EU milk quotas allowing the industry to grow. Overall dairy cattle numbers increase by 26% over the period, whereas non-dairy cattle numbers decline until 2015, then remain broadly stable to 2020, giving an overall decrease of 13%. Pig numbers are projected to increase by 41% over the period 2010 to 2020, as the sector takes advantage of increased demand from the expected growth in pork consumption worldwide. No projections were available for 2020 to 2030, so it was assumed that livestock numbers remain constant over this period.

The total quantity of volatile solids (VS) produced in the form of slurry for dairy cattle, non-dairy cattle and pigs was calculated using the EPA's figures for average daily VS excretion and the proportion of waste managed using liquid (slurry) systems.[56] The VS quantity was converted to quantity of slurry using typical dry matter (DM) and VS content values for cattle and pig slurry, as published by the SEAI.[57]

FIGURE 15: PROJECTED LIVESTOCK NUMBERS 2010-2020[58]



55 FAPRI (2011) Scenario 2: Food Harvest 2020 Scenario. Table A9: Scenario 2 Activity Levels for Irish Agriculture - Housing Period. Data provided by Kevin Hanrahan, Teagasc.

56 Environmental Protection Agency (2012). Ireland's GHG Inventory-CRF Downloads. IRL-2012-2010-v1.3.xls. TABLE4.B(a) (Sheet 1 of 2) SECTORAL BACKGROUND DATA FOR AGRICULTURE. CH4 Emissions from Manure Management. (Sheet 1 of 2)

57 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

58 FAPRI (2011). Scenario 2: Food Harvest 2020 Scenario. Table A9: Scenario 2 Activity Levels for Irish Agriculture – Housing Period. Data provided by Kevin Hanrahan, Teagasc.

Accessible resource estimate

Processing animal slurries through AD is more likely to be viable on or near farms with greater livestock numbers. Slurries produced in small quantities or remote areas will be much more difficult to access for AD. To estimate the accessible slurry resource, it was assumed that 10% of dairy cattle slurry, 5% of other cattle slurry and 75% of pig slurry would be accessible to AD. Some discussion of how these estimates were derived is provided below.

Digestion of animal slurries does not produce a great deal of methane compared with other feedstocks. Furthermore, the typical water content of slurry is over 90%, making it heavy and prohibitively expensive to transport. Therefore, for AD plants to use significant quantities of slurry, it must be available in large quantities within a relatively short distance of the plant. Combining slurry with other feedstocks, such as food waste, grass silage or other purpose-grown crops, can greatly improve the economics of slurry-based AD and also help to smooth out seasonal variations in availability.

The average Irish dairy herd size was around 123 cows in 2007.[59] Analysis of the size distribution of the Irish dairy herds in 2005[60] indicates that only around 13% of dairy cattle were in herds of more than 100 animals.[61] Beef cattle herds tend to be smaller, the average herd being around 51 animals. Irish pigs farms tend to keep larger numbers of animals, with the average pig herd in 2007 being around 2,033 pigs.

Based on standard AD delivery models, an AD a plant with a generation capacity of 250kWe would be considered a small plant, although some would argue that, for widespread uptake of farm-based AD, plants below 150kWe will be required. To feed a plant of this size on slurry alone would require many times more animals than typically kept on single farms.

In reality, many farm-based AD plants are likely to be cooperative ventures between groups of farmers and will co-digest other feedstocks along with animal slurries, meaning that slurry from smaller farms may be accessible to AD.

Available resource estimate

It was assumed that there are no competing demands for animal slurries and all of the accessible resource is available to AD. 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 is most commonly returned to agricultural land in a similar manner to slurry. Therefore AD and slurry land spreading are not, generally, in competition.

The energy potential of the available slurry resource is derived by multiplying the VS content of the waste and methane potential (m^3 CH_4/kg VS) for cattle and pig slurry,[62] and applying a technical conversion efficiency of 75%.[63]

7.3 PRICE

For farmers processing slurry produced on their 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, but 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 10km from the farm of origin.

Although animal slurries have an intrinsic value to the farmer as a fertiliser, processing them through an AD plant does not compete with this use. Where slurries are sourced as a feedstock for a third-party AD plant, the farmer and the operator are likely to enter into a reciprocal arrangement whereby the farmer receives treated digestate in return for slurry.

Due to their abundance and low energy content, it is unlikely (as noted above) that animal slurries would be transported far from the farm of origin. A report by FEC Services[64] looked at the cost of transporting slurry for a contractor with a 20t road tanker and a farmer/contractor with a tractor and 8t tanker. The results, including the fuel costs as well as loading

59 CSO (2008). Farm Structure Survey 2007

60 This is the most recent data available which gives both average herd size and livestock numbers versus size of herd for different types of cattle: http://www.cso.ie/px/pxeirestat/Database/eirestat/. The data published by Teagasc for the 2011 National Farm Survey does not provide this level of detail, so could not be used.

61 Data from CSO Farm Analysis by Size of Herd, Type of Cow and Year.

62 Environmental Protection Agency (2012). Ireland's GHG Inventory – CRF Downloads. IRL-2012-2010-v1.3.xls. TABLE4.B(a)(Sheet 1 of 2) Sectoral Background Data for Agriculture. Ch4: Emissions from Manure Management (sheet 1 of 2)

63 AEA (2011). Report to DECC: UK and Global Bioenergy Resource – Annex 1 report: details of analysis.

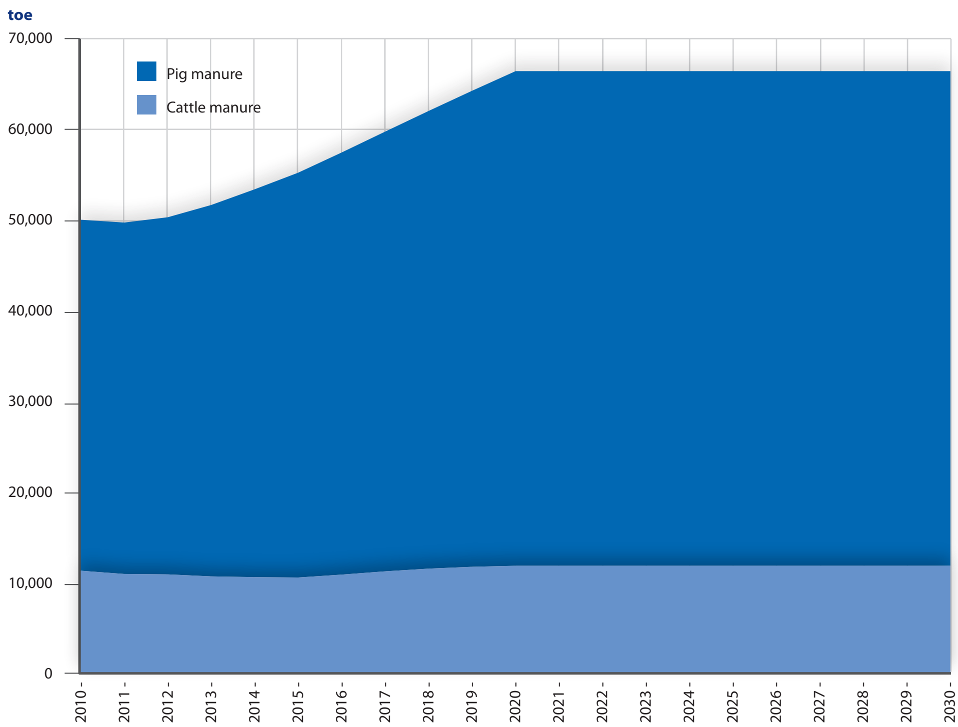
64 FEC Services (2003). Anaerobic digestion, storage, oligolysis, lime, heat and aerobic treatment of livestock manures. Final report.

and unloading costs, show that the cost of transporting the resource grows rapidly with small increases in distance travelled – almost doubling with each 5km travelled for a farm tanker.

The price per tonne of slurry assumed in our analysis excludes transport costs. Therefore the lowest price that slurry will be made available at is €0/tonne. As discussed above, it was assumed that AD does not compete with the use of slurry as a fertilizer. It was thus assumed that 100% of the available resource can be brought to market at a price of €0/tonne, excluding transport costs.

The total resource is shown in Figure 16. Quantities of slurry have been converted to the potential quantity of biogas they can produce based on the methodology described above. The resource estimate is driven by the changes in livestock numbers as projected by Teagasc for the strategy document Food Harvest 2020. The cattle manure resource increases slightly, as the forecast increase in dairy cattle (to take advantage of the abolition of EU milk quotas in 2014) more than offsets the decline in the number of non-dairy cattle. The pig manure resource increases significantly as the pig population is forecast to increase by around 40% between 2010 and 2020, as pork consumption worldwide is expected to grow steadily over the period to 2020.

FIGURE 16: FORECAST OF POTENTIAL MANURE RESOURCE 2010-2030



8 BIODEGRADABLE PORTION OF MSW AND COMMERCIAL WASTE

8.1 OVERVIEW

In 2010, Ireland produced approx. 2.85 million tonnes of municipal solid waste (MSW), of which 1.82 million tonnes was biodegradable municipal waste (BMW), paper, card, textiles, timber, food waste and parks and garden waste.[65] Some of this waste is recycled (e.g. some paper, card, timber) and some is composted (e.g. food waste and parks and garden waste). The remainder has historically been sent to landfill, but this is likely to change in the future as the EU Landfill Directive (1999/31/EC) requires member states to progressively reduce the amount of BMW sent to landfill,[66] so other waste management routes will be required.

Two waste management routes that allow the recovery of energy from BMW are:

1. Combustion of BMW in a plant where energy is recovered
2. Anaerobic digestion of some components of BMW (typically food waste) to produce biogas, which can then be combusted to produce heat and/or power or upgraded to produce a gas suitable for use as a vehicle fuel or injection into the gas grid

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, which can be burnt in a dedicated WtE plant, or used as a fuel in another combustion plant.

Separate collection of food waste allows it to be sent to an anaerobic digestion plant. The Waste Framework Directive (2008.98/EC) requires member states to take measures to encourage the separate collection of biowaste; to implement this, Ireland introduced the Waste Management (Food Waste) Regulations 2009.[67] These entered into force in July 2010, and require all major producers of food waste to be provided with a separate brown-bin collection of that food waste. In 2010, the Government indicated its intention to oblige waste collectors to provide or arrange for the separate collection of household food waste through the publication of draft regulations.[68] The draft regulations specified that separate collection would be required for all urban households (agglomerations greater than 1,500).

This study estimates each of these potential waste resources:

- the biological component of residual MSW and commercial waste, i.e. waste that is collected after dry recyclables and food waste have been collected separately
- the resource available in food waste which has been separately collected and can thus be used for anaerobic digestion

The key sources used in estimating the waste resource are shown in Table 18. For both resources, the first step was to forecast the amount of waste generated, which was based on projections 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. The ISus model estimates a reduction in the growth rate (-0.8%) in 2011, and a growth rate not exceeding 1% per annum until 2015 and beyond, and anticipates that the total tonnage of municipal waste generated may increase by about 825,000t within the next 15 years. The amount of residual waste collected and its composition, and amount of food waste collected separately were then estimated by combining data on the fraction of households in rural and urban areas served by 1, 2 or 3 bin-style collections, together with data on the quantity and composition of waste in the residual and 'brown' bin in each type of collection. The fraction of households in each type of collection system was projected forward, taking into account the draft household food waste regulations and projections from the Central

65 EPA, 2012. National Waste Report 2010.

66 To 50% of 1995 levels by July 2013 and 35% of 1995 levels by July 2016.

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

68 http://www.environ.ie/en/Environment/Waste/PublicConsultations/#DraftRegulationsRequiringtheProvision of Food Waste Collections

Statistics Office (CSO) on urban versus rural populations. The modelling shows the level of recycling increasing as more two-bin collections are implemented.

The BMW resource available for use in energy from waste plants is estimated using the above methodology, to estimate the total amount of BMW in residual waste; then the amount of waste likely to still be landfilled (assuming that as much BMW as is permitted by the Landfill Directive targets is landfilled) is subtracted. The food waste resource collected separately in brown-bin collections, which is also estimated using the methodology described above, is converted to a biogas equivalent, assuming biogas yields for food waste provided by SEAI.

TABLE 18: DATA SOURCES USED TO ESTIMATE THE BMW RESOURCE

DATA	SOURCE
Projections for MSW generated	ISus model from the Economic and Social Research Institute
Projection for commercial waste generated	Assumed to follow similar trend as MSW generated
Types of collection (1 bin, 2 bin and 3 bin) (current)	National Waste Report 2010 (EPA, 2011)
Projection of population in urban areas (used to estimate future trends in collection types – based on assumption that all urban areas will have 3-bin collection)	Data to 2015 from CSO statistics; extrapolated assuming continued trend towards urbanisation
Quantity and composition of residual waste and waste in brown-bin collections	National Waste Report 2010 (EPA, 2011). EPA, 2008. Municipal Waste Characterisation Report 2008. Surveys of Residual Waste from Businesses provided with Organic Waste Source Separated Collection Systems, RPS, 2010 for EPA
Biogas yield for food waste	Based on 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

8.2 RESOURCE

The starting-point for the forecast of the MSW resource is the forecast by the Economic and Social Research Institute (ESRI) for the Environmental Protection Agency (EPA) of MSW. The MSW forecast was produced using ISus, and is based on economic forecasts of production and consumption per sector. The forecast was extended from 2025 to 2030 based on the growth rate from 2025 to 2030.

The growth rate in the forecast of waste arisings was then combined with data on quantities of waste collected from households, commercial waste and cleansing waste in 2010 to produce a forecast for each of these waste streams to 2010. All waste streams were assumed to grow at the same rate.

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

[70] See:http://www.esri.ie/research/research_areas/environment/isus/

Household waste

Household waste was divided into waste arising from urban and rural households, based on forecasts of rural and urban population, and then subdivided further by type of collection system: one-bin (mixed residual waste only), two-bin (additional bin for dry recyclables) and three-bin system (additional 'brown' bin for food or food and garden waste). In 2010, 5% of all households were on a one-bin system, 61% on a two-bin system and 34% on a three-bin system. The proportion of households on a three-bin system is likely to increase as the proposed Waste Management (Household Food Waste Collection) Regulations 2010[71] would require that households within agglomerations greater than a population of 1,500 have a separate food waste collection.[72] It is assumed the regulations will come into effect at the earliest by 2014; this date is based on discussion held with industry professionals but it is at best an estimate. It is assumed that all urban households currently have a two- or three-bin collection and that no rural households are currently on a three-bin collection. Table 19 estimates that by 2020 all urban households and 20% of rural households will be on three- bin collection.

The amount of residual waste arising from collections and the BMW content of that residual waste is calculated using data from the National Waste Report 2010, and data from an EPA report characterising the composition of wastes from different types of collection. The third bin collection can be for food waste, food and garden waste, or garden waste only. The amount of food waste in the organic waste collected in the third bin is estimated based on the same waste characterisation data; currently food accounts for 29% of waste collected in the third bin, and this fraction is assumed to remain constant over time. Garden waste, the other main fraction of waste collected, can be used in AD, but has a very poor biogas yield so is not included in the resource.

TABLE 19: EXPECTED EVOLUTION OF MUNICIPAL COLLECTION SYSTEMS

	2010	2014	2020
% of urban h/holds on 1 bin collection	0%	0%	0%
% of urban h/holds on 2 bin collection	45%	30%	0%
% of urban h/holds on 3 bin collection	55%	70%	100%
% of rural h/holds on 1 bin collection	13%	0%	0%
% of rural h/holds on 2 bin collection	87%	90%	80%
% of rural h/holds on 3 bin collection	0%	10%	20%

Commercial waste

As no separate forecast of commercial waste arising is available within the ISus model results, generation of commercial waste was assumed to grow in line with the forecast of total waste arisings. As shown in the 2010 National Waste Report, 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, it seems reasonable to assume the same growth rate for commercial waste arisings.

In 2010, 44.5% of commercial waste (508 kt) was recovered, leaving 633kt of residual waste, which was landfilled. Future quantities of residual waste were calculated by subtracting food waste recovered (estimated as described below) and recyclables recovered from the residual waste. Recyclables recovered in 2010 was taken as the difference between total waste recovered and the estimate of food waste recovered, and this recovery level was assumed to be maintained into the future. All commercial premises were assumed to be on either a two- or three-bin system and the BMW of the residual waste in these bins was calculated by applying the BMW fractions reported in the EPA waste characterisation reports.[74]

71 http://www.environ.ie/en/Environment/Waste/PublicConsultations/#DraftRegulationsRequiringtheProvision of Food Waste Collections

72 This requirement was proposed to come in by 2012. This is not the case; for the purposes of this analysis is the proposed regulations are assumed to come into effect in 2014, based on discussions with key industry professionals.

73 EPA (2008). Municipal Waste Characterisation Report 2008.

The amount of food waste arisings is calculated from total commercial waste arisings and data on waste characterisation giving the food fraction as 31.3%. It is assumed that 50% of commercial premises are currently on a three-bin collection, allowing food waste to be collected separately, and that such collections recover 50% of the food waste, i.e. at present 25% of food waste is recovered. It is assumed that all commercial premises have a three-bin collection by 2013.

8.3 TOTAL RESOURCE

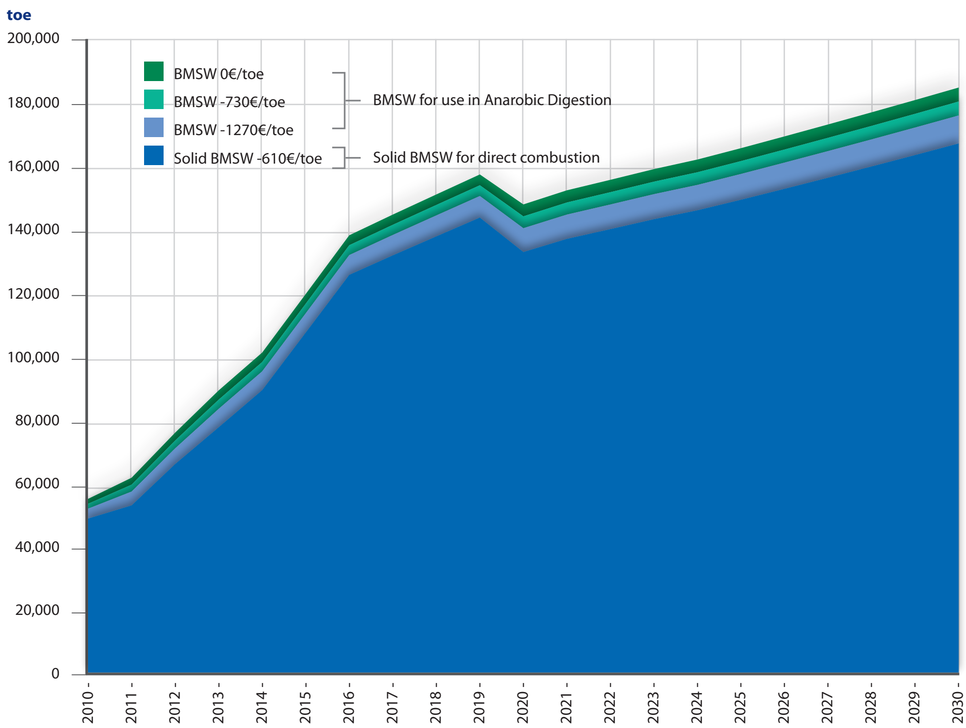
Solid BMW

The total solid BMW resource is calculated as the BMW content of the residual waste collected from household and commercial waste as described above, plus a small quantity from civic amenity sites and street sweepings. It is then assumed that as much BMSW as is permitted by the Landfill Directive targets is landfilled. This approach is consistent with that taken in the national greenhouse-gas emission projections to forecast future methane emissions from landfill. The remaining resource is assumed to be available for bioenergy.

Food waste

The total food waste resource is calculated as the sum of food waste collected via a third bin from households and commercial premises. The energy content of the food waste is expressed as the energy content of the biogas it will produce when anaerobically digested.[75] The total resource over time is shown in Figure 17.

FIGURE 17: FORECAST OF POTENTIAL BMW RESOURCE 2010-2030



74 EPA Municipal Waste Characterisation Report 2008 at http://www.epa.ie/downloads/pubs/waste/plans/name,11659,en.html) and www.epa.ie/downloads/pubs/waste/wastecharacterisation/3rd_Bin_Commercial_Waste_Characterisation_2010.pdf

75 2.3 GJ of biogas/t food waste based on Based on 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

8.4 PRICE

Solid BMW

The price for solid BMW 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. The levy rose from €30/t in 2010 to €65/t in July 2012, and will go up to €75/t in July 2013;[76] there is legal provision for the levy to be raised to a maximum of €120/t, but discussions with the EPA suggest that this is unlikely. It is therefore assumed that the levy plateaus at €75/t after 2013.

Food waste

In the case of food waste, the main alternative disposal route is composting. Price data for composting is available from a 2012 market report by RX3, which gives the gate fee for biowaste from brown bins at composting sites as €80/t. No data is available for gate fees for AD sites. Gate fees for AD in the UK vary from £35 to £60/t (with a median of £41/t) (equivalent to €41 to €71/t, with a median of €48/t). In the UK the gate fee is influenced by supply and demand, and the capacity in the region; 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.

It is assumed that in Ireland gate fees at AD plants would need to be lower than at composting plants to attract food waste resource. It is therefore assumed that, at a gate fee of €70/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.

76 As set out in the Environment Act 2010; see http://www.epa.ie/media/00061_EPA_table8.2.pdf

9 RECYCLED VEGETABLE OIL

9.1 OVERVIEW

Recycled vegetable oil (RVO), also referred to as recovered waste vegetable oil, used cooking oil (UCO) or simply waste vegetable oil, can be collected, filtered and used as a feedstock in production of biodiesel. A large biodiesel plant which uses a variety of feedstocks including used cooking oil, tallow and plant oils began operation in Wexford in 2008.

The main sources of UCO are catering premises, food factories and households. UCO from catering premises and food factories can be collected; and some companies supplying oil to catering companies offer an integrated service which includes free collection of used oil. Until recently most of the collected UCO was used in animal feed production, but this has recently been banned. Some UCO is exported for conversion to biofuels or used in biodiesel production plant in Ireland.

The amount of UCO available was estimated using the same methodology as in a previous SEAI study; i.e. the quantity of cooking oil consumed was calculated based on consumption per head and population statistics, and it was then assumed that 70% of this is recoverable. While oil collection from catering premises and food factories is well established, the recovery of oil from households is less developed.

TABLE 20: DATA SOURCES USED IN ESTIMATING THE RECYCLED VEGETABLE OIL (RVO) RESOURCE

DATA	SOURCE
Population projection	Provided by SEAI
Consumption of cooking oil per head and potential recovery rate	Clearpower Ltd (2003). A Resource Study on Recovered Vegetable Oil and Animal Fats. Sustainable Energy Ireland
Price data	Current price data from collection companies via internet; AEA (2011) 'UK Global Bioenergy Resource', and Clearpower (2003) (see above)

9.2 RESOURCE

To obtain the theoretical used oil quantity available, it was assumed that 5kg of oil are consumed per year per capita.[77] The economic forecast that underpinned the most recent national energy forecast was used as a basis for the population growth assumptions.[78] Of this potential resource, 70% is assumed to be realistically recoverable.[79] Achieving this recovery rate depends on the market price and on availability of options for appropriate disposal, as well as incentives to do so.

Previously the biggest use for recovered oil was for animal feed, but to safeguard animal health and the entire food chain, using cooking oil in animal feed is now banned. Therefore, it was assumed that animal feed is no longer a competing demand for RVO and the entire accessible resource is available for energy use.

[77] Clearpower Ltd (2003). A Resource Study on Recovered Vegetable Oil and Animal Fats. Sustainable Energy Ireland.

[78] SEAI, Energy Forecasts for Ireland to 2020, 2011 report, SEAI 2011.

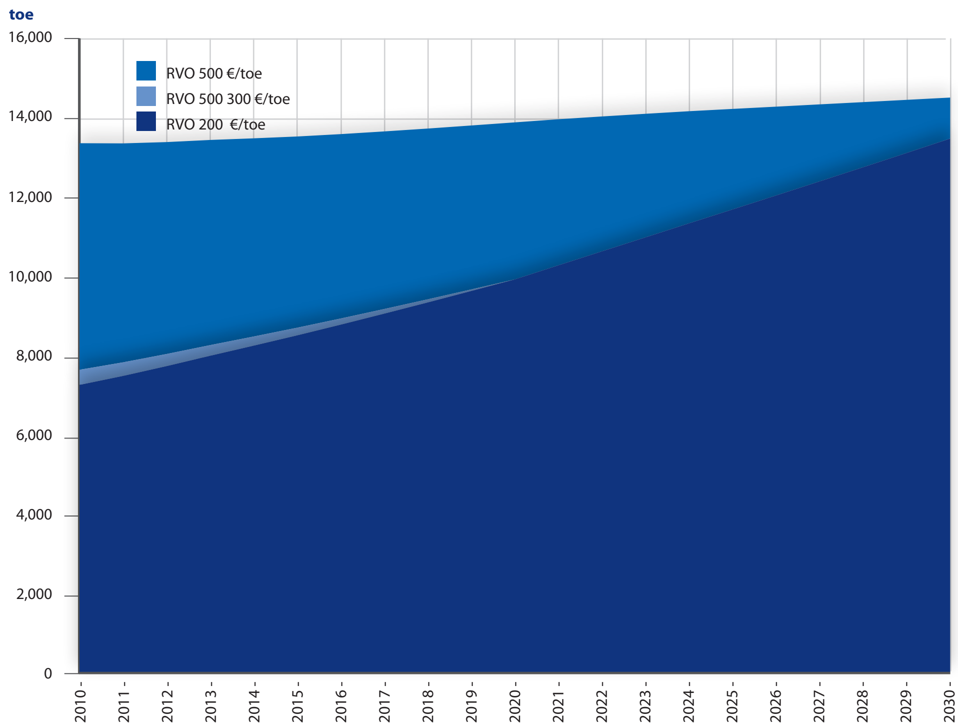
[79] Based on Austrian estimates in Clearpower ltd. (2003). A Resource Study on Recovered Vegetable Oil and Animal Fats. Sustainable Energy Ireland

9.3 PRICE

A study in 2003 estimated the price of bulk filtered RVO to be €179/t; no price data was publicly available for current prices paid for RVO in Ireland to update this data. Current prices paid for RVO in the UK range widely, from £80/t (€95/t) to £360/t (€425/t), with most prices in the range of £200 to £290/t (€236 to €342/t). In this study, the quantity of recycled vegetable oil available at different prices has been based on a previous study by AEA in 2010,[80] which estimated the quantity available at low, medium and high prices, which equate to about €170/t, €260/t and €430/t RVO – i.e. within the range of prices currently being paid in the UK. It is expected that prices for RVO in Ireland would follow a similar trend to those in the UK.

The quantities of RVO available at each price level are shown in Figure 18. A significant part of the resource is believed to be available at or below 200 €/toe (€170/t RVO). It is believed that, at the medium price of 300 €/toe, little additional RVO would become available, and a higher price approaching 500 €/toe is required to make the remaining resource available. It is assumed that this higher price is necessary to encourage the set-up of infrastructure to allow collection of used cooking oil from households, either directly or via civic amenity sites or household recycling centres/bring banks. Over time, as the collection infrastructure is developed, then the quantity available at a lower price increases.

FIGURE 18: FORECAST OF AVAILABLE RVO RESOURCE 2010-2030



[80] AEA et al. (2010) UK and Global Bioenergy resource – Annex 1 report: details of analysis

10 TALLOW

10.1 OVERVIEW

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:[81]

- 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, and make considerable use of Category 1 tallow as a heating fuel within the industry. A substantial proportion of Category 3 tallow currently goes to the oleochemicals industry. Both Category 1 and Category 3 tallow can be used as either a heating fuel, or as a feedstock to produce biodiesel.

The resource was estimated using the methodology set out in a previous, more detailed study of the tallow resource done in 2003.[82] The methodology estimates the amount of tallow production based on the herd size in Ireland, and this latter was updated using the recent projections produced for the Food Harvest 2020 report. Other assumptions regarding tallow production from carcasses were retained, as was the split between Category 1 and Category 3 tallow. Key sources used are summarised in Table 21.

TABLE 21: DATA SOURCES USED IN MODELLING THE TALLOW RESOURCE

DATA	SOURCE
Projections for livestock numbers	FAPRI (2011) data provided by Teagasc for Food Harvest 2020 Scenario
Tallow production per head livestock and competing uses	Clearpower Ltd (2003). A Resource Study on Recovered Vegetable Oil and Animal Fats.
Price data	AEA (2011). UK Global Bioenergy Resource. AEA (2008). Advice on the Economic and Environmental Impacts of Government Support for Biodiesel Production from Tallow. Clearpower Ltd (2003). A Resource Study on Recovered Vegetable Oil and Animal Fats.

10.2 RESOURCE

The tallow resource was estimated using the methodology set out in a previous study in 2003, which forecast the tallow resource to 2020 based on projections of herd numbers and animals coming to slaughter.[82] Projections of livestock populations were taken (as for animal manures) from the FAPRI forecast produced for the Food Harvest 2020 report[83] and are included in Appendix 5. The same assumptions were made as in the previous 2003 tallow study regarding carcass weight, post processing carcass material reaching the renderers and amount of tallow produced per tonne of carcass weight.

81 Regulation (EC) No 1774/2002) and, more recently, Regulation 1069/2009.

82 Clearpower Ltd (2003). A Resource Study on Recovered Vegetable Oil and Animal Fats. Sustainable Energy Ireland.

83 FAPRI (2011). Scenario 2: Food Harvest 2020 Scenario.

Irish rendering plants produce Category 1 tallow, which is high-risk, and can only be used as a fuel or for biodiesel production, and Category 3 tallow, which 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. As in the previous study, it was assumed that 44% of tallow production in Ireland is Category 1, and that 85% of Category 3 production goes into the oleochemicals industry.

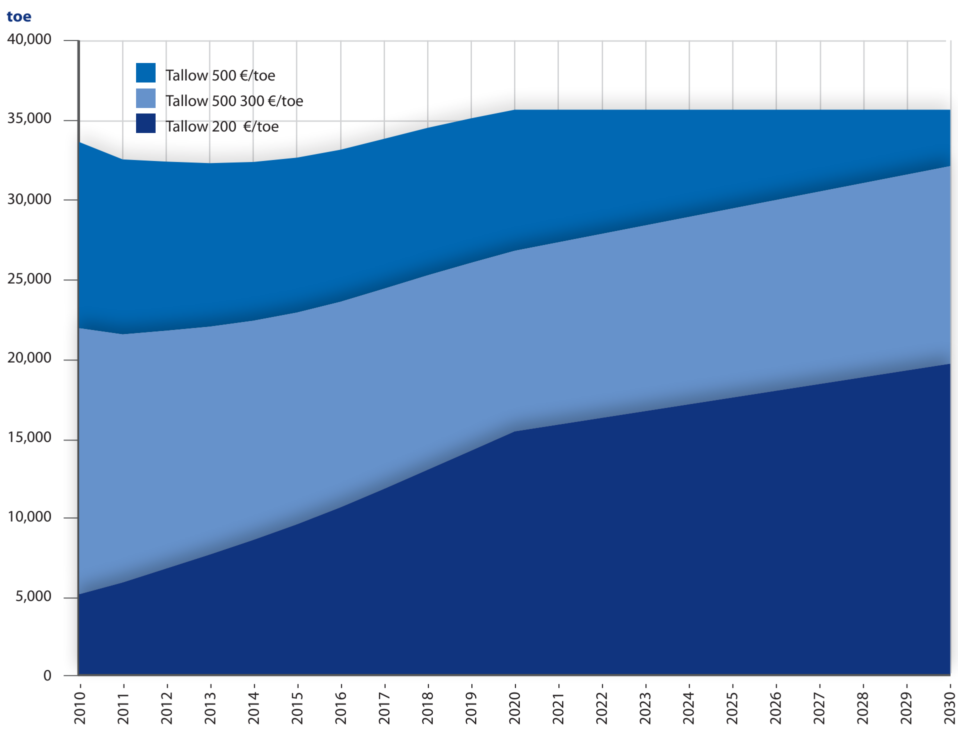
The rendering industry has to date made considerable use of tallow as a fuel within the industry; use varies depending on the difference between value of the tallow as sold into other industries, and the price of mineral oil for heating.

10.3 PRICE

The previous study noted a price in 2003 of €240-350 per tonne, depending on the grade of tallow; the price for Category 3 tallow was dictated by the world vegetable oil and fats market. A 2008 report[84] 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 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, as tallow is not generally traded on the open market but through direct contracts between companies, the study estimated that the price of Category 1 tallow was about £150/t (€177/t). No information was available on the price of Category 3 tallow.

A 2010 study for the UK estimated the percentage of the tallow resource in the UK that might be available at a low, medium and high price (of €165, €248 and €413/t respectively). Due to the closed nature of the tallow market and difficulty in obtaining more up-to-date data for the Irish tallow market, the assumptions from this 2010 study have been used. The quantity of tallow available at each price is shown in Figure 19.

FIGURE 19: FORECAST OF AVAILABLE TALLOW RESOURCE 2010-2030



84 AEA (2008). Advice on the Economic and Environmental Impacts of Government Support for Biodiesel Production from Tallow, a Report to Department of Transport.

84 AEA et al (2010). UK and Global Bioenergy resource – Annex 1 report: details of analysis.

11 INTERNATIONAL TRADE OF BIOENERGY RESOURCES

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 will probably be informed by price determined on the commodity market. There is already small-scale trading of biomass between Northern Ireland and the Republic of Ireland at the domestic and small commercial scale; this is likely to fluctuate under market and economic conditions, such as the exchange rate. A potential exists that larger volumes of wood could be exported to Northern Ireland and other parts of the UK if the incentives for renewable energy production are more attractive there. As a relatively small consumer of biomass, it seems likely that Ireland will be a price taker from the international market, and the quantity available from Ireland will not influence the setting of prices.

The potential international supply and price of these commodities has been estimated previously in work for the UK Department of Energy and Climate Change (DECC),[85] and formed the basis of estimates of international supply of bioenergy to the UK in the UK's recent bioenergy strategy. These forecasts of future bioenergy supply are uncertain, and depend on a number of assumptions – e.g. about general future development scenarios, the amount of land which may become available for energy crops, and the level of domestic demand for bioenergy in potential supply regions of the world.

The model developed for this previous work for UK DECC has been used to consider five scenarios which span the range of potential supply. These are defined in Table 22, with further background to the scenarios given in Box 3. The biomass demand scenarios are based on a 'reference' demand scenario as predicted in the IEA World Energy Outlook 2009,[86] which was updated to reflect any more recent biofuels mandates. The high biomass demand scenario is based on the '450 scenario' included in the IEA World Energy Outlook: "an alternative world, with an energy sector that is substantially cleaner, more efficient and more secure, and in which annual energy-related CO_2 emissions peak just before 2020 before falling to put the world on track for stabilisation of the atmospheric concentration of greenhouse gases at 450 parts per million (ppm) of CO2–equivalent". Under this scenario, there is a substantial increase in the use of biofuels, principally second-generation biofuels, and increased use of biomass for electricity generation. These higher domestic demands for biomass significantly affect the amount of biomass available for trade.

In the short to medium term, the model predicts that one of the main importers of biomass will be the European Union. It is therefore assumed that the amount of biomass the model predicts will be available to trade internationally, after all domestic demands forecast have been satisfied, will predominantly come to the EU. In order to estimate how much of this will be available to Ireland, it is assumed that Ireland will obtain 0.9% of the total amount of biomass or biofuels available; the value of 0.9% has been estimated by looking at Ireland's primary energy demand as a fraction of the EU's primary energy demand.

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

86 IEA (2010). IEA World Energy Outlook.

BOX 3: DESCRIPTION OF DEVELOPMENT SCENARIOS

BUSINESS AS USUAL (BAU)

Under this scenario, there is high technology development, the world economy grows at an average of 2% per annum, and poorer regions of the world show good development and growth. It is assumed that this encourages development of infrastructure, and food trade is maximal.

In this scenario current trends for bioenergy production prevail. It is assumed that development of agricultural resources and infrastructure will occur regionally on much the same basis as at present (i.e. those countries already successfully developing their infrastructure and technology continue to do so, but regions where this is not happening continue to lag behind). This means that much of the bioenergy potential of less developed regions will not be available under this scenario.

The maximum rate at which planting of energy crops could occur was estimated based on an assumption about the maximum rate at which the area planted each year could be expanded. This was 20% per year for developed economies, 10% per year for transition economies and 5% per year for emerging economies. Planting is not assumed to begin to increase until 2015.

BAU + HIGH INVESTMENT

This scenario provides opportunities for development of bioenergy, both domestically and through investment from richer countries. There is good technology transfer, enabling yield improvements in all countries. Facilitating trade is important, so product quality standards are developed to allow commodity trading of various grades of fuel. These standards also ensure consistent product quality, which, together with reliable delivery, encourages investment by demand-side sector. Developing countries are assumed to have the capacity to implement sustainability requirements and demonstrate that they have been met. Importing countries are assumed to develop good infrastructure to deal with large quantities of imports (e.g. facilities at ports).

Planting rates for energy crops increase more rapidly in this scenario.

In summary, this scenario presents an optimistic view of the potential for bioenergy from the land available (but not a theoretical maximum). Supply is increased substantially from the BAU scenario, due to increased planting and the removal of some barriers by investment, but a large proportion of land that could potentially be used remains unplanted in some regions.

LOW DEVELOPMENT

Under this scenario technology development is slower, and there is less intensification of agriculture and less improvement in yields. Growth in global GDP is lower than for the other scenarios (at 1.6 % per annum), and there is reduced international food trade. These traits combine to give lower potential land availability for bioenergy production.

In addition, there is less infrastructure development in developing countries, as it will not be developed for food crops; and developed countries do not invest in developing biomass supply in developing countries. Yields of energy crops only improve at 1.2% p.a. (compared to 1.6% in BAU) and yields of biofuels crops at half the rate assumed in the BAU scenario. Planting rates for energy crops are also lower.

The quantities of wood-based biomass potentially available to Ireland and the range of international trade prices under each scenario are shown in Figure 20. Data for each scenario is also given in Appendix 3.

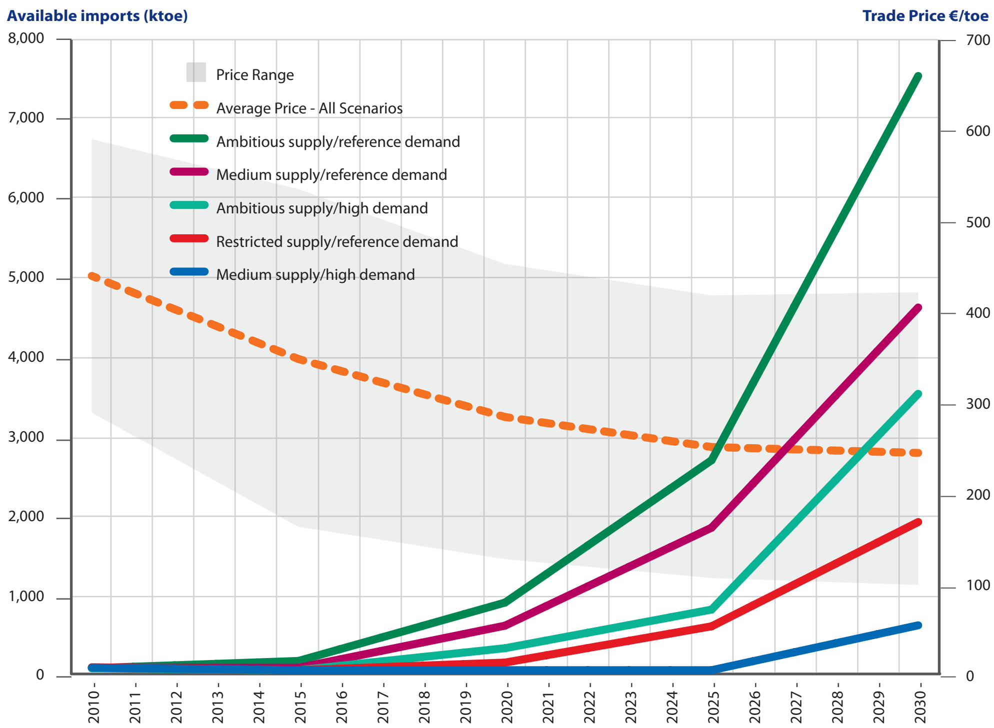
TABLE 22: INTERNATIONAL BIOMASS SUPPLY SCENARIOS

SCENARIO	DEVELOPMENT SCENARIO	BIOMASS DEMAND
Restricted supply/reference demand	Low investment	Reference
Medium supply/reference demand	BAU	Reference
Ambitious supply/reference demand	BAU + High Investment	Reference
Medium supply/high demand	BAU	High biomass demand
Ambitious supply/high demand	BAU + High Investment	High biomass demand

The rapid increase after 2020 in the supply of woody biomass under most scenarios is due to the development of perennial energy crops (such as SRC willow) in various regions of the world. The trade price will determine how much of Ireland's native biomass may be exported. The higher prices mean that more of the domestic resources that may be available for biomass will be harvested and processed for export.

The model estimates that supplies of international woody biomass are available for import in most scenarios. The quantities available will be an important determinant for the amount of domestic biomass that will used to produce bioenergy, and the price for wood chips and pellets. The most recent national energy forecast estimates that the total demand for thermal energy in Ireland will be 4,126 ktoe by 2020, and close to 480 ktoe of bioenergy will be required to reach the renewable heat target. In the low-availability scenarios, imports may be limited to less than 100 ktoe. The high-availability scenarios show that adequate imports are possible to meet the 2020 targets.

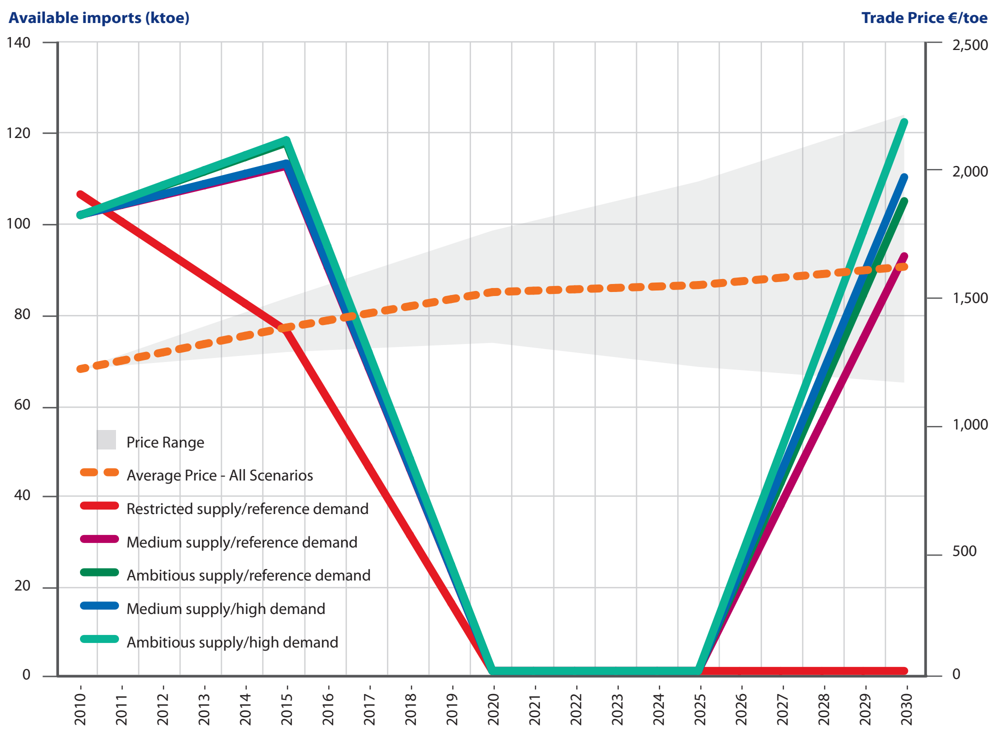
FIGURE 20: POTENTIAL WOODY BIOMASS AVAILABLE FOR IMPORT TO IRELAND AND RANGE OF INTERNATIONAL TRADE PRICE 2010-2030



In the case of biodiesel and bioethanol, the supply scenario also takes into account the sustainability standards for biofuels in the Renewable Energy Directive whereby from 2017 biofuels (from existing production plant) must show a 50% greenhouse-gas (GHG) saving compared to fossil fuels.[87] For each of the world regions in the model, an estimate is made of the average GHG savings that biodiesel produced in that region currently achieves. For regions where this average saving is less than the 50% saving required by RED, it is assumed that in reality, for actual production, there will be a spread of values round this average value, and that a fraction of the potential supply (the most efficiently produced) will meet the 50% saving and be available for use in the EU. The smaller the difference between the average saving and the 50% criterion, the greater the fraction of potential supply that is assumed to be available. The fraction available is also assumed to increase over time, as the GHG intensity of biofuels production improves.

Figure 21 shows the potential availability of biodiesel and the possible range of international trade prices. The requirement for 50% GHG savings significantly reduces supplies of biodiesel under all scenarios as many sources of biodiesel would not currently meet this criterion, and for a period, demand is greater than supply so that the availability of biodiesel for import falls to zero. Supplies do increase again over time, as it is assumed that producers improve the GHG balance of their production to ensure that it meets the relevant criteria, and after 2025, sustainable biodiesel is available for import.

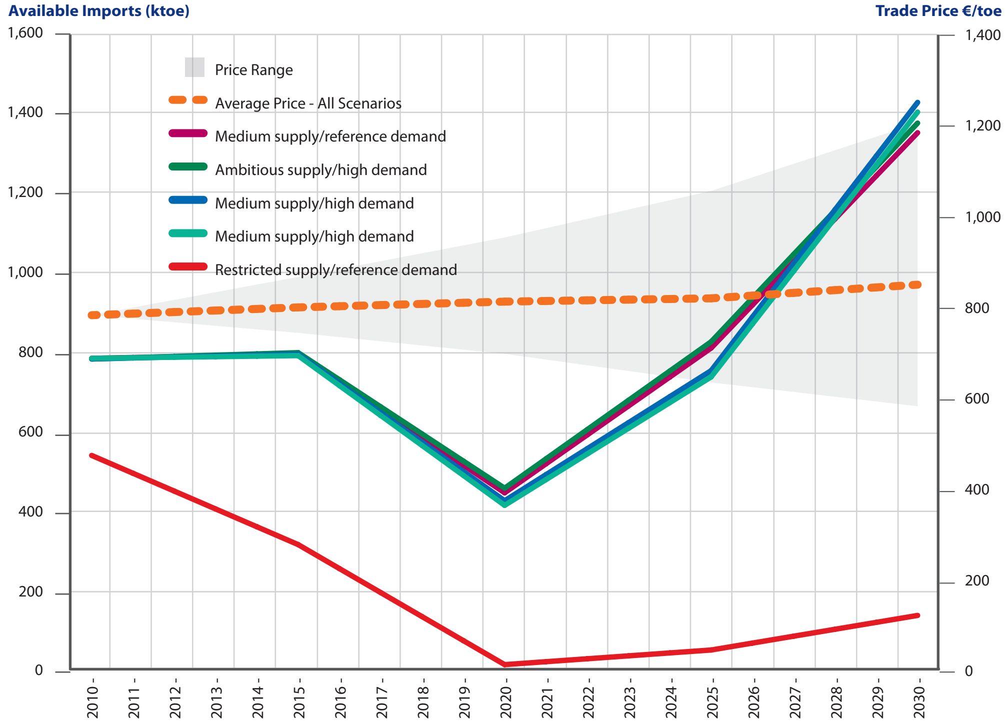
FIGURE 21: POTENTIAL SUSTAINABLE BIODIESEL AVAILABLE FOR IMPORT TO IRELAND AND RANGE OF INTERNATIONAL TRADE PRICE 2010-2030



In the case of bioethanol, the availability of the starch and sugar crops (mainly wheat, maize, sugar beet and sugar cane) is projected to be much higher than that of vegetable oils for biodiesel, as more land is considered suitable for growing these crops. This leads to a much higher potential supply of bioethanol than of biodiesel, as shown in Figure 22. In addition, the imposition of a 50% criterion does not lead to as significant a reduction in supply as for biodiesel, as GHG savings from bioethanol for many feedstocks are higher than GHG savings from biodiesel.

87 Biofuels from all plants must show a GHG saving of 50% from 2017 and biofuels from new plants (post 2016) a 60% saving from 2018 onwards. The 50% value is used as a cut-off in the modelling as it is assumed that no new plant producing biodiesel for export to the EU would be built unless it was considered that the 60% savings could be achieved. All plant are required to deliver at least 35% GHG savings from 2015.

FIGURE 22: POTENTIAL SUSTAINABLE BIOETHANOL AVAILABLE FOR IMPORT TO IRELAND AND RANGE OF INTERNATIONAL TRADE PRICE



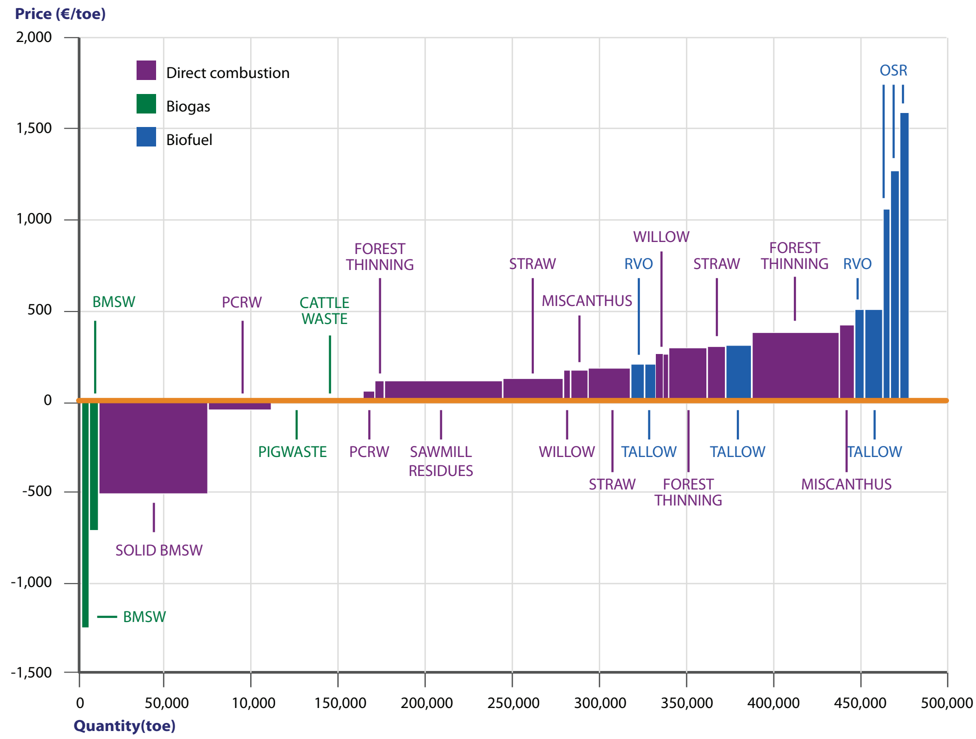
12 SUPPLY CURVES

This section examines the resource supply curves established in the previous sections based on how the resource is likely to be used to produce bioenergy – through direct combustion, through conversion into biofuels or through conversion into biogas. The supply curve of all the raw resources allows a consistent comparison of the costs across all resources by focusing on the cost of harvesting the resources at the resource location and excluding the costs associated with processing resources into biofuels, biogas or wood pellets, or the cost of transporting the resources to bioenergy customers.

12.1 SUPPLY CURVE FOR DOMESTIC RESOURCES

The analysis of the previous sections allows the relative costs of each resource to be compared in a single supply curve. The market price for bioenergy will determine how much of these resources will ultimately be brought into production. The market price is in turn influenced by the quantity of imports available and the prevailing international trade price. Figure 23 shows the 2012 supply-curve characteristics for all the resources examined.[88] They indicate the quantity of each resource that could be available in 2012 (the width in each step of the graph) and the price at which it is available (the height of the bar). The curve shows what may be used for bioenergy if the market price is at or above a certain point.[89,90]

FIGURE 23: DOMESTIC RESOURCE SUPPLY CURVE FOR IRELAND, 2012



88 These estimates are at the location of the resource and as such exclude the impact of transport costs. Transport costs should be included in modelling that use these curves as many of the resources examined have low energy densities and can be expensive to transport.

89 E.g. SEAI's BEAM model can use these supply curves along with projections of the bioenergy demand in heat, transport and electricity to estimate the resource use.

90 For comparison, the current Brent crude oil price of 110 $/bbl is equivalent to 570 €/toe. It should be noted that the costs of processing and using biomass resources for energy can deviate substantially from the costs of processing oil and using oil for energy production. These supply curves are the raw unprocessed cost of the biomass resources at the resource location.

A total of 480 ktoe of bioenergy is estimated to be available from biomass resources in 2012. The bioenergy available at negative/low market price is from waste materials. These resources receive a negative/low price as the disposal of them in landfill or through other waste treatment routes attracts a fee. A waste producer can instead sell this resource to a bioenergy-producing plant. These resources are used in the anaerobic digestion (AD) plant to produce biogas or combusted in waste-to-energy (WtE) plant to produce electricity. While these resources are available at negative price, several other important barriers may affect use of these resources to produce energy.

The mid range of the curve is comprised of woody biomass and energy crops used in combustion to produce energy for heat and electricity. The analysis estimates that 280 ktoe could be available in the price range between 100 €/toe and 420 €/toe. The cost of transportation and processing into wood pellets or wood chips will further increase the cost of these resources. The current cost of wood fuels ranges from 470 €/toe for wood chips to 770 €/toe for wood pellets.[91 92]

The resources commonly used in the production of biofuels are available in the price range between 200 €/toe and 1,590 €/toe. The wide price range reflects the cost difference between byproduct/waste resources such as tallow or recycled vegetable oil (RVO) and the higher-cost activity of growing dedicated energy crops for biofuel, such as wheat or oil seed rape (OSR).

Figure 24 shows the estimated supply curve for 2020. The results can be compared with the level of bioenergy required to meet domestic targets for renewable energy in 2020 as modelled in SEAI's energy forecast.[93] The 2011 forecast shows that about 1,000 ktoe of bioenergy is required to meet domestic targets for renewable energy in 2020. This is made up of 370 ktoe for transport, 475 ktoe for heat and 155 ktoe for electricity, which contribute to the individual RES-T (10%), RES-H (12% and RES-E (40%) targets. A key finding of this analysis suggests that a price of 380 €/ktoe could bring enough domestic biomass into production to satisfy the heat and electricity demand. A potential domestic resource of about 180 ktoe could be available for producing biofuels; however, even at the highest price point of 1,590 €/toe, this would not bring enough domestic resources into production to meet the RES-T target.

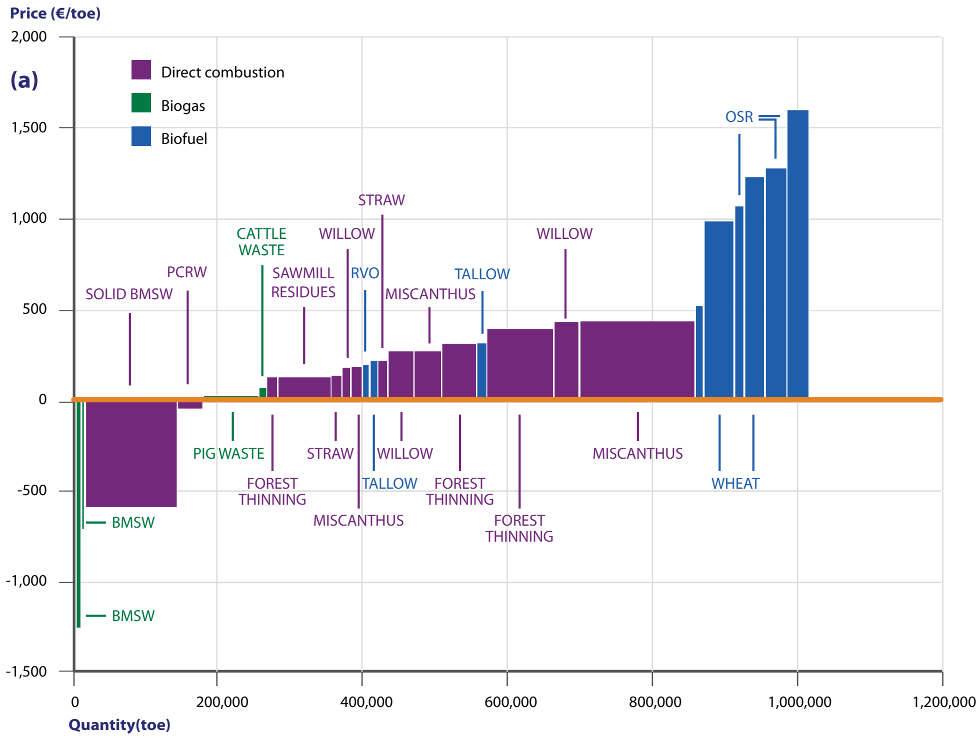
By 2030 (Figure 24 (b)) the estimated domestic potential is estimated to be 3,000 ktoe – a threefold increase from 2020. This is driven by a large increase in the expected availability of energy crops, particularly SRC willow and miscanthus, at higher market prices. These higher prices provide more farmers with the incentive to invest in the equipment and expertise required to grow the crops over the time horizon. A market price of 405 €/toe could see the potential from both of these crops brought into production. The potential at this high price represents about 60,000 ha in 2020 and 428,000 ha by 2030. This contrasts with the development of energy crops should current prices prevail into the future. At these lower prices, 6,000 ha of energy crops could be planted by 2020 and 9,000 ha by 2030. The quantities of energy crops available for biofuel production remain close to the 2020 levels. Other resources see smaller changes in the potential availability out to 2030.

91 Energy Policy Statistical Support Unit, Fuel Cost Comparison, available at: www.seai.ie/Publications/Statistics.../Fuel_Cost_Comparison/

92 For comparison, the current Brent crude oil price of 110 $/bbl is equivalent to 570 €/toe. It should be noted that the costs of processing and using biomass resources for energy can deviate substantially from the costs of processing oil and using oil for energy production. These supply curves are the raw unprocessed cost of the biomass resources at the resource location.

93 SEAI (2011). Energy Forecast for Ireland to 2020 – 2011 Report, SEAI Dublin.

FIGURE 24: (A) DOMESTIC RESOURCE SUPPLY CURVE FOR IRELAND 20 20; (B) DOMESTIC RESOURCE SUPPLY CURVE FOR IRELAND 2030



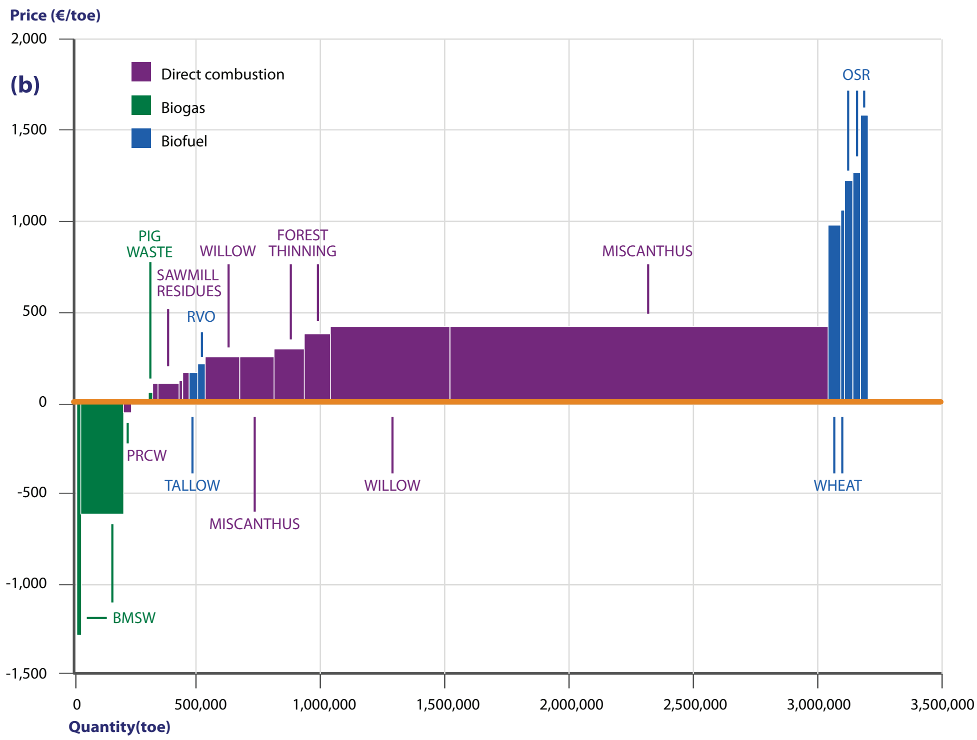
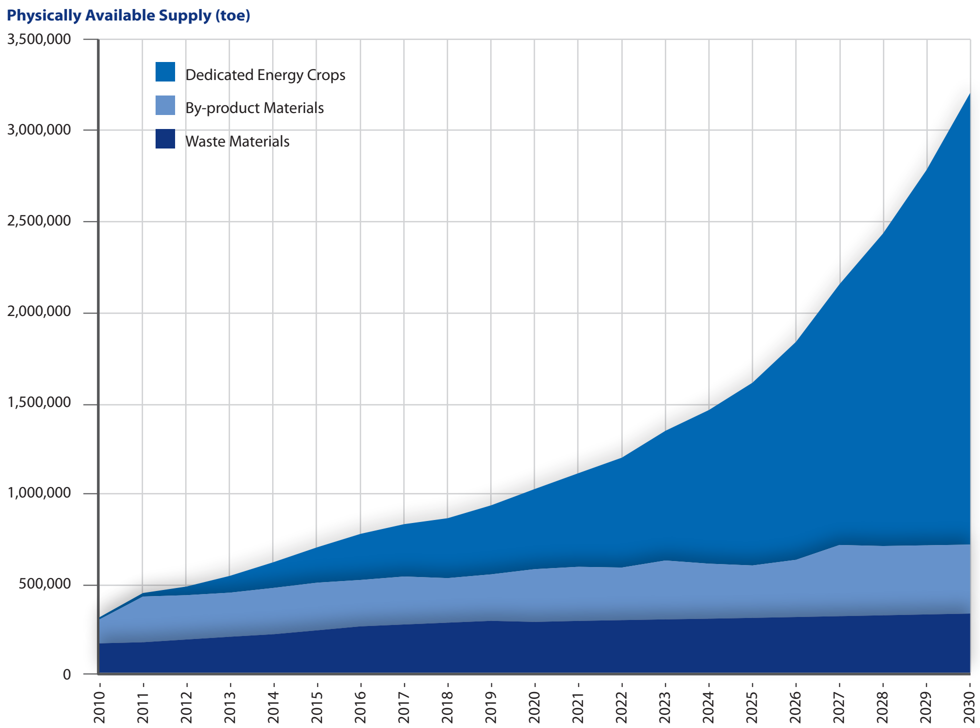


Figure 25 shows the physically available resource estimated from 2010 to 2030. This represents the available resource at the highest point along the supply curve. The largest increase in potential is expected to come from energy crops, with more modest increases in the resources available from waste materials and by-products of other activities. The following sections look in more detail at the supply curves based on how the resources are commonly used for bio-energy[94] and how international trade of these resources will interact with domestic supply. These are the direct combustion of a resource to produce heat and/or electricity, the conversion of a resource to biogas through AD, and the processing of resources to produce biofuels.

FIGURE 25: PHYSICALLY AVAILABLE DOMESTIC BIOMASS RESOURCE 2010-2030



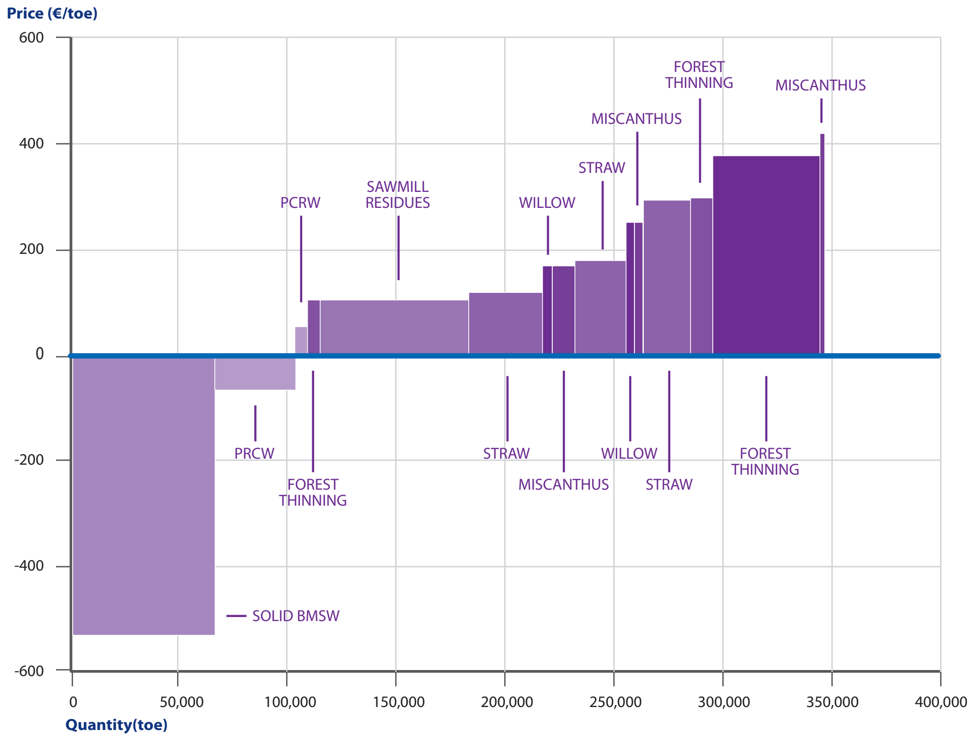
12.2 DIRECT COMBUSTION

Several resources can be burned to produce heat or steam for electricity generation. Solid biomass resources from wood, energy crops or solid biodegradable municipal solid waste (BMSW) are commonly used for these purposes. Figure 26 shows the supply curve for these resources for 2012. The curve shows how much of these resources may be available for direct combustion or transformation into wood pellets or wood chips at various market prices. The estimates do not include the cost of transportation, fuel handling or further processing.[95] A price of 430 €/toe at the resource location could bring up to 350 ktoe of biomass into production.

94 Several resources can be used to produce biofuel or biogas, or for direct combustion. E.g. straw can be used to produce biogas. Many of these processes are still in the research and development phase. The grouping of resources allows for comparison of the cost of resources commonly used in each application.

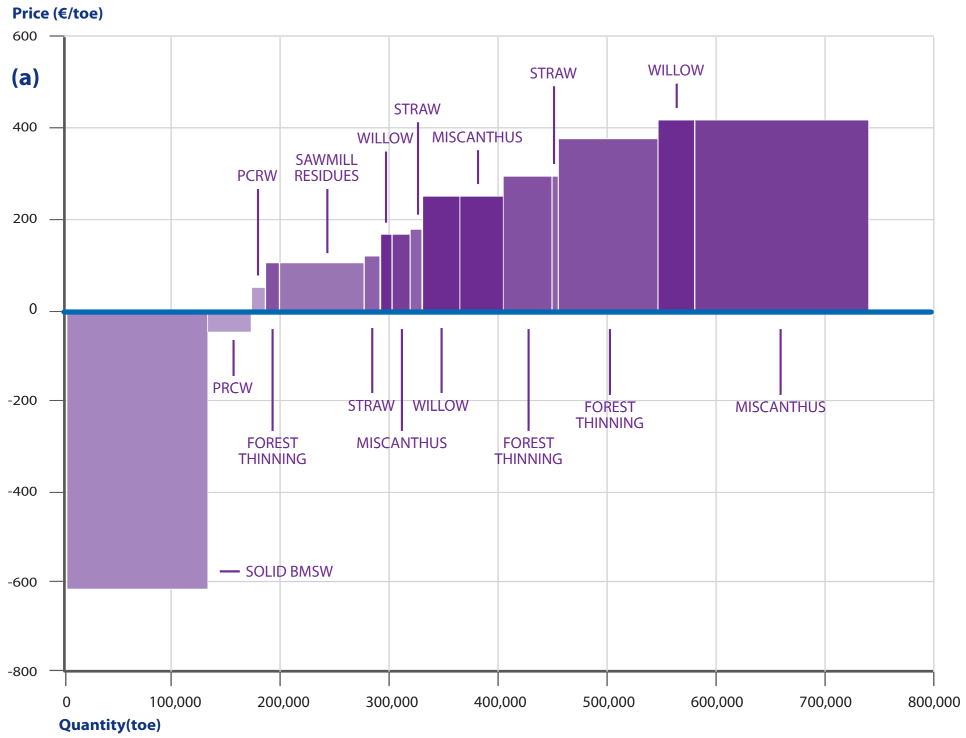
95 Transport costs are included in the BEAM model. The estimates here are at the resource location. Transport costs can be significant; the location of the resource in relation to demand points has a significant influence on the cost of producing bioenergy.

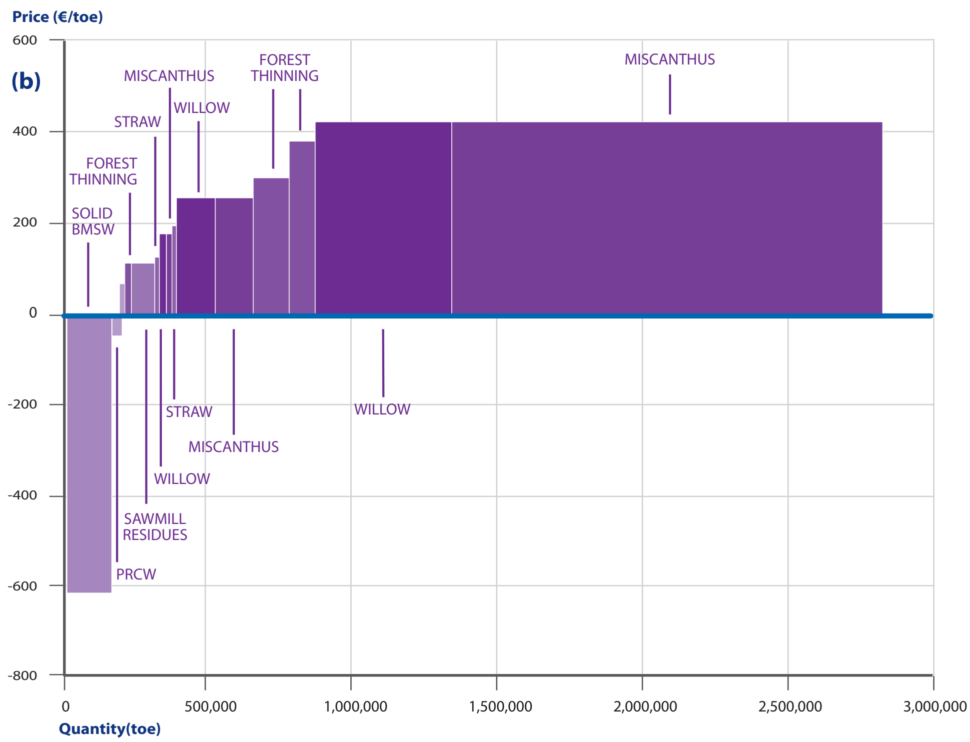
FIGURE 26: SUPPLY CURVE OF DOMESTIC RESOURCES AVAILABLE FOR DIRECT COMBUSTION, 2012



The estimates show that the total available physical resource increases across the time horizon to 2020 and 2030. This is due to the increase in activity in the forestry and wood processing sector. Energy crops also see an increase in availability at higher market prices. Higher prices will result in more farmers choosing to grow these crops and thus an increase in confidence. At the lower market prices, little expansion occurs in the physical availability of energy crops. Overall, these factors result in significant increases in the available resource at the higher market prices through 2020 to 2030. Figure 27 (a) shows the supply curve estimate for 2020 and Figure 27 (b) shows the curve for 2030.

FIGURE 27: (A) DOMESTIC RESOURCE SUPPLY CURVE (DIRECT COMBUSTION) FOR IRELAND 2020; (B) DOMESTIC RESOURCE SUPPLY CURVE (DIRECT COMBUSTION) FOR IRELAND 2030

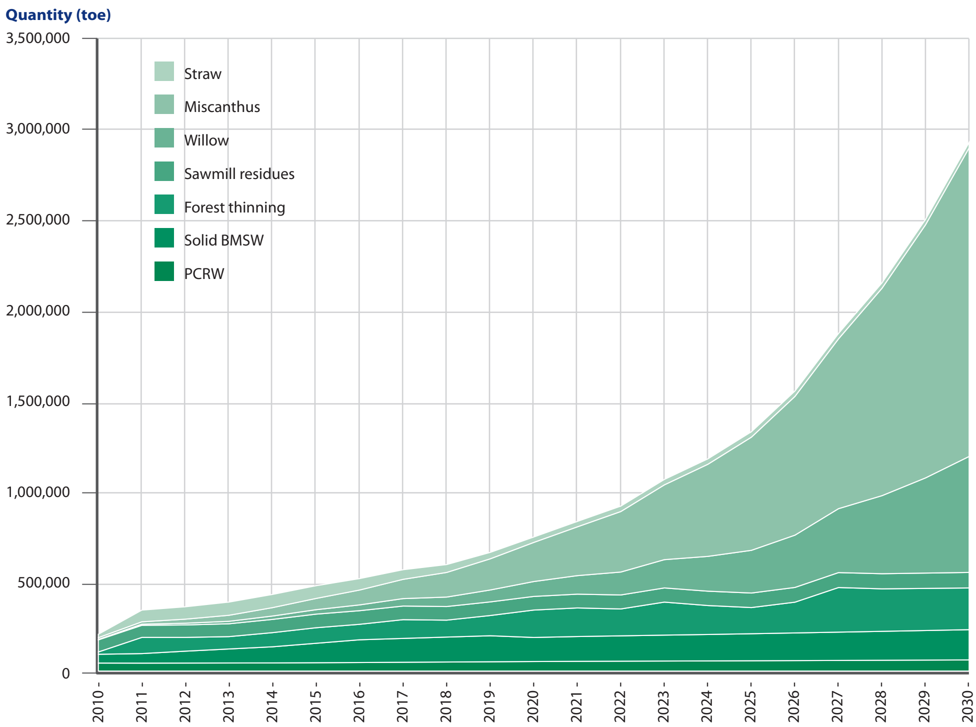




The main increase in economic potential comes from willow and miscanthus at higher market prices. These higher prices would make these crops more attractive for farmers; the estimates show that many of the current barriers could be overcome. Higher prices for bioenergy may also stimulate increased activity in forest management practices. This will result in more forest thinning being available for bioenergy.

Figure 28 shows how the total available resource for direct combustion is estimated to increase at the highest market price. Up to 3,000 ktoe could be available by 2030. Estimates from the most recent national energy forecast suggest that up to 600 ktoe of bioenergy may be needed from direct combustion to produce the heat and electricity required to meet the 2020 renewable energy targets.[96]

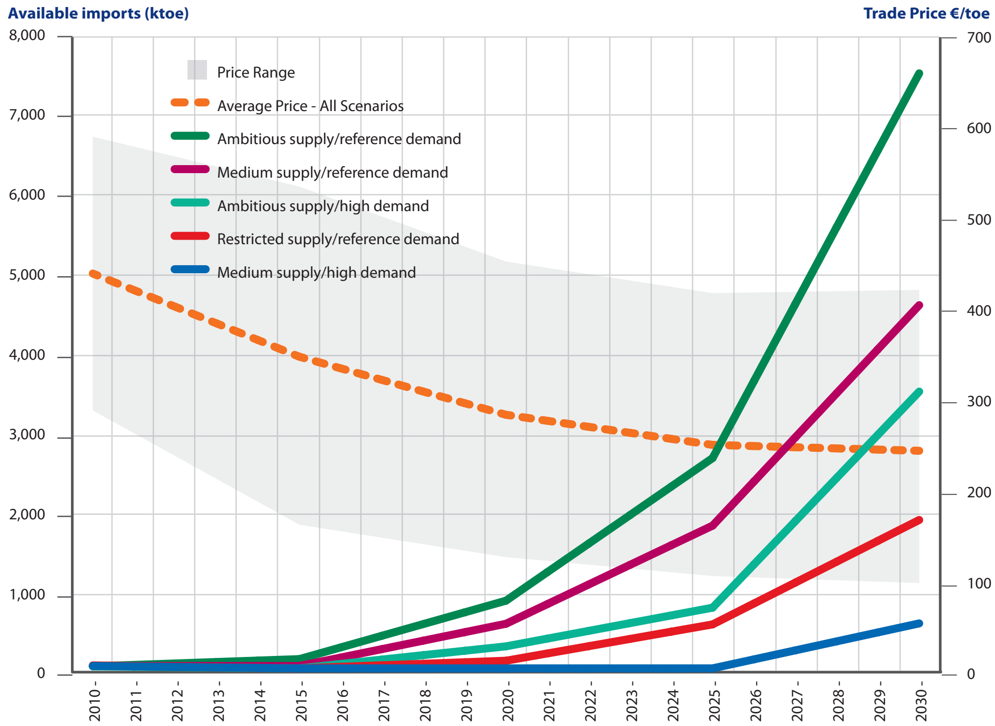
FIGURE 28: AVAILABLE DOMESTIC BIOMASS AT HIGHEST MARKET PRICE



The trade of wood chips and wood pellets will affect the amount of domestic resource that will be produced. If the international price is above the cost of resources in Ireland, these resources are likely to be processed for export. Should the international price be lower than domestic resources, wood chips and wood pellets are likely to be imported before the domestic resource is harvested. The quantity of resource available to import will also have a bearing on the amount of domestic resource that may be used. The actual demand for wood chips and pellets will be determined by the relative cost of producing energy from these resources when compared to the alternatives. Higher prices are likely to dampen demand. Figure 29 shows the outcome of the international trade analysis described in section 11.

96 SEAI (2011). Energy Forecast for Ireland to 2020 – 2011 report, SEAI 2011.

FIGURE 29: POTENTIAL WOODY BIOMASS AVAILABLE FOR IMPORT TO IRELAND AND RANGE OF INTERNATIONAL TRADE PRICE

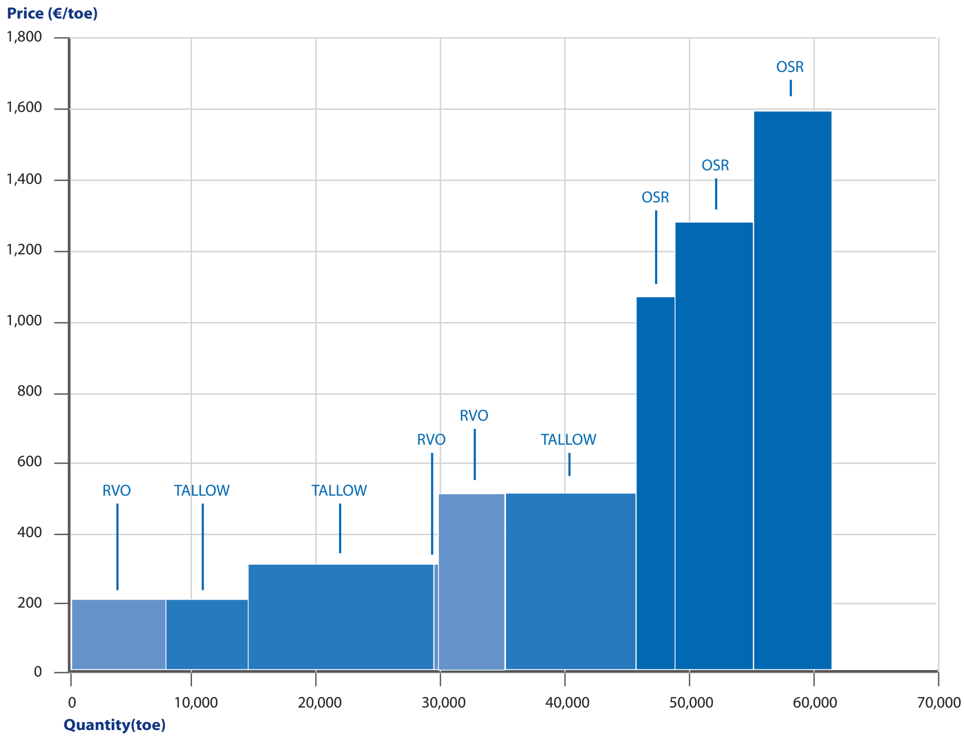


The price of wood chips and wood pellets available for import decreases across all scenarios examined over the time horizon. Quantities of biomass are available to import in 2020 in a price range between 120 €/toe and 450 €/toe and at prices between 100 €/toe and 420 €/toe in 2030. The price will affect domestic production of biomass resources in two significant ways. (1) Domestic resource that can be produced at a lower cost than the international price will be used for domestic demand, with any excess being available for export. (2) Domestic resources that cost more than the international trade price are unlikely to be harvested for bioenergy, with the exception of the scenarios where there is low availability of wood chips and pellets for import.

12.3 BIOFUEL PRODUCTION

Domestic resources commonly used for biofuel production include waste material such as tallow and RVO as well as dedicated energy crops such as OSR and wheat. These materials are refined in biodiesel or bioethanol plant to produce biofuel. International trade of biofuels is characterised by well-developed commodity markets, and trade is having an influence on production of biofuels in Ireland. Figure 30 shows the estimated 2012 supply curve for resources commonly used to produce biofuels. These costs do not include the cost of processing the resources into biofuels.

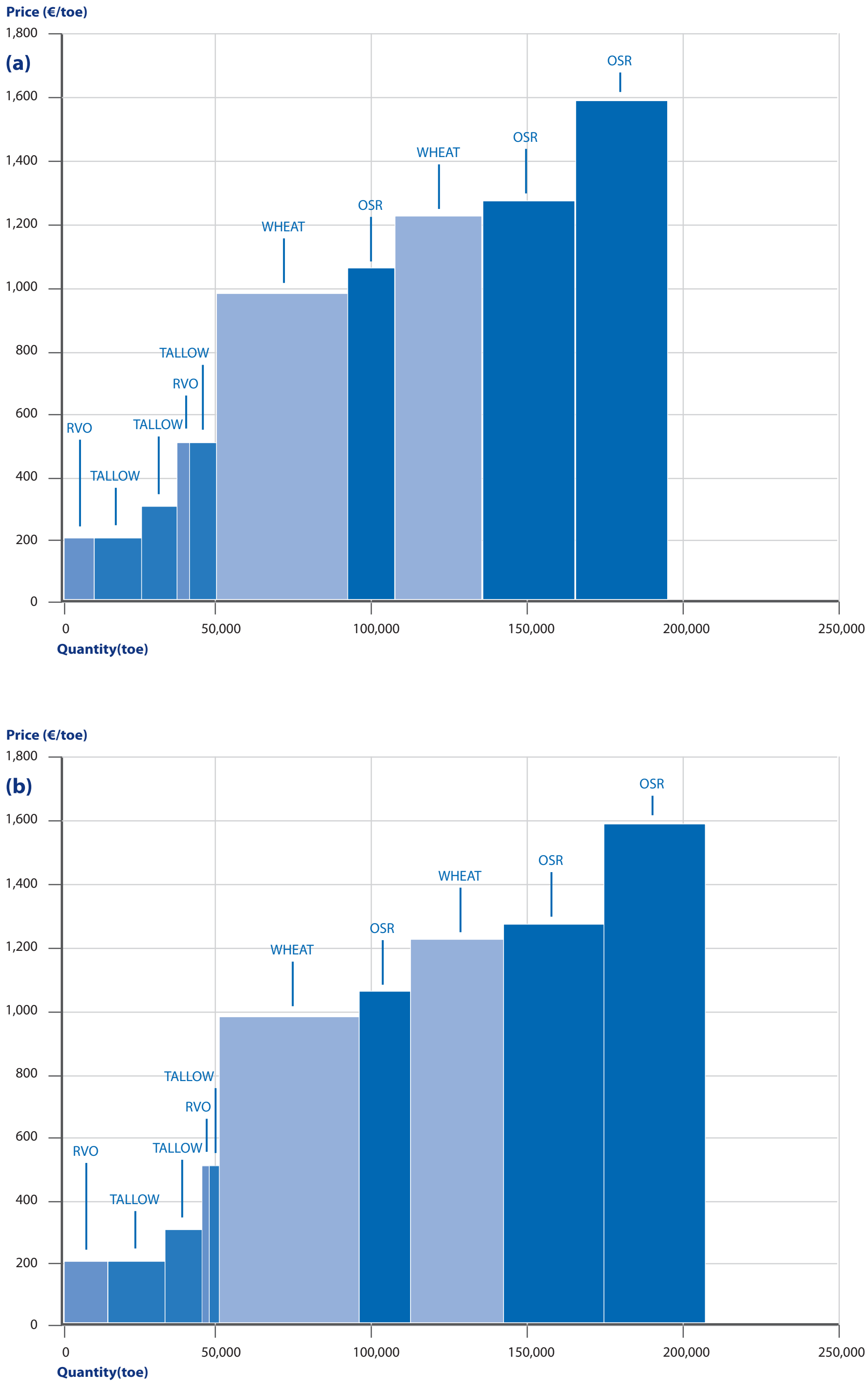
FIGURE 30: SUPPLY CURVE OF DOMESTIC RESOURCES AVAILABLE FOR BIOFUELS, 2012



The large price range reflects the differing costs associated with producing biofuels from waste/by-product material such as tallow and RVO as compared to the higher price required for the growing of dedicated energy crops. The curve shows that up to 60 ktoe of resource is currently available from domestic sources. Ireland currently uses 24 ktoe of biofuels sourced from indigenous sources from a total demand of 100 ktoe.[97] Figure 31 (a) shows the supply curve for 2020 and Figure 31 (b) shows the supply curve for 2030.

97 EPSSU(2012).EnergyInIreland1990-2012–2012report,SEAI2012.

FIGURE 31: (A) 2020 DOMESTIC RESOURCE SUPPLY CURVE (BIOFUELS) FOR IRELAND; (B) 2030 DOMESTIC RESOURCE SUPPLY CURVE (BIOFUELS) FOR IRELAND



The quantity of resources available from domestic sources increases through to 2030. Forecast estimates show that at least 345 ktoe of biofuels will be required by 2020 to meet the requirements of the renewable energy target in transport. By 2020, the estimates suggest that less than 200 ktoe of biofuels will be available from domestic resources. Figure 32 (a) shows the project quantities of biodiesel that may be available for import and the project range for the international trade price. Figure 32 (b) shows the same picture for bioethanol.

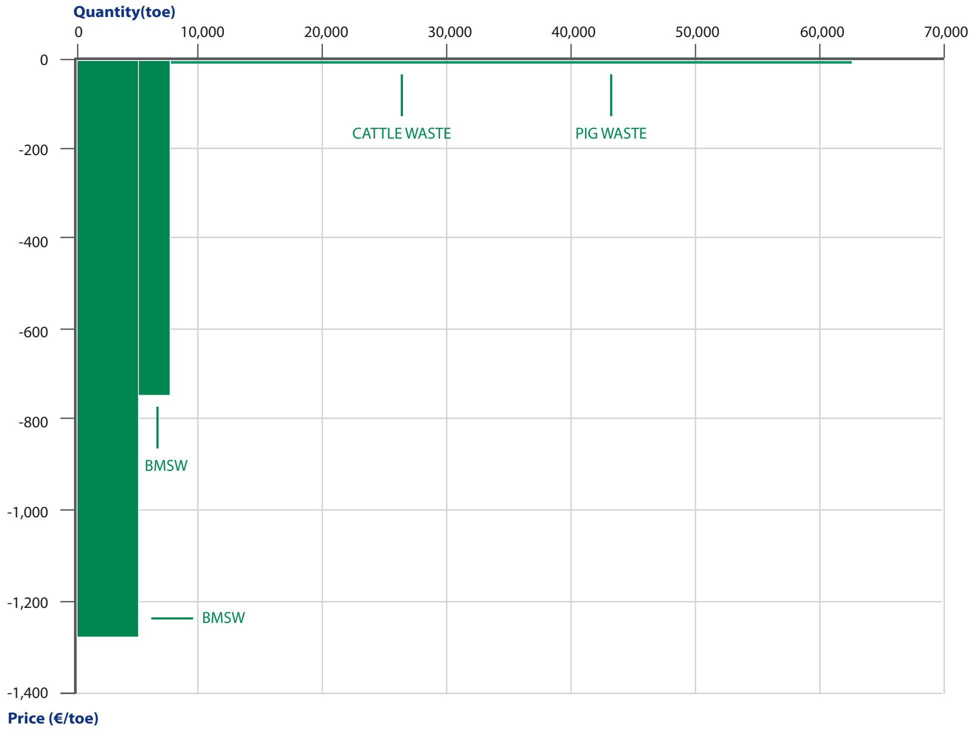
FIGURE 32: (A) AVAILABLE IMPORTS OF BIOETHANOL AND INTERNATIONAL TRADE PRICE TO 2030; (B) AVAILABLE IMPORTS OF BIODIESEL AND INTERNATIONAL TRADE PRICE TO 2030

The limited availability of biodiesel means that the shortfall between domestic supplies of biodiesel and the expected demand may not be bridged by imported biodiesel. The projections show that the situation may improve towards 2030 in most of the scenarios examined as production process adapt to the sustainability criteria and become less carbon-intensive. Bioethanol may see a higher availability of sustainably produced fuel available for import.

12.4 BIOGAS PRODUCTION

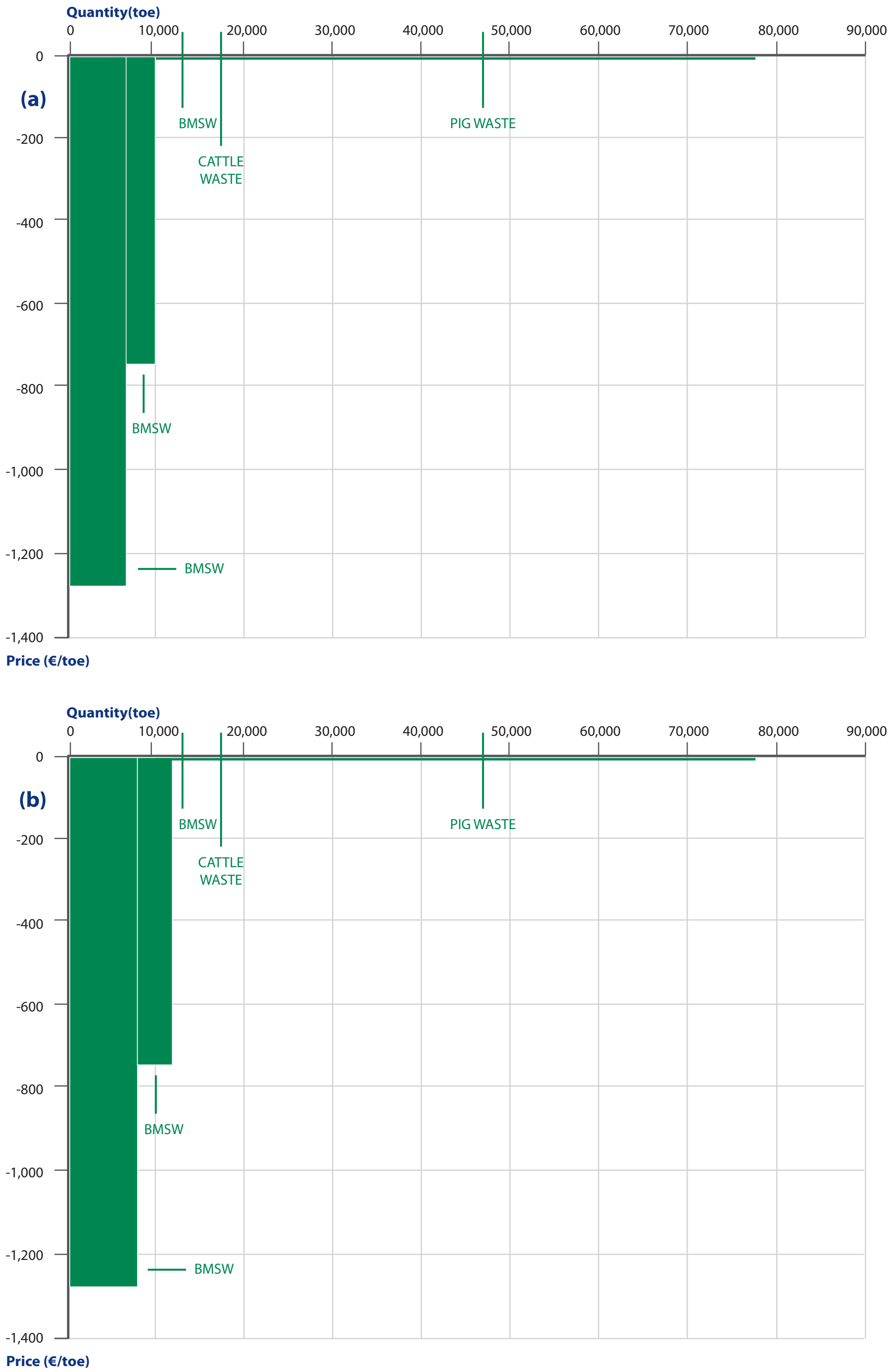
Waste materials for agricultural activities and municipal waste streams are commonly use to produce biogas in AD plant. Biogas can be burned directly to produce heat or electricity, injected into the natural gas grid or used in cars designed to run on liquefied natural gas. Figure 33 shows the 2012 supply curve for these resources.

FIGURE 33: SUPPLY CURVE OF DOMESTIC RESOURCES AVAILABLE FOR BIOGAS, 2012



As producers of waste are charged a fee to dispose of waste, these resources see a negative price. The farm-based waste materials are typically available at no cost. The analysis shows that up to 60 ktoe of bioenergy is currently available for biogas production. Figure 34 (a) shows the supply curve for 2020 and Figure 34 (b) shows the 2030 estimate.

FIGURE 34: (A) DOMESTIC RESOURCE SUPPLY CURVE (BIOGAS) FOR IRELAND 2020; (B) DOMESTIC RESOURCE SUPPLY CURVE (BIOGAS) FOR IRELAND; 2030



[98] Grass has the potential to add substantially to the potential biogas available. Current estimates suggest that a price of 850€/toe may be required to stimulate the use of grass to produce biogas. Clancy et al, 'The economic viability of biomass crops versus conventional agricultural systems and its potential impact on farm incomes in Ireland', Energy Policy, 2012.

The resource availability increases slightly, driven by the projected increase in animal numbers. The availability of BMW remains static over the period. By 2030 up to 80 ktoe of bioenergy may be available from the resources examined.[98]

12.5 SUMMARY

The above analyses together enable an assessment of how much bioenergy may be available for use in Ireland at various market prices to 2030. They also provide detailed information for incorporation into further analysis that examines all the factors that influence bioenergy use. This helps to provide evidence for targeted policy measures to help the bioenergy sector overcome the market barriers. Based on this analysis several useful insights are gained.

The analysis shows that the physical potential of domestic biomass resources available for bioenergy has the capability to grow in the years ahead. How much of the potential is actually used to produce bioenergy will depend on the future price of these resources in the energy market. The price of competing energy sources (fossil and renewable) the demand for bioenergy resources, the supporting policies and the price and availability of bioenergy in the international market will all impact on the actual future market price for bioenergy in Ireland.

Should current prices levels for bioenergy resources prevail into the future, it is likely that much of the available domestic potential will not be developed. A 50% increase in price, particularly for woody biomass resources, could see a significant increase in the quantity of domestic bioenergy resources consumed. For the resources examined, a 250% increase could see almost all of the available domestic resource potential being brought into production with the large potential for the expansion of SRC willow and miscanthus contributing most.

The majority of the available domestic resources are suitable for use in heat and electricity generation. A 50% increase in the market price is likely to bring enough resource into production to cover the requirements of the renewable energy targets in heat and electricity as estimated in the 2011 National Energy Forecast to 2020.

The availability of potential resources for transport energy is much more restricted. Even at the highest price examined, the biofuel requirements for the 2020 renewable transport target are unlikely to be met from domestic sources alone. The scenarios for the availability of biofuels in international markets show that while there is likely to be adequate quantities of bioethanol available, biodiesel supply looks set to shrink out to 2020. This is as a result of the EU sustainability criteria for biofuels which requires a reduction total life cycle emissions from biofuels of 50% when the impact of land use change, harvesting and transportation, among other factors, are considered. The trend in Ireland towards diesel use in transport means that this may have implications for how the 2020 renewable transport target is achieved.

International markets for bioenergy resources are likely to strongly influence the bioenegry market in Ireland. The analysis shows that the range of market prices for internationally traded bioenergy commodities in a number of scenarios are below the cost of production for many of the domestic resources. The quantity of these internationally traded commodities for import are limited in several scenarios. Should these scenarios arise in the future, the lower volume of imports would limit the impact of international price on the domestic market.

This analysis focuses on the supply of bioenergy resources. Further modelling that incorporates the analysis from this report with deatial on the technology costs and energy demand can help identify the most cost effective use of the available bioenergy resources across heat, electricity and transport and incorporate the impact of factors such as increasing fossil fuel prices, policy support and transport costs on bioenergy demand.

GLOSSARY

AD	Anaerobic Digestion
BAU	Business as Usual
BEAM	Bioenergy Analysis Model
BMW	Biodegradable Municipal Waste
CAP	Common Agricultural Policy
C&D	Construction and Demolition
CHP	Combined Heat and Power
COFORD	Council for Forest Research and Development
CSO	Central Statistics Office
DAFM	Department of Agriculture, Food and the Marine
DCENR	Department of Communications, Energy and Natural Resources
DM	Dry Matter
DTI	(British) Department of Trade and Industry
EC	European Commission
EPA	Environmental Protection Agency
ESRI	Economic and Social Research Institute
FAPRI	Food and Agricultural Policy Research Institute
GHG	Greenhouse Gas
GJ	Giga Joule
IEA	International Energy Agency
ISus	Sustainable Development Model for Ireland
Ktoe	Kilo Tonnes of Oil Equivalent (i.e. a thousand tonnes of oil equivalent)
MDF	Medium Density Fibreboard
MSW	Municipal Solid Waste
NCV	Net Calorific Value
odt	Oven Dried Tonne
OSR	Oil Seed Rape
RED	Renewable Energy Directive
ROI	Republic of Ireland
RVO	Recycled Vegetable Oil
SEAI	Sustainable Energy Authority of Ireland (previously SEI)
SRC	Short Rotation Coppice
t	Tonne (metric)
toe	Tonne of Oil Equivalent
Teagasc	The Irish Agriculture and Food Development Authority
UCO	Used Cooking Oil
VS	Volatile Solids
WtE	Waste to Energy

APPENDIX 1
DOMESTIC BIOENERGY RESOURCE DESCRIPTION

TABLE A. 1: BIOENERGY RESOURCES AND TYPICAL USES

RESOURCE	SOURCE	BIOENERGY USE
Forest thinnings	Small roundwood which is removed from the forest to thin plantations, allowing larger diameter trees to flourish (i.e. thinnings), and smaller-size material which is produced when the forest is finally harvested and is unsuitable for use as sawlogs.	Wood can be burnt to produce heat and/or power. Forest residues and waste wood are typically chipped before use. Wood chips may be further processed into pellets, which are a drier more, energy dense form of fuel, that are easier to handle and transport.
Sawmill residues	Wood chips, sawdust and bark produced when harvested timber is processed in a sawmill to produce lumber of a specific size.	
Waste wood	Wood extracted from the waste stream including wood collected from kerbside waste collections or civic amenity sites, wood used in commercial packaging, and wood from construction and demolition.	
Short rotation coppice (willow) and miscanthus	Woody energy crops planted specifically for energy purposes; miscanthus is a perennial energy crop which is harvested annually; willow is typically harvested every 4 years.	Willow can be chipped and burnt to produce heat and/or electricity. It is more suitable for small-scale heating plants and existing power plants in Ireland than miscanthus which is suitable for combustion in purpose-designed plant.
Straw	By-product of cereal production.	Straw can be combusted to produce electricity and/or heat. Typically straw is chopped or shredded before combustion in purpose-built plant, although it can be pelletised to allow cofiring in existing power plant.
Wheat	Arable crop planted specifically as a feedstock for the production of bioethanol.	Bioethanol can replace petrol (in blends of up to about 10%) or can be used at higher concentrations in specially designed vehicles.
Oil seed rape (OSR)	Arable crop planted specifically as a feedstock for the production of biodiesel.	Biodiesel can replace conventional diesel in transport applications. It can also be used a fuel for combustion.

RESOURCE	SOURCE	BIOENERGY USE
Pig and cattle manure	Pig and cattle slurry can be anaerobically digested to produce a methane-rich biogas.	Biogas can be used to generate heat and/or power or upgraded to biomethane for use as vehicle fuel or injection to the gas grid.
Food and garden waste	Food and garden waste from households and the commercial sector which is collected separately can be anaerobically digested to produce a methane-rich biogas.	Biogas can be used to generate heat and/or power or upgraded to biomethane for use as vehicle fuel or injection to the gas grid.
Biological component of solid waste	The biological component of residual municipal and commercial waste, i.e. waste that is collected after dry recyclables and food waste have been collected separately; typically composed of paper, card, textiles, timber, food waste and parks and garden waste.	Residual waste can be combusted in a dedicated waste-to-energy plant, equipped with suitable emission abatement equipment.
Tallow	Tallow is a by-product of meat processing, produced when offal and carcass/butchers wastes are processed at rendering plants.	Tallow can be used as a heating fuel, often in the rendering sector, or as a feedstock for the production of biodiesel.
Recycled vegetable oil (RVO)	Used cooking oil e.g. from food factories or catering premises, which is collected and then filtered.	Filtered RVO can be used as a feedstock for the production of biodiesel.

APPENDIX 2
DOMESTIC BIOENERGY RESOURCE

TABLE A. 2: SUPPLY CURVE DATA BY RESOURCE

RESOURCE	ATTRIBUTE	2010	2015	2020	2025	2030
Forest thinnings - Lo	Maximum quantity (toe/y)	768	5,206	14,333	12,684	18,821
Forest thinnings - Lo	Cost of resource (€/toe)	105	105	105	105	105
Forest thinnings - Me	Maximum quantity (toe/y)	6,533	23,735	44,828	60,227	117,608
Forest thinnings - Me	Cost of resource (€/toe)	293	293	293	293	293
Forest thinnings - Hi	Maximum quantity (toe/y)	5,388	56,743	91,987	71,261	93,467
Forest thinnings - Hi	Cost of resource (€/toe)	377	377	377	377	377
Sawmill residues - Lo	Maximum quantity (toe/y)	66,581	75,064	75,064	80,178	85,599
Sawmill residues - Lo	Cost of resource (€/toe)	105	105	105	105	105
PCRW - Lo	Maximum quantity (toe/y)	37,484	39,114	37,325	32,255	26,345
PCRW - Lo	Cost of resource (€/toe)	-47	-47	-47	-47	-47
PCRW - Me	Maximum quantity (toe/y)	0	0	7,465	16,127	26,345
PCRW - Me	Cost of resource (€/toe)	0	0	0	0	0
PCRW - Hi	Maximum quantity (toe/y)	6,615	6,902	7,904	8,538	9,298
PCRW - Hi	Cost of resource (€/toe)	47	47	47	47	47
Solid BMSW - Lo	Maximum quantity (toe/y)	0	107,132	132,534	149,008	166,752
Solid BMSW - Lo	Cost of resource (€/toe)	-610	-610	-610	-610	-610
Solid BMSW - Me	Maximum quantity (toe/y)	0	0	0	0	0
Solid BMSW - Me	Cost of resource (€/toe)	-510	-510	-510	-510	-510
Solid BMSW - Hi	Maximum quantity (toe/y)	48,522	0	0	0	0
Solid BMSW - Hi	Cost of resource (€/toe)	-370	-370	-370	-370	-370
Tallow - Lo	Maximum quantity (toe/y)	5,036	9,449	15,312	17,448	19,585
Tallow - Lo	Cost of resource (€/toe)	201	201	201	201	201
Tallow - Me	Maximum quantity (toe/y)	16,785	13,359	11,395	11,929	12,463
Tallow - Me	Cost of resource (€/toe)	301	301	301	301	301
Tallow - Hi	Maximum quantity (toe/y)	11,750	9,775	8,902	6,231	3,561
Tallow - Hi	Cost of resource (€/toe)	502	502	502	502	502
RVO - Lo	Maximum quantity (toe/y)	8,441	9,095	9,896	10,391	10,860
RVO - Lo	Cost of resource (€/toe)	201	201	201	201	201
RVO - Me	Maximum quantity (toe/y)	444	225	0	1,153	2,353
RVO - Me	Cost of resource (€/toe)	301	301	301	301	301
RVO - Hi	Maximum quantity (toe/y)	4,443	4,178	3,958	2,649	1,267
RVO - Hi	Cost of resource (€/toe)	502	502	502	502	502
Straw -w Lo	Maximum quantity (toe/y)	9,414	35,054	14,962	14,962	14,962
Straw - Lo	Cost of resource (€/toe)	118	118	118	118	118

RESOURCE	ATTRIBUTE	2010	2015	2020	2025	2030
Straw - Me	Maximum quantity (toe/y)	6,590	24,538	10,474	10,474	10,474
Straw - Me	Cost of resource (€/toe)	177	177	177	177	177
Straw - Hi	Maximum quantity (toe/y)	2,824	10,516	4,489	4,489	4,489
Straw - Hi	Cost of resource (€/toe)	296	296	296	296	296
Cattle waste - Lo	Maximum quantity (toe/y)	11,216	10,469	11,765	11,765	11,765
Cattle waste - Lo	Cost of resource (€/toe)	0	0	0	0	0
Pig waste - Lo	Maximum quantity (toe/y)	38,835	44,791	54,731	54,731	54,731
Pig waste - Lo	Cost of resource (€/toe)	0	0	0	0	0
BMSW - Lo	Maximum quantity (toe/y)	3,097	6,072	7,495	8,124	8,806
BMSW - Lo	Cost of resource (€/toe)	-1,270	-1,270	-1,270	-1,270	-1,270
BMSW - Me	Maximum quantity (toe/y)	1,549	3,036	3,747	4,062	4,403
BMSW - Me	Cost of resource (€/toe)	-730	-730	-730	-730	-730
BMSW - Hi	Maximum quantity (toe/y)	1,549	3,036	3,747	4,062	4,403
BMSW - Hi	Cost of resource (€/toe)	0	0	0	0	0
Willow - Lo	Maximum quantity (toe/y)	2,455	6,748	12,039	17,934	24,435
Willow - Lo	Cost of resource (€/toe)	167	167	167	167	167
Willow - Me	Maximum quantity (toe/y)	0	12,621	35,988	73,877	133,340
Willow - Me	Cost of resource (€/toe)	251	251	251	251	251
Willow - Hi	Maximum quantity (toe/y)	0	5,059	34,051	143,508	481,614
Willow - Hi	Cost of resource (€/toe)	419	419	419	419	419
Miscanthus - Lo	Maximum quantity (toe/y)	9,811	12,393	16,124	20,218	24,674
Miscanthus - Lo	Cost of resource (€/toe)	167	167	167	167	167
Miscanthus - Me	Maximum quantity (toe/y)	0	14,073	39,474	79,637	141,617
Miscanthus - Me	Cost of resource (€/toe)	251	251	251	251	251
Miscanthus - Hi	Maximum quantity (toe/y)	0	35,509	159,900	524,075	1,534,945
Miscanthus - Hi	Cost of resource (€/toe)	419	419	419	419	419
Wheat - Lo	Maximum quantity (toe/y)	0	0	0	0	0
Wheat - Lo	Cost of resource (€/toe)	814	814	814	814	814
Wheat - Me	Maximum quantity (toe/y)	0	30,062	42,273	43,768	45,262
Wheat - Me	Cost of resource (€/toe)	977	977	977	977	977
Wheat - Hi	Maximum quantity (toe/y)	0	20,041	28,182	29,179	30,175
Wheat - Hi	Cost of resource (€/toe)	1,221	1,221	1,221	1,221	1,221
OSR - Lo	Maximum quantity (toe/y)	0	11,791	14,997	15,607	16,241
OSR - Lo	Cost of resource (€/toe)	1,058	1,058	1,058	1,058	1,058
OSR - Me	Maximum quantity (toe/y)	0	23,583	29,995	31,214	32,483
OSR - Me	Cost of resource (€/toe)	1,270	1,270	1,270	1,270	1,270
OSR - Hi	Maximum quantity (toe/y)	0	23,583	29,995	31,214	32,483
OSR - Hi	Cost of resource (€/toe)	1,587	1,587	1,587	1,587	1,587

APPENDIX 3
POTENTIAL IMPORTS OF BIOENERGY

The following tables refer to potential import scenarios for bioenergy to Ireland, as described in Section 11.

TABLE A. 3: RESTRICTED SUPPLY/REFERENCE DEMAND

	UNIT	2010	2015	2020	2025	2030
Wood chips	toe	9,358	0	24,163	139,233	470,124
Wood chips	€/toe	288	162	126	106	98
Wood pellets	toe	28,075	0	72,490	417,699	141,0371
Wood pellets	€/toe	590	385	300	251	232
Bioethanol	toe	535,616	310,101	6,531	43,493	130,927
Bioethanol	€/toe	779	740	693	630	577
Biodiesel	toe	106,129	757,25	0	0	0
Biodiesel	€/toe	1,209	1,276	1,312	1,218	1,156

TABLE A. 4: MEDIUM SUPPLY/REFERENCE DEMAND

	UNIT	2010	2015	2020	2025	2030
Wood chips	toe	7,640	7,551	141,276	452,161	115,0679
Wood chips	€/toe	288	218	174	149	142
Wood pellets	toe	22,921	22,653	423,827	1,356,482	3,452,038
Wood pellets	€/toe	590	446	356	305	291
Bioethanol	toe	781,304	791,507	441,100	807,242	1,351,788
Bioethanol	€/toe	779	761	736	695	665
Biodiesel	toe	101,544	112,421	0	0	92,339
Biodiesel	€/toe	1,209	1,313	1,389	1,334	1,312

TABLE A. 5: AMBITIOUS SUPPLY/REFERENCE DEMAND

	UNIT	2010	2015	2020	2025	2030
Wood chips	toe	6,382	29,323	214,410	666,226	1,885,232
Wood chips	€/toe	288	257	211	187	183
Wood pellets	toe	191,47	87,968	643,231	1,998,677	5,655,695
Wood pellets	€/toe	590	514	423	374	367
Bioethanol	toe	779,549	795,568	452,796	823,157	1,376,225
Bioethanol	€/toe	779	792	799	792	801
Biodiesel	toe	101,448	117,598	0	0	104,602
Biodiesel	€/toe	1,209	1,367	1,500	1,506	1,550

TABLE A. 4: 6: MEDIUM SUPPLY/HIGH DEMAND

	UNIT	2010	2015	2020	2025	2030
Wood chips	toe	7,640	0	0	0	142,382
Wood chips	€/toe	288	226	185	165	162
Wood pellets	toe	22,921	0	0	0	427,146
Wood pellets	€/toe	590	462	379	338	331
Bioethanol	toe	781,304	788,018	409,398	734,123	1,404,121
Bioethanol	€/toe	779	824	866	911	986
Biodiesel	toe	101,544	112,987	0	0	109,936
Biodiesel	€/toe	1,209	1,420	1,605	1,694	1,832

TABLE A. 7: AMBITIOUS SUPPLY/HIGH DEMAND

	UNIT	2010	2015	2020	2025	2030
Wood chips	toe	6,382	0	69,709	192,223	876,934
Wood chips	€/toe	288	267	226	209	211
Wood pellets	toe	191,47	0	209,128	576,669	2,630,803
Wood pellets	€/toe	590	535	452	418	421
Bioethanol	toe	779,549	792,079	421,094	750,039	1,428,558
Bioethanol	€/toe	779	864	951	1054	1204
Biodiesel	toe	101,448	118,165	0	0	122,199
Biodiesel	€/toe	1,209	1,488	1,755	1,948	2,212

APPENDIX 4
COMPARISON OF WOOD SUPPLY ESTIMATES

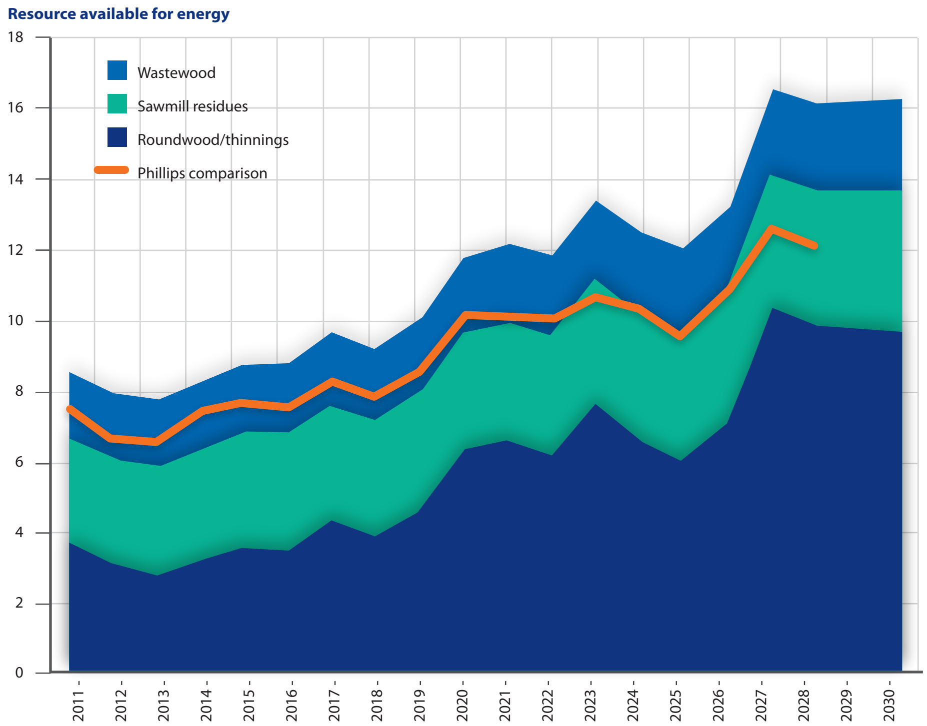
Figure A. 1 compares the estimates made in this study of the wood resource available for bioenergy with an estimate made by Phillips (2011) in the All-Ireland Roundwood Production Forecast 2011-2028.

In this study the combined availability of resource available for energy – i.e. from forestry thinnings and downgrades, forestry residues, sawmill residues and waste wood – increases from just over 8 PJ in 2011 to 16 PJ in 2016. This increase is largely determined by the availability of roundwood and thinnings, which increase significantly over the period 2020-2030. This change is driven by the All-Ireland Roundwood Production Forecast where the volumes of sawlog class timber being processed increases towards 2030. Consequently the volume of roundwood downgrades increases and makes up a greater proportion of the roundwood for energy resource, rising from just over 25% to 43% by 2030.

The comparison with Phillips (2011) shows that the AEA estimates are in the same order of magnitude but generally around 20% higher. Potential reasons for this difference include:

- Waste wood availability: The AEA estimate includes waste wood collected from poorer-quality waste streams (e.g. construction and demolition). It is not clear whether the potential resource in this lower-grade wood is included in the Phillips estimate, which assumes little increase in waste wood availability with time, and is significantly lower than the AEA estimate.
- Higher volume of sawmill residues, based on 2010 data. This study assumes that 52.5% of the sawlog volume processed ended up as sawmill residues; this is slightly higher than the 50% assumed by Phillips (2011). After 2020 as the volume of sawlogs processed rises, this increases the availability of sawmill residues.

FIGURE A. 1: COMPARISON OF ESTIMATES OF WOOD BIOENERGY RESOURCE



APPENDIX 5
AGRICULTURAL PROJECTIONS

TABLE A. 8: AGRICULTURAL PROJECTIONS BASED ON FOOD HARVEST 2020 (SOURCE TEAGASC)

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Dairy Cows	000 head	1,022	1,027	1,044	1,036	1,035	1,032	1,106	1,172	1,224	1,264	1,293
All Other Cattle	000 head	5,209	4,891	4,783	4,629	4,561	4,543	4,505	4,533	4,571	4,580	4,551
Sheep	000 head	4,695	4,605	4,890	5,231	5,168	5,105	5,108	5,102	5,089	5,081	5,077
Pigs	000 head	1,500	1,502	1,527	1,588	1,658	1,731	1,805	1,880	1,957	2,035	2,115
Poultry	000 head	16,248	15,742	15,374	15,177	15,164	15,322	15,541	15,813	16,149	16,539	17,158
Wheat Area	000 ha	77.8	95.3	97.8	98.5	99.3	100	100.2	100.2	100	99.5	98.9
Barley Area	000 ha	174.8	179.8	177	174	170.8	167.3	163.3	159.3	155.4	151.7	148.1
Oats Area	000 ha	19.7	21	20.7	20.3	20	19.7	19.4	19.1	18.7	18.4	18.1

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