Transport Sector in Ireland: Can 2020 National Policy Targets Drive Indigenous Biofuel Production to Success?

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Abstract:

Ireland's transport sector consumes just slightly less than one third of all energy in Ireland and is heavily dependent on oil imports, especially diesel. The European Union has set targets that are to be met by 2020, in order to guarantee a sustainable future for Europe and assure security of energy supply. There is an increase of biofuel usage in the transport sector, to reduce GHG emissions and encourage indigenous production of renewable sources. Currently Ireland has only two licensed suppliers of biodiesel. The Irish government has issued a number of policy support mechanisms, and while that has increased the use of biofuels in Ireland, it has not necessarily aided the domestic suppliers of biofuels. The aim of this paper is to detail the existing policies and support mechanisms in Ireland and to examine whether it is possible for Ireland to produce biofuels indigenously while meeting the 2020 targets and competing with the alternative conventional imports. Alternatives to the current supply scenario will be considered, including alternatives such as electric vehicles, RVO and grass gasification for bio-methane for natural gas vehicles.

Keywords – transport sector, biodiesel, bioethanol, national targets 2020, alternative fuels, Ireland.

1 Introduction

Biofuels are renewable fuels produced from biomass. They produce fewer emissions than the conventional fossil fuels and can be subdivided into three groups: biodiesel, bioethanol and pure plant oil (PPO). Biofuels, a renewable source of fuel, have received much attention in the last decade due to the rise in oil prices, the increase in greenhouse gas (GHG) emissions from fossil fuels and the need for security of energy supply produced in a sustainable and competitive manner. In Ireland in 2009 biofuels were mostly imported rather than produced indigenously [1].

1.1 Transport sector in Ireland

Transport is the fastest growing sector in Ireland, in terms of primary energy demand and carbon dioxide emissions (CO_2) [2]. In 2007, transport accounted for 43% of final energy demand and 36% (17,014 kt CO_2) of Ireland's energy-related CO_2 emissions (higher than any other sector).

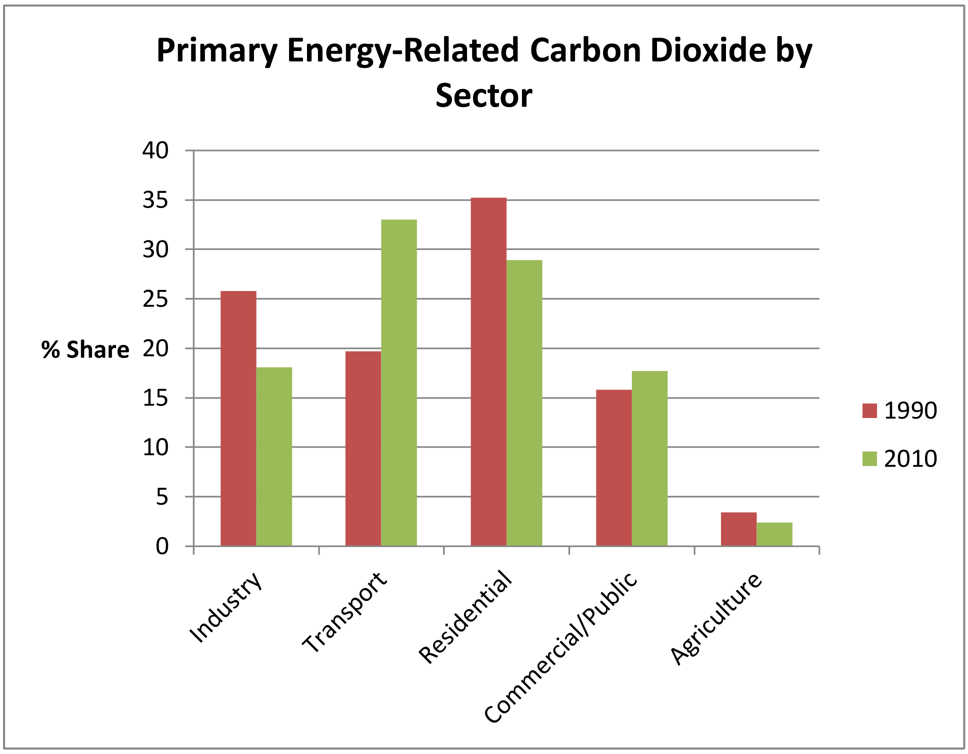

Figure 1 - Primary Energy-Related Carbon Dioxide by Sector [3].

Figure 1 illustrates the primary energy demand and carbon dioxide emissions by sector from 1990 to 2010. While almost all sectors have experienced a decline, the increase in the transport sector is significant. From 1990 to 2010, the average growth of energy use in transport sector is 4.3% per annum, which totals to 132% over the twenty years [3]. Overall the transport sector consumes slightly less than one third of all energy in Ireland [3].

The transport sector is entirely depended on oil imports. In 2008, 89% of Ireland's energy was imported; in comparison only 55% of energy was imported in the EU as a whole [1]. The fact that Ireland's energy imports have remained at around 90% since 2001 [1], has serious implications for the security of energy supply. In 2009 oil accounted for 60% of total energy imports representing the 5th highest in the EU in 2009 [1]. Ireland therefore must look to indigenous alternative renewable fuels if it is to reduce its import energy dependency.

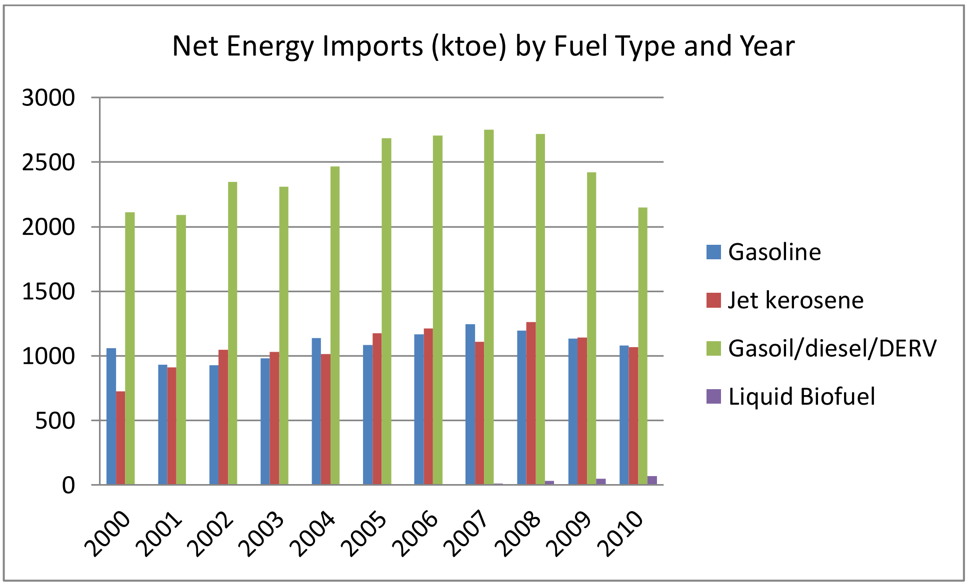

Figure 2 - Fuel Imports (2000 -2010) [4]

Figure 2 demonstrates Ireland's dependency on imports, especially diesel. Imports have decreased since 2008, nevertheless this is mostly due to the decrease in the economic activity rather than a reduced dependency on imports.

Thus policy implementations and mechanisms are necessary in the transport sector if Ireland is to reach its 2020 EU targets, and guarantee security of energy supply and a competitive and sustainable energy in the future.

Transport final energy demand for 2020 is 5,375 ktoe [5]. Achieving the biofuels target would require 345 ktoe by 2020 (14.4 PJ).

2 Policy

2.1 EU directives

In 2007, the European Union agreed new climate and energy targets- 20-20-20 by 2020 – 20% reduction in greenhouse gas emissions; 20% increase in energy efficiency and 20% of the EU's energy consumption to be from renewable sources by 2020. The European Union supports the use of biofuels through two main directives: The directive on the promotion of the use of biofuels and other renewable fuels for transport or biofuels directive (2003/30/EC) [6] and the Renewable Energy Directive (2009/28/EC) [7].

2.1.1 The Biofuels Directive

The Biofuels directive 2003/30/EC entered into force in May 2003 and is primarily concerned with the promotion of the use of biofuels in the transport sector. Each member state was required to replace 5.75% of all transport fossil fuels with biofuels by 2010. The directive also set an intermediate target of 2% by December 2008. The Irish Government White Paper committed to achieving the 5.75% of road and rail transport energy from renewable sources by 2010 [8] but this was later revised to 3% [9]. This was replaced with Directive 2009/28/EC detailing targets of 10% by 2020 for every member EU state [3].

2.1.2 The Renewable Energy Directive (RED)

The European Union has committed to reduce greenhouse gas emissions under the Kyoto Protocol [10]. In order to reach the 8% binding target on 1990 levels between 2008 and 2012 and to develop a sustainable energy plan for Europe, a renewables directive came into force in 2009, the Fuel Quality Directive 2009/30/EC. This directive outlines targets to be achieved by 2020; 20% of total energy to come from renewable sources, a 20% reduction in GHG emissions and a 20% increase in energy efficiency [11]. Each member state was assigned specific targets in order to achieve the overall target. Ireland's target is set at 16% by 2020 [7]. A 10% target is set for all member states to be achieved in the transport sector from renewable sources [7]. Due to concerns regarding food security and land use change, the European Commission has decided to limit the contribution of food-based biofuels to 5% of the overall transport target [12]. Any fuel above this target must not be based on food crops. The fuel quality directive also outlines sustainability criteria for biofuels that monitor how and where they are produced. All biofuels must achieve at least 35% GHG emissions reduction from 2013 in comparison to conventional fossil fuels. This figure rises to 50% in 2017, and further to 60% for biofuels produced in installations in which production started on or after January 2017 [7].

2.2 National Policies and Support Mechanisms

The government first outlined its commitment to reaching the 2020 targets in the Government White Paper on Energy in 2007 . It set national targets, in line with the EU targets, committing to a 20% target to be achieved across the electricity, heat and transport energy sectors by 2020. In the transport sector renewables would account for 5.75% of all road transport by 2010 and 10% by 2020. The National Climate Change Strategy 2007 to 2012, detail further measures in which Ireland would meet its Kyoto commitments and enable Ireland to meet the 2020 targets [13] . A National Biofuels Obligation was set at 5% by 2010 for all fuel suppliers . However, in 2008 it was lowered to 4% by 2010 due to concerns with the impact of biofuels on food prices [1]. According to the NORA statistics, only 2.2% target was met in 2010. The fuel blend reached 2.87% for biodiesel in motor fuel and 3.42% for bioethanol in petrol for 2012 [14].

The Irish government outlined its commitment to sustainable energy production in the publications mentioned above and it introduced various policy support schemes and mechanisms.

2.2.1 Mineral Oil Tax Relief Scheme (MOTR)

The Mineral Oil Tax Relief Scheme (MOTR) was a pilot scheme introduced in 2005 and granted motor tax relief to approved biofuel suppliers. It developed into a more substantial scheme in 2006 that ran until 2010. It was designed to incept a national biofuels industry by offering tax incentives whereby producers could sell the biofuels without excise duty, thus making it cheaper than the conventional fossil fuel alternative. This was mostly targeted towards captive transport fleets that used their own fuel tanks on site or in the truck or bus depots. The total excise derogation would stand to the cost the tax payer €205 million. MOTR II was introduced in 2006 and ran until 2010. As a scheme it failed to reach the desired results and outcome as; 1) Only 16 companies were granted a place in the scheme,

2) Many companies did not have facilities that were required to produce biofuels, thus although they were under the scheme, they did not produce anything; 3) changing market conditions and the availability of cheaper imported alternatives made it difficult to compete in the commercial market [15]. The uptake of MOTR II was slow, with less than 28% of the relief used by the end of 2009 [15]. Although this scheme was always going to be temporary, and the sector would have had to survive on its own in the commercial market, without the exemption from the excise duty, producing biofuel at competitive market prices is proving difficult.

2.2.2 Biofuels Obligation Scheme 2010

In 2010 when MOTR II scheme ended, the Biofuels Obligation Scheme was introduced. A subsidy scheme was replaced by an obligation scheme, under which all road transport fuel suppliers are obliged to use biofuel in the fuel mix (4 litres of biofuel in every 100 litres of transport fuel) to ensure that a certain percentage is represented in the annual sales [15, 16]. The scheme is administered by the National Oil Reserve Administration (NORA) and began on July 1st 2010. The starting penetration rate is 4% per annum and will be increased over time [15, 16]. Under the BOS scheme, a fuel supplier must apply to NORA (National Oil Reserves Agency) for a cert every time it puts 1 litre of biofuel on the market. The certs are totalled at the end of the year and if the supplier has put enough biofuel on the market then the certs will testify this. If not, then the fuel supplier must either buy certs from a surplus fuel supplier or either pay a buy-out levy for approximately 45 cent/litre. The share of transport energy from biofuels has increased from 1 ktoe in 2005 (0.03%) to 92 ktoe in 2010 (2.4% in energy terms) [3]. While this scheme has so far increased the use of biofuels, it has not necessarily increased the production of indigenous biofuels as pre-blended fuels are imported at more competitive prices. Overall the scheme has resulted in major fuel companies bypassing smaller indigenous producers. Furthermore, the value of the biofuel certs issued to biofuel producers cannot be determined until the end of the year [17].

2.2.3 Vehicle registration and annual motor tax change

Under the Kyoto Protocol, Ireland is legally bound to meet its set target of 13% reduction in GHG emissions above 1990 levels in the period 2008 to 2012 [3]. Transport is the largest CO2 emitting sector. In 2010 CO2 emissions were 129% higher than in 1990 (4.2% average annual growth rate), falling for the first time in 2008 by 1.8%. In the 2008 Budget it was announced that the vehicle registration (VRT) and annual motor tax (AMT) systems would base the tax rates on the specific CO_2 emissions (CO_2 grams per kilometre – g/km) rather than engine size. This incentive came into effect in July 2008 and is aimed at encouraging the consumer to purchase more fuel efficient vehicles with lower GHG emissions [3]. Of the 86 932 new private cars licensed in 2011, 23 246 (27%) were petrol based while 61 730 (71%) were diesel. Prior to the change in this tax based system in 2008, the trend for petrol cars was always higher than diesel. In 2008, 92 298 petrol cars and 50 560 diesel cars were newly licensed. This began to swap around from 2009 onwards when the trend was 22 802 petrol cars and 30 645 diesel in 2009. In 2010, the figures were 27 124 petrol cars and 53 998 diesel cars [18].

2.2.4 The National Renewable Energy Action Plan 2010

The government published the National Renewable Energy Action Alan (NREAP) in 2010 in accordance with the requirements of the EU directive 2009/28/EC. It sets out the strategic approach measures that will be used to meet Ireland's 16% energy target of renewables by 2020. In reference to transport the Government plans to reduce the dependency on oil imports by increasing the use of biofuels and the use of electric vehicles [16].

2.3 Policy constraints

2.3.1 EU Sustainability criteria

The increased use of biomass for biofuel production has led to concerns regarding the sustainability of this practice. Concerns surround the methods of cultivating and producing biofuels, particularly in regard to actual greenhouse gas emissions reductions in comparison with fossil fuels, and in concerns with land use change due to increased demand for arable land for biomass production. In order to ensure the sustainability of biofuel used to achieve the targets in the EU, the European Commission proposed a set of sustainability criteria in the Directive 2009/28/EC on the promotion of the use of energy from renewable sources. The sustainability criteria consist of the following main points:

- The directive lays out certain greenhouse gas emissions reductions to be achieved from the use of biofuels. In the case of biofuels and produced by installations that were in operation on 23 January 2008, GHG emissions savings must be at least 35%

from 2013. This figure rises to 50% in 2017, and further to 60% for biofuels produced in installations in which production started on or after January 2017.

- The raw materials sourced for biofuel production, from within the EU or from third countries, should not be obtained from land with high biodiversity value, land with a high carbon stock, or land that was peatland in 2008 .

These criteria, while undoubtedly good for the sustainable production of biofuels, may restrict growth of the biofuel production industry in Ireland as biofuels must meet certain minimum criteria.

2.3.2 Common Agricultural Policy (CAP)

The common agricultural policy has mixed effects on the growth of energy crops. On one hand energy crop production is supported by the energy crops scheme which provides grant aid, and by non-food set aside policy. On the other hand, the land available for energy crop production is restricted by the cross-compliance policy. Cross-compliance restricts the conversion of grassland to arable cropping. Cross-compliance regulations require that the ratio of the area of permanent pasture to the total agricultural area of each Member State must not decrease by 10% or more from the 2003 reference ratio (EC, 2004). Ireland is therefore under obligation not to allow any significant reduction in the total area of permanent pasture (91% of agricultural land area in Ireland) [19], which restricts the type of energy crops that can be grown [20].

A reform of the common agricultural policy is due with new rules coming into effect in 2014 which may affect the production of biomass in the EU.

3 Biofuels

The two liquid biofuels that penetrate the transport sector in Ireland are bioethanol and biodiesel, both 'first generation' fuels due to the type of feedstock and technologies used to produce them.

3.1 Bioethanol

Bioethanol is a biofuel produced by from agricultural feedstocks which are high in sugar or starch such as sugarcane, sugar beet, corn (maize), and wheat, as well as lignocellulosic crops.

Bioethanol suitable for EU blending requirements can be produced via a number of pathways. The general production pathway involves pretreatment of feedstocks, a saccharification process to release the fermentable sugars from polysaccharides, fermentation of released sugars, and finally a distillation step to separate ethanol from the liquid product [21, 22]. The technology used to liberate the sugar molecules, and where the sugar is liberated from, are the two factors which generally differentiate between one production process and another. Ethanol production from sugar crops such as sugar beet and cane is the most straightforward process as the sugar molecules are relatively easy to liberate [21]. Bioethanol production from starch crops is more complex as it requires a pretreatment step. These two processes are 'first generation' processes. Ethanol production from lignocelluloisc biomass, such as agricultural residues, is a 'second generation' process, requiring a more complex production system involving either thermochemical or biochemical processes [23].

Bioethanol is suitable for use in conventional petrol engines, without any modification, when blended up to a rate of 5% with fossil petrol fuel. It can be blended up to 85% (known as B85) for use in engines which have been specifically modified for this purpose [24]. Several cities in Europe are using higher blends of biofuels in 'captive fleets' such as public transport systems and in employee vehicles [6].

The largest world producer of bioethanol is the USA [25], followed by Brazil [26], as outlined in figure 3. Brazil produces bioethanol from sugar cane, which accounts for 40% of overall fuel use in Brazil [21]. The USA is currently the largest producer of bioethanol, while at the same time it is also the largest importer of Brazilian bioethanol [26]. Costs of producing bioethanol in Brazil are less than half of those in Europe, approximately $0.20 per litre for new plants, in comparison to approximately $0.55 per litre, including subsidies in Europe [27]. Production of bioethanol from sugar cane (or sugar beet in Ireland's case) could prove to be a low cost source of biofuel in the future [28], with overall ethanol production expected to increase as the production costs will decrease faster than those of biodiesel. There are efforts now to revive sugar beet production in Ireland and to develop a bioethanol facility that requires 1 million tonnes of sugar beet and 56 000 tonnes of grain to produce 154 000 tonnes of sugar and 50 million litres of ethanol at an estimated plant construction cost of €350 - €400 million [29].

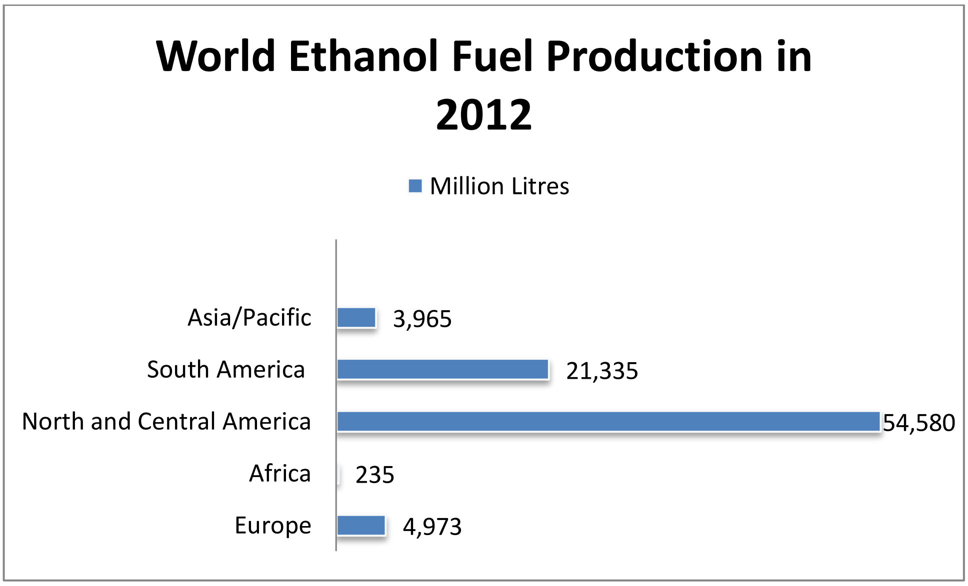

Figure 3: World ethanol production[30]

3.2 Biodiesel

Biodiesel is a biofuel produced from oil-rich crops such as oil-seed rape, soybeans, and jatropha, or residues such as recovered waste vegetable-oils (RVO) and animal fats (tallow). A number of different production pathways can be followed to produce boiodiesel. Firstly, the vegetable oil must be extracted from the feedstock using chemical or mechanical means. Following extraction, the oil-rich mixture is treated to remove impurities such as large particles (pieces of plant tissue, mucilages, resinous products), fine colloidal particles (invisible in transparent oil), free fatty acids produced by acylglycerols hydrolysis and colored and semi-volatile substances dissolved in the oil [31]. The oil from the feedstock is then processed by transesterification to produce methyl ester. Transesterification is a chemical process which requires the use of alkaline, acid or enzymatic catalyzers and ethanol or methanol, and produces fatty acid (biodiesel) as the main product and glycerine as a by-product [21]. A number of different pathways can be followed depending on type of catalyst, biphasic or monsphasic reaction systems, and pressure and temperature, depending on the feedstock used [32].

Biodiesel can be used in conventional compression-ignition diesel engines, normally between a 5% and 7% blend to avoid any effect on engine performance [24]. Biodiesel can be used as a pure fuel with only minor modifications to the engine compared to pure bioethanol [33].

The European Union is currently the largest producer of biodiesel, accounting for approximately 52% of worldwide production (Figure 4) .

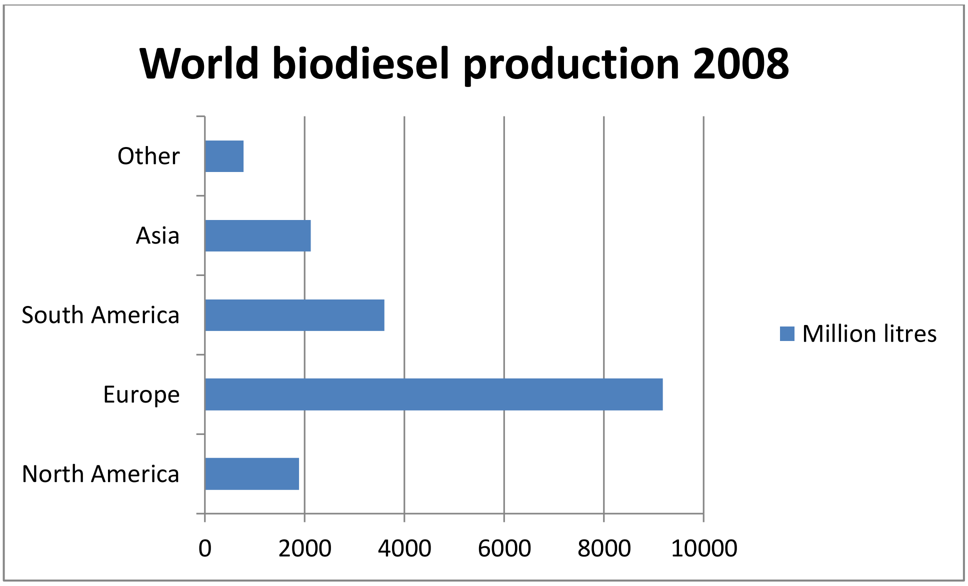

Figure 4: World biodiesel production [34]

3.3 Indigenous production

As outlined previously, there is very little production of indigenous biofuels in Ireland. The two main sources of feedstock for ethanol production in Ireland are sugar beet and wheat [35]. Despite the availability of these resources, there is no ethanol producing facility in the country except for Carbery based in Co Cork who produce and export ethanol from whey which is a by-product of their cheese making plant. All of the ethanol contained in fuel blends is currently imported.

Ethanol production in Ireland faces a major obstacle; it requires government subsidies to be able to produce it at competitive prices when compared to traditional fossil fuels [35]. For example, the proposed ethanol production site at Mallow required economic support in order to produce ethanol at competitive prices and under the conditions of MOTR II it could have only survived if further incentives or excise relief had been available.

A further limitation on the development of the biofuels industry in Ireland is the amount of land required to produce it. There are several competing uses for agricultural land in Ireland; arable land for crop production (9%), grassland for beef and dairy production and set aside (91%) [19]. Production of biofuels on land traditionally used for food production or for recreation could cause a significant public outcry over the use of this land for biofuels, as well as conflicting with the CAP as outlined above [24]. Recent discussions in Europe suggest that the target for crop based biofuels will be changed from a minimum of 10% to a

maximum of 5%. This will undermine any potential investments for biofuel industries in Ireland and beyond. Murphy and Power [36] have estimated that, to meet the biofuels directive of 5.75% using biodiesel produced from rapeseed oil, then 6.3% of Irish agricultural land is required to produce the crop, this equates to 70% of arable land. If the target is met using ethanol produced from wheat, 3.9% of Irish agricultural land is required.
Green Biofuels Ireland (GBI), based in New Ross, County Wexford, operate a state-of-the-art 30 000 ton capacity plant that uses RVO and tallow to produce 34.5 million litres of biodiesel annually. When compared to the greenhouse gas emissions from fossil diesel, this biodiesel makes an 83% saving, important for EU sustainability criteria. The biodiesel is sold to major oil distributors in both the Republic and Northern Ireland [17].

Tallow availability

Tallow refers to the inedible animal fats produced as a by-product to the renderingindustry and produced by the rendering process. Singh et al. [19] takes into consideration the different existing markets for tallow, and predicts half of the tallow available for sale in 2020 (19,000 t) will be converted to biodiesel. This results in a practical energy of 0.715 PJ per annum.

RVO availability

Recovered vegetable oil is a waste product of the food industry. Singh et al. [19] predicts that, with better collection networks and waste management strategies, two thirds of available RVO will be collected in 2020 and that 75% of this will be converted to biodiesel. This equates to 0.45 PJ of practical energy per annum.

Rapeseed

Oilseed rape, a crop grown for its high oil yield, is one of the primary feedstocks or biodiesel production in Ireland. It is grown in rotation, 1 year in every 4 or 5, with conventional agricultural crops such as wheat [37]. The pure plant oil is extracted from the seed of the rape plant by crushing, it is then filtered and can be used in modified vehicle engines without further processing, or can be further process into biodiesel [38]. The process residue is compacted into rape cake, a high-protein animal feed, thus improving the sustainability of the system [17].

Oilseed rape is becoming progressively more attractive at farm level, with prices increasing, resulting in the crop becoming a key profit generator [39]. As such, the area of oilseed rape planted has almost doubled from 6 300 ha in 2009 to 12 400 in 2011, resulting in the production of 55 800 tonnes in 2011 which is a 97% increase on 2009 figures. The yields of the crop have also improved dramatically from 3.7 tonnes / Ha in 2009 to 4.5 tonnes / Ha in 2011. A rise of 22% [18]. Despite the increasing levels of oilseed rape production, the rapeseed biodiesel production is currently present with GBI Ltd. There has recently been a new biodiesel plant developed in Wicklow Port, Co Wicklow with potential capacity of 36 000 tonnes which will see a market for tallow and used cooking oil. With the end of the MOTR scheme in 2010, plants which had been producing rape methyl ester (RME) were shut down as they could no longer survive without support [17, 39]. With the appropriate supports, indigenous production of biodiesel from oilseed rape has the potential to thrive. Hamelinck, van den Broek [40] has estimated that the realistic potential production of oilseed rape in the medium term is 10-15 kha, equating to 17.3 million litres or 0.6 PJ per annum at the higher end. This equates to 24.6% of the total biodiesel blended in motor fuel in 2012. 70 292 126 litres of biodiesel and 55 648 948 litres of bioethanol was blended in Ireland in 2012[14]

4 Alternatives

4.1 CNG

Compressed natural gas is a promising alternative fuel which offers benefits relative to liquid fossil fuels. Compressed natural gas is a form of fossil energy so cannot be classified as a renewable source of energy, however it has environmental benefits when compared to gasoline and diesel and poses a lesser affect to contaminate land, air or water if there is a leak [41]. In addition CNG powered vehicles emit 85% less NOX, 70% less reactive HC’s, and 74% less CO than similar gasoline powered vehicles [42]. An advantage over current electric vehicles is that CNG can be used in heavy vehicles [43].

Compressed natural gas is replacing traditional fossil fuels in transport systems across the world. There are 15 million natural gas vehicles operating around the world with almost 20,000 natural gas fuelling stations in operation [44]. Ireland has considerable natural gas resources, 9.11 billion m^3 [45], thus CNG represents an indigenous source of fuel that can reduce reliance on imported gasoline and diesel. Bus Eireann has announced the first trial of the country's first natural-gas powered bus which will be running on the streets of Cork City. This trial is being carried out in partnership with Bord Gais Networks with the ultimate aim being the purchase of a fleet of natural gas vehicles[46] .

Instead of natural gas, biogas can also be used, thus making the fuel renewable [43]. As such, the production of biogas has received attention as a renewable source of energy for transport [47, 48]

4.2 Grass biomethane

Biomethane has emerged as a potential source of biofuel amid concerns over the availability of land required to produce energy crops from biofuel production. Biomethane is produced by upgrading biogas, itself produced by the anaerobic digestion of a range of feedstocks, to the same standard as natural gas. Biogas can be produced by the anaerobic digestion of biomass such as green waste, grass, food waste, and animal slurry [20].

The feasibility of utilising grass for biomethane production has been examined in a number of papers[35 36, 49-52].

Grass is a crop with considerable yields in the Irish climate. Smyth et al. [53] have shown that grass biomethane has a very good energy balance (comparable to palm oil biodiesel), does not require land use change, and does not affect farming practices. Furthermore, it is estimated that 10% of Irish grasslands could fuel over 55% of the Irish private car fleet [54]. In Ireland, grasslands account for 3.94 Mha (90% of the agricultural land). By 2020, 0.39 Mha of agricultural grassland may be surplus to animal feed requirements due to destocking of the national herd. This refers to a destocking of the cattle herd under the National Climate Change Strategy 2007[13] where the agricultural sector must reduce its GHG emissions by 2.4 Mt of CO2e – in this case the CO2e coming from the methane emissions of cattle which are responsible for 86.6% of methane emissions from ruminant animals. If the cattle herd is reduced, mainly in the beef sector as opposed to dairy then 0.39 MHa of agricultural grassland may be surplus by 2020. According to Singh et al. [19] 0.39 Mha of surplus grass has the potential to generate 47.58 PJ/a energy, and if by a conservative estimate, only 25% of this area (0.1 Mha) was used to produce biomethane, there would be the potential to generate 11.9 PJ energy.

Biofuels produced from grass may also earn double credits towards the EU renewable energy targets as grass is considered to be a ligno-cellulosic material [55].

4.3 Algae

The cultivation of algal biomass for the production of third generation biofuels has received increasing attention in recent years as they can be produced in the marine environment and on non-arable lands, thus bypassing the food versus fuel debate. There are two types of algae; seaweeds (macroalgae) and phytoplanktons (microalgae).

Macroalgae are appropriate for biofuel production, however they do not generally contain lipids and are being considered for the natural sugars and other carbohydrates they contain, making them suitable for biogas and ethanol production rather than biodiesel. Macroalgae has a negative lower heating value and a high moisture content (circa 80-85%), as such the most appropriate method of processing for energy is fermentation by anaerobic digestion, to create biogas, or ethanol fermentation [56].

Currently the majority of seaweed collection in Ireland is for human consumption and for hydrocolloid production, with 29,000 tonnes harvested in 2006 for Arramara Teo, a state owned company [56]. Ireland has considerable macroalgal resources, with an estimation of 3 million tonnes of standing kelp stock, however this estimation is highly uncertain [56]. Barriers exist to the further exploitation of marine biomass, in particular any potential effects on marine biodiversity [56].

Microalgae are particularly suited to biofuel production due to their high photosynthetic growth rate, high lipid content, low land usage and high carbon dioxide absorption [57]. Algae absorb freely available sunlight and can utilise waste streams to provide essential nutrients for cultivation. Algae can convert waste CO2 from power plant exhaust gas to organic biomass which can then be converted to energy [56]. Moreover, municipal wastewater streams can be harvested to provide additional nutrients [58].

Biorefinery-type processes may be the most economical method of producing algal biofuels as several commercial products can be obtained from the algal biomass. Lipids can be extracted for biodiesel production, while other products can be fermented to produce ethanol and biogas. It is also possible to produce protein-rich feed for both animal and human consumption [56]. Bulk markets for the co-products are potentially available [58].

Further research and development is required into the production of algal biofuels, as such any contribution to Irelands 2020 targets is likely to be minimal. Bruton (2009) [56] has stated that up to 447 TJ of energy may be generated from macroalgae by 2020 (approximately

0.2% of current national road-fuel demands). Similarly it has been estimated that about 79 TJ could come from microalgae resources by 2020.

4.4 Cynar

Cyn-diesel is a synthetic diesel fuel produced by the Cynar Process from the pyrolysis of a wide range of waste plastics including; unsorted and unwashed including commercial and industrial packaging as well as heavily contaminated agricultural wastes [59]. The system consists of stock in-feed system, pyrolysis gasification chamber, contactor, condensers, centrifuge, oil recovery line, off-gas cleaning, and adulterant removal. A Cynar plant can produce up to 9500 litres of high-grade synthetic fuel from 10 tonnes of waste plastics (polyethylene, polypropylene and polystyrene), with systems ranging from 10 to 20 tonnes per day. The Cyn-diesel is essentially equivalent to regular diesel. Blends of Cyn-diesel with fossil diesel have been tested in accordance with EU fuel standards specified in the EN 590 standard in order to determine its suitability for use in a diesel fuel blend, with blends up to 40% complying with the standards [59].

Alternative fuels produced from non-biomass waste are not incorporated in both European and Irish biofuel policies at present. However, they represent an ideal opportunity to divert waste from landfill while producing a clean fuel which can contribute to renewable energy targets. It is important that alternative fuels are considered in any policy updates to allow their contribution, to the European and national renewable energy targets.

4.5 Electric vehicles

The Renewables Energy Directive requires 10% of transport to be generated from renewable sources. Considering the substantial resources of ocean and wind energy available in Ireland, the Government has set a target of 10% of all vehicles to be electric vehicles by 2020 [16]. Foley et al. [60] have estimated that 284,383 electric vehicles will be required in the vehicle fleet by 2020 to meet this target [60]. New electric vehicles registered in 2010 numbered 23 in total. This figure rose to 48 in 2011 and stands at 16 for the first six months of 2012 [61]. The rate of adoption of electric vehicle will need to increase significantly towards 2020 to meet the target. If this target is met, it can be expected that the electric vehicle will initially produce 1.5% of energy from renewable sources [2]. This not only would help Ireland to reach the 10% renewable targets by 2020 but also reduce CO2 emissions, provided the electricity is produced in an environmentally friendly way. In 2009 the Government introduced grant support and tax incentives to encourage electric vehicle uptake; up to €5,000 for the purchase of Battery Electric Vehicles (BEVs) and up to €2,500 for the purchase of Plug-in Hybrid Electric Vehicles (PHEVs), available from 2011 to 2012, with zero Vehicle Registration Tax (VRT) on BEVs and VRT relief of up to €2,500 for PHEVs[1]. This scheme will only be applicable to small and light vehicles.

In 2010, ESB installed the first on-street charge points in Dublin and has set the following targets to be met in the future; 2000 home charge points, 1500 public charge points and 30 fast charge points. Two Irish companies, M2Cand JTM Power are developing new charging infrastructures. The SEAI has also initiated the Aran Islands Project, which involves developing technologies and methods to use high amounts of wind or ocean energy available on the islands to power electric vehicles. There are eight Mega ECity electric cars currently operating on the islands on trial basis and it is expected that up to 24 will be in operation in the future.

5 Greenhouse gas emissions reductions

As discussed previously, the EU has introduced sustainability criteria regarding the greenhouse gas emissions associated with biofuel production which may have a significant impact on the types of biofuels viable for use in the future. From 2013 to 2017, biofuels must achieve a minimum 35% reduction in greenhouse gas emissions versus fossil fuels. According to table 1 which summarises the GHG emissions from the production of indigenous biofuels in Ireland, only biodiesel produced from residues meets this minimum reduction. In 2017 the targeted reduction increases to 50%, which both biodiesels from residues can meet. However, beyond 2017 the target reaches 60%, which only biodiesel from recovered vegetable oil can meet. As it is, biodiesel from oil seed rape, bioethanol and biomethane from wheat, barley and sugar beet, and biomethane from grass, all fail to meet even the minimum sustainability criteria. This shows the improvements necessary in current biomass production and processing methods required to increase the sustainability of these biofuels. For example, Korres et al. [62] found that by improving current biomethane production by using electricity from wind, improving digester configuration, and by using a vehicle optimized for gaseous fuel the GHG reduction for grass biomethane can be increased to 54%.

Table 1: GHG emissions associated with indigenous biofuel production in Ireland

	Total GHG emissions (kg CO2-eq/GJ)	% reduction in GHG emissions versus fossil fuels
Biodiesel		
Rapeseed[a]	62.16	29
Tallow[b]	40	54
Recovered vegetable oil[b]	27.11	69
Bioethanol		
Wheat, barley, sugar beet[c]	69	28
Biomethane		
Wheat, barley, sugar beet[c]	64	27
Grass[d]	69.4	21

[a] 63

[b] 64

[c] 65

[d] 62

6 Discussion and conclusion

- An analysis of the potentially available feedstocks in Ireland by 2020 is carried out in this paper. Table 2 shows that if all available resources considered are utilised, Ireland can achieve approximately 98.5% of the biofuel target by 2020.

Table 2: Potential availability of biofuels by 2020

Biofuel	*Quantity (PJ)*	*% contribution*
Target	**14.4**	**100**
Current fuels		
Tallow	0.715	5
RVO	0.45	3
Rapeseed	0.6	4.2
Potential fuels		
Grass biomethane	11.9	82.6
Algae	0.526	3.7
Total	**14.191**	**98.5**

- Any fuels contributing to the EU target will have to meet minimum greenhouse gas reductions. This will put further pressure indigenous biofuel production as the only fuel that meets the minimum 60% greenhouse gas emissions reduction, coming into force in 2017, is RVO biodiesel which contributes only 4.2% to the overall biofuel target.
- Ireland only has a very small indigenous production of biodiesel, 34.5 million litres per annum. A newly developed biodiesel plant, Irish Production Biofuels Ltd has the capacity for 36 000 tonnes of biodiesel per annum to be sold into the Irish fuel market through RVO and tallow. Ireland currently has no indigenous ethanol industry but Carbery in Co. Cork produce ethanol from whey which is a by-product of their main cheese manufacturing facility, but this ethanol is currently exported after the excise relief was removed after MOTR II. As such, all policy efforts have so far failed to create an indigenous biofuels industry in Ireland, causing the country to remain heavily reliant on fuel imports.
- The MOTR schemes I and II effectively failed in the sense that they did not meet the targets of biofuel incorporated into the market in the 4 years that it existed. There were also issues around many of the successful applicants who could sell the biofuel

without the excise never actually producing any fuel indigenously in the timeframe but simply imported the biofuel and pocketed the subsidy. When the subsidy was finished it effectively terminated any OSR operations also.

- The Biofuel Obligation Scheme is a slight improvement in that it is getting the biofuel into the market. The original target of 4.166% (volume) has been easily reached and as of January 2013 a new target of 6.383% has been introduced. But this isn't necessarily driving the home grown biofuel as fuel suppliers are mostly importing the fuel pre-blended. What potentially should happen is that the main fuel suppliers should liase with indigenous biofuel producers and blend the fuel themselves. This approach would help drive the success of the industry in Ireland and also develop a more secure supply of biofuel into the market.

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