

Novel Low Carbon Transport Fuels and the RTFO: sustainability implications

Scoping paper for the
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Authors:

Brian Denvir, Richard Taylor, Ausilio Bauen (E4tech)
Gemma Toop, Sacha Alberici (Ecofys)



Foreword

A number of different types of 'novel low carbon transport fuels' are in development and nearing the stage where they may enter the market. Many of these fuels have the potential to deliver high carbon savings without using any land, thereby avoiding both direct and indirect land use change as well as impacts on food or feed prices.

This scoping paper by E4tech and Ecofys presents a classification framework for various types of transport fuels, and the potential sustainability risks and practical implications of widening the scope of the UK's Renewable Transport Fuel Obligation (RTFO) to encompass 'novel low carbon transport fuels' other than biofuels.

The overall context for the study was to consider whether, and how, an emerging class of 'novel low carbon transport fuels' (which are not currently covered by the RTFO) could receive policy support similar to the support extended to biofuels today under the RTFO. The paper identifies that the current terminology and definitions used under the RTFO would need to be amended in order to accommodate such fuels within a policy framework. A new comprehensive classification framework is proposed that covers all types of transport fuel while remaining consistent with the Renewable Energy Directive (RED). The classification framework presented here identifies several new categories of fuels other than biofuels and proposes some broad definitions. Whilst several supporting terms are yet to be formally defined, this paper represents a starting point for considering the role of such 'novel low carbon transport fuels' within transport fuel policy, and for engaging in discussions with stakeholders as to the advantages and disadvantages of these new fuels.

The paper was commissioned by the UK Department for Transport (DfT) but the views expressed herein are of the authors and do not necessarily represent those of the DfT. However, the DfT and the authors welcome feedback on the content and findings of this paper, which can be sent to Biofuels.Transport@dft.gsi.gov.uk

Table of Contents

Foreword	2
1 Introduction	2
2 Definition and Classification	4
2.1 Current definitions	4
2.2 Proposed definitions	6
2.2.1 Fossil fuel	8
2.2.2 Sustainable biofuel	8
2.2.3 Low carbon fuel	9
2.2.4 Renewable liquid or gaseous fuel of non-biological origin (RFNBO)	10
2.3 Classification	11
2.3.1 Classification of mixed fuels	13
2.4 Carbon Sources	14
3 Overview of known examples of novel low carbon transport fuels	15
4 Risk identification and mitigation	19
4.1 Carbon source	19
4.2 Energy source	21
4.3 Hydrogen source	23
4.4 Overview of risks	23
5 Practical implications of expanding the RTFO	26
6 Conclusions	27

1 Introduction

The Renewable Transport Fuel Obligation (RTFO) was introduced in April 2008, with the aim of increasing the supply of biofuel and reducing greenhouse gas (GHG) emissions from transport. The aim of the policy has since been extended to include compliance with the EU Renewable Energy Directive (RED), which sets a 10% target for energy from renewable sources in transport by 2020.

The RTFO currently only supports biofuels made from biomass feedstocks. These biofuels also have to comply with mandatory sustainability criteria transposed from the RED and FQD¹. In April 2014, as part of the Government response² to the Advanced Fuels Call for Evidence and the 2013/14 Post-Implementation Review of the RTFO, the Department for Transport (DfT) announced its intention to look at the possibility of adding 'synthetic fuels from renewable electricity' to the list of fuels eligible for future support under the RTFO. The intention was that this category of fuels would also include renewable hydrogen from electricity, used in fuel cell vehicles.

The category 'synthetic fuels from renewable electricity' could encompass a range of different fuels, made from a variety of raw materials via different processes and technologies. The majority of such fuels are currently at the research and development or demonstration stages, although some are already close to market albeit in small volumes. In addition, a plethora of other novel low carbon transport fuels are being developed by different companies and research groups. Examples of such fuels include:

- Hydrogen via electrolysis powered by renewable electricity
- Methanol via catalytic fuel synthesis of renewable hydrogen
- Diesel via pyrolysis of non-recyclable waste plastics
- Ethanol via fermentation of steel mill waste gases
- Gasoline via syngas from renewable electrolysis and solar thermochemical reaction of CO₂

Several of these fuels have already demonstrated considerable potential to deliver environmental benefits similar to or better than those afforded by biofuels – for example, Carbon Recycling International recently achieved ISCC PLUS certification for their renewable methanol fuel³. Preliminary assessments indicate significant potential for GHG savings by substituting conventional fossil fuels with such fuels. Furthermore, since these fuels are not derived from biomass, many of the land-use concerns associated with biofuels do not apply. Thus, the DfT may wish to consider providing policy support to some or all of these promising new fuels, either as part of an amendment to the RTFO, or via another policy mechanism.

If fuels other than biofuels are to be supported then there are several important factors that must be considered. One factor is how the new fuels fit in within the context of the RED and FQD targets – what are the characteristics that a fuel must demonstrate in order to be eligible to contribute?⁴ A second factor to consider is if there are possible sustainability concerns associated with these new types of fuels and if these could be exacerbated by incentivisation of the fuels. If mandatory sustainability criteria are to be extended to these new fuels then the nature of these criteria needs consideration. It is also important to consider any practical issues around the administration of the support mechanism (i.e. the RTFO) for these fuels that could arise.

¹ RED : Directive 2009/28/EC, Articles 17(2)-(6). FQD : Directive 2009/30/EC, Article 7b.

² https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/307129/joint-government-response.pdf

³ February 6, 2013: ISCC PLUS certificate issued by SGS for Icelandic renewable methanol plant (<http://bit.ly/1KyuAFq>)

⁴ A further factor, which is outside the scope of this paper, is the role for these fuels beyond 2020 and how they might fit into a 2030 policy framework.

This scoping paper by E4tech and Ecofys presents a classification framework for various types of transport fuels, and the potential risks and practical implications of widening the scope of the RTFO to encompass novel low carbon fuels other than biofuels. The main objectives of the paper are:

1. To **classify** the various types of fuels in order to understand their standing in the context of the RED, FQD and current RTFO, and establish the makings of a comprehensive, consistent classification framework for transport fuels
2. To identify **sustainability risks** or unintended consequences that supporting novel low carbon transport fuels could lead to and consider how these can be mitigated
3. To consider some of the **practical implications** of expanding the RTFO to encompass these new fuels

The first point is considered in **Section 2** of the report, with some consideration given to the classification of the fuels of notable emerging companies/technologies in **Section 3**. The second and third points are discussed in **Sections 4 and 5** respectively. The key messages are summarised in **Section 6** along with some questions and points which need further consideration/enquiry.

2 Definition and Classification

The purpose of this Section is to consider the characteristics a fuel needs in order to be considered eligible for support under the RTFO (or similar mechanism), or to contribute to the RED or FQD targets. The ultimate objective is to establish a fuel classification system (a '**classification framework**') which can be used to distinguish between various fuel types, and establish a new set of definitions for these fuels. Note that the definitions and classifications proposed here are provisional and are intended to provide a starting point towards development of a consistent, comprehensive classification framework.

2.1 Current definitions

In considering the role of new novel fuels alongside conventional biofuels in the RTFO, establishing a clear set of definitions and criteria for these fuels is crucial in order to understand a) whether the fuel should be eligible for support, and b) whether the fuel could contribute to RED or FQD targets.

The reasons for this become clear when one considers the existing definitions applied to eligible fuels under the RTFO. At present in the RTFO only 'wholly & partially renewable fuels'⁵ are eligible to receive RTFCs. The process guidance gives the following definitions:

- ***RTFO Definition:*** A **wholly renewable fuel** means one where all of that fuel was derived from feedstocks that are wholly of biological origin.
- ***RTFO Definition:*** A **partially renewable fuel** is one where part of that fuel was derived from feedstocks from biological origin and part from feedstocks of fossil origin.
- ***RTFO Definition:*** A **biofuel** is a type of renewable fuel

It should first be noted that the only sources of carbon encompassed within the above definitions are carbon atoms from biomass feedstocks (i.e. carbon that has been recently fixated in biomass). At present it is only these types of fuels which are supported under the RTFO. Recently some novel fuels have emerged which contain carbon from sources other than biomass feedstocks (e.g. waste CO₂ sources from power plants), or which do not contain any carbon (e.g. renewable hydrogen). Several of these fuels have been shown to demonstrate excellent GHG savings⁶ while also avoiding the concerns around land-use change often associated with conventional biofuels. Thus they demonstrate potential to reduce GHG emissions from transport and there may therefore be a case for considering support of such fuels. If there is a case for support, then it is important to consider the various types of carbon, hydrogen and energy sources (beyond those from biomass feedstocks) and whether the risks associated with these new sources are sufficiently manageable to merit support.

It should also be noted that whilst the interpretation of 'renewable' in these current RTFO definitions is in line with the RTFO, the RED has a broader definition of renewable. The definitions are sufficient to address the fuels currently supported by the RTFO (i.e. biofuels), but do not cover other prospective fuels which could be considered to be 'renewable.' For instance, hydrogen generated from electrolysis of water using wind power would not be classified as a wholly or partially renewable fuel

⁵ Note that the Energy Act (2004) sets out a broad definition of 'renewable transport fuel.' This definition allows for the understanding of what is considered as a 'renewable transport fuel' to be defined within the RTFO Order. Chapter 5, Section 132 (1) (d) of the Energy Act states that a 'renewable transport fuel' means '...any solid, liquid or gaseous fuel which is of a description of fuel designated by an RTF order as a renewable transport fuel.' Thus there is some flexibility to redefine 'renewable transport fuel' within the RTFO Order.

⁶ Based on voluntary GHG certification standards (e.g. ISCC PLUS, RSB) for individual fuels, but acknowledging that a common methodology for calculating the GHG emissions of these fuels is yet to be developed

based on these current RTFO definitions⁷. This is an important point, because the 10% target in the RED is for 'energy from renewable sources in transport' and so there is a need to define what is meant by a 'renewable fuel'. Thus in considering the introduction of new novel fuels it is important that the definitions and classifications used are consistent, and capture all fuels that will be eligible.

It is not straightforward to ascertain exactly what is meant by 'renewable' in the context of the RED, since an explicit definition of a 'renewable fuel for transport' is absent from the Directive and accompanying communications. However it is possible to infer that the definition of renewable is based on the origin of the 'energy content of the fuel'. In particular, in the *Communication from the Commission on the practical implementation of the EU biofuels and bioliquids sustainability scheme and on counting rules for biofuels* (2010/C 160/02), paragraph 5.1 sets out the method for accounting for fuels that come from partially non-renewable sources:

*"Certain fuels consist only partly of renewable material. For some of these, such as ETBE, Annex III to the Directive indicates what percentage of the fuel is renewable for the purpose of target accounting (1). For such fuels not listed in Annex III, including fuels produced in flexible processes that do not always deliver consignments with the same mix of sources, analogy can appropriately be drawn from the rule for electricity generated in multi-fuel plants: **'the contribution of each energy source is to be taken into account on the basis of its energy content'**"*

This indicates that within the RED, the renewable content of a fuel is determined based on the source of the energy content of the fuel, rather than simply on the source of the carbon atoms within it. This is substantiated by the fact that 'renewable hydrogen' (hydrogen from renewable energy sources) is considered within the RED to count towards the renewable transport target - i.e. hydrogen whose energy comes from renewable sources is a renewable fuel. The assertion that 'renewability' is determined by the origin of the energy content of the fuel is further supported by the definition for a 'renewable liquid or gaseous fuel of non-biological origin' which appears in Annex IX of a European Parliament proposal amending the RED & FQD⁸. This defines a new category of fuel:

- ***RED (working) Definition: Renewable liquid and gaseous fuels of non-biological origin*** means gaseous or liquid fuels other than biofuels whose energy content comes from renewable energy sources other than biomass and which are used in transport.

Interpretation of this definition relies on three further definitions set out in the existing RED:

- ***RED Definition: Energy from renewable sources*** means energy from renewable non-fossil sources, namely wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases
- ***RED Definition: Biofuels*** means a liquid or gaseous fuel for transport produced from biomass
- ***RED Definition: Biomass*** means the biodegradable fraction of products, waste and residues from biological origin from agriculture (including vegetal and animal substances), forestry and related industries including fisheries and aquaculture, as well as the biodegradable fraction of industrial and municipal waste

⁷ However, the Energy Act (2004) allows scope for policies to incentivise many of the prospective fuels as 'renewable transport fuel' – so primary legislation may not be required to alter or add to the RTFO definitions. Chapter 5, Section 132 (1) (c) states that a 'renewable transport fuel' means... any solid, liquid or gaseous fuel (other than fossil fuel or nuclear fuel) which is produced (i) wholly by energy from a renewable source; or (ii) wholly by a process powered wholly by such energy.'

⁸ Note that this European Parliament proposal has not yet been approved and is subject to change

Note that the above interpretation of 'renewable' in the definition of renewable liquid and gaseous fuel of non-biological origin (RFNBO) makes no reference to the source of carbon (if any) in the fuel. It could be argued that only certain carbon sources should be permitted within this definition – for example, one could envisage a scenario in which coal could be burnt solely to produce a CO₂ stream, and then combined with renewable hydrogen for the production of methanol. This kind of practice would not be desirable from a climate change perspective, so an improved definition should safeguard against this.

It is possible therefore to build on these RED definitions to classify the new generation of novel fuels in a way that is consistent with the existing approach taken in the RED. These classifications should be based around the two key features of the fuels discussed here:

1. The source of the carbon atoms in the fuel; and
2. The source of the energy content of the fuel

Classifying fuels based on these parameters allows for consistency with the European Commission interpretation of 'biofuel' and 'renewable fuel' while also allowing for some distinction to be made between sources of carbon which is important from a sustainability perspective.

2.2 Proposed definitions

The following working definitions for an expanded set of fuel categories are proposed below. These are proposed to supersede the current RTFO and RED definitions given above.

- **Fossil fuel:** coal, substances produced directly or indirectly from coal, lignite, natural gas, crude liquid petroleum or petroleum products
- **Biofuel:** a liquid or gaseous transport fuel produced from biomass feedstock. Two⁹ sub-sets of sustainable biofuels can be considered:
 - **Sustainable biofuel (wholly renewable):** A biofuel which meets the required sustainability criteria¹⁰ whose energy content comes entirely from renewable energy sources
 - **Sustainable biofuel (partially renewable):** A biofuel which meets the required sustainability criteria, and whose energy content comes partially from renewable energy sources
- **Renewable liquid or gaseous fuel of non-biological origin (RFNBO)¹¹:** A liquid or gaseous fuel other than a biofuel whose energy content comes exclusively from renewable energy sources (other than biomass) and which is used in transport. If the fuel is derived from fossil carbon sources, these must be waste/residue fossil carbon sources. The fuel must also meet the required sustainability criteria
- **Low carbon fuel:** A fuel which meets the required sustainability criteria¹², is not a fossil fuel, and, if containing carbon, whose carbon atoms come from either a waste/residue fossil carbon

⁹ Note that a further subset of biofuels will be 'unsustainable biofuel' – this falls into the category 'unsustainable fuel.'

¹⁰ 'Sustainability criteria' here refers to the existing RTFO sustainability criteria for biofuels, including both land-use and GHG requirements

¹¹ This definition is an adaptation of the definition provided in the European Parliament proposal (see Section 2.2.4)

¹² A full set of sustainability criteria has not yet been defined for these novel fuels. At this stage it is assumed that in order to be considered under the RTFO, non-biofuels should as a minimum be required to meet the same land-use (if relevant) and GHG requirements as biofuels (acknowledging that the details of the GHG calculation methodology have not yet been worked out)

source or an atmospheric/naturally occurring carbon source. Three sub-categories of low carbon fuel can be considered:

- **Low carbon fuel (wholly renewable):** A low carbon fuel for which 100% of the energy content of the fuel comes from renewable sources
 - **Low carbon fuel (partially renewable):** A low carbon fuel for which part of the energy content of the fuel comes from renewable sources
 - **Low carbon fuel (non-renewable):** A low carbon fuel for which none of the energy content of the fuel comes from renewable sources
- **Unsustainable fuel:** A fuel which does not meet the required sustainability criteria

In addition to the above, the following terms should also be defined in the new classification framework:

- **Energy from renewable sources:** Energy from renewable non-fossil sources, namely wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases
- **Waste fossil carbon source:** A waste carbon source whose origin is fossil fuel based
- **Atmospheric/naturally occurring carbon source:** Carbon atoms originating from the atmosphere (i.e. artificially air-captured carbon, that has not become biomass) or carbon from recent geological activity (e.g. volcanic carbon)

Four further definitions are crucial to this classification framework, but require further detailed consideration:

- **Energy content:** the lower heating value of a fuel is a simple concept, and an inherent property of fuel, based on the chemical potential energy stored within it – the RED gives values for common fuels. However, much more complex issues arise when trying to quantify where this energy content comes from, and hence assess whether a fuel is wholly or partially renewable. Distinctions must be made between:
 - Feedstock energy that is used in the production of the fuel that ultimately ends up embodied within the fuel (i.e. energy that contributes to the calorific content of the final fuel);
 - Feedstock energy that does not make it into the fuel (i.e. is wasted through inefficiencies);
 - Process energy inputs that are used somewhere in the fuel production chain and which end up embodied within the fuel (e.g. electricity used in electrolysis of H₂)¹³; and
 - Process energy inputs that are used somewhere in the fuel production chain but which do not end up embodied within the fuel (e.g. natural gas used in the drying of raw material).

It is only the feedstock energy and process energy that ends up embodied within the fuel that the term 'energy content' needs to refer to, and a definition of this term will need to set out this distinction clearly. Ideally the definition would be accompanied by a calculation methodology which sets out how to determine the 'renewable share' of the energy content.

¹³ Note that it is not clear yet under the proposed framework whether the electricity used to produce hydrogen as described here would be classified as a 'feedstock' or as 'process energy'

- **Feedstock and Process energy:** Nowhere does the RED give any guidance about their definitions or distinction between feedstock and process energy, yet the distinction could have profound implications for the percentage renewability of several novel fuels¹⁴.
- **Waste (and Residue):** various definitions of the term 'waste' exist in different contexts (e.g. the Waste Framework Directive (WFD), the RTFO Guidance). The WFD definition of a waste would not be sufficient here as it excludes gaseous effluents emitted to the atmosphere, which would exclude the waste gaseous CO₂ sources exploited by several of the companies referenced in Section 3. It should also be noted that the WFD aims to control the movement of (hazardous) waste materials, so may take a conservative approach and classify more substances as wastes than the RTFO Guidance which aims to ensure that only genuine wastes without other economic uses are given extra incentives. Great care must be taken with any definition of waste introduced, since incentivising the use of waste resources should avoid encouraging wasteful behaviour. A flexible definition could be foreseen which allows for a similar approach to classifying wastes and residues as that used for the double counting mechanism under the current RTFO. Further work is needed here.

The primary definitions from above are discussed in more detail in the following sub-sections.

2.2.1 Fossil fuel

The above definition for 'fossil fuel' has been taken from the current RTFO Order. Although in theory it is possible for a non-waste fossil fuel (like natural gas) to deliver some modest GHG savings in relation to the fossil baseline (liquid diesel/petrol), it is unlikely that the DfT would wish to provide support to non-waste fossil fuels under the RTFO. However, this definition of 'fossil fuel' may need to be amended as substances produced 'indirectly' from fossil fuels (i.e. waste/residue fossil CO₂ streams) could be eligible as raw materials for producing low carbon fuels.

There is one notable exception to the above discussion of fossil fuels with modest GHG savings, relating to hydrogen produced from fossil feedstocks with carbon capture and storage (CCS), e.g. natural gas steam reforming with CCS, coal gasification with CCS, or oil refining operations with CCS. This could potentially be very 'low carbon' in terms of lifecycle GHG emissions, and hence contribute to FQD policy goals. However, this hydrogen is still a fossil fuel, not derived from waste, and is non-renewable. Whilst there could be a separate policy mechanism that supports non-waste fossil fuels that only contribute to the FQD target, we are in this paper focusing on discussing the RTFO.

2.2.2 Sustainable biofuel

The defining characteristic of a biofuel is that the majority of carbon and hydrogen atoms within the fuel come from biomass feedstocks, i.e. carbon atoms that were recently extracted from the atmosphere **and** hydrogen atoms that were recently extracted from water, both by photosynthetic organisms using sunlight¹⁵. The biofuel is considered 'wholly renewable' only if the energy content of the fuel comes exclusively from renewable sources – such a case can most simply be achieved when all the carbon and hydrogen atoms come from biomass feedstocks.

¹⁴ Note that whether inputs are deemed to be a feedstock or processing input should not affect the GHG balance (it should be the same regardless of which classification is used). However, if the definition of feedstock involves expansion of the system boundary, this may have implications for the GHG calculations. For example, whether power station flue gas CO₂ is a feedstock, or the original coal or biomass that fed the power station.

¹⁵ If there are no carbon atoms in the fuel, then the hydrogen atoms still need to originate from a biomass feedstock. Similarly, if there are no hydrogen atoms in the fuel, then the carbon atoms still need to originate from a biomass feedstock. The origin of the oxygen atoms is unimportant, as if present, they do not contribute any energy content to the fuel

In order to be considered sustainable, the consignment of biofuel must meet the sustainability criteria. However, it does not necessarily need to be wholly 'renewable' to be considered a sustainable biofuel. Partially renewable sustainable biofuels will commonly combine a majority of carbon and hydrogen atoms from biomass feedstocks with some (non-waste) fossil atoms.

Bio-ETBE, Bio-MTBE and Bio-TAEE are not biofuels themselves, but rather partially renewable transport fuels produced by combining mostly fossil feedstocks with modest percentages of biofuel feedstocks (22-37% bio-ethanol or bio-methanol, by energy). Support under the RTFO is based on the amount of biofuel feedstock compared to the total feedstocks used to create the oxygenate fuel.

It should also be noted that the distinction between wholly and partially renewable biofuel has been made in the definitions in the RTFO; however, the current allocation of RTFCs is not based in all cases on the share of the fuel that is considered 'renewable'. There are two types of partially renewable biofuel which receive 1 full RTFC per litre (namely FAME biodiesel made from vegetable/animal oil and fossil methanol, and HVO made from vegetable/animal oil and fossil hydrogen). In other cases (e.g. Bio-ETBE, Bio-MTBE), the allocation of RTFCs is based on the share of the fuel that is considered 'renewable' (e.g. based on the bio-ethanol or bio-methanol content). This different treatment for different partially renewable biofuels is ultimately a policy choice that needs careful consideration.

2.2.3 Low carbon fuel

These are fuels for which the source of the carbon is not from a biomass feedstock, but which still deliver material GHG savings¹⁶. As with biofuels they can be wholly or partially renewable, but they can also be non-renewable – for example, Lanzatech's ethanol uses a waste fossil source of carbon (steel mill carbon monoxide derived from coal) which also contributes all of the energy content of the fuel and is thus non-renewable. However, provided it can meet the sustainability criteria (acknowledging again that the details of such sustainability criteria for these fuels have not yet been established, including the GHG emissions calculation methodology), Lanzatech's ethanol could be considered a non-renewable low carbon fuel.

An important point for DfT to consider, related to the comments above on sustainable biofuels, is whether the share of the fuel which is renewable affects the level of support the fuel receives. At present, there are partially renewable fuels such as FAME which receive 1 full RTFC per litre under the RTFO, as a result of specific policy decisions regarding those fuels¹⁷. Other partially renewable fuels with a much lower 'renewable component' such as ETBE receive a partial RTFC based on the renewable content of the fuel. The treatment of partially renewable 'low carbon fuels' (i.e. partially renewable fuels without a biological component) in this respect needs to be considered – i.e. whether they would receive a *partial* RTFC based on the share of the fuel that is renewable or a full RTFC per litre supplied. Note that if the former is chosen, then a non-renewable low carbon fuel would receive 0 RTFCs per litre, even if it met the GHG saving requirement.

Non-renewable low carbon fuels are not currently eligible to count towards the RED target, as the fuel cannot be argued to contain 'energy from renewable sources' under the RED definition. However, given that these low carbon fuels could deliver material GHG savings, they could contribute to the FQD GHG target – and for that reason could be considered for support under the RTFO or a separate

¹⁶ See footnote 12 above – the details of the full sustainability requirements of non-biofuels have not yet been determined

¹⁷ Note that while Annex III of the RED (which gives the energy content of different fuels) indicates that fuels such as ETBE, MTBE and TAEE are partially renewable, it does not identify FAME and HVO as partially renewable (despite assumptions in the subsequent GHG calculations that fossil methanol and hydrogen are used in their production).

policy. If implemented, the latest proposed changes to Annex IX of the RED may also end up allowing some non-renewable low carbon fuels to (multiple) count towards to the RED target¹⁸.

Note that 'low carbon fuel' excludes fuels for which all of the hydrogen atoms in the fuel are classified as 'hydrogen from renewable sources other than biomass', as these fuels are RFNBOs. This means if the hydrogen atoms come from biomass feedstocks, the fuel remains as a low carbon fuel.

2.2.4 Renewable liquid or gaseous fuel of non-biological origin (RFNBO)

This definition adapts the version in the European Parliament proposal to exclude fuels derived from non-waste fossil carbon sources. The definition of RFNBO includes hydrogen from renewable energy sources (where there are no carbon atoms in the fuel), as well as cases where hydrogen from renewable energy sources is combined with CO₂ (from waste/residue fossil carbon sources or atmospheric/naturally-occurring carbon sources) to make various transport fuels. The carbon source must¹⁹ be CO₂ since other carbon compounds (e.g. CO, CH₄) will contribute towards the energy content of the fuel (chemical potential energy that is transferred into the fuel) – making the fuel either a fossil fuel, biofuel or low carbon fuel (dependent on the feedstock), instead of a RFNBO²⁰. CO₂ will not contribute to the energy content of the fuel, because it has a lower heating value of zero, and cannot be oxidised further.

In practice, because the CO₂ sources (if any are used) do not contribute any energy to the final fuel, all the hydrogen atoms in the fuel have to be generated using renewable energy sources (other than biomass) in order for the fuel to be wholly renewable, as well as from non-biological origin.

It is possible to argue that since such fuels can be conceived as renewable they should therefore be eligible to contribute to the RED transport target (as well as the FQD GHG target). This would mean that such fuels could in theory be considered for support under the RTFO. While strictly speaking the sustainability criteria set out in the Directive apply only to biofuels and bioliquids, it is assumed that some similar requirement to demonstrate sustainability would also be imposed on these fuels (acknowledging the details of such sustainability criteria for these fuels have not yet been set).

¹⁸ <http://www.europarl.europa.eu/sides/getDoc.do?type=REPORT&mode=XML&reference=A8-2015-0025&language=EN>

¹⁹ It could technically be possible to produce a RFNBO fuel from a RFNBO feedstock, but the original feedstock still must be CO₂

²⁰ Commission staff have indicated that CO₂ does not fall within the RED definition of 'biomass', hence a renewable fuel arising from a waste CO₂ stream could not be classified as a biofuel, even if the CO₂ were originally produced from e.g. a biomass power station. The fuel would be of non-biological origin, and hence a RFNBO. Similarly, a waste CO₂ stream that was originally produced from a coal power station does not make the fuel a fossil fuel. However, this relies on the CO₂ being classified as a feedstock and there being a system boundary between the CO₂ source (e.g. power station) and fuel production plant – if the CO₂ source (e.g. power station) and fuel production plant are combined within the same 'black box' system boundary, then CO₂ being produced as an intermediate is irrelevant, and the fuel will be a biofuel or a fossil fuel (depending on the inputs into the combined system).

2.3 Classification

With these definitions in mind it is possible to construct a flow chart for carbon-based fuels which allows for the classification of various emerging novel fuels based on their carbon source, hydrogen source and energy content. This is shown in Figure 1 below. The subsequent notes relating to the questions in the blue boxes assist the reader in applying the flow chart. Note that this flow chart should be used at the level of an administrative consignment of fuel (although in practice fuels coming from a single biofuel producer are likely to have a consistent classification). Note also that the flow chart does not distinguish between biofuels from waste and non-waste feedstocks, nor stipulate whether the carbon source is a waste fossil source or atmospheric/naturally occurring source. These issues are discussed in Section 2.4.

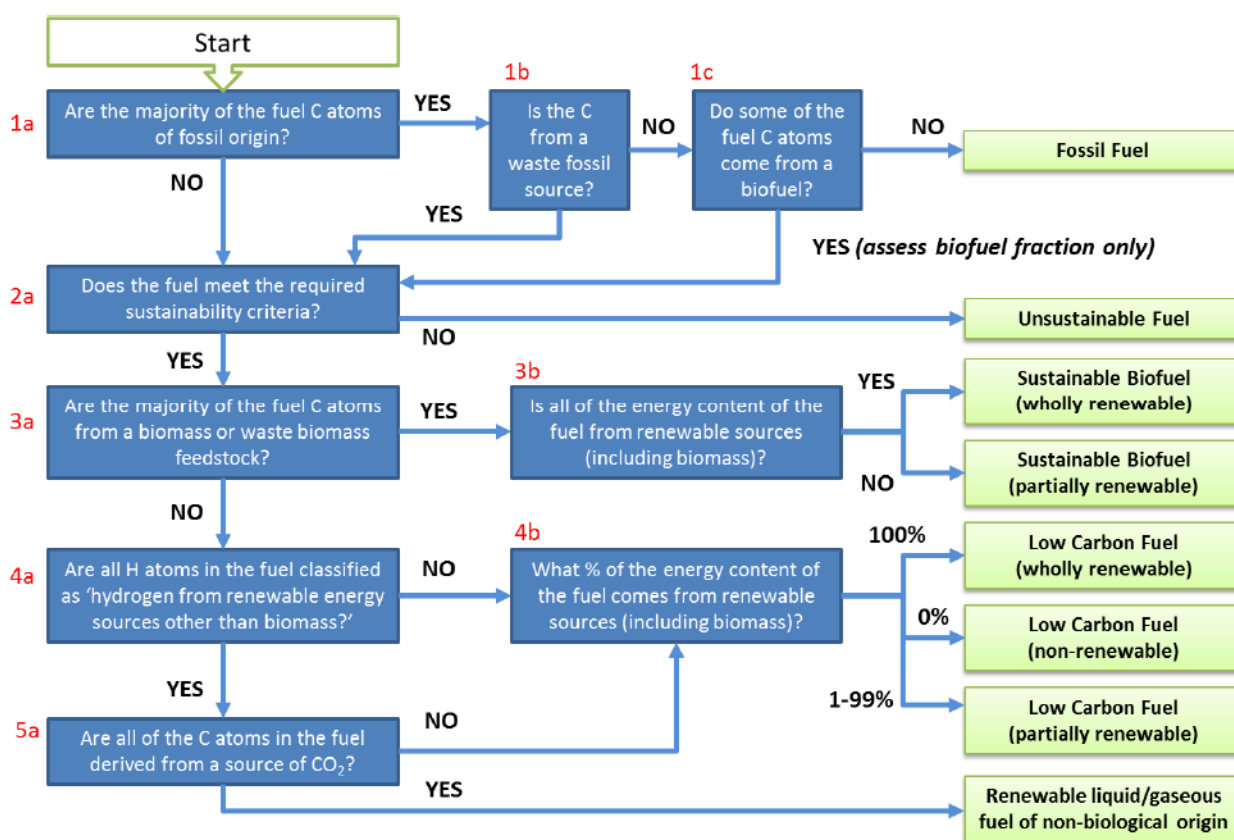


Figure 1: Fuel classification flow chart for all carbon-based fuels (i.e. excluding hydrogen)

Below, we discuss each of the decision boxes in Figure 1:

1a) The term 'majority' is used here since some biofuels (e.g. FAME) will contain some fossil carbon atoms. The answer to this question for oxygenates such as Bio-ETBE will be 'YES', while for fuels like FAME it will be 'NO.' This majority can be set at an explicit limit, e.g. 50%, if required

1b) Waste fossil carbon sources are not excluded at this stage

1c) This question is intended to separate pure fossil fuels from blended fuels such as ETBE/MTBE that use a biofuel feedstock. If the answer is 'YES' the reader is requested to assess only the biofuel fraction only (e.g. only the bio-ethanol part of ETBE)

2a) This is crucial in order for any fuel to be considered under the RED (and RTFO); however the details of the methodology for determining compliance are yet to be determined (e.g. unclear whether fuels from 'waste CO₂' should be exempt from the land criteria as for other fuels from wastes, and how the novel fuels should calculate their GHG emissions).

3a) Again the use of the term 'majority' is to account for fuels such as FAME. This question separates the biofuels from the other remaining fuels

3b) This separates wholly and partially renewable biofuels (it is impossible to have a non-renewable biofuel). FAME would be considered partially renewable due to the energy provided by the fossil methanol. Since for the oxygenates at this stage we are assessing only the biofuel fraction, these will be considered 'wholly renewable' (e.g. we are assessing the renewable bioethanol part of the ETBE)

4a) This must hold true in order for a fuel to be considered a renewable fuel of non-biological origin.

4b) This will determine whether the fuel is wholly, partially or non-renewable

5a) CO₂ will be the only carbon source at this point which will not contribute energy content to the fuel. Use of carbon monoxide, methane or even pure carbon char will result in the fuel being classified as a partially renewable low carbon fuel

Figure 2 below presents a similar flow chart for hydrogen fuel, to which the same principles apply.

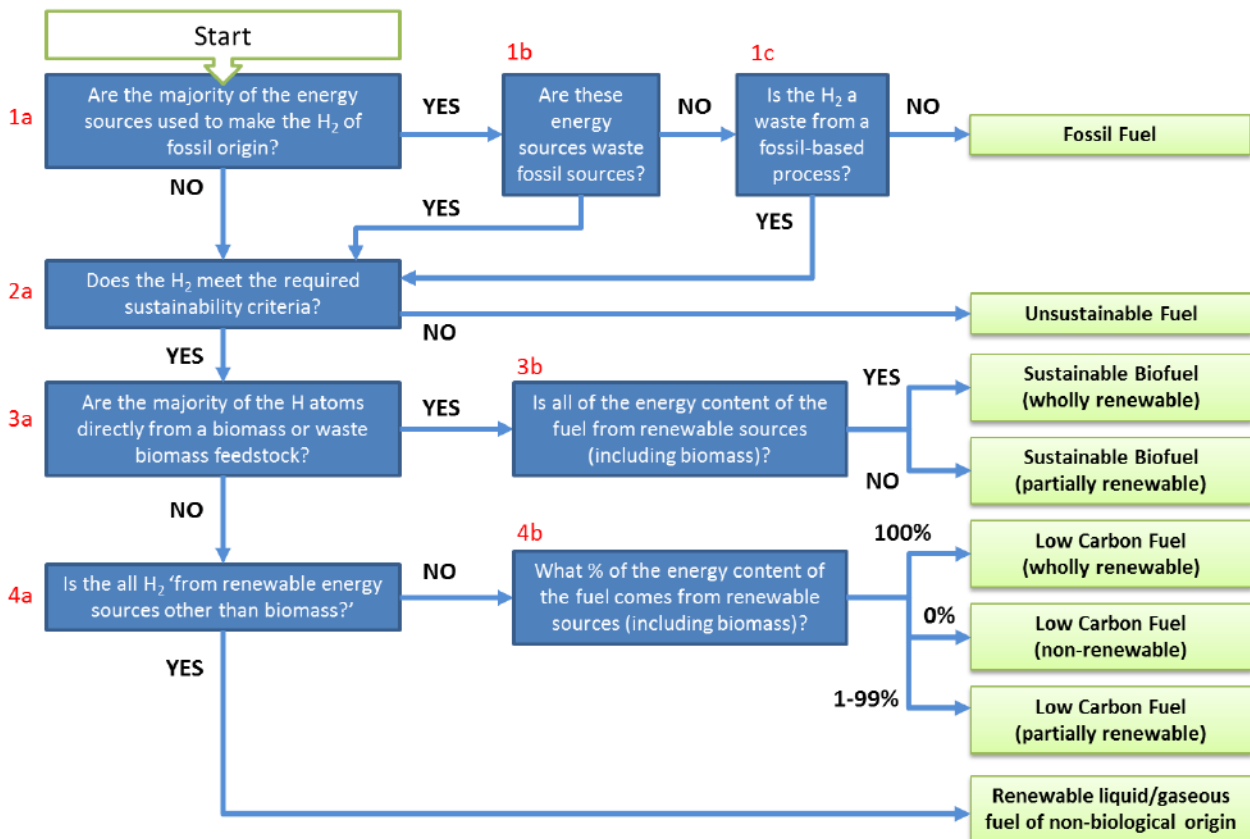


Figure 2: Fuel classification flow chart for hydrogen

2.3.1 Classification of mixed fuels

We note that this classification framework appears robust and simple to use when assessing a process with a single feedstock – for example, when making an individual fossil fuel, an individual biofuel (potentially with some fossil inputs), low carbon fuels (potentially with some fossil inputs) or an individual RFNBO (where the origin of any CO₂ does not matter). However, the current RTFO definitions of a partially renewable transport fuel only consider one ‘degree of freedom’ – wholly fossil fuel to wholly biofuel, due to using fossil or biomass feedstocks. With the addition of two new fuel categories (low carbon fuels and RFNBOs) and their new carbon and hydrogen sources as two further ‘degrees of freedom’, there are now many more possible combinations of the four fuel categories.

As well as the current definitions in the RTFO needing to change to incorporate these new fuel categories, DfT would also have to decide on how to treat mixed fuels that have a larger number of feedstocks. For example, a theoretical process could be envisaged that has to use 20% natural gas, 30% wood chips, 20% waste fossil carbon monoxide and 30% hydrogen from onsite wind-power electrolysis in order to derive a single consignment of transport fuel²¹. The classification flow chart in Figure 1 above would struggle to assign this as a single fuel category – depending on the exact fuel made and definitions of feedstock vs. process energy, this example would most likely be a partially renewable low carbon fuel – but there are clearly significant biofuel and RFNBO elements.

We can therefore see three possible approaches:

- For some of the mixed fuels, this could be resolved by having a very clear definition of the term feedstock, in order to select only one feedstock for the consignment, with the rest of the raw materials being considered as process inputs. In the example above, if wood chips in the were defined as the feedstock, and the natural gas, CO and H₂ as processing inputs, the fuel would end up classified as a partially renewable biofuel.
- In the absence of a clear definition of feedstock, or it being impossible to reduce to a single feedstock (e.g. carbon atoms from both the wood chips and CO make it into the fuel), then another solution could be to consider the categorisation of mixed fuels that are part-fossil, part-biofuel, part-low carbon fuel and part-RFBNO. Then, much like the RTFO currently does for biofuels, DfT could provide incentives in relation to the percentage share of each of the four fuel categories. It will be a policy decision for DfT to decide what percentage is large enough to revert to assigning a fuel a single label, rather than assigning parts. In the example above, the fuel might be awarded 30% biofuel, 20% low carbon fuel and 30% RFNBO credits.
- The final alternative is simply to stick with the single fuel categorisation in the above section, and accept that a majority (or lack of a majority) of feedstock atoms making it into the fuel is a good enough determinant for assessing the category of a fuel. The example fuel would therefore likely be a partially renewable low carbon fuel.

The definitions and GHG accounting rules that will be set up for the novel low carbon transport fuels in this paper need to be able to consider these mixed fuels – because although they may currently seem to be unlikely to be developed, depending on future policy choices, technology availability and market trends, these routes could become competitive. There is no guarantee that developers will always follow the simplest routes with fewest inputs, if future profitability can be found in these combination routes – particularly if one of the new fuel categories is more heavily incentivised than the other or than existing biofuels (or one of the new categories is not eligible under the RTFO).

²¹ At present, a consignment of transport fuel is defined based on a single feedstock, even though multiple raw materials / inputs can be included in the fuel production process

2.4 Carbon Sources

The definitions within the categories 'low carbon fuel' and RFNBO presented here do not distinguish between carbon that comes from a waste/residue fossil source, or an atmospheric/naturally occurring carbon source. When considering broadening the acceptable 'carbon-base' beyond biomass feedstock sources it is critical to understand what sustainability and other risks could arise. Figure 3 maps a variety of different fuels based on the potential sources of carbon and indicative embodied GHG emissions.

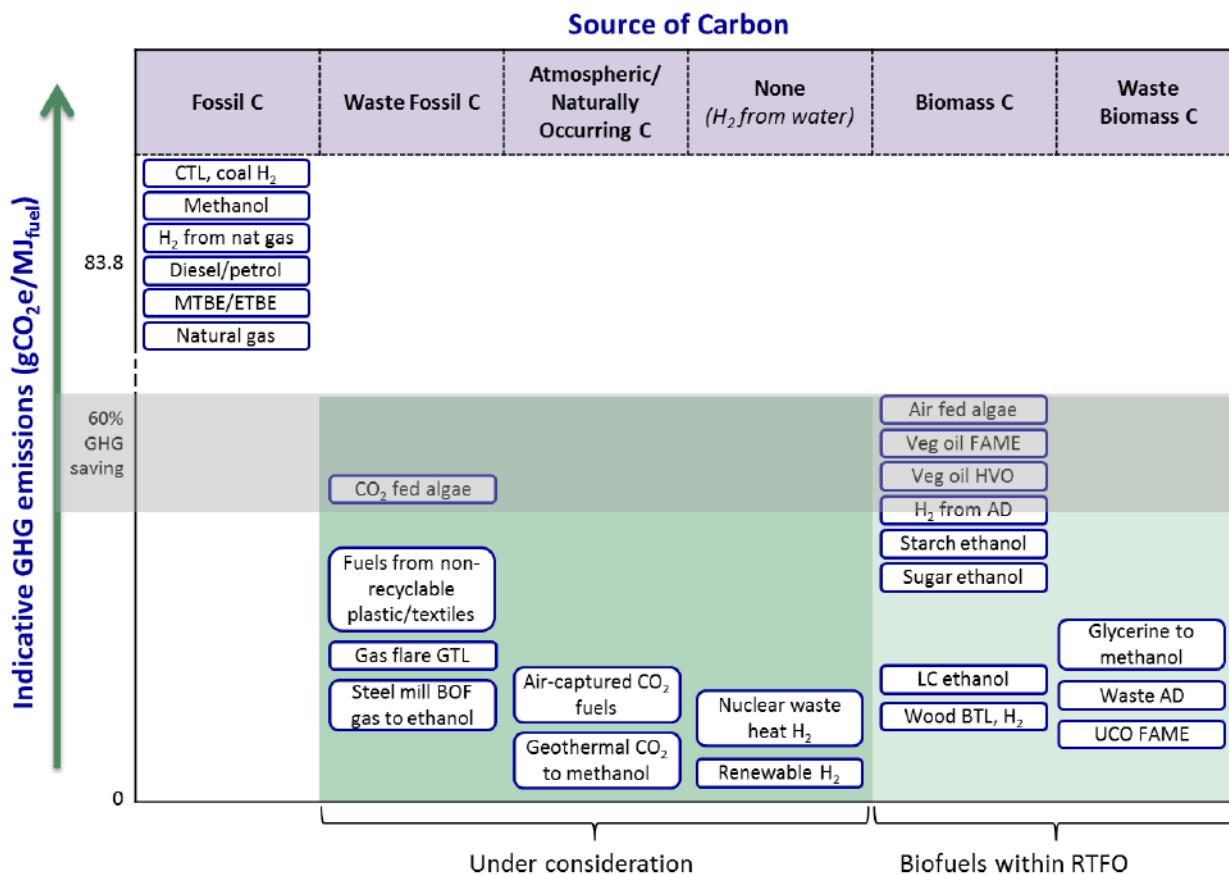


Figure 3: Fuels mapped based on carbon source and indicative GHG emissions.

Note the y-axis is not to scale, and this chart is not intended to present a 'GHG ranking' of the various fuels (the positioning is merely indicative)

The wholly/partially renewable biofuels in the light green segment in the bottom right-hand corner are those that are currently eligible for RTFCs (assuming they meet the broader sustainability criteria). The low carbon fuels and RFNBOs in the darker green segment represent those that could be considered in the future. Note that the lifecycle GHG emissions shown here are only indicative and could vary considerably for each fuel-type depending on the specific carbon source and process inputs used²².

The possible sustainability risks associated with these new categories are explored in Section 4 in order to understand whether expanding the carbon-base could lead to unintended negative consequences.

²² Some novel fuels could even have negative lifecycle GHG emissions, e.g. hydrogen derived from biomass with CCS

3 Overview of known examples of novel low carbon transport fuels

In this Section we highlight known examples of companies developing the types of fuels discussed in this paper.

It should be noted that many of the fuels being developed by the companies listed are at an early stage of development. Key parameters, including the carbon source, the hydrogen source and the energy source that make up the fuel, may therefore change as the technology and pilot plants are developed further. The examples cited are our current understanding of the fuels, technologies and plants being developed by these companies and the indicative classifications given in Table 1 (in line with Section 2 above) may therefore be subject to change. These classifications do not guarantee the final classification of the fuel produced by the companies listed, nor do they guarantee eligibility for support under the RTFO for the fuels produced by those companies or in those pilot plants. In addition, it is assumed that a prerequisite for support under the RTFO would be that fuels comply with the RED sustainability and GHG criteria (acknowledging that the GHG calculation methodology for these new fuels is yet to be established and that DfT may wish to impose a different GHG savings threshold).

Table 1: Examples of companies developing novel fuels grouped by indicative fuel classification (in line with Section 2)

Company	Fuel(s) produced	Carbon source	Hydrogen source	Energy source of fuel	Process	Stage of development	Capacity and location of operational plants
Renewable liquid or gaseous fuel of non-biological origin							
Air Fuel Synthesis (AFS) ¹	Methanol	CO ₂ from air or point sources	H ₂ O	Wind electricity	Electrolysis of H ₂ O and catalytic synthesis	Laboratory	Demonstrator unit commissioned in March 2012 with capacity of 5-10 litres per day 1 tonne per day (1,200 litres) plant now operational
Audi e-gas ²	H ₂ and synthetic natural gas	CO ₂ (not specified)	H ₂ O	Excess renewable (wind) electricity	Electrolysis of H ₂ O and methanisation	Demonstration	Plant in Werlte, Germany, 1,000 tonnes of e-gas per year, Start-up in 2013
Carbon Recycling International (CRI) ³	Methanol	CO ₂ from geothermal power plant – mix of naturally occurring and fossil (i.e. accelerated release from ground)	H ₂ O	Geothermal electricity	Electrolysis of H ₂ O and catalytic fuel synthesis	Large demonstration	5 million litres per year located in Svartsengi, Iceland Start-up Q4 2011 Aim is to scale up to 50 million litres per year
ClimeWorks ⁴	Synfuels (not specified)	CO ₂ from air	H ₂ O	Renewable electricity	H ₂ O	Laboratory	-
Dioxide materials ⁵	Synfuels (petrol, diesel, kerosene, industrial chemicals)	CO ₂ from point sources (power plants)	H ₂ O	Excess wind electricity	Electrolyser to convert CO ₂ into C ₁ building blocks and subsequent chemical conversion into synfuels using catalysts (metal and organic)	Laboratory	-
ITM Power P2G (Power-to-Gas) ⁶	H ₂ or synthetic natural gas	Not specified, potentially CO ₂ from biogas or CCS	H ₂ O	Excess renewable (wind) electricity	H ₂ production via PEM electrolysis and (depending on final fuel) methanisation	Demonstration	H ₂ gas grid injection in Schielestrasse, Frankfurt as part of Thüga Group project. RWE Deutschland plant in Ibbenbüren. Multiple other H ₂ electrolysers in EU/US (not grid injecting). Yet to demonstrate methanation at scale Isle of Wight H ₂ pilot.
Joule / Audi ⁷	Ethanol (Sunflow-E), Diesel (Sunflow-D)	CO ₂ from point sources (industrial facilities)	H ₂ O	Sunlight	Ethanol-producing micro-organisms (modified cyanobacterium) feeding off CO ₂	Demonstration	Hobbs, New Mexico Aim is to produce 25,000/15,000 gallons ethanol/diesel per acre per year at commercial scale

Company	Fuel(s) produced	Carbon source	Hydrogen source	Energy source of fuel	Process	Stage of development	Capacity and location of operational plants
Sandia National Laboratories (SNL) ⁸	"Sunshine to petrol" (including methanol, ethanol)	CO ₂ from air or point sources	H ₂ O	Solar heat	'Sunshine to petrol' – production of syngas from CO ₂ stream (concentrated solar thermochemical reaction to produce CO) and electrolysis of water	Experimental	-
Solar jet ⁹	Kerosene	CO ₂ from air	H ₂ O	Solar heat	Two-step solar thermochemical cycle based on non-stoichiometric ceria redox reactions using the Fischer-Tropsch process	Laboratory	-
Sunfire ¹⁰	Synfuels (petrol, diesel, kerosene, methanol)	CO ₂ (not specified, but assumed to be point sources)	H ₂ O via steam electrolysis	Renewable electricity	Electrolysis of H ₂ O and catalytic fuel synthesis	Laboratory	-
Low carbon fuel (non-renewable)							
Cynar ¹¹	Diesel, lite oil and kerosene	Non-recyclable waste plastics (Groups 4-7)			Pyrolysis	Large demonstration	Demonstration plant in Portlaoise, Ireland, Start-up in 2008 Commercial plants in Bristol, UK capacity of ~4 MLpa diesel; Almeria and Seville (2015), Spain
Lanzatech ¹²	Ethanol	CO from point sources, currently steel mills (possibly CO ₂ in future)	H ₂ O (H ₂ is fixed by microbes)	CO (fossil) waste gases from steel mills	Ethanol-producing micro-organisms feeding off CO	Demonstration	Shanghai, China at BaoSteel Steel Mill, 300 tonnes per year (100,000 gallons per year), Start-up 2012 Beijing, China at Shougang Steel Mill, 300 tonnes per year, Start-up 2013
PYReco ¹³	No.2 grade semi-refined diesel oil	Non-bio component of waste tyres			Pyrolysis (based on Metso tire pyrolysis patented process)	Pilot	Metso operate a pilot plant in Danville, Pennsylvania, 23 tonnes per day PYReco aims to build a commercial scale plant in Teesside, UK
Velocys waste-to-liquids ¹⁴	Synfuels (petrol, diesel, kerosene)	Non-bio component of MSW			Cracking to syngas, Fischer-Tropsch catalysis to produce long-chain hydrocarbons	Commercial	FT supplier to Solena Fuels plant (East London), planned to be EU's first commercial scale sustainable jet facility producing 50kt of kerosene, 50kt of FT diesel and naphtha (and renewable power), Aims to be operational in 2017
Velocys gas-to-liquids ¹⁴	Synfuels (petrol, diesel, jet)	Flared gas or 'problem' gas (stranded gas reserves from crude oil production, that would currently be re-injected)			Cracking to syngas, Fischer-Tropsch catalysis to produce long-chain hydrocarbons	Commercial	Supplying technology for a 1,000 bpd GTL plant for Calumet at its Karns City, PA site, planned to start in 2014

Table references:

1. <http://www.airfuelsynthesis.com/>
2. http://www.audi.com/com/brand/en/vorsprung_durch_technik/content/2013/10/energy-turnaround-in-the-tank.html
3. <http://www.carbonrecycling.is/>
4. <http://www.climeworks.com/>
5. <http://www.dioxidematerials.com/>
6. <http://www.itm-power.com/sectors/power-to-gas-energy-storage>
<http://www.itm-power.com/news-item/decc-funding-award-for-the-production-of-synthetic-methane>
7. <http://www.ioleunlimited.com/>
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14. <http://www.velocys.com/>

4 Risk identification and mitigation

When considering whether and how to extend support under the RTFO to cover these new classifications of fuel, it is important to first fully understand any associated risks, and hence whether extending support could lead to unintended negative consequences. Fuels that fall into the category 'fossil fuel' and 'unsustainable fuel' are not supported under the RTFO. 'Sustainable biofuels' are already supported under the RTFO today, as long as they can demonstrate that they meet the mandatory sustainability criteria on direct land-use and GHG saving. Although the RED land-use criteria and GHG threshold apply only to biofuels and bioliquids that are supplied under the Directive, it is recommended that DfT requires any other fuels supported under the RTFO to demonstrate that they meet *at least* the same sustainability criteria. Therefore, for the purpose of identifying risks, it is assumed that the same sustainability criteria would be applied to any new fuels supported under the RTFO, including the GHG thresholds and analogous rules on exemptions from the land-use criteria for non-land using fuels made from wastes or residues.

The focus in this Section is therefore on identifying any *additional* risks associated with the new classifications of 'low carbon fuel' and 'renewable liquid or gaseous fuel of non-biological origin'. The risks are considered according to the three defining characteristics of the fuels: their carbon source, their energy source and their hydrogen source.

The main carbon, energy and hydrogen sources are described in the following Sections, along with a brief description of the key risks associated with fuels from these sources and mitigation options that are recommended to DfT. Risks are summarised in Table 2 and associated recommendations are summarised in Table 3.

4.1 Carbon source

'Low carbon fuels' and 'Renewable liquid or gaseous fuels of non-biological origin' can be further sub-categorised according to whether the source of carbon is (primarily) from a waste/residue fossil source, or an atmospheric/naturally occurring carbon source, as illustrated in Figure 3.

Possible sources of waste/residue fossil carbon include:

- Waste fossil plastics, rubber and textiles that cannot be recycled. Note that these sources may also be combined as a mixed source, in the form of the non-biological component of municipal solid waste (MSW) or commercial & industrial (C&I) waste streams;
- Flared gas / problem gas;
- Industrial point source (e.g. steel mill), either within an emissions trading scheme (ETS) or not.

Possible sources of atmospheric/natural carbon²³ include:

- Air;
- Volcanic/geothermal vents/mofettes²⁴.

We exclude carbon from ocean/seas exchange of CO₂ with the atmosphere, along with soil respiration, decomposition and sequestration of greenhouse gases, since although these are relatively large flows of GHGs, they are far too disperse to collect. We also exclude soil carbon stocks and

²³ Note any carbon sources originating from biomass feedstock would be categorised under 'biofuel'.

²⁴ http://www.ieaghg.org/docs/general_publications/naturalreleases.pdf

methane hydrates – these are all also ‘natural’ sources of carbon, but would not be sustainable to exploit (as they would lead to accelerated climate change).

From a sustainability risk perspective, none of the sources of carbon listed above use land. Volcanic / geothermal vents / mofettes may take up a small amount of land, but it is not land that is currently used or could usefully be used for any other purpose, so land use change is not considered a risk. With the exception of air, all the sources of carbon could be considered waste materials, although some do have potential alternative uses, mainly for energy, but also enhanced oil recovery in the case of flared or problem gas. The use of CO₂ in air is considered to be net carbon neutral as the CO₂ captured and converted into fuel is released again on combustion. The GHG emissions associated with taking the CO₂ emissions from the air may be substantial, however, and would have to be included within the scope of the GHG calculation.

The main risks identified are:

- Non-biodegradable fossil plastics and textiles (e.g. waste tyres) are often burnt for energy recovery applications, but also commonly used for land reclamation or sent to landfill²⁵. Due to their non-biodegradable nature, these inert “storage” applications can provide a useful carbon sink for several hundreds of years and it is questionable whether it is positive from a climate perspective to turn such sources into fuels that will be burned and produce emissions in a much shorter timeframe.

In this case a policy choice would need to be made by DfT, in consultation with DECC and Defra, whether to support such fuels and how to appropriately account for any GHG savings from the use of such fuels.

- In the case of flared/problem gas and industrial point sources of gas, DfT would need to ensure that the emissions of such gases are not accelerated by offering such fuels support, and that GHG savings associated with the low carbon fuel are not claimed twice by also claiming an emission reduction in the jurisdiction in which the point source of emissions is regulated. This could either occur within the EU in the EU ETS, or in an emissions trading system outside the EU. For example, in the case of a steel mill in China, it would be important to ensure that emissions savings are not claimed within the Chinese ETS as well as an emissions saving being claimed in the RTFO for the fuel. In addition, DfT would want to avoid setting incentives at a level that would be considered to support fuel production from fossil fuel industrial point sources, thereby extending the life of fossil based conversion facilities and making fossil resource extraction more economic.

For fossil gases within an emissions trading system, we recommend that DfT requires independently verified evidence (as part of the carbon and sustainability reporting) that the emissions saving has not been claimed twice. In addition, we recommend that DfT carefully considers an appropriate level of support for such fuels, if they are supported, to avoid accelerating the use of fossil fuels to produce the ‘waste’ gases.

- Similarly, even within the EU, it would be important to ensure that emissions savings are not claimed twice under the EU ETS and under the FQD. Upstream emissions from flared gas are currently not included within the scope of the FQD, so it would be important to ensure that any

²⁵ Note that some waste fossil plastics are biodegradable (and vice versa, some bio-based plastics are not biodegradable). The ability of plastics to rot / be broken down is largely unrelated to the original source of the carbon atoms. Biodegradable waste fossil plastics do not have the same sustainability risk, as they would have decomposed and produced emissions to atmosphere (potentially highly potent methane) in a short timeframe anyway – hence turning them into transport fuel could actually be highly beneficial (as the carbon only gets emitted as CO₂). This counterfactual argument is however outside of the scope of RED accounting methodology

associated GHG savings are accounted for in a consistent manner within the RTFO that does not lead to UK mis-reporting under the FQD.

This risk would be mitigated by further work to ensure that DfT can put in place appropriate GHG accounting rules for this situation.

- For the use of CO₂ from volcanic/geothermal vents/mofettes, it is important to understand the extent to which the emission of any of the gases used is being accelerated. If this is the case, any accelerated emissions must be included within the scope of the GHG calculation. While this sounds straightforward, there is currently no methodology for how to account for these emissions.

Further research is needed to understand the uncertainty around any accelerated emissions. In the meantime DfT is recommended to set out a conservative GHG reporting approach for such fuels to ensure that any emissions savings are not over-stated. Any accelerated emissions must be included within the GHG calculation scope.

4.2 Energy source

There are a large number of potential energy sources for these fuels (noting that the term 'energy source' in this context also needs to be more precisely defined, see discussion in Section 2.2). The energy sources in the examples of companies and fuels identified in Section 3 are:

- Renewable heat or electricity (non-bio);
- Biomass heat or electricity;
- Waste fossil carbon monoxide (steel mill basic oxygen furnace (BOF) gas);
- Excess (waste) industrial heat;
- Waste hydrocarbons;
 - Plastics / textiles / non-biological MSW;
 - Flared gas / problem gas.

The key risks identified are:

- If a fuel is supported solely on the basis that it is from a renewable source, then providing evidence of the source of renewable heat or electricity becomes paramount to avoid any fraudulent claiming.

We recommend that DfT requires evidence of the renewable heat or electricity source to be included in the scope of the independent verification (as part of the carbon and sustainability reporting). Such evidence would require an appropriate traceability system to be in place. Evidence could include, for example, contracts with the renewable energy generator or guarantees of origin (if the RED allows this)²⁶

²⁶ There is one major caveat here, in that the GHG accounting rules for low carbon fuels and RFNBOs have not yet been established. If the exact same RED approach for biofuels is utilised, e.g. **under the ILUC proposals**, Annex V.C.11 would appear to forbid the fuel plant from importing power on a "green" tariff in order to use a renewable GHG intensity factor. BioGrace states "It is not allowed to decrease the GHG emissions of electricity used by buying green certificates from a Green certificate scheme" <http://tinyurl.com/kroxwmp>. All biofuel plants that import power from the grid have to use an average grid factor for their defined region (usually country level) – not insignificant in the UK. A renewables GHG factor can only be used if the renewable generation is onsite, or on a private wire network (i.e. not connected to the grid). However, if the UK/EC does **not** copy over Annex V.C.11 when establishing GHG accounting rules for low carbon fuels and RFNBOs, then the renewable energy guarantees of origin (REGO) approach, as used in a few Member States, could be entirely valid. DECC have a current call for evidence out on a 'green' hydrogen standard, touching on some of these same issues – so the UK approach is still uncertain. Whilst modest for most biofuels, the grid vs. renewable GHG difference will be vital for most RFNBO plants due to their large power use.

- Additionally, DfT may wish to ensure that the transport fuel is not subsidised in addition to the renewable heat or electricity receiving subsidies. This is an important policy risk to mitigate as renewable heat and power subsidies can be significant.

Again, we recommend that DfT requires such evidence to be included in the scope of the independent verification, as part of the carbon and sustainability reporting. The nature of the evidence required will depend on where the renewable heat or power is generated. In the UK, for example, DfT may wish to ensure that Renewables Obligation Certificates (ROCs) / Levy Exemption Certificates (LECs), or the Renewable Heat Incentive (RHI) equivalent, are retired before the transport fuel is granted supported under the RTFO.

- Sustainability of biomass electricity or heat is currently not taken into account if biomass is used as a processing energy input for biofuel, however if a fuel is supported *purely* on the basis that it is produced from biomass electricity or heat, there may be a question of how the sustainability of any biomass input should be ensured. Depending on the legislative environment that the biomass heat or power project is operating in, policy mechanisms may or may not be in place to ensure the sustainability of the biomass used.
 - If the biomass electricity or heat is generated in the EU, the European Commission has made an assessment and judged that there is currently no need for EU-wide sustainability criteria. This may be reviewed in future and some Member States – the UK included – have introduced sustainability requirements that would apply. In the UK, for example, the Renewables Obligation (electricity) and Renewable Heat Incentive (heat) both include sustainability criteria which are intended to become mandatory from 1 October 2015. The sustainability criteria are based on the RED criteria for non-wood-based fuels and on the UK Timber Standard (which includes requirements on sustainable forest management) for wood fuels.
 - If the biomass electricity or heat is generated outside the EU, the sustainability assurance will depend on the national legislation.

The sustainability of biomass used for heat and power in such projects is something that DfT may wish to keep under review. However, currently the fuels that are produced using renewable electricity or heat are only commercially viable because they are using abundant renewable energy sources, such as geothermal electricity in Iceland. Biomass electricity and heat are, by comparison, currently relatively expensive options, so the risk that a project is using significant biomass as a process energy input is considered low for the foreseeable future. Such a project would be more likely to use any biomass electricity or heat directly, rather than using it to create a transport fuel.

We nevertheless recommend that DfT monitors the use of biomass as an energy source, in the case that fuel is supported purely on the basis that it is produced from biomass electricity or heat. DfT is recommended to ask fuel suppliers to report certain basic information about the biomass projects that generated the input energy, e.g. country of the project, to enable them to do this.

4.3 Hydrogen source

The sources of hydrogen identified in the known examples of companies and fuels in Section 3 are:

- Water;
- Waste fossil hydrocarbons;
 - Plastics / textiles / non-biological MSW;
 - Flared gas / problem gas;
- Biomass²⁷

Where the source of hydrogen is a hydrocarbon or biomass, this is also the source of energy in the fuel, so we do not consider it further as a risk associated with the source of hydrogen.

Where the source of hydrogen is water, a potential risk could arise if projects are using significant quantities of water in areas of water scarcity. Naturally, companies should ensure responsible water use, avoiding contributing to water contamination and avoiding the use of water in areas of water scarcity. This is a potential sustainability impact that policy makers may wish to take into account in the future, although we are not aware of any of the current projects being developed in areas of water scarcity, so the risk is considered to be low. Water impacts are included in the RTFO Biofuel Sustainability Standard criteria and indicators, however in the RED they are included in the criteria that it is not mandatory for economic operators to address. It may therefore be challenging from a legislative perspective for DfT to address water impacts in a mandatory way within the current RED framework.

We therefore recommend that in the first instance DfT asks fuel suppliers to report basic information about relevant projects, such as the location of the project, to enable the monitoring of whether projects are being developed in areas of water scarcity or stress.

In terms of the GHG emissions, we recommend that the process energy inputs to produce the H₂ from water are included in the scope of the GHG calculation.

4.4 Overview of risks

This Section shows an overview of the risks identified, with Table 2 giving an overview of the risks per carbon, energy and hydrogen source and Table 3 giving an overview of the mitigation actions recommended to DfT.

As described in Table 2 below, the new types of fuel do not use land, so land-use change risks do not apply. They are often from sources that can be considered wastes, which presents similar risks to those biofuels from waste materials supported under the RTFO today. Those risks require careful monitoring, but they are similar in nature to the risks already monitored and managed by the RTFO unit.

The additional risks identified will need careful consideration to mitigate, and some will require further research. However no 'show-stoppers' are identified. The nature of the risks and mitigation options identified are in general similar to the nature of risks managed under the RTFO today. A summary of the recommendations to DfT to address key risks and uncertainties is shown in Table 3.

²⁷ Note that biomass can be the source of hydrogen without the final fuel necessarily being a biofuel (e.g. H₂ from AD combined with waste fossil CO₂). Under the classification framework in this paper, this would likely be a low carbon fuel, as although the carbon in the fuel is not from biomass feedstocks, the hydrogen comes from biomass, so the fuel cannot be a RFNBO.

Table 2: Assessment of risks associated with novel fuels (bold text indicates the presence of a key risk)

	Does it use land? (Sustainability and ILUC)	Is it a waste/residue?	Are there (current) alternative uses? (indirect effects)	GHG / policy double claiming risk	Fraud risk
Source of waste/residue fossil carbon					
Non-recyclable waste fossil plastic/rubber/textiles (non-biological MSW/C&I)	No	Yes	Combustion, landfill (sequestration)		Risk if it is not a true waste, intending to discard (e.g. could have been recycled)
Flared gas / problem gas	No	Yes	Enhanced oil recovery	Claiming under both ETS and for low carbon fuel (or FQD) Extending lifetime of fossil assets	
Waste industrial carbon point source (in ETS or non-ETS)	No	Yes	Yes – heat and power (generally low efficiency)	Claiming under both ETS and for low carbon fuel (or FQD) Extending lifetime of fossil assets	Risk if it is not a true waste, intending to discard. Avoid intentional burning of fossil fuel to generate ‘waste’ emissions.
Source of atmospheric / natural carbon					
Air	No	No	No		
Volcanic/ geothermal vents	No (not useable land)	Yes?	?	Any accelerated release of emissions must be included in GHG scope	
Energy source					
Renewable heat or electricity (non-bioenergy)	Use of land is dependent on technology type	No	Yes	Claiming support for renewable electricity/heat and fuel Buying a “green” tariff to use a zero GHG factor – could potentially be against RED V.C.11	Need to prove use of renewable heat or electricity that has not been supported
Biomass heat or electricity	Possible	Possible	Possible	Claiming support for renewable electricity/heat and fuel Buying a “green” tariff to use a zero GHG factor – could potentially be against RED V.C.11	Need to prove use of renewable heat or electricity that has not been supported
Waste industrial carbon point source (in ETS or non-ETS)	See Waste industrial carbon point source row above				
Excess (waste) industrial heat	No	Yes	No		Use of non-excess (waste) industrial heat
Waste hydrocarbons e.g. plastics, flared gas	See Waste plastics or Flared gas rows above				

Table 3: Summary of recommendations to address key risks and uncertainties

Risk	Recommendation
Non-biodegradable plastics (e.g. waste tyres) can provide a carbon sink if used for land reclamation / landfill.	Policy choice is required (DfT, DECC, Defra) whether to support such fuels and how to appropriately account for any GHG savings.
For flared/problem gas and industrial point source gases, it is important to ensure that GHG savings are not claimed twice at the industrial point source and from the use of the fuel in the RTFO.	Require independently verified evidence (as part of the carbon and sustainability reporting) that the GHG saving has not been claimed twice. Additionally DfT should carefully consider the appropriate level of support for such fuels, if they are supported, to avoid accelerating the use of fossil fuels to produce the 'waste' gases and extending fossil asset lifetimes
Upstream emissions from flaring are not included with the current scope of the FQD.	Further work on GHG accounting methodology for RED and FQD to ensure appropriate GHG accounting rules are put in place for this situation.
For CO ₂ from volcanic/geothermal vents, it is important to understand the extent to which the emission of any of the gases used is being accelerated.	Further research needed to understand the uncertainty around any accelerated emissions. In the meantime conservative emission factors could be developed. Any accelerated emissions <u>must</u> be included within the scope of the GHG calculation.
If a fuel is supported solely on the basis that it is from a renewable source, then providing evidence of the source of renewable heat or electricity becomes paramount to avoid any fraudulent claiming.	Evidence of the renewable energy source should be included in the scope of the independent verification (as part of the carbon and sustainability reporting) ²⁸ .
Ensure that the fuel is not subsidised in addition to the renewable heat or electricity receiving subsidies.	Important policy risk. Evidence that renewable subsidy has not already been claimed should be included in the scope of the independent verification (as part of the carbon and sustainability reporting).
Sustainability of biomass electricity and heat is currently not taken into account if biomass is used as a processing energy input for biofuel, however if a fuel is supported <i>purely</i> on the basis that it is produced from biomass electricity, there may be a question of how the sustainability of any biomass used to generate the electricity input should be ensured.	Considered low risk. DfT recommended to collect basic information to enable monitoring of sustainability of biomass used for heat and power inputs.
Where the source of hydrogen is water, companies should ensure responsible water use, avoiding contributing to water contamination and avoiding the use of water in areas of water scarcity.	Considered low risk. DfT recommended to monitor whether projects are being developed in areas of water scarcity or stress.
Process energy inputs to produce H ₂ from water should be included in the scope of the GHG calculation.	Inclusion in GHG calculation .

²⁸ Note that the RED Annex V, Part C.11 states that biofuel production plants importing electricity from the grid have to use a country average electricity carbon intensity in their processing input GHG calculations – it does not allow the plant to buy 'guarantees of origin' for renewable electricity from a generator for the purposes of improving transport fuel GHG reporting. If these rules were to also apply to low carbon fuels and RFNBOs (as suggested by the new RED proposals with Annex IX), it could have a dramatic impact on their GHG intensities, and could disqualify most RFNBOs as they would no longer be wholly renewable (unless they used onsite/off-grid renewable power).

5 Practical implications of expanding the RTFO

The practical implications of expanding the RTFO to encompass new fuels (or introducing an equivalent policy mechanism) must be considered carefully. Introducing a new suite of fuels with different characteristics and sustainability risks into the RTFO raises several important practical questions and elements of the existing legislation and guidance for economic operators that would need to be updated. Some noteworthy considerations are briefly summarised below:

- **Type and level of support:**
 - DfT will need to decide which categories of novel low carbon transport fuels should be supported (RFNBOs and/or Low carbon fuels), and whether they should be supported under the RTFO, or under a different mechanism.
 - As noted in Section 2.2.3, an important consideration will be whether or not differential support is given to fuels based on the portion of the fuel classified as 'renewable' under the proposed framework. Partially renewable fuels already receive the same level of support as wholly renewable fuels under the RTFO. Regardless, non-renewable fuels could still potentially count towards the FQD even if they cannot count towards the RED.
 - Many of the new fuels heavily interact with the electricity and heat sectors, and hence new transport fuel policies will need to be carefully designed in conjunction with other government departments (such as DECC) to maintain an overall holistic approach to GHG emission reduction across the whole of the energy sector.
- **GHG calculation methodology:** A new GHG calculation methodology will need to be defined for non-biofuels. This is not trivial, given that there is currently no definition of 'raw material' in the RED. Defining raw material is crucial in order to distinguish between what is a feedstock and what is a processing input. A new methodology would need to establish whether inputs such as renewable electricity and carbon dioxide are considered to be feedstocks or processing inputs to allow reporting parties to correctly define their biofuel consignment. This could also require an update to the *UK Biofuels Carbon Calculator*²⁹.
- **Land-related sustainability criteria:** For process renewable electricity or heat used in fuel production there are currently no specific land-related sustainability requirements imposed under the RTFO (biodiversity and carbon stock requirements are imposed on the raw material only). As noted in Section 4.2, there could potentially be a risk if renewable power produced from biomass is used as a process fuel, in the absence of sustainability criteria for bio-electricity in the country of production. The practicalities and relevance of introducing additional land-related sustainability criteria for electricity need to be weighed up.
- **Extending the scope of carbon and sustainability reporting:** As noted in Section 4, there are several risks that should be mitigated by extending the scope of reporting to DfT by economic operators, for example providing evidence of a renewable source of electricity/heat and evidence that renewable energy has not already received subsidies in the event that a fuel is supported solely on the basis that it is from a renewable source.
- **Double counting for wastes/novel fuels:** Consideration needs to be given to whether renewable fuels derived from waste fossil CO₂ sources are deemed to be classified as fuels from waste and thus double count towards the RED target. This could potentially open up a perverse incentive, so some caution is required.

²⁹ <http://bit.ly/1i7vj1S>

6 Conclusions

An emerging class of interesting new fuels offer potential for substituting conventional fossil fuels with alternatives which can deliver high GHG savings whilst maintaining minimal land-use impacts. There is a good case for considering the introduction of these fuels within the scope of the RTFO or a similar policy mechanism; however, there are several important issues arising from this which have been considered in this paper. In summary:

- A clear and consistent set of **definitions** for fuels and technical terms is critical when considering new fuels. There is an absence of definitions of important terms used in the context of the RED (e.g. renewable, raw material, energy content). It is important to ensure there is alignment with the European interpretation of these terms. Within the classification framework outlined in this paper there is still a need to further develop several definitions, in particular those for 'energy content' and 'waste' (especially in the context of a fossil waste).
- It is crucial to consider the **policy goal** of the RTFO if it were to be extended to encompass new fuels – is it to support truly renewable fuels and meet the RED target, or is it to support low carbon fuels and help decarbonise road transport (i.e. contribute to the policy goals of the FQD)? It is likely that only fuels classified as renewable will be eligible to contribute to the UK's RED transport target, but it is important to also consider policy goals beyond 2020.
- Supporting fuels based on '**renewability**' can lead to practical complications – there remain questions as to the level of support (or proportion of certificates) that new types of partially (or non-) renewable fuels ought to receive, given that currently some partially renewable fuels are deemed to be wholly renewable under the RTFO order. Rewarding fuels based on their GHG emission savings might allow for a more consistent approach (provided other sustainability criteria are met).
- Any fuels supported under the RTFO should be required to meet at least the same, or equivalent, **sustainability criteria**. This should be based on RED mandatory criteria, with possible additional requirements to mitigate any different risks associated with the new fuels.
- There are lots of promising fuels using **feedstocks other than biomass**. Like any new 'feedstock' there are possible sustainability risks but no show-stopper concerns were identified. Most risks identified can be mitigated by the inclusion of additional evidence within the scope of the annual independent carbon and sustainability verification, or by monitoring of meta-data by DfT. There are, however, several unresolved questions regarding implementation, including the GHG accounting approach for several of the fuels, which would require further development, and providing evidence of the use of renewable energy if a fuel is supported solely on the basis that it is produced from renewable energy sources.
- Support for these new fuels could be provided under the RTFO, but could also to some extent be provided through other mechanisms, such as **differentiated fuel duty**, particularly if a fuel may not be counted towards RED or FQD targets and as such a role for that fuel within the RTFO was not seen as appropriate.
- While this paper has focussed on the possible risks and challenges, it is important to emphasise the **positive attributes** of many of the new fuels discussed here. Several fuels have demonstrated significant GHG savings with no negative land-use impacts, and represent a value-added use of wastes and residues. Many of these fuels represent a sustainable means of displacing fossil fuel demand without requiring adaptations to vehicle technology. The positive impacts of displacing fossil fuels with such alternatives should not be overlooked.