Department for Transport

Annex A
Renewable Transport Fuel Obligations Cost Benefit Analysis

Moving Britain Ahead

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Annex A: Cost Benefit Analysis

A.1 When responding to the consultation, please comment on the analysis of costs and benefits, giving supporting evidence wherever possible.

A.2 Please also suggest any alternative methods for reaching the objective and highlight any possible unintended consequences of the policy, and practical enforcement or implementation issues.

1. Executive summary

This consultation proposes policy options for amending the RTFO in order to contribute to meeting future carbon budgets. For the purposes of this cost benefit analysis (CBA), we focus on the proposed policy changes with the highest expected impacts, namely the increase in the RTFO obligation, the level of the crop cap and which fuels qualify for the development fuel sub-target. To illustrate the expected impacts of these, we compare three policy scenarios (options) against a do-nothing baseline (see Table 1: Summary of options).

1.1 To ensure long-term carbon savings and investor certainty, all three options propose to set RTFO obligation levels from 2017 to 2030 and the costs and benefits are estimated for this time period. All three options also contibute to meeting the UK's third Carbon Budget (2018-2022) and the amended Fuel Quality Directive as well as compliance with the EU Renewable Energy Directive, as amended. They also introduce a sub-target to support fuels made from specific kinds of wastes and a crop cap. The options differ in two key points: a) the level of the crop cap and b) which fuels qualify for the sub-target for advanced renewable fuels.

Table 1: Summary of options

	Sub-target	Approach to crop-based renewable fuels (% total fuel volume)
Option 1	Broad definition	Increase use of crops (up to 7%)
Option 2 (preferred)	Fuel-specific	Maintain current crop use (up to 2%)
Option 3	Fuel-specific	Phase out crop use (0%)

1.2 As estimated in this analysis (see table 2), the proposed measures are expected to add slightly to fuel pump prices, though any increase is more than offset by improvements in vehicle efficiency in recent years, which has been supported by government regulations.[1] The total cost in 2020 is estimated to be £332m (0.9 ppl) for option 1, £366m (1 ppl) for the recommended option 2, and £554m (1.6 ppl) for option 3. These cost estimates are driven by the expected

[1] We estimate that the average petrol car on the road is around 8% more fuel efficient in 2016 than the average in 2009. Given petrol prices around 110ppl at the pump this fuel saving reduces driving costs by the equivalent of 9ppl.

price spreads between fossil fuels and renewable fuels in global markets. However, as these cost projections are inherently uncertain, alternative market price scenarios have been modelled which provide a wider range of cost estimates (0.3 to 2.4 ppl or £113m to £729m in total, in 2020).

1.3 Option 1 is expected to cost least because moving from option 1 to 2, and from option 2 to 3 results in an increasing emphasis on less carbon-intensive fuels, which may be more expensive to supply, especially as demand increases. Option 1, however leaves open the possibility that large amounts of crop biodiesel could be used in the UK, with the potential associated impacts on indirect land use change (ILUC), deforestation and food prices.

1.4 Option 2 is our preferred option, since it incentivises the development of a new industry supplying advanced transport fuels which we expect to play an important role in decarbonising transport in the longer term. These fuels are important for our strategic direction and are suitable for aviation and heavy goods vehicles. This option also supports suppliers of the most sustainable fuel currently available - the waste biofuel industry - whilst maintaining an important market for existing UK crop ethanol producers.

1.5 Option 3 would achieve higher carbon savings still and further accelerate the move to long-term sustainable fuels, phasing out all crop-derived fuels by 2020. However, it would also be expected to jeopardise the UK ethanol industry and is also expected to be the most expensive.

1.6 All options increase the demand for biofuels. Currently, the majority of biofuels used in the UK are also processed in the UK and we estimate that this adds at least £60 million per year to the UK economy (net value added). We expect the proposed policy options to increase this contribution and estimates are included in table 3 below under 'Present value benefits'.

Table 2: 2020 pump price impact, and carbon abatement cost

Costs are additional to baseline in 2020, 2015 prices	2020 Cost impact, £m (range)	2020 Pump price impact, ppl (range)	2020 Crop share (% by volume)	2020 GHG savings[2] ($MtCO_2e$)	Abatement cost (£/tCO_2e) in 2020
Option 1	332 (113- 697)	0.9 (0.3-1.9)	2.54% (0-7%)	2.3	142 (48-298)
Option 2	366 (143- 729)	1.0 (0.4-2.0)	2% (0-2%)	2.7	137 (53-273)
Option 3	554 (331- 729)	1.6 (0.9-2.1)	0%	2.9	193 (115-254)

[2] GHG estimates take into account lifecycle emissions (e.g. agricultural, processing and transport emissions) and estimated impacts of indirect land use change (ILUC)

Table 3: Summary of present value estimates (2017-2030)

Additional to baseline, 2015 prices	Total additional carbon savings ($MtCO_2e$)	Present value benefits (£m)	Present value costs estimate (£m)	Average abatement cost present value (£/tCO_2e) 2017-30	Present value costs (£m) range	Net present value (£m) range	Net present value (£m) central estimate
Option 1	30.3	1980	2536	87	848 to 5733	1132 to -3753	-556
Option 2	33.6	2303	3107	95	1213 to 6313	1090 to -4011	-804
Option 3	35.2	2299	4405	124	2623 to 5976	-324 to -3677	-2106

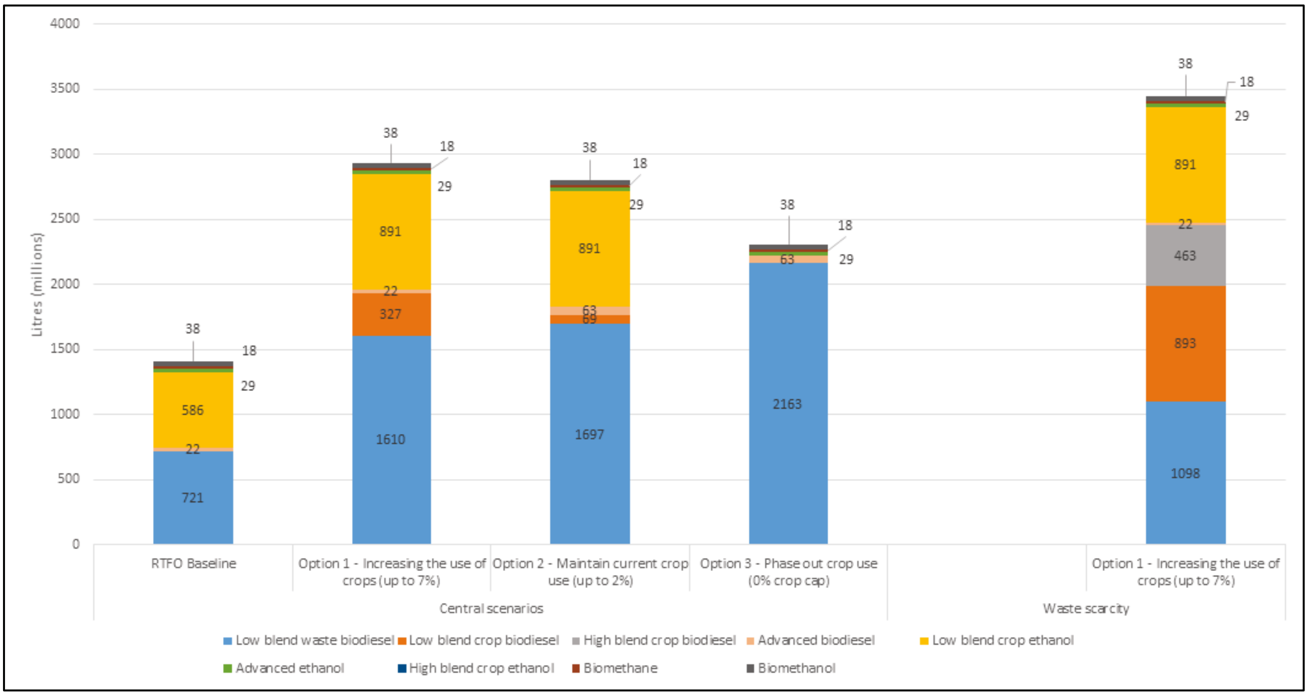
1.7 The central net present value (NPV) estimates are negative, since we expect the cost of renewable fuels to exceed the value of the benefits (carbon savings and GDP benefits associated with domestic production). This holds true under the Government's published central and low non-traded carbon value projections.[3] When we use the high carbon value projections for sensitivity analysis, the NPVs are still negative but are close to zero.

1.8 The central scenario assumes high levels of waste availability for all three policy options, which leads to a maximum expected crop share of only 2.54% by volume in 2020. However, it is important to note that under policy option 1, a much higher uptake of crop derived fuels, and especially crop biodiesel, is possible. We have addressed this as a sensitivity with an illustrative scenario where waste derived biodiesel becomes scarce and expensive at relatively low levels of supply, 1.1 billion litres or 1.5 times current supply, and significant amounts of high-blend crop biodiesel are also used to meet the obligation.

1.9 Table 3 above shows the expected impacts over the duration of the policy. The range of net present value estimates are based on three different long-term price scenarios (driven by global markets).

[3] The non-traded carbon values represent the Government's estimate of the marginal global cost of reducing a tonne of carbon in each year consistent with global climate goals.

Figure 1: Summary of renewable fuels supplied and abatement cost in 2020 under different policy options, central assumptions (left) and waste scarcity (right)



Carbon abatement cost £/tCO_2e in 2020 (2015 prices)				
135	142	137	193	262

1.10 Figure 1[4] summarises the different impacts, in 2020 only, on fuel used under the different policy scenarios. It also highlights the risk of high crop biodiesel uptake, which would lead to significantly lower carbon savings and higher carbon abatement cost for option 1, which could occur for example if waste biodiesel prices are high due to high global demand and fuel suppliers chose to blend large volumes of crop biodiesel instead.

1.11 If waste biodiesel becomes significantly more expensive in the run-up to 2020, the cost impact of all policy options increases, while GHG savings will fall only under policy option 1, which means carbon abatement cost would increase to a greater degree under policy 1. Further details of these sensitivities can be found in section 5, section 6 and section 7.

[4] NB - costs and GHG savings for Options 1, 2 and 3 are those additional to the baseline. Cost estimates use central cost projections, except for the illustrative scenario shown on the right, which addresses the possibility that waste biodiesel becomes more expensive, for baseline supply and for additional supply under policy option 1, which increases costs and also increases the use of crop biodiesel.

2. Full list of questions

For each of the following questions, please set out the reasons for your answers, including the impacts of any alternative that you may propose and any anticipated implications. Please also provide any supporting evidence you may have.

- Q.45: Do you have any evidence on the supply cost of 'development fuels' or any other evidence that could inform the level of the buy-out price?
- Q.46: Do you agree with the approach taken to calulating net value added to the economy by UK biofuel production?
- Q.47: Do you have any additional evidence we should consider in estimating the costs and benefits of the policy options?
- Q.48: Do you have any evidence of waste feedstock availability to 2020 and how markets are likely to react to increased demand in the run up to 2020?
- Q.49: Do you have any additional evidence regarding expected future supply cost of renewable fuels, and specifically of waste biodiesel?
- Q.50: Do you have any evidence of UK refining and refuelling infrastructure that precludes or supports a moderate introduction of E10? How does this compare to other countries such as Germany and France with similar retail forecourt facilities (i.e. limited to two pumps for petrol grades)?
- Q.51: Do you have any evidence on the supply cost of waste-derived drop-in fuels that can be used either in aviation or in diesel (in excess of B7, still meeting the diesel standard EN590)?
- Q.52: Do you expect to see any significant changes in the share of renewable fuels used in non-road mobile machinery? Can you provide any evidence of these changes?
- Q.53: Do you have any additional evidence regarding expected deployment of gas-powered vehicles and likely future demand for biomethane as a transport fuel?
- Q.54: Do you agree that the impacts of proposed operational changes listed in table 7 and covered by Sections 2, 3, 4 and 5 of the consultation document are relatively minor? Do you have any evidence that would help us identify and quantify impacts of any of these amendments?
- Q.55: Do you have any evidence on the impact of proposed changes to RTFC carry-over in 2020?
- Q.56: Do you have any additional evidence that you consider relevant to this cost benefit analysis?

3. Problem under consideration and rationale for intervention

3.1 The Climate Change Act sets a target of an 80% reduction in greenhouse gas emissions by 2050 compared to 1990 levels. As around one quarter of UK carbon emissions are from transport, decarbonisation of the transport sector is vital to achieving this long term goal. Renewable fuels are expected to have an important role to play in delivering this long-term decarbonisation. Despite increased uptake of electric vehicles, a significant share of road vehicles and virtually all planes and ships are expected to still use liquid or gaseous fuels until at least 2030, showing the need for further low-carbon options and for a strategy beyond meeting the 2020 targets. Advanced renewable fuels could be key to this long-term decarbonisation, as they may provide a means to decarbonise heavy goods vehicles (HGVs), ships and aircraft, where electrification is difficult or impractical, few alternatives to liquid or gaseous fuels are available and increased supply of first generation biofuels is either unavailable or unsustainable.

3.2 Currently, UK fuel suppliers are obligated to provide 4.75% (by volume) of road transport fuel from renewable sources, under the Renewable Transport Fuel Obligations (RTFO). However, this falls short of what is required to meet carbon budgets and also falls short of the Renewable Energy Directive's transport sub-target, which requires 10% of road transport fuel by energy to be from renewable sources in 2020.

3.3 Current supply of renewable fuels under the RTFO is 3.3% by volume (4.75% if you double count waste derived fuels) and 2.6% by energy (4% with double counting).

4. Policy options

4.1 This cost benefit analysis assesses the costs and benefits of three policy options against a *'do-nothing'* baseline, which assumes the RTFO remains as it is with an obligation level of 4.75% by volume, with double rewarding of waste-derived fuels, no sub-target for development fuels and no limit on the contribution from crops. The policy options were informed by the requirements of meeting the Renewable Energy Directive in 2020 as well as the requirements of carbon budgets. The baseline is not considered as a viable policy option because it does not ensure biofuels make an effective contribution towards carbon budgets or compliance with the minimum requirements of the RED.

4.2 The three policy options all require an increased uptake of biofuels, however they put a different emphasis on the source and the sustainability of those biofuels. All three policy options increase the RTFO obligation, extend the framework to 2030, introduce a sub-target for specific 'development' renewable fuels and put a cap on crop derived renewable fuels. They differ in relation to two aspects: a) the level of the crop cap and b) how 'development' biofuels are defined under the development sub-target. The options are described in more detail in the section below and the key differences are summarised in table 4 below.

Table 4: Summary of differences between options

	'Development' sub-target	Approach to crop-based renewable fuels (% total fuel volume)
Option 1	**Broad definition**	Allow increased use of crop biofuels (up to 7%)
Option 2 (preferred)	**Fuel-specific**	Restrict crop biofuel use to current levels (up to 2%)
Option 3	**Fuel-specific**	Phase out crop use (0%)

Proposed amendments common to policy options 1, 2 and 3

4.3 All policy options incorporate the following aspects:

a. Increase the obligation level to 2020 -

All policy options propose the same overall trajectory of volume obligation target levels, which will ensure a significant contribution from renewable fuels to Carbon Budgets Three and Four and will also enable the UK to comply with the RED transport sub-target in 2020.

b. Set obligation levels to 2030 -

All policy options propose to continue RTFO obligation target levels to 2030, which is driven by the UK's need to decarbonise road transport in the long run, to meet Carbon Budgets Four and Five and also by the need to provide investor certainty to biofuel producers.

c. Introduce development fuel sub-target -

All policy options also propose the same volume targets for advanced fuels in the form of a development fuel sub-target which is required to incentivise the commercialisation of advanced biofuels.

d. Set a limit on the contribution from crop-derived renewable fuels -

All options include a crop cap. Below, these measures are described in detail.

e. Introduce a number of operational amendments -

A number of operational amendments are also included (see list in table 7).

4.4 Below, these measures are described in detail.

a: Increase the obligation level to 2020

4.5 Currently the RTFO requires obligated suppliers to supply 4.75% by volume of their fuel as renewable fuels. Waste-derived fuels count twice towards this obligation. The proposed obligation level for 2020 is 9.75%, which will contribute to meeting the third Carbon Budget (2018-2022) and the 10% transport energy sub-target required by the RED when combined with the 1.1% estimated to be provided by renewable electricity used in electric vehicles and trains.[5] The proposal is to increase the obligation level as below, while still awarding double certificates to waste-derived fuels.

Table 5: Proposed obligation levels to 2030

Obligation period	Specified amount, as share of fossil fuel, by volume	Target (obligation) level, as share of total liquid fuel by volume, may include double rewarding[6]
15.4.2017-14.4.2018	6.38%	6.00%
15.4.2018-31.12.2018*	7.82%	7.25%
1.1.2019-31.12.2019	9.29%	8.50%
From 1.1.2020 & for subsequent obligation periods	10.80%	9.75%

*note 2018 is a short obligation period so that we can switch to a calendar year from 2019.

[5] The renewable portion of electricity used in rail and road transport can be counted towards the RED transport sub-target, with multipliers of 2.5x and 5x respectively. The proportion of electricity that is renewable has been assumed at the RED accounting default of 30%. The net result is that 1.1% of the 10% transport sub-target is met through renewable electricity in transport.

[6] The first column shows the obligation as a share of fossil fuel, the second column shows the obligation as a share of total liquid (fossil+renewable) fuel. Therefore, the obligation in the second column appears to be lower.

b: Set RTFO obligation levels to 2030

4.6 Considering the necessity for a long term carbon reduction strategy, meeting carbon budgets and providing investor certainty, we propose to set RTFO policy now for the period 2017 to 2030. Biofuels are expected to play an important role in meeting carbon budgets, which is reflected in BEIS emission projections and carbon budgets already set for the post 2020 period. The proposal is to keep overall obligation levels constant from 2020 to 2030 at 9.75% by volume, including double rewarding. This will provide industry certainty, and a platform for further increases if warranted.

c: Introduce a sub-target for particular 'development' fuels

4.7 To take advantage of the commercial opportunities and environmental benefits of advanced fuels we propose the introduction of a 'development fuels sub-target' to incentivise the production of new, more sustainable advanced fuels, primarily from waste feedstocks. This sub-target could potentially be met with a wide range of fuels as described in the RED Annex IX, but we propose to focus on specific fuels that are most consistent with the UK's long term strategic needs, including those suited for aviation and road freight where electrification options are most limited. To give industry time to ramp up supply, the proposal is to require 0.05% of fuels (by volume) to come from 'development' fuels in 2017/18, increasing to 0.2% in 2020 and to 1.2% in 2030. There will be separate certificates awarded for development fuels under the RTFO. These will be used to meet the development fuels sub-target, or alternatively can be used to meet the main obligation. The development fuel sub-target will have its own buy out price.

4.8 Under the current RTFO, each litre of waste-derived renewable fuel can earn two conventional RTFCs whilst crop derived renewable fuel receives one RTFC per litre. There is a buy-out price of 30 p per RTFC - which creates an incentive of 60 p per litre for waste derived biofuel.[7] Qualifying 'Development' fuels made from wastes will receive two 'development RTFCs' per litre and will have a separate buy-out price. We expect to set the buy-out price for development RTFCs at least at the same level or above the buy-out for the current RTFO, in recognition of the additional long-term benefits of using them as well as the higher costs to produce these fuels compared to conventional renewable fuels. We are seeking views on how to determine the development fuels buy-out price through this consultation. We propose it should be between 30 and 60 p per development RTFC. For waste derived fuels used under the development target, this creates an incentive of 60 to 120 ppl. Even at a buy-out price of 30 p per development RTFC, we expect that the traded value of development RTFCs would be above that of conventional RTFCs, since all fuels that qualify for these are more expensive to produce.

Q.45: Do you have any evidence on the supply cost of 'development fuels' or any other evidence that could inform the level of the buy-out price?

[7] This level applies to liquid biofuels.

4.9 To explore different options in this consultation, the policy options have different approaches to what qualifies under the development fuel sub-target, while the proposed level of the volume obligation is always the same.

Table 6: Proposed volume requirements of the development fuels sub-target

Obligation period	Sub target (obligation) level, counts towards RTFO obligation and includes double rewarding	Resultant 'development' renewable fuel supply as proportion of total fuel supply (by volume)
15.4.2017 to 14.4.2018	0.1%	0.05%
15.4.2018 to 31.12.2018*	0.2%	0.10%
1.1.2019 to 31.12.2019	0.3%	0.15%
1.1.2020 to 31.12.2020	0.4%	0.20%
1.1.2021 to 31.12.2021	0.6%	0.30%
1.1.2022 to 31.12.2022	0.8%	0.40%
1.1.2023 to 31.12.2023	1.0%	0.50%
1.1.2024 to 31.12.2024	1.2%	0.60%
1.1.2025 to 31.12.2025	1.4%	0.70%
1.1.2026 to 31.12.2026	1.6%	0.80%
1.1.2027 to 31.12.2027	1.8%	0.90%
1.1.2028 to 31.12.2028	2.0%	1.00%
1.1.2029 to 31.12.2029	2.2%	1.10%
1.1.2030 to 31.12.2030 and subsequent obligation periods	2.4%	1.20%

d: Set a limit on crop-derived renewable fuels

4.10 To ensure that an increase in the RTFO obligation leads to the supply of sustainable fuels, we propose to limit the amount of crop-derived fuels that can be supplied under the RTFO. This is intended to reduce the risk of additional carbon emissions from indirect land use change (ILUC), which can occur in the production of crop-based biofuels and varies across each of the policy options. See paragraphs between 4.11 to 4.17 for further details.

e: Implement all operational changes

(These are covered in sections 2, 3, 4 and 5 of the consultation document)

4.11 All policy options include the introduction of some operational changes to the RTFO, which are listed in table 7 and described in further detail in the main body of the consultation document. These are expected to have relatively minor impacts, which have not been quantified in this analysis. The likely impacts of operational change (14), changes to carry over in 2020, are qualitatively addressed in table 8.

Table 7: Further operational changes to the RTFO

	Further operational changes
1	Defining wastes to meet the definition given in the RED.
2	Introducing the waste hierarchy concept to ensure wastes with higher value end uses are not incentivised for biofuel production through double rewards under the RTFO.
3	To incentivise, through double rewards under the RTFO, the production of renewable fuels made from wastes that meet the new definition and the hierarchy
4	Labelling RTFCs ‘crop’ for fuels derived from most crop feedstocks so the market can trade them effectively to comply with the crop cap.
5	To make renewable aviation fuel eligible for reward under the RTFO. Suppliers would be issued with RTFCs but would not be obligated to supply a certain percentage of the overall supply.
6	To define, and make eligible for reward, non-biological renewable fuels, such as renewable hydrogen.
7	To ensure these renewable fuels of non-biological origin are delivered sustainably by applying existing greenhouse gas savings criteria to them.
8	To increase the level of reward for hydrogen to 4.58 RTFCs to reflect its higher energy content compared to the average for liquid renewable fuels supplied under the RTFO (in line with the approach for other gaseous renewable fuels), and use the point of sale as the 'control point'.
9	To remove rewards for renewable fuels created using precursor fuels already rewarded under another Member State’s incentive scheme. An example of this is when subsidised methane is used to produce methanol.
10	Update the RTFO’s sustainability criteria to include a definition of highly biodiverse grasslands.
11	To amend the definitions of new and old chain installations and set the corresponding thresholds for greenhouse gas savings the biofuels produced must meet.
12	Remove the requirement to share, amongst compliant suppliers, the monies received from suppliers choosing to buy-out of their obligation. Removing it prevents the RTFO scheme from being classified as a state aid scheme and having to comply with the associated regulations.
13	To align RTFO reporting requirements with calendar years. This will ease the burden on suppliers as the reporting deadlines will more closely align with those in the Greenhouse Gas Emissions Reporting Regulations, and simplify our reporting to the EU Commission.
14	Suspend the carry over of RTFCs in 2020. The 2020 target must be met with fuel supplied in that year, and we propose to suspend the carry over of RTFCs issued in 2019 to 2020. To maintain some flexibility for suppliers, the RTFCs issued in 2019 will be eligible for carry over in the 2021 obligation year.
15	To expand the circumstances in which suppliers are required to report data on the carbon intensity of the biofuel they supply.
16	Removal of the duty on the Secretary of State to review whether the RTFO obligation level is sufficient to meet the 2020 transport target in the Renewable Energy Directive, as we propose to set a trajectory to that target through these amendments.

Proposed amendments that differ across option 1, option 2 and option 3

Option 1

- Broad definition of development fuel sub-target;
- Increase use of crop based biofuels up to 7% by volume.[8]

4.12 Policy option 1 proposes to allow a significant increase in the use of crop based biofuels from current levels at around 2% by volume, up to a maximum of 7% of obligated fuels by volume. It also proposes that the development fuel sub-target can be met with a wide range of fuels. These are the same feedstocks that are also listed in Annex IX part A of the amended Renewable Energy Directive.

4.13 The consultation document also asks for views on a declining crop cap post 2020. We have not modelled this as a separate policy option. In this CBA the crop cap is assumed to be constant from 2020 to 2030, but the use of crop-derived fuels is still expected to decline post 2021. See section 6 for our projections of fuels supplied under each policy option.

Option 2 - preferred

- Introduce a fuel specific development fuel sub-target;
- Limit use of crop based biofuels to 2% by volume.

4.14 Policy option 2 would introduce a crop cap at the level of current supply. The increasing RTFO obligation would therefore have to come from waste-derived fuels. The proposed level is 2% by volume.

4.15 The consultation document also asks for views on a declining crop cap post 2020. We have not modelled this as a separate policy option. In this CBA the crop cap is assumed to be constant from 2020 to 2030, but the use of crop-derived fuels is still expected to decline post 2021.

4.16 Under option 2, we also assume a fuel specific 'development fuels' sub-target. The rationale behind this is to tailor the development fuel sub-target to those fuels that will meet long-term requirements in the UK market for renewable fuels, namely:

- 'Drop-in' fuels that can exceed current blending constraints and still meet the relevant fuel standards.
- Fuels that contribute to the long-term decarbonisation of sectors where alternatives (e.g. electrification) are expected to be limited, e.g. aviation, HGVs.

4.17 This leads to the following definition of 'development fuel': any fuel that meets the following conditions

- A renewable transport fuel (as defined in Article 3 (12) of the Order) which is either:

[8] The RTFO continues to include fuels used in Non-Road Mobile Machinery, which do not count towards the RED-transport sub-target. Due to this, a 7% cap by volume in the RTFO would also achieve a 7% cap by energy for the relevant fuels under the RED.

- made from a sustainable waste or residue (other than UCO or tallow) which meets the requirements of the waste hierarchy for use as a fuel (see above paragraphs on changes to the eligibility of waste feedstocks in the RTFO); or
- a renewable fuel of non-biological origin (Chapter 2 of the RTFO consultation document).

And:

- A fuel type that meets the UK's long term strategic objectives, i.e. one of the following specified fuel types:
  - Hydrogen (Chapter 2 of the RTFO consultation document);
  - Biomethane;
  - Aviation fuel (kerosene or avgas) (Chapter 2 of the RTFO consultation document);
  - Hydrotreated Vegetable Oil;
  - Biobutanol.
- Alternatively, a qualifying fuel could also be a fuel with the following characteristics:
  - Fuel that can be blended at rates of at least 15%/20%/30%/other (multiple options being consulted on) and still meet the relevant fuel standard i.e. EN228 for petrol, EN590 for diesel.

Option 3

- Introduce a fuel specific development fuel sub-target
- Phase out the use of crop-based fuels (reducing crop use to zero)

4.18 Policy option 3 also proposes the same fuel specific development sub-target as option 2 and sets a zero contribution from crops, based on concerns around ILUC. Under this scenario, crop-derived fuels would have to be phased out between 2017 and 2020.

Additional options around carry over from 2019 to 2020

4.19 Under the existing RTFO regime, a significant share of the 2020 obligation could be met through carry over from 2019, i.e. with renewable fuels being supplied and certificates earned in 2019. With a view to meeting the RED transport target, this would lead to a shortfall of renewable energy being supplied in 2020. This issue is independent of the policy options discussed so far, and we address its impacts qualitatively at the end of section 7. Regarding carry over from 2019 into 2020, four different options are being considered in table 8 below, with option D being the preferred one:

Table 8: Options for amending carry over in 2020

A. Carry over permitted as now but the obligation is increased to prevent a shortfall in 2020;
B. Reduce carry over into 2020 to 15%, obligation in 2020 increased by 15%;
C. No carry over into 2020, and no carry over out of 2019;
D. No carry over into 2020, suppliers can carry out of 2019 (and out of 2020) into 2021 instead - carry over into 2021 remains capped at 25%.

5. Analytical approach, evidence, uncertainties and sensitivities

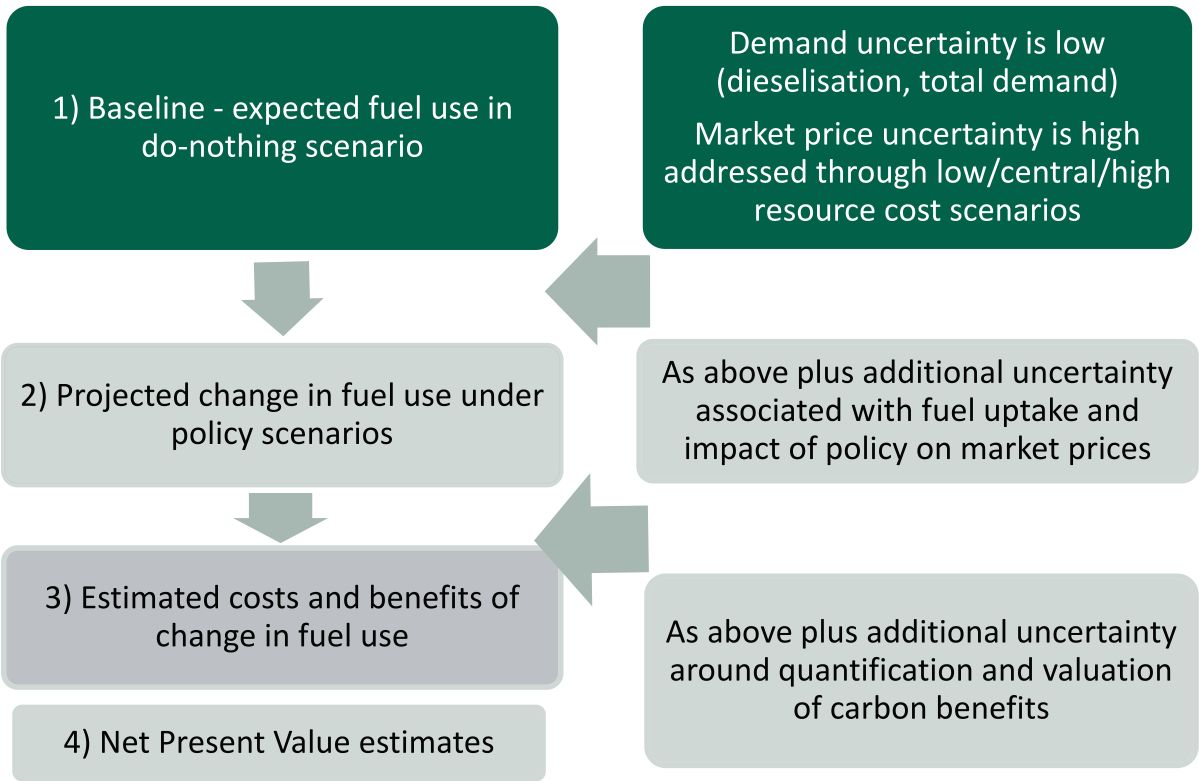
Analytical approach

Estimating changes in fuel use, resource cost and carbon savings

5.1 The impacts of the proposed amendments are estimated in four steps:

1	Determine the volume of different fuels supplied under the 'do nothing' baseline;
2	For each policy option, quantify the expected change in fuels used relative to the baseline scenario (i.e. less fossil, more renewable, and a changing share of feedstocks);
3	Based on this change, estimate carbon saved/emitted through the increased use of renewable fuels (benefit estimate) and change in resource cost (cost estimate). In addition, we estimated net value added to the UK economy as a benefit;
4	Use cost and benefit estimates to generate a range of net present value estimates.

5.2 The flow chart below shows the four steps and highlights where there is considerable uncertainty around key inputs:



5.3 To estimate the quantity of different renewable fuels supplied under the baseline and policy options (steps 1 and 2), we assume that fuel suppliers meet the obligation at least cost subject to certain constraints. The estimated supply of fuels under the baseline and policy options is based on assumptions about overall demand for road transport fuel, the petrol/diesel split, blending limits and projections of the relative costs of supplying different types of fuel.

5.4 The calculation of fuel costs and carbon benefits for each policy option (step 3) draws on the estimated fuels supplied, estimated in steps 1 and 2. To estimate the costs of each option we combine the estimated fuels supplied under the baseline and relevant policy option with estimates of the resource cost differential between renewable fuels and fossil fuels.[9] This uses resource cost estimates in £/MWh, to account for the different energy density of different fuels.

5.5 To estimate the benefits of each option, we combine the estimated fuels supplied under the baseline and relevant policy option with estimates of the greenhouse gas intensity of renewable and fossil fuels. This allows us to calculate the change in carbon emissions relative to the baseline. We then value the changes in emissions in each year following the methodology published in the Green Book supplementary guidance on valuation of energy use and greenhouse gas emissions for appraisal.[10]

Estimating net value added to the UK economy

Estimating economic value added per litre:

5.6 We calculate an average cost of the inputs to each fuel (UCO for biodiesel, wheat for ethanol). We then look at the corresponding price data for the outputs (biodiesel, ethanol and the by-product 'dried distillers grains with solubles' (DDGS), which is used as animal feed), to calculate gross value added per litre of biofuel.

Estimating share of RTFO supply coming from UK sources:

5.7 We then estimate what share of additional biofuel feedstocks come from UK sources. Combined with our processing assumptions, this gives us the total additional biofuels supply processed in the UK. To calculate this, we looked at the total of each biofuel supplied in year 7 (2014/15) of the RTFO, calculated the share that came from UK sources, and developed three scenarios for sources of additional future supply:

- Optimistic: Same proportions from UK/abroad as present;
- Pessimistic: All additional biofuel comes from abroad;
- Central: Halfway between the optimistic and pessimistic scenarios.

[9] Please note that the cost of blending renewable fuels and generating RTFCs depends on the difference in market prices between fossil fuels and renewable fuels, which is why we use the terms 'price projections' and 'cost projections' interchangeably in this CBA.
[10] https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

Estimating share of biofuels processed in UK:

5.8 For this, we assume that all biofuels that come from UK feedstocks and that are supplied into the UK are also processed here. For biofuels that are sourced from abroad, we first calculate the current share of UK-processed biofuels that come from non-UK feedstocks, by taking total production of that biofuel and the total quantity of that biofuel supplied into the UK that also uses a UK feedstock. Once this share is calculated, we again create three scenarios that match up with those above:

- Optimistic: 50% increase in current proportion of imported biofuel feedstocks processed in UK;
- Pessimistic: 50% decrease in current proportion of imported biofuel feedstocks processed in UK;
- Central: Processing - same proportion of imported biofuel feedstocks processed in UK as present.

Estimating gross value added

5.9 To calculate the gross value added to the UK economy by the biofuels industry, we use the figures outlined above to calculate what proportion of the additional biofuels supplied under the RTFO CBA scenarios are produced in the UK in each year, and then multiply this by our economic value added per litre estimates.

Factoring in additionality

5.10 Gross value added, however, does not provide a full picture of the economic impacts. It is very likely that at least some of the capital investment and jobs created in this industry will simply be diverted from other uses and are therefore not really additional. We must therefore estimate how much of this impact is additional to a 'do-nothing' baseline.

5.11 To do so, we have calculated three 'additionality' percentages, which estimate what proportion of the gross impacts are additional to the baseline and therefore a benefit attributable to the policy. These are based on information given to us by the biofuels industry, and match up to the three scenarios outlined above. These are then multiplied by their respective gross value-added estimates to give us a range of net value-added estimates.

Converting to net present values (NPVs)

5.12 Once we have net value-added figures for each year, we time-discount these according to the standard Green Book guidance, using an annual discount rate of 3.5% and taking 2015 as the base year. This gives us the final monetised impacts that can be compared and combined with the rest of the RTFO CBA analysis.

Assumptions

5.13 Profit and spending on capital and labour are considered additional to the baseline; feedstock and operating costs are not. All biofuels supplied under the RTFO and with feedstocks sourced from the UK are assumed to have been processed/produced in the UK. The value-added per litre of biofuel remains constant in real terms until 2030.

5.14 Due to limited information, at present we assume that the share of advanced biofuels processed in the UK is equivalent to that of waste biodiesel. This assumption may be revised if further information comes to light.

5.15 There are a range of other economic benefits that are extremely difficult to quantify. These include the potential benefits for energy security from associated UK production and reduced reliance on imported animal feed. We have not attempted to quantify these.

5.16 The final step in the analysis is to combine all the estimated costs and benefits of each option, and discount them to produce net present value estimates.

Q.46: Do you agree with the approach taken to calulating net value added to the economy by UK biofuel production?

Evidence and assumptions

5.17 The evidence and assumptions we use to model impacts build on the evidence agreed by Working Group 1 of the Transport Energy Taskforce in early 2015[11] and have more recently been shared and tested with stakeholders, at a workshop in December 2015. They are explained in detail in appendix 1 and include:

- Projections for road transport energy demand from BEIS Energy and Emissions Projections;
- Projections for petrol/diesel split from BEIS Energy Projections;
- Price projections for the different types of renewable fuels supplied under the RTFO;
- Different scenarios for E10 uptake: No E10, High E10 and mid-point;
- Contribution of electricity to meeting the RED sub-target;
- Availability of waste-derived fuels;
- Assumed carbon intensity of different fuels;
- Value of carbon savings.

Q.47: Do you have any additional evidence we should consider in estimating the costs and benefits of the policy options?

[11] http://www.lowcvp.org.uk/projects/transport-energy-task-force.htm

Key uncertainties and sensitivity analysis

5.18 Below, we explain what we consider to be the main uncertainties in the modelling, by order of impact/importance, and how we have addressed the uncertainty:

- Difference in costs of supplying renewable fuels and fossil fuels;
- Waste biodiesel price/availability;
- Uptake of E10 fuel;[12]
- Valuing carbon savings;
- Dieselisation of the vehicle fleet;
- ILUC factors;
- 'Development' renewable fuels availability;
- Biomethane uptake;
- The uncertainties around blending of biofuels into NRMM (fuels used for non-road mobile machinery).

Difference in costs of supplying renewable fuels and fossil fuels

5.19 The uncertainty around the policy costs is driven by a range of factors. The key single factor we have identified is uncertainty around market price developments, i.e. how renewable fuel prices change in relation to fossil fuel prices. Global energy and commodity markets are inherently volatile and future market developments are notoriously difficult to predict, and the price spread between fossil fuels and renewable fuels determines the cost impact of our policy options. To capture this uncertainty, we have developed low/central/high projections of the price spreads between renewable fuels and fossil fuels (see appendix 1 for details).[13] These are based on historical spreads and are projected independently of the underlying fossil fuel prices and commodity prices. In the analysis, they are used to generate ranges of cost estimates and net present values.

5.20 In our central price scenarios, the spreads between fossil fuels and renewable fuels fall steadily, since historically the cost of renewable feedstocks has fallen faster than the cost of fossil fuels. We also consider the possibility of spreads either rising (high price scenario) or falling faster (low price scenario).

Waste biodiesel availability/price

5.21 The market for waste biodiesel has a slightly different dynamic from the other renewable fuels, since it has fewer uses and would not be traded globally if it was not for European demand for it as a transport fuel. The demand for waste biodiesel is driven by EU renewables policy and is set to increase between now and 2020. In addition to the uncertainty of global commodity markets, which

[12] A blend of petrol and ethanol with up to 10% ethanol.
[13] Please note that the cost of blending renewable fuels and generating RTFCs depends on the difference in market prices between fossil fuels and renewable fuels, which is why we use the terms 'price projections' and 'cost projections' interchangeably in this CBA.

indirectly affect waste biodiesel prices, there is also significant uncertainty around the availability of waste feedstocks and how the prices of waste derived fuels will respond to a significant increase in European (including UK) demand in the run-up to 2020.

5.22 Although some waste derived ethanol is already supplied in the UK, we expect future increases of waste derived fuels to come mainly from waste biodiesel. In the run-up to 2020, all EU Member States need to increase their use of renewable fuels, and this increase in demand, along with possible supply constraints, could increase the market price of waste biodiesel.

5.23 Following discussion with stakeholders, we have assumed in our core low, central and high price scenarios that sufficient amounts of waste feedstocks are available in the market to meet the requirements of all three policy options, but that at higher levels of demand 'waste scarcity' sets in and the price of waste biodiesel increases. Policy options 1, 2, and 3 therefore use different price projections for waste-derived biodiesel.

5.24 Furthermore, to reflect the inherent uncertainty surrounding waste biodiesel prices, and the central role these assumptions play in our analysis, we have performed two sensitivity tests using alternative assumptions about waste biodiesel prices. The first of these considers the possibility of global waste biodiesel prices being significantly higher than we have assumed for reasons other than the introduction of the policy options considered in this CBA. The second sensitivity considers the possibility that the significant increase in demand for waste biodiesel resulting from options 2 and 3 results in significantly greater increases in price than we have assumed in our core low, central and high price scenarios.

5.25 Appendix 1 provides further details of the assumptions used in these sensitivity tests and the impacts of these sensitivity tests on fuels supplied, and the costs and benefits of the policy options are summarised in sections 6 and 7 respectively.

Q.48: Do you have any evidence of waste feedstock availability to 2020 and how markets are likely to react to increased demand in the run up to 2020?

Q.49: Do you have any additional evidence regarding expected future supply cost of renewable fuels, and specifically of waste biodiesel?

Uptake of E10 fuel

5.26 We have modelled different scenarios for E10 uptake - a blend of fuel which is not currently on the market.There is high uncertainty around the future uptake of E10 due to a range of factors including consumer acceptance. However, the impacts of different levels of E10 uptake are less significant for cost and benefit estimates than the uncertainty around future market prices. The scope for using ethanol is limited by the size of the petrol-powered vehicle fleet. If we compare the impacts of 'no E10 uptake' and 'high E10 uptake' on the total amount of renewable energy used, the difference is 0.4% of total transport energy or 4% of renewable energy required under the RED target (see table 11). By comparison, the estimated total cost of policy option 2 under low price projections is around a fifth of the estimated total cost under high price projections (see table 28).

5.27 Since ethanol has significantly lower energy density than renewable diesel, whether E10 is introduced and the extent of uptake affects how much total renewable energy is supplied. We have developed three different uptake scenarios for E10 to estimate the impact on total renewable energy being supplied (see section 6) and the impact on the RED target.

5.28 The different E10 uptake scenarios are:

a. no uptake (the UK continues to use E5).

b. medium uptake (a mid point between E5 and high uptake). This is the central scenario.

c. high uptake (85% E10 and 15% E5).

5.29 For quantifying costs and benefits, we use the central scenario 'moderate E10 uptake'.

5.30 Sections of industry have commented that they consider a 'moderate' E10 uptake highly unlikely, because there are limitations to the refining and refuelling infrastructure that make it challenging to supply a wider variety of fuel grades than currently available. As such, the view of some stakeholders in the industry is that the 'no E10 uptake' and 'high E10 uptake' are more likely than our central scenario. However, the experience in other countries which have deployed E10 has generally not been a wholesale switch of the standard grade of petrol from E5 to E10. In Germany, France and the Netherlands there has been a moderate uptake of E10, with some refuelling stations offering E5 whilst others offer E10. As in the UK, there are few forecourts in these countries that offer more than two grades of petrol (typically 'super' and standard grade), so typically individual fuel stations either have E5 or E10 as the standard grade.

Q.50: Do you have any evidence of UK refining and refuelling infrastructure that precludes or supports a moderate introduction of E10? How does this compare to other countries such as Germany and France with similar retail forecourt facilities (i.e. limited to two pumps for petrol grades)?

5.31 The central scenario for E10 uptake has been used for estimating costs and benefits of policy options. If E10 uptake is actually higher (under policy option 1) or lower (under policy options 1 or 2), this would affect overall carbon savings and cost impacts.

5.32 High E10 under policy option 1: As a sensitivity, we have examined the effects of high E10 uptake, where 85% of petrol fuel supplied in 2020 and beyond is E10, and 15% E5.

5.33 No E10 under policy options 1 and 2: We have examined the effects of a ‘No E10’ scenario, where ethanol blending into petrol remains at E5.

Valuing carbon savings

5.34 We use the Government's carbon values published in the supplementary Green Book Guidance (2015) for carbon savings in the non-traded sector to estimate carbon saving benefits. We have used the high and low range of the published carbon values for the sensitivity analysis.

Dieselisation of the vehicle fleet

5.35 The dieselisation of the fleet is relevant, since it determines how much ethanol can be blended, and blending ethanol is expected to remain the most cost-effective option for generating RTFCs. There is some uncertainty around the future dieselisation rate. In recent years, more new diesel cars than petrol cars entered the fleet. BEIS' latest energy demand projections expect this trend to continue, which affects the relative shares of ethanol and renewable diesel that can be supplied under the RTFO. It is possible, however, that this trend may reverse. To address this uncertainty, we have assessed the impacts of a reversal in trend and an increase in the petrol share between now and 2020 as a sensitivity.

5.36 To estimate the sensitivity of results to this, we have assumed that between 2015 and 2020 the dieselisation rate reverses back to 2010 levels. In this case, the petrol/diesel ratio of fuels used would be 42/58% respectively, and not 30/70%, which is our standard assumption throughout this CBA. If dieselisation of the fleet does not progress as projected by BEIS, the share of petrol in the fossil fuel mix would be higher than we have assumed here, and under our central E10 uptake scenario, more ethanol would also be required than can be accommodated under a 2% crop cap.

ILUC factors, and GLOBIOM ILUC factors as a sensitivity test

5.37 There is some uncertainty around the amount of carbon saved under different policy options, and specifically around the importance of indirect land use change for different renewable fuels.

5.38 The greenhouse gas intensities we use reflect lifecycle emissions and take account of ILUC emissions factors published in the revised Renewable Energy Directive, which provide current best evidence on the net greenhouse gas benefits of using biofuels (see appendix 1 for values).

5.39 Recent research published by the GLOBIOM consortium, commissioned by the European Commission, has suggested that ILUC emissions from crop-based biofuels may be significantly higher than previous estimates.[14] This is especially so for crop-based biodiesels. As a sensitivity, we also repeat the analysis with ILUC factors from this.

5.40 We have therefore examined the effects of a 'GLOBIOM' scenario on options 1 and 2. ILUC values from the directive and from the GLOBIOM study are shown in appendix 1. Using GLOBIOM values reduces carbon savings across both options, more significantly so in 1 due to its higher supply of crop biofuels. NPVs are shown in appendix 4.

[14] https://ec.europa.eu/energy/sites/ener/files/documents/Final%20Report_GLOBIOM_publication.pdf

'Development' renewable fuels availability

5.41 There is some uncertainty regarding the availability of development fuels in the early years of the sub-target, especially under the narrower definition of development fuels in policy options 2 and 3. In addition, we have limited evidence regarding the production cost of these fuels and how much support may be required to bring them to market. In 2020, these development fuels would need to account for 0.2% by volume or 0.4% of the obligation after double rewarding. If there is some buy-out in the early years of the sub-target, this will not have a significant impact on overall fuel supply or cost impact. Therefore we have not explicitly addressed this as a sensitivity, but we seek evidence through this consultation.

Q.51: Do you have any evidence on the supply cost of waste-derived drop-in fuels that can be used either in aviation or in diesel (in excess of B7, still meeting the diesel standard EN590)?

Non-road mobile machinery (NRMM)

5.42 There is also uncertainty regarding the future share of renewable fuels that is used in non-road mobile machinery. This fuel counts towards the RTFO but not towards the RED. If there was a significant increase in renewable fuels being used in NRMM, this would increase the risk of the RED target not being met. We have not looked at the impacts of this uncertainty in detail but we would be interested in receiving relevant evidence.

Q.52: Do you expect to see any significant changes in the share of renewable fuels used in non-road mobile machinery? Can you provide any evidence of these changes?

Biomethane

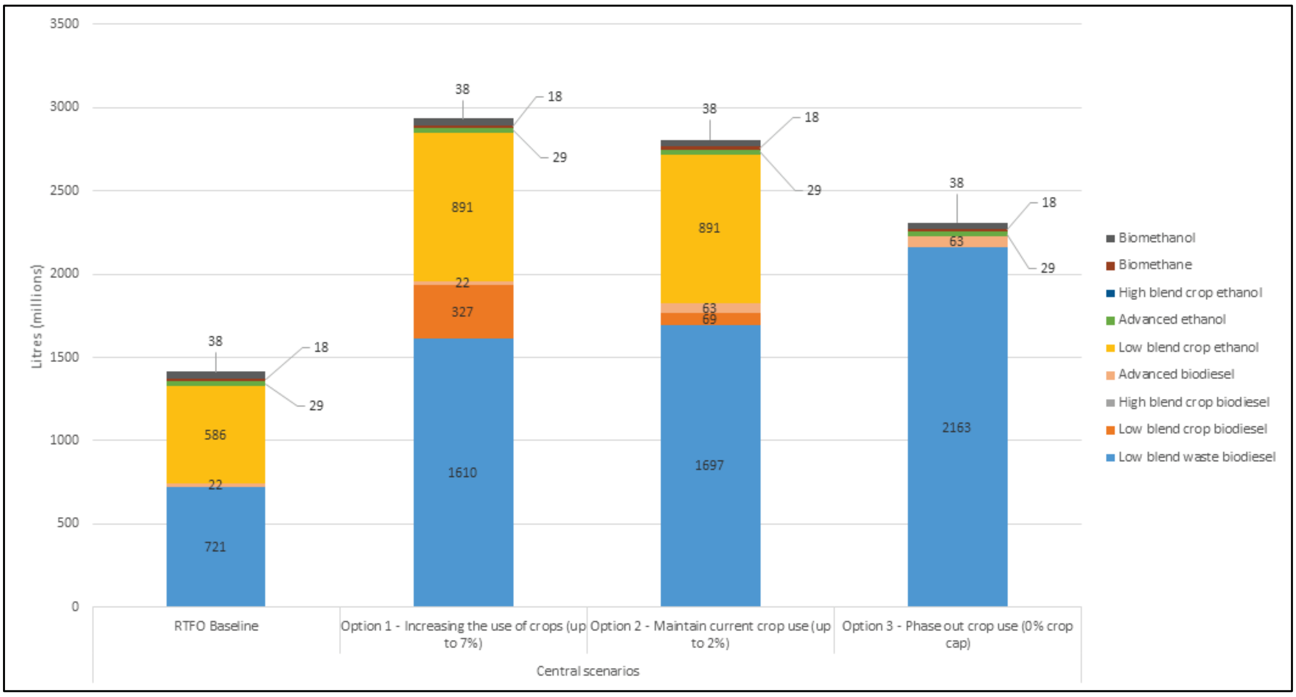
5.43 Biomethane uptake scenarios were developed for the 2015 amendments to the RTFO and are also included in the baseline of this analysis (details are in appendix 1). Relative to observed uptake these scenarios look optimistic and we therefore seek views on likely biomethane deployment through this consultation.

Q.53: Do you have any additional evidence regarding expected deployment of gas-powered vehicles and likely future demand for biomethane as a transport fuel?

6. Impacts of the proposed policy options on fuels supplied and GHG emissions

Overview of renewable fuels supplied under each option in 2020 and contribution to GHG target

Figure 2: Overview of renewable fuels supplied in 2020 by volume - central scenario*



	RTFO Baseline (central waste)	Option 1 (central waste)	Option 2 (central waste)	Option 3 (central waste)
GHG savings (MtCO2e)	*2.4*	+2.3	+2.7	+2.9
% total fuel volume	*3%*	6.1%	5.8%	4.8%
Crop share (energy, %)	*0.8%*	2%	1.4%	0%

*NB - GHG savings for options 1, 2 and 3 are those additional to the baseline.

6.1 Under the baseline, we do not expect the fuels supplied to vary between low/central/high price scenarios. This is because the relative cost effectiveness of generating RTFCs from different fuels is not expected to change between different price scenarios (e.g. ethanol is always expected to be the cheapest per litre, and the price of waste biodiesel is always higher than the price of crop biodiesel per litre). However, the fuels supplied are expected to vary between the three different policy options.

6.2 Moving from option 1 to 3, the crop cap tightens. It is not expected to have any effect in option 1, whereas crop biodiesel is largely forced out of the fuel mix in option 2, and then crop ethanol and any remaining crop biodiesel are forced out in option 3. Suppliers increasingly turn to waste-derived diesel instead to meet their obligations. Option 2 and option 3 also contain higher quantities of advanced biodiesel (or kerosene or other development drop-in fuel), due to their fuel-specific sub-targets.

6.3 As the share of crop-derived fuels with associated ILUC impacts decrease as you go from option 1 to option 2, and from option 2 to option 3, the carbon savings increase. Under our central scenarios, the total carbon savings of the three policy options are similar (around 30, 33.5 and 35 $MtCO_2$ over the period 2017-2030 respectively) and so is their contribution to the GHG target (table 9). This is because we expect relatively high levels of waste biodiesel to be supplied under option 1 as well as options 2 and 3, since the RTFO already encourages waste derived fuels over the use of crops through 'double rewarding' (where two RTFCs are issued to one litre of waste derived fuel).

6.4 The amended Fuel Quality Directive requires a 6% reduction in GHG intensity of transport fuels by 2020, relative to a 2010 baseline. The renewable fuels delivered under these policy options make a significant contribution to meeting this target. As with total carbon savings, they do not differ more strongly across the policy options, since we assume similar amounts of waste biodiesel to be used under the three policy options in our central scenario, as discussed above.

Table 9: Contribution to the 2020 GHG target

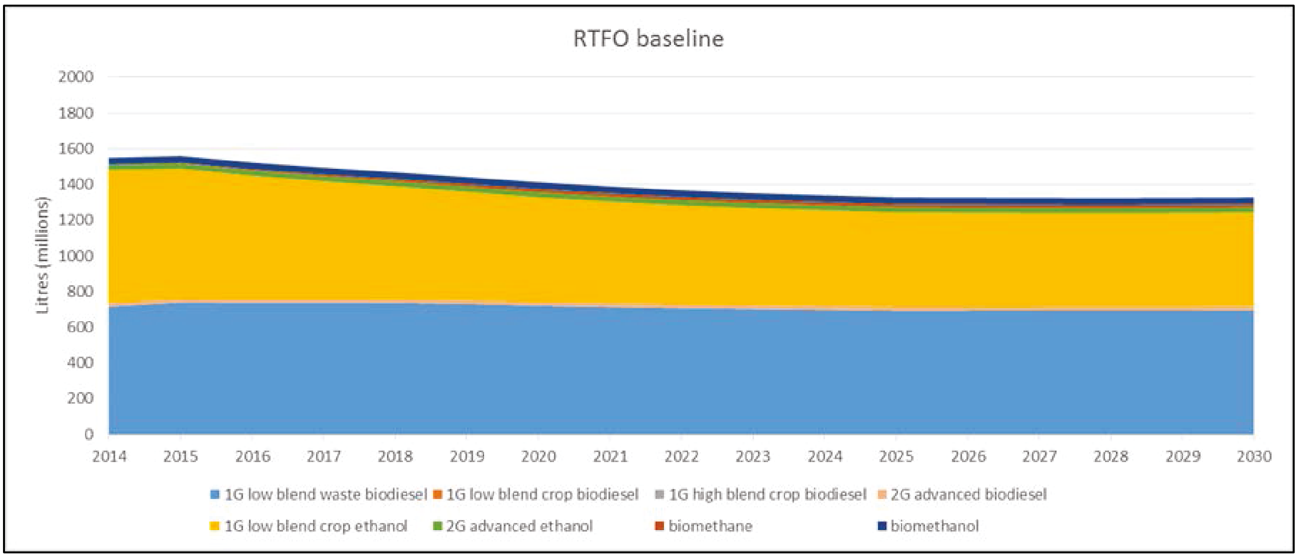
% contribution to 6% GHG target, in percentage points	2017	2018	2019	2020
option 1	2.67%	3.27%	3.82%	4.47%
option 2	2.67%	3.27%	3.83%	4.41%
option 3	2.66%	3.25%	3.79%	4.34%

Baseline fuel supply

6.5 In the absence of any amendments, we would expect the proportion of renewable fuels to continue at similar levels to those seen in recent years (details are shown in appendix 1). Based on BEIS' Energy and Emissions Projections 2015 (EEP),[15] we expect a slight decrease in overall volumes due to declining demand as a consequence of increasing fuel efficiency of road transport (leading to a reduction in overall fossil fuel volumes on which the obligation is calculated), and a slight increase in the relative share of biodiesel, based on an increasing dieselisation rate of the fleet. Projected baseline volumes are shown in figure 3.

[15] https://www.gov.uk/government/collections/energy-and-emissions-projections

Figure 3: Expected volume of renewable fuels supplied under the baseline, million litres



Fuel supply under policy option 1

Impacts of the increased obligation and development fuels sub-target

6.6 Increasing the RTFO obligation and introducing a development fuel sub-target requires larger volumes of renewable fuels to be used than under the baseline. These volume requirements are the same for all three policy options.

Table 10: Renewable fuels as proportion of total liquid road fuels, with development fuel sub-target in place

Obligation period	Target (obligation) level, as share of total fuel by volume	'Development' sub-target (counted twice towards RED)	Remaining obligation to be met with other renewable fuels
From 15.4.2017 To 14.4.2018	6.00%	0.05%(0.10%)	5.90%
From 15.4.2018 To 31.12.2018*	7.25%	0.10%(0.20%)	7.05%
From 1.1.2019 To 31.12.2019	8.50%	0.15%(0.30%)	8.20%
From 1.1.2020 To 31.12.2020	9.75%	0.20%(0.40%)	9.35%
2021	9.75%	0.30%(0.60%)	9.15%
2022	9.75%	0.40%(0.80%)	8.95%
2023	9.75%	0.50%(1.00%)	8.75%
2024	9.75%	0.60%(1.20%)	8.55%
2025	9.75%	0.70%(1.40%)	8.35%
2026	9.75%	0.80%(1.60%)	8.15%
2027	9.75%	0.90%(1.80%)	7.95%
2028	9.75%	1.00%(2.00%)	7.75%
2029	9.75%	1.1%(2.20%)	7.55%
2030	9.75%	1.2%(2.40%)	7.35%

*Note 2018 is a short obligation period so that we can switch to a calendar basis.

Increasing the use of crop-derived fuels (up to 7%)

6.7 If RTFO targets are raised and crop use is allowed up to 7% by volume, it would be possible to more than triple the current use of crops (from current levels of 2%). However, there is significant uncertainty around which renewable fuels would be used to meet the overall obligation.

6.8 To quantify cost and benefit impacts, we have constructed three E10 uptake scenarios, which have different implications for the overall amount of energy delivered. For the purposes of further analysis, we have taken the second of these scenarios (moderate E10) as our central scenario, to take account of uncertainty around actual uptake levels.

Table 11: Progress towards meeting the RED target[16]

Obligation period	Target (obligation) level, as share of total liquid fuel by volume	% of transport sub-target met through renewable fuels with **E5** (estimate, includes double rewarding and development fuel sub-target) by energy	% of transport sub-target met through renewable fuels with **moderate E10***** (estimate, includes double rewarding and development fuel sub-target) by energy	% of transport sub-target met through renewable fuels with **high E10**** uptake (estimate, includes double rewarding and development fuel sub-target) by energy
15.4.2017-14.4.2018	6.00%	5.57%	5.52%	5.47%
15.4.2018 - 31.12.2018*	7.25%	6.88%	6.78%	6.67%
1.1.2019 - 31.12.2019	8.50%	8.11%	8.03%	7.87%
1.1.2020 – 31.12.2020	9.75%	9.50%	9.29%	9.07%
2020 contribution renewable electricity		1.1% (4.77 TWh)	1.1% (4.77 TWh)	1.1% (4.77 TWh)
Total		10.6%	10.4%	10.2%

*Note 2018 is a short obligation period so that we can switch to a calendar basis.

** Assumes 15% of E5 and 85% of E10 on average across the entire petrol supply, i.e. an overall ethanol content of 9.05% by volume

*** Assumes 59.5% of E5 and 40.5% of E10 on average across the entire petrol supply, i.e. an overall ethanol content of 6.825% by volume. This is half way between no E10 and high E10 and is intended to reflect uncertainty around actual E10 uptake.

6.9 Under the Renewable Energy Directive, renewable electricity used in electric road vehicles and trains will also count towards meeting the requirements of the Directive. We expect this to account for 4.77 TWh or 1.1% of the transport sub-target in 2020, based on methodology provided by the RED.[17]

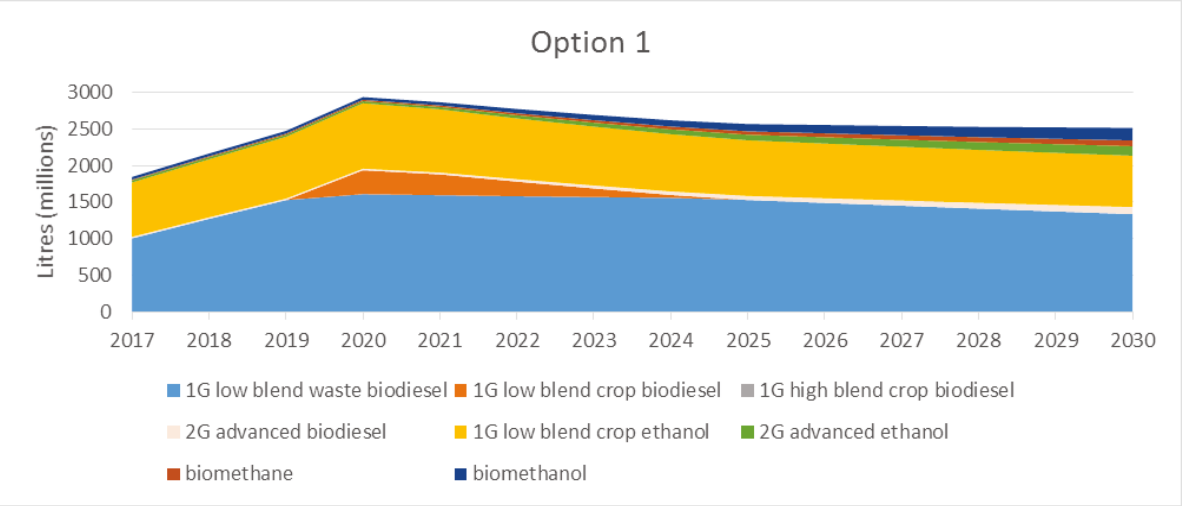
6.10 In addition to the contribution from E5, E10 and development fuels, we would expect the majority of renewable fuel to come from biodiesel, either waste-derived or crop-derived. This is because there is significant room to deploy biodiesel within the 7% 'blend wall' provided by the diesel standard EN590 (nationally, deployment is currently around 3%). We also expect small amounts of other renewable fuels, such as renewable methanol.

[16] Some columns are by volume Some are by energy

[17] Article 3, paragraph 4, point c, page 14 of the amendments document here: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015L1513&rid=2.

6.11 Appendices 2 and 3 show how we would expect supply to develop, both in volume and in energy terms. The figure below shows the overall trajectory.

Figure 4: The proposed trajectory 2017-2030 (million litres), option 1



'Broad' definition of 'development fuel'

6.12 Under the development fuels sub-target, the same volumes of development fuels will be required for all three policy options. However, the qualifying fuels differ across policy options. Under policy option 1, a wide range of fuels qualify as 'development fuels' for the sub-target. Due to pre-existing supply of some of these fuels, supply in the table below exceeds the requirements of the sub-target until 2019, and we do not expect supply to increase significantly from current levels until after 2020.

Table 12: Projected volumes of fuels supplied under the development fuel sub-target, broad definition.

Millions of litres supplied*	Biodiesel	Ethanol	Biomethane	Biomethanol	Total
2017	22	29	9	38	98
2018	22	29	12	38	101
2019	22	29	15	38	104
2020	22	29	18	38	106
2021	25	34	20	44	123
2022	33	44	27	58	163
2023	41	55	33	73	202
2024	49	66	40	86	240
2025	56	76	46	100	278
2026	64	87	53	114	318
2027	72	97	59	128	357
2028	80	108	66	142	396
2029	88	119	72	157	437
2030	97	130	79	171	477

6.13 For modelling purposes, current supply for qualifying biodiesel, bioethanol and biomethanol is expected to stay constant until the development fuels sub-target exceeds current supply in 2021. The biomethane uptake scenarios were developed for the 2015 amendments to the RTFO and are also included in the baseline of this analysis. These may be too high now and we seek views on likely biomethane deployment through this consultation (see section 5).

6.14 Any development fuel volumes supplied in excess of the sub-target would still be awarded development fuel RTFCs, which could either be carried over for use in the following year (with the exception of into 2020) or can be used to meet the overall obligation.

Renewable fuel supply above baseline - option 1

6.15 In summary, we expect the below volumes to be supplied under policy option 1, in addition to the baseline.

Table 13: Option 1, renewable fuel additional to baseline

Fuel supplied additional to RTFO baseline	1G Ethanol TWh (million litres)	Crop biodiesel TWh (million litres)	Waste biodiesel TWh (million litres)	Fuels supplied under the development fuel sub-target (including biomethane) TWh (million litres/kgs)	Total TWh (million litres)
2017/18	0.48 (82)	-	2.45 (269)	-	2.93 (351)
2018[18]	0.94 (159)	-	4.89 (536)	-	5.82 (695)
2019	1.38 (234)	-	7.27 (797)	-	8.65 (1031)
2020	1.80 (305)	2.98 (327)	8.10 (889)	-	12.88 (1520)
2021	1.72 (291)	2.60 (285)	8.03 (881)	0.12 (17)	12.47 (1474)
2022	1.62 (273)	1.83 (201)	7.96 (873)	0.41 (56)	11.81 (1403)
2023	1.52 (257)	1.07 (118)	7.90 (867)	0.70 (96)	11.20 (1338)
2024	1.44 (243)	0.36 (39)	7.85 (862)	0.98 (134)	10.63 (1278)
2025	1.35 (229)	-	7.62 (836)	1.27 (172)	10.24 (1237)
2026	1.29 (217)	-	7.26 (797)	1.55 (211)	10.10 (1226)
2027	1.22 (206)	-	6.91 (758)	1.84 (251)	9.97 (1215)
2028	1.15 (195)	-	6.55 (719)	2.13 (290)	9.83 (1203)
2029	1.09 (184)	-	6.19 (680)	2.43 (330)	9.71 (1194)
2030	1.03 (174)	-	5.84 (641)	2.73 (371)	9.59 (1186)

Impacts of operational changes

6.16 We currently do not have sufficient evidence to quantify the impacts of the operational changes in table 7, but we do not anticipate them to be substantial relative to the total impacts of increasing the RTFO obligation. We seek additional information on the impacts of these measures through this consultation.

Q.54: Do you agree that the impacts of proposed operational changes listed in table 7 and covered by Sections 2, 3, 4 and 5 of the consultation document are relatively minor? Do you have any evidence that would help us identify and quantify impacts of any of these amendments?

Carbon savings under policy option 1

6.17 The main benefits that we expect to see from the increased use of renewable fuels are savings in carbon emissions above the baseline of the existing RTFO obligation. The exact savings depend on which fuels are used to meet the increased RTFO obligation and also the development fuel sub-target.

[18] This is a shorter year which runs from April 2018 to December 2018

6.18 From the volumes of renewable fuels that are supplied and the volumes of fossil fuel that they displace, we have modelled the savings for the fuel use projected under the central scenario for each of the policy options.

Table 14: Estimated total carbon savings additional to baseline under the different policy options, including ILUC, $MtCO_2$

GHG savings additional to baseline, $MtCO_2e$	Option 1
2017	0.7
2018	1.4
2019	2.1
2020	2.3
2021	2.3
2022	2.4
2023	2.4
2024	2.5
2025	2.5
2026	2.4
2027	2.4
2028	2.4
2029	2.3
2030	2.3
Total	30.3

Fuel supply under policy option 2

6.19 Under policy option 2, the same volume requirements apply as under policy option 1, regarding the increased RTFO obligation and the development sub-target. However, the level of crop-derived fuels differs.

Maintain current use of crop-derived fuels (up to 2%)

6.20 If the RTFO is amended to set a level for the use of crops at current levels of around 2% by volume, there is less uncertainty than under policy option 1 around which fuels can be supplied. There is still uncertainty around the uptake of E10, which could be supplied up to our central uptake scenario. However, a cap set at this level would prevent the High E10 uptake scenario which would require around 2.5% by volume (1.7% by energy) to be derived from crops. Following the proposed amendments to the RTFO obligation under policy option 2, we expect the fuel supply to meet the renewable energy requirements of the RED as follows:

Table 15: Progress towards meeting the RED target under policy option 2

Obligation period	Target (obligation) level, as share of total liquid fuel by volume	% of transport sub-target met through renewable fuels with **E5** (estimate, includes double rewarding and development fuel sub-target) by energy	% of transport sub-target met through renewable fuels with **moderate E10**** (estimate, includes double rewarding and development fuel sub-target) by energy
From 15.4.2017 To 4.4.2018	6.00%	5.57%	5.52%
From 15.4.2018 To 31.12.2018*	7.25%	6.88%	6.78%
From 1.1.2019 To 31.12.2019	8.50%	8.19%	8.03%
From 1.1.2020 To 31.12.2020	9.75%	9.50%	9.29%
2020 contribution renewable electricity		1.1% (4.77 TWh)	1.1% (4.77 TWh)
Total		10.6%	10.4%

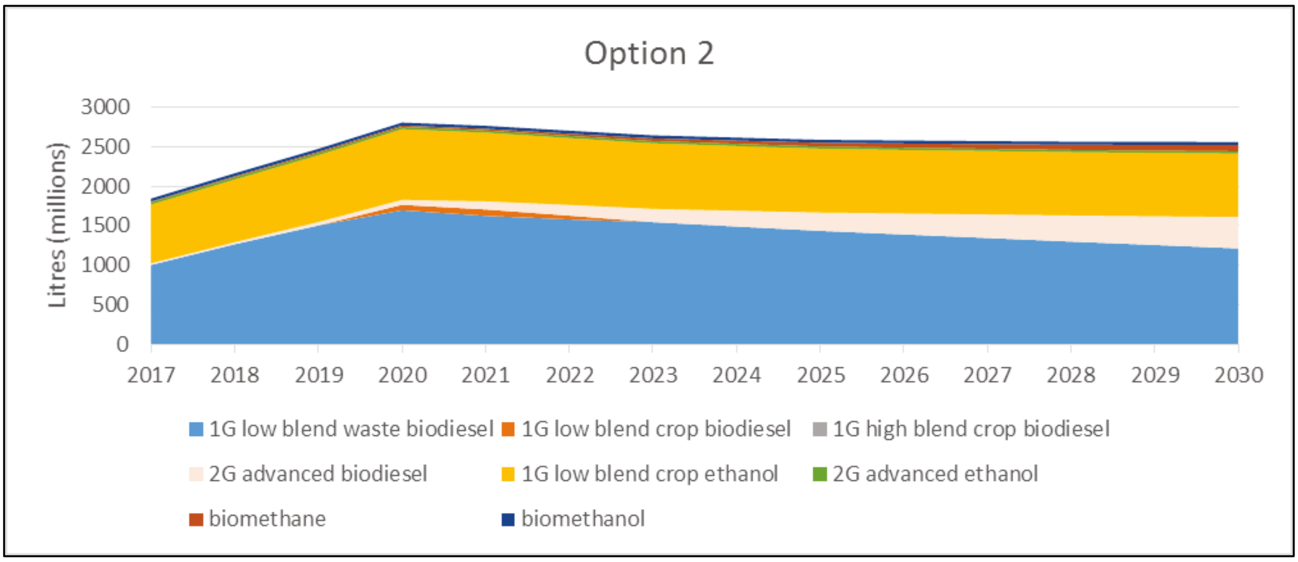
* Note 2018 is a short obligation period so that we can switch to a calendar year basis.

** Assumes 59.5% of E5 and 40.5% of E10 on average across the entire petrol supply, i.e. an overall ethanol content of 6.825% by volume. This is half way between no E10 and high E10.

6.21 Where crop use is restricted to current levels, whether there is uptake of E10 also determines whether there is any flexibility around the source of biodiesel. We expect blending ethanol to remain the most cost effective way of generating RTFCs. With no E10 uptake, less ethanol is used and there is room under the crop cap for some crop-derived biodiesel. With moderate E10 uptake, more ethanol is used and there is very little room under the crop cap for crop-derived biodiesel. Under the 2% crop cap, we consider moderate E10 uptake as the central scenario, which means the vast majority of biodiesel has to come from waste feedstocks. In this scenario, we would expect the overall trajectory of renewable fuels to develop as shown below, with 'advanced biodiesel' being delivered under the fuel specific sub-target (this category could also include renewable kerosene or another drop-in fuel).

6.22 Appendices 2 and 3 show how we would expect supply to develop, both in volume and in energy terms. The figure below shows the overall trajectory.

Figure 5: Renewable fuel supply trajectory 2017 - 2030, option 2, million litres



'Fuel specific' development fuels sub-target

6.23 Option 2 and option 3 propose to use a different definition of which fuels are incentivised through the 'development fuel' sub-target than option 1. In terms of volume requirements, there is no difference between policy options 1, 2 and 3. The focus on specific development fuels under options 2 and 3 would increase both the carbon savings of the sub-target and the costs, which we address in section 6.

'Narrow' definition of development fuels

Table 16: Projected volumes of fuels supplied under the development fuel sub-target, narrow definition of 'development fuels'

Millions of litres supplied*	Biodiesel/kerosene/ Other drop-In fuel	Biomethane	Total
2017	22	9	31
2018	26	12	38
2019	44	15	59
2020	63	18	80
2021	103	20	124
2022	136	27	163
2023	168	33	201
2024	200	40	240
2025	232	46	278
2026	265	53	317
2027	297	59	357
2028	330	66	396
2029	363	72	436
2030	397	79	476

*millions of kilograms for biomethane

6.24 Under the narrow definition, little current supply would qualify as 'development fuel', so volumes supplied start from a lower base than under policy option 1, even though the volume requirements of the sub-target are the same.

6.25 Total volumes of renewable fuels supplied under policy option 2 and above the baseline are shown in the table below.

Table 17: Option 2, renewable fuel additional to baseline*

Fuel supplied additional to RTFO baseline	1G ethanol TWh (million litres)	Crop biodiesel TWh (million litres)	Waste biodiesel TWh (million litres)	Fuels supplied under the development fuel sub-target (including biomethane) TWh (million litres/kgs)	Total TWh (million litres)
2017/18	0.48 (82)	-	2.45 (269)	-	2.93 (351)
2018	0.94 (159)	-	4.85 (532)	0.04 (4)	5.82 (695)
2019	1.38 (234)	-	7.06 (774)	0.21 (23)	8.65 (1031)
2020	1.80 (305)	0.63 (69)	8.89 (976)	0.37 (41)	11.70 (1391)
2021	1.75 (296)	0.75 (82)	8.31 (912)	0.78 (84)	11.59 (1374)
2022	1.71 (289)	0.44 (48)	7.96 (873)	1.17 (124)	11.27 (1334)
2023	1.68 (283)	-	7.69 (845)	1.55 (162)	10.92 (1290)
2024	1.65 (280)	-	7.23 (794)	1.94 (201)	10.82 (1274)
2025	1.63 (276)	-	6.77 (744)	2.31 (239)	10.72 (1258)
2026	1.63 (275)	-	6.36 (698)	2.70 (278)	10.69 (1251)
2027	1.62 (274)	-	5.95 (653)	3.09 (317)	10.66 (1245)
2028	1.62 (274)	-	5.54 (608)	3.48 (357)	10.64 (1238)
2029	1.62 (274)	-	5.13 (564)	3.87 (396)	10.63 (1234)
2030	1.62 (275)	-	4.73 (519)	4.27 (437)	10.62 (1230)

* More 1G ethanol is supplied here than under policy option 1, since policy option 1 contains more advanced ethanol under 'development fuels' and less under 1G ethanol.

Carbon savings under policy option 2

6.26 From the volumes of renewable fuels that are supplied and the volumes of fossil fuel that they displace, we have modelled the GHG savings for the fuel use projected under the central scenario for each of the policy options.

Table 18: Estimated total carbon savings additional to baseline under the different policy options, $MtCO_2$, including ILUC

GHG savings additional to baseline,$MtCO_2e$	Option 2
2017	0.7
2018	1.4
2019	2.1
2020	2.7
2021	2.6
2022	2.7
2023	2.7
2024	2.7
2025	2.7
2026	2.7
2027	2.7
2028	2.7
2029	2.7
2030	2.7
Total	33.6

Fuels supplied under policy option 3

6.27 Under policy option 3, the same volume requirements apply as under policy options 1 and 2, regarding the increased RTFO obligation and the development sub-target. However, the level of crop-derived fuels is expected to fall to zero by 2020.

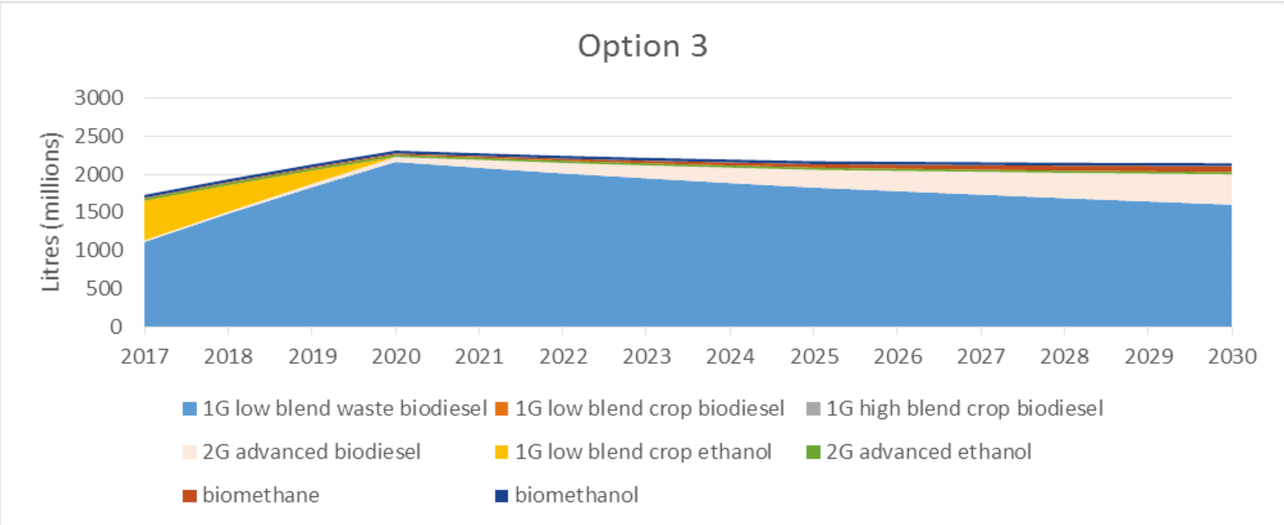
6.28 If crop use is phased out by 2020, no crop-derived ethanol would be supplied and all biodiesel would have to come from waste feedstocks, plus a small amount of waste derived ethanol (under 'other renewable fuels'), which is already supplied now. There is only one scenario for E10 uptake, which is 'no E10', the volume of ethanol in current petrol is significantly reduced and mostly replaced with fossil petrol.

Table 19: Progress towards meeting the RED target

Obligation period	Target (obligation) level, as share of total liquid fuel by volume	% of transport sub-target met through renewable fuels (estimate, includes double rewarding and development fuel sub-target, by energy)
From 15.4.2017 To 14.4.2018	6.00%	5.68%
From 15.4.2018 To 31.12.2018*	7.25%	7.09%
From 1.1.2019 To 31.12.2019	8.50%	8.49%
From 1.1.2020 To 31.12.2020	9.75%	9.90%
2020 contribution from renewable electricity		1.1% (4.77 TWh)
2020 Total		11%

6.29 Appendices 2 and 3 show how we would expect supply to develop, both in volume and in energy terms. The figure below shows the overall trajectory.

Figure 6: Renewable fuel supply trajectory 2017-2030, option 3, million litres



Renewable fuel supply above baseline

6.30 The impact of the proposed policy changes is the difference between the RTFO baseline and the projections, so for the cost benefit analysis, the relevant additional fuel supply is below.

Table 20: Option 3, renewable fuel additional to baseline

Fuel supplied additio-nal to RTFO baseline	1G Ethanol TWh (million litres)	Crop biodiesel TWh (million litres)	Waste biodiesel TWh (million litres)	Fuels supplied under the development fuel sub-target (including biomethane) TWh (million litres/kgs)	Total TWh (million litres)
2017/18	-0.83 (-141)	-	3.44 (378)	-	2.61 (237)
2018	-1.69 (-287)	-	6.83 (749)	0.04 (4)	5.17 (467)
2019	-2.57 (-434)	-	10.02 (1100)	0.21 (23)	7.66 (688)
2020	-3.46 (-586)	-	13.14 (1442)	0.37 (41)	10.05 (897)
2021	-3.36 (-568)	-	12.50 (1372)	0.78 (84)	9.92 (888)
2022	-3.27 (-554)	-	11.89 (1305)	1.17 (124)	9.79 (875)
2023	-3.21 (-543)	-	11.34 (1245)	1.55 (162)	9.69 (864)
2024	-3.16 (-535	-	10.83 (1188)	1.94 (201)	9.60 (854)
2025	-3.12 (-528)	-	10.33 (1133)	2.31 (239)	9.51 (844)
2026	-3.11 (-526)	-	9.90 (1086)	2.70 (278)	9.49 (838)
2027	-3.10 (-525	-	9.48 (1040)	3.09 (317)	9.47 (833)
2028	-3.10 (-524)	-	9.06 (994)	3.48 (357)	9.44 (827)
2029	-3.10 (-524)	-	8.66 (951)	3.87 (396)	9.44 (823)
2030	-3.10 (-525)	-	8.26 (907)	4.27 (437)	9.43 (818)

Carbon savings under policy option 3

6.31 From the volumes of renewable fuels that are supplied and the volumes of fossil fuel that they displace, we can calculate carbon savings.

Table 21: Estimated total carbon savings additional to baseline under the different policy options, including ILUC, $MtCO_2$

GHG savings additional to baseline, $MtCO_2e$	Option 3
2017	0.7
2018	1.5
2019	2.2
2020	2.9
2021	2.9
2022	2.8
2023	2.8
2024	2.8
2025	2.8
2026	2.8
2027	2.8
2028	2.8
2029	2.8
2030	2.8
Total	35.2

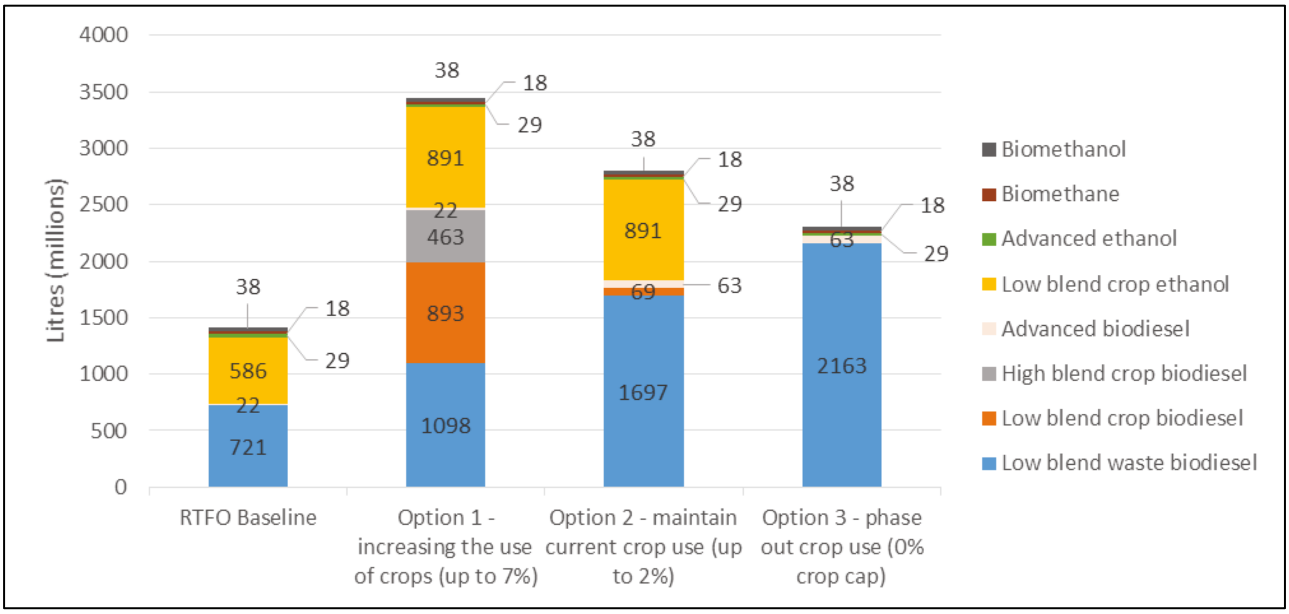
Sensitivity analysis

Overview of renewable fuels supplied under high-crop scenario

6.32 Without an effective cap under policy option 1, there is a risk that less waste biodiesel and more crop biodiesel are supplied than we show in our central scenario. This could be an outcome of an exogenous increase in waste biodiesel prices, or of some other unexpected change in the market, which makes crop biodiesel more attractive to fuel suppliers than waste biodiesel. Below, we show fuel supplied under an illustrative scenario where waste biodiesel becomes scarce and expensive at 1.5 times current supply, e.g. demand increases gradually in the years before 2020 and suppliers find that in 2020 using high blend crop-biodiesel is economically attractive. If this risk were realised, it would significantly reduce carbon savings achieved under this option, as in effect fuel would be supplied that increases rather than decreases carbon emissions when ILUC is accounted for.

6.33 The impact summary below shows that in this illustrative scenario carbon savings in 2020 would only be 1.1 $MtCO_2e$ above the baseline, less than half of the 2.3 $MtCO_2e$ estimated for option 1 with our central projections of crop use and only 40% of the 2.7 $MtCO_2e$ estimated savings for option 2.

Figure 7: Summary of fuels supplied and carbon saved under high-crop sensitivity

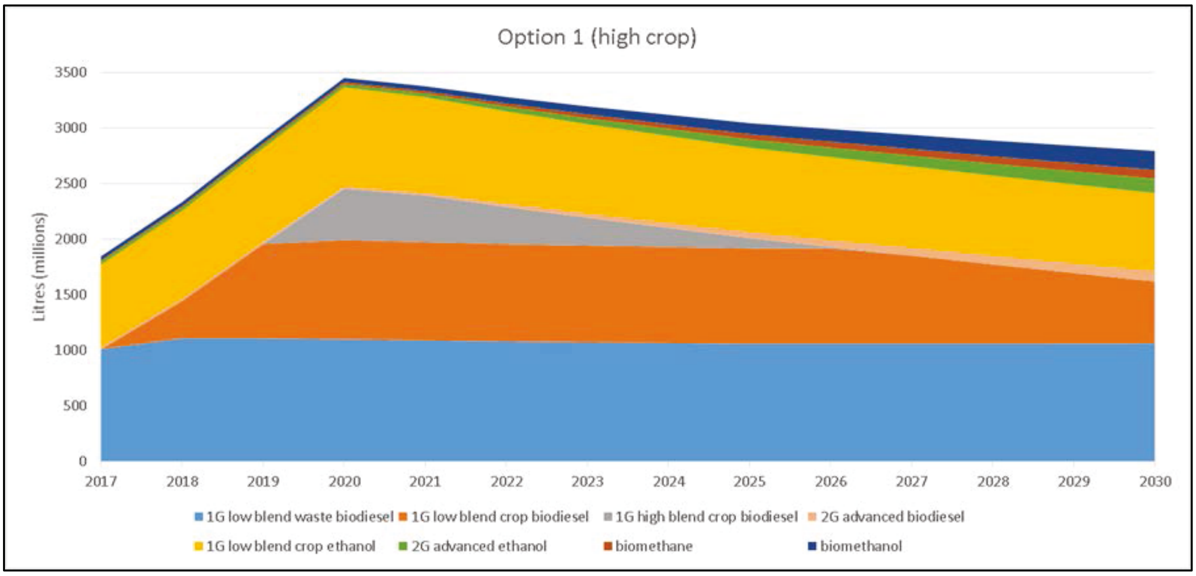


	RTFO Baseline	option 1	option 2	option 3
GHG savings ($MtCO_2e$)	*2.4*	+1.1	+2.7	+2.9
% total fuel volume	*3%*	7.2%	5.8%	4.8%
Crop share (energy, %)	*0.8%*	4.2%	1.4%	0%

NB - GHG savings for options 1, 2 and 3 are those additional to the baseline.

6.34 The corresponding long-term trajectory of a high-crop scenario under policy option 1 could be as below:

Figure 8: Possible high-crop trajectory 2017-2030 (million litres), option 1



6.35 For policy option 1, this would make crop biodiesel more attractive, and other exogenous factors could have the same effect under policy option 1, so that more crop and less waste biodiesel is supplied than in our central scenario.

6.36 The corresponding sensitivity for policy options 2 and 3 assumes that the same volumes of waste biodiesel are supplied even under scarcity and high prices, but that the cost goes up significantly. If the higher cost of waste biodiesel is considered exogenous, then the higher cost of fuels used in the baseline is not a consequence or an impact of the policy option and does not count as such.

E10 sensitivity

6.37 A high uptake of E10 could increase the crop share under option 1 to at least 2.5% by volume. This would likely have the effect in and shortly after 2020 of displacing crop biodiesel relative to our central case, which improves GHG savings. However, from 2025, this extra ethanol may displace waste biodiesel instead, slightly reducing GHG savings. Overall these impacts are quite small.

6.38 No uptake of E10 would likely result in increased supply of both crop-derived biodiesel and waste-derived biodiesel, driven by blend walls and double rewarding. This increase in waste biodiesel demand under option 1 would be expected to drive up its price slightly. There would likely be a small increase in carbon savings under both options, and a small increase in costs in option 1, relative to the central scenarios. NPVs for different E10 uptake sensitivities are shown in appendix 4.

Dieselisation sensitivity

6.39 To estimate the sensitivity of results to the dieselisation rate of the fleet, we have assumed that between 2015 and 2020 the dieselisation rate reverses back to 2010 levels. In this case, the petrol/diesel ratio of fuels used would be 42/58% respectively, and not 30/70%, our standard assumption throughout this CBA.

6.40 In this scenario there would be more demand for ethanol and less demand for biodiesel than under our central assumptions and the 2% crop cap could become a limiting factor for E10 uptake. Under this dieselisation rate, a volume crop cap of 2.7% would be required to accommodate the central E10 uptake scenario, which assumes 59.5% of E5 and 40.5% of E10 on average across the entire petrol supply, or an overall ethanol content of 6.825% by volume. Estimated NPVs are shown in section 7 and appendix 4.

6.41 We have not addressed the possible impacts of a change in NRMM fuel volumes or different biomethane uptake scenarios but are asking for relevant evidence through this consultation.

7. Costs and benefits of the policy options

Summary of costs and benefits

7.1 Moving from option option 1 to option 3, the fuel mix becomes gradually less carbon intensive but also more expensive. Between options 1 and 2, crop biodiesel is squeezed out of the fuel mix and different fuels are delivered under the 'development fuel' sub-target. Between options 2 and 3, crop ethanol is squeezed out of the fuel mix and suppliers increasingly turn to waste biodiesel instead to meet their obligations. As the share of crop-derived fuels and associated ILUC impacts decrease, the carbon savings increase. We assume that this increase in demand for waste biodiesel also pushes up the price of waste biodiesel, especially for option 3, and that therefore the carbon abatement cost increases. But it is highly uncertain at which point an increase in demand will start to affect prices.

7.2 The two tables below show a summary of impacts both for the duration of the policy and for 2020. The range presented in these tables does not cover the full range of values presented in the CBA as it does not include sensitivities.

Table 22: Summary of net present value estimates of the three options (2017-2030)

Additional to baseline, 2015 prices	Total additional carbon savings ($MtCO_2e$)	Present value benefits (£m)	Present value costs central estimate (£m)	Present value costs (£m) range	Net present value (£m) range, (benefits minus costs)	Net present value (£m) central estimate
Option 1	30.3	1980	2536	848 to 5733	1132 to -3753	-556
Option 2	33.6	2303	3107	1213 to 6313	1090 to -4011	-804
Option 3	35.2	2299	4405	2623 to 5976	-324 to -3677	-2106

Table 23: 2020 pump price impact, crop share, carbon abatement and RED compliance cost

Costs are additional to baseline in 2020, 2015 prices	2020 resource cost impact, £m (range)	2020 pump price impact, ppl (range)	2020 crop share (% by volume)	RED compliance cost (£/MWh)	Abatement cost (£/tCO_2e) in 2020	Average Abatement cost present value (£/tCO_2e) 2017-30
Option 1	332 (113- 697)	0.9 (0.3-1.9)	2.5% (0-7%)	25.8	142 (48-298)	87
Option 2	366 (143- 729)	1.0 (0.4-2.0)	2% (0-2%)	31.2	137 (53-273)	95
Option 3	554 (331- 729)	1.6 (0.9-2.1)	0%	55.1	193 (115-254)	124

7.3 The quantified benefits of the proposed changes are lower carbon emissions from transport as well as value added to the UK economy from domestic biofuel production. This includes the expected development of an industry that can deliver low carbon transport fuel in the long run. The main cost impacts are higher fuel costs, since renewable fuels are more expensive than fossil fuels per unit of energy.

7.4 These proposed carbon savings are already included in BEIS' latest emissions projections. If they were not realised, additional carbon savings would need to be generated elsewhere in order to meet carbon budgets.

7.5 There is considerable uncertainty around the cost estimates, since the cost impact is driven by two volatile variables, the market price of fossil fuels and the market price of renewable fuels. In spite of significant uncertainties, we have developed projections of the price differential between fossils and renewables (See appendix 1). The price projections are first derived per MWh and not per litre, to account for the different energy content of different fuels. To make them accessible to the audience, we also present them in terms of pence per litre spreads.

7.6 In our central scenario, even though option 1 would allow a significant increase in crop derived fuels, we forecast the supply of such fuels in 2020 to be only 2.5% by volume, roughly doubling what is in the baseline at 1.2%, delivered mainly in crop biodiesel. The relatively limited impact on the quantity of crop derived fuels supplied is driven by the assumption that double rewarding will continue to incentivise the use of wastes over crops and that this would ensure sufficient waste biodiesel was made available to the UK market to meet levels of demand generated under options 1 and 2 (up to 1.7bn litres) without significantly increasing the price.

7.7 There is a risk though that relative prices of crop and waste biodiesel develop such that it would be cost effective to use more crop biodiesel and less waste under option 1. There is also a risk that waste biodiesel prices increase and the cost of all policy options are higher than in the central scenario.

7.8 Under option 3, less crop biofuels are used but there is an increased risk that the Carbon Budget and RED targets will not be met. Option 3 would also remove the UK market for UK ethanol producers, which could adversely affect their businesses. It might be possible for some producers to switch from crop-derived ethanol production to advanced, waste-derived ethanol production, but this would require significant further investment.

7.9 UK bioethanol production uses animal feed wheat, not milling wheat used for human consumption. As a coproduct, it generates a valuable animal protein supplement, reducing reliance on imported soy as animal protein feed. This industry could also be put at risk by policy option 3.

7.10 Based on our central price projections, the methodology outlined in section 5, and the evidence outlined in appendix 1, the estimated cost impacts and carbon savings of the three policy options is shown below:

i - Quantified impacts

7.11 The tables below show central estimates of quantified costs and benefits over the duration of the policy

Table 24: Cost impacts and carbon savings of option 1 (2015 prices, undiscounted)

Additio-nal to RTFO baseline	Energy used (TWh)	Price premium (£/MWh)	Cost impact (£m)	Pump price impact (ppl)	Carbon savings without ILUC ($MtCO_2e$)	Carbon savings with ILUC ($MtCO_2e$)	Abatement cost* (£/tCO_2e)
2017-8	2.93	29.8	87	0.2	0.81	0.70	125
2018	5.82	29.7	173	0.5	1.61	1.40	124
2019	8.65	29.1	252	0.7	2.39	2.07	121
2020	12.88	25.8	332	0.9	3.28	2.34	142
2021	12.47	25.0	312	0.9	3.20	2.34	134
2022	11.81	25.1	296	0.9	3.08	2.37	125
2023	11.20	25.1	281	0.8	2.97	2.42	116
2024	10.63	25.1	266	0.8	2.87	2.46	108
2025	10.24	24.7	252	0.7	2.79	2.46	103
2026	10.10	24.1	244	0.7	2.74	2.42	101
2027	9.97	23.6	235	0.7	2.69	2.39	98
2028	9.83	23.0	226	0.7	2.64	2.35	96
2029	9.71	22.3	217	0.6	2.60	2.32	93
2030	9.59	21.7	208	0.6	2.56	2.29	91

*includes ILUC factors

Table 25: Cost impacts and carbon savings of option 2 (2015 prices, undiscounted)

Additio-nal to RTFO baseline	Energy used (TWh)	Price premium (£/MWh)	Cost impact (£m)	Pump price impact (ppl)	Carbon savings without ILUC ($MtCO_2e$)	Carbon savings with ILUC ($MtCO_2e$)	Abatement cost* (£/tCO_2e)
2017-8	2.93	29.8	87	0.2	0.81	0.70	125
2018	5.82	30.1	175	0.5	1.61	1.40	125
2019	8.65	31.5	272	0.7	2.39	2.09	130
2020	11.70	31.2	366	1.0	3.19	2.67	137
2021	11.59	31.3	363	1.0	3.16	2.64	138
2022	11.27	31.4	354	1.0	3.10	2.65	134
2023	10.92	31.7	346	1.0	3.04	2.69	129
2024	10.82	31.3	338	1.0	3.02	2.68	126
2025	10.72	30.8	330	1.0	2.99	2.66	124
2026	10.69	30.4	325	1.0	2.98	2.67	122
2027	10.66	30.0	320	0.9	2.98	2.67	120
2028	10.64	29.5	314	0.9	2.97	2.68	117
2029	10.63	28.9	307	0.9	2.97	2.69	114
2030	10.62	28.2	300	0.9	2.97	2.70	111

*includes ILUC factors

Table 26: Cost impacts and carbon savings of option 3 (2015 prices, undiscounted)

Additional to RTFO baseline	Energy used (TWh)	Price premium (£/MWh)	Cost impact (£m)	Pump price impact (ppl)	Carbon savings without ILUC ($MtCO_2e$)	Carbon savings with ILUC ($MtCO_2e$)	Abatement cost* (£/tCO_2e)
2017-8	2.61	31.1	81	0.2	0.82	0.73	111
2018	5.17	31.9	165	0.5	1.63	1.46	113
2019	7.66	45.1	345	1.0	2.43	2.18	158
2020	10.05	55.1	554	1.6	3.20	2.87	193
2021	9.92	54.8	543	1.6	3.16	2.85	191
2022	9.79	53.9	528	1.5	3.12	2.82	187
2023	9.69	52.9	513	1.5	3.08	2.80	183
2024	9.60	51.9	499	1.5	3.05	2.79	179
2025	9.51	50.9	484	1.4	3.03	2.77	175
2026	9.49	50.0	475	1.4	3.02	2.77	171
2027	9.47	49.2	465	1.4	3.01	2.78	167
2028	9.44	48.2	455	1.4	3.01	2.78	163
2029	9.44	47.1	444	1.3	3.00	2.79	159
2030	9.43	46.0	433	1.3	3.00	2.80	155

*includes ILUC factors

Net Present Values

7.12 The tables below show the net present values (NPV = discounted benefits minus discounted costs) for different options and different price projection scenarios, i.e. they show different NPVs for low/central/high scenarios.

Table 27: Summary of NPVs for option 1

£m, 2015 prices	Discounted							
			Low		Central		High	
	Total carbon benefits	Net value added	Resource cost	Net cost/ benefit	Resource cost	Net cost/ benefit	Resource cost	Net cost/ benefit
2017	42	8	36	15	82	-31	129	-79
2018	83	16	63	35	156	-58	253	-155
2019	120	22	80	62	219	-77	410	-268
2020	133	25	95	63	279	-121	587	-429
2021	131	25	79	77	254	-98	564	-408
2022	130	27	67	90	233	-76	529	-372
2023	130	28	60	98	213	-55	497	-338
2024	130	30	60	100	195	-35	467	-307
2025	128	31	59	99	179	-21	439	-281
2026	123	31	57	98	167	-12	415	-260
2027	119	32	54	97	155	-4	392	-240
2028	115	33	50	98	144	4	370	-222
2029	112	33	46	99	134	11	350	-205
2030	108	34	41	101	124	18	331	-189
Total	1605	375	848	1132	2536	-556	5733	-3753

Table 28: Summary of NPVs for option 2

£m, 2015 prices	Discounted							
			Low		Central		High	
	Total carbon benefits	Net value added	Resource cost	Net cost/ benefit	Resource cost	Net cost/ benefit	Resource cost	Net cost/ benefit
2017	42	8	36	15	82	-31	129	-79
2018	83	16	65	34	158	-59	256	-157
2019	121	25	97	50	237	-91	428	-282
2020	152	33	120	65	308	-123	614	-429
2021	147	36	114	70	295	-112	590	-406
2022	146	39	104	80	279	-94	563	-379
2023	145	41	98	88	263	-77	537	-351
2024	142	43	98	87	248	-64	515	-330
2025	138	44	96	87	234	-51	493	-310
2026	136	46	91	91	223	-41	473	-291
2027	134	48	85	96	212	-31	455	-274
2028	131	49	78	102	201	-20	437	-257
2029	129	50	70	109	190	-10	420	-240
2030	127	51	61	117	179	-1	404	-225
Total	1773	529	1213	1090	3107	-804	6313	-4011

Table 29: Summary of NPVs for option 3

£m, 2015 prices	Discounted							
			Low		Central		High	
	Total carbon benefits	Net value added	Resource cost	Net cost/ benefit	Resource cost	Net cost/ benefit	Resource cost	Net cost/ benefit
2017	44	6	32	18	76	-26	116	-66
2018	87	11	59	39	149	-51	230	-132
2019	127	18	162	-17	301	-156	481	-336
2020	164	24	278	-90	466	-278	614	-426
2021	159	28	260	-72	442	-254	576	-388
2022	155	31	239	-53	415	-229	543	-357
2023	151	33	226	-41	389	-205	514	-329
2024	147	35	222	-39	366	-183	486	-303
2025	144	37	215	-34	343	-162	459	-278
2026	141	39	207	-26	325	-145	435	-254
2027	139	41	198	-18	308	-128	412	-232
2028	136	43	187	-8	291	-112	390	-211
2029	134	44	176	3	275	-96	369	-191
2030	132	46	163	14	259	-81	350	-172
Total	1861	438	2623	-324	4405	-2106	5976	-3677

NPVs under sensitivity analysis

7.13 Detailed NPV estimates for sensitivity analyses are shown in appendix 4. The summary tables below show some of the main findings

Table 30:[19] Summary of net present value estimates of the three options (2017-2030) for sensitivity analysis 'high exogenous waste biodiesel price and high crop use'

Additional to baseline, 2015 prices	Total additional carbon savings ($MtCO_2e$)	Present value benefits (£m)	Present value costs central estimate (£m)	Net present value (£m) central estimate
Option 1	17.4	1191	3415	-2223
Option 2	33.6	2303	4269	-1966
Option 3	35.2	2299	4758	-2459

Table 31: Summary of NPV estimates for sensitivity analysis 'high endogenous waste biodiesel price'

Additional to baseline, 2015 prices	Total additional carbon savings ($MtCO_2e$)	Present value benefits (£m)	Present value costs central estimate (£m)	Net present value (£m) central estimate
Option 2	33.6	2303	5344	-3041
Option 3	35.2	2299	5833	-3534

Table 32: Summary of net present value estimates of the three options (2017-2030) for sensitivity analysis 'high carbon values'

Additional to baseline, 2015 prices	Total additional carbon savings ($MtCO_2e$)	Present value benefits (£m)	Present value costs central estimate (£m)	Net present value (£m) central estimate
Option 1	30.3	2783	2536	247
Option 2	33.6	3189	3107	82
Option 3	35.2	3230	4405	-1175

[19] In this scenario, the baseline costs are also higher due to the increased waste biodiesel price being present in all scenarios, regardless of UK policy.

Table 33: NPV with GLOBIOM ILUC factors

Additional to baseline, 2015 prices	Total additional carbon savings ($MtCO_2e$)	Present value benefits (£m)	Present value costs central estimate (£m)	Net present value (£m) central estimate
Option 1	27.3	1811	2536	-725
Option 2	32.2	2229	3107	-878
Option 3	36.9	2389	4405	-2016

7.14 For dieselisation and E10 uptake, the impacts on NPVs are relatively minor and are shown in appendix 4.

ii - Non-quantified impacts

7.15 Beyond the impacts on resource costs and carbon savings that have been quantified for this cost benefit analysis, we would expect to see wider economic impacts which we have not attempted to quantify.

Impacts on motorists

7.16 Increasing the RTFO obligation level with a crop cap at or above current levels of crop-derived supply (options 1 or 2) will increase the likelihood of E10 being introduced to the market. E10 introduction needs to be carefully managed to minimise consumer impacts, including:

- A need to ensure access to E5 on forecourts, for drivers of older, incompatible cars. This only applies to older petrol cars (primarily those made before the year 2000). By current estimates this will affect around 5% of petrol cars by 2020.
- The cost per mile driven increases marginally due to the lower energy content of ethanol.

Impacts on fuel suppliers

7.17 All policy options represent an increase in demand for the renewable fuels industry as a whole. However, policy option 3 would have significant impacts on existing UK ethanol suppliers. To continue supplying to the UK market under a zero crop cap, they would be required to move from crop feedstocks to waste feedstocks and 'advanced ethanol' at high cost, which could adversely affect their businesses.

7.18 The additional requirement on the UK to report ILUC impacts of crop-derived fuels will not generate an administrative burden on fuel suppliers but could affect the public image of some fuel suppliers.

7.19 The changes to the 'carry-over' of RTFCs will also have an impact on fuel suppliers see section section iii).

Impacts on the wider economy

7.20 Apart from contributing to UK carbon budgets, all three policy options contribute to meeting the requirements of the Fuel Quality Directive, the transport-specific

RED sub-target, and the cross-sector 2020 RED target, the latter of which requires 15% of energy to come from renewable sources across heating, electricity generation and transport. This contribution varies slightly across the three policy options.

7.21 An increase in the RTFO obligation and the introduction of the 'development fuels' sub-target increase the risk that fuel suppliers will choose to buy out, which would generate additional revenue for HMT. This is most likely under policy option 3, where we expect the high UK demand may lead to a price increase for waste-derived biodiesel.

7.22 The lower energy content of ethanol also means additional revenue for HMT, since larger volumes of E10 would be needed to drive the same mileage as with E5.

7.23 In line with changes to the obligation level and the development fuels sub-target, we would expect wider economic impacts such as job creation in the advanced fuels industry and potentially job creation or job losses in the conventional biofuel industry.

7.24 Policy option 3 could increase the demand for imported animal protein feed, if it affects the UK production of ethanol. This currently generates protein animal feed as a coproduct.

7.25 For the UK economy as a whole, fuel security is expected to increase as dependence on imported fossil fuels decreases.

iii - Impacts of amending carry over

Table 34: Assessment of carry over options

Options	Flexibility for suppliers	Risk of increased costs	Risk to meeting the RED target, under supply of renewables
0. No change - carry over permitted as now, obligation reaches 9.75% in 2020.	High flexibility as now.	No risk of additional costs from obligation; potentially high costs from EU infraction proceedings.	High risk of under supply in year 2020.
A. Carry over permitted as now but the obligation is increased by a further 15% or 25%.	High flexibility as now.	Very high increased costs due to increased obligation. Mitigated slightly by flexibility.	Low risk of under supply in year 2020.
B. Reduce carry over into 2020 to 15% but the obligation is increased by a further 15%.	Reduced flexibility.	High risk of increased costs due to increased obligation	No significant risk of under supply in year 2020
C. No carry over into 2020, and no carry over out of 2019.	No flexibility.	Higher risk to costs due to very limited flexibility.	No significant risk of under supply in year 2020.
D. No carry over into 2020, supplier can carry out of 2019 into 2021 instead. Carry over into 2021 remains capped at 25%.	Some reduced flexibility.	Some risk of increased costs.	No significant risk of under supply in year 2020.

7.26 The changes to the 'carry-over' of RTFCs under options B, C, and D may have a positive or negative impact on costs to fuel suppliers, depending primarily on the comparative price of biofuels in 2019 versus 2020, and to a lesser extent 2021. If biofuel costs are higher in 2019 than expected by suppliers for 2020, there is little to no cost for suppliers under the options proposed.

7.27 Option 0 has no direct cost but risks infraction should there be a big variation in the market for RTFCs e.g. a low price in 2019 and high carry over into 2020.

7.28 The highest cost option would be option A, carry over as now with an increased obligation level to avoid under delivering on the 2020 target. In order to mitigate the infraction risk, the obligation level would need to increase by around 15% to 25% in 2019, beyond the trajectory proposed above, based on the fact that historically around 15% of the obligation has been met with carry over. This would help ensure that the 10% transport target for renewable energy is met.

7.29 Since 2020 will be a peak demand year for biofuels, it is more likely that restrictions on carry over into 2020 will impose lower costs on fuel suppliers than an increase in the obligation to compensate for carry over. We have not estimated this impact due to the high price volatility of the biofuels market and the high uncertainty around how much carry over would or would not be exercised in 2020.

7.30 Option D (the preferred option) allows some flexibility but at a lower cost than option C and seems unlikely to be more costly than option B.

7.31 Option D (like options A and B) offers the benefit of ensuring the value of RTFCs earnt/biofuel supplied in 2019 is not written off, but with the added benefit of addressing the risk that we miss the RED target.

Q.55: Do you have any evidence on the impact of proposed changes to RTFC carry-over in 2020?

Q.56: Do you have any additional evidence that you consider relevant to this cost benefit analysis?

8. Appendices

Appendix 1 - Details of analytical evidence and assumptions

Current share of biofuels and baseline renewable share

8.1 The current share of biofuels is used to estimate biofuel use under the baseline. The table below shows UK biofuels historically supplied under the RTFO, as recorded in RTFO statistics.[20]

Table 35: Renewable fuels supplied under the RTFO by volume

million litres	2012/13 (Year 5)	2013/14 (Year 6)	2014/15 (Year 7)
Total fuel use	44,706	50,417	50,882
Single rewarded renewable fuels	805	933	835
Double rewarded renewable, after double reward	1,058	1,621	1,662
Single + double rewarded renewable	1,863	2,554	2,496
as % of total	4.2%	5.1%	4.9%

Table 36: Fuels supplied historically under the RTFO as % of energy supplied and baseline projections

Fuel	2012/13 (Year 5)	2013/14 (Year 6)	2014/15 (Year 7)	Baseline (2017/18)
Biodiesel	1.05%	1.63%	1.57%	1.53%
Ethanol	1.09%	1.01%	0.98%	0.93%
Other fuels	0.07%	0.07%	0.02%	0.14%
Total	2.21%	2.71%	2.57%	2.60%
RED contribution (including fuels that are double rewarded)	3.24%	4.12%	4.01%	4.27%

[20] https://www.gov.uk/government/collections/biofuels-statistics

Demand projections

8.2 Projections for road transport energy demand have been taken from BEIS' Energy and Emissions Projections (EEP) 2015, Reference scenario (www.gov.uk/government/collections/energy-and-emissions-projections). All existing and planned UK government policies are taken into account. It projects that total energy demand will come to 421 TWh and 468 TWh in 2020 (for the purposes of the RED and FQD respectively). Given the relative stability of total energy demand, we have not modelled sensitivities around this.

Figure 9: Transport energy demand projections, TWh

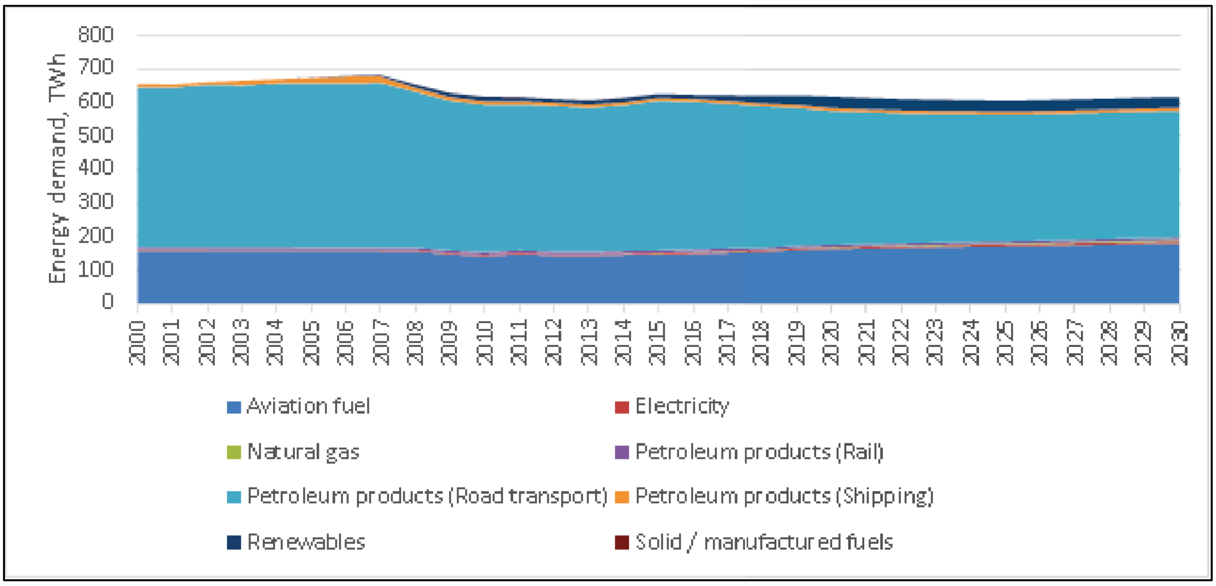
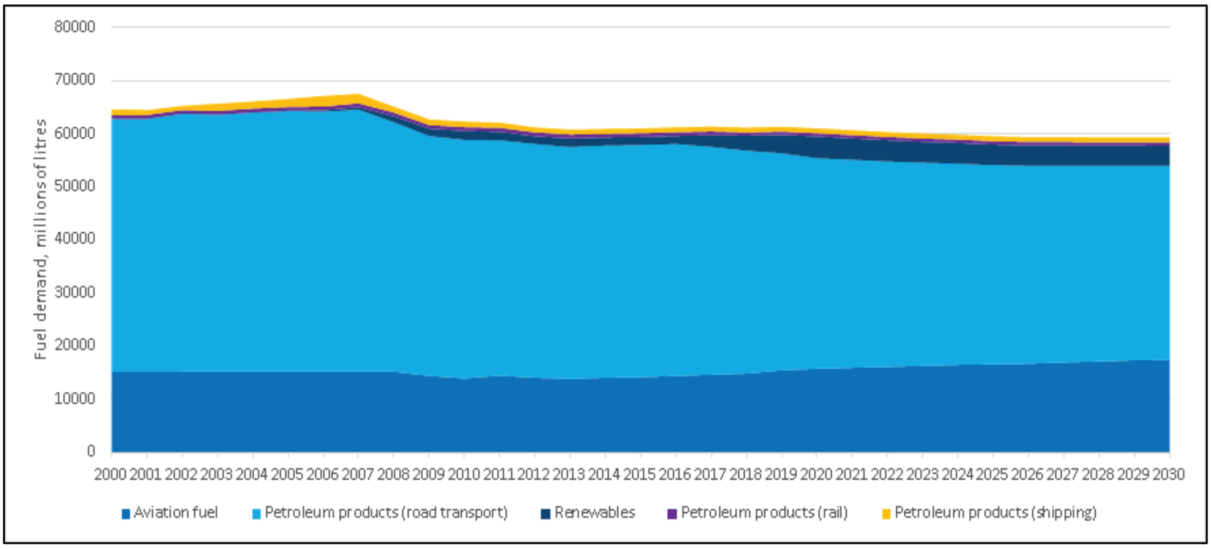


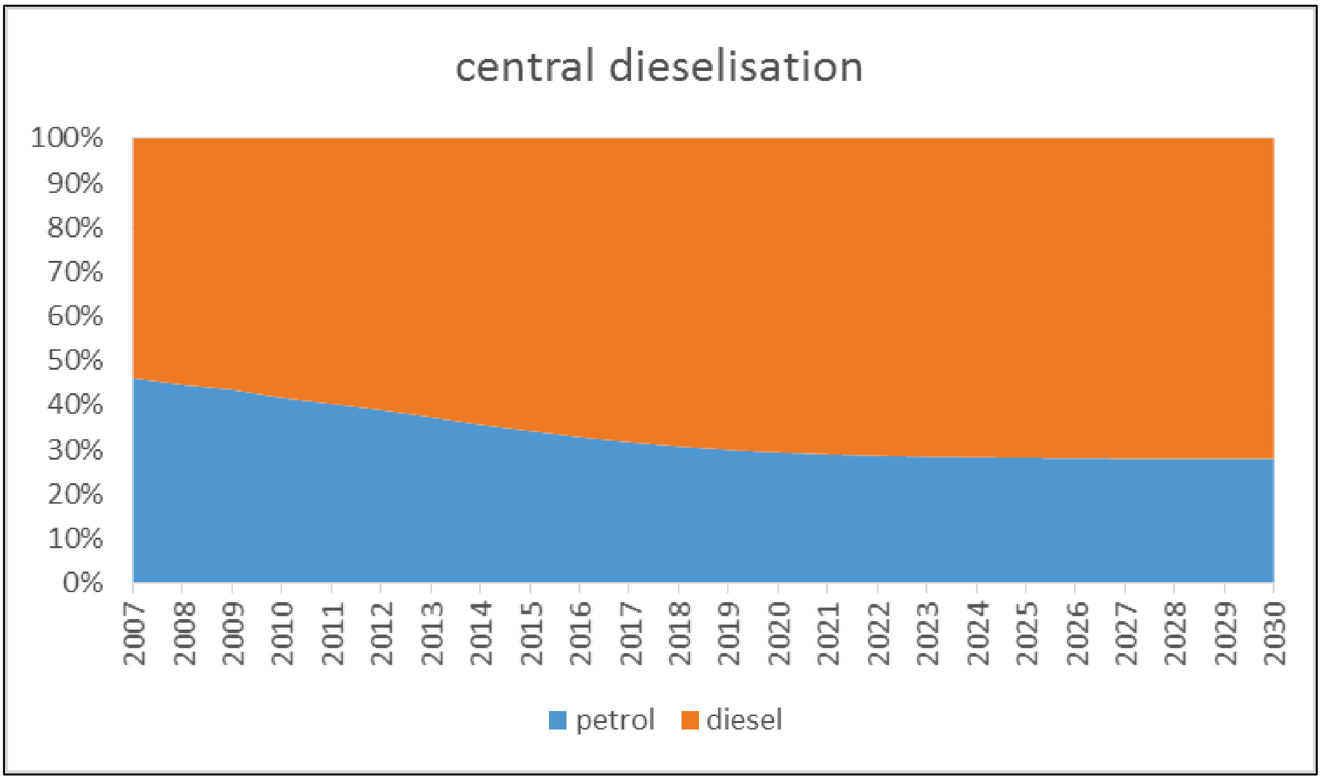
Figure 10: Transport energy demand projections, million litres



Projections for petrol/diesel split from EEP 2015

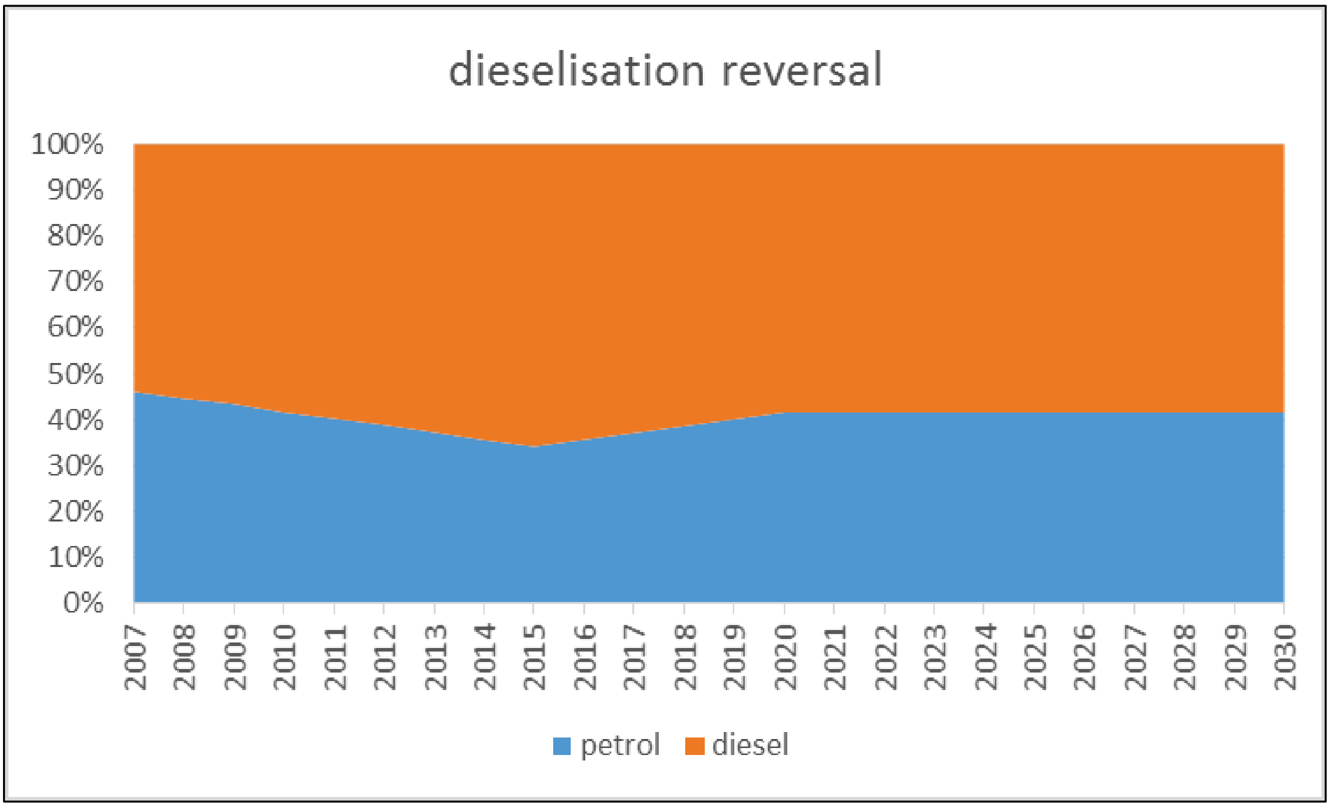
8.3 This is also taken from BEIS' EEP 2015, available at: www.gov.uk/government/collections/energy-and-emissions-projections. It projects that the diesel share of road transport energy will rise from 65% in 2015 to 70% in 2020. Given potential uncertainty, we have also modelled a 'low dieselisation' scenario, where we examine the impact of a reversal in the dieselisation trend back to 2010 levels (58%) in 2020.

Figure 11: Central dieselisation projections, source EEP



8.4 For this sensitivity, we assume the dieselisation of the fleet reverses between 2015 and 2020 back to the same level as in 2010 and then remains constant to 2030.

Figure 12: Low dieselisation projections for sensitivity test



Energy densities per litre

8.5 For modelling purposes, we use the below energy densities.

Table 37: Energy densities of different fuels[21]

Fuel	Energy density (MJ/l)*
Diesel	35.77
Petrol	32.95
Ethanol	21.28
Biodiesel	32.8
Biomethane	50
Biomethanol	16

*MJ/kg for biomethane

[21] Annex 2, DTI 'Technology Status Review and Carbon Abatement Potential of Renewable Transport Fuels in the UK', www.fcrn.org.uk/sites/default/files/DTI_Technology_status_review.pdf

Cost projections for renewable fuels supplied under the RTFO

8.6 The cost of blending renewable fuels and generating RTFCs depends on the difference in market prices between fossil fuels and renewable fuels, which is why we use the terms 'price projections' and 'cost projections' interchangeably in this CBA.

8.7 Global energy and commodity markets are inherently volatile and future market developments are notoriously difficult to predict. To capture this uncertainty, we have developed low/central/high projections of the price spreads between renewable fuels and fossil fuels (Figures 14, 16, 18). These are projected independently of the underlying fossil fuel prices and commodity prices.

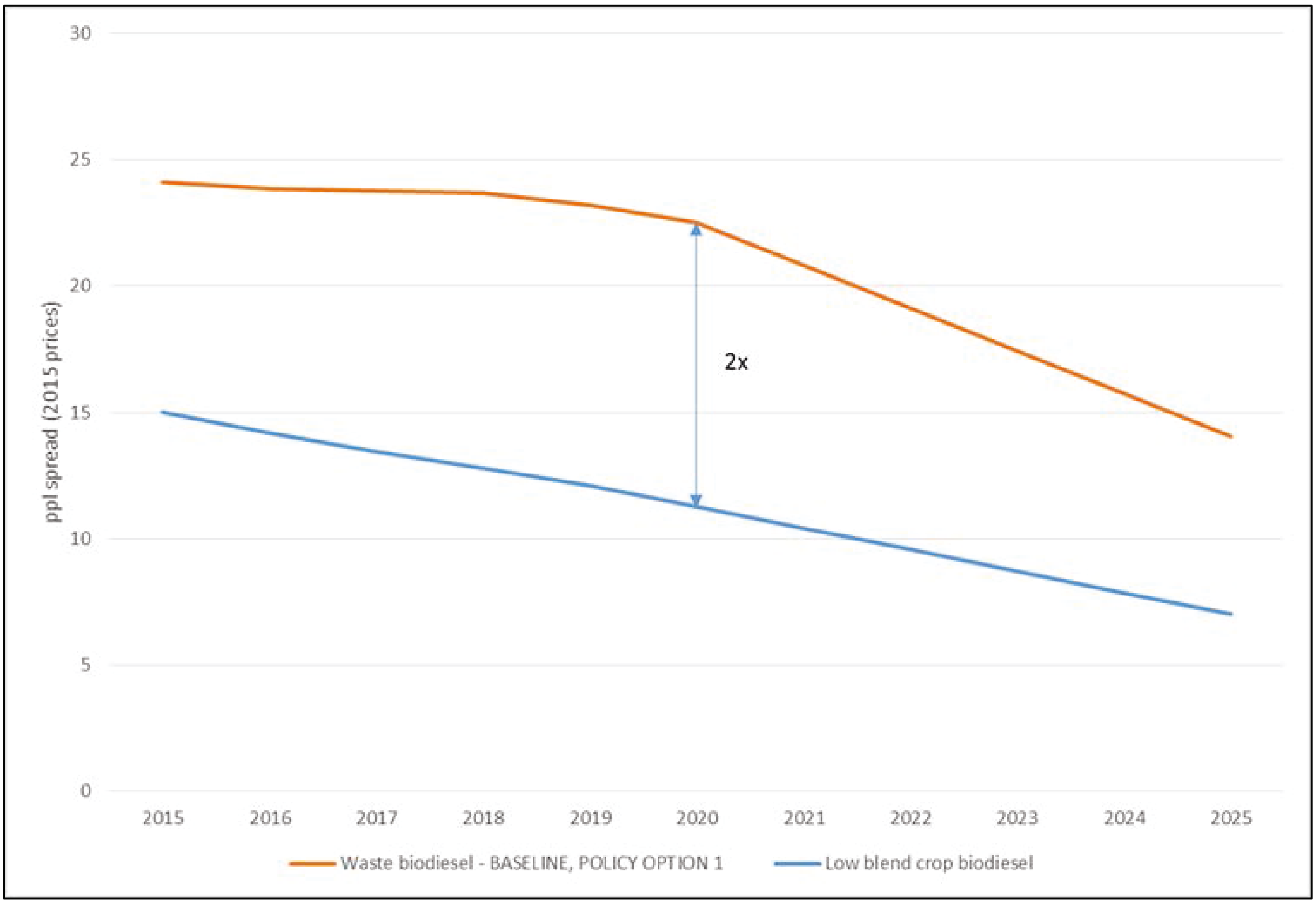
8.8 The low/central/high cost projections were developed for the price spreads between fossil fuels and renewable fuels per unit of energy and reflect different possible future developments of global fossil oil, vegetable oil and ethanol markets. To make them more accessible to the audience, we have also translated these into price projections per litre (Figures 15, 17, 19).

8.9 In our central cost projections, the spreads between fossil fuels and renewable fuels fall steadily, since historically the cost of renewable feedstocks has fallen faster than the cost of fossil fuels. We also consider the possibility of spreads either rising (high cost projections) or falling faster (low cost projections).

8.10 Though the majority of our projections predict ethanol will be more expensive than crop biodiesel in energy terms (£/MWh), as the RTFO is a volume-based measure and ethanol has a relatively low energy density, we anticipate ethanol will still be cheaper by volume (p/litre). We expect that generating RTFCs from blending ethanol will therefore remain most cost-effective for suppliers, and ethanol will be supplied in preference to other fuels up to the blendwall (E5 or E10) and subject to the crop cap.

8.11 The cost projections for 'waste biodiesel' are based on the following: 2015 value based upon observed historical diesel- waste biodiesel spreads. This increases to two times the crop biodiesel spread per litre (not per MWh) in 2020, due to a significant increase in demand for waste biodiesel. From 2020, the waste biodiesel spread tracks the crop biodiesel spread (times 2) over the period to 2030.

Figure 13: Waste biodiesel spreads, central projection



8.12 As illustrated in Figures 16 and 17, under the high cost projections, waste biodiesel prices reach the buy out price in 2020 and stay at the buy-out price (in real terms) from then onwards.

8.13 For the purposes of labelling, 'low blend' biodiesel is defined as biodiesel blended into fossil diesel at proportions up to 7%. All biodiesel used in blends above 7% is defined as 'high blend', which is not suitable for all diesel engines, and is modelled with a cost uplift of 9 pence per litre to represent the higher costs of using this fuel. This is a DfT estimate, which has been validated by stakeholders with experience of using high blend biodiesel.

Box1: Central cost projection methodology

Resource cost projections were derived as below:

- 1G (1st generation) crop ethanol – 2015 value based upon observed historical petrol-ethanol spreads with a gradual decline over time reflecting a gradually rising oil price and agricultural productivity improvements which allow supply to keep pace with increased demand without significant agricultural commodity price rises.
- 1G low blend crop biodiesel – 2015 value based upon observed historical diesel-crop biodiesel spreads, with a gradual decline over time reflecting a gradually rising oil price and agricultural productivity improvements which allow supply to keep pace with increased demand without significant agricultural commodity price rises.
- 1G high blend crop biodiesel – low blend crop biodiesel plus 9 ppl.
- 1G waste biodiesel - 2015 value based upon observed historical diesel- waste biodiesel spreads. Going forward, it is a function of the crop biodiesel spread per litre, reaching two times the crop biodiesel spread per litre in 2020. Post-2020 it tracks the crop biodiesel spread (2x) over the period to 2030.

Cost projections for waste biodiesel under policy options 2 and 3

8.14 For all fuels except waste biodiesel we assume that the policy options considered in this consultation will have no impact on their market price. In contrast, we assume that at higher levels of UK demand for waste biodiesel, the increase in UK demand resulting from the policy options is sufficient to increase the price of waste biodiesel.

8.15 Following discussions with stakeholders, we have adopted the central modelling assumption that significant supply constraints (or price increases) do not occur at levels of supply below 1.7 billion litres of waste biodiesel in 2020, which is just over two times current supply. As shown in section 6, while option 1 results in a significant increase in the demand for waste biodiesel relative to the baseline, fuel suppliers retain flexibility to supply crop biodiesel instead. We assume that the price of waste biodiesel is the same under policy option 1 as in the baseline. Under option 2, the crop cap results in a further small increase in the demand for waste biodiesel relative to option 1. Of itself, we would not expect this increase in demand to be sufficient to increase the price of waste biodiesel. However, under option 2, the low crop cap restricts suppliers' ability to use crop biodiesel instead of waste biodiesel. We assume this marginally increases the price of waste biodiesel paid. For modelling purposes we have assumed a one penny per litre premium.

8.16 Under option 3, UK waste biodiesel use increases to 2.16 billion litres, significantly above the 1.7bn litres expected under policy option 2 and above the level at which we expect price increases to set in, reflecting the likelihood of significant supply constraints in meeting this level of demand. There is high uncertainty surrounding how an increase in demand of this scale will affect the price that UK suppliers pay for waste biodiesel.

8.17 In assessing the impact of option 3 on prices, we define the concept of a 'max scarcity' price of biodiesel. This is defined as being the price of biodiesel that we would see if significant additional demand for waste biodiesel across Europe put pressure on the market and if other EU member states were restricted in their ability to use low blend biodiesel (e.g. by the blend wall). In this situation, the closest substitute for waste biodiesel for some member states would be high blend crop biodiesel and we would expect the international price of waste biodiesel to be driven up to the point where it would cost the same to use one litre of waste biodiesel or two litres of high blend crop biodiesel.

8.18 In a situation where this 'max scarcity' scenario is combined with a low crop cap in the UK, we expect the price to increase above this 'max scarcity' price, given that the low crop cap will limit UK suppliers' ability to substitute waste biodiesel for any blend of crop biodiesel. For the purposes of modelling we assume that prices increase to one penny per litre above the 'max scarcity' price (represented by the highest price projection in figures 20-23).

8.19 Under option 3, we assume that the significant increase in demand for waste biodiesel coupled with a crop cap significantly increases the likelihood that the price of waste biodiesel increases to the 'max scarcity' price plus a one penny premium. For the purposes of modelling policy option 3, we assume the price spread increases to a point exactly half way between the waste biodiesel price under a low crop cap and no scarcity (baseline plus 1 penny premium) and the 'max scarcity' price plus one penny premium.

8.20 The waste biodiesel price projections converge for policy options 1, 2 and 3, under the high price projections because they all hit the buy-out price in 2020/21. Beyond 2020, the price projections track the buy-out price and decline, as the buy-out price falls in real terms.

Figure 14: Central cost projections for different feedstocks 2015-2030, £/MWh spread over fossil fuels, 2015 prices

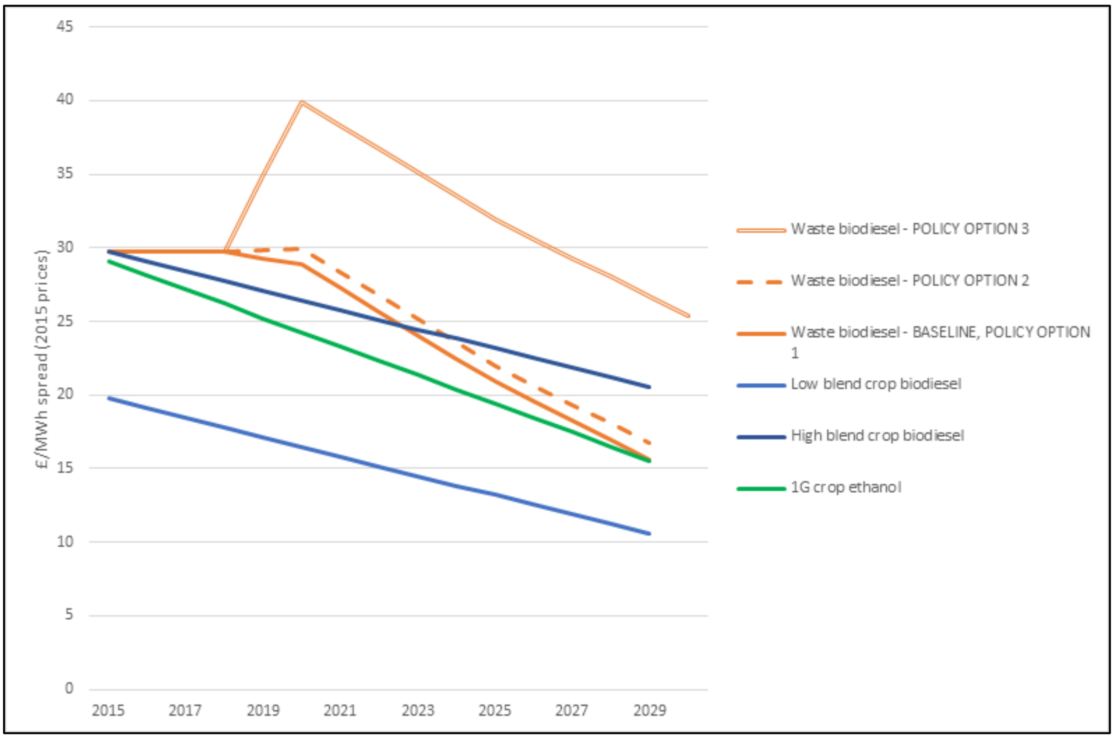


Figure 15: Central cost projections for different feedstocks 2015-2030, ppl spread over fossil fuels, 2015 prices

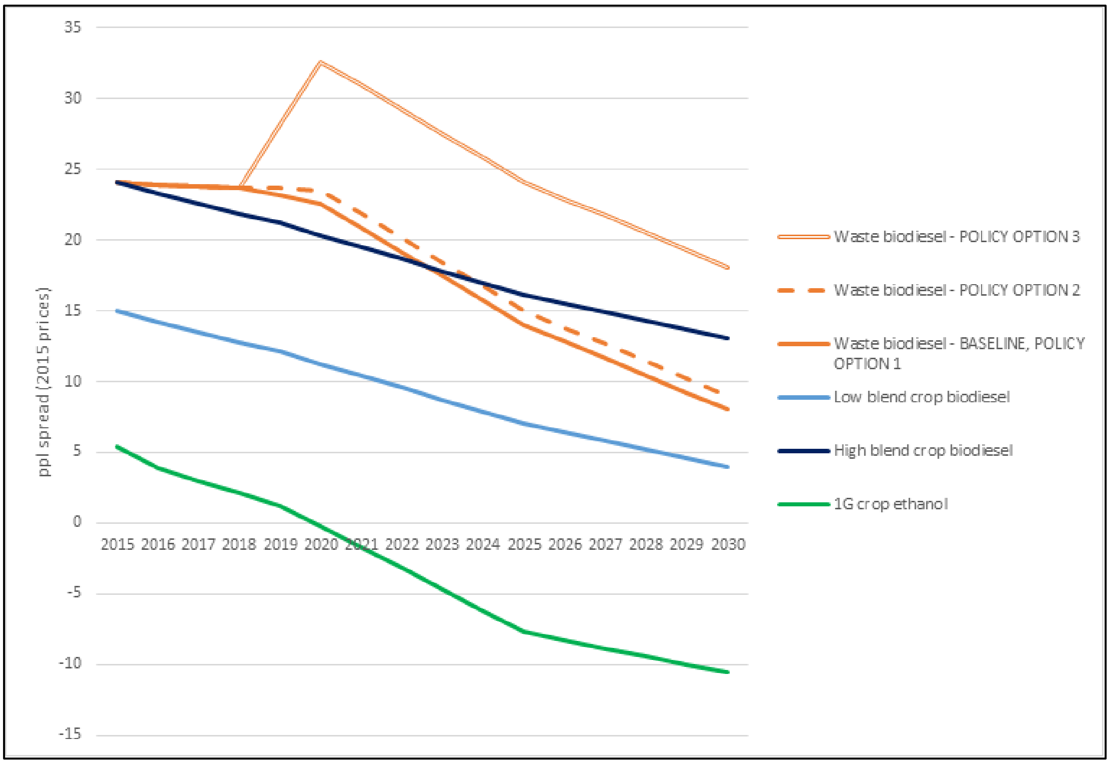


Figure 16: High cost projections for different feedstocks 2015-2030, £/MWh spread over fossil fuels, 2015 prices

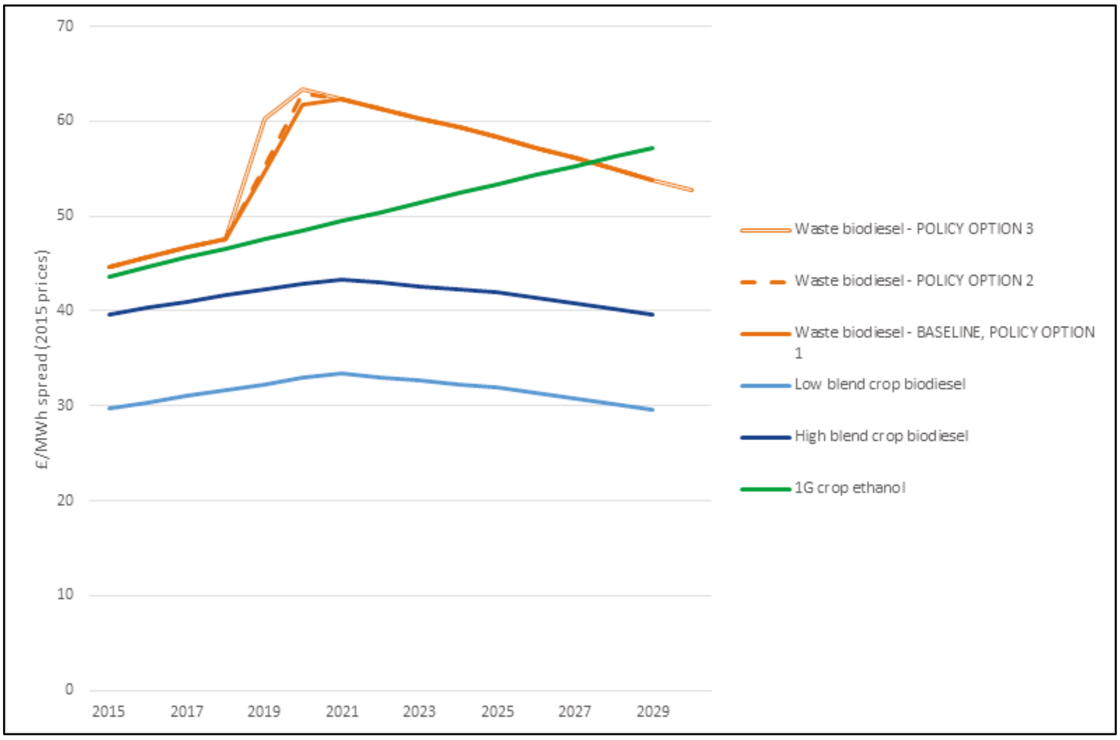


Figure 17: High cost projections for different feedstocks 2015-2030, ppl spread over fossil fuels, 2015 prices

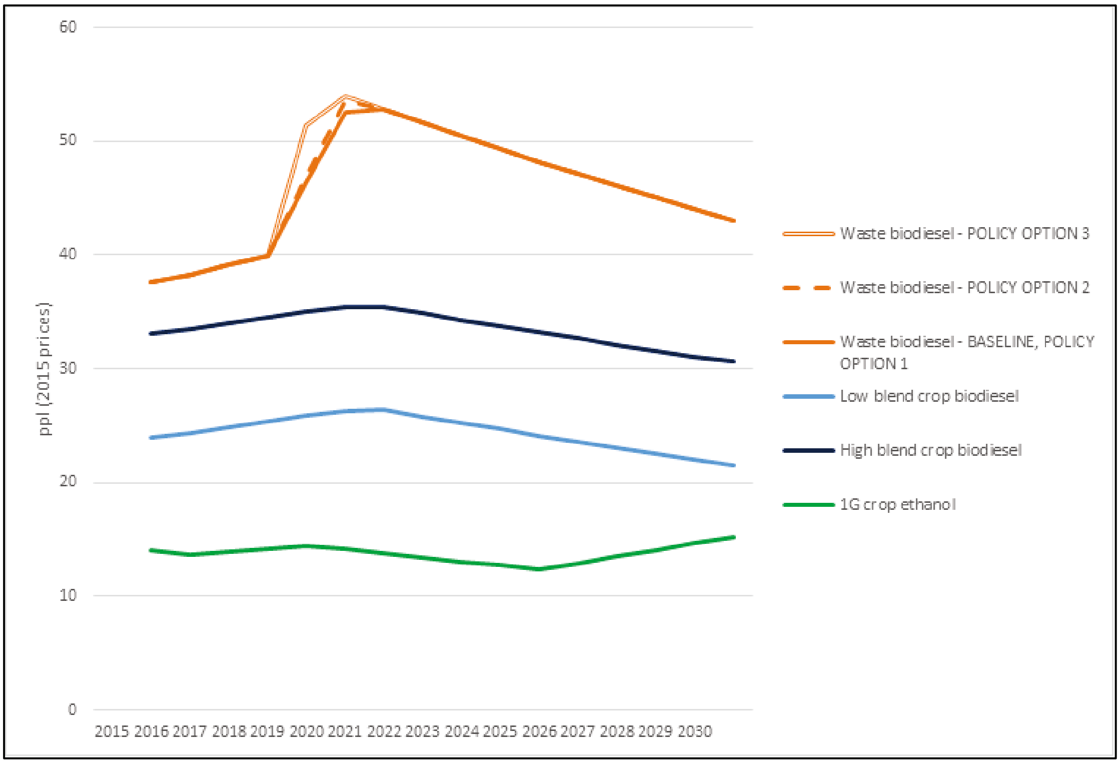


Figure 18: Low cost projections for different feedstocks 2015-2030, £/MWh spread over fossil fuels, 2015 prices

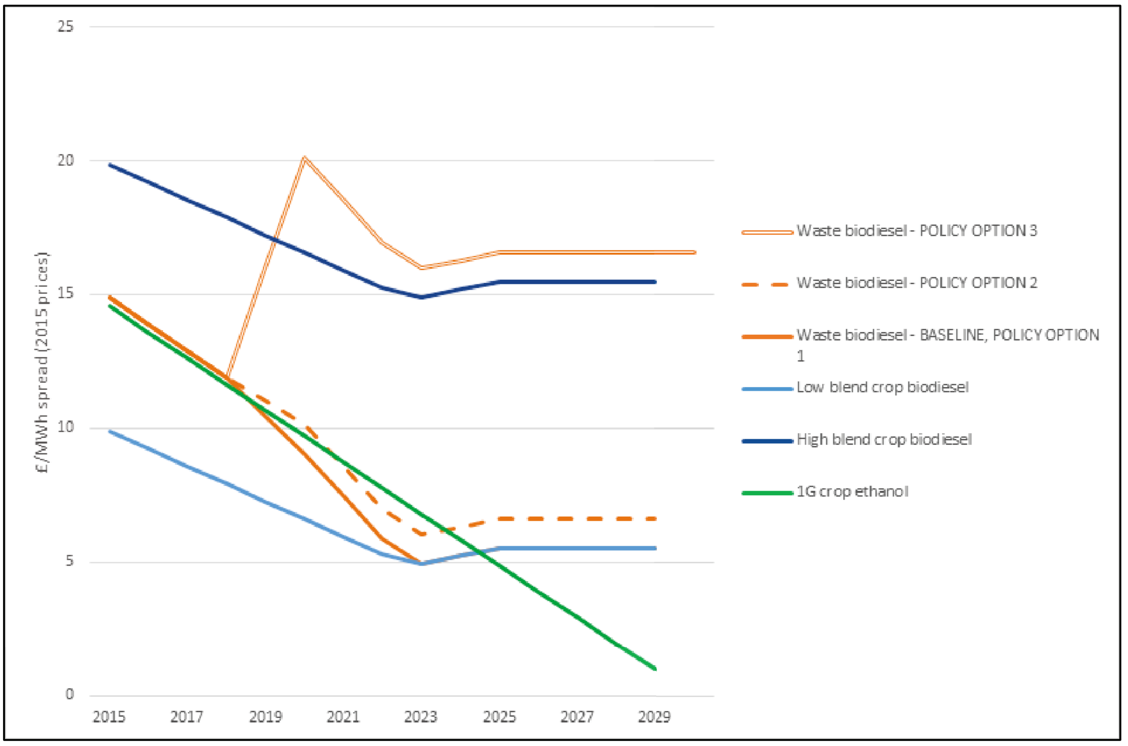


Figure 19: Low cost projections for different feedstocks 2015-2030, ppl spread over fossil fuels, 2015 prices

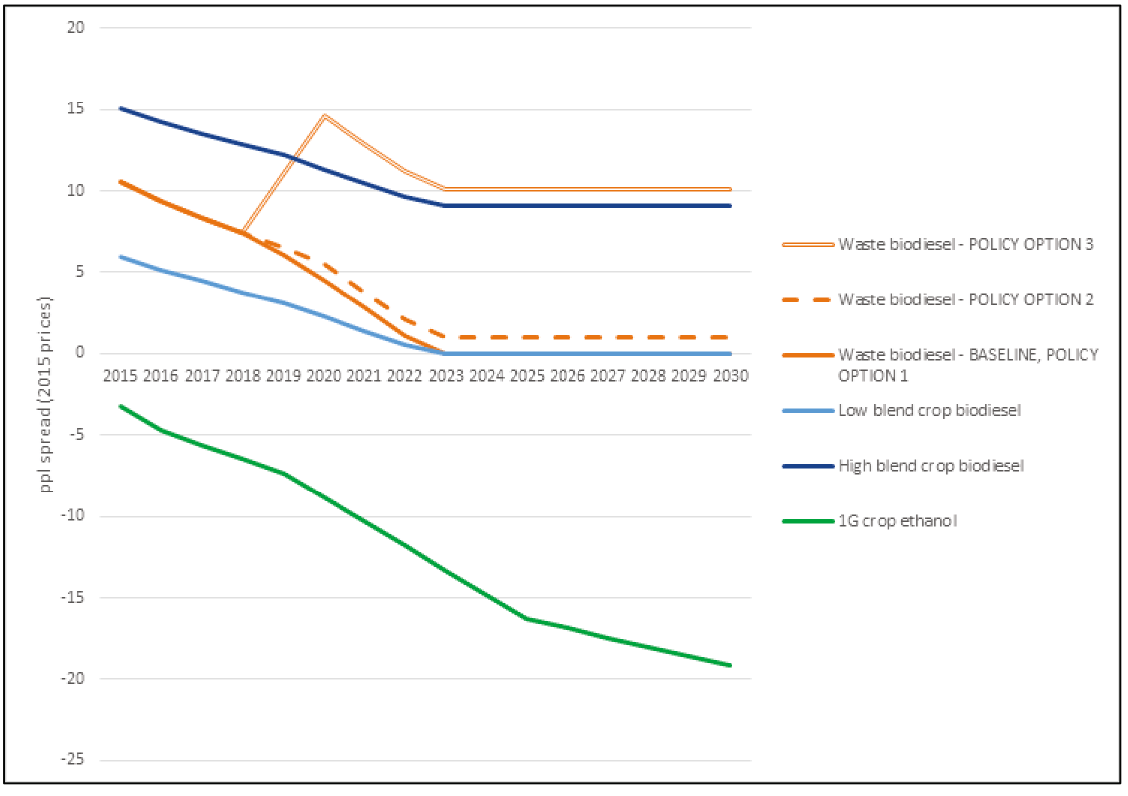


Figure 20: Cost projections assuming higher waste biodiesel prices under baseline (£/MWh), 2015 prices

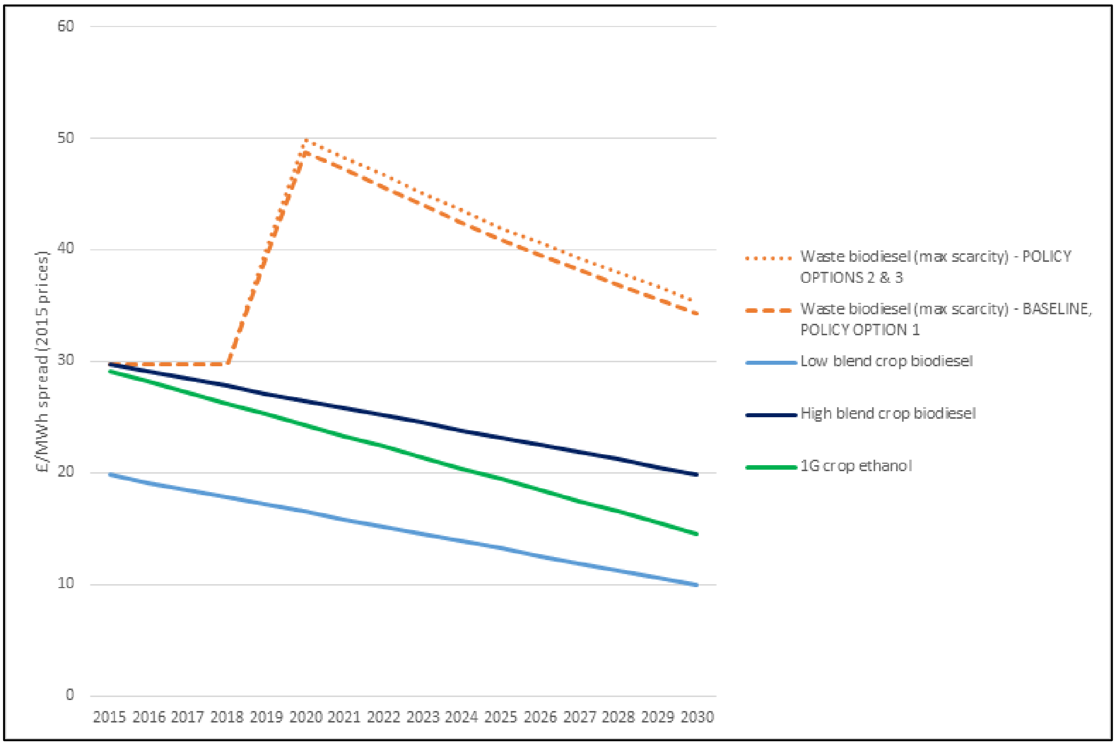
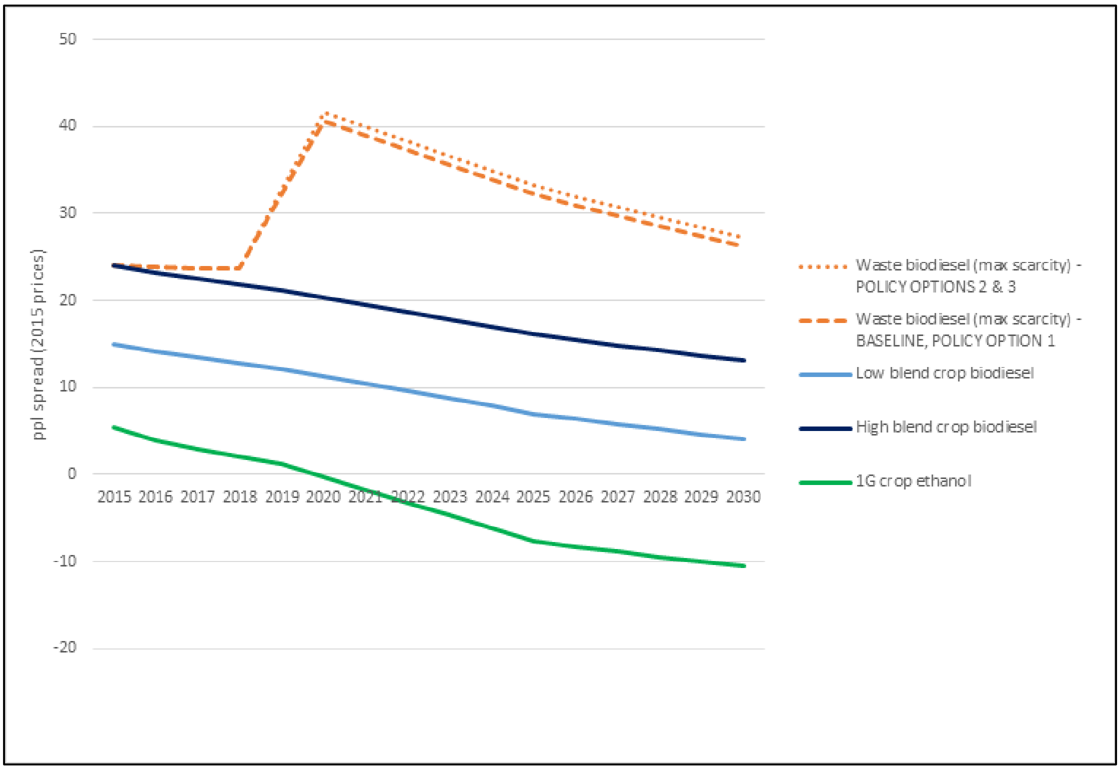


Figure 21: Cost projections assuming higher waste biodiesel prices under baseline (pence per litre), 2015 prices



Additional cost projections for waste biodiesel - sensitivity analysis

8.21 We have performed two sensitivity tests using alternative assumptions about waste biodiesel prices. The first of these considers the possibility that biodiesel prices are significantly higher than we have assumed for reasons other than the introduction of the policy options considered in this CBA and their impact on UK demand (exogenous price increase). In this scenario we have assumed that the international price of waste biodiesel increases to the 'max scarcity' price (see 8.19 above). We also assume that the UK waste biodiesel price increases slightly more under option 2 and option 3 as a result of the low crop cap restricting the ability of suppliers to substitute crop biodiesel for waste biodiesel. For modelling purposes, we assume this premium is one penny per litre. The cost projections are set out in figures 20 and 21 below, and the figures show that most of the cost increase also occurs in the baseline.

8.22 The second sensitivity considers the possibility that while baseline waste biodiesel prices are as assumed in our central cost projections, the significant increases in UK demand for waste biodiesel resulting from options 2 and 3 result in significantly greater increases in price than we have assumed in our core low, central and high price scenarios (endogenous price increase). For options 2 and 3 we assume that the price of waste biodiesel increases to the 'max scarcity' price (as defined in paragraph 8.19) plus a 1 penny premium to account for the low crop cap as above. The cost projections are set out in figures 22 and 23 below, and the figures show that for this sensitivity, most of the cost increase does not occur in the baseline.

Figure 22: Cost projections assuming higher waste biodiesel prices as a result of policy options (£/MWh), 2015 prices

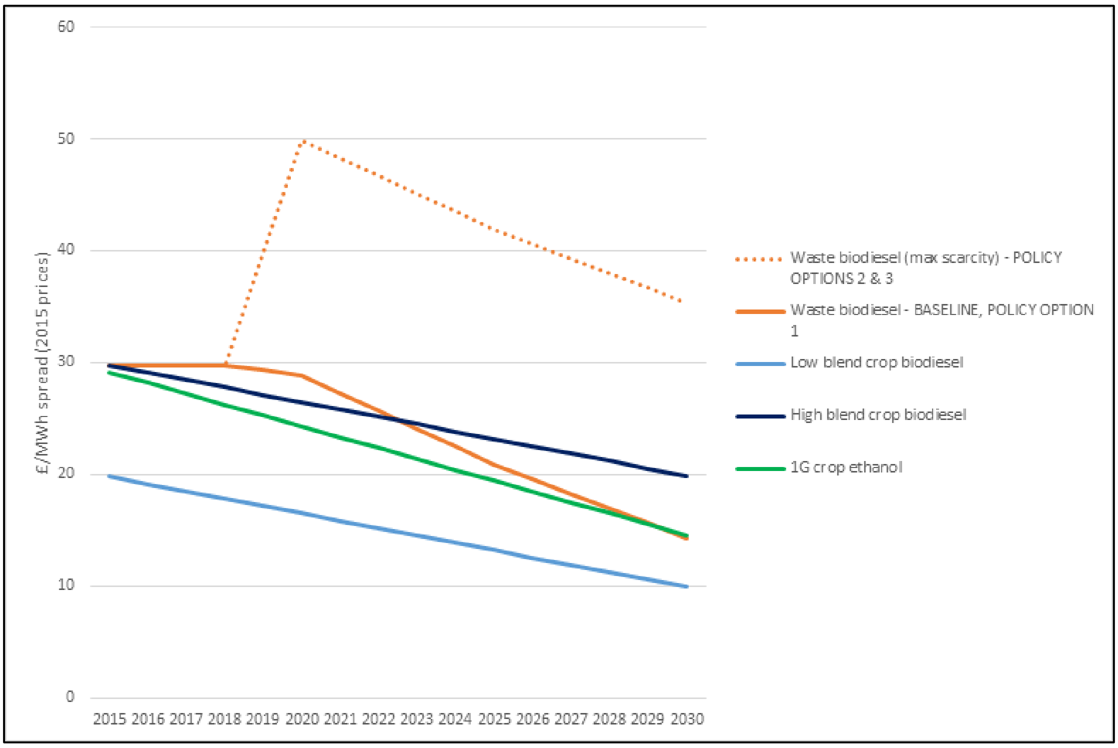
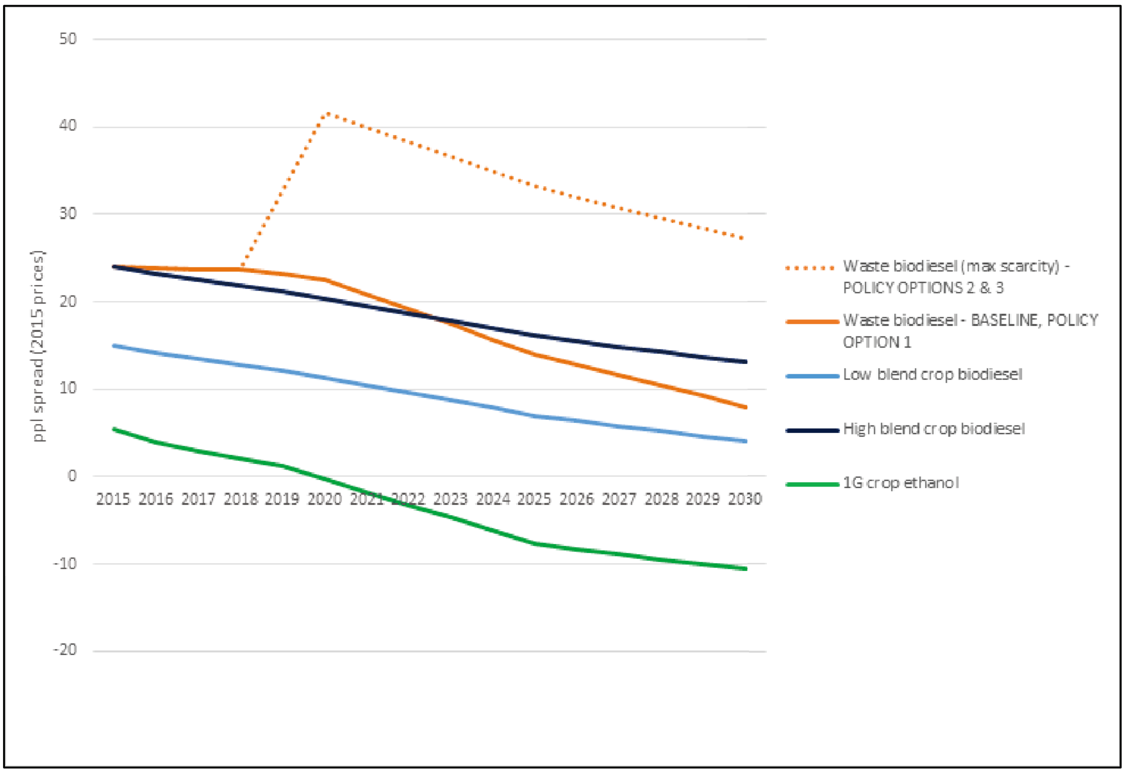


Figure 23: Cost projections assuming higher waste biodiesel prices as a result of policy options (pence per litre), 2015 prices



Cost projections for fuels supplied under development fuels sub-target

Figure 24: Price projections for fuels supplied under the development sub-target, £/MWh, 2015 prices

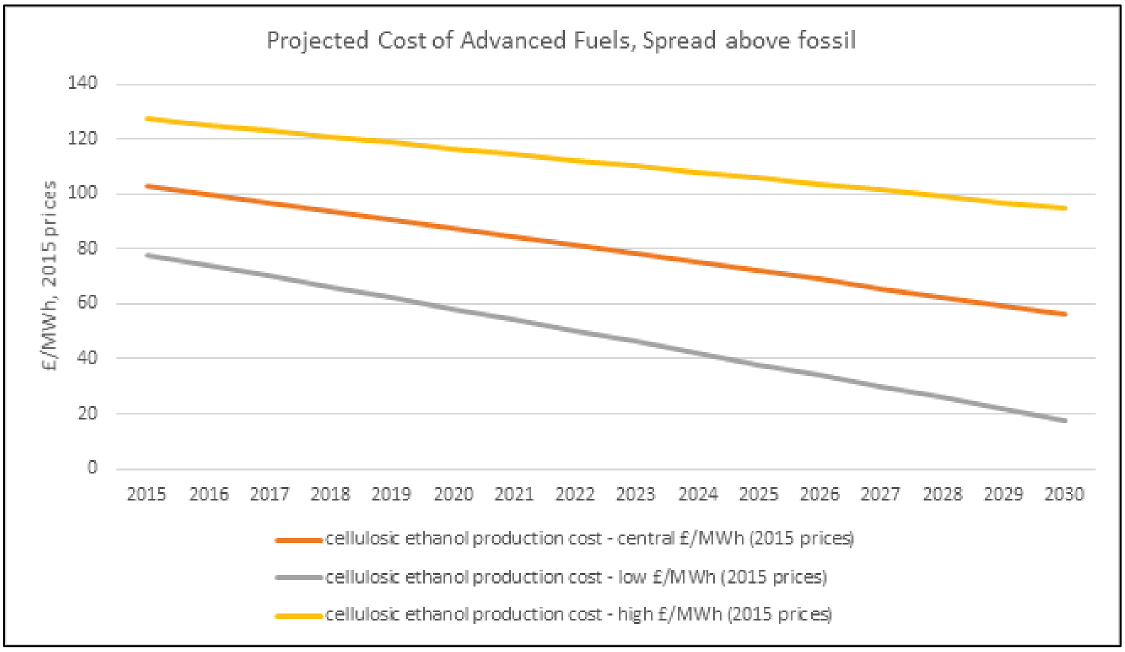
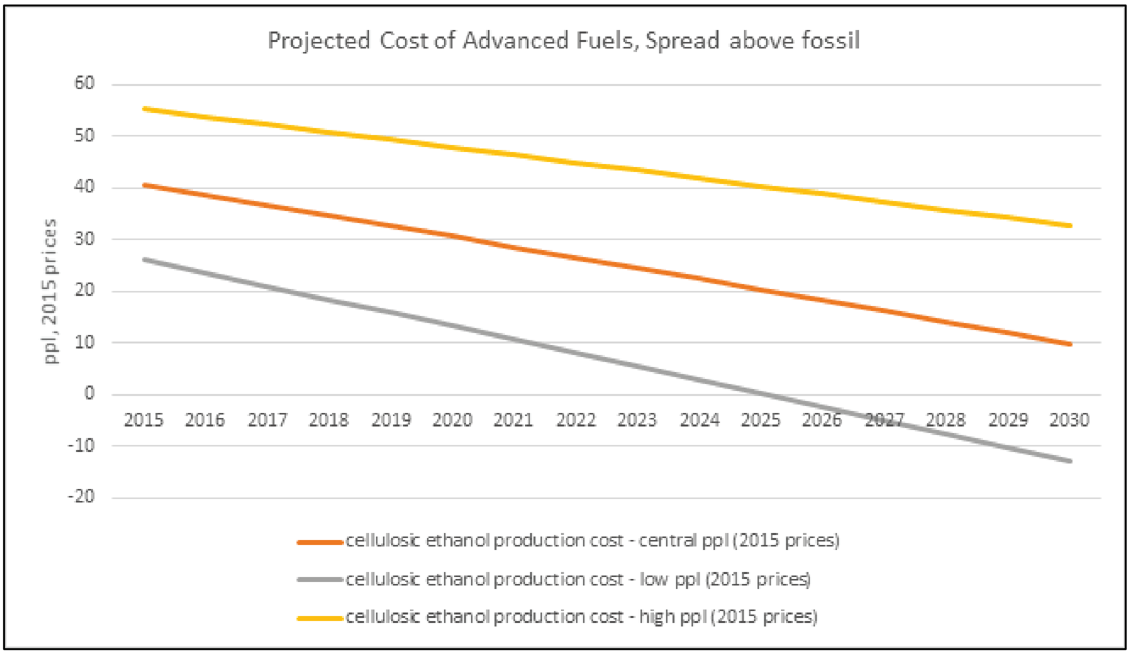


Figure 25: Price projections for fuels supplied under the development sub-target, ppl, 2015 prices



8.23 The price projections (£/MWh) for cellulosic ethanol are also used as a proxy for advanced biodiesel and other waste-derived drop in fuels. Biodiesel has a higher energy content per litre, so the price per litre is higher for advanced biodiesel than for cellulosic ethanol. This means we use the supply cost (£/MWh) of advanced ethanol as a proxy for supply cost of other advanced fuels, due to a lack of other evidence.

Different scenarios for E10 uptake

8.24 For E10, we have three uptake scenarios in 2020 (with gradual ramp up from 2017 to 2020 and constant from 2020 onwards).

Uptake scenario used:	Effective ethanol blend across all petrol
No E10, current levels	E 4.6
High E10: (85% E9.8 + 15% E4.6)	E 9.05
Mid-point, central scenario: (59.5% E4.6 + 40.5% E9.8)	E 6.825

Contribution of electricity to meeting the RED sub-target

8.25 We assume approximately 300,000 electric road vehicles in the UK in 2020, and that 40% of total energy used in rail comes from electricity. These come from BEIS' Energy and Emissions Projections 2015. Based on the RED, we assume the default value of 30% of this energy being from renewable sources. Based on the EEP electricity and total transport energy demand figures and methodology provided by the RED[22], the contribution of electric rail and vehicles

[22] Article 3, paragraph 4, point c, page 14 of the amendments document: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015L1513&rid=2

towards the RED is projected to be 4.77TWh or 1.1% of transport energy demand in 2020.

Table 38: Contribution of electricity to meeting the RED Target, TWh

TWh		2017	2018	2019	2020
Total demand	Rail	4.50	5.17	5.20	5.23
	Road	0.21	0.31	0.43	0.56
	Total	4.71	5.47	5.62	5.79
Conversion factors Demand ►contribution	Rail	30% from renewable, x 2.5 (multiplier)			
	Road	30% from renewable, x 5(multiplier)			
RED contribution	Rail	3.37	3.88	3.90	3.92
	Road	0.31	0.46	0.64	0.85
	Total	3.68	4.34	4.54	4.77

8.26 For modelling purposes, the following fuels are assumed to be supplied under the sub- target:

Fuels supplied under the 'broad' definition sub-target	Fuels supplied under the fuel specific 'narrow' definition sub-target
Advanced ethanol	advanced kerosene or biodiesel*
'Advanced' biodiesel from Annex IX feedstock	Biomethane
Methanol	
Biomethane	

*This is assumed to be a drop-in fuel, and thus not restricted by blend walls

'Broad' definition

Table 39: Volume of 'development fuels' supplied in the model under a broad definition of the develoment fuels sub-target.

Millions of litres supplied*	Biodiesel	Ethanol	Biomethane	Biomethanol	Total
2017	22	29	9	38	98
2018	22	29	12	38	101
2019	22	29	15	38	104
2020	22	29	18	38	106
2021	25	34	20	44	123
2022	33	44	27	58	163
2023	41	55	33	73	202
2024	49	66	40	86	240
2025	56	76	46	100	278
2026	64	87	53	114	318
2027	72	97	59	128	357
2028	80	108	66	142	396
2029	88	119	72	157	437
2030	97	130	79	171	477

8.27 The broad definition includes fuels which are already supplied today and between 2017 and 2020, the volumes shown above exceed the sub-target. During these years, a share of these fuels would have to claim conventional RTFCs instead of development fuel RTFCs.

'Narrow' definition

Table 40: Volume of fuels supplied in the model under a narrow definition of the development fuels sub-target

Millions of litres supplied*	Biodiesel/ kerosene/ other development fuel	Biomethane	Total
2017	22	9	31
2018	26	12	38
2019	44	15	59
2020	63	18	80
2021	103	20	124
2022	136	27	163
2023	168	33	201
2024	200	40	240
2025	232	46	278
2026	265	53	317
2027	297	59	357
2028	330	66	396
2029	363	72	436
2030	397	79	476

*millions of kilograms for biomethane

Table 41: Central biomethane uptake scenario

	2014	2015	2016	2017	2018	2019	2020
No. of gas HGVs in fleet, 12.5% of fuel is biomethane	500	1650	2800	3950	5100	6250	7400
Energy from biomethane, TWh	**0.02**	**0.05**	**0.09**	**0.13**	**0.17**	**0.21**	**0.24**

Assumed carbon intensity of different fuels

8.28 carbon intensity of fossil fuels and renewable fuels are set out in the tables below:

Table 42: Carbon intensity of fossil fuels gCO_2/MJ

Fuel Type	Emissions (gCO_2/MJ)
Petrol	93.3
Diesel	95.1
Gas	74.5

- Petrol/diesel GHG intensities are based upon Fuel Quality Directive default values - http://iet.jrc.ec.europa.eu/about-jec/sites/iet.jrc.ec.europa.eu.about-jec/files/documents/report_2014/wtt_appendix_4_v4a.pdf
- Gas GHG intensities are taken from European Commission's JRC Well-to-Wheels report (GRLG1), April 2014 - http://iet.jrc.ec.europa.eu/about-jec/sites/iet.jrc.ec.europa.eu.about-jec/files/documents/report_2014/wtt_appendix_4_v4a.pdf

Table 43: Carbon intensity of renewable fuels gCO_2/MJ

Fuel Type	Total Ems (gCO_2/MJ)	Direct Ems (gCO_2/MJ)	Indirect Ems (gCO_2/MJ)
1G waste biodiesel (UCO)	14.9	14.9	0.0
1G waste biodiesel (tallow)	72.9	14.9	58.0
1G crop biodiesel	96.8	42.0	54.8
2G advanced biodiesel (land using)	21.0	6.0	15.0
2G advanced biodiesel (non land using)	4.0	4.0	0.0
1G waste ethanol	29.2	29.2	0.0
1G crop ethanol	47.0	35.5	11.5
2G advanced ethanol (land using)	35.0	20.0	15.0
2G advanced ethanol (non land using)	17.0	17.0	0.0
Biomethane	21.4	21.4	0.0
Biomethanol	36.1	36.1	0

- 1st generation biofuel emissions (direct) are based upon historical RTFO data (from year 4b onwards) - https://www.gov.uk/government/collections/biofuels-statistics
- 2nd generation biofuel emissions (direct) have been taken from Renewable Energy Directive, Annex V, Part E - http://faolex.fao.org/docs/pdf/eur88009.pdf
- 1st generation crop biofuel emissions (indirect) and 2nd generation biofuel emissions (indirect) have been taken from the European Commission ILUC impact assessment - http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014SC0127&from=EN
- 1st generation tallow biodiesel emissions (indirect) have been taken from Ecofys research http://webarchive.nationalarchives.gov.uk/20110407094507/http://www.renewablefuelsagency.gov.uk/sites/rfa/files/_documents/Appendix_7_-_Tallow_Case_Study_200912231729.pdf

8.29 We recognise that for carbon budgets, biofuels are assumed to have zero carbon emissions associated with them

Valuing carbon savings

8.30 To estimate the value of carbon saved, we have used non-traded carbon values as laid out in Green Book supplementary guidance, available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/483278/Valuation_of_energy_use_and_greenhouse_gas_emissions_for_appraisal.pdf

Table 44: Carbon prices and sensitivities for appraisal, 2015 £/tCO_2e

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Low	31	32	32	33	33	34	34	35	35	36	36
Central	62	63	64	65	66	67	68	69	71	72	73
High	94	95	96	98	99	101	103	104	106	108	109

Additional evidence already received

8.31 Bio-LPG may be supplied in the UK from 2016 onwards but is not reflected in our modelling due to a lack of evidence around its use and impacts and expected small volumes.

Appendix 2 - Share of renewable fuels supplied by volume and by energy

Option 1

Table 45: Renewable fuels as share of overall road transport fuels, option 1

Fuels supplied, share of total by volume	1G ethanol, central scenario	1G crop biodiesel	Total crop	1G waste biodiesel (double-rewarding in brackets)	Development fuels (double-rewarding in brackets)	Other biofuels (double-rewarding in brackets)
Baseline	1.38%[23]	-	1.38%	1.48% (2.96)	0.20% (0.41)	-
2017	1.50%	-	1.50%	2.04% (4.08)	0.22% (0.43)	-
2018	1.61%	-	1.61%	2.59% (5.19)	0.23% (0.46)	-
2019	1.73%	-	1.73%	3.15% (6.29)	0.24% (0.48)	-
2020	1.86%	0.68%	2.54%	3.35% (6.71)	0.25% (0.51)	-
2021	1.82%	0.60%	2.42%	3.37% (6.74)	0.30% (0.60)	-
2022	1.77%	0.43%	2.20%	3.38% (6.76)	0.40% (0.80)	-
2023	1.73%	0.25%	1.98%	3.39% (6.78)	0.50% (1.00)	-
2024	1.69%	0.09%	1.78%	3.39% (6.79)	0.60% (1.20)	-
2025	1.66%	-	1.66%	3.35% (6.70)	0.70% (1.40)	-
2026	1.63%	-	1.63%	3.27% (6.54)	0.80% (1.60)	-
2027	1.60%	-	1.60%	3.18% (6.37)	0.90% (1.80)	-
2028	1.58%	-	1.58%	3.10% (6.20)	1.00% (2.00)	-
2029	1.55%	-	1.55%	3.01% (6.02)	1.10% (2.20)	-
2030	1.53%	-	1.53%	2.92% (5.85)	1.20% (2.40)	-

[23] This appears lower than the share of ethanol supplied in recent years. The difference is mainly driven by the fall in the share of petrol. There is also some advanced ethanol being supplied, which is reported as 'ethanol' under the RTFO but appears in this table under 'Development fuels'.

Table 46: Share of fuels by energy, option 1

By energy as % share of fuel supply under RED definition	1G Ethanol**	1G Crop biodiesel	1G Waste biodiesel	Fuels supplied under the development fuels sub-target (including biomethane)	Other fuels currently supplied under the RTFO	Total	Total with double rewarding
Baseline	0.93%	-	1.53%	0.14%	-	2.60%	4.27%
2017/18	1.00%	-	2.11%	0.15%	-	3.26%	5.52%
2018	1.08%	-	2.69%	0.16%	-	3.93%	6.78%
2019	1.16%	-	3.26%	0.17%	-	4.60%	8.03%
2020	1.25%	0.71%	3.48%	0.19%	-	5.62%	9.29%
2021	1.22%	0.63%	3.50%	0.22%	-	5.57%	9.28%
2022	1.19%	0.45%	3.51%	0.29%	-	5.44%	9.25%
2023	1.16%	0.26%	3.52%	0.37%	-	5.32%	9.20%
2024	1.14%	0.09%	3.53%	0.44%	-	5.19%	9.16%
2025	1.12%	-	3.49%	0.51%	-	5.12%	9.11%
2026	1.10%	-	3.39%	0.58%	-	5.07%	9.05%
2027	1.08%	-	3.30%	0.66%	-	5.04%	9.00%
2028	1.06%	-	3.21%	0.73%	-	5.00%	8.94%
2029	1.04%	-	3.12%	0.80%	-	4.97%	8.89%
2030	1.03%	-	3.03%	0.87%	-	4.93%	8.83%

** From 2020 onward, this assumes 59.5% of E5 and 40.5% of E10 on average across the entire petrol supply, i.e. an overall ethanol content of 6.825%

Option 2

Table 47: Share of renewable fuels supplied by volume, option 2

Fuels supplied, share of total by volume	1G ethanol, central scenario	1G crop biodiesel	Total crop	1G waste biodiesel (double-rewarding in brackets)	Development fuels (double-rewarding in brackets)	Other biofuels (double-rewarding in brackets)
Baseline	1.38%[24]	-	1.38%	1.48% (2.96)	0.07% (0.14)	0.13% (0.27)
2017	1.50%	-	1.50%	2.04% (4.08)	0.08% (0.16)	0.14% (0.27)
2018	1.61%	-	1.61%	2.59% (5.17)	0.10% (0.20)	0.14% (0.27)
2019	1.73%	-	1.73%	3.10% (6.20)	0.15% (0.30)	0.14% (0.28)
2020	1.86%	0.14%	2.00%	3.54% (7.07)	0.20% (0.40)	0.14% (0.28)
2021	1.83%	0.17%	2.00%	3.44% (6.87)	0.30% (0.60)	0.14% (0.28)
2022	1.80%	0.10%	1.91%	3.38% (6.77)	0.40% (0.80)	0.14% (0.29)
2023	1.78%	-	1.78%	3.34% (6.69)	0.50% (1.00)	0.15% (0.29)
2024	1.77%	-	1.77%	3.25% (6.50)	0.60% (1.20)	0.15% (0.29)
2025	1.76%	-	1.76%	3.15% (6.31)	0.70% (1.40)	0.15% (0.29)
2026	1.76%	-	1.76%	3.06% (6.11)	0.80% (1.60)	0.15% (0.29)
2027	1.75%	-	1.75%	2.96% (5.92)	0.90% (1.80)	0.15% (0.30)
2028	1.75%	-	1.75%	2.86% (5.72)	1.00% (2.00)	0.15% (0.30)
2029	1.75%	-	1.75%	2.76% (5.53)	1.10% (2.20)	0.15% (0.29)
2030	1.75%	-	1.75%	2.66% (5.33)	1.20% (2.40)	0.15% (0.29)

[24] This appears lower than the share of ethanol supplied in recent years. The difference is mainly driven by the fall in the share of petrol. There is also some advanced ethanol being supplied, which is reported as 'ethanol' under the RTFO but appears in this table under 'other biofuels'.

Table 48: Share of different renewable fuels by energy under option 2

By energy as % share of fuel supply under RED definition	1G ethanol	1G crop biodiesel	1G waste biodiesel	Fuels supplied under the development sub-target (including biomethane)	Other fuels currently supplied under the RTFO	Total	Total with double rewarding
Baseline	0.93%	-	1.53%	0.07%	0.08%	2.60%	4.27%
2017/18	1.00%	-	2.11%	0.07%	0.08%	3.26%	5.52%
2018	1.08%	-	2.68%	0.09%	0.08%	3.93%	6.78%
2019	1.16%	-	3.21%	0.14%	0.08%	4.60%	8.03%
2020	1.25%	0.15%	3.67%	0.19%	0.08%	5.34%	9.29%
2021	1.23%	0.18%	3.57%	0.29%	0.08%	5.35%	9.30%
2022	1.21%	0.11%	3.51%	0.39%	0.08%	5.31%	9.30%
2023	1.20%	-	3.47%	0.49%	0.08%	5.25%	9.30%
2024	1.19%	-	3.37%	0.59%	0.08%	5.24%	9.29%
2025	1.19%	-	3.27%	0.69%	0.09%	5.24%	9.28%
2026	1.18%	-	3.17%	0.78%	0.09%	5.22%	9.26%
2027	1.18%	-	3.07%	0.88%	0.09%	5.21%	9.25%
2028	1.18%	-	2.96%	0.98%	0.09%	5.20%	9.23%
2029	1.18%	-	2.86%	1.08%	0.09%	5.20%	9.21%
2030	1.18%	-	2.75%	1.17%	0.08%	5.19%	9.20%

Option 3

Table 49: Share of renewable fuels by volumes, option 3

Fuels supplied, share of total by volume	1G crop ethanol, central scenario	1G crop biodiesel	Total crop	1G waste biodiesel (double-rewarding in brackets)	Development fuels (double-rewarding in brackets)	Other biofuels (double-rewarding in brackets)
Baseline	1.38%	-	1.38%	1.48% (2.96)	0.07% (0.14)	0.13% (0.27)
2017	1.05%	-	1.05%	2.26% (4.52)	0.08% (0.16)	0.14% (0.27)
2018	0.70%	-	0.70%	3.04% (6.07)	0.10% (0.20)	0.14% (0.27)
2019	0.36%	-	0.36%	3.78% (7.57)	0.15% (0.30)	0.14% (0.28)
2020	-	-	-	4.54% (9.07)	0.20% (0.40)	0.14% (0.28)
2021	-	-	-	4.43% (8.87)	0.30% (0.60)	0.14% (0.29)
2022	-	-	-	4.33% (8.66)	0.40% (0.80)	0.14% (0.29)
2023	-	-	-	4.23% (8.46)	0.50% (1.00)	0.15% (0.29)
2024	-	-	-	4.13% (8.26)	0.60% (1.20)	0.15% (0.29)
2025	-	-	-	4.03% (8.06)	0.70% (1.40)	0.15% (0.30)
2026	-	-	-	3.93% (7.86)	0.80% (1.60)	0.15% (0.30)
2027	-	-	-	3.83% (7.66)	0.90% (1.80)	0.15% (0.30)
2028	-	-	-	3.73% (7.46)	1.00% (2.00)	0.15% (0.30)
2029	-	-	-	3.63% (7.27)	1.10% (2.20)	0.15% (0.30)
2030	-	-	-	3.53% (7.07)	1.20% (2.40)	0.15% (0.30)

Table 50: Share of fuels by energy, option 3

By energy as % share of fuel supply under RED definition	1G crop ethanol	1G crop biodiesel	1G waste biodiesel	Fuels supplied under the development fuels sub-target (including biomethane)	Other fuels currently supplied under the RTFO	Total	Total with double rewarding
Baseline	0.93%	-	1.53%	0.07%	0.08%	2.60%	4.27%
2017/18	0.70%	-	2.33%	0.07%	0.08%	3.19%	5.68%
2018	0.47%	-	3.14%	0.09%	0.08%	3.78%	7.09%
2019	0.24%	-	3.90%	0.14%	0.08%	4.37%	8.49%
2020	-	-	4.68%	0.19%	0.08%	4.95%	9.90%
2021	-	-	4.58%	0.29%	0.08%	4.95%	9.90%
2022	-	-	4.47%	0.39%	0.08%	4.95%	9.90%
2023	-	-	4.37%	0.49%	0.08%	4.94%	9.89%
2024	-	-	4.27%	0.59%	0.08%	4.94%	9.88%
2025	-	-	4.16%	0.69%	0.09%	4.94%	9.87%
2026	-	-	4.05%	0.78%	0.09%	4.92%	9.84%
2027	-	-	3.95%	0.88%	0.09%	4.91%	9.83%
2028	-	-	3.84%	0.98%	0.09%	4.91%	9.81%
2029	-	-	3.74%	1.08%	0.09%	4.90%	9.80%
2030	-	-	3.63%	1.17%	0.08%	4.89%	9.78%

Appendix 3 - Total volumes of renewable fuels supplied

Baseline

Table 51: Total volumes of renewable fuels supplied under RTFO baseline

Total volumes of renewable fuel supplied	1G Ethanol (million litres)	Crop biodiesel (million litres)	Waste biodiesel (million litres)	Fuels that would qualify under a broad development fuels sub-target (million litres/kg)	Total (million litres)
2017/18	657	-	739	98	1494
2018	631	-	737	101	1469
2019	606	-	731	104	1441
2020	586	-	721	106	1413
2021	568	-	714	106	1389
2022	554	-	708	106	1368
2023	543	-	703	106	1352
2024	535	-	699	106	1340
2025	528	-	694	106	1328
2026	526	-	694	106	1326
2027	525	-	694	106	1325
2028	524	-	694	106	1324
2029	524	-	695	106	1326
2030	525	-	696	106	1328

Option 1

Table 52: Total volumes of renewable fuels supplied under option 1

Total volumes of renewable fuel supplied	1G Ethanol (million litres)	Crop biodiesel (million litres)	Waste biodiesel (million litres)	Fuels supplied under the development fuels sub-target (including biomethane) (million litres/kg)	Other fuels supplied under the RTFO (million litres)	Total (million litres)
2017/18	739	-	1007	98	-	1845
2018	790	-	1273	101	-	2164
2019	840	-	1529	104	-	2472
2020	891	327	1610	106	-	2933
2021	860	285	1595	123	-	2863
2022	827	201	1581	163	-	2771
2023	800	118	1570	202	-	2690
2024	778	39	1560	240	-	2618
2025	757	-	1530	278	-	2566
2026	744	-	1491	318	-	2552
2027	730	-	1452	357	-	2540
2028	719	-	1413	396	-	2528
2029	709	-	1375	437	-	2520
2030	699	-	1338	477	-	2513

Option 2

Table 53: Total volumes of renewable fuels supplied under 2

Total volumes of renewable fuel supplied	1G Ethanol (million litres)	Crop biodiesel (million litres)	Waste biodiesel (million litres)	Fuels supplied under the development fuels sub-target (including biomethane) (million litres/kg)	Other fuels supplied under the RTFO (million litres)	Total (million litres)
2017/18	739	-	1007	31	67	1845
2018	790	-	1269	38	67	2164
2019	840	-	1506	59	67	2472
2020	891	69	1697	80	67	2804
2021	864	82	1626	124	67	2763
2022	842	48	1581	163	67	2701
2023	826	-	1547	201	67	2642
2024	815	-	1492	240	67	2614
2025	804	-	1437	278	67	2586
2026	801	-	1392	317	67	2578
2027	799	-	1348	357	67	2570
2028	798	-	1302	396	67	2563
2029	799	-	1259	436	67	2560
2030	800	-	1216	476	67	2558

Option 3

Table 54: Total volumes of renewable fuels supplied under option 3

Total volumes of renewable fuel supplied	1G Ethanol (million litres)	Crop biodiesel (million litres)	Waste biodiesel (million litres)	Fuels supplied under the development fuels sub-target (including biomethane) (million litres/kg)	Other fuels supplied under the RTFO (million litres)	Total (million litres)
2017/18	517	-	1117	31	67	1732
2018	345	-	1486	38	67	1936
2019	172	-	1831	59	67	2129
2020	-	-	2163	80	67	2310
2021	-	-	2086	124	67	2277
2022	-	-	2013	163	67	2243
2023	-	-	1948	201	67	2216
2024	-	-	1887	240	67	2194
2025	-	-	1827	278	67	2172
2026	-	-	1780	317	67	2165
2027	-	-	1735	357	67	2158
2028	-	-	1689	396	67	2152
2029	-	-	1646	436	67	2149
2030	-	-	1603	476	67	2146

Appendix 4 - NPVs and carbon abatement cost for sensitivity scenarios

NPVs for waste biodiesel scarcity scenario, high UK demand

Table 55: NPV estimates for 'max waste scarcity', option 2

Option 2			**Central**	
£m, 2015 prices	Total carbon benefits	Total industry VA benefits	Resource cost	Net cost/ benefit
2017	42	8	82	-31
2018	83	16	158	-59
2019	121	25	358	-212
2020	152	33	571	-387
2021	147	36	539	-356
2022	146	39	508	-324
2023	145	41	479	-293
2024	142	43	450	-266
2025	138	44	422	-239
2026	136	46	399	-217
2027	134	48	376	-195
2028	131	49	354	-174
2029	129	50	333	-154
2030	127	51	313	-135
Total	1773	529	5344	-3041

Table 56: NPV estimates for 'max waste scarcity', option 3

Option 3			**Central**	
£m, 2015 prices	Total carbon benefits	Total industry VA benefits	Resource cost	Net cost/ benefit
2017	44	6	76	-26
2018	87	11	149	-51
2019	127	18	374	-230
2020	164	24	634	-446
2021	159	28	598	-411
2022	155	31	561	-375
2023	151	33	526	-342
2024	147	35	494	-311
2025	144	37	463	-281
2026	141	39	438	-257
2027	139	41	414	-234
2028	136	43	391	-211
2029	134	44	368	-190
2030	132	46	347	-169
Total	1861	438	5833	-3534

NPVs for waste biodiesel scarcity scenario, high global demand

Table 57: NPVs for waste biodiesel scarcity scenario, high global demand, option 2

Option 2			**Central**	
£m, 2015 prices	Total carbon benefits	Total industry VA benefits	Resource cost	Net cost/ benefit
2017	42	8	82	-31
2018	83	16	158	-59
2019	121	25	299	-153
2020	152	33	459	-275
2021	147	36	432	-249
2022	146	39	405	-221
2023	145	41	381	-195
2024	142	43	356	-171
2025	138	44	331	-148
2026	136	46	311	-129
2027	134	48	291	-110
2028	131	49	272	-92
2029	129	50	254	-75
2030	127	51	236	-58
Total	1773	529	4269	-1966

Table 58: NPVs for waste biodiesel scarcity scenario, high global demand, option 3

Option 3			**Central**	
£m, 2015 prices	Total carbon benefits	Total industry VA benefits	Resource cost	Net cost/ benefit
2017	44	6	76	-26
2018	87	11	149	-51
2019	127	18	316	-171
2020	164	24	522	-334
2021	159	28	491	-303
2022	155	31	458	-272
2023	151	33	427	-243
2024	147	35	399	-216
2025	144	37	372	-191
2026	141	39	350	-169
2027	139	41	329	-149
2028	136	43	309	-129
2029	134	44	289	-111
2030	132	46	270	-93
Total	1861	438	4758	-2459

NPVs for alternative E10 uptake scenarios

Table 59: NPVs for high E10 uptake scenario

Option 1			**Central**	
£m, 2015 prices	Total carbon benefits	Total industry VA benefits	Resource cost	Net cost/ benefit
2017	42	9	84	-33
2018	81	17	159	-60
2019	118	25	223	-80
2020	151	31	278	-96
2021	148	31	254	-75
2022	141	31	234	-61
2023	136	32	216	-48
2024	131	33	199	-36
2025	126	33	184	-25
2026	121	34	171	-16
2027	117	34	160	-8
2028	114	35	148	0
2029	110	35	138	7
2030	106	36	128	14
Total	1643	417	2576	-516

Table 60: NPVs for no E10 uptake scenario, option 1

Option 1			**Central**	
£m, 2015 prices	Total carbon benefits	Total industry VA benefits	Resource cost	Net cost/ benefit
2017	43	7	80	-29
2018	84	14	153	-55
2019	119	19	210	-72
2020	148	24	272	-100
2021	140	23	248	-85
2022	128	23	230	-78
2023	117	23	213	-72
2024	115	25	196	-56
2025	115	26	179	-37
2026	116	28	165	-21
2027	117	29	152	-6
2028	117	31	140	7
2029	113	31	130	15
2030	110	32	120	21
Total	1584	336	2488	-569

Table 61: NPVs for No E10 uptake scenario, option 2

Option 2			**Central**	
£m, 2015 prices	Total carbon benefits	Total industry VA benefits	Resource cost	Net cost/ benefit
2017	43	7	80	-29
2018	84	14	155	-56
2019	123	23	234	-88
2020	144	28	307	-135
2021	134	31	295	-131
2022	129	33	279	-117
2023	132	36	262	-94
2024	135	39	247	-73
2025	137	42	231	-52
2026	138	44	219	-38
2027	135	45	208	-28
2028	133	47	197	-18
2029	131	48	187	-8
2030	129	49	176	2
Total	1727	487	3077	-863

NPVs for GLOBIOM ILUC factors

Table 62: GLOBIOM ILUC factors, option 1

Option 1			**Central**	
£m, 2015 prices	Total carbon benefits	Total industry VA benefits	Resource cost	Net cost/ benefit
2017	41	8	82	-32
2018	80	16	156	-60
2019	117	22	219	-80
2020	85	25	279	-170
2021	89	25	254	-140
2022	100	27	233	-106
2023	112	28	213	-73
2024	122	30	195	-44
2025	125	31	179	-24
2026	121	31	167	-15
2027	117	32	155	-6
2028	113	33	144	1
2029	109	33	134	9
2030	106	34	124	16
Total	1436	375	2536	-725

Table 63: GLOBIOM ILUC factors, option 2

Option 2			**Central**	
£m, 2015 prices	Total carbon benefits	Total industry VA benefits	Resource cost	Net cost/ benefit
2017	41	8	82	-32
2018	80	16	158	-62
2019	118	25	237	-94
2020	138	33	308	-137
2021	132	36	295	-127
2022	135	39	279	-105
2023	141	41	263	-80
2024	138	43	248	-67
2025	135	44	234	-55
2026	132	46	223	-44
2027	130	48	212	-34
2028	128	49	201	-24
2029	126	50	190	-14
2030	124	51	179	-4
Total	1700	529	3107	-878

NPVs for low carbon values

Table 64: Low carbon values, option 1

Option 1			**Central**	
£m, 2015 prices	Total carbon benefits	Total industry VA benefits	Resource cost	Net cost/ benefit
2017	21	8	82	-52
2018	41	16	156	-99
2019	60	22	219	-137
2020	67	25	279	-188
2021	65	25	254	-164
2022	65	27	233	-141
2023	65	28	213	-120
2024	65	30	195	-101
2025	64	31	179	-84
2026	62	31	167	-74
2027	60	32	155	-64
2028	58	33	144	-54
2029	56	33	134	-45
2030	54	34	124	-36
Total	803	375	2536	-1358

Table 65: Low carbon values, option 2

Option 2			**Central**	
£m, 2015 prices	Total carbon benefits	Total industry VA benefits	Resource cost	Net cost/ benefit
2017	21	8	82	-52
2018	41	16	158	-101
2019	61	25	237	-151
2020	76	33	308	-199
2021	74	36	295	-185
2022	73	39	279	-167
2023	73	41	263	-149
2024	71	43	248	-135
2025	69	44	234	-120
2026	68	46	223	-109
2027	67	48	212	-97
2028	66	49	201	-86
2029	65	50	190	-75
2030	64	51	179	-64
Total	887	529	3107	-1691

Table 66: Low carbon values, option 3

Option 3			**Central**	
£m, 2015 prices	Total carbon benefits	Total industry VA benefits	Resource cost	Net cost/ benefit
2017	22	6	76	-48
2018	43	11	149	-94
2019	63	18	301	-219
2020	82	24	466	-360
2021	80	28	442	-334
2022	78	31	415	-306
2023	76	33	389	-281
2024	74	35	366	-257
2025	72	37	343	-234
2026	71	39	325	-215
2027	69	41	308	-197
2028	68	43	291	-180
2029	67	44	275	-163
2030	66	46	259	-147
Total	931	438	4405	-3036

NPVs for high carbon values

Table 67: High carbon values, option 1

Option 1			**Central**	
£m, 2015 prices	Total carbon benefits	Total industry VA benefits	Resource cost	Net cost/ benefit
2017	64	8	82	-10
2018	124	16	156	-16
2019	181	22	219	-17
2020	200	25	279	-55
2021	196	25	254	-33
2022	196	27	233	-11
2023	195	28	213	10
2024	195	30	195	30
2025	191	31	179	43
2026	185	31	167	50
2027	179	32	155	56
2028	173	33	144	61
2029	167	33	134	67
2030	162	34	124	72
Total	2408	375	2536	247

Table 68: High carbon values, option 2

Option 2			**Central**	
£m, 2015 prices	Total carbon benefits	Total industry VA benefits	Resource cost	Net cost/ benefit
2017	64	8	82	-10
2018	124	16	158	-18
2019	182	25	237	-30
2020	228	33	308	-47
2021	221	36	295	-38
2022	218	39	279	-22
2023	218	41	263	-4
2024	213	43	248	7
2025	207	44	234	18
2026	204	46	223	27
2027	200	48	212	36
2028	197	49	201	45
2029	194	50	190	54
2030	191	51	179	63
Total	2660	529	3107	82

Table 69: High carbon values, option 3

Option 3			**Central**	
£m, 2015 prices	Total carbon benefits	Total industry VA benefits	Resource cost	Net cost/ benefit
2017	67	6	76	-4
2018	130	11	149	-8
2019	190	18	301	-93
2020	245	24	466	-197
2021	239	28	442	-174
2022	233	31	415	-151
2023	227	33	389	-130
2024	221	35	366	-109
2025	216	37	343	-90
2026	212	39	325	-74
2027	208	41	308	-58
2028	205	43	291	-44
2029	201	44	275	-29
2030	198	46	259	-15
Total	2792	438	4405	-1175

Sensitivity analysis for carbon abatement cost estimates

Table 70: Carbon abatement cost estimates for sensitivity scenarios

Average abatement cost, present value (£/tCO_2e) 2017-30	Central assumptions	Low waste/ high crop	GLOBIOM ILUC values
Option 1	87	215	102
Option 2	95	128	98
Option 3	124	135	120

Appendix 5 - Costs and benefits of a fuel-specific sub-target

8.32 Going from a sub-target with a broad definition of 'development fuel' to a fuel specific sub-target generates additional costs and benefits that are included in the above estimates for policy options 2 and 3 and we have presented them here separately:

Table 71: Additional carbon savings from fuel-specific 'narrow' sub-target

	Change in emissions savings ($MtCO_2e$)
2017	0.00
2018	0.00
2019	0.01
2020	0.12
2021	0.22
2022	0.28
2023	0.27
2024	0.22
2025	0.21
2026	0.25
2027	0.28
2028	0.32
2029	0.36
2030	0.40
Total	2.94

Table 72: Present value impacts of moving from a broad definition sub-target to a fuel specific sub-target

£m, 2015 prices	Discounted						
		Low		Central		High	
	Total carbon benefits	Resource cost	Net cost/ benefit	Resource cost	Net cost/ benefit	Resource cost	Net cost/ benefit
2017	-	-	-	-	-	-	-
2018	0	2	-2	2	-2	3	-2
2019	1	9	-8	11	-10	11	-11
2020	7	14	-7	17	-10	15	-8
2021	12	23	-10	28	-16	26	-14
2022	15	24	-9	33	-18	32	-17
2023	15	25	-11	37	-22	38	-23
2024	11	26	-15	41	-30	43	-32
2025	11	25	-15	44	-33	48	-37
2026	12	24	-11	45	-33	51	-38
2027	14	22	-8	47	-33	53	-39
2028	16	19	-3	47	-31	55	-40
2029	17	16	1	47	-30	57	-40
2030	19	12	6	47	-28	59	-41
Total	149	241	-92	445	-296	492	-342