Options and recommendations to meet the RED transport target – APPENDICES

29/05/2014

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This document is issued alongside the main report 'Options and recommendations to meet the RED transport target'; it compiles the Appendix that provides modelling assumptions and more detailed outputs.

Appendix A. List of organisations part of the Steering Group and consulted organisations

- The Steering Group (SG) was chaired by the LowCVP and comprised representatives from the DfT and from the following organisations: British Sugar , CNG Services, RAC Foundation, REA, SMMT, UKLPG, UKPIA. The UKPIA, SMMT and REA gathered feedback on the analysis findings from their members.
- The table below shows the SG members from the industry, along with consulted industry stakeholders. Some participants were consulted twice (at the start of the consultation process for inputs validation and at the end to discuss findings)

List of interviewed stakeholders and members of Steering Group per topic

<table>
<tr><th></th><th>Fuel producers and suppliers</th><th>Infrastructure</th><th>OEMs / supplier</th></tr>
<tr><td rowspan="2">Liquid fuels

[ethanol, FAME, fossil fuels]</td><td>• British Sugar (ethanol)
• Ensus (ethanol)
• INEOS bio (ethanol, FAME)
• Renewable Energy Association (biofuel producers)</td><td>• UKPIA</td><td rowspan="2">• SMMT
• Iveco</td></tr>
<tr><td colspan="2">• BP (obligated supplier)
• Greenergy Fuels (obligated supplier)
• Shell (obligated supplier)</td></tr>
<tr><td rowspan="2">Gaseous fuels
[natural gas, bio-methane, LPG]</td><td>• Gasrec (bio-LNG)
• UKPLG (LPG)</td><td colspan="2"></td></tr>
<tr><td colspan="3">• CNG Services (CNG and CBM projects)
• Gas Bus Alliance (CBM)</td></tr>
</table>

Appendix B. NRMM case – This sector is represented in a simple way to reflect the lack of data and limited technology options

- The government estimates the fuel use of NRMM at **3,079 million litres**, constant from 2012 to 2030. Estimate of units and cost associated with transition to biodiesel:

NRMM fuel filter replacement costs[1]

	Number of units	Unit cost	Total cost
General NRMM	643,772	£16	£10,300,352
Rail (locomotives)	4,285	£165	£707,025
Recreational vessels	66,200	£16	£1,059,204
Commercial vessels	516	£165	£85,140
TOTAL	**714,773**		**£12,151,721**

Other costs (tank cleaning of vessels) bring total cost to **£53million**

- General NRMM[2]: agricultural tractors (~290k units), portable generators (~120k), refrigeration unit engines on HGVs (~50k), air compressors, forklifts, excavators, paving equipment, airport machinery, combine harvesters, cranes, bulldozers, scrapers, etc.
- Since April 2013, fuel for NRMM is included in the RTFO but the 5% target has been revised down to 4.7% (i.e. amount of biofuel supplied unchanged by inclusion of NRMM).
- The obligated volume is however **4,185 million litres** as the chosen definition is based on sulphur level (10 ppm sulphur) and thus include some heating oil (as some users have only 1 tank and use 10ppm for all applications). For the modelling, the obligated volume is used, kept constant to 2020.
- Government's findings will be used for cost of NRMM transition from B0 to B5/B7, with an additional £7 million for general NRMM to represent the fleet turnover, based on an average of 10 years life.
- These costs do not include the costs required to ensure long term storage stability.

1 – Amendments to the RTFO for compliance with the Fuel Quality Directive – NRMM, Impact Assessment, 2012
2 – Dft 2013 for tractors and AEA, Non-Road Mobile Machinery Usage, Life and Correction Factors, 2004 for the rest

Appendix C1. Powertrain pathway summary

Cars and vans 2020 share of fleet

	BASE		HIGH AFV	
	Cars	Vans	Cars	Vans
HEV	4.9%	1.7%	7.3%	3.2%
PHEV	0.3%	0.1%	1.2%	0.2%
BEV	0.2%	0.5%	0.5%	1.8%
Total	**5.4%**	**2.3%**	**9.0%**	**5.2%**

- Cars and vans: based on Element Energy uptake modelling and consumer research
- Cars and vans: high case at the limit of estimated plug-in vehicles supply

HGVs and buses 2020 share of fleet

	BASE		HIGH AFV	
	HGVs	Buses	HGVs	Buses
HEV	0.6%	5%	1.3%	-
Gas dedicated	1.3%	1.0%	2.5%	-
Total	**1.9%**	**6%**	**3.8%**	**-**

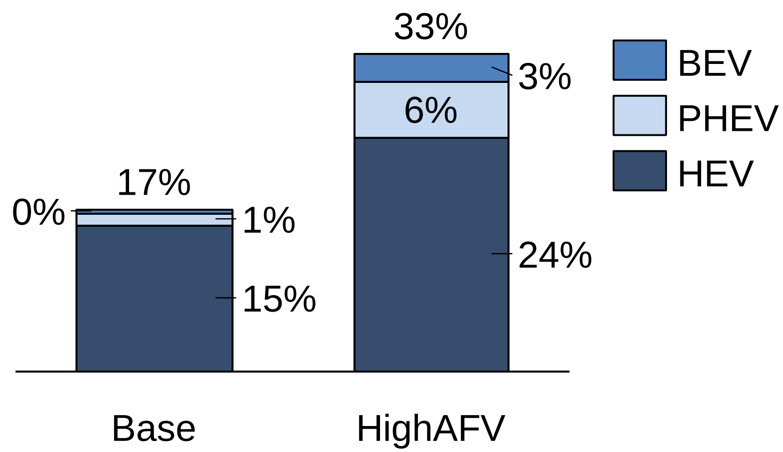
- HGVs: limited potential for HEV due to cost limited supply; gas vehicles potential assumed greater based on better total of ownership proposition
- Buses: London target main driver for high uptake
- Reviewed by consulted industry stakeholders

NOTE: only one powertrain type for NRMM

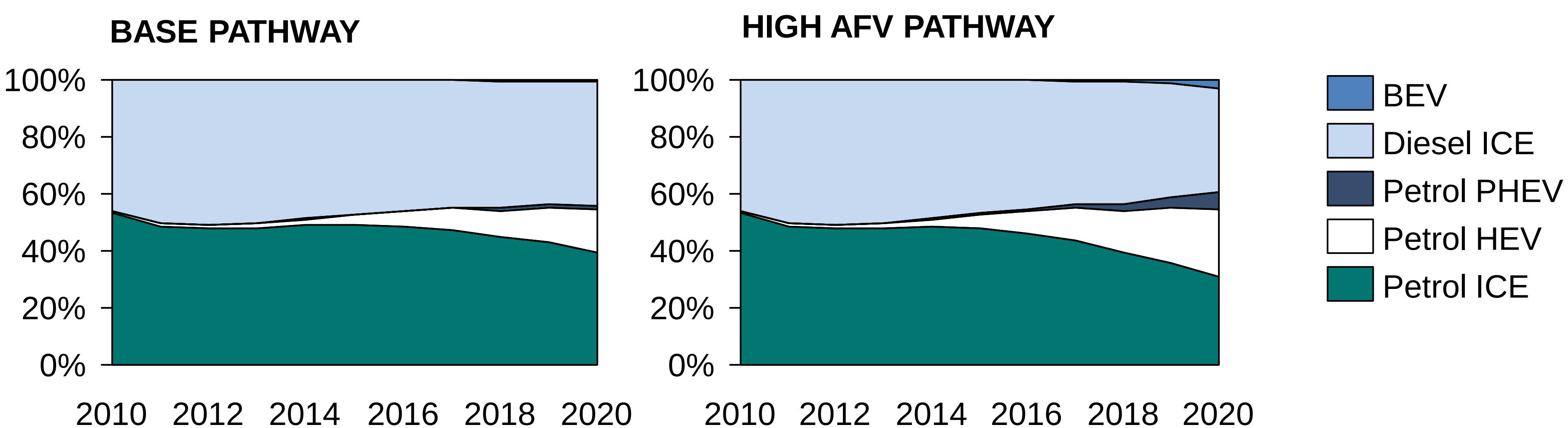
Appendix C2. Car powertrain pathways: 17% to 33% AFV market share by 2020, equivalent to 6% to 9% of fleet

- Baseline pathway based on Element Energy consumer choice model (first developed for the Energy Technology Institute in 2011, extended for DfT in 2012, updated in 2013)
- ‘High AFV’ pathway based on 9% market share for plug-in vehicles, as per Element Energy analysis of EV supply for the CCC. This assumes strong policy support in place until 2020 for EVs.
- **By 2020, the car fleet is made of 6% to 9% of AFVs.**

2020 Alternative Fuel Vehicle market share



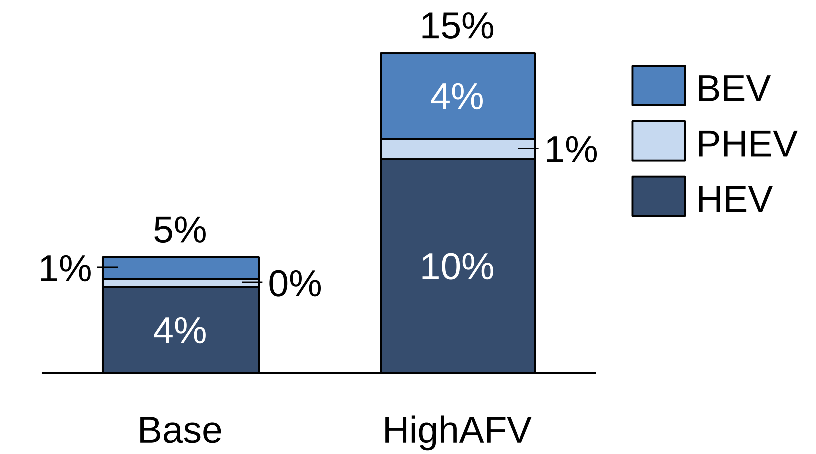
Market share of powertrains



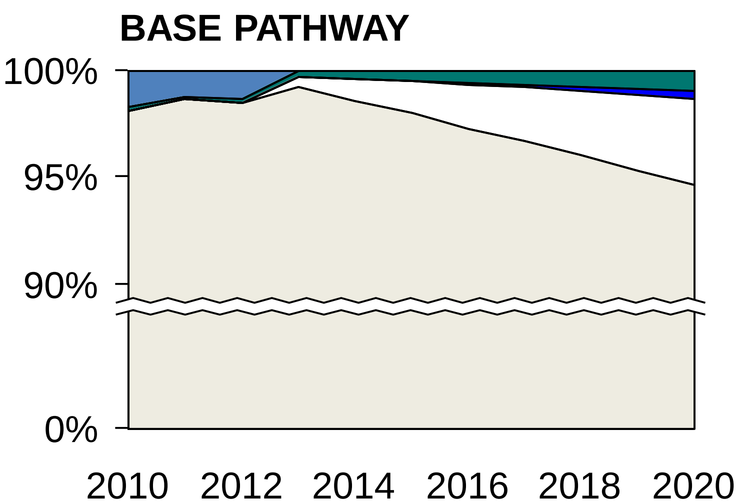
Appendix C3. Van powertrain pathways: 5% to 15% AFV market share by 2020, translating into 2% to 5% of fleet

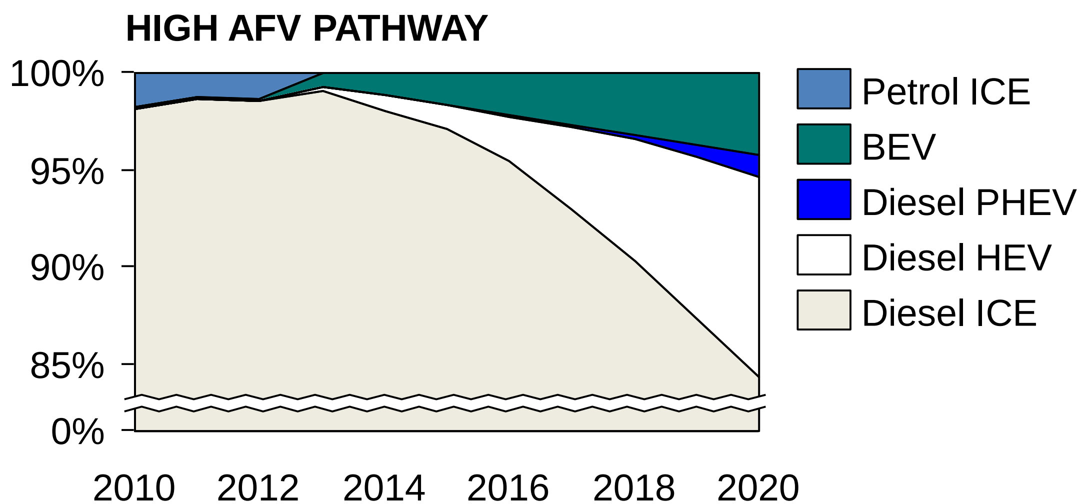
- Pathways based on Element Energy study for DfT of van fleet managers’ willingness to pay for EVs and supply of AFV.
- No PHEV van currently on the market, supply starting in 2015 at earliest.
- The market share of AFV doubles in the AFV case compared to base case – high case assumes high supply and policy support
- **By 2020, the van fleet is made of 2% to 5% of AFVs.**

2020 Alternative Fuel Vehicle market share



Market share of powertrains





Appendix C4. HGV powertrain pathways: 5% to 9% AFV market share 2020, with a greater potential for CNGVs based on vehicle availability

Proposed HIGH AFV pathway, 2020 share

	% market share	Comment
HEV	3%	Lower than van BASE case – based on industry feedback
Gas dedicated	6%	Higher potential than HEV based on higher supply

Proposed BASE pathway, 2020 share

	% market share	Comment
HEV	1.5%	Based on half the HIGH case potential
Gas dedicated	3%	Based on half the HIGH case potential

- For HEVs, literature suggests quick diffusion of new technology in HGVs fleet with estimates of 3.6% to 8.3% HEV market share by 2020 at EU level[1]
- HEV supply is however low and lack of CO_2 legislation in the 2020 timeframe suggests low potential for high supply
- Dedicated gas vehicles available (outside of the UK): more than twice the number of HEV[2]
- Share of gas vehicles using biomethane to be limited by bio-methane supply (see Appendix E3)

1 - When will hybrid technologies dominate the heavy-duty vehicle market? Forecasting Using Innovation Diffusion Models; Jesper Brauer, Master of Science thesis, 2011 2 – Alternative Fuel Data Centre, US DoE

Appendix C5. Bus powertrain pathway: based on small contribution to overall transport energy use, only 1 powertrain pathway developed

Proposed BASE pathway, 2020 share

	% market share	Comment
HEV	13%	Based on London buying 100% and other cities/buyers 2% HEVs
Gas dedicated	3%	Based on industry feedback

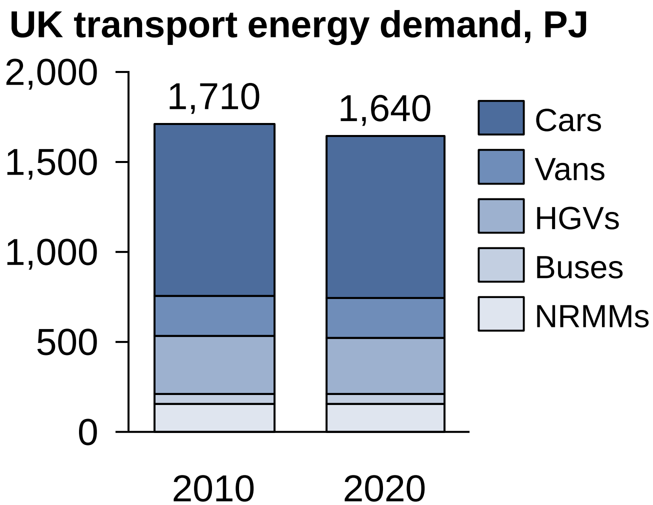
HEVs

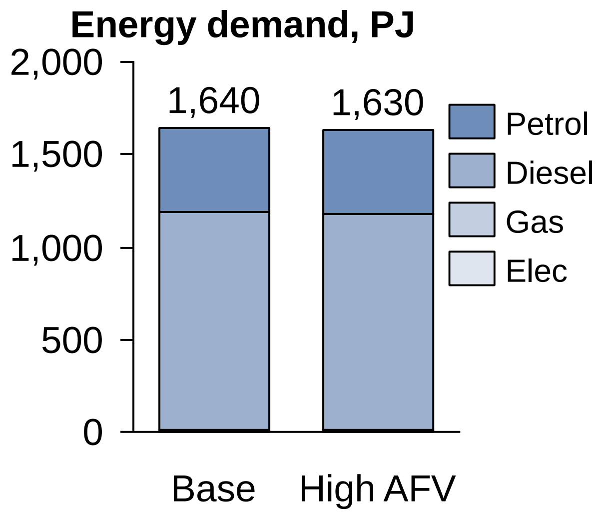
- Already over 300 HEV buses in London alone (~0.2% UK fleet)
- London Mayor target for 2020: 100% of London to be hybrids.
- London bus fleet ~10% UK fleet. Assuming London meets its target, UK bus fleet will have a minimum of 10% HEVs.
- Proposed pathway assumes 2% market share for HEV outside London, based on industry feedback

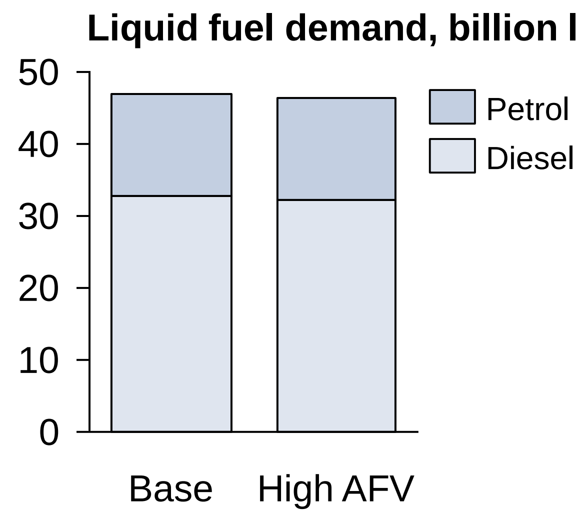
Dedicated gas buses

- 60 gas buses in operation (<0.05% UK fleet)
- Potential assessed as higher than for HEV (once Bus Green Fund is terminated) outside London based on payback time

Appendix D. Transport demand - 2020







Modelling of the transport demand

- Extensive fuel input database and powertrain pathways based on EE analysis and reviewed by industry
- Stock turnover, fleet size and vehicle travelled as per DfT published data and projections
- Improvement of new vehicle MJ/km as per Ricardo-AEA for the CCC (2012)
- NRMM energy demand set constant, based on current obligated volume (4.18 billion l, 151 PJ) that also covers some heating applications.

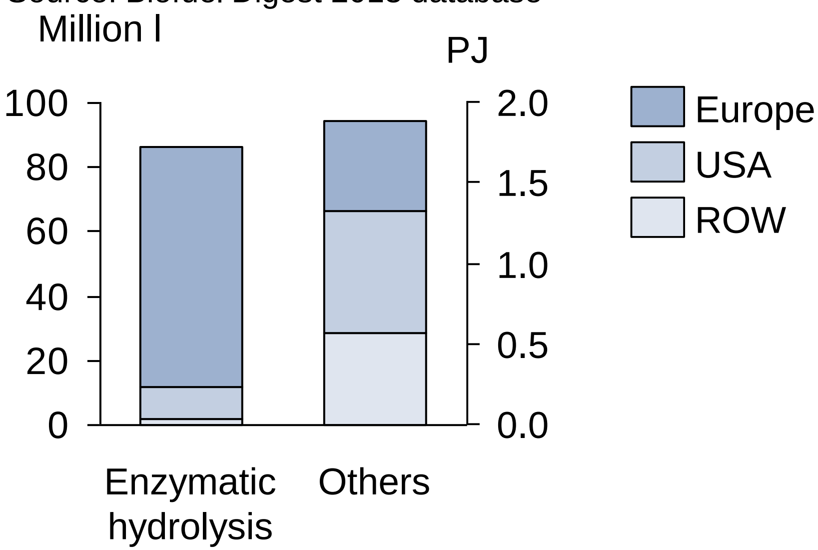
2020 transport demand:

- Equivalent to 14.2 billion l petrol and 32.7 billion l diesel, overall 1,640 PJ (4% less than 2010)
- Gas demand modest:
  - 110 kt (5 PJ) in base case
  - 203 kt (9.3 PJ) in HighAFV case
- Electricity demand very modest:
  - 304 GWh (1.1 PJ) in base case
  - 1,014 GWh (3.6 PJ) in HighAFV case

Reminder: Under the 'HighAFV' case, there is a greater uptake alternative powertrains (HEV, PHEV and BEV for cars and vans; HEV and dedicated gas for HGVs and buses)

Appendix E1. Supply of ethanol 2G

Ethanol 2G- current production capacity
Source: Biofuel Digest 2013 database



Level of ethanol 2G supply assumed for UK

		2017	2020
High	Ml	60	120
	PJ	1.3	2.5
Stretch	Ml	60	240
	PJ	1.3	5.0

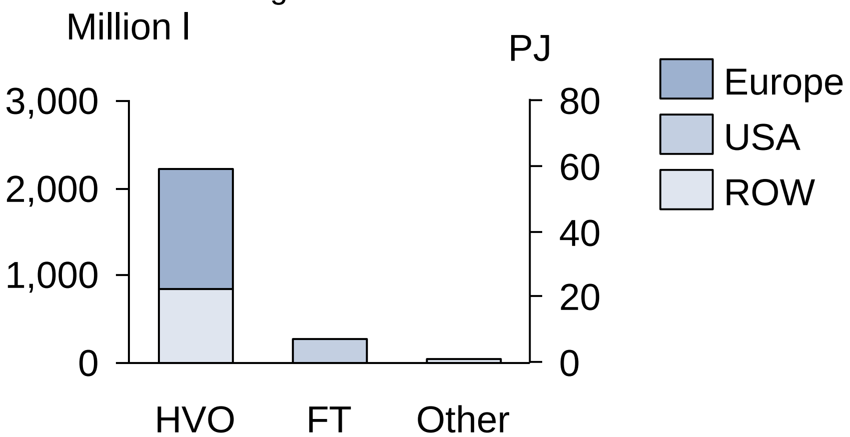
High case: two 60Ml plants in UK
Stretch: large imports

- Europe currently largest producer of ethanol 2G, with first commercial plant in Crescentino (Italy).
- BetaRenewables plant to output 60-70 Ml of ethanol per year, made from non-food biomass. Investment of €150 million.
- No production in the UK yet but several companies are part of the DfT Advanced biofuels UK demonstration program:
  - Earliest year for UK plant: 2017
  - Size similar to Crescentino envisaged – based on industry consultation
  - A ramp up to 120 Ml by 2020 would correspond to 2 UK plants of similar size than Crescentino (or imports)
  - 240 Ml would require large imports and is a ‘stretch’ case

1 - TNO report for DG Energy “Bringing Biofuels on the market – Options to increase EU biofuels volumes beyond the current blending limits, 2013

Appendix E2. Supply of drop-in diesel

Drop-in diesel - current production capacity
Source: Biofuel Digest 2013 database



Level of drop-in diesel supply assumed for UK

		2017	2020
High	Ml	32	127
	PJ	1.1	4.3
Stretch	Ml	32	253
	PJ	1.1	8.6

High case: one 750kt plant in EU
Stretch: two large plants in EU

In DfT Modes 3 study, FT supply: 2.4-19.1 PJ

- HVO not considered as same feedstock than FAME:
  - From food crop: little WTW savings advantage over FAME and uncertainty over ILUC stopping investment
  - From non-food (UCO, waste oils & fats): feedstock already accounted for in FAME
- Production of FT renewable diesel:
  - None in Europe at the moment
  - Solena plant coming to UK in 2015, capacity of 65Ml (50kt): for aviation use primarily. Max 50% of output for transport
  - Max best case for EU: "*1 larger scale plant in the EU, with a capacity of max. 500–1,000 kt/year. However, it is still very uncertain whether this will indeed be realized under current policies and financial conditions*."[1]
  - UK 'fair share' set at 13%: current UK transport energy share of EU transport energy

1 - TNO report for DG Energy "Bringing Biofuels on the market – Options to increase EU biofuels volumes beyond the current blending limits, 2013

Appendix E3. Supply of bio-methane

- Current incentives (see tables below), favour the use of biogas for grid injection or electricity production, rather than for its application in the transport sector
- Green Gas Certificates have been introduced, they allow the traceability of bio-methane injected into the grid. However, it is unlikely that the bio-methane receiving the Renewable Heat Incentive (RHI) would also count towards the RED target – although not clear in the regulatory framework.

FiT for electricity generation
Guaranteed for 20 years

Size (kWe)	FiT (p/kWh)*
< 250	~ 7.6
250 - 500	~ 7
500 - 5,000	~ 4.6
+ Export tariff : 4.64 p/kWh	

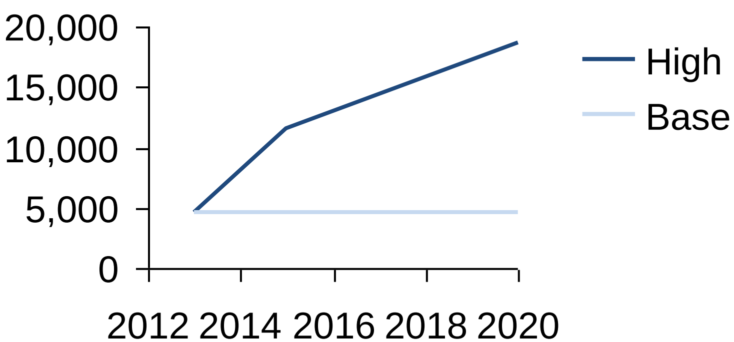
RHI for grid injection
Guaranteed for 20 years, until 2021

Description	RHI (p/kWh)
Biogas combustion up to 200 kW	7.3
Biomethane grid injection	7.3
+ Export value: 2.2 p/kWh	

RTFC for use in transport**
No guaranteed value: set entirely by market

Year	RTFC (p/kg)	RTFC (p/kWh)
2012-2013	30	2.16
2008-2009	0	0

UK Biomethane production used in transport, tonnes

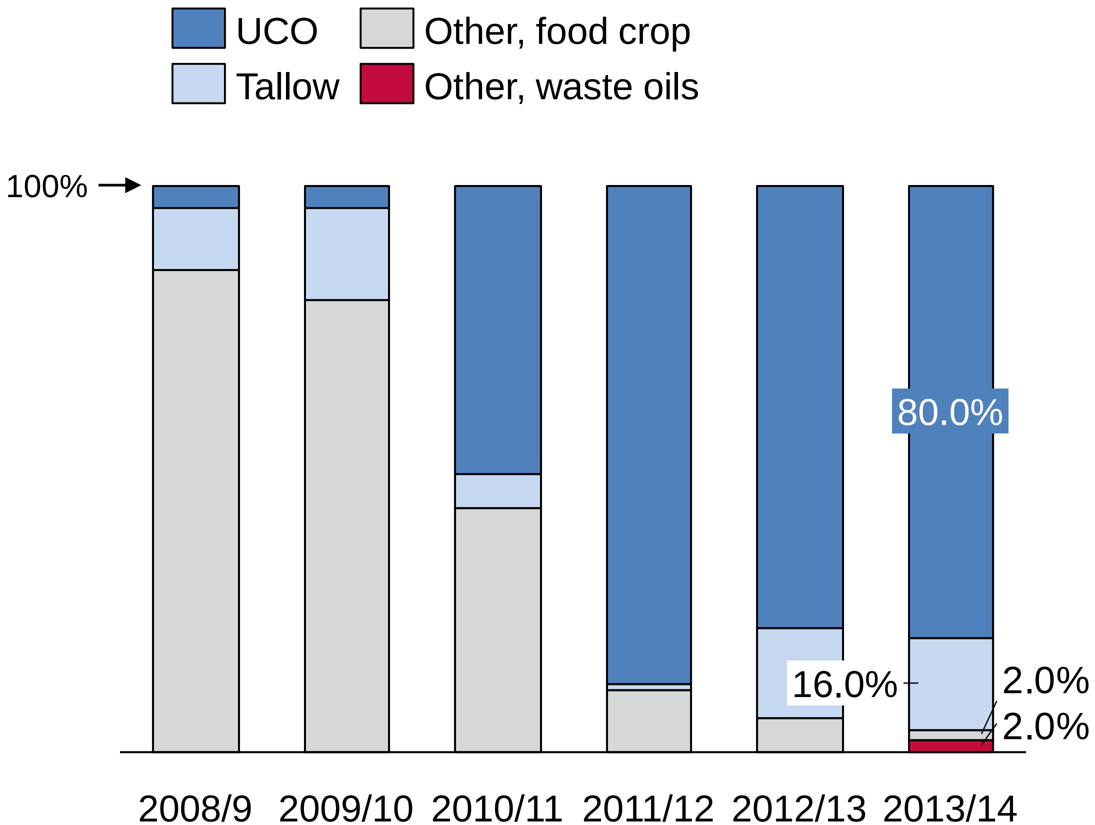


- 'Base' case assumes that production remains constant at the levels provided by GasRec (4,600 t). This is a non-grid injectable fuel and does not qualify for RHI.
- 'High' case implies the bio-methane production corresponding to current largest site (Rainbarrow Farm at Poundbury expected to provide 14,000 t by 2020) is captured by the transport sector, which would require a change in the incentive regime

* Conversion factor of 50% assumed. FiT: Feed in Tariff. A certain use of waste heat is assumed to increase the value from 40% efficient gas engine
** Provided that Biomethane is dutiable and produced wholly from biomass. The energy value of bio-methane used as vehicle fuel assumed to be the same as natural gas bought from the grid

Appendix E4. Supply of FAME

FAME use in the UK per feedstock type, as per RTFO reports years 1-6



- For the last three years, UCO and tallow have been the main feedstock for the production of FAME used in the UK
- In the last RTFO report, new waste sources other than UCO and tallow (i.e. brown grease, palm oil mill effluent and spent bleached earth) were reported
- Although their contribution is still negligible (~2%of total FAME), this trend reflects the effect of the double accounting rules for biofuel coming from waste streams

Appendix F. Cost assumptions for fuels and electricity (p/L) (1/2)

Fuel cost (excl. tax) in p/l (p/kg for gas; p/kWh for electricity). 2010 GBP

Fuel	Current	2020	Comments
FAME	72	79 (central) 75 (low) 93 (high)	Central price in line with industry feedback, reflecting expectations of feedstock costs (oil / animal protein) increasing and tightening of sustainability criteria creating a supply pressure on ‘good’ biodiesel.
BTL	93 (from 2017)	82 73 93	Based on IEA roadmap and checked by industry; will require volume production, i.e. investment support and certainty
Diesel	58	65	DECC central projections (DECC, 2012)
E1G	48	48 42 51	Central price to stay constant, in line with industry feedback and in line with a very slight decrease in costs 2011-2020 as shown in DfT IA
E2G	99 (from 2017)	59 25 99	• Central price, as per literature and approved by industry • Low price, based on prices reported for Crescentino plant by NNFCC
Petrol	52	59	DECC central projections (DECC, 2012)
Biomethane*	83	83	• Current value based on cost premium on CNG as per Paterson et al, 2011 (38%) • Assume cost stays constant
Natural gas*	60	77	• Current values as in Ricardo, 2013 • 2020: increases equivalent to industrial gas prices increase, as DECC
Electricity	14	19	DECC central projections (DECC,2012)

*LBM and LNG cost set equal to CBM and CNG

Appendix F. Cost assumptions for fuels and electricity (p/MJ) (2/2)

Fuel cost (excl. tax) in p/MJ. 2010 GBP

Fuel	Current	2020	Comments
FAME	2.2	2.4 (central) 2.3 (low) 2.8 (high)	Central price in line with industry feedback, reflecting expectations of feedstock costs (oil / animal protein) increasing and tightening of sustainability criteria creating a supply pressure on ‘good’ biodiesel.
BTL	2.7 (from 2017)	2.4 2.2 2.7	Based on IEA roadmap and checked by industry; will require volume production, i.e. investment support and certainty
Diesel	1.60	1.85	DECC central projections (DECC, 2012)
E1G	2.3	2.3 2.0 2.4	Central price to stay constant, in line with industry feedback and in line with a very slight decrease in costs 2011-2020 as shown in DfT IA
E2G	4.7 (from 2017)	2.8 1.2 4.7	• Central price, as per literature and approved by industry • Low price, based on prices reported for Crescentino plant by NNFCC
Petrol	1.62	1.81	DECC central projections (DECC, 2012)
Biomethane*	1.8	1.8	• Current value based on cost premium on CNG as per Paterson et al, 2011 (38%) • Assume cost stays constant
Natural gas*	1.3	1.3	• Current values as in Ricardo, 2013 • 2020: increases equivalent to industrial gas prices increase, as DECC
Electricity	3.9	5.3	DECC central projections (DECC,2012)

*LBM and LNG cost set equal to CBM and CNG

Appendix G1. WTW GHG emission assumptions – savings compared to fossil fuels (as % savings) (1/2)

WTW emission savings of biofuels for the RED scenarios – compared to fossil gasoline

	2013	2020	Notes
Ethanol 1G	58%	70%	2013 based on RTFO weighted average 2020 as per observed high performing plants/feedstocks
Ethanol 2G	76%	76%	RED default values

WTW emission savings of biofuels for the RED scenarios – compared to fossil diesel

	2013	2020	Notes
FAME non food	80%	85%	2013: based on RTFO weighted average 2020: as per RED default value for UCO FAME
FAME food	40%	50%	2013: based on RTFO weighted average 2020: as per RED sustainability criteria for plants commissioned before 2017
BTL	93%	93%	RED default values ‘farmed wood FT diesel’ default RED value
CBM	123%	123%	WTT emissions: Average of several JRC pathways[1] based on Gas Bus Alliance process (Anaerobic Digestion plants consuming a range of agri-waste, CBG grid injected), as per (Ricardo, 2013)[2] (See Appendix G2)
LBM	72%	72%	WTT emissions: Aiming at reproduce Gasrec approach, combination of several JRC pathways[1] (Gasrec process: AD plants or landfill, LBM delivered by tanker), as per (Ricardo, 2013)[2]
CNG	19%	19%	JRC WTW Study V4 – “from EU mix NG supply”, reduced to reproduce the shorter UK average pipeline, as per (Ricardo, 2013)[2]
LNG	9%	9%	JRC WTW Study V4 – “remote LNG, vaporisation at retail point”

1- JRC/EUCAR/CONCAWE, 2013

2 - Ricardo for LowCVP, “*Preparing a low CO2 technology roadmap for buses*”, July 2013

Appendix G1. WTW GHG emission assumptions –absolute values: gCO_2e/MJ (2/2)

WTW emission of biofuels for the RED scenarios gCO_2e/MJ

	2013	2020	Notes
Ethanol 1G	35	25	2013 based on RTFO weighted average 2020 as per observed high performing plants/feedstocks
Ethanol 2G	20	20	RED default values

WTW emission of biofuels for the RED scenarios gCO_2e/MJ

	2013	2020	Notes
FAME non food	17	13	2013: based on RTFO weighted average 2020: as per RED default value for UCO FAME
FAME food	50	42	2013: based on RTFO weighted average 2020: as per RED sustainability criteria for plants commissioned before 2017
BTL	6	6	RED default values 'farmed wood FT diesel' default RED value
CBM	-19	-19	WTT emissions: Average of several JRC pathways[1] based on Gas Bus Alliance process (Anaerobic Digestion plants consuming a range of agri-waste, CBG grid injected), as per (Ricardo, 2013)[2] (See Appendix G2)
LBM	23	23	WTT emissions: Aiming at reproduce Gasrec approach, combination of several JRC pathways[1] (Gasrec process: AD plants or landfill, LBM delivered by tanker), as per (Ricardo, 2013) [2]
CNG	68	68	JRC WTW Study V4 – "from EU mix NG supply", reduced to reproduce the shorter UK average pipeline, as per (Ricardo, 2013)[2]
LNG	76	76	JRC WTW Study V4 – "remote LNG, vaporisation at retail point"

1- JRC/EUCAR/CONCAWE, 2013

2 - Ricardo for LowCVP, "*Preparing a low CO2 technology roadmap for buses*", July 2013

Appendix G2. Assumptions for CBM WTW savings

WTT emissions (as per Ricardo 2013[1])

- In the UK there are currently two main pathways for CBG production as transport fuel:
  - Gas Bus Alliance (GBA) process, with anaerobic digestion plants fed by a range of agricultural waste, CBG grid injected
  - Gasrec process, through anaerobic digestion plants or landfill, and LBM delivered by tanker
- However, these pathways are not equivalent to those identified by CONCAWE
- For the GBA-advocated approach, because of the feedstock used, it is logical to average OWGC2, OWGC3 & OWGC5, giving -75.7 gCO_2eq/MJ

TTW emissions (as per JRC/EUCAR/CONCAWE,2013[2])

- Assumed to be equal for CNG, CBM, LNG and LBM, at 56.2 gCO_2e/MJ

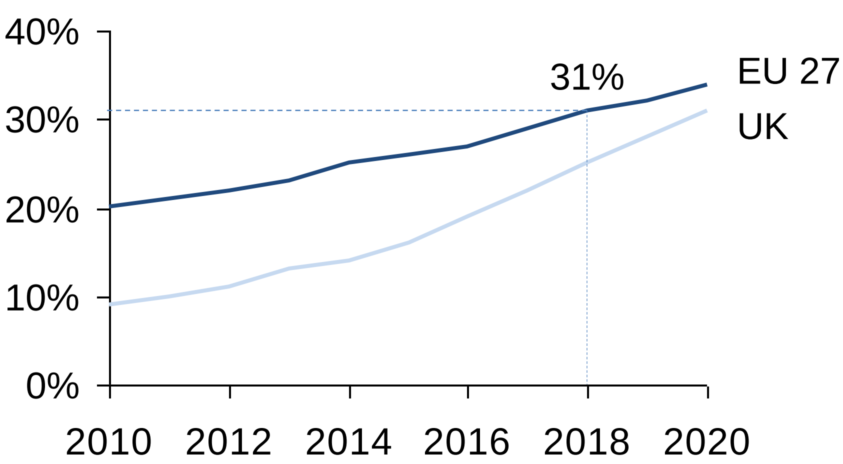
Summary of the WTT emissions[2] – gCO_2e/MJ

CONCAWE pathway	Process	WTT (gCO_2e/MJ)
OWCG1	Municipal waste to CBG	-39.5
OWCG2	Liquid manure to CBG	-140.6
OWCG3	Dry manure to CBG	-54.9
OWCG4	Whole wheat plant to CBG	-34.8
OWCG5	Double cropped maize + barley to CBG	-31.5

1 - Ricardo for LowCVP, "*Preparing a low CO2 technology roadmap for buses*", July 2013
2- JRC/EUCAR/CONCAWE, 2013

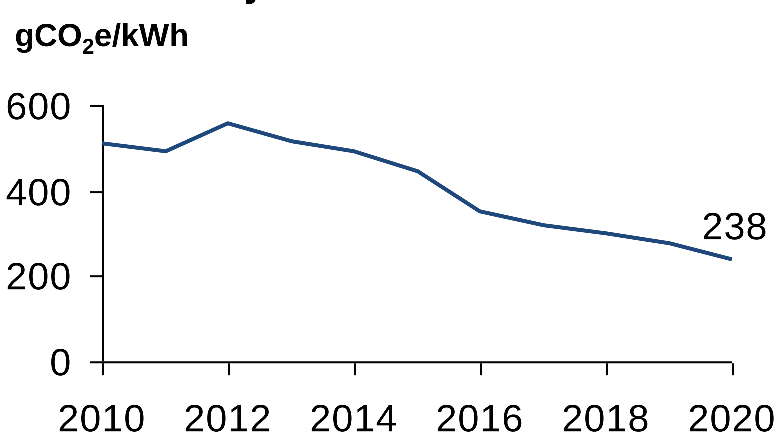
Appendix G3. Assumptions for electricity: share of renewable electricity and grid carbon intensity

Share of electricity generation from renewables[1]



- Share of renewable electricity based on EU share, measured two years before the year in question (RED Art. 3 (4c))[3], i.e. for 2020, share of 2018 counts (31%)
- As per RED rules, energy from electricity is multiplied by a factor of 2.5, both in the numerator and denominator
- Grid carbon intensity based on DECC projections, for calculation of WTW emissions

UK electricity emission factors[2]



1 – For UK, DECC Updated Energy & Emissions Projections - October 2012. Central scenario

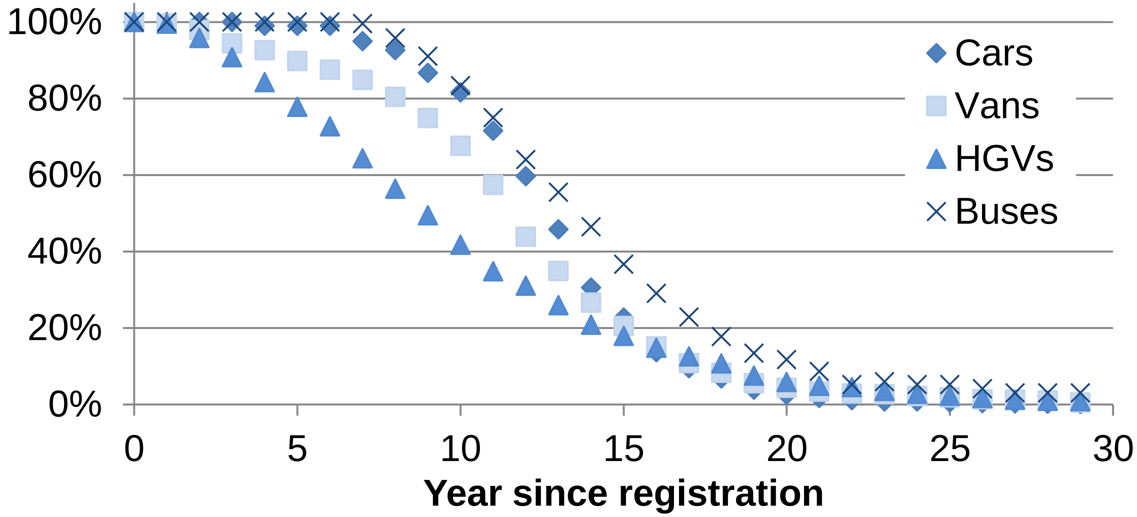
For EU, ECN Renewable energy projections in the National Renewable Actions Plans of the European MS, 2011

2 – DECC appraisal guidance September 2013

3 – ''for the calculation of the contribution from electricity produced from renewable sources Member States may choose to use either the average share of electricity from renewable energy sources in the Community or the share of electricity from renewable energy sources in their own country as measured two years before the year in question

Appendix H1. Other model assumptions: existing stock

Survival rate of vehicles



Average lifetime of vehicles – derived from survival rates

	Cars	Vans	HGVs	Buses
Years	12.5	11.5	9.0	13.5

% NI adds to GB stock and sales, 2007-2011 average

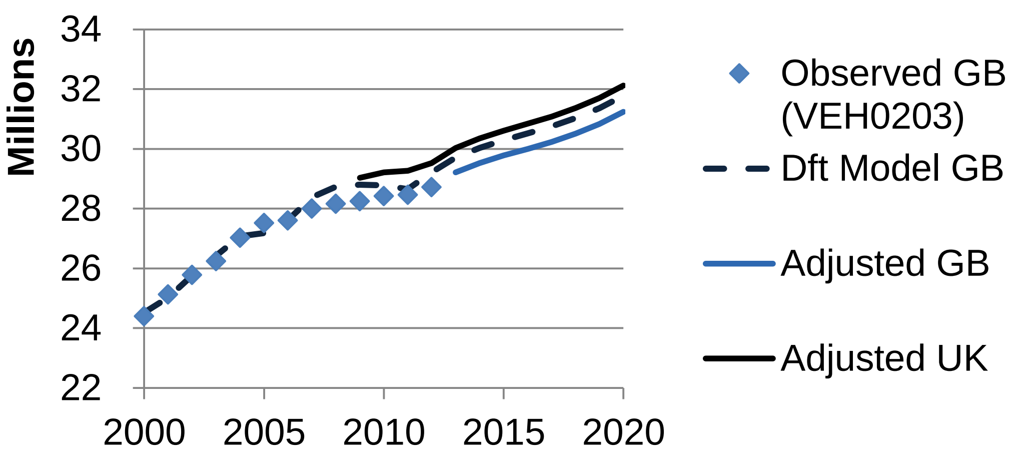
	Cars	Vans	HGVs	Buses
Stock	3.1%	2.6%	5.1%	1.7%
Sales	4.3%	4.0%	8.5%	5%

- Survival rates based on Dft GB data (tables VEH0211, VEH0411, VEH0511, VEH0611)
- Adjusted to reproduce stock as reported in Dft series (tables VEH0203, VEH0403, VEH0503, VEH0603)
- Data from DRDNI for Northern Ireland used to create UK stock
- Vehicle km based on Dft data (TRA0101), adjusted for NI based on NI/GB stock ratio
- DECC Energy Consumption UK data series (Mtoe per fuel per vehicle class) used to calibrate fleet MJ/km

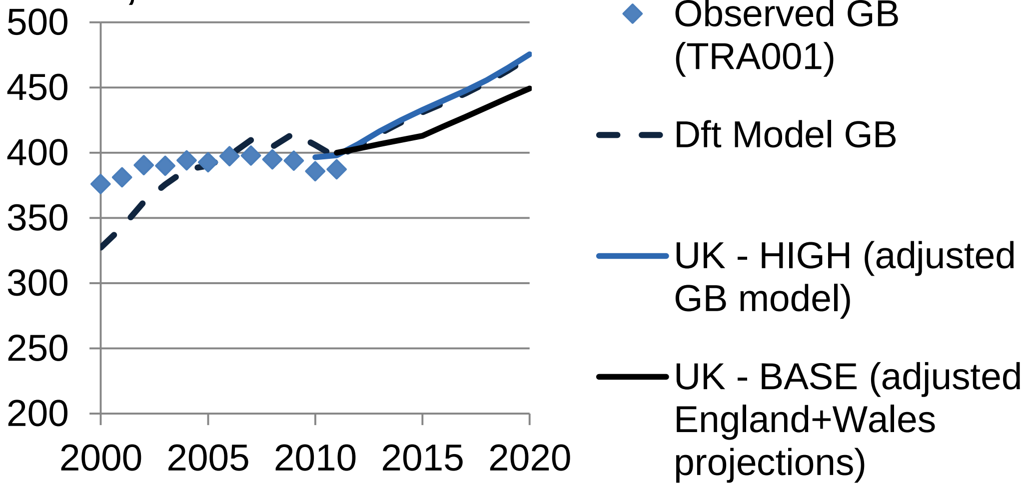
DRDNI: Department for Regional Development Northern Ireland ; NI: Northern Ireland

Appendix H2. Other model assumptions: future car fleet

Car fleet, millions



Vehicle km, billions



- Overall car fleet and mileage set to follow the DfT modelled values, adjusted to observed trends and UK level
- The model accounts for diesel higher mileage over gasoline: National Travel Survey shows that diesel cars average mileage is 1.4 times all cars average
- Gasoline ICE, derived powertrains and plug-in vehicles assumed to have the same mileage – set at 0.9 of national average to reproduce diesel longer mileage
- NOTE: 2020 vkm DfT model value 5% higher than projections based on adjustments of England and Wales traffic forecasts (473 vs. 449 bn km)
- Base case: use lowest value (449bn km). +13% vkm in 2020 compared to 2010; high case: +20%

Dft model: National Travel Model data provided by Dft to EE on 04/10/2013

Appendix H3. Other model assumptions: travel trends. Based on published trends, giving overall increase of 14% vkm by 2020 compared to 2010

UK vehicle travelled, billions

	Cars	Cars - HIGH	Vans	HGVs	Buses
2010	396.7	396.7	67.8	27.7	5.1
2015	413.2	433.0	72.2	26.8	5.2
2020	449.4	475.5	82.5	28.1	5.2

UK fleet size, thousands

	Cars	Cars - HIGH	Vans	HGVs	Buses
2010	29,217	29,217	3,295	499	171
2015	30,613	30,613	3,506	508	175
2020	32,116	32,116	4,008	533	175

Average annual mileage, km

	Cars	Cars - HIGH	Vans	HGVs	Buses[1]
2010	13,578	13,578	20,582	55,433	29,635
2015	13,497	14,143	20,580	52,691	29,635
2020	13,993	14,806	20,580	52,691	29,635

- CARS: as described in previous slide
- VANS, HGVs and BUSES:
  - vkm as per Dft England and Wales traffic forecasts, adjusted to UK level . Adjustment based on past observed ratios
  - Fleet size set to get target annual mileage
  - Annual mileage assumed constant
- Overall trends:
  - Vans vkm to increase 22% by 2020 compared to 2010
  - HGVs vkm to decrease first then increase again, overall +2% by 2020.
  - Buses vkm predicted to be stable, +2% by 2020

1 - Average values are lowered down by old buses running low mileage. New buses typically drive c.60,000 km p.a. in London and 75,000 km outside London

Appendix H4. Other model assumptions: cost of new vehicles, MJ/km of new vehicles

Costs

- From Ricardo-AEA, *A review of the efficiency and cost assumptions for road transport vehicles to 2050, for the Committee on Climate Change*, 2012
- Margins added to vehicle costs, as per (EE, 2011)
- HGVs costs: weighted average of values for rigid and articulated trucks, as per observed sales

MJ/km of new vehicles

- Stock of vehicles calibrated over last decade: the resulting stock ‘Real world’ MJ/km combined with DfT mileage data reproduces the Mtoe figure of ECUK Table 2.02: *Road transport energy use by vehicle type*
- New vehicles MJ/km based on (Ricardo-AEA, 2011) with adjustments:
    - Cars : values adjusted down in line with ECUK Table 2.08: *Fuel consumption factors for cars and lorries*
    - HGVs: rigid / articulated values weight averaged on total energy use, in line with ECUK Table 2.08
    - Vans and buses: no direct data on consumption figures, adjustment in line with calibrated stock values

Appendix H5. New vehicle compatibility assumptions for high biodiesel blends and existing stock compatibility

HGVs Marginal cost over diesel ICE
Source: industry consultation

	Capital cost	Maintenance
B30	£1k	£1.7k p.a.
B100	£2k	£1.7k p.a.

Buses Marginal cost over diesel ICE
Source: industry consultation

	Capital cost	Maintenance
B30	£1.2k	£1.7k p.a.
B100	£2.5k	£1.7k p.a.

Existing stock compatibility in 2013
Source: AEA, Biofuels Modes Project 3, for the DfT, 2011

	HGVs	Buses
B30	38%	12%
B100	27%	8%

Depot refuelling potential

- The usage of high blends (B30, B100) is set as a % of depot refuelling.
- Estimate of total diesel depot refuelling[1]:
  - 60% for HGVs (artic / rigid weight average on energy use)
  - 65% for buses (average buses/ coaches)

Cost implications

- Cost implications based on industry feedback:
  - Buses have lower mileage but more frequent oil filter change so same maintenance costs for buses and trucks

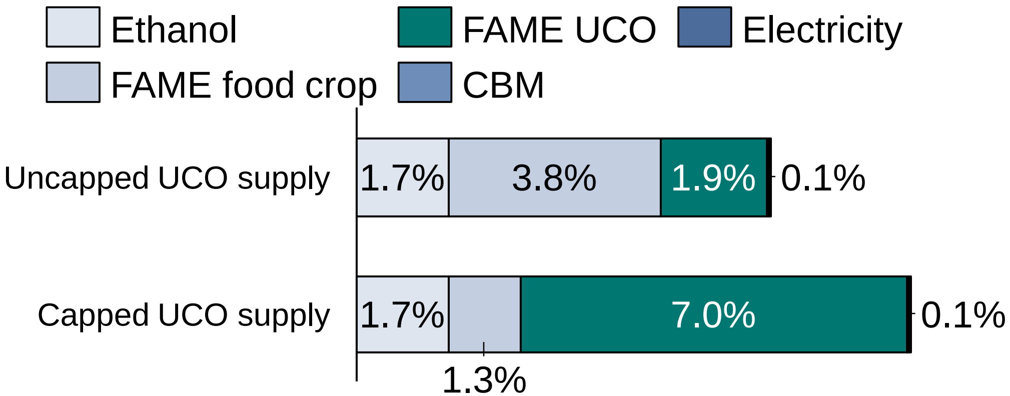
Existing stock compatibility

- 2013 stock compatibility based on 2011 estimates

Appendix I1. Detailed RED scenario analysis. E10 & B7 scenario 1/2

Scenario: E10 and B7 at forecourts, E5 protection grade (effective ethanol blend 8.8%vol), B2 for NRMM. No drop-in fuel, no E2G. Base powertrain pathway

Contribution to RED target



- The uncapped UCO case meets the target but implies large supply of UCO FAME/HVO: 1.7bl of UCO fuel (57 PJ). This represents :
  - 4.5 times UCO and waste fats FAME volumes reported in RTFO 2012/13
  - 50% of identified EU UCO fuel production (instead of 13% fair share)

Top barriers for E10 introduction as reported by industry stakeholders

- Some fuel retailers are not fuel suppliers, i.e. they are non-obligated (supermarket sell ~40% of retail petrol and diesel)
- Lack of government support (fuel duty on volume base, lack of endorsement, RTFO cap)
- Consumer acceptance: refrain non obligated as well as obligated retailers.
- Lack of rollout coordination

Challenges around high supply of UCO based fuel

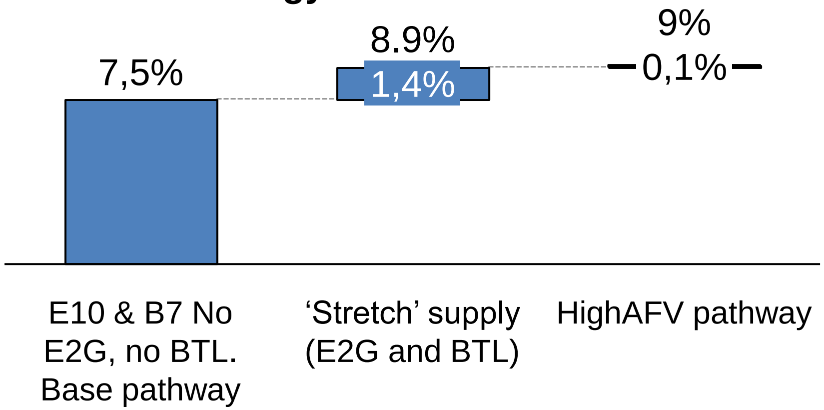
- Securing sustainable supply in light of expected competition for supply
- FAME UCO: fuel quality concerns voiced by distribution infrastructure industry and OEMs – although high quality UCO FAME already achieved by main UK producer
- HVO UCO: no quality concern but facilities not in place for high volumes yet

Appendix I1. Detailed RED scenario analysis. E10 & B7 scenario 2/2

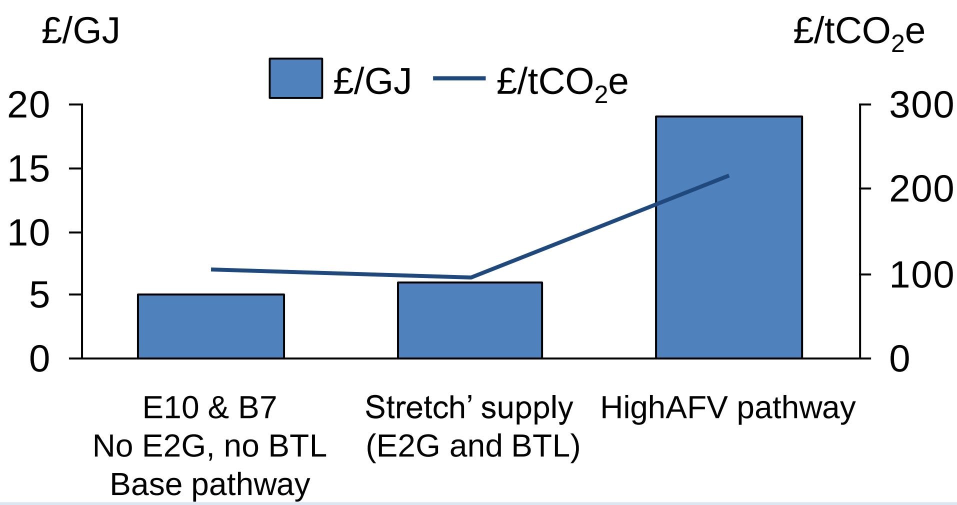
UCO supply limited at 450 Ml. Two levers considered:

- ► Double counting fuels (E2G, BTL drop-in diesel)
- ► High AFV powertrain pathway

% renewable energy under RED



Cost effectiveness comparison



- Not possible to meet the target in E10&B7 scenario (if UCO cap exists) without exceeding the 'Stretch' supply limits for E2G and BTL or Alternative Fuel Vehicle uptake.
- Negligible contribution of HighAFV to the target, while remarkably increasing costs as £/GJ and £/tCO_2e (bottom graph).

Options to meet the 10% target: increase of double counting fuels beyond Stretch supply

EITHER for E2G :

- ► 1 billion litres of E2G (23 PJ) – 1.4 times E1G supplied to UK in 2012/13

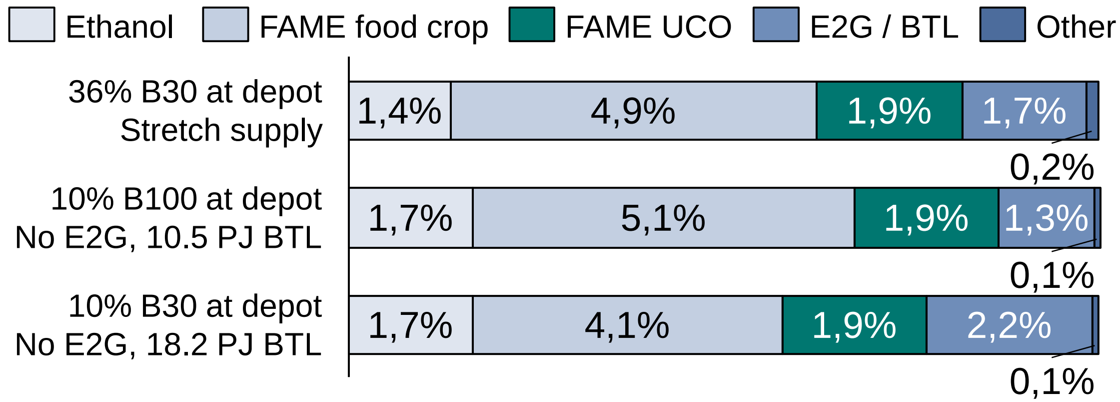
OR for BTL :

- ► 500 million litres of BTL fuel (17.5 PJ) – giving effective blend of 8.8%vol of renewable fuel in diesel
- ► **Values 4.5 and 2 times higher than the Stretch supply caps. BTL more cost effective**

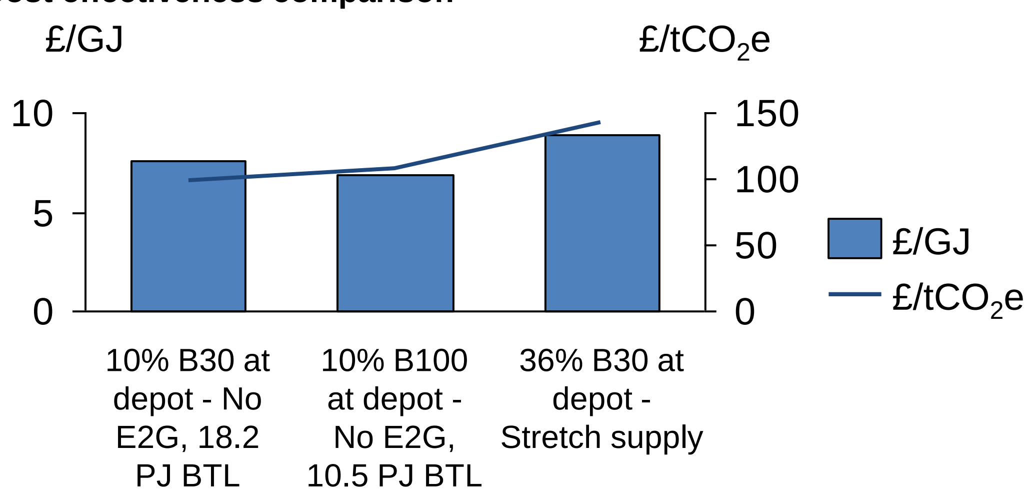
Appendix I2. Detailed RED scenario analysis. Depot scenario focus

Scenario: E10 and B7 at forecourts, E5 protection grade (effective ethanol blend 8.8%vol), B2 for NRMM. Base powertrain pathway. Levers: share of depot refuelling HGVs and buses using B30 or B100; supply of BTL diesel

Contribution to RED target



Cost effectiveness comparison



- The 10% RED target can be met:
  - With **10% depot refuelling vehicles using B30 and twice the Stretch supply BTL** (535 Ml); or
  - With **10% depot refuelling vehicles using B100 and 1.2 times the Stretch supply of BTL** (309 Ml); or
  - With **36% depot refuelling vehicles using B30 and High BTL.**
- Use of FAME food crop: 2-2.5 billion l
- Most cost-effective combination:
  - 10% uptake of B30 among depot fleet
  - 535 ml BTL (18.2 PJ)
  - 7.6 £/GJ and 98 £/tCO_2e
- Past biodiesel incentives achieved less than 10% uptake among depot refuel[1]. *Assumptions of 10% and 36% uptake are therefore ambitious.*

Reminder of assumptions: 60% HVGs refuel at depot, 65% of buses refuel at depot.

1 – Source: UKPIA

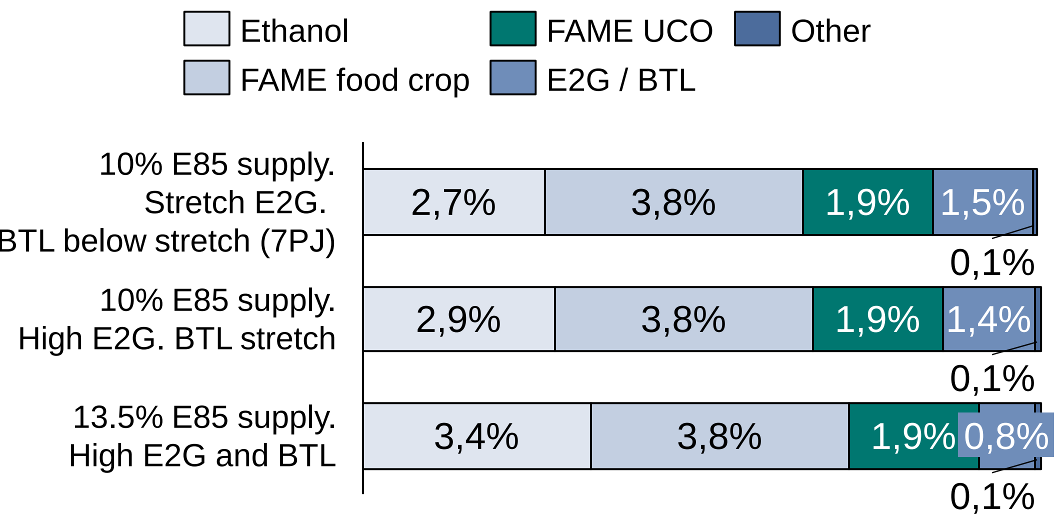
Appendix I3. Detailed RED scenario analysis. High blends at forecourts

Scenario: E10 and B7 at forecourts, E5 protection grade, B2 for NRMM. Base powertrain pathway.

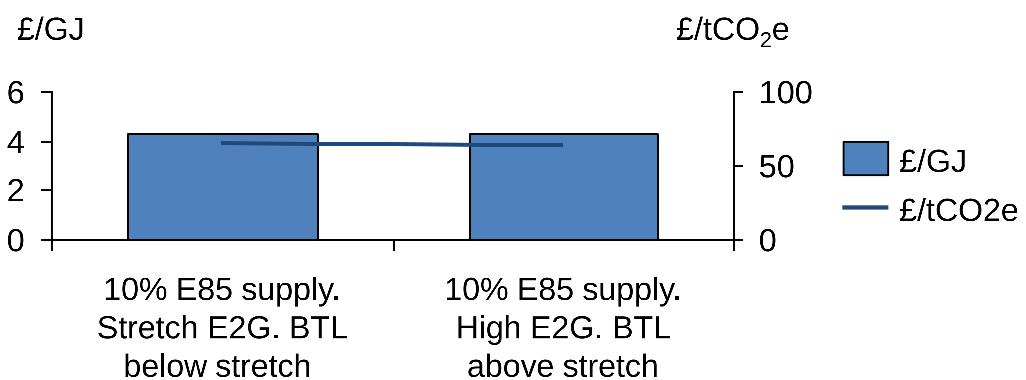
Cases investigated: E20, E85 and B10

Extra lever: supply of E2G and BTL diesel

E85 case - contribution to RED target



Cost effectiveness comparison



- Earliest possible introduction of E20 or B10 compatible vehicles is 2019 – meaning very low % of 2020 fleet would be compatible.
- As a consequence, E20 or B10 on their own cannot meet the 10% target and need unrealistic supply of drop-in fuel.
- The case of E85 presents more realistic options:
  - 10% of pumps supplying E85 by 2020. Stretch supply for E2G. BTL 0.8 Stretch supply. Effective petrol blend: E14.4
  - 10% of pumps supplying E85 by 2020. High supply for E2G. Stretch BTL supply. Effective petrol blend: E15
  - 13.5% of pumps supplying E85 by 2020. High supply for E2G, BTL. Sales of E85 cars escalating to 1.3 m by 2020.

E20: earliest car sales in 2019. Assumed 40% of cars sold in 2019 are E20 compatible, 50% in 2020. Same timeline for B10. E85: See appendix I4 (next slide)

Appendix I4. New blends introduction at forecourts and E85 deployment assumptions

Start introduction dates and % of supply cap at pumps by 2020

Blend	Start date for blend at forecourt	% supply at forecourts
E10	2016	100%*
E85	2015	10%

The introduction of E10 could be earlier than 2016. 2016 corresponds to the date E10 becomes the certification fuel, i.e. it is the latest date for introduction.

Sales of E85 compatible ICE cars

	2013	2014	2015	2016	2017	2018	2019	2020
% over petrol cars	0%	0%	5%	9%	18%	26%	33%	43%
% over total cars	0%	0%	3%	5%	10%	14%	18%	24%
Absolute numbers	-	-	69,217	125,964	258,902	370,412	478,188	630,801

Stock of E85 compatible ICE cars

	2013	2014	2015	2016	2017	2018	2019	2020
% over petrol cars	0%	0%	0%	1%	3%	5%	7%	11%
% over total cars	0%	0%	0%	1%	1%	3%	4%	6%
Absolute numbers	-	-	69,217	195,181	454,083	824,495	1,301,961	1,931,446

*All forecourts are assumed to offer E10 by 2020, but E10 sales are modelled with a 80% cap, in order to capture consumer behaviour and remaining vehicles not compatible with E10

Appendix I5. Detailed RED scenario analysis. The case of ILUC factors

WTW emissions ('central scenario') and ILUC contributions for E1G and FAME food (gCO_2e/MJ)

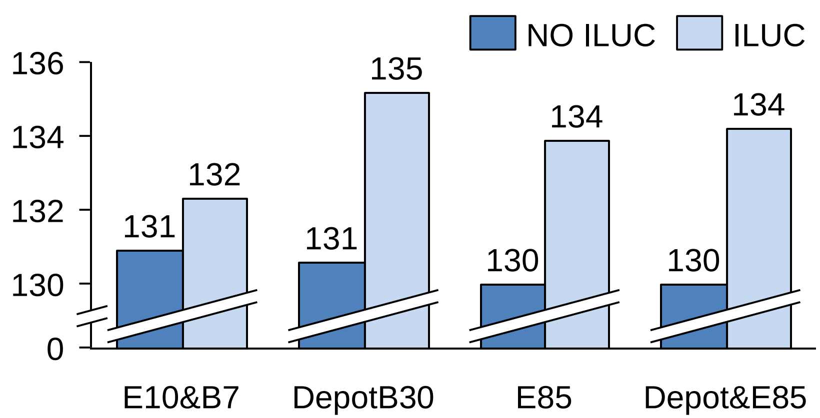
Fuel	ILUC factor [1]	2013 inc. ILUC	2020 inc. ILUC	Petrol and Diesel
E1G	13	48	38	83.8
Crop FAME	55	105	97	83.8

ILUC factors as proposed by the EC in 2012[1] make the WTW emissions of FAME food higher than diesel

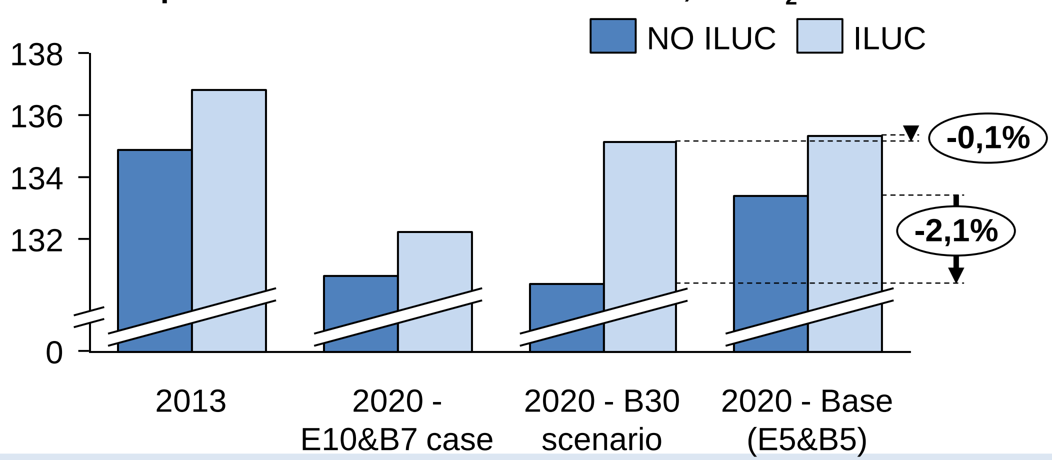
- The inclusion of ILUC factors implies additional cumulative absolute emissions of 1.5- 4.5 $MtCO_2e$ in 2020, and of 20-30 $MtCO_2e$ in total 2014-2020 WTW cumulative emissions (2-3% of total cumulative emissions)

- The savings of the scenarios compared to the baseline are almost eliminated when ILUC factors are included (reductions of 2014-2020 WTW cumulative savings by 70-98%)

Comparison of 2020 total WTW emissions, $MtCO_2e$



Comparison of annual WTW emissions, $MtCO_2e$



1- Source: COM(2012) 595 final

Appendix J. Scenario results: fuel use in 2020 (1/2)

Fuel use breakdown in 2020

Fuel	E10 & B7	Depot B30	E85	E85 & B30
Ethanol 1G (Ml)	1,292	1,052	2,238	2,238
Ethanol 2G (Ml)	-	240	120	120
FAME waste oils (Ml)	1,732	480	480	480
FAME food crop (Ml)	654	2,437	1,906	2,054
BTL (Ml)	-	253	253	162
Biomethane (t)	4,600	18,600	4,600	4,600
Renewable electricity (GWh)	94	94	94	94

% of E2G and FAME non-food in total bio-ethanol and bio-diesel in 2020

	E10 & B7	Depot B30	E85	E85 & B30
% E2G over total ethanol	0 %	19 %	5 %	5 %
% FAME non-food over total FAME	73 %	16 %	20 %	19 %

Appendix J. Scenario results: effective blends (2/2)

The effective blend in 2020, %vol

	E10&B7	DepotB30	E85	E85&B30
E1G	9%	7%	17%	17%
E2G	0%	2%	1%	1%
FAME*	6-7%	8-9%	6-7%	6-8%
BTL	0%	1%	1%	0.5%
HVO (up to, based on 15PJ supply)	1%	1%	1%	1%

* Lower band corresponds to the case where max HVO supply is used

Appendix K. Other sensitivities

Bio-methanol

Current supply to the UK is around 50 Ml in 2013, a doubling by 2020 (100 Ml, 1.6 PJ) would mean bio-methanol (a double counting fuel under RED rules) could displace 0.7%vol. of the total petrol demand (and between 4-8%vol. of total ethanol demand)

Contribution of NRMMs

NRMMs are assumed to be fuelled from a blend of FAME food only (as they are more sensitive to the potential quality issues of FAME waste oil). Therefore going to B5 instead of B2 (by 2020) would decrease the use of other fuels in other sectors:

- E10 & B7, 15 % reduction in the volume of FAME from waste oils needed (~250 Ml reduction)
- DepotB30 scenario, reduction of the number of depots providing the high blend from 36% to 21%
- E85 case, reduction of the level of BTL provided, from ‘Stretch’ cap to ‘High’ cap
- Depot&E85, reduction of the level of BTL below ‘High’ (60 million litres, 2 PJ; 45% reduction)

Contribution of High car mileage to the target

E10 & B7, 3% increase in the volume of FAME waste oil needed (~60 million increase). 59PJ needed, 1,788 Ml

Impact of E10 demand by 2020

100% demand of E10 by 2020 would mean a 4.5% reduction (~76 Ml) in the use of FAME from waste oils – compared to 80% demand modelled in the RED scenarios