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ENVIRONMENTAL SCIENCE FOR THE EUROPEAN REFINING INDUSTRY

JEC Biofuels and Well to Wheels Analyses

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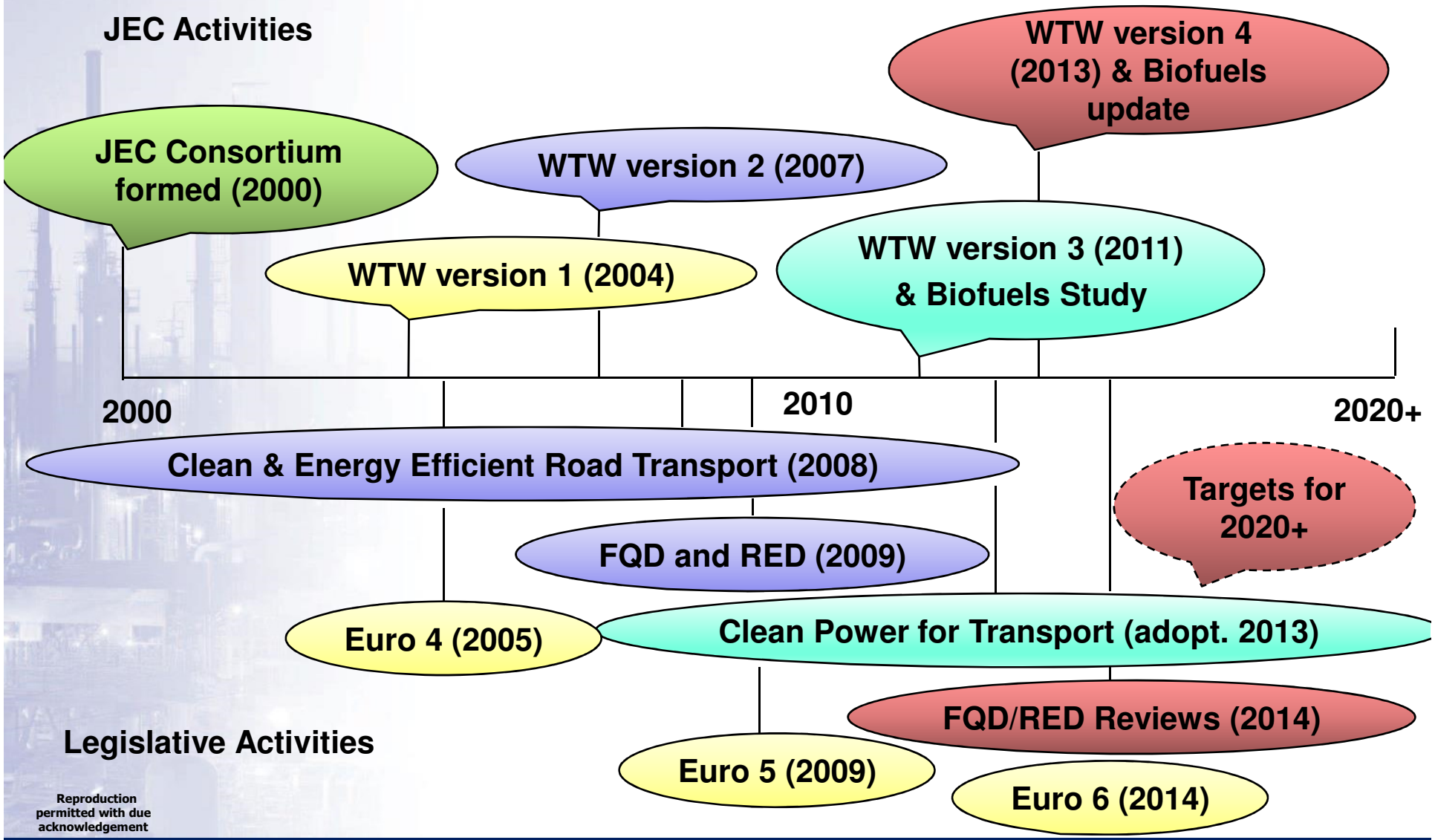
European Biofuels Technology Platform Meeting

Brussels, October 14th 2014

JEC and Evolution of Transportation Legislation



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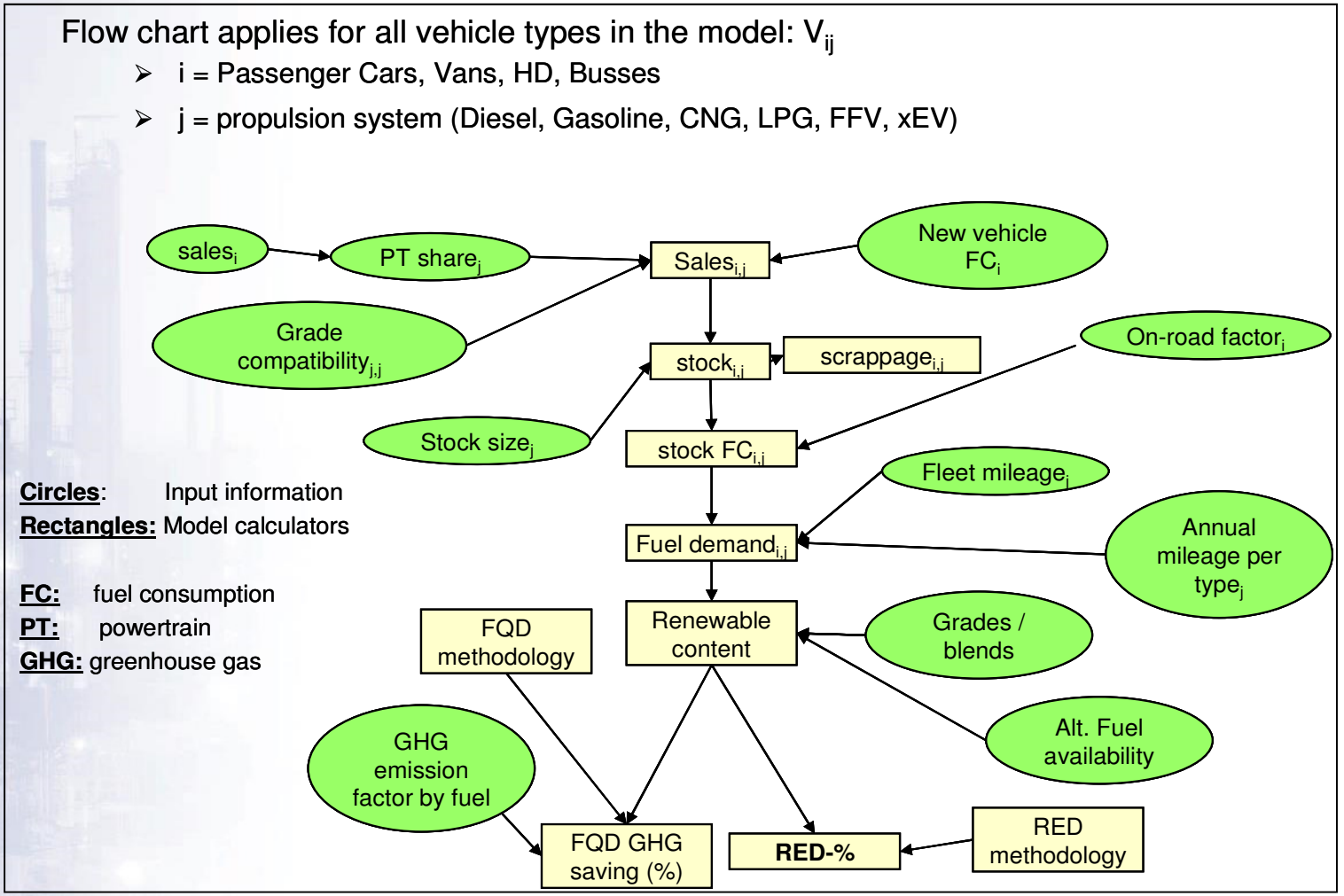
Fleet and Fuels Model is Heart of JEC Biofuel Study

Flow chart applies for all vehicle types in the model: V_{ij}

- i = Passenger Cars, Vans, HD, Busses
- j = propulsion system (Diesel, Gasoline, CNG, LPG, FFV, xEV)



- 2013 update includes changes with respect to legislative initiatives, vehicle fleet, fuel and biofuel demand, and the availability of advanced biofuels

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2013 JEC Biofuels Study: Objectives

- Objectives of the 2013 JEC Biofuels Study:
  - Clarify the opportunities and barriers to achieve 10% renewable energy in the transport sector by 2020 and a 6% reduction in GHG emissions
  - Extend F&F model to test different legislative concepts for RED and FQD amendment (such as accounting caps on conventional biofuels, multiple counting factors, and GHG savings based on specific production pathways)
  - Update the EU27+2 “Fleet & Fuels” model baseline from 2005 to 2010
  - Update fixed demand values for non-road transport modes
  - Focus on conventional and alternative fuels and biofuel blends while accounting for growth in alternative powertrains share from 2010-2020
  - Update the advanced biofuel supply outlook from the bottom up
  - Assess realistic biofuel implementation scenarios for 2020

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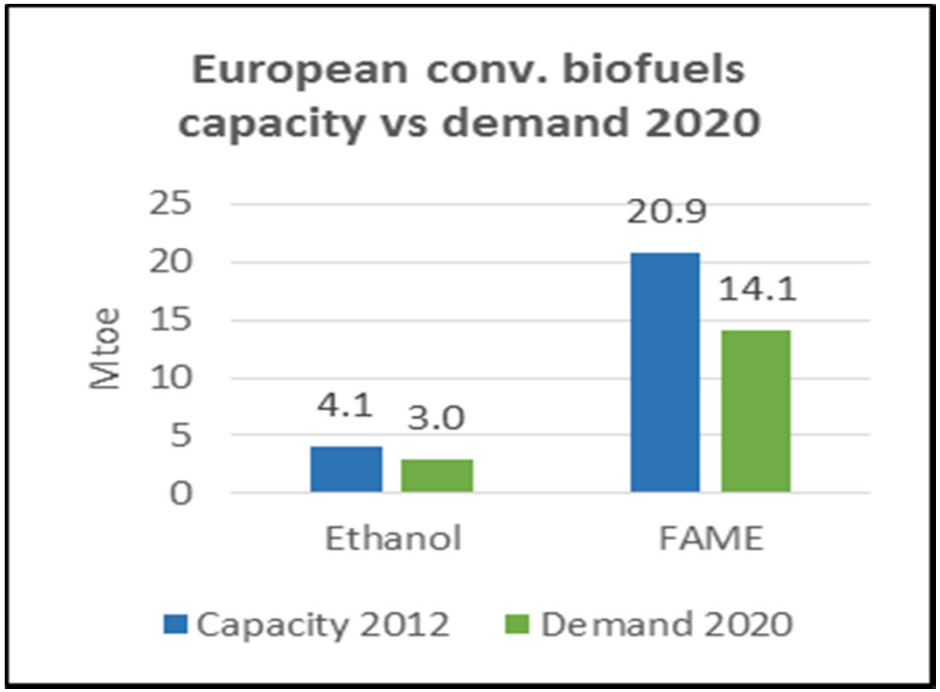
Conventional Biofuels: EU demand vs capacity



- Current European installed production capacity of ethanol and FAME is sufficient to cover the projected demand in 2020
- Comparison with Hart's Energy projections shows slight differences
  - Hart's more optimistic on E10 uptake
  - JEC more optimistic on biodiesel uptake

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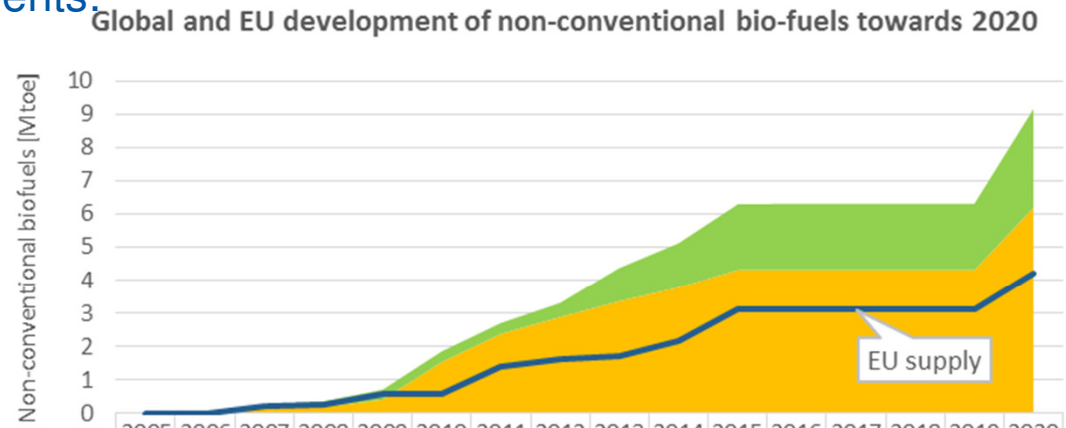
Non-conventional biofuels: Supply Outlook

- Bottom-up approach to collect and analyse global announced projects
- Scope is bio-derived components:
  - Ligno-cellulosic Ethanol
  - Butanol
  - Methanol
  - HVO/Co-processing
  - Biomass-To-Liquid
  - DME



	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Non-conv. Bio-gasoline	0.0	0.1	0.1	0.2	0.3	0.3	0.3	0.4	1.0	1.3	2.0	2.0	2.0	2.0	2.0	3.0
Non-conv. Bio-diesel	0.0	0.0	0.2	0.2	0.4	1.5	2.4	2.9	3.4	3.8	4.3	4.3	4.3	4.3	4.3	6.2
EU non-conv. Biofuels	0.0	0.0	0.2	0.3	0.6	0.6	1.4	1.6	1.7	2.2	3.1	3.1	3.1	3.1	3.1	4.2

- Main sources are:
  - Hart Energy (2012); “Advanced biofuels outlook 2025”
  - IEA Task 39; “Status of Advanced Biofuels Demonstration Facilities in 2012”
  - NER300 projects funded by European Commission
  - Additional public announced projects and Member Companies consultation
- World Outlook of non-conventional biofuels in 2020 is ~9.2 Mtoe, EU is ~4.2 Mtoe

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Fuel demand scenarios: background

- 4 implementation scenarios were run for the 2010-2020 time period based on
  - CEN specifications for mass market fuels and vehicle compatibility outlook
  - Market experience in E10 uptake (Germany, France, and Finland)

Scenario 1 (ref)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Gasoline Grade 1	E5										
Gasoline Grade 2			E10 with ramp-up								
Diesel Grade 1	B7										
Diesel Grade 2											

Scenario 2	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Gasoline Grade 1	E5									E10	
Gasoline Grade 2			E10 with ramp-up							E20 with ramp-up	
Diesel Grade 1	B7										
Diesel Grade 2											

Scenario 3	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Gasoline Grade 1	E5										
Gasoline Grade 2			E10 with ramp-up								
Diesel Grade 1	B7										
Diesel Grade 2								B10 captive HD fleet*			

Scenario 4	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Gasoline Grade 1	E5									E10	
Gasoline Grade 2			E10 with ramp-up							E20 with ramp-up	
Diesel Grade 1	B7										
Diesel Grade 2								B10 captive HD fleet*			

* 2.5% of total HD diesel demand is B10

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Reference Scenario 1

E10 & E5 'protection grade'
B7 diesel grade

Scenario 2:

E20 introduced in 2019
E10 becomes 'protection grade'

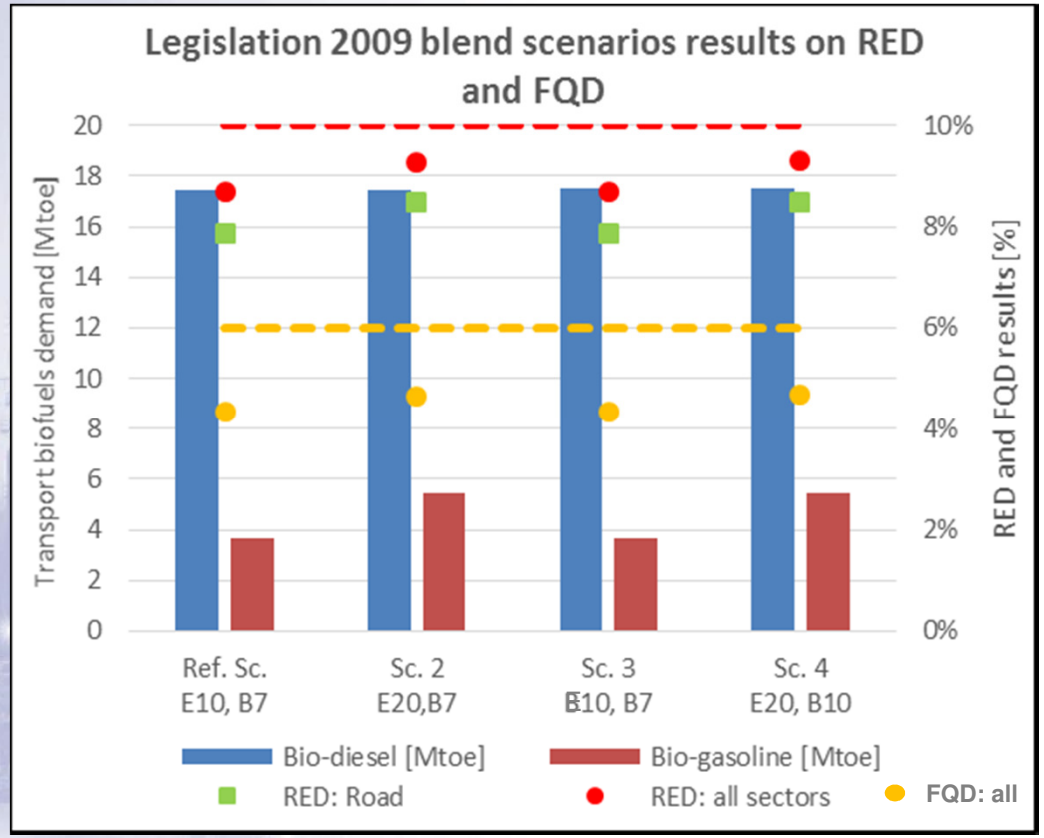
Scenario 3:

E10 & E5 'protection grade'
B7 diesel main grade
B10 diesel for HD captive fleet

Scenario 4:

Combination of Scenarios 2 & 3

Fuel demand scenarios: Results



	Ref. Scenario	Scenario 2 [E10,E20,B7]	Scenario 3 [E5,E10,B7,B10]	Scenario 4 [E10,E20,B7,B10]
Bio-gasoline [Mtoe]	3.7	5.4	3.7	5.4
Bio-diesel [Mtoe]	17.46	17.46	17.52	17.52
RED%	8.7%	9.3%	8.7%	9.3%
FQD%	4.3%	4.7%	4.3%	4.7%

- Higher market blend introduction can be expected to have limited impact
- Introducing a new grade to the market takes time to implement

- Legislative concepts explored in this 2013 study include:
  - Caps on conventional biofuels applied to both RED and FQD Art. 7a, 2.5% target for advanced biofuels, and ILUC factor reporting and multiple counting factors for feedstocks and/or fuels

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Comparison legislative concepts: Results

For Reference Scenario		RED	FQD [w/o ILUC]	FQD [w/ ILUC]
TARGET		**10%**	**6%**	**NA**
2011 JEC Biofuel Study	2009 RED & FQD	9.7%	4.4%	NA
2013 JEC Biofuel Study	2009 RED & FQD	8.7%	4.3%	NA
	2012 EC Proposal	7.8%	4.3%	1.0%[1]
	2013 EP 1st Reading	8.2%	NA	1.0%
	2013 Council Text	8.7%	4.3%	1.0%[1]

1) iLUC reporting only

- 2011 study indicated that RED and FQD 2020 targets were not likely to be met
- The 2013 Biofuels Study results conclude that achieving the 2020 targets is now less likely compared to the 2011 assessment
  - Older vehicles, slower uptake of E10 than expected, advanced biofuels uncertain

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Well to Wheels study and Objectives

- A Well-to-Wheels analysis is the essential basis to assess the impact of future fuel and powertrain options.
- Both fuel production pathway and powertrain efficiency are impacting the GHG emissions as well as total and fossil energy use.
- A common methodology and data-set has been developed providing a basis for the evaluation of pathways.
  - Including biofuels as well as other alternative fuels
- Objectives were to establish, in a transparent and objective manner, a consensual Well-to-Wheels evaluation of
  - energy use and GHG emissions
  - wide range of automotive fuels and powertrains relevant to Europe in 2020 and beyond
- To have the outcome accepted as a reference by all relevant stakeholders.

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Well-to-Wheels "Pathway" for Fossil Fuels

Well

Produce primary fuel

Transport primary fuel

Produce road fuel

Distribute road fuel

Fuel vehicle

Burn fuel in vehicle

Wheels

Well-to-Tank (WTT)

Crude Production
1 – 4%

Refining
8 – 10%

Distribution & Retail
1%

Tank-to-Wheels (TTW)

Similar pathways can be calculated for alternative fuels

For each "WTW" pathway calculate:

- Total energy required
- Total GHG intensity

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Source: Conventional vehicles and fuels: JEC Well to Wheels Study (2005)

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Scope of Tank to Wheels

- Define and characterize reference vehicle & vehicle technologies
  - Generic C-segment vehicles (e.g. VW Golf, Ford Focus, PSA 307)
- All vehicles are based on same reference for comparability
  - All vehicles share same glider as reference (body & chassis)
  - Alternative vehicles are defined by virtually removing and adding specific components
  - Weight impact of tanks, extra batteries, etc. is covered
- New European Driving Cycle (NEDC) & UNECE R101 applied
  - Fuel consumption & electric energy consumption
- GHG emissions: CO_2, CH_4 & N_2O
- Comprehensive vehicle simulations with AVL Cruise
  - Data, calibrations, controls, etc. agreed amongst the EUCAR and AVL expert team
- Timeline: 2010 & 2020+

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Well-to-Wheels Pathways included in WTW4

Resource

Crude oil

Coal

Natural Gas

Shale Gas

Biomass

Wind

Nuclear

Electricity

Fuels

Conventional Gasoline/Diesel/Naphtha

Synthetic Diesel

CNG, CBG, SNG

LPG

MTBE/ETBE

Hydrogen
(compressed / cryo-compressed)

DME

Ethanol

Bio-diesel (inc. FAEE)

HVO

Electricity

Powertrains

Spark Ignition:
Gasoline, LPG, CNG, CBG, SNG, Ethanol

Compression Ignition:
Diesel, DME, Bio-diesel

Fuel Cell

xEVs:

HEV, PHEV, REEV, BEV

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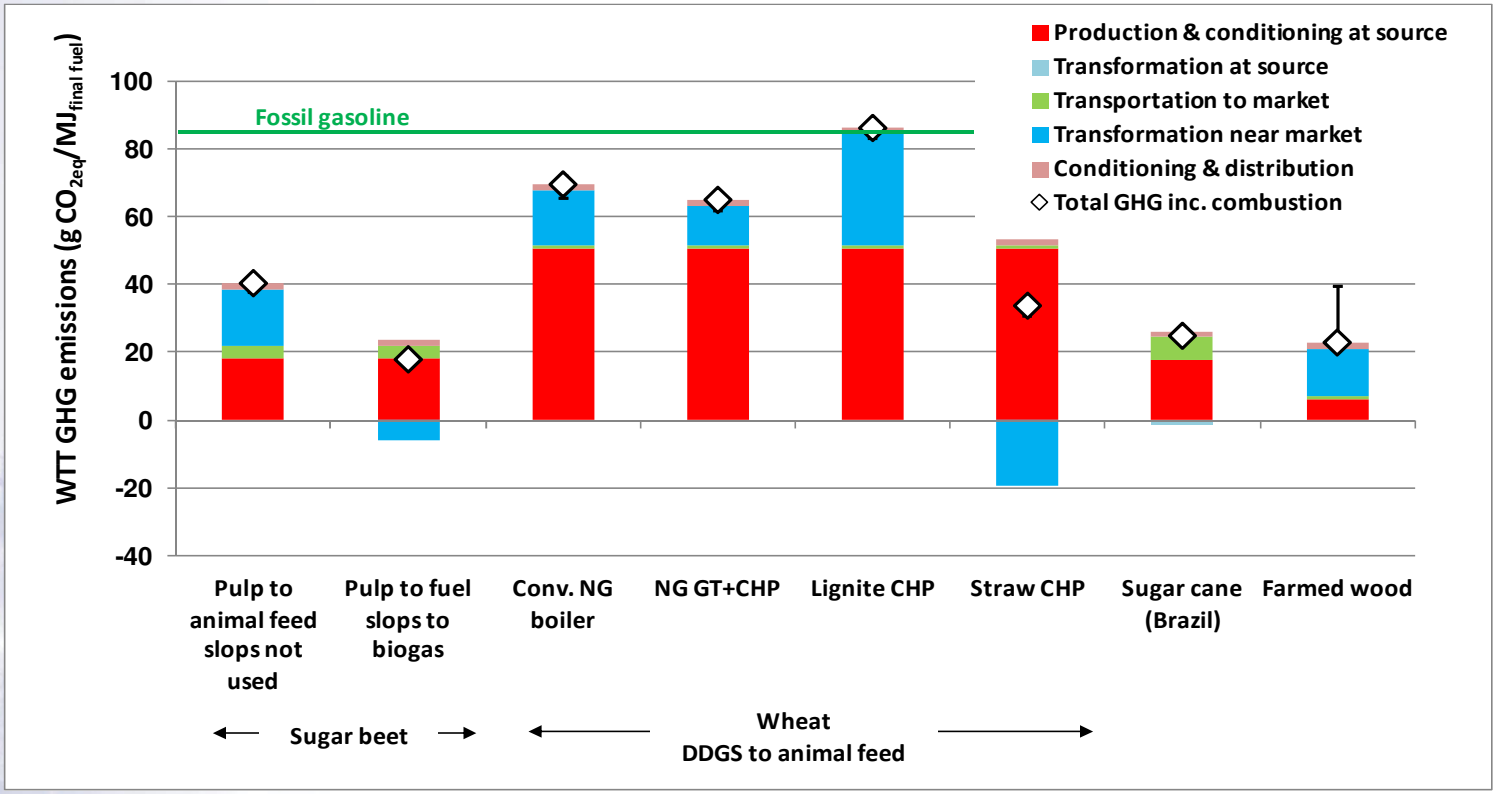
Well-to-Tank: Bio-ethanol



- Net GHG emissions from production of bio-ethanol depend critically on
  - The technology and energy source used
  - The disposition of the co-products
- Ethanol from sugar cane or cellulosic materials (wood or straw) produces lower emissions than ethanol from wheat

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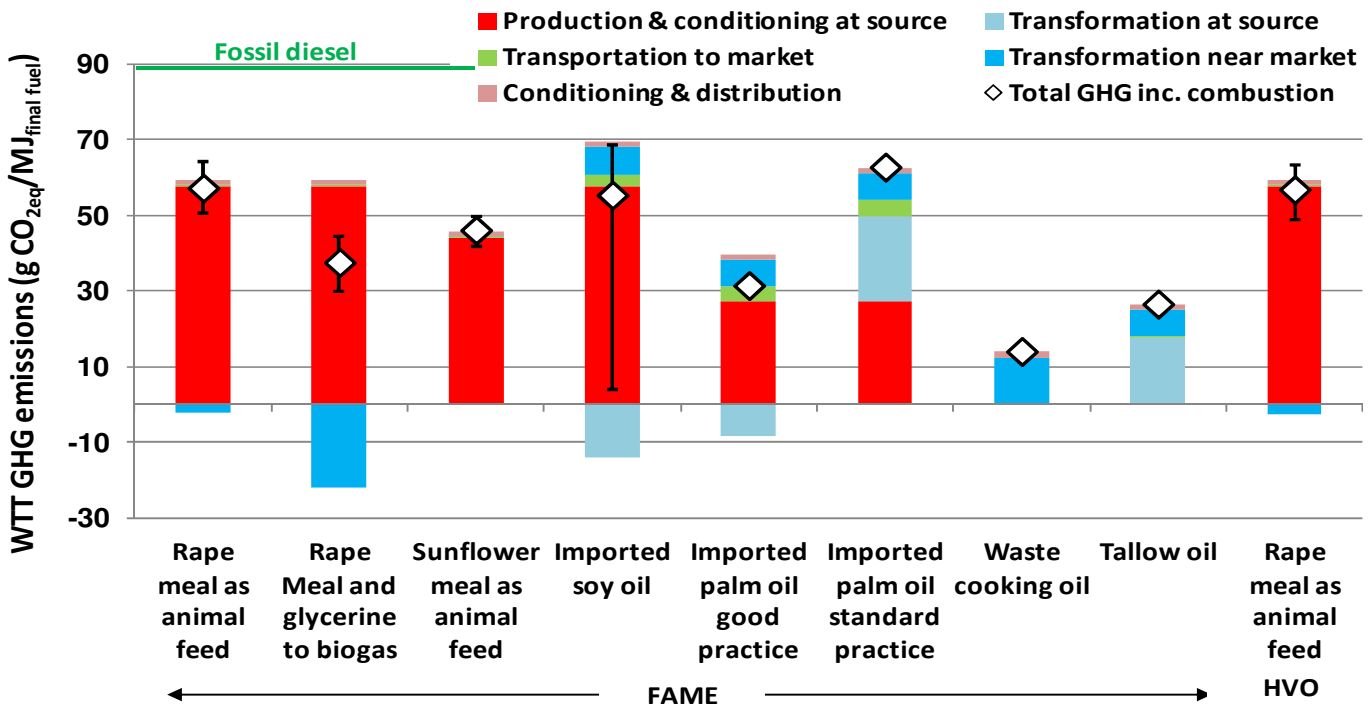
Well-to-Tank: Bio-diesel (FAME, FAEE and HVO)



- GHG emissions for bio-diesel depend on the feedstock
  - Waste oils and tallow have the lowest emissions, because emissions from feedstock production are avoided.
- Co-product disposition plays a role but less so than with bio-ethanol
  - Good practice can reduce emissions significantly

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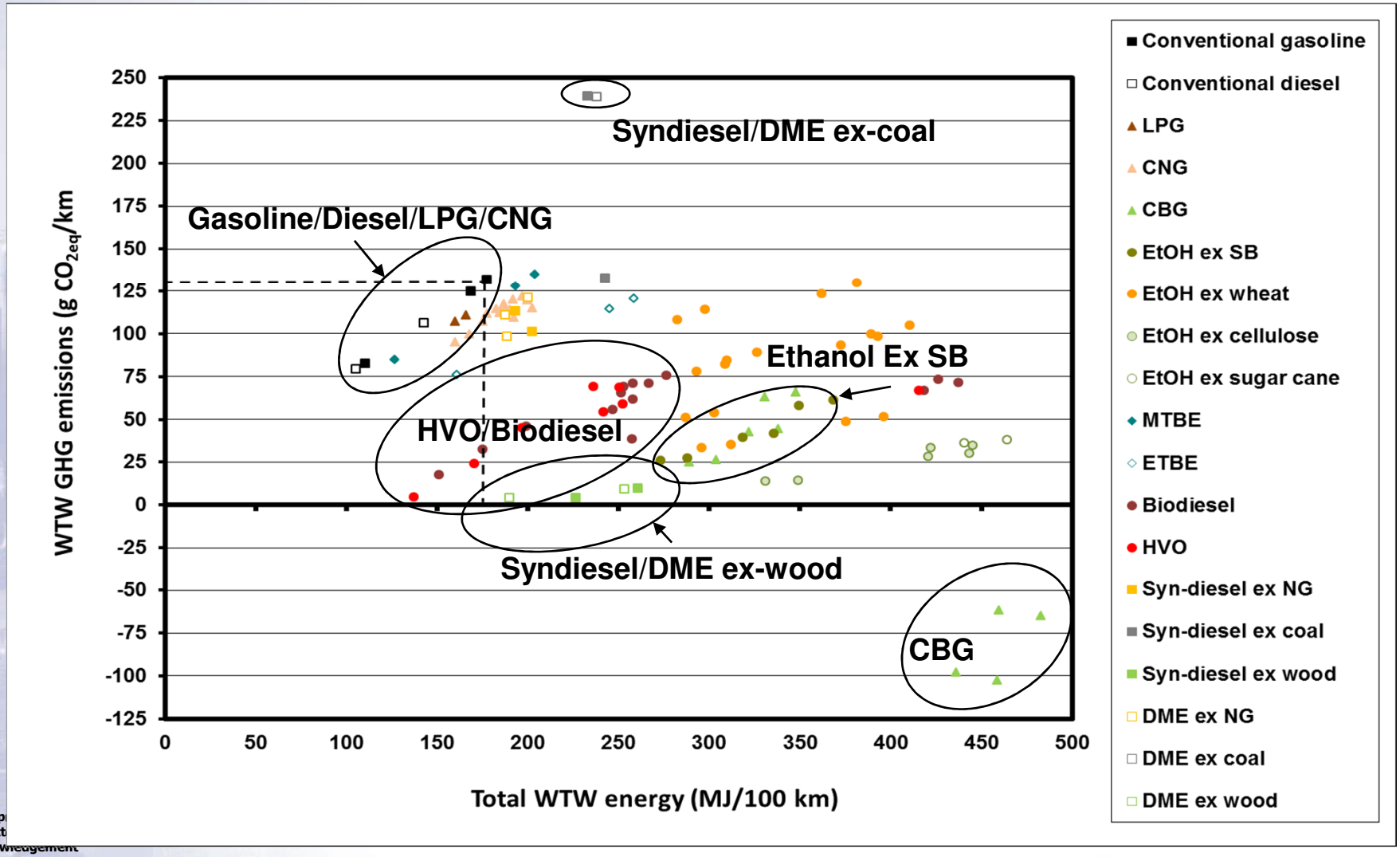
Well-to-Wheels – Biofuel

WTW energy expended and GHG emissions for some biofuel pathways (2020+ vehicles)



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Conclusions

- **2011 Biofuels Study** suggested that **RED and FQD** 2020 targets will **not** be met
- The **2013 Biofuels Study results** conclude that achieving the 2020 targets is now **less likely** compared to the 2011 assessment
- A **Well-to-Wheels** analysis is the **essential basis** to assess the impact of **future fuel and powertrain options**
- A **common methodology** and **data-set** has been developed providing a basis for the **evaluation of pathways** which can be updated as technologies evolve
- An **integrated approach** across all energy using sectors is essential to reduce energy consumption and GHG emissions most effectively
- A **shift to renewable/low-carbon routes** may offer a **significant GHG reduction** potential **but generally requires more total energy**
  - The specific pathway is critical

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