Advanced biofuels – an overview

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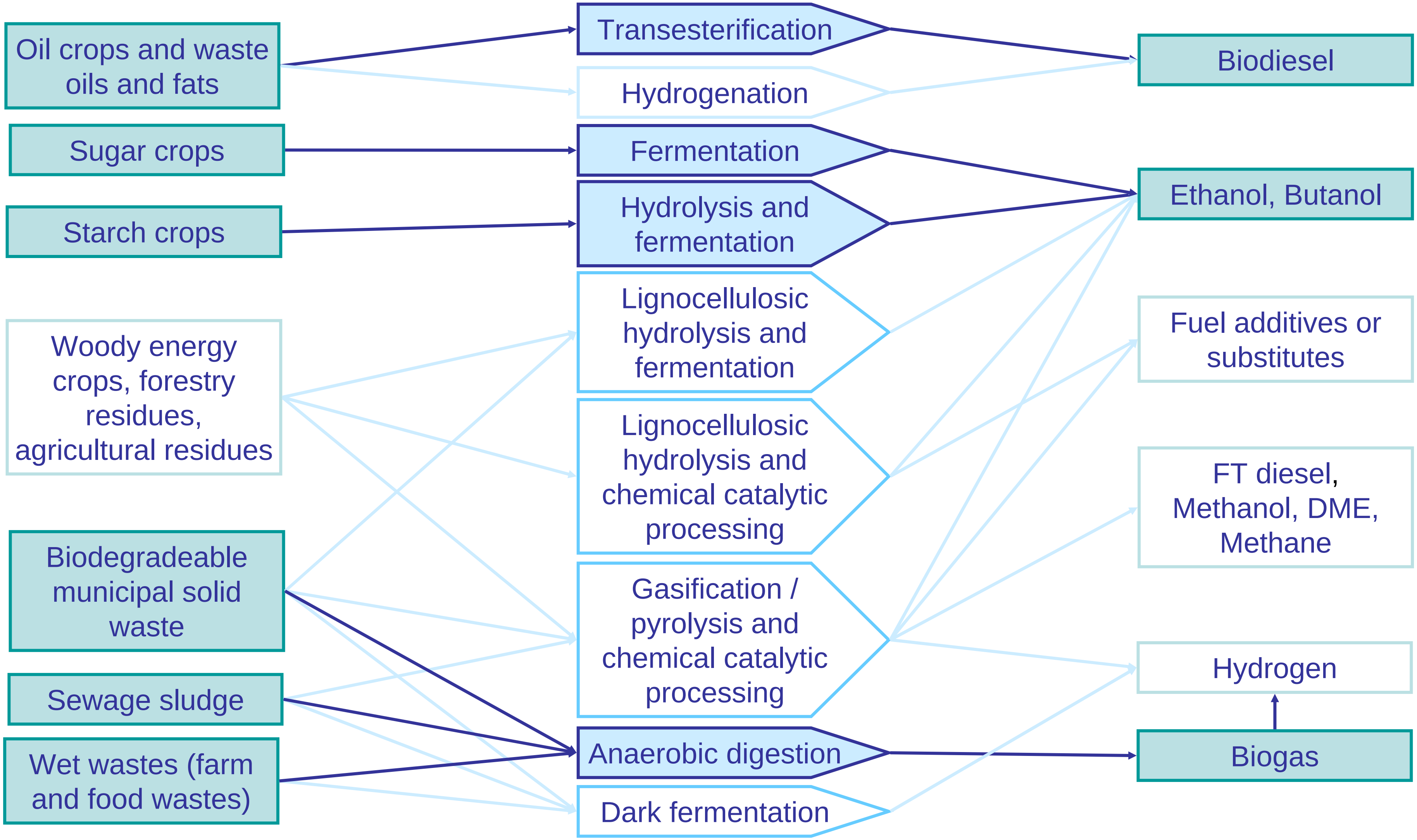
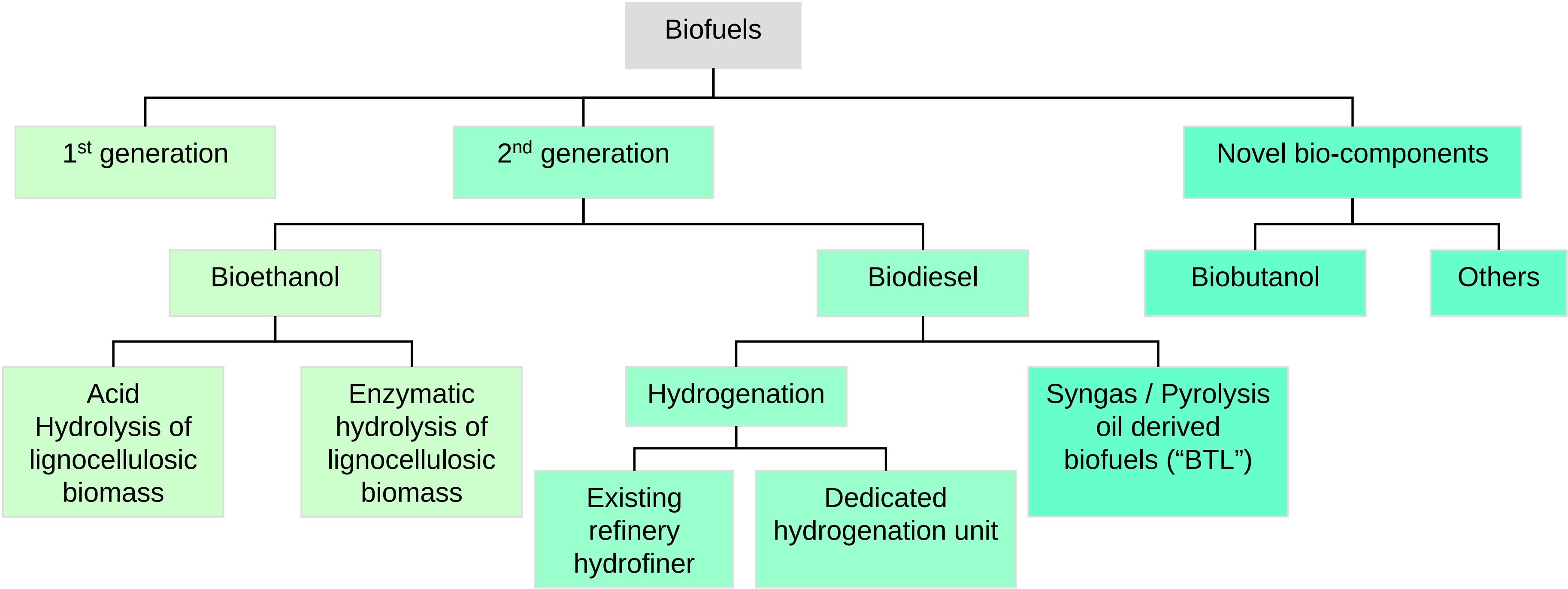
There are many different routes to biofuels. Currently commercial biofuels are often described as ‘first generation’



Commercially available, or 1st generation, routes are shaded blue, next generation routes are unshaded

Taxonomy of 2nd generation (2G) biofuels

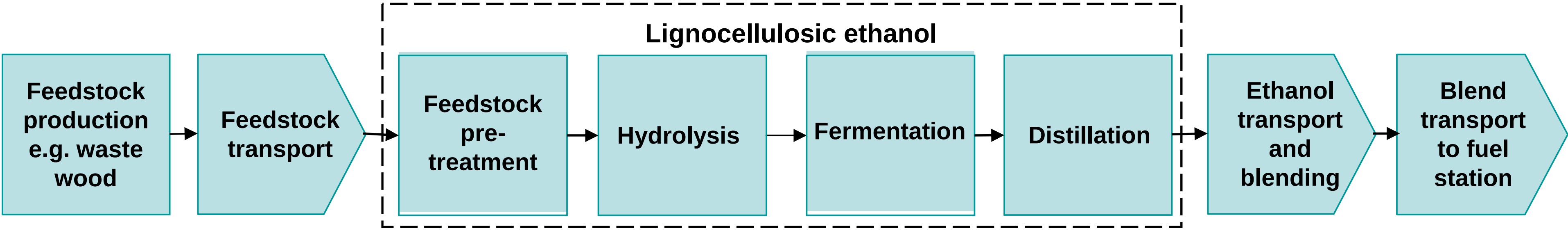
- **First generation biofuels:** currently commercial; use only *part* of the plant. 1G biofuels also include bio-methane production from the digestion of wet biomass.
- **Second generation biofuels:** routes that are potentially close to commercialisation; generally meant to encompass hydrolysis-based lignocellulosic ethanol and FT-biodiesel; use a*ll* of the plant, lignocellulosic components found in MSW.
- **Novel bio-components:** being developed but currently further from commercialisation than lignocellulosic ethanol and biodiesel produced from syngas using Fischer-Tropsch synthesis.



2G biofuels – Lignocellulosic bioethanol

Lignocellulosic ethanol – The biological or chemical hydrolysis of cellulose and hemi-cellulose, followed by fermentation to produce ethanol. Residual lignin is left over.

Typical fuel chain for biodiesel production from syngas



2G biofuels – Lignocellulosic bioethanol

Status

Demonstration, but much development needed to improve efficiency and costs

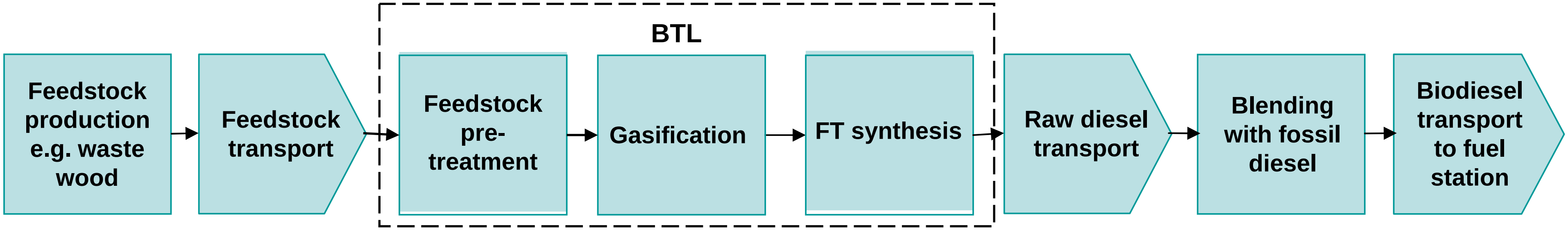
Development needs

- Pre-treatment (cell structure breakdown and hemicellulose hydrolysis)
    - Reduce energy consumption
    - Reduce pentose degradation and inhibition from degradation products
    - Improve reactivity of cellulose fibre
    - Improve separation techniques
    - Determine suitability of different feedstocks
- Cellulose hydrolysis
    - Improve enzymatic hydrolysis (rates, costs, inhibition)
    - Trade-offs between SHF and SSF
    - Find the ideal organism (consolidated bioprocesing)
- Distillation
    - Reduce energy and costs

2G biofuels – FT-biodiesel

Fischer-Tropsch(FT)-biodiesel (aka Biomass-to-Liquids (BTL) - gasification of biomass followed by chemical catalytic processing in a synthesis step known as the Fischer-Tropsch (FT) process.

Typical fuel chain for biodiesel production from syngas



2G biofuels – FT-biodiesel

Status

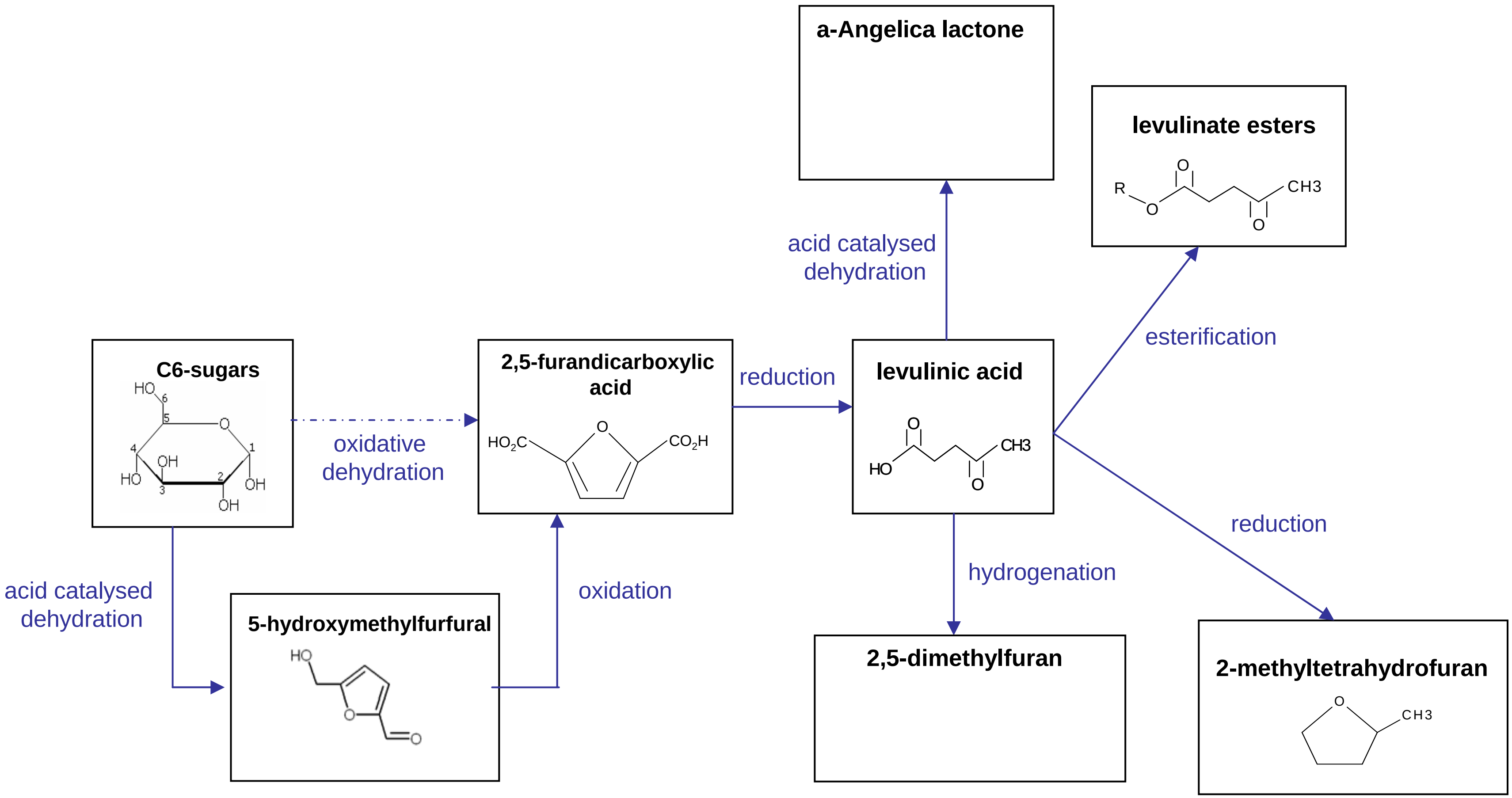
Demonstration – one demonstration plant in Germany

Development needs

- Much experience exists with coal-to-liquids production, but very limited commercial experience with biomass gasification and biomass-to-liquids
- Selection of appropriate gasification technology producing high quality syngas (entrained flow?)
- Low cost syngas cleaning meeting syngas quality requirements
- Product selectivity control through catalyst development
- Optimisation of co-product mixes and types
- Plant concept and siting optimisation to reduce costs

3G biofuels? – Chemical synthesis using sugars

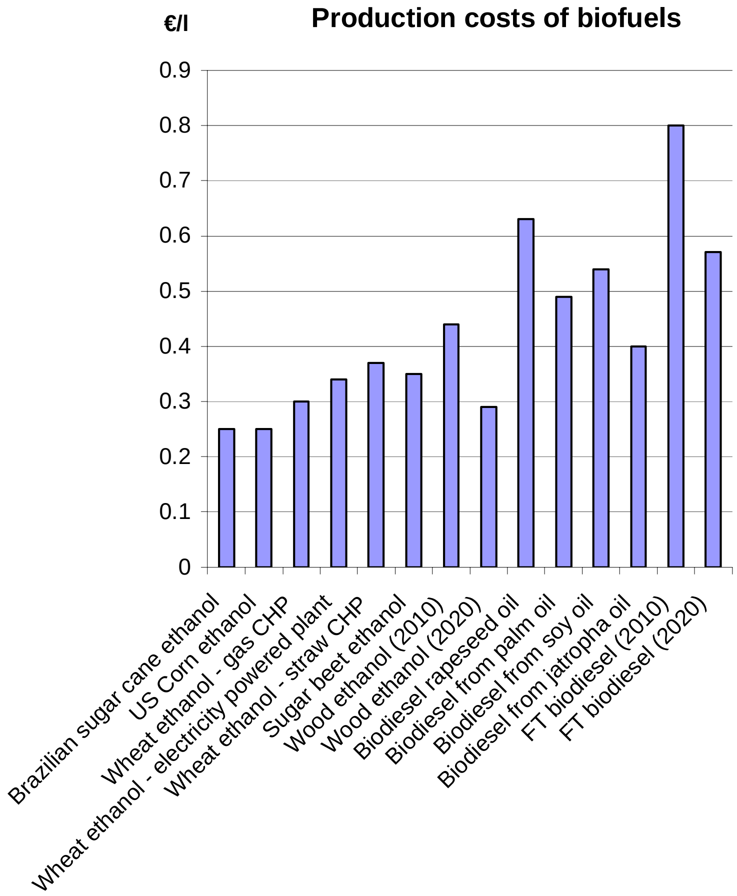
Example: sugars (hexose) to platform chemicals (levulinic acid) to fuel additives



Competitiveness of different biofuels

Feedstock and process	€/GJ	€/l	Feedstock price, €/tonne (dry)
Brazilian sugar cane ethanol	11.8	0.25	55
US Corn ethanol	11.8	0.25	62*
Wheat ethanol - gas CHP	14.2	0.30	100
Wheat ethanol - electricity powered plant	16.2	0.34	100
Wheat ethanol - straw CHP	17.5	0.37	100
Sugar beet ethanol	16.3	0.35	25
Wood ethanol (2010)	20.6	0.44	42
Wood ethanol (2020)	13.4	0.29	42
Biodiesel rapeseed oil	18.8	0.63	600
Biodiesel from palm oil	14.6	0.49	450
Biodiesel from soy oil	16.0	0.54	500
Biodiesel from jatropha oil	11.8	0.40	350
FT biodiesel (2010)	23.2	0.80	50
FT biodiesel (2020)	16.5	0.57	50

***current corn prices about twice this value**



Competitiveness of different biofuels compared to oil

Oil price, $/bbl	Fuels which are competitive above this oil price
60	Brazilian sugar cane ethanol US corn ethanol Biodiesel (jatropha – estimate)
70	Wheat ethanol – with gas CHP plant Biodiesel (rape, palm, soy) **Wood ethanol (2020)**
80	Wheat ethanol - electricity powered plant
90	Sugar beet ethanol Wheat ethanol – with straw CHP plant **FT biodiesel (2020)**
100	Biodiesel (current rapeseed oil prices)
110	**Wood ethanol (2010)**
120	**FT biodiesel (2010)**

Carbon savings from different biofuels

Type of biofuel	Well to tank emissions, g/km	Reduction in GHG emissions, %	Further explanation
Ethanol from sugar cane	20	80 [compared with gasoline]	
Ethanol from sugar beet	111 (58)	32 (64) [compared with gasoline]	Pulp used for animal feed (Pulp used for process heat)
Ethanol from wheat	49-114	7-77 [compared with gasoline]	The wide range depends on the production process used and the use of co-products
Ethanol from lignocellulosic biomass	10-40	73-94 [compared with gasoline]	Emissions vary depending on feedstock
Biodiesel from rapeseed	83 [Average]	46 [compared with diesel-38% if used for animal feed, 57% if used for energy]	Figures based on conventional base catalysis. Savings vary depending on whether rape meal is used for animal feed or for energy
Syngas derived biofuels	9 [Estimate]	94 [reduction compared with diesel]	Early technology status means only estimates are currently available

What if future policies link the biofuel obligation to carbon intensity?

- Obligations on volumes favour lowest cost commercial options within technical limits of blending
- Levels of tax exemptions could be used to discriminate between different biofuel production routes
- Linking obligations to carbon savings is most efficient way of achieving CO_2 reduction objective
- A CO_2 savings obligation would render 2G biofuels more competitive, and drive CO_2 savings in 1G biofuels

Example

For a 5% reduction in CO_2 emissions from diesel (from 155 to 147.5gCO_2/km):

- 1G biodiesel (RME) releases 83gCO_2/km and would need to be blended with diesel at **10.8%** by volume
- BTL releases 9gCO_2/km and would only need to be blended with diesel at **5.4%** by volume

2G biofuels could be much more attractive due to the smaller volume required to meet the carbon saving.

Production costs for BTL could be up to twice as expensive as for 1G biodiesel and still be competitive.