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GHG INTENSITY OF NOVEL TRANSPORT FUELS

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European Commission

Summary

- Introduce JRC role in European policy development
- Novel Fuels LCA main principles
  - Elastic or rigid raw materials
  - Additional renewable electricity
  - GHGi of national electricity mix
  - Industrial CO_2 sources
- Pathways covered in the Delegated Act
- Summary graph of GHGi Novel Transport Fuels

JRC helping develop new European policy

- The Joint Research Centre (JRC) is the European Commission's scientific arm, and helps develop European policies by giving input to various Commission departments (DGs).
- According to the Fuel Quality Directive (FQD) (valid until 2020), the Commission must calculate default values for fuels in the following two categories:

  (i) Renewable liquid and gaseous transport fuels of non-biological origin (REFUNOBIOs); and

  (ii) Carbon capture and utilisation for transport purposes (CCUFs)

- The fuels have been collectively called Novel Transport Fuels.

Approach used in the Delegated Regulation

- JRC created **principles** for calculating emissions savings from Novel Transport Fuels, published September 2017[1].
- Industry used the principles as a guide and sent **information** on pathways they believed would qualify as novel transport fuels.
- JRC assessed this information, estimated the GHGi for the eligible pathways (as default value or formulae); this will be part of a Delegated Act
    - No reference to companies for legal reasons.
    - We combined similar processes in a common formula.
    - Formula made so companies can reproduce, with a good approximation, the results JRC calculated using the specific input data in their proposal.
    - In theory, companies with similar processes allowed use the proposed values.

[1]. 'Data requirements and principles for calculating the life cycle GHG intensity of novel transport fuels and invitation to submit data'

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Principles

‘Data requirements and principles for calculating the life cycle GHG intensity of novel transport fuels and invitation to submit data’

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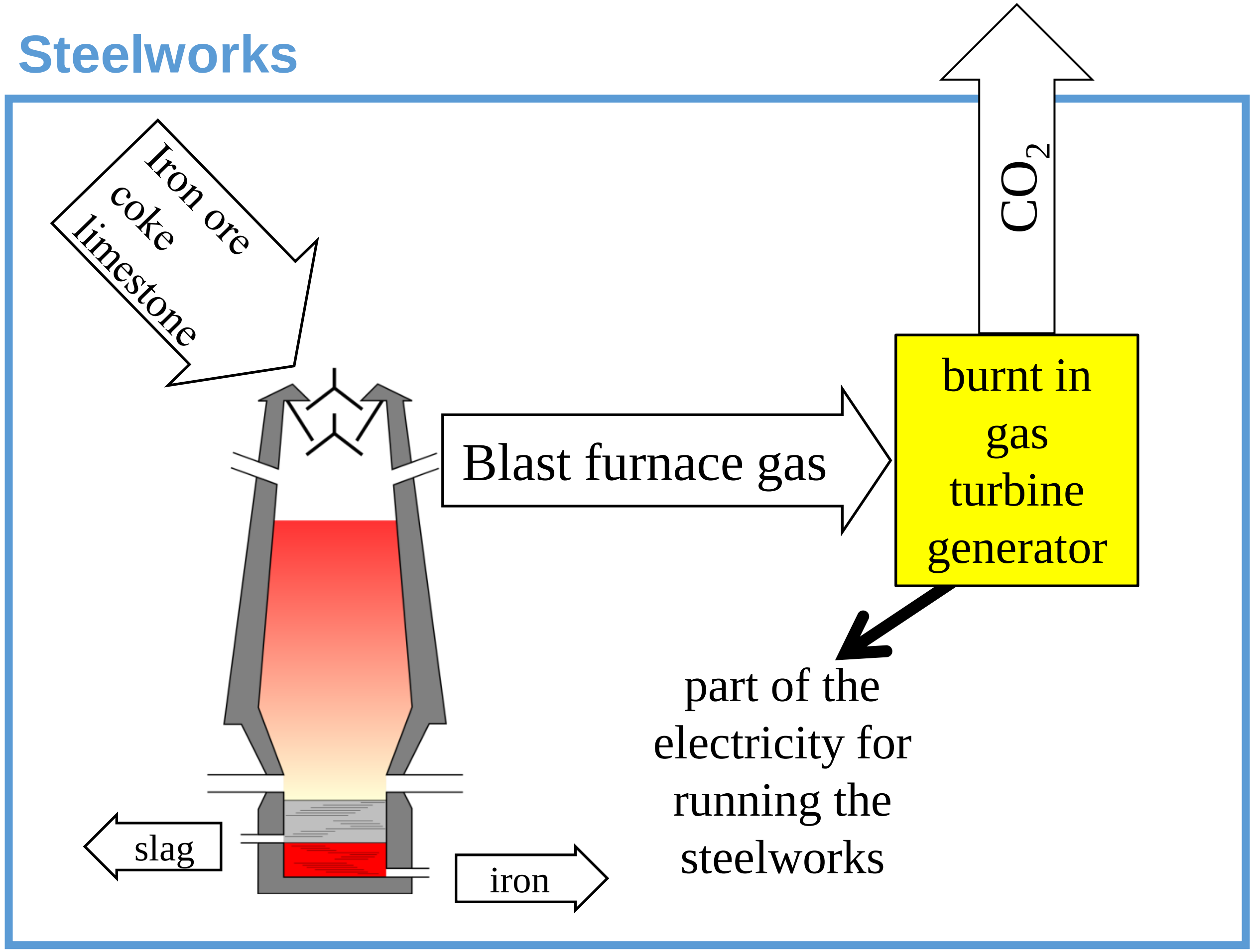
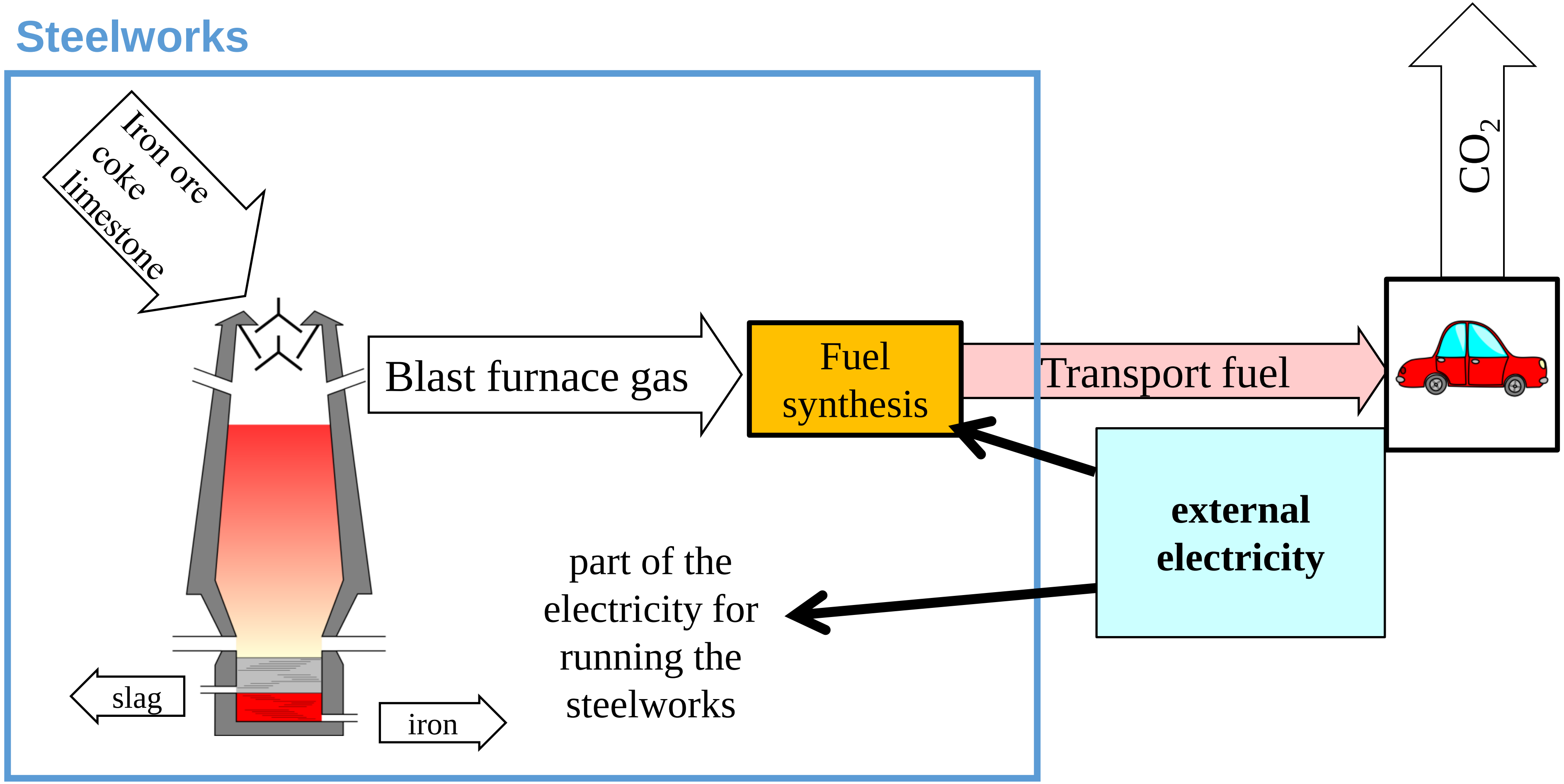
Example pathway – Steel mill blast furnace gas



Example pathway – Steel mill blast furnace gas



Attributional LCA result is crazy: blast furnace gas ~230 gCO2/MJ

1. Find the **total GHG emissions** from the steel mill + transport fuel process.
2. Add the **upstream emissions** for providing the coal, iron ore, scrap, electricity, etc.
3. **Allocate** the total GHG emissions between products. (there is no basis for allocation market value because blast furnace gas does not leave the steelworks) according to their LHV energy content**:
    1. steel (theoretical LHV = 6.6 GJ/tonne, practical LHV = 0)
    2. slag? (sold at ~5 to ~100 Eur/tonne)
    3. Blast furnace gas

The allocation rule means all products get the same emissions per MJ (LHV), and as steel is by far the biggest product…

Emissions for blast furnace gas ≈ emissions for steel ≈ **230 g CO_{2e}/MJ**
…on the other hand if you say blast furnace gas is a "waste or residue" in RED its emissions are zero: a game of semantics.

** (there is no basis for allocation by market value because blast furnace gas is used entirely inside the steelworks)

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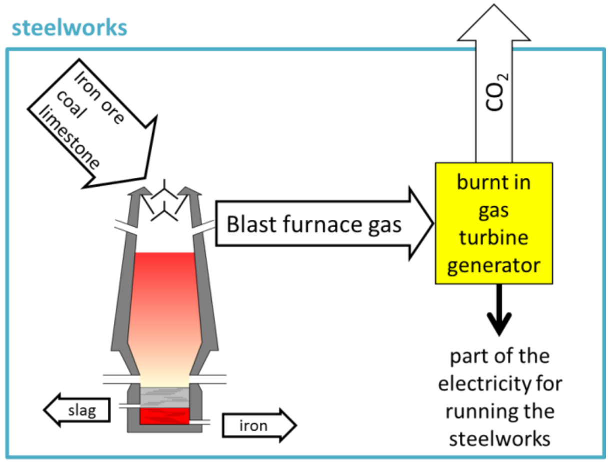
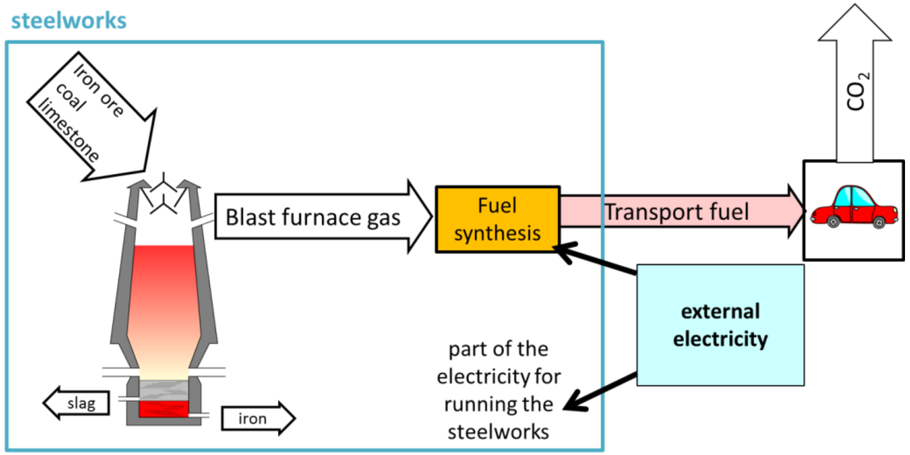
…and if we use common sense?….



BEFORE



AFTER

…we only added external electricity

Carbon intensity of transport-fuel	=	emissions from providing external electricity

FQD method looks at the ***difference*** in whole-plant emissions "before" and "after" extra production of transport fuel.

Rigid vs. Elastic Feedstocks

- To calculate GHG intensity of a feedstock for a fuel process…
- it **doesn’t matter** what you call it (product, waste, residue, by-product, co-product, intermediate product…)
- The first question is…
  “is the source **elastic or rigid**?”

Rigid vs. Elastic Feedstocks

- **Elastic** if the supply increases with increasing demand:
  - e.g. crude oil, crops, algae
  - Conventional LCA: emissions for increasing the supply
- **Rigid** if the supply doesn't expand if you increase the demand:
  - e.g. municipal waste
  - intermediate products of existing processes, e.g. black liquor
  - by-products that don't change the process profitability much
  - therefore it can only be diverted from an existing use
- The GHG intensity is the emissions saved in its existing use
  - can be negative, e.g. if municipal waste is otherwise burnt without energy recovery

Renewable Electricity for making fuels must be additional

- If electricity used to make fuels is to be considered renewable, with low GHG intensity, it must be **additional** to the renewable electricity that would be consumed anyway

- Otherwise you are just diverting it from another user

- For e.g. a new wind farm, not grid-connected

GHG intensity of national electricity mix

- In the absence of any scheme for providing low-emission electricity, the **national average emission** intensity is taken;

- **EU national GHGis** for Medium Voltage electricity provided to operators;

- These are for average electricity **CONSUMED** (taking trade into account), and include upstream emissions for e.g. NG and coal provision;

- The latest data we have is for 2013, but we have included an '**improvement factor**' to allow more recent GHGi data to be used;

- We give a **formula** to estimate consistent GHGis for **outside EU** (including trade if the country imports more than 5% of its electricity consumption);

- Most submissions did not include electricity losses going to low voltage. To avoid penalizing everyone with national-average low-voltage emissions, we take the medium-voltage data and assume **1% losses** on-site.

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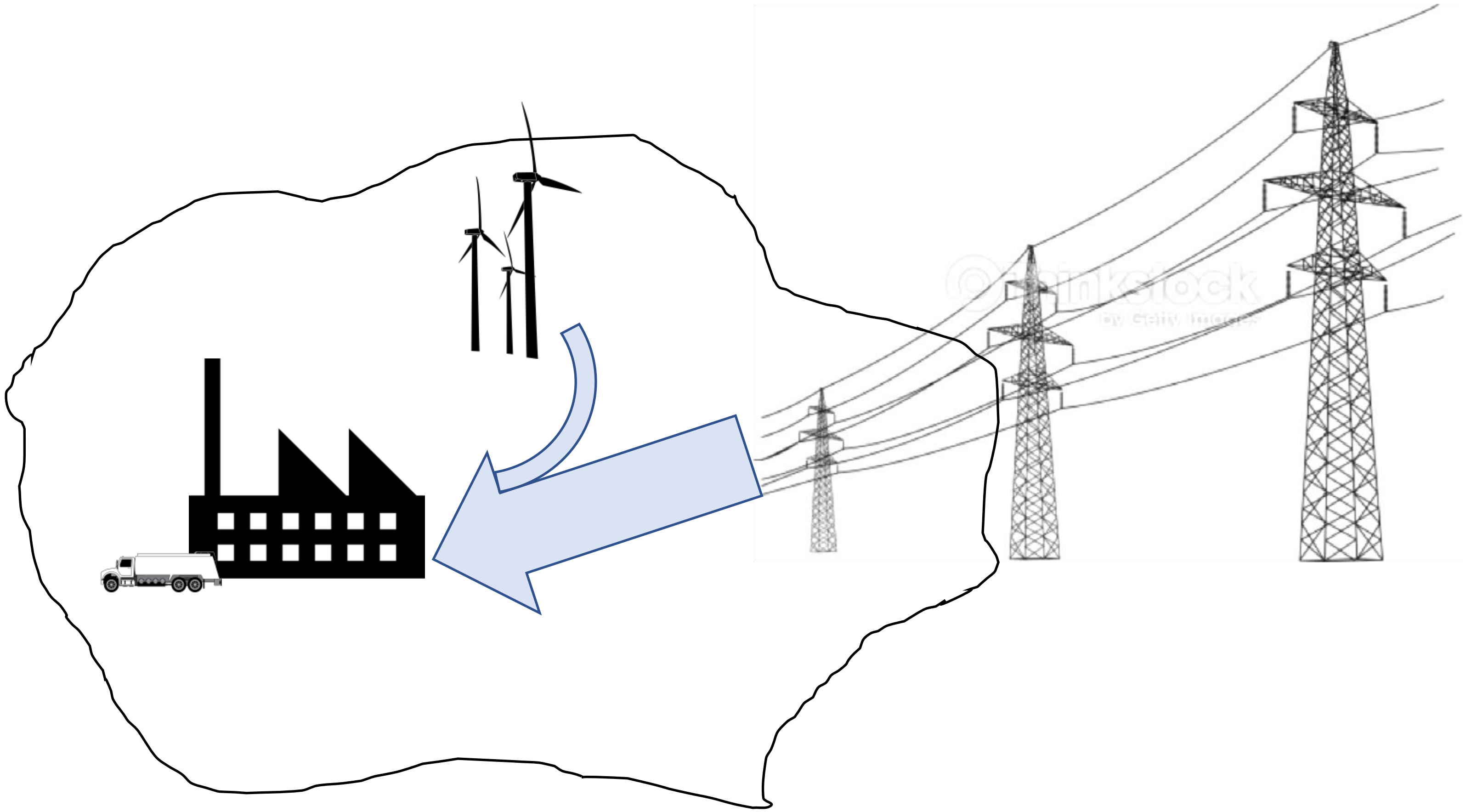
It’s CONSUMED electricity that matters



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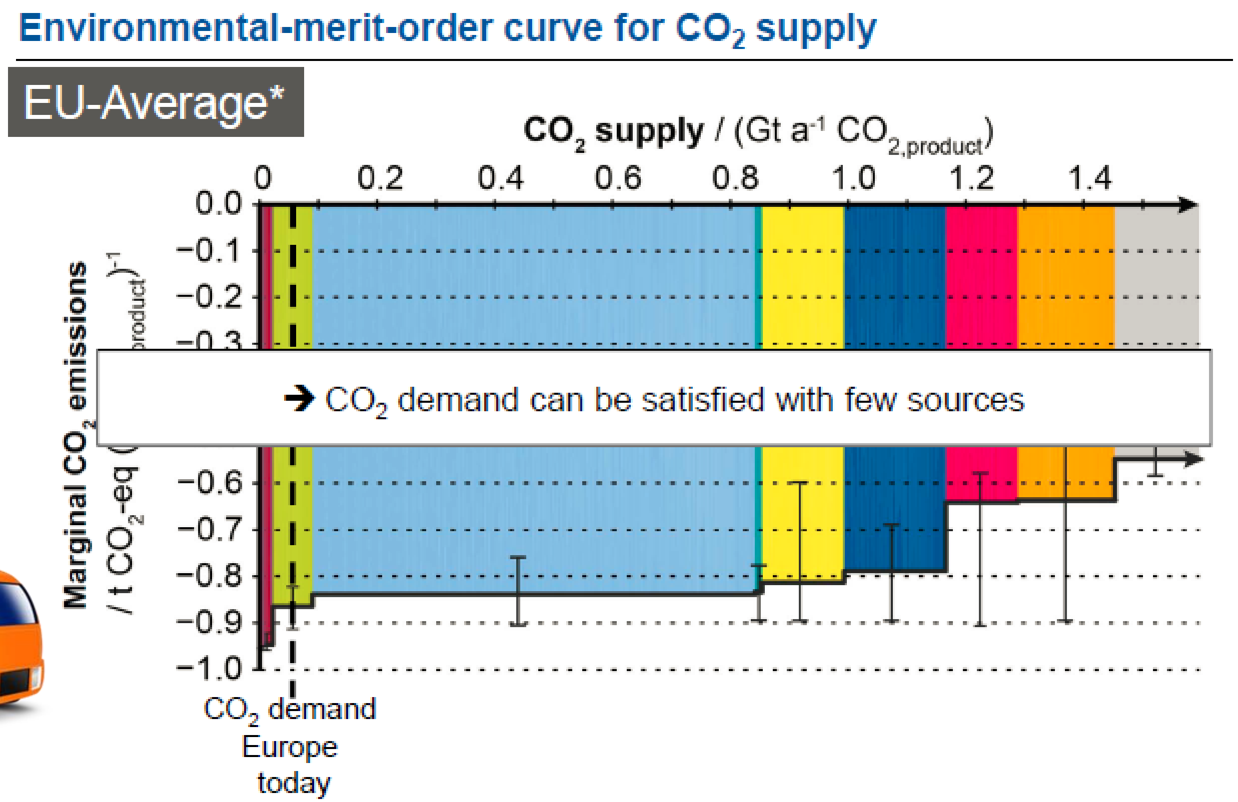
Industrial CO2 is always sequestered

All industrial CO_2 sold in EU comes from processes that would otherwise release it to the atmosphere.

- Therefore we should not count its carbon content as an emission.
- Its emissions intensity comes only from purification + compression + transport

More such CO_2 is available than the market can use.



Reference: N. von der Assen, L.J. Müller, A. Steingrube, P. Voll, A. Bardow, Environ. Sci. Technol., 2016, 50 (3), pp 1093–1101

Pathways included

Novel transport fuel pathways (1)

1. Methanol (MeOH) synthesis processes

    - Methanol synthesis integrated in a stand-alone coke oven plant that delivers the coke oven gas (COG) to a coal fired power plant. H_2 is separated by pressure swing adsorption (PSA) from the coke oven gas. CO_2 is captured by amine-based post combustion capture (PCC). Purge gases return to the PSA and flash gases and PSA-off-gases are burnt for heat and power. The plant exports surplus heat to a regional heat grid.

    - Other H_2 and CO_2, methanol synthesis

2. Ethanol from off-gases and bacterial processing

    - Industrial off-gases from the steel industry

    - Industrial off-gases from oil refineries

    - Industrial off-gases from ferrochrome or ferromanganese production

Novel transport fuel pathways (2)

3. Synthetic petrol or diesel from hydrogen from solid-oxide electrolysis cell (SOEC) and CO2 from various sources

   - Fischer-Tropsch (FT) petrol or diesel using H2 from solid-oxide electrolysis cell (SOEC) and CO2 from various sources. All process energy is supplied by electricity. All off-gases are flared without heat recovery.

4. Ethanol from sewage-gases using plasma and bacterial processing

   - Ethanol produced by bacterial processing of a mixture of natural gas and sewage gas after treatment in a concentrated plasma reactor; the sewage gas is diverted from heat and/or electricity production where it is replaced by natural gas

Example formula

Pathway 2

2) Ethanol from off-gases and bacterial processing

Raw material source and process	Fuel placed on the market	Life cycle GHG intensity (GHGi) expressed in gCO_{2eq}/MJ fuel
Industrial off-gases from the steel industry, oil refineries and ferrochrome or ferromanganese production, bacterial processing	Ethanol	See **formula**, data and possible pathways below

Formula

GHGi (gCO_{2eq} / MJ Eth) =

Feedstock emissions (gCO_{2eq} / MJ Eth)

+

Processing emissions (gCO_{2eq} / MJ Eth)

+

Ethanol Transport and Distribution emissions (gCO_{2eq} / MJ fuel)

where:

- Feedstock emissions (gCO2eq / MJ Eth) = emissions arising from **feedstock displacement**; see Table 3 for input or emissions for each possible pathway
- Processing emissions (gCO2eq / MJ Eth) = emissions arising from **ethanol production**; see Table 3 for input or emissions for each possible pathway
- Ethanol **Transport and distribution emissions** = 1.58 g CO2eq / MJ eth

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Table 3 – Input data for ethanol production (1)

Steps	Possible pathways	Input (formula)	Input (data)
Feedstock emissions (from displacement of electricity generation[5])	1. Steel mill off gases; a mixture of basic oxygen furnace gas (BOF) and blast furnace (BF) gas, LHV energy content: 4 - 5 MJ/Nm3	Electricity * GHGi el	0.55 MJ elec/MJ eth[6]
	2. Steel mill off gases (with co-products)[7] using basic oxygen furnace gas (BOF), LHV energy content: 7 - 8 MJ/Nm3		0.56 MJ elec/MJ eth
	3. Oil refinery off-gases[8], typical energy content: 8.5 – 10.5 MJ/Nm3		0.50 MJ elec/MJ eth[6]
	4. Ferrochrome/ferromanganese production off gases, LHV energy content: 10.1 - 11.5 MJ/Nm3		0.58 MJ elec/MJ eth
Feedstock emissions (off-gas diverted from flaring)	Ferrochrome/ferromanganese production off gases, LHV energy content: 10.1 - 11.5 MJ/Nm3	0	0 g CO_{2eq}/MJ eth

[5] Without use of heat from the existing electricity generator using the off-gases. Electrical efficiency of existing power plant was assumed to be 35% on average.
[6] The feedstock gas was previously used for electricity generation in the steel mill/oil refinery. After passing the ethanol synthesis process, the remaining gas stream is returned for the same purpose. The amount of electricity generated is based on the loss in the energy in the gas stream, not the total energy.
[7] This steel mill pathway considers ethanol production along with minor biogas & steam exports (these co-products amount to approx. 6% of total exergy out). If steam is exported, proof must be provided that an external user is using the steam.
[8] If a plant imports electricity, it should consider the national grid GHGi where the refinery is located. It is not acceptable (due to resulting high emissions) to replace off-gases previously used for electricity production, with other light refinery products.

Table 3 – Input data for ethanol production (2)

Steps	Possible pathways	Input (formula)	Input (data)
Processing emissions	1. Steel mill off gases; a mixture of basic oxygen furnace gas (BOF) and blast furnace (BF) gas, LHV energy content: 4 - 5 MJ/Nm3	Non–elec emissions	1.8 g CO_{2eq}/MJ eth
		Electricity * GHGi el	0.25 MJ elec/MJ eth
	2. Steel mill off gases (with co-products)[7] using basic oxygen furnace gas (BOF), LHV energy content: 7 - 8 MJ/Nm3	Non–elec emissions	1.8 g CO_{2eq}/MJ eth
		Electricity * GHGi el	0.13 MJ elec/MJ eth
	3. Oil refinery off-gases[8], typical energy content: 8.5 – 10.5 MJ/Nm3	Non–elec emissions	0.4 g CO_{2eq}/MJ eth
		Electricity * GHGi el	0.13 MJ elec/MJ eth
	4. Ferrochrome/ferromanganese production off gases, LHV energy content: 10.1 - 11.5 MJ/Nm3	Non–elec emissions	1.5 g CO_{2eq}/MJ eth
		Electricity * GHGi el	0.12 MJ elec/MJ eth

[7] This steel mill pathway considers ethanol production along with minor biogas & steam exports (these co-products amount to approx. 6% of total exergy out). If steam is exported, proof must be provided that an external user is using the steam.
[8] If a plant imports electricity, it should consider the Member State's grid GHGi where the refinery is located. It is not acceptable (due to resulting high emissions) to replace off-gases previously used for electricity production, with other light refinery products.

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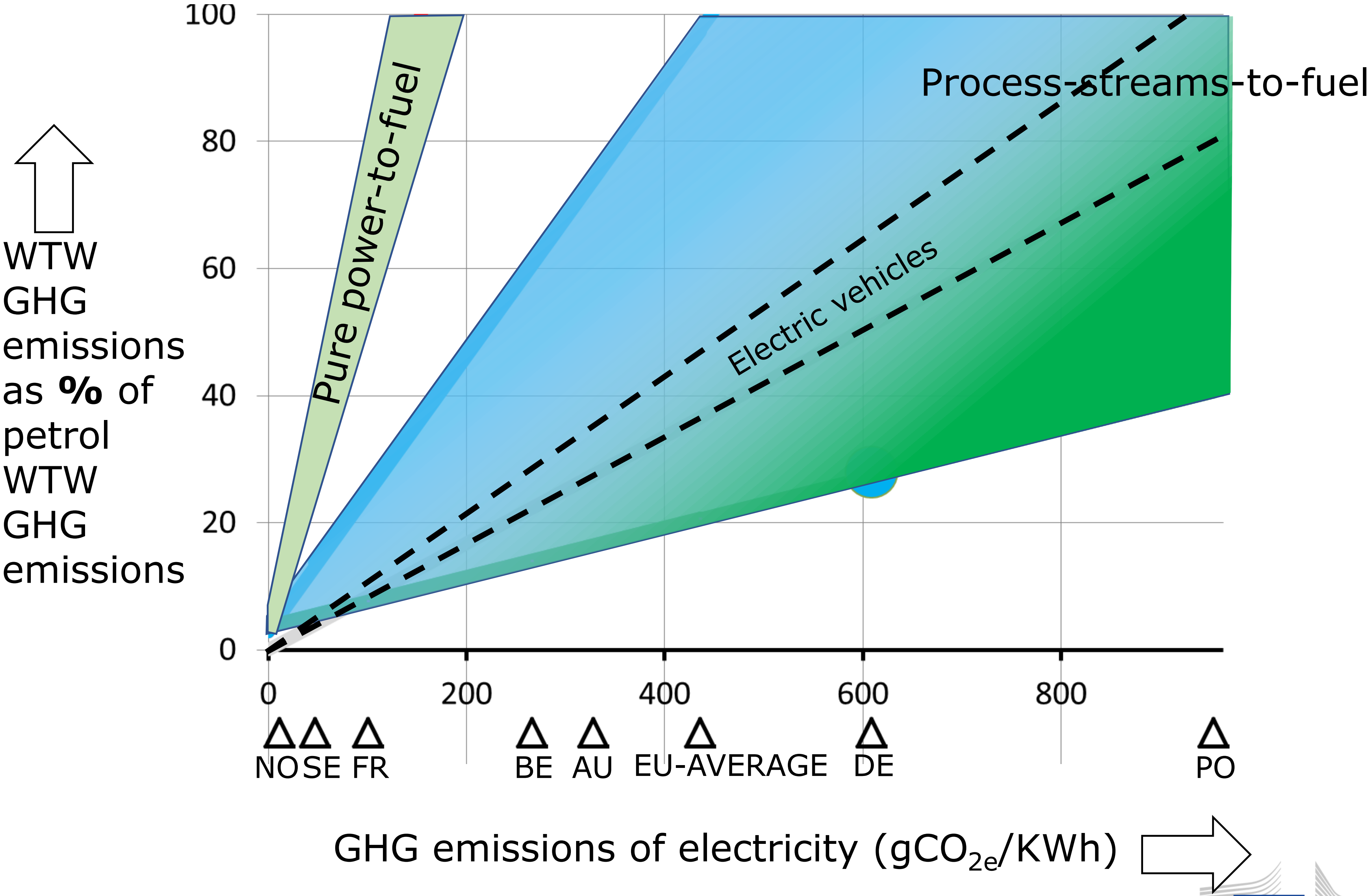

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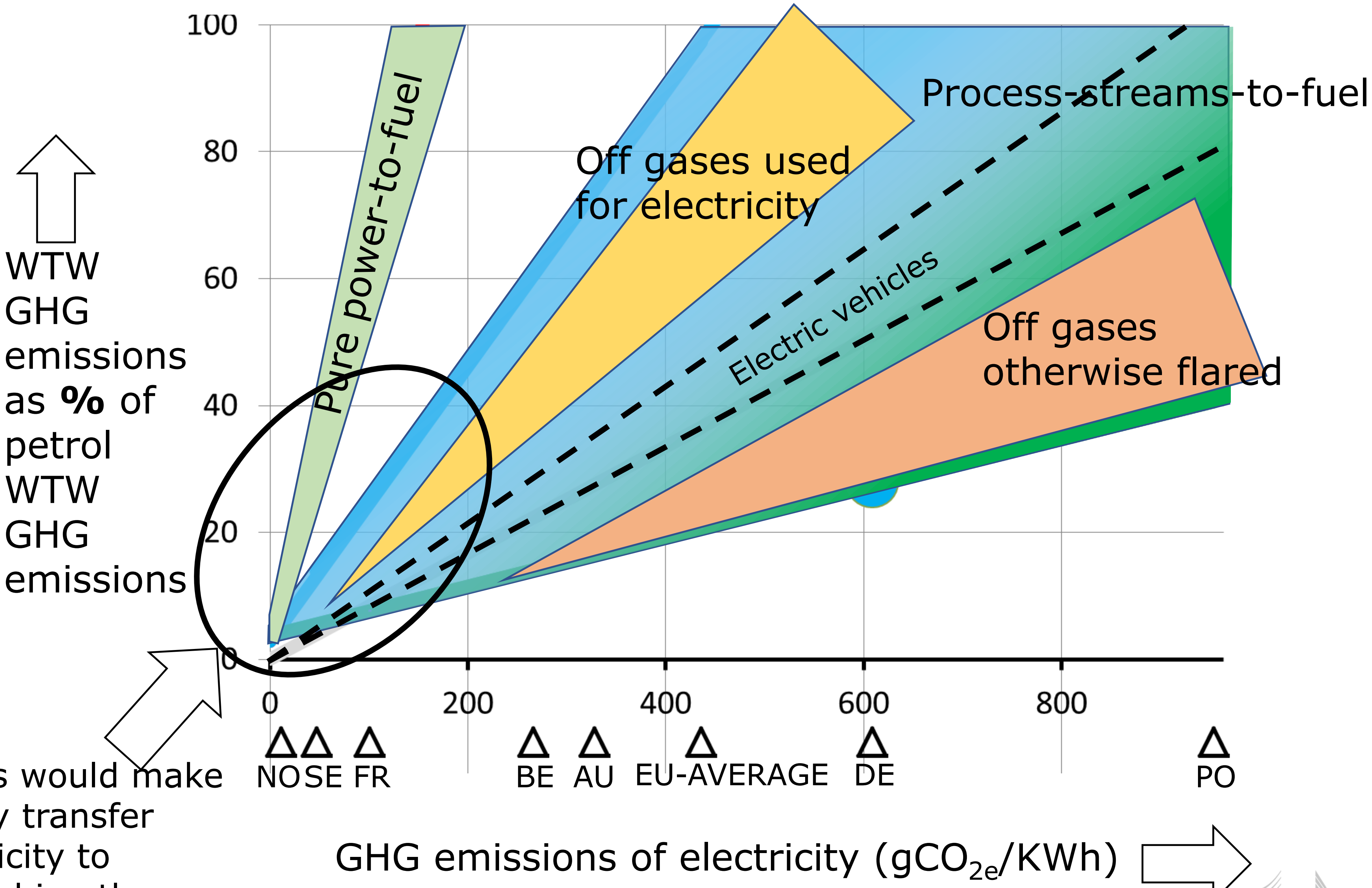

These plants would make sense if they transfer low-C electricity to transport fuel in other countries

Thank you

Any questions?

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Approach used in the Delegated Regulation

- No reference to companies for legal reasons.
- In theory, all companies with similar processes are allowed to use the proposed values.
- We combined similar processes in a common formula.
- The formula is made so that companies can reproduce, with a good approximation, the results JRC calculated using the specific input data in their proposal.

Allocation to multiple products

- Substitution using (GHG saved by the other products) runs into trouble for minor products, and can shift emissions savings from other sectors into transport sector
- RED effectively uses allocation by exergy
  - **For materials + fuels = energy content "wet LHV"**
  - **For electricity = kWh**
  - **For steam, exergy is calculated from temperature**
- We prefer to use this method if we can: works for fuels, electricity and steam, but not always for materials
  (LHV may be zero, RED's ad-hoc rule for straw…)
- Economic allocation often works (even in refineries), where the products have a known value*.
  - Doesn't work for intermediate products or steam, because no market value
- No one method suits every situation!

** Can use average market value over e.g. last 10 years, to avoid uncertainty*

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Discussion document:

“GHG INTENSITY OF NOVEL TRANSPORT FUELS”

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1) Methanol (MeOH) synthesis processes

(The same emissions per MJ methanol shall be considered also if the methanol is blended into transport fuel by incorporating it in methyl-tertio-butyl-ether (MTBE))

Raw material source and process	Fuel placed on the market	Life cycle GHG intensity or GHGi expressed in gCO_{2eq}/MJ fuel
H_2 and CO_2, methanol synthesis	Methanol	See **formula**, data and possible pathways below
Methanol synthesis integrated in a stand-alone coke oven plant that delivers the coke oven gas (COG) to a coal fired power plant. H_2 is separated by pressure swing adsorption (PSA) from the coke oven gas. CO_2 is captured by amine-based post combustion capture (PCC). Purge gases return to the PSA and flash gases and PSA-off-gases are burnt for heat and power. The plant exports surplus heat to a regional heat grid.	Methanol	25.6

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Formula

GHGi (gCO_{2eq} / MJ MeOH) =

$$\left[\begin{array}{c} (\Sigma(\text{Input}_{H2} * \text{GHGi}_{input})_{H2\ supply}) * (\text{kg } H_2 / \text{kg MeOH}) \\ + \\ (\Sigma(\text{Input}_{CO2} * \text{GHGi}_{input})_{CO2\ supply}) * (\text{kg } CO_2 / \text{kg MeOH}) \\ + \\ \Sigma(\text{Input}_{MeOH} * \text{GHGi}_{input})_{MeOH\ reac.\ and\ pur.} \\ + \\ \Sigma(\text{Input}_{w\text{-}w\text{-}t} * \text{GHGi}_{input})_{waste\text{-}water\text{-}treat.} \end{array}\right]$$

$$\div$$

$$(\text{LHV MeOH})$$

$$+$$

MeOH transport and distribution emissions (gCO_{2eq} / MJ MeOH)

where:

- Input H_2 = see inputs in Table 2 in '**H2 supply**' step
- Input CO_2 = see inputs in Table 2, '**CO2 supply**' step
- Input MeOH = see inputs in Table 2, '**Methanol reaction and purification'** step
- Input w-w-t = see inputs in Table 2, '**Waste-water-treatment**' step
- GHGi input = **GHG intensity of inputs** in Table 2
- kg H_2 / kg MeOH; kg CO_2 / kg MeOH = **conversion yields** are listed in Table 1
- LHV (MeOH) = 19.9 MJ / kg MeOH
- **MeOH transport and distribution emissions** = 2.15 gCO_{2eq} / MJ MeOH

Table 1 – Hydrogen and carbon conversion yields

	kg H_2 / kg MeOH	kg CO_2 / kg MeOH
No recovery of H_2 or CO_2 and no purge gas recycling	0.25	1.8
With recycling, as reactant, of the H_2 content of purge gas	0.195	1.4

Table 2 – Input data in methanol synthesis processes (1)

Steps	Possible pathways	Input (formula)	Input (data)
H_2 supply	1. High Concentration H_2 (>90%) produced as a by-product of existing process Emissions equals those generated in substituting the existing use of the H_2 as follows:	Input * GHGi (input)	See pathway 1a or pathway 1b
	1a. H_2 is diverted from generating electricity, which is replaced from external supply	Electricity * GHGi el	48 MJel/kg H_2
	1b. H_2 is diverted from a boiler; the heating value of the H_2 is replaced by another fuel[3]	Fuel replacing diverted H_2 * GHGi fuel	120.1 MJ_{fuel}/kg H_2
	2. Alkaline water electrolysis	Electricity * GHGi el	180 MJel/kg H_2

[3] In the case that the diverted hydrogen is replaced by another process gas from inside the plant, it is the GHGi of the fuel which replaces that process gas in its existing use that is counted. Generalizing for any reconfiguration of the plant to allow diversion of the hydrogen, what is counted is the increase in the total GHGi of all inputs resulting from the diversion

Table 2 – Input data in methanol synthesis processes (2)

Steps	Possible pathways	Input (formula)	Input (data)
CO_2 supply	1. Waste High Concentration CO_2 (> 90%) requiring a purification step in addition to a simple guard vessel	Electricity * GHGi el	0.05 MJel/kg CO_2
		Steam * GHGi steam	3.0 MJth/kg CO_2
		Other consumables emissions	1.0 gCO_{2eq}/ kg CO_2
	2. Waste High Concentration CO_2 (> 90%) pure enough to require only guard vessel	Electricity * GHGi el	0.06 MJel/kg CO_2
		Other consumables emissions	1.0 gCO_{2eq}/ kg CO_2
	3. Amine-based post-combustion capture (PCC) from gas (with >7% vol. CO_2)	Electricity * GHGi el	0.20 MJel/kg CO_2
		Steam * GHGi steam	3.0 MJth/kg CO_2
		Other consumables emissions	7.0 gCO_{2eq}/ kg CO_2
	4. Pressure swing adsorption (PSA) from coal power plant flue gas (14% CO2), 90% recovery (pure enough to require only guard vessel)	Electricity * GHGi el	2.6 MJel/kg CO_2
		Other consumables emissions	7.0 gCO_{2eq}/ kg CO_2

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Table 2 – Input data in methanol synthesis processes (3)

Steps	Possible pathways	Input (formula)	Input (data)
Methanol reaction and purification	1. Includes: CO_2 compression, syngas compression; recycled gas compression; methanol processing; methanol purification	Electricity * GHGi el	5 MJ el / kg MeOH if MeOH production < 20 tonnes MeOH / hour 1.7 MJ el / kg MeOH if MeOH production > 20 tonnes MeOH / hour
		Steam * GHGi steam	4 MJ th / kg MeOH if MeOH production < 20 tonnes MeOH / hour 1.6 MJ th / kg MeOH if MeOH production > 20 tonnes MeOH / hour
	2. Methanol production using excess hydrogen produced in an existing methanol plant making methanol from steam-reformed NG. Includes CO_2 liquefaction and the transport of liquid CO_2	(Electricity for purification and liquefaction) * GHGi el	0.56 MJel/kg MeOH
		(Electricity use for additional recycle and purification pumps) * GHGi el	0.6 MJel/kg MeOH
		CO_2 transport emissions	32 g CO2eq / kg MeOH
Waste-water-treatment		Electricity * GHGi el	0.07 MJel/kg MeOH

3) Synthetic petrol or diesel from hydrogen from solid-oxide electrolysis cell (SOEC) and CO2 from various sources

Raw material source and process	Fuel placed on the market	Life cycle GHG intensity (GHGi) expressed in gCO_{2eq}/MJ fuel
Fischer-Tropsch (FT) petrol using H_2 from solid-oxide electrolysis cell (SOEC) and CO_2 from various sources. All process energy is supplied by electricity. All off-gases are flared without heat recovery.	Synthetic petrol	See **formula** and data below
Fischer-Tropsch (FT) diesel using H_2 from solid-oxide electrolysis cell (SOEC) and CO_2 from various sources. All process energy is supplied by electricity. All off-gases are flared without heat recovery.	Synthetic diesel	See **formula** and data below

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Formula

GHGi (gCO_{2eq} / MJ fuel) =

[

(Total electr. input (MJ el / MJ FT-products) * GHGi el (gCO_{2eq} / MJ el)

+

(CO_2 supply emissions (g CO_{2eq} / kg CO_2) * (kg CO_2 / MJ FT-products)

]

÷

Refining Yield (MJ fuel / MJ FT-products)

+

Refining emissions (gCO_{2eq} / MJ fuel)

+

Fuel transport and distribution emissions (gCO_{2eq} / MJ fuel)

where:

- Fuel = the final fuel: synthetic petrol or diesel
- **Total electr. input** = 1.90 MJ el / MJ FT-products
- **GHGi el** (gCO_{2eq} / MJ el) = GHG intensity elect in ANNEX A
- **CO_2 supply emissions** (g CO2eq / kg CO_2) = see possible pathways in Table 1
- **kg CO_2 / MJ FT-products** = 0.073 kg CO_2 / MJ FT-products
- **Refining Yield** = MJ of final fuel in the refinery from 1 MJ of FT-products (JEC-WTWv4a)
  - for petrol : refining yield = 1/(1 + 0.08) = 0.93
  - for diesel: refining yield = 1/(1 + 0.1) = 0.91
- **Refining emissions** (gCO_{2eq} / MJ_{fuel}) =
  - for petrol = 7.0 gCO_{2eq} / MJ_{fuel}
  - for diesel = 8.6 gCO_{2eq} / MJ_{fuel}
- **Fuel transport and distrib emissions** (gCO_{2eq} / MJ_{fuel}) =
  - for petrol = 1.2 gCO_{2eq} / MJ_{fuel}
  - for diesel = 1.1 gCO_{2eq} / MJ_{fuel}

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Table 4 – Input data for CO_2 supply pathways

Steps	Possible pathways	Input (formula)	Input (data)
CO_2 supply	1. Waste High Concentration CO_2 (> 90%) requiring a purification step in addition to a simple guard vessel	Electricity * GHGi el	0.05 MJel/kg CO_2
		Steam * GHGi steam	3.0 MJth/kg CO_2
		Other consumables emissions	1.0 gCO_{2eq}/ kg CO_2
	2. Waste High Concentration CO_2 (> 90%) pure enough to require only guard vessel	Electricity * GHGi el	0.06 MJel/kg CO_2
		Other consumables emissions	1.0 gCO_{2eq}/ kg CO_2
	3. Amine-based post-combustion capture (PCC) from gas (with >7% vol. CO_2)	Electricity * GHGi el	0.20 MJel/kg CO_2
		Steam * GHGi steam	3.0 MJth/kg CO_2
		Other consumables emissions	7.0 gCO_{2eq}/ kg CO_2
	4. Pressure swing adsorption (PSA) from coal power plant flue gas (14% CO2), 90% recovery (pure enough to require only guard vessel)	Electricity * GHGi el	2.6 MJel/kg CO_2
		Other consumables emissions	7.0 gCO_{2eq}/ kg CO_2

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4) Ethanol from sewage-gases using plasma and bacterial processing

Raw material source and process	Fuel placed on the market	Life cycle GHG intensity (GHGi) expressed in gCO_{2eq}/MJ fuel
Ethanol produced by bacterial processing of a mixture of natural gas and sewage gas after treatment in a concentrated plasma reactor; the sewage gas is diverted from heat and/or electricity production where it is replaced by natural gas	Ethanol	See **formula**, data and possible paths below

Formula

GHGi (gCO_{2eq} / MJ Eth) = (Ethanol scenario emissions – Reference scenario emissions) + Ethanol Transport and Distribution emissions

Ethanol scenario

Natural gas input (MJ NG / MJ eth) * GHGi NG (gCO_{2eq} / MJ NG)

+

Elect. input to plasma reactor (MJ el / MJ eth) * GHGi el (gCO_{2eq} / MJ el)

+

Elec. input to ethanol unit (MJ el / MJ eth) * GHGi el (gCO_{2eq} / MJ el)

+

Emissions associated with nutrients for ethanol production (gCO_{2eq} / MJ eth)

-

Reference scenario

Natural gas input (MJ NG / MJ eth) * GHGi NG (gCO_{2eq} / MJ NG)

+

Elect. input (MJ el / MJ eth) * GHGi el (gCO_{2eq} / MJ el)

+

Ethanol Transport and Distribution emissions (gCO2eq / MJ fuel)

where:

- **Ethanol scenario** (gCO_{2eq} / MJ Eth) = emissions arising during system producing ethanol; see Table 5 for input or emissions
- **Reference scenario** (gCO_{2eq} / MJ Eth) = emissions in existing system before ethanol production; see Table 5 for input or emissions
- **Ethanol transport and distribution emissions** = 1.58 g CO_{2eq} / MJ eth

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Table 5 – Input data for ethanol production

Steps	Pathway steps	Input (formula)	Input (data)
Ethanol scenario emissions	Natural gas into plasma reactor	Natural gas inputs * GHGi natural gas	1.5 MJ NG/MJ eth
	Electricity into plasma reactor	Electricity * GHGi el	0.7 MJ elec/MJ eth
	Electricity ethanol production unit	Electricity * GHGi el	0.06 MJ elec/MJ eth
	Emissions associated with nutrients for ethanol production	gCO_{2eq}/MJ ethanol	2 gCO2eq/MJ eth
Reference scenario	Natural gas into boiler	Natural gas inputs * GHGi natural gas	0.4 MJ NG/MJ eth
	Electricity in from grid	Electricity * GHGi el	0.2 MJ elec/MJ eth