IEA Bioenergy

European Commission

ADVANCED MOTOR FUELS
IEA-AMF
Technology Collaboration Programme on
Advanced Motor Fuels

The Contribution of Advanced Renewable Transport Fuels to **Transport Decarbonisation** in 2030 and beyond

Electrofuels contribution

Dr Ilkka Hannula

All products currently made from oil could also be made from CO_2 and hydrogen

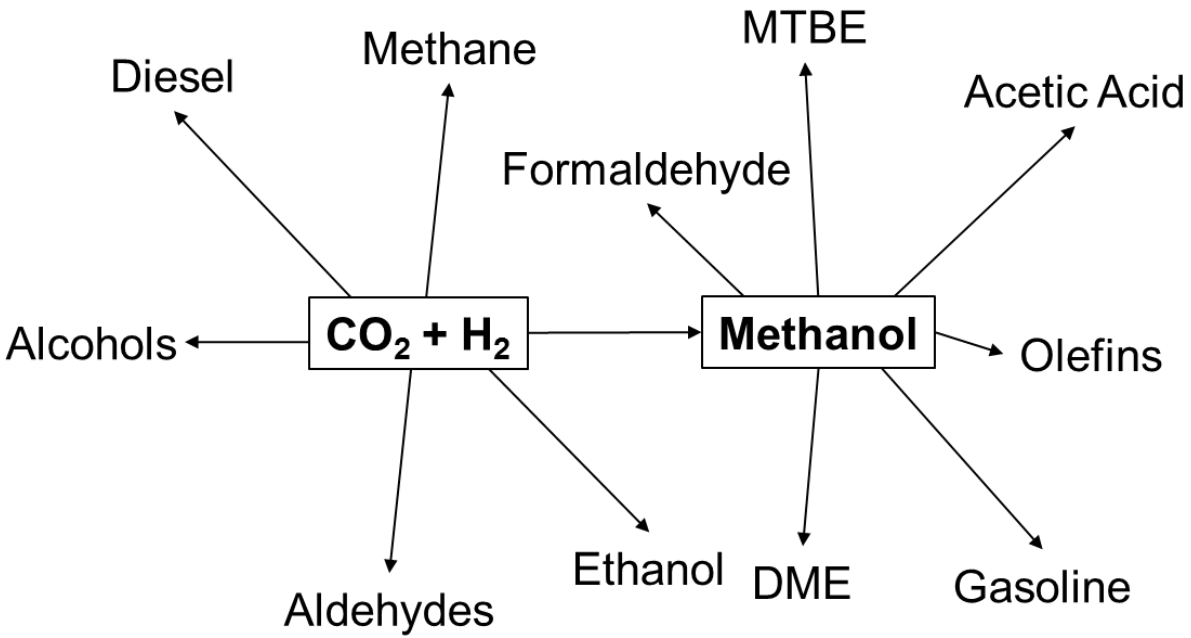


Figure modified from Spath & Dayton 2003, NREL/TP-510-34929

Electrolysis of water

- Hydrogen (H_2) can be produced by passing an electric current through two electrodes immersed in water.
- In the process, water molecules are split to produce oxygen and hydrogen.
- Presently electrolytic H_2 is limited to small or special applications
- Larger quantities are produced by steam reforming of natural gas or other fossil fuels.

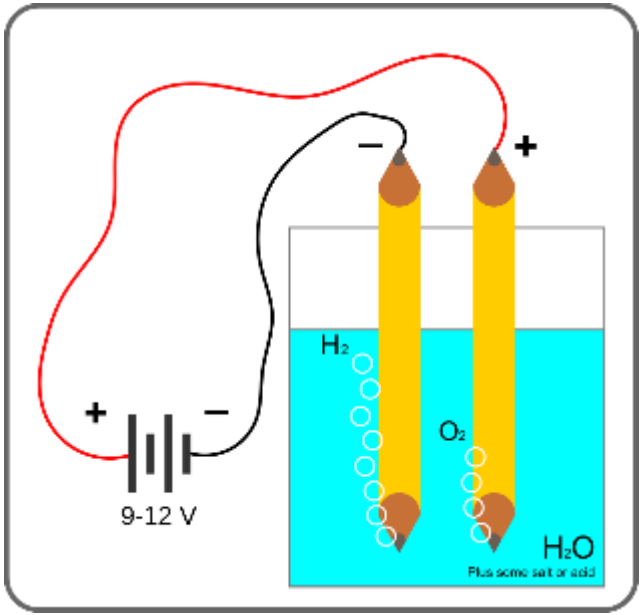
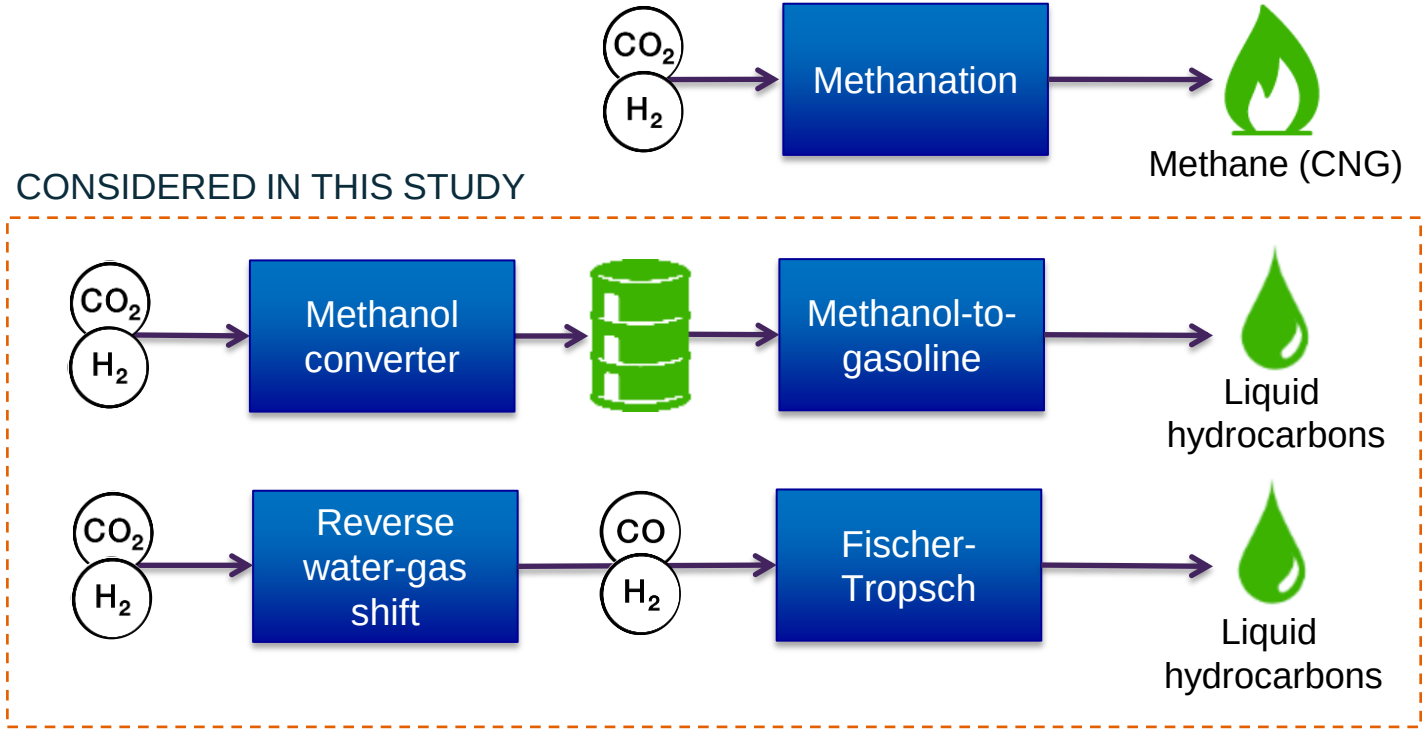
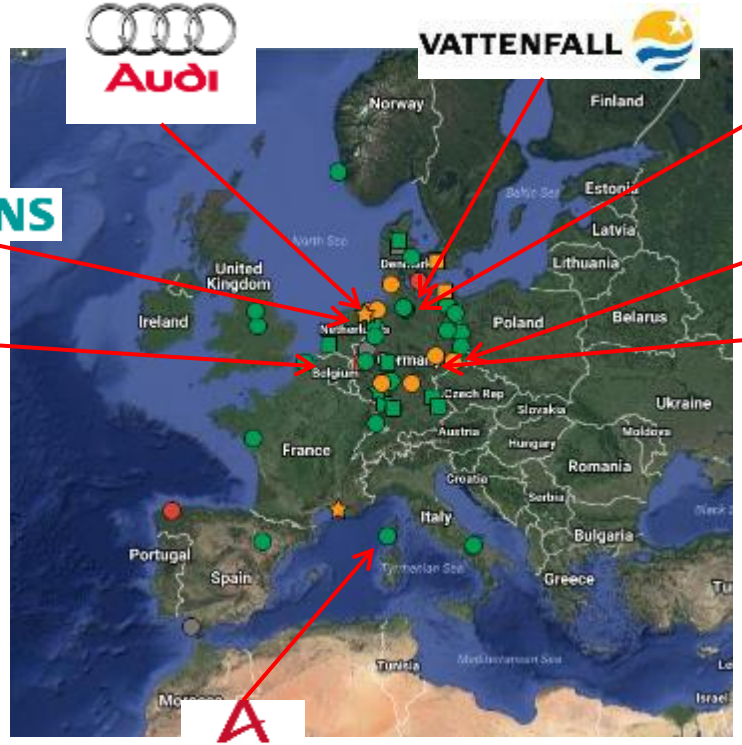


Figure by Nevit Dilmen, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=10959462

Relevant routes for transport decarbonisation via electrofuels



Power-to-X demonstration activities



Audi

VATTENFALL

Shell

SIEMENS

Linde

TOTAL
COMMITTED TO BETTER ENERGY

AREVA

Operational
- Hydrogen
- Methane
- Hydrogen / Methane

Planned
- Hydrogen
- Hydrogen / Methane
- Methane

Nel + H2V product
- 100 MW alkaline electrolyser, 46 M€
- Renewable electricity
- Injection of H2 to NG grid

- Currently 76 projects in Europe
- 37 in Germany
- Most projects H2 only
- 13 projects with CO2 capture and utilisation (CCU) to produce fuels.

Source: http://www.europeanpowertogas.com/

Audi E-gas Plant

Location: Werlte, Germany
Start-up: 2014
Electricity input: 6 MW
Methane output: 3.2 MW
Net efficiency: 54 % (LHV)
Investment: 20 M€

CRI Georg Olah Renewable Methanol Plant

Location: Iceland

Commissioned: 2011

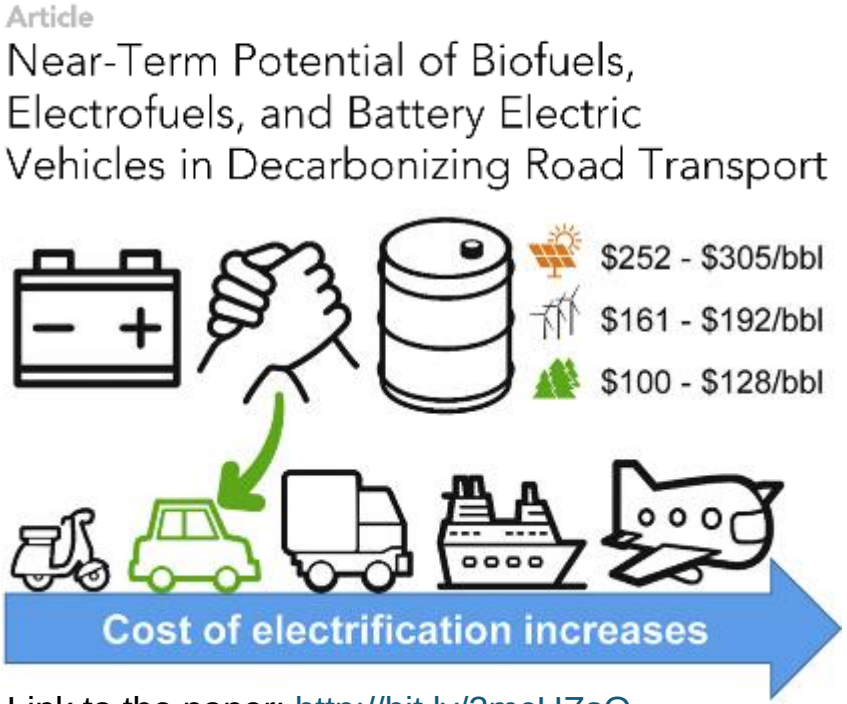
Upgraded: 2014-2015.

Electricity input: 5.7 MW (three alkaline electrolysers)

CO_2 source: geothermal

Methanol output: 4 000 t/yr

”Apples-to-apples” comparison* of road transport decarbonisation options



Link to the paper: http://bit.ly/2mcUZsO

- Sustainable fuels found competitive over long distances even as electric vehicles become cheaper
- Electrofuels remain expensive in the near term and are difficult to scale up in the longer term.
- Synthetic biofuels identified as being more competitive than electrofuels at the present time.
- At this state, we need a wide portfolio where we focus on learning-by-doing and economies of scale.

*) *Hannula, I. and Reiner, D.M. The role of carbon-neutral synthetic fuels and battery electric vehicles in a sustainable transport system. Joule 2019;3. DOI: 10.1016/j.joule.2019.08.013.*

Near-term production cost estimates for electrofuels at commercial scale

Plant configuration	Capacity factor	Energy cost[a] $/MWh	BEOP[b] $/bbl	Electricity gCO_2/kWh[c]	End-product gCO_2/MJ[d]	Emissions relative to fossil [e]
Synthetic biofuels	85%	8	100 - 128		5	7%
Generator-connected electrofuels						
Solar PV - Utility scale						
Crystalline	30%	46	269 - 325	18	13	16 %
Thin film	32%	43	252 - 305	18	13	16 %
Wind						
Onshore	55%	30	161 - 192	7	5	6 %
Offshore	50%	71	292 - 326	8	6	7 %
Grid-connected electrofuels						
EU-28	90%	126	423 - 442	447	310	410 %
Germany	90%	165	539 - 558	615	427	564 %
France	90%	99	340 - 359	105	73	96 %
Sweden	90%	73	263 - 282	47	33	43 %
Norway	90%	90	313 - 332	9	6	8 %

Source: Hannula, I. and Reiner, D.M. The role of carbon-neutral synthetic fuels and battery electric vehicles in a sustainable transport system. Joule 2019;3. DOI: 10.1016/j.joule.2019.08.013.

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Unit conversions from $/bbl:
- ***Divide by 1.5 to get $/MWh***
- ***Multiply by 8 to get $/tonne***

[b] Breakeven oil price (BEOP) is the price of crude oil at which the electrofuels production cost (on a $/GJ LHV basis) equals the wholesale (refinery-gate) price of the equivalent petroleum-derived products.

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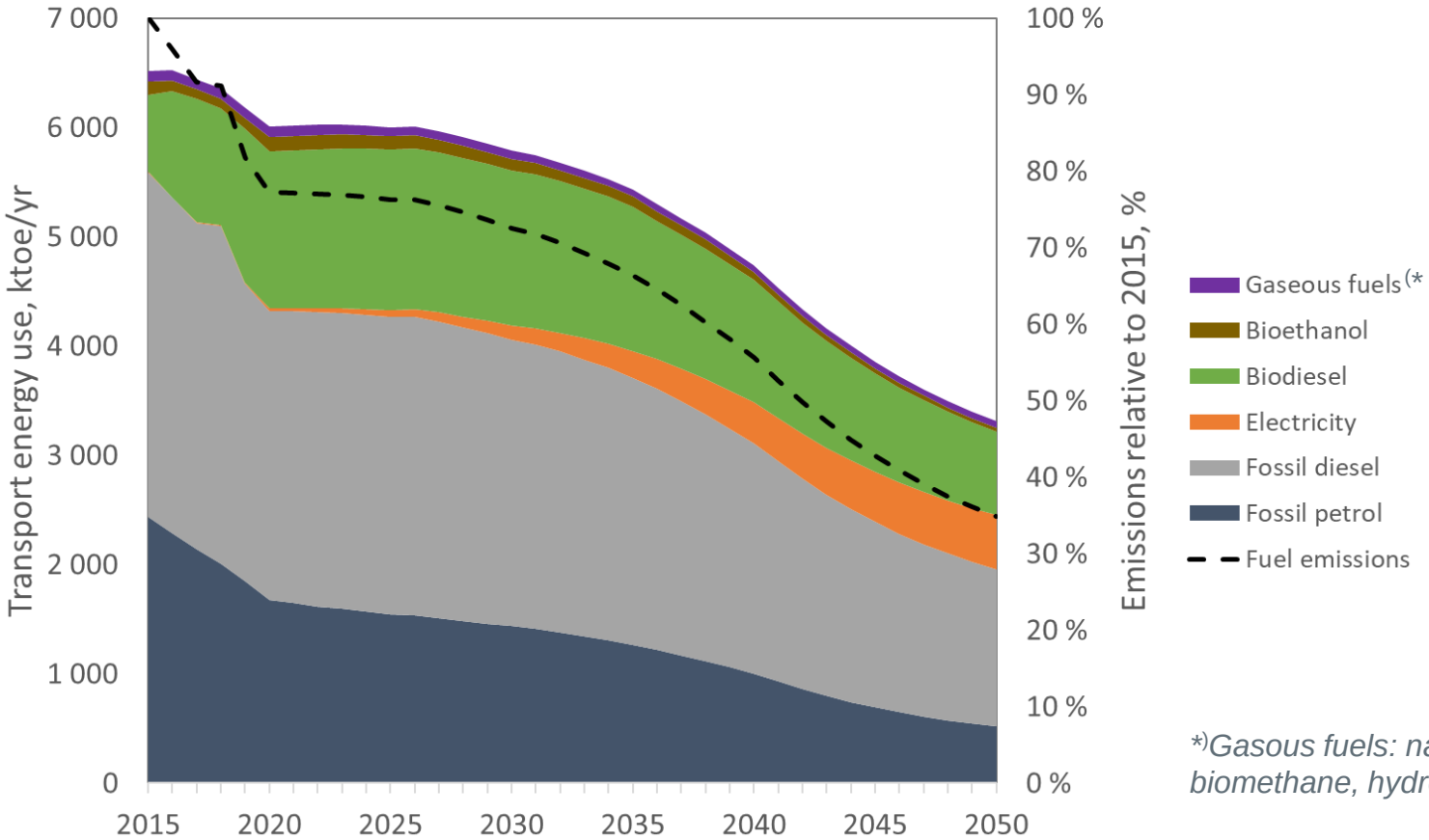
Sweden

11/19/2019

Sweden, Stated Policies scenario



*)Gasous fuels: natural gas, biomethane, hydrogen

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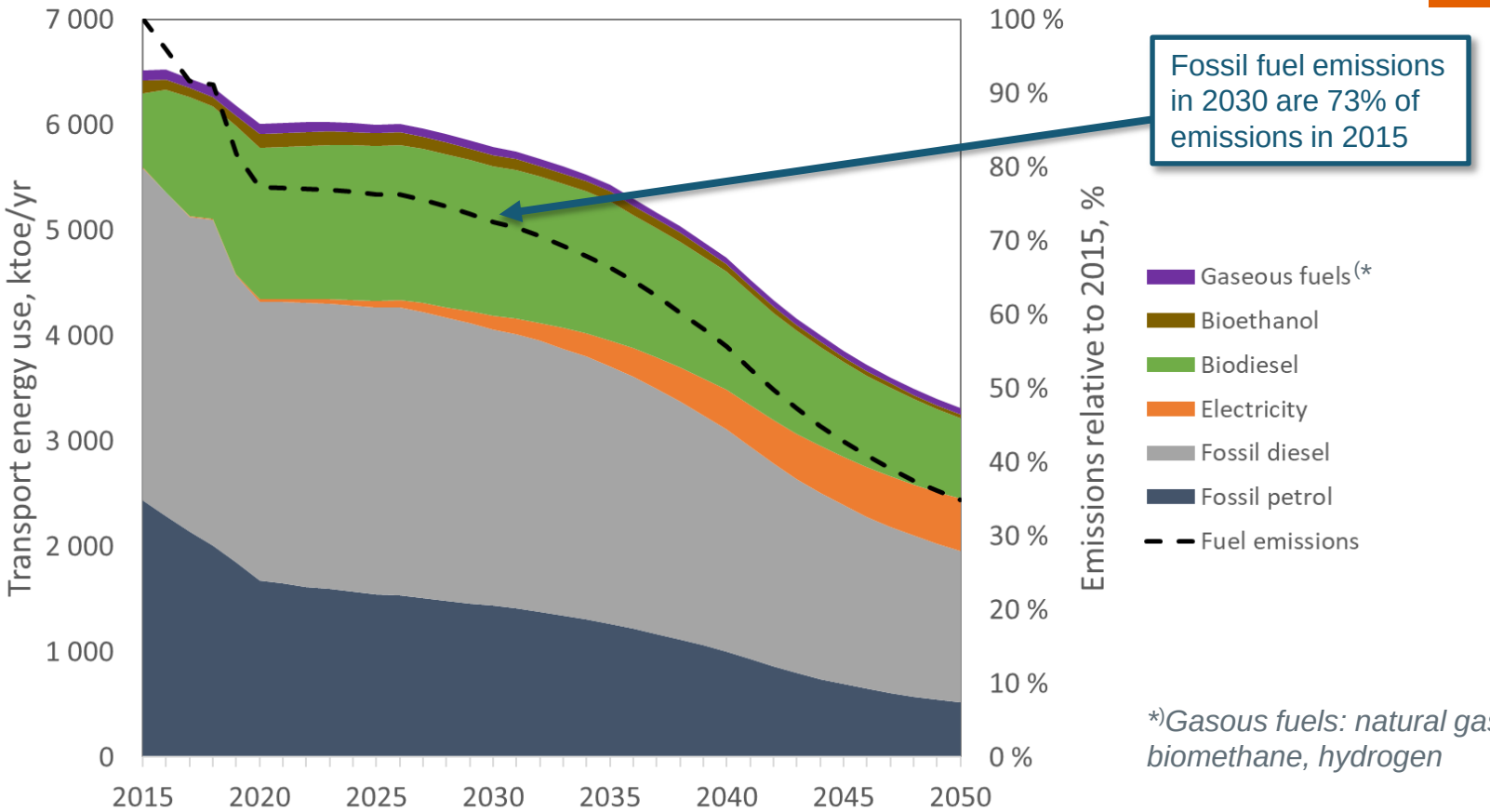

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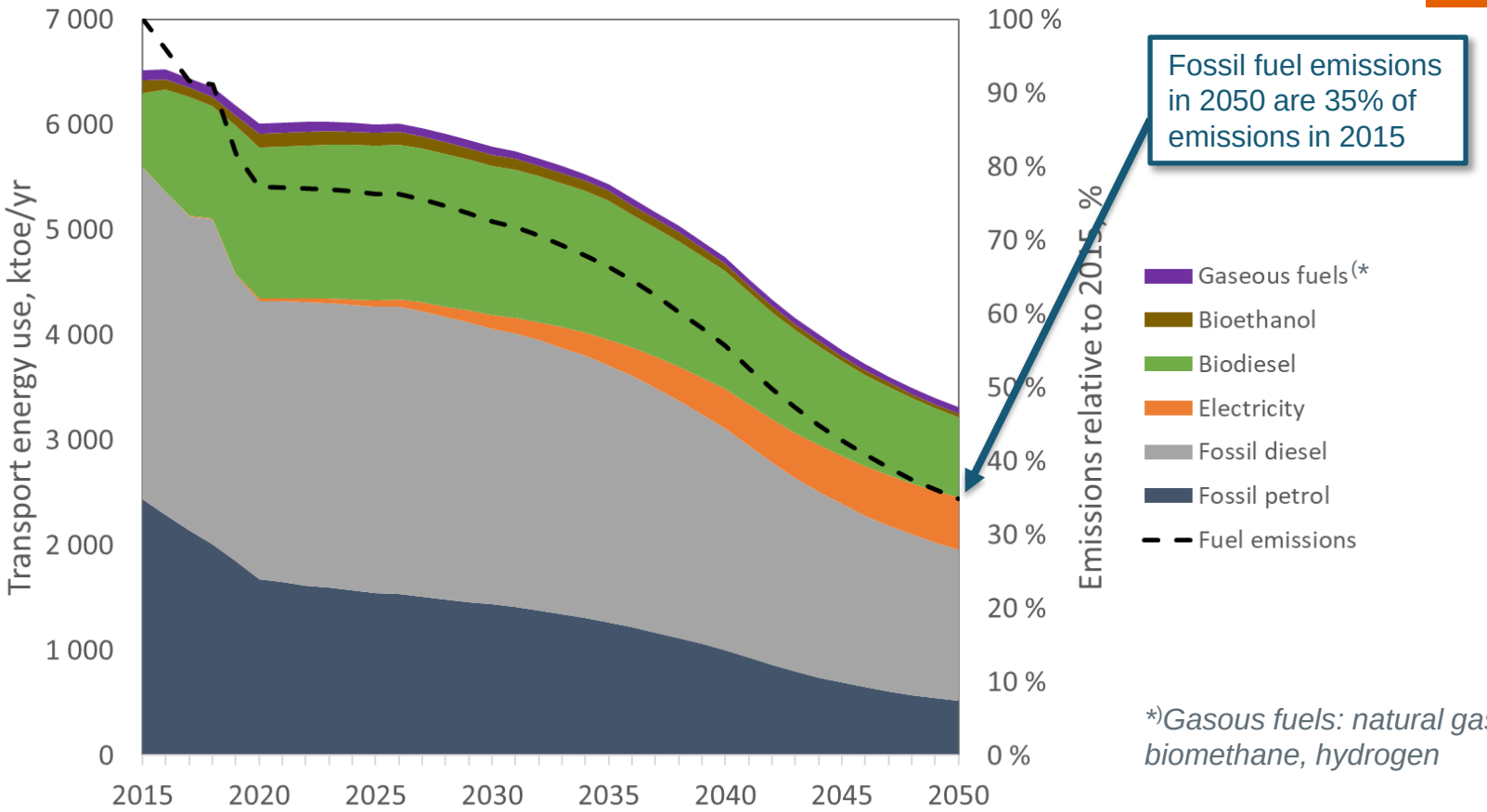

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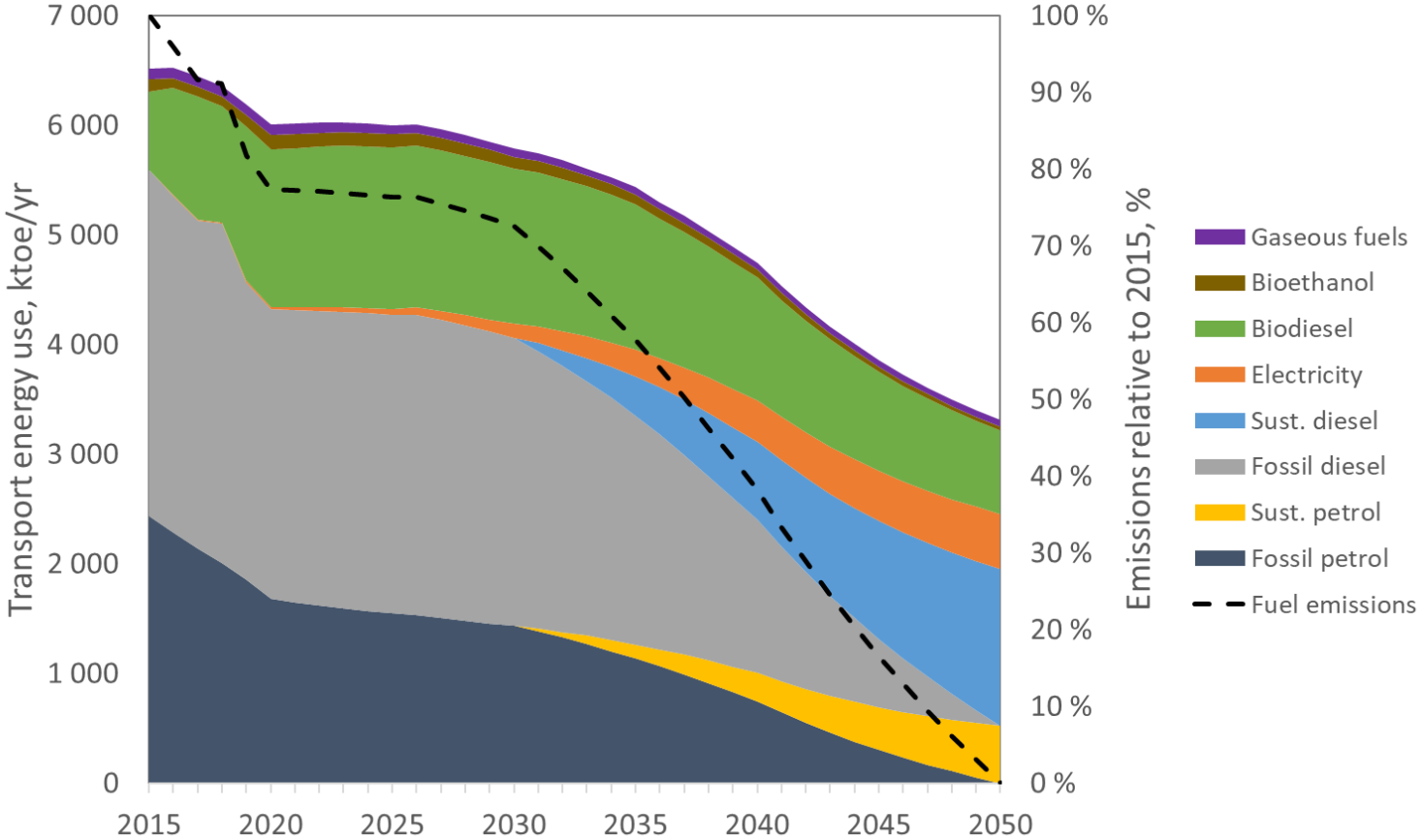
Sweden, Fossil-free Transport scenario



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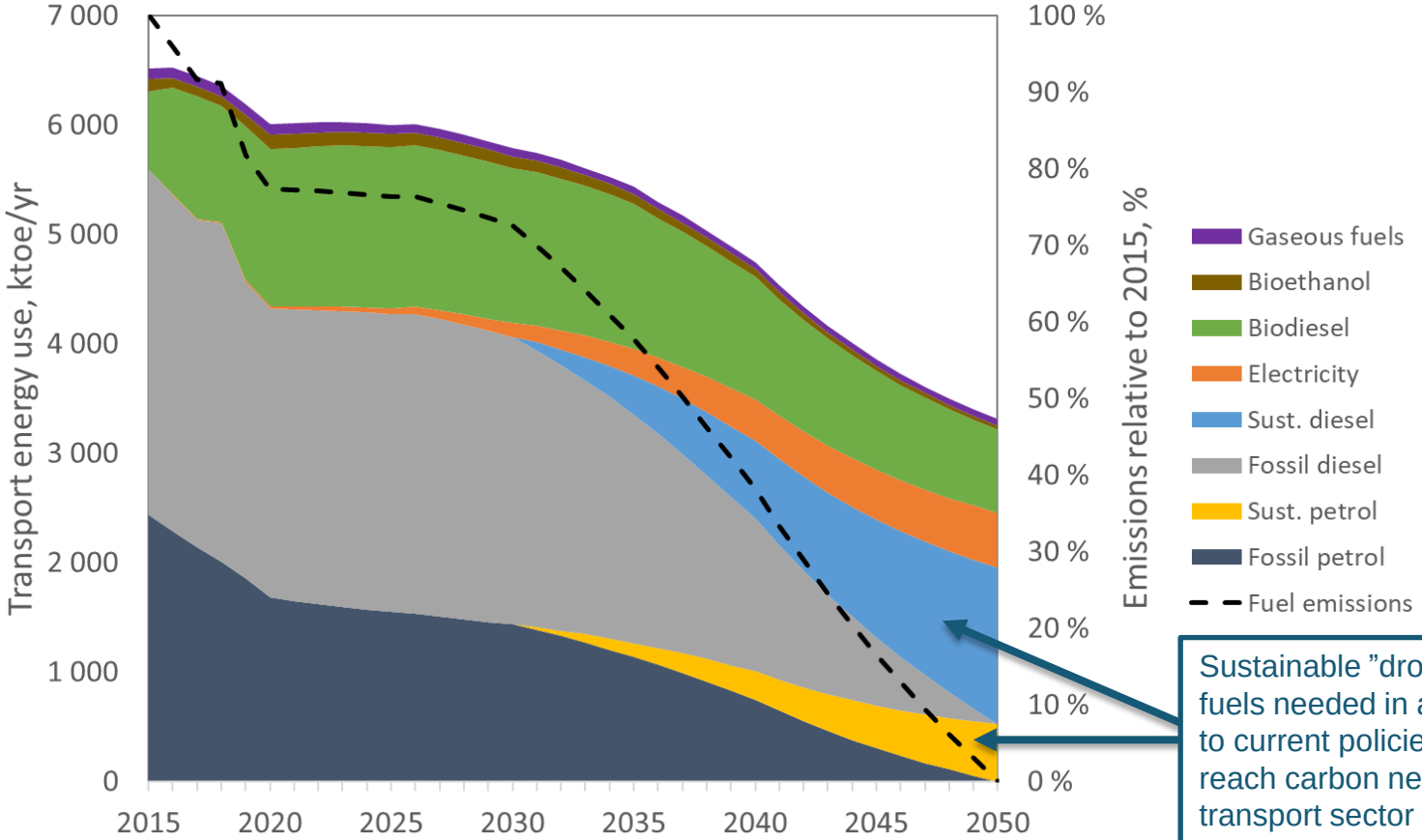
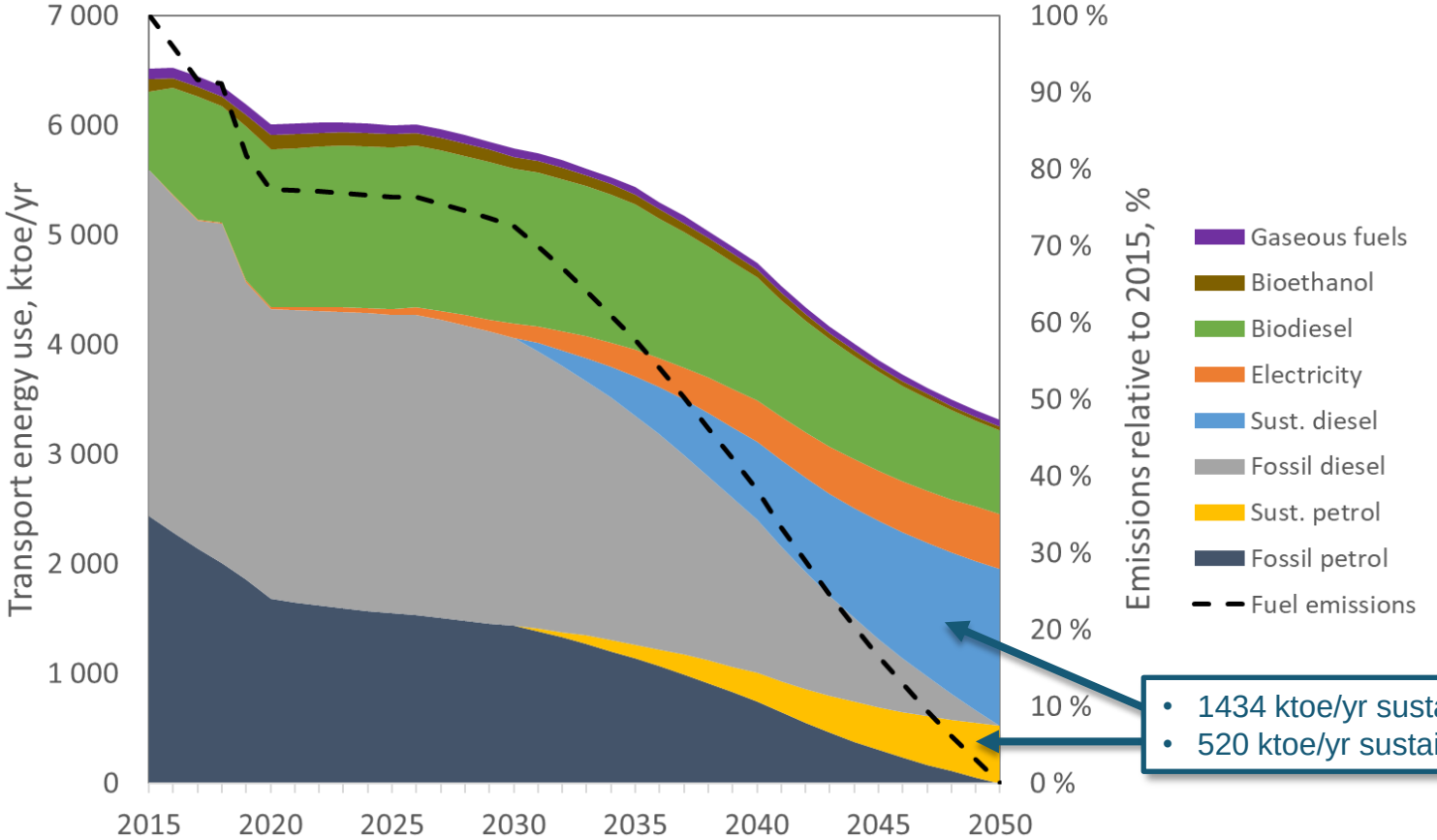


Sustainable ”drop-in” fuels needed in addition to current policies to reach carbon neutral transport sector by 2050

Sweden, Fossil-free Transport scenario



- 1434 ktoe/yr sustainable diesel
- 520 ktoe/yr sustainable petrol

Results for Sweden

- Additional amount of sustainable fuels could come from a combination of domestically produced & imported advanced biofuels

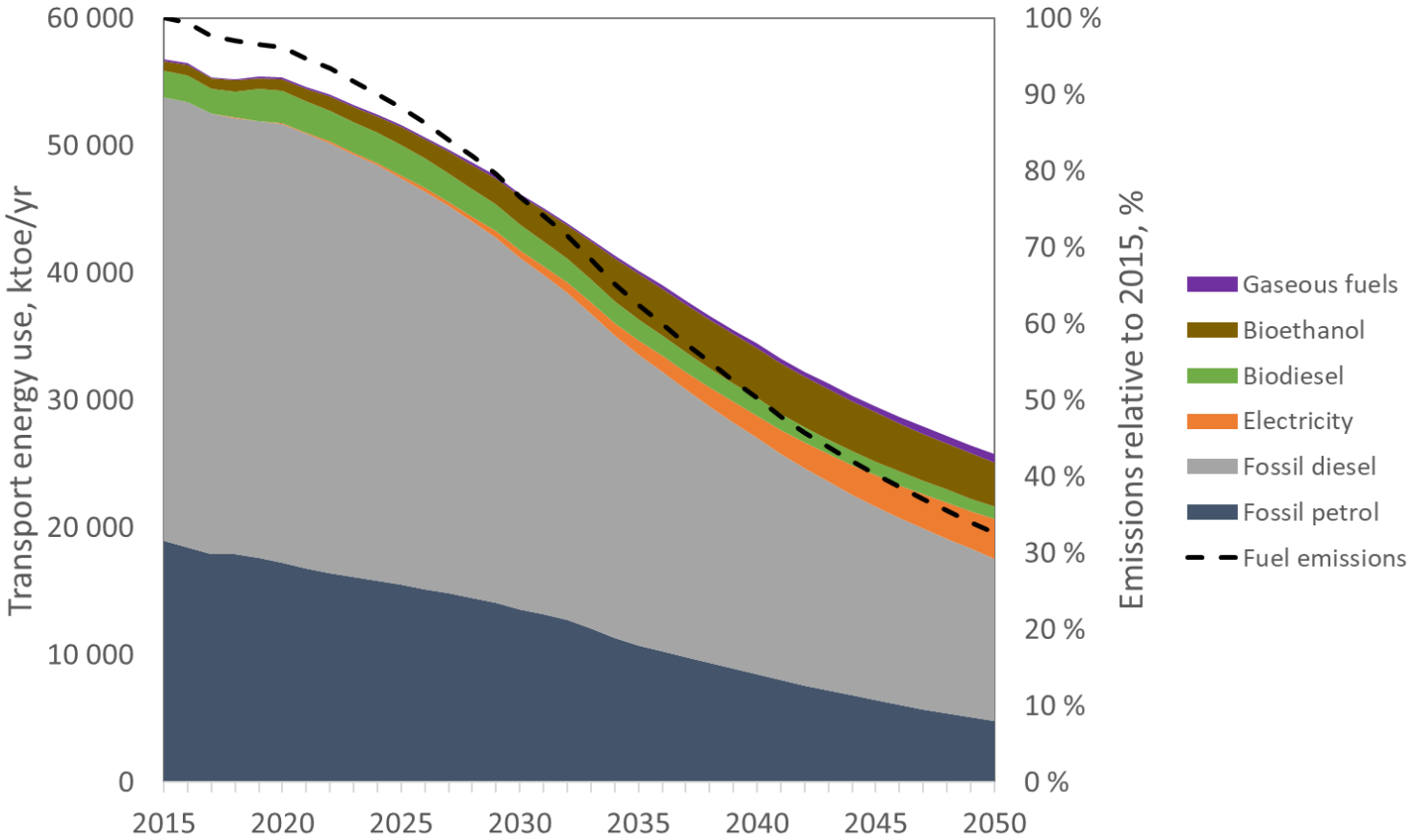
- However, if supplied as electrofuels, it would require
  - 8 Mt of CO_2/yr, ~19% of Sweden's industrial emissions (39 $MtCO_2$)*, and
  - 57 TWh/yr of electricity that is
    - **30%** of Sweden's current **total** power generation of 191 TWh/yr
    - **36%** of Sweden's current **low-carbon** power generation of 157 TWh/yr
    - **61%** of Sweden's current **renewables** generation of 94 TWh/yr

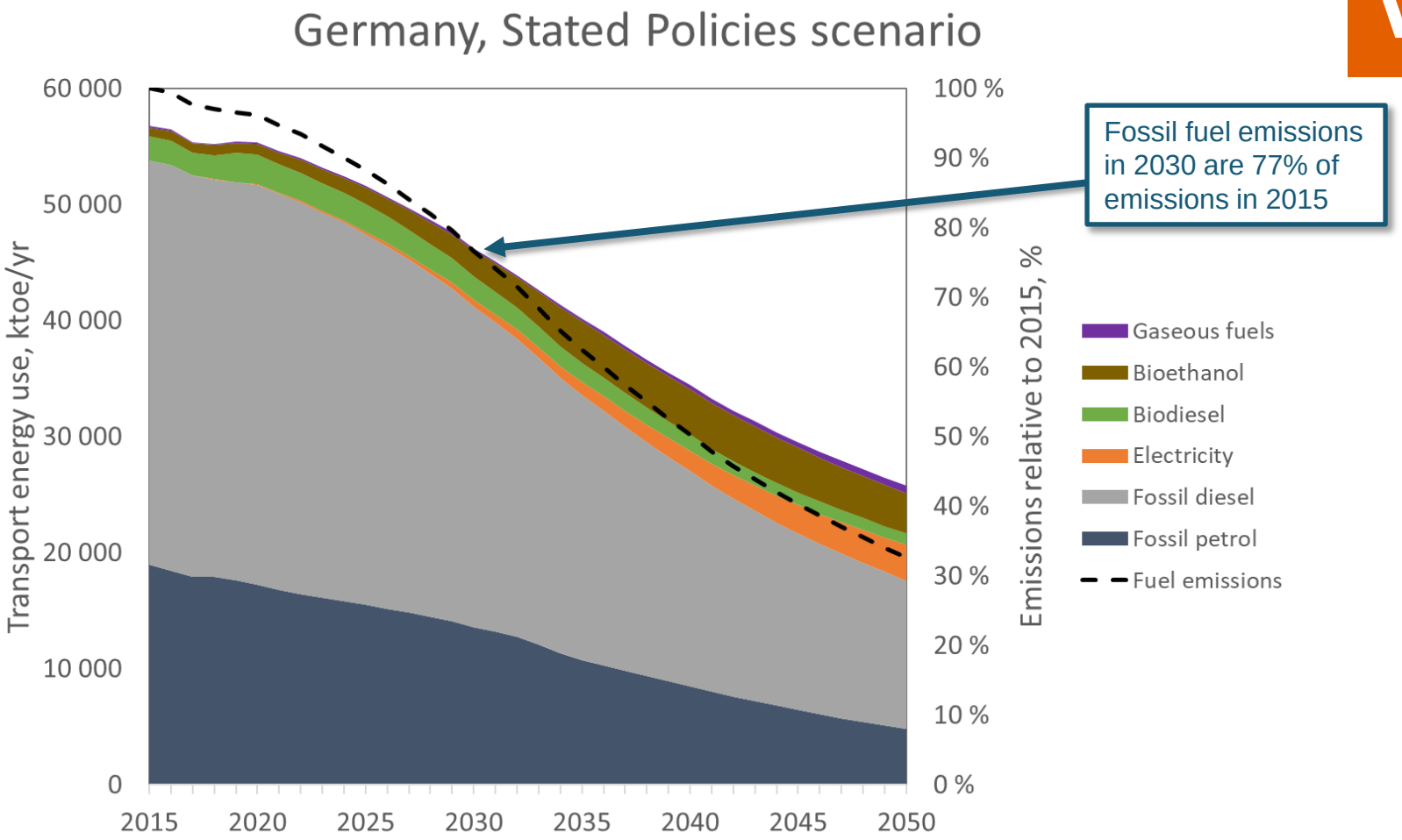
*)*Hansson et al. The Potential for Electrofuels Production in Sweden Utilizing Fossil and Biogenic CO2 Point Sources. Frontiers in Energy Research, 2017,* ***5****.*

Germany

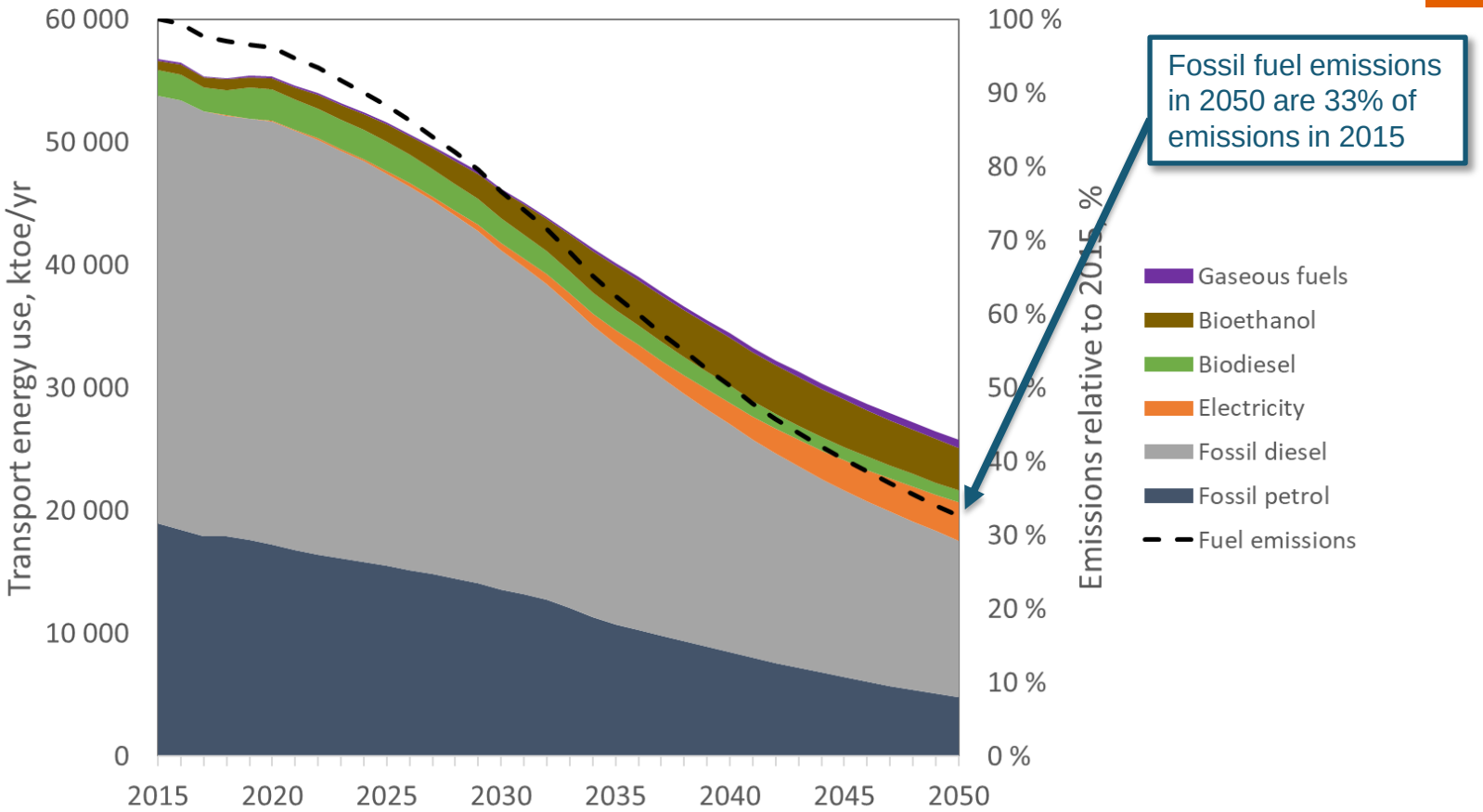
11/19/2019

Germany, Stated Policies scenario

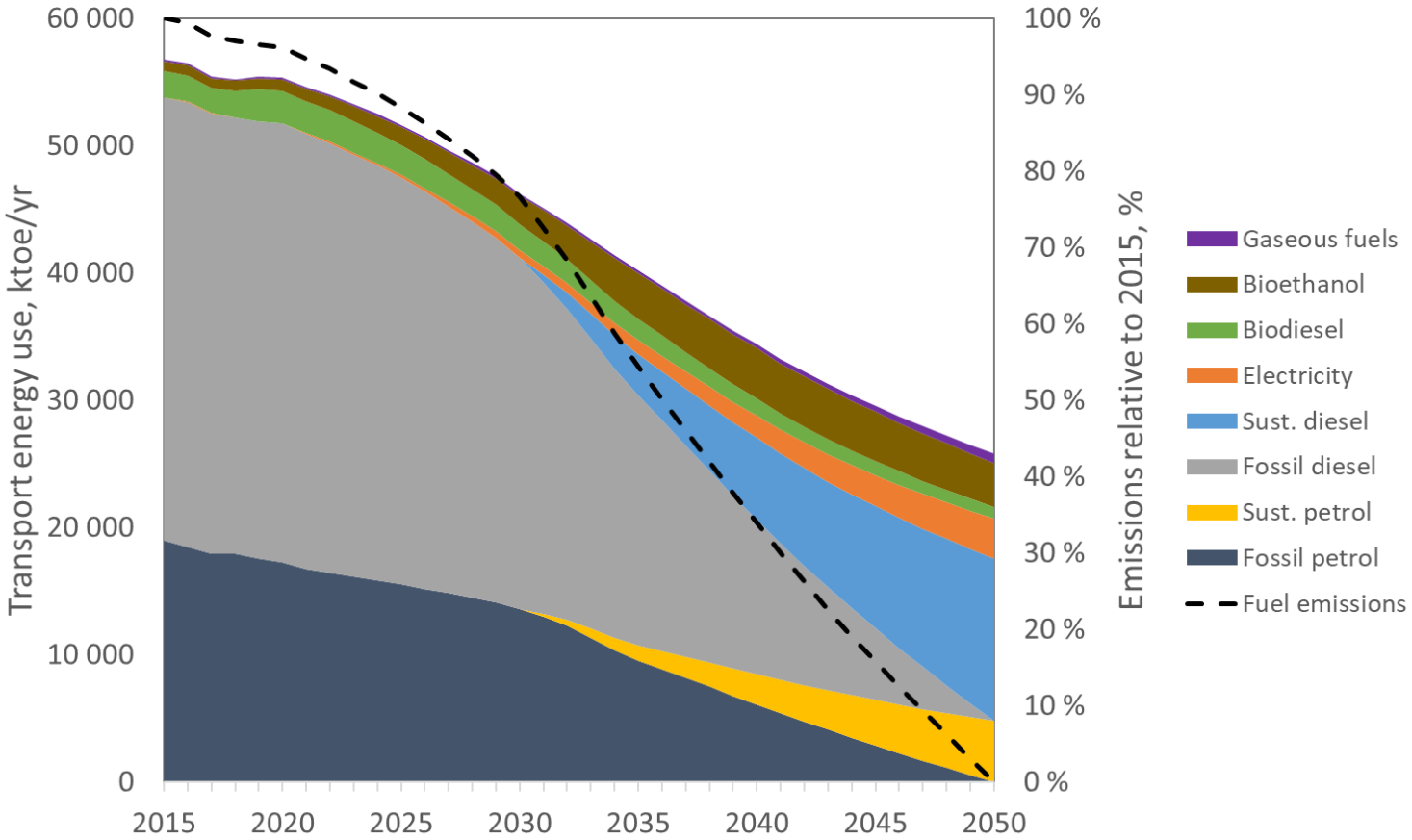



Germany, Stated Policies scenario
Transport energy use, ktoe/yr
60 000
50 000
40 000
30 000
20 000
10 000
0
Emissions relative to 2015, %
100 %
90 %
80 %
70 %
60 %
50 %
40 %
30 %
20 %
10 %
0 %
2015
2020
2025
2030
2035
2040
2045
2050
Fossil fuel emissions in 2030 are 77% of emissions in 2015
Gaseous fuels
Bioethanol
Biodiesel
Electricity
Fossil diesel
Fossil petrol
Fuel emissions

Germany, Stated Policies scenario



Germany, Fossil-free Transport scenario



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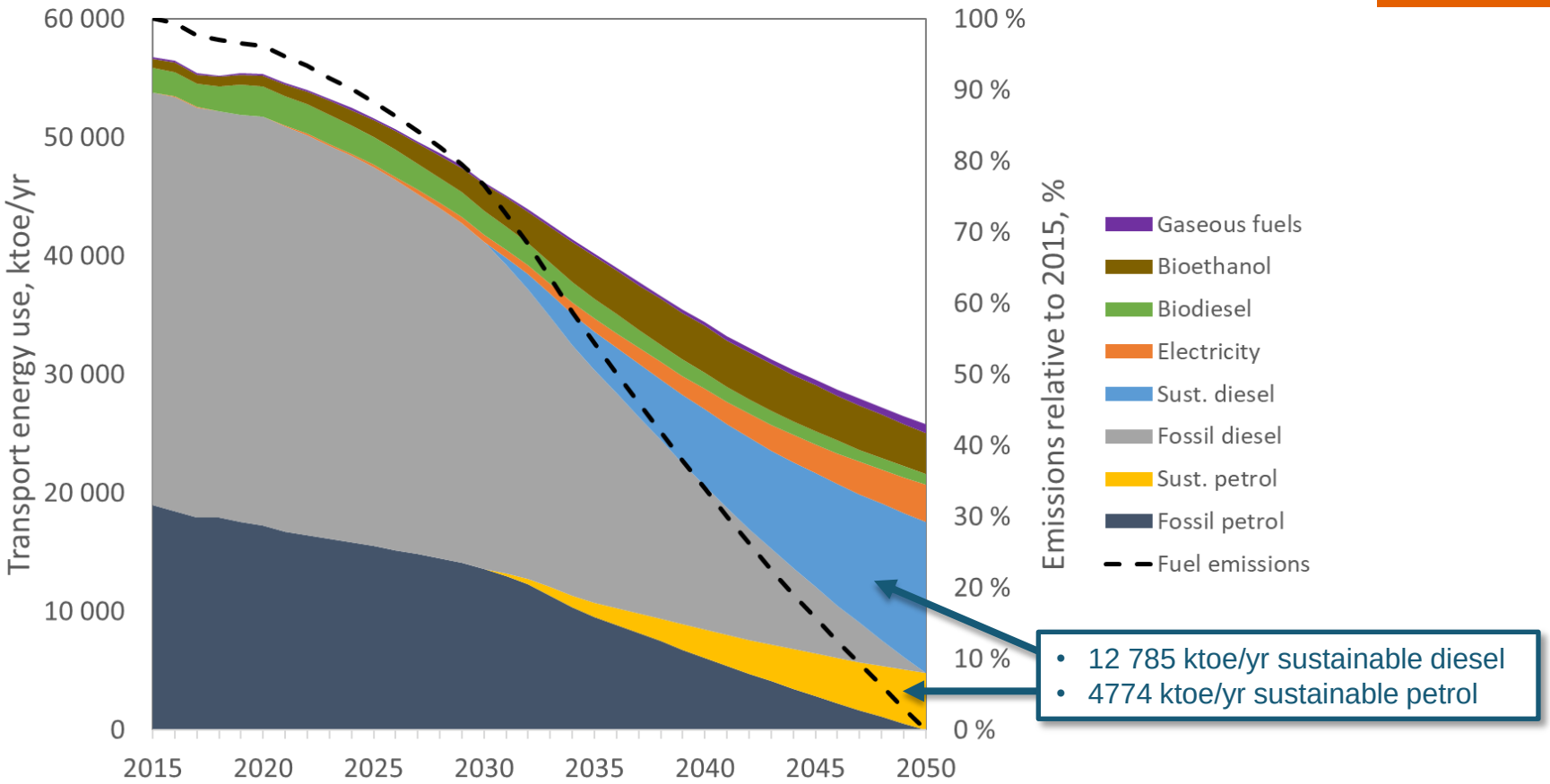

Results for Germany

- Additional amount of sustainable fuels could come from a combination of domestically produced & imported advanced biofuels

- However, if supplied as electrofuels, it would require
  - 68 Mt of CO_2/yr ~37% of Germany's industrial emissions (184 $MtCO_2$)*, and
  - 511 TWh/yr of electricity that is
    - **70%** of Germany's current **total** power generation of 729 TWh/yr
    - **169%** of Germany's current **low-carbon** power generation of 302 TWh/yr
    - **225%** of Germany's current **renewable** power generation of 226 TWh/yr

*) *https://www.umweltbundesamt.de/en/indicator-greenhouse-gas-emissions-in-industry*

Brazil

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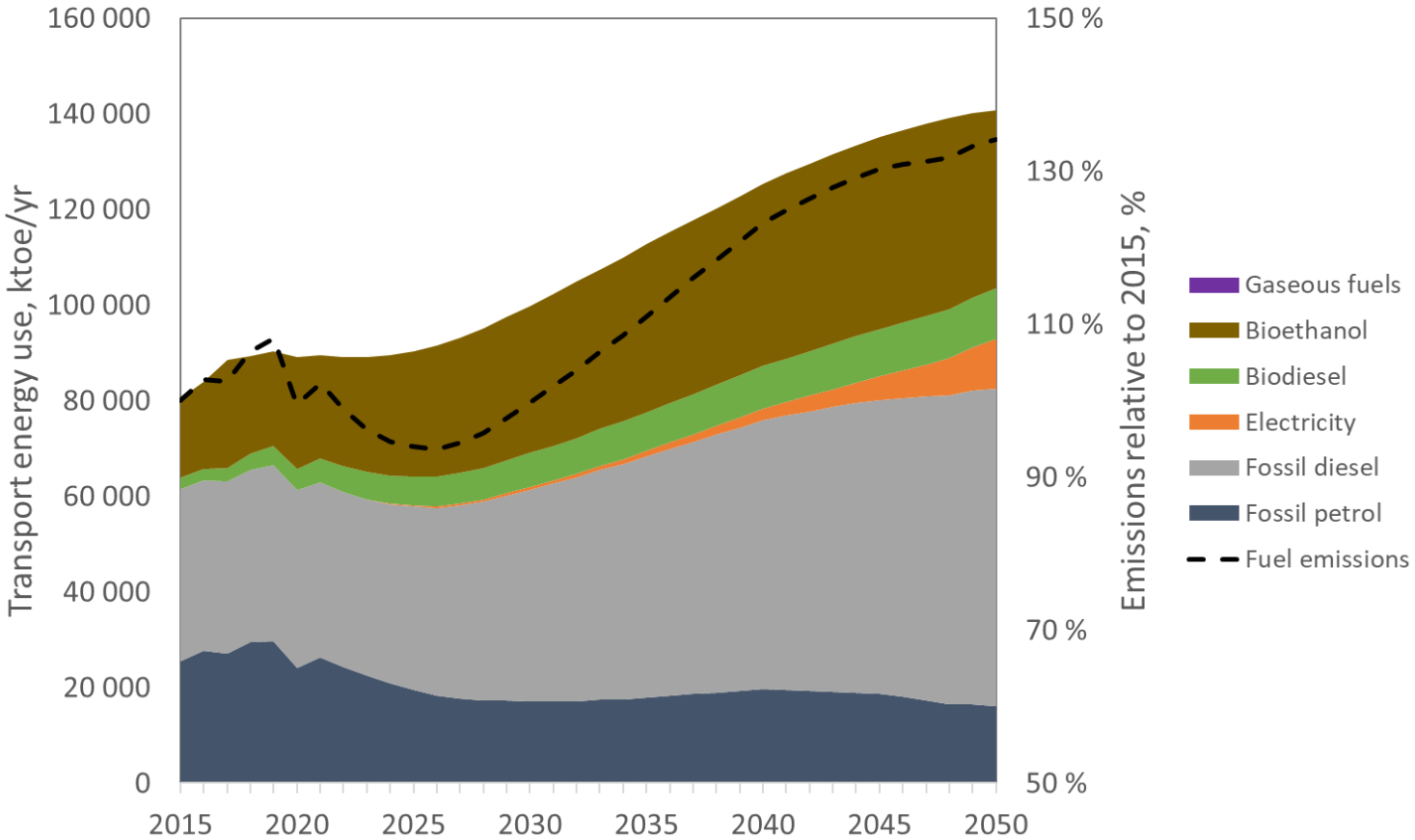
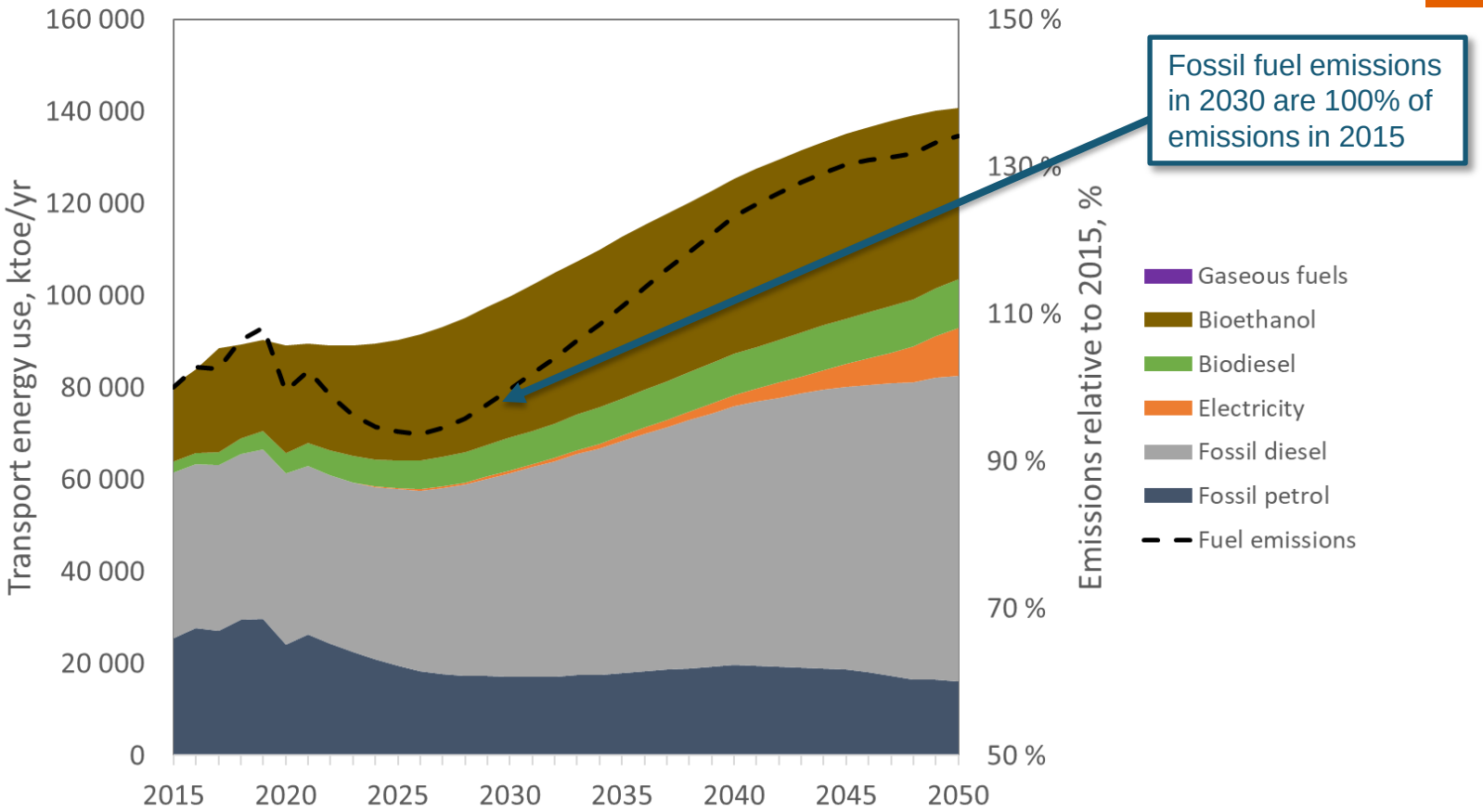
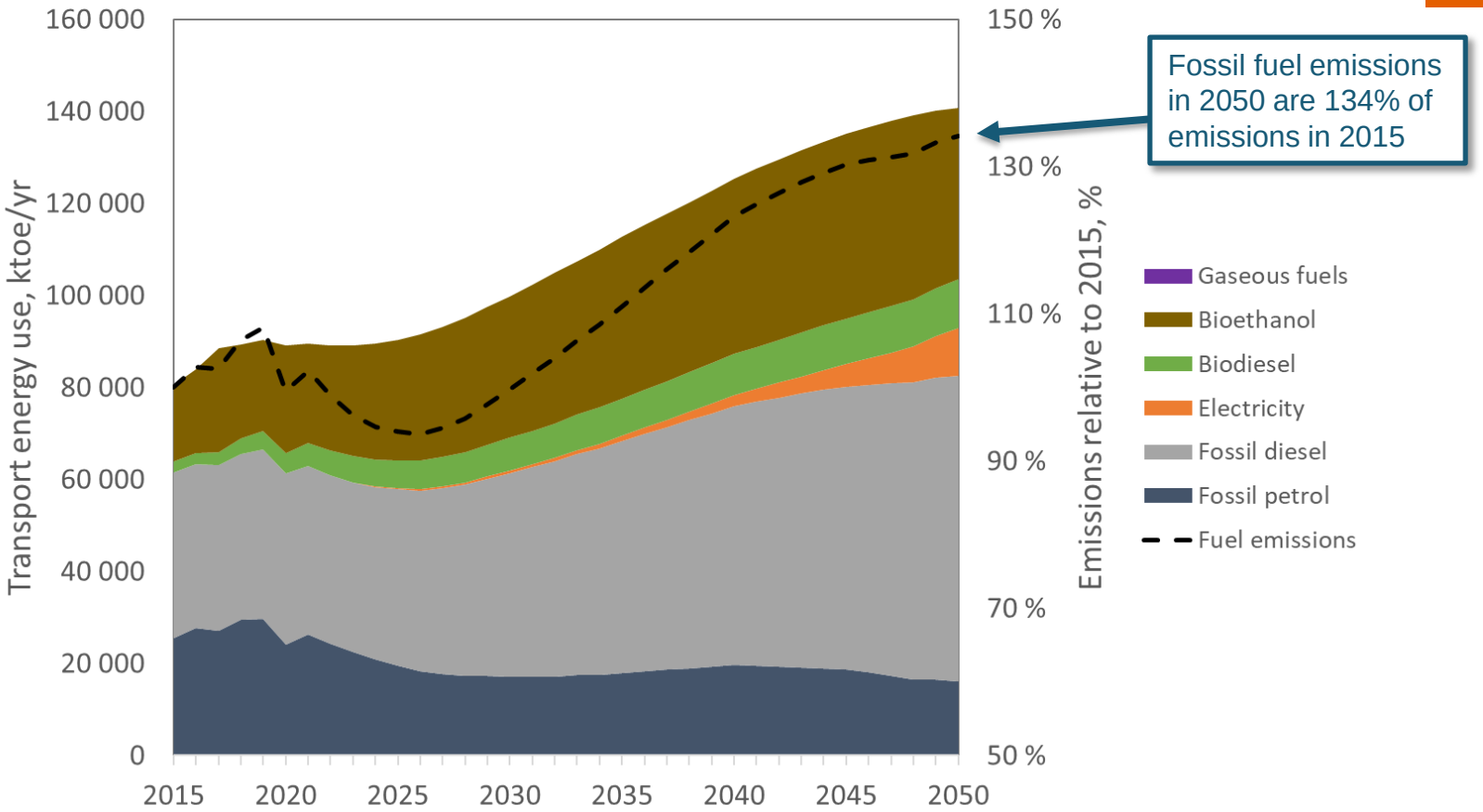
Brazil, Stated Policies scenario



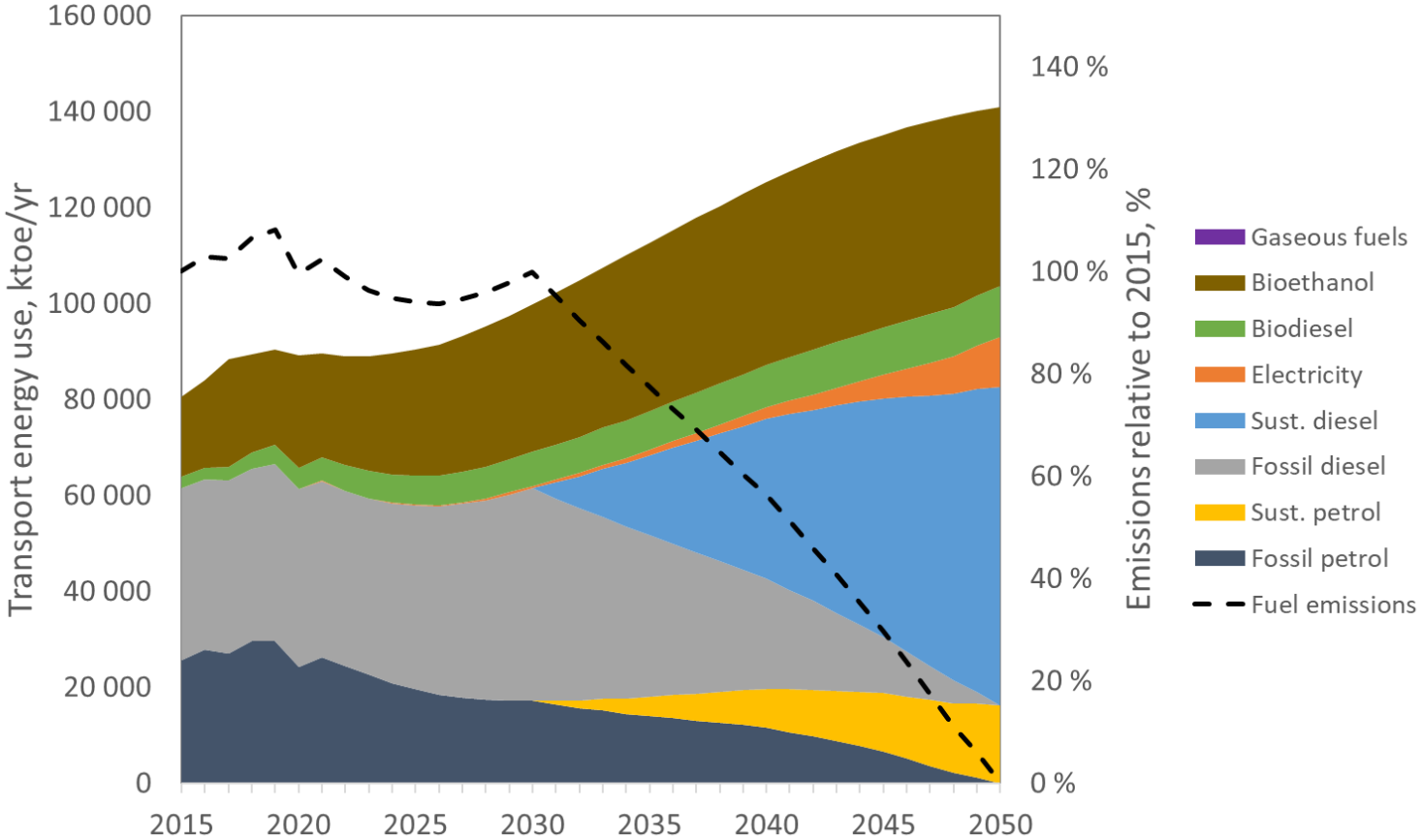
Brazil, Stated Policies scenario



Brazil, Stated Policies scenario



Brazil, Fossil-free Transport scenario



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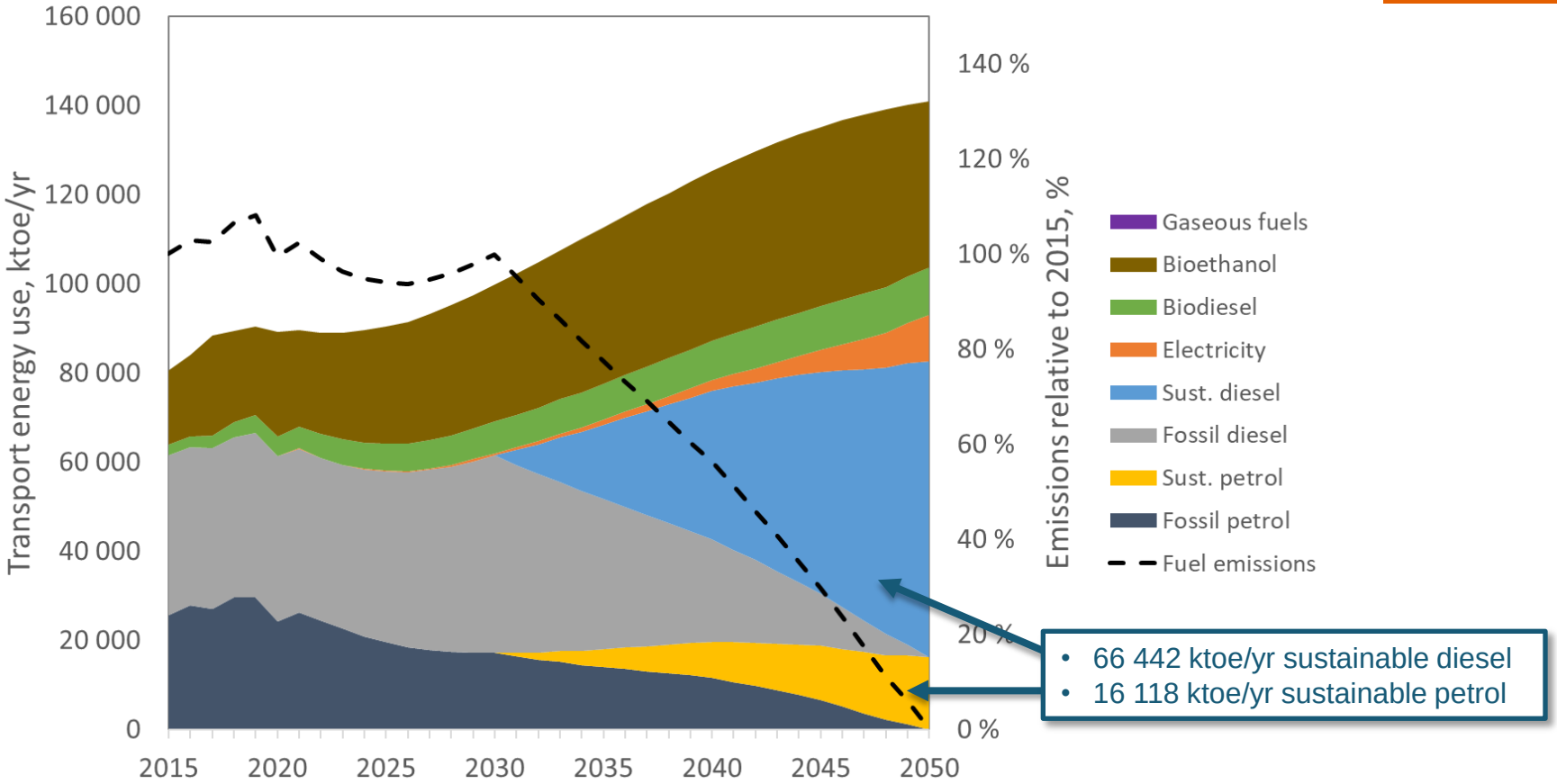


Results for Brazil

- Additional amount of sustainable fuels could come from a combination of domestically produced & imported advanced biofuels

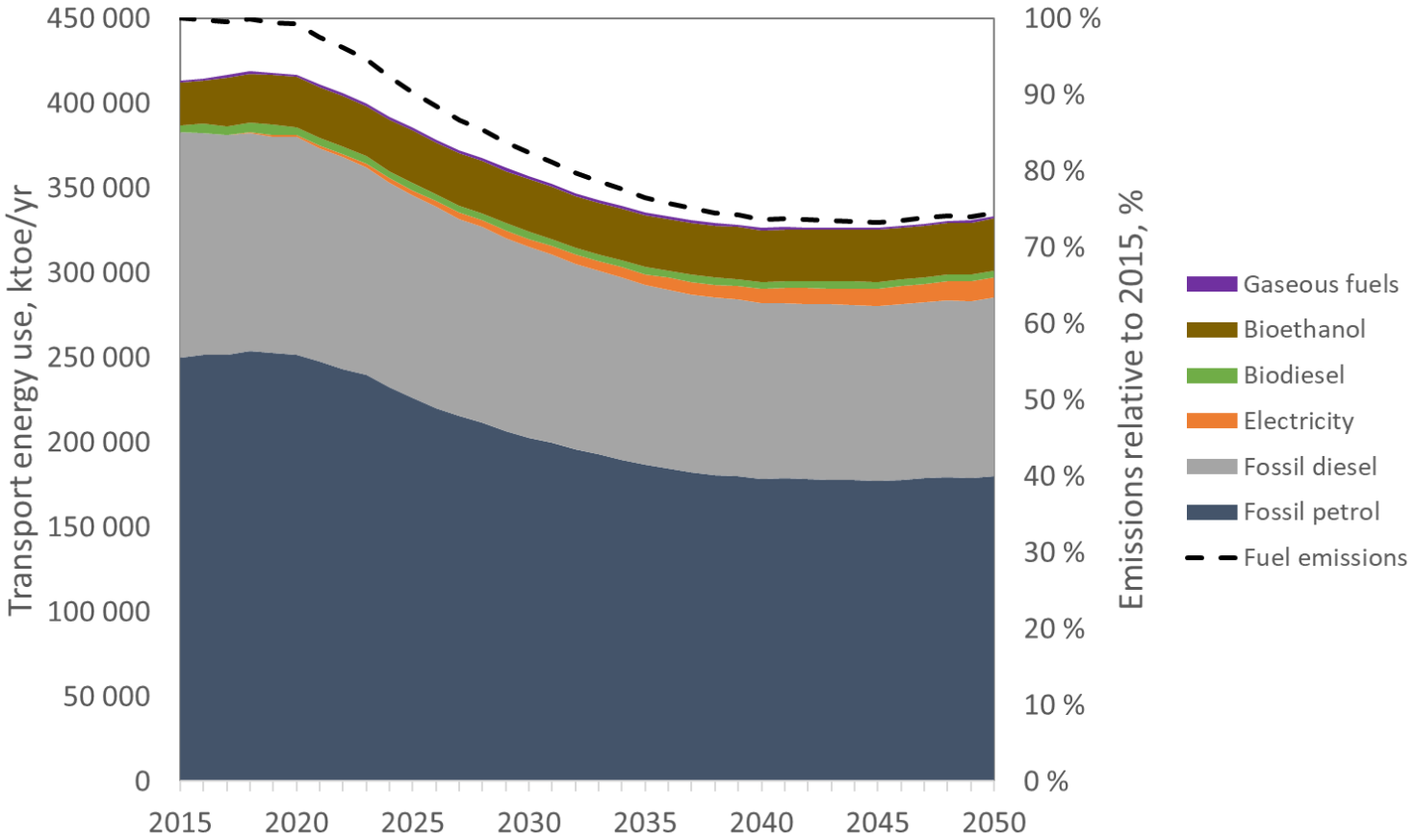
- However, if supplied as electrofuels, it would require
  - 320 Mt of CO_2/yr that is 242% of Brazil's industrial emissions (132 $MtCO_2$)*, and
  - 2400 TWh/yr of electricity
    - 462% of Brazil's current **total** power generation of 520 TWh/yr**
    - 577% of Brazil's current **renewable** power generation of 416 TWh/yr**

*) https://www.worldometers.info/co2-emissions/brazil-co2-emissions/
*) https://www.iea.org/countries/brazil/

USA

11/19/2019

USA, Stated Policies scenario



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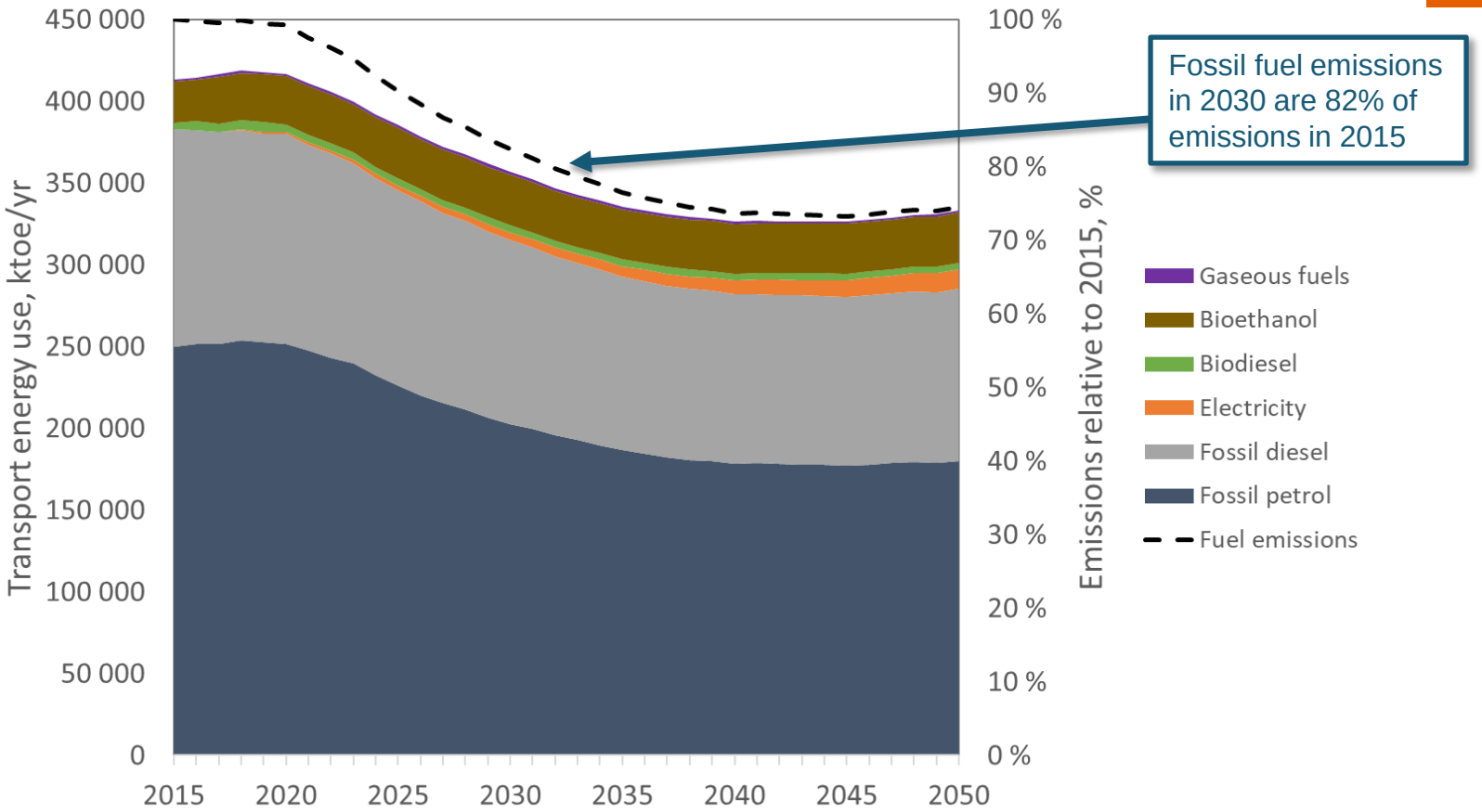

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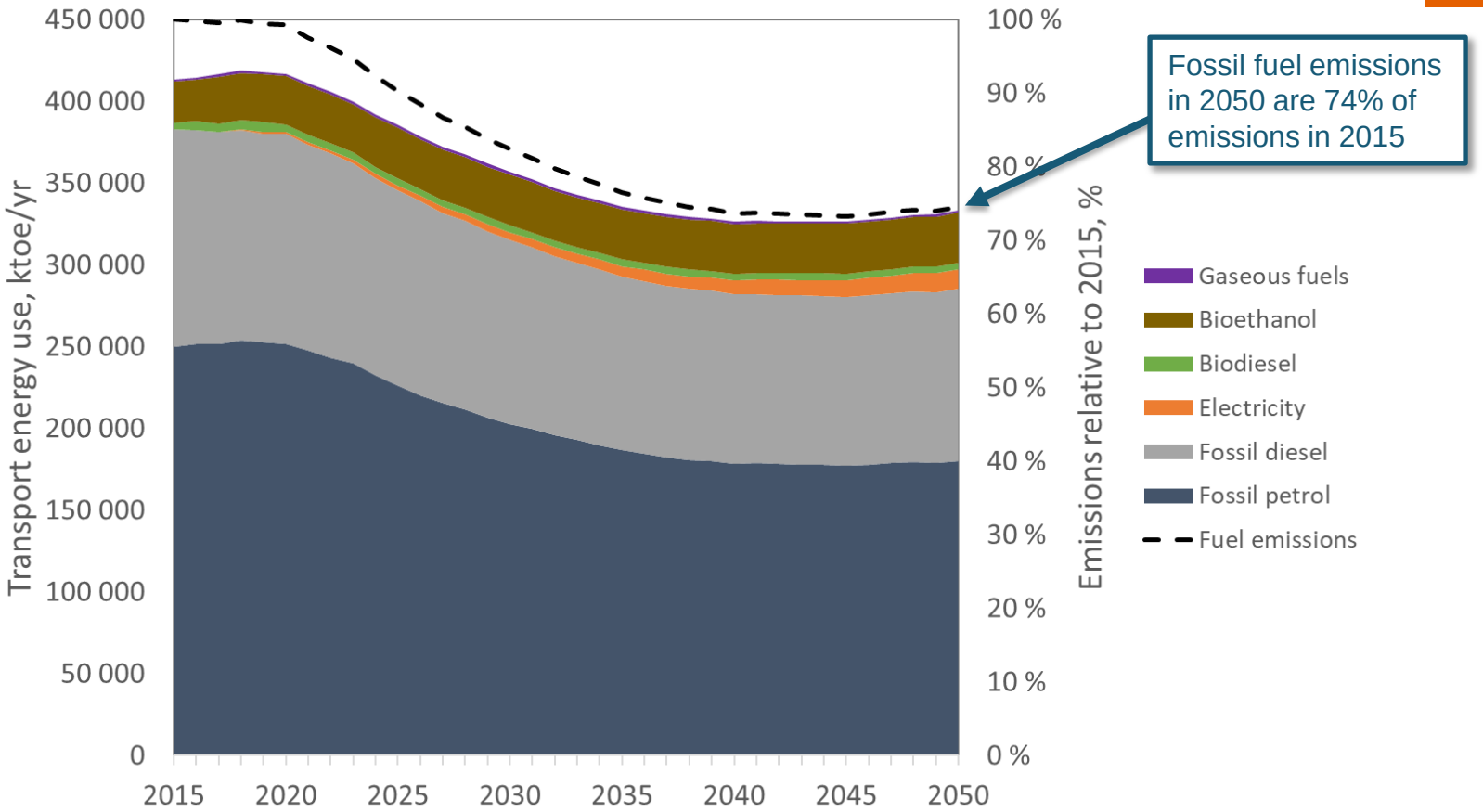
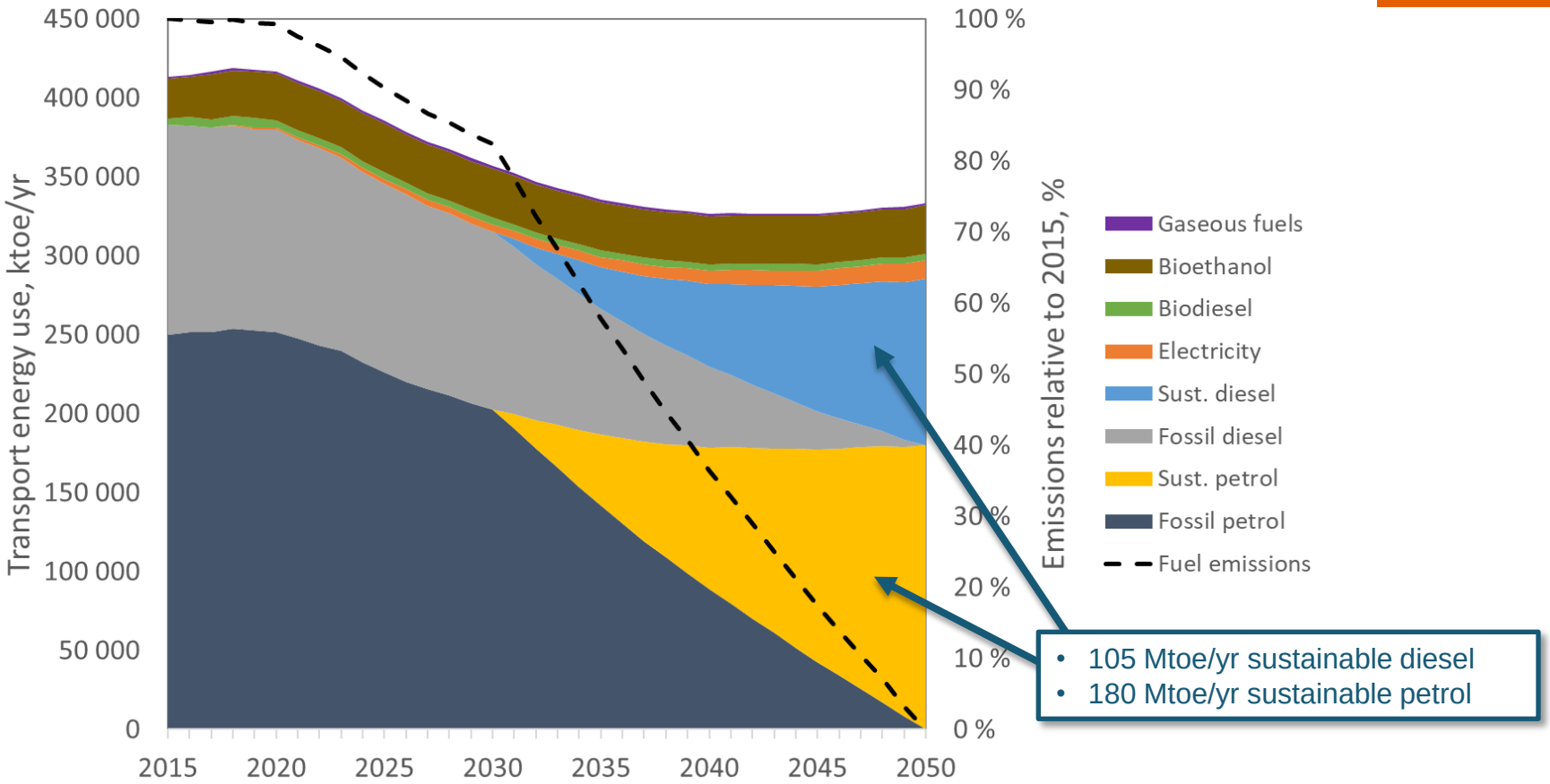


USA, Fossil-free Transport scenario



Results for the USA

- Additional amount of sustainable fuels could come from a combination of domestically produced & imported advanced biofuels

- However, if supplied as electrofuels, it would require
  - 1105 Mt of CO_2/yr ~78% of USA's industrial emissions (1421 $MtCO_2$)*, and
  - 8288 TWh/yr of electricity that is
    - **198%** of USA's current **total** power generation of 4196 TWh/yr
    - **537%** of USA's current **low-carbon** power generation of 1543 TWh/yr
    - **1129%** of USA's current **renewable** power generation of 734 TWh/yr

*) *https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions*

Results for the USA

Year	Power grid emissions, gCO_2/kWh	Electrofuels emissions relative to fossils
2010	552	506%
2015	471	431%
2020	390	357%
2025	364	334%
2030	351	322%
2035	332	304%
2040	317	290%
2045	305	279%
2050	291	267%

Summary of results

Country	Stated Policies emissions in 2050 relative to 2015	Fossil-free transport via E-fuels: Low-C power share*	Fossil-free transport via E-fuels: Industrial CO_2 demand
Sweden	35%	36%	19%
Germany	33%	169%	37%
Brazil	134%	577%	242%
USA	74%	537%	78%

*) *Electricity need for electrofuels production divided by current electricity generation from non-fossil sources*

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More information: https://iea-amf.org/content/news/TD-WS

Contact: dina.bacovsky@best-research.eu