Advanced Biofuels & Beyond
Alternative Fuels vs. Electric Mobility

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Mathematics of Climate Protection

Climate change is a phenomenon of natural physics.

Francis Bacon: “Nature, to be commanded, must be obeyed".

Those who want to control climate change must consider physical laws.

Physical laws are not politically negotiable!

The mathematics of climate protection, derived from its physics, is presented on the next slide.

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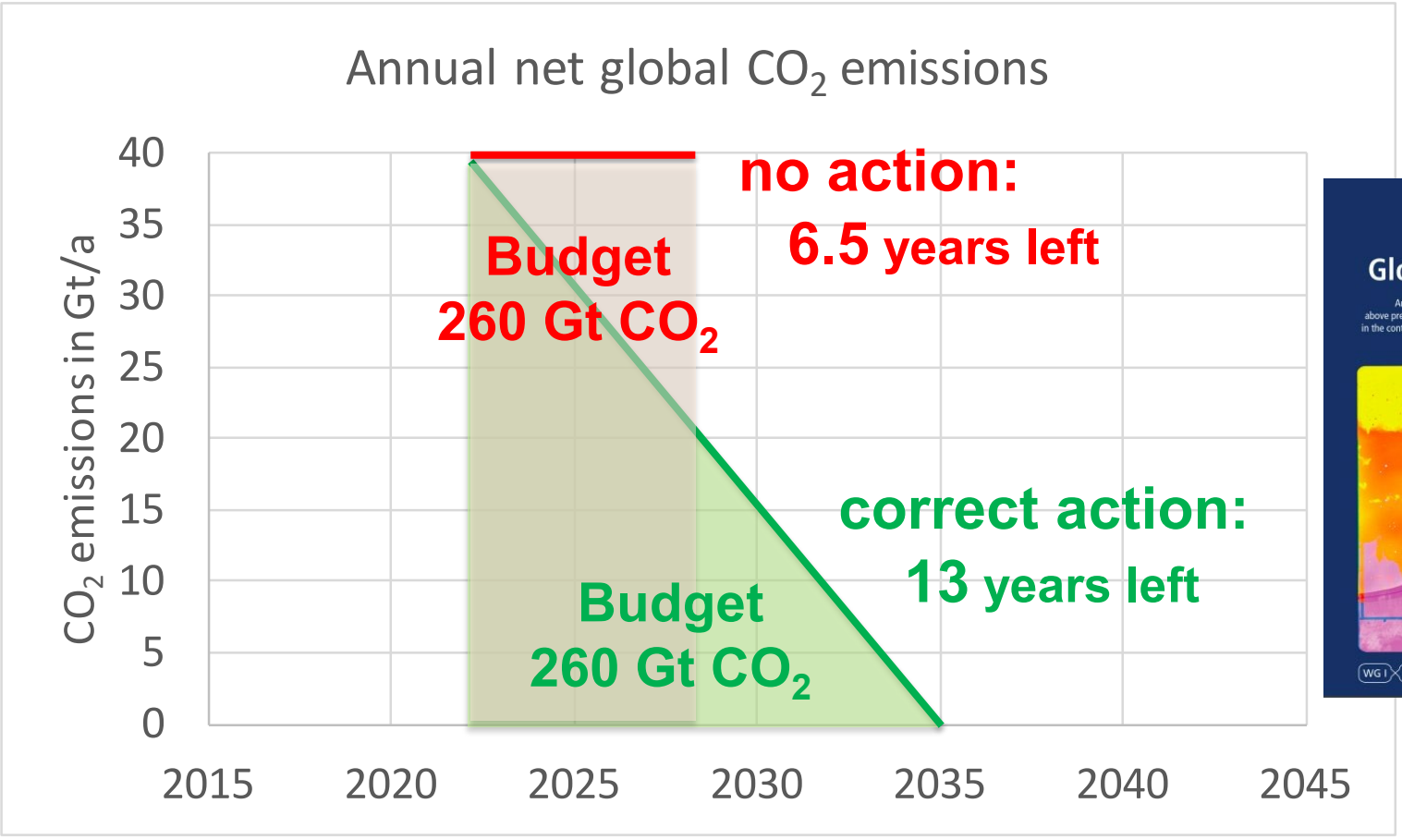
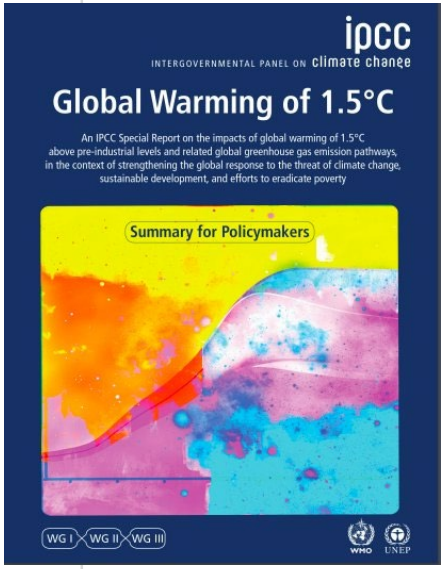
Mathematics of Climate Protection

Global CO_2 emission budget (1.5-degree target) at the beginning of 2022: 260 Gt CO_2

Current global level of annual CO_2 emissions: 40 Gt/a CO_2





Source: IPCC (2018) Special Report on Global Warming of 1.5° C, October 2018

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Derived Criteria for Climate Protection Measures

3 criteria that climate protection measures must generally fulfil

No delay

Immediate effect of GHG reduction measures when implemented.

(see “correct-action” scenario)

No GHG export

Entire value chain: No upstream or downstream GHG emissions in other countries or sectors.

Fast roll-out (of successful technologies)

Climate protection is a global task and can only succeed in international cooperation.

GHG = Greenhouse gas

Source: Willner (2020)

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Problems of Battery Electric Vehicles (BEVs)

- **BEVs do not meet any of the three climate protection criteria:**
  - **Long delay: Battery Backpack: More CO2 rather than less CO2**
  - **High GHG export: 1. More CO2 in countries of battery production**
    2. More CO2 from power production

    Note: Calculation with power mix is wrong!
    Correct is fossil marginal power![1-5]

    3. More CO2 for new infrastructure and battery recycl.
  - **Fast roll-out: Does not make sense due to failure in the first two criteria**

Result: BEVs are definitely no suitable climate protection measure!

- **BEV ramp-up maximizes the raw material dependence on China**
- **BEV ramp-up would maximize the risk of blackouts:**
  - **Extremely high power peaks!**

Result: Focus on BEVs would be a major strategic mistake!

Sources: [1] Koch, Böhlke (2021), [2] Böhmeke, Koch (2021), [3] FVV (2021), [4] Schmidt (2020), [5] Stahl et al. (2020)

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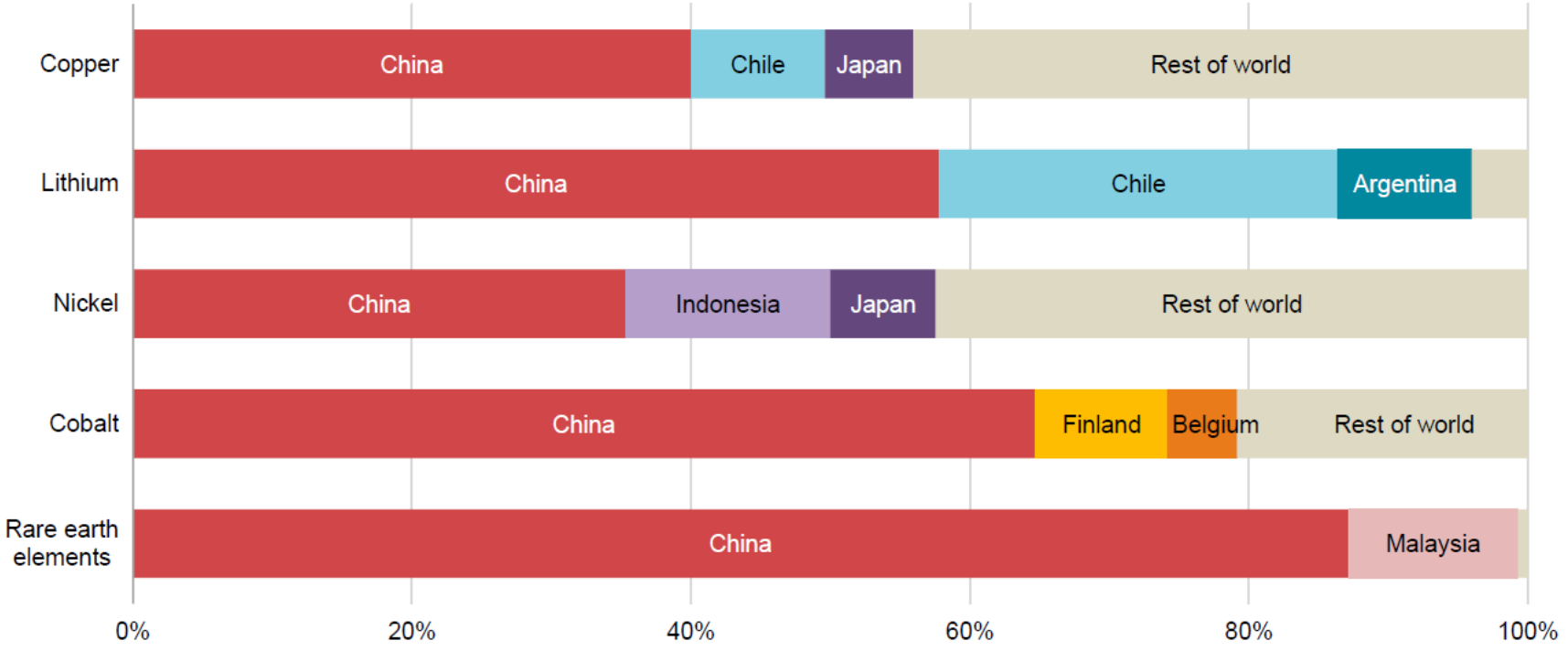
Raw Material Strategy

The focus on all-electric concepts would be a major strategic mistake:

It would maximize the raw material dependence on China



Processing of critical raw materials for all-electric scenarios, status 2019 Source: IEA (2021)

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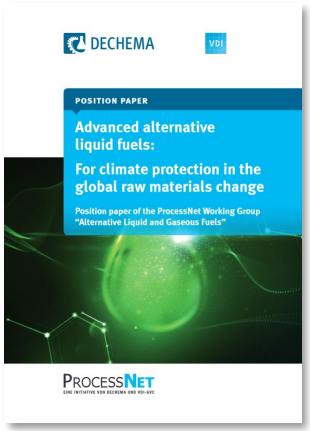
Alternative Fuels (ReFuels)

Scientific analysis (see below for relevant literature) clearly shows:

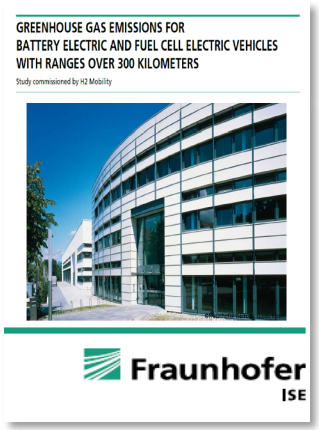
- **Sustainable ReFuels can meet all 3 criteria for effective climate protection**

Result: ReFuels must be promoted as a matter of priority

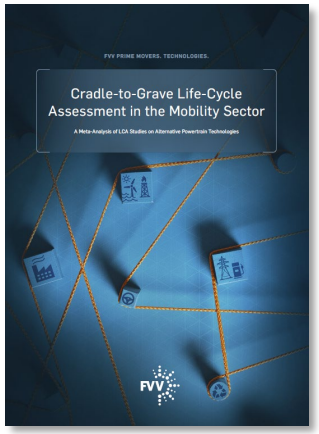


DECHEMA / ProcessNet 2018

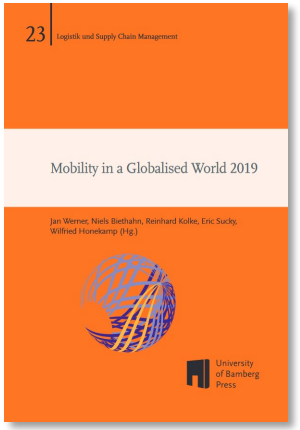
Joanneum Research 2019



Fraunhofer ISE 2019



Frontier Economics 2020



Willner 2020

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Alternative fuels (liquids and gases) are manifold with huge potential

We need not only biodiversity, but also technology diversity

1. **1G biofuels as a by-product of animal feed production (biodiesel and bioethanol) and bio-methane from agricultural crops**
2. **2G biofuels including hydrogen and bio-methane from waste and residues from agriculture, forestry, wood processing and food industry**
3. **Recycled carbon fuels (RCF) from non-biogenic waste such as plastic waste**
4. **Renewable electricity-based fuels (PtX fuels, e-fuels) including hydrogen, synthetic methane and ammonia from countries with a surplus of RE**
5. **Efficient combinations (hybrids) (e.g. biomass or waste based PtX fuels)**

1G = 1st generation, 2G = 2nd generation, RE = renewable energy, PtX = Power to X

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Alternative Fuels: Group 2

2G Biofuels (Advanced Biofuels) from Waste and Residues of Agriculture, Forestry, Wood Industry, Food Industry etc.:

Many reaction pathways possible: e.g. via pyrolysis or via synthesis gas (syngas)

Example: BtL concept via gasification of biomass for syngas production + Fischer-Tropsch (FT) synthesis or methanol synthesis or other syntheses:

Example: Model reaction: Gasification by partial oxidation + FT or methanol

1. Gasification: $CH_{1,5}O_{0,7}$ (Biomass) + 0,15 O_2 → CO + 0,75 H_2

2. Shift: $CO + H_2O \rightarrow CO_2 + H_2$

3. FT for liquid HC fuels (CH_2): $CO + 2\ H_2 \rightarrow -(CH_2)- + H_2O$

   or methanol (CH_3OH) synthesis: $CO + 2\ H_2 \rightarrow CH_3OH + H_2O$

2G = 2nd Generation; BtL = Biomass to Liquid; HC = Hydrocarbon for drop-in biofuels

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Alternative Fuels: Group 2

2G Biofuels (Advanced Biofuels) from Waste and Residues of Agriculture, Forestry, Wood Industry, Food Industry etc.:

Air Liquide

Pyrolysis + Gasification + Synthesis:

bioliq[R] pilot plant at KIT in Germany:
0.5 t/h straw, 2 MW_{th}

thyssenkrupp engineering. tomorrow. together. et al.

Torrefaction + Gasification + Synthesis:

BioTfuel[R] demo plant in France:
4 t/h wood, 15 MW_{th}

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Alternative Fuels: Group 3

Recycled carbon fuels (RCF) from non-biogenic waste such as plastics:

OMV

Pyrolysis + Co-Processing:

ReOil^{R} pilot plant on the OMV refinery site in Austria:

0.1 t/h plastic waste

Planned expansion steps:

Demo: 20,000 t/a

Production: 200,000 t/a

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Alternative Fuels: Group 4

Renewable electricity-based fuels (PtX fuels, e-fuels) from countries with a surplus of renewable energy

SIEMENS energy

PORSCHE

thyssenkrupp engineering. tomorrow. together.

et al.

$3\ H_2 + CO_2 = CH_2$ (liquid fuel) $+ 2\ H_2O$

Haru Oni e-fuel project in Chile
2022 planned: 100 t/a e-fuel
2024 planned: 40,000 t/a e-fuel
2026 planned: 400,000 t/a e-fuel

$3\ H_2 + N_2 = 2\ NH_3$ (ammonia)

Neom solar project in Saudi Arabia:
One of the biggest electrolysis plants for H_2 with 4 GW solar power + PtG (NH_3) planned

Alternative Fuels: Group 5

Waste based e-fuels: High efficiency + low costs

NEXXOIL
https://nexxoil.com/

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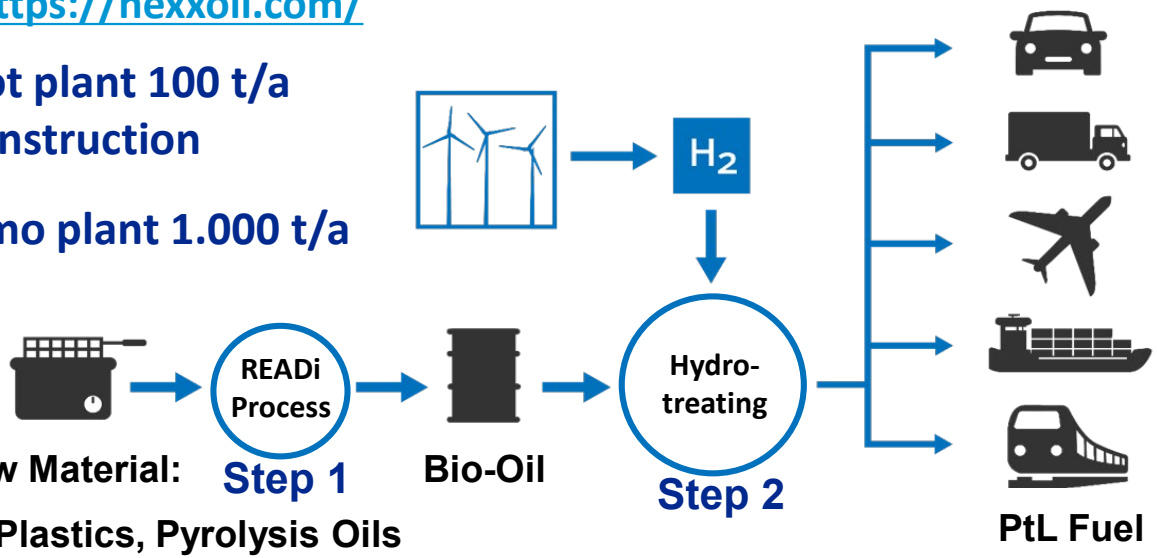
2022 pilot plant 100 t/a under construction

2023 demo plant 1.000 t/a planned



READi-PtL process:

1st step: reactive distillation for cracking and deoxygenation

2nd step: hydrotreating for drop-in fuel production

E-fuel with low power demand: only 5 kWh per 100 km

That is by a factor 3 to 5 less than for BEVs!

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Conclusions

- Alternative fuels (ReFuels) can meet all 3 criteria for climate protection.
- All 5 process groups of alternative fuels are equally important!
- The global potential of ReFuels is more than enough available.
- Waste based E-Fuels can be ramped up immediately (low power demand).
- The production costs for ReFuels are lower than commonly expected.
- We need all effective options for the energy transition and transport transition! E-Mobility is definitely no effective option for climate protection.

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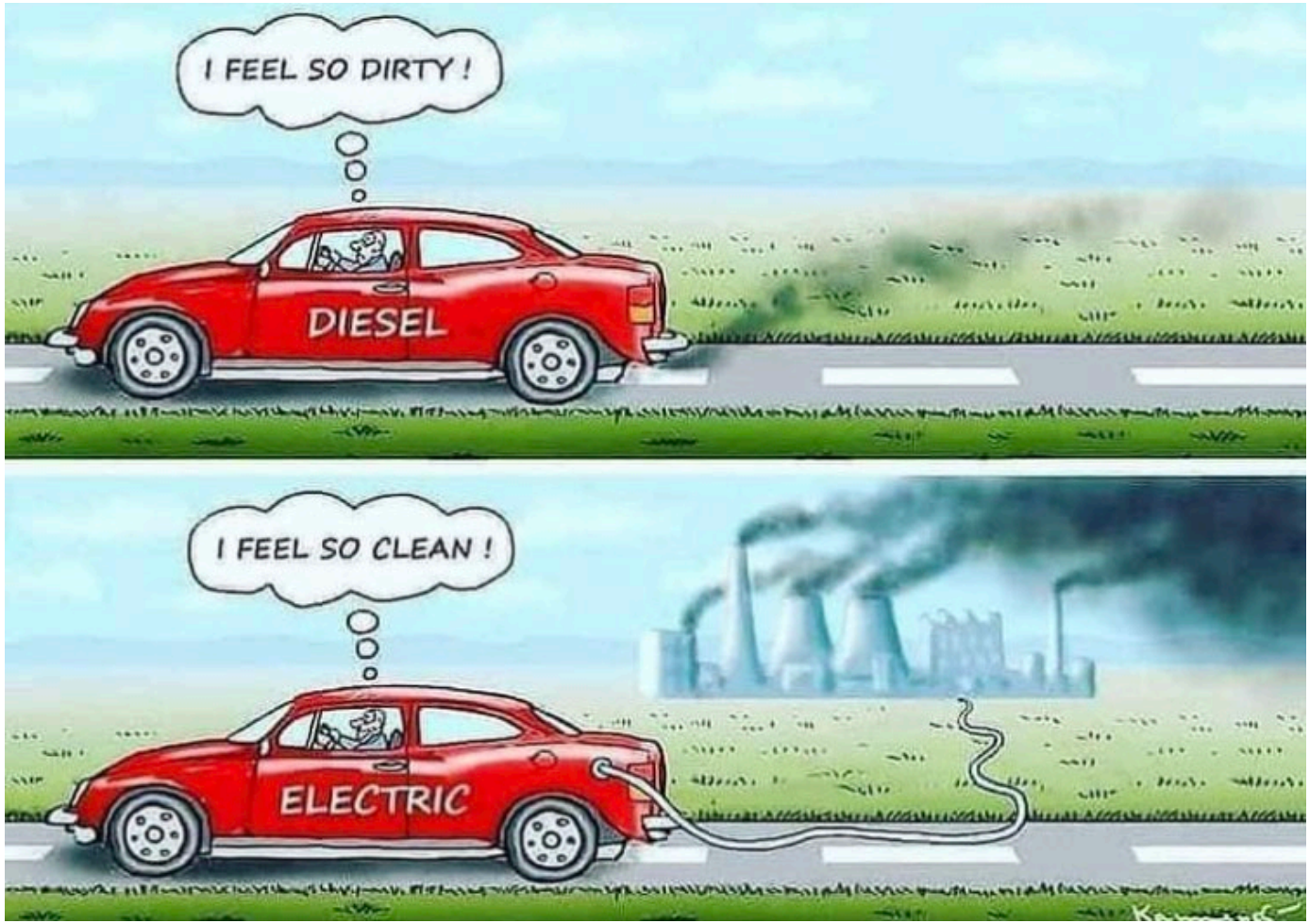
Thank you



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