CCSHFC 2022

The NEC
28 June 2022

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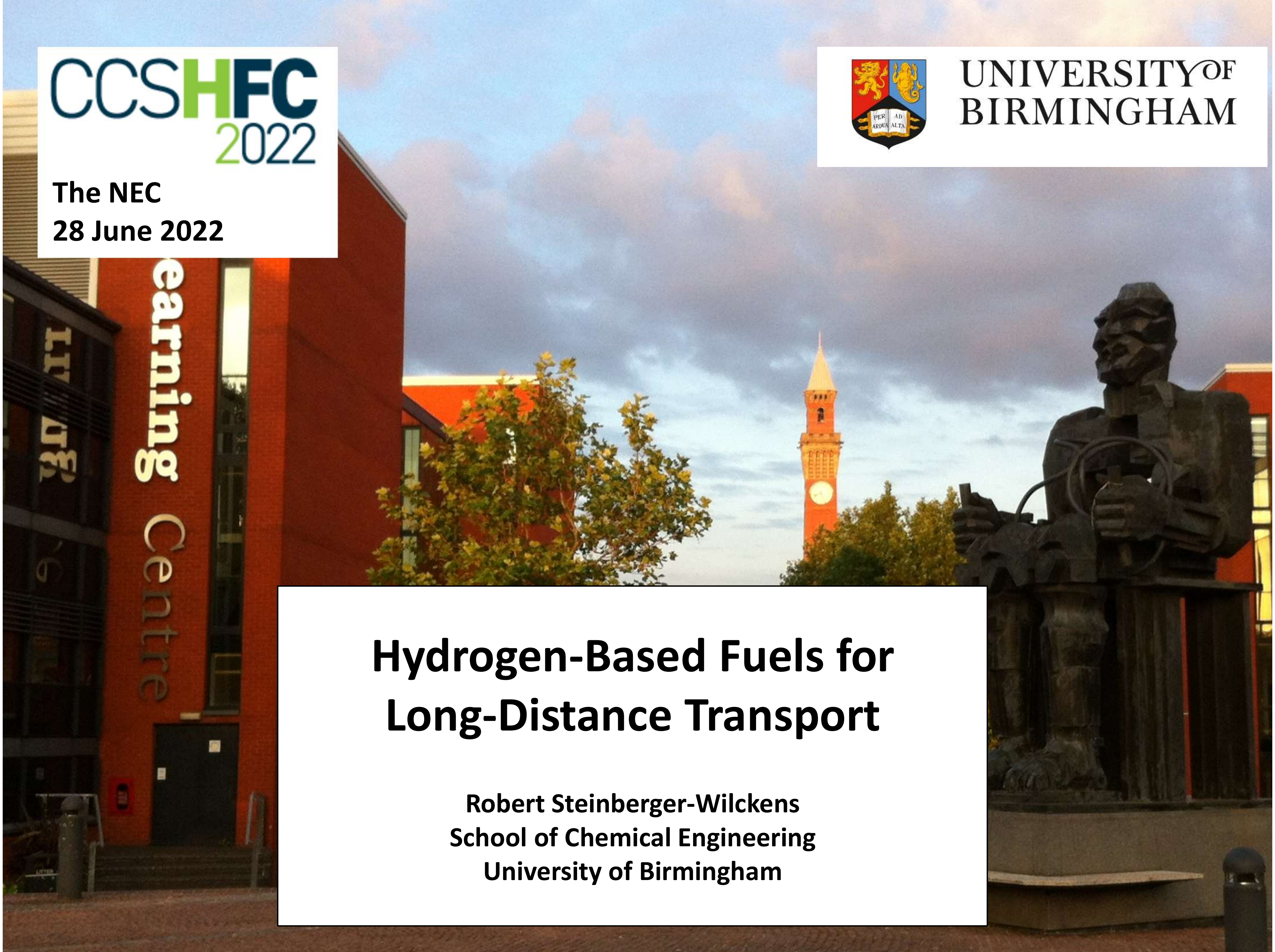
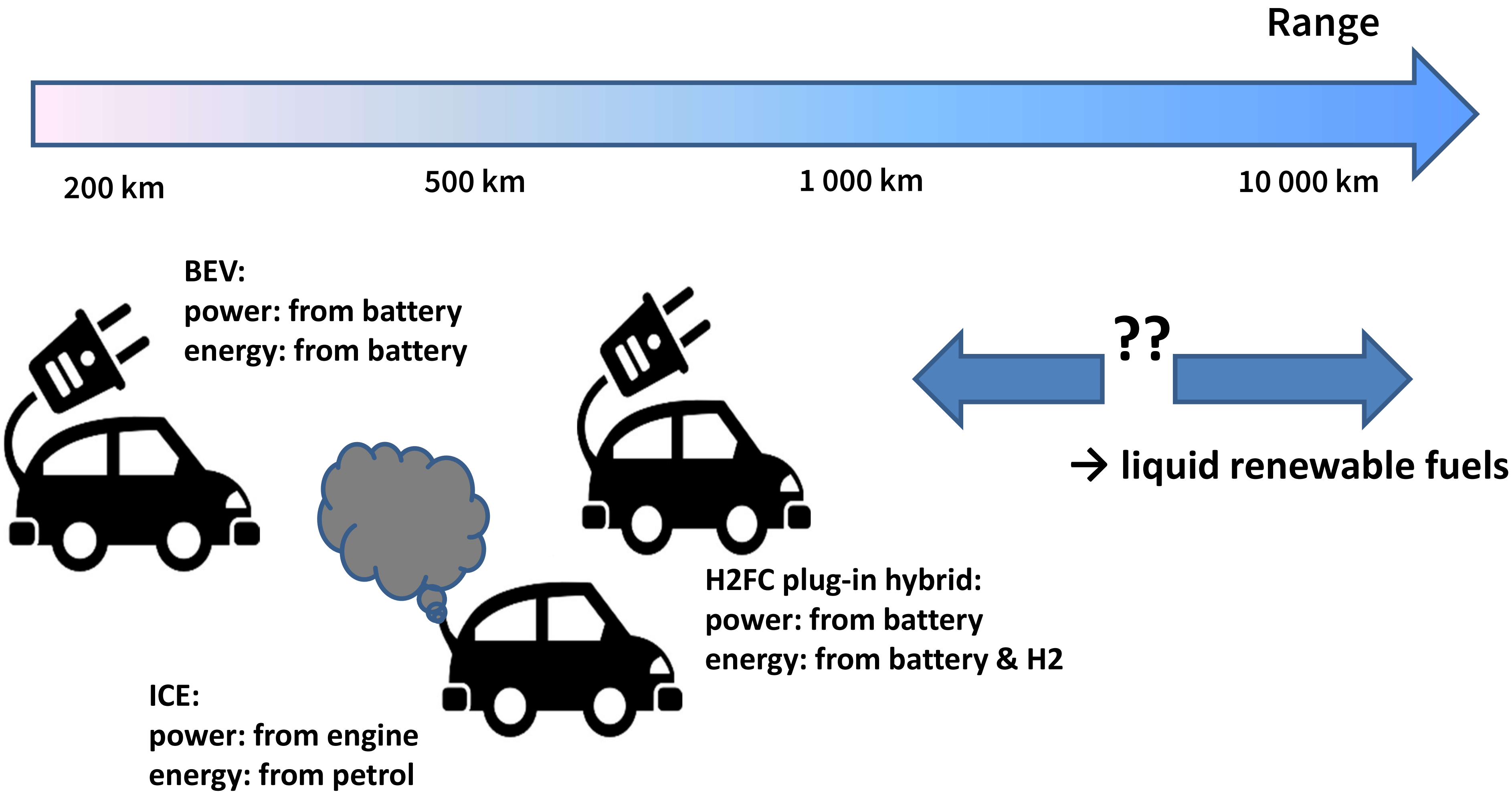


Hydrogen-Based Fuels for Long-Distance Transport

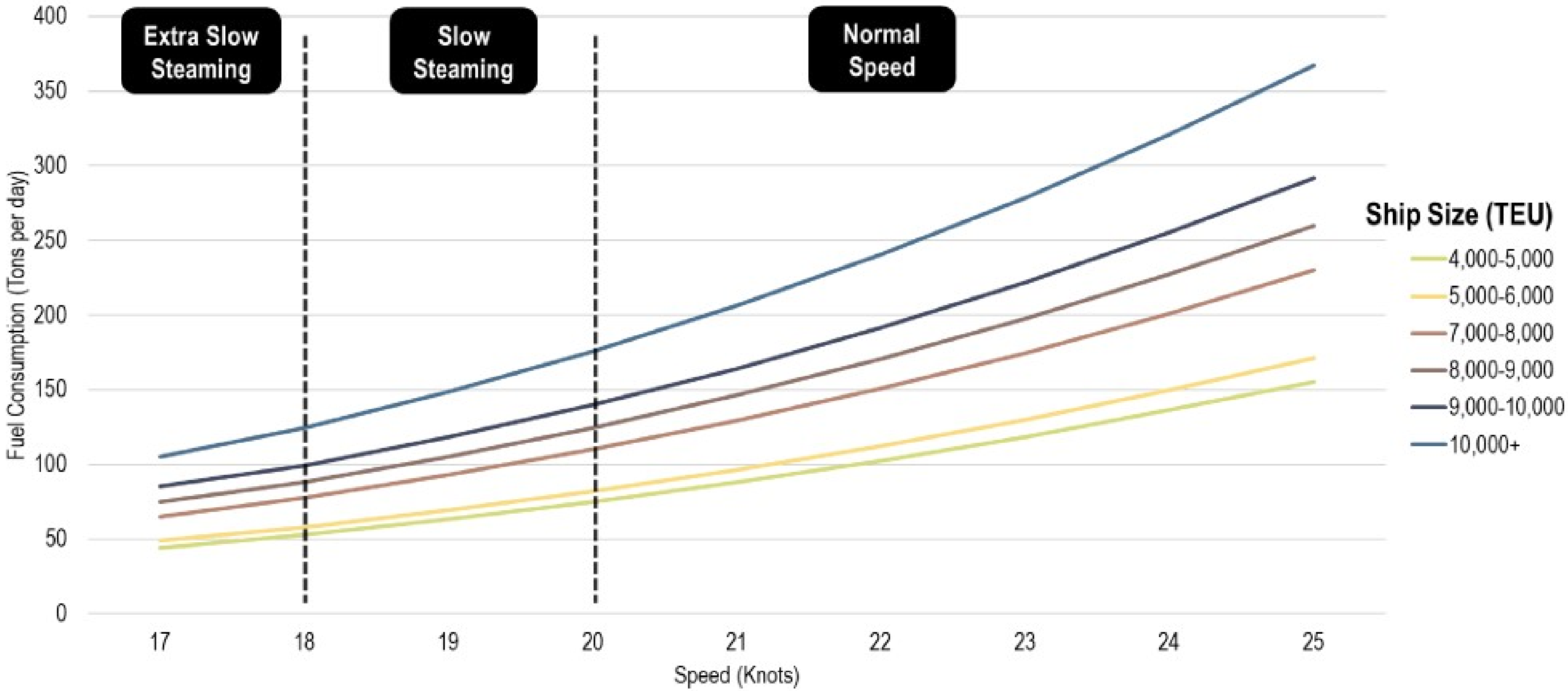
Robert Steinberger-Wilckens
School of Chemical Engineering
University of Birmingham

Electric Transport Solutions



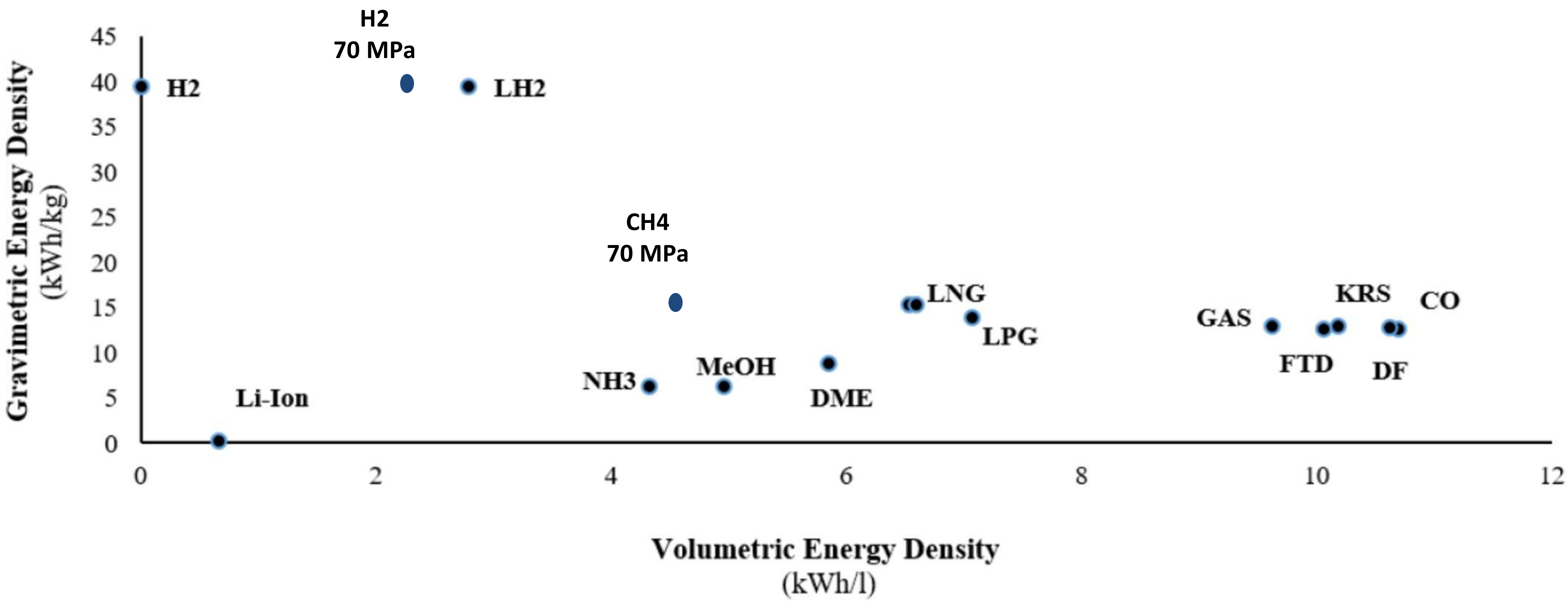
What Amounts of Fuel are we talking about?

- steaming distance 10 days, 150 to/dy, 16 500 MWh



source: transportgeography.org

Energy Density Comparisons



Where: GAS is gasoline, KRS is kerosene, DF is diesel fuel and CO is crude oil.

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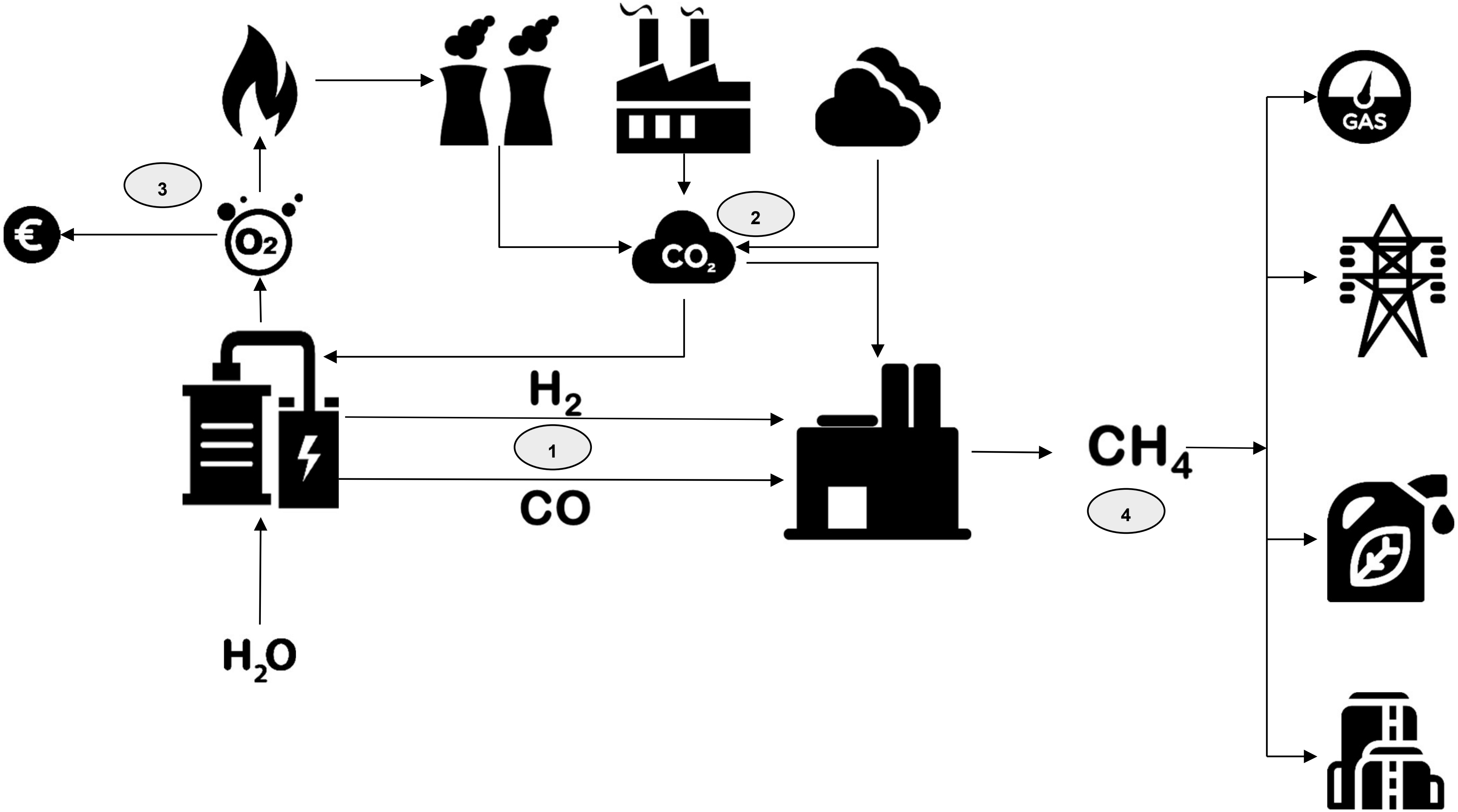
Comparison: Fuel Weight & Volume

- steaming distance 10 days, 150 to/dy, 16 500 MWh

	Boil. Temp. [K]	Heat.Val. [kWh/kg]	Heat.Val. [kWh/L]	Heat.Val. [kWh/ Ncbm]	bunker-volume [cbm]	Fuel weight [to]	
LH2	20	33	2.3	---	7000	500	
LSNG	111	14	6.3	---	3200	1200	
LNG	120	12.5	5.6	---	3500	1300	
H2	---	33	---	3	9900	500	**70 MPa**
CH4	---	14	---	9	8900	1300	**25 MPa**
NH3	240	5.2	3.2	3.9	5200	3350	
CH3OH	---	5.5	4.4	---	3750	3250	
M.Diesel	---	12	10	---	1500	1500	

Power to Gas from CCU



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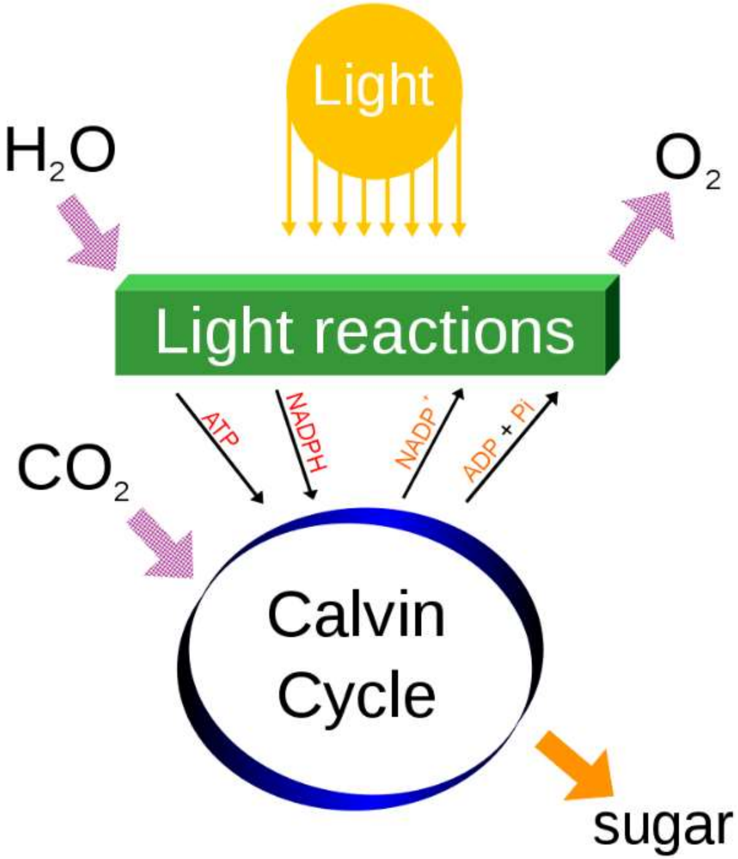
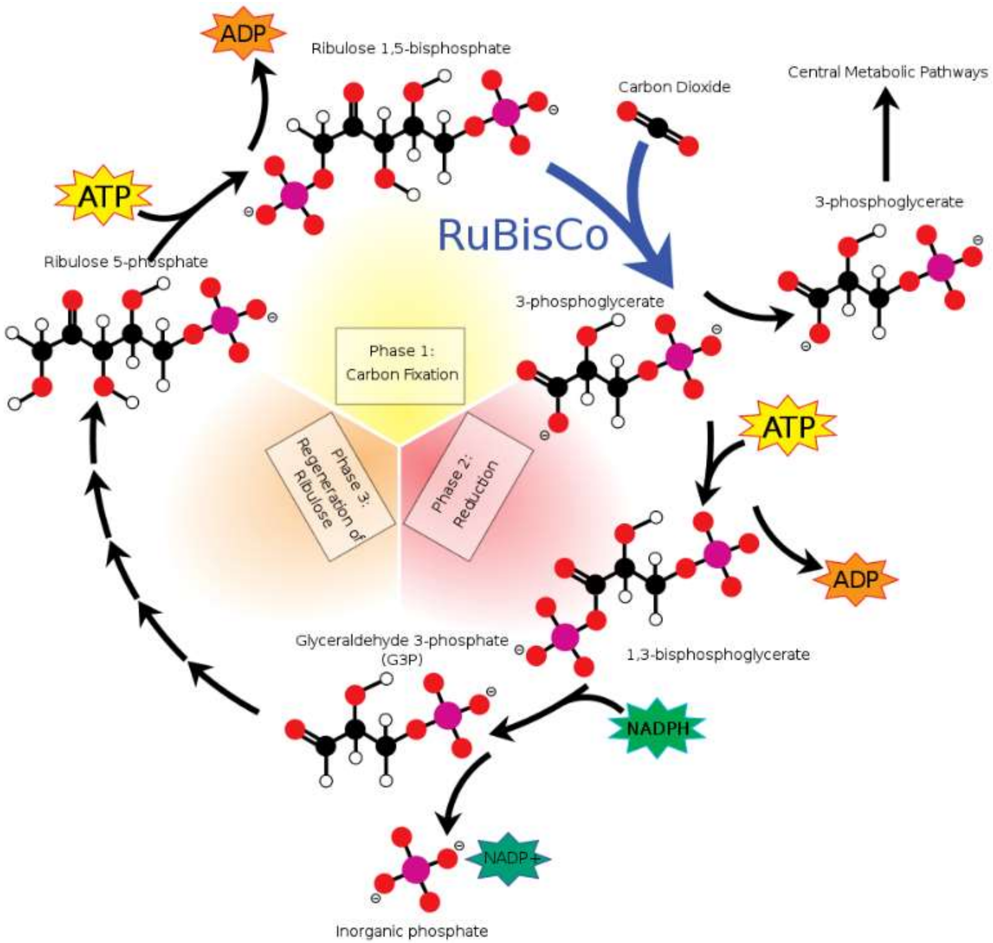
Mimicking Photosynthesis?





https://commons.wikimedia.org/wiki/File:Simple_photosynthesis_overview.svg
https://commons.wikimedia.org/wiki/File:Calvin-cycle4.svg

Turning Carbon into e-fuels

- Sabatier reaction

$$\mathrm{CO_{2(g)}} + 4\,\mathrm{H_{2(g)}} \rightleftharpoons \mathrm{CH_{4(g)}} + 2\,\mathrm{H_2O_{(g)}}, \qquad \Delta H^{\circ} = -164.7\ kJmol^{-1}$$

$$\mathrm{CO_{2(g)}} + \mathrm{H_{2(g)}} \rightleftharpoons \mathrm{CO_{(g)}} + \mathrm{H_2O_{(g)}}, \qquad \Delta H^{\circ} = 41.1\ kJmol^{-1}$$

$$\mathrm{CO_{(g)}} + 3\,\mathrm{H_{2(g)}} \rightleftharpoons \mathrm{CH_{4(g)}} + \mathrm{H_2O_{(g)}}, \qquad \Delta H^{\circ} = -206.0\ kJmol^{-1}$$

- methanol

$$\mathrm{CO_2} + 3\,\mathrm{H_2} \rightleftharpoons \mathrm{CH_3OH} + \mathrm{H_2O}$$

$$\mathrm{CO} + 2\,\mathrm{H_2} \rightleftharpoons \mathrm{CH_3OH} + \mathrm{H_2O}$$

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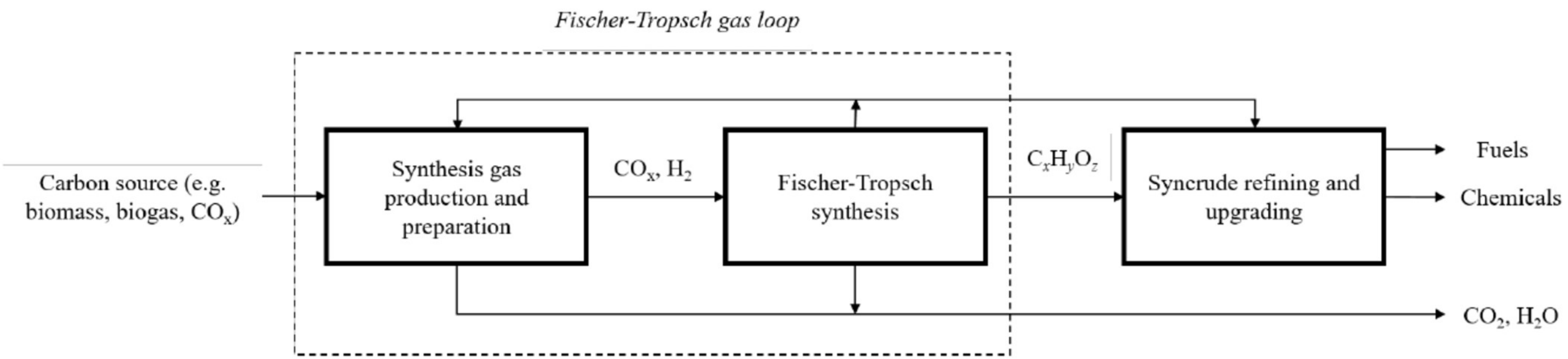
Turning Carbon into e-fuels (2)

- Fischer Tropsch reaction

$$nCO + 2(n + \xi)H_2 \longrightarrow CnH_{2(n+\xi)} + nH_2O$$

$$nCO + 2(n - \xi)H_2 \longrightarrow CnH_{(2n+1-\xi)}O + (n - 1)H_2O$$

where ξ is 0 or 1



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Critical Points of CCU

- Source of carbon:
  - needs to be non-fossil carbon
- Atmospheric carbon
  - effectively biomass
  - potentially DAC (energy balance and cost?)
  - other non-fossil (are they sustainable?)
- Yield of capture
- Circularity?

Sources of non-fossil Carbon

- Biogas
- Food industry
- Biomass conversion (biomass gasification, wood/biomass combustion)

Doubtful sources:

- Cement industry
- Waste gasification / incineration

The Cycle of Zero-Carbon Methane

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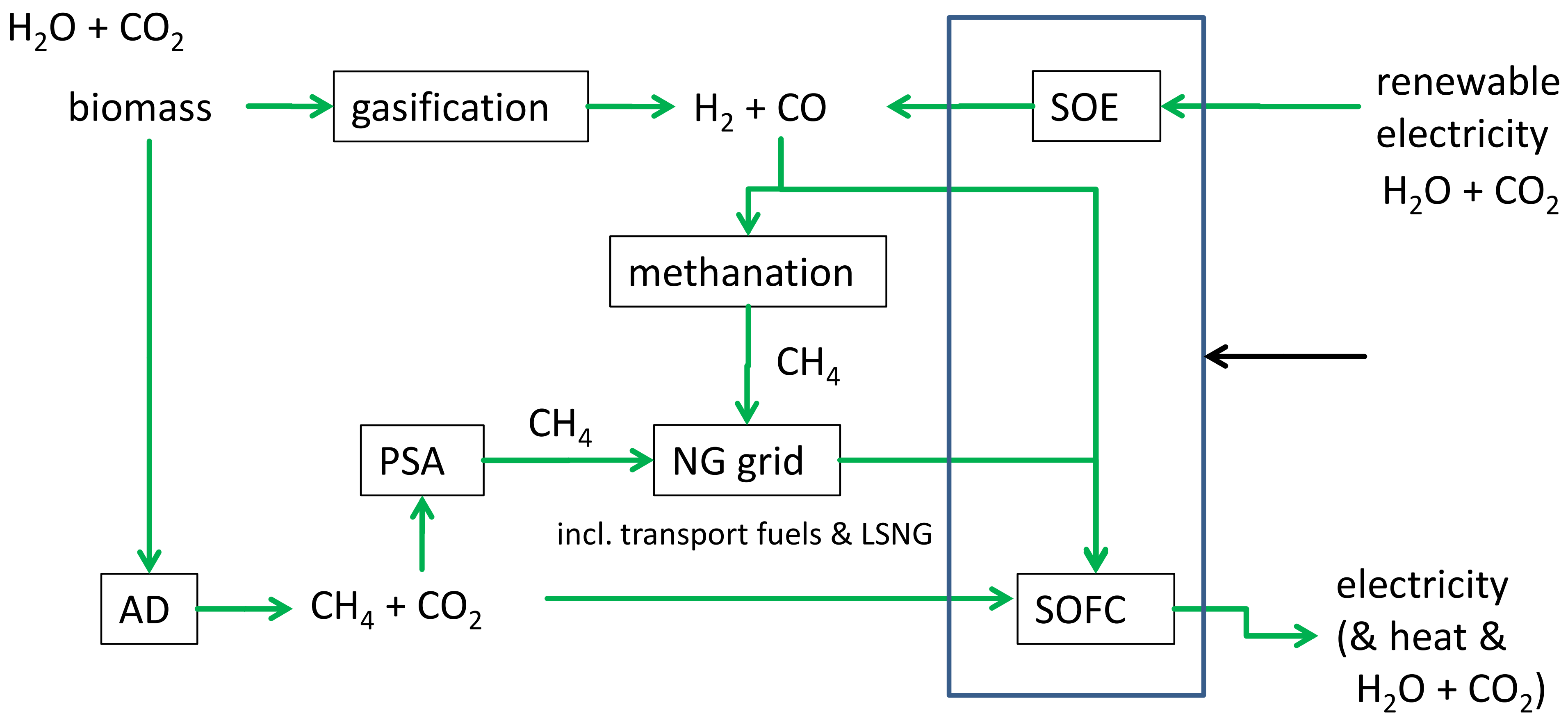
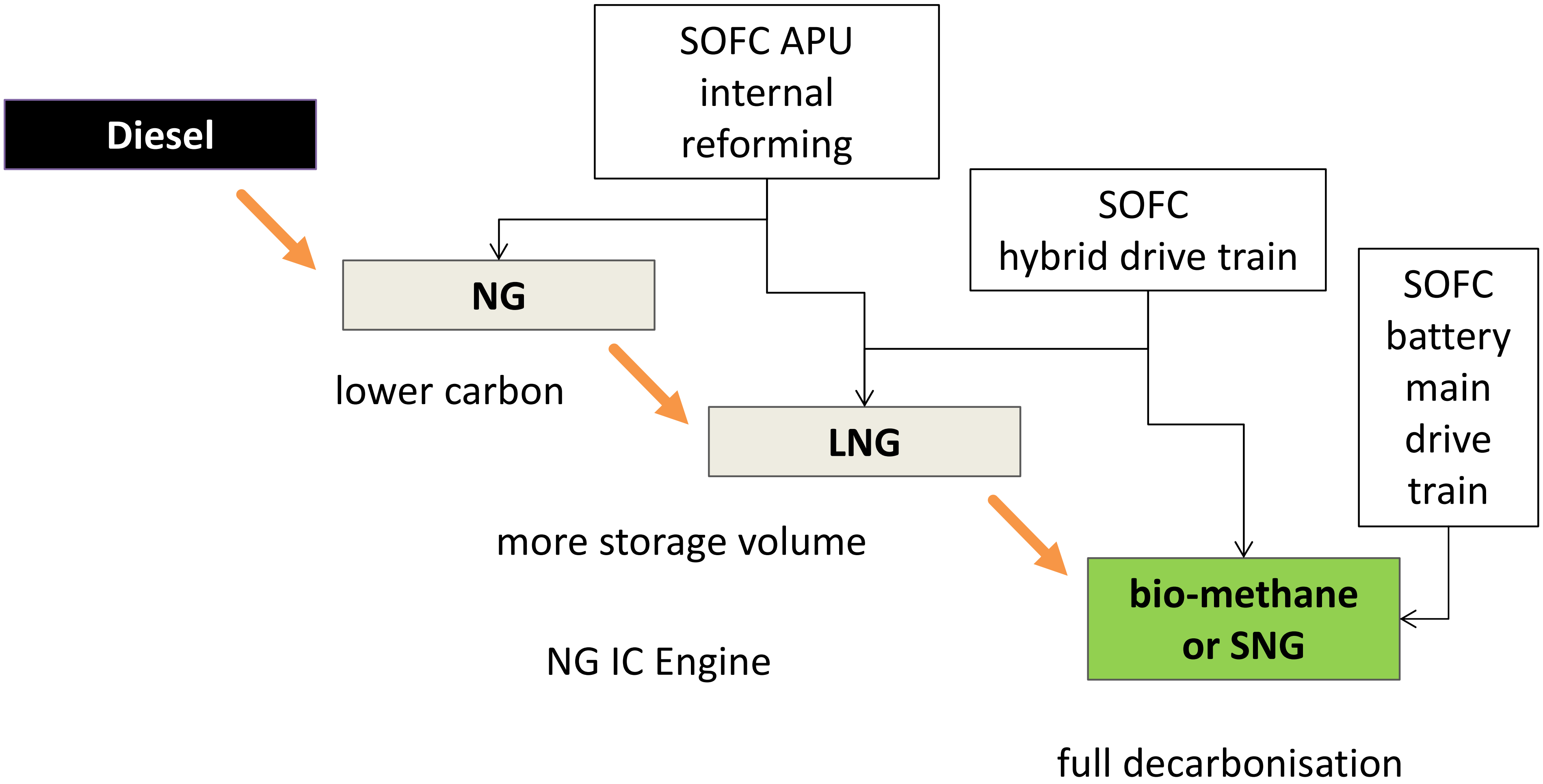


supplies synthetic natural gas for stationary applications and transport fuels without any fossil carbon conversion involved

HT Fuel Cell Propulsion for Freight Road Transport (HDV/HGV), Rail, Aircraft, and Maritime Applications



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Summary Conclusions

- Volume and handling of the amounts of hydrogen required for long-distance will cause issues
  - cryogenic hydrogen – handling and energy demand
  - 70 Mpa hydrogen - volume
- Further ‘compression’ by ‘carbonisation’
- Hydrocarbons require higher temperature for condensation, thus more easily liquified and more dense
- Non-fossil hydrocarbons require non-fossil carbon sources
- Conversion losses can be compensated for by use of ‘hydrogen carriers’ in Solid Oxide Fuel Cells
- Use of non-fossil hydrocarbon energy vectors is fully compatible with the current energy system and infrastructure and avoid part of additional investment

Upcoming events:

JESS 2022 – Joint European Summer School,
11 to 15 & 18 to 22 Sept 2022,
Athens

www.jess-summerschool.eu

JESS

Thank you for your Attention!

Any Questions?

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