Framing the story of decarbonised transport
(Warning: contains fuels)

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Decarbonisation of transport

- Possibly the most difficult aspect of climate change mitigation
- Lack of attention (electricity, electricity, electricity)
- Many confusing aspects/arguments around the problem:
  - King BEV: Battery electric vehicles will solve the problem
  - McKinsey curve argument: important, but not yet
  - Mixing resource crisis (peak oil) with environmental crisis (climate): Oil price fantasy vs. cost dynamics
  - Intricate sustainability issues: biomass as an umbrella term
  - Alternative or drop-ins? (ethanol, hydrogen, methane, DME, FT-diesel, MTG-gasoline)
  - Different applications of Power-to-fuels operate under different logic and economic boundary conditions
    - Energy storage solution
    - Energy system management solution
    - Transportation fuel solution
Global transportation energy demand in 2050

[Bar chart showing energy demand in 2009 IEA Demand, 2050 IEA Baseline Demand, and 2050 IEA 2DS Demand for different modes of transportation: Rail, Sea, Air, Heavy road, Light road, and the energy values for each category.]
Global transportation energy demand in 2050

Global transportation energy demand in the reference year 2010 (data currently from 2009)
Global transportation energy demand in 2050

IEA baseline estimate for transportation energy consumption in 2050 is 161 EJ/yr.
Global transportation energy demand in 2050

IEA estimate for transportation energy demand in 2050 that is consistent with 2°C scenario is 99 EJ/yr. (2357 Mtoe/a)
Global transportation energy demand in 2050

Global transport emissions in 2010 were 8 GtCO$_2$-eq/yr

To achieve 80% reduction (relative to 2010), 2050 emissions < 1.6 GtCO$_2$-eq/yr
Global transportation energy thought experiment*

”Though Experiment” created to highlight energy supply needs in 2050.

*Adapted from Larson et al. 2012
Global transportation energy thought experiment*

To cap emissions to **1.6 GtCO₂-eq/yr**, only **19 EJ/yr** Crude Oil Derived Products (CODPs) allowed. Balance needs to come from carbon-neutral electricity & fuels

*Adapted from Larson et al. 2012*
Scenario "IEA BEV" (BEV = Battery Electric Vehicle) is based on IEA 2050 estimate on transportation electricity demand: 9 EJ/yr.

*Adapted from Larson et al. 2012*
Whatever the balance of 74 EJ/yr will be, it needs to fulfill two requirements:
1) Be a fuel
2) Be carbon-neutral

*Adapted from Larson et al. 2012
Scenario "Max BEV" assumes complete electrification of the light road sector.

*Adapted from Larson et al. 2012
The need for carbon-neutral fuels in this scenario is 36 EJ/yr

*Adapted from Larson et al. 2012*
Carbon-neutral synfuels

Indirect recycling of atmospheric carbon --->

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Audi E-gas Plant

- Location: Werlte, GER
- Start-up: 2014
- Electrolysers: 6.6 MW electricity input
- End product: 3.6 MW methane
- (fuel for about 1500 CNG cars)
- Investment: 20 M€
- Runs during ”excess” VRE production
- Annual operating hours: 4000 h
CRI Georg Olah Renewable Methanol Plant

- Location: Iceland
- Start-up in 2012 with one 1.9 MWe electrolyser
- Start-up in 2015 with two more electrolysers (combined 5.7 MWe).
- CO2 from geothermal power station (steam contains about 10% CO2)
- End product: 4 000 t/a methanol
GoBiGas Biomethane Plant

“World’s first plant producing biomethane via gasification”

- Location: Gothenburg, Sweden
- Start-up: 2013
- Investment: 149 M€

Capacity:
- 30 MW biomass input
- 20 MW methane output

Biomethane injected to Sweden’s natural gas grid and used as vehicle fuel, feedstock for process industry and fuel for CHP or heat production

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Historical development of unsubsidised Levelised Cost of Electricity (LCOE, $/MWh) and synthetic methane production (LCOF, $/MWh). Electricity cost data from Lazard (2015). CCU-fuel plant directly connected to electricity generation plant assuming following capacity factors: 40% for On-Shore Wind, 25% for Utility-Scale Solar PV (crystalline), and 90% for nuclear. For all synfuel plants: WACC 7%, and economic project life 25 yr. For synthetic biomethane plant: biomass residues 100 €/t\_dry, availability 8000 h/a.
CAPEX contribution to production cost, $/BOE
CO2 intensity of CCU-fuels

- Fossil fuel comparator
  \[ \approx 85 \text{ gCO2/MJ} \]
  \[ (300 \text{ gCO2/kWh}) \]
- RED demands minimum 60 % GHG reduction:
  emissions < 34 gCO2/MJ
  \[ (122 \text{ gCO2/kWh}) \]
- Assuming 50% overall eff.
  --> electricity < 17 g/MJ
  \[ (61 \text{ gCO2/kWh}) \]
"The CCU-fuel trilemma"

- **Direct connection** to wind/solar ensures carbon-neutral product, but prices soar due to limited operational hours
- **Grid connected** CCU-plants solve availability problems but require *fully* decarbonated grids (Iceland, Quebec, Nordics?)
- **Peak levelling** using power-to-fuels technology is low-carbon, but modest impact towards 36 – 74 EJ/yr supply target
Indicative requirements for electricity and CO2

Numbers relative to combined global nuclear and renewable electricity generation, and global energy related CO2 emissions in 2012.
Closing thoughts

• World is going to a more CCU-fuels friendly direction
  – Climate change accelerates (Cost of emissions up)
  – Cost of VRE likely to decrease in the future as well
  – Break-even point closing in
• Global impact possible only after major grids decarbonated
• Large-scale supply of CCU-fuels might remain expensive (relative to crude oil)
  – Cheap RE somewhere doesn’t mean cheap RE everywhere
  – Displacement of petroleum before peak oil will be expensive
• The need for carbon-neutral fuels is real: You got to start somewhere
  – Harness best places first (might not be in Europe?)
  – Monetising stranded VRE reserves, but co-location of concentrated CO2 possibly a problem?
Thank you for your attention!