Overall HYGCEL research presentation

HYGCEL WP2 T2.2 Results from transportation feasibility studies

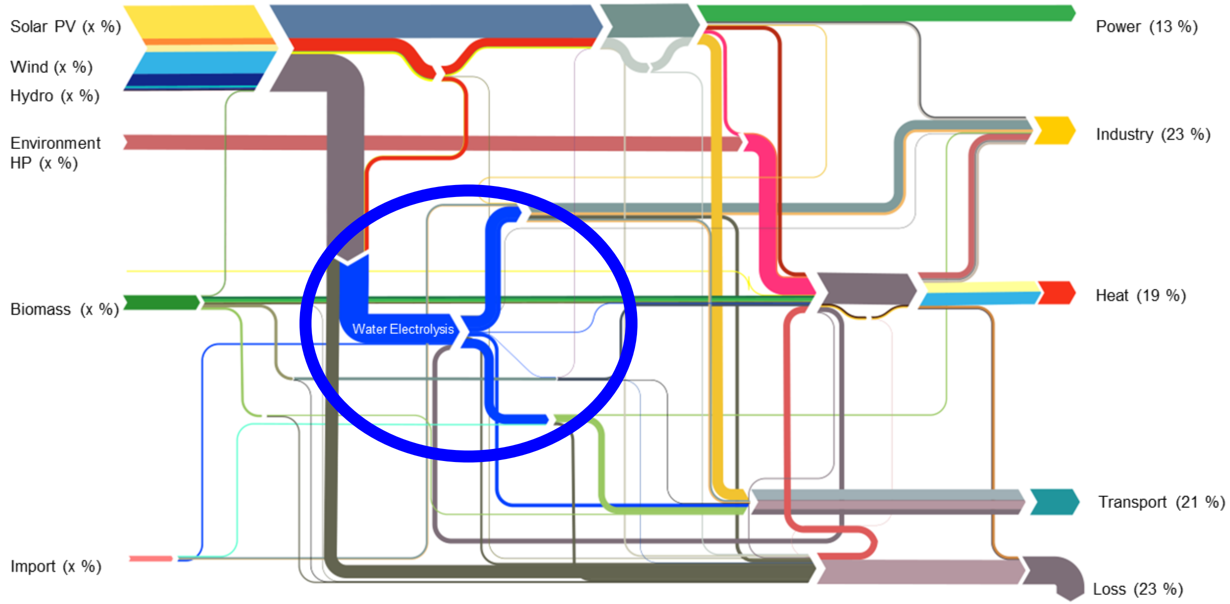
HYGCEL final seminar
Lahti, October 1, 2024

The role of hydrogen in the value chain and a transportation case example “Southeast-Ostrobothnia”

Topics of this presentation

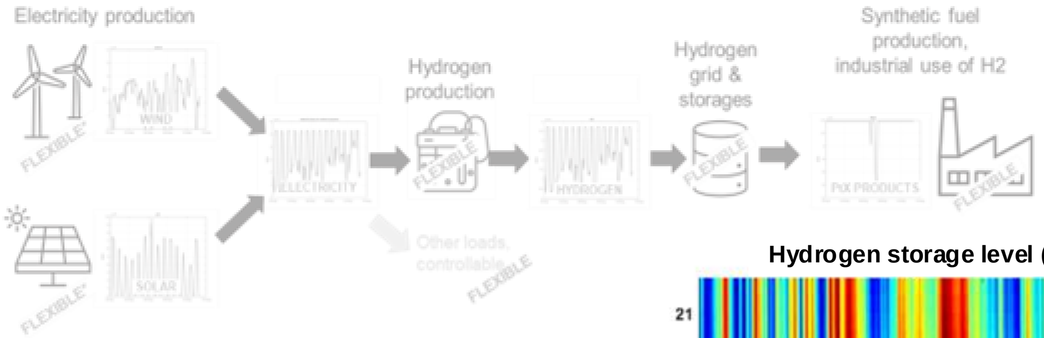
- The role of hydrogen in the energy system
- Feasibility of hydrogen transportation
- The transportation case Southeast-Ostrobothnia
- Challenges and opportunities for chemicals in Europe

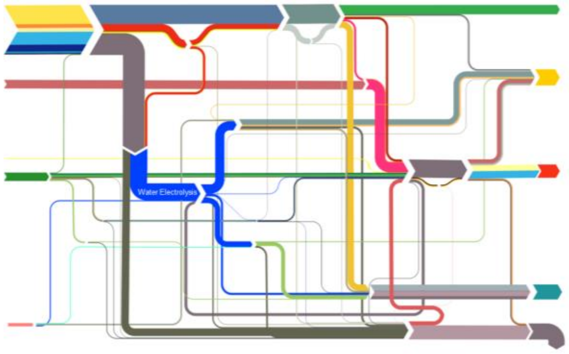
Role of Hydrogen in the Value Chain

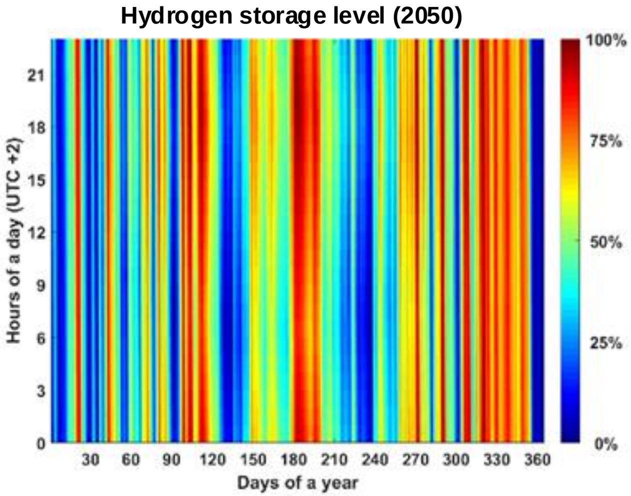


- **Hydrogen** is **important for applications** that cannot be directly electrified: e-fuels, e-chemicals, e-materials
- The **value chain** is complex and comprises several steps, such as electricity generation, transport, and **hydrogen** and final product production
- By far largest share of **hydrogen** is as an **intermediate** product for the **final** product, such as ammonia, methanol, kerosene jet fuel
- **Final products** are easier to transport as **hydrogen**

Flexibility provided by hydrogen storage

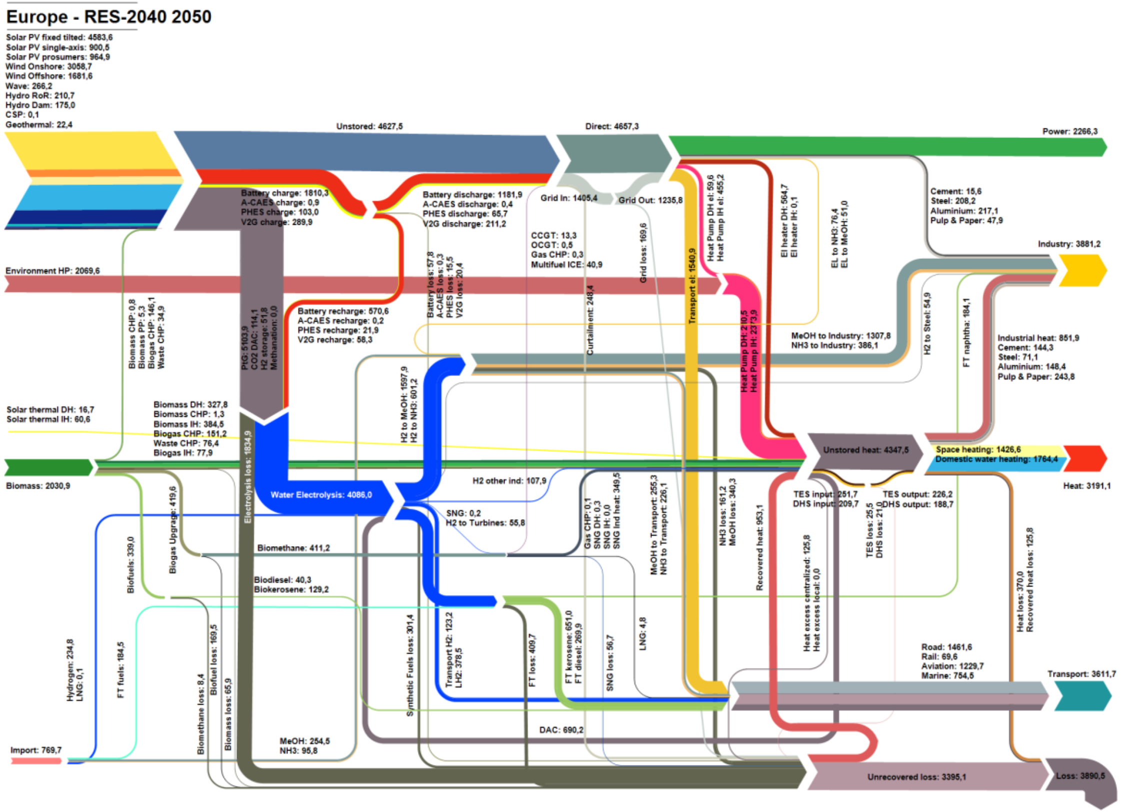






- Hydrogen storage **connects variable** renewable **electricity** with less flexible **demand** profiles such as PtX production
- Hydrogen storage **buffers** the low-cost renewable electricity for times of demand
- The **flexible** hydrogen storage for PtX production enables massive **additional benefits** for the **energy system**, avoiding inefficient and costly overdimensioning of renewable generation capacities.

Power-to-X Economy as new characteristic Term



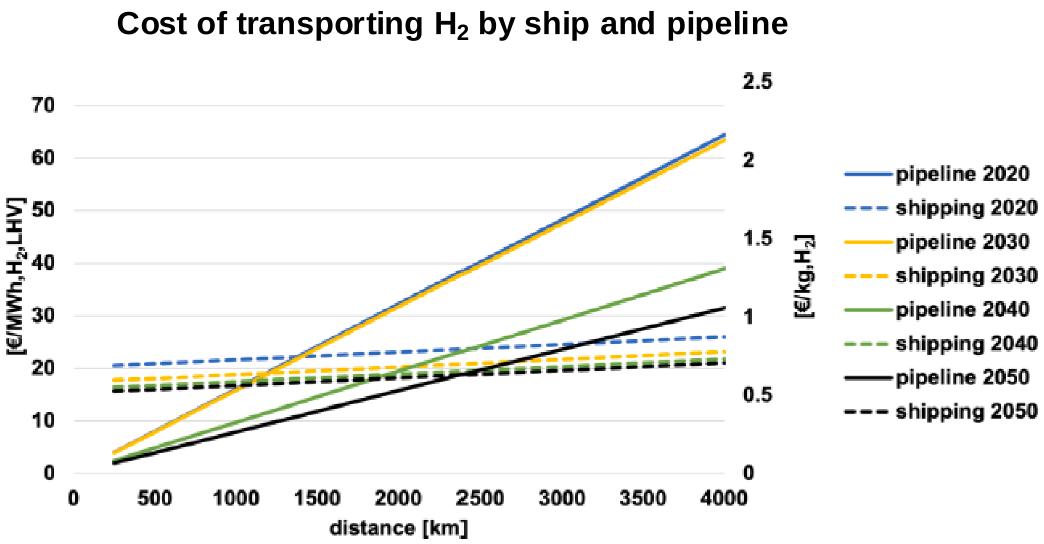
- Zero CO_2 emission low-cost energy system is based on electricity
- Core characteristic of energy in future: Power-to-X Economy
  - Primary energy supply from renewable electricity: mainly PV plus wind power
  - Direct electrification wherever possible: electric vehicles, heat pumps, desalination, etc.
  - Indirect electrification for e-fuels (marine, aviation), e-chemicals, e-steel; power-to-hydrogen-to-X

Source:
Power-to-X economy: Breyer, Bogdanov, Ram, Khalili, Lopez, et al., 2023, Progress in Photovoltaics

Breyer et al., 2024, International Journal of Hydrogen Energy

Diagram: Greens/EFA, 2022
scenario: RES-2040 for 2050

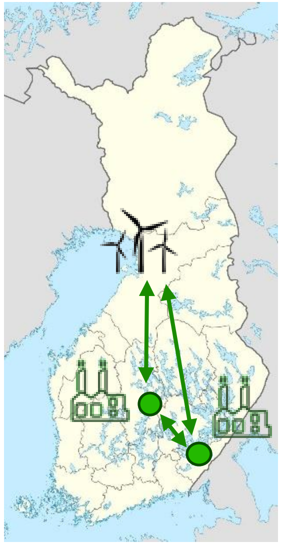
Analysing transport costs



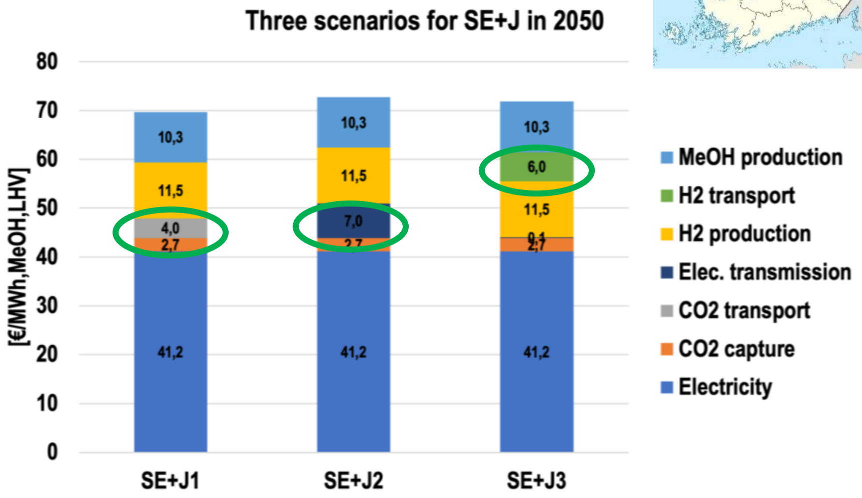
- **Transportation of final PtX products is more attractive than transportation of H_2**
  - 2000 km **hydrogen** transport by pipeline: about 15-20 €/$MWh_{H2,LHV}$
  - 2000 km **ammonia** transport by ship: about 1.5-2 €/$MWh_{NH3,LHV}$
- **Short distance** hydrogen transportation is **feasible**, whereas **long-distance** transportation might **not** be **attractive**
  - Short distance (several 100s km) transport is no cost burden
  - Long distance (> several 100s km) **transport** chains for hydrogen are **unlikely** due to high cost … it also means that Europe may not import hydrogen by ship from overseas

- Source: Galimova et al. (2023a; 2023b)
- Impact of international transportation chains on cost of green e-hydrogen: Global cost of hydrogen and consequences for Germany and Finland
- Feasibility of green ammonia trading via pipelines and shipping: Cases of Europe, North Africa, and South America

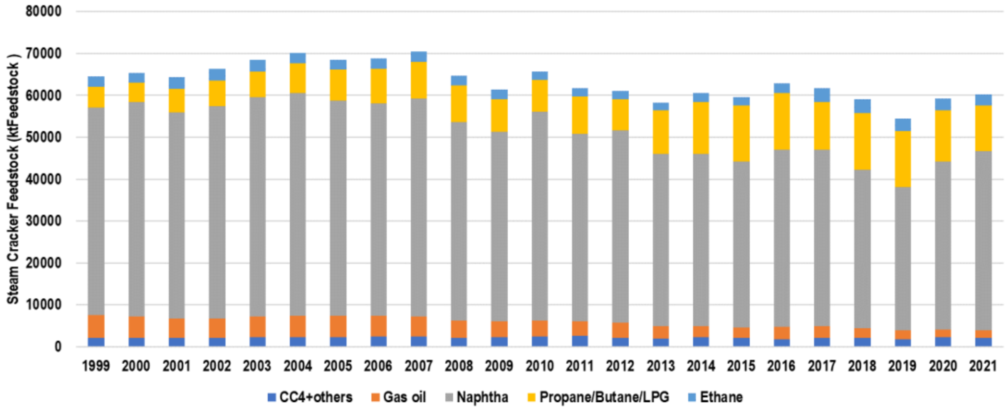
Transport case – Southeast - Ostrobothnia

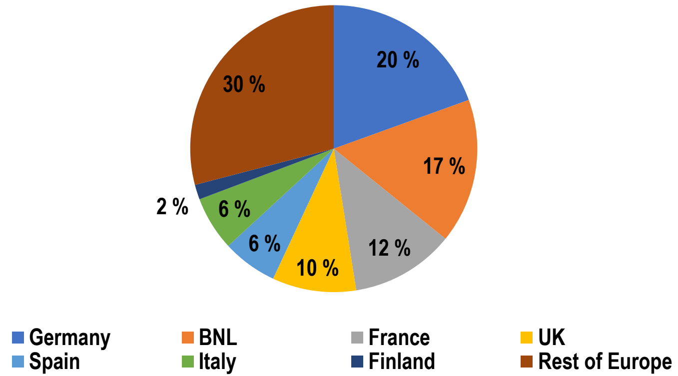


- Several **industrial cases involve** electricity and/or hydrogen **transmission** from wind sites to bio-CO_2 sites, or CO_2 transport from CO_2 sites to a wind site.
- We studied methanol production for the case of Finland combining **best wind resources in North Ostrobothnia** and **bio-CO_2 in the southeast**.
- **CO_2 transport** seems to be the **least cost** transport option.
- Transporting **H_2** or **electricity** cost almost the same, but **power lines** have **multiple valuable roles** in an **electrified energy system**.
- Despite slightly higher cost **sending the energy to Southeast Finland may be still attractive** for regional industry policy reasons.



Background: Current Ethylene Production Landscape in Europe

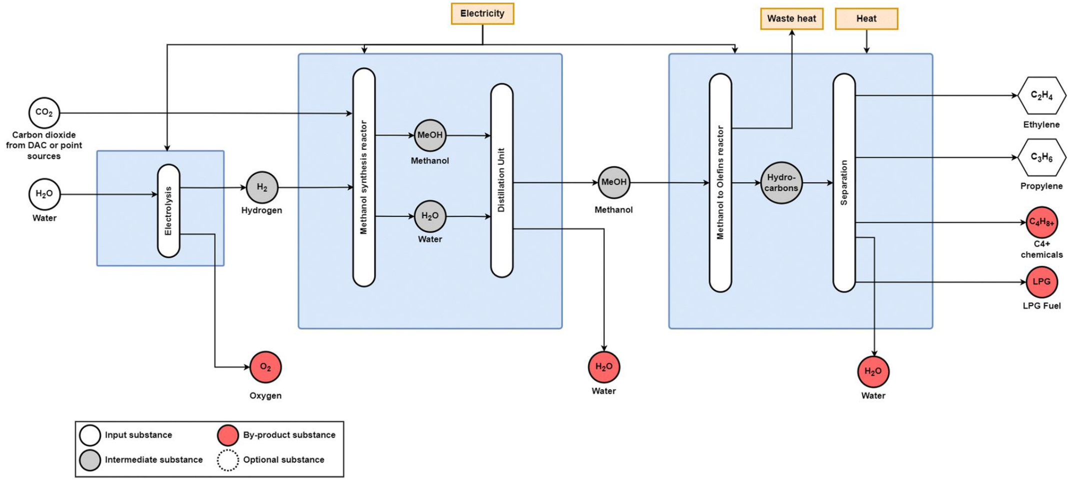




- Chemical production in the EU was responsible for 925 $MtCO_{2eq}$ in 2020 globally, and is the third largest emitting sector in the EU
  - Emissions have been reduced by 55% relative to 1990
  - Due to embedded carbon, only ~20% of emissions come from process emissions, as majority are related to fossil fuel combustion
  - EU targets to be climate neutral include both direct and indirect emissions
- Ethylene is most produced chemical with total production capacity of 23.5 MtC_2H_4, with naphtha as the dominating feedstock
- Germany and Belgium and the Netherlands have 37% of all EU steam cracker capacities

- Source: Lopez et al. (2024)
- Assessing European supply chain configurations for sustainable e-polyethylene production from sustainable CO2 and renewable electricity Impact of international

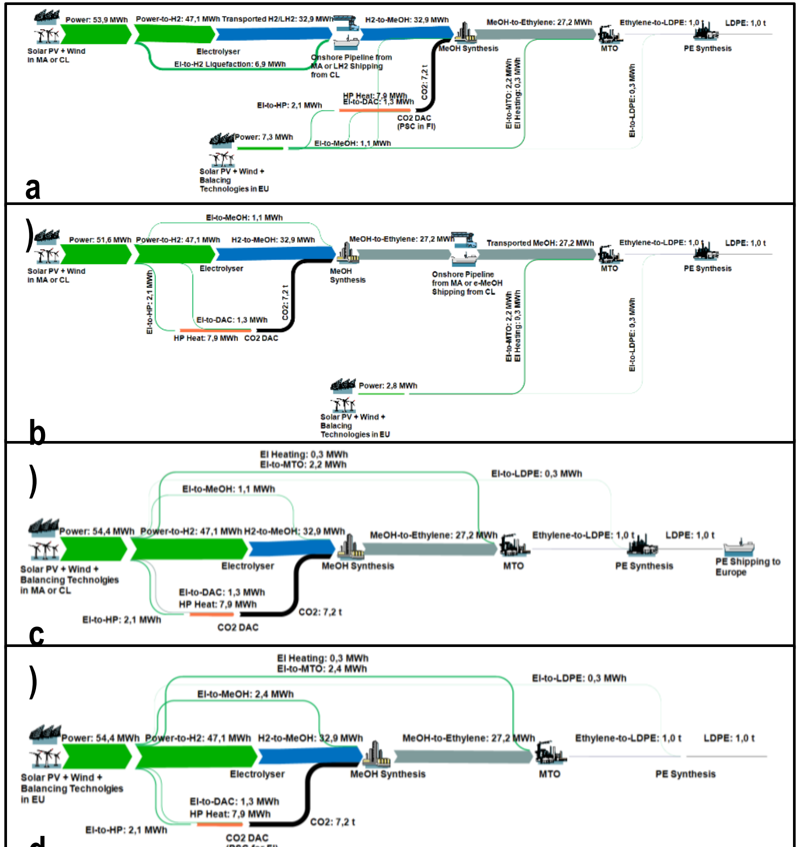
Background: Green Ethylene Alternatives



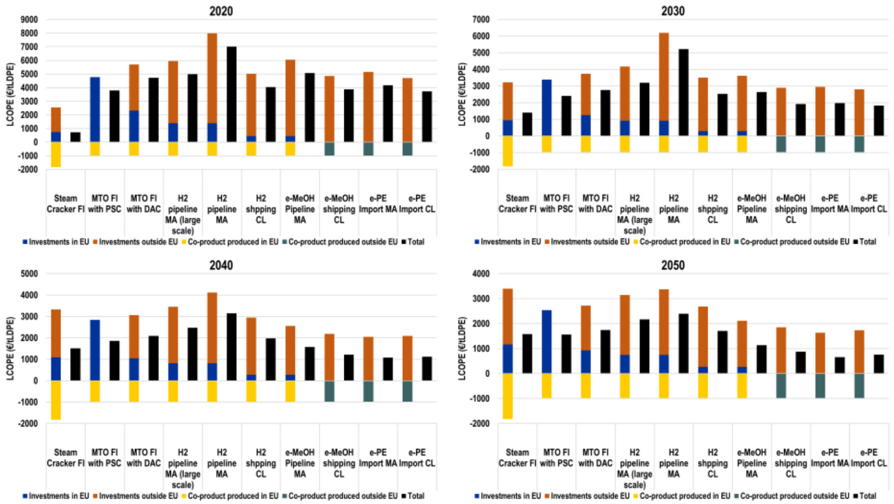
- **Primary routes to defossilise ethylene production include:**
  - Biomass-based polyethylene
  - Electricity-based polyethylene
- **Many processes, including methanol-to-olefins (MTO), Fischer-Tropsch synthesis-to-olefins, and oxidative coupling of methane can use both biomass- and electricity-based feedstocks**

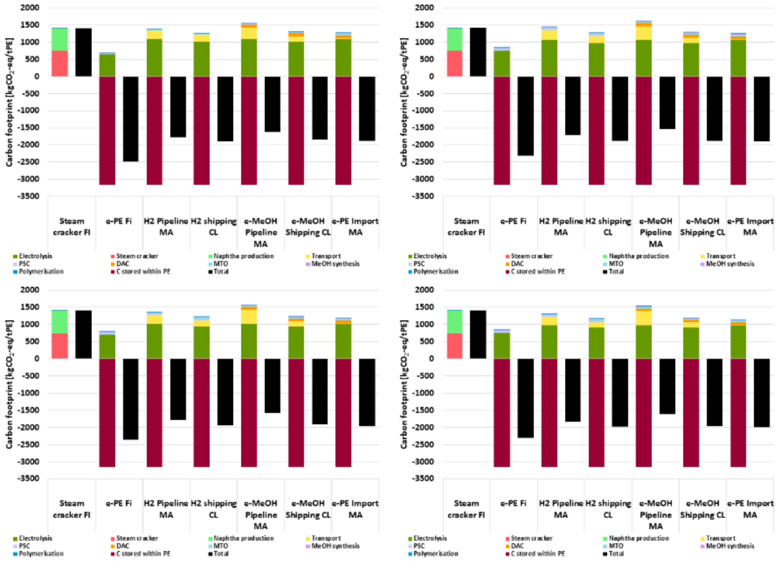
Methods: System Definition for Case Study

- **Four configurations studied:**
  - e-Hydrogen imports from Morocco or Chile
  - e-Methanol imports from Morocco or Chile
  - e-PE imports from Morocco or Chile
  - Full local e-PE production in Europe
- **Hydrogen storage and electricity balancing components including battery and hydrogen gas turbines used to operate the H-DR and EAF at 8000 h/a**
  - Salt cavern hydrogen storage used in Germany, Belgium and the Netherlands, Spain, and Morocco
  - Rock cavern hydrogen storage used in Finland and Chile
- **Direct air capture of CO_2 used in Germany, Belgium and the Netherlands, Spain, Morocco, and Chile**
- **CO_2 point source capture from a pulp and paper plant used in Finland**



Results: Levelised Costs of e-PE for Finland





- LCOPE highest in Finland of the case countries considered
  - However, hydrogen imports still consistently see higher LCOPE
- Import of e-methanol and e-PE most appealing for Finland
  - e-PE imports are 72-78% of local LCOPE in 2030 and decrease to 43-49% in 2050
  - e-Methanol imports similarly attractive at 76-104% of local LCOPE in 2030 and 53-68% in 2050
- Impact of pipeline transportation on carbon footprint most noticeable due to high pipeline requirements

Discussion: Main Findings

- With GHG pricing mechanisms, e-PE imports in Europe from Morocco and Chile as well as local e-PE production in Spain are the lowest cost e-PE supplies starting in 2040
  - Cost of fossil PE could be increased if total life-cycle emissions were considered
- Results from Spain suggest that e-PE can be produced at competitive prices compared to imports
  - Germany, Belgium and the Netherlands are area limited
  - Finland, though slightly more expensive, could expand production and serve as export option within Europe
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  - Next 10-15 years are an important window of opportunity
- Affordable hydrogen is the key factor in reducing costs for chemical production
  - Locally produced green hydrogen is cost-competitive with imports from regions with the best solar and wind resources
- e-Methanol feedstock business maybe in strong competition among the regions of low hydrogen production costs

Thank you for your attention …

… and to the team!

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