# Leveraging Sector Couplings within a Hydrogen Valley to Advance Sustainability Goals: Case BalticSeaH2

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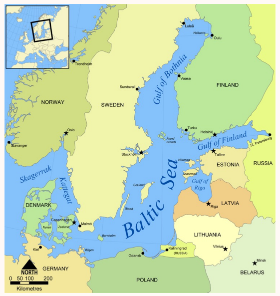
## Abstract

The European Union has set itself an ambitious goal of becoming the world's first climate-neutral continent by 2050. One of the backbones in this green transition is to leverage green hydrogen as a versatile energy carrier that can be utilized for hard-to-electrify sectors, such as maritime transportation or steel industry. Sector couplings, e.g., using excess heat for district heating or getting CO2 from biogenic sources, play a critical role in making green hydrogen a viable alternative. In this paper, we study a EU-funded BalticSeaH2 project and the potential of sector couplings within the regional hydrogen valley being built in it. First, we build a system-dynamic model of the green hydrogen value chain encompassing supply and demand of green electricity, hydrogen, main derivatives, and with support for key sector couplings. Second, we run a simulation using Finland as a case example to study the impact and potential of sector couplings for realizing the green hydrogen market and eventually for lowering CO2 emissions. Our work contributes to the energy systems modeling by building a model of the green hydrogen value chain that takes into account sector couplings and offering a draft estimate of their potential in a regional hydrogen valley.





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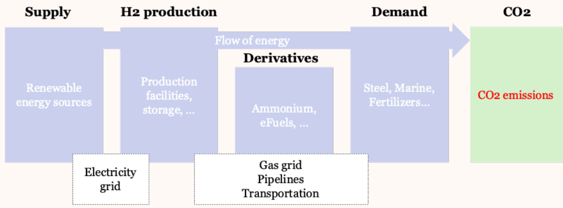
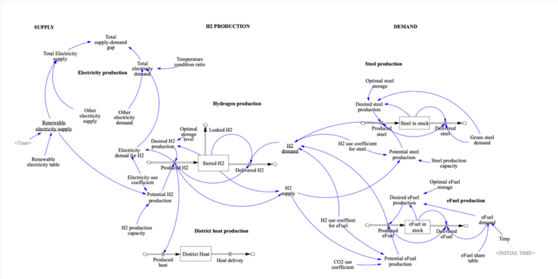
## Hydrogen valley model




**Supply** subsystem models renewable electricity production that is used for H2 production. **H2 production** subsystem models hydrogen production, storage, and delivery for users. **Demand** subsystem models two use cases for H2: green steel production and eFuel. (cf. Healthcare model in Duggan 2016)




- Renewable electricity supply provides electricity for green H2 production and excess supply for other uses (total electricity demand)
- H2 production is defined in the model as a minimum function of desired H2 production (based on the demand and the quantity of stored H2) and potential H2 production (based on the supply of renewable electricity and production capacity)
- Green steel production and eFuel production are defined similarly with minimum functions of desired production (based on assumed demand scenarios) and potential production

### Sector couplings

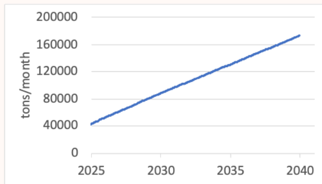
- The model includes also district heat that is produced as a side stream of H2 production based on the utilization rate of 14% presented in Roest et al. (2023)
- Potential production of eFuel depends also on the supply of CO2

## Simulation results

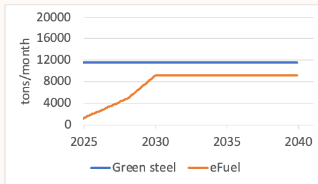
Our simulated scenarios for Finland use Fingrid's and Gasgrid's forecasts for renewable electricity production as an input (we picked moderate scenario)

- The estimated renewable electricity production in Finland is 22.4 TWh in 2024
- Furthermore, we used estimates of renewable electricity demand for green H2 production during years 2030 (58 TWh) and 2040 (114 TWh)

**Potential H2 supply**

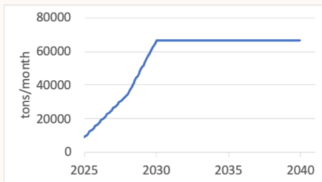



**Demand by green steel and eFuel**

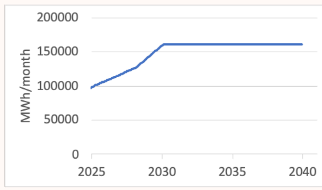



- Contemporary electrolyzers need 55 MWh electricity for producing one ton of H2
- One green steel plant produces 233,000 tons of steel monthly, which requires approximately 11,650 tons of H2 (i.e., 50 kg of H2 for 1 ton of steel)
- Assuming a second steel plant and doubling the share of H2 in fuels would not even use the projected renewable energy growth by 2030

**CO2 demand by eFuel**




**Excess heat from electrolysis**




- Producing 1 liter of eFuel requires 0.5 kg of hydrogen and 3.6 kg CO2 (D'Adamo et al., 2024). This means that roughly 1 ton of hydrogen is enough for producing 2000 liters of eFuel, whereas 1 ton of CO2 is enough for producing 278 liters of eFuel.
- Estimated yearly CO2 emissions from pulp mills in Finland are currently 2 million tons per month, which exceeds multiple times the CO2 demand for eFuel production
- The total consumption of district heating in Finland in 2022 was around 2750 GWh per month. Our scenario estimates 150 GWh excess heat per month.

*There is a vast potential for producing green H2 also for other uses in Finland and for export*

*There is no need in Finland to harvest CO2 from other than biogenic sources, such as direct air capture*

*All excess heat could be easily used in district heating to replace fossil-based production*