Industrial energy demand and GHG emission scenarios under changing technologies
A concise and exhaustive bottom-up methodology - an Austrian case study

Themenbereich: (5) Dekarbonisierung: Industriesektor

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Motivation und zentrale Fragestellung

Motivation and Research Question

What are the decarbonization options and -pathways for Austrian industry subsectors? Investigations on this question must consider two levels:

1. The technological level:
   - What processes are relevant in industrial production in each subsector and what technological options exist in the time frame until 2050 for their decarbonisation?
2. The stakeholder level:
   - How can industrial stakeholders be involved in the visioning process, thereby laying an important basis for the subsequent implementation of developed pathways towards climate neutrality?

Scenarios developed considering these two distinct but equally important levels of investigation can provide answers to the following questions, regarding climate neutrality in an economic sector which in 2019 [1,2] accounted for 34% (25 Mt CO_2e) of Austria's total greenhouse gas emissions (GHG) and 27% (110 TWh/a) of gross domestic energy consumption [2]:

- Which fuels and energy carriers will the manufacturing industries utilize in the future based on both scientific and industrial assessment?
- What are the projected aggregate fuel demands and GHG emissions for the applied processes?

The established methodology of analyzing *final* energy demand fails to provide coherent answers to these questions. Solely adding process emissions on top without deeper process investigations does not provide any insight into the structure of energy consumption. Inclusion of these dynamics and dependencies into demand models is therefore necessary to project future changes and shifts. Technological change is the driver of these, industrial stakeholders the most important decisionmakers for implementation. Therefore, we propose and demonstrate a novel bottom-up methodology of projecting the future technology mix, energy demands and GHG emissions in the Austrian manufacturing industry.

Methodische Vorgangsweise

Methodology

The questions raised above are answered by the methodology developed in the NEFI_Lab project by a novel approach for assessing technology deployment and energy consumption of the Austrian manufacturing industry. The methodology consists of two main pillars:

1. A bottom-up analysis of current and future technologies and
2. the balancing of resulting energy demands and GHG emissions from this technology changes.

A key element in both pillars is extensive industry interviews with chief technical officers on the status quo of energy demand and GHG emissions as well as an assessment on which production processes they are planning to employ in the future. Their assessments are accompanied by extensive literature research on best-available and breakthrough-technologies. By disaggregating the manufacturing industries into thirteen industrial subsectors in accordance with the United Nation's International Recommendations for Energy Statistics [3], the diverse technological structure can be accounted for. This is necessary as process technologies for e.g. steel production cannot be compared with e.g. cement, petro-chemical or machinery production processes and technologies. Furthermore, feedstocks such as hydrogen are increasingly integrated and technologically intertwined in energy provision and transformation. This, together with a subsector-specific roll-out assessment of cross-sectoral technology

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solutions such as heat pumps, allows for deriving the future energy carrier demand and volumes. From these, aggregate energy demands and resulting GHG emissions can be robustly developed in detail. Therefore, only this bottom-up technological approach together with accounting for energetic feedstocks can provide for a sufficiently accurate model for projecting future energy demands and GHG emissions. Three scenarios, one baseline and two transitional scenarios, have been developed:

- Scenario Business as usual (BAU), a trend scenario following [4].
- Scenario Pathway of industry (POI), a foresight scenario according to [5].
- Scenario Zero emission (ZEM), using a backcasting approach as introduced by [6].

The applied balance border is visualised in Figure 1 and explained in detail in [7]. After generating energy demand scenarios for each subsector, models are extended with separate approaches for the calculation of GHG intensities of the infrastructure-bound energy carriers electricity and gas.

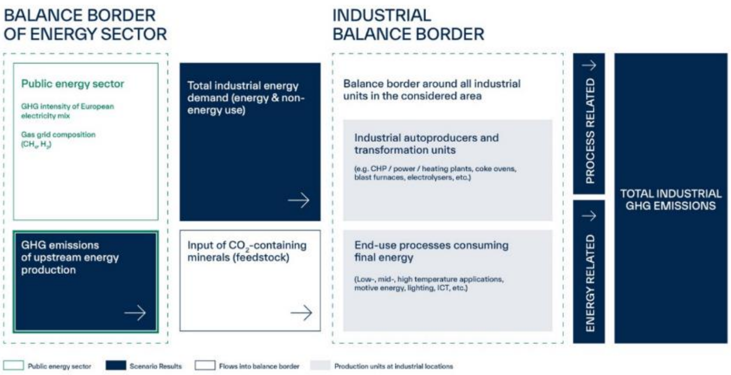

Figure 1: Applied balance border for industrial and necessary upstream processes

Ergebnisse und Schlussfolgerungen

Results

Results indicate that the manufacturing industry in Austria is on a path of reducing GHG emissions by 85% in the pathway of industry ('POI') scenario. This is achieved by an extensive technological change in nearly all sectors and processes. All fossil fuels are phased out and replaced by either bio fuels, electricity or hydrogen. Total energy demand rises if conversion losses - mostly for hydrogen production - are taken into account. Energy efficiency gains from marginal technology improvements such as motors and drives just compensate demand growth from an assumed growth in value added of 1% per year on average. Results for the POI scenario are shown in Figure 2.

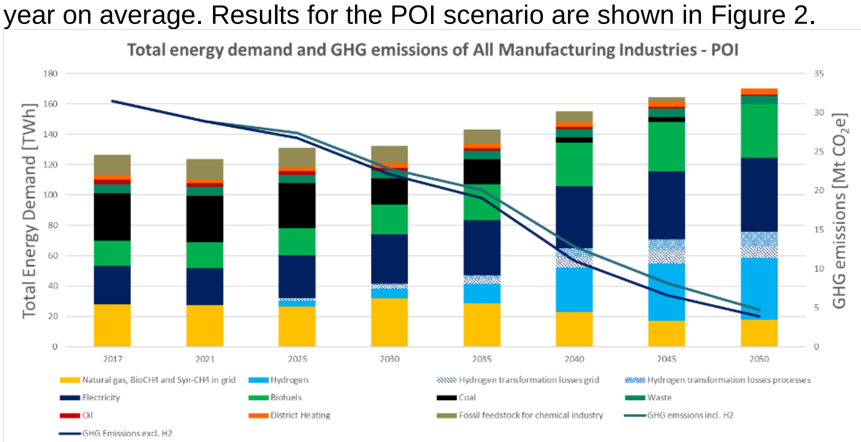

Figure 2: Total energy demand and GHG emissions of Austrian industry in the POI scenario

As emissions do not reach net zero in the year 2050 in the POI scenario, in a second scenario this goal was normatively set and the implied pathway derived by backward iteration. This 'zero emission scenario' ('ZEM') is based on POI with an extended uptake of high TRL technologies such as high temperature heat pumps and gradual direct electrification of heating processes above 200°C. In some sectors, established technologies with high TRL were substituted with more energy efficient ones with lower TRL later on. Examples are oxyfuel technology instead of amine scrubbing for carbon capture in cement production and a higher biomass share of the feedstock for methanol production, replacing naphtha in olefine production in the petrochemical industry. Results of the ZEM scenario are given in Figure 3.

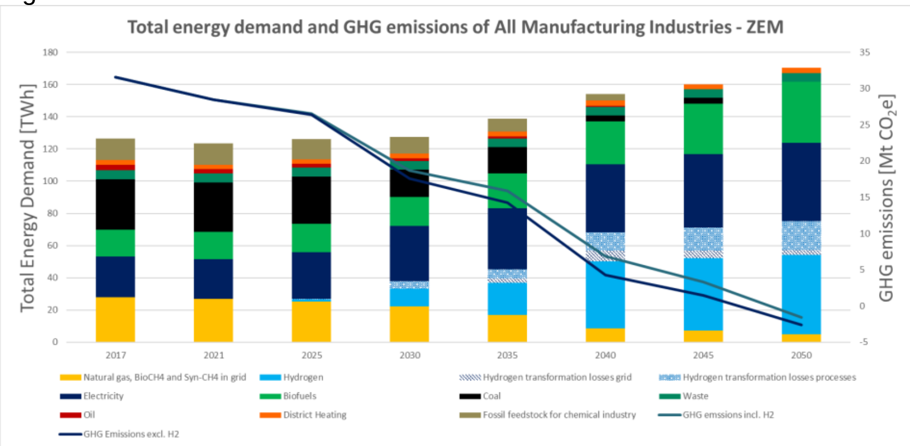

Figure 3: Total energy demand and GHG emissions of Austrian industry in the ZEM scenario

While their principal methodology of development is distinctively different, POI and ZEM scenarios feature very similar results indicating great robustness of the models.
In both POI and ZEM scenarios, the chemical and petrochemical sector serves as the necessary CO_2 sink for counteracting remaining GHG emissions from Austrian manufacturing industries. Overall, a net total of up to 5 Mt CO_2 is absorbed by the sector. A biomass demand of approximately 35 to 40 TWh/a is calculated and approximately 50 TWh/a of electricity for final energy applications is needed in the scenarios. In addition to general electrification efforts (e.g., heat pumps), electricity demand is driven in particular by the transformation of process-emission-intensive sectors such as iron and steel and non-metallic minerals. In these sectors, the introduction of electric arc furnaces and carbon capture plants accounts for a significant demand in final electricity. Taking into account the possible additional electricity demand for hydrogen production via electrolysis, total electricity demand for industrial production in Austria rises to a projected 121 TWh/a.

Key-Take-Aways

- The one central enabler of industry decarbonisation is the availability of abundant CO_2-neutral electricity. Large amounts of hydrogen- based energy carriers will need to be imported on top of that.
- Electrification provides large efficiency gains and better process control, possibly enabling product quality increases.
- Individual implementation concepts are necessary foreach industry sector’s processes. To that end, additional R&D is necessary.

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