AN OPEN-SOURCE BUSINESS MODEL EVALUATION TOOL FOR SECTOR COUPLING TECHNOLOGIES: APPLICATION ON GREEN HYDROGEN USE CASES

Johannes Giehl

Chair of Energy and Resource Management | Technische Universität Berlin | YEEES | Copenhagen | 07./08.09.2022

00 Agenda

01 Motivation

Global Trends

- **Paris Agreement** and **German defossilization plan** to reach the 2°C / 1.5°C goal
- Fundamental **shift to renewable, CO_2^*-neutral energies** within global energy supply
- **Sector coupling** is an important element of energy transition

Renewable hydrogen as a key element

➡ **Defossilization** by transfer of climate-neutral, renewable energy to consumption sectors

- Hydrogen demand will rise until the 2040s
- Application in process heat generation, industrial processes, power sector, mobility (and heating sector)
- Sufficient technological maturity for operation given

➡ **Current business models not economically attractive**

- Market penetration barely exists
- Market framework has high impact on economical feasibility

Bundesregierung (2019); European Parliament (2020); Gea-Bermúdez et al (2021); Hou et al. (2017); Kopp et al (2017); Robinius et al. (2017); United Nations (2015); van Renssen (2021); van Leeuwen and Mulder (2018); CO_2 = Carbon Dioxide

02 Research Goals and linked Question

Creating an **open-source tool** to evaluate sector coupling business models

- Various existing analyses but no reuse of tools possible

➡ **GOAL**: Provide a generically structured and easily usable tool

Sector coupling business models and the **current market and framework conditions** in Germany

- Most **additional fees and levies removed** for renewable hydrogen production in Germany
- Funding source of additional infrastructure (storage and transportation) not defined
- **Currently high power prices**
  - Impact on hydrogen production using own RE* capacities?
  - Improving XtP* business cases?

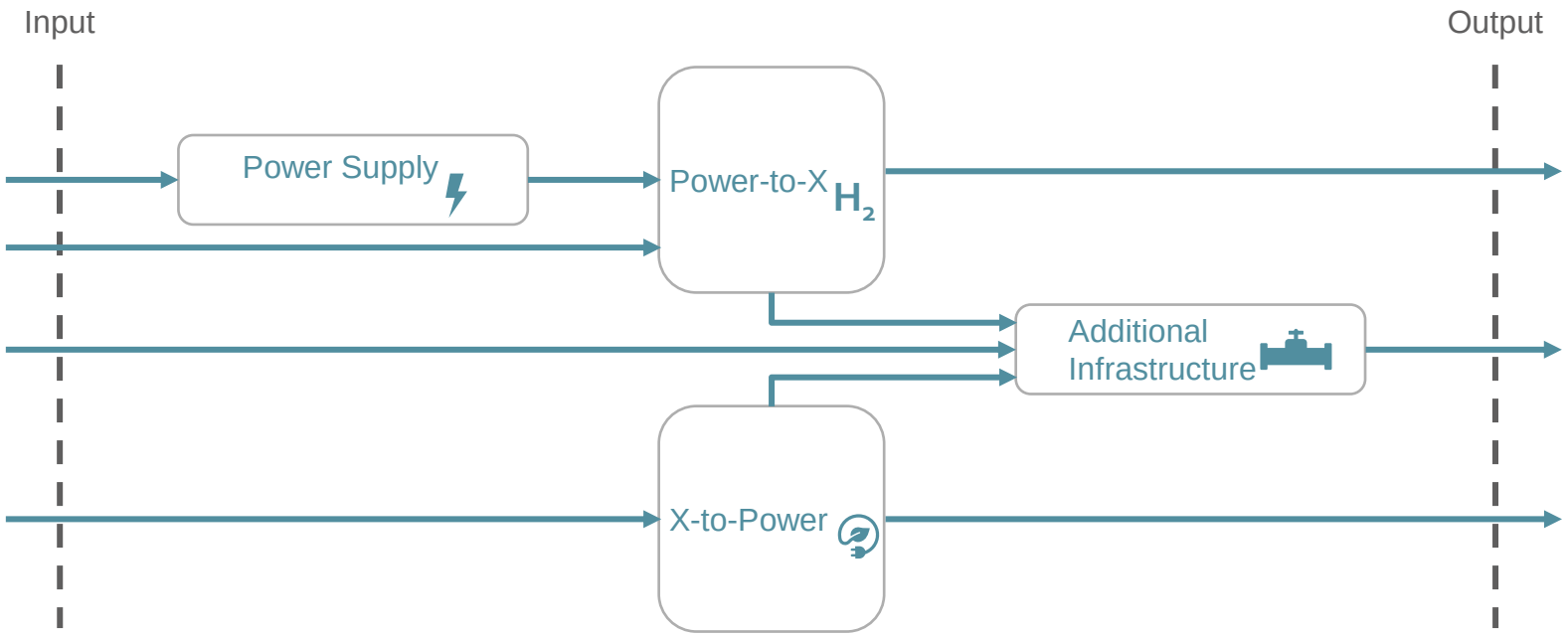
➡ **QUESTION: Possibilities to establish PtG* business models** on the current market?

Application on **three hydrogen business cases**

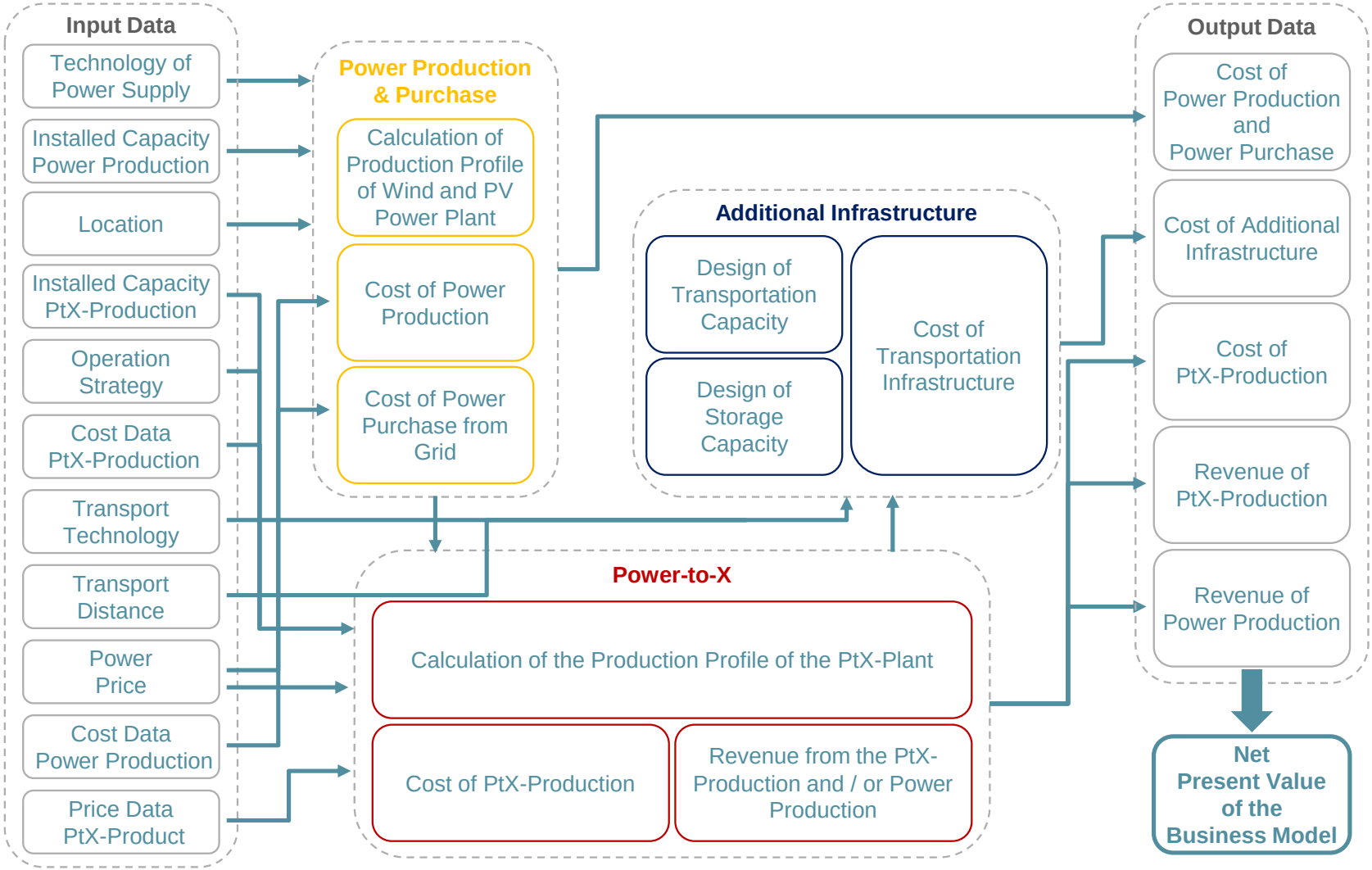
- Operation of electrolysis with own PV capacity
- Extension of electrolysis by transport infrastructure
- Power and heat production with a hydrogen turbine

03 The open-source business model evaluation tool for sector coupling ($OBMET_{SC}$)

Splitting the sector coupling process into four different parts

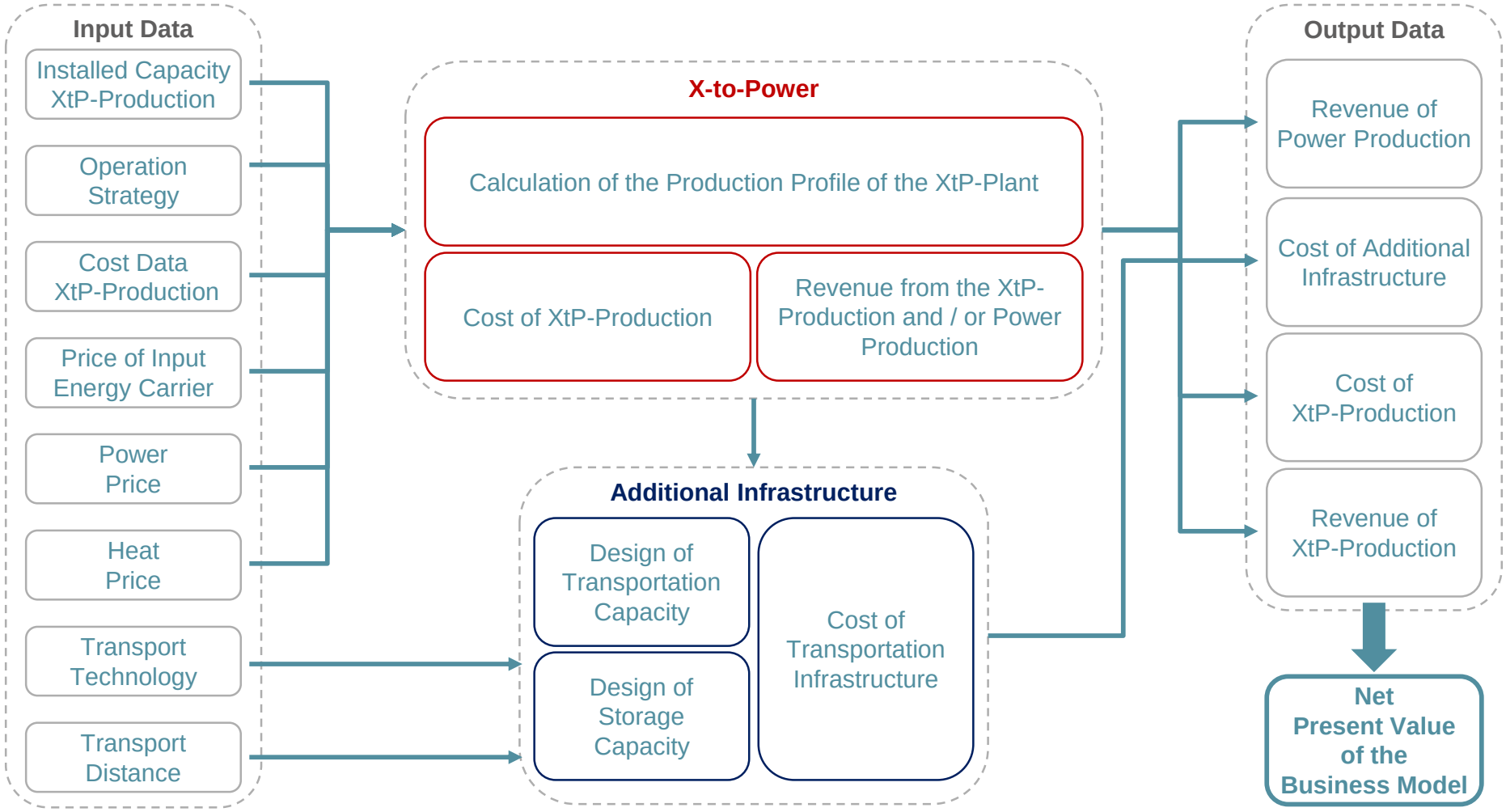


03 The steps of the Power-to-X calculation in OBMET$_{SC}$



 PtX = Power-to-X; PV = Photovoltaics;

03 The steps of the X-to-Power calculation in of OBMET$_{SC}$



04 Parameters are either provided by $OMBET_{SC}$ or set by the user

Four categories of input parameters

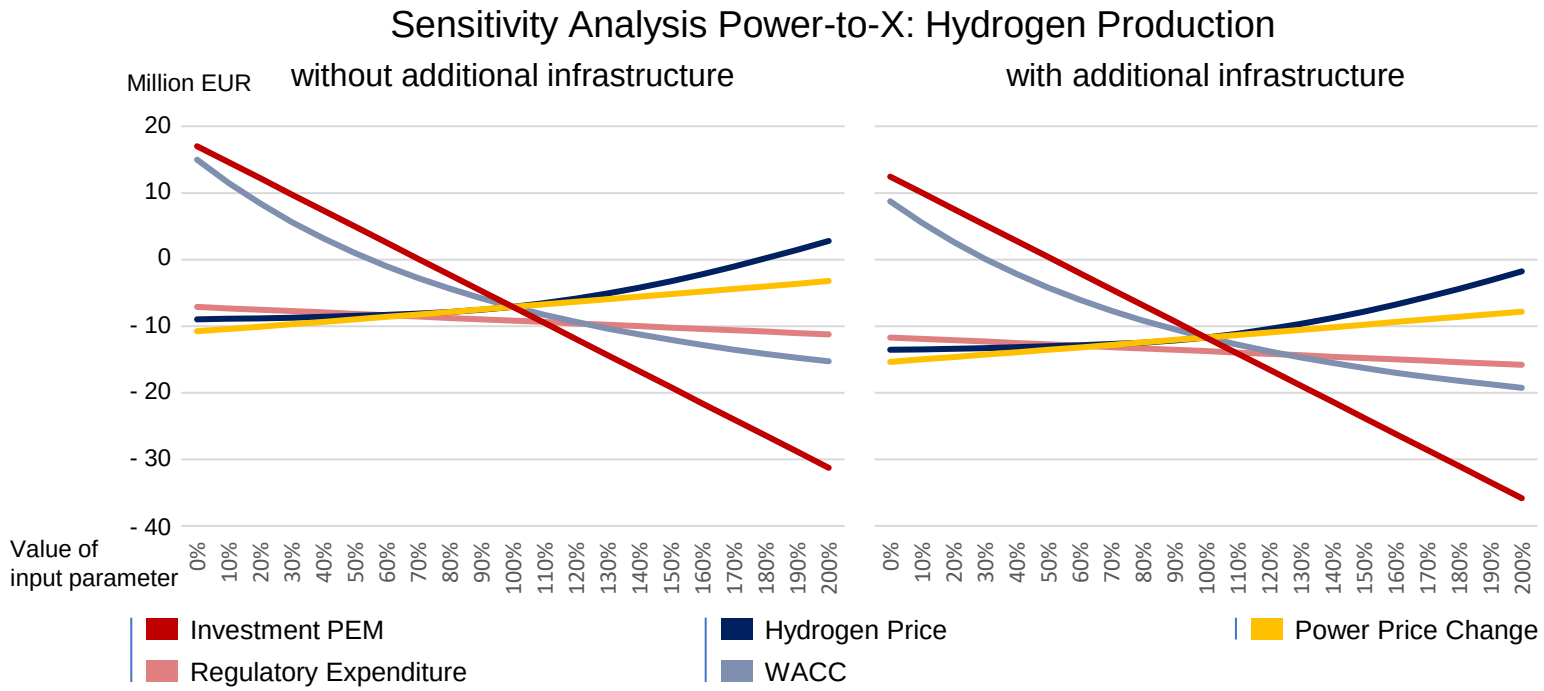
- Database parameters
  - Wind and solar power generation profiles
  - Energy Carrier prices and series based on 2021
  - Technology specific data
- Input parameters set by the user
  - Capacity
  - Lifetime
  - Location
  - Operation Mode etc.
- Opt-in parameters
  - Using the additional infrastructure module
  - Technology and business case specific
- Output parameters
  - Transfer between the modules
  - Results

Data basis for calculations

- PEM* electrolysis for PtX*
  - 10 MW_{el} with 1,610 EUR/kW_{el} investment
  - 20 MW_{el} PV plant with 650 EUR/kW_{el} investment
  - Location Bavaria in southern Germany
  - Hydrogen customer in 1 km distance
- Hydrogen Turbine
  - 30 MW_{el} with 550 EUR/kW_{el} investment
- Economical conditions
  - 25 years lifetime
  - 7 % WACC
  - Power price (mean 2021) of 96,85 EUR/MWh
  - 15 % increase of power price over lifetime
  - Hydrogen price 90 EUR/MWh_{H2}
  - Revenue from selling heat is 20 EUR/MWh

PEM = Polymer electrolyte membrane; PtX = Power-to-X; WACC = Weighted average cost of capital;

05 Hydrogen production not economical in most cases



Currently high negative NPVs

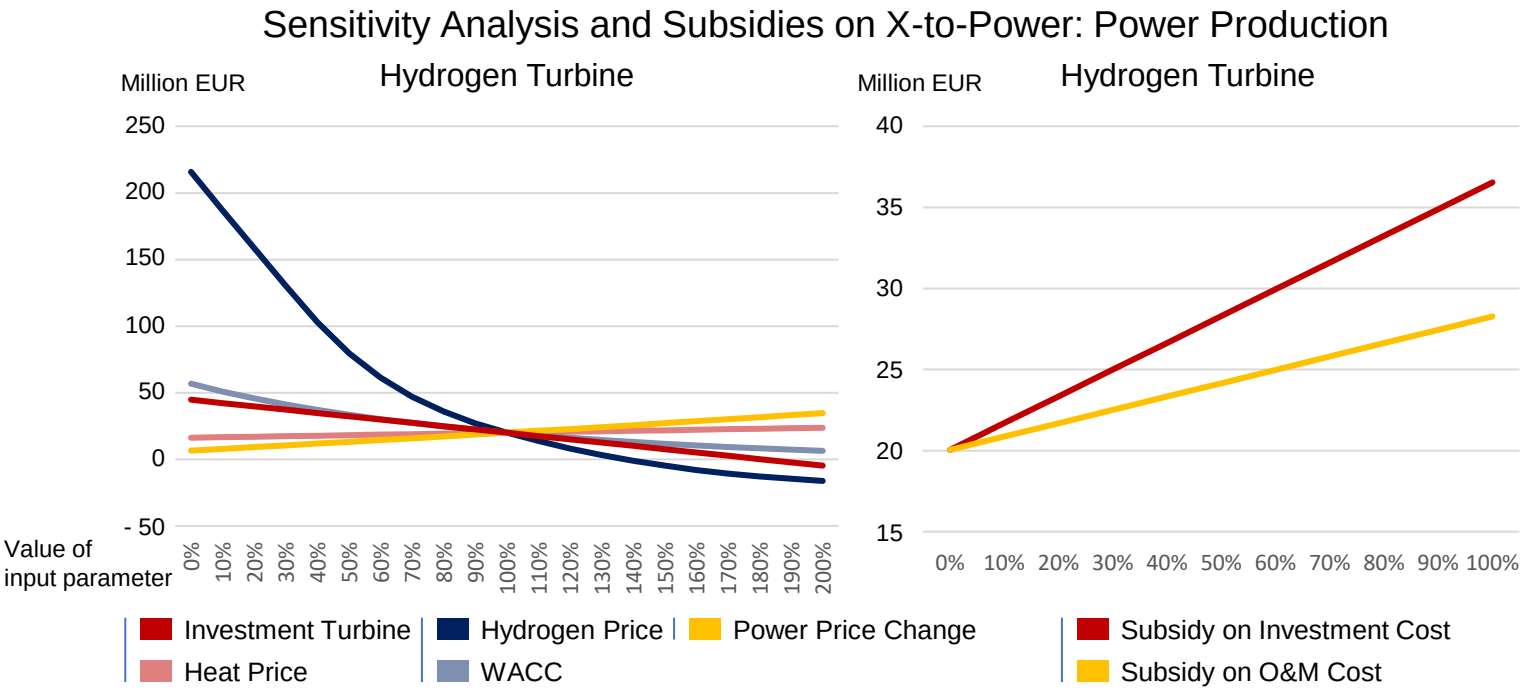
- Hydrogen production only -7.1 million EUR
- Including infrastructure -11.7 million EUR
- **Only 14.9% of revenue based on hydrogen**
- BUT: Total revenue higher than expenditure

Incentives to produce hydrogen

- Low investment cost or low WACC ensure positive business cases
- Only high hydrogen prices allow positive NPV based on hydrogen production
- Subsidy on investment with highest impact

NPV = Net present value; WACC = Weighted average cost of capital

05 Hydrogen based power production profitable at current power prices



High power prices drive the profitability

- Positive NPV of 20.0 million EUR
- 96.4 % of revenue from power market
- Expenditure mostly driven by hydrogen procurement (79.2 %)

Higher cost still allow positive NPV

- Negative NPV only if
  - 90% higher investment cost
  - 40% increase of hydrogen price
- Subsidies currently not necessary but will be when using renewable hydrogen

06 Conclusions and Further Research

Main messages

- **High electricity prices support the XtP business model but jeopardise the PtX** business model for green hydrogen and vice versa
- **Renewable hydrogen production not economical** under current market conditions and political framework
  - High power prices favor the direct sale of electricity
  - Renewable hydrogen too expensive compared to fossil options
  - Infrastructure financing situation reduces attractiveness
- **Political framework conditions still not sufficiently supportive**
  - Subsidies and / or guarantee of demand might be additional solutions
  - Need for supportive framework conditions to create necessary transportation infrastructure

Further Research

- **Application of the tool beyond Germany**
  - Possible by customising the input data
  - Update of the database for RE generation and market data
- **Finding a way of exploiting the potential of all parts of the value chain**
  - Success of RE, PtX and XtP mutually dependent

Thank you for your attention

Chair of Energy and Resource Management

Johannes Giehl
giehl@er.tu-berlin.de

Sekr. H 69
Raum H 6118
Straße des 17. Juni 135
10623 Berlin

www.er.tu-berlin.de

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A Appendix