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FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG

TECHNISCHE FAKULTÄT

# Scenario-based Analysis for the Integration of Renewable Gases into the German Gas Market


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## Motivation

In 2016, about 50% of the German heat demand was covered by natural gas. Only approx. 13% of the overall heat was provided by renewable energies [1]. This leads to high dependencies on natural gas and uncertainties regarding future security of supply and prices. In order to reduce those issues, numerous technologies aim to produce substitutes for natural gas from renewable energies, such as:

- Biomethane (BioCH4) through the treatment of biogas
- Substitute Natural Gas (SNG) by methanation of synthesis gas (SynGas) from thermo-chemical conversion of ligneous biomass
- Hydrogen production by use of renewable electricity (Power-to-Hydrogen, PtH) as well as its conversion to synthetic natural gas (Power-to-Methane, PtM).

The project "SustainableGas" aims to simulate possible market scenarios for the integration of those renewable gases into the German gas market until 2050, investigating the influence of different funding strategies and heights. A special focus is laid on local environmental and social structures which are integrated additionally to the energy economics in cooperation with project partners from LMU Munich and FAU Erlangen-Nuremberg.

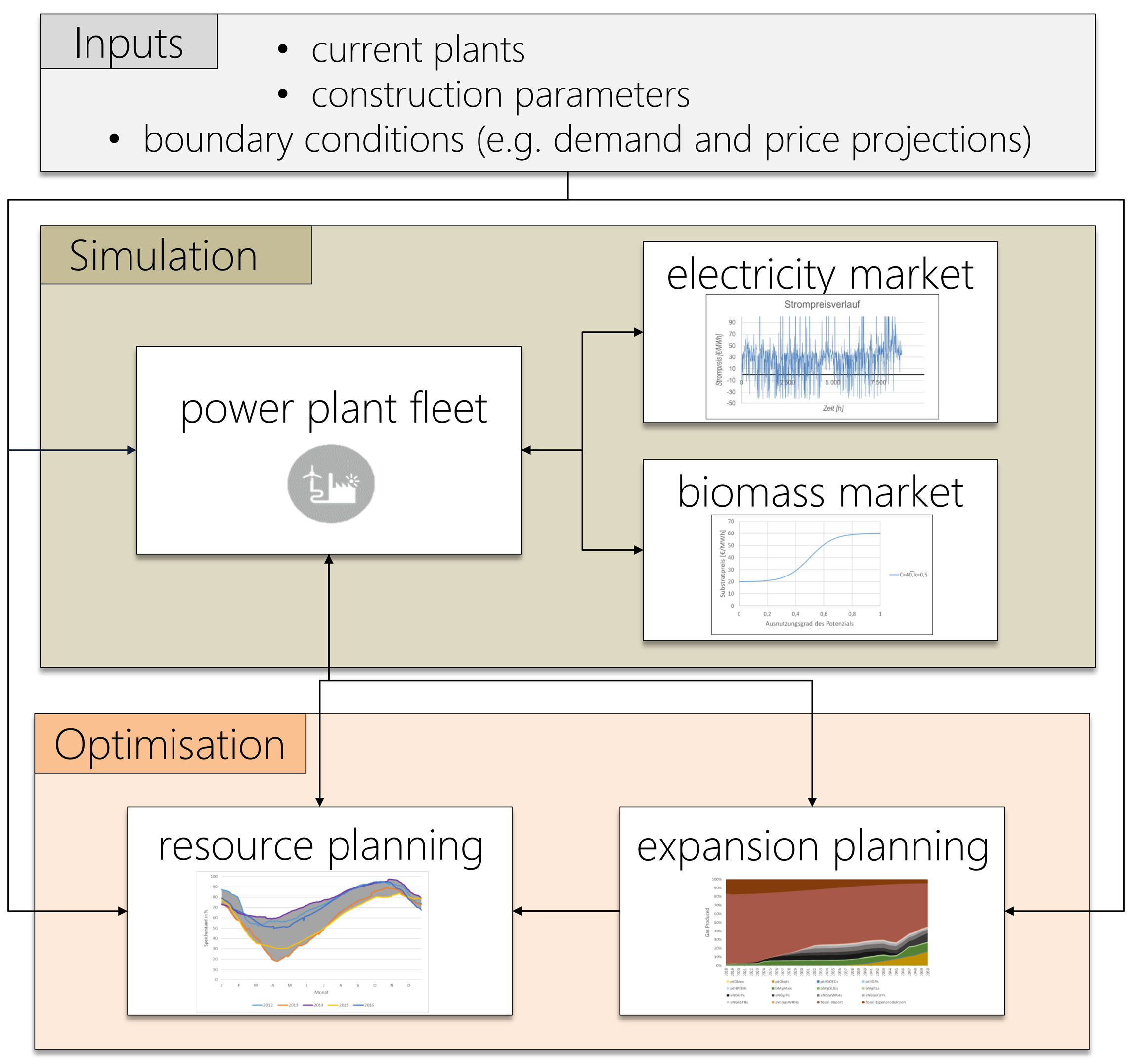


*Figure 1: schematic setup of MIREG*

## Modelling Approach

For the dynamic simulation and evaluation of different scenarios, the simulation-based optimisation model MIREG (Model for the Integration of Renewable Gases) was implemented at the Chair of Energy Process Engineering.

In the MIREG model, methods of system dynamic simulations are combined with non-linear and mixed integer linear optimisation techniques (figure 1). In the *power plant fleet*, each installed unit is modelled system dynamically and agent-based using the multimethod modelling environment AnyLogic. The simulation generates values for productivity and prices based on market and weather conditions for every plant built in the scenario in hourly resolution. A high degree of technical detail, input data in high temporal resolution as well as the integration of an electricity and biomass market agent allow to evaluate the system's parameters – in particular the fluctuating properties of the PtH and PtM plants – in depth.

The optimisation steps are implemented in Matlab and the results are sequentially exchanged with AnyLogic. In the *resource planning*, the influences of scenario-based changes in supply and demand structures on gas prices are estimated using non-linear optimisation. Based on the annual simulation results of the *power plant fleet*, exogenously specified elasticities, demand and supply developments and by varying storage usage and gas prices, the consumer's surplus is maximized. This enables to model a gas operator which describes the real gas market's behavior and compensates seasonal differences in demand and prices by strategically storing and releasing gas. The optimised gas prices in turn allow AnyLogic agents to decide how and when to run their plants.

To identify expansion paths, a rolling *expansion planning* is carried out before each simulation year using a mixed integer linear optimisation. The expansion planning optimises the ideal plant construction yearly, taking into account given targets as well as the simulation results from the *power plant fleet*. It optimises the entire simulation period until 2050 in each run, while only the decisions for the upcoming year are implemented in AnyLogic.

## Exemplary Results

The main results from MIREG are time-resolved developments of the German gas mix and the resulting changes in CO2 and gas prices. Figure 2 shows a possible development of the gas mix assuming an increase in CO2-certificates four times higher than currently predicted. In Figure 3, the resulting CO2-emission curve for this scenario is displayed and compared to the Business as Usual (BAU) and a fossil only scenario.

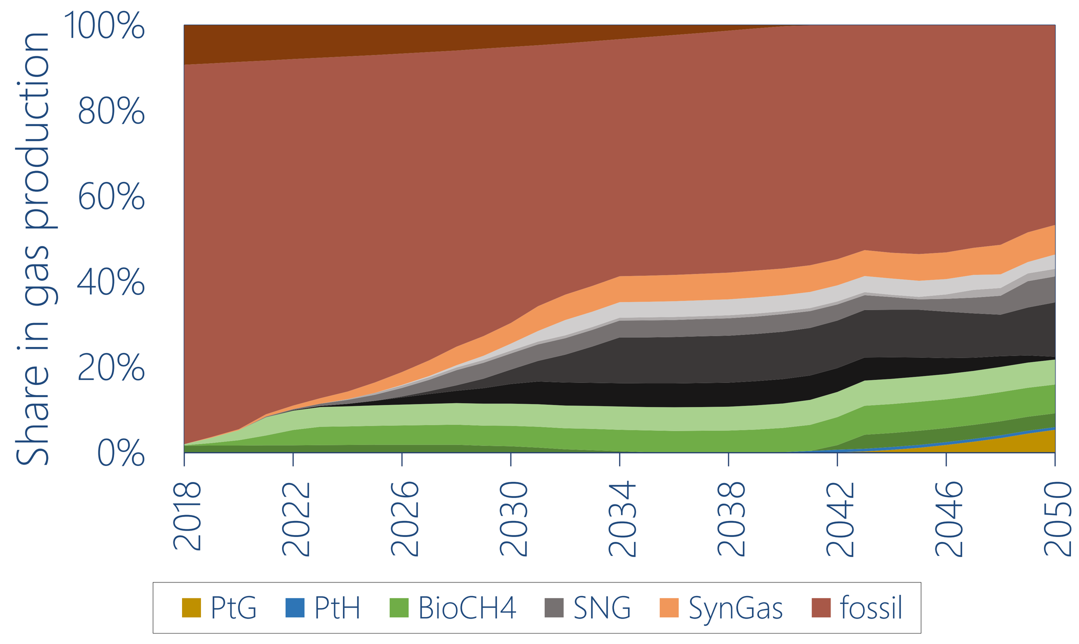


*Figure 2: development of gas production in scenario* $"4 * C\_CO_2"$

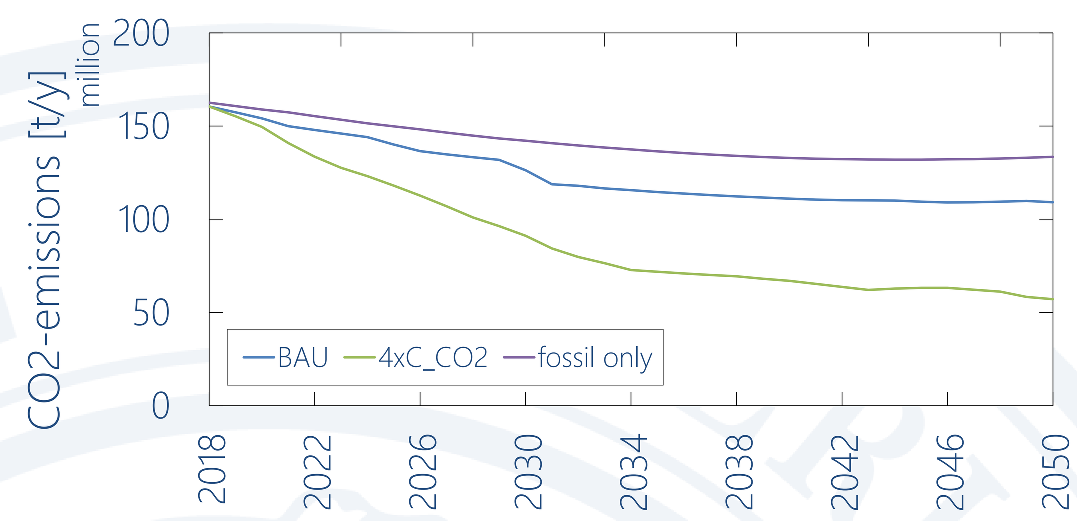


*Figure 3: development of CO2-emissions in different scenarios*

The main statements resulting from the different scenario runs include:

- Under the current market conditions, no noteworthy increase in renewable gases can be expected.
- Biomethane can contribute as a short-term option, PtH and PtM in the long-term.
- The biomass potential of Germany is limited; international solutions should be pursued.
- Investment and agricultural subsidies alone don't turn out to be effective.


[1] Federal Ministry for Economic Affairs and Energy, Energy Data, www.bmwi.de



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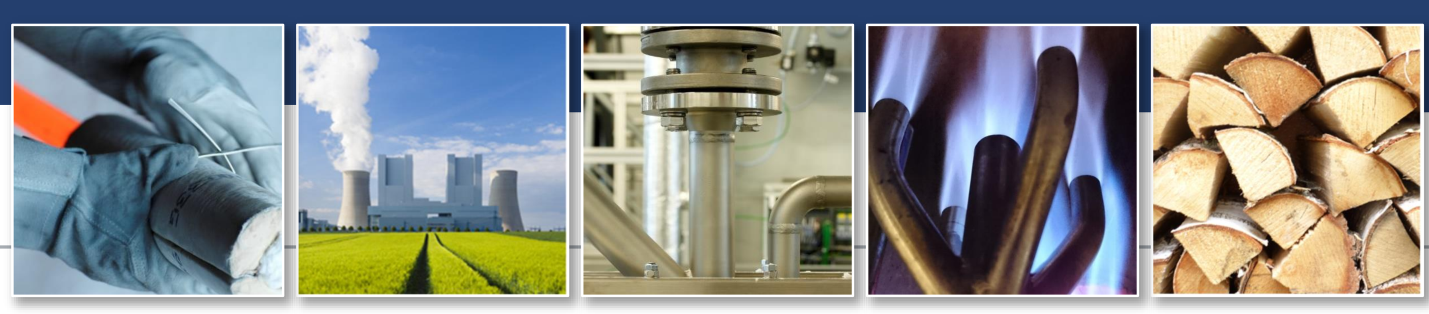


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