L-0 | Operation Optimization of CCU-based Urea Production with Renewable Energy

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Utilization of steel mill exhaust gases for urea production is a promising carbon capture and utilization (CCU) pathway. By coupling these carbon and nitrogen-rich emissions with volatile renewable energy sources for hydrogen production, a flexible operational approach offers significant economic and ecological potential. Within the scope of L-0, an economically optimized operational mode for ammonia and urea production using the process logistic model (PLM) is being investigated. The outcome of this poster presents a single scenario (UREA_V02) along with the reactors' load profiles, which is analyzed thoroughly.

Methodology of the PLM and the investigated process concept

The PLM uses simplified linear relations between technical plants and couples them with timeseries (grid mix, off-gases, heat demands, etc.). The results indicate the time-dependent optimal operational mode of individual plants. Different scenarios can show different future potentials for economic or ecological best operations.

The process concept is developed in the L-0 simulation community. Plant sizes (e. g., Single-Train) and technical parameters are specified in AP6 (DesignBasis). Future prices of raw materials and products are mainly derived from the project's base scenarios. The primary source of carbon and nitrogen are blast furnace gas (BFG), while coke oven gas (COG) serves as an internal hydrogen source. The power supply is represented by the time-dependent ESDP-2035 grid mix, predominantly employed for external hydrogen production via PEM-electrolysis. Hence, the grid mix price governs the optimal load profiles of the CCU-plants, while penalty costs for ramping and shutdowns lead to profile smoothing. All surplus gases in the CCU-Block are utilized in the power plants section (e. g., Fig. 1).

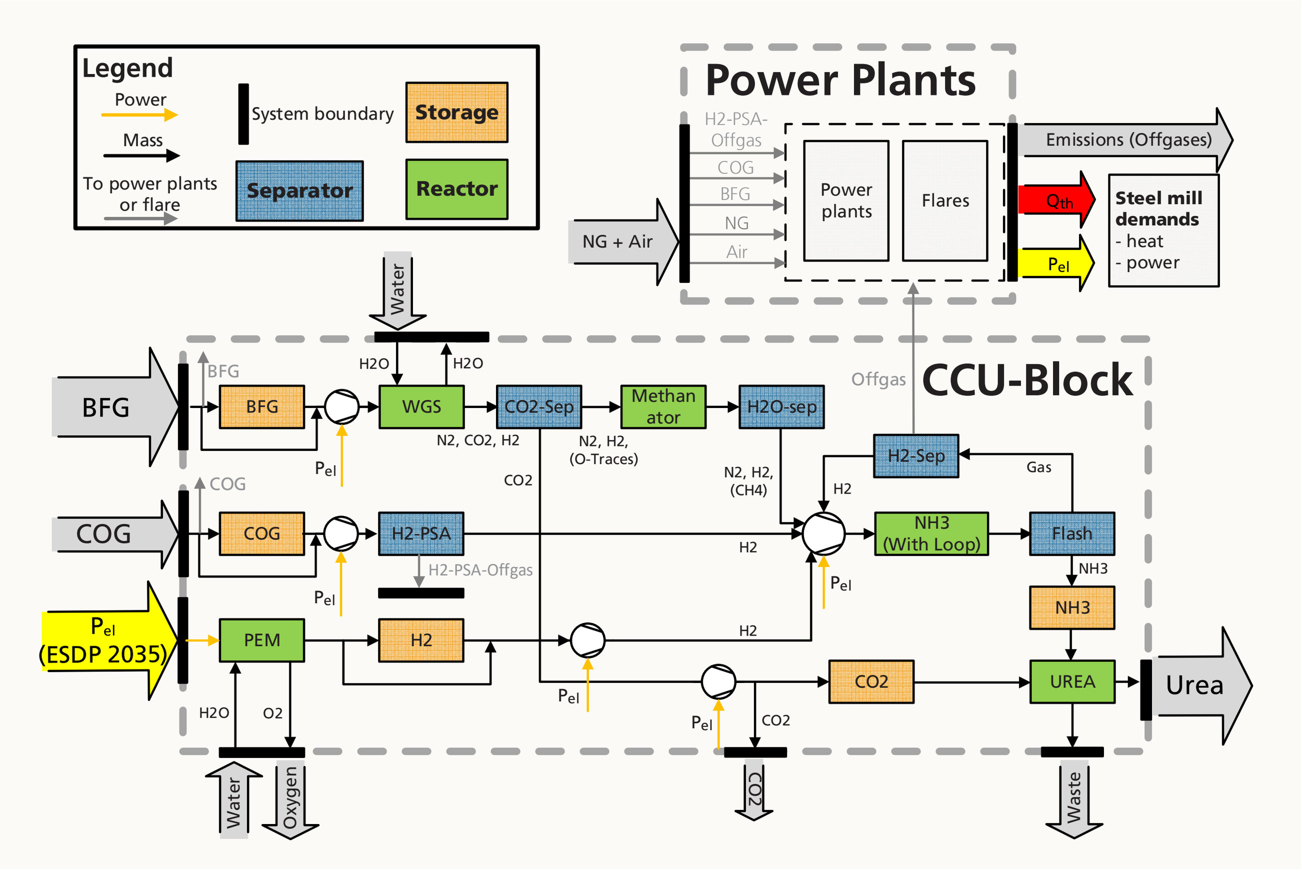

Figure 1: Process concept of the CCU-based urea production system with external hydrogen supply generated from the ESDP-2035 grid mix.

Results of the reactor load profiles for a single scenario (UREA_V02)

The results are the economically optimized operational mode of the ammonia and urea reactors in 15-minute resolution over one year. The profiles remain consistent as storage capacities of the ammonia storage is zero (Fig. 2).

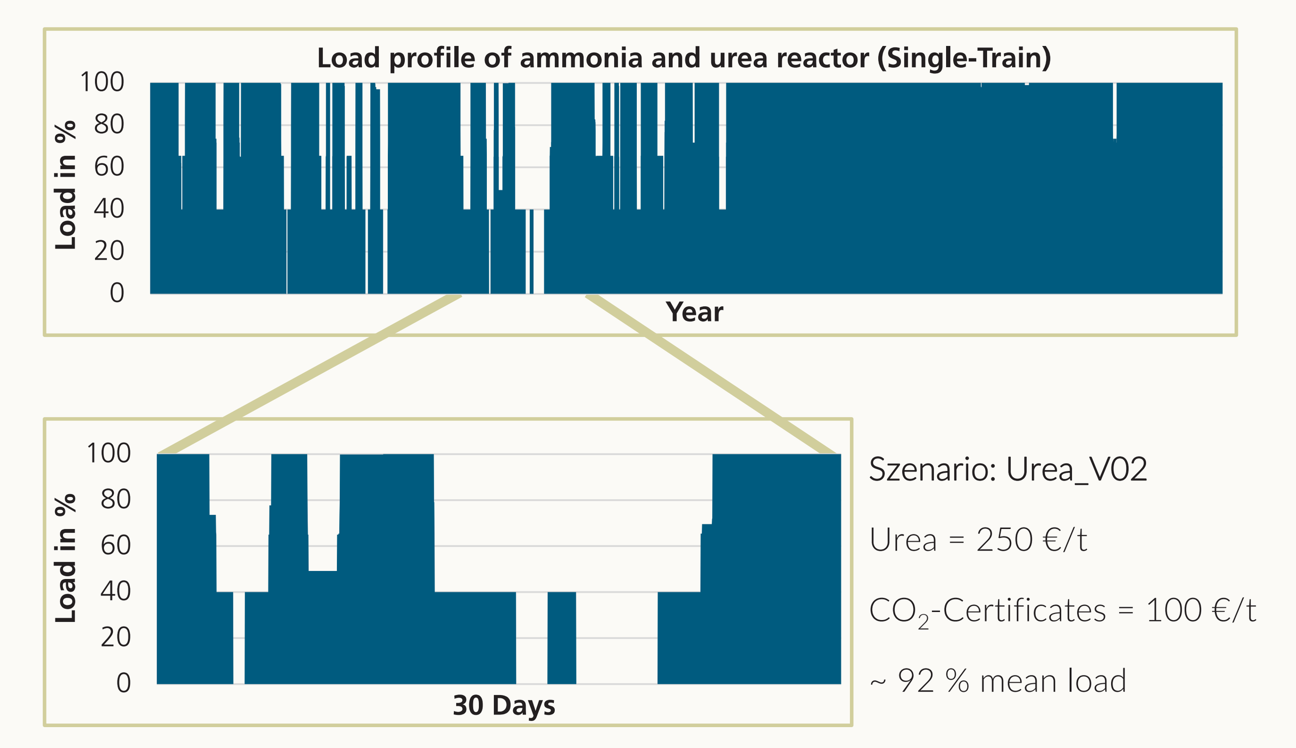

Figure 2: Load profile of the reactors for one year and for one month with the highest variations in the transient grid-mix prices.

At 100 %, full load urea production is economically optimal due the low power price. However, for higher prices, it becomes advantageous to operate at the compressor kickback restriction (65 %) or minimal part load restriction of the ammonia reactor (40 %). These limitations enable a higher relative utilization of internal hydrogen, which incurs no external costs like external hydrogen (Fig. 3). In the case of extremely high-power prices occurring in less then 2 % of the year, the reactor shuts down.

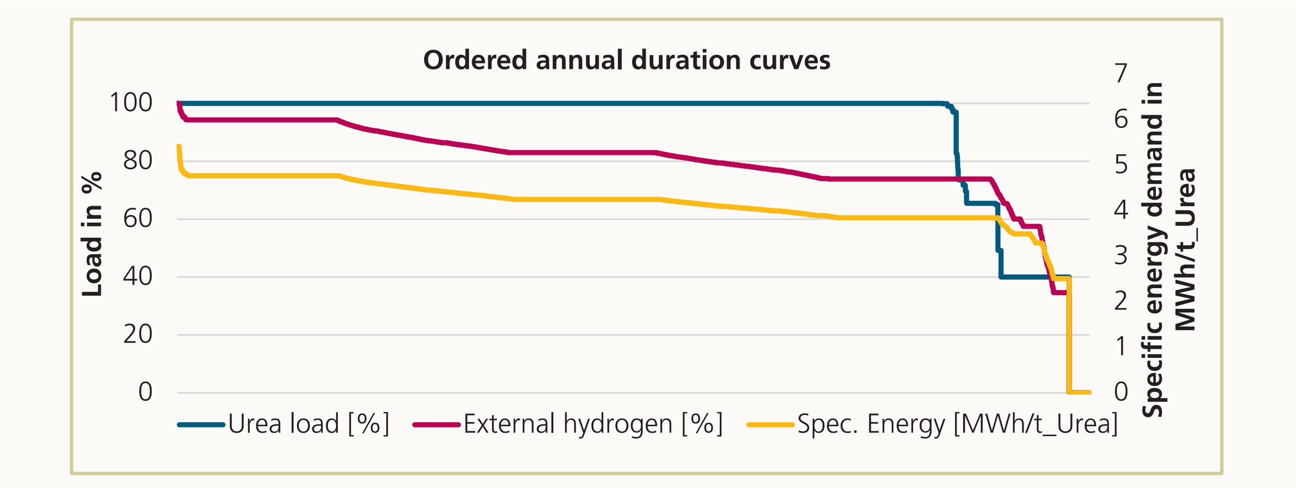

Figure 3: Ordered annual duration curves for reactors (petrol), external hydrogen share (red) and the energy demand for urea production (orange).

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