FACULTY OF ENGINEERING AND ARCHITECTURE

INDUSTRIAL SYSTEMS ENGINEERING AND PRODUCT DESIGN

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INDUSTRIAL PLANNING OF ELECTRICALLY HEATED CATALYTIC REACTORS WITH AN INTERMITTENT POWER SUPPLY

This research optimizes the supply of energy to a chemical plant that converts waste products CO_2 and H_2S into industrial chemicals. Energy comes from renewable sources, which are less predictable than conventional energy sources.

Converting waste CO_2 and H_2S to useful chemicals

- A chemical plant (schematic below) has reactors for two chemical reactions:

$$CO_2 + H_2S \rightarrow COS + H_2O$$
$$COS \rightarrow CO + S$$

- The plant is powered by solar and wind energy.
    - Intermittent
    - Difficult to predict with high accuracy
- To manage fluctuations in energy generation, a battery is used as a first buffer, and then a connection to the grid serves as a backup.

Research goals:

1. Developing a simulation model for evaluating what-if scenarios using a discrete-event Monte Carlo simulation based on varying energy inputs.
2. Create an industrial process planning module using mathematical/stochastic optimization algorithms.

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A Multidisciplinary team:

- Our department is developing the economic model.
- The UGent Laboratory for Chemical Technology (LCT) is developing micro-kinetic models for the reactions.
- Our industry partners below also play a critical role:

Benkei (BENKEI)

Kemijski Inštitut / National Institute of Chemistry (NIC)

Centre national de la recherche scientifique CNRS (CNRS-LCS)

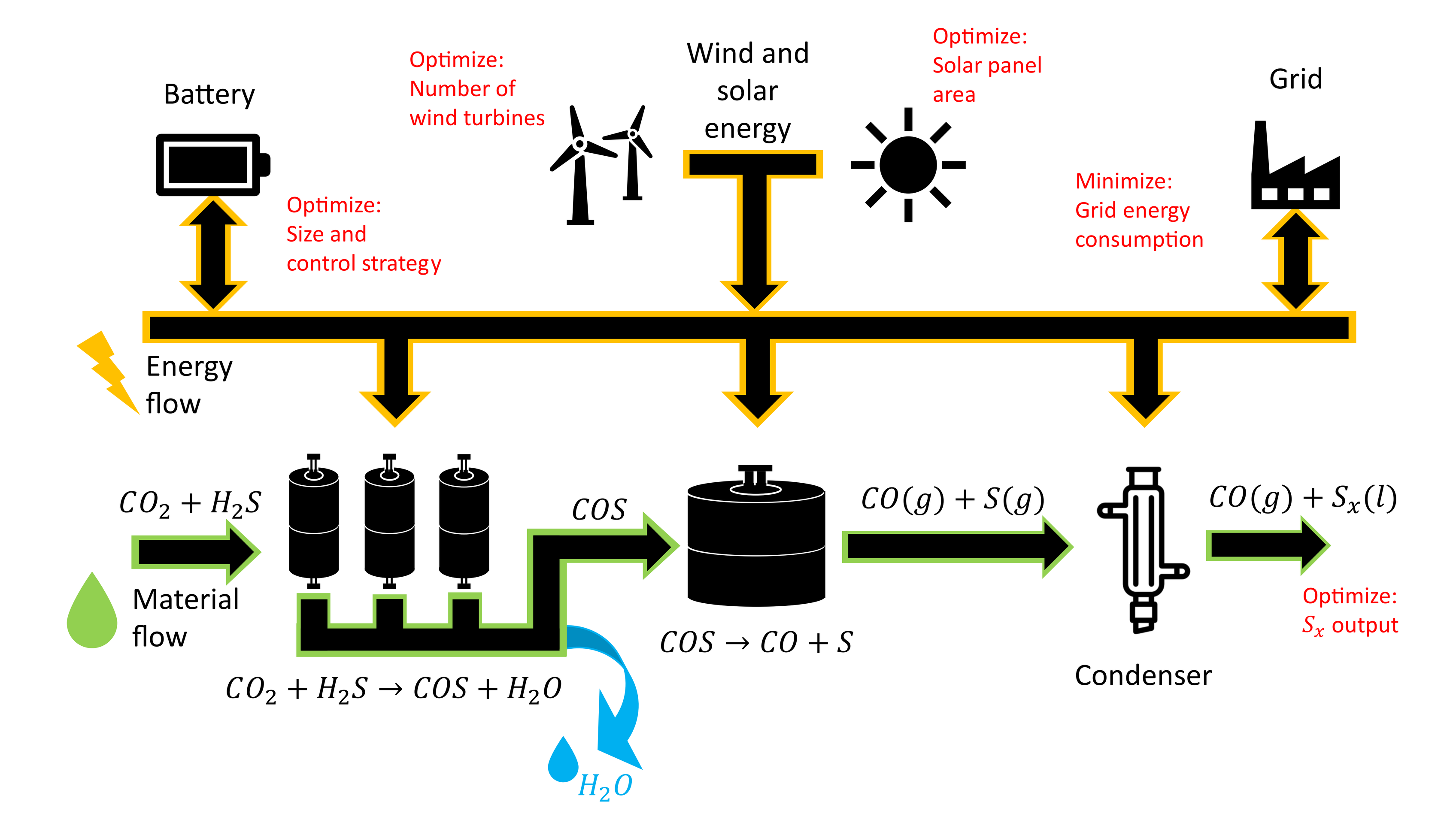
PDC Research Foundation (PDC)

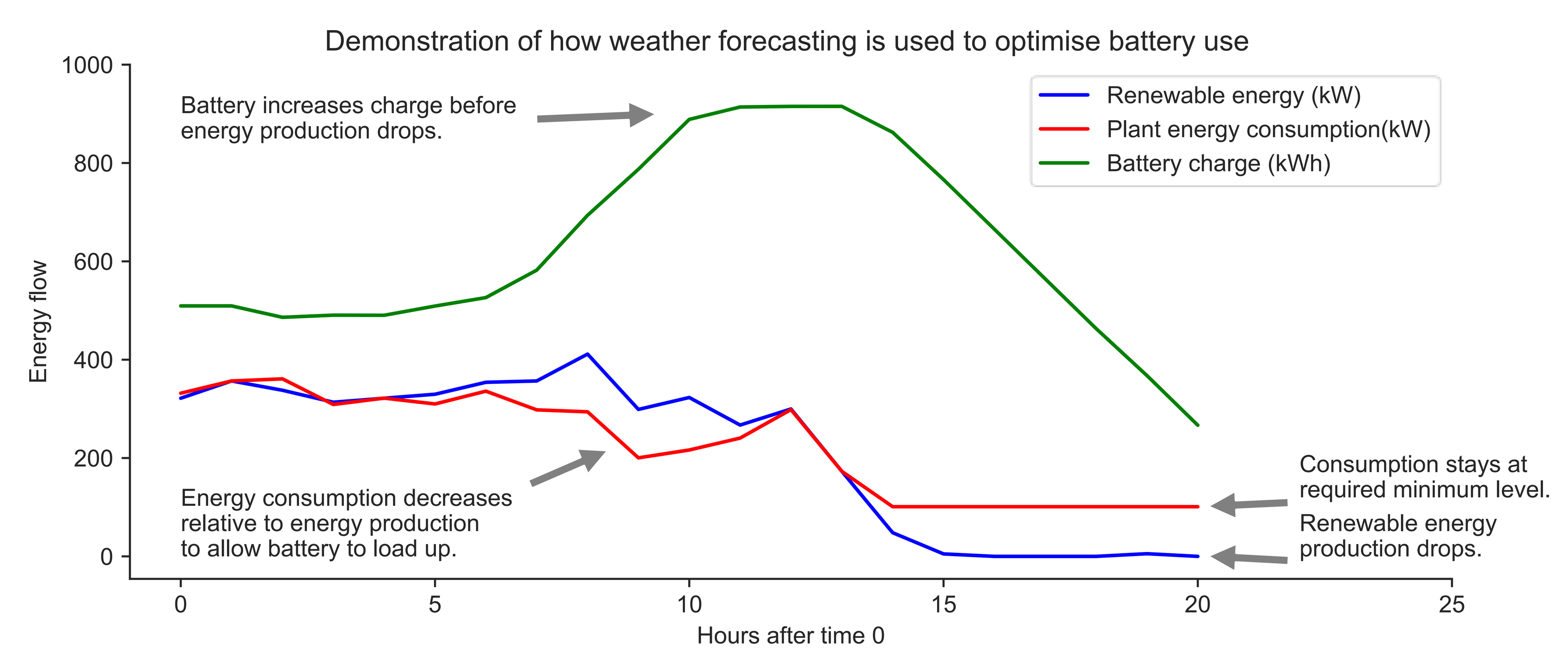
Center Odličnosti Nizkoogljične tehnologije Zavod (CO NOT)

Saint-Gobain Centre de Recherches et d'Etudes Europeen (SG CREE)

Dechema Gesellschaft für Chemischetechnik und Biotechnologie (DECHEMA)

TotalEnergies One Tech Belgium (TOTB)



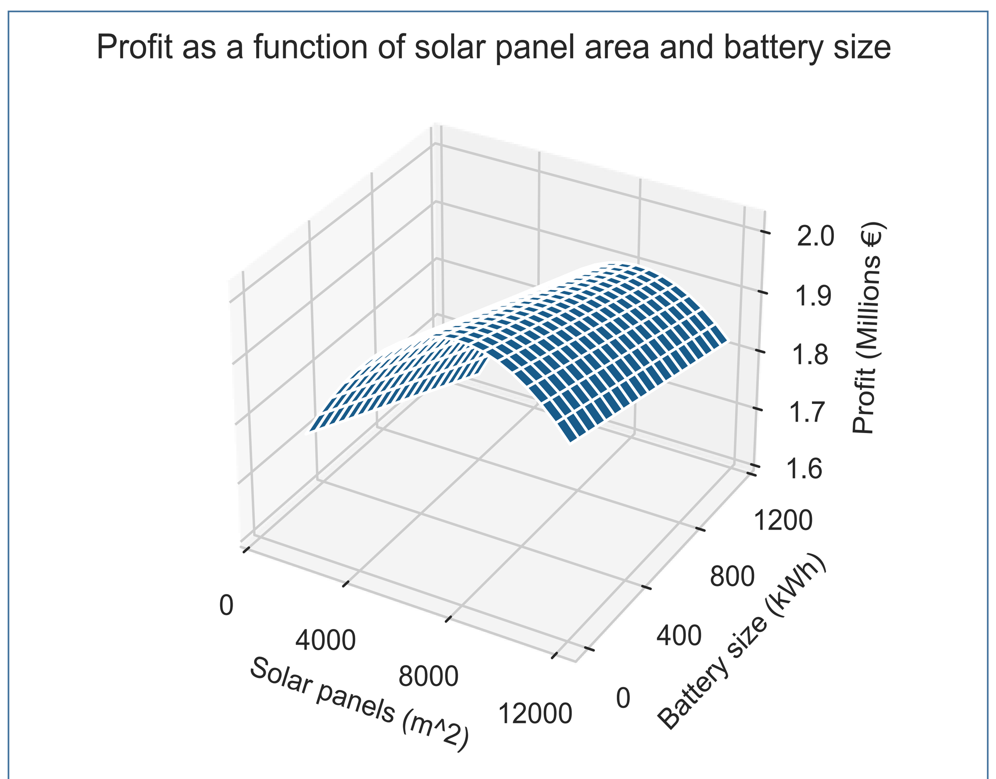


Battery control logic

- Employing an energy store, such as a battery, is critical for buffering fluctuations in solar and wind energy.
- Forecasted weather conditions are used in production planning.
    - When low energy production is forecasted, production decreases to allow the battery to load up.
- The battery set point is controlled using the ratios of the total forecasted production for hours 0-3 and 4-6 after the present to an approximated average energy production. If the forecasted energy production is lower than average, the battery set point will increase, and vice versa.

Capex Optimisation

- Our model allows us to run simulations while varying:
    - Solar panel area
    - Wind turbine count
    - Battery size
    - Several control parameters
- Simulations were treated as a DOE
    - Full factorial with two levels
    - Box-Behnken with three levels
    - A 2nd-order polynomial model was fit to the results
- Optimisation
    - Based on our model, we could optimise the features to choose the most economical plant design and control parameters that maximize profitability.
- Example
    - Below is an example of the results using real weather data from 2013 – 2020.
    - The graph shows the relationship between profitability, solar panel area, and battery size when the other parameters are held constant.



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