Real time predictions in process industry using hybrid-models – a case from Viking Malt A/S

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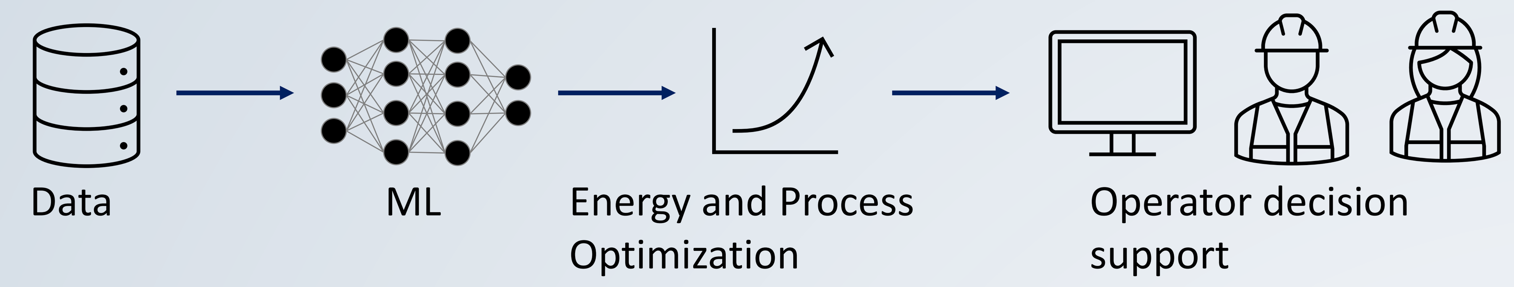
1 Machine Learning for Energy and Process Optimization

This work is a part of the project "Machine Learning for Energy and Process Optimization" (MLEEP) in which machine learning (ML) is directly integrated in 5 different Danish industrial companies to highlight the potential for energy and process optimization using ML applications.

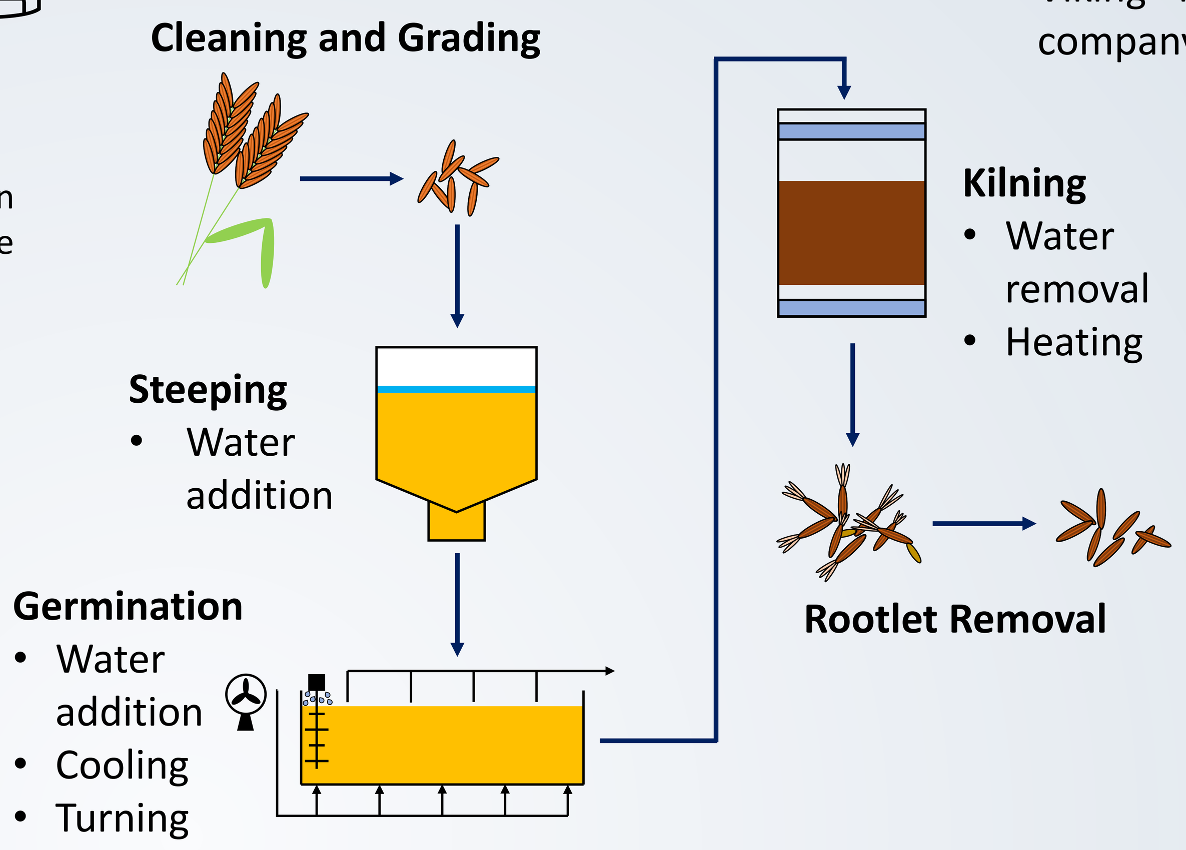
More info on MLEEP



Models are developed using only existing data from industry. Suitable models are introduced in real time applications at the industrial production plants. The optimal inputs determined by the model are presented for operators through a user-friendly UI.

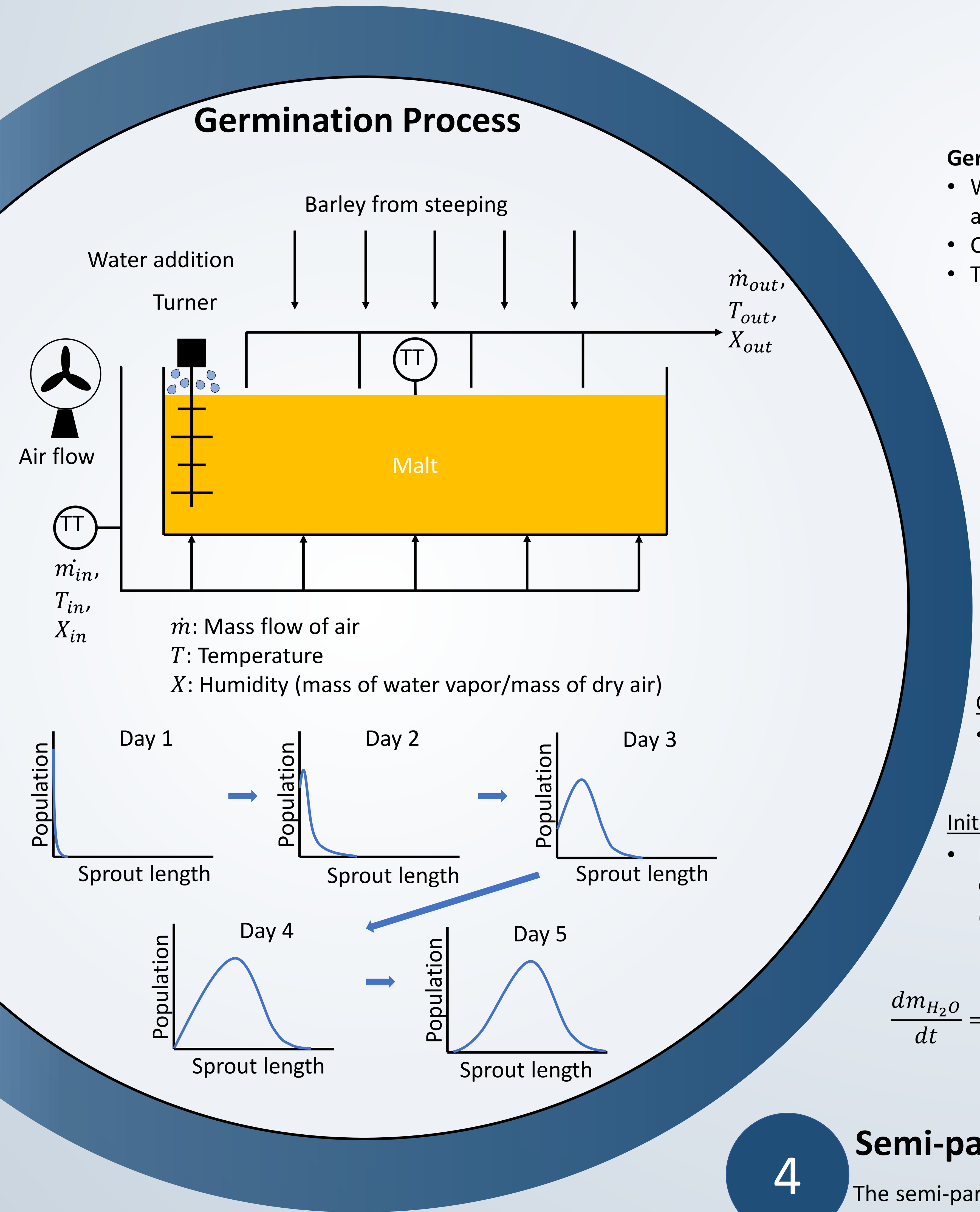
2 Malting Process

Malt is used in beer and whiskey production as a source for sugar for the fermentation process. Viking Malt is the world's leading malting company producing special malts.



Malting is an energy intensive process due to the need for evaporation of water, cooling during germination, and heating during kilning. The objective of this work is to introduce energy and process optimization to the malting process at the Viking Malt manufacturing plant in Vordingborg through real time model predictions of the germination process.

Germination Process



Starch in the barley kernels is broken down to sugars by enzymes during germination. The sugars are used in the kernel for providing energy for the growth of rootlets and sprouts. The length of the rootlets and sprouts provides insight into the progress of the germination and is an important process parameter.

3 Mechanistic Modelling

When modelling the germination process a semi-parametric hybrid-modelling approach is used combining mechanistic modelling with ML [1].

Water Mass Balance

In:
- Water entering the system in inlet air ($X_{in} \cdot \dot{m}$)
- Water addition from turner ($\dot{m}_{H_2O,Turner}$)

Out:
- Water leaving the system in outlet air ($X_{out} \cdot \dot{m}$)

Initial Conditions:
- Initial water content is equal to water content in steeping ($m_{H_2O}(0) = m_{H_2O,steep}$)

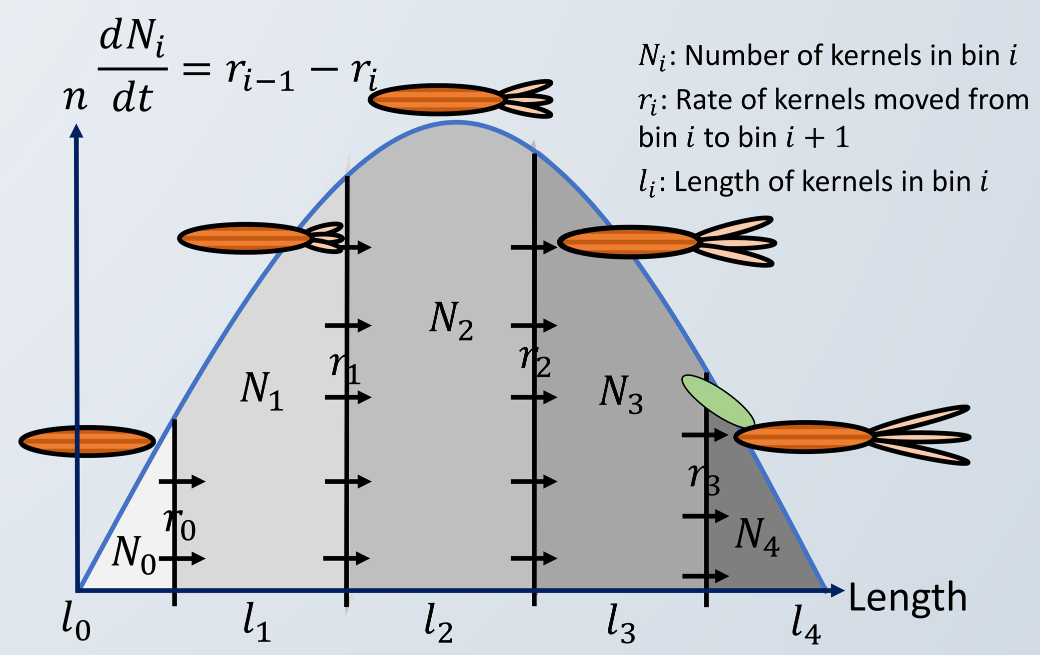
Accumulated = In - Out

$$\frac{dm_{H_2O}}{dt} = \dot{m} \cdot (X_{in} - X_{out}) + \dot{m}_{H_2O,Turner}$$

Sprout Length Population balance

Change in the length of sprouts is only due to growth

$$\frac{dN_i}{dt} = r_{i-1} - r_i$$



Rate of particles moved from bin i to bin $i+1$ due to growth:

$$r_i = N_i G_i$$

Rate of particles moved from bin i-1 to bin i due to growth:

$$r_{i-1} = N_{i-1} G_{i-1}$$

4 Semi-parametric Hybrid-model

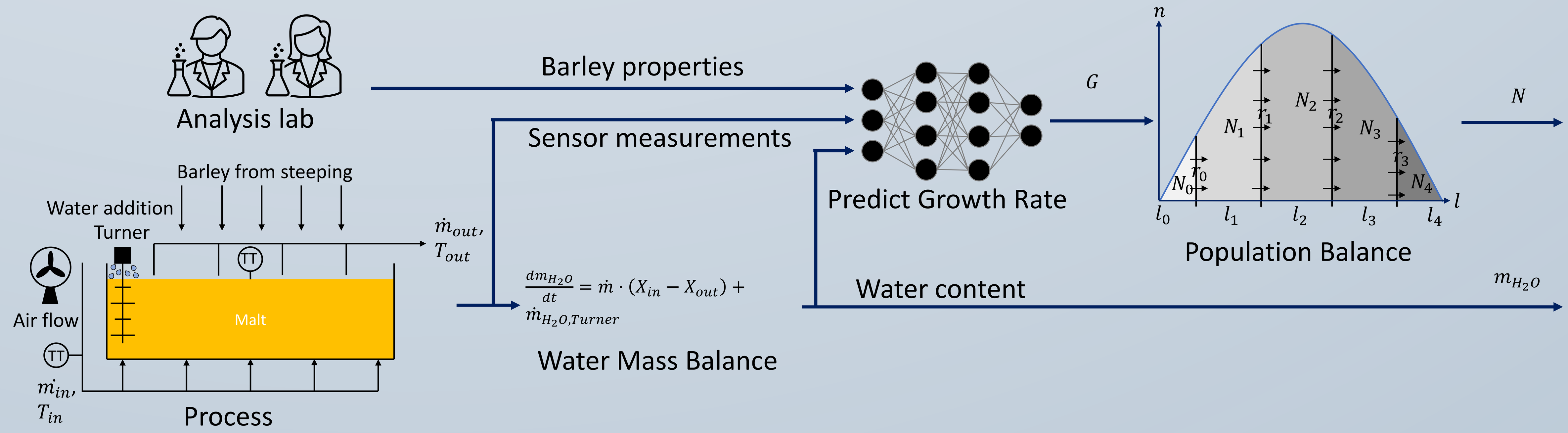
The semi-parametric hybrid-model consists of 3 parts:

1) Water mass balance
Predicts water content to be used in Neural Network and in energy optimization
2) Neural Network
Predicts growth rate coefficients for population balance
3) Population Balance
Predicts sprout length distribution for optimization

Growth rate coefficients predicted using Neural Network

Input:
- Barley properties (Sort of barley, Crop year, lab measurements)
- Sensor measurements (Temperature, Air flowrate)
- Predicted water content (m_{H_2O})

Output
- Growth rate coefficient for each bin in population balance (G)



5 Future Perspectives

- Energy optimization using model predictions
- Introduction of UI for operator decision making support
- Real time test at the Viking Malt A/S manufacturing plant
- Introduce similar modelling approaches to 4 other Danish industrial companies within different sectors

Acknowledgements

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References:

[1] M. von Stosch et. al., Hybrid semi-parametric modeling in process systems engineering: Past, present, and future, Computers and Chemical Engineering, 2014, 60, 86-101

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