# Robust implementation of optimal operation of LNG refrigeration cycles

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# Process Description

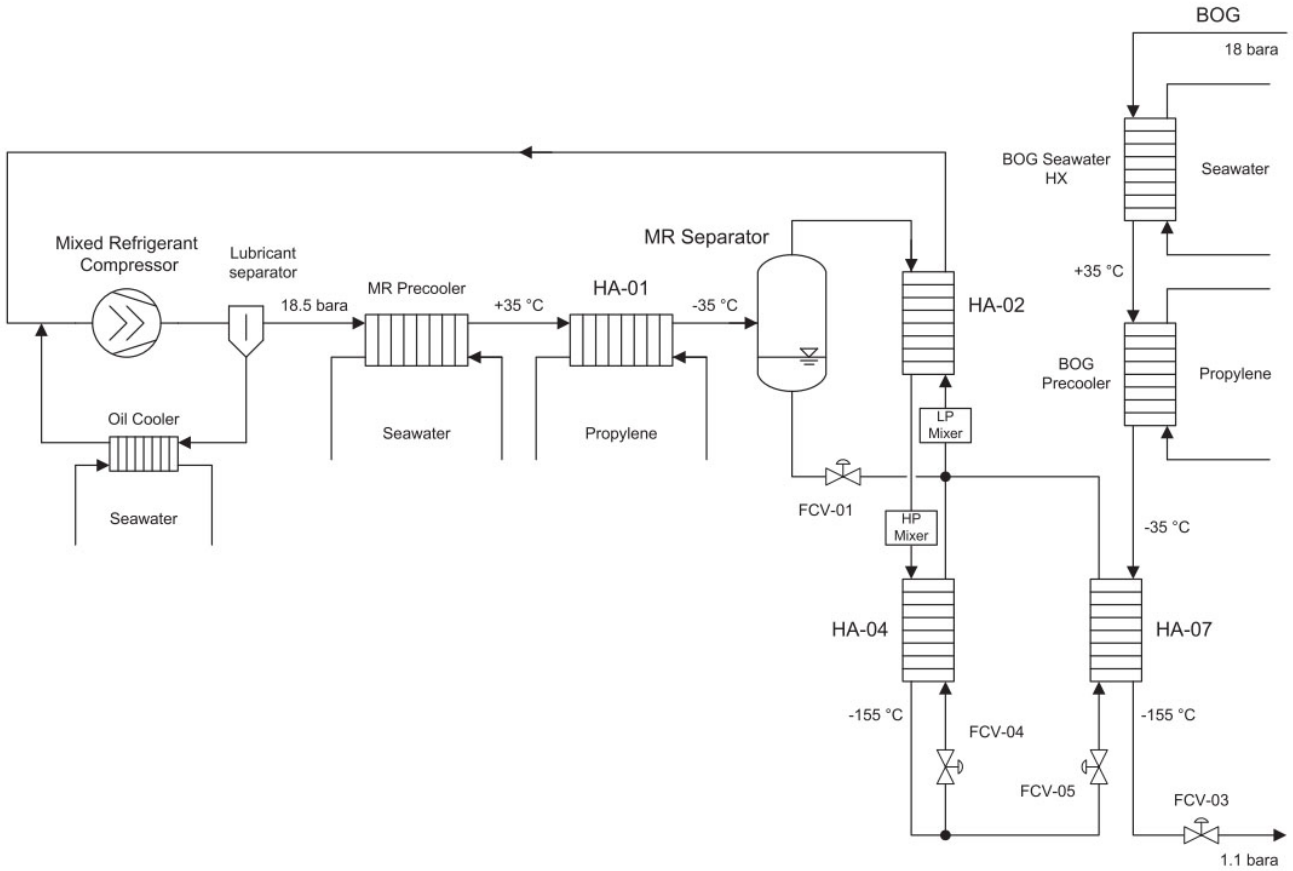


Figure: Mini LNG Configuration [Neksået al., 2010]

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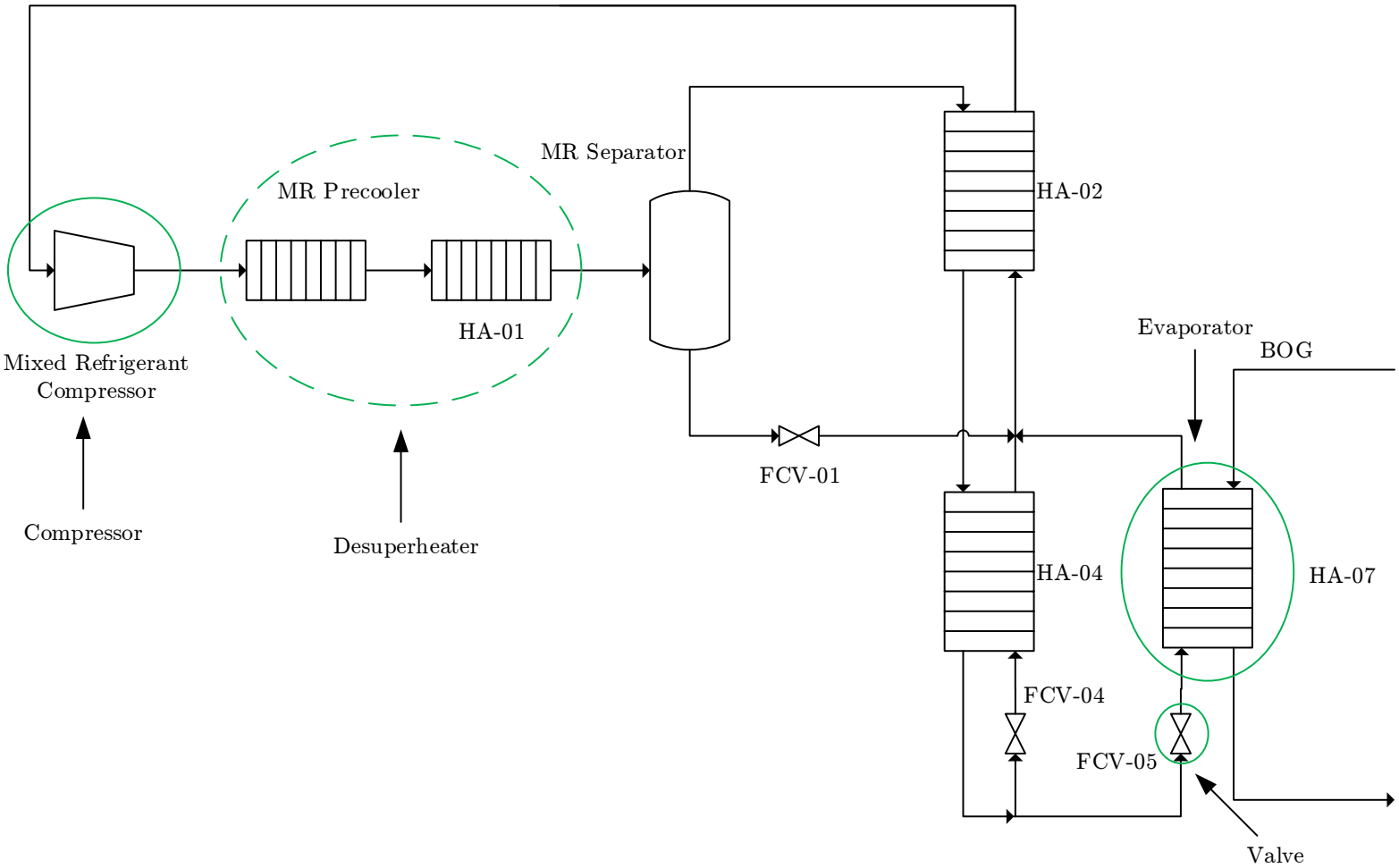



Figure: Simplified mini LNG PFD

## Objective: Propose a model for optimization

Criteria for the model

- Reliable
- Robust

Approach

- Software: Aspen Hysys® or Matlab
- Modular Sequential or Equations Oriented

The models (except for the thermodynamics) are made from scratch
The units used simplified models

# Operation Degrees of Freedom

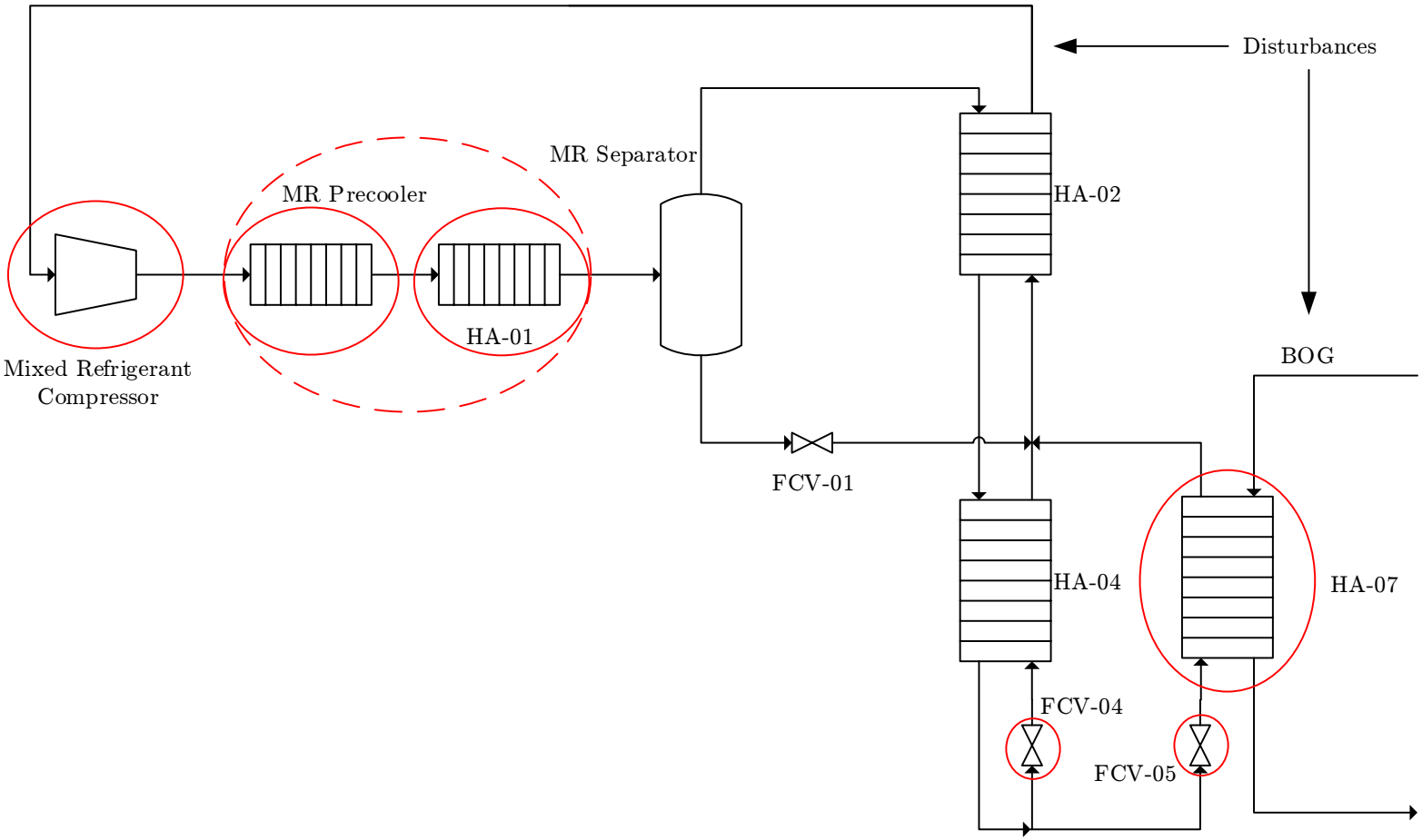



Figure: MiniLNG PFD showing the operation degrees of freedom for the model

# Model Assumptions

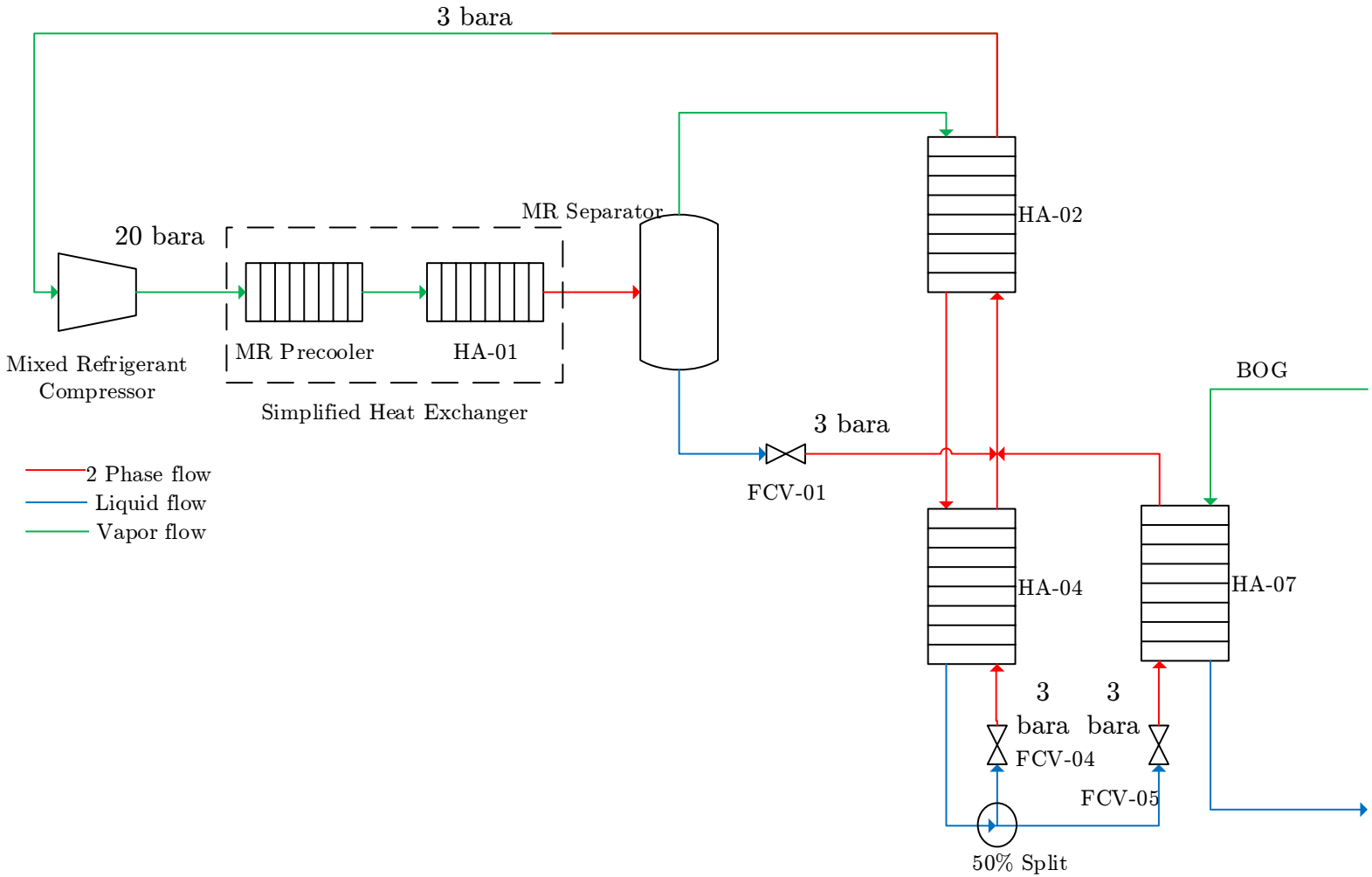


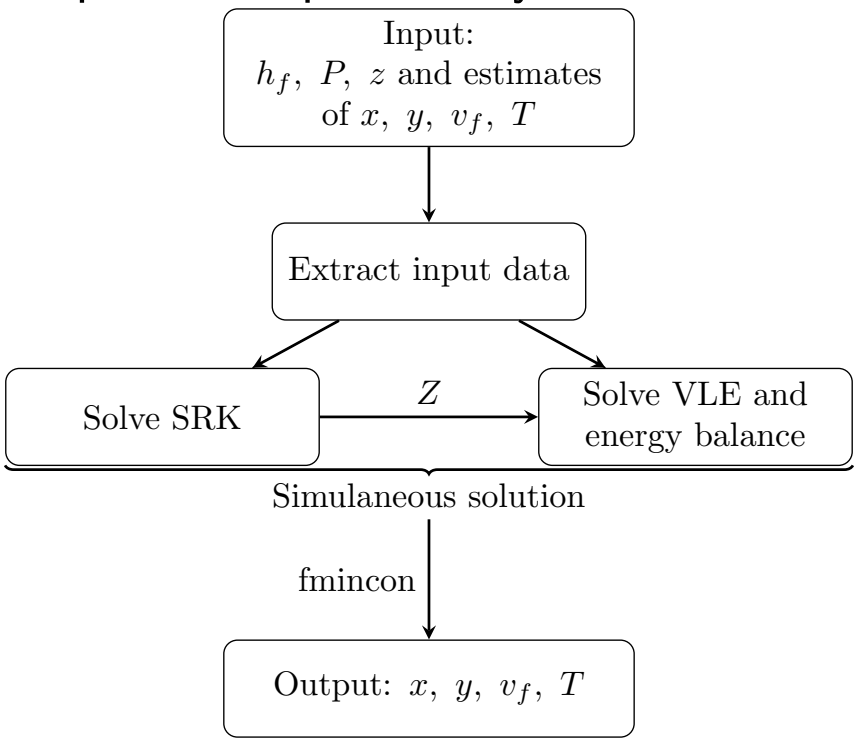

Figure: MiniLNG PFD showing the main assumptions for the model

# Thermodynamics

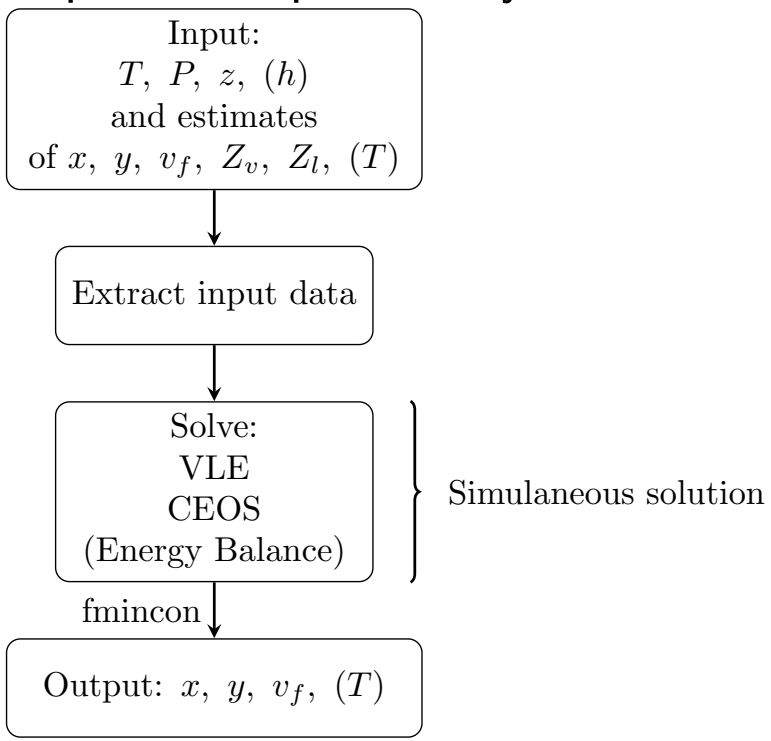
The properties of the refrigerant and the gas are modelled using Soave's modification of the Redlich-Kwong equation of state [Soave, 1972].

Flash calculations algorithms,based on [Skogestad, 2014]:

## Implicit compressibility calculation

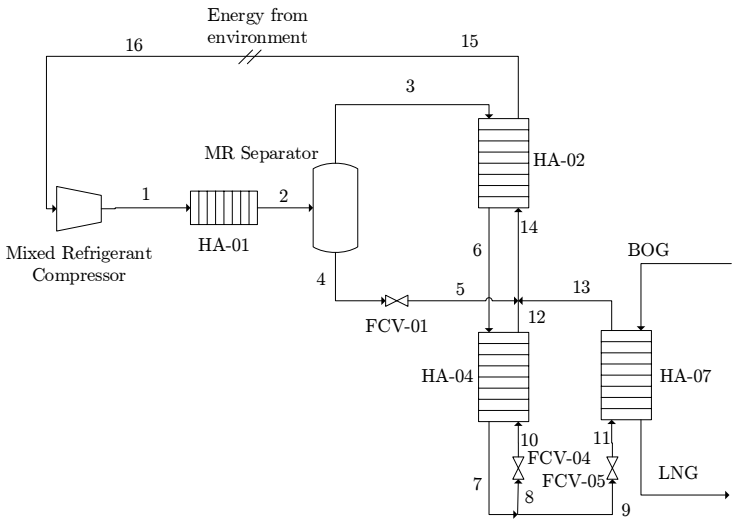


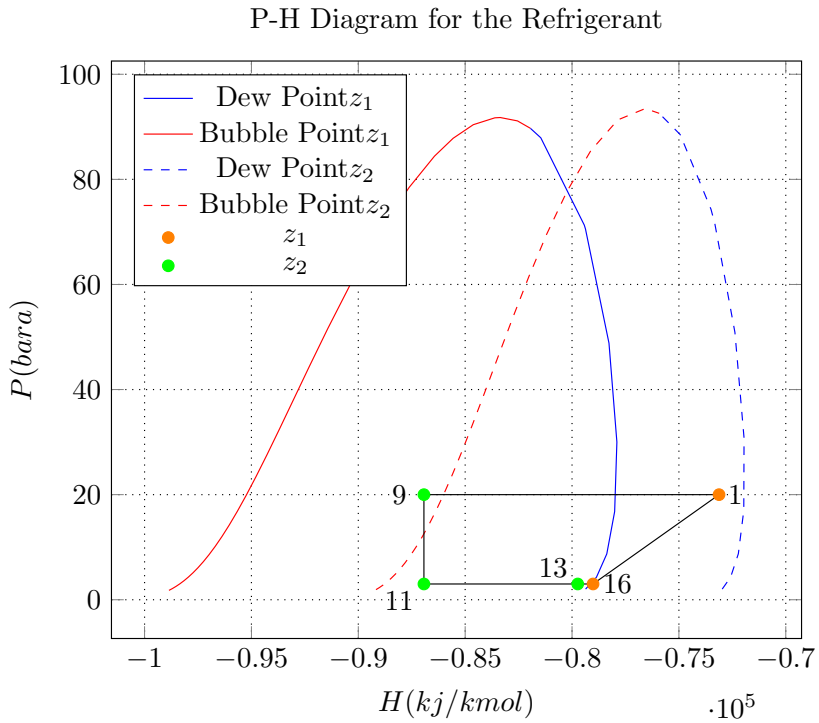

## Explicit compressibility calculation



# Model Results

Simulation results: The model in Matlab was consistent with the results from Aspen Hysys®



# Conclusions

- It was possible to proposed a model reliable enough for the conditions described by [Neksået al., 2010]
- The model is robust enough for points that are far enough from the two phase boundaries. However, for points in which there can be one or two phases, the model requires a more careful initialization.
- An initial framework using the degrees of freedom analysis towards the optimization was done.

# Further work

- Improve the robustness of the model towards optimization
  - Implement the model as a fully equations oriented model
  - Further improve the flash calculations for points close to the change phase boundaries
- Further define the optimization problem
  - Maximum capacity or optimal energy consumption. This can lead to modifications in the degrees of freedom analysis
- Optimize the plant

# References



Nekså, P., Brendeng, E., Drescher, M., and Norberg, B. (2010).
Development and analysis of a natural gas reliquefaction plant for small gas carriers.
*Journal of Natural Gas Science and Engineering*, 2(2-3):143–149.


Skogestad, S. (2014).
Srk - flash.
"http://www.nt.ntnu.no/users/skoge/book-cep/matlab/srk-flash/".


Soave, G. (1972).
Equilibrium constants from a modified Redlich-Kwong equation of state.
*Chemical Engineering Science*, 27(6):1197–1203.

Thanks for you attention!