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Carbon Capture Simulation Initiative

Simulation-Based Optimization Framework with Heat Integration

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Simulation-Based Optimization

\+ Treats simulation as black box (does not require mathematical details of model)

⟶ **Easy to implement**

\+ Does not require simplification of the process model

⟶ **High-fidelity models applied**

\+ Readily adapted for parallel computing

⟶ **Computational time reduced**

− Not well suited for problems with many variables such as heat integration, and superstructure optimization

⟶ **Heat integration is a separate module in optimization**
Superstructure optimization pre-determines best configuration

Goal: Develop a simulation-based optimization framework with heat integration for large-scale high-fidelity process models.

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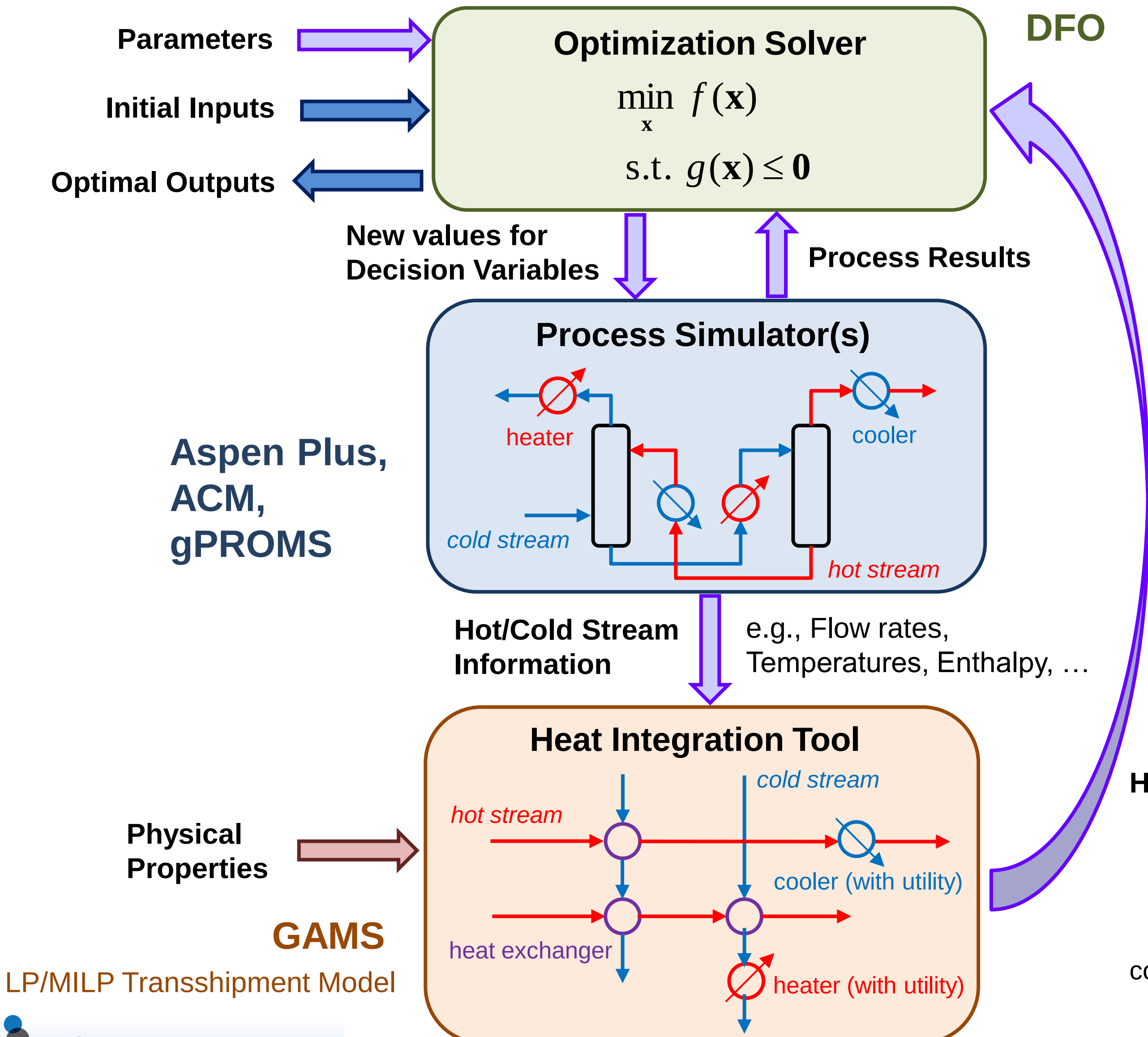
Simulation-Based Optimization with Heat Integration



Simultaneous process optimization and heat integration are achieved in this framework

Heat Integration Results:

- Hot/cold utility consumptions
- Minimum utility cost
- Minimum number of heat exchangers
- Optimal matches between hot and cold streams

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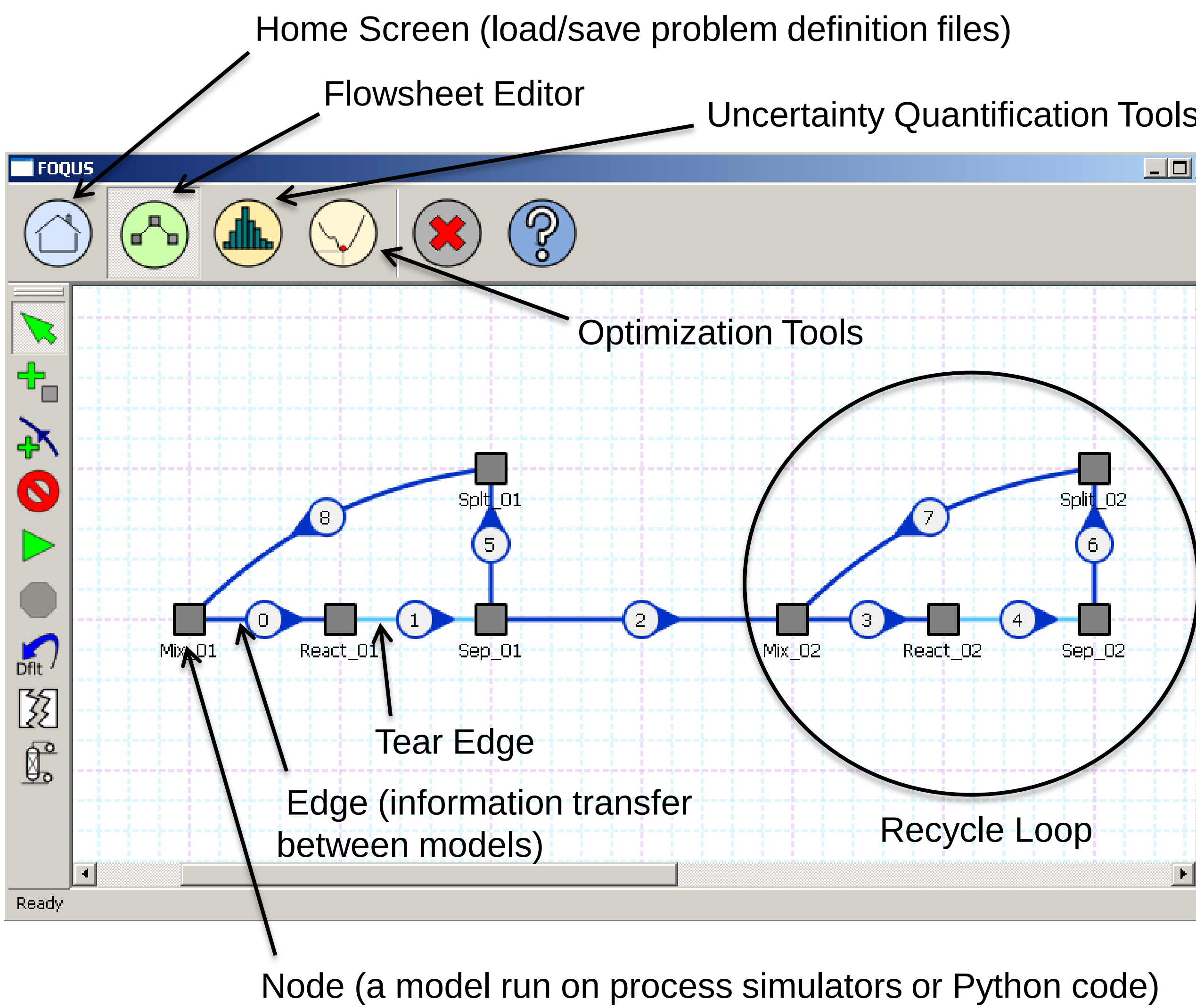
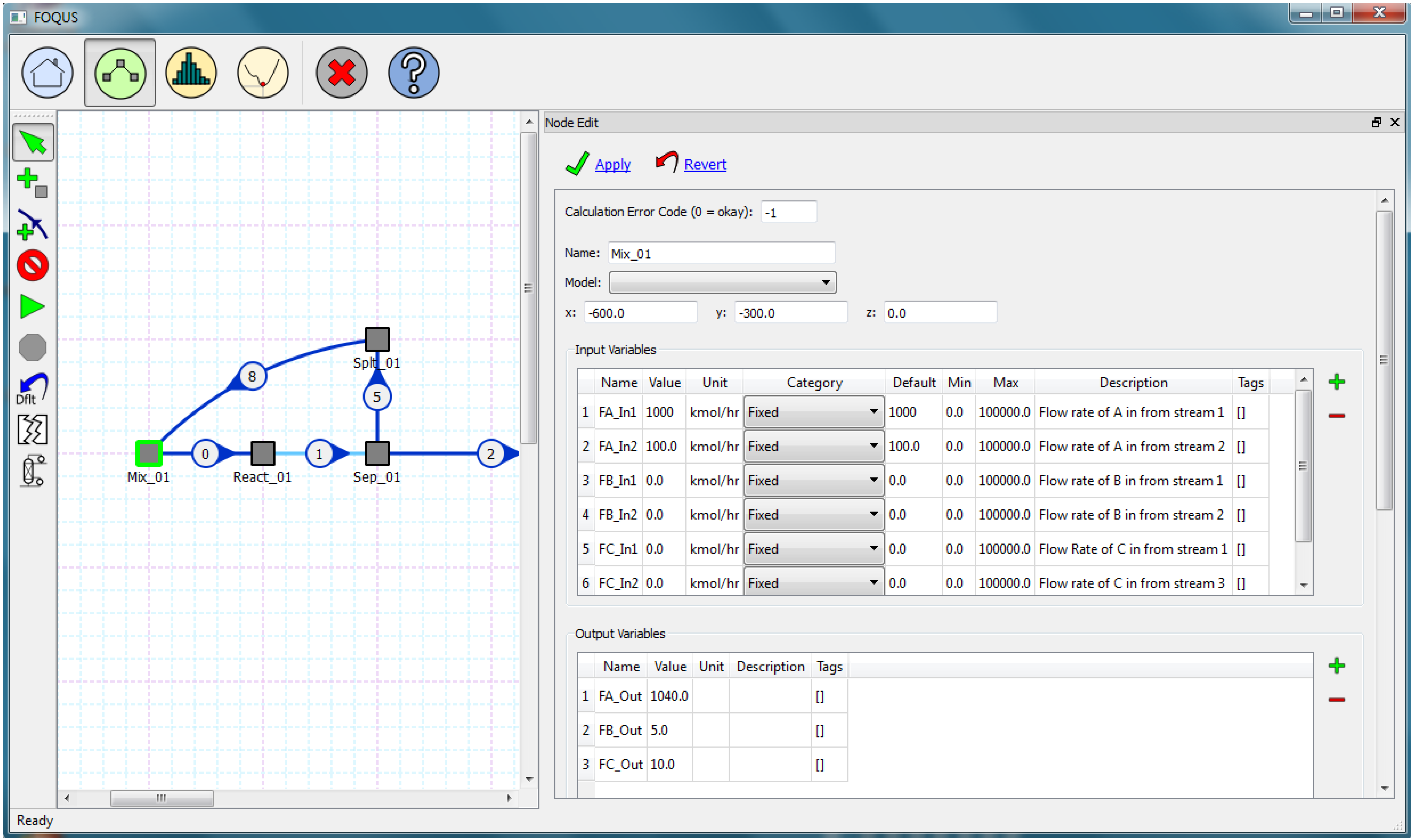
Graphic User Interface



Simulation/Calculation Task



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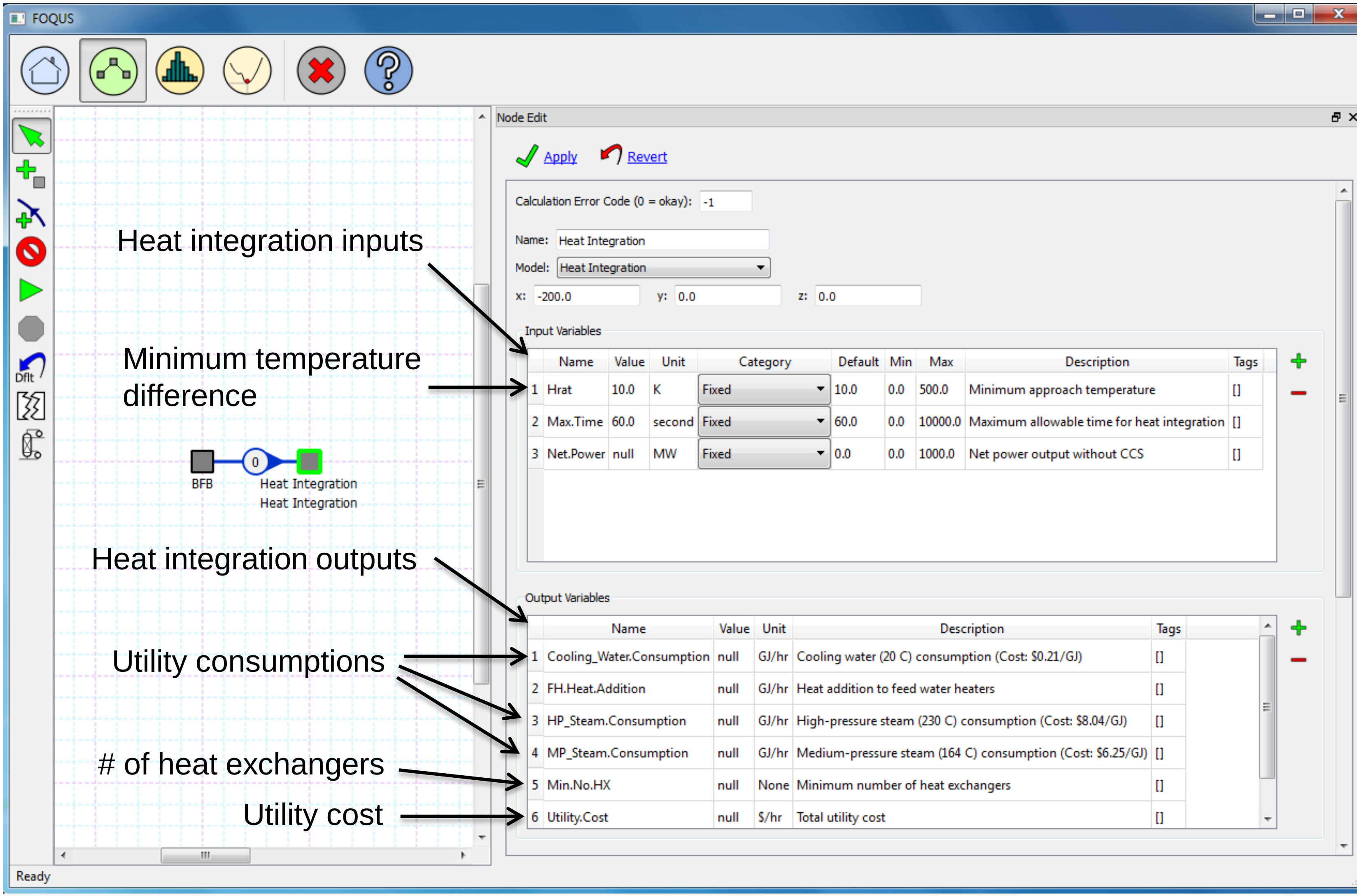
Heat Integration Interface



Optimization Problem Setting

Solver selection and parameters

Select decision variables

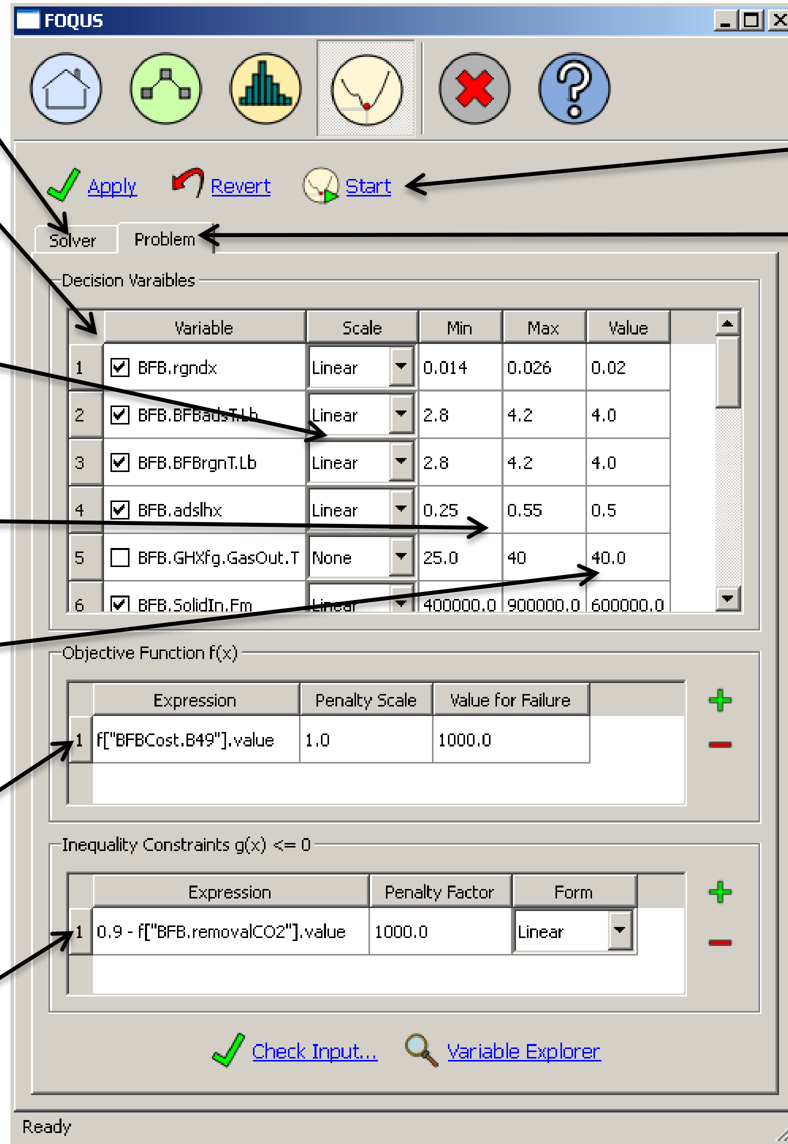
Variable Scaling Method
input variables are scaled
to be 0 at min and 10 at max

Min/Max constraints

Current Value
(initial guess)

Objective function
Python expression

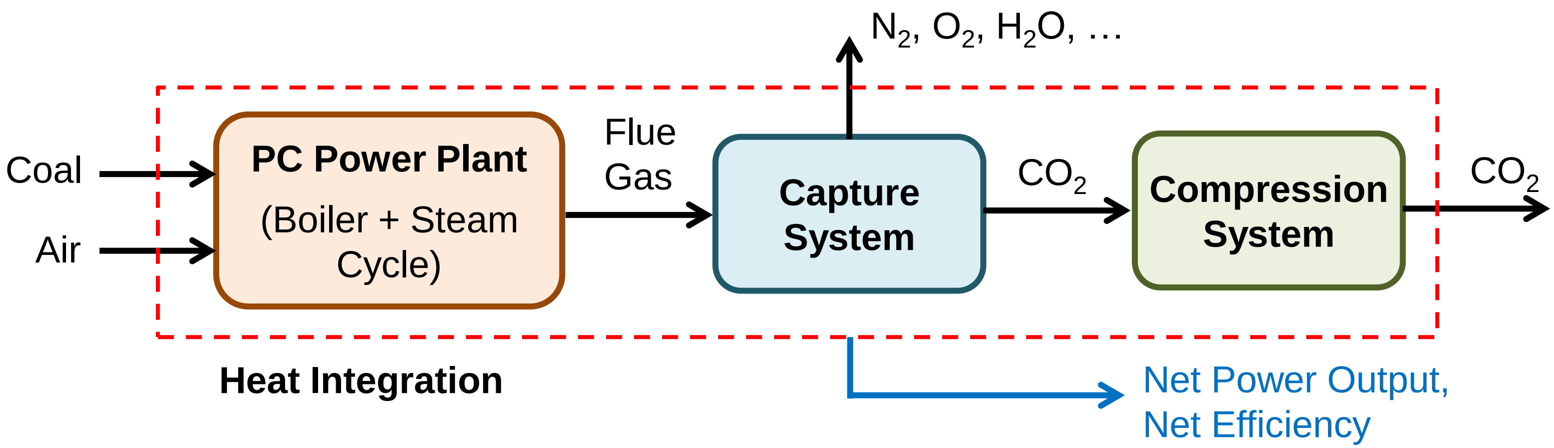
Inequality constraint
Python expression
(enforced with penalty)

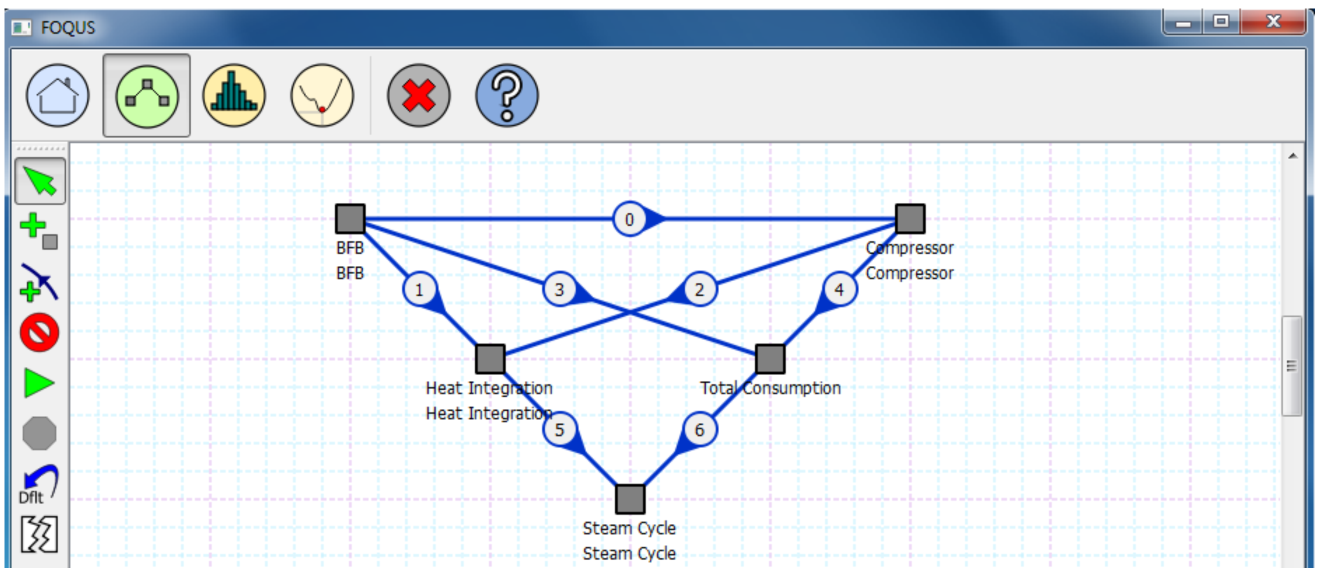


Start/Monitor Optimization

Problem Definition

Case Study


N$_2$, O$_2$, H$_2$O, …
Coal
Air
PC Power Plant
(Boiler + Steam Cycle)
Flue Gas
Capture System
CO$_2$
Compression System
CO$_2$
Heat Integration
Net Power Output,
Net Efficiency


FOQUS
0
BFB
BFB
Compressor
Compressor
1
3
2
4
Heat Integration
Heat Integration
Total Consumption
5
6
Steam Cycle
Steam Cycle
Dflt

Case Study Results

Objective Function: Maximizing net efficiency

Constraint: CO_2 removal ratio ≥ 90%

Decision Variables (17): Bed length, diameter, sorbent and steam feed rate

Base case w/o CCS: 650 MW_e, **42.1 %** with CCS: 419.6 MW_e, **27.2 %**	**Simultaneous** optimization and heat integration approach	**Sequential** optimization and heat integration approach	Optimization w/o heat integration
Net power efficiency (%)	**32.6**	**31.8**	**30.0**
Net power output (MW_e)	504.3	491.5	463.9
CO_2 removal ratio (%)	**91.9**	**90.2**	**90.2**
Electricity consumption (MW_e)	86.9	75.1	75.1
IP steam withdrawn from power cycle (kg/s)	0	0	0
LP steam withdrawn from power cycle (kg/s)	93.9	125.3	139.0
Cooling water consumption (m^3/s)	12.8	10.4	20.7
Heat addition to feed water (MW_{th})	135.4	139.8	0

Optimization and heat integration significantly increased net efficiency of power plant with CCS.

Software: FOQUS

Framework for Optimization and Quantification of Uncertainty and Sensitivity

- Builds on Sinter and the Turbine Gateway
- Common framework for model execution
  - simulation based optimization
  - uncertainty quantification (UQ)
  - steady state reduced model building (coming soon)

More information: https://www.acceleratecarboncapture.org

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