# Modelling and Design Optimisation of Heat Recovery and Waste Heat to Power with the EINSTEIN Software Tool

I-Therm Workshop, October 2017

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energyXperts.NET

*This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 680599.*

- What is EINSTEIN – general overview
- Heat recovery
- Heat to power conversion
- Link with monitoring data and energy management
- Continous time adaptation and optimisation

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# EINSTEIN

## Expert System for Thermal Auditing in Industry

www.einstein-energy.net

# What is EINSTEIN ?

- A methodology and a software tool (expert system) for thermal energy audits and development of alternative energy concepts

- Results:
  - Detailed energy statistics for present state
  - Quantitative pre-design and evaluation of alternative energy concepts

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# The software tool

DATA ACQUISITION AND CHECK

DATA ACQUISITION (QUESTIONNAIRE)

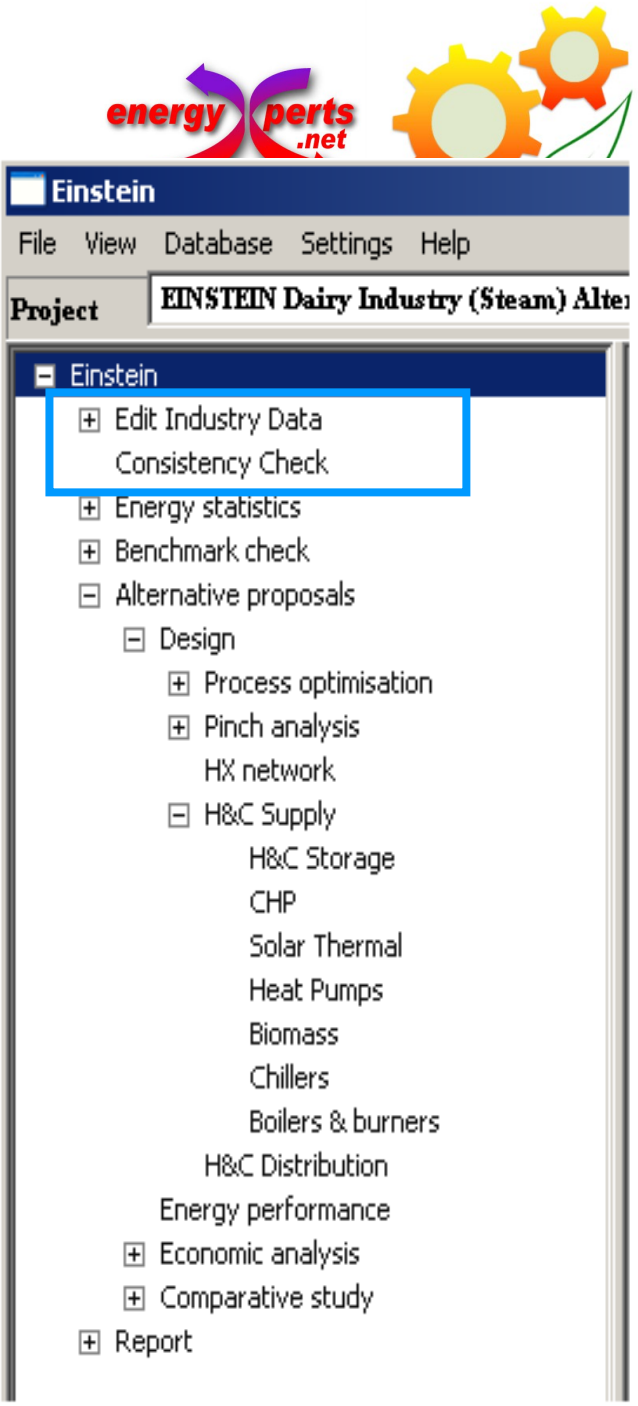
CONSISTENCY CHECK

DATA ANALYSIS

ALTERNATIVE PROPOSALS: DESIGN

ALTERNATIVE PROPOSALS: EVALUATION

REPORT



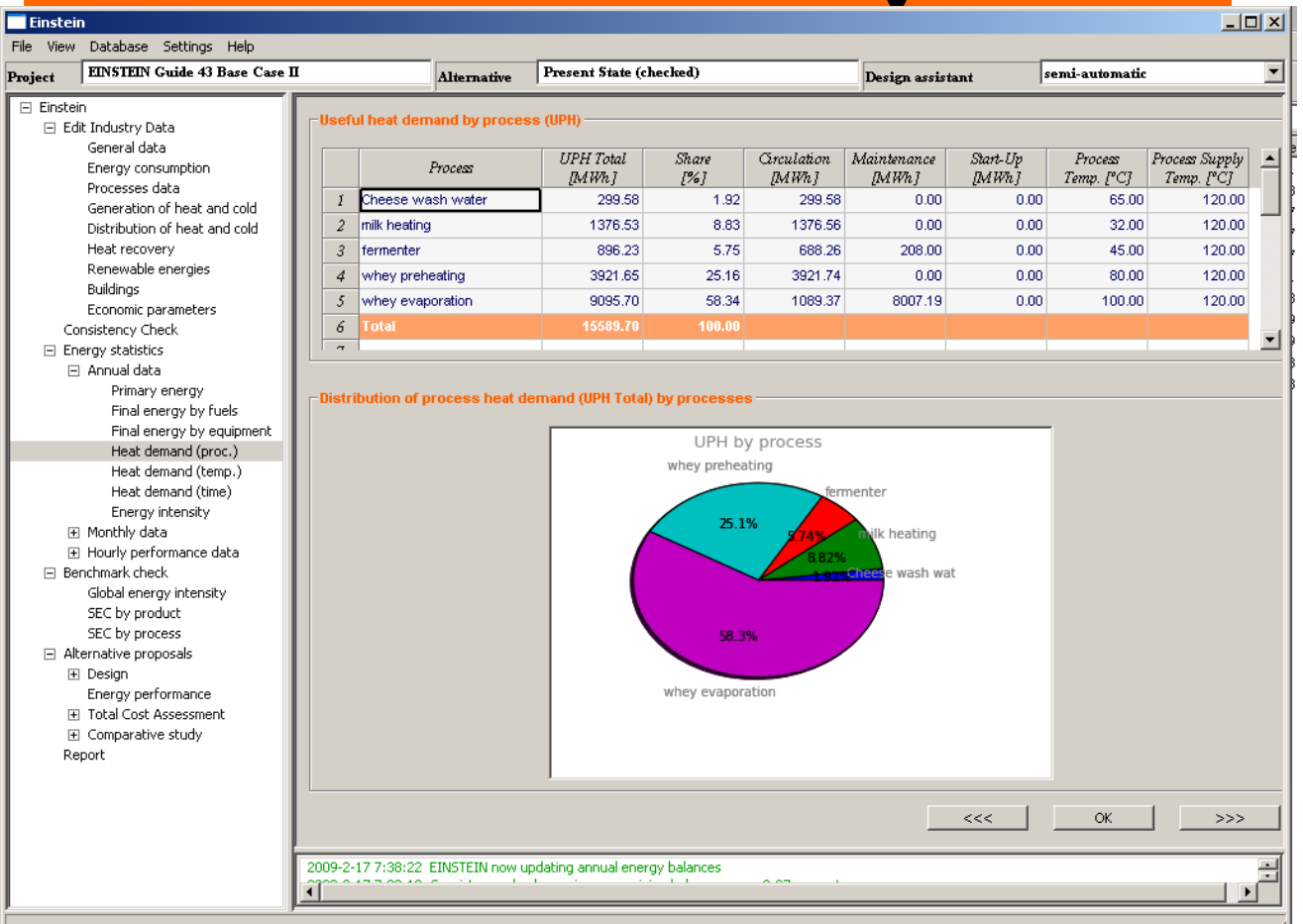
# The software tool

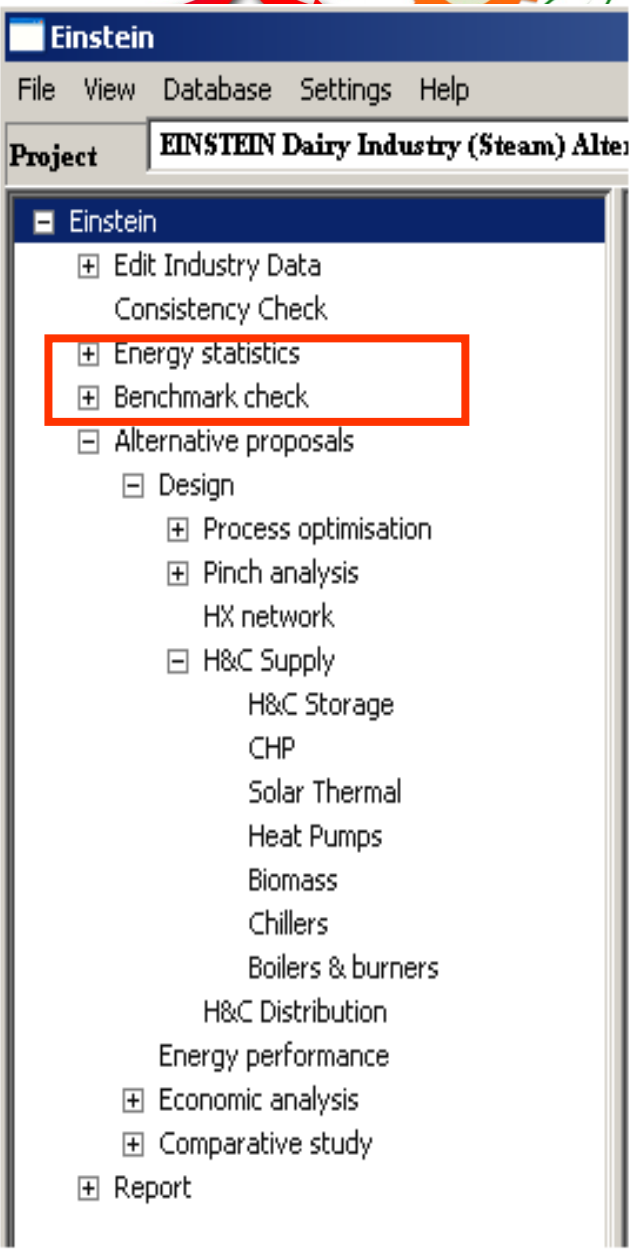
DATA ACQUISITION AND CHECK

DATA ANALYSIS

ENERGY STATISTICS

BENCHMARKING



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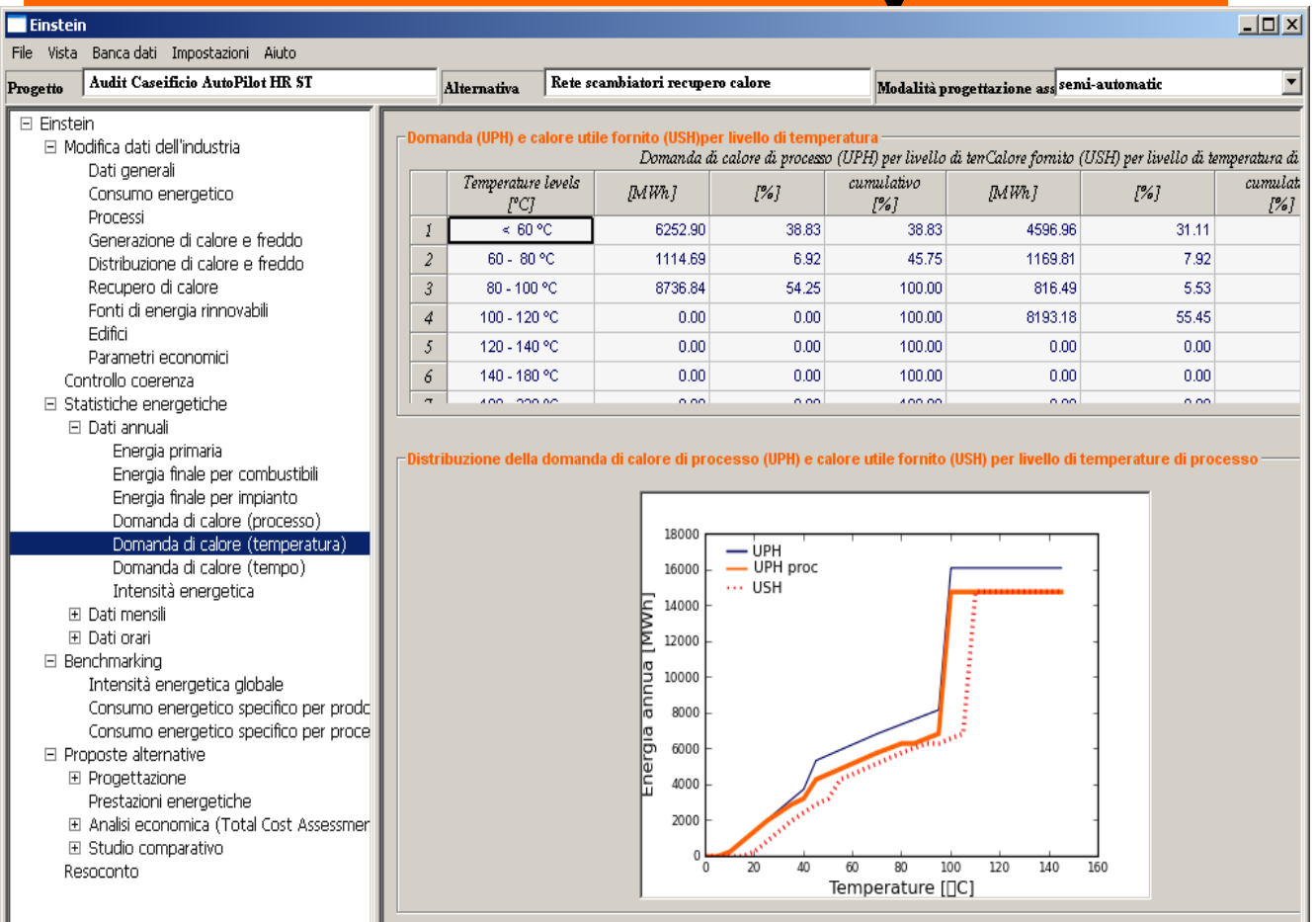


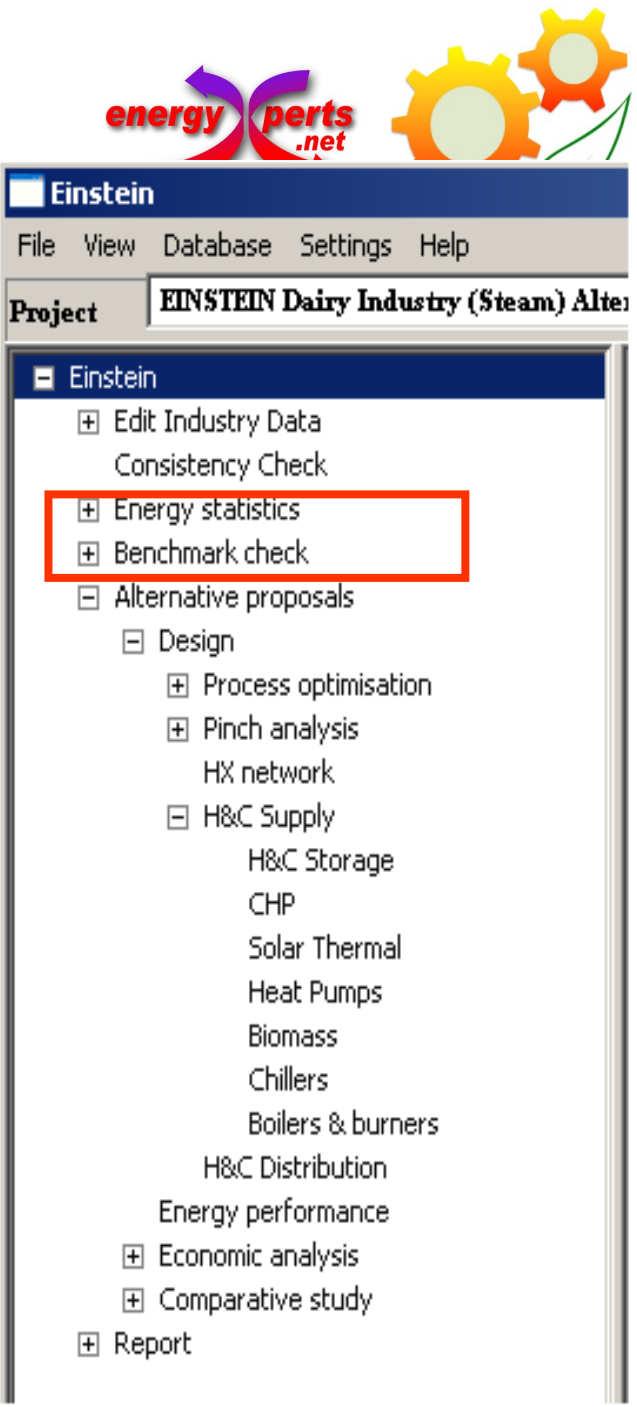

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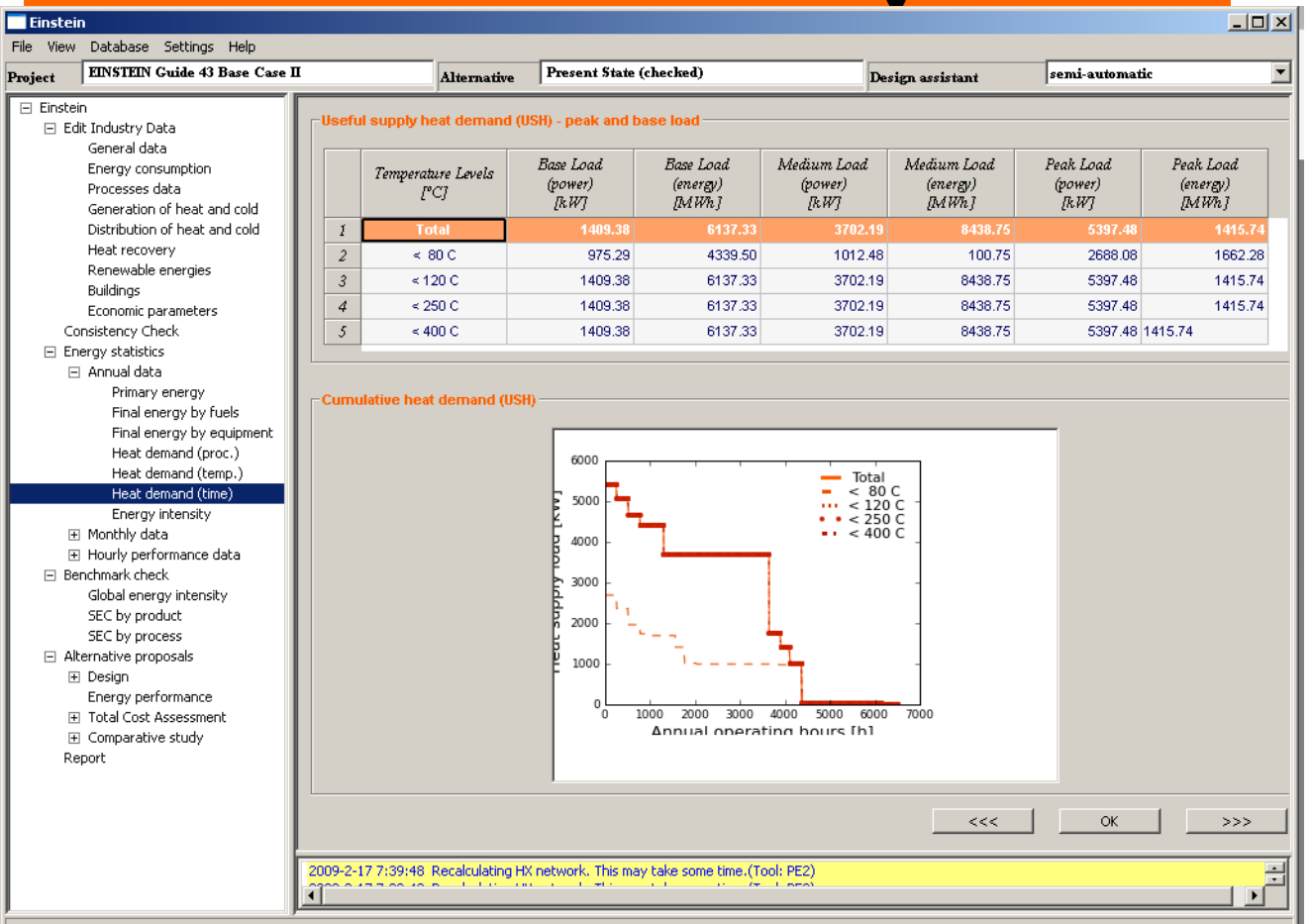


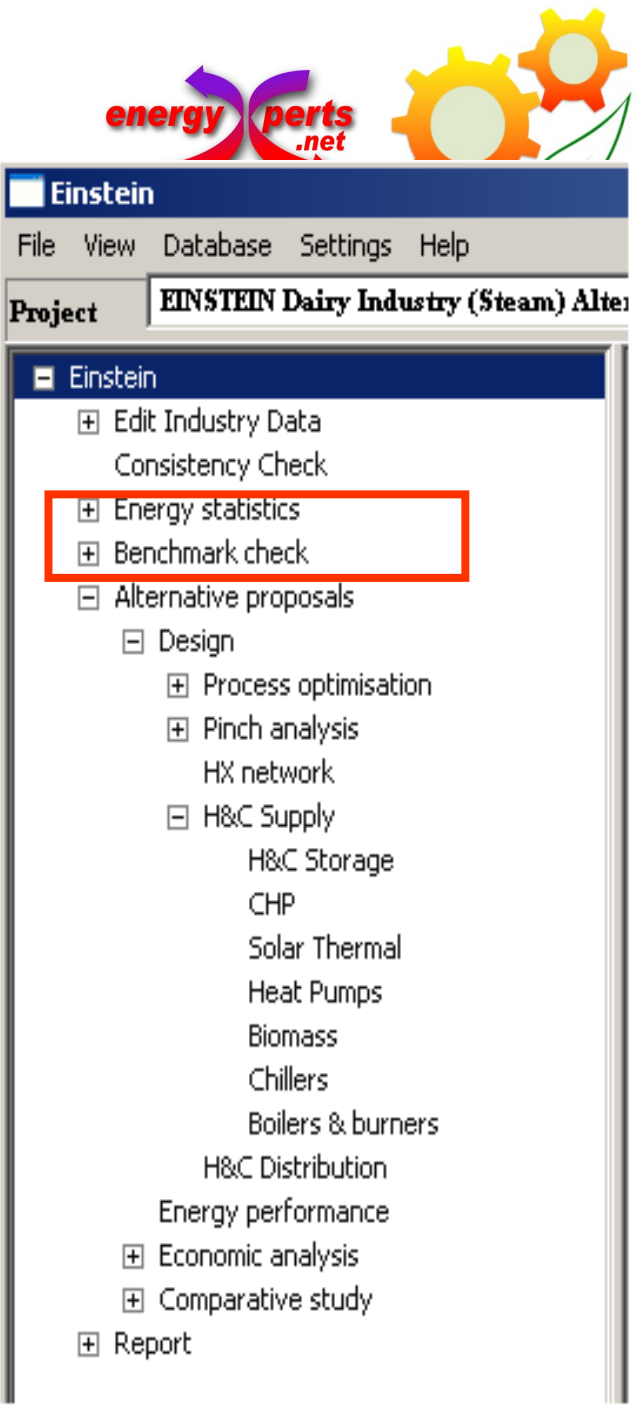

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DATA ANALYSIS

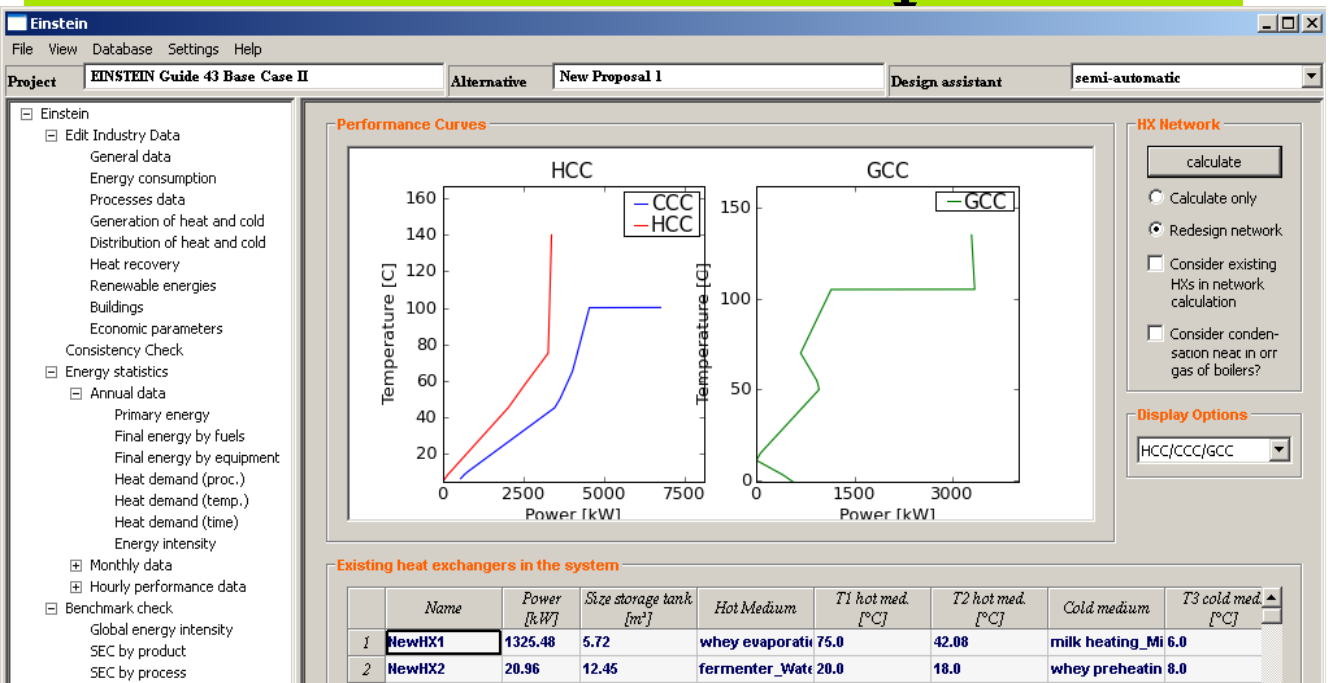
ALTERNATIVE PROPOSALS: DESIGN

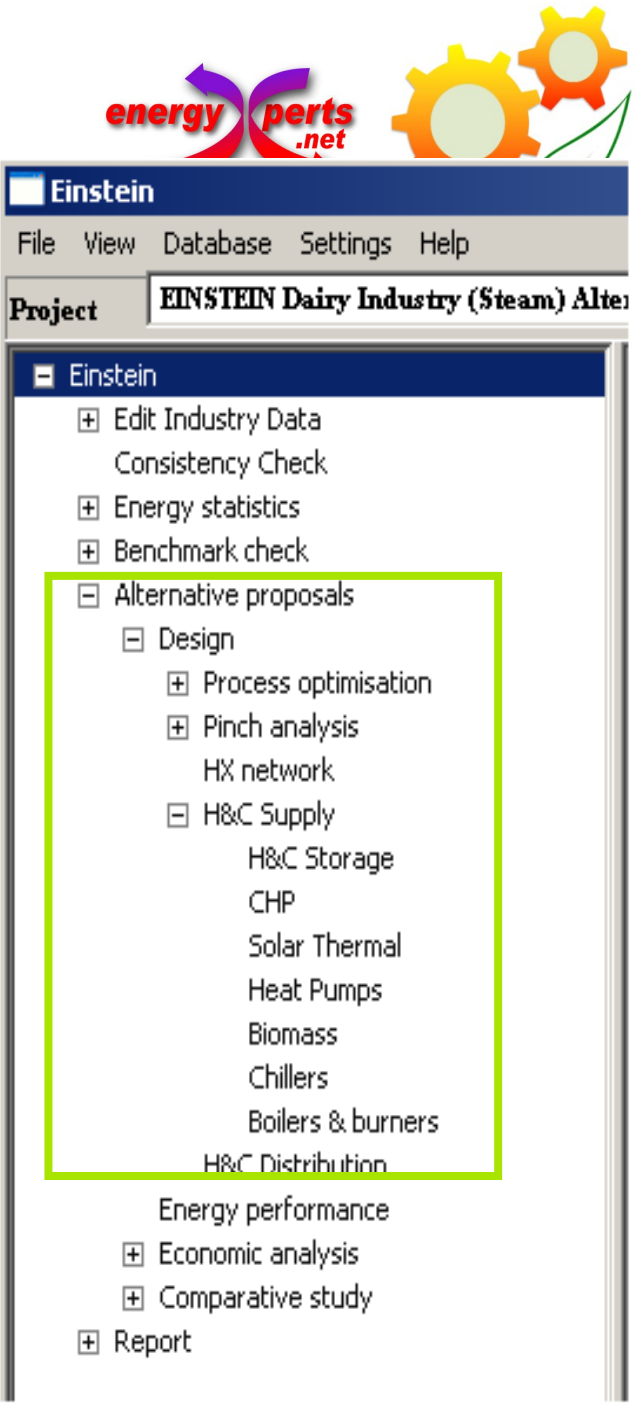
PROCESS OPTIMISATION

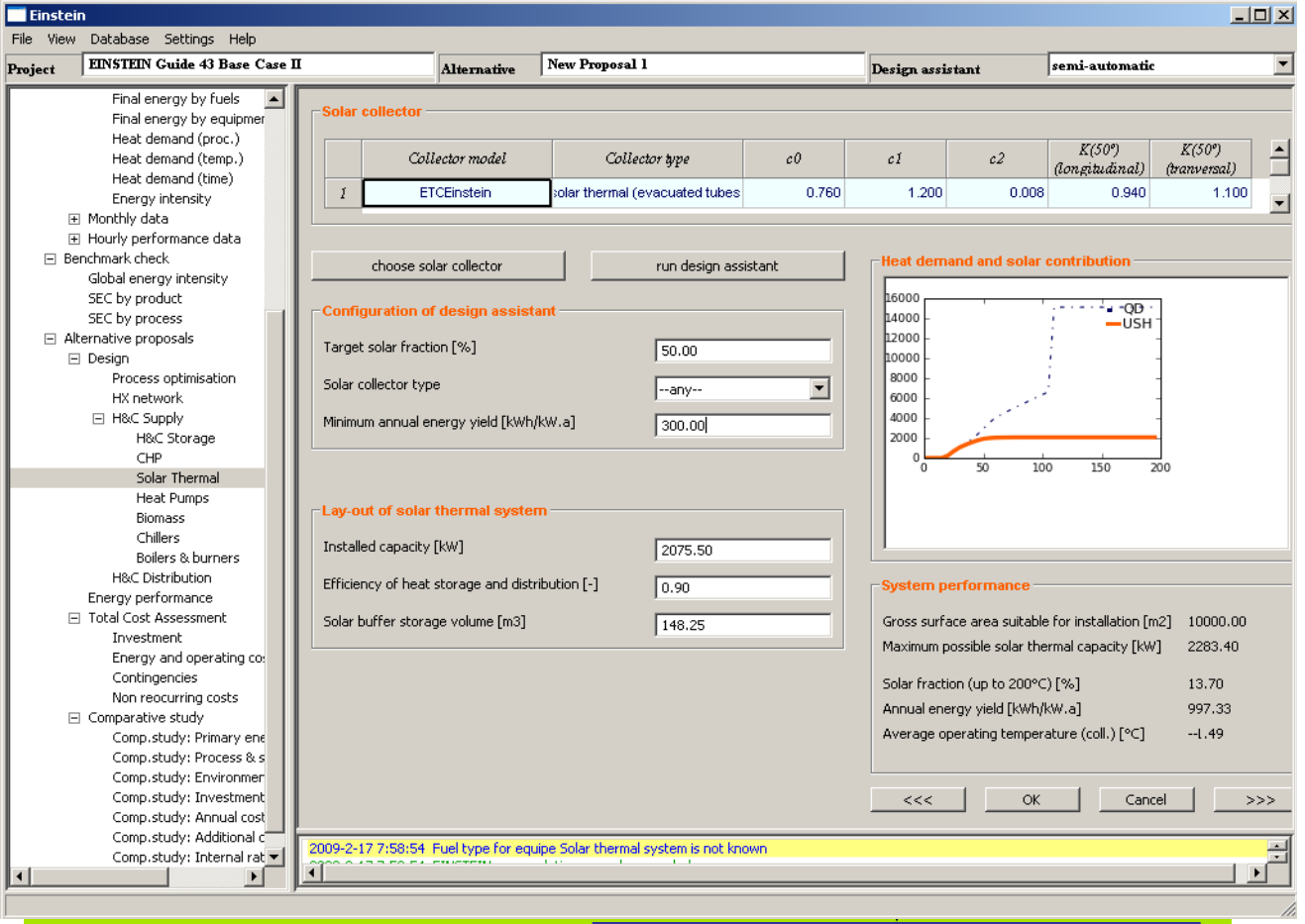
↓

HEAT RECOVERY

↓



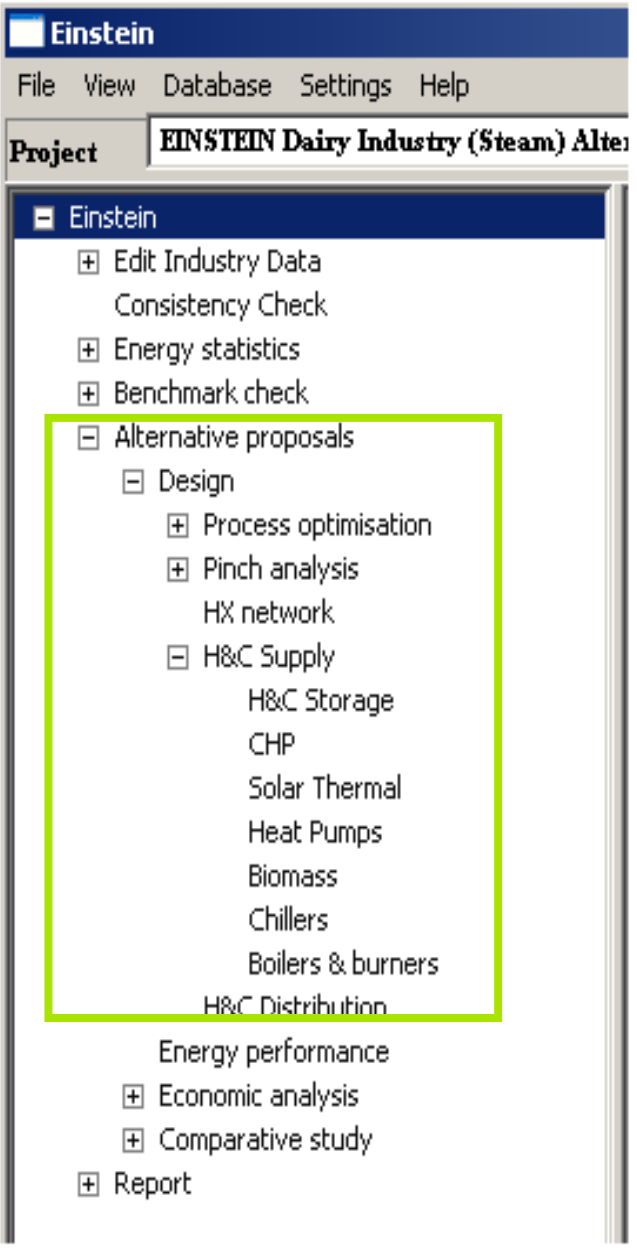






HEAT&COLD SUPPLY SYSTEMS

ALTERNATIVE PROPOSALS: EVALUATION

REPORT



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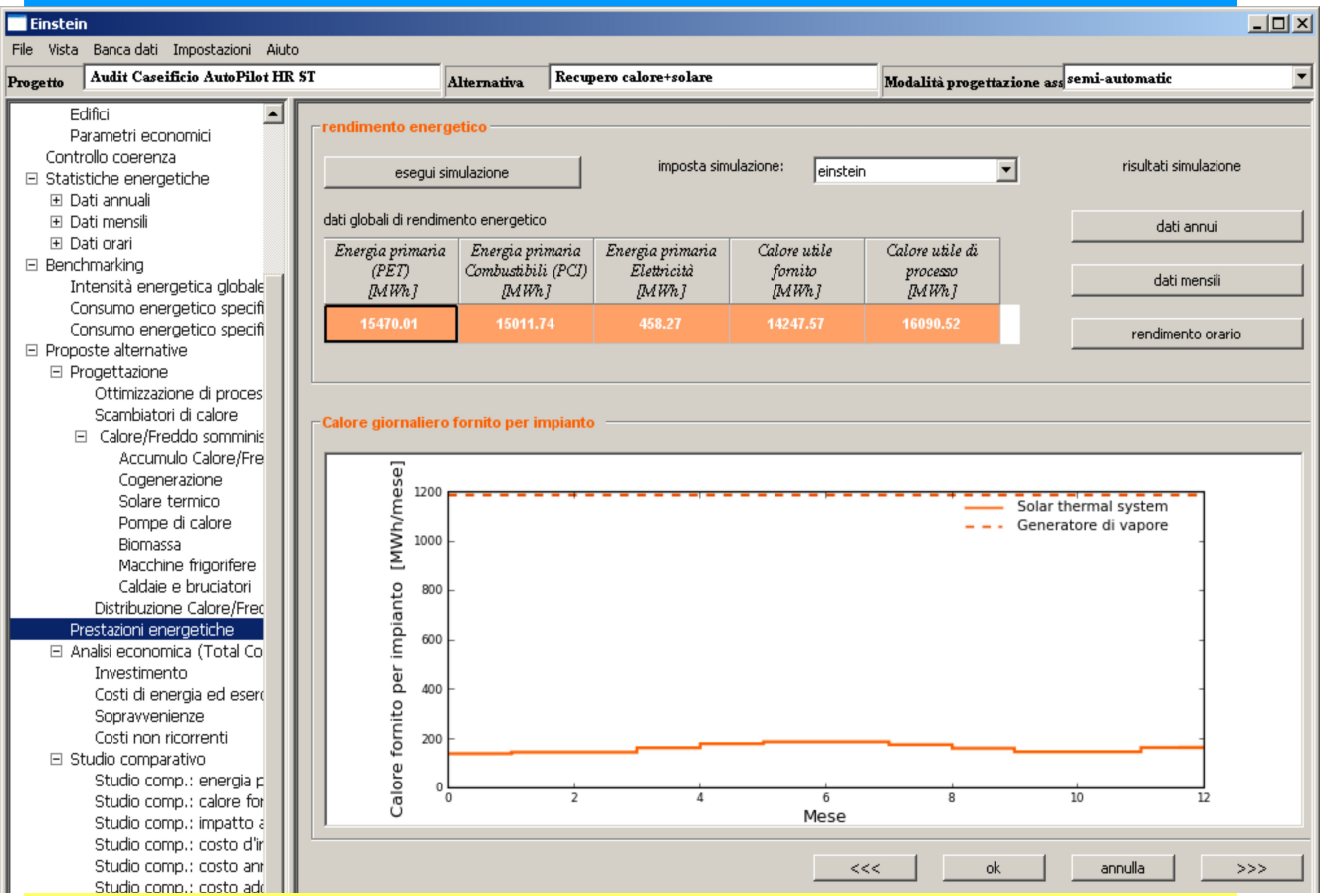


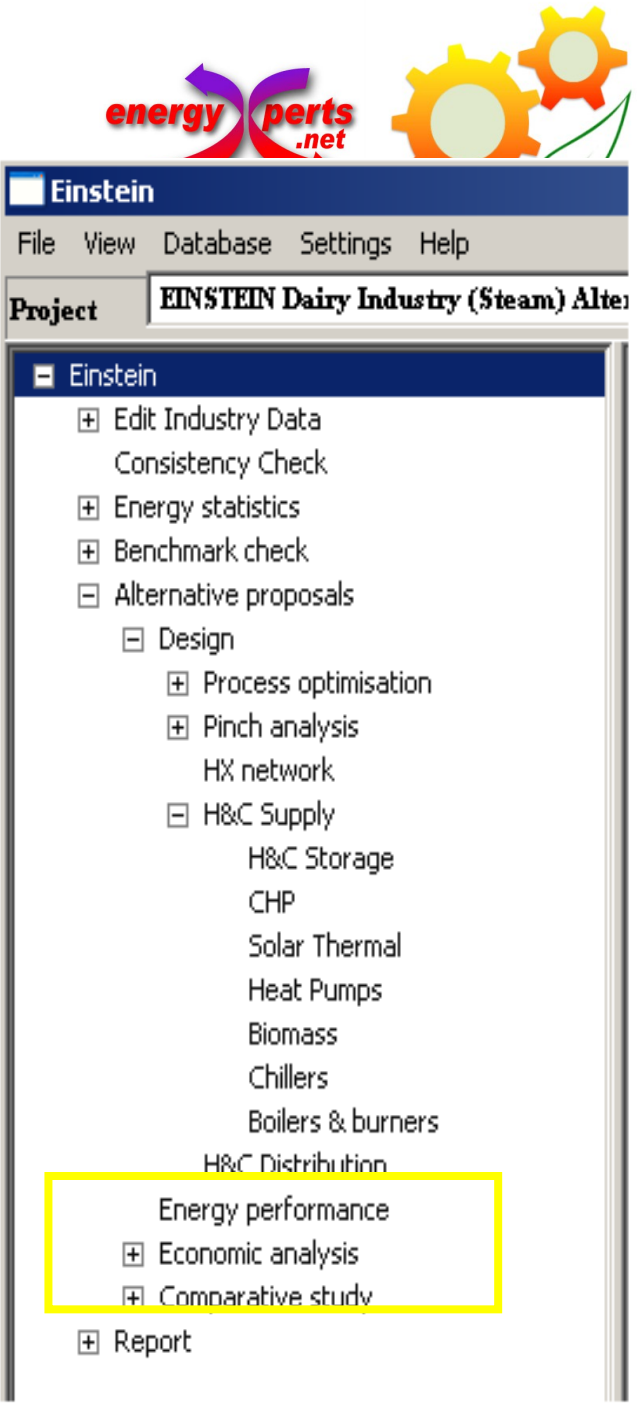

ALTERNATIVE PROPOSALS: EVALUATION

ENERGY AND ENVIRONMENTAL PERFORMANCES

ECONOMIC ANALYSIS

ALTERNATIVES COMPARISON

REPORT



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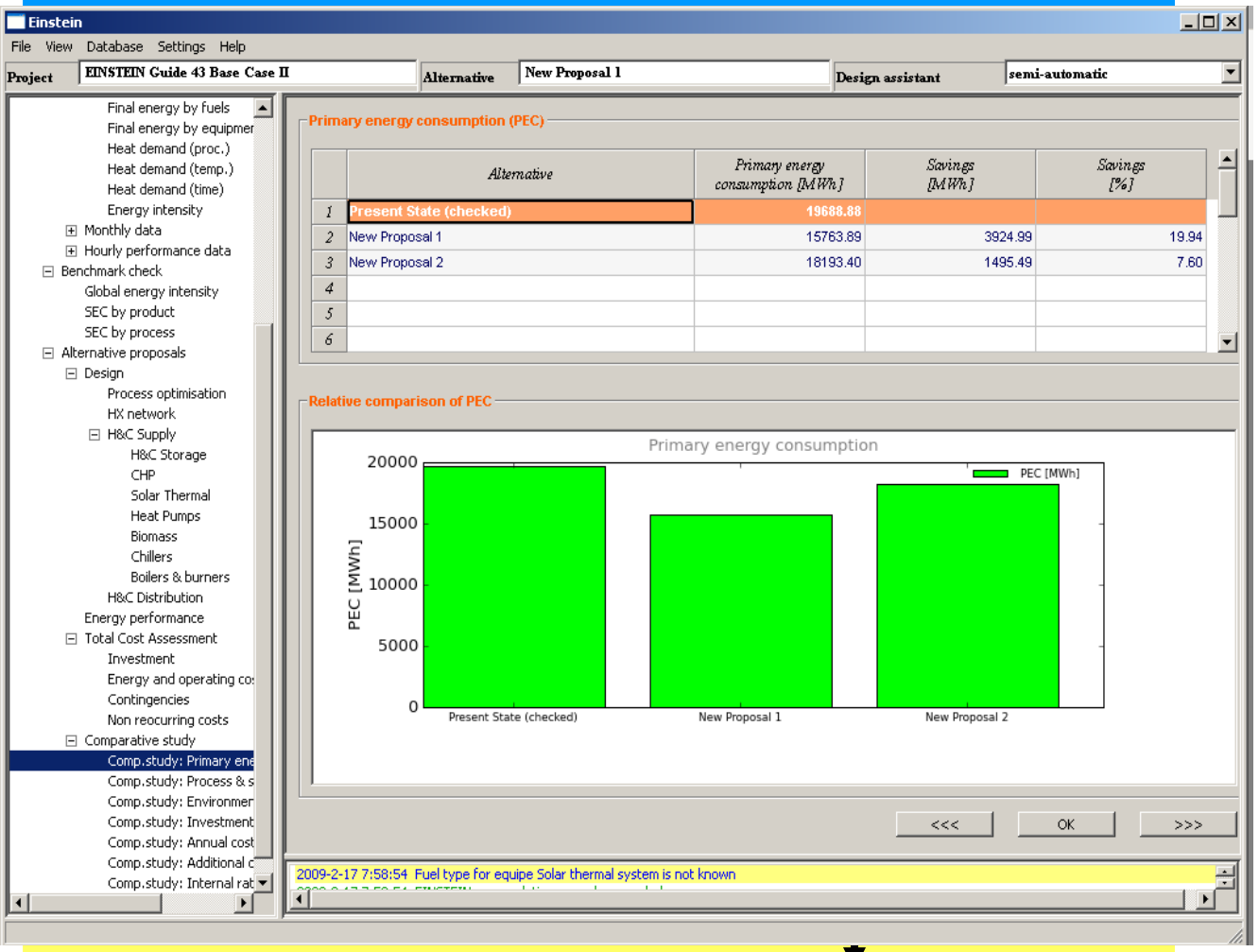


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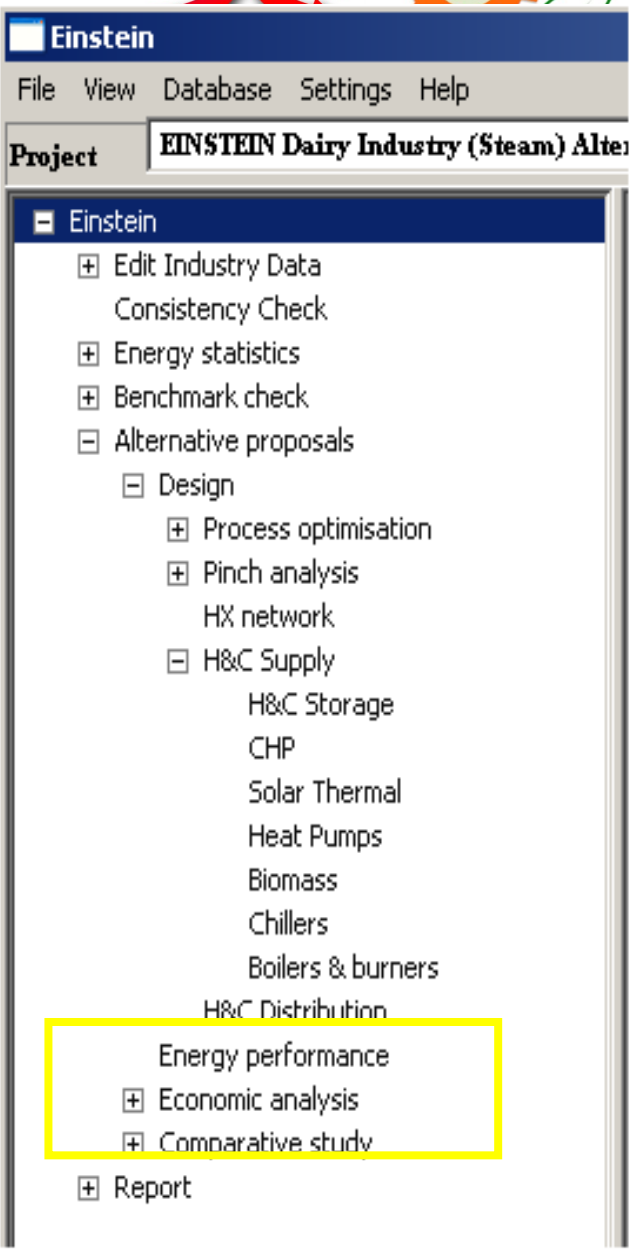

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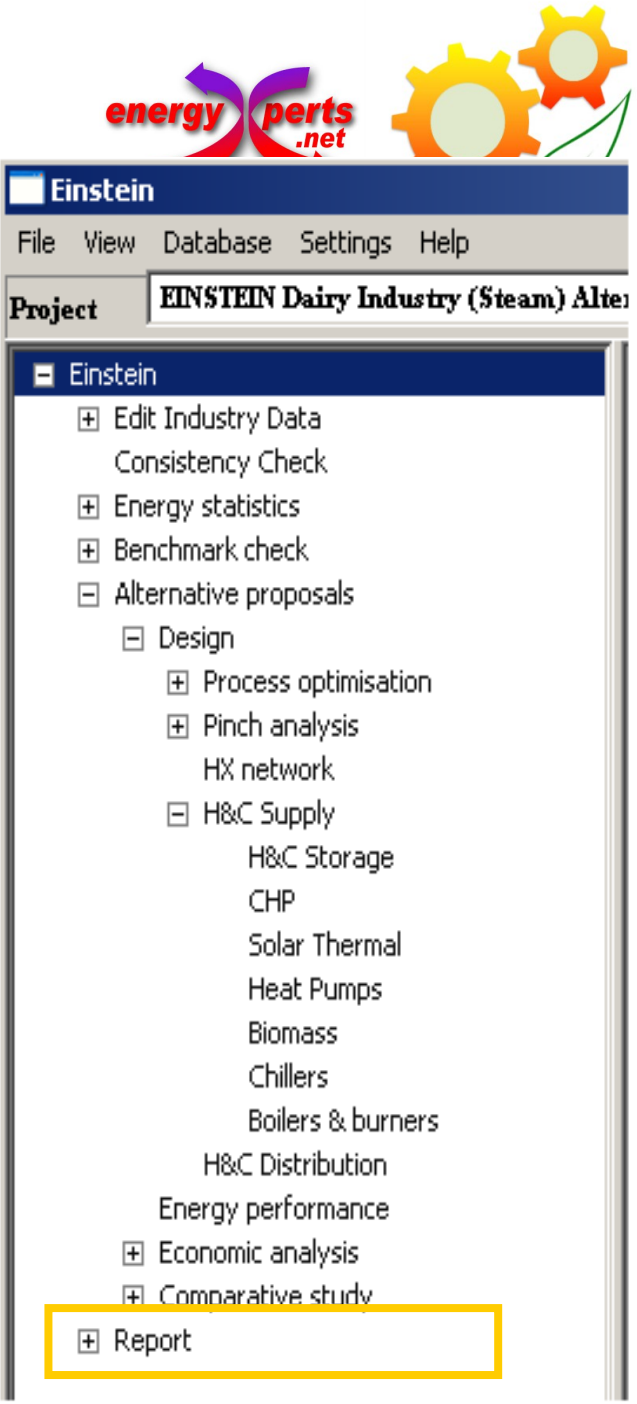

# Optimisation of heat recovery with EINSTEIN

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# EINSTEIN software: heat recovery

- Analysis of heat demand and waste heat as a function of *temperature* and *time.*
- Plot of hot and cold streams
- Plot of heat exchanger network
- Dynamic simulation of heat exchangers with/without storage
- Tools for Pinch-analysis
- Automatic design of optimised heat exchanger networks

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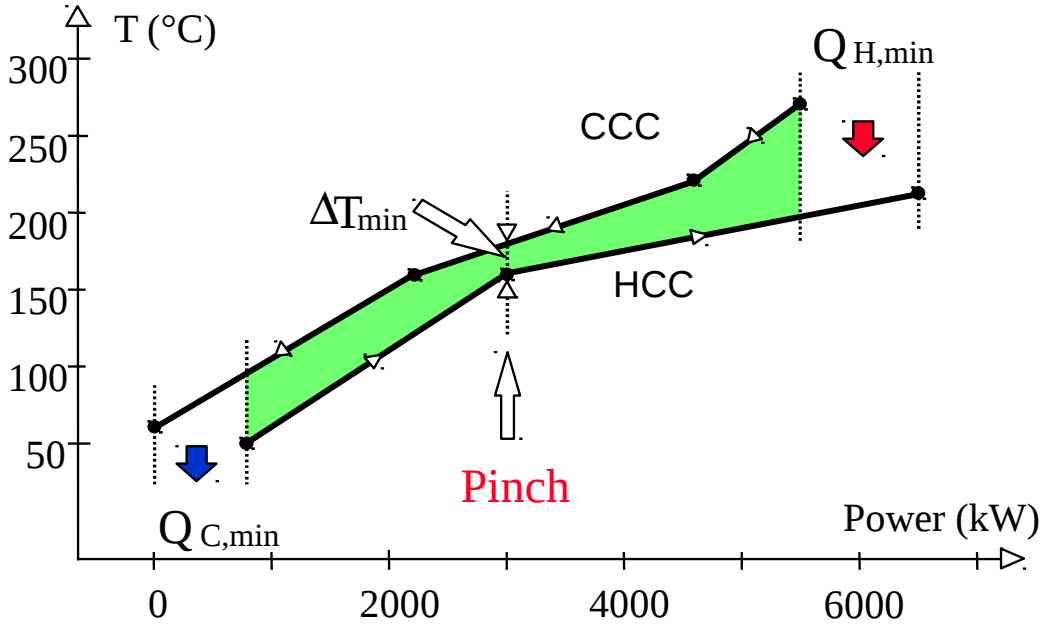
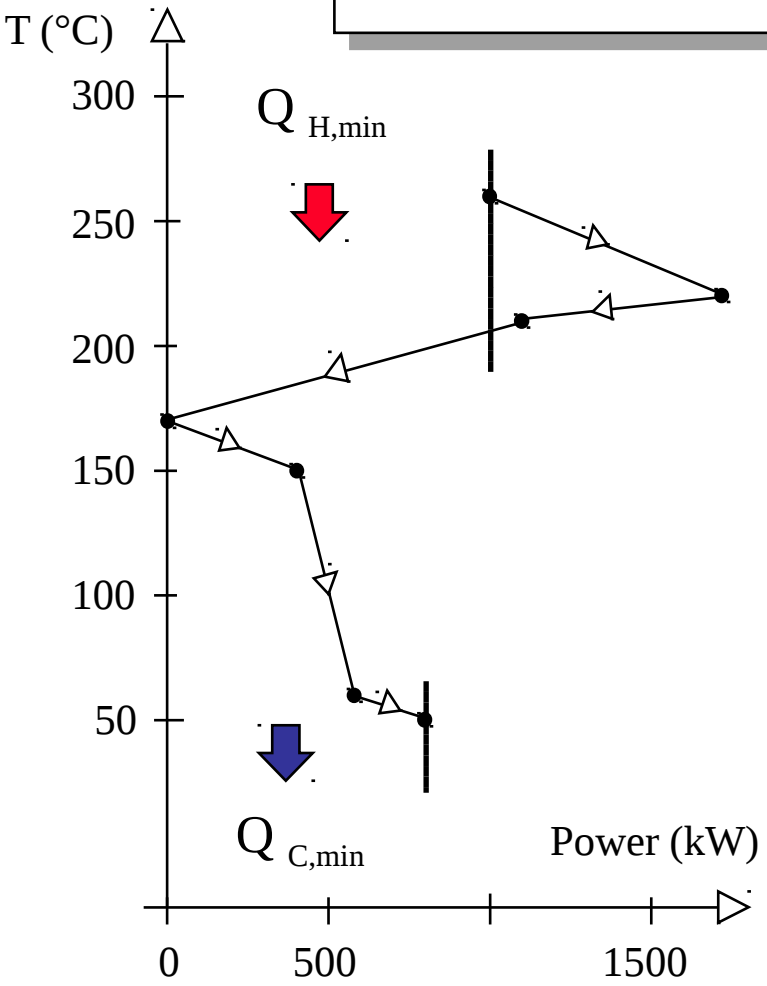
# Pinch analysis

## Pinch Analysis

- Hot and cold composite curve
- Grand composite curve
  -> energy and exergy targets for heat recovery



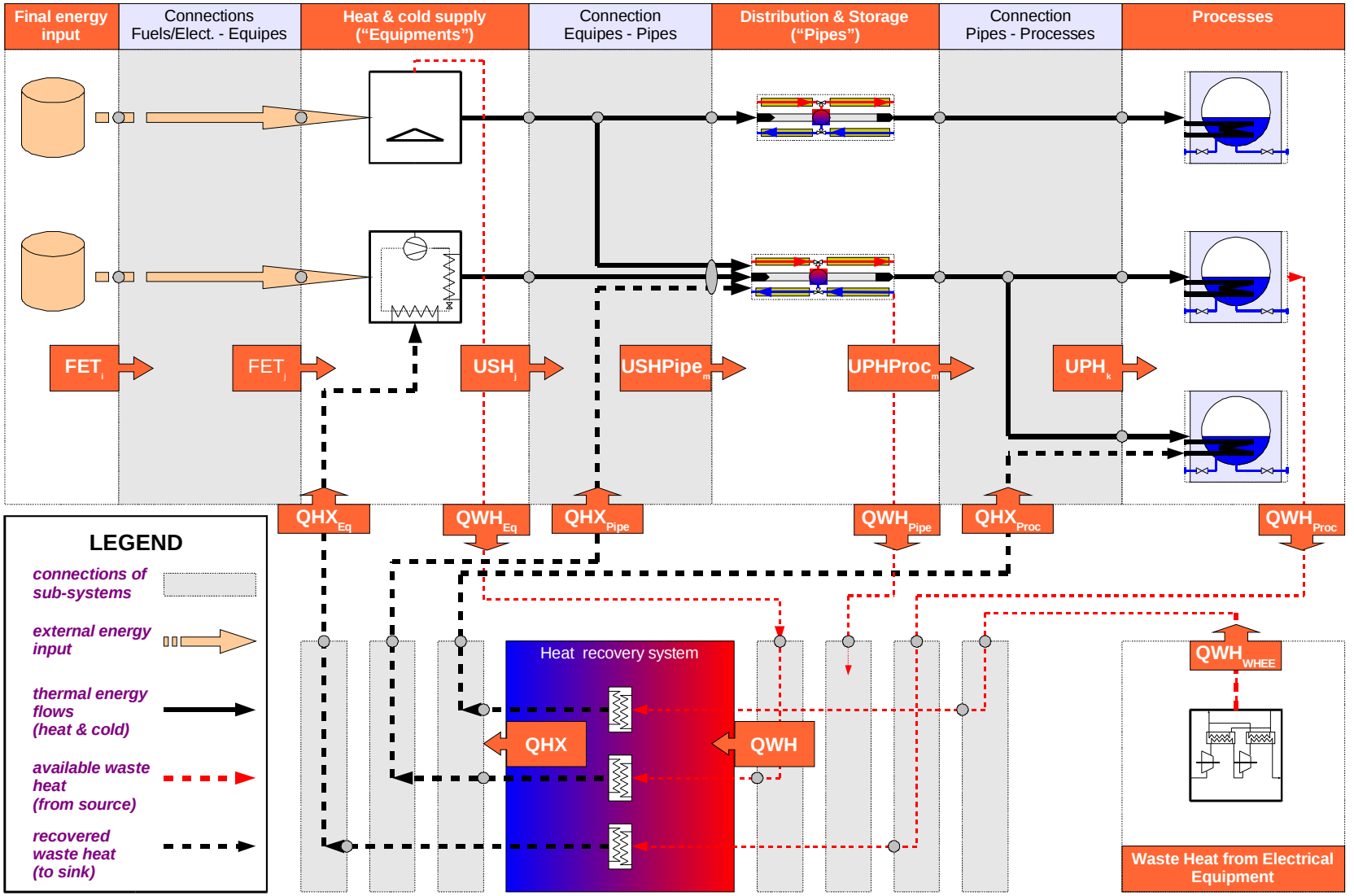

$\Delta T_{min}$ = 20 K
$Q_{H,min}$ = 1000 kW
$Q_{C,min}$ = 800 kW
$T_{pinch}$ = 180/160°C




Source: T. Gundersen. IEA. Process Integration, www.tev.ntnu.no/iea/pi

# Heat exchanger network

## Streams in EINSTEIN - Energy flows



# Heat exchanger network

- Tool for automatic design of optimised heat exchanger network
- Different optimisation criteria possible:
  - minimum size of heat exchangers
  - exergy optimisation
  - fine tuning by selection of $\Delta T_{min}$

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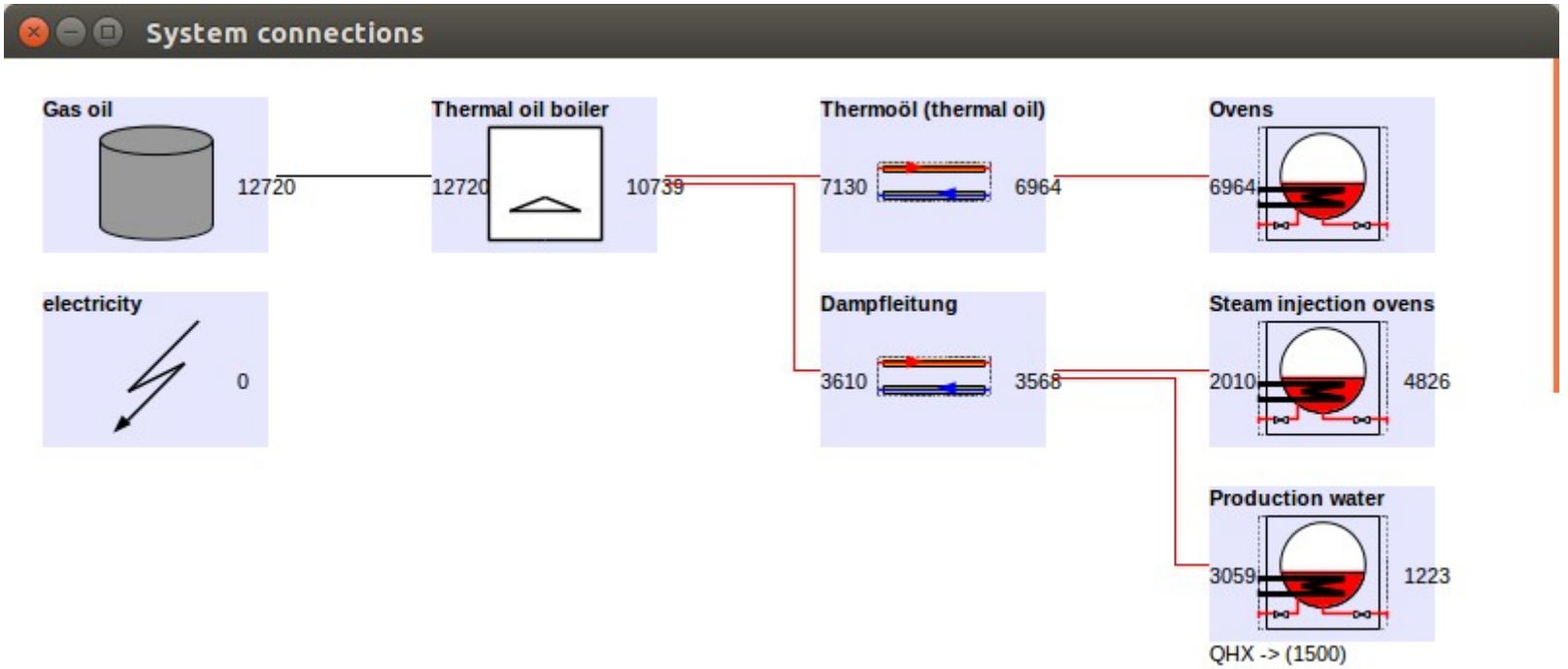
# Use case: heat pipe economiser

- Similar to iTherm-Demo: ARLUY (WP7)
- Heat pipe economiser using boiler exhaust gas for water preheating

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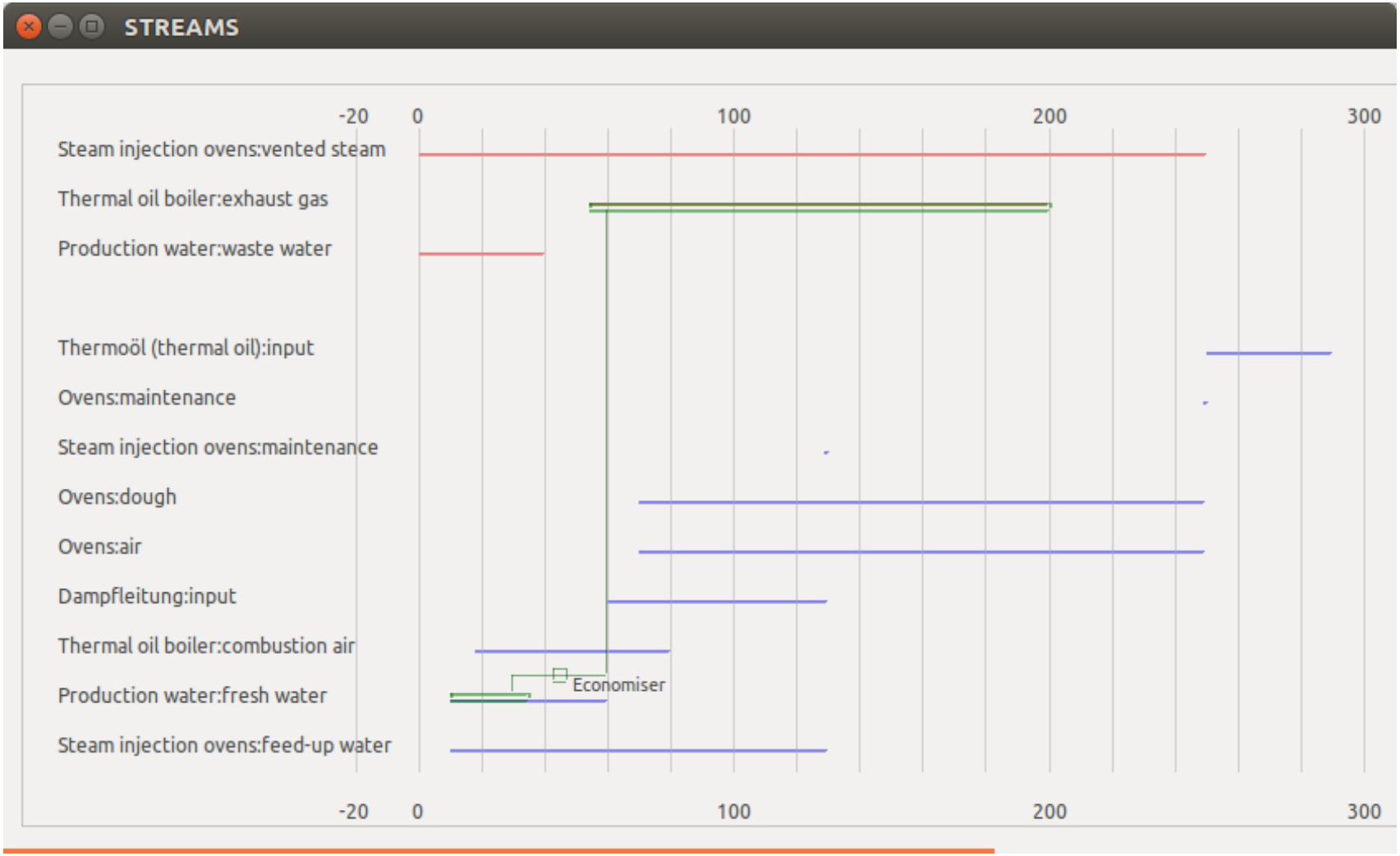
# Use case: heat pipe economiser stream plot

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# Optimisation of waste heat to power with EINSTEIN

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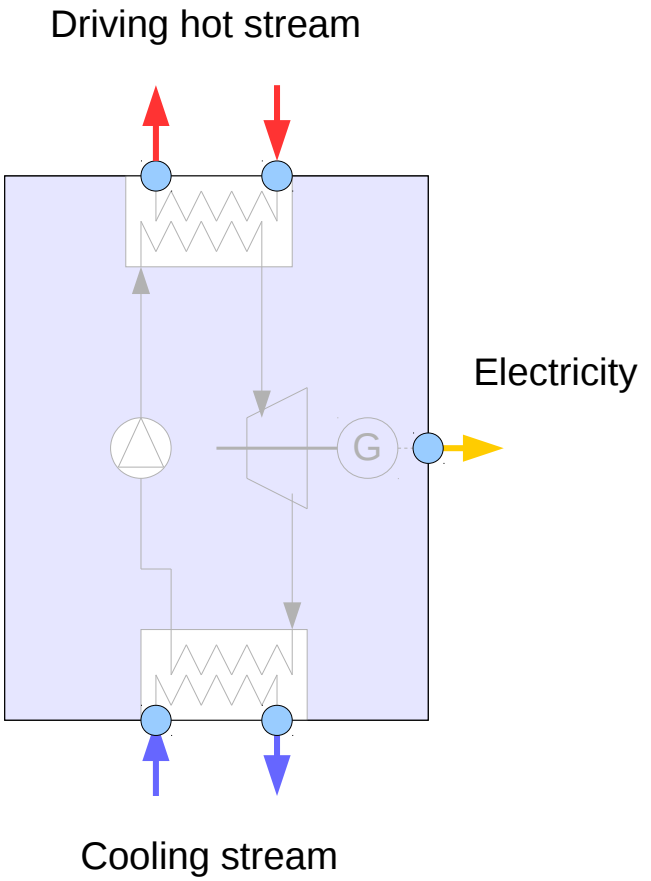
# EINSTEIN software: (waste-) heat to power

- Black box model for heat to power generating units

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## Model features

- Control:
  - by availability of waste heat
  - by external master control

  (supply of required heat input has to be assured by waste heat and/or appropriate heat supply equipment).

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## Model features

- Temperature dependence and part load behaviour:
  - Variable heat rejection temperature depending on ambient air temperature
  - Corrections of conversion efficiency as a function of

    a) temperatures (supply, heat rejection)

    b) part load ratio

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# EINSTEIN software: (waste-) heat to power (2)

Model types supported

- Rankine cycle (steam turbines, ORC, sCO2)
  - low / moderate temperature drop at heat supply
  - outlet temperature of supply medium well above ambient
- Trilateral flash cycle
  - high temperature drop
  - outlet temperature of supply medium close to ambient

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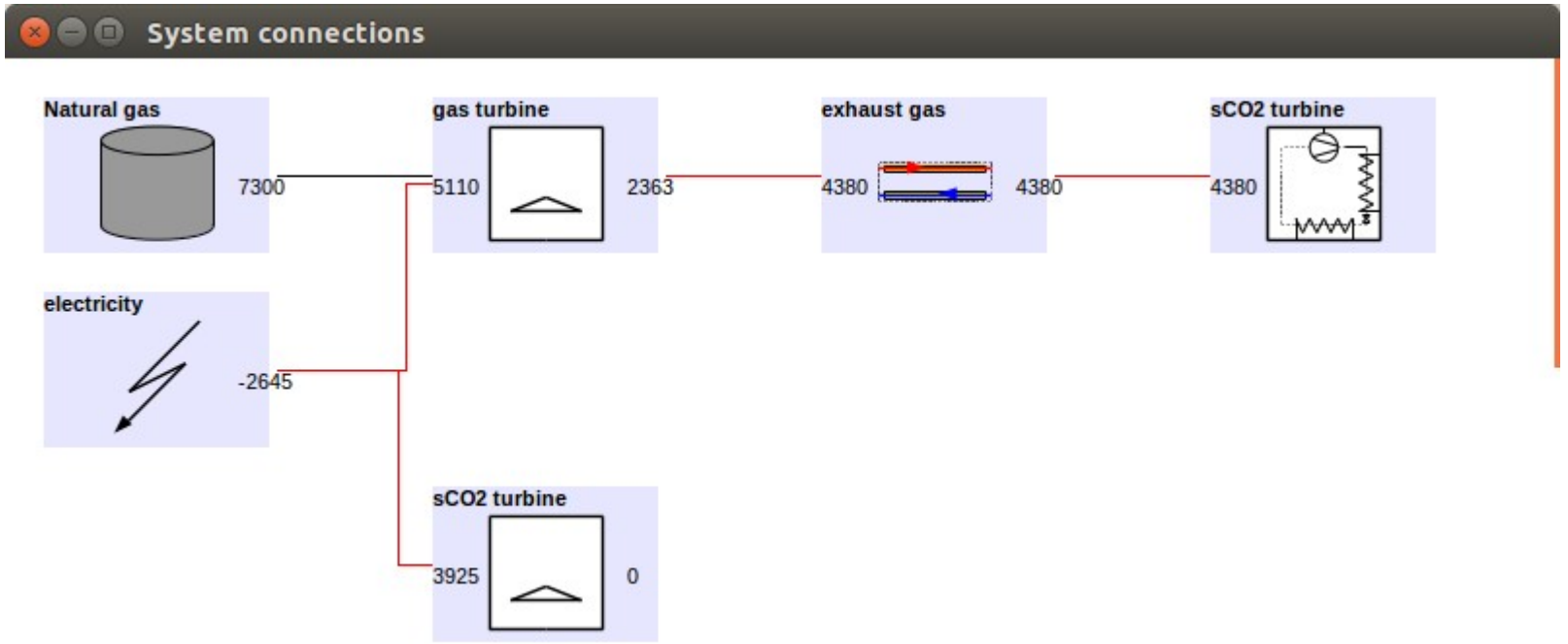
# Use case
# sCO2-turbine + gas turbine

- Similar to iTherm-Demo: UBRUN (WP5)
- sCO2-turbine supplied by exhaust gas from gas turbine or gas boiler

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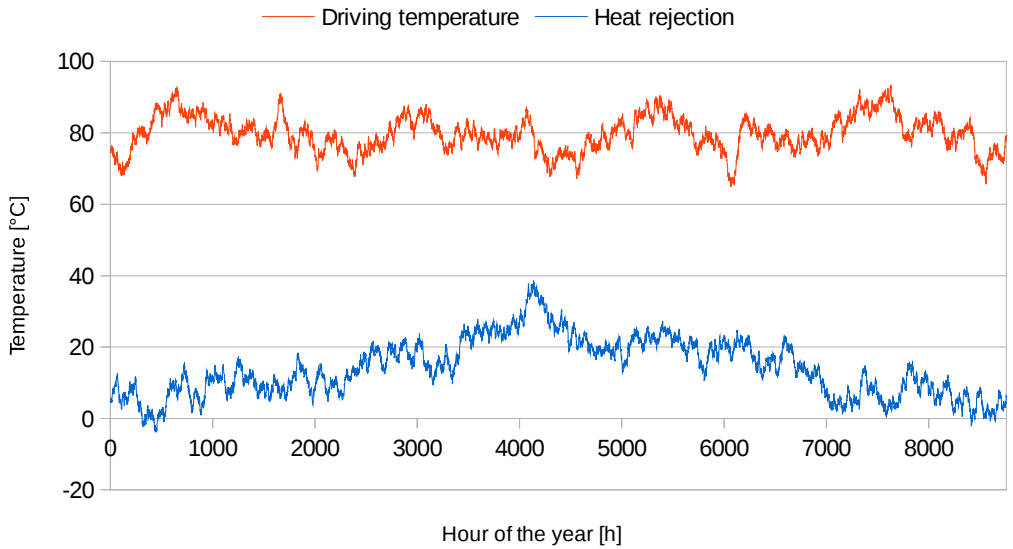
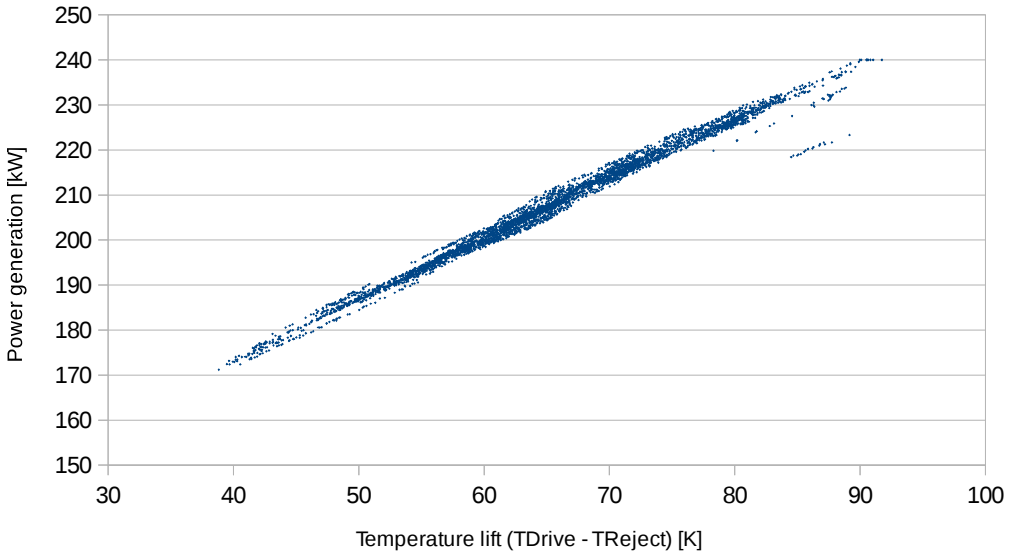
# Use case
# sCO2-turbine + gas turbine

- Example: analysis of conversion efficiency as a function of driving and heat rejection temp.

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# Link with monitoring data and energy management

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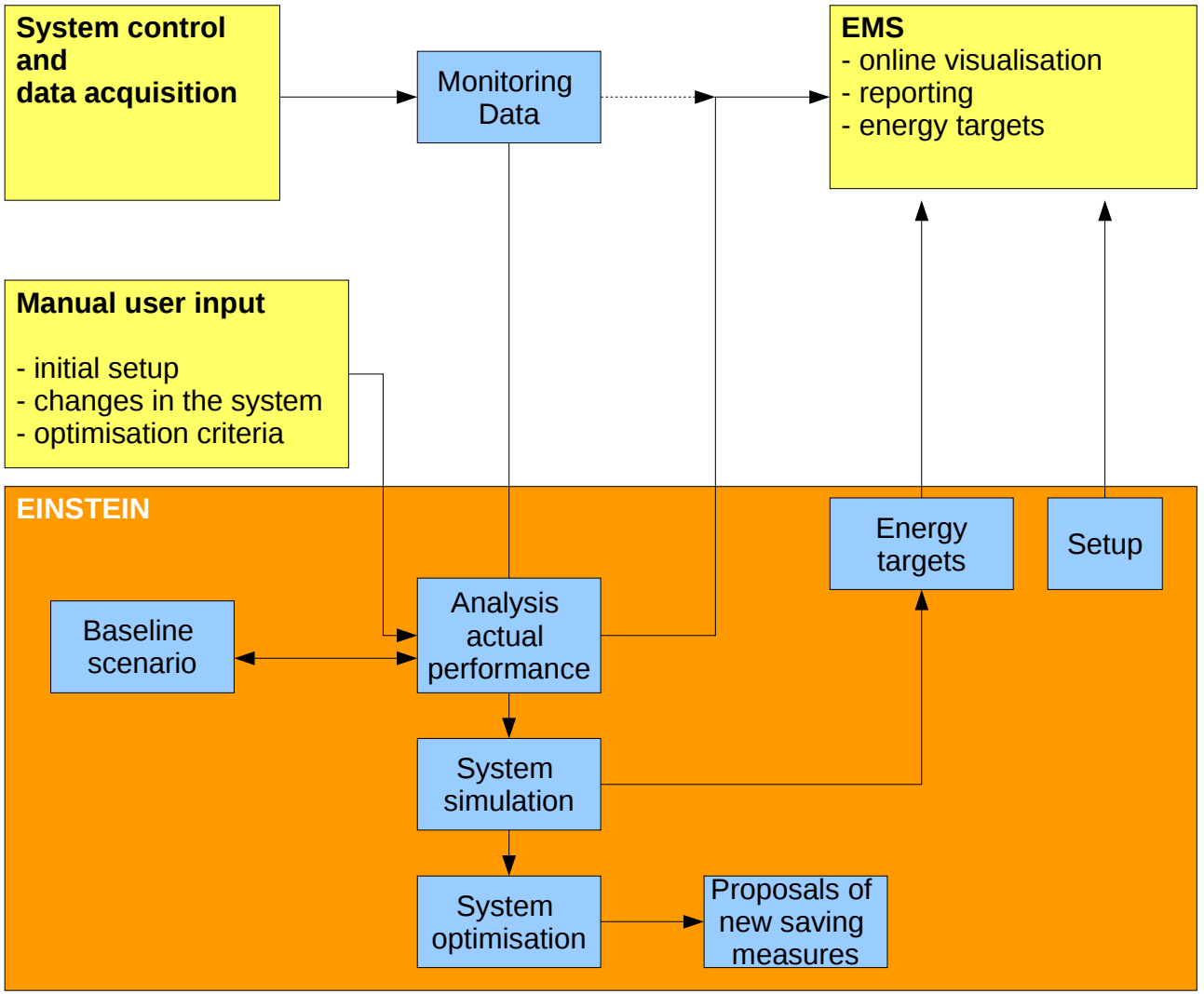
# Link with monitoring data

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# Link with monitoring data

- Use of historical monitoring data for present state analysis and calibration of system model
  - algorithm for automatic processing of monitoring data for model calibration
  - forecast of system performance for definition of energy and performance targets
  - type of data to be processed:
    - periodic aggregate data on consumption (e.g. energy bills, production volume, lecture of counters, ...)
    - time series (e.g. energy consumption, flow rates, etc.)

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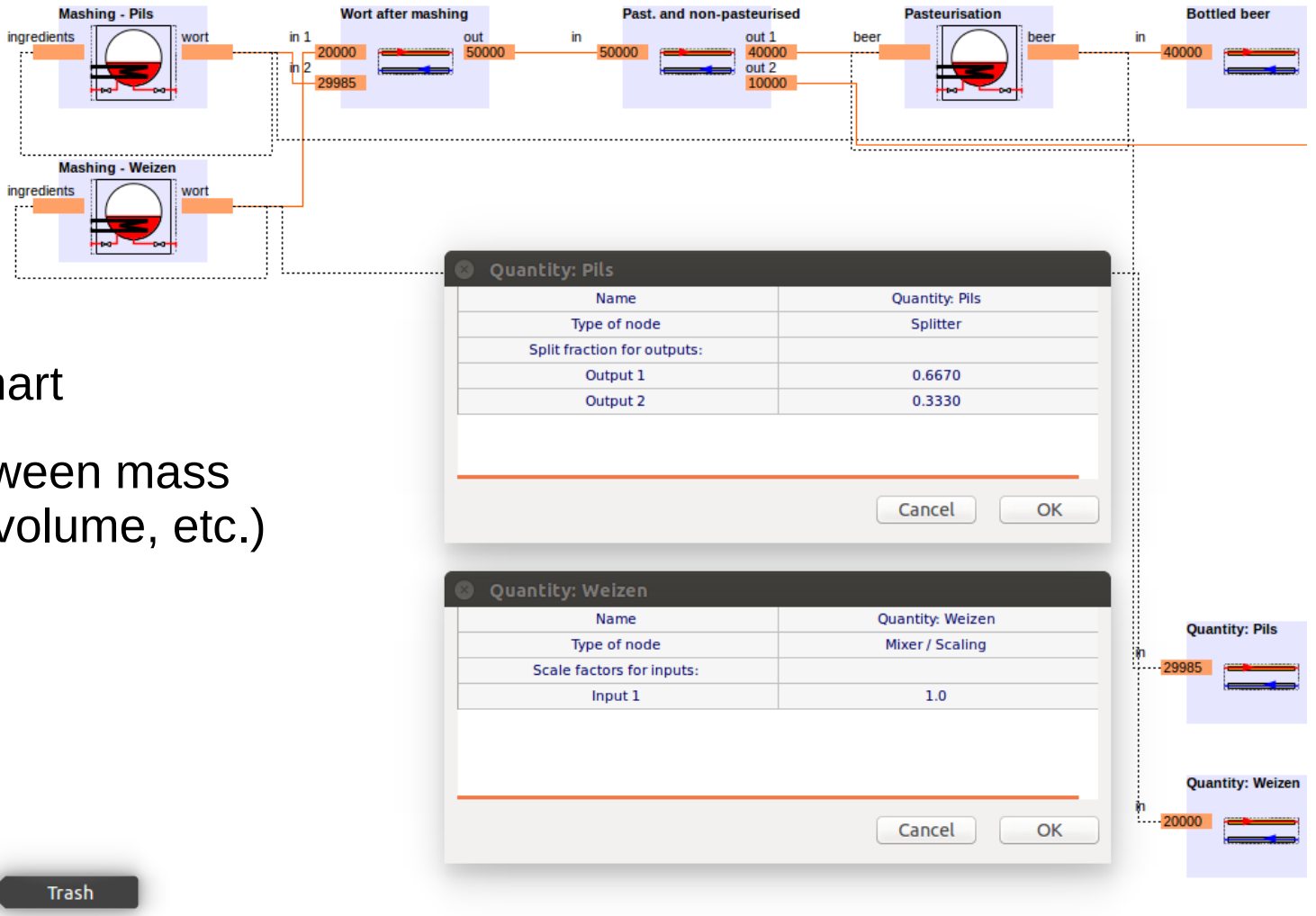
# Link with monitoring data




Production flow chart

-> Correlation between mass flows (production volume, etc.) and energy flows

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# Link with monitoring data

- Periodic system optimisation and adaptation to changes in the production process
  - algorithm for semi-automatic and automatic generation of energy saving proposals (e.g. heat recovery optimisation)
  - based on calibrated model (from Task 3.3.a)

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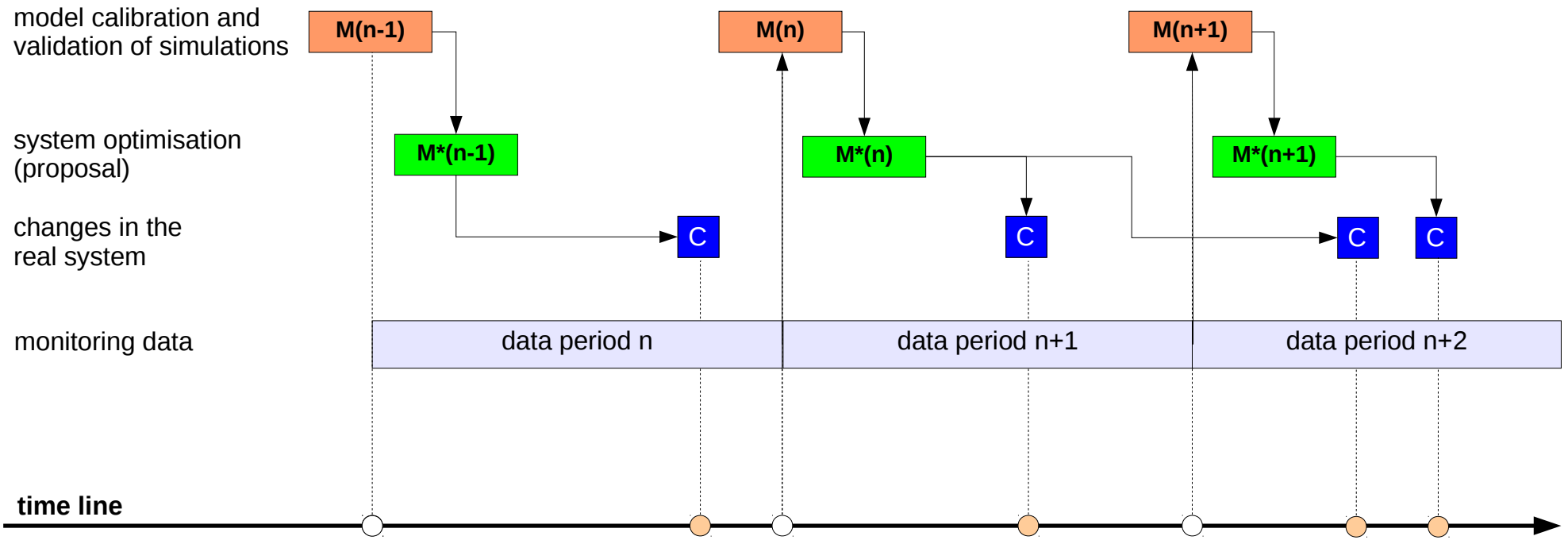
# Link with monitoring data

Sequence of model calibration, system optimisation and changes in the real system.

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