

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

I-Therm Workshop, October 2017

Hans Schweiger
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
- Continuous time adaptation and optimisation

A photograph of an industrial facility featuring several large, orange-colored storage tanks. Above the tanks, there are complex networks of blue-painted pipes and metal walkways. The scene is set against a clear blue sky. The word "EINSTEIN" is overlaid in large white letters across the middle of the image.

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

The software tool

DATA ACQUISITION
AND CHECK

DATA ACQUISITION
(QUESTIONNAIRE)

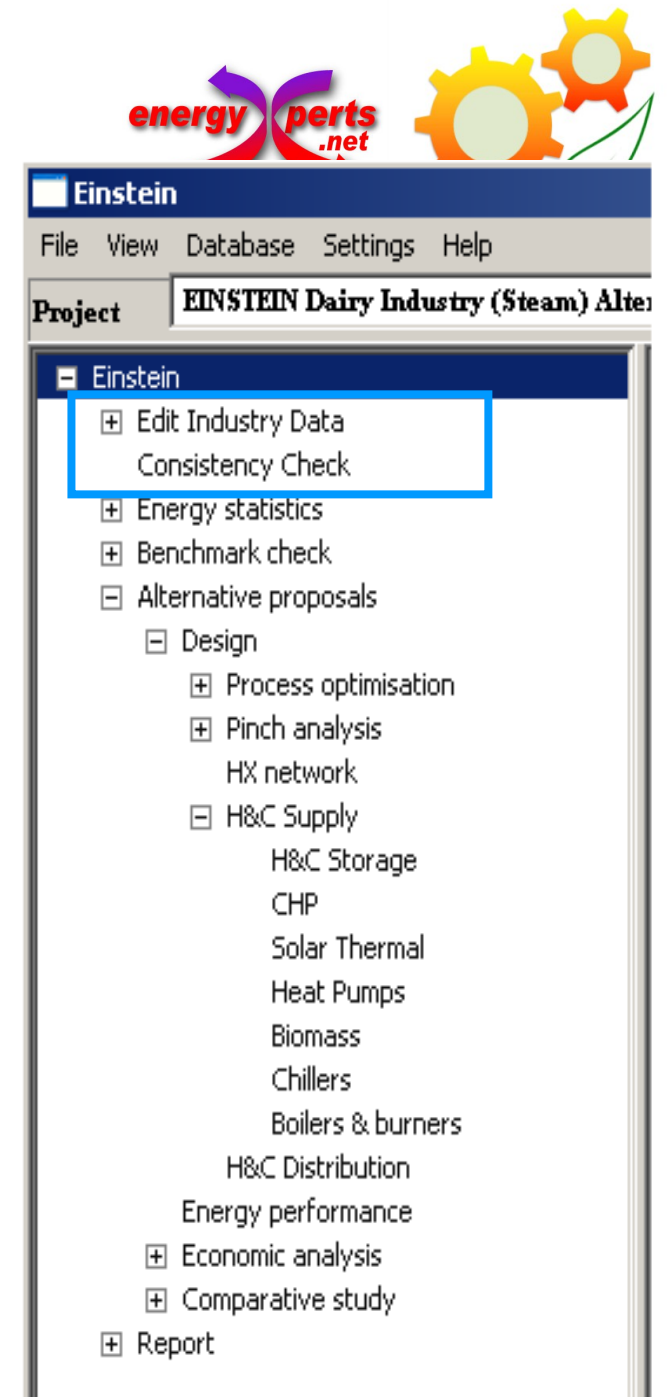
CONSISTENCY CHECK

DATA ANALYSIS

ALTERNATIVE
PROPOSALS:
DESIGN

ALTERNATIVE
PROPOSALS:
EVALUATION

REPORT



The software tool

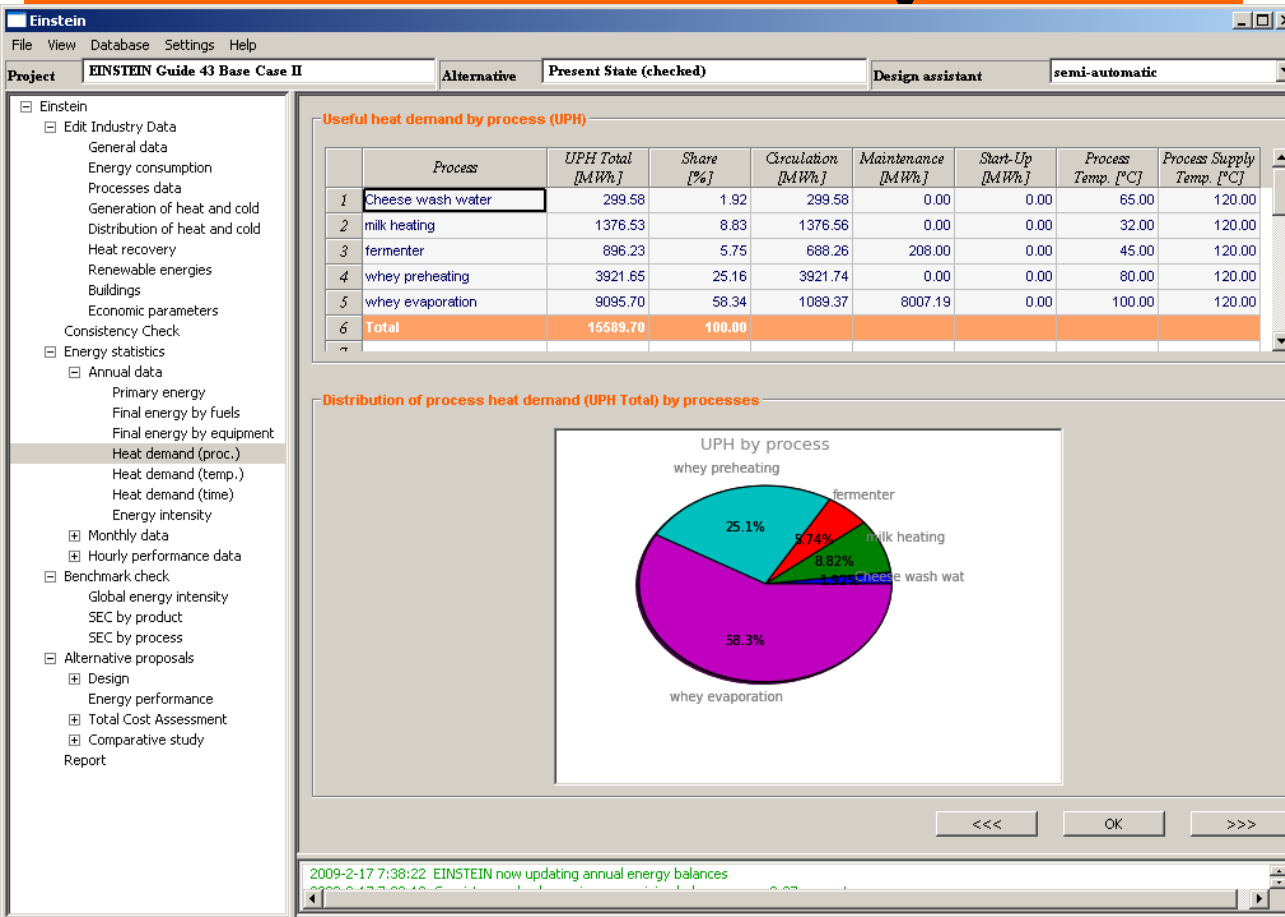


DATA ACQUISITION
AND CHECK

DATA ANALYSIS

ENERGY STATISTICS

BENCHMARKING



Einstein
File View Database Settings Help

Project: **EINSTEIN Dairy Industry (Steam) Alter**

- ☒ Einstein
 - ☒ Edit Industry Data
 - Consistency Check
 - ☒ Energy statistics
 - ☒ Benchmark check
 - ☒ Alternative proposals
 - ☒ Design
 - ☒ Process optimisation
 - ☒ Pinch analysis
 - HX network
 - ☒ H&C Supply
 - H&C Storage
 - CHP
 - Solar Thermal
 - Heat Pumps
 - Biomass
 - Chillers
 - Boilers & burners
 - H&C Distribution
 - Energy performance
 - ☒ Economic analysis
 - ☒ Comparative study
 - ☒ Report

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Einstein

File Vista Banca dati Impostazioni Aiuto

Progetto **Audit Caseificio AutoPilot HR ST** Alternativa **Rete scambiatori recupero calore** Modalità progettazione ass **semi-automatic**

- Einstein
 - Modifica dati dell'industria
 - Dati generali
 - Consumo energetico
 - Processi
 - Generazione di calore e freddo
 - Distribuzione di calore e freddo
 - Recupero di calore
 - Fonti di energia rinnovabili
 - Edifici
 - Parametri economici
 - Controllo coerenza
 - Statistiche energetiche
 - Dati annuali
 - Energia primaria
 - Energia finale per combustibili
 - Energia finale per impianto
 - Domanda di calore (processo)
 - Domanda di calore (temperatura)**
 - Domanda di calore (tempo)
 - Intensità energetica
 - Dati mensili
 - Dati orari
 - Benchmarking
 - Intensità energetica globale
 - Consumo energetico specifico per prod
 - Consumo energetico specifico per proce
 - Proposte alternative
 - Progettazione
 - Prestazioni energetiche
 - Analisi economica (Total Cost Assesmer
 - Studio comparativo
 - Resoconto

Domanda (UPH) e calore utile fornito (USH) per livello di temperatura

Domanda di calore di processo (UPH) per livello di tem Calore fornito (USH) per livello di temperatura di

	Temperature levels [°C]	[MWh]	[%]	cumulativo [%]	[MWh]	[%]	cumulat [%]
1	< 60 °C	6252.90	38.83	38.83	4596.96	31.11	
2	60 - 80 °C	1114.69	6.92	45.75	1169.81	7.92	
3	80 - 100 °C	8736.84	54.25	100.00	816.49	5.53	
4	100 - 120 °C	0.00	0.00	100.00	8193.18	55.45	
5	120 - 140 °C	0.00	0.00	100.00	0.00	0.00	
6	140 - 180 °C	0.00	0.00	100.00	0.00	0.00	
7	180 - 200 °C	0.00	0.00	100.00	0.00	0.00	

Distribuzione della domanda di calore di processo (UPH) e calore utile fornito (USH) per livello di temperature di processo

Einstein

File View Database Settings Help

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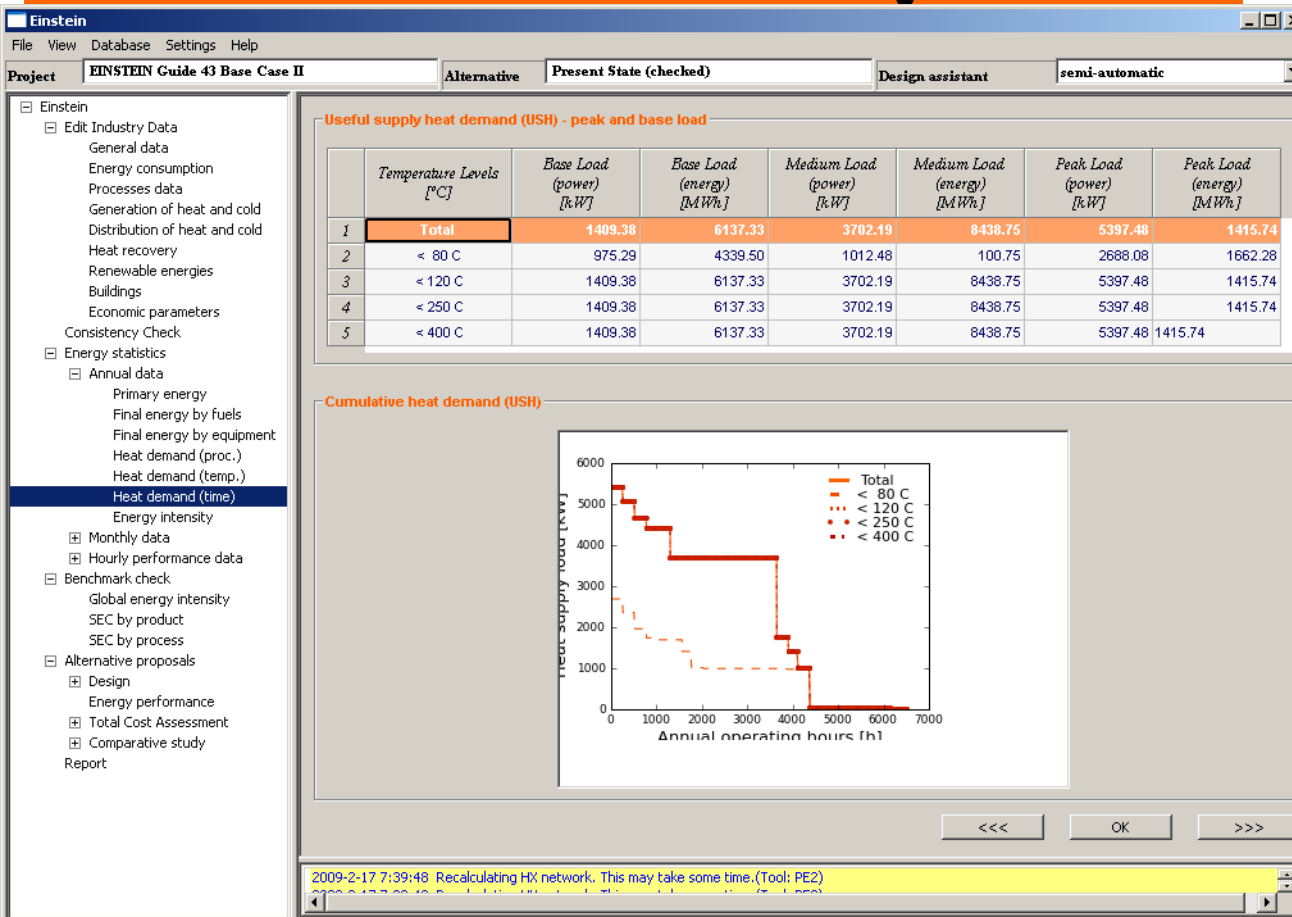


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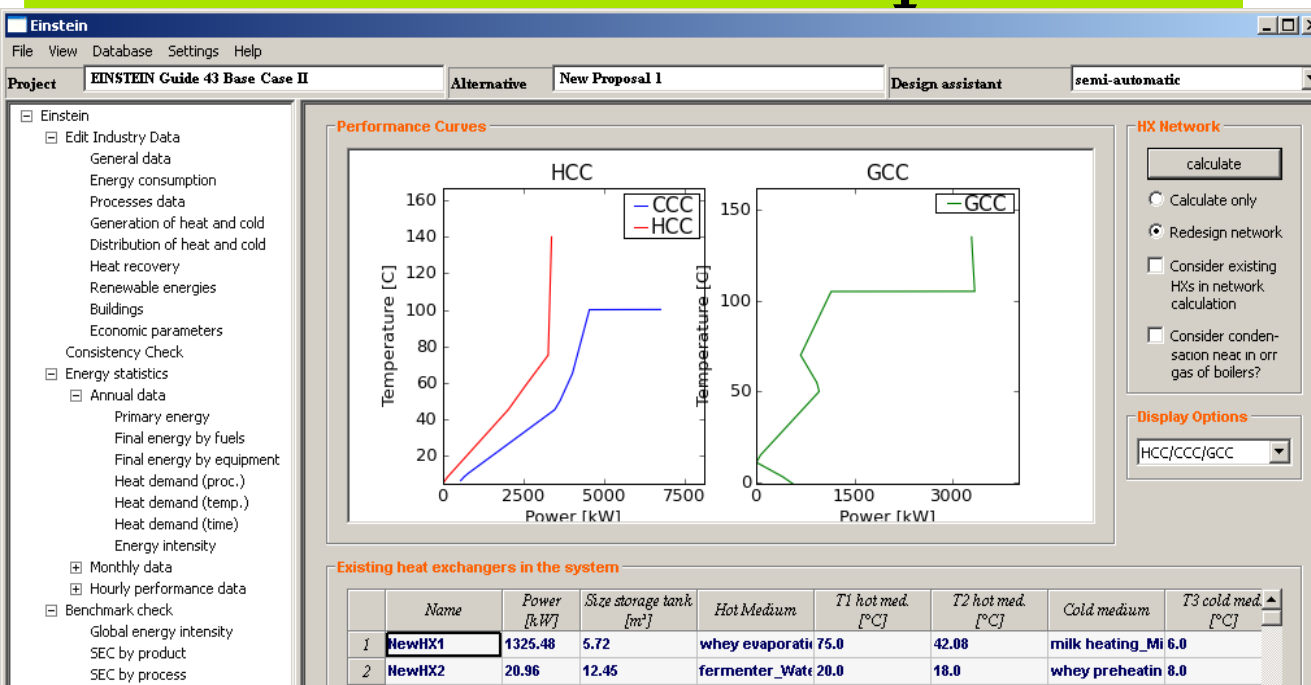
DATA ANALYSIS

PROCESS OPTIMISATION



HEAT RECOVERY

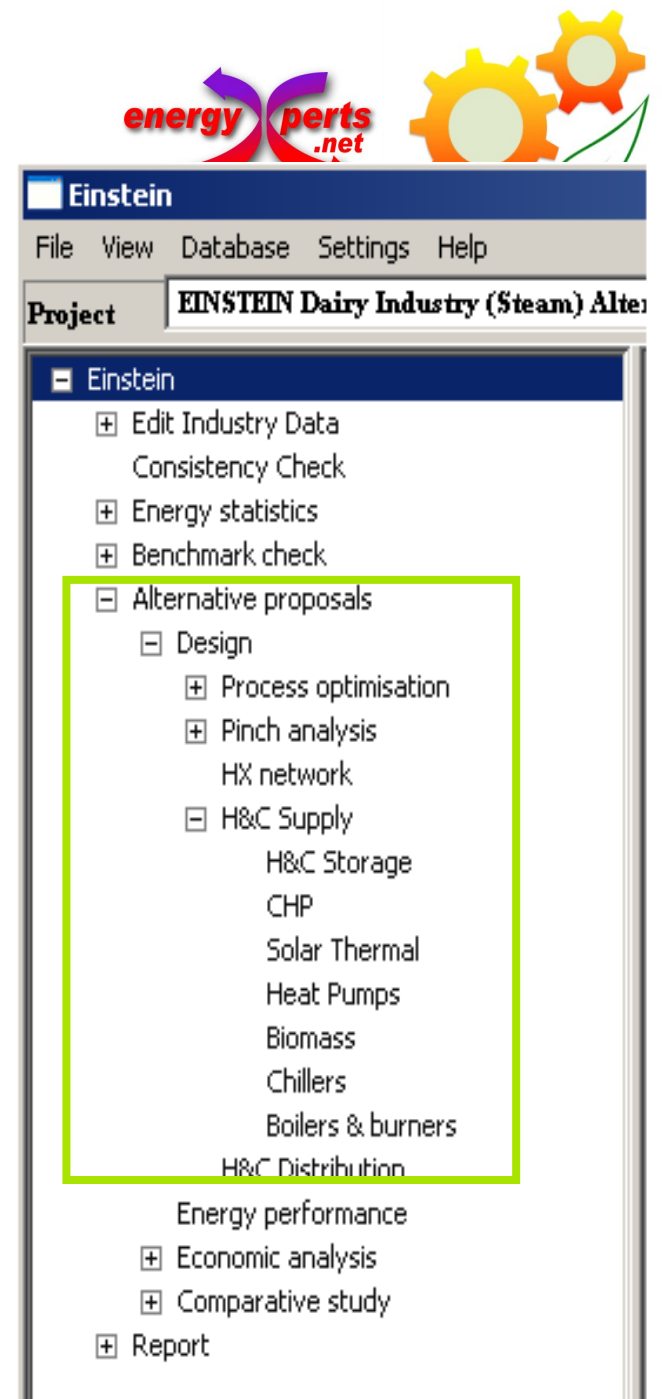
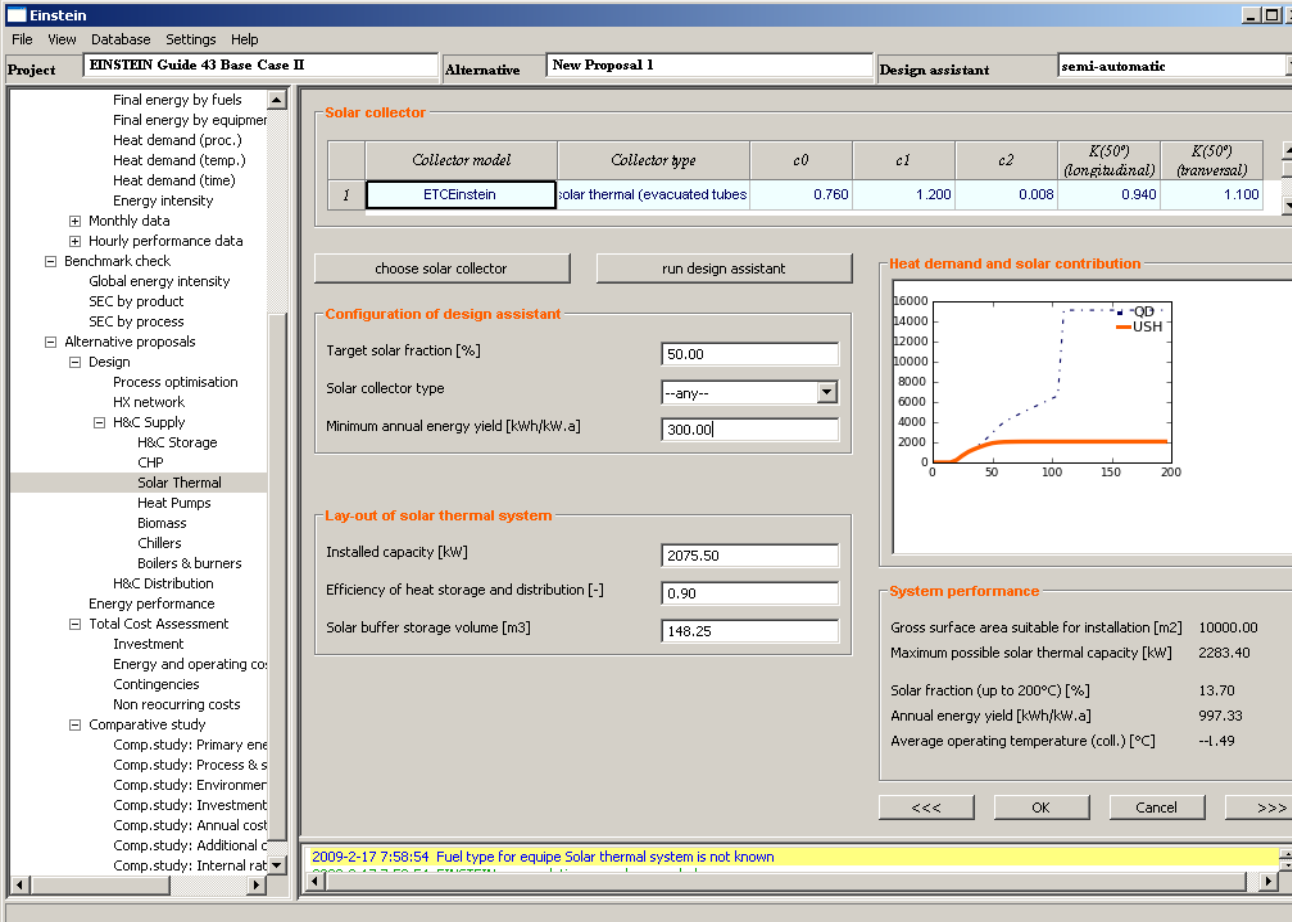
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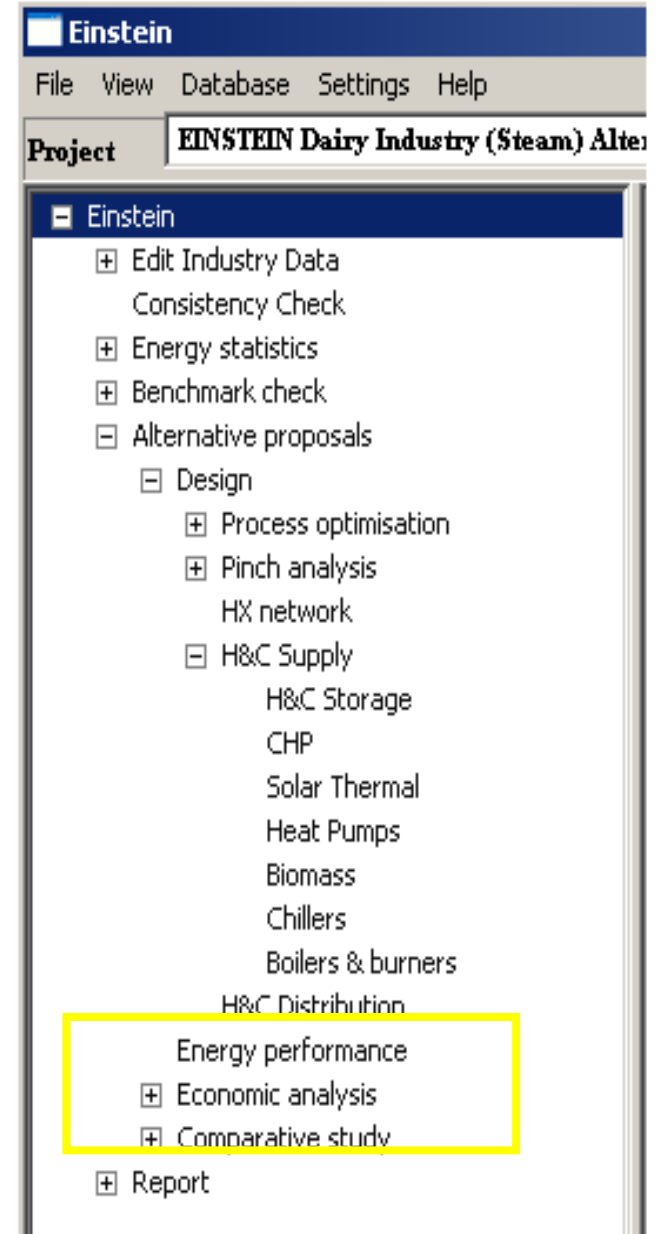
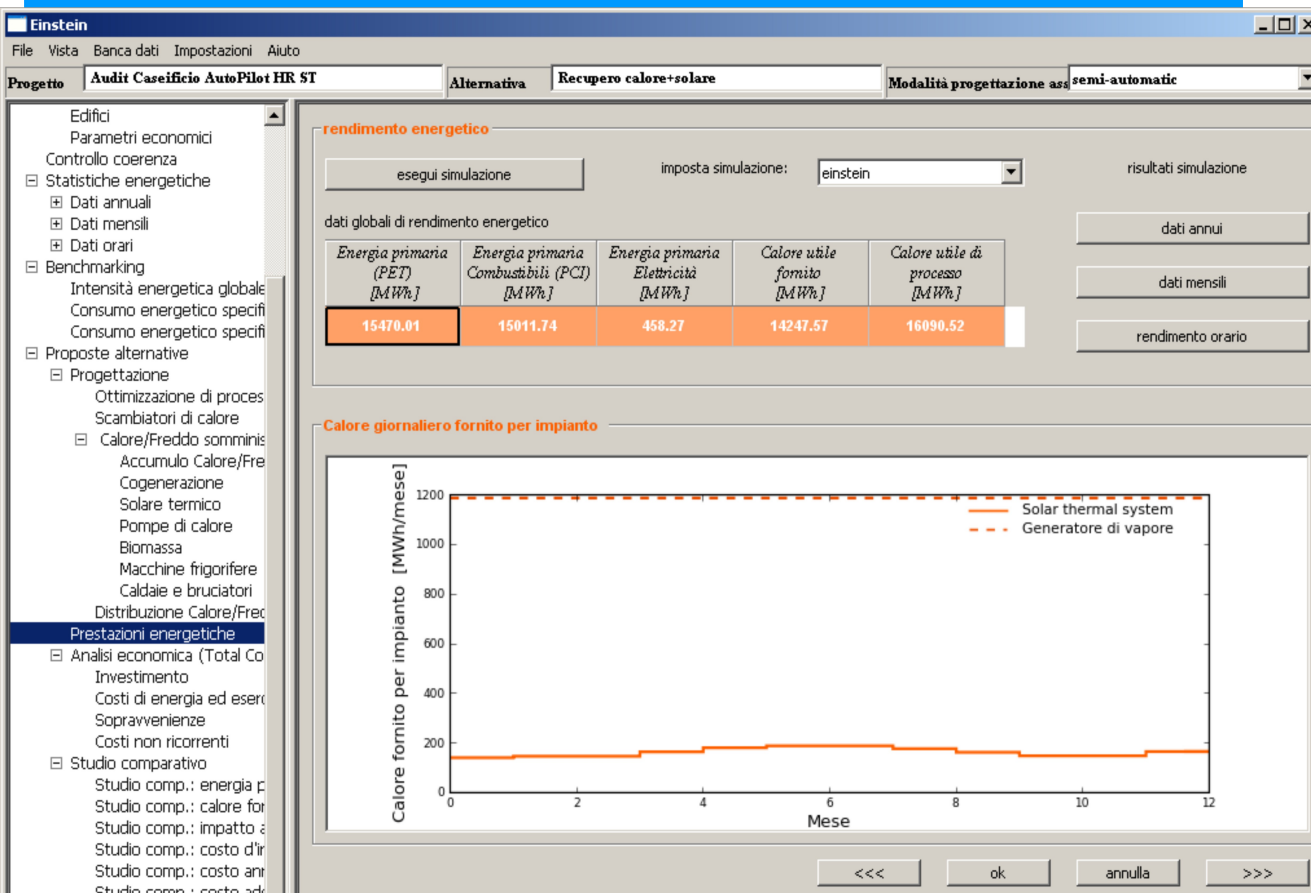


HEAT&COLD SUPPLY SYSTEMS

ALTERNATIVE
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ALTERNATIVE PROPOSALS: EVALUATION

ENERGY AND ENVIRONMENTAL PERFORMANCES

ECONOMIC ANALYSIS

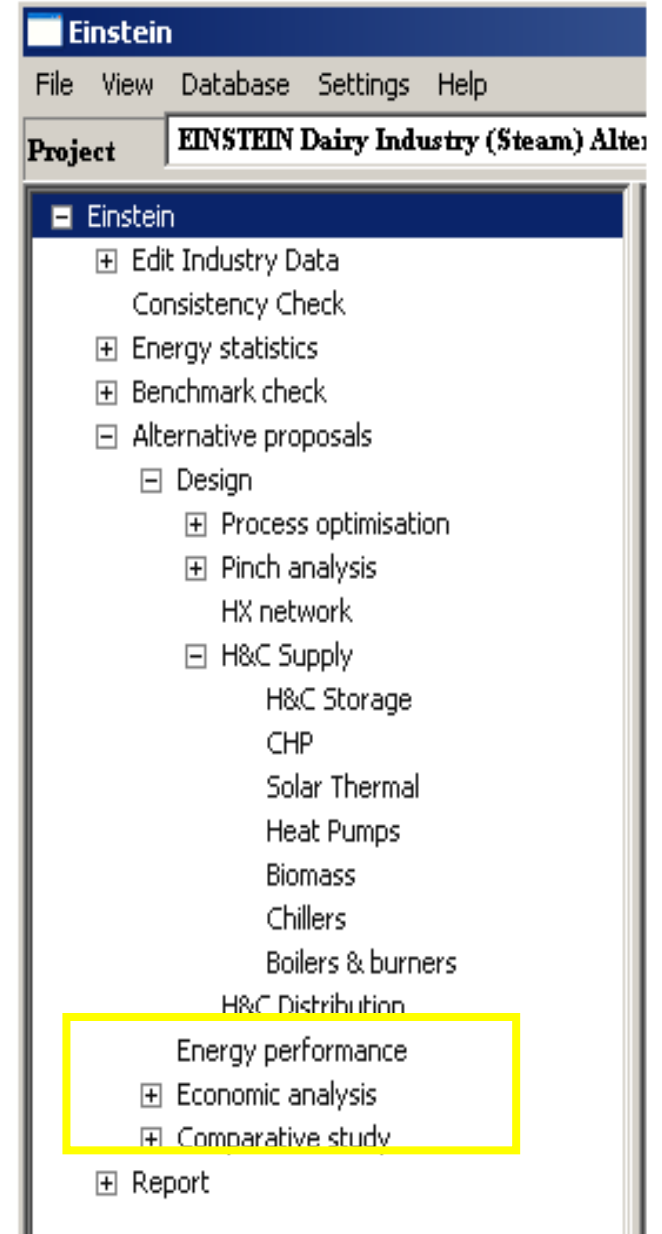
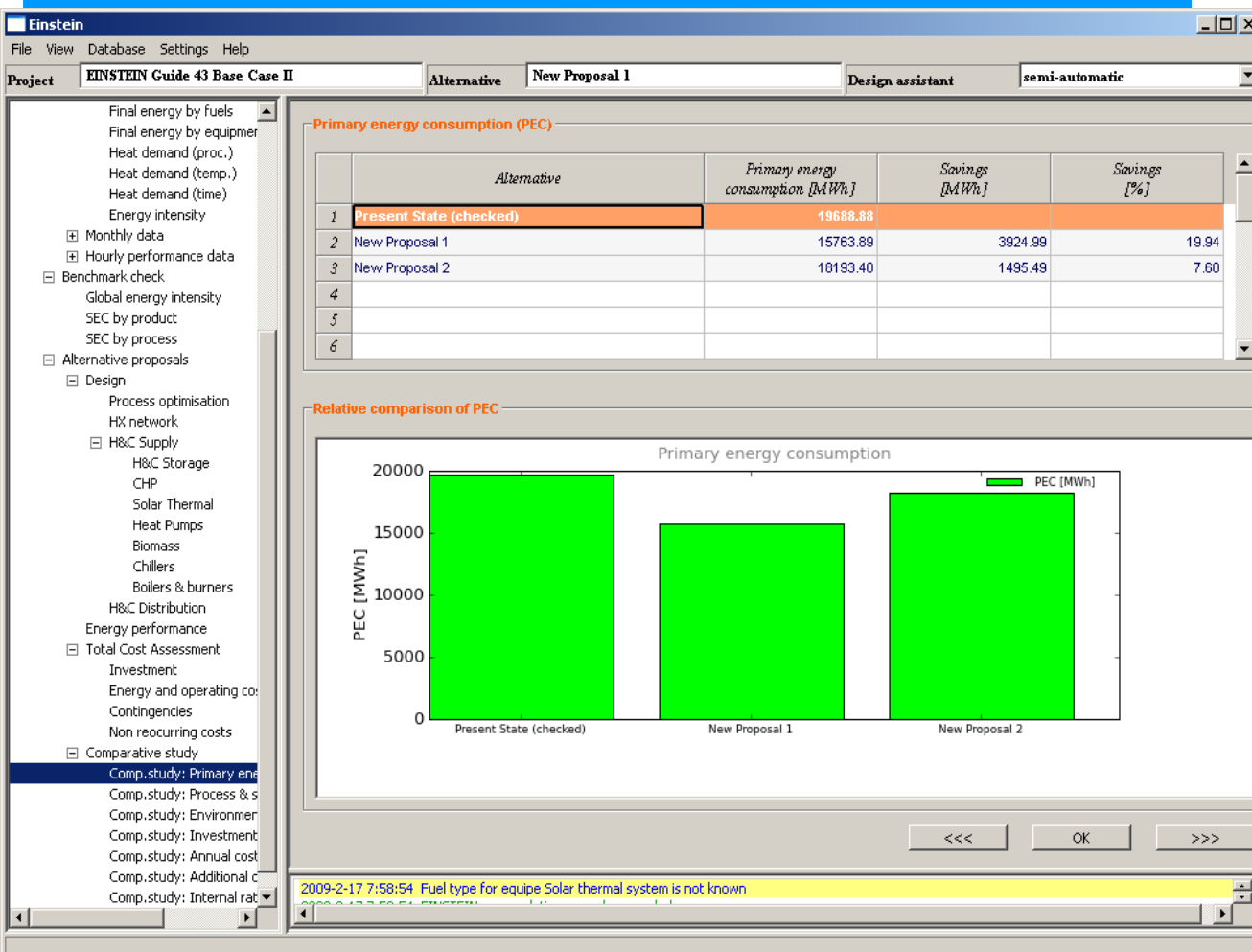
ALTERNATIVES COMPARISON

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DATA ACQUISITION AND CHECK



ALTERNATIVES COMPARISON

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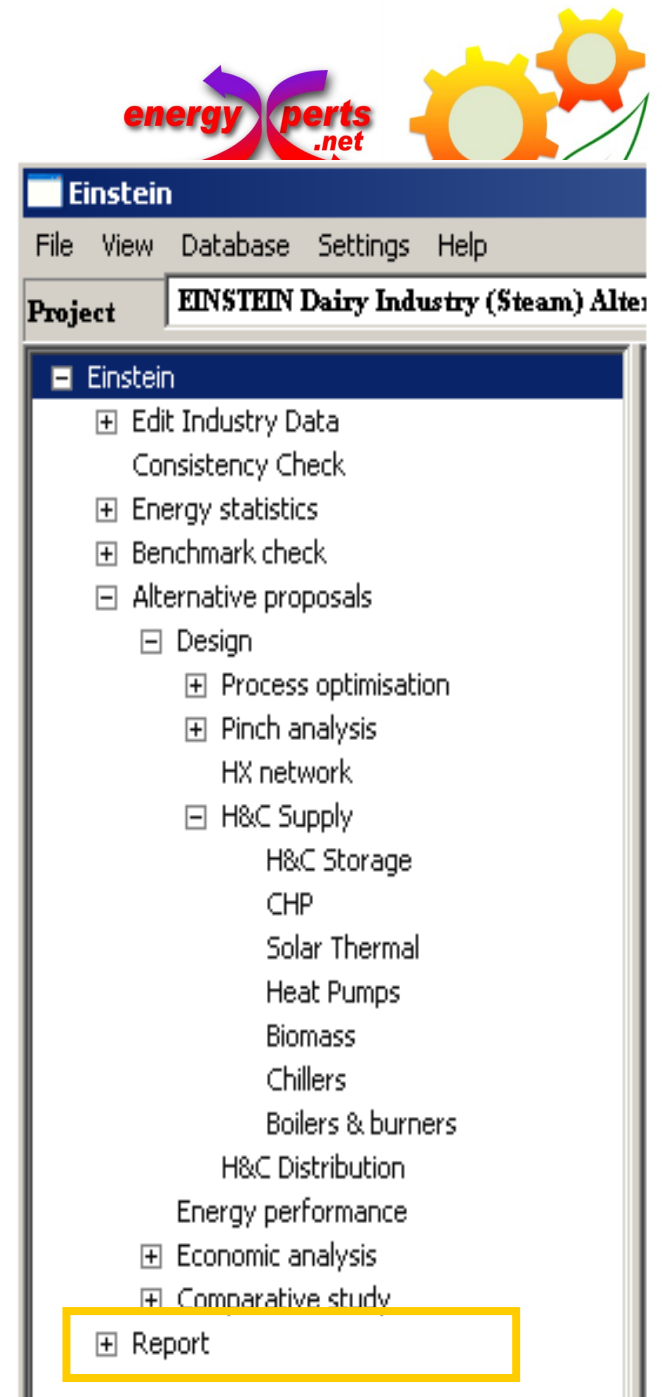
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Optimisation of heat recovery with EINSTEIN



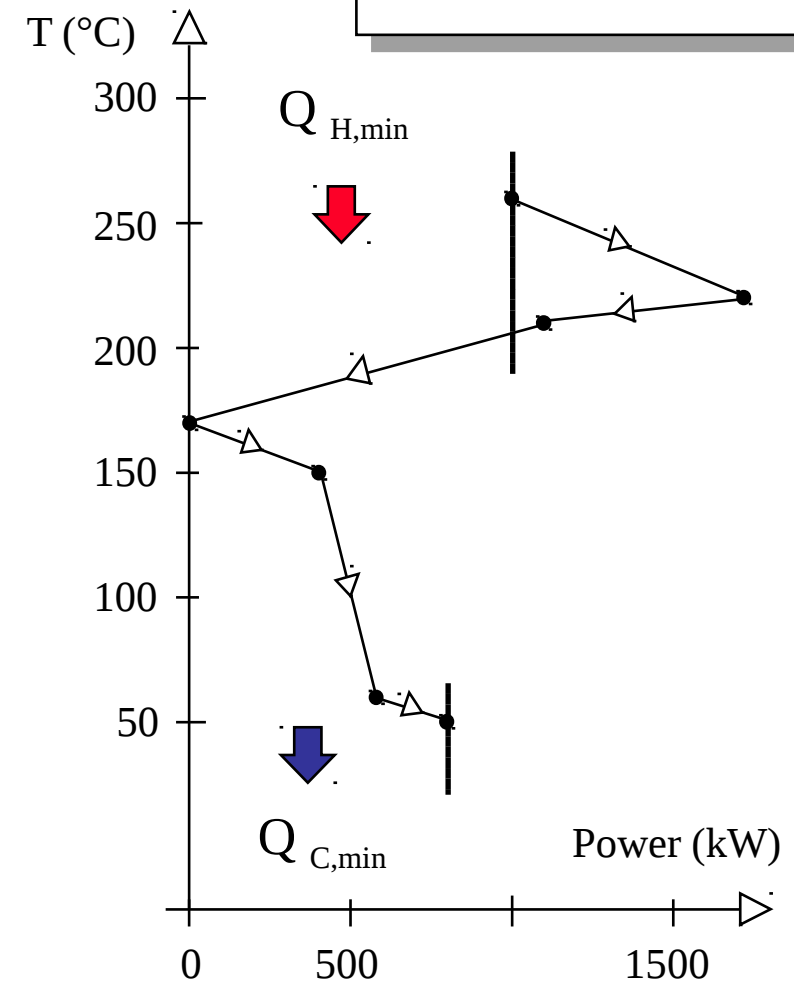
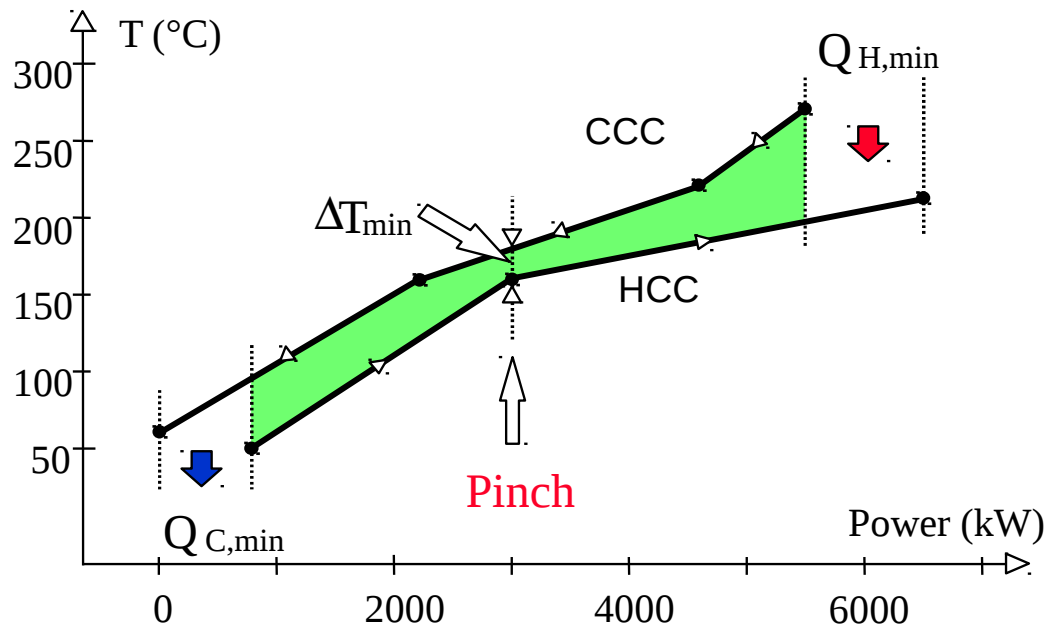
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 680599.

- 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

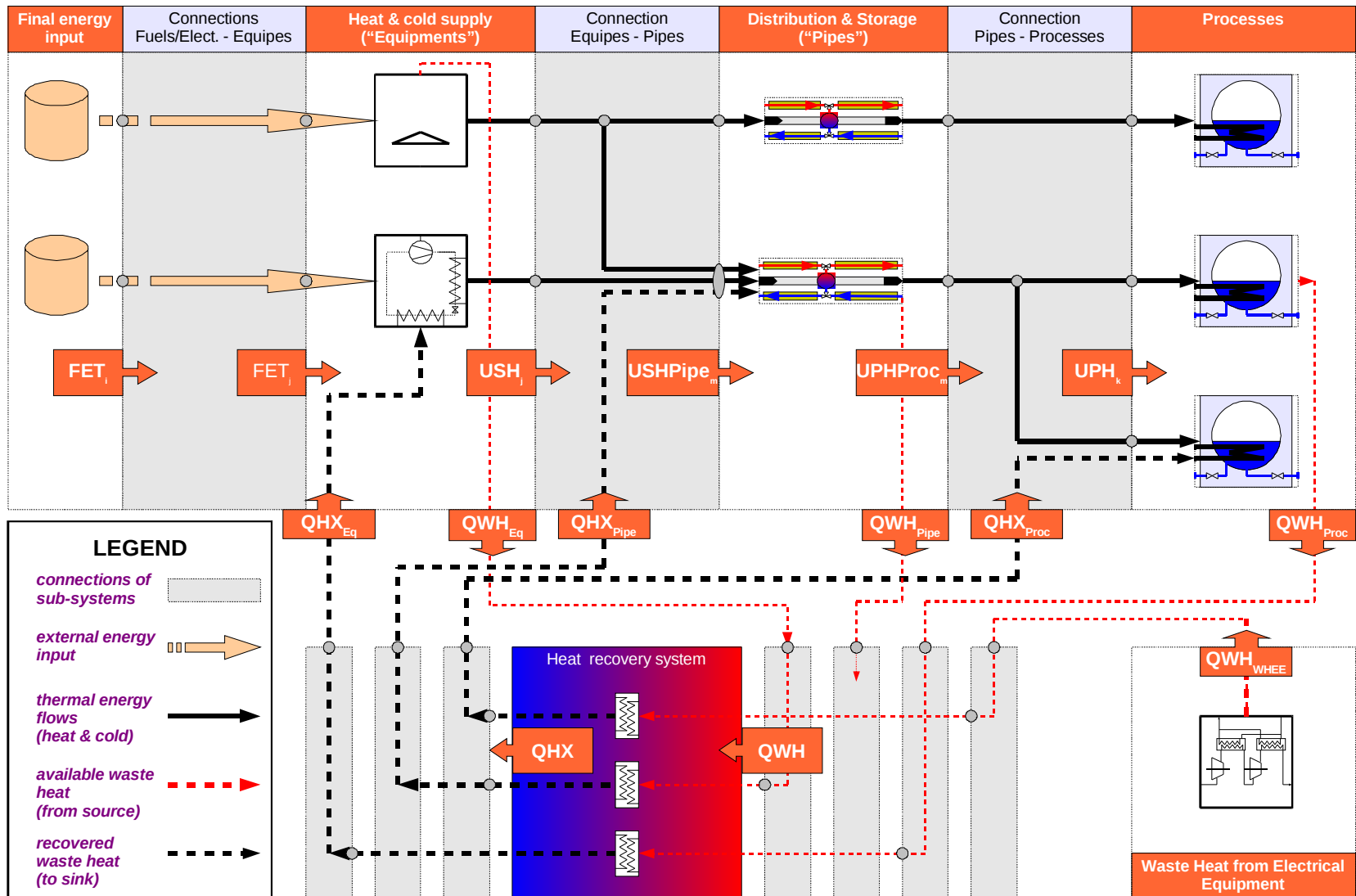
Pinch Analysis

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

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

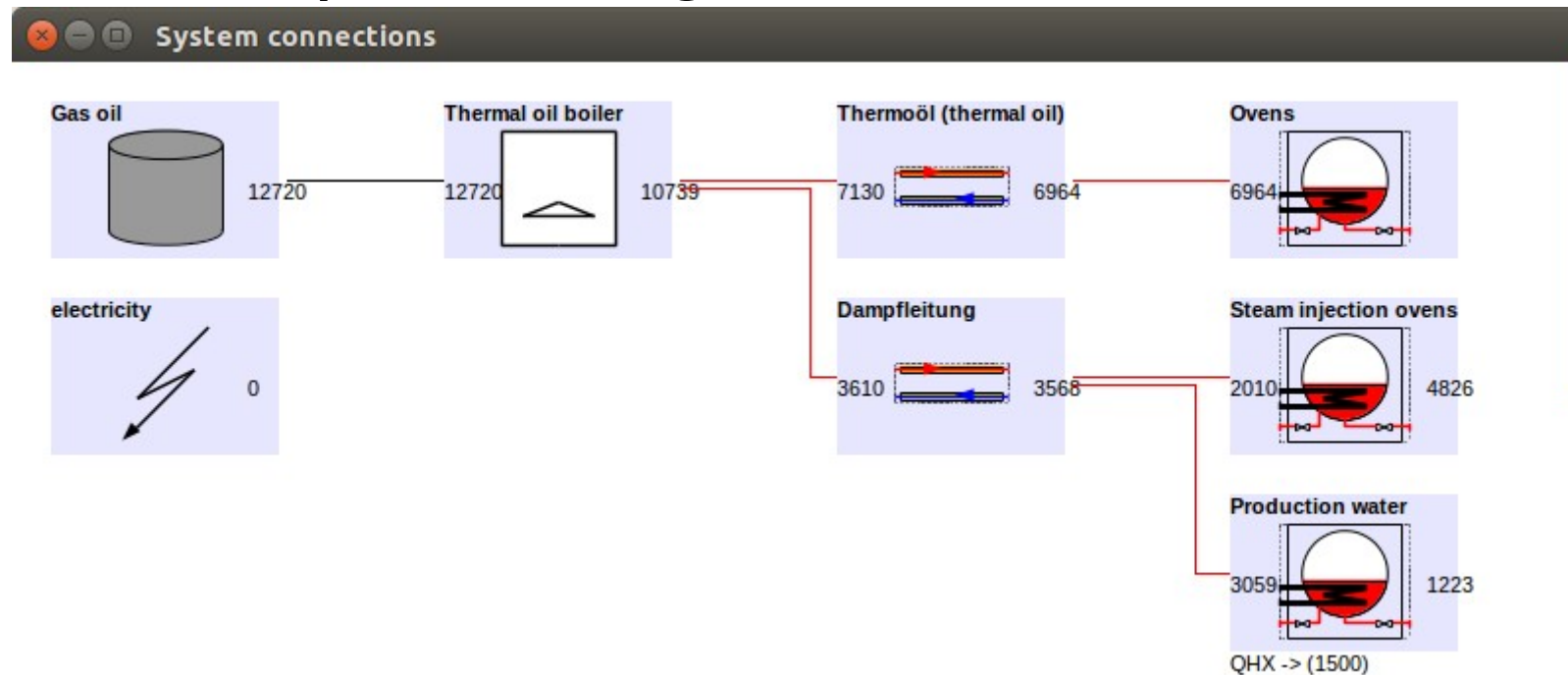


Streams in EINSTEIN - Energy flows

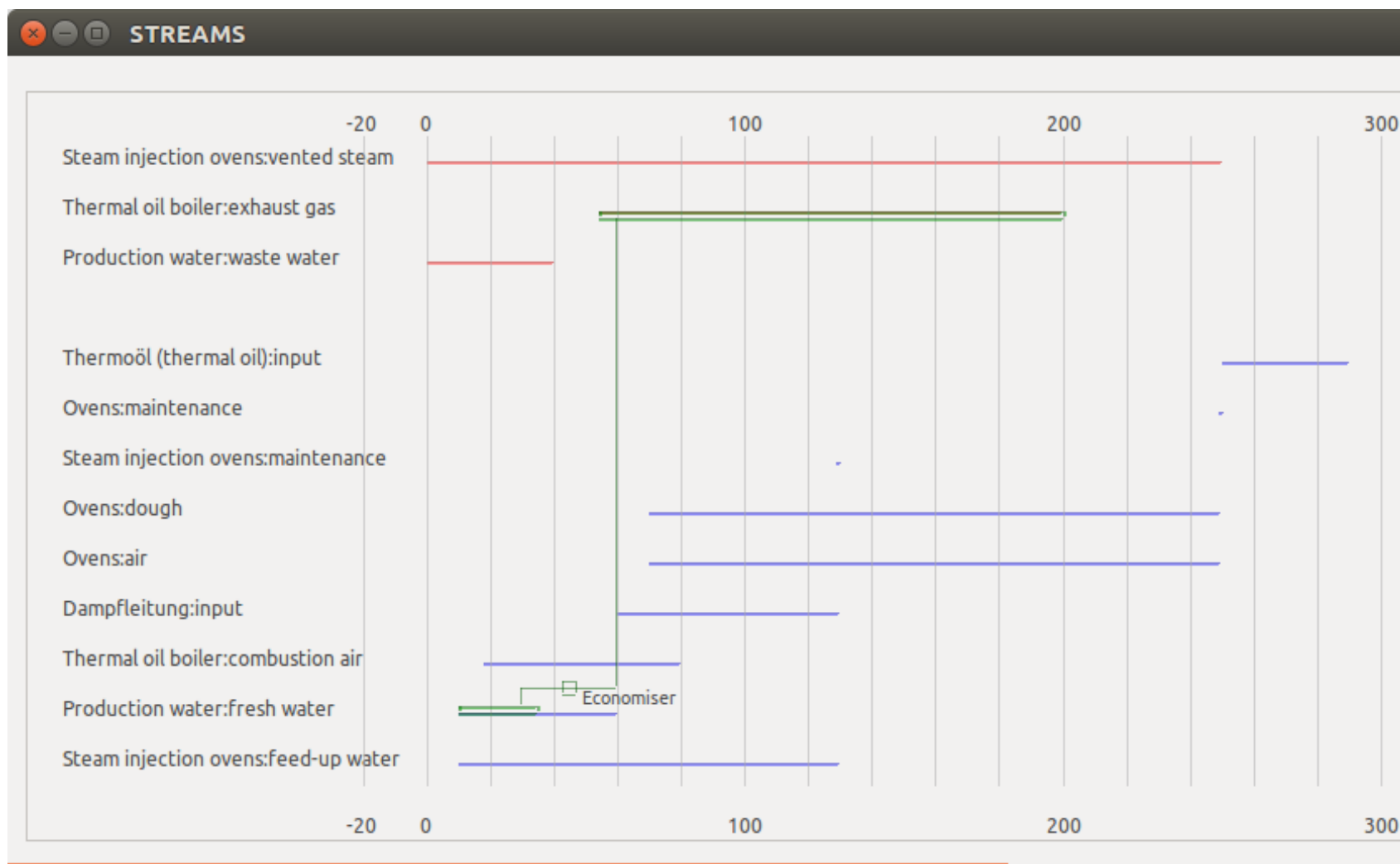


- Tool for automatic design of optimised heat exchanger network
- Different optimisation criteria possible:
 - minimum size of heat exchangers
 - exergy optimisation
 - fine tuning by selection of ΔT_{\min}

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



Use case: heat pipe economiser stream plot

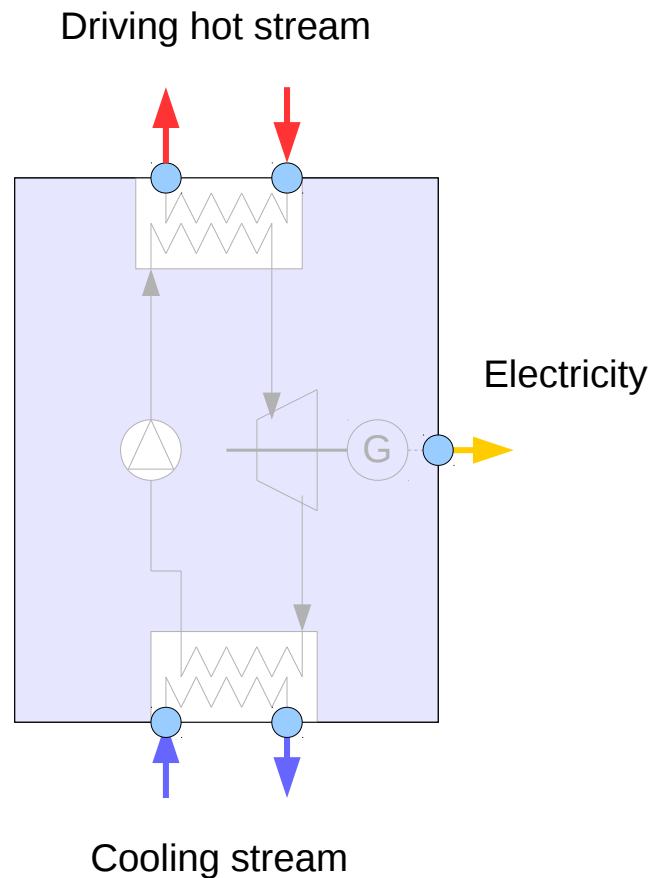


Optimisation of waste heat to power with EINSTEIN



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- Black box model for heat to power generating units



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).

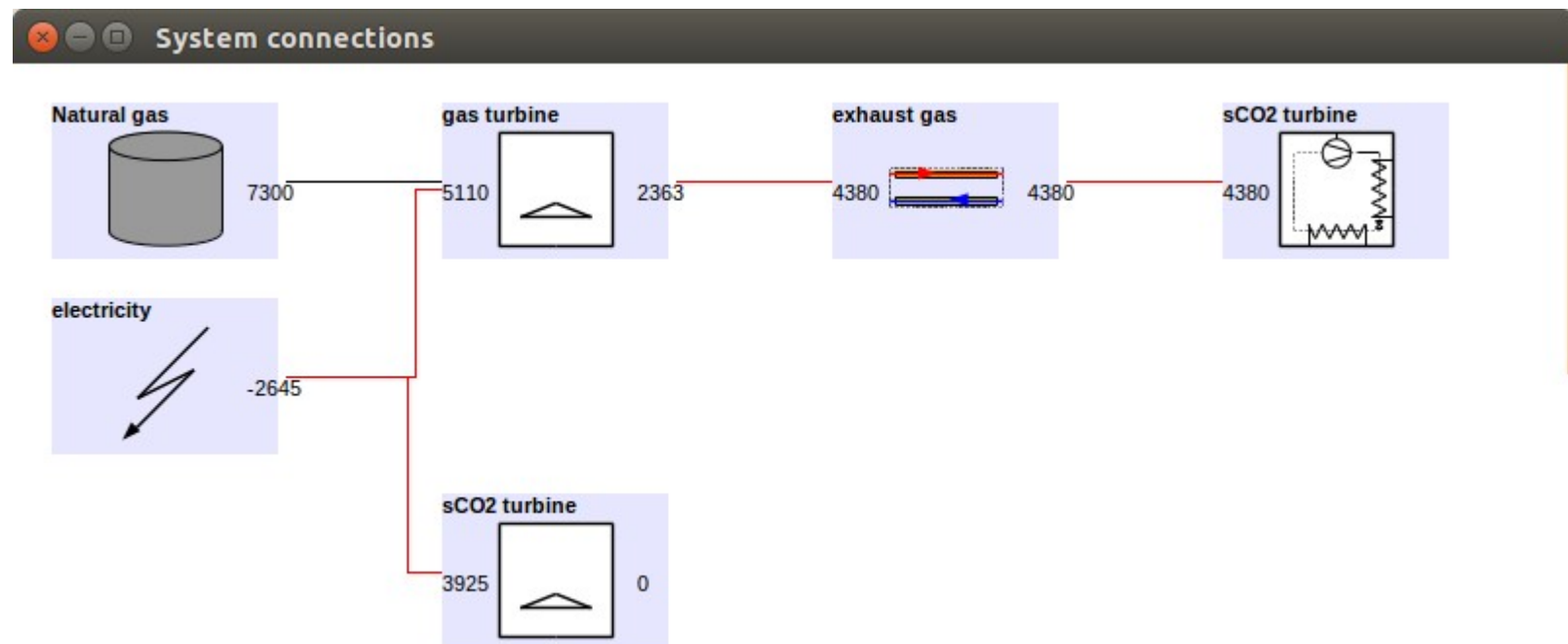
Model features

- 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

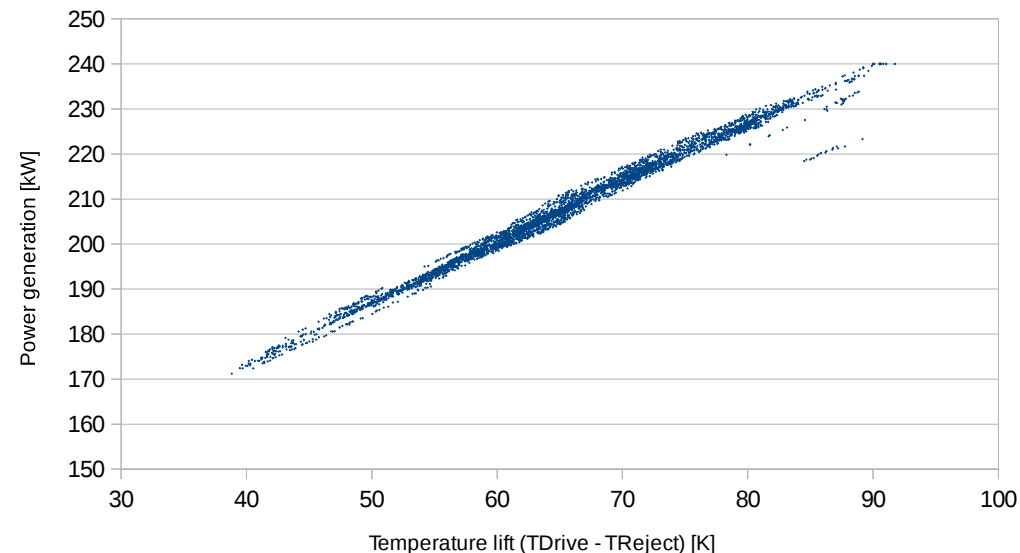
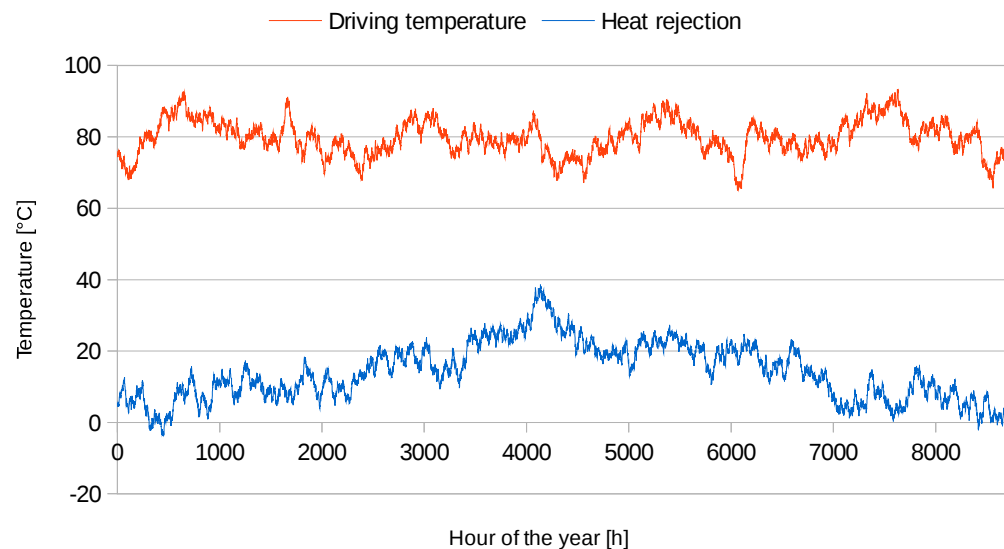
Model types supported

- 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

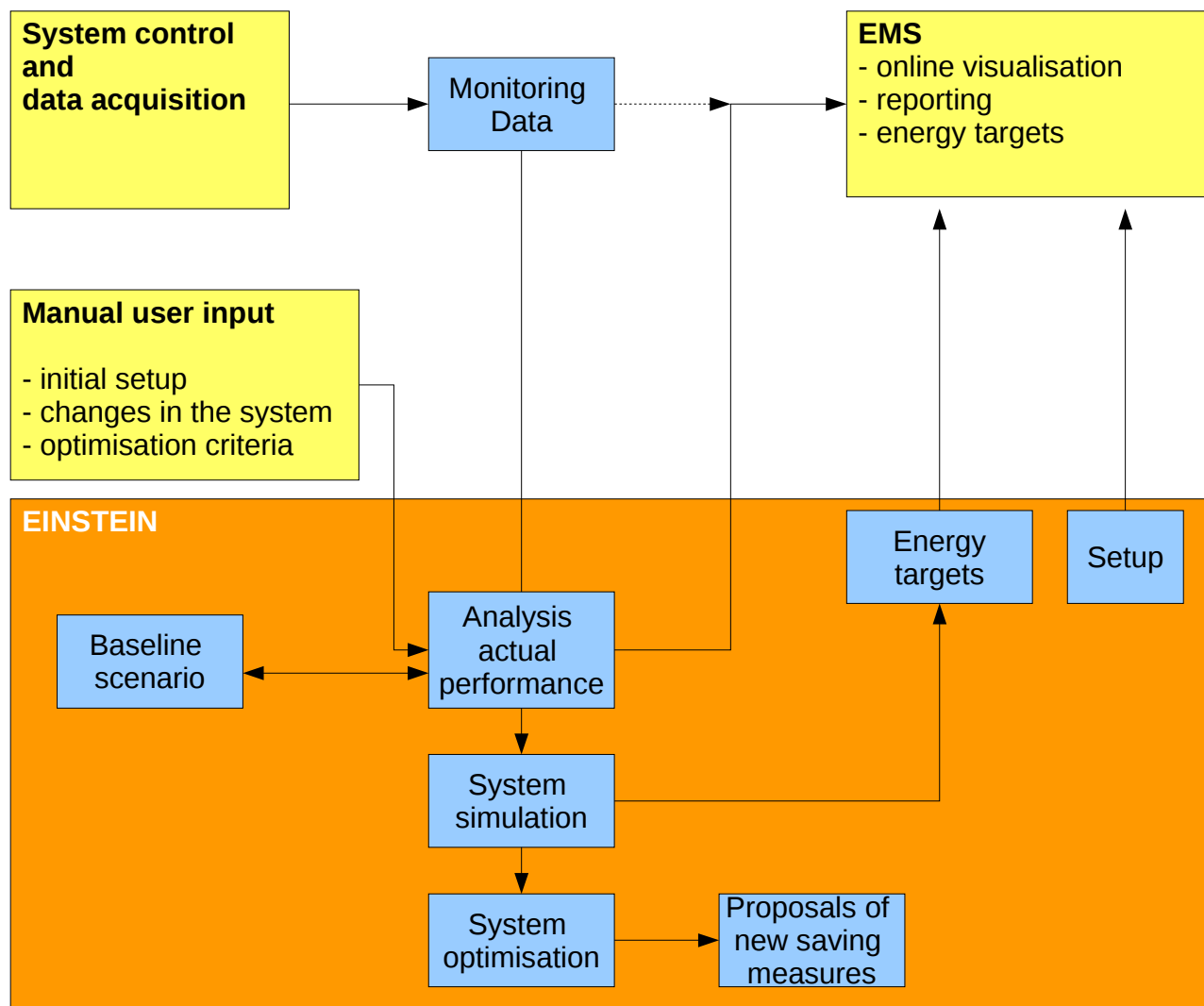
- Similar to iTherm-Demo: UBRUN (WP5)
- sCO₂-turbine supplied by exhaust gas from gas turbine or gas boiler



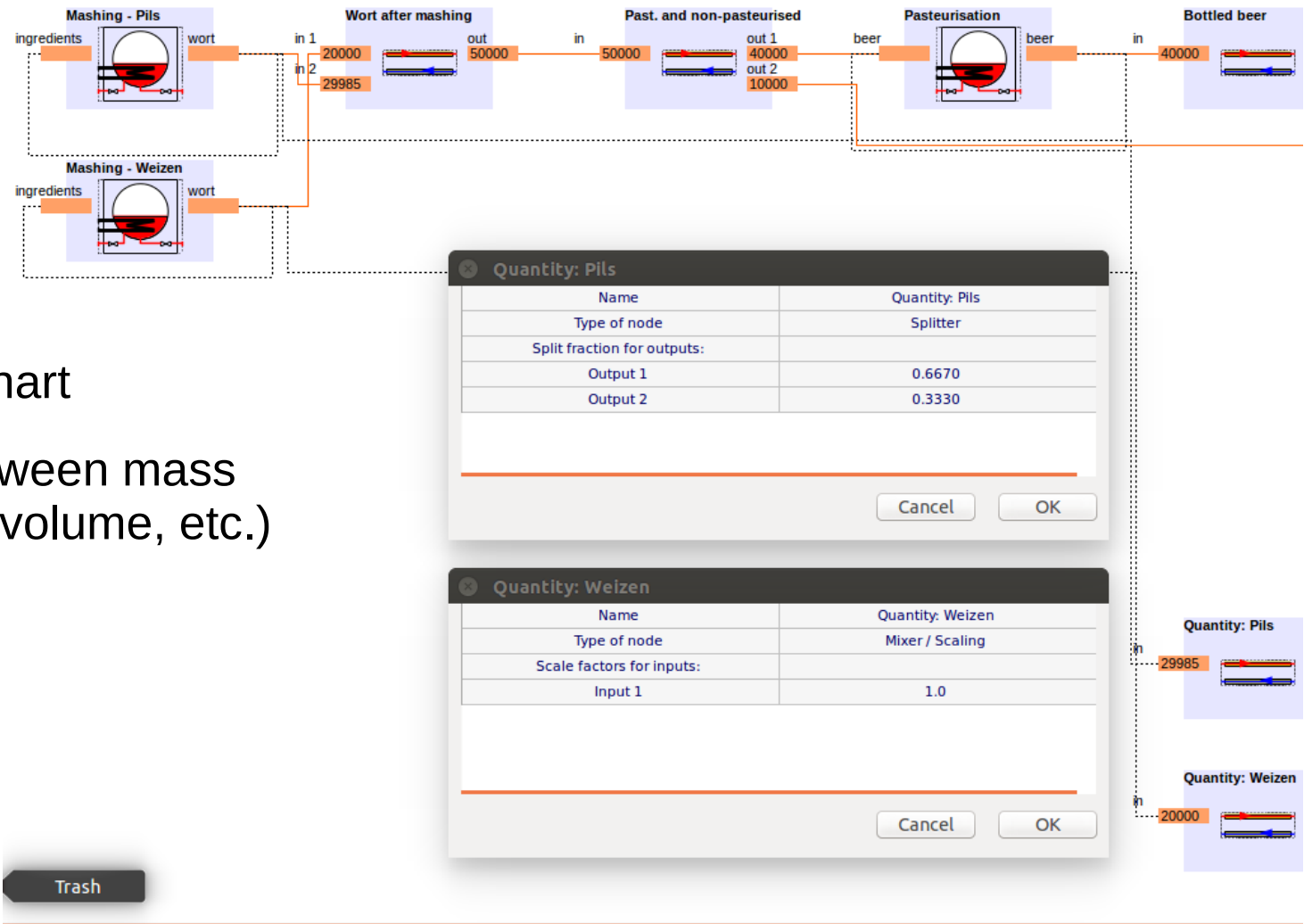
- Example: analysis of conversion efficiency as a function of driving and heat rejection temp.



Link with monitoring data and energy management



- 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.)



Production flow chart

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

- 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)

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

