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

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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
E I N S T E I N

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

The software tool provides a comprehensive suite of tools for energy management, including data acquisition and check, data analysis, energy statistics, and benchmarking. The tool is designed to support various aspects of energy management, such as energy statistics and benchmark checking, which are highlighted in the image. The interface is user-friendly, with options for selecting different modules such as energy statistics and benchmark check. The tool also offers a variety of report options, including economic analysis, comparative study, and report generation.
The software tool

DATA ACQUISITION AND CHECK

DATA ANALYSIS

ENERGY STATISTICS

BENCHMARKING

The software tool allows for data acquisition and check, energy statistics, and benchmarking. It includes features for energy consumption analysis, alternative proposals, and project management for dairy industries.
The software tool

DATA ACQUISITION AND CHECK

DATA ANALYSIS

ENERGY STATISTICS

BENCHMARKING

The software tool allows for comprehensive energy analysis and benchmarking through its various features such as data acquisition and check, energy statistics, and benchmarking. It provides tools for data analysis and energy performance evaluation, making it a valuable resource for industries aiming to optimize their energy usage and reduce costs.

Energy statistics and benchmark check options are highlighted, indicating the software's capability to evaluate energy performance and compare results with industry standards.
The software tool
The software tool

HEAT&COLD SUPPLY SYSTEMS

ALTERNATIVE PROPOSALS: EVALUATION

REPORT
The software tool for energy and environmental performances, economic analysis, and alternatives comparison. It includes features for data acquisition and check, as well as various alternative proposals for design and evaluation. The software provides energy performance analysis, economic analysis, and comparative study reports.
The software tool

ALTERNATIVES COMPARISON

REPORT
The software tool

DATA ACQUISITION AND CHECK

DATA ANALYSIS

ALTERNATIVE PROPOSALS: DESIGN

ALTERNATIVE PROPOSALS: EVALUATION

REPORT

REPORTING
Optimisation of heat recovery with EINSTEIN
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

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


\[ \Delta T_{\text{min}} = 20 \text{ K} \]
\[ Q_{\text{H, min}} = 1000 \text{ kW} \]
\[ Q_{\text{C, min}} = 800 \text{ kW} \]
\[ T_{\text{pinch}} = 180/160^\circ \text{C} \]
Heat exchanger network

Streams in EINSTEIN - Energy flows

Final energy input
Connections Fuels/Elect. - Equipes
Heat & cold supply ("Equipments")
Connection Equipes - Pipes
Distribution & Storage ("Pipes")
Connection Pipes - Processes
Processes

LEGEND
connections of sub-systems
external energy input
thermal energy flows (heat & cold)
available waste heat (from source)
recovered waste heat (to sink)

Heat recovery system
QHX
QWH

Waste Heat from Electrical Equipment
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 $\Delta T_{\text{min}}$
Use case: heat pipe economiser

- 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
EINSTEIN software: (waste-) heat to power

- Black box model for heat to power generating units

![Diagram of heat to power system](image)
EINSTEIN software: (waste-) heat to power

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).
EINSTEIN software: (waste-) heat to power

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
Use case
sCO2-turbine + gas turbine

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

• Example: analysis of conversion efficiency as a function of driving and heat rejection temp.
Link with monitoring data and energy management
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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.)
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)
Link with monitoring data

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

- Model calibration and validation of simulations
- System optimisation (proposal)
- Changes in the real system
- Monitoring data

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