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Simulation based performance evaluation of biomass fired cogeneration plant with ORC

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Agenda

- Project background
- Project description
- Initial modeling studies
- Research plant
- Conclusions

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POLISH - GERMAN
SUSTAINABILITY RESEARCH PROGRAMME STAIR

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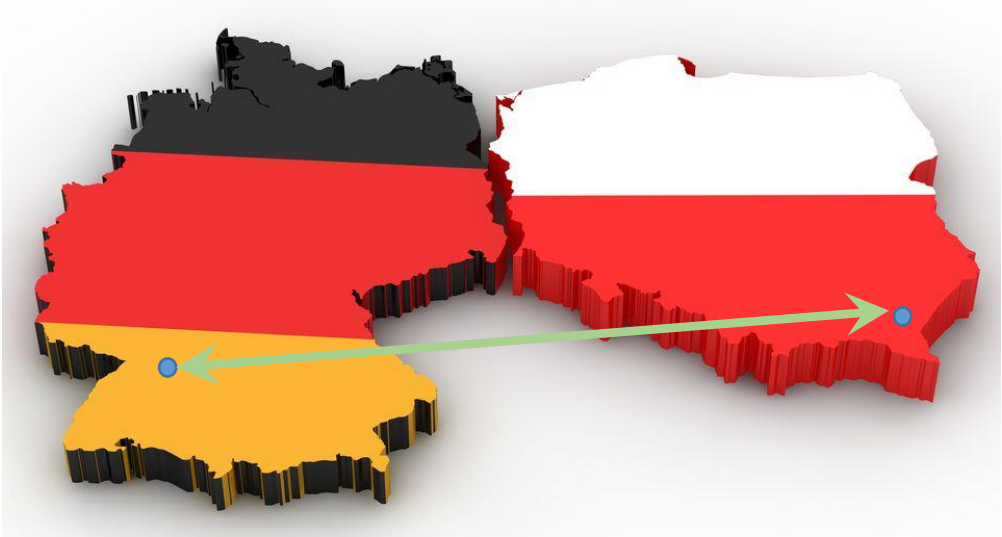
Project:
System integration of biomass fired cogeneration plants



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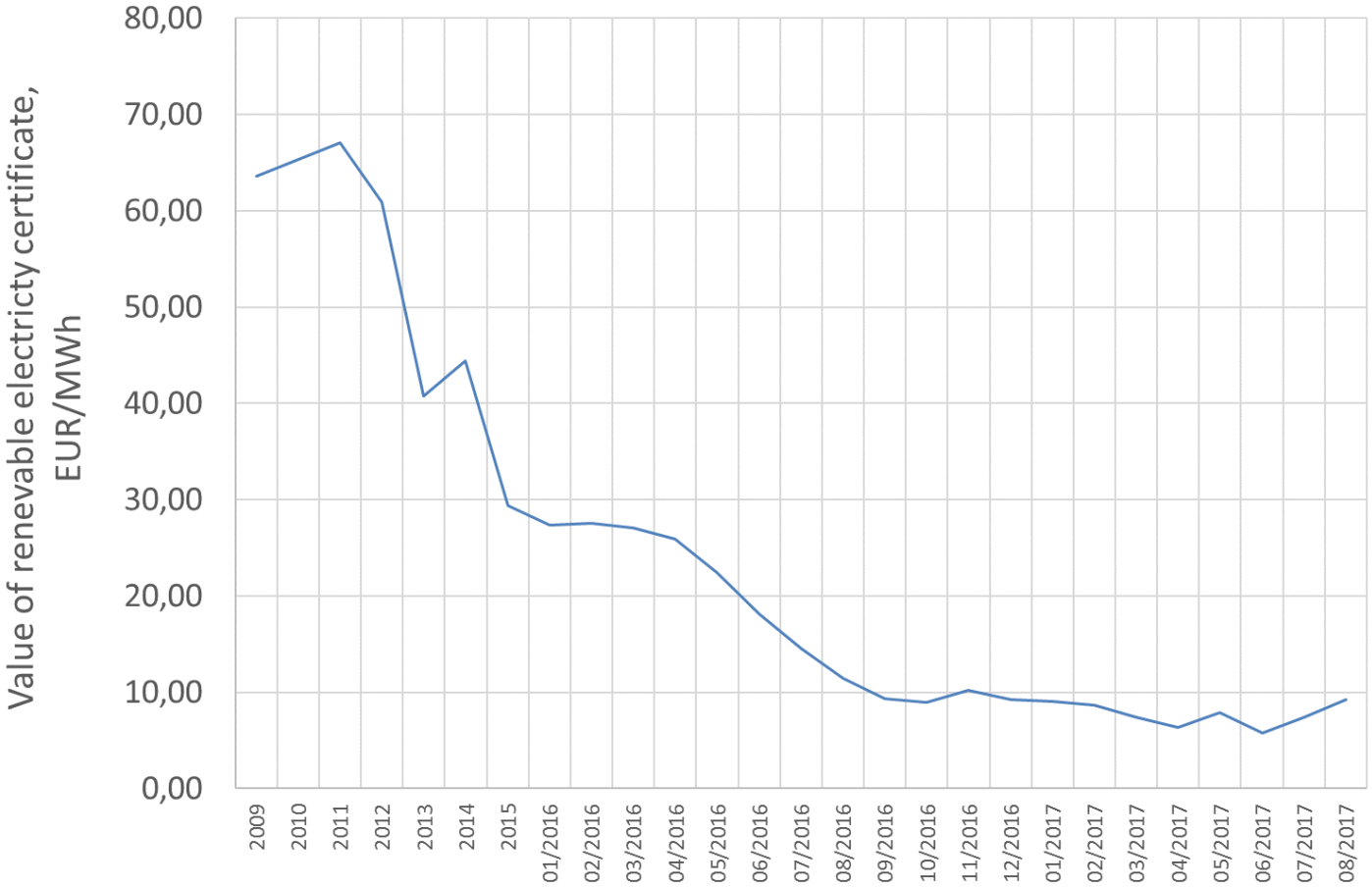
Project background

Status of biomass fired cogeneration in Poland:

- Several conventional steam plants (P > 2 MWel)
- Several gasification + ICE plants (R&D)
- 11 ORC plants (0.2 MWel < P < 1.5 MWel)
- ORC plants of single manufacturer (Turboden + VAS; Turboden + Politechnik)

Project background

Support mechanism for electricity from RES in Poland is based on tradeable certificates of origin:



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Project background

Resource efficient, price competitive and low-carbon energy management *requires in production plants relevant decision support systems (DSS) implemented in the form of* ***software tools*** *with a specific functionality.*

Key features of such system are ***optimal control of plant operation and on-line diagnostics****.*

Project background

To trigger implementation of new solutions the following are required:

- *technical studies for demo systems;*
- *control and diagnostics tools;*
- *transfer of knowledge and dissemination of new solutions.*

Therefore the IntBioCHP project include applied research activities oriented on 'proof of concept', pre-commercial demonstration and market uptake studies.

Concept

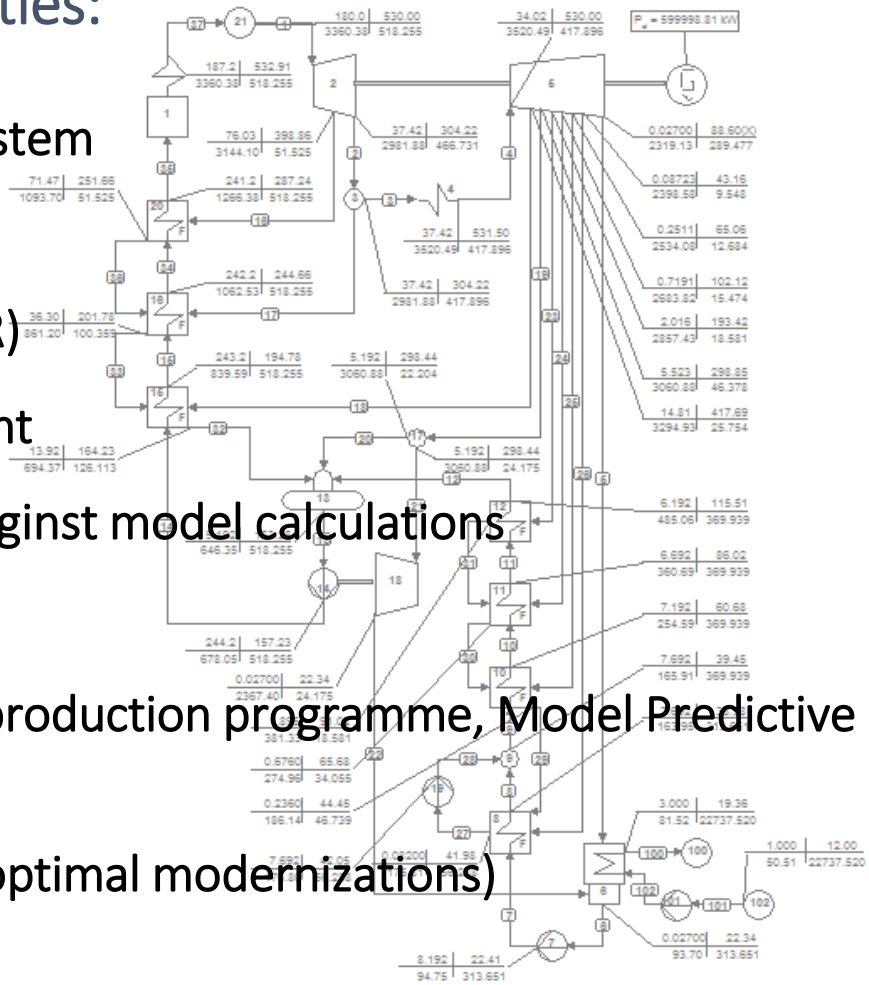
Thermal diagnostics and optimization of operation of cogeneration plants

New automation systems oppened possibilities for development of software tools for supporting decisions in the fields of plant operation parameters as well as in modernisation projects.

Concept

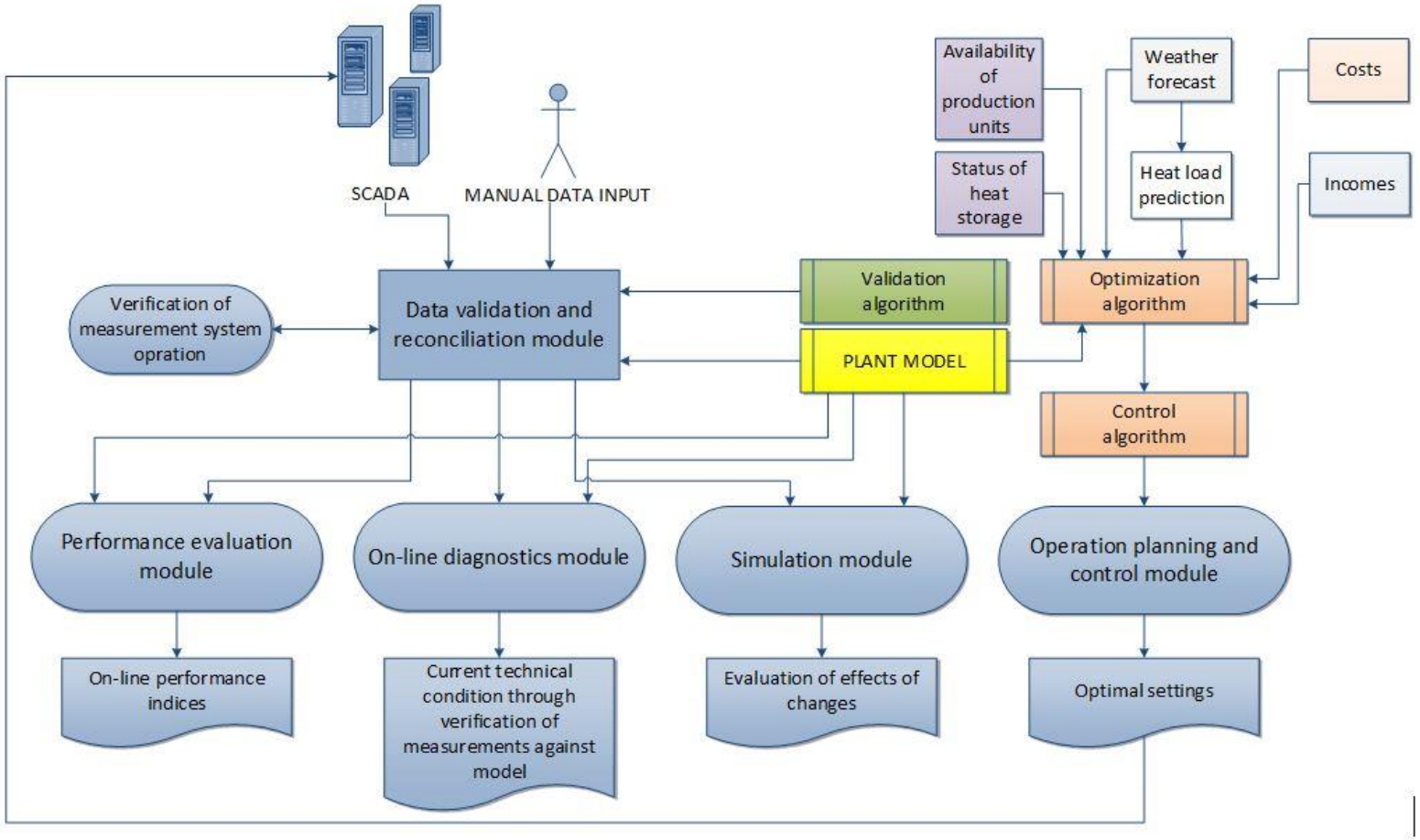
Decision Support System functionalities:

- Mathematical model of the existing system
- Data acquisition
- Data validation and reconsiliation (DVR)
- Verification of measurement equipment
- Verification of measured parameters aginst model calculations
- Load predictions
- Optimal operation decisions (optimal production programme, Model Predictive Control)
- Optimal future investment decisions (optimal modernizations)



Concept

Block diagram of an advanced Decision Support System



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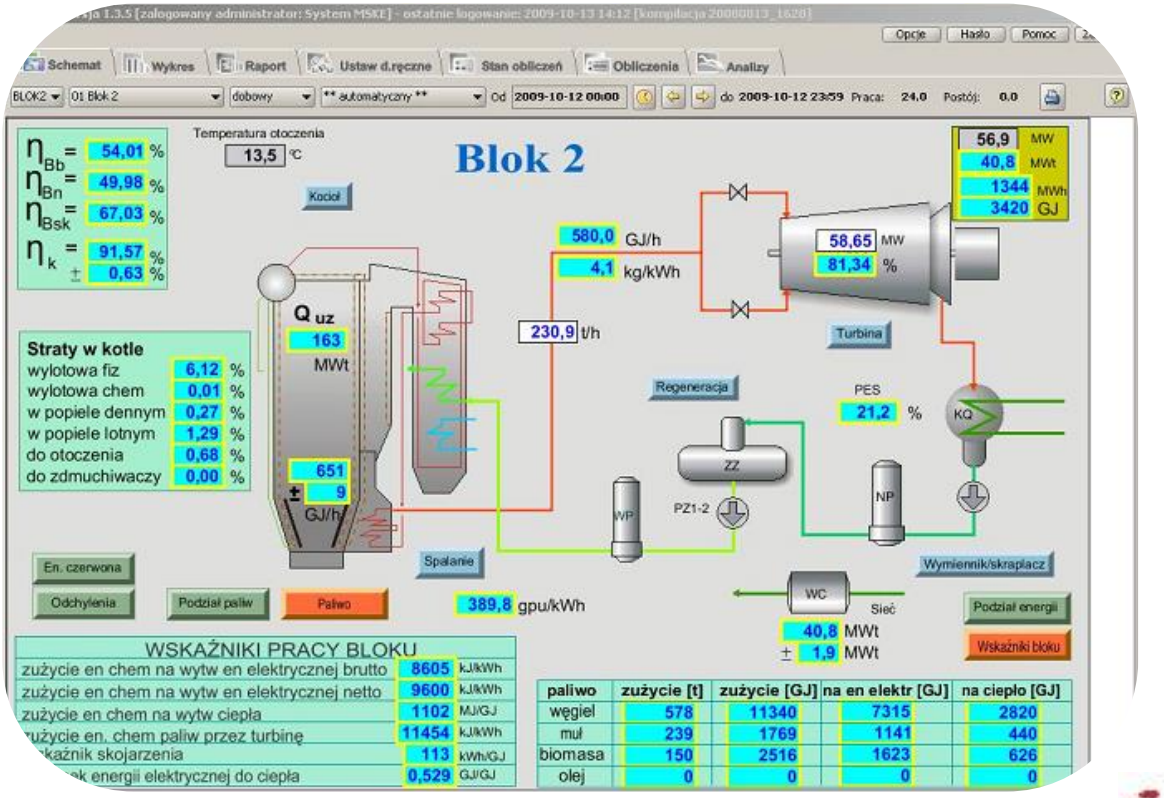
References

Meskan System

meskan

- Opole power plant (4 power blocks)
- FORTUM Wrocław Cogeneration (2 blocks)
- Jaworzno II power plant (2 cogeneration blocks)



PROCOM SYSTEM

References

Implementation of heat storage

- Reference: Białystok cogeneration plant

IntBioCHP expected results

- Improvement of load forecasting
- Adaptation of the methodology to small-scale biomass fired plants
- Identification of biomass combustion and ORC processes
- Combination of plant model and SCADA system into MPC algorithm
- Relevant design documentaion

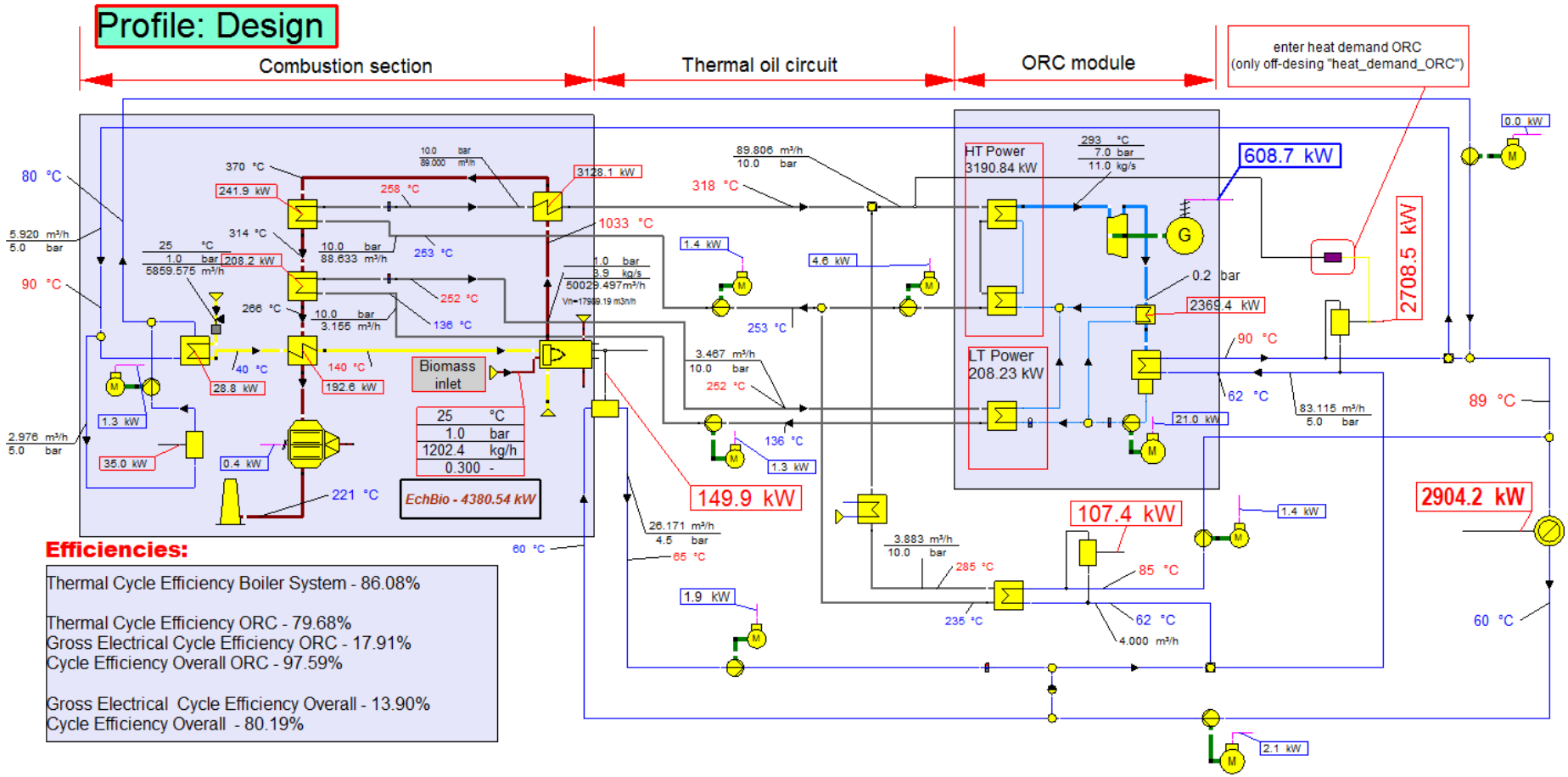
Initial modeling studies

Technical specification of the system consisting of VAS biomass fired thermal oil boiler and the Turboden T6−CHP ORC unit

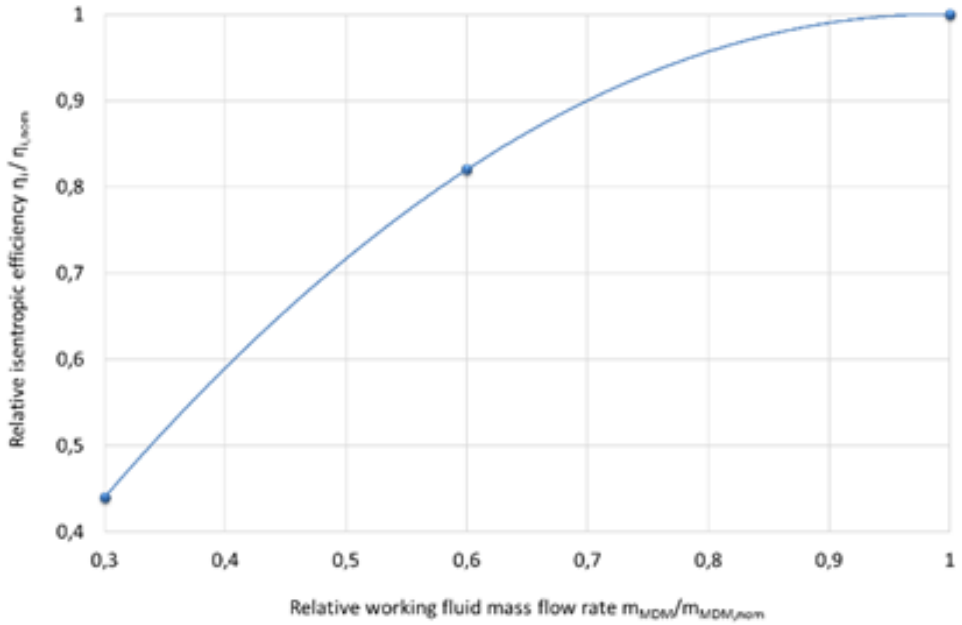
Specification parameter	Unit of measure	Value		
		100% load*	60% load*	30% load*
Generator power output	kW	606	298	71
Fuel power input (@30% water content)	kW	4395	2681	1362
ORC electric efficiency (related to thermal oil power input)	%	18	15	7
Plant electric efficiency related to fuel power input	%	14	11	5
Cogeneration plant overall efficiency	%	80	78	77

* The load is regarded as fuel power input

Initial modeling studies



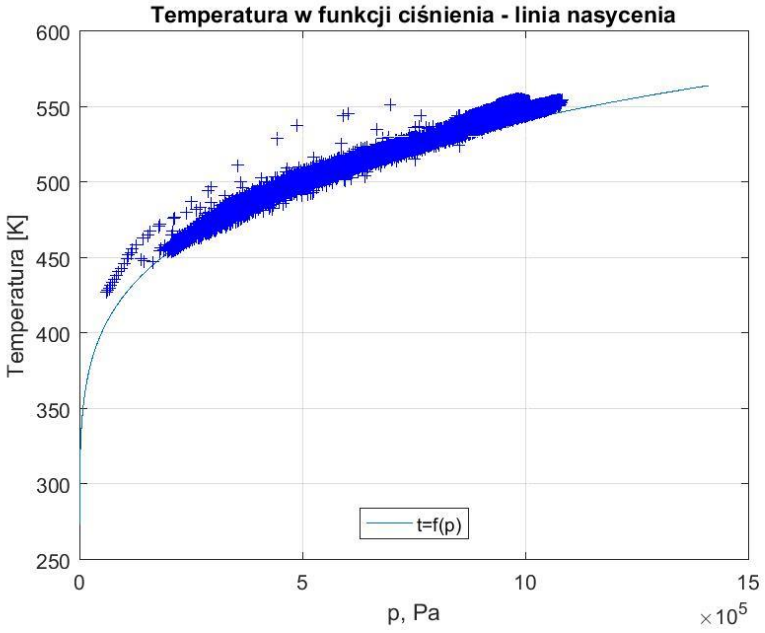
Initial modeling studies

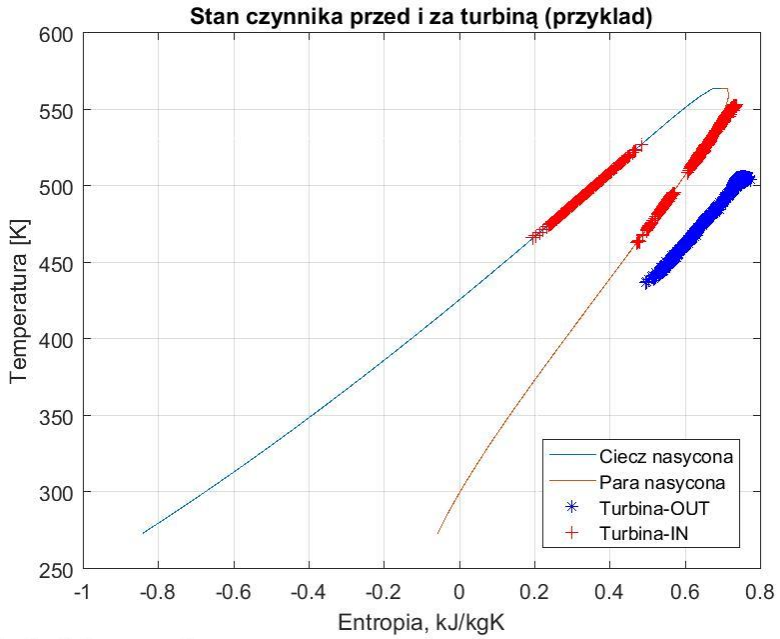


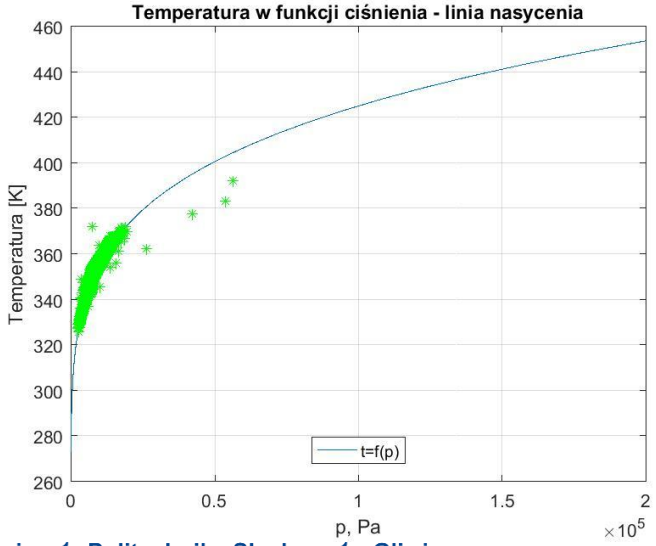
$$\frac{\eta_i}{\eta_{i,nom}} = f\left(\frac{\dot{m}_{MDM}}{\dot{m}_{MDM,nom}}\right)$$

The relation between isentropic efficiency and the working fluid mass flow rate was elaborated assuming **constant turbine inlet and outlet conditions** and power output as specified in the technical documentation

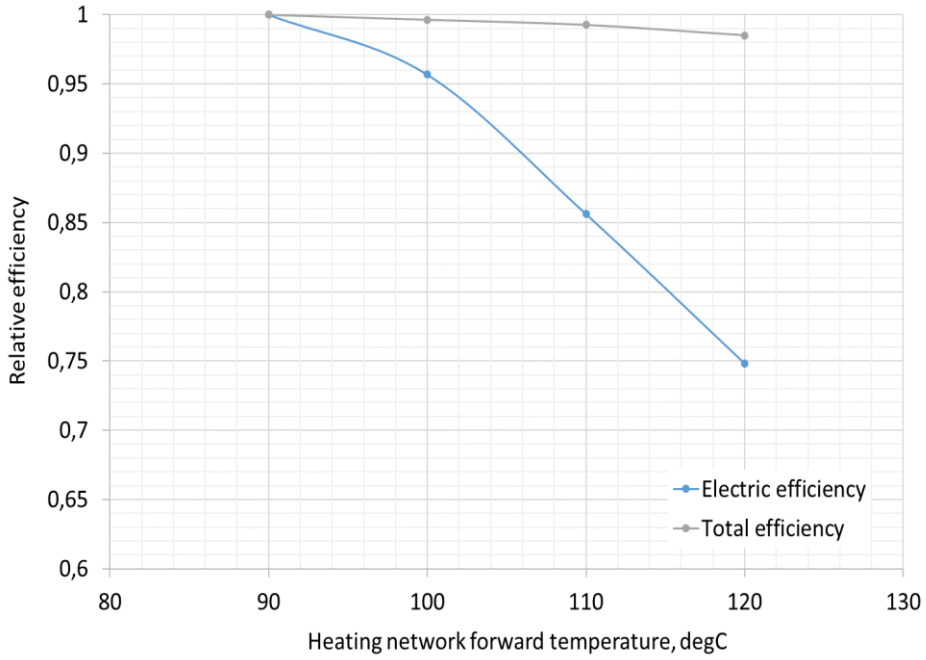
Real plant operation

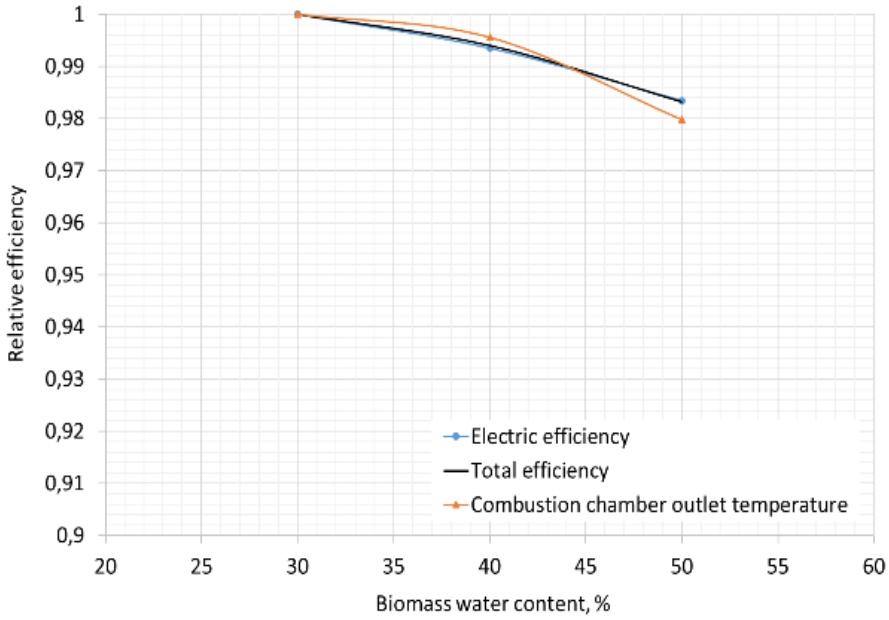




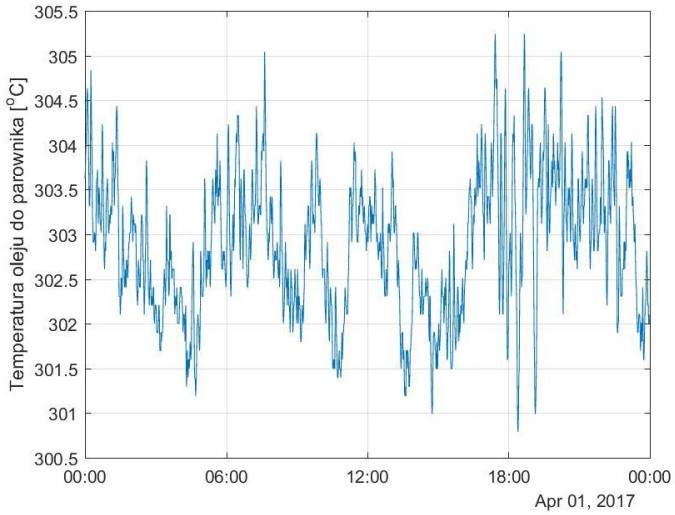


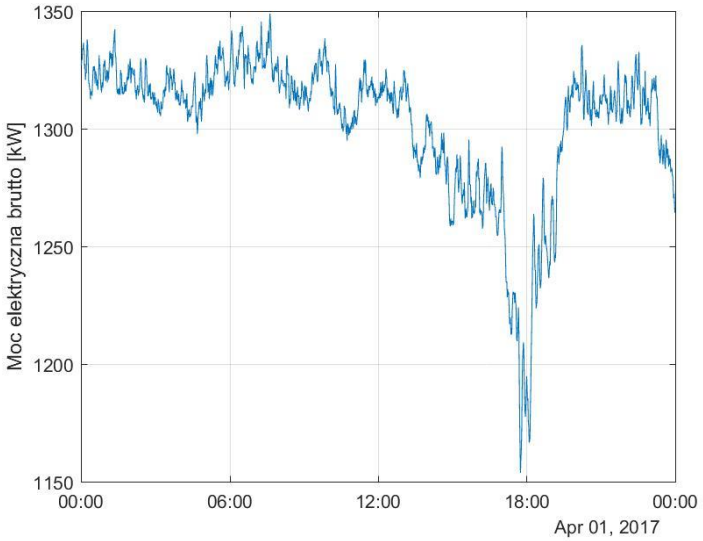
Initial modeling studies

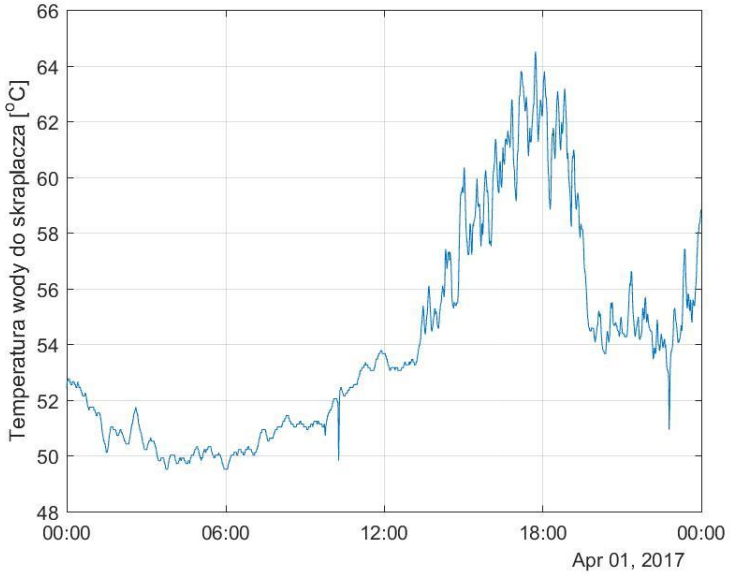




Real plant operation





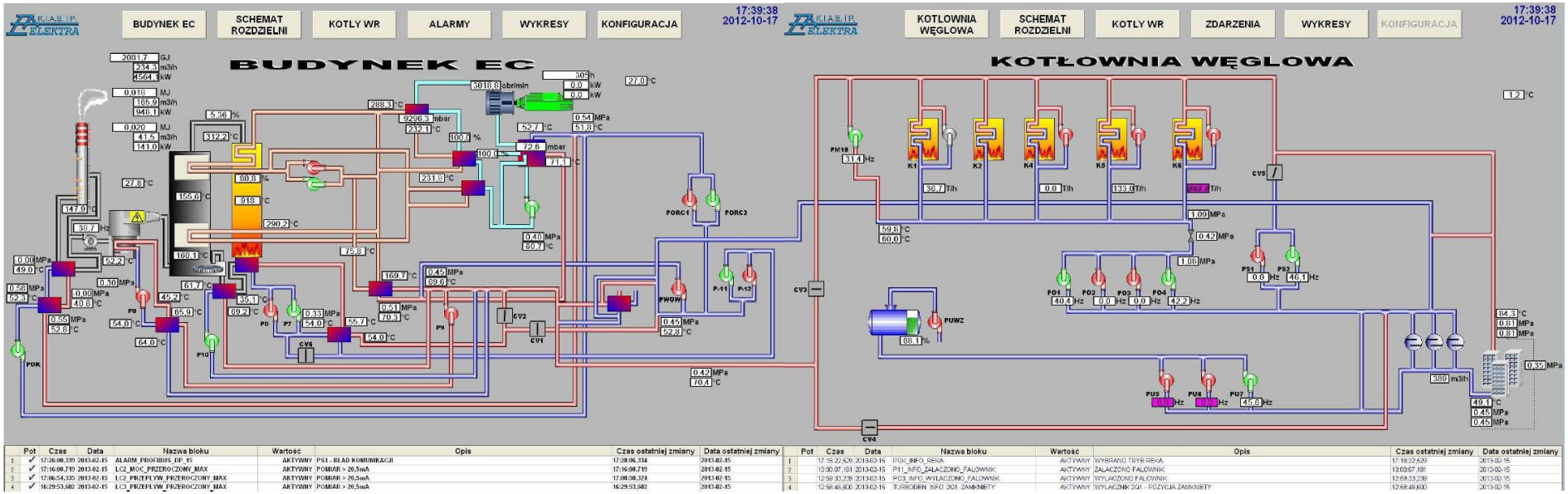


The research plant

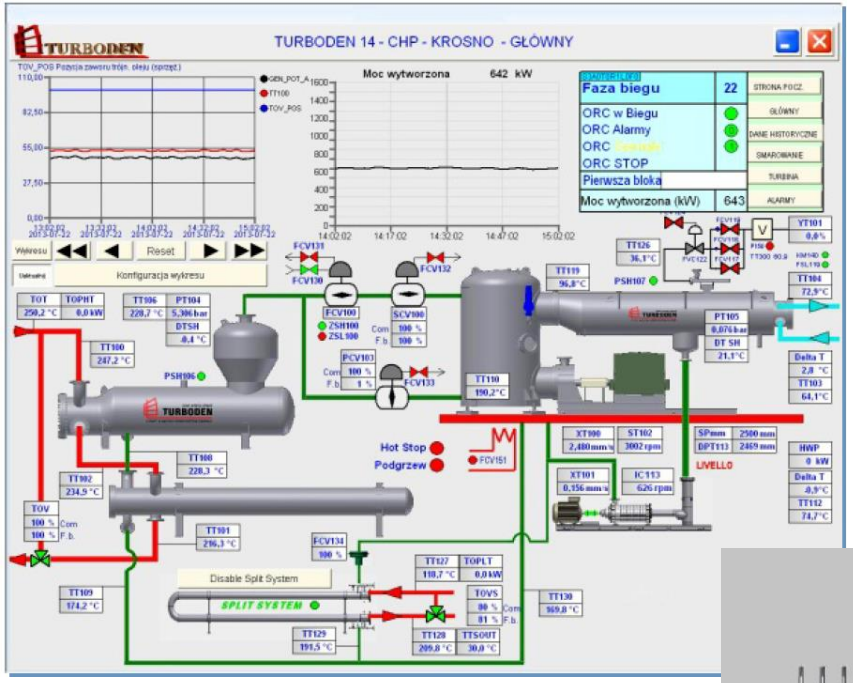
- MPGK Krosno Ltd – Municipal Holding
  - 1.255 MWe, 6.7 MWth ORC cogeneration plant in operation since 2013
  - 4 x WR coal fired boilers of 34,8 MWth

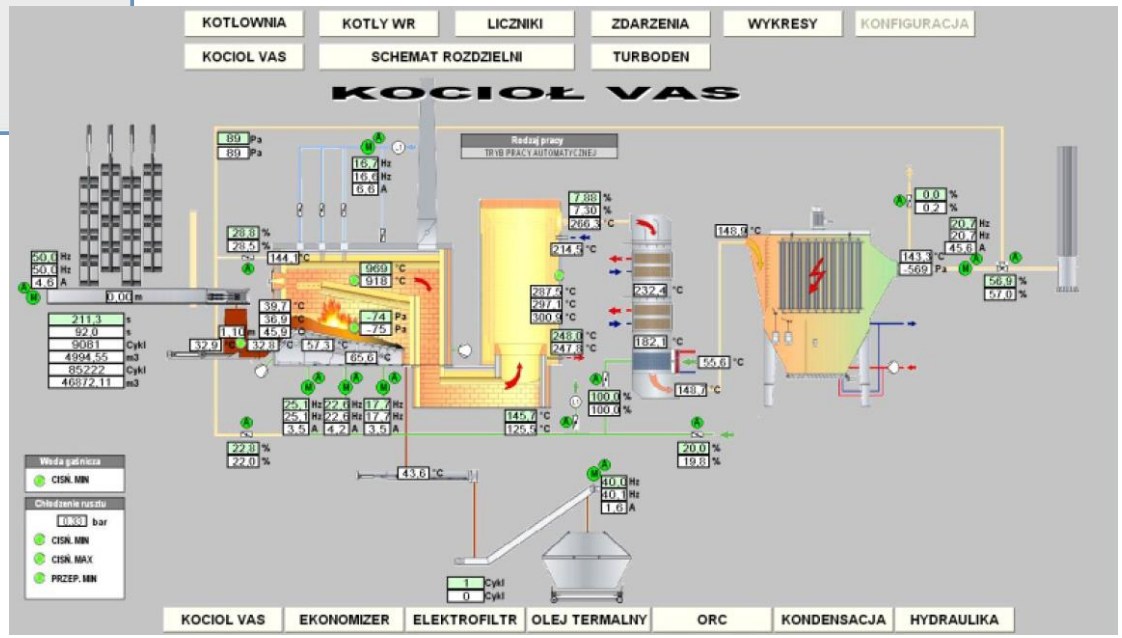
ORC + Coal boilers

- ORC plant in Krosno is operated simultanously with coal fired boilers



Krosno Plant ORC





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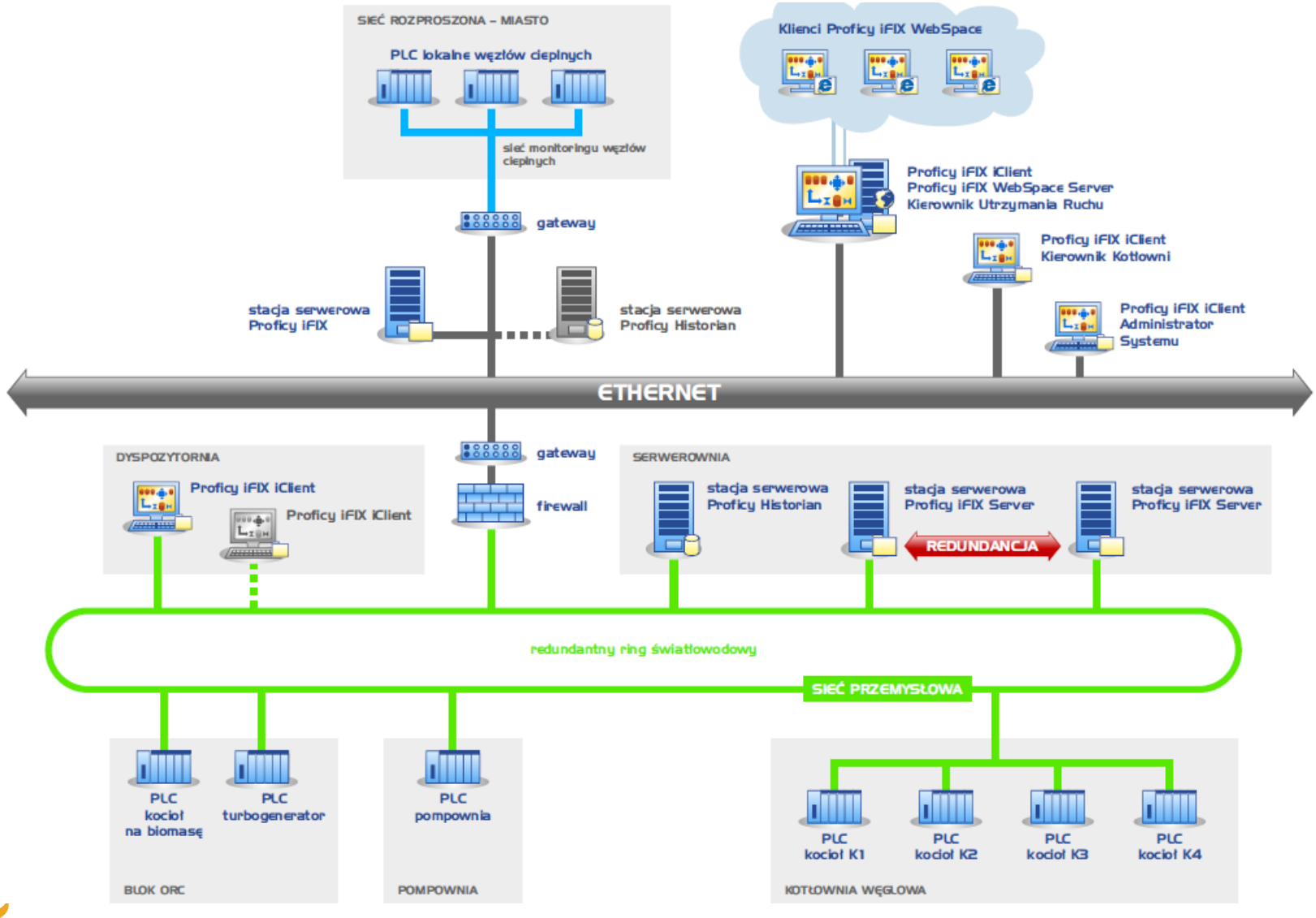
Krosno Plant SCADA



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Conclusions

- The paper presents the concept of a DSS software tool.
- The results presented in the paper were obtained using commercial software that allowed creation of reference models and initial studies of the behavior of the system. The model was able to reproduce parameters of the system under variable operating conditions.
- Simulations showed that sensitivity of the energy conversion efficiency to the parameters such as load factor, biomass water content and DHS network water temperature is high. Initial studies of measurment data confirmed this high sensitivity to external parameters.
- Plant performance and economics can be improved by incorporating the mathematical models into the diagnostics and control systems.

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Thank you for your attention

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