IntBioCHP

POLISH - GERMAN
SUSTAINABILITY RESEARCH PROGRAMME STAIR

SYSTEM INTEGRATION OF BIOMASS FIRED COGENERATION PLANTS

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Federal Ministry of Education and Research

ITC www.itc.polsl.pl Instytut Techniki Cieplnej Politechnika Śląska Gliwice

Hochschule für Technik Stuttgart

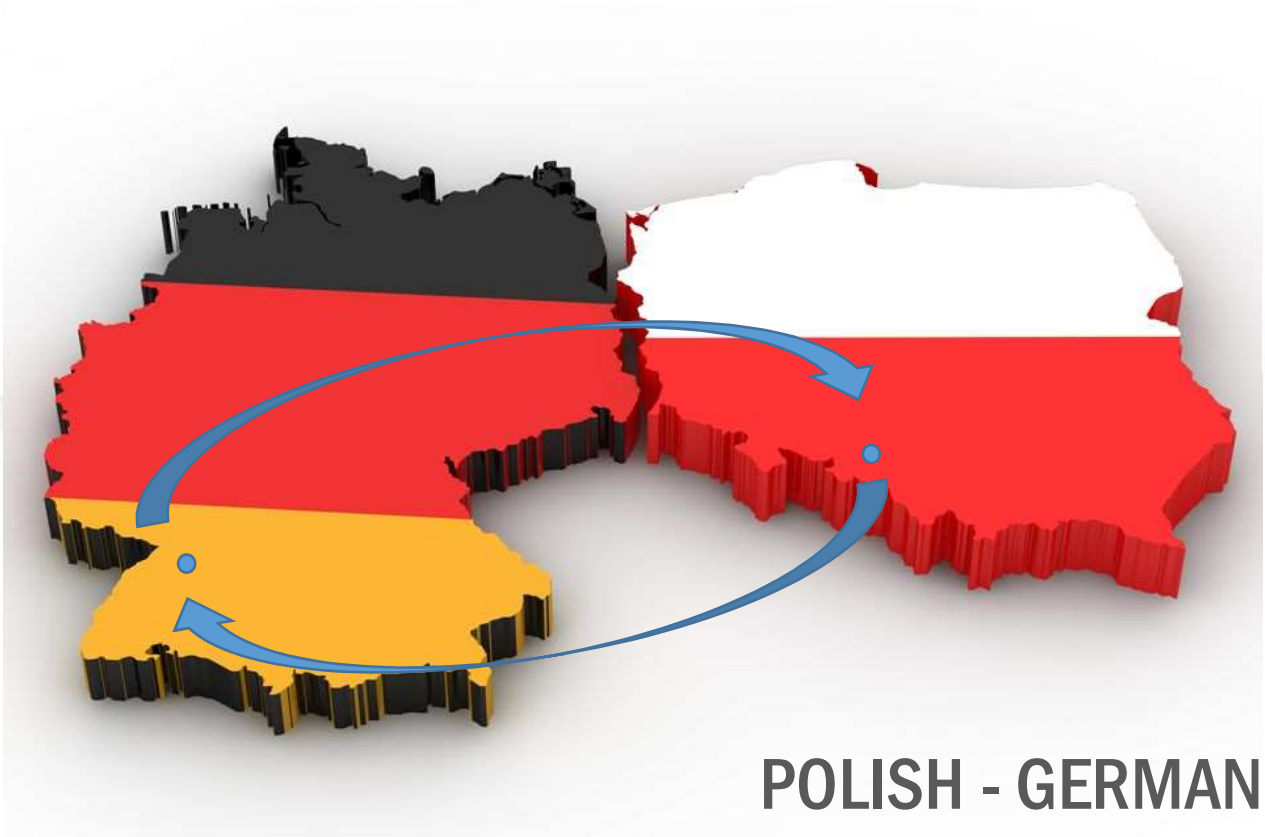
IntBioCHP

Agenda

- Introduction
- Objectives
- Initial conditions
- Product characteristics
- Sample results
- Conclusions

IntBioCHP

System integration of biomass- fired cogeneration plants



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Project objectives

- Development of plant operation suport system (software tool), which would enable optimization of the heat and power plants in a daily operation.
- Development of alternative schemes of the biomass fired ORC plant integration with industrial and municipal heat consumers.
- Development of mathematical simulation models of the proposed technological systems and energy management scenarios.
- Development of tools for predictions of heat load profiles.
- Testing on-line biomass properties measurements.
- Simulation based studies of cogeneration plant operation.
- Assessment and analysis of effectiveness of the proposed technology solutions.

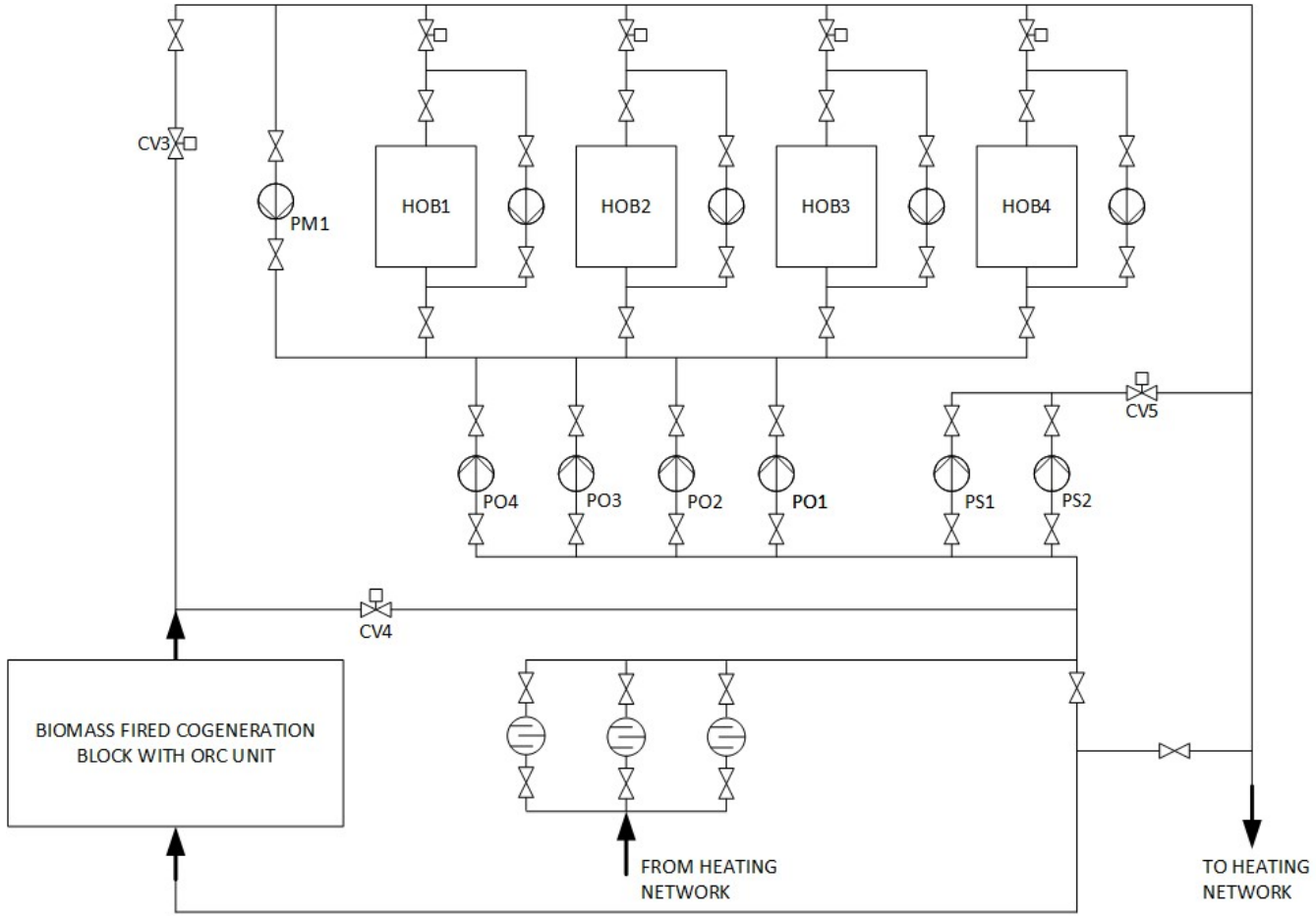
Research plants

Holzheizkraftwerk Scharnhauser Park (DE)
ORC + Gas boilers

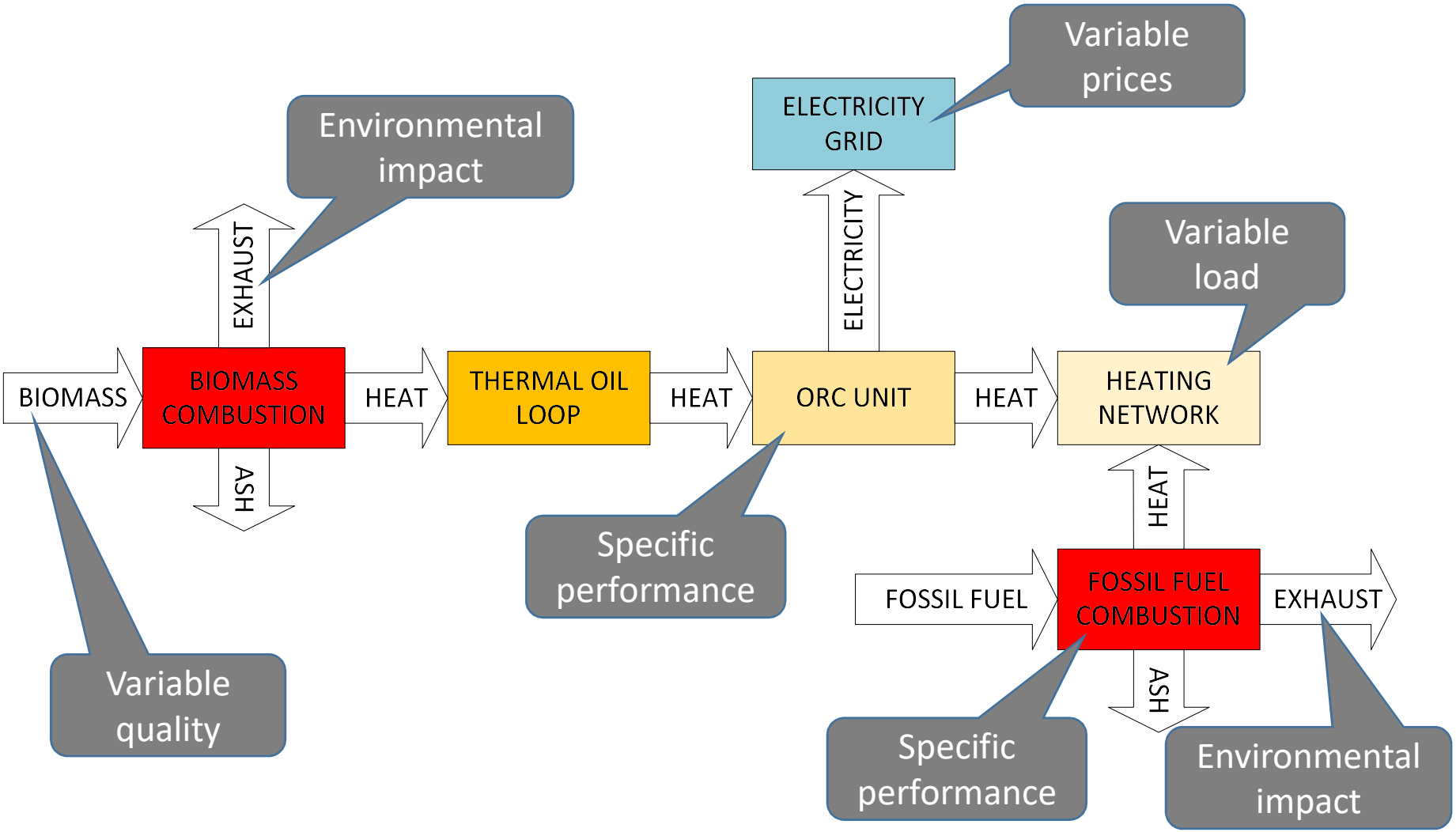
MPGK Krosno Ltd – Municipal Holding (PL)
ORC + Coal boilers

Technological system

Both systems are similar and cosist of biomass-fired ORC cogeneration module fossil-fuel-fired heat only boilers.

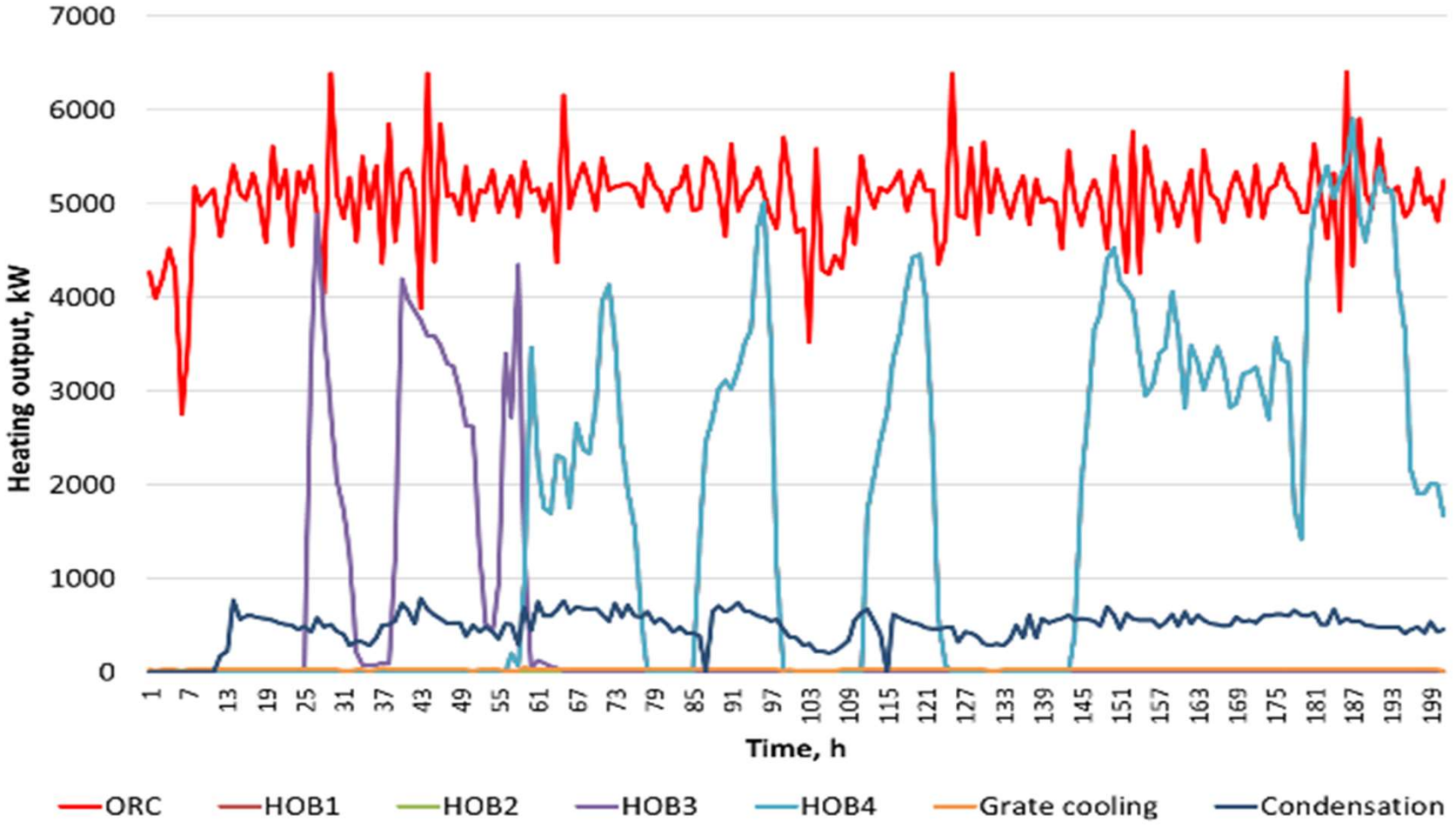


Key conditions



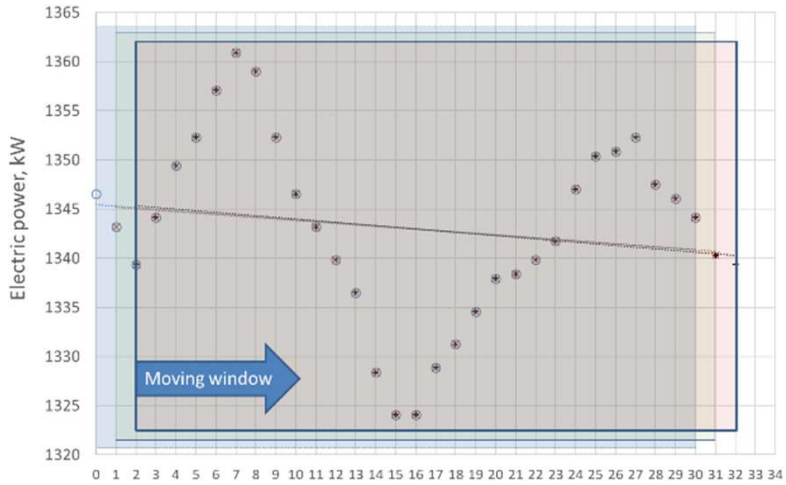
IntBioCHP

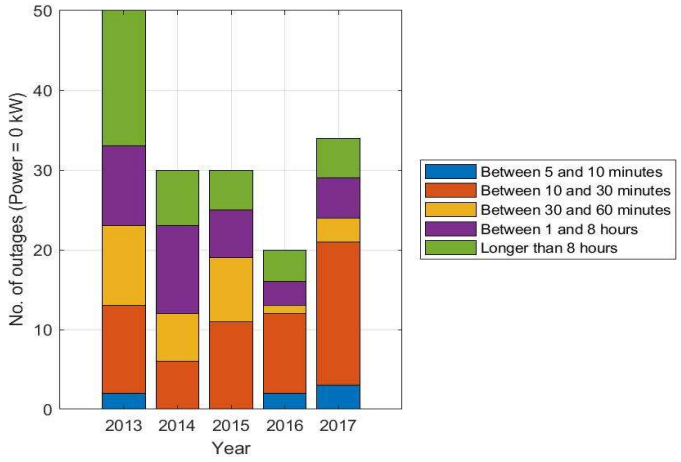
Equipment operation within sample period of 200 hours



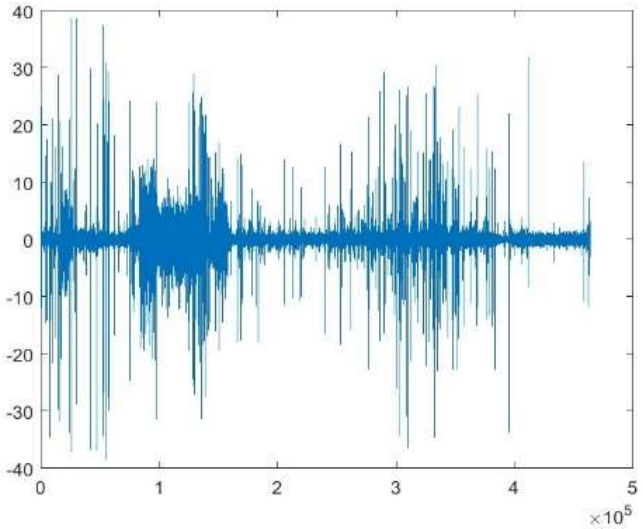
Operational characteristics

System stationarity tests

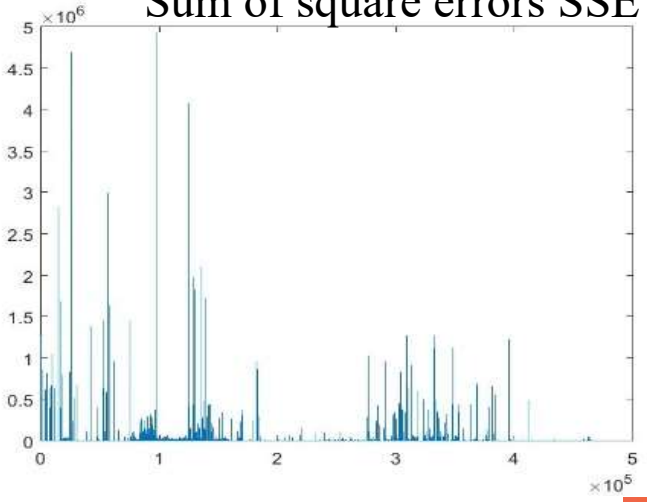




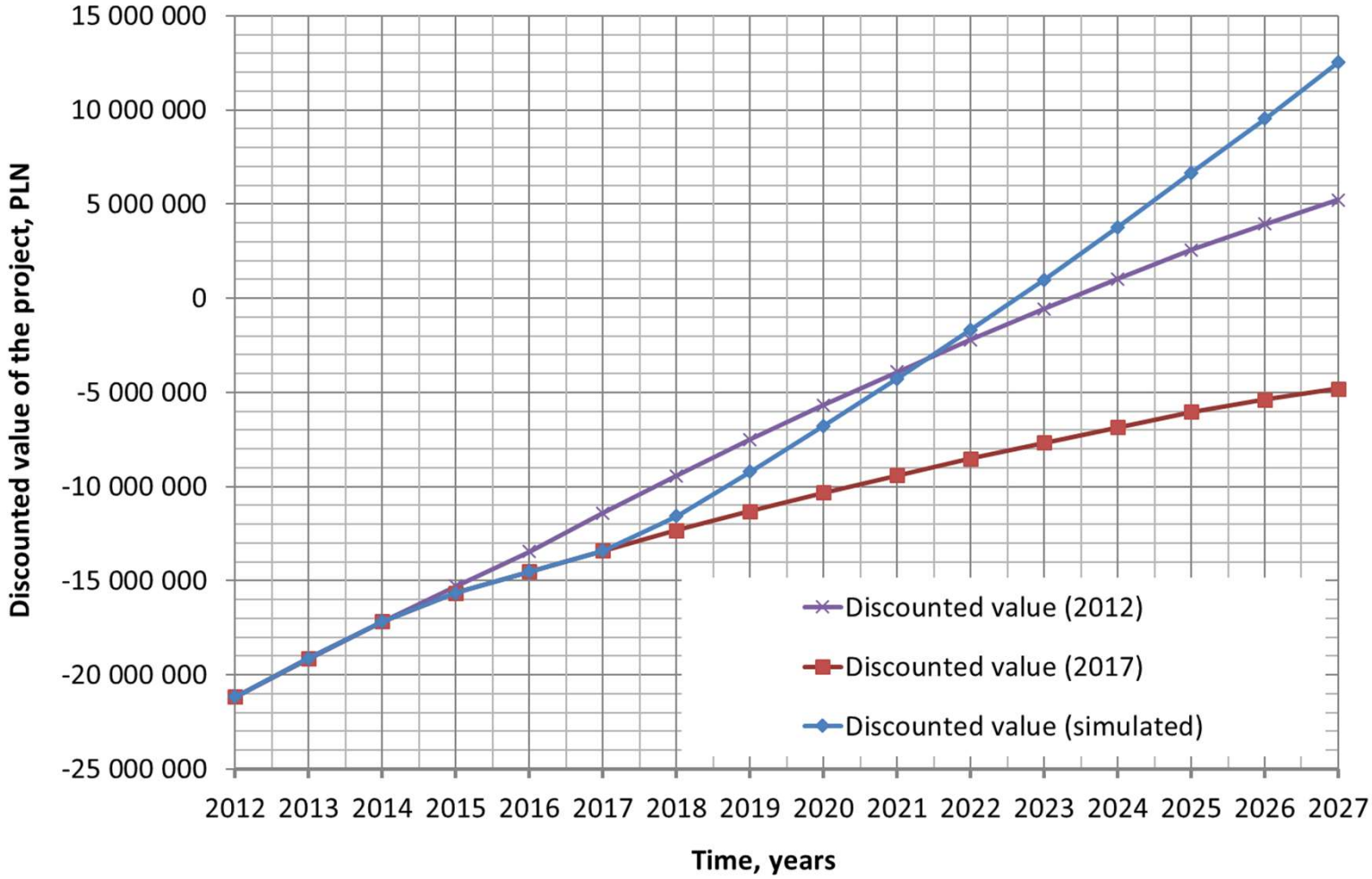
Gradient



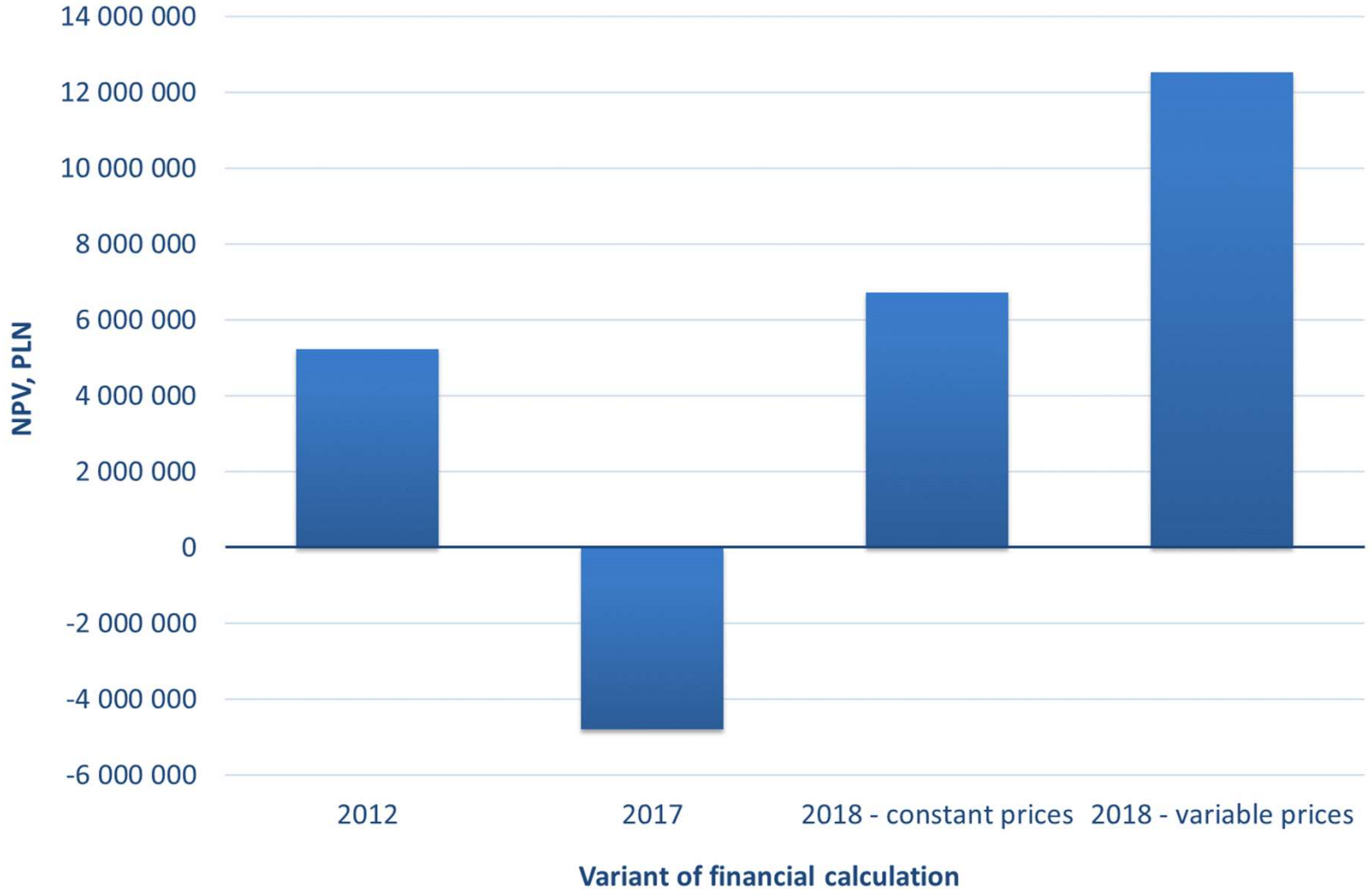
Sum of square errors SSE



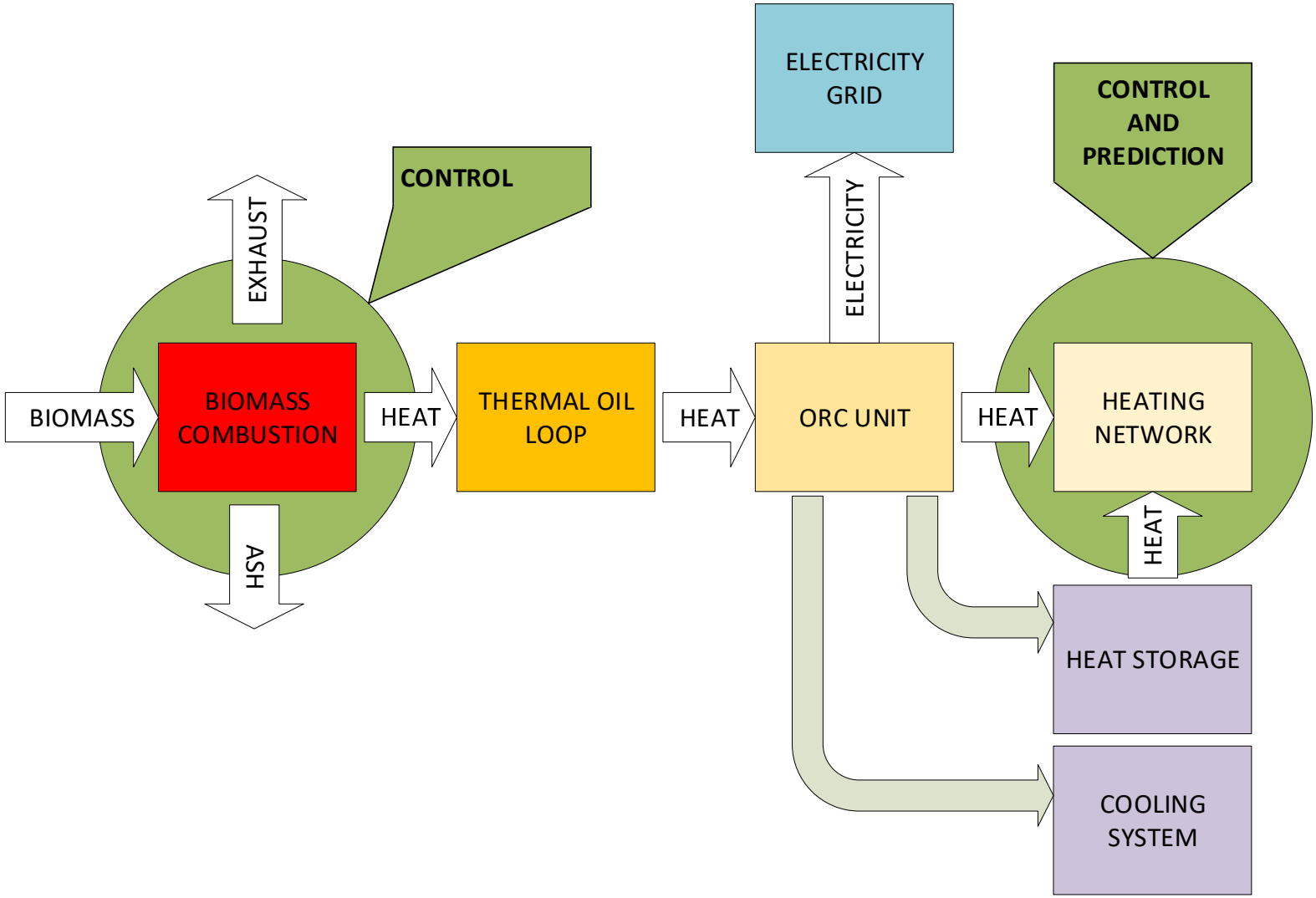
Anticipated financial results of the Krosno project



Anticipated financial results of the Krosno project



Possible improvements

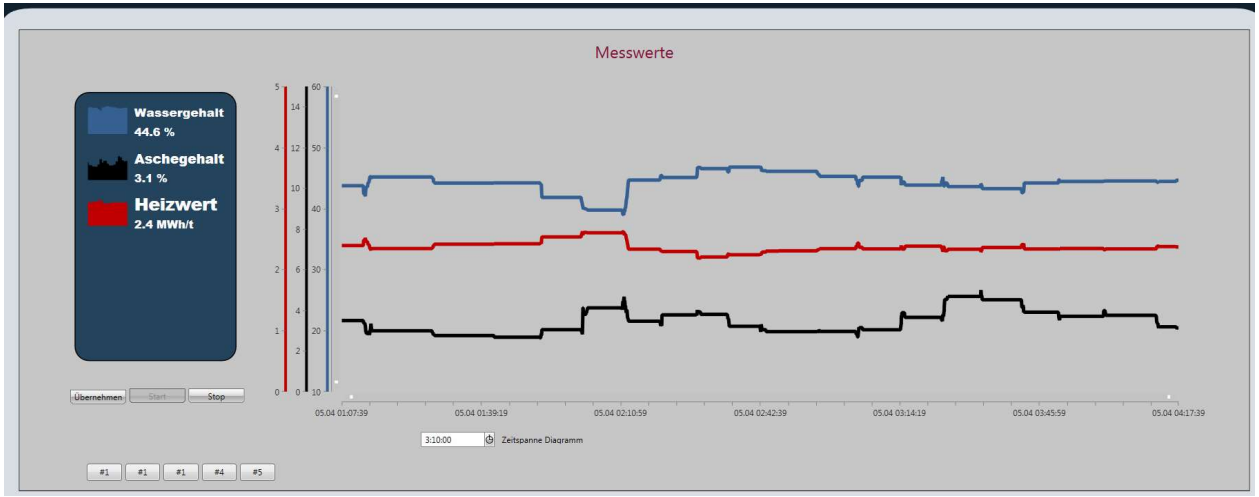


List of IntBioCHP project products

- ProcessOPT system for online measurements of biomass quality – hardware tool.
- Control algorithm for biomass combustion process.
- IntBioCHP_DSS – expert system concept and software
- Software tools for heat load forecasting – different methods.
- Design documentation of IntBioCHP_DSS integration.
- Design documentation of heat storage tank
- Techno-economic studies and computer simulations
- Journal and conference papers

Monitoring of biomass quality

New hardware components - Near Infrared Spectroscopy (NIRS)



Monitoring of biomass quality

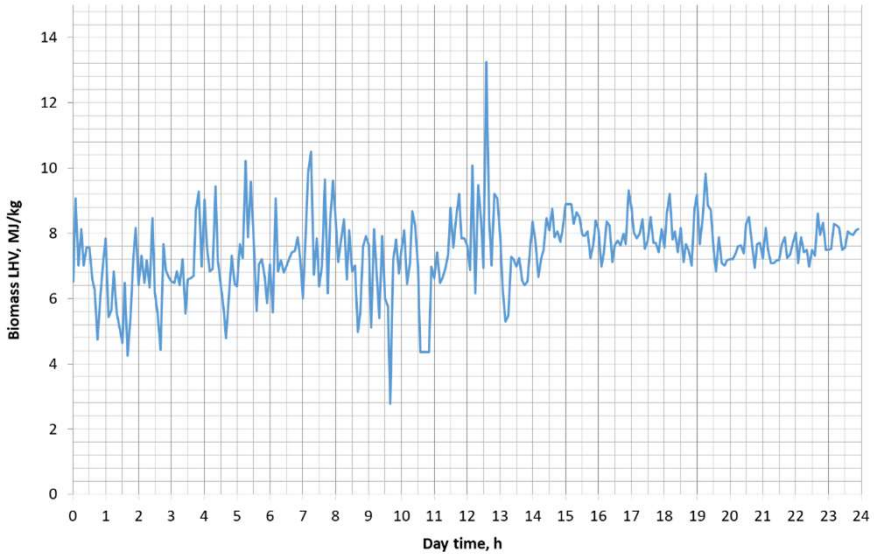
- Biomass fuel – as received

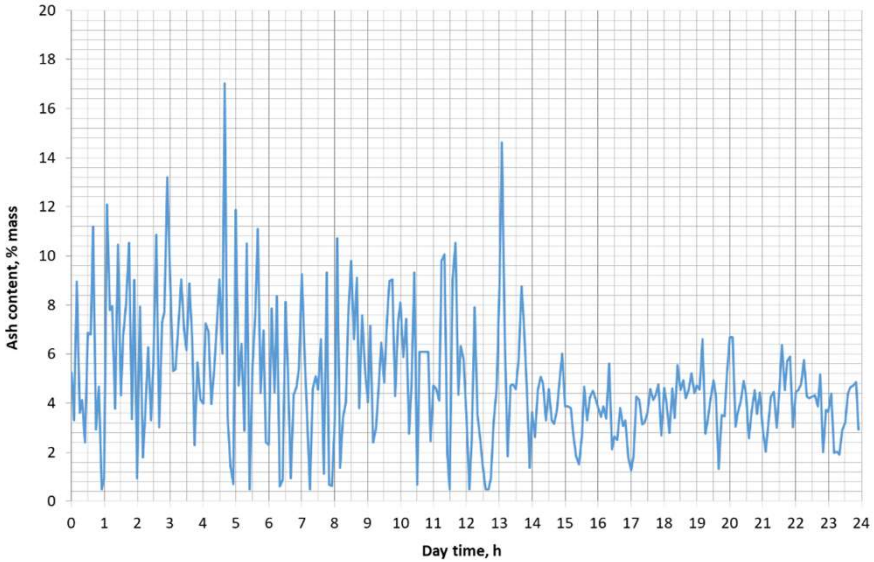
(DE)
Low quality biomass

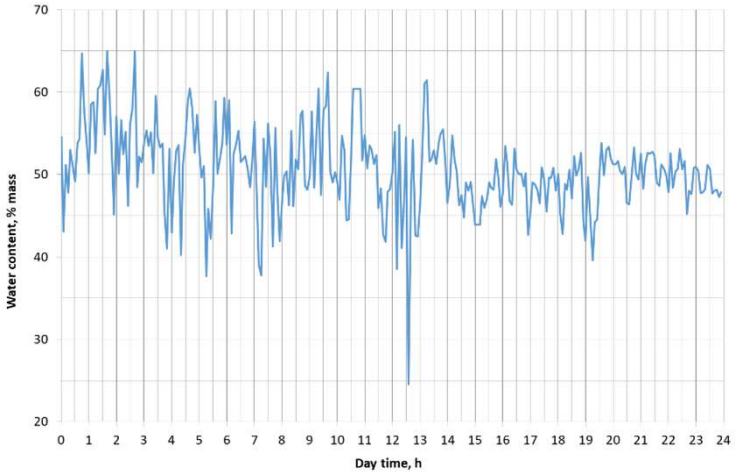
(PL)
High and medium quality biomass

Monitoring of biomass quality

Biomass Properties: LHV, ash content, water content

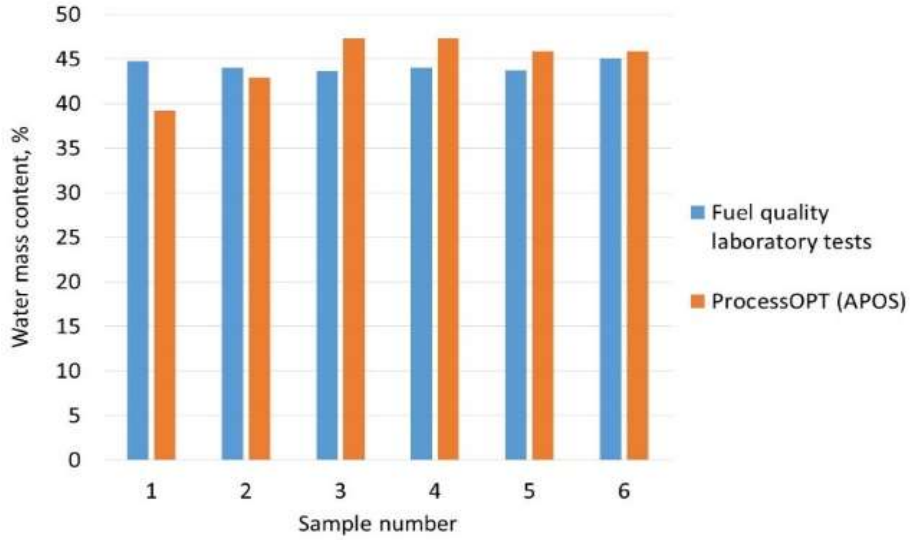


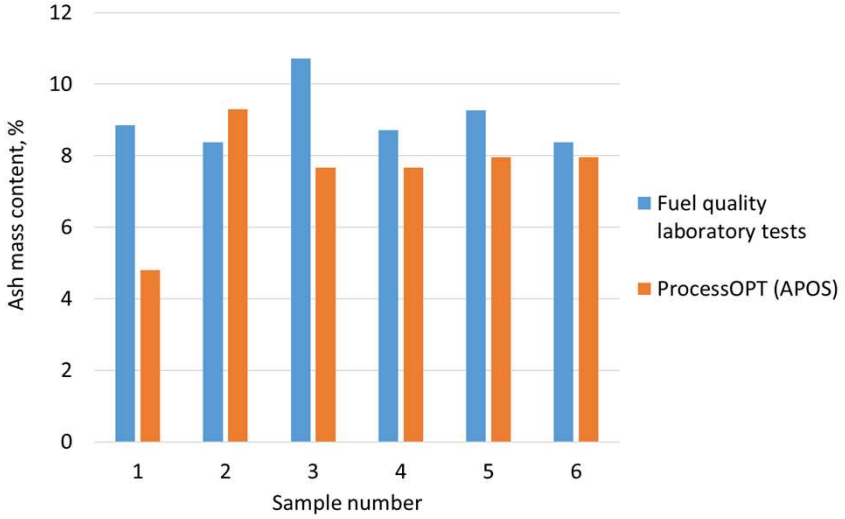


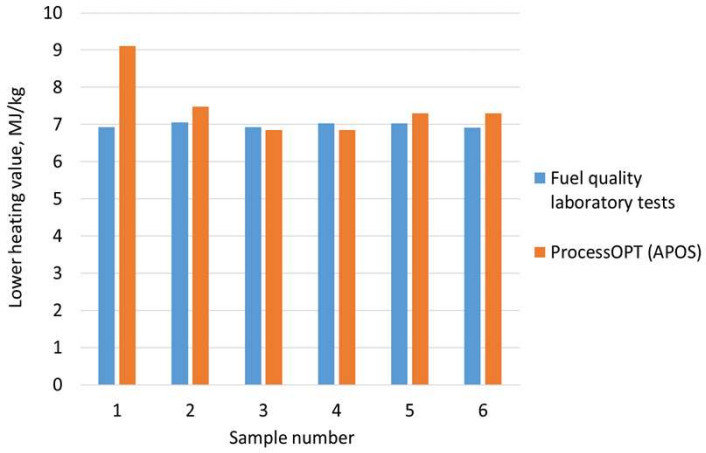


Monitoring of biomass quality

Equipment accuracy assessment

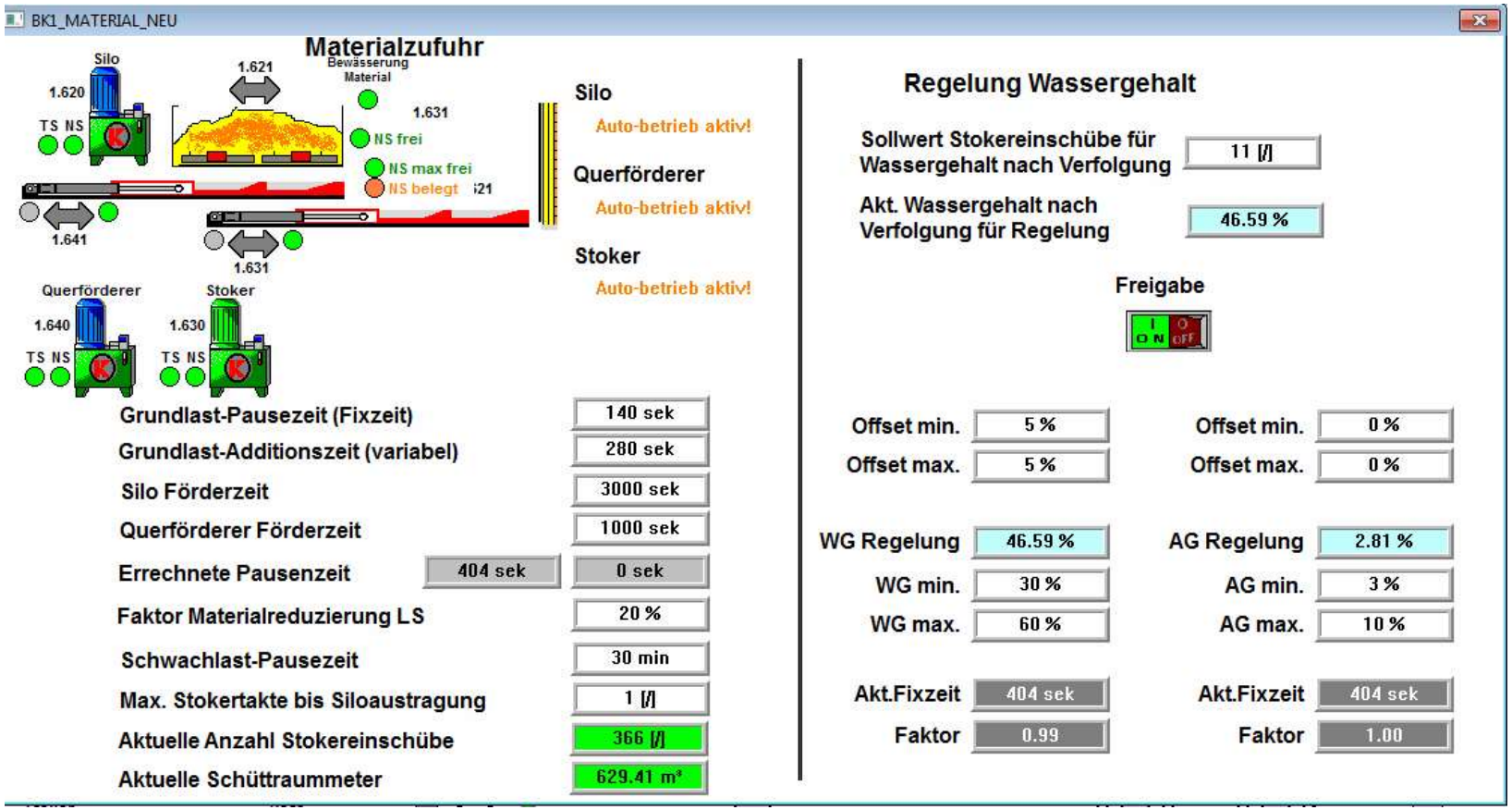




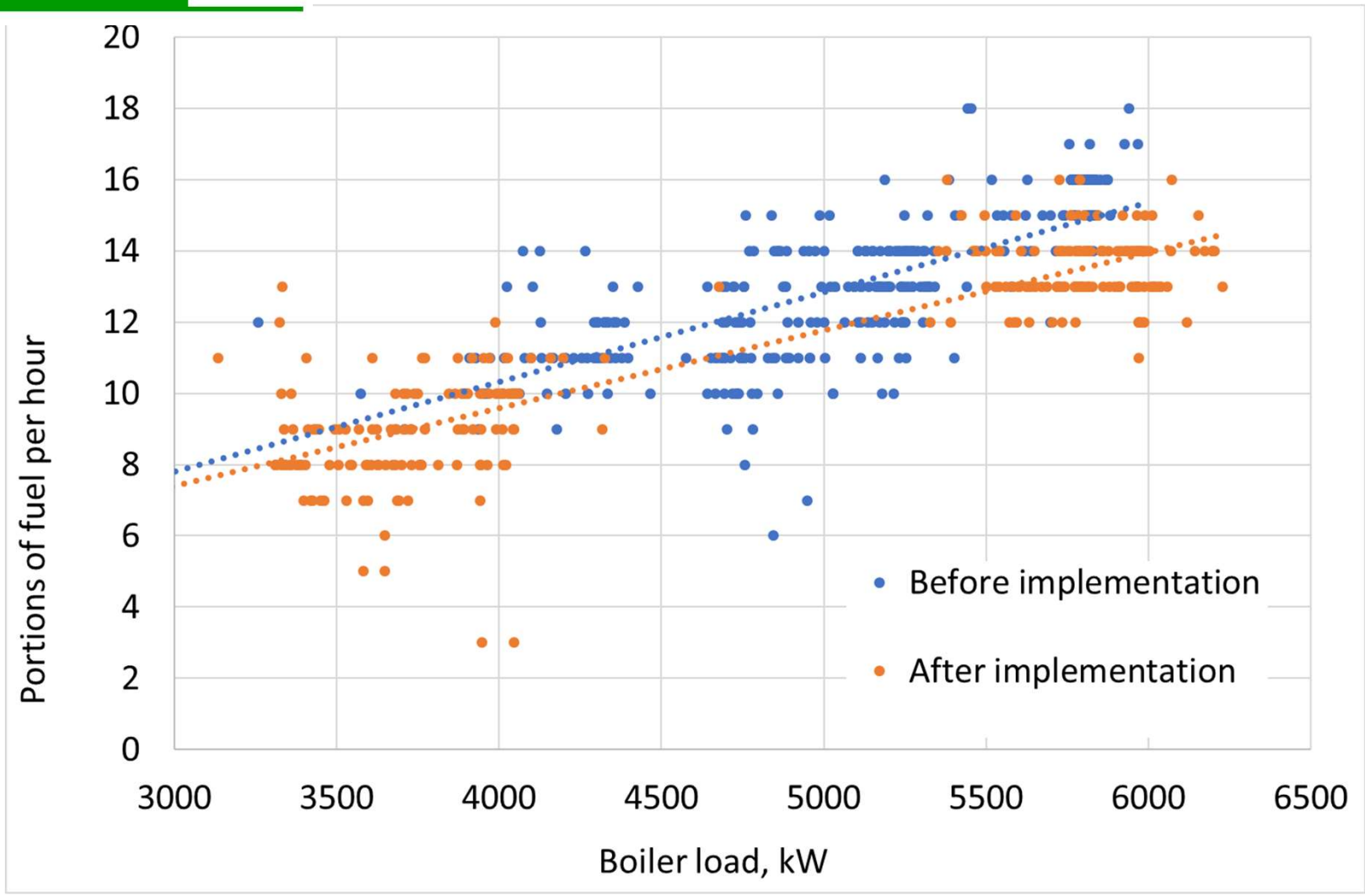


Monitoring of biomass quality

- New combustion control algorithm and software have been developed and tested.

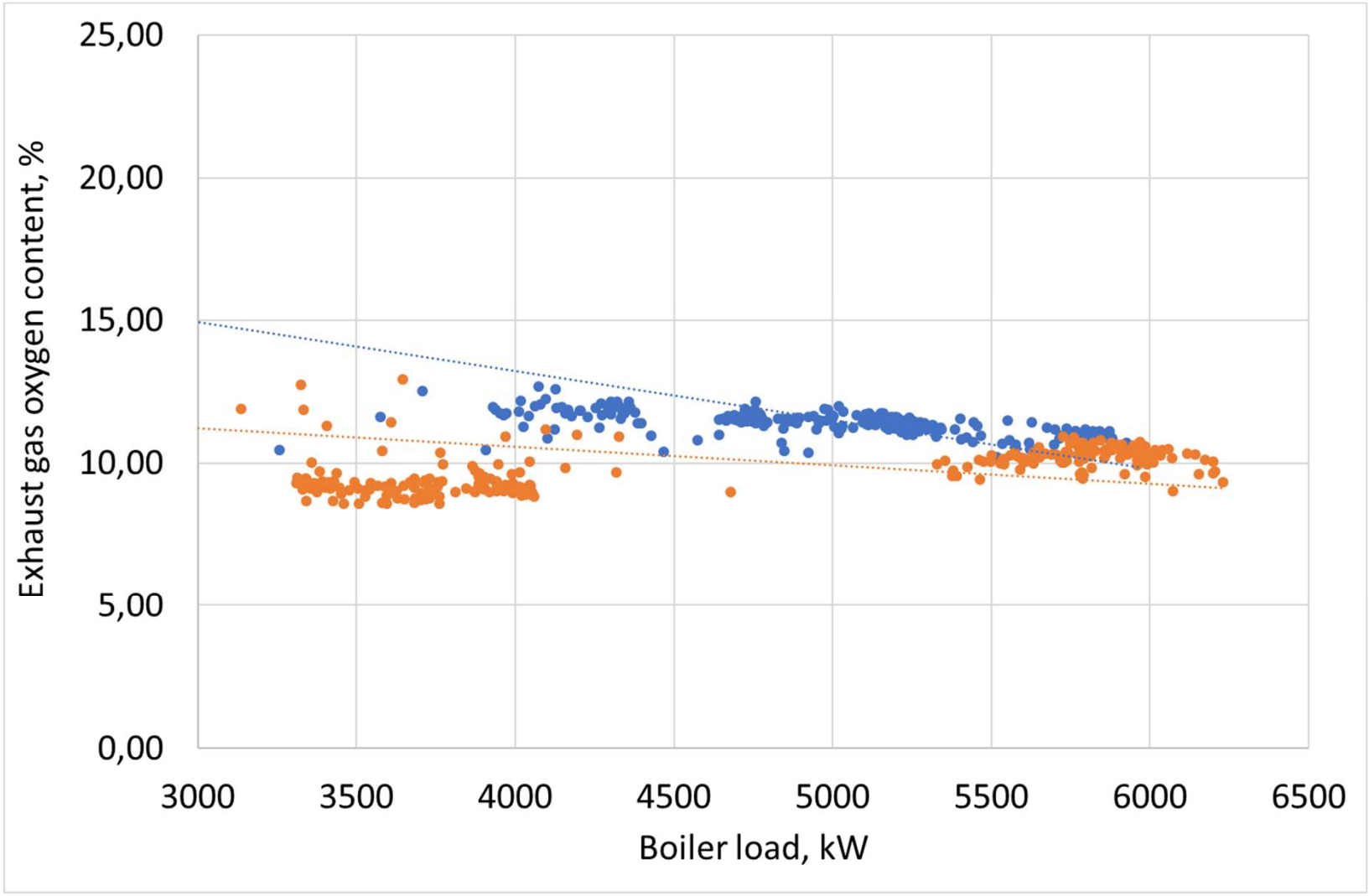


Results



- One transport of fuel per week has been reported by operators after control system implementation.

Results


25,00
20,00
15,00
10,00
5,00
0,00
Exhaust gas oxygen content, %
3000
3500
4000
4500
5000
5500
6000
6500
Boiler load, kW

DSS Concept

The IntBioCHP_DSS is is a computer program (expert system), which uses knowledge and inference procedures to solve tasks that are typicaly solved by the human expert (plant operator).

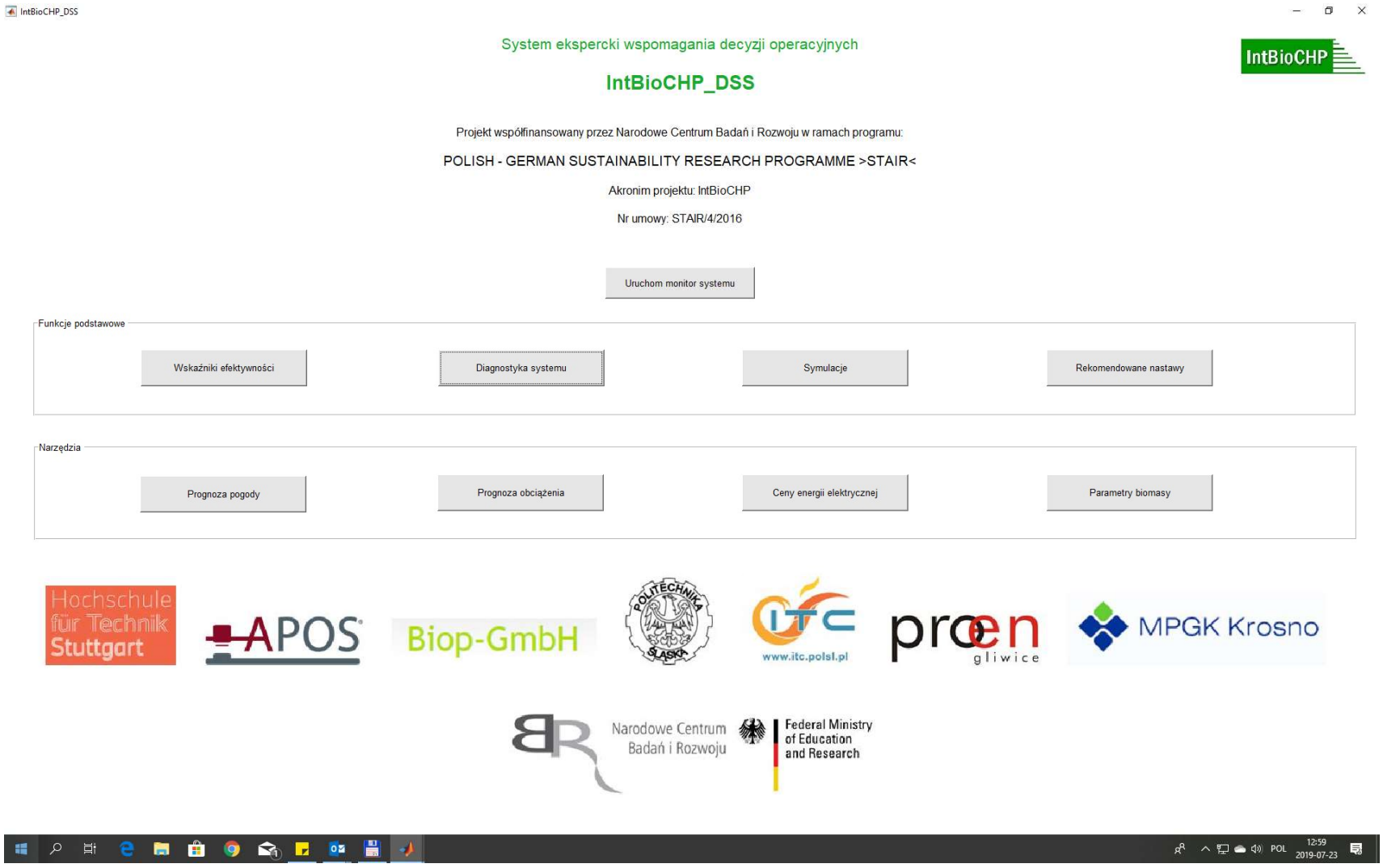
- Operational optimisation of both heating networks and heating plants, which is based on predictions of weather conditions, loads and prices.
- Supporting plant maintenance.
- Frequent examination of measurement devices and early fault detection.

DSS Functionalities

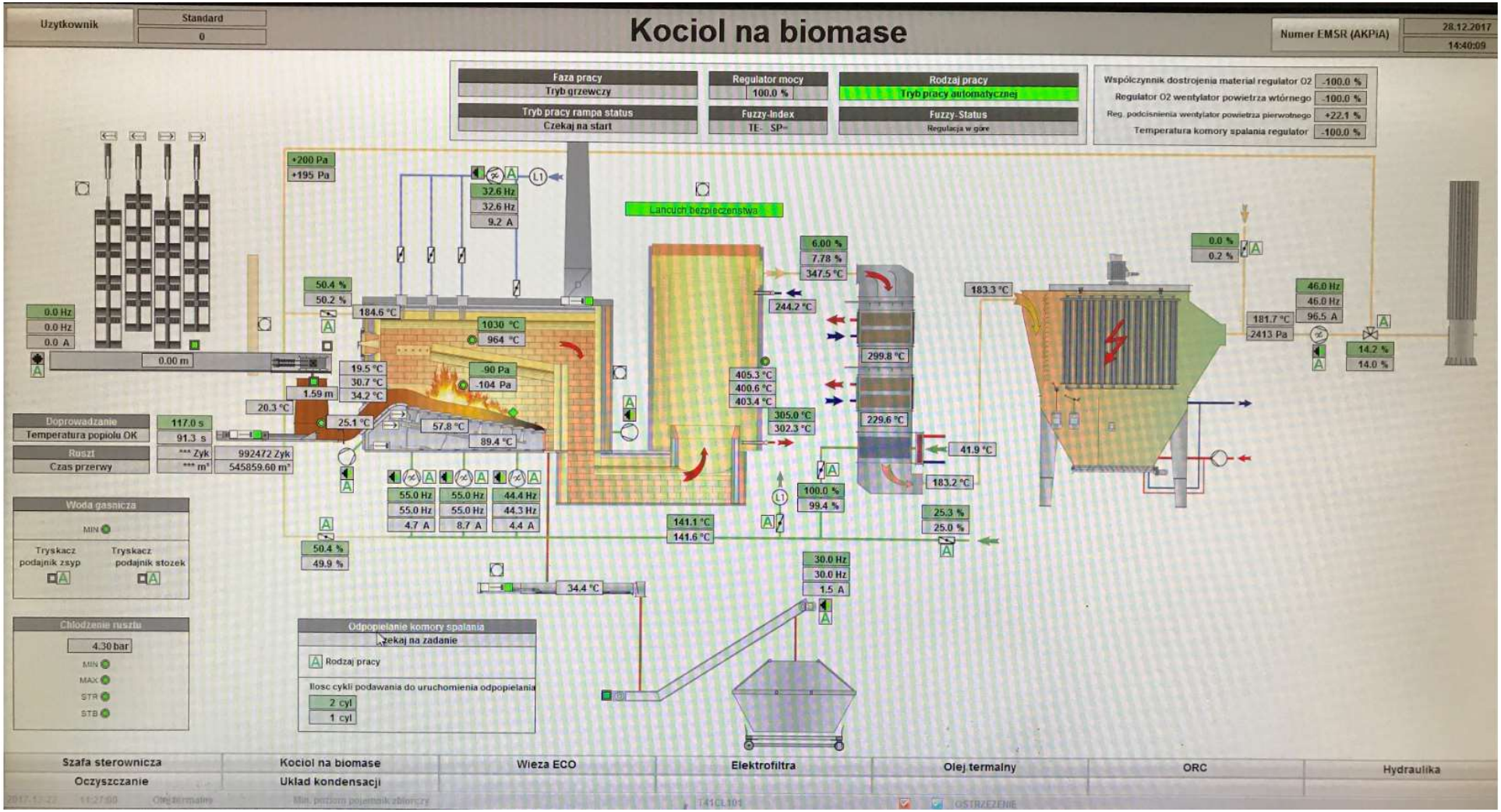
There have been assumed four specific functional modules:

- **Performance evaluation module**, which generates current performance indices and reports;
- **On-line diagnostics module**, which allows monitoring of current technical conditions and verification of measurements;
- **Simulation module**, which allows operator to examine effects of changes before they are implemented into the physical system;
- **Operation planning and control module**, which generates recommendations for optimal settings, including equipment scheduling.

IntBioCHP_DSS User Interface



SCADA vs DSS



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SCADA vs DSS

System wspomagania decyzji - kocioł VAS

Wymagana pilna reakcja

Można poprawić działanie

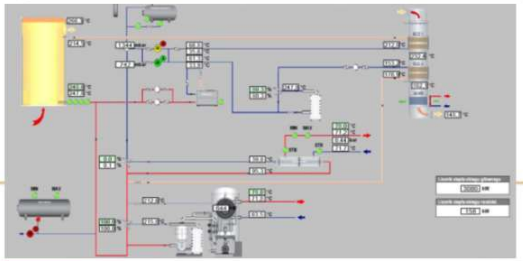
Parametry prawidłowe

Bieżące parametry obiegu oleju termalnego

Zadana temperatura oleju termalnego = 230,2 °C
Moc OG = 5235 kW
Moc OR = 640 kW
Efektywność wymiany ciepła = 87%

Bieżące parametry pracy kotła biomasowego

Moc cieplna paleniska = 8352 kW
Stopień wykorzystania paliwa = 83%



Strata wylotowa = 13%

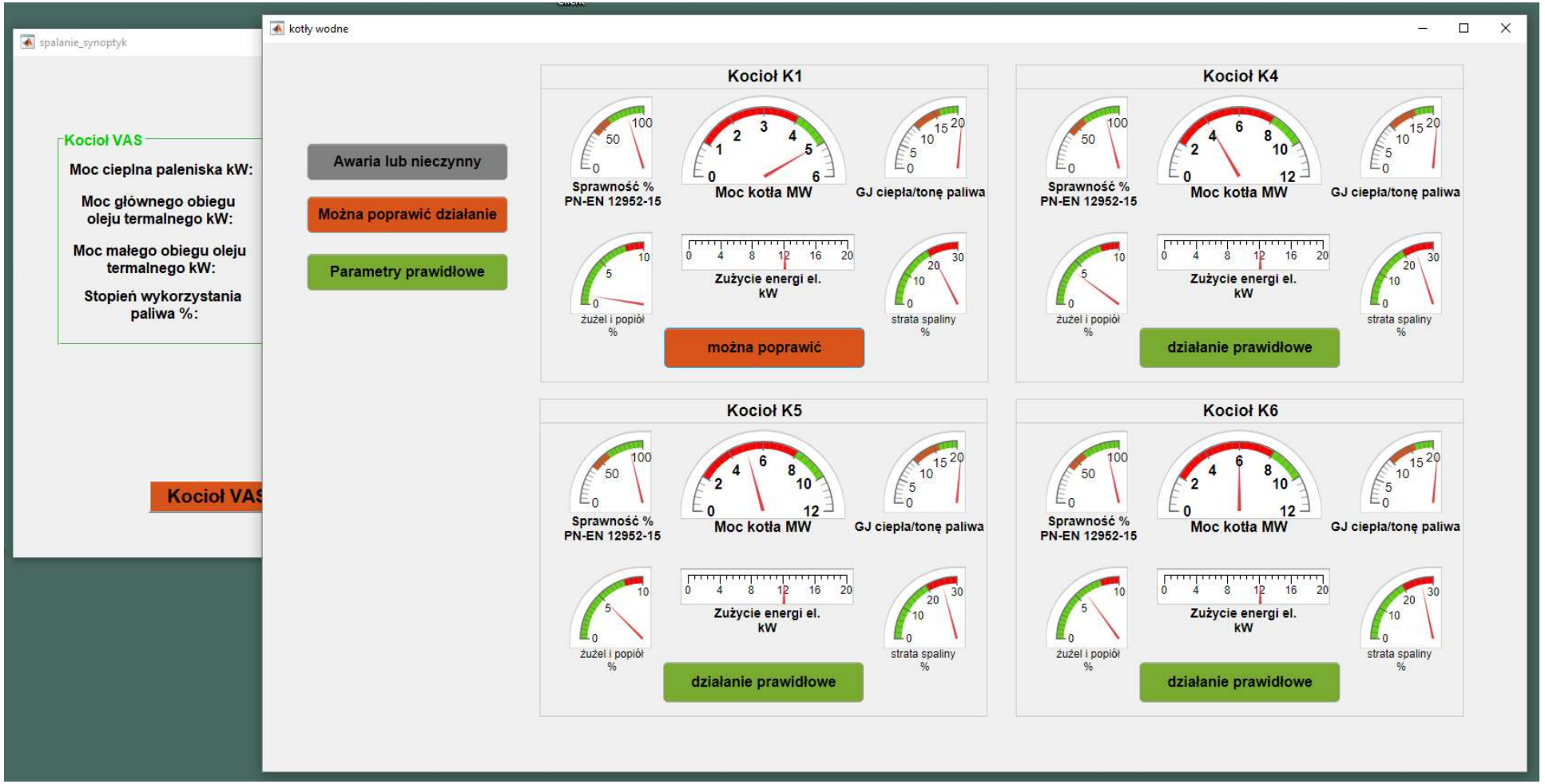
Bieżące parametry biomasy (ewaluowane)

Wd= 5235 kJ/m^3
Wilgotność = 43%

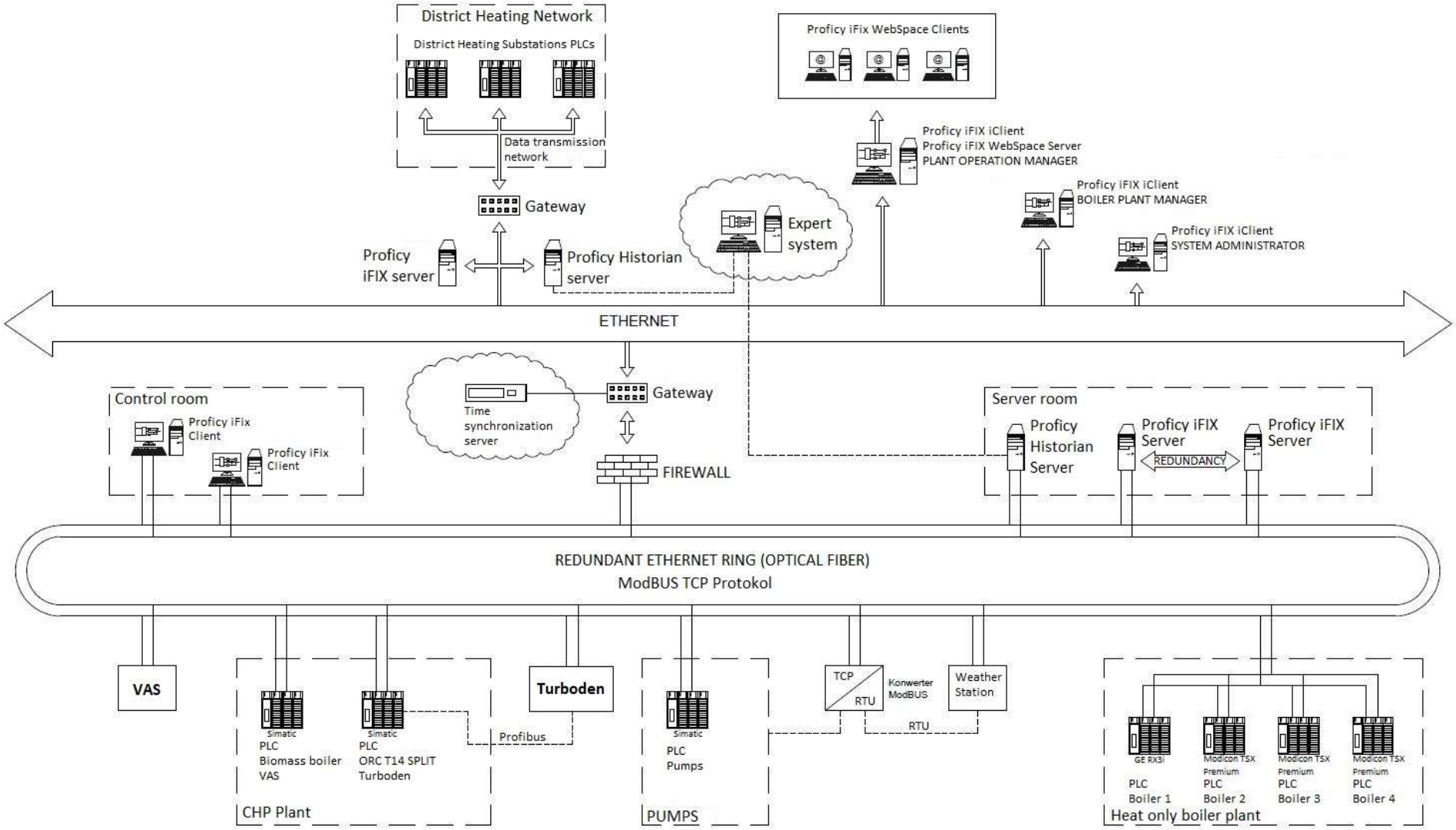
Strata niedopału = 5%

Uruchomić układ kondensacji

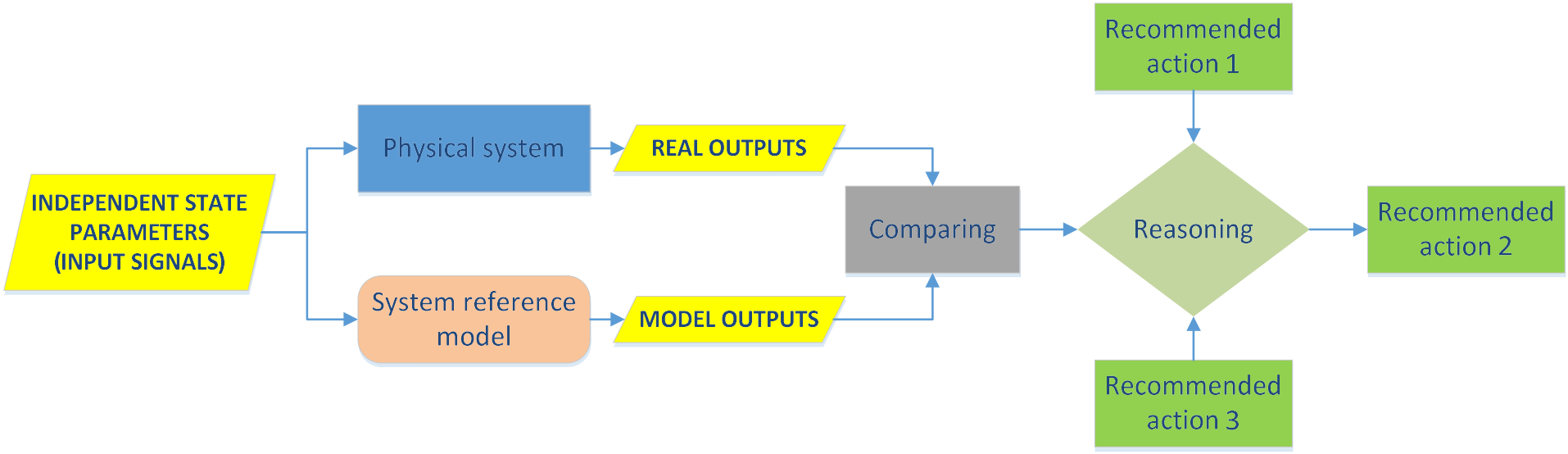
SCADA vs DSS – coal boilers



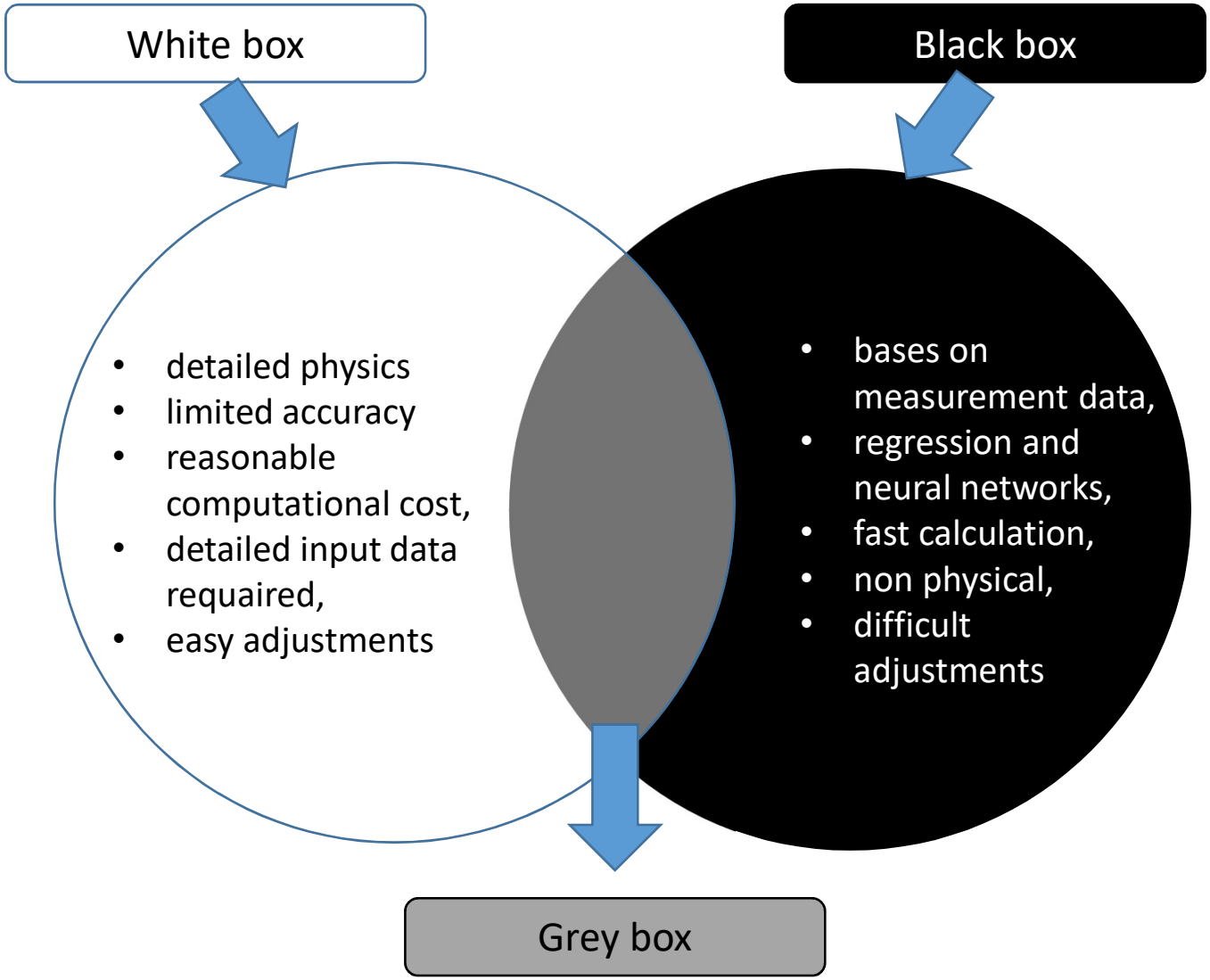
Expert system hardware



Expert system framework for technical condition monitoring

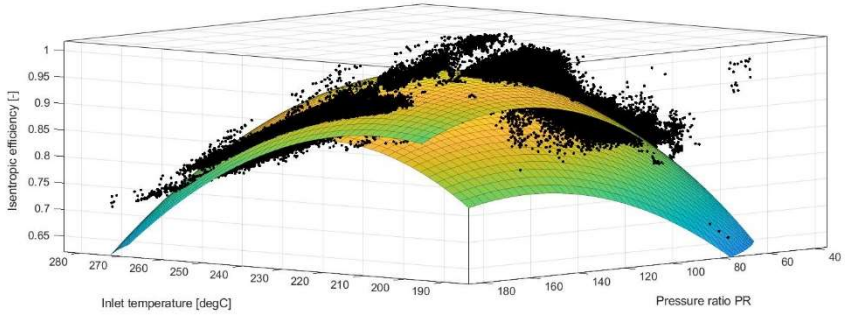


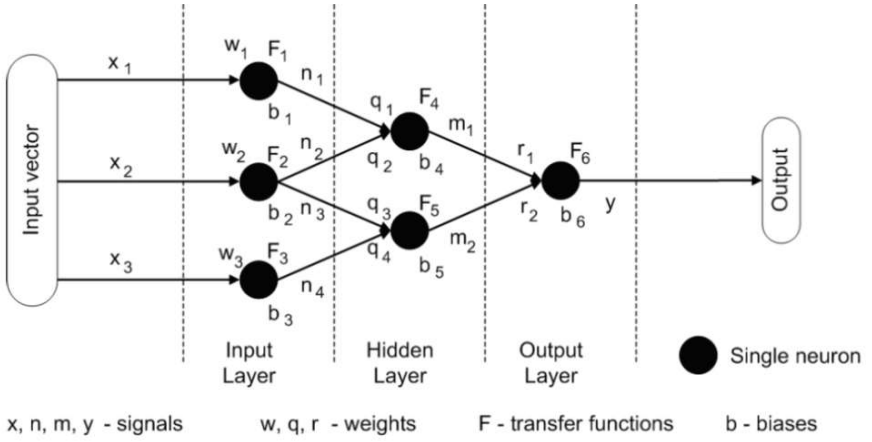
Equipment models



Equipment models

Black box



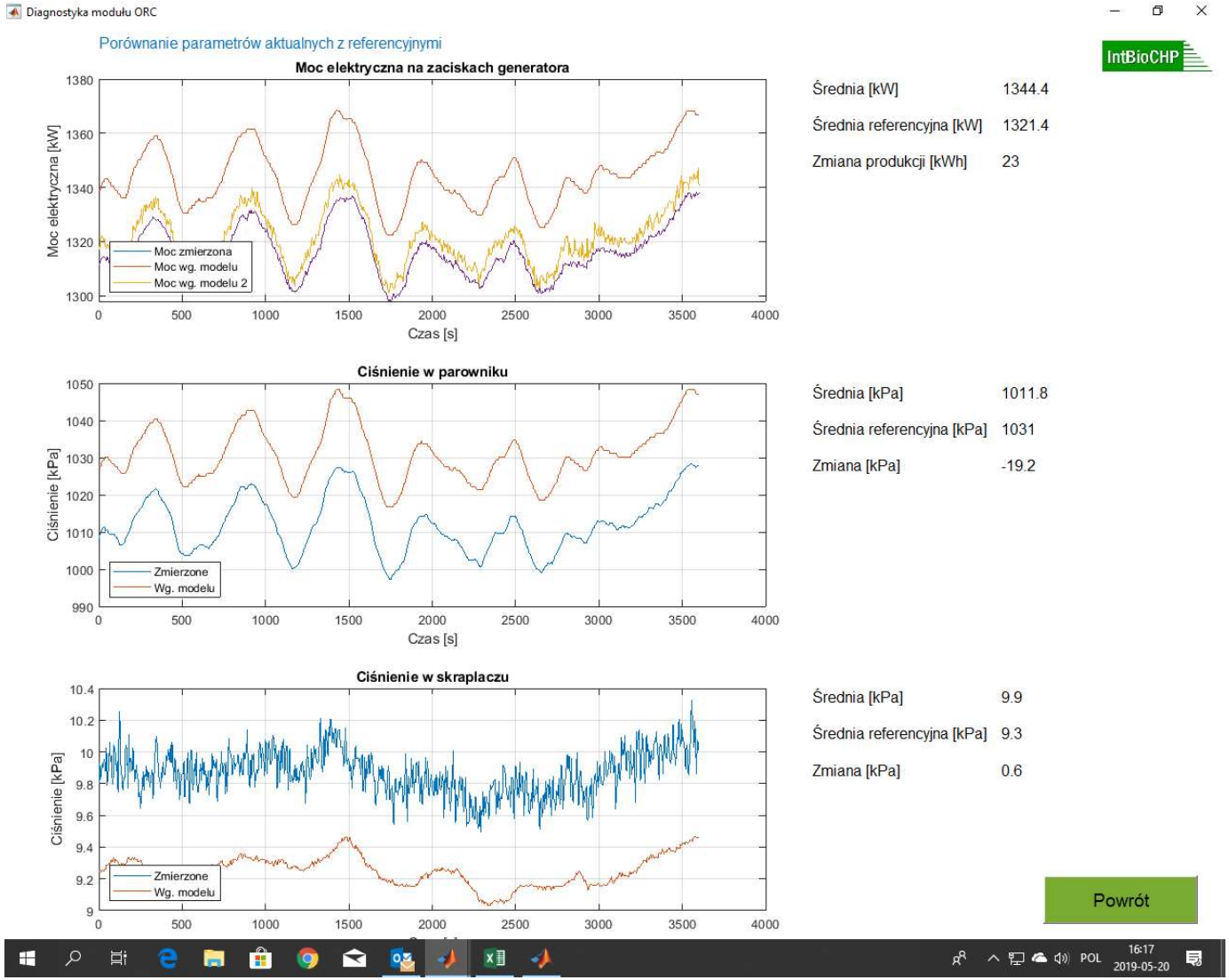


Regression models

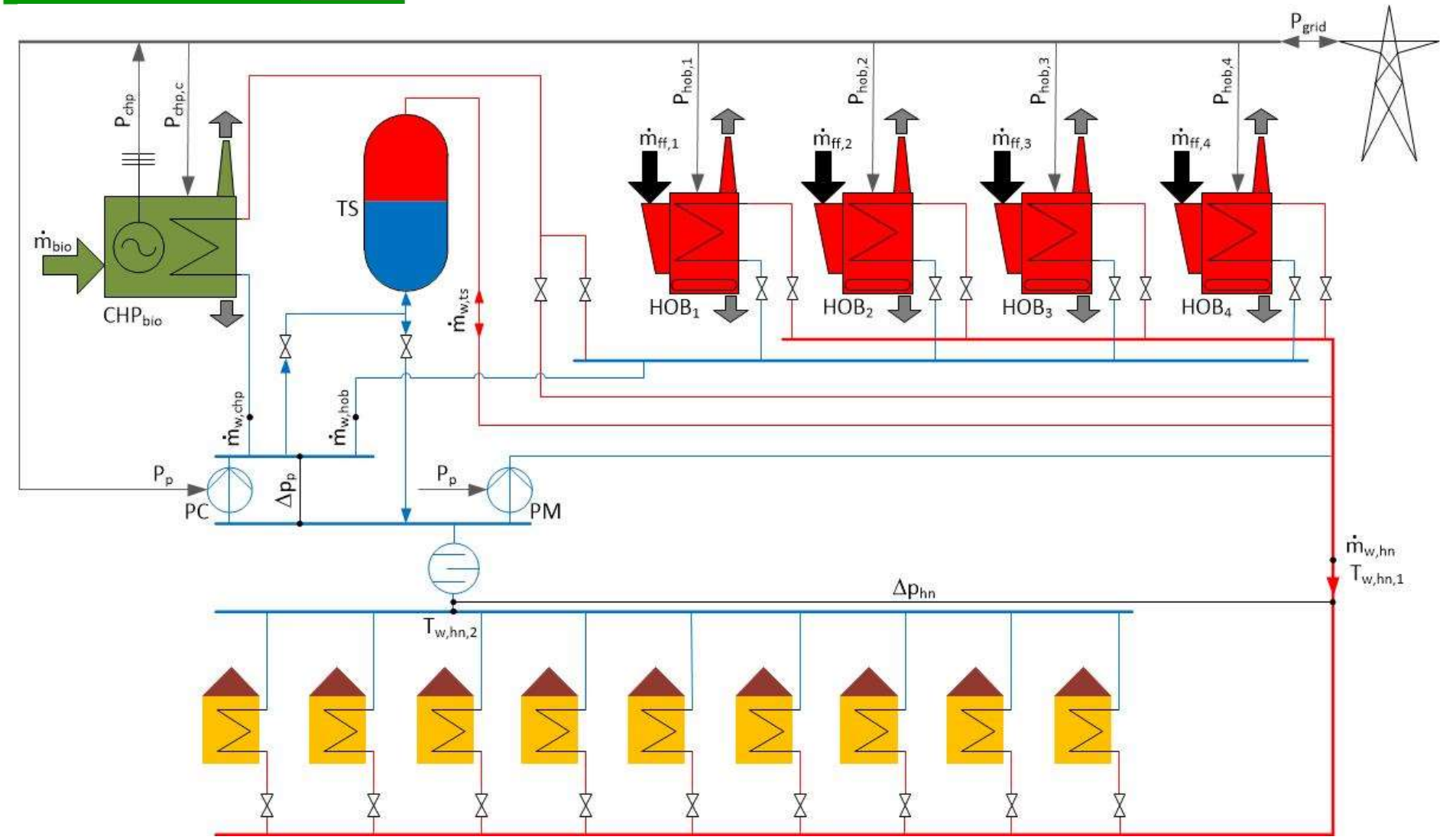
Artifical Neural Networks

Diagnostics of ORC module

Diagnostics of ORC module

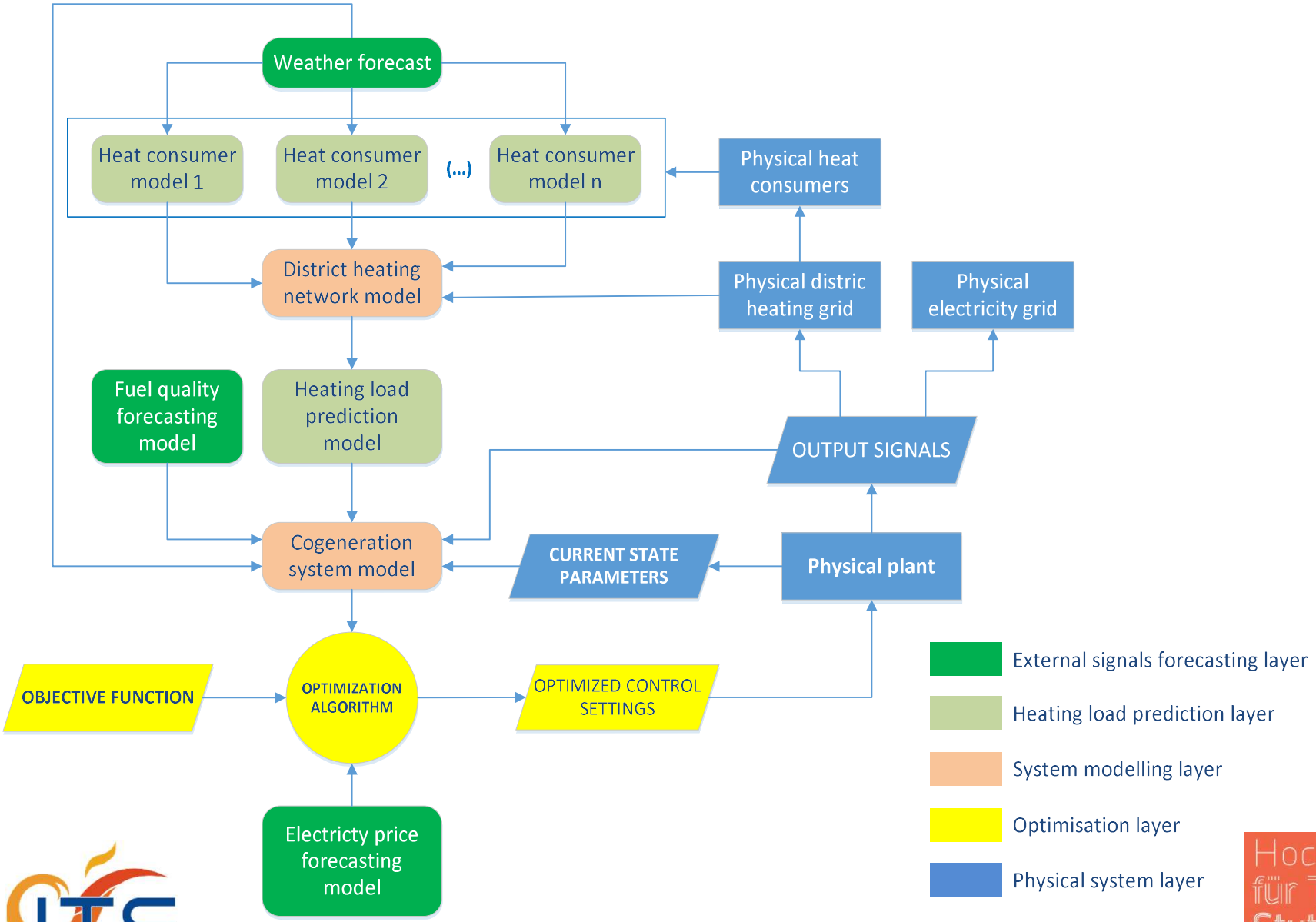


Integrated system optimisation



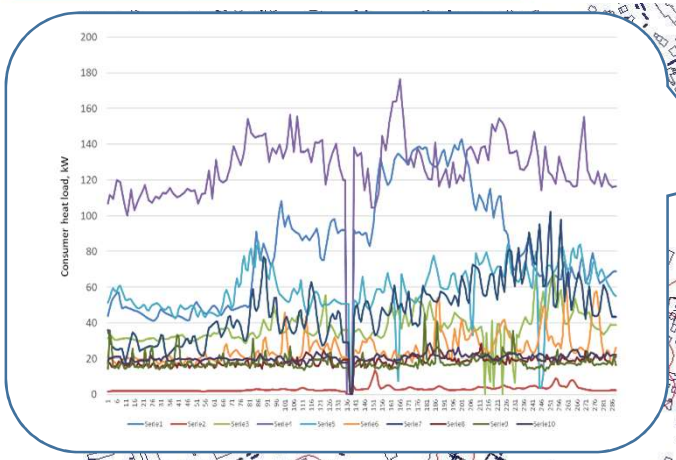
IntBioCHP

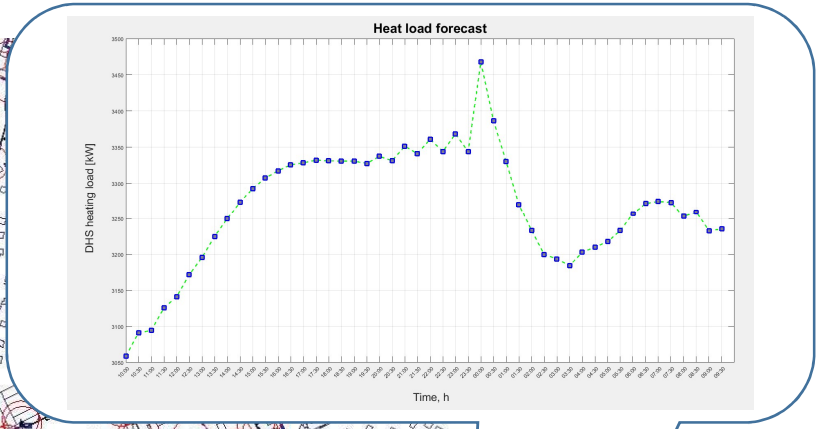
Expert system framework for optimisation of operational parameters

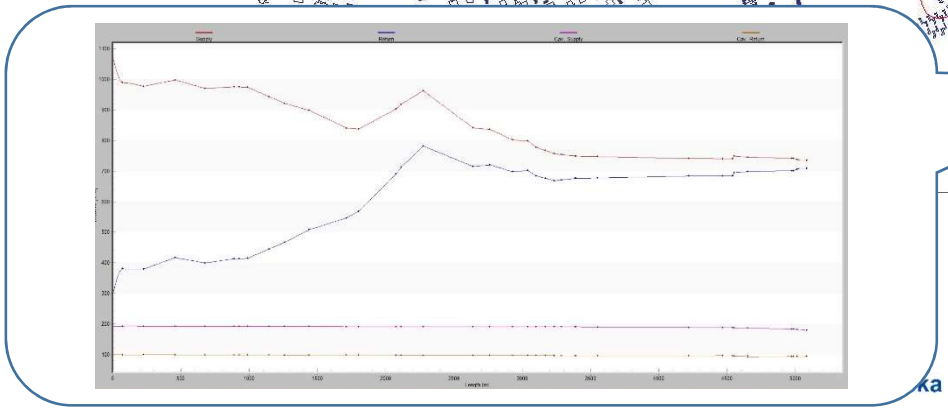


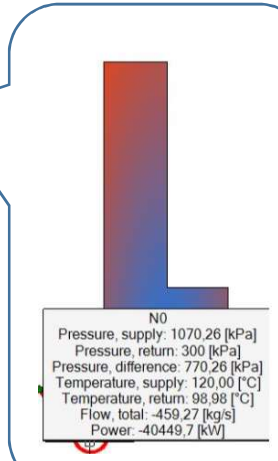
IntBioCHP

Calculation scheme









Gliwice

Integrated system optimisation

$$\min J = \sum_{t=1}^{t=N} \bar{C}_t$$

$$\bar{C}_t = \sum_i \left(m_{f,i} sc_f + m_{env,i} sc_{env} + m_{m,i} sc_m + E_{el,i} sc(t) \right)_t - E_{el,exp,t} p_{el,exp}(t) - E_{el,gen,t} \sum_{sup} f_{sup}(t)$$

IntBioCHP

Simulated financial effects

Adjustment of boiler operation without TES

Koszty ostateczne po uwzględnieniu kary - 01.01.2016.

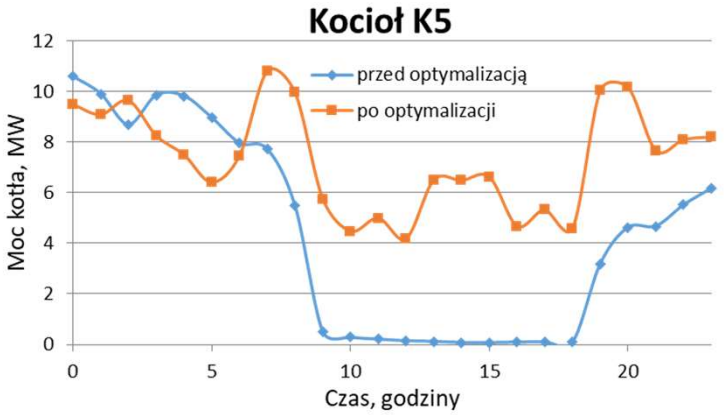
Suma kosztów dziennych po optymalizacji, PLN	24867,00
Kara za start/stop jednostek, PLN	51,36
Procent dodatkowych kosztów kary, -	0,015
Skorygowane koszty dzienne po optymalizacji, PLN	24918,36
Różnica w kosztach przed i po optymalizacji, PLN	2,61

Koszty ostateczne po uwzględnieniu kary - 17.03.2016.

Suma kosztów dziennych po optymalizacji, PLN	15626,78
Kara za start/stop jednostek, PLN	63,86
Procent dodatkowych kosztów kary, -	0,015
Skorygowane koszty dzienne po optymalizacji, PLN	15690,64
Różnica w kosztach przed i po optymalizacji, PLN	356,58

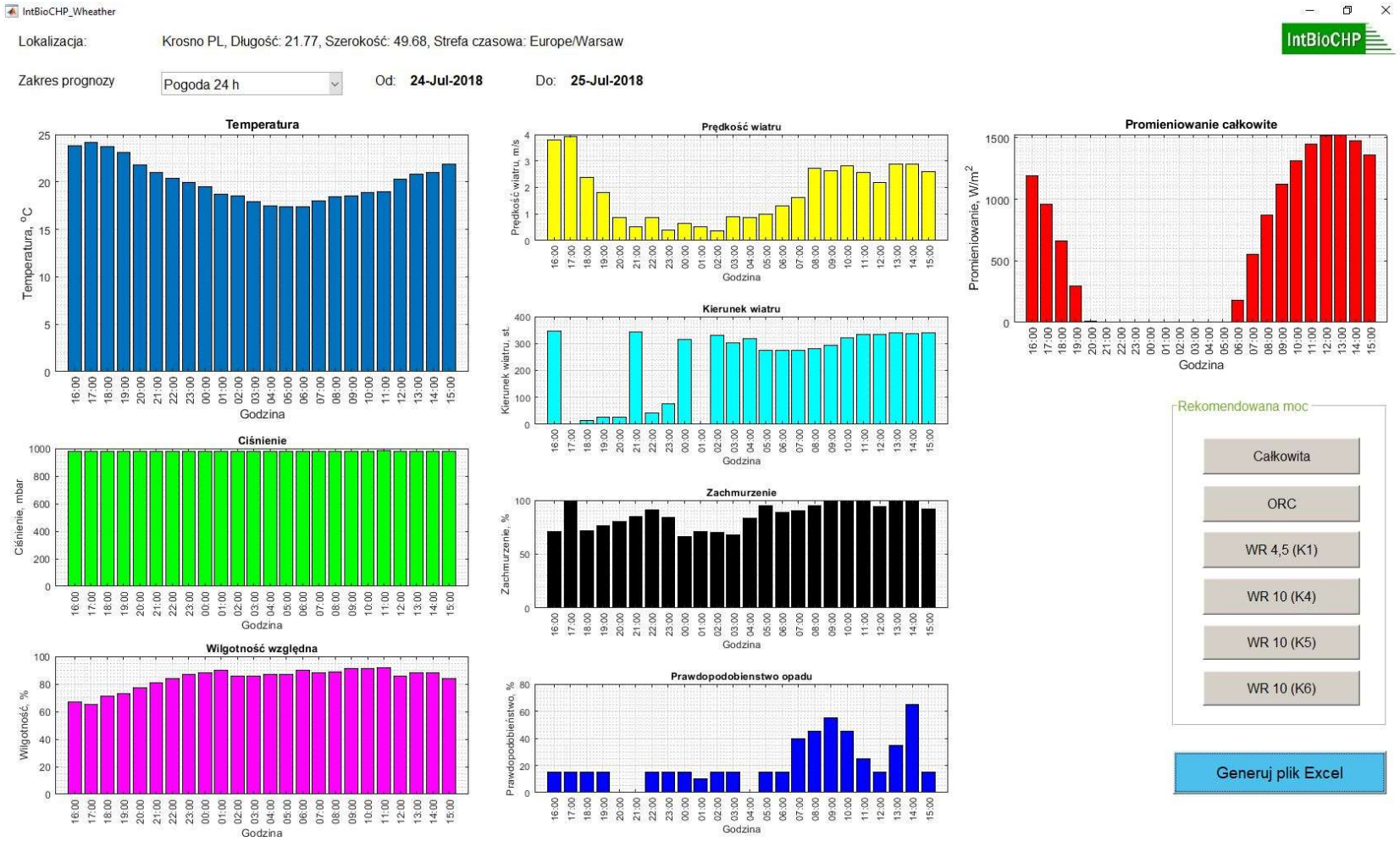
Koszty ostateczne po uwzględnieniu kary - 31.12.2016.

Suma kosztów dziennych po optymalizacji, PLN	19692,15
Kara za start/stop jednostek, PLN	91,78
Procent dodatkowych kosztów kary, -	0,015
Skorygowane koszty dzienne po optymalizacji, PLN	19783,93
Różnica w kosztach przed i po optymalizacji, PLN	1494,33

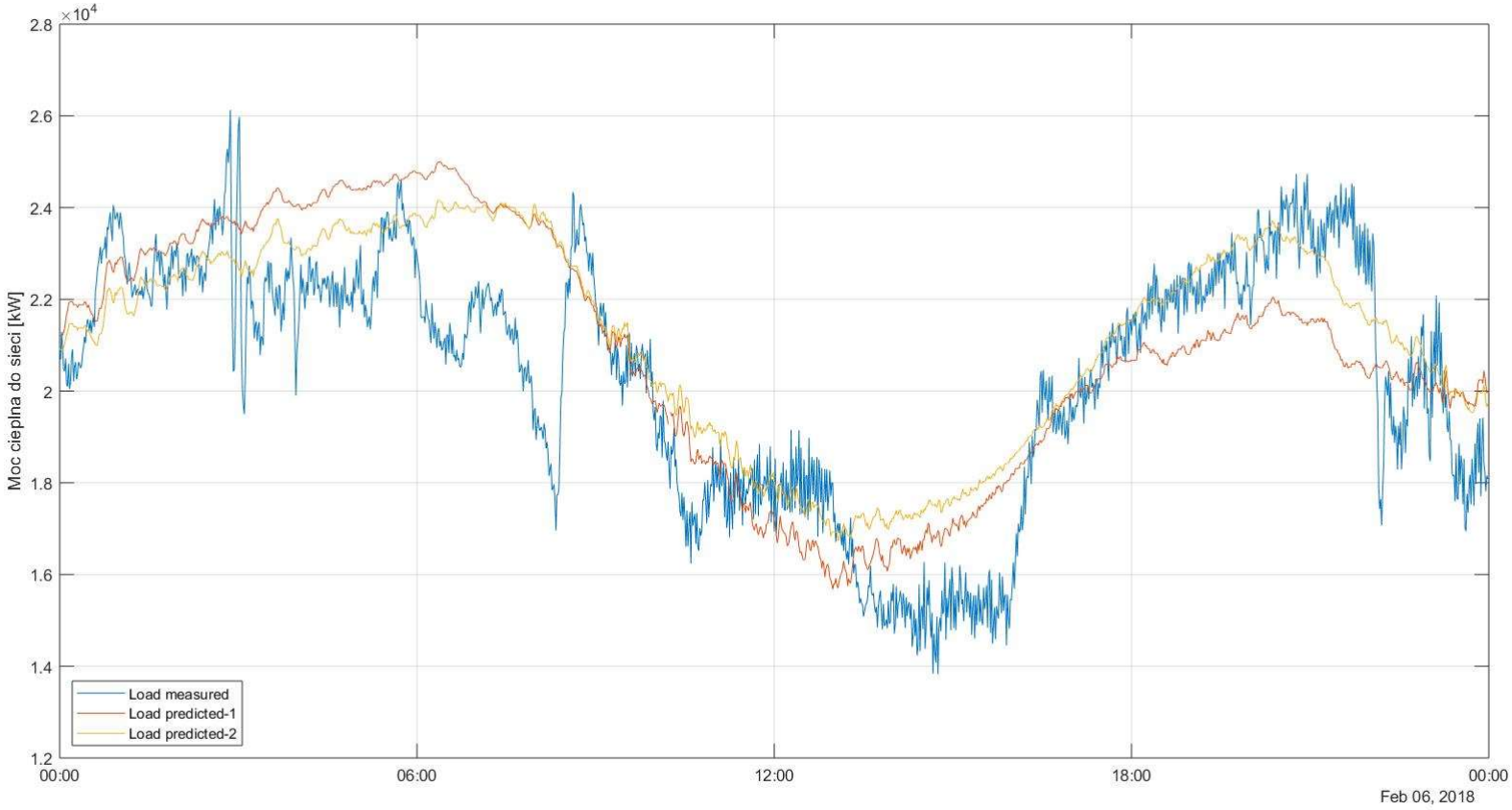


Annual effect
~ 100 000 PLN

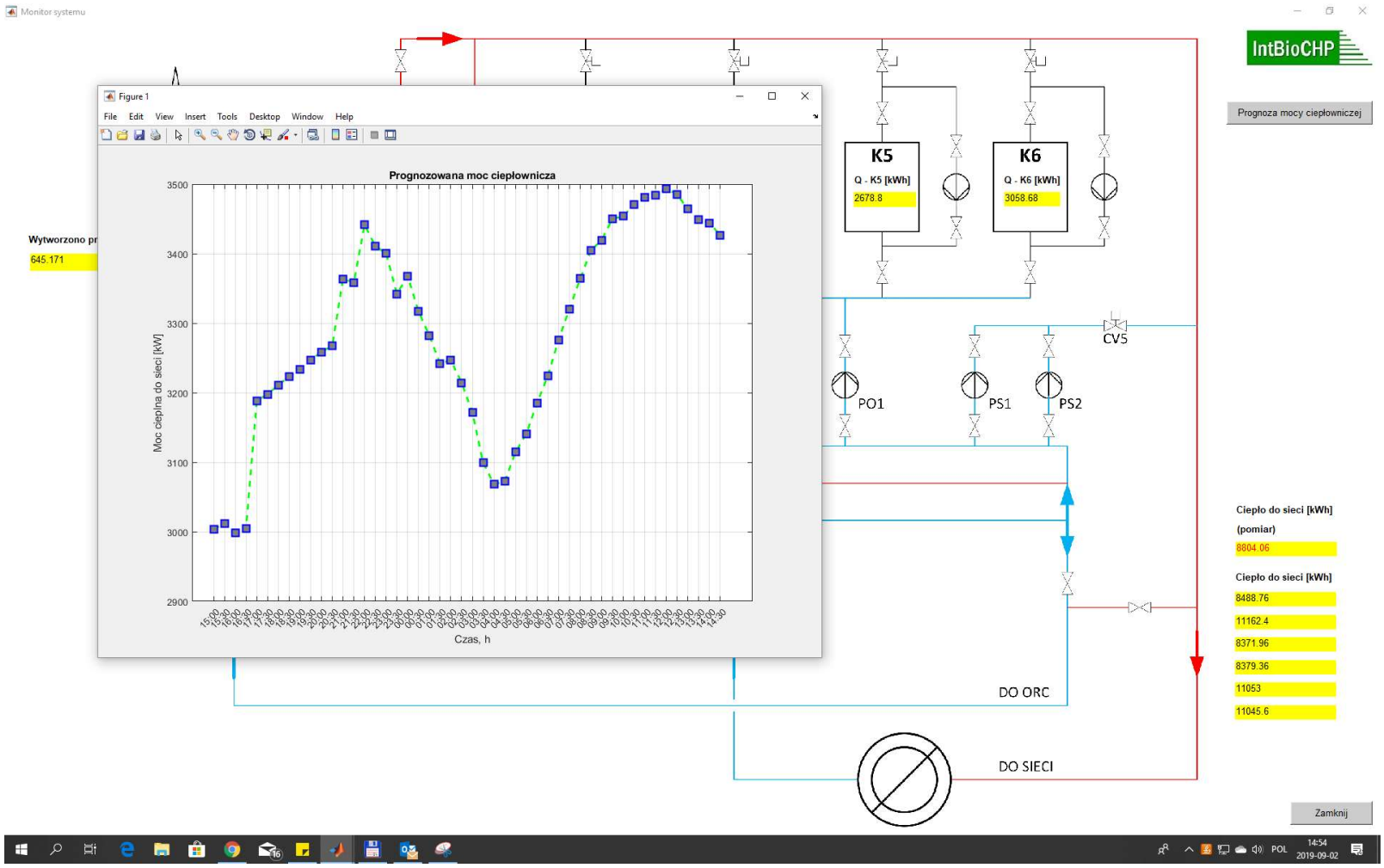
Weather forecasting tool



Load preditions – Neural Network Aproach



Heating load predictions within IntBioCHP_DSS

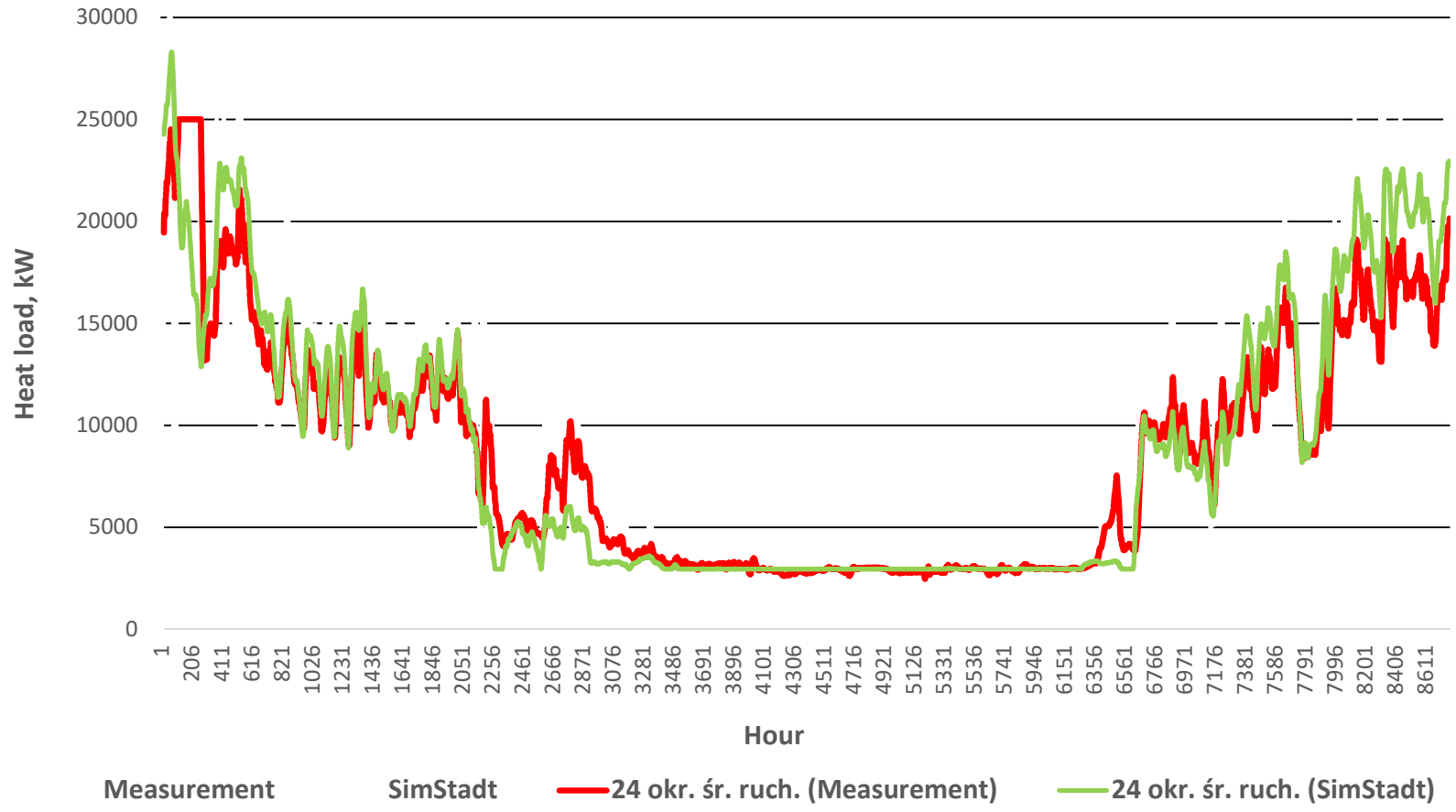


SimStadt simulations of Krosno DHS

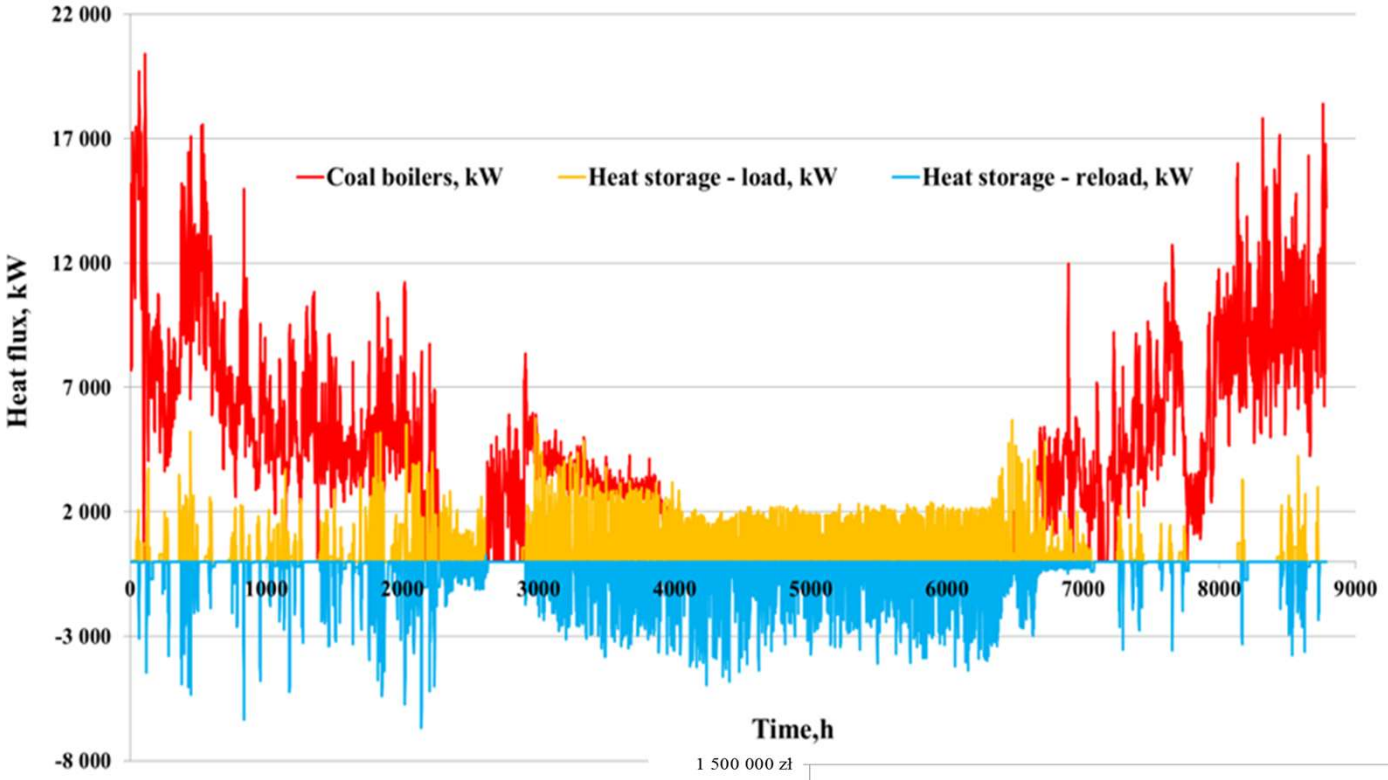
IntBioCHP

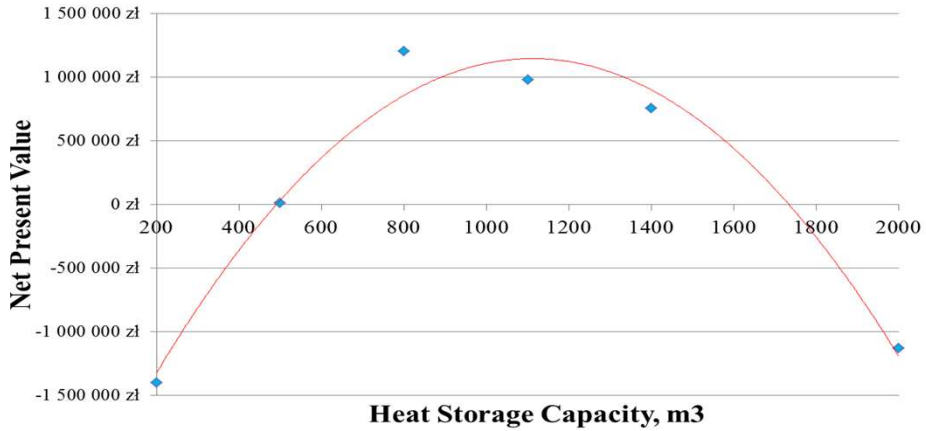
SimStadt simulations of Krosno DHS

Comparison hourly heat load profiles

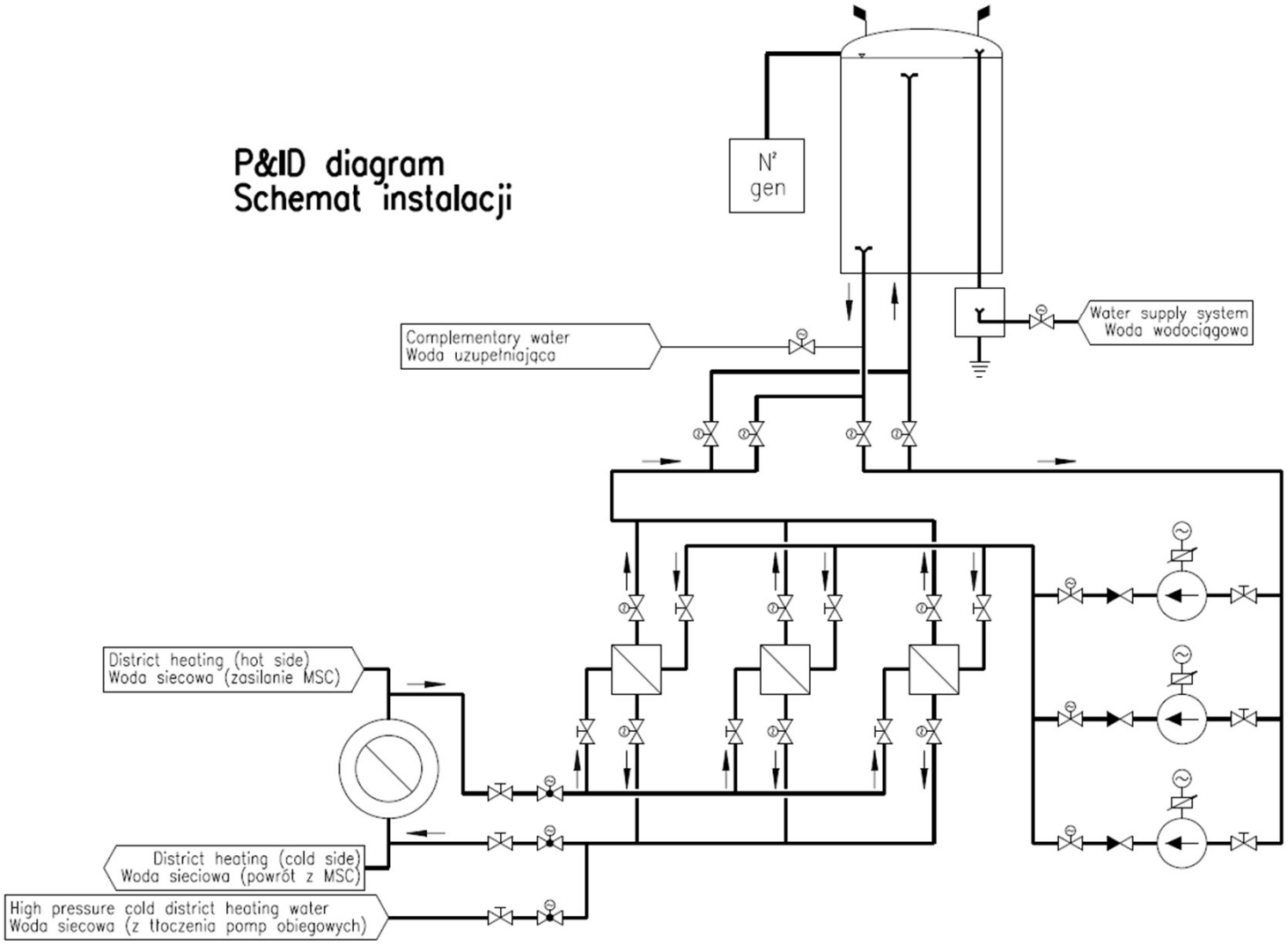


Sizinig of heat storage tank

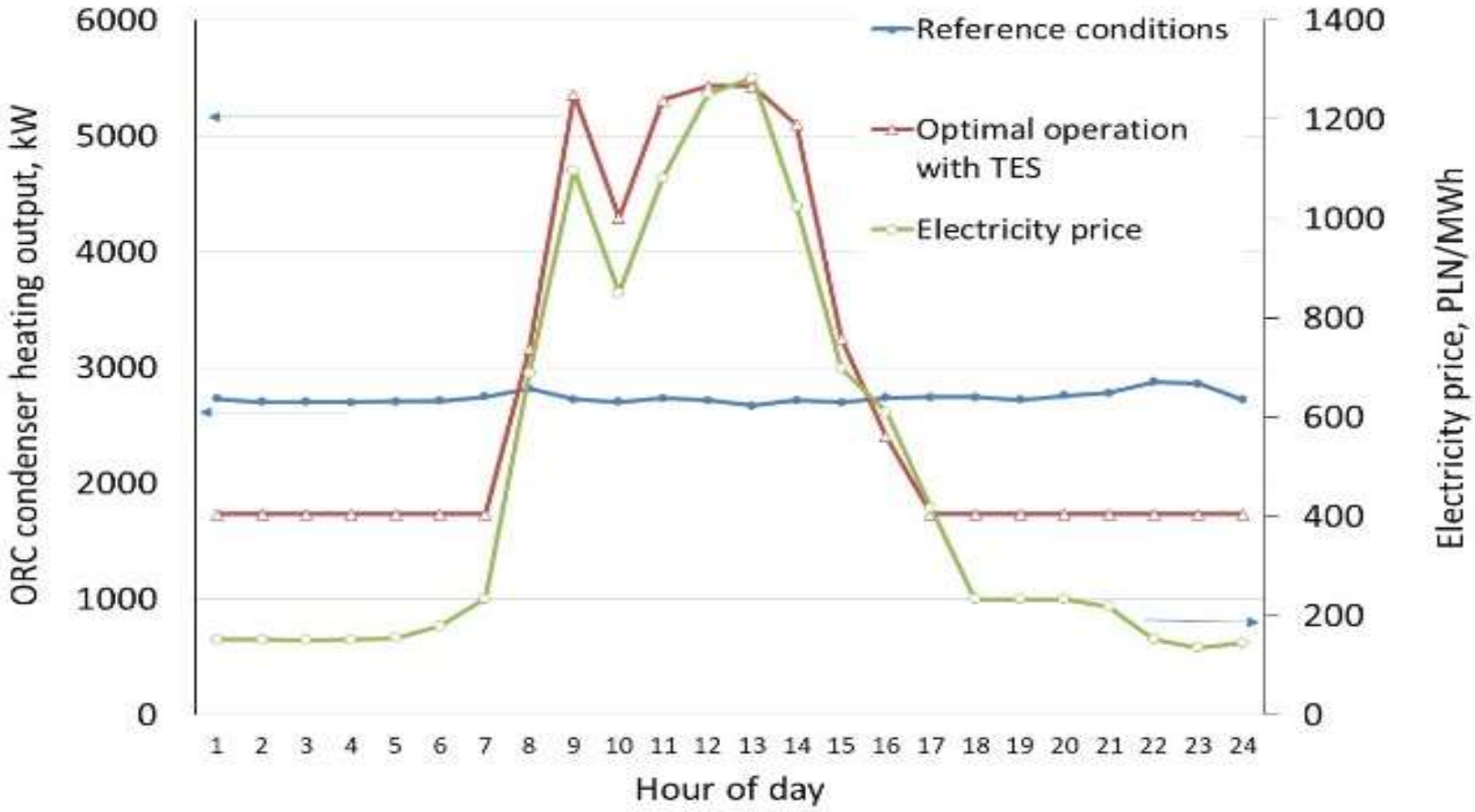




Design of heat storage tank



Results of heating profile optimisation within sample summer day



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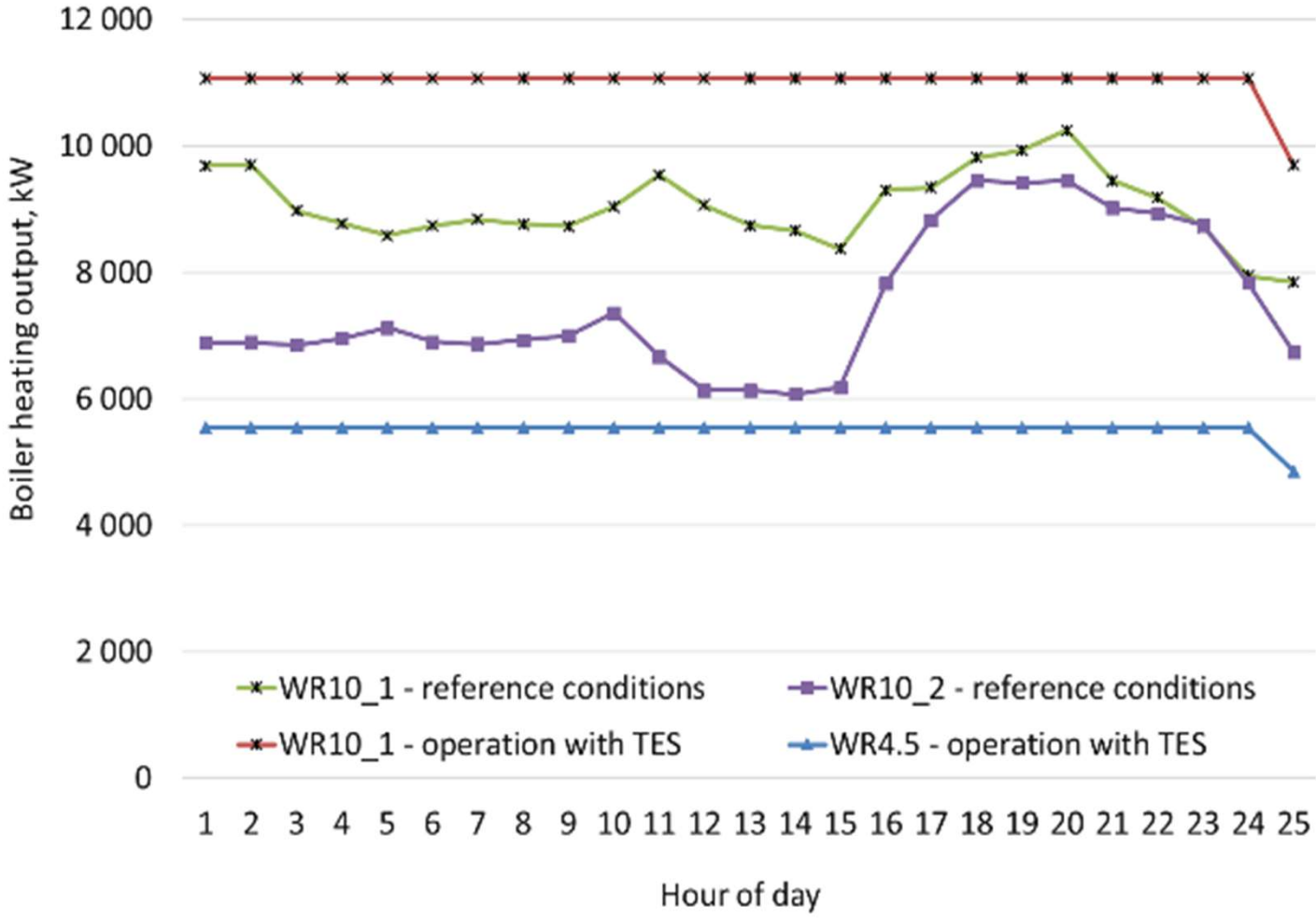
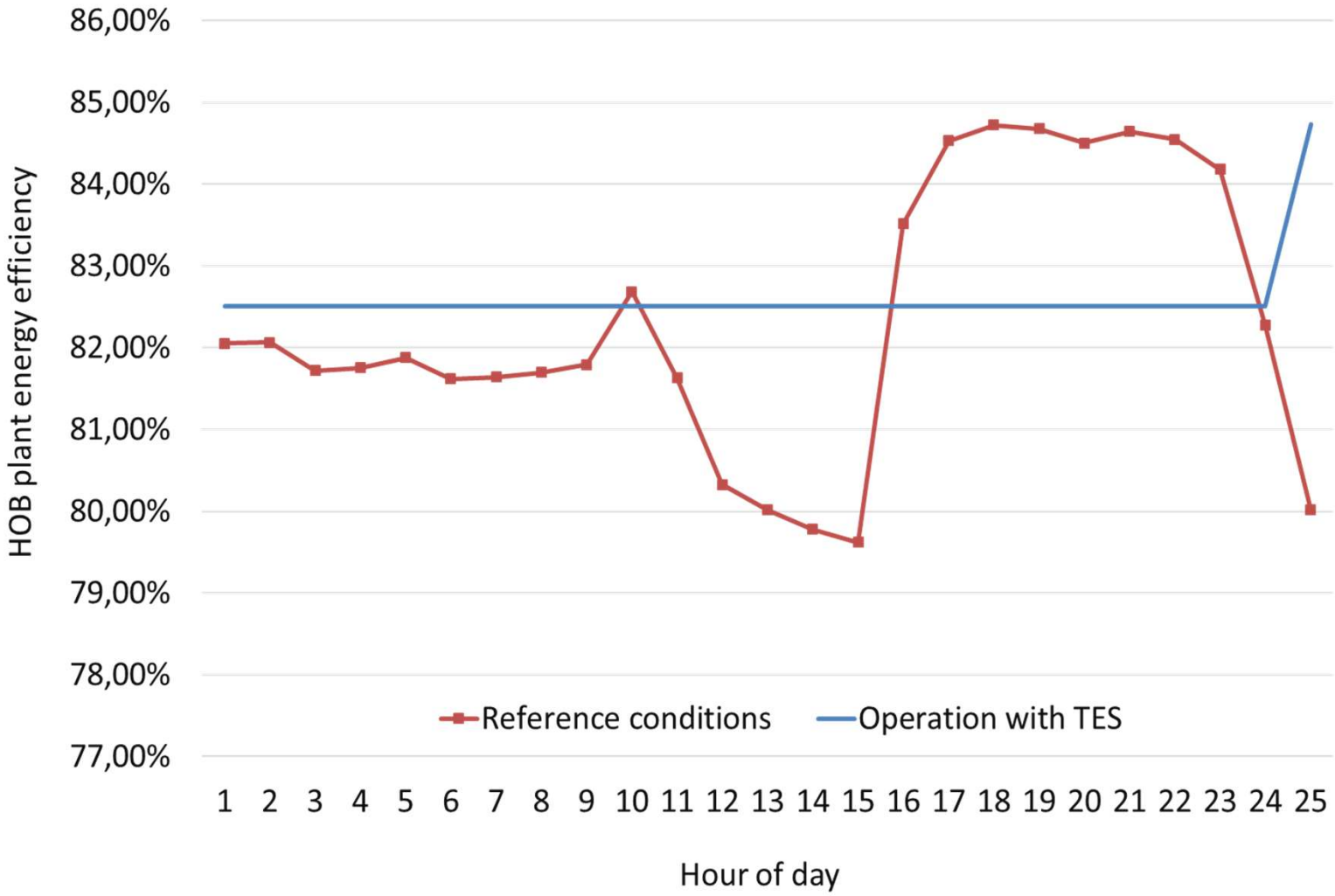
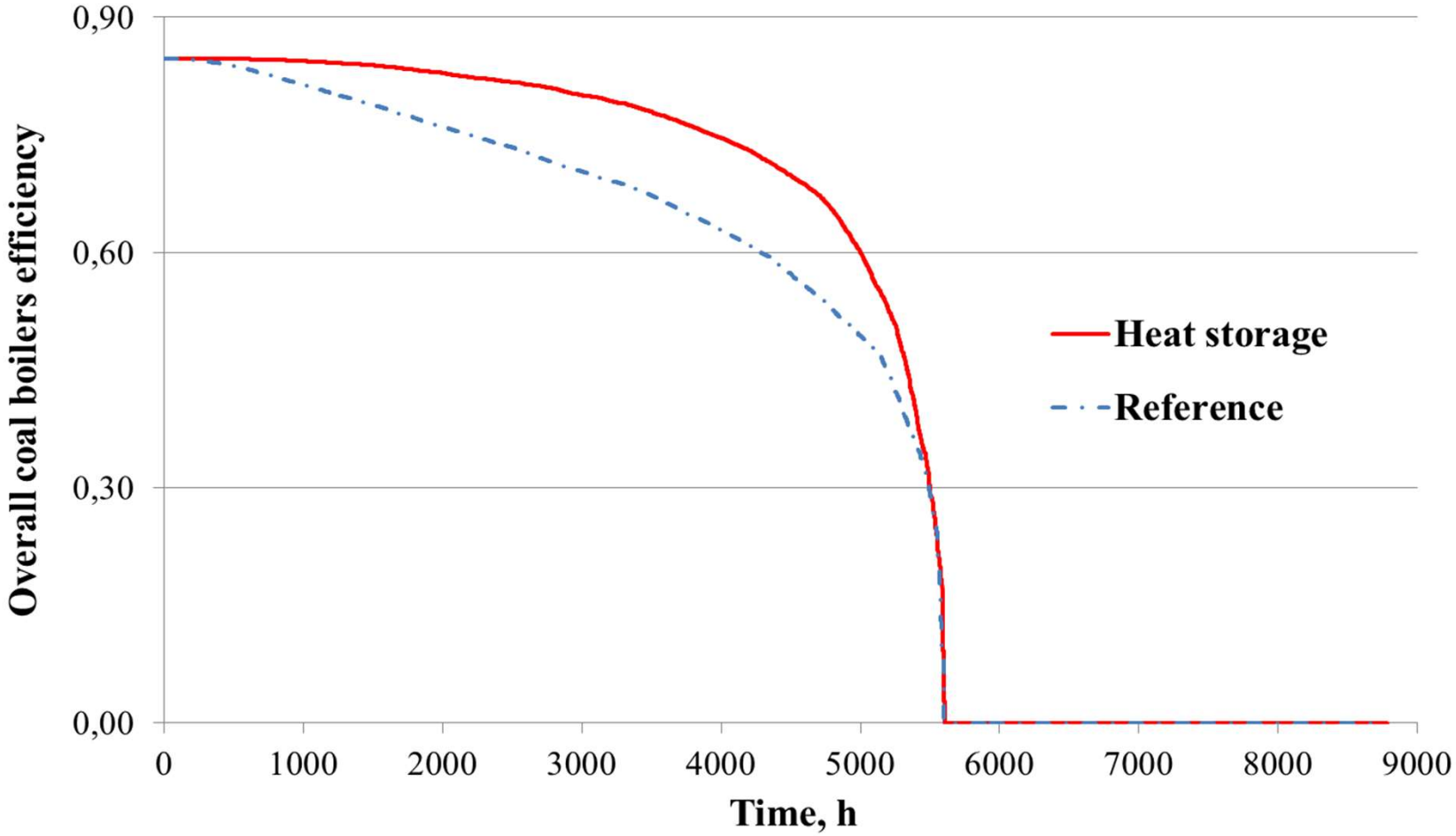
Results of optimisation HOB plant operation within sample winter day



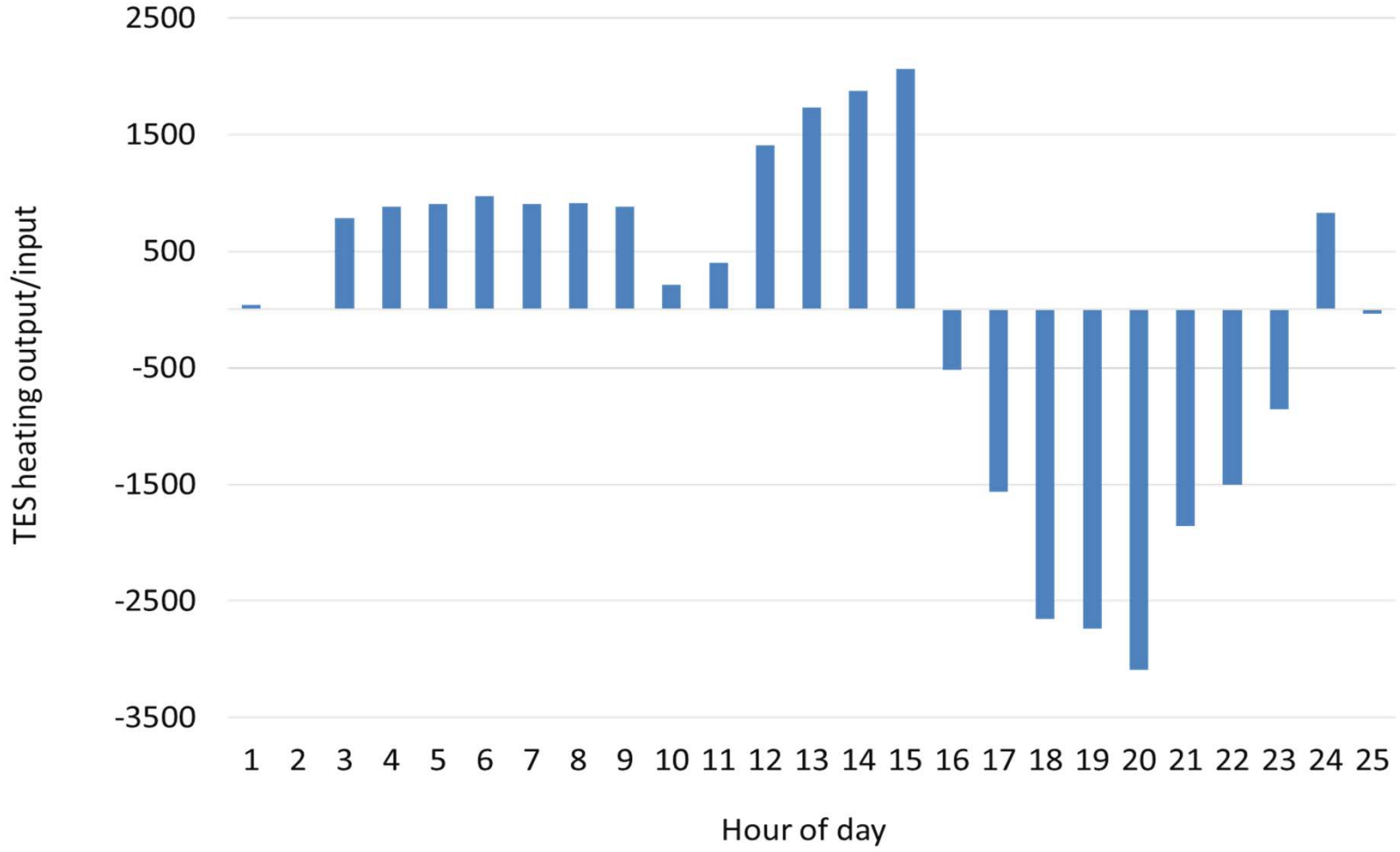
HOB plant energy efficiency gains in sample winter day



HOB plant energy efficiency gains – annual curve



Sample recommendations for TES operation

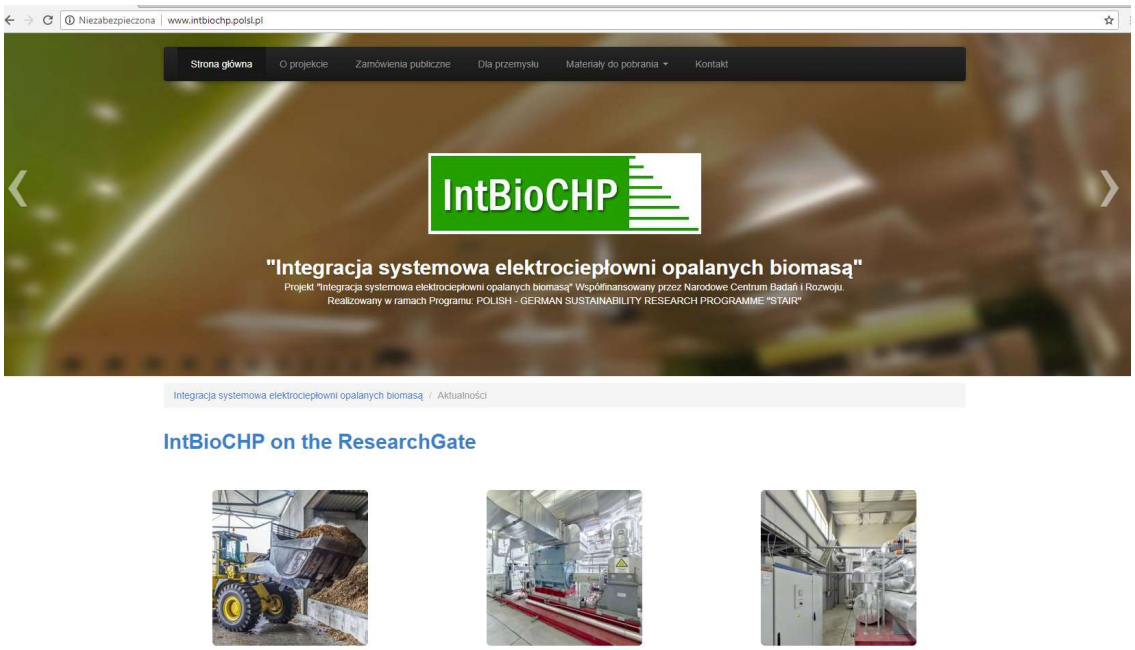


Conclusions

- Currently the ORC cogeneration techology does not bring favourable financial results.
- Data analysis and simulations showed that plant performance and economics can be improved by incorporating the mathematical models into the diagnostics and control systems.
- A base for an improvement is better system integration based on software and hardware solutions.
- Additional revenues can be generated by improved electricity generation performance (power and efficiency) and sales on balancing market.

Project web page

http://www.intbiochp.polsl.pl/



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Thank you for your attention

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