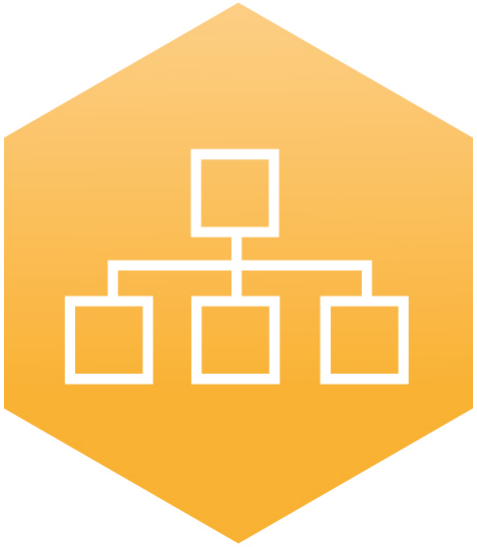
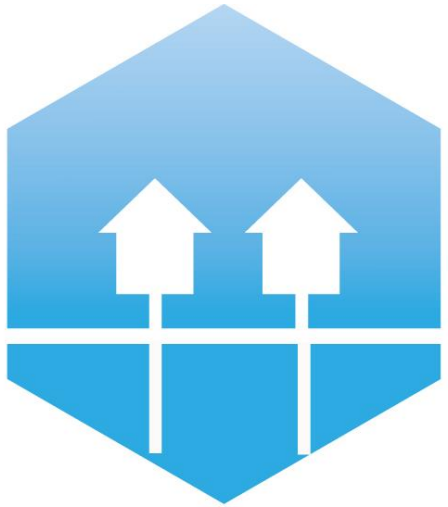
2nd International Conference on Smart Energy Systems and 4th Generation District Heating
Aalborg, 27-28 September 2016

Optimal heat sources for cooling buildings using absorption chiller technology

Sebastian Bykuć, Marta Kierek, Anders N. Andersen,
Poul Alberg Østergaard,
Katarzyna Bogucka-Bykuć





AALBORG UNIVERSITY
DENMARK

4DH
4th Generation District Heating
Technologies and Systems

2nd International Conference on Smart Energy Systems and 4th Generation District Heating
Aalborg, 27-28 September 2016

Optimal heat sources for cooling buildings using absorption chiller technology

Sebastian Bykuć, Marta Kierek, Anders N. Andersen,
Poul Alberg Østergaard,
Katarzyna Bogucka-Bykuć

Twinning for a **Su**stainable, **P**roactive **R**esearch partnership in distributed **E**nergy systems planning, **M**odelling and manag**E**ment

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 692197

Centrum Badawcze PAN KEZO Konwersja Energii i Źródła Odnawialne

SuPREM

IMP PAN GDAŃSK

AALBORG UNIVERSITY
DENMARK

4DH
4th Generation District Heating Technologies and Systems

Optimal heat sources for cooling buildings using absorption chiller technology

4DH
4th Generation District Heating Technologies and Systems

KEZO Centre- Test-side for devices producing and storing heat, cold and electricity from RES as well as test side of software for management of generation and consumption of energy

Centrum Badawcze PAN
KEZO Konwersja Energii i Źródła Odnawialne

-**Demonstrators** of modern technologies (majority of them is not yet available at the Polish market)
- **research object** (metering, data acquisition and analysis, control)
- **functional systems** supplying building of the Center in heat, cold and electricity

AALBORG UNIVERSITY
DENMARK

2nd International Conference on Smart Energy Systems and
4th Generation District Heating, Aalborg, 27-28 September 2016

Production of electricity

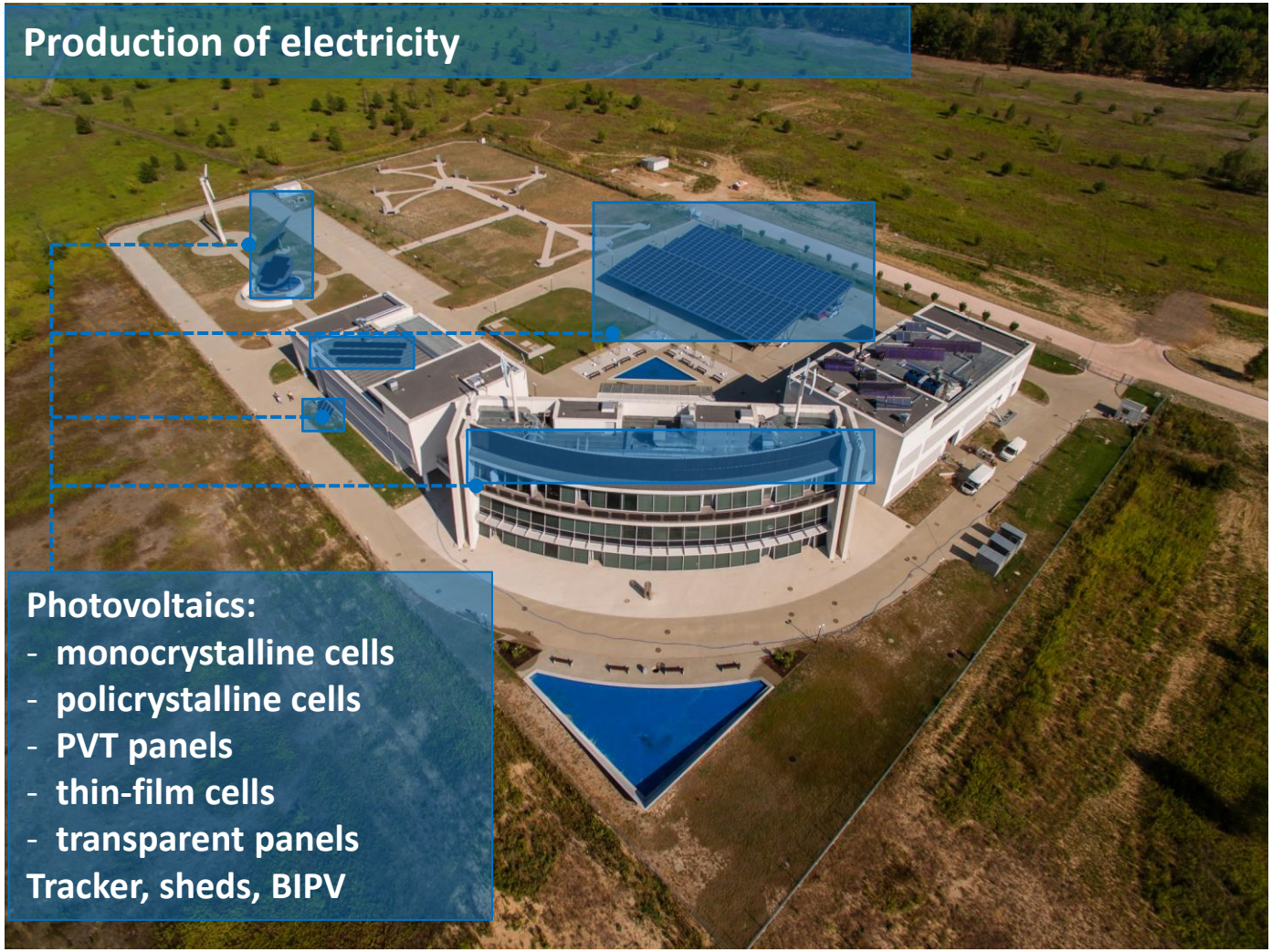
Wind turbines:
- **with horizontal axis**
- **with vertical axis- 2 Darrieus turbines**

4DH
4th Generation District Heating Technologies and Systems

AALBORG UNIVERSITY
DENMARK

Centrum Badawcze PAN
KEZO Konwersja Energii i Źródła Odnawialne

Production of electricity



Photovoltaics:
- monocrystalline cells
- policrystalline cells
- PVT panels
- thin-film cells
- transparent panels

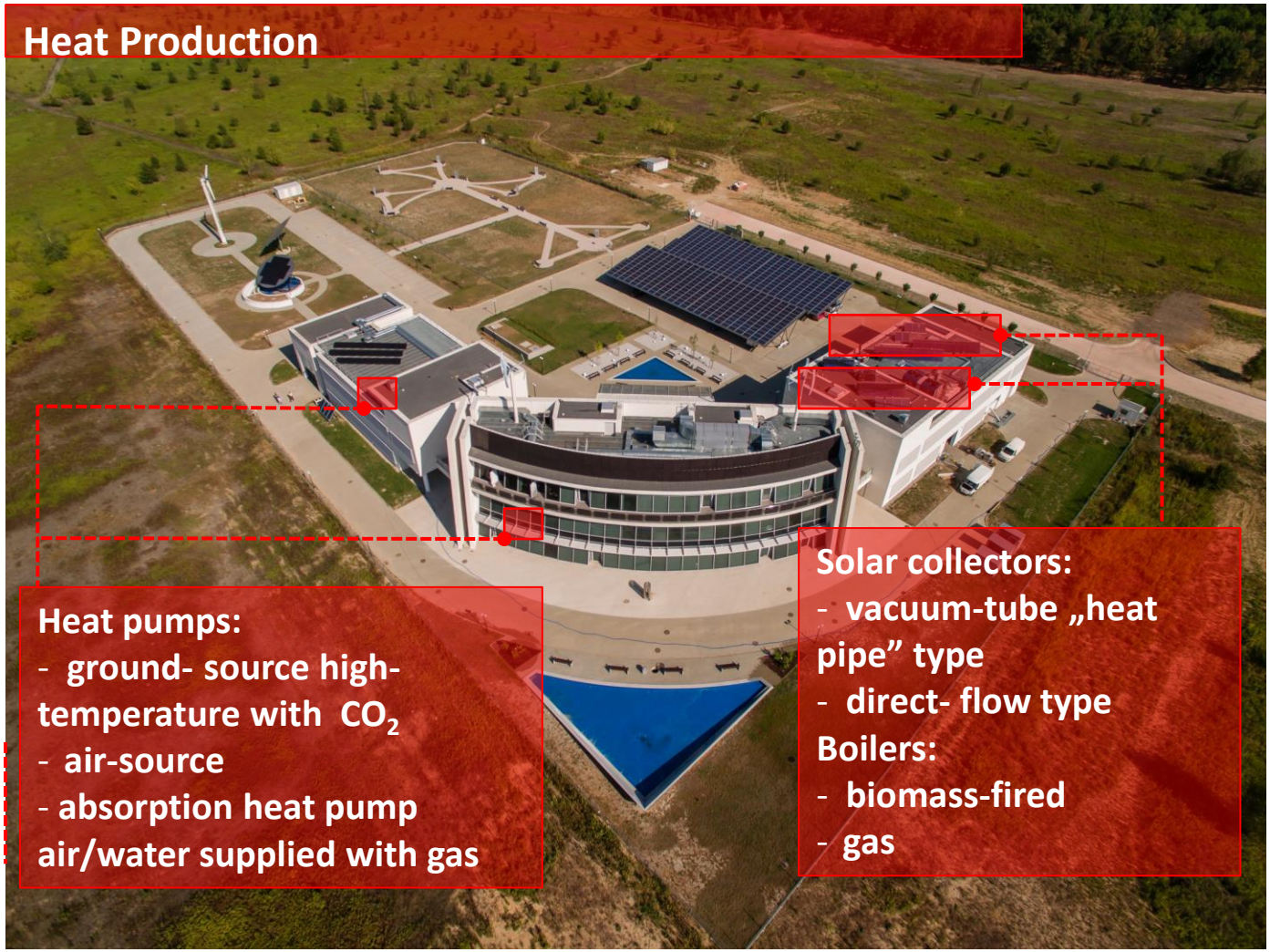
Tracker, sheds, BIPV

4DH
4th Generation District Heating Technologies and Systems

AALBORG UNIVERSITY
DENMARK

Centrum Badawcze PAN
KEZO Konwersja Energii i Źródła Odnawialne

Heat Production



Heat pumps:
- ground- source high-temperature with CO_2
- air-source
- absorption heat pump air/water supplied with gas

Solar collectors:
- vacuum-tube „heat pipe" type
- direct- flow type

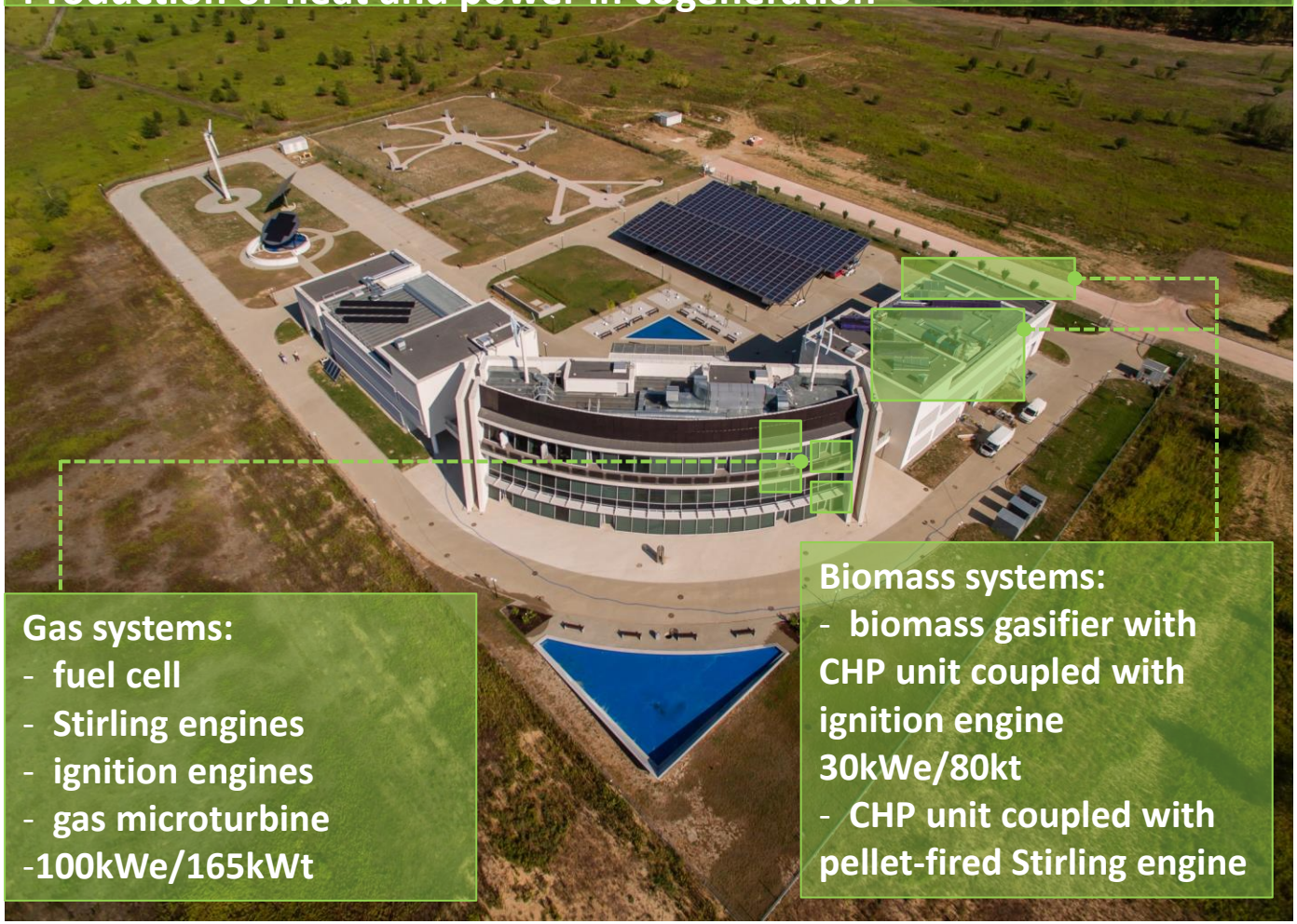
Boilers:
- biomass-fired
- gas

4DH
4th Generation District Heating Technologies and Systems

AALBORG UNIVERSITY
DENMARK

Centrum Badawcze PAN KEZO Konwersja Energii i Źródła Odnawialne

Production of heat and power in cogeneration



Gas systems:
- fuel cell
- Stirling engines
- ignition engines
- gas microturbine
-100kWe/165kWt

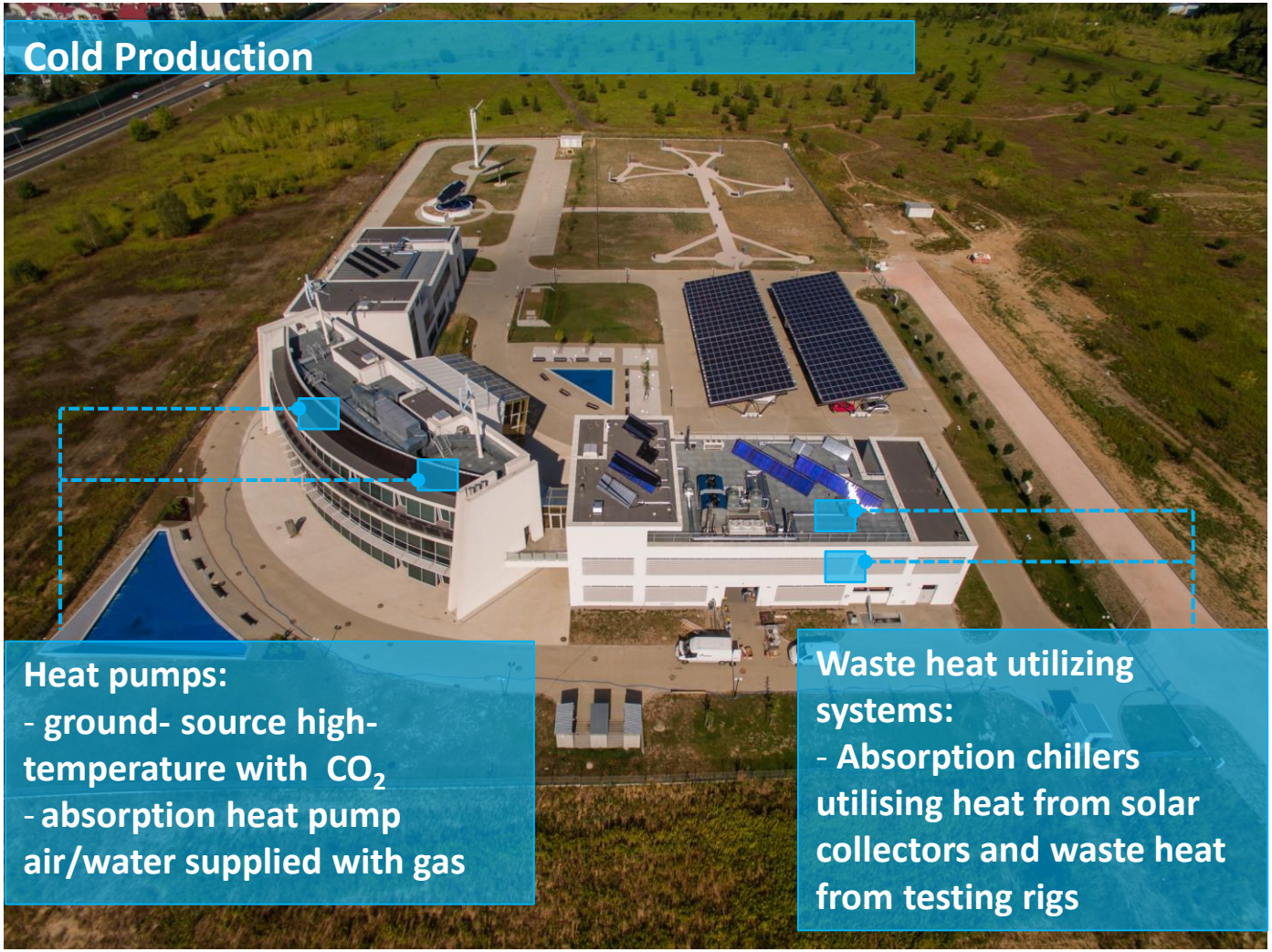
Biomass systems:
- biomass gasifier with CHP unit coupled with ignition engine 30kWe/80kt
- CHP unit coupled with pellet-fired Stirling engine

4DH
4th Generation District Heating Technologies and Systems

AALBORG UNIVERSITY
DENMARK

Centrum Badawcze PAN
KEZO Konwersja Energii i Źródła Odnawialne

Cold Production



Heat pumps:
- ground- source high-temperature with CO_2
- absorption heat pump air/water supplied with gas

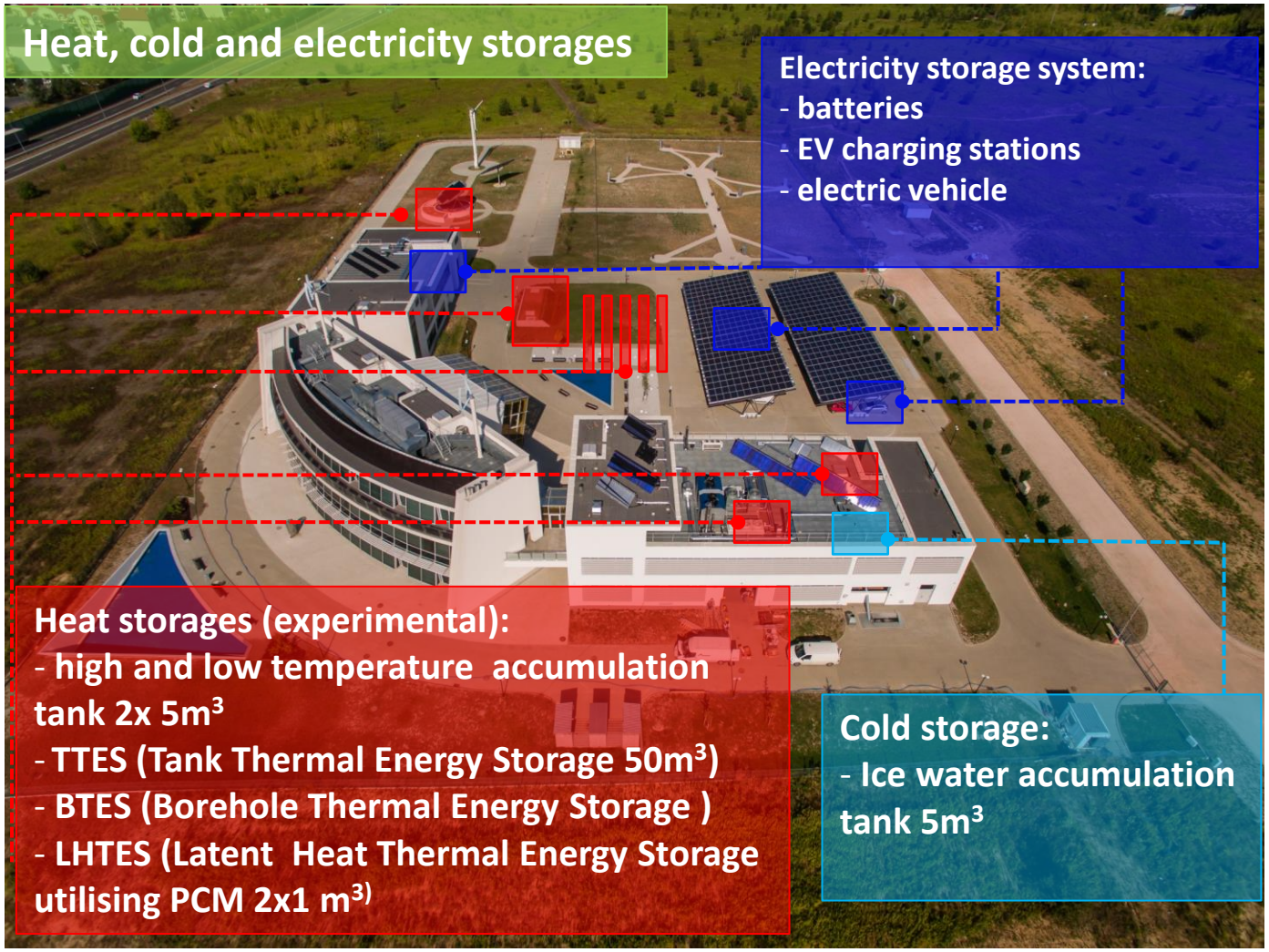
Waste heat utilizing systems:
- Absorption chillers utilising heat from solar collectors and waste heat from testing rigs

4DH
4th Generation District Heating Technologies and Systems

AALBORG UNIVERSITY
DENMARK

Centrum Badawcze PAN
KEZO Konwersja Energii i Źródła Odnawialne

Heat, cold and electricity storages



Electricity storage system:
- batteries
- EV charging stations
- electric vehicle

Heat storages (experimental):
- high and low temperature accumulation tank 2x 5m^3
- TTES (Tank Thermal Energy Storage 50m^3)
- BTES (Borehole Thermal Energy Storage)
- LHTES (Latent Heat Thermal Energy Storage utilising PCM 2x1 m$^{3)}$

Cold storage:
- Ice water accumulation tank 5m^3

4DH
4th Generation District Heating Technologies and Systems

AALBORG UNIVERSITY
DENMARK

Centrum Badawcze PAN
KEZO Konwersja Energii i Źródła Odnawialne

Building of a Centre is **the space for work**,
but also **the living laboratory**.

4DH
4th Generation District Heating Technologies and Systems

We utilize all the locally available sources of RES:

- Sun
- Wind
- Geothermal energy
- Biomass

We store heat, cold and electricity:

- BTES
- TTES
- LHTES (with PCM)
- batteries of accumulators

We utilize waste heat:

- production of electric power
- production of cold

We support development of ecological transport:

- EV charging station
- e-vehicle

We monitor and manage production and consumption of energy in Centre

- Expanded BMS : a local micro „Smart Energy System ” in the future

Cooling options analysis:

- Technologies available onsite:
  - Absorption chillers: 100-140kW cooling power
  - Evacuated tube Solar collectors 120m^2
  - Storage: 5m^3 heat, 5m^3 cold
  - PV: 160kWe
  - Gas boiler 100kWh
  - Biomas boiler 100kWh
  - CHP
    - 4x 1kWe, 20kWh - Stirling
    - 9kWe, 19kWh – gas engine
    - 100kWe, 165kWh - gas turbine
    - 30kWe, 90kWh – gas turbine

Cooling options analysis:

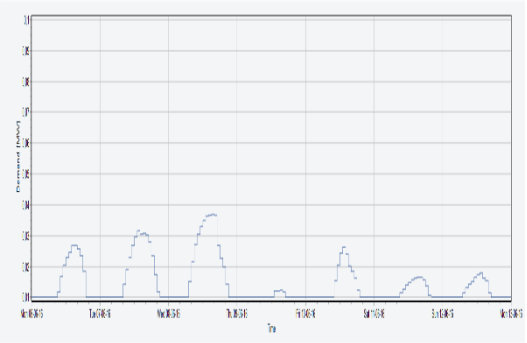
- Questions:
  - How to cool the building in different situations?
  - Is there an optimum mix of technologies?
  - Which one is the cheapest to operate?
  - New investments needed?

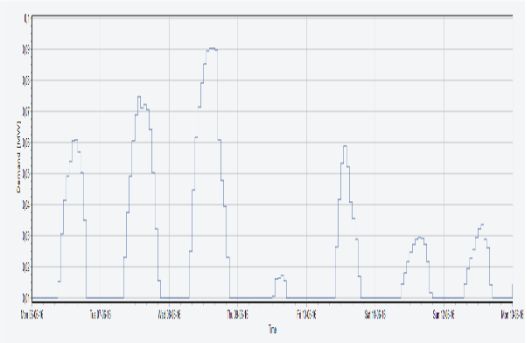
3 scenarios -3 sets of demands

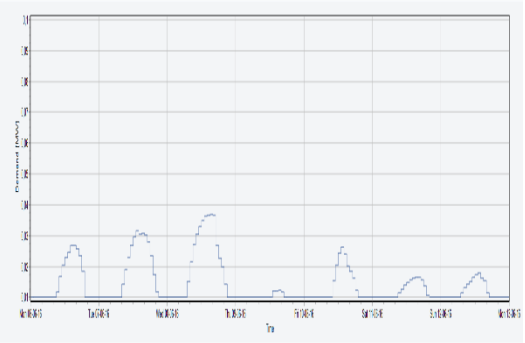
KEZO „usual summer week”

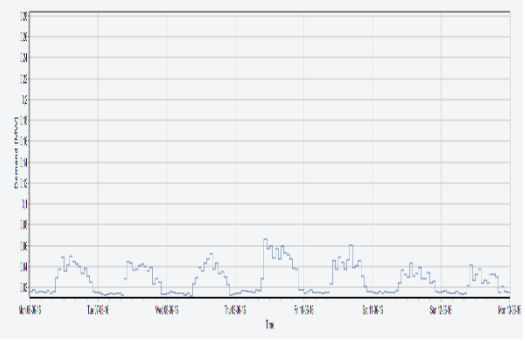
KEZO „conference summer week”

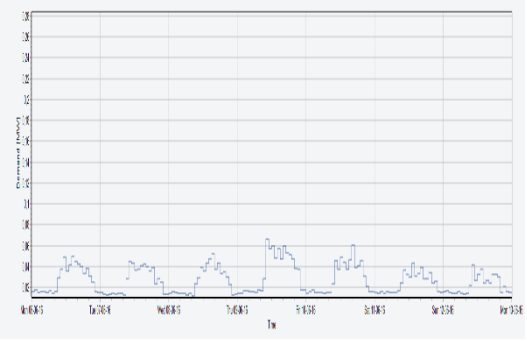
KEZO „experiment summer week”







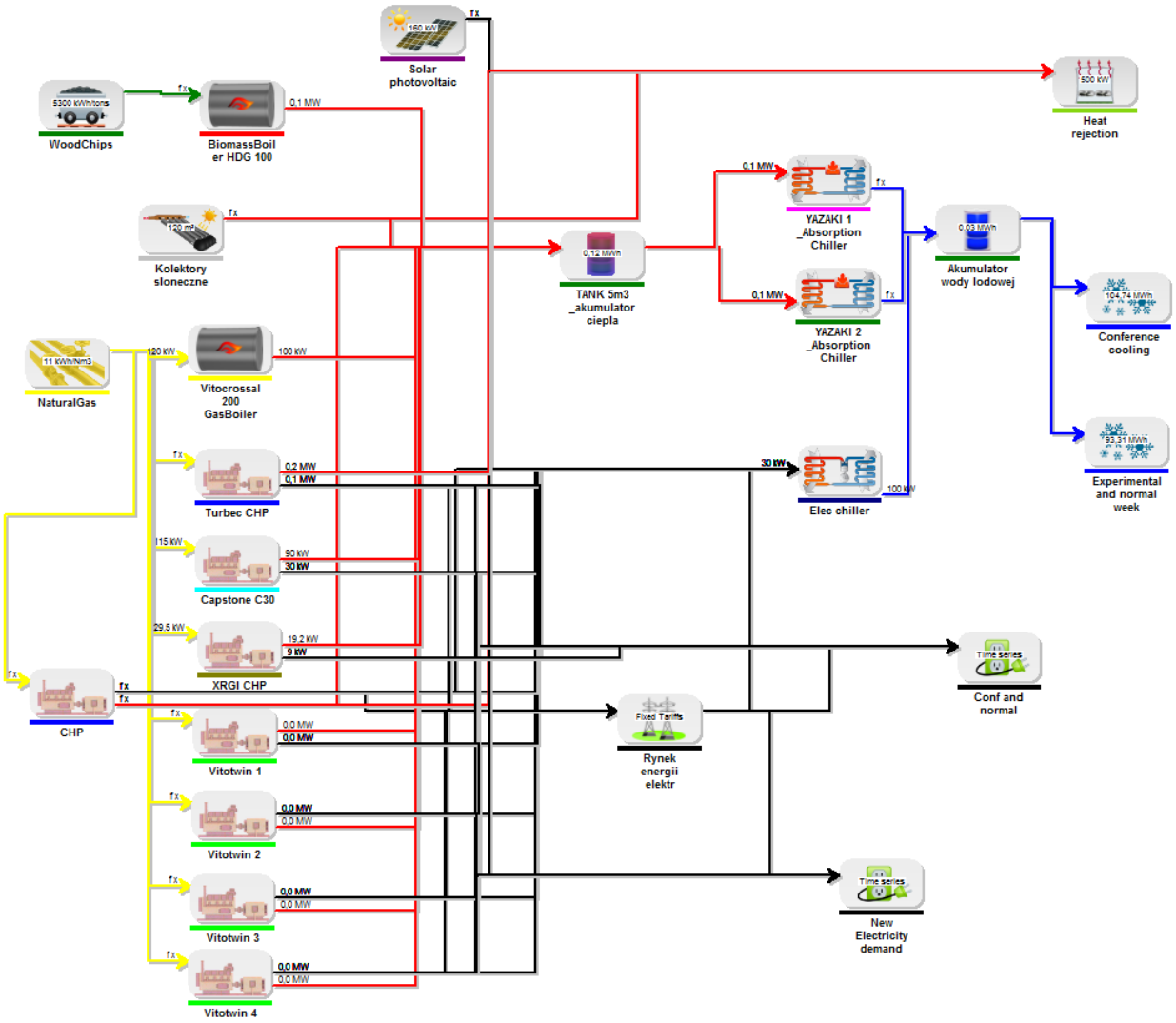




4DH
4th Generation District Heating Technologies and Systems

AALBORG UNIVERSITY
DENMARK

EnergyPRO model



4DH
4th Generation District Heating Technologies and Systems

AALBORG UNIVERSITY
DENMARK

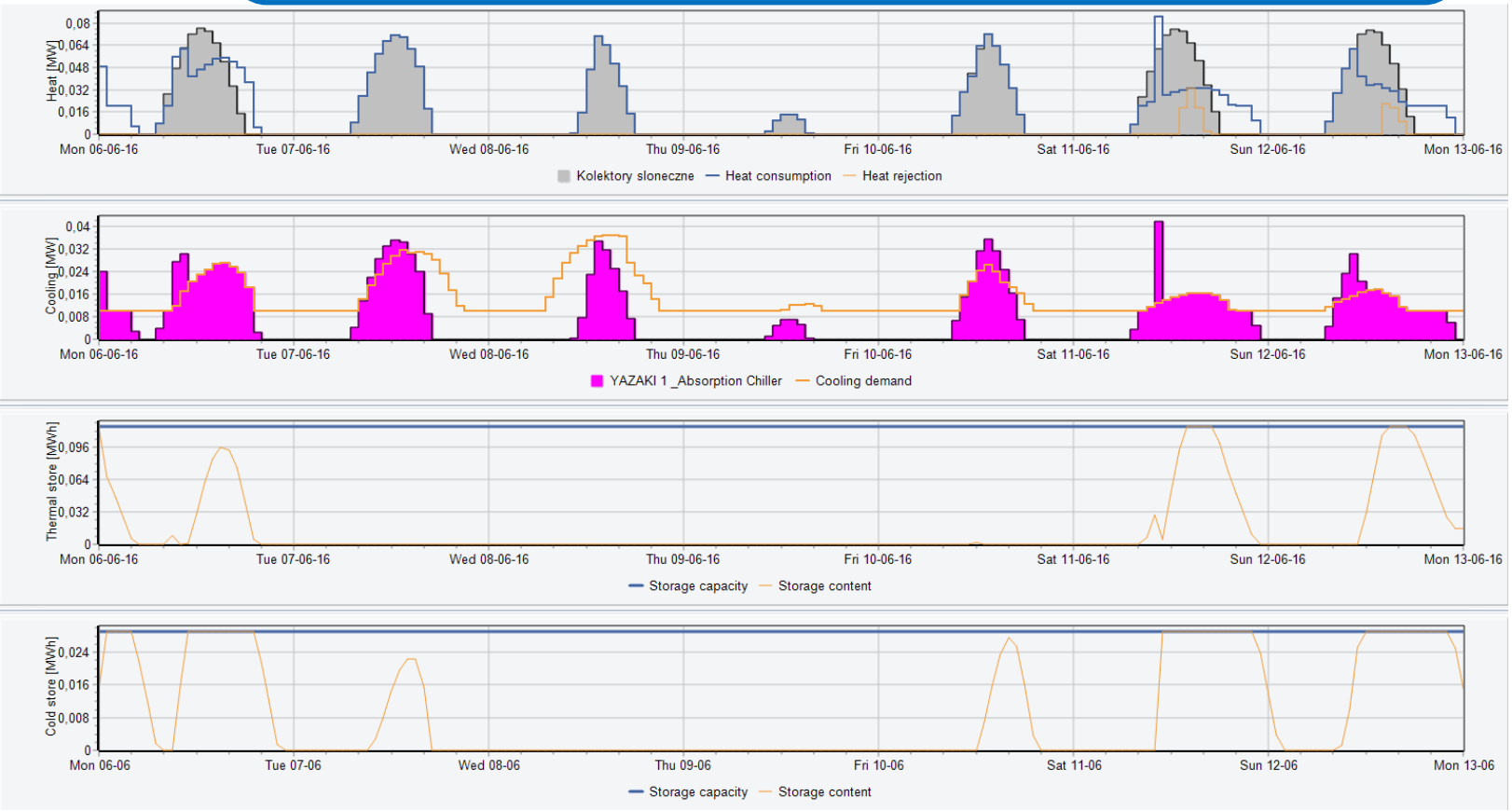
EnergyPRO analysis

- **27 options analysed**

- **9 selected combinations of available technologies**
- **6 with additional investments**

KEZO „usual and experimantal summer week”

„100%” renewable cooling

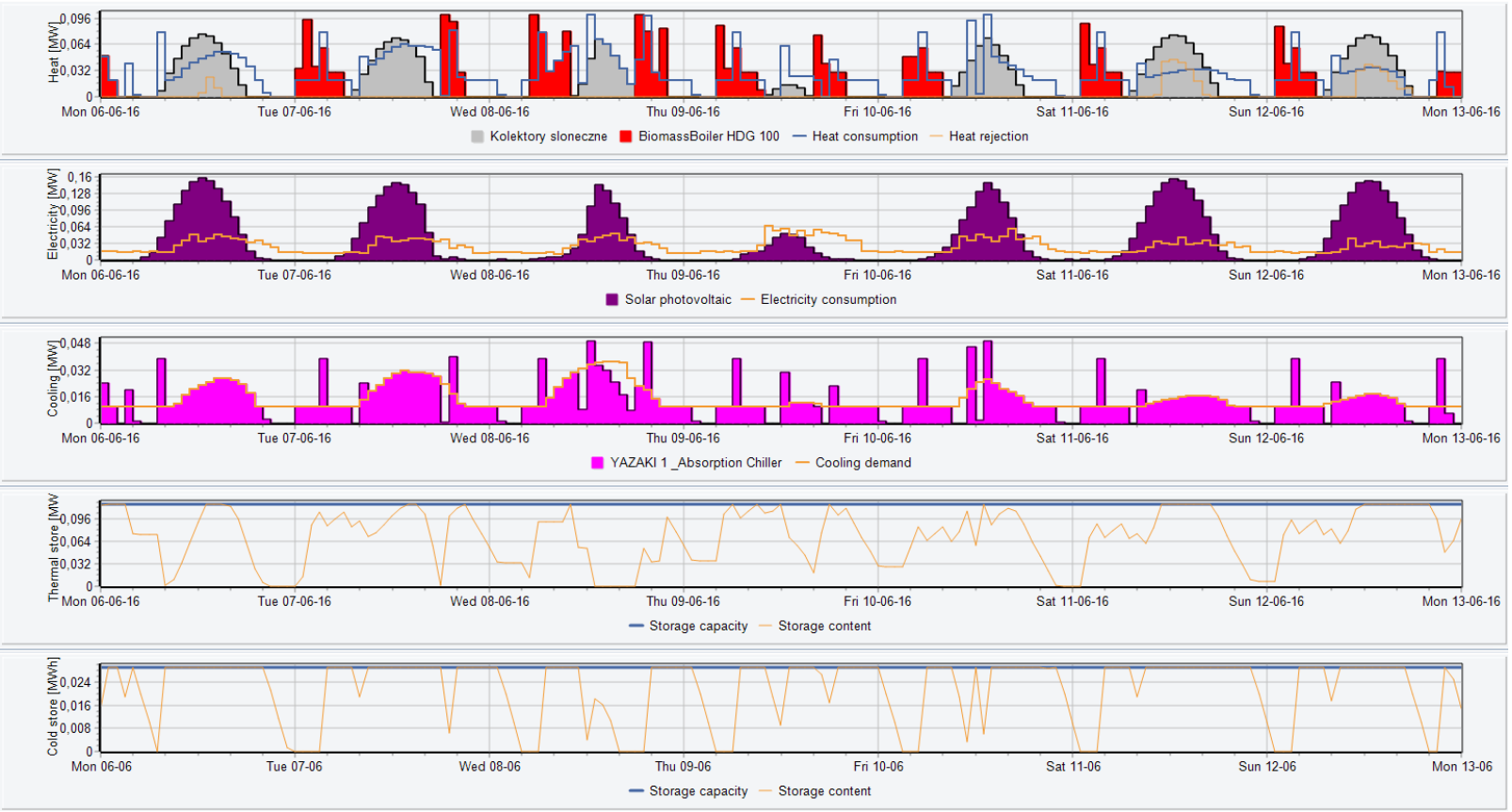


4DH

4th Generation District Heating Technologies and Systems

Cooling demand not met

KEZO „usual summer week”
Mix Solar Collectors+Biomass boiler+PV

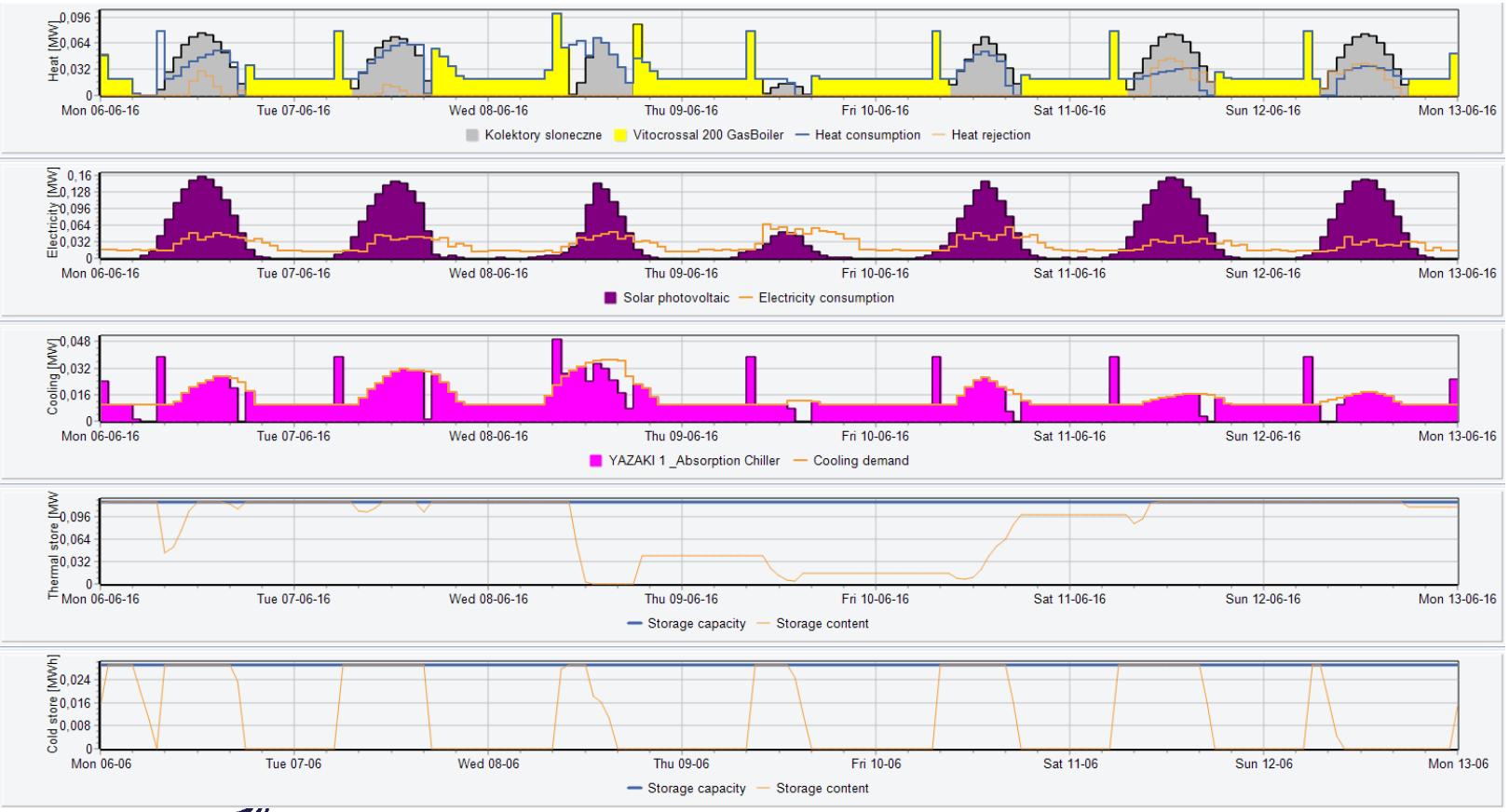


4DH
4th Generation District Heating Technologies and Systems

Aditional Investment: „0”
Operation cost: 517PLN

AALBORG UNIVERSITY
DENMARK

KEZO „usual summer week”
Mix Solar Collectors+Gas boiler+PV

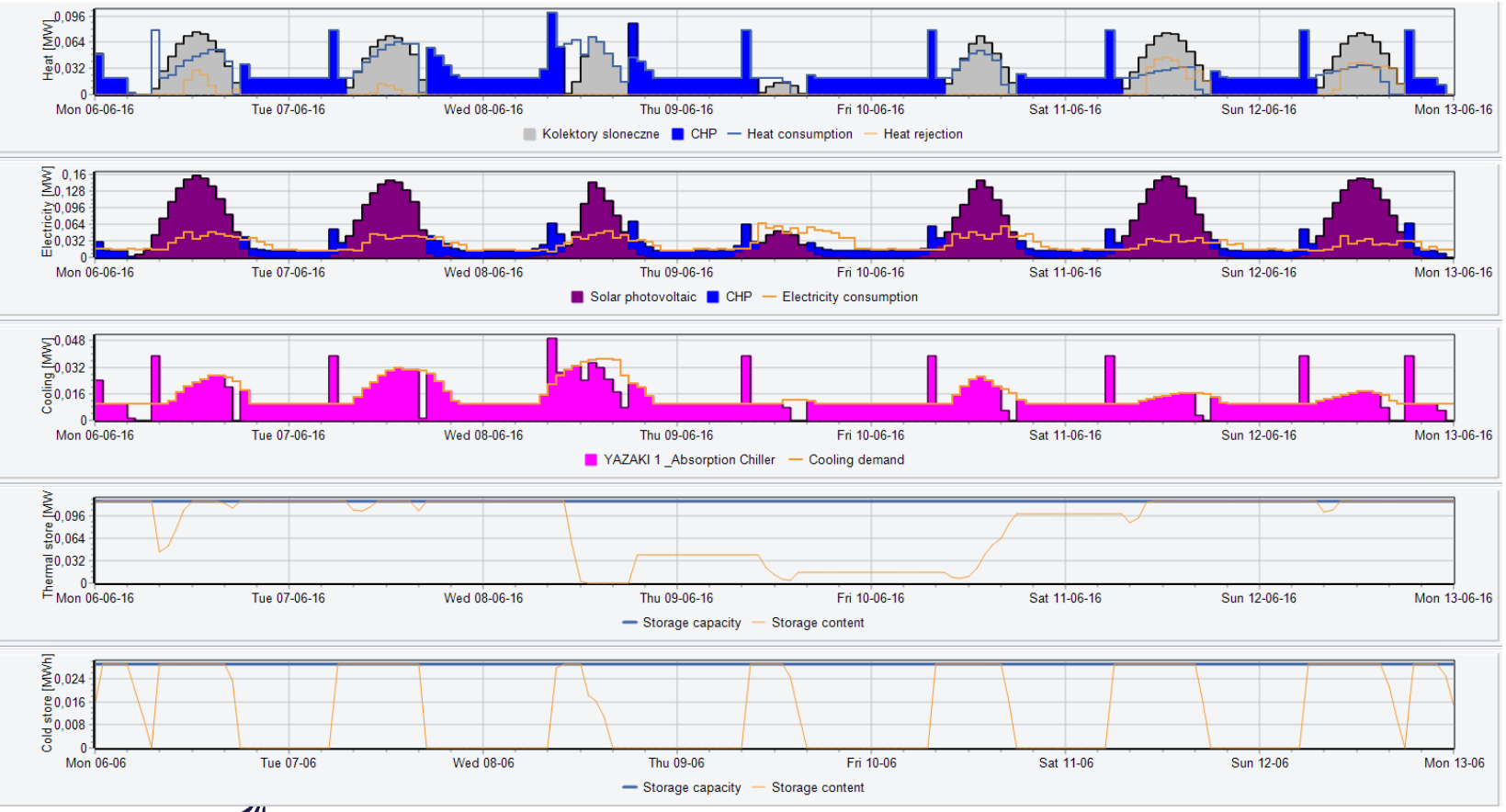


4DH
4th Generation District Heating Technologies and Systems

Aditional Investment: „0”
Operation cost: 798PLN

AALBORG UNIVERSITY
DENMARK

KEZO „usual summer week”
Mix Solar Collectors+CHP+PV



Aditional Investment: „0”
Operation cost: 355PLN

EnergyPRO analysis

4DH
4th Generation District Heating Technologies and Systems

KEZO „usual summer week”

Cooling system:	Operation cost PLN
SC+biomass+PV	517
SC+gas+PV	798
Sc+CHP+PV	355

KEZO „conference summer week”

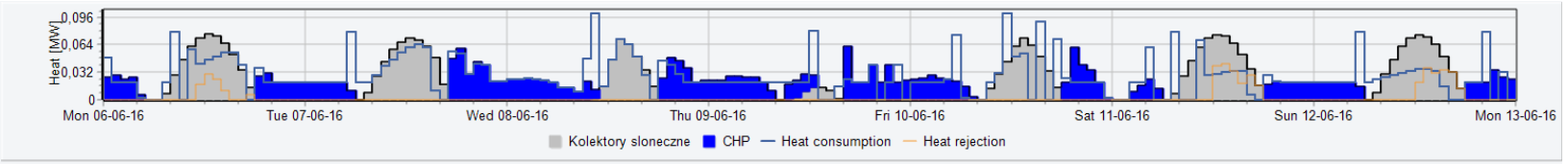
Cooling system:	Operation cost PLN
SC+biomass+PV	825
SC+gas+PV	1296
Sc+CHP+PV	1142

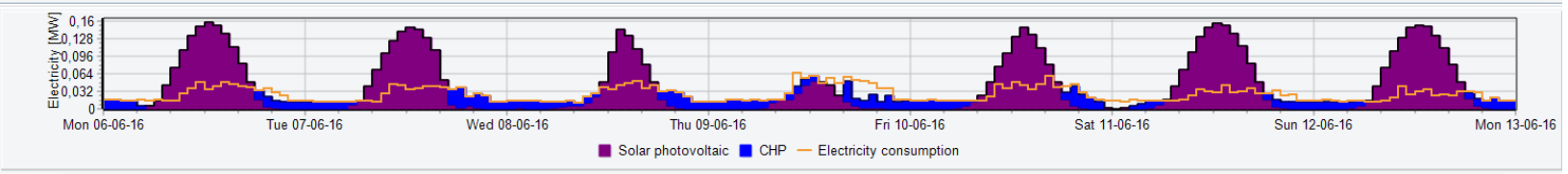
KEZO „experiment summer week”

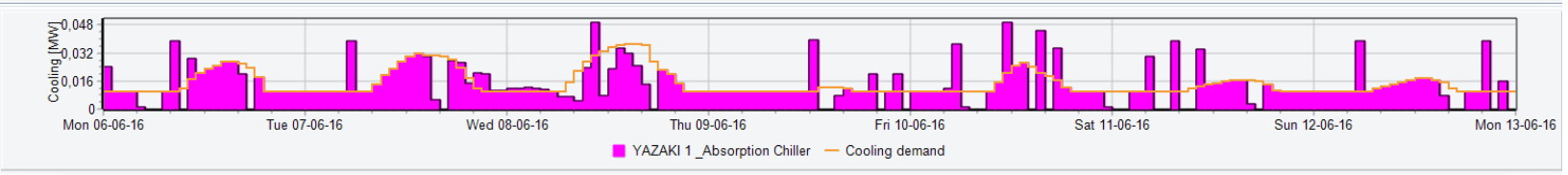
Cooling system:	Operation cost PLN
SC+biomass+PV	2027
SC+gas+PV	2267
Sc+CHP+PV	1862

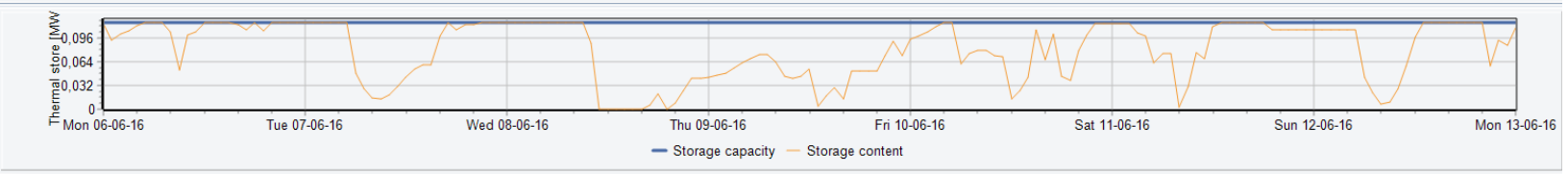
KEZO „usual summer week”

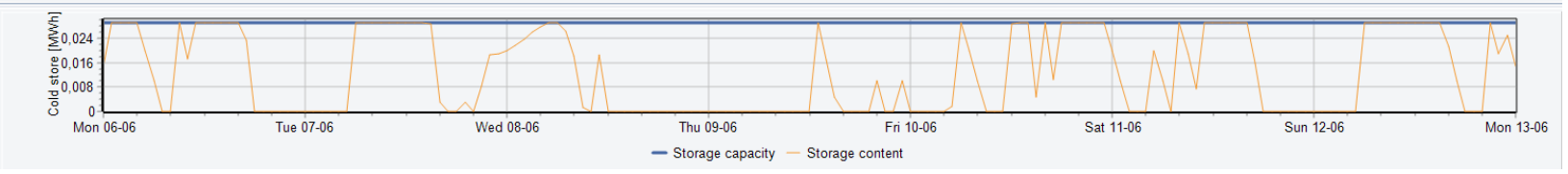
Cooling system:	Operation cost PLN
SC+biomass+PV	517
SC+gas+PV	798
Sc+CHP+PV	355









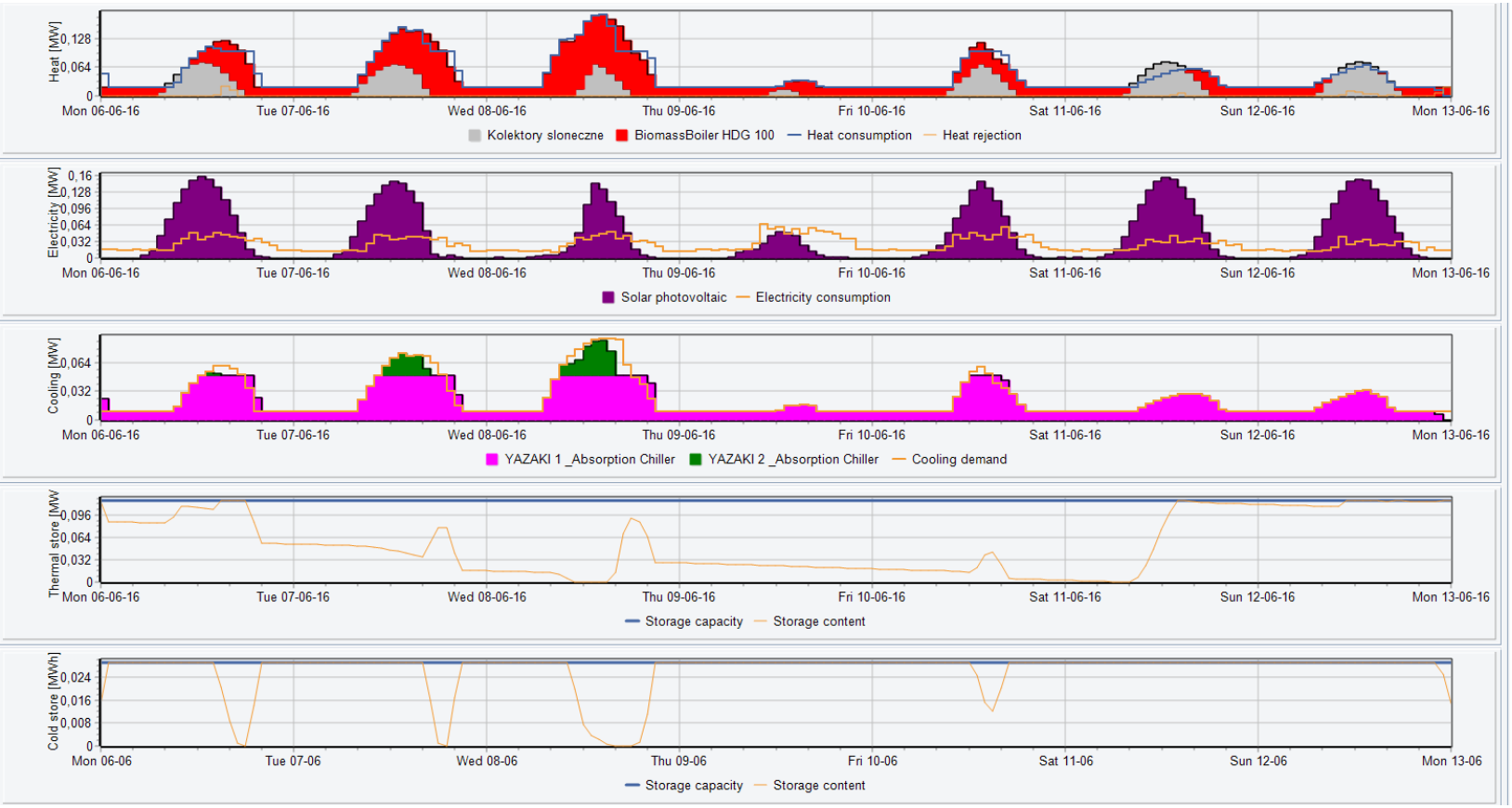


4DH
4th Generation District Heating Technologies and Systems

AALBORG UNIVERSITY
DENMARK

KEZO „conference summer week”

Cooling system:	Operation cost PLN
SC+biomass+PV	825
SC+gas+PV	1296
Sc+CHP+PV	1142

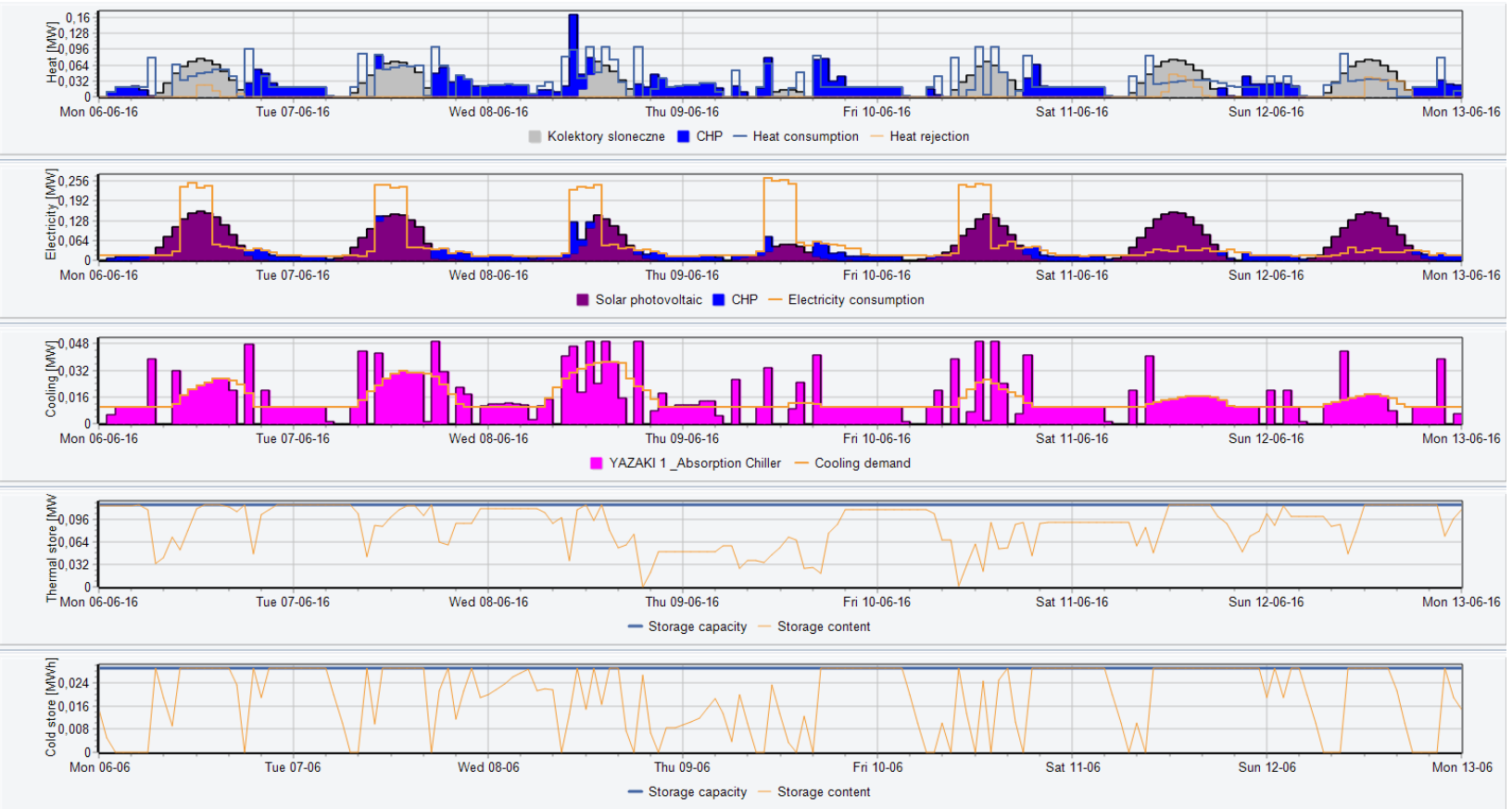


4DH
4th Generation District Heating Technologies and Systems

AALBORG UNIVERSITY
DENMARK

KEZO „experiment summer week”

Cooling system:	Operation cost PLN
SC+biomass+PV	2027
SC+gas+PV	2267
Sc+CHP+PV	1862



4DH
4th Generation District Heating Technologies and Systems

AALBORG UNIVERSITY
DENMARK

EnergyPRO analysis

4DH
4th Generation District Heating Technologies and Systems

KEZO „usual summer week”

Cooling system:	Operation cost PLN
SC+biomass+PV	517
SC+gas+PV	798
Sc+CHP+PV	355

KEZO „conference summer week”

Cooling system:	Operation cost PLN
SC+biomass+PV	825
SC+gas+PV	1296
Sc+CHP+PV	1142

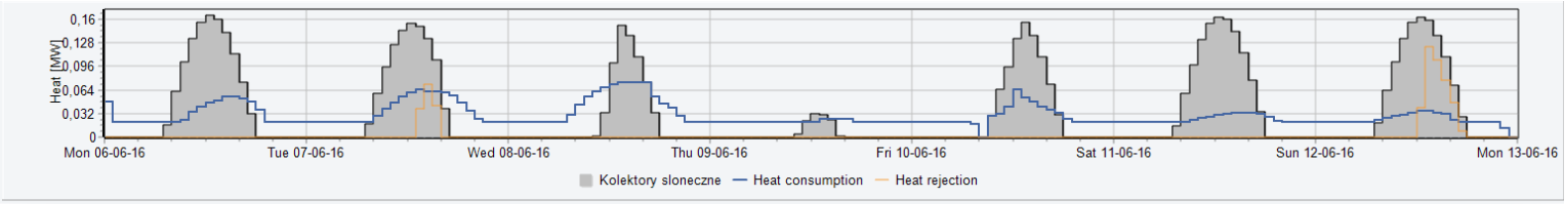
KEZO „experiment summer week”

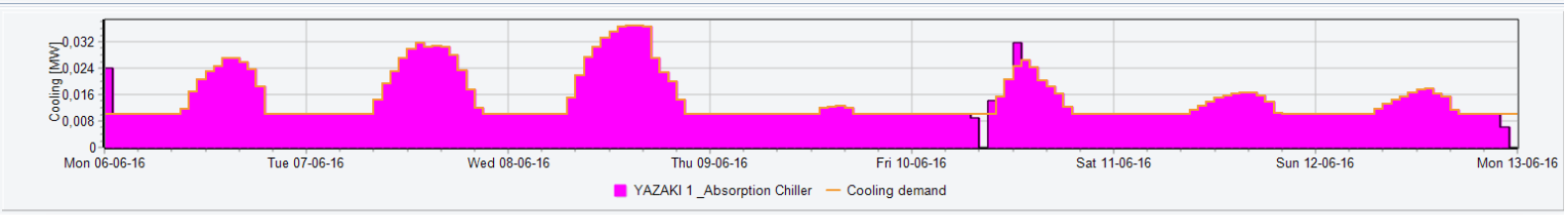
Cooling system:	Operation cost PLN
SC+biomass+PV	2027
SC+gas+PV	2267
Sc+CHP+PV	1862

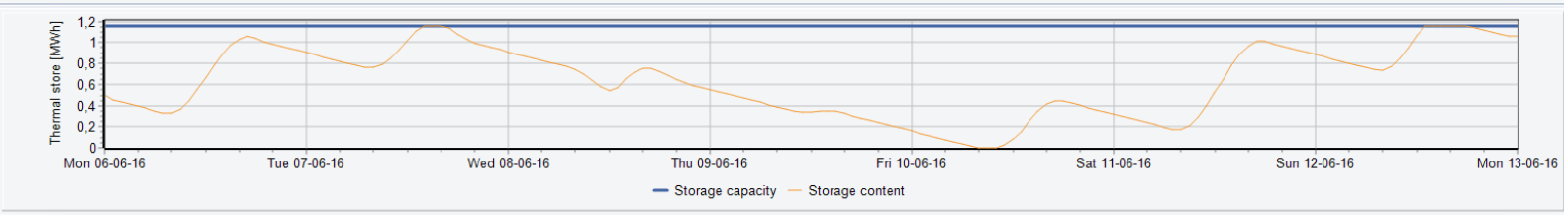
Other options - Investments ?

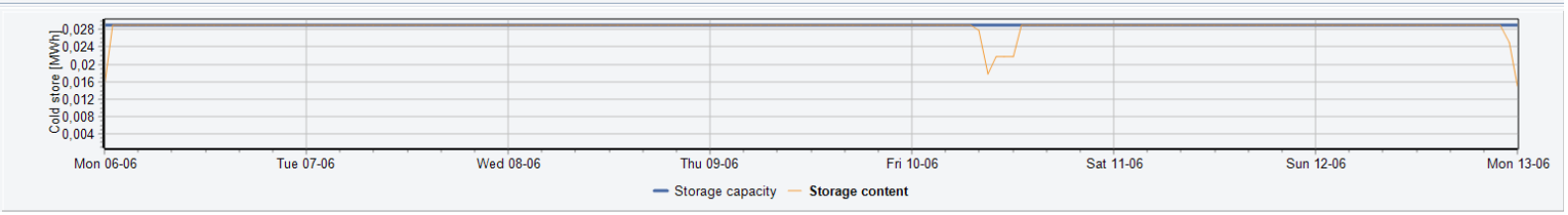
KEZO „usual and experimantal summer week”

„100%” renewable cooling - investment









„normal, experiment” = +100m2 solar collectors
+45m3 heat storage

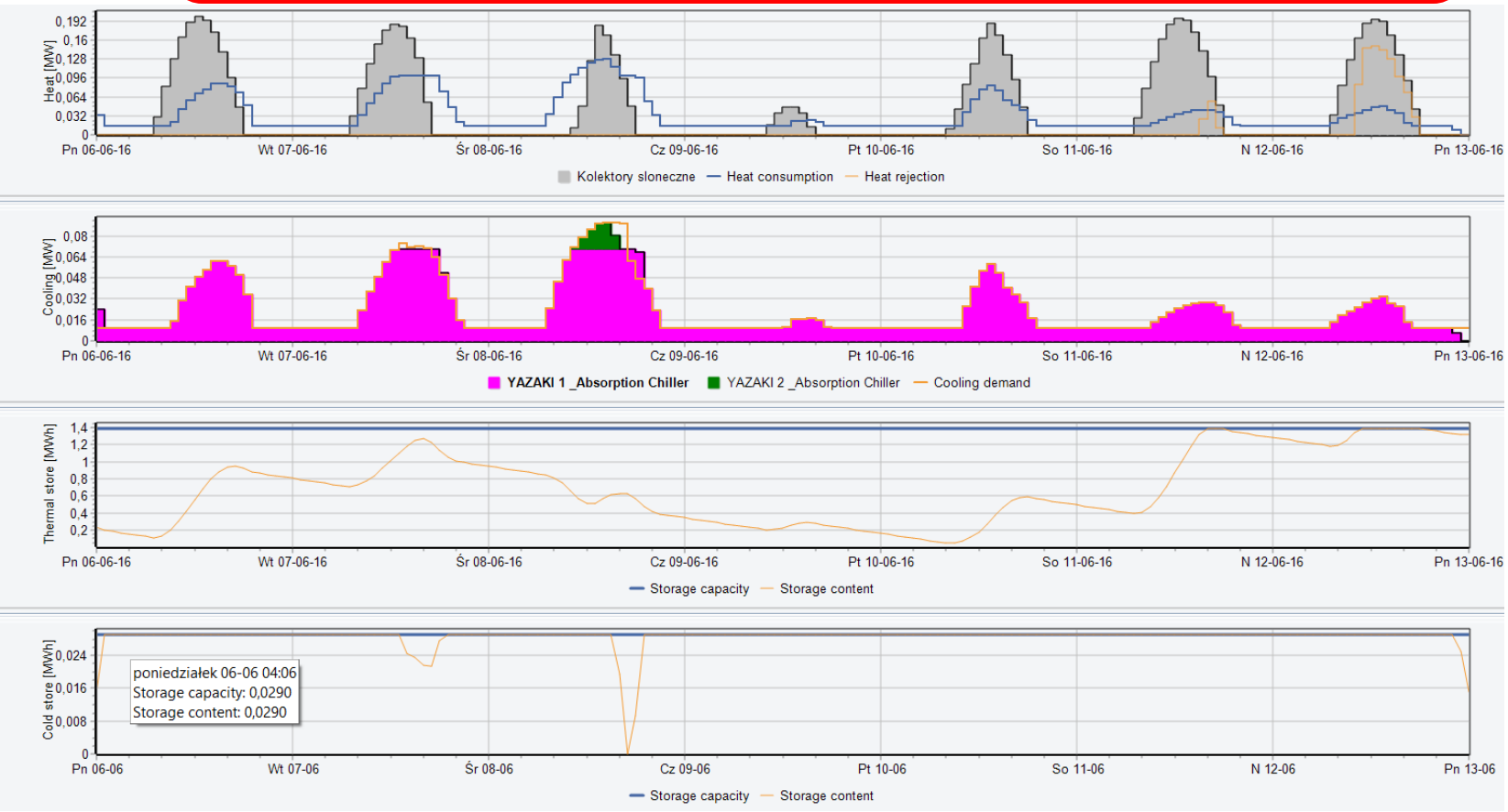
Aditional Investment: ≈ 300KPLN

4DH
4th Generation District Heating Technologies and Systems

AALBORG UNIVERSITY
DENMARK

KEZO „conference summer week”

„100%” renewable cooling - investment



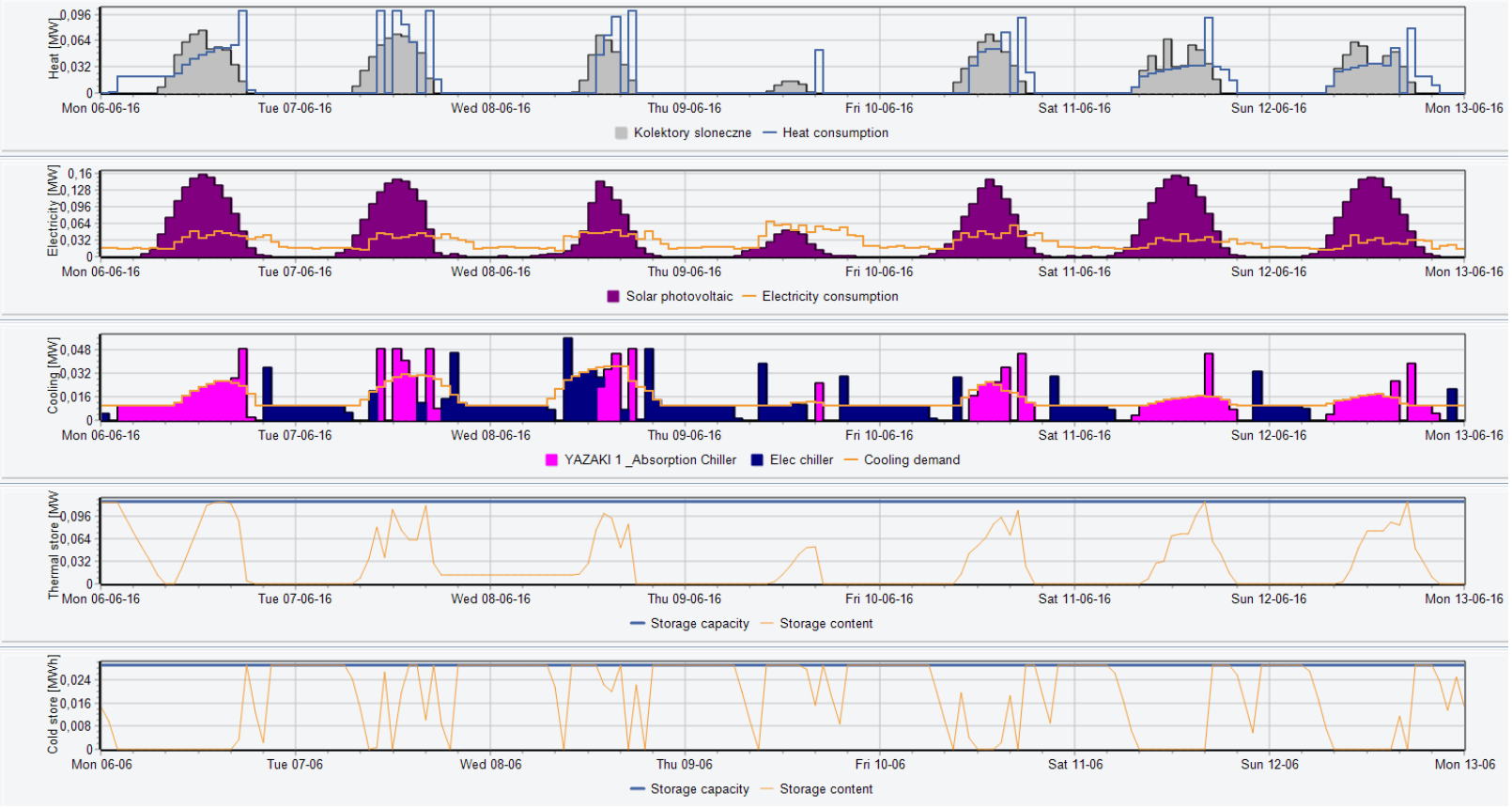
4DH
4th Generation District Heating Technologies and Systems

„conf” = +310m2 solar collectors +75m3 heat storage

Aditional Investment: ≈800KPLN

AALBORG UNIVERSITY
DENMARK

KEZO „usual summer week”
Mix Chiller+Solar Collectors +Electrical Chiller



4DH
4th Generation District Heating Technologies and Systems

+ electrical chiller

Aditional Investment: 60KPLN

AALBORG UNIVERSITY
DENMARK

EnergyPRO analysis

4DH
4th Generation District Heating Technologies and Systems

KEZO „usual summer week"

Cooling system:	Operation cost PLN
SC+biomass+PV	517
SC+gas+PV	798
SC+CHP+PV	355
Investment	≈60 000
SC+AC+PV	349
Investment	≈300 000
SC+PV	207

KEZO „conference summer week"

Cooling system:	Operation cost PLN
SC+biomass+PV	825
SC+gas+PV	1 296
SC+CHP+PV	1 142
Investment	≈10 0000
SC+AC+PV	469
Investment	≈ 800 0000
SC+PV	207

KEZO „experiment summer week"

Cooling system:	Operation cost PLN
SC+biomass+PV	2 027
SC+gas+PV	2 267
SC+CHP+PV	1 862
Investment	≈60 000
SC+AC+PV	1 858
Investment	≈300 000
SC+PV	1713

Concluding remarks

- depending on the cooling and electricity demand profiles, different heat sources should be combined with the absorption chillers for cooling purposes to get optimal economic configuration in options analyzed
- electricity produced should be used for covering own demand
- cost of electricity exported strongly affects the optimal system configuration
- more detailed analysis should be taken into account when considering investments

Thank You!

Sebastian Bykuć

sebastian.bykuc@imp.gda.pl

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 692197

AALBORG UNIVERSITY
DENMARK

4DH
4th Generation District Heating Technologies and Systems