International Conference on Smart Energy Systems and 4th Generation District Heating
Copenhagen, 25-26 August 2015

Contributing global CO_2 mitigation by utilisation of food industry heat into smart Croatian DHS via Total Site heat recovery

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4DH
4th Generation District Heating
Technologies and Systems

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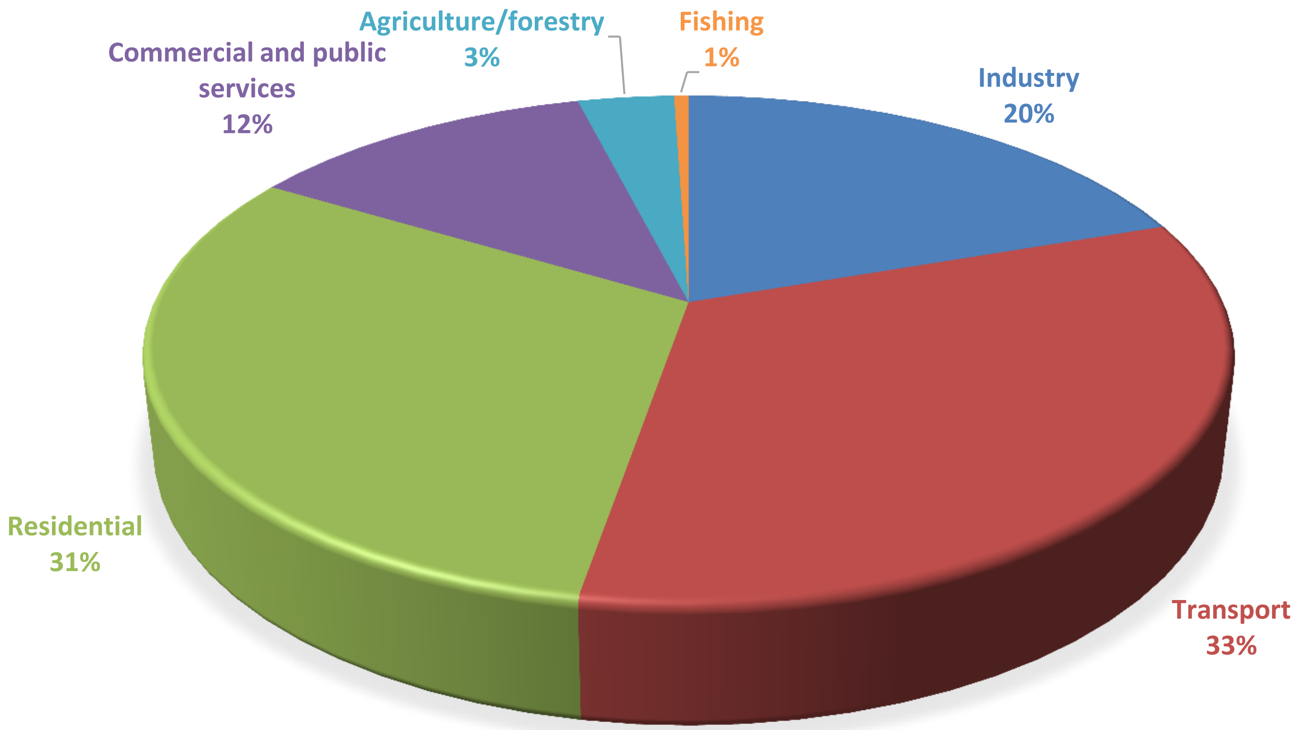
Outline

- Introduction
- Objectives
- Methodology
- Case study
- Results
- Summary and future works

Introduction

- **To produce 1 J of food energy 10 J of primary energy is required**
- **The population growth required the annual energy consumption rise on 24 – 40%**
- **On the other hand it leads to fast deterioration of environment, to CO_2, NO_x, SO_x, dust, soot and other industrial emissions**

Croatian Energy Balance for 2012



Total final consumption 6381 thousand tonnes of oil equivalent (ktoe)

The source is IEA *http://www.iea.org/statistics/statisticssearch/report*

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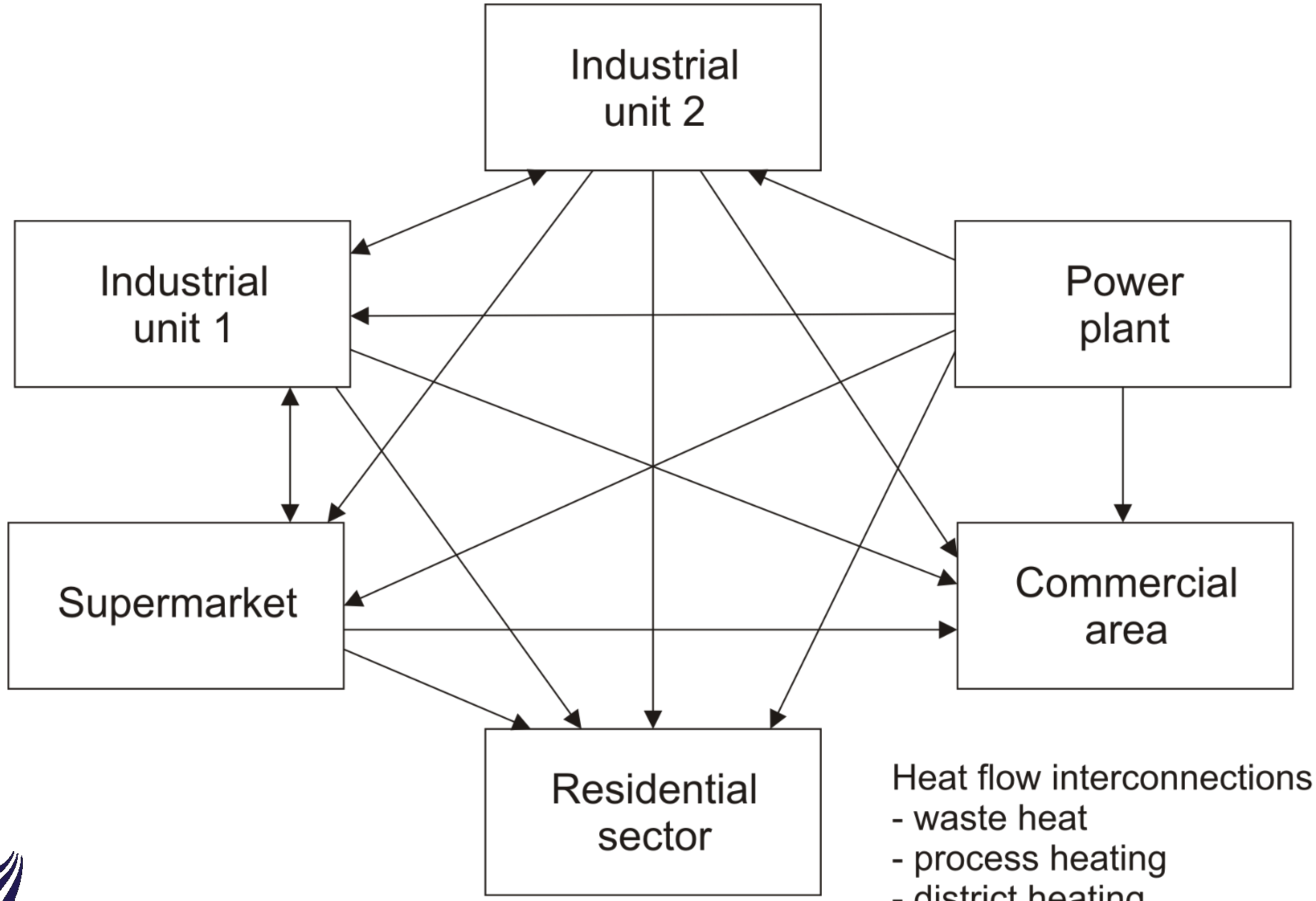
Simple site



Heat flow interconnections:
- waste heat
- process heating
- district heating
- hot water supply

Main challenges

- **Is it possible to reduce the energy consumption?**
- **How much we can save?**
- **What will be the real energy targets?**
- **How to estimate an investment level?**
- **What will be the payback time?**

Methodology

Process level

- **Data extraction**
- **Set a cost effective targets for industrial processes**
- **Waste heat identification**

Total Site level

- **Total Site Profiles**
- **Site heat recovery targeting**
- **Calculation of heat transfer area and units numbers**
- **Economic indicators**

Process level

- **Data tables**
- **Cost data**
- **Composite curves**
- **Grand Composites**

Data collection

Process A – industrial

Process B – industrial

Process C – residential and commercial area

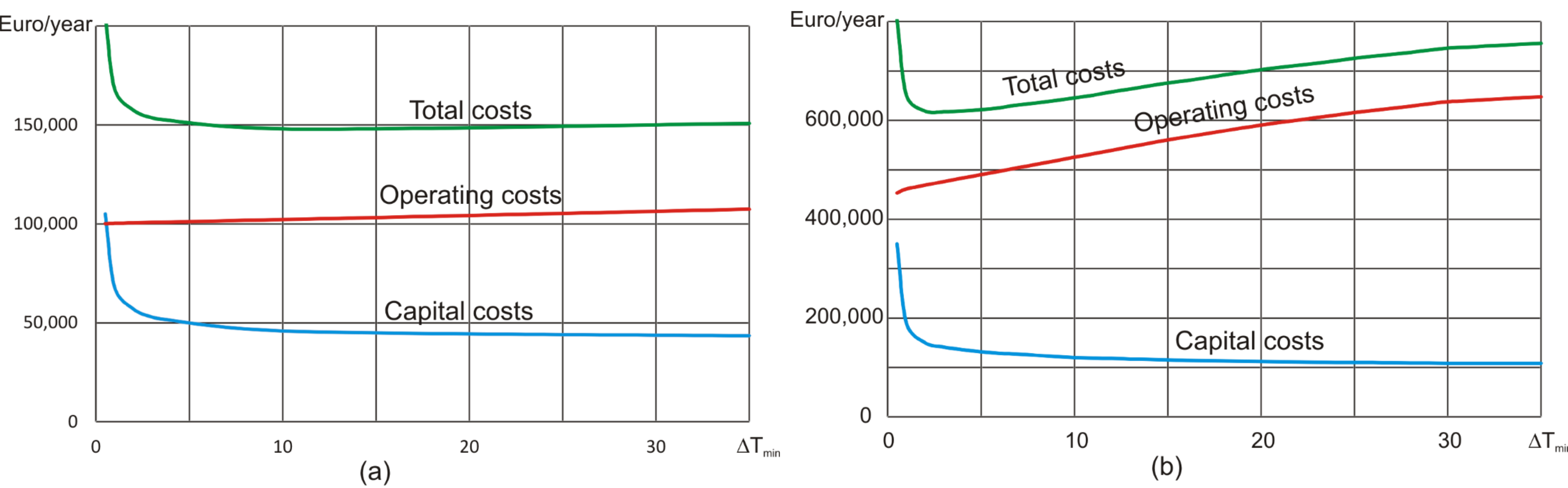
Stream	Type	TS (°C)	TT (°C)	CP (kW/°C)	ΔH (kW)	*h* (kW/(m^2 C))
Heating of power substation	cold	50	90	3.490	139.6	1.0
Hot water of residential area	cold	20	50	16.296	488.9	1.0
Hot water of commercial area	cold	20	50	6.984	209.5	1.0
Stream 6 evaporation	cold	109	109	2264*	381.11	6.0
Stream 7 evaporation	cold	114	114	2141*	703.10	6.0
Stream 8 heating	cold	55	90	2.682	93.86	0.8
Stream 9 heating	cold	60	109	2.721	133.30	0.8
Stream 10 heating	cold	50	80	1.493	44.80	1.0
Stream 11 heating	cold	20	36	18.620	298.00	1.0
Stream 12 heating	cold	45	75	11.640	349.20	1.3
Stream 13 heating	cold	75	102	5.250	141.80	1.4

* – latent heat of phase change

Data collection

- **Price of hot utility is 366 EUR/kWy (prices of natural gas 0.042 EUR/kWh)** ***[ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_and_natural_gas_price_statistics]***
- **Price cold utility is 36 EUR/kWy**
- **Specific price of heat transfer area is 800 EUR/m2**
- **Installation costs with revamp of 1 heat exchanger are 10,000 EUR**
- **The coefficient of nonlinearity of heat transfer area price is 0.87**
- **Plant life is 5 year**
- **Return on investment employed of 10%.**

Selection of optimal ΔT_{min}



Process A - ΔTmin=10 °C

Process B - ΔTmin=3 °C

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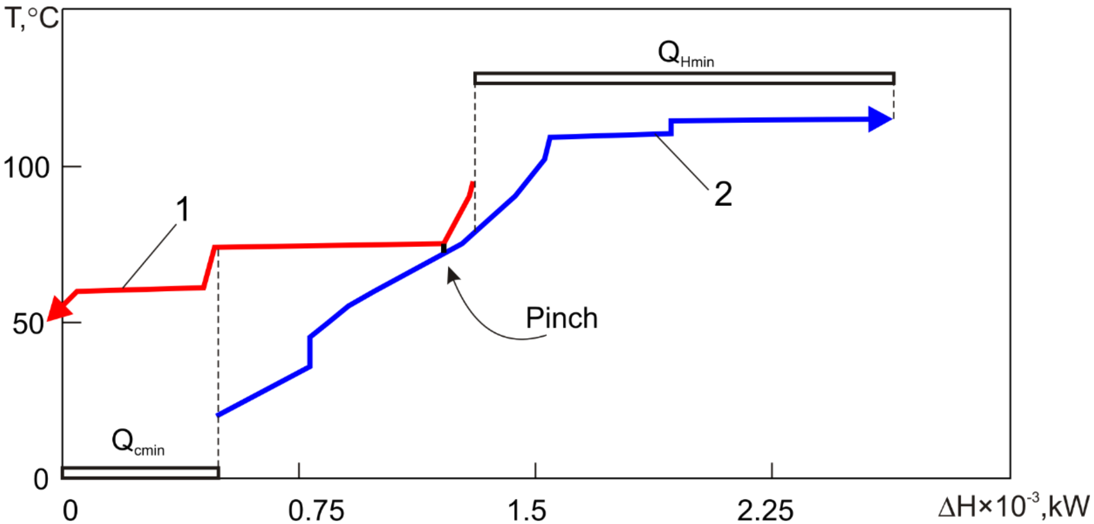
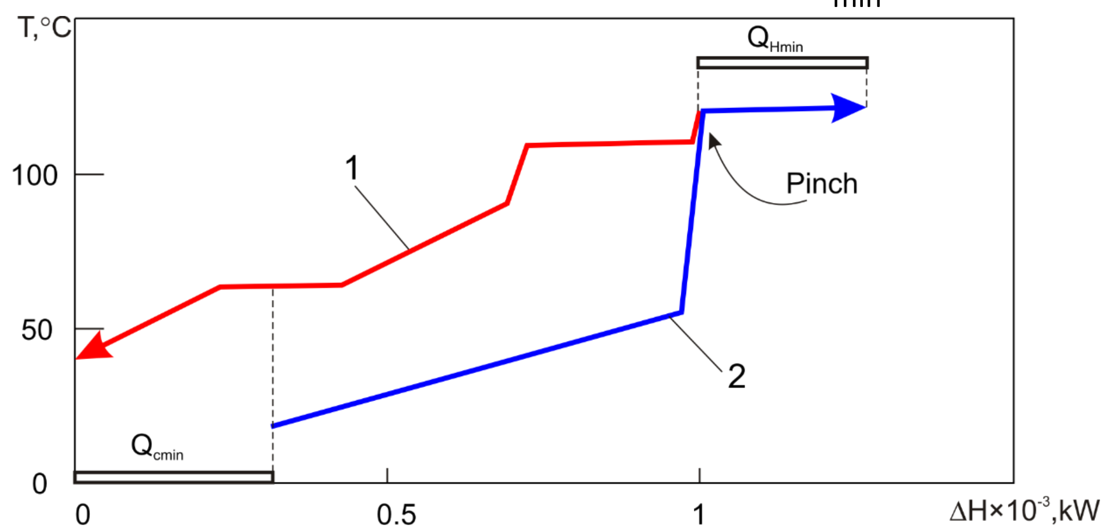
Waste heat identification



Process A - ΔT_{min}=10 °C

Process B - ΔT_{min}=3 °C



Composite curves

Qhmin – heating targets

QCmin

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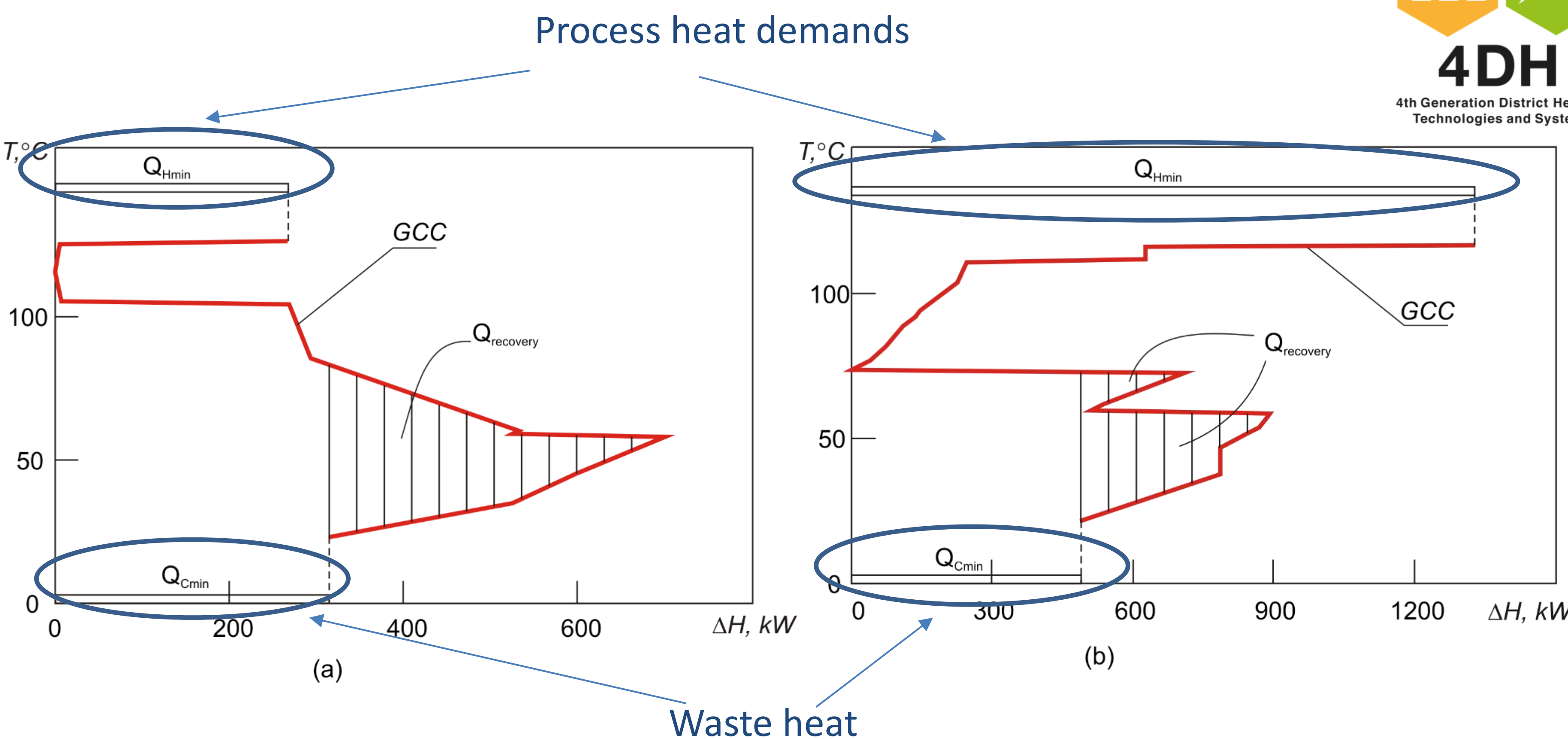
Waste heat identification

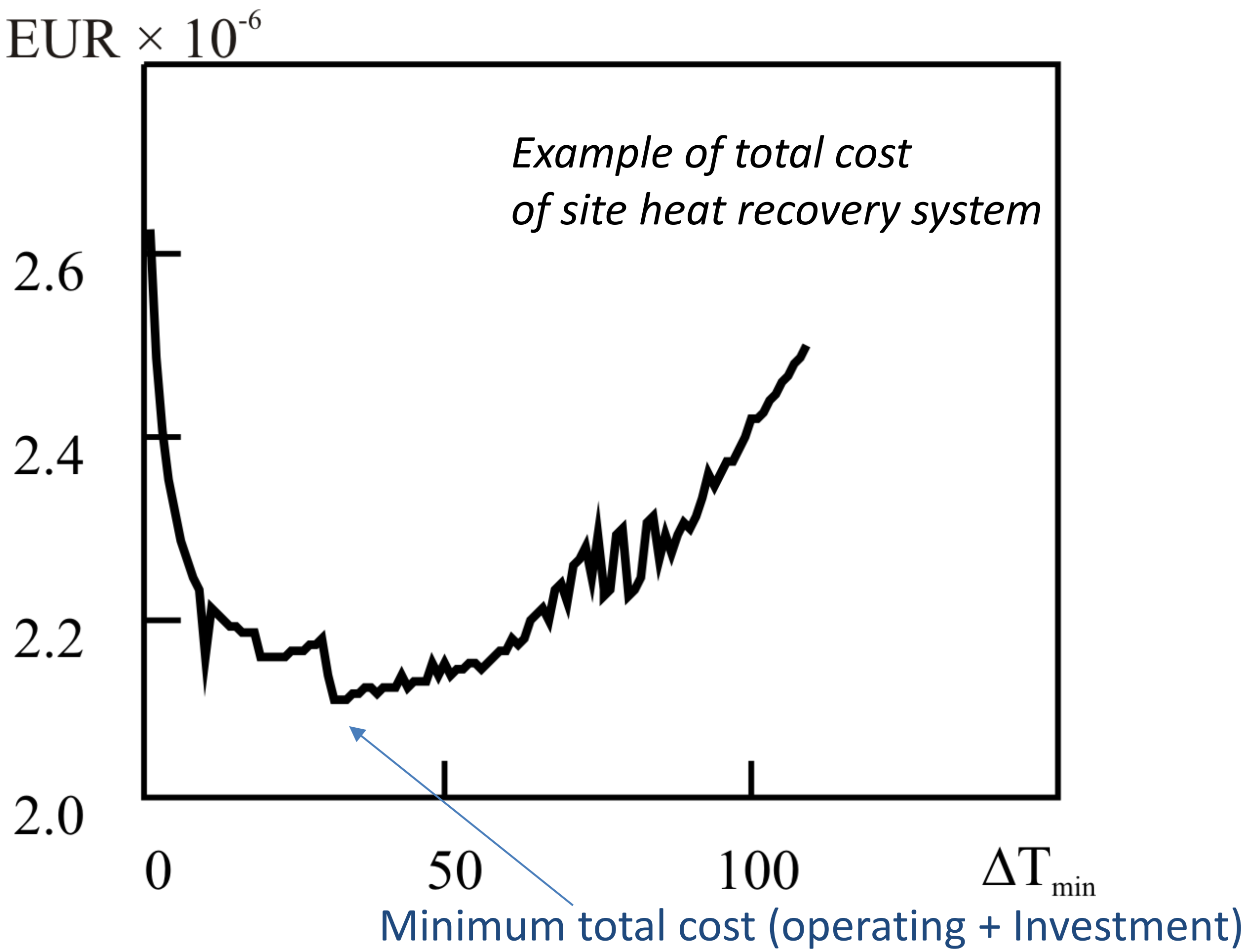


(a) – Process A, Q_{Hmin}=267 kW; Q_{Cmin}=320 kW, $Q_{recovery}$=684 kW;
(b) – Process B, Q_{Hmin}=1328 kW; Q_{Cmin}=485 kW, $Q_{recovery}$=817 kW.

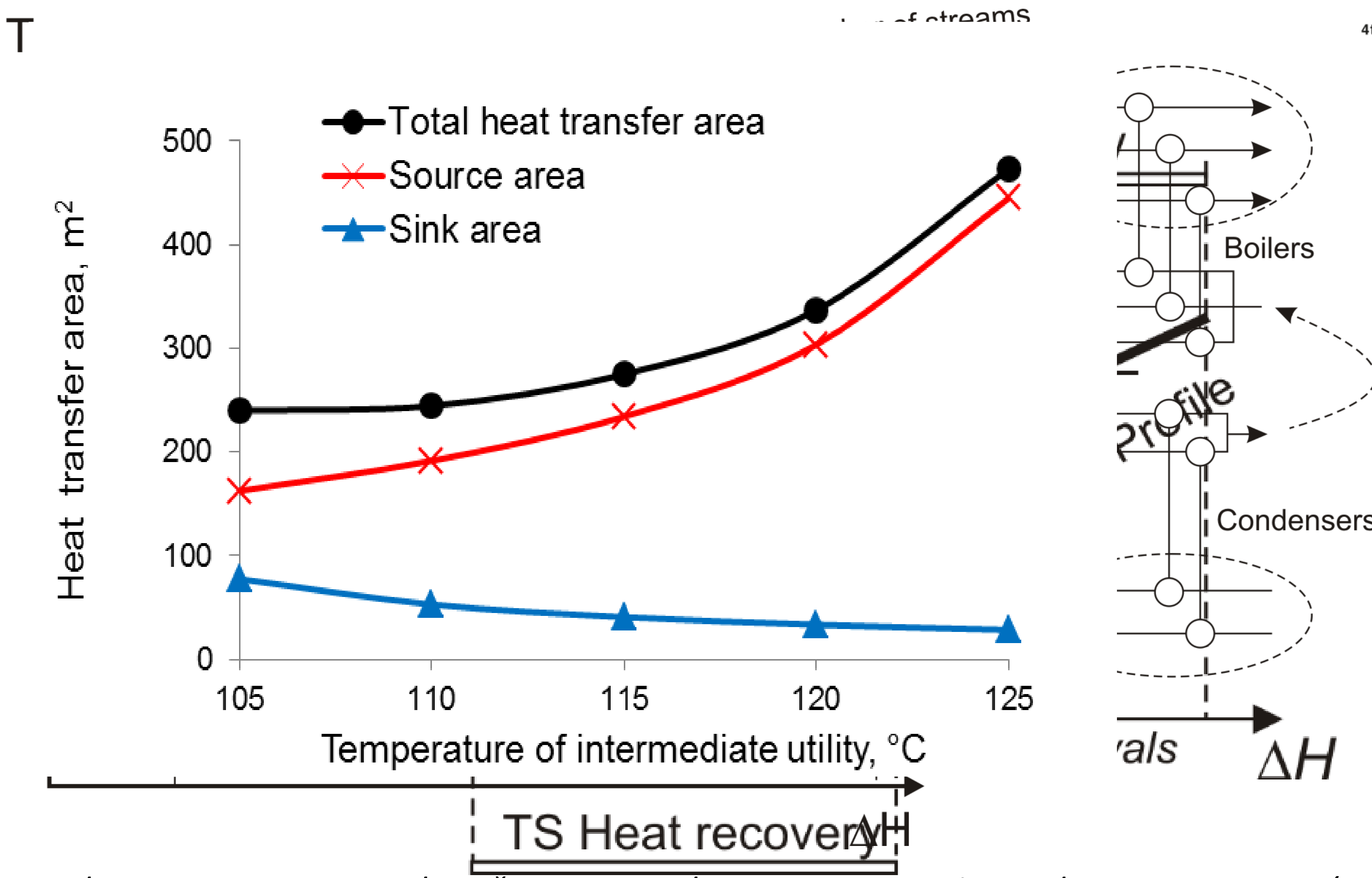
Total Site Analysis

- **TS profiles construction with use of stream data of individual processes eliminating heat recovery**
- **Set initial TS ΔT_{min} between profiles and definition enthalpy intervals created by Sink and Source Profiles**
- **Calculation HT area (IM levels) and number of units. For each enthalpy interval minimum heat transfer area and number of heat exchangers are calculated**
- **Calculation of total cost for defined heat exchangers network considering heat transfer area and number of heat exchangers**
- **Changing ΔTmin. Increasing the temperature approach between the TS Profiles and repeating the calculation procedure**
- **Selection of most profitable solution with minimum total cost**

Optimum site heat recovery



Total Site targets



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Heat transfer area and units number

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$$A_{TSCU}=\sum_{j=1}^{p}\min_{t1<t_{CU}<t2}\frac{1}{\Delta T_{LM}^{C}}\left(\sum_{i=1}^{n}\frac{Q_i}{h_i}+\frac{Q_{CU}}{h_{CU}}\right)_j$$

$$A_{TSHU}=\sum_{i=1}^{l}\min_{t1<t_{HU}<t2}\frac{1}{\Delta T_{LM}^{C}}\left(\sum_{j=1}^{m}\frac{Q_j}{h_j}+\frac{Q_{HU}}{h_{HU}}\right)_i$$

$$A_{TSHR}=\sum_{z=1}^{k}\min_{t1<t_{IM}<t2}\left(\frac{1}{\Delta T_{LM}^{H}}\left(\sum_{i=1}^{n}\frac{Q_i}{h_i}+\frac{Q_{IM}}{h_{IM}^{H}}\right)+\frac{1}{\Delta T_{LM}^{C}}\left(\sum_{j=1}^{m}\frac{Q_j}{h_j}+\frac{Q_{IM}}{h_{IM}^{C}}\right)\right)_z$$

Heat transfer area targets

$$N_{HR}=\sum_{i=1}^{k}n_i^h+n_i^c$$

$$N_{CU}=\sum_{i=1}^{p}n_i^h$$

$$N_{HU}=\sum_{i=1}^{l}n_i^c$$

Number of heat exchangers

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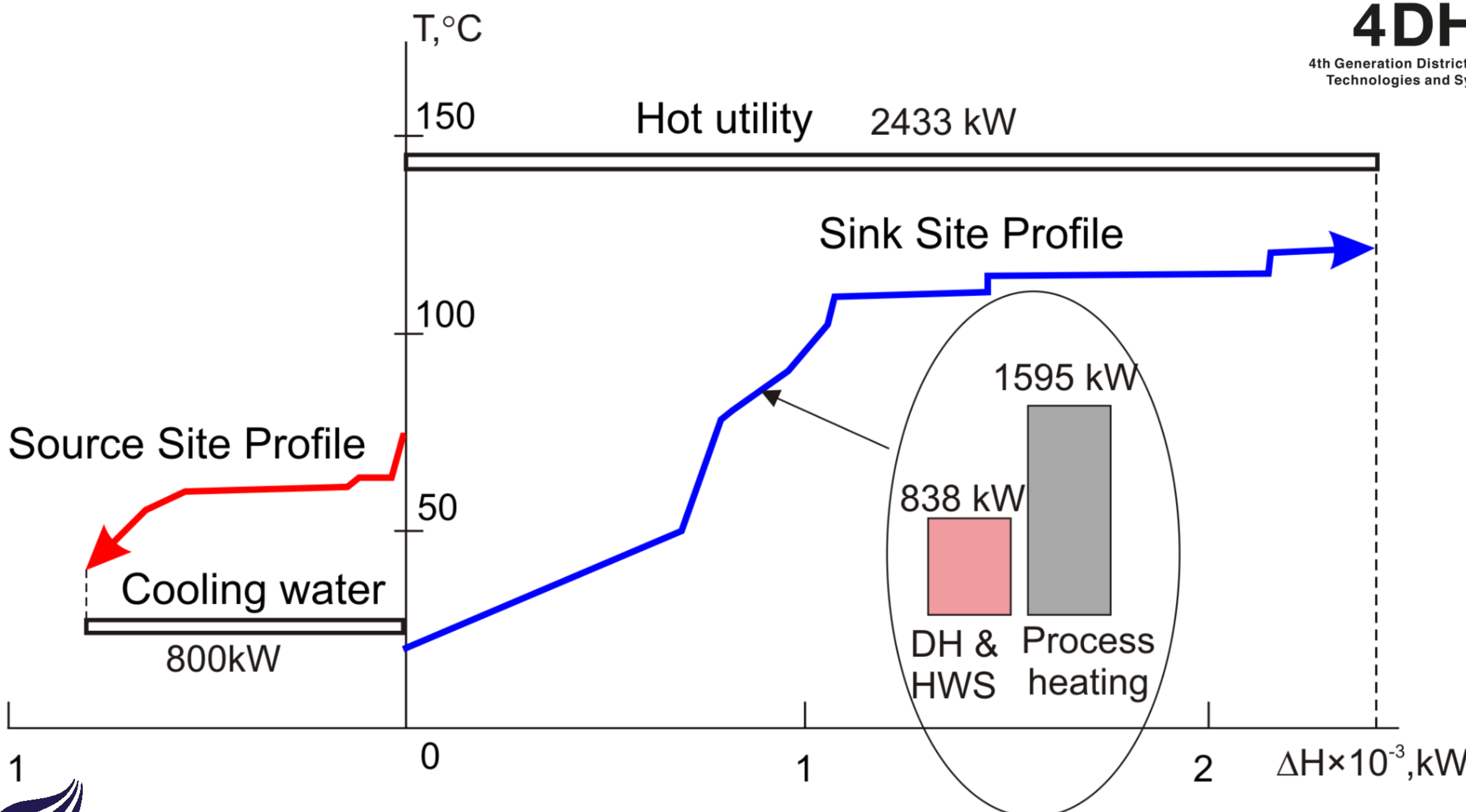
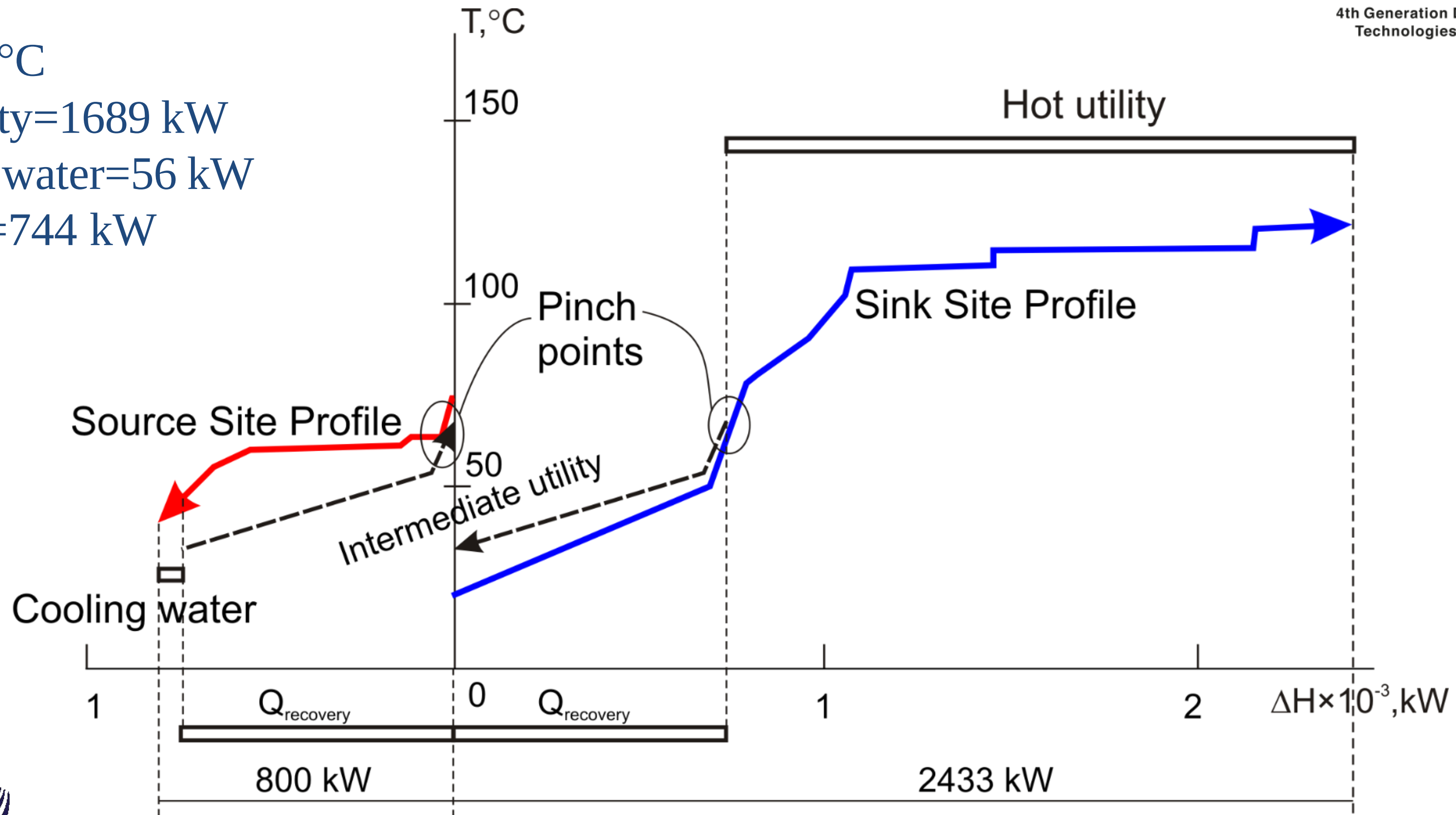
Total Site Profiles – case study



Total Site Profiles – heat recovery

ΔT_{min}=5°C
Hot utility=1689 kW
Cooling water=56 kW
$Q_{recovery}$=744 kW



Results

	Hot utility (kW)	Cold utility (kW)	Recovery (kW)	Heat transfer area, m^2	No of heat exchanger	Investment (EUR)	Saving (EUR)	Payback time (months)
Existing site	2,433	800	0	–	–	–	–	–
Retrofitted site	1,689	56	744	272	8	297,600	182,490	19,6

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Conclusion and future work

- **District heating systems can be integrated with industrial systems by Total Site Analysis**
- **Fuel consumption and harmful emmisions can be reduced by site heat recovery**
- **Heat transfer area and number of units can be targeted**
- **Conceptual design for technical realisation can be proposed**
- **Possible future integration and interactions with renewables, CHP units accounting different energy prices**
- **Potential application not only for Croatian energy systems**

Acknowledgements

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Thank you very much!

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