INTEGRATING RENEWABLE ENERGY SOURCES INTO ENERGY SYSTEMS FOR THE REDUCTION OF CARBON FOOTPRINTS

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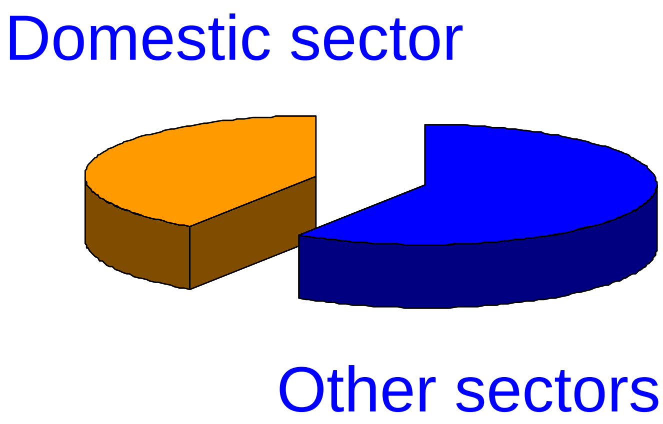
Domestic Sector Energy Use

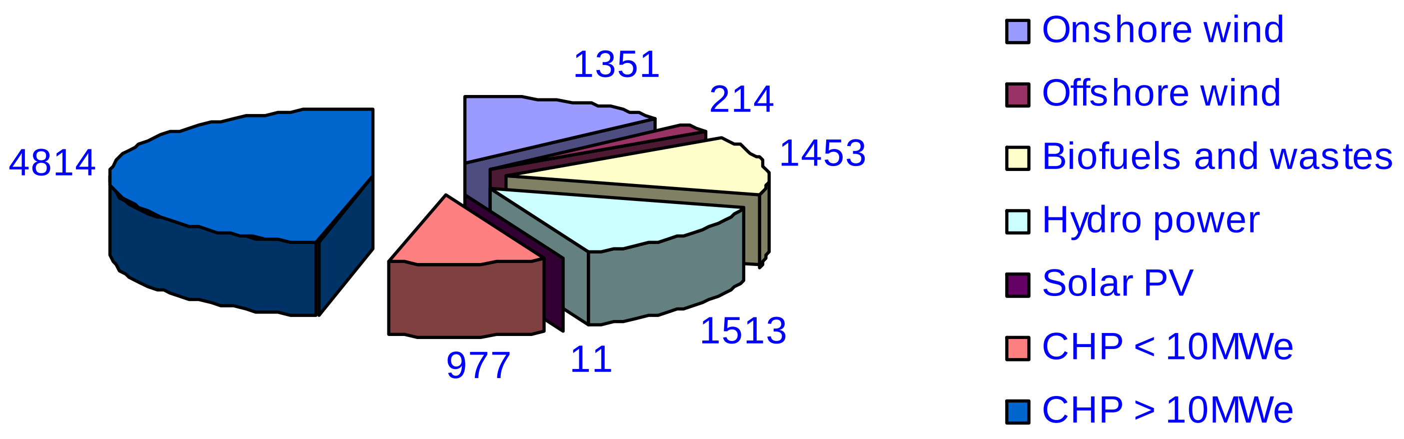


The domestic sector is responsible for around 30 % to 50 % of all energy use. This contributes considerably towards CO_2 production and should be assessed by LCA to determine its **Carbon Footprint** (**CFP**)

Domestic Sector Carbon Footprint

Carbon Footprint is defined as the total amount of CO_2 and other greenhouse gases emitted over the full life cycle of a process or product.

Technologies and their CFPs



Current Capacity of CHP and Renewable Generation in UK [MW]

Meeting the Energy Challenge A White Paper on Energy, May 2007
Department of Trade and Industry, UK

µCHP

Annual reduction in CO_2 emissions	[$kgCO_2$]
Stirling engine – unrestricted thermal surplus (1 kW system)	- 145 (+3%)
Stirling engine – restricted thermal surplus (1 kW system)	+ 574 (-10%)
Stirling engine – restricted thermal surplus and part-load capacity (1 kW system)	+ 512 (-9%)
Fuel cell (1 kW)	+ 892 (-16%)
Fuel cell (3 kW)	+ 2247 (-40%)

A.D Peacock., M. Newborough: Impact of micro-CHP systems on domestic sector CO_2 emissions, Applied Thermal Engineering 25, 2005, 2653–2676

Vollrad Kuhn, Jiří Klemeš, Igor Bulatov: ***MicroCHP: Overview of selected technologies, products and field test results, Applied Thermal Engineering, 28 (16), November 2008, 2039-2048***

Biomass

In the UK, the carbon footprint of biomass can vary widely depending on the kind of the feedstock:
25 gCO_2/kWh (high-density wood gasification) to
93 gCO_2/kWh (combustion of low density miscantus).

Parliamentary Office for Science and Technology (POST), 2006. Carbon Footprint of Electricity Generation

MARIE CURIE ACTIONS

Contribution to CFP in gCO_2/kWh primary energy

Origin of biomass	Germany	Baltic	Sweden	Russia	Canada
Palletising	11	13	15	20	13
Local transport	1	1	2	2	2
Sea/River transport	4	6	5	7	15
River transport	2	2	2	2	2
TOTAL	**18**	**22**	**24**	**31**	**32**

Ryckmans Y. 2007. Biomass sustainability certification in Belgium, presentation at IEA Bioenergy Task 40 and EUBIONET 2 Joint Workshop, Rotterdam, The Netherlands

Solar

For building integrated PV systems, the total LC emissions of CO_2 are between 13 - 731g CO_2 per kWh produced (depending mainly on PV cell technology). Life cycle CO_2 emissions for UK PV power systems are currently 58 gCO_2eq/kWh.

NB Dependent on the geographical location: in South European countries, the CFP can be about 35gCO_2eq/kWh, due to more sunlight, longer operating hours and higher energy output

www.nei.org/index.asp?catnum=2&catid=260, accessed 12/09/2008

Wind

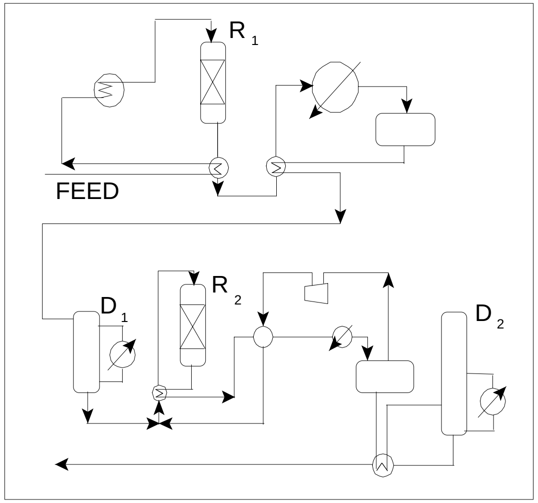
Wind generated electricity has one of the lowest CFPs. Manufacturing and construction account for almost all of the carbon emissions, the rest being maintenance. In the UK, a typical wind generation CFP is about 4.64 gCO_2eq/kWh. The availability should be also taken into consideration, and in most cases is rarely above 20 - 30 %. Back-up systems increase the effective CFP.

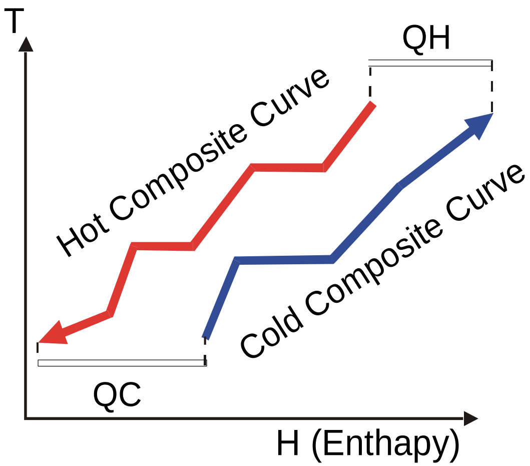
Parliamentary Office for Science and Technology (POST), 2006. Carbon Footprint of Electricity Generation

CFPs of the some technologies

Technology	CFP [gCO_2eq/kWh]	Factors
Coal large scale	**790 - 830**	Power station type, coal quality, distance from the source, mine type, efficiency, emission treatment
Gas large scale	**400 - 420**	Power station type, distance from the source of gas, gas extraction, efficiency, emission treatment
μCHP gas	**200 - 250**	Materials used, type of CHP and its efficiency, type of fuel, distance from the manufacturer, maintenance
Biomass	**25 - 93**	Distance from the source of biomass, type of the transport used, type of biomass, type of combustions process, its efficiency, emission (e.g. NO_X) treatment
Solar	**30 – 80** (backup not included)	Geographical location to sun, distance from the manufacturer, type of Solar Cells and their efficiency, materials used, maintenance needed, backup
Wind	**2 – 8** (backup not included)	Location related to wind, place of installation, distance to the manufacturer, maintenance needed related to the environment, back-up

Existing Process Integrating Technologies





Process Integration is a long-established technology initially developed (Centre for Process Integration, The University of Manchester) for single process analysis, design and understanding

Linnhoff, B. and D. R. Vredeveld, 1984, Pinch Technology has Come of Age, Chemical Engineering Progress, July 1984, 33-40.

Existing Process Integrating Technologies (Cont.)

It was further developed bringing in new concepts and methodologies have combined thermodynamics and mathematical modelling into an integrated systematic approach to the design and analysis of small and large energy based systems.

Klemeš, J., V. R. Dhole, K. Raissi, S.J. Perry and L. Puigjaner, 1997, Targeting and Design Methodology for Reduction of Fuel, Power and CO2 on Total Sites, Applied Thermal Engineering, 17, 993 - 1003

Varbanov, P., S. Doyle and R. Smith, 2004, Modelling and Optimisation of Utility Systems, Chemical Engineering Research and Design, 82, 561-578.

Varbanov, P., S. Perry, Y. Makwana, X X Zhu and R. Smith, 2004, Top-Level Analysis of Site Utility Systems, Chemical Engineering Research and Design, 82(A6), 784-795.

Varbanov, P., S. Perry, J. Klemeš and R.Smith, 2005, Synthesis of industrial utility systems: cost-effective de-carbonisation, Applied Thermal Engineering, 25, 985 – 1001.

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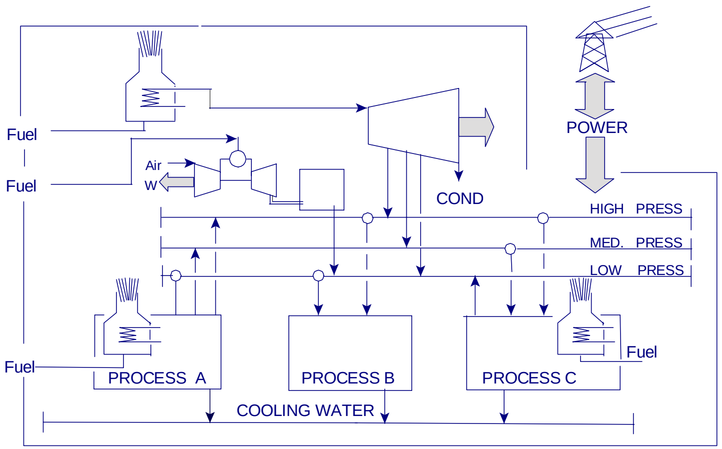
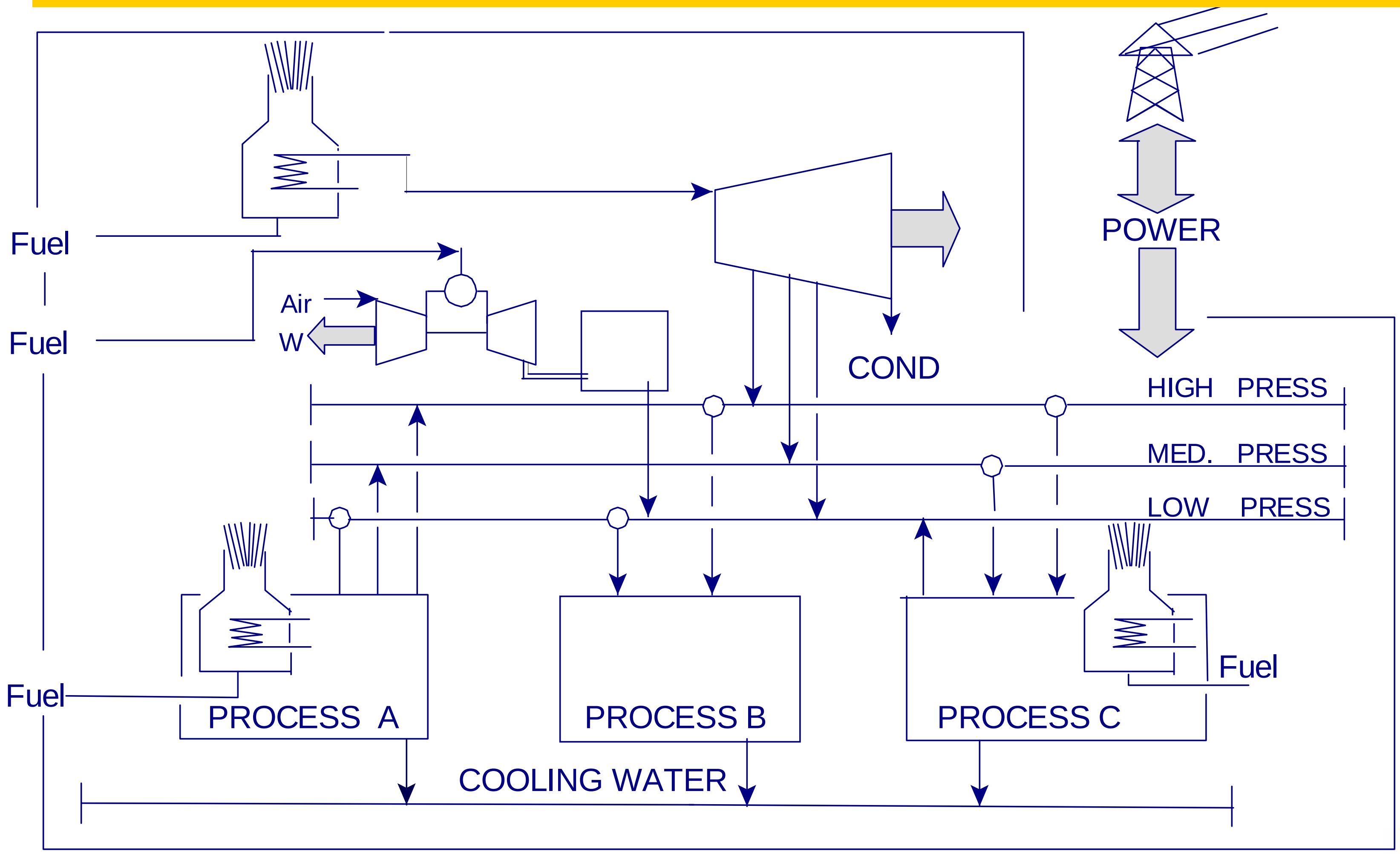
Existing Process Integrating Technologies (Cont.)



A typical industrial site comprises different process production units linked to a common utility system The centralised utility system meets the demands for heat and power, creating indirect links between the processes.

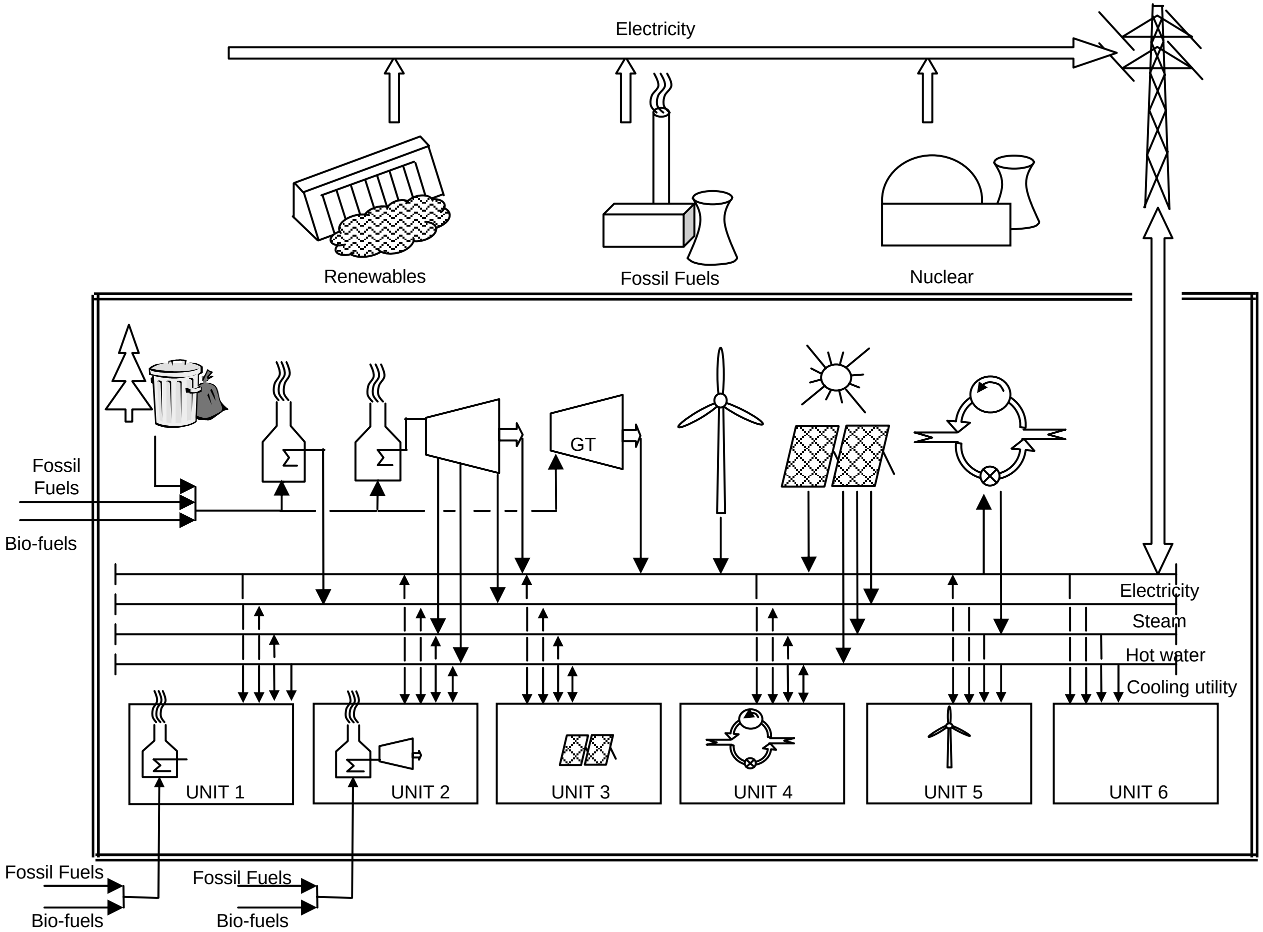
A typical industrial site



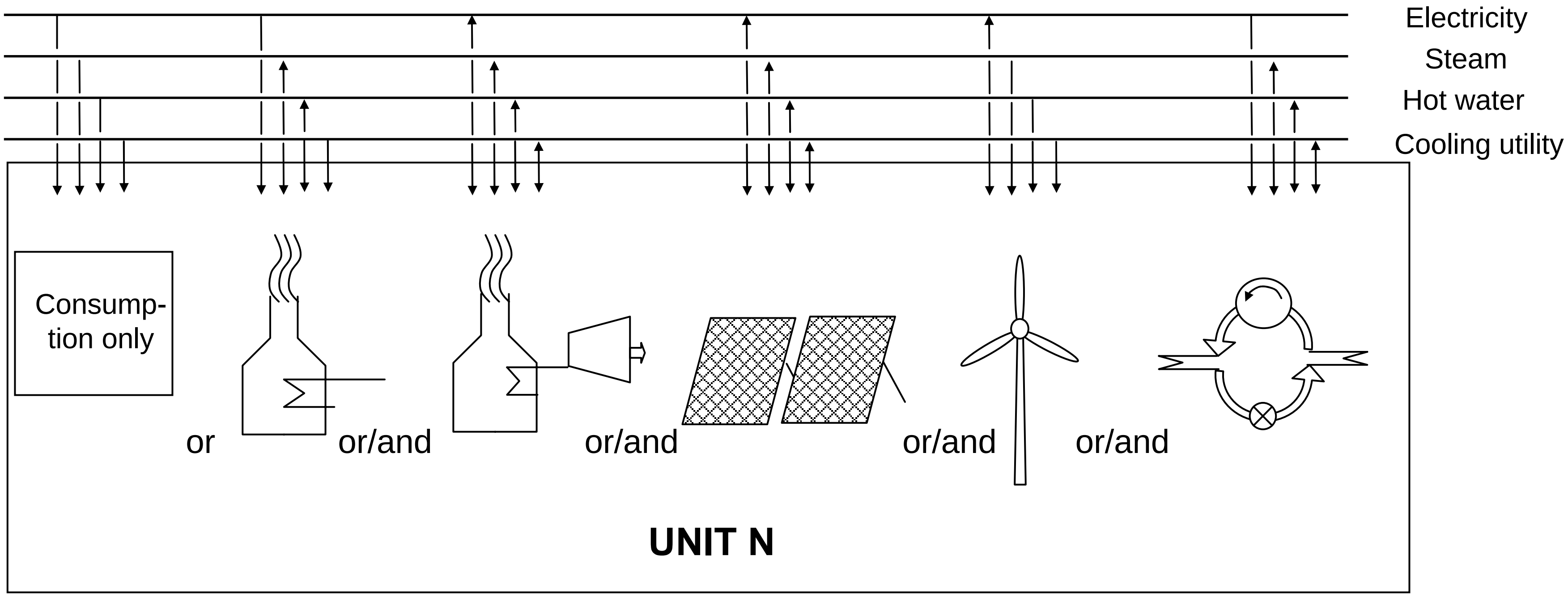
Integrating Micro Renewable Energy Sources

The concept of an integrated energy system for the production of heat and power meeting local needs can be applied to systems involving demands produced by individual buildings and building complexes

Integrating Micro Renewable Energy Sources

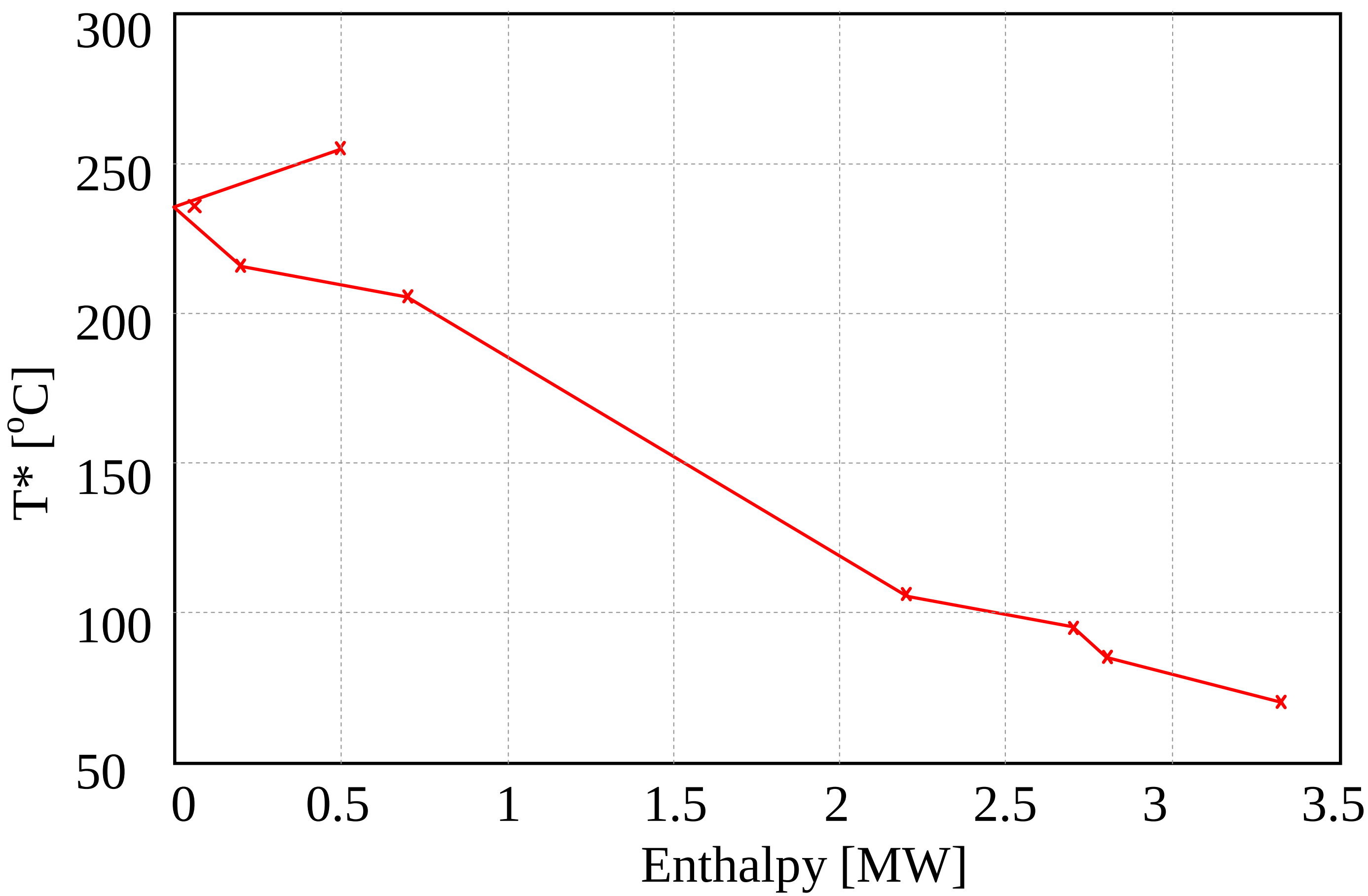


Integrating Micro Renewable Energy Sources

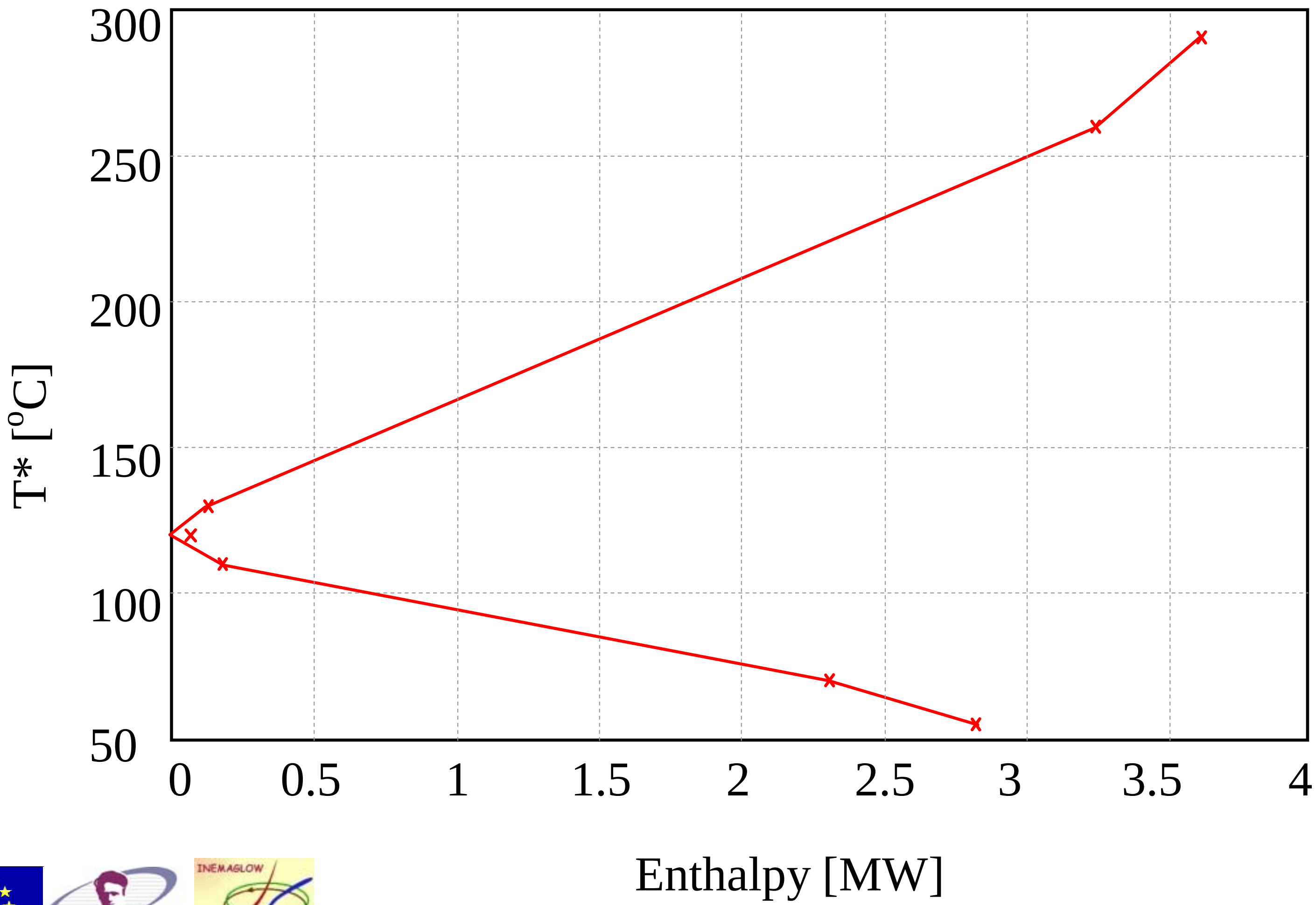


Energy consumption/generation within a unit N

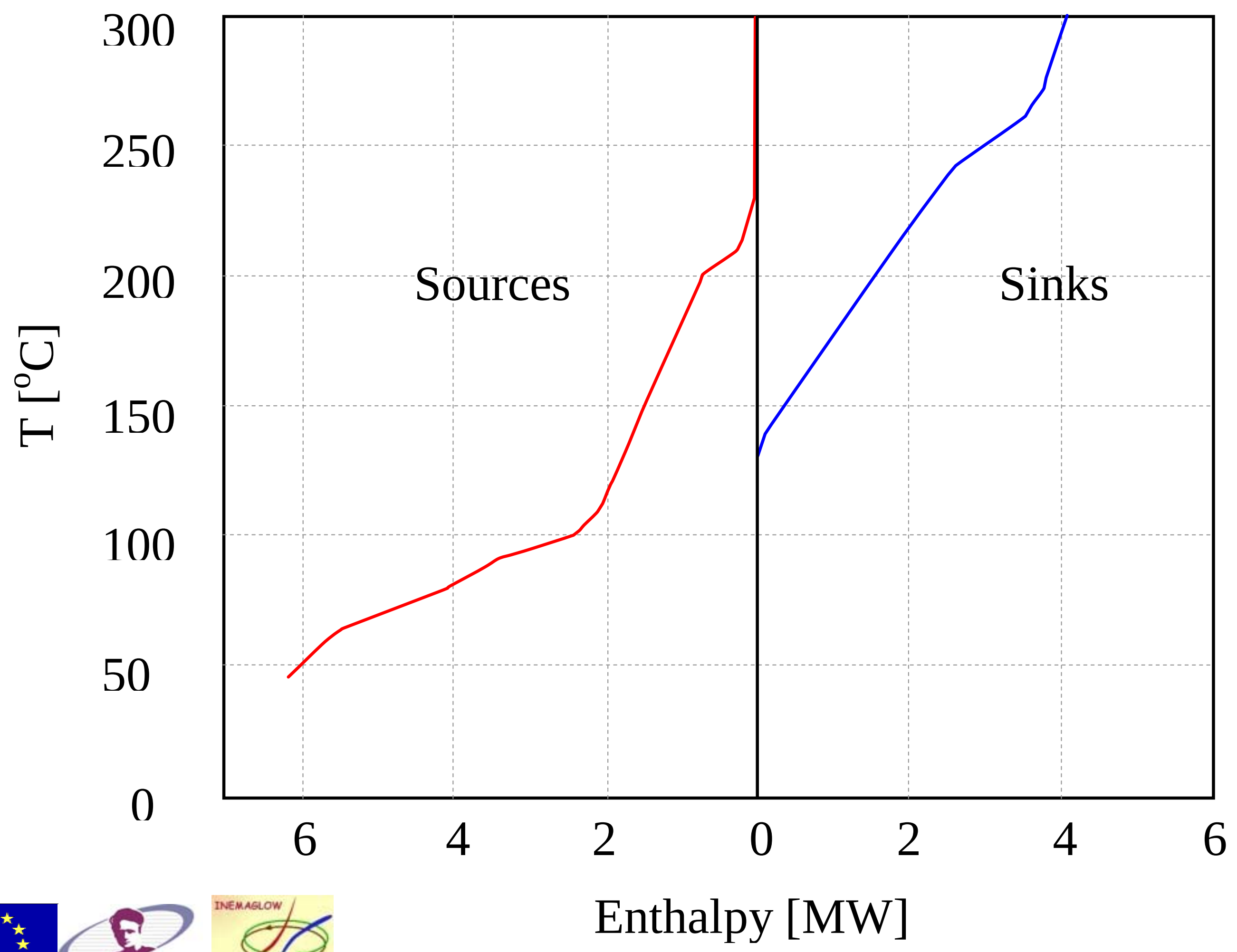
Plant 1: Grand Composite Curve with ΔT_{min} = 10ºC



Plant 2: Grand Composite Curve with ΔT_{min} = 20ºC



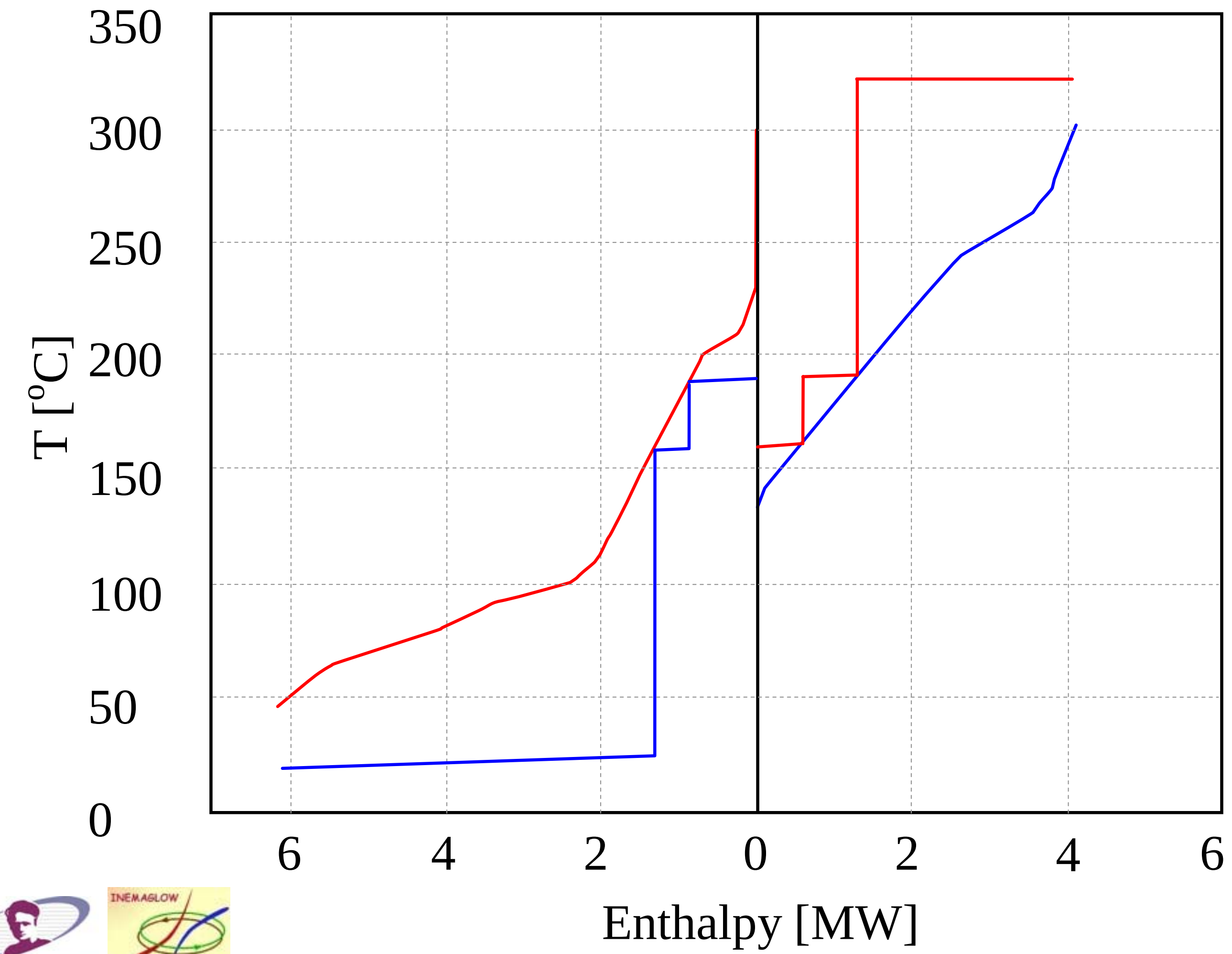
Site Profiles



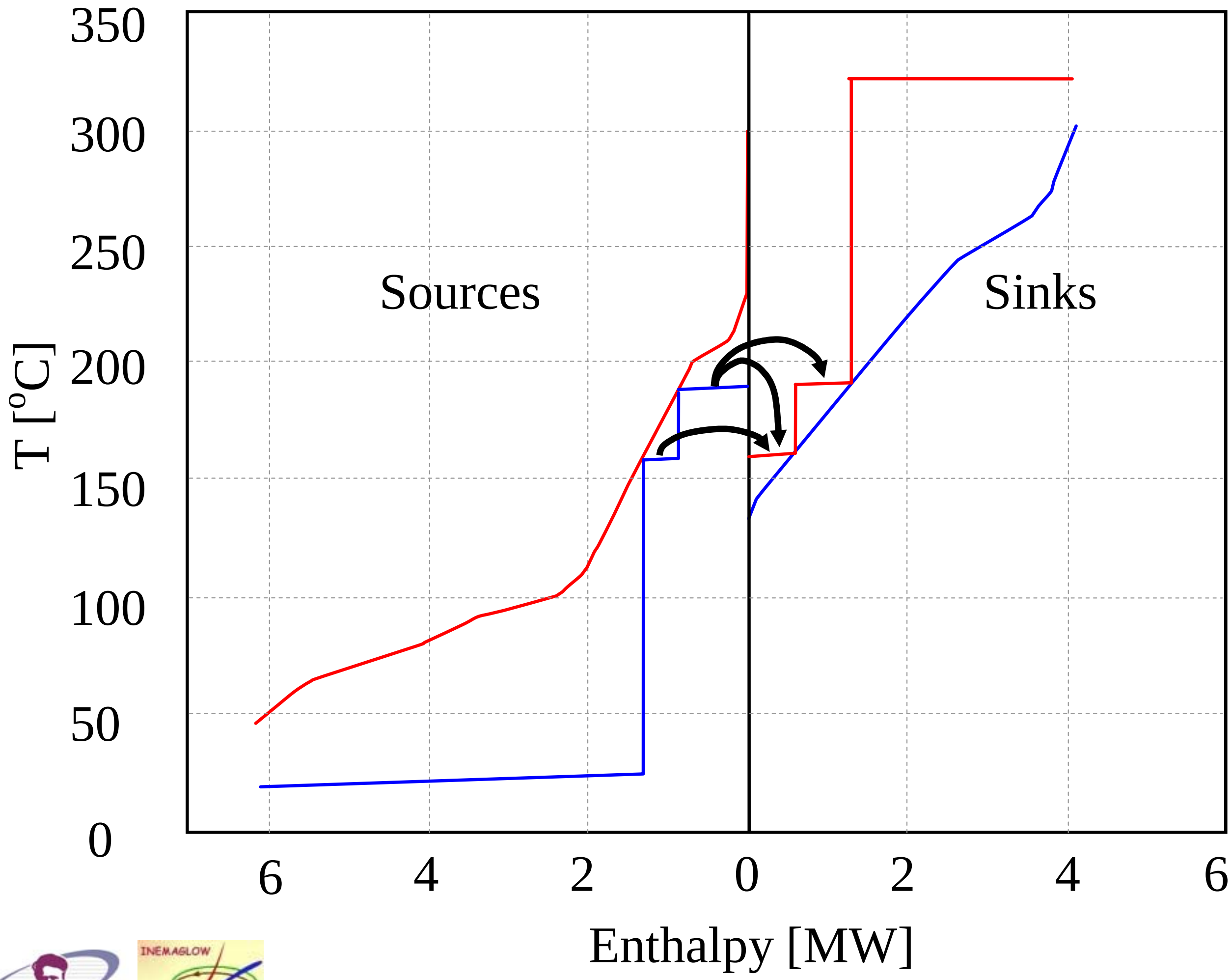
Utilities and their parameters

Steam Main	Saturation Temperature [°C]	Used load [MW]	Generated Load [MW]
VHP	320	2.78	0
HP	190	0.72	0.87
MP	160	0.6	0.45
CW	25	4.83	0

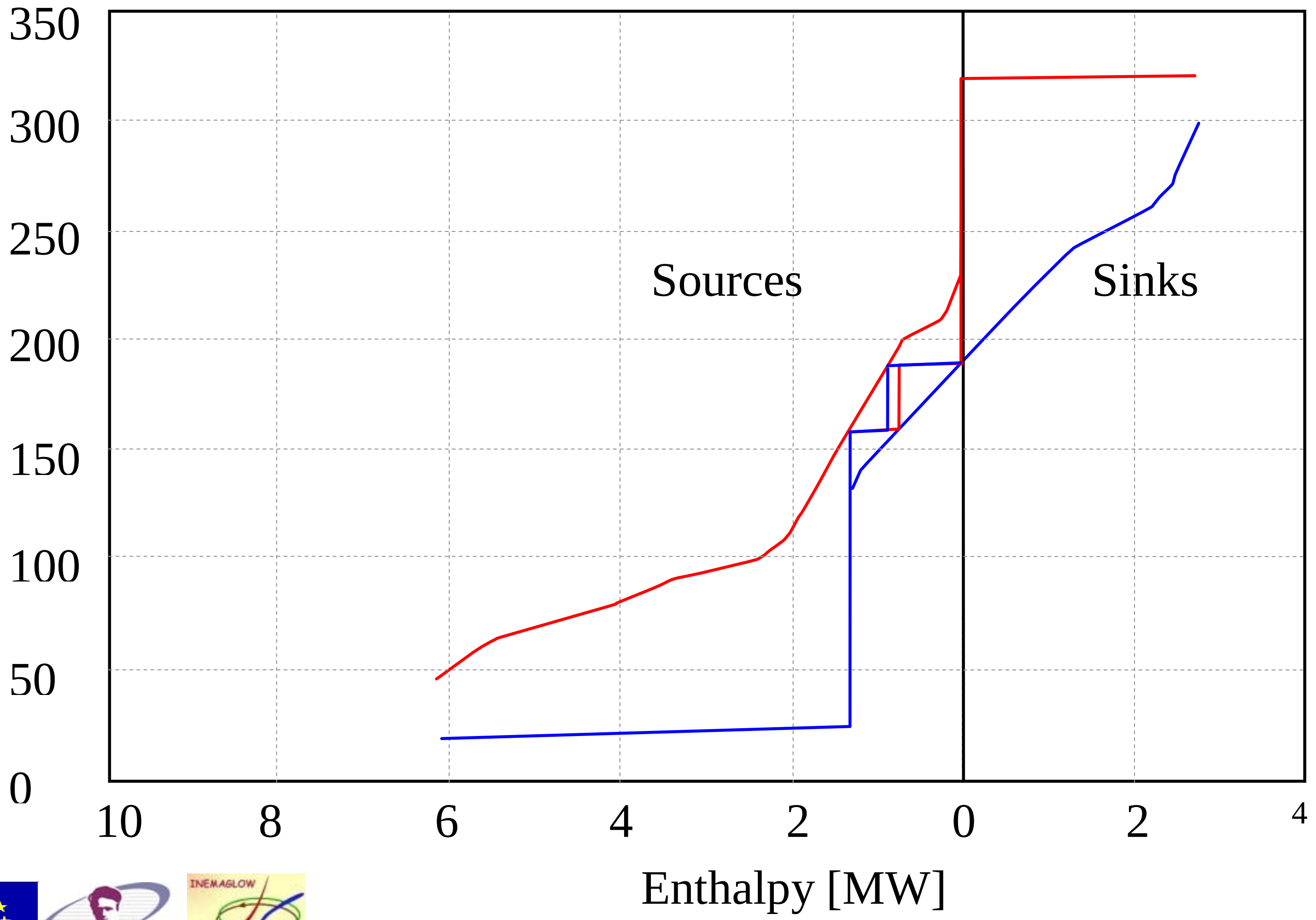
Total Site Profiles



Total Site Profiles with potential steam heat recovery



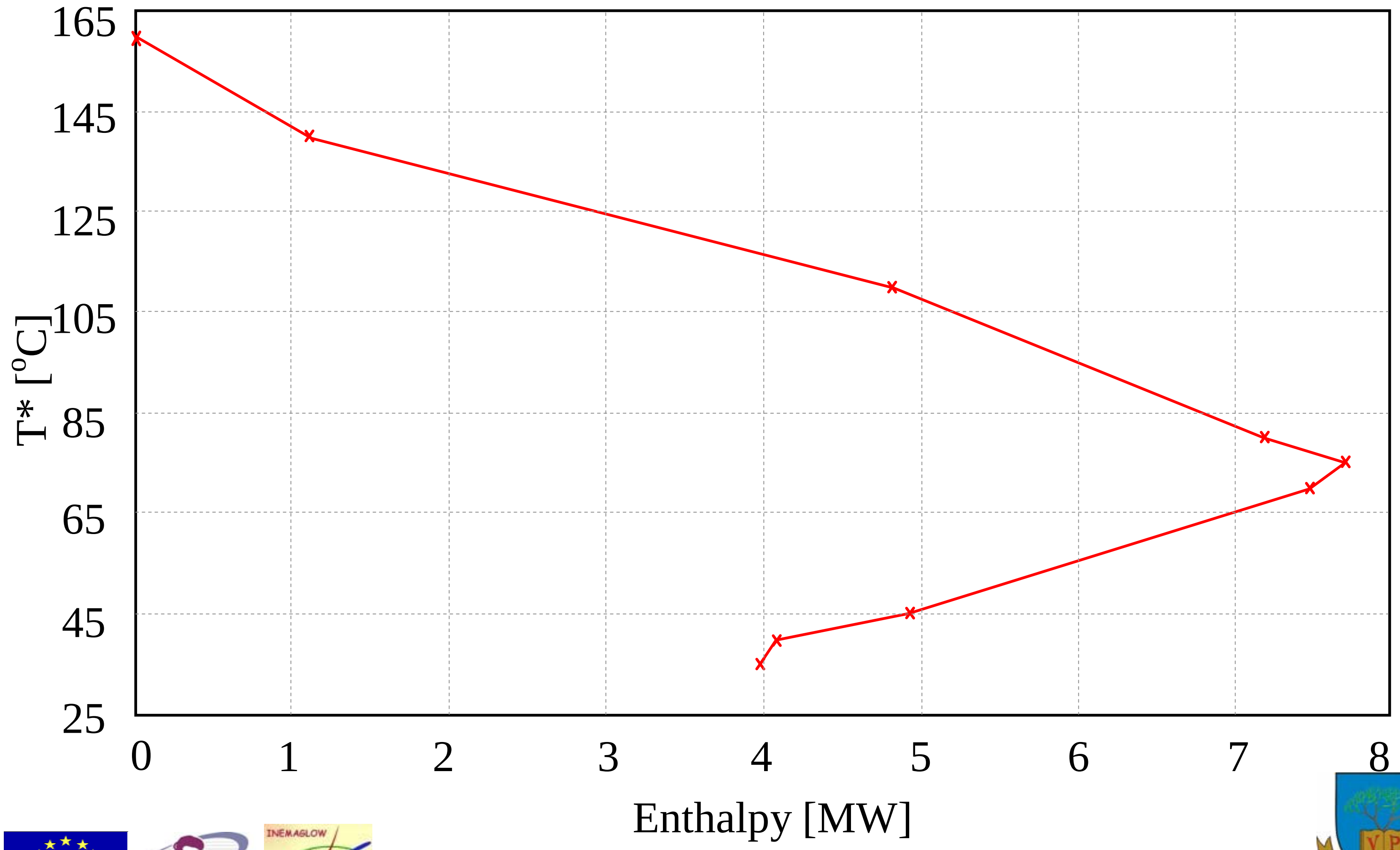
Total Site Profiles with steam heat recovery



Process plant A stream data

Stream	Name	Tsupply [^oC]	T target [^oC]	DH [MW]	CP [kW/^oC]
1 Hot	A2	170	80	5.000	55.5556
2 Hot	A1	150	55	6.477	68.1818
3 Cold	A5	25	100	1.500	20.0000
4 Cold	A6	70	100	0.750	35.0000
5 Cold	A7	30	65	5.250	150.0000

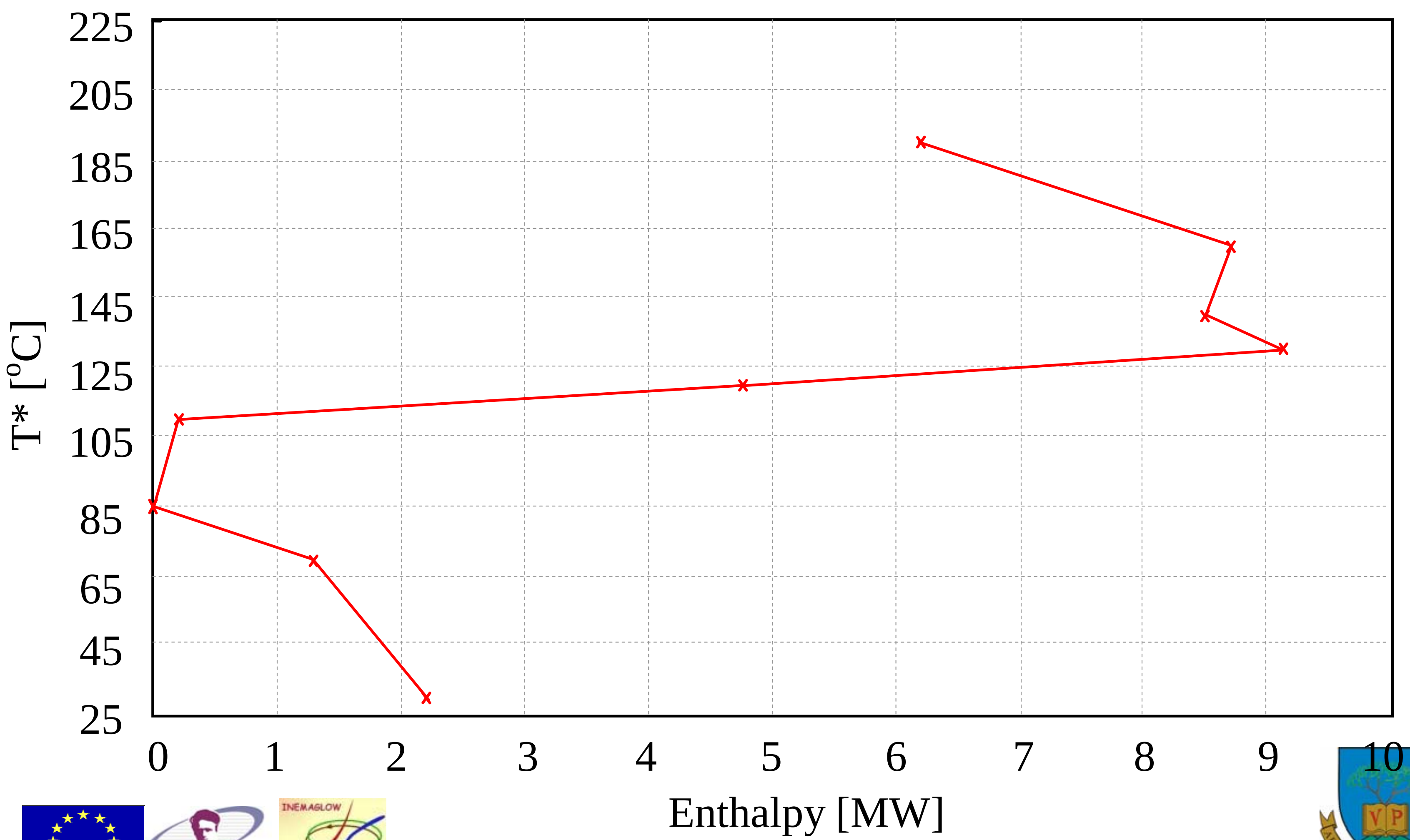
Process Grand Composite
Process Plant A (ΔT_{min} = 20 °C)



Process plant B stream data

Stream	Name	Tsupply [^oC]	T target [^oC]	DH [MW]	CP [kW/^oC]
1 Hot	B1	200	80	10.000	83.3333
2 Cold	B2	20	100	4.000	50.0000
3 Cold	B3	100	120	10.000	500.0000
4 Hot	B4	150	40	8.000	72.7273
5 Cold	B5	60	110	1.000	20.0000
6 Cold	B6	75	150	7.000	93.3333

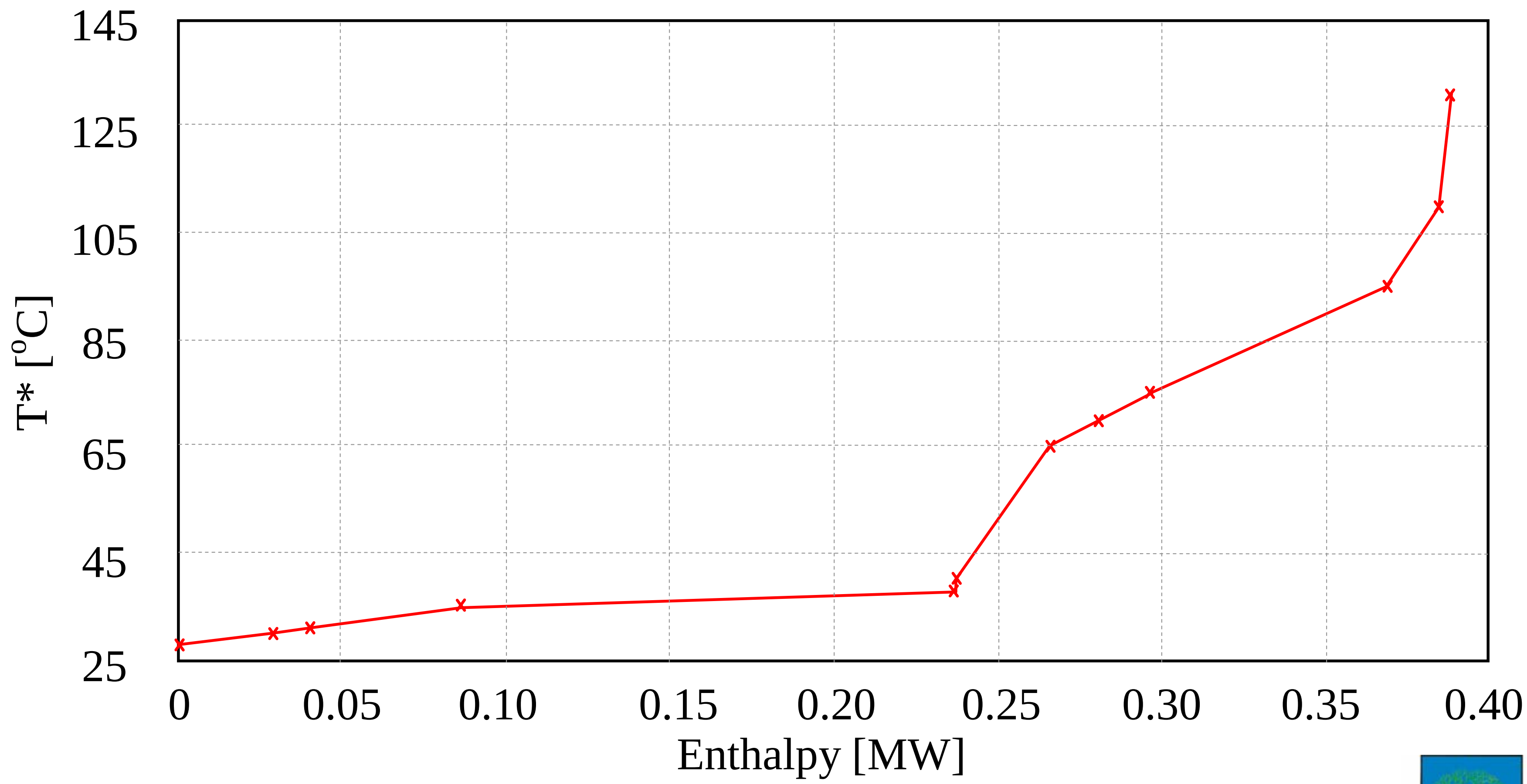
Process Grand Composite
Process Plant B (ΔT_{min} = 20 °C)



Stream data of a hospital (Plant C)

Stream	Name	T supply [^oC]	T target [^oC]	DH [kW]	CP [kW/^oC]
1 Hot	Soapy water	85	40	23.85	0.53
2 Hot	Condensed steam	80	40	96.4	2.41
3 Cold	Laundry sanitary water	25	55	17.7	0.59
4 Cold	Laundry	55	85	77.4	2.58
5 Cold	Boiler feed water	33	60	7.2	0.24
6 Cold	Sanitary water	25	60	77	2.2
7 Cold	Sterilization	30	121	12.74	0.14
8 Cold	Swimming pool water	25	28	151.68	50.56
9 Cold	Cooking	30	100	59.5	0.85
10 Cold	Heating	18	25	100.8	14.4
11 Cold	Bedpanwashers	21	121	5	0.05

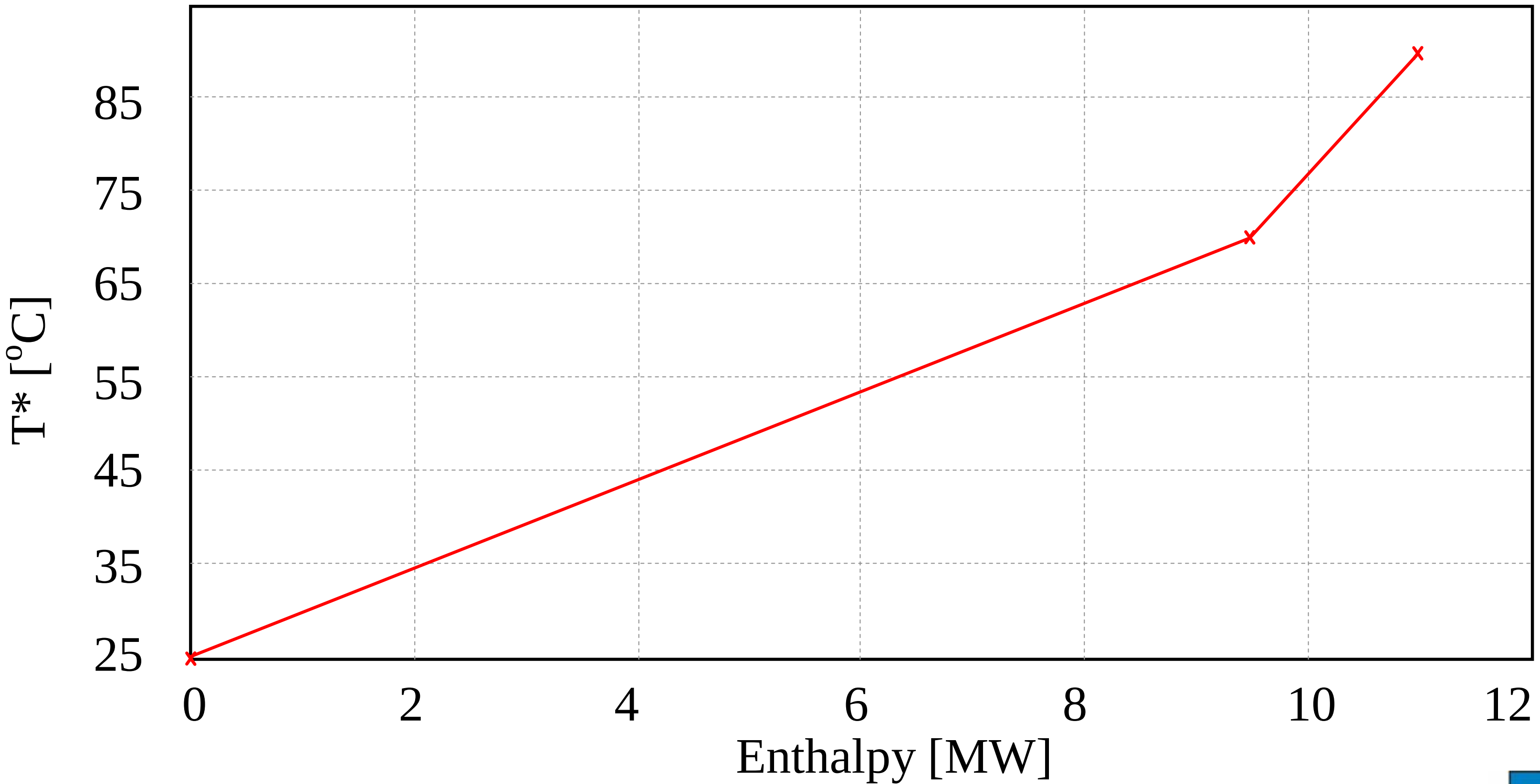
Process Grand Composite of a hospital complex (Plant C, ΔT_{min} = 20 °C)



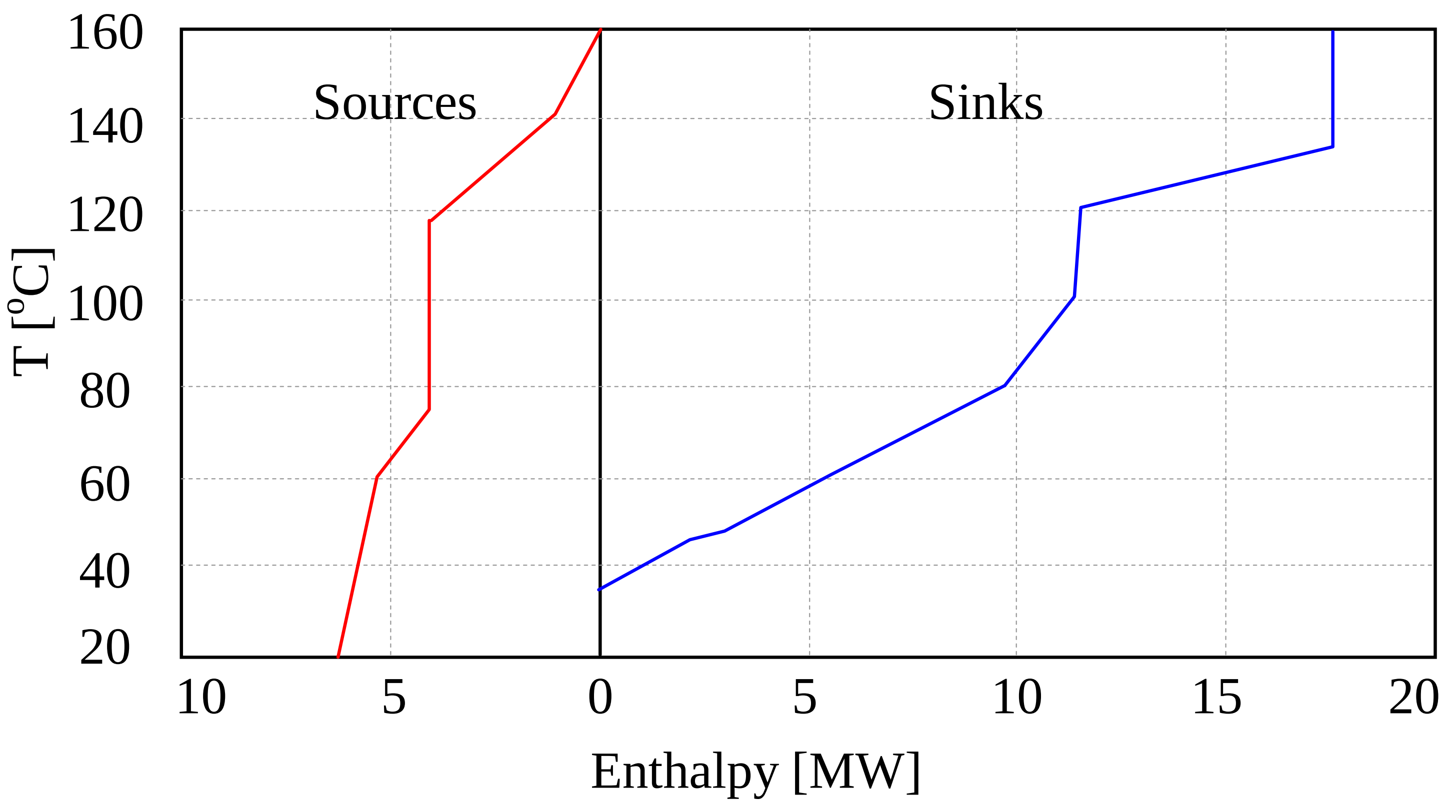
Process Stream data of residential and office complex (Plant D)

Stream	Name	T supply [^{0}C]	T target [^{0}C]	DH [MW]	CP [kW/^{0}C]
1 Hot	District heating	15	60	6.000	133.333
2 Hot	Hot water	15	80	5.000	76.9232

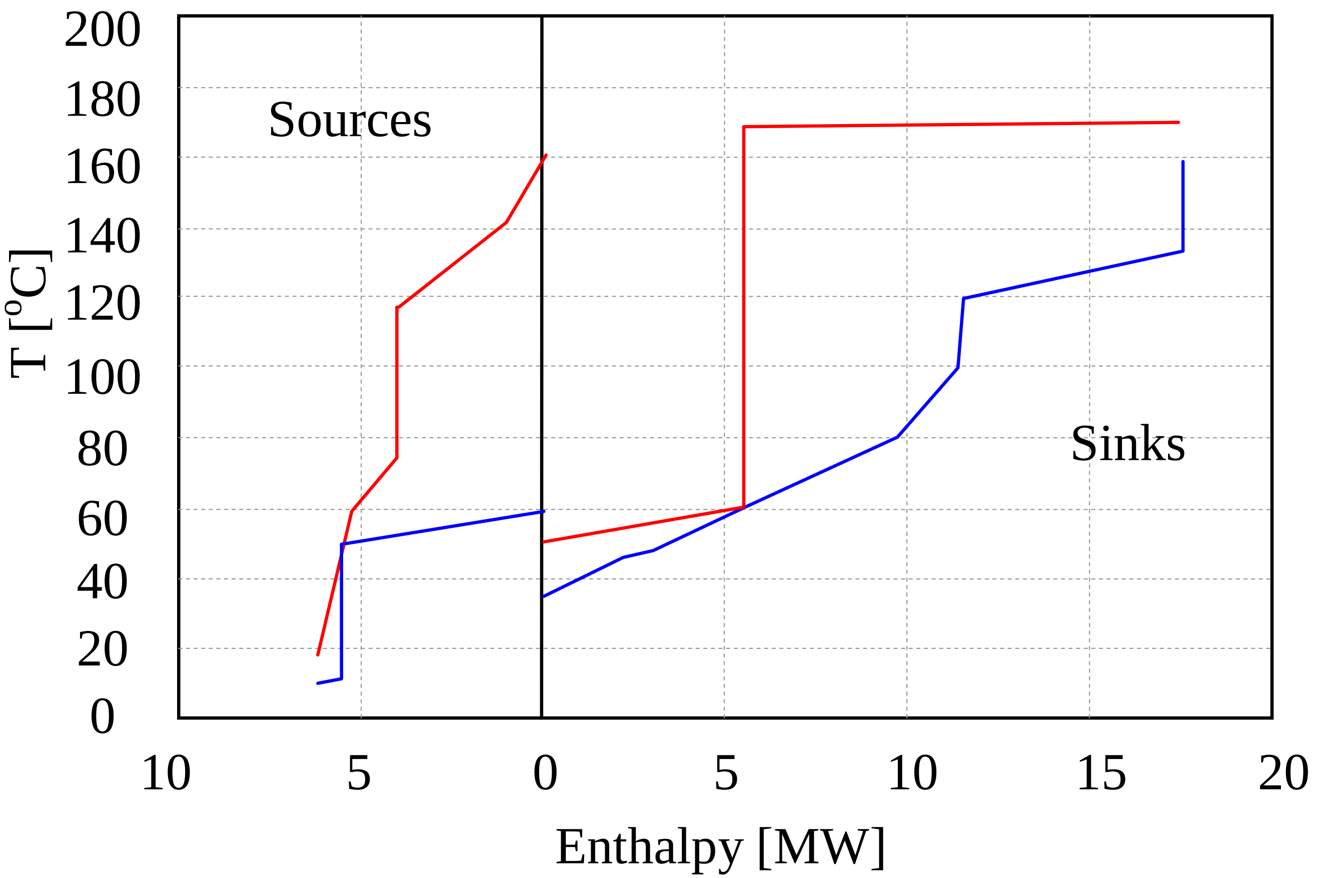
Process Grand Composite of residential and office complex (Plant D, ΔT_{min} = 20 °C)



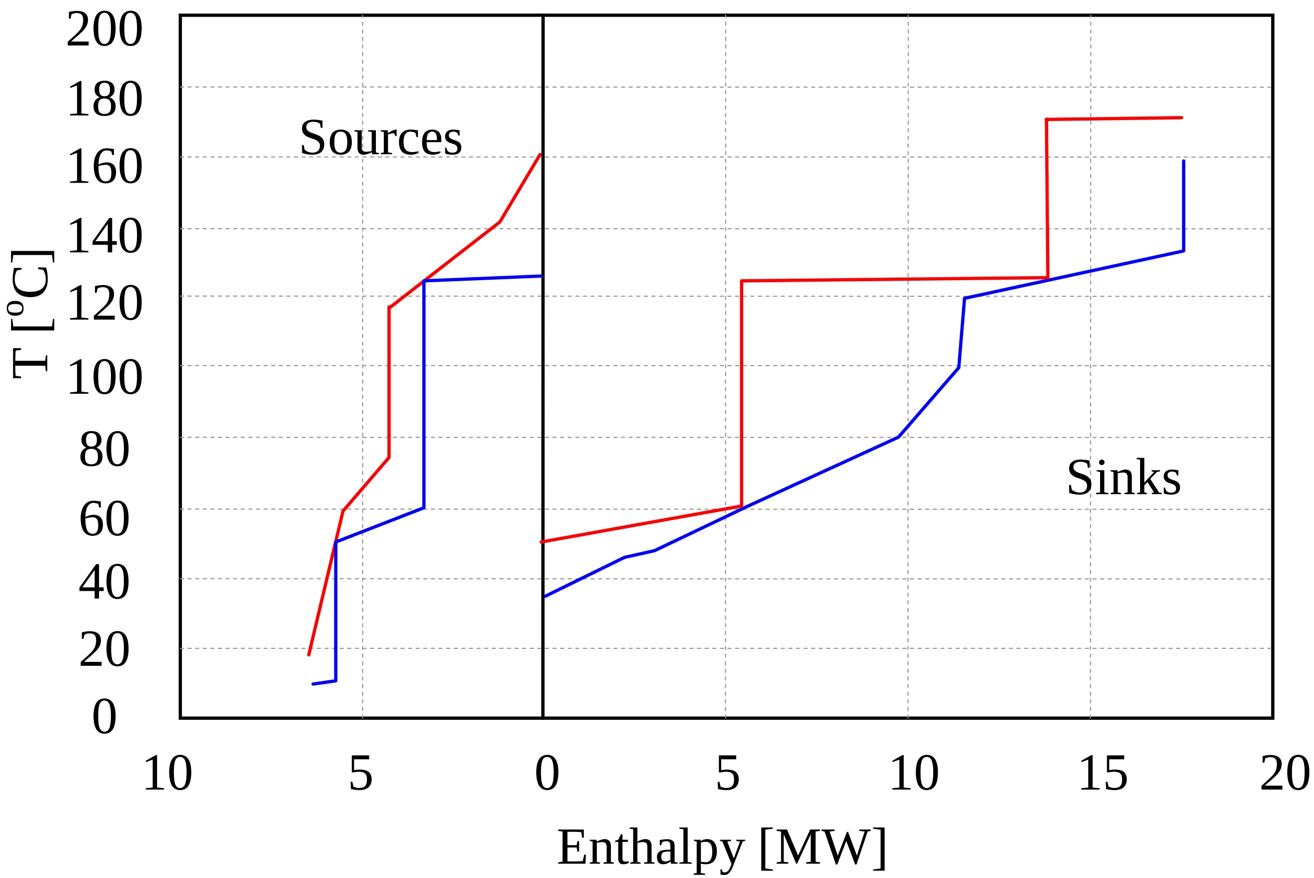
Site Profiles



Scenario α – Total Site Profiles



Scenario β – Total Site Profiles



Conclusions

- Plant as well as building complexes, as individual dwellings, offices, leisure facilities, and service providers, have large energy demands in the form of electrical power and heating/cooling.

- Some of them can be met by small local renewable sources, but their CO_2 contribution may be larger than initially realised and better estimates can be made through the application of carbon footprints assessment

Conclusions

- The use of integrated energy systems, including renewables, incorporating supply and demand at both the local and district level, would likely produce overall better energy efficiencies and consequently reduced emissions and carbon footprint

- The application of proven design strategies adopted from the process and energy generating industries could provide the key to successful reductions.

More details available in

S. Perry, J. Klemeš, I. Bulatov

Integrating Waste and Renewable Energy to reduce the Carbon Footprint of Locally Integrated Energy Sectors,

Energy 33 (10) October 2008, 1489-1497

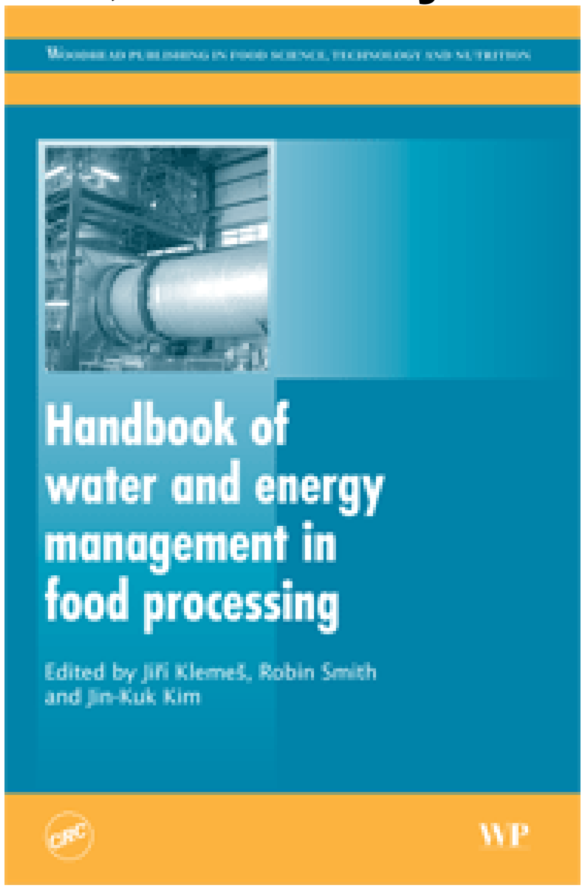
doi: 10.1016/j.energy.2008.03.008

Handbook of Water and Energy Management in Food Processing

Edited by

J Klemeš, University of Pannonia

R Smith and J-K Kim, University of Manchester, UK



EMINET 2 Workshop

Energy for Sustainable Future

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Future Work

Several other footprints should be considered to provide the whole picture:

- **Water Footprint**
- **Energy Footprint**
- **Emissions Footprint**
- **Work Environment Footprint**
- **…………………**

Let us discuss and further develop it !

Future Work

More results are coming in

“The Environmental Performance Strategy Map: an Integrated LCA approach to support the Strategic Decision Making Process”

in “Journal of Cleaner Production”

Acknowledgements

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