Regional waste heat valorisation: a mixed integer linear programming method for energy service companies

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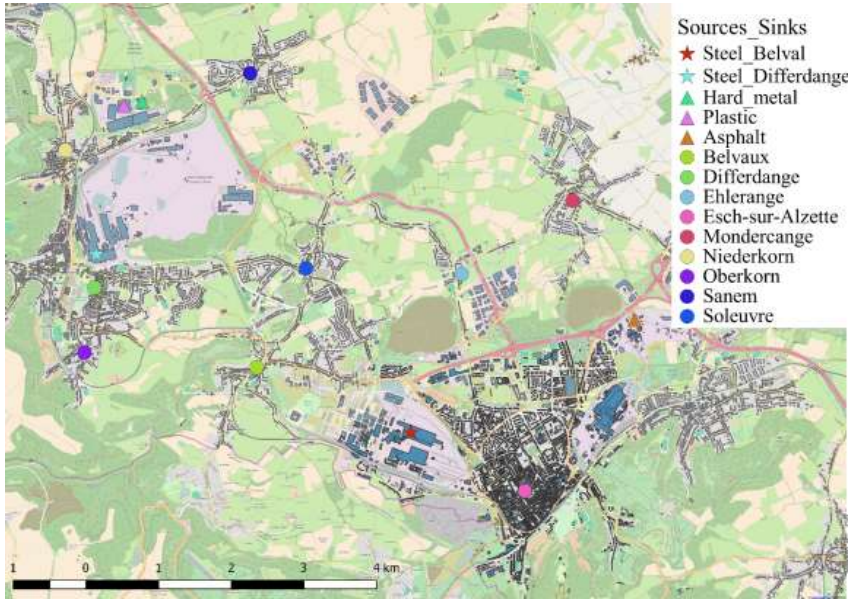
A. CONTEXT

- Large scale heat exchanger networks approaches: *Tveit2006, Stijepovic2011, Stijepovic2012, Nemet2015, Mian2016*;
- Urban valorisation: *Morandin2014, Eriksson2015, Dou2016, Li2016, Sandvall2016;*
- Regional methods : *Perry2008, Varbanov2011, Cucek2013, Oh2014, Fazlollahi2014*;

A. CONTEXT

→ Reluctance of heat sources and sinks as to investing, planning and managing task: *Ammar2012, Brueckner2014, Päivärinne2015*

→ No optimal valorisation of waste heat as resource, considering specific energy prices at various heat sinks, demand, etc.



A. CONTEXT

Objective: development of an optimisation method, using an operations research approach (mathematical optimisation), for the regional waste heat valorisation (transport) by ESCos

B. METHOD

Multiperiod Mixed Integer Linear Programming (MILP) Model:

Objective function: $max \sum_{i_H \in H} P_{i_H} + \sum_{j_C \in C} P_{j_C}$

Economic constraints

Profits from waste heat turbine: $P_{i_H} = \sum_{t=1,...TP} \sum_{k \in IT_t} (R^{Elec}_{i,k,t} - C^{Op}_{i,k,t}) - C^{I}_{i_H}$

Profits from waste heat supply: $P_{j_C} = \sum_{t=1,...TP} \sum_{k \in IT_t} (R^{Heat}_{j,k,t} + R^{Elec}_{j,k,t} - C^{Op}_{j,k,t}) - \sum_{i_H \in H} C^{I}_{i_H j_C}$

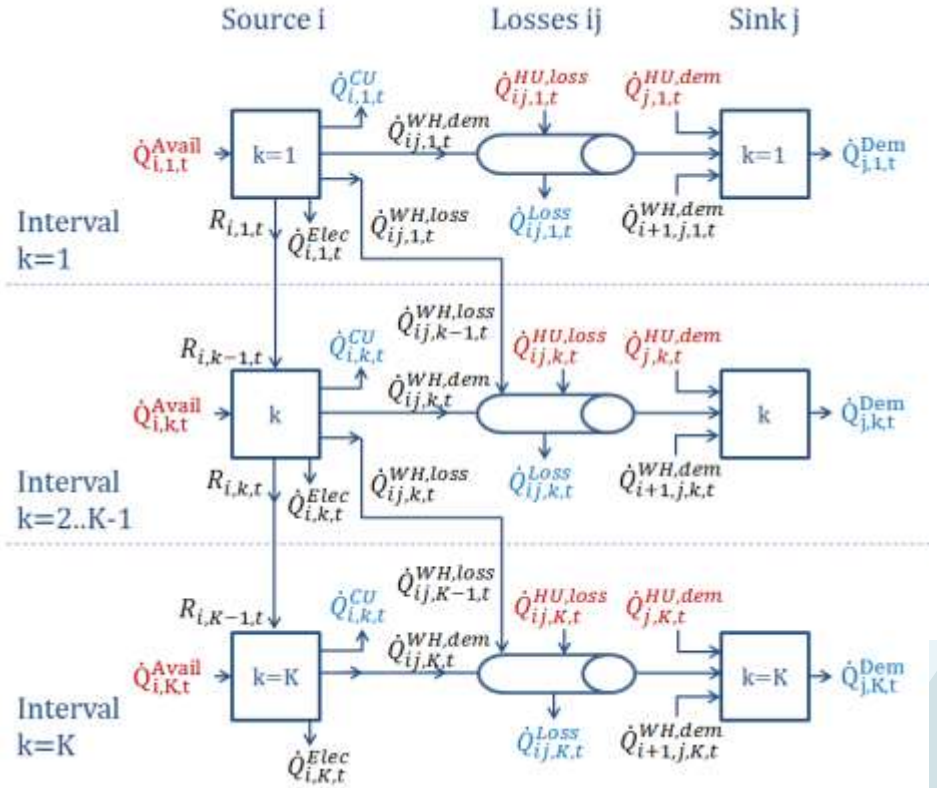
Operating costs: $C^{Op}_{j,k,t} = \left[\sum_{i \in H_k} (\dot{Q}^{WH}_{ij,k,t} * p^{Heat,b}_{i,t}) + (\dot{Q}^{Bo}_{j,k,t} * \eta^{Bo}_{j} * p^{Gas}_{j,t}) + (\dot{Q}^{CHP}_{j,k,t} * \eta^{CHP}_{j} * p^{Gas}_{j,t}) + (\dot{Q}^{HP}_{j,k,t} * \eta^{HP}_{j} * p^{Elec,b}_{j,t}) \right] * d_t$

Investment costs (annualised): $C^{Inv}_{J} = C^{HE_I}_{IJ} + C^{HE_J}_{IJ} + C^{Pip}_{IJ} + C^{HU}_{J}$

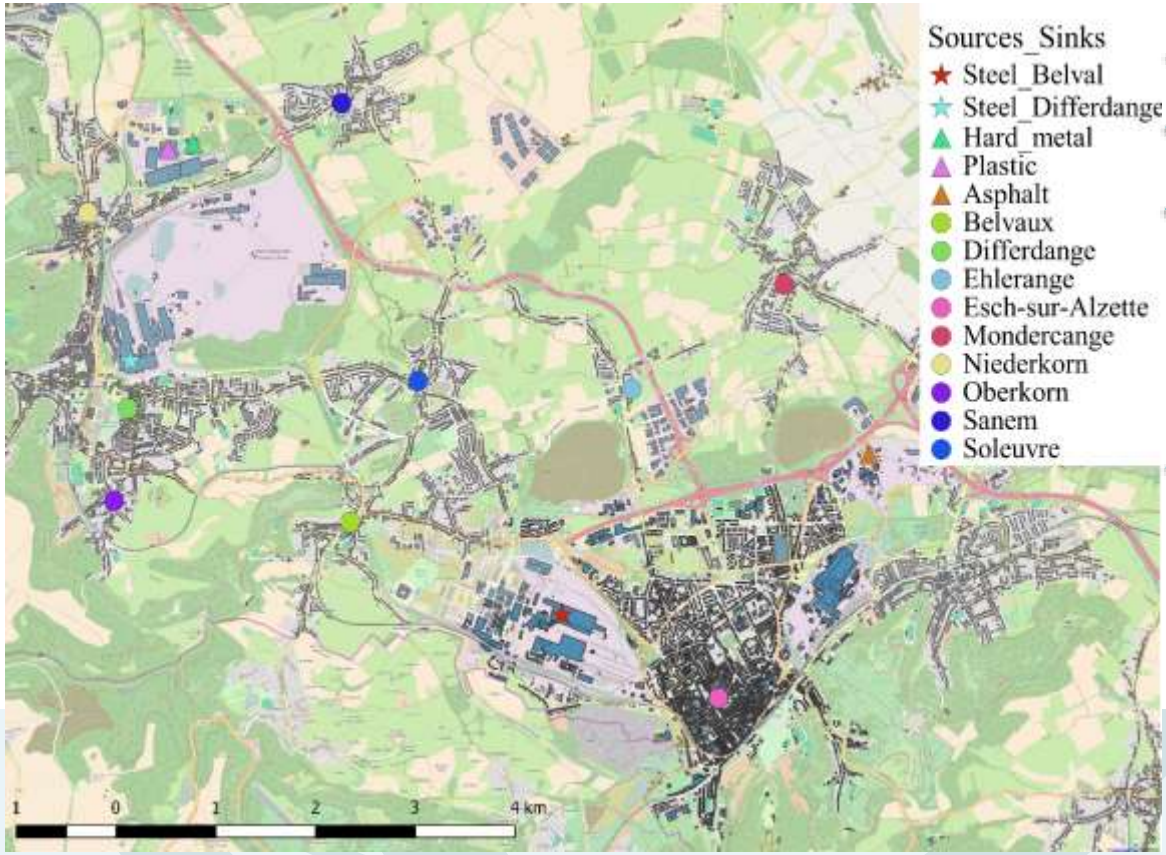
B. METHOD

MILP model: Technical constraints

Regional heat cascade:
Matching heat sources and sinks according to temperature intervals (pinch analysis)



C. CASE-STUDY

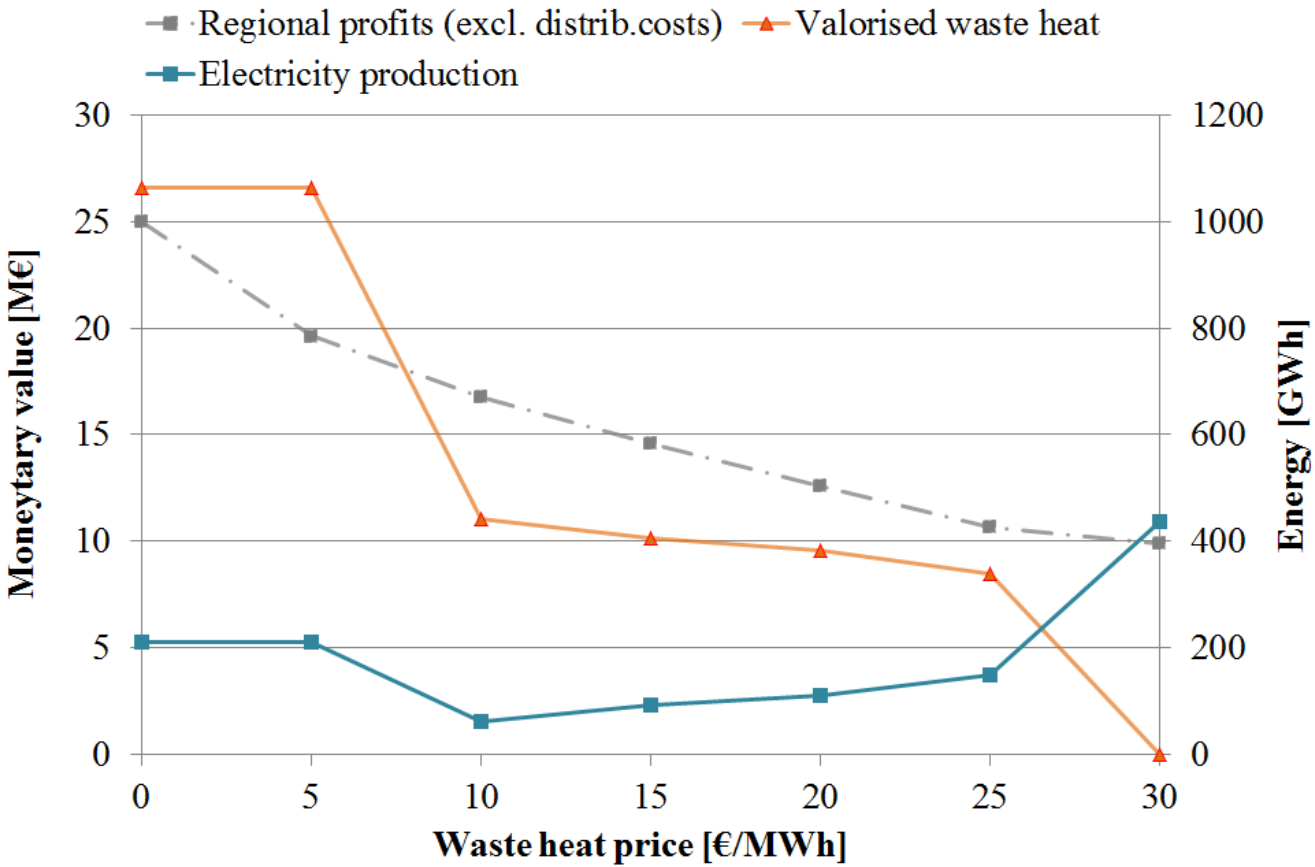


Industrial heat sources

Industrial heat sinks

Urban heat sinks

C. CASE-STUDY


Regional profits (excl. distrib.costs)
Valorised waste heat
Electricity production
Moneytary value [M€]
Energy [GWh]
Waste heat price [€/MWh]
0
5
10
15
20
25
30
200
400
600
800
1000
1200

C. CASE-STUDY

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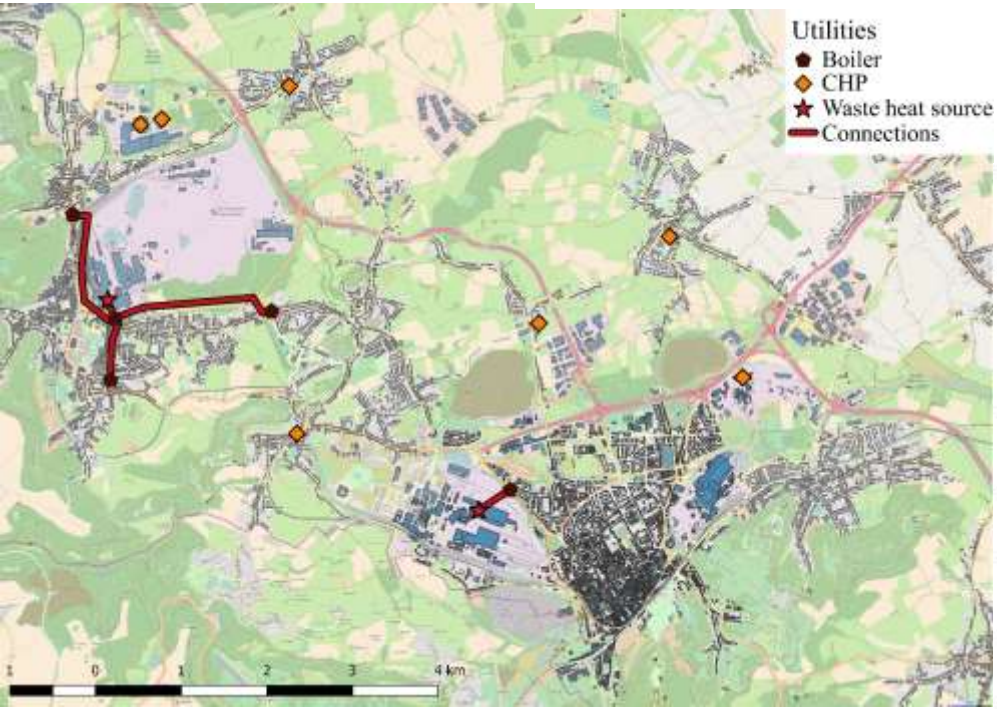
Solution at 25€/MWh



Sink [-]	Total investment	Yearly operating	Heat supply	Electricity production	Payback time [a]

Waste heat supply

Sink [-]	Source [-]	Load at t_1 [kW / %]	Load at t_2 [kW / %]	Load at t_4 [kW / %]	Pipe type [-]
Esch-sur-Alzette	Steel_Belval - EAF off gases after post combustion	22'194 (27%)	22'199 (84%)	2'714 (100%)	DN500
	Steel_Belval - EAF off gases end of water jacket	4'130 (5%)	4'134 (16%)	-	DN250
Differdange	Steel_Differdange - EAF off gases end of water jacket	11'004 (32%)	11'006 (100%)	1'015 (100%)	DN400
Niederkorn	Steel_Differdange - EAF off gases end after quenching	6'016 (32%)	6'022 (100%)	493 (100%)	DN300
Oberkorn	Steel_Differdange - EAF off gases after post combustion	4'007 (31%)	4'014 (100%)	305 (100%)	DN250
Soleuvre	Steel_Differdange - EAF off gases after post combustion	6'690 (31%)	6'703 (100%)	430 (100%)	DN300

D. CONTRIBUTIONS AND FUTURE WORKS

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Contributions:

- Selection of heat sinks including specific sink price
- More precise results with to standard pipe size consideration

Future works:

- Include LCA, distribution networks and mobile heat transport systems
- Reformulate model for material flow qualitative optimisation

THANK YOU FOR YOUR ATTENTION
ANY QUESTIONS?

A. Bertrand, A. Mian, I. Kantor, R. Aggoune, and F. Maréchal. Regional waste heat valorisation: a mixed integer linear programming method for energy service companies. Submitted to Energy, 2017.