EPFL

Energy efficiency in industry: Innovative process design and integration for Swiss industry sectors

Xiang Li, Dr. Sophia Wallerand and Prof. François Maréchal

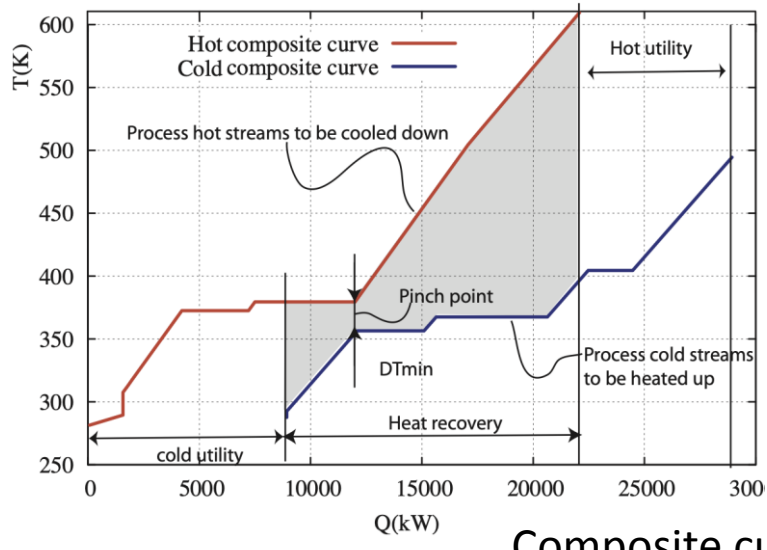
SCCER FURIES
sccer future energy efficient buildings & districts
sccer mobility
SCCER SoE
SWISS COMPETENCE CENTER for ENERGY RESEARCH
SUPPLY of ELECTRICITY
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Swiss Confederation
Innosuisse – Swiss Innovation Agency
SCCER CREST
SCCER EFFICIENCY OF INDUSTRIAL PROCESSES
Storage
Swiss Competence Center for Energy Research
biosweet
Swiss Competence Center for Energy Research

Innovative process design and integration for Swiss industry sectors

Pinch analysis

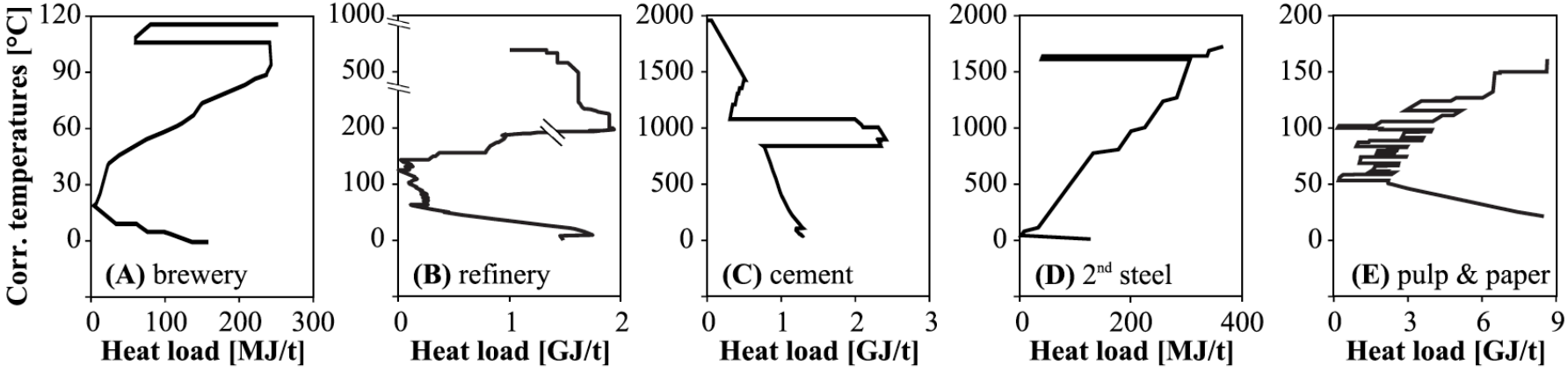
Thermodynamic analysis of the system

- Above/below the pinch
- MER (maximal energy recovery)
- Hot/cold utilities



Composite curve

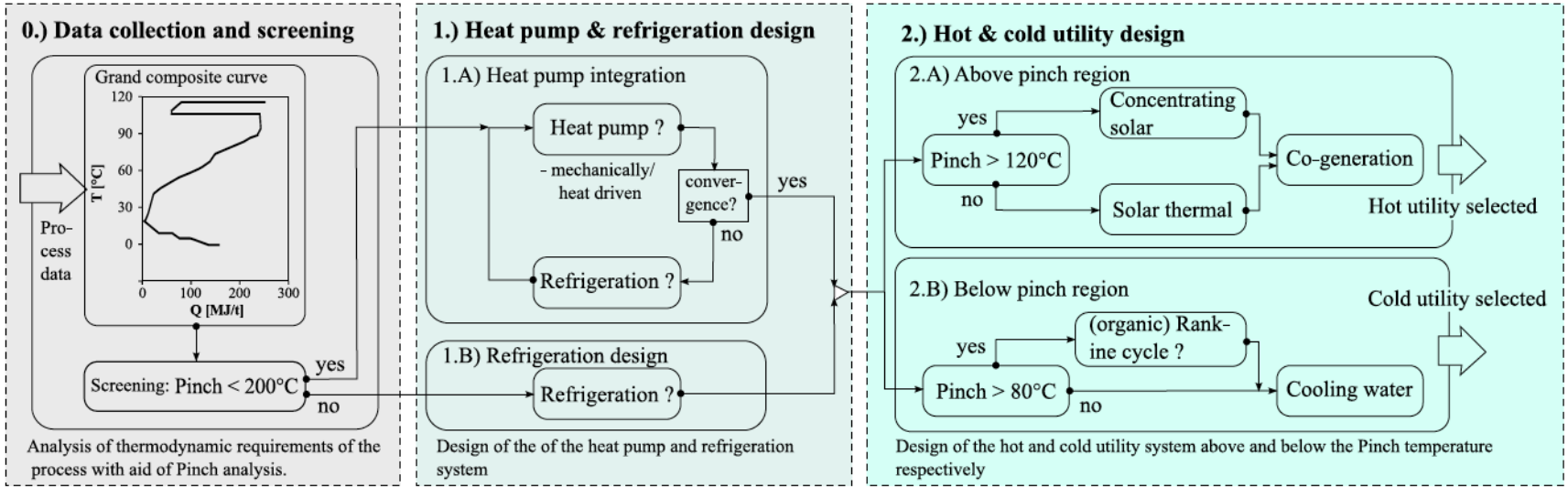
Thermal profiles in Swiss industries



Ground composite curve (GCC) for major industry sectors

Utility integration

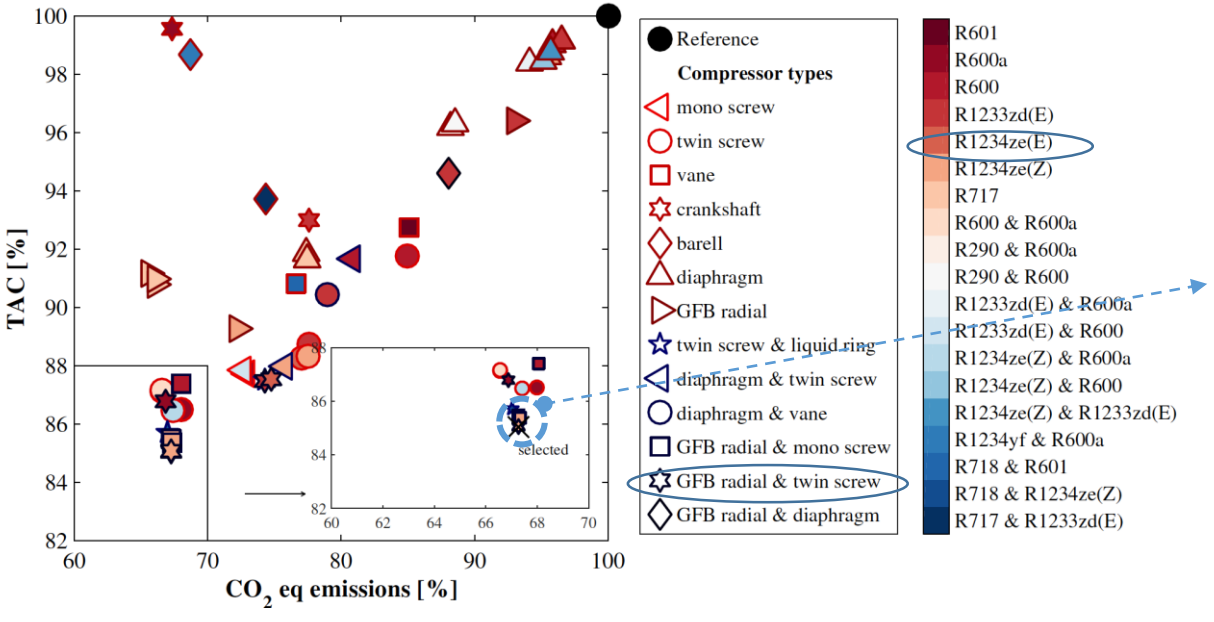
- Initial screening: using MILP subprocess from Wallerand et al. 2019 for HP integration.
- For each process thermal profile, 1,000 samples were created with various combinations of two compressor types (>12 types) and two fluid types (>14 types).
- In each run of the MILP, the total annualized costs (TAC) are minimized.



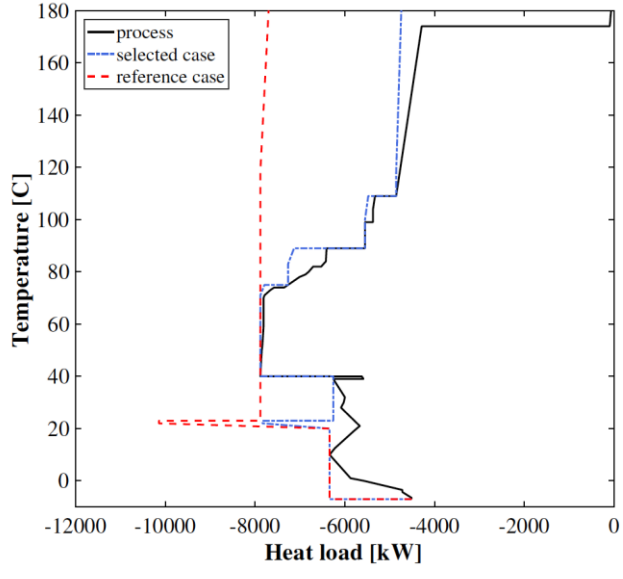
- ✓ Heat recovery (HR)
- ✓ Direct efficiency improvement measures:
  - Heat pumping (HP): combined heating/cooling
  - Organic Rankine Cycle (ORC)

Innovative process design and integration for Swiss industry sectors

Example: Cheese making industry



Results of HP screening step



IGCC with utility integration of selected and reference case

- The heat pump: approx. 50% of the hot utility → boiler ↓ → 33% emission ↓
- Pay back time: 2.4 years

Sector / process specifications				Swiss (CH) annual consumption					Spec. consumpt. BAU[00]		Saving potential ΔMER[01]		Saving potential Δdirect[02]		EO[03]
Sector	SFOE No.	Process	NOGA	Electricity (EL) TJ/y (% Total SFOE)		FUEL TJ/y (% Total SFOE)		Flow rate t/y	EL MJ/t	FUEL MJ/t	EL %red	FUEL %red	EL Δ%red	FUEL Δ%red	☆☆☆
Food & beverage	1	Dairy	10.1501,3,.52	303[05]	(4%[04])	524[05]	(6%[04])	2,021,983[10]	150[11]	259[12]	3%[12]	29%[12]	-8[13]	30%[13]	★★½[14]
	1	Cheese	10.1502	132[05]	(2%[04])	869[05]	(10%[04])	188,806[10]	698[15]	4600[16]	20%[17]	30%[17]	-42%[18]	22%[18]	★★½[14]
	1	Brewery	11.05	90[05]	(1%[04])	310[05]	(3%[04])	346,364[19]	260[1a]	894[1b]	15%[1c]	72%[1c]	-3%[1d]	18%[1d]	★★½[1e]
	1	Sugar	10.81	235[05]	(3%[04])	1,436[05]	(16%[04])	233,600[1f]	1,008[1g]	6,145[1g]	N/A[1h]	N/A[1h]	45%[1i]	42%[1i]	★★★[1k]
	1	Total (calc.)[06]	10, 11	761	(10%[04])	3138	(35%[04])				9% (8%)[0a]	37 (30%)[0a]	3% (5%)[0a]	32% (30%)[0a]	
	1	**Total (SFOE)**[07]	10, 11, 12	7,381	(14%[08])	9,108	(14%[08])				1%[0b]	6%[0b]	1%[0b]	10%[0b]	
Pulp & paper	3	Pulping (sulphite)	17.11	(*) 142[05]	(3%[04])	(*) 647[05]	(11%[04])	53,942[30]	2,640[31]	12,000[31]	N/A	28%[32]	N/A		★★½[33]
	3	Pulping (thermo-mechanical)	17.11	(*) 481[05]	(9%[04])	(*) 449[05]	(8%[04])	80,914[34]	5,950[31]	5,550[31]	N/A	62%[32]	N/A		★★½[33]
	3	Paper-making	17.12	3,471[05]	(68%[04])	5,606[05]	(96%[04])	1,042,355[30]	3,330[35]	5,378[35]	N/A	28%[32]	N/A		★★½[33]
	3	Total (calc.)[06]	17.1	(*) 3,471[05]	(68%[04])	(*) 5,606[05]	(96%[04])				-	28% (22%)[0c]	-	-	
	3	**Total (SFOE)**[07]	17, 18	5,097	(10%[08])	5,857	(9%[08])				-	21%[0b]	-	-	
Chemicals	4	Refining	19.2, 20	555[05]	(6%[04])	11,605[05]	(62%[04])	3,626,640[40]	153[41]	3,200[41]	0%[42]	69%[42]	N/A		★★☆[43]
	4	Total (calc.)[06]	19.2, 20	555[05]	(6%[04])	11,605[05]	(62%[04])				0% (0%)[0a]	62% (41%)[0a]	-		
	4	**Total(SFOE)**[07]	19, 20, 21	8,668	(17%[08])	18,799	(30%[08])				0%[0b]	25%[0b]	-		
Cement	5	Dry process	23.51	1390[05]	(83%[04])	13,514[05]	(114%[04])	3,860,000[50]	360[51]	3,500[51]	0%[52]	0%[52]	50%[53]	0%[53]	★☆☆[54]
	5	Total (calc.)[06]	23.51	1390[05]	(83%[04])	13,514[05]	(114%[04])				0% (0%)[0a]	0% (0%)[0a]	50% (15%)[0a]	0% (0%)[0a]	
	5	**Total (SFOE)**[07]	23.32, 23.51, 23.52	1,684	(3%[08])	11,896	(19%[08])				0%[0b]	0%[0b]	12%[0b]	0%[0b]	
Steel	7	EAF	24.10	3,691[05]	(71%[04])	3,093[05]	(85%[04])	1,400,000[70]	2,637[71]	2,209[71]	0%[72]	87%[72]	23%[73]	0%[73]	★☆☆[74]
	7	Total (calc.)[06]	24.10	3,691[05]	(71%[04])	3,093[05]	(85%[04])				0% (0%)[0a]	87% (9%)[0a]	23% (2%)[0a]	0% (0%)[0a]	
	7	**Total (SFOE)**[07]	24.10,.20,.31-34,.51-52	4,049	(8%[08])	3,589	(6%[08])				0%[0b]	8%[0b]	2%[0b]	0%[0b]	
Non-ferrous metals	8	Aluminum (2nd)	24.42	63[05]	(5%[04])	532[05]	(35%[04])	140,000[80]	450[81]	3,800[81]	0%[82]	52%[82]	N/A		★☆☆[83]
	8	Total (calc.)[06]	24.42	63[05]	(5%[04])	532[05]	(35%[04])				0% (0%)[0a]	52% (5%)[0a]	-		
	8	**Total (SFOE)**[07]	24.41-.46	1,300	(3%[08])	1,533	(2%[08])				0%	2%[0b]	-		
Sector total	1,3-5,7,8	Total (calc.)[0c]	10,11,17,19, 20,23,24	10,491	(37%)	38,051	(75%)				1% (1%)[0f]	36% (19%)[0f]	27% (6%)[0f]	5% (5%)[0f]	
	1,3-5,7,8	Total (SFOE)[0d]	10-12,17-23,24	28,179	(55%)	50,782	(81%)								
	1-12	**Total (SFOE)**[0e]	10-33	**51,535**	(100%)	**62,795**	(100%)				0%[0g]	11%[0g]	1%[0g]	1%[0g]	

This qualitative indicator relies on expert opinion (EO) to judge safety constraints, heat transfer restrictions and the maturity of required equipment.

★☆☆: Technically very challenging realization (due to safety, technical maturity)

★★☆: Technically feasible, but with challenges to face

★★★: Technically possible, even economically feasible

Conclusion

- Bottom-up modeling optimization approach
- Saving potential huge, strategies vary in sectors
  - Electrification of industry
- Cost effective, mitigation effect significant

Sector	ΔMER						Δdirect						**Δtotal**					
	Electricity			Primary thermal			Electricity			Primary thermal			Electricity			Primary thermal		
	Opt.	Techn.	Cons.	Opt.	Techn.	Cons.	Opt.	Techn.	Cons.	Opt.	Techn.	Cons.	Opt.	Techn.	Cons.	Opt.	Techn.	Cons.
Food & beverage (1)	9%	8%	1%	37%	30%	10%	3%	5%	1%	32%	30%	10%	12%	13%	1%	69%	59%	16%
Pulp & paper (3)		N/A		28%	22%	21%		N/A			N/A			N/A		28%	22%	21%
Chemicals (4)		0%		69%	41%	25%		N/A			N/A			0%		69%	41%	25%
Cement (5)		0%			0%		50%	15%	12%		0%		50%	15%	12%		0%	
Steel (7)		0%		87%	9%	8%	23%	2%	2%		0%		23%	2%	2%	87%	9%	8%
Non-ferrous metals (8)		0%		52%	5%	2%		N/A			N/A			N/A		52%	5%	2%
Total industry (weighted)	1%	1%	0%	36%	19%	11%	27%	6%	1%	5%	5%	1%	28%	7%	1%	42%	24%	12%

EPFL

Thank you for your attention!

Visit us on www.sccer-jasm.ch

SCCER FURIES

sccer future energy efficient buildings & districts

sccer mobility

SCCER SoE
SWISS COMPETENCE CENTER for ENERGY RESEARCH
SUPPLY of ELECTRICITY

SCCER CREST

SCCER EFFICIENCY OF INDUSTRIAL PROCESSES

Storage
Swiss Competence Center for Energy Research

biosweet
Swiss Competence Center for Energy Research

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Innosuisse – Swiss Innovation Agency