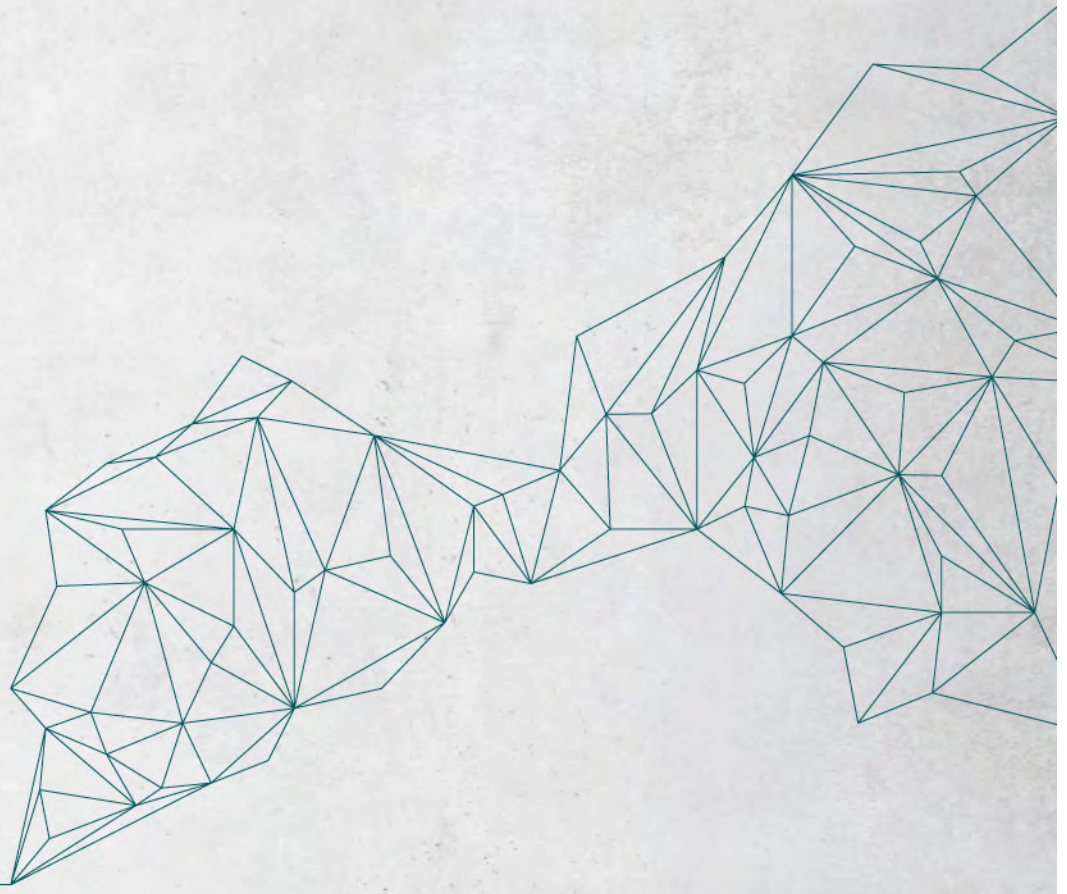
CHILLVENTA

Chillventa CONGRESS 2018

CONNECTING EXPERTS.



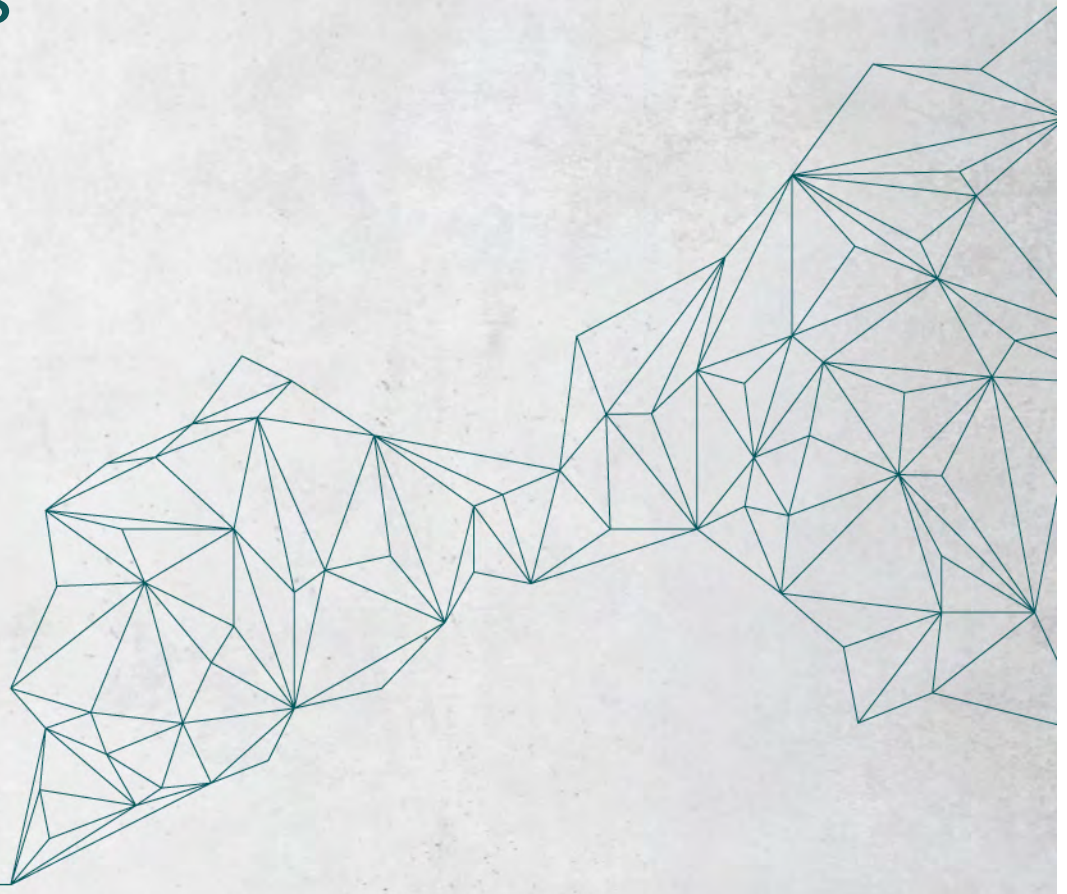
Dr. Anna S. Wallerand, anna.wallerand@epfl.ch; anna.wallerand@gmail.com

IEA Industrial Heat Pump Annex 48 – Task 3

CHILLVENTA

“Application of existing models”

CONNECTING EXPERTS.



Dr. Anna S. Wallerand, anna.wallerand@epfl.ch; anna.wallerand@gmail.com

Outline

Introduction

Task 3 – overview

Task 3 – key outcome

Conclusions

Dr. Anna S. Wallerand, anna.wallerand@epfl.ch; anna.wallerand@gmail.com

Outline

CHILLVENTA

Introduction

Task 3 – overview

Task 3 – key outcome

Conclusions

Dr. Anna S. Wallerand, anna.wallerand@epfl.ch; anna.wallerand@gmail.com

Who are we?

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE | VALAIS WALLIS

IPESE
INDUSTRIAL PROCESS AND ENERGY SYSTEMS ENGINEERING

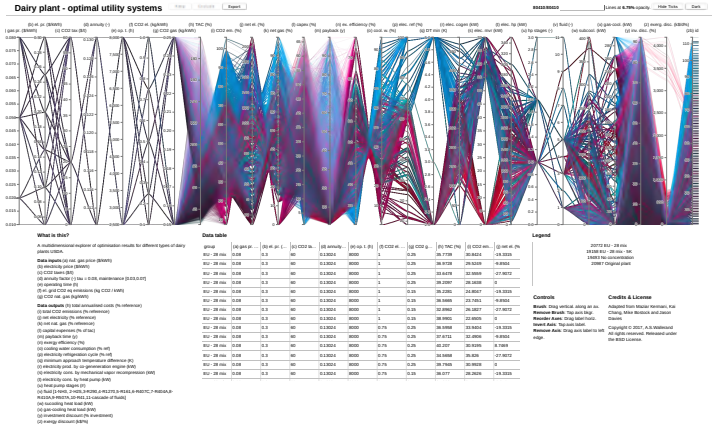
- 25 researchers (15 PhD)
- 25y of industrial energy efficiency & integration
- Focus: modeling & optimization of
  - energy efficiency in industrial systems
  - process system design
  - energy systems design
- **1 of 2 contributions from Switzerland to IEA Annex 48**
- **Focus on task 3:** “Application of existing models”

Dr. Anna S. Wallerand, anna.wallerand@epfl.ch; anna.wallerand@gmail.com

About me

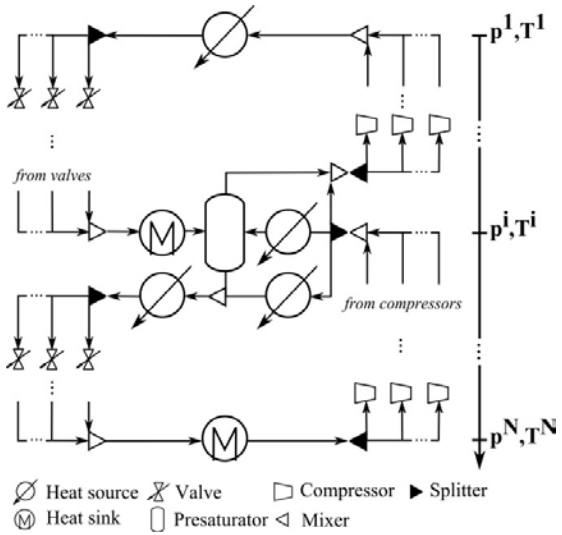
PhD thesis (2018)

- Energy efficiency and emission reductions in industry
  - Solar integration[1,2]
  - Optimal heat pump integration[3,4]



Post-doctoral researcher

- Energy efficiency in industry



[1] Wallerand et al. “Optimal design of solar-assisted industrial processes considering heat pumping: Case study of a dairy”, Renewable Energy, 2018

[3] Wallerand et al. “Optimal heat pump integration in industrial processes”, Applied Energy, 2018

[2,4] Wallerand et al. “Method for generic pre-feasibility assessment of industrial energy integration measures: part I & II”, Energies, submitted → Open Access

Dr. Anna S. Wallerand, anna.wallerand@epfl.ch; anna.wallerand@gmail.com

Outline

Introduction

Task 3 – overview

Task 3 – key outcome

Conclusions

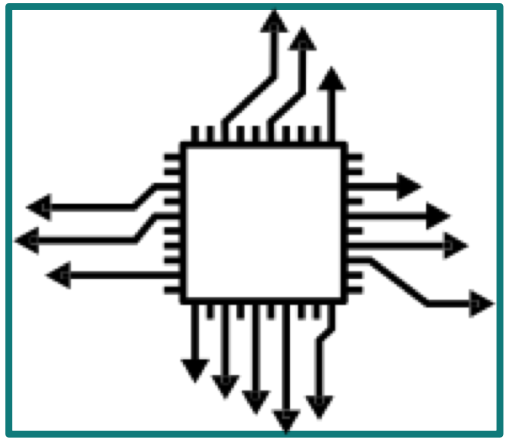
Dr. Anna S. Wallerand, anna.wallerand@epfl.ch; anna.wallerand@gmail.com

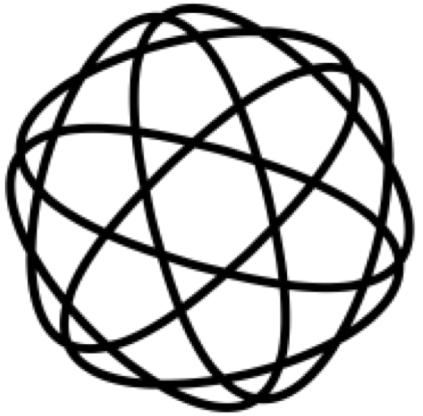
"Application of existing models"

Previous **Annex 35 Task 2**: *"Modeling, calculation and economic models"*

Main conclusions:

- limited dissemination and restricted usability of the available tools
- complexity and specific training required for the use of most **available tools** as well as the **theoretical principles** behind them





Dr. Anna S. Wallerand, anna.wallerand@epfl.ch; anna.wallerand@gmail.com

"Application of existing models"

Previous **Annex 35 Task 2**: *"Modeling, calculation and economic models"*

Main conclusions:

- limited dissemination and restricted usability of the available tools
- complexity and specific training required for the use of most **available tools** as well as the **theoretical principles** behind them

Goals of **Annex 48 Task 3**: *"Application of existing models"*

Main contributions:

- dissemination and clarification of theoretical principles
- easy-to-use set of guidelines to follow (with/out use of tools)
- application to a case study, highlighting the use of some of the tools

Dr. Anna S. Wallerand, anna.wallerand@epfl.ch; anna.wallerand@gmail.com

"Application of existing models"

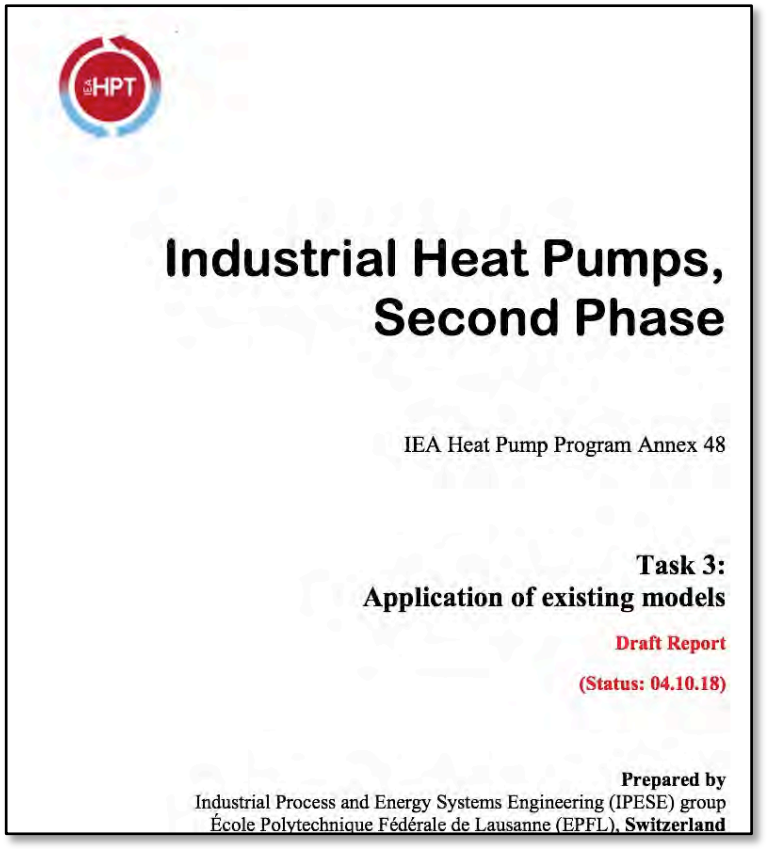
Structure

(1) Theoretical principles (concise)

(2) Overview of various tools

(3) Guidelines

(4) Case-study with insights



Dr. Anna S. Wallerand, anna.wallerand@epfl.ch; anna.wallerand@gmail.com

Outline

Introduction

Task 3 – overview

Task 3 – key outcome

Conclusions

Dr. Anna S. Wallerand, anna.wallerand@epfl.ch; anna.wallerand@gmail.com

"Application of existing models"

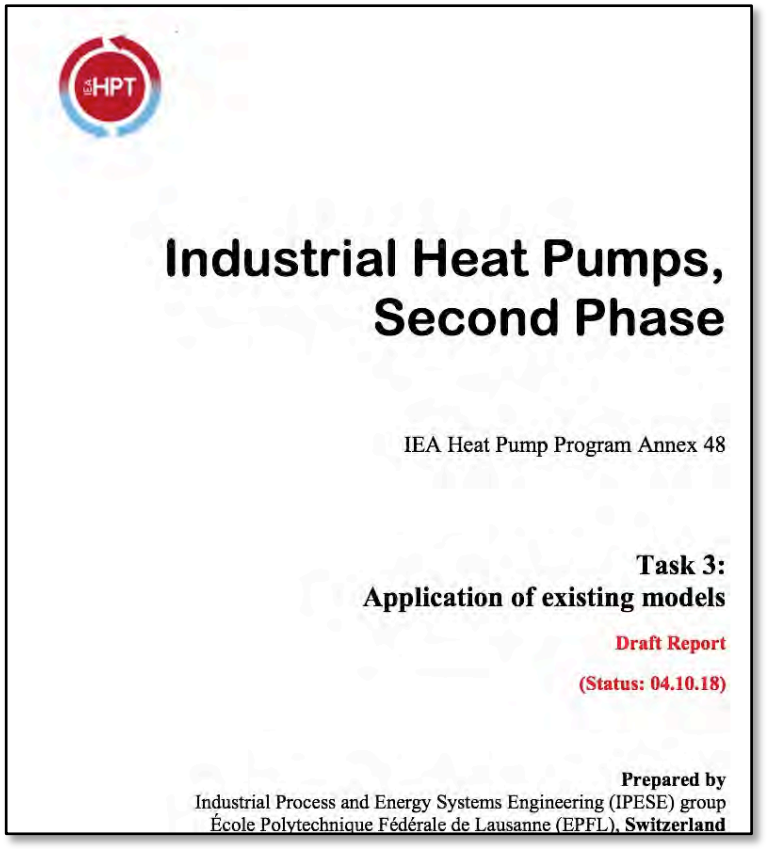
Structure

(1) **Theoretical principles (concise)**

(2) Overview of various tools

(3) Guidelines

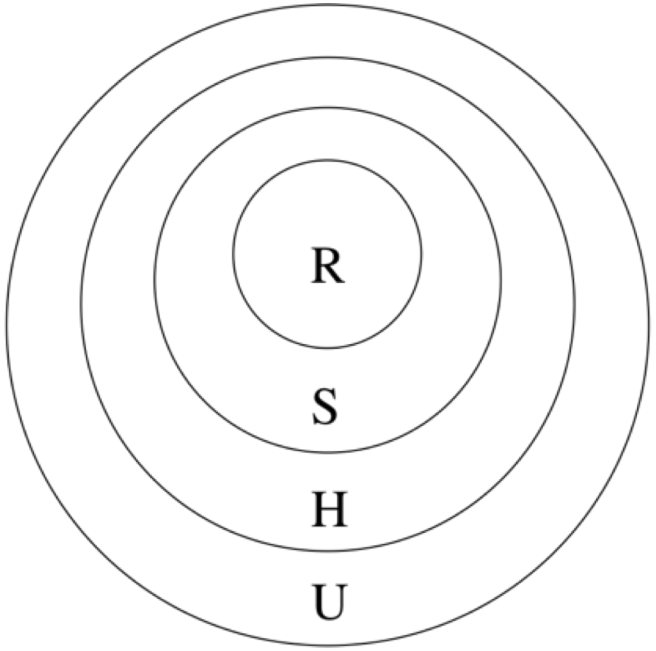
(4) Case-study with insights



Dr. Anna S. Wallerand, anna.wallerand@epfl.ch; anna.wallerand@gmail.com

Task 3 – theoretical principles

Industrial process synthesis approach[1]



R – reactor system

S – separator system

H – heat recovery system

U – utility system

Pinch analysis

[1] Kemp, 2011

Dr. Anna S. Wallerand, anna.wallerand@epfl.ch; anna.wallerand@gmail.com

Task 3 – theoretical principles

Pinch analysis[1]

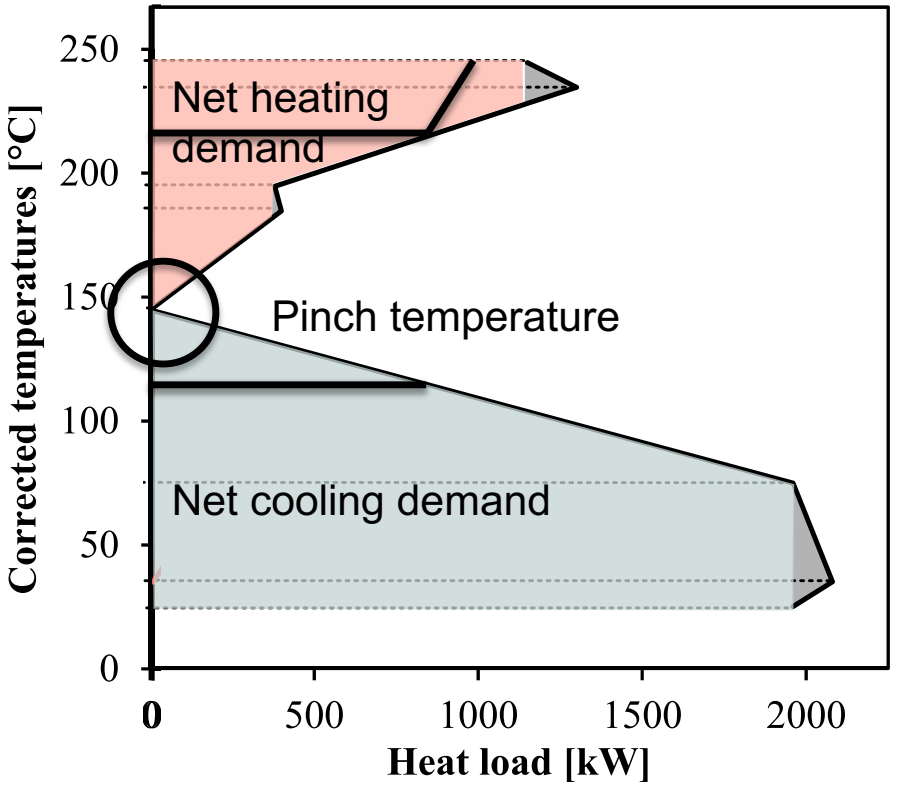
- Methods developed in the 1980's
- Systematic approach to increase heat recovery in industry
- Decomposition of process into set of heating and cooling requirements (= **streams**)

[1] Linnhoff and Flower 1978

Dr. Anna S. Wallerand, anna.wallerand@epfl.ch; anna.wallerand@gmail.com

Pinch analysis[1]
Grand composite curve & thermodynamic rules

- No demand in self-sufficient pockets
- **Hot utilities**: above pinch temperature
- **Cold utilities**: below pinch temperature
- **Heat pumping only beneficial <u>across</u> the pinch temperature**

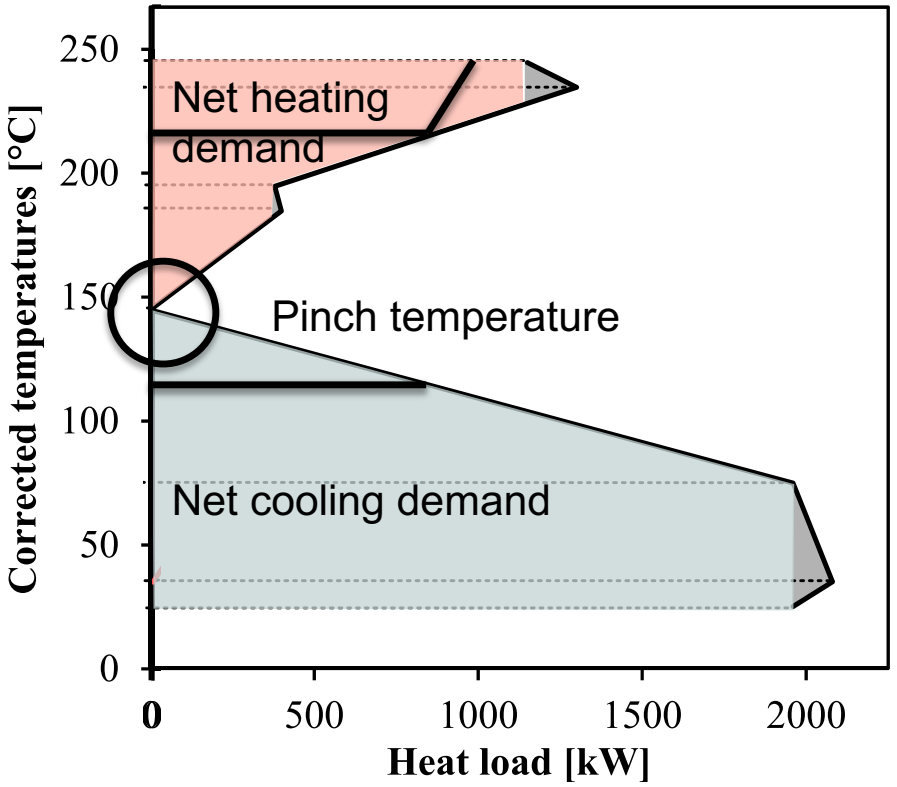


[1] Linnhoff and Flower 1978

Dr. Anna S. Wallerand, anna.wallerand@epfl.ch; anna.wallerand@gmail.com

Pinch analysis[1]
Thermodynamic rules: exceptions

- Refrigeration !
- COP * $\eta_{electricity}$ < 1



[1] Linnhoff and Flower 1978

Dr. Anna S. Wallerand, anna.wallerand@epfl.ch; anna.wallerand@gmail.com

"Application of existing models"

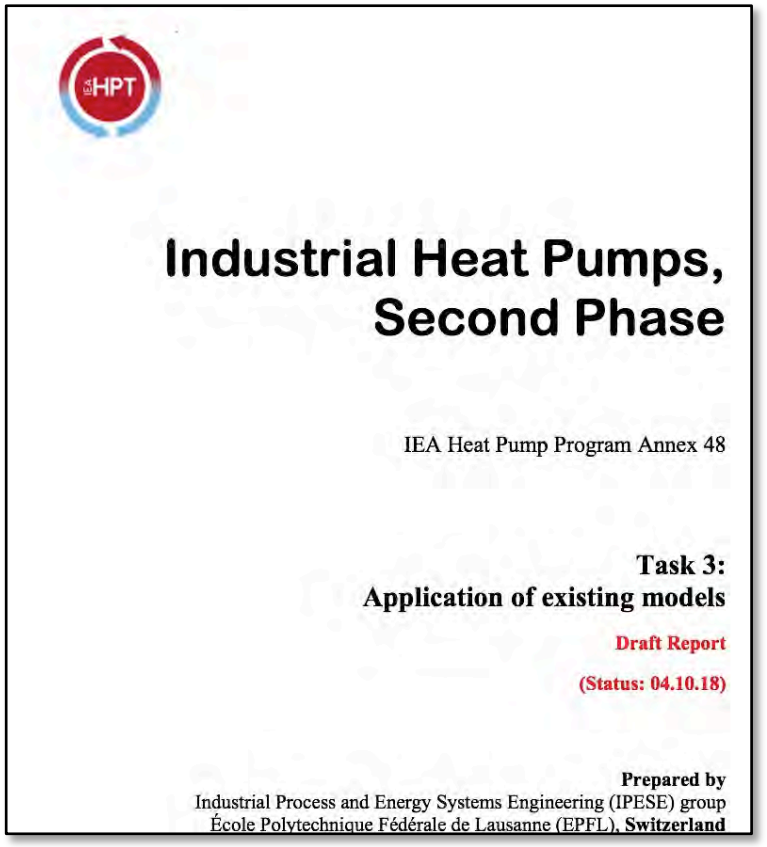
Structure

(1) Theoretical principles (concise)

(2) Overview of various tools

(3) Guidelines

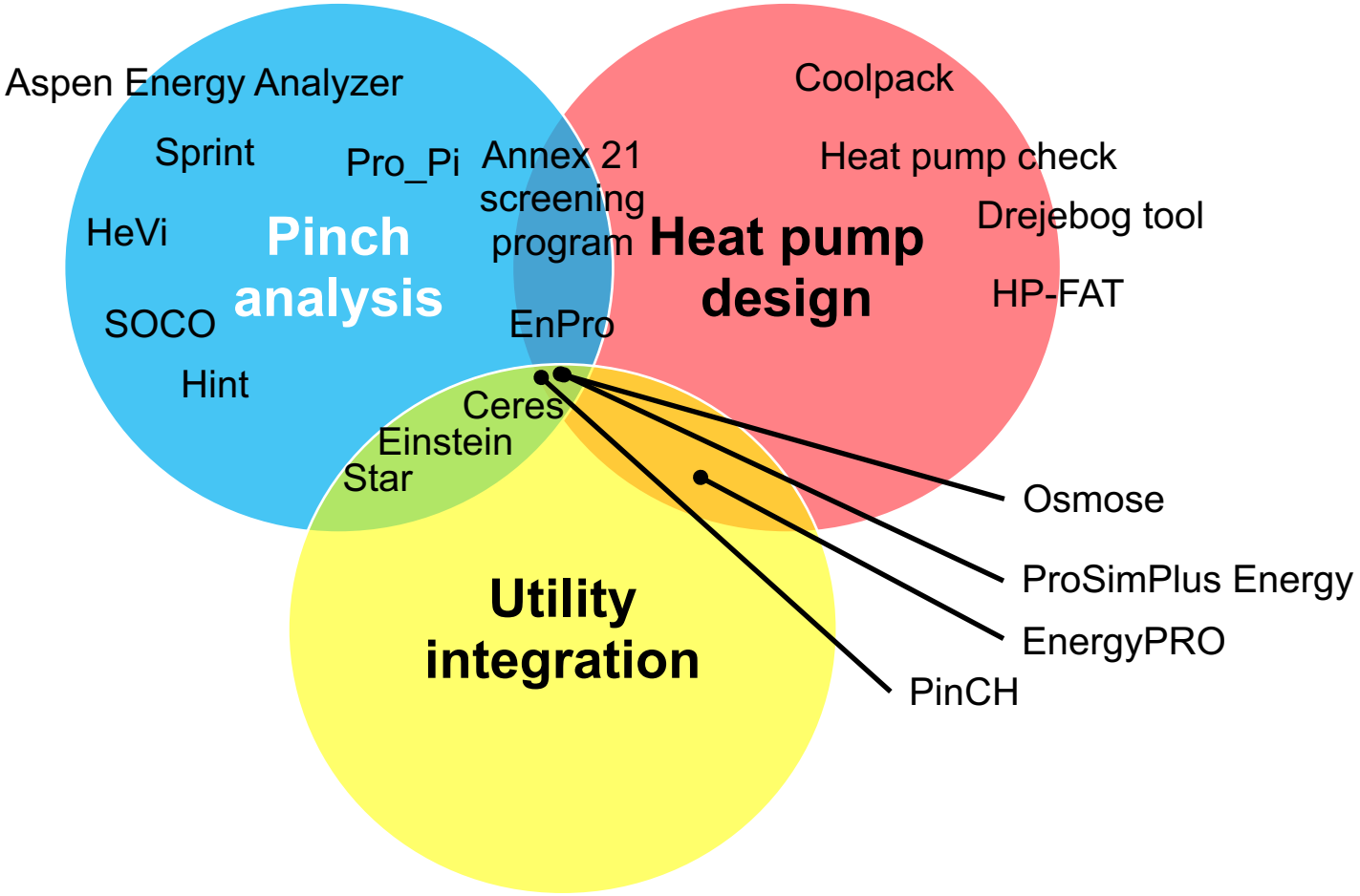
(4) Case-study with insights



Dr. Anna S. Wallerand, anna.wallerand@epfl.ch; anna.wallerand@gmail.com

Task 3 – tools

Focus



Dr. Anna S. Wallerand, anna.wallerand@epfl.ch; anna.wallerand@gmail.com

Task 3 – tools

Focus
Comparative table: 20 tools

Table 2 Overview of available heat pump tools. User prof. – user proficiency: * - low to ***- high, PA: pinch analysis, HEN: heat exchanger network synthesis, HP: heat pump design, Opt – optimization algorithms. UT: utility integration, ST: steam network, CG: co-generation, ST: solar thermal, TP: thermodynamic property data included. HVAC: heating ventilation and air conditioning, THEE: thermal energy engineering.

Name	Institution	Language	Latest release	First release	Functionalities	License	Main use	Interface	Targeted user	User prof.	PA	HEN	HP	Utilities	Industry	Opt.	Comments	Source
CoolPack	DTU Copenhagen	English	v1.5	1995	HP	Open access	Research	GUI	HVAC engineers	** (HVAC)	X	X	✓, multi-stage, TP	-	-	X	(+) tool is mainly developed for heat pump design considering various features, (-) no prcess integration possible	[24]
Sprint	UMIST – The university of Manchester	English	2018, v2.9	v1.4	PA, HEN	Academic	Research	GUI	students, energy auditors	**	✓	✓	X	X	all	✓	(+) GUI, (-) license required	[25]
Star	UMIST - The university of Manchester	English	2018, v2.9	v1.4	PA, HP, UT	Academic	Research	GUI	students, energy auditors	**	✓	X	?	SN	all	✓	(+) GUI, (-) license required	[25]
TOP Energy	RWTH Aachen	English	2018, v2.8.5	?	HP, UT	Proprietary	Commercial	Flowsheet	energy auditors, industry	*** (THEE)	X	✓	✓, single-stage	✓	all	X	(+) flowsheet software, simulation (-) no pinch analysis	[26]
PinCH 3.0	HSLU - Lucerne University of Applied Sciences and Arts	English	2018, v3.0	2010	PA, HEN, UT	Proprietary, academic	Industry, teaching	GUI	energy auditors, industry, students	** (THEE)	✓	✓ (heuristic rules)	✓, single-stage (TP)	✓	all	(✓) rule based	(+) user friendly/GUI, (+) 10 steps to completing PA, tutorials, (+) documentation material & website, (-) proprietary	[27]
Einstein	energyXperts.NET (E4-Experts GmbH, Berlin, Germany)	English, various	2017, v2.5	2007, v1.0	PA, HEN, UT	Open access (v2.4) (v2.5- 850-2800 Euro)	Commercial/industrial	GUI + flowsheet	energy auditors, industry	** (THEE)	✓ (no time slices)	✓ (heuristic rules)	✓ (black box, no TP)	✓	all (limitations above 400°C)	(✓) rule based	(+) integrated approach, one tool for full energy audit, (+) transparency, (+) open-source version, (+) method for auditiong, (-) User-friendliness of interface could be improved	[9]
EnPro Bewertungstool	AEE INTEC, AIT, TUW	German	2017, v3.0	2017	HP, PA	Open access	Research	Excel interface	process operators, preliminary	** (THEE)	✓ (20 streams)	(✓)	✓, single-stage	ST	all	X	(+) easy to use user interface, (-) not more than 20 process streams can be defined → limited use for industry	[8,28]

Dr. Anna S. Wallerand, anna.wallerand@epfl.ch; anna.wallerand@gmail.com

"Application of existing models"

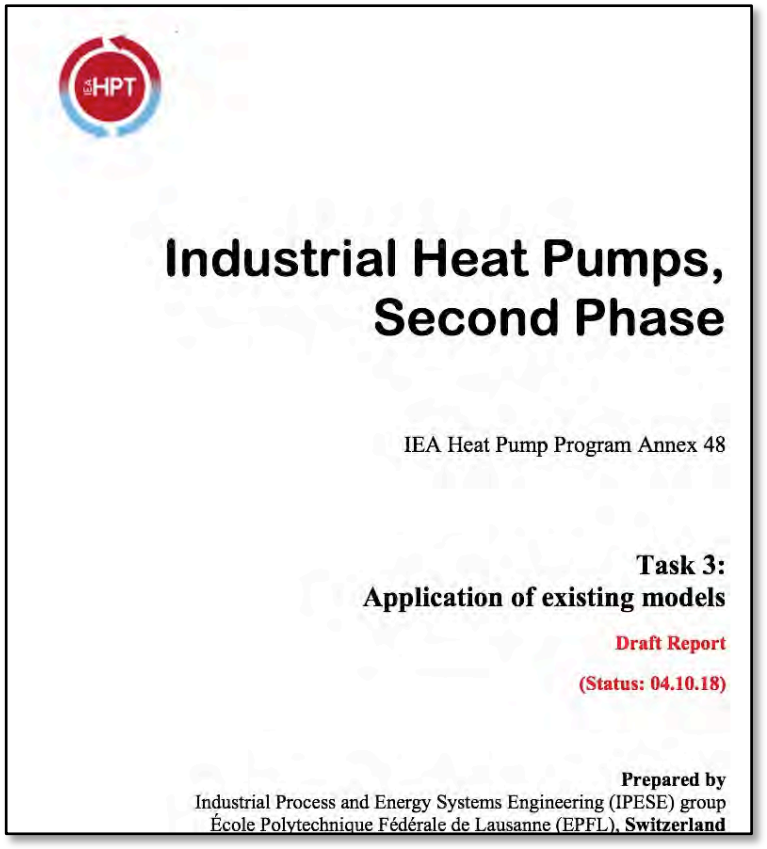
Structure

(1) Theoretical principles (concise)

(2) Overview of various tools

(3) Guidelines

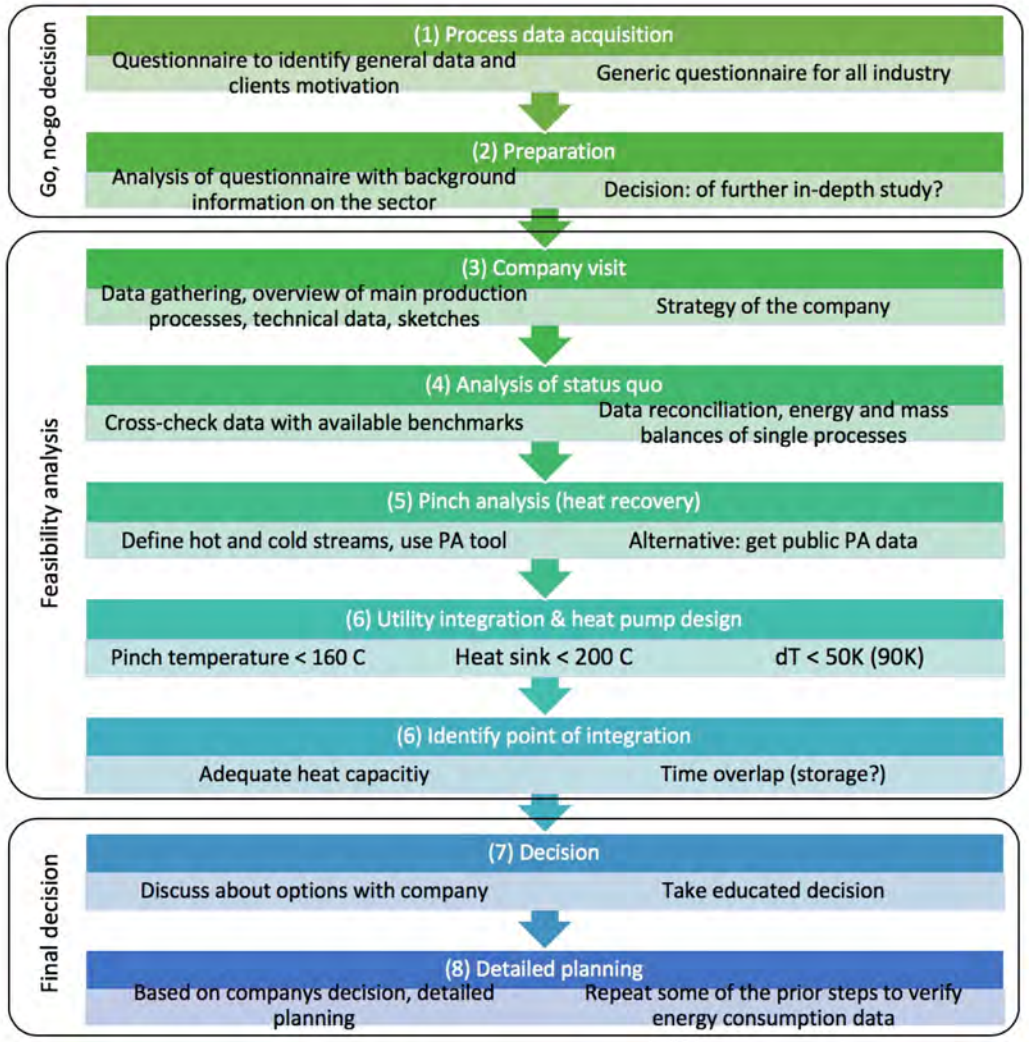
(4) Case-study with insights



Dr. Anna S. Wallerand, anna.wallerand@epfl.ch; anna.wallerand@gmail.com

Task 3 – guidelines

- Set of steps
- Energy audit
- How to best integrate heat pumps in industry, considering fundamentals of process design
- Which steps are recommended with tools



Inspired by IEA SHC Task 49[1]

[1] I.B. Hassine, IEA SHC Task 49 - Deliverable B2, 2015

Dr. Anna S. Wallerand, anna.wallerand@epfl.ch; anna.wallerand@gmail.com

"Application of existing models"

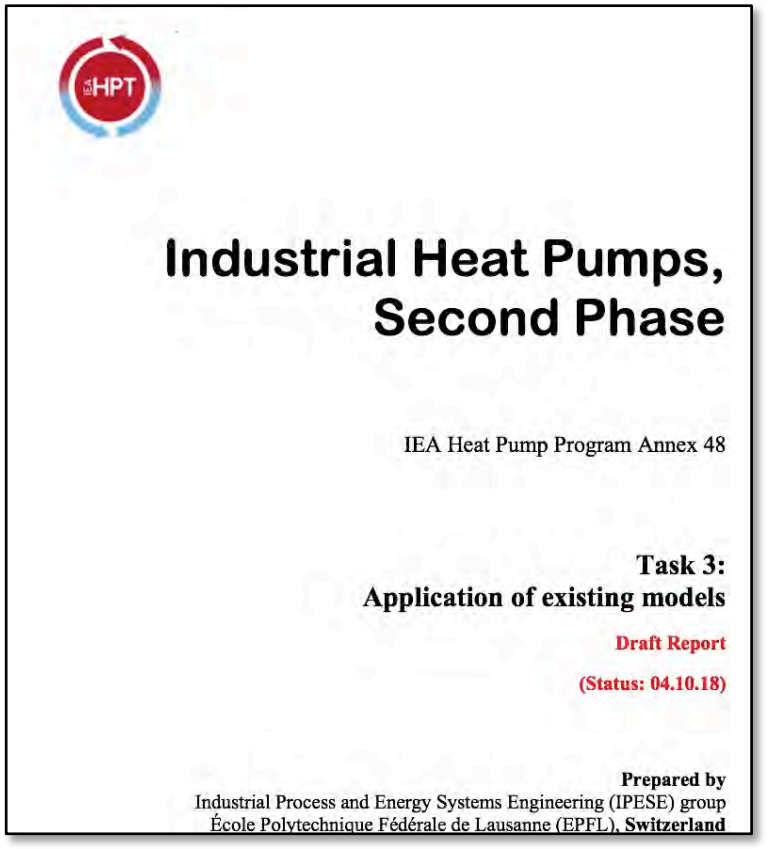
Structure

(1) Theoretical principles (concise)

(2) Overview of various tools

(3) Guidelines

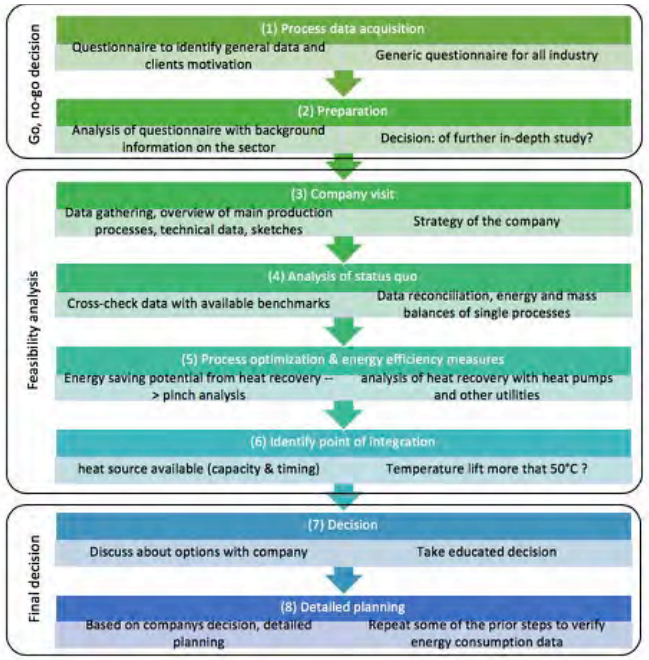
(4) Case-study with insights



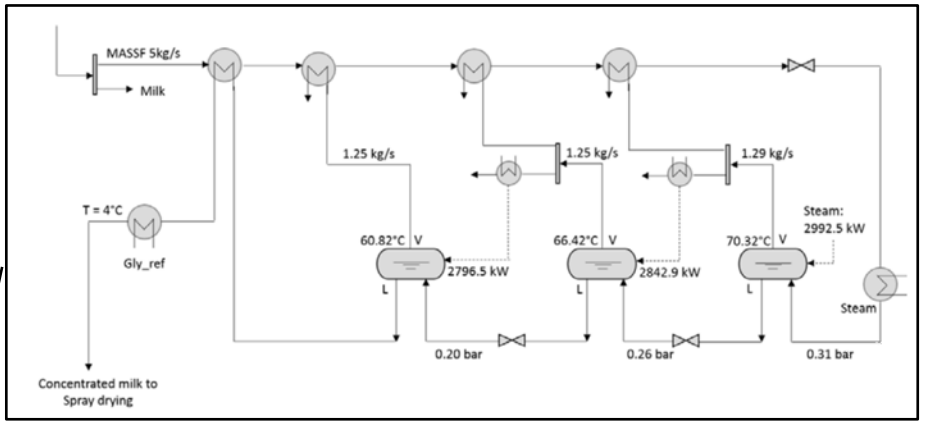
Dr. Anna S. Wallerand, anna.wallerand@epfl.ch; anna.wallerand@gmail.com

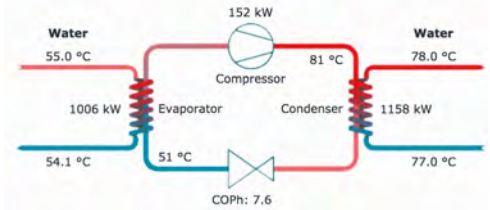
Task 3 – case study with insights

Dairy plant[1]

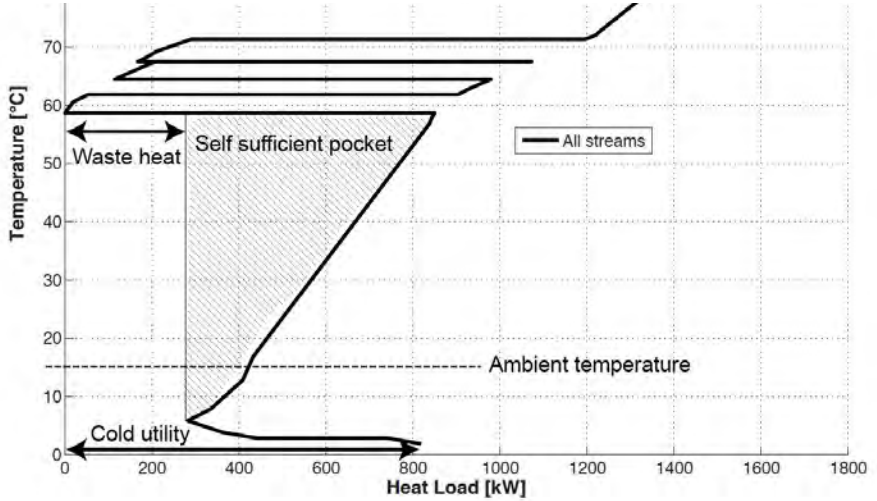


	Pasteurized milk, yogurt, cream	
	10	kg/s
	2,500	h
	0.081	€/kWh gas
	0.142	€/kWh electricity
	2,333	kW gas
	167	kW electricity (refrigeration)
	472,500	€ gas
	59,285	€ electricity
	5.9087	€/t total
Refrigeration requirement	500	kW
Operating temperature ranges	0	°C (min)
	100	°C (max)
Constant temperature requirements (chemical reactions, evaporation, condensation)	multi-stage evaporation, 60°C	





Tools
Heat pump design: CoolPack, Feasibility check, etc. …
http://tools.industrialheatpumps.nl



Tools
Pinch analysis: Sprint, HeVi, Hint, etc. …
PA and HP design: EnPro, Einstein, PinCH

Results: Ammonia heat pump & modified refrigeration
CO_2 : -42%, payback: <4 yrs

[1] Becker, These, 2018

Dr. Anna S. Wallerand, anna.wallerand@epfl.ch; anna.wallerand@gmail.com

Outline

Introduction

Task 3 – overview

Task 3 – key outcome

Conclusions

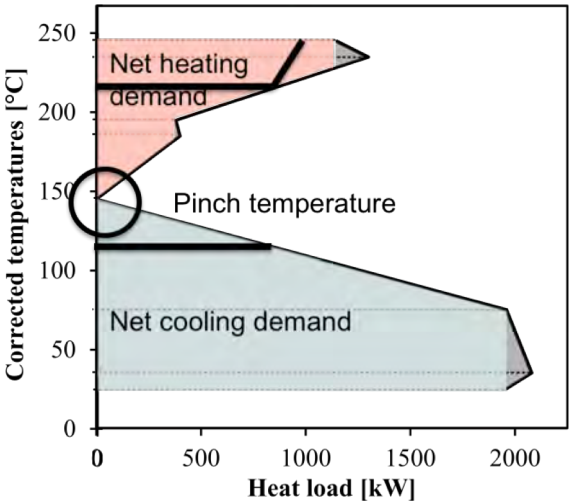
Dr. Anna S. Wallerand, anna.wallerand@epfl.ch; anna.wallerand@gmail.com

Conclusions

IEA industrial heat pump Annex 48

Task 3: *"Application of existing models"*

- Summary from Annex 35 Task 2: dissemination & clarification
- Theoretical background: Pinch analysis is powerful
- Tools: comprehensive overview, three categories of tools
- Set of guidelines to perform sound heat pump integration
- Case study: guide step-by-step, use of tools

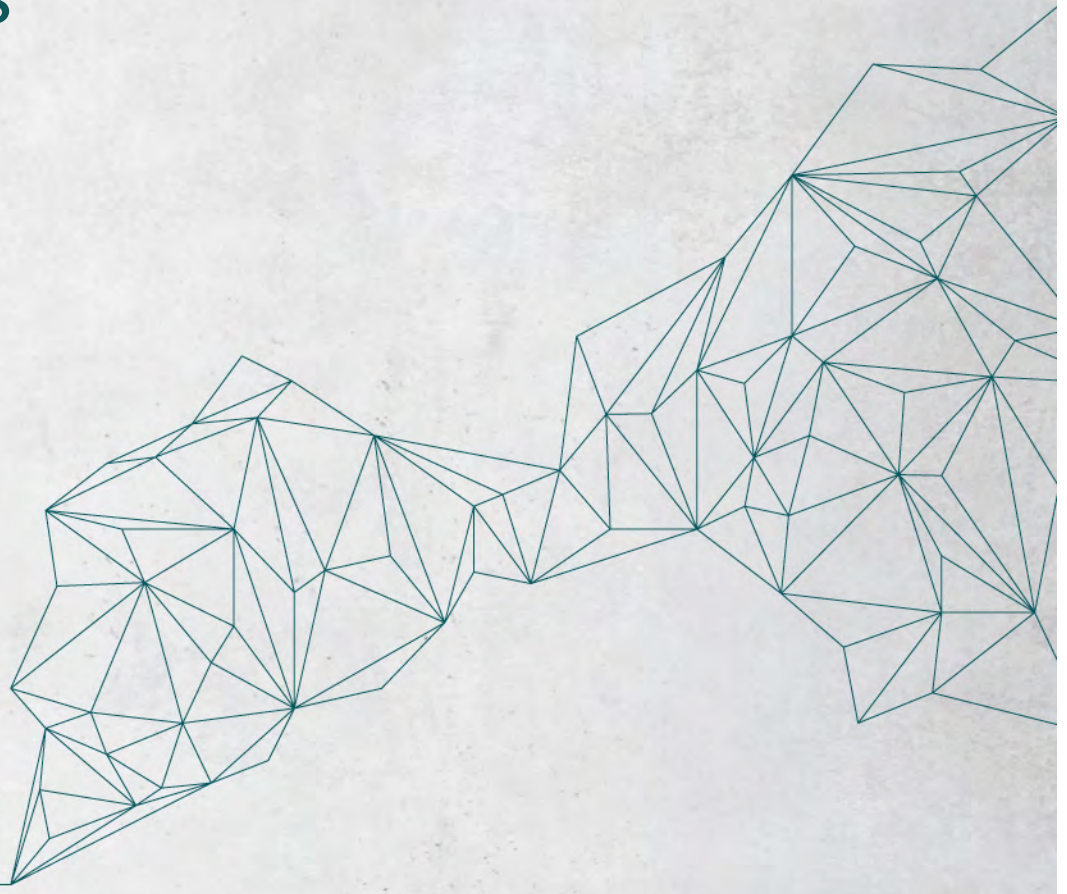


Dr. Anna S. Wallerand, anna.wallerand@epfl.ch; anna.wallerand@gmail.com

CHILLVENTA

“Application of existing models”

CONNECTING EXPERTS.



Dr. Anna S. Wallerand, anna.wallerand@epfl.ch; anna.wallerand@gmail.com