Industrial heat pumps in Germany - potentials, technological development and application examples

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Application of industrial heat pumps

Improving energy-efficiency of industrial processes

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Types of Heat Pumps

Open Cycles:

- Mechanical Vapour Recompression (MVR)

  direct compression of vapour by means of a mechanical compressor

- Thermal Vapour Recompression

  direct compression of vapour by means of a steam driven jet nozzle

Closed Cycles:

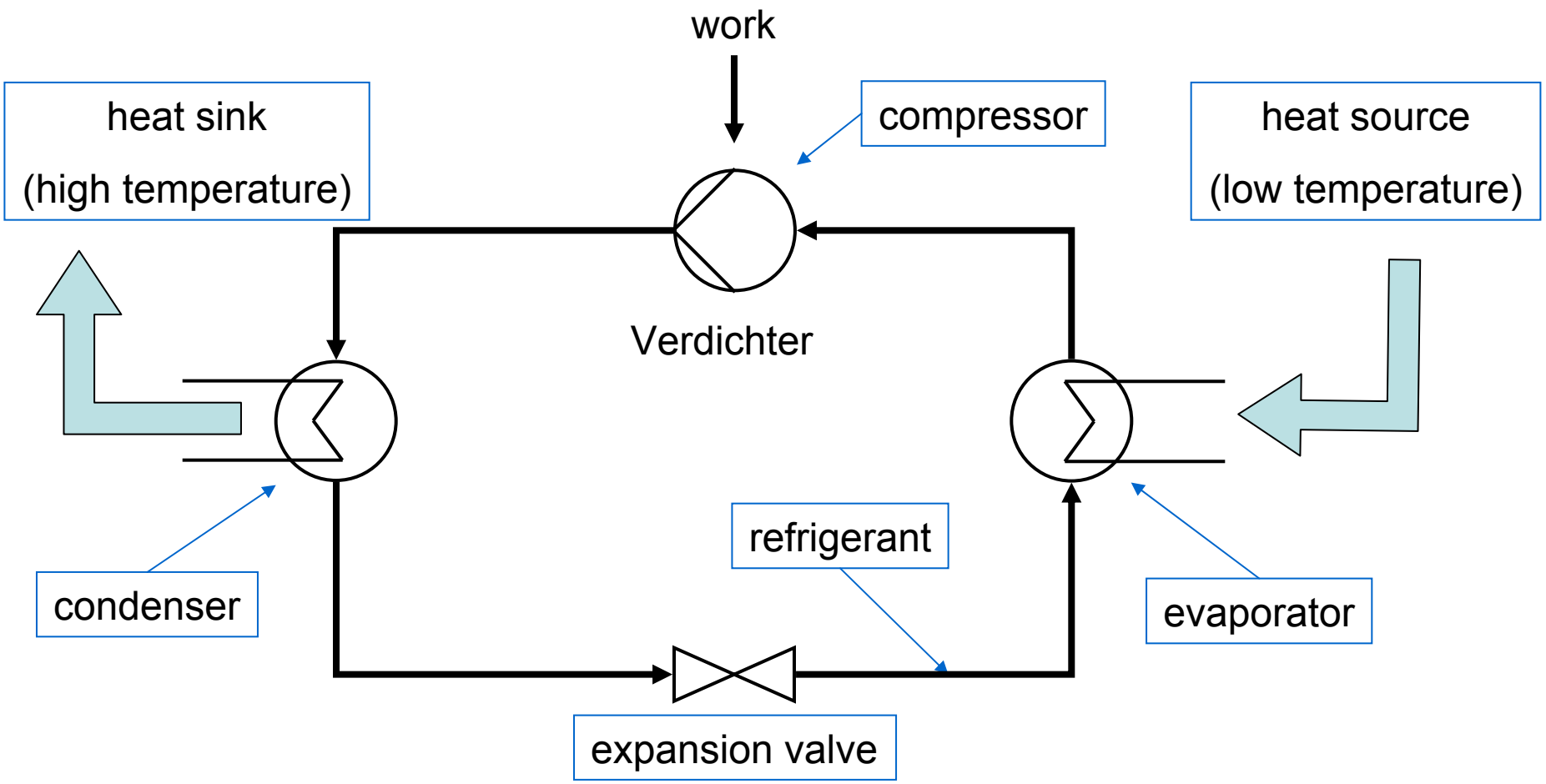
- Absorption/Adsorption heat pump

  thermal compressor driven by waste heat or primary energy

- Compression heat pump

  electrical driven mecanical compressor

Working Principle of Compression Heat Pumps



Heat pump efficiency

Indicator:

- Coefficient of performance (COP)

$$COP = \frac{usable\ heat/cold}{drive\ energy}$$

Positive effects on COP:

- low temperature difference between heat source and heat sink (< 50 K)
- continuous operation preferably at full load
- using of heat and cold delivered by the heat pump

State of the art of compression heat pumps

Heat source	water, brine, waste heat, waste water/air (heat recovery)
Refrigerant	R134a, R407C, R410A, R717
Heating capacity [kW]	20 to 2800
Compressor type	scroll, screw, turbo, piston
Numbers of compressors	1 to 4
Power adjustment [%]	25 to 100
Temperature range heat source [°C]	-10 to 40
Temperature range heat supply [°C]	50 to 80
COP heating	2.5 to 5.8
Cooling function	50% of manufacturers offer cooling functions
Cooling capacity [kW]	20 to 2500
COP cooling	1 to 6

Industrial heat pumps – A matter of the right refrigerant

Requirements for refrigerants:

- High critical temperature
- Low pressure range
- no ozone depletion Potential (ODP)

} must

- low global warming potential (GWP)
- not flamable
- not toxic
- etc.

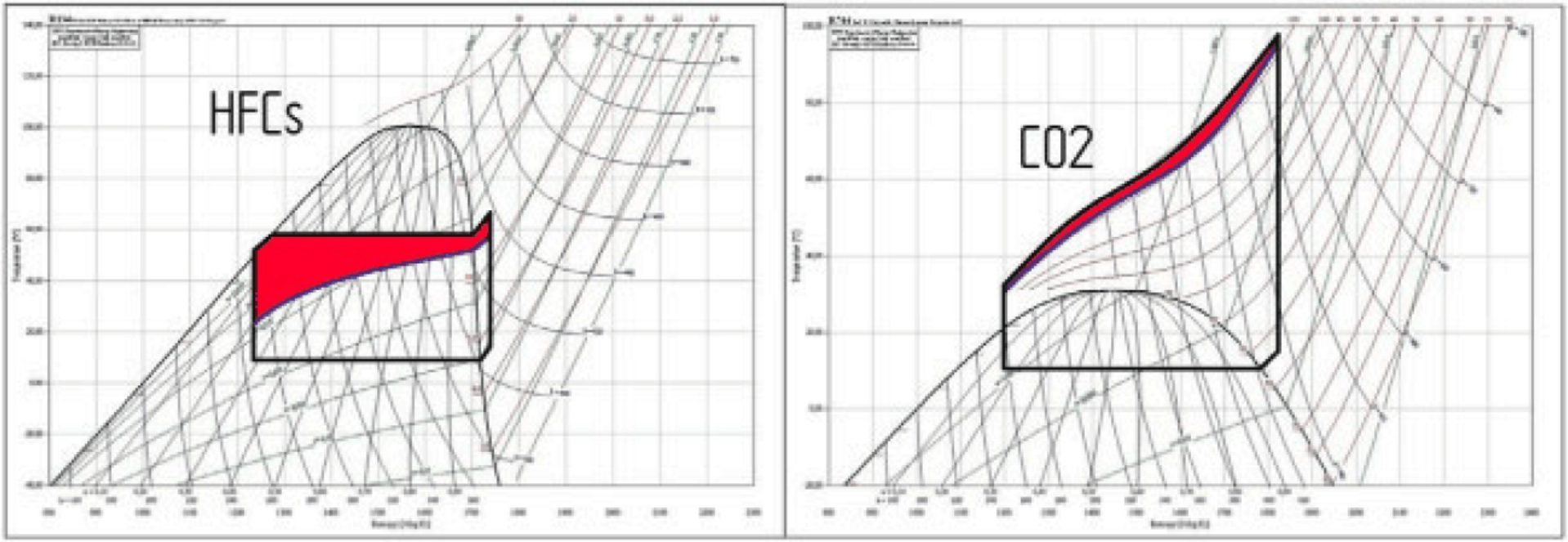
} preferable

Selection of refrigerants for industrial heat pumps

Refrigerant	maximum sink temperature	minimum source temperature	GWP	Toxicity	Flamability
R245fa	140 °C	15 °C	950	yes	no
R600a (Isobutane)	140 °C	0 °C	< 1	no	high
R717 (Ammonia)	110 °C	- 30 °C	0	yes	medium
DR-2	160 °C	35 °C	9.4	no	no
SES36	160 °C	35 °C	low	n/a	n/a
R744 (CO_2)	130 °C	about - 10 °C	1	no	no

CO_2 – heat pumps

- supercritical process with large temperature glide in the gas cooler
- niche product for heating water from low to high temperatures



water refrigerant exergetic losses

Imagesource: Wobst et al. 2008

Conclusion on refrigerants

When to use which refrigerant:

- R134a, R407C, R410A for low temperature applications (< 80 °C)
- R600a (Isobutane) just in very small plants
- R245fa (T_{max} = 140 °C) and R717 (Ammonia) (T_{max} = 110 °C) in high temperature applications (> 80 °C)
- CO_2 (T_{max} = 130 °C) for heating up water from low to high temperatures

Heat pumps in industrial processes

Requirements for suitable industrial processes:

- Temperature level below 140 °C (below 160 °C in nearer future)
- Heat source with relatively high temperature level

(not more than 50 °C below process temperature for a COP above 3)

- Constant availability of the heat source
- Long operation periods at constant heat load

Promising processes for heat pump integration

Sector	Process	Technological status	Temperature [°C]
General	Process heat networks	high temp. HP	110 to 120
	Preheating	high temp. HP	< 100
	Washing	common / high temp. HP	30 to 90
Chemicals	Biochemical reactions	common HP	20 to 60
	Distillation	high temp. HP	> 100
	Cooking	high temp. HP	80 to 110
	Thickening	very high temp. HP	130 to 140
Paper	Bleaching	very high temp. HP	40 to 150
	De-inking	common HP	50 to 70
	Cooking	very high temp. HP	110 to 180
	Drying	high temp. HP	> 90

Sources: Lauterbach et al. 2011, IER

Promising processes for heat pump integration

Sector	Process	Technological status	Temperature [°C]
Food	Blanching	common / high temp. HP	60 to 90
	Scalding	common / high temp. HP	50 to 90
	Evaporating	high temp. HP	40 to 130
	Cooking	high temp. HP	70 to 120
	Pasteurization	very high temp. HP	60 to 150
	Smoking	common HP	20 to 80
	Cleaning	common / high temp. HP	60 to 90
	Sterilization	high temp. HP	100 to 140
	Tempering	common HP	40 to 80
	Drying	common / high temp. HP	> 40

Sources: Lauterbach et al. 2011, IER

Processes that already use heat pumps

Drying of wood and food products:

(air dehumidification)

- Heat source: warm and humid air from the drying chamber
- Heat sink: air recycled to the drying chamber

Continuous band washer:

(air dehumidification and process heat generation)

- Heat source: warm and humid air from the washing tunnel
- Heat sink: supply air, washing water tanks

Application opportunities in retrofit

Prefabricated house manufacturer:

High temperature heat pump to deliver the base heat load to wood drying chambers:

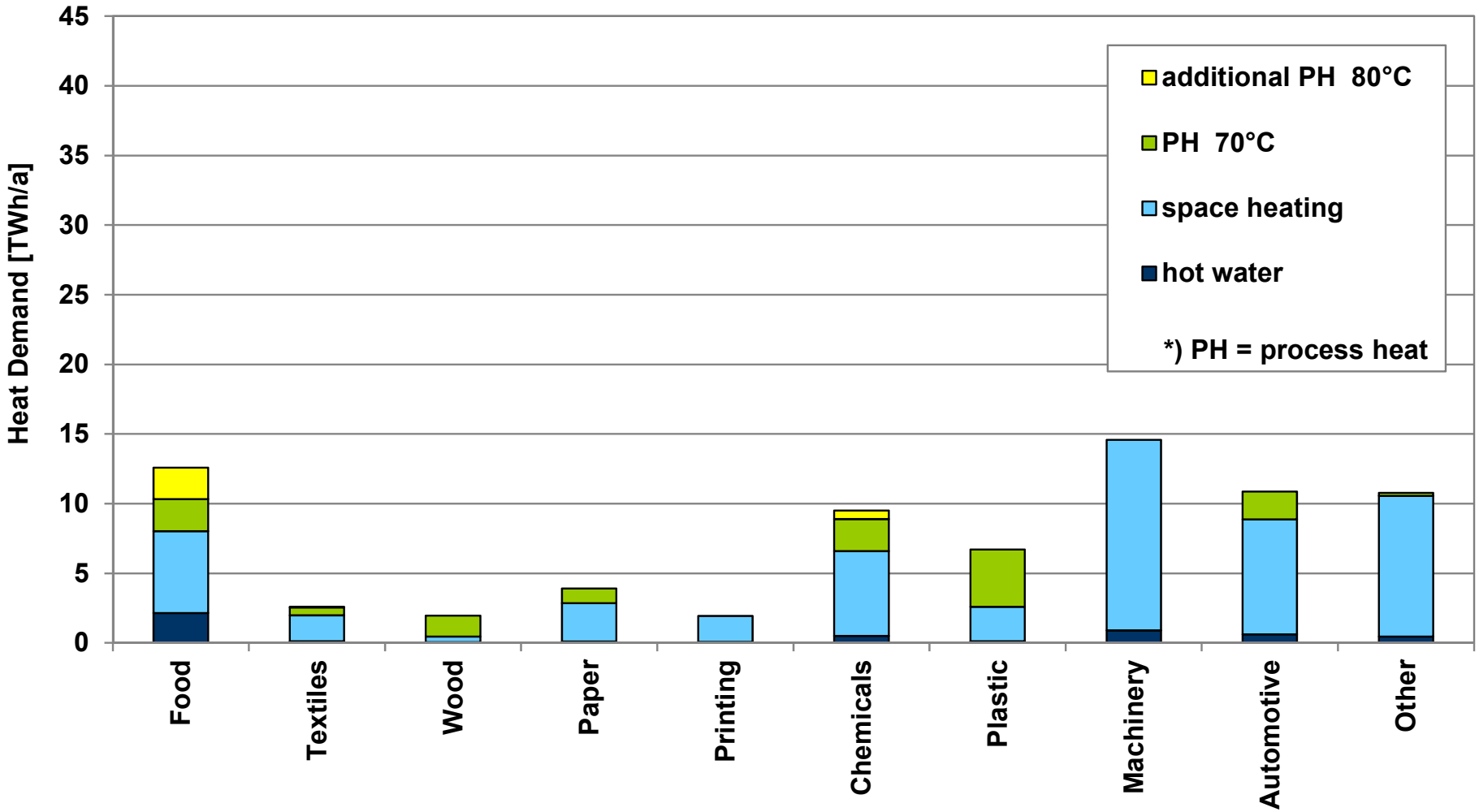
- Heat source: Waste heat from a biomass power plant
- Heat sink: Drying chamber (90 to 120 °C)

Electroplating shop:

Heat pump to supply heat to degreasing baths:

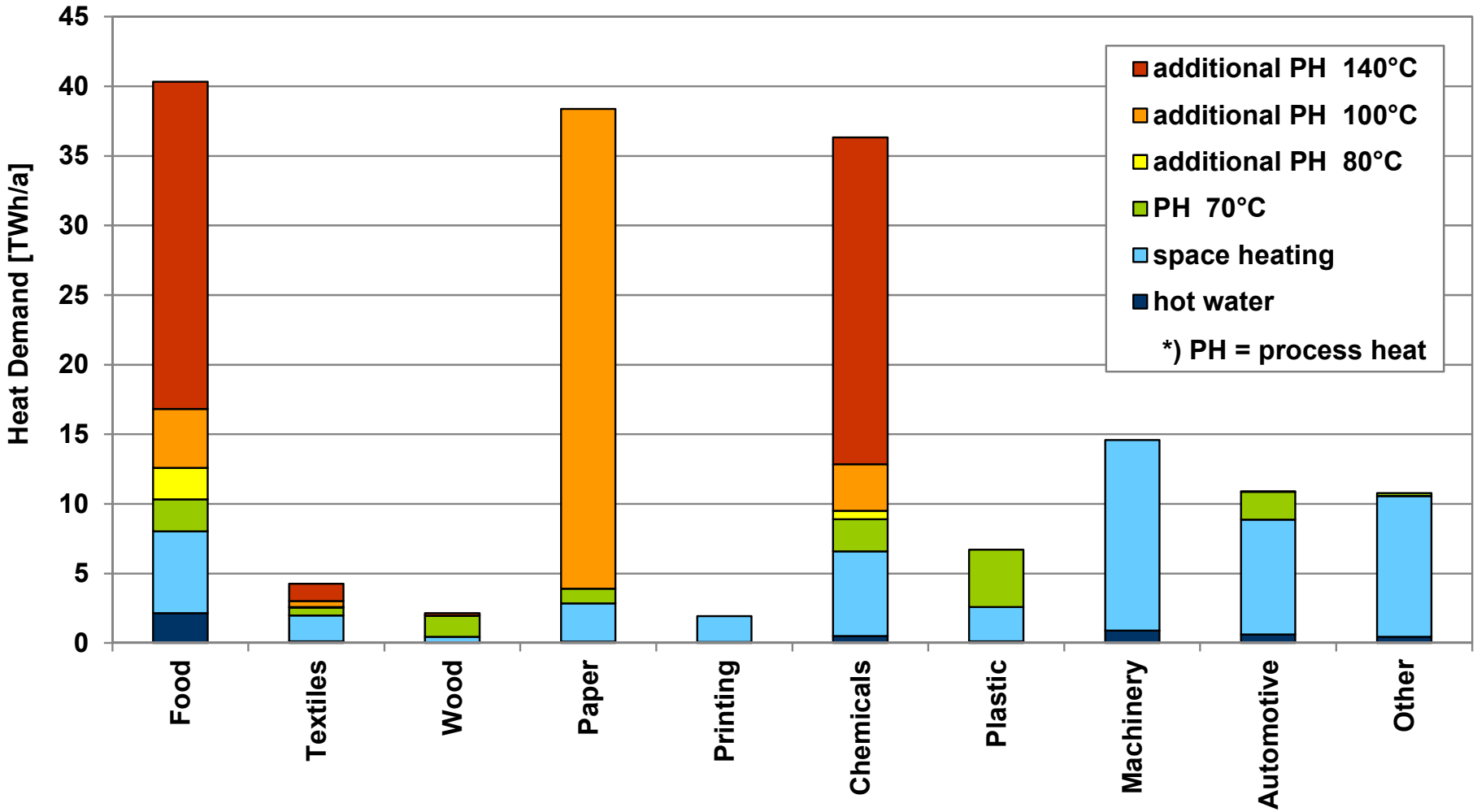
- Heat source: Waste heat from different processes
- Heat sink: Degreasing baths / space heating (< 110 °C)

Technical potential for industrial heat pumps in Germany



Sources: Blesl et al. 2012

Technical potential for industrial heat pumps in Germany



Sources: Blesl et al. 2012

Discussion of the potential

- Temperature level 70 °C: 73 TWh
- Temperature level 80 °C: 75 TWh
- Temperature level 140 °C: 166 TWh

166 TWh correspond to **33 %** of the **industrial heat demand** and to **16 %** of the entire **final energy demand** of the German industry.

Discussion of the potential

- Temperature level 70 °C: 73 TWh
- Temperature level 80 °C: 75 TWh
- Temperature level 140 °C: 166 TWh

166 TWh correspond to 33 % of the industrial heat demand and to 16 % of the entire final energy demand of the German industry.

Barriers to be overcome:

- Relatively high investment costs
- Lack of knowledge among planers and customers
- Lack of knowledge about energy demands and possible heat sources in industrial plants

Conclusion

- Heat source (waste heat) and heat sink (process heat) have to match ($\Delta T < 50$ K).

- The right heat pump has to be chosen depending on the use case:
  i. For temperature levels below 80 °C well proven heat pump technology can be used
  ii. The technology for temperature levels up to 140 °C is available and needs to be implemented and documented
  iii. Temperature levels of up to 160 °C can be reached in the nearer future

Thank you for your attention

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