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SOLAR AUTOMOTIVE

Experimental Assessment of Solar Process Heat Potential of German Plastic Injection Moulders

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International Sustainable Energy Conference – ISEC 2018

Bundesministerium für Wirtschaft und Energie

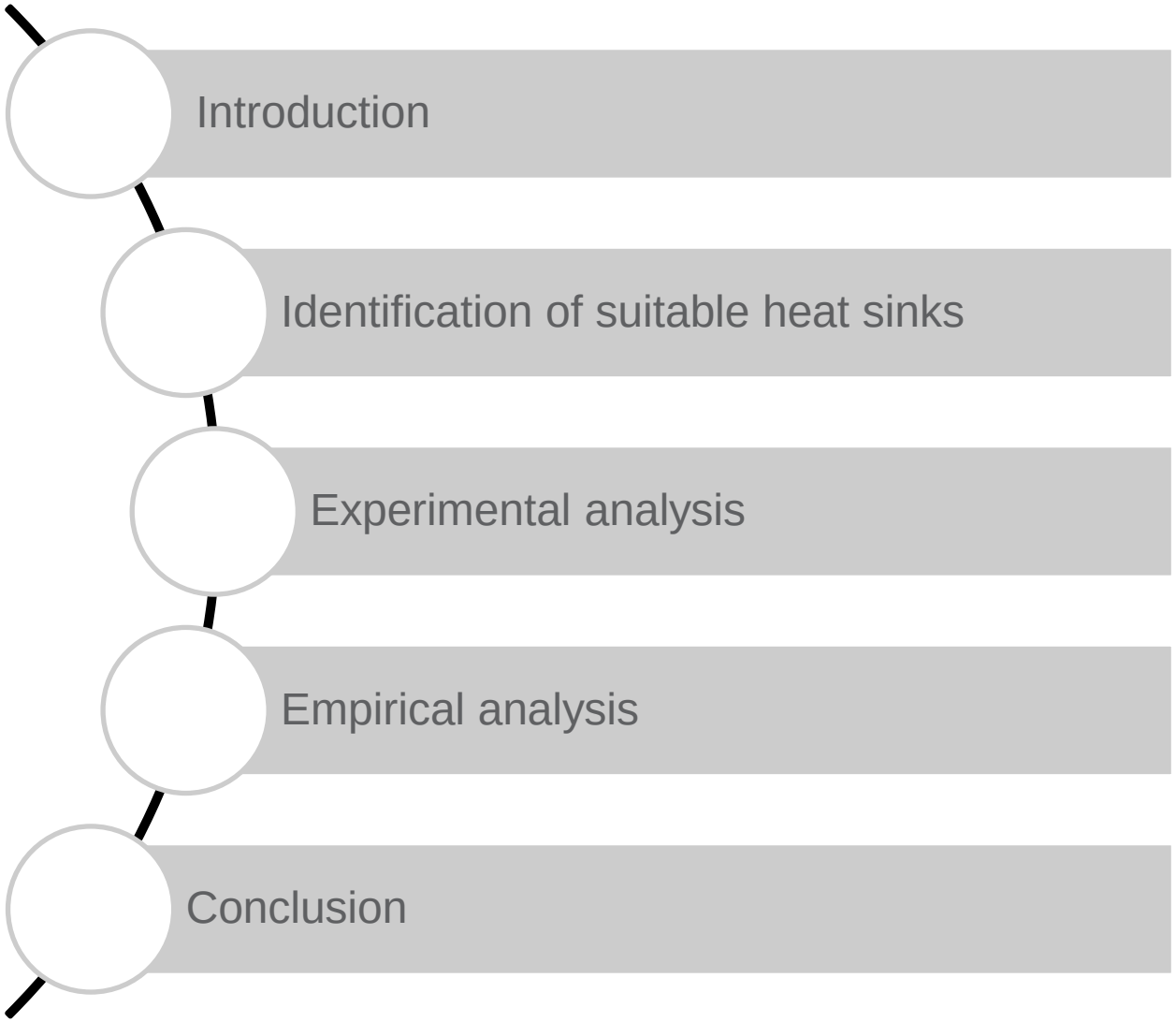
ptj Projektträger Jülich Forschungszentrum Jülich

Graz, 04.10.2018

klima+ energie fonds

FFG

Agenda


Introduction
Identification of suitable heat sinks
Experimental analysis
Empirical analysis
Conclusion

Department sustainable products and processes (upp)

Head: Prof. Dr.-Ing. Jens Hesselbach

Research activities

- Climate, energy and resource efficient production
- Collection, evaluation and benchmarking of energy data
- Flexible energy supply and load management
- Modelling, simulation and regulation of production and the environment

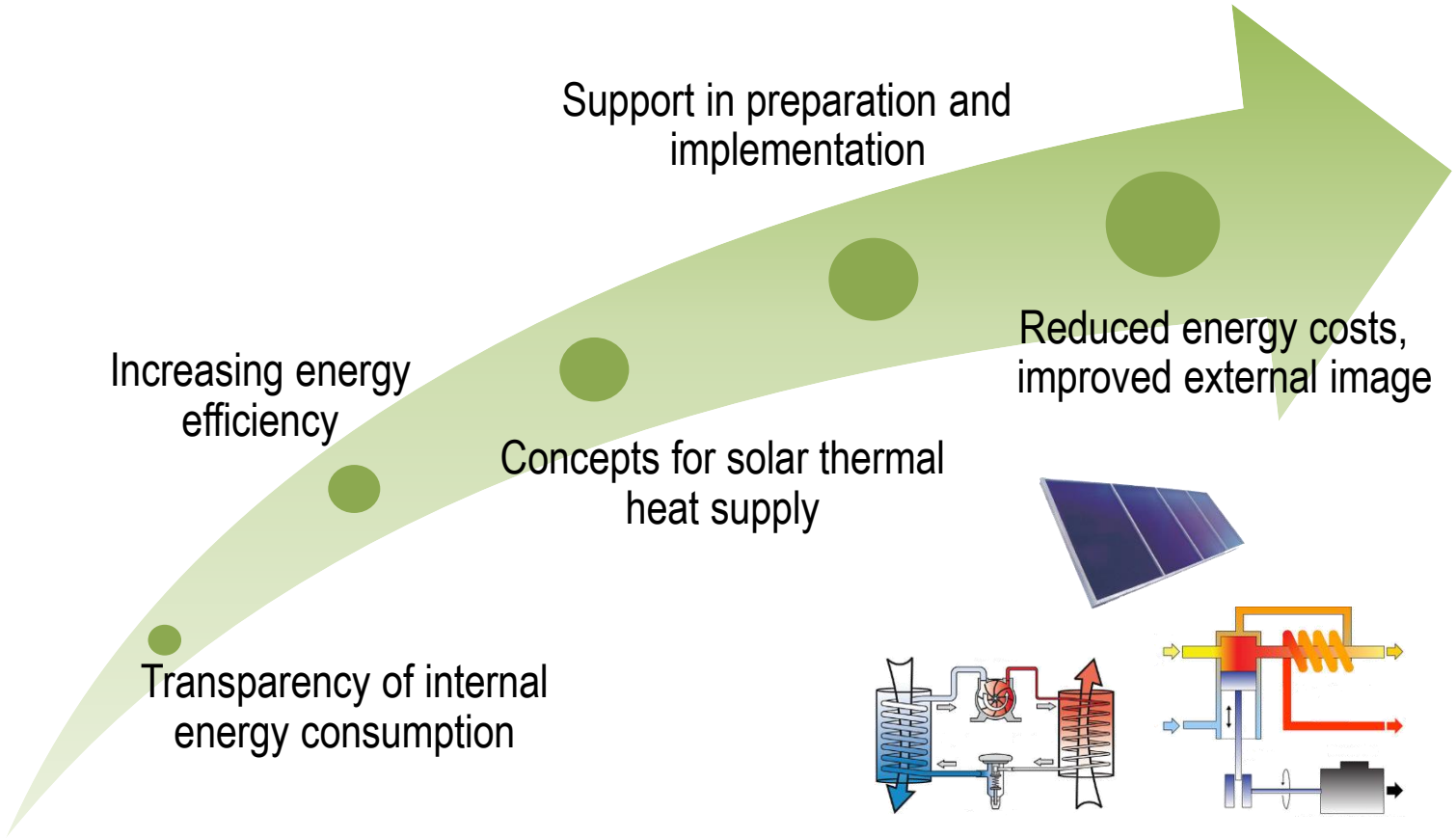
Lectureships

- Life cycle engineering
- Measurement of material and energy flows
- Energy efficiency in industrial processes
- Energy management systems
- Simulation and controlling of production and energy systems

For further information:
http://www.upp-kassel.de

Motivation - Strengthening sustainability

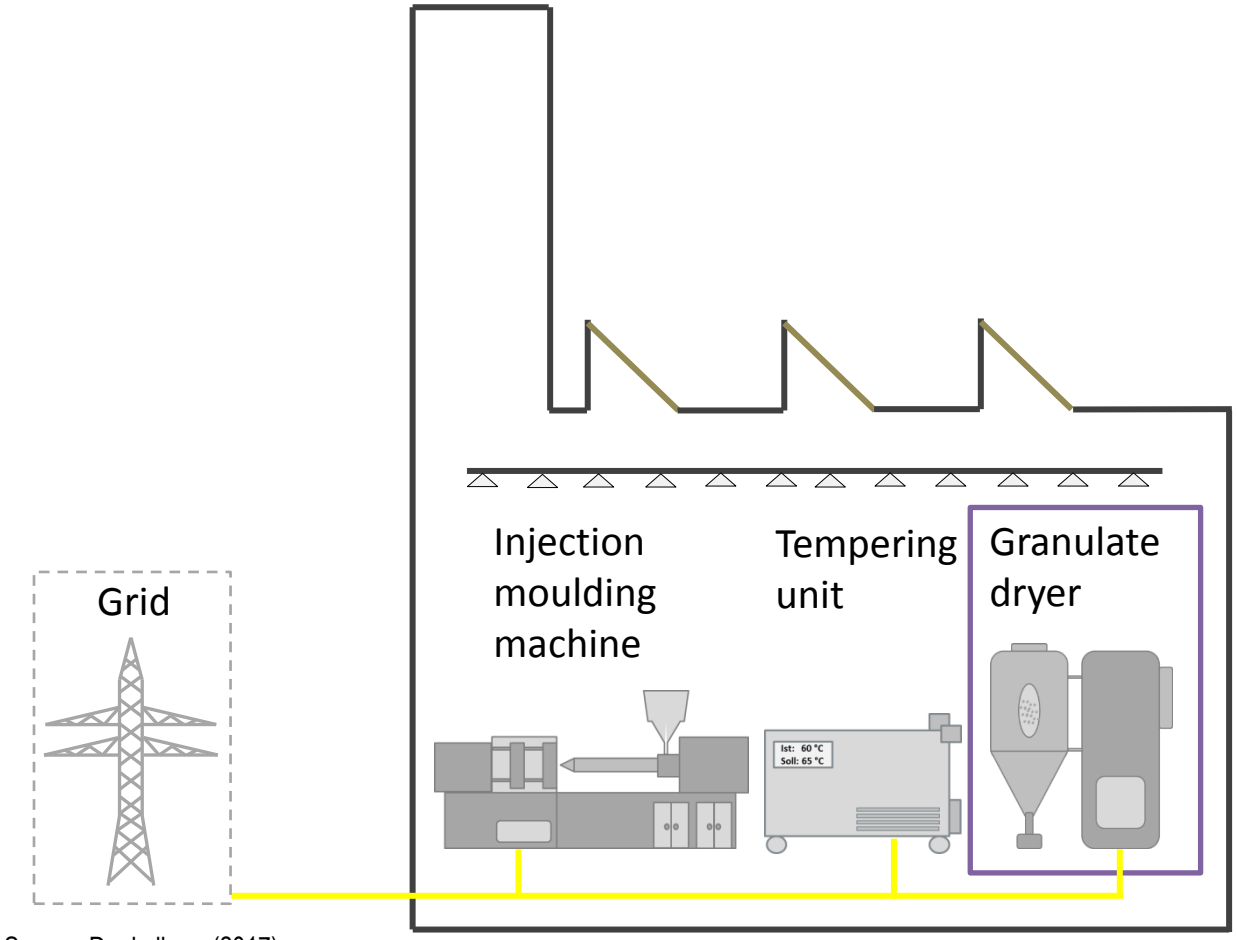
- Running time: 05/2016 - 04/2019
- Potential for the integration of solar process heat in the automotive sector
- Substitution of fossil fuels and reduction of CO_2 emissions
- Realization of beacon projects
- Characterisation of suitable companies



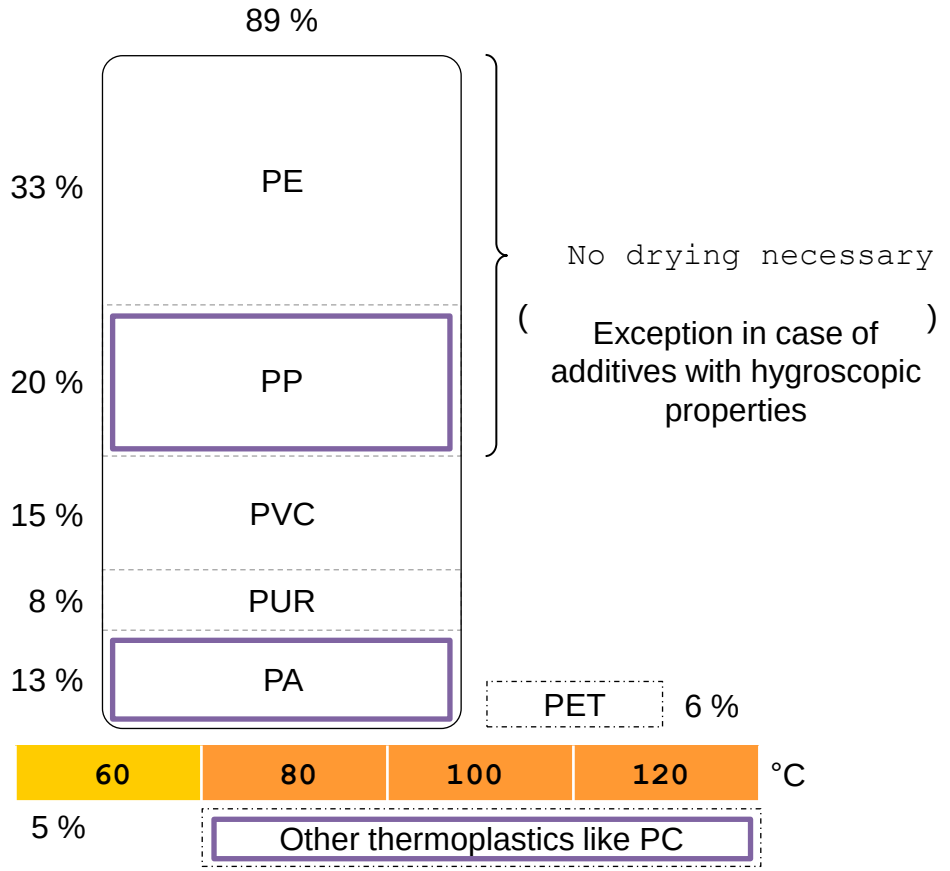
Funded by the Federal Ministry of Economics and Energy. Funding code: 0325863A

Initial state – injection moulding industry

- Identification of suitable heat sinks

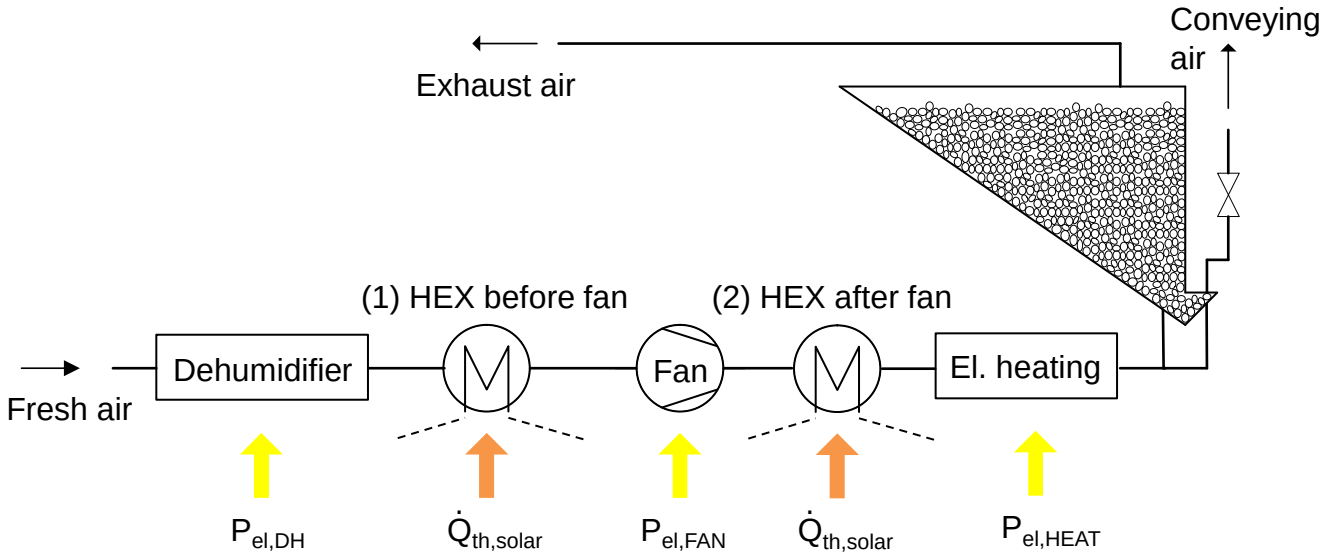


Source: Dunkelberg (2017)

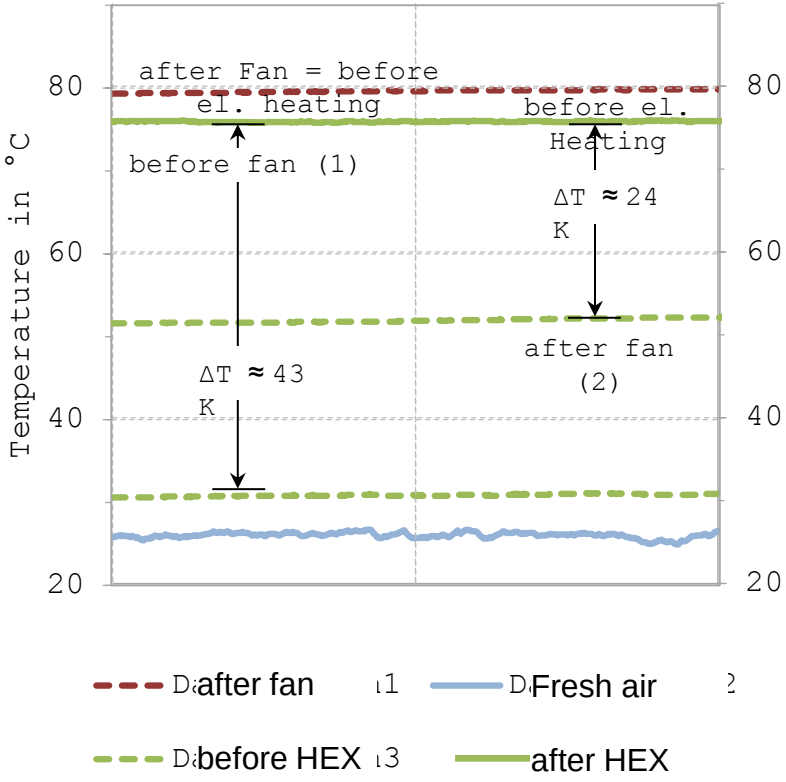


Experimental investigation of integration points

- Integration before (1) or after (2) the fan:

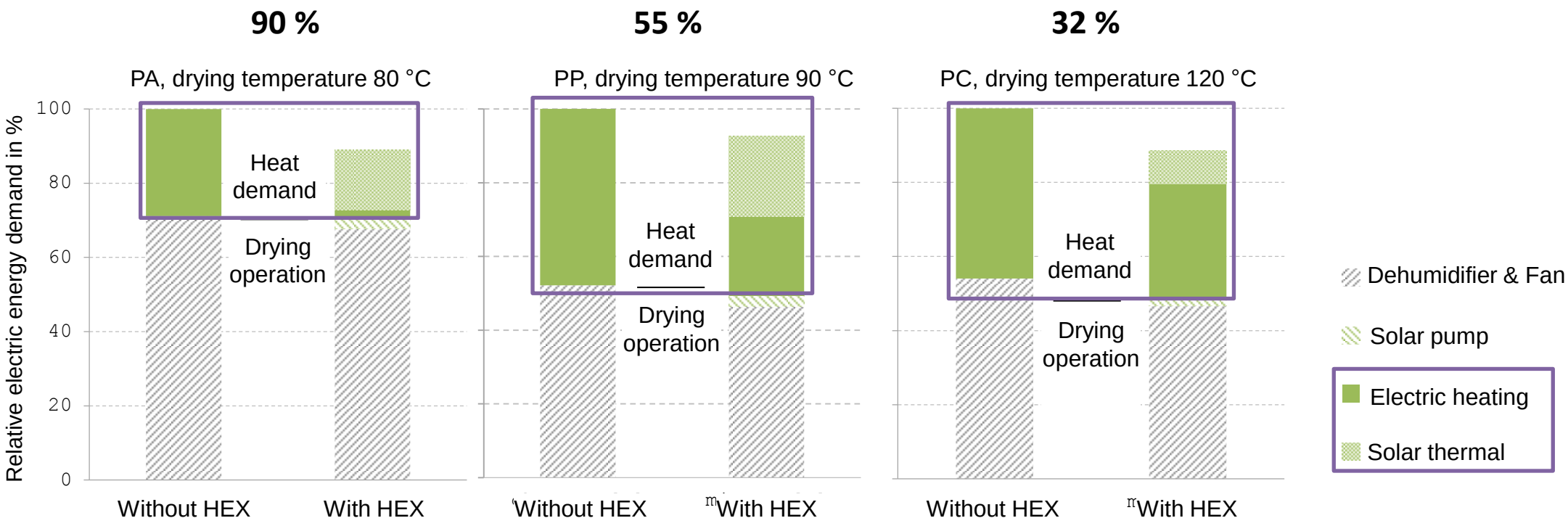


- Integration before the fan
  - More efficient utilisation of solar process heat
  - Higher collector efficiency

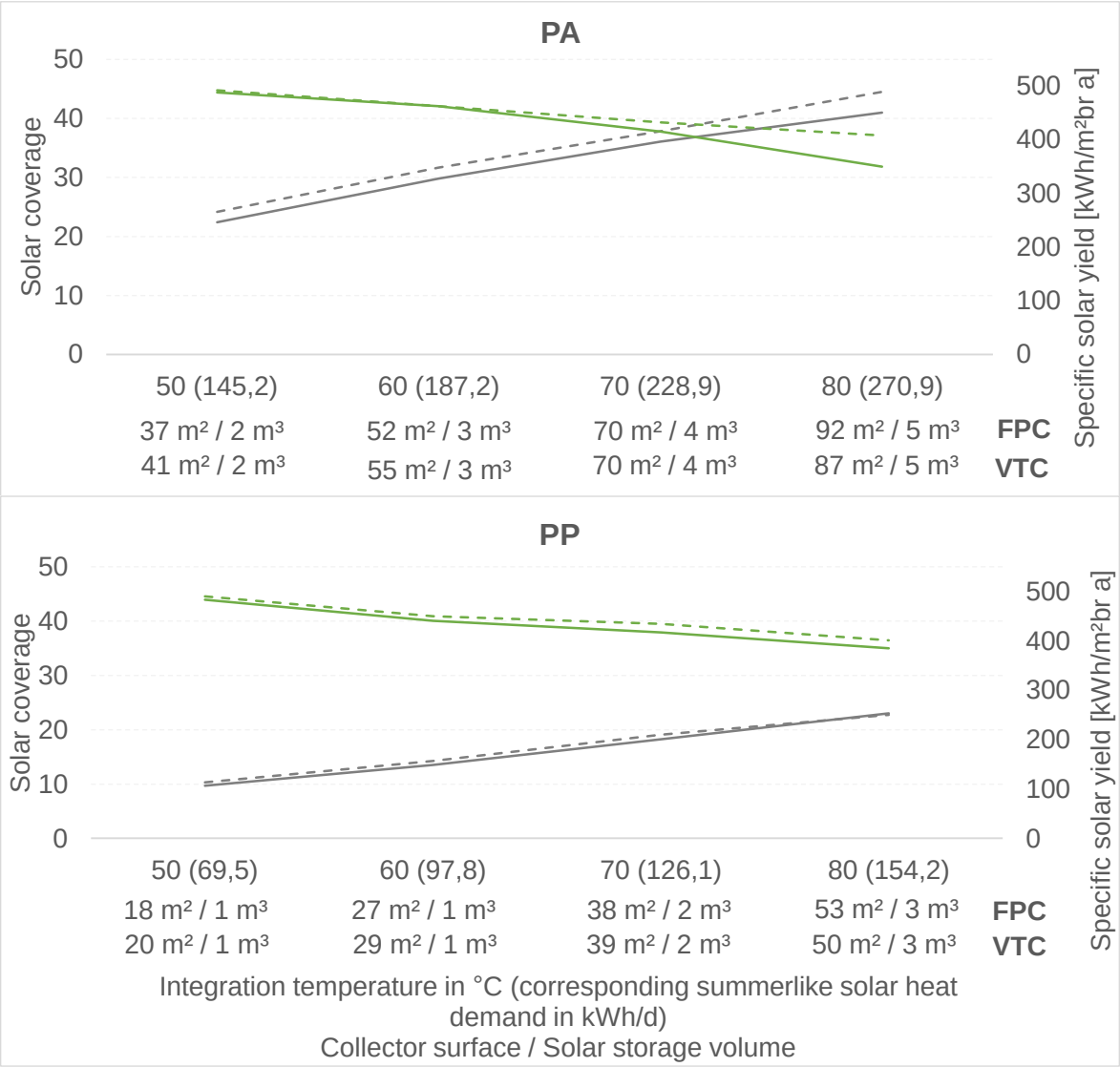


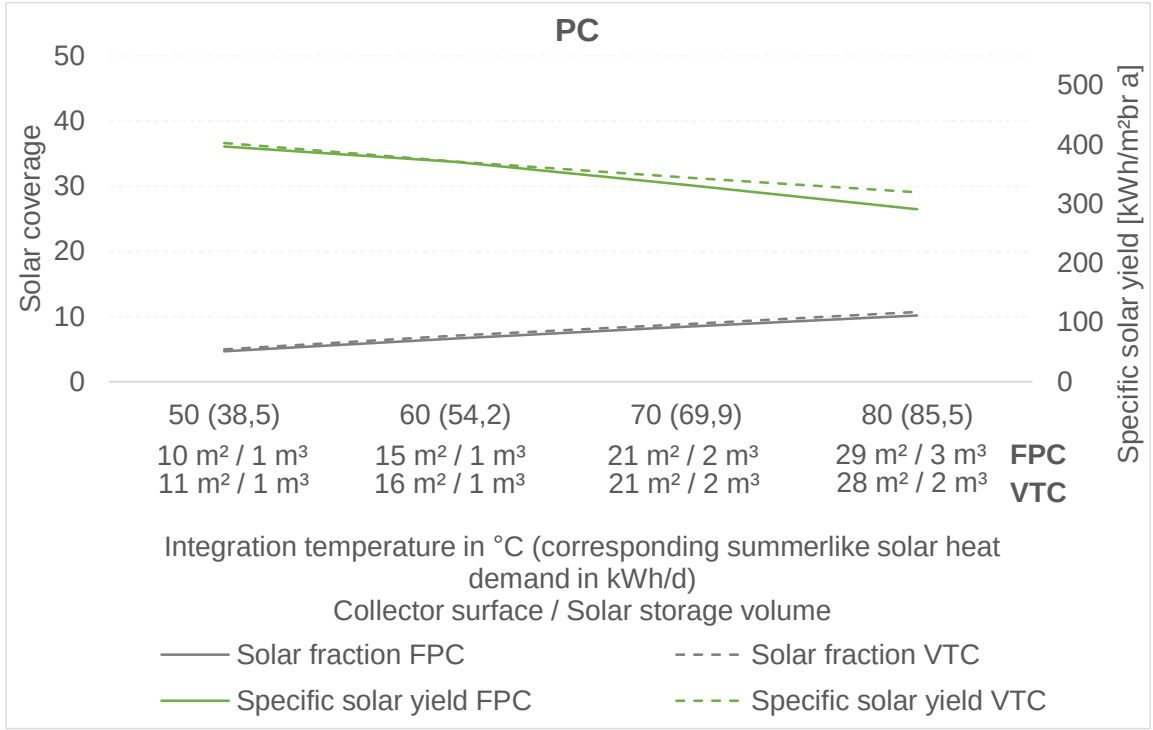
Experimental analysis

- Thermal energy savings (green share) regarding the electrical heat demand of the conventional system (Without HEX) for a collector temperatures of 82 °C:



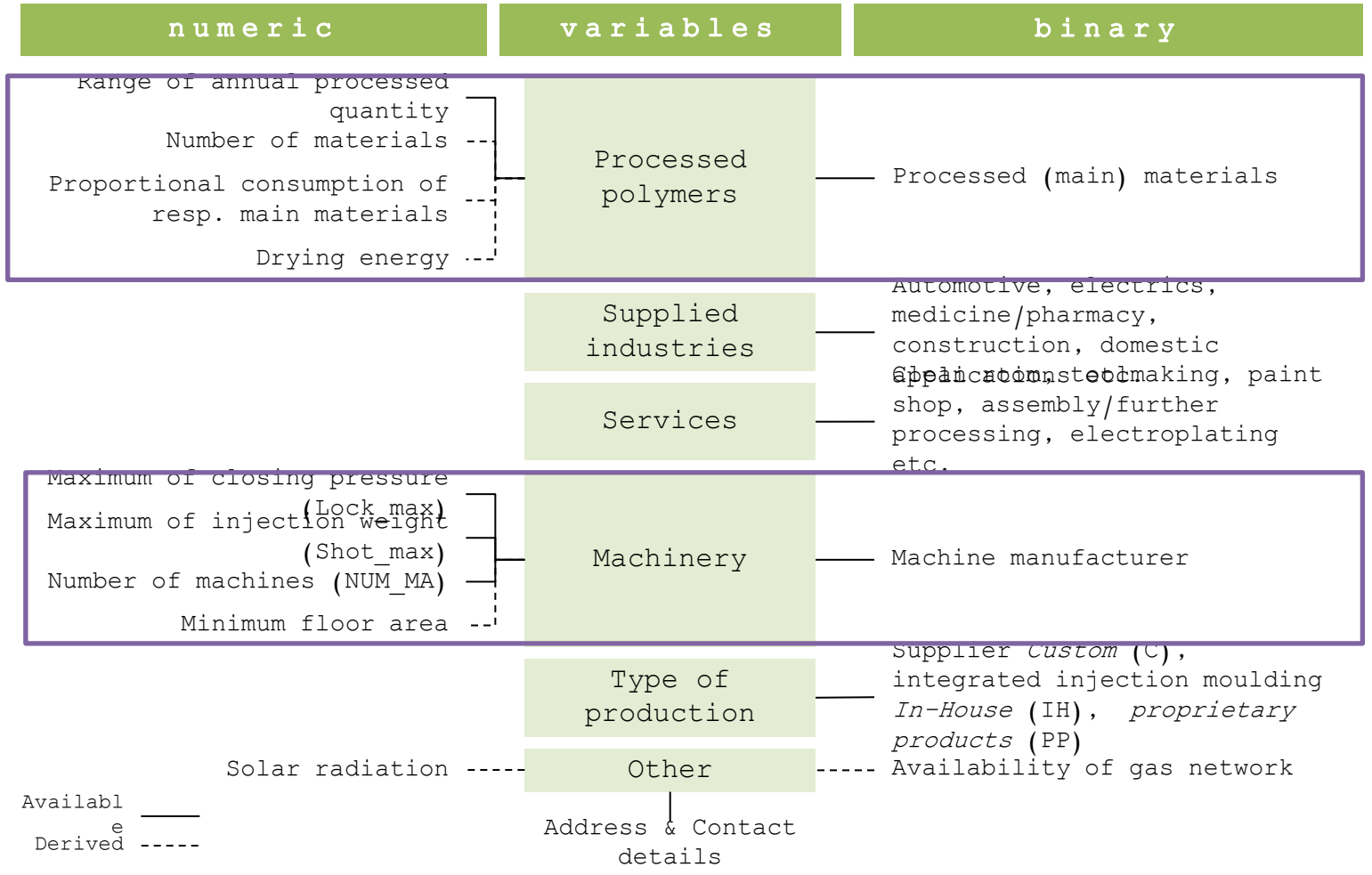
Assessment of integration setups





Empirical potential analysis

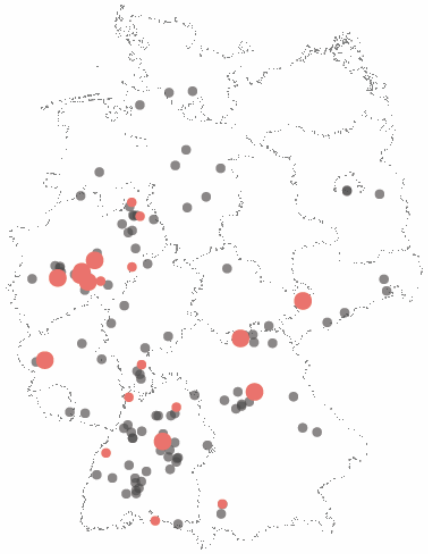
- Objective:
  - National integration potential of solar process heat for German Injection Moulders
- Method:
  - Determine the property structure of the medium-sized injection moulding industry
  - Identify classifications / clusters of suitable companies
  - Derive national potential



Empirical potential analysis

- Property structure
  - Typical material consumption from 500 t/a to 1,000 t/a
  - Machinery of ca. 30 medium sized plants
  - Mainly/exclusively plastics with drying temperatures up to 90 °C

- Thermal drying requirement for materials with drying temperatures up to 90 °C (without PE/PP):



Proposed potential

All 2349 Processors

Ca. 15.7 GWh/a for all 2,349 German Injection Moulders

Ca. 1.8 GWh/a for all Top 128 Injection Moulders

Conclusion

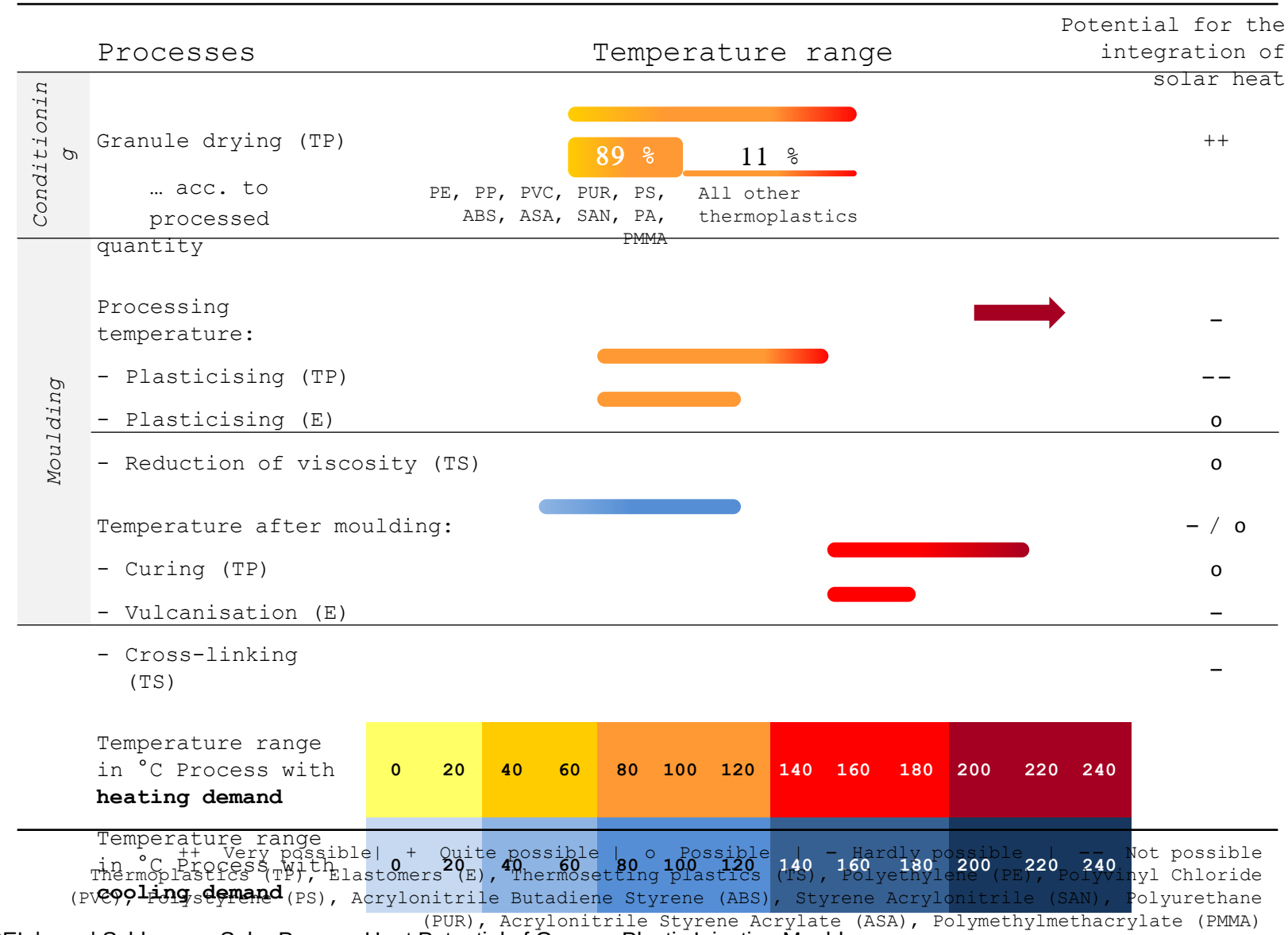
Summary

- Integration before the fan in central granulate dryer
- Potential: 128 companies with a thermal drying energy demand of 1.8 GWh/a for materials with drying temperatures up to 90 °C
- Positive characteristic values:
  - Continuously high drying demand below 90 °C
  - Large roof area

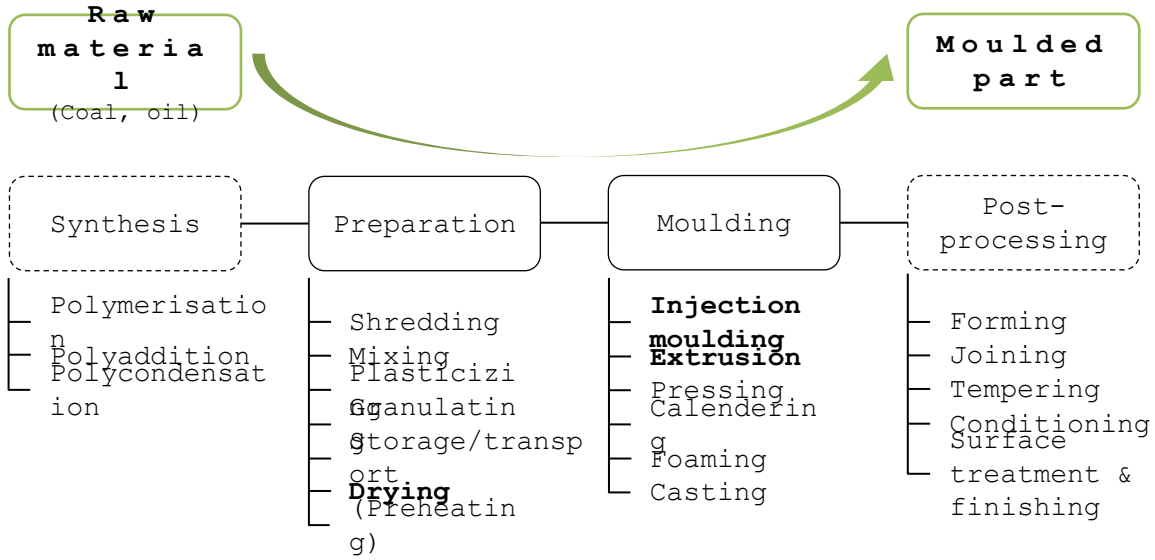
Outlook

- Transfer to the integration of other low-temperature heat sources, such as heat pumps or CHP
- Transfer to other sectors
  - Prerequisite: comprehensive database

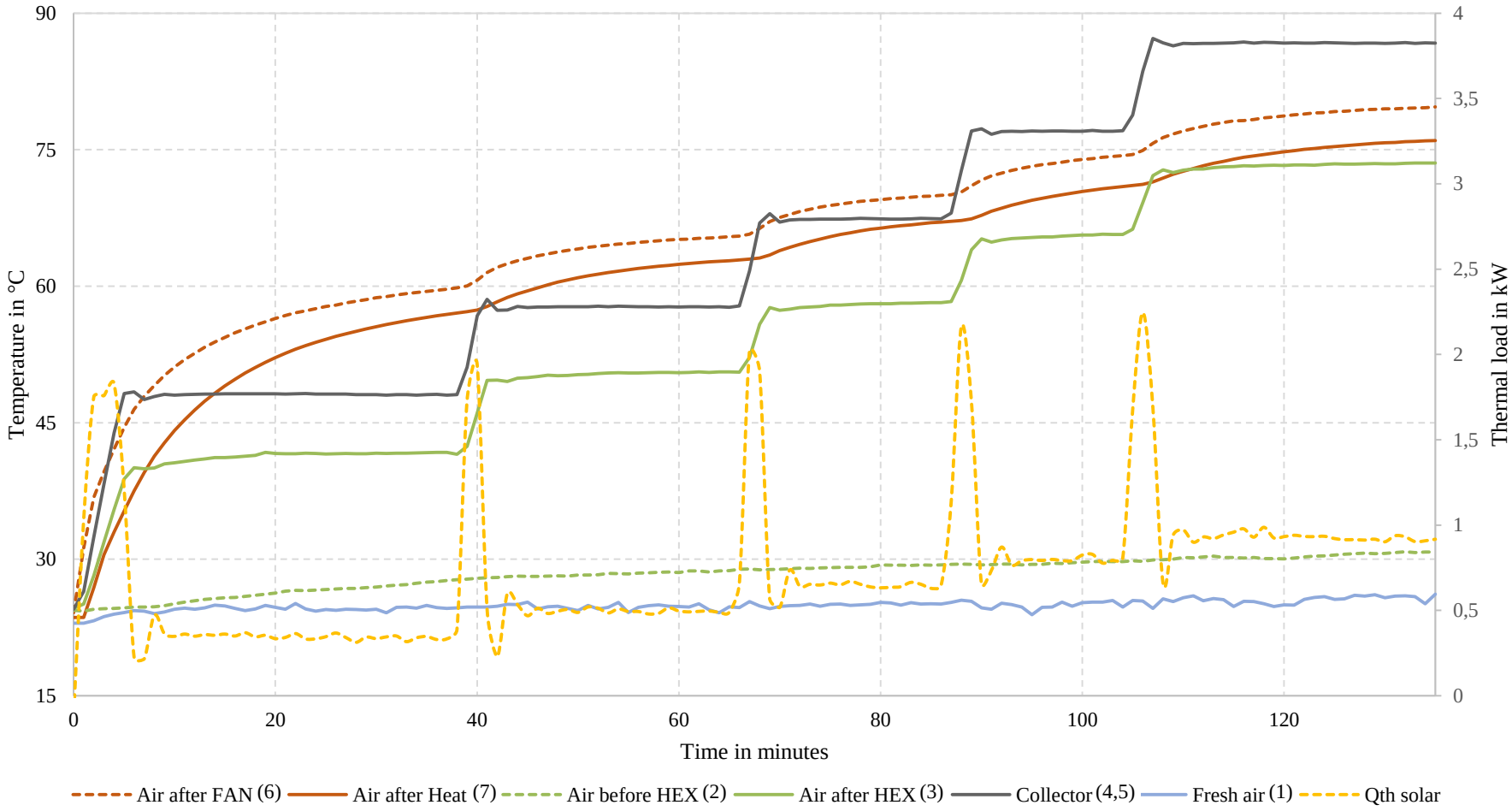
Backup

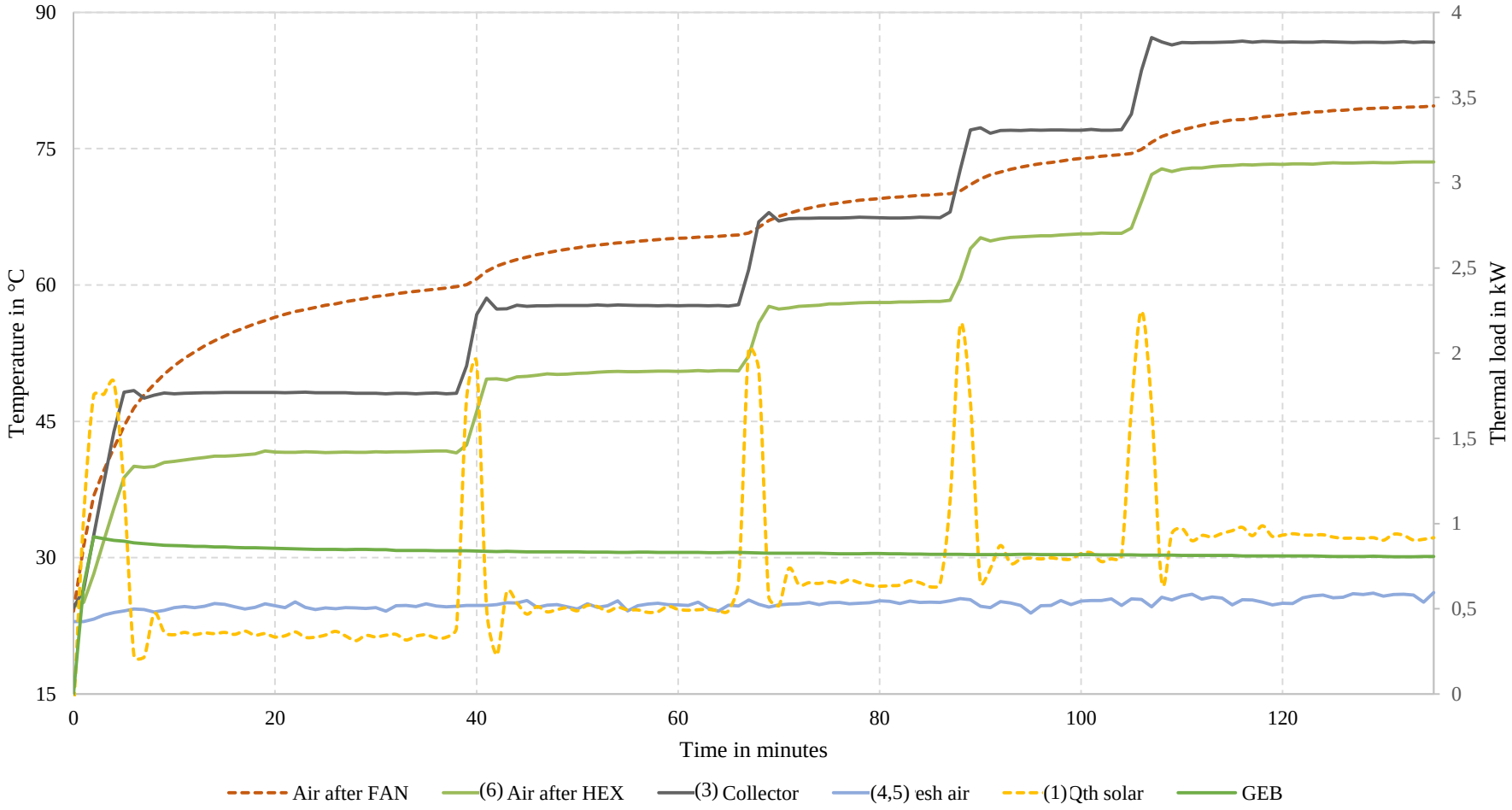

Processes
Temperature range
Potential for the integration of solar heat
Conditioning
Granule drying (TP)
… acc. to processed quantity
89 %
11 %
PE, PP, PVC, PUR, PS, ABS, ASA, SAN, PA, PMMA
All other thermoplastics
++
Moulding
Processing temperature:
- Plasticising (TP)
- Plasticising (E)
-
--
o
- Reduction of viscosity (TS)
o
Temperature after moulding:
- Curing (TP)
- Vulcanisation (E)
- / o
o
-
- Cross-linking (TS)
-
Temperature range in °C Process with heating demand
Temperature range in °C Process with cooling demand
0 20 40 60 80 100 120 140 160 180 200 220 240
++ Very possible | + Quite possible | o Possible | - Hardly possible | -- Not possible
Thermoplastics (TP), Elastomers (E), Thermosetting plastics (TS), Polyethylene (PE), Polyvinyl Chloride (PVC), Polystyrene (PS), Acrylonitrile Butadiene Styrene (ABS), Styrene Acrylonitrile (SAN), Polyurethane (PUR), Acrylonitrile Styrene Acrylate (ASA), Polymethylmethacrylate (PMMA)

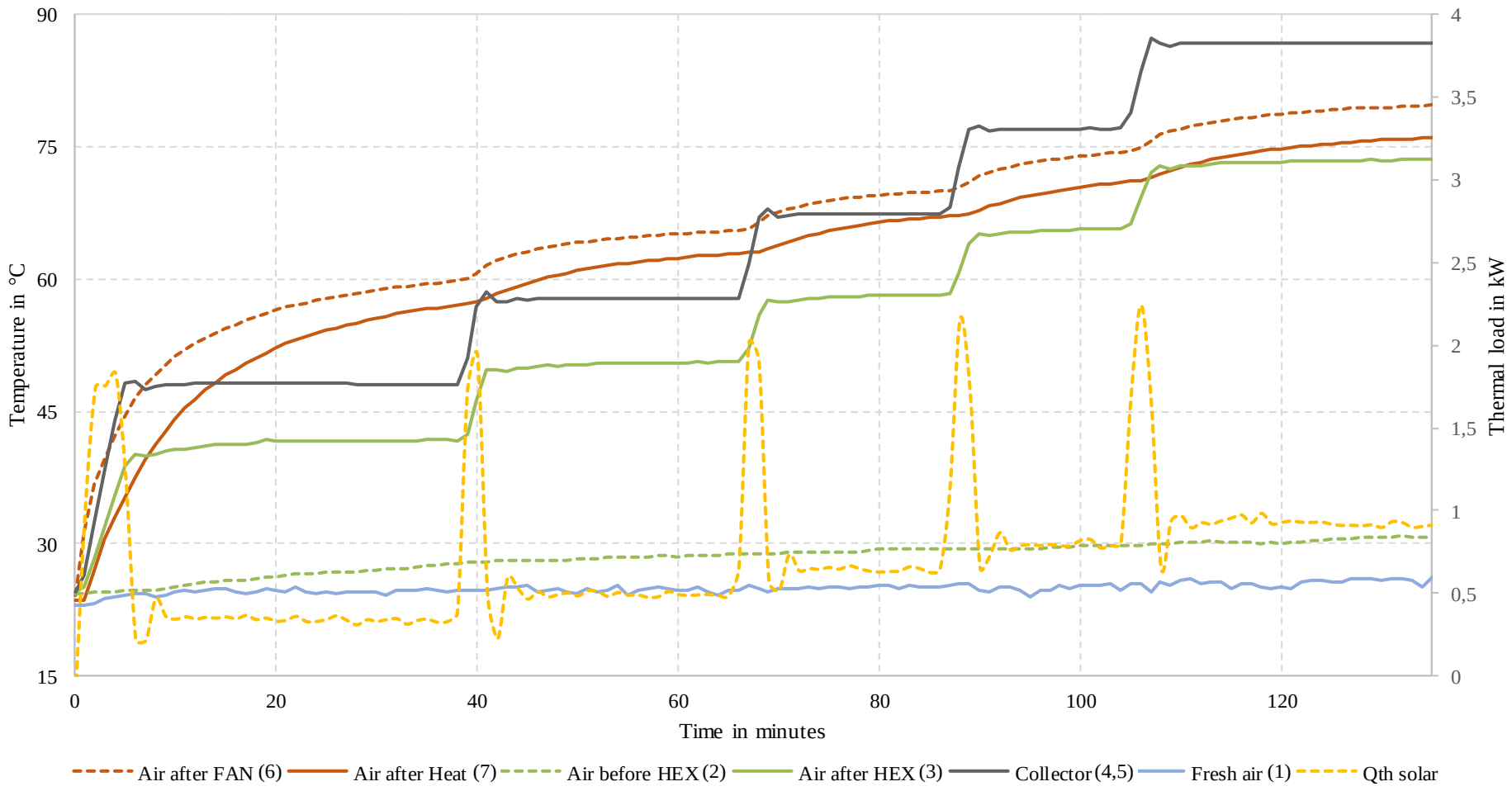
71x160


Raw material
(Coal, oil)
Moulded part
Synthesis
Polymerisation
Polyaddition
Polycondensation
Preparation
Shredding
Mixing
Plasticizing
Granulating
Storage/transport
Drying
(Preheating)
Moulding
Injection moulding
Extrusion
Pressing
Calendering
Foaming
Casting
Post-processing
Forming
Joining
Tempering
Conditioning
Surface treatment & finishing

Number of companies in data set		**2.349**	100%
IH		- 80	
PP-IH		- 134	
C-PP-IH		- 103	
Number of machines (NUM_MA)	< 10	- 408	
	>100	- 26	
	not stated	- 137	
Lock_max	not stated	- 34	
Shot_max	not stated	- 50	
Deleted elements (total)		- 972	
Companies in adjusted data set		**1.377**	59%


90
75
60
45
30
15
Temperature in °C
4
3,5
3
2,5
2
1,5
1
0,5
0
Thermal load in kW
0
20
40
60
80
100
120
Time in minutes
Air after FAN (6)
Air after Heat (7)
Air before HEX (2)
Air after HEX (3)
Collector (4,5)
Fresh air (1)
Qth solar


90
75
60
45
30
15
Temperature in °C
4
3,5
3
2,5
2
1,5
1
0,5
0
Thermal load in kW
0
20
40
60
80
100
120
Time in minutes
Air after FAN
(6) Air after HEX
(3) Collector
(4,5) esh air
(1) Qth solar
GEB

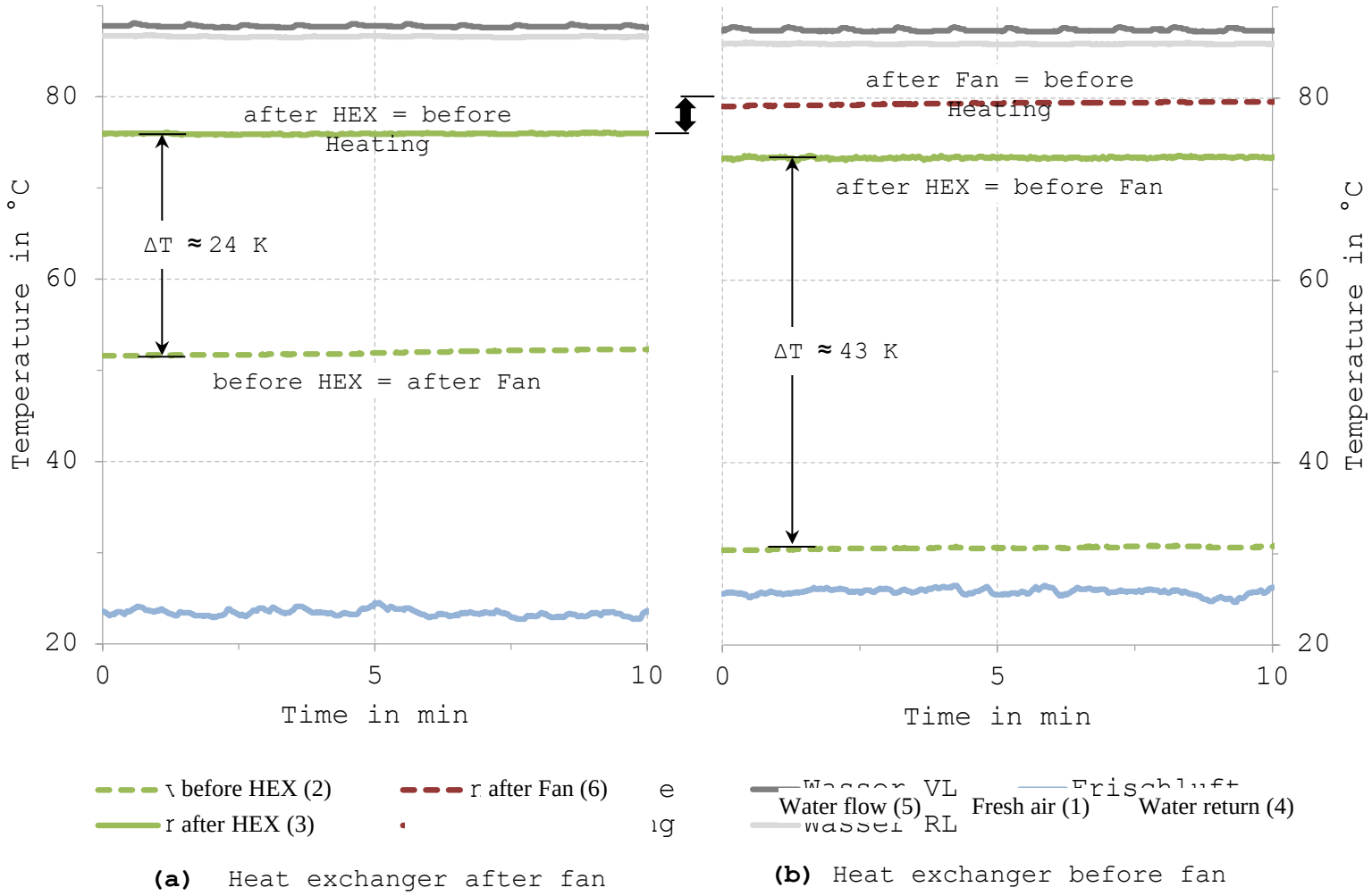

90
75
60
45
30
15
Temperature in °C
4
3,5
3
2,5
2
1,5
1
0,5
0
Thermal load in kW
0
20
40
60
80
100
120
Time in minutes
Air after FAN (6)
Air after Heat (7)
Air before HEX (2)
Air after HEX (3)
Collector (4,5)
Fresh air (1)
Qth solar

	PA	PP	PC
Load in kW			
Peak load TOT	2,52	2,09	3,93
Peak load HEAT	0,93	1,19	2,37
Total	1,37	1,19	2,18
Heating	0,05	0,37	0,86
Fan	0,81	0,79	0,83
Dehumidifier	0,49	-	0,46
Primary energy savings in % (without/with HEX)			
Total (incl. Q_{th})	11,0	7,3	11,3
Total (excl. Q_{th})	27,2	29,1	20,3
Electric heating	91,5	54,9	32,1

		Veitengruber (2018)			Wolff (2015)	Determined theoretically		
	Unit	PP*	PA	PC	PE*	PVC	PS	ABS/SAN
Energy demand for material heating:								
c	kJ/(kgK)	1,8	1,7	1,17	2,4	0,9	1,3	1,3
T_{start}	°C	23,29	27,11	25,07	20,7	20	20	20
T_{target}	°C	89,4	80,82	118,43	89,29	70	80	80
ΔT	K	66,11	53,71	93,36	68,59	50	60	60
q_{MAT}	kWh/t	33,06	25,36	30,34	45,73	12,50	21,67	21,67
Energy demand for evaporating of the water								
$Humidity_A$	%	0,075	0,83	0,235	0,155	0,1	0,3	0,4
$Humidity_E$	%	0,055	0,09	0,028	0,021	0,08	0,2	0,2
Diff. humidity	kg_W/kg_G	0,0002	0,0074	0,0021	0,0013	0,0002	0,0010	0,0020
ΔH_V	kJ/kg_W	2284,2	2306,0	2206,7	2284,5	2333,1	2308,1	2308,1
q_{EVA}	kWh/t	0,13	4,74	1,27	0,85	0,13	0,64	1,28
Specific drying energy demand:								
q_{TOT}	kWh/t	33,18	30,10	31,61	46,58	12,63	22,31	22,95

* If drying required

Plastic	Unit	PA				PP					PC					
Collector temperature	°C	50	60	70	80	50	60	70	80	90	50	60	70	80	90	120
Summerlike process heat demand:																
$Q_{th,solar}$	kWh/d	145.2	187.2	228.9	270.9	69.5	97.8	126.1	154.2	182.5	38.5	54.2	69.9	85.5	101.2	101.2
Solar fraction of different collector types																
Flat collector	-															-
Air collector	-															-
Vacuum tube collector																

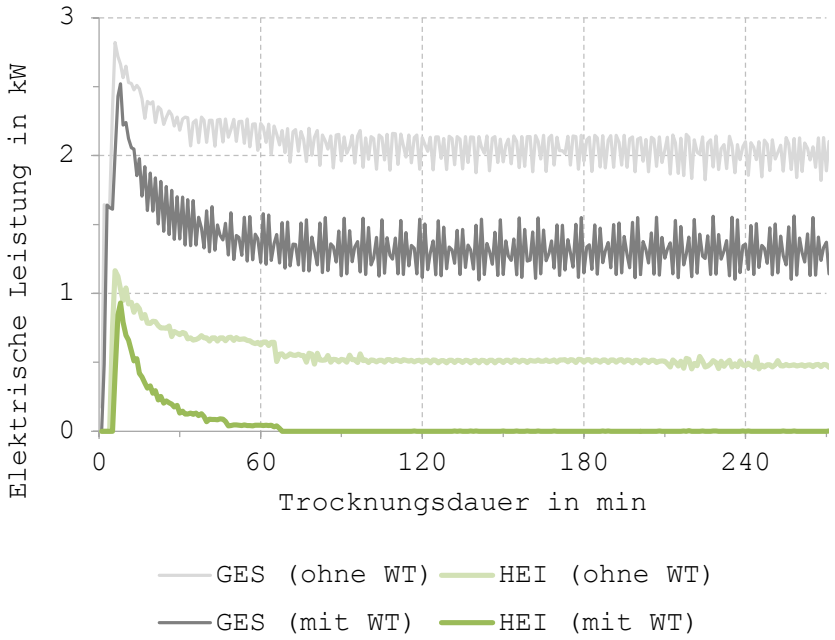


(a) Heat exchanger after fan

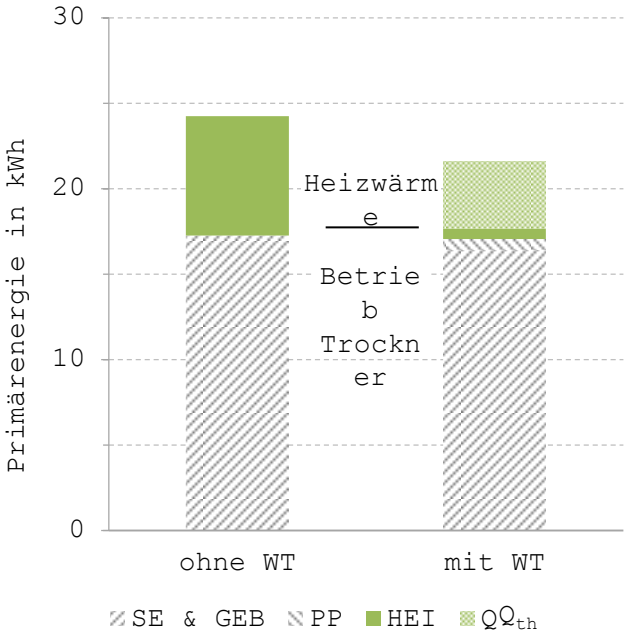
(b) Heat exchanger before fan

		Veitengruber (2018)			Wolff (2015)	Determined theoretically		
	Unit	PP*	PA	PC	PE*	PVC	PS	ABS/SAN
Specific drying energy demand: q_{TOT}	kWh/t	33,2	30,1	31,6	46,6	12,6	22,3	23,0

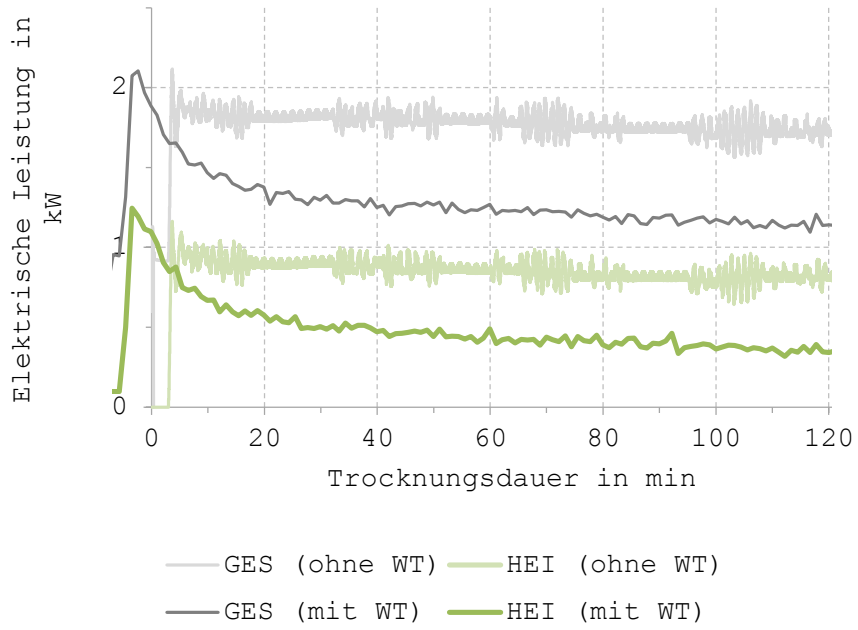
* If drying required.



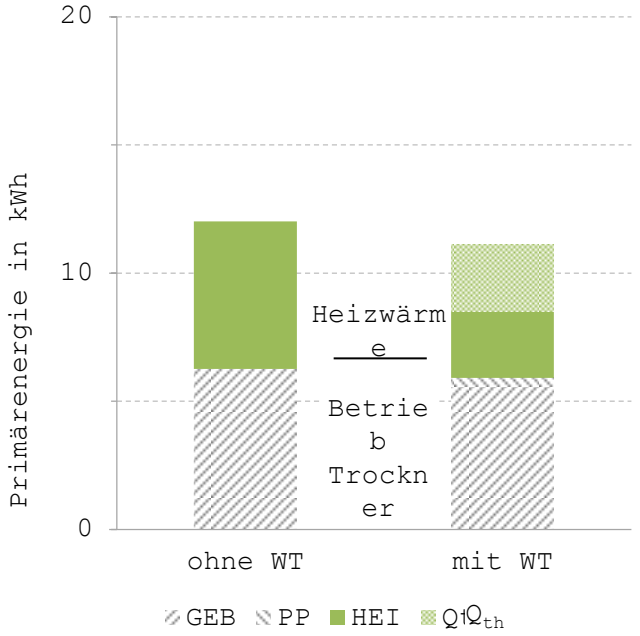
(a) Vergleich der Leistungsaufnahme



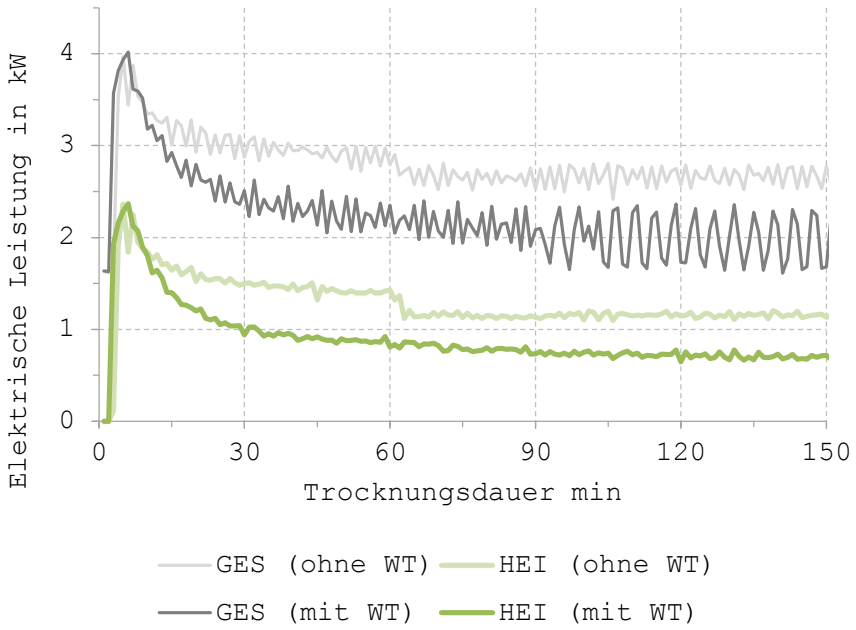
(b) Primärenergetischer Vergleich



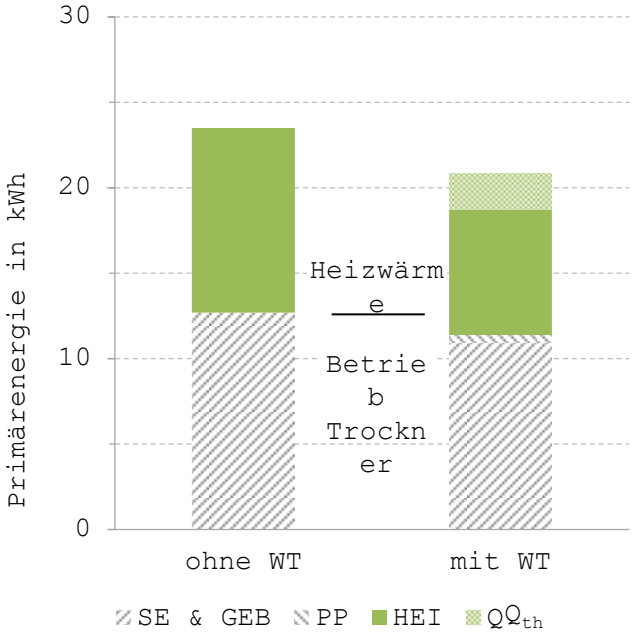
(a) Vergleich der Leistungsaufnahme



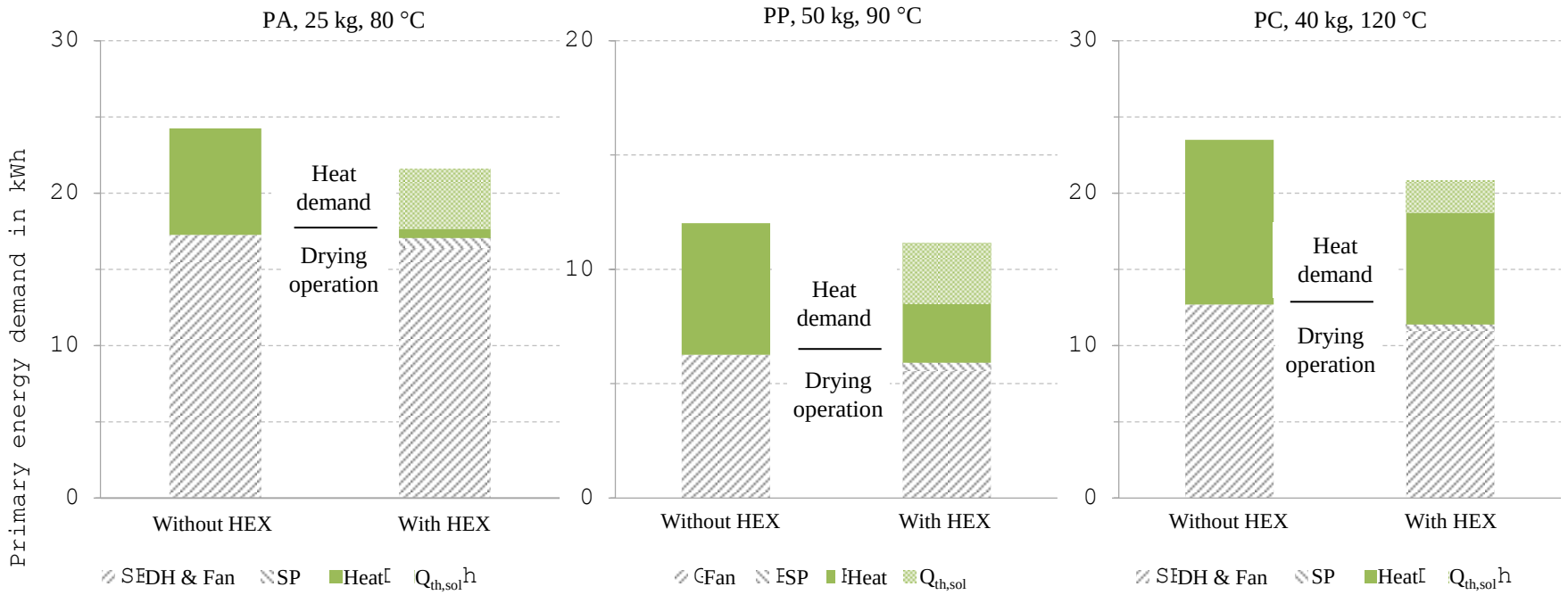
(b) Primärenergetischer Vergleich



(a) Vergleich der Leistungsaufnahme



(b) Primärenergetischer Vergleich


PA, 25 kg, 80 °C
PP, 50 kg, 90 °C
PC, 40 kg, 120 °C
Primary energy demand in kWh
30
20
10
0
Heat demand
Drying operation
Without HEX
With HEX
SDH & Fan
SP
Heat
$Q_{th,sol}$