5th International Conference on Smart Energy Systems
Copenhagen, 10-11 September 2019
#SESAAU2019

Optimization of temperature levels in decentralized solar feed-in heat grids

A case study of Dutch refurbished building in a residential neighbourhood

Saleh Mohammadi, Sabine Jansen, Sam van der Zwan, Cees Mager

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Decentralized Low Temperature Feed-in Heat Grids with PVT

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DeZONNET Consortium

DeZONNET is a TKI* Urban Energy project funded by the Netherlands Enterprise Agency (RVO)

*Topconsortia voor Kennis en Innovatie

Background information

(Neighborhood and Case study building)

Natural gas-free neighborhoods (Aardgasvrije wijken)

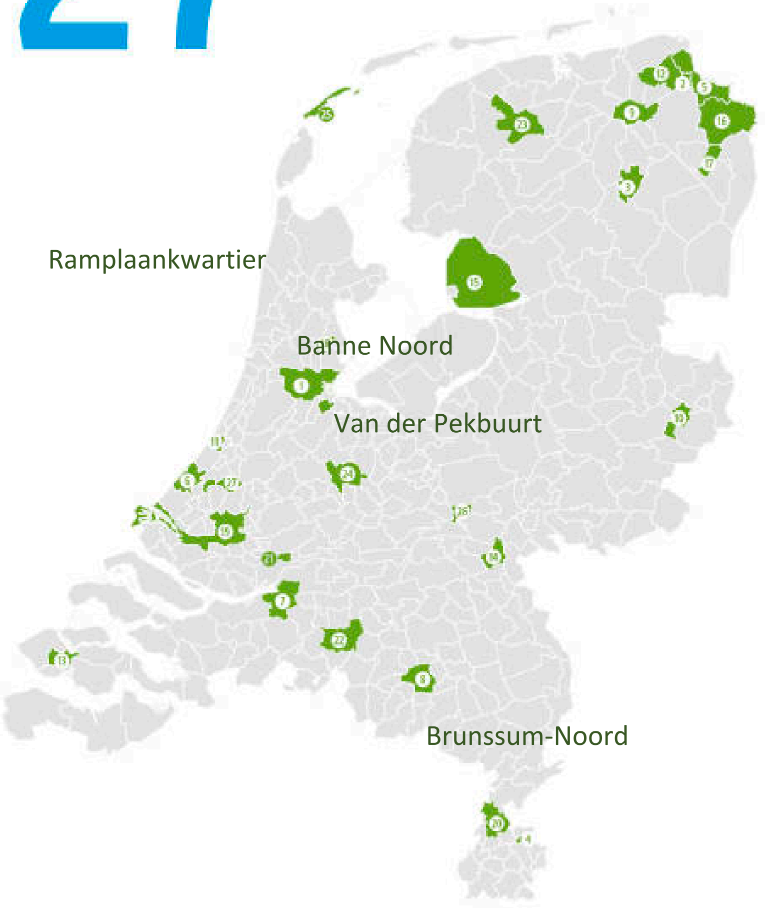
120 miljoen euro voor 'proeftuinen' aardgasvrije wijken in 27 gemeenten

SPAARgas
DOE MEE!

1	Amsterdam	Van Der Pekbuurt
2	Appingedam	Opwierde-Zuid
3	Assen	Lariks West
4	Brunssum	Brunssum-noord
5	Delfzijl	Delfzijl Noord
6	Den Haag	Bouwlust/Vrederust
7	Drimmelen	Terheijden
8	Eindhoven	t Ven
9	Groningen	Paddepoel en Selwerd
10	Hengelo	Nijverheid
11	Katwijk	Smartpolder
12	Loppersum	Loppersum-'t Zandt- Westeremden
13	Middelburg	Dauwendaele
14	Nijmegen	Dukenburg
15	Noordoostpolder	Nagele
16	Oldambt	Nieuwolda-Wagenborgen
17	Pekela	Boven Pekela en de Doorsneebuurt
18	Purmerend	Overwhere-Zuid
19	Rotterdam	Pendrecht
20	Sittard-Geleen	Limbrichterveld-Noord
21	Sliedrecht	Sliedrecht-Oost
22	Tilburg	Quirijnstok
23	Tytsjerksteradiel	Garyp
24	Utrecht	Overvecht Noord
25	Vlieland	Duinwijck
26	Wageningen	Benedenbuurt
27	Zoetermeer	Palenstein

Natural gas-free neighborhoods (Aardgasvrije

27 aardgasvrije wijken



120 miljo
in 27 ger

1	Amsterdam	Van Der Pekbuurt
2	Appingedam	Opwierde-Zuid
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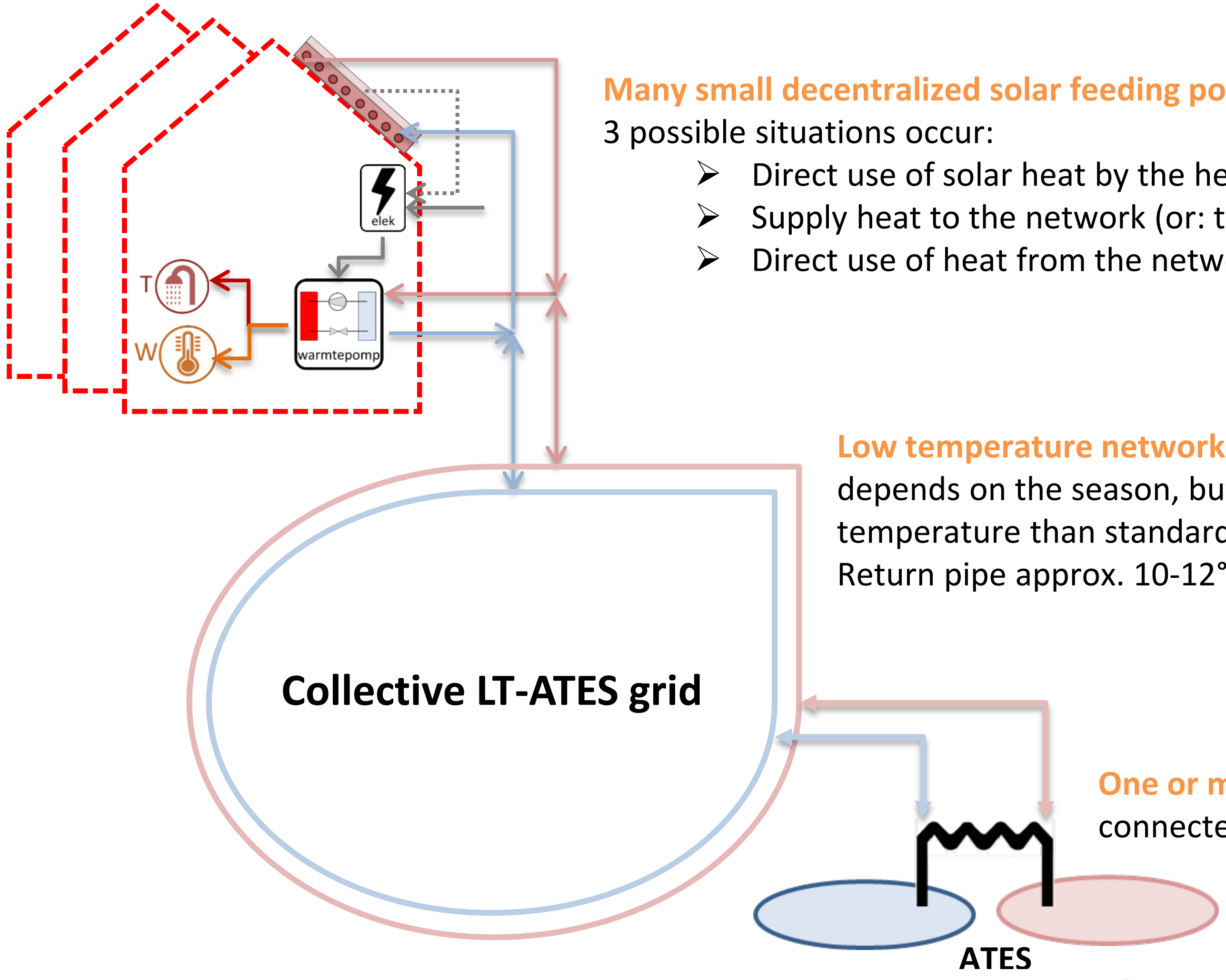
Duurzaam Ramplaankwartier

***Natural gas free neighborhood** & local generation as much as possible*

DeZONNET Concept



Many small decentralized solar feeding points with PVT

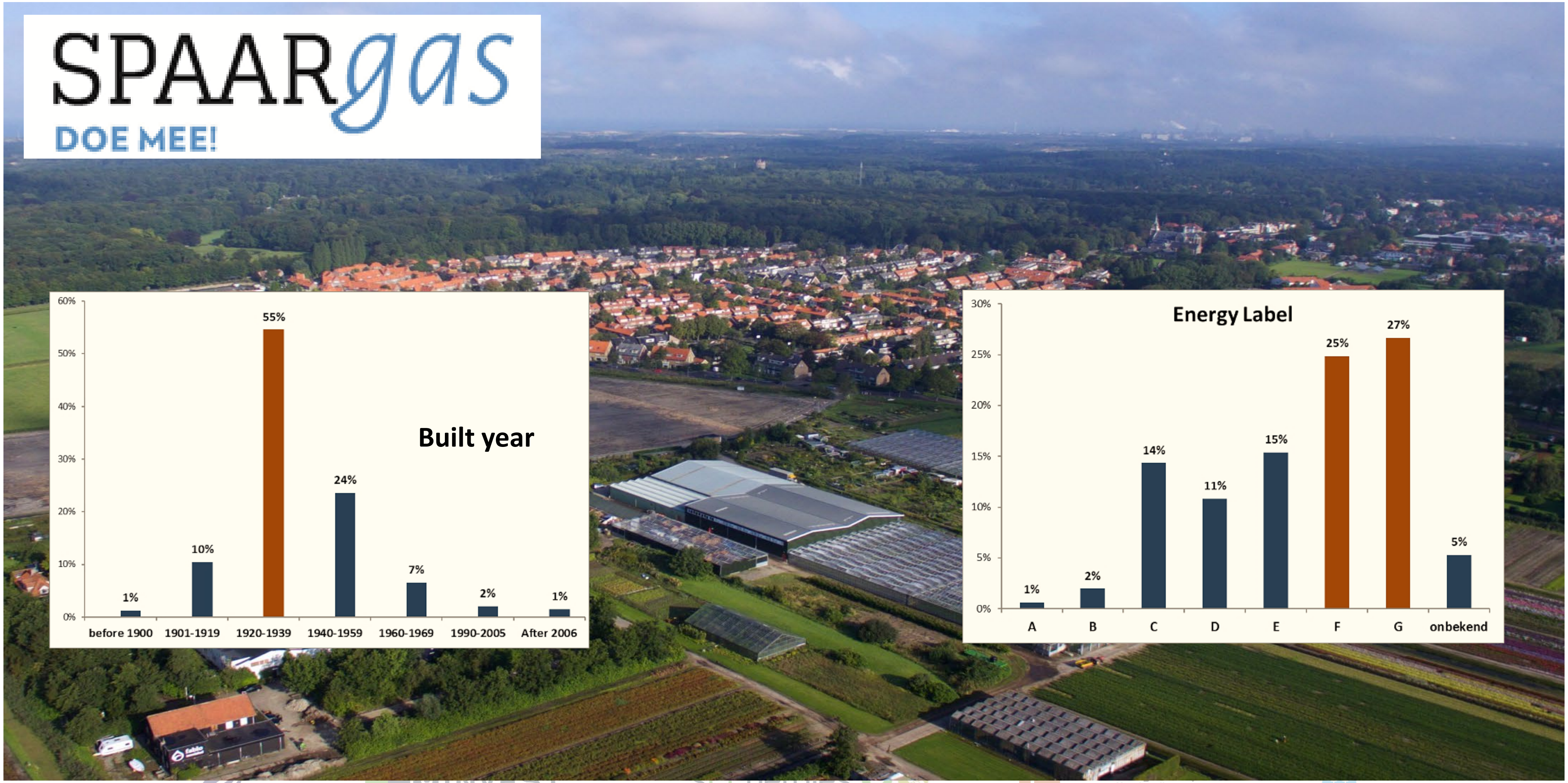
3 possible situations occur:

- Direct use of solar heat by the heat pump in the house
- Supply heat to the network (or: take cold from the network)
- Direct use of heat from the network

Low temperature network with the supply around 20°C (this depends on the season, but in any case it has higher temperature than standard ATES net.
Return pipe approx. 10-12°C)

One or more ATES systems
connected to the LT grid


SPAARgas
DOE MEE!
Duurzaam Ramplaankwartier
Natural gas free neighborhood & local generation as much as possible
DE RAMPLAAN
duurzame energie in onze wijk


SPAARgas
DOE MEE!
Built year
60%
50%
40%
30%
20%
10%
0%
1%
10%
55%
24%
7%
2%
1%
before 1900
1901-1919
1920-1939
1940-1959
1960-1969
1990-2005
After 2006
Energy Label
30%
25%
20%
15%
10%
5%
0%
1%
2%
14%
11%
15%
25%
27%
5%
A
B
C
D
E
F
G
onbekend

Selected building case study

A dwelling located in Pieter Wantelaan 4, 2015EB Haarlem municipality is selected. The building was designed by Brahen & Buma and built in 1958.

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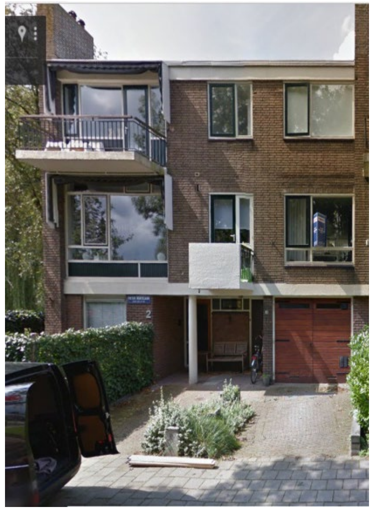
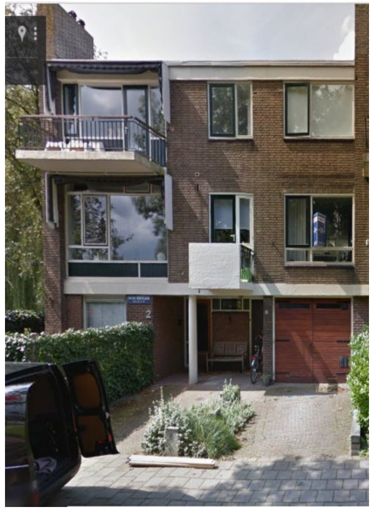
Renovation scenarios

Status quo



Ground floor
$U = 2.53\ W/m^2k$
Roof
$U = 1.48\ W/m^2k$
Wall
$U = 1.38\ W/m^2k$
Windows
$U = 4.80\ W/m^2k$

C Renovation (C label)



Ground floor
$U = 1.41\ W/m^2k$
Roof
$U = 0.44\ W/m^2k$
Wall
$U = 0.56\ W/m^2k$
Windows
$U = 2.00\ W/m^2k$

B Retrofitting (B label)

Ground floor
$U = 0.36\ W/m^2k$
Roof
$U = 0.36\ W/m^2k$
Wall
$U = 0.36\ W/m^2k$
Windows
$U = 1.72\ W/m^2k$

A Deep Retrofitting

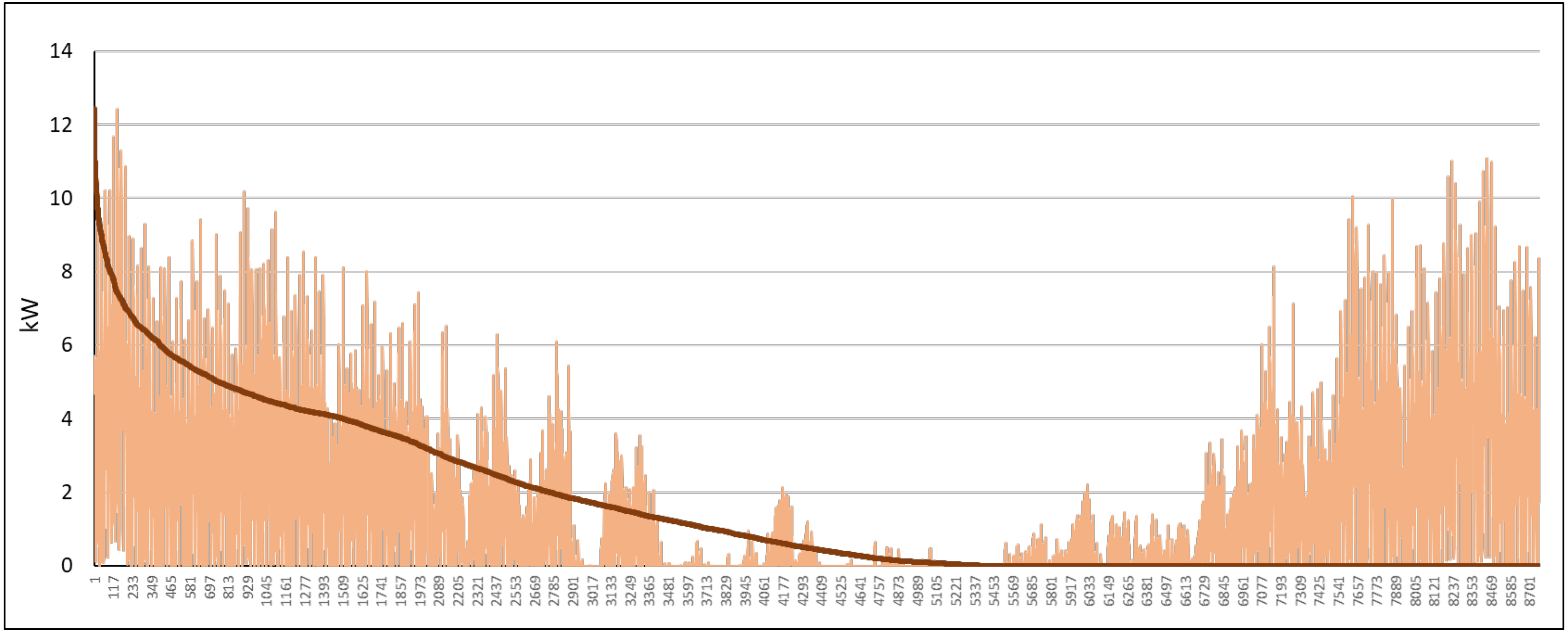
Ground floor
$U = 0.12\ W/m^2k$
Roof
$U = 0.10\ W/m^2k$
Wall
$U = 0.10\ W/m^2k$
Windows
$U = 0.90\ W/m^2k$

Annual energy demand of the study building for different renovation scenarios

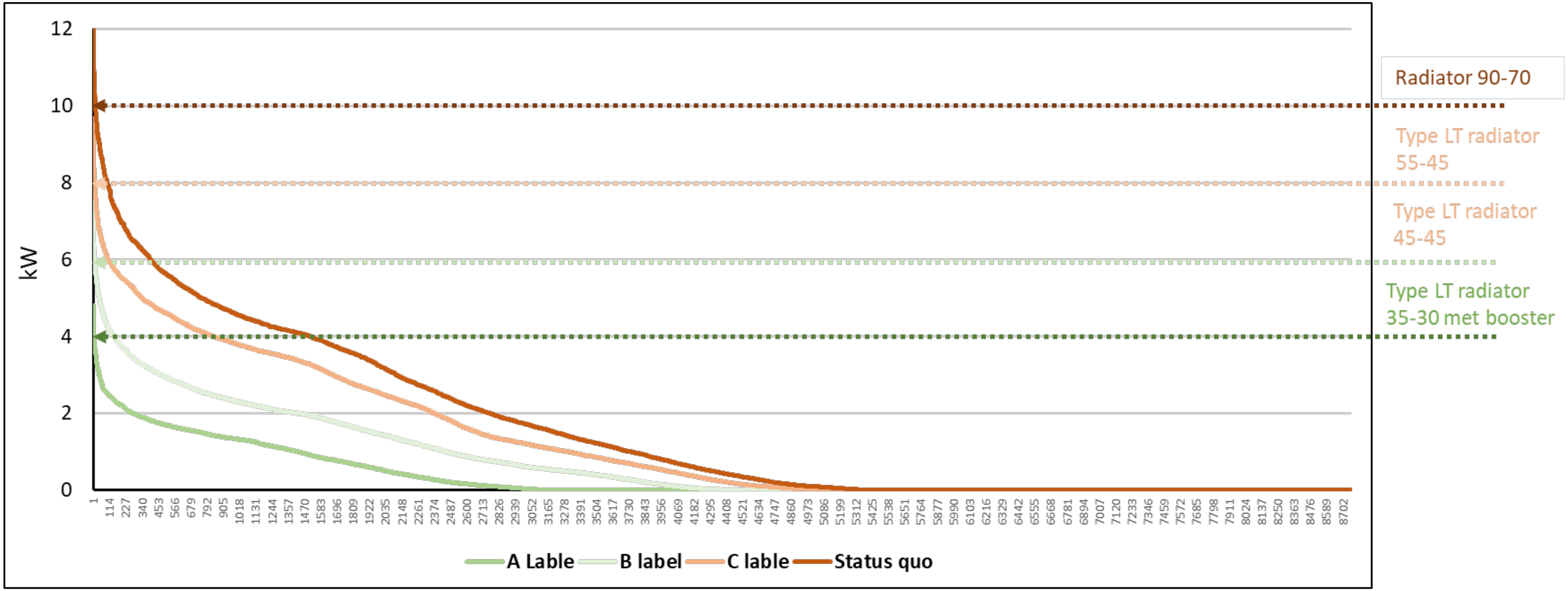
Scenarios	Electricity demand [kWh/y]	Space Heating (SH) [kWh/y]	Domestic Hot Water (DHW) [kWh/y]	SH Equivalent gas volume [Nm^3/y]	DWH Equivalent gas volume [Nm^3/y]
Status quo	3,144	**14,055**	3011	1,701	423
C Renovation	3,144	**10,951**	3011	1,325	423
B Retrofitting	3,144	**6,513**	3011	788	423
A Deep Retrofitting	3,144	**3,044**	3011	368	423

* With the efficiency ratio of **85%**
With the efficiency ratio of **73%

Load duration curve (kW) of the study building (Space heating- Status quo)



Effect of the renovation scenarios on load duration curve and heating power demand



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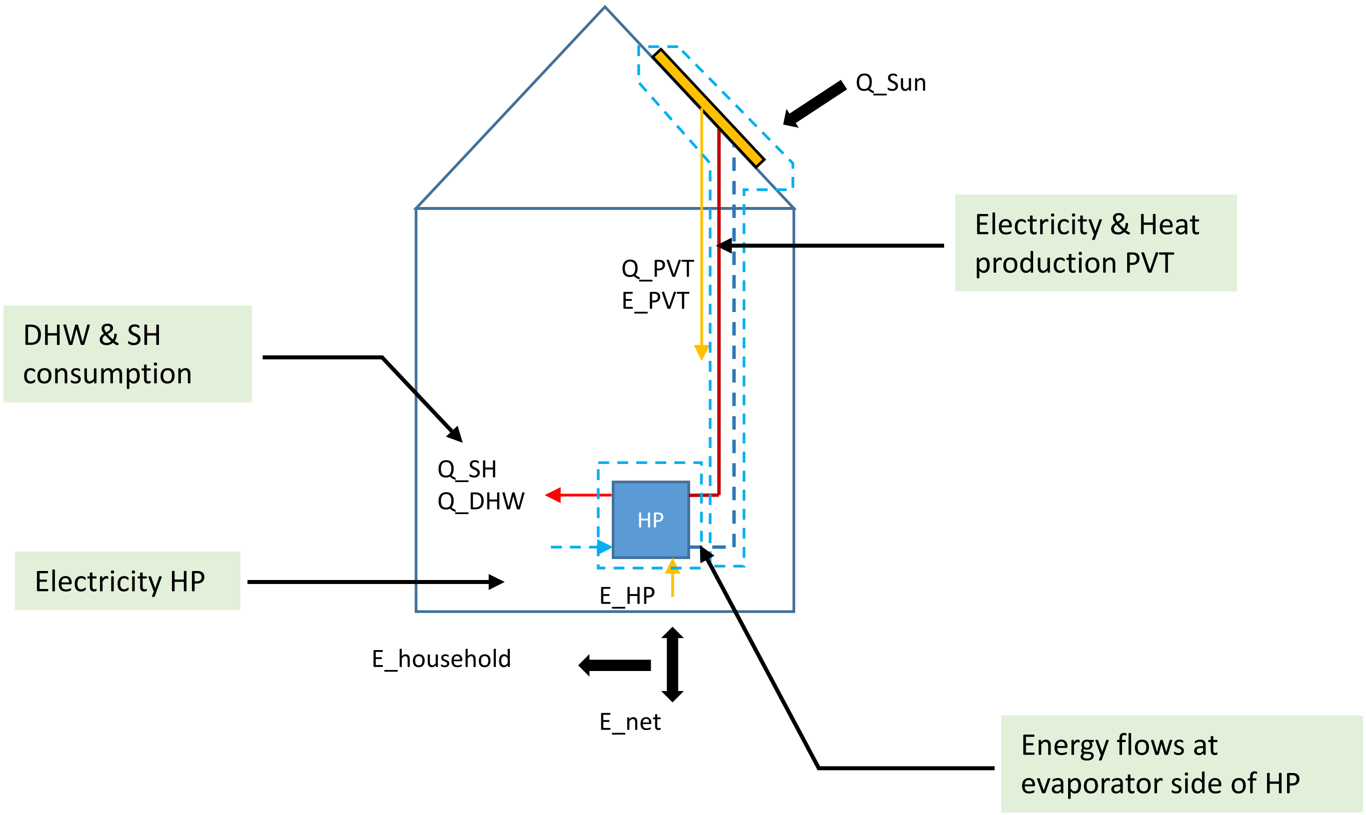
Modelling the Stand-alone Situation

(TRIPLE-SOLAR System Replication and Validation)

Concept – Building Levels



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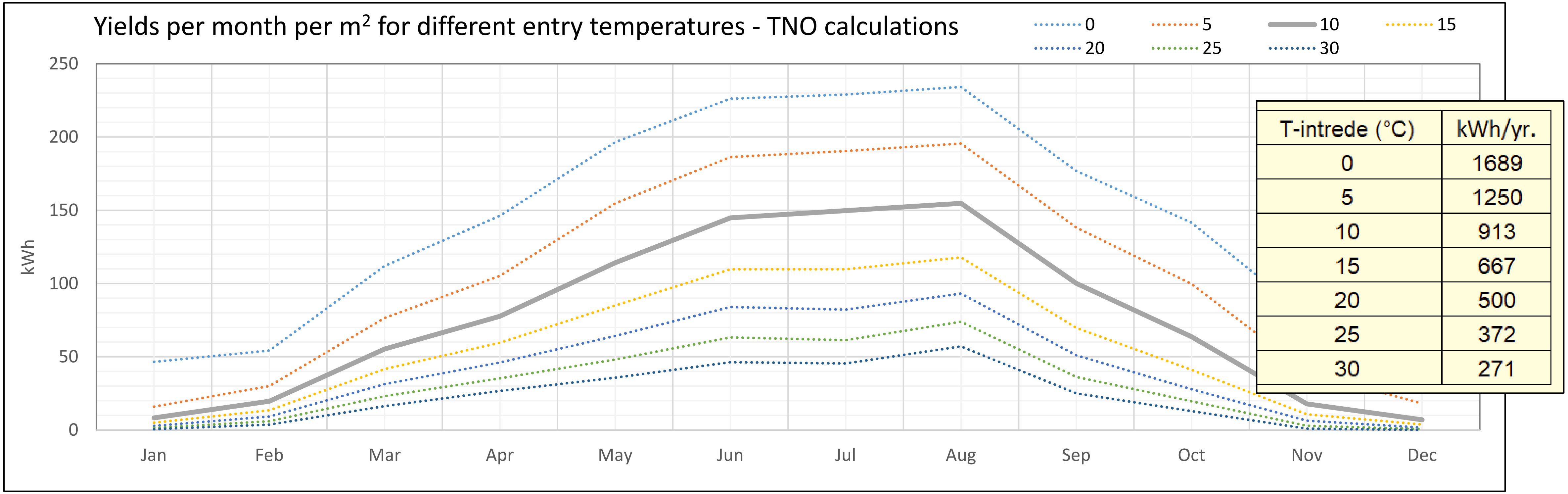
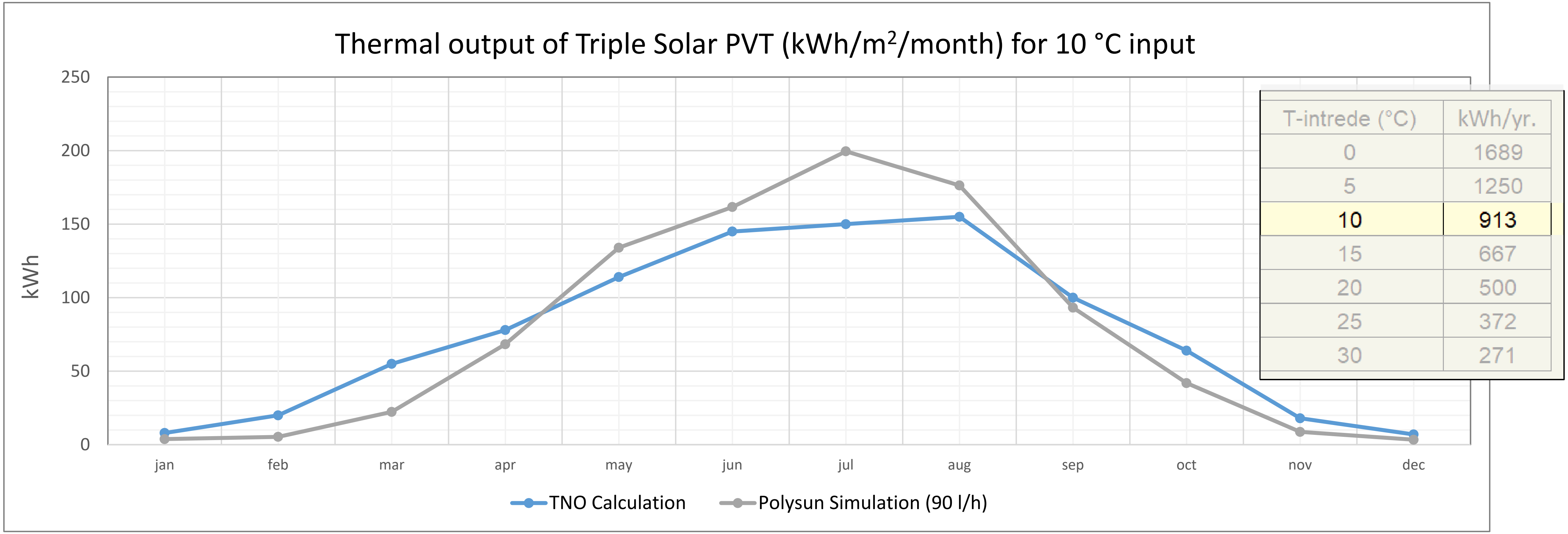
Measured output of the applied PVT for fixed input temperature (Consolar Solink PVT)



T-intrede (°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total (kWh)
10	8	20	55	78	114	145	150	155	100	64	18	7	**913**

Measured output of the applied PVT for fixed input temperature (Consolar Solink PVT)



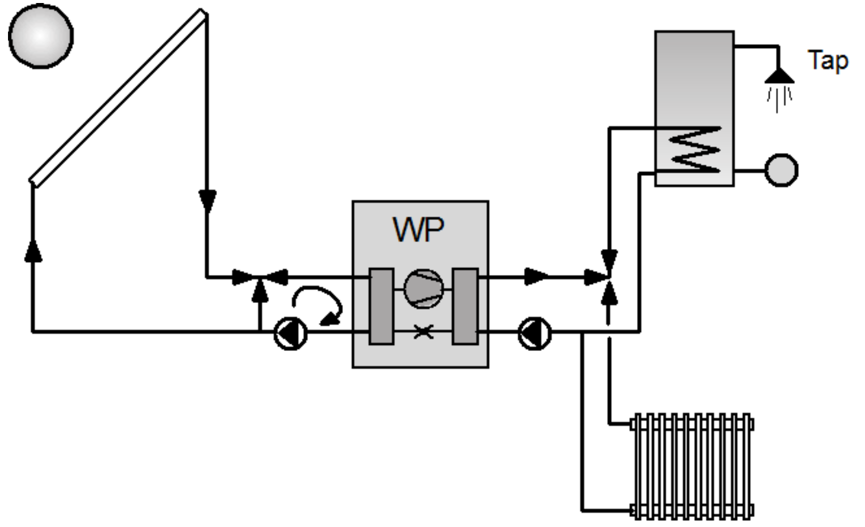
T-intrede (°C)	kWh/yr.
0	1689
5	1250
10	913
15	667
20	500
25	372
30	271

Collector field yield for 10 °C input temperature and 90 l/h flow: 919 kWh/m²/Year

OMGEVINGSCOLLECTOR/ WARMTEPOMPSYSTEEM VAN TRIPLE-SOLAR (Gelijkwaardigheidsverklaringen)

Important assumptions:

- **NIBE F1255 6 kW**,
- Maximum temperature of **30ºC** on the evaporator side
- Tap water tank with a capacity of **180 liters**
- With the PVT surface of **12 and 16 m²**
- Gross heat demand of **5-10-20-30-40-50 GJ/year**
- For an indoor temperature of **20°C**
- generation efficiency for space heating and hot tap water



	Bruto warmtebehoefte QH;dis;nren [GJ]					
	2,5	5	10	20	40	60
ηH;opw [-] @ QH;dis / Ag;tot ≤ 150 MJ/m2	4,16	4,91	5,39	5,63	5,45	5,54
ηH;opw [-] @ QH;dis / Ag;tot > 150 MJ/m2	3,84	4,76	5,39	5,76	5,92	5,73

	Tapwatervraag QW;dis;nren [GJ]			
	6,5	9	11,5	14
ηW;opw [-] @ QH;dis / Ag;tot ≤ 150 MJ/m2, en > 150 MJ/m2	3,46	3,61	3,68	3,77

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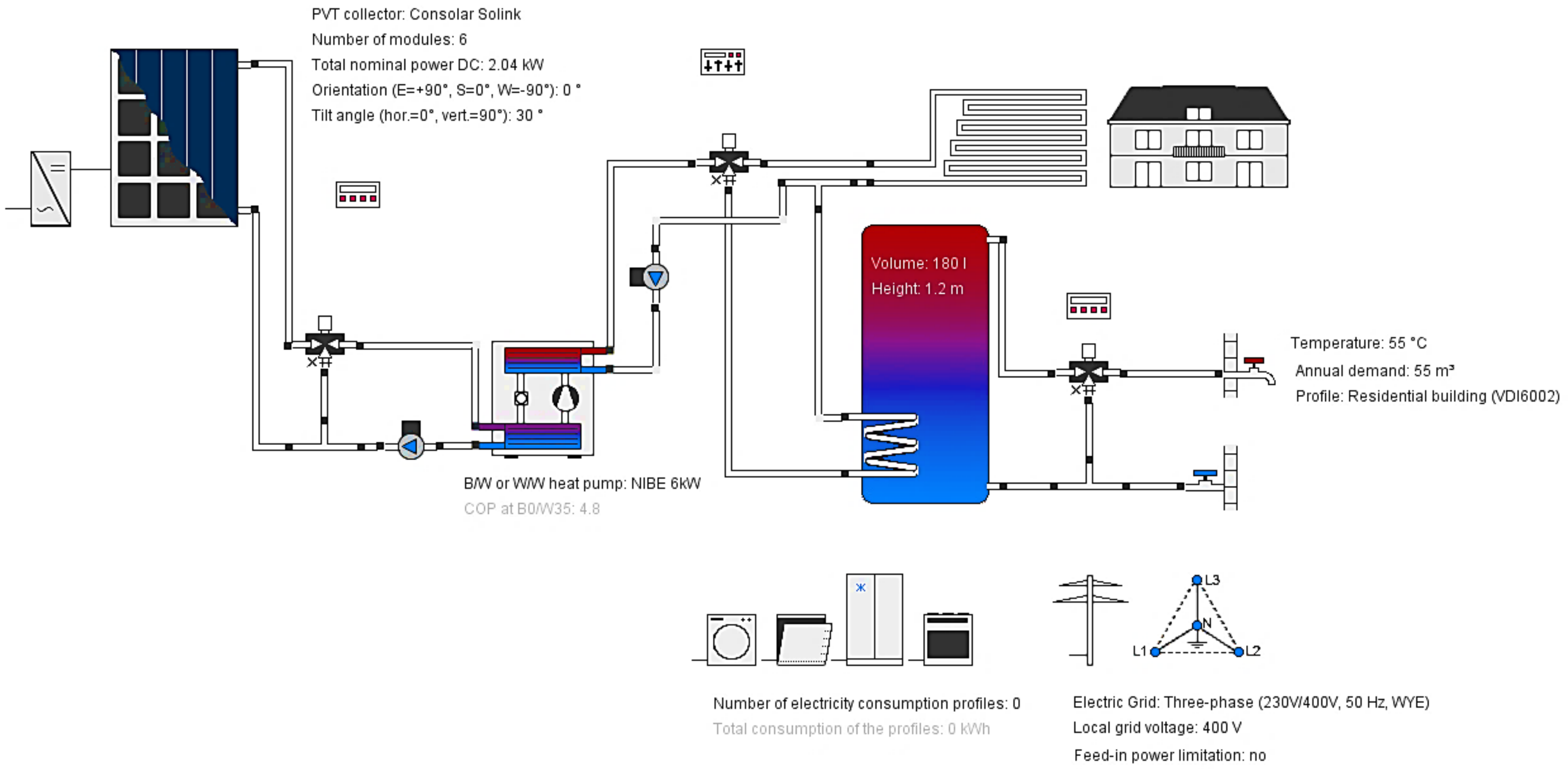
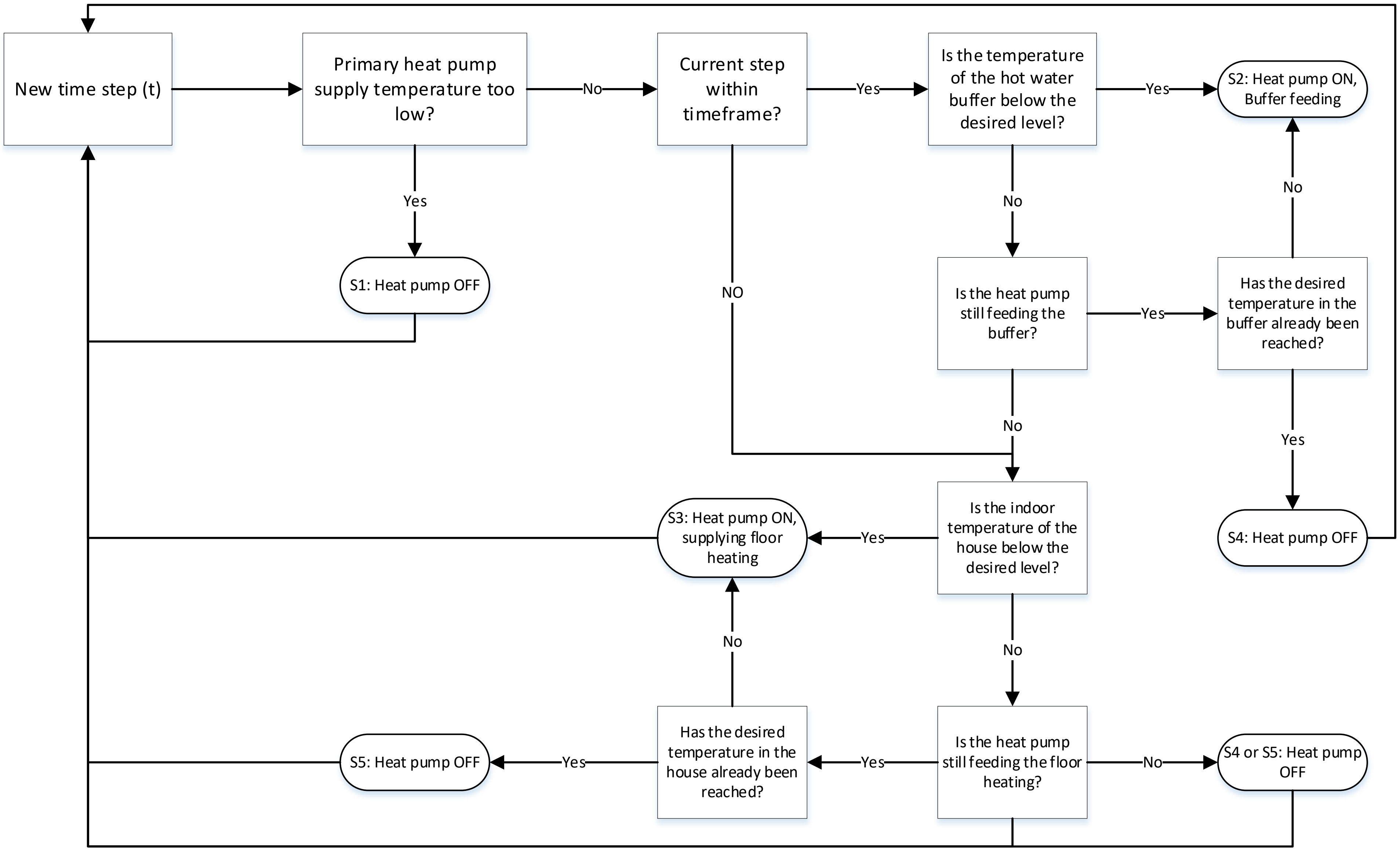
Simulated setup for the stand-alone scenarios

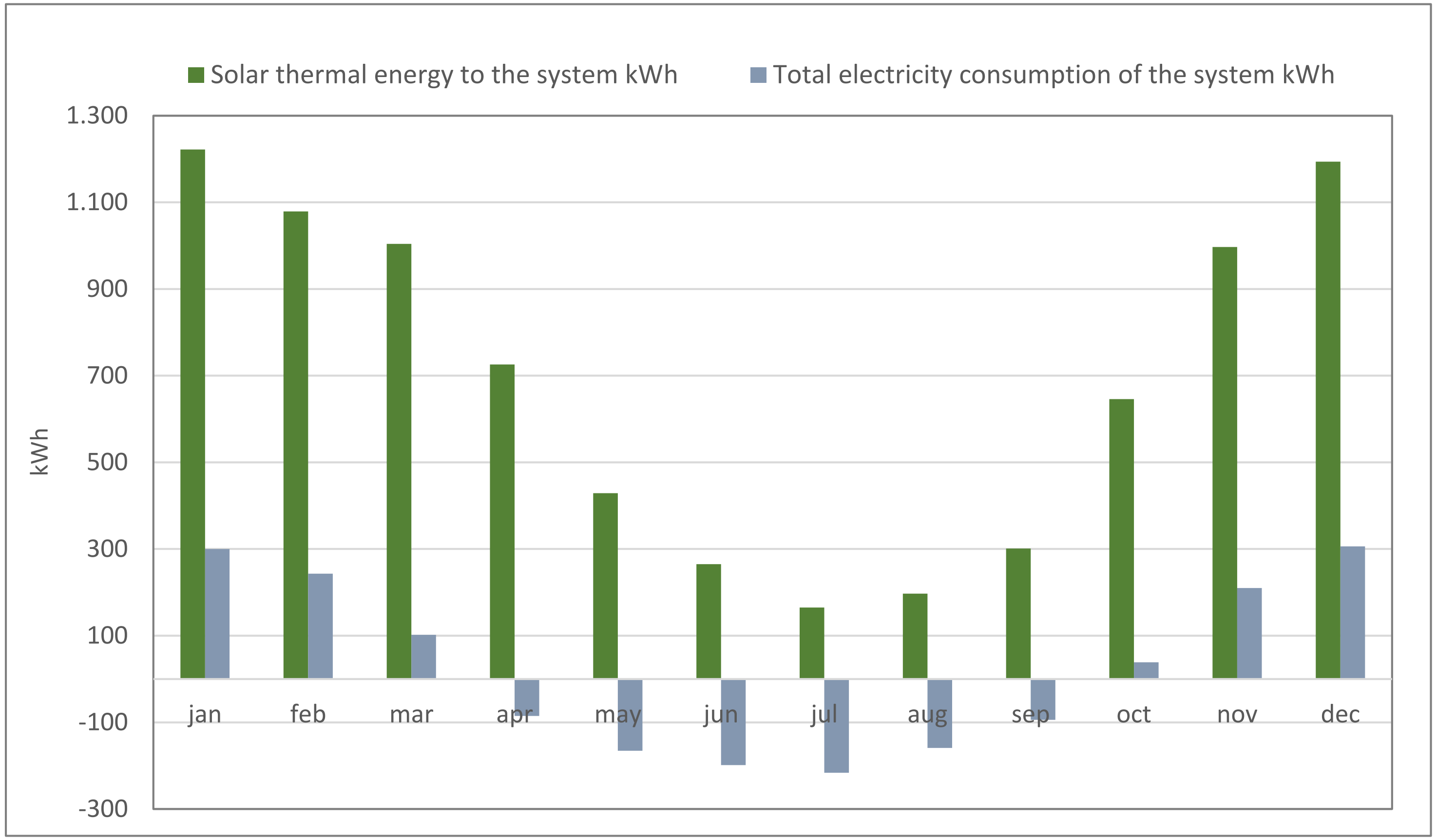


Control system implemented for the stand-alone model

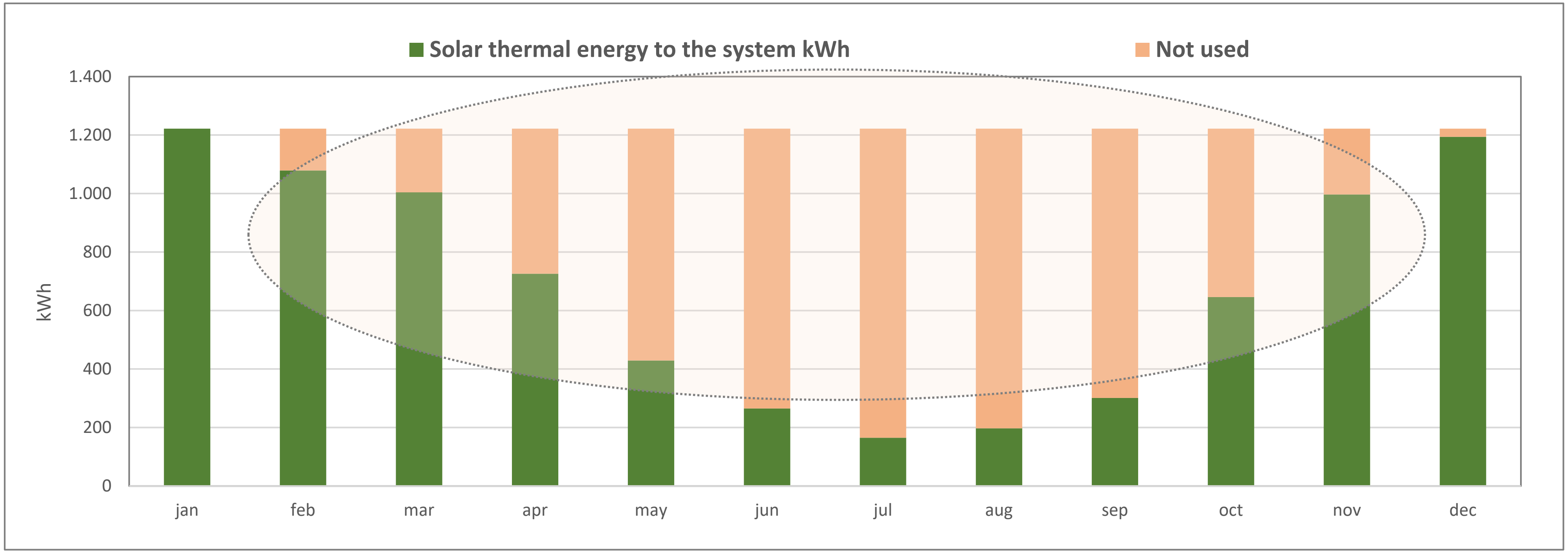


Simulated setup for the stand-alone scenarios

SH: 6513 kWh (23 GJ) DHW: 3011 kWh (10 GJ)
6 Consolar Solink PVT Panels
NIBE 6kW Heat Pump
180l portable DHW Buffer
Flow rate: 55 l/h/m^2
Seasonal performance factor: 4.8
Collector field yield: 692 kWh/m²/year
Total electricity consumption of the system: +280 kWh



Simulated setup for the stand-alone scenarios



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Modelling the Grid-connected Situation (Feed-in grid scenario)

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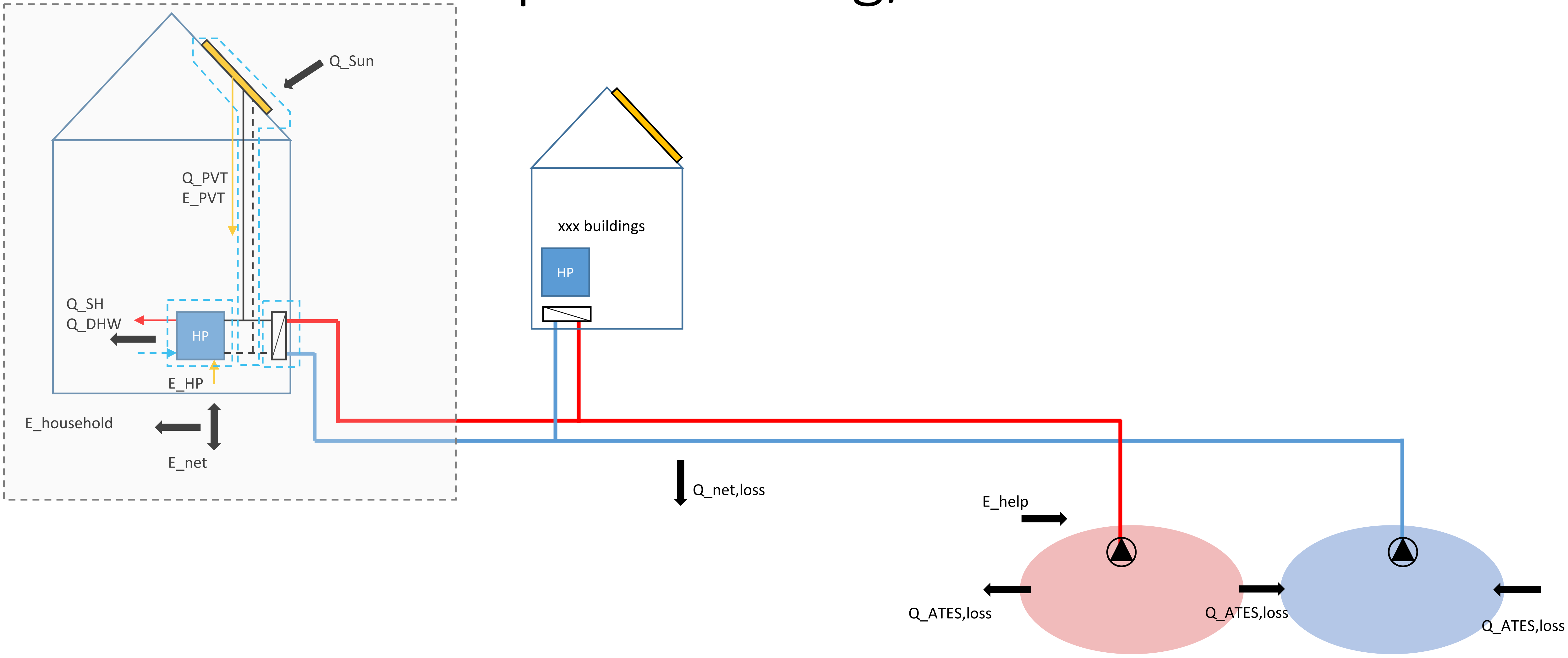
Concept – Building/Area Levels



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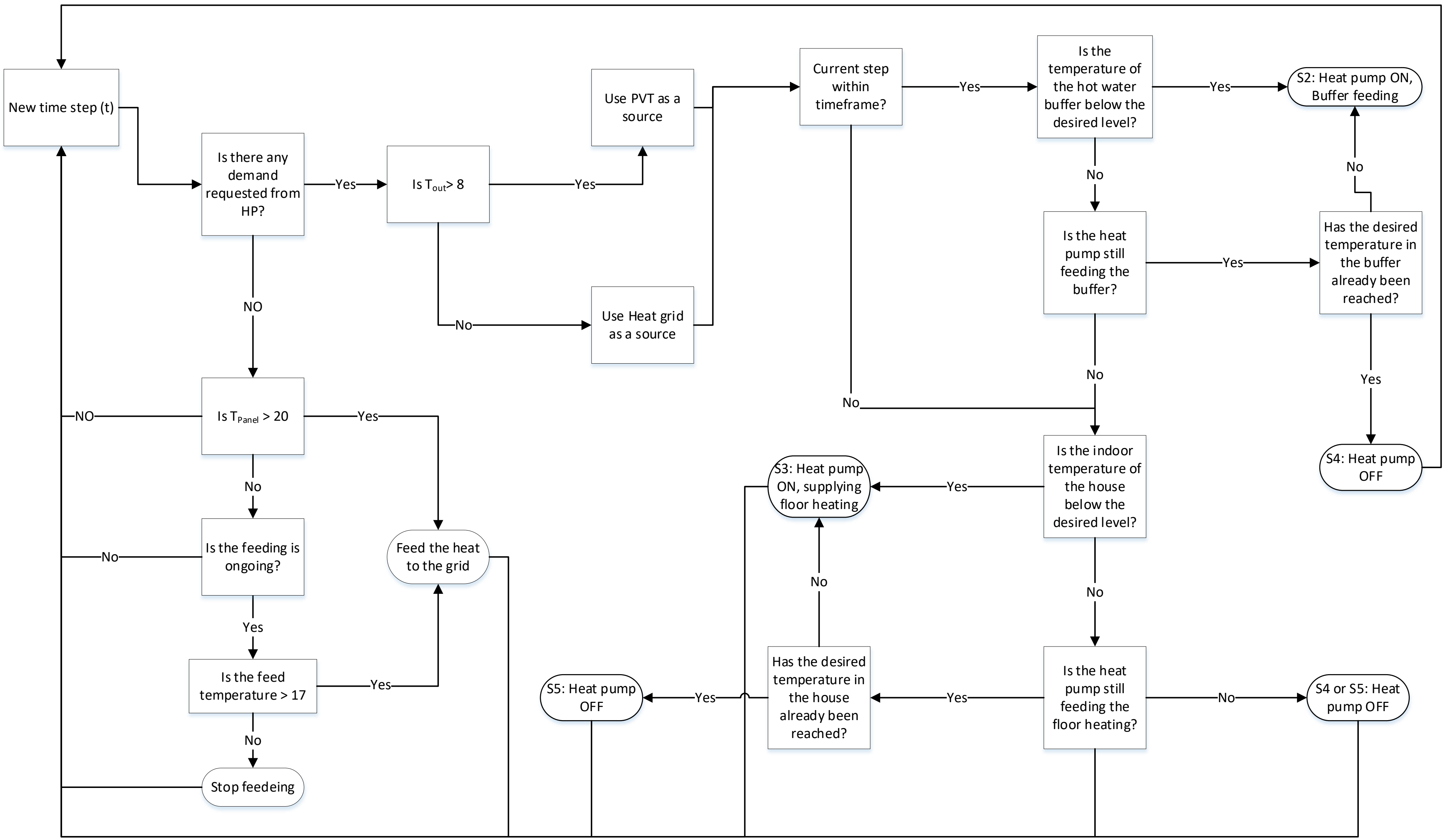
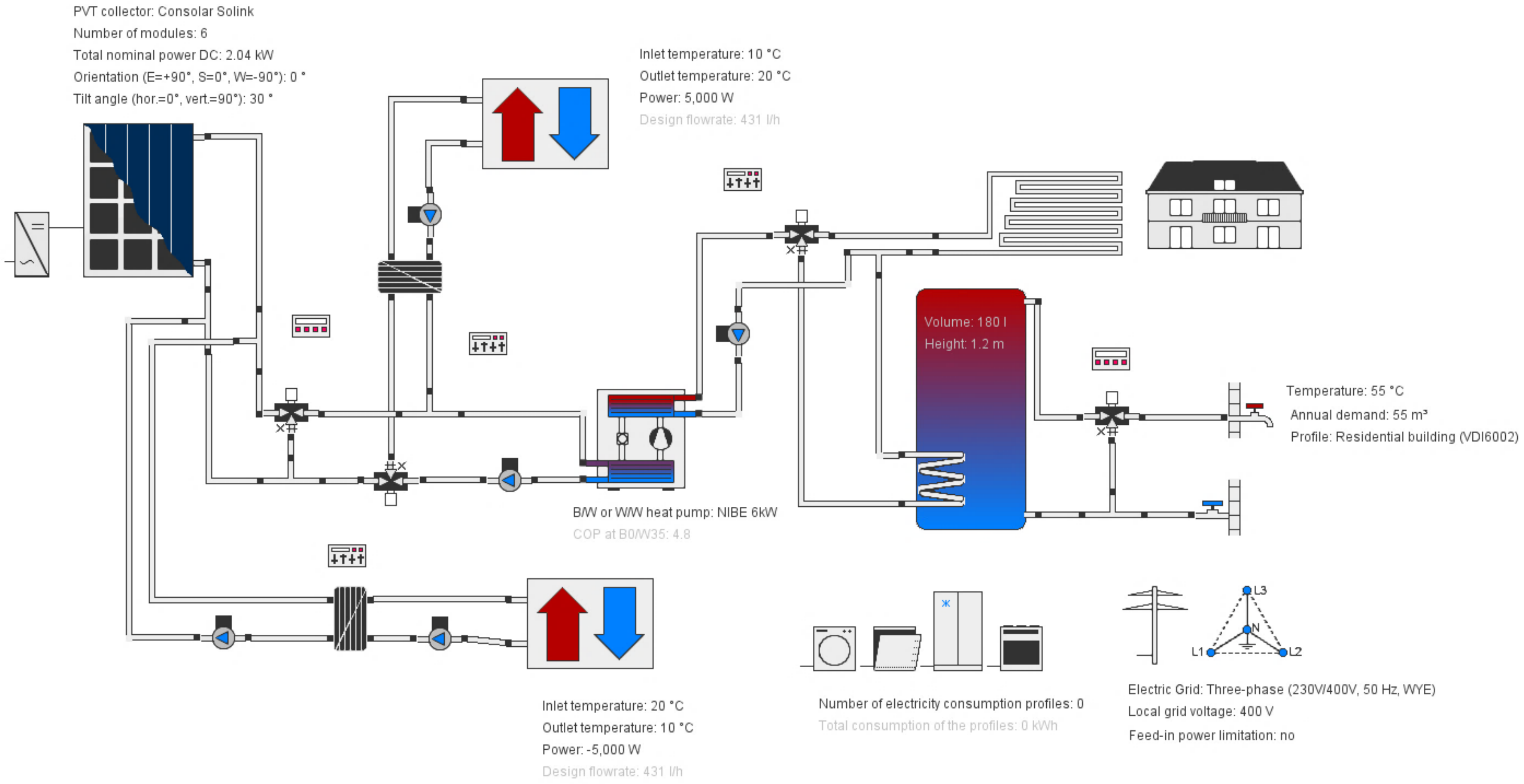
Control system implemented for the grid-connected model



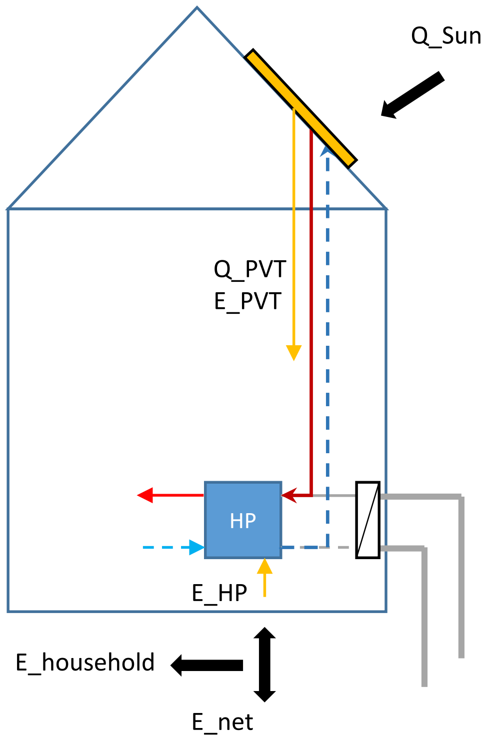
Simulated setup for the grid-connected scenarios



3 possible situations on the building level:

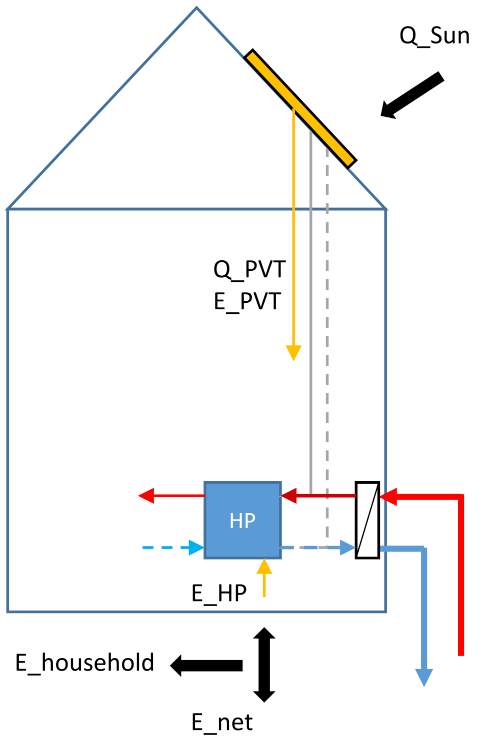
Direct use of solar thermal by the heat pump

- *If there will be a demand in the building*
- *If outdoor T_e> 8, 6 & 4 °C*



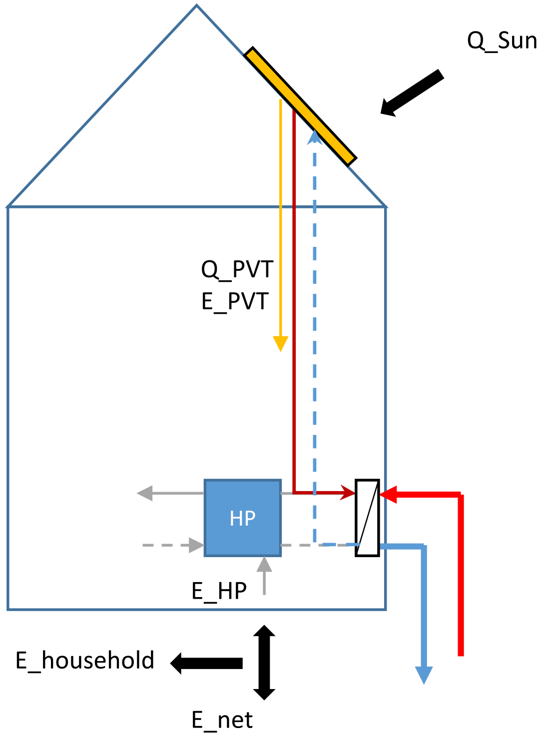
Direct use of heat from the grid

- *If there will be a demand in the building*
- *If outdoor T_e≤ 8, 6 & 4 °C*



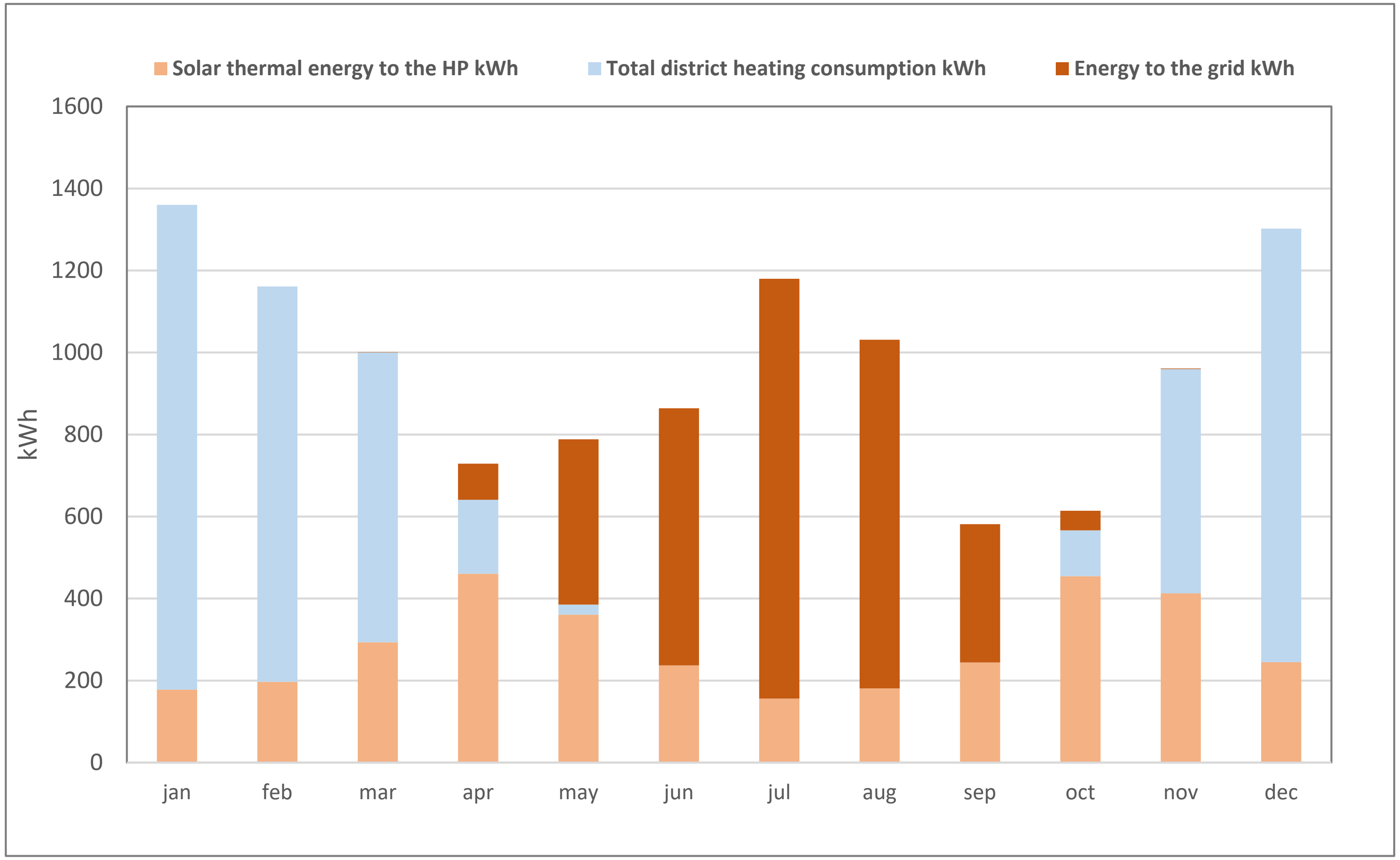
Supply heat to the grid

- *only valid for summer months*
- *If there is no demand in the building*
- *If PVT mean temperature ($T_{m\ (PVT)}$)≥ 20°C*



Grid-connected models for the B Retrofitting scenario (6 PVT and T_e> 8°C)

SH: 6513 kWh (23 GJ) DHW: 3011 kWh (10 GJ)
6 Consolar Solink PVT Panels
NIBE 6kW Heat Pump
180l portable DHW Buffer
Flow rate: 55 l/h/m^2
Seasonal performance factor: 7.1
Collector field yield:572 kWh/m²/year
Total district heating consumption: 4774 kWh
Energy to the grid: 3378 kWh
Total electricity consumption of the system: -93 kWh
Unbalanced capacity: -1395 kWh



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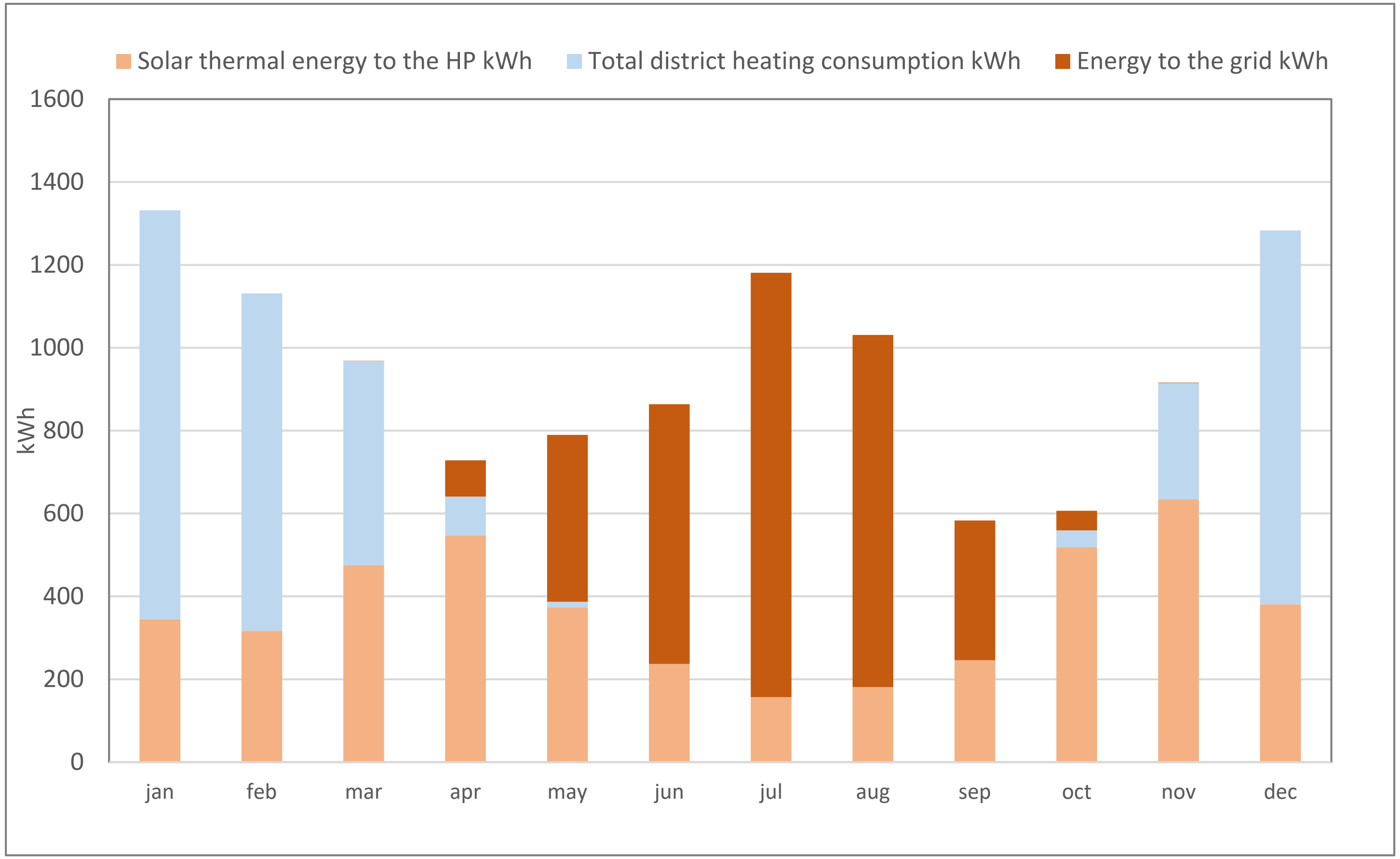
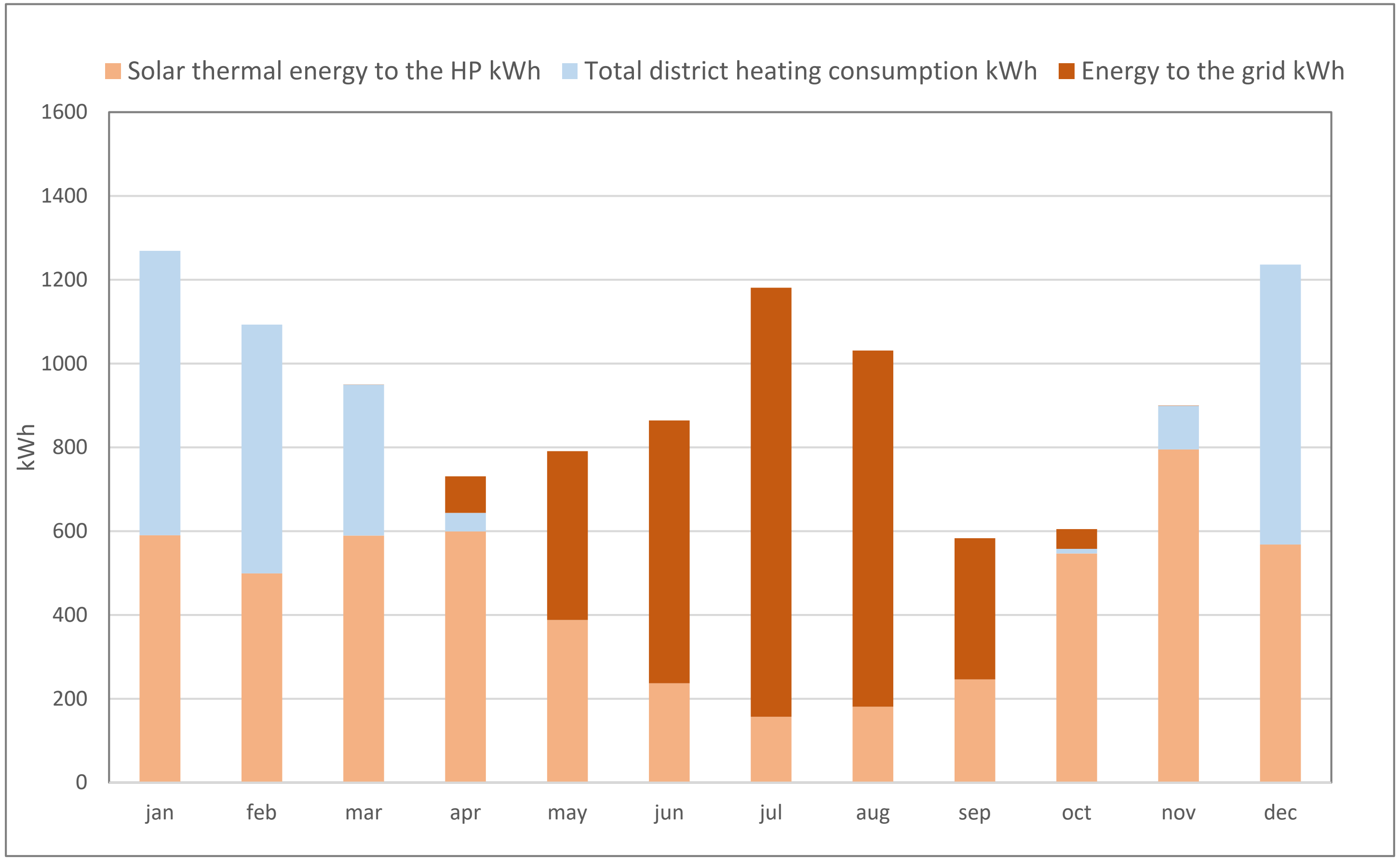
Grid-connected models for the B Retrofitting scenario (6 PVT and T_e> 6°C)

SH: 6513 kWh (23 GJ) DHW: 3011 kWh (10 GJ)
6 Consolar Solink PVT Panels
NIBE 6kW Heat Pump
180l portable DHW Buffer
Flow rate: 55 l/h/m²
Seasonal performance factor: 6.9
Collector field yield:655 kWh/m²/year
Total district heating consumption: 3625 kWh
Energy to the grid: 3378 kWh
Total electricity consumption of the system: -63 kWh
Unbalanced capacity: -247.2 kWh



Grid-connected models for the B Retrofitting scenario (6 PVT and T_e> 4°C)

SH: 6513 kWh (23 GJ) DHW: 3011 kWh (10 GJ)
6 Consolar Solink PVT Panels
NIBE 6kW Heat Pump
180l portable DHW Buffer
Flow rate: 55 l/h/m^2
Seasonal performance factor: 6.7
Collector field yield:738 kWh/m²/Year
Total district heating consumption: 2460 kWh
Energy to the grid: 3378 kWh
Total electricity consumption of the system: -24 kWh
Unbalanced capacity: 917.4 kWh



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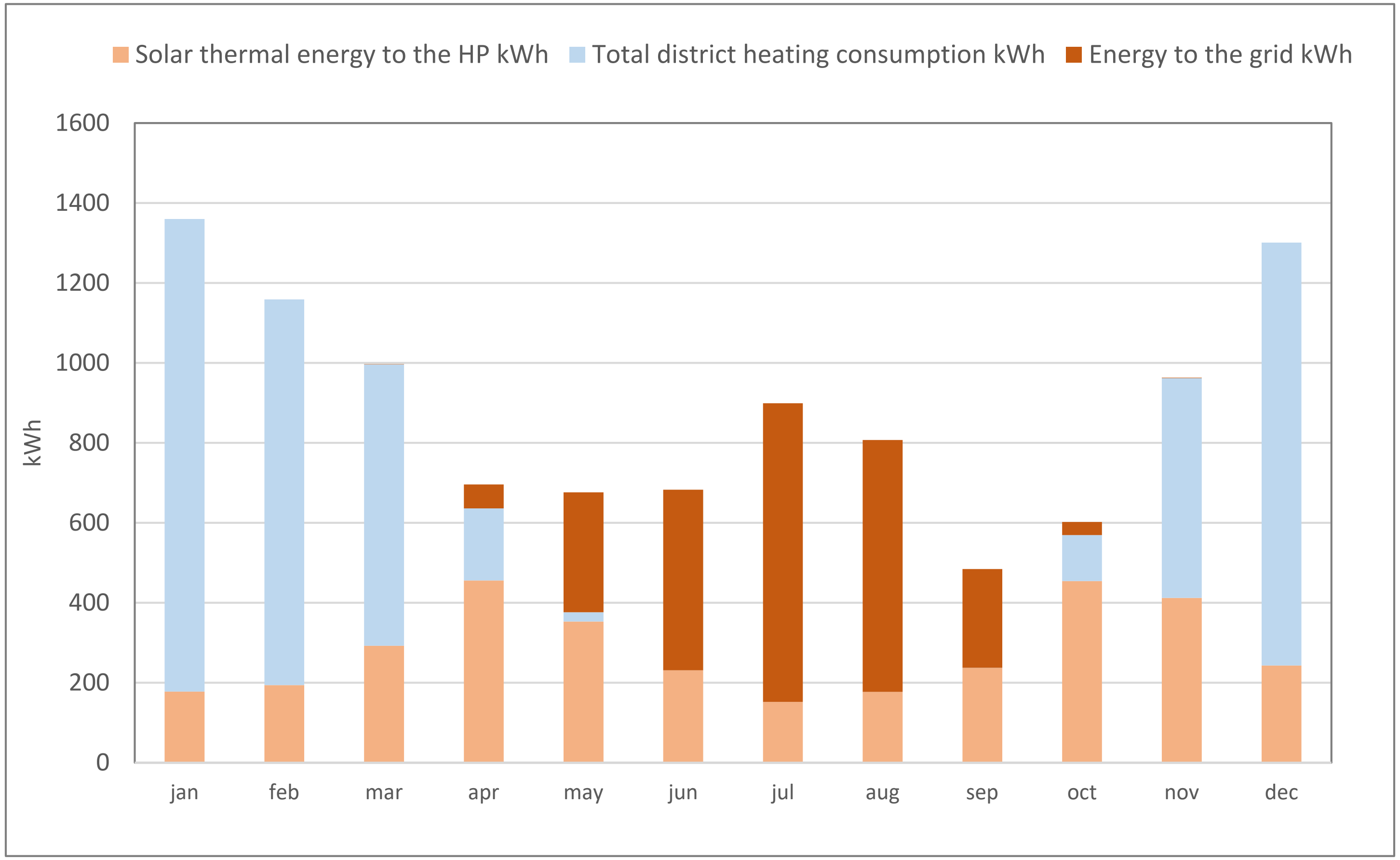
Grid-connected models for the B Retrofitting scenario (4 PVT and T_e> 8°C)

SH: 6513 kWh (23 GJ) DHW: 3011 kWh (10 GJ)
4 Consolar Solink PVT Panels
NIBE 6kW Heat Pump
180l portable DHW Buffer
Flow rate: 55 l/h/m^2
Seasonal performance factor: 6.4
Collector field yield:738 kWh/m²/Year
Total district heating consumption: 4778 kWh
Energy to the grid: 2470 kWh
Total electricity consumption of the system: 631 kWh
Unbalanced capacity: -2307 kWh



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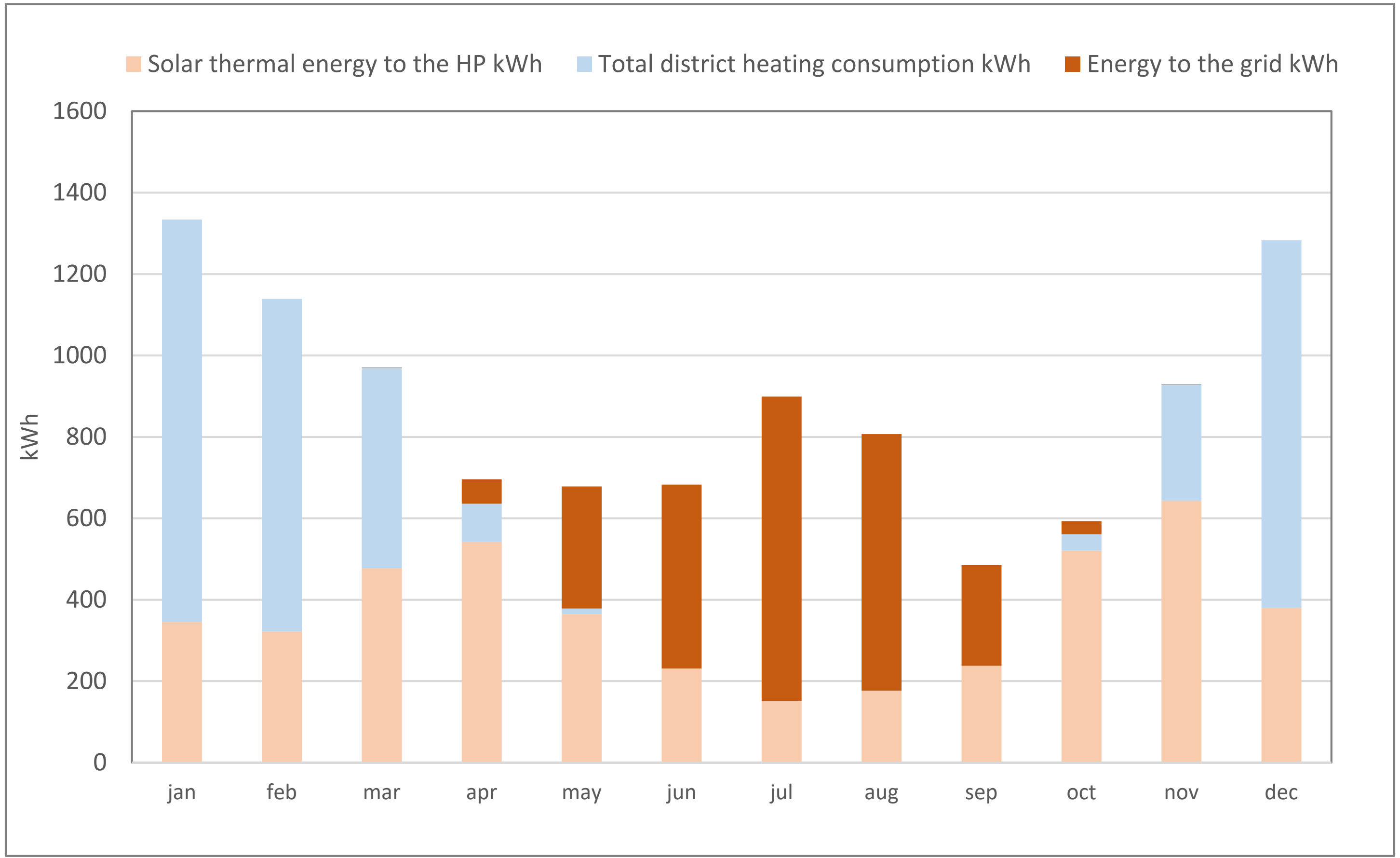
Grid-connected models for the B Retrofitting scenario (4 PVT and $T_e > 6°C$)

SH: 6513 kWh (23 GJ) DHW: 3011 kWh (10 GJ)
6 Consolar Solink PVT Panels
NIBE 6kW Heat Pump
180l potable DHW Buffer
Flow rate: 55 l/h/m²
Seasonal performance factor: 6.3
Collector field yield:866 kWh/m²/Year
Total district heating consumption: 3634 kWh
Energy to the grid: 2470 kWh
Total electricity consumption of the system: 678 kWh
Unbalanced capacity: -1165 kWh



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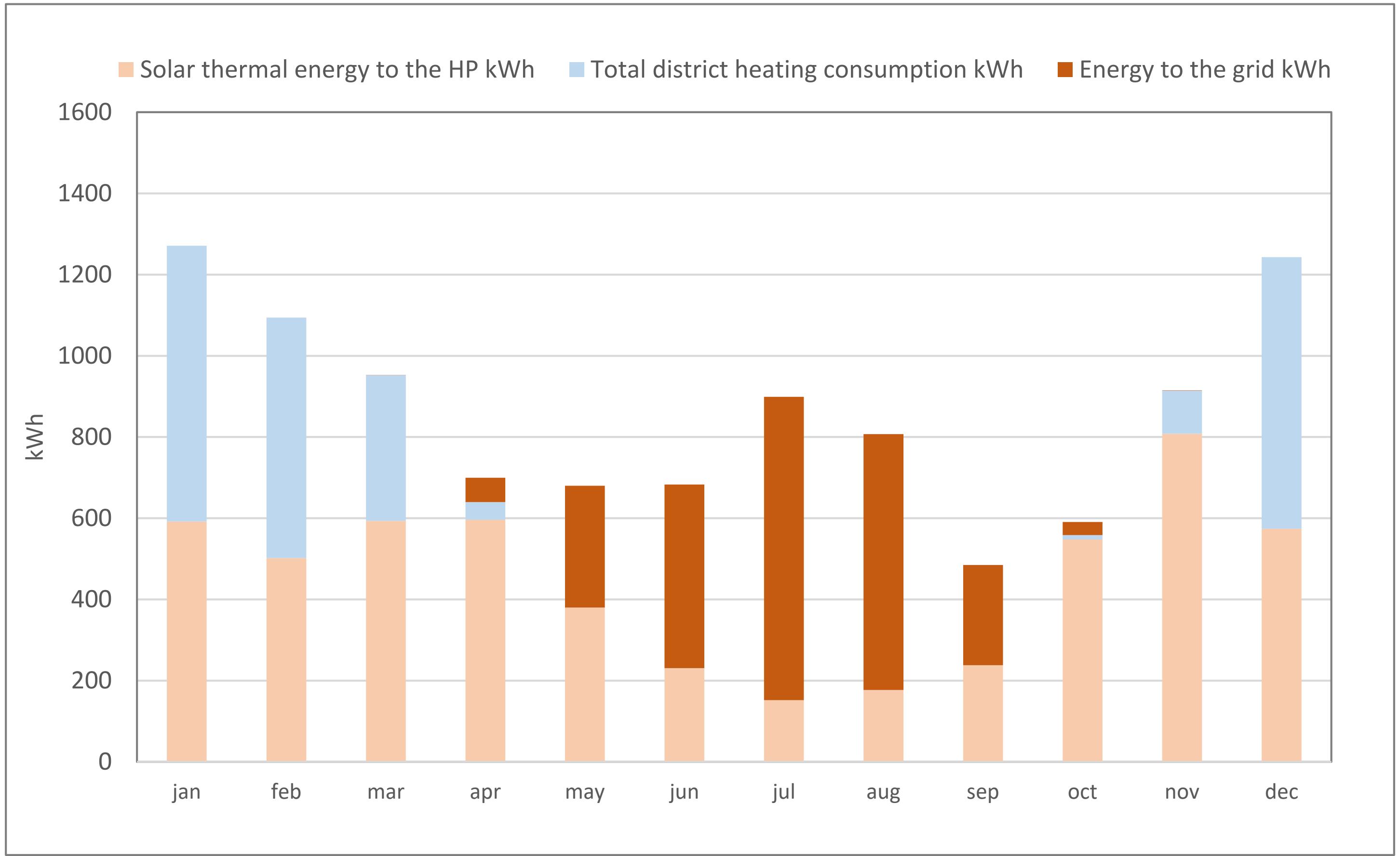
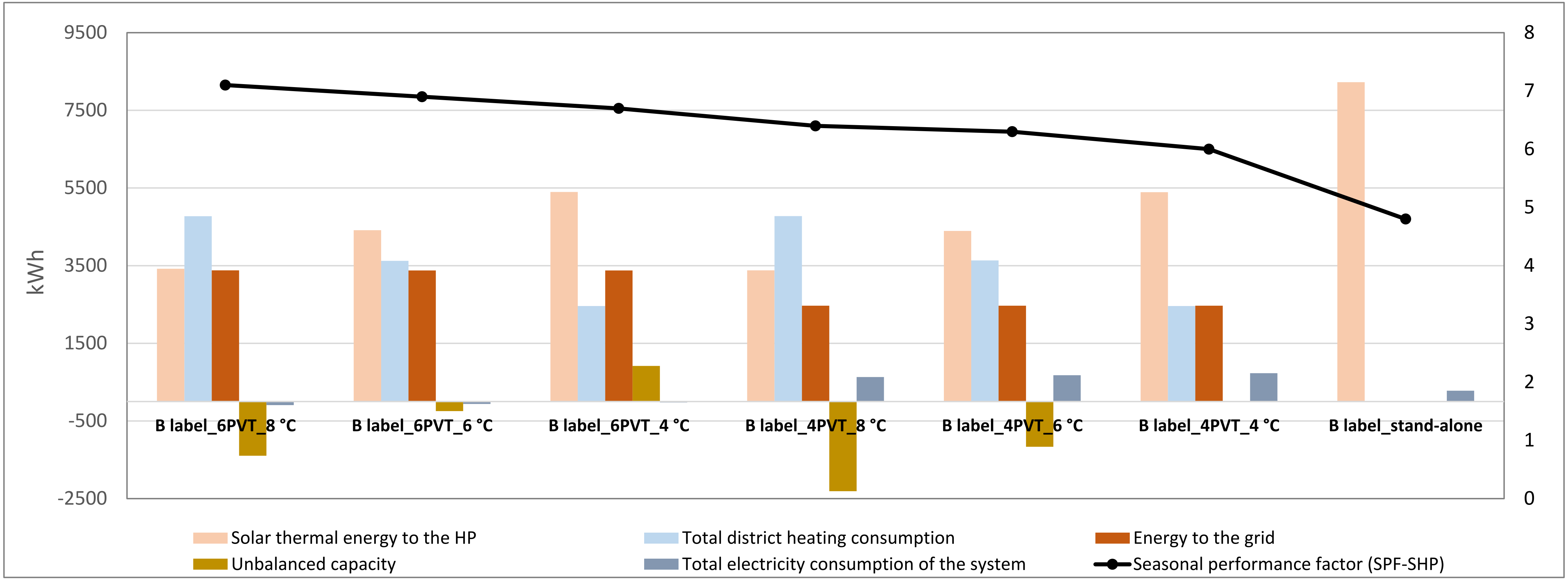
Grid-connected models for the B Retrofitting scenario (4 PVT and $T_e > 4°C$)

SH: 6513 kWh (23 GJ) DHW: 3011 kWh (10 GJ)
6 Consolar Solink PVT Panels
NIBE 6kW Heat Pump
180l potable DHW Buffer
Flow rate: 55 l/h/m²
Seasonal performance factor: 6
Collector field yield: 992 kWh/m²/Year
Total district heating consumption: 2460 kWh
Energy to the grid: 2470 kWh
Total electricity consumption of the system: 731 kWh
Unbalanced capacity: 10 kWh



Comparing the scenarios for the B Retrofitting scenario



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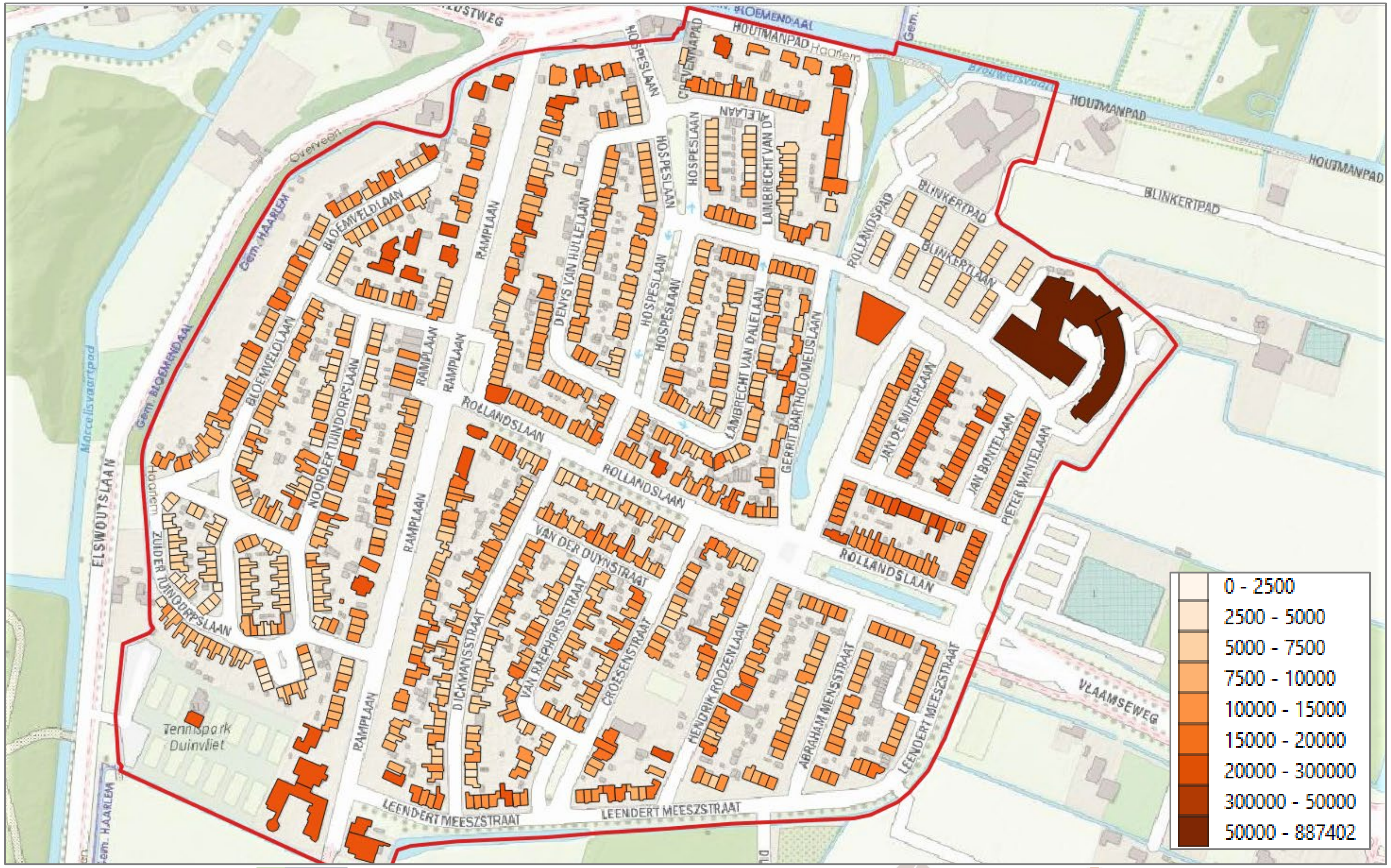
PVT Potential Map (kWh)



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Conclusions

- Decentralized solar feed-in not only led to a higher temperature in the grid, which makes the HPs efficient, but also the PVT ensures the regeneration of the ATES over the year
- Decreasing the outside temperature threshold increase the self-sufficiency of the system on the building level, however decrease the COP of HPs
- Number of PVTs is one of the important constraints of the systems that has to be optimized to balance the shortage and surplus of the ATES system
- The model helps to identify the influential factors on the performance of the feed-in grid system