THE ENERGY ROOF

INTEGRATED WITH PHOTOVOLTAIC-THERMAL, HEAT PUMP, VENTILATION, STORAGE AND HEAT RECOVERY FOR THE ‘NUL OP DE METER’ RENOVATION

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Master Building Technology | Climate Design
Technical University Delft

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External examiner: Ir. Salome Bentinck

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SHIFTING TO RENEWABLES

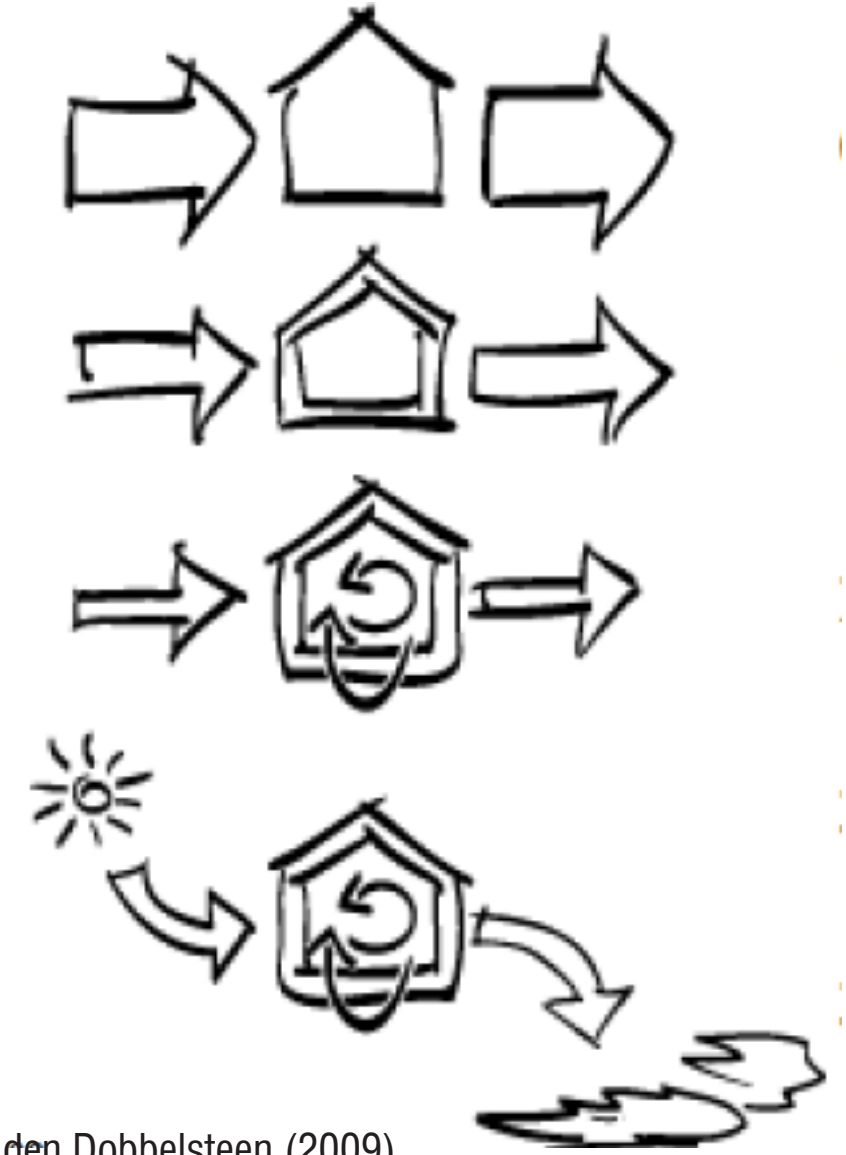
INTRODUCTION

“The first pillar of the Third Industrial Revolution is shifting to renewable energy”

- Jermey Rifkin

NEW STEPPED STRATEGY (NSS)

INTRODUCTION



Van den Dobbelsteen (2009)

0 standard building

1 reduce the demand

2 reuse the waste streams

3a produce the remaining demand with renewables

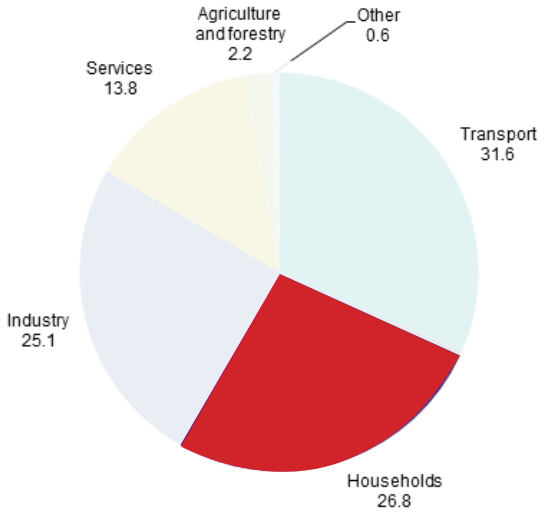
3b waste = food

ENERGY

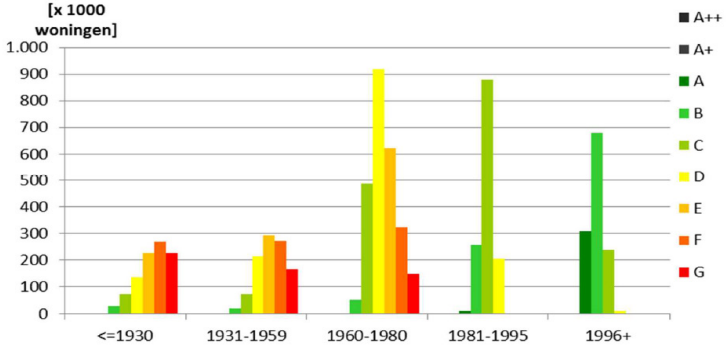
THE NETHERLANDS

Renewables 5.5% (2014)

Dwellings 27% total energy



Low energy labels

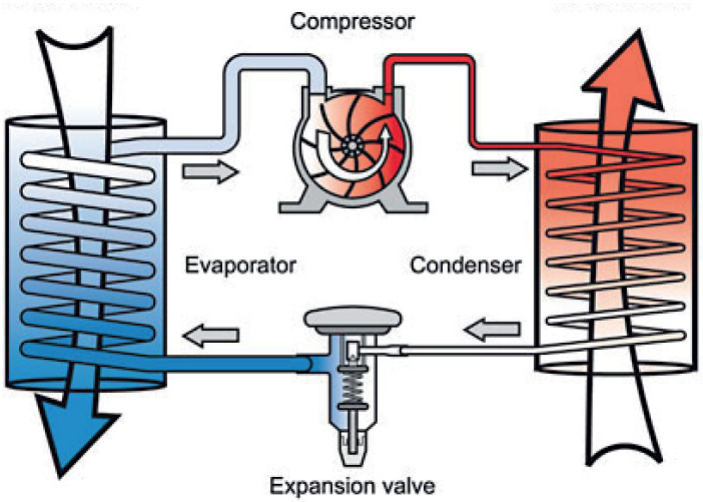


Annual 1% new build

Stroomversnelling

TECHNOLOGY NOM

HEAT PUMP



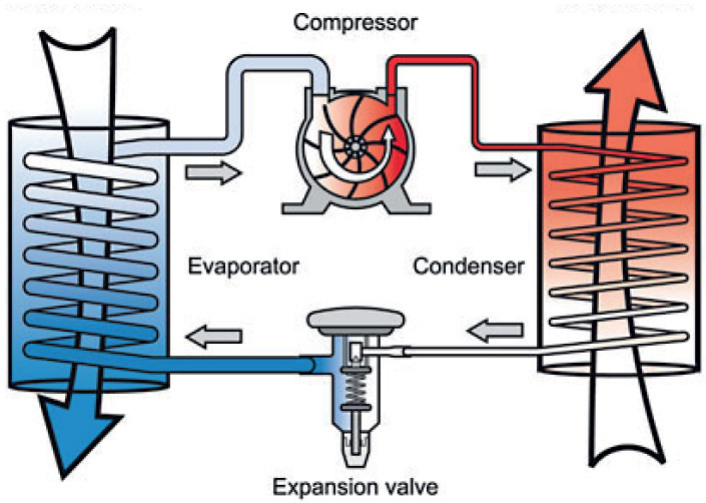
GROUND SOURCE - HP

AIR SOURCE - HP

SOLAR ASSISTED - HP

TECHNOLOGY NOM

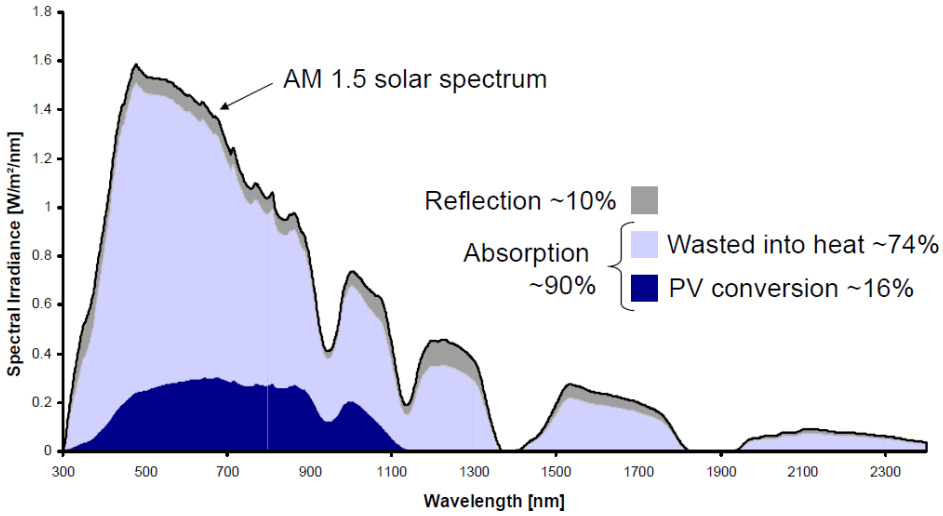
HEAT PUMP

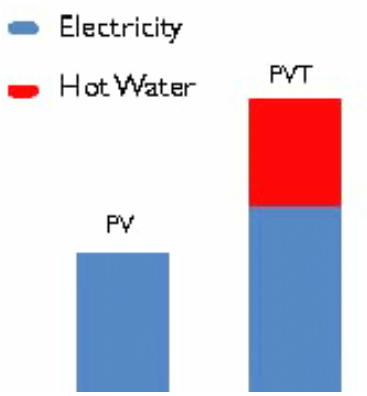


GROUND SOURCE - HP	AIR SOURCE - HP	SOLAR ASSISTED - HP
disadvantage	disadvantage	advantage
expensive ground drilling	outside unit	lower investment cost
not suitable for 1-day renovation	noise pollution	high efficient with solar irradiation
	high investment cost	

TECHNOLOGY NOM

PHOTOVOLTAIC PANELS



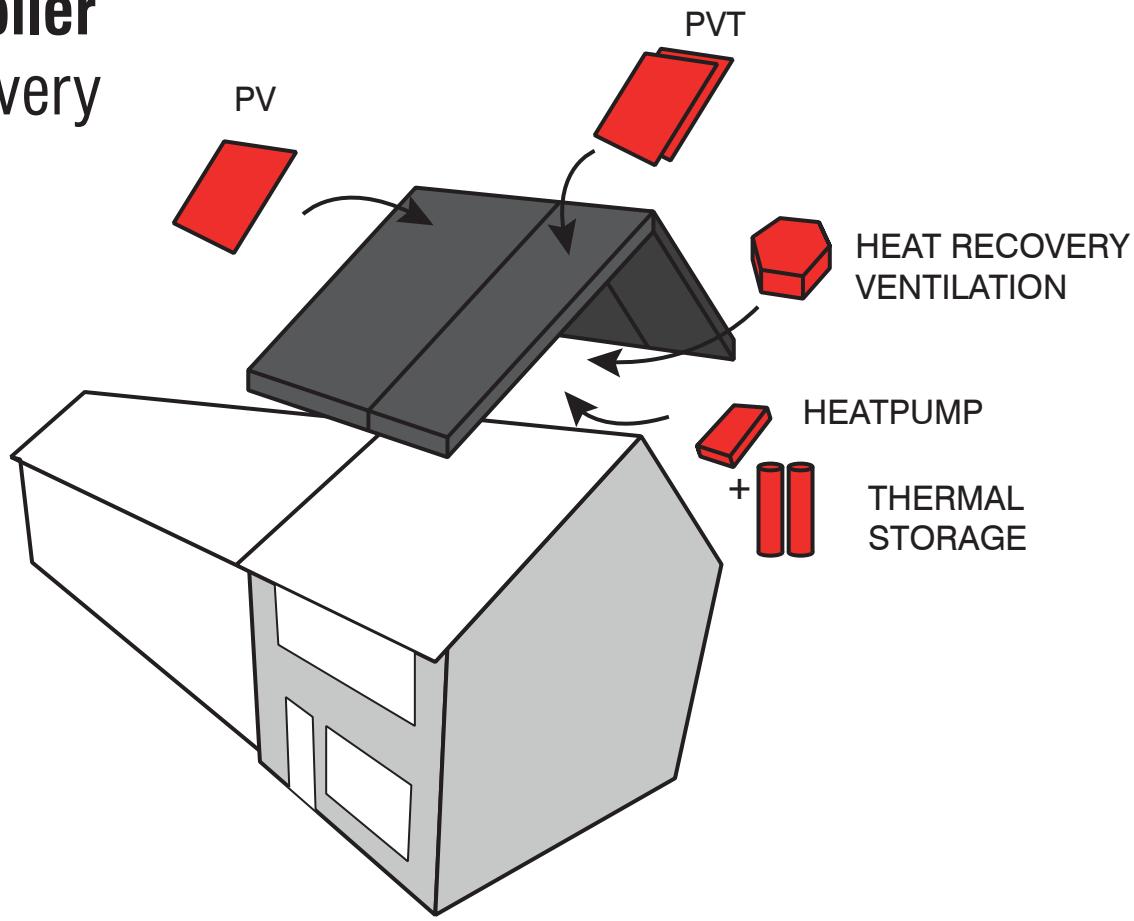


THE ENERGY ROOF

INTRODUCTION

The Energy Roof is:

- an **aesthetic** full-roof PV design
- with **PVT-SAHP** and **PVT solar boiler**
- storage, ventilation and heat recovery
- provide the **total** energy demand
- with **renewables** as source
- suitable for **industrial production**
- and a **one-day** renovation
- to Nul-op-de-Meter



RESEARCH QUESTION

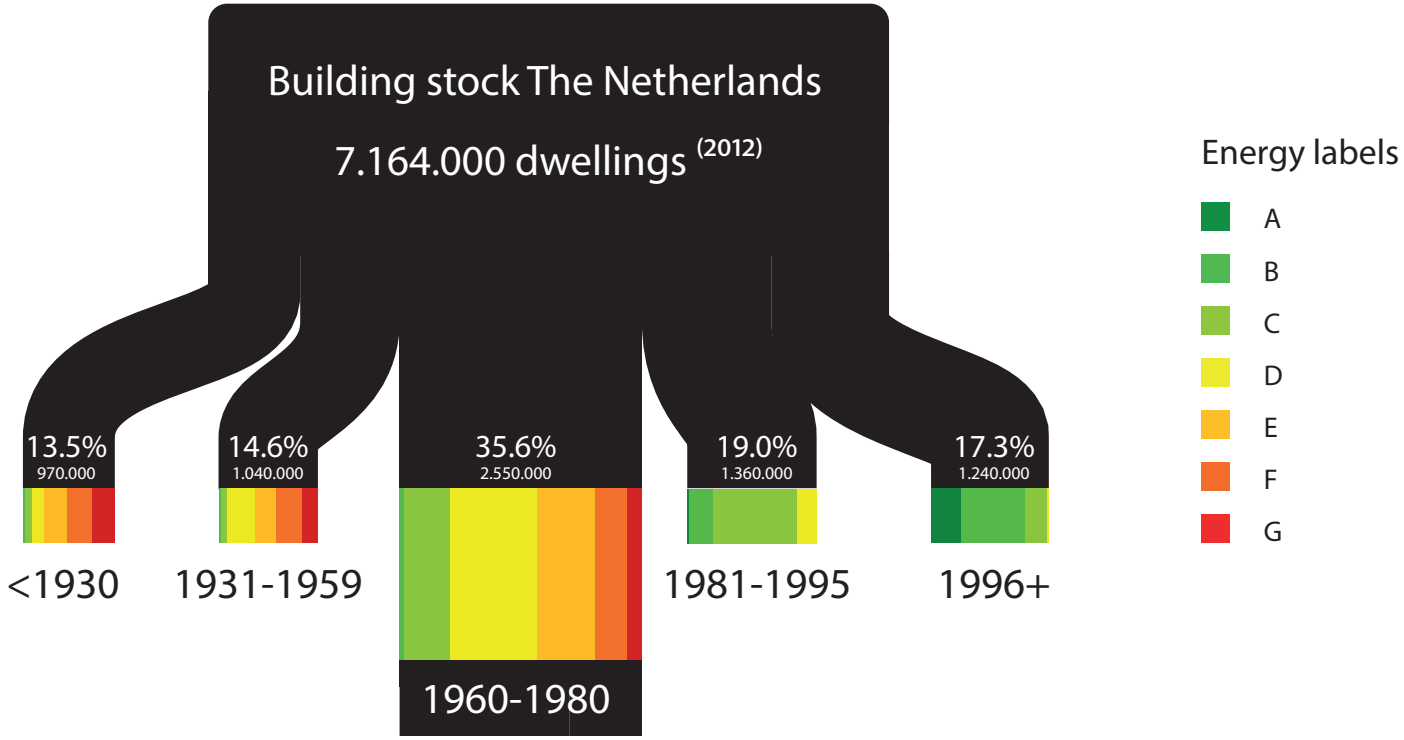
Is the Energy Roof technically and financially feasible for ‘Nul-op-de-Meter’ renovation of Dutch dwellings?

LITERATURE STUDY

BUILDING TYPE

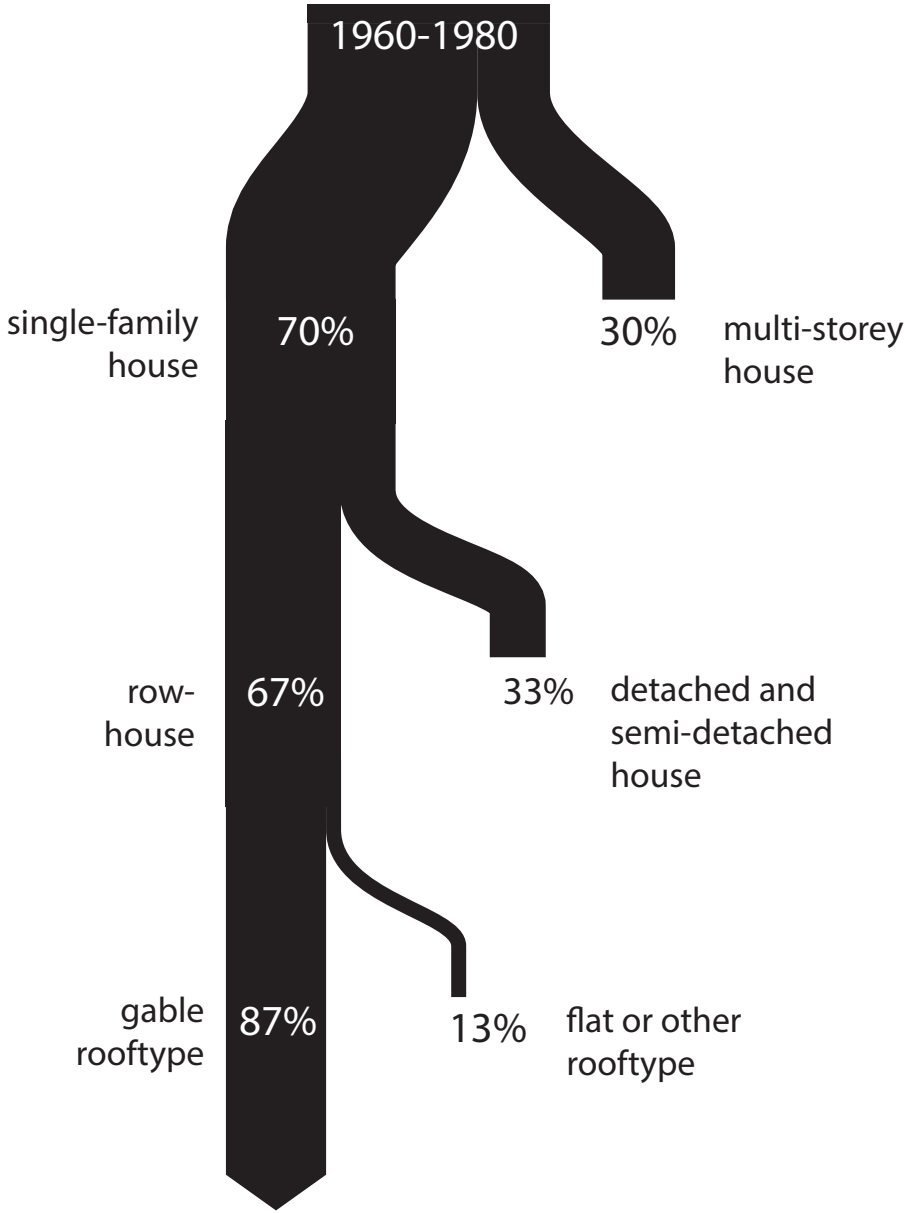
LITERATURE

Selection criteria:
amount // energy label // single family dwelling // pitched roof



BUILDING TYPE

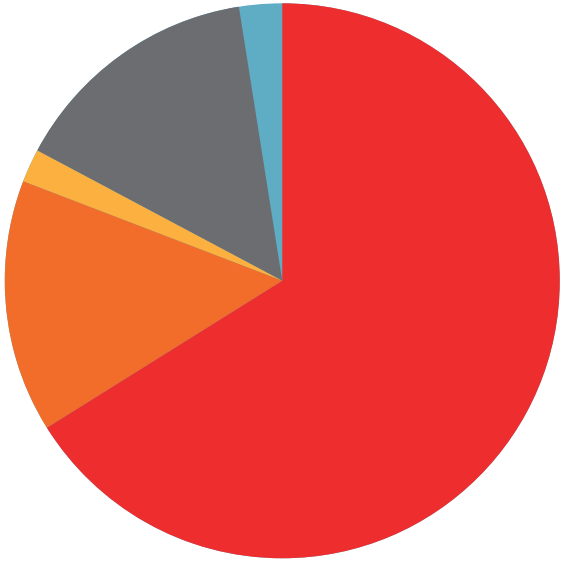
LITERATURE



ENERGY DEMAND

LITERATURE

67 GJ
final energy
(78.5 GJ primary)



Average house 1960-1980
energy demand

1.750 m3 gas
3.200 kWh electric

4.2 ton CO2 emission

19.4 GJ

NoM renovated row-house
electrical production

5.400 kWh - 5,6 kWP

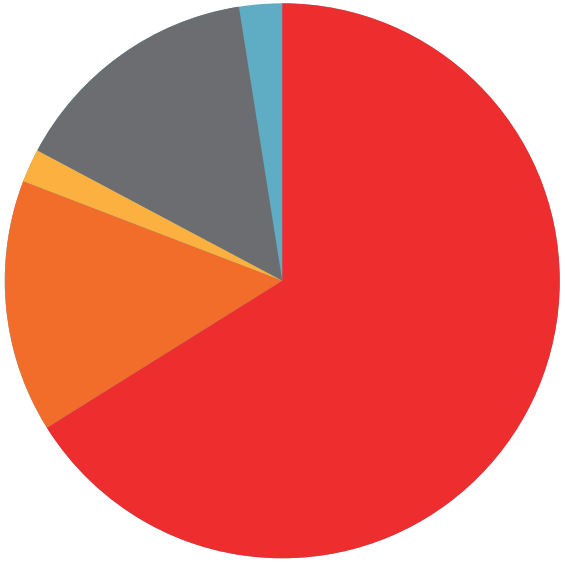
ENERGY DEMAND

LITERATURE

Energy demand

- heating
- hot tap water
- cooking
- appliances
- lighting
- ventilation

67 GJ
final energy
(78.5 GJ primary)



Average house 1960-1980
energy demand

1.750 m3 gas
3.200 kWh electric

4.2 ton CO2 emission

18.3 GJ

NoM renovated row-house
energy demand (full electric)

5.000 kWh

19.4 GJ

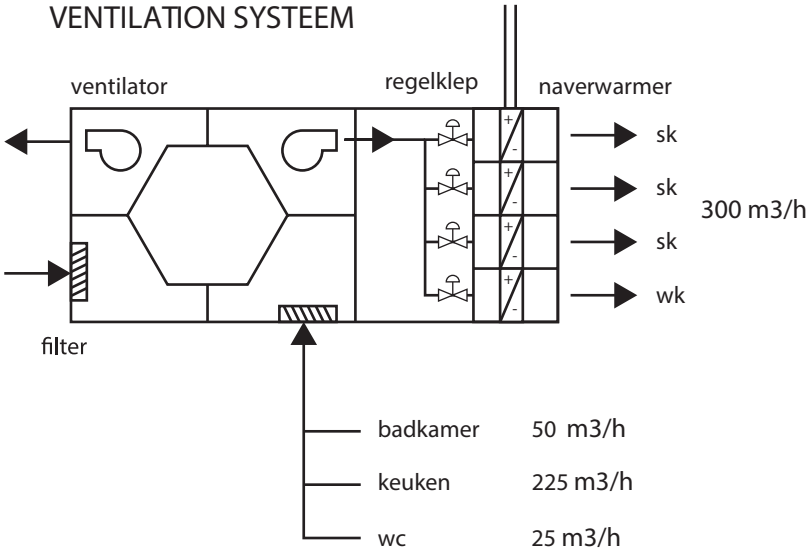
NoM renovated row-house
electrical production

5.400 kWh - 5,6 kWP

SYSTEM DEVELOPMENT

HYDRAULIC CIRCUIT

SYSTEM DEVELOPMENT



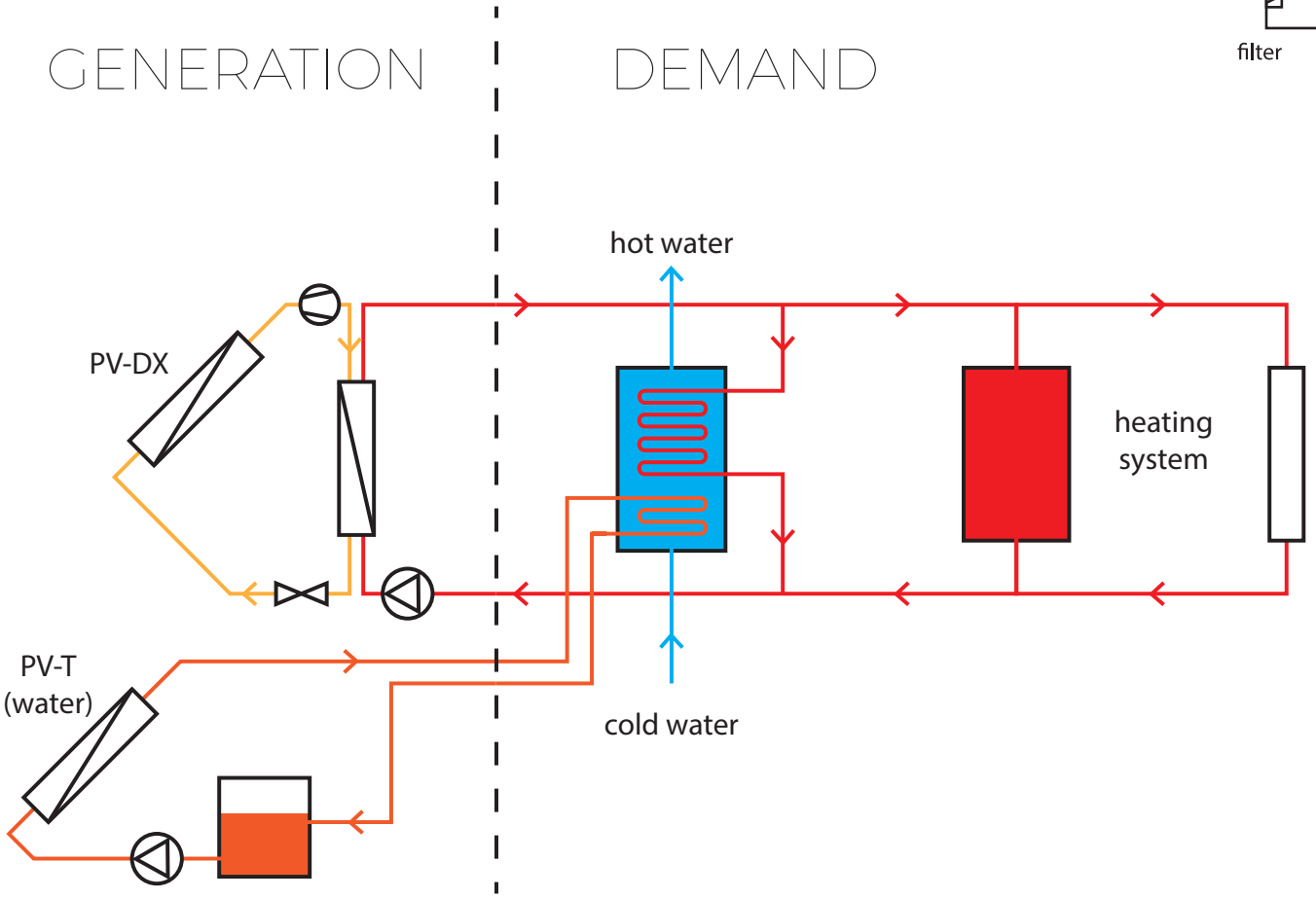
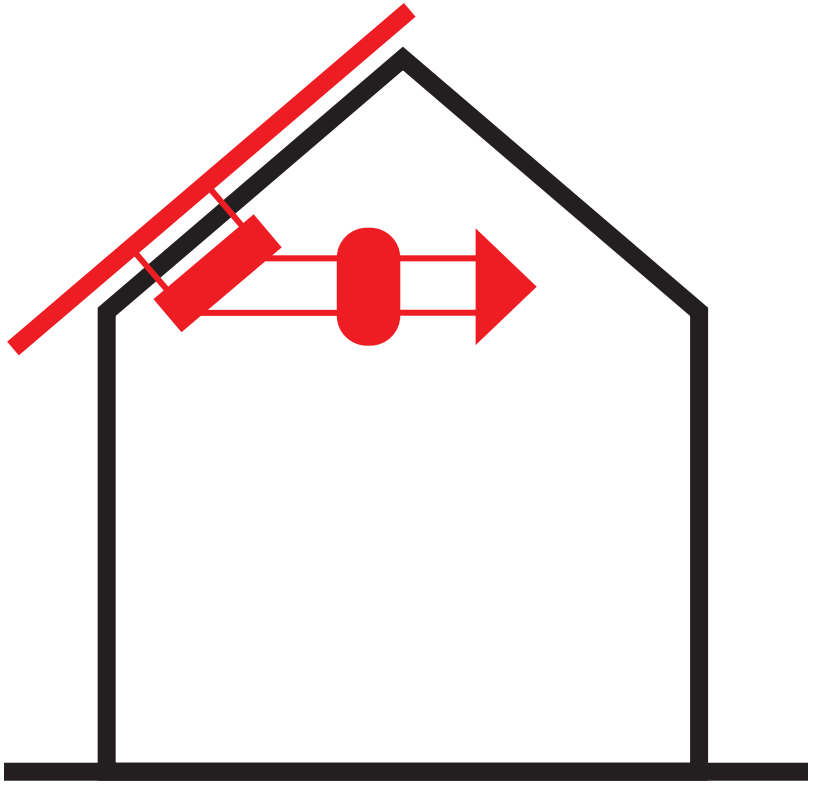


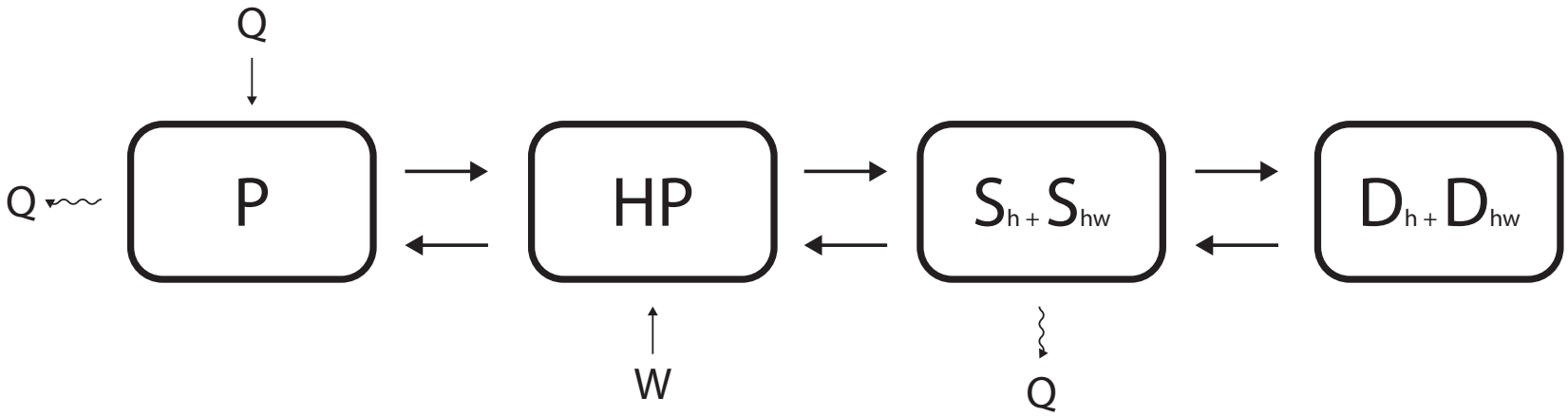
Diagram legend

YELLOW line	- heat pump refrigerant circuit
ORANGE line	- drain down boiler water circuit
RED line	- heating water circuit
BLUE line	- domestic water circuit
	- compressor
	- expansion valve
	- pump
	- storage tank
	- emission system

MODEL

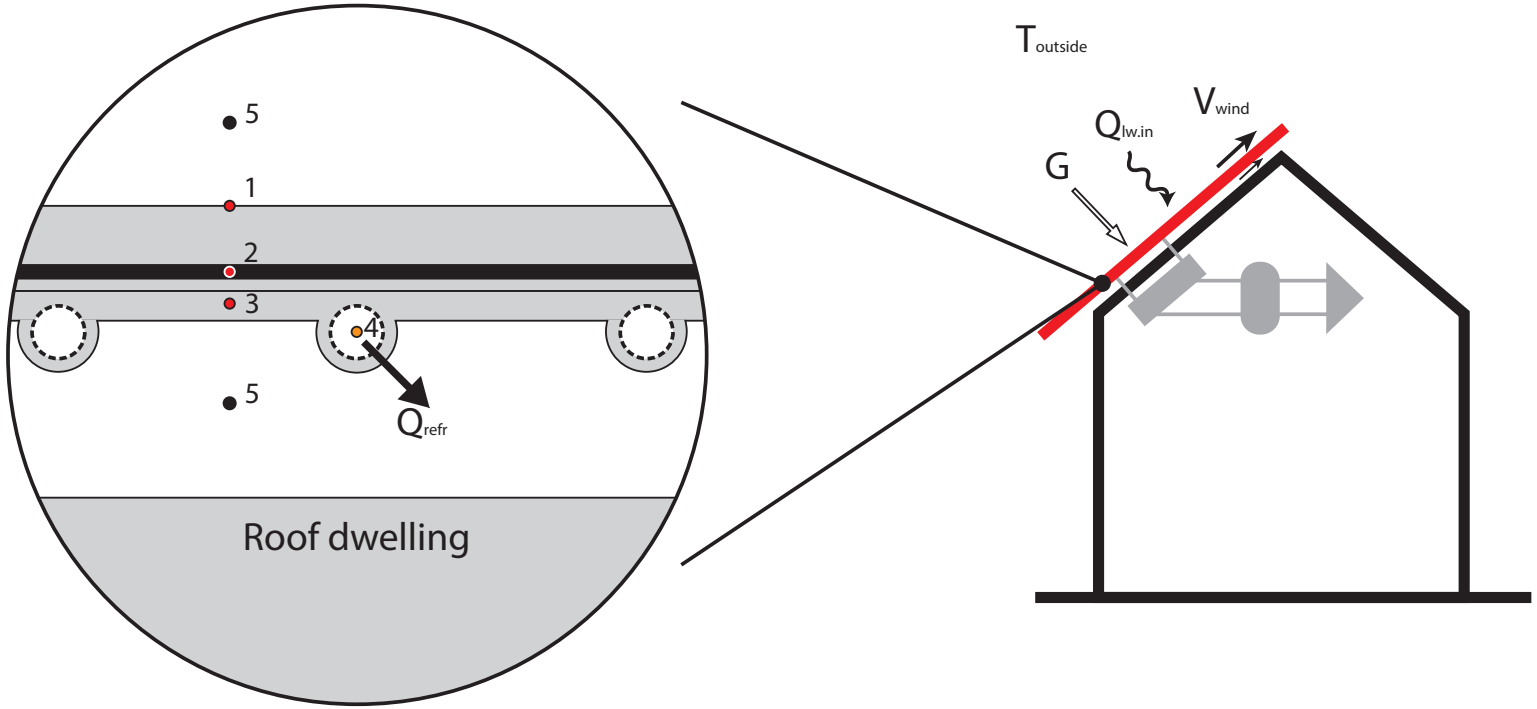
SYSTEM DEVELOPMENT

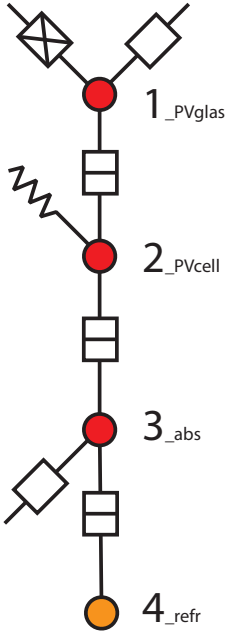


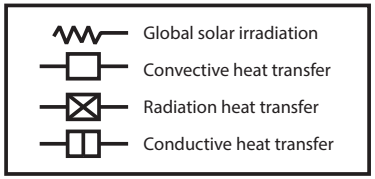


PANEL

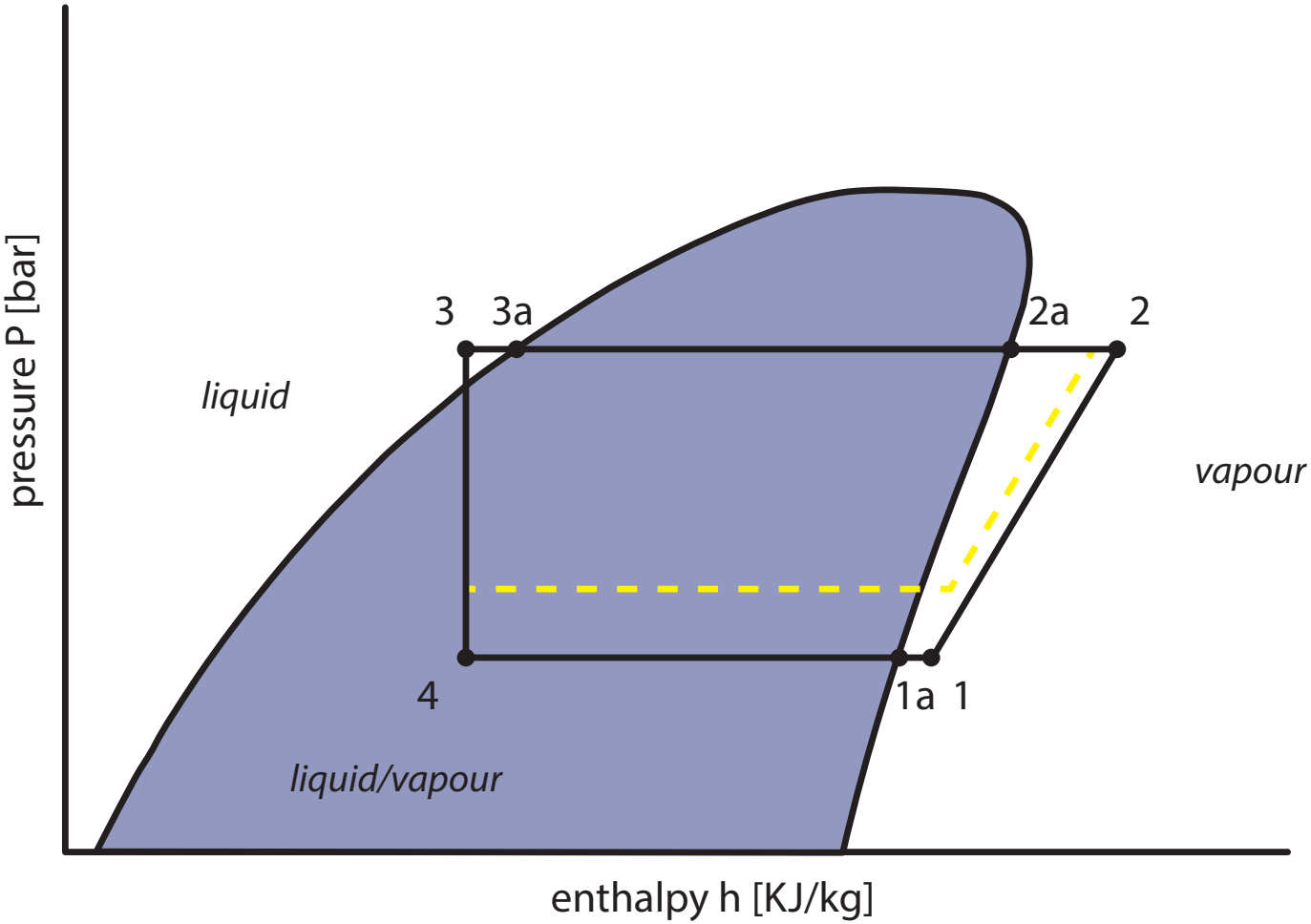
MODEL

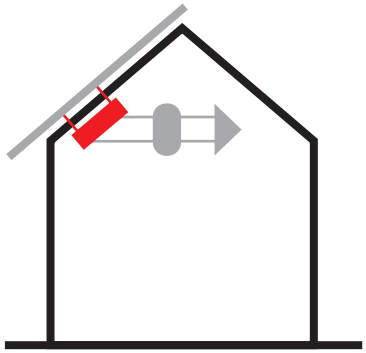

5
1
2
3
4
5
Q refr
Roof dwelling
T outside
V wind
Q lw.in
G


1 _PVglas
2 _PVcell
3 _abs
4 _refr


Global solar irradiation
Convective heat transfer
Radiation heat transfer
Conductive heat transfer

Solar Assisted Heat Pump (on/off) R134a





STORAGE TANK

MODEL

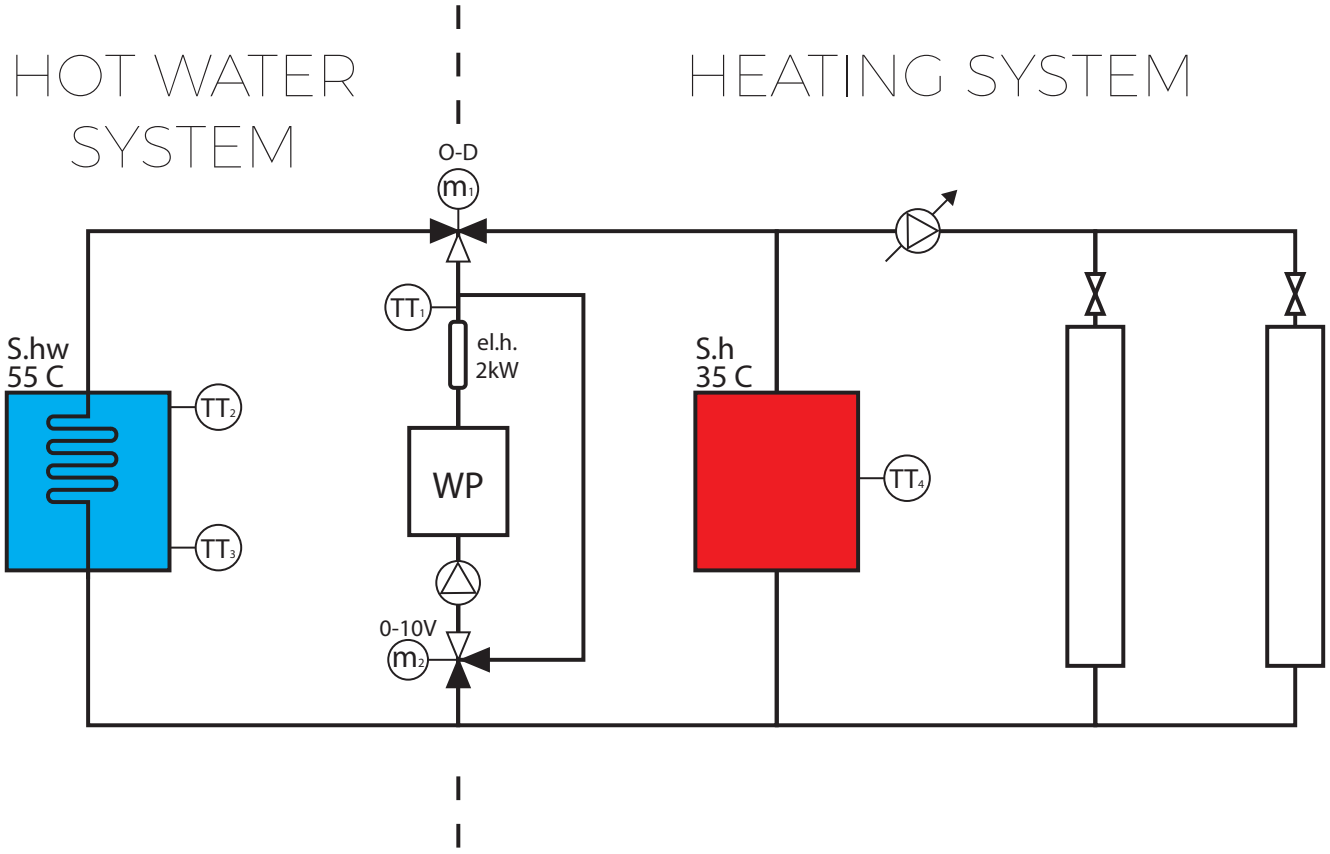
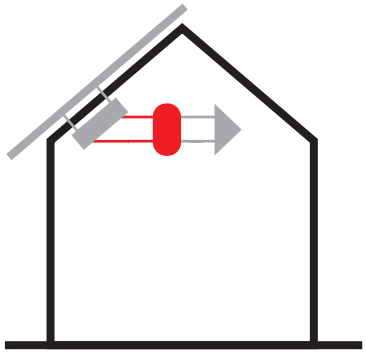


Diagram legend

- pump
- modulating pump
- temperature sensor
- valve
- 3 way valve (open/close or 0-10V)
- electrical heater
- storage tank (heating or hot water)



minimal buffer content
hot water tank: 150L (25 min shower)
heating tank: 100L (max. start/stops)

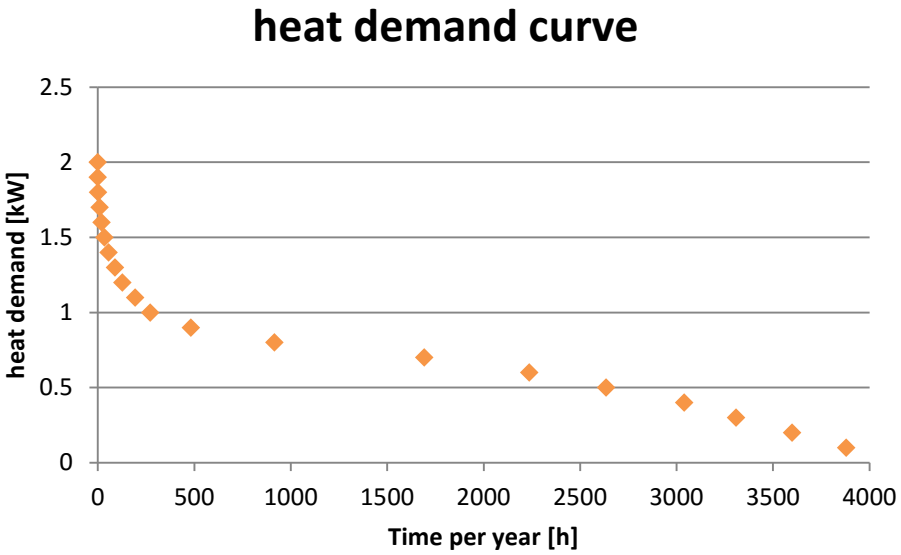
DEMAND

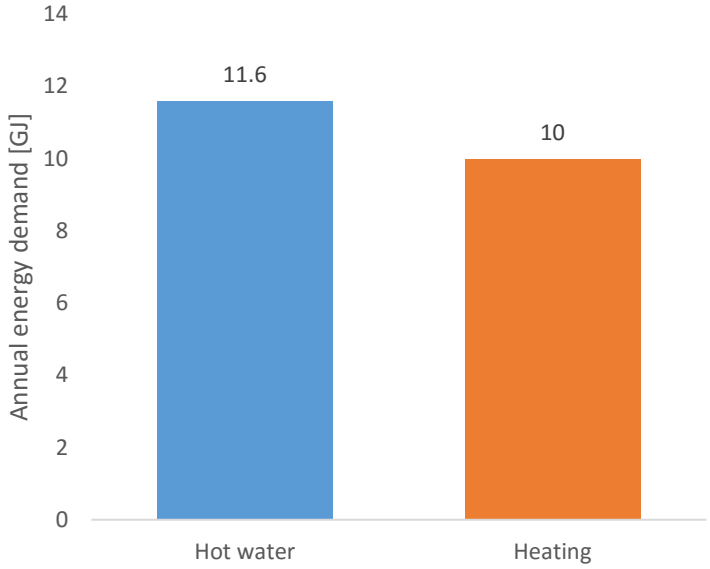
MODEL

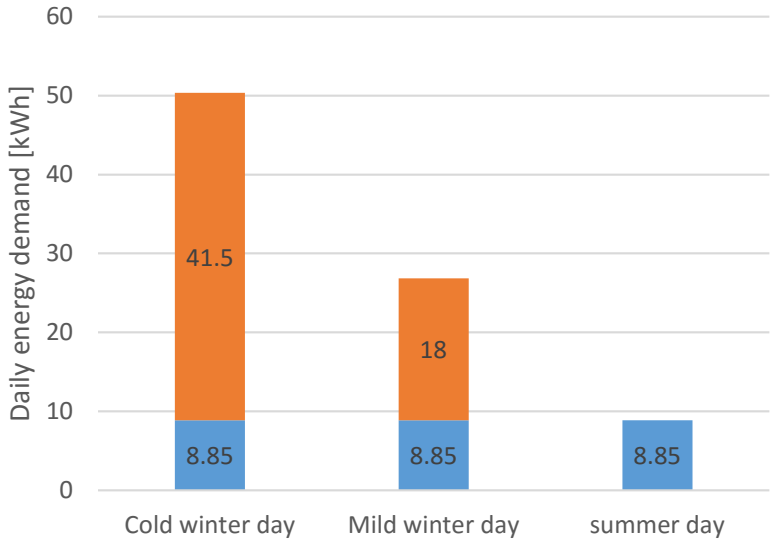
Hot water demand: 11.6 GJ

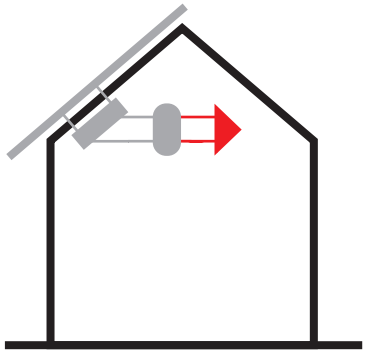
Heating demand: 10 GJ

- NoM renovated dwelling
- Heat demand < 30 kwh_th/m2
- Low temperature emission system







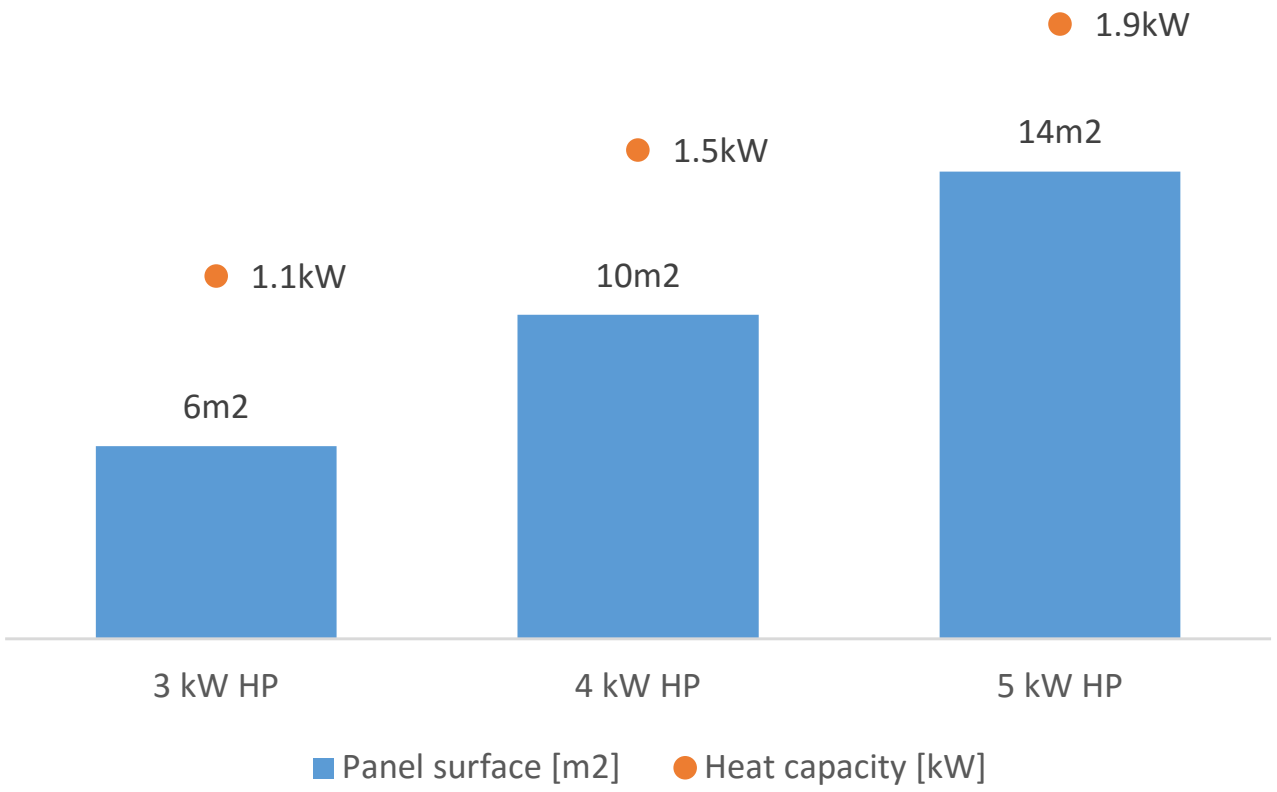


RESULTS

MINIMAL PV-DX PANEL SURFACE

SYSTEM DEVELOPMENT

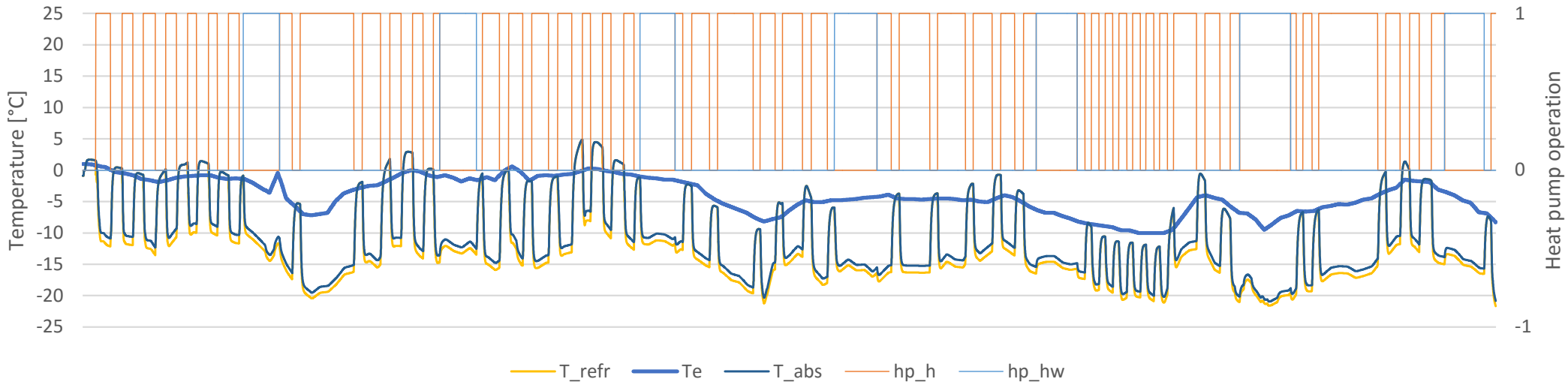
Cold winter night -15 °C



WINTER WEEK

RESULTS

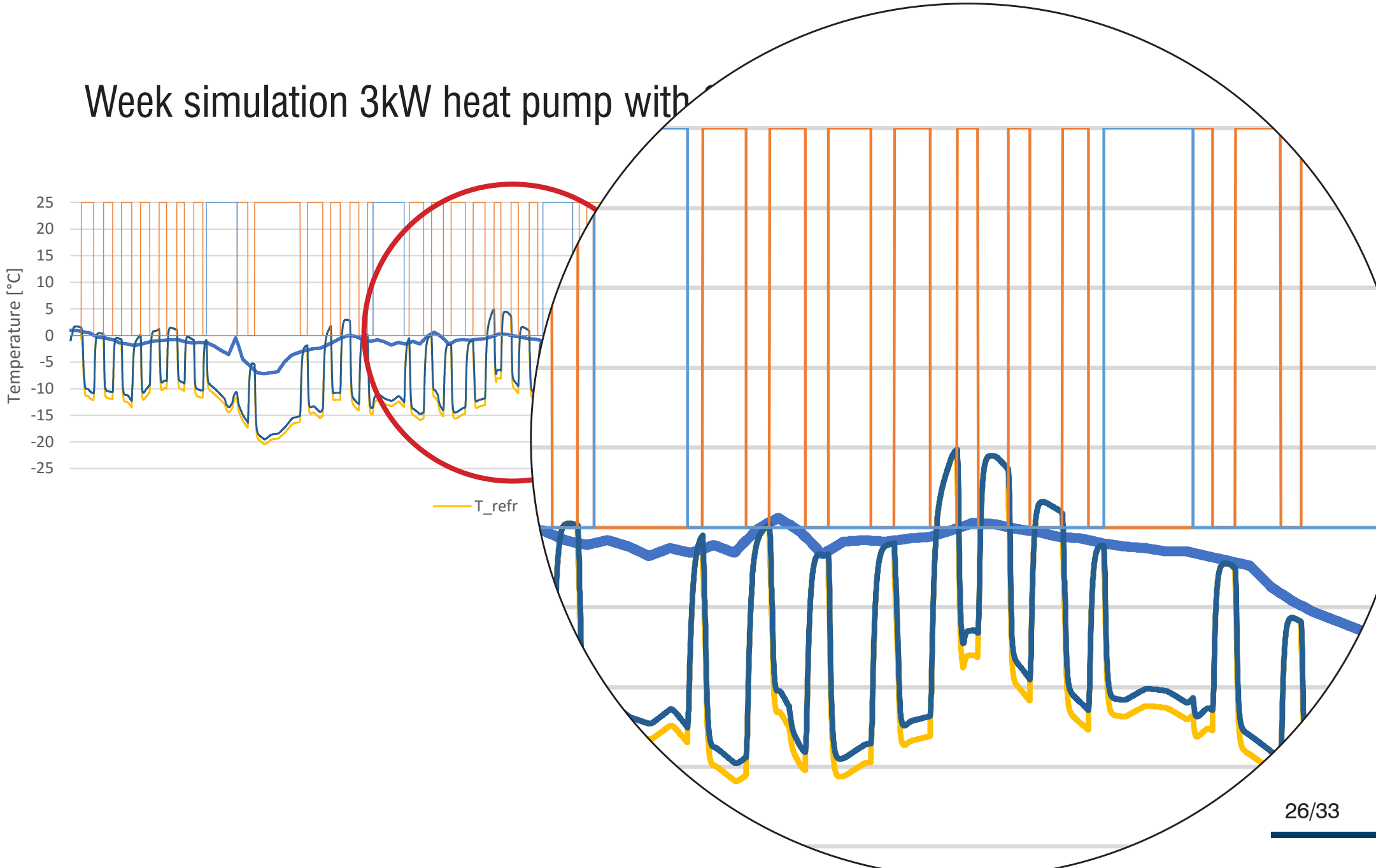
Week simulation 3kW heat pump with 6 m2 panel



WINTER WEEK

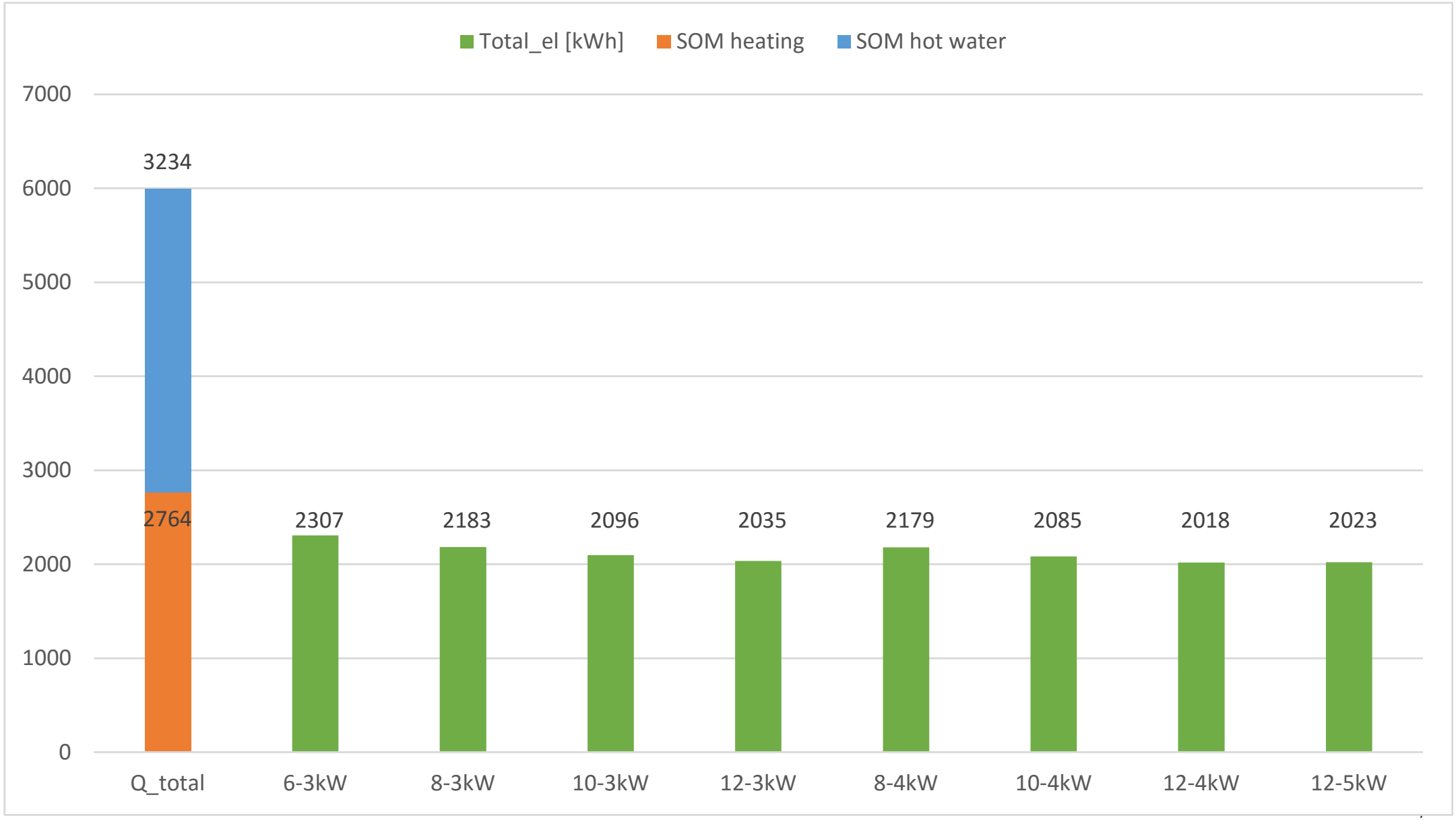
RESULTS

Week simulation 3kW heat pump with



ANNUAL SIMULATION

ELECTRICAL CONSUMPTION



NOM ROOF SURFACE

RESULTS

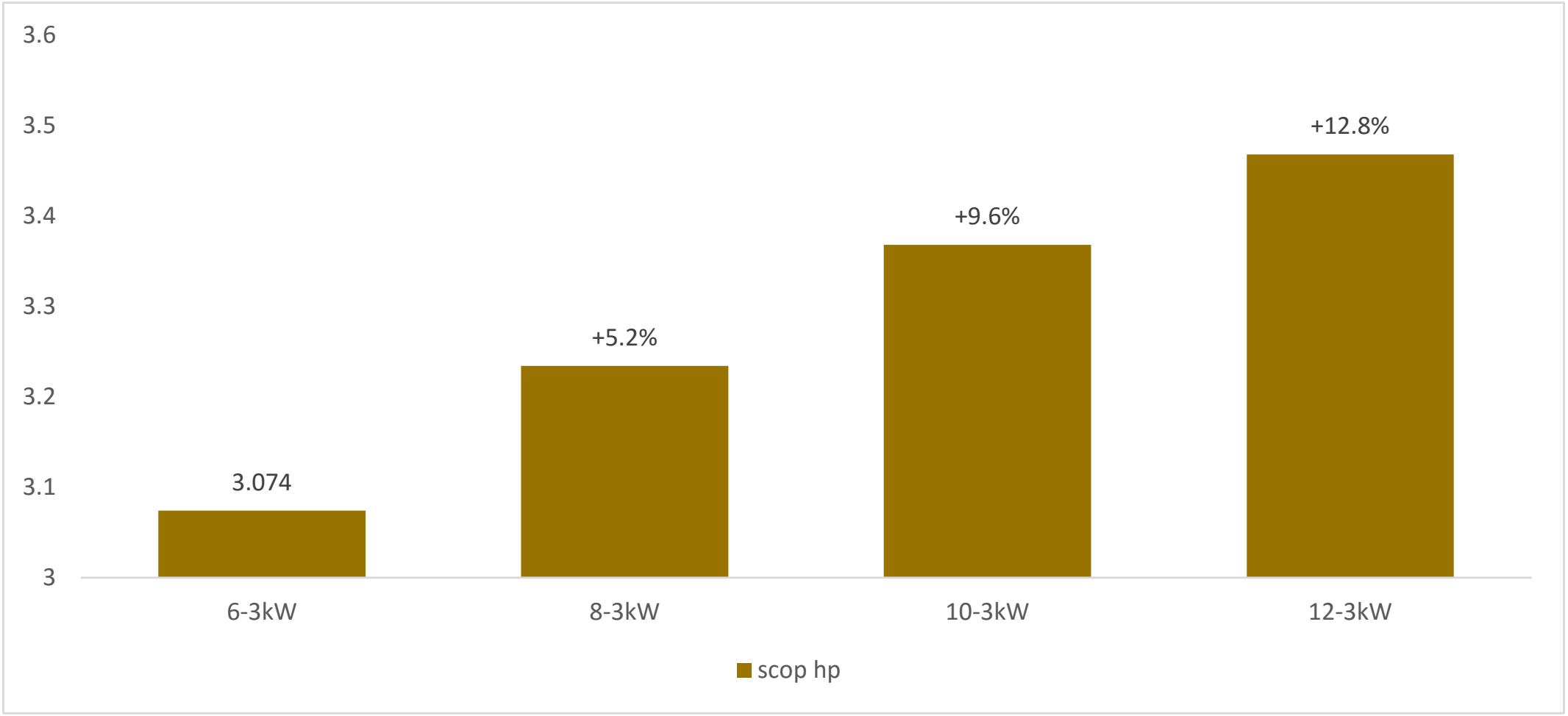
system	Total_el [kWh]	SCOP	Produced el. [kwh]	PV-DX East [m2]	PV East [m2]	Net PV-DX	Net East	m2 PV West
6-3kW	2307	2.601	896.6	6	28	-1410	-828	6.8
8-3kW	2183	2.747	1191	8	26	-992	-704	5.8
10-3kW	2096	2.861	1487	10	24	-609	-616	5.1
12-3kW	2035	2.947	1782	12	22	-253	-555	4.6
8-4kW	2179	2.753	1191	8	26	-988	-700	5.8
10-4kW	2085	2.876	1486	10	24	-599	-606	5.0
12-4kW	2018	2.972	1781	12	22	-237	-539	4.4
12-5kW	2023	2.966	1781	12	22	-242	-544	4.5
6-3kW (S)	2284	2.627	988.2	6	28	-1296	-279	2.8 (N)

Available roof area: 34 m2

Annual energy demand apliances, light and ventilation: 3545 kWh

PERFORMANCE HEAT PUMP

RESULTS



CONCLUSION

CONCLUSION

NoM with the Energy Roof is technical possible! ..with both roof surfaces

- The surface of the PV-DX has more influence on the SCOP than the capcity of the heat pump;
- PV-DX improves the efficiency of the PV panel with 0.8%;
- NoM is very sensitive to the user related energy (>50%);
- Potential reduction of 2.4% of the total Dutch carbon emission (4.2 million ton CO2);

RECOMMENDATIONS

CONCLUSION

- Further research is required for the wind convective heat transfer
- Including a model to predict the influence of ice formation
- Test prototype as validation of the model
- The model can be used with different inputs

Planned for P5:

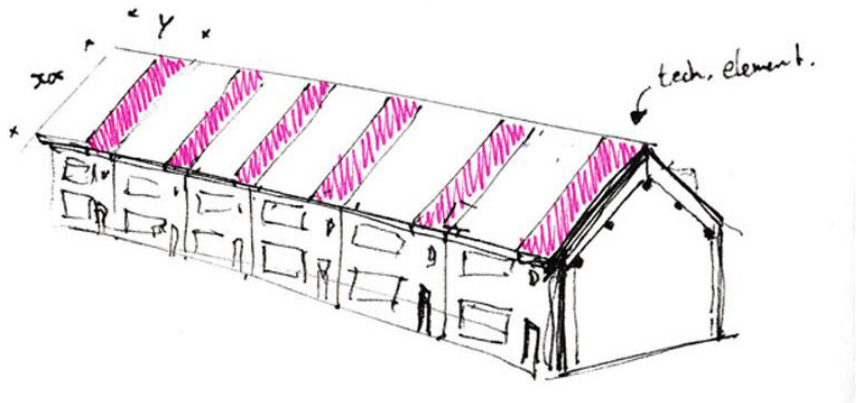
Include the PVT and smart control in the model, financial feasibility, report and presentation

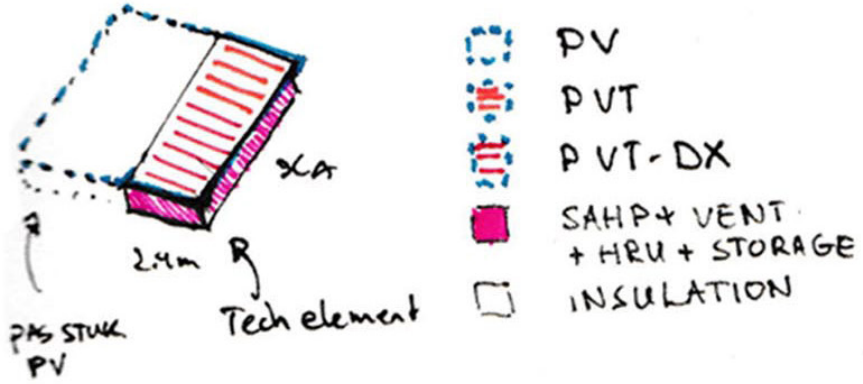
THANK YOU FOR YOUR ATTENTION

THE FULL ENERGY ROOF
GET READY FOR THE FUTURE

COMPONENT INTEGRATION

RESULTS





Unidek

Solrif BIPV

Roll-bond evaporator