Graduation thesis - Final presentation

Towards Energetic Circularity

greenhouse-supermarket-dwelling energy exchange

P.N. ten Caat - Jan '18

Toward Energetic Circularity | P5 Presentation (provisional)

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dr. Dirk Dubbeling - Delegate of the board of examiners

Delft, 26.1.18

Welcome

TU Delft & Lidl?

- Lidl goals: building stock and operational processes circular
- Luuk Graamans & Andy v/d Dobbelsteen
- 02.2017 - 01-2018

Student thesis

- Building related & operation/user related energy demand

Since the industrial revolution the world runs on fossil based energy

At the cost of global climate

More independence fossil fuel

Trias energetica: reduce, **reuse** & produce

Energy cascading

- Exergetic inefficiency
- Large scale
- Regional

Problem statement

How can we combine the energy flows of a supermarket and a greenhouse and connect them to the adjacent dwelling to reduce the cumulative environmental footprint of the three functions?

Research question

General: reduce the CO_2 emission due to the **cumulative building related** energy demand

↓

lower the building related energy demand

↓

Design a **local**, small scale energy network

↓

enable energy sharing, connect local supply & demand

Research objective

General: reduce the CO_2 emission due to the **building related** energy demand

↓

lower the building related energy demand

↓

Design a **local**, small scale energy network

↓

enable energy sharing, connect local supply & demand

new element: **Urban rooftop greenhouse**

Research objective

1. Context
2. Circularity
3. Concept
4. Energy: supply & demand
5. Energy system
6. Balancing in the system
7. Urban Design
8. Conclusion

Index

Context

Location, city block, components

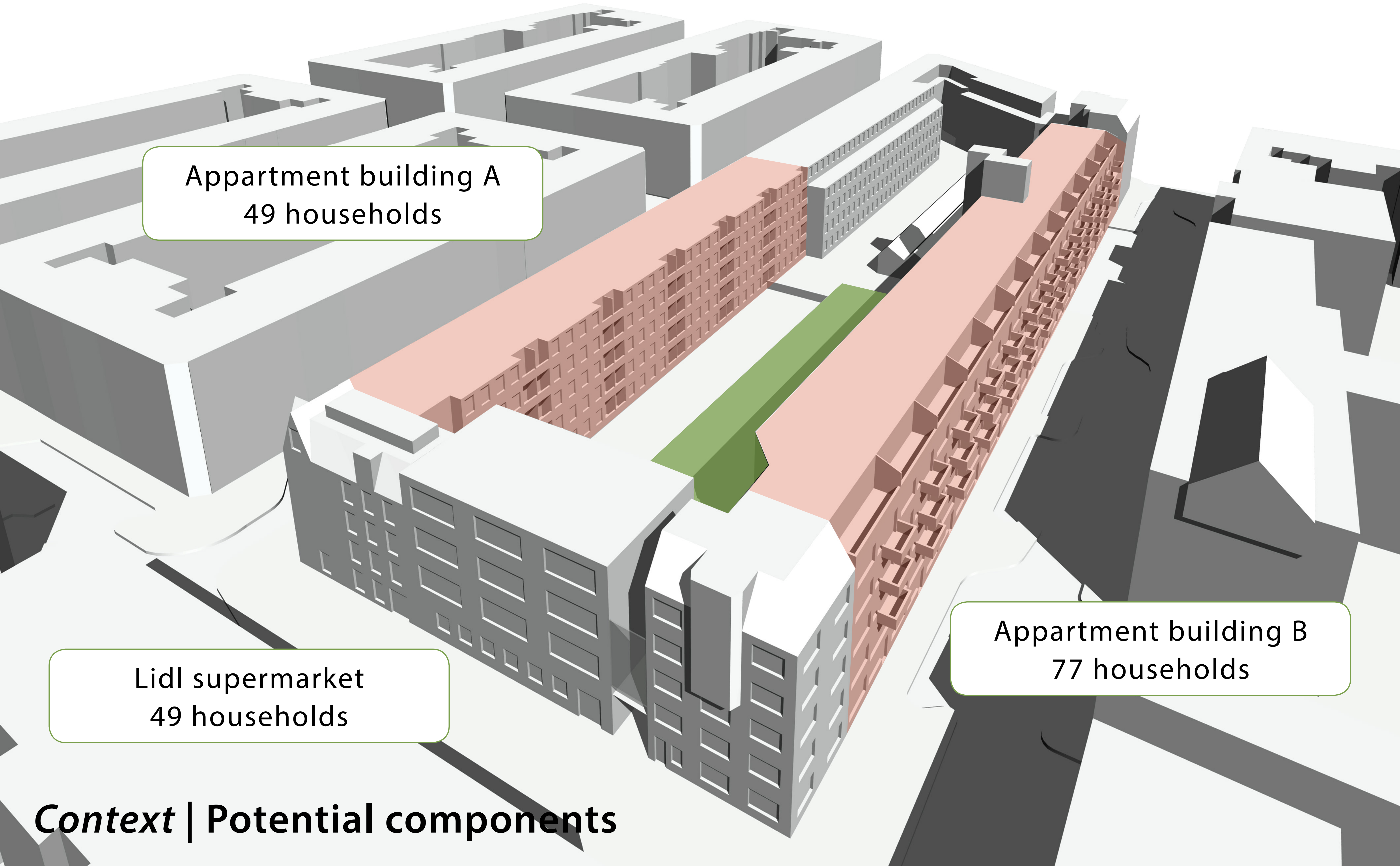
part 1/8

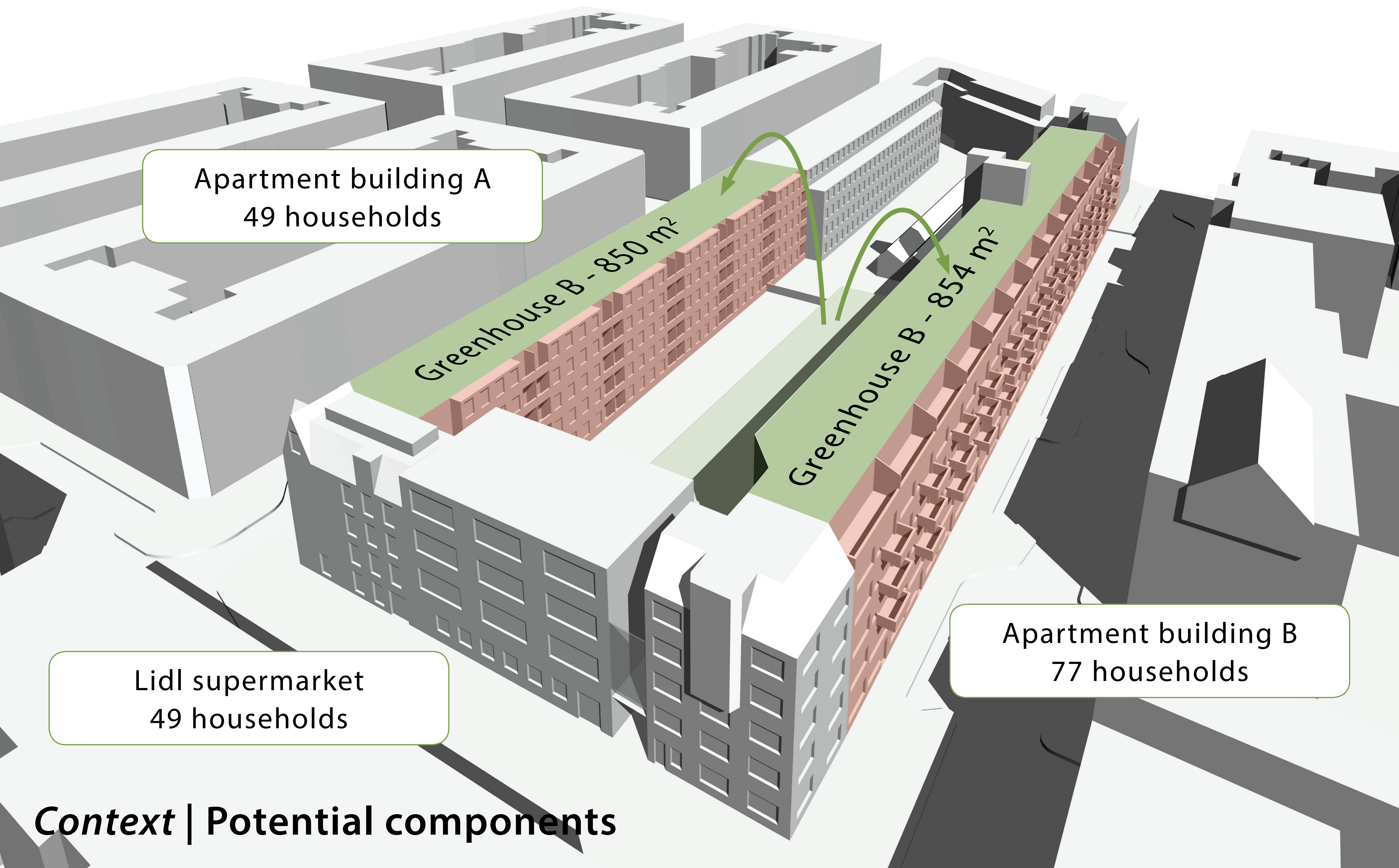
Context | Location

Context | Lidl Helmersbuurt

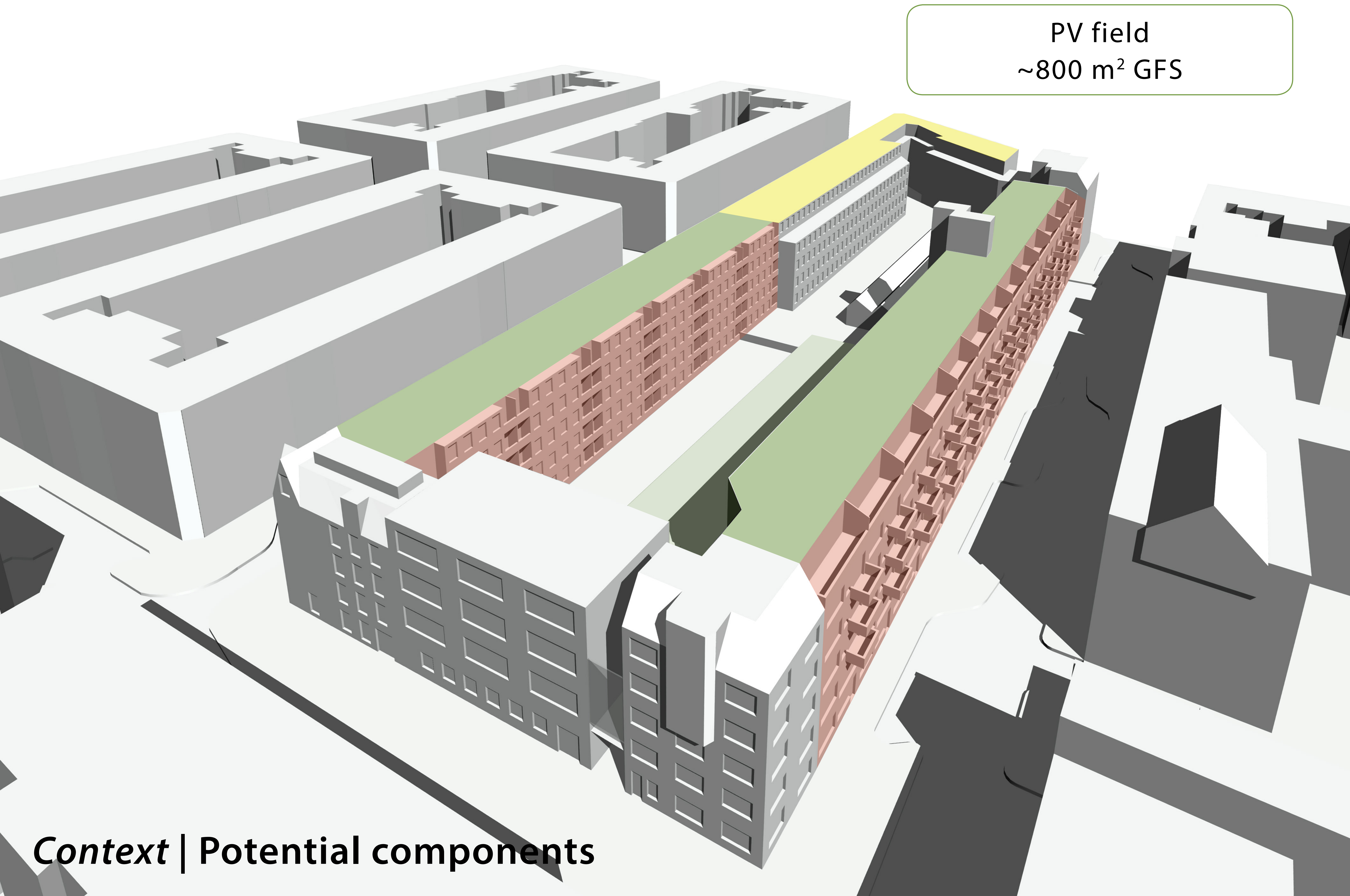
Source: Google Earth, ©2018 Google

Context | Potential components





Context | Potential components



Context | Potential components

Circularity

Circularity, Energetic circularity, roadmap

part 2/8

circularity in the built environment

Linear economy: take-use-dispose

Circular economy: take-use-reuse

Linear economy -> circular economy

Materialistic circularity

Goal: No more destruction of raw materials

Energetic circularity

Goal: Independance from fossil based energy (autarkic) *example: supermarket*

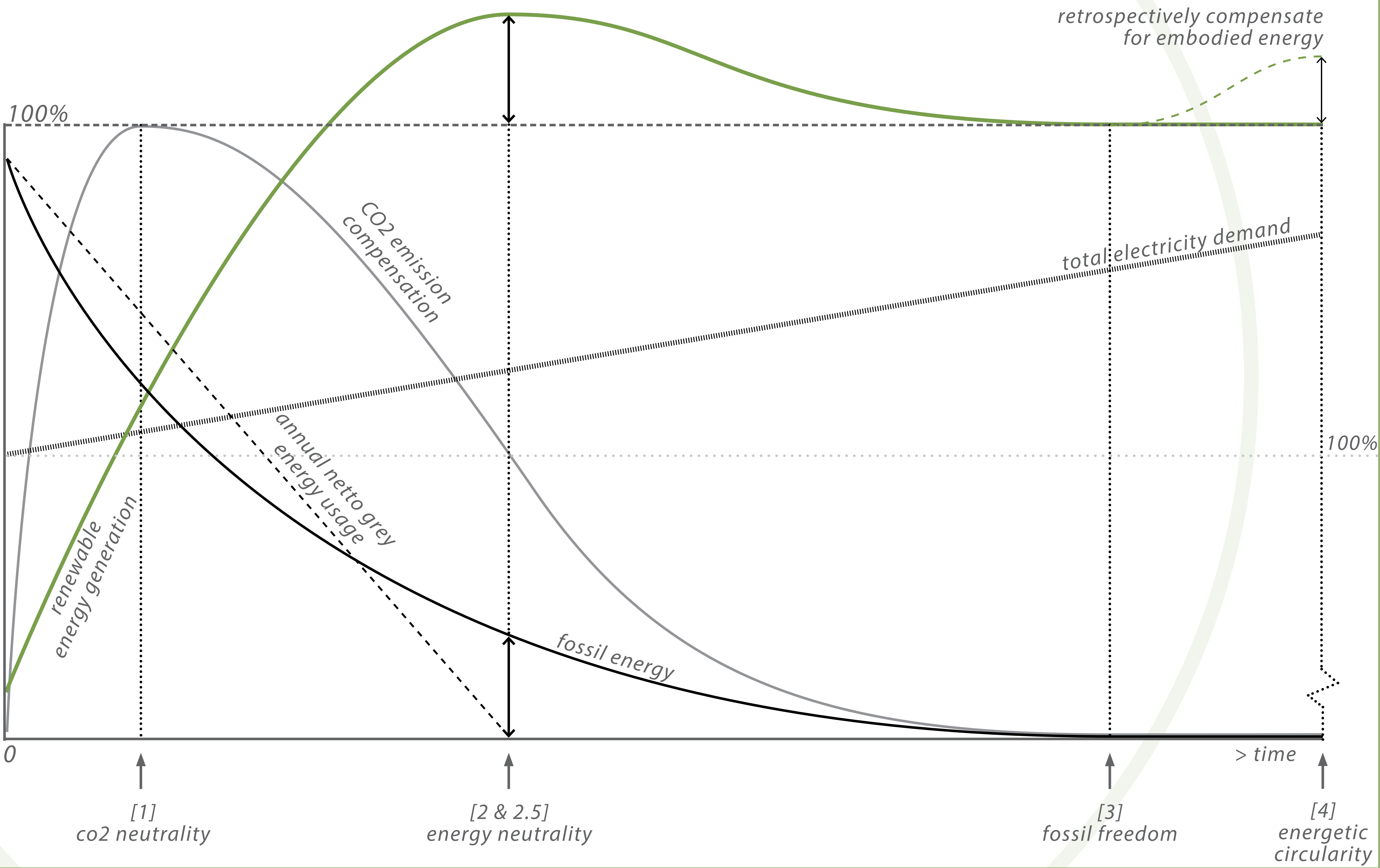
[1] CO_2 neutrality > compensation programs

[2] Energy neutrality > grey electricty = green electricity

[2.5] Energy neutrality 2.0 > including user/operation energy

[3] Fossil free > full disconnection from fossil fuels

[4] Energetic circularity > investment energy



Circularity | Roadmap

Achieving energetic circularity

Technically = solution is easy.

In practise = extremely hard (2018)

Lack of space;

Inefficient power generating installations;

High temperature heating systems.

Practical objectives:

Disconnection from gas network.

Increase local energy generation

Concept

Core elements

part 3/8

Local energy grid:

- Small scale;
- Short energy lines;
- Low temperatures; (industry = absent)
- Easy / cheap interventions. (existing environment)

Seek energetic potentials

Establish smart energetic connections

In this study:

- Lidl <> greenhouse energy exchange
- Greenhouse > Dwelling
- Lidl excess heat > System

Concept | Local energy grid

Fossil freedom = abandon gas

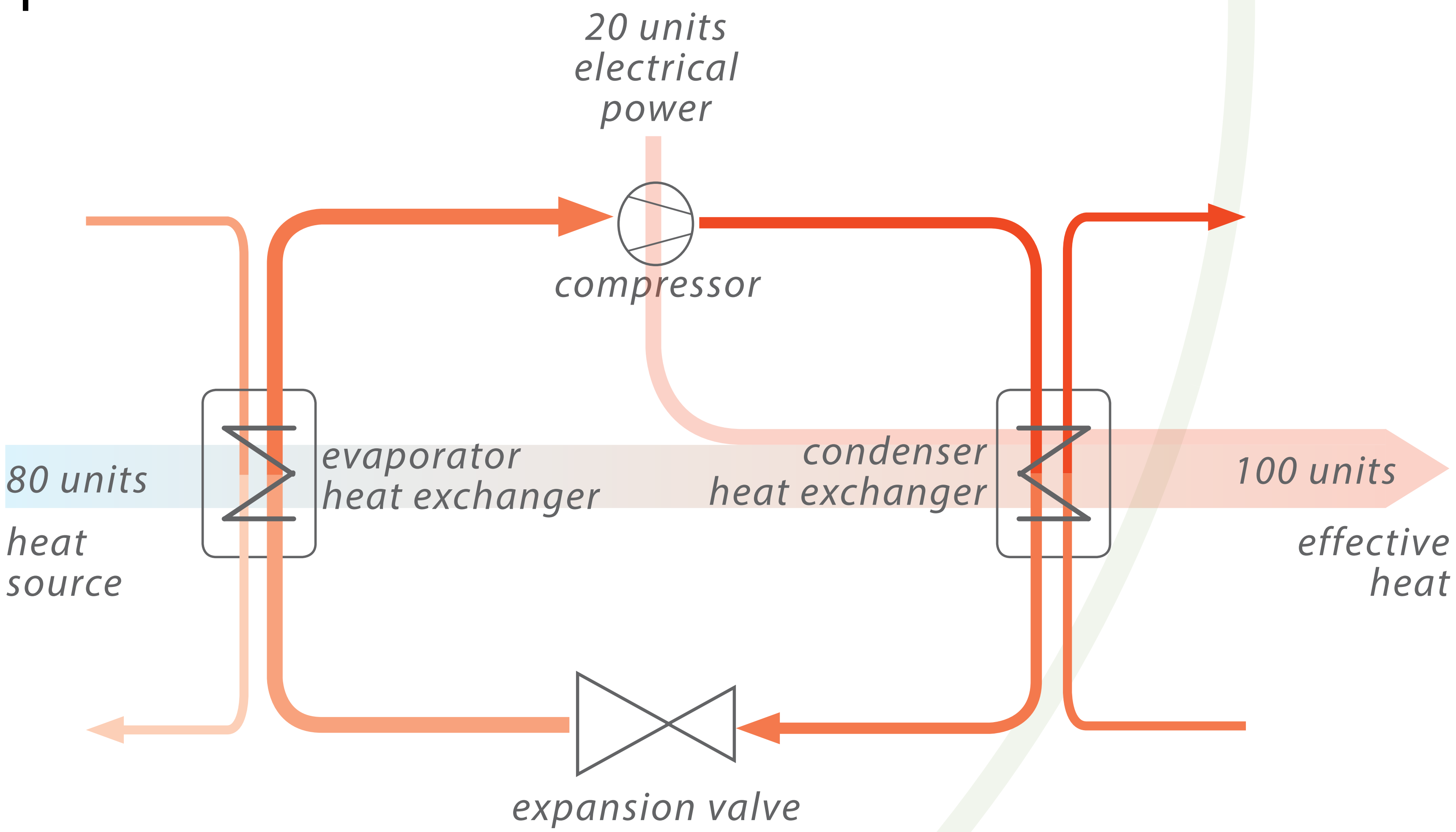
Alternative heat source: rooftop greenhouse solar collector

Alternative heating system: heat pumps

Heat pumps

Minimal electric investment

Free heat source;
COP: the higher, the better;
Small temperature jumps.



Concept | **Phase out gas > install heat pumps**

Greenhouse solar collector = thermal energy

2 types:

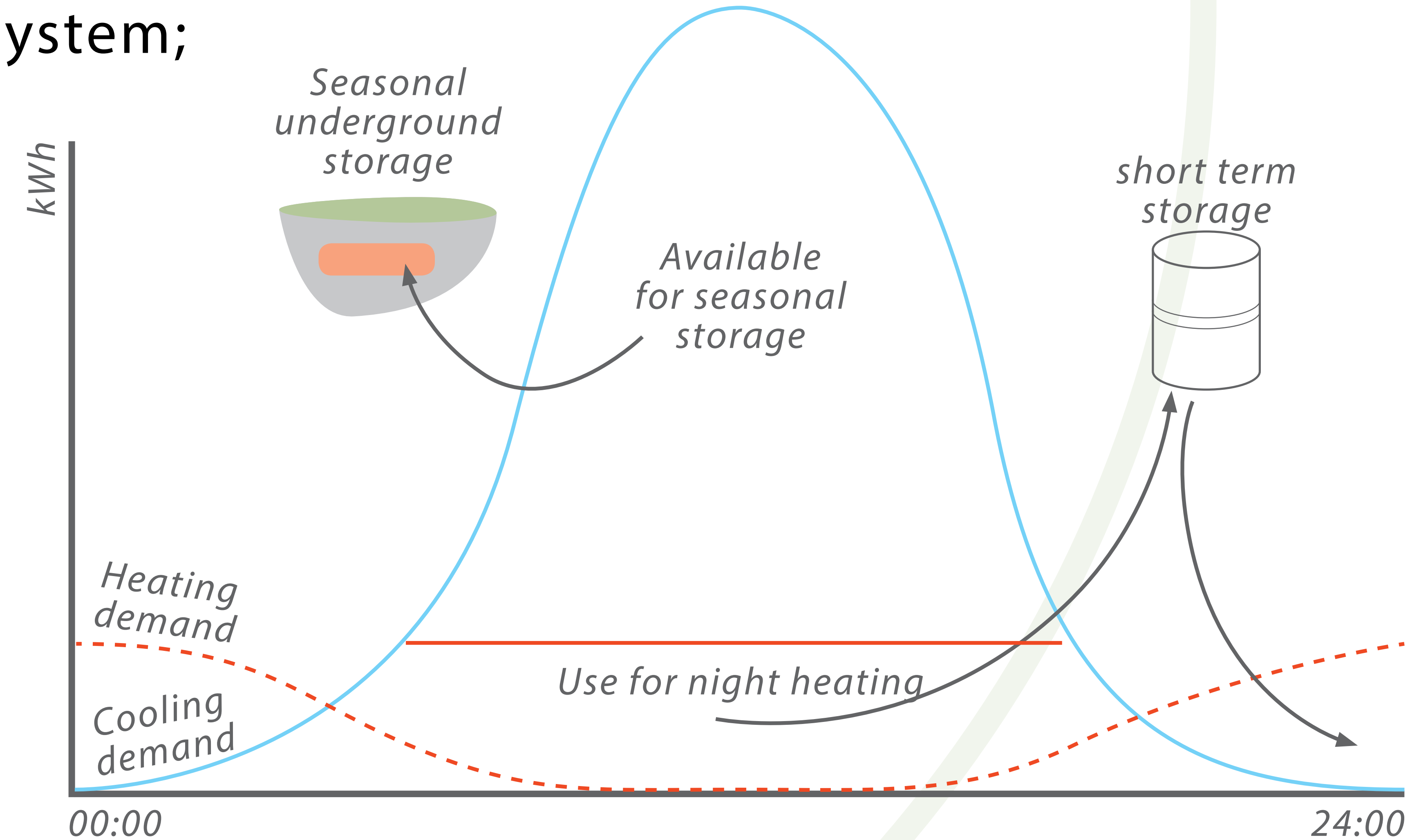
short term - warm water reservoir
seasonal - underground energy storage

Underground energy storage:

Underground water layers: aquifers;
Cold & Warm storage: doublet system;
Open source;
Infiltration T =25°C;
Extraction T= ~8°C & ~16°C.

Most important:

Balance



Concept | Thermal energy storage

assume: tomato production

Optimal greenhouse climate conditions:

- Closed greenhouse
- Hydroponic farming
- Nutrient Film Technology
- Temperature 18.5°C - 26.5°C
- Relative humidity 75%
- Root zone temperature 25°C
- CO_2 concentration 1000PPM

Is this sustainable?

assume: tomato production

Sustainable greenhouse climate conditions:

- ~~Closed greenhouse~~ > Semi-closed greenhouse
- Hydroponic farming
- Nutrient Film Technology
- ~~Temperature 18.5°C - 26.5°C~~ > 15°C-30°C
- ~~Relative humidity 75%~~ > variable / ambient
- Root zone temperature 25°C
- ~~CO_2 concentration 1000PPM~~ > ambient

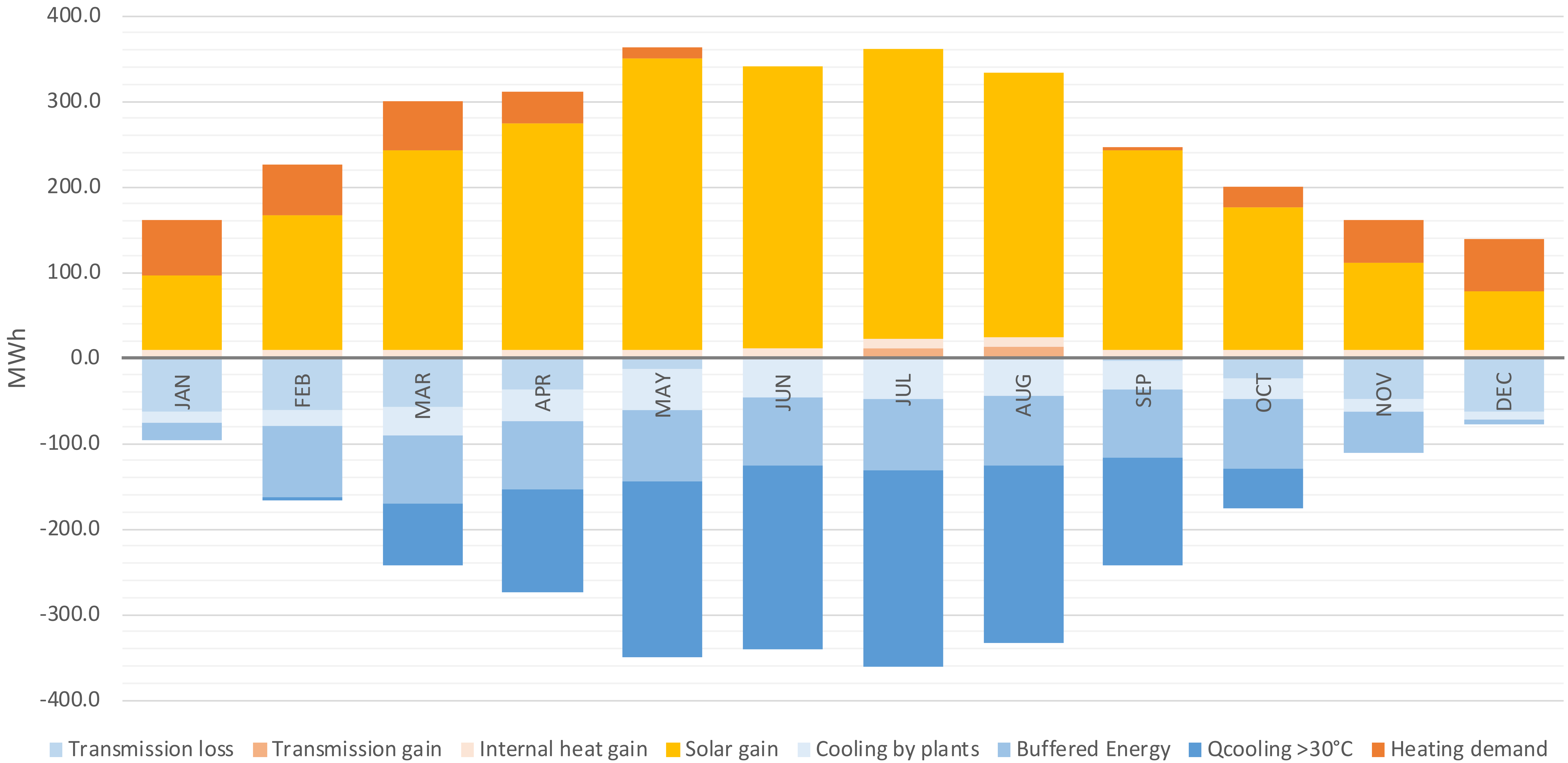
Better option.

Concept | Greenhouse climate

Energy

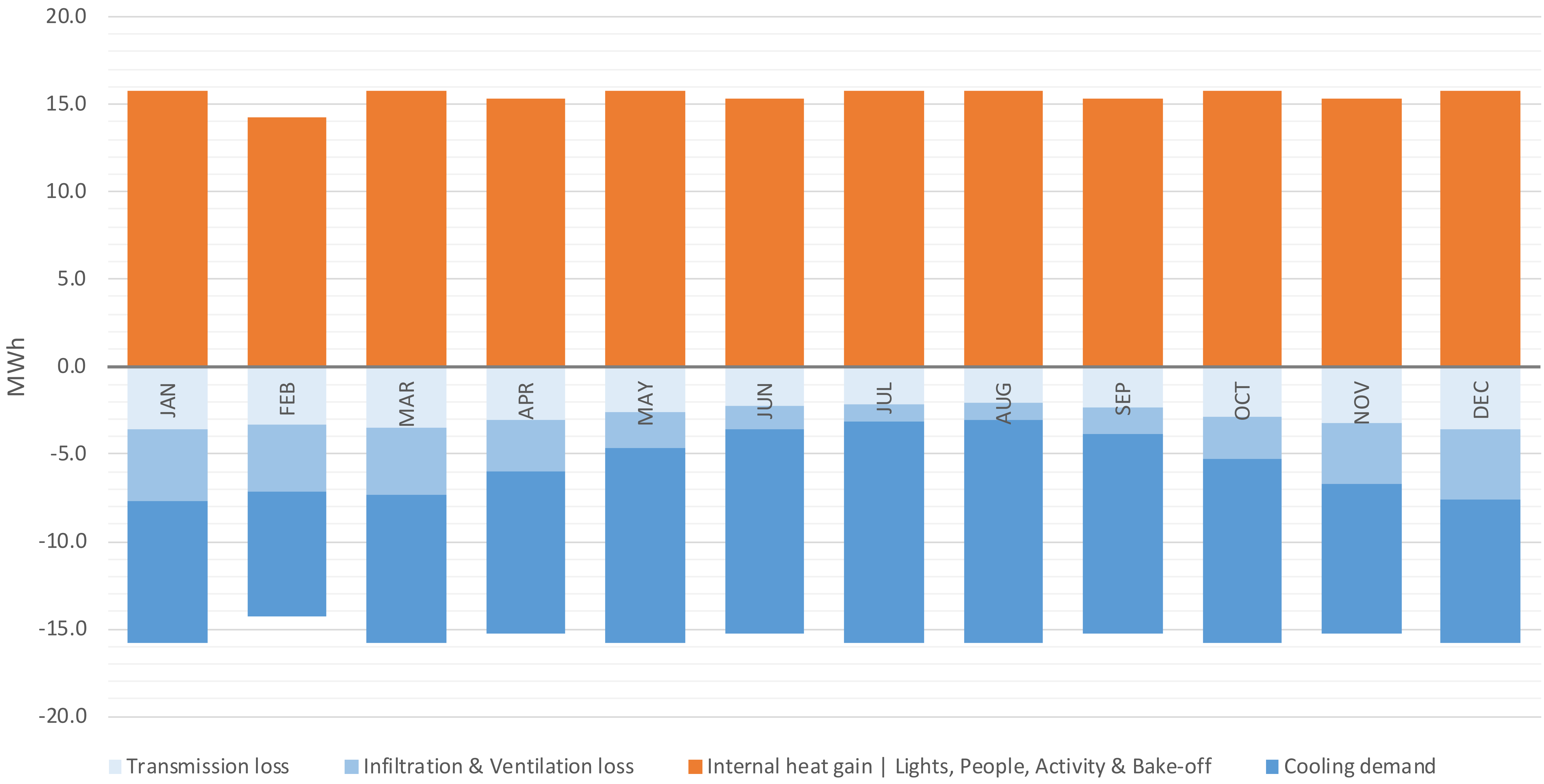
Supply & Demand

part 4/8



2 greenhouses on their maximum size & T_{IN} = 15°C-30°C

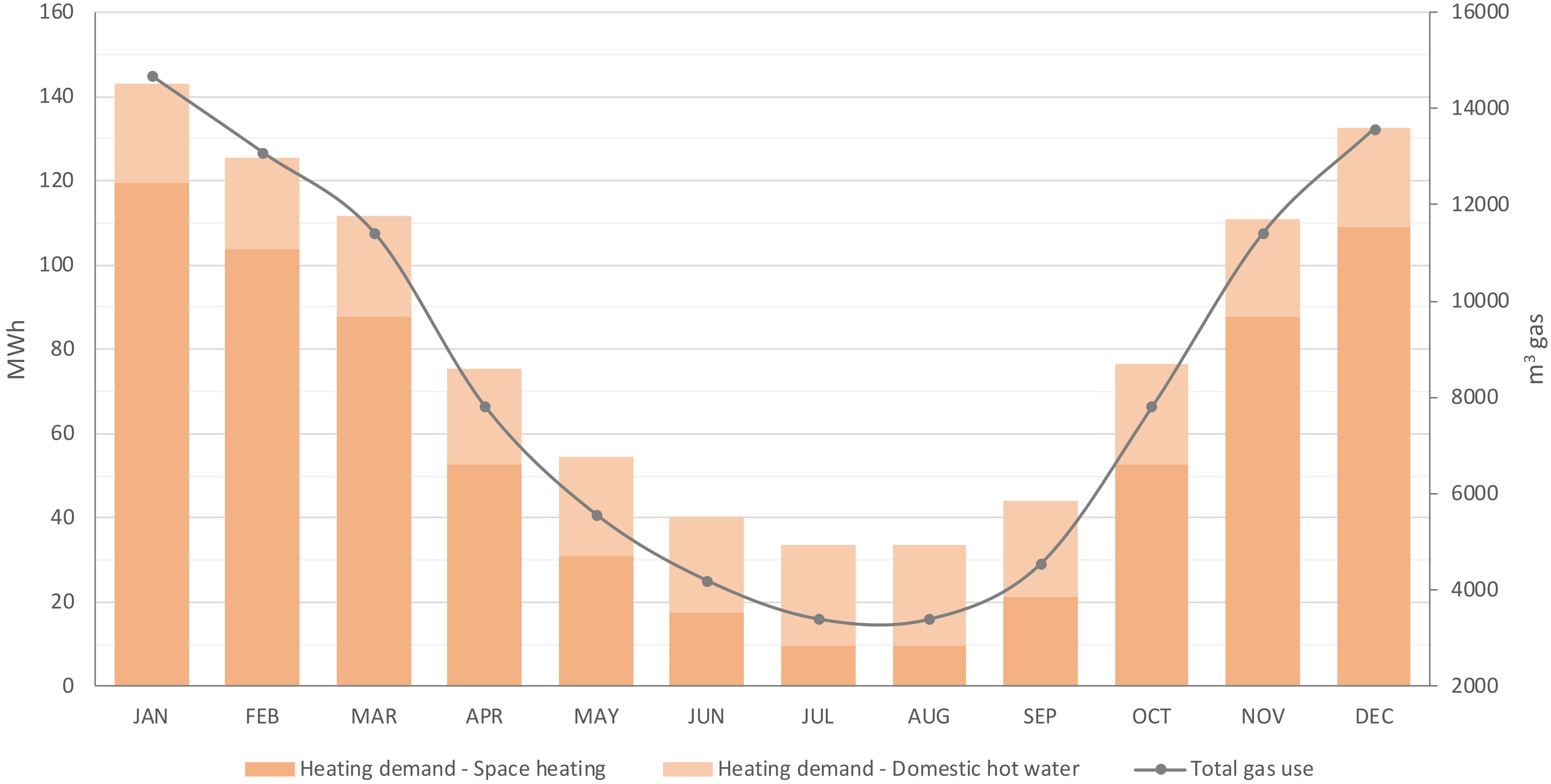
(U= 2.7W/m².K, STC=0.6, facade orientation reduction factors included)



Condioned area = 15.4m x 46m x 2.9m & T_{IN} *= 21°C*

(U_{ROOF}*= 0.17W/m²,* U_{FACADE}*=0.22W/m².K ,* U_{FLOOR}*= 0.25W/m².K, Inf.rate = 0.443m³/s, Vent. rate = 0.1m³/s,* $q_{CUSTOMER}$ *= 131W/person)*

Energy | Lidl energy balance



124 households & 810 m³ gas/hh

(230 m³ domestic water, 580 m³ space heating)

Energy | Dwelling heat demand

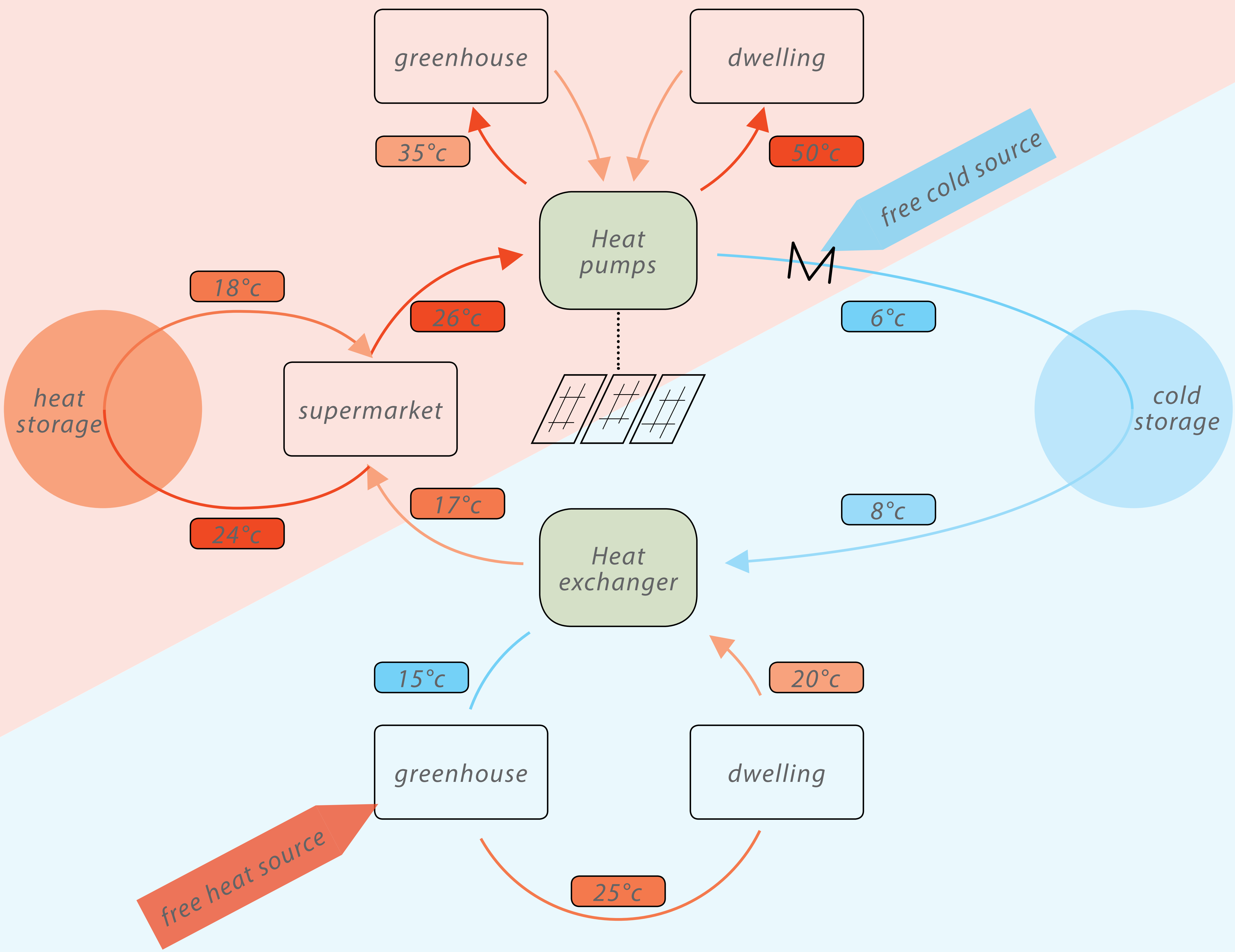
	Dwelling	Greenhouse	Supermarket
Winter heating	- 700 MWh	- 316 MWh	-
Summer heating	- 282 MWh	- *	-
Winter cooling	-	-	+51 MWh
Summer cooling	-	+ 1104 MWh	+69 MWh

Summer = April - September
Winter = Oktober - March
**short term energy demand excluded*

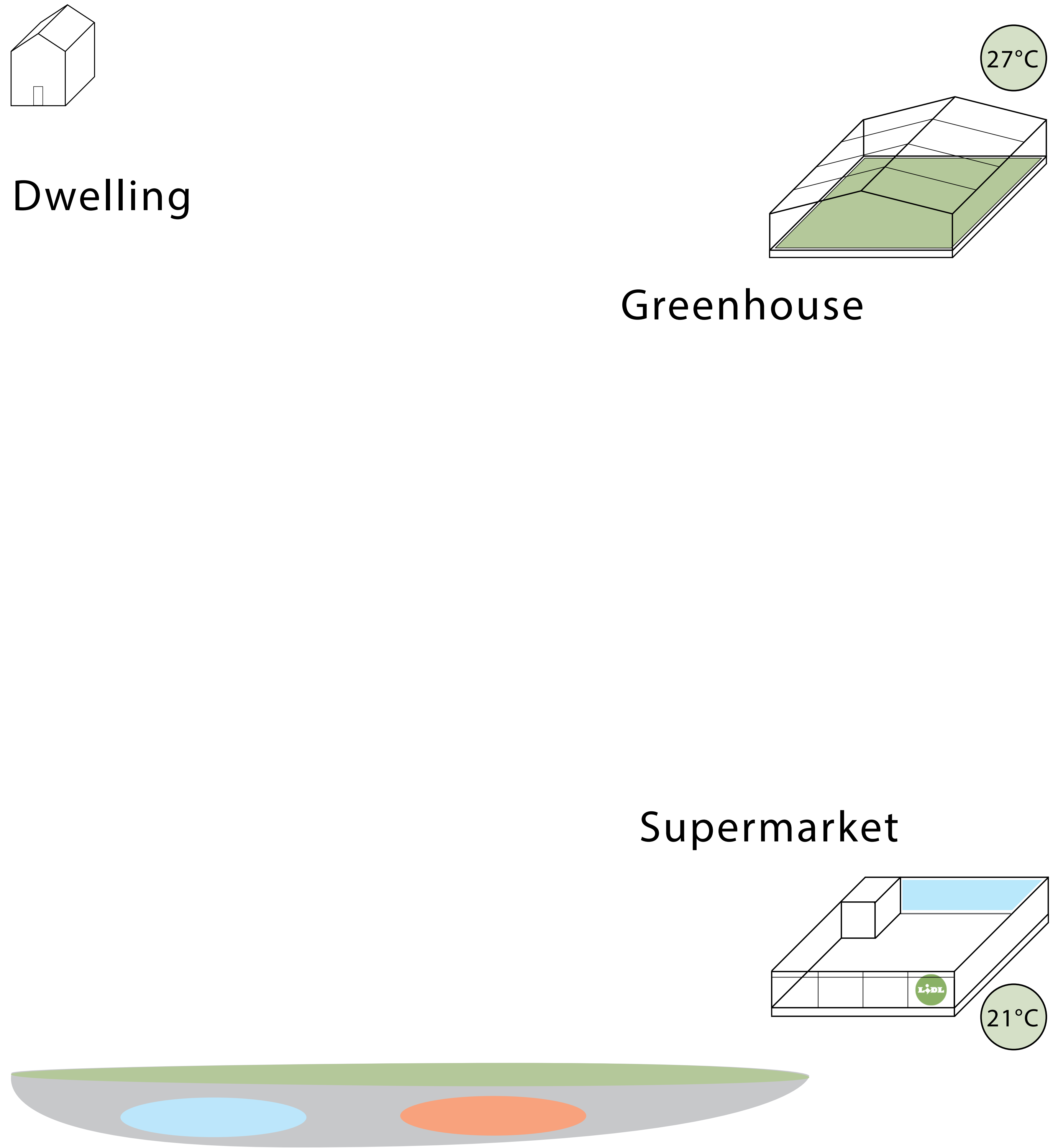
Energy system

Energy circulation, summer system & winter system

part 5/8

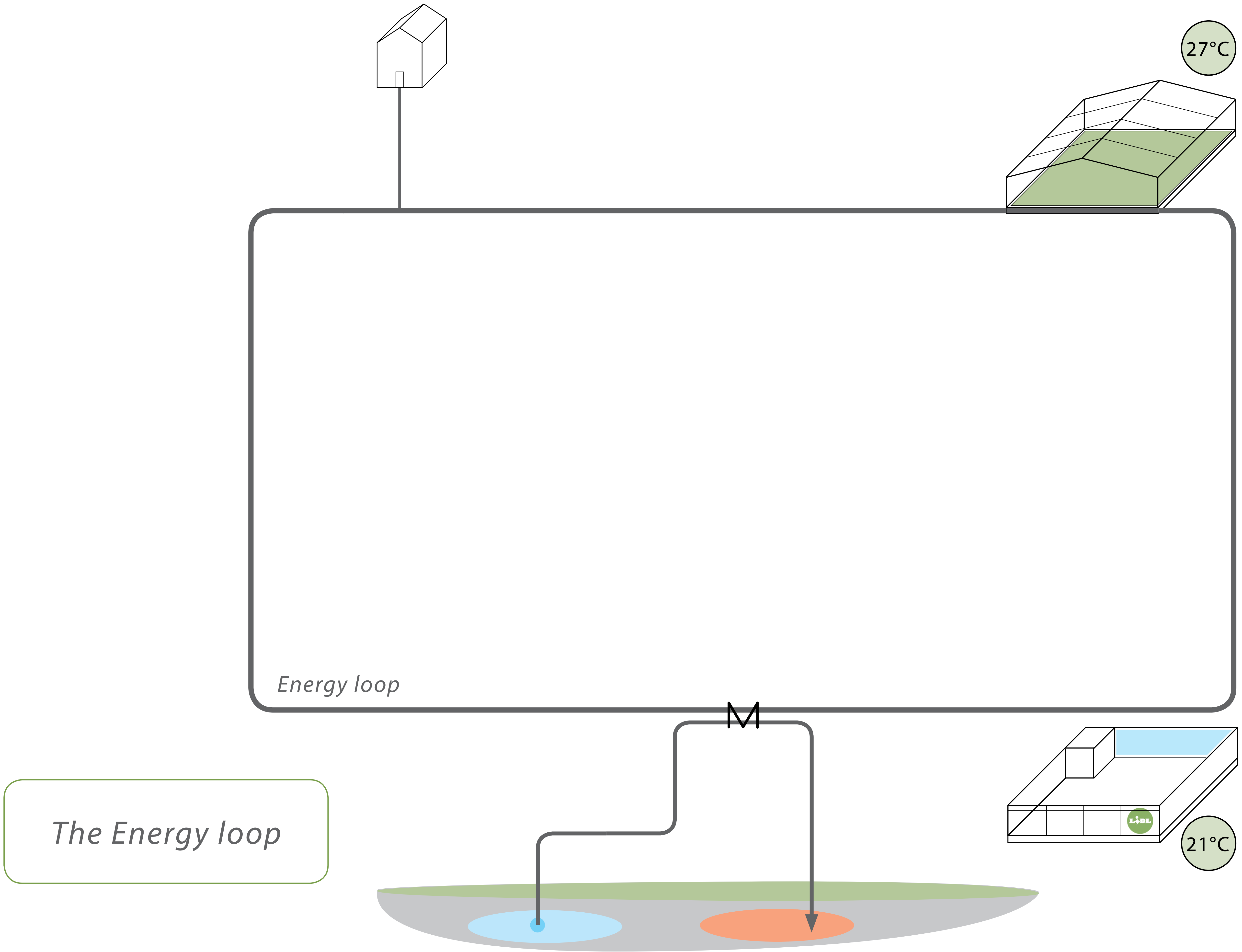


Energy system **| Annual balance**

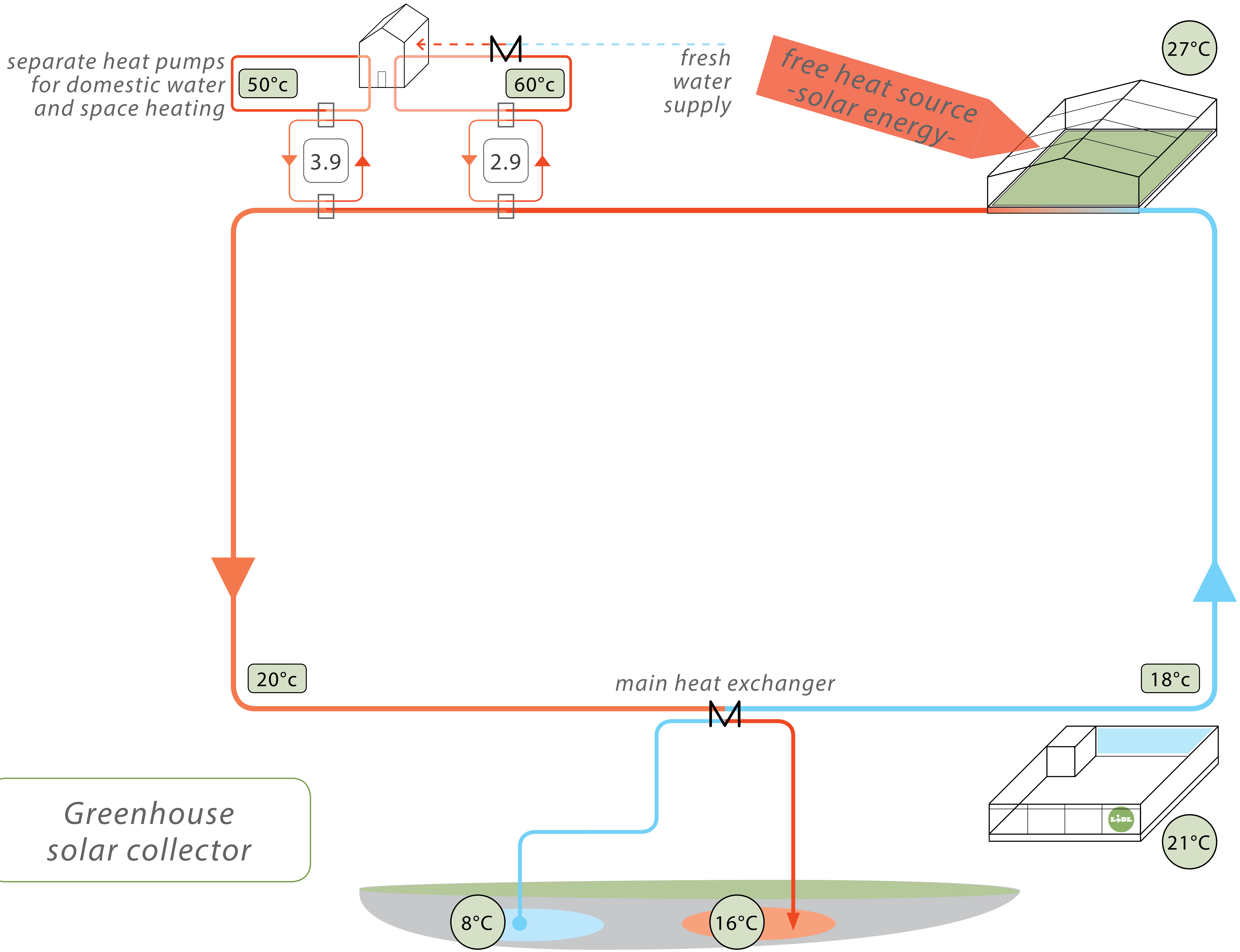


Energetic triangle

Energy system |[1/7] The 3 components

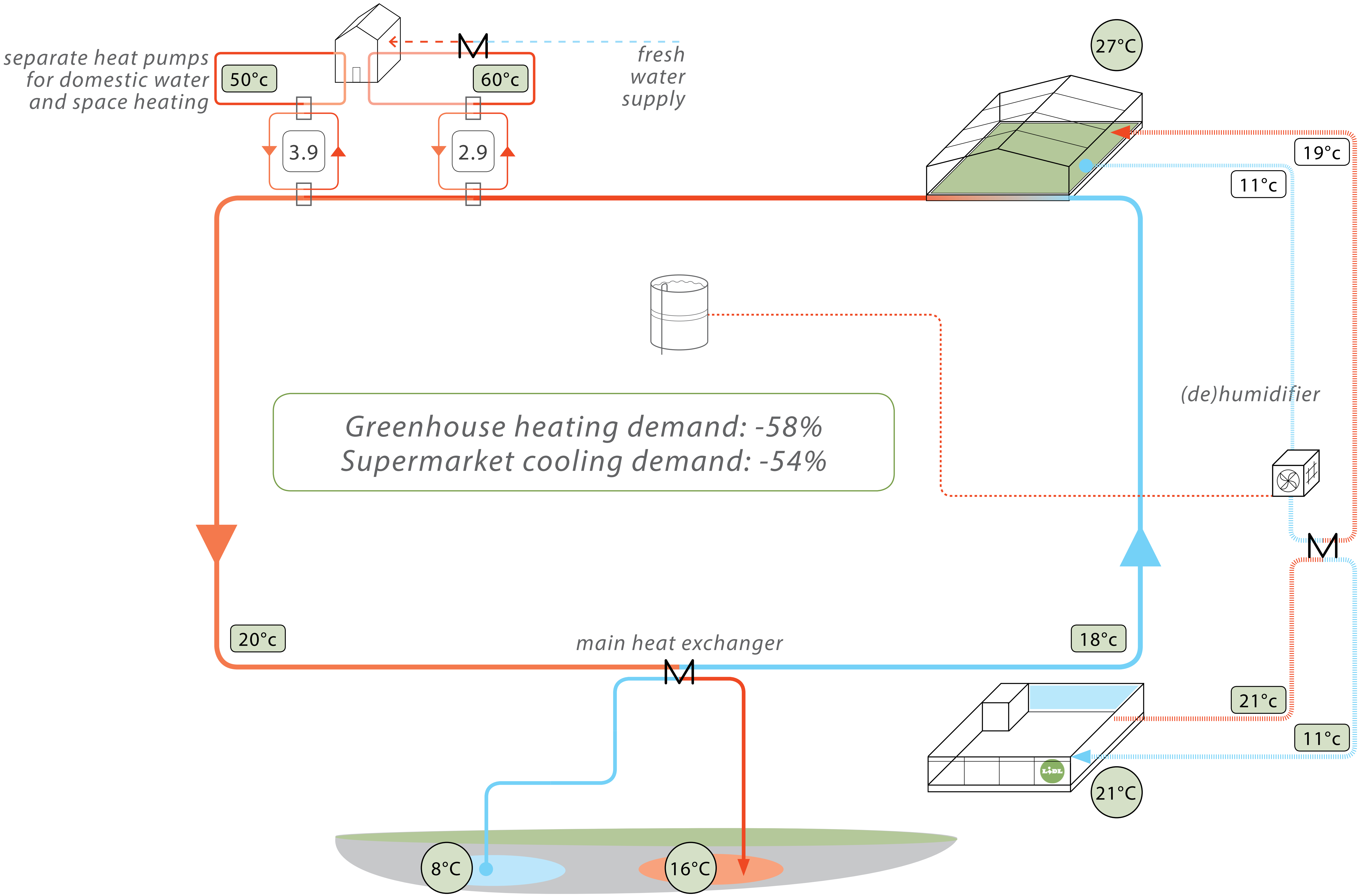


Energy system |[2/7] The energy loop

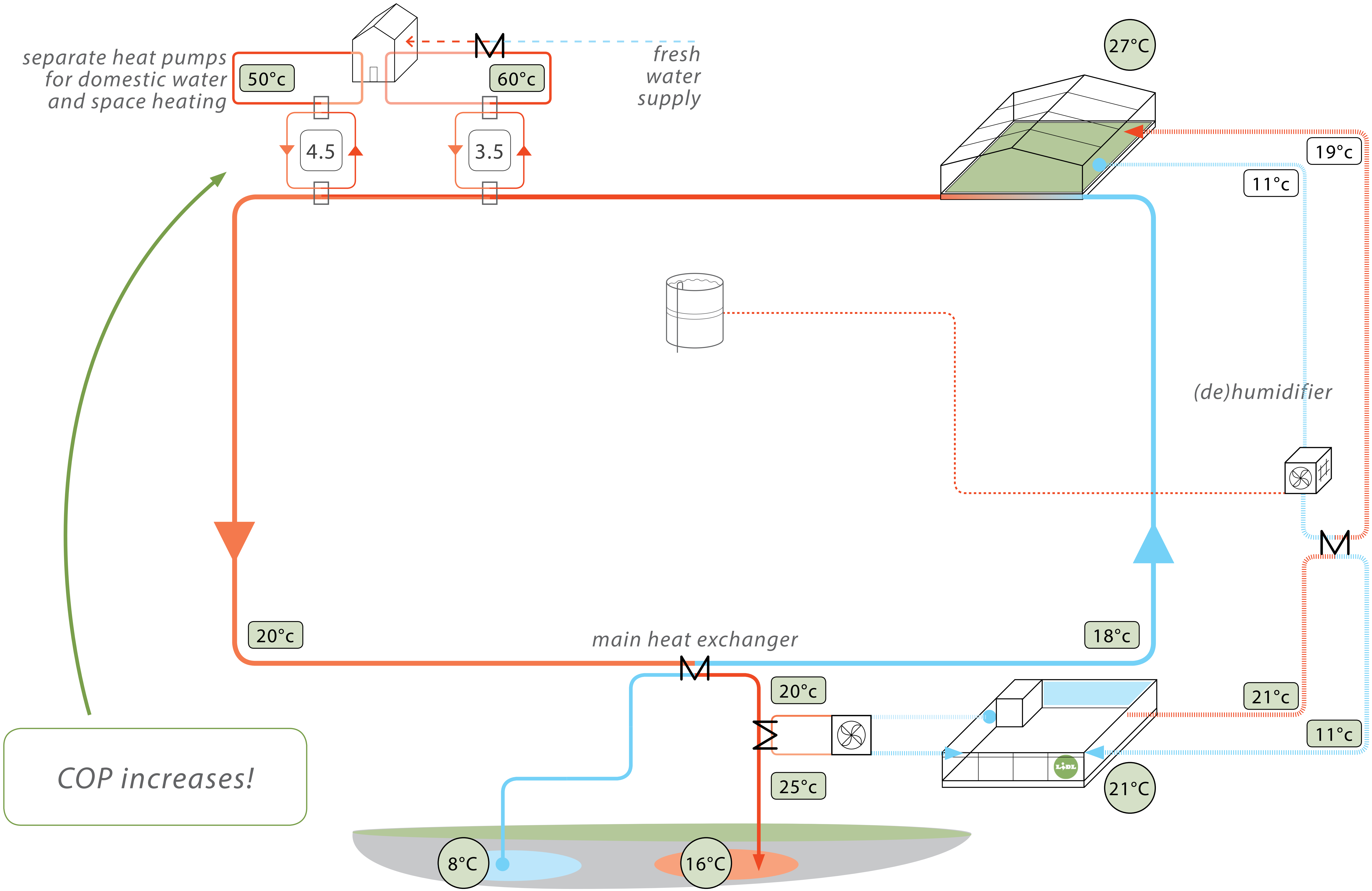


Greenhouse
solar collector

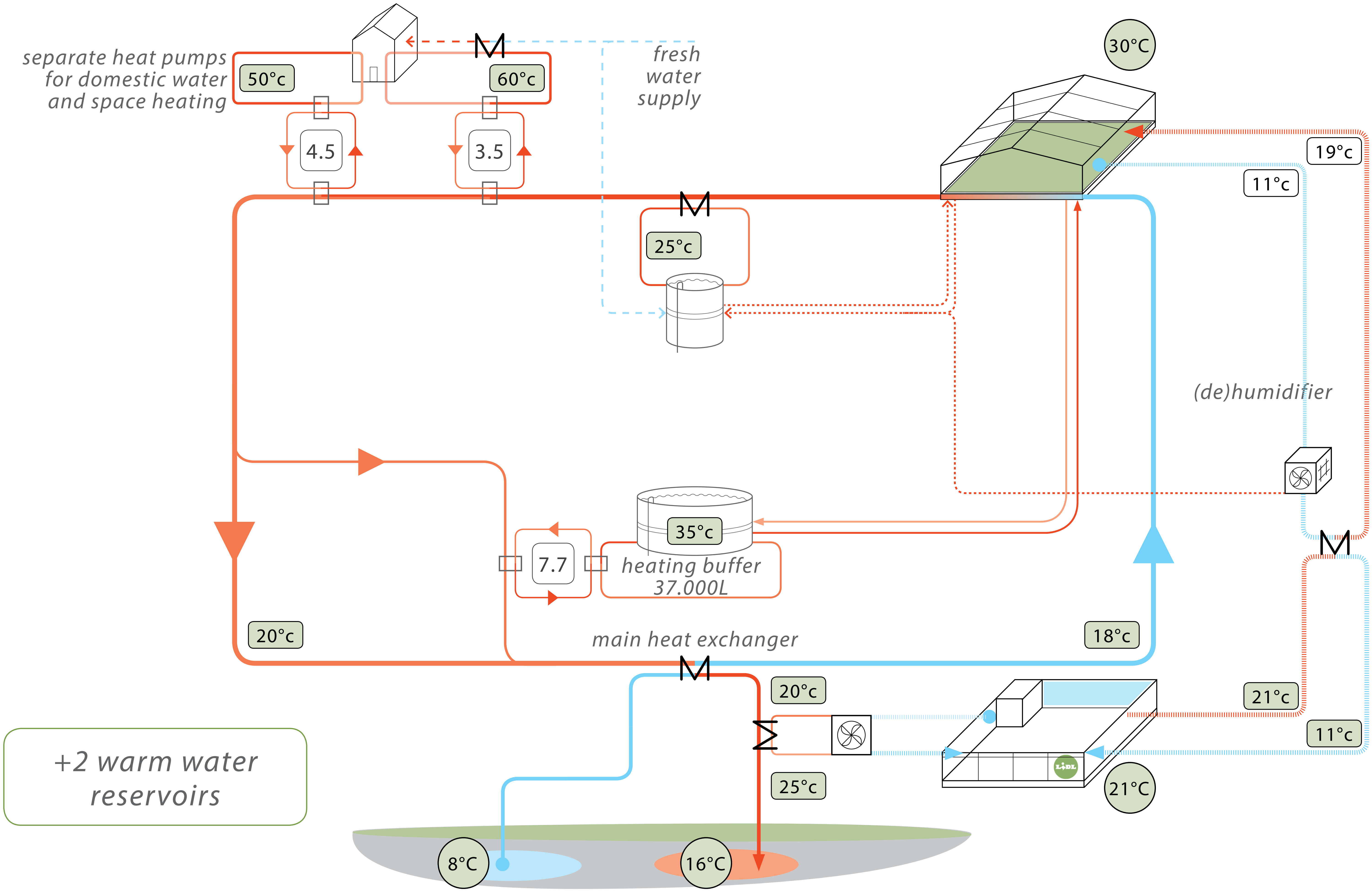
Energy system |[3/7] Solar collector



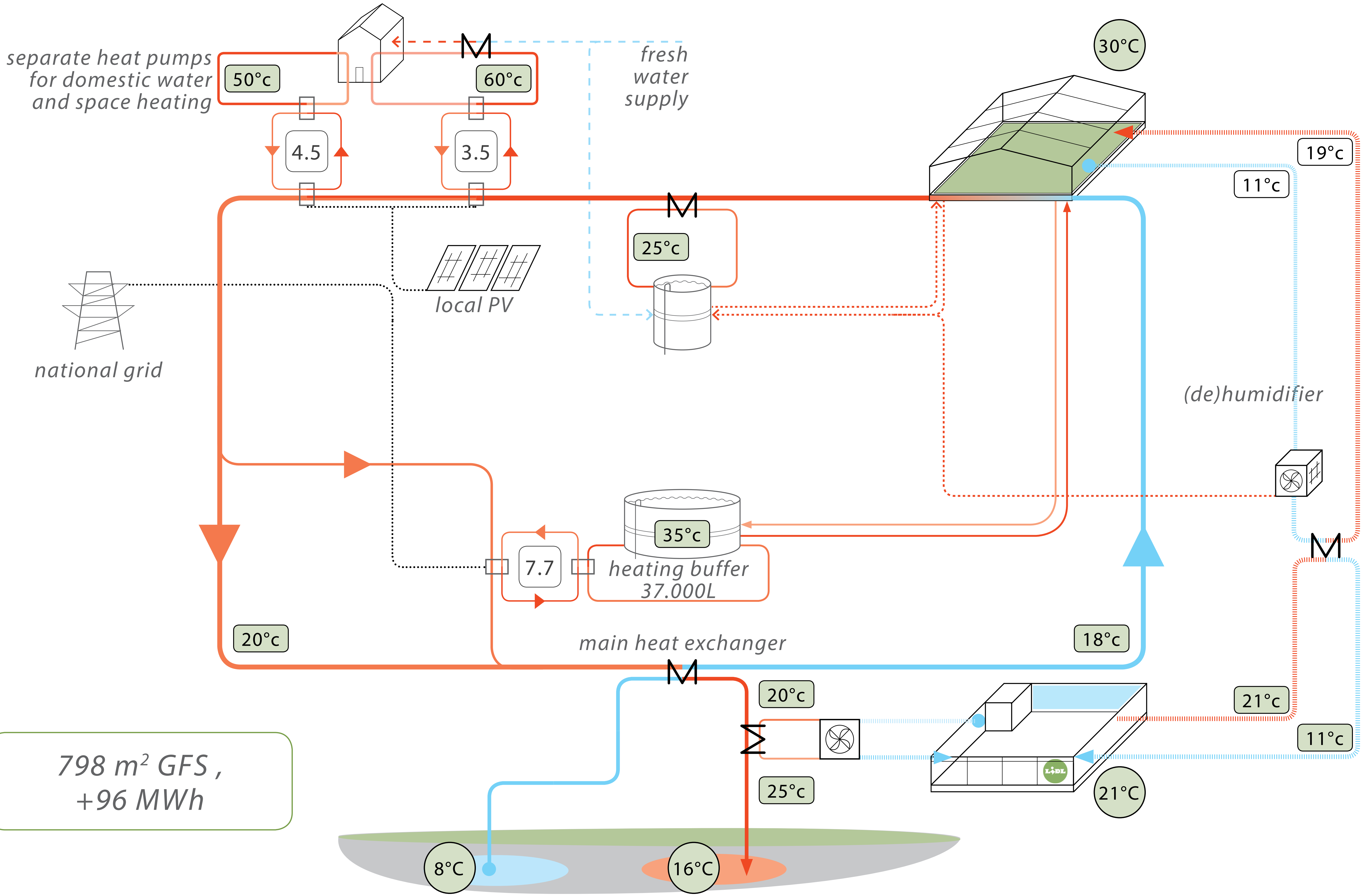
Energy system |[4/7] The Lidl supermarket I



Energy system |[5/7] The Lidl supermarket II



Energy system |[6/7] The greenhouse



798 m² GFS ,
+96 MWh

Energy system |[7/7] Solar electricity

Summer system

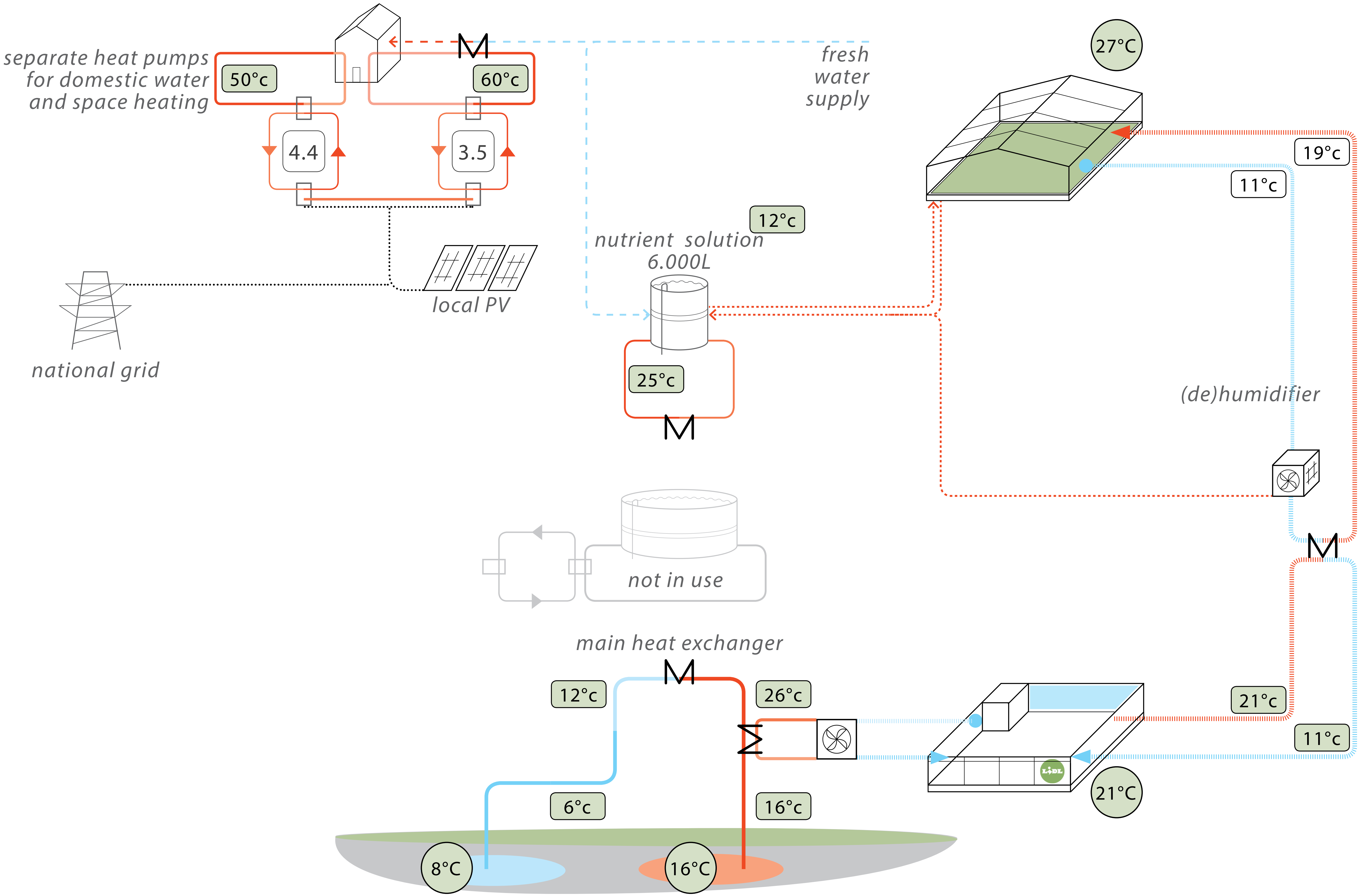
Main purpose: greenhouse cooling + provide heat fot the apartments

Underground storage:
- Cold storage = extracted
- Warm storage = charged

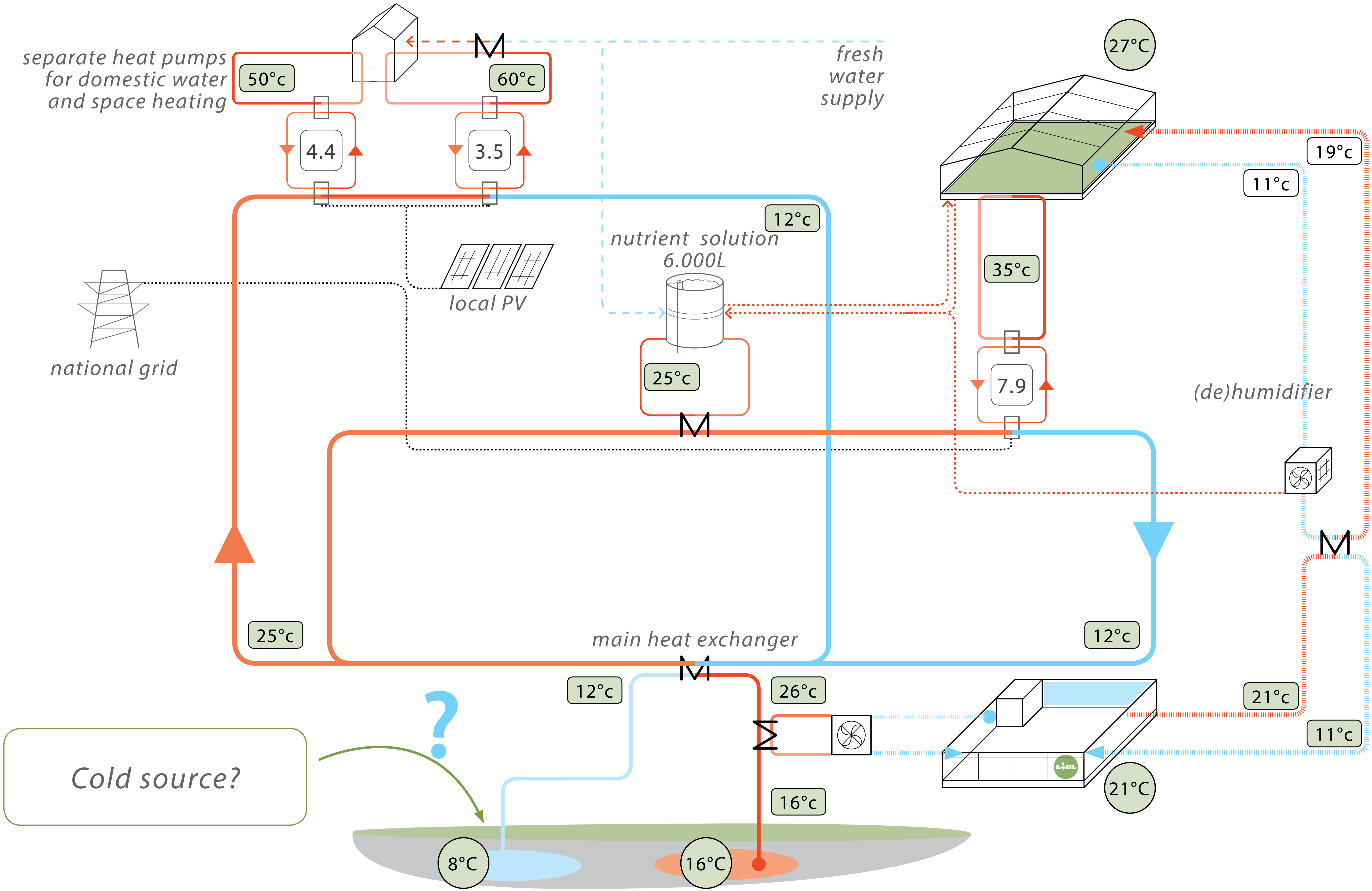
Winter system - *System is reversed*

Main purpose: dwelling heating + greenhouse heating

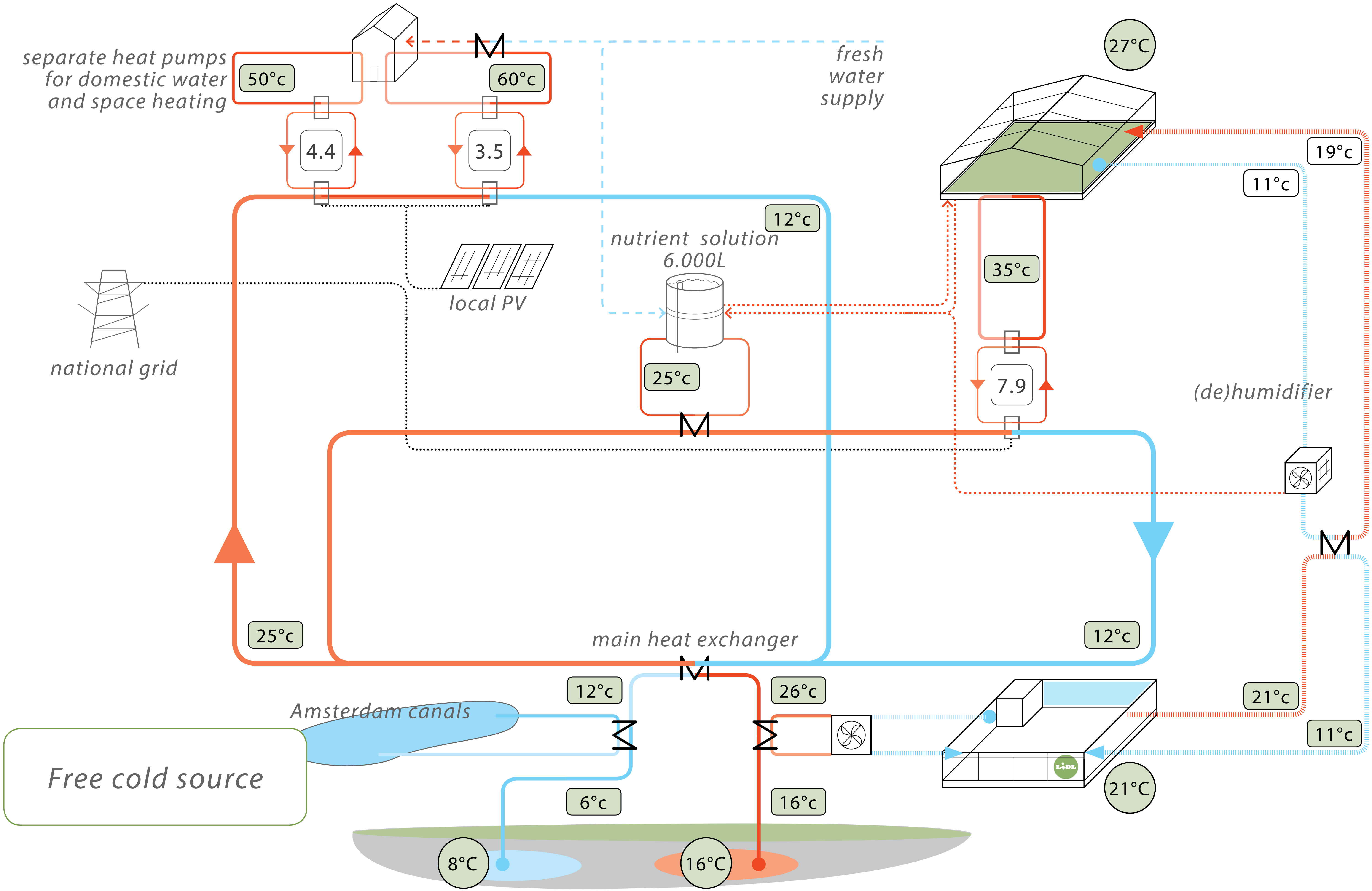
Underground storage:
- Cold storage = charged
- Warm storage = extracted



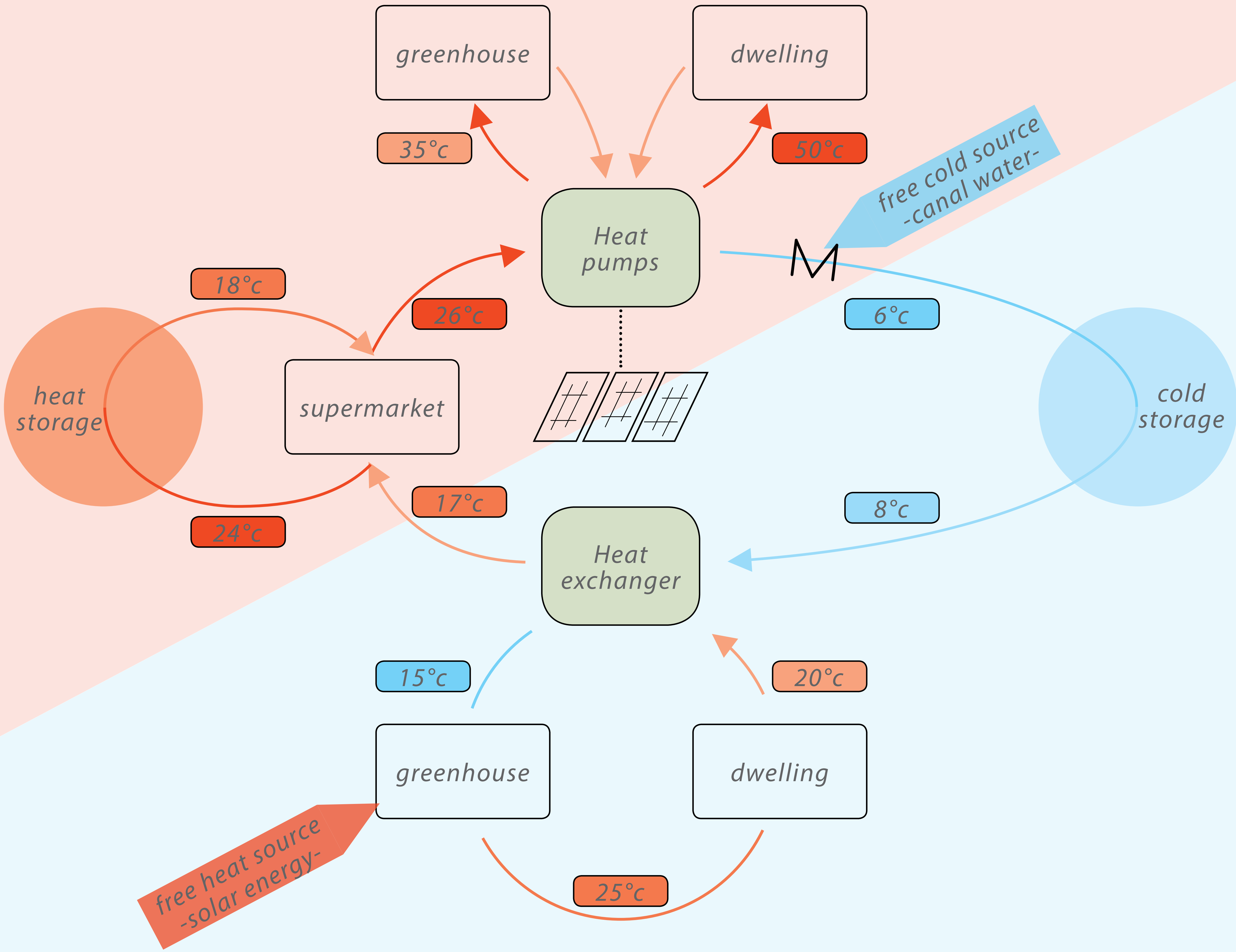
Energy system |[1/3] Similarities



Energy system |[2/3] System is reversed!



Energy system |[3/3] Cooling the system

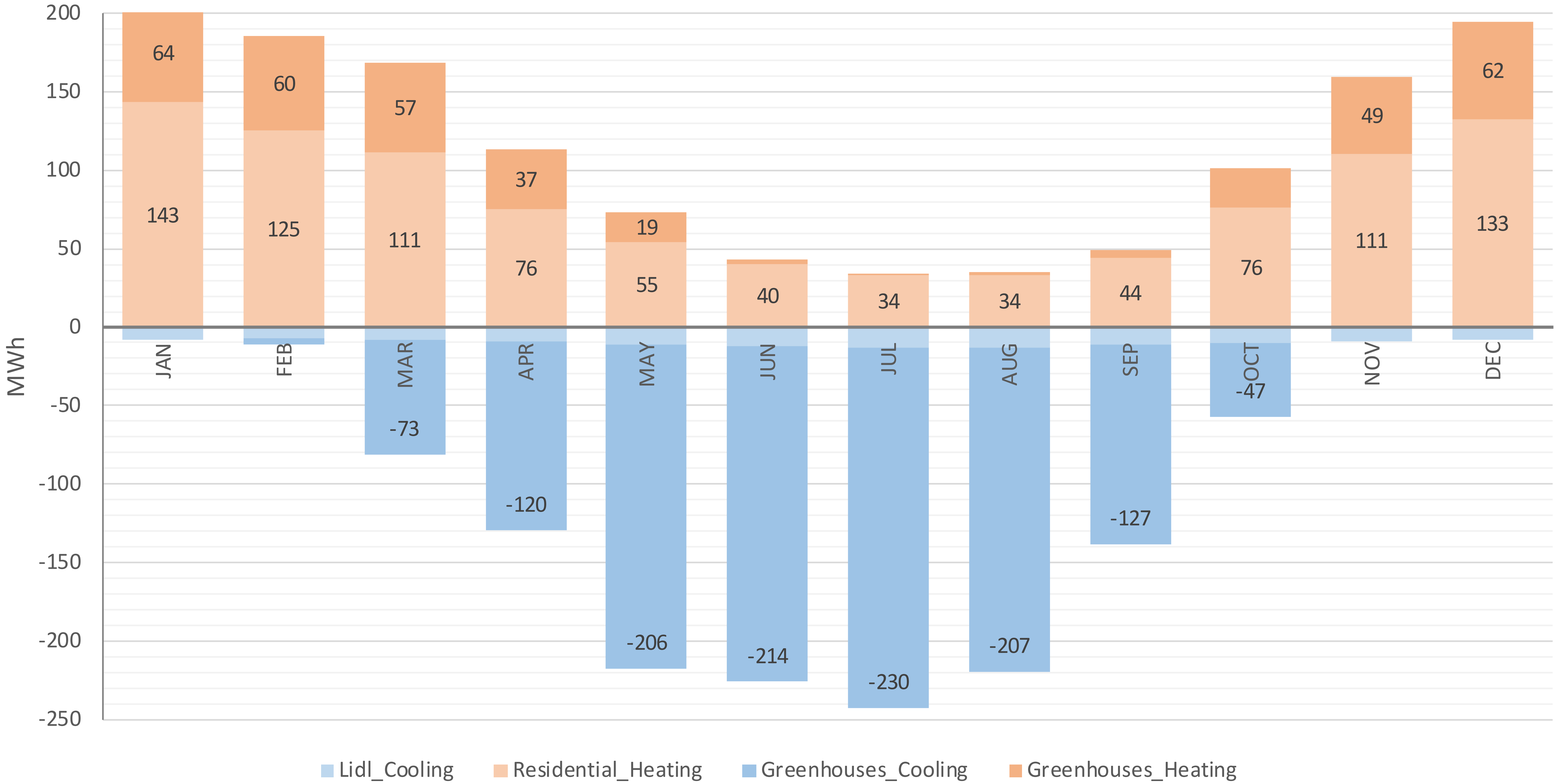


Energy system | Summary

Balanced system

Part V

part 6/8

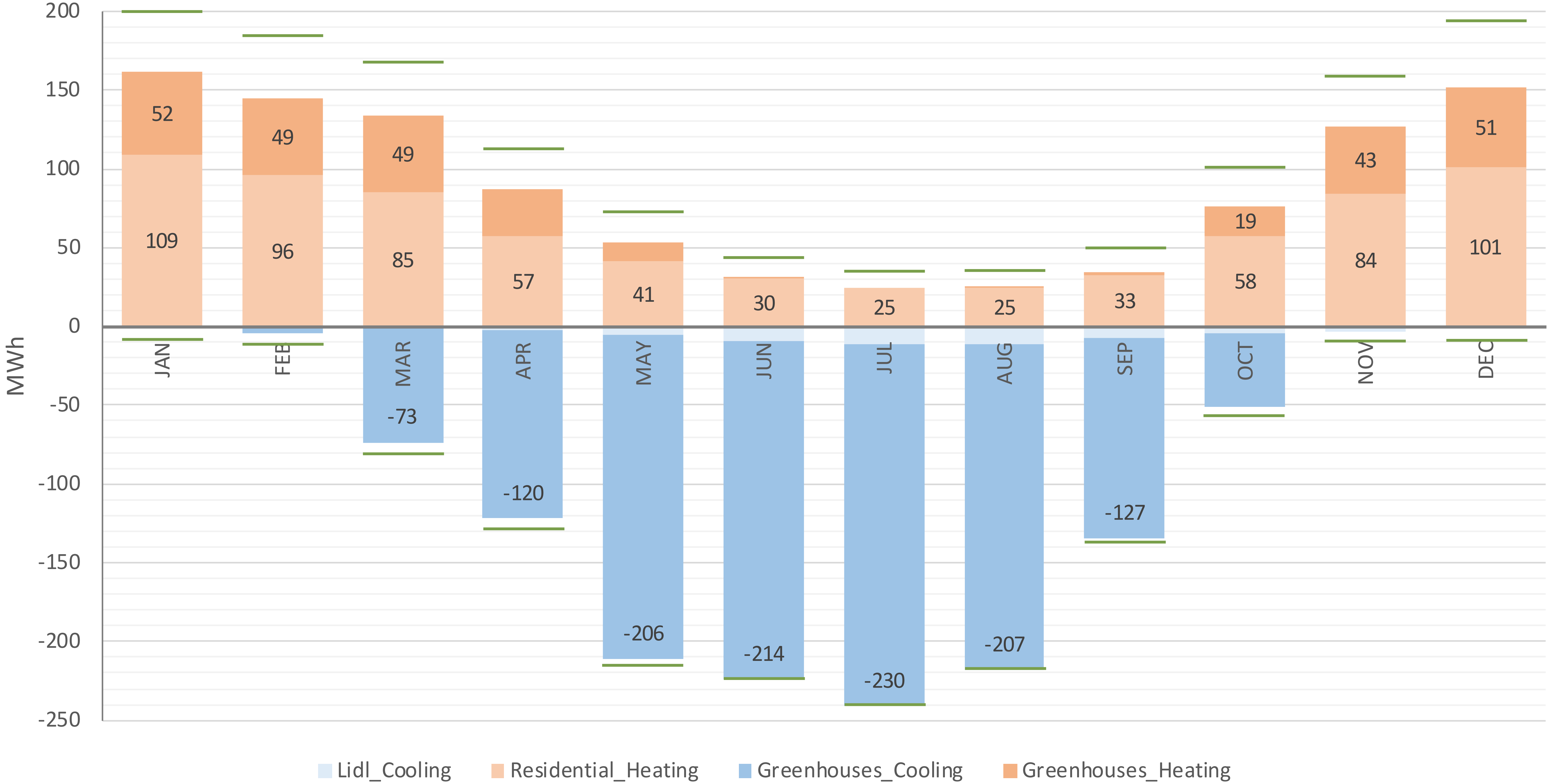


2 greenhouses on their maximum size

2 apartment building, 124 households in total

1 Lidl supermarket

Balance | Total heating/cooling demand - Individual components

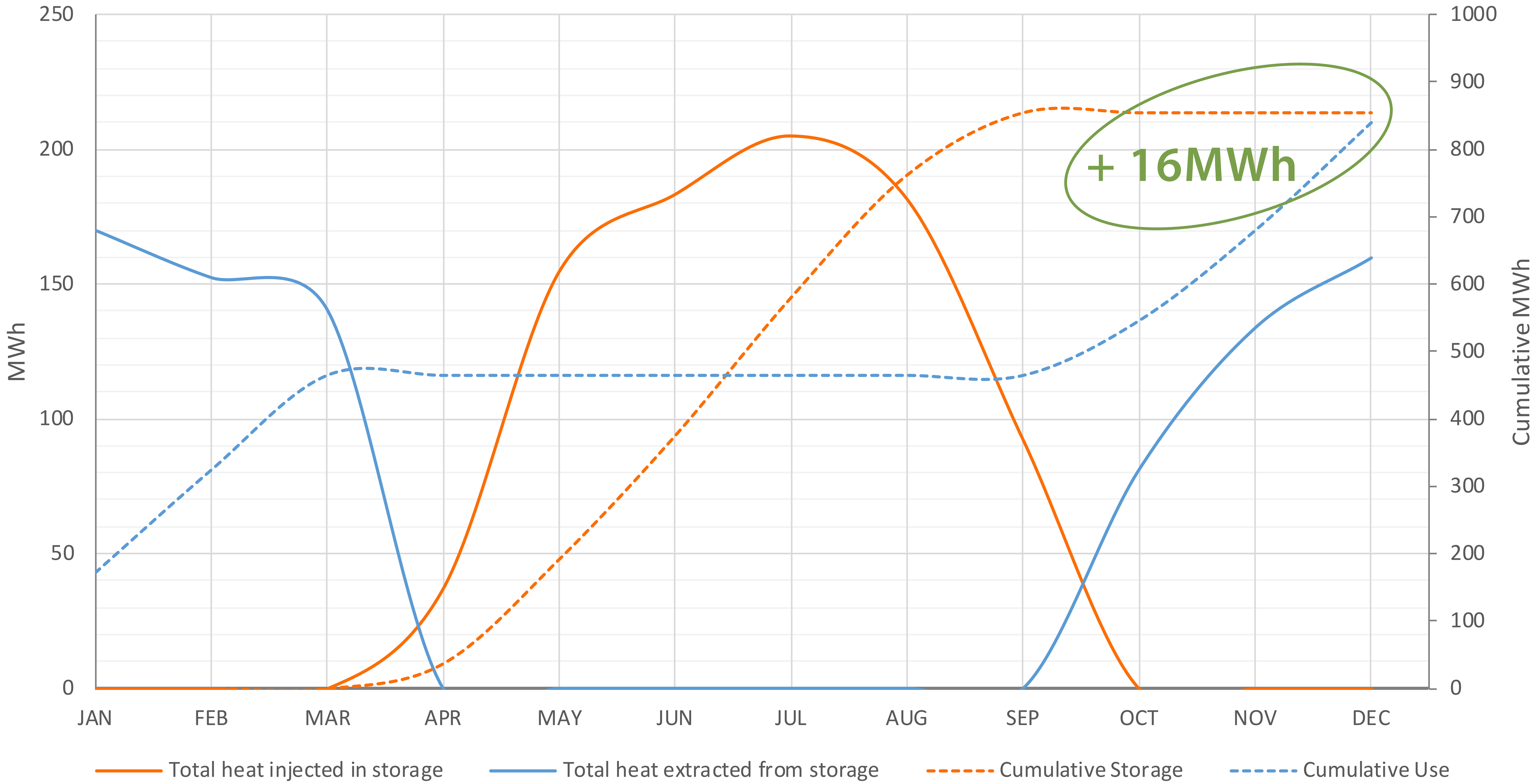


Heating & cooling demand reduces:

(1) Supermarket <> Greenhouse heat exchange

(2) Heat pumps.

Balance | Total heat demand - System integration



Remember: the first rule of underground thermal energy storage >>> Balance

Balance | Problem: unbalance

Greenhouses

Greenhouse A (North)
10.8 x 78.8m
T_{IN} = 15°C - 30°C

Greenhouse B (South)
8.0 x 107m
T_{IN} = 15°C - 30°C

Dwelling

Apartment building A
77 households
830 m3 gas/hh

Apartment building B
49 households
830 m3 gas/hh

Supermarket

Lidl Supermarket
15.4 x 46m
T_{IN} = 21°C

PV system

Potential roof space
798 m^2 GFS

Many other parameters not mentioned

Balance | Problem: unbalance, current core parameters

Greenhouses

Greenhouse A (North)
10.8 x 78.8m
$T_{IN} = 15°C - 30°C$

Greenhouse B (South)
8.0 x 102m
$T_{IN} = 15°C - 30°C$

Dwelling

Apartment building A
77 households
830 m3 gas/hh

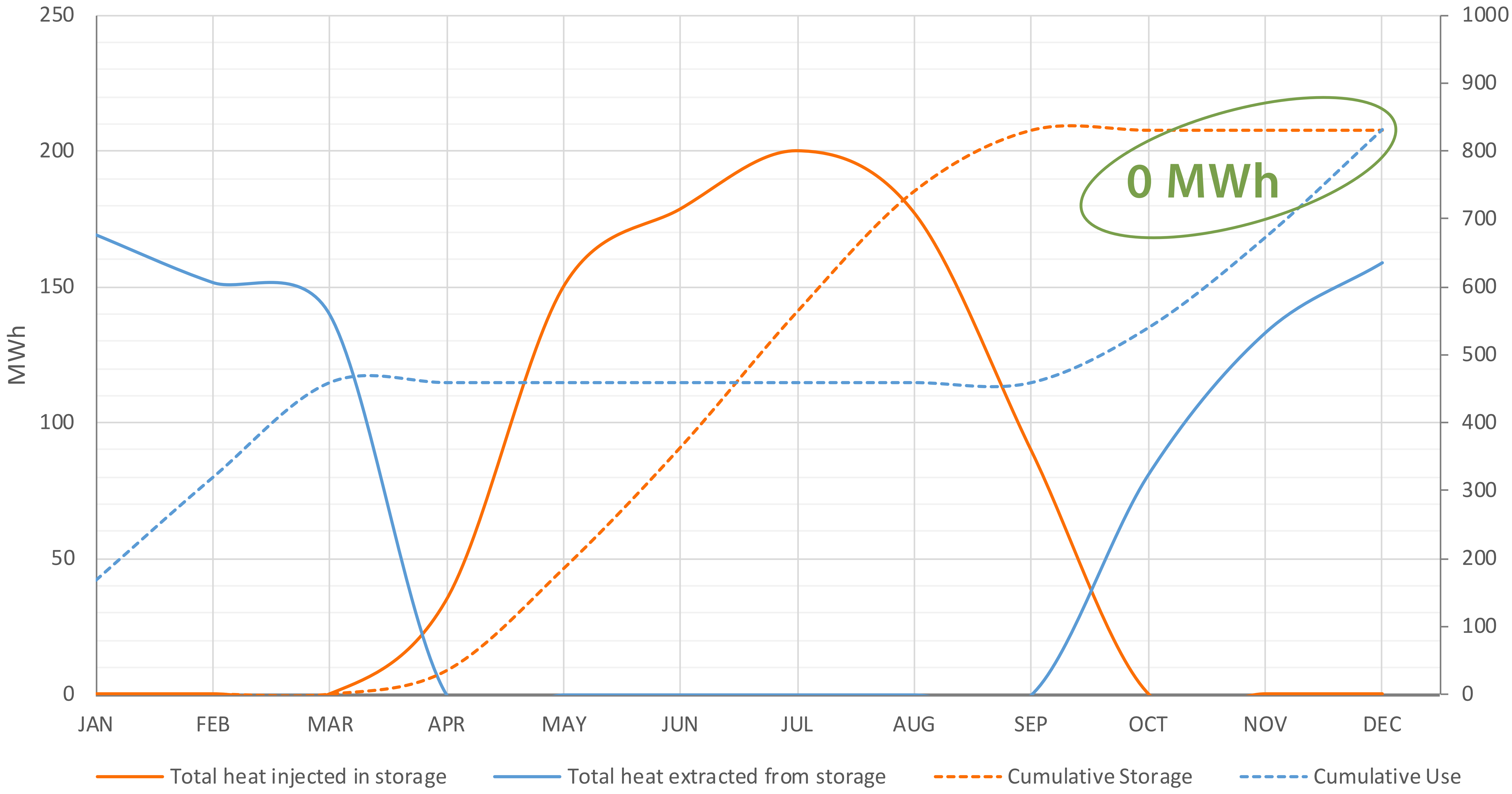
Apartment building B
49 households
830 m3 gas/hh

Supermarket

Lidl Supermarket
15.4 x 46m
$T_{IN} = 21°C$

PV system

Potential roof space
798 m^2 GFS



thermal energy injected = thermal energy extracted

Balance | **Easy to obtain**

Can we sustain the energy system by using only 1 greenhouse?

Half the investment cost;
Half the maintenance cost;
Less complicated logistics;
Less urban interference;
Half the water consumption.

2 options:

94 households, 810 m^3 gas/year/household

124 households, 619 m^3 gas/year/household

33% heat demand reduction by means of cheap & simple interventions

examples:

Smart thermostats / ventilation;
Place coated windows;
Insulation retention wall.

Greenhouses

~~Greenhouse A (North)~~
~~*10.8 x 78.8m*~~
~~T_{IN} = 15°C - 30°C~~

Greenhouse B (South)
8.0 x 107m
T_{IN} = 11°C - 27°C

Dwelling

Apartment building A
77 households
619 m3 gas/hh

Apartment building B
49 households
619 m3/hh

Supermarket

Lidl Supermarket
15.4 x 46m
T_{IN} = 21°C

PV system

Potential roof space
1649 m² GFS

Urban Design

Part V

part 7/8

Urban rooftop greenhouse agriculture

Urban rooftop greenhouse agriculture

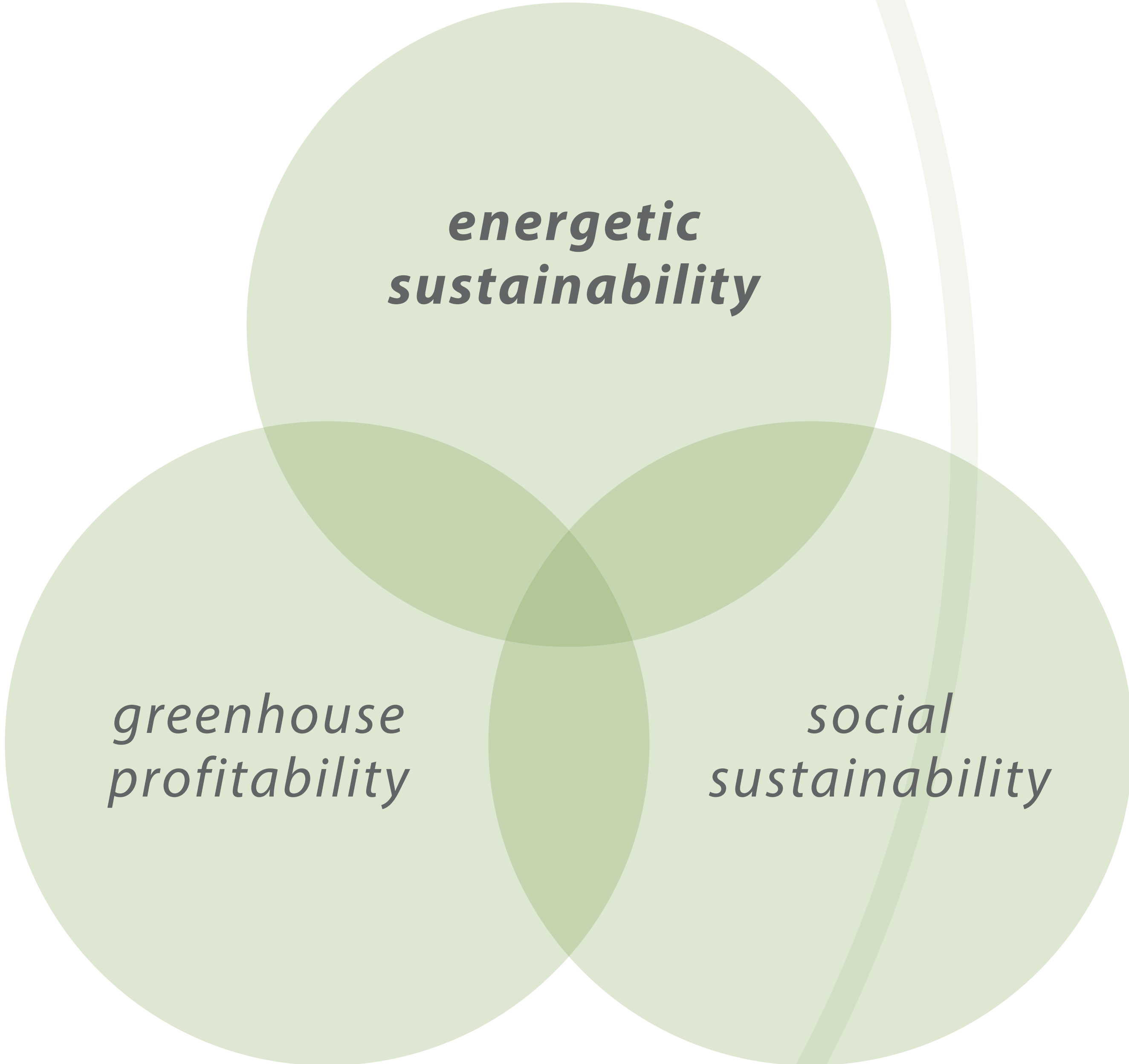
Initial greenhouse design:

thermal energy collector;
food production;
marketing.

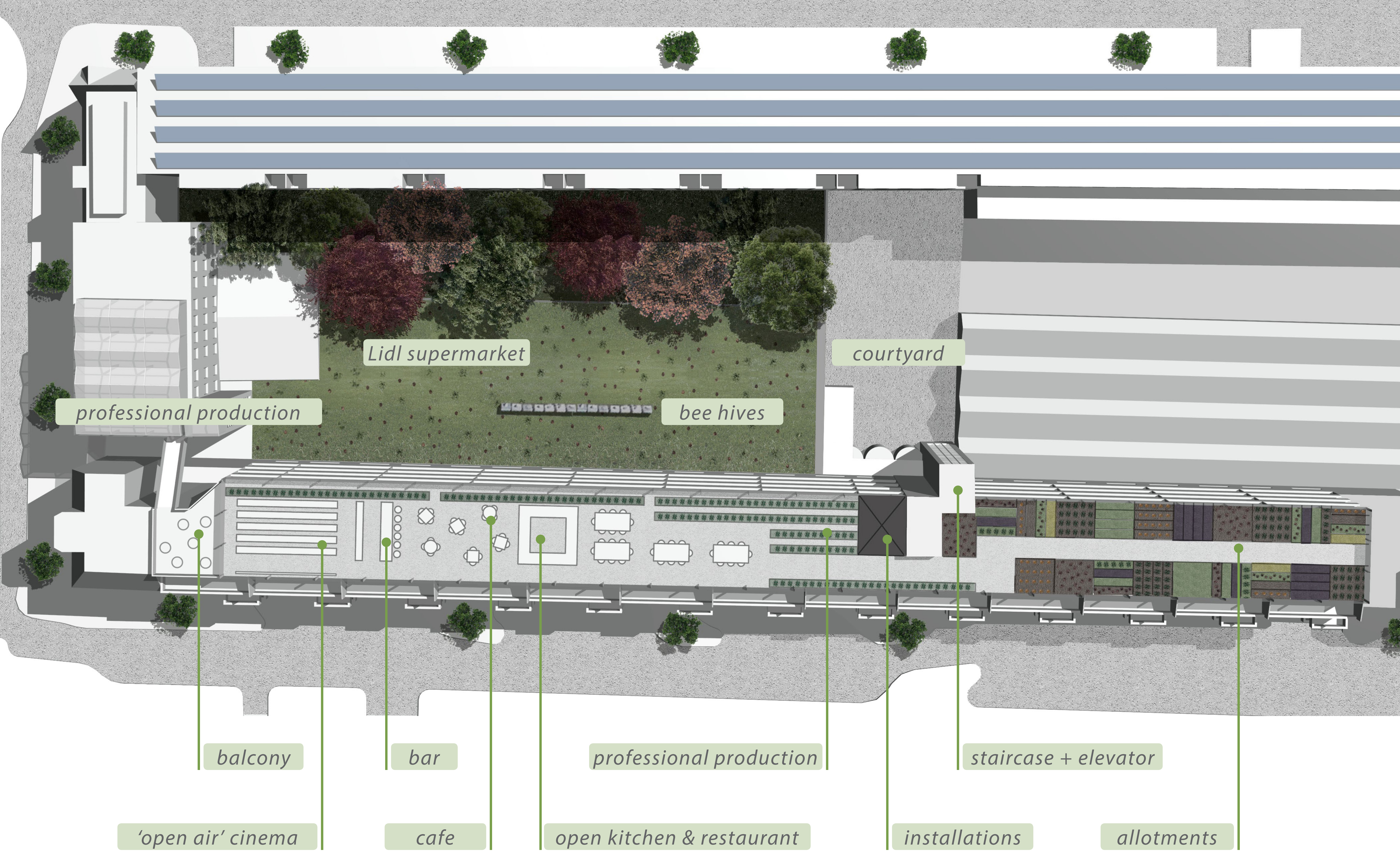
Greenhouse can be something else!

Prioritise social cohesion
above direct profitability.

Make neighbourhood more attractive.



Alternative function? Social function!



The greenhouse as a social hub! A proposal

Conclusion

CO_2 emission cutback, discussion

part 8/8

1 Lidl supermarket
15 x 46m, T_{IN} = 21°C

+

1 rooftop greenhouse
8 x 107m, T_{in} = 11-27°

+

124 households
619m3 gas/household

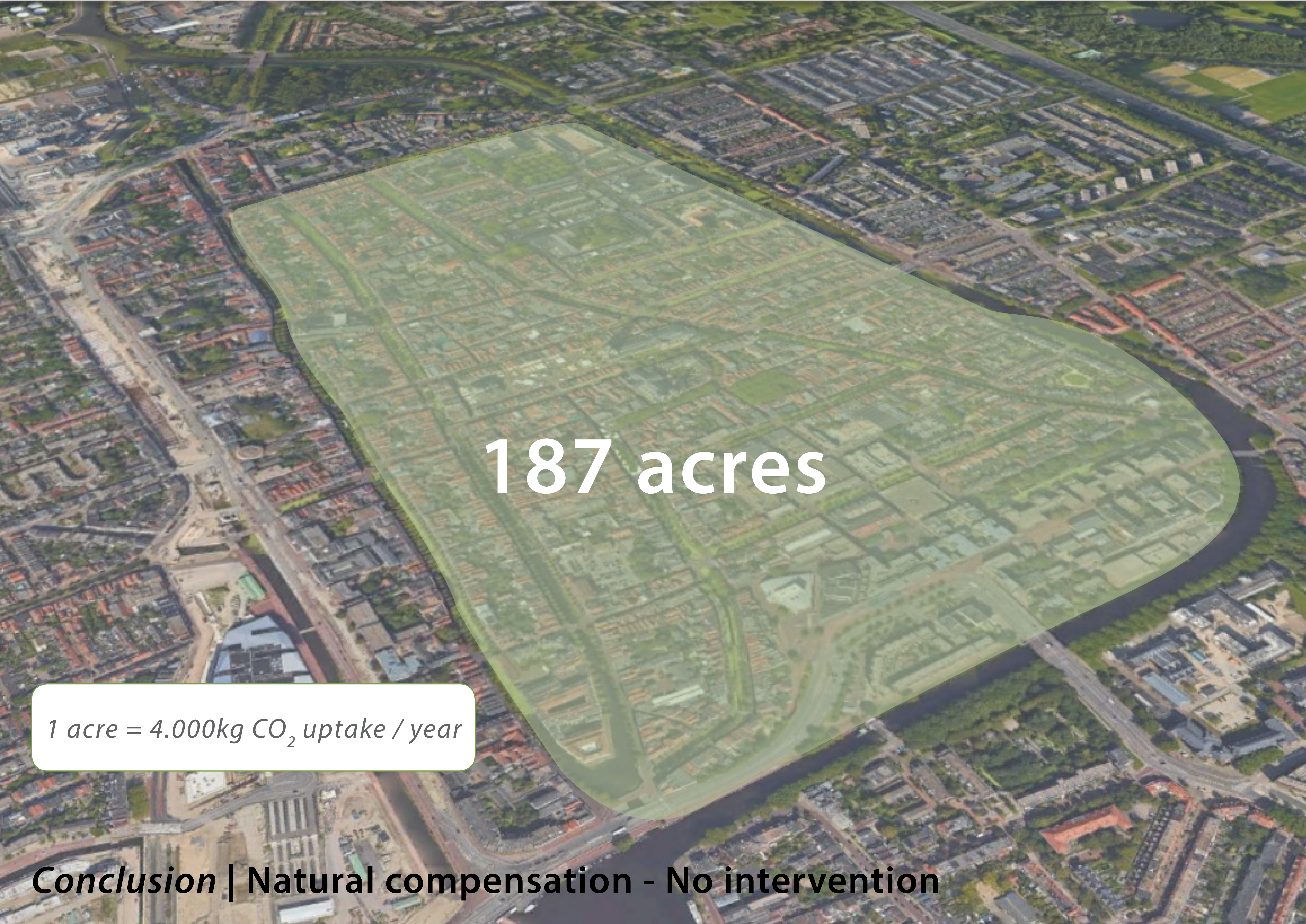
connected according to energy model

60% cumulative CO2 reduction

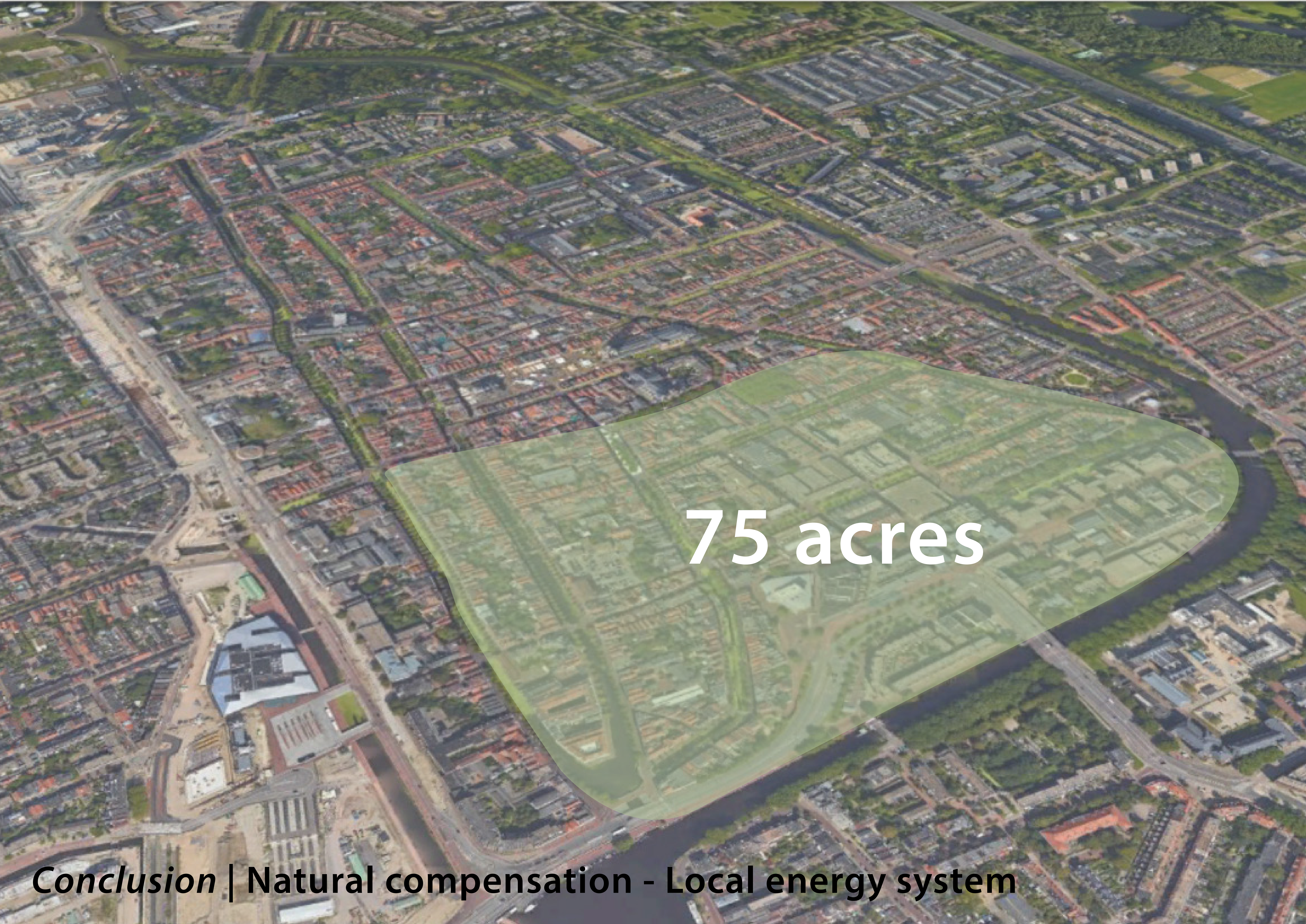
or **452** ton CO_2/year

Conclusion | CO_2 emission cutback

Conclusion | **Natural compensation**



Conclusion | Natural compensation - No intervention



Conclusion | Natural compensation - Local energy system

High temperature heating system | inefficient

Sustainability > Profitability | business model?

33% dwelling heat demand reduction | achieveable in practise?

Conclusion | Points of Discussion

Thank you

Questions?

The photographs/illustrations used in the tabs are retrieved from the following sources [in order of appearance]:

Slide 1 & 66 - Presentation cover photo
Inner Stance. (n.d.). Supermarket Issues Inner Stance [Photograph]. Retrieved January 4, 2018, from http://www.innerstance.nl/wp-content/uploads/2017/02/Supermarkt_Issues_Inner_Stance.png

Slide 9 - Context
ADAS U.K.. (2017, February 16). New categorisation of food scares will help develop strategies to prevent food chain being compromised [Photograph]. Retrieved January 4, 2018, from http://www.adas.uk/News/new-categorisation-of-food-scares-will-help-developstrategies-to-prevent-food-chain-being-compromised

Slide 15 - Circularity
Gotham Greens. (2015, October 24). 3 friends built a greenhouse on a roof and got 625 tons of produce! [Photograph]. Retrieved January 4, 2018, from http://www.collective-evolution.com/2015/10/24/3-friends-built-a-greenhouse-on-a-roof-got-625-tons-of-produce/

Slide 20 - Concept
Eginoire, S. (2015, January 1). Wholesum Harvest employee Jesus Solis harvests ripe tomatoes off hanging vines; these tomatoes will get shipped across the country. [Photograph]. Retrieved January 4, 2018, from http://ediblebajaarizona.com/high-tech-organicwholsum-harvest

Slide 26 - Energy
Mucci Farms. (2015, 26 januari). Mucci Farm Greenhouse Interior [Foto]. Geraadpleegd op 22 januari 2018, van http://muccifarms.com/blog/wp-content/uploads/2015/01/muccci_farms_greenhouse_interior.jpg

Slide 31 - Energy system
Zegwaard, M. (2016, 9 september). UrbanFarmers_UF002-De-Schilde_001 [Foto]. Geraadpleegd op 22 januari 2018, van https://impactcity.nl/wp-content/uploads/2016/09/UrbanFarmers_UF002-De-Schilde_001-by-Martijn-Zegwaard-1.jpg

Slide 45 - Balanced system
Urban Farmers. (2014, February 25). A rendering of an UrbanFarmers rooftop greenhouse [Illustration]. Retrieved January 23, 2018, from https://torontoist.com/2014/02/public-works-urban-farming-in-your-own-backyard/

Slide 55 - Urban Design
Duurzaam Den Haag. (2016, April). Dakboerderij De Schilde op 20 mei open voor publiek [Photograph]. Retrieved January 4, 2018, from http://duurzaamdenhaag.nl/dit-zijn-we/blog/dakboerderij-de-schilde-20-mei-open-publiek

Slide 60 - Conclusion
Gotham Greens. (2017, 7 augustus). Gotham Greens, New York [Foto]. Geraadpleegd op 23 januari 2018, van https://japantoday.com/category/features/food/can-agritech-save-the-future-of-food

Slide 62,63,64 -Conclusion | Natural compensation
Satelite images by Google Earth

References