Energy flatness in the renovation of non-residential existing buildings

P5 Presentation

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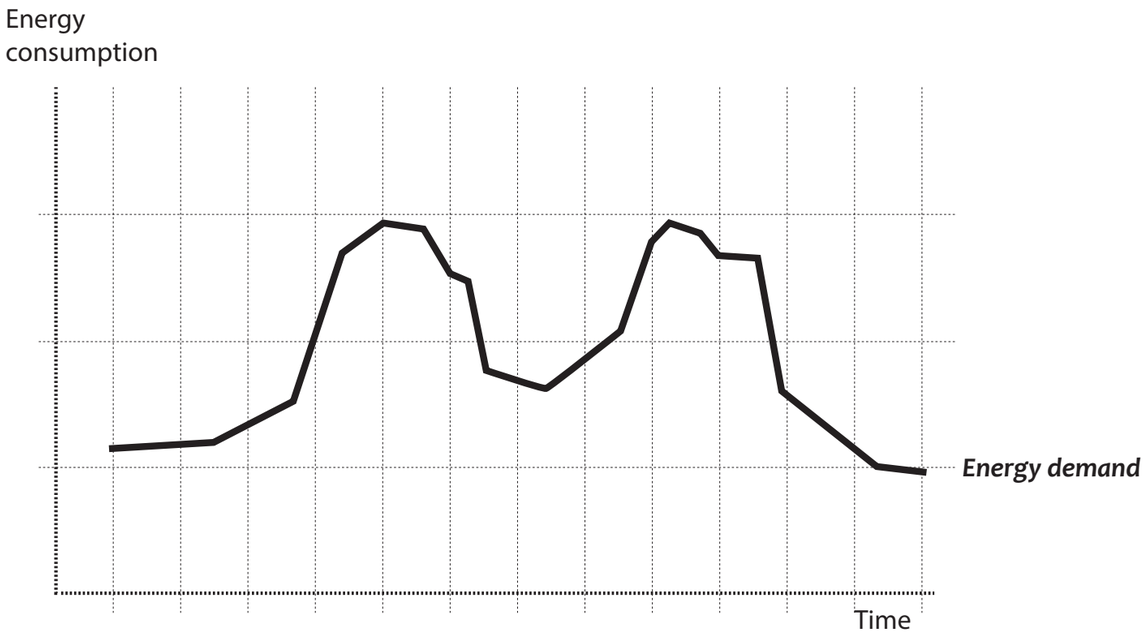
Company mentor Ir. Vincent Höfte from ABT
Delegate examiner Dr.ir. Martijn Stellingwerff

abt TU Delft

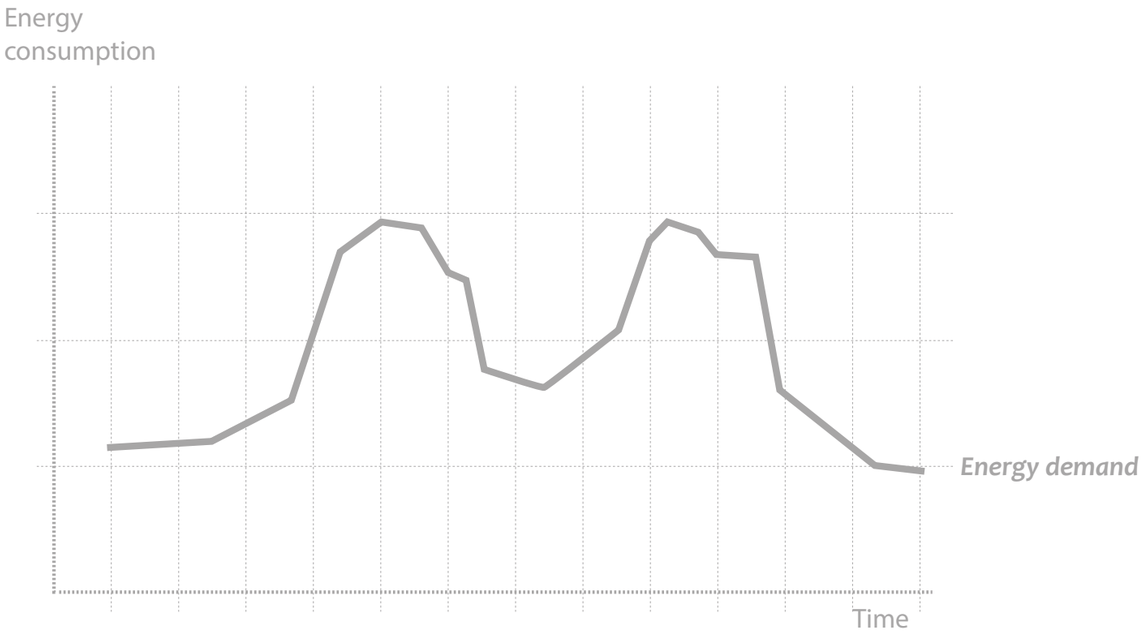
Content of the presentation

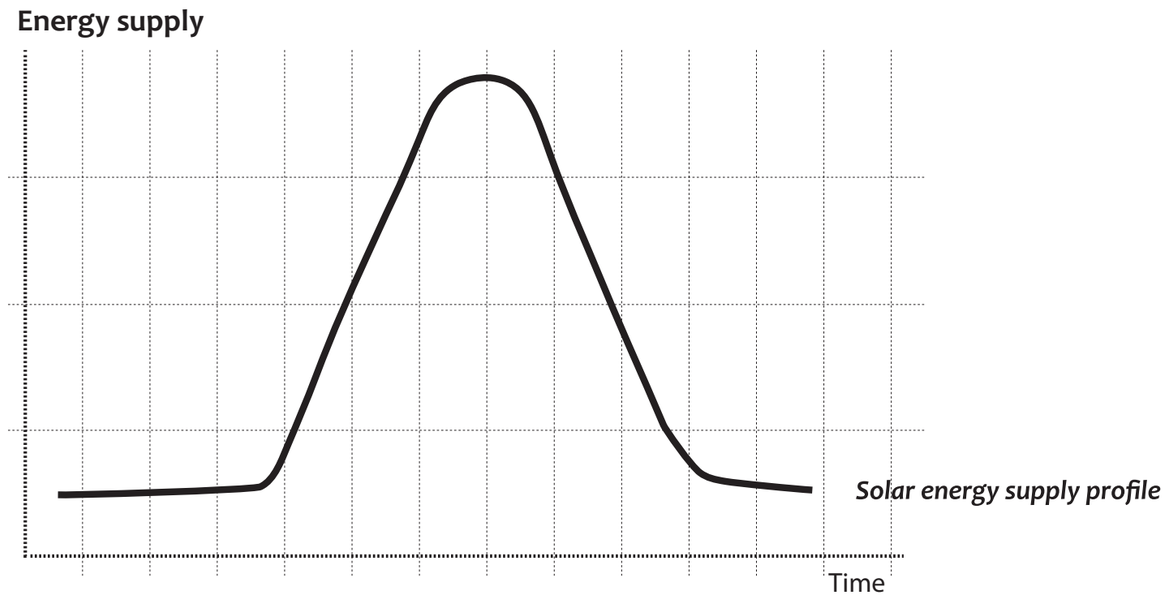
Problem Statement
Methodology
Energy Flatness
Case study
Renovation proposal
Conclusions / Discussion / Recommendations for further research



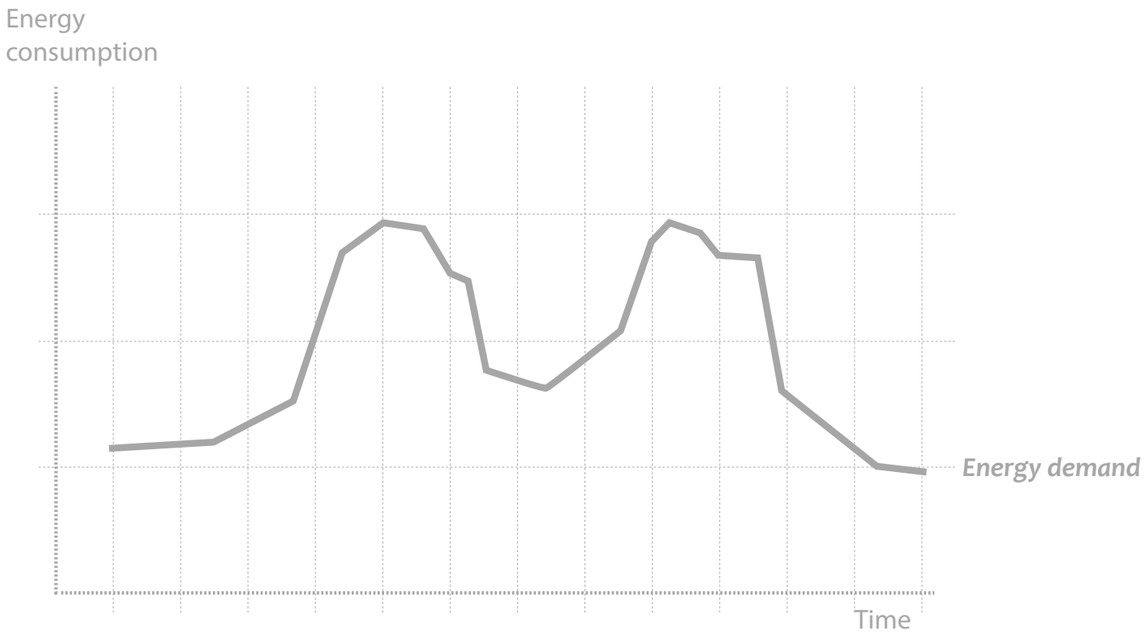
Increasing & unpredictable demand

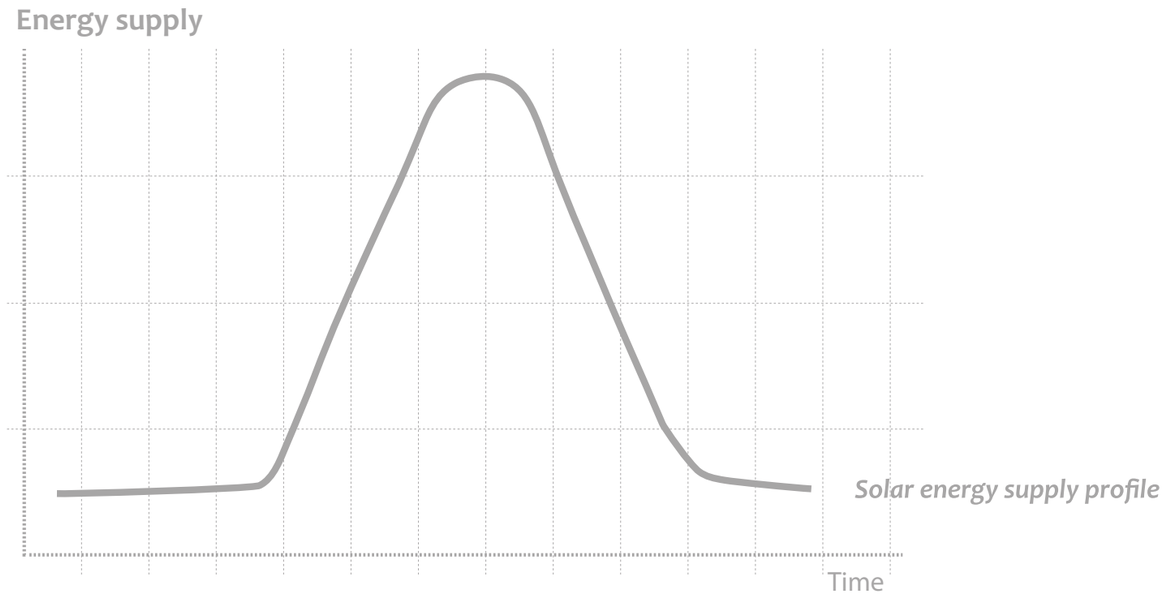
Problem

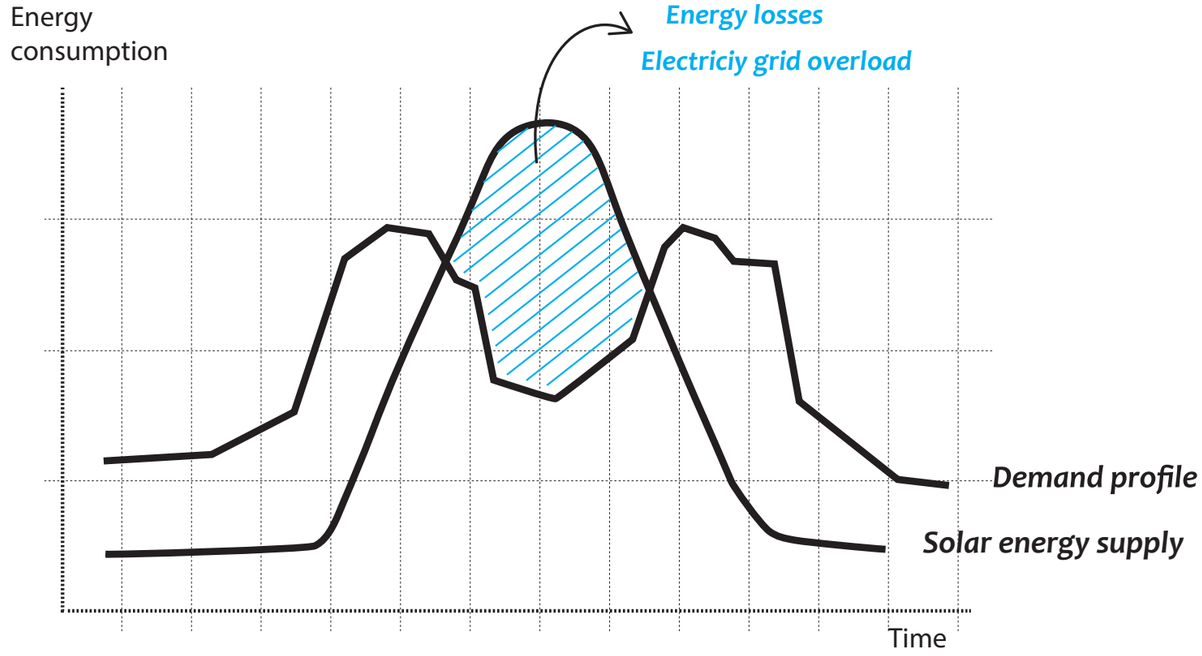


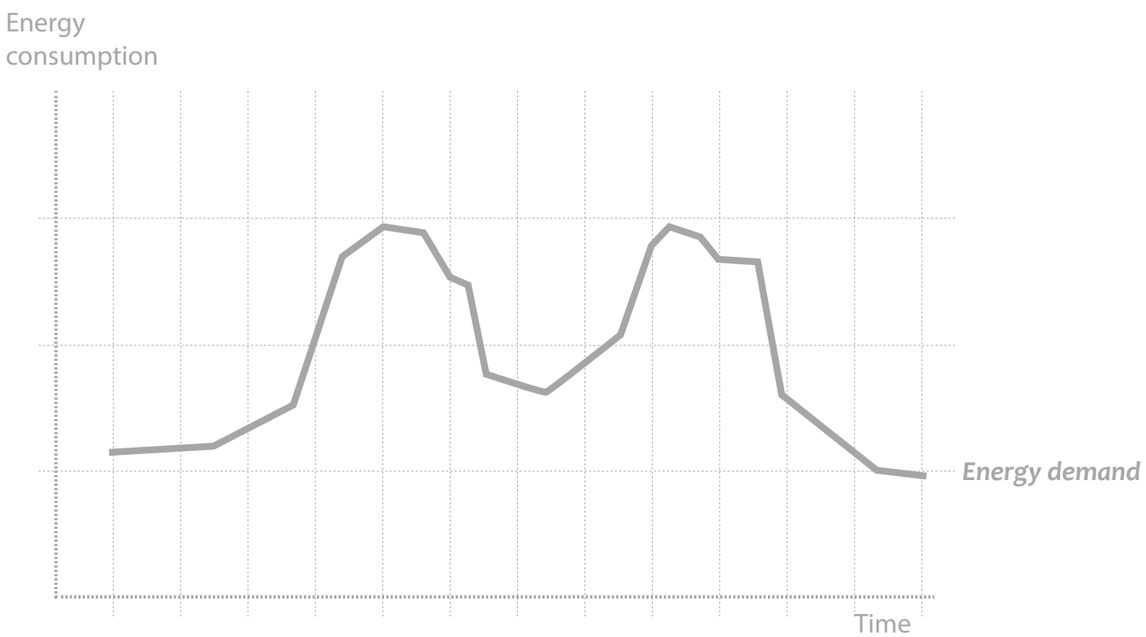


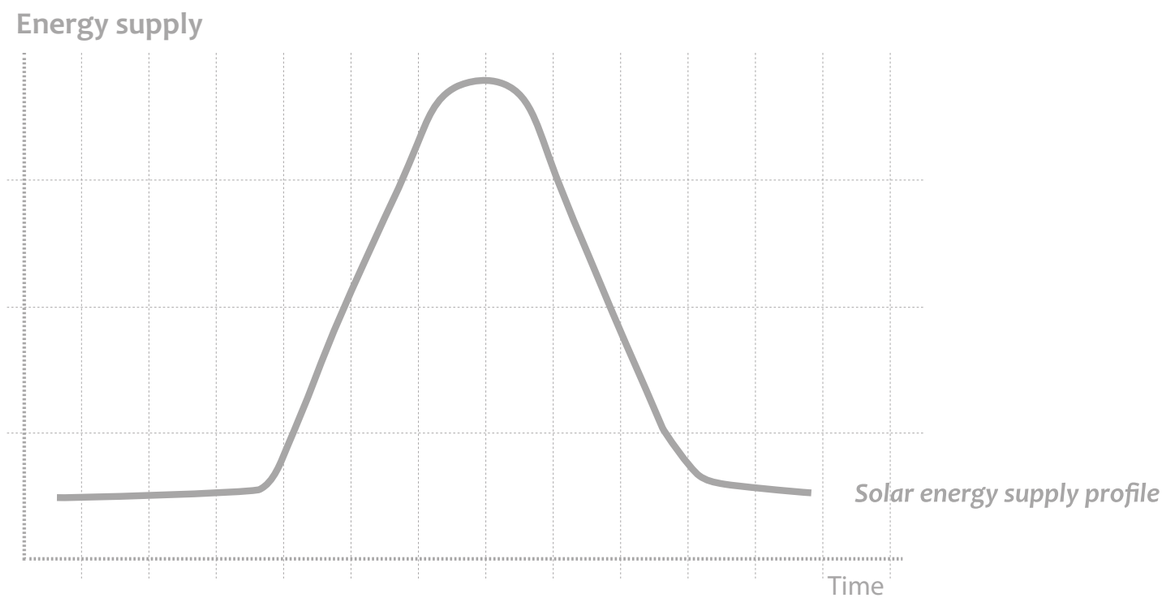
Increasing & Solar dependent supply

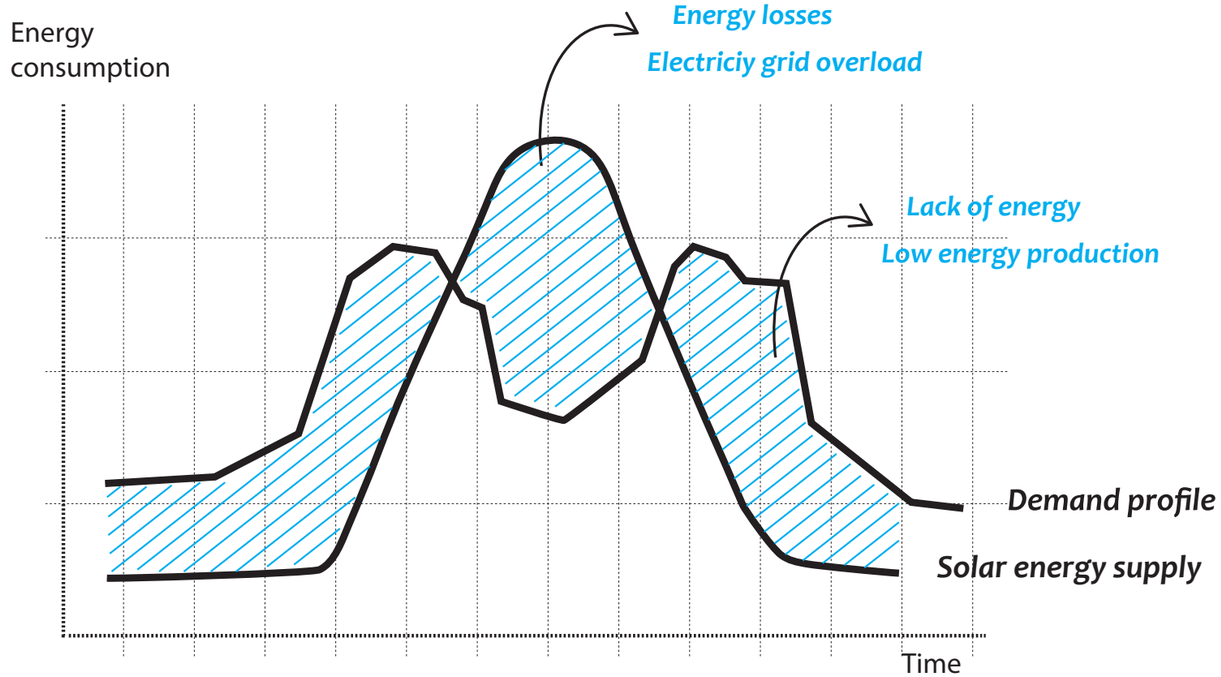

Energy
consumption
Energy demand
Time


Energy supply
Solar energy supply profile
Time


Energy
consumption
Energy losses
Electriciy grid overload
Demand profile
Solar energy supply
Time

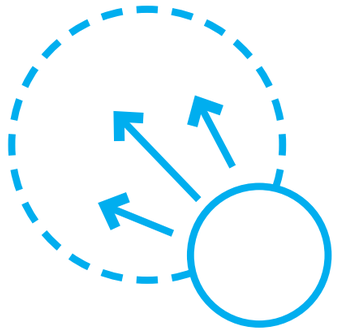




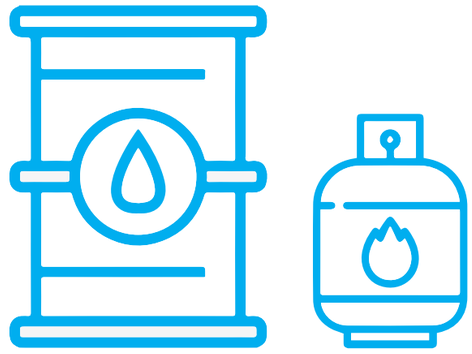


Energy Mismatch

Increase in electricity bills



Oversized energy grid



Dependance on other energy sources

7.5 CONCLUSION

In this section, an answer was given to the question *"What does an energy-flat design look like?"*. This is done by describing the two preliminary designs, which focus on optimizing supply and demand separately. T
knowledge of the parameter studies, translat
which are summarized in a toolbox. Finally, t
consists of building design drawings, the ene
energy-flatness in the design.

Both a demand-oriented and a supply-orient
thermal mass, pre-heating and pre-cooling a
effective solutions for energy-flatness. From
that the east and west facades are essential
afternoon demand, that the northern orientat
stable supply profile and that there is a certa
general, the solutions for demand are effecti
shorter timesteps. The supply-oriented soluti
decreasing the total profile, and focus more

From the previously mentioned designs and
energy-flat design. It consists of design solut
performance of a residential building which r
principles are linked to energy-flatness goals
research. Also, two sketch-level examples o
inspiration for designers and to show the rel

The final design is a non-typical kind of archi
design has the shape of a quarter elliptical s
south. This façade is glazed for 80% and the
The façade is covered with rotating, insulate
block solar in summer and reduce transmiss
sheltered for an increased amount of therma
ventilation, a comfortable indoor climate, effe
systems are integrated for optimal energy-fla

V.R.M. Höfte

Energy-flat housing

Towards continuous balance in the residential energy system

TUDelft

Problem

Currently there is not so much research on how to reduce the mismatch in non-residential existing buildings

Objective

To develop knowledge on how to reduce the mismatch between energy demand and supply in non-residential existing buildings.

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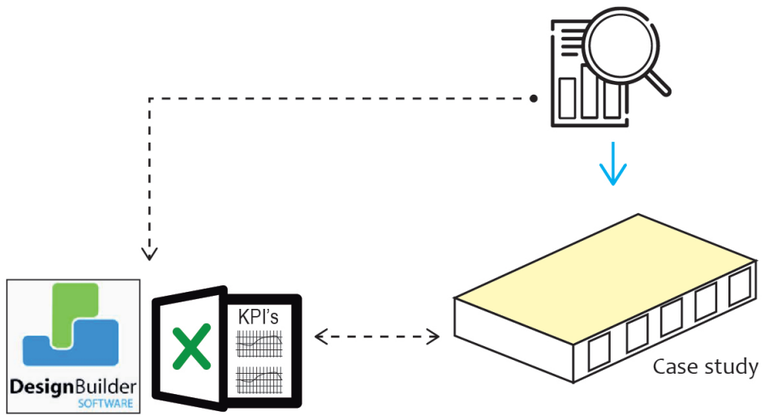
Research question

Which are the parameters and technologies that could help to reduce the mismatch between demand and supply in the renovation of non-residential existing buildings by proposing the renovation of a case study building towards energy flatness?

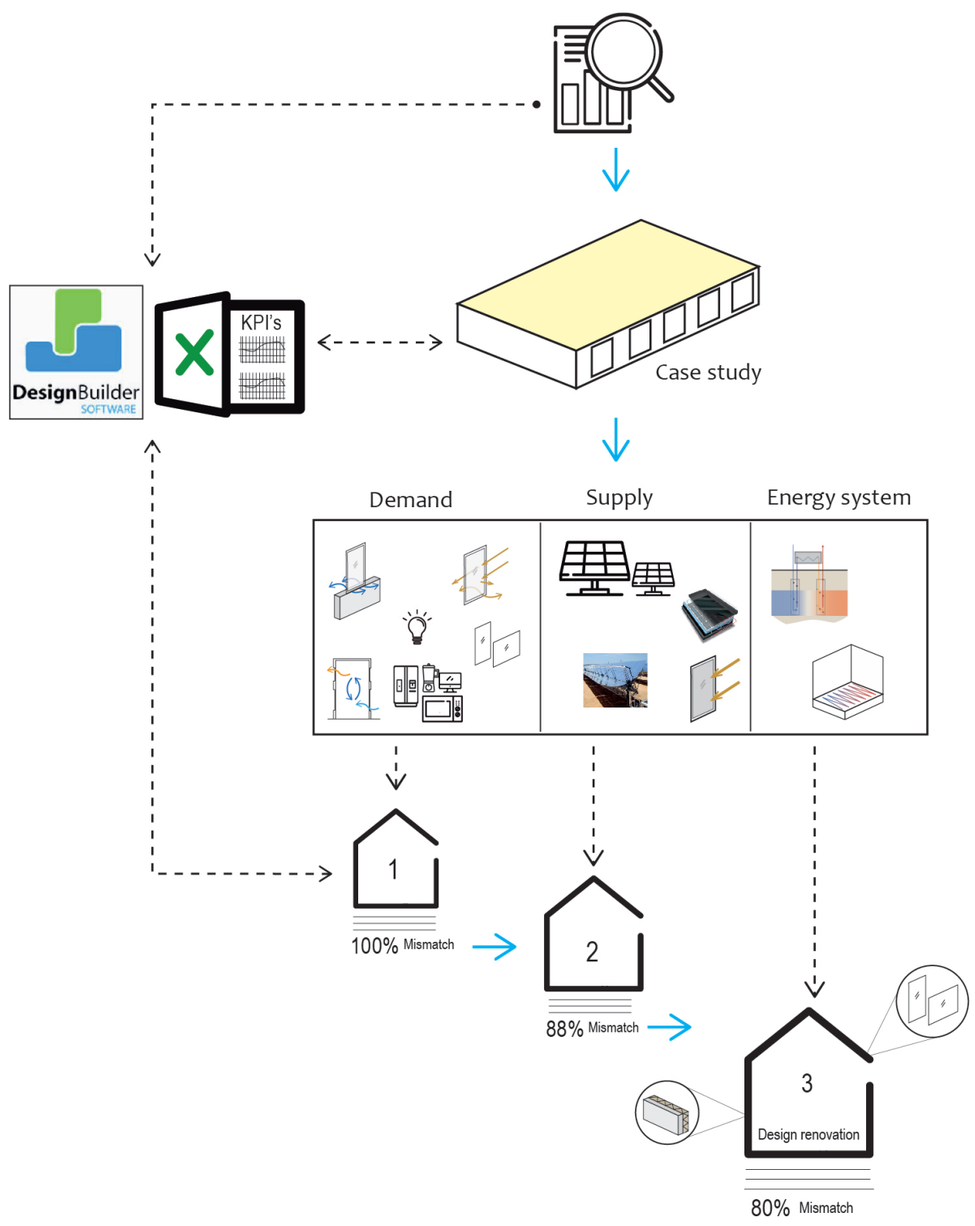
Methodology



What is energy flatness?
Definitions, system boundaries and KPI's

What is the mismatch in the case study?
- Parameters influencing the demand
- What is the mismatch of the building and the KPI's?

Methodology



What is energy flatness?
Definitions, system boundaries and KPI's

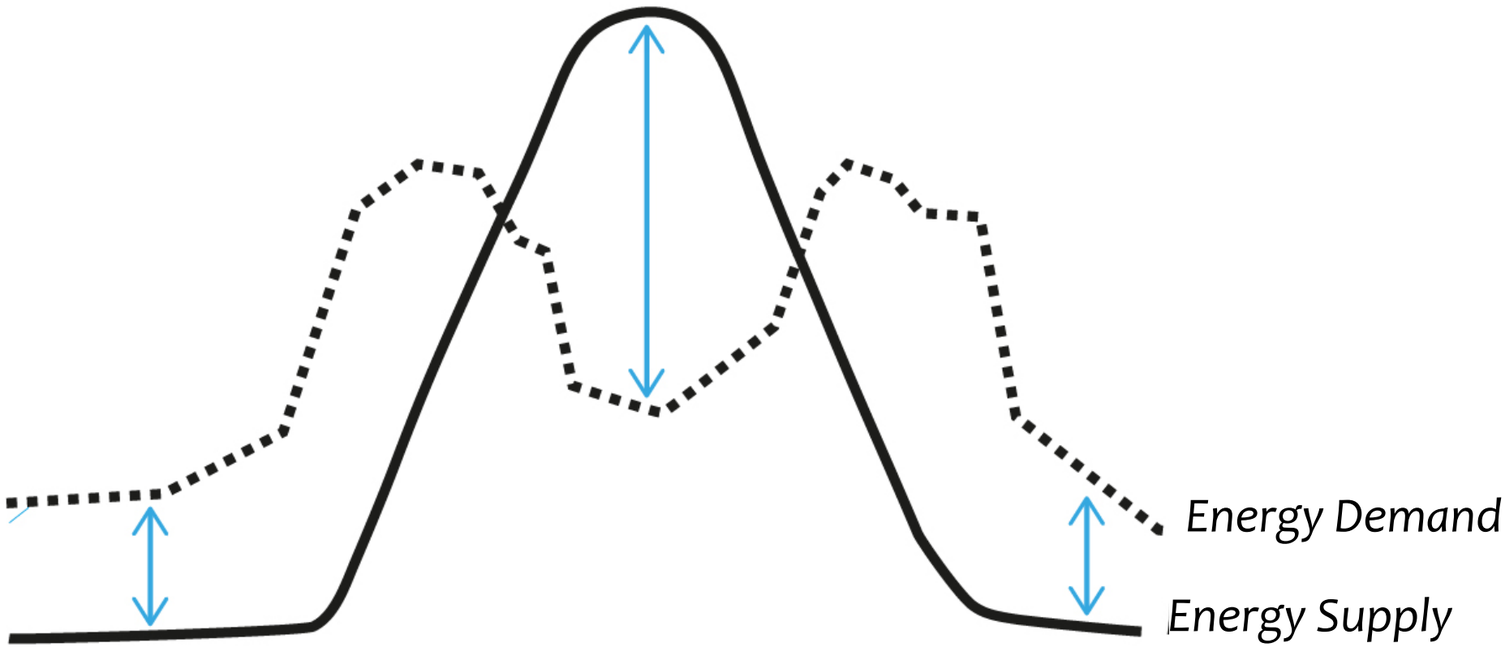
What is the mismatch in the case study?
- Parameters influencing the demand
- What is the mismatch of the building and the KPI's?

How to reduce the mismatch in the case study?
Steps
1. Energy demand reduction
2. On-site solar energy supply
3. Complementary energy system

What would the design renovation of the case study look like?
Architectural plans and details

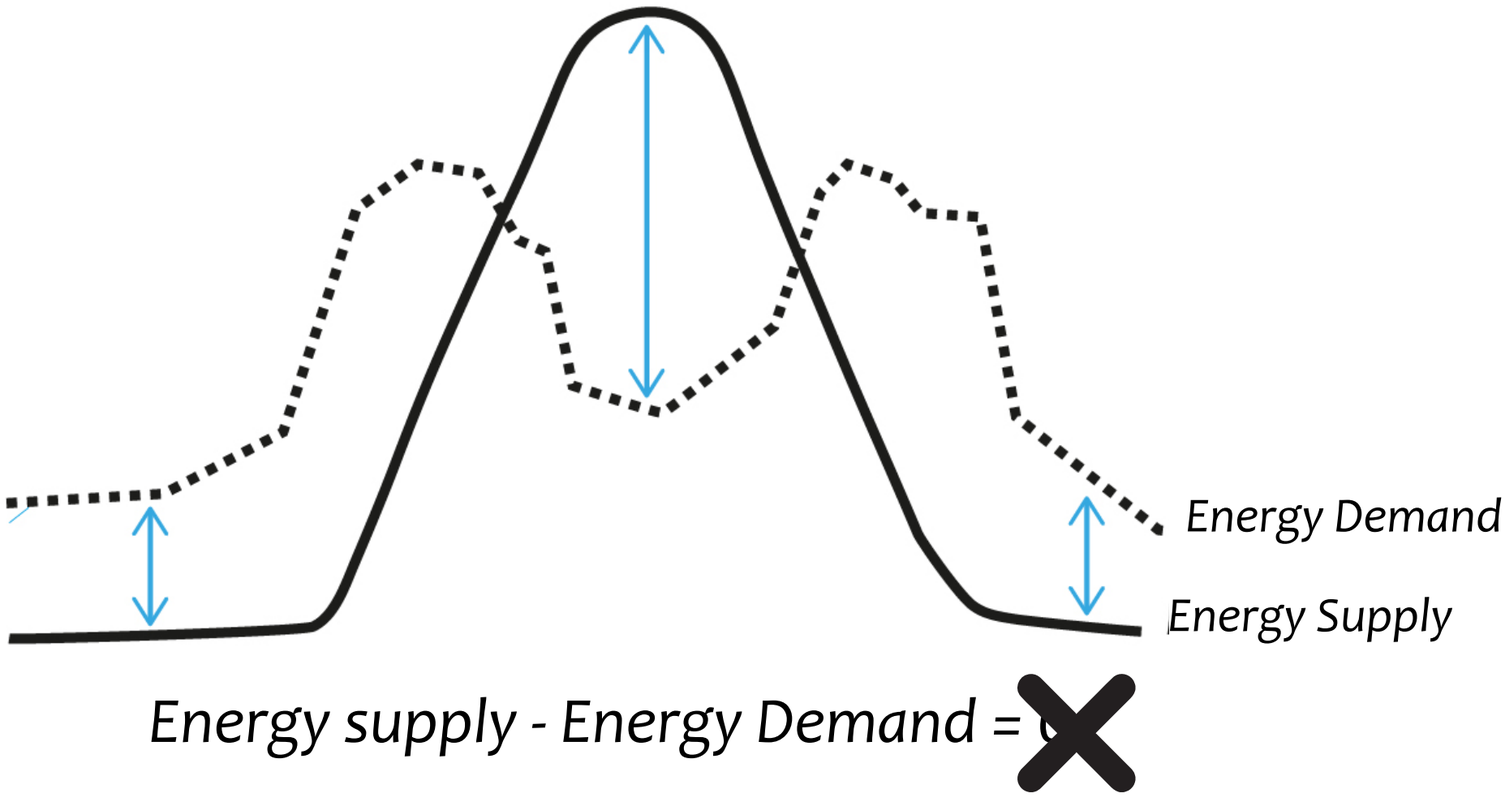
Which parameters and technologies of the case study can be implemented for the reduction of the mismatch in the renovation of non-residential existing buildings?
Toolbox / Conclusions and reflections

Energy flatness



Energy supply - Energy Demand = 0

Energy flatness *is a state in which the energy demand and supply match at any time of the year (Höfte, 2018)*



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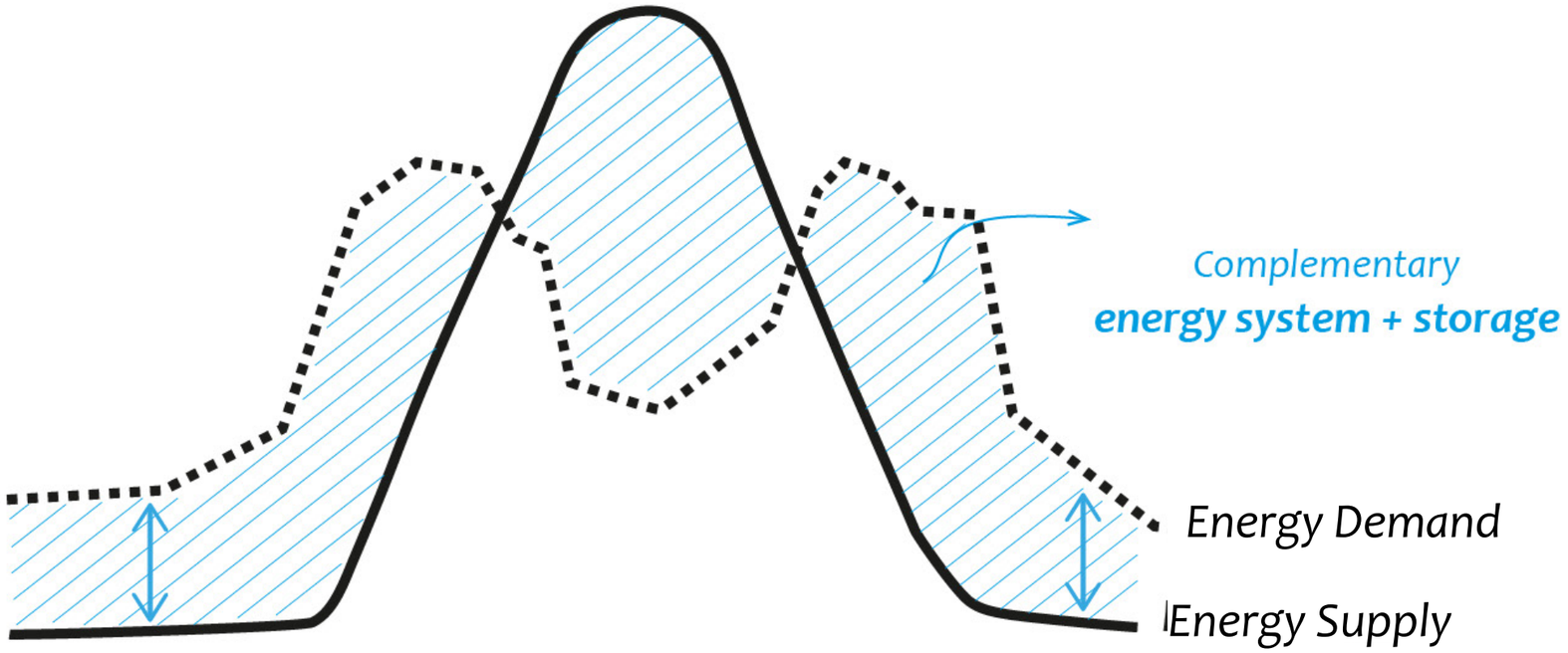
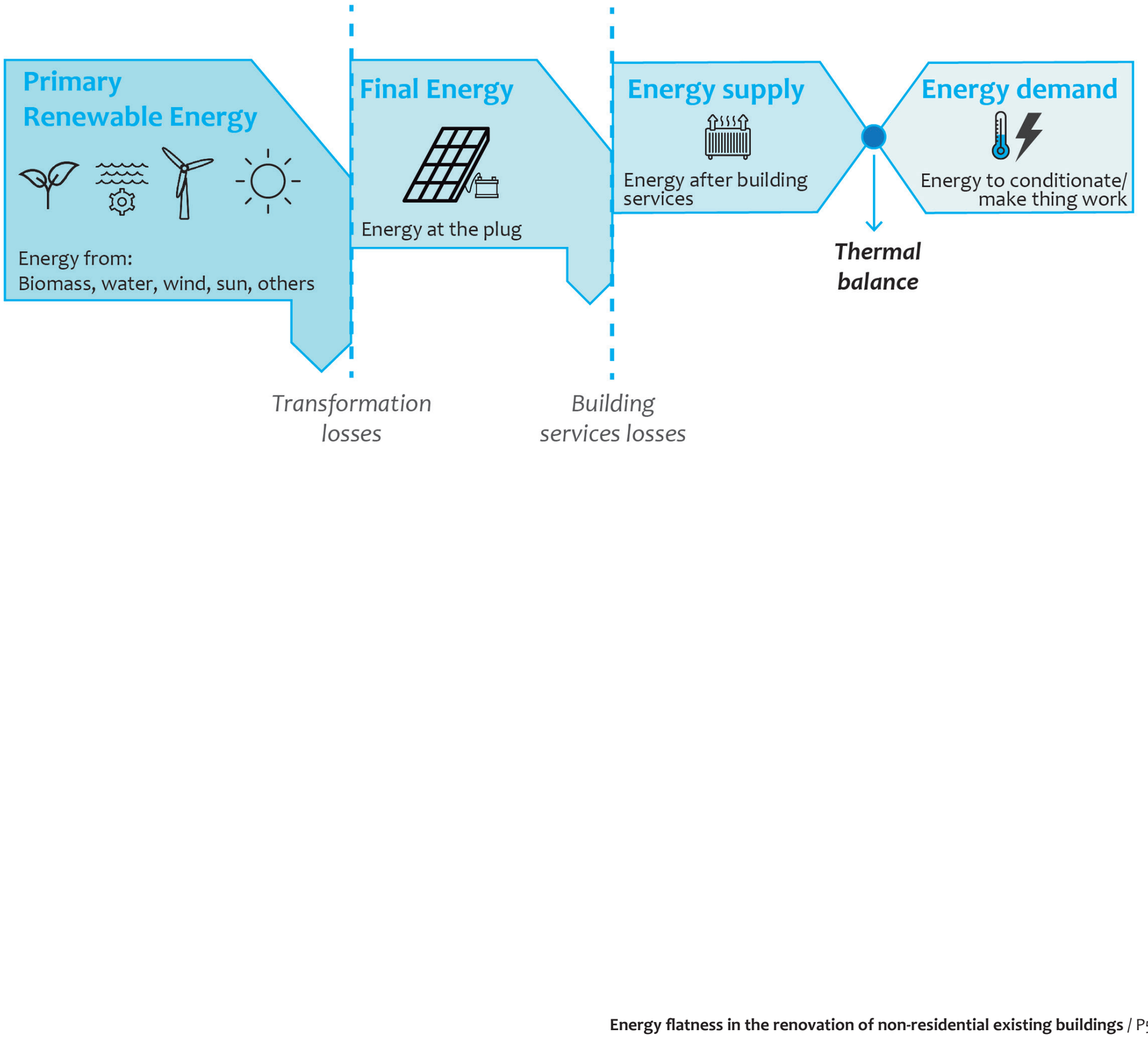


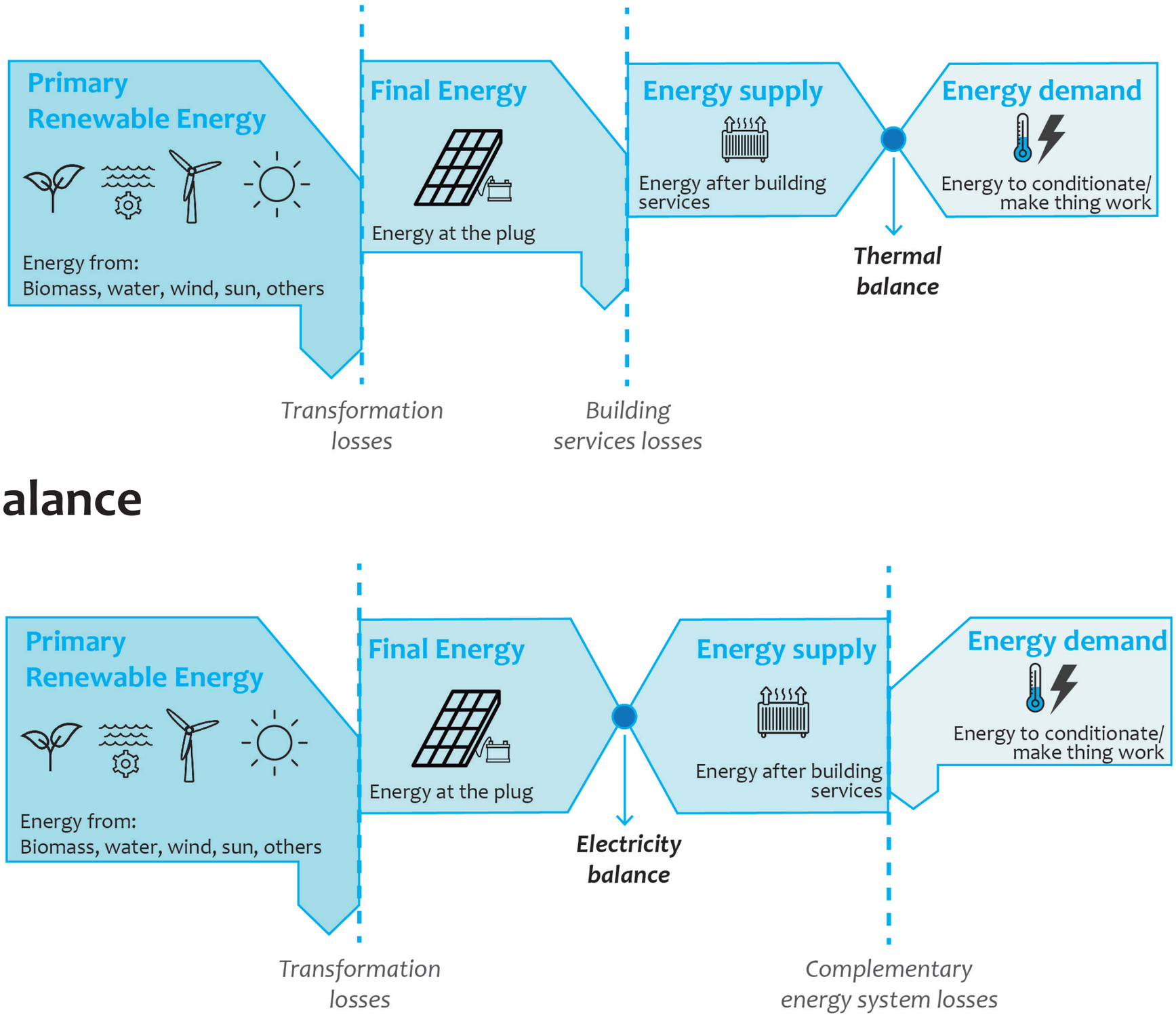
Energy supply - Energy Demand - ***Complementary energy system*** *= 0*

Energy flatness *is a state in which the energy produced and the energy demand match at any time of the year*

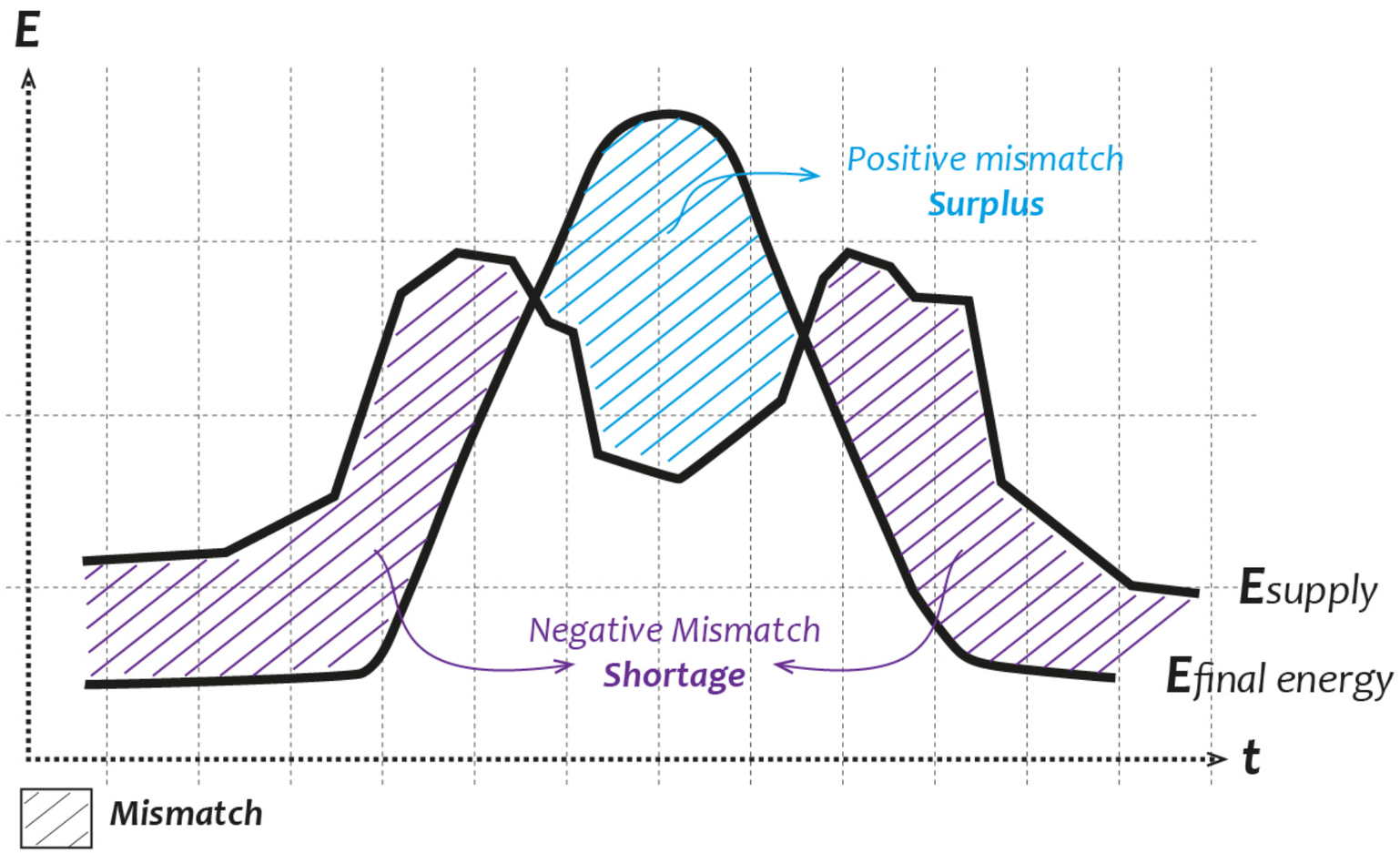
Thermal balance



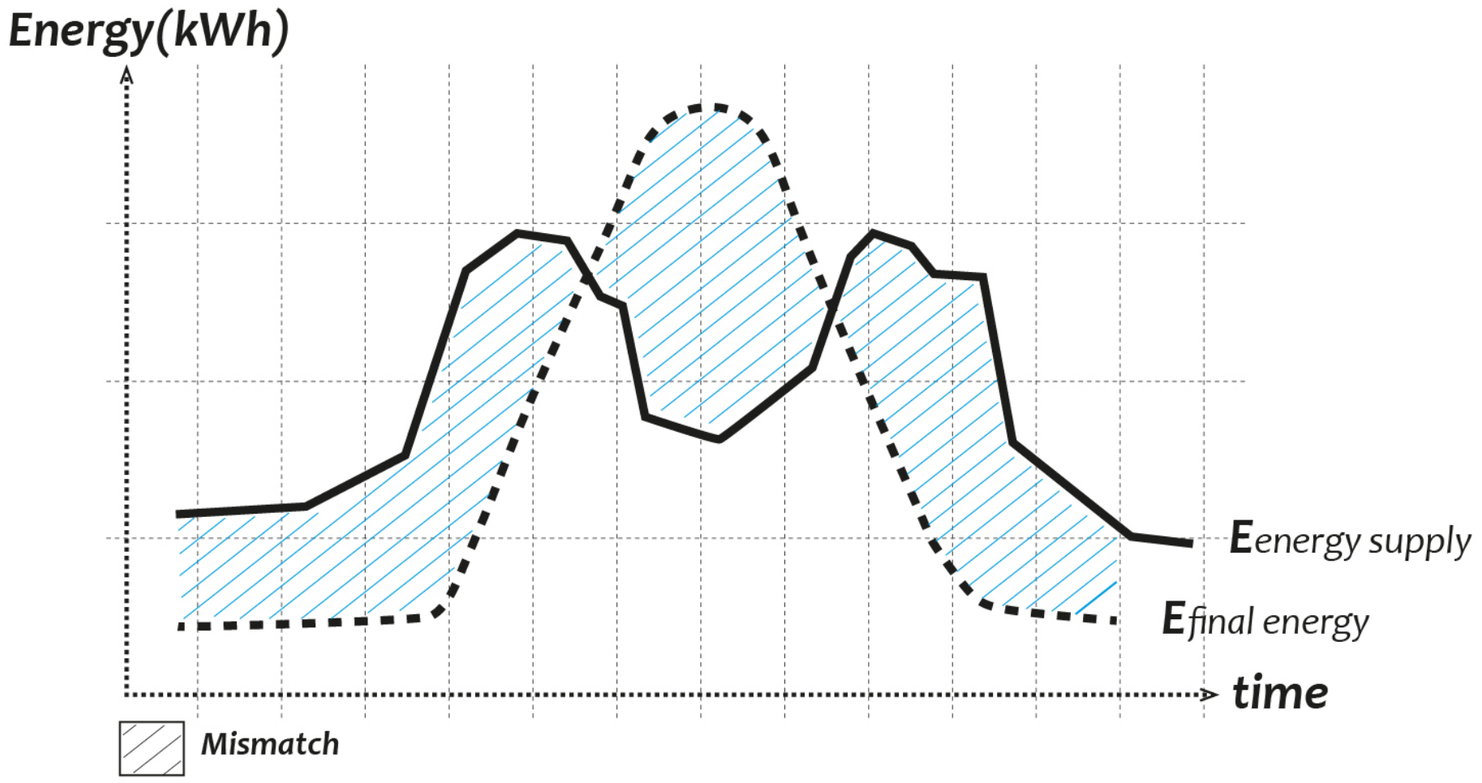
Thermal balance



Electricity balance

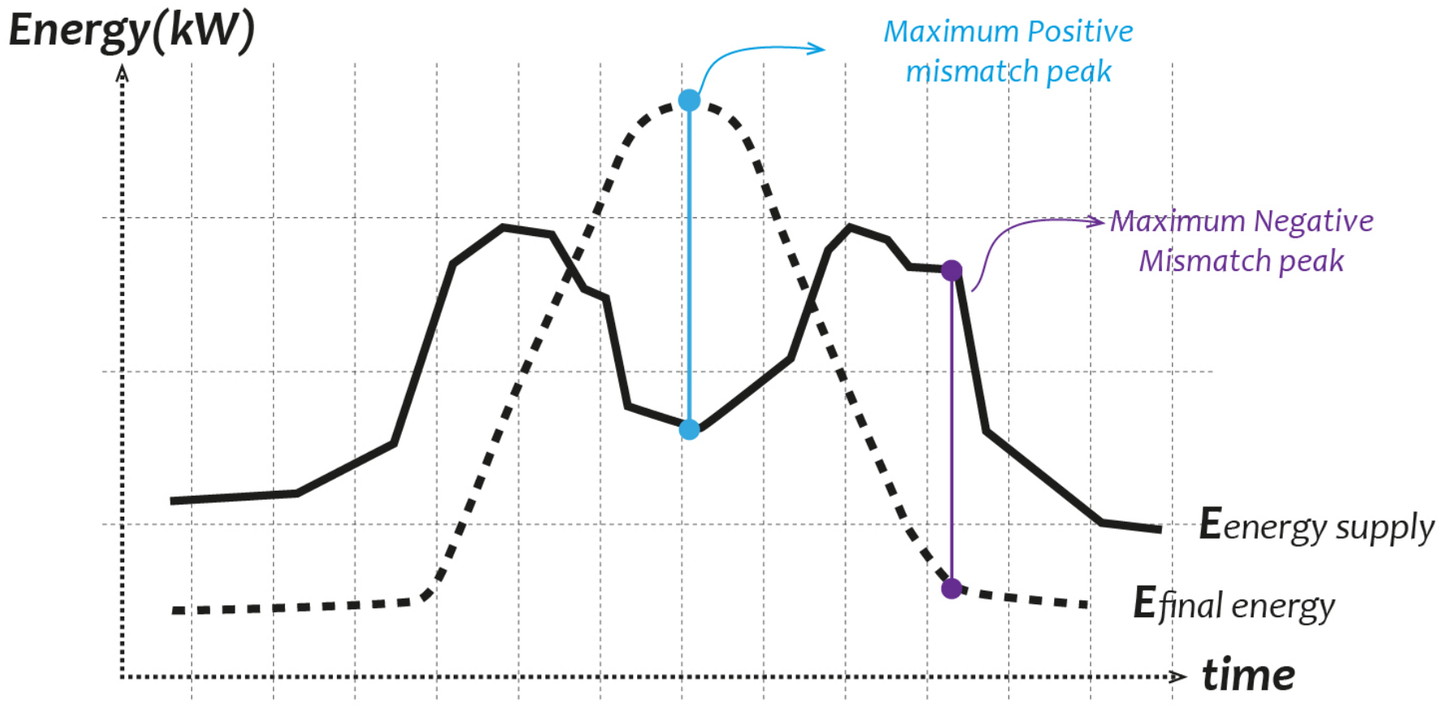

E
Positive mismatch
Surplus
Esupply
Efinal energy
Negative Mismatch
Shortage
t
Mismatch

KPI 1 - Absolute energy Flatness



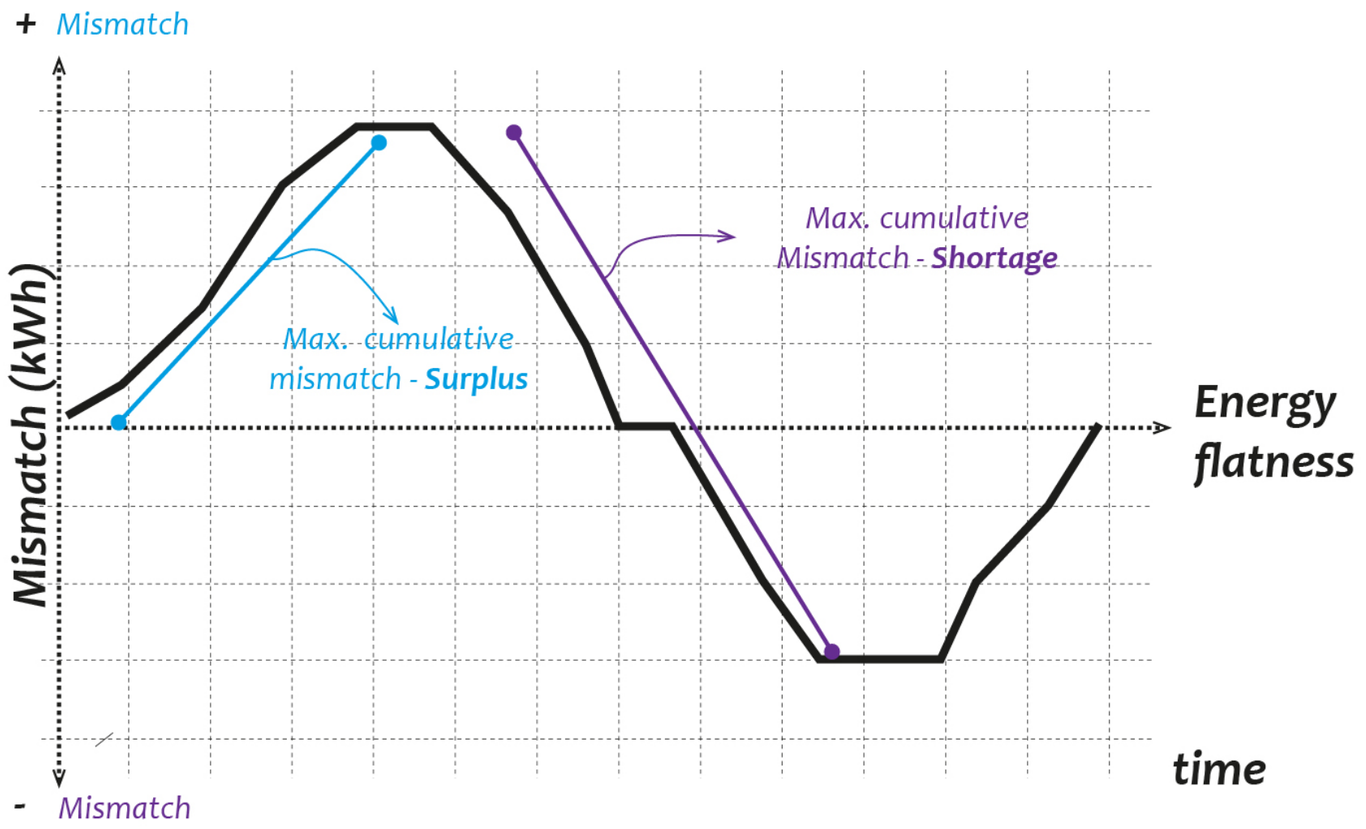
$$\sum_{t=1}^{t=8760} \left| E_{final\ energy(t)} - E_{Energy\ Supply(t)} \right|$$

KPI 2 - Maximum Mismatch Peak



$$MMP = \max_{0 \le t \le 8760} \left| E_{Final\ energy(t)} - E_{Energy\ supply(t)} \right| \ [kW]$$

KPI 3 - Maximum Cumulative Energy Mismatch



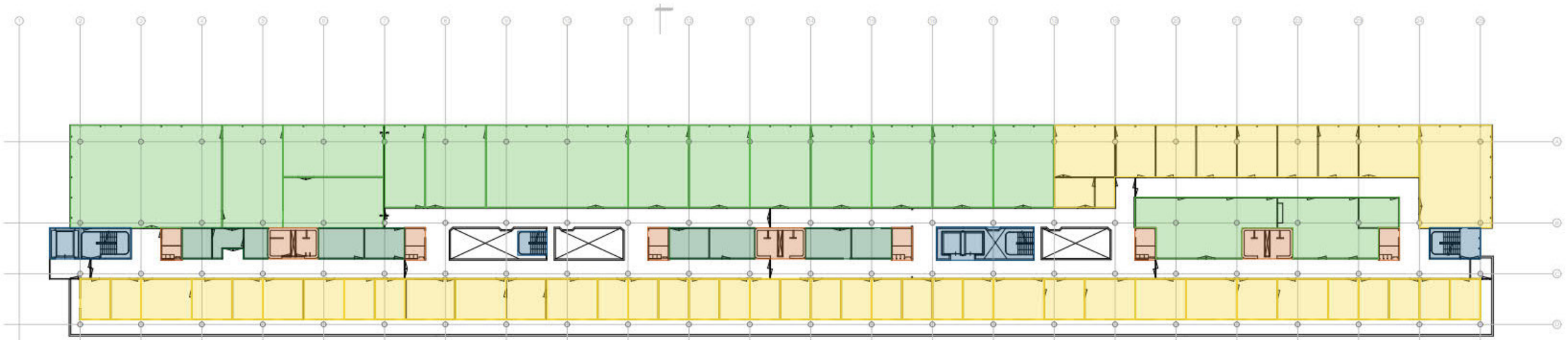
$$MCEM = \max_{0<a<8760} positive\left(CEM\_positive_{(a)}\right) - \max_{0<b<8760} negative\left(CEM\_negative_{(b)}\right)\ [kWh]$$

CEM = Cumulative Energy Mismatch

to analyze the mismatch I used a
case study building

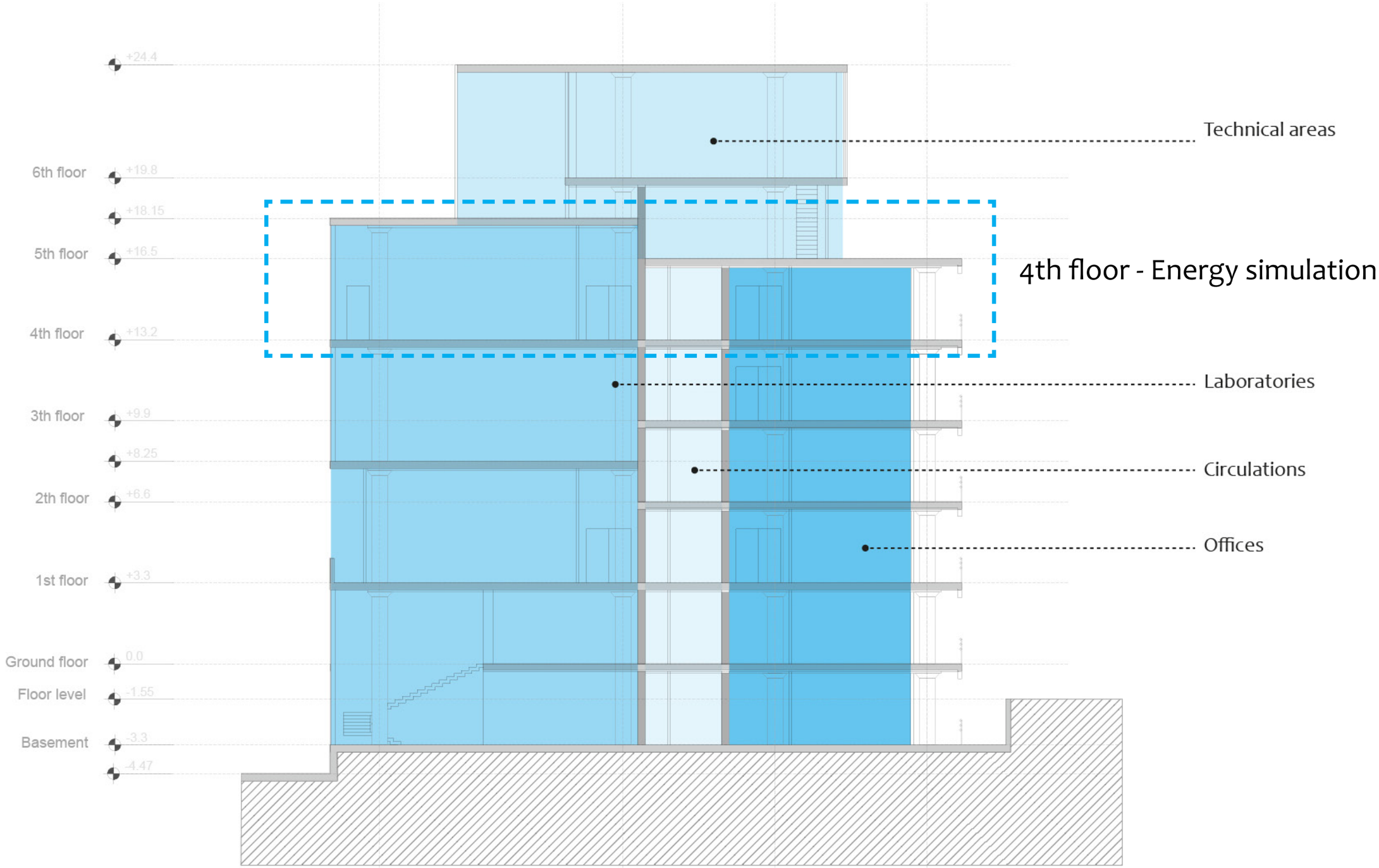
Case study - Gemini south

Gemini South building - Technical University of Eindhoven



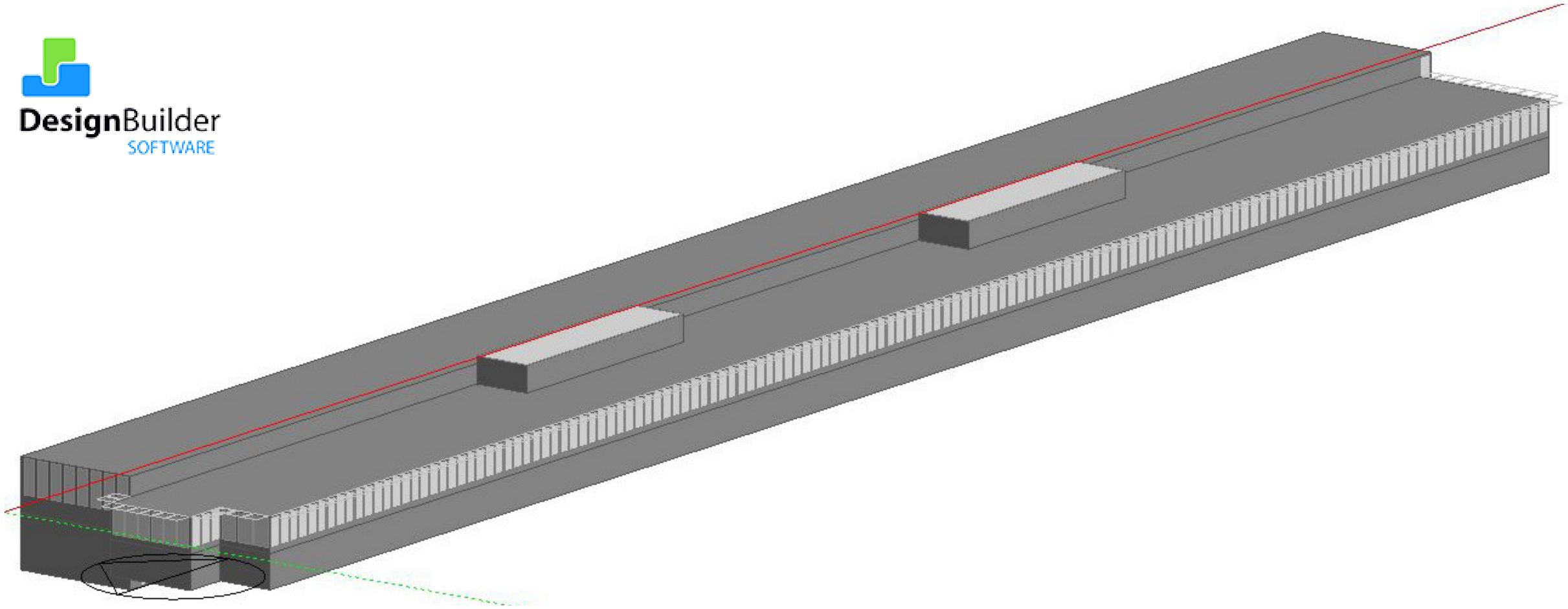
Areas 4th floor - Gemini building

Technical areas and W.C.	177m2	6%
Offices	1234m2	32%
Laboratories & educational	1424m2	37%
Other educational areas	157m2	4%
Vertical circulation	120m2	21%
Horizontal circulation	727m2	
Total area	3839,5m2	

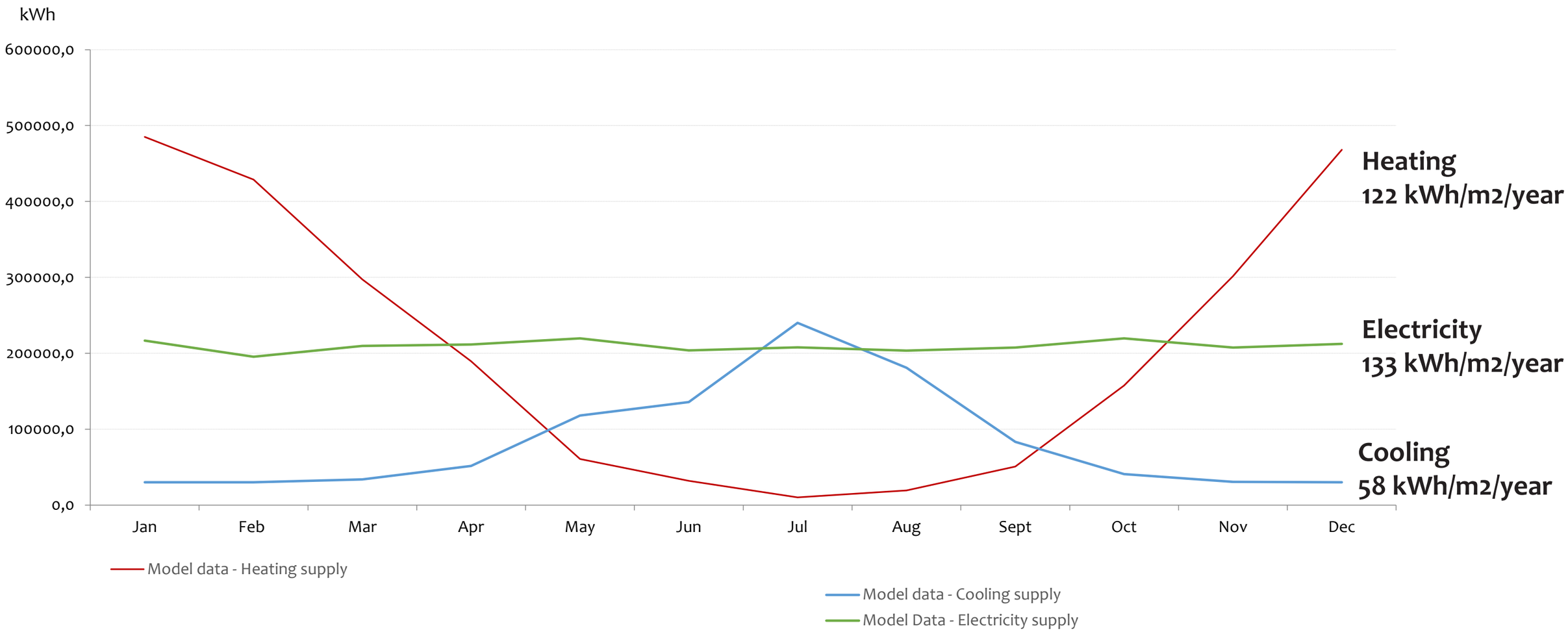


Gemini South building - Technical University of Eindhoven

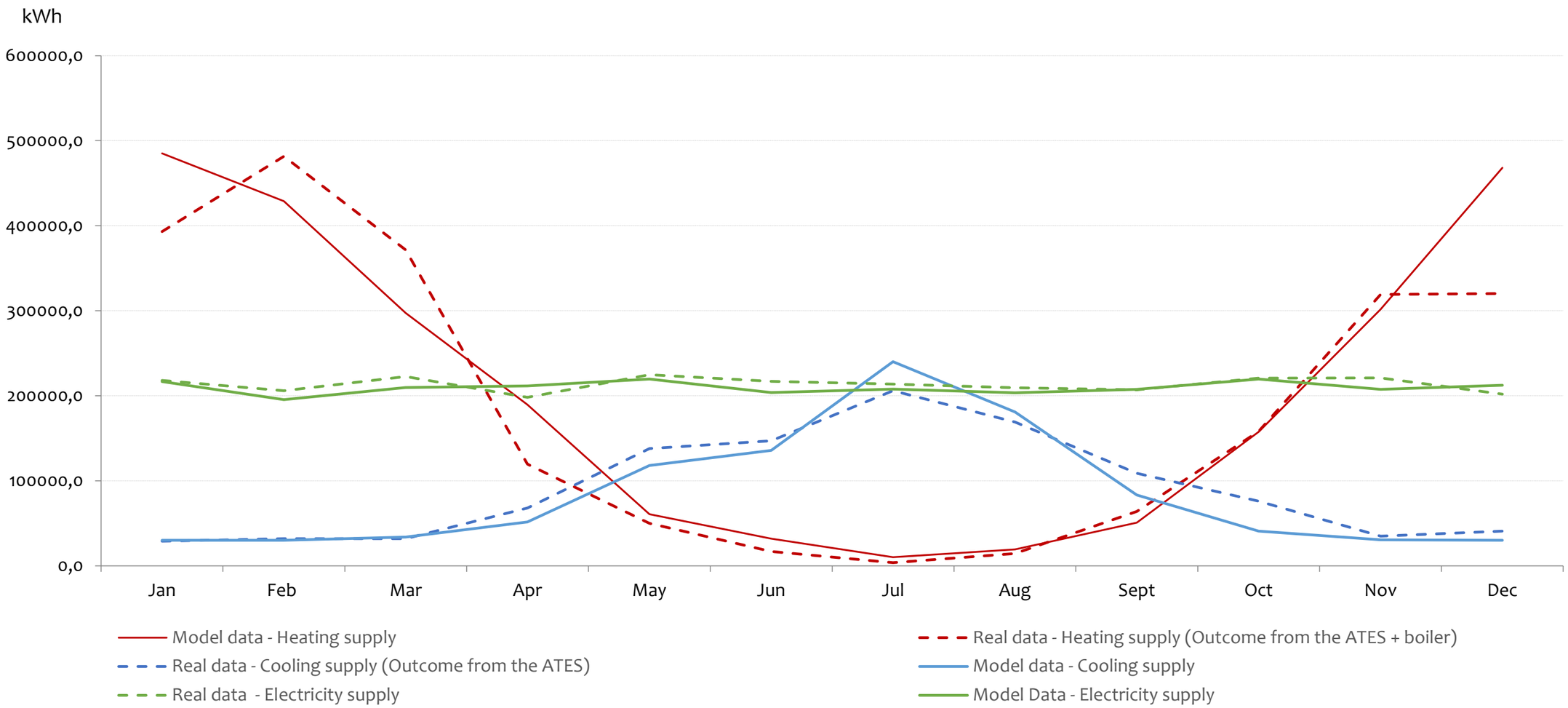
DesignBuilder SOFTWARE



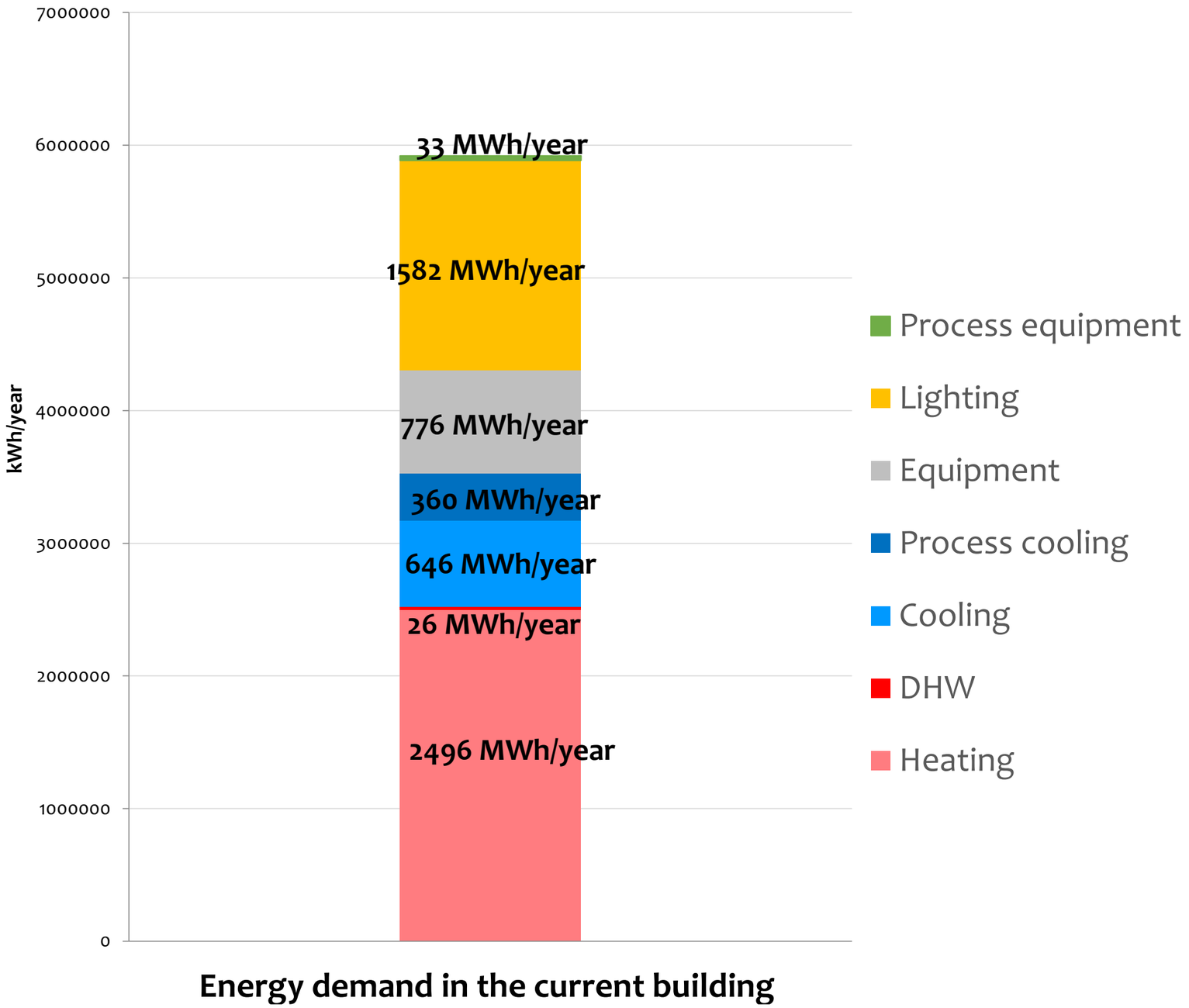
Current energy demand



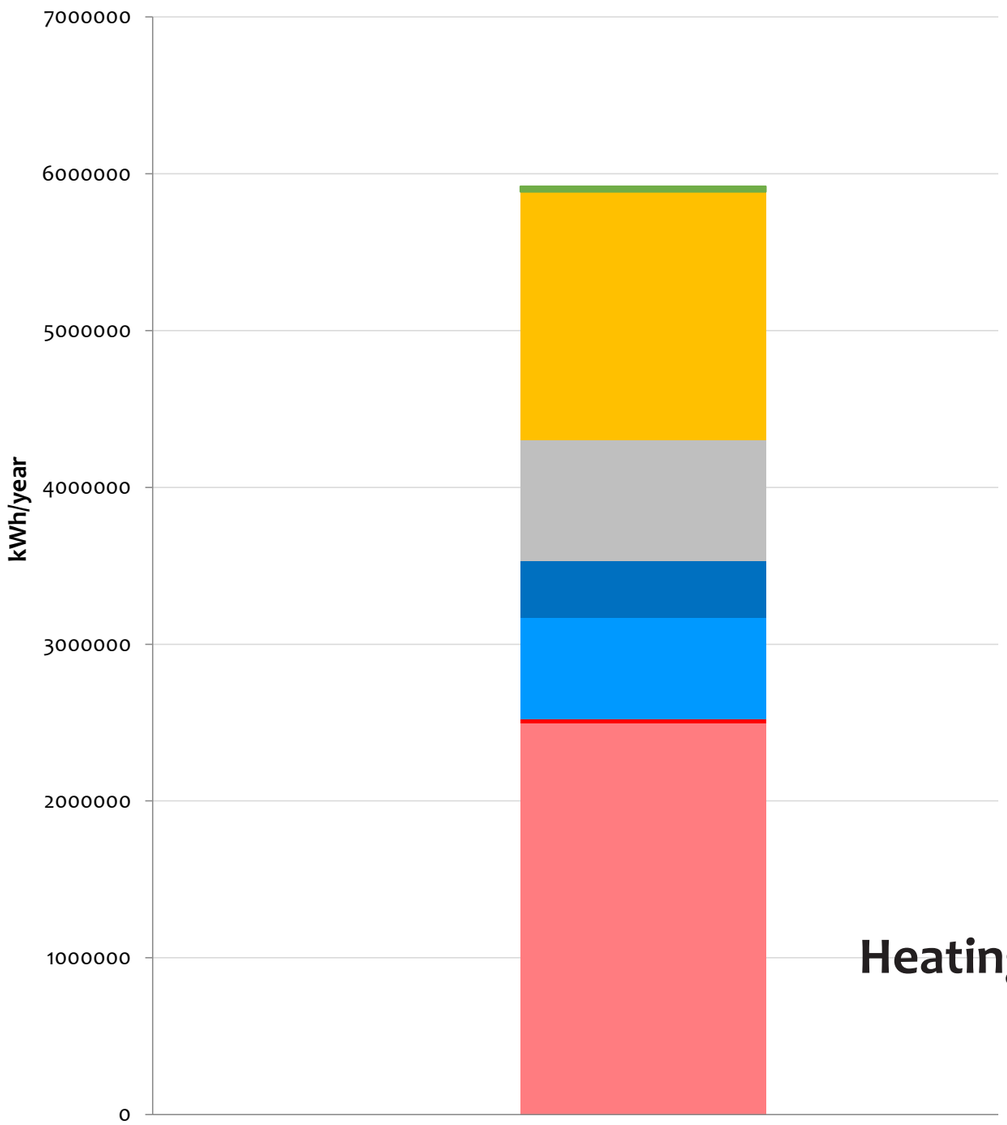
Validation

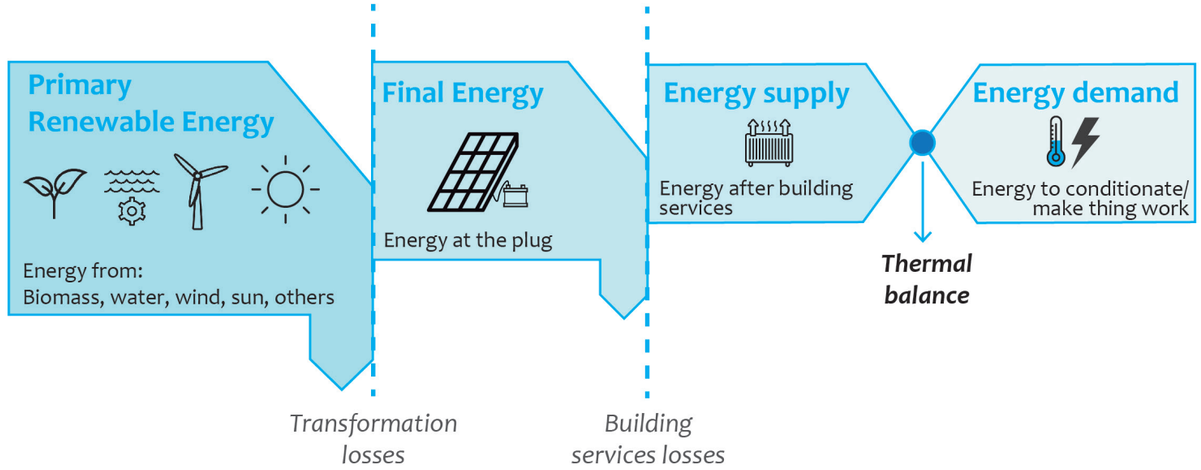

kWh
600000,0
500000,0
400000,0
300000,0
200000,0
100000,0
0,0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec
Model data - Heating supply
Real data - Heating supply (Outcome from the ATES + boiler)
Real data - Cooling supply (Outcome from the ATES)
Model data - Cooling supply
Real data - Electricity supply
Model Data - Electricity supply

Current energy demand



Current mismatch of energy - KPI 1

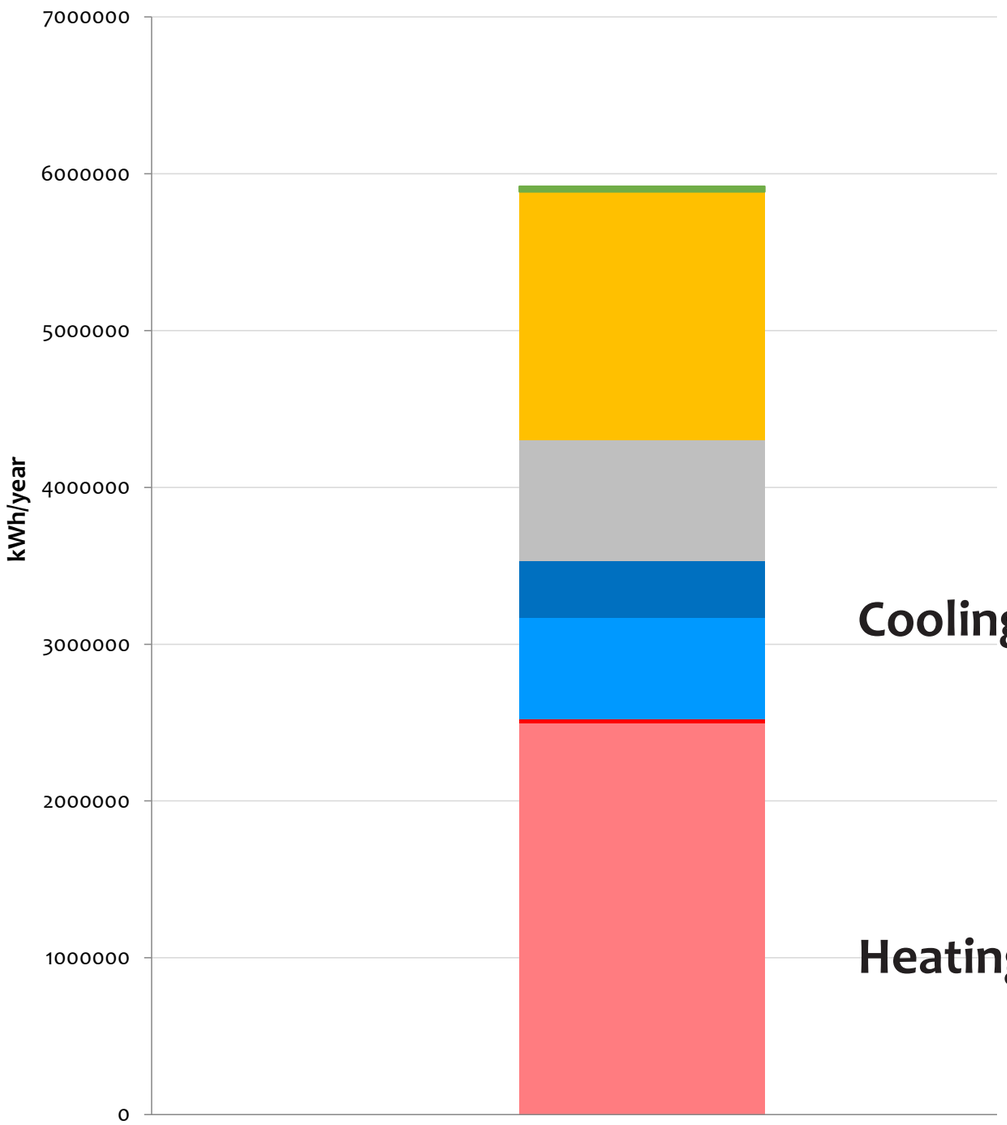


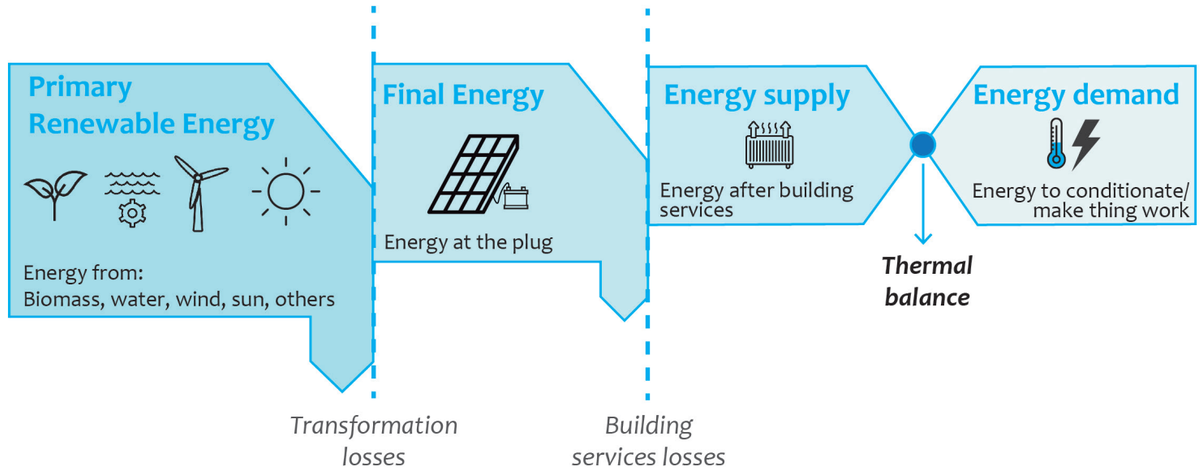


Heating =

$$\left|\mathbf{0}_{(8760)} - \mathbf{2522}\ \boldsymbol{MWh}_{(8760)}\right|$$

Current mismatch of energy - KPI 1

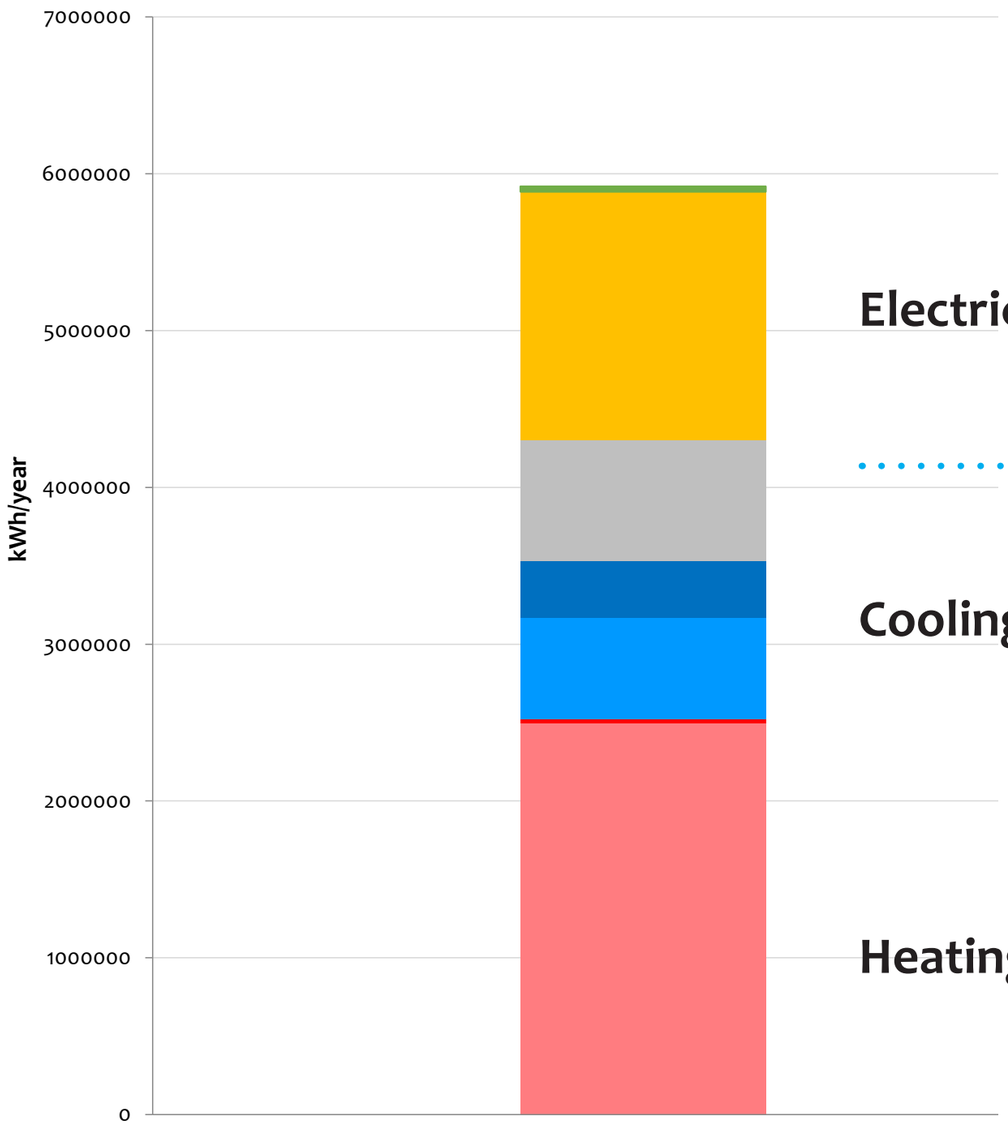


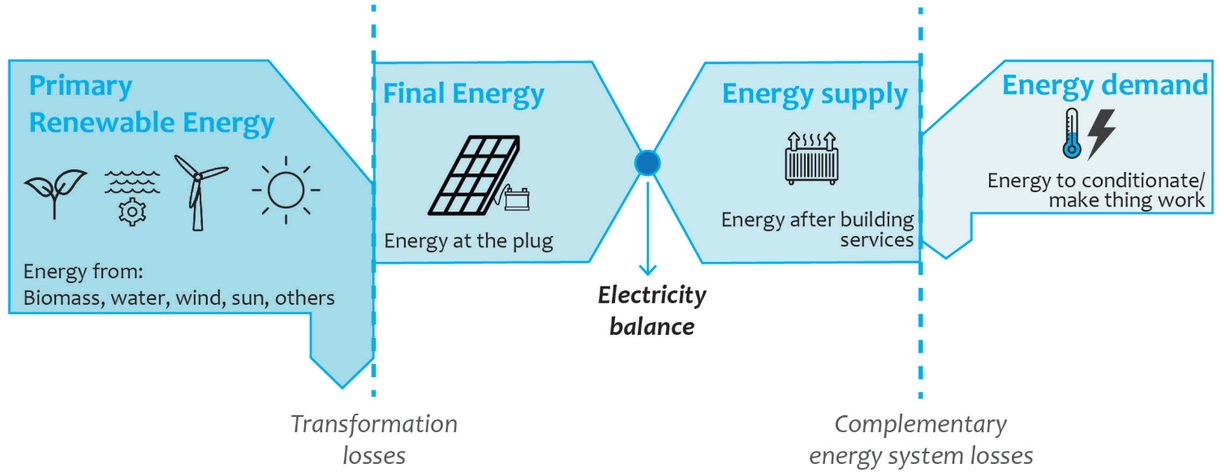


Cooling = $\left|0_{(8760)} - 1005\ MWh_{(8760)}\right|$

Heating = $\left|0_{(8760)} - 2522\ MWh_{(8760)}\right|$

Current mismatch of energy - KPI 1



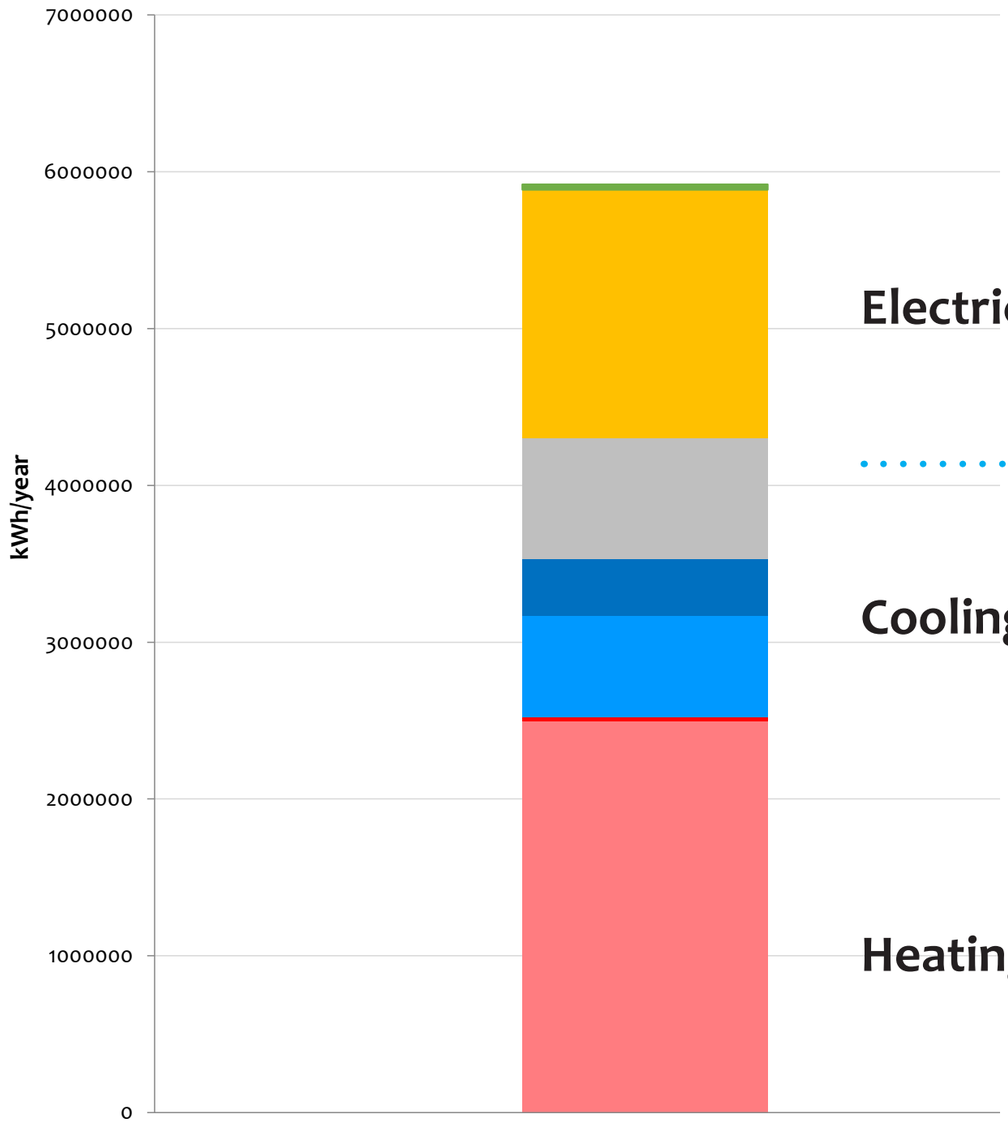


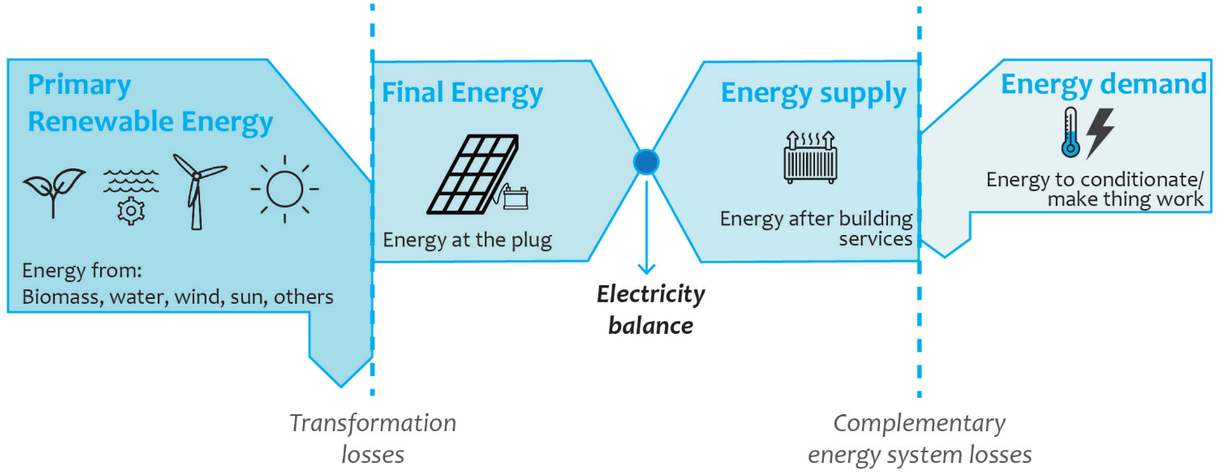
Electricity = $\left|0_{(8760)} - 2391\ MWh_{(8760)}\right|$

Cooling = $\left|0_{(8760)} - 1005\ MWh_{(8760)}\right|$

Heating = $\left|0_{(8760)} - 2522\ MWh_{(8760)}\right|$

Current mismatch of energy - KPI 1



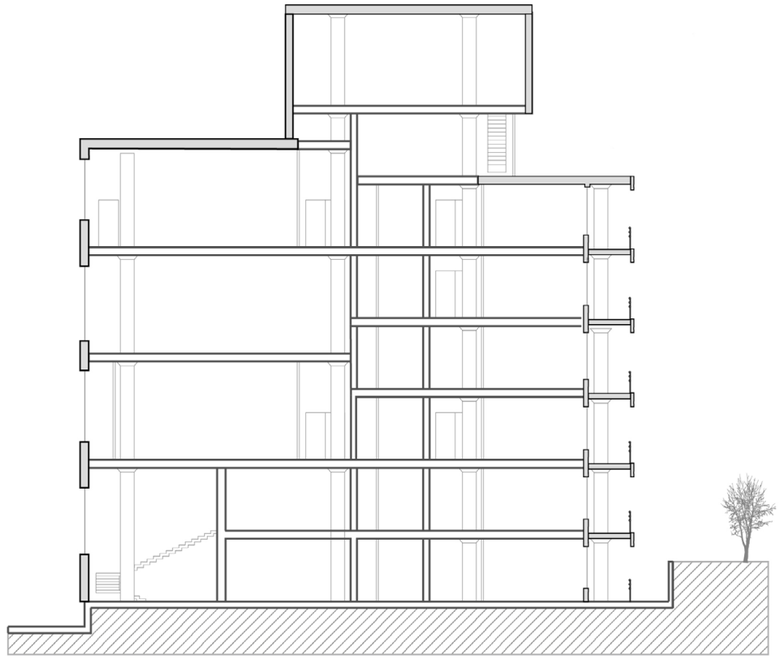


Electricity = $\left|0_{(8760)} - 2391\ MWh_{(8760)}\right|$

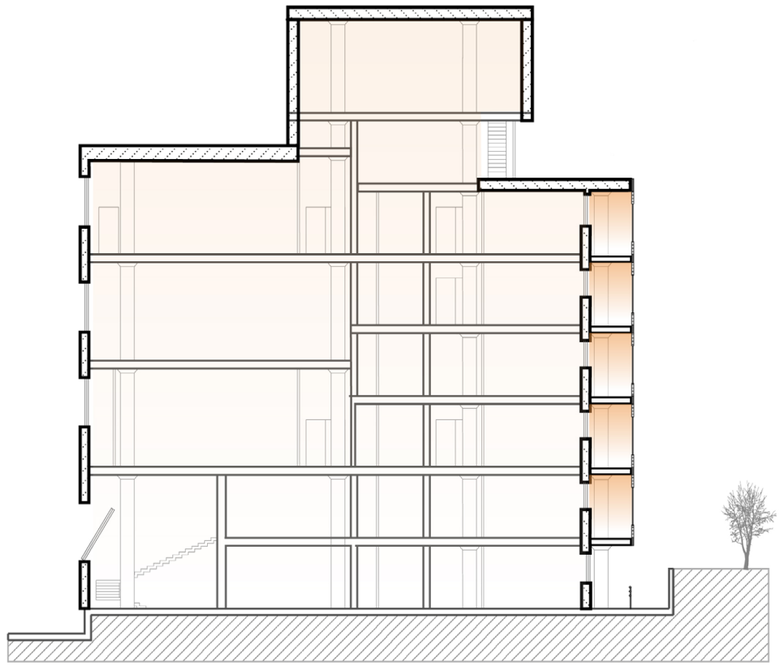
Cooling = $\left|0_{(8760)} - 1005\ MWh_{(8760)}\right|$

Heating = $\left|0_{(8760)} - 2522\ MWh_{(8760)}\right|$

Renovation in 3 steps

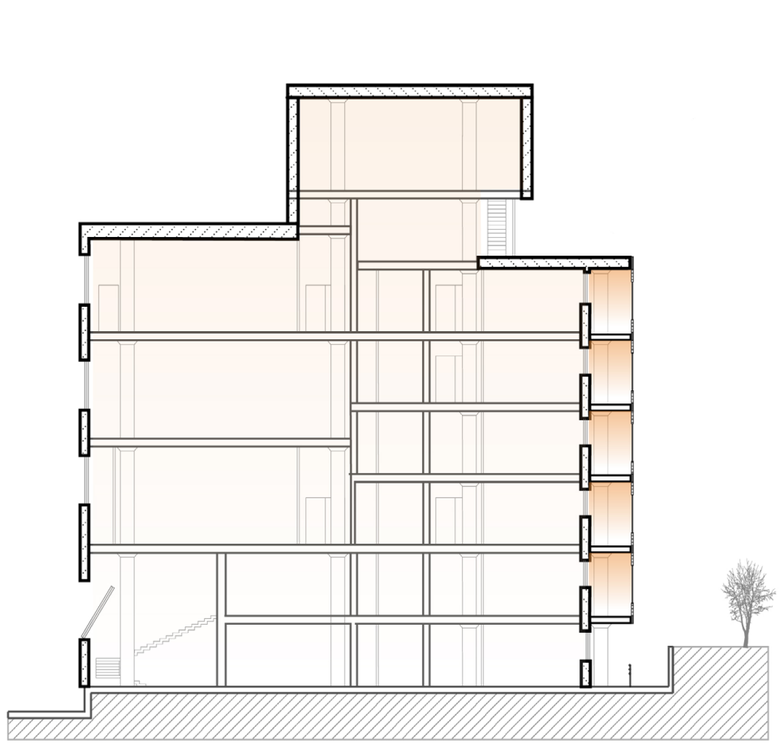


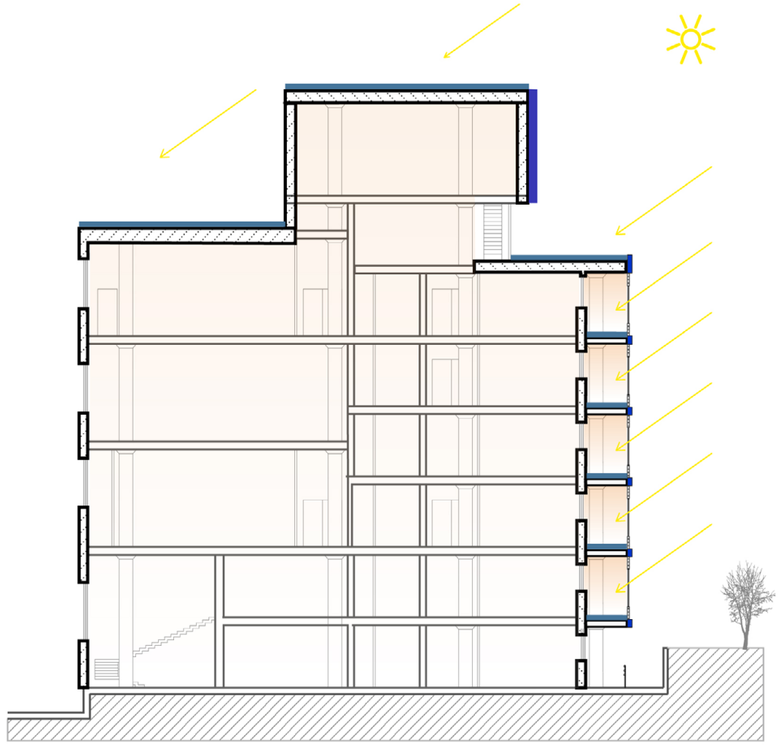
1 Demand Reduction



1

2 On-site energy production

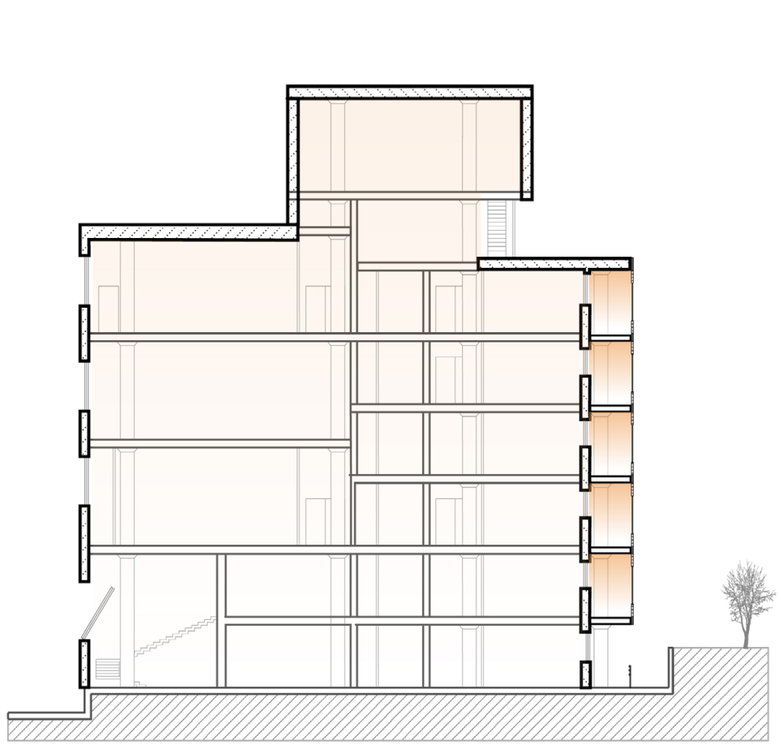


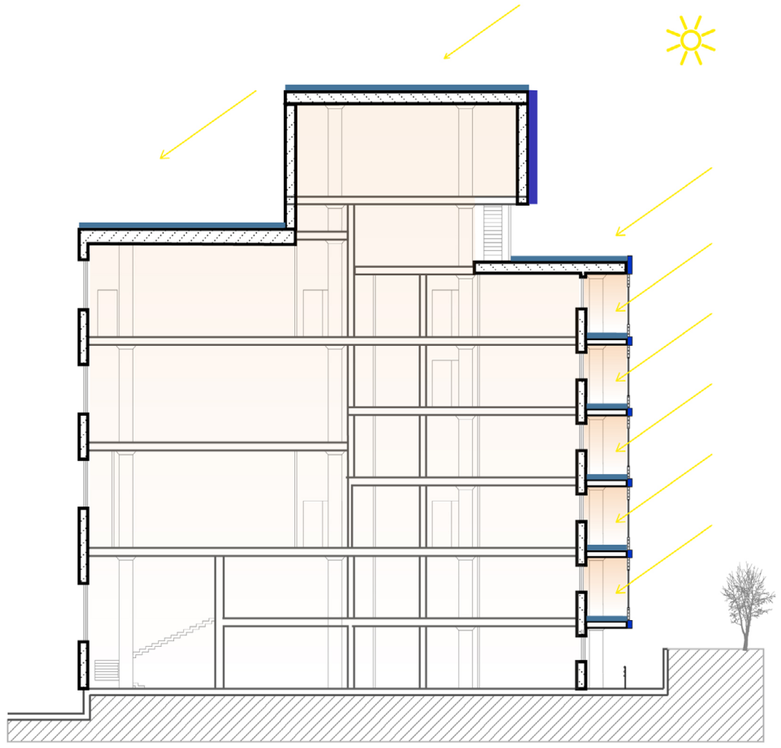


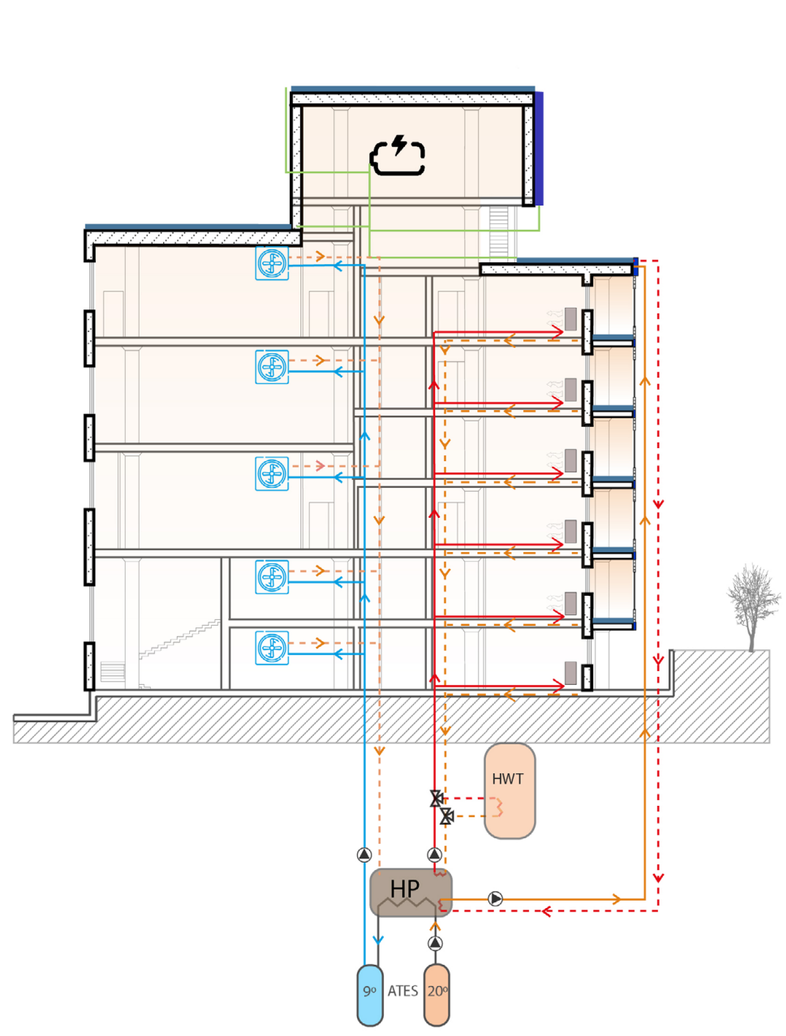
1

2

3 Complementary system

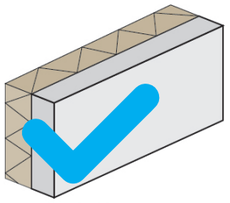


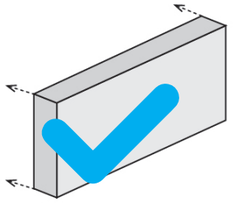


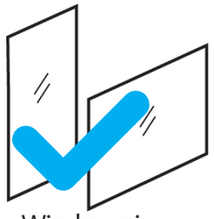


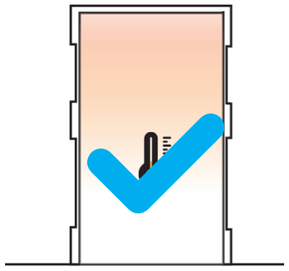
1 STEP
Energy demand reduction

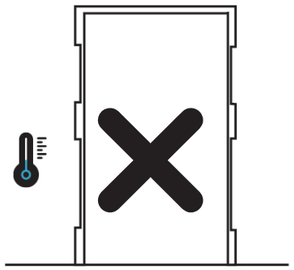
1

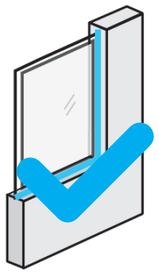

Insulation


Thermal mass


Window size

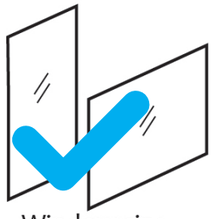

Temperature inside


Temperature outside

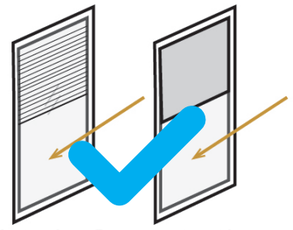

Air tightness

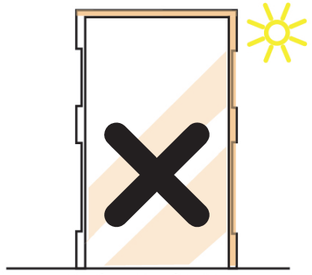
To reduce heat losses through infiltration and transmission

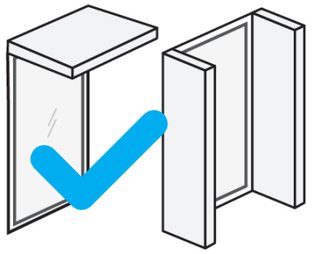
1

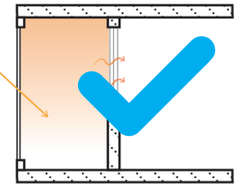

Window size

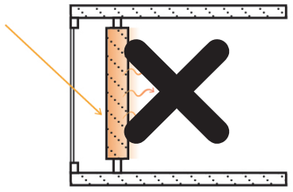

Window properties

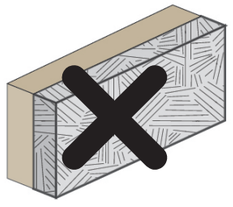

Interior Sun protection


Solar Radiation


Exterior sun protection

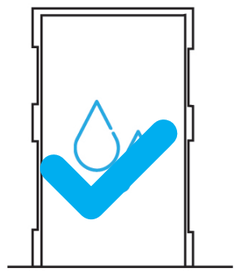

Solar buffer


Trombe wall

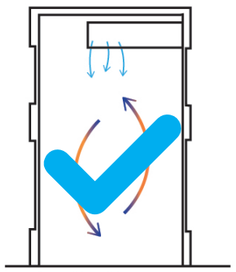

PCM

To increase solar gains

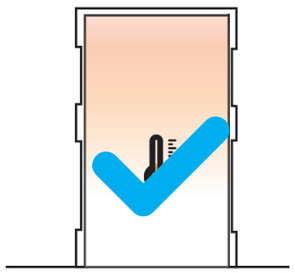
1



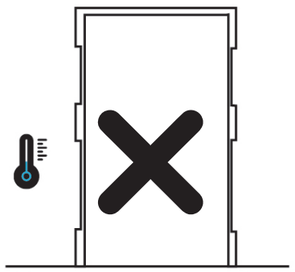
Relative Humidity



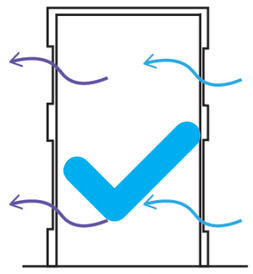
Ventilation rate



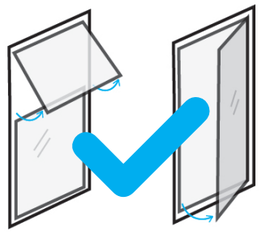
Temperature inside



Temperature outside



Night Ventilation



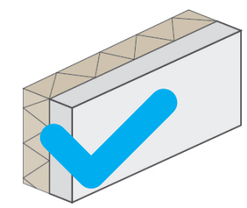
Openable window

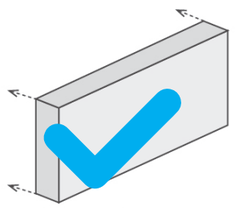
To allow for natural ventilation

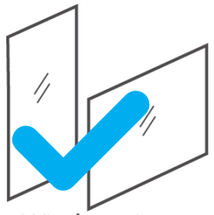
1

To optimize equipment electricity demand

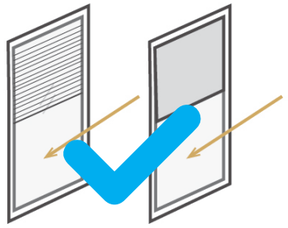
1

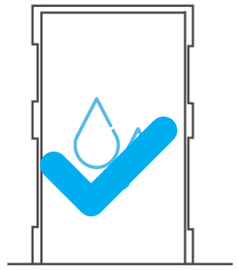

Insulation

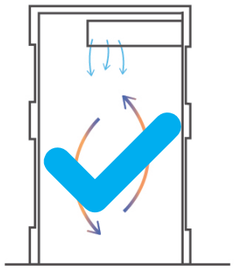

Thermal mass

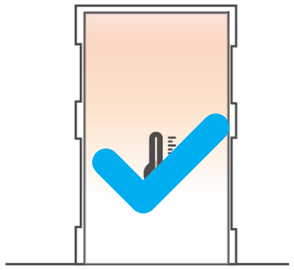

Window size

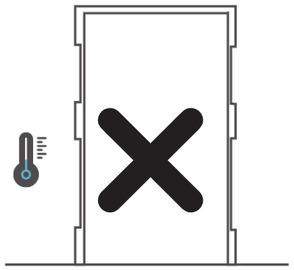

Window properties

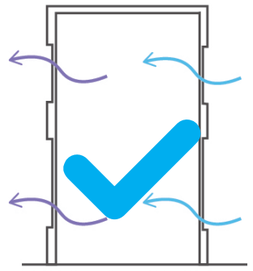

Interior Sun protection


Relative Humidity


Ventilation rate


Temperature inside


Temperature outside

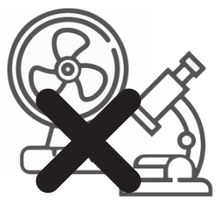

Night Ventilation

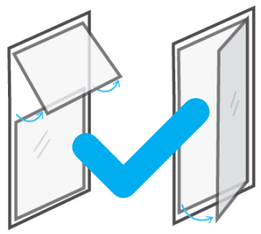

Lighting

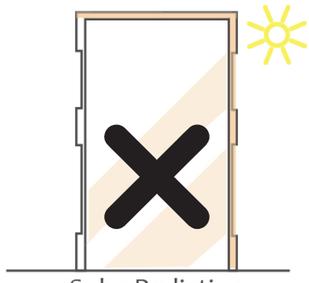

Equipment

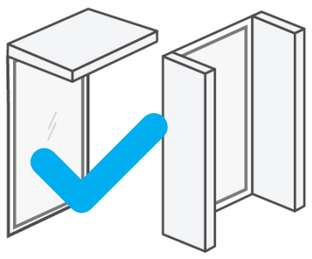

People


Process cooling

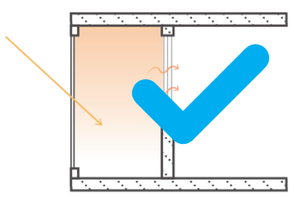

Process equipment

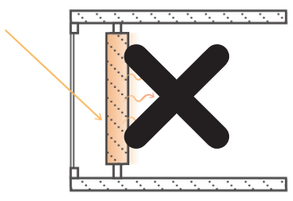

Openable window

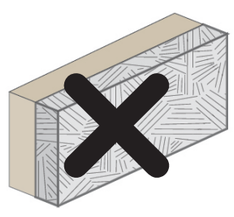

Solar Radiation


Exterior sun protection

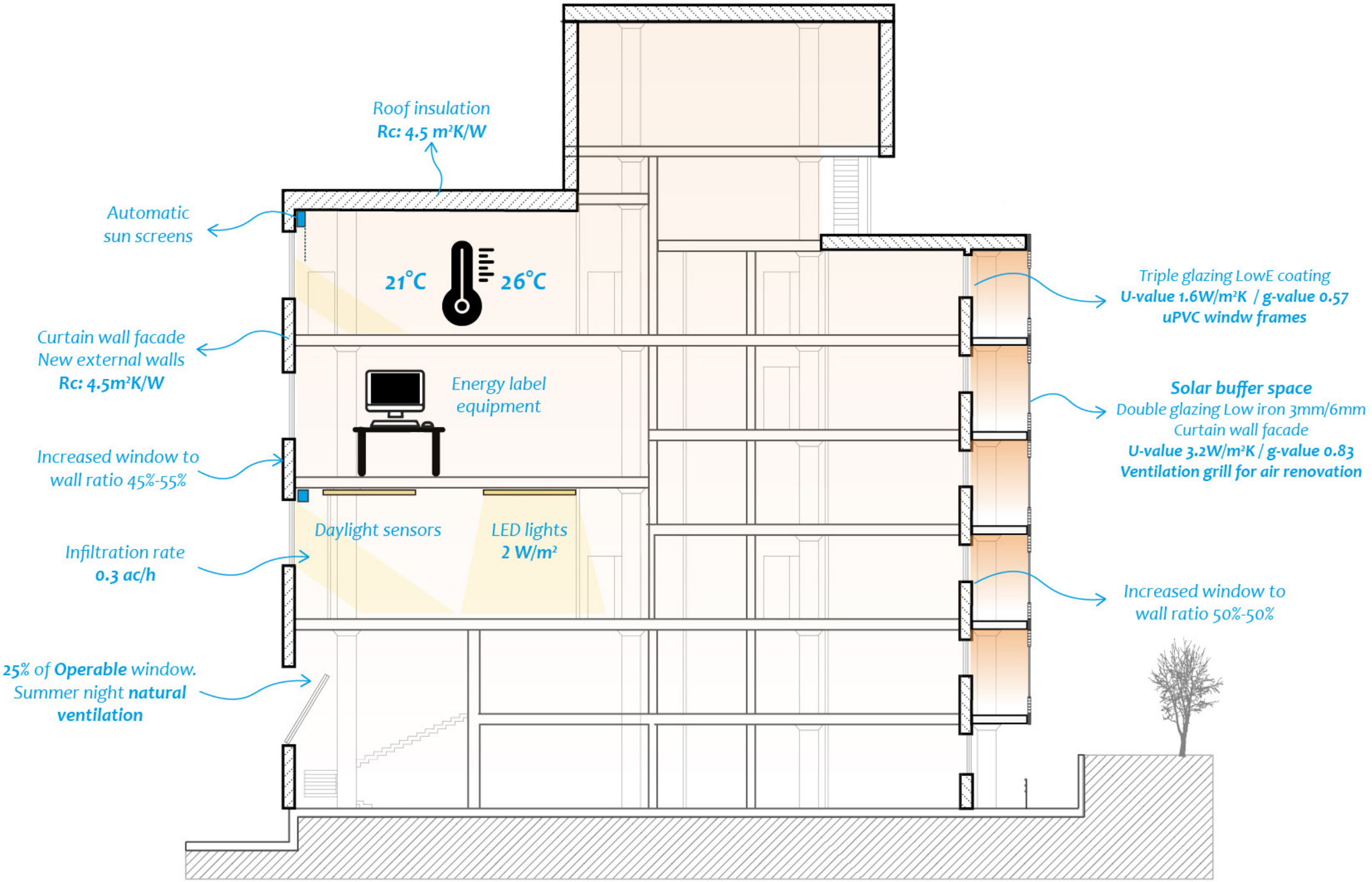

Air tightness


Solar buffer

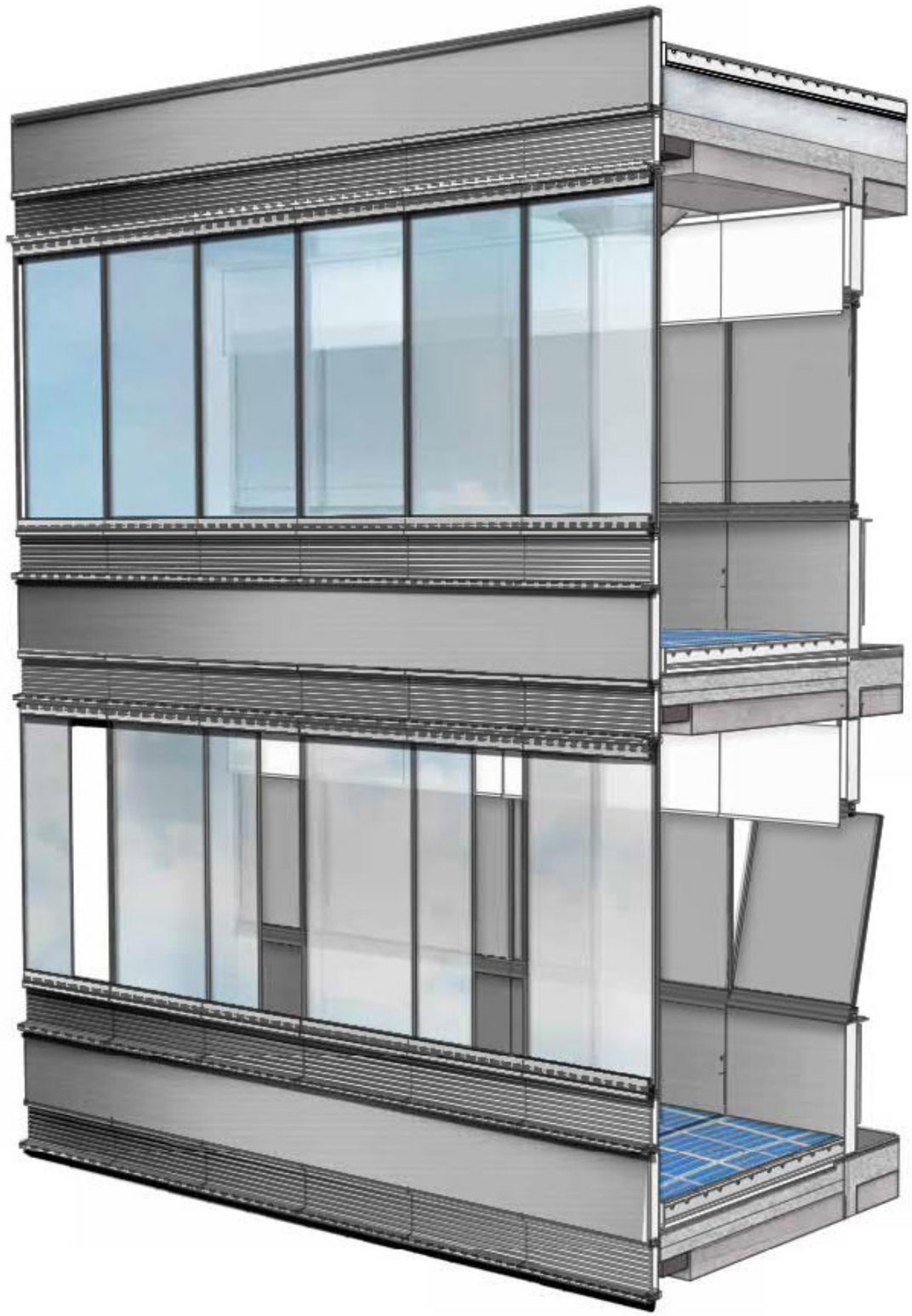

Trombe wall


PCM

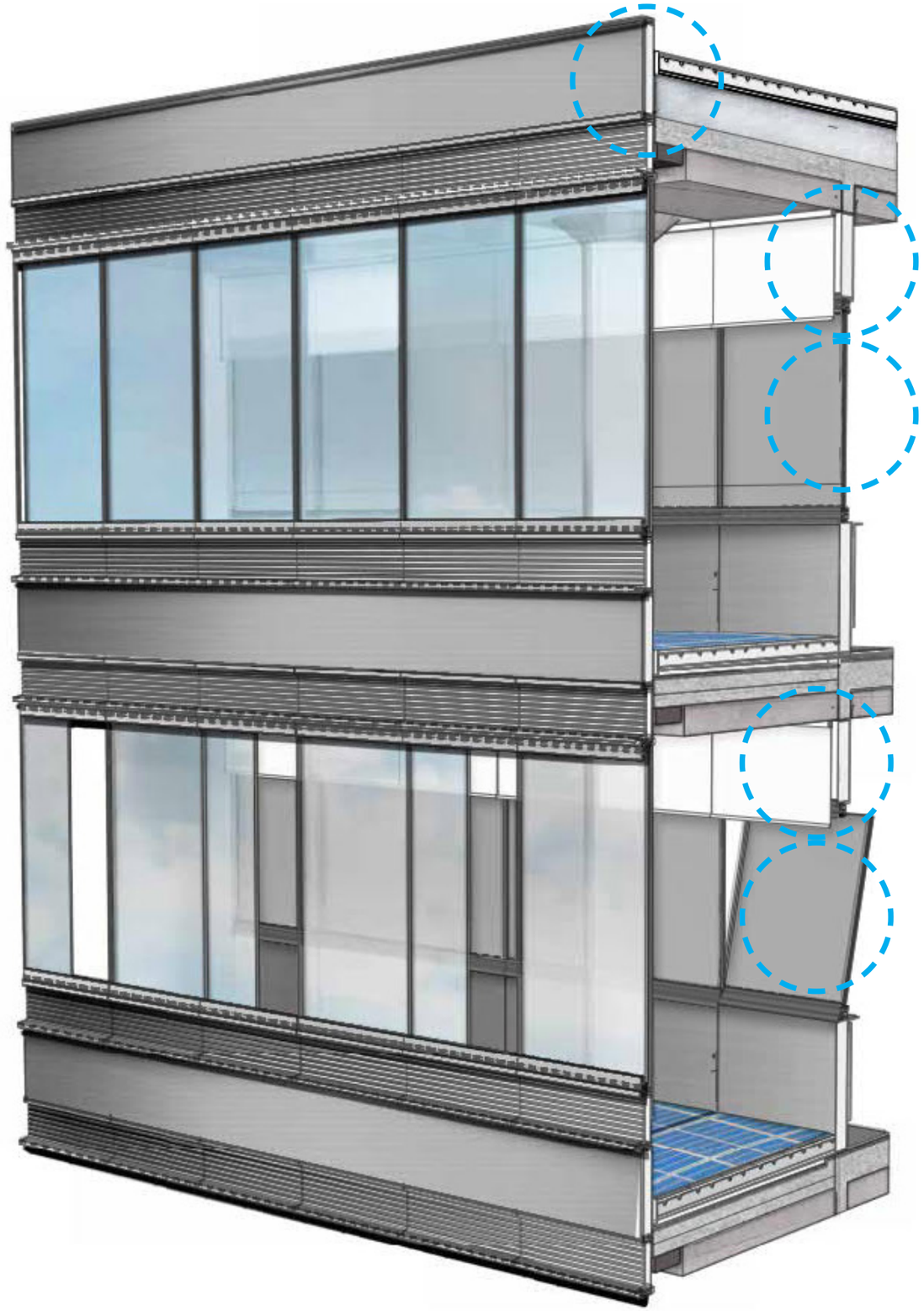
1

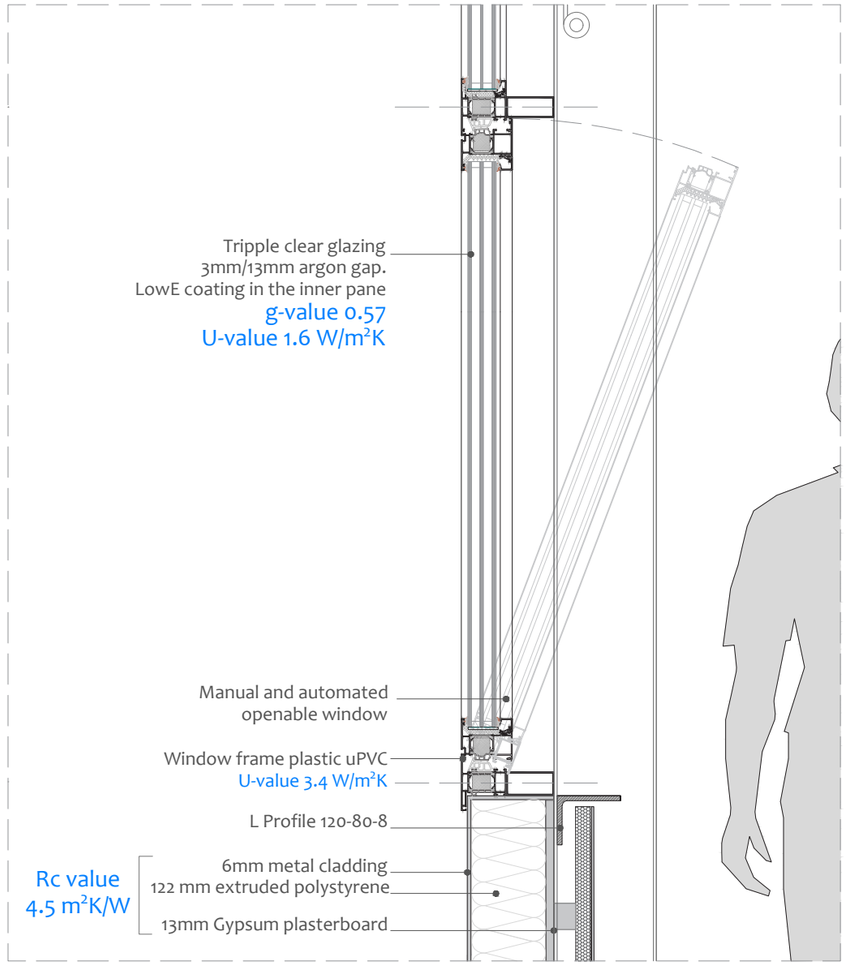

Roof insulation
Rc: 4.5 m²K/W
Automatic
sun screens
21°C
26°C
Curtain wall facade
New external walls
Rc: 4.5m²K/W
Energy label
equipment
Increased window to
wall ratio 45%-55%
Daylight sensors
LED lights
2 W/m²
Infiltration rate
0.3 ac/h
25% of Operable window.
Summer night natural
ventilation
Triple glazing LowE coating
U-value 1.6W/m²K / g-value 0.57
uPVC windw frames
Solar buffer space
Double glazing Low iron 3mm/6mm
Curtain wall facade
U-value 3.2W/m²K / g-value 0.83
Ventilation grill for air renovation
Increased window to
wall ratio 50%-50%

Renovation south façade

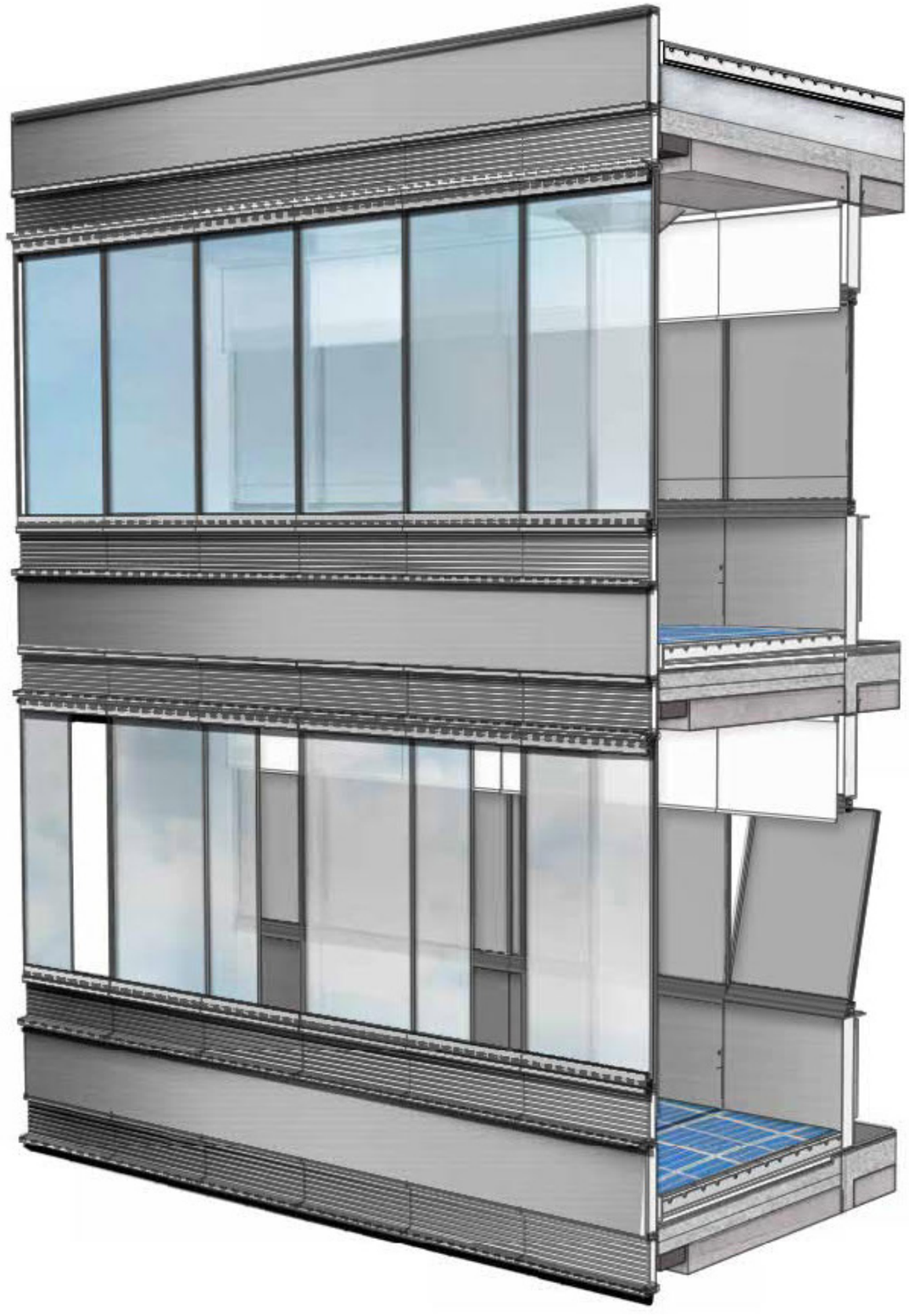


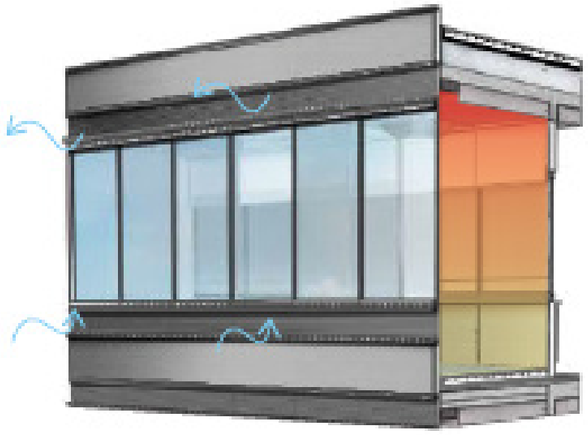
Renovation South façade





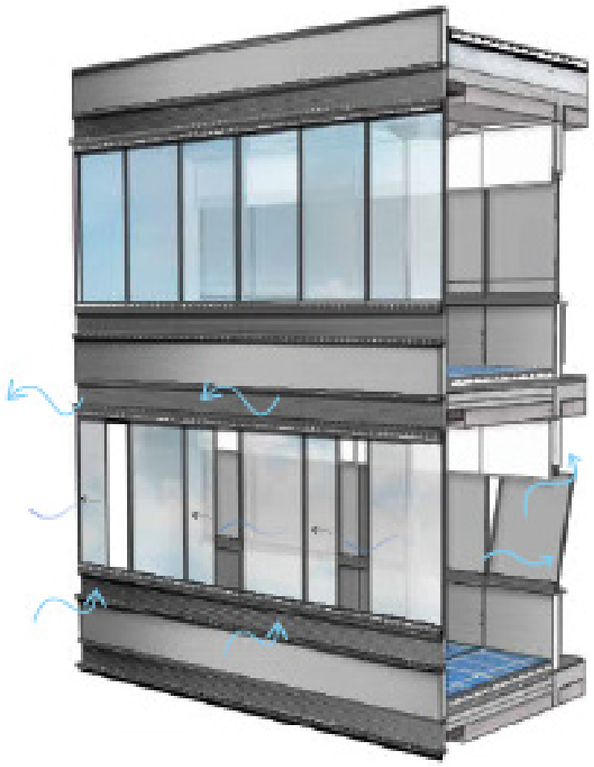
Renovation south façade



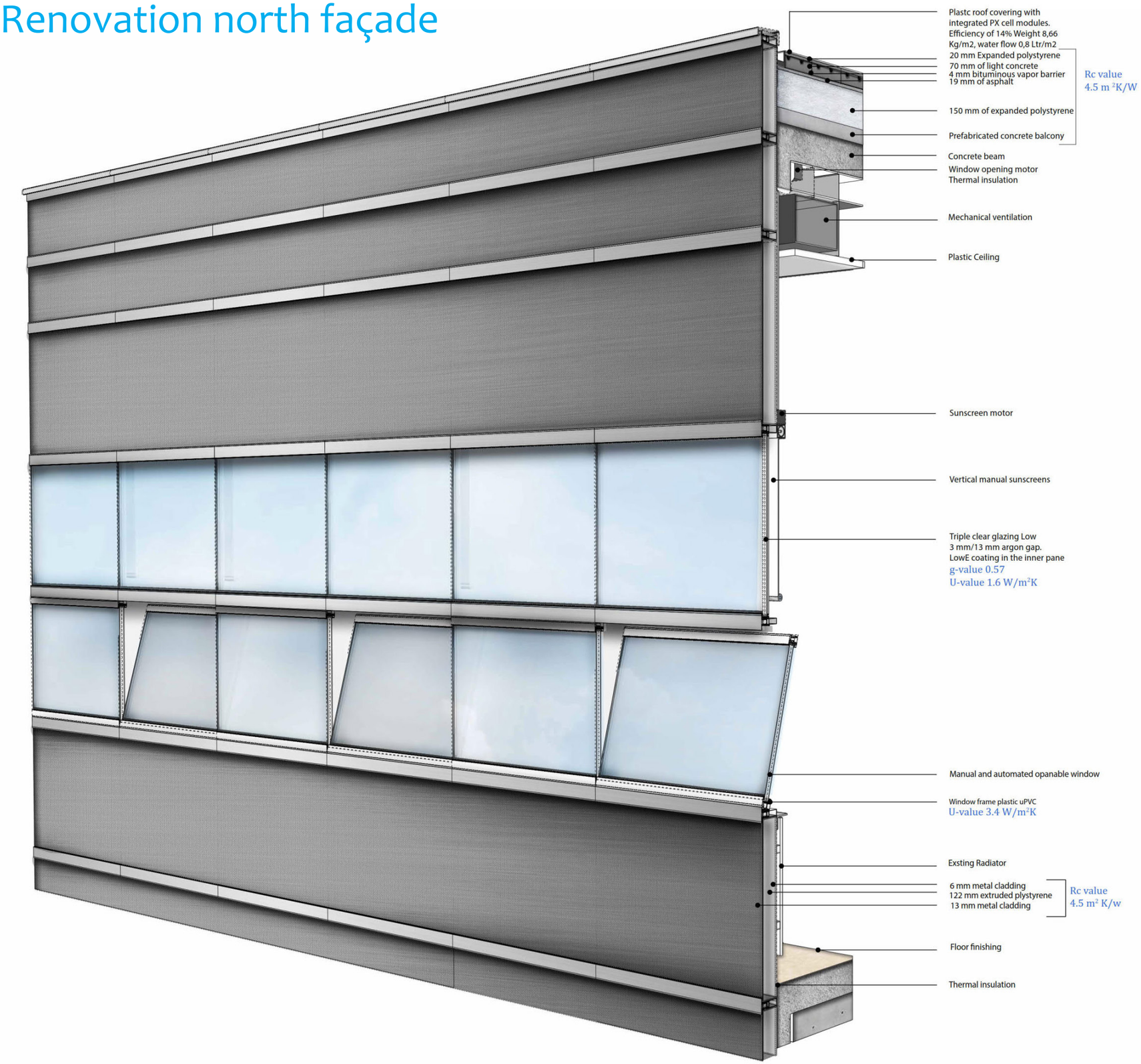


Winter situation

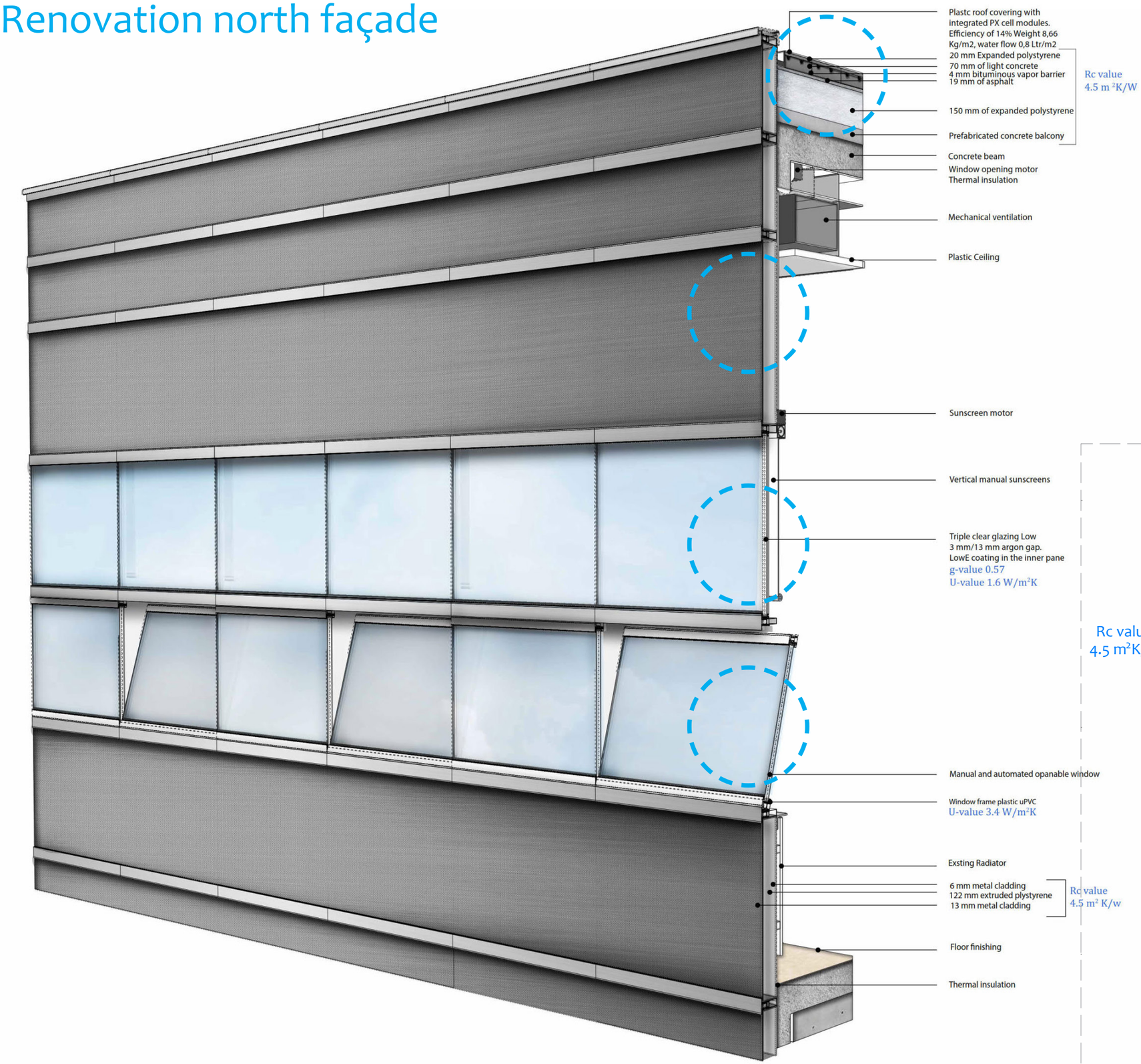
Renovation south façade

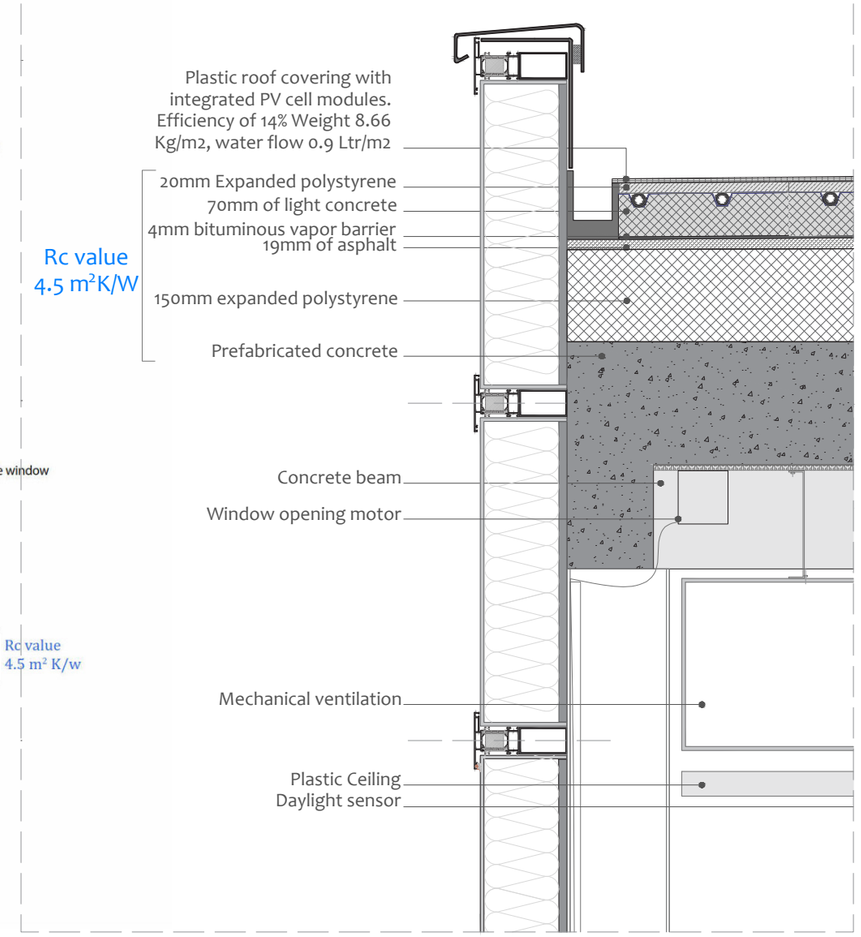


Renovation north façade

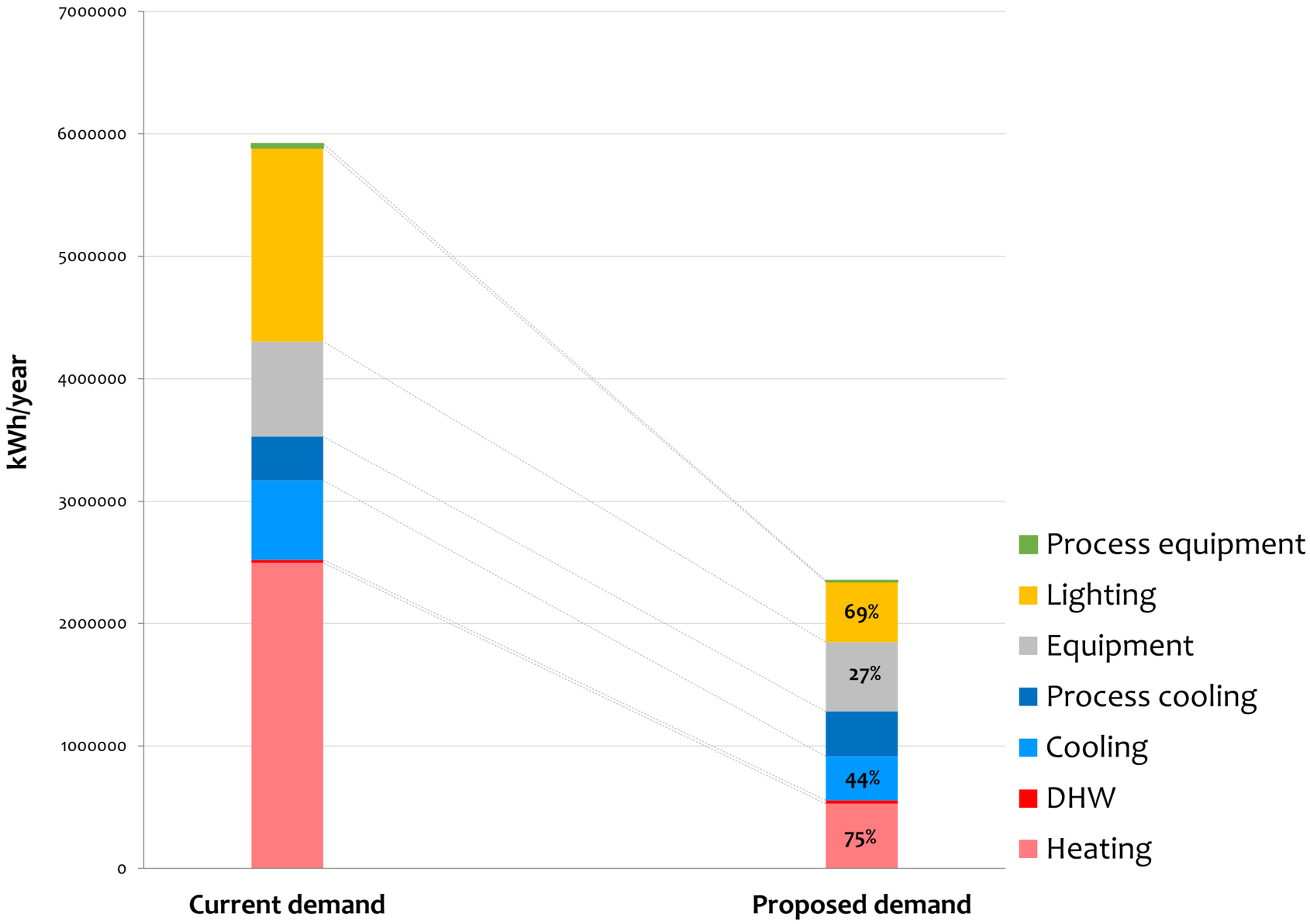


Renovation north façade

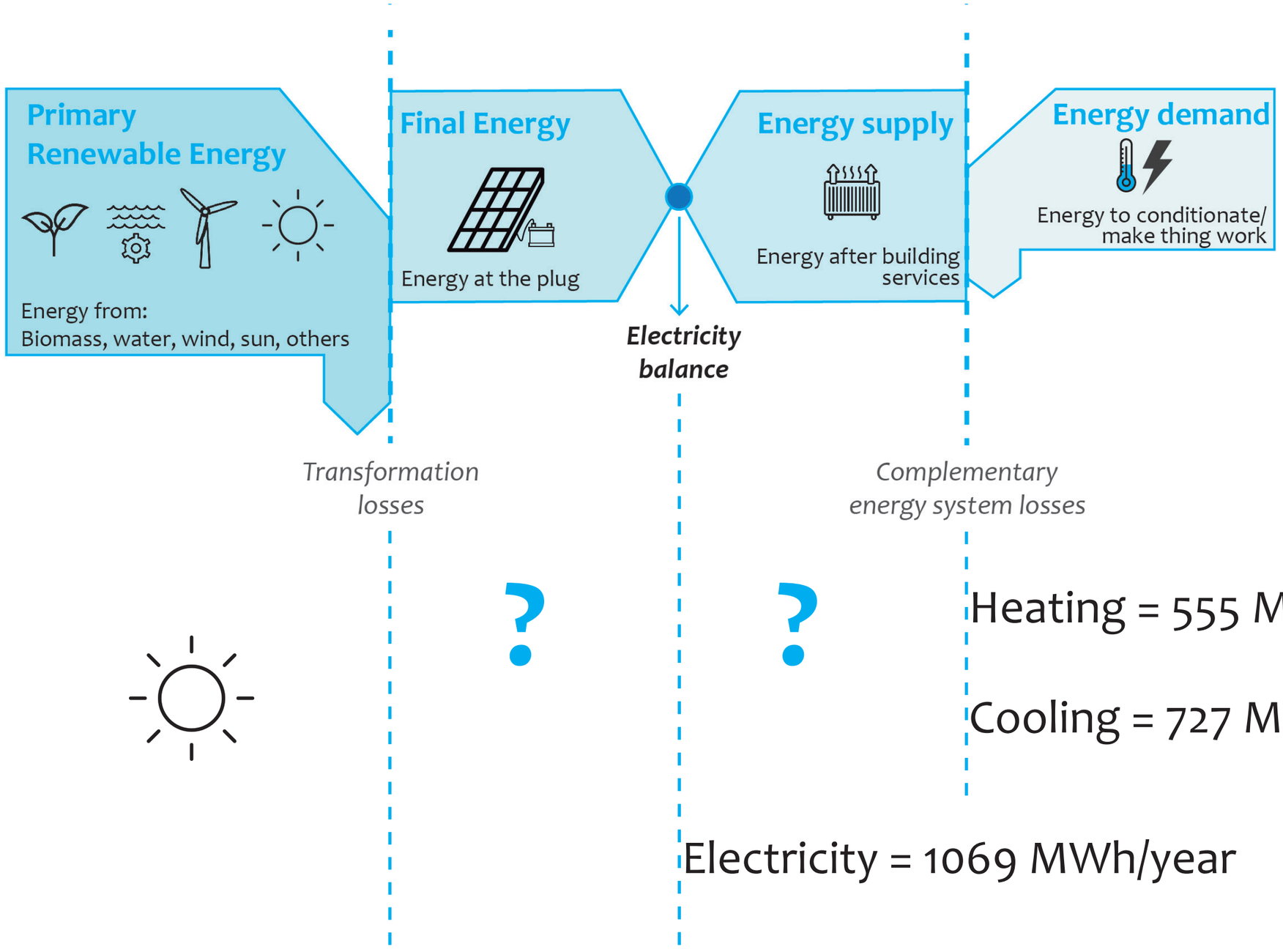




1 Demand reduction



1 Mismatch analysis



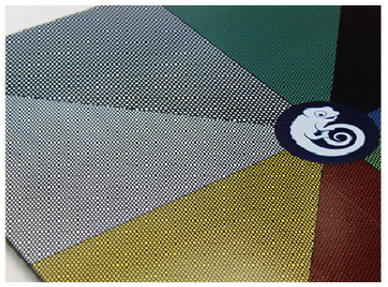
2 STEP
On-site energy production

2

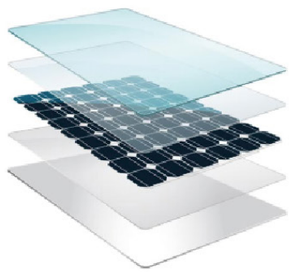
Flat plate collectors

Evacuated tube collectors

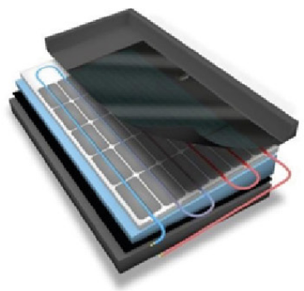
Concentrated solar power



Kameleon solar



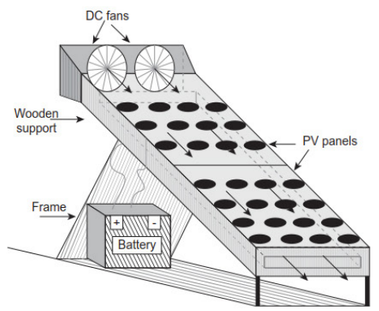
PV in glass



EnergieDak

PV in sunscreens

Monocrystalline



PV/T air

Heat and electricity for the building

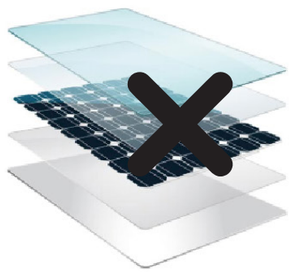
2

Flat plate collectors

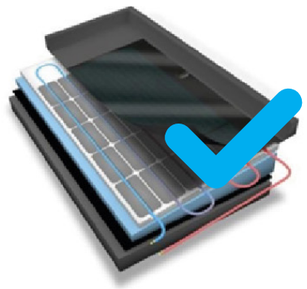
Evacuated tube collectors

Concentrated solar power

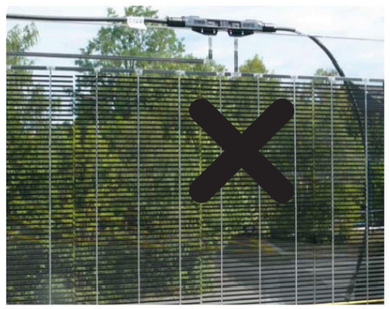
Kameleon solar



PV in glass

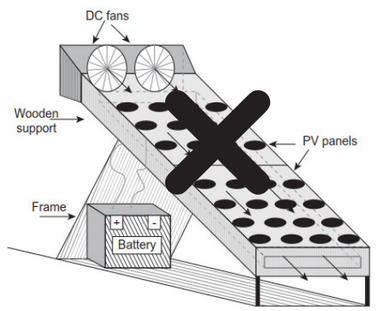


EnergieDak



PV in sunscreens

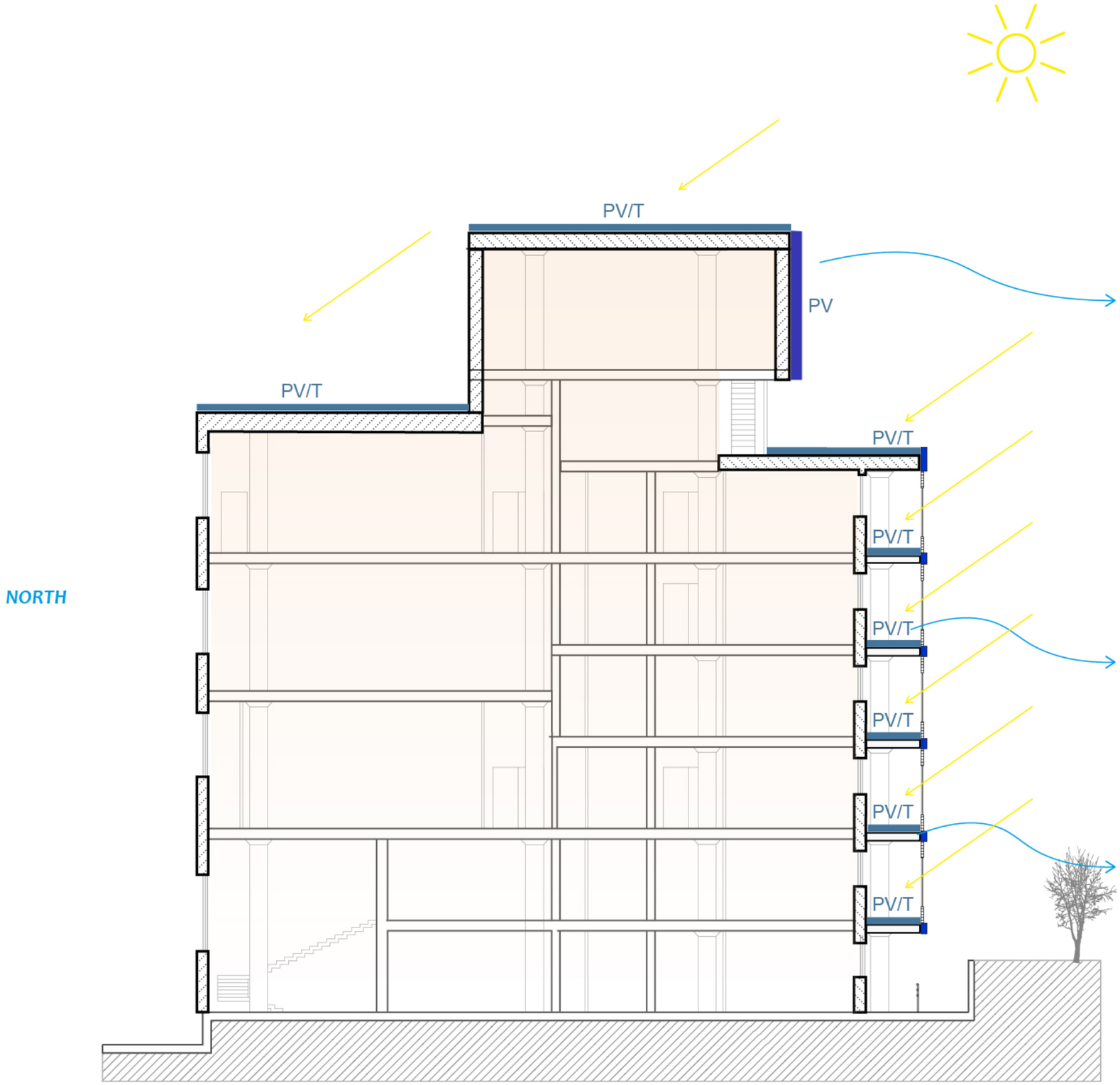
Monocrystalline



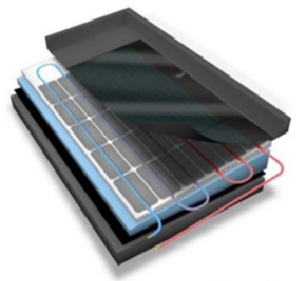
PV/T air

More integration with the building and building services

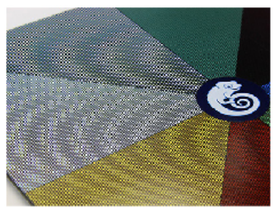
2



179m² *of Monocrystalline PV panel*
20% efficiency

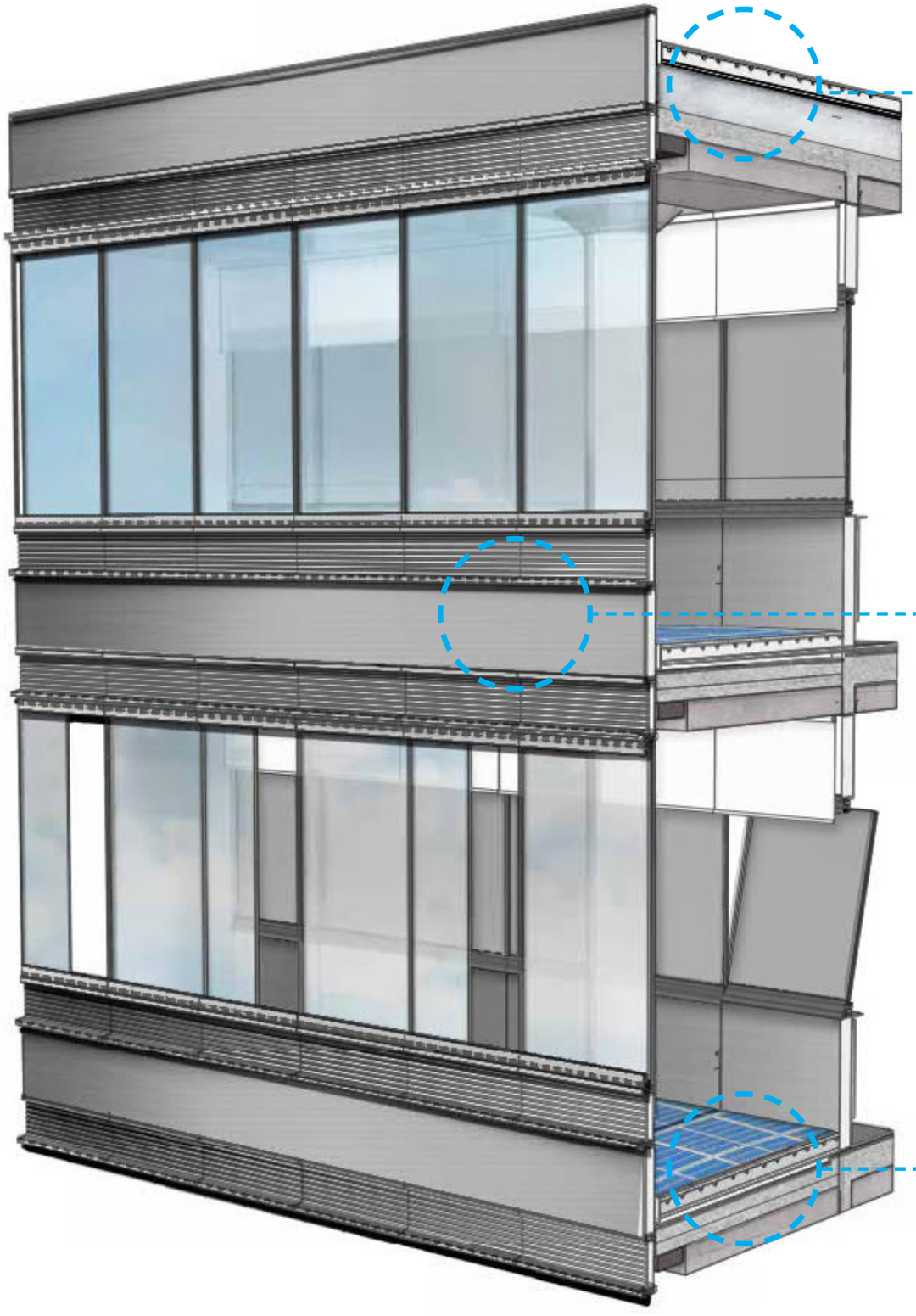


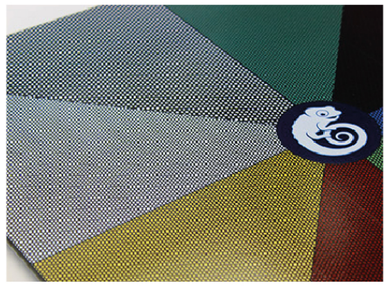
3422m² of EnergieDak Plus
PV + Solar thermal
PV 16% & ST 45% efficiency



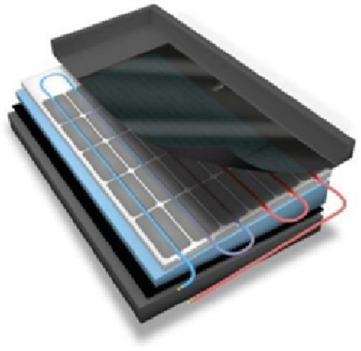
522m² of Kameleon solar
PV glazing
14% efficiency

Renovation south façade

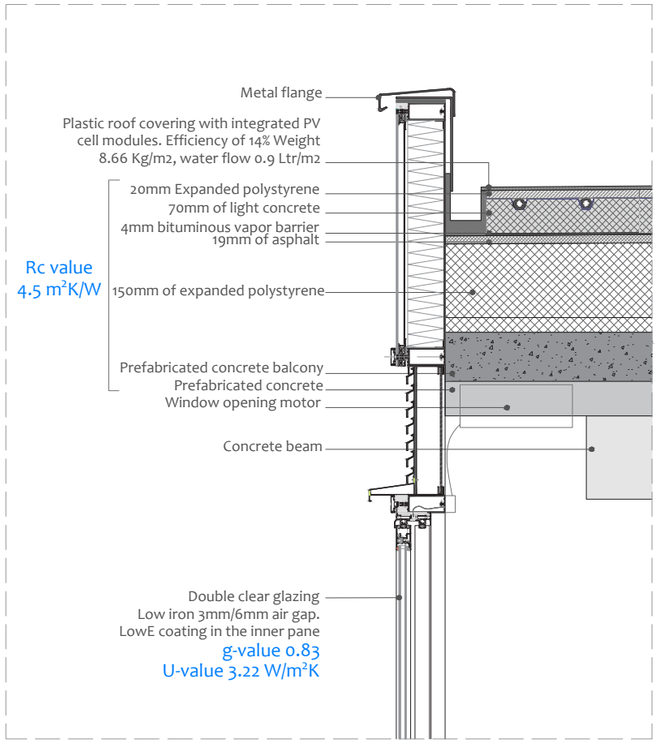


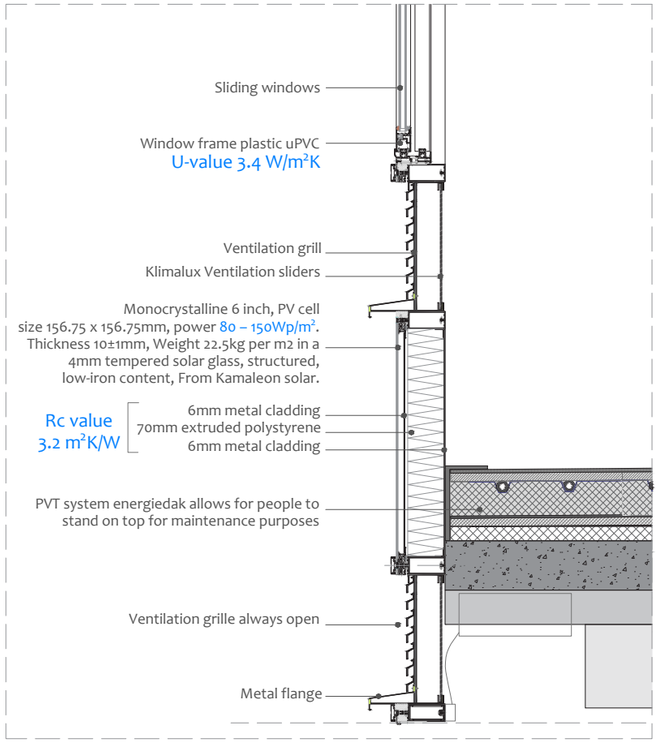


Kameleon solar

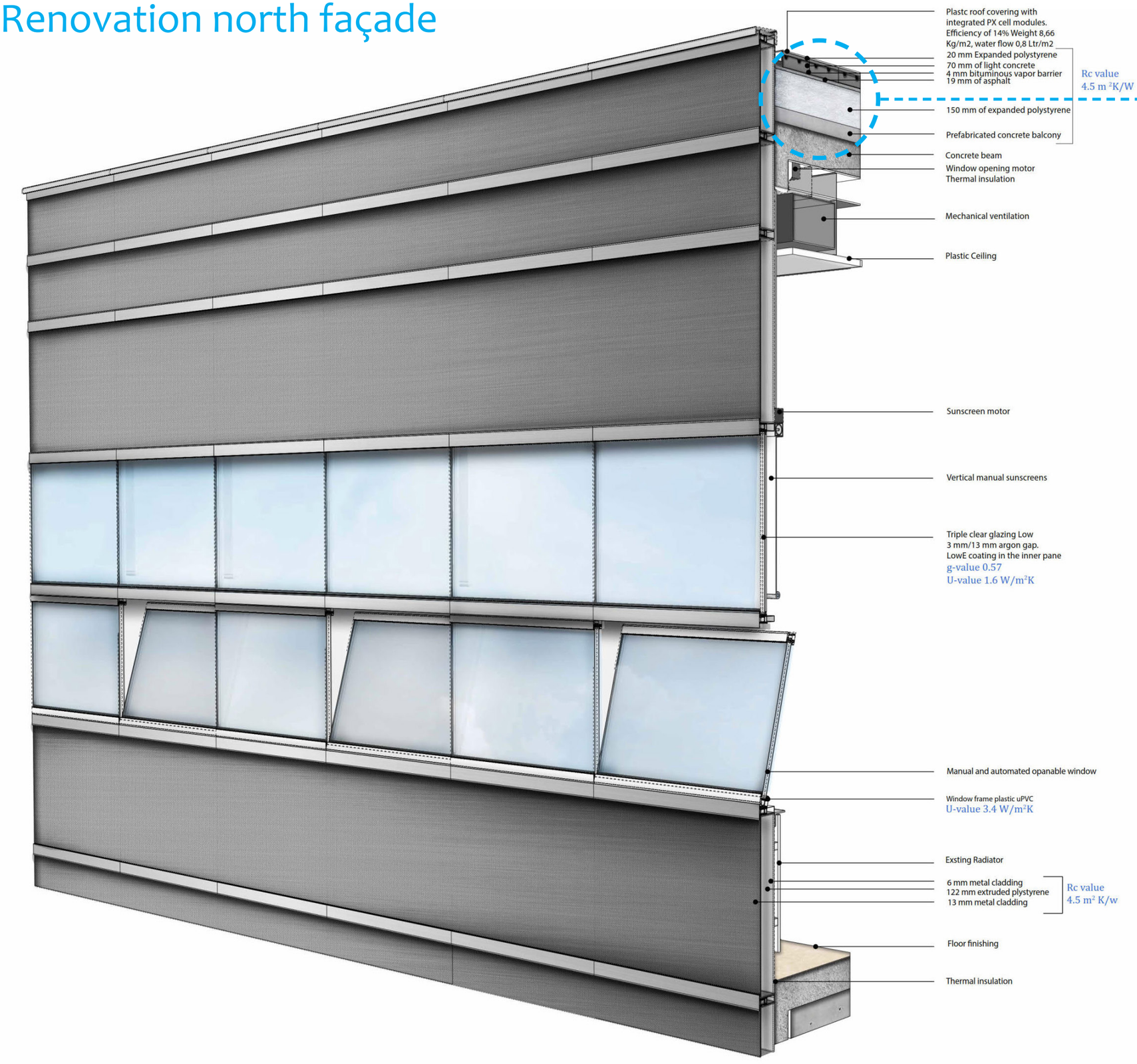


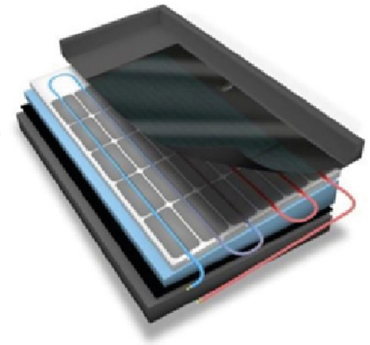
EnergieDak





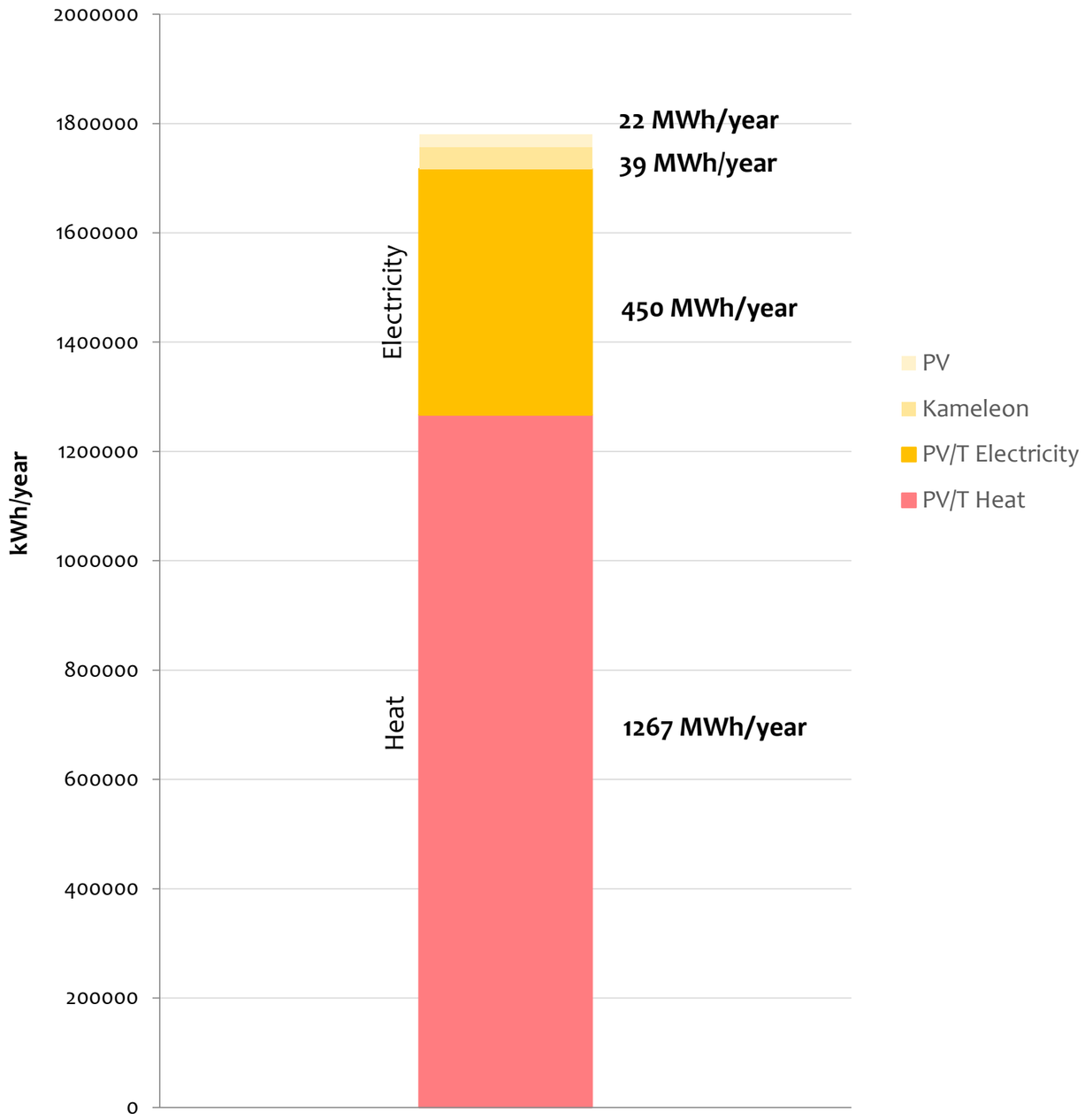
Renovation north façade



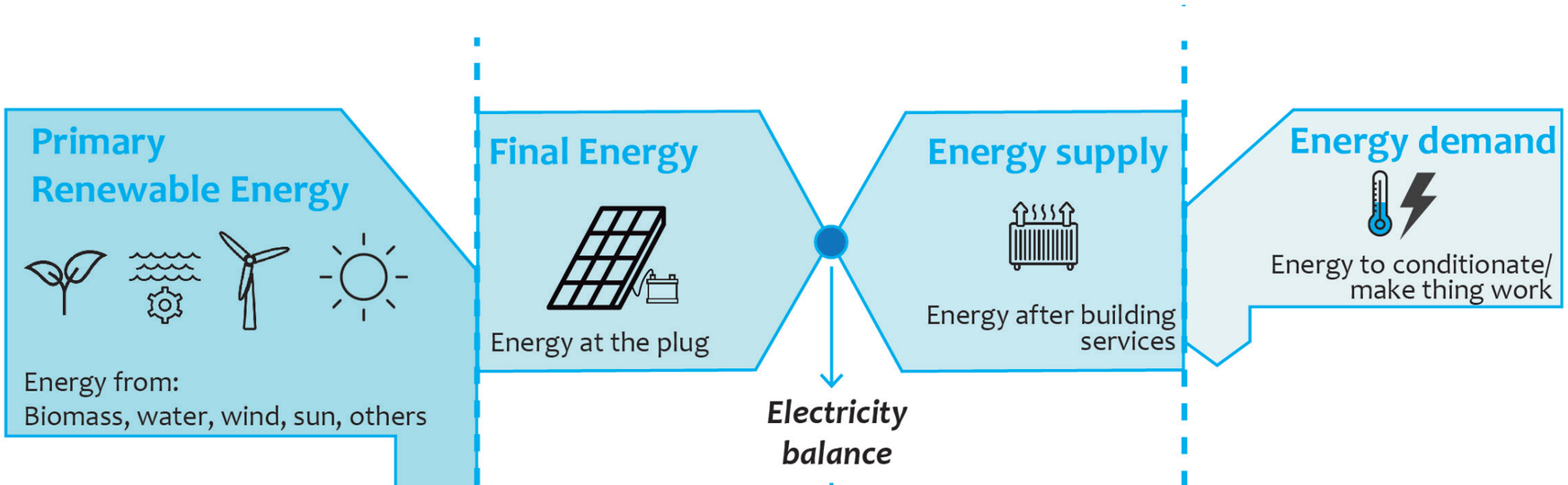


EnergieDak

2 On-site energy production



2 Mismatch analysis



1267 MWh/year = Heating

?

Heating = 555 MWh/year

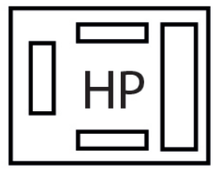
Cooling = 727 MWh/year

512 MWh/year = Electricity

Electricity = 1069 MWh/year

3 STEP
Complementary energy system

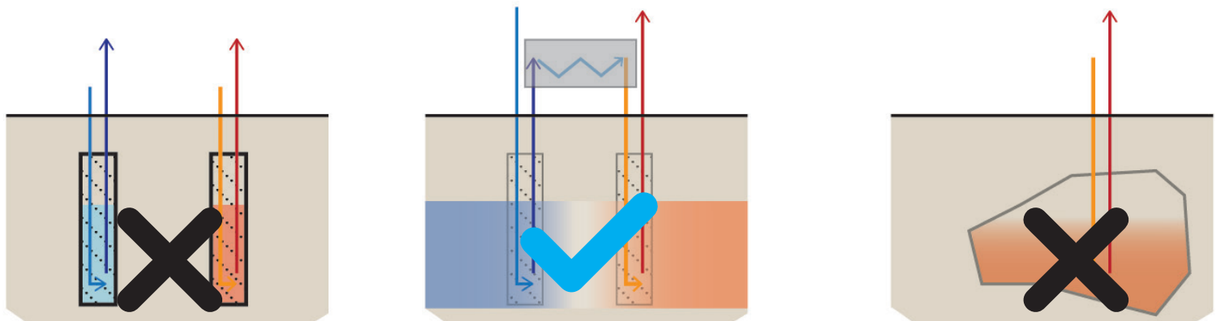
3



Heat pump

Transforming energy for the building

3



Heat exchanger

ATES

Cavern storage

Water tank

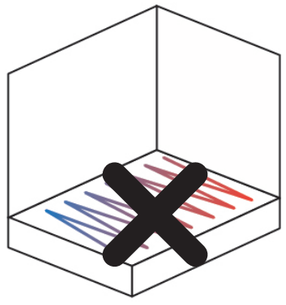
Chemical storage

Electrical Battery

Storing energy in the building

3

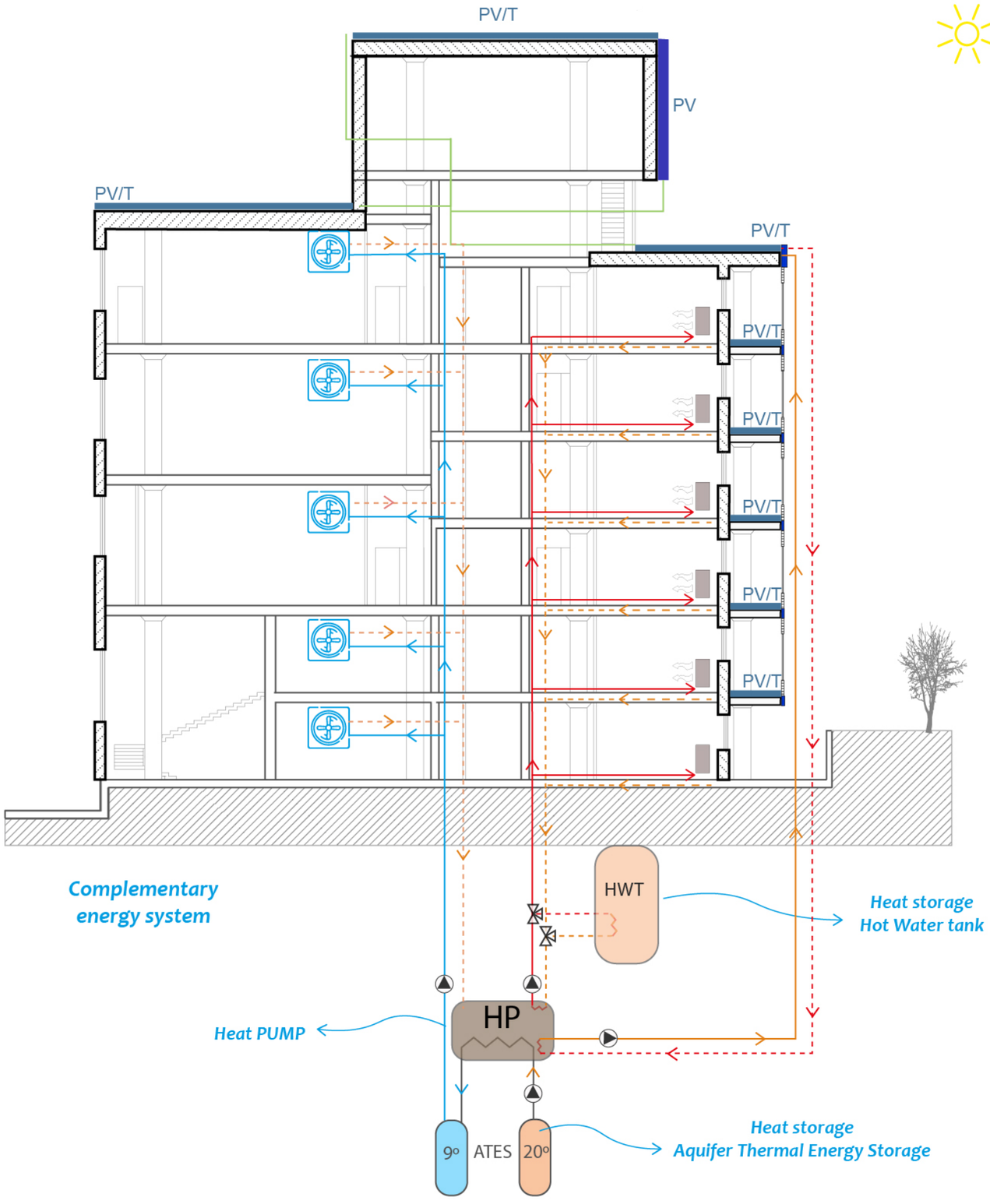
Radiator



Floor/wall heating

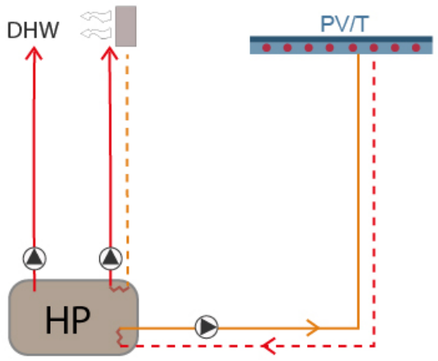
Distributing energy in the building

3

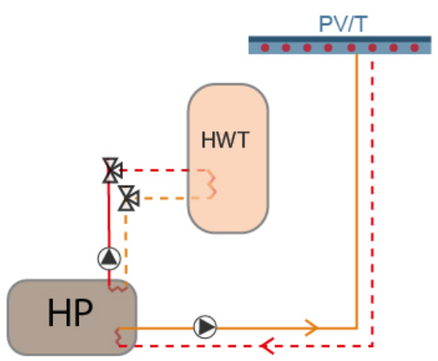

PV/T
PV
PV/T
PV/T
PV/T
PV/T
PV/T
Complementary energy system
HWT
Heat storage Hot Water tank
HP
Heat PUMP
9º
ATES
20º
Heat storage Aquifer Thermal Energy Storage

3

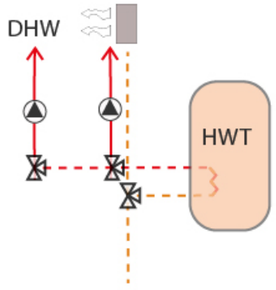
1. Solar Heat production



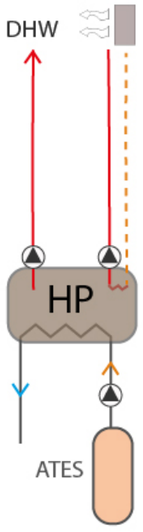
2. Surplus of heat



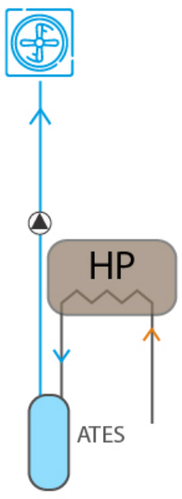
3. Heat storage



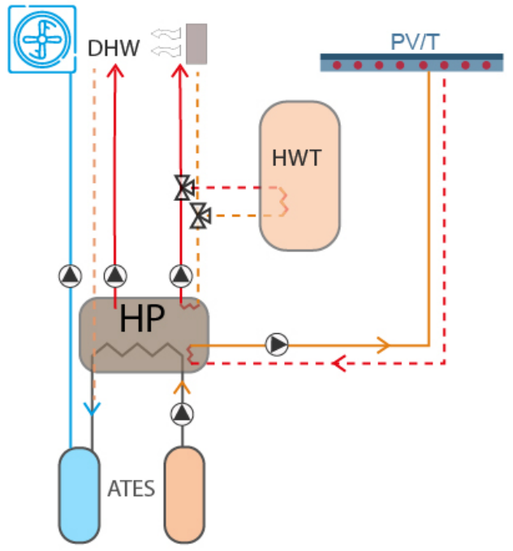
4. No heat production, no storage



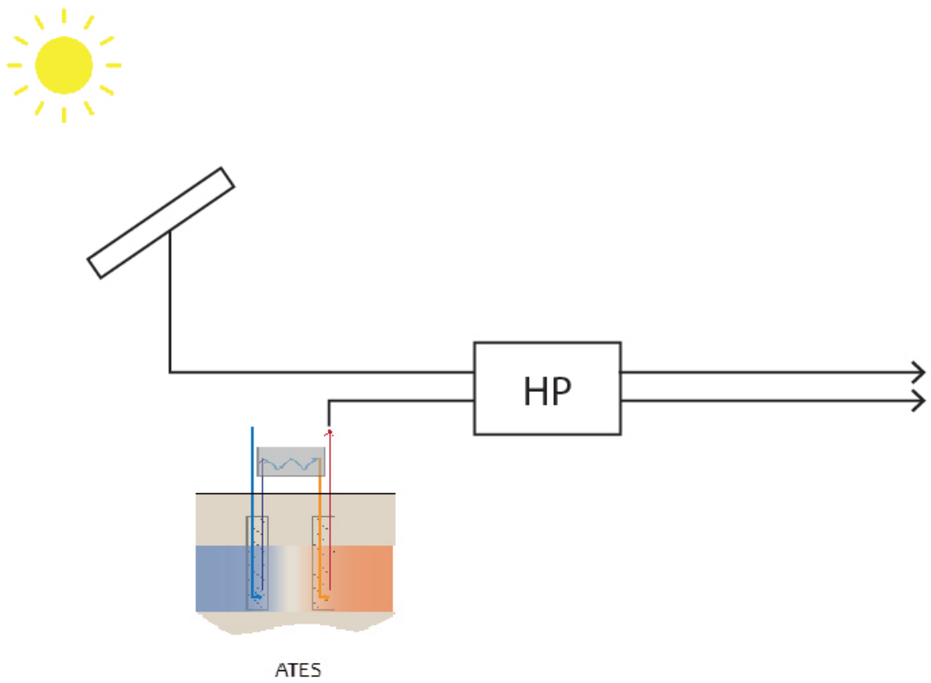
Cooling mode



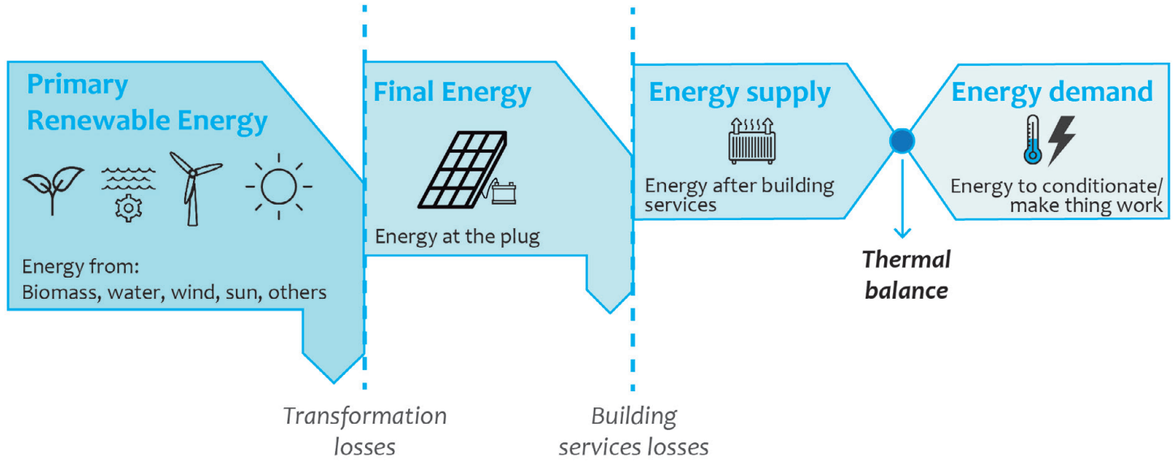
Complementary energy system



3 Complementary energy system Without Storage

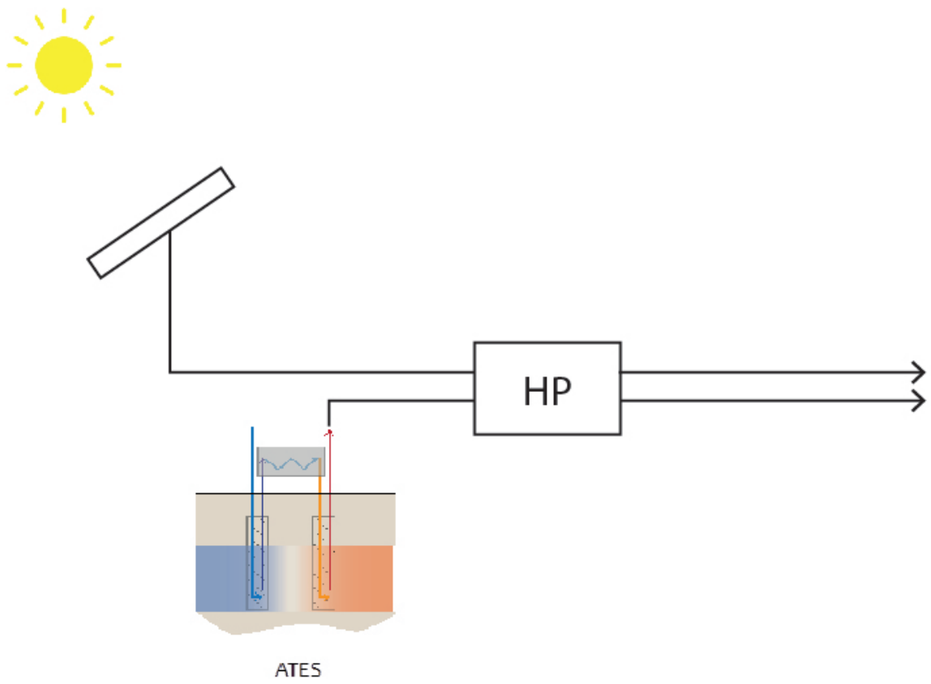


Thermal balance

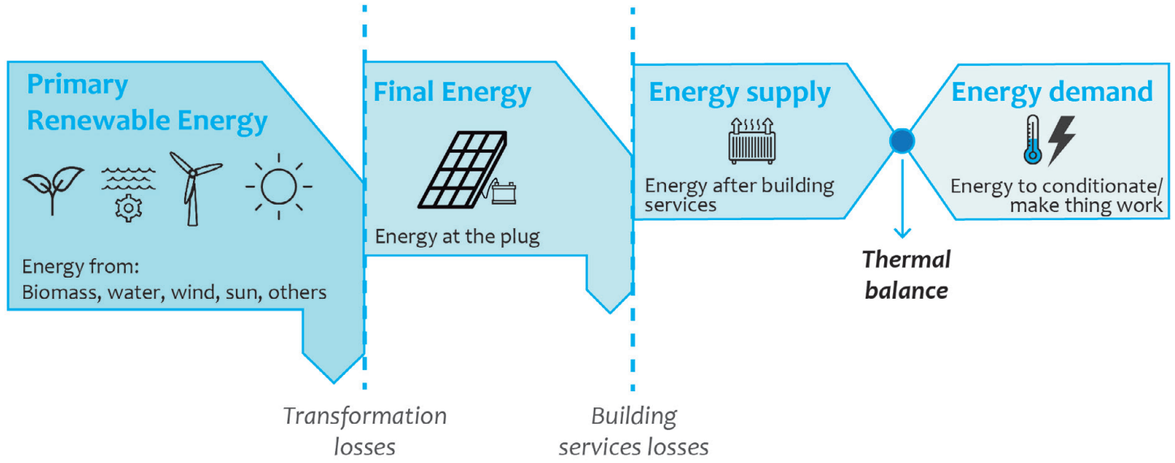


$$\sum_{t=1}^{t=8760} |1600\ \text{MWh}\ (8760\text{h}) - 555\ \text{MWh}\ (8760\text{h})| = 1044\ MWh\ (8760h)$$

3 Complementary energy system Without Storage



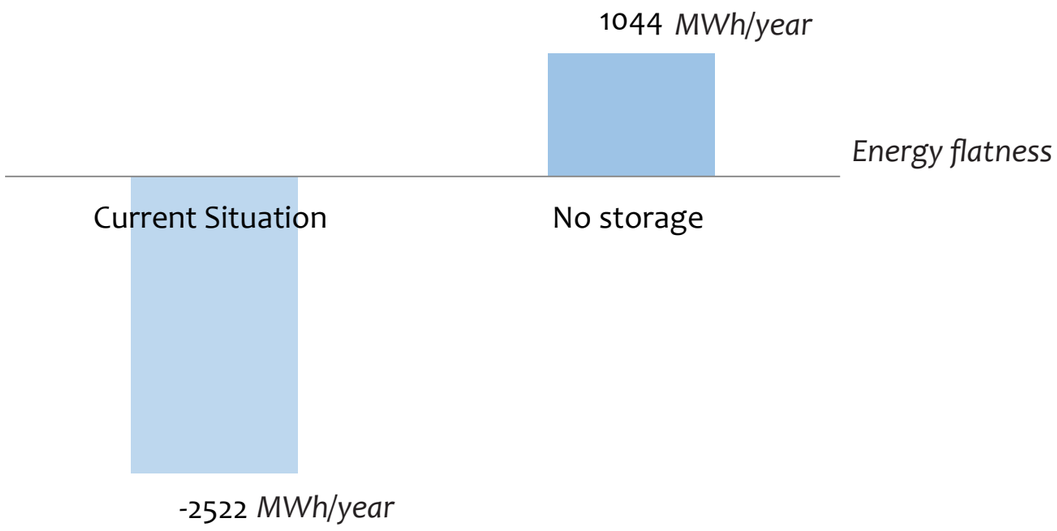
Thermal balance



$$\sum_{t=1}^{t=8760} |1600\ \text{MWh}\ (8760\text{h}) - 555\ \text{MWh}\ (8760\text{h})| = 1044\ MWh\ (8760h)$$

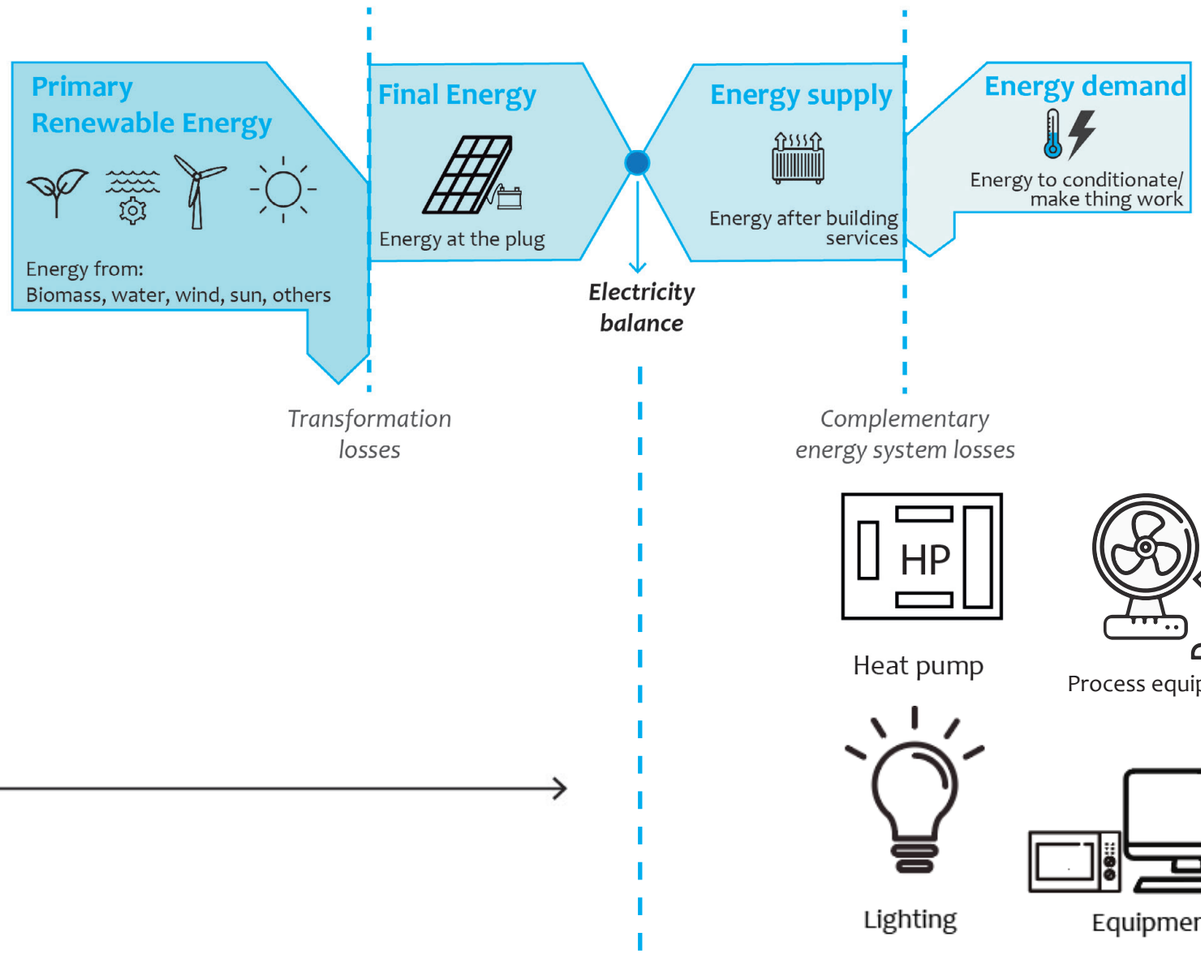
Positive mismatch
Storage potential

140%



3 Complementary energy system Without Storage

Electricity balance

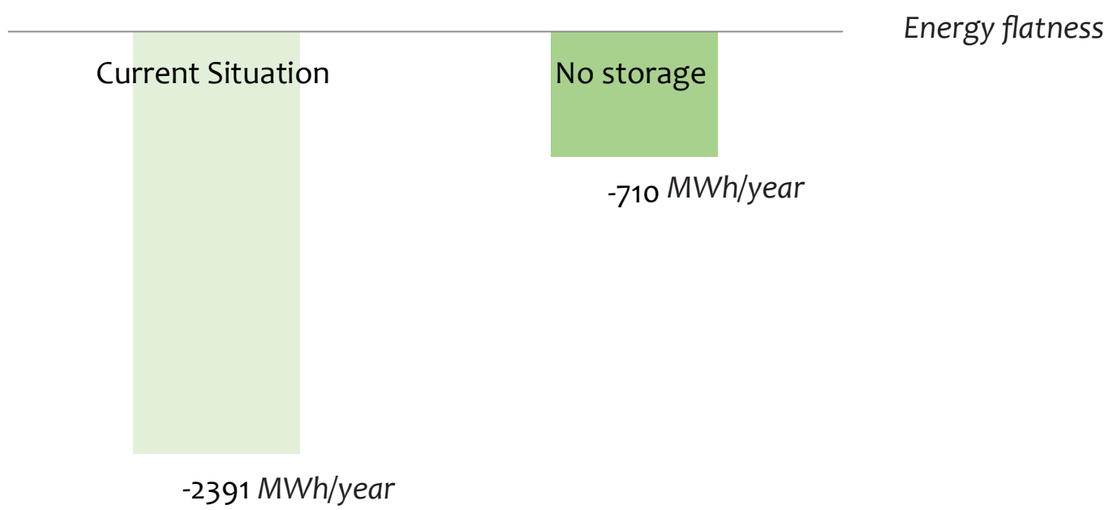


$$\sum_{t=1}^{t=8760} \left| 512\ MWh_{(8760h)} - 1222 MWh_{(8760h)} \right| = -710\ MWh\ (8760h)$$

3 Complementary energy system Without Storage

Electricity balance

70%



Negative mismatch
Shortage of energy

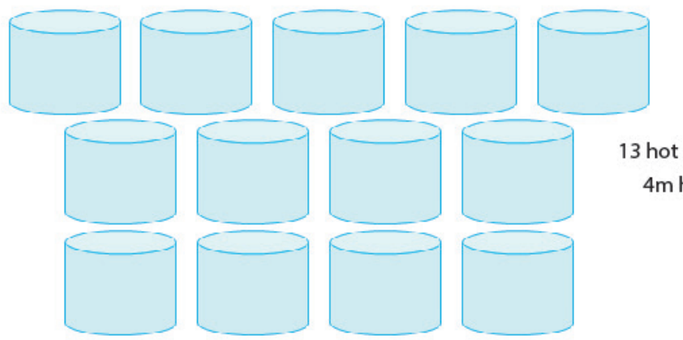
$$\sum_{t=1}^{t=8760} \left| 512\ MWh_{(8760h)} - 1222 MWh_{(8760h)} \right| = -710\ MWh\ (8760h)$$

3 Complementary energy system With Storage

$h = V / \pi r^2$

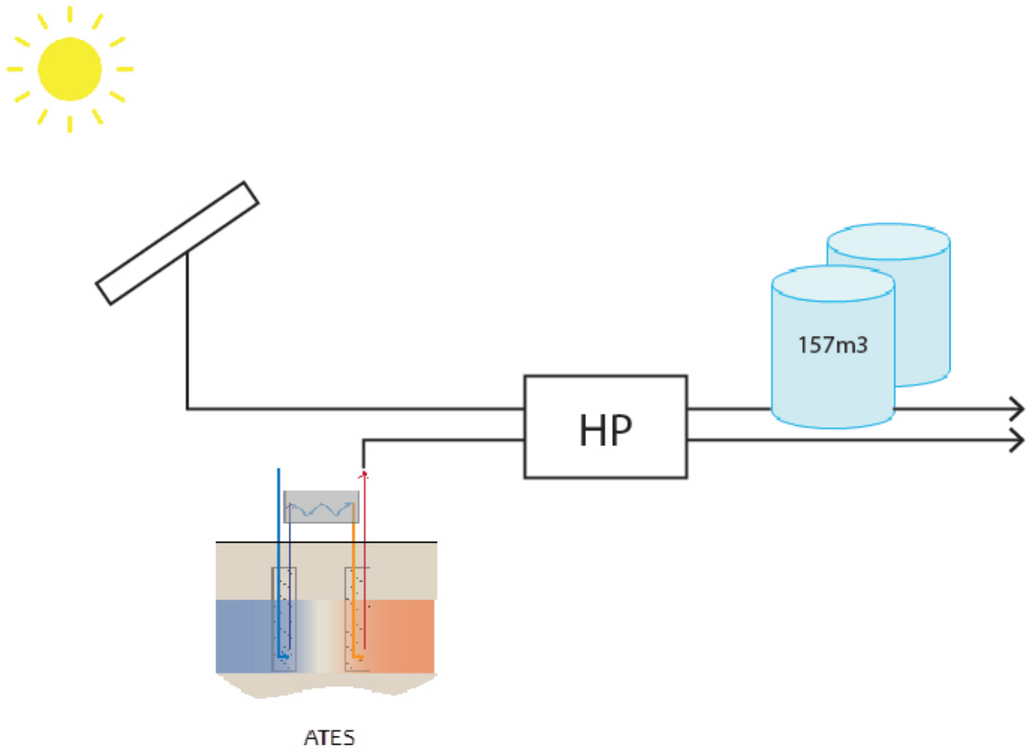
$h = 1047m^3 / \pi (2.5m)^2$

$h = 53.3\ m$

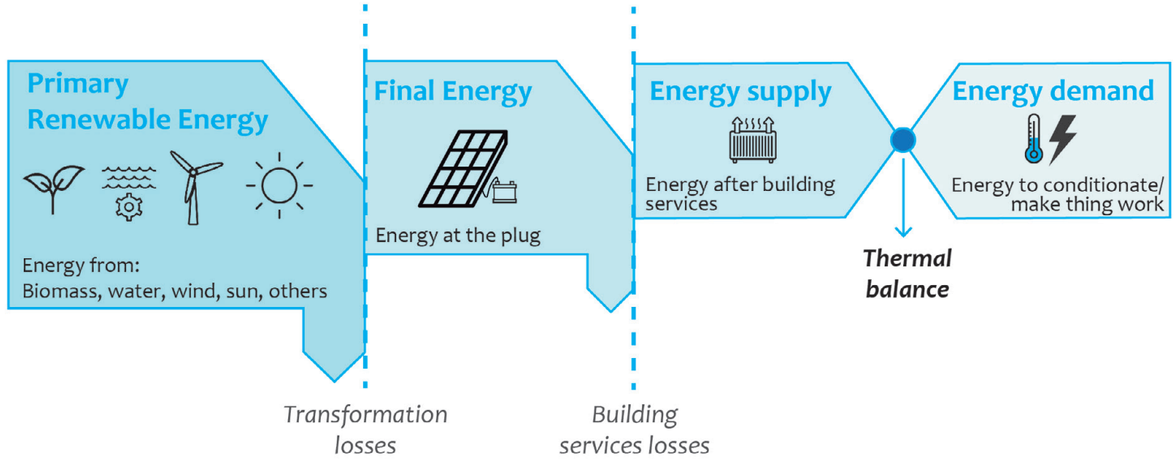


13 hot water tanks of 4m height each

3 Complementary energy system With Storage

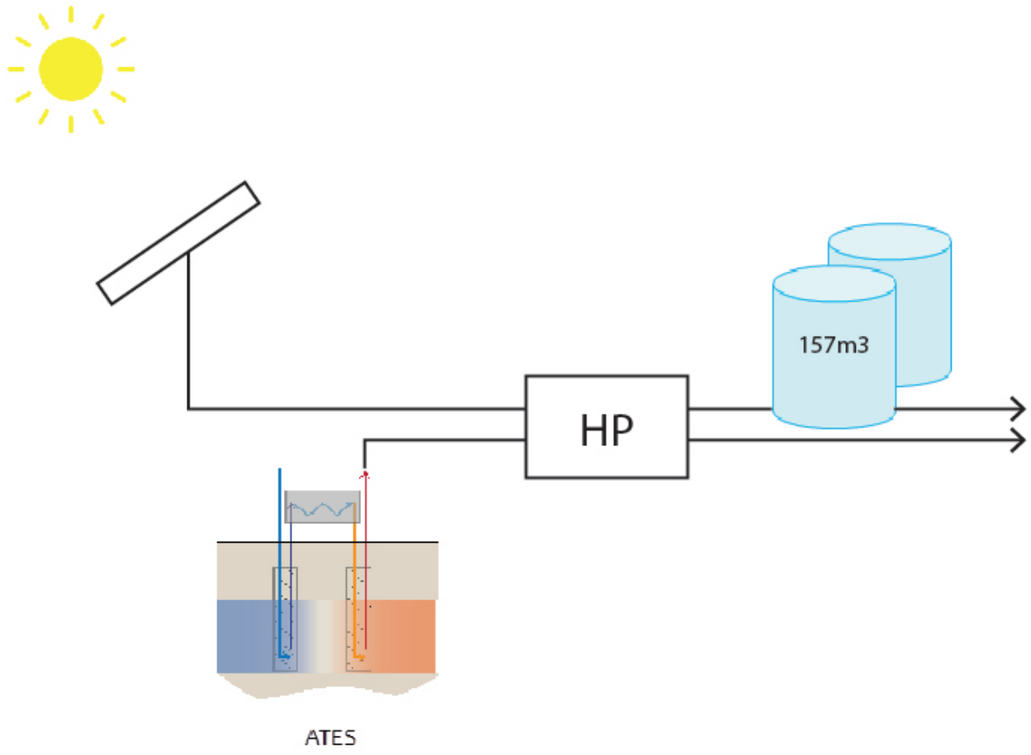


Thermal balance

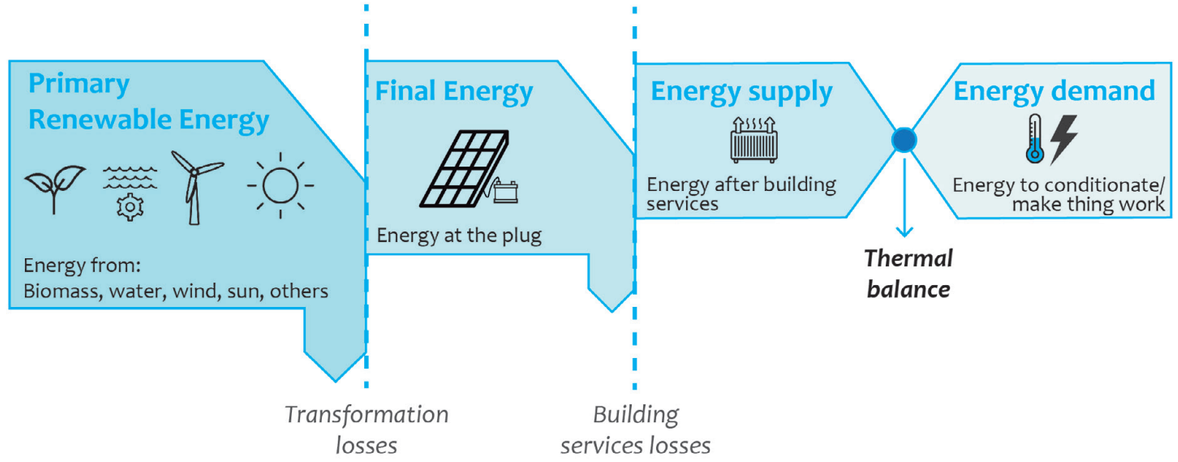


$$\sum_{t=1}^{t=8760} \left|1066\ MWh_{(8760h)} - 555\ MWh_{(8760h)}\right| = 511\ MWh\ (8760h)$$

3 Complementary energy system With Storage



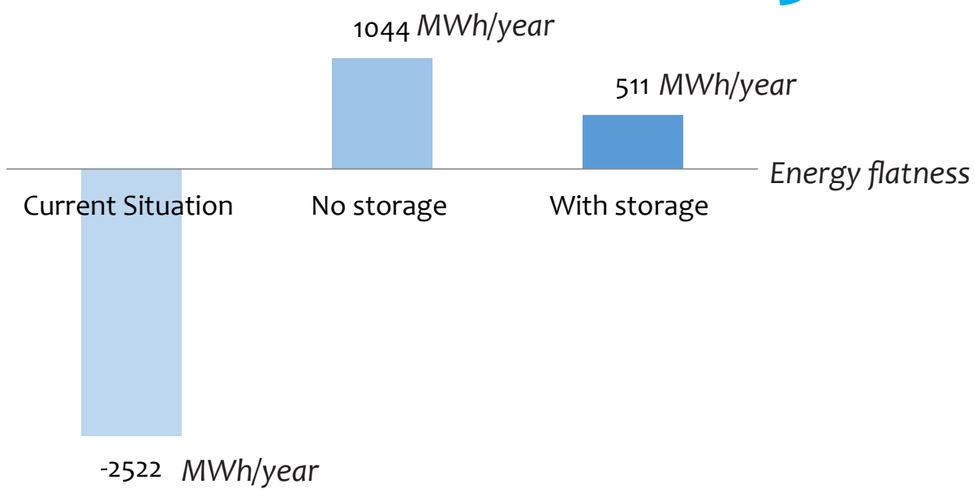
Thermal balance



$$\sum_{t=1}^{t=8760} \left|1066\ MWh_{(8760h)} - 555\ MWh_{(8760h)}\right| = 511\ MWh\ (8760h)$$

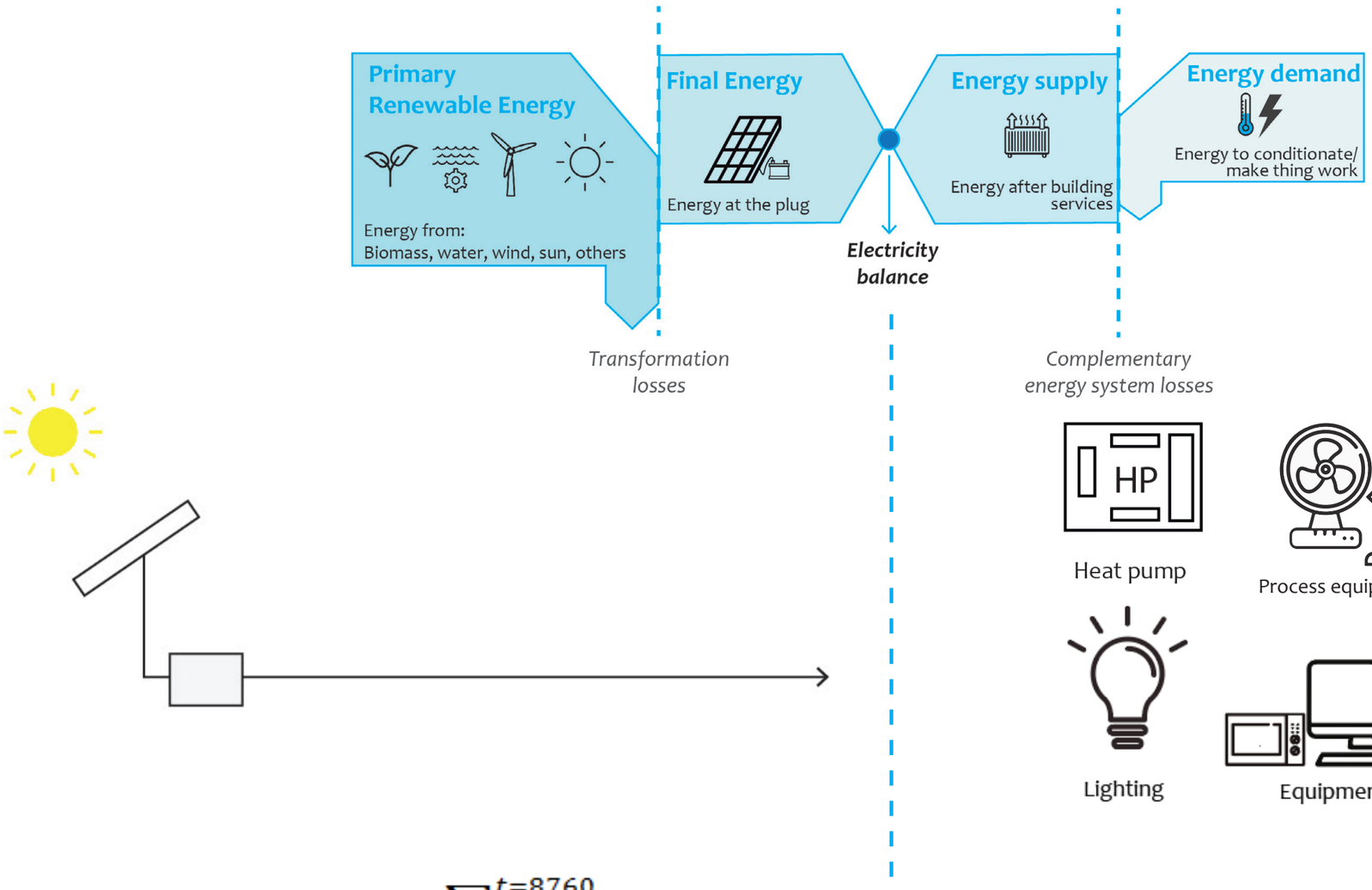
Positive mismatch
Energy export

51%



3 Complementary energy system With Storage

Electricity balance

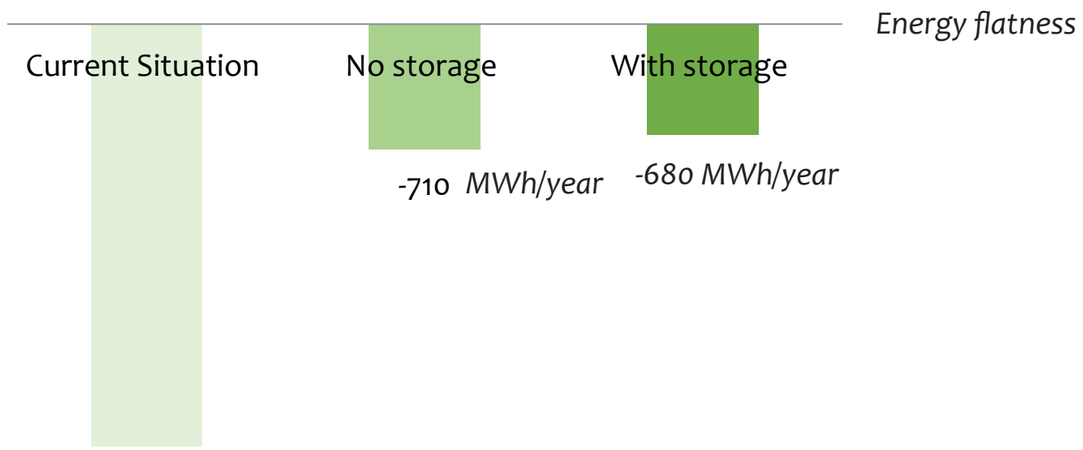


$$\sum_{t=1}^{t=8760} \left| 512\ MWh_{(8760h)} - 1192_{(8760h)} \right| = -680\ MWh\ (8760h)$$

3 Complementary energy system With Storage

Electricity balance

11%



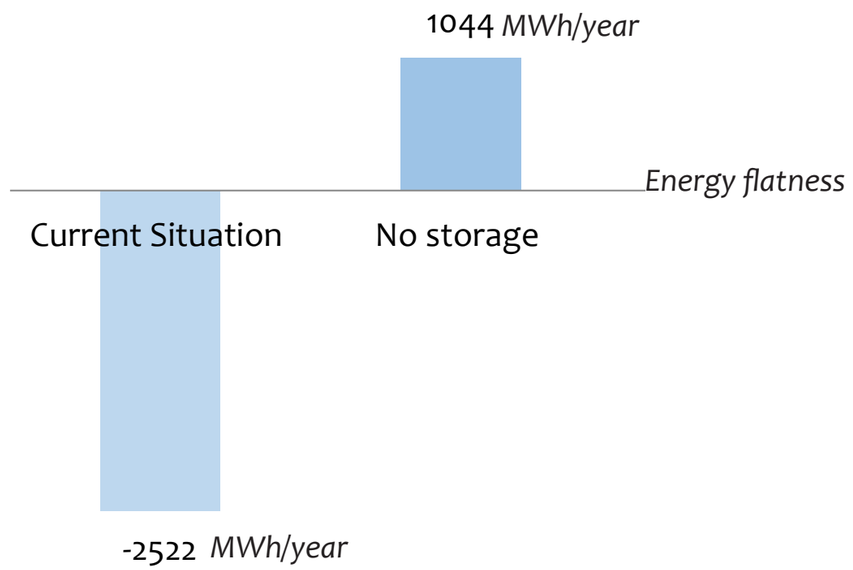
Negative mismatch
Shortage of energy

$$\sum_{t=1}^{t=8760} \left| 512\ MWh_{(8760h)} - 1192_{(8760h)} \right| = -680\ MWh\ (8760h)$$

3 Final mismatch

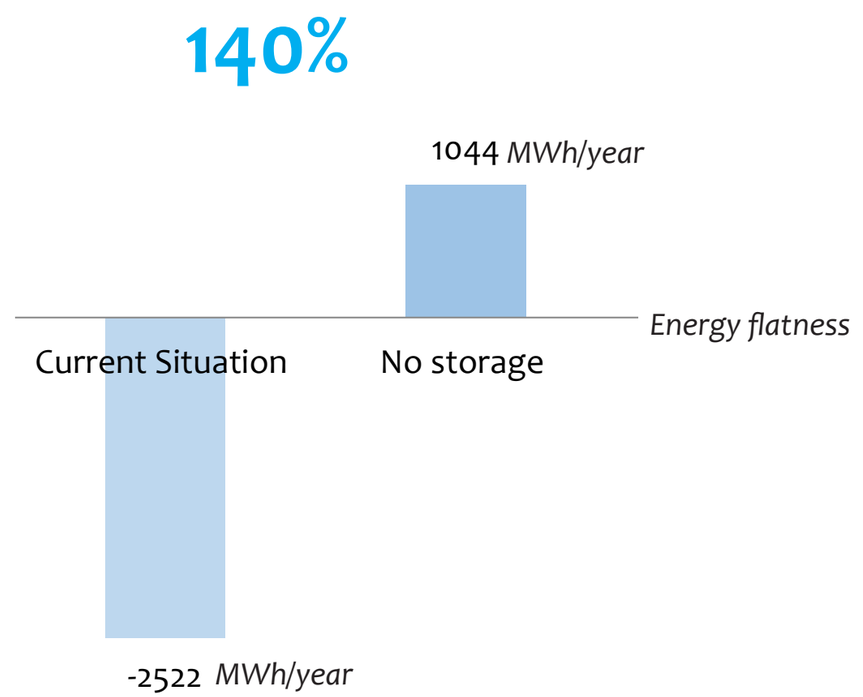
KPI 1 - Thermal balance

140%

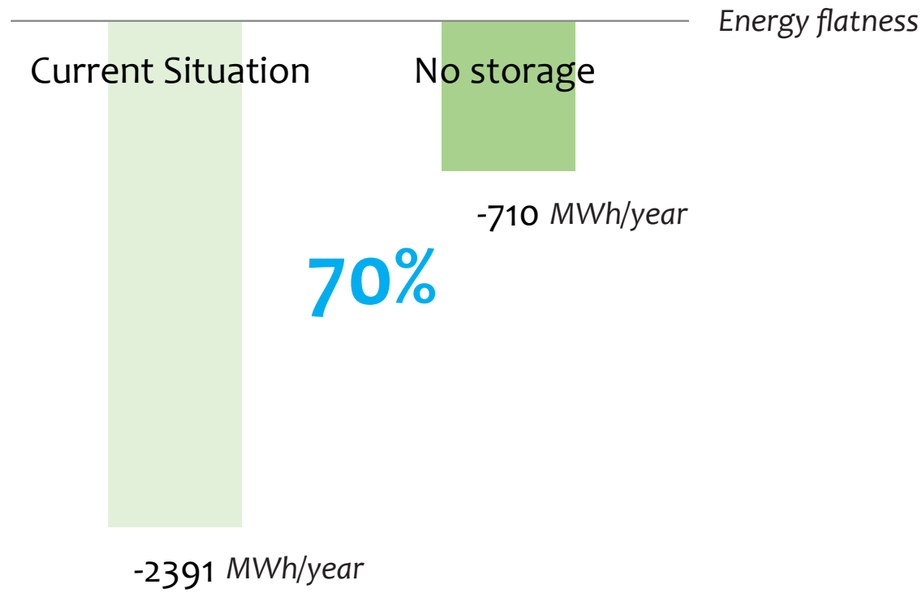


3 Final mismatch

KPI 1 - Thermal balance

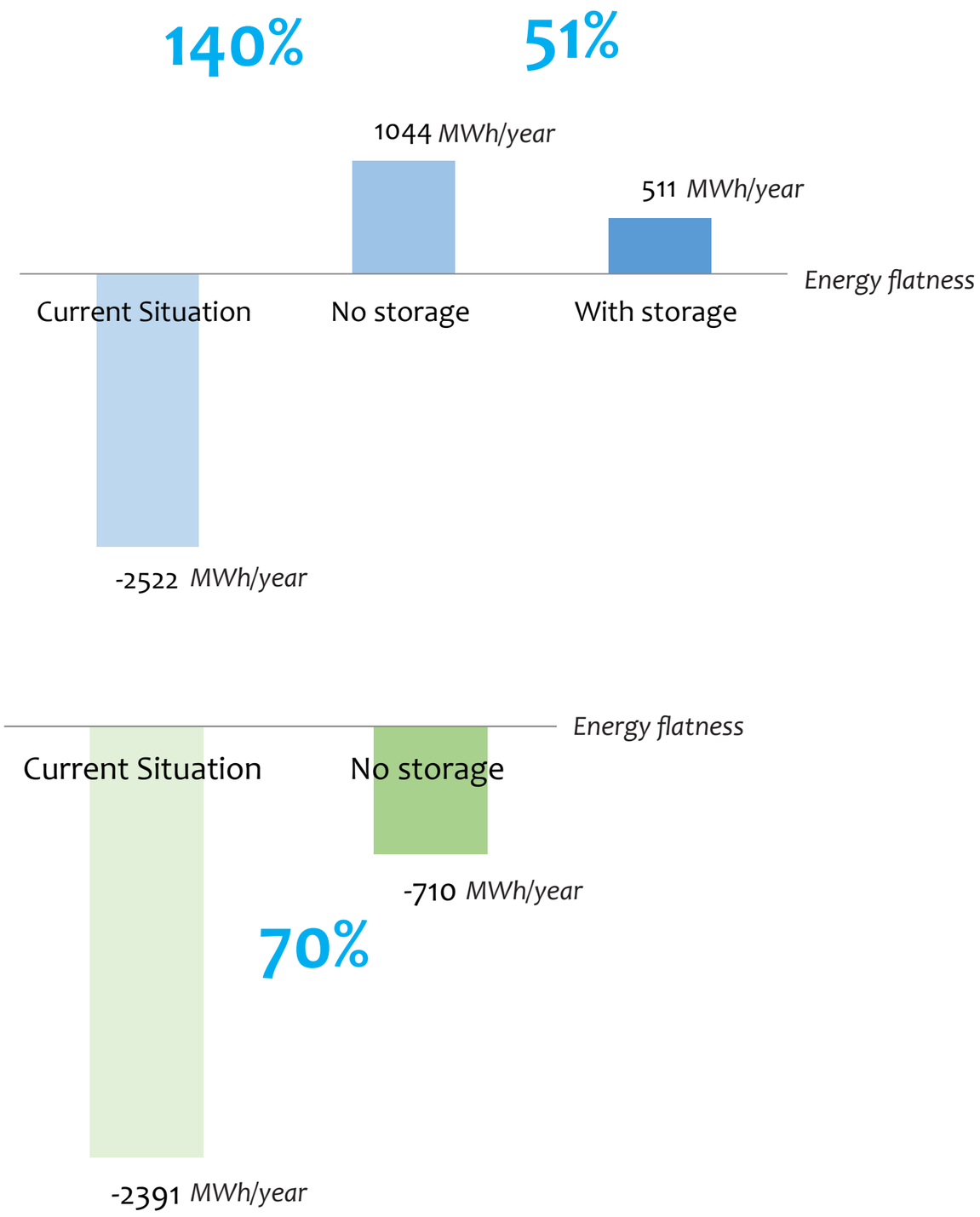


KPI 1 - Electricity balance



3 Final mismatch

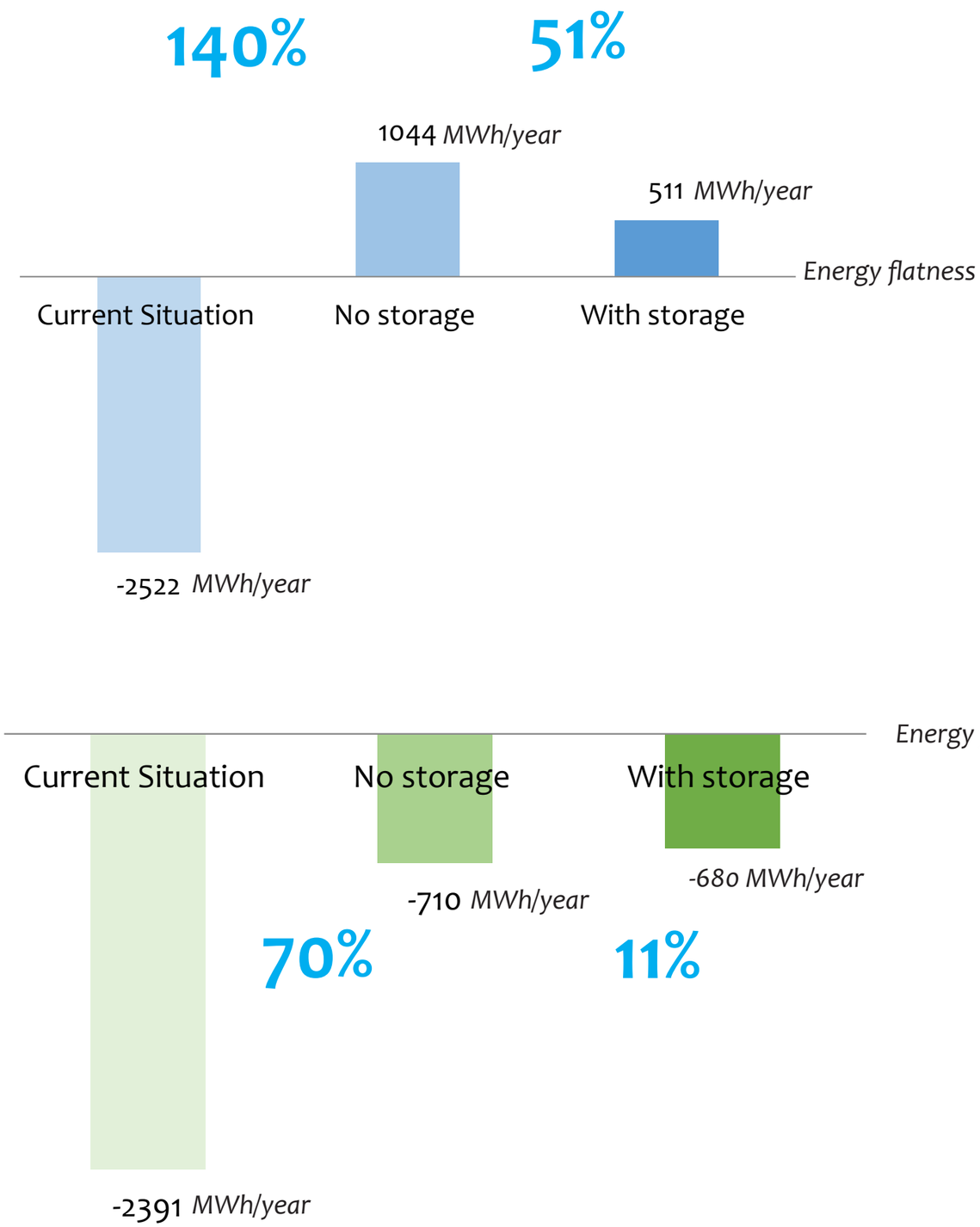
KPI 1 - Thermal balance



KPI 1 - Electricity balance

3 Final mismatch

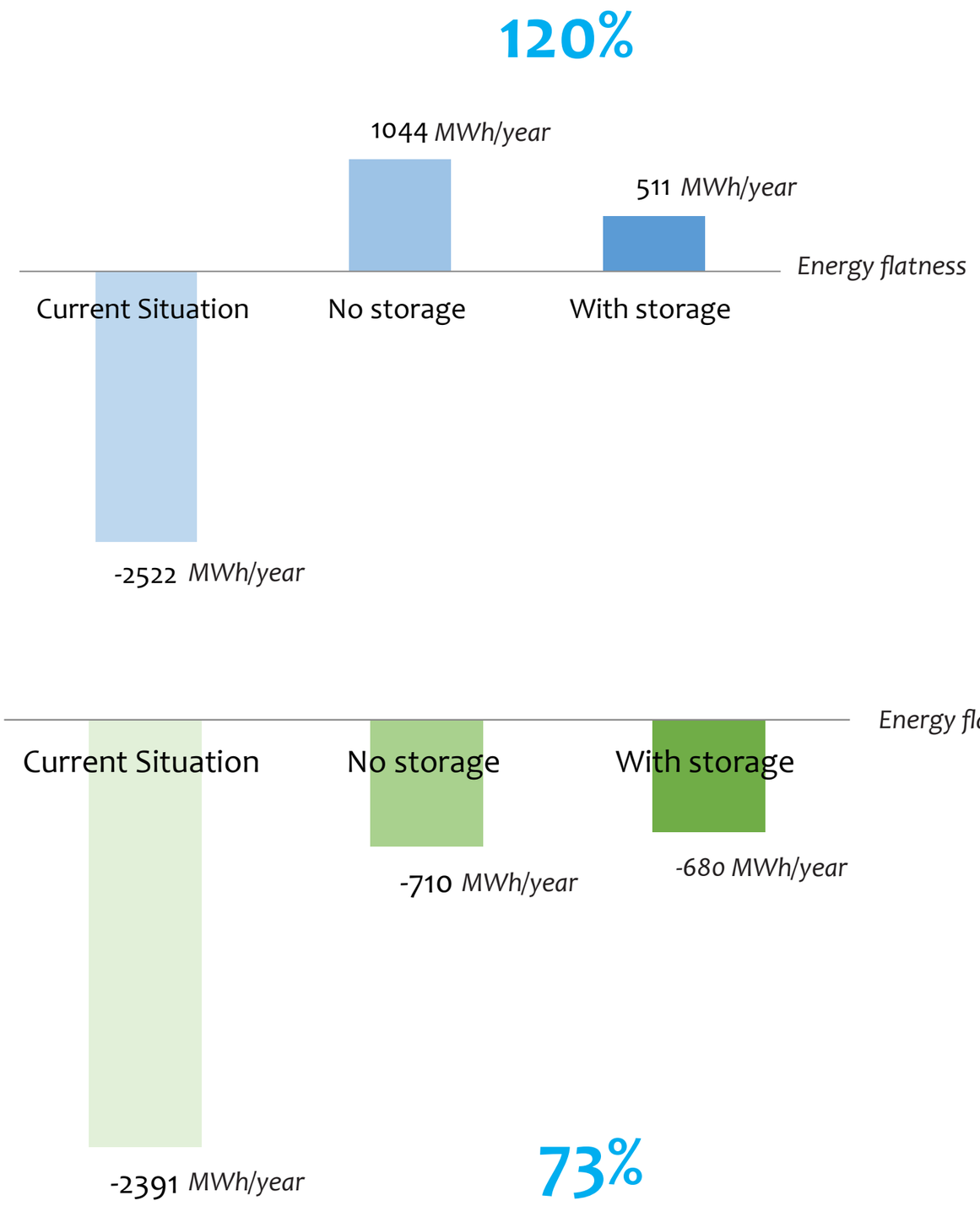
KPI 1 - Thermal balance



KPI 1 - Electricity balance

3 Final mismatch

KPI 1 - Thermal balance

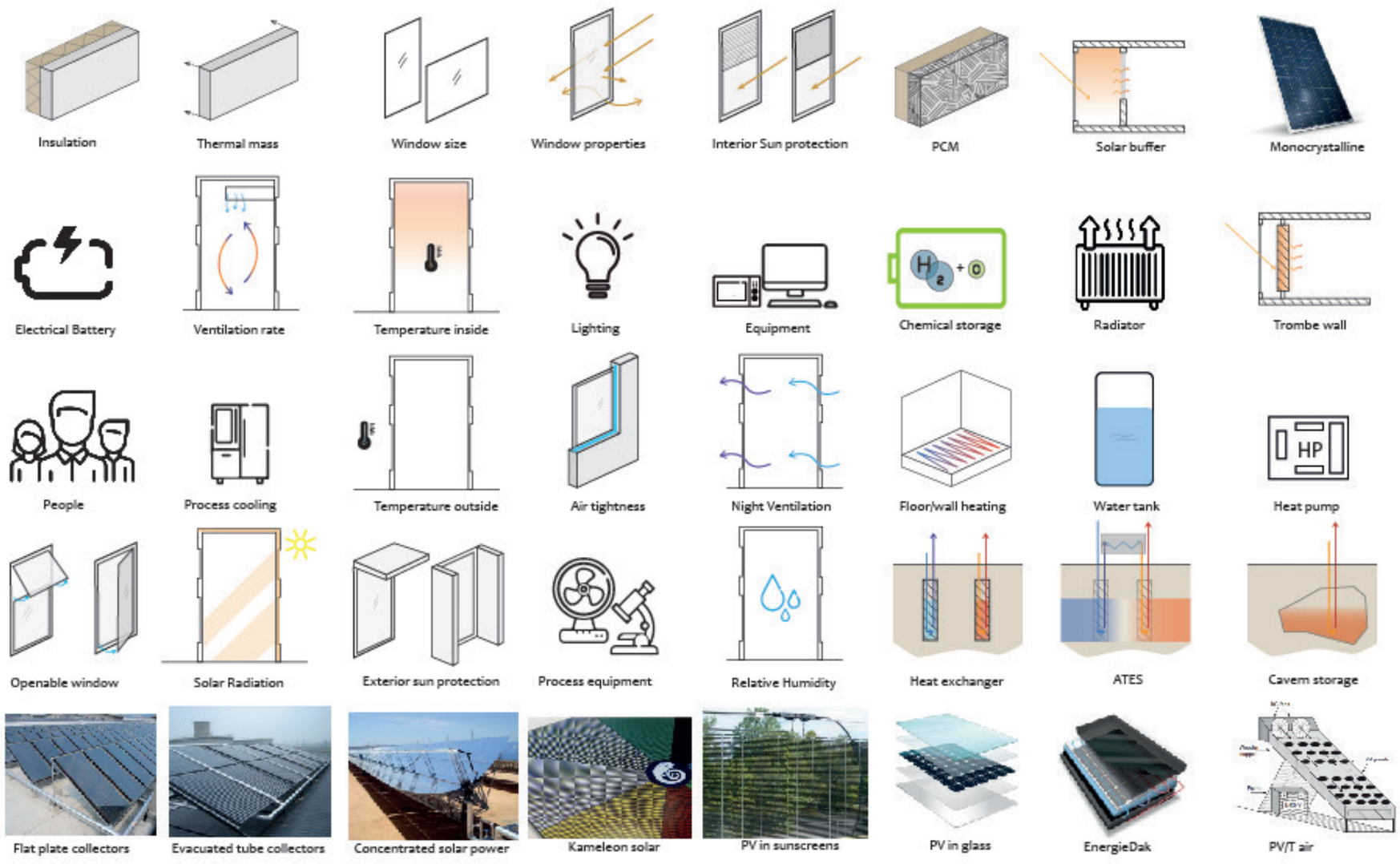


KPI 1 - Electricity balance

Conclusions

Conclusions

1. The adaptation of the parameters and technologies analized in this research HELPED reduce the energy mismatch in a non-residential existing building.



Conclusions

1. The adaptation of the parameters and technologies analized in this research HELPED reduce the energy mismatch in a non-residential existing building.

2. Physical parameters and location constrain the demand reduction

3. Solar radiation and avaliable area constrain the on-site energy production
- More production of solar thermal than electricity in the same area

4. Demand and production constrain the integration of the complementary energy system

Conclusions

1. The adaptation of the parameters and technologies analized in this research HELPED reduce the energy mismatch in a non-residential existing building.

2. Physical parameters and location constrain the demand reduction

3. Solar radiation and avaliable area constrain the On-site energy production
- More production of solar thermal than electricity in the same area

4. Demand and production constrain the Complementary energy system is limited

5. Energy flatness was not reached, however:
- Thermal energy can be exported
- Electricity has to be imported

Discussion

1. Only solar technologies were considered
2. Cost feasibility was not part of the scope
3. The connection between other buildings to solve the mismatch was not considered

Further Research

1. Cost analysis of the technologies and parameters
2. Research on other renewable energy sources (wind, biomass, water, etc)
3. Buildings of different functions
4. Optimization of the system
5. Connection with other buildings in the campus

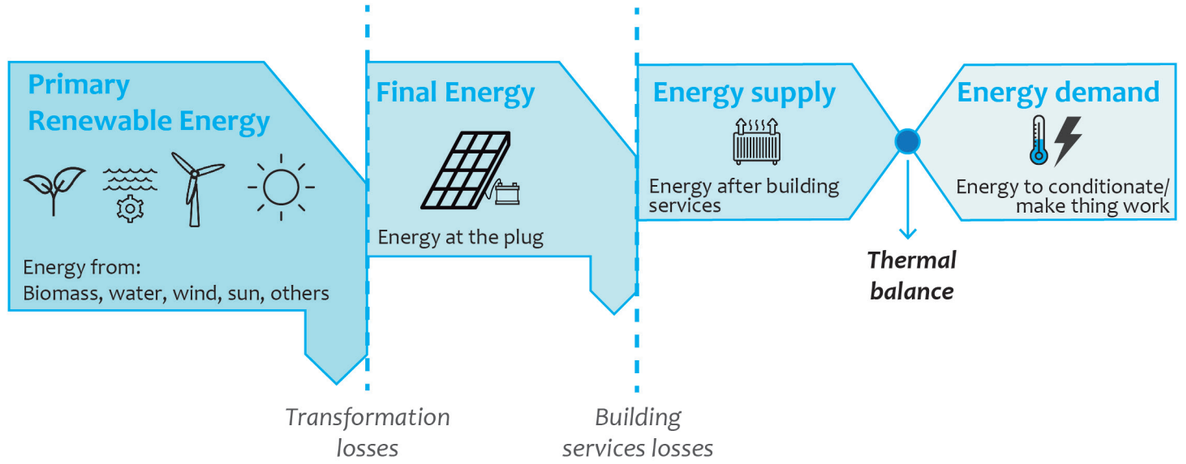
Questions

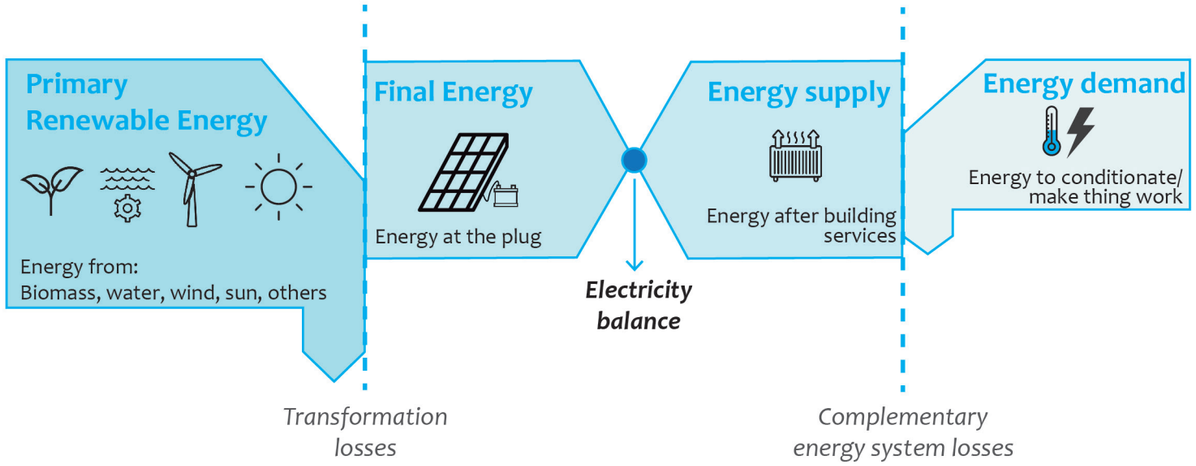
Thank you !

Gracias !

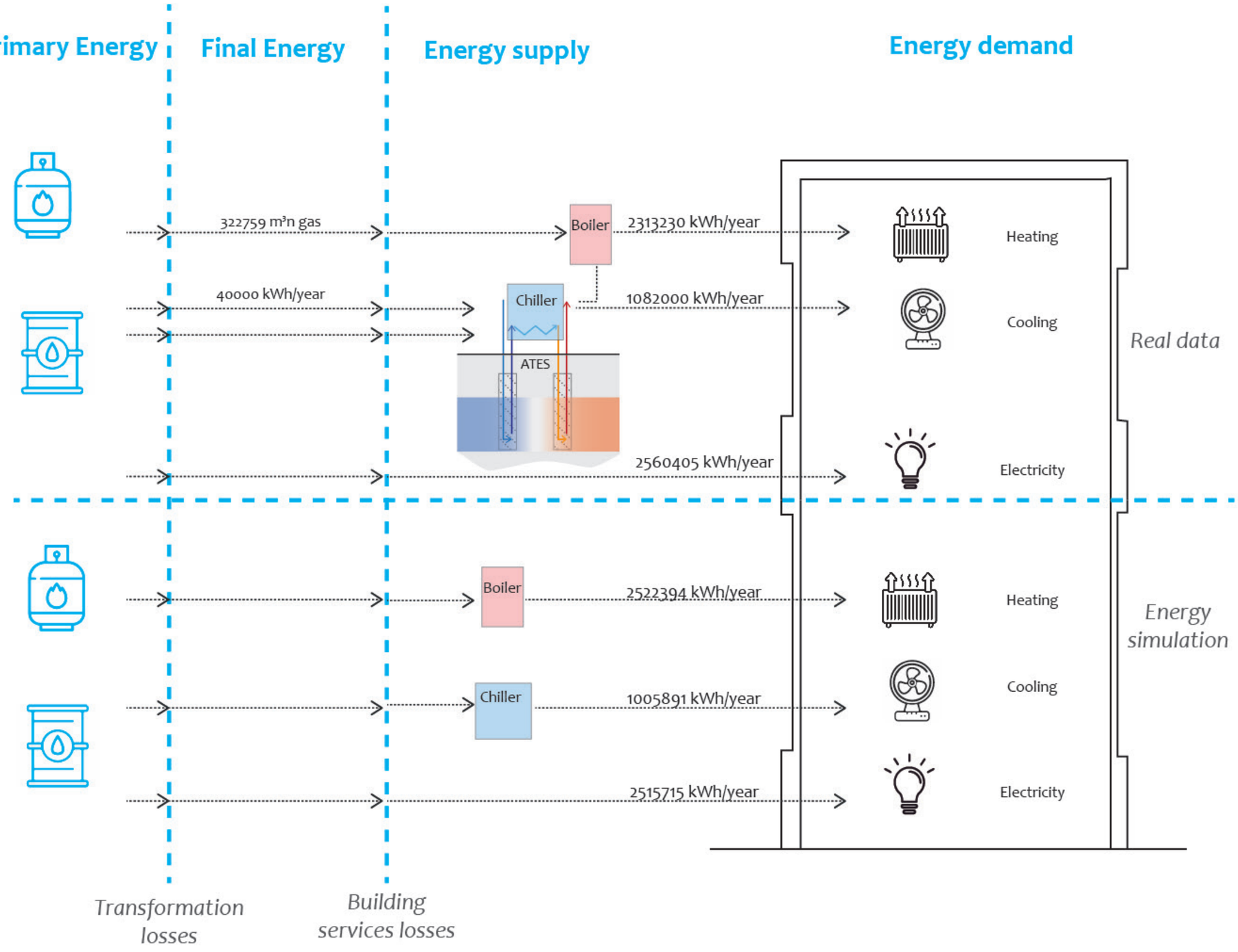
Dank je!

Appendix 1


Primary
Renewable Energy
Energy from:
Biomass, water, wind, sun, others
Final Energy
Energy at the plug
Energy supply
Energy after building services
Energy demand
Energy to conditionate/ make thing work
Thermal balance
Transformation losses
Building services losses


Primary
Renewable Energy
Energy from:
Biomass, water, wind, sun, others
Final Energy
Energy at the plug
Energy supply
Energy after building services
Energy demand
Energy to conditionate/ make thing work
Electricity balance
Transformation losses
Complementary energy system losses

Appendix 2


Primary Energy
Final Energy
Energy supply
Energy demand
322759 m³n gas
40000 kWh/year
Boiler
Chiller
ATES
2313230 kWh/year
1082000 kWh/year
2560405 kWh/year
Heating
Cooling
Electricity
Real data
Boiler
Chiller
2522394 kWh/year
1005891 kWh/year
2515715 kWh/year
Heating
Cooling
Electricity
Energy simulation
Transformation losses
Building services losses