Energy-flat housing

Towards continuous balance in the residential energy system

Graduation presentation, January 26, 2018

by Vincent Höfte

energy-flatness when the on-site residential supply and demand of energy are continuously equal

0

INTRODUCTION

A welcome and an overview of the contents

THE TEAM

student Vincent Höfte

first mentor Prof. dr. ir. Andy van den Dobbelsteen

second mentor Dr. ir. Sabine Jansen

company mentor Ing. Hans van Hauwe

DPA | Cauberg-Huygen

Delegate of BoE Dr. Nico Nieboer

GOAL OF THE PRESENTATION

Explain the topic of **energy-flatness**

Show the **process**

Explain the **results**

Conclude and **reflect**

1

Problem statement & research outline

Explaining the mismatch and setting the research outline

PROBLEM STATEMENT

PROBLEM STATEMENT

Supply

Intermittent by

- orientation
- solar power
- cloudiness

PROBLEM STATEMENT

Supply

Intermittent by

- orientation

- solar power

- cloudiness

Demand

Intermittent by

- climate

- inhabitant

- building properties

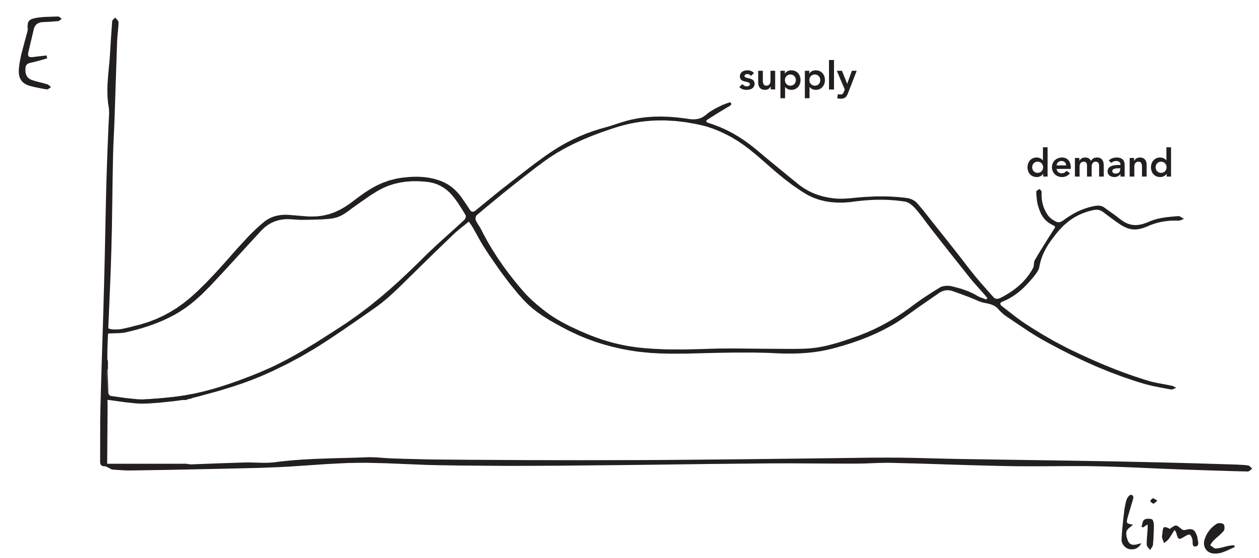
ENERGY TRENDS

1 Global energy demand increases

2 Share of renewable energy increases

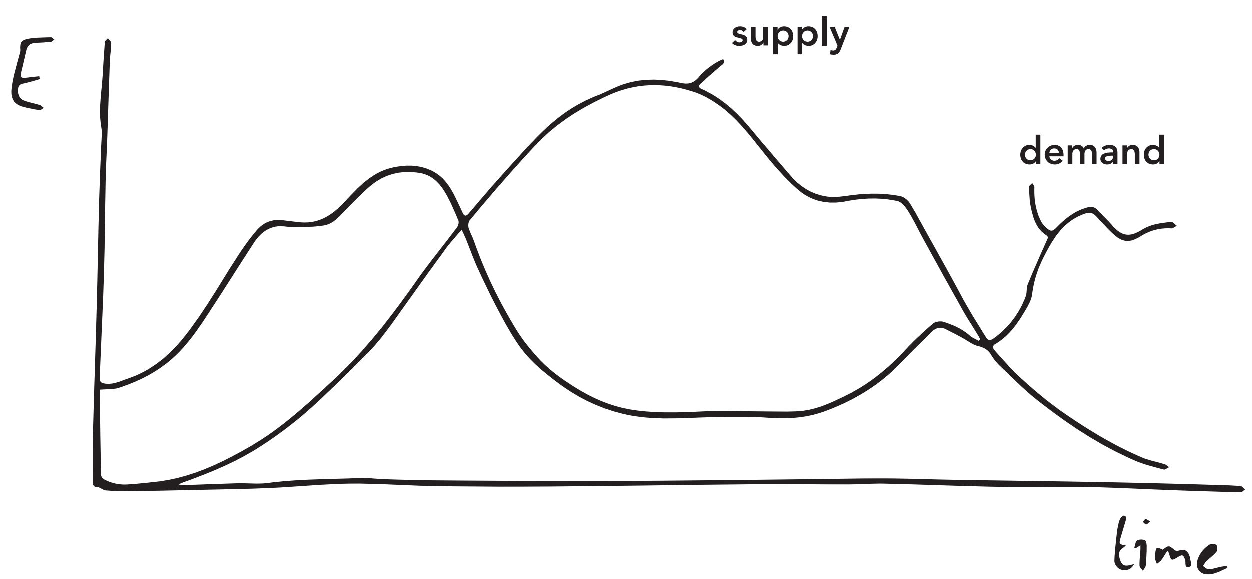
3 Dutch policies neglect the intermittencies

PROBLEM STATEMENT



1 Supply and demand are intermittent

PROBLEM STATEMENT

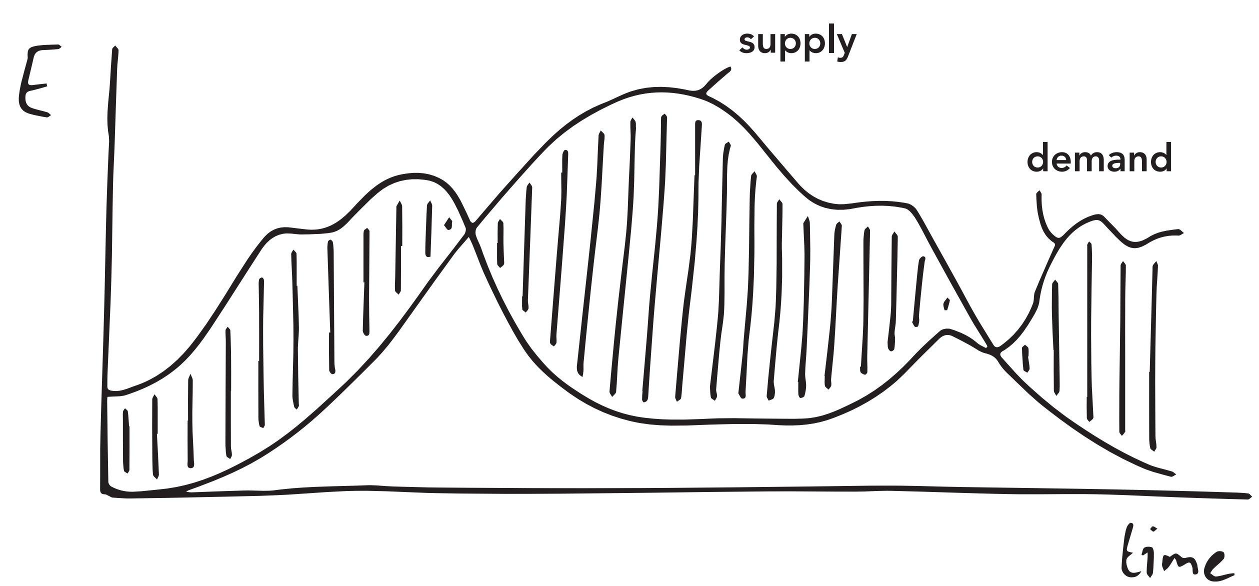


1 Supply and demand are intermittent

2 Renewable supply increases

Demand increases

PROBLEM STATEMENT



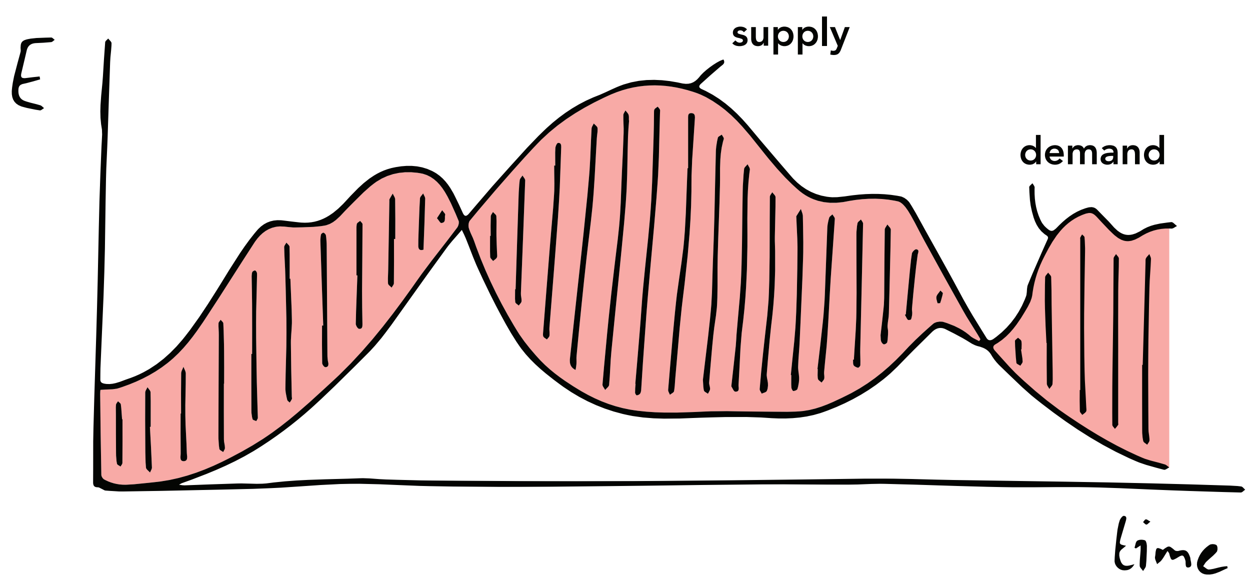
1 Supply and demand are intermittent

2 Renewable supply increases

Demand increases

3 Current approach increases mismatch

PROBLEM STATEMENT



1 Supply and demand are intermittent

2 Renewable supply increases

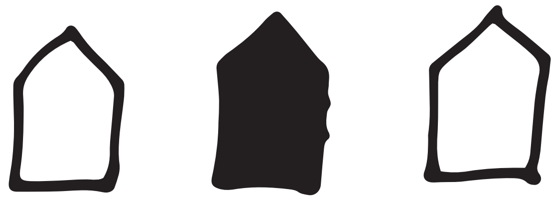
Demand increases

3 Current approach increases mismatch

RESEARCH QUESTION

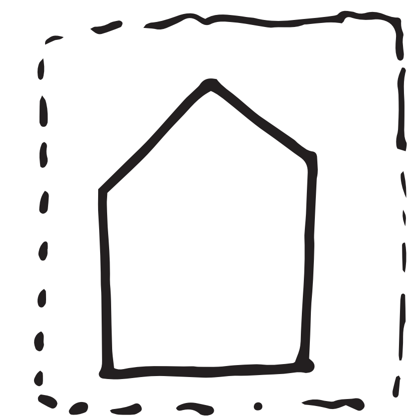
How can the residential energy mismatch of supply and demand be solved by architectural design?

SCOPE

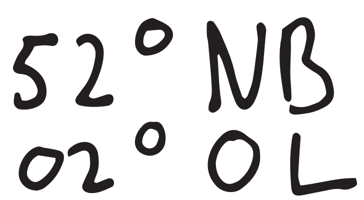


One detached house

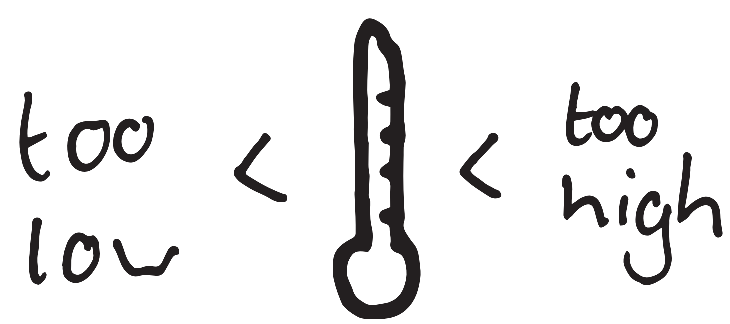
Architectural solutions



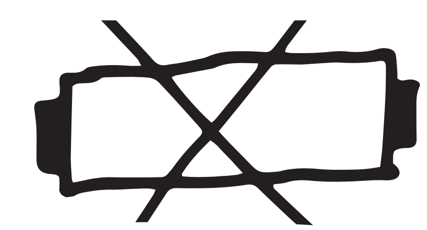
All is on-site



Dutch climate and data

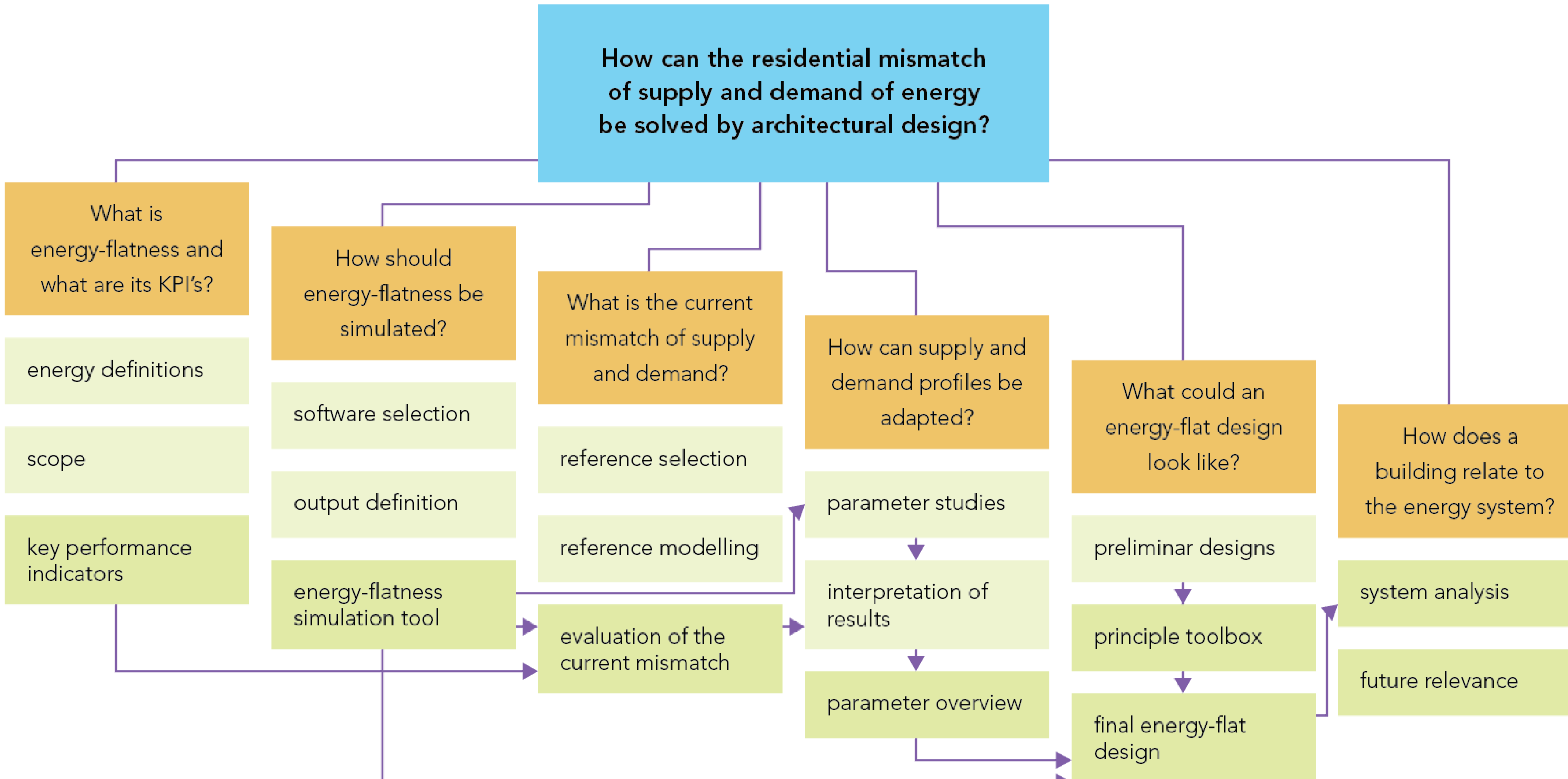


Heating/cooling of a building



Storage is avoided

RESEARCH OUTLINE



2

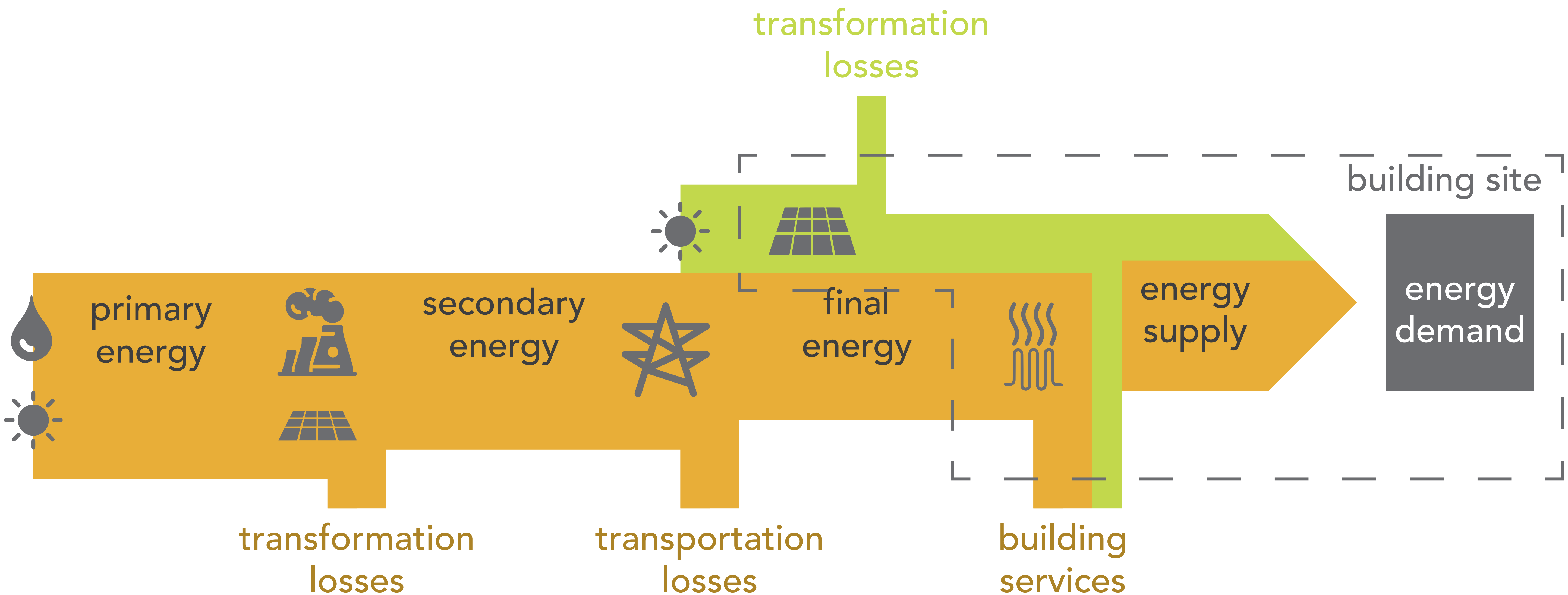
What is energy-flatness?

Answering the first sub-question

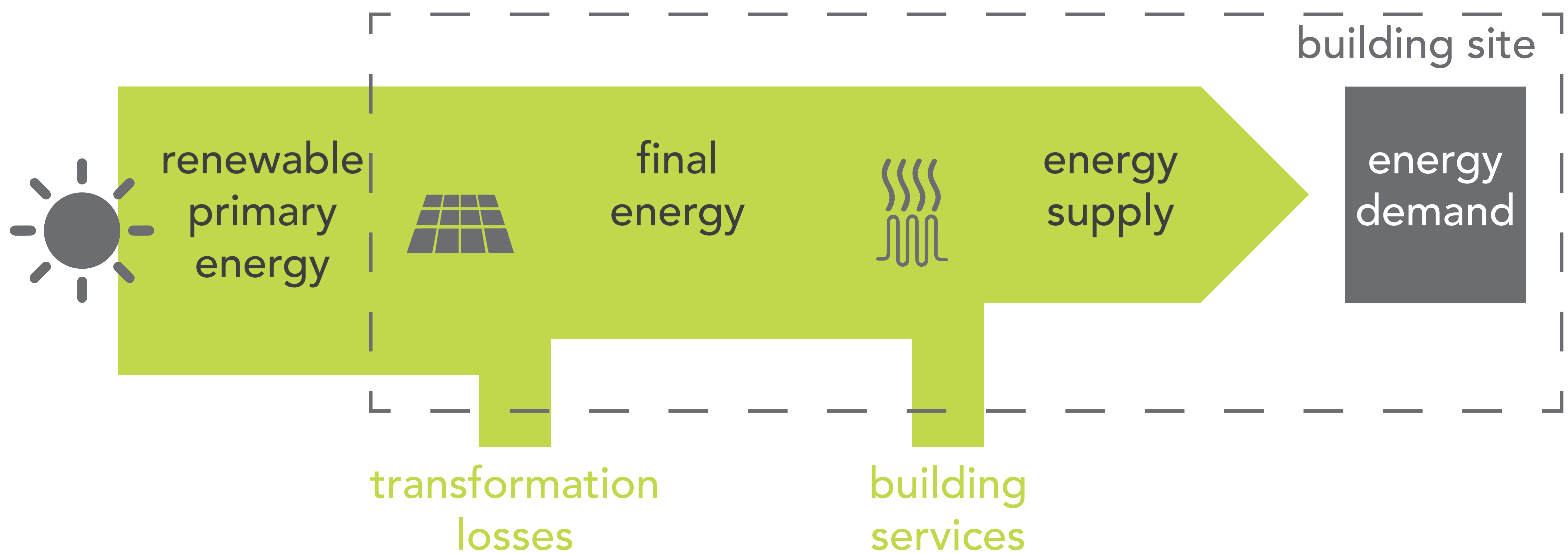
What is energy-flatness?

ENERGY DEFINITIONS

ENERGY DEFINITIONS

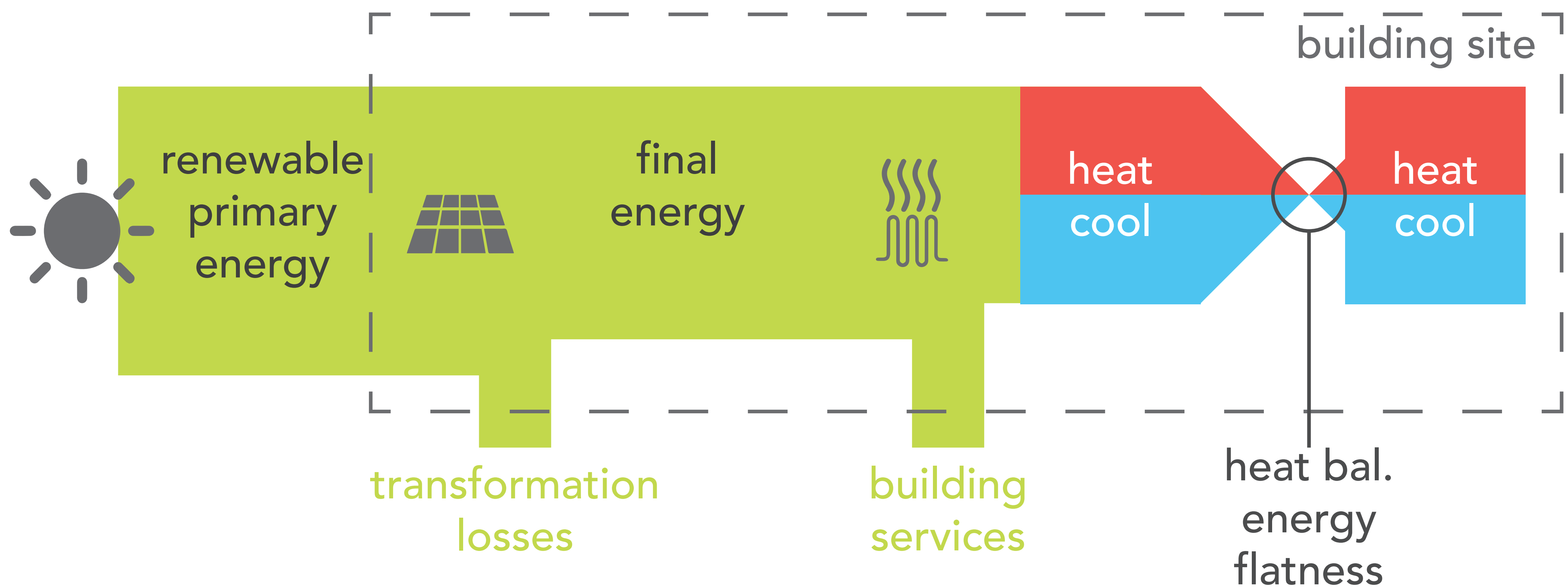


ENERGY DEFINITIONS



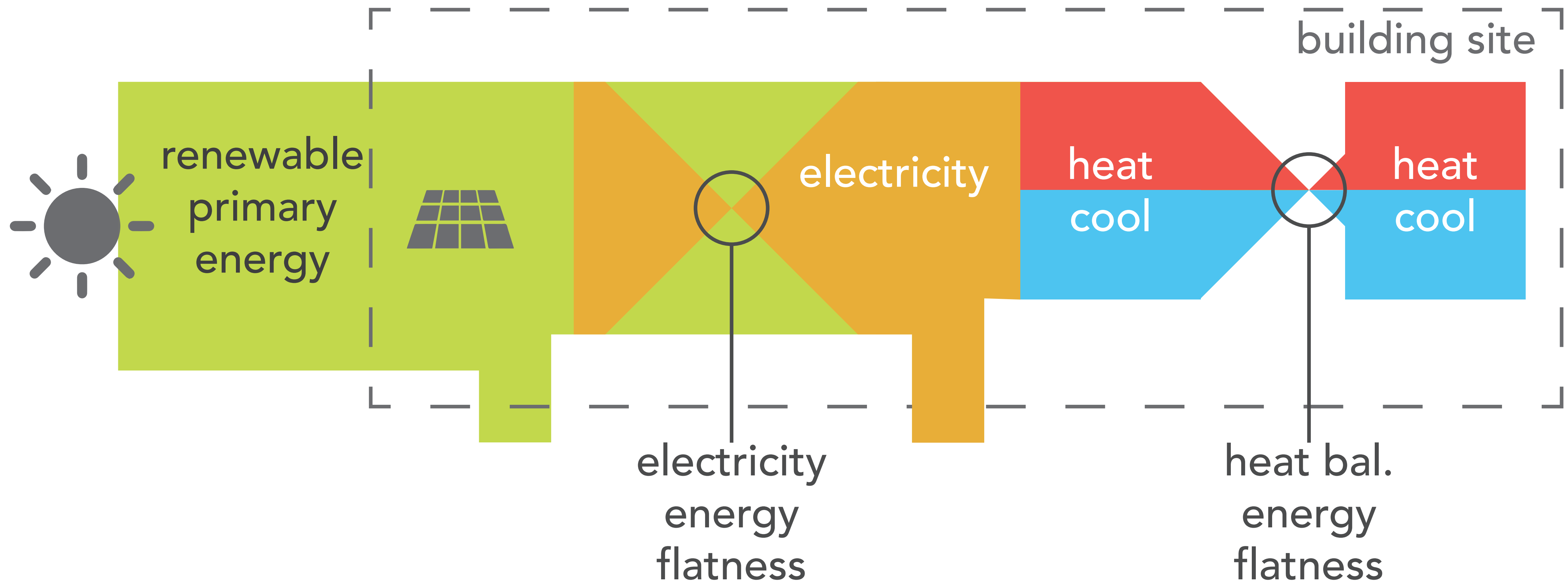
What is energy-flatness?

ENERGY DEFINITIONS

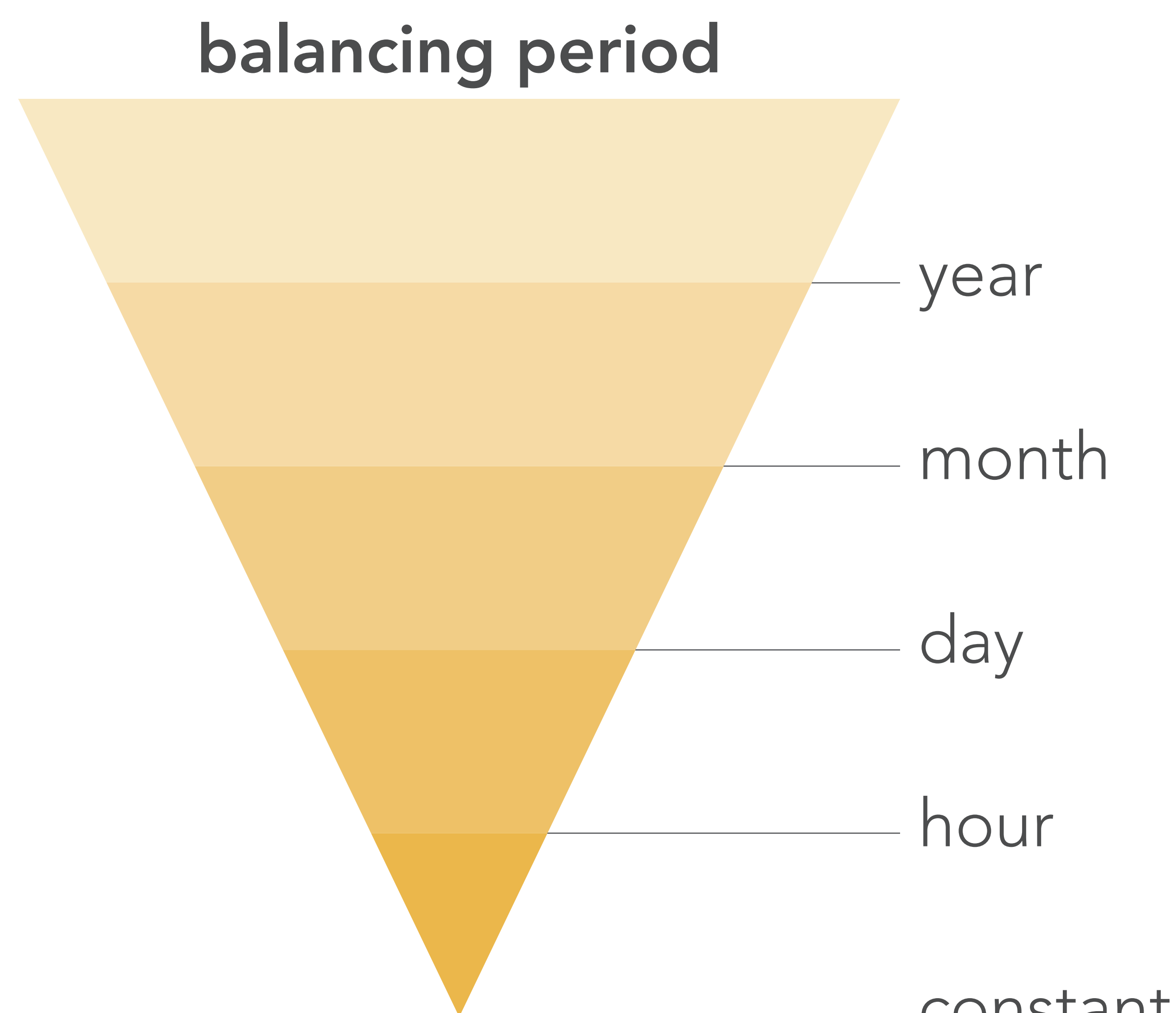


What is energy-flatness?

ENERGY DEFINITIONS

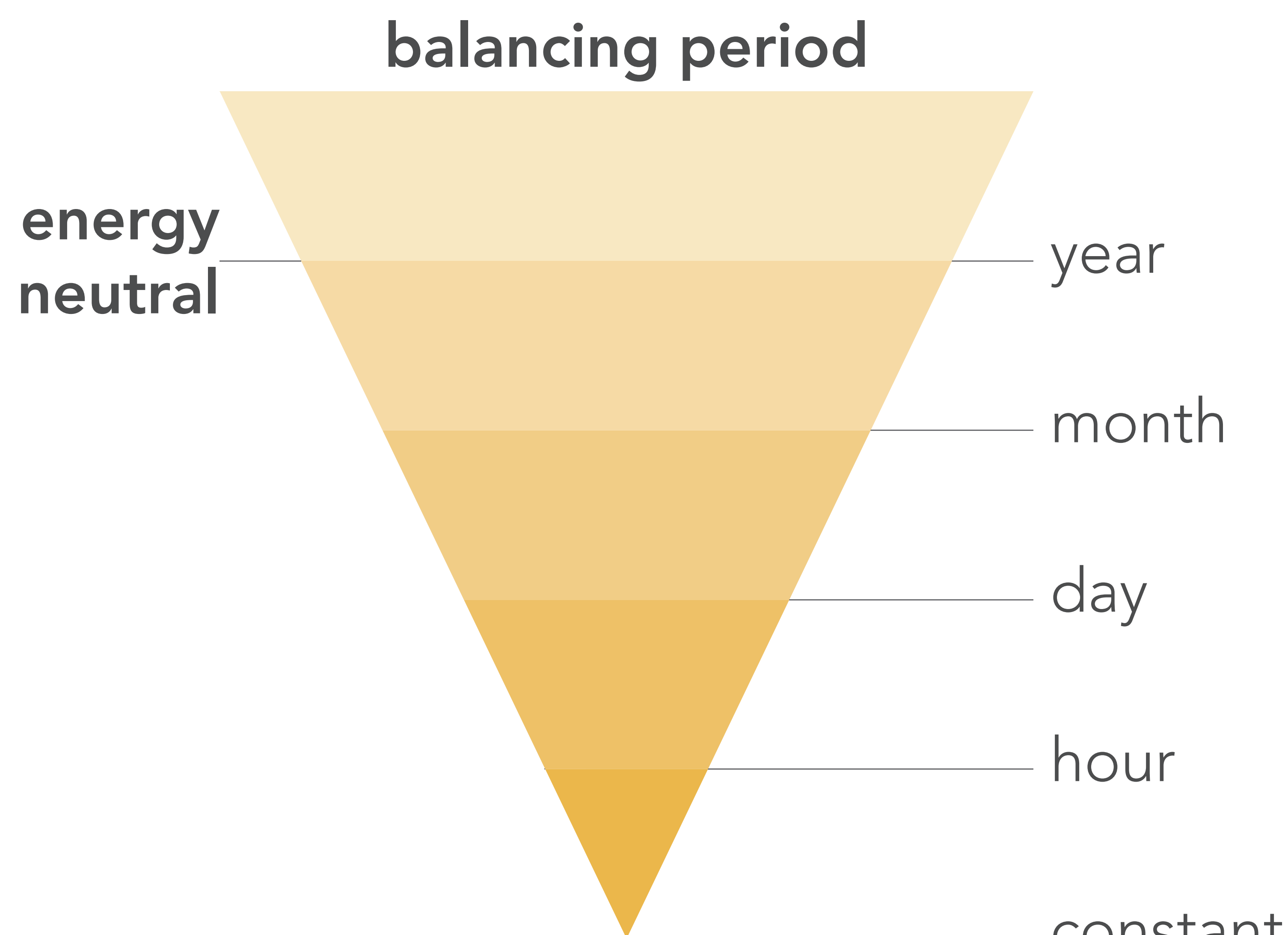


ENERGY DEFINITIONS



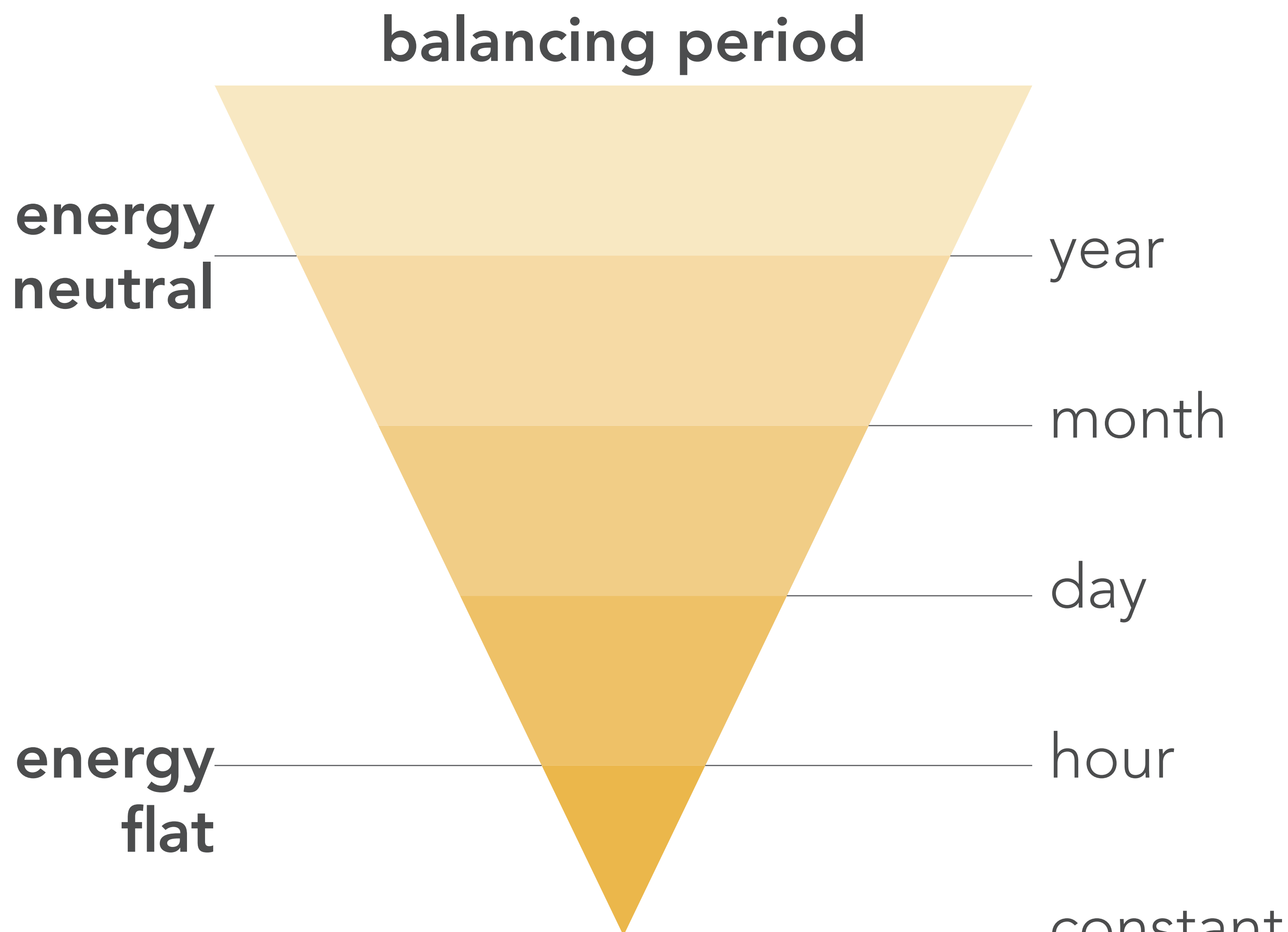
What is energy-flatness?

ENERGY DEFINITIONS



What is energy-flatness?

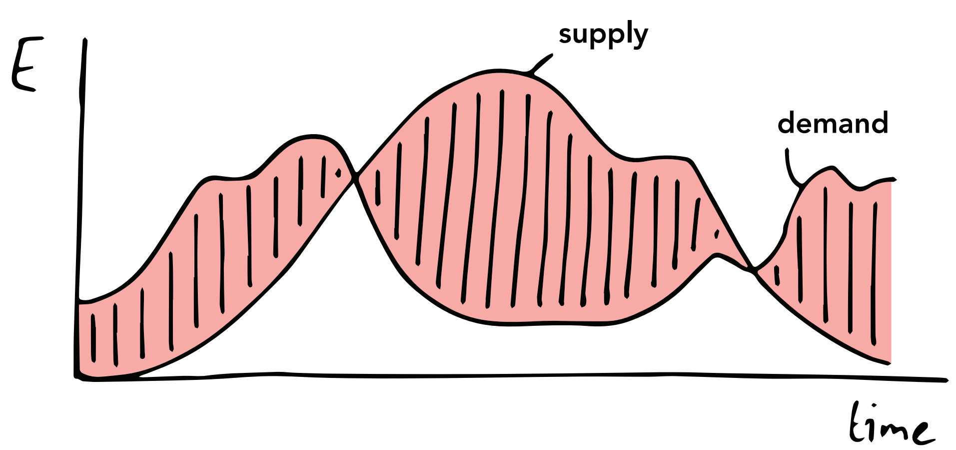
ENERGY DEFINITIONS



KEY PERFORMANCE INDICATORS (KPI)

KPI 1

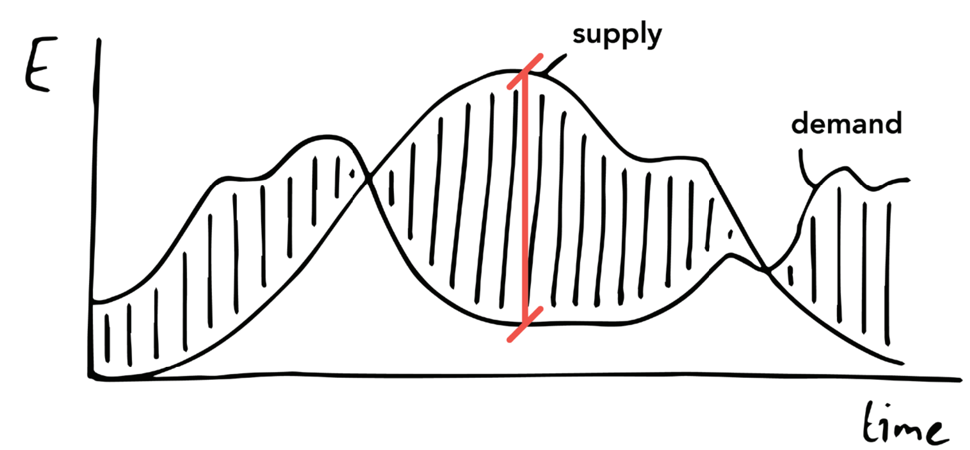
absolute flatness



$$\int_0^{8760} |E_{prod}(t) - E_{cons}(t)|\, dt$$

KPI 2

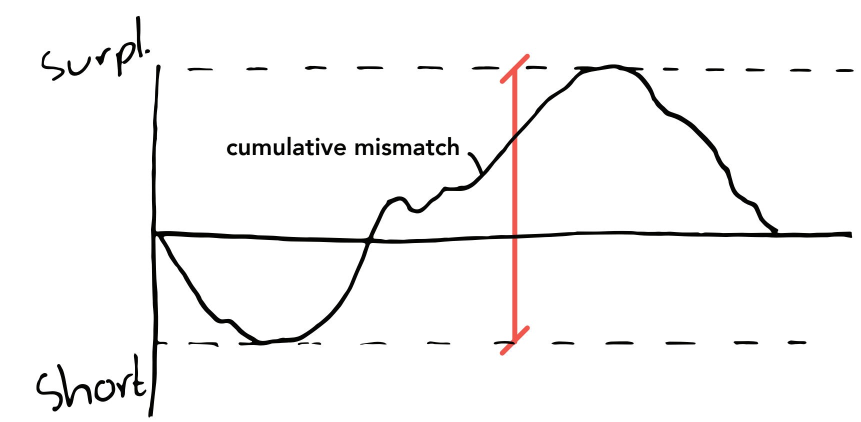
maximum peak



$$\max_{0 \leq t \leq 8760} (|E_{prod}(t) - E_{cons}(t)|)$$

KPI 3

maximum cumulative mismatch



$$\left(\max_{0 \leq a \leq b \leq 8760} - \min_{0 \leq a \leq b \leq 8760} \right) \int_a^b E_{cons}(t) - E_{prod}(t) dt$$

image source: Hegger et al., 2008

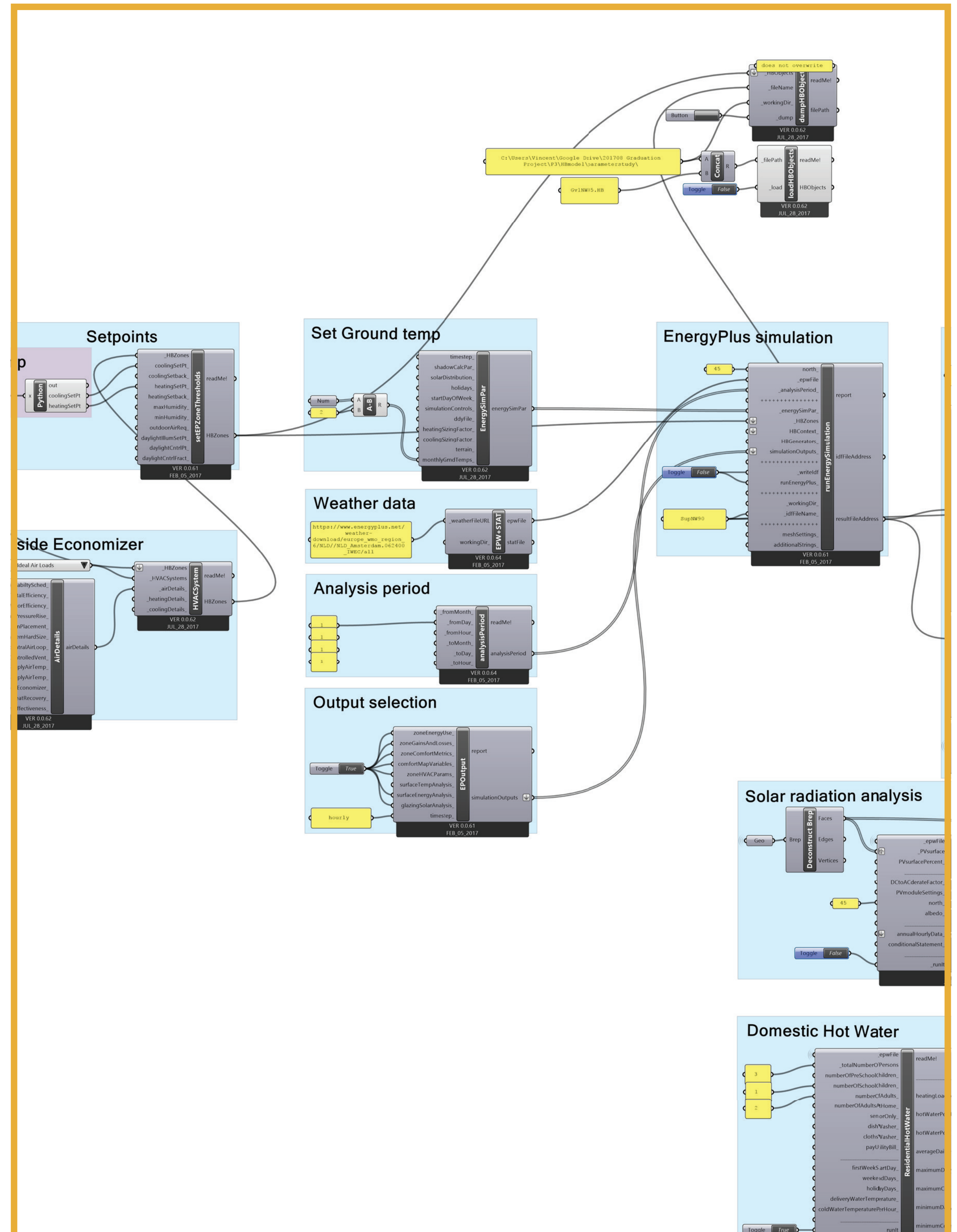
3

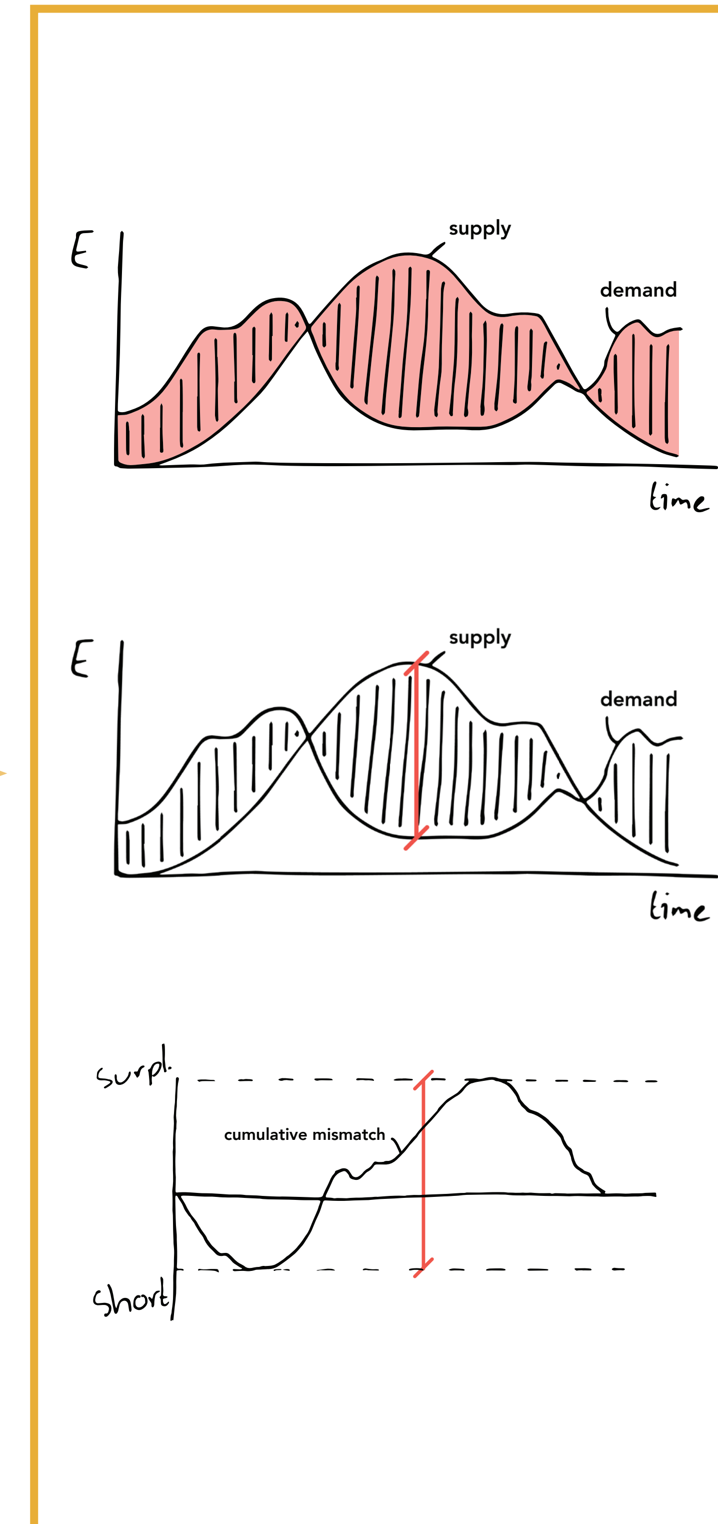
Simulation of energy-flatness

Setting up a dynamic energy model

Simulation of energy-flatness

ENERGY-FLATNESS SIMULATION TOOL





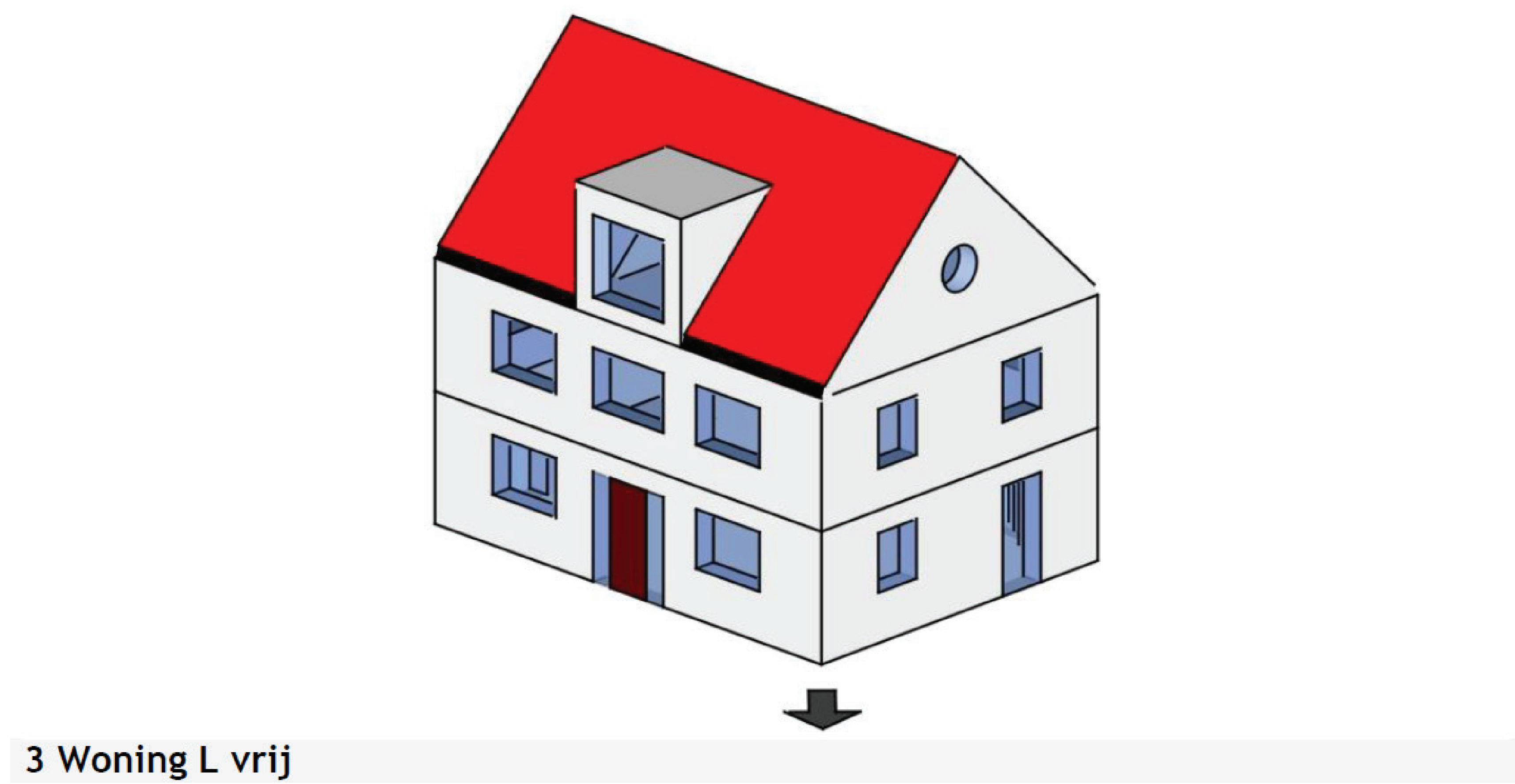
4

What is the current residential energy mismatch?

Analysing the reference design

Third sub-question

CURRENT RESIDENTIAL MISMATCH



SenterNovem BENG referentiewoning, by DGMR (2016)

Third sub-question

CURRENT RESIDENTIAL MISMATCH

Subject	Specification	Value [kWh]
Heat	Total annual heating demand	3732.5
Cool	Total annual cooling demand	3675.1
Supply	Total annual supply potential	7793.6
KPI 1 - heat	Total mismatch for heating	-3323.6
KPI 1 - cool	Total mismatch for cooling	-1292.8
KPI 1 - supply	Total supply surplus	4902.3
KPI 2 - heat	Maximum heat shortage peak	-3.3
KPI 2 - cool	Maximum cool shortage peak	-4.6
KPI 2 - supply	Maximum supply surplus peak	5.0
KPI 3	Maximum cumulative mismatch	2766.3

Third sub-question

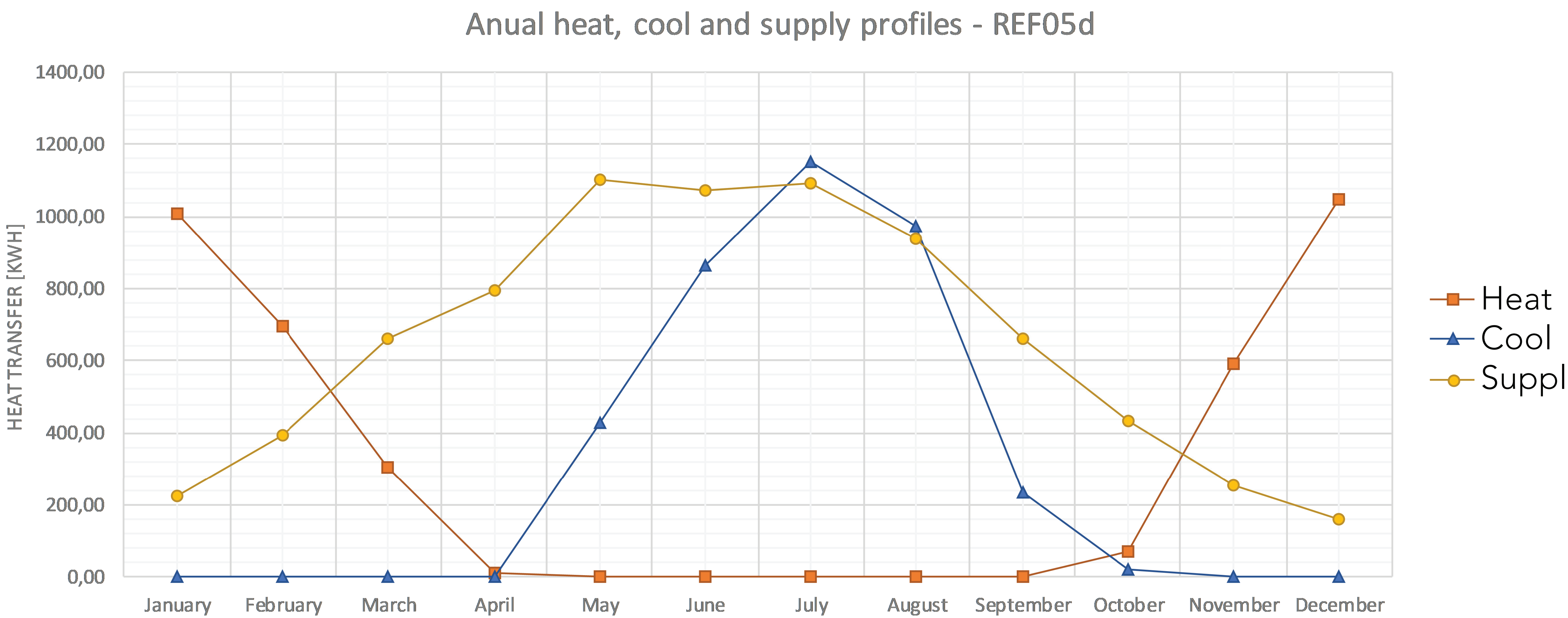
CURRENT RESIDENTIAL MISMATCH

Subject	Specification	Value [kWh]
Heat	Total annual heating demand	3732.5
Cool	Total annual cooling demand	3675.1
Supply	Total annual supply potential	7793.6
KPI 1 - heat	Total mismatch for heating	-3323.6
KPI 1 - cool	Total mismatch for cooling	-1292.8
KPI 1 - supply	Total supply surplus	4902.3
KPI 2 - heat	Maximum heat shortage peak	-3.3
KPI 2 - cool	Maximum cool shortage peak	-4.6
KPI 2 - supply	Maximum supply surplus peak	5.0
KPI 3	Maximum cumulative mismatch	2766.3

Total mismatch $= 9518.7\ kWh_{th}$

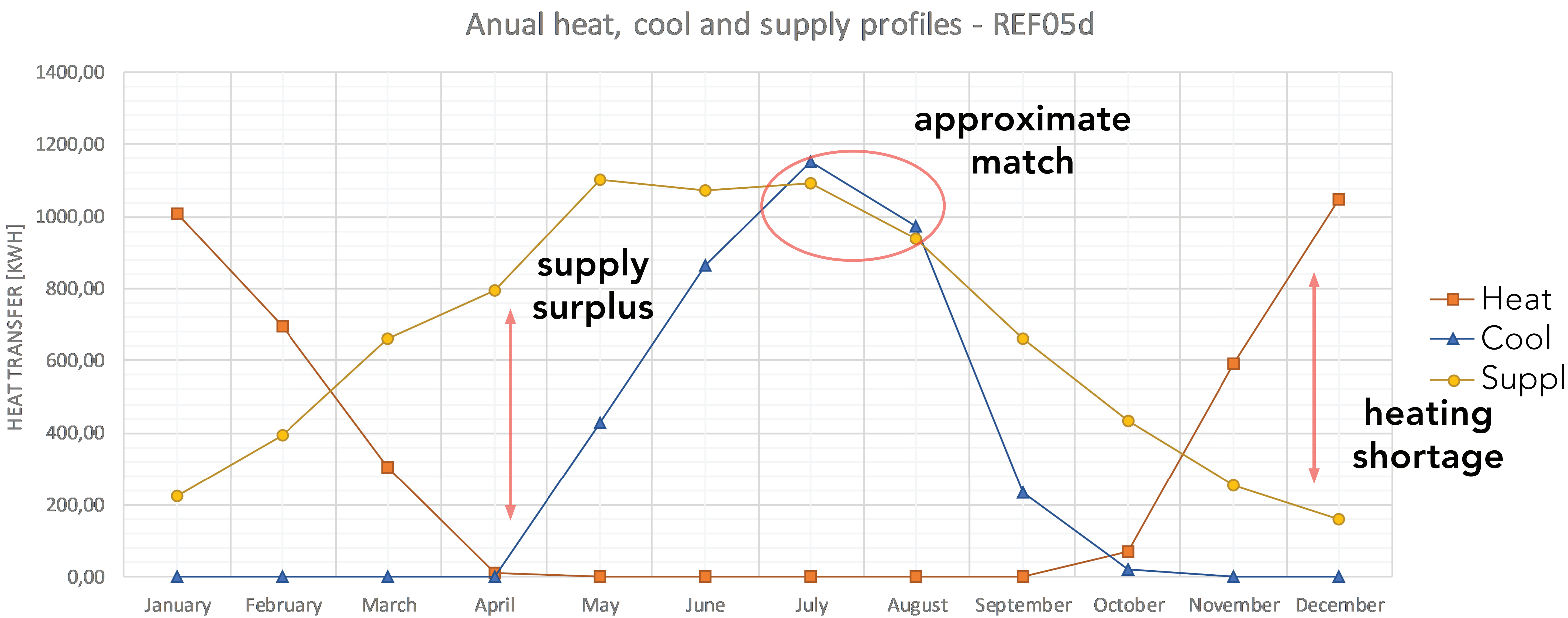
Third sub-question

CURRENT RESIDENTIAL MISMATCH



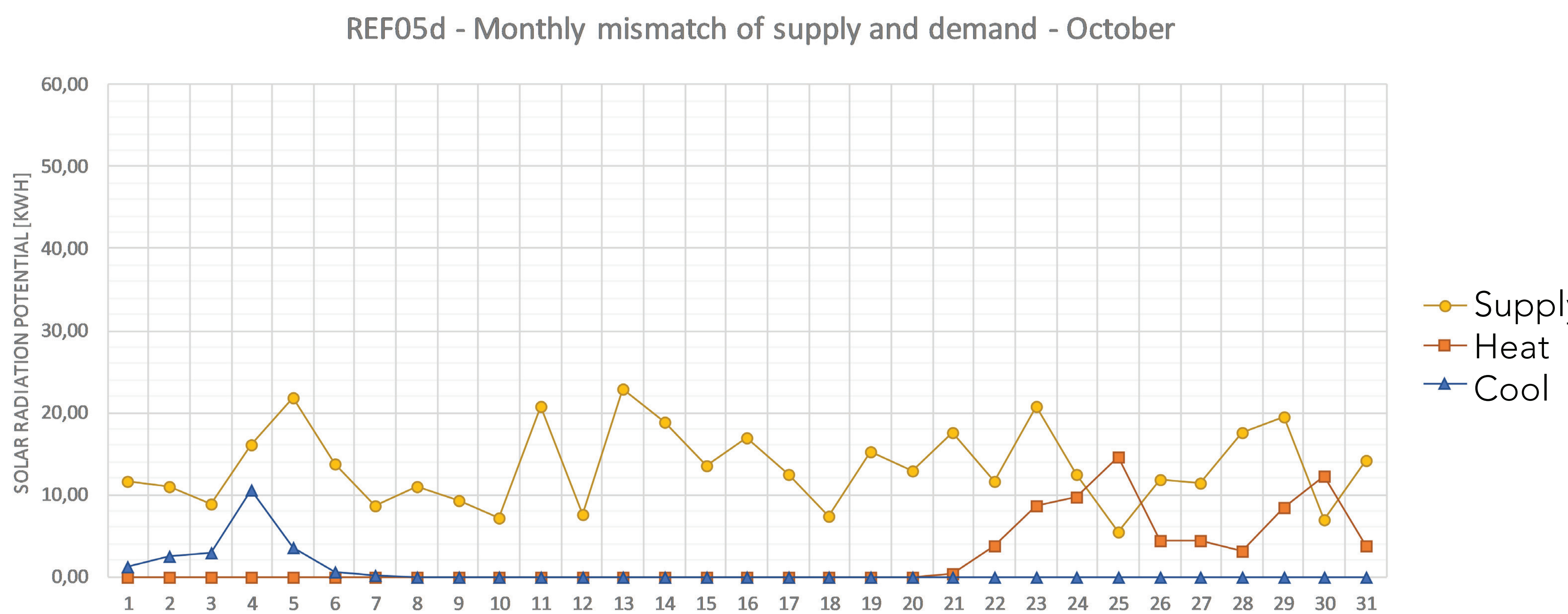
Third sub-question

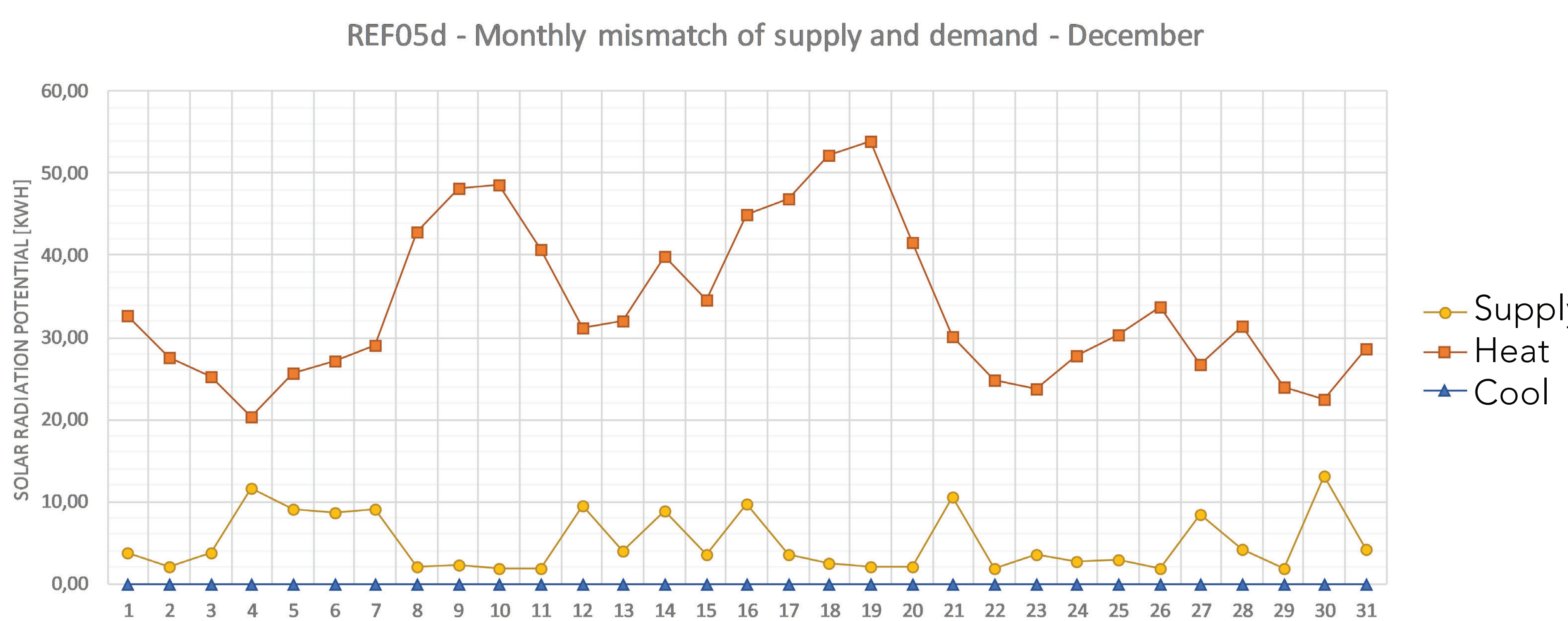
CURRENT RESIDENTIAL MISMATCH



Third sub-question

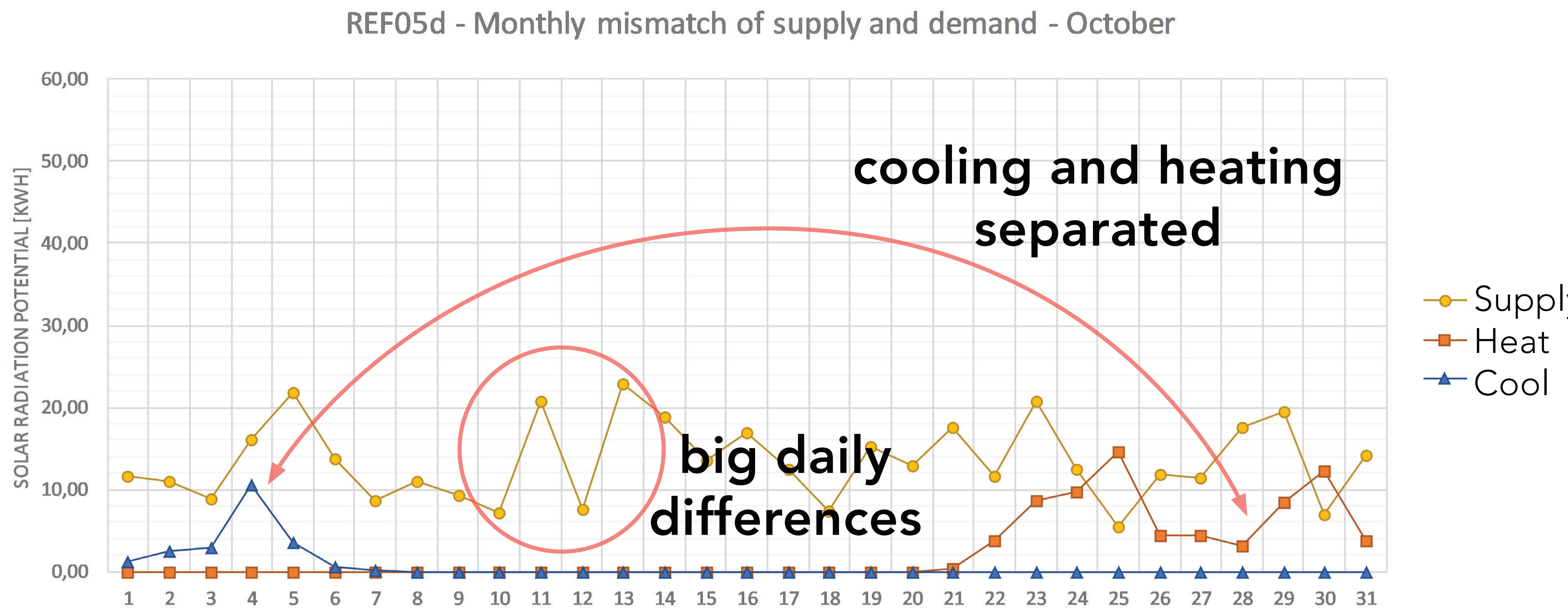
CURRENT RESIDENTIAL MISMATCH

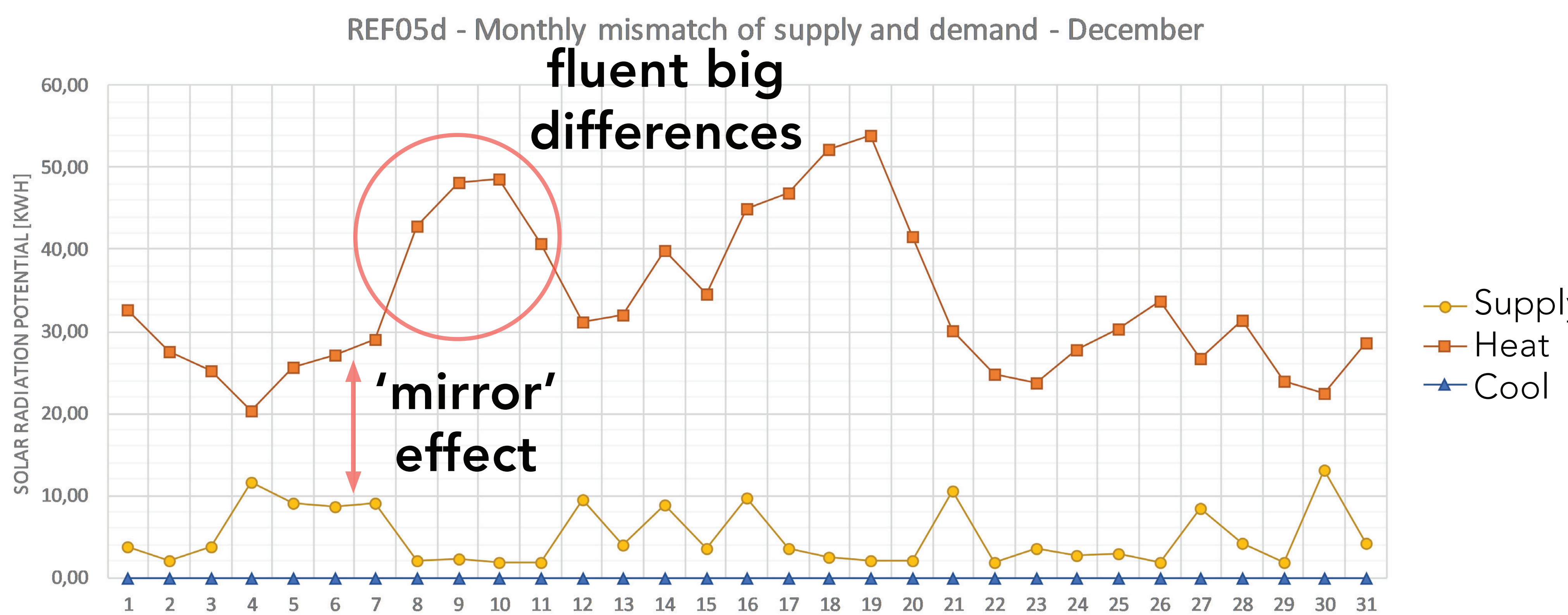




Third sub-question

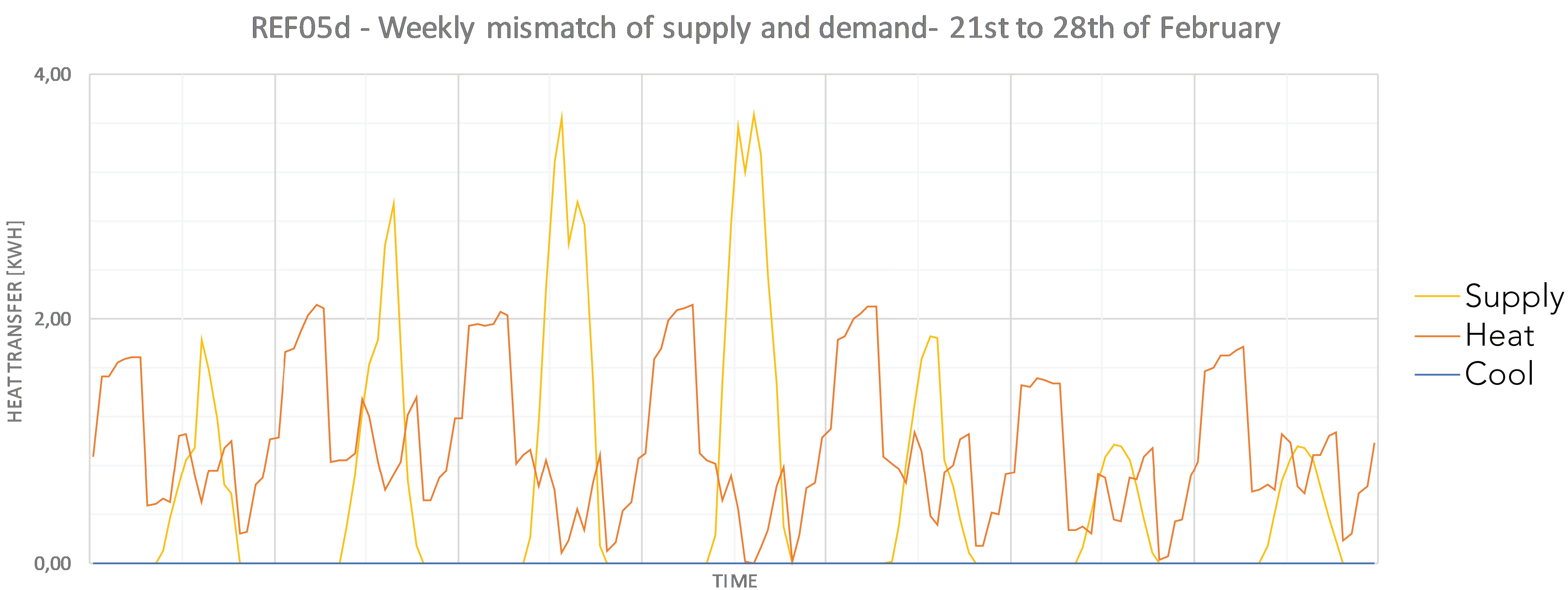
CURRENT RESIDENTIAL MISMATCH





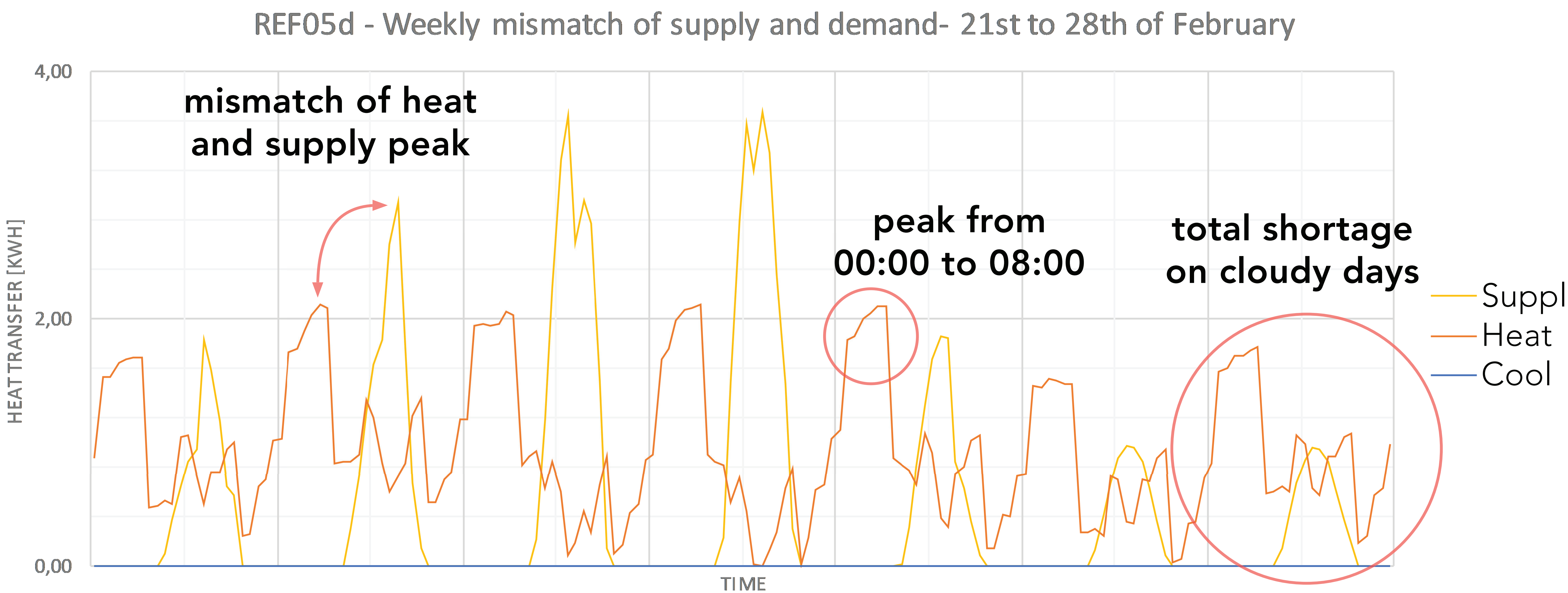
Third sub-question

CURRENT RESIDENTIAL MISMATCH



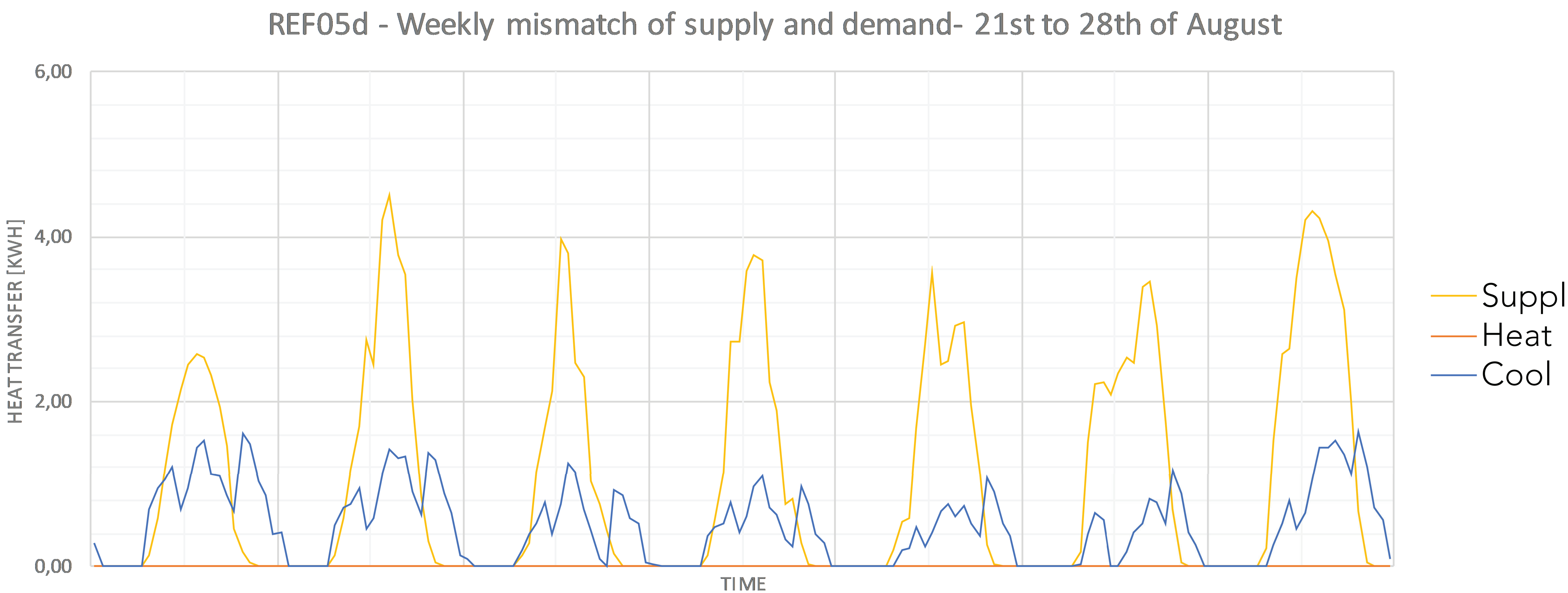
Third sub-question

CURRENT RESIDENTIAL MISMATCH



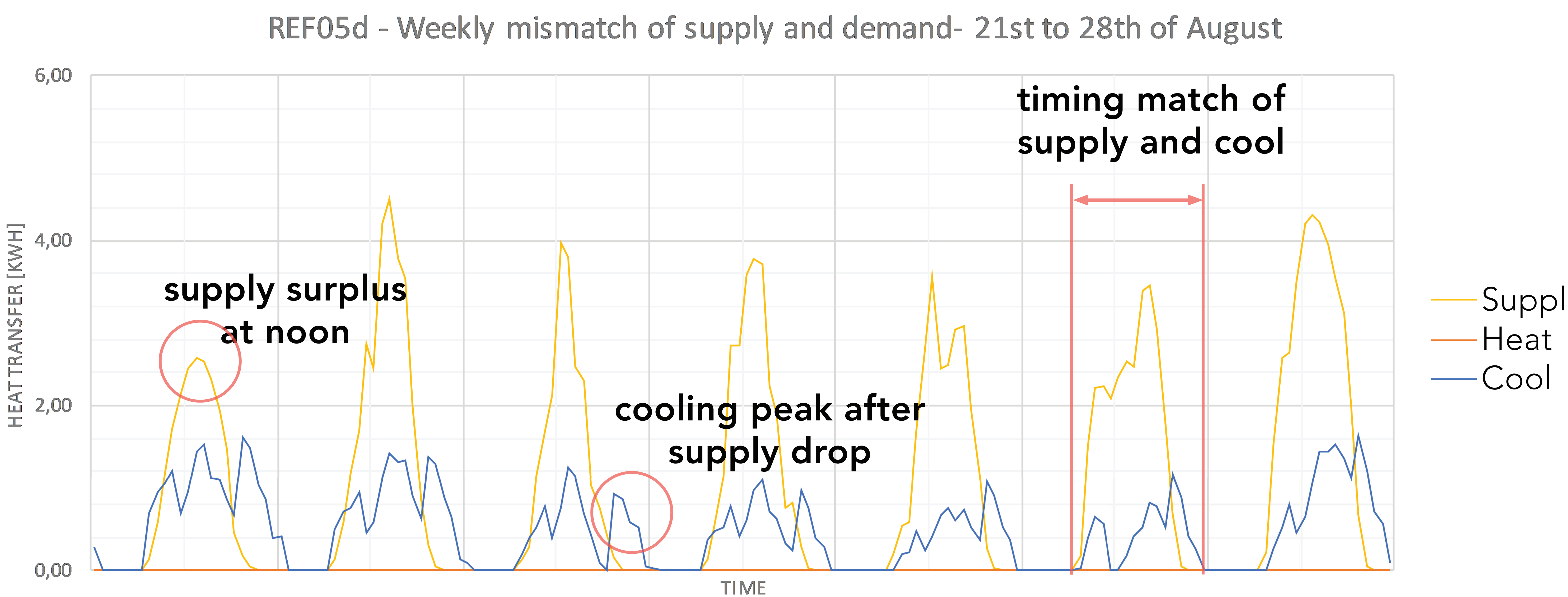
Third sub-question

CURRENT RESIDENTIAL MISMATCH



Third sub-question

CURRENT RESIDENTIAL MISMATCH



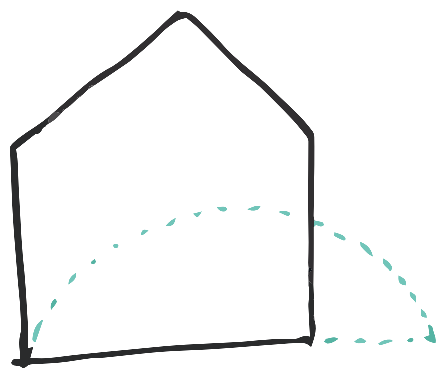
5

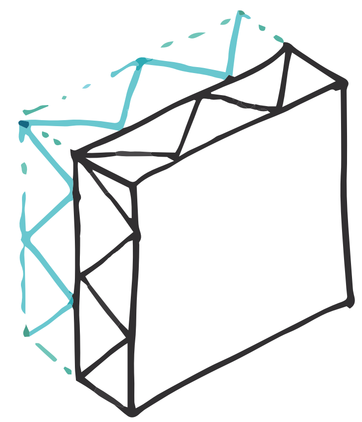
Which building parameters influence energy-flatness?

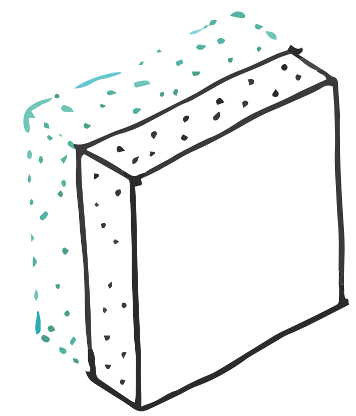
Parameter study

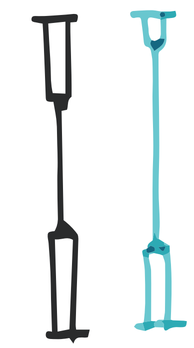
Fourth sub-question

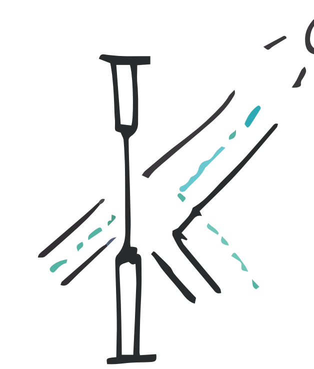
PARAMETER STUDY

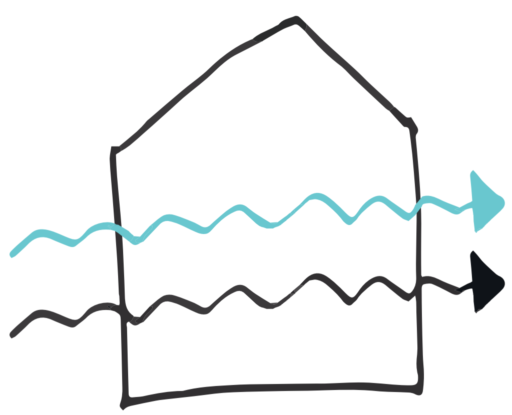

surface/floor ratio

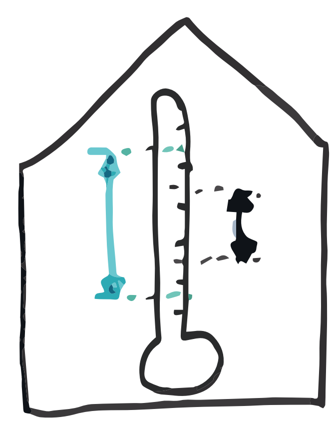

insulation

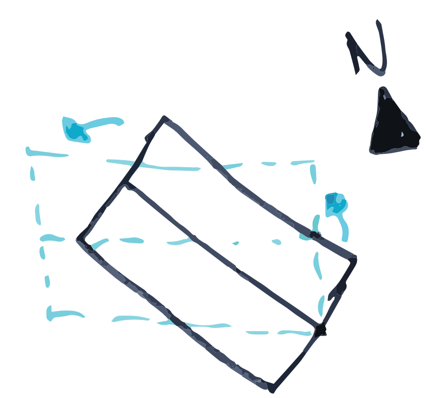

thermal mass


window share

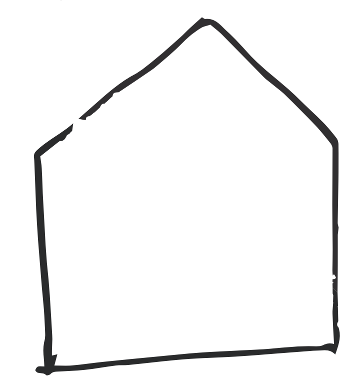

g-value


ventilation rate


temperature range

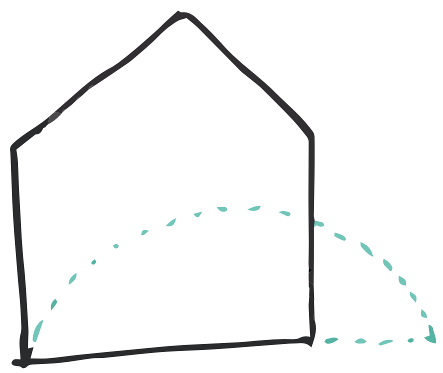


orientation


supply per surface

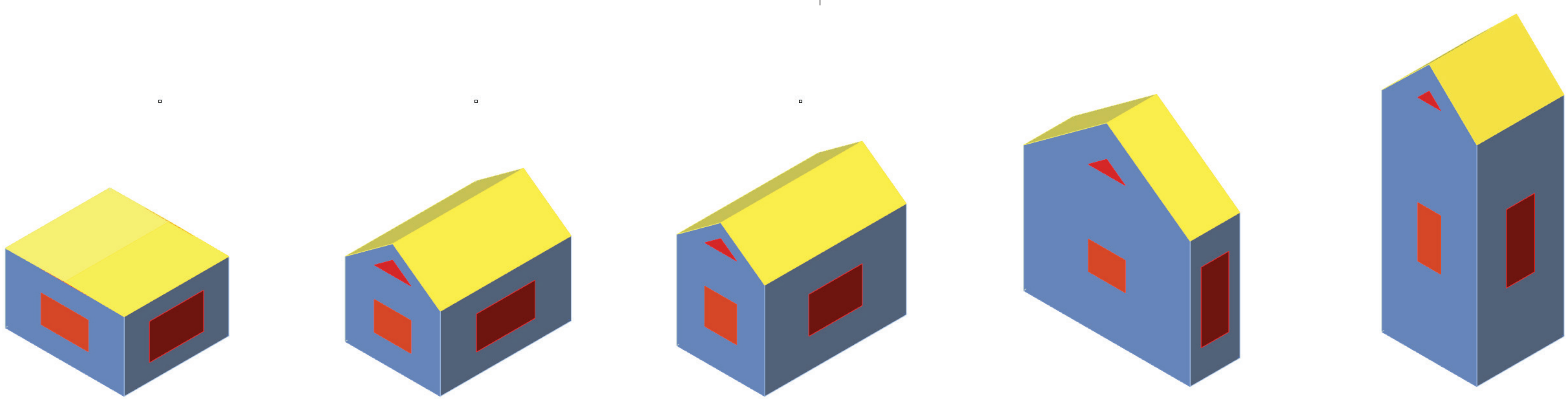
Fourth sub-question

PARAMETER STUDY



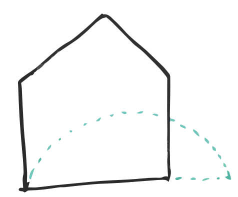
surface/floor ratio

	unit	GeoSrf_A	REF05d	GeoSrf_C	GeoSrf_D	GeoSrf_E
Parameter change						
Building skin surface area	m2	306.6	367.9	441.5	529.8	652.7
Relative change	%	83.33 %	100.0 %	120.0 %	144.0 %	172.8 %
Inevitable side changes						
Volume	m3	512.6	674.1	831.6	771.7	1146.6
Thermal mass	10^6* J/K	96.0	110	120	130	160

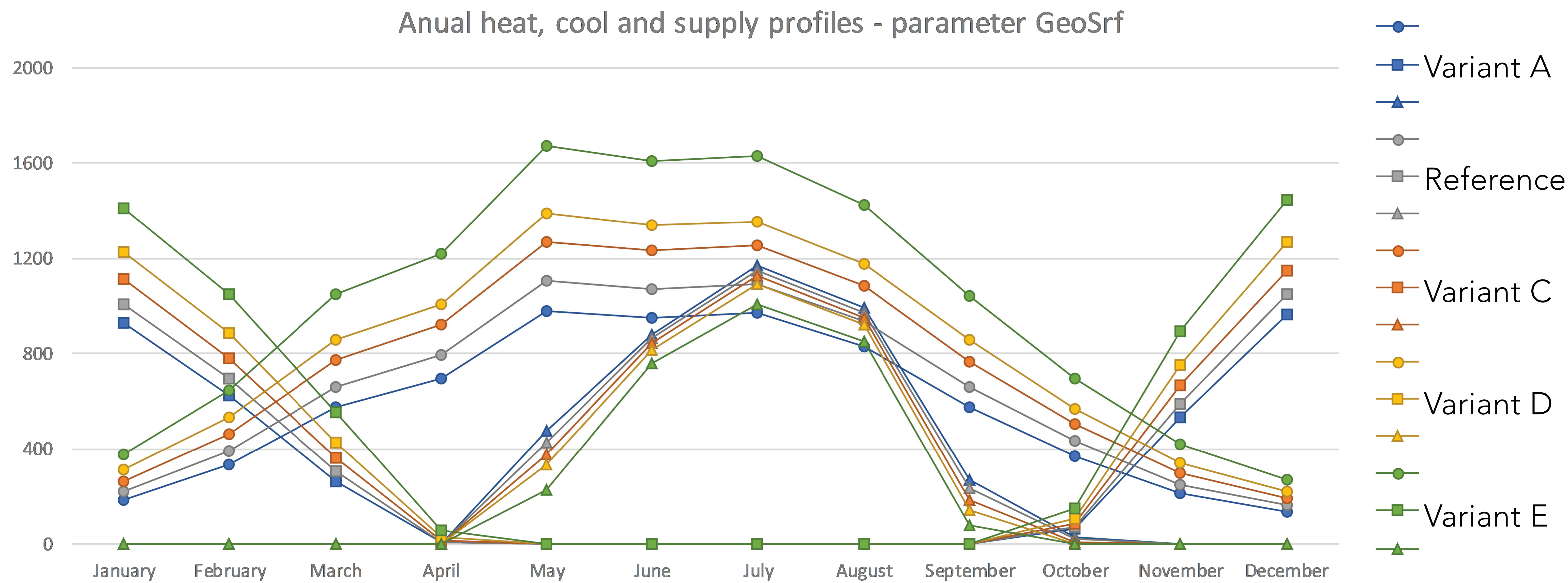


Fourth sub-question

PARAMETER STUDY

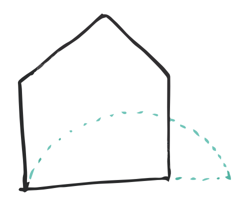


surface/floor ratio

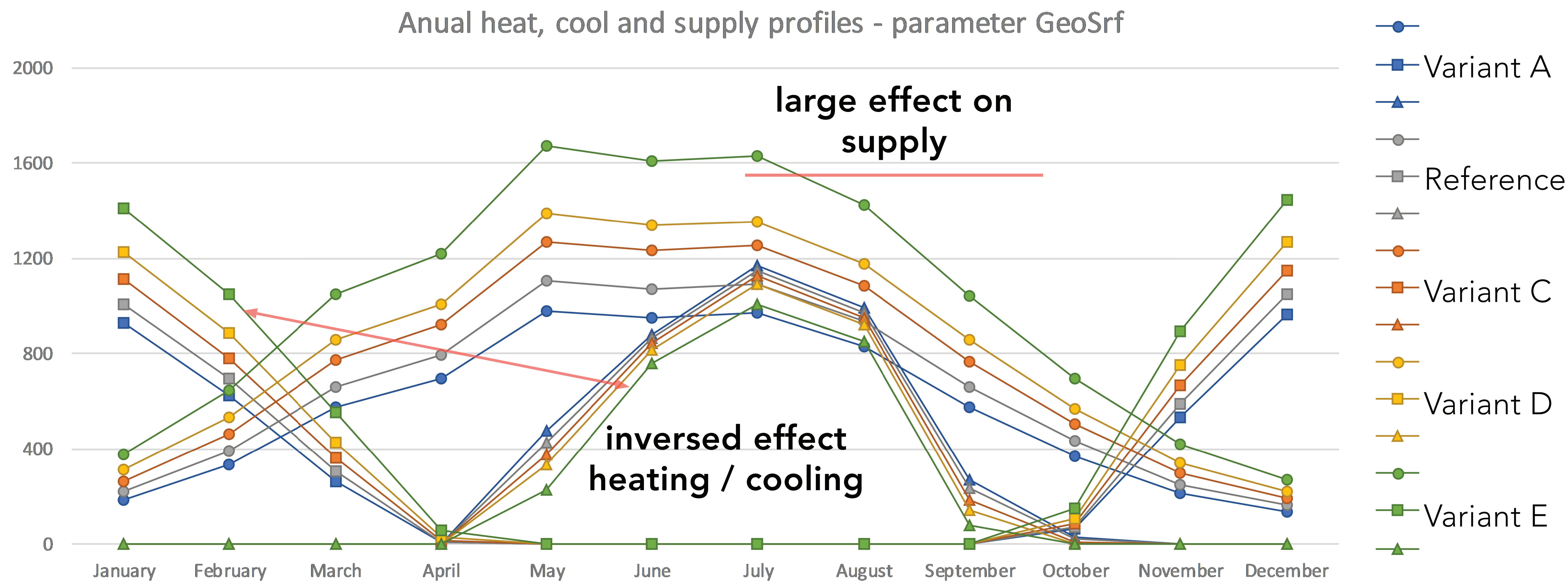


Fourth sub-question

PARAMETER STUDY



surface/floor ratio



Fourth sub-question

PARAMETER STUDY

	Best for energy-flatness			
	All year	Winter	Summer	Remarks
surface/floor ratio	Minimize			Big unintended effect on supply
insulation	Maximize			
thermal mass	Maximize			Superficial thermal mass is effective
ventilation rate		Minimize	Maximize when Tout < Tin	
temperature range	Maximize	Lower heating setpoint		Consider comfortable indoor climate
window share	Minimize on northern facades	Maximize southern when radiation is present		
window g-value		Maximize on southern windows	Minimize on southern windows	South-west window is significant
orientation	Orient building to south			Very little effect
supply per surface	none	Maximize	Opt. lower supply	Supply surplus should be considered

6

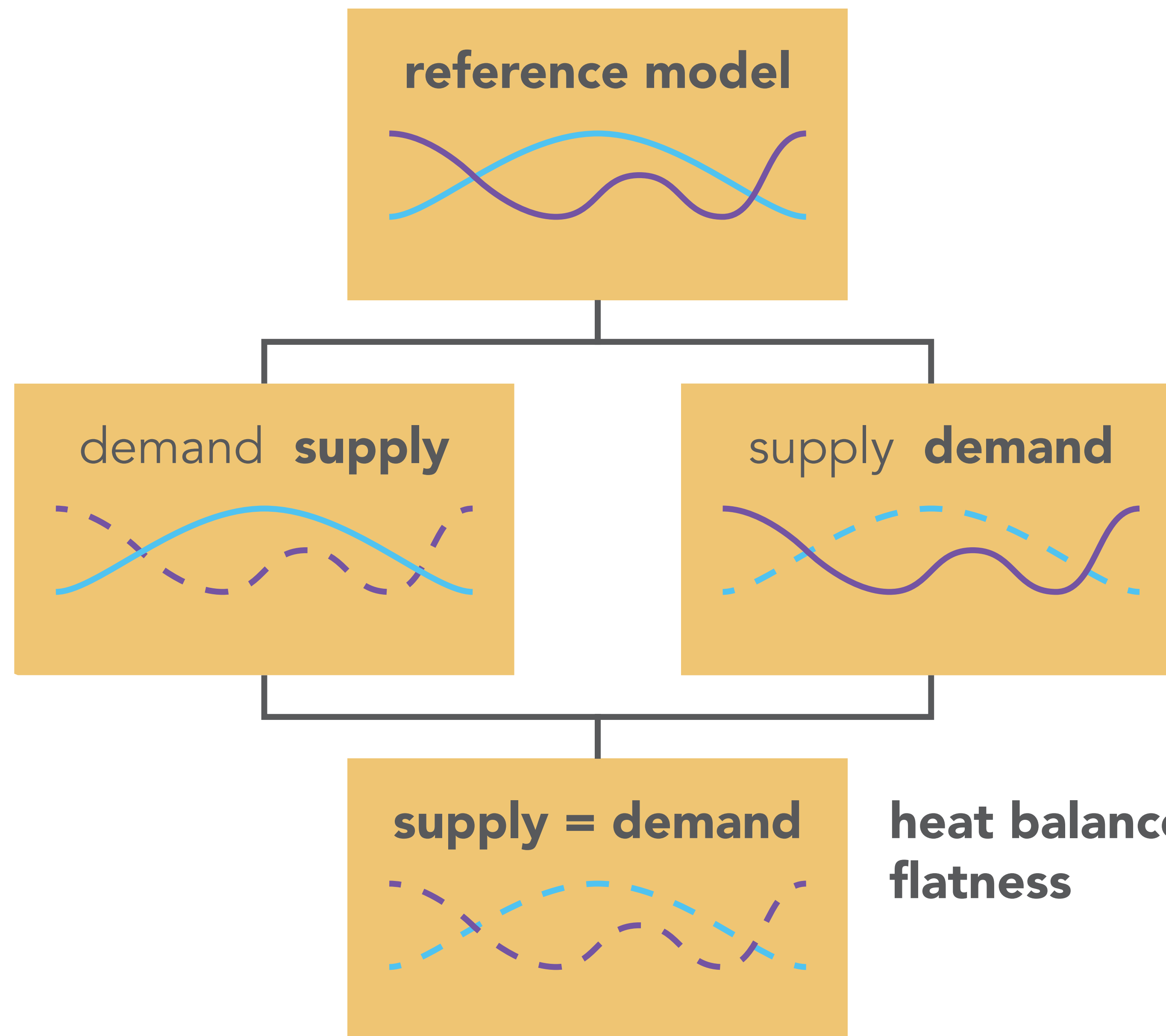
Energy-flat design

Designs, toolbox and energy-flat performance

CONTENTS

Energy-flat design

APPROACH

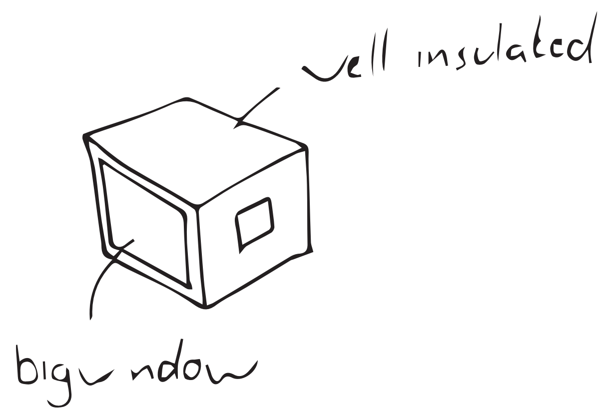


heat balance
flatness

DEMAND-ORIENTED DESIGN

DEMAND-ORIENTED DESIGN

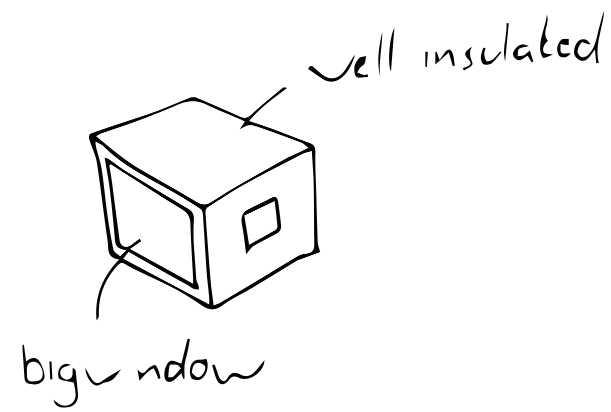
First design iteration



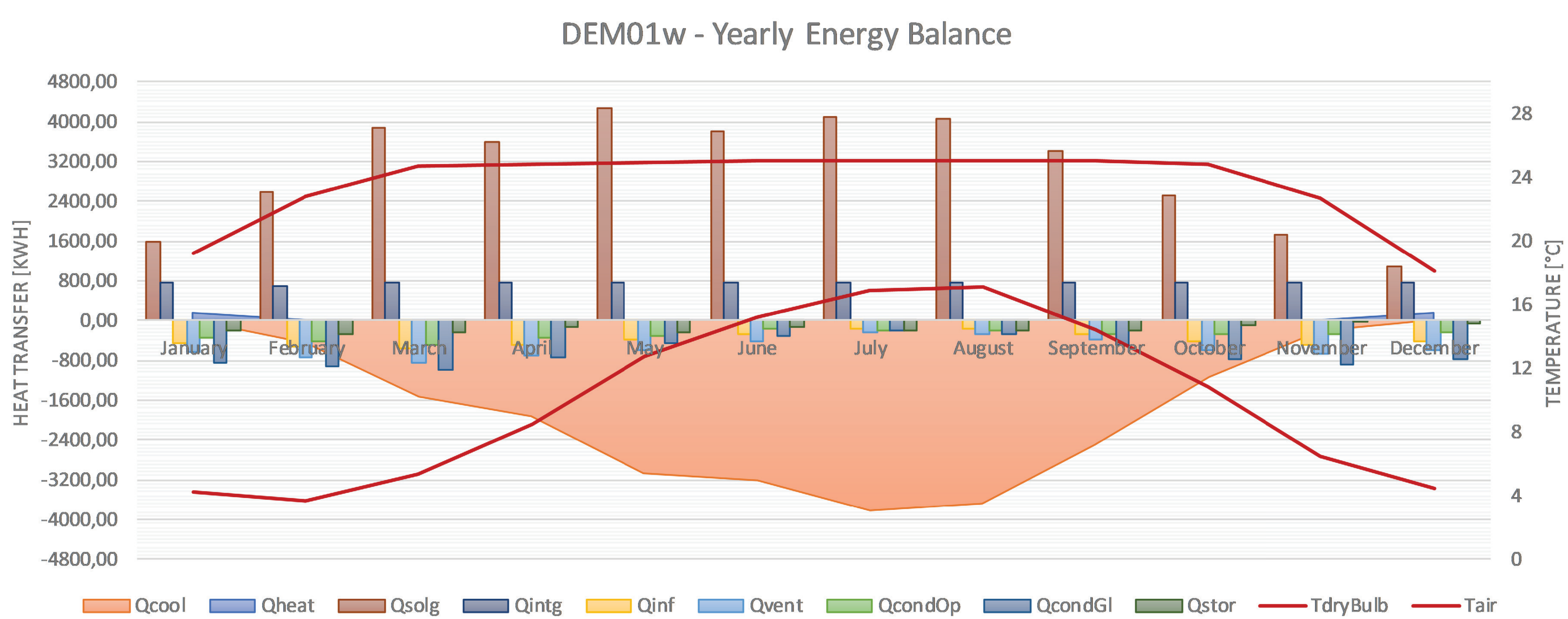
input based on parameter study

DEMAND-ORIENTED DESIGN

First design iteration

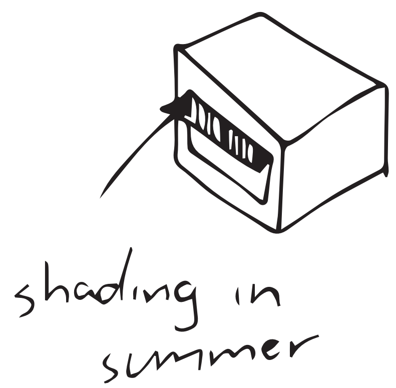


input	based on parameter study
conclusions	low thermal losses are essential
problems	excessive cooling load



DEMAND-ORIENTED DESIGN

Second design iteration

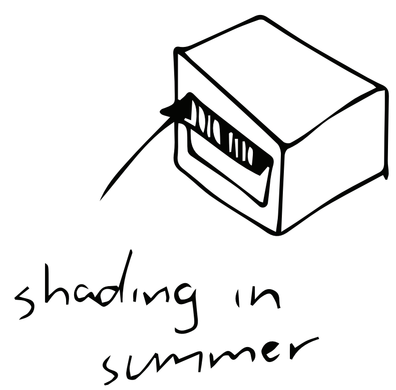


input shading during summer days

slightly smaller window

DEMAND-ORIENTED DESIGN

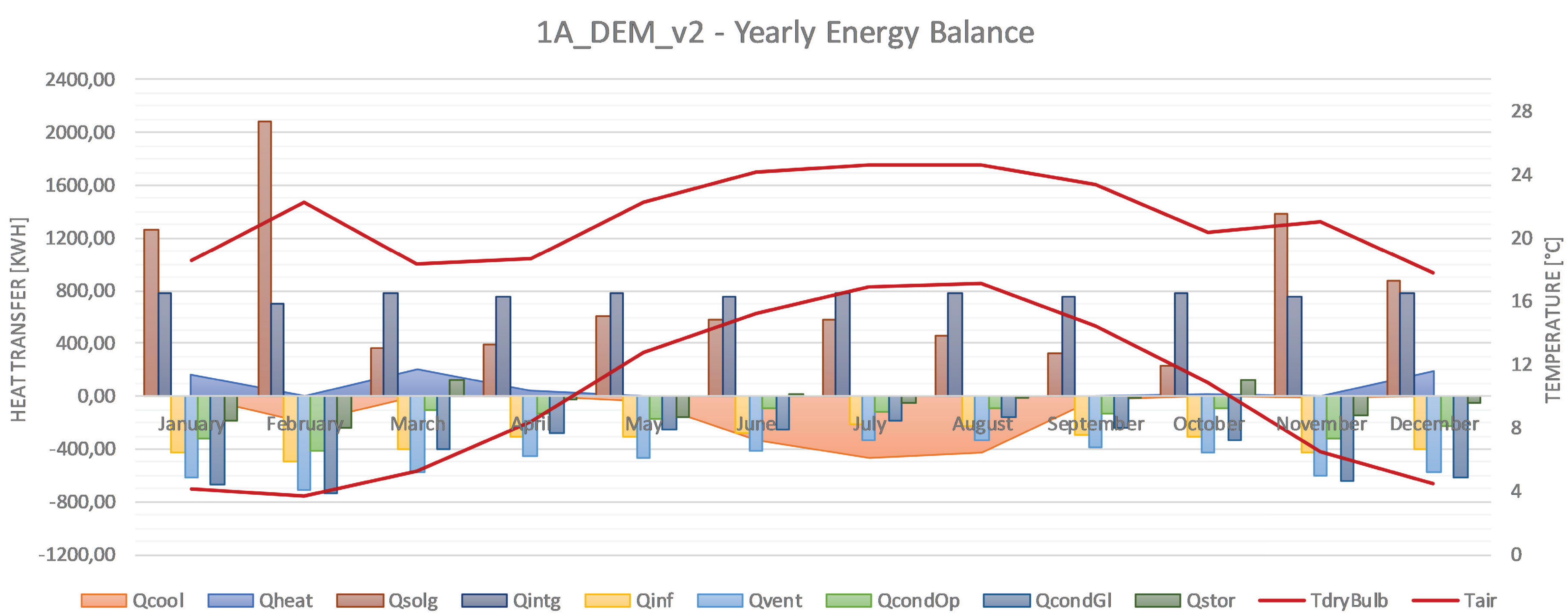
Second design iteration



input shading during summer days

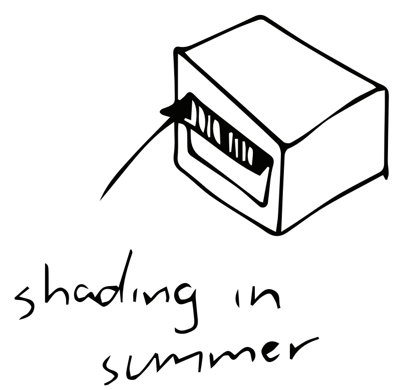
slightly smaller window

conclusions solar blinds are effective

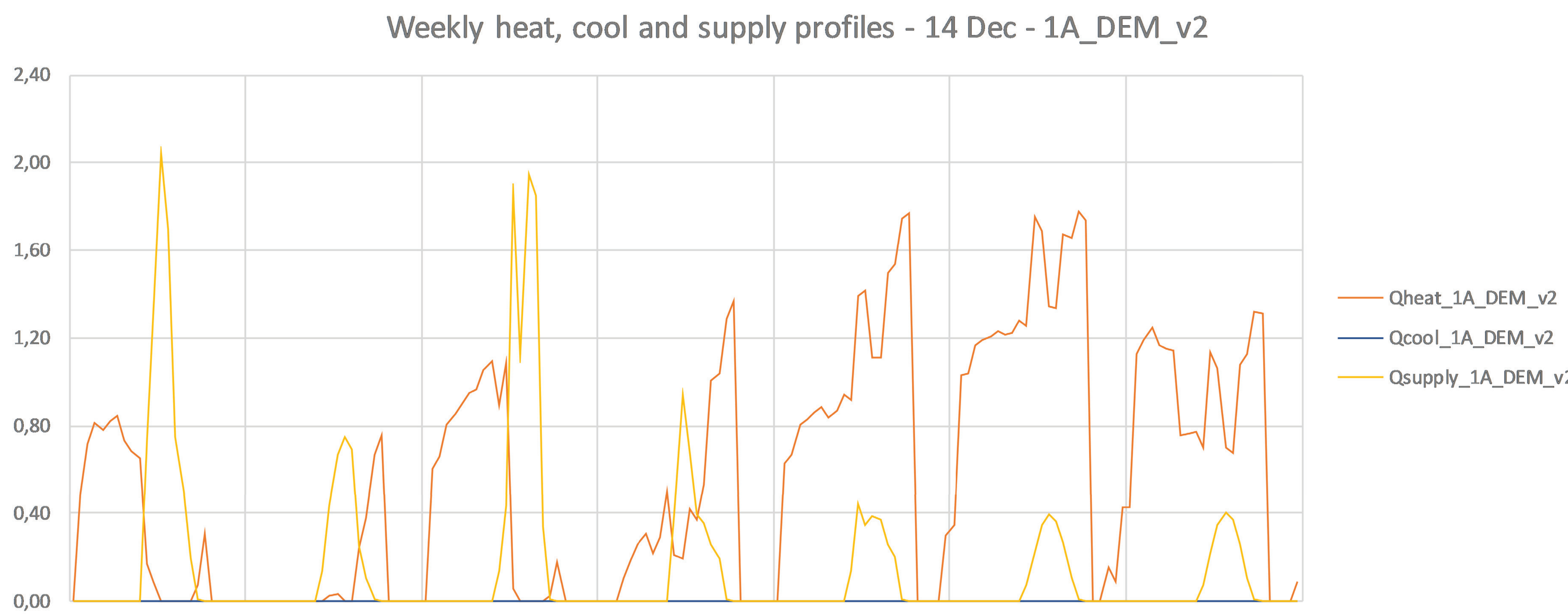


DEMAND-ORIENTED DESIGN

Second design iteration

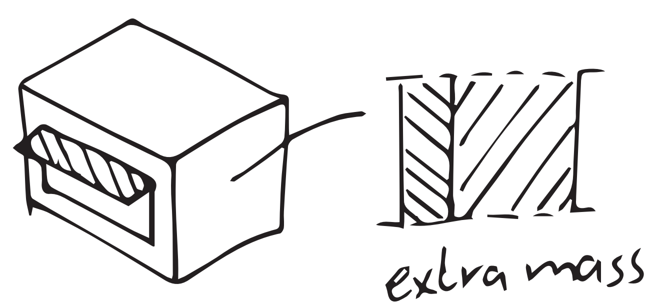


input	shading during summer days
	slightly smaller window
conclusions	solar blinds are effective
problems	heating mismatch winternight



DEMAND-ORIENTED DESIGN

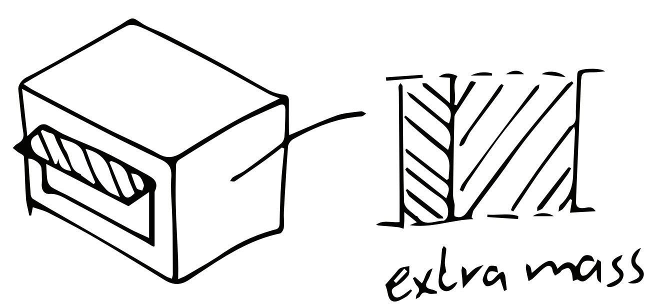
Third design iteration



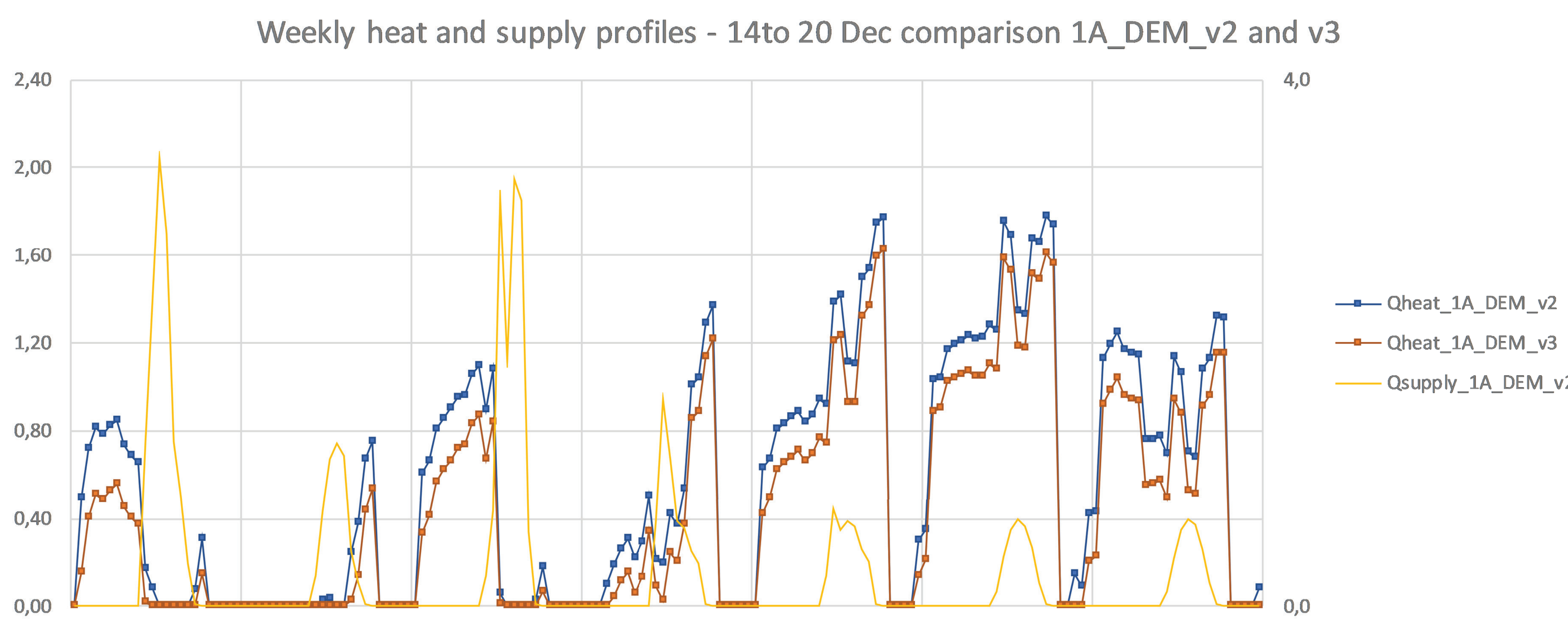
input thermal mass is added

DEMAND-ORIENTED DESIGN

Third design iteration



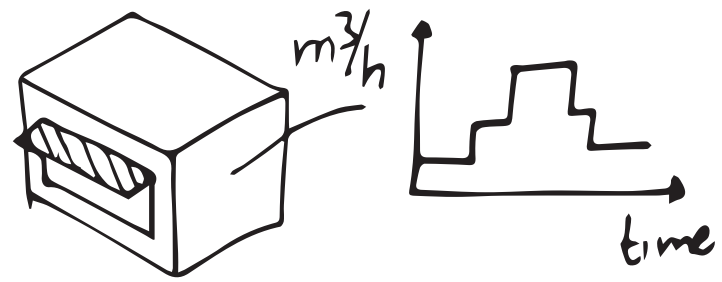
input	thermal mass is added
conclusions	mitigated peaks
problems	still a large heating mismatch



DEMAND-ORIENTED DESIGN

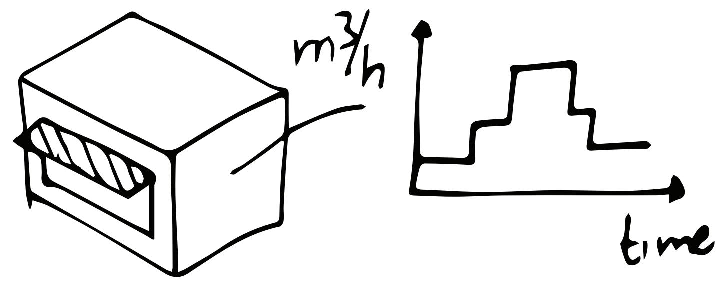
Fifth design iteration

input adaptive ventilation schedule



DEMAND-ORIENTED DESIGN

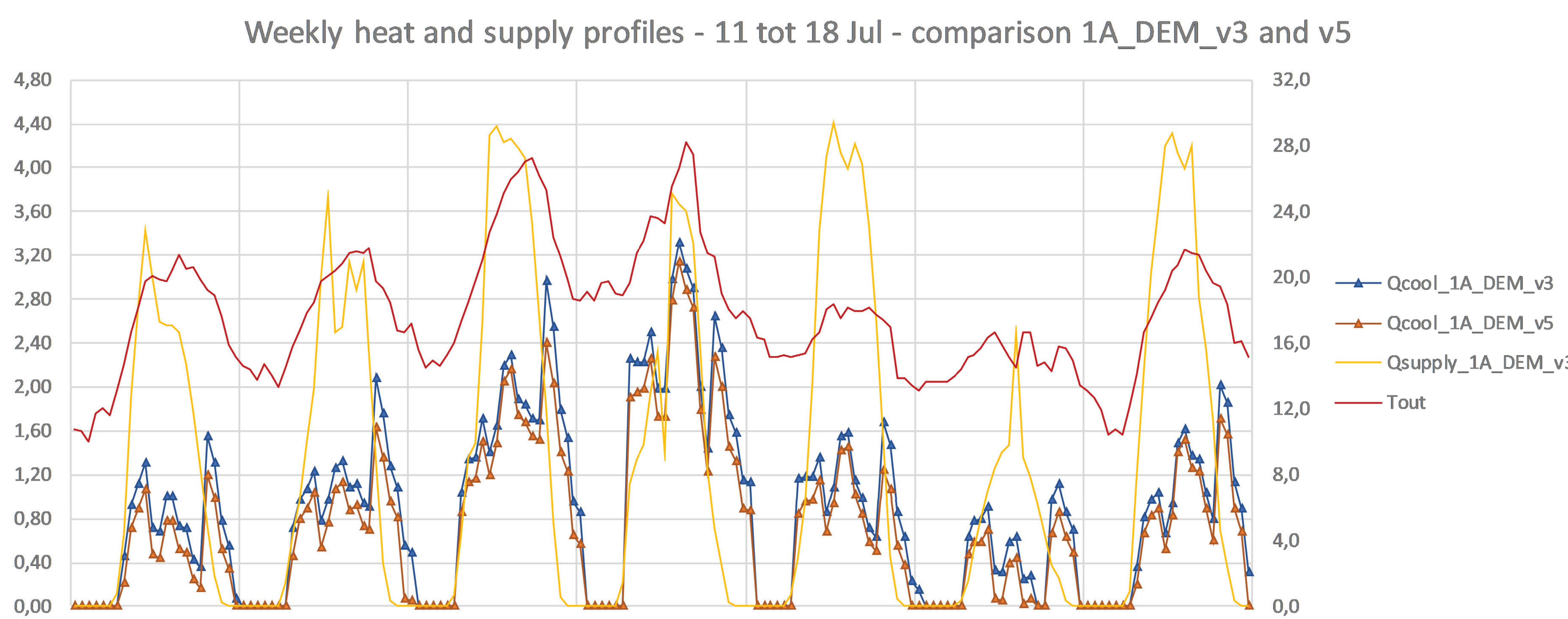
Fifth design iteration



input adaptive ventilation schedule

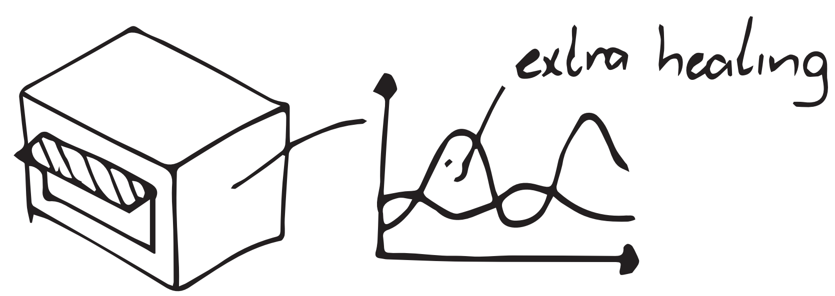
conclusions heating load effectively lowered

problems mismatch still not solved



DEMAND-ORIENTED DESIGN

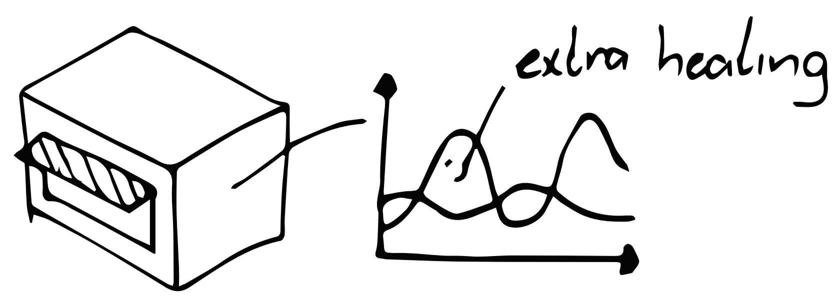
Sixth design iteration



input pre-heating and pre-cooling

DEMAND-ORIENTED DESIGN

Sixth design iteration

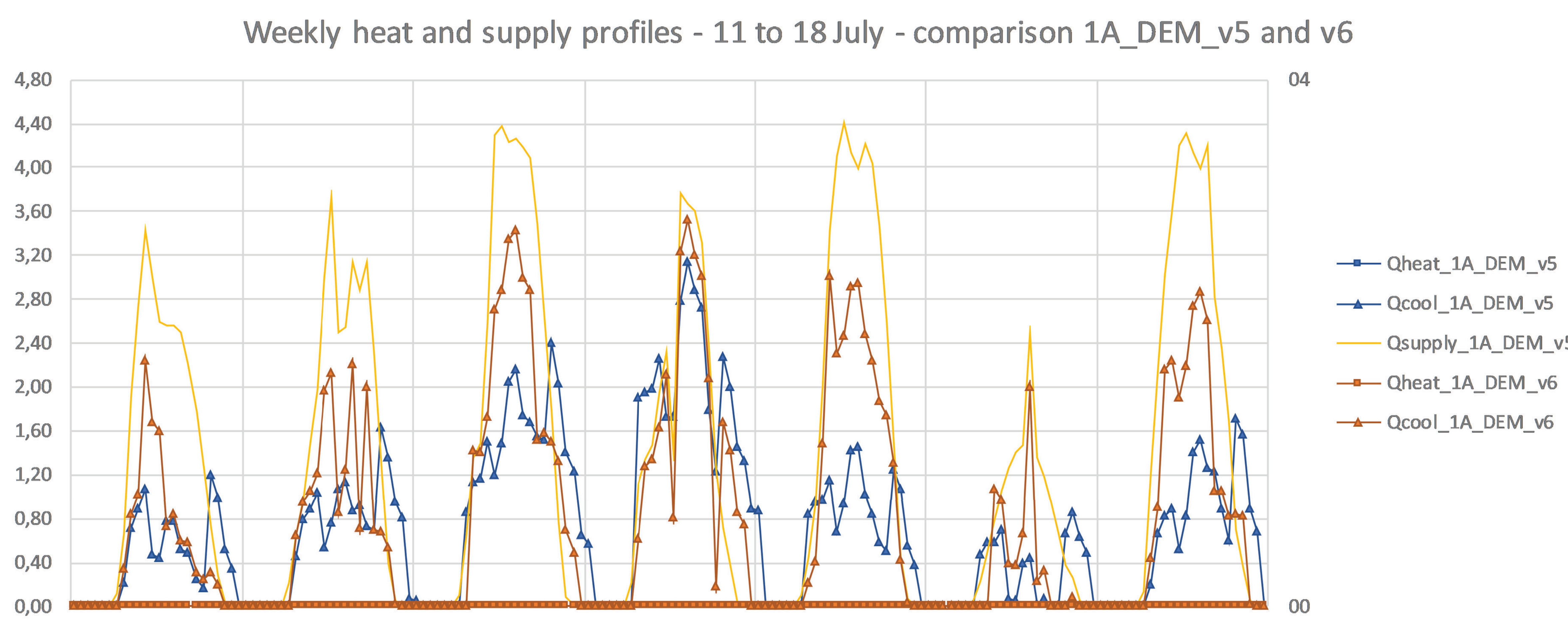


input pre-heating and pre-cooling

conclusions approach is very effective.

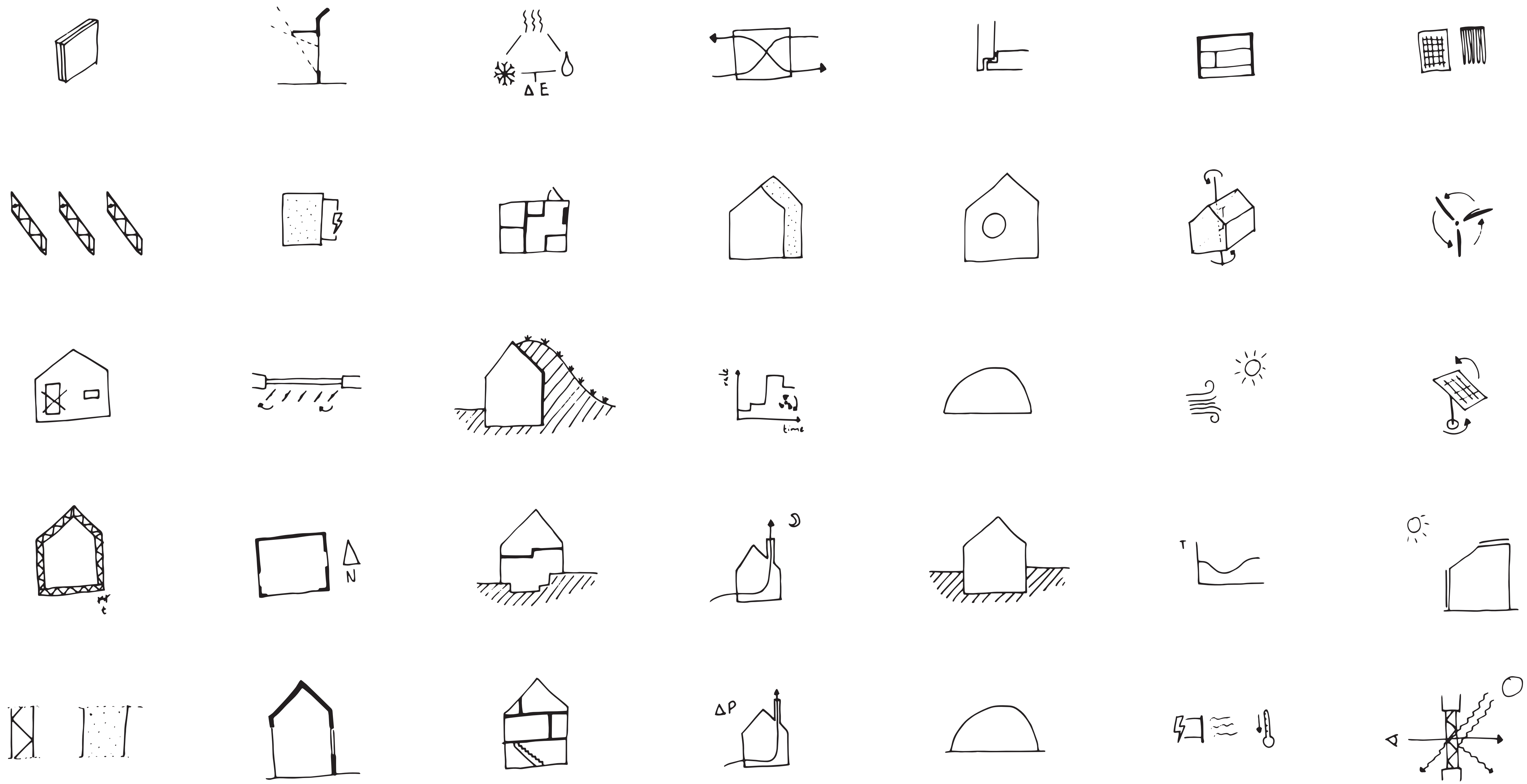
total heating+cooling is higher,

but mismatch is lower



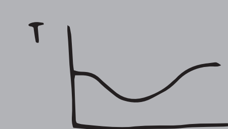
ENERGY-FLAT DESIGN TOOLBOX

ENERGY-FLAT DESIGN TOOLBOX

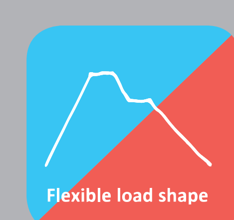


ENERGY-FLAT DESIGN TOOLBOX

16. adaptive thermal comfort



studies have shown that lower indoor temperatures are accepted in times of lower outdoor temperatures.



element transmission, ventilation, infiltration

impact • •

Functionality
To maintain the desired indoor comfort, certain heating and cooling setpoints are assumed by most standards. These setpoints, however, are constant all year and studies have shown them to be not representative for an actual comfortable temperature. Adaptive thermal comfort relies on the seasonal changes in comfortable indoor temperatures based on the running mean outdoor temperature. This means a lower heating setpoint in winter and higher cooling setpoint in summer.

Effects on energy profiles
- reduced heating loads and reduced cooling loads as a result of lower differences between the indoor air temperature and outdoor temeprature.

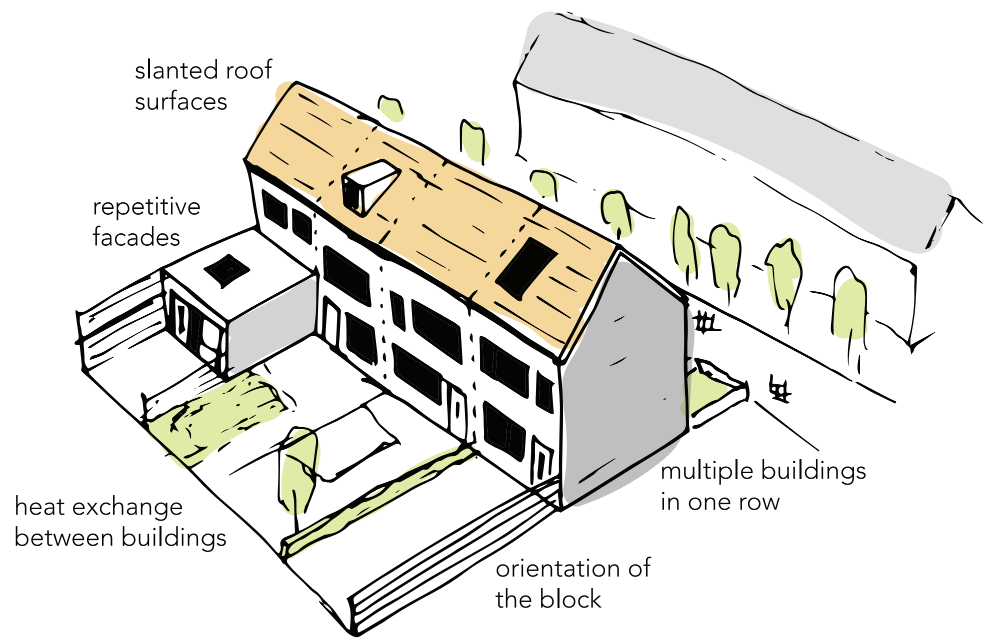
- a slightly more flexible load shape, because less energy is required to manage the comfort in the building

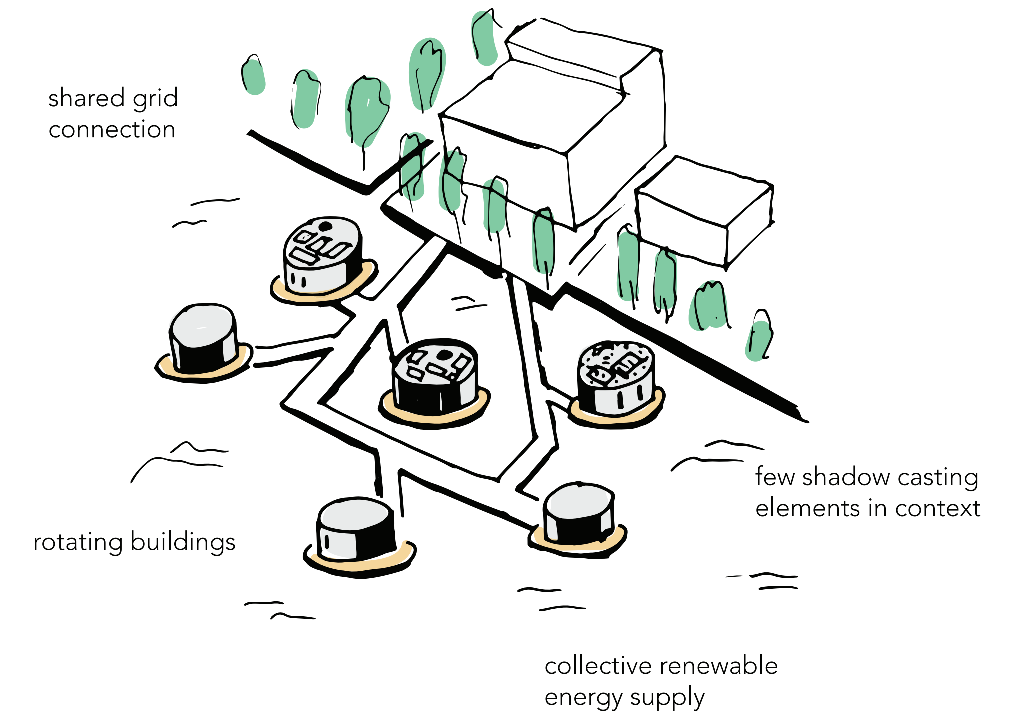
Technical
The adaptive thermal comfort studies regard changes in thermal comfort over the season. It might be interesting to also have adaptive thermal comfort within the timeframe of one day, so energy can be saved during the night, in favour of energy-flatness.

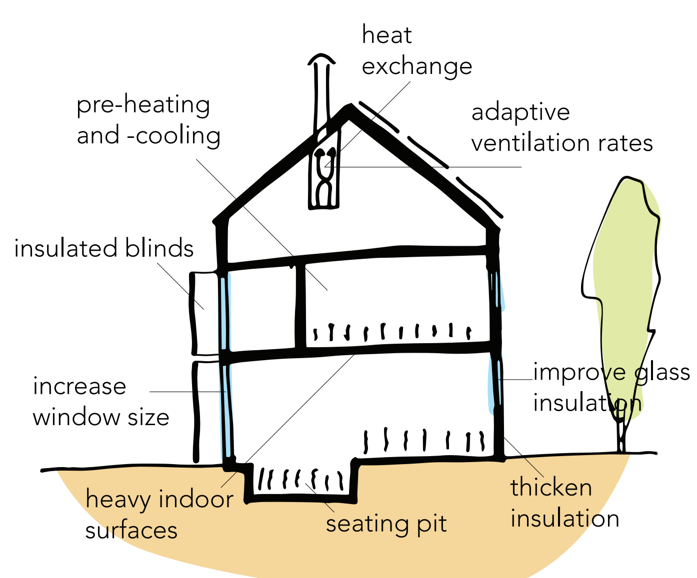
Considerations
The adaptive thermal comfort might be combined with radiative heating for even better energy-flat performance.

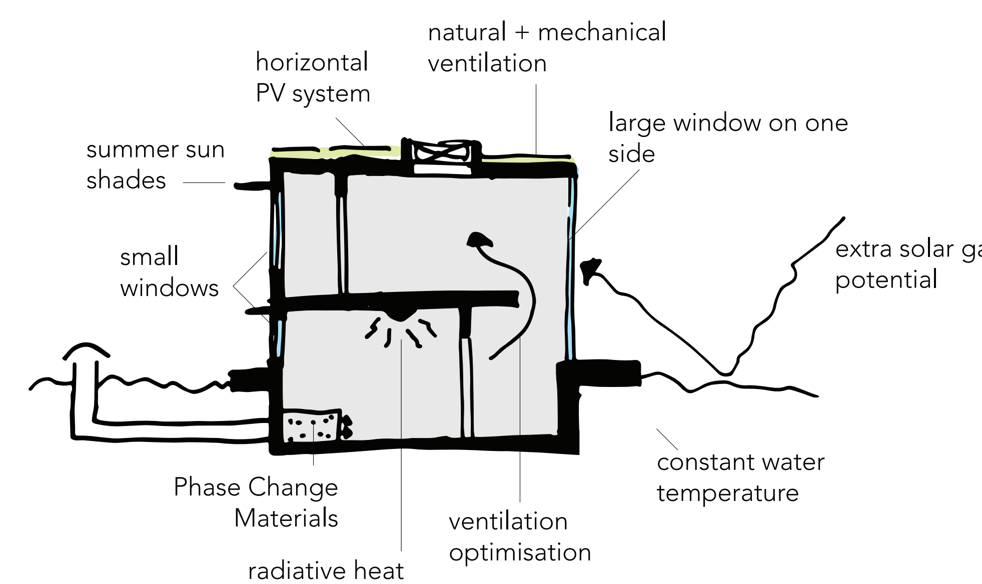
ENERGY-FLAT DESIGN TOOLBOX

ENERGY-FLAT DESIGN TOOLBOX





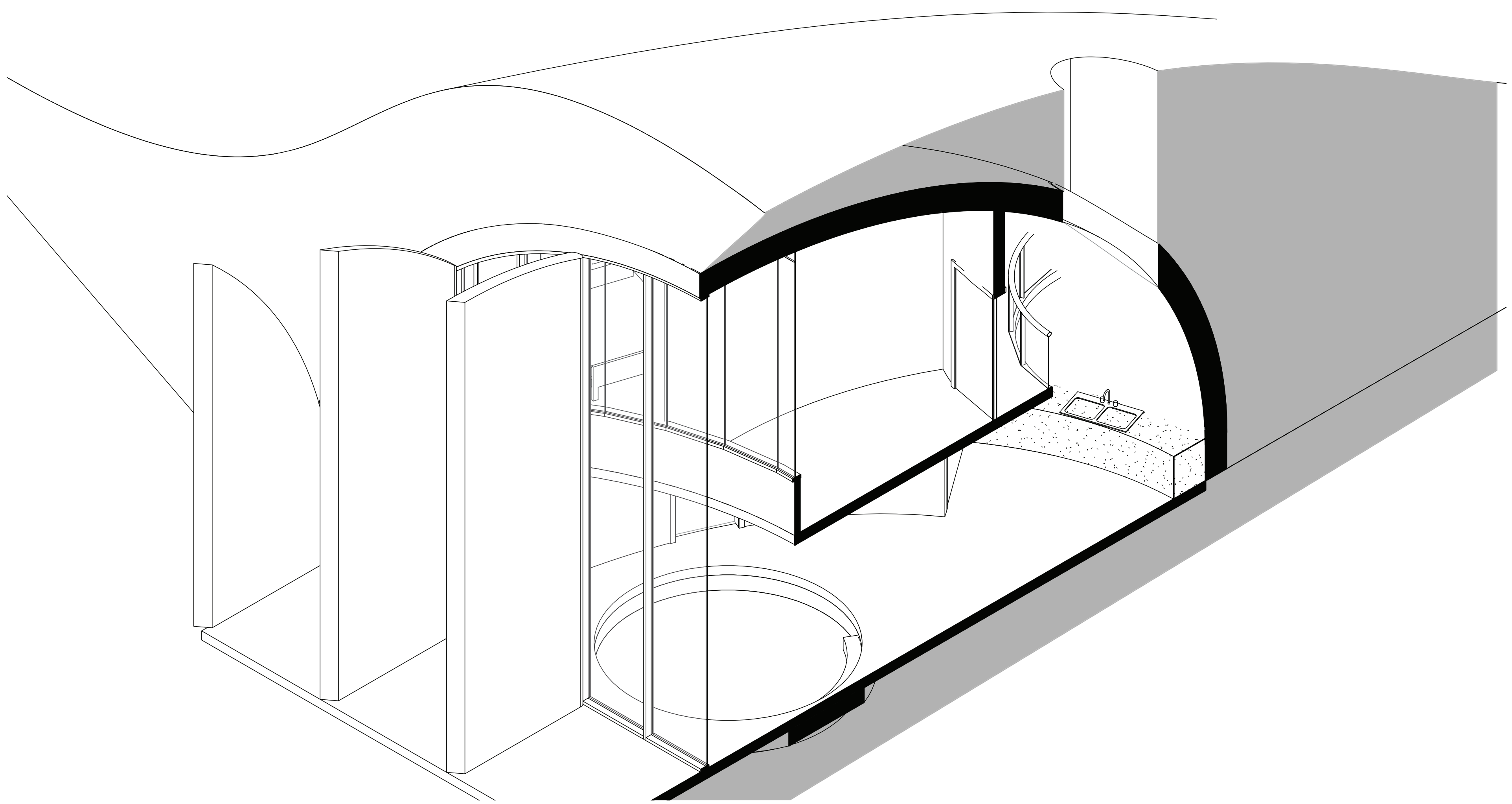




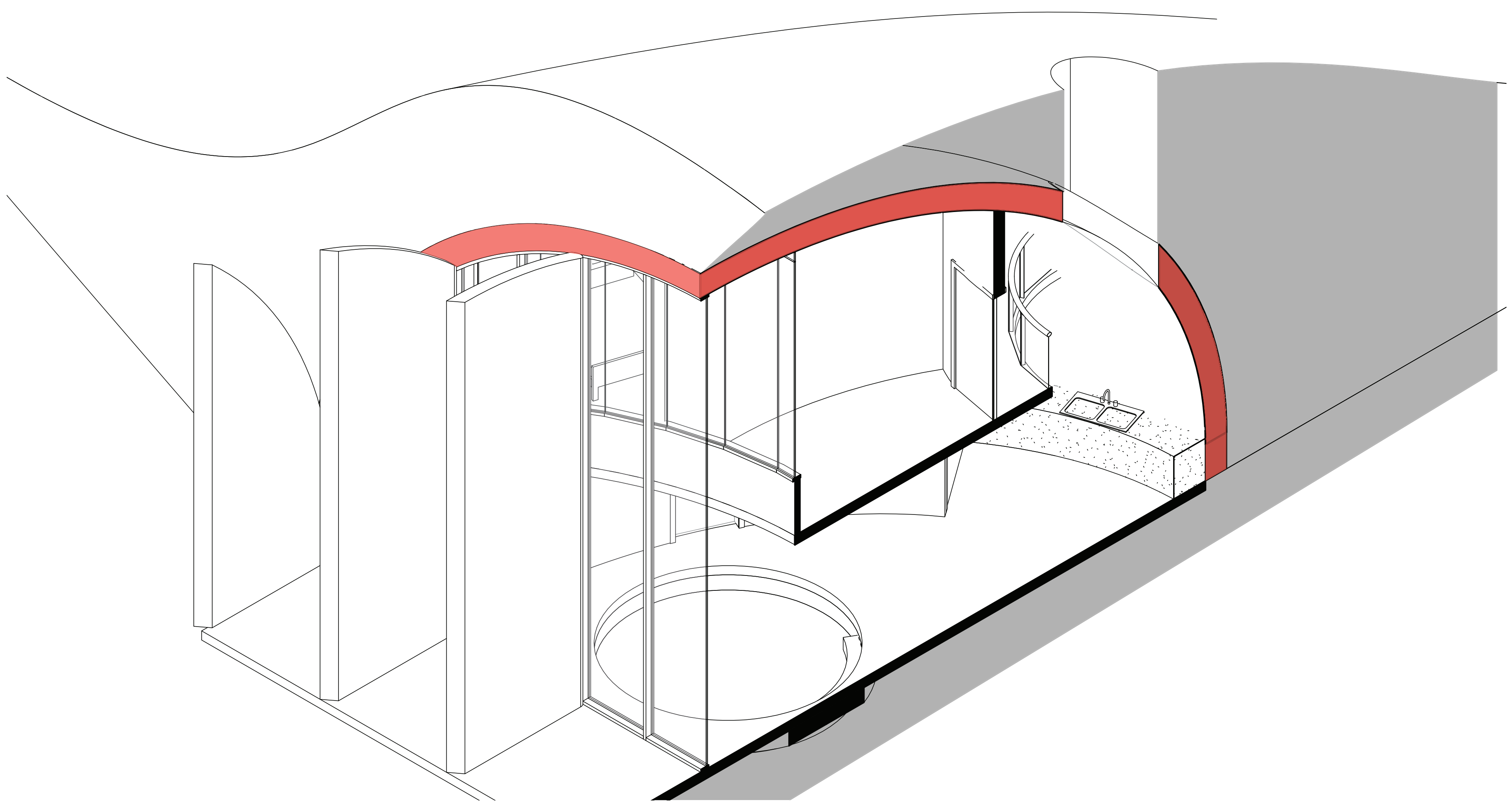
FINAL ENERGY-FLAT DESIGN

FINAL ENERGY-FLAT DESIGN

FINAL ENERGY-FLAT DESIGN



FINAL ENERGY-FLAT DESIGN



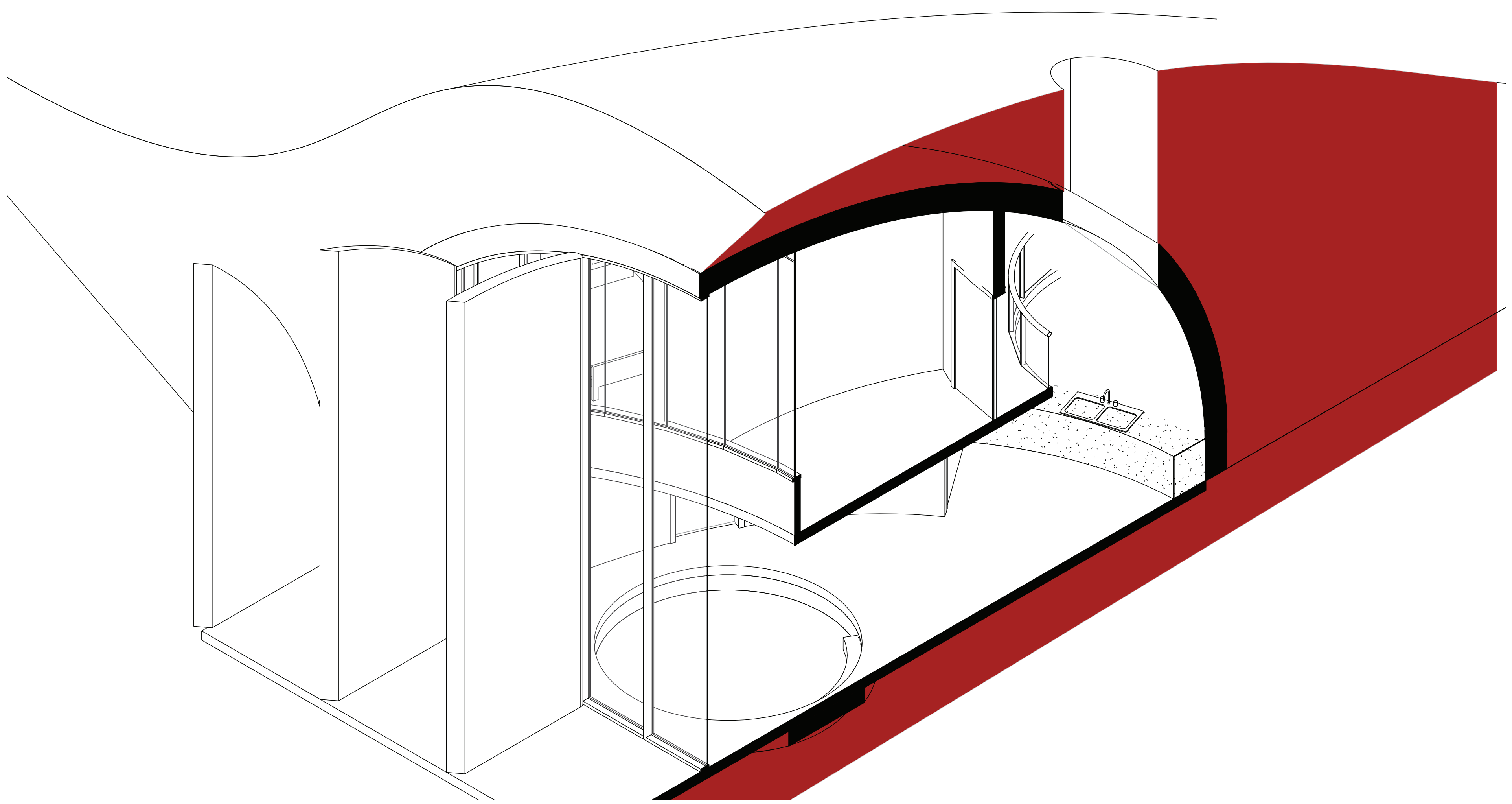
Spherical shape

minimize energy losing surface

larger volume for adaptive

ventilation

FINAL ENERGY-FLAT DESIGN



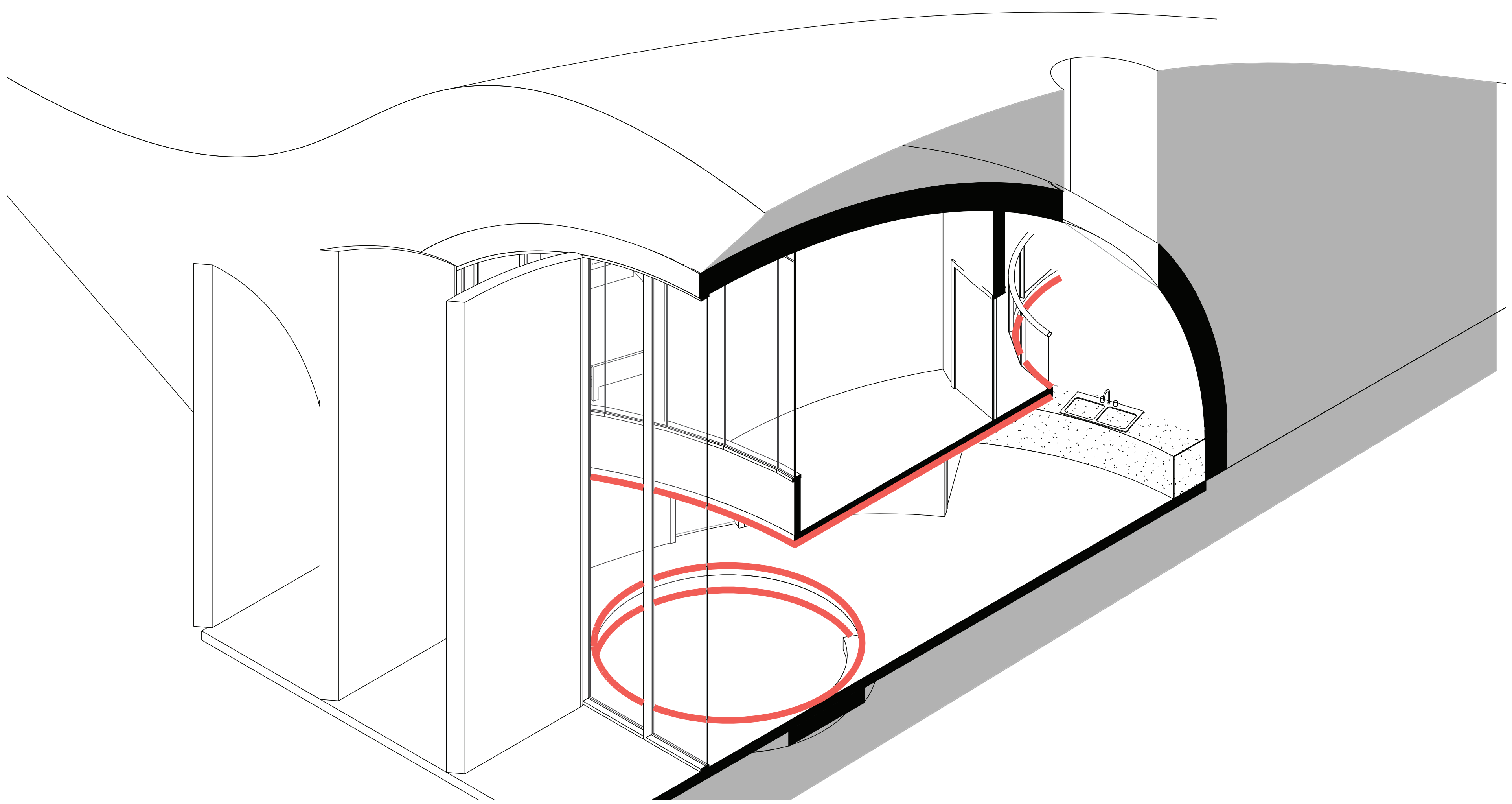
Earth sheltered

big increase of thermal mass

mitigates temperature

changes

FINAL ENERGY-FLAT DESIGN



Level differences & floor plan

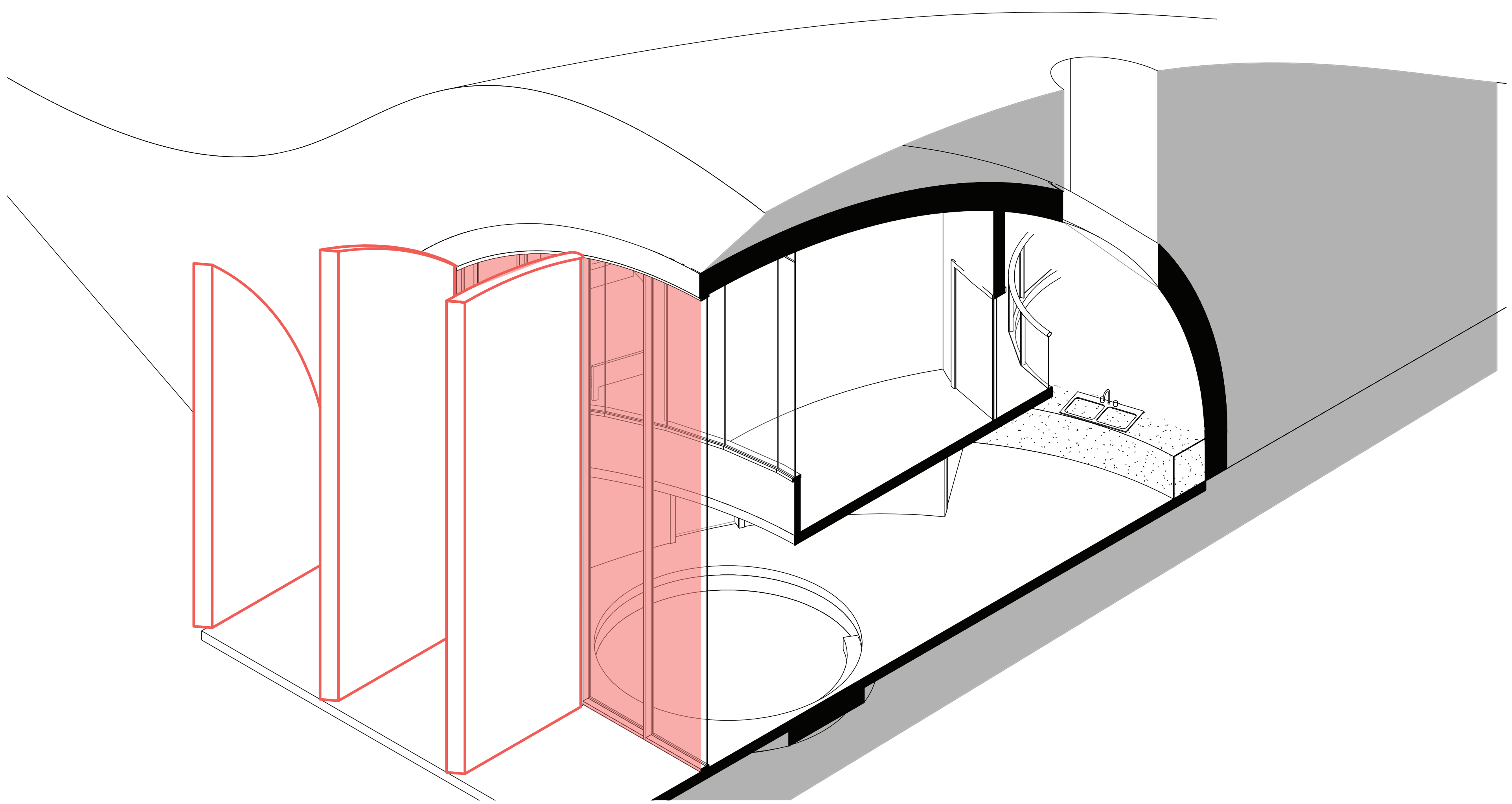
increase the thermal mass

surface area

allow solar radiation to enter

deep into the building

FINAL ENERGY-FLAT DESIGN



Big southern window

allow passive solar heat to enter the building

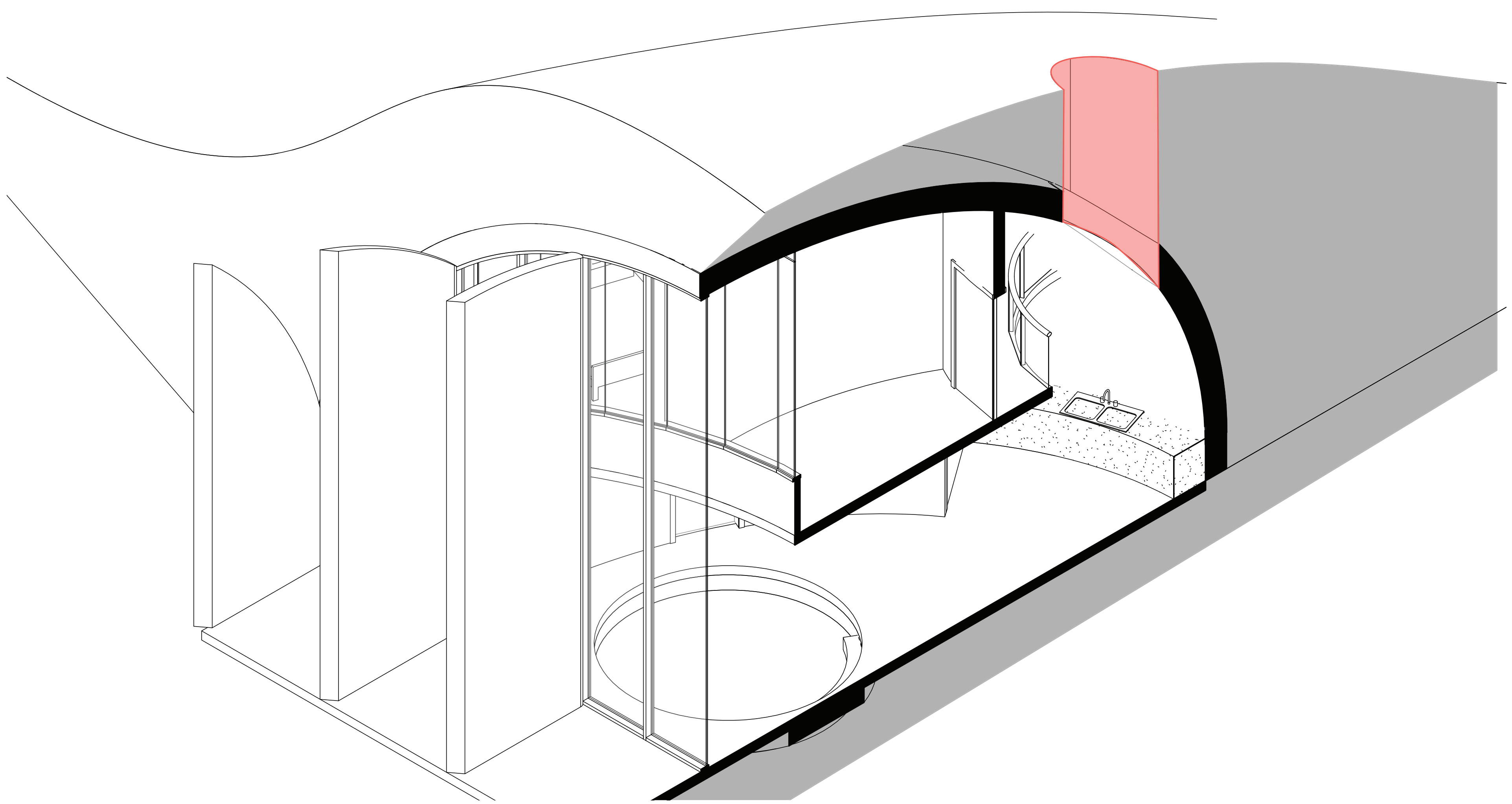
Insulated rotating blinds

insulate window in cold nights

allow solar radiation in winter

block solar radiation in summer

FINAL ENERGY-FLAT DESIGN



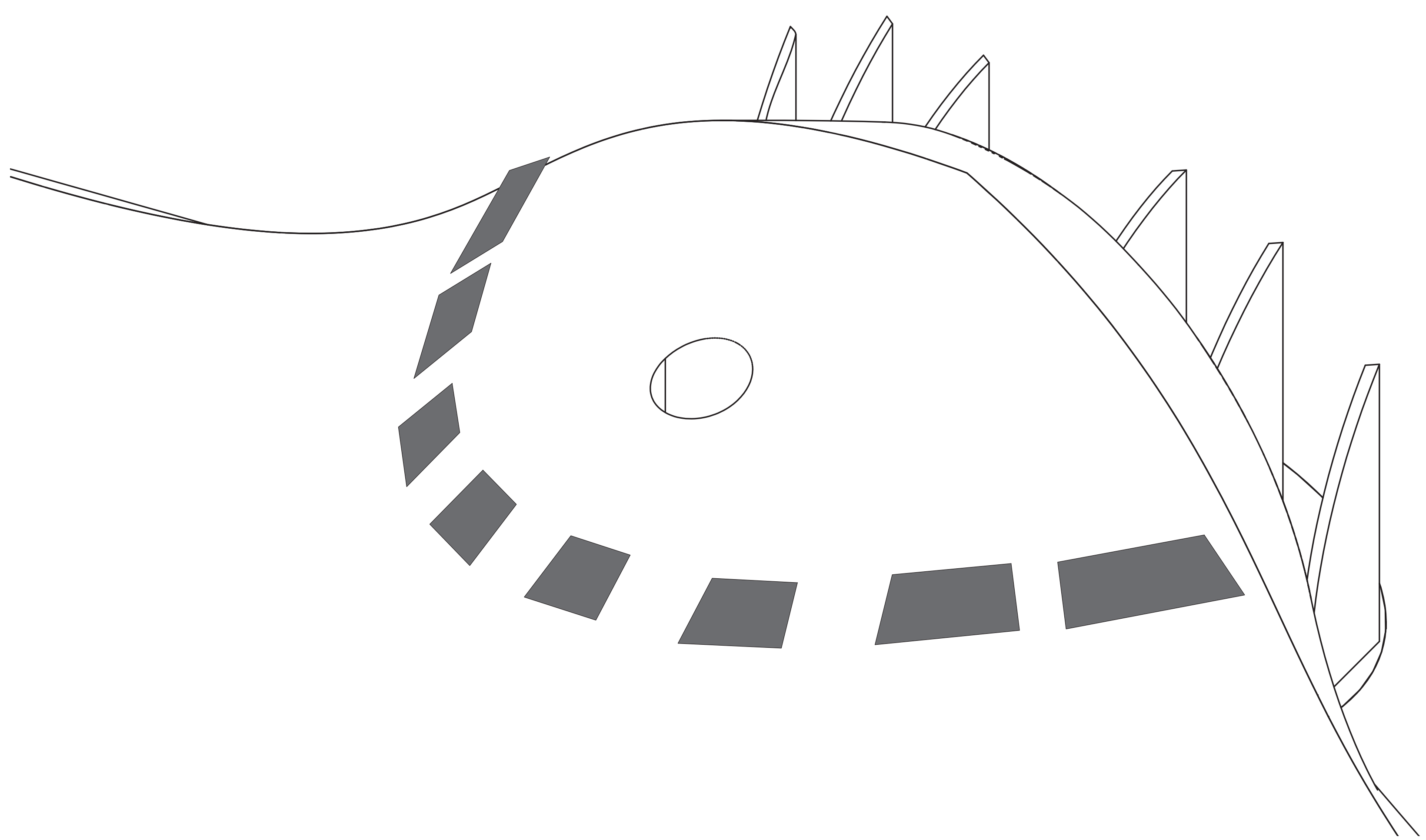
Ventilation shaft

allows for both natural and mechanical ventilation

heat exchange is integrated

architectural comfort

FINAL ENERGY-FLAT DESIGN



Supply

east, north and west are

dominant orientations

ENERGY-FLAT PERFORMANCE OF DESIGN

ENERGY-FLAT PERFORMANCE OF DESIGN

		unit	Reference design	Final design	Relative difference
Annual loads	Total heating load	kWh	3732.5	486.0	-87 %
	Total cooling load	kWh	3675.1	1759.4	-52 %
	Total supply	kWh	7793.6	2290.9	-71 %
KPI 1	Heating shortage	kWh	-3223.6	-356.4	-89 %
	Cooling shortage	kWh	-1292.8	-425.0	-67 %
	Supply surplus	kWh	4902.3	826.9	-83 %
KPI 2	Peak heating shortage	kW	-3.3	-2.4	-25 %
	Peak cooling shortage	kW	-4.6	-2.1	-54 %
	Peak supply surplus	kW	5.0	1.6	-68 %
KPI 3	Maximum cumulative mismatch	kWh	2766.3	610.0	- 78%

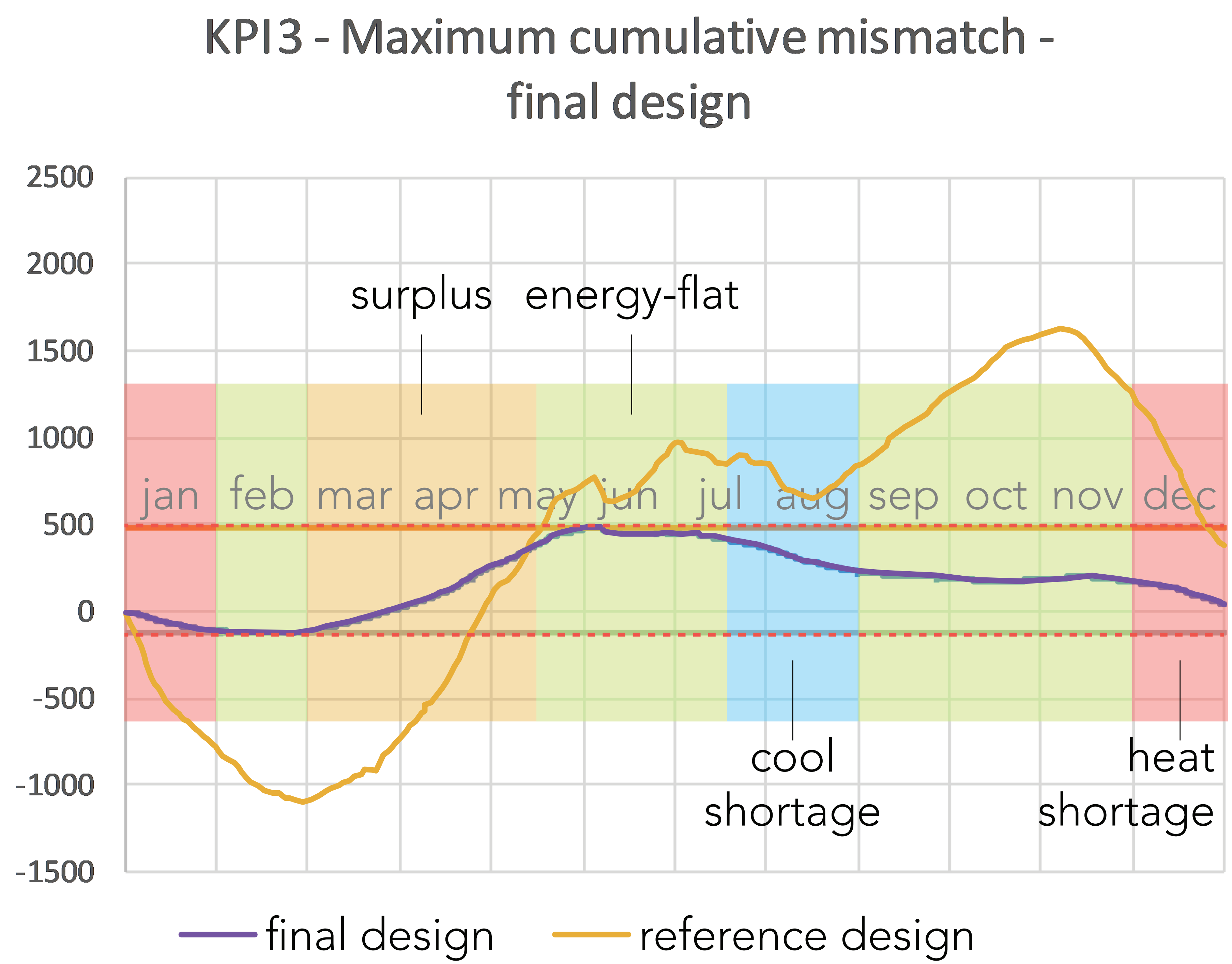
Table 5: total energy consumption and key-performance indicators of the reference design and final energy-flat design

Total mismatch

Ref. = 9518.7 kWh_{th}

Final = 1608.3 kWh_{th}

ENERGY-FLAT PERFORMANCE OF DESIGN

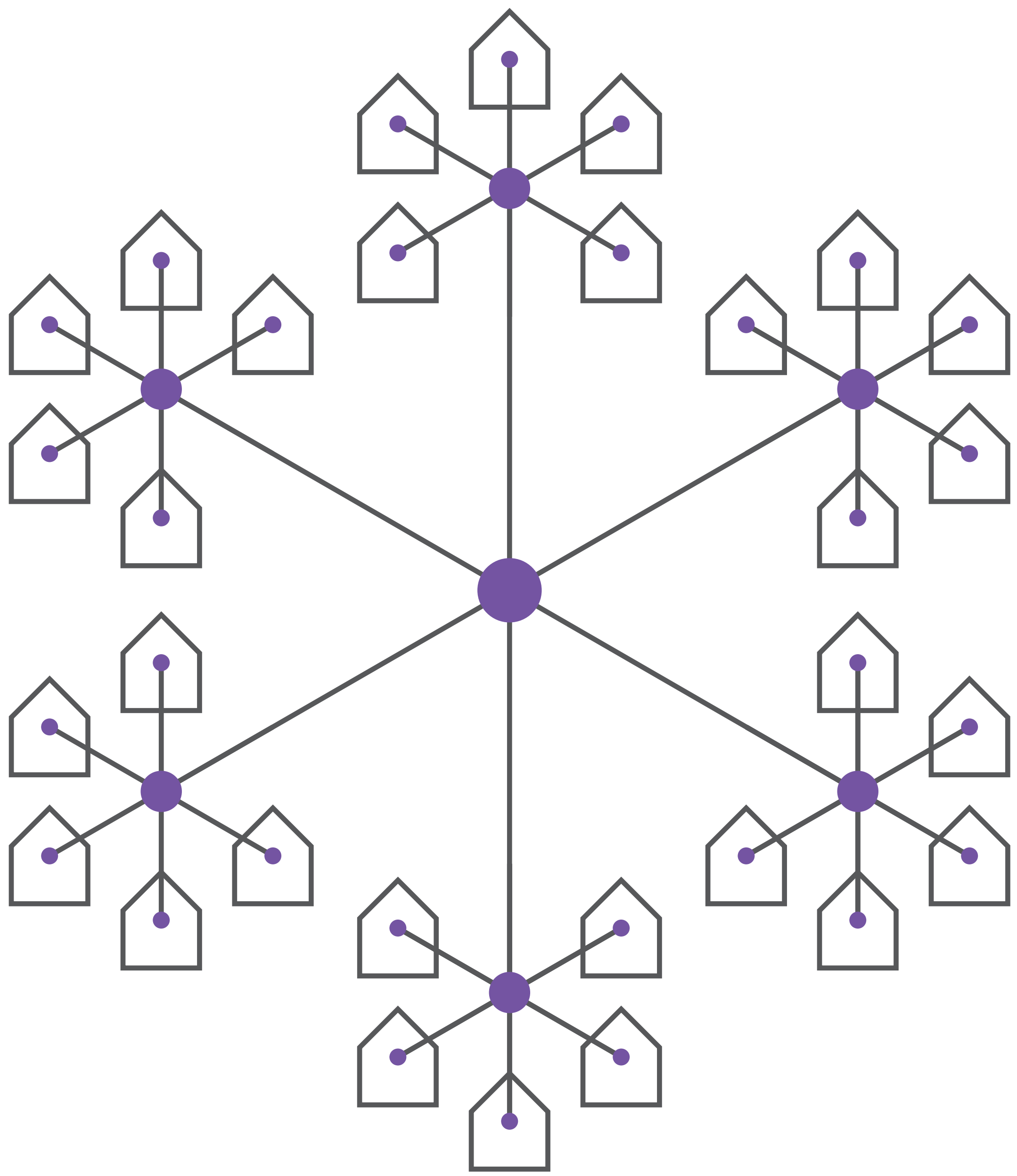


6

ENERGY-FLATNESS IN THE BIGGER SYSTEM

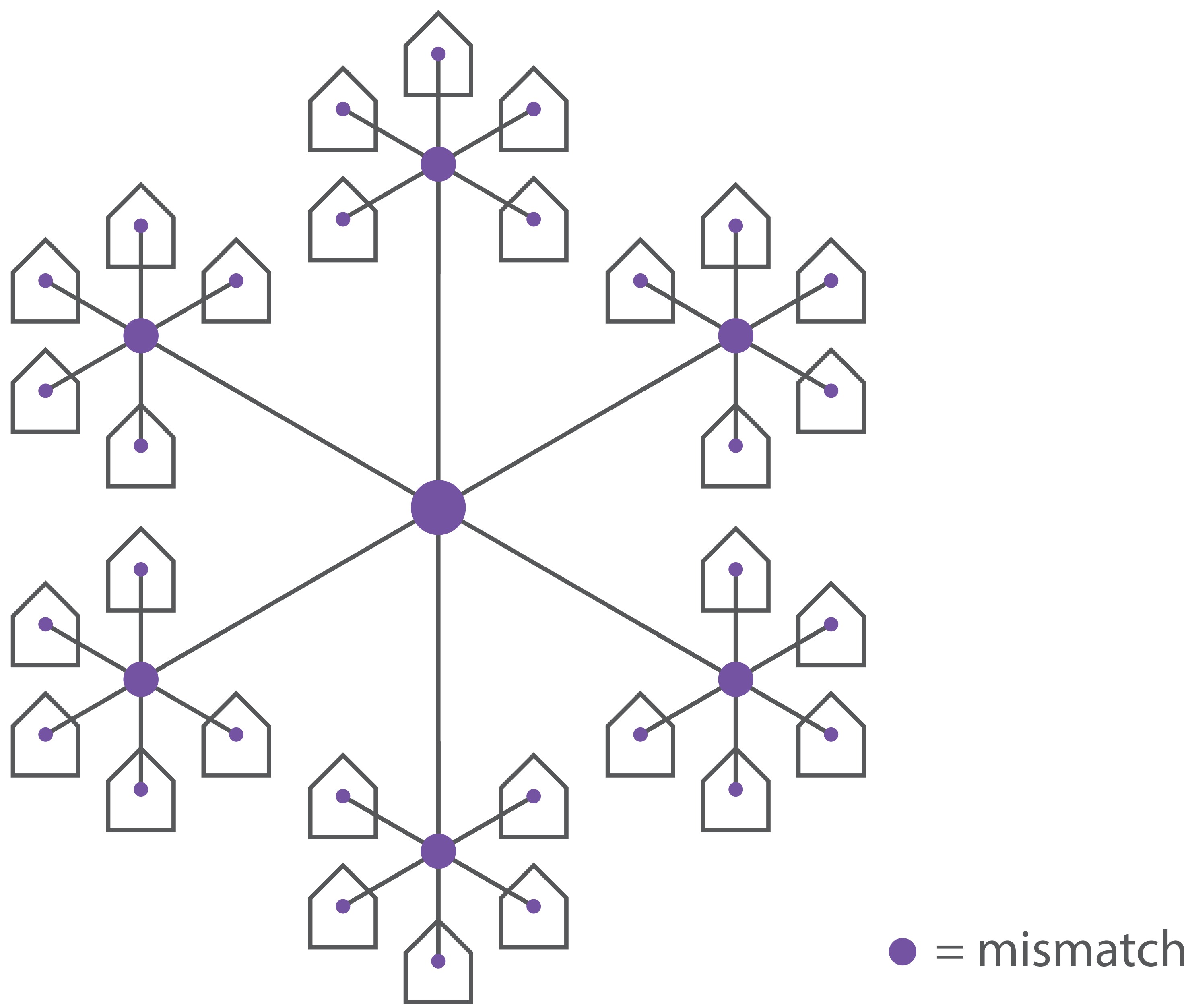
how is an energy-flat building positioned in the system

THE AGGREGATED MISMATCH IN THE SYSTEM



● = mismatch

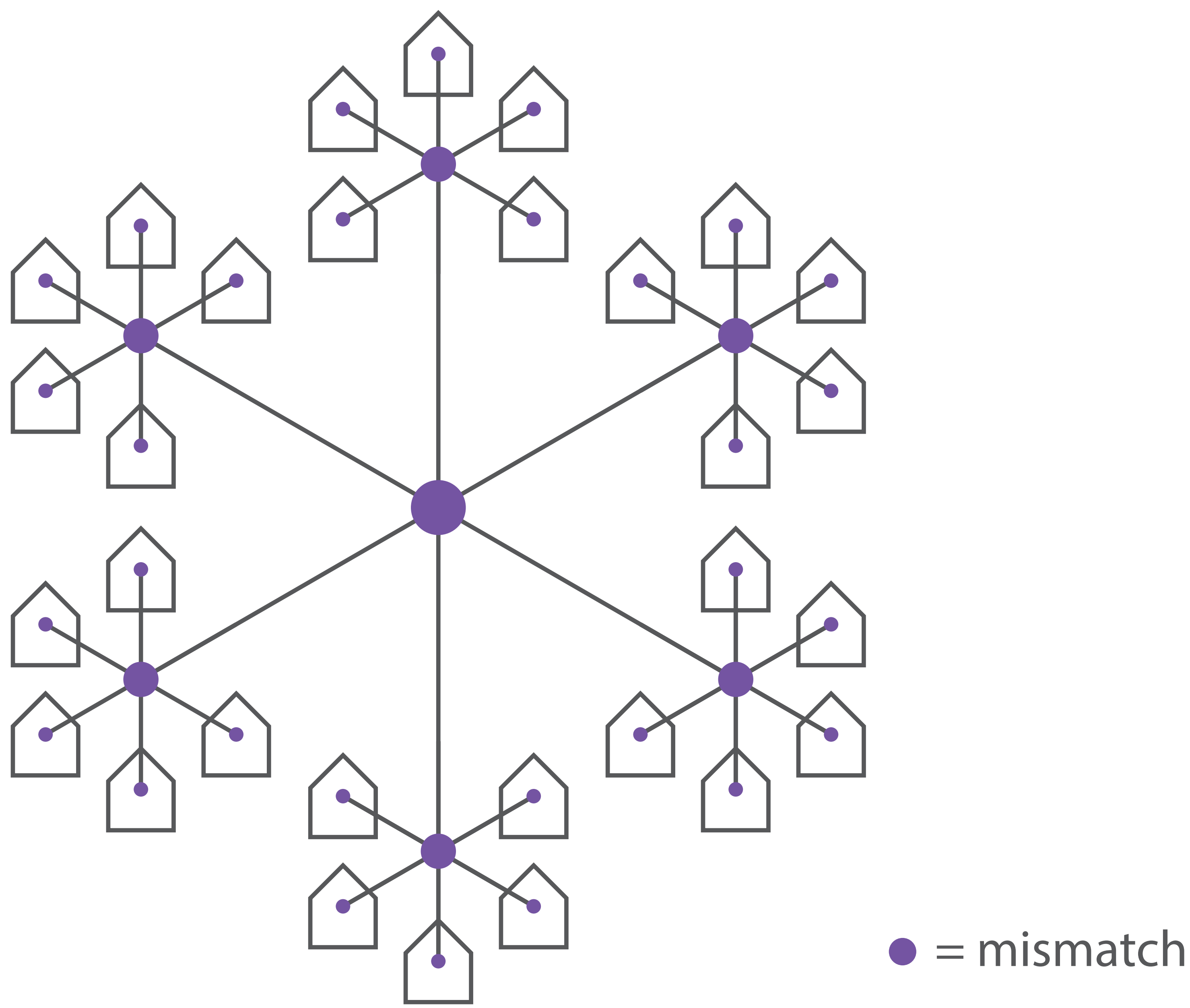
THE AGGREGATED MISMATCH IN THE SYSTEM



The final mismatch is the sum of the individual mismatches

mismatch can be negative or positive

THE AGGREGATED MISMATCH IN THE SYSTEM



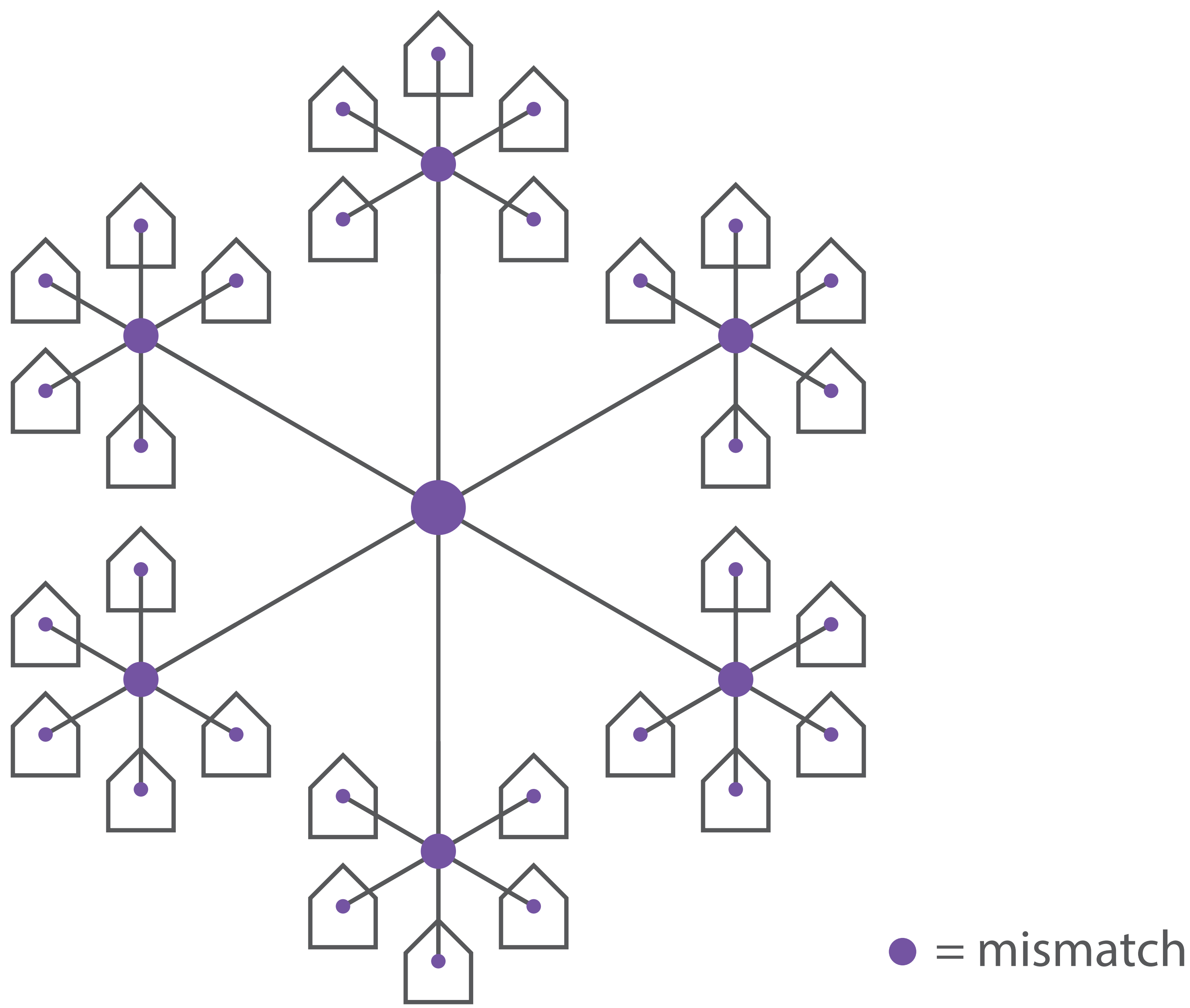
The final mismatch is the sum of the individual mismatches

mismatch can be negative or positive

theoretically

100% flat buildings means 100% balance in the system

THE AGGREGATED MISMATCH IN THE SYSTEM



The final mismatch is the sum of the individual mismatches

mismatch can be negative or positive

theoretically

100% flat buildings means 100% balance in the system

preferred

every level takes its own most effective measures

7

Conclusion, discussion & recommendations

Summary of the results, discussion and future research

CONCLUSION

How can the residential energy mismatch of supply and demand be solved by architectural design?

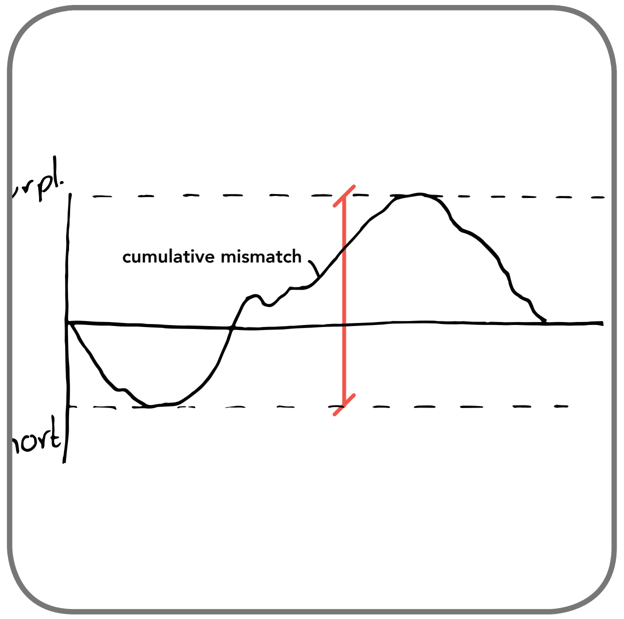
CONCLUSION

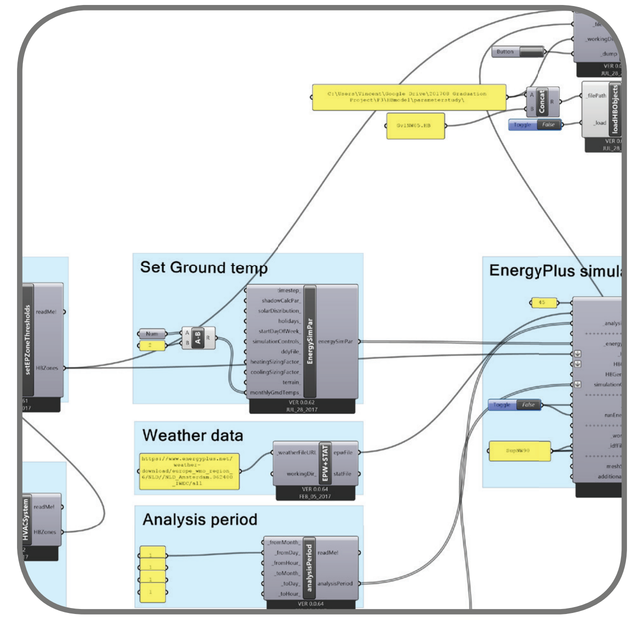
How can the residential energy mismatch of supply and demand be solved by architectural design?

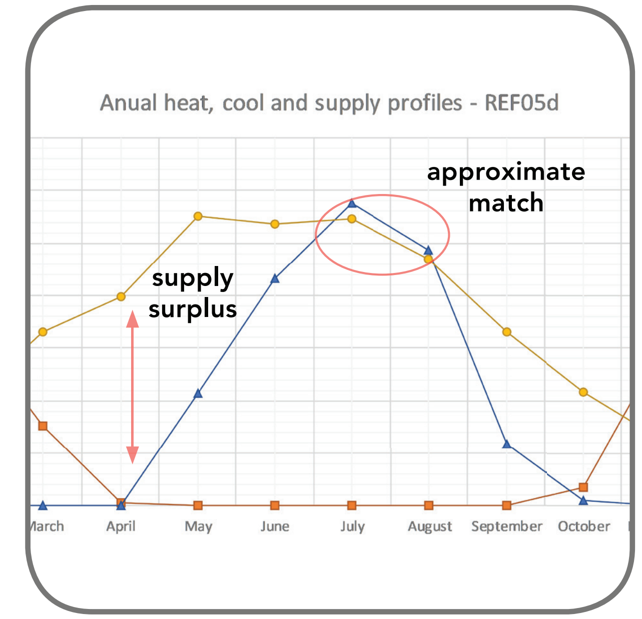
Architecture can significantly contribute to energy-flatness

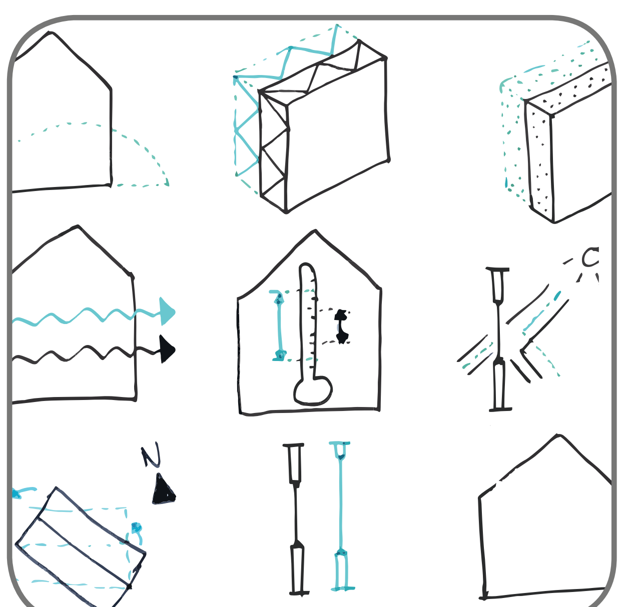
Conclusion, discussion & recommendations

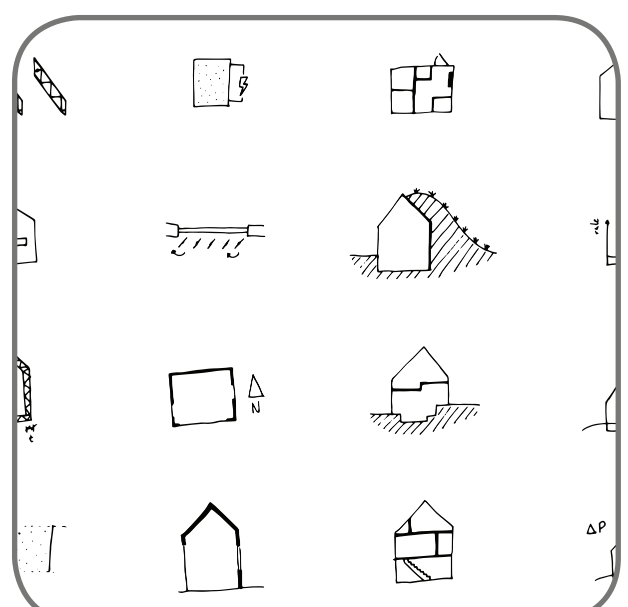
CONCLUSION

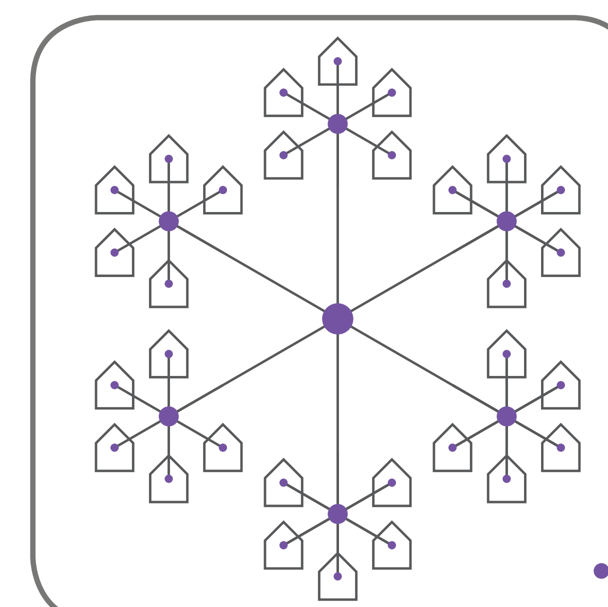












DISCUSSION

DISCUSSION

1 Scoped focus on heat balance

DISCUSSION

1 Scoped focus on heat balance

2 Design possibilities

DISCUSSION

1. Scoped focus on heat balance
2. Design possibilities
3. Energy storage is not considered

DISCUSSION

1. Scoped focus on heat balance
2. Design possibilities
3. Energy storage is not considered
4. Only solar potential is considered

RECOMMENDATIONS

RECOMMENDATIONS

1 Building services & electricity energy-flatness

RECOMMENDATIONS

1 Building services & electricity energy-flatness

2 Districts and other typologies

RECOMMENDATIONS

1. Building services & electricity energy-flatness
2. Districts and other typologies
3. Focus on adaptive, smart systems

Questions

Vincent Höfte
v.r.m.hofte@gmail.com

Appendix

BIBLIOGRAPHY (1/2)

Arasteh, D., Selkowitz, S., Apte, J., & LaFrance, M. (2006). Zero energy windows. Lawrence Berkeley National Laboratory.
Bokel, R., Jansen, S., & van der Voorden, M. (2004). Investigation of the feasibility of an environmentally friendly adaptable façade. Paper presented at the Plea2004. The 21st Conference on Passive and Low Energy Architecture, Eindhoven, The Netherlands.
Castleton, H. F., Stovin, V., Beck, S. B., & Davison, J. B. (2010). Green roofs; building energy savings and the potential for retrofit. Energy and Buildings, 42(10), 1582-1591.
CBS. (2013). Zonnestroomsystemen; handel in panelen, werkgelegenheid en omzet, 1991-2012. http://statline.cbs.nl/StatWeb/publication/?VW=T&DM=SLNL&PA=70949ned&LA=NL
CBS. (2015). Households; size, position in the household, 1 January 1995-2013. Retrieved June 12 2017, from http://statline.cbs.nl/StatWeb/publication/?VW=T&DM=SLEN&PA=37312eng&LA=EN
CBS. (2016). Hernieuwbare energie in Nederland 2015. Den Haag: Centraal Bureau voor de Statistiek.
De Dear, R. J., Brager, G. S., Reardon, J., & Nicol, F. (1998). Developing an adaptive model of thermal comfort and preference/discussion. ASHRAE transactions, 104, 145.
Depecker, P., Menezo, C., Virgone, J., & Lepers, S. (2001). Design of buildings shape and energetic consumption. Building and Environment, 36, 627--635.
DGMR. (2016). BENG referentiegebouwen. Den Haag: Rijksdienst voor Ondernemend Nederland.
Donker, J., Huygen, A., Westerga, R., & Weterings, R. (2015). Naar een toekomstbestendig energiesysteem: Flexibiliteit met waarde (pp. 89). Delft: TNO.
EnergyPlus. (2017). EnergyPlus™ building simulation software. Retrieved Jul 28, 2017, from https://www.energyplus.net/
Eurostat. (2017). Share of renewables in energy consumption in the EU still on the rise to almost 17% in 2015 [Press release]
Fanger, P. O. (1970). Thermal comfort. Analysis and applications in environmental engineering. Thermal comfort. Analysis and applications in environmental engineering.
Gellings, C. W., & Smith, W. M. (1989). Integrating demand-side management into utility planning. Proceedings of the IEEE, 77(6), 908-918.
GIW. (2008). GIW/ISSO-publicatie 2008 Ontwerp- en montageadviezen nieuwbouw, eengezinswoningen en appartementen. Rotterdam: Stichting GIW en Stichting ISSO.
Goorden, J. (2016). Integration of seasonal thermal energy storage in refurbishment projects. (Master of Science), TU Delft, Delft.
grasshopper3d.com. (2015, Dec 7, 2015). forumpost: “problem setting Energy plus fields in Honeybee”. Retrieved Sep 26, 2017, from http://www.grasshopper3d.com/group/ladybug/forum/topics/problem-setting-energy-plus-fields-in-honeybee
Hafemeister, D. (2014). Physics of Societal Issues: Springer New York.
Hardin, G. (1968). The tragedy of the commons. Science, 162(3859), 1243-1248.
Hasnain, S. (1998). Review on sustainable thermal energy storage technologies, Part I: heat storage materials and techniques. Energy conversion and management, 39(11), 1127-1138.
Hegger, M., Fuchs, M., Stark, T., & Zeumer, M. (2008). Energy manual-sustainable architecture: Institut für Internationale Architekturdokumentation/Birkhäuser.
Heide, D., Von Bremen, L., Greiner, M., Hoffmann, C., Speckmann, M., & Bofinger, S. (2010). Seasonal optimal mix of wind and solar power in a future, highly renewable Europe. Renewable energy, 35(11), 2483-2489.
IEA. (2008-2013). Annex 52 Towards Net Zero Energy Solar Buildings. Retrieved May 25, 2017, from http://www.ecbcs.org/annexes/annex52.htm
IEA. (2011). Harnessing Variable Renewables: A guide to the Balancing Challenge. Paris, France: International Energy Agency.
IEA. (2016). International Energy Outlook 2016. Washington, DC 20585: Office of Energy Analysis, U.S. Department of Energy.
IPIN. (2015). Position paper kennis- en leertraject Thema visie Utrecht: RVO.
ISSO. (1976). Publicatie 3 - Zonstralingstabellen. Rotterdam: ISSO.
Itard, L., & Meijer, F. (2008). Towards a Sustainable Northern European Housing Stock: Figures, Facts, and Future (Vol. 22): Ios Press.
Jaffal, I., Ouldboukhitine, S.-E., & Belarbi, R. (2012). A comprehensive study of the impact of green roofs on building energy performance. Renewable energy, 43, 157-164.
Jonker, M. (2017). Een jaar in een Tiny House. www.marjoleininhetklein.com. Retrieved 1 June 2017, from https://www.marjoleininhetklein.com/2017/05/23/een-jaar-in-een-tiny-house/
Juodis, E. (2006). Extracted ventilation air heat recovery efficiency as a function of a building's thermal properties. Energy and Buildings, 38(6), 568-573.
Kelly, N. (2012). Future Energy Demand in the Domestic Sector Retrieved from Glasgow:
Kingspan Insulation Ltd. (2017). Kooltherm K100 - Frequently Asked Questions. Retrieved Oct 1, 2017, from http://www.kingspaninsulation.co.uk/Knowledge-Base/Kooltherm-K100.aspx
Kok, K. (2013). The PowerMatcher: smart coordination for the smart electricity grid. TNO: The Hague, The Netherlands, 241-250.
Konstantinou, T. (2014). Facade Refurbishment Toolbox; Supporting the Design of Residential Energy Upgrades. Delft University of Technology, Delft.
Ladybug Tools. (2017). Honeybee/Ladybug Tools. Retrieved Jul 28, 2017, from http://www.grasshopper3d.com/group/ladybug
Langen, S. v., Tol, P. v., Quak, T., & Bruggen, M. v. (2017). Profielen elektriciteit 2017. http://www.nedu.nl/portfolio/verbruiksprofielen/
Laverge, J., Van Den Bossche, N., Heijmans, N., & Janssens, A. (2011). Energy saving potential and repercussions on indoor air quality of demand controlled residential ventilation strategies. Building and Environment, 46(7), 1497-1503.
LenteAkkoord. (2017). Woningbouw volgens BENG; Do's en dont's voor bijna energieneutraal bouwen. In LenteAkkoord (Ed.), www.lente-akkoord.nl. Voorburg: Lente-akkoord.

Appendix

BIBLIOGRAPHY (2/2)

Lund, H., Marszal, A., & Heiselberg, P. (2011). Zero energy buildings and mismatch compensation factors. Energy and Buildings, 43(7), 1646-1654.
Luo, X., Wang, J., Dooner, M., & Clarke, J. (2015). Overview of current development in electrical energy storage technologies and the application potential in power system operation. Applied Energy, 137, 511-536.
Maréchal, K. (2009). An evolutionary perspective on the economics of energy consumption: the crucial role of habits. Journal of Economic Issues, 43(1), 69-88.
Meggers, F., Ritter, V., Goffin, P., Baetschmann, M., & Leibundgut, H. (2012). Low exergy building systems implementation. Energy, 41(1), 48-55.
Newton, C. (2010). Entwicklung einer Räuber-Beute-Population zu erstem Lotka-Volterra-Gesetz. In LotkaVoltera1.gif (Ed.): German Wikipedia.
Palmero-Marrero, A. I., & Oliveira, A. C. (2010). Effect of louver shading devices on building energy requirements. Applied Energy, 87(6), 2040-2049.
Peeters, L., De Dear, R., Hensen, J., & D'haeseleer, W. (2009). Thermal comfort in residential buildings: Comfort values and scales for building energy simulation. Applied Energy, 86(5), 772-780.
Pérez-Lombard, L., Ortiz, J., & Pout, C. (2008). A review on buildings energy consumption information. Energy and Buildings, 40(3), 394-398.
PHYSEE. (2017). PowerWindow. Retrieved Oct 4, 2017, from http://www.physee.eu/products/
ReVolt House. (2011). ReVolt House, Deliverable #3 - Press Release [Press release]. Retrieved from http://www.sdeurope.org/wp-content/uploads/downloads/2011/10/TUD_PR3_2011-09-14.pdf
ReVolt House. (2012). ReVolt House, Deliverable #4 - Project Manual. Delft: TU Delft.
Robinson, P., & Hutchins, M. (1994). Advanced glazing technology for low energy buildings in the UK. Renewable energy, 5(1-4), 298-309.
RVO. (2015). Cloud Power Texel Smart Grid Pilot Projects. Utrecht: RVO.
S. Klijn Velderman, D. Hughes, M. Witkamp, & Verduijn, S. (2016). Handboek NOM Keur (Versie 1.04 ed.). Den Haag: Vereniging De BredeStroomversnelling.
Sadineni, S. B., Madala, S., & Boehm, R. F. (2011). Passive building energy savings: A review of building envelope components. Renewable and Sustainable Energy Reviews, 15(8), 3617-3631.
Salom, J., Widén, J., Candanedo, J., Sartori, I., Voss, K., & Marszal, A. (2011). Understanding net zero energy buildings: evaluation of load matching and grid interaction indicators. Paper presented at the proceedings of building simulation.
Salpakari, J., & Lund, P. (2016). Optimal and rule-based control strategies for energy flexibility in buildings with PV. Applied Energy, 161, 425-436.
Santamouris, M., & Asimakopoulos, D. (1996). Passive cooling of buildings (Vol. 1): James & James London;.
Santamouris, M., Sfakianaki, A., & Pavlou, K. (2010). On the efficiency of night ventilation techniques applied to residential buildings. Energy and Buildings, 42(8), 1309-1313.
Sartori, I., Napolitano, A., & Voss, K. (2012). Net zero energy buildings: A consistent definition framework. Energy and Buildings, 48, 220-232.
Schellen, L., van Marken Lichtenbelt, W., Loomans, M., Toftum, J., & De Wit, M. (2010). Differences between young adults and elderly in thermal comfort, productivity, and thermal physiology in response to moderate temperature drift and a steady-state condition. Indoor air, 20(4), 273-283.
Shameri, M., Alghoul, M., Sopian, K., Zain, M. F. M., & Elayeb, O. (2011). Perspectives of double skin façade systems in buildings and energy saving. Renewable and Sustainable Energy Reviews, 15(3), 1468-1475.
Shaviv, E., Yezioro, A., & Capeluto, I. G. (2001). Thermal mass and night ventilation as passive cooling design strategy. Renewable energy, 24(3), 445-452.
Stichting Schoonschip. (2018). Schoonschip Amsterdam. Retrieved Jan 14, 2018
Tillie, N., Van Den Dobbelsteen, A., Doepel, D., Joubert, M., De Jager, W., & Mayenburg, D. (2009). Towards CO2 neutral urban planning: presenting the Rotterdam Energy Approach and Planning (REAP). Journal of Green Building, 4(3), 103-112.
Torcellini, P., Pless, S., Deru, M., & Crawley, D. (2006). Zero energy buildings: a critical look at the definition. National Renewable Energy Laboratory and Department of Energy, US.
TRNSYS. (2017). TRNSYS Transient System Simulation Tool. Retrieved Jul 28, 2017, from http://www.trnsys.com/
Van den Dobbelsteen, A. (2008). 655: Towards closed cycles-New strategy steps inspired by the Cradle to Cradle approach. Paper presented at the PLEA2008, UCD, Dublin.
Van der Linden, A. (2005). Zonnestraling en zonstralingsgegevens.
Van der Linden, A., Boerstra, A. C., Raue, A. K., Kurvers, S. R., & De Dear, R. (2006). Adaptive temperature limits: A new guideline in The Netherlands: A new approach for the assessment of building performance with respect to thermal indoor climate. Energy and Buildings, 38(1), 8-17.
van Sark, W., Segaar, P., Gerrissen, P., Esmeijer, K., Moraitis, P., van den Donker, M., . . . Bosselaar, L. (2014). Opbrengst van zonnestroomsystemen in Nederland: Utrecht: Universiteit Utrecht.
Wang, R., Yu, X., Ge, T., & Li, T. (2013). The present and future of residential refrigeration, power generation and energy storage. Applied Thermal Engineering, 53(2), 256-270.
Widén, J., Wäckelgård, E., & Lund, P. D. (2009). Options for improving the load matching capability of distributed photovoltaics: Methodology and application to high-latitude data. Solar Energy, 83(11), 1953-1966.
Xu, L., & Ojima, T. (2007). Field experiments on natural energy utilization in a residential house with a double skin façade system. Building and Environment, 42(5), 2014-2023.

1 Reduce supply surplus by using different sources

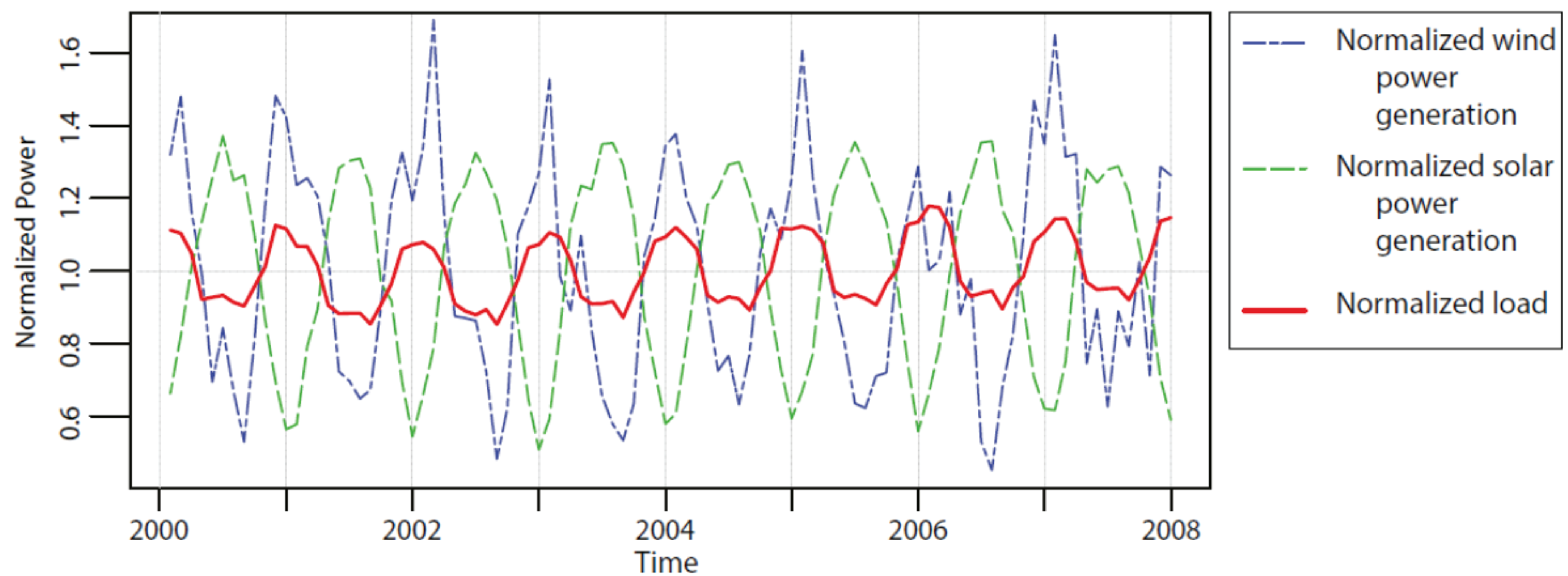


Figure 108: Normalized wind power generation (blue), solar power generation (green) and load (red) time series aggreggated over Europe. Each series is shown in a one-month resolution and is normalized to its 8 years average.(Heide et al., 2010)

Appendix

CONSIDERATIONS

1 Reduce supply surplus by using different sources

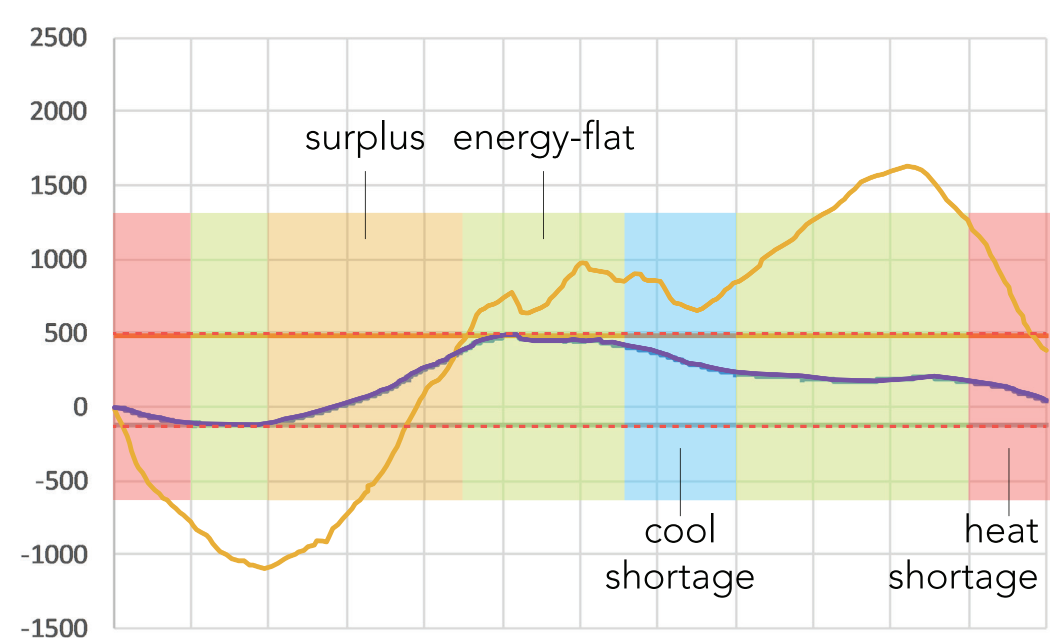
2 Turning off the supply

CONSIDERATIONS

1 Reduce supply surplus by using different sources

2 Turning off the supply

3 Make use of the centralized timing of surplus



CONSIDERATIONS

1. Reduce supply surplus by using different sources
2. Turning off the supply
3. Make use of the centralized timing of surplus
4. Climate change