ENERGY FLAT BUIKSLOTERHAM

On how to design energy flat multifunctional urban blocks

Kjell-Erik Prins // P5 Presentation // July 4th 2019

DELFT UNIVERSITY OF TECHNOLOGY

TU Delft

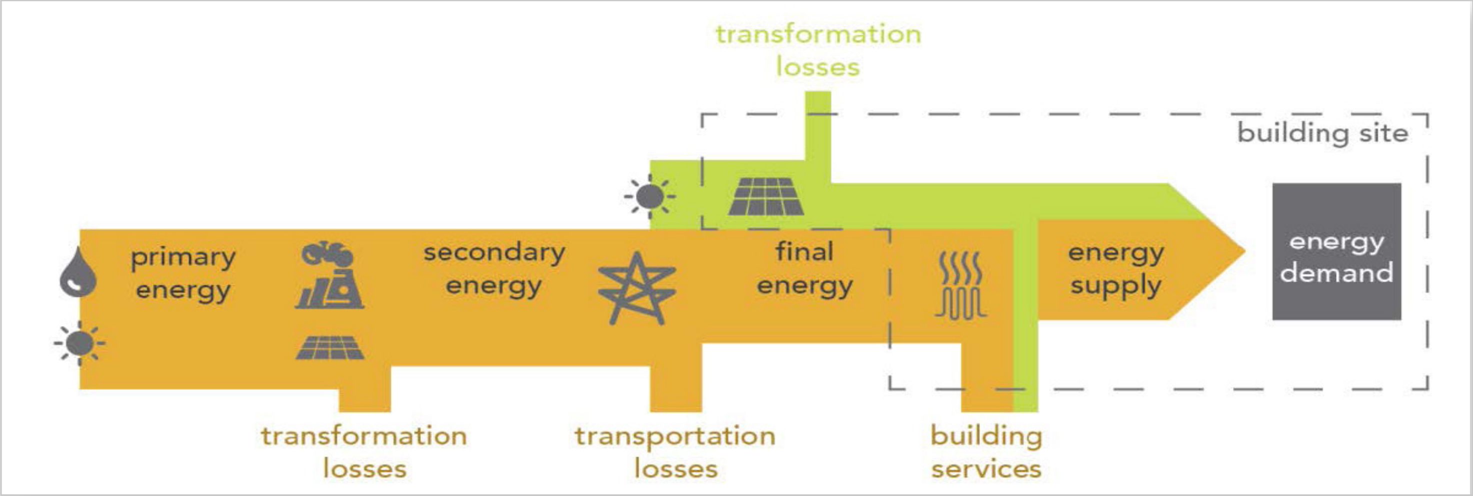
PRESENTATION OVERVIEW

Explain research **context**
Show my **approach**
Explain the **results**
Conclude and **summarize**

1 Research framework

- Introduction
- Problem statement and research question
- Methodology

RESEARCH FRAMEWORK
INTRODUCTION



Conventional energy system (Höfte, 2018)

RESEARCH FRAMEWORK

INTRODUCTION

1

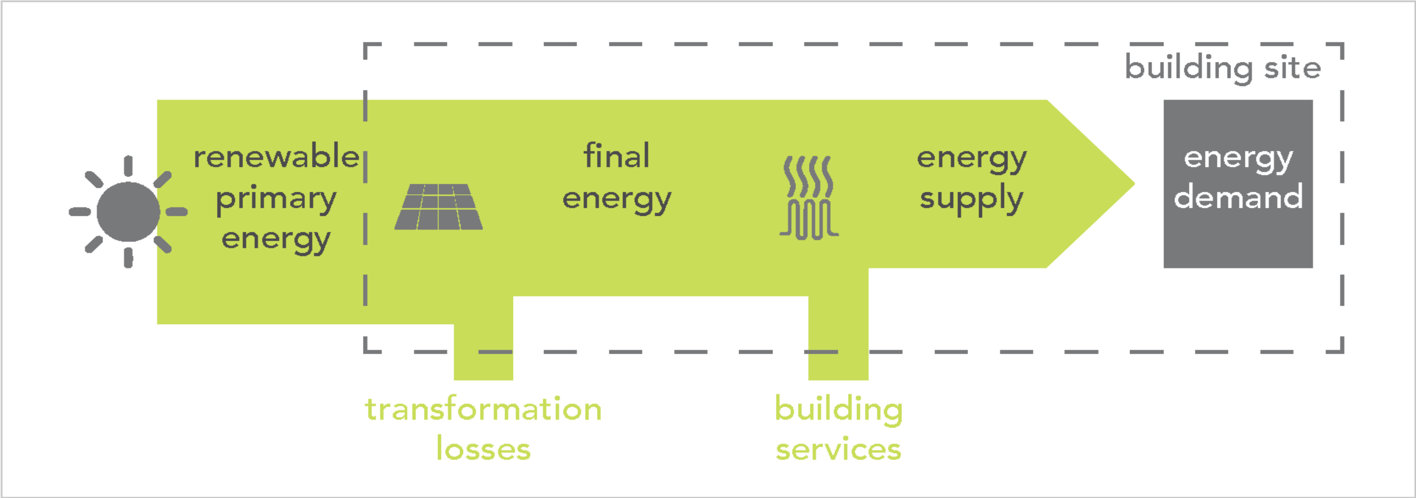
CHANGE TO A MORE SUSTAINABLE SYSTEM

- Paris energy agreement (2015)
- Het Klimaatakkoord (2019)
- 6.6 % (2017) -> 16 % (2023) -> ~ 100 % (2050)
  Energy from renewable resources

RESEARCH FRAMEWORK

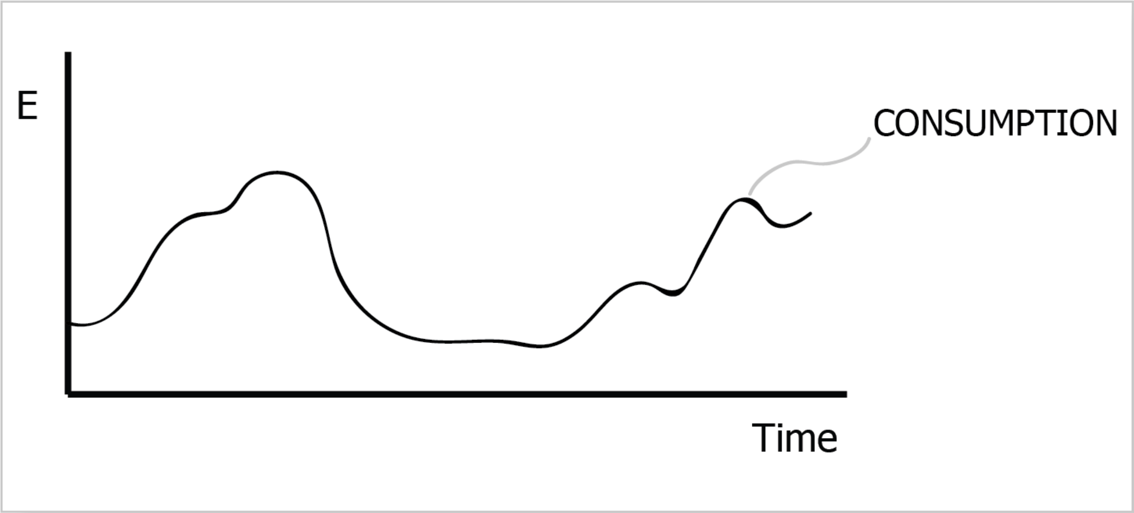
INTRODUCTION

1



Sustainable energy system (Höfte, 2018)

RESEARCH FRAMEWORK
PROBLEM STATEMENT



RESEARCH FRAMEWORK
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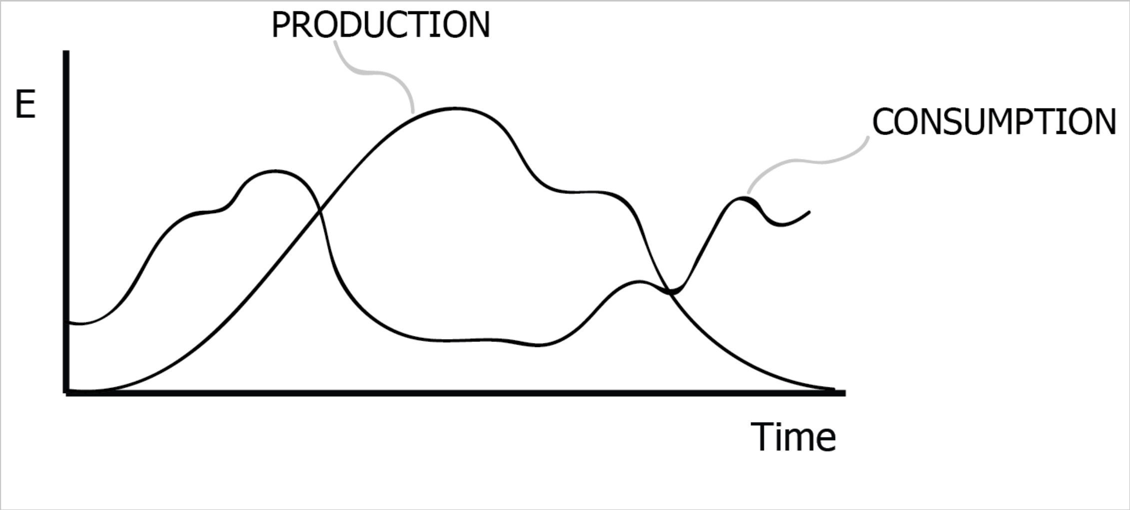
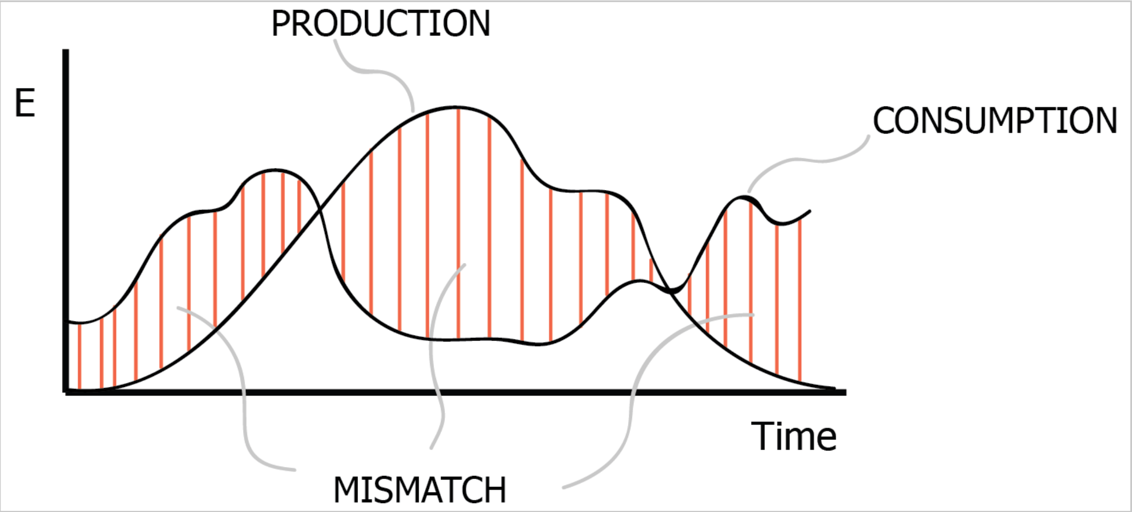


RESEARCH FRAMEWORK
PROBLEM STATEMENT



RESEARCH FRAMEWORK
PROBLEM STATEMENT

CURRENT RESEARCH	Several studies on how to reduce the mismatch Limited to one function type at a time Do not combine several ways to balance supply and demand

CASE STUDY	Multi functionality Governance Energy exchange

RESEARCH FRAMEWORK

RESEARCH QUESTION

How can you design an energy flat multifunctional urban block in the Netherlands and what does this imply for governance?
[Case study Buiksloterham, Amsterdam]

1 RESEARCH FRAMEWORK

DEFINITION

Energy flat urban block	An urban block where the local energy supply and demand are equal at any given time of the year

RESEARCH FRAMEWORK

METHODOLOGY

BACKGROUND RESEARCH

PROBLEM STATEMENT

RESEARCH QUESTIONS

Main: How can you design an energy flat multifunctional urban block in the Netherlands and what does this imply for governance [Case study Buiksloterham, Amsterdam]?

Sub questions:
- What parameters influence energy profiles and how can these be adapted?
- To what extent can different functions exchange energy?
- In what way does [thermal] energy storage influence energy flatness?
- How can the energy flatness of a multifunctional urban block be evaluated?
- What stakeholders play a role in the energy system of an urban block and how do they play a role?
- What are barriers and potentials [laws & regulations, subsidies and socio-economic] for governance aspects in the current (governmental/society) system?
- Under what governance conditions could the energy flat concept work??

LITERATURE STUDY

ENERGY FLATNESS

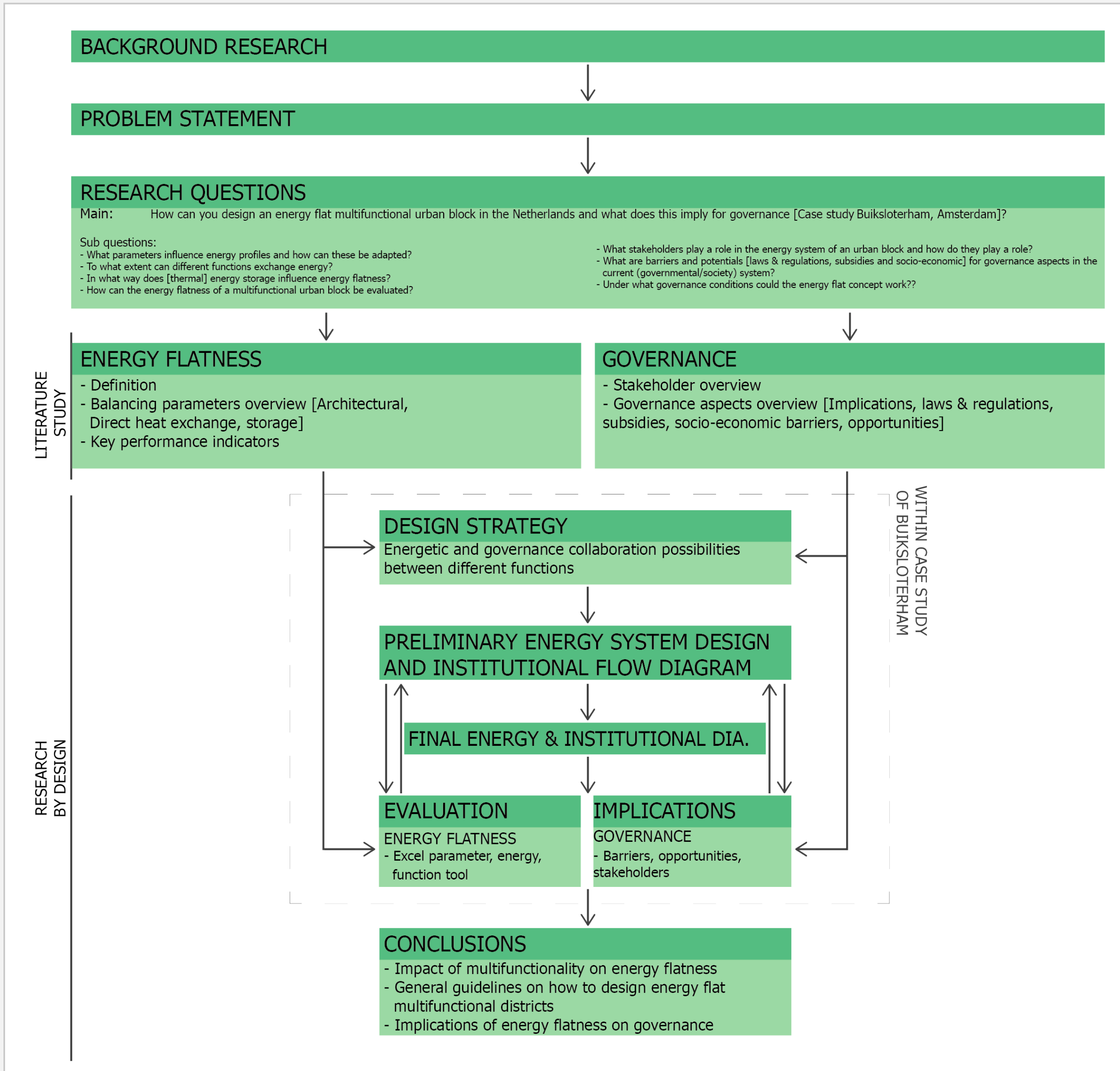
- Definition
- Balancing parameters overview [Architectural, Direct heat exchange, storage]
- Key performance indicators

GOVERNANCE

- Stakeholder overview
- Governance aspects overview [Implications, laws & regulations, subsidies, socio-economic barriers, opportunities]

RESEARCH FRAMEWORK

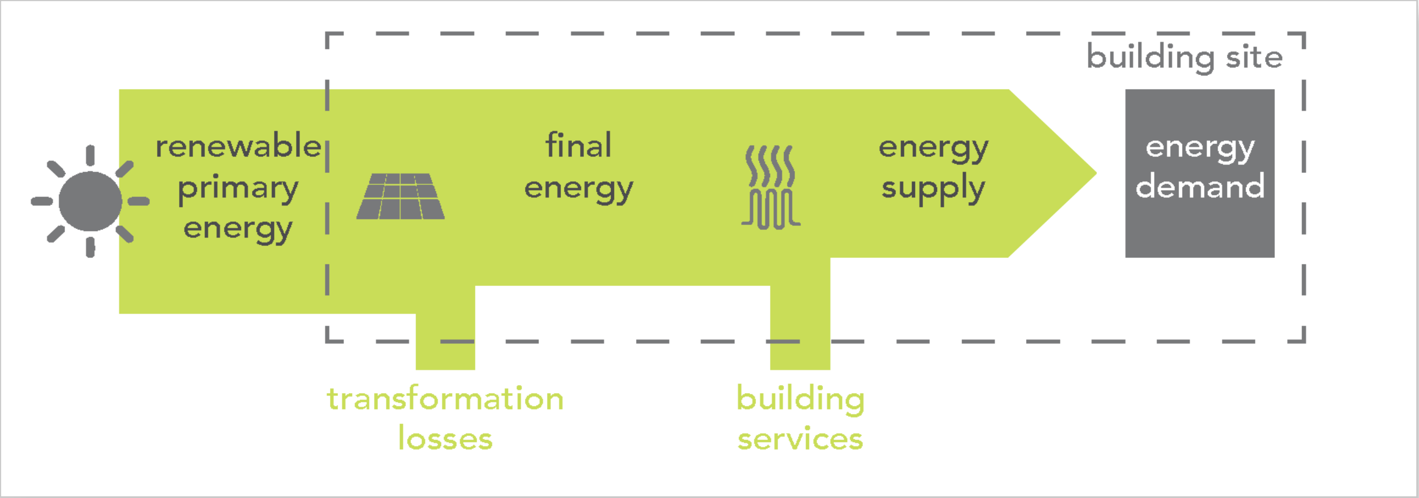
METHODOLOGY



2 Energy flatness

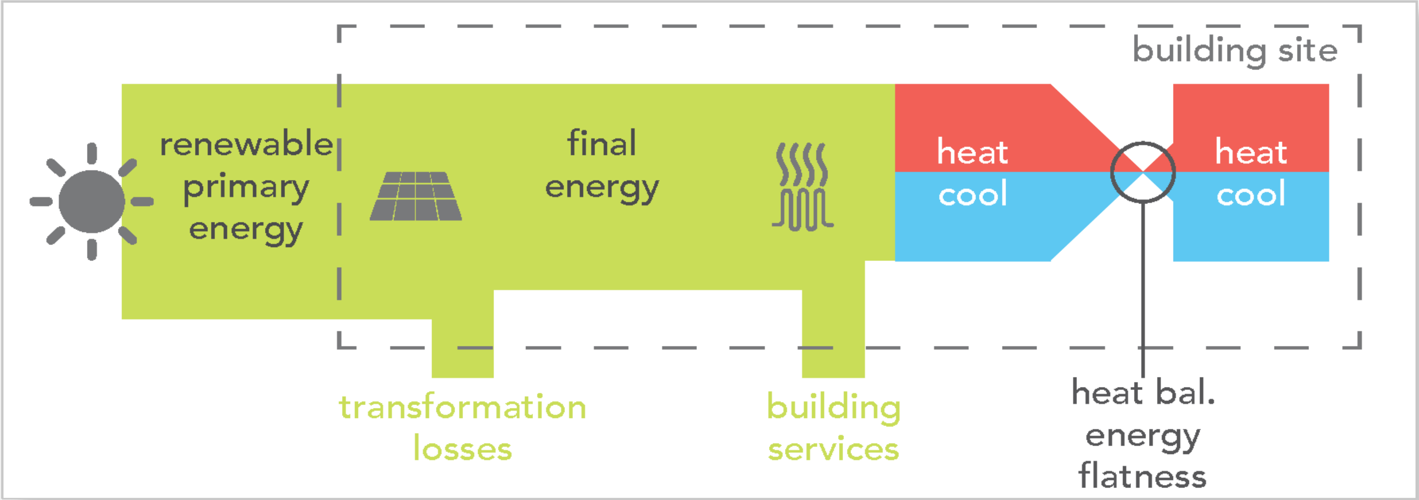
- What is energy flatness?
- How can it be evaluated?

ENERGY FLATNESS
BALANCE BOUNDARY



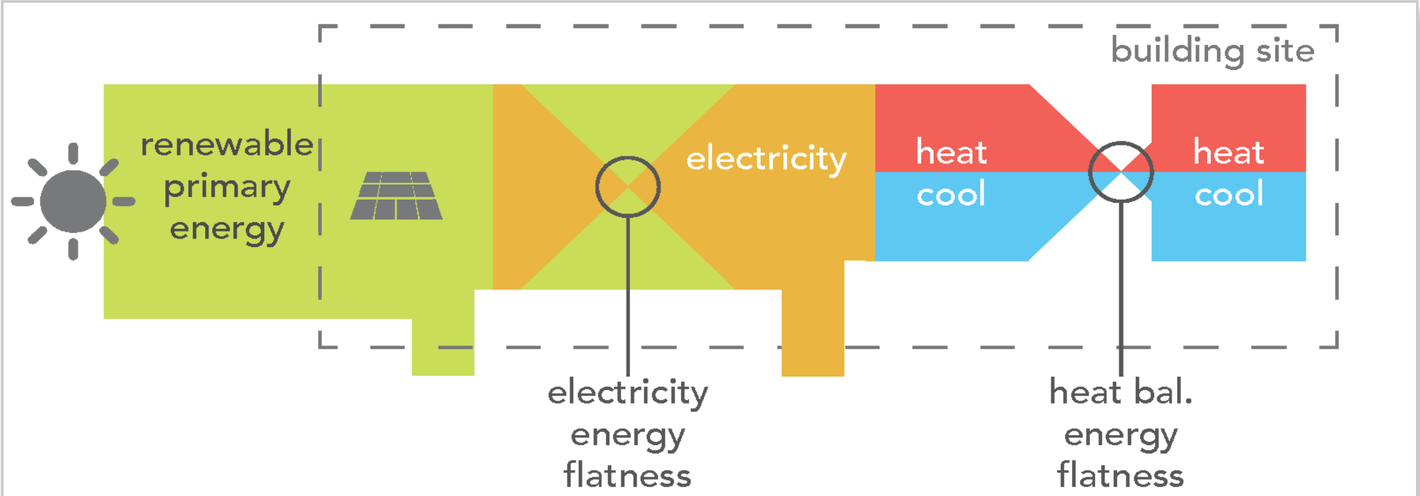
Sustainable energy system (Höfte, 2018)

ENERGY FLATNESS
BALANCE BOUNDARY



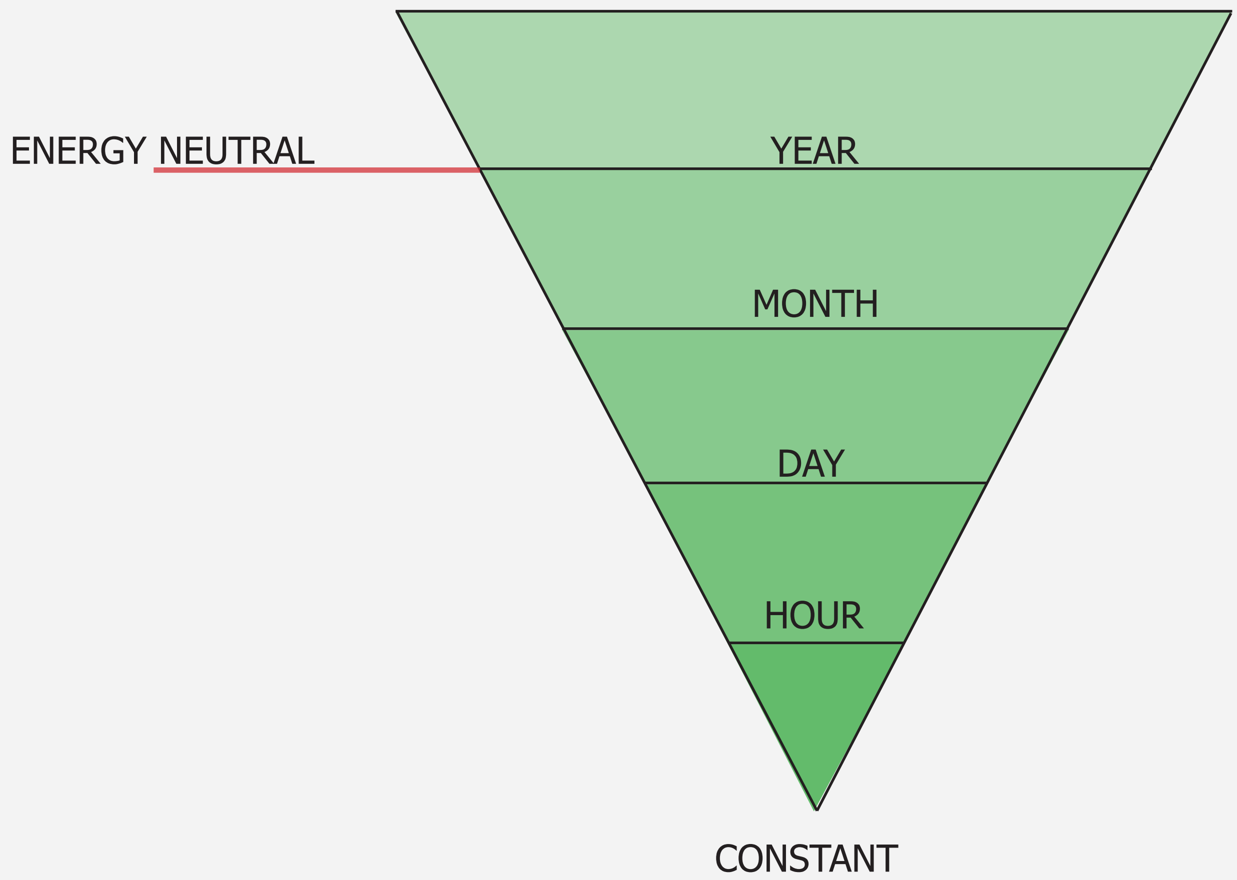
Thermal energy balance (Höfte, 2018)

ENERGY FLATNESS
BALANCE BOUNDARY



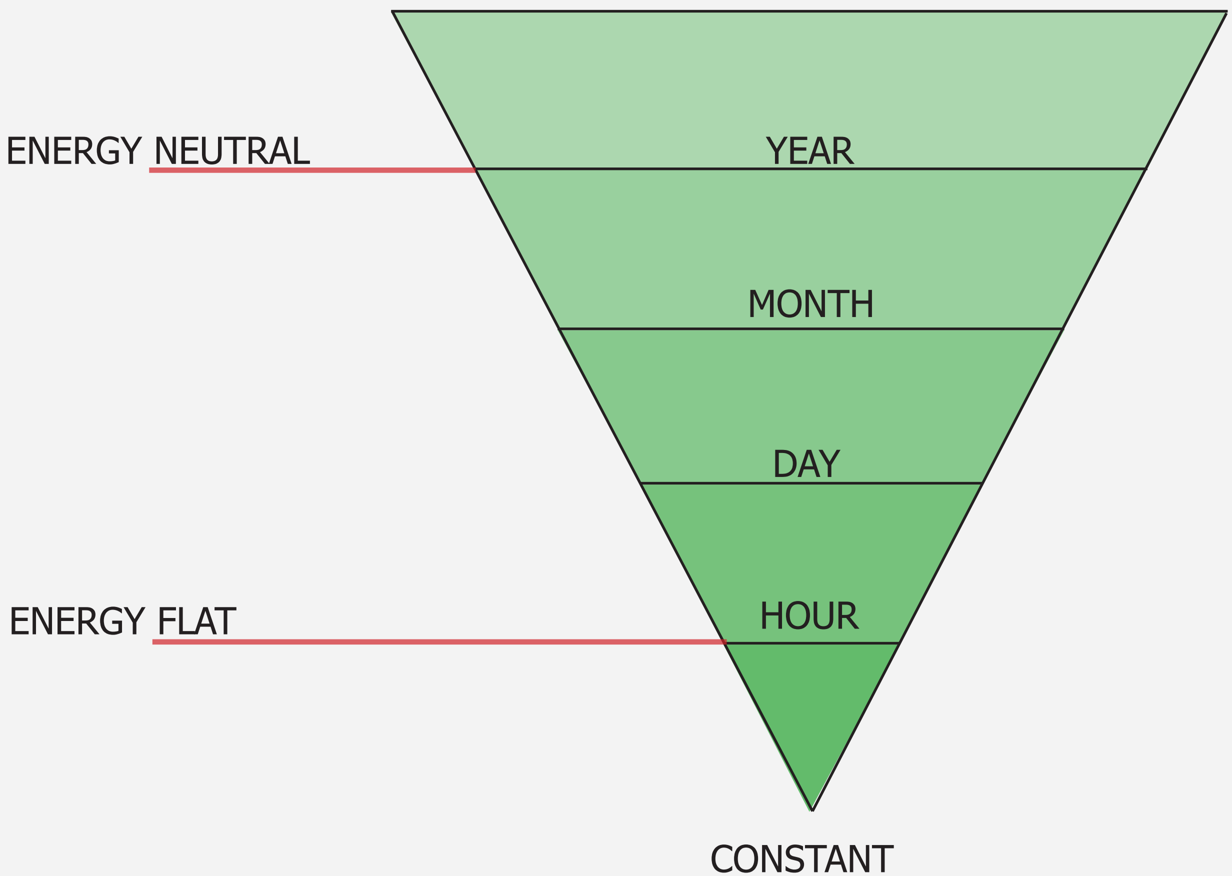
Electrical energy balance (Höfte, 2018)

ENERGY FLATNESS
BALANCING PERIOD

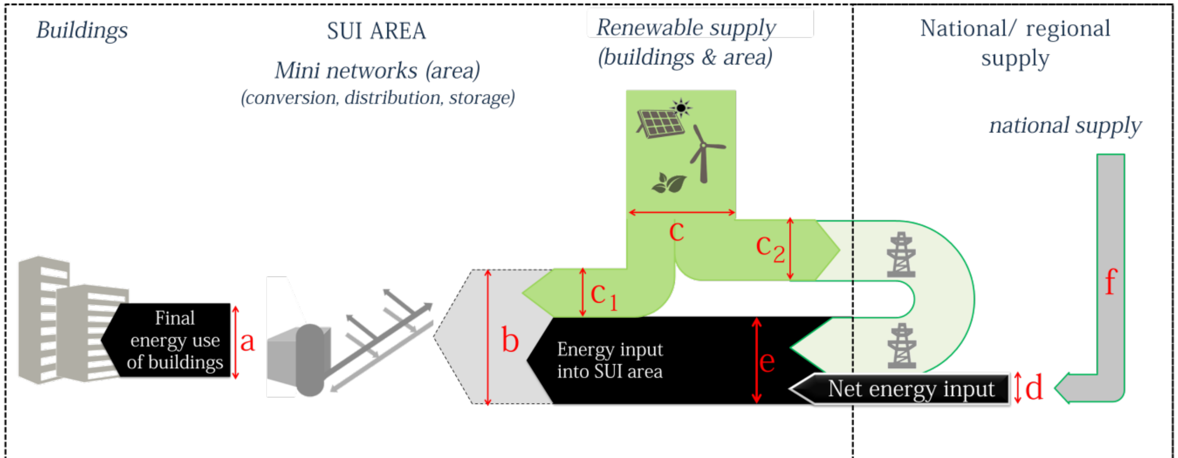


ENERGY FLATNESS

BALANCING PERIOD



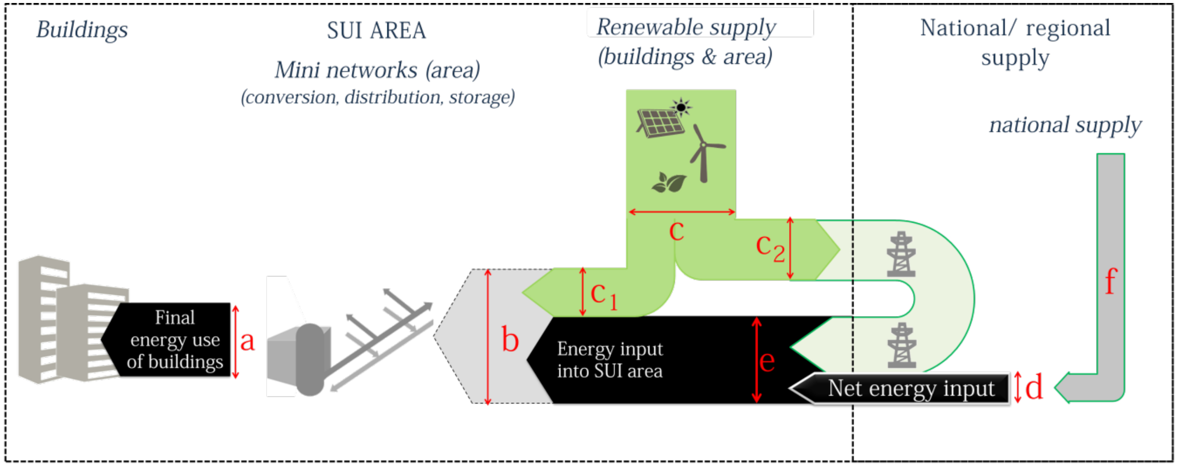
ENERGY FLATNESS
KEY PERFORMANCE INDICATORS (KPI)



explanation:
a1 = total final energy used in buildings (building & user related)
b = total energy input needed for the area, including area (distribution) losses etc.
c = energy produced from local renewable resources
1. = directly used in the area
2. = exported to the grid (due to mismatch in time of demand & supply)
e = total energy imported into the area (b-c1)
f = net energy input into the area (b-c)

KPI 1 = Energy neutrality
KPI 2 = Fraction of autonomy
KPI 3 = Maximum power mismatch
KPI 4 = Maximum cumulative mismatch
KPI 5 = Fraction of energy exchange

ENERGY FLATNESS
KEY PERFORMANCE INDICATORS (KPI)



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KPI 1
Energy neutrality

$$KPI1.A = C - B = \sum_{t=0}^{t=8760} E_{On-site_{supply(t)}} - \sum_{t=0}^{t=8760} E_{final_{used(t)}} \quad [kWh/yr]$$

$$KPI1.B = C/B = \frac{\sum_{t=0}^{t=8760} E_{On-site_{supply(t)}}}{\sum_{t=0}^{t=8760} E_{final_{used(t)}}} \quad [\%]$$

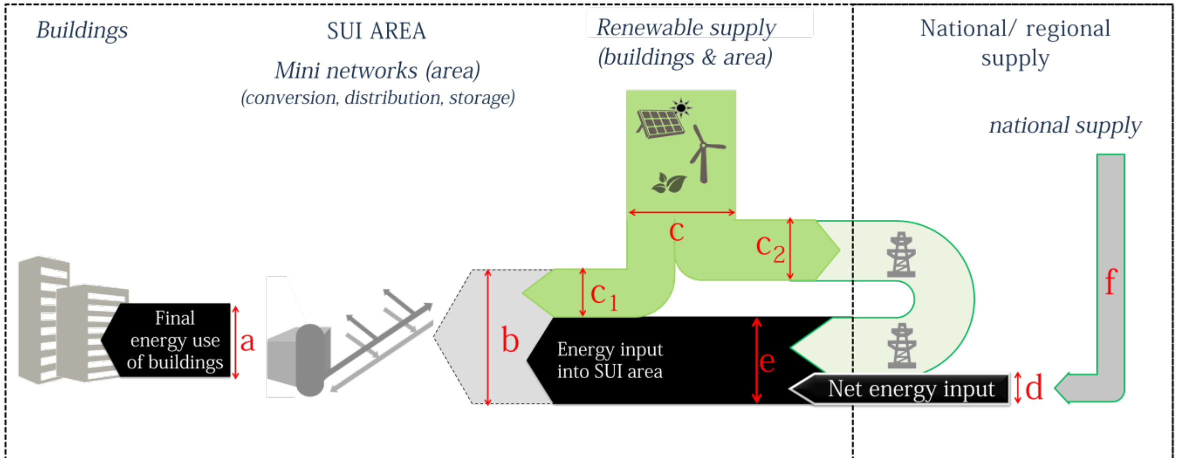
KPI 2
Fraction of autonomy

$$KPI2.A = C1 = \sum_{t=0}^{t=8760} E_{Directly\ used_{supply(t)}} \quad [kWh/yr]$$

$$KPI2.B = C1/B = \frac{\sum_{t=0}^{t=8760} E_{Directly\ used_{supply(t)}}}{\sum_{t=0}^{t=8760} E_{final_{used(t)}}} \quad [\%]$$

ENERGY FLATNESS

KEY PERFORMANCE INDICATORS (KPI)



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KPI 3

Maximum power mismatch

$$KPI3.A = \max(C - B) =$$

$$\max_{0 \leq t \geq 8760}(E_{On-site_{supply(t)}} - E_{final_{used(t)}})\ [W]$$

$$KPI3.B = \min(C - B) =$$

$$\min_{0 \leq t \geq 8760}(E_{On-site_{supply(t)}} - E_{final_{used(t)}})\ [W]$$

KPI 4

Maximum cumulative mismatch

$$KPI4 =$$

$$\max_{0<t<8760}(CEM_{(t)}) - \min_{0<t<8760}(CEM_{(t)})\ [KWh]$$

(Battery size)

KPI 5

Fraction of energy exchange

$$KPI5 = \frac{\sum_{t=0}^{t=8760} E_{reused\ (t)}}{\sum_{t=0}^{t=8760} E_{final_{used(t)}}}\ [\%]$$

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3 Case study design

- Approach
- Explain case study design

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CASE STUDY DESIGN
APPROACH

3

***S**mart*
***U**rban*
***I**sle*
Method

1 Case study description

2 Energy status quo

3 Energy concept potentials

4 Conceptual energy network

5 Evaluation and selection

6 Institutional energy flow diagram

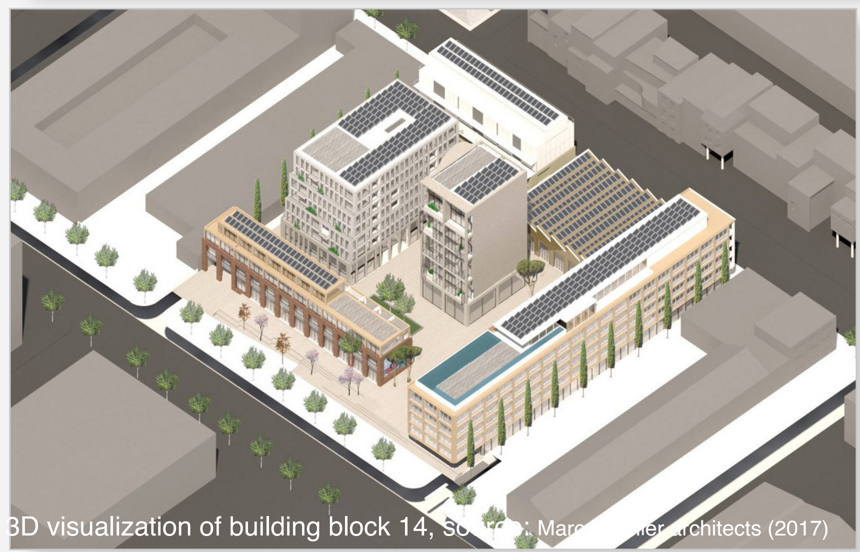
3.1 Case study description

- Site characteristics
- Functional program
- Context & Boundaries [Governance]

3 CASE STUDY DESIGN
CASE STUDY DESCRIPTION

Kavel 14
Buiksloterham, Amsterdam
14.710 m2
South-West orientation
6 Buildings

Aerial picture of the location, source: Marc Koehler architects (2017)

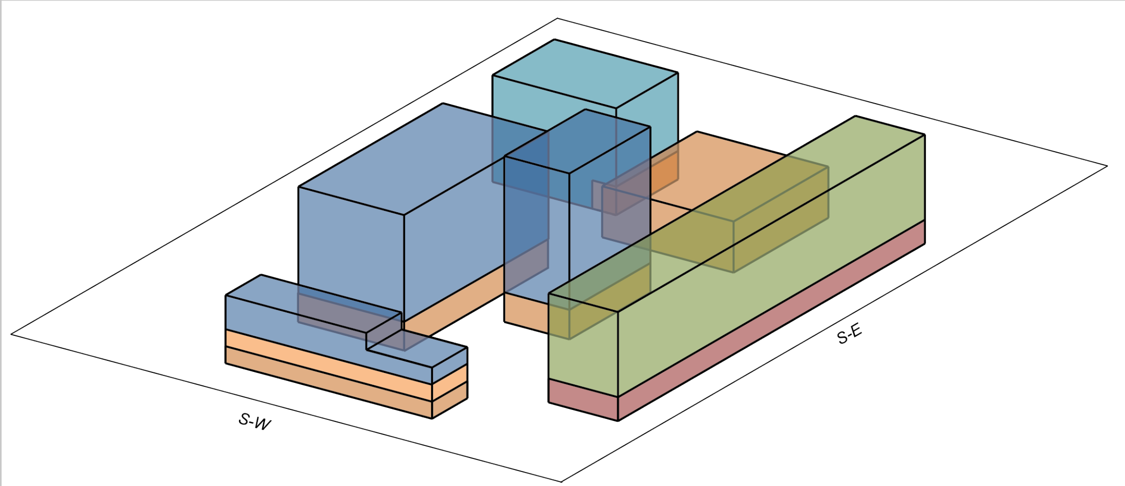

3D visualization of building block 14, source: Marc Koehler architects (2017)

CASE STUDY DESIGN
CASE STUDY DESCRIPTION

Visualization of kavel 14 by Marc Koehler Architects (2019)

CASE STUDY DESIGN

CASE STUDY DESCRIPTION



Functional 3D visualization kavel 14

	Residential (buy)	4696 m2
	Residential (rent)	1700 m2
	Commercial (non-hotel)	1909 m2
	Commercial (hotel)	820 m2
	Hotel	5079 m2
	Office	300 m2

CASE STUDY DESIGN
STAKEHOLDERS

STAKEHOLDERS ACTIVE IN **ENERGY SERVICES**	STAKEHOLDERS ACTIVE IN **DESIGN, DEVELOPMENT & CONSTRUCTION**	STAKEHOLDERS ACTIVE IN **THE USAGE PHASE**
Network operator electricity and gas	Real estate developer	Owners association
Heating network operator	Contractor	Private home and commercial unit ownership
Electricity and gas production companies	Architect	Housing association, commercial rent corporation and hotel
Third party as local network operator	Building physics, structural and fire safety engineer	Tenants (residential) and tenants (commercial)
	Mechanical, electrical and plumbing engineer	
	Local government	

3 CASE STUDY DESIGN

STAKEHOLDERS

	Expected benefits	Expected barriers
NETWORK OPERATOR	▪ Less peaks in national grid	▪ Is obligated by law to provide a physical connection with the grid
Building physics engineer	▪ Optimized system could benefit the indoor climate	▪ More collaboration with other specialists ▪ Lack of knowledge
TENANTS/ RESIDENTS	▪ Energy system that is sustainable, safe and cheap as possible.	▪ Has to be part of the system ▪ No freedom to choose its supplier

CASE STUDY DESIGN
BARRIERS

3

	Influence on energy flatness	Influence on stakeholders
ELECTRICITY LAW	▪ Network operator CANNOT both produce and distribute electricity	▪ Electricity CANNOT directly be exchanged between stakeholders ▪ Monopolist status

	Influence on energy flatness	Influence on stakeholders
SOCIAL BEHAVIOR	▪ Conservatism ▪ Minimal requirements	▪ Influence on all design parties ▪ Stakeholder collaboration should be high

3 CASE STUDY DESIGN
OPPORTUNITIES

	Influence on energy flatness	Influence on stakeholders
NUMEROUS LAWS	▪ Allow to deviate from Electricity law when permission is granted [Experiment status]	▪ Possibilities to implement innovation into designs ▪ Owners association is allowed to arrange the energy system

	Influence on energy flatness	Influence on stakeholders
NUMEROUS SUBSIDIES	▪ Experiments with payment rates can be carried out	▪ Reduce financial worries for high initial investment

3.2 Energy status quo

- Demand
- *Energy infrastructure*
- *Current local supply*

CASE STUDY DESIGN
ENERGY STATUS QUO

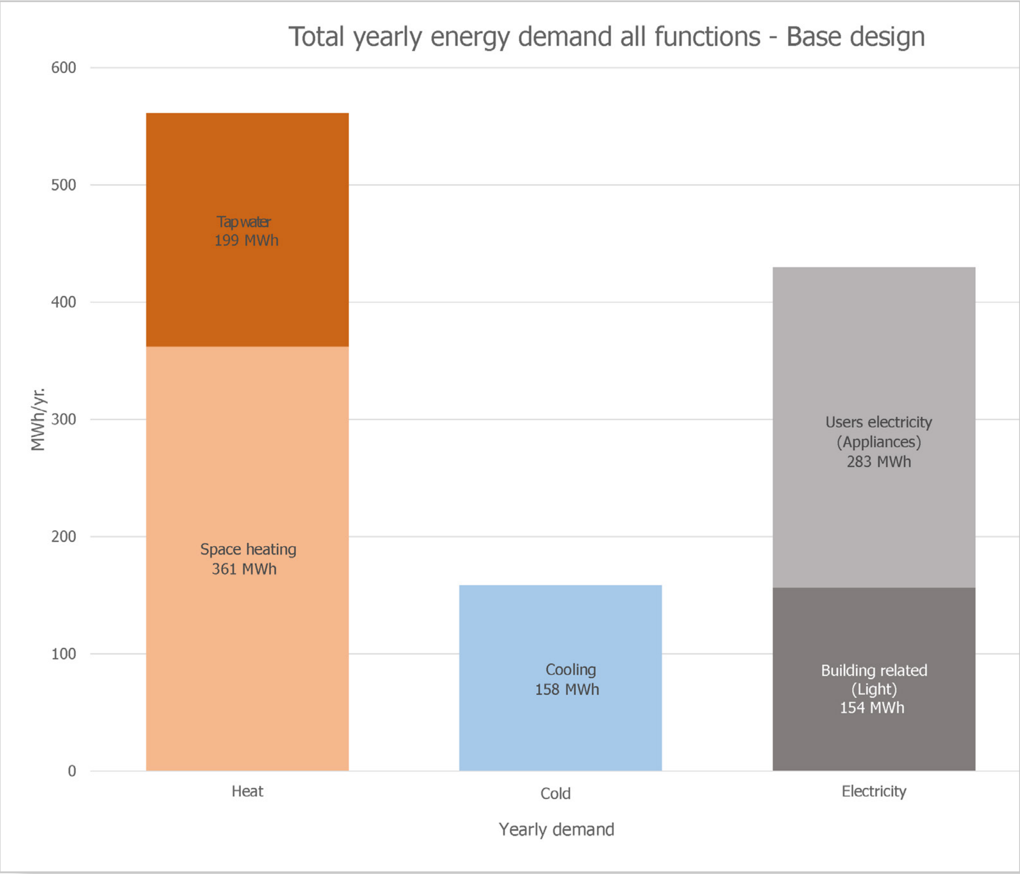
Base design

Minimal requirements Dutch building decree (Bouwbesluit)

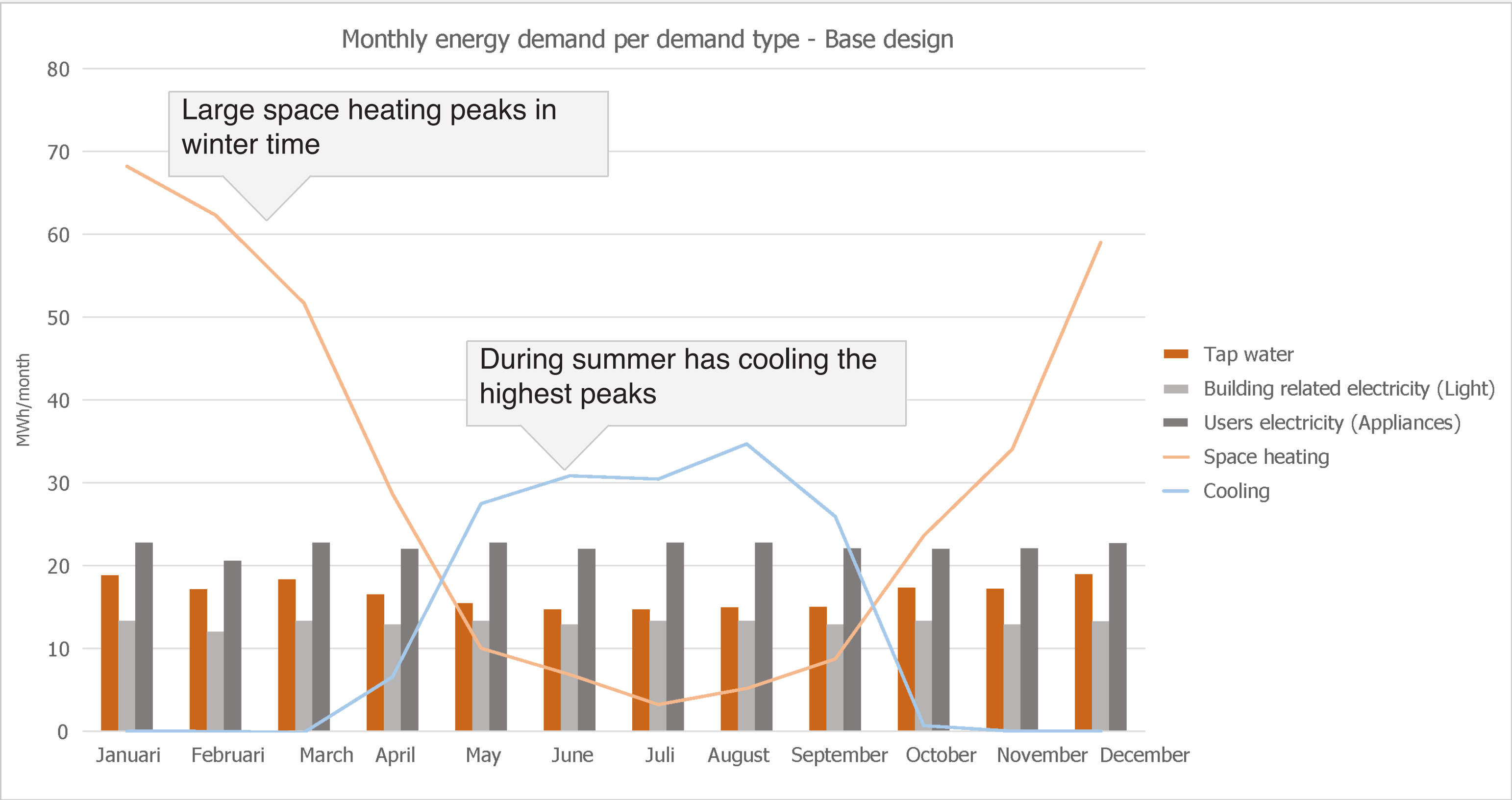
Based on architectural design

Total energy of **1155 MWh/year**

Space heating the biggest

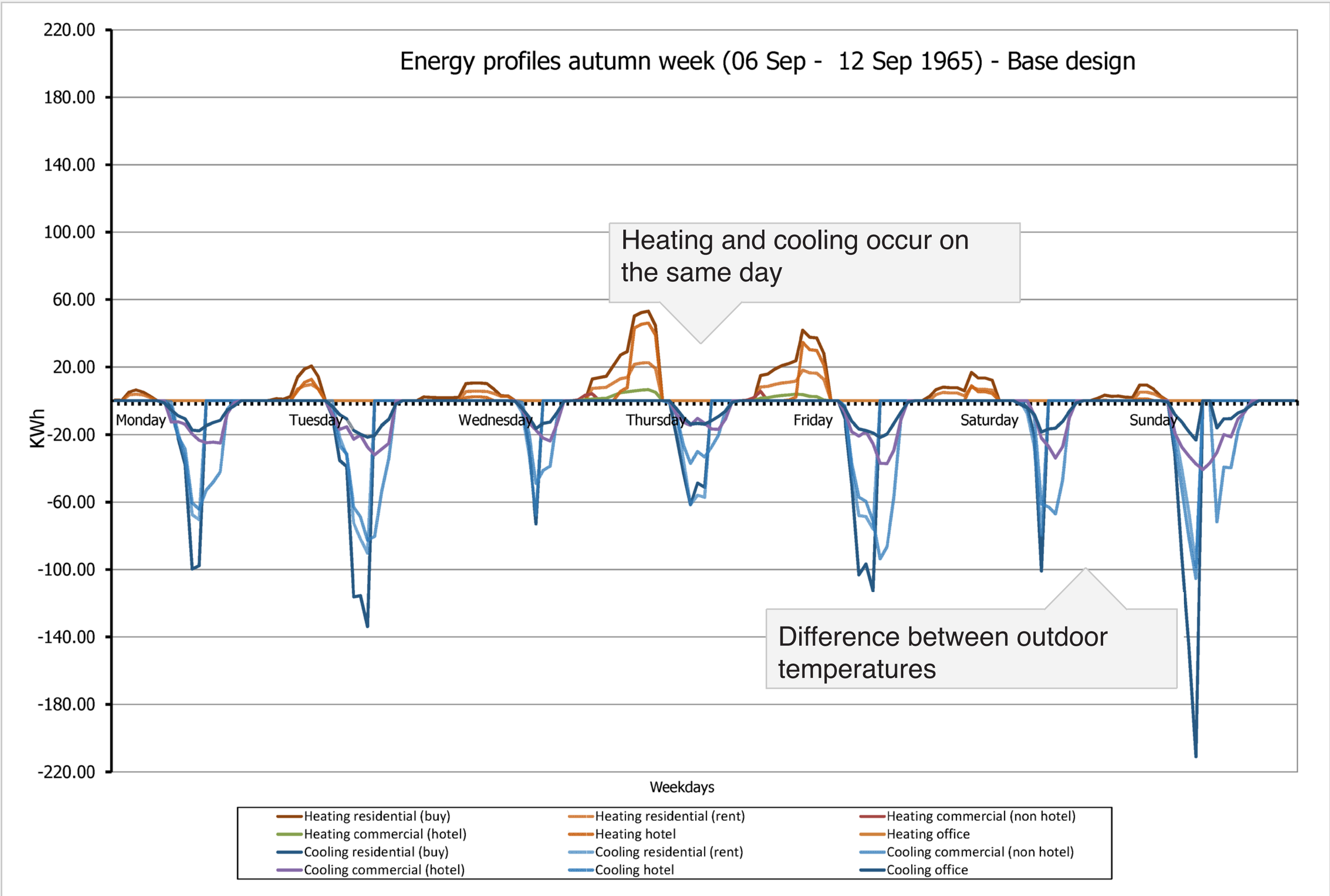


CASE STUDY DESIGN
ENERGY STATUS QUO



CASE STUDY DESIGN

ENERGY STATUS QUO



3.3 Energy concept potentials

- Adapting demand: Bioclimatic/Architectural design
- Energy exchange
- Adapting supply

CASE STUDY DESIGN
ADAPTING DEMAND

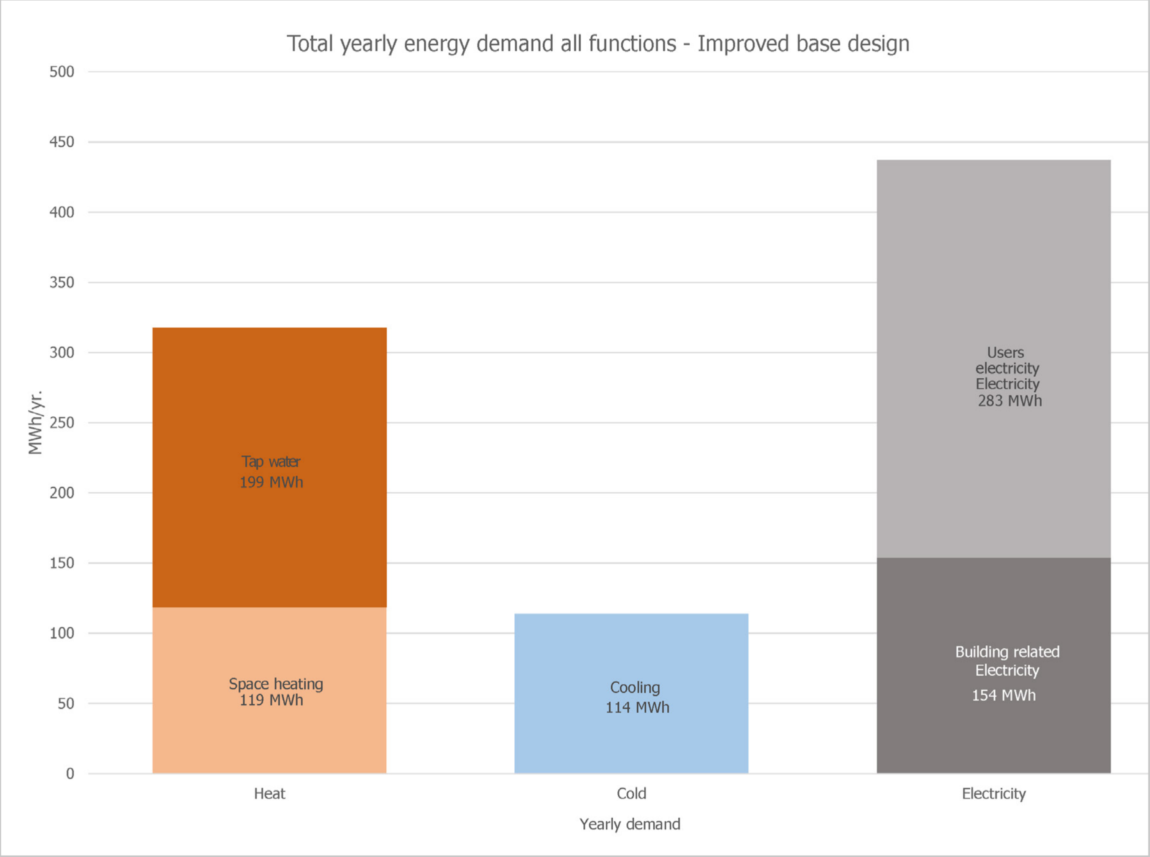
Improved base design

Bioclimatic design

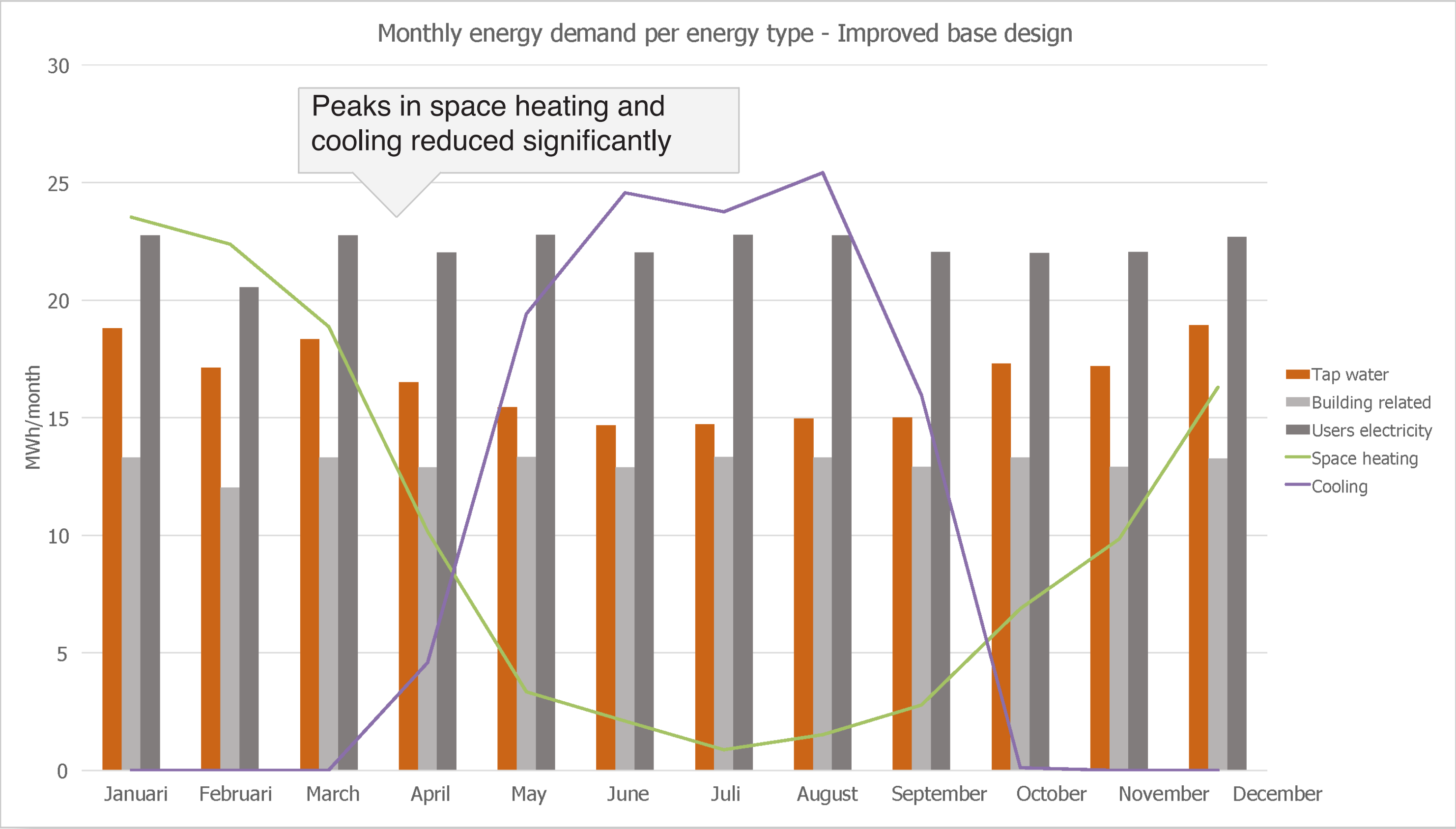
Façade and seasonal approach

Total energy of **856 MWh/year**

26 % reduction

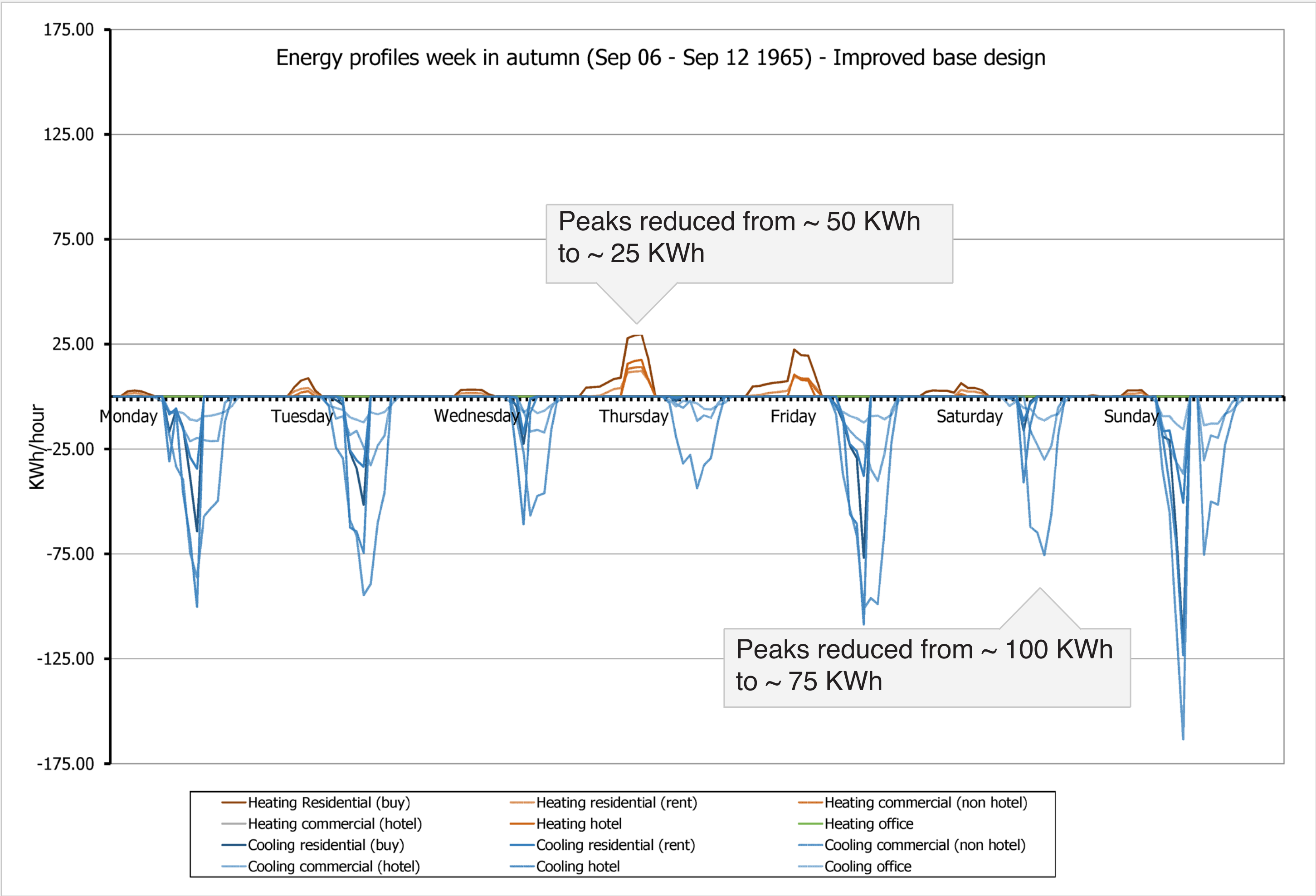


CASE STUDY DESIGN
ADAPTING DEMAND



CASE STUDY DESIGN

ADAPTING DEMAND



CASE STUDY DESIGN

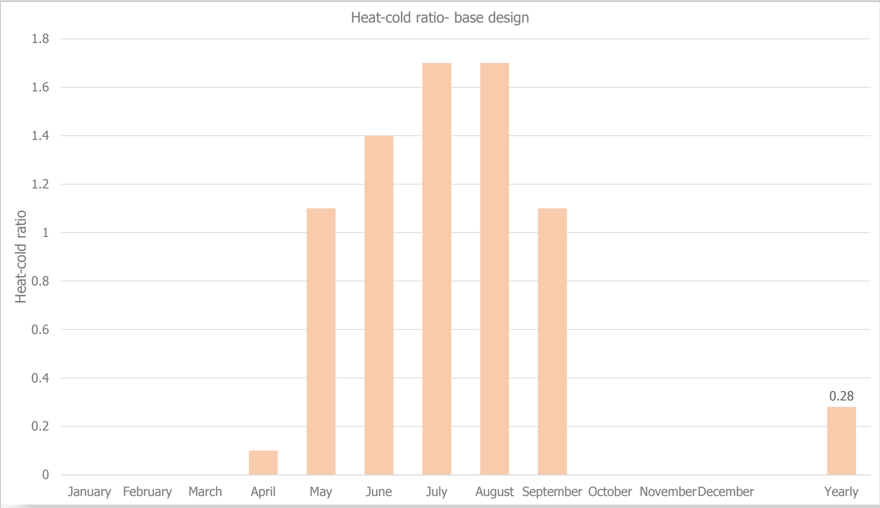
ENERGY EXCHANGE

- Subtracting heat through cooling of a building
- Extra design: Continuous cooling
- Defined as the heat-cold ratio

$$Heat - cold\ ratio = \frac{Amount\ of\ cooling\ over\ time\ x}{Amount\ of\ space\ heating + tap\ water\ over\ time\ x} \quad [-]$$

- Total per month
- Per function per year

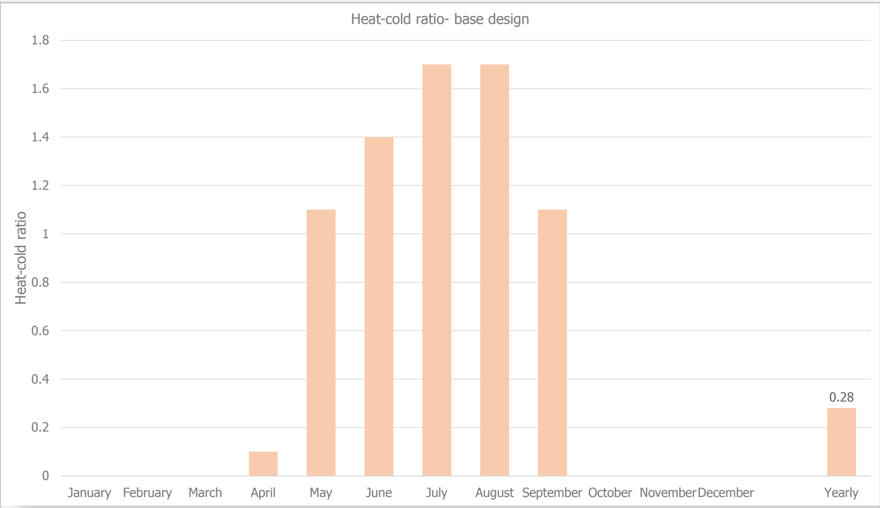
Base design



Function	Heating [kWh]	Cooling [kWh]
Residential (buy)	1	0.2
Residential (rent)	1	0.3
Commercial (non-hotel)	1	1.3
Commercial (hotel)	1	0.5
Hotel	1	0.17
Office	1	2.6

Yearly heat-cold ratio per function

Base design



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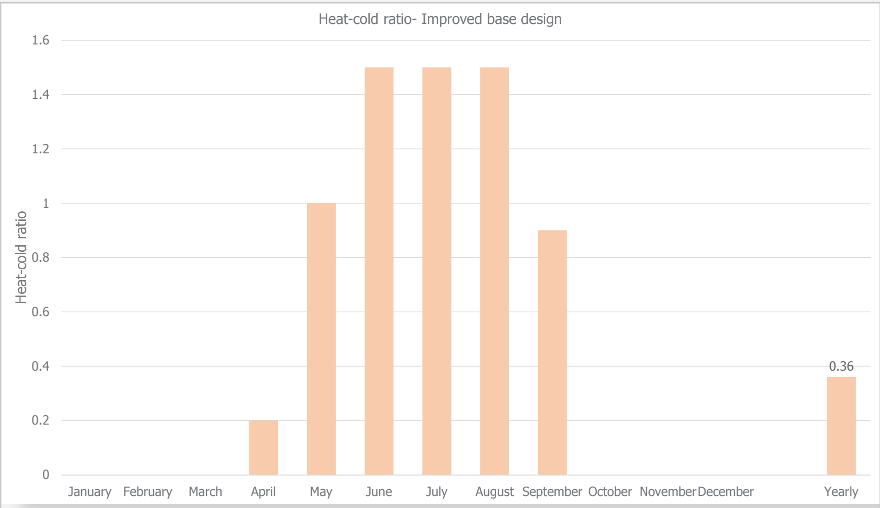
Commercial (hotel)	1	0.5
Hotel	1	0.17
Office	1	2.6

Yearly heat-cold ratio per function

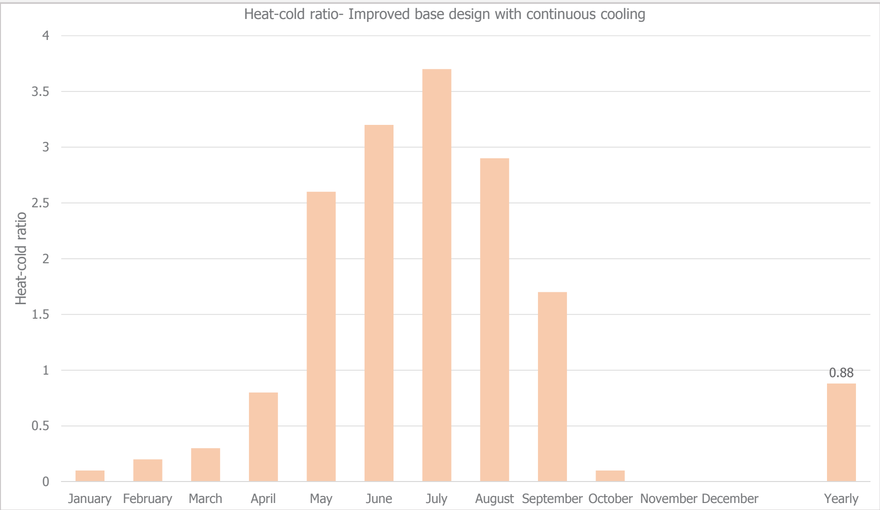
Improved base design



Function	Heating [kWh]	Cooling [kWh]
Residential (buy)	1	0.1
Residential (rent)	1	0.2
Commercial (non-hotel)	1	9.7
Commercial (hotel)	1	8.3
Hotel	1	0.12
Office	0	18.5

Yearly heat-cold ratio per function

Improved base design with continuous cooling

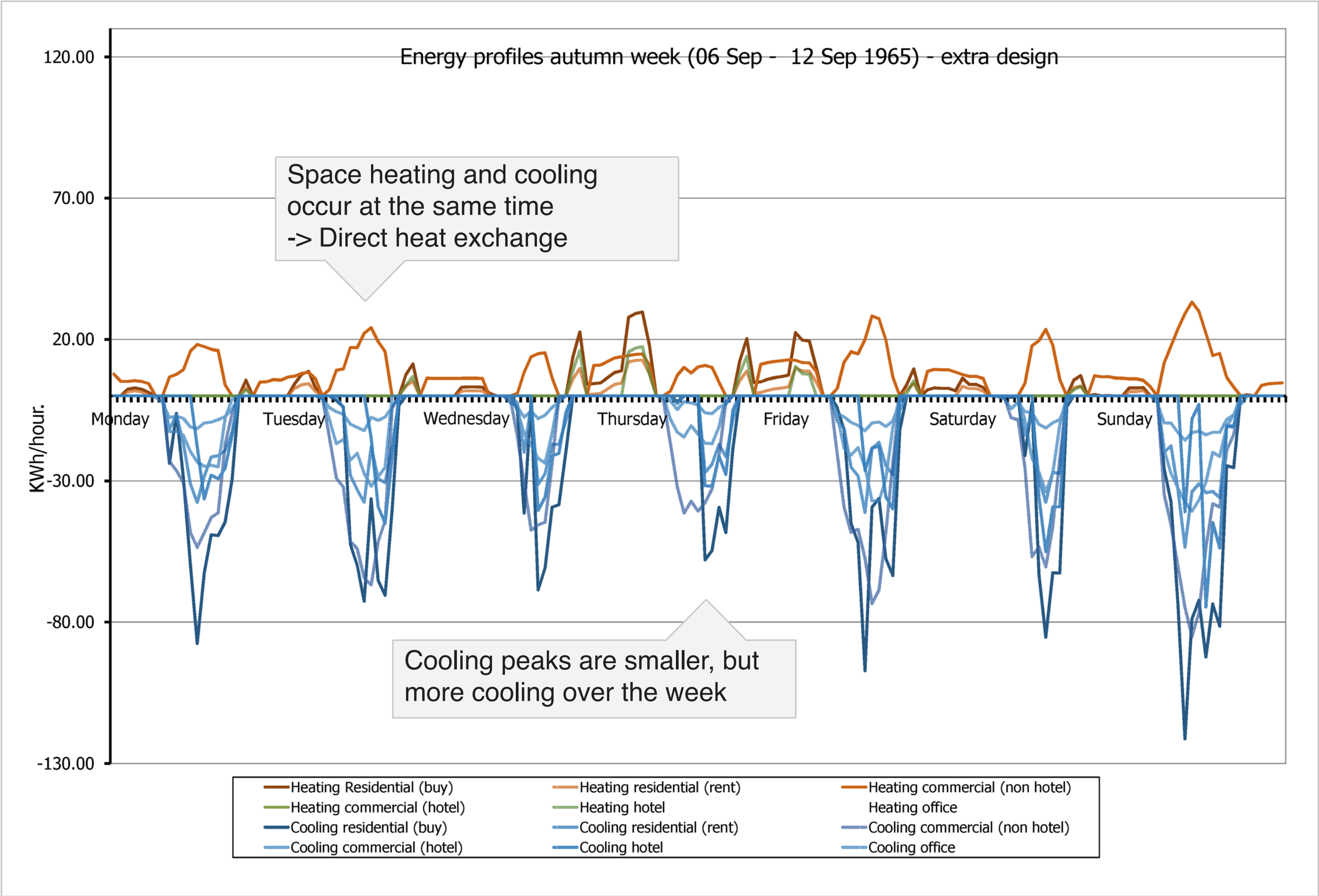


- Overall higher heat-cold ratio
- Exchange possible throughout the year
- Introduction of direct heat exchange

Function	Heating [kWh]	Cooling [kWh]
Residential (buy)	1	0.7
Residential (rent)	1	0.9
Commercial (non-hotel)	1	14.6
Commercial (hotel)	1	13.8
Hotel	1	0.3
Office	1	22.1

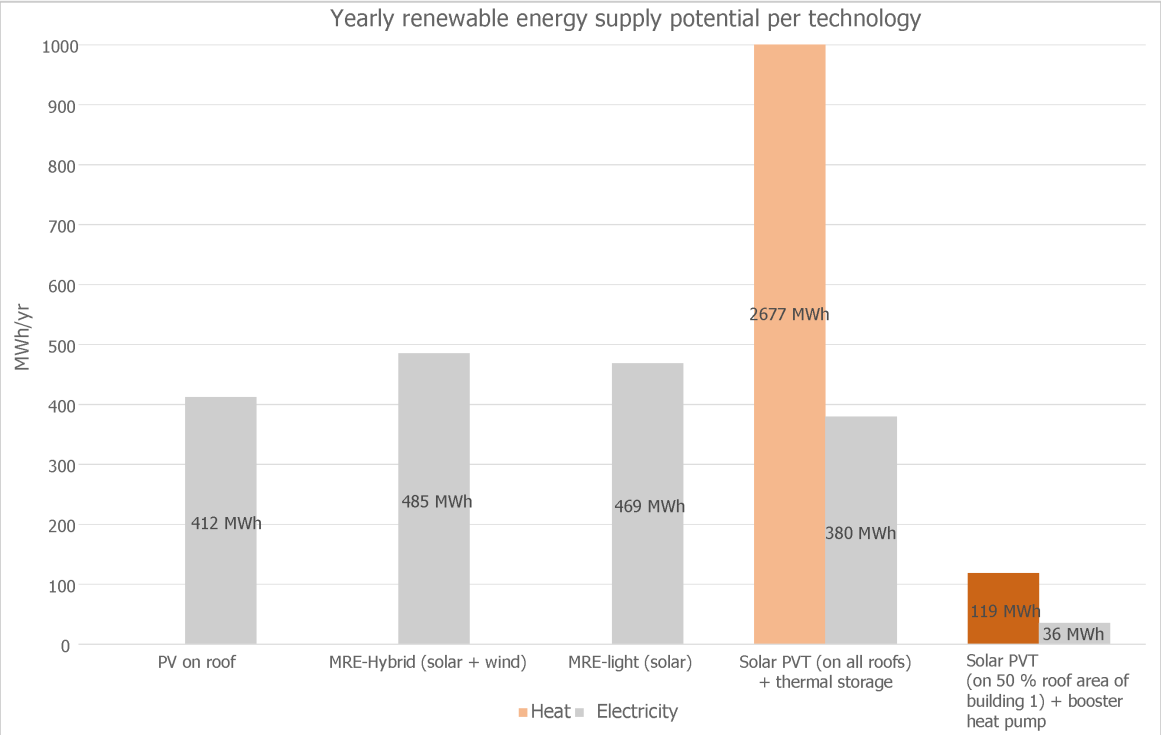
Yearly heat-cold ratio per function

CASE STUDY DESIGN
ENERGY EXCHANGE



CASE STUDY DESIGN

ADAPTING SUPPLY



PV panels

MRE-hybrid (wind + solar)

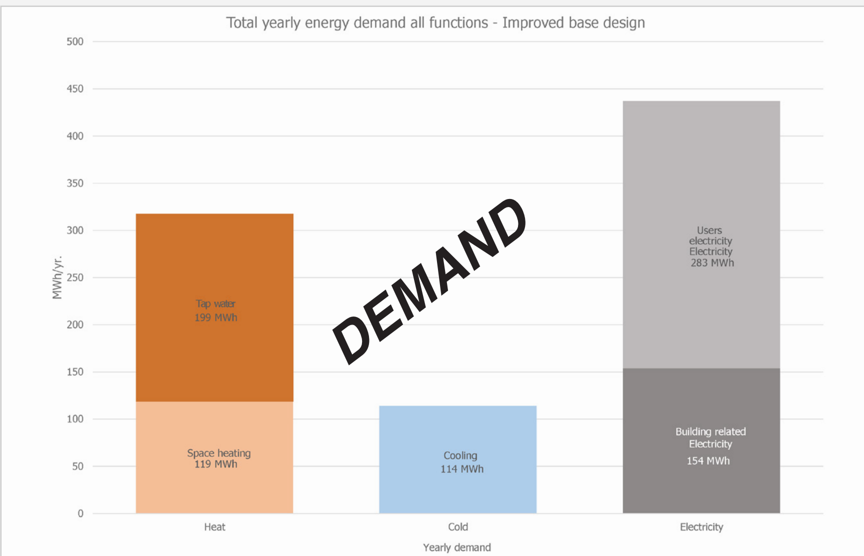
P(V)T panels

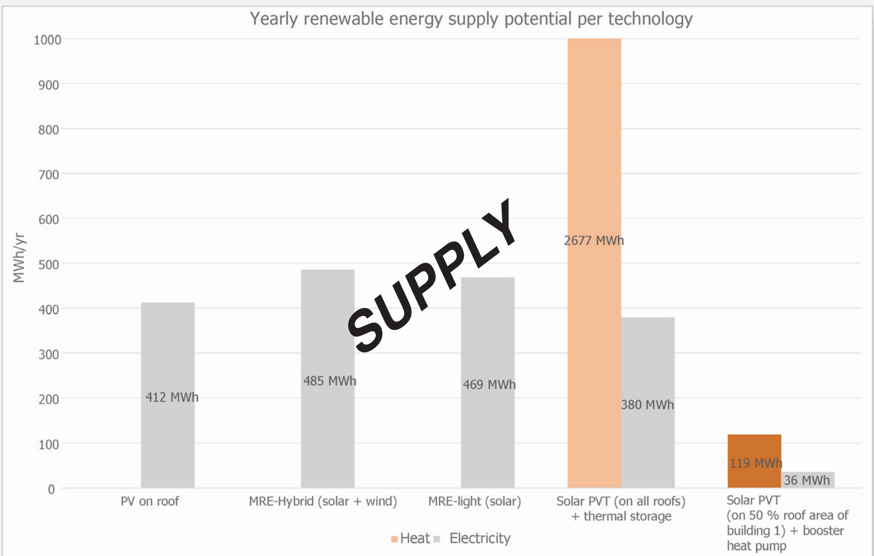
3.4 & 3.5 Conceptual energy network & Evaluation and selection

- Connecting supply and demand
- Energy system design principles
- Evaluation and selection
- Energy system design for case study

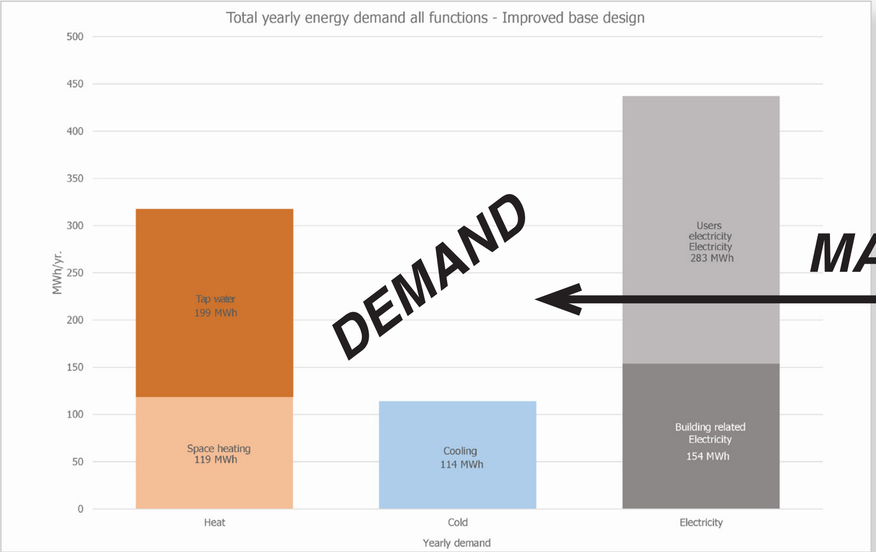
CASE STUDY DESIGN

CONNECTING SUPPLY AND DEMAND





CASE STUDY DESIGN
CONNECTING SUPPLY AND DEMAND



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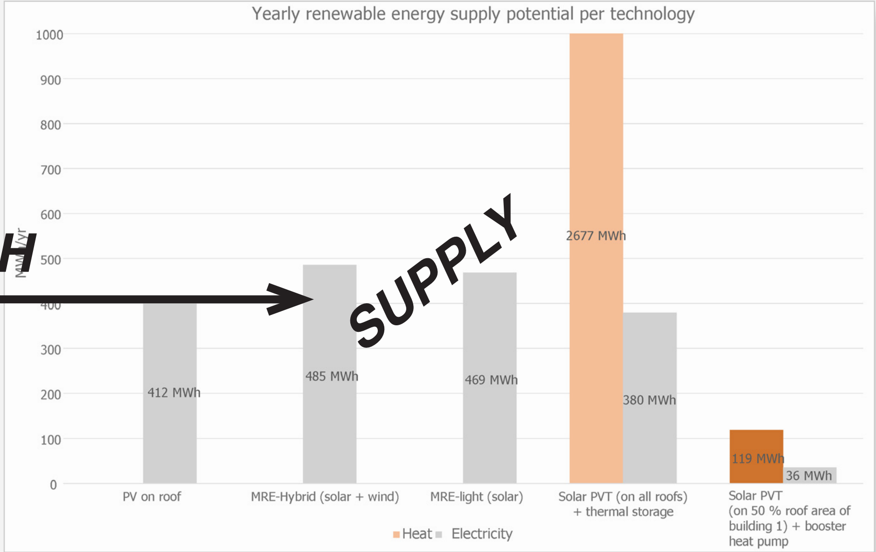
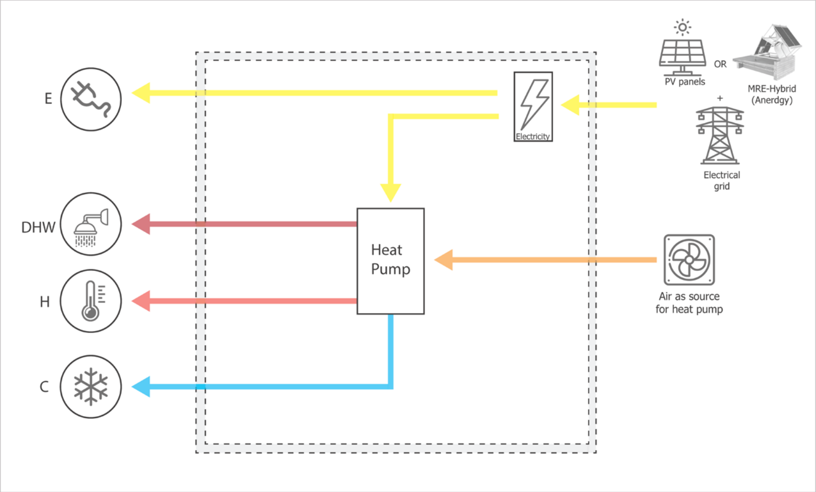
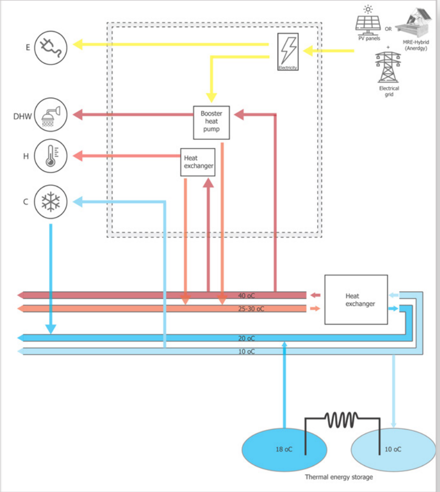


CASE STUDY DESIGN
ENERGY SYSTEM DESIGN PRINCIPLES

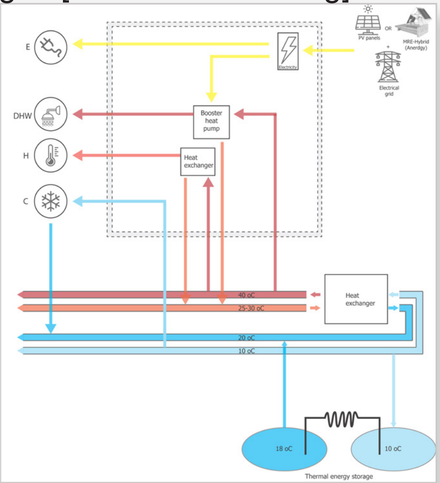
All-Electric (Individual heat pump per building)



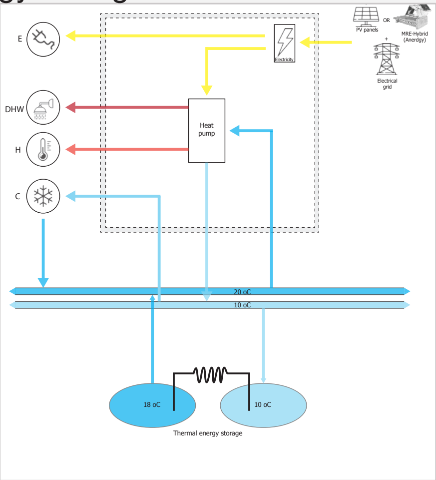
Medium temperature thermal grid + separate cooling grid



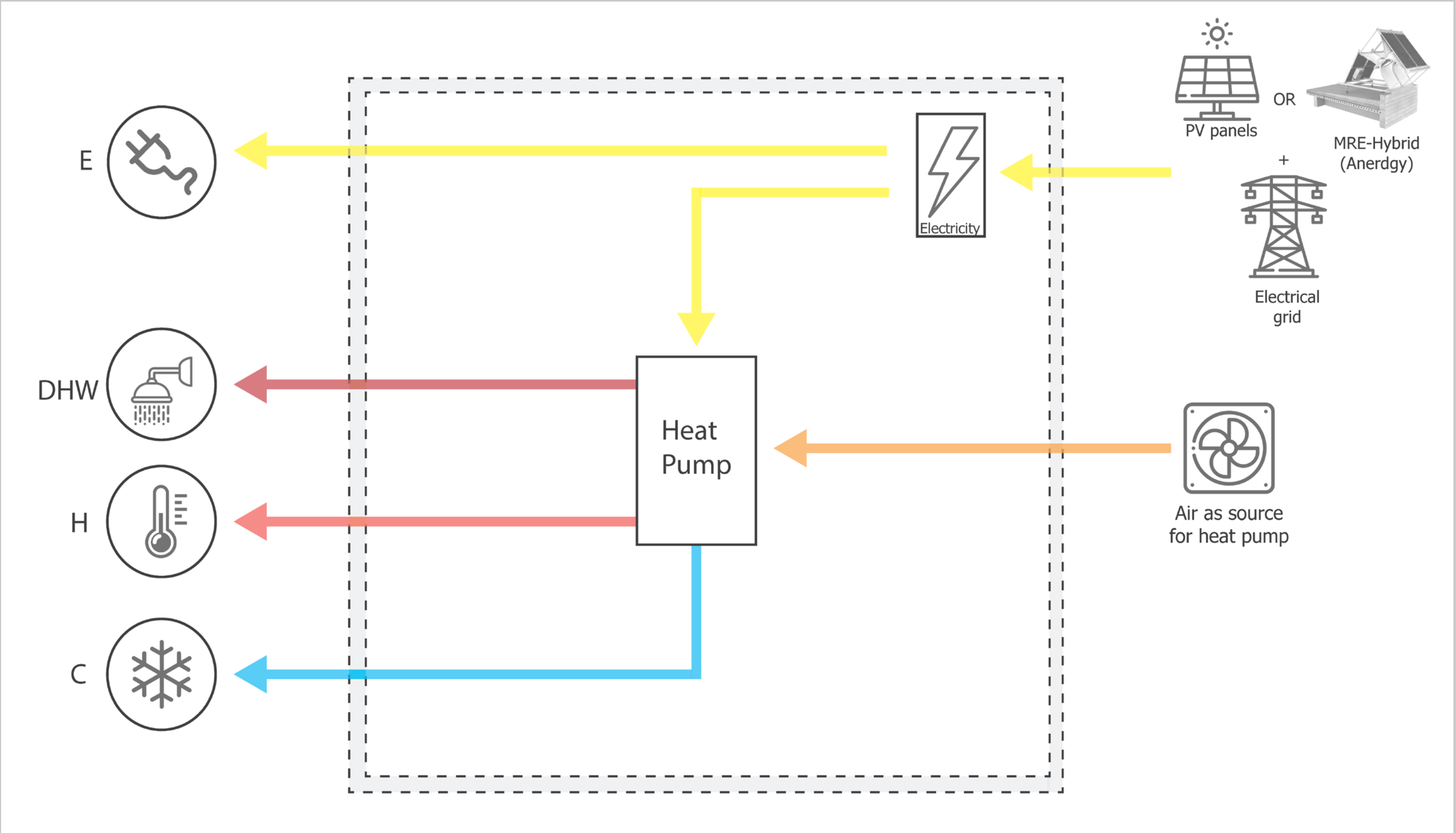
Medium temperature thermal grid + separate cooling grid [Continuous cooling]



Low temperature thermal grid + thermal energy storage

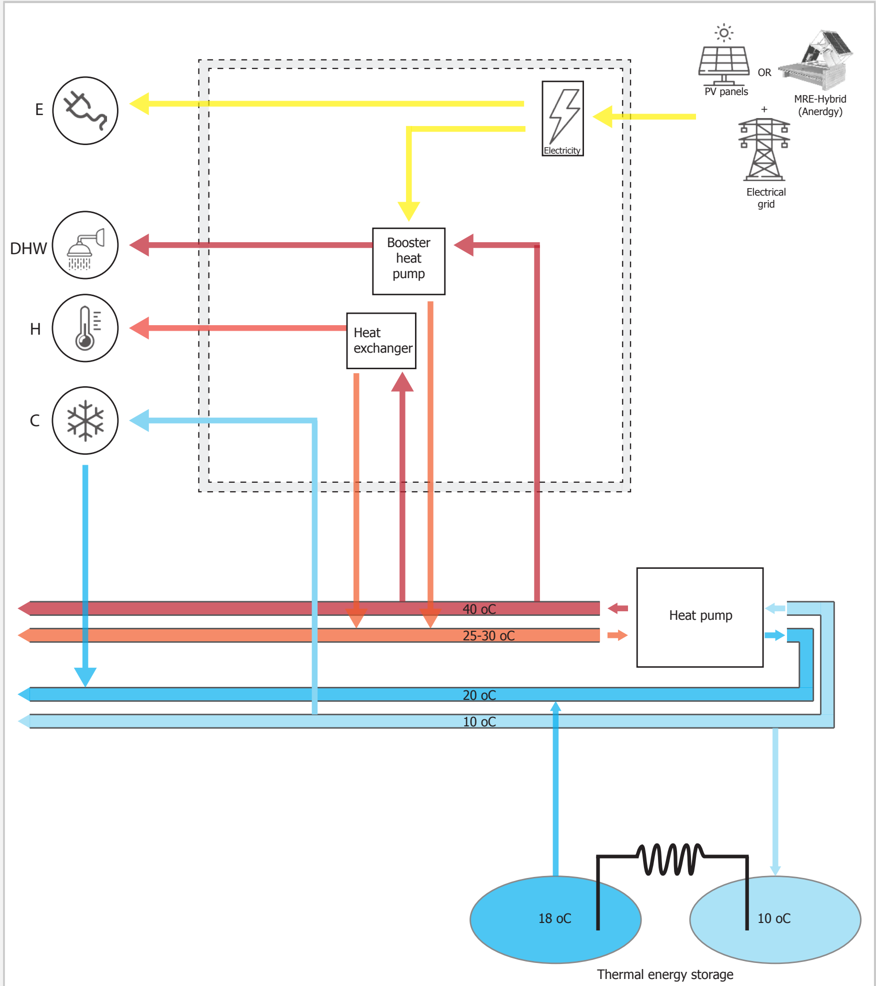


CASE STUDY DESIGN
ENERGY SYSTEM DESIGN PRINCIPLES



Option 1: All-electric (Individual heat pump per building]

CASE STUDY DESIGN
ENERGY SYSTEM DESIGN PRINCIPLES

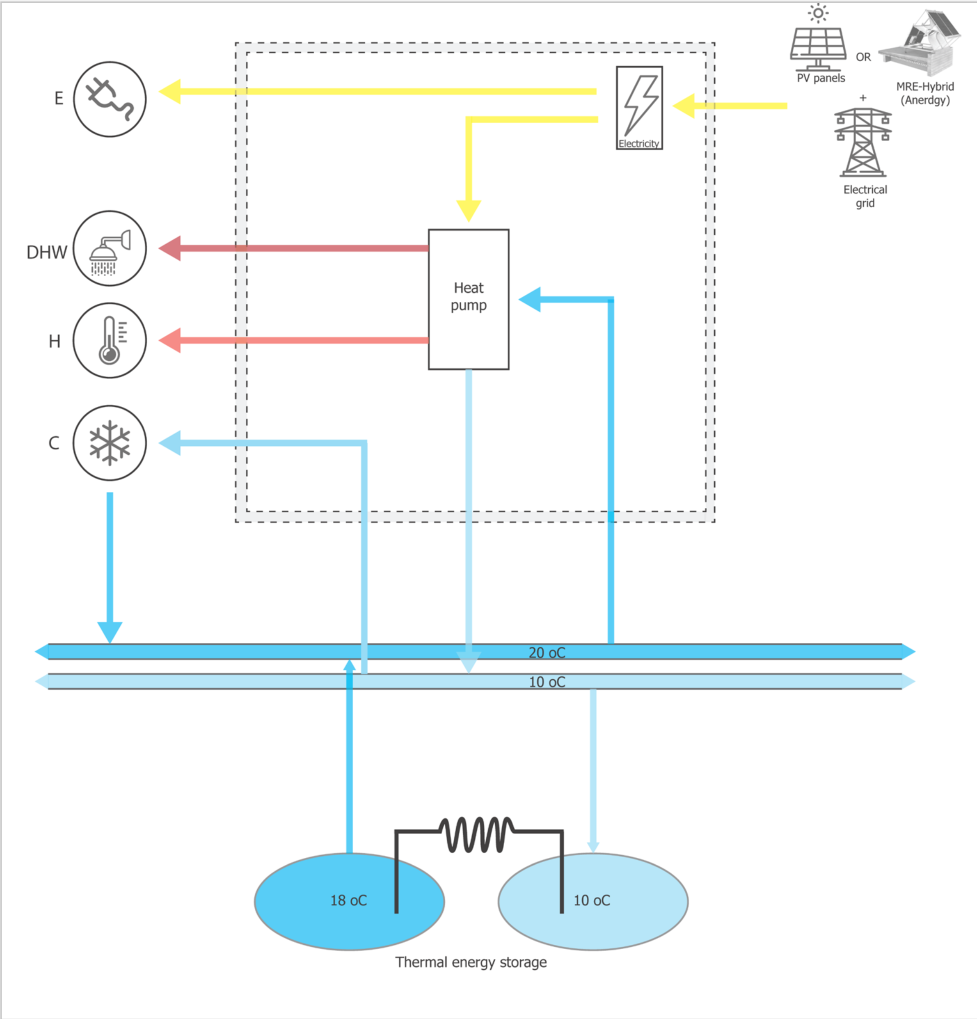


Option 2a: Medium temperature thermal grid + separate cooling grid

Option 2b: Medium temperature thermal grid + separate cooling grid [Continuous cooling]

CASE STUDY DESIGN

ENERGY SYSTEM DESIGN PRINCIPLES



Option 3: Low temperture thermal grid + thermal energy storage

CASE STUDY DESIGN

EVALUATION AND SELECTION

Network configurations	Options			
	All-electric	Medium temperature thermal grid + separate cooling grid		Low temperature thermal grid + thermal storage
	1	2a: Heating/cooling when people present	2b: With continuous cooling	3
KPI 1: Energy neutrality (MWh/yr.)/fraction of local renewable supply per year (%)				
Heating (MWh/yr.) [%]	n.a.	0 [100 %]	0 [100 %]	0 [100 %]
Electricity (MWh/yr.) [%]	4 [101 %]	1 [100 %]	1 [100 %]	5 [101 %]

CASE STUDY DESIGN
EVALUATION AND SELECTION

Network configurations	Options			
	All-electric	Medium temperature thermal grid + separate cooling grid		Low temperature thermal grid + thermal storage
	1	2a: Heating/cooling when people present	2b: With continuous cooling	3
KPI 1: Energy neutrality (MWh/yr.)/fraction of local renewable supply per year (%)				
Heating (MWh/yr.) [%]	n.a.	0 [100 %]	0 [100 %]	0 [100 %]
Electricity (MWh/yr.) [%]	4 [101 %]	1 [100 %]	1 [100 %]	5 [101 %]
KPI 2: Fraction of autonomy; Direct energy supply use (MWh/yr.) [%]				
Heating (MWh/yr.) [%]	63 [11 %] *	30 [9 %] **	30 [9 %] **	30 [9 %] **
Electricity (MWh/yr.) [%]	226 [39 %]	193 [36 %]	194 [37 %]	188 [37 %]

CASE STUDY DESIGN
EVALUATION AND SELECTION

Network configurations	Options							
	All-electric		Medium temperature thermal grid + separate cooling grid				Low temperature thermal grid + thermal storage	
	1		2a: Heating/cooling when people present		2b: With continuous cooling		3	
KPI 1: Energy neutrality (MWh/yr.)/fraction of local renewable supply per year (%)								
Heating (MWh/yr.) [%]	n.a.		0 [100 %]		0 [100 %]		0 [100 %]	
Electricity (MWh/yr.) [%]	4 [101 %]		1 [100 %]		1 [100 %]		5 [101 %]	
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Heating (MWh/yr.) [%]	63 [11 %] *		30 [9 %] **		30 [9 %] **		30 [9 %] **	
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KPI 3: Maximum power mismatch (kW) [positive and negative]								
Electricity (kW)	388	-188	382	-178	386	-178	381	-158

CASE STUDY DESIGN
EVALUATION AND SELECTION

Network configurations	Options			
	All-electric	Medium temperature thermal grid + separate cooling grid		Low temperature thermal grid + thermal storage
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KPI 3: Maximum power mismatch (kW) [positive and negative]				
Electricity (kW)	388 -188	382 -178	386 -178	381 -158
KPI 4: Maximum cumulative mismatch (MWh)				
Electricity (MWh)	145	128	139	138

CASE STUDY DESIGN

EVALUATION AND SELECTION

Network configurations	Options							
	All-electric		Medium temperature thermal grid + separate cooling grid				Low temperature thermal grid + thermal storage	
	1		2a: Heating/cooling when people present		2b: With continuous cooling		3	
KPI 1: Energy neutrality (MWh/yr.)/fraction of local renewable supply per year (%)								
Heating (MWh/yr.) [%]	n.a.		0 [100 %]		0 [100 %]		0 [100 %]	
Electricity (MWh/yr.) [%]	4 [101 %]		1 [100 %]		1 [100 %]		5 [101 %]	
KPI 2: Fraction of autonomy; Direct energy supply use (MWh/yr.) [%]								
Heating (MWh/yr.) [%]	63 [11 %] *		30 [9 %] **		30 [9 %] **		30 [9 %] **	
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KPI 4: Maximum cumulative mismatch (MWh)								
Electricity (MWh)	145		128		139		138	
KPI 5: Fraction of inter-exchange of energy (%)	n.a		34		85		36	

3 CASE STUDY DESIGN
EVALUATION AND SELECTION

Network configurations	Options: All-electric	Medium temperature thermal grid + separate cooling grid		Low temperature thermal grid + thermal storage
	1	2a: Heating/cooling when people present	2b: With continuous cooling	3
KPI 1: Energy neutrality (MWh/yr.)/fraction of local renewable supply per year (%)				
Heating (MWh/yr.) [%]	n.a.	0 [100 %]	0 [100 %]	0 [100 %]
Electricity (MWh/yr.) [%]	4 [101 %]	1 [100 %]	1 [100 %]	5 [101 %]
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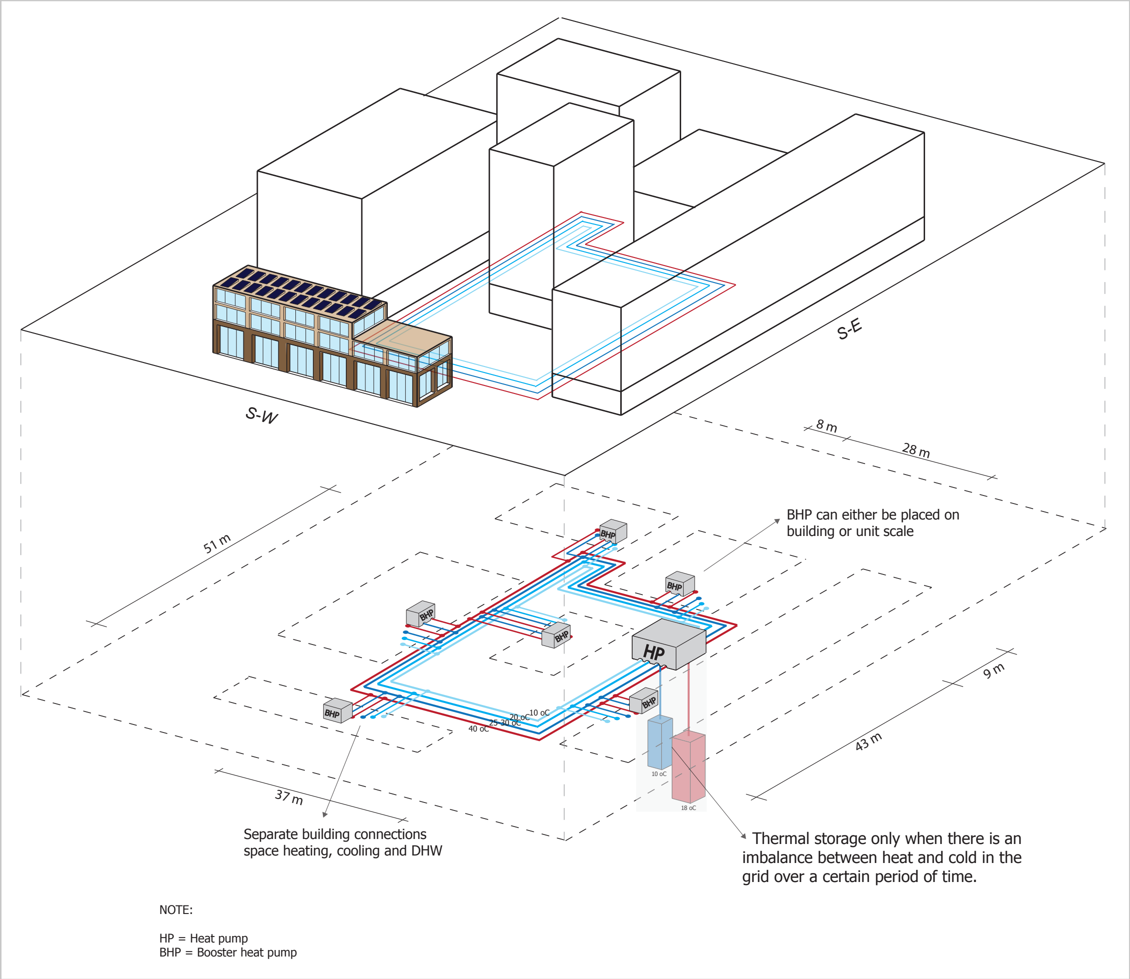
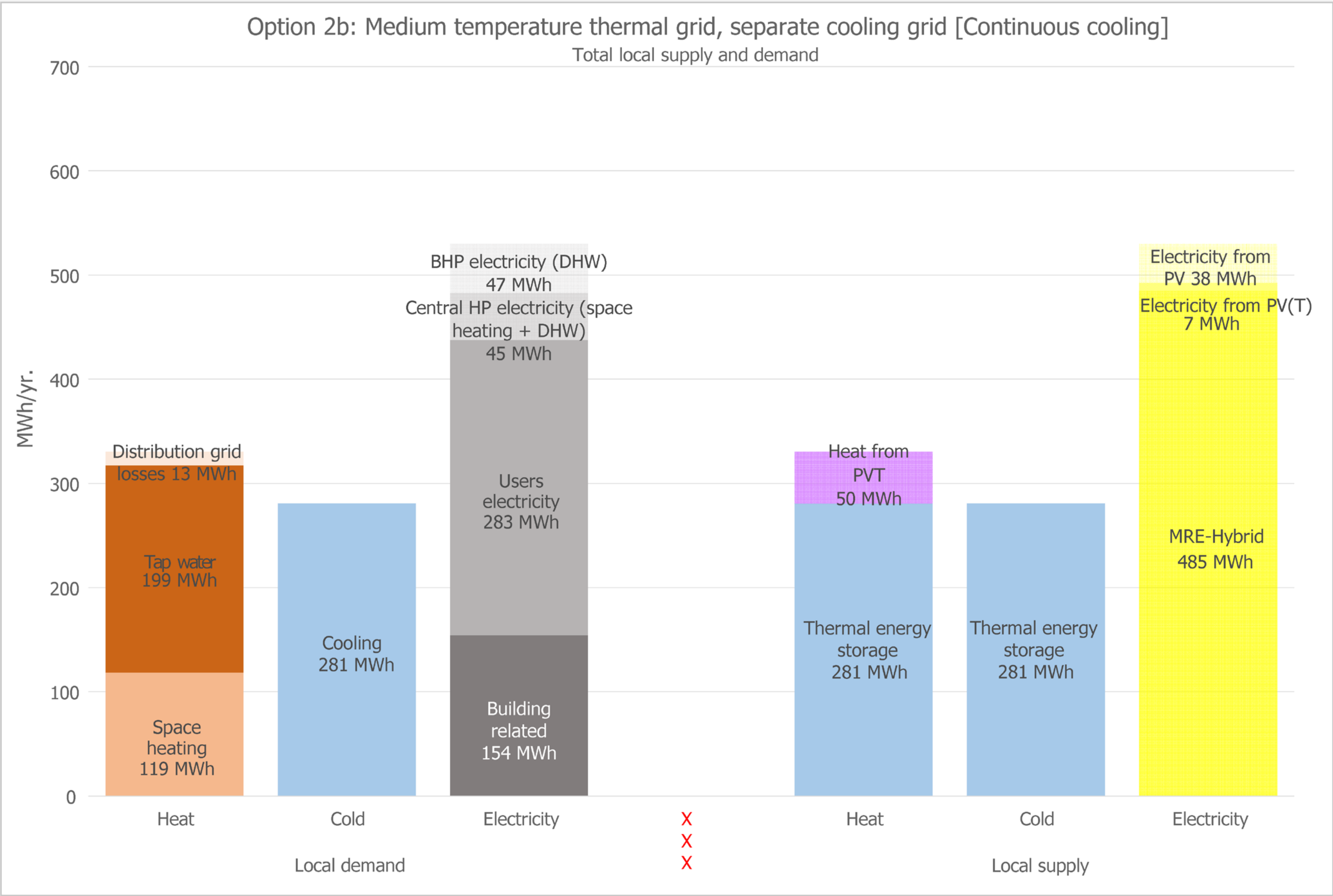
KPI 3: Maximum power mismatch (kW) [positive and negative]				
Electricity (kW)	388 / -188	382 / -178	386 / -178	381 / -158
KPI 4: Maximum cumulative mismatch (MWh)				
Electricity (MWh)	145	128	139	138
KPI 5: Fraction of inter-exchange of energy (%)	n.a	34	85	36

CASE STUDY DESIGN

CASE STUDY ENERGY SYSTEM

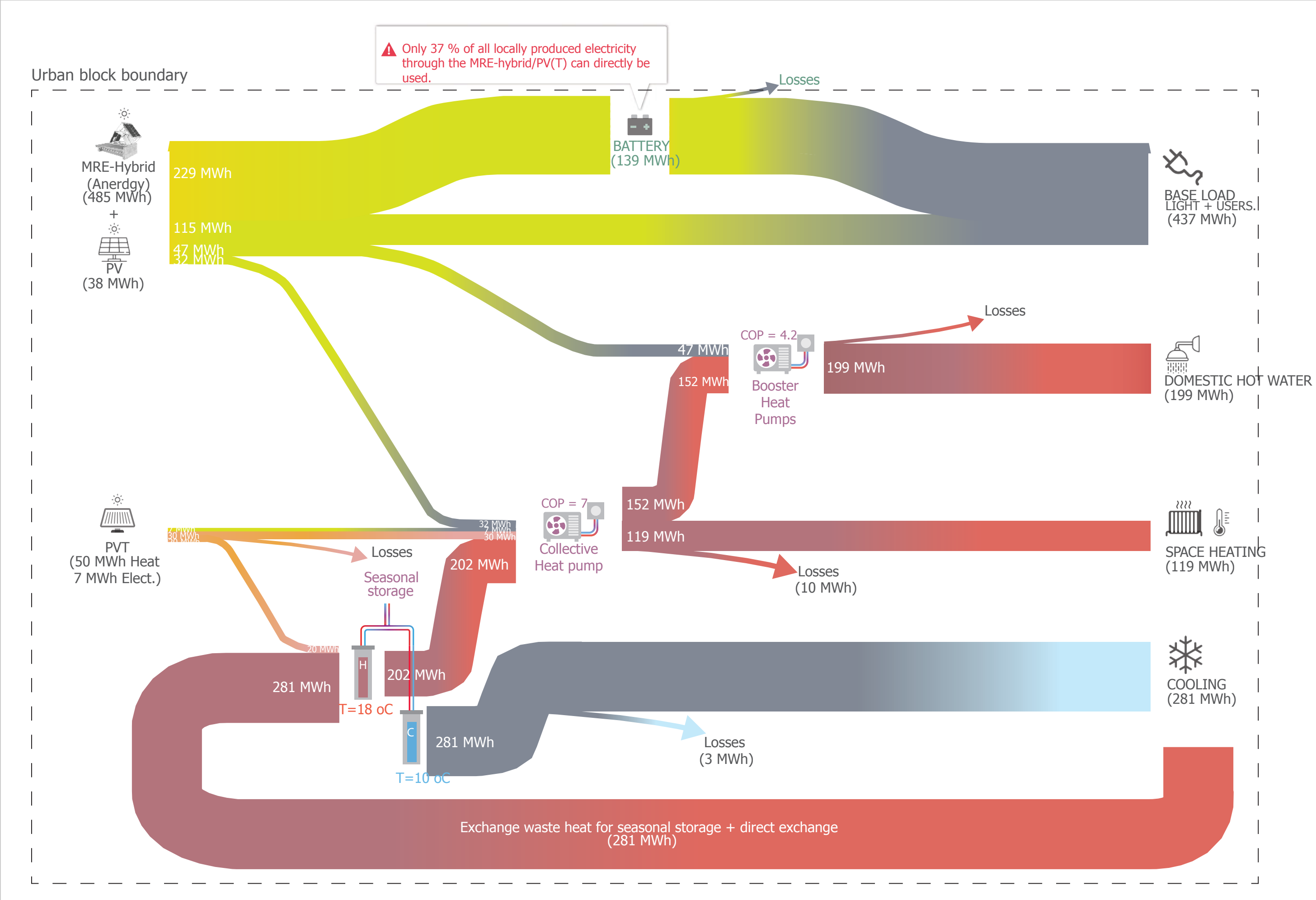


CASE STUDY DESIGN
CASE STUDY ENERGY SYSTEM



CASE STUDY DESIGN

CASE STUDY ENERGY SYSTEM

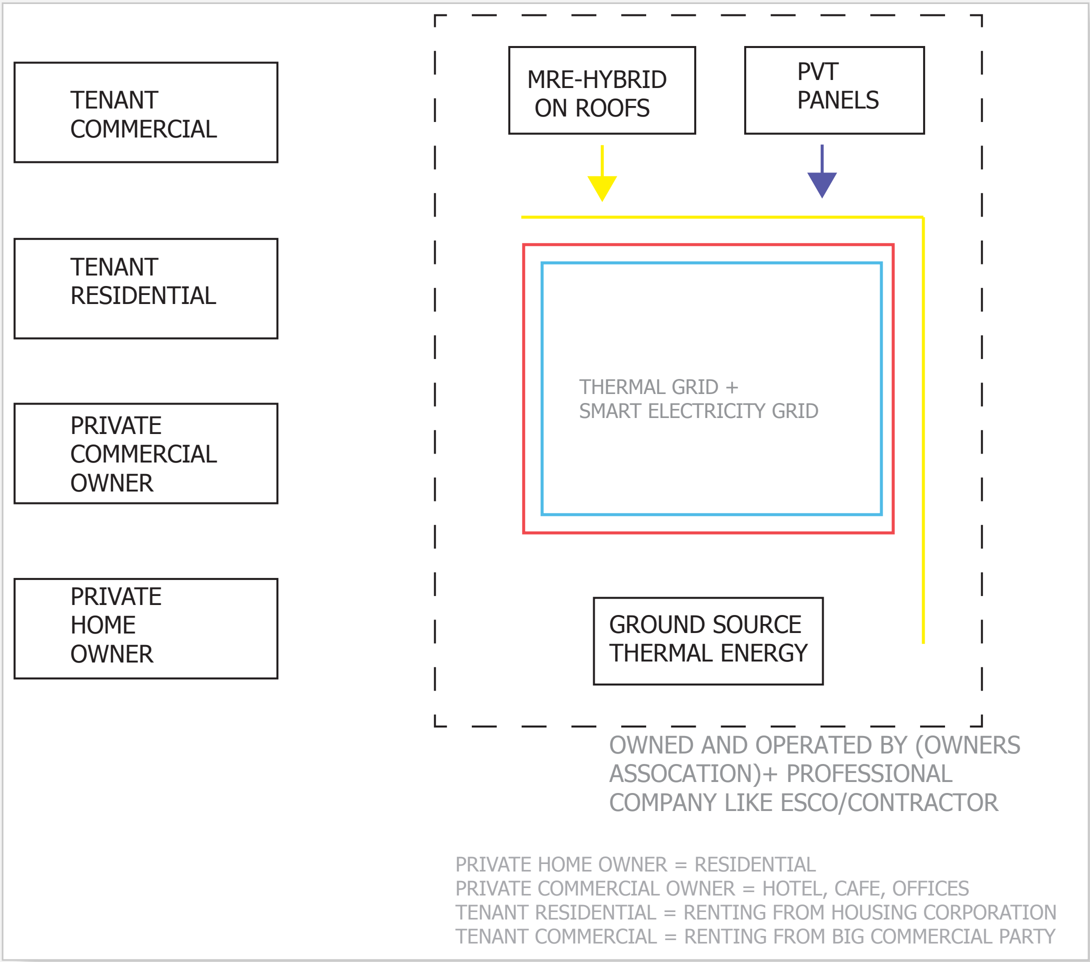


3.6 Institutional energy flow diagram

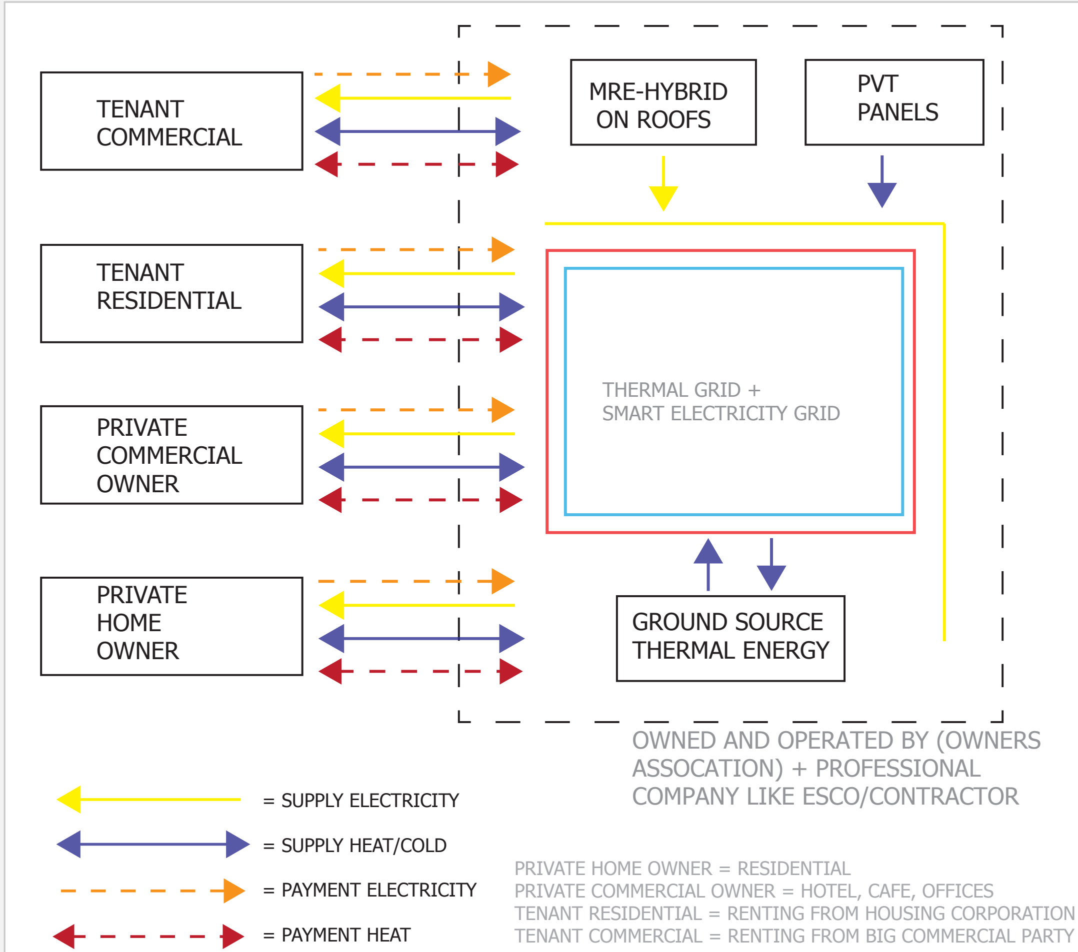
- Principle - How can it be arranged?
- 2 Options
- Implications

CASE STUDY DESIGN

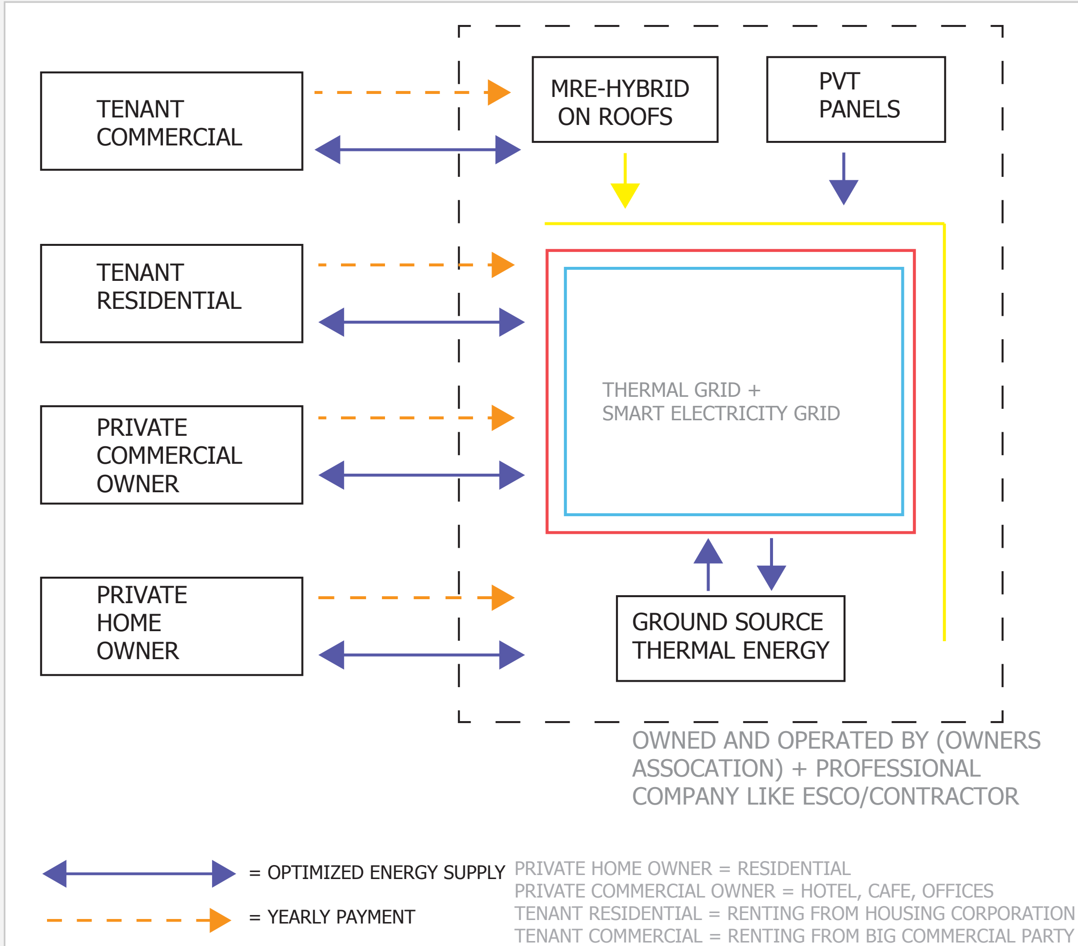
INSTITUTIONAL ENERGY FLOW DIAGRAM



CASE STUDY DESIGN
TWO WAY PAYMENT



CASE STUDY DESIGN
ONE WAY PAYMENT



CASE STUDY DESIGN

IMPLICATIONS

3

- Stakeholder participation
- Integral approach to optimize overall system
- Electricity law
- Revised Heat law

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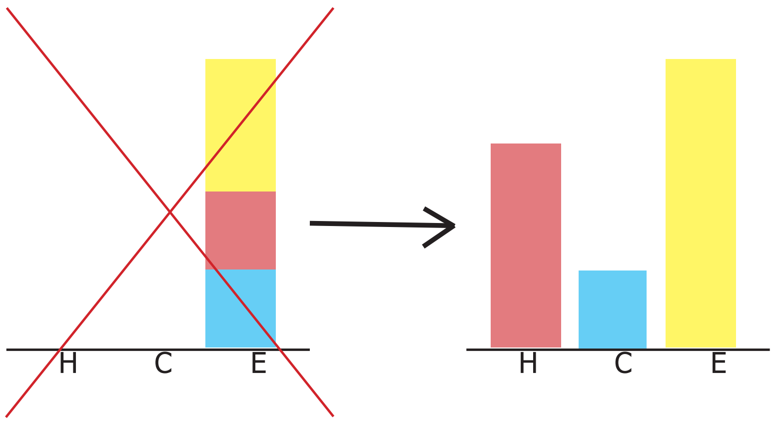
4 Conclusion

- Research question
- Summary of research results

How can you design an energy flat multifunctional urban block in the Netherlands and what does this imply for governance?
[Case study Buiksloterham, Amsterdam]

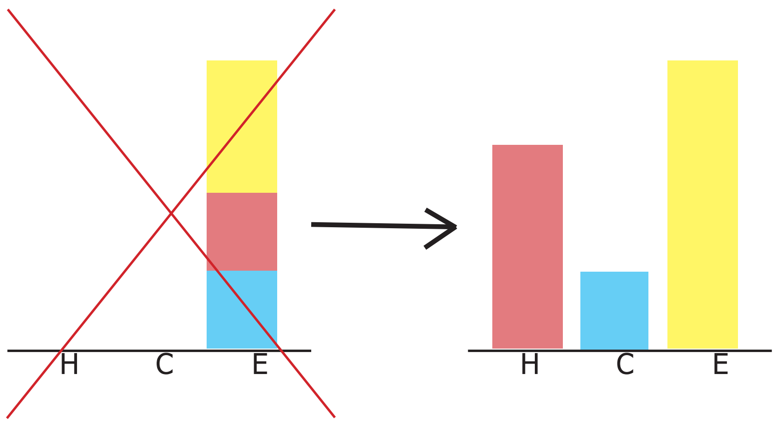
SEPARATE ALL ENERGY TYPES



CONCLUSION

RESEARCH RESULTS

SEPARATE ALL ENERGY TYPES

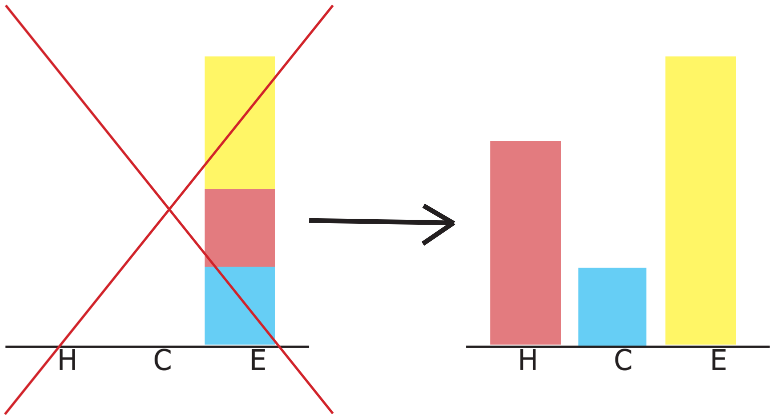


REDUCING MISMATCH

- Architectural design ↓ Heating ↑ Cooling
- ↑ Energy exchange
  - Multi functionality
  - Continuous cooling
- Local supply to match the rest

CONCLUSION
RESEARCH RESULTS

SEPARATE ALL ENERGY TYPES



REDUCING MISMATCH

- Architectural design ↓ Heating ↑ Cooling
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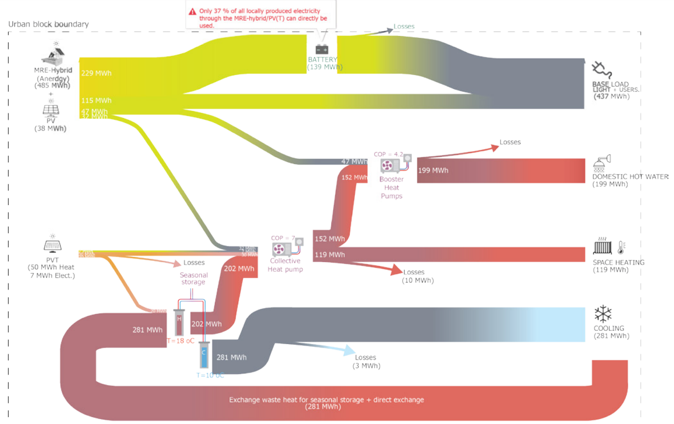
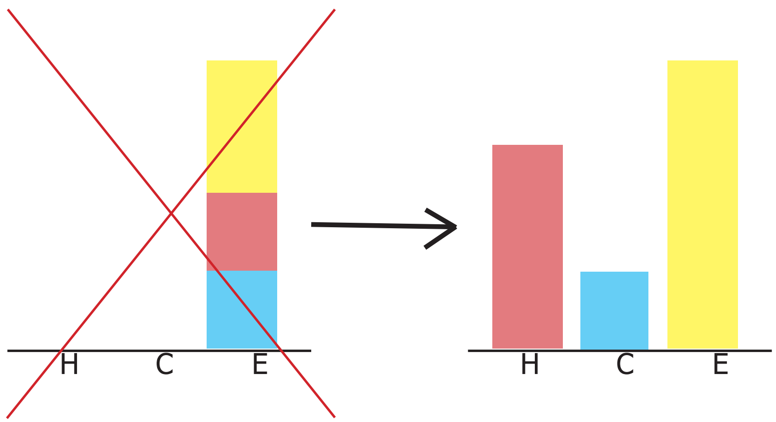
TO CREATE AN ENERGY NETWORK



CONCLUSION

RESEARCH RESULTS

SEPARATE ALL ENERGY TYPES



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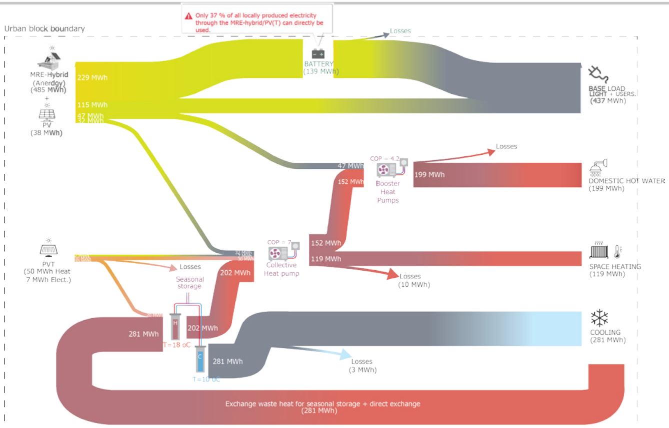
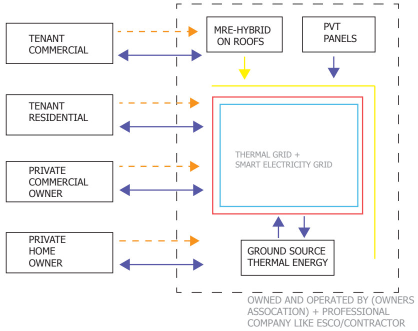
TO CREATE AN ENERGY NETWORK



THAT IS FEASIBLE TO OVERCOME BARRIERS USING EXISTING POTENTIALS WITH THIRD PARTY INVOLVEMENT



THANK YOU! QUESTIONS?

Kjell-Erik Prins // P5 Presentation // July 4th 2019

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