ENERGY TRANSITION FOR SPACE HEATING IN RAMPLAANKWARTIER

Outline

Research framework

Literature

Case study

Heat demand & energy/storage potentials

Configuration designs

Assessment

Conclusion

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Research framework

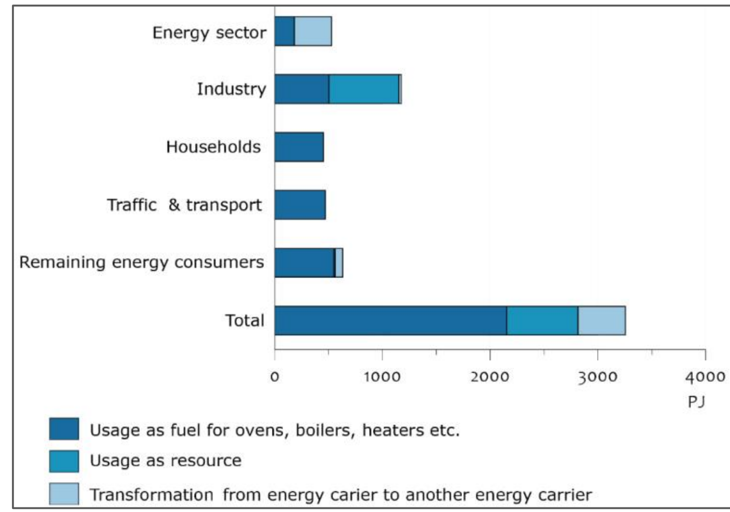
Underlying problem

1. Climate change

2. Political tensions

3. Growing resistance


Primary energy use per sector:

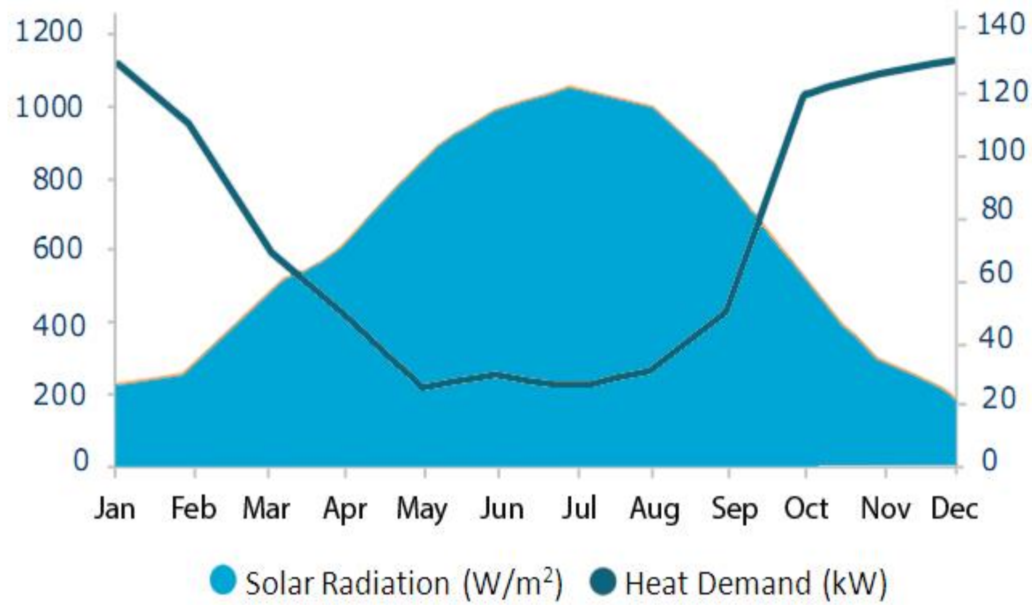


(Compendium voor de Leefomgeving, 2014)

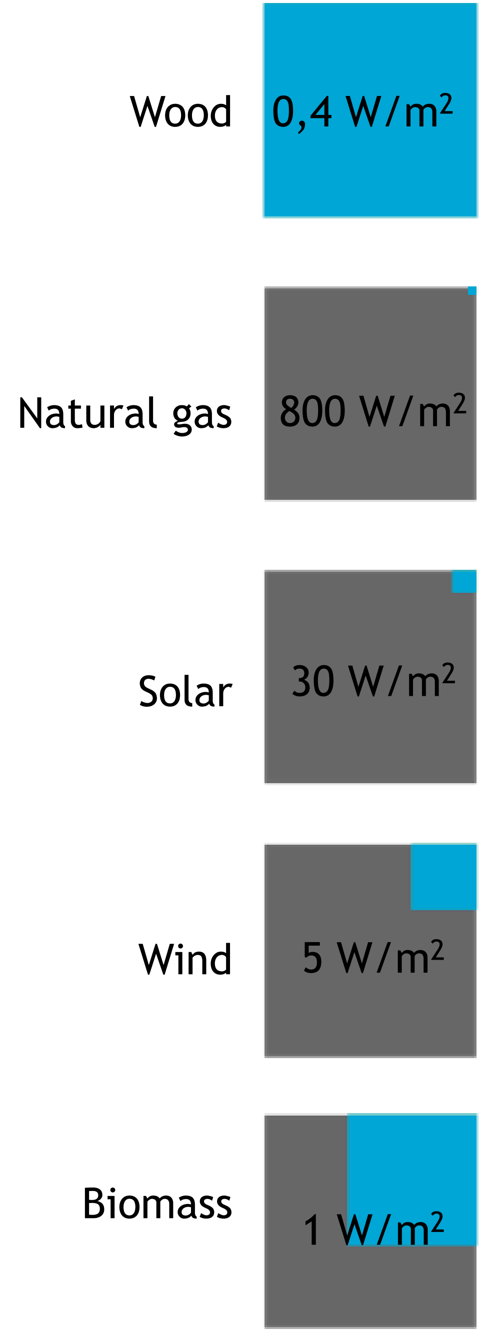
Renewable energy grid

Problem statement

1. Bigger spatial footprint
2. Additional technologies
3. More local energy production



(E-hub, 2013)



(Chen, 2013)

Challenge:

New urban design with a different spatial footprint resulting in a different experience of our living environment.

Objective:

- Explore the **technical possibilities** of supplying space heating with solar renewable energy.
- Explore the **spatial impact** of implementing a self-sufficient renewable energy system for space heating.

Main research question:

*How can a **renewable self-sufficient** energy system for space heating be **spatially integrated** in selected urban blocks of the neighbourhood Ramplaankwartier?*

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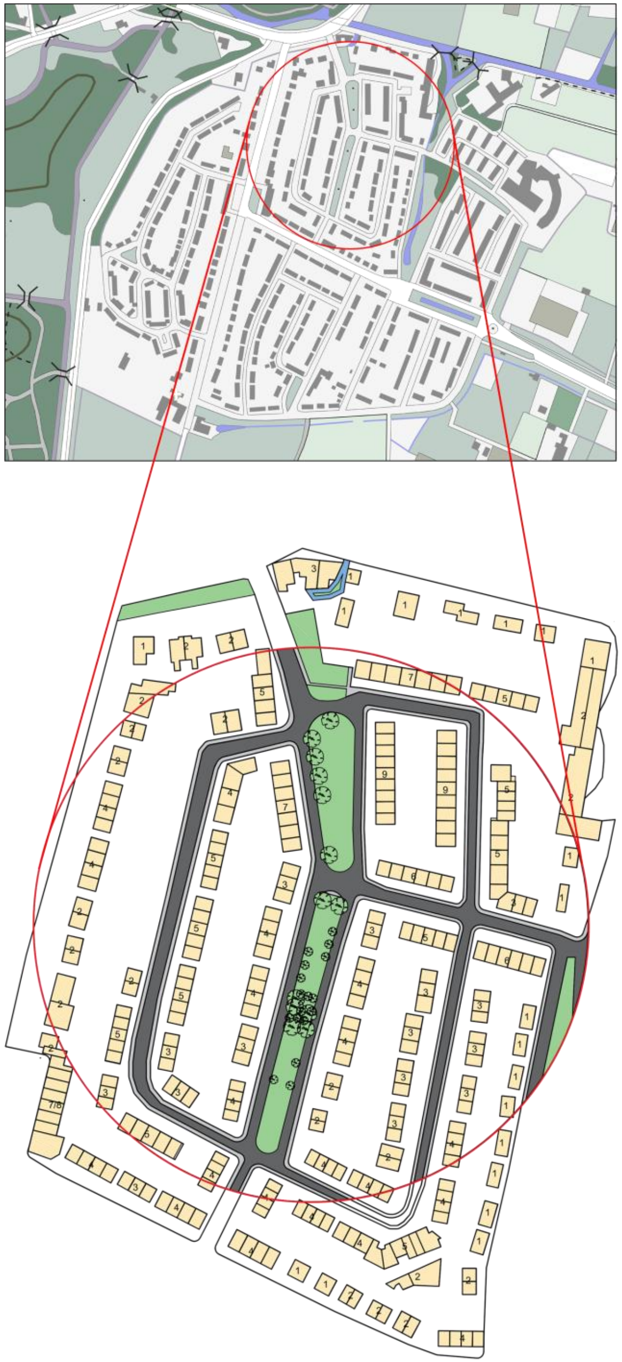


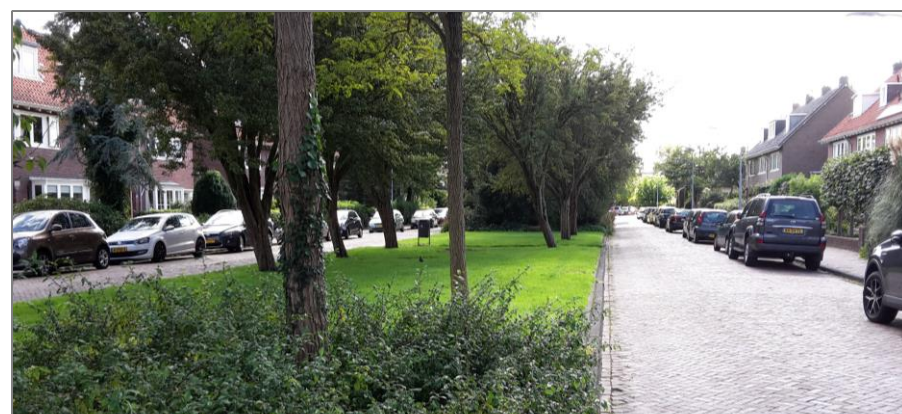
Case study

Haarlem

Ramplaankwartier

1167 buildings

113 buildings in the selected urban blocks



Societal relevance:

- Contribute to research searching for smart and innovative renewable energy systems.
- Contribute to the energy transition by visualizing the spatial impact of energy systems.

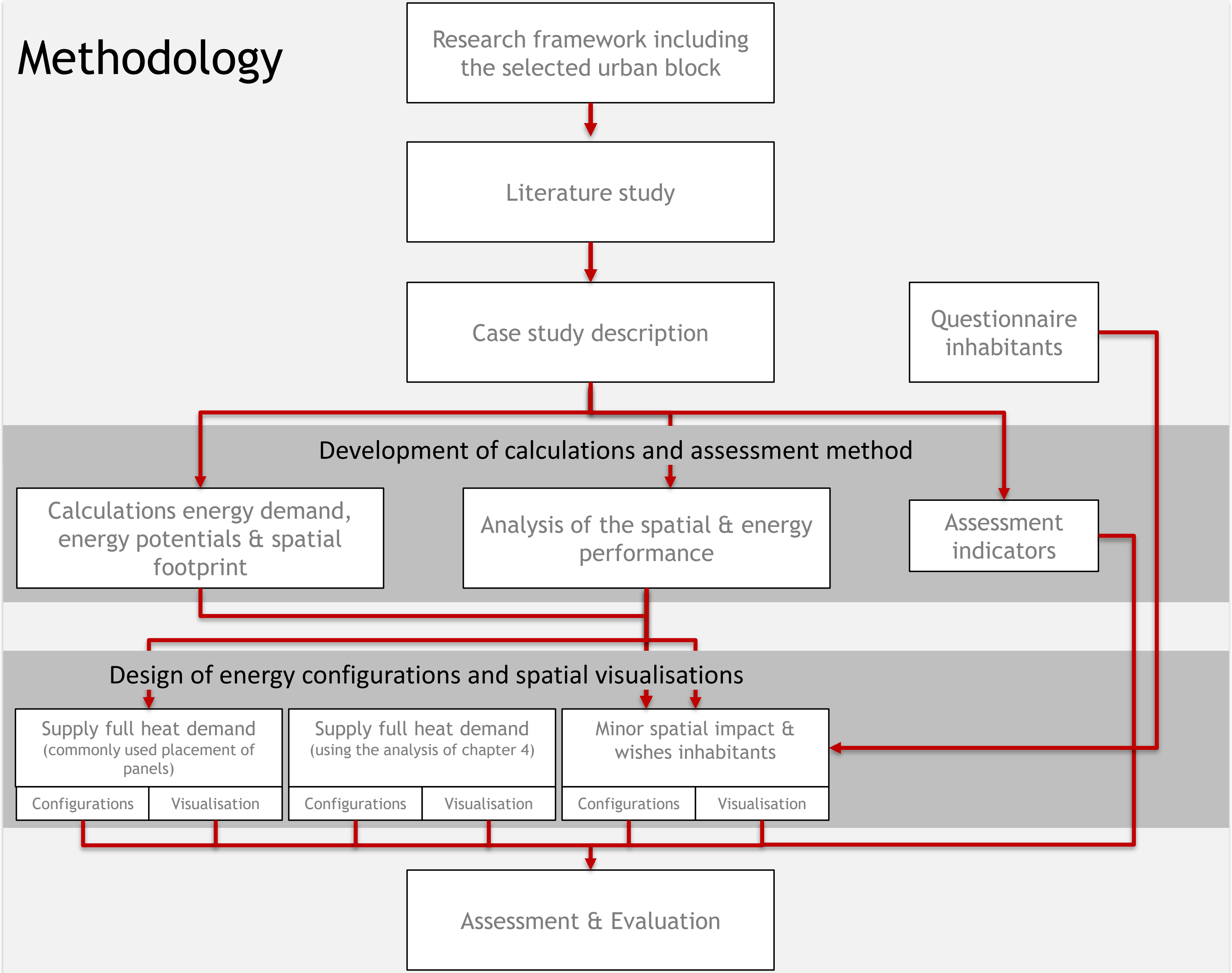
Scientific relevance:

- Contribute to the smart urban isle project (SUI).

Constraints:

- Self-sufficient energy system
- Focus on the heat demand of the existing buildings
- Reduced heat demand (feasible renovations)
- Low temperature heating for households

Methodology



Literature

A. Renewable energy production technologies
B. Energy storage technologies
C. Additional technologies

A. Renewable energy production technologies:

Wind

Hydro

Solar

Geothermal

Biomass

Photovoltaic

- Monocrystalline silicon
- (TF) cadmium telluride

Solar collectors

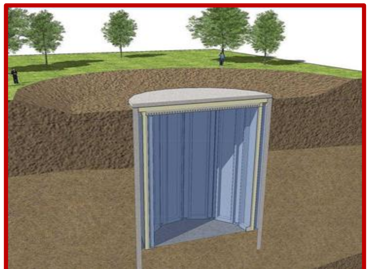
- Evacuated tube collector
- Flat plate collector

Hybrid (PVT)

+

B. Energy storage technologies:

Thermal



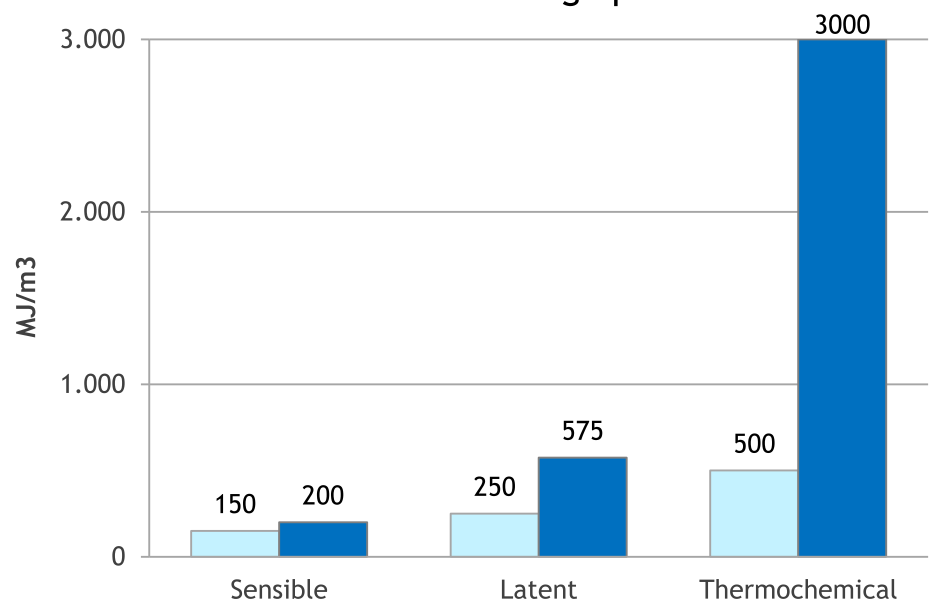
Chemical

Electrical

Mechanical

- Sensible (water)
- Latent (salt)
- Thermo-chemical

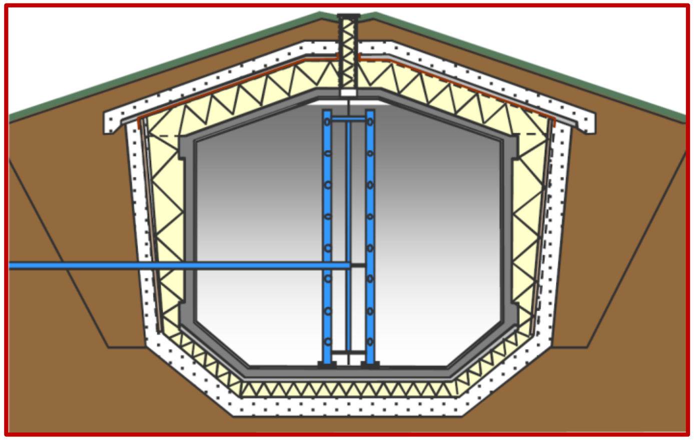
Minimal & maximal storage potential:



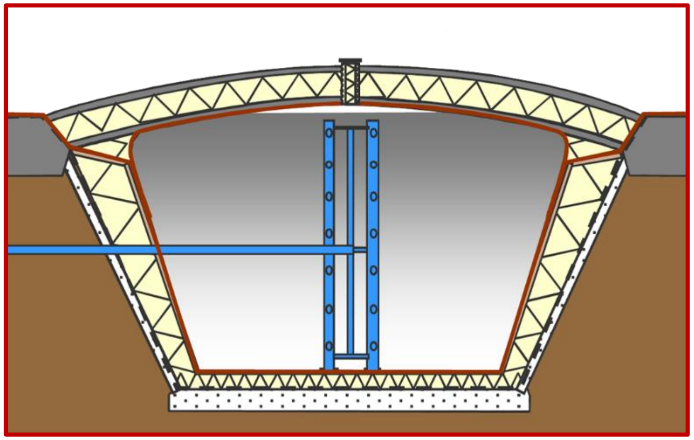
(Bakker, 2009)

B. Energy storage technologies:

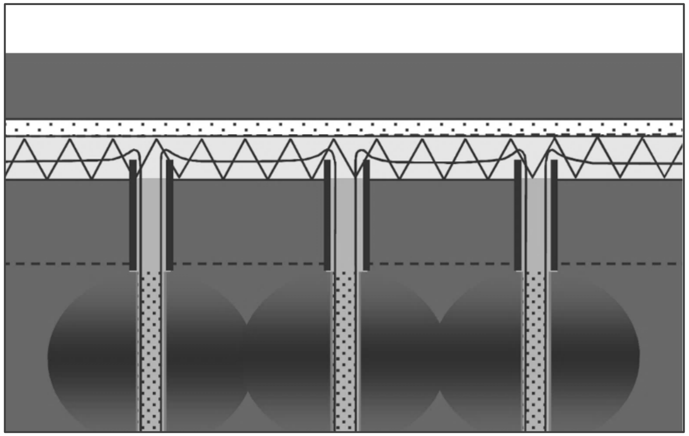
Tank



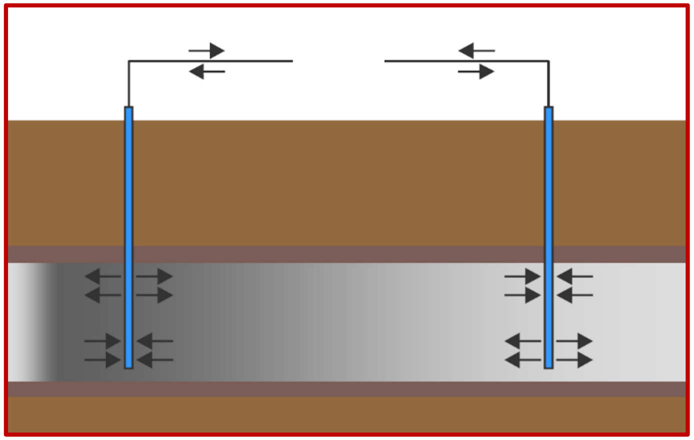
Pit



Borehole



Aquifer



(Schmidt & Miedaner, 2012)

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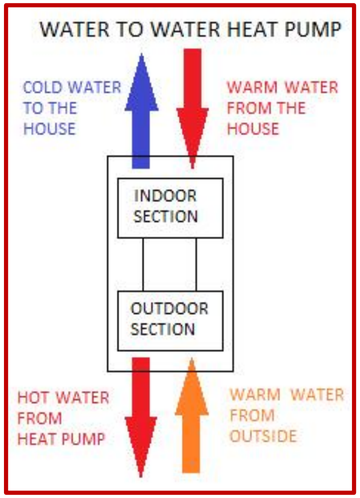
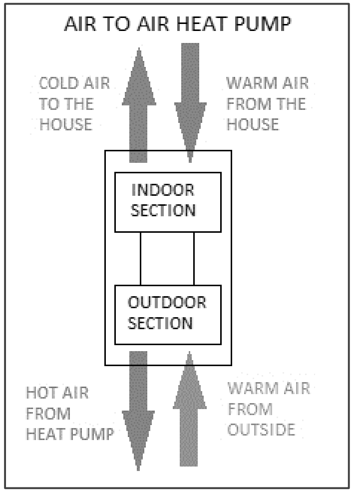
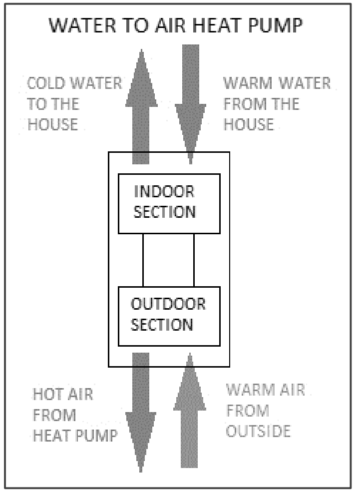
C. *Additional technologies:*

Heat pump:







Heat network:

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Case study *Spatial characteristics*

Type of spatial characteristic		Public areas	Private areas
Land use	Blocks (urban structure)	X	X
	Buildings		X
	Green areas	X	
	Roads/pavement	X	X
	Parking	X	
Building	Roof areas	X	X
	Roof interruptions		X
	Shape		X
	Typology		X
	Storage buildings		X
Orientation		X	X
Angle/slope		X	X
Shadow	Shadows caused by buildings	X	X
	Shadows caused by vegetation	X	X
	Shadows caused by dormers		X

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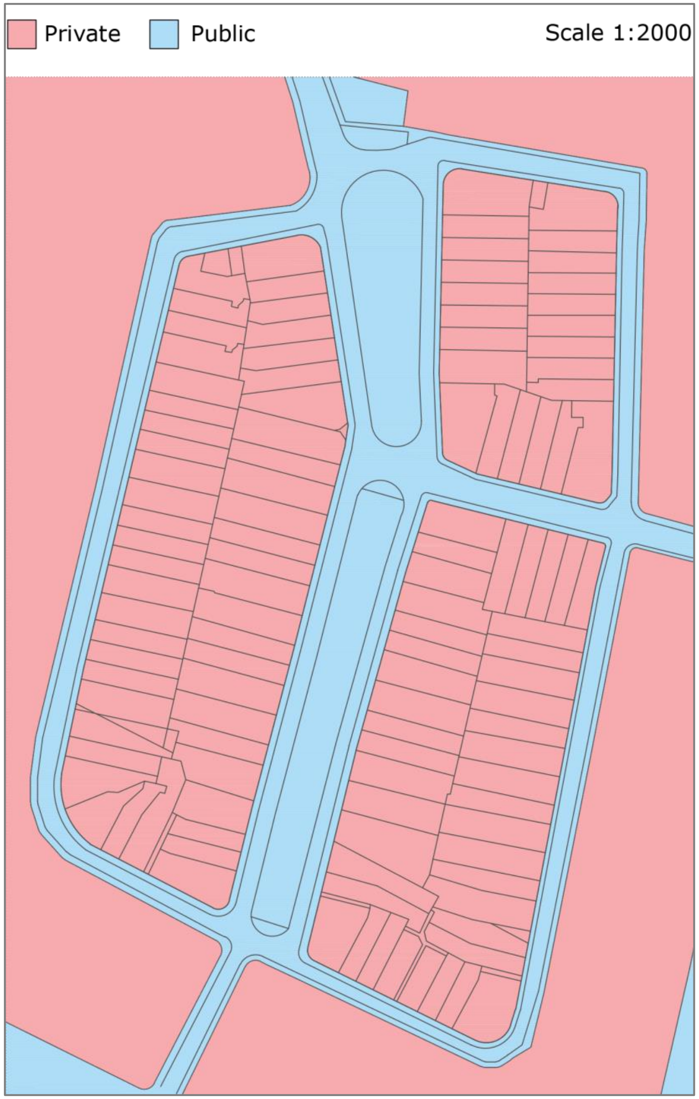
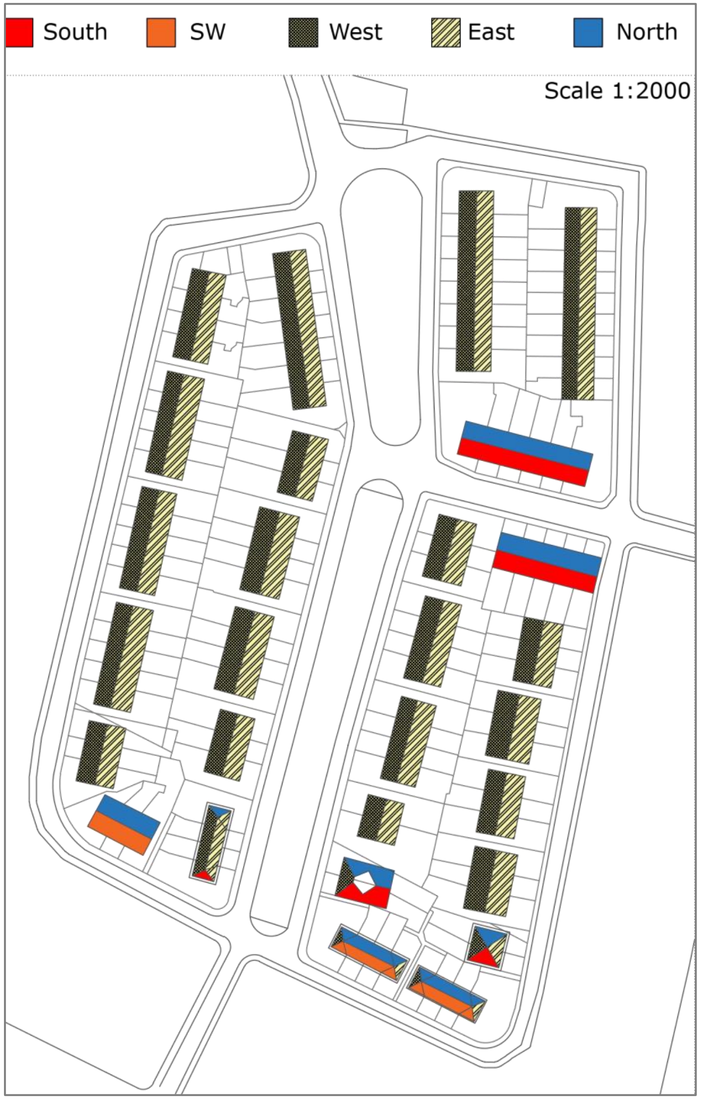
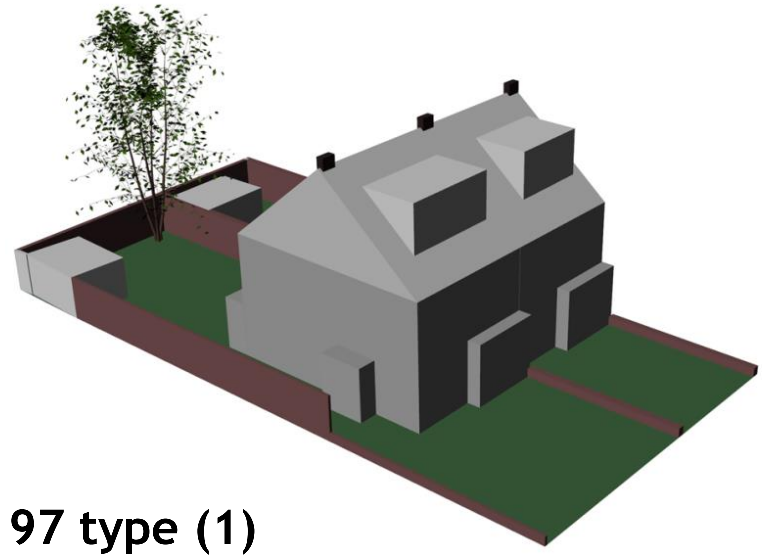
Private/public areas



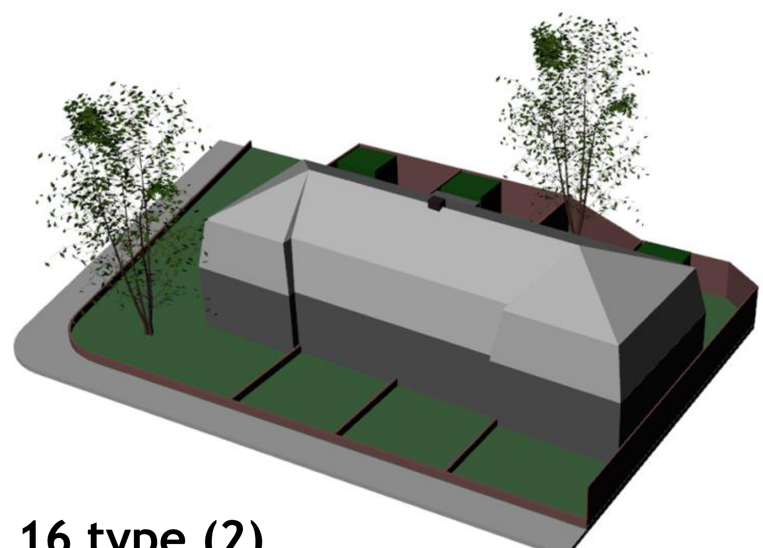
Orientation



Building typology



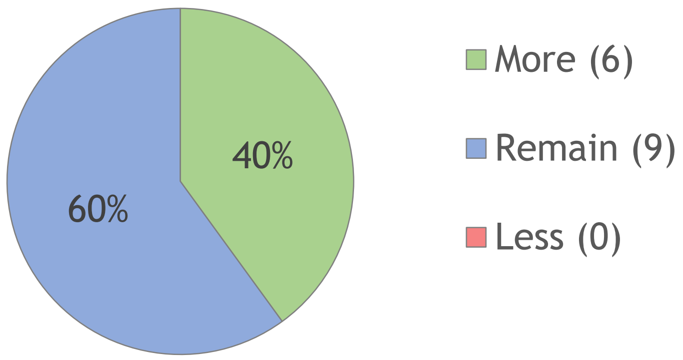
97 type (1)



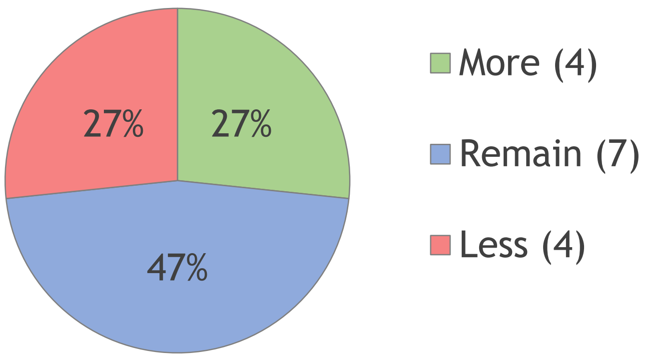
16 type (2)

Questionnaire inhabitants

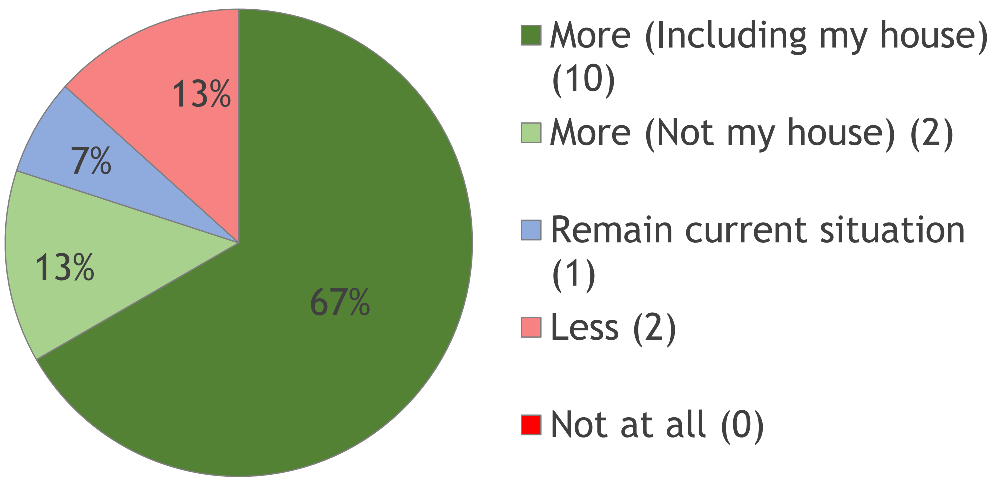
(2) Amount of public green



(4) Amount of parking space



(7) Visibility of technologies for sustainable energy generation placed on households?



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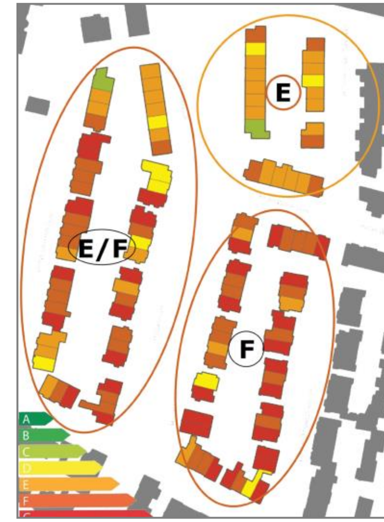
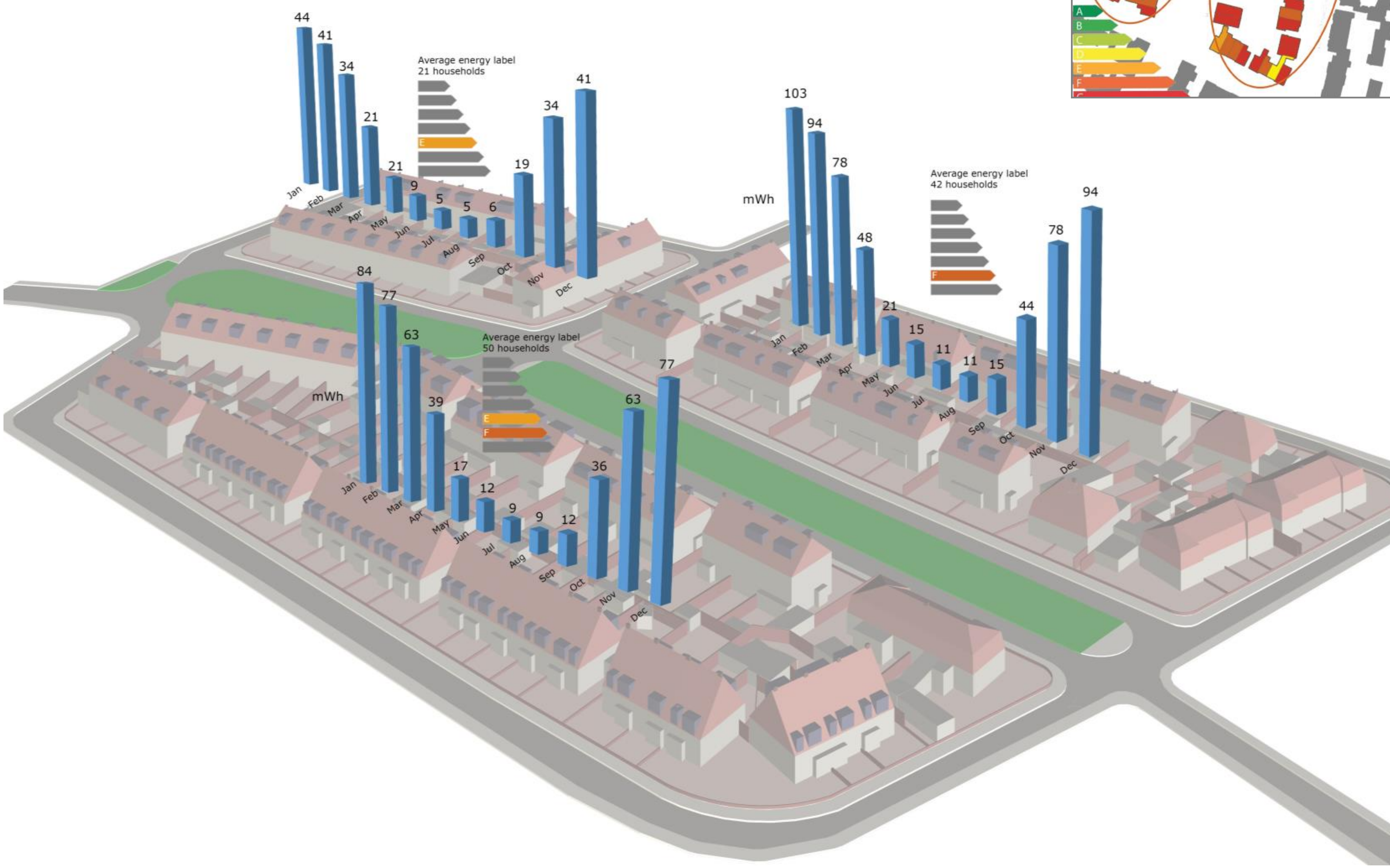
Heat demand

113 buildings energy label C

Annual heat demand: 1,38 x10^3 mWh.





Energy potentials

Orientation	*: West*
Angle	*: 45 C°*
Panels per household	*: 10,5*
Annual thermal heat production:	*(40C°) 14.700 kWh*
	(80C°) 12.265 kWh

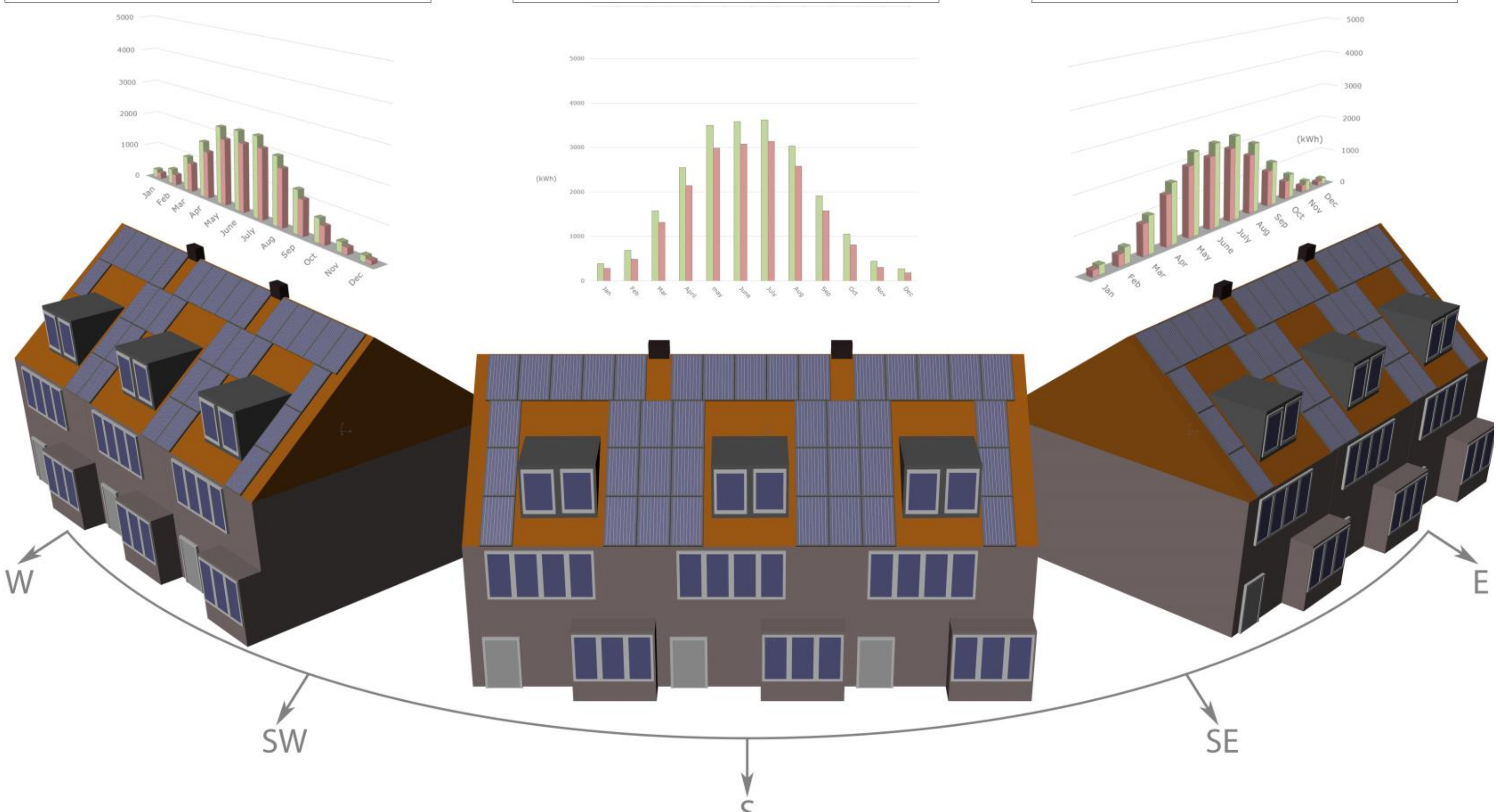
Monthy thermal heat production per household in kWh

Orientation	*: South*
Angle	*: 45 C°*
Panels per household	*: 12,5*
Annual thermal heat production:	*(40C°) 22.646 kWh*
	(80C°) 18.895 kWh

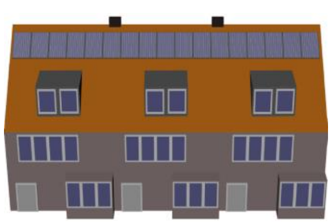
Monthy thermal heat production per household in kWh

Orientation	*: East*
Angle	*: 45 C°*
Panels per household	*: 10,5*
Annual thermal heat production:	*(40C°) 14.700 kWh*
	(80C°) 12.265 kWh

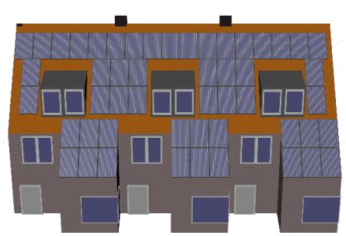
Monthy thermal heat production per household in kWh



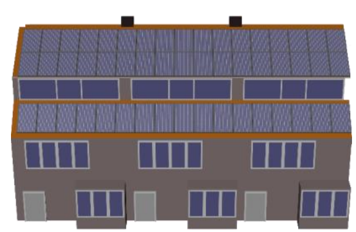
Minor



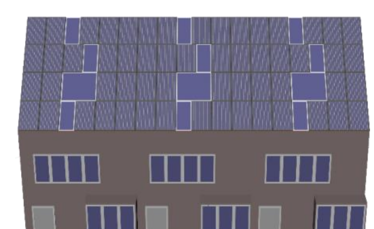
Extension



Partly refurbished



Fully refurbished



Storage potentials

Height storages: 6,5m

Volume: 18.262 m^3

Volume/surface ratio: 2,01

Storage potential: 526.331 kWh

Height storages 7m

Volume: 25.064 m^3

Volume/surface ratio: 1,96

Storage potential = 749.470 kWh

Configuration designs

A. Configurations using the commonly used placement of panels on roofs, replacing **100%** heat demand.
B. Configurations based on the energy potential analysis, replacing **100%** heat demand.
C. Configurations aiming for minor spatial impact & including inhabitants interests and wishes, **variable** percentage replaced heat demand.

Used technologies

Goal	Config.	MPV	FPC	PVT	HP	PTES	LTES	AQS	DC
A	A.1		x			x			
	A.2	x			x	x		x	
	A.2 Extra	x			x	x		x	x
B	B.1		x			x			
	B.2		x				x		
	B.3			x	x	x			
C	C.1					x			
	C.2	x			x	x		x	x
	C.3						x		
	C.4			x	x	x			

MPV = monocrystalline PV
FPC = flat plate collector
PVT = photovoltaic + solar collector
HP = heat pump

PTES= pit thermal energy storage
LTES = latent thermal energy storage
AQS = aquifer storage
DC = drycooler

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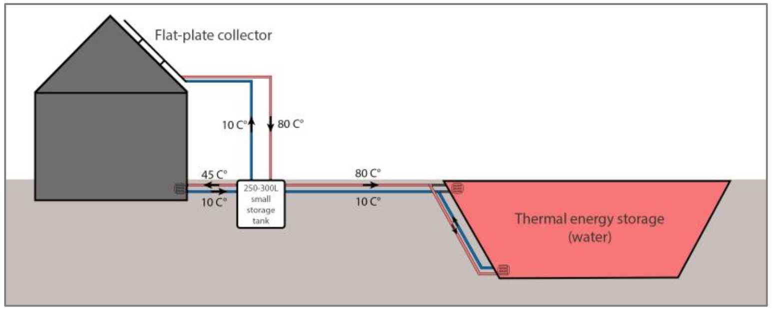
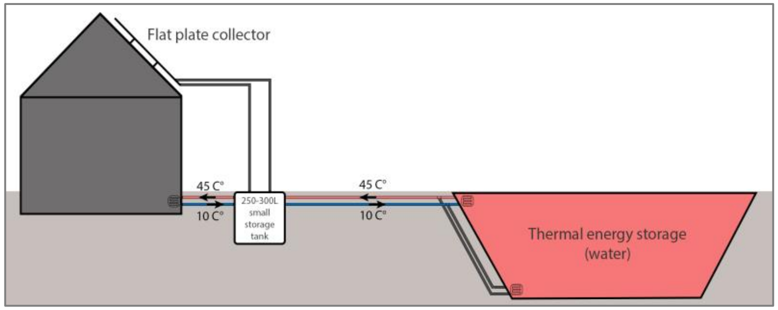
Configuration settings

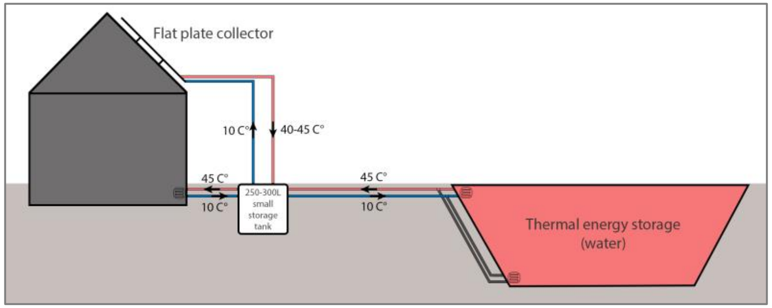
During summer months (sunny hours):



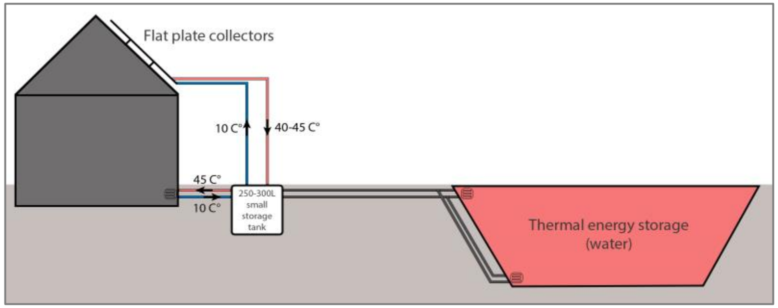
During summer months (cloudy hours):



During winter months:



During months that energy potential = heat demand:



Formulas used:

$$Q_{stored/extracted}\,(kWh) = Q_{produced} - Q_{demand} - Q_{transmissionlosses} - Q_{transportlosses}$$

$$Q_{stored/extracted}\,(kWh) = V * \rho * c_p \cdot (T_{start} - T_{end}) \quad (+\ Q_{Latent} = V \cdot \rho * L)$$

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Self-sufficiency:

A.1 *Flat plate collectors + water filled pit TES*

100%

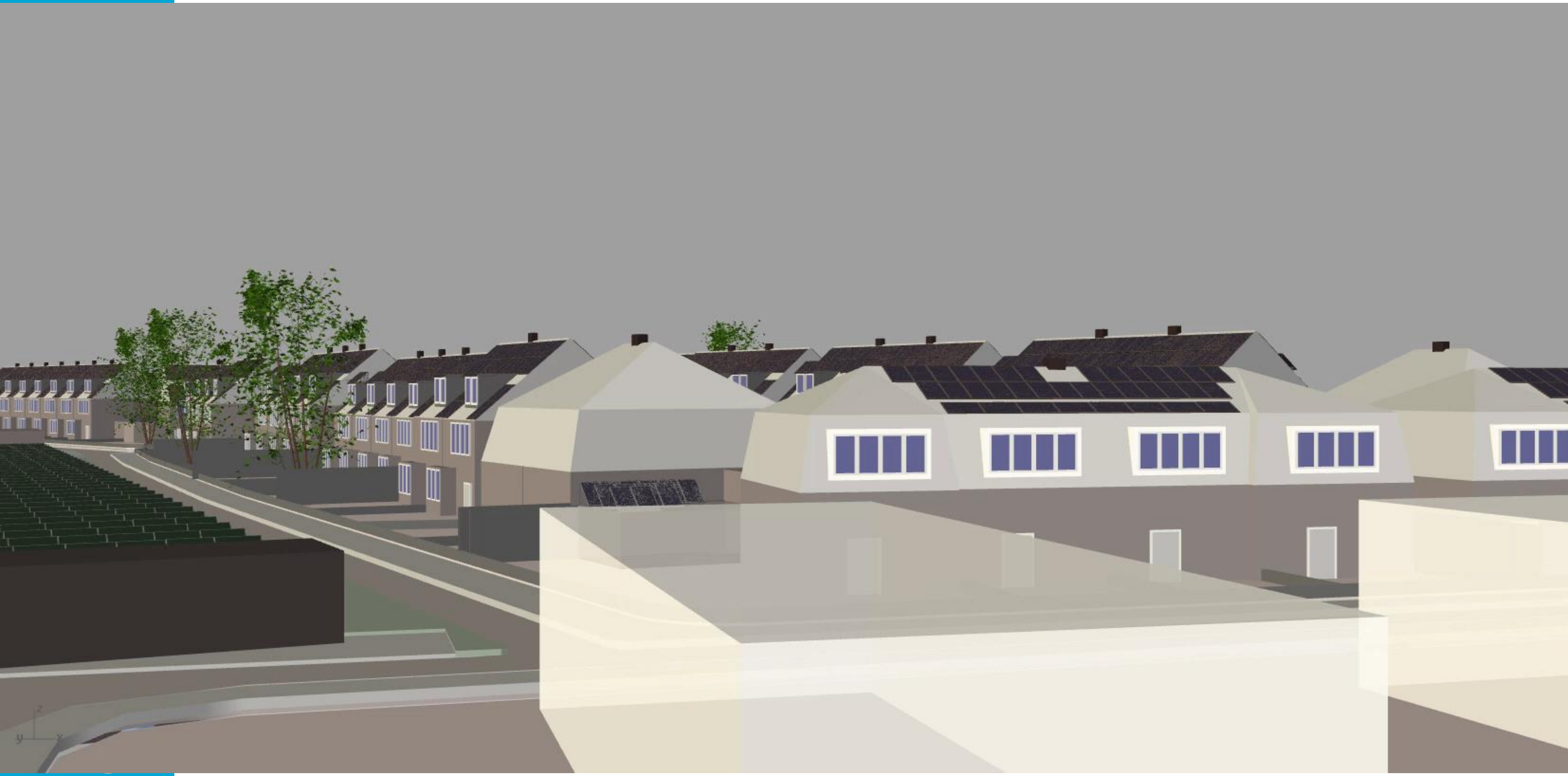
Self-sufficiency:

A.1 *Flat plate collectors + water filled pit TES*

100%

Self-sufficiency:

A.2 *Monocrystalline PV panels + water filled pit TES + large scale heat pump + aquifer storage.* 72%



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Self-sufficiency:

A.2 *Monocrystalline PV panels + water filled pit TES + heat pump + aquifer storage.* 72%

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Self-sufficiency:

B.1 *Flat plate collectors + water filled pit TES*

100%

Self-sufficiency:

B.1 *Flat plate collectors + water filled pit TES*

100%

C.3 *Flat plate collectors + salt filled latent TES*

Self-sufficiency: **94%**

C.3 *Flat plate collectors + salt filled latent TES*

Self-sufficiency:
94%

Self-sufficiency:

C.4 *PV/T panels + water filled pit TES + heat pump* **75%**

Self-sufficiency:

C.4 *PV/T panels + water filled pit TES + heat pump* 75%

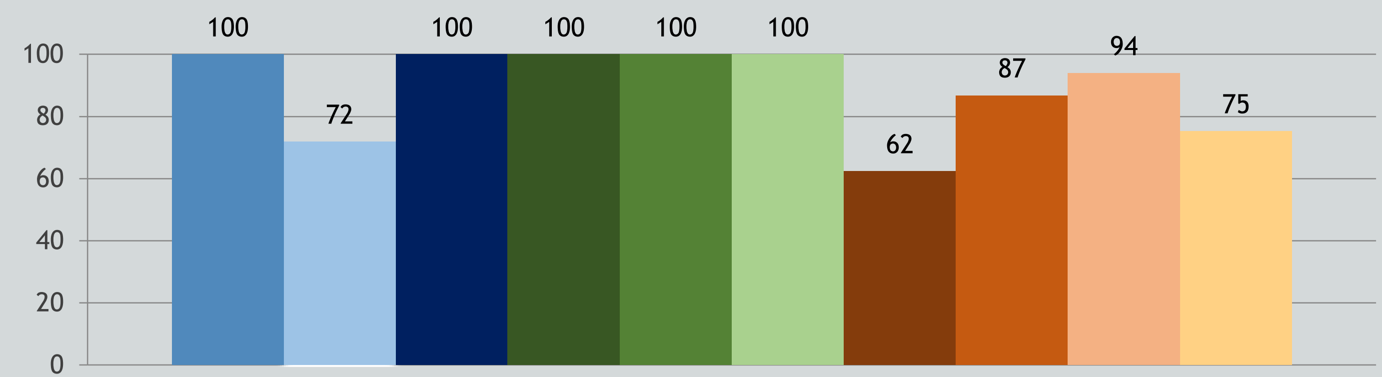
Quantitative assessment

	Energy indicator	Units
E1.1	Fraction of self-sufficiency	%(kWh/kWh)
E1.2	Energy losses caused by the energy system	%(kWh/kWh)
E2.1	Renewable delivered energy / m^2 private used areas	kWh/m^2
E2.2	Renewable delivered energy / m^2 public used areas	kWh/m^2
E3.1	Renewable produced energy on roof / m^2 used roof area	kWh/m^2
E3.2	Efficient used roof areas	% (m^2/m^2)
E4.1	Volumetric compactness of storages	kWh/m^3
E4.2	Volume intake / used areas in the public space	m^3/m^2
	Spatial indicators	
S.1	Public space used for visible integration of the energy system	% (m^2/m^2)
S2.1	Increase or decrease in public green areas	% (m^2/m^2)
S2.2	Increase or decrease in public parking areas	% (m^2/m^2)

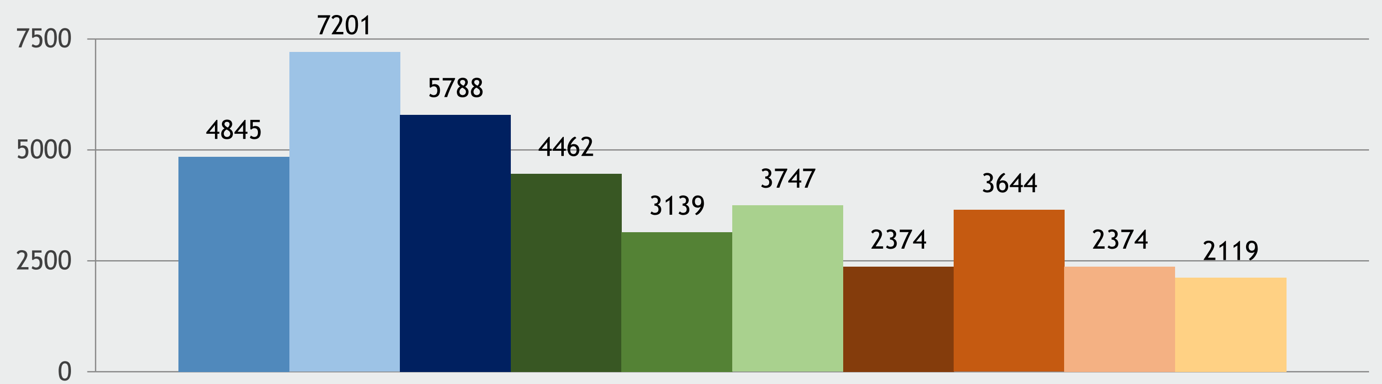
Indicator

A.1 A.2 A.2E B.1 B.2 B.3 C.1 C.2 C.3 C.4

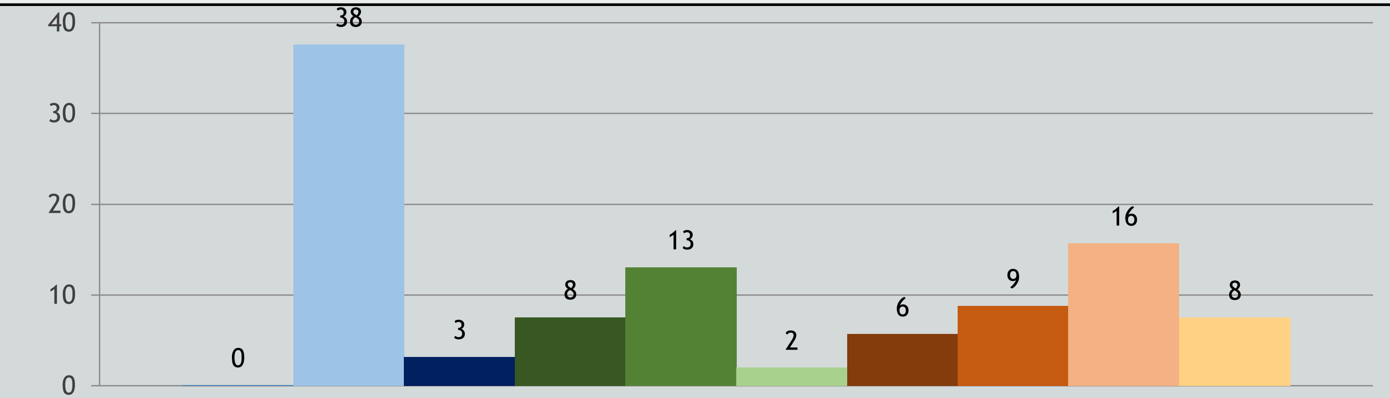
E1.1
Fraction of self-sufficiency



E2.1 & E2.2
m² of solar panels used



S.1
Percentage public space used



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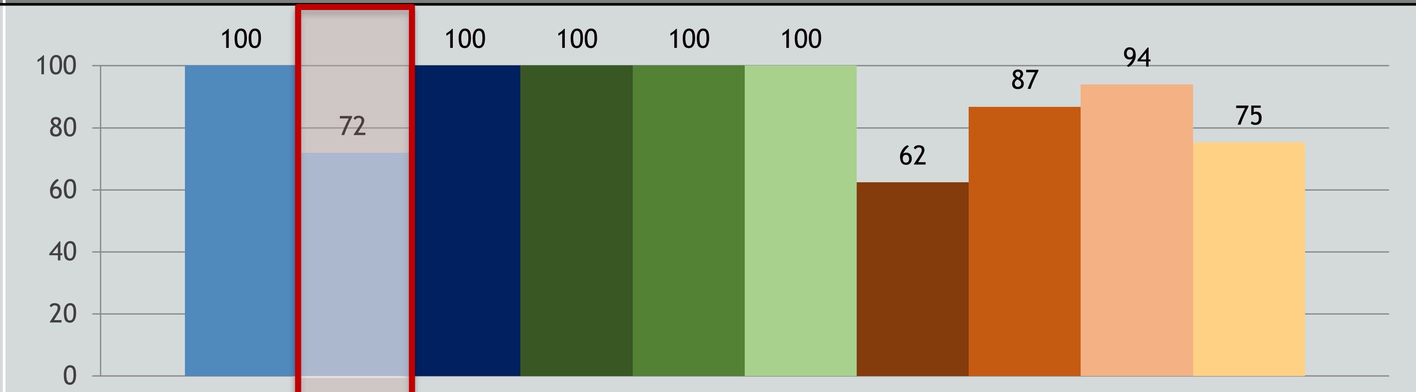
A.2 *Monocrystalline PV panels + water filled pit TES + heat pump + aquifer storage.*

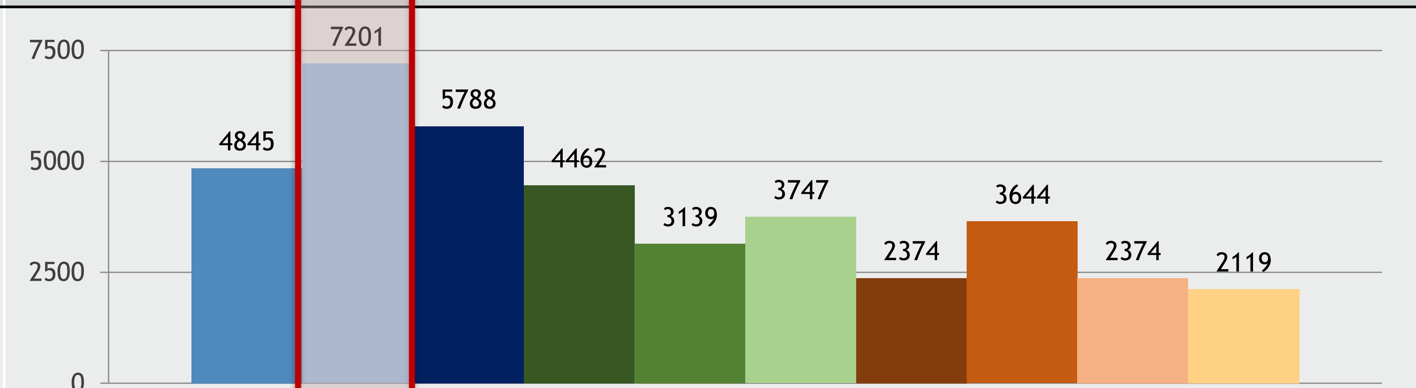
Indicator

A.1 A.2 A.2E B.1 B.2 B.3 C.1 C.2 C.3 C.4

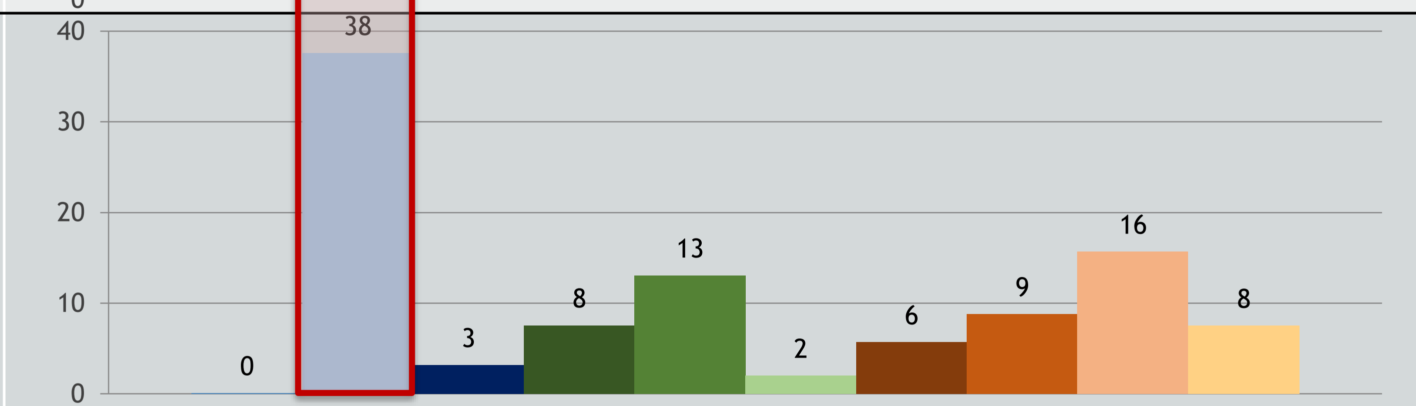
E1.1
Fraction of self-sufficiency



E2.1 & E2.2
m² of solar panels used

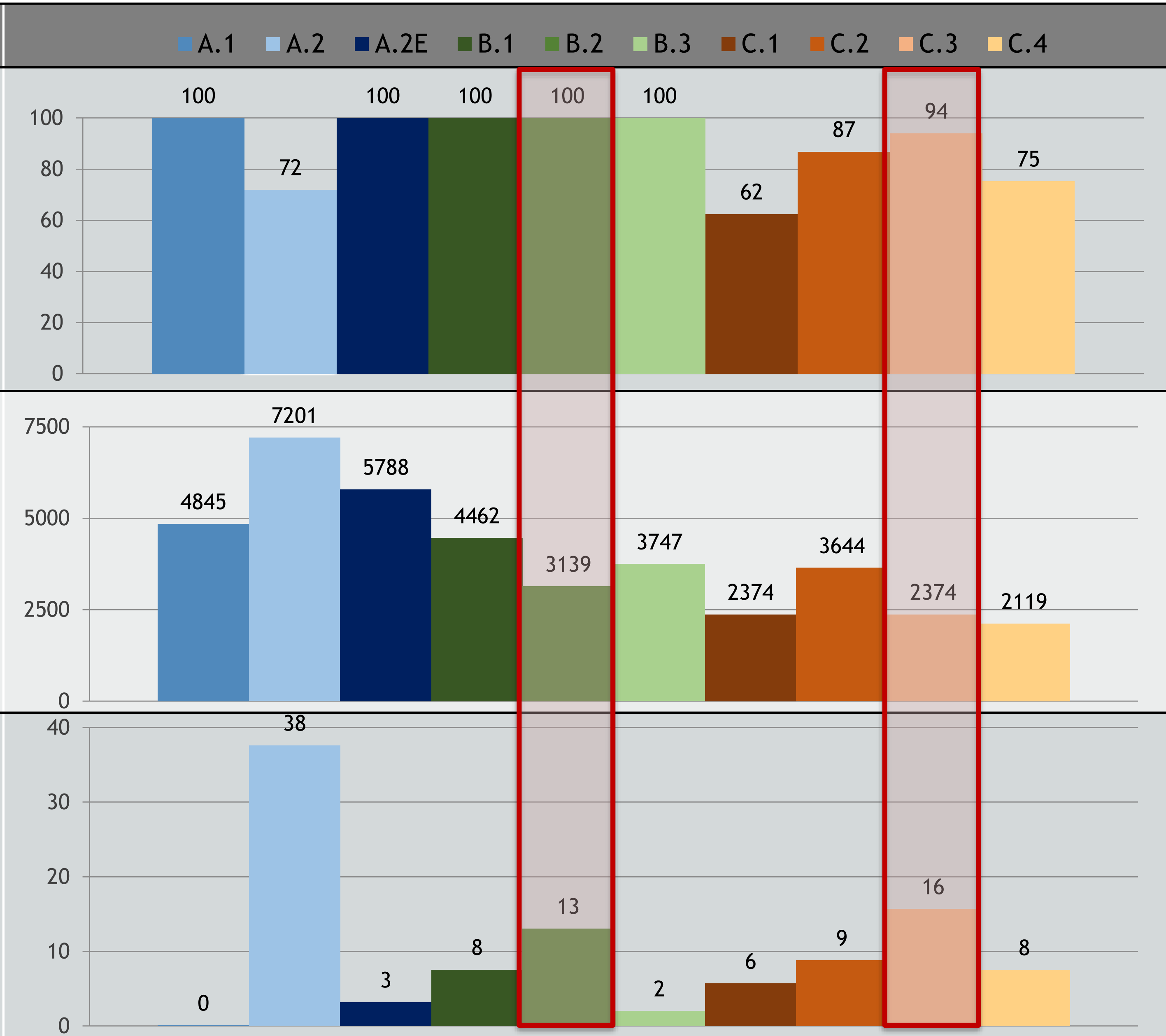


S.1
Percentage public space used



Latent thermal energy storage

Indicator
E1.1 Fraction of self-sufficiency
E2.1 & E2.2 m^2 of solar panels used
S.1 Percentage public space used

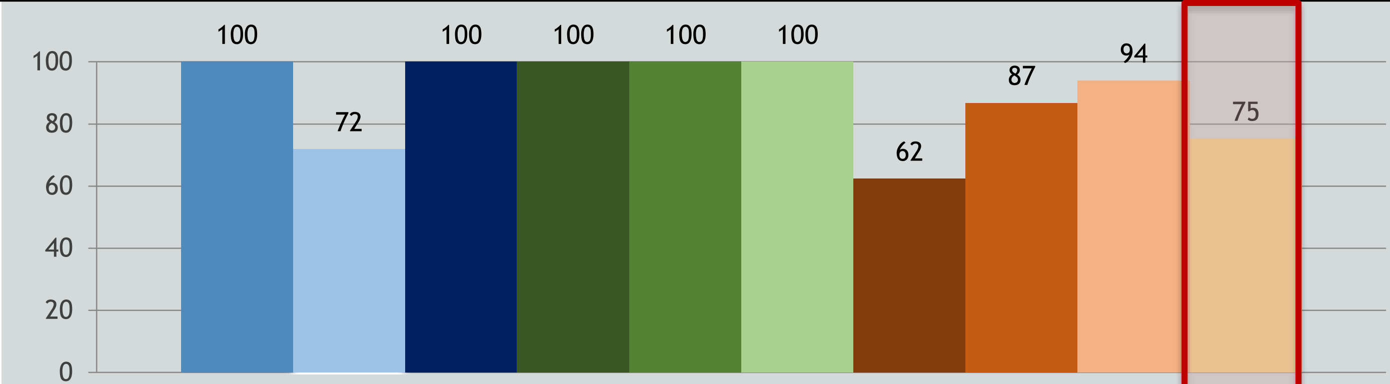


A.2 *Monocrystalline PV panels + water filled pit TES + heat pump + aquifer storage.*

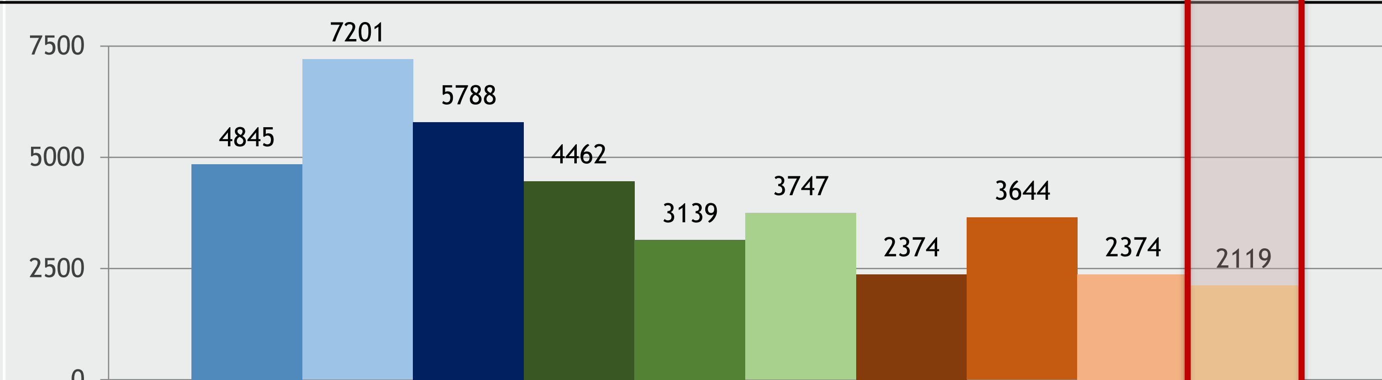
Indicator

A.1 A.2 A.2E B.1 B.2 B.3 C.1 C.2 C.3 C.4

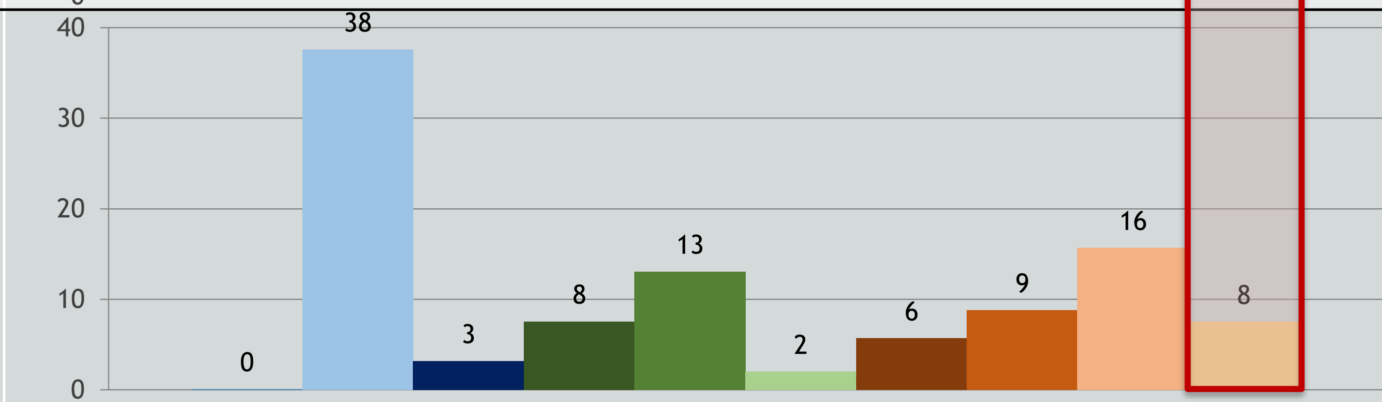
E1.1
Fraction of self-sufficiency



E2.1 & E2.2
m^2 of solar panels used



S.1
Percentage public space used



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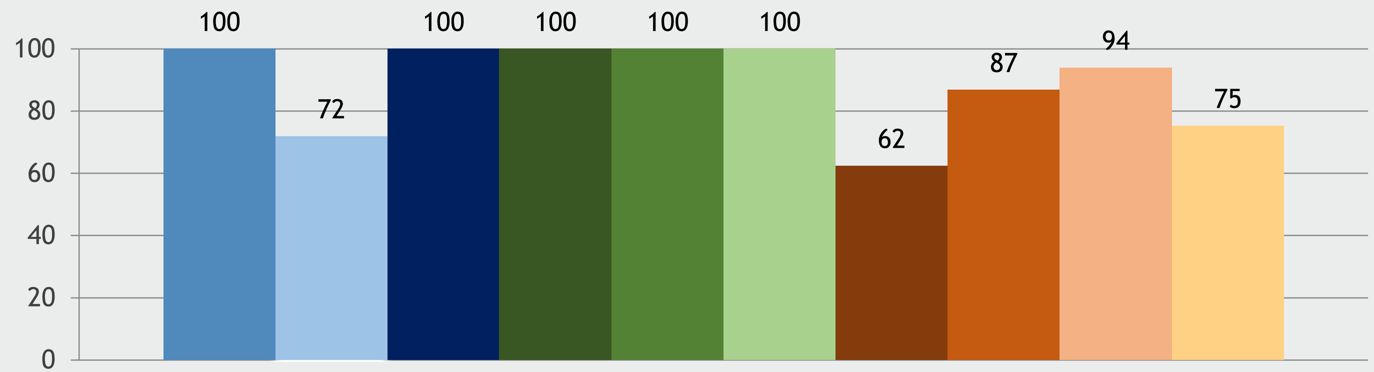
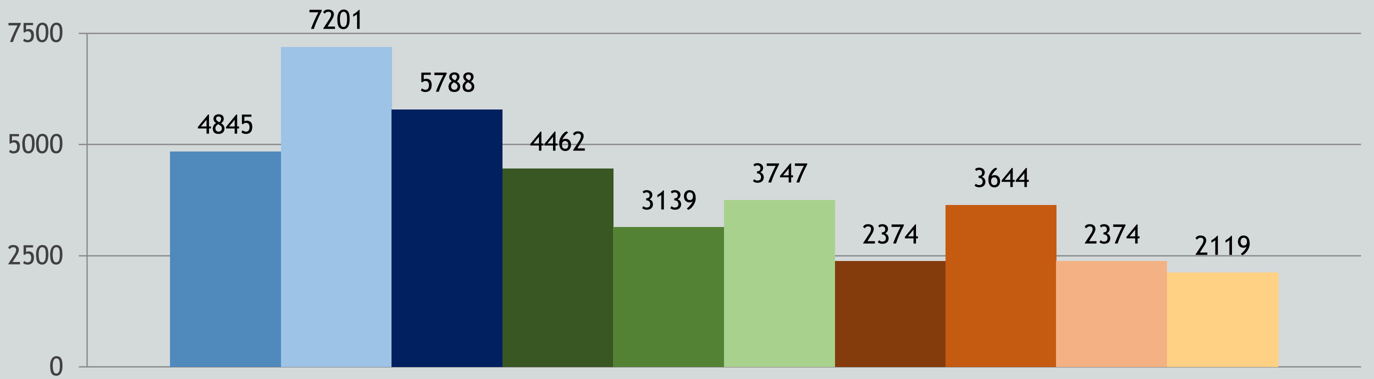
Perceptual analysis	A.1	A.2	A.2E	B.1	B.2	B.3	C.1	C.2	C.3	C.4
Indicator	Positive	Negative	-	Moderately positive	Moderately negative	Moderately positive	Moderately positive	Neutral	Moderately negative	Neutral

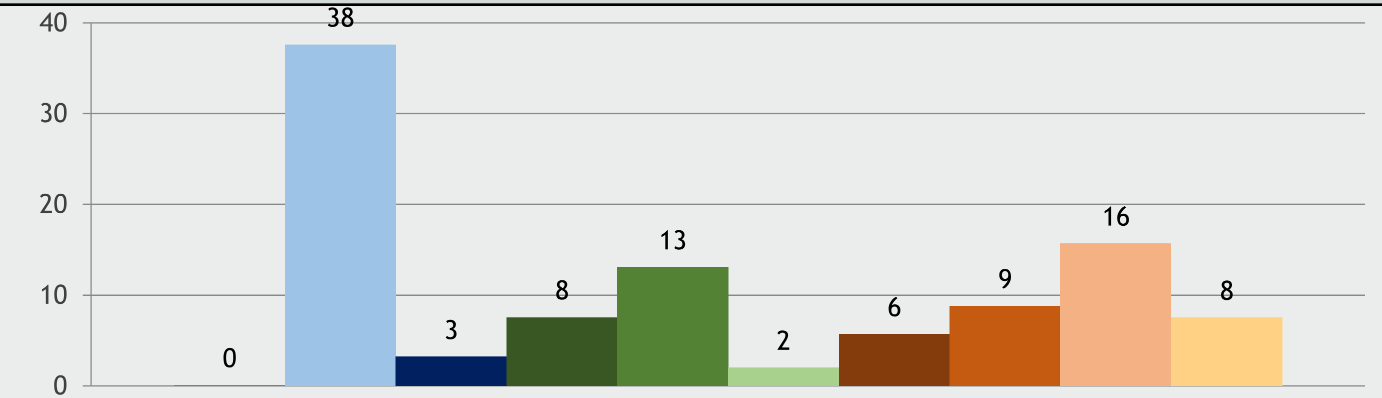
E1.1
Fraction of self-sufficiency



E2.1 & E2.2
m^2 of solar panels used



S.1
Percentage public space used



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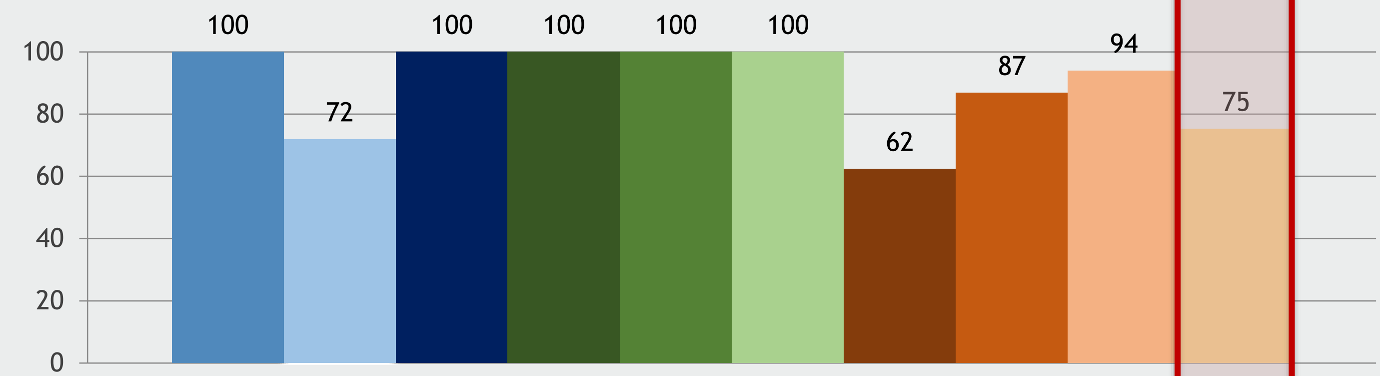
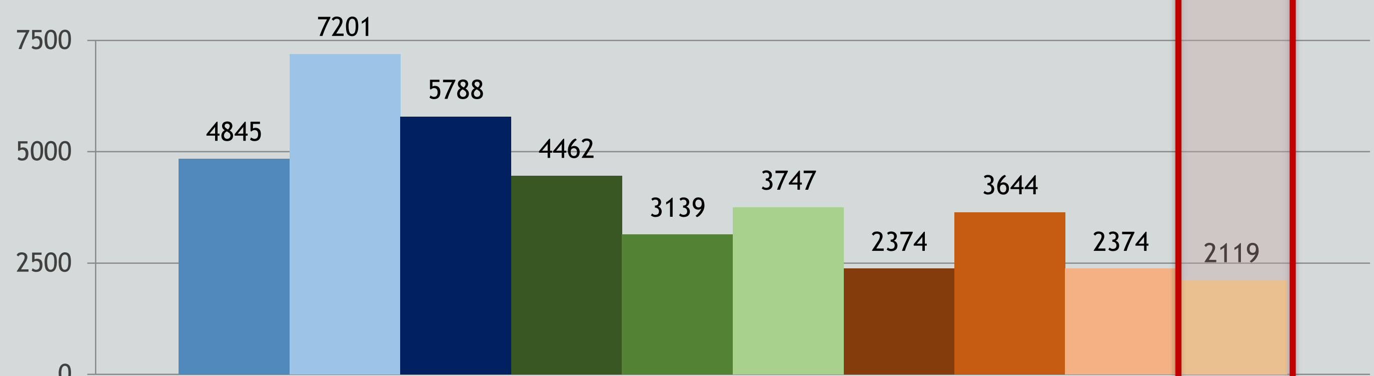
Perceptual analysis	A.1	A.2	A.2E	B.1	B.2	B.3	C.1	C.2	C.3	C.4
Indicator	Positive	Negative	-	Moderately positive	Moderately negative	Moderately positive	Moderately positive	Neutral	Moderately negative	Neutral

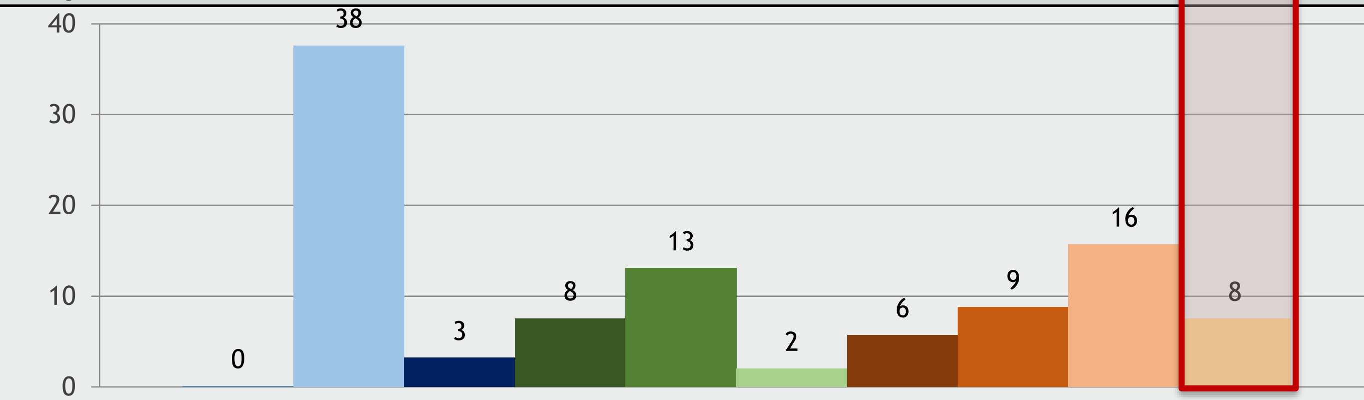
E1.1
Fraction of self-sufficiency



E2.1 & E2.2
m^2 of solar panels used



S.1
Percentage public space used



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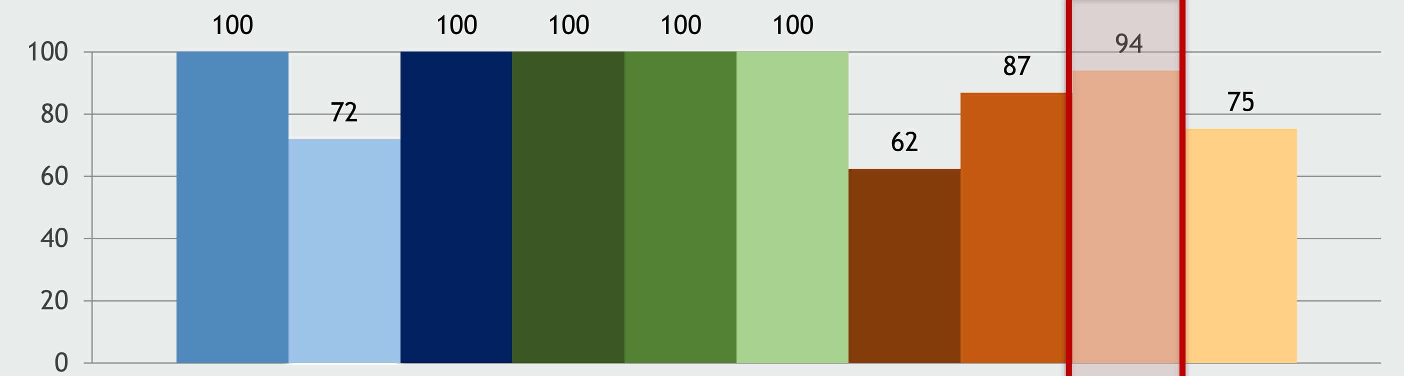
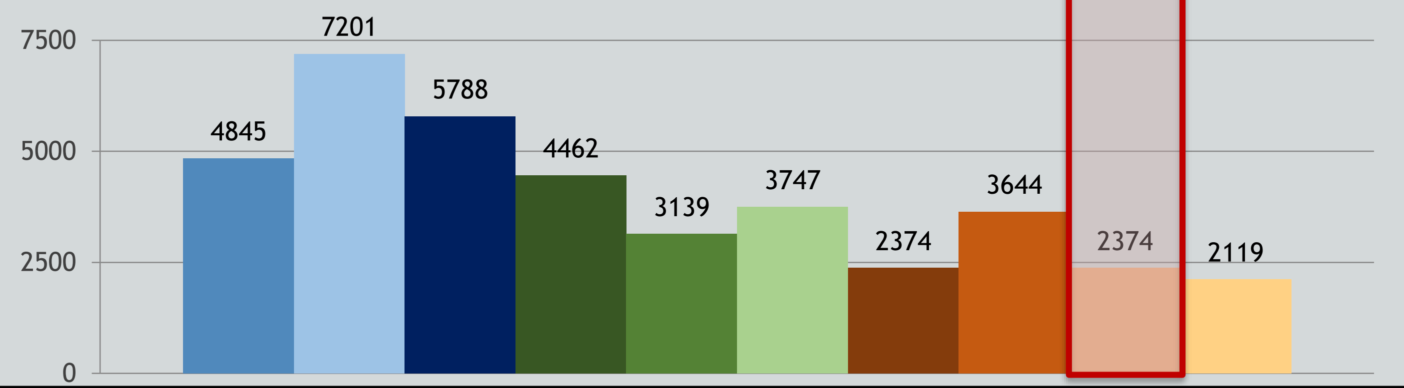
Perceptual analysis

Indicator	A.1	A.2	A.2E	B.1	B.2	B.3	C.1	C.2	C.3	C.4
	Positive	Negative	-	Moderately positive	Moderately negative	Moderately positive	Moderately positive	Neutral	Moderately negative	Neutral

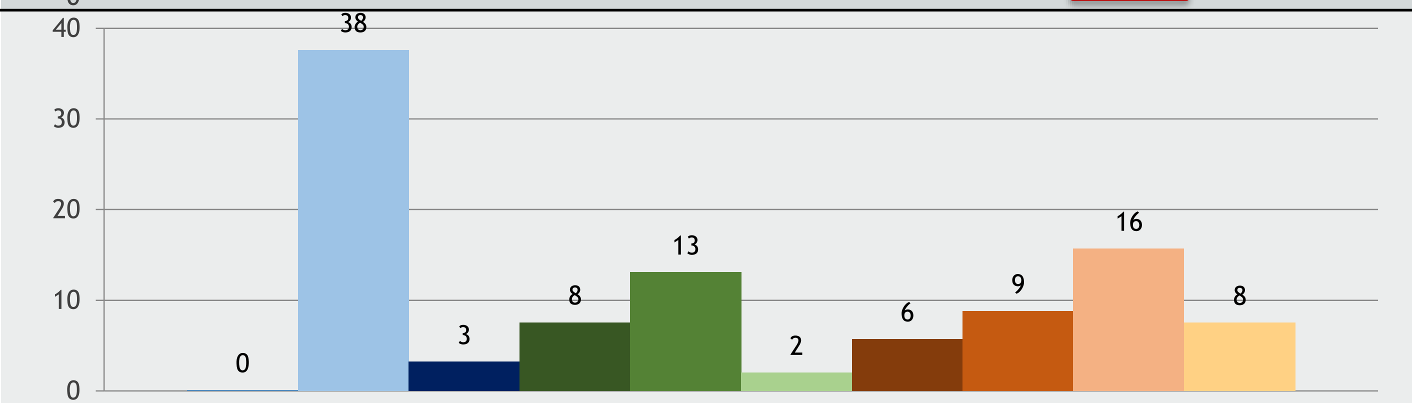
E1.1
Fraction of self-sufficiency



E2.1 & E2.2
m^2 of solar panels used



S.1
Percentage public space used



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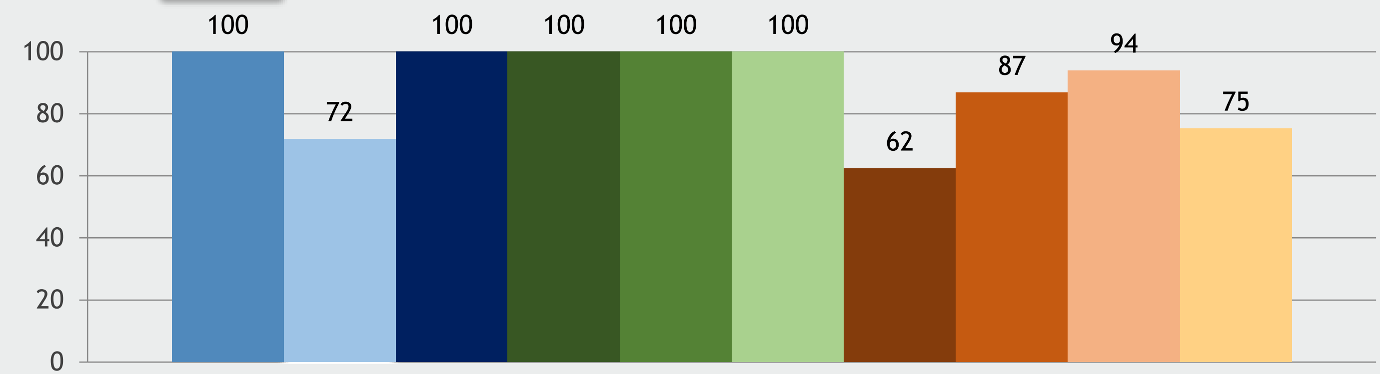
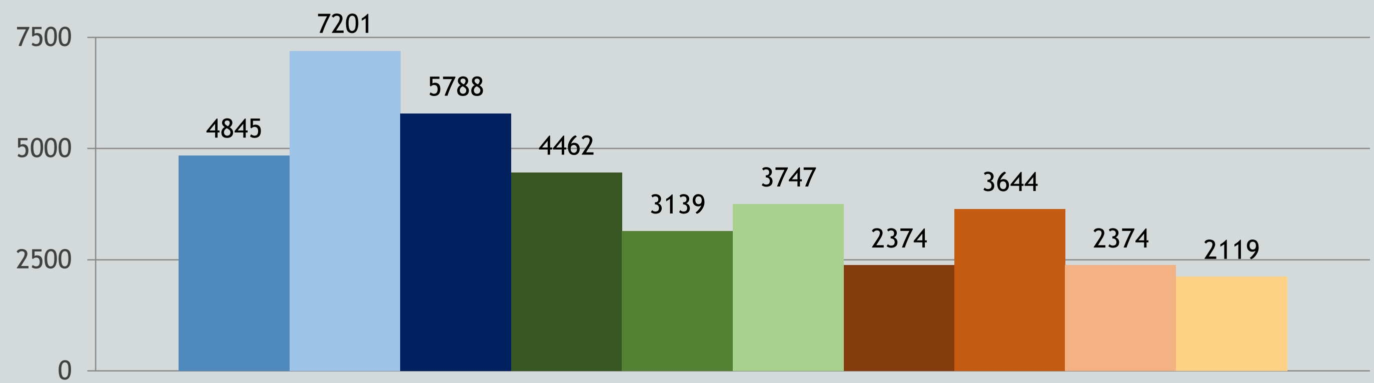
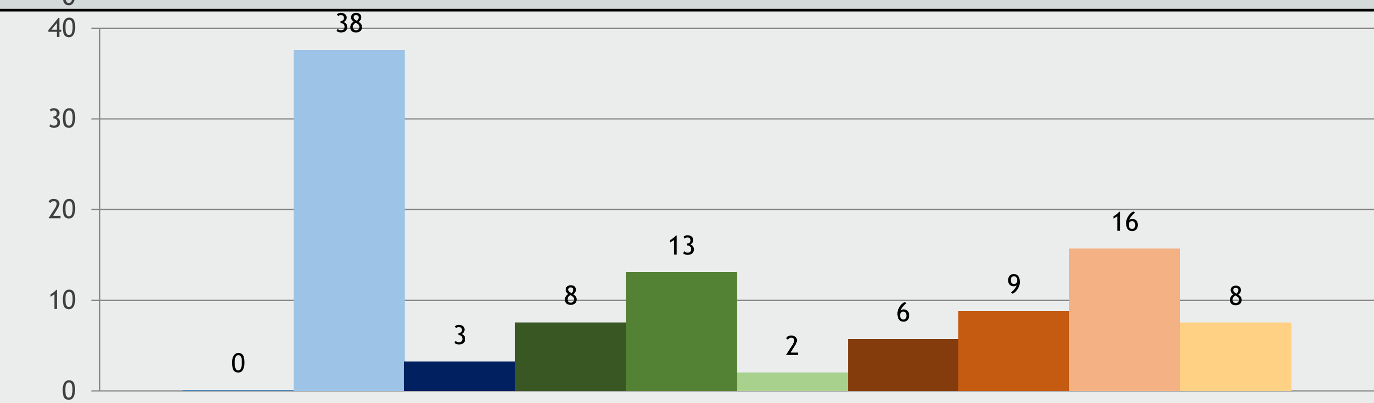


E2.1 & E2.2
m^2 of solar panels used



S.1
Percentage public space used



TUDelft

Conclusion

How can a renewable self-sufficient energy system for space heating be spatially integrated in selected urban blocks of the neighbourhood Ramplaankwartier?

Considering the following arguments:

- Energy potential
- Spatial impact
- Inhabitants acceptance
- Amount of m^2 used energy production panels & additional technologies.

C.4: PVT + large scale heat pump + pit thermal energy storage

Purely based on the energy characteristics replacing 100% of the gas use:

(Combination C.3 & C.4): PVT + large scale heat pump + latent thermal energy storage.

If zero spatial impact in public areas is the set goal:

(B.1 or C.1): Flat-plate collectors (not in covered parking) + pit thermal energy storage (underground).

General guidelines

1. Spatial analysis
2. Analysis suitable technologies
3. Energy production & storage potentials
4. Analyse wishes inhabitants
5. Design of the configuration with different levels of spatial/visual impact.
6. Quantitative & perceptual analysis

Not aiming for self-sufficiency:

- Include external energy resources & storage options.

Recommendations future research

1. Include costs
2. Thermochemical energy storage
3. Material scarcity

Now do it yourself!

1. Dig a hole in your garden
2. Strengthen the sides with concrete
3. Insulate & cover
4. Fill it with water
5. Replace your PV panels with PVT

And really get self-sufficient!

Questions?