ZEHR-Ø

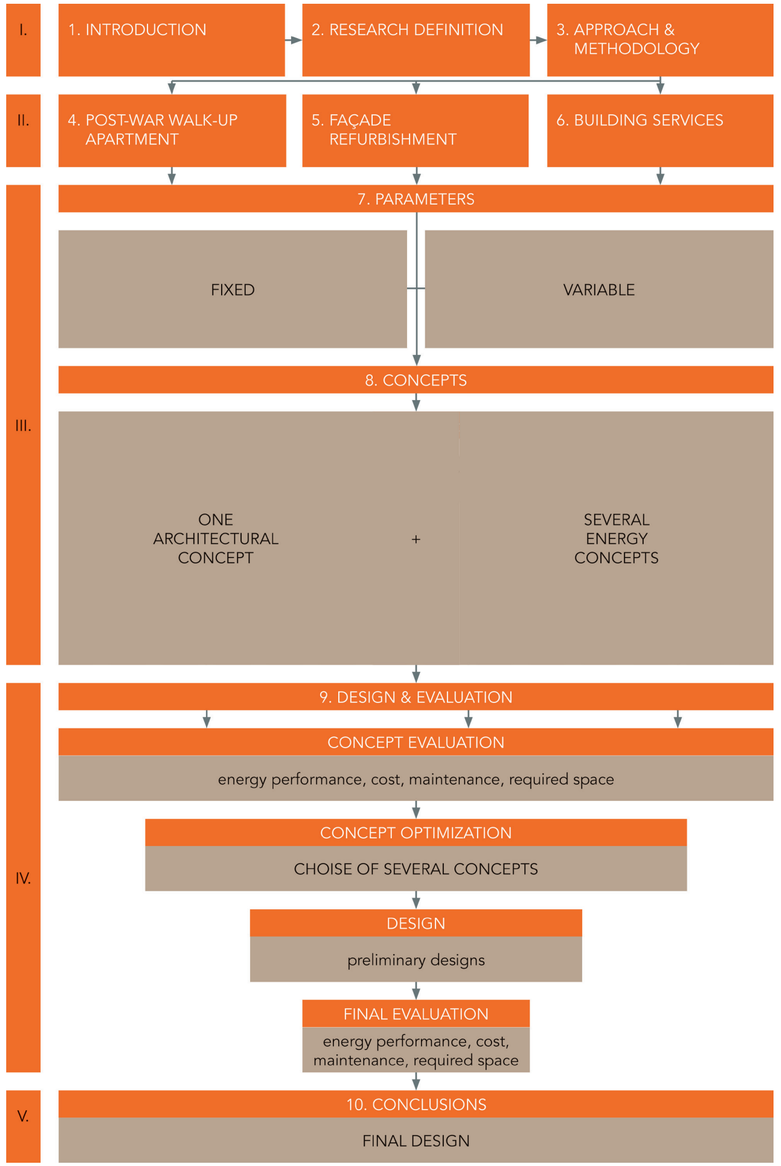
SERVICE INTEGRATION IN FAÇADES FOR ZERO ENERGY HOUSING REFURBISHMENT

4622138 | André van den Boomgaard

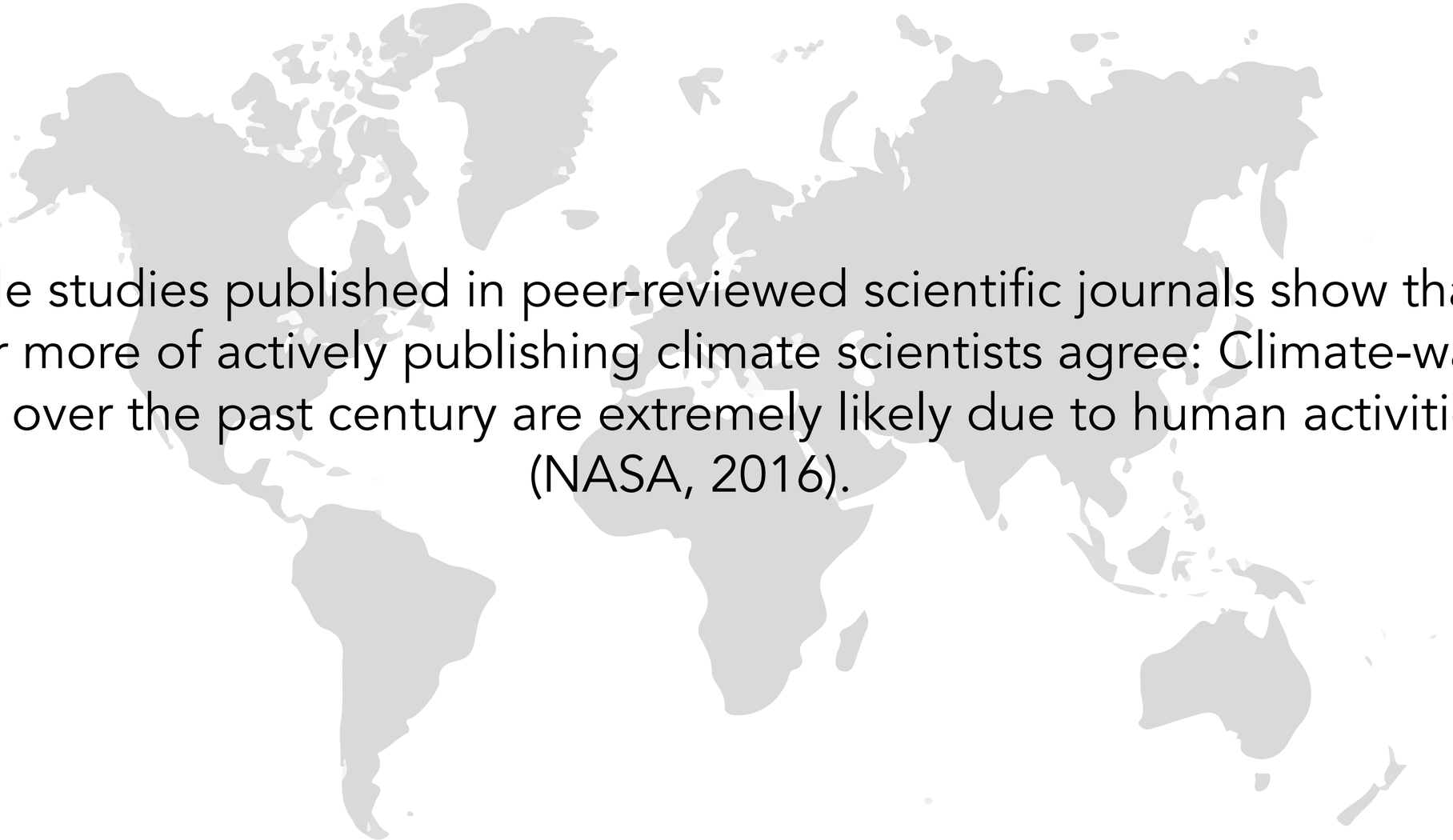
July 3, 2019

CONTENT

I. Research definition
II. Literature review
III. Determination of parameters and concepts
IV. Design & Evaluation
V. Conclusion



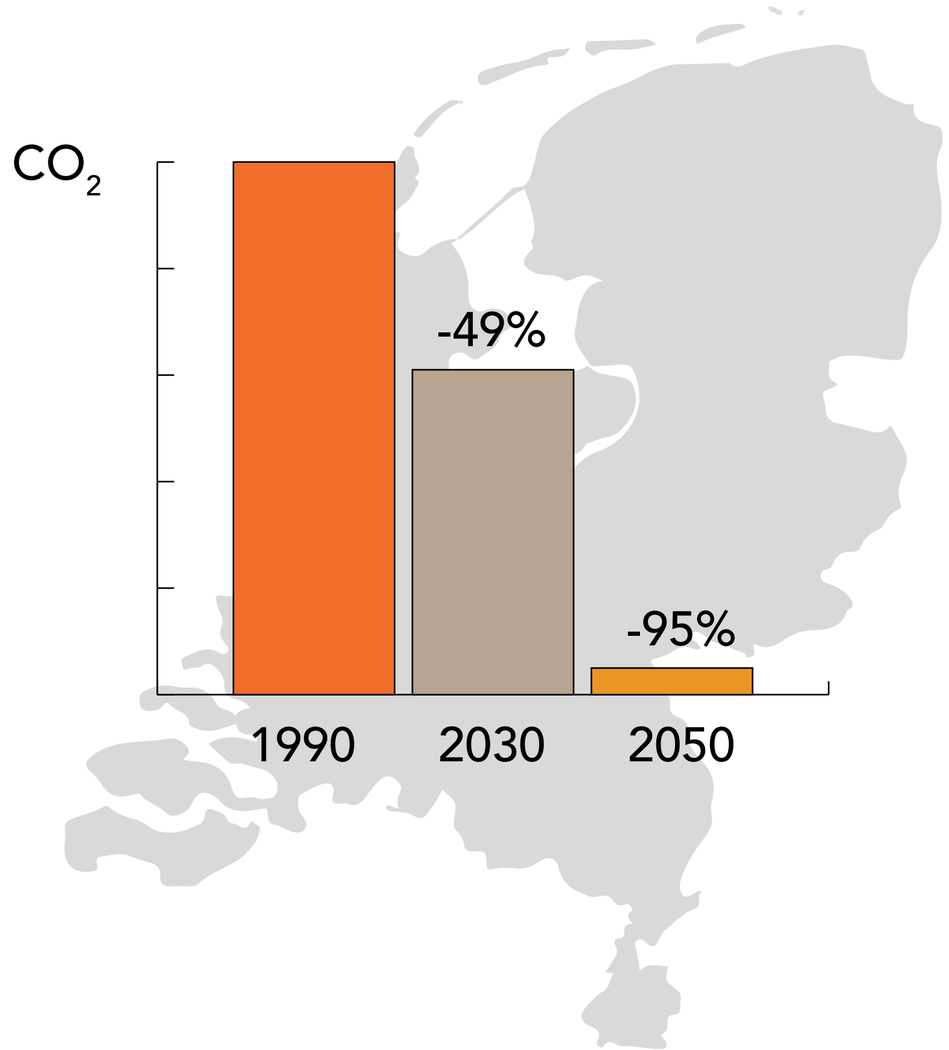
I. 1. introduction
Background



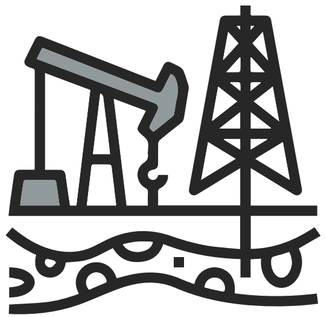
"Multiple studies published in peer-reviewed scientific journals show that 97 percent or more of actively publishing climate scientists agree: Climate-warming trends over the past century are extremely likely due to human activities" (NASA, 2016).

I. 1. introduction

CO_2 reduction on the Dutch housing market



I. 1. introduction
Energy agenda



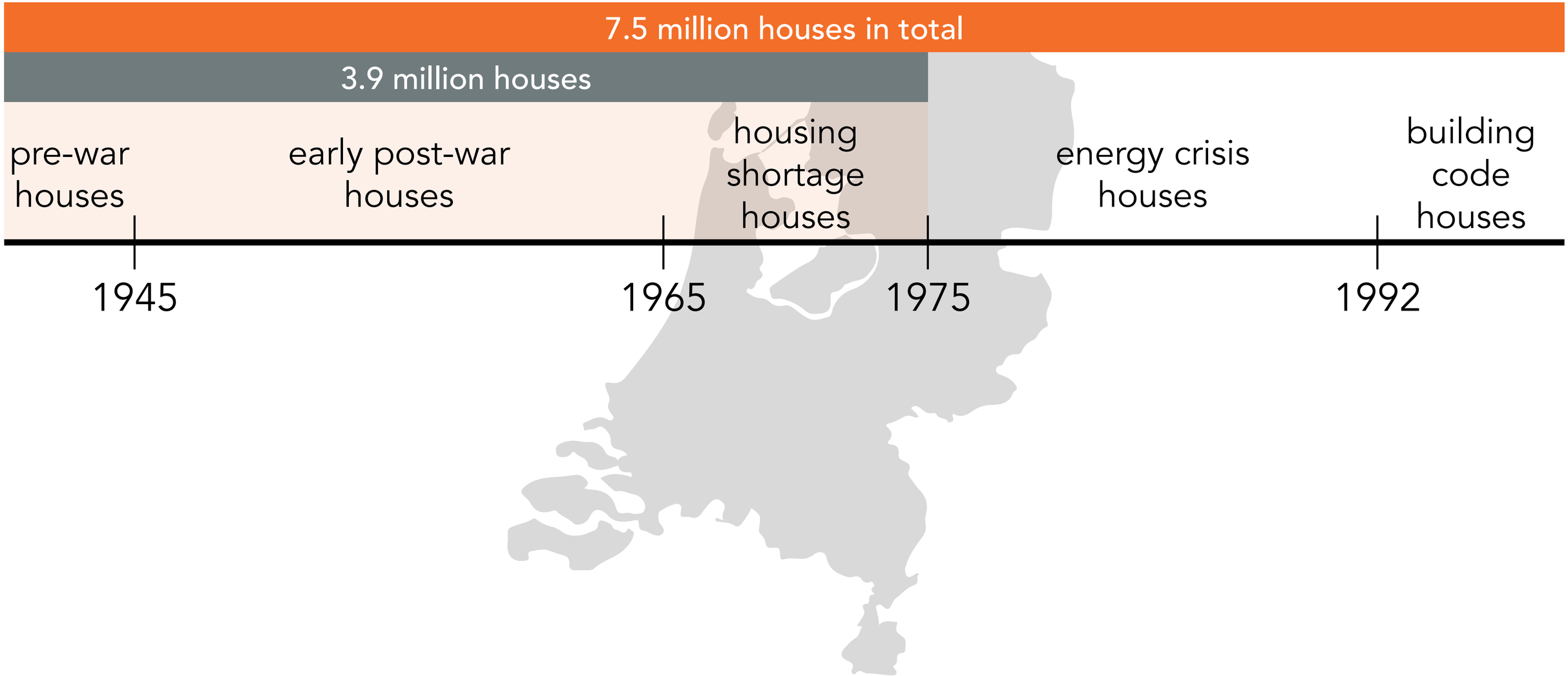
reduce usage of fossil fuels

electricity will be generated sustainable

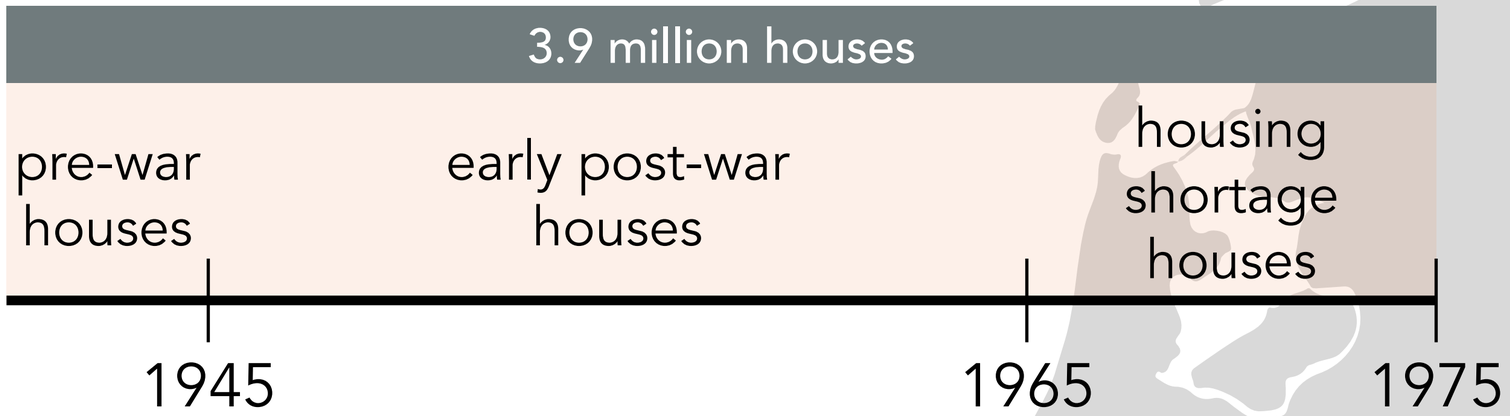
heating mostly by geothermal energy and electricity

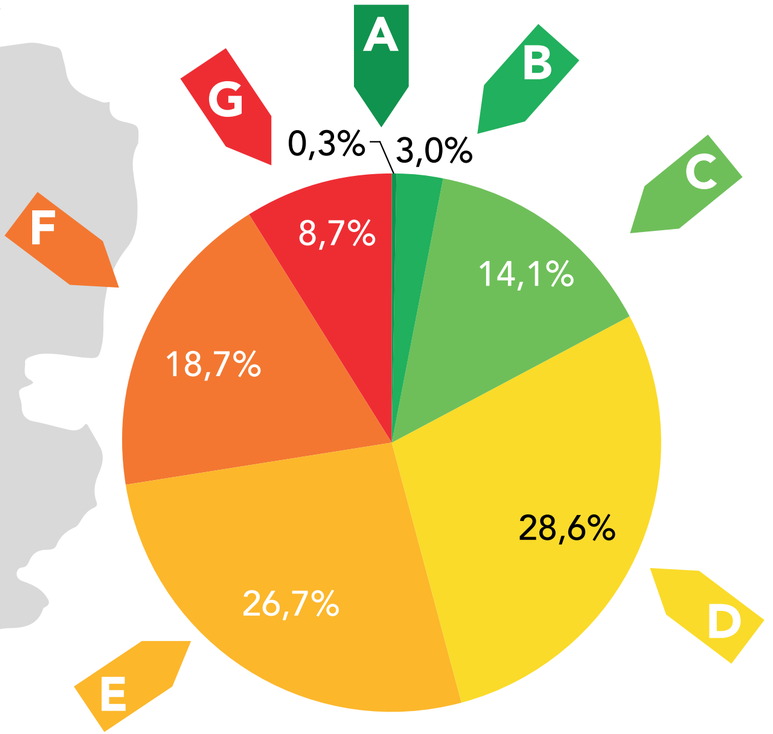
people will no longer cook on gas

I. 1. introduction
Dutch housing stock



I. 1. introduction
Dutch housing stock





source: Compendium voor de Leefomgeving 2017

I. 1. introduction
Post-war walk-up apartments

3.9 million houses

16%
635.000 walk-up apartments

source: Google Maps

I. 2. research definition
2ndSKIN project

source: Climate-KIC, 2017

I. 2.research definition
2ndSKIN project

I. 2. research definition
Cupboard

source: Climate-KIC, 2017

I. 2. research definition
Cupboard

source: Climate-KIC, 2017

I. 2. research definition
Cupboard

ground floor

source: Berkhout, 2018

1st floor

source: Berkhout, 2018

2nd floor

source: Berkhout, 2018

I.

2. research definition

2ndSKIN key findings & recommendations

€

Investment costs are high

- subsidy was required

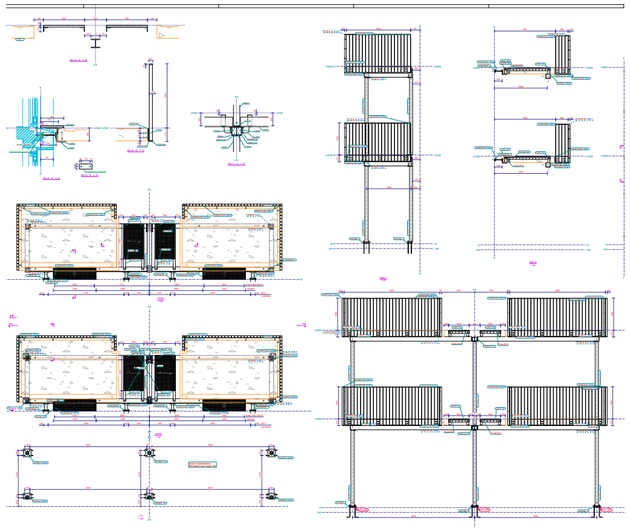
I. 2. research definition
2ndSKIN key findings & recommendations

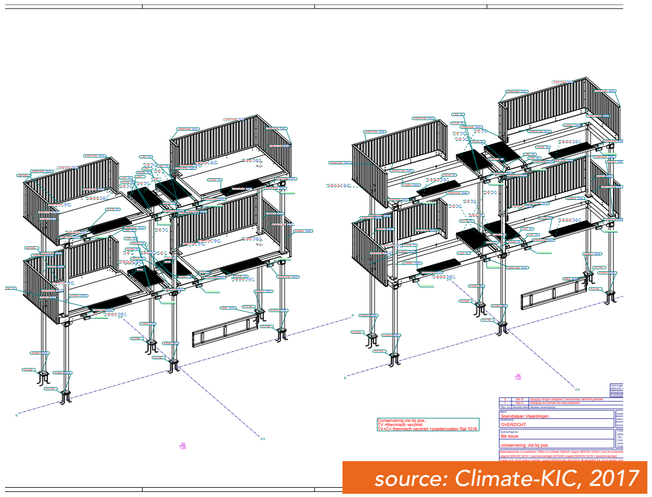
Investment costs are high

- subsidy was required

Balcony replacement is a costly investment

- extra benefit for users
- good space for building services





source: Climate-KIC, 2017

source: Climate-KIC, 2017

I. 2. research definition
2ndSKIN key findings & recommendations

Investment costs are high

- subsidy was required

Balcony replacement is a costly investment

- extra benefit for users
- good space for building services

Ground-to-air heat pump is:

- 'messy'
- not always possible
- expansive

source: 2ndSKIN facebook 2018

source: 2ndSKIN facebook 2018

I. 2. research definition
2ndSKIN key findings & recommendations

Investment costs are high

- subsidy was required

Balcony replacement is a costly investment

- extra benefit for users
- good space for building services

Ground-to-air heat pump is:

- 'messy'
- not always possible
- expansive

more prefabricated façade system can reach:

- similair cost levels
- higher quality and built speed

source: Climate-KIC, 2017

I. 2. research definition
Main problem ZEHR-Ø

*The current renovation methods that integrate heating, ventilation and hot water in the buildings envelop are still **too big** and **costly** to constitute realistic renovation methods for post-war walk-up apartments.*

I. 2. research definition
Sub-problems ZEHR-Ø

*The current renovation methods that integrate heating, ventilation and hot water in the buildings envelop are still **too big** and **costly** to constitute realistic renovation methods for post-war walk-up apartments.*

1. High investment **cost** needs to be tackled before large-scale implementation will take place.
2. **Balcony** construction possibly has more potential than how it is currently used.
3. Current simple and less expansive **façade system** does not have the potential a new façade system would have.
4. **Ground-to-air heat pumps** create a ‘terrible mess’ and air-to-air are less effective and are oversized when installed per relatively small apartments.

I. 2. research definition
Main objective ZEHR-Ø

The design of a new prefabricated zero-energy renovation concept for post-war walk-up apartments, that integrates the building-services in a space and cost-efficient way.

I. 2. research definition
Sub-objectives ZEHR-Ø

The design of a new prefabricated zero-energy renovation concept for post-war walk-up apartments, that integrates the building-services in a space and cost-efficient way.

1. Optimisation of **balcony structure** with integration of building-services.
2. **Design of new façade system.**
3. Look for different building service concepts, **heat pump alternatives** and possibilities of integrating them in the façade.

I.

2. research definition

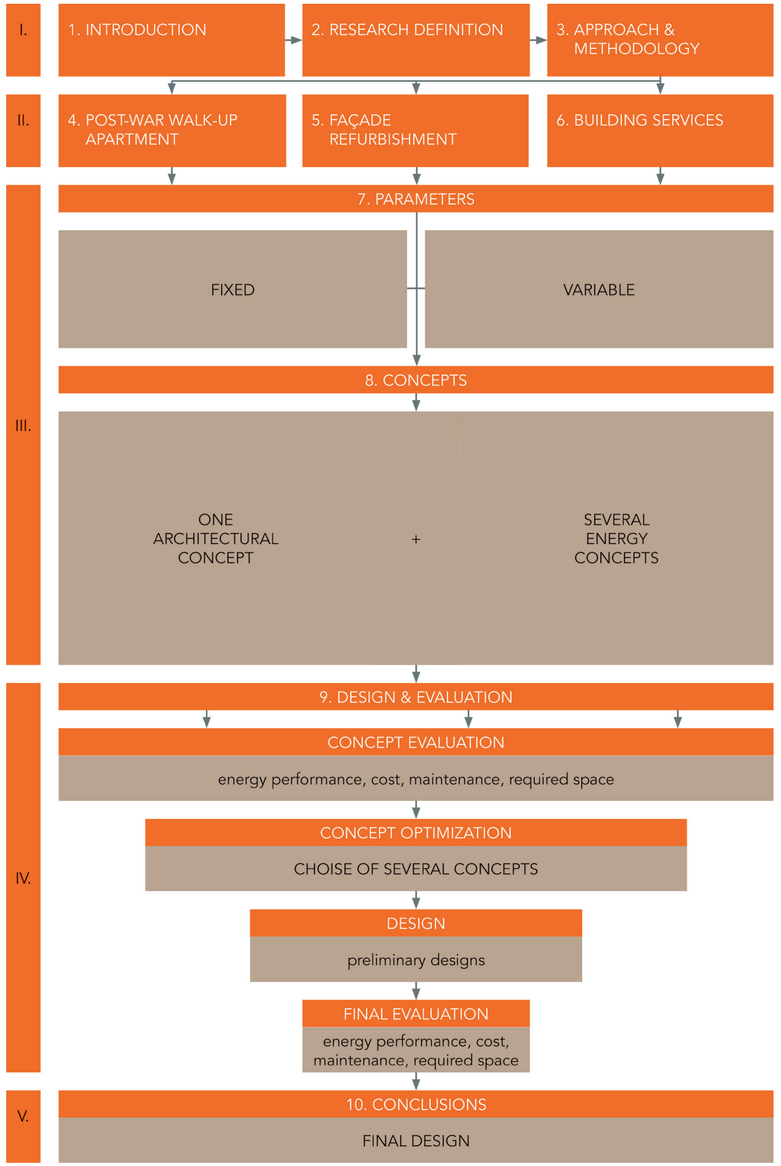
Main research question ZEHR-Ø

How can the integration of building services in façades, for zero-energy renovation methods in Dutch post-war walk-up apartments, be optimised in terms of space and costs?

I. 3.approach & methodology
Step-by-step approach

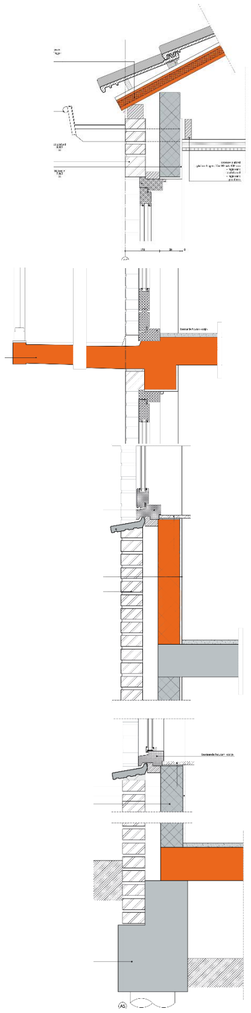
II. Literature review

II.	4. POST-WAR WALK-UP APARTMENT	5. FAÇADE REFURBISHMENT	6. BUILDING SERVICES



II. 4. post-war walk-up apartment
Case in Vlaardingen

source: Google Maps



source: Climate-KIC, 2017

roof
wood wool cement slabs

balcony
continuous concrete slab

window
double glazing

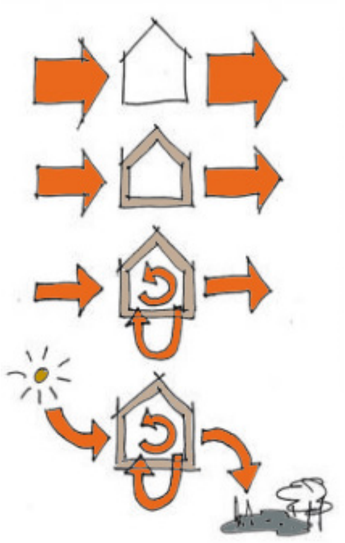
wall
uninsulated cavity wall

ground floor
uninsulated concrete slab with crawl space

foundation
uninsulated foundation

II. 5. façade refurbishment
Strategy

New step strategy



source: Yanovshtchinksy, 2013

1. reduce energy demand

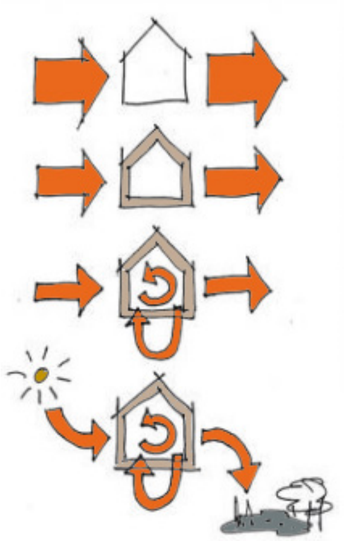
2. reuse rest flows

3a. resolve remaining demand, sustainable

3b. waste = food

II. 5. façade refurbishment
Strategy

New step strategy



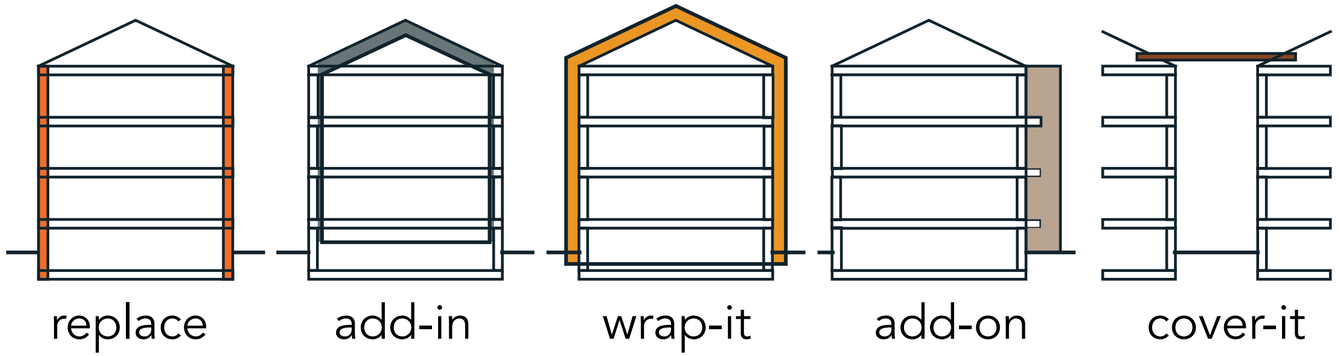
1. reduce energy demand

2. reuse rest flows

3a. resolve remaining demand, sustainable

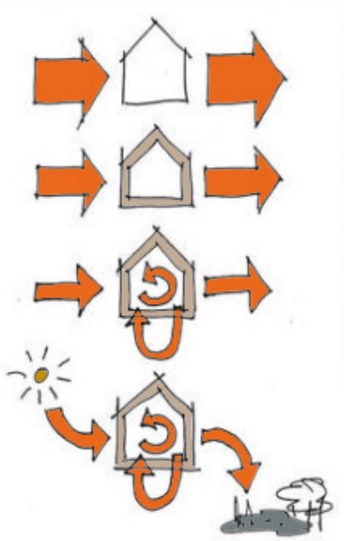
3b. waste = food

source: Yanovshtchinksy, 2013



II. 5. façade refurbishment
Strategy

New step strategy



1. reduce energy demand

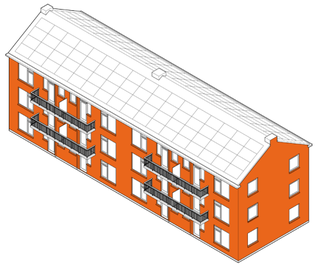
2. reuse rest flows

3a. resolve remaining demand, sustainable

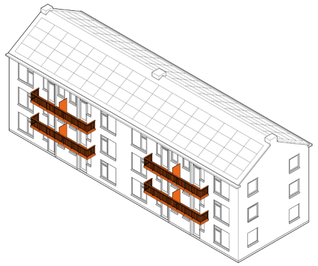
3b. waste = food

source: Yanovshtchinksy, 2013

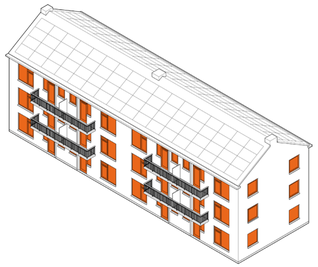
replace | add-in | wrap-it | add-on | cover-it



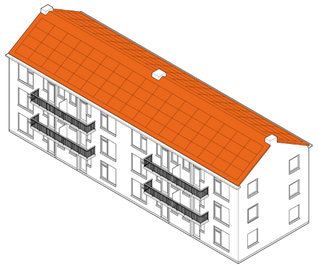
externall wall



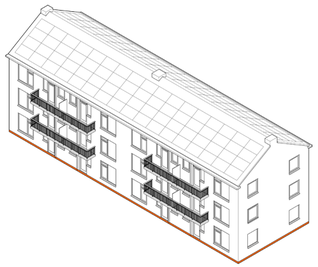
balconies



windows

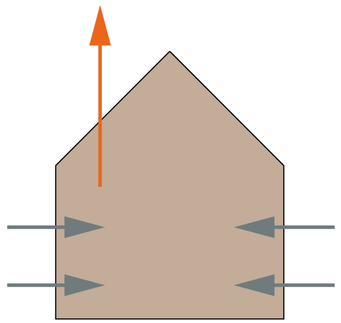


roof

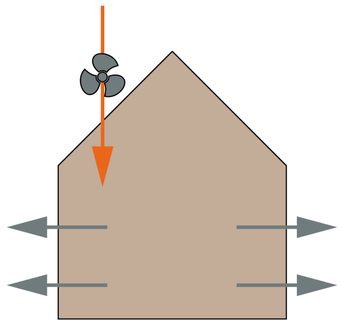


ground floor

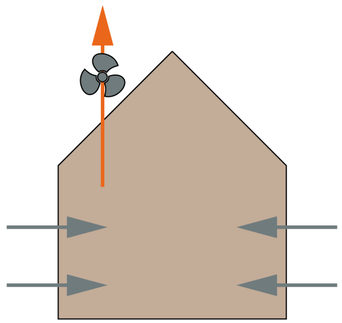
II. 6. building services
Ventilation



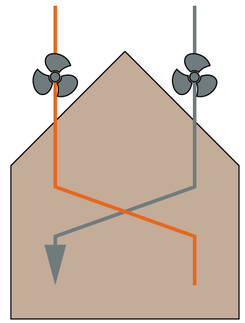
A) natural supply and extract



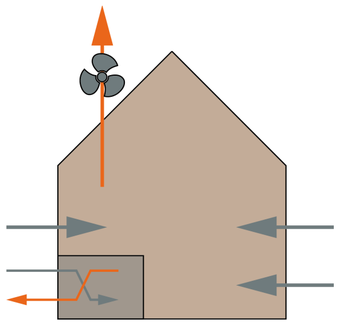
B) mechanical supply and natural extract



C) natural supply and mechanical extract

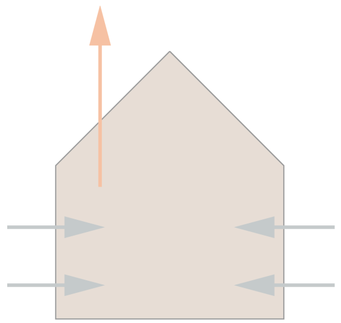


D) mechanical supply and extract

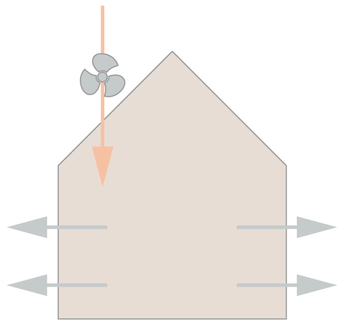


X) combination of systems

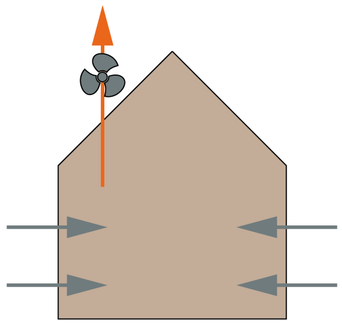
II. 6. building services
Ventilation



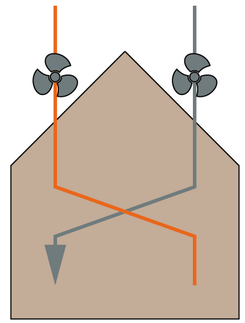
A) natural supply and extract



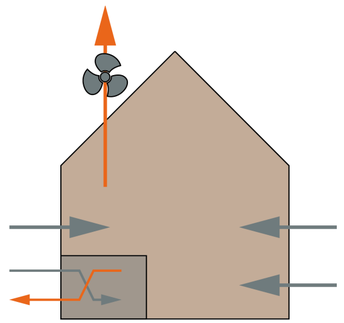
B) mechanical supply and natural extract



C) natural supply and mechanical extract



D) mechanical supply and extract



X) combination of systems

II. 6. building services
Heating and domestic hot water

heating boiler

source: warmteservice.nl

solar water heater

source: verbouwkosten.com

(hybrid) heat pump

source: cvtotaal.nl

electric boiler

source: hpwarehouse.co.uk

HRe boiler

source: warmteservice.nl

pellet stove

source: hgb-trading.nl

II. 6. building services
Heating and domestic hot water

heating boiler

source: warmteservice.nl

solar water heater

source: verbouwkosten.com

(hybrid) heat pump

source: cvtotaal.nl

electric boiler

source: hpwarehouse.co.uk

HRe boiler

source: warmteservice.nl

pellet stove

source: hgb-trading.nl

III. 7. parameters
Parameters in renovation

façade system	floor area	materials	ventilation system
number of houses	roof type (angle)	building components	domestic hot water
construction method	refurbishment strategy	building orientation	heat generation
airtightness	passive use of solar energy	building's structure	heat delivery

III. 7. parameters
Parameters in renovation

FIXED			VARIABLE
façade system	floor area	materials	ventilation system
number of houses	roof type (angle)	building components	domestic hot water
construction method	refurbishment strategy	building orientation	heat generation
airtightness	passive use of solar energy	building's structure	heat delivery

III. 7. parameters
Parameters in renovation

FIXED			VARIABLE
façade system	floor area	materials	ventilation system
number of houses	roof type (angle)	building components	domestic hot water
construction method	refurbishment strategy	building orientation	heat generation
airtightness	passive use of solar energy	building's structure	heat delivery

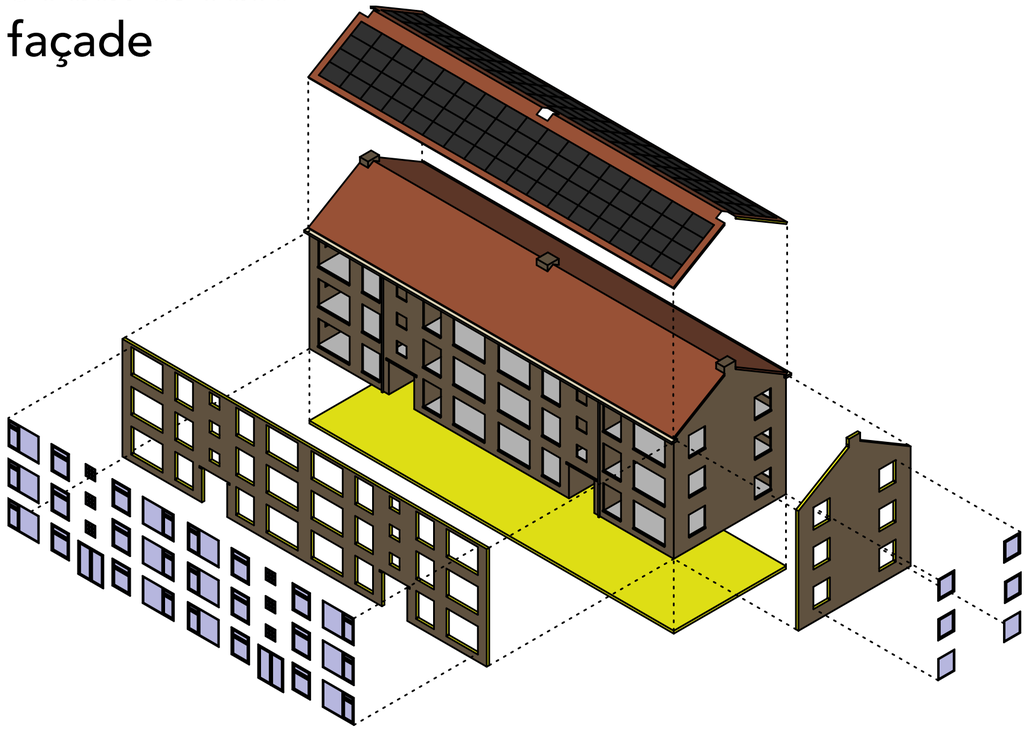
III. 8. concepts
Design concepts

design concepts

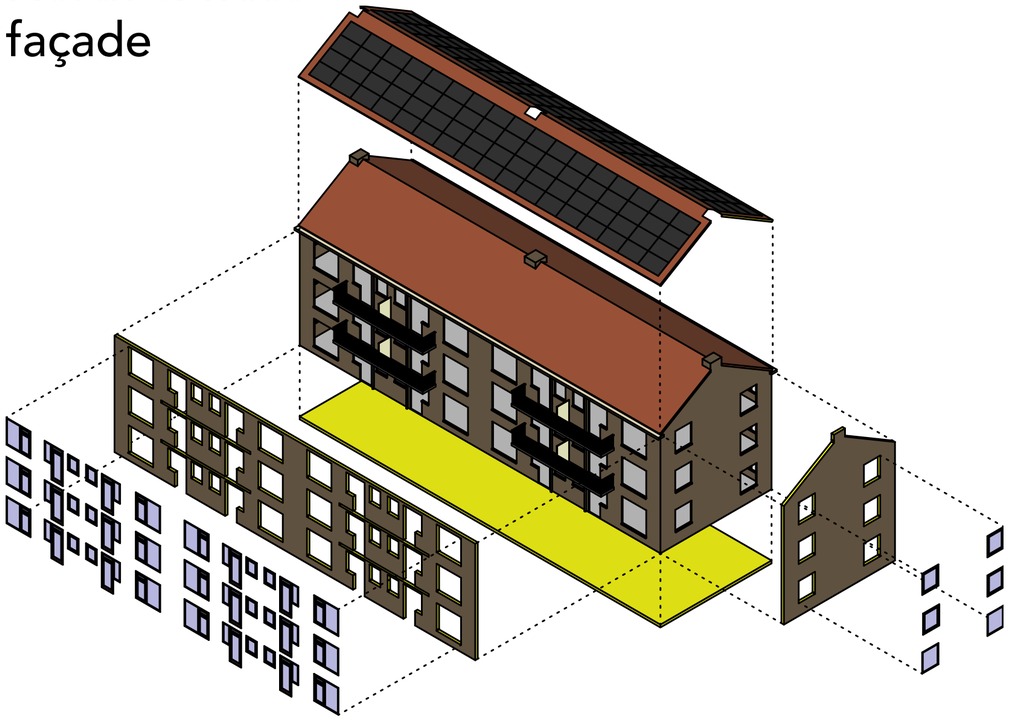
one architectural concept + multiple energy concepts

III. 8. concepts
Architectural concept

South & east façade



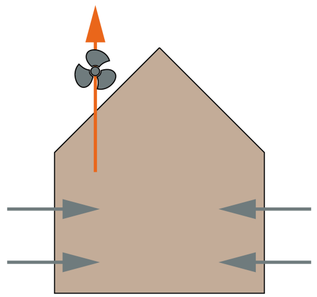
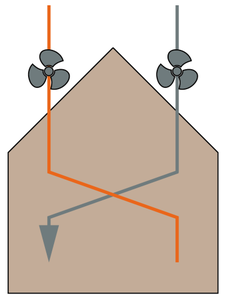
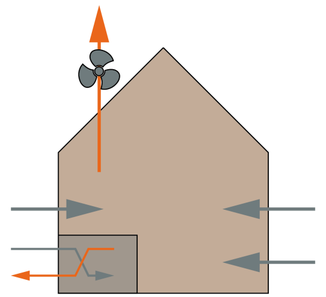
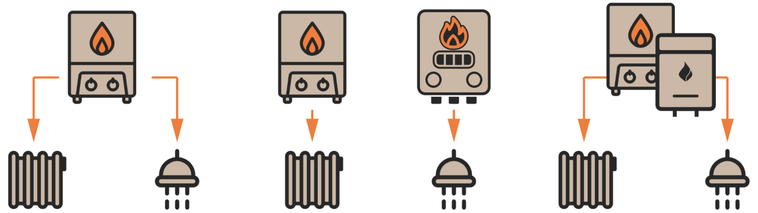
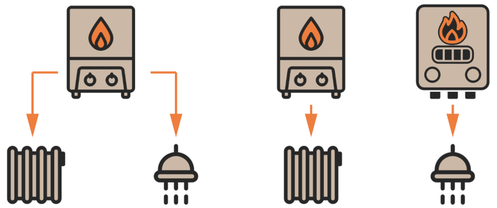
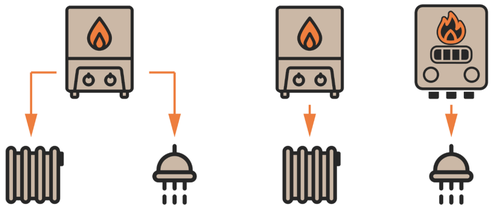
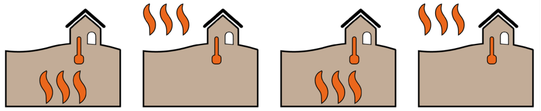
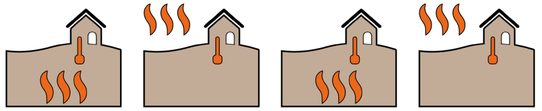
North & west façade



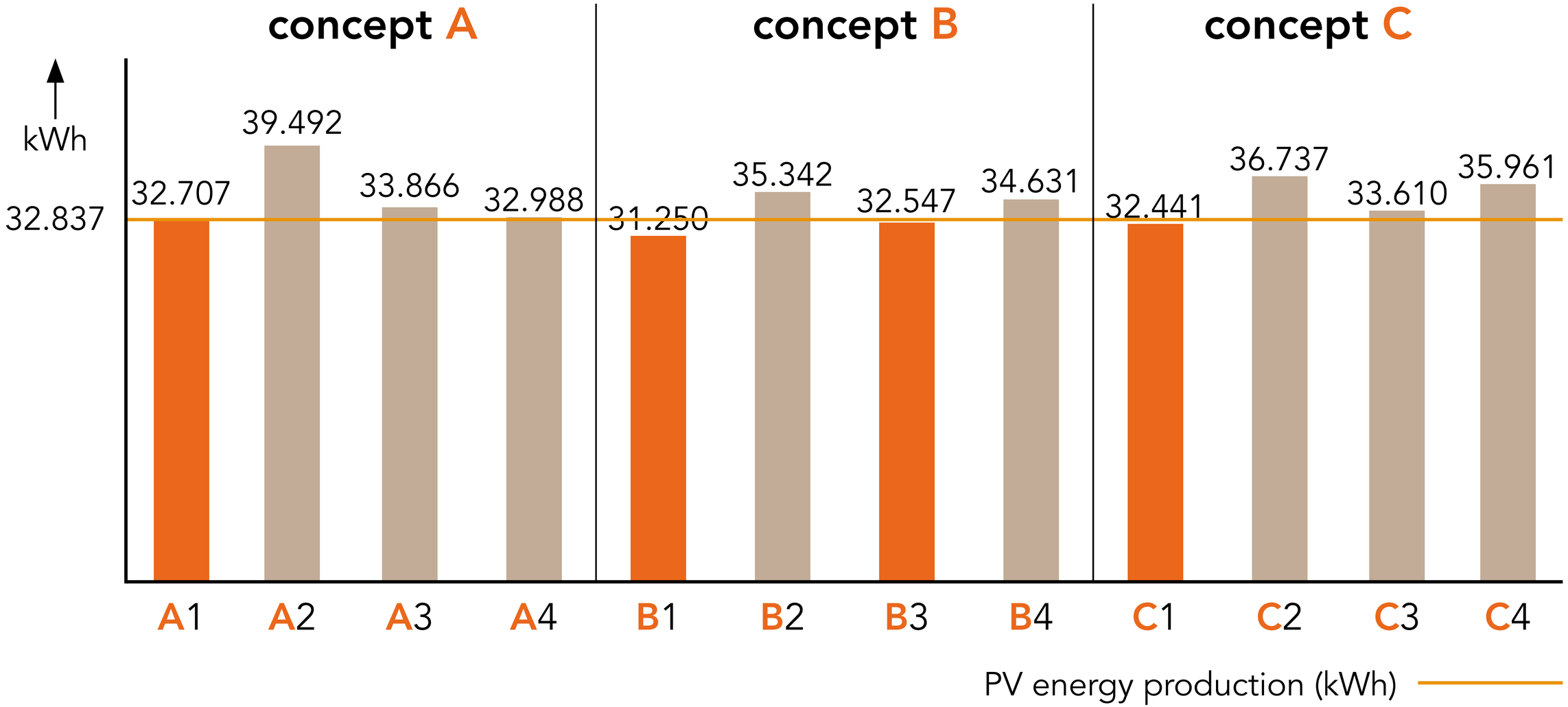
Prefabricated elements with new insulation:

roof:	Rc =	7,0	m²K/W	doors:	Rc =	3,4	m²K/W
façade:	Rc =	6,5	m²K/W	windows:	U =	1,0	W/m²K
floor:	Rc =	3,5	m²K/W		ZTA =	0,8	

III. 8. concepts
Energy concepts

	concept A	concept B	concept C
ventilation	 C.4b mechanical + CO_2 sensors	 D5.a balanced with heat recovery + CO_2 sensors on exhaust and zoning	 D5.b balanced with decentral heat recovery + CO_2 sensors on exhaust and zoning
heating + DHW	 combi heat pump / individual heat pump / hybrid heat pump	 combi heat pump / individual heat pump	 combi heat pump / individual heat pump
source	 ground / air / ground / air / ground / air	 ground / air / ground / air	 ground / air / ground / air
	A1 A2 A3 A4 A5 A6	B1 B2 B3 B4	C1 C2 C3 C4

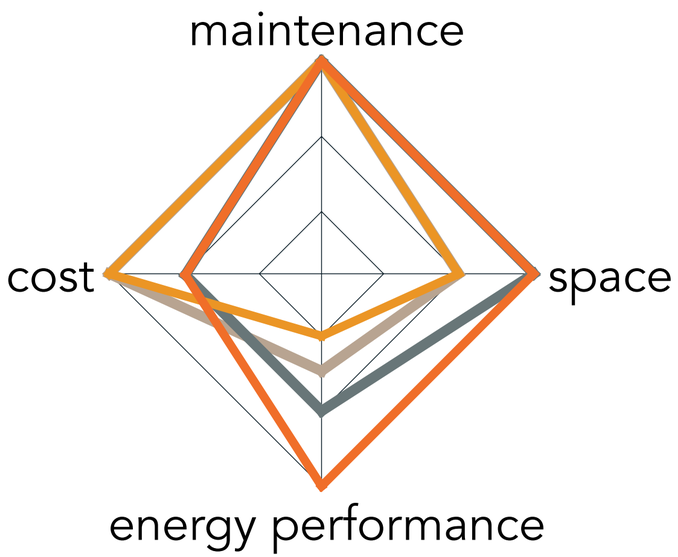
IV. 9. design & evaluation
Required energy (whole building)



IV.

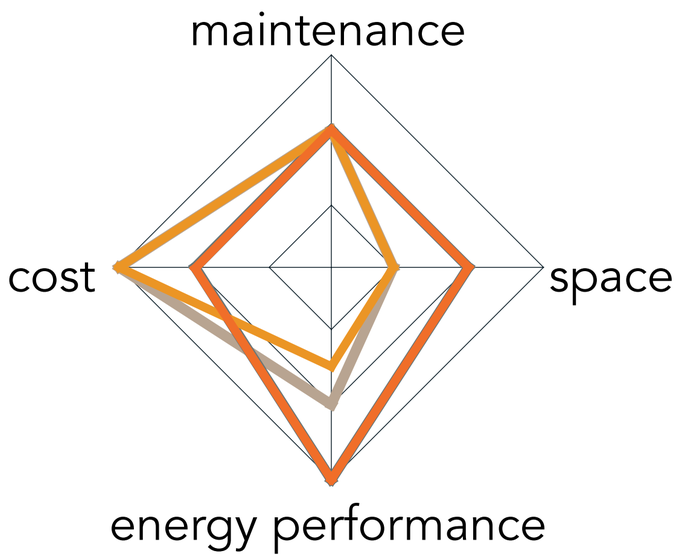
9. design & evaluation
Overall evaluation

concept A



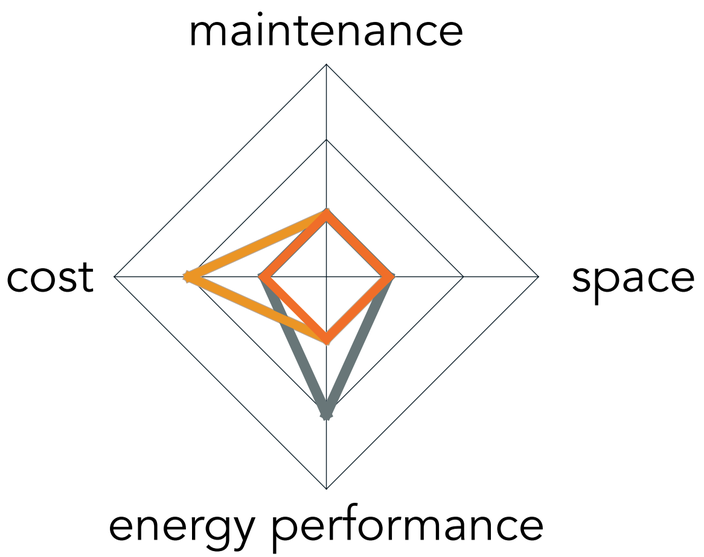
A1 —— A3 ——
A2 —— A4 ——

concept B



B1 —— B3 ——
B2 —— B4 ——

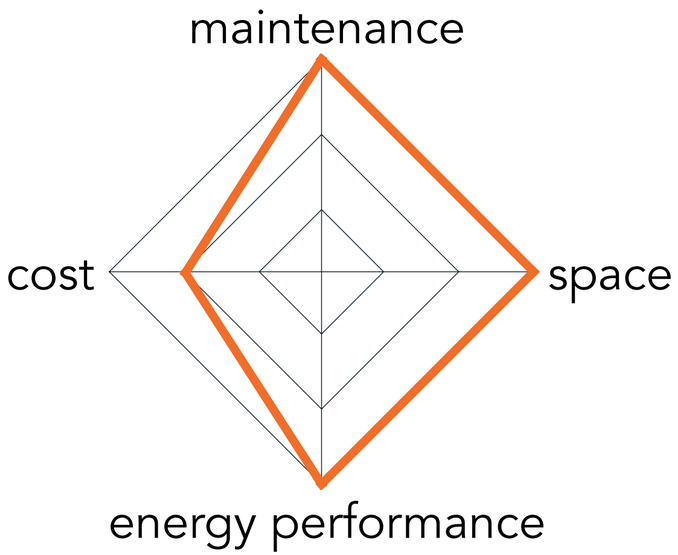
concept C



C1 —— C3 ——
C2 —— C4 ——

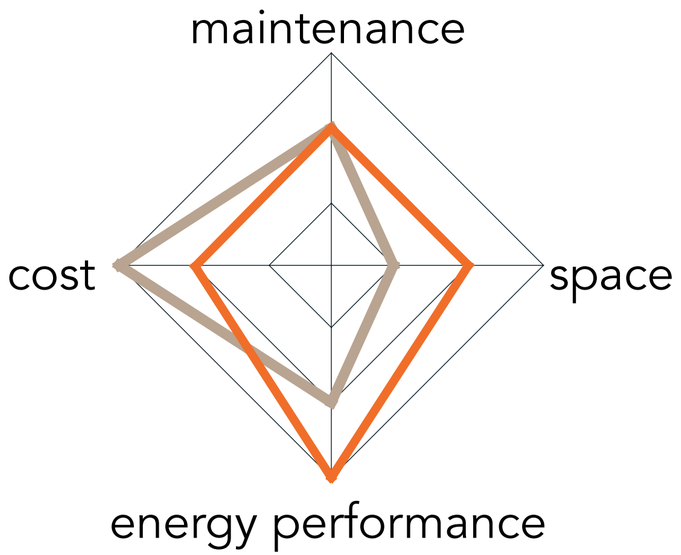
IV. 9. design & evaluation
Overall evaluation

concept A



A1

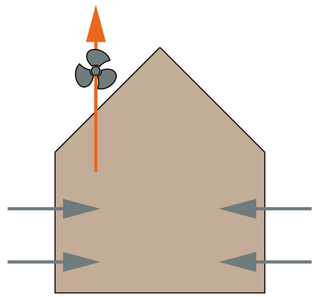
concept B



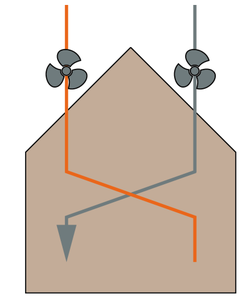
B1

B4

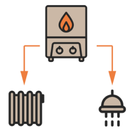
building services



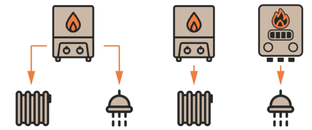
mechanical



balanced + heat recovery



combi heat pump



combi heat pump

individual heat pump

ground

A1

ground

B1

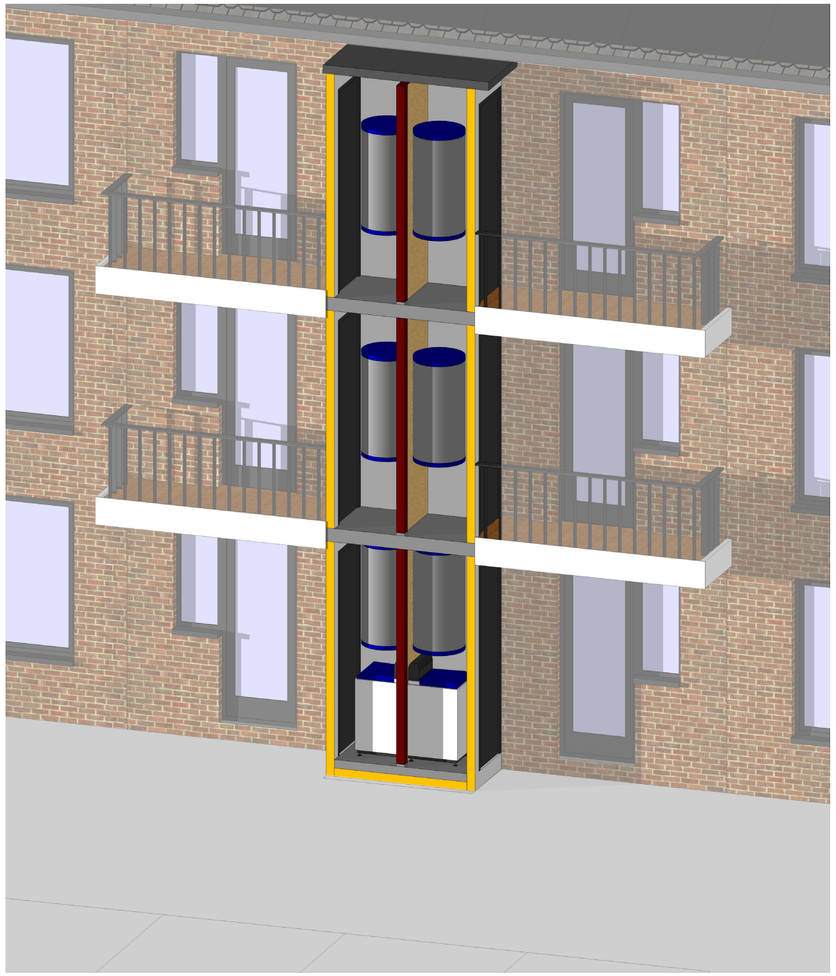
air

B4

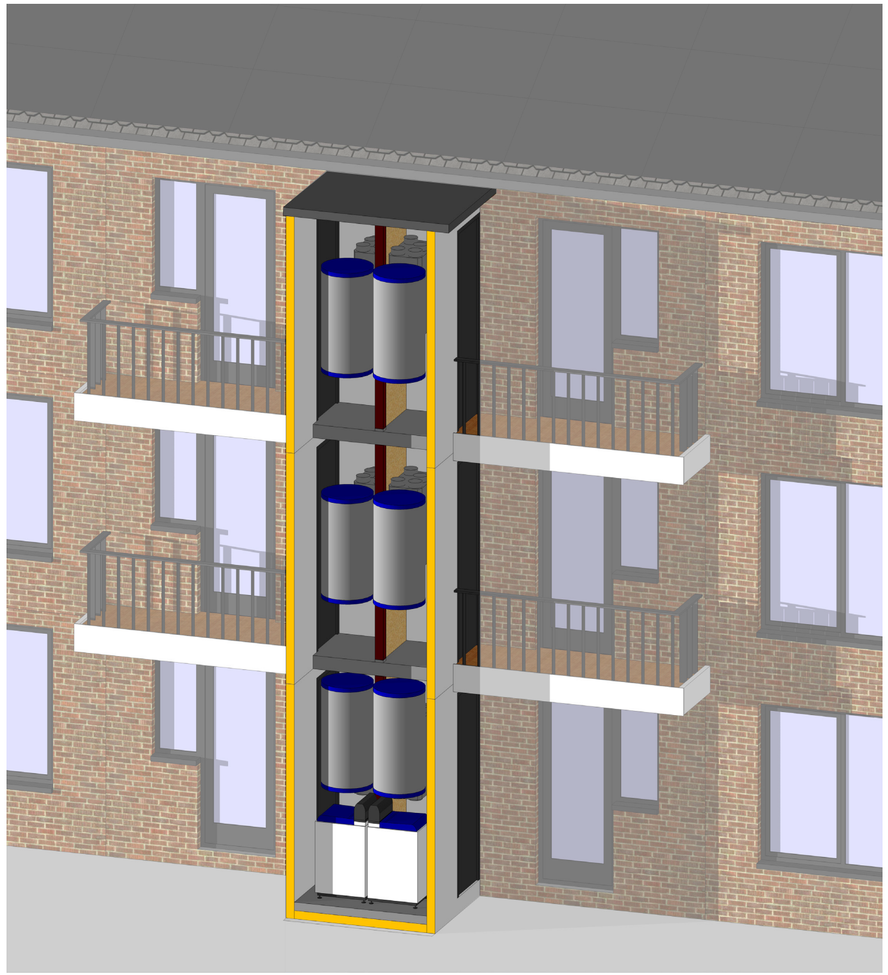
IV. 9. design & evaluation
Preliminary design

IV. 9. design & evaluation
New cupboards

Design A1



Design B1



IV. 9. design & evaluation
Cupboard structure

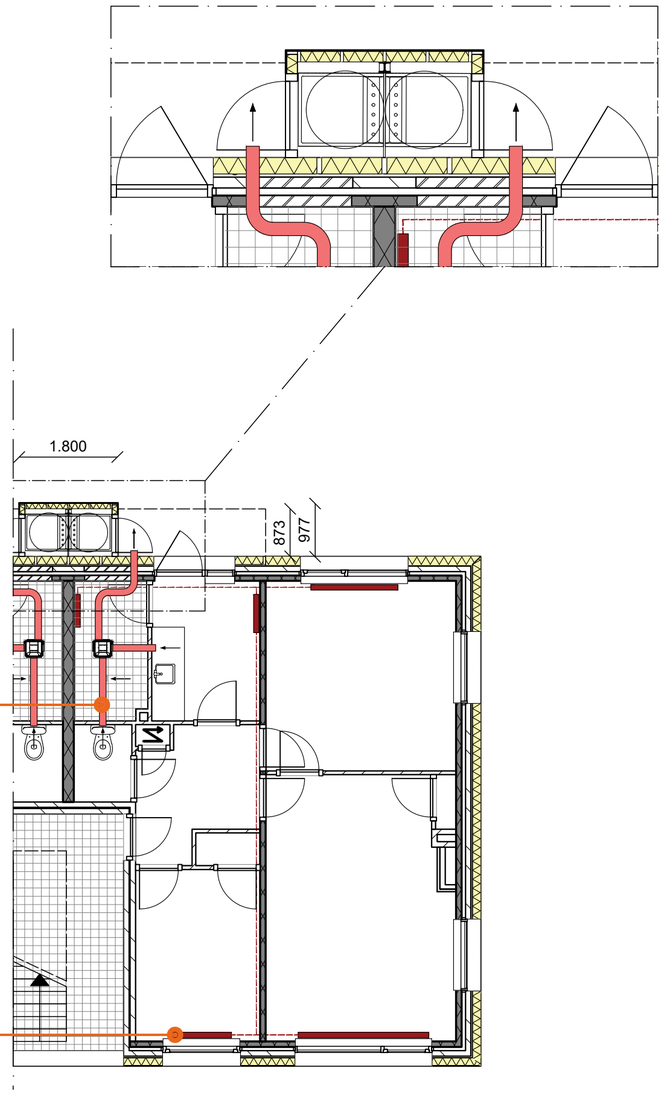
new steel column between existing concrete slabs

new insulation for foundation beams

new foundation

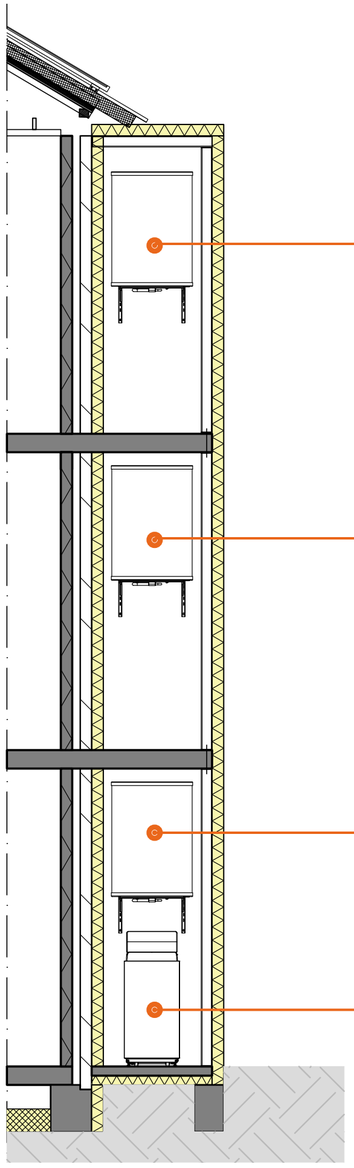
IV. 9. design & evaluation
New cupboards / services

Design A1



mechanical exhaust ducts in suspended ceilings

new radiators

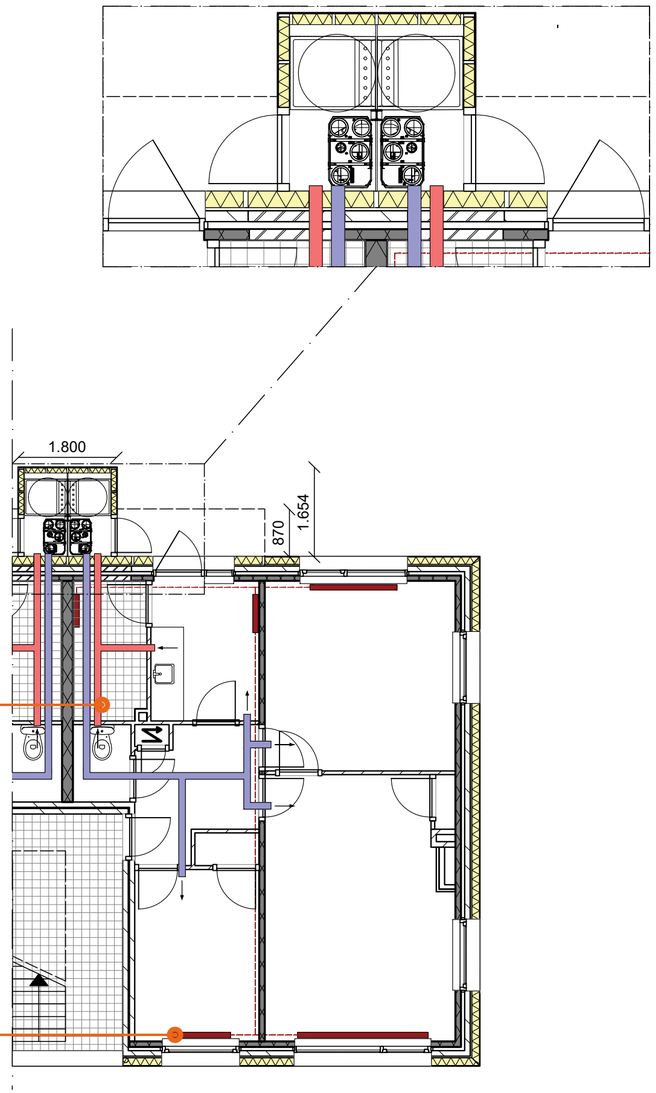


buffer per apartment

ground source heat pump per 3 apartments

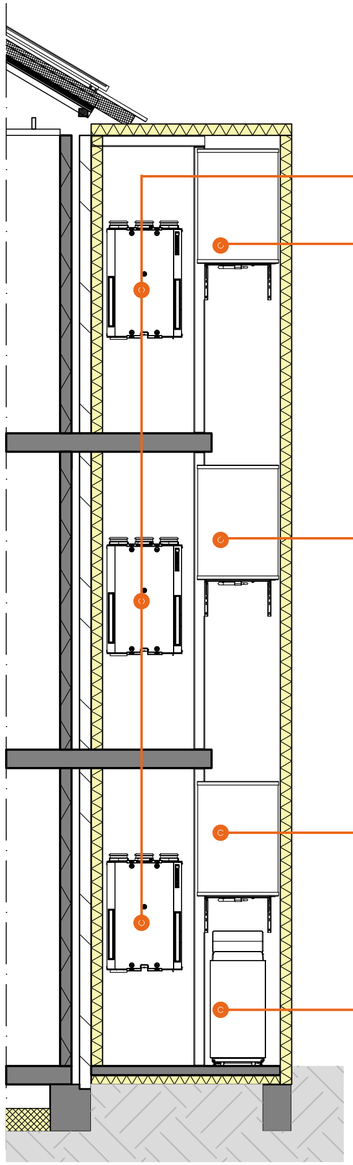
IV. 9. design & evaluation
New cupboards / services

Design B1



ventilation ducts

new radiators



ventilation unit with heat recovery per apartment

buffer per apartment

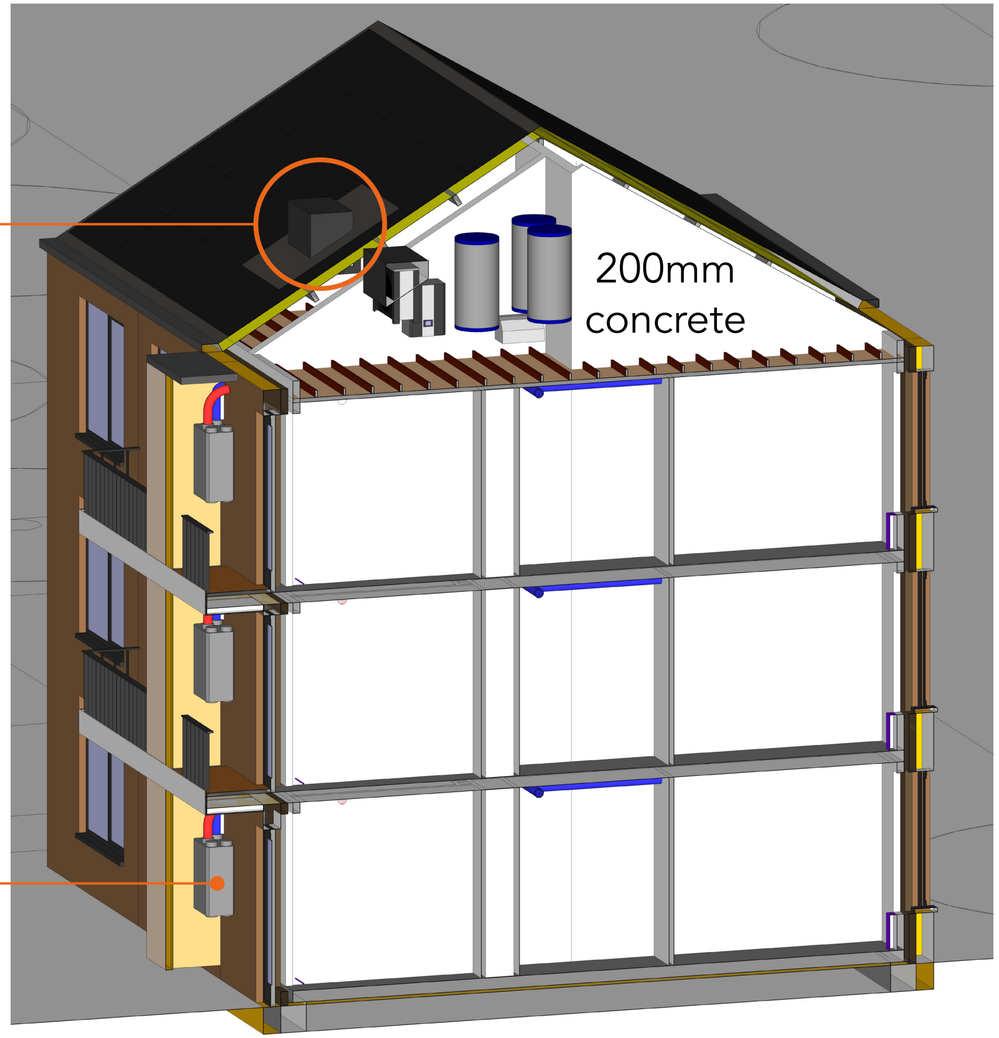
ground source heat pump per 3 apartments

IV. 9. design & evaluation
New cupboards / services

Design B4

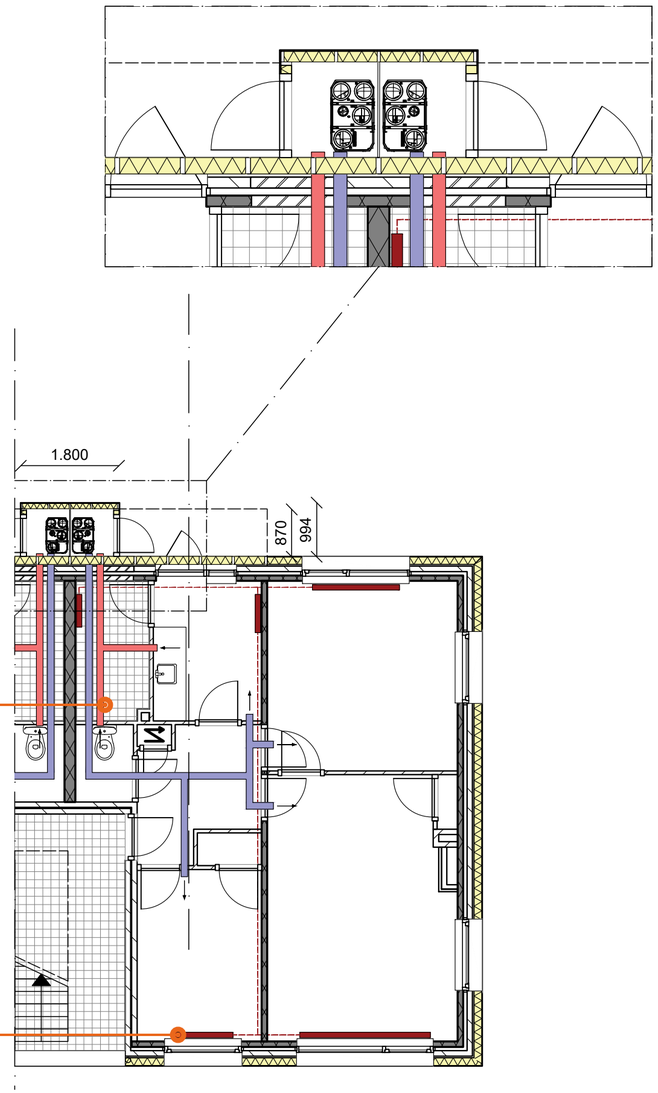

source: Breman Schoorsteentechniek

ventilation unit with heat recovery per apartment



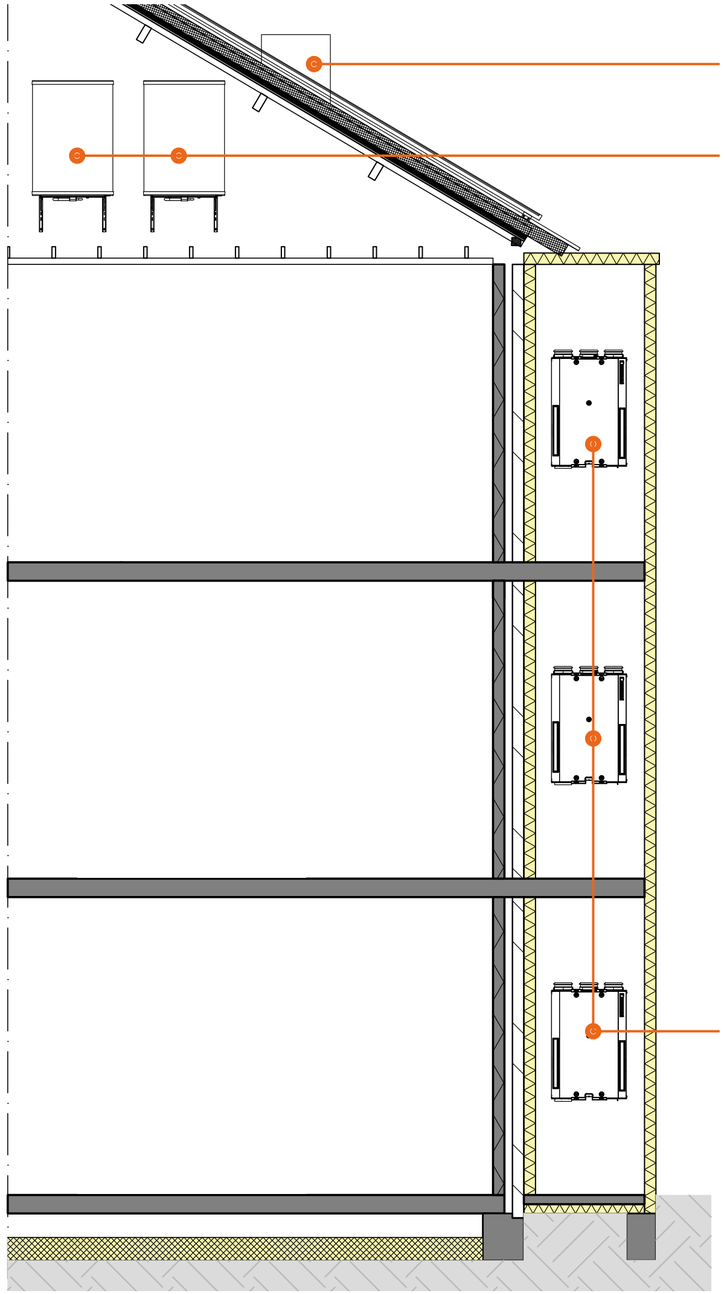
IV. 9. design & evaluation
New cupboards / services

Design B4



ventilation ducts

new radiators

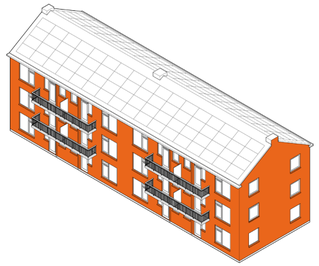


outside unit

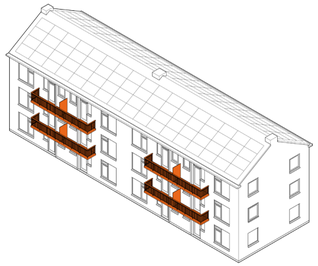
air source heat pump per 3 apartments and buffers per apartment on the attic

ventilation unit with heat recovery per apartment

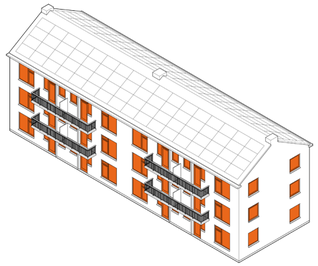
IV. 9. design & evaluation
Preliminary design



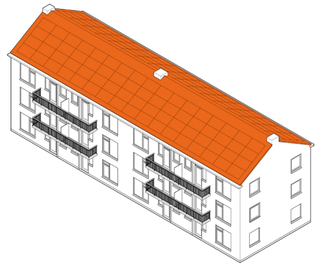
externall wall



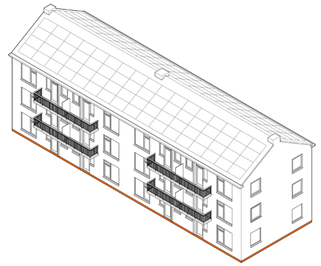
balconies



windows



roof



ground floor

wrap-it

Design of a more prefabricated façade system.
Optimisation of balcony structure with integration of building-services.

IV. 9. design & evaluation
Externall wall

Cocoonz system

source: NBU 2016

Wooden sandwich element

Berekening Warmteweerstand
Houtskeletbouw-elementen en voorzetwanden hout

Laag	Bron	Materiaal	Dikte (mm)	λ_{calc} W/m·K)	R_m (m^2·K/W)
Wandafwerking 1	Eigen invoer		0	0.000	0.0000 [1]
Wandafwerking 2	N.v.t.				
Folie binnenzijde	VoRa Trading BV	SuperFOIL SF19+ (dampdichte meerlaagse isolatiefolie)	45	0.000	1.5400
Samengestelde laag					1.9438
Hout en regelwerk	NEN1068	Naaldhout (500 kg/m3) Percentage hout: 10%	90	0.130	
Isolatie	Isover	Systemroll 400	90	0.037	
Extra isolatie laag	Isover	Multimax 30	45	0.030	1.5000
Ankers	N.v.t.				
Folie buitenzijde	VoRa Trading BV	SuperFOIL SF19BB (dampopen meerlaagse isolatiefolie)	40	0.000	1.4500
Spouw		Ongeventileerd	30		0.1800
Buitenspouwblad	Eigen invoer	Steen strips	7	0.800	0.0088
		Totale dikte constructie:	257		

R_{si}	= 0.13 m^2·K/W	**R_C Bouwbesluit = 6.3 m^2·K/W**	U_T	= 0.15	W/m^2·K
R_{se} Buitenlucht	= 0.04 m^2·K/W		ΔU	= 0.01	W/m^2·K
R_T	= 6.79 m^2·K/W		U_C = U_T + ΔU	= 0.15	W/m^2·K
ΔU_{fa}	= 0.00 W/m^2·K		R_C = 1/U_C - R_{si} - R_{se}	= 6.30	m^2·K/W
ΔU_w = 0.05 * U_T	= 0.01 W/m^2·K		R_C Bouwbesluit	= 6.3	m^2·K/W

Opmerkingen:

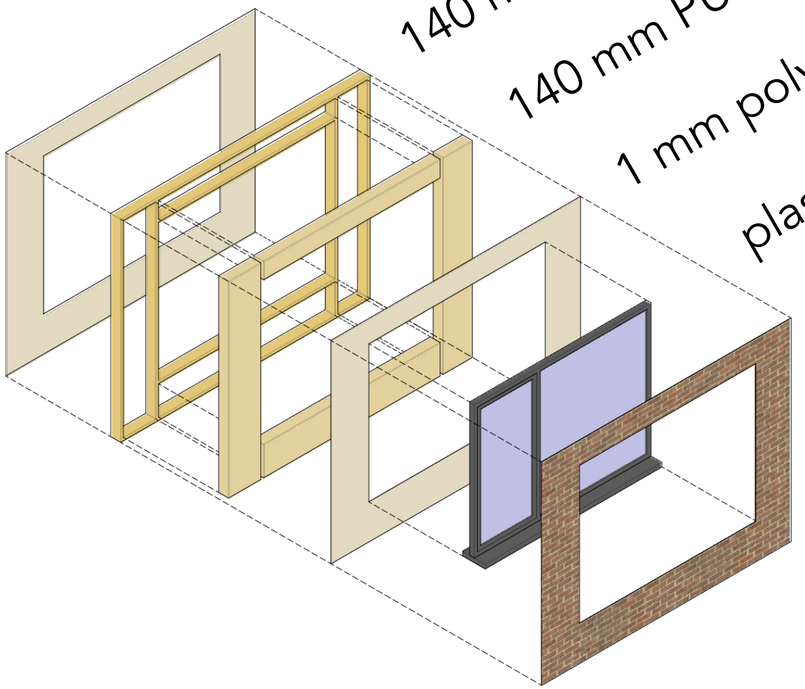
1. λ_{calc} of dikte is niet opgegeven!

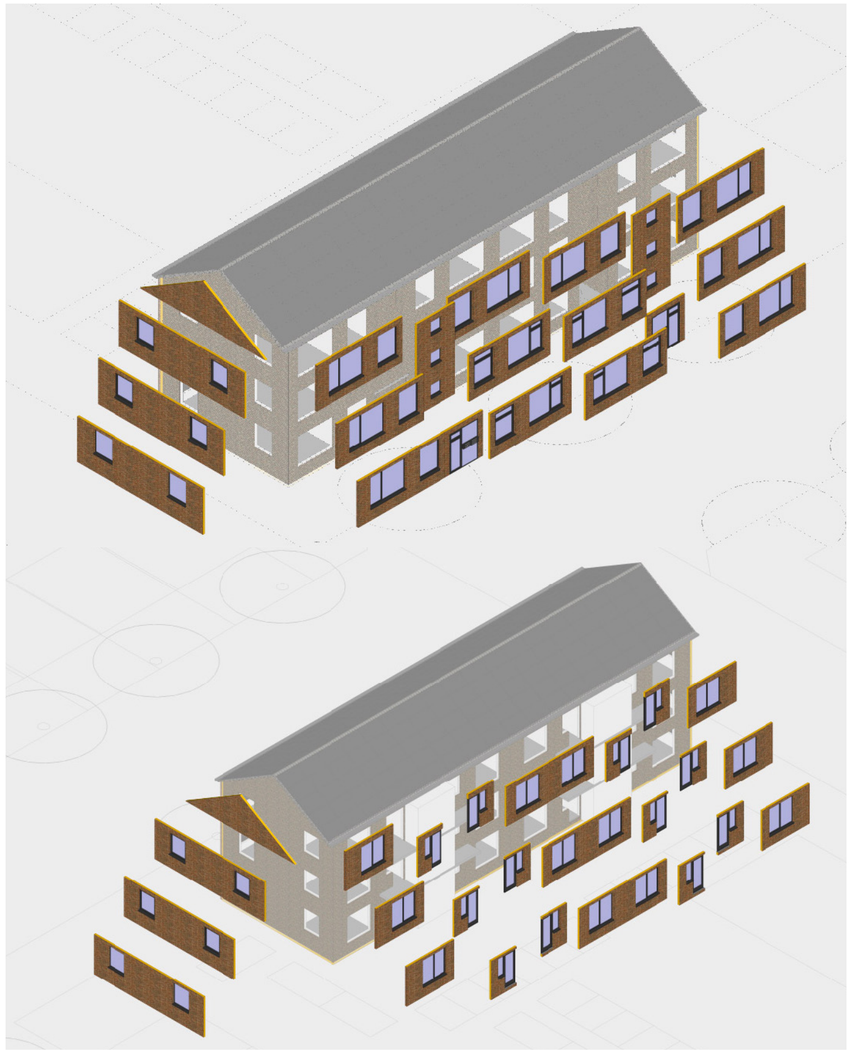
source: SBRCUR net

IV. 9. design & evaluation
Externall wall

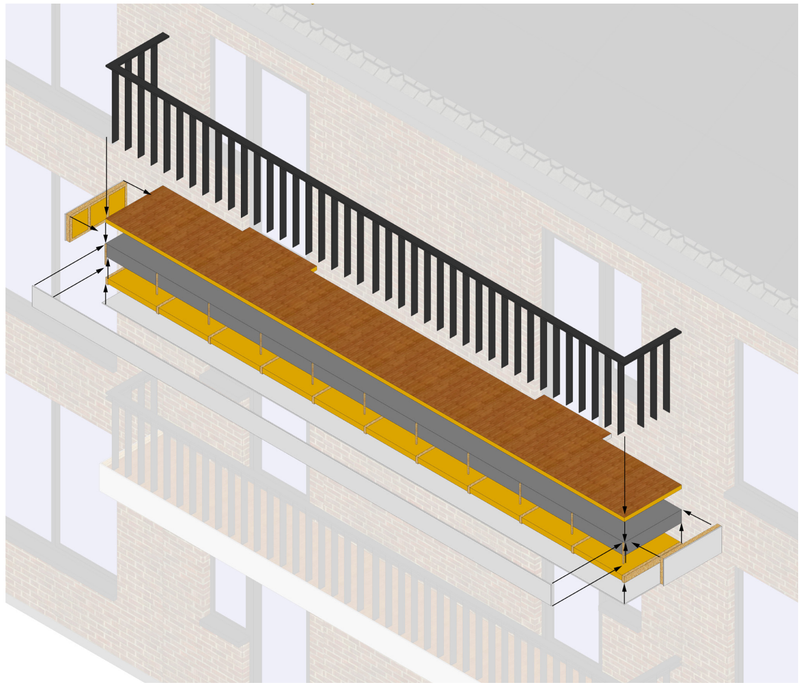
	Cocoonz system	Wooden sandwich element
	light weight	
Rc = 6,5	150 mm	257 mm
	€ 440,- / m^2	€ 240,- / m^2
	€ 65,79 / m^3	€ 62,10 / m^3

IV. 9. design & evaluation
Externall wall

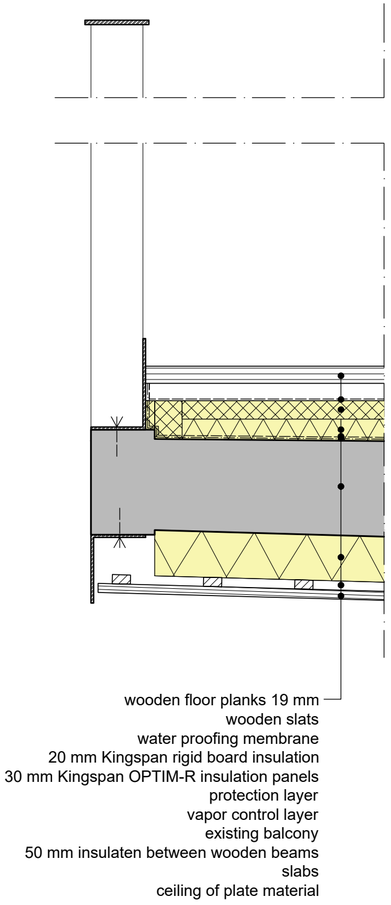




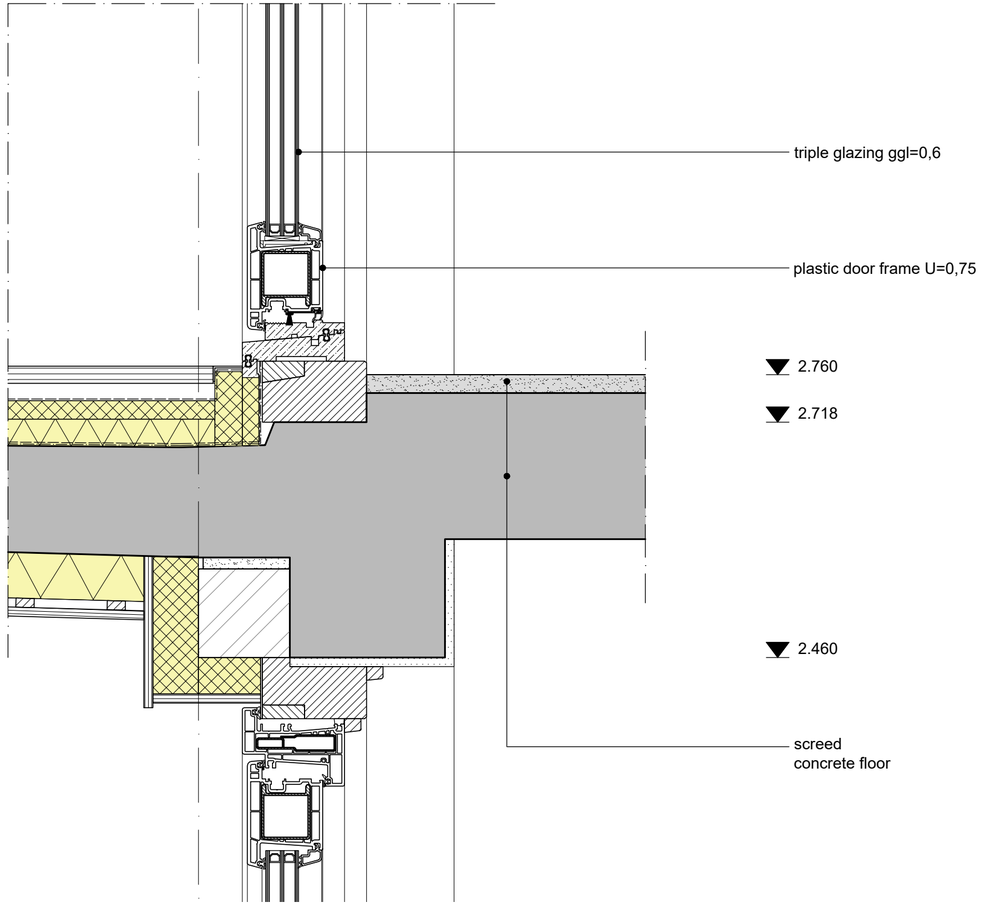
IV. 9. design & evaluation
Balcony



source: Kingspan.nl

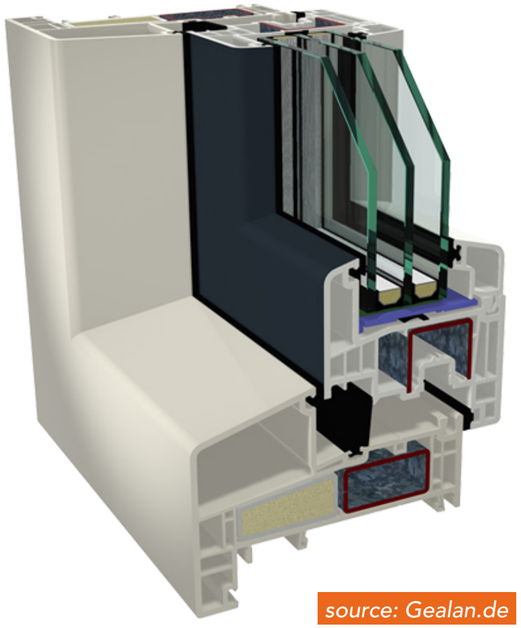


wooden floor planks 19 mm
wooden slats
water proofing membrane
20 mm Kingspan rigid board insulation
30 mm Kingspan OPTIM-R insulation panels
protection layer
vapor control layer
existing balcony
50 mm insulaten between wooden beams
slabs
ceiling of plate material



IV. 9. design & evaluation
Remaining building components

windows



source: Gealan.de

S9000 NL Gealan

U =0,75 W/m²K

roof

source: Climate-KIC, 2017

Kingspan panels

Rc = 7,0 m²K/W

ground floor

source: Climate-KIC, 2017

expanded polystyrene insulation

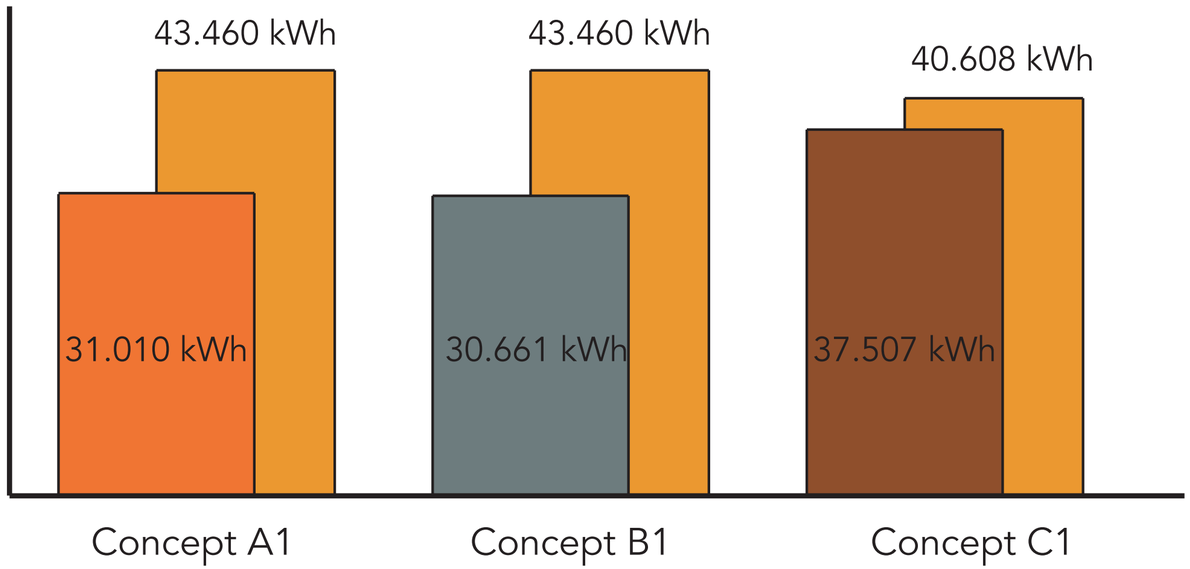
Rc = 3,5 m²K/W

IV. 9. design & evaluation
Required energy (whole building)

	concept A1	concept B1	concept B4
Building related energy [kWh]	10.606	10.257	17.102
User related energy [kWh]	20.404	20.404	20.404
Total:	**31.010**	**30.661**	**37.507**

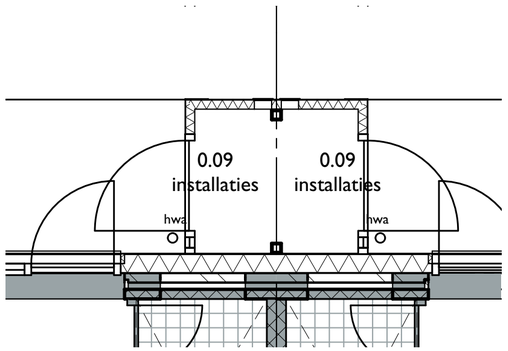
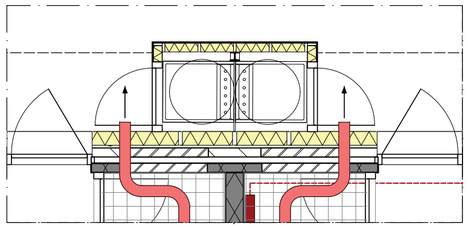
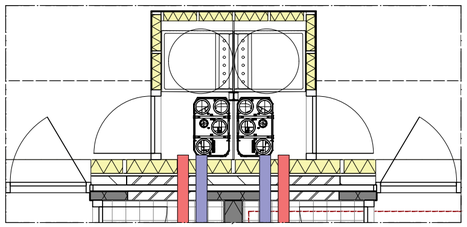
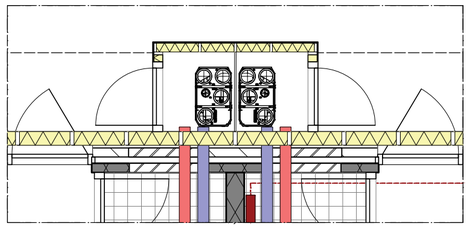
IV. 9. design & evaluation
Required energy (whole building)

	concept A1	concept B1	concept B4
Building related energy [kWh]	10.606	10.257	17.102
User related energy [kWh]	20.404	20.404	20.404
Total:	**31.010**	**30.661**	**37.507**



IV. 9. design & evaluation
Space evaluation

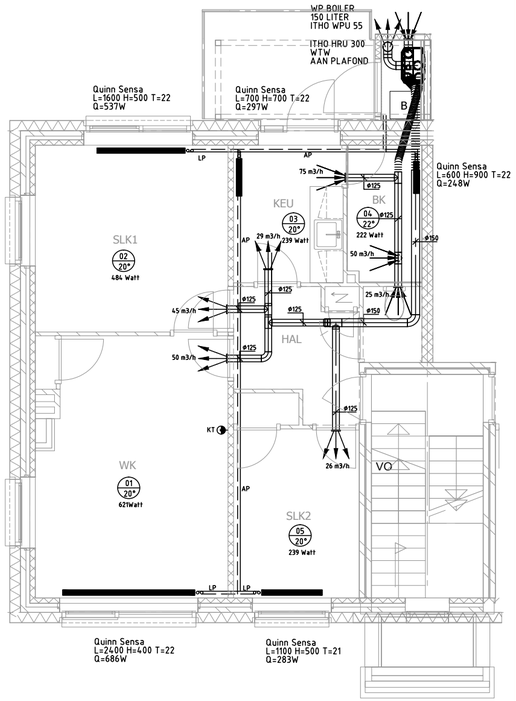
cupboard

2ndSKIN	concept A1	concept B1	concept B4
			
23,8 m^3	15,1 m^3	23,8 m^3	15,1 m^3

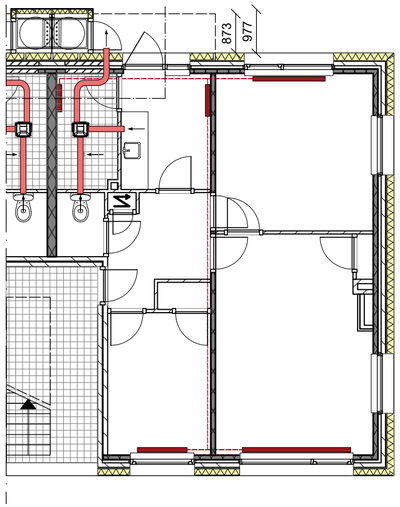
IV. 9. design & evaluation
Space evaluation

ventilation system

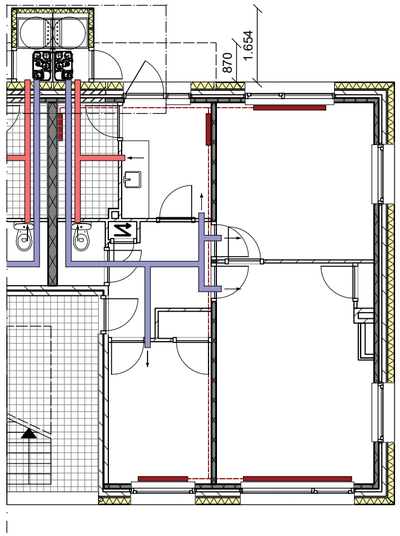
2ndSKIN



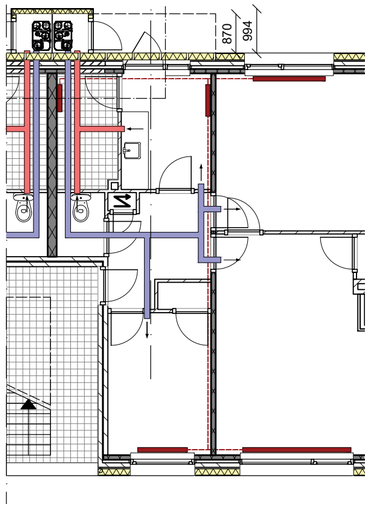
concept A1



concept B1

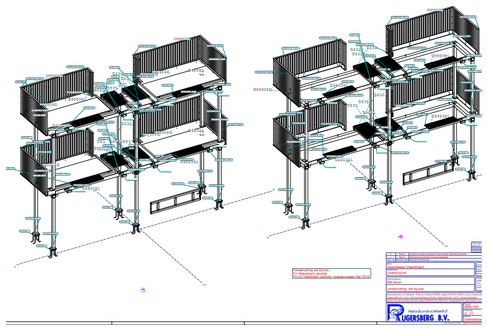
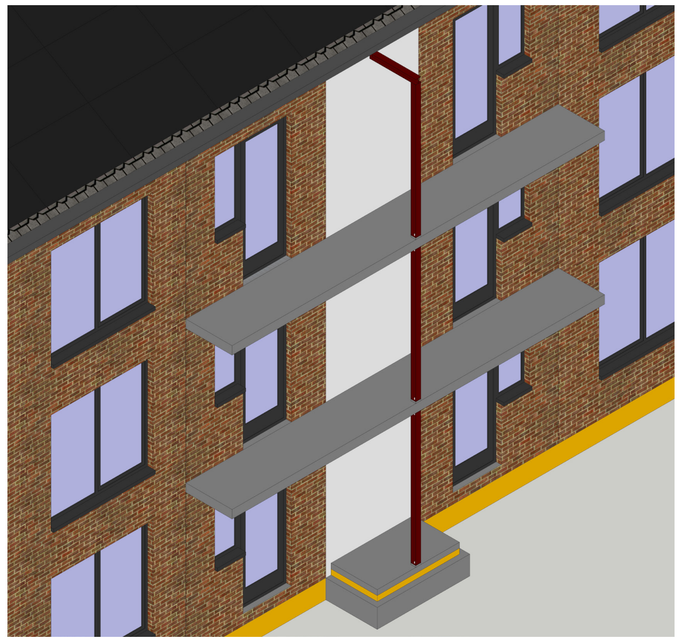


concept B4



IV. 9. design & evaluation
Cost evaluation

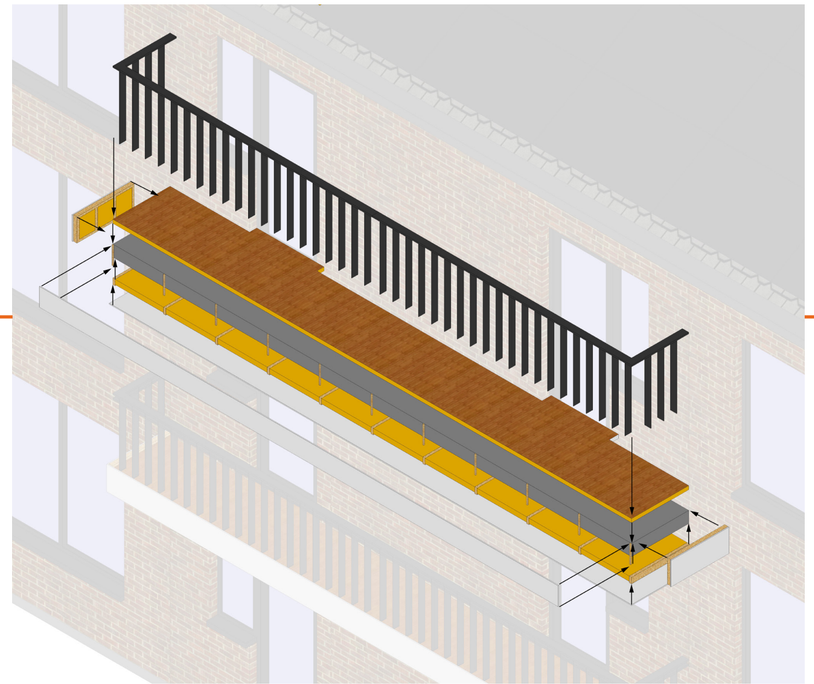
structural intervention

2ndSKIN	concept A1	concept B1	concept B4
			-

IV. 9. design & evaluation
Cost evaluation

balcony

2ndSKIN	concept A1	concept B1	concept B4



IV. 9. design & evaluation
Cost evaluation

heating

2ndSKIN	concept A1	concept B1	concept B4
	ground source heat pump		air source heat pump + booster heat pump
			
	€ 60.000 - € 100.000		€ 40.000 - € 60.000 € 8.000

IV. 9. design & evaluation
Cost evaluation

ventilation

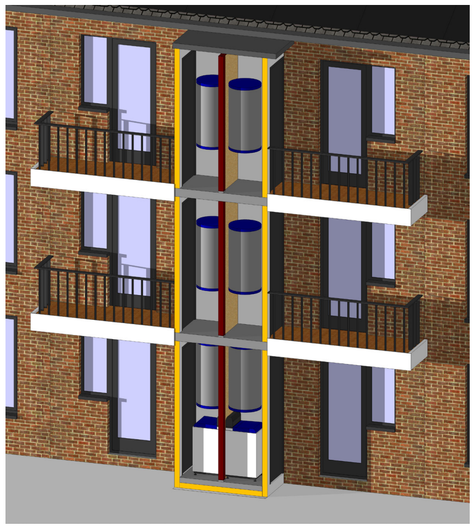
2ndSKIN	concept A1	concept B1	concept B4
HRU ECO 300	Itho CVE-S ECO	HRU ECO 300	
			
€ 35.100	€ 6.720	€ 35.100	

V. 10. conclusion
Research question ZEHR-Ø

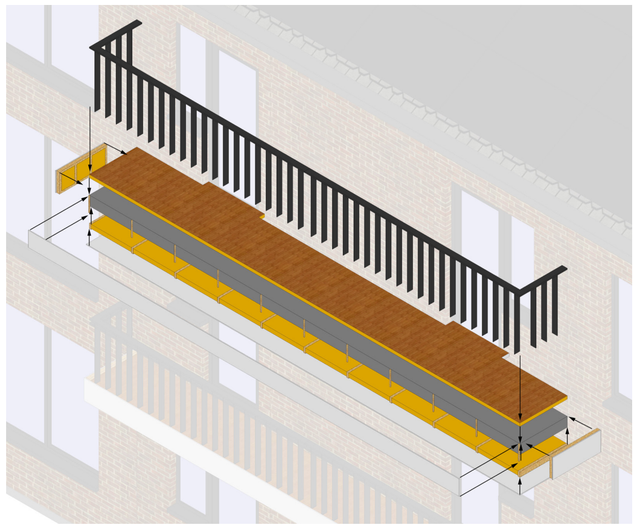
How can the integration of building services in façades, for zero-energy renovation methods in Dutch post-war walk-up apartments, be optimised in terms of space and costs?

V. 10. conclusion
Research question ZEHR-Ø

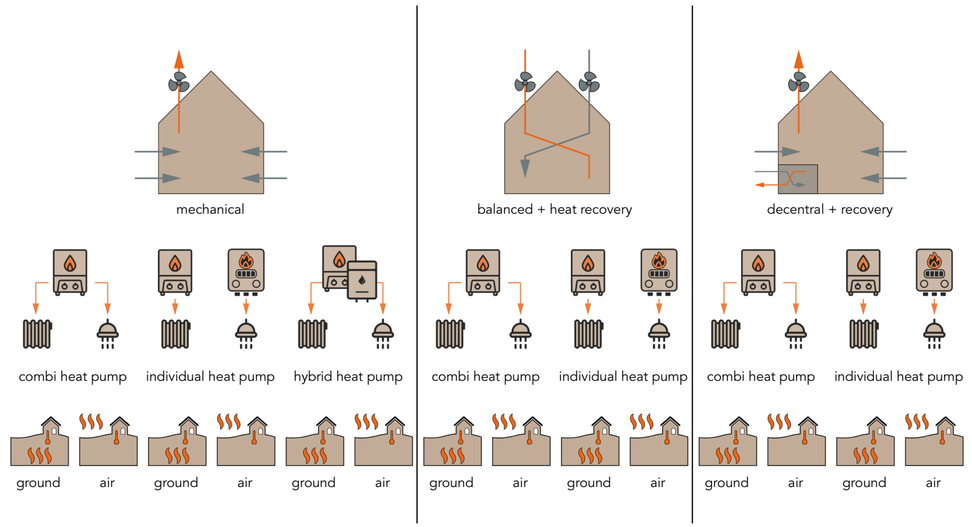
How can the integration of building services in façades, for zero-energy renovation methods in Dutch post-war walk-up apartments, be optimised in terms of space and costs?



cupboard



impact on balcony



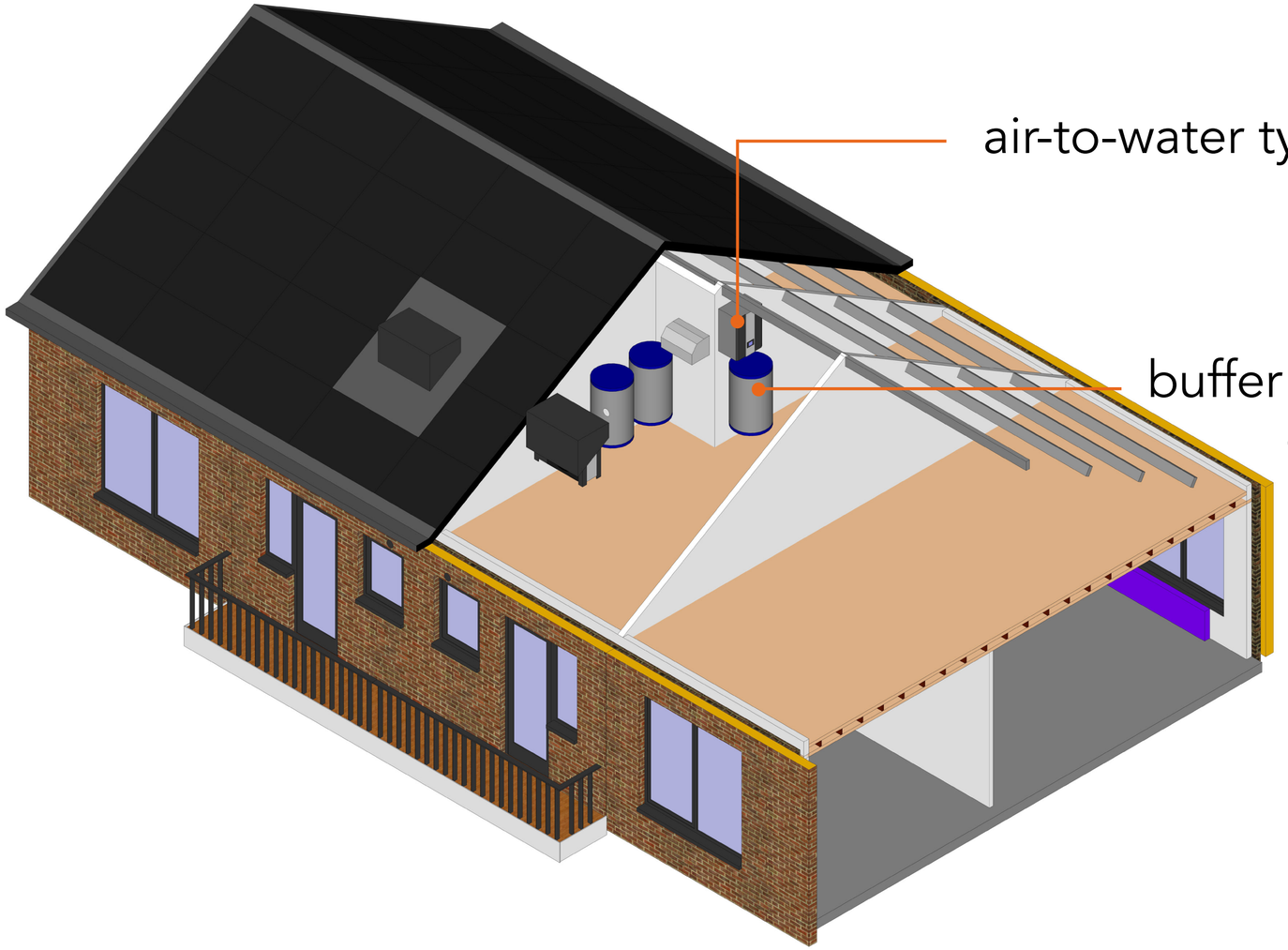
building services

V. 10. conclusion
Research question ZEHR-Ø

How can the integration of building services in façades, for zero-energy renovation methods in Dutch post-war walk-up apartments, be optimised in terms of space and costs?

This is done by making and comparing different variations of building services in combination with architectural options - that reach zero-energy levels - in terms of space and cost.

V. 10. conclusion
Final design

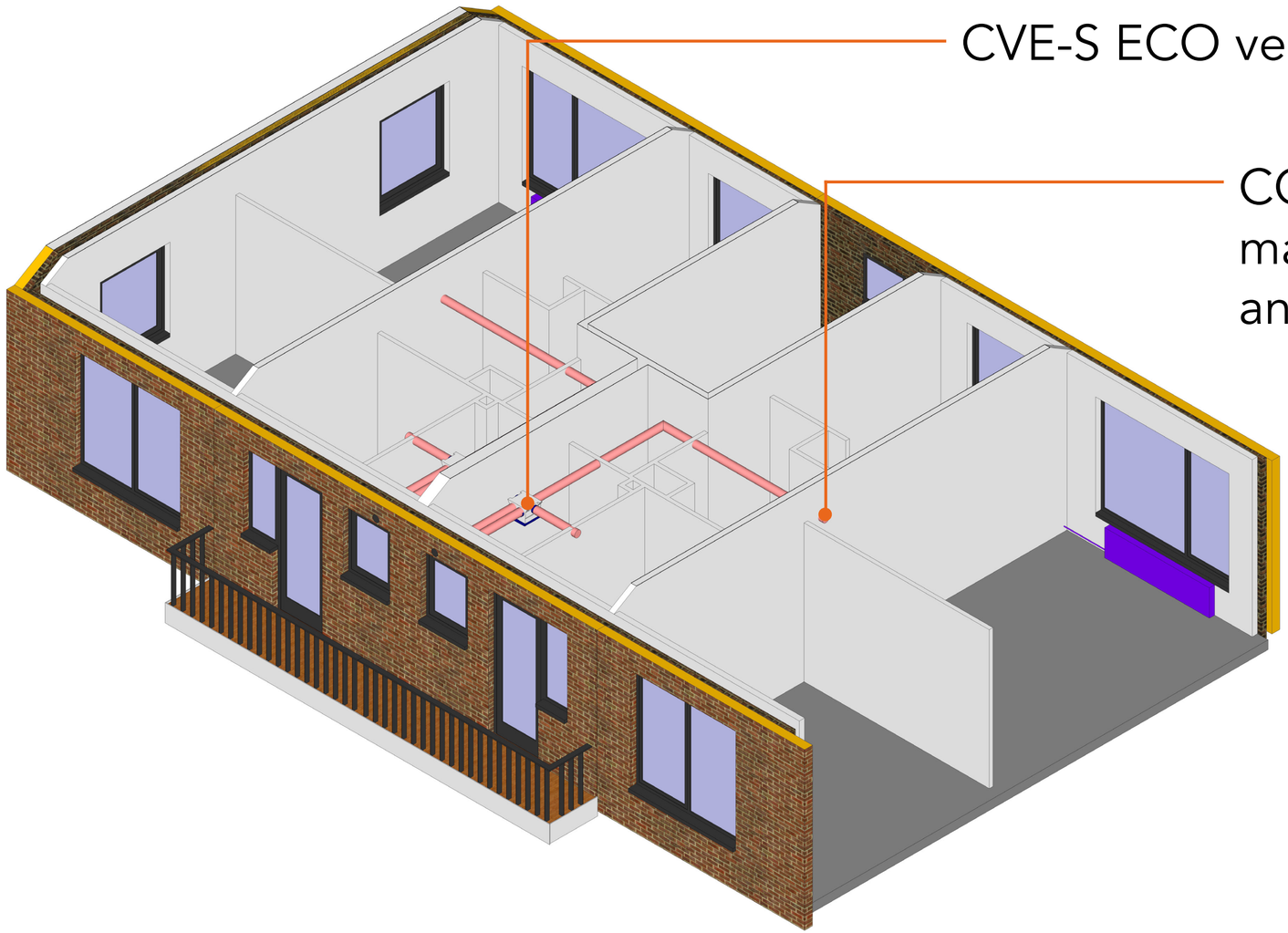


use of attic

air-to-water type heat pump

buffer per apartment
+ booster heat
pump

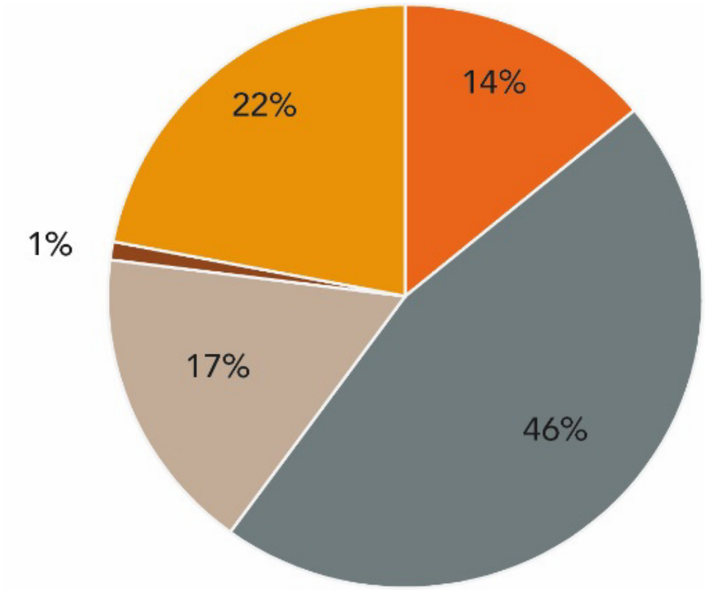
V. 10. conclusion
Final design



V. 10. conclusion
Energy performance final design

Primary energy consumption annually for whole building (12 apartments)

heating	EH;P	17.288	MJ	
auxiliary energy		3.697	MJ	
domestic hot water	EW;P	35.041	MJ	
auxiliary energy		34.755	MJ	
cooling	EC;P	25.142	MJ	
auxiliary energy		-	MJ	
vents	EV;P	1.555	MJ	
lighting	EL;P	33.541	MJ	+
	Total:	**151.019**	**MJ**	



Annually electricity demand and production for whole building (12 apartments)

Produced energy	40.608	kWh			
Building related energy	16.387	kWh		1.366	kWh per apartment
User related energy	20.404	kWh	-	1.700	kWh per apartment
Exported energy	**3.817**	**kWh**			

V. 10. conclusion
Energy performance final design

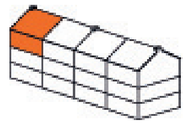
ground floor corner apartment

Primary			
heating	EH;P	1.967	MJ
auxiliary energy		308	MJ
domestic hot water	EW;P	2.920	MJ
auxiliary energy		2.896	MJ
cooling	EC;P	2.860	MJ
auxiliary energy		0	MJ
vents	EV;P	130	MJ
lighting	EL;P	2.795	MJ
	Total:	13.876	MJ
	=	267	MJ/m2

first floor corner apartment

Primary			
heating	EH;P	1.098	MJ
auxiliary energy		308	MJ
domestic hot water	EW;P	2.920	MJ
auxiliary energy		2.896	MJ
cooling	EC;P	1.596	MJ
auxiliary energy		0	MJ
vents	EV;P	130	MJ
lighting	EL;P	2.795	MJ
	Total:	11.743	MJ
	=	226	MJ/m2

second floor corner apartment



Primary			
heating	EH;P	1.372	MJ
auxiliary energy		308	MJ
domestic hot water	EW;P	2.920	MJ
auxiliary energy		2.896	MJ
cooling	EC;P	1.995	MJ
auxiliary energy		0	MJ
vents	EV;P	130	MJ
lighting	EL;P	2.795	MJ
	Total:	12.417	MJ
	=	239	MJ/m2

average primairy energy consuption:

242 MJ/m²

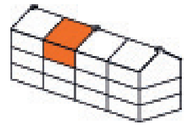
ground floor corner apartment

Primary			
heating	EH;P	1.807	MJ
auxiliary energy		308	MJ
domestic hot water	EW;P	2.920	MJ
auxiliary energy		2.896	MJ
cooling	EC;P	2.627	MJ
auxiliary energy		0	MJ
vents	EV;P	130	MJ
lighting	EL;P	2.795	MJ
	Total:	13.483	MJ
	=	259	MJ/m2

first floor corner apartment

Primary			
heating	EH;P	1.006	MJ
auxiliary energy		308	MJ
domestic hot water	EW;P	2.920	MJ
auxiliary energy		2.896	MJ
cooling	EC;P	1.463	MJ
auxiliary energy		0	MJ
vents	EV;P	130	MJ
lighting	EL;P	2.795	MJ
	Total:	11.519	MJ
	=	222	MJ/m2

second floor corner apartment



Primary			
heating	EH;P	1.395	MJ
auxiliary energy		308	MJ
domestic hot water	EW;P	2.920	MJ
auxiliary energy		2.896	MJ
cooling	EC;P	2.029	MJ
auxiliary energy		0	MJ
vents	EV;P	130	MJ
lighting	EL;P	2.795	MJ
	Total:	12.473	MJ
	=	240	MJ/m2

average primairy energy consuption apartment with EPC 0,4

352 MJ/m²

source: RVO, 2015

V.

10. conclusion
Recommendations

- Financial feasability
- Comfort
- Effect of user behaviour
- Circularity
- Impact of building services for house owner and occupant.

Thank you for you attention.