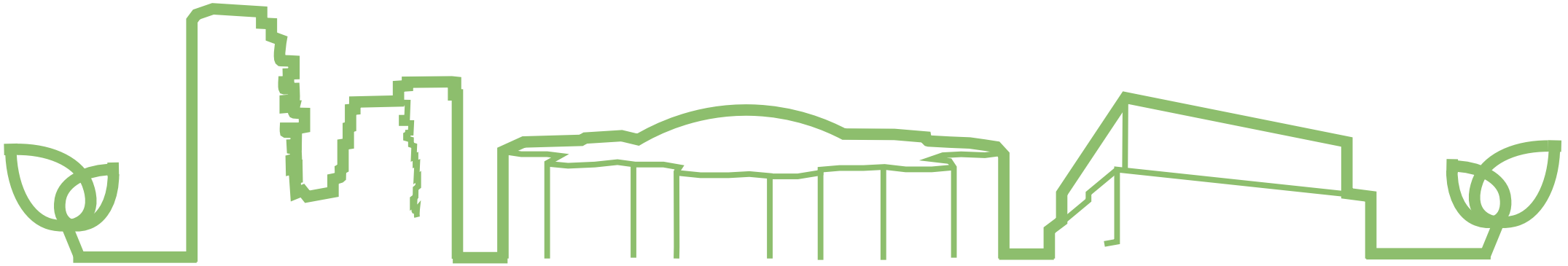

The ‘new’ zero-energy office building

The impact of Dutch regulatory changes on the development of energy efficient office buildings

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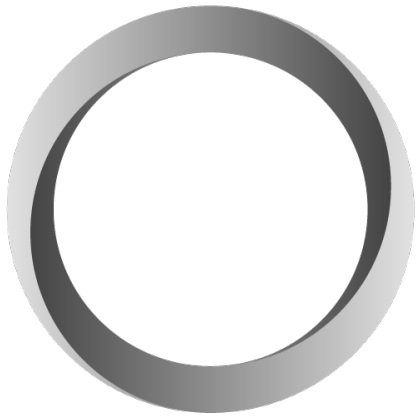
Lukas van Veen | P5 | June 2020



EDGE

Problem identification

Bijna Energie Neutrale Gebouwen
(Nearly Zero Energy Buildings)

Scope definition

- **Office buildings** in Business districts of Amsterdam
- Energy efficiency according to the **BENG framework**
- **Operational energy.** Embodied & demolition energy not considered
- **Building-related energy**: Heating, cooling, ventilation, lighting, warm water and (de-) humidification

Main research question

How can zero-energy offices buildings be developed considering new energy regulations?

Sub research questions

Policies

What are the new energy policies and which policies are most influential?

Technical feasibility

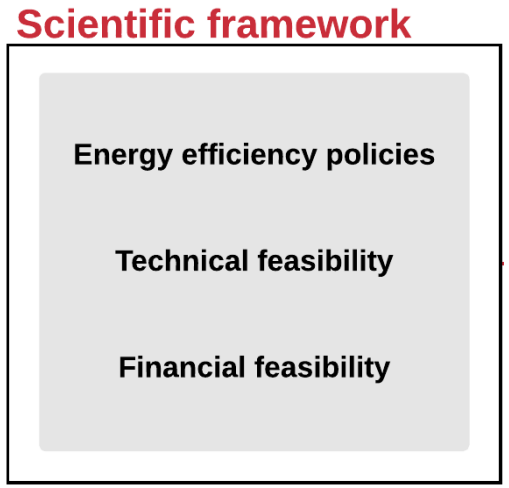
What are technical characteristics of zero-energy office buildings within the framework of current and new energy policies?

Financial feasibility

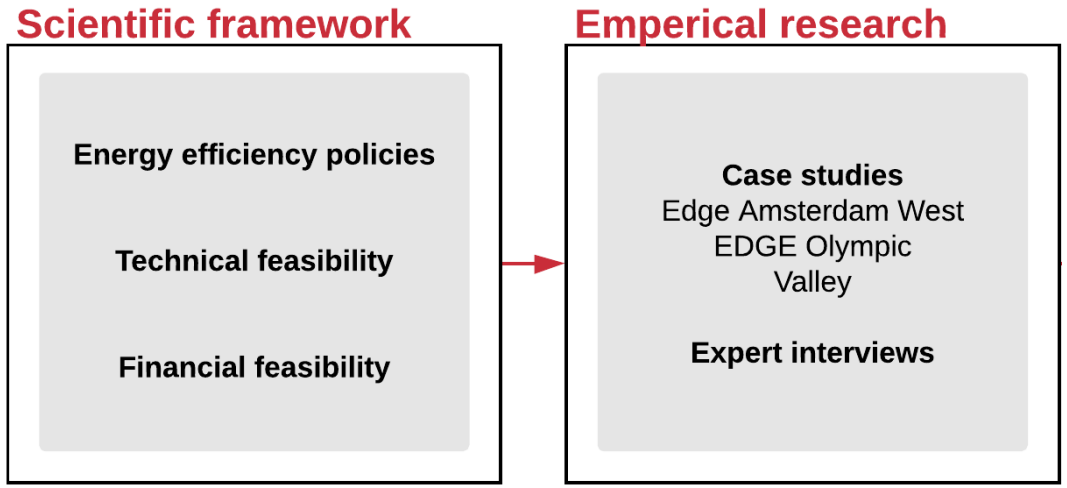
What are the costs and benefits of zero-energy office buildings within the framework of current and new energy policies?

Research framework

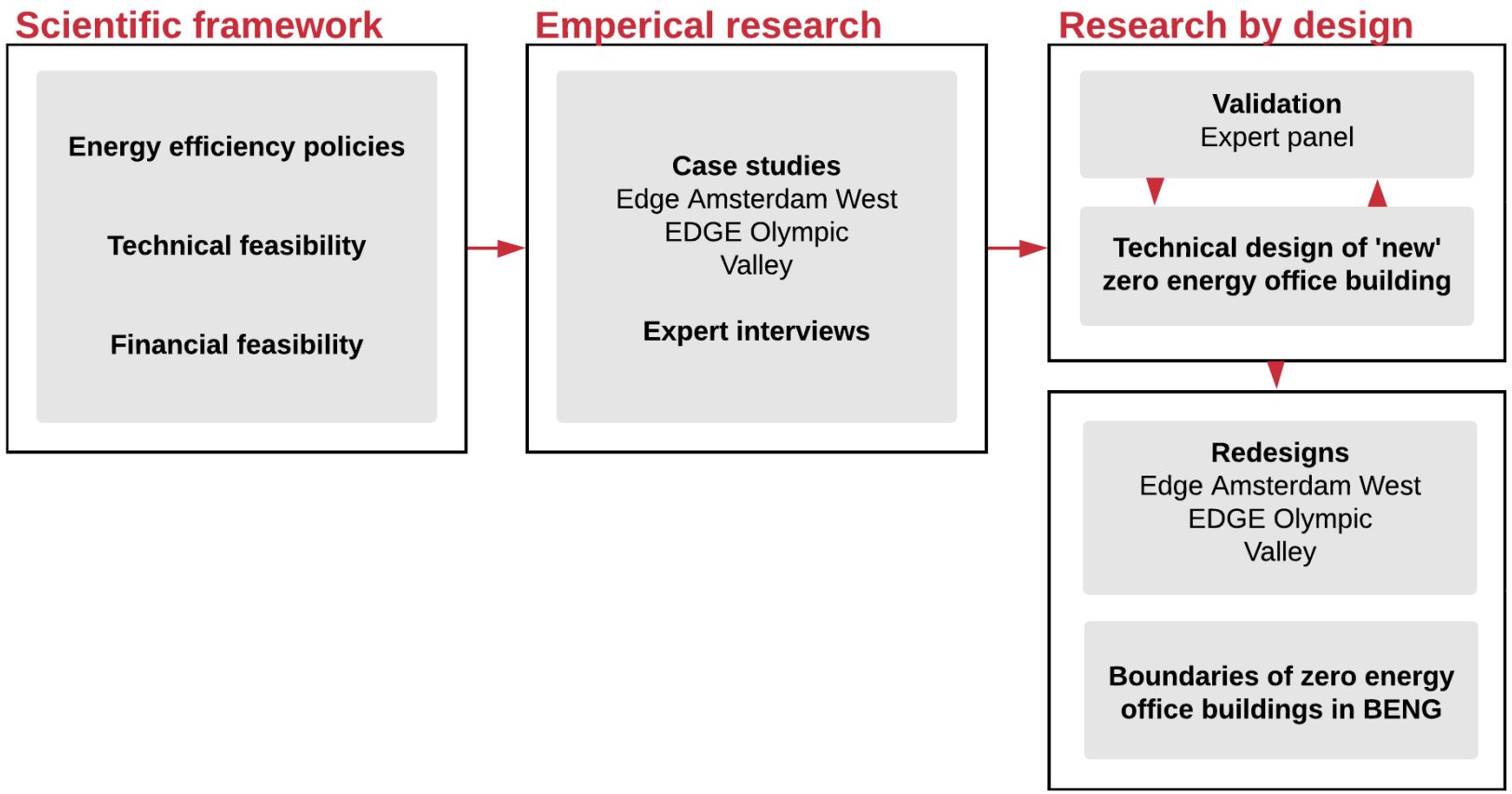
Research framework



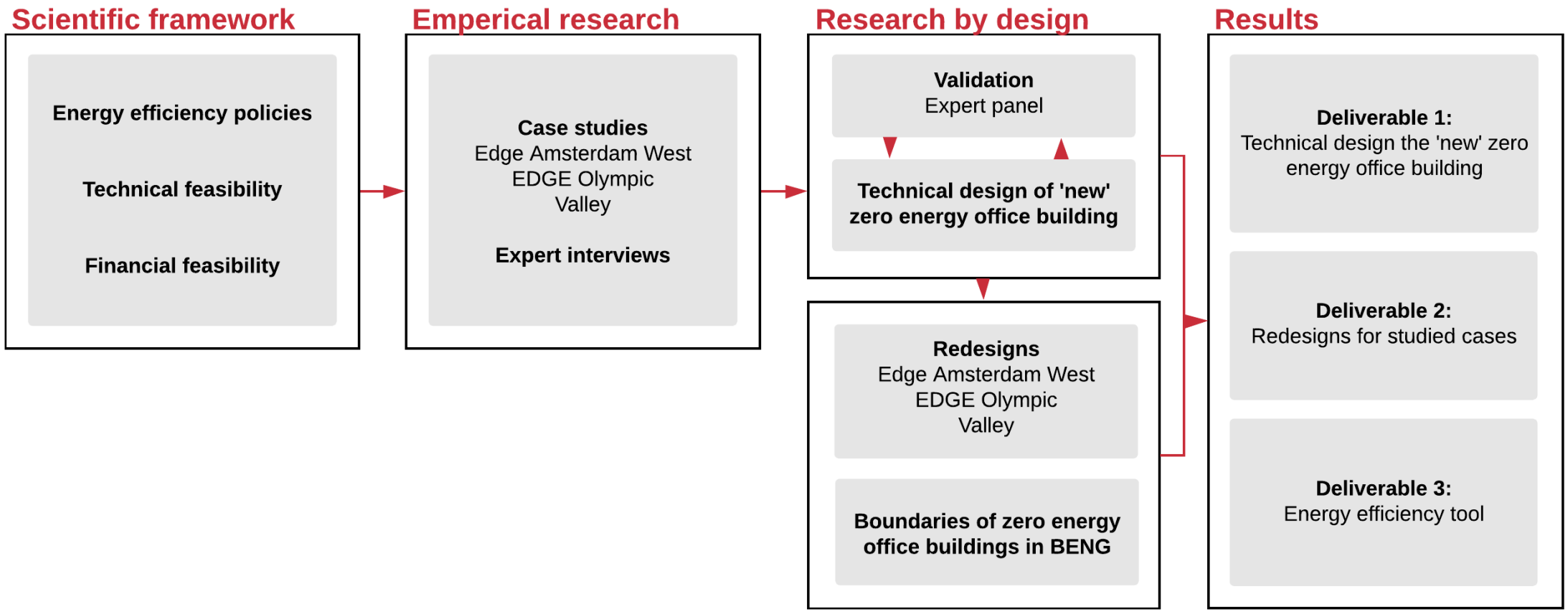
Research framework



Research framework



Research framework



I. SCIENTIFIC FRAMEWORK

Policy development

United Nations Paris Climate Agreement (2015)

↓

European Union EPBD (2018)

↓

EPC & NEN7120 → BENG & NTA8800 (2021)

BENG 1

The maximum energy requirement [kWh / m² per year]

≤ **90**

BENG 2

The max. energy consumption after netting [kWh / m² per year]

≤ **40**

BENG 3

Minimal share of renewable energy [%]

≥**30**

Without allocation of energy generated outside the building plot!

Policy compatibility

Paris Agreement Proof → 30 kWh/m²

BENG & NTA8800 → 40 kWh/m²

European Union EPBD (2018)

"...energy required should be covered to a very significant extent from renewable sources..."

BENG & NTA8800 (2021)

Minimal share of renewable energy → 30%

Policy independency

“not striving for the minimal requirements imposed by a policy”

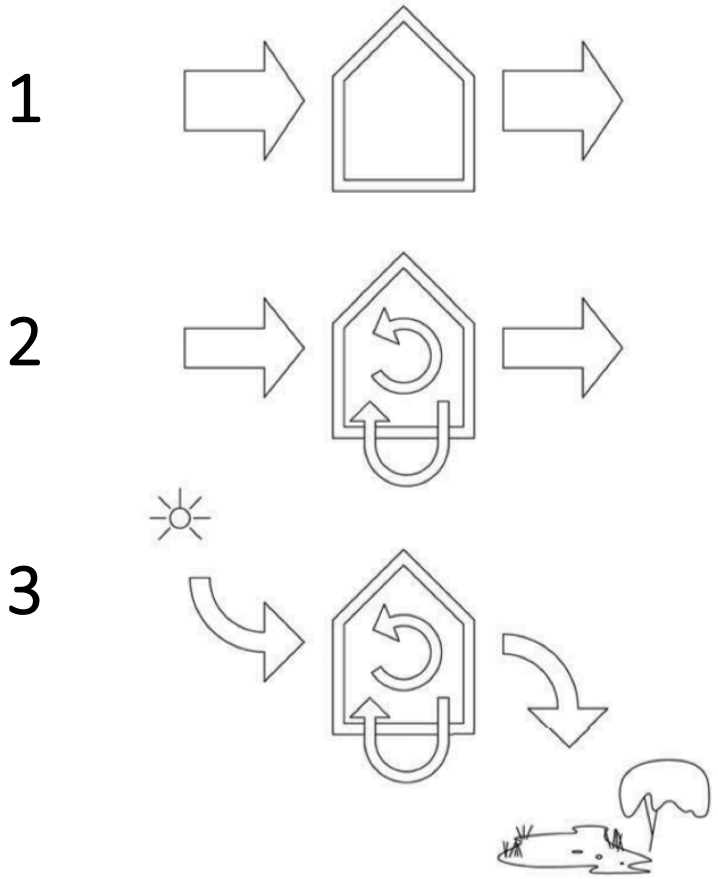
Technical feasibility

New Stepped Strategy

1: reduce energy consumption

2: Reuse residual energy

3: Generate renewable energy



New Stepped Strategy & BENG

BENG 1

Determined by envelope characteristics & bioclimatic design strategies

Step 1 of New Stepped Strategy

BENG 2

Determined by the efficiency of installations & renewable energy supply

Step 1 & 3 of New Stepped Strategy

BENG 3

Determined by the renewable energy supply

Step 2 & 3 of New Stepped Strategy

Financial feasibility

Financial feasibility

Higher investment costs

BREEAM: **0% – 3.3%**

Higher market value & gross rental income

Higher market value: **8,6% - 9,10%**
Higher rental income: **8,4% - 13,8%**

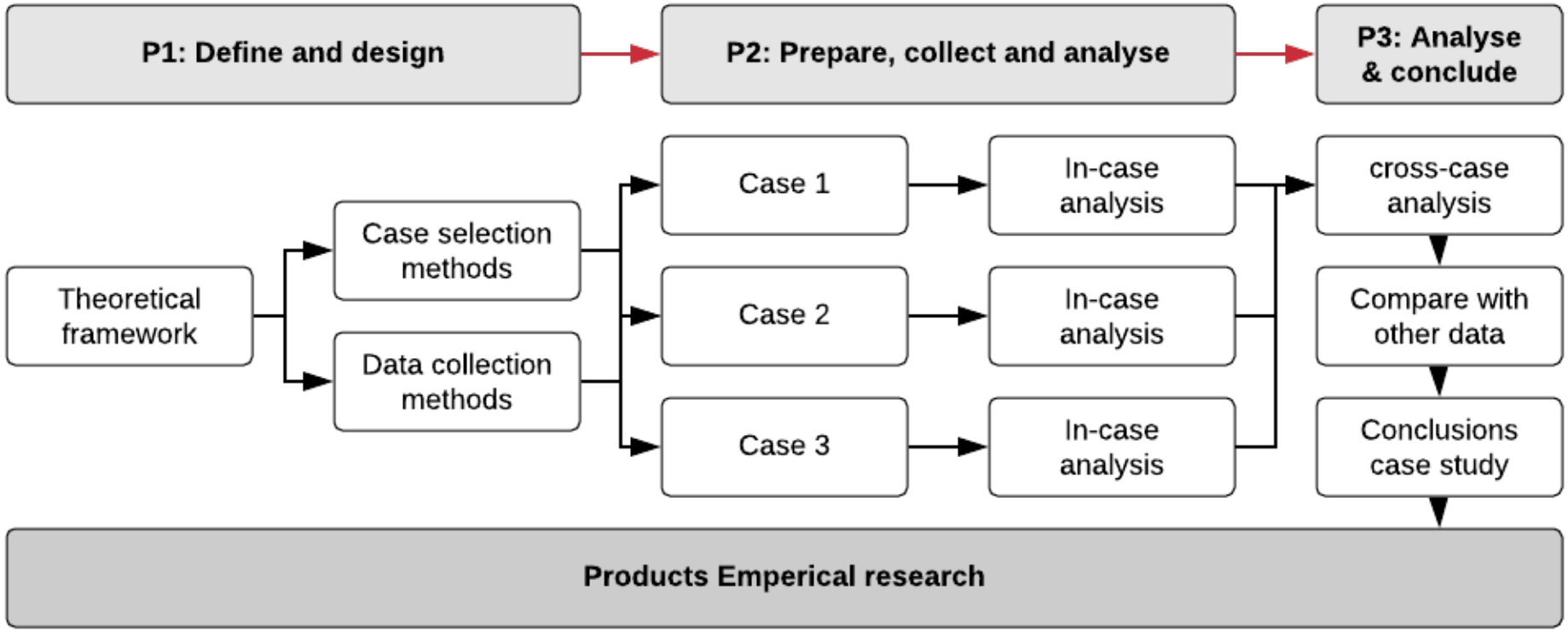
Other benefits

- **Increased occupancy rates**
- **Increased lease renewals**
- **Increased tenant satisfaction**
- **Improved corporate reputation**
- **Reduced operating costs**

Feasible & profitable

II. EMPERICAL RESEARCH

Case study protocol



EDGE Amsterdam West

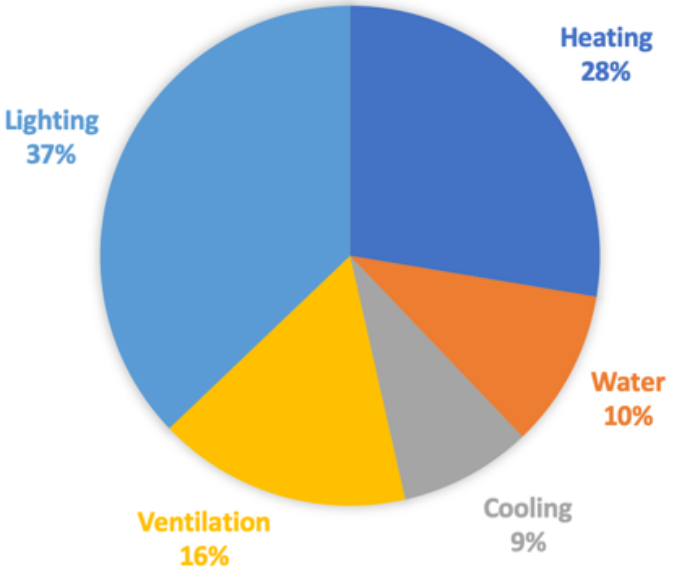
Redevelopment 1970 office building

Under construction

48,000 m^2 LFA Office

Zero energy on-site

Thermal energy storage systems & PV



EDGE Olympic

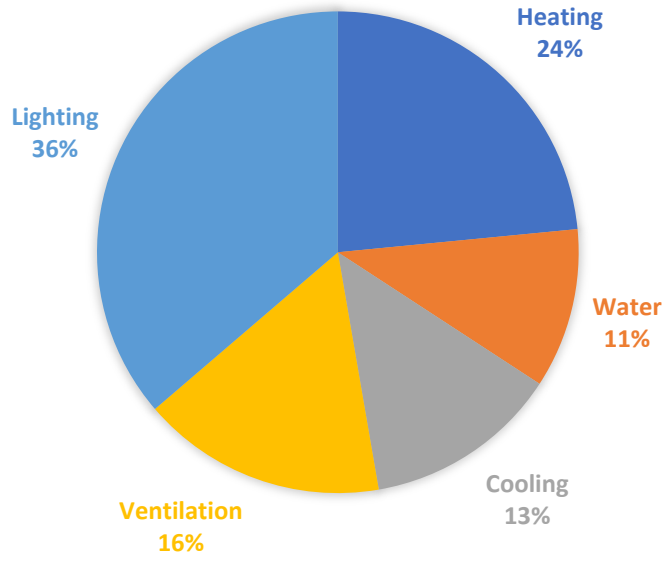
Redevelopment 1990 office building

Delivered in may 2018

Office 8.639 m^2 LFA Office

Zero energy building

District heating & PV



Valley

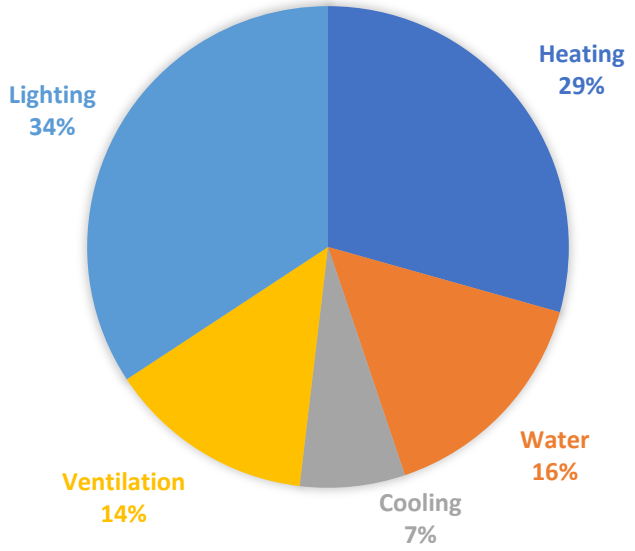
Newly build multifunctional building

Under construction

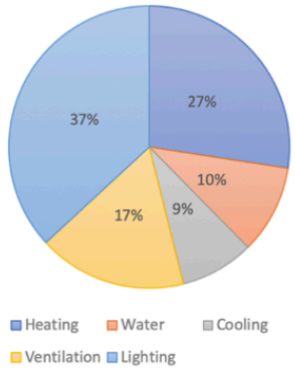
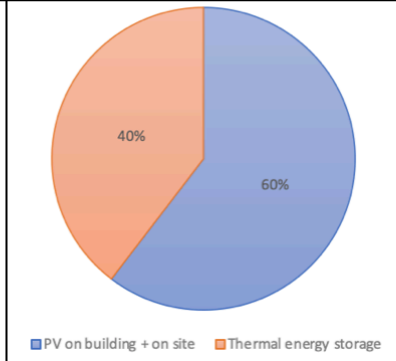
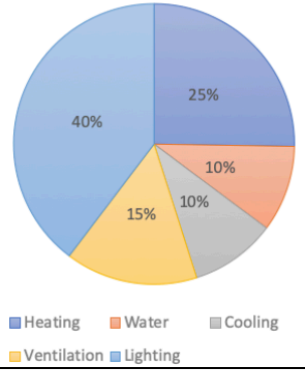
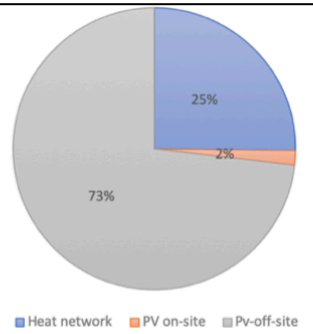
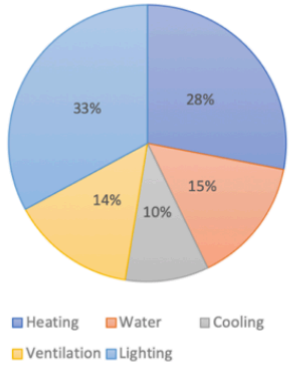
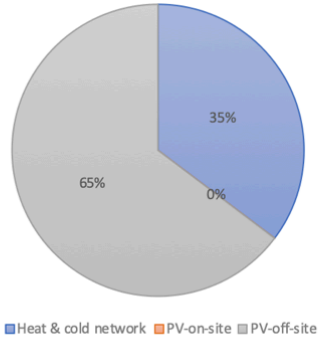
46,200 m^2 LFA mixed functions

Energy positive building

District heating & PV



Cross-case: technical perspective

	Energy demand	Relative energy demand	Energy supply	Relative energy supply	Energy systems
EDGE Amsterdam West	2.656.659 kWh/year 52,02 kWh/m²/year		2.656.883 kWh/year 52,03 kWh/m²/year		**Heating & Cooling:** Thermal energy storage system **Electricity:** PV on roof of the building(s) PV on surrounding plot
EDGE Olympic	808.295 kWh/year 70,18 kWh/m²/year		808.295 kWh/year 70,18 kWh/m²/year		**Heating:** Heat network **Electricity:** PV on roof of the building(s) + PV-off-site
Valley	2.960.567 kWh/year 66,47 kWh/m²/year		3.331.672 kWh/year 74,81 kWh/m²/year		**Heating & Cooling:** Heat & Cold network **Electricity:** PV-off-site

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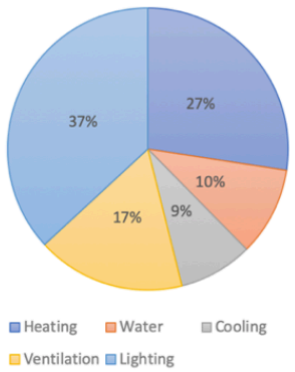
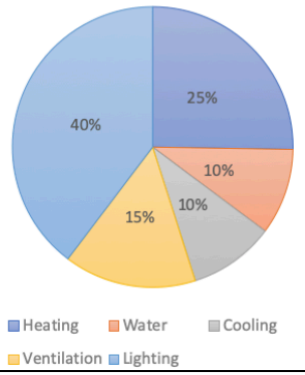
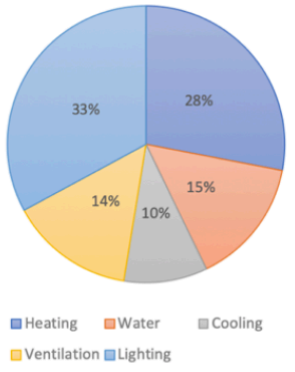
EDGE Amsterdam West	2.656.659 kWh/year 52,02 kWh/m²/year		2.656.883 kWh/year 52,03 kWh/m²/year		Heating & Cooling: Thermal energy storage system Electricity: PV on roof of the building(s) PV on surrounding plot
EDGE Olympic	808.295 kWh/year 70,18 kWh/m²/year		808.295 kWh/year 70,18 kWh/m²/year		Heating: Heat network Electricity: PV on roof of the building(s) + PV-off-site
Valley	2.960.567 kWh/year 66,47 kWh/m²/year		3.331.672 kWh/year 74,81 kWh/m²/year		Heating & Cooling: Heat & Cold network Electricity: PV-off-site

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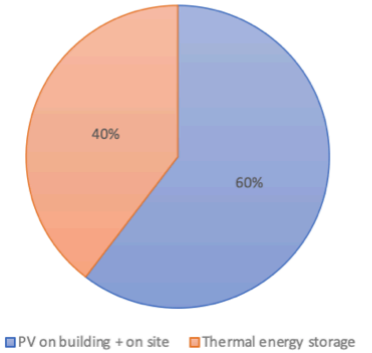
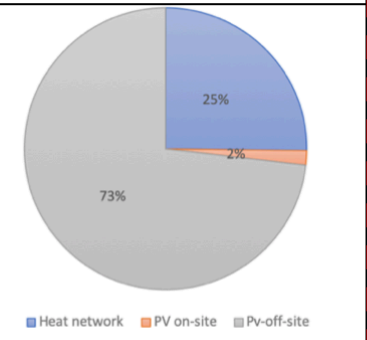
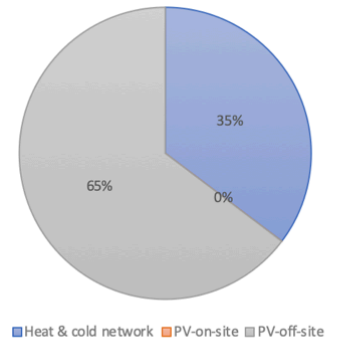
EDGE Amsterdam West	2.656.659 kWh/year 52,02 kWh/m²/year		2.656.883 kWh/year 52,03 kWh/m²/year		Heating & Cooling: Thermal energy storage system Electricity: PV on roof of the building(s) PV on surrounding plot
EDGE Olympic	808.295 kWh/year 70,18 kWh/m²/year		808.295 kWh/year 70,18 kWh/m²/year		Heating: Heat network Electricity: PV on roof of the building(s) + PV-off-site
Valley	2.960.567 kWh/year 66,47 kWh/m²/year		3.331.672 kWh/year 74,81 kWh/m²/year		Heating & Cooling: Heat & Cold network Electricity: PV-off-site

Cross-case: technical perspective

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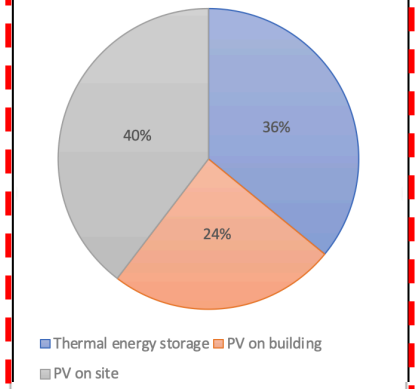
EDGE Amsterdam West	2.656.659 kWh/year 52,02 kWh/m²/year		2.656.883 kWh/year 52,03 kWh/m²/year		**Heating & Cooling:** Thermal energy storage system **Electricity:** PV on roof of the building(s) PV on surrounding plot
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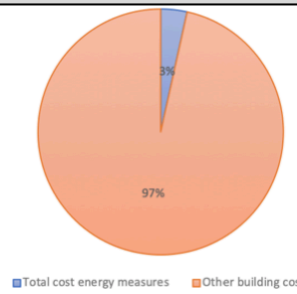
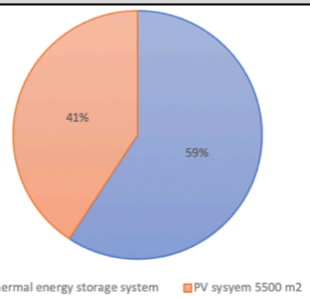
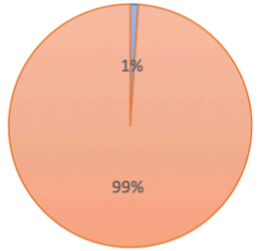
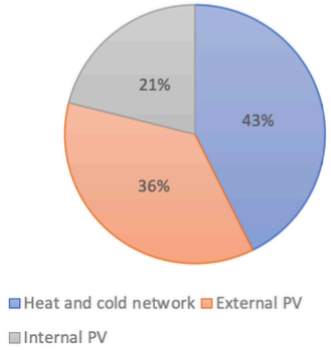
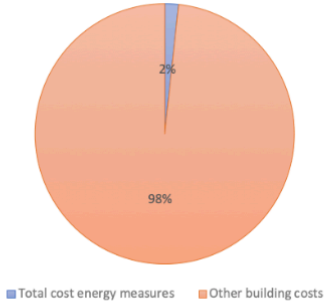
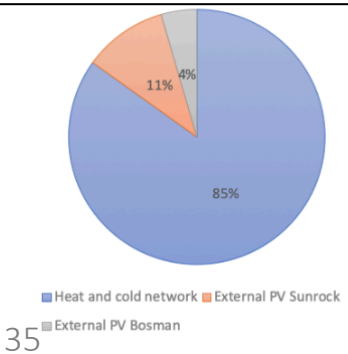
Cross-case: financial perspective

	construction costs	Relative construction costs energy supplying measures	energy supplying measures	Financial structures	Local rent levels
EDGE Amsterdam West	€ 82.400.282, - € 1.613,59 / m²	 € 55,80 / m²		***Construction costs*** *TESS:* € 1.688.138,03 / € 1,77 / kWh *On-site PV:* € 1.161.557,51 / € 0,68 / kWh ***Payback periods Eneco*** *TESS:* 23.6 years *On-site PV:* 9.1 years	€190 - 250, - / m² / year (2020)
EDGE Olympic	€ 16.399.000, - € 1.399,71 / m²	 € 14,99 / m²		***Construction costs*** *Heat network:* € 50.589, / € 0,25 / kWh *On-site PV:* € 25.000, / € 1,87 / kWh *Off-site PV:* € 43.000, -/ € 0,07 / kWh	€300 - €325 / m² / year. (2016) €400 - €450 / m² / year. (2020)
Valley	€ 130.080.000, - € 2.920,65 / m²	 € 49,96 / m²		***Construction costs*** *Heat and Cold network:* € 1.889.351, / € 1,69 / kWh *Off-site PV installation:* € 335.750, / € 0,16 / kWh	€400 - €450 / m² / year. (2020)

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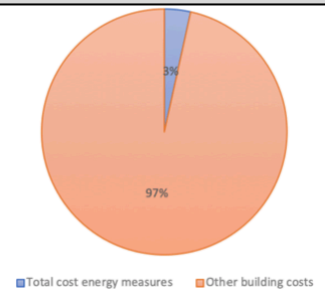
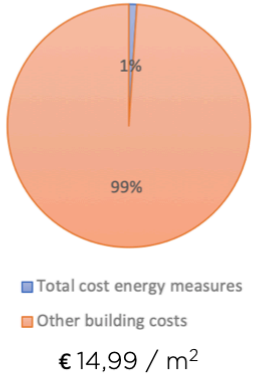
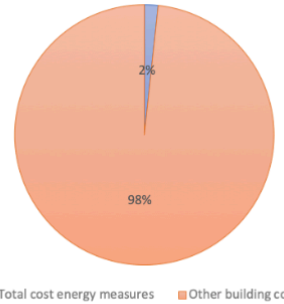
EDGE Amsterdam West	€ 82.400.282, - € 1.613,59 / m²	 € 55,80 / m²		*Construction costs* *TESS:* € 1.688.138,03 / € 1,77 / kWh *On-site PV:* € 1.161.557,51 / € 0,68 / kWh *Payback periods Eneco* *TESS:* 23.6 years *On-site PV:* 9.1 years	€190 - 250, - / m² / year (2020)
EDGE Olympic	€ 16.399.000, - € 1.399,71 / m²	 € 14,99 / m²		*Construction costs* *Heat network:* € 50.589, / € 0,25 / kWh *On-site PV:* € 25.000, / € 1,87 / kWh *Off-site PV:* € 43.000, -/ € 0,07 / kWh	€300 - €325 / m² / year. (2016) €400 - €450 / m² / year. (2020)
Valley	€ 130.080.000, - € 2.920,65 / m²	 € 49,96 / m²		*Construction costs* *Heat and Cold network:* € 1.889.351, / € 1,69 / kWh *Off-site PV installation:* € 335.750, / € 0,16 / kWh	€400 - €450 / m² / year. (2020)

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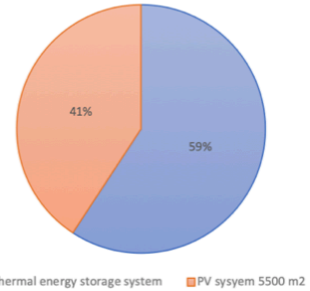
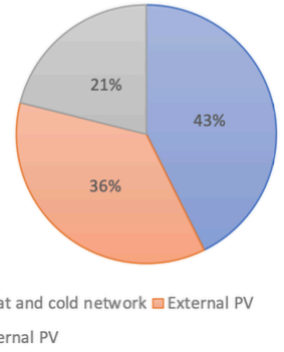
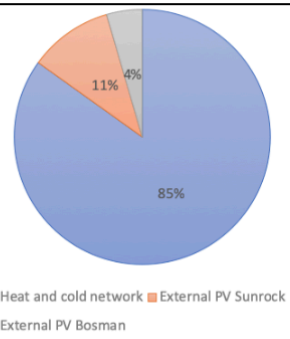
EDGE Amsterdam West	€ 82.400.282, - € 1.613,59 / m²	€ 55,80 / m²		*Construction costs* *TESS:* € 1.688.138,03 / € 1,77 / kWh *On-site PV:* € 1.161.557,51 / € 0,68 / kWh *Payback periods Eneco* *TESS:* 23.6 years *On-site PV:* 9.1 years	€190 - 250, - / m² / year (2020)
EDGE Olympic	€ 16.399.000, - € 1.399,71 / m²	€ 14,99 / m²		*Construction costs* *Heat network:* € 50.589, / € 0,25 / kWh *On-site PV:* € 25.000, / € 1,87 / kWh *Off-site PV:* € 43.000, -/ € 0,07 / kWh	€300 - €325 / m² / year. (2016) €400 - €450 / m² / year. (2020)
Valley	€ 130.080.000, - € 2.920,65 / m²	€ 49,96 / m²		*Construction costs* *Heat and Cold network:* € 1.889.351, / € 1,69 / kWh *Off-site PV installation:* € 335.750, / € 0,16 / kWh	€400 - €450 / m² / year. (2020)

Cross-case: policy perspective

	EPC: NEN 7120	BENG: NTA 8800	Paris proof
EDGE Amsterdam West	EPC 0,000 Energy label A++++ Zero energy on-site office building	***2015 - NEN 7120*** *BENG 1* ≤ 50: 33,6 *BENG 2* ≤ 25: 0,0 *BENG 3* ≥ 50: 100 ***2019 - NTA 8800 (NEN 7120)*** *BENG 1* ≤ 90*: 33,6 *BENG 2* ≤ 40: 0,0 *BENG 3* ≥ 30: 100	*Building-related energy consumption:* 0 kWh / m ^{2} / year *Max building-related energy consumption Paris Proof:* 30-35 kWh / m ^{2} / year 0 ≤ 30-35 → Paris Proof
EDGE Olympic	EPC -0,002 Energy label A++++ Zero energy office building	***2015 - NEN 7120*** *BENG 1* ≤ 50: 39,6 *BENG 2* ≤ 25: 44,4 *BENG 3* ≥ 50: 26,7 ***2019 - NTA 8800 (NEN 7120)*** *BENG 1* ≤ 90*: 39,6 *BENG 2* ≤ 40: 44,4 *BENG 3* ≥ 30: 26,7	*Building-related energy consumption:* 34,59 kWh / m ^{2} / year *Max building-related energy consumption Paris Proof:* 30-35 kWh / m ^{2} / year 44,36 ≥ 30-35 ≠Paris Proof
Valley	EPC -0,309 Energy label A++++ Energy positive office building	***2015 - NEN 7120*** *BENG 1* ≤ 50: 40,1 *BENG 2* ≤ 25: 41,4 *BENG 3* ≥ 50: 30,8 ***2019 - NTA 8800 (NEN 7120)*** *BENG 1* ≤ 90*: 40,1 *BENG 2* ≤ 40: 41,4 *BENG 3* ≥ 30: 30,8	*Building-related energy consumption:* 34,59 kWh / m ^{2} / year *Max building-related energy consumption Paris Proof:* 30-35 kWh / m ^{2} / year 41,4 ≥ 30-35 ≠Paris Proof

Cross-case: policy perspective

	EPC: NEN 7120	BENG: NTA 8800	Paris proof
EDGE Amsterdam West	EPC 0,000 Energy label A++++ Zero energy on-site office building	*2015 - NEN 7120* BENG 1: ≤ 50 — 33,6 BENG 2: ≤ 25 — 0,0 BENG 3: ≥ 50 — 100 *2019 - NTA 8800 (NEN 7120)* BENG 1: ≤ 90* — 33,6 BENG 2: ≤ 40 — 0,0 BENG 3: ≥ 30 — 100	*Building-related energy consumption:* 0 kWh / m ² / year *Max building-related energy consumption Paris Proof:* 30-35 kWh / m ² / year 0 ≤ 30-35 → Paris Proof
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Cross-case: policy perspective

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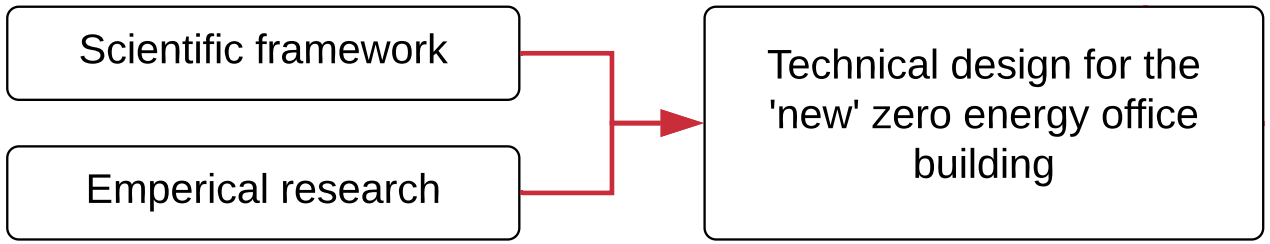
III. RESEARCH FOR DESIGN

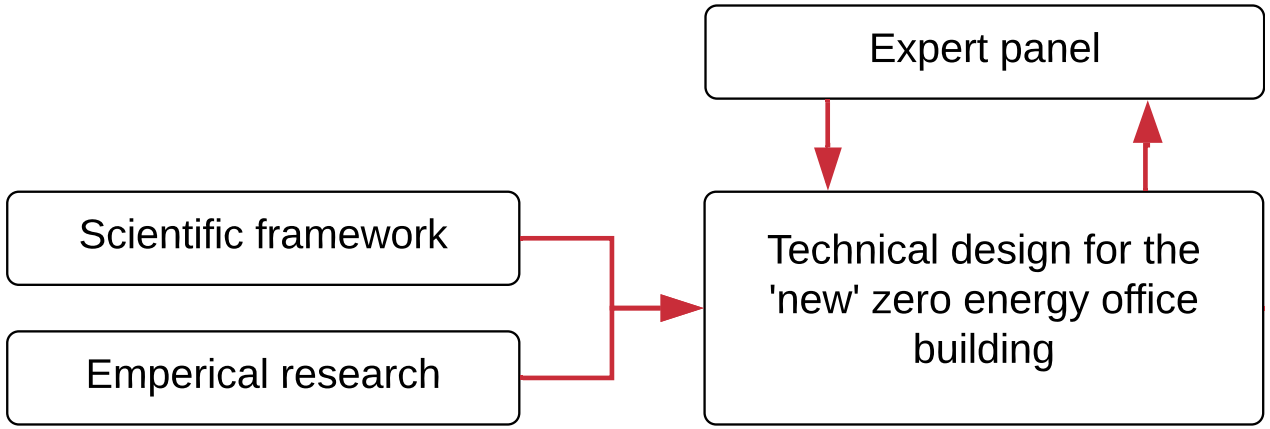
Technical design

Technical design for the 'new' zero energy office building

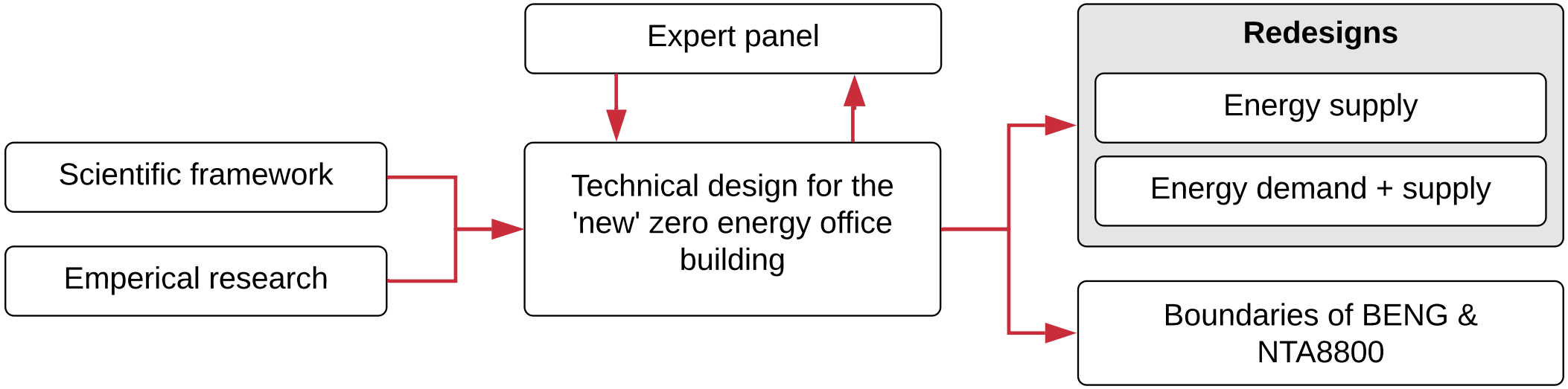
Design protocol



Design protocol



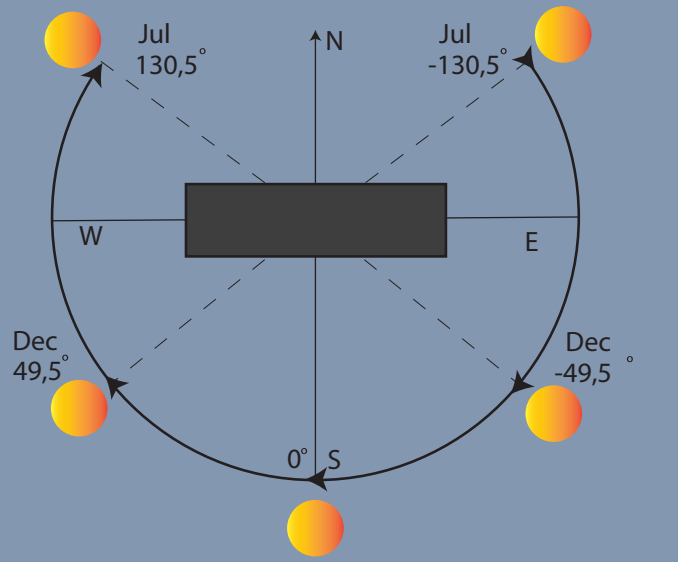
Design protocol

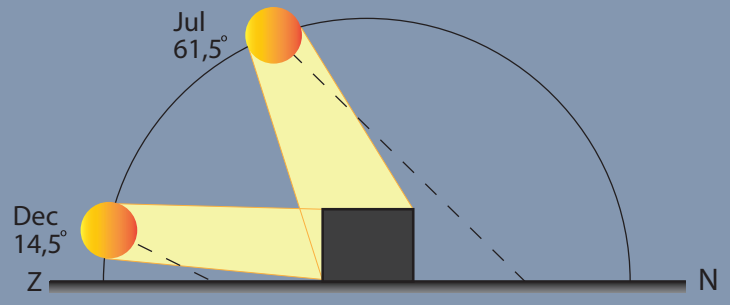


Technical design for the ‘new’ zero-energy office building (TD)

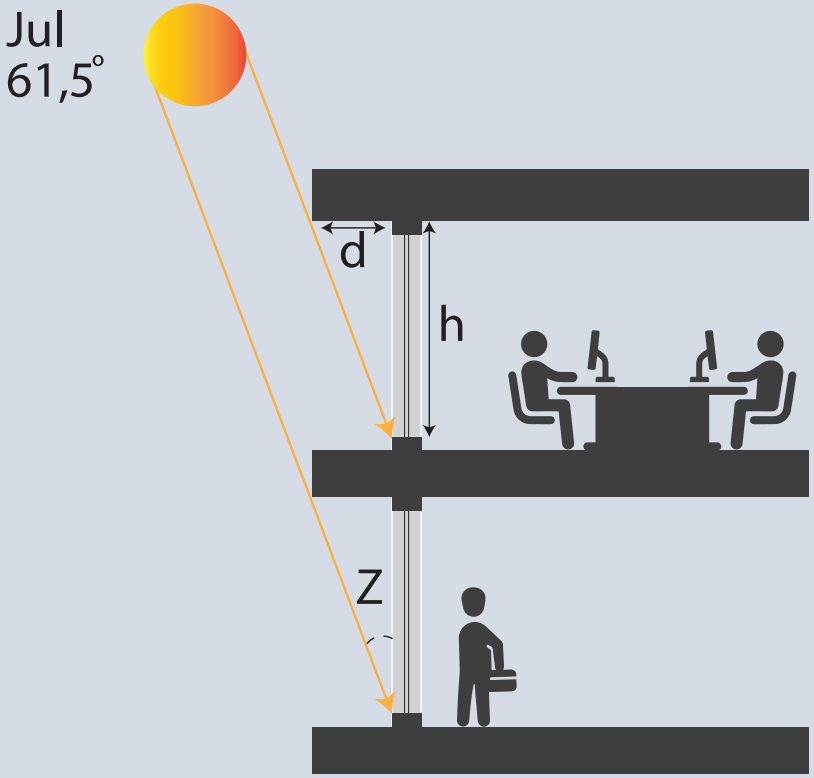
TD step 1 – Minimize energy demand

Building orientation

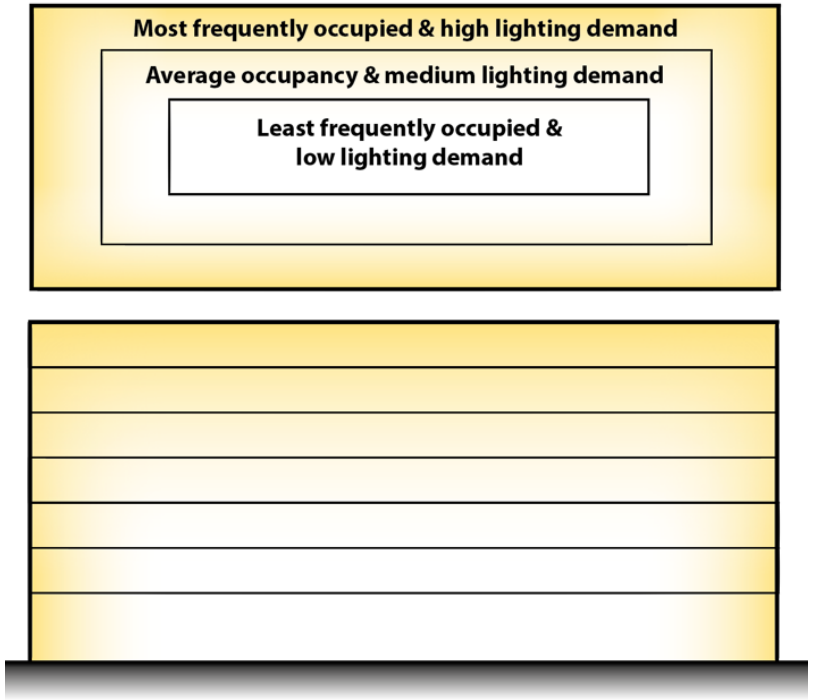




Sun shading



Building layout



TD step 1 – Minimize energy demand

Artificial lighting

- Multilevel switching
- Manual dimming
- Occupancy sensors
- Area dependant illuminances
- Daylight linked lux sensors

HVAC

- Heat recovery systems
- Hybrid ventilation systems
- Occupancy based HVAC

TD step 2 – Reuse energy in buildings

Attune

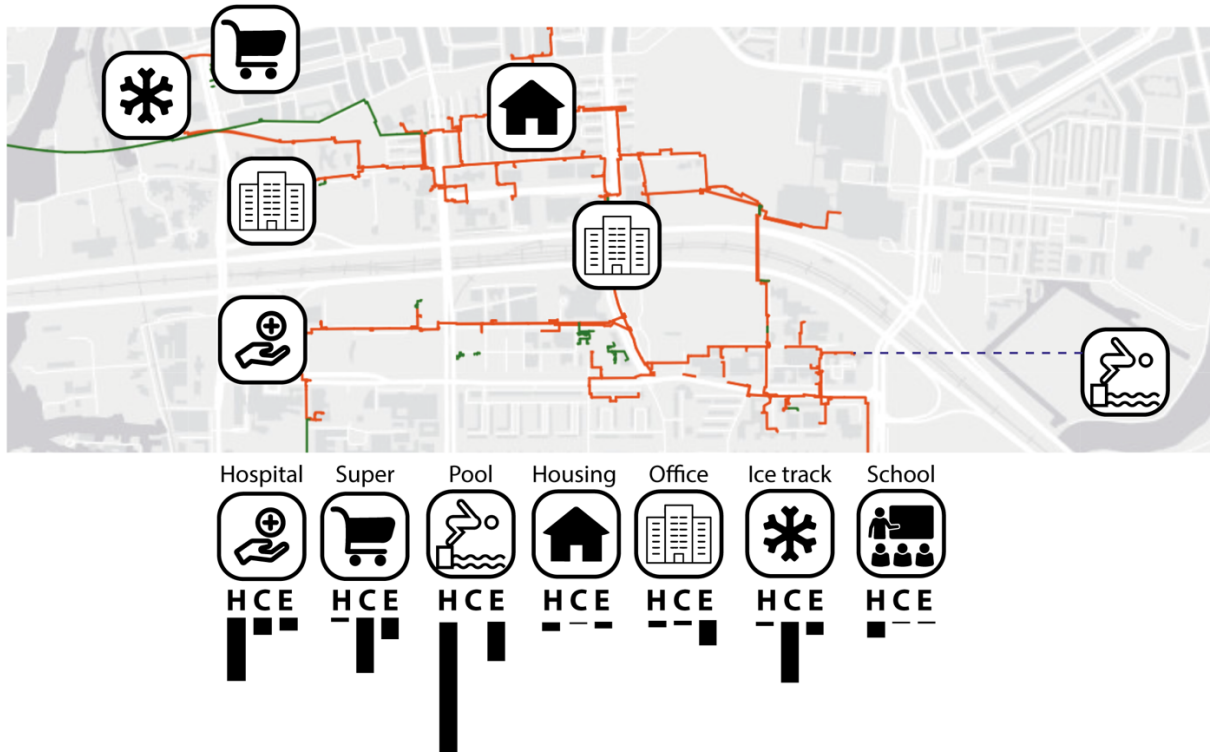
- Compartmentalize building layout
- Attune building layout

Store

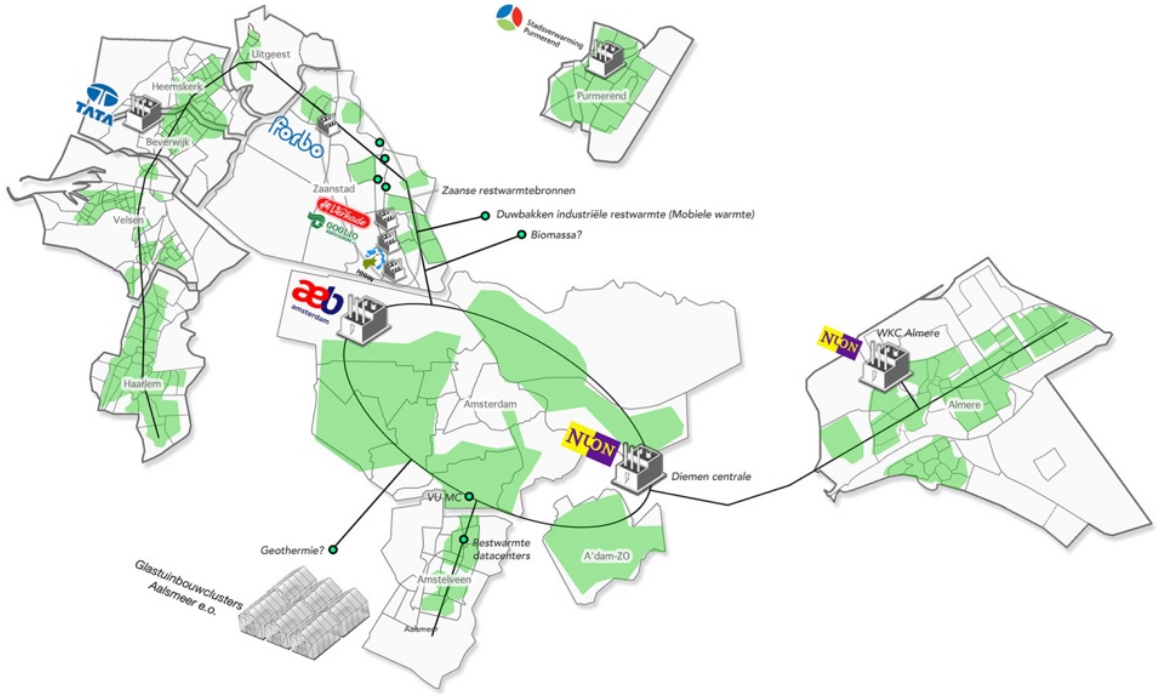
- Thermal energy storage systems
- Electrical energy storage systems

TD step 2 – Reuse energy in areas

Neighbourhood level



City level

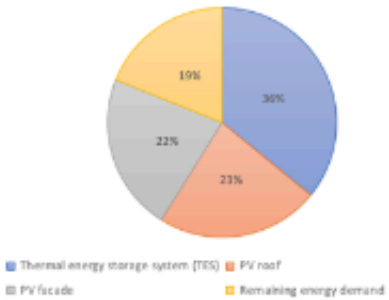
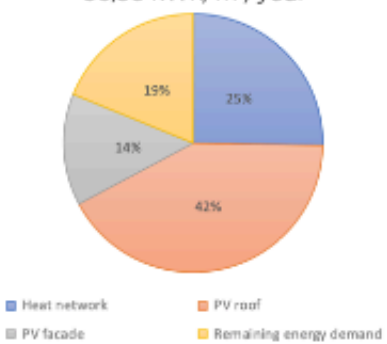
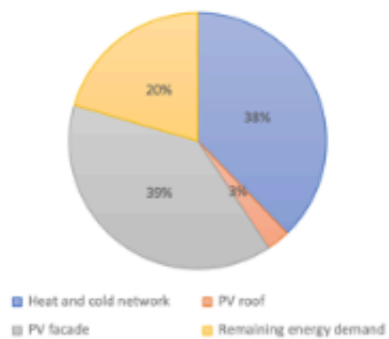


TD step 3 – Renewable energy supply

- Photovoltaic panels
  - Industrial PV
  - Building integrated PV
- Heat pumps
  - Air source
  - Water source
  - Ground source
- Biomass

Redesigns of studied cases

Redesign: changing the energy supply

	Energy demand (intact)	Moddeled energy systems	Moddeled energy supply	BENG	Paris Proof
EDGE Amsterdam West	2.656.659 kWh/year 52,02 kWh/m²/year	**Heating & Cooling:** Thermal energy storage system **Electricity:** PV on roof of the building(s) + PV on facades	2.154.133,47 kWh/year 42,18 kWh/m²/year 	***2015 - NEN 7120*** *BENG 1* ≤ 50: 35,1 *BENG 2* ≤ 25: 9,8 *BENG 3* ≥ 50: 81,1 ***2019 - NTA 8800 (NEN 7120)*** *BENG 1* ≤ 90*: 35,1 *BENG 2* ≤ 40: 9,8 *BENG 3* ≥ 30: 81,1	9,84 ≤ 30-35 → Paris Proof
EDGE Olympic	808.295 kWh/year 70,18 kWh/m²/year	**Heating:** Heat network **Electricity:** PV on roof of the building + PV on facades	655.716,04 kWh/year 56,93 kWh/m²/year 	***2015 - NEN 7120*** *BENG 1* ≤ 50: 40,1 *BENG 2* ≤ 25: 13,2 *BENG 3* ≥ 50: 81,3 ***2019 - NTA 8800 (NEN 7120)*** *BENG 1* ≤ 90*: 40,1 *BENG 2* ≤ 40: 13,2 *BENG 3* ≥ 30: 81,3	13,2 ≤ 30-35 → Paris Proof
Valley	2.960.567 kWh/year 66,47 kWh/m²/year	**Heating & Cooling:** Heat & Cold network **Electricity:** PV on roof of the building(s) + PV on facades	605.862,92 kWh/year 52,86 kWh/m²/year 	***2015 - NEN 7120*** *BENG 1* ≤ 50: 39,2 *BENG 2* ≤ 25: 13,6 *BENG 3* ≥ 50: 79,5 ***2019 - NTA 8800 (NEN 7120)*** *BENG 1* ≤ 90*: 39,2 *BENG 2* ≤ 40: 13,6 *BENG 3* ≥ 30: 79,5	13,6 ≤ 30-35 → Paris Proof

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Redesign: changing the energy supply

Changing the renewable energy supply is not sufficient for developing zero-energy office buildings

Redesign Olympic: demand + supply

Redesign EDGE Olympic

Reduce energy demand

- Exterior shading elements
- Hybrid ventilation system
- Smart installation systems
- Closed thermal energy loops

Redesign EDGE Olympic

	BENG 1 **Energy requirement** **[kWh/m².yr]**	**BENG 2** **Primary energy consumption** **[kWh/m².yr]**	**BENG 3** **Share renewable energy** **[%]**
2015 - NEN 7120	≤ 50	≤ 25	≥50
Redesign EDGE Olympic	**33,1**	**-0,56**	**101,1**
2019 - NTA 8800	*Als/Ag* ≤ 1,8 BENG 1 ≤ 90 *Als/Ag*> 1,8 BENG 1 ≤ 90 + 30 * (Als/Ag -1,8)	≤ 40	≥30
Redesign EDGE Olympic	**33,1**	**-0,56**	**101,1**

Redesign EDGE Olympic

	BENG 1 Energy requirement [kWh/m².yr]	**BENG 2 Primary energy consumption [kWh/m².yr]**	BENG 3 Share renewable energy [%]
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2019 - NTA 8800	*Als/Ag* ≤ 1,8 BENG 1 ≤ 90 *Als/Ag*> 1,8 BENG 1 ≤ 90 + 30 * (Als/Ag -1,8)	**≤ 40**	≥30
Redesign EDGE Olympic	**33,1**	**-0,56**	**101,1**

Redesign: EDGE Olympic financials

Investment for redesign

Additional investments	
Additional solar panels roof	*€ 686.549*
BIPV facade	*€ 609.480*
Avoided investments	
Allocation external PV	*€ 43.000*
Façade finish replaced	*€ 135.000*
Total additional investment	*€ 1.118.029*

Payback period

Total payback period of redesign = 16,83 years

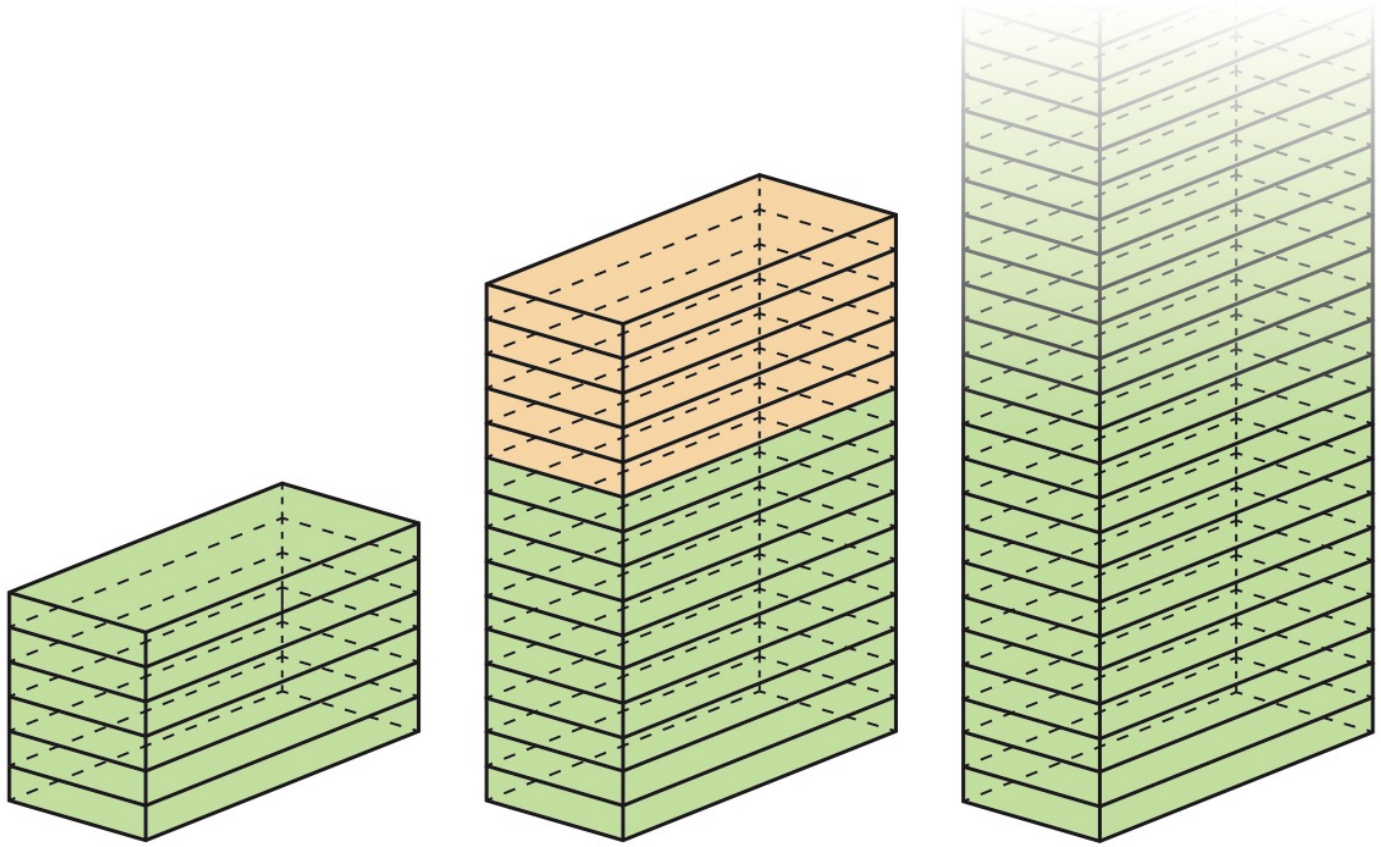
	Industrial PV Roof	BIPV façade East / west	BIPV façade South
Yields [kWh/yr]	338.524	42.170	55.809
Investment	€ 686.549	296.055	313.425
Payback Periods	9,6 years	30,3 years	24,3 years

Redesign: EDGE Olympic

Redesign of EDGE Olympic energy positive

What are the boundaries within BENG?

Boundaries within BENG



Zero-energy
Max. 6 floors
RFR < 0,5
B.C.I. = 0,671

Paris Proof
Max. 10-15 floors
RFR < 0,3 - 0,2
B.C.I. = 0,515 - 0,439

BENG compliant
Infinite floors
RFR = ∞
B.C.I. = ∞

Reduce energy demand

Building compactness
< 0,67

External shading:
Overhanging / lammelas

Hybrid ventilation
natural in, mechanical out

Energy efficient **building layout**

Optimal building orientation
East-West

N

Reuse residual energy

compartmentalized layout

HVAC: Closed energy loops

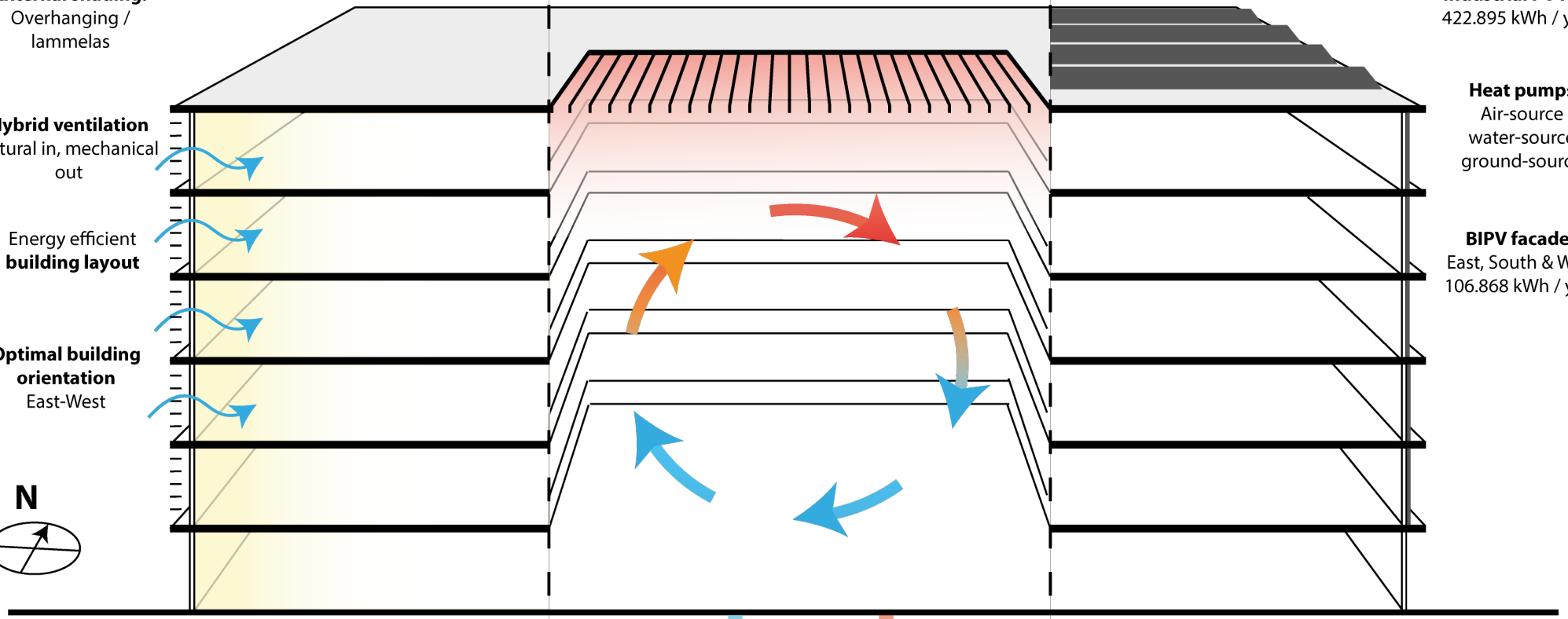
Thermal energy storage systems

Produce renewably

Industrial PV roof
422.895 kWh / year

Heat pumps
Air-source
water-source
ground-source

BIPV facades
East, South & West
106.868 kWh / year



	kWh / m2 * year	kWh / year
Heating	14,3	254.281
Warm water	5,29	94.330
Cooling	4,42	78.816
Ventilation	8,88	158.346
Lighting	19,17	341.835
Total	52,02	927.610

	kWh / m2 * year	kWh / year
PV Roof	23,72	422.895
BIPV facades	6,37	106.868
TESS	24,44	113.560
Total	54,52	972.273

IV.
CONCLUSIONS

Conclusions policies

New vs current policies

BENG can be considered an improvement with current EPC policy

Policy compatibility

National energy efficiency regulations not in line with international climate goals

Future problems

Buildings that are build according to new regulations will form problems for the near future

Conclusions technical feasibility

Current designs

Two out of three studied cases do not comply with BENG

BENG compliant & Paris Proof

By redesigning the energy supply all cases can become BENG & Paris Proof

Zero-energy

Cases need to reduce energy demand in order to become zero energy

Technically feasible

Technically feasible to develop zero-energy office buildings within BENG framework up to 6 floors

Conclusions financial feasibility

Higher market values and gross rent income

Higher investments & lower operating costs.

Change in energy supply causes higher investment and lower operating costs.

Payback period redesign EDGE Olympic < 17 years

Financially feasible

Financially feasible to develop zero-energy office buildings within BENG framework up to 6 floors

Main research question

How can zero energy offices buildings be developed considering new energy regulations?

Recommendations

Practice

Be policy independent

Use the technical design prescribed by this thesis

Analyse & implement new innovative technologies

Revaluate & discuss market standards

Policy makers

Improve norms to match international agreements

Maximise transparency

Reduce uncertainty

Future research

Lower market rents

Comparative research on possibilities on locations with lower market rents

Reusing residual energy in neighbourhoods

Applicability and stakeholder collaboration in neighbourhoods

Energy efficient use

Research on how developers can steer and contribute to the energy-efficient use of (office) buildings.

Discussion

Discussion: Limitations

High market rents Amsterdam

Energy efficiency data

Policy independency: catch 22

Functionality, aesthetics & sustainability

Discussion: Theory vs practice

Theoretical energy savings vs actual energy savings

Reusing residual energy in neighbourhoods.

Building-related & user-related energy consumption


Questions?