Graduation presentation

Bart Pieters 4036255

Building Technology
Green Building Innovations

Tutors:
Ir. S. Broersma - Dr. Ir. H. Zijlstra - Ir. T. Konstantinou

External examiner:
Ir. W.J. Quist
Part 1: Introduction
Part 1: Introduction

Part 2: Design
Part 1: Introduction

Part 2: Design

Part 3: Results
Part 1

INTRODUCTION
What Is my graduation about?
TRANSFORMATION
TRANSFORMATION

Rezoning of vacant office buildings to residential buildings
Former office building, Wageningen
Former tax office, Utrecht

- Gerbrandystraat 20, Utrecht;
- Originally built in 1981;
- Structural vacant since 2010;
Original drawing
Low-rise (3 storeys)
Low-rise (3 storeys)

Original drawing
Low-rise (3 storeys)
Low-rise (3 storeys)

Original drawing

SIDE - ENTRANCE

ENTRANCE
high-rise (11 storeys)
From office towards an energy-neutral residential building
From office towards an energy-neutral residential building
From office towards an energy-neutral residential building
Why This specific topic?
EMPTY OFFICE CITY
• Dutch office market 46.5 million m²
- Dutch office market: 46.5 million m²
- Office vacancy: 6.6 million m² (14%)
• Dutch office market 46.5 million m$^2$
• Office vacancy 6.6 million m$^2$ (14%)
• Healthy market 5-6 %
• Dutch office market 46.5 million m²
• Office vacancy 6.6 million m² (14%)
• Healthy market 5-6 %
• Over supply 4.2 million m² (9%)
• Dutch office market 46.5 million m²
• Office vacancy 6.6 million m² (14%)
• Healthy market 5-6 %
• Over supply 4.2 million m² (9%)
• Expectancy 2020 12.2 million m² (26%)
- Dutch office market: 46.5 million m²
- Office vacancy: 6.6 million m² (14%)
- Healthy market: 5-6%
- Over supply: 4.2 million m² (9%)
- Expectancy 2020: 12.2 million m² (26%)
- Flex working: 22.2 million m² (48%)
22.2 millon m² = 3100 soccer fields of 7140 m²
Housing shortage 600,000

5% ↑

Residents (x million)

EMPTY OFFICE CITY
### Energy Consumers

<table>
<thead>
<tr>
<th>Products</th>
<th>Energy</th>
<th>Consumers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>16%</td>
<td>31 kWh/p/d</td>
</tr>
<tr>
<td><strong>Energy</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>20%</td>
<td>39 kWh/p/d</td>
</tr>
<tr>
<td></td>
<td>12%</td>
<td>24 kWh/p/d</td>
</tr>
<tr>
<td></td>
<td>13%</td>
<td>25 kWh/p/d</td>
</tr>
<tr>
<td></td>
<td>3%</td>
<td>6 kWh/p/d</td>
</tr>
<tr>
<td><strong>Built environment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>41%</td>
<td>39 kWh/p/d</td>
</tr>
<tr>
<td><strong>National transport</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>25%</td>
<td>23 kWh/p/d</td>
</tr>
<tr>
<td><strong>Industry</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>27%</td>
<td>25 kWh/p/d</td>
</tr>
<tr>
<td><strong>agriculture</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7%</td>
<td>7 kWh/p/d</td>
</tr>
<tr>
<td><strong>Other fossil</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>8%</td>
<td>3 kWh/p/d</td>
</tr>
<tr>
<td></td>
<td>7%</td>
<td>3 kWh/p/d</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100%</td>
<td>94 kWh/p/d</td>
</tr>
<tr>
<td><strong>International aviation and maritime</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>20%</td>
<td>38 kWh/p/d</td>
</tr>
<tr>
<td><strong>Conversion Losses</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>16%</td>
<td>30 kWh/p/d</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100%</td>
<td>193 kWh/p/d</td>
</tr>
</tbody>
</table>
Spring agreement 2008

2011: 25% $\text{co}_2$ reduction
2015: 50% $\text{co}_2$ reduction
2020: Energy neutral
From office towards an energy-neutral residential building
Former tax office, Utrecht?
Why the former tax office?

Former tax office, Utrecht

- Energy crisis 1973;
- Gloomy colours;
- Modular structure;
- Prefabrication of elements.
Research question

(How) Is it possible to transform the former tax office in Utrecht to an energy-neutral residential building?
Research question

(How) Is it possible to transform the former tax office in Utrecht to an energy-neutral residential building?

Thesis objective

The transformation of the former tax office in Utrecht towards an energy neutral residential building’
From office to energy-neutral residential building
from office to energy-neutral residential building
Energy-neutral definition

The energy within the project boundary is equal to the amount of renewable energy that is generated within the project boundary (PEGO, 2009)
Energy-neutral definition

The energy within the project boundary is equal to the amount of renewable energy that is generated within the project boundary (PEGO, 2009)

3 energy streams
Energy-neutral definition

1. Building related energy
Energy-neutral definition

1. Building related energy
2. User related energy
Energy-neutral definition

1. Building related energy
2. User related energy
3. Material related energy
Energy-neutral definition

1. Building related energy
2. User related energy
3. Material related energy
How is this objective achieved?
1 Transformation design
1  Transformation design

2  BRE  - EPC ENORM
     - Manual calc

3  URE  - Greencalc+

4  MRE  - Greencalc+
     - Manual calc
1 Transformation design

2 BRE - EPC ENORM - Manual calc

3 URE - Greencalc+

4 MRE - Greencalc+ - Manual calc

Mega joules (GJ)
1 Transformation design

2 BRE - EPC ENORM - Manual calc

3 URE - Greencalc+

4 MRE - Greencalc+ - Manual calc

5a Energy consumption (GJ)
1. Transformation design

2. BRE → EPC ENORM → Manual calc → Mega Joules (GJ)

3. URE → Greencalc+ → +

4. MRE → Greencalc+ → Manual calc → +

5a. Energy consumption (GJ)

5b. Energy production (GJ)

6. Energy balance (GJ)
Part 2
TRANSFORMATION DESIGN
Design aims
Design aims
Design aims
Design assumptions

Program

• Starter housings: 5330 m²
• Business premises: 720 m²
• Dorm rooms: 3500 m²
• Communal area: 1450 m²

Total: 11000 m²
**Design assumptions**

<table>
<thead>
<tr>
<th>Program</th>
<th>User comfort</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Starter housings:</td>
<td>• Two-sided openable windows and daylight access</td>
</tr>
<tr>
<td>5330 m²</td>
<td></td>
</tr>
<tr>
<td>• Business premises:</td>
<td>• Outdoor space for every building user</td>
</tr>
<tr>
<td>720 m²</td>
<td></td>
</tr>
<tr>
<td>• Dorm rooms:</td>
<td></td>
</tr>
<tr>
<td>3500 m²</td>
<td></td>
</tr>
<tr>
<td>• Communal area:</td>
<td></td>
</tr>
<tr>
<td>1450 m²</td>
<td></td>
</tr>
<tr>
<td><strong>Total:</strong> 11000 m²</td>
<td></td>
</tr>
</tbody>
</table>
1. Define habitable floor area
### SPATIAL DESIGN

<table>
<thead>
<tr>
<th></th>
<th>stair cases</th>
<th>deep dark areas</th>
<th>sufficient daylight</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 m²</td>
<td>50 m²</td>
<td>34 m²</td>
<td>50 m²</td>
</tr>
<tr>
<td>50 m²</td>
<td>50 m²</td>
<td>34 m²</td>
<td>50 m²</td>
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<td>50 m²</td>
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<td>34 m²</td>
<td>50 m²</td>
</tr>
<tr>
<td>50 m²</td>
<td>50 m²</td>
<td>34 m²</td>
<td>50 m²</td>
</tr>
<tr>
<td></td>
<td>50 m²</td>
<td>15 m²</td>
<td>50 m²</td>
</tr>
</tbody>
</table>

**Total Area:**
- **2900 m² (35%)**
- **4800 m² (63%)**
Program division
Low-rise, more adjustments
High-rise, less adjustments
SPATIAL DESIGN

1. Define habitable floor area
2. Increase habitable floor area
Spatial Design

- Staircases
- Deep dark areas
- Sufficient daylight

Dimensions:
- 2900 m² (35%)
- 4900 m² (60%)
**SPATIAL DESIGN**

**Original volume**

11000 m² (15 storeys)

**Extended volume**

13000 m² (16 storeys)

+ 1600 m²

+ 400 m²
SPATIAL DESIGN

• 13,000 m² is a rough estimation
SPATIAL DESIGN

• 13,000 m² is a rough estimation
• Optimized to gain floor space
SPATIAL DESIGN

• 13,000 m² is a rough estimation
• Optimized to gain floor space
• Specification required
• Influenced by climate design
CLIMATE DESIGN
CLIMATE DESIGN

1. Thermal boundary
2. Ventilation
3. Heating / Tap water
4. Cooling
5. Energy production
Former tax office
Former tax office

Office area
Office area
Office area
Office area
Basement
Former tax office
## 1. Thermal boundary

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vertical section</strong></td>
<td><strong>Horizontal section</strong></td>
<td><strong>Description</strong></td>
<td><strong>Possible threats</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Internal element insulation. (maintaining original facade)</td>
<td>Probability of failure during execution</td>
</tr>
<tr>
<td></td>
<td></td>
<td>External insulation layer. (maintaining original facade)</td>
<td>Probability of failure during execution</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Internal insulation. Box in box principle. (maintaining original facade)</td>
<td>Low Probability of failure, but no thermal mass utilization</td>
</tr>
<tr>
<td></td>
<td></td>
<td>External insulation layer. (facade removal or displacement)</td>
<td>Low probability of failure during execution</td>
</tr>
<tr>
<td><strong>Thermal mass</strong></td>
<td><strong>Transmission</strong></td>
<td><strong>Cold bridges</strong></td>
<td><strong>Possible threats</strong></td>
</tr>
<tr>
<td>Maximal utilization of thermal mass, two side: floor, upper floor</td>
<td>Lower quality insulation by re-use of existing facade elements</td>
<td>High risk at the point of floor-facade connection</td>
<td>Probability of failure during execution</td>
</tr>
<tr>
<td>Maximal utilization of thermal mass, two side: floor, upper floor, facade</td>
<td>Lower insulation values</td>
<td>High-risk through re-use of aluminium window frames</td>
<td>Probability of failure during execution</td>
</tr>
<tr>
<td>No use of thermal mass</td>
<td>Low transmission through internal boxes</td>
<td>Low-risk, depending on the type of timber structure.</td>
<td>Low Probability of failure, but no thermal mass utilization</td>
</tr>
<tr>
<td>Medium use of thermal mass: facade beams and upper floor</td>
<td>Low transmission through better performance facade</td>
<td>Medium risk, depending on the type of thermal bridge breaks for balconies</td>
<td>Low probability of failure during execution</td>
</tr>
</tbody>
</table>
1. Thermal boundary

OUTSIDE

ATRIUM

Thermal mass
1. Thermal boundary

winter solar gain

OUTSIDE

ATRIUM
2. Ventilation
2. Ventilation

Natural air supply

OUTSIDE

ATRIUM
2. Ventilation

OUTSIDE

ATRIUM

Extended living room
2. Ventilation

OUTSIDE

bypass

ATRIUM
2. Ventilation

FORMER TAX OFFICE

TRANSFORMATION ZERO
2. Ventilation
2. Ventilation

40% reduction
2. Ventilation
2. Ventilation
4. Heating - Cooling - Tap water
5. Energy production
5. Energy production

**PV panels**
- Type: ZEN power cp
- Location: Roof low-rise

**Solar glass**
- Type: Optisol screen
- Location: Conservatories

**PV-T panels**
- Type: Volther hybrid
- Location: Roof high-rise
Electrical energy
1205 GJ

Thermal energy
1461 GJ
Living room: 28.48 m²
Bed room: 10.3 m²
Bathroom: 5.75 m²
Toilet: 2.4 m²
Balcony: 1.51 m²
Final program

Low-rise (4 storeys):  7000 m²
High-rise (12 storeys):  6600 m²

Total:  13600 m²
FORMER TAX OFFICE

TRANSFORMATION ZERO
Part 3

ENERGY BALANCE RESULTS
1. **BRE**

2. **URE**

3. **MRE**

---

Energy Balance (GJ)
ENERGY SCALE

1 GJ
ENERGY SCALE

1 GJ = 1000 MJ
ENERGY SCALE

1 GJ = 1000 MJ = 278 kWh
ENERGY SCALE

1 GJ = 1000 MJ = 278 kWh

Electricity consumption average domestic household
3300 kWh/J = 12 GJ/J
1. BRE
1. BRE

VENTILATION
E 390,037 MJ
LIGHTING
E 313,344 MJ

TAP WATER
H 1,294,513 MJ
E 11,820 MJ
HEATING
H E 1,670,762 MJ 467,439 MJ
COOLING
C E 357,512 MJ 62,669 MJ

12˚C 6˚C
LT-CV
OUT
40˚C
LT-CV
IN
35˚C
HT-CV
OUT

TAP WATER
70˚C
HT-CV
IN
40˚C

70˚C
LT-CV
IN
40˚C
LT-CV
OUT

70˚C
HEAT PUMP
condenser
70˚C
HEAT PUMP
evaporator

40˚C
LT-CV
IN
35˚C
LT-CV
OUT

12˚C 21˚C
LT-CV / HT-CV

HEAT PUMP
condenser
70˚C
HEAT PUMP
evaporator

12˚C
STS
IN
12˚C
STS
UIT
21˚C
STS
IN
21˚C
STS
UIT

GAS ENGINE

PV-PANELS
E 1,204,526 MJ

THERM-PANELS
H 1,460,870 MJ

SELF

Electricity
897,479 MJ
Electricity export
1,353,394 MJ
Heat
80,198 MJ
Cold
80,198 MJ

Avoided use
1,671,696 MJ
Gas
946,989 MJ

SEASONAL THERMAL STORE
1. BRE
Primary energy consumption 2935 GJ

Avoided energy consumption ($\text{nEP}_{\text{us}}$) - 637 GJ

Energy production - uptake ($\text{EP}_{\text{us}}$) - 307 GJ

Energy production - export ($\text{EP}_{\text{exp}}$) - 2331 GJ +

Energy performance ($\text{EP}_{\text{tot}}$) - 340 GJ

Specific EP per m$^2$ (13600 m$^2$) - 25 GJ
BRE | BALANCE

Primary energy consumption 2935 GJ

Avoided energy consumption ($nEP_{us}$) - 637 GJ
Energy production - uptake ($EP_{us}$) - 307 GJ
Energy production - export ($EP_{exp}$) - 2331 GJ +

Energy performance ($EP_{tot}$) - 340 GJ
Specific EP per m² (13600 m²) -25 GJ

EPC -0.07
EPC-requirement 0.6
BRE | BALANCE

2935 GJ  
3275 GJ  
-340 GJ

Enough to compensate for the **URE** and **MRE**?
2935 GJ
63.5%

Consumption

- Heating (43%)
- Appliances (92%)
- Interior (2%)
- Installations (16%)
- Roofs (19%)
- Floors (20%)
- Partitions (15%)
- Facade (28%)
- Lichting (11%)
- Tap water (27%)
- Water (8%)
- Cooling (6%)
- Ventilation (13%)

2935 GJ
63.5%
1094 GJ
23.7%
592 GJ
12.8%
-307 GJ
-637 GJ
-2331 GJ
1347 GJ
### ENERGY BALANCE

**Consumption**

- **2935 GJ** (63.5%)
  - Tap water (27%)
  - Lichting (11%)
  - Cooling (6%)
  - Ventilation (13%)
  - Heating (43%)

- **1094 GJ** (23.7%)
  - Water (8%)
  - Appliances (92%)
**ENERGY BALANCE**

Consumption:
- Heating (43%): 2935 GJ (63.5%)
- Appliances (92%): 1094 GJ (23.7%)
- Facade (28%): 592 GJ (12.8%)
- Other
  - Tap water (27%)
  - Lighting (11%)
  - Cooling (6%)
  - Ventilation (13%)
  - Water (8%)
  - Interior (2%)
  - Installations (16%)
  - Roofs (19%)
  - Floors (20%)
  - Partitions (15%)

2935 GJ
63.5%
1094 GJ
23.7%
592 GJ
12.8%
ENERGY BALANCE

Consumption

- Heating (43%)
  - Appliances (92%)
  - Interior (2%)
  - Installations (16%)
  - Roofs (19%)
  - Floors (20%)
  - Partitions (15%)
  - Facade (28%)
  - Water (8%)
  - Lichting (11%)
  - Cooling (6%)
  - Ventilation (13%)
- Tap water (27%)

Production

- 1094 GJ (23.7%)
  - Appliances (92%)
  - Water (8%)
- 592 GJ (12.8%)

Balance

- 2935 GJ (63.5%)
- 1347 GJ
- -307 GJ
- -637 GJ
- -2331 GJ
How to bridge 30% energy shortage
ENERGY BALANCE

• Less energy consumption
ENERGY BALANCE

• Less energy consumption
• More efficient building services
ENERGY BALANCE

- Less energy consumption
- More efficient building services
- More energy production on site
ENERGY BALANCE

• Less energy consumption
• More efficient building services
• More energy production on site

PV-panels:
• $2000 \text{ m}^2 = 374 \text{ MWh} = 1350 \text{ GJ (}240 \text{ wp/m}^2\text{)}$
ENERGY BALANCE

PV-panels:

- **2000 m² = 374 mWh = 1350 GJ (240 wp/m²)**
- **1748 m² = 317 mWh = Shortage of 57 MWh**
ENERGY BALANCE

- PV-panels: 4% more efficient
- Applied panel: 16% efficient
- Latest advances: 27% efficient

- Not yet available for commercial use
Is it possible to transform the former tax office in Utrecht to an energy-neutral residential building?
MAIN-QUESTION

Is it possible to transform the former tax office in Utrecht to an energy-neutral residential building?

Answer

It is not yet possible if all energy streams are included, but future improvements in technology should make it possible
SUB-QUESTION

Is new build more sustainable than transformation in case of the former tax office in Utrecht?
Scenarios

1. Transformation SSH
2. Transformation Benraad
3. Demolition / New build
SUSTAINABILITY REPORT

Scenarios

1. Transformation SSH
2. Transformation Benraad
3. Demolition / New build
ENVIRONMENTAL CALCULATION

Index

Materials 135
Energy 220
Water 186
Total 173
SUB-QUESTION

Is new build more sustainable than transformation in case of the former tax office in Utrecht?

Answer

Transformation is a more sustainable alternative than New build in case of the former Tax office. Transformation Zero performs 40% better.
Environmental Index
Milieu Index Gebouw (Dutch)

- Accuracy: ± 10%
- Completion: 20xx

<table>
<thead>
<tr>
<th>Material</th>
<th>Energy</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABCDEFG</td>
<td>ABCDEFG</td>
<td>ABCDEFG</td>
</tr>
</tbody>
</table>

**Environmental Impact**

- Low environmental impact
  - 215 - 329
  - Transformation Zero
  - Requirement
  - 105 - 124
  - Former tax office

- High environmental impact

**MIG**

- 309

**Environmetnal Index**
• Performance: 11% above Dutch average
• Performance: 11% above Dutch average
• Performance: 37% above Dutch average
Acknowledgment

There have been many contributors to this work with which I have consulted or bounced ideas off. I’d like to thank them for their time and patience.

TUTORS:
ir. Siebe Broersma
Dr.ir. H. Zijlstra
ir. Thaleia Konstantinou

CONSULTS:
Dr.ir. L.J.J.H.M. Gommans
Dr.ir. W.H. van der Spoel
Ir. E.R. van den Ham
Ir. G.J. Arends
Ir. J. van der Vliet

SOUNDING BOARD:
ir. Erik van der Thiel
ir. Theo Mestemaker
Nick Veerman
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Ir. J. van der Vliet

SOUNDING BOARD:
ir. E. van der Thiel
ir. T.W.J. Mestemaker
Nick Veerman
**ENVIRONMENTAL CALCULATION**

**Own index**
Operation: Modified reference building
Result: Comparison New built

**Environmental index (MIG)**
Operation: Maintained reference building
Result: Comparison with reference building from 1990
**ENVIRONMENTAL CALCULATION**

Table of environmental costs:

<table>
<thead>
<tr>
<th></th>
<th>Milieuwinkosten per jaar</th>
<th>Milieuwinkosten/m² BVO</th>
<th>Eigen-index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materiaal</td>
<td>€ 16,768,-</td>
<td>€ 22,608,-</td>
<td>€ 0.81</td>
</tr>
<tr>
<td>Energie</td>
<td>€ 11,377,-</td>
<td>€ 24,997,-</td>
<td>€ 0.55</td>
</tr>
<tr>
<td>Water</td>
<td>€ 6,806,-</td>
<td>€ 12,688,-</td>
<td>€ 0.33</td>
</tr>
<tr>
<td>Totaal</td>
<td>€ 34,951,-</td>
<td>€ 60,293,-</td>
<td>€ 1.69</td>
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</table>