Energy producing Architecture

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TU Delft, AE || P5, 27 June 2014
Content

1. introduction
2. research
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1. introduction
Problem statement & relevance

Buildings are responsible for approximately 40% of total world energy consumption (Kapsalaki et al., 2012)
Problem statement & relevance

Most of this energy provided by fossil fuel energy, which will be depleted in 50 – 80 years...
Problem statement & relevance
The main objective is to research the feasibility of a CO2 neutral energy producing building
2. research
Location
Location
RINGAR PÅ VATTNET

Kunskap sprids i samhället som ringar på vattnet. De byggnader vi föreslår är startpunkten för Johanneberg Science Park. De har en planform som tecknar en serie ringar som symbol för spridandet av idéer och kunskap.
Research limitations

Hard requirements
- building regulations
- building envelope restrictions
- “miljöbyggnad” green building certification system
- program for the building

Soft requirements
- urban context
- architectural ambitions of the client (competition brief)

Minimum energy production requirements
- 221 400 kWh/year, based on the case study (JSP)
Research frame

Research methods

- literature review
  - aspects influencing building energy performance
  - correlation with an architectural design

- case study JSP evaluation
  - energy performance evaluation

- research by design
  - sub-researches on particular aspect of building energy performance
  - exposing the possible impact of energy performance on architecture
  - validation

- calculations
  - comparison research results

- additional case studies
Research

Architecture
- Site and context
- Orientation and shape
- Plan and section
- Facade composition
- Materialization
- Interior

Energy supply & demand
- Building equipment
  - Lighting
  - Pumps
  - Humidification
  - Warm tap water
  - Ventilation
  - Cooling
  - Heating
  - Integration sustainable energy supply

Building energy optimization aspects
- Renewable energy sources analysis and integration
- Bioclimatic analysis
- Orientation
- Daylighting
- Sun shading
- Compactness (shape efficiency)
- HVAC
  - User behaviour
  - Orientation of the internal spaces within the shape
  - Building equipment: elevators, escalators, automatic doors
  - Reuse energy streams building scale

Minimum net glazed area calculation
- Insulation material and thickness
- Integration of the energy suppliers
- Sun shading
- Infiltration
Research

1. Renewable energy sources analysis
2. Bioclimatic analysis
3. Renewable energy sources integration optimization
4. Orientation
5. Daylighting
6. Sun shading
7. Compactness (shape efficiency)
8. HVAC
9. User behaviour
10. Orientation of the internal spaces within the shape
11. Building equipment: elevators, escalators, automatic doors
12. Reuse energy streams building scale
14. Thermal resistance of the building envelope
15. Infiltration
Research

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15. Infiltration
Research

Architecture

objective:
to find an optimal energetic solution on each aspect within given limitations.

Energy
Research

... according to Lechner (2008) about 5 meters from exterior facade can be fully day lit ... additionally 10 meters atrium width provide, daylight factor >1.2%, accounting 24.8 meters height, based on $A_{\text{glazing}} = (D F x 2 A_{\text{total}} (1 - R_{\text{mean}})) / T_{\text{vis}} \theta$, (O'Connor et al., 1997)
Research

...general rule is to provide buildings longest wall with south orientation will give the most benefits in terms of energy performance (Mingfang, 2002).
Gross floor space: 8064 m²
PV area: 1200 m²
Footprint: 1662 m²

Gross floor space: 6750 m²
PV area: 1400 m²
Footprint: 2124 m²

Gross floor space: 4868 m²
PV area: 1467 m²
Footprint: 2124 m²
Research

+ 65 degrees south: and 8 degrees obstructions, about 90% efficiency

- 25 degrees south gives about 95% efficiency
Research

- external
  - cheaper
  - easier to construct
  - more maintenance friendly

- self shading
  - about 40% more compact volume
  - more architectural potential: perception, identity, public space...
Research

Natural ventilation (heating season)

- Additional fan
- Local heating units: radiator or convector
- Fresh air supply through underground tunnel -4 m.
- Rock formation ~8°C

Mechanical ventilation with heat recovery (heating season)

- Additional fan
- Local heating units: radiator or convector
- Heat recovery
- Pre-heating fresh air
- Fresh air supply through underground tunnel -4 m.
- Seasonal heat storage
- Rock formation ~8°C

Natural ventilation (cooling season)

- Additional fan
- Fresh air supply through underground tunnel -4 m. (if the outside air is too hot for cooling)

Mechanical ventilation with heat recovery (cooling season)

- Additional fan
- Local cooling units: climate ceiling
- Heat recovery
- Pre-heating fresh air
- Fresh air supply through underground tunnel -4 m.
Minimum net glazed area

\[ A_{\text{glazing}} = \frac{D F \times 2 A_{\text{total}} (1 - R_{\text{mean}})}{T_{\text{vis}} \theta}, \]

- **visible sky angle (obstructions)**

Minimum net glazed area calculation.

visible sky angle (O’Connor et al., 1997)

- **vertical window configuration and glass transmittance**

- **interior configuration**

- **daylight factor requirements (green council req.)**

- **interior materialization (reflectance) color and material choice**
conclusion

The building generates 89% more electric energy than it needs + additionally it provides heat and cold energy for the heating of the adjacent buildings.
Research

**Conclusion**

The building generates 89% more electric energy than it needs + additionally it provides heat and cold energy for the heating of the adjacent buildings.
3.1 design considerations
Architecture
1. Renewable energy sources analysis
2. Bioclimatic analysis
3. Renewable energy sources integration & optimization
4. Orientation
5. Daylighting
6. Sun shading
7. Compactness (shape efficiency)
8. Climate design (HVAC)
9. User behaviour
10. Orientation of the internal spaces within the shape
11. Building equipment: elevators, escalators, automatic doors
12. Reuse energy streams building scale
14. Thermal resistance of the building envelope
15. Infiltration
### Gravity of the Aspects Depending on the Context

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Implemented Measures Within the Context</th>
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<tbody>
<tr>
<td>1. Renewable energy sources analysis</td>
<td>solar, geothermal, algea array</td>
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<tr>
<td>2. Bioclimatic analysis</td>
<td></td>
</tr>
<tr>
<td>3. Renewable energy sources integration</td>
<td>1. solar energy (~1000 m²), 2. geothermal (due to climate concept) 3. algal biomass (optional)</td>
</tr>
<tr>
<td>4. Orientation</td>
<td>north-south orientation</td>
</tr>
<tr>
<td>5. Daylighting</td>
<td>atrium daylight optimization</td>
</tr>
<tr>
<td>6. Sun shading</td>
<td>dynamic shading</td>
</tr>
<tr>
<td>7. Compactness (shape efficiency)</td>
<td></td>
</tr>
<tr>
<td>8. Climate design (HVAC)</td>
<td>hybrid ventilation concept + ground source heat pomp in combination with a heat/cold storage</td>
</tr>
<tr>
<td>9. User behaviour</td>
<td></td>
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<td>10. Orientation of the internal spaces within the shape</td>
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<td>13. Minimum net glazed area calculation</td>
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<td>14. Thermal resistance of the building envelope</td>
<td>average R = 10; dynamic facade system</td>
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<td>15. Infiltration</td>
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</table>
3.2 design: fitting into the context
Location analysis

green for the next 50 years

green for the next 50 years
Location analysis
Location analysis
3.2 design: program & planning
Situation
Johanneberg Science Park program

**Office complex**
- several users – flexible space.
- public character

**Program**
- flexible office space
- conference space
- formal meeting spaces
- research facility: labs, library, flexible individual work space
- showroom
- small exhibition
- restaurant

**Additional:**
- café
- fitness

Gross floor space about 7 000 m²
Plans

ground floor
Plan

**ground floor**

connected to the atrium:

- entrance hall/showroom
- restaurant
- meeting rooms
- toilets
- circulation cores
Planes

ground floor

connected to the atrium:
- entrance hall/showroom
- restaurant
- meeting rooms
- toilets
- circulation cores

connected to the square:
- cafe
- fitness
- entrance bike parking
ground floor

calculated to the atrium:

- entrance hall/showroom
Plans

ground floor

connected to the atrium:

- entrance hall/showroom
- restaurant/kitchen
- meeting rooms
Plans

ground floor

connected to the atrium:

- entrance hall/showroom
- restaurant
- meeting rooms
- toilets
- circulation cores
Plans

ground floor

connected to the atrium:
- entrance hall/showroom
- restaurant
- meeting rooms
- toilets
- circulation cores

connected to the square:
- cafe
- fitness
- entrance bike parking
first floor

- digital library
first floor

- digital library
- office modules
- office open space
first floor

- digital library
- office modules
- office open space
- connection core (open kitchen)
first floor
- digital library
- office modules
- office open space
- connection core (open kitchen)
- office services
first floor
- digital library
- office modules
- office open space
- connection core (open kitchen)
- office services
- toilets, fire escapes and shafts
second floor
Plans

forth floor

- 62 m², technic: air handling
- east wing
- 250 m², open office space (atelier type)
- 95 m², flex space
- 12 m², fire escape
- 23 m², services
- 55 m², air handling west wing
- 32 m², Room
- 42 m², rest

forth floor
forth floor

- office atelier type
forth floor

- office atelier type
- installation spaces
Plans

forth floor

- office atelier type
- installation spaces
- rest space

23 m²

250 m² open office space (atelier type)

56 m²

95 m² flex space

12 m² fire escape

62 m² technic: air handling east wing

55 m²

32 m² Room

42 m² rest

365 m²

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3.3 design: energy vs. architecture
energy production
energy production

solar energy

North

South

seasonal heat storage

SouthNorth
climate design vs. interior architecture

- solar energy
- primary wind direction
- seasonal heat storage

North

South
Section: climate design winter

- Heat recovery with pre-heating fresh air
- Seasonal heat storage
- GSHP
dynamic facade concept (north side)
dynamic facade concept (north side)
dynamic facade concept (south)
dynamic facade concept (south)
Facade: south dynamic
Facade: south dynamic
Facade detail
Facade detail
Facade detail: creating ornament
Legend

1. Roof
   - plants
   - growing medium
   - drainage layer
   - waterproofing
   - triplex 20 mm
   - rigid insulation
   - fibreboard acoustic floor 280 mm
   - waterproof wrapping
2. Wooden batten: 20 mm triplex, 42 x 80 mm wood
3. Lifting mechanism 1-3 level
4. Aluminium parapet
5. Aluminium profile (solar screen frame)
6. Solar panel (sunpower x21 345)
7. Massive wood panel
8. Rigid insulation
9. Wooden batten
10. Wall composition R>10:
    - interior finishing layer
    - damp proof layer
    - cellulose insulation
    - wooden frame
    - cellulose insulation
    - waterproof layer
    - exterior finishing layer
    - aluminium profile (solar screen)
11. Natural ventilation inlet
12. Massive wood panel
13. Aluminium frame triple glazing (U=0.6)
14. Suspended ceiling
15. Sealing
Design: impression main entrance
Design: impression south entrance
Design: impression east entrance
Design: impression east entrance
Conclusion

70 % energy positive; building energy efficiency 21 kWh/m²/year
Conclusion

70 % energy positive; building energy efficiency 21 kWh/m²/year

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<td>5. facade composition</td>
<td>Thermal resistance of the building envelope, minimum net glazed area calculation, infiltration</td>
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main tutor: Annebregje Snijders
second tutor: Maarten Meijs
third tutor: Regina Bokel
external adviser: Thijs Asselbergs

Energy producing Architecture

project by: Sergey S. Fedatsenka

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