Energy City

R & D center
for the renewable energy in architecture

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1. Introduction
Background

How much energy consumes?


Toe (Ton of Oil Equivalent, 1 toe = $10^7$ Kcal)
Background

How much natural sources consume per year?

![Graph showing energy consumption](image)

**Figure 1.3**
Primary energy consumption between 1978 – 2005

- Oil
- Natural gas
- Nuclear energy
- Hydroelectricity
- Coal

Most consumption of energy is fueled in essence by fossil energy sources, to a very small degree, by hydro-electric power.
Background

How much

The value of CO₂ will be doubled in 22C (from 360ppm in 21C to 560ppm in 22C)

Background

Global warming

Climate changes will break the environment of human and all living things on the earth.
Background

Resource Depletion

Oil production will be decreasing within 20~30yrs later.
Gas production will be decreasing within 20~30yrs later.
Coal production will be decreasing within 160~180yrs later.
Now

The existing energy system

System of energy supply
Energy comes from a big provider such as the power plant. This modernized energy system
Problem of the modernized electricity network - energy independence, emergency resilience
Existing grid system is not efficient anymore. It needs an innovation.
Researchers have studied smart grid system which can make a balance both of energy providing and consuming. This system needs a self sufficient energy supply building in its structure.
Future

The smart grid system

Individual buildings can produce energy by themselves. They can sell rest energy to the others or the power plant. This system can reduce the consumption of natural resources.
Scenario

Now: A huge generating plants supply energy to the building.
Future: Building will be able to generate energy by using new energy technology.

Building

Energy Plants

Building + Energy technology
Methodology / Schedule

Design

- Analyzing urban context
- Master plan
- Building concept
- Options
- Preliminary Design
- System Design
- Final Design

Research

- Research issues
- Technical concept
- Investigation technics
- Applying technics

P1 : Nov. 2009

P2 : Jan. 2010

P3 : Mar. 2010

P4 : May. 2010

P5 : Jun. 2010
2. Urban scenario
(Master plan)
Haarlem
On the edge of the Randstad plan

Haarlem places outside of the Randstad plan. Road connection between Haarlem and Schiphol is not convenience. Water connection between Haarlem and Amsterdam faded away.
Suggestion
Making a new port for Haarlem

4 green ports which combine a horticulture industry and research center.

**Energy port** can be suggested for Haarlem as city attraction.
Urban strategy

Energy port

Haarlem
Outskirt of Haarlem

- Starting Point
  - Station for the NS and Light Railway
  - Research and develop center
  - Education facility
  - Offices
  - Retails
- Solar PV farm
- Wind farm
- Biomass farm
- Biomass Plants
- Geothermal plants
Inside of Haarlem

Hot spot
(Ecoboulevard by Ecosistema Urbano)
Border
Spaarnwoude

A. Spaarnwoude is placed between Amsterdam and Haarlem. - Gateway for Harrelem area.

B. Three strong lines
1. Motor way (A200)
2. Rain way
3. Canal

C. Symbolic icon
1. IKEA building
2. Office building (10th fl.)
3. Flyover
4. Overpass

D. South : Residential area
North : Office and factory area
East : Suburban, Green area
Site Image

View from Amsterdam to Haarlem

Ikea on the right side.
Site Image
View from Haarlem to Amsterdam

Ns railway and A200 motor way
Height restriction: Around 45m of height.
Site impression
Boring / Difficulty / Desolation

There are no facilities for the passenger
It is hard to cross the road for bicycle owner and disabled
Nobody stay at there. Nothing people can do in this area.
Remind P1 project

Daily passing passengers, cars and train make a vibration energy. Piezoelectric system was used as a energy producing device of this pavilion.

This pavilion can produce **571 kWh/day**. This is same as a level of electric consumption for **2 houses per 1 month**.
Changing
Motorway / Railway

Motorway changes its direction to the north.
Railway is elevated its level.
Waterway connection is recovered
Green area replaces motorway area and connects south and north part.
Cityscape

New entrance image of Haarlem

Creating new cityscape of the entrance, Haarlem. Green area makes a visual connection between outskirt and city.
Location
of the master plan area

The place is located at Spaarnwoude station which is border of Haarlem.
Total master plan area is approx. 118,600 m².
Master plan has several networking layers and zone dividing to use the area more efficiently.
Master plan
New gate for Haarlem

- Road network is on the ground level.
- Green network connects each building in the master plan.
Suggested site is facing at the outside of Haarlem directly.

Building will be a **new face and entrance** of Haarlem.
Master plan provides site **approx. 12,000m²** for the building, R&D center. (10% of the whole plaster plan area)
This area has a height restriction of **45m** for the Schiphol airport.
**8~10th** floor building will be possible.
3. Building design
Program
for the design project

R&D center
for the renewable energy in architecture

Research center for the new technology of renewable energy in architecture.
Analysis

Mass options

Design focus is
Building has to have a new face for Haarlem.
a huge entrance for the visitors.
an efficiency for its function.
Concept 1
New gate for Haarlem

From far distance – Horizontal line
From mid distance - Facade
From close distance - Gate
Concept 2
Borderless

Building places on the border line of Haarlem. Make a borderless condition.
To express overflowing from nature, from the outskirt of Haarlem. Conceptual surface clads building mass and connects inside and outside area visually. This surface is called as a new face of the building.
New technology has new image.
Various façade systems will be invented by new technology.
New face of building will be a test field for the new façade system and new technology.

Concept 4
New face for Haarlem
Every building represents a level of technology in each era. Each pattern in a quilt work represents a technology or material in the building at that time, era. New face of the building can express its own aesthetic beauty.
Building has 4 parts.

For the cooperation with ECN in Petten, it has 7 departments inside of research center.
Program area

<table>
<thead>
<tr>
<th>Category</th>
<th>Area</th>
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<tbody>
<tr>
<td>Research</td>
<td>23,000 m²</td>
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<tr>
<td>Administration</td>
<td>5000 m²</td>
</tr>
<tr>
<td>Public</td>
<td>15,000 m²</td>
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<tr>
<td>Visitor and education</td>
<td>12,000 m²</td>
</tr>
<tr>
<td>ECT</td>
<td>5000 m²</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>60,000 m²</strong></td>
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Total floor area is 60,000 m²

The largest part is for research facilities as 40 % of total.
The entrances of research center and visitor area are separated.

Media center connects two of functions on the top with good vista.
Design Develop
Model 01

Checking a balance between building mass and new face.
Design Develop
Mass design process 1

Building masses are divided by three parts. Two lower masses and one oblong mass on the top. Looking for suitable mass shape for each part.
Each mass can have own façade pattern.
Design Develop

2nd Model

Result of first design development.
It has one direction for new façade.
Design Develop
Mass design process 3

Second option has two direction for the new face. It connects one side and the other side of the building.
Design Develop
Mass design process 4
Design Develop

3rd model
Design Develop

Façade design

Character of material

Material A: Changeable, Colorful, Artificial

Material B: Hard, natural material

Material C: Soft, natural material
Design Develop

Façade design
Design Develop

Entrance hall
Design Develop

Entrance hall structure
For the energy efficient building design, it is needed to consider which material and system can be used within the building.
Climate system
For the energy generating unit

A. Atrium and garden space within the mass will help to make a natural air flow
B. Ventilation fan within the building service area help to make a air flow within the workshop area
C. Laboratory needs an active air conditioning system to keep its constant condition.
Climate system
Basic principle of the façade and the floor

Façade system will follow general ventilation flow of the building. Insulation layer will have compact thickness and high heat resistance to reduce energy loss and consumption. Concrete core activation system will be a main heat and cooling system. Floor convector will support an extra heat and cooling demand.
Building body is clearly divided by three parts on the section image.
Structure system has a same rhythm in order to fulfill design purpose.
Concrete structure will be used for the lower part. It continues from the basement to the 6th floor.
Large void space such as a hall and workshop will be constructed by the steel frame structure.

10 meter height steel truss structure will cover a span of 90 meter in the bridge part.
Structure system

Steel structure for the upper part

Upper part is also constructed by the I shaped steel structure
Structure system
Steel frame structure for the energy surface

The energy surface has a curved shape. To accomplish this shape, the outline of the surface will be divided by 66 segments. The length of each segment is approximately 1.5 meters.
Definition of the energy surface is a universal façade system which can realize various test for the new energy technology.
Module system is needed to make a universal field.
Each module has 1.5 meter of height and 3 meter of width
66 modules along vertical direction makes one column, 3 columns make one group
Main structure for the energy surface has to solve not only a structural behavior but also a systemic behavior.

A hollow type profile is selected to carry a pipe system inside of the structure.
To resist wind pressure from the outside of the building well, the triangle profile is selected to develop the main structure. Secondary structure will be added to the main structure with a pipe system inside of its body.
Movable work plate will be built to maintain the energy surface.

The gap area can be used as a maintenance space and exhibition course for the visitors.
Façade system 01

Sketch for the detail process
Façade system 01

Construction method

Rendering image
Façade system 01

Section G

Section H

West Elevation
Façade system 02
Concept for the building facade

Wood pattern
1.5 meter width of module is used to build one façade element.
Façade system 02
Material for the insulation

2cm thickness of VIP system has a 5 m²K/W as R-value, it is enough to cover Dutch standard for the insulation. (2.5m²K/W)

Vacuum Insulation Panel (VIP)
Façade system 02
Top part of the west facade
Façade system 02
Middle part of the west facade

Section C
Façade system 02
Low part of the west facade
Façade system 02

Partial elevation image
4. Technical research
Energy harvesting

Various research for the new method of the energy harvesting

Solar energy
Wind energy
Hydro energy

PV panel  Solar collector  Algae system  Piezoelectric leaf  Humdinger wind generator

Energy source from the nature is used to harvest the energy.
Various technologies for the energy harvesting are researching and trying.
Weather condition
Haarlem, the Netherlands

Average highest point: A. Solar insulation: 150 kWh/m² in May, Jun, Jul
B. Temperature: 24°C in Jul, Aug
C. Wind speed: 7.7 m/s in Jan, Dec
D. Precipitation: 163 mm in Nov
Energy surface
Properties and capacities

Energy surface is divided by 3 parts according to the direction.
Total number of the energy panels : 4,428
Total area of panels : 16,117.92 m²
Solar energy
PV panel

Property of the PV panel

Size: 1.4m x 0.6m x 3cm
Capacity: 140W
Each panel has various angles from 0° to 126° to the horizontal direction.
$$P = \frac{G}{1000} \times P_{pk} \times \text{eff}_{rel}(G,T_m)$$

The actual power depends on the irradiance ($G$), the nominal peak power ($P_{pk}$) and the real module efficiency ($\text{eff}$).

Result will be shown as a table which shows the amount of the electric production in a day, month and year.

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Solar energy

Simulation program

PV potential estimation utility

Result of the calculation

Location: 52°22′58″ North, 4°13′ East, Elevation: 2 m a.s.l.

Nominal power of the PV system: 0.6 kW (crystalline silicon)
Estimated losses due to temperature: 7.2% (using local ambient temperature)
Estimated loss due to angular reflectance effects: 4.3%
Other losses (cables, inverter etc.): 14.0%
Combined PV system losses: 23.7%

<table>
<thead>
<tr>
<th>Month</th>
<th>$E_a$</th>
<th>$E_n$</th>
<th>$H_a$</th>
<th>$H_n$</th>
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<tbody>
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<td>7.61</td>
<td>0.60</td>
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<tr>
<td>Feb</td>
<td>0.59</td>
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<td>Mar</td>
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<td>30.8</td>
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<td>Apr</td>
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<td>Nov</td>
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<td>0.80</td>
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<tr>
<td>Dec</td>
<td>0.18</td>
<td>5.49</td>
<td>0.45</td>
<td>14.0</td>
</tr>
</tbody>
</table>

$E_a$: Average daily electricity production from the given system (kWh)
$E_n$: Average monthly electricity production from the given system (kWh)
$H_a$: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m²)
$H_n$: Average sum of global irradiation per square meter received by the modules of the given system (kWh/m²^2)

Total for year: 422

Yearly average: 1.16, 35.1, 2.71, 82.5
Solar energy
Simulation result

One PV panel which has the angle of 10 ° to the east can produce 452 kWh in one year

A. East part – 241,983 kWh/year  
B. Roof part – 3,292,833 kWh/year  
C. West part – 120,691 kWh/year  

Total amount of the electric energy is **3,655 MWh/year**
Wind energy

Wind-cell panel

Size: 1m x 1m x 5cm
Capacity: 7.2 kWh/month (In 6m/s average wind speed condition)
Wind energy

Simulation program

General condition
- Wind speed : 6.93 m/s
- Wind direction : West-east

General note
- The deviation of the wind speed is too huge within each day
- To get a precise data of the wind speed, more wind data and probes are needed
Wind energy
Checking the wind speed on the energy surface

Average wind speed - East point: 0.21 m/s
Roof point: 1.65 m/s
West point: 0.85 m/s
Wind energy
Simulation result

If wind cell system is applied on the whole energy surface,
A. East part – 6,950.4 kWh/year
B. Roof part – 183,414 kWh/year
C. West part – 7,217.64 kWh/year
Total amount of the electric energy is 197.5 MWh/year
PVDF (polyvinylidene fluoride) polymer
The vibration created by a raindrop impacting a PVFD membrane produces electricity.
In the recent research, the precipitation of 700mm/yr can produce 1Wh/m²
Hydro energy
Calculation

Area of the roof = 9,434.88 m²
Precipitation of Haarlem = 1,127 mm/year
Piezo-sensor can produce 1Wh/m²

Then,
Total amount of the electric energy is
15.2 kWh/year

Too tiny value than the other system
Comparison
1 year on the energy surface

- PV: 3500 MWh/Year
- Wind cell: ~100 MWh/Year
- Piezo system: ~10 MWh/Year
5. Result and conclusion
Perspective
Perspective
Perspective
Perspective
Interior view

Void of hall
Interior view

Inside atrium for the short stay housing
Conclusion

1. Energy harvesting technology can be a part of the building.

2. Energy harvesting technology can give us a impressive building image as a design motif.

3. $3,852\text{MWh/year}$ can be produced by using PV, wind-cell and piezoelectric technologies which are invented nowadays.

4. PV technology can produce $18.5$ times more energy than the wind cell technology.

5. Piezoelectric technology needs to improve its efficiency for the wide use
The End