Zero Energy Refurbishment
Revitalization of the gallery apartment building
Characteristics and potentials
Characteristics and potentials

Embodied energy
Characteristics and potentials

Embodied energy

Effect of the user on operational energy
Characteristics and potentials
### Sun

- **Flat**
  - Electric: 226.100 – 226.800 kWh/year
  - Electric + heat combination: 237.400 – 238.140 kWh/year + 82.4 GJ/year

- **35° south**
  - Electric: 93.800 – 95.200 kWh/year
  - Electric + heat combination: 103.180 – 104.720 kWh/year + 50.4 GJ/year

### Wind

- **Vertical axis**
  - At roof level wind speeds of 4.5 m/s, not feasible

- **Wing**
  - Should be investigated in integrated approach

### Combination of wind + sun

- 360.000 kWh/year (based on company numbers)
Integrated Roof Wind & Solar Energy System
- Full Roof Modular Solution -

**PowerNEST**

Most Effective Solution for Energy Generation on Buildings in Urban and Coastal Environments

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Visit our website for more information or contact us directly to see if your building qualifies.

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### Seasonal Output Wind & Sun Combination

<table>
<thead>
<tr>
<th>Months</th>
<th>Power Output (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>200</td>
</tr>
<tr>
<td>2</td>
<td>250</td>
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<tr>
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<td>650</td>
</tr>
<tr>
<td>11</td>
<td>700</td>
</tr>
<tr>
<td>12</td>
<td>750</td>
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</tbody>
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### Specifications for PowerNEST (1 module)

- **Physical Information**
  - Size: 7.2 m x 10.8 m
  - Height: 4.9 m
  - Weight: 9000 kg
  - 115 kg/m²
  - Material: Steel, Aluminium, Composites
  - Color: RAL9006/Customizeable

- **Turbine**
  - Axis: Vertical
  - Height: 4.2 m
  - Diameter: 4 m
  - Material: Steel + Composites
  - Color: RAL9006/Customizeable

- **Performance**
  - Max Power Output: 3.5 kWp
  - Cut-in Wind Speed: <3 m/s
  - Cut-out Wind Speed: 15 m/s
  - Rated Wind Speed: 12 m/s
  - Survival Wind Speed: 60 m/s
  - Generator Efficiency: >0.90
  - Noise: <40 dB
  - Output: 230 VAC
  - Temperature Range: -10°C to +40°C

- **Solar Energy**
  - PV Cell Type: Monocrystalline
  - Surface Area: 75 m²
Embodied energy
$$R_{\text{back facade}} = \frac{A_{\text{wall}} \cdot R_{\text{wall}} + A_{\text{window frame}} \cdot R_{\text{window frame}} + A_{\text{air grid}} \cdot R_{\text{air grid}} + A_{\text{console}} \cdot R_{\text{console}} + A_{\text{balcony}} \cdot R_{\text{balcony}}}{A_{\text{total}}}$$

$$R_{\text{back facade}} = \frac{4.32 \cdot 0.95 + 3.07 \cdot 0.53 + 0.32 \cdot 0.15 + 0.14 \cdot 0.26 + 1.56 \cdot 0.16}{9.41} = 0.65 \text{ m}^2 \cdot \frac{K}{W}$$
$R_{\text{cavity current}} = \frac{1}{\alpha_{\text{cond}} + \alpha_{\text{conv}} + \alpha_{\text{rad}}} = \frac{1}{1,6 + 4,8} = 0,16 \ m^2 \cdot \frac{K}{W}$

$R_{\text{cavity improved}} = \frac{1}{\alpha_{\text{cond}} + \alpha_{\text{conv}} + \alpha_{\text{rad}}} = \frac{1}{1,6 + 0,54} = 0,47 \ m^2 \cdot \frac{K}{W}$
Double glazing, 15 mm argon filled cavity and a low-e coating:

R-value: $0,91 \ m^2 \cdot \frac{K}{W}$

Total embodied energy in material and production: $475 \ MJ/m^2$

Double layer ETFE foil

R-value: $2,0 \ m^2 \cdot \frac{K}{W}$

Total embodied energy in material and production: $19 \ MJ/m^2$
Natural gas usage [m$^3$/year]

Rc - value [m$^2$-K/W]

SSE  WSW
Effect of the user on operational energy
Study of J. E. Petersen et al. shows a reduction in energy usage of 32% when giving real time visual feedback on energy usage
Final design
Building process
Stage 7: Young's vs. Embodied energy (MJ/m³)

- Young's modulus (GPa)
  - 0
  - 50
  - 100
  - 150
  - 200

- Embodied energy, primary production / volume (MJ/m³)
  - -100000
  - -50000
  - 0
  - 50000
  - 100000
  - 150000
  - 200000
  - 250000
  - 300000
  - 350000
  - 400000
  - 450000
  - 500000
  - 550000
  - 600000
  - 650000
  - 700000

- Materials:
  - High strength low alloy steel, YS550 (hot rolled)
  - Structural steel, S275N (Normalised)
  - Aluminum, 6060, T6
  - Aluminum, 7020, T6
  - Aluminum, 6082, T6
  - Pine (Pinus ponderosa) (l)
  - Spruce (Picea rubens) (l)
  - Bamboo (longitudinal)
  - Concrete (structural lightweight)
  - Concrete (high performance)
  - Glulam