Scenarios for a zero-carbon inner city university campus using 3D modeling

An inner city campus case study

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Simulation Platform
INSEL 4D: Software Architecture for Urban Energy and Building Simulation
SimStadt workflow

Building Physics Library
- Different refurbishment scenarios available
- Material properties of buildings can be adjusted

Usage Library
- Internal gains, heating and cooling etc., can be adjusted
- Schedules can be adjusted

<table>
<thead>
<tr>
<th>Variant ID</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MediumRefurbishment</td>
<td>Medium full refurbishment recommended by Institut für Bauforschung (IBF)</td>
</tr>
<tr>
<td>AdvancedRefurbishment</td>
<td>Advanced full refurbishment recommended by Institut für Bauforschung (IBF)</td>
</tr>
<tr>
<td>EnEV2015</td>
<td>EnEV2015 - Minimum requirements of German Energy Efficiency Ordinance (EnEV)</td>
</tr>
<tr>
<td>EffizienzHaus70</td>
<td>Energy label KfW EffizienzHaus 70 - German Energy Efficiency Ordinance (EnEV)</td>
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<tr>
<td>EffizienzHaus40</td>
<td>Energy label KfW EffizienzHaus 40 - German Energy Efficiency Ordinance (EnEV)</td>
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</tbody>
</table>
Overview HFT-Campus / Buildings and Energy

**Key Facts HFT-Campus**
- 4,000 Students & 350 staff members
- 28,850 m² heated area (Bau 1 bis 4)
- 4 main buildings (+ new construction 2016)

**Key Facts Energy Consumption**
- **electricity consumption**
  ~ 1,600 MWh/a
- **heat consumption**
  ~ 2,700 MWh/a
- **CO₂ emissions**
  ~ 525 t CO₂/a
Simulation Results – Campus HFT Stuttgart

Bau 1
130 kWh/m²
1.150 MWh/a

Bau 2
90 kWh/m²
860 MWh/a

Bau 3
95 kWh/m²
710 MWh/a

Bau 4
120 kWh/m²
360 MWh/a

specific heating value
Weather analysis

Differences between simulation up to 37% in 2014

Reason: TMY Stuttgart is the longterm average at the Stuttgart airport in Echterdingen, 10km from the city center, with a significantly different climate from the annual measured values at the city center of Stuttgart.
Simulation with the actual weather data (monthly mean values for each year) of a station in the Stuttgart city center results in very low differences of -3% to 12% from the measured consumption. These differences can be attributed to changes in user behaviour.
EU1  2012 - 2016
Eicker, Ursula; 23.03.2018
Refurbishment scenarios – Campus HFT Stuttgart

- 17%
Bau 3
80 kWh/m²
585 MWh/a

- 23%*
Bau 4
60 kWh/m²
180 MWh/a

- 35%
Bau 1
85 kWh/m²
750 MWh/a

- 25%
Bau 2
70 kWh/m²
640 MWh/a

„Standard“
- 27%

specific heating value

Bau 2
Bau 3
Bau 4
Bau 1
Neubau Bau 8
Refurbishment scenarios – Campus HFT Stuttgart

- 52 %
Bau 3
45 kWh/m²
340 MWh/a

- 67 %
Bau 4
40 kWh/m²
120 MWh/a

- 64 %
Bau 1
45 kWh/m²
410 MWh/a

- 62 %
Bau 2
35 kWh/m²
320 MWh/a

"Pilot"
- 59 %

specific heating value
Step 1 - SimStadt:
- automated analysis of solar radiation for all roof areas
- usable surface ratio parameter → PV capacity (kWp) & yearly PV yield (kWh/a)

Step 2 - INSEL:
- manual selection of suitable roof areas for more detailed analysis
  → hourly Simulation of PV yield

<table>
<thead>
<tr>
<th>Location</th>
<th>kWh/kWp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bau 1 - SW</td>
<td>1070</td>
</tr>
<tr>
<td>Bau 1 - SO</td>
<td>1060</td>
</tr>
<tr>
<td>Bau 1 - NO</td>
<td>830</td>
</tr>
<tr>
<td>Bau 3 - SW</td>
<td>1240</td>
</tr>
<tr>
<td>Bau 3 - SO</td>
<td>1050</td>
</tr>
<tr>
<td>Bau 3 - NO</td>
<td>640</td>
</tr>
</tbody>
</table>
Generating a hourly annual load profile for the heating demand

**INPUT**

- Heating demand (Simstadt)
- Ambient temp. (local weather data)

**OUTPUT**

- Hourly heating demand

**Parameters:**
- Heating limit temperature: 15 °C
- Heating setpoint temperature: 20 °C

**Optional:**
- Heating season: Sep - Mai
- Night set-back: 24:00 – 06:00

**Heating degree days method**
Hochschule für Technik Stuttgart

Parametrization of energy supply concepts

Using the annual load duration curves for the dimensioning process

- heat demand
- electricity demand: From monitored load profiles
- cooling demand: Only cooling of computer center and library, combination with monitored data

Guided parametrization of various energy supply systems

- CHP
- heat pump
- vapor-compression refrigeration
- absorption refrigerator
- heat & cold storage
- PV(T) modules
- solar thermal collectors
Scenario modeling of energy supply concepts for renovation scenario „Pilot“:

**Heat pump (monovalent) + PV**

- CHP (base load) + heat pump (medium load) + district heating (peak load) + PV

- Demand HFT
- HP share
- CHP share
- PV reduction
Results of various concepts

<table>
<thead>
<tr>
<th></th>
<th>primary energy savings</th>
<th>avoided emissions</th>
<th>amortization</th>
</tr>
</thead>
<tbody>
<tr>
<td>standard</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pilot</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lighting</td>
<td></td>
<td></td>
<td>56 a</td>
</tr>
<tr>
<td>campus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>car park</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Campus + car park</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>energy supply systems</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>CHP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>heat pump</td>
<td></td>
<td></td>
<td>35 a</td>
</tr>
<tr>
<td>CHP + heat pump</td>
<td></td>
<td></td>
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</tbody>
</table>

- **Primary Energy Savings**: Measured in units of energy savings.
- **Avoided Emissions**: Measured in terms of avoided emissions.
- **Amortization**: Measured in years.

Legend:
- Yellow bars represent energy savings.
- Green bars represent avoided emissions.
- Grey bars represent amortization.

- The 'lighting' category shows the highest avoided emissions, with 56 years of amortization.
- The 'heat pump' category shows the highest amortization, with 35 years.
- The 'Campus + car park' category shows the highest primary energy savings.

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Recommendations:

2018  renovation Bau 4 (approved)

2019  LED installation

2020  PV Hofdiener Garage

2022  standard renovation Bau 1-4

2023  PV Bau 1-4

bis 2030  heat pump
Thank you for your attention!
BackUp
PV Potential Ermittlung HFT
**Hochschule für Technik Stuttgart**

**RealLabor Campus – Darstellung Fassaden-PV Hofdiener Garage**

<table>
<thead>
<tr>
<th>Südost Fassade</th>
<th>Südwest Fassade</th>
<th>Aufzug ca. 150m²</th>
<th>Dachfläche 1300m² bei 5° Grad Neigung</th>
</tr>
</thead>
<tbody>
<tr>
<td>620m²</td>
<td>560m²</td>
<td></td>
<td>Modulgröße = 1,60m x 1,60m</td>
</tr>
</tbody>
</table>

GESAMTFLÄCHE = 2625m²

Photovoltaikmodule haben zum jetzigen Stand des Entwurfs eine Größe von ca. 0.80m x 0.80m.

**Verschattungs- & Ertragssimulation mit PVSol für vereinfachten Entwurf**