Low-Carbon City Electricity End-Use Load Curve Simulation

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Requisites for Low carbon city

Urban Energy System

Energy efficiency of Building Stock
- Quality of service, Indoor environment
- Occupants behavior
- Building envelope design
- Energy efficiency of appliances, EMS
- On-site renewable (PV, Solar thermal) and CHP

City planning (Land use)
- Variety of households and non-residential buildings (Building size, density, demographic parameters)

Electricity Load Curve

Urban Scale Infrastructure
- District heating and cooling
- Micro & Smart Grid
- Urban & district energy management system

Electricity Load Curve

National scale energy supply system
- Power plants, Fuel supply

Total Environment Load (GHG, etc)
Smart Grid, Low Carbon City and Electricity Load Curve

Smart House (HEMS)
- Energy efficient room air conditioner and appliances, LED
- Household fuel cell, Heat pump WH
- Photovoltaic
- Electric Vehicle
- Battery

Smart Community
- Smart City
- Community Energy Management
- District Heating and Cooling System
- Micro Grid, Battery
- Combined heat & Power
- Large Scale Photovoltaic

Smart Building (BEMS)
- Energy efficient HVAC systems and Office Automations, LED
- Computer, Data Center,
- Co-generation, Heat pump system,
- Heat storage system
- Photovoltaic, Electric Vehicle
- Battery

Regional & national Grid system
- Mega Solar
- Wind Power
- Regional Energy Network
Building, District, City and Regional-level end-use simulation

- Evaluate effect of the energy efficiency measures in all levels (from occupants behavior to district level measures) on total energy consumption and electricity load curve.

- Residential sector model
  - Diversity of household and building type is considered.
  - Energy use schedule model and dynamic heating and cooling model are coupled.

- Non-residential sector model
  - Diversity of building use and HVAC equipment is considered.
Features of residential sector end-use model

- Considering the diversity of household type and building type.
- Bottom up simulation model from each appliance level (consider occupants behavior, dissemination ratio and efficiency of appliances).
- Coupling of bottom up simulation and heat load calculation (consider climate condition).
- Evaluate the various measures to reduce energy use in residential sector and on-site electricity generation by PV and co-generations.
Occupants’ behavior schedule model

- Appliances energy use model
- Hot water energy use model
- Heating and Cooling model (Heat load simulation)

Annual energy use of each household category

Regional scale energy consumption of residential sector

912 household categories loop
19 family types, 12 building types, 4 insulation levels

Input data

National time use survey
(Japan Broadcasting Corporation)

- Dissemination rate of appliances
- Power consumption of appliances
- Amount of hot water use
- Weather data
- Thermal characteristics of the house
- Number of households for each category
- Distribution of each insulation level
Activity Schedule of a male worker.
## Settings for Home Electric Appliances

<table>
<thead>
<tr>
<th>Appliances</th>
<th>Room</th>
<th>Number of holdings (per 100 households)</th>
<th>Power consumption [W]</th>
<th>Operating mode</th>
<th>Standby</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice cooker</td>
<td>Kitchen</td>
<td>88.1</td>
<td>1250.0</td>
<td>1000.0</td>
<td>35.0</td>
</tr>
<tr>
<td>Dishwasher</td>
<td>Kitchen</td>
<td>22.2</td>
<td>35.0</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>TV</td>
<td>Living &amp; bedroom</td>
<td>238.1</td>
<td>114.0</td>
<td>600.0</td>
<td>2.4</td>
</tr>
<tr>
<td>Refrigerator*</td>
<td>Kitchen</td>
<td>122.8</td>
<td>126.0</td>
<td>62.7</td>
<td>No standby</td>
</tr>
<tr>
<td>Washing Machine</td>
<td>Bathroom</td>
<td>109.3</td>
<td>1300.0</td>
<td>3.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Tumble dryer</td>
<td>Bathroom</td>
<td>26.4</td>
<td>21.0</td>
<td>3.3</td>
<td>0.2</td>
</tr>
<tr>
<td>VCR</td>
<td>Living &amp; bedroom</td>
<td>127.4</td>
<td>62.7</td>
<td>3.3</td>
<td></td>
</tr>
<tr>
<td>PC</td>
<td>Bedroom</td>
<td>47.6</td>
<td>**</td>
<td>35.0</td>
<td></td>
</tr>
<tr>
<td>Shower toilet</td>
<td>Toilet</td>
<td>53.4</td>
<td>**</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Heating and cooling model.

(a) Apartment house 68.7m$^2$

(b) Detached house 87.2m$^2$
Simulation results for single house.

- Green: CO2HP electricity demand
- Blue: Other electricity demand
- Red: PV generation

Power system load [kW]

- Blue: Without storage battery
- Red: Installed storage battery
- Green: SOC

State of charge [SOC]
Non-residential sector model

Database

Climatic condition

All buildings property in the district
- floor area & configuration
- number of floor
- usage of all floors
- shading obstacles

Space heat load calculation

Air-conditioning system model

Space electrical load calculation

Electrical load summation

Building heat and electricity demand model

Energy demand profile of buildings

Energy production system model

Simulation output

Climatic condition

Heat-source system composition
District and City-level energy consumption

Energy consumption = \int \text{energy consumption of a building}

= \int f \left( \begin{array}{c}
\text{occupants behavior,} \\
\text{number of occupants,} \\
\text{number and efficiency of appliances} \\
\text{insulation level of building,} \\
\text{Climate}
\end{array} \right)
Examples for district scale simulation

Area 1

- Total floor area: $3.81 \times 10^4 \text{m}^2$
- Detached house with PV: 53%
- Apartment house: 37%
- Commercial building: 10%
Examples for district scale simulation

Area 1

- Total floor area: $3.81 \times 10^4 \text{m}^2$
- Detached house with PV: 53%
- Apartment house: 37%
- Commercial building: 10%

Electricity Balance in Summer
Examples for district scale simulation

- **Area 2**
  - Total floor area: $1.89 \times 10^4 \text{m}^2$
  - Detached house with PV: 22%
  - Apartment house: 35%
  - Commercial building: 43%
City-level Simulation:
Electricity load curve of Osaka City’s Residential Sector (Summer)
Validation of simulated Electricity load curve of Osaka City’s Residential Sector

Normalized Electricity Consumption

Electricity load curve normalized by maximum value


Simulated
measured
Japanese 25% GHG reduction plan (Japanese Ministry of Environment 2011)

- Reduce 25% GHG from 1990 level.
- Residential Sector Measures
  - For 53 million households in Japan,
  - PV: 6.5-10 million (13 to 20% of total household)
  - High efficiency water heater: 29 – 38 million (70-100% of total non-single household)
  - 1999 heat insulation standard: 20%
Examples of Heat Pump Operation

- Electricity consumption
- COP
- Water heating demand
- Heat storage

Graph showing energy consumption, COP, water heating demand, and heat storage over time.
Examples of SOFC operation
Osaka City’s electricity load curve in residential sector under new water heater dissemination
Regional load curve prediction

- Kinki Region
  (Population: 20.9 million, Area: 27,335km²)

- Residential Sector & Non residential Sector only. (Industry and transportation are ignored)
Regional load curve prediction

2005 (Present)

2030 (GHG reduction measures are implemented)
Thank you for your attention!

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Publication list


