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

Climate

Electricity Load Curve

City planning (Land use)

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

Urban Scale Infrastructure

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

Electricity Load Curve

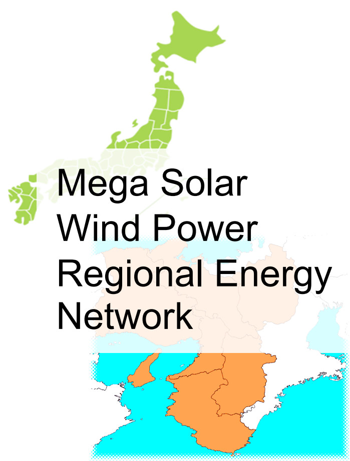
National scale energy supply system

Power plants, Fuel supply

Total Environment Load (GHG, etc)

Smart Grid, Low Carbon City and Electricity Load Curve

Regional & national
Grid system

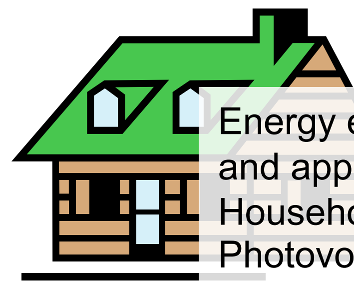


Mega Solar
Wind Power
Regional Energy
Network

Smart Community
Smart City

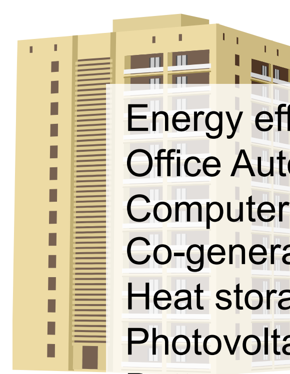
Community Energy
Management
District Heating and
Cooling System
Micro Grid, Battery
Combined heat & Power
Large Scale
Photovoltaic

Smart House (HEMS)



Energy efficient room air conditioner
and appliances, LED
Household fuel cell, Heat pump WH
Photovoltaic
Electric Vehicle
Battery

Smart Building (BEMS)



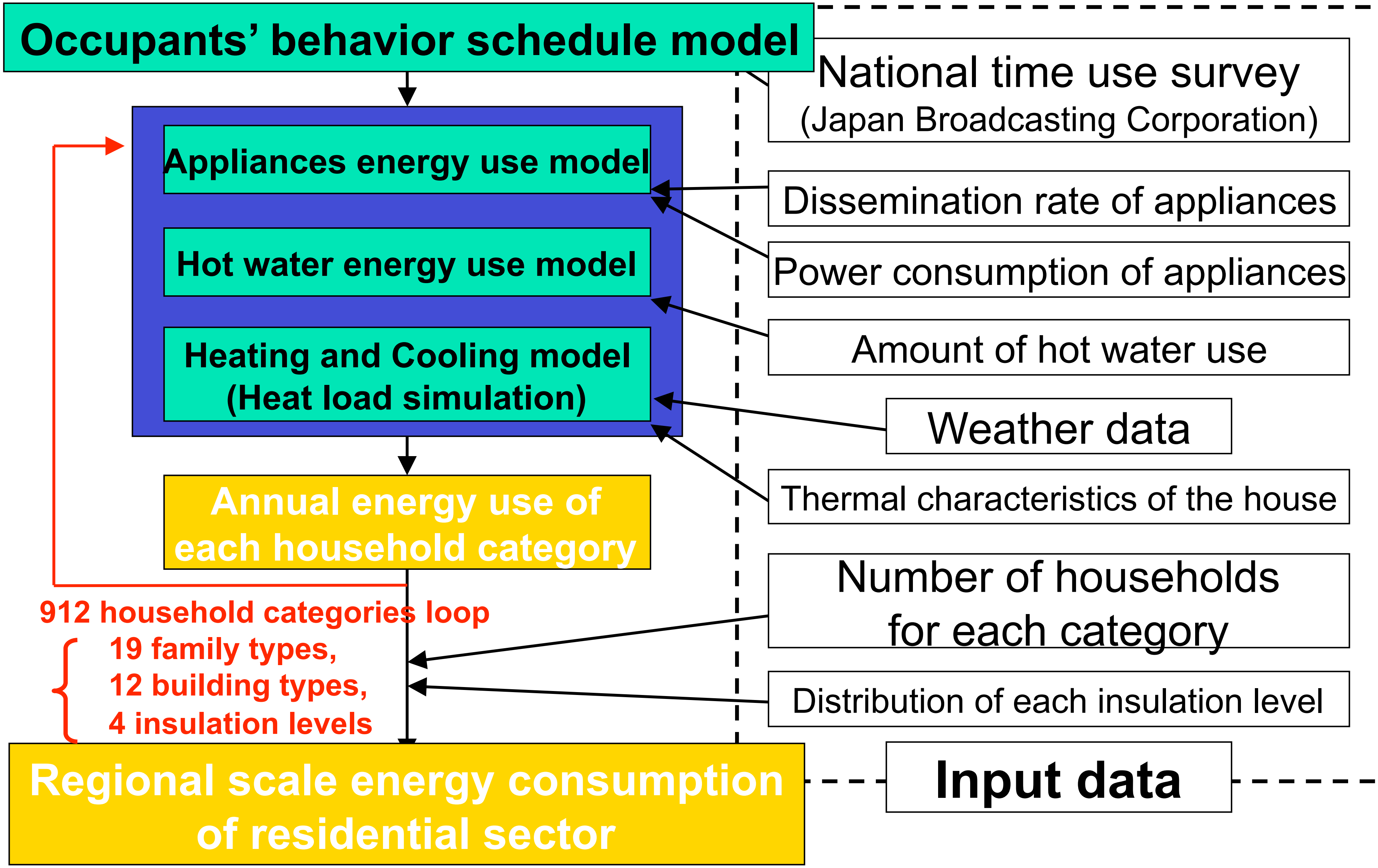
Energy efficient HVAC systems and
Office Automations, LED
Computer, Data Center,
Co-generation, Heat pump system,
Heat storage system
Photovoltaic, Electric Vehicle
Battery

Building, District, City and Regional-level end-use simulation

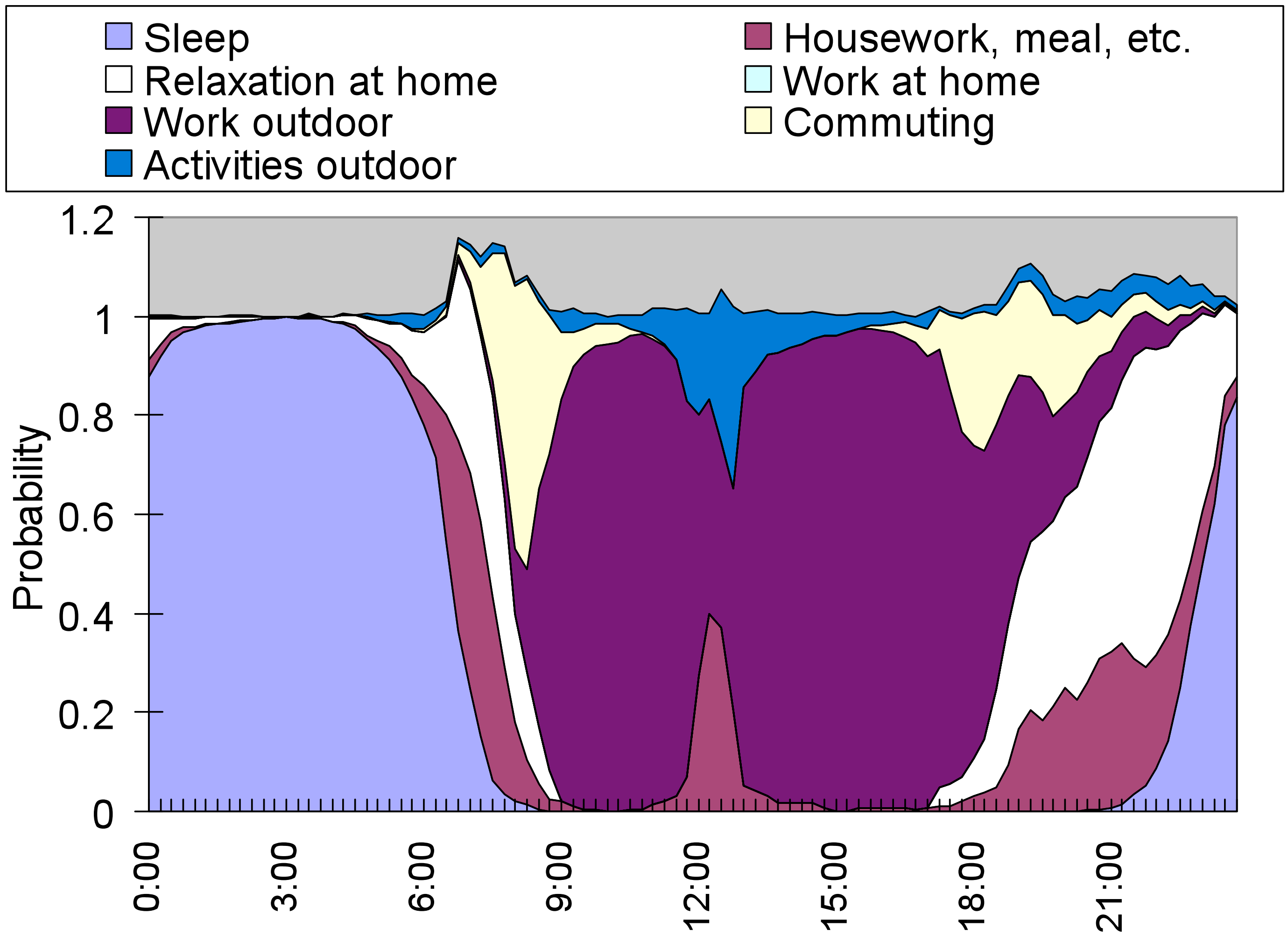
- Evaluate effect of the energy efficiency measures in all levels (from occupants behavior to district level measures) on total energy consumption and electricity load curve.
- Residential sector model
  - Diversity of household and building type is considered.
  - Energy use schedule model and dynamic 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-genelarion.


Occupants' behavior schedule model
National time use survey
(Japan Broadcasting Corporation)
Appliances energy use model
Hot water energy use model
Heating and Cooling model
(Heat load simulation)
Dissemination rate of appliances
Power consumption of appliances
Amount of hot water use
Weather data
Thermal characteristics of the house
Annual energy use of
each household category
912 household categories loop
19 family types,
12 building types,
4 insulation levels
Number of households
for each category
Distribution of each insulation level
Regional scale energy consumption
of residential sector
Input data

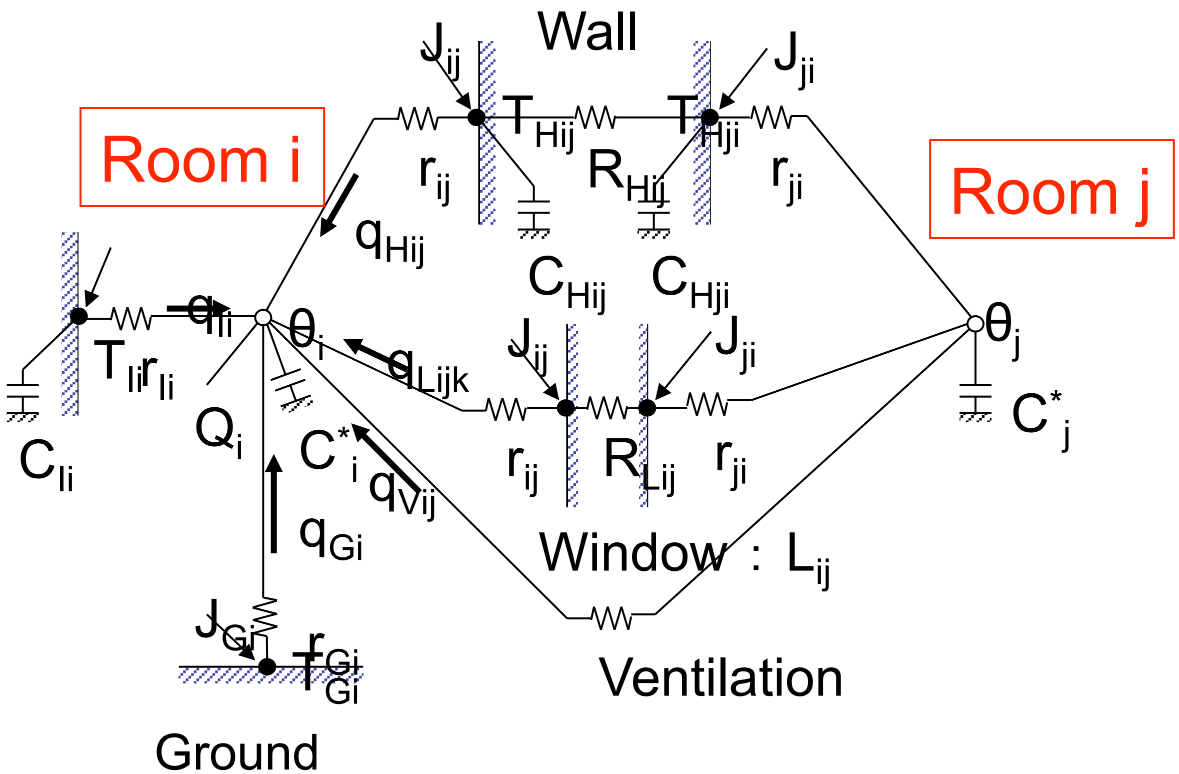
Activity Schedule of a male worker.

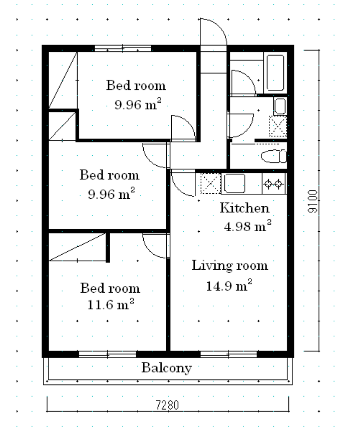


Settings for Home Electric Appliances

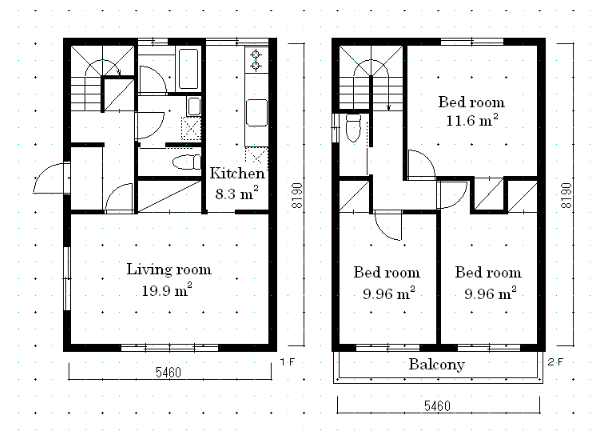
Appliances	Room	Number of holdings (per 100 households)	Power consumption [W]	
			Operating mode	Standby
Rice cooker	Kitchen	88.1	1250.0	35.0
Dishwasher	Kitchen	22.2	1000.0	3.0
TV	Living & bedroom	238.1	114.0	2.4
Refrigerator*	Kitchen	122.8	600.0	No standby
Washing Machine	Bathroom	109.3	126.0	0.7
Tumble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

Heating and cooling model.



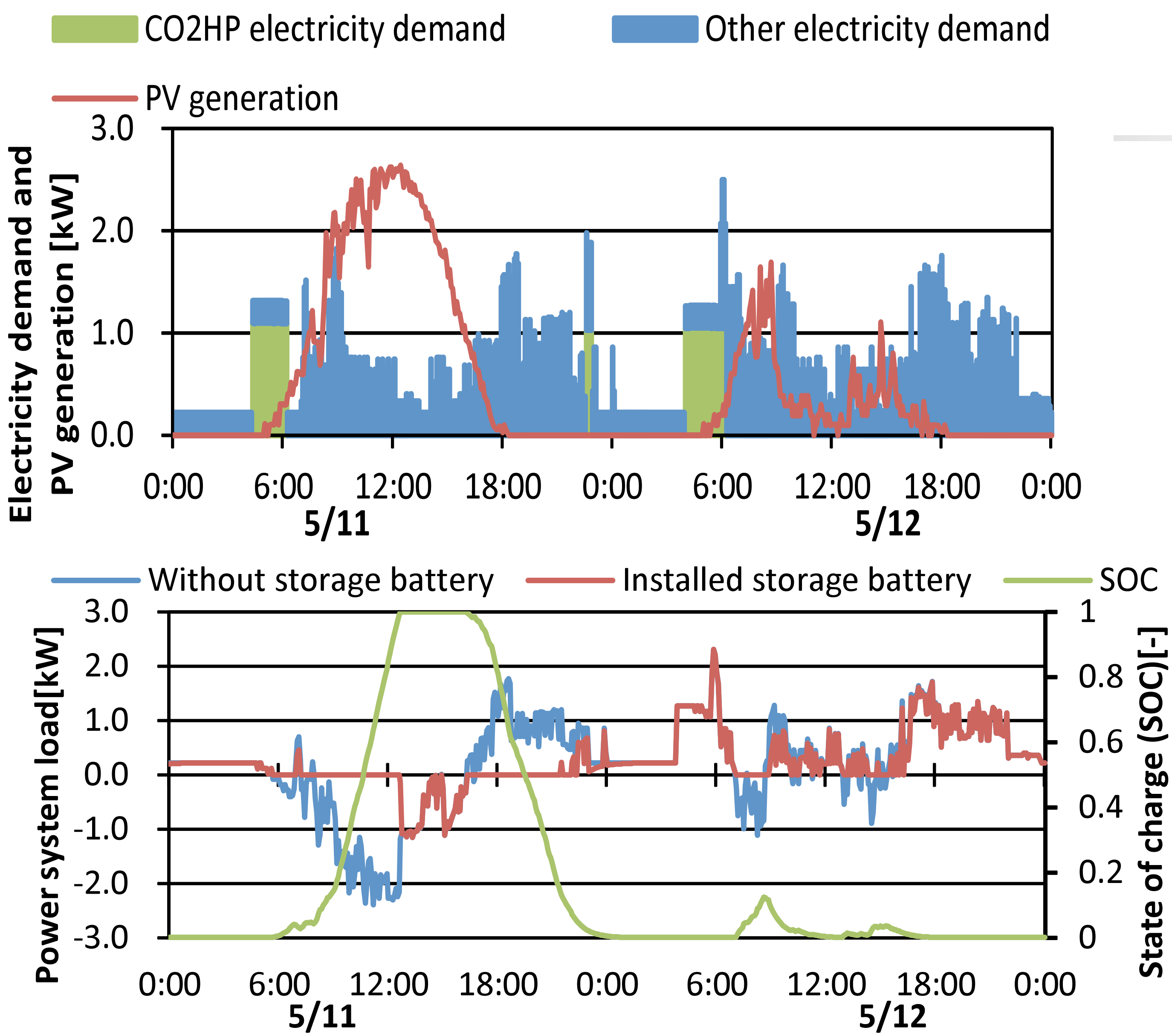


(a) Apartment house 68.7m²

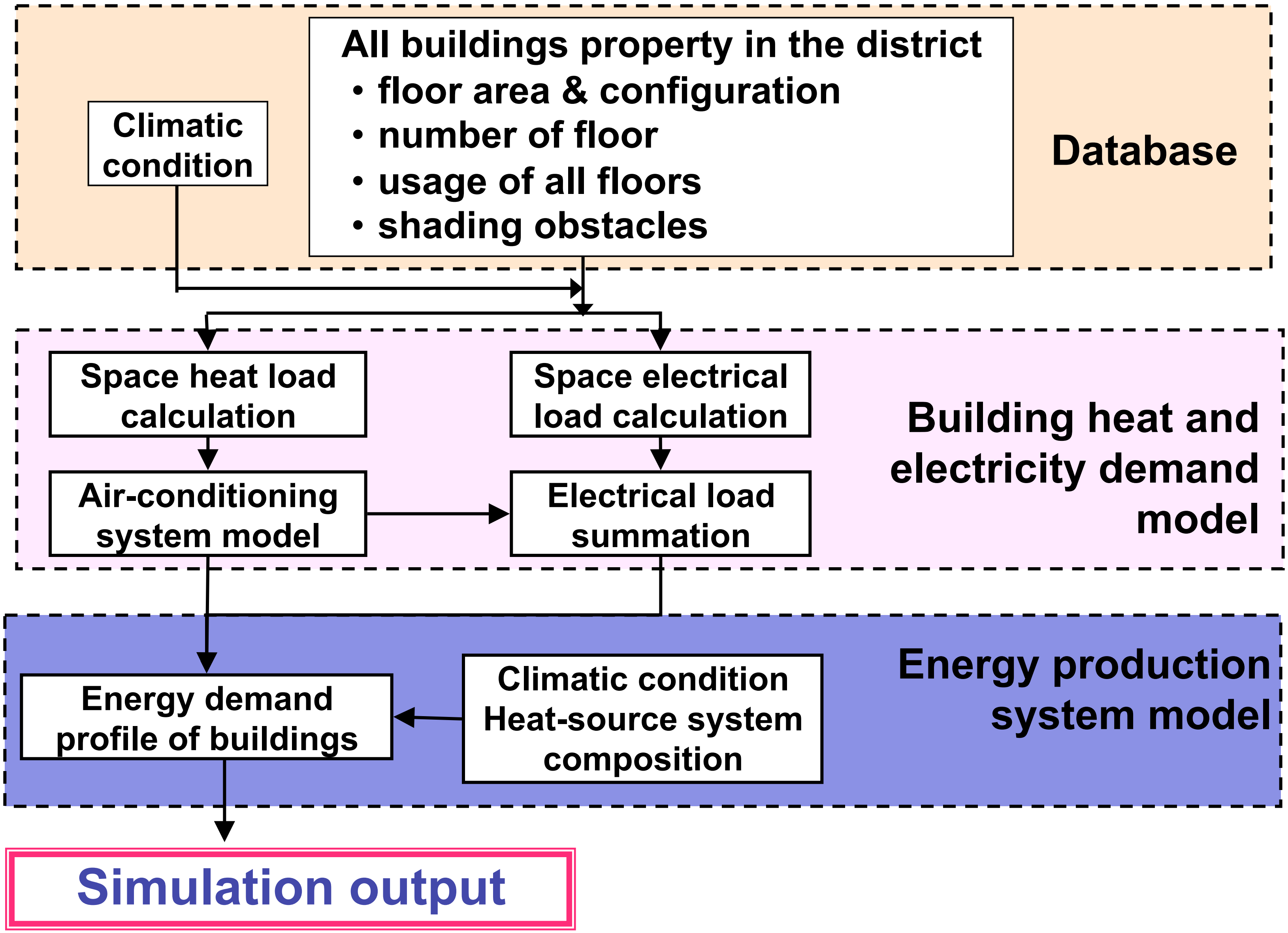


(b) Detached house 87.2m²

Simulation results for single house.



Non-residential sector model



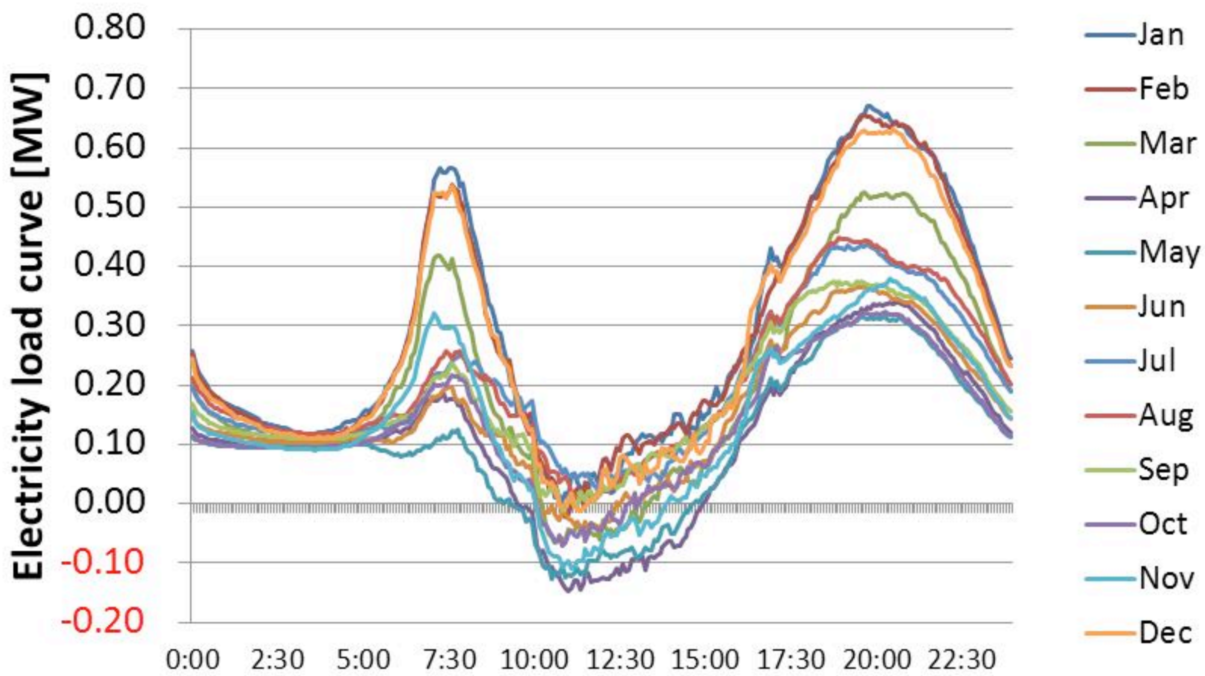
District and City-level energy consumption

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

$$= \int f \begin{pmatrix} \textit{occupants behavior}, \\ \textit{number of occupants}, \\ \textit{number and efficiency of appliances}, \\ \textit{insulation level of building}, \\ \textit{Climate} \end{pmatrix}$$

Examples for district scale simulation

- Area 1
  - Total floor area : $3.81 \times 10^4 m^2$
  - Detached house with PV :53%
  - Apartment house :37%
  - Commercial building :10%



Examples for district scale simulation

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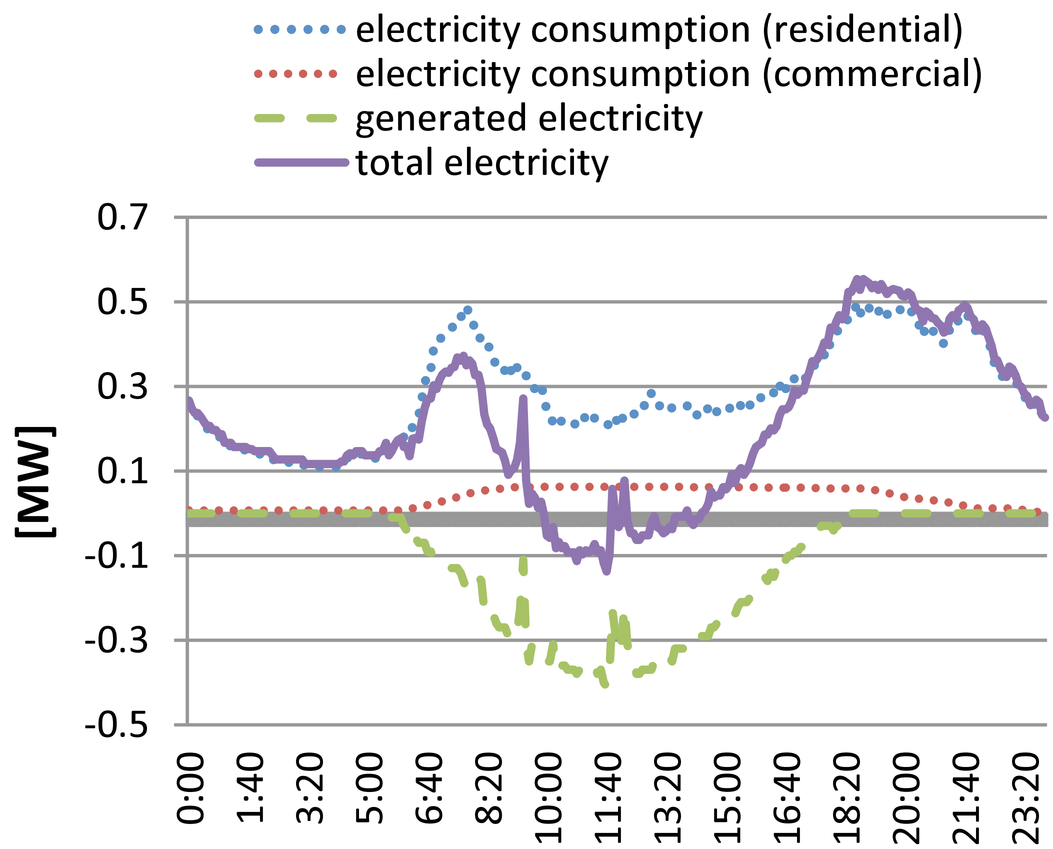
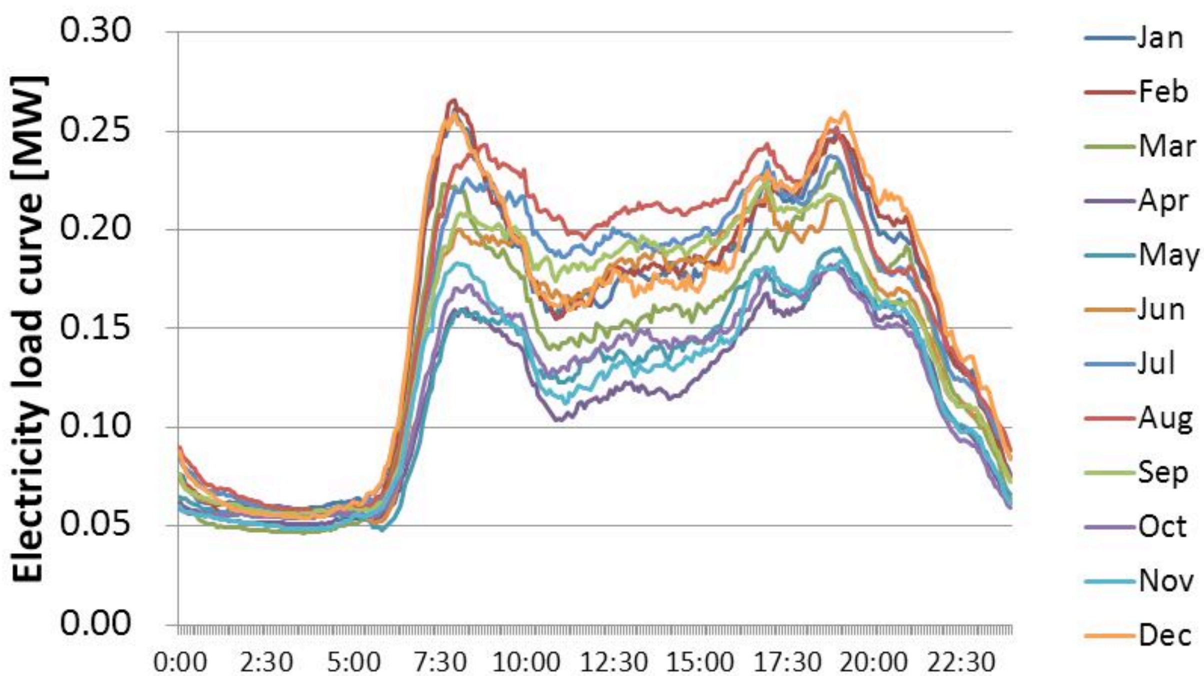


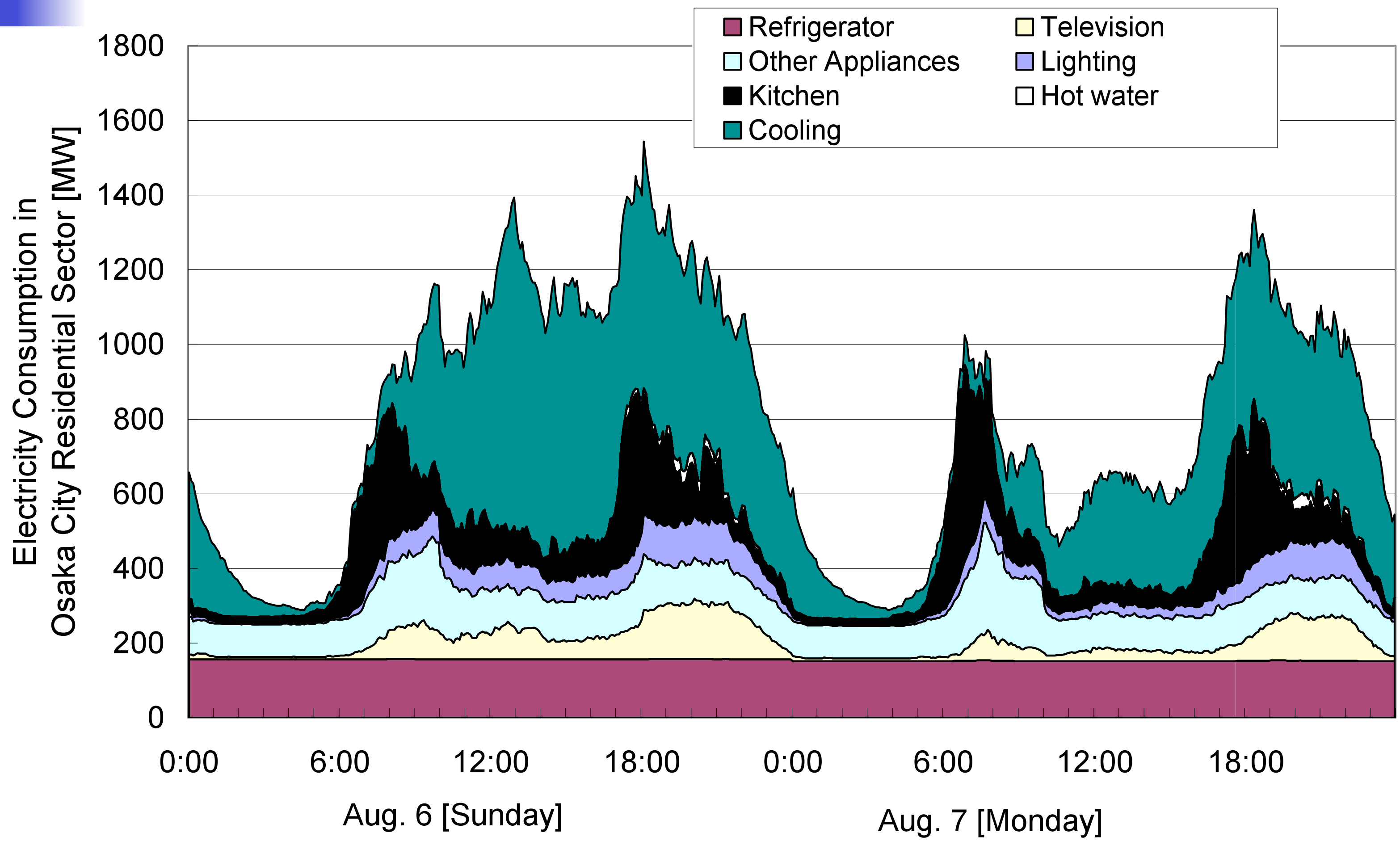
Electricity Balance in Summer

Examples for district scale simulation

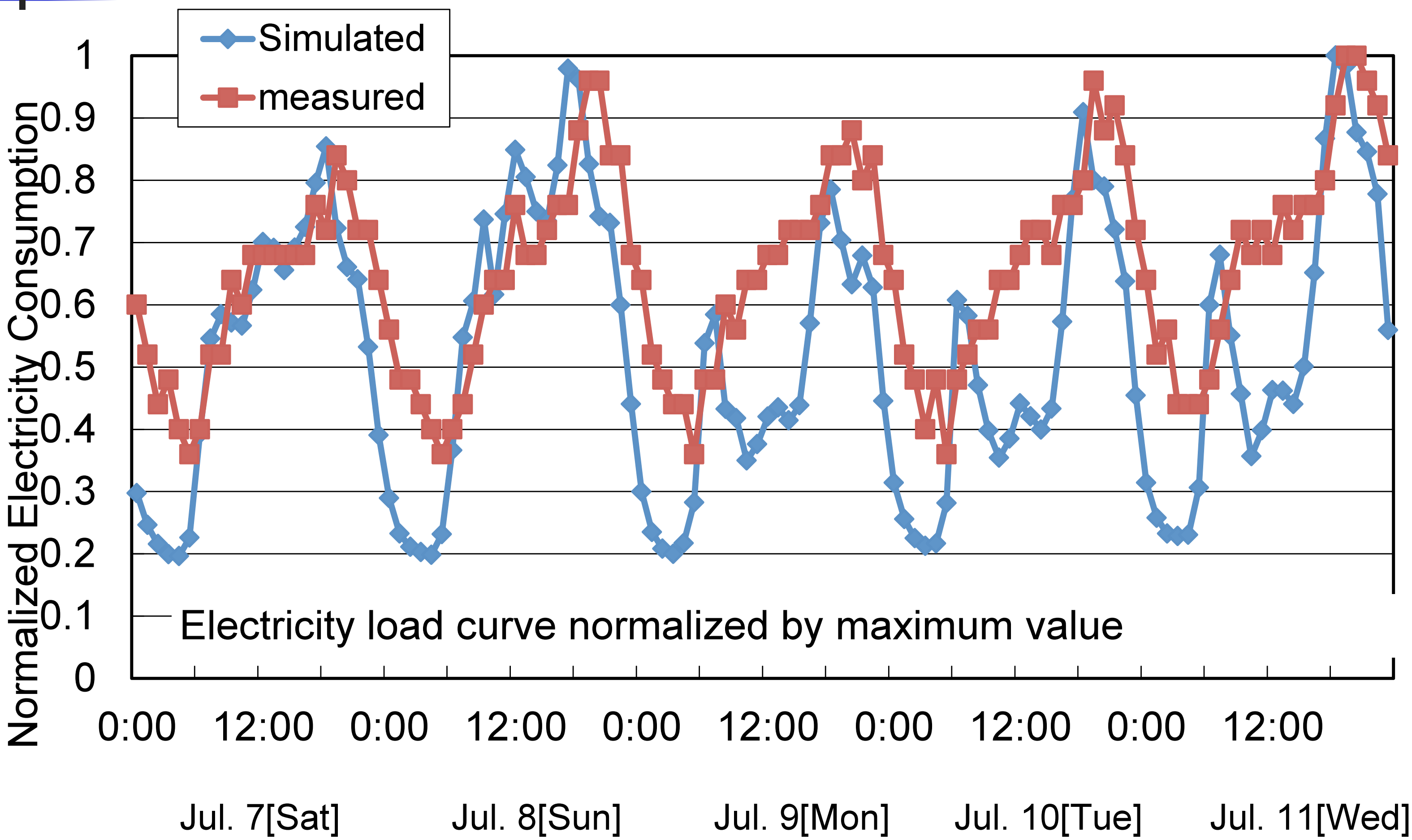
- Area 2
  - Total floor area : $1.89 \times 10^4 m^2$
  - Detached house with PV :22%
  - Apartment house :35%
  - Commercial building :43%



City-level Simulation:
Electricity load curve of Osaka City's Residential Sector (Summer)



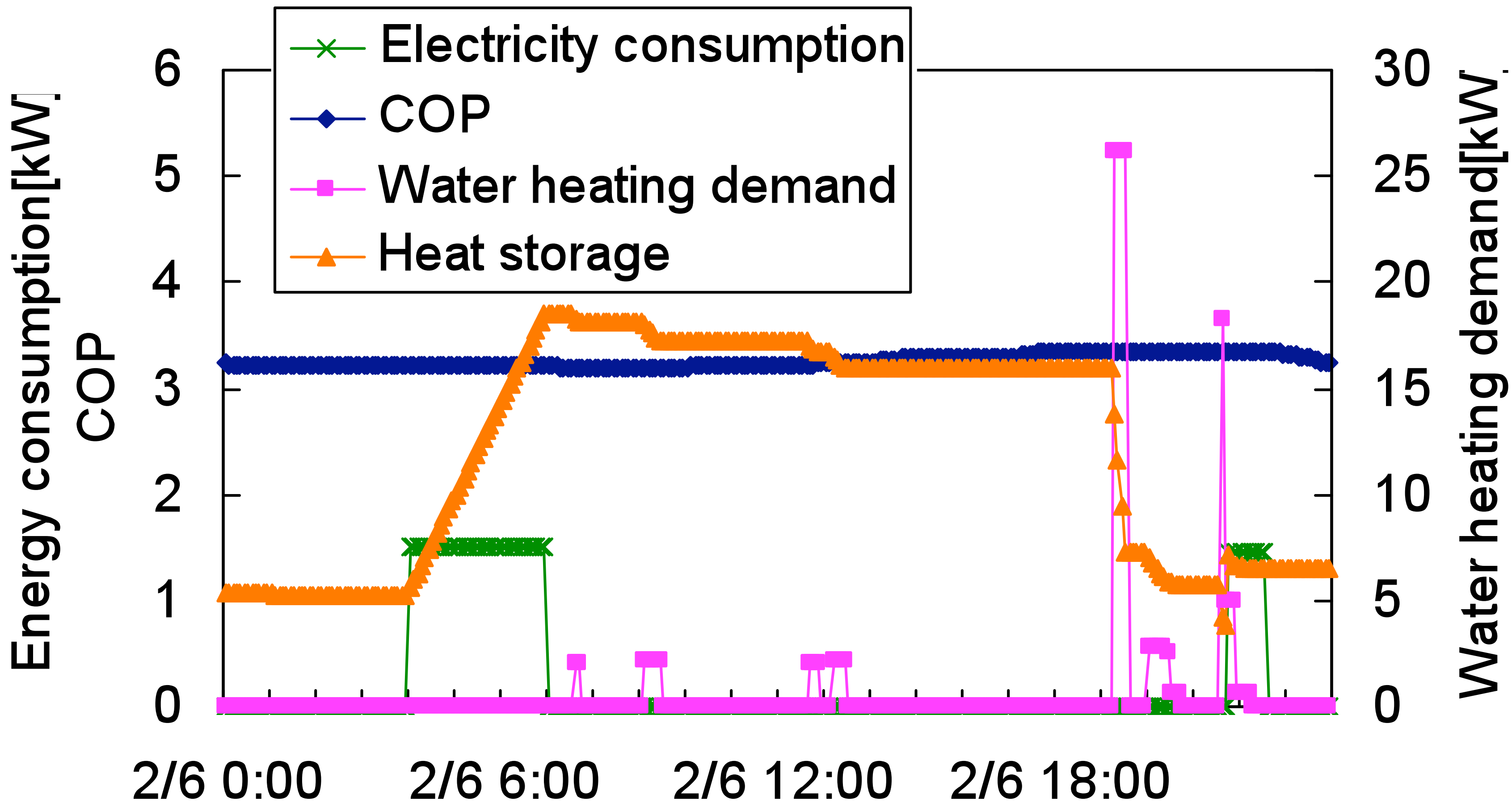
Validation of simulated Electricity load curve of Osaka City's Residential Sector



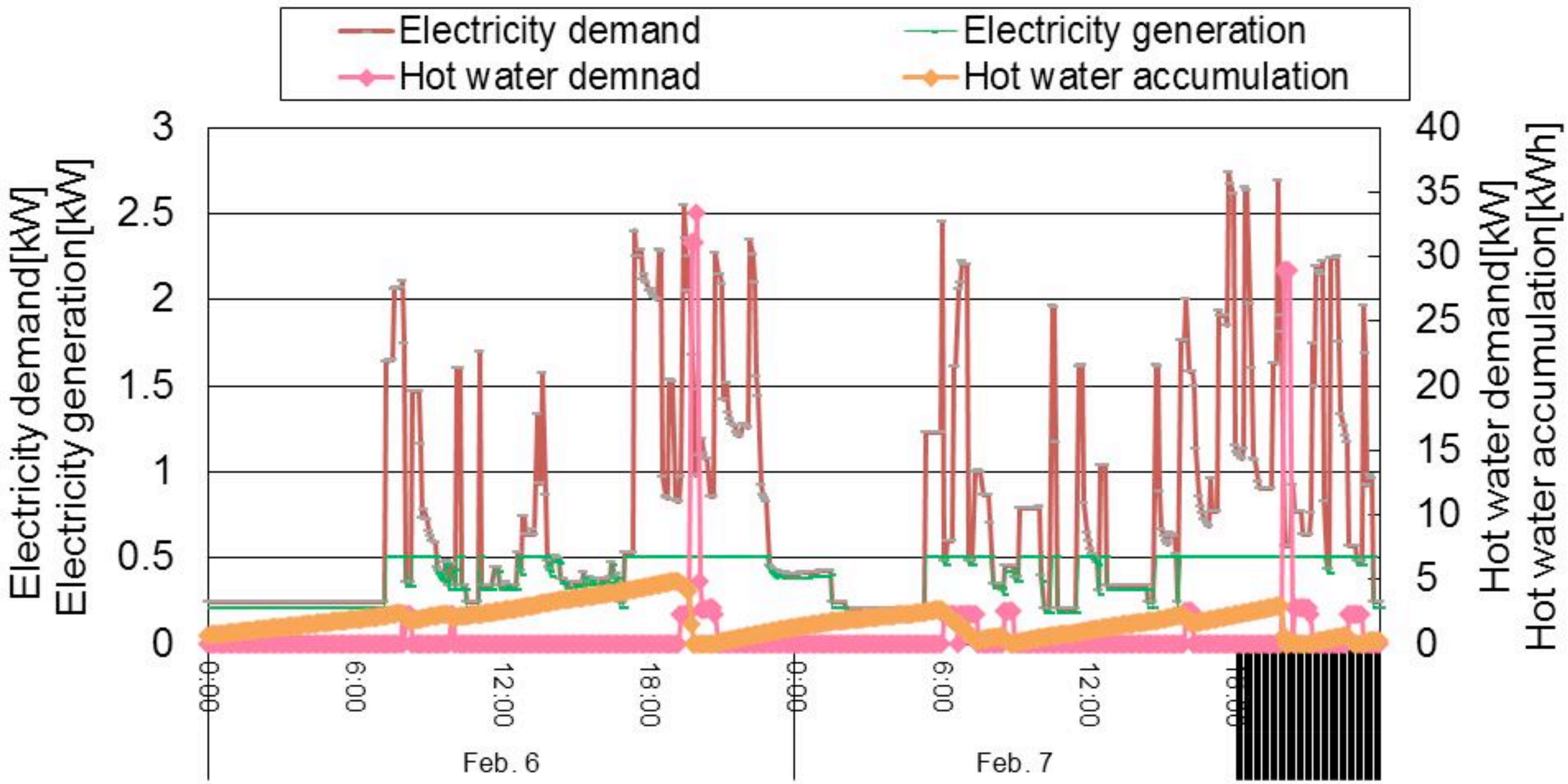
Japanese 25% GHG reduction plan (Japanese Ministry of Environment 2011)

- 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%

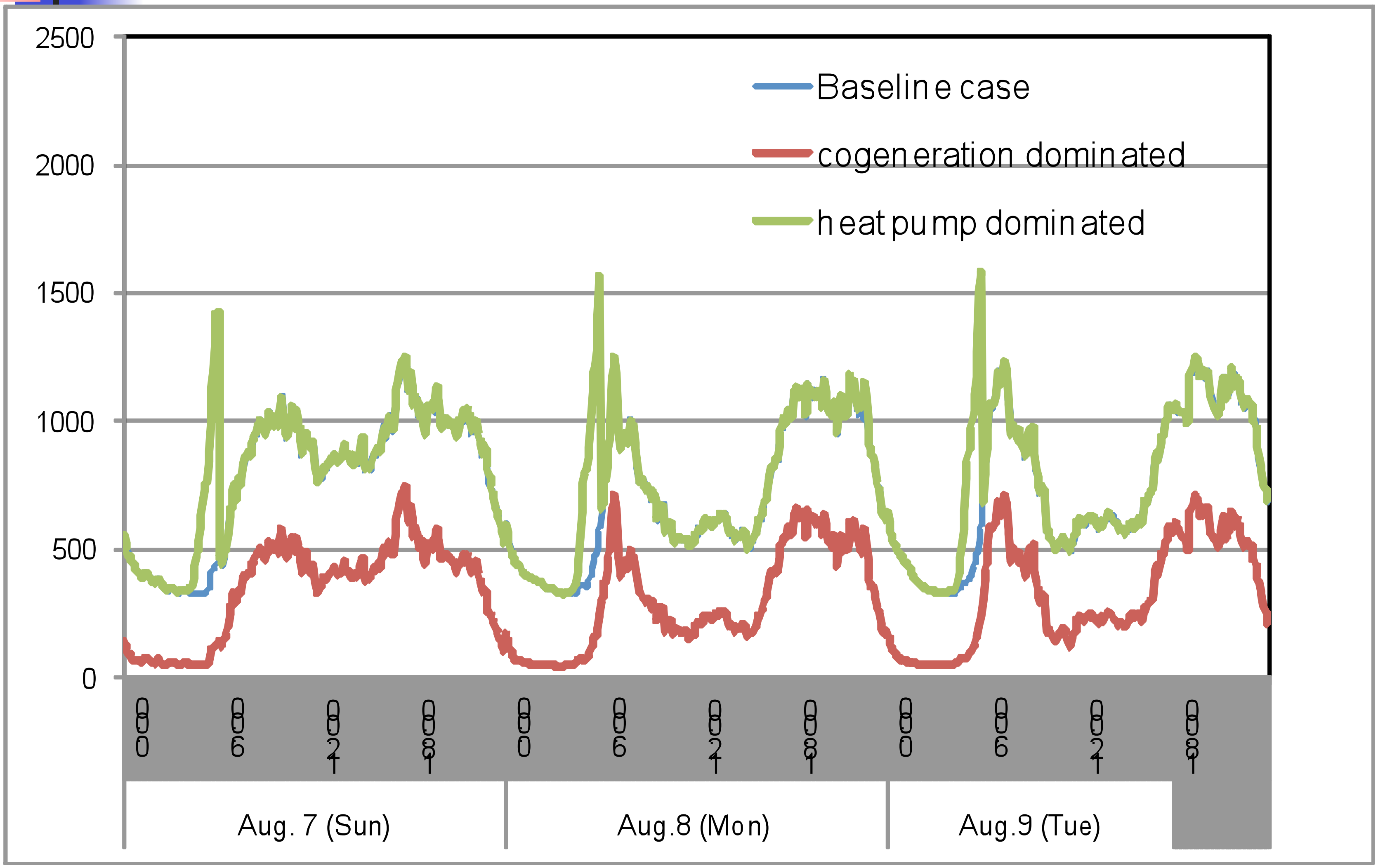
Examples of Heat Pump Operation



Examples of SOFC operation

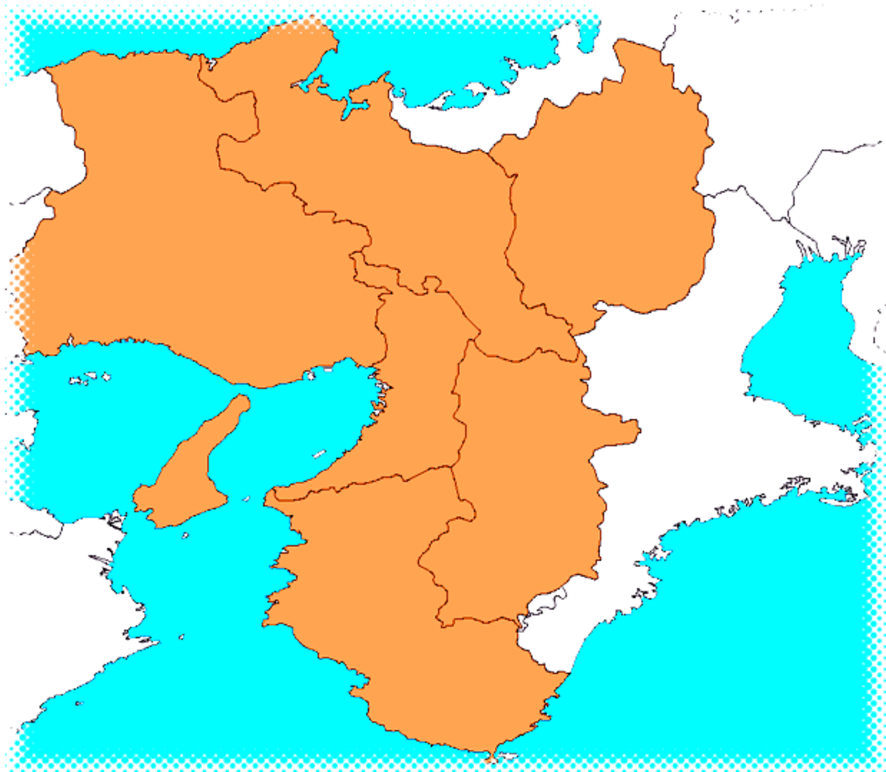


Osaka City's electricity load curve in residential sector under new water heater dissemination



Regional load curve prediction

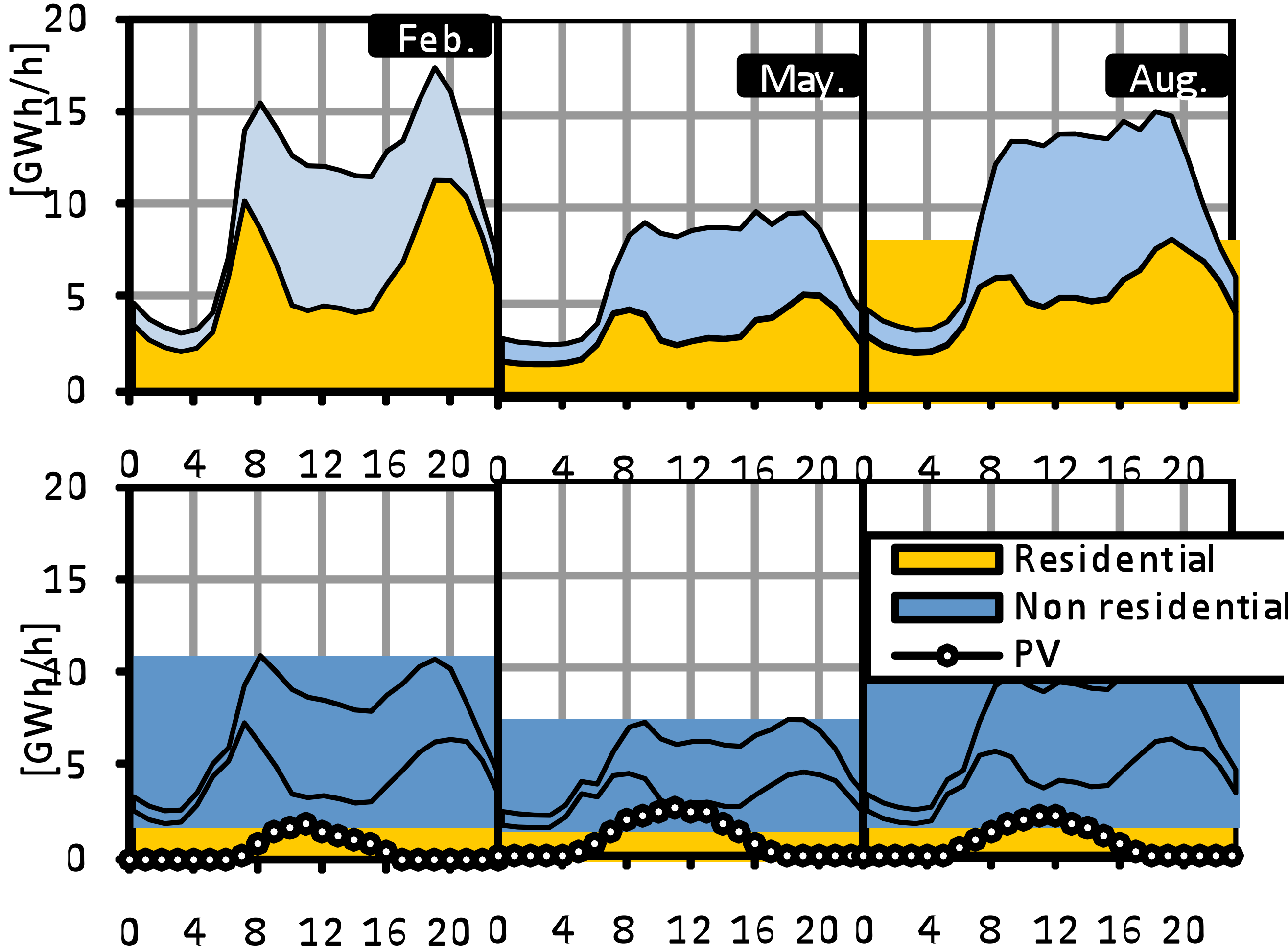
- Kinki Region (Population: 20.9 million, Area: 27,335km^2)
- Residential Sector & Non residential Sector only. (Industry and transportation are ignored)



Regional load curve prediction

2005 (Present)

2030 (GHG reduction measures are implemented)



Thank you for your attention!

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Publication list

- Yoshiyuki Shimoda, Takahiro Asahi, Ayako Taniguchi, Minoru Mizuno: Evaluation of city-scale impact of residential energy conservation measures using the detailed end-use simulation model, Energy, 32-9(2007), pp.1617-1633
- Yoshiyuki Shimoda, Yukio Yamaguchi, Tomo Okamura, Ayako Taniguchi, Yohei Yamaguchi: Prediction of Greenhouse Gas Reduction Potential in Japanese Residential Sector by Residential Energy End-Use Model, Applied Energy, 87, (2010), pp.1944-1952
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- Yohei Yamaguchi, Yoshiyuki Shimoda, Minoru Mizuno: Transition to a sustainable urban energy system from a long-term perspective: case study in a Japanese business district, Energy and Buildings, 39-1(2007), pp.1-12
- Yohei Yamaguchi, Yoshiyuki Shimoda, Minoru Mizuno: Proposal of a modeling approach for evaluation of city level energy management considering urban form, Energy and Buildings, 39-5(2007), pp.580-592
- Yohei Yamaguchi, Yoshiyuki Shimoda: "District-scale Simulation for Multi-purpose Evaluation of Urban Energy Systems", Journal of Building Performance Simulation, 3-4(2010), pp.289-305