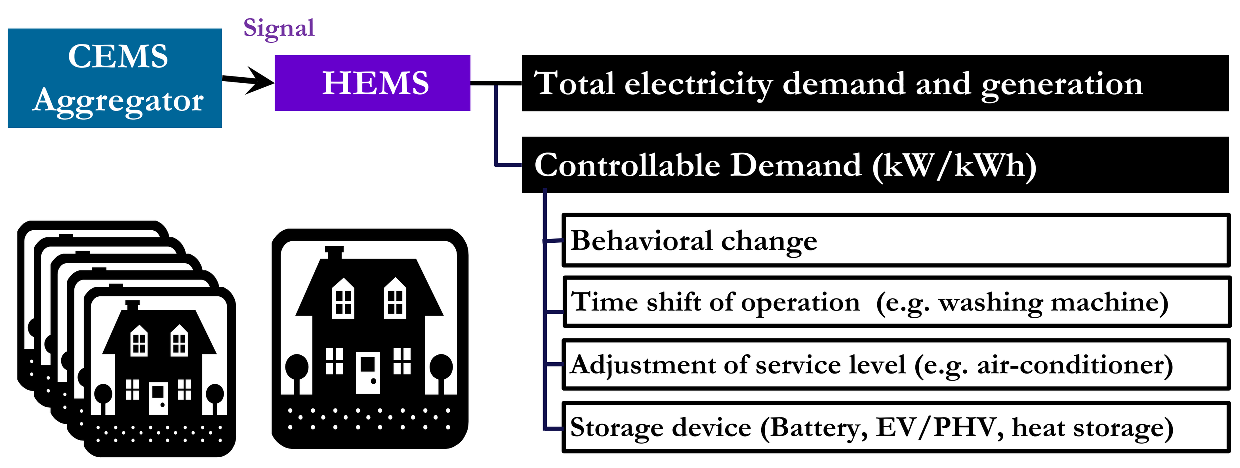
# Development of a Bottom-up Type Residential Energy End-use Model

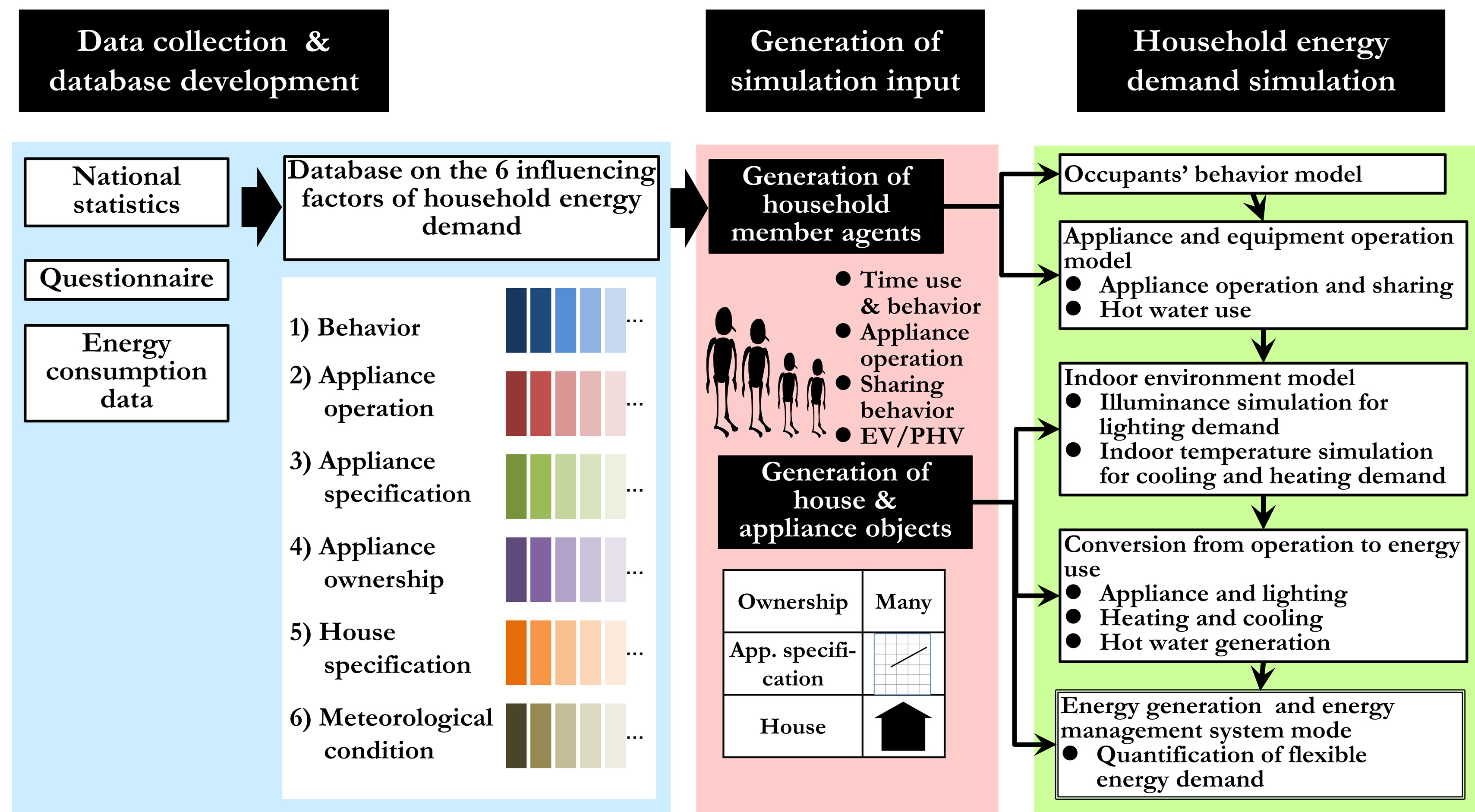
Yoshiyuki Shimoda, Yohei Yamaguchi and Ayako Taniguchi
Graduate School of Engineering, Osaka University contact: shimoda@see.eng.osaka-u.ac.jp

## Background

- In the design, planning and evaluation of EMS, disaggregate demand data is absolutely indispensable. To estimate the potential of demand response, the amount of "Controllable demand" should be quantified. In addition, to assess the potential of EMS in the future, change of total energy demand and controllable energy demand in the future must be predicted.
- The authors developed a model that simulates energy end-use demand of residential buildings based on a bottom-up modeling approach in which the total energy demand is quantified as a sum of the consumption of all appliances/equipments.



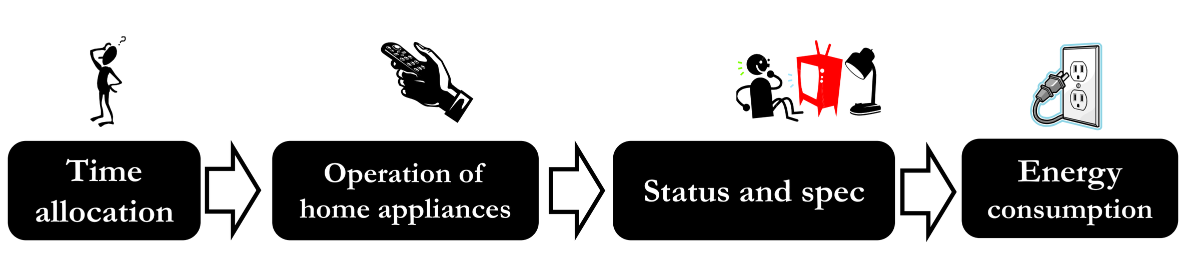

## Influencing factors of residential energy demand and database for generating variety energy demand in city

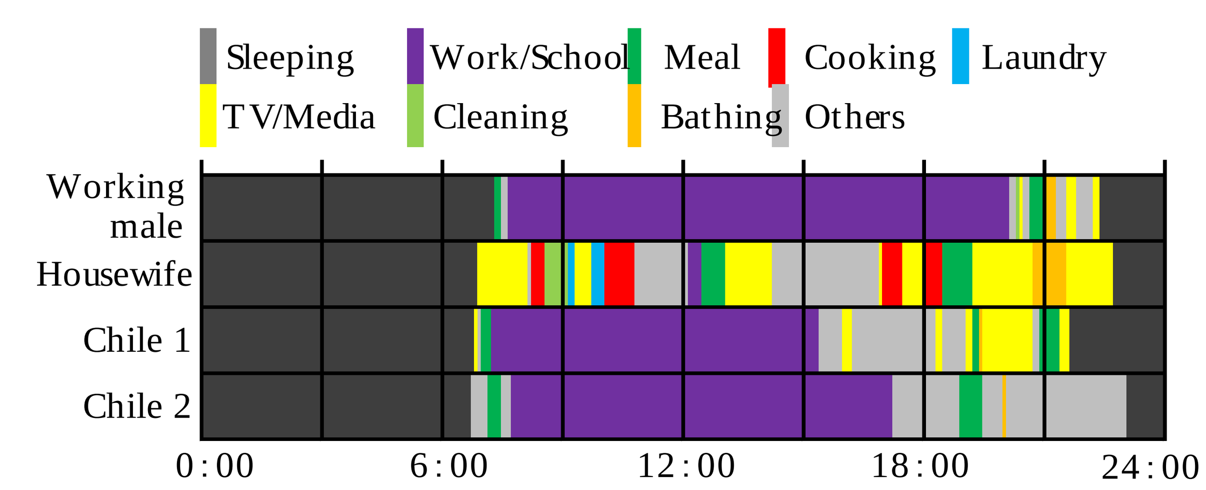


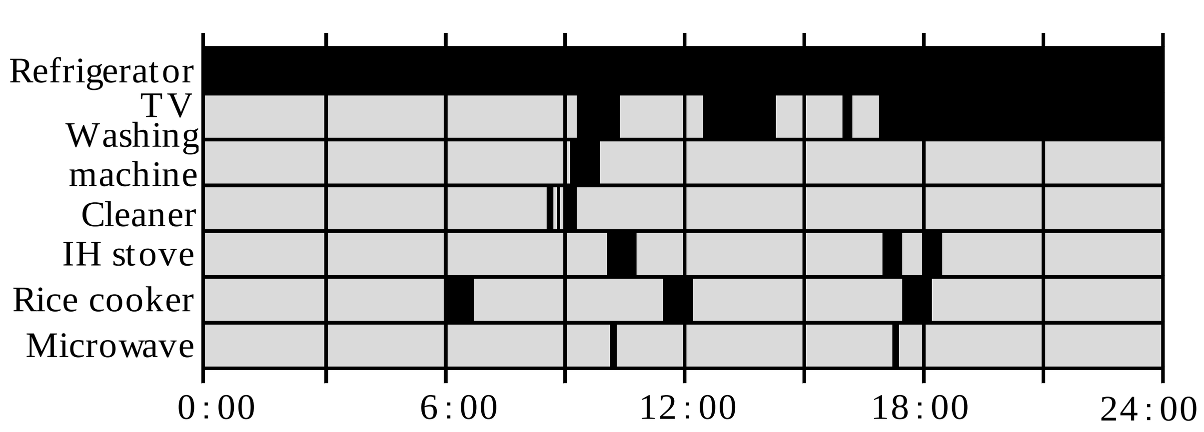

## Features of energy demand simulator

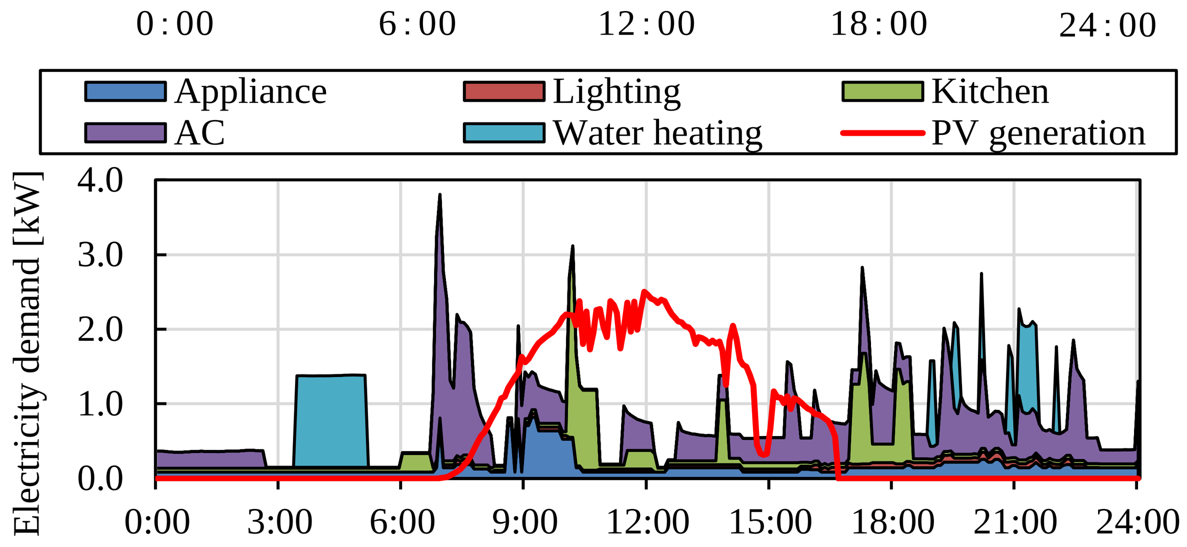
- Controllable demand given by the four methodologies listed above can be modelled.
- Deterioration in the service (comfort) level due to energy management can be quantified.
- The variety in energy demand among households can be considered by developing database on the influencing factors: 1) occupants behavior, 2) operation, 3) specification (energy efficiency) and 4) ownership of appliance/equipment, 5) specification of house, and 6) meteorological condition.
- Disaggregated component level information, e.g. response to DR signals, can be understood at the power system level.

## Structure of Residential Energy End-use Model

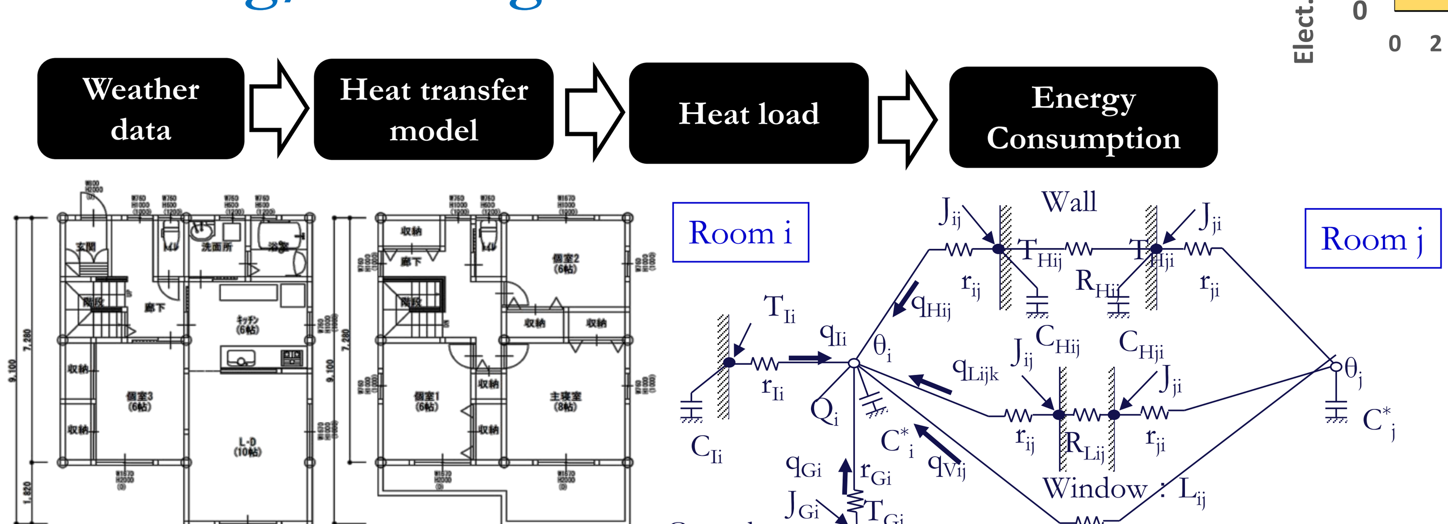


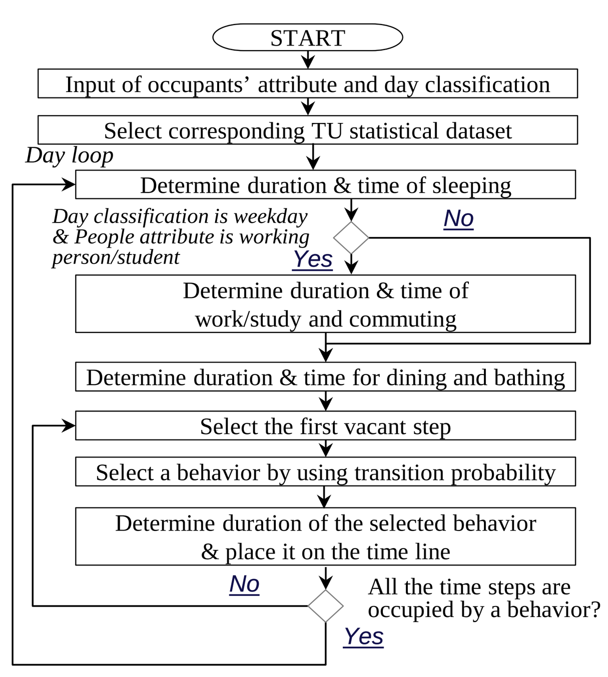




## Heating/Cooling Sub model

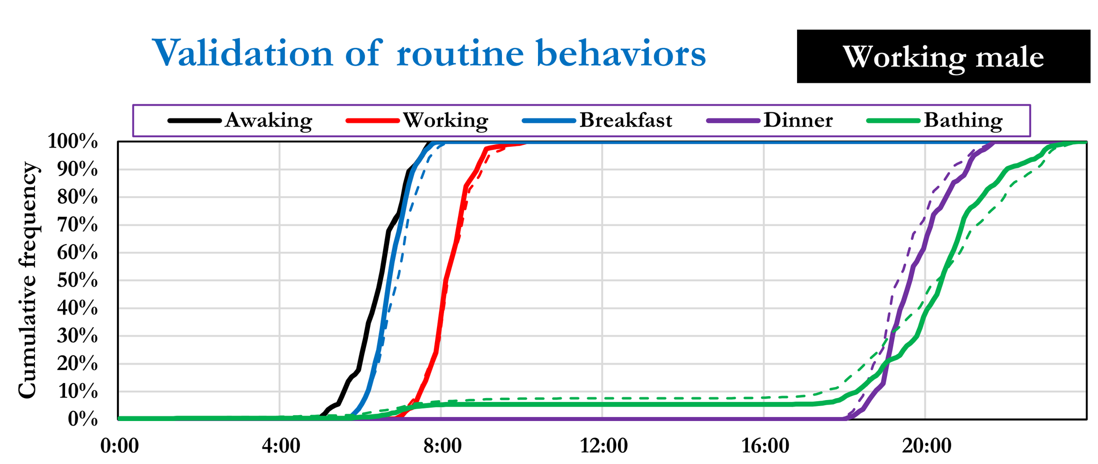


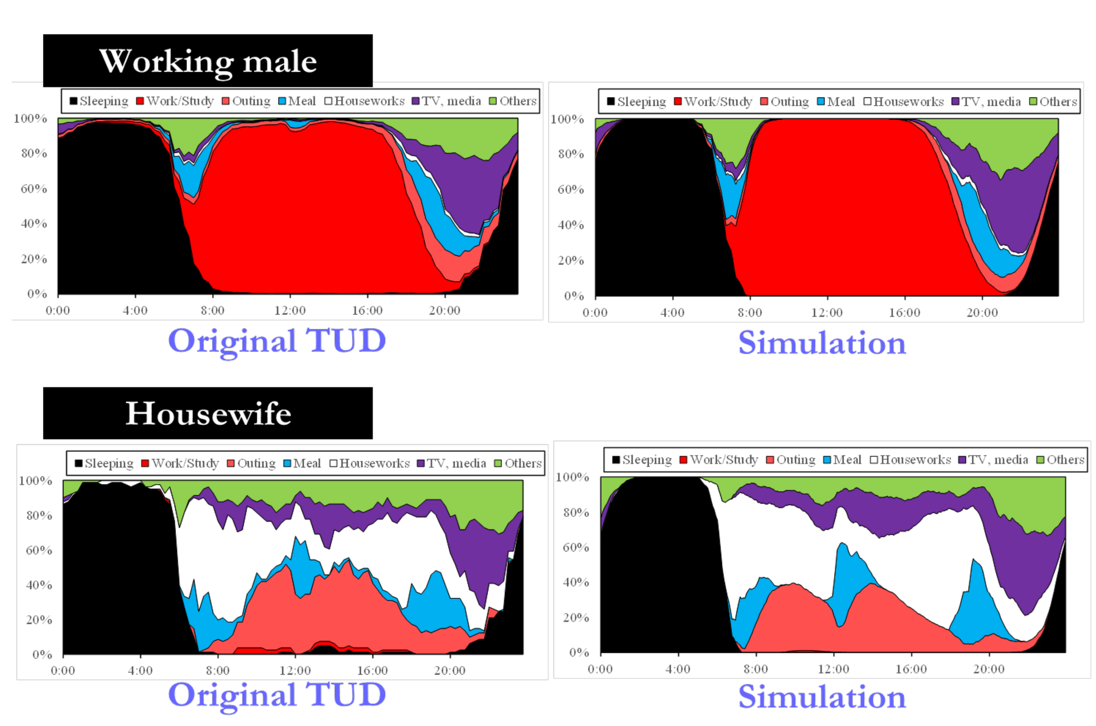

## 1: New occupants' behavior model

- Define routine behaviors and consider interactions among family member
  1)Sleeping,
  2)Having meals,
  3)Bathing
- Place routine behaviors first. Then non-routine behaviors fill the gaps

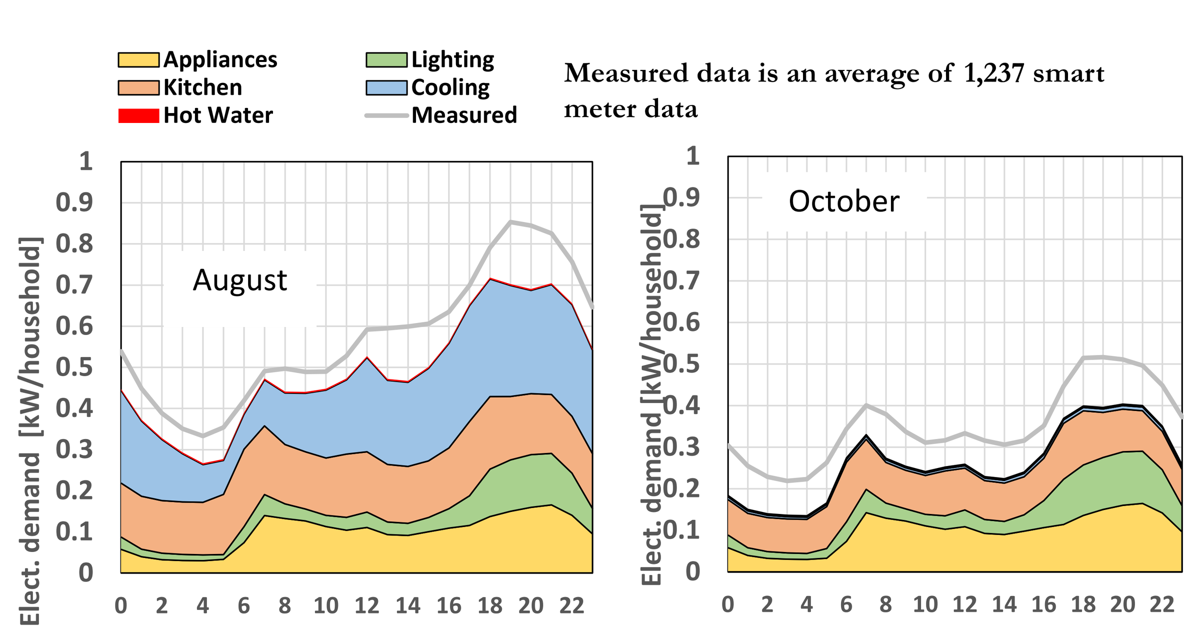



Validation of routine behaviors

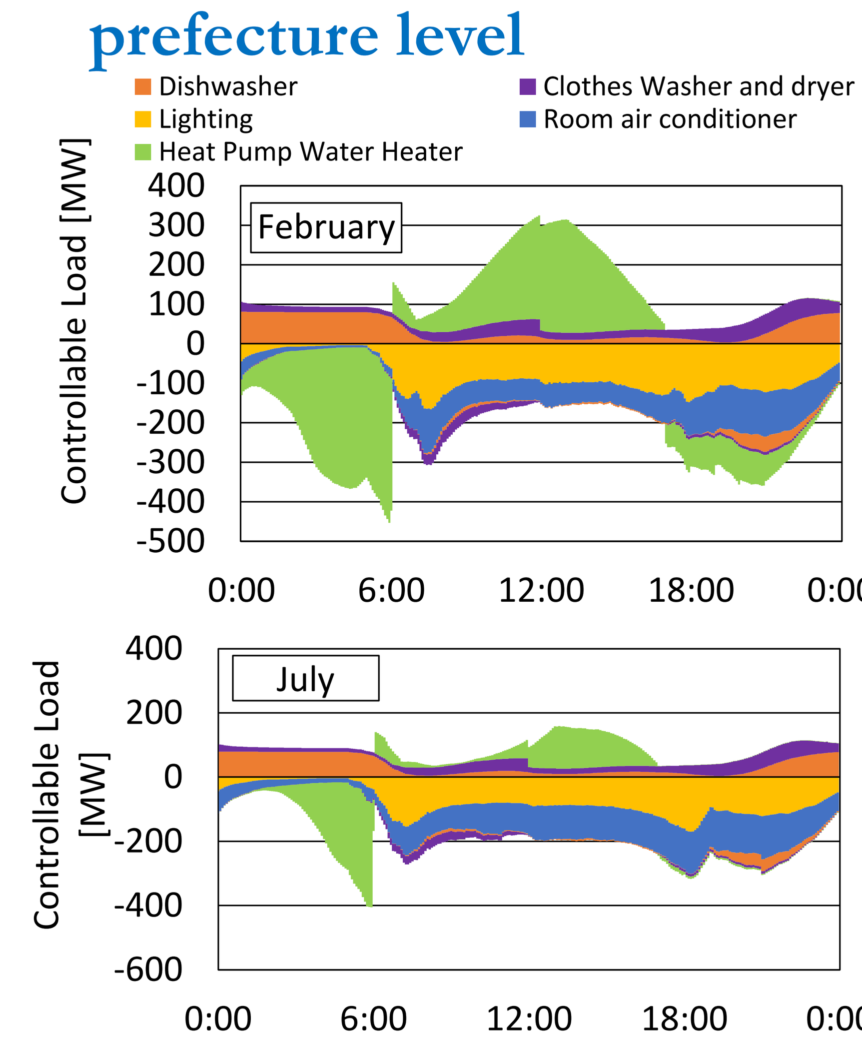



## 2: Validation of the electricity load curve in power system level

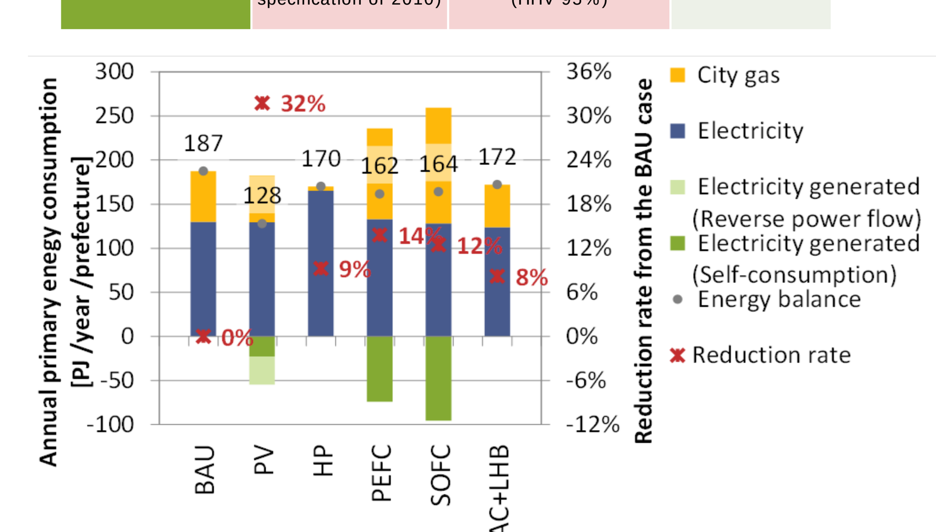


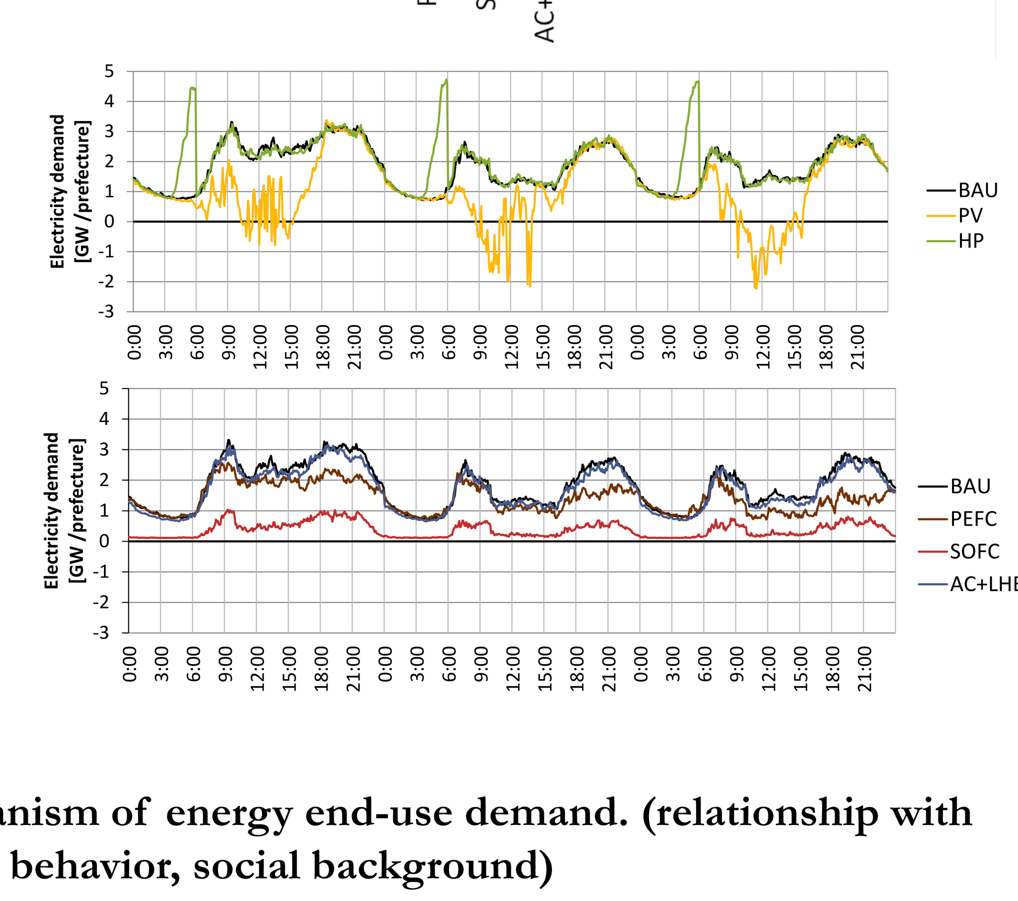

## 3: Estimation of demand response resource in prefecture level




## 4: Estimation of prefecture-scale impact of the new Japanese energy saving standard

| | Heating and Cooling | Water heater | Photovoltaic power generation |
|---|---|---|---|
| BAU case | Air conditioner (Usual specification) | Gas water heater (HHV 78%) | No adoption |
| Photovoltaic power generation | Apartment house; Same specification as AC+LHB case | | Detached house; 3 kW |
| Heat pump water heater | Air conditioner (Usual specification) | Heat pump water heater | No adoption |
| PEFC cogeneration | | PEFC cogeneration (700 W) | |
| SOFC cogeneration | | SOFC cogeneration (700 W) | |
| High-efficiency air conditioner + Condensing gas water heater | Air conditioner (the most efficient specification of 2010) | Condensing gas water heater (HHV 95%) | |




## Future works :

- Deeper analysis on generating mechanism of energy end-use demand. (relationship with meteorological condition, occupants' behavior, social background)
- Modelling of energy use in non-residential buildings. (Development of 'Virtual City Model')
- Possibility of EMS which contains energy end-use simulator (i.e. Breakdown of end-use demand by real time data, forecasting of energy demand)