Agent-based modelling of occupant behaviour for residential buildings in dynamic building performance simulation

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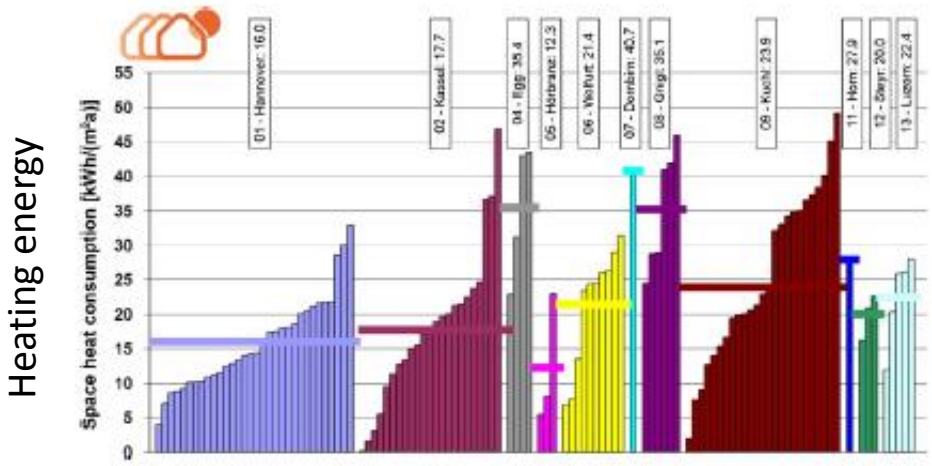
- Introduction
- General aspects of occupant behaviour in buildings
- Overall integrated model structure and overview
- Appliances use in residential buildings

Introduction

- In practice:
  - Large differences between predicted and simulated energy use
  - Large variability in measured performance of similar buildings



(Schnieders and Hermelink, 2006)

- Rapid increase in computational resources

→ Simulation community moves towards probabilistic approach

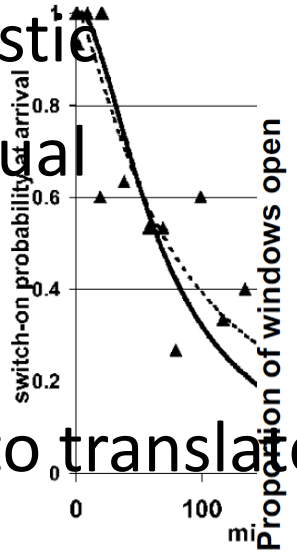
Introduction

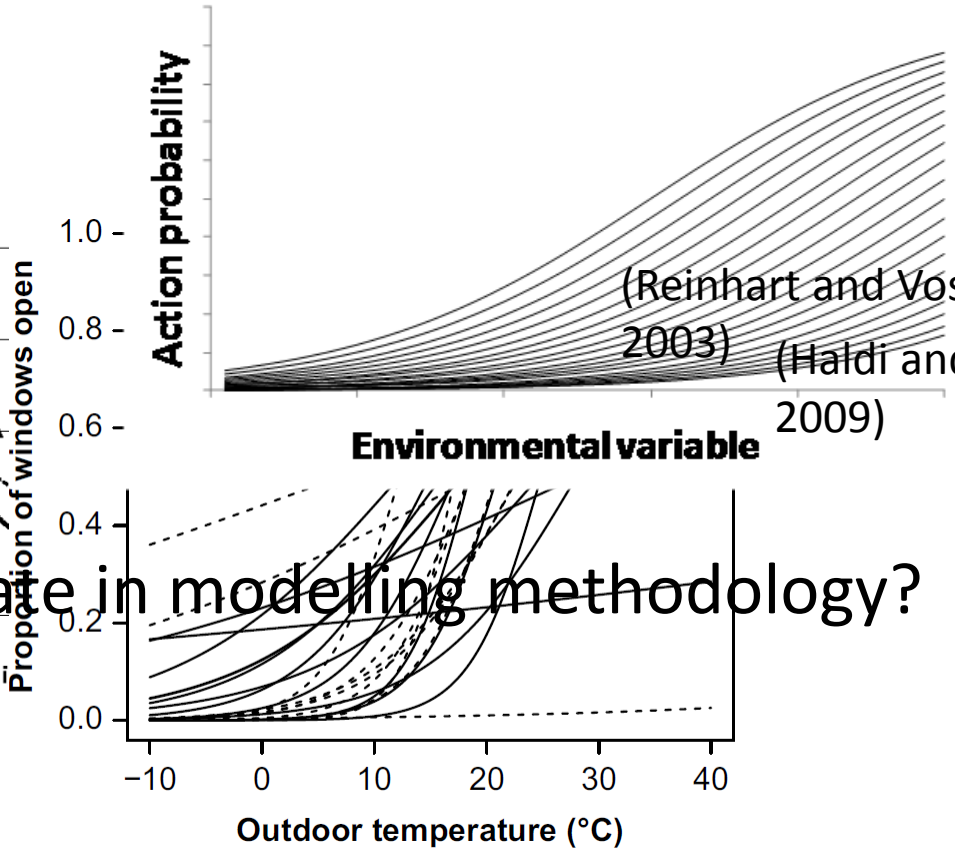
- Much effort invested in uncertainty and sensitivity analysis algorithms
- Lack of empirical data on input uncertainty linked to occupancy and occupant behaviour

→ Integrated methodology proposed, assembling empirical studies on different behavioural subfields

General nature of occupant behaviour

- Characteristics:
  - Adaptive
  - Stochastic
  - Individual





(Reinhart and Voss, 2003)

(Haldi and Robinson, 2009)

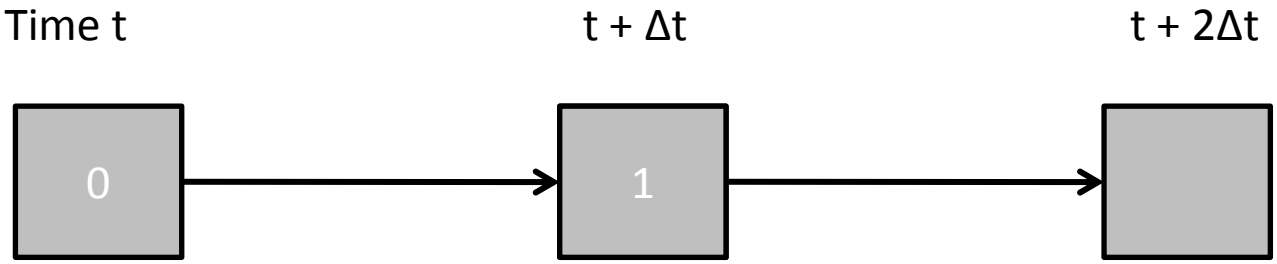
→ How to translate in modelling methodology?

General nature of occupant behaviour

- Modelling architecture
  - → Focus on agent-based models
    - Inclusion of occupant on multi-scale
    - Extrapolatable
    - Consistent and coupled modelling of all aspects
  - → Explicit modelling of each person and action
- Modelling methodology
  - → Typically first-order inhomogeneous Markov chain

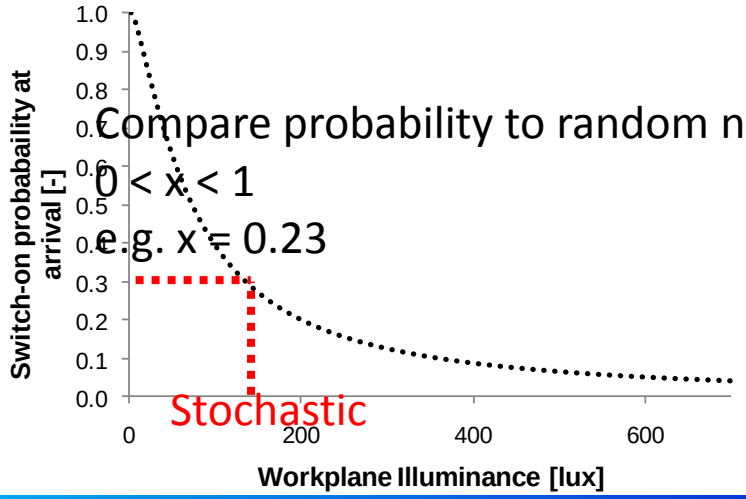
General nature of occupant behaviour

- First-order inhomogeneous Markov chain



'Occupant arrives'
(→ *occupancy model*)
'150 lux on workplane'
(→ *daylight simulation*)

Adaptive



Compare probability to random number
$0 < x < 1$
e.g. $x = 0.23$

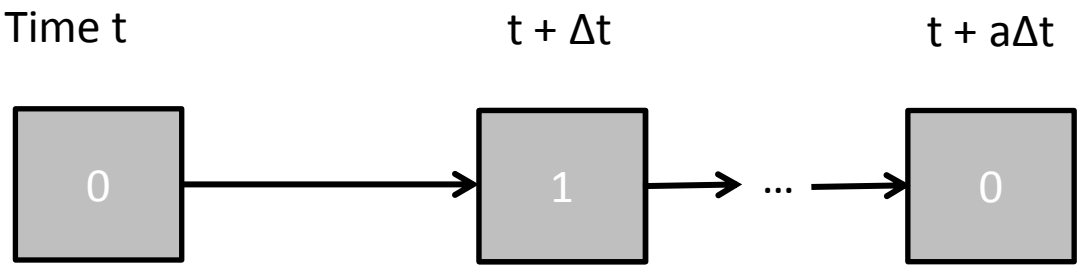
Stochastic

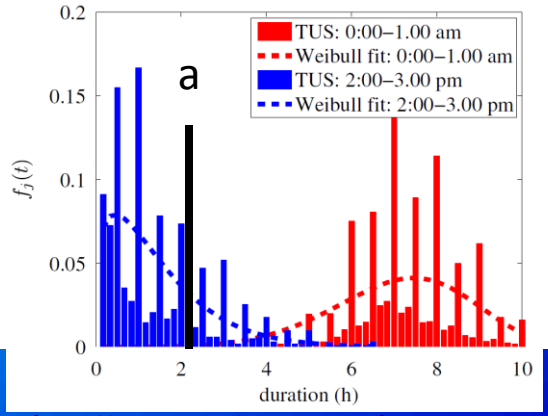
General nature of occupant behaviour

- First-order inhomogeneous Markov chain
  - time-step dependent transition probabilities

    → Discrete event modelling
  - Inability to coherently model state duration distributions

    → Hybrid approach: duration sampling when state changes (survival analysis)

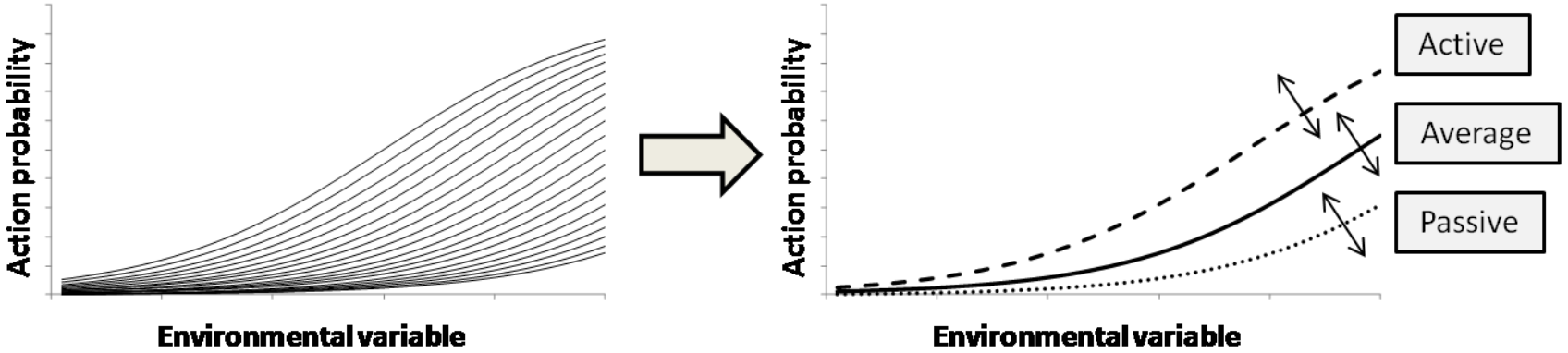


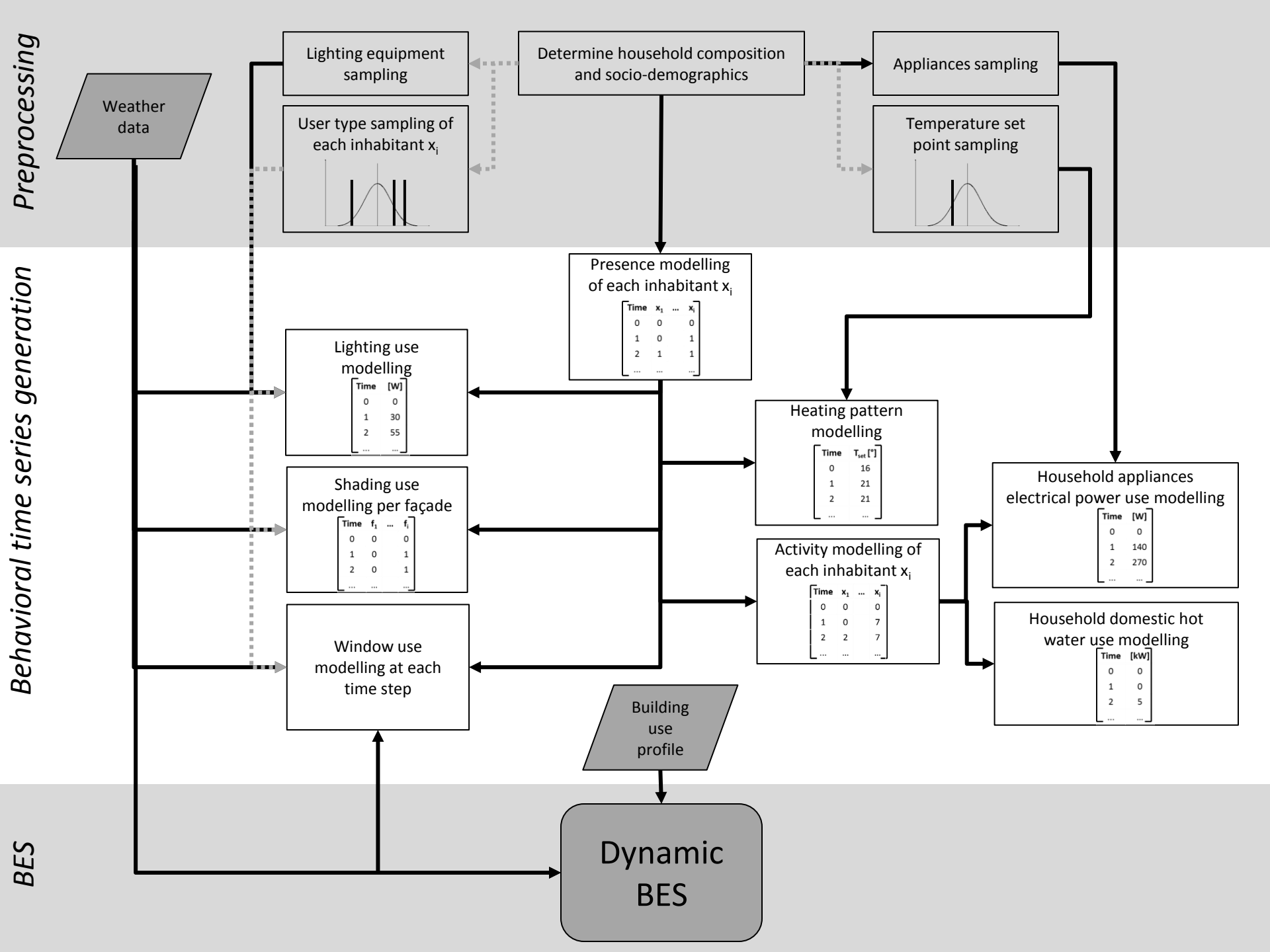


(Wilke et al., 2013)

General nature of occupant behaviour

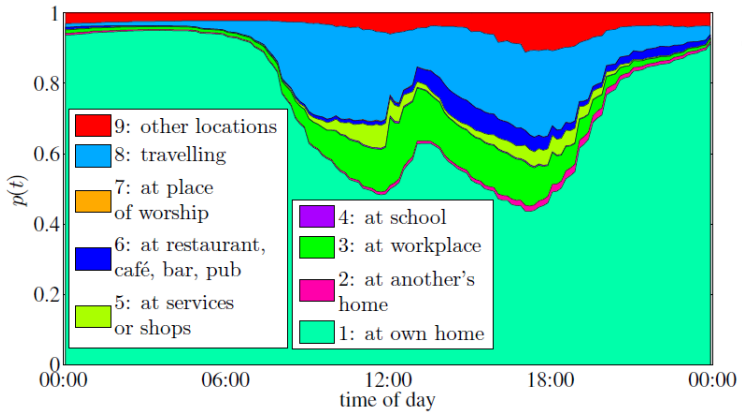
- Inclusion of individual variability aspect
  - → Use of individual transition probability functions
  - → Define representative classes of users
    - active/passive approach
    - **Socio-demographic classes**




Preprocessing
Behavioral time series generation
BES
Weather data
Lighting equipment sampling
Determine household composition and socio-demographics
Appliances sampling
User type sampling of each inhabitant x_i
Temperature set point sampling
Presence modelling of each inhabitant x_i
Time x_1 ... x_i
0 0 0
1 0 1
2 1 1
... ...
Lighting use modelling
Time [W]
0 0
1 30
2 55
... ...
Heating pattern modelling
Time T_{set} [°]
0 16
1 21
2 21
... ...
Household appliances electrical power use modelling
Time [W]
0 0
1 140
2 270
... ...
Shading use modelling per façade
Time f_1 ... f_i
0 0 0
1 0 1
2 0 1
... ...
Activity modelling of each inhabitant x_i
Time x_1 ... x_i
0 0 0
1 0 7
2 2 7
... ...
Household domestic hot water use modelling
Time [kW]
0 0
1 0
2 5
... ...
Window use modelling at each time step
Building use profile
Dynamic BES

Residential submodels

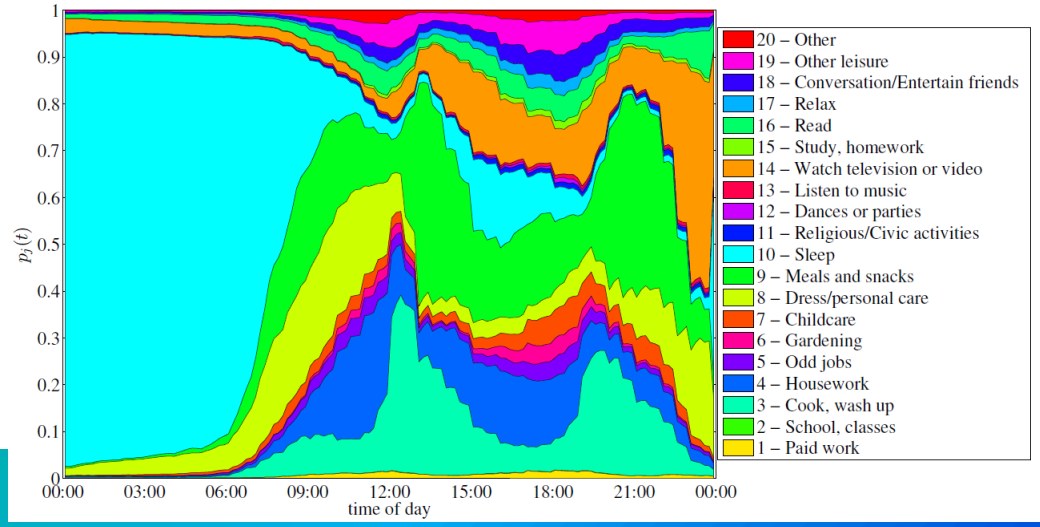
- Presence: Wilke 2013
  - First-order Markov chain
  - Based on French Time-Use Survey
  - Differentiated for 7 week days
  - Differentiated for 17 socio-demographic variables



(Wilke 2013)

Residential submodels

- Activity: Wilke 2013
  - Hybrid approach
  - Based on French Time-Use Survey: 20 activities
  - Differentiated for 7 week days
  - Differentiated for 17 socio-demographic variables



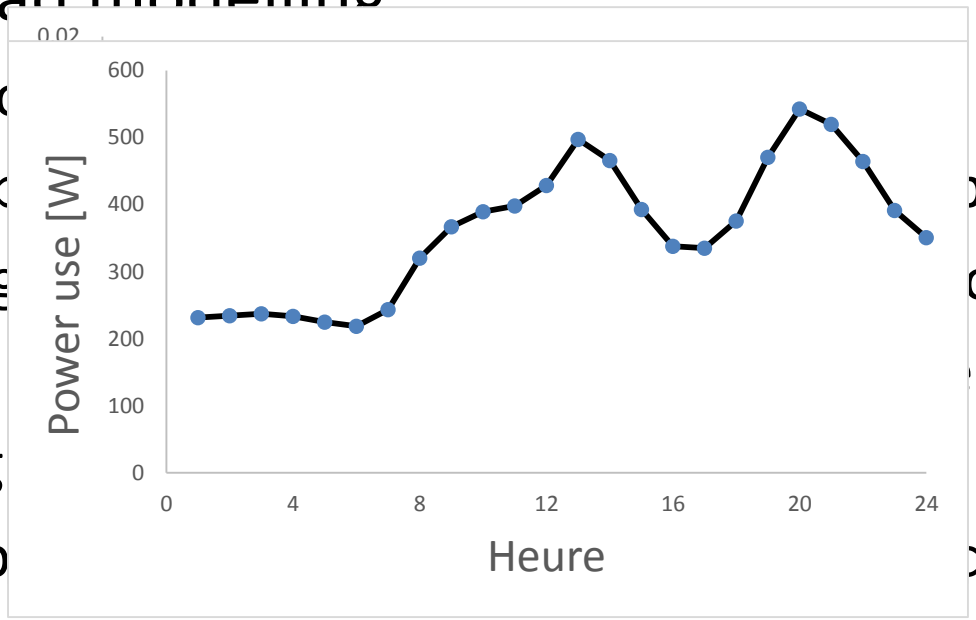
(Wilke 2013)

Residential submodels

- Appliances use
  - Step 1: ownership sampling (Wilke 2013)
    - Cold appliances, entertainment, kitchen, washing
      → Covers on average ± 80% of household appliance electricity use
    - Dependent on 10 socio-demographic variables
      → Multivariate logit regression
    - Based on Swiss household data

Residential submodels

- Appliances use
  - Step 2: load modelling



→ Based c

- Cold app ble
- Washing ower sample
- Entertai r sample
- Cooking

→ Probab consumption data

→ Additional constant power use calibrated with total household power use

Merci de votre attention!

Questions?