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From domestic energy demand to household activity patterns

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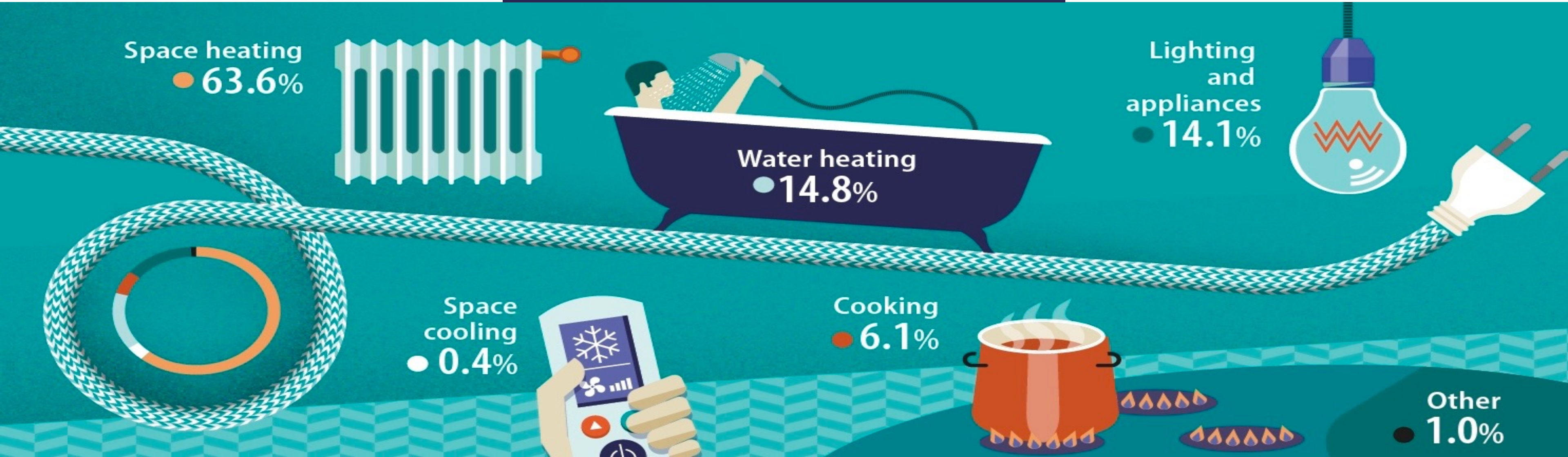


Outline

- Motivation
- Introduction
- Methodological approach
- Datasets and analysis
- To conclude

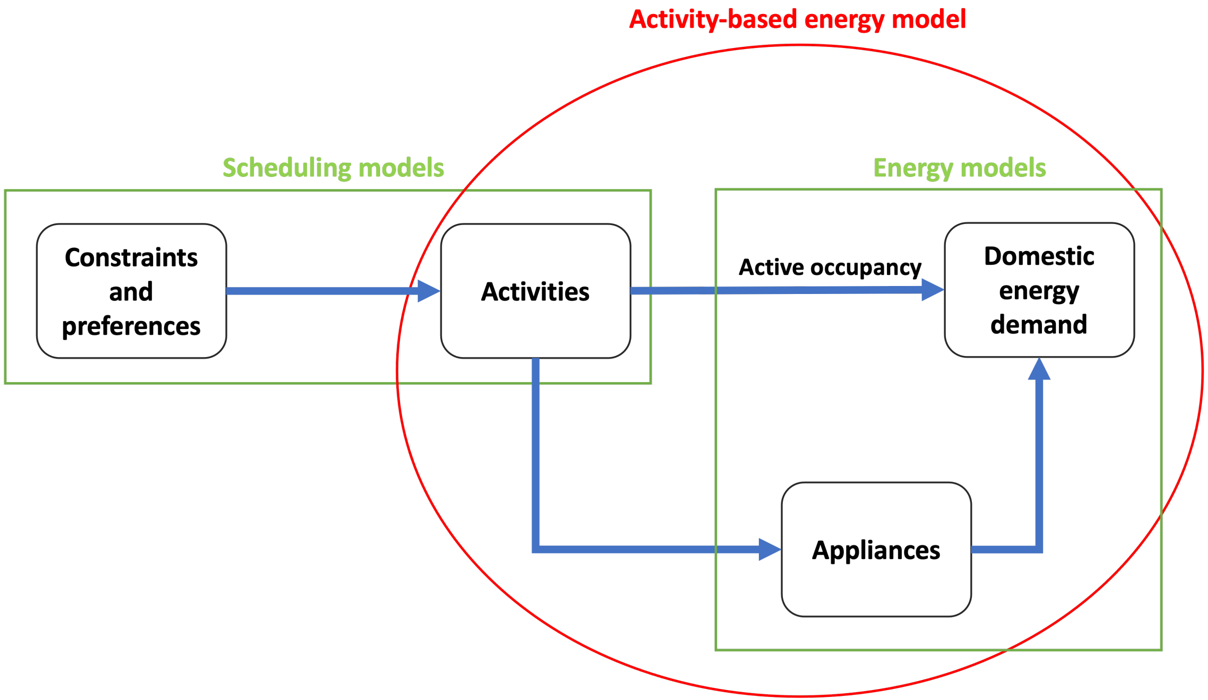
Motivation

- **Domestic energy usage** can be considered as being derived from the **activity patterns** of individuals inside the home (Rezvany et al. 2021).
- Domestic energy usage: energy used in residential buildings including electricity, heating, and hot water.
- As such an **activity-based energy demand model** that can create in-home energy usage profiles from household activity patterns is the key to a better building energy demand analysis.

Activity-based models (ABMs)

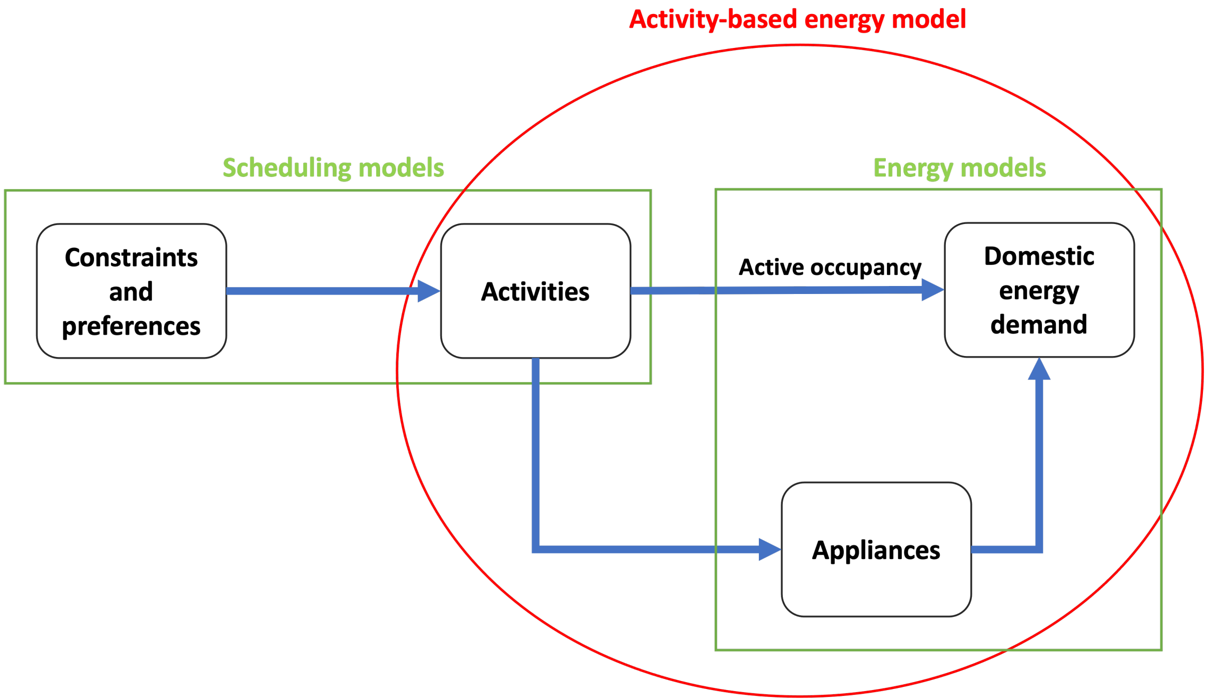
- **Activity-based models** portray how people plan their activities and travels over a period of time such as a day.
- This approach has been of **interest** to **transport modellers** as the demand for travel is assumed to be driven by participation in activities which are distributed in space and time.
- However, using **ABMs** in the domain of **domestic energy demand** research is still very **limited** and the human behaviour element is frequently neglected in the energy demand literature.

Activity-based energy demand scheme



High-level research question

High-level research question: "How can we simulate the domestic energy demand from household activity schedules from first principles?"



Research questions

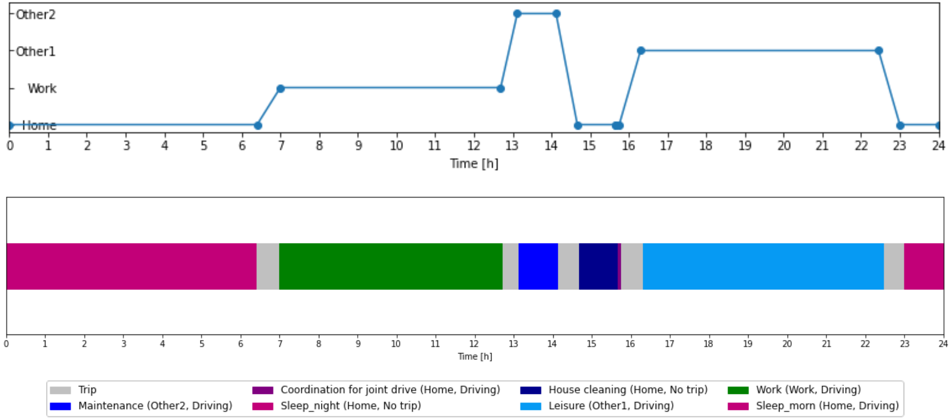
- In order to achieve this high-level objective, we should answer the following research questions:

1. How to incorporate **in-home** and **out-of-home activity scheduling** in a **single** scheduling model with **intra-household interactions**? (Rezvany et al. 2023)
2. How can we create **in-home energy usage profiles** from **household activity patterns**?

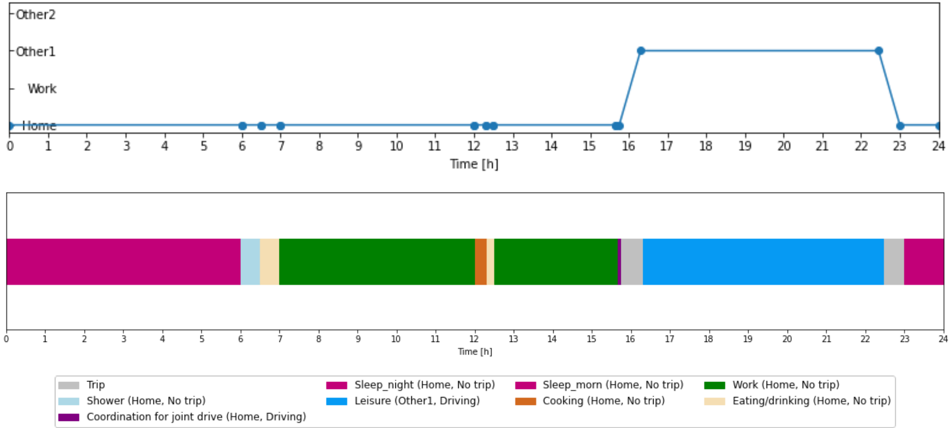
EPFL

A framework for joint simulation of in- and out-of-home activities, capturing intra-household interactions (Rezvany et al. 2023)

Occupant 1



Occupant 2



How can we create in-home energy usage profiles from activity patterns?

- **Goal:** find the **relation between building energy usage and activity profiles**
  - ***Ideal scenario***: **overlapping energy** usage data with **activity** diary survey data
  - ***Pragmatic scenario***: However, there is **no data** containing information on **both household activity schedules** and **energy usage**.

- **BUT** we have **detailed da*ta* on building energy usage**, as well as, **detailed time-use-data**, **separately** (no overlap between data**).**

How can we create activity patterns from in-home energy usage profiles?

- **New goal:** How do we use energy data to enhance existing activity models?
  - Add functionality to ABM model
  - Generate energy demand profiles
  - Without having overlapping data to train it

- We looked in the literature to see if anyone tried to link energy and activity data to create a joint model.

- Now, however, there are parallels to similar problems in other contexts (e.g. detecting pedestrian activity patterns from WiFi signatures)

From Wifi traces to activity episodes

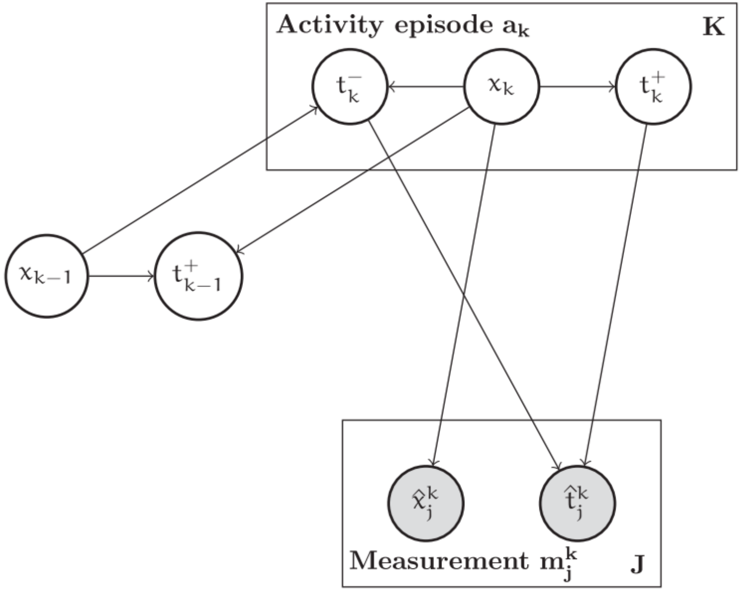
- Wifi traces are **not accurate**; either precise sensors with incomplete coverage or full coverage with imprecise sensors.
- As a result, data are **scarce**, **fuzzy**, or both.

- How this is relevant to our problem?
  - Cooking hob on → We do not know if they are doing another activity on the side (e.g. chopping food simultaneously)/ multiple people are helping in the cooking at the same time → not exact indication of the start and end time of food preparation process → Noisy representation of activity → need a joint probabilistic model

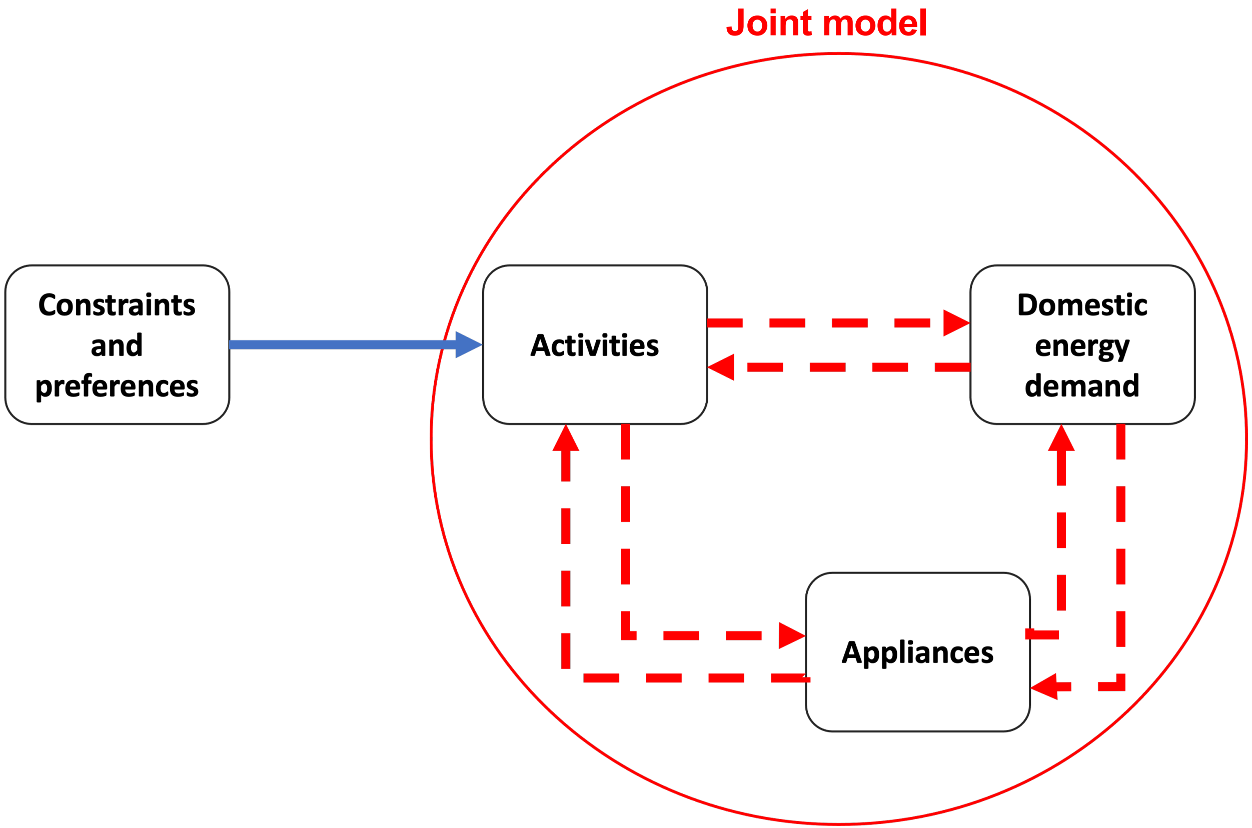
Appliance use ≠ Activity pattern

A Bayesian approach to detect pedestrian destination-sequences from WiFi signatures (Danalet et al. 2014)

- **Goal:** extract the **possible activity-episode sequences** performed by pedestrians from **digital traces** in a communication network.
- **Methodology:** a **Bayesian approach** merges measured **network traces** and **pedestrian semantically-enriched routing graph** to compute the **likelihood** that a **given sequence of activity episodes** has actually generated the observed traces.
- **Output: candidate activity schedules** associated with the **likelihood** to be **the true one**.



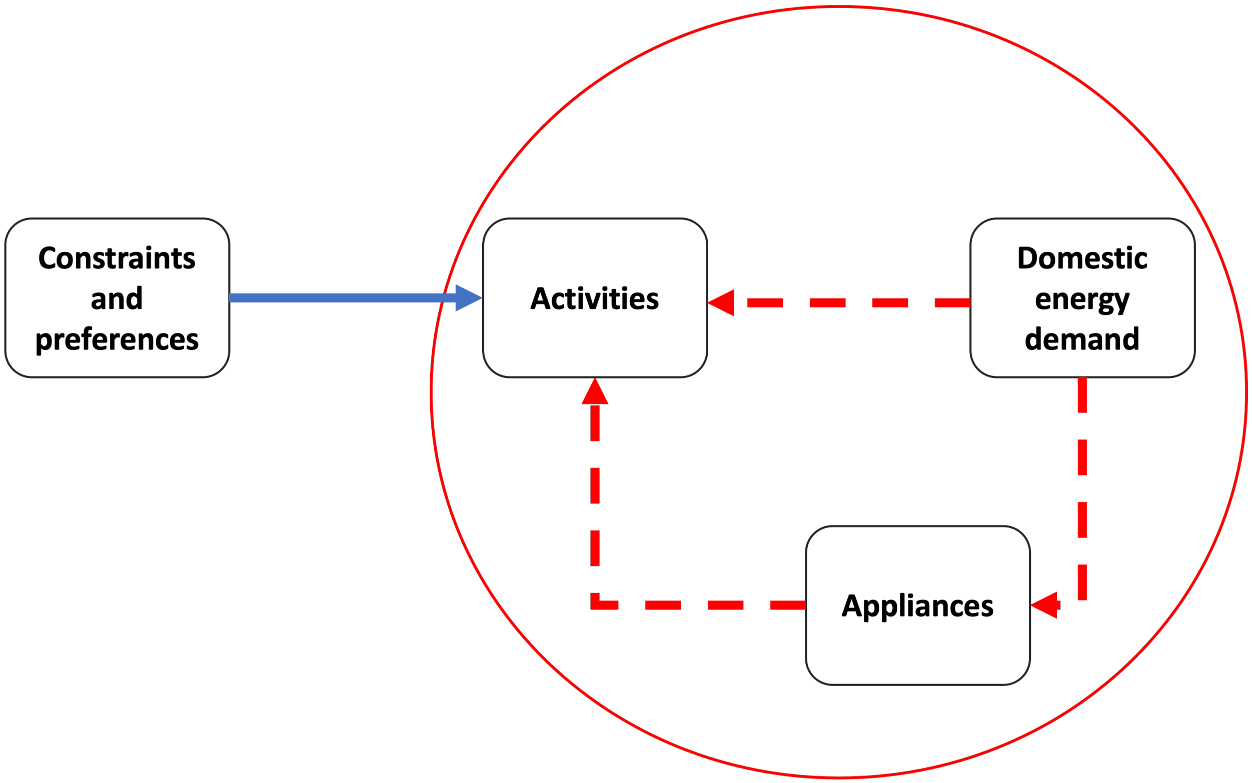
Schematic view of our approach



Methodological approach

- A **Bayesian approach** merging the **measured building energy profiles** and **semantically-enriched activity-related energy demand profiles** to compute the **likelihood** that a given **sequence of activity episodes** has actually generated the observed energy profiles.

Schematic view of our approach



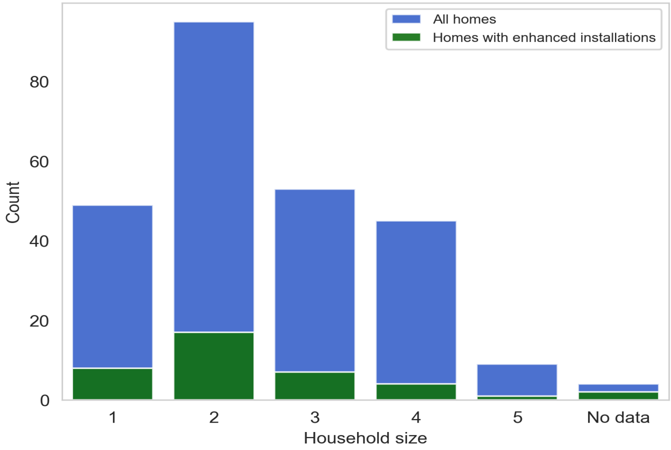
Datasets

Energy dataset

Intelligent Domestic Energy Advice Loop (IDEAL)

(Pullinger et al., 2021; Goddard et al., 2021)

- Comprises data from 255 homes in Edinburgh and the nearby regions.
- Collected over a 20-month period between August 2016 and June 2018.
- Enhanced appliance-level energy monitors in 39 of 255 homes.

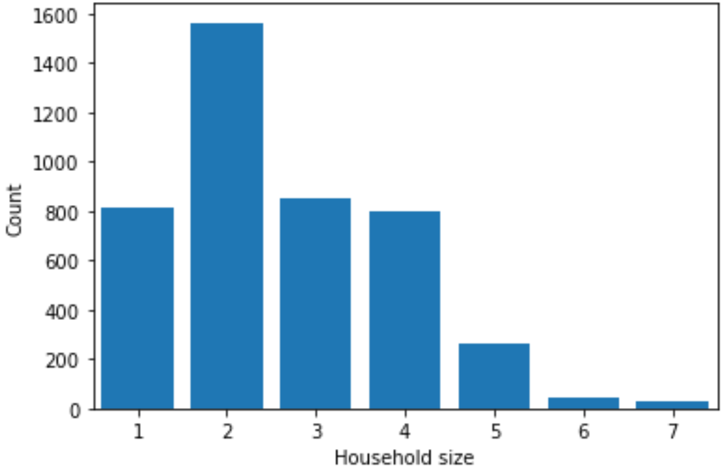


Time use survey

CaDDI* survey - 2016-2020 UK TUS

(Gershuny and Sullivan, 2021)

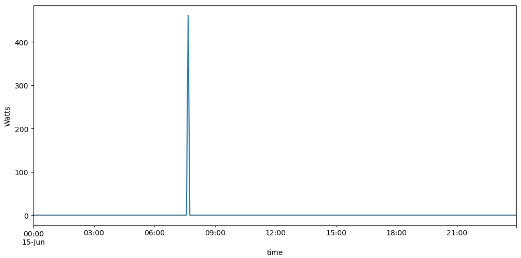
- 4’360 diaries from 2’202 individuals across 4 waves
- *4 waves* (2016 & late May-June, August, November 2020)
- Contains 1 to 3 time-use diaries per respondent (include 1 weekday and 1 weekend day)
- Includes information on socio-demographic variables, activities, location, enjoyment, and co-presence

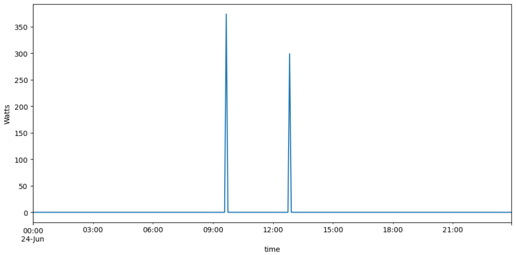


* Click and drag diary

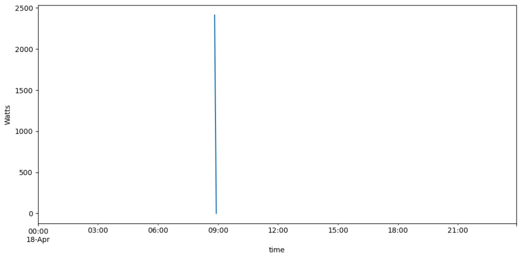
Exploration of data: Appliance energy profiles

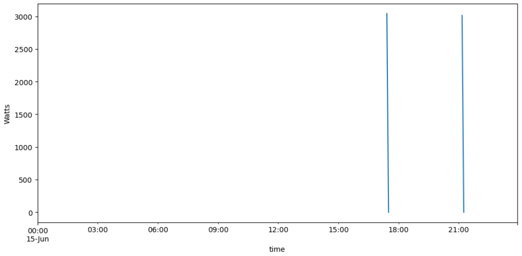
Toaster:



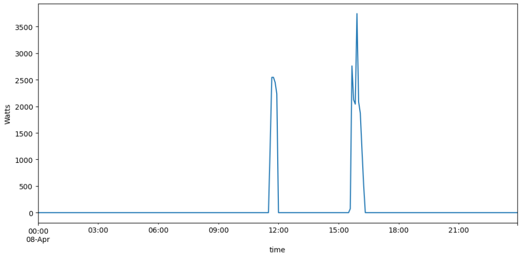


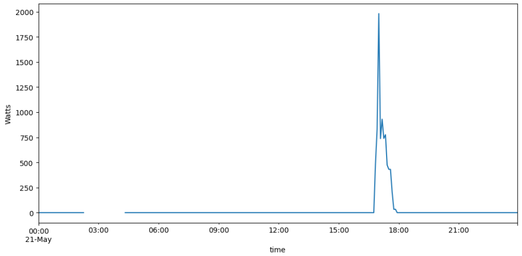
Kettle:





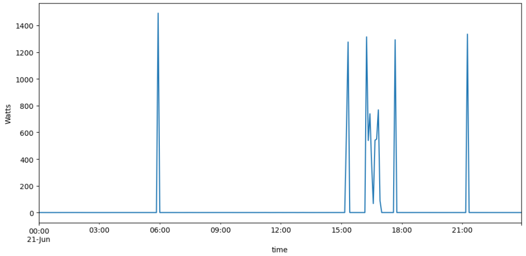
Cooker:

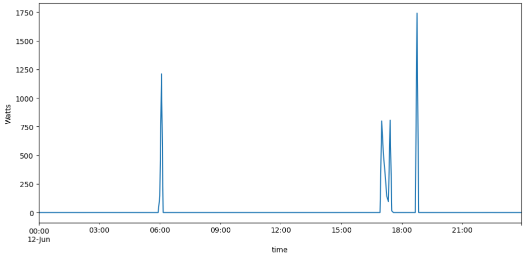




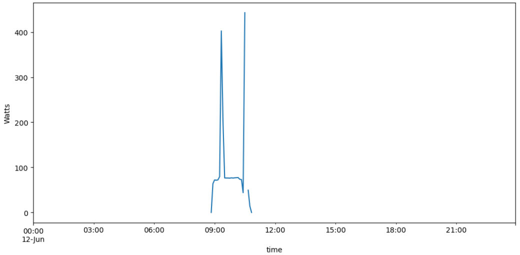
Exploration of data: Appliance energy profiles

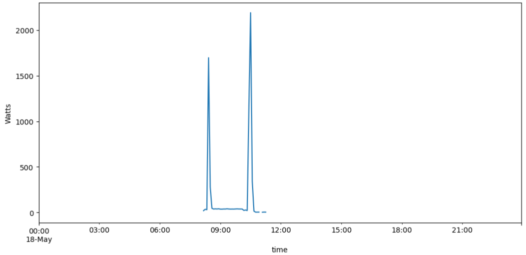
Cooking hob:





Dishwasher:

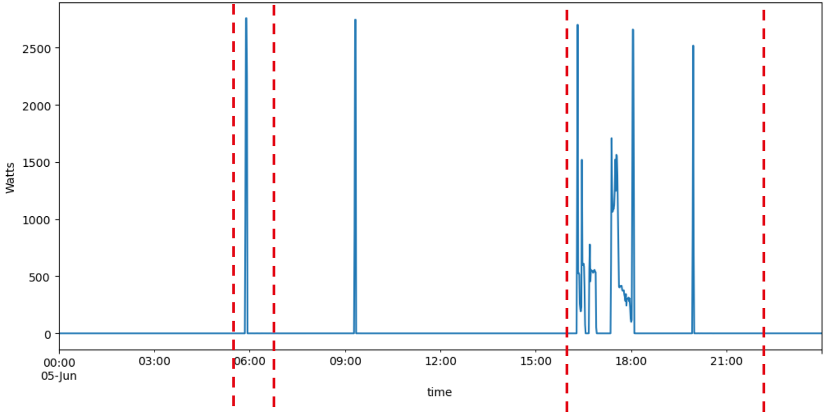




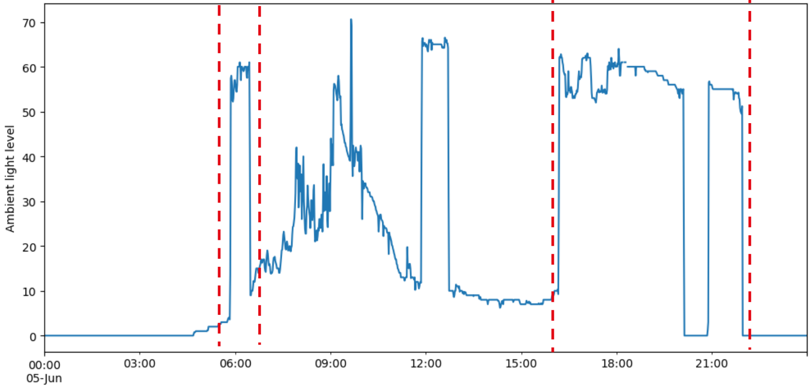
→ **looking for a set of patterns and rules…**

Exploration of data: Ambient light-level vs energy profiles

Electricity usage – cooking hub:

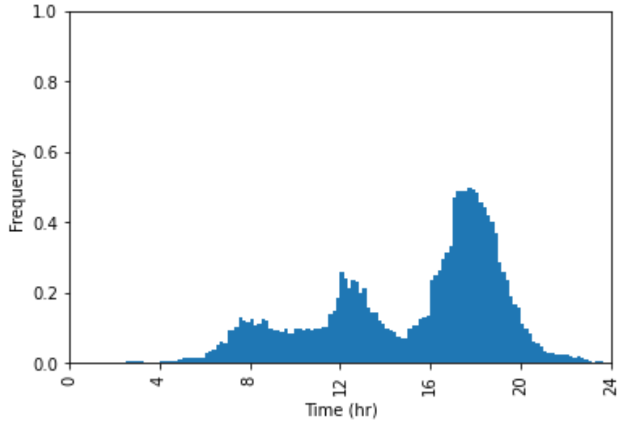


Kitchen ambient light:

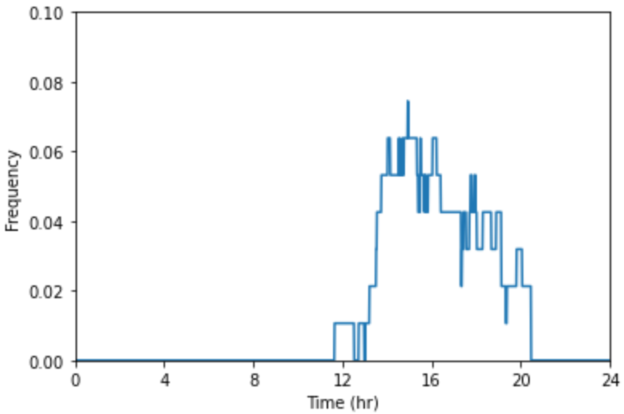


Exploration of data: Parallels at aggregate level

Distribution of "Preparing food/cooking" activity:

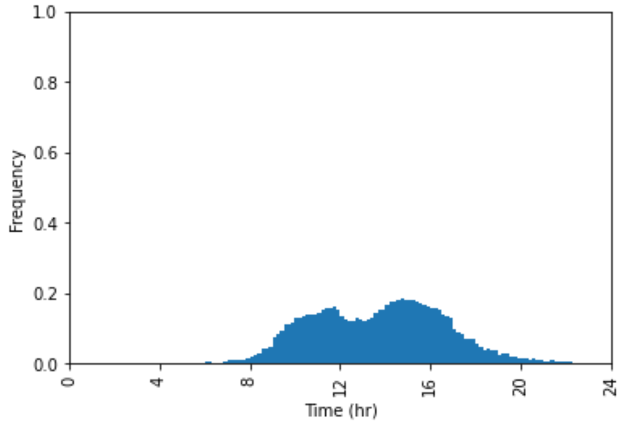


Distribution of "electric oven" usage:

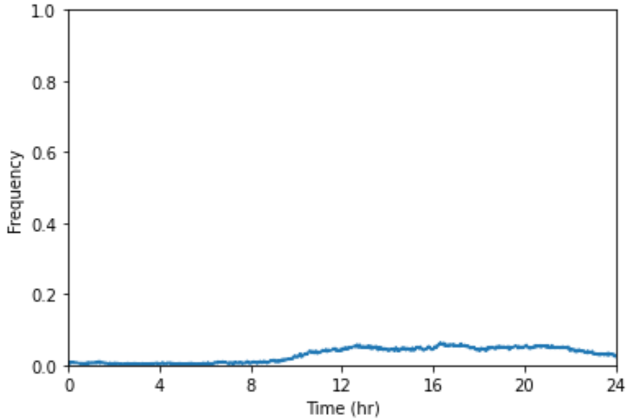


Exploration of data: Parallels at aggregate level

Distribution of ”Housecare" activity



Distribution of ”vacuum cleaner " usage



To conclude

Summary:

- Joint model of domestic energy and activity profiles
- Recreate household activity patterns from domestic energy usage profiles
- Non-overlapping data
- Probabilistic model - Bayesian approach

References

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Thank you!