WP2a: Presentation of Findings

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SYSTEMS AND ENGINEERING TECHNOLOGY

FRAZER-NASH CONSULTANCY

Outline

- Aims of the work package (3 Tasks)
- Findings & Discussion for each task
- Next Steps for Model Development
- Appliance Selection

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Work Package Aims

WP2a		Hold Point Decision
Task 1	Training Dataset	The proposed training dataset generation is appropriate
Task 2	Validation Dataset	A validation dataset will be obtainable
Task 3	Deployed Platform Architecture	The process to obtain customer data once the platform is deployed is agreed

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Task 3: Deployed Platform Architecture

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- Internally hosted platform with manual update of Smart Meter data
- Can update proposal to a cloud hosted platform with an API
- Long term data source tbc still…
  - Discussion?

Is the process to obtain customer data once the platform is deployed is agreed?

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Task 2: Validation Dataset

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- Had workshop, agreed to continue with:
  - Access to SERL: We will internally start the process of gaining permission to their dataset by partnering with them and completing the approvals.
  - Direct Customer Engagement: We will write a proposal to cover sending letters to obtain permission to use data, obtaining data through N3RGY.
    - Currently working with other organisations (including WREN) to identify communities and households who are already engaged in similar projects, to most efficiently obtain the participation we require for data validation and to minimise the need for widespread lettering.
    - Proposal to be issued when we have confirmed the approach.

Is a validation dataset will be obtainable?

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Task 1: Training Dataset

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Is the proposed training dataset generation appropriate?

- Deliberately open-ended
- Need to build confidence in approach
  - Take learnings from existing research
  - Investigate data
  - Trial methods

Literature Review

- Non-Intrusive Load Monitoring (NILM)
  - Appliance disaggregation from overall usage
  - Heavily researched area
  - High level of success for recognising appliances at small timesteps
  - Difficulty using half hourly usage
  - Difficulty accounting for unknown appliances

Use learnings in half hourly disaggregation, shift approach if required

- Overall sequence recognition
  - Learn trends in overall usage
  - Quantify changes to overall usage
  - No attempt at appliance recognition

Worth pursuing, but won't give full picture

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Initial Model Development

Approach

1. Determine power consumption for key appliances
2. Extract appliance usage statistics: when are they used, how long for etc.
3. Fit distributions to each property of the appliance usage statistics
4. Monte-Carlo sample from these distributions to generate synthetic usage profile
5. Compare to the real household profiles

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Approach

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Research datasets

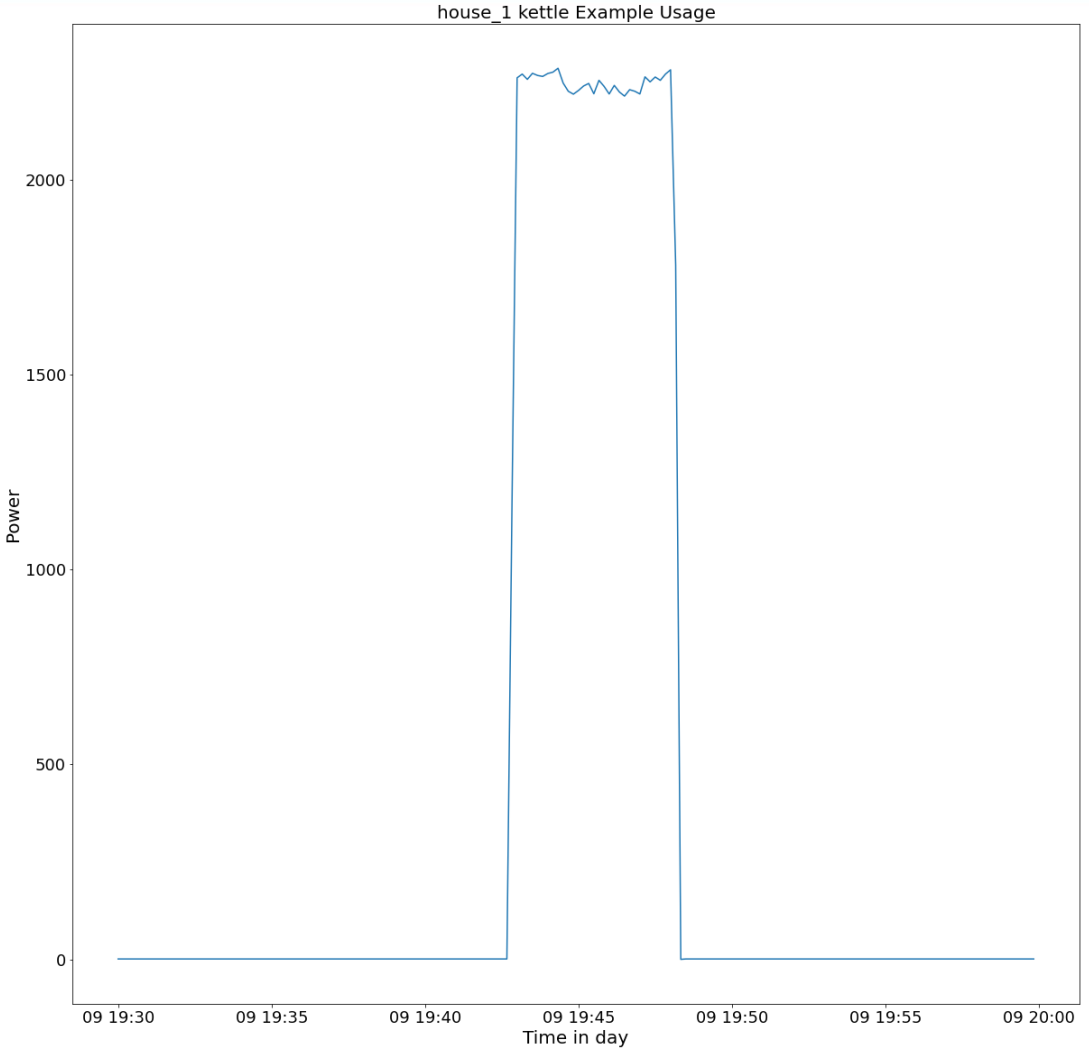
- Access to 10 second usage data from up to 50 appliances across 5 households
- Know the household makeup and appliance types
- Use this to determine whether appliance disaggregation and sampling are possible

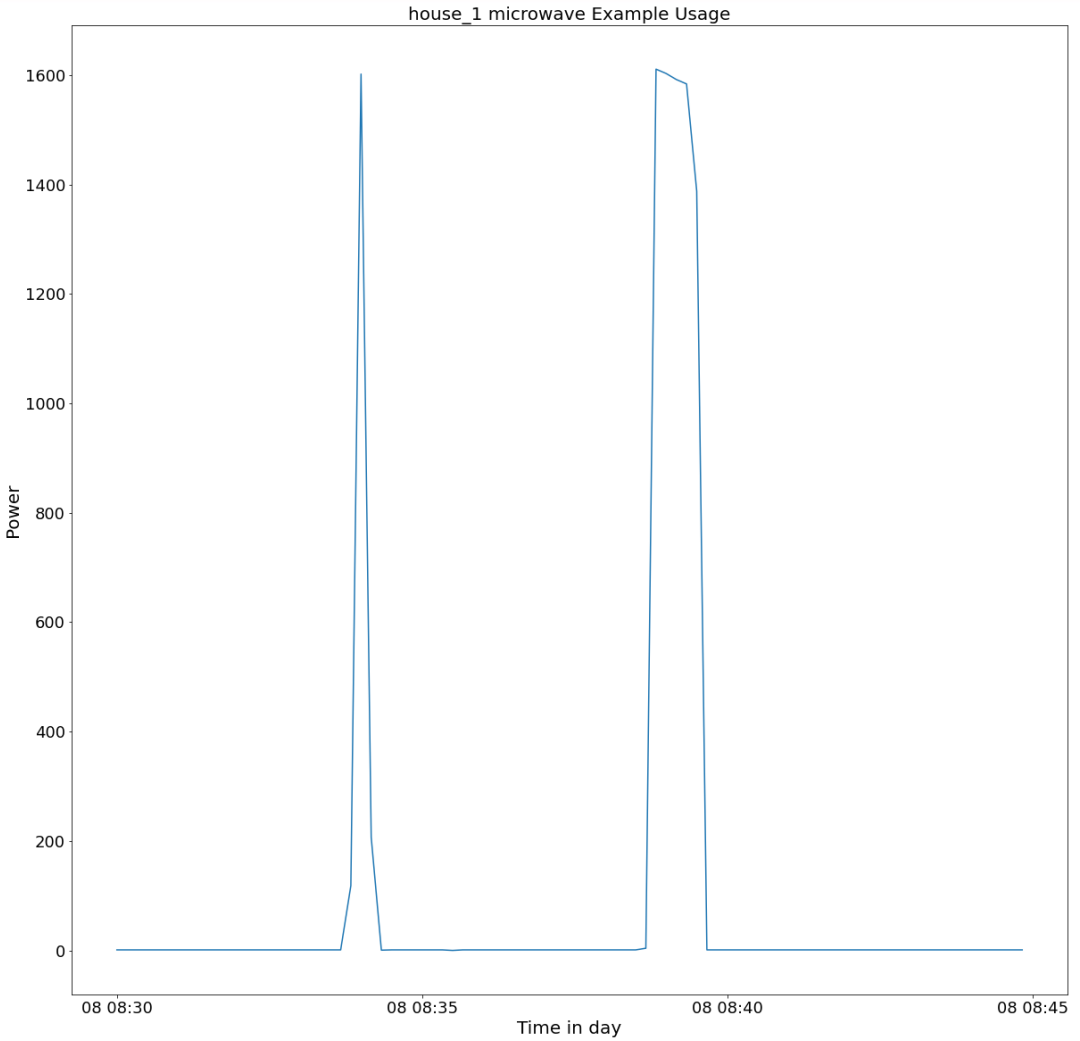
- Appliances:

Boiler, solar_thermal_pump, laptop, washing_machine, dishwasher, tv, kitchen_lights, htpc, kettle, toaster, fridge, microwave, lcd_office, hifi_office, breadmaker, amp_livingroom, adsl_router, livingroom_s_lamp, soldering_iron, gigE_&_USBhub, hoover23 kitchen_dt_lamp, bedroom_ds_lamp, lighting_circuit, livingroom_s_lamp2, iPad_charger, subwoofer_livingroom, livingroom_lamp_tv, DAB_radio_livingroom, kitchen_lamp2, kitchen_phone&stereo, utilityrm_lamp, samsung_charger, bedroom_d_lamp, coffee_machine, kitchen_radio, bedroom_chargers, hair_dryer, straighteners, iron, gas_oven, data_logger_pc, childs_table_lamp, childs_ds_lamp, baby_monitor_tx, battery_charger, office_lamp1, office_lamp2, office_lamp3, office_pc, office_fan, LED_printer

- Biggest power users: washing machine, dishwasher, kettle, toaster, microwave

Appliance Power Consumption Profiles





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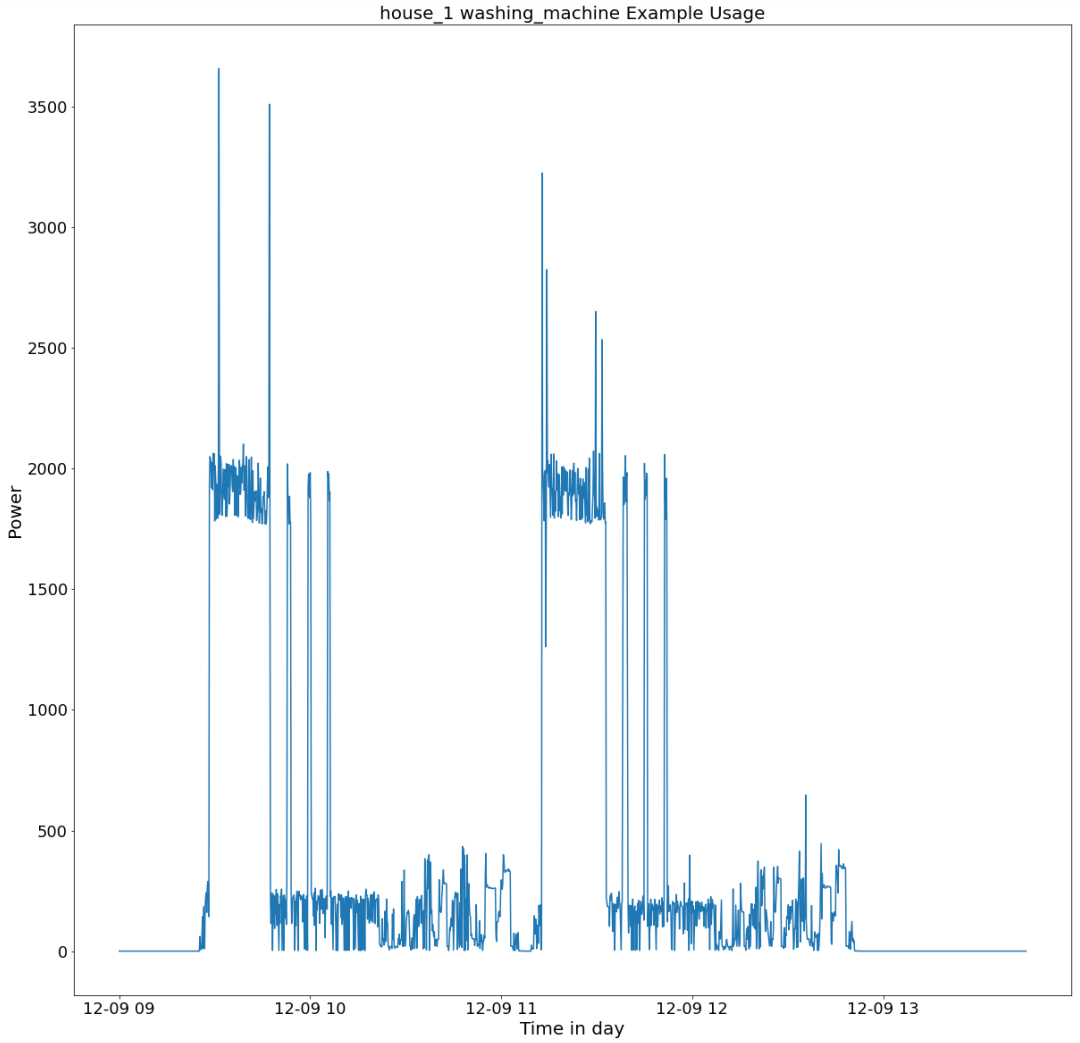

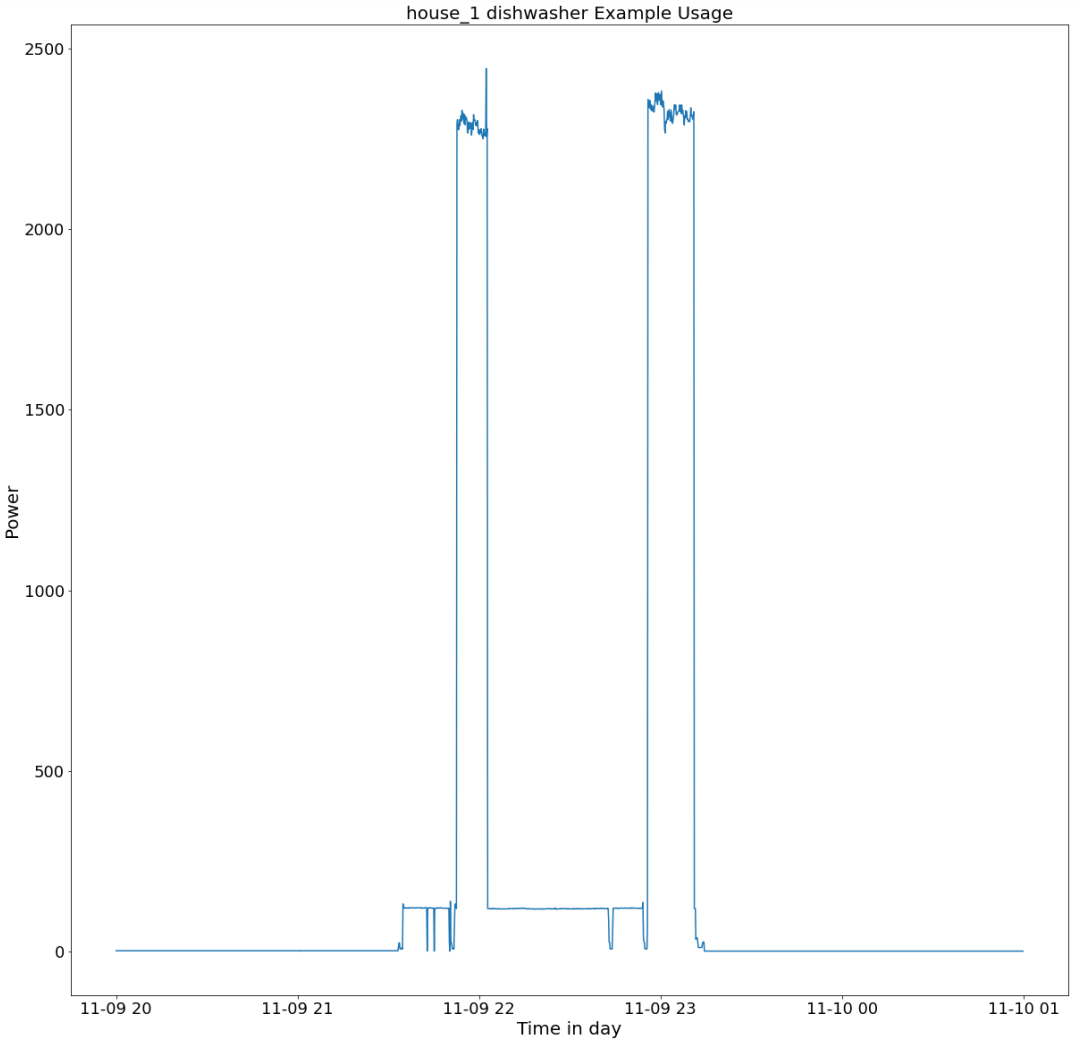

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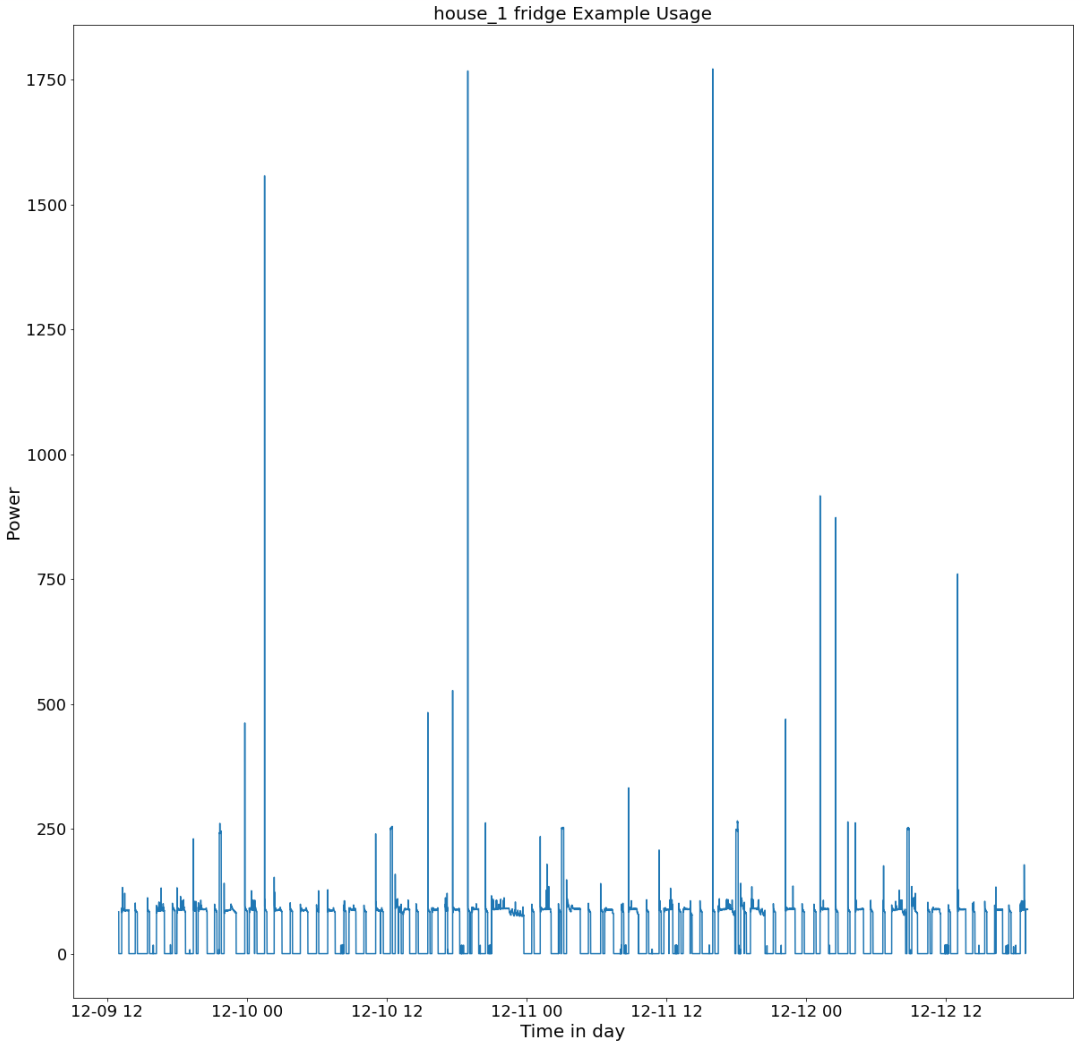

Appliance Categorisation

Type I	Single Switch State	a constant usage power when used	Kettle
Type II	Finite State	a set of predetermined usage powers when used	Dishwasher
Type III	Infinite State	unknown number of usage powers when used	Sewing machine
Type IV	Constant	a constant power state at all times	Wi-fi router

- Can now characterise every appliance
- As long as we can characterise appliance, we can use it in the profile generation
- This puts less necessity on obtaining exact power consumption profiles for all appliances

Approach

1. Determine power consumption for key appliances
2. Extract appliance usage statistics: when are they used, how long for etc.
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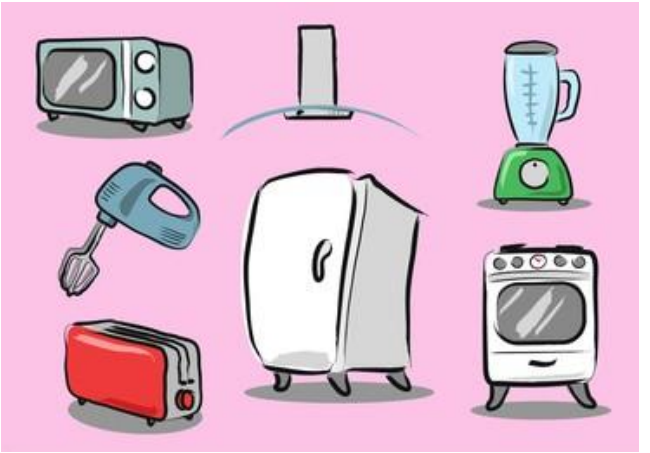
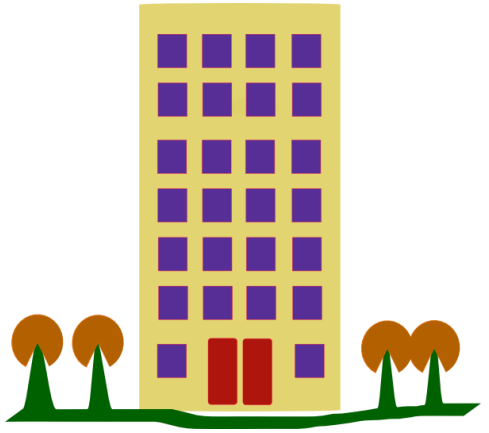
Appliance Usage Statistics

- For each appliance, need to determine:
  - When is it used
  - How many times is it used a day
  - How long is it used for
  - What power does it draw when used



- For this scoping we looked at: washing machine, kettle, toaster, microwave

- Compared for two houses:
  - House 1: Five person, large townhouse
  - House 2: Two person, flat

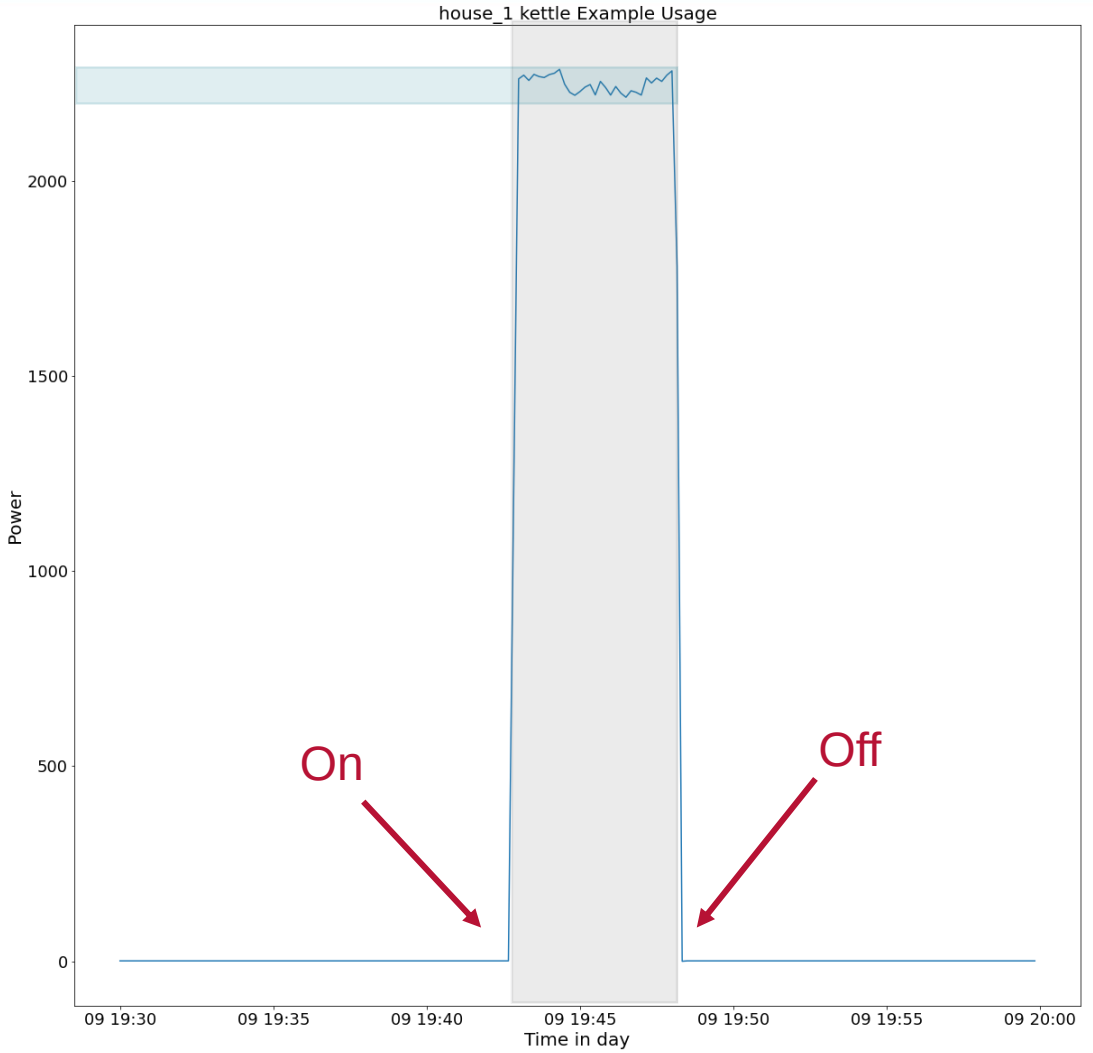


Bespoke Characterisation Algorithm

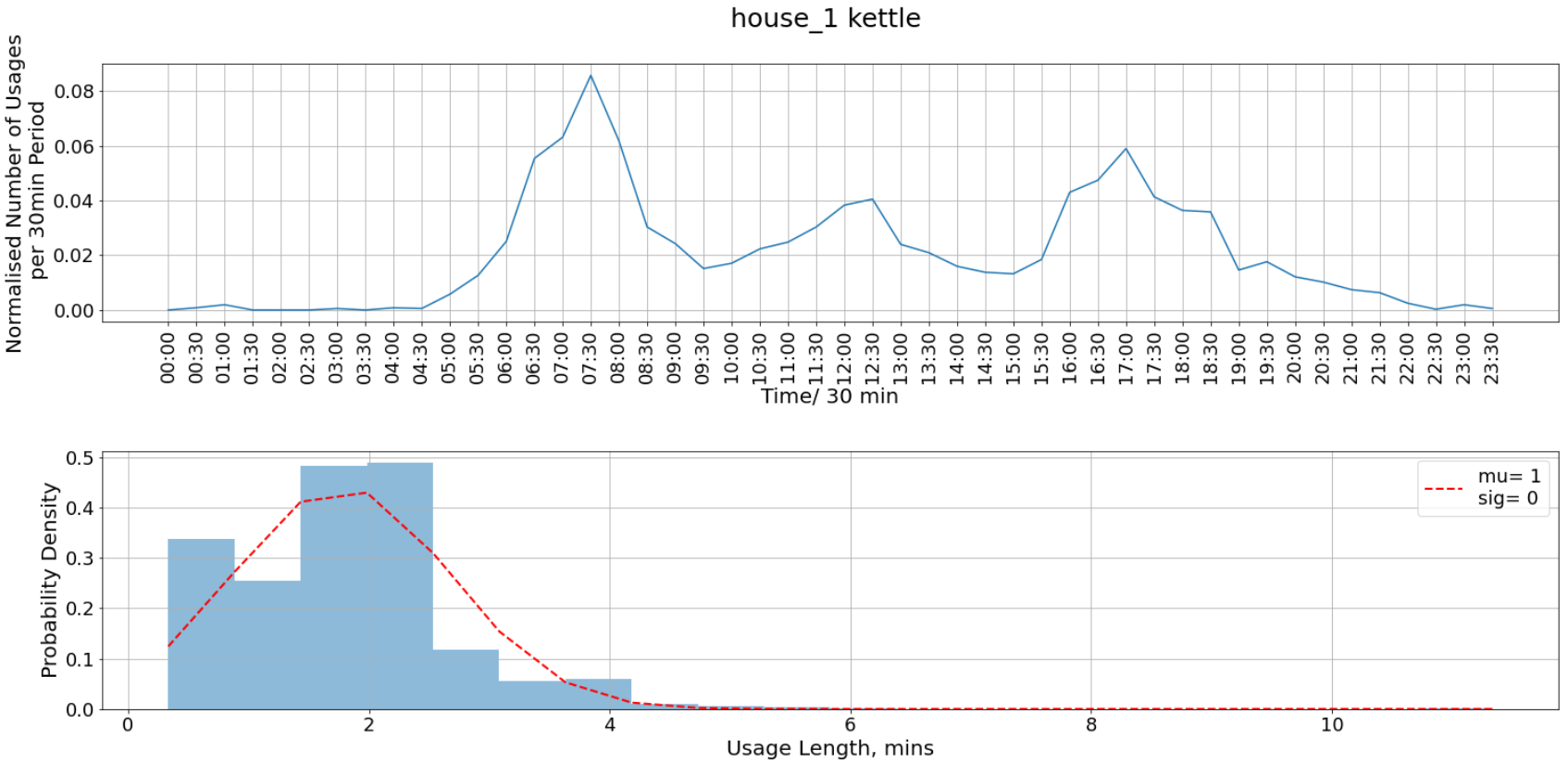
Generated an algorithm to identify when appliance is being used:

- When appliance in usage
- Includes noise reduction
- Currently for Type I only
- Unique for every appliance for now

- Extracted appliance usage statics for the four appliances and the two households



Usage Statistics: Kettle



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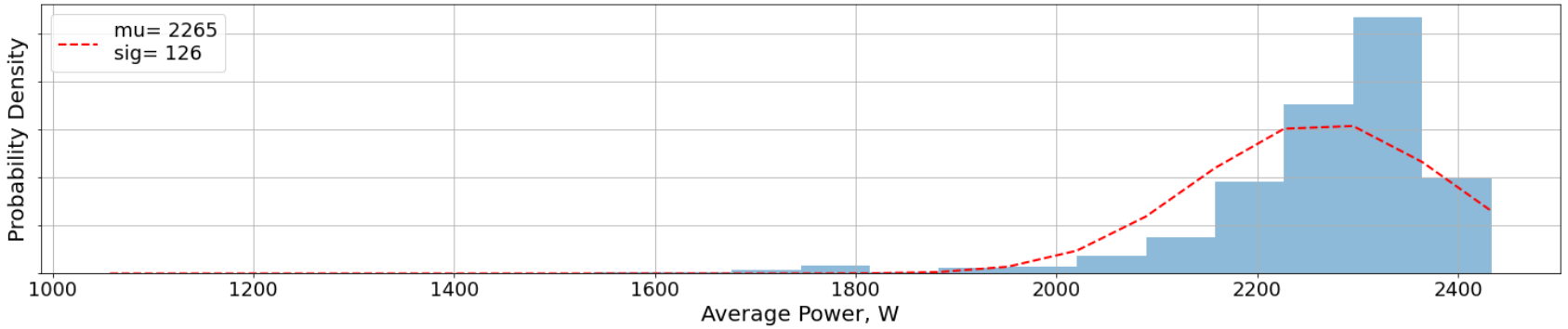

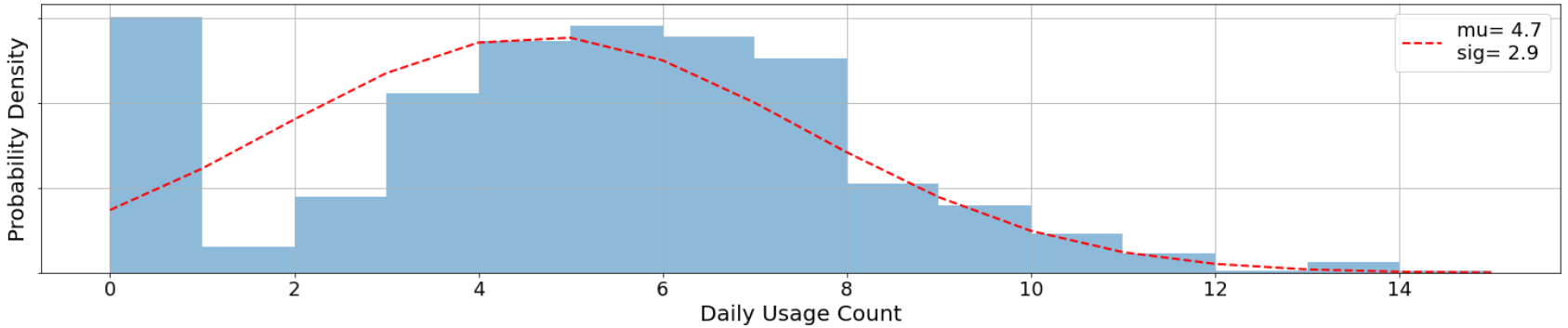

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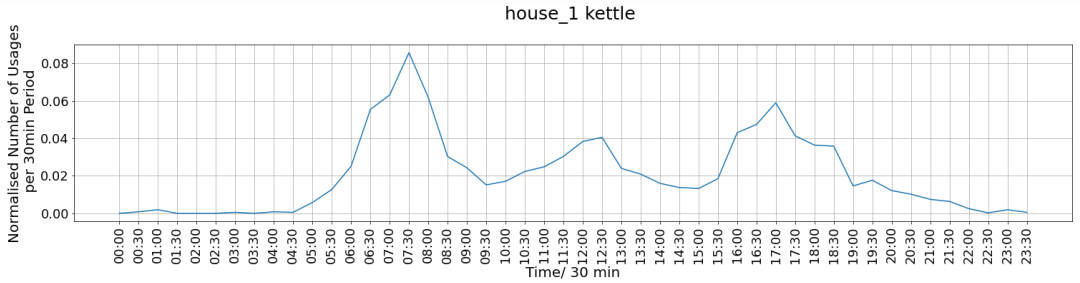
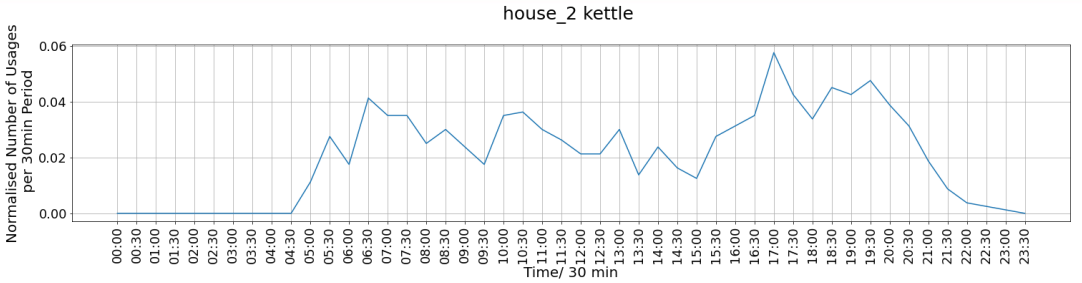
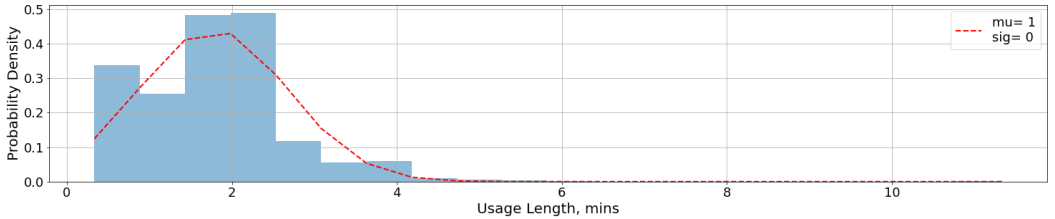
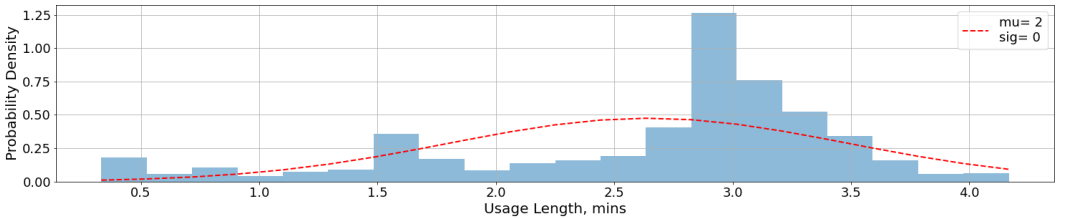
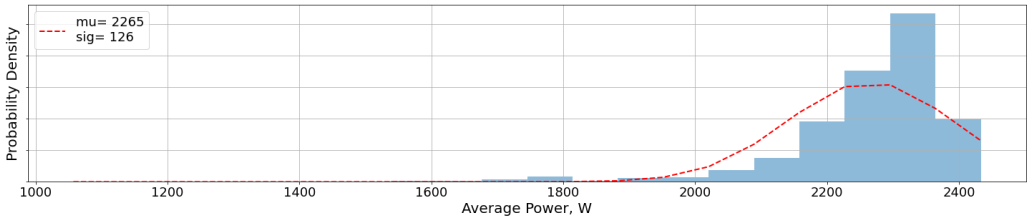
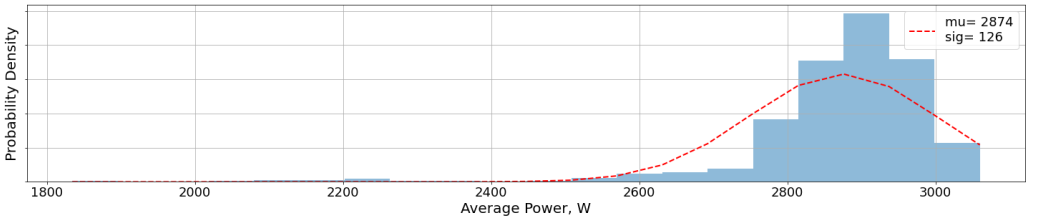


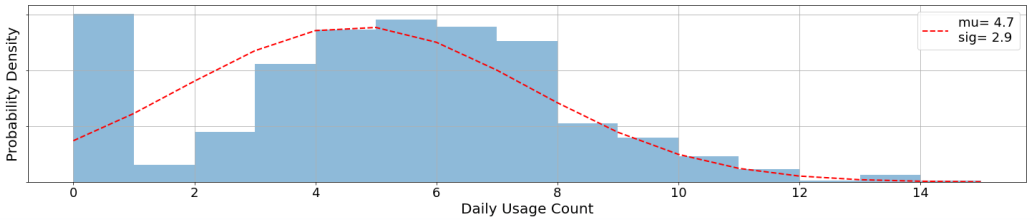


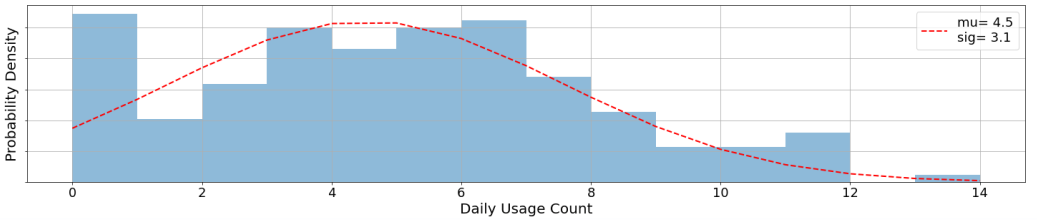




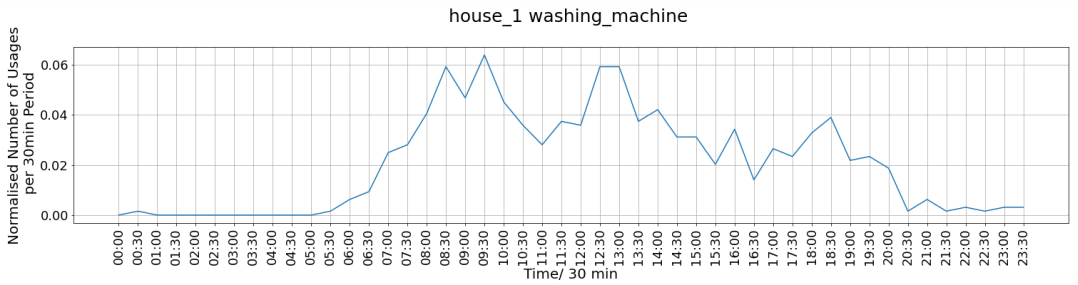


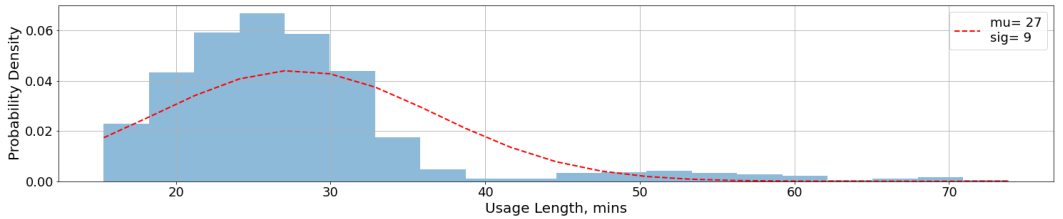


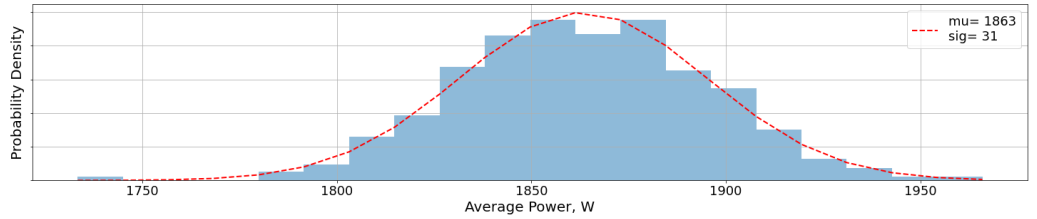


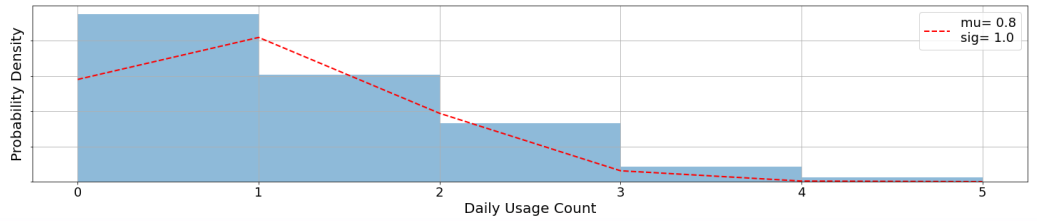


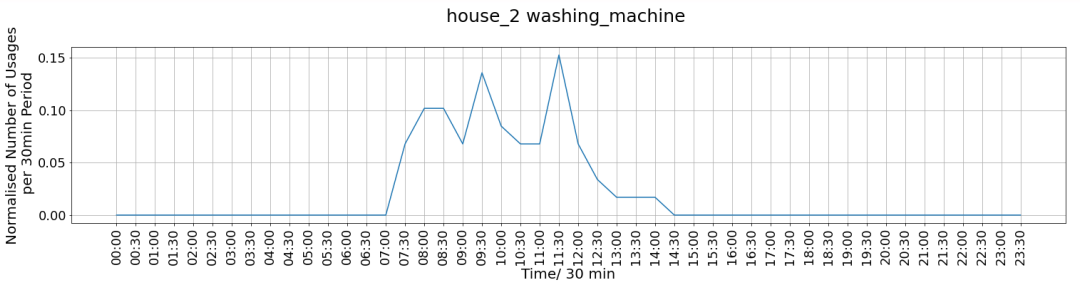
Usage Statistics: Washing Machine

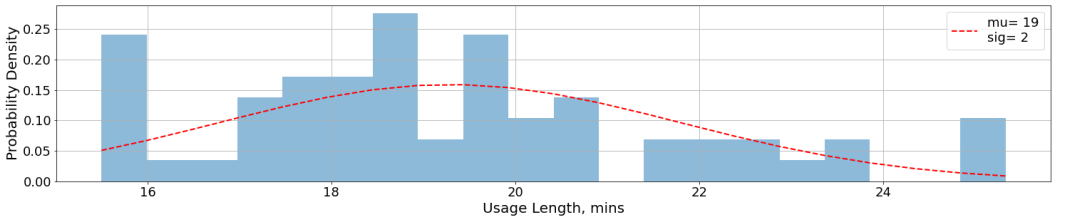


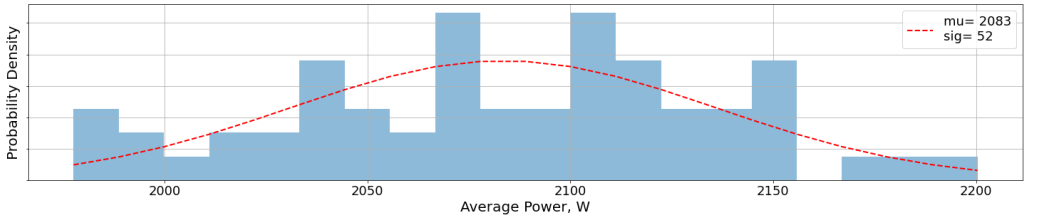


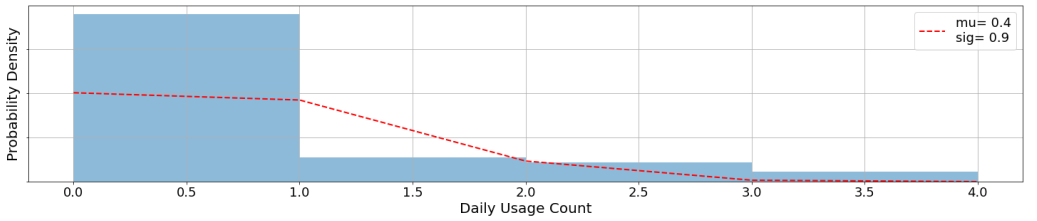












Approach

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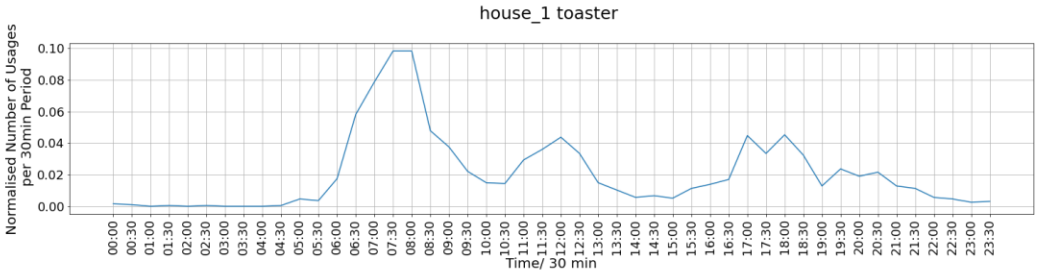
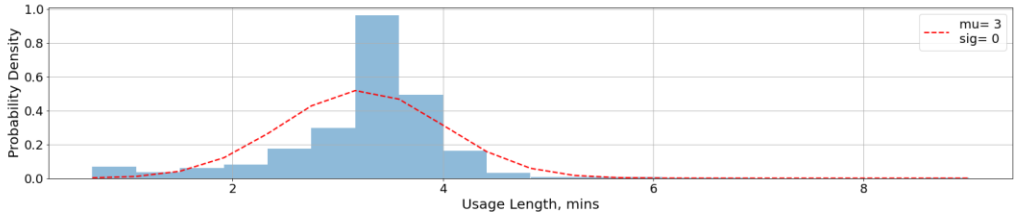
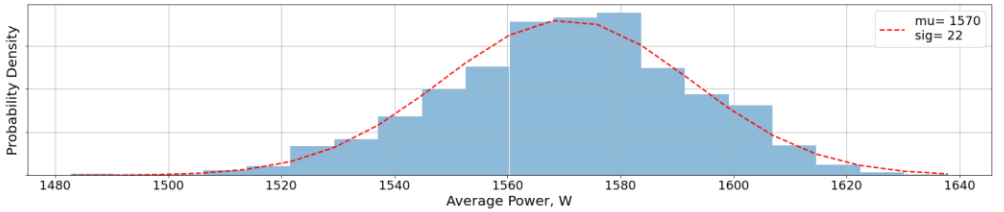
Sampling to Create Daily Usage

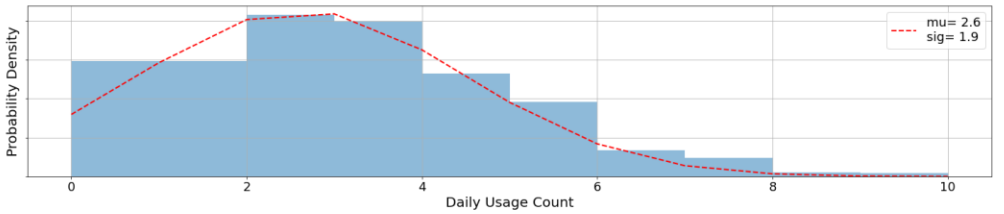
- We have the probability distributions
- Can randomly select a value from the distribution
- Generate a usage profile that uses the appliance at those values

- Do this for all appliances
- Add a base load value
- Aggregate to get household usage









Sample from Appliance Statistics

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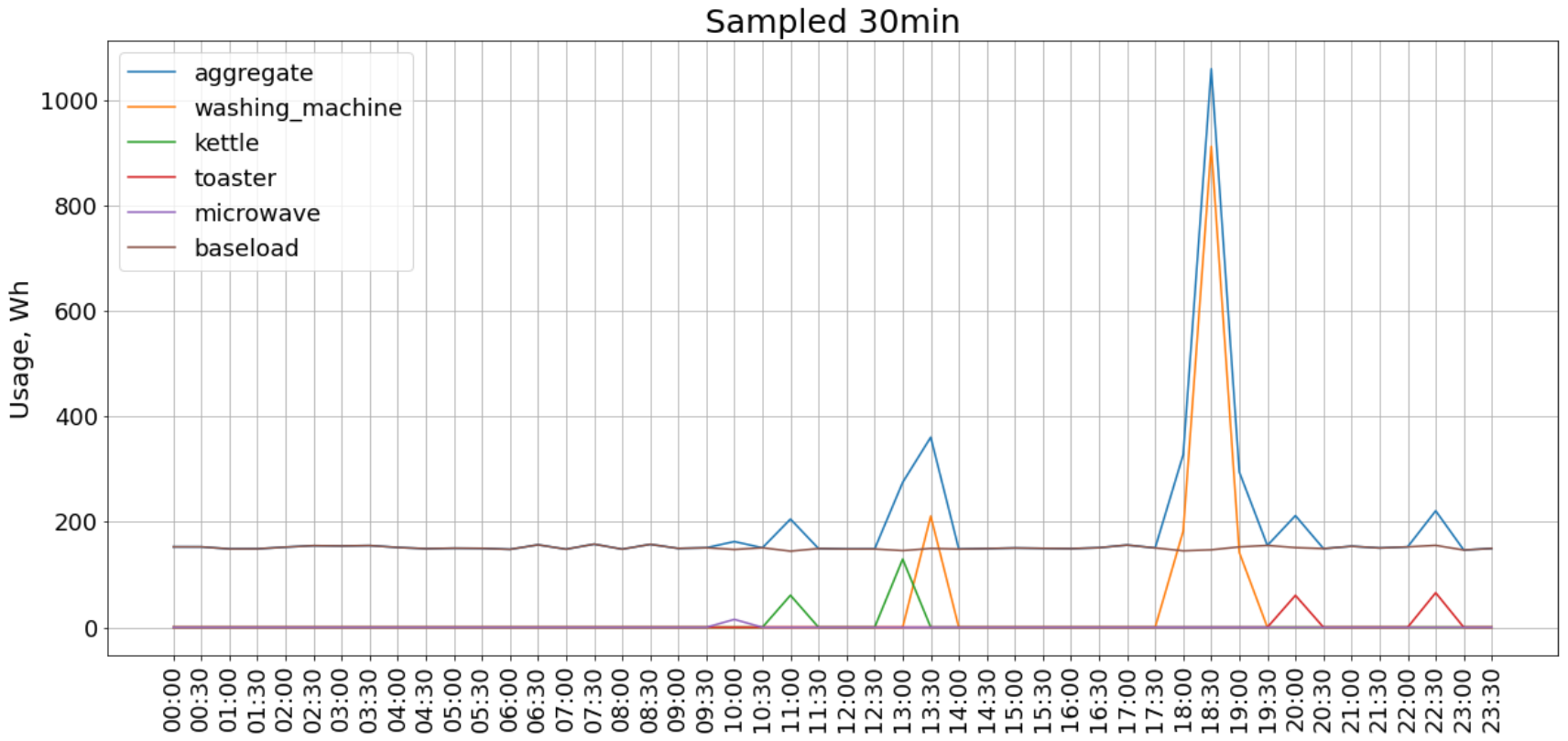
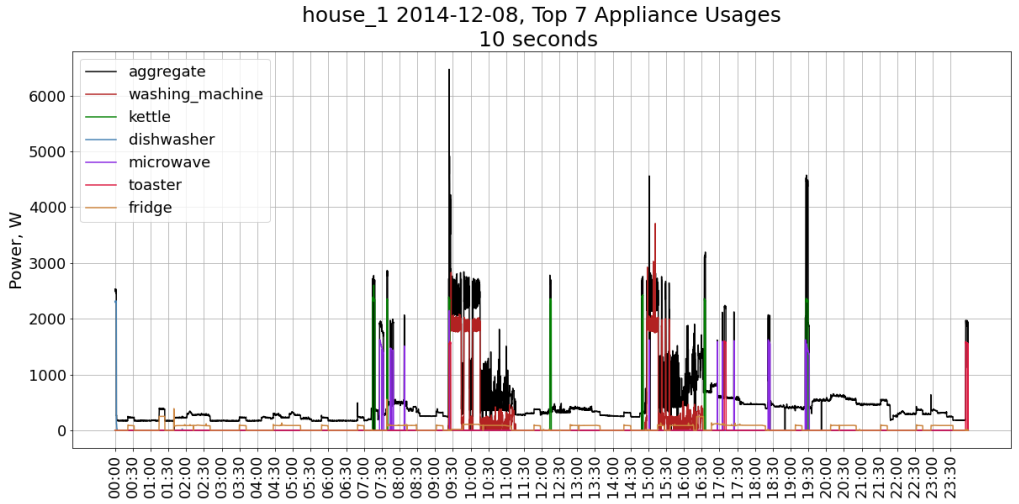
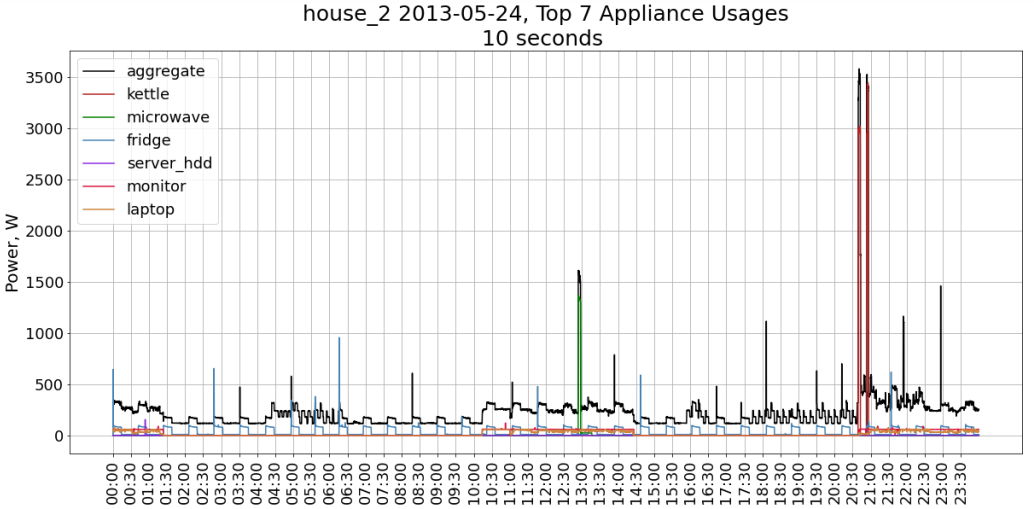
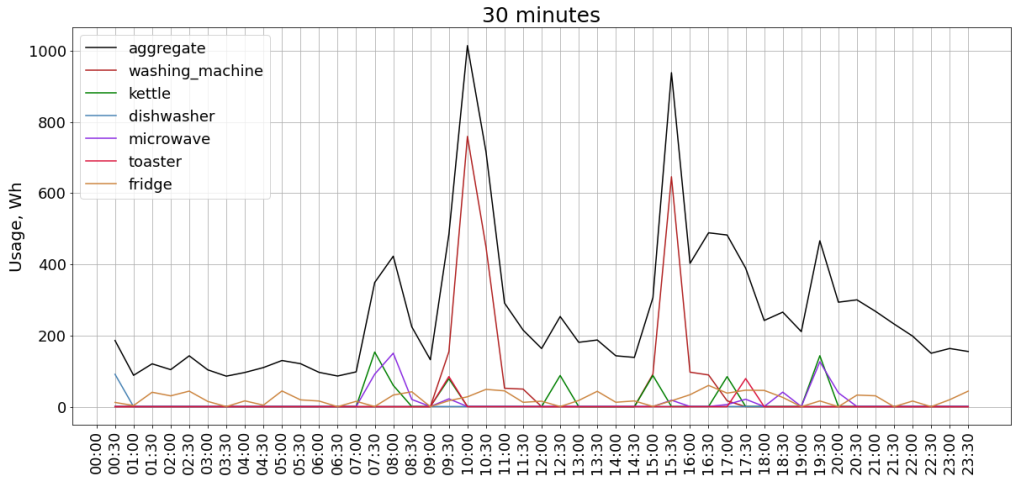
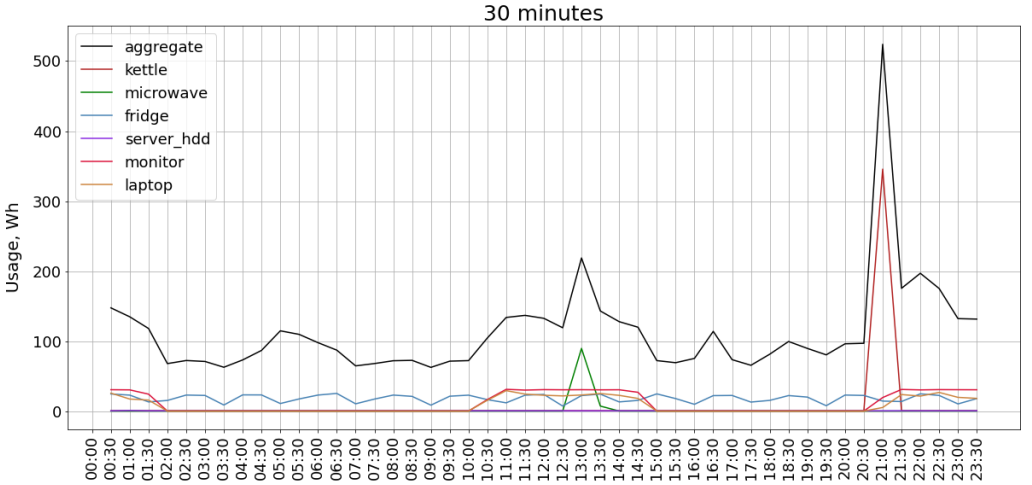


Top appliances for actual households

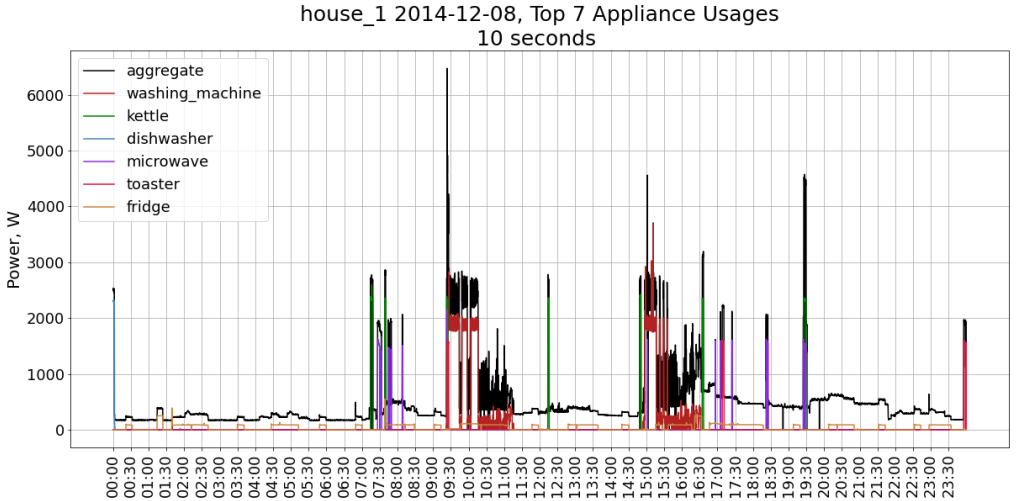


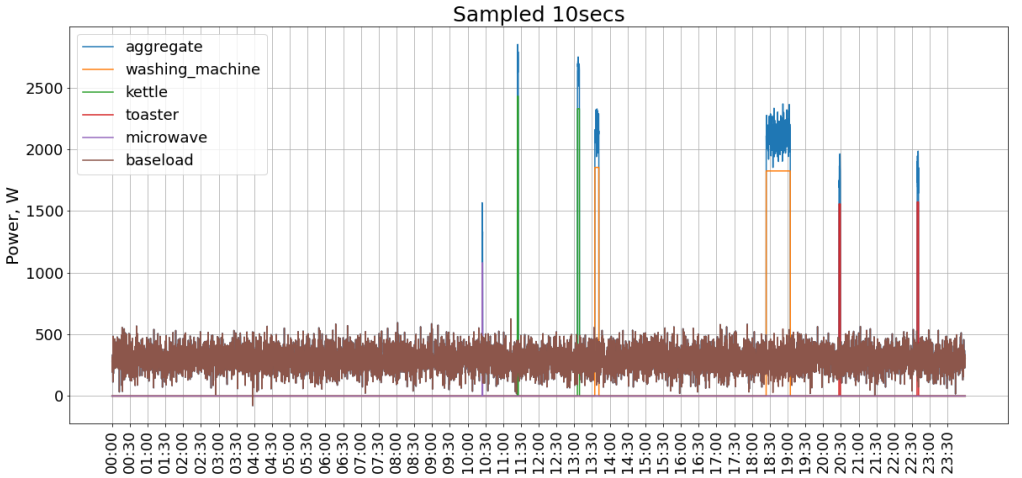


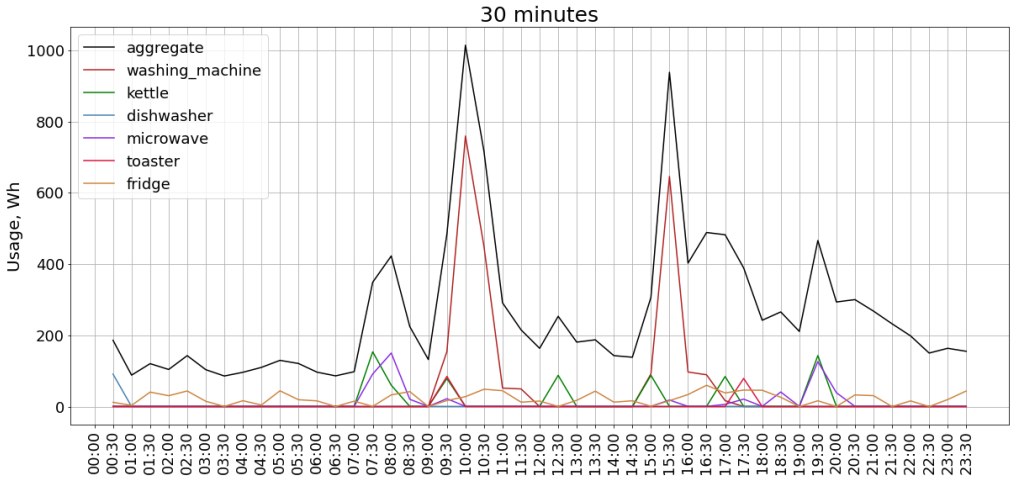


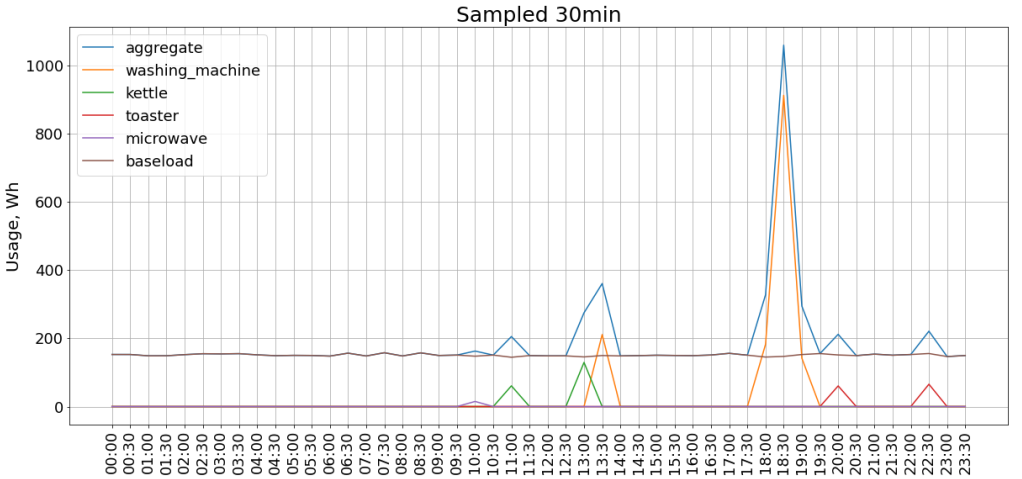


Comparison to Reality









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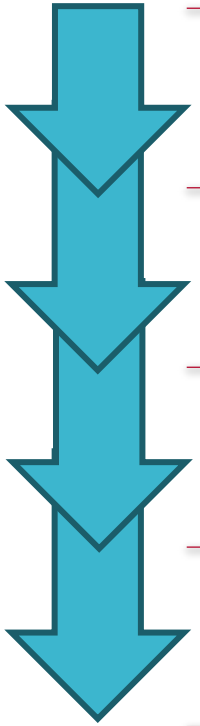
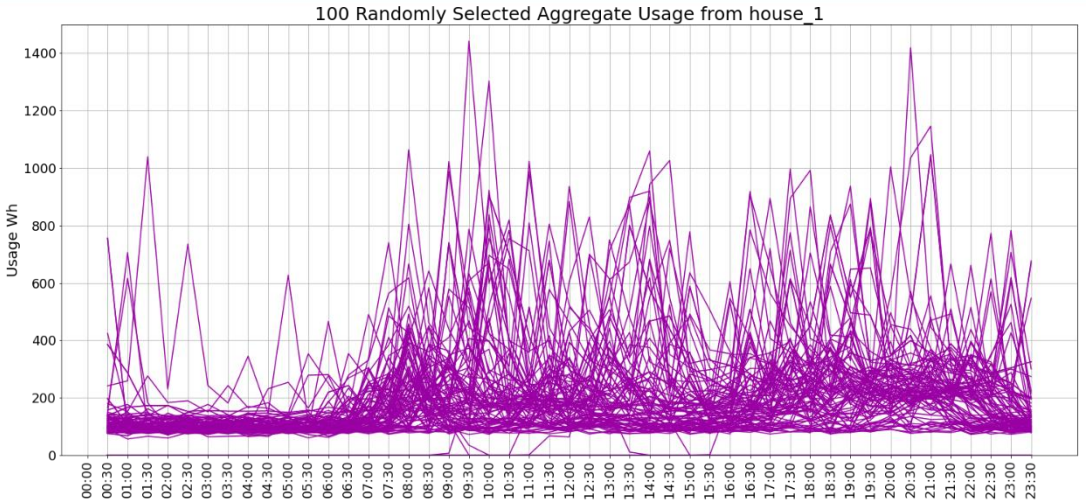
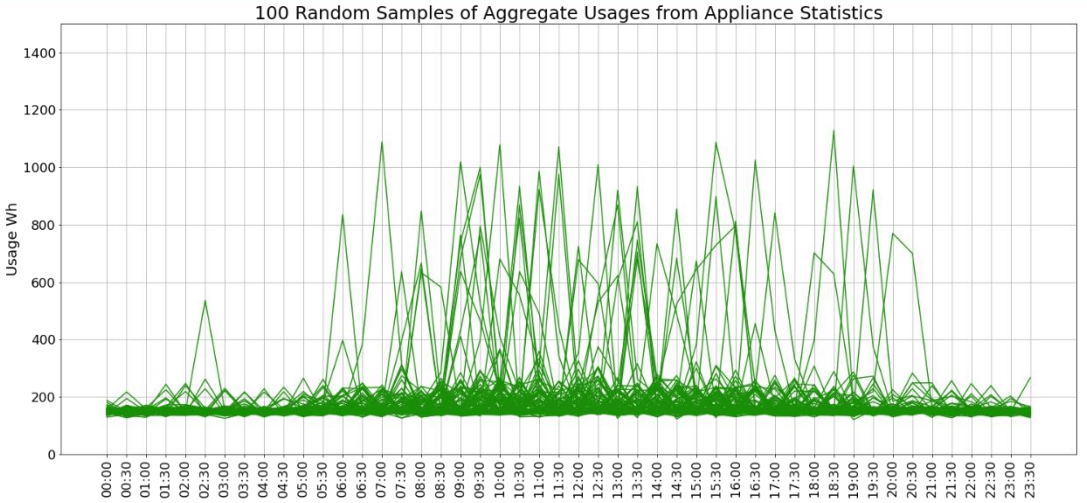
Multiple Samples

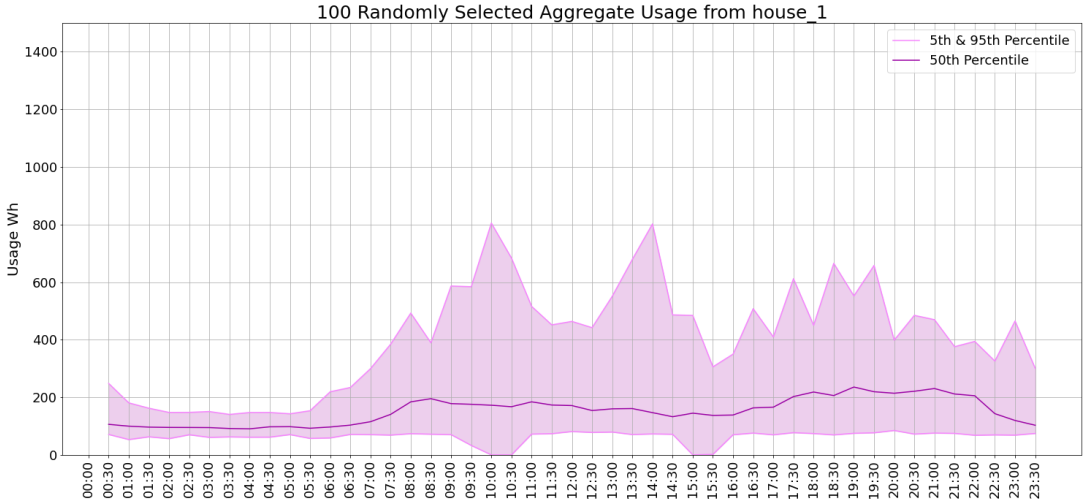


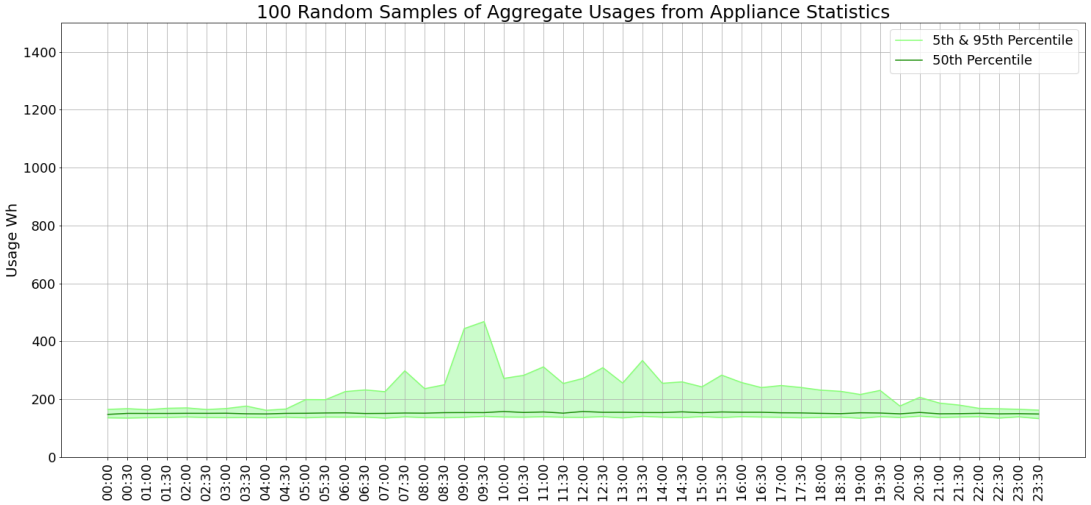
1. Repeat this process (Monte-Carlo Sampling)
2. Each has different appliance usage times, number a day, power consumption
3. Look at the change in overall power generated profiles
4. Compare to actual overall power for random days

Multiple Samples: House 1

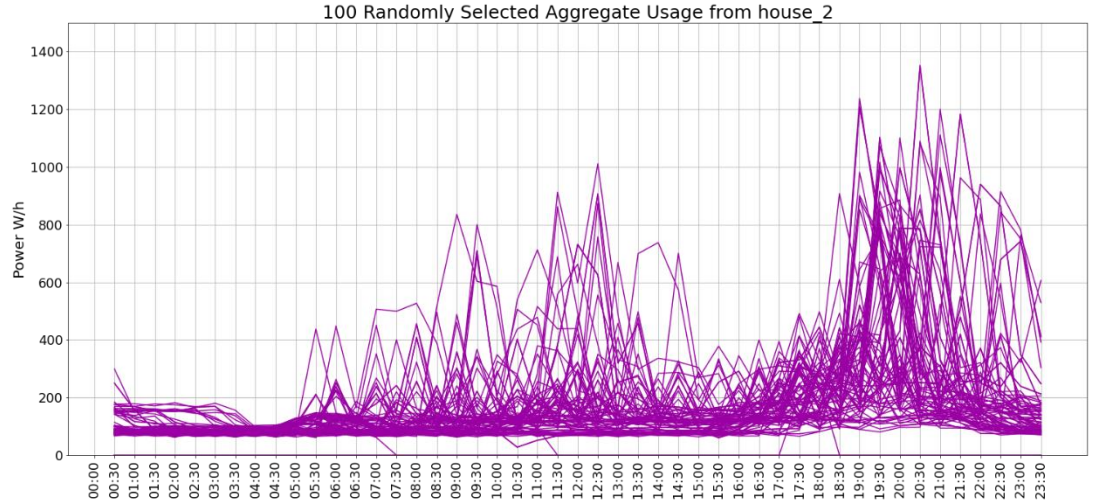


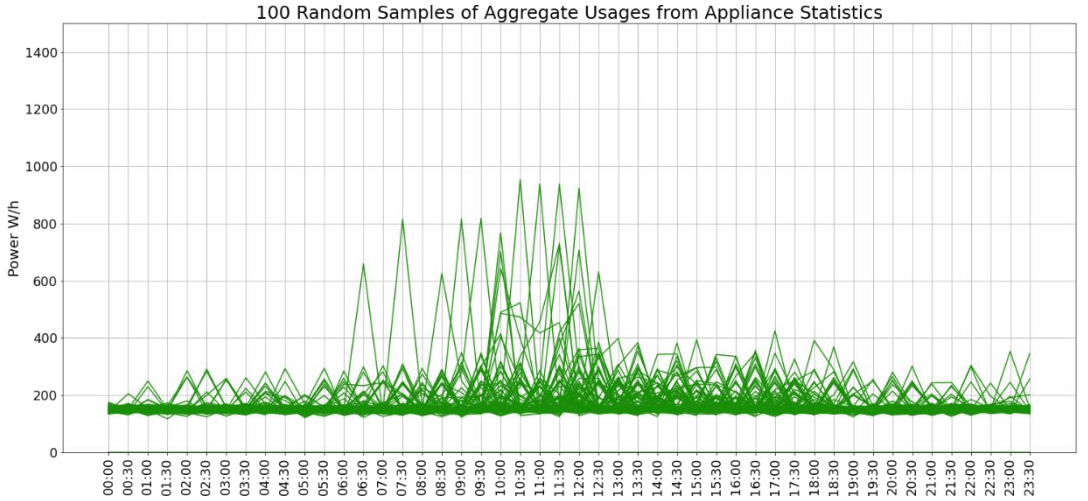


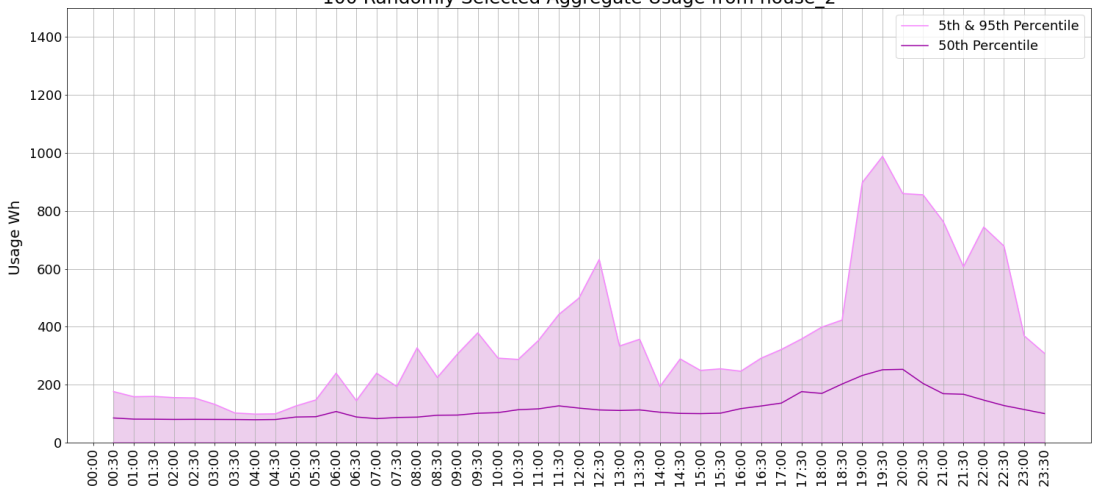


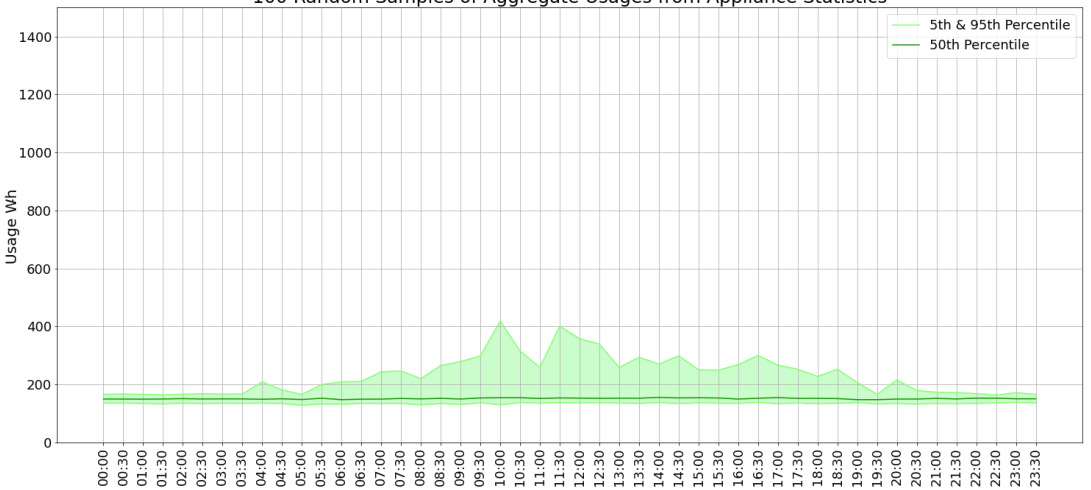


Multiple Samples: House 2









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What does this mean?

Summary

- ✓ We can build representative profiles
- ✓ Categorising into appliance types helps with collation of power profiles
- ✓ Research into identifying overall behavioural changes has been successful
- × Existing research shows large uncertainty for appliance disaggregation in thirty minute data
- × Accounting for unknown appliances is difficult

- Slight shift in approach:
  - We hoped that the data would allow disaggregation into **exactly** which appliances were being used
  - Instead, we propose to disaggregate into which appliances are **likely to be being** used
  - Using a probabilistic approach making use of Bayes law – which we've used extensively elsewhere
    - This will calculate the probability of appliance use by combining our prior judgement with the likelihood the data is consistent with those priors

Is the proposed training dataset generation appropriate?

Proposed Model Development Workstreams

1. Disaggregate the thirty minutes into appliances
   - Collate power profiles for all the appliances
   - Determine the usage statistics for each appliance and household type (these are our priors)
   - Build pattern recognition model to identify likelihood of appliance usage, using the priors
   - Model builds on historic behaviour to update the priors for each household

2. Overall usage characteristics recognition
   - Characterise overall features – use of FFTs may appropriate to look at periodic usage patterns
   - Pattern recognition to recognise shifts in behaviour
   - Quantify the shift in behaviour

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Appliance List

Appliance List

- Need to agree shortlist of appliances
- Can collate power consumption and build into model
- Appliance Types reduces the requirement, but still needed
  - De-risked as it'll take maximum 3h ours per appliance rather than potentially a day
  - Don't want to miss important appliances, especially medical ones

Medical Appliance List

- Current Household appliance list is 92 long…
- Contains LCTs
- We can add additional as information should be public knowledge/ appliances obtainable
- Would like agreement on the medical appliances:

Medical Appliances	
Defibrillator	Feeding Pump
Stair Lift	Oxygen Concentrators
Bath Hoist/ Lift	Infusion Pumps
Adjustable bed	Ultrasound Therapy
Dialysis Machine	Cough Assist Machine
Ventilator	Suction Machine
Nebuliser	Blood Pressure Monitor
Sleep Apnoea Monitor	Glucose Tester
Medicine Refrigeration	

Actions & Next Steps

Actions & Next Steps

WP2a		Hold Point Decision
Task 1	Training Dataset	The proposed training dataset generation is appropriate
Task 2	Validation Dataset	A validation dataset will be obtainable
Task 3	Deployed Platform Architecture	The process to obtain customer data once the platform is deployed is agreed

- Halt model development work until Hold Point decision is made
- Will continue the Vulnerability Outreach work started at risk
- Send appliance list for review and agreement

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Thank you