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University of Strathclyde Engineering

REFIT: Smart Homes & Energy Demand Reduction

Energy Feedback enabled by Load Disaggregation

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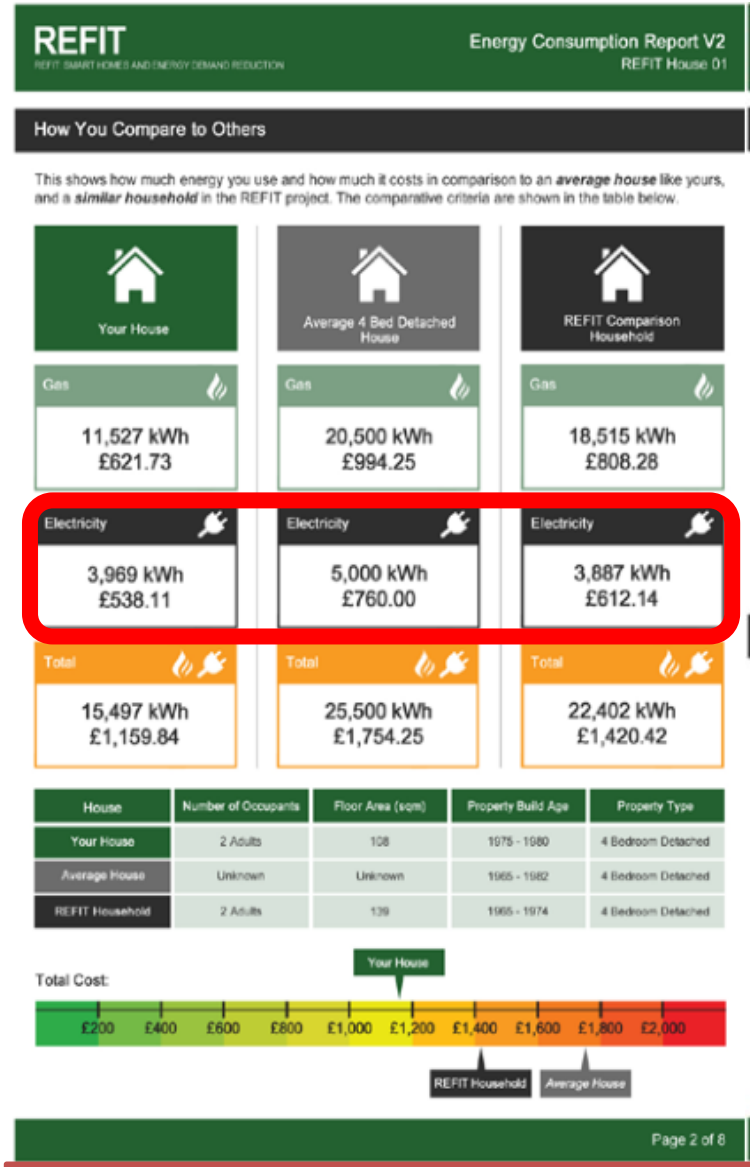
REFIT Energy Feedback & Findings



REFIT
REFIT: SMART HOMES AND ENERGY DEMAND REDUCTION

Energy Consumption Report V2
REFIT House 01

How You Compare to Others

This shows how much energy you use and how much it costs in comparison to an ***average house*** like yours, and a ***similar household*** in the REFIT project. The comparative criteria are shown in the table below.

	Your House	Average 4 Bed Detached House	REFIT Comparison Household
Gas	11,527 kWh £621.73	20,500 kWh £994.25	18,515 kWh £808.28
Electricity	3,969 kWh £538.11	5,000 kWh £760.00	3,887 kWh £612.14
Total	15,497 kWh £1,159.84	25,500 kWh £1,754.25	22,402 kWh £1,420.42

House	Number of Occupants	Floor Area (sqm)	Property Build Age	Property Type
Your House	2 Adults	108	1975 - 1980	4 Bedroom Detached
Average House	Unknown	Unknown	1965 - 1982	4 Bedroom Detached
REFIT Household	2 Adults	139	1965 - 1974	4 Bedroom Detached

Total Cost:

Your House

£200 £400 £600 £800 £1,000 £1,200 £1,400 £1,600 £1,800 £2,000

REFIT Household Average House

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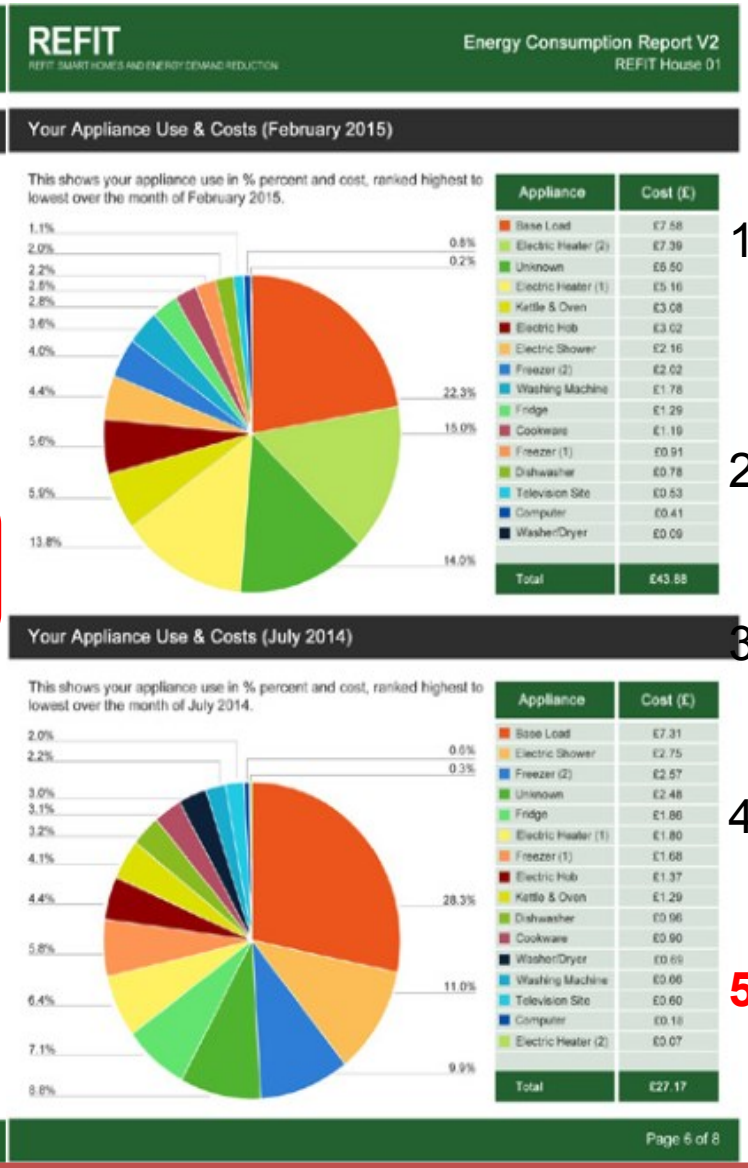

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Energy Consumption Report V2
REFIT House 01

Your Appliance Use & Costs (February 2015)

This shows your appliance use in % percent and cost, ranked highest to lowest over the month of February 2015.

1.1% 2.0% 2.2% 2.6% 2.8% 3.6% 4.0% 4.4% 5.6% 5.9% 13.8% 0.8% 0.2% 22.3% 15.0% 14.0%

Appliance	Cost (£)
Base Load	£7.58
Electric Heater (2)	£7.39
Unknown	£6.50
Electric Heater (1)	£5.16
Kettle & Oven	£3.08
Electric Hob	£3.02
Electric Shower	£2.16
Freezer (2)	£2.02
Washing Machine	£1.78
Fridge	£1.29
Cookware	£1.19
Freezer (1)	£0.91
Dishwasher	£0.78
Television Site	£0.53
Computer	£0.41
Washer/Dryer	£0.09
Total	£43.88

Your Appliance Use & Costs (July 2014)

This shows your appliance use in % percent and cost, ranked highest to lowest over the month of July 2014.

2.0% 2.2% 3.0% 3.1% 3.2% 4.1% 4.4% 5.8% 6.4% 7.1% 8.8% 0.6% 0.3% 28.3% 11.0% 9.9%

Appliance	Cost (£)
Base Load	£7.31
Electric Shower	£2.75
Freezer (2)	£2.57
Unknown	£2.48
Fridge	£1.86
Electric Heater (1)	£1.80
Freezer (1)	£1.68
Electric Hob	£1.37
Kettle & Oven	£1.29
Dishwasher	£0.96
Cookware	£0.90
Washer/Dryer	£0.69
Washing Machine	£0.66
Television Site	£0.60
Computer	£0.18
Electric Heater (2)	£0.07
Total	£27.17

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1. Comparison with that of the previous month or year => 100%
2. Comparison with other households => 50%
3. Monthly consumption => 65%
4. Daily or weekly consumption => 25%.
5. **Appliance-specific use => 70%**

Load Disaggregation via Non-intrusive Appliance Load Monitoring (NILM)

for smart-meter aggregate load data

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- Supervised NILM methods[1,2] — relatively simple, robust, and require short training periods
- Unsupervised method[1,3] —does not require a labelled set of appliances for training
- Training-less method[4] —does not require any prior knowledge of appliances or a training period

Smart electricity meters and **IHD**s tell us about real-time household electricity use, but they don't tell us which appliances were running, nor **what to do about it**.

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Energy disaggregation tells us **when**, **how long** an appliance was used and **how much energy** it consumed, but nothing about **why** it was used.

Beyond NILM

Enhanced feedback on electricity consumption

- advice on non-efficient usage of an appliance
- inform appliance upgrades
- opportunities for (appliance) load shifting
- predict appliance electricity demand
- relating energy consumption to activities in the home, such as cooking or laundering

Appliance Modelling & Informing Energy Savings

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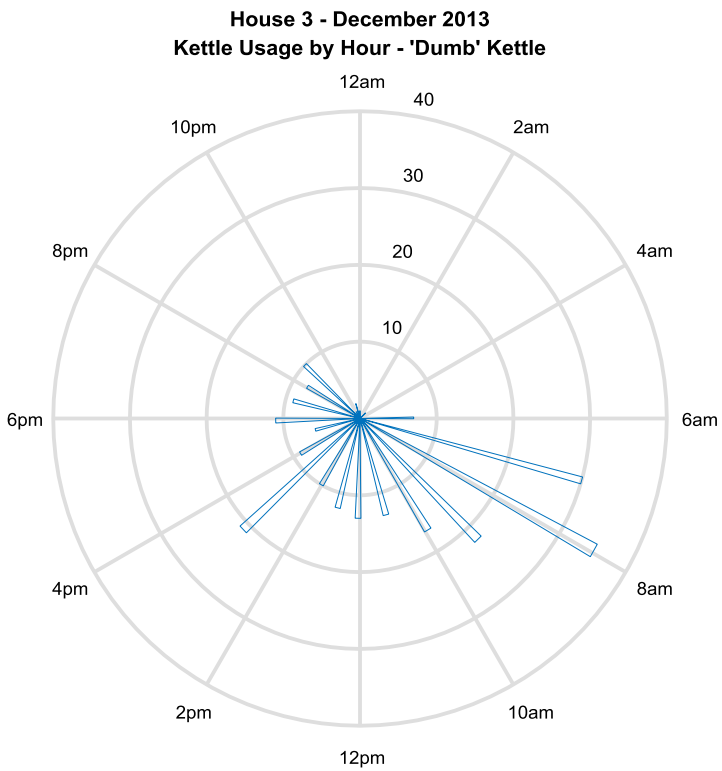
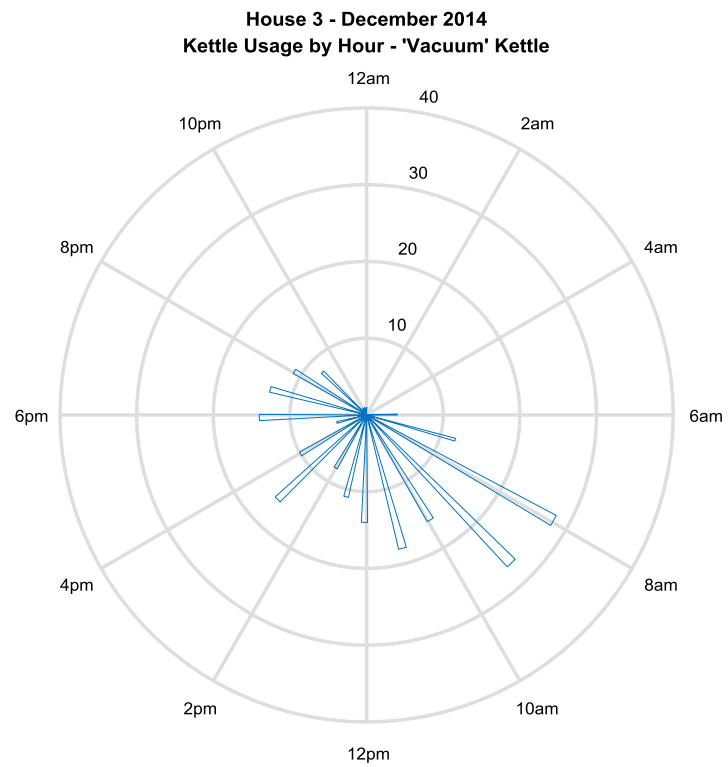
- Kettle: Model inferring the volume of water used purely from disaggregated electricity consumption
- Estimating best usage scenarios to reduce waste

House	Months Recorded	Total Consumption (kWh)	Optimal Volume (mL)	Consumption Above Optimal (kWh)	**Savings per Year (kWh)**
2	20	255.32	825	126.76	**15.32**
3	20	251.16	550	171.06	**28.85**
5	21	314.66	825	148.85	**17.32**
6	19	273.6	550	122.75	**16.67**
8	18	245.68	550	171.83	**23.41**
9	18	312.36	550	271.31	**73.71**
11	12	182.02	500	83.78	**29.99**
12	15	163.92	825	105.54	**20.98**
17	15	183.63	550	98.98	**16.99**

Informing Appliance Upgrade

Case study of a household upgrading from a standard kettle to a vacuum kettle

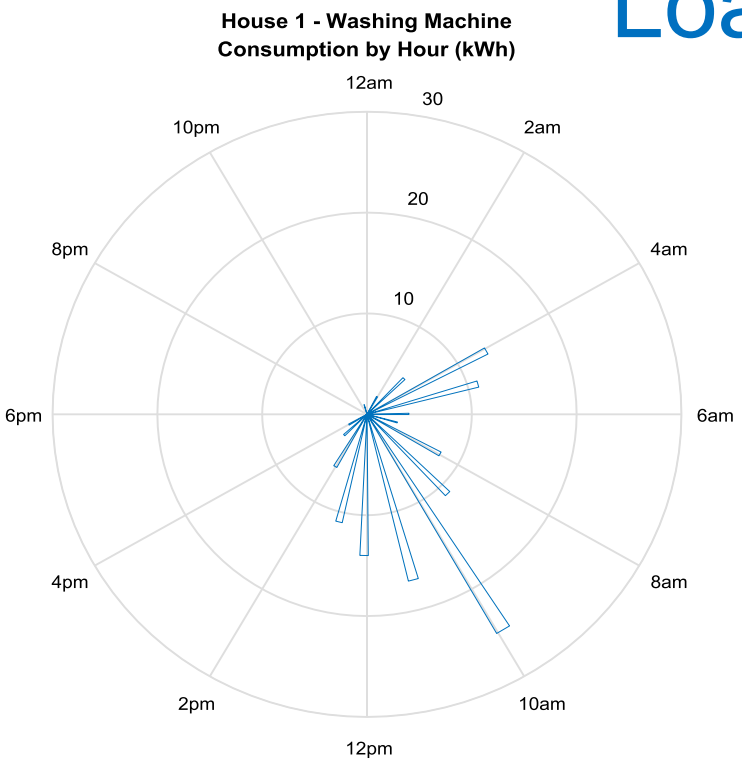




Year	Uses	Consumption (kWh)
Dec 2013 – Standard	238	17.2
Dec 2014 – Vacuum	217	14.8

- Reduction in the number of re-heats
- ~5% reduction per use
- ~14% total reduction
- Continued economical usage style

Load Shifting



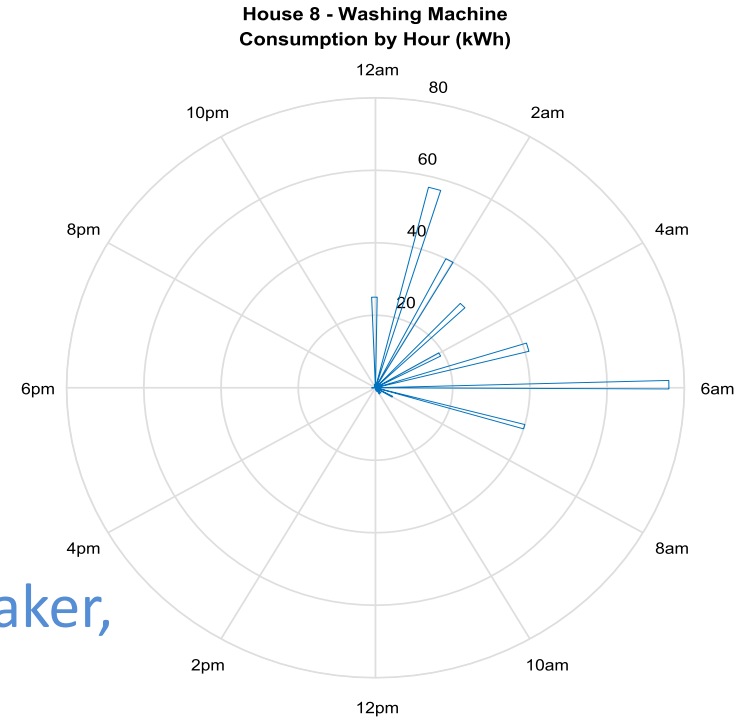
Non Off-Peak uses: 344

Total load that can be shifted: 99.77 kWh

Day Price: £13.05

Night Price: £7.54

Possible Savings: ~ £5.10



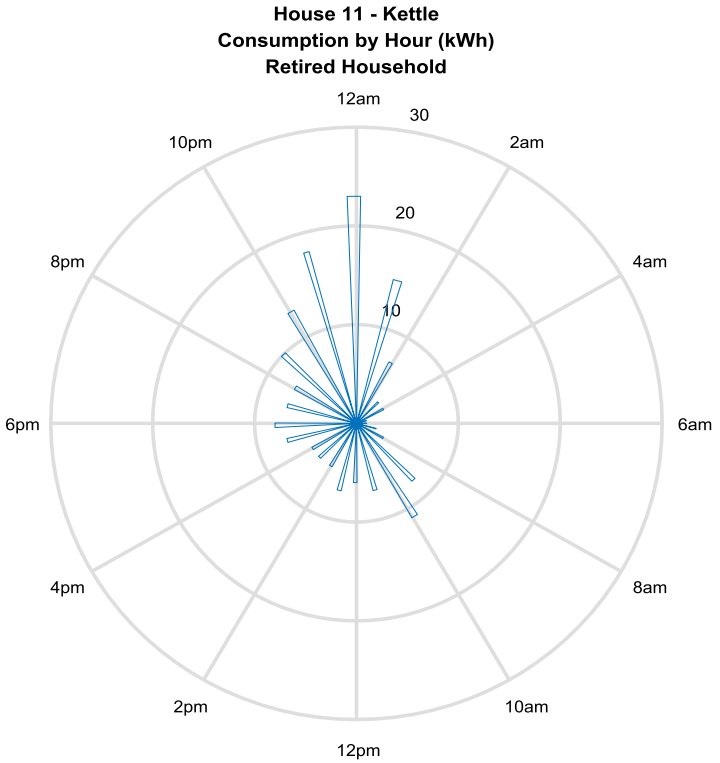
65% of REFIT households would consider adjusting the timing of their appliance use to benefit from a better tariff.

- dishwasher, washing machine and tumble dryer, hobbies, charging devices, bread-maker, computing, and charging their car.

Temporal Patterns of Appliance Use

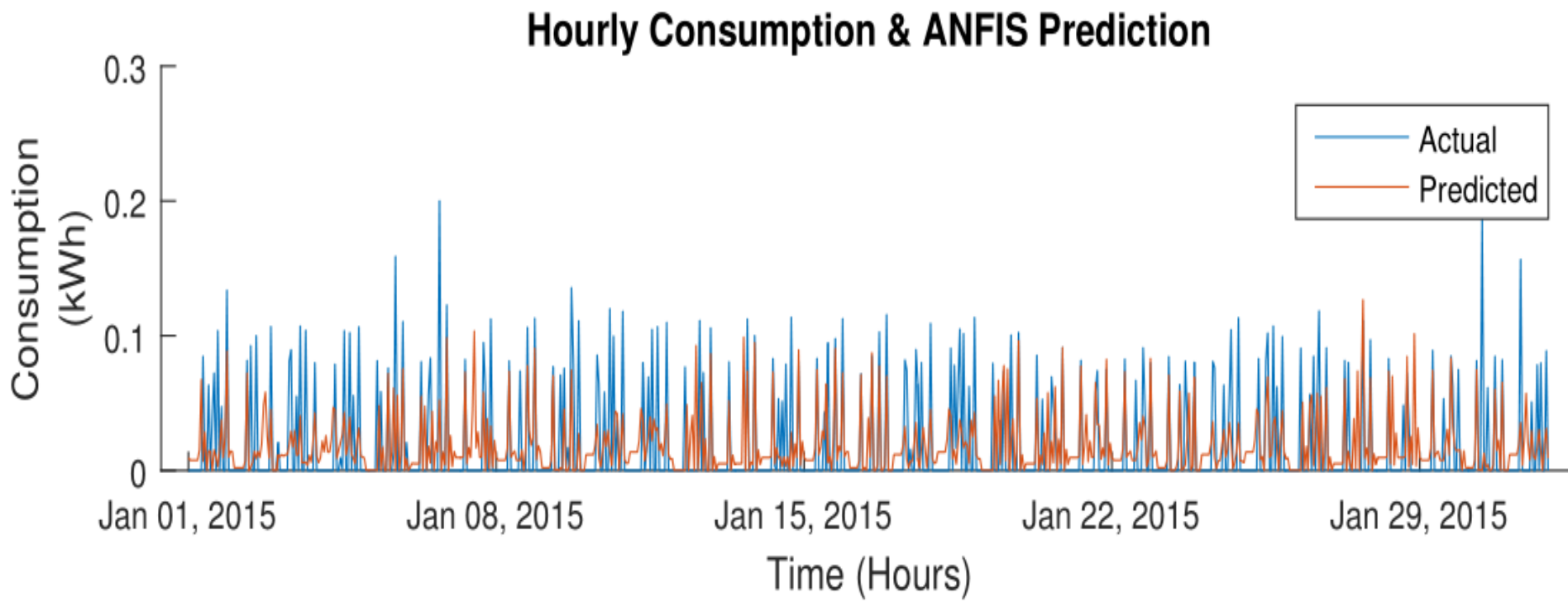
House 12 (Working)

House 11 (Retired)



Kettle Demand Prediction

Deeper understanding and more accurate prediction of appliances will enable more accurate load simulation



Meaningful & salient feedback

Feedback is important "*in making energy more visible and more amenable to understanding and control*".

Moving away from 'energy-centric' approach in which information feedback directly concerns energy consumption

To an 'activity-centric' approach, where the emphasis shifts from energy use to households' lived experience, i.e., routines, habits and activities that constitute the majority of life at home.

Understanding the linkages between appliance use and common activities in the house by integrating **quantitative smart home data** with **qualitative household ethnography** to identify activities at home

Develop, test, and validate a multi-step methodology for making robust activity-based inferences in households

Demonstrate how smart energy meter data can be used to feed back information to households on the time profile of everyday activities in the home and their energy-using consequences

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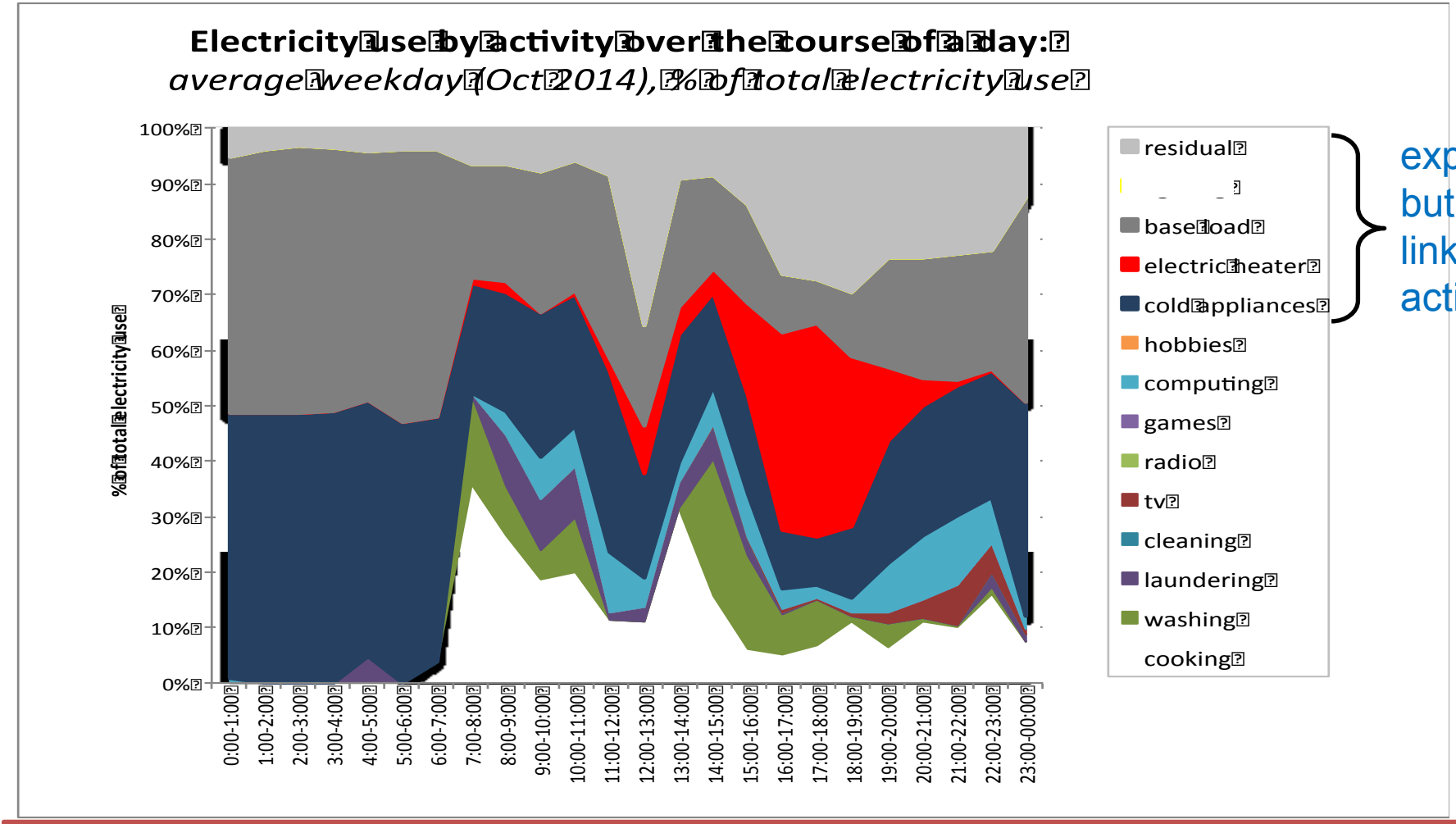
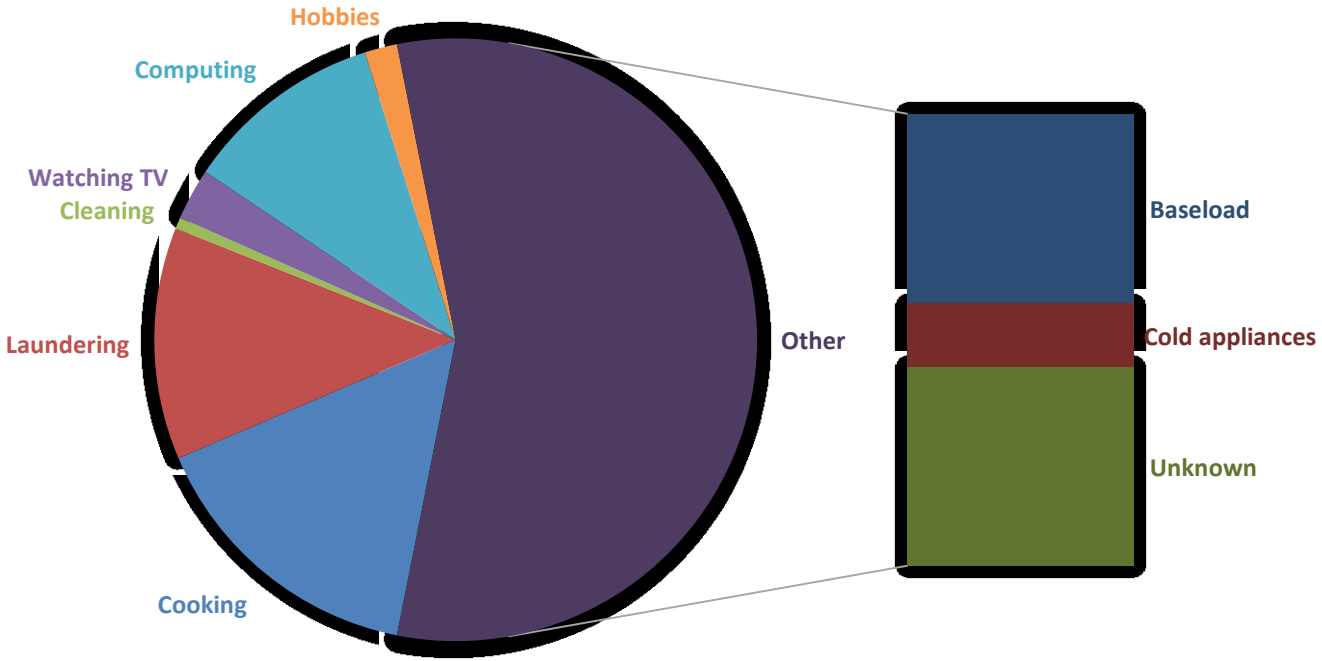
Linkages between Time-use (Activities) and Energy

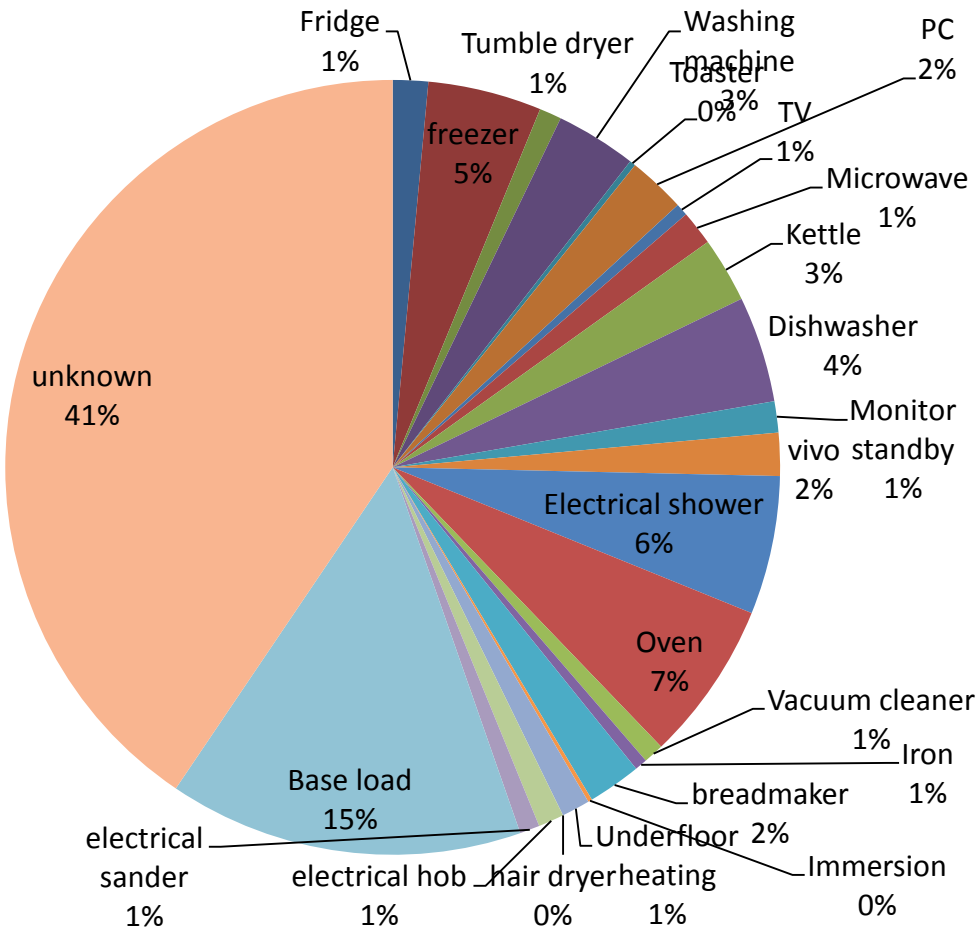


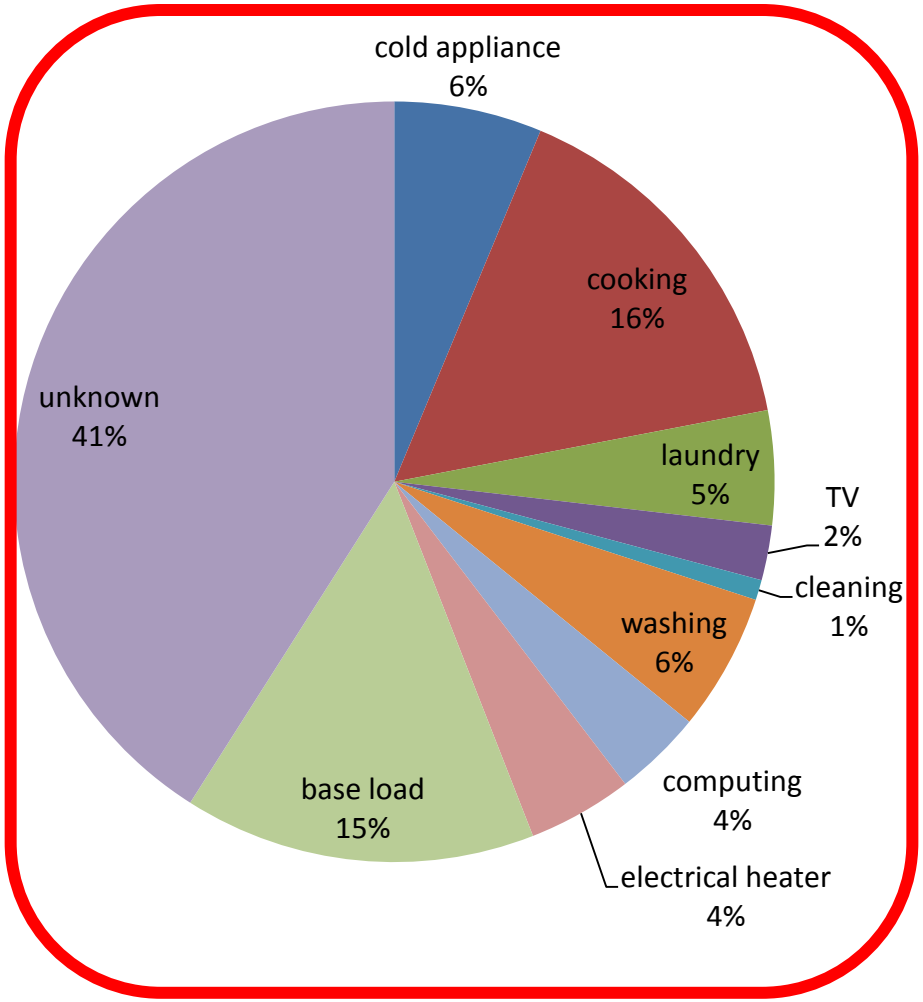
Understanding Energy Demand through Activities

In this household, detected activities can account for almost 50% of the monthly total electricity consumption, with cooking and laundering playing a significant part.



Monthly electricity breakdown





- The total electricity use explained by activity inferences is 33%. The rest is accounted for by lighting, cold appliances, base load, and heating.

NILM-facilitated Energy Feedback

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- Using disaggregated information about the when, duration and energy consumption of each appliance use:
  - Time use statistics to quantify, predict and inform (efficient) appliance use and upgrade
  - Identify opportunities for load shifting of particular appliances & quantify energy savings due to shifting appliance use
  - Understanding electricity demand through the lens of activities by integrating **quantitative smart home data** with **qualitative household ethnography** to identify activities at home

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