Identifying Household Activities from Smart Meter Data

ECEEE, June 2015

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EPSRC Engineering and Physical Sciences Research Council

Smart meters tell us about real-time energy use, but they don't tell us **why**, nor **what to do about it**.

(1) The routines and scheduling of domestic life explain why and when energy is used.

(2) To be meaningful and salient, energy feedback needs to reflect households' lived experience.

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activities: *what did you do today?*



Activities are described by **time use**.
Collecting data on time use is effortful and costly.

national STATISTICS

The Time Use Survey, 2005

How we spend our time

A report on research using the ONS Omnibus Survey produced on behalf of the Economic and Social Research Council (ESRC), Department of Culture, Media and Sport (DCMS), Department for Education and Skills (DfES), Department of Health (DH), Department for Transport (DfT), Office for National Statistics (ONS)

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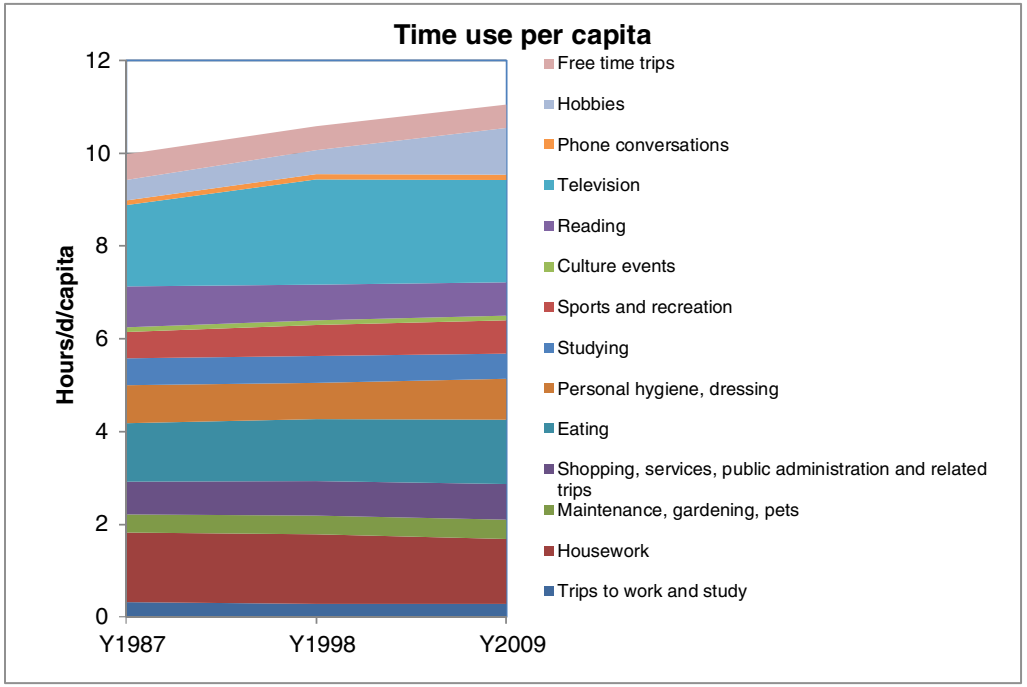
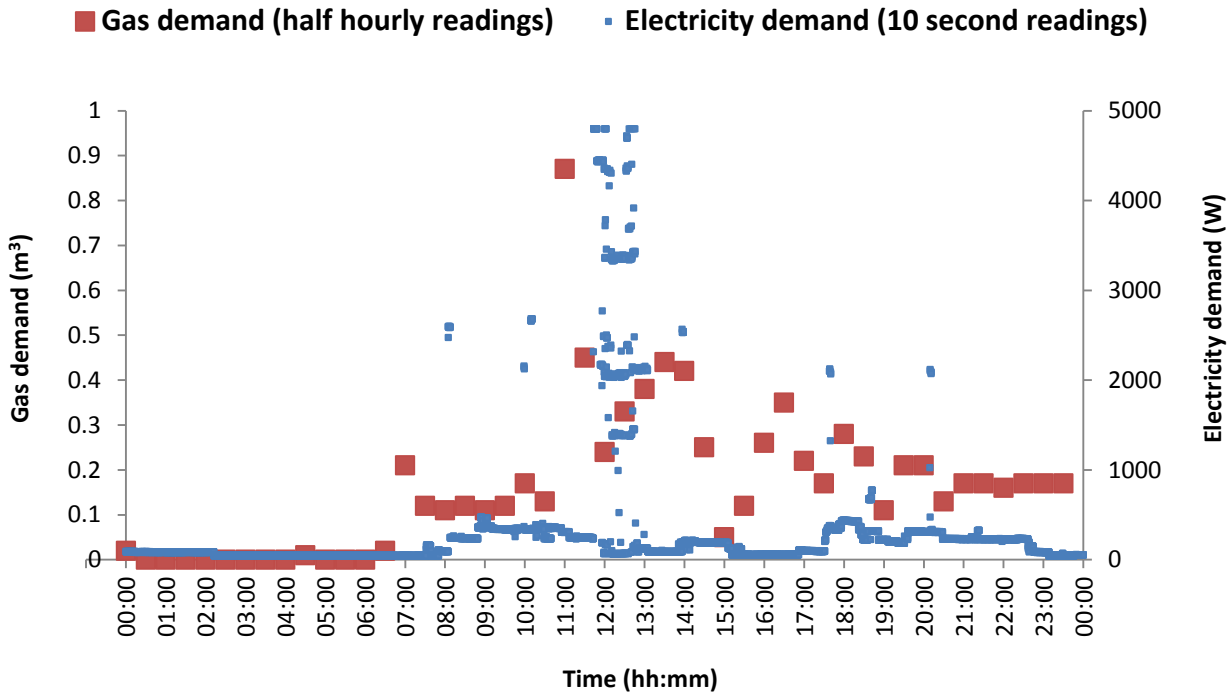
July 2006



Jalas & Juntunen (2015). *Ecological Economics* 113: 51-59.

Can we make **reliable inferences** about household **activities** using smart meter data?



Firth, S. (2014). ”The REFIT Household Study.” TEDDInet conference. April 2014.

Energy Saving Advice Service 0300 123 1234

HELPING CONSUMERS | 13

Smart meters

What is a smart meter?

Smart meters are the next generation of gas and electricity meters and provide near real time information about the amount of energy a household uses. Smart meters will bring an end to estimated billing.

As well as the meter itself, householders will also be offered an In Home Display which shows how much energy is being used in pounds and pence, and should help households to budget better.

Together, the In Home Display linked to a smart meter will put households in control and help them to avoid wasting money and energy.

Consumer protection

The Government is ensuring that consumer benefits and protection are at the heart of the smart meter programme.

This means:

- No sales during the installation visit
- Installers must provide energy efficiency advice as part of the visit and they will need the consumer's permission before the visit if they want to talk to them about their own products
- Protecting the privacy of individuals and putting them in control of smart meter data

Suppliers and consumer groups are working together to ensure consumers get accurate and helpful information about their smart meter.

When will households get smart meters?

Most households will have smart meters installed between 2015 and 2020, although some energy companies are starting to install smart meters now.

How much will it cost to get a smart meter installed?

Households will not be charged separately for a smart meter or for the In Home Display.

By the end of June 2013 almost **90,000** smart meters have been installed in homes across Great Britain

Little things save a lot

Lynne is a busy stay-at-home mum with 2 young children: Daniel, aged 7 and Connor, aged 2. The family home is a 3 bedroom semi-detached property built in the 1970s.

Energy cost saving achieved

£76.49

Through a series of small daily changes, Lynne has managed to reduce her energy use by 16% in just 12 months.

*"My smart meter really helped me see what appliances used most energy in our home. Not only is the smart meter **saving us money**, it's also helped us **adopt some great energy saving habits** which we are passing on to our children"*

Method … Results … Applications

Method … results … applications

Method (6 Steps)

1. Define activities
2. Collect energy and household data
3. Disaggregate electricity data
4. Map technology <-> activity relationships
5. Make activity inferences
6. Validate activity inferences

Method: *Step 1*. Develop a comprehensive set of **activities** to describe household life and energy use.

***DAILY ROUTINES*:**



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***DAILY ROUTINES*:**



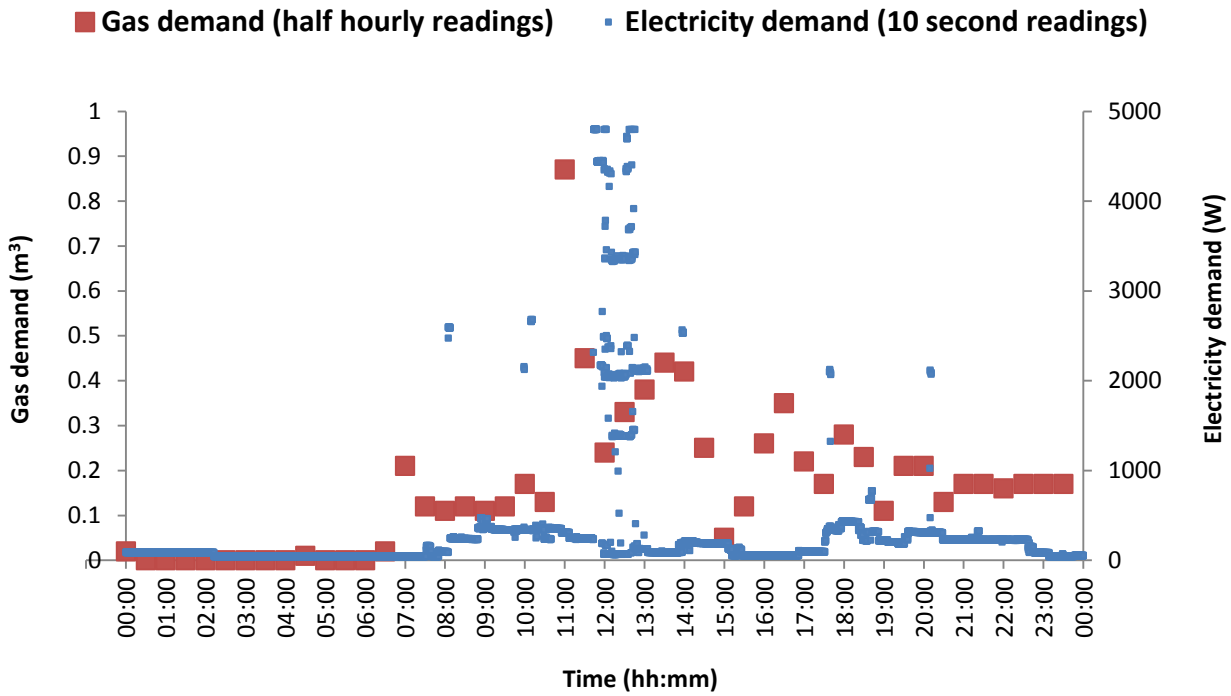



***INTERACTING*:**
communicating
socialising

***LEISURE & ICTs*:**
watching TV
listening to radio/music
gaming
computing

***OTHER ACTIVITIES*:**
hobbies
caring
working
other

Method: *Step 2*. Collect **data** on **energy** & household routines from 6 homes (of 20 homes in a field trial).



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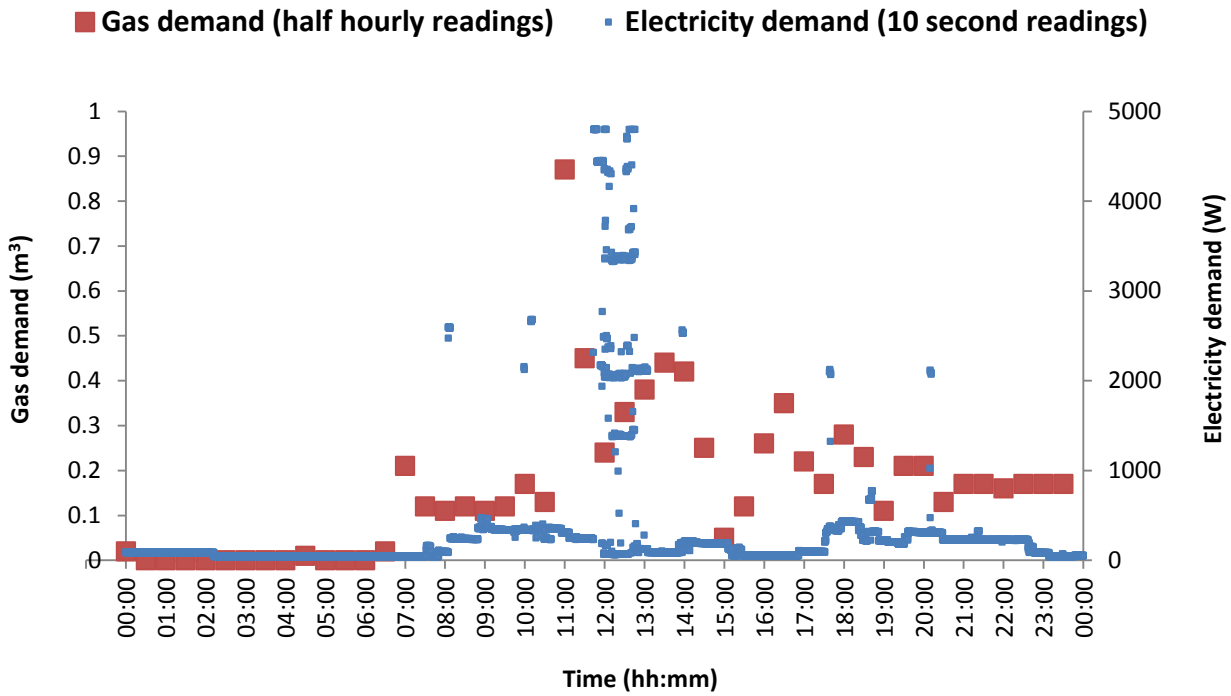

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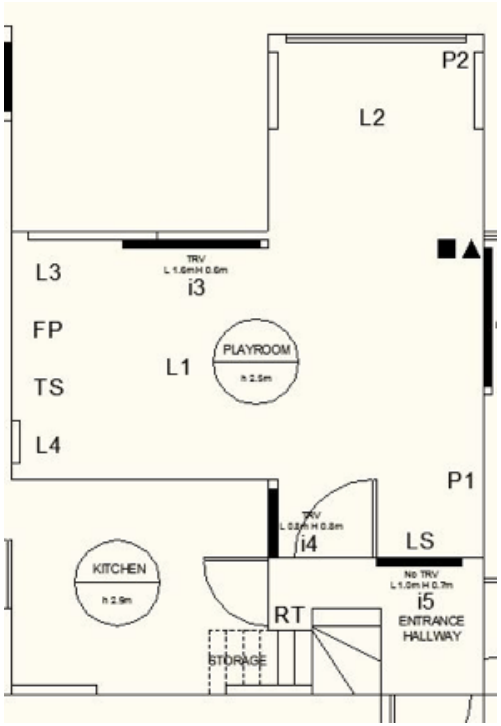

Method: *Step 3*. **Disaggregate** real-time electricity data.

- appliance-specific plug monitors
- non-intrusive appliance load monitoring (NALM)
  - validated by appliance time diaries

Method: *Step 4*. Map **relationships** between activities and technologies in an 'activities ontology'.

APPLIANCES		ACTIVITIES									
		daily routines						ICT-related leisure			
Type	**Appliance / Technology**	**cooking**	**eating**	**washing**	**laundering**	**cleaning**	**sleeping**	**tv**	**radio**	**games**	**computing**
electricity	kettle	x	o								
electricity	toaster	x	o								
electricity	microwave	x	o								
elecricity	washing machine				x						
electricity	vacuum cleaner					x					
electricity	food processor	x									
electricity	PC									~	x
electricity	laptop									~	x

+ additional information on:
- location
- typical usage patterns

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electricity	vacuum cleaner					x					
electricity	food processor	x									
electricity	PC									~	x
electricity	laptop									~	x

+ additional information on:
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x = marker technology
~ = auxiliary technology
o = associated activity

Method … results … applications

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Method … **Results** … applications

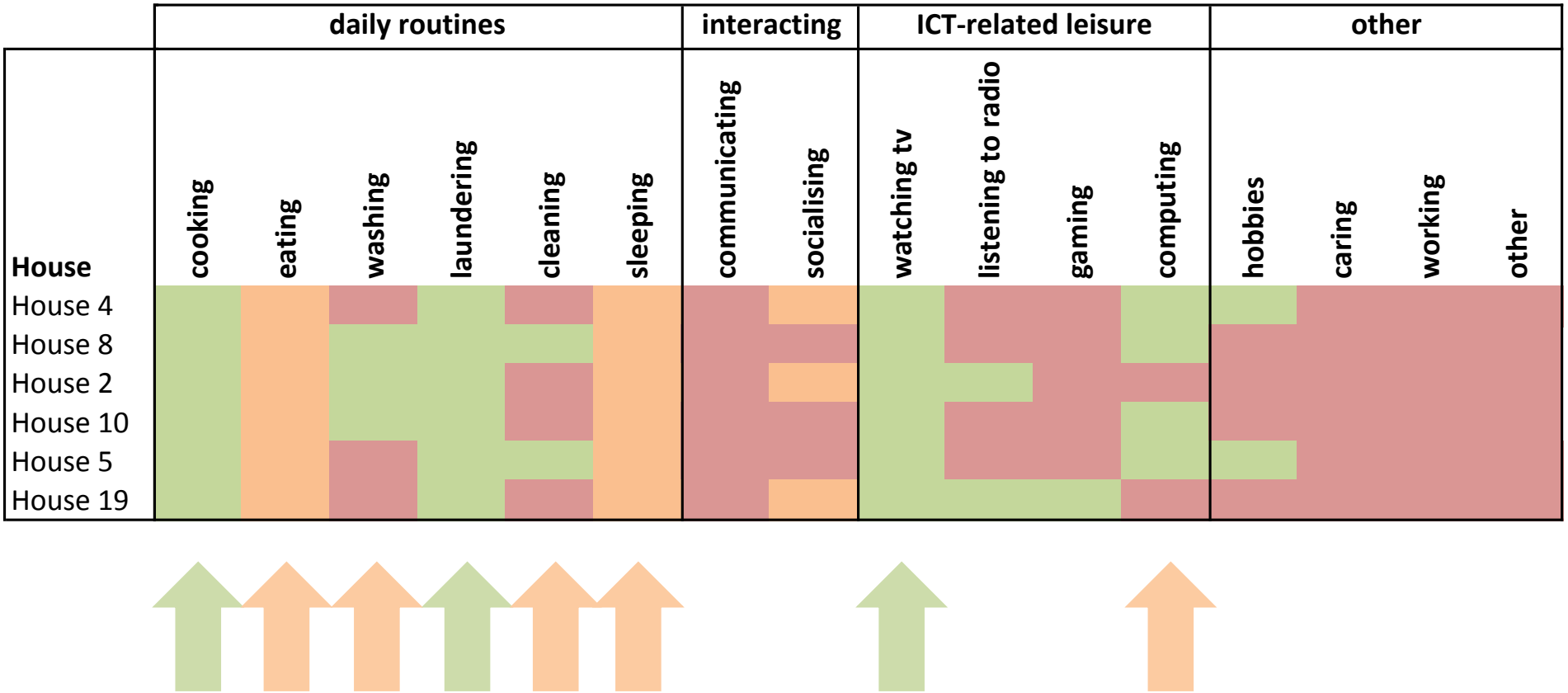
Key Results (so far)

1. 6-8 activities are inferrable per household
2. Some time use profiles are stable, others vary
   - within household
   - between household
3. Some activities are temporally inter-linked, others are not
4. Activities usefully and meaningfully characterise energy use

Results 1. Activity-inference methodology applied to **6 homes** for **1 month** (October 2014).

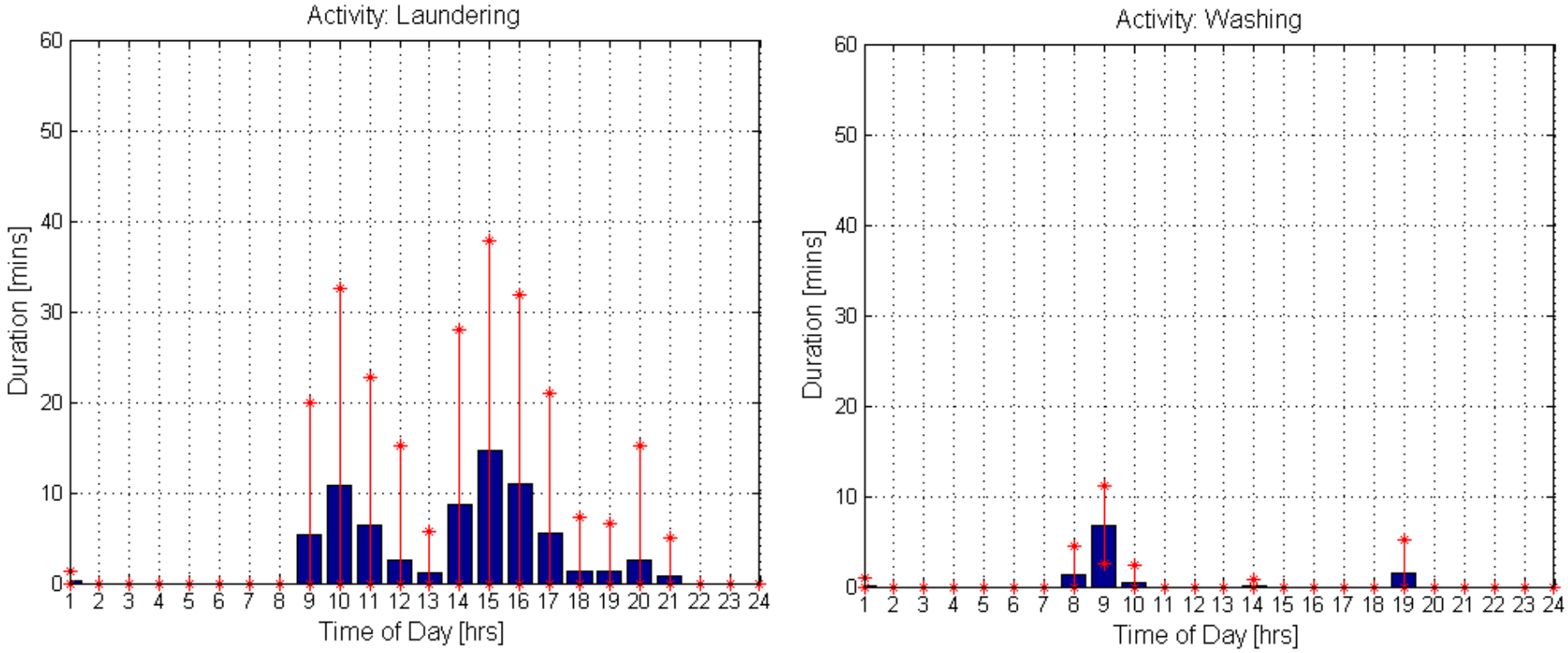
House	**Size & Composition**
House 4	2 retired adults
House 8	2 retired adults
House 2	2 adults + 2 pre-school children
House 10	2 adults + 2 pre-school children
House 5	2 adults + 2 school children
House 19	2 adults + 2 school children

Results 1. 6-8 activities were **inferrable** (remainder were not inferrable or **not occurring** in that home).



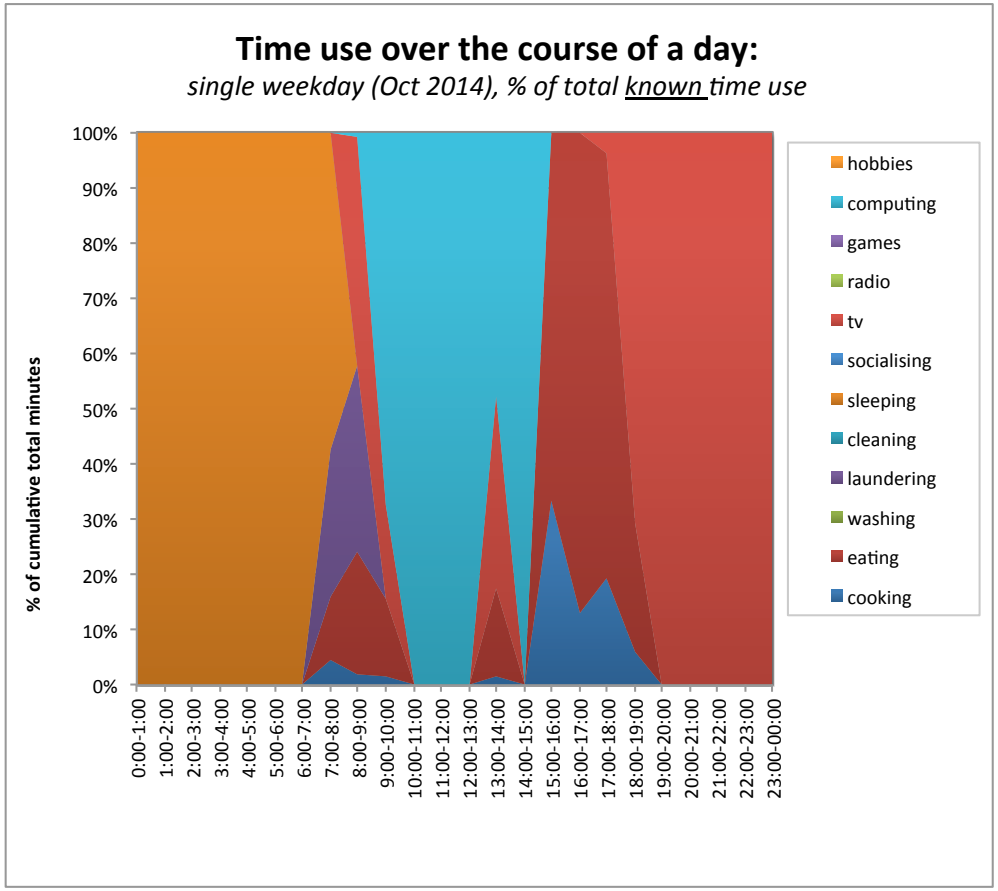
Results 2. Activities varied in the **regularity** of their **routine** (when and for how long).

mean (and 90% C.I.) of hourly time use profiles over a month



House 2. 2 adults + 2 pre-school children

Results 2. Some … but not all activity time profiles **varied** from **day to day**.



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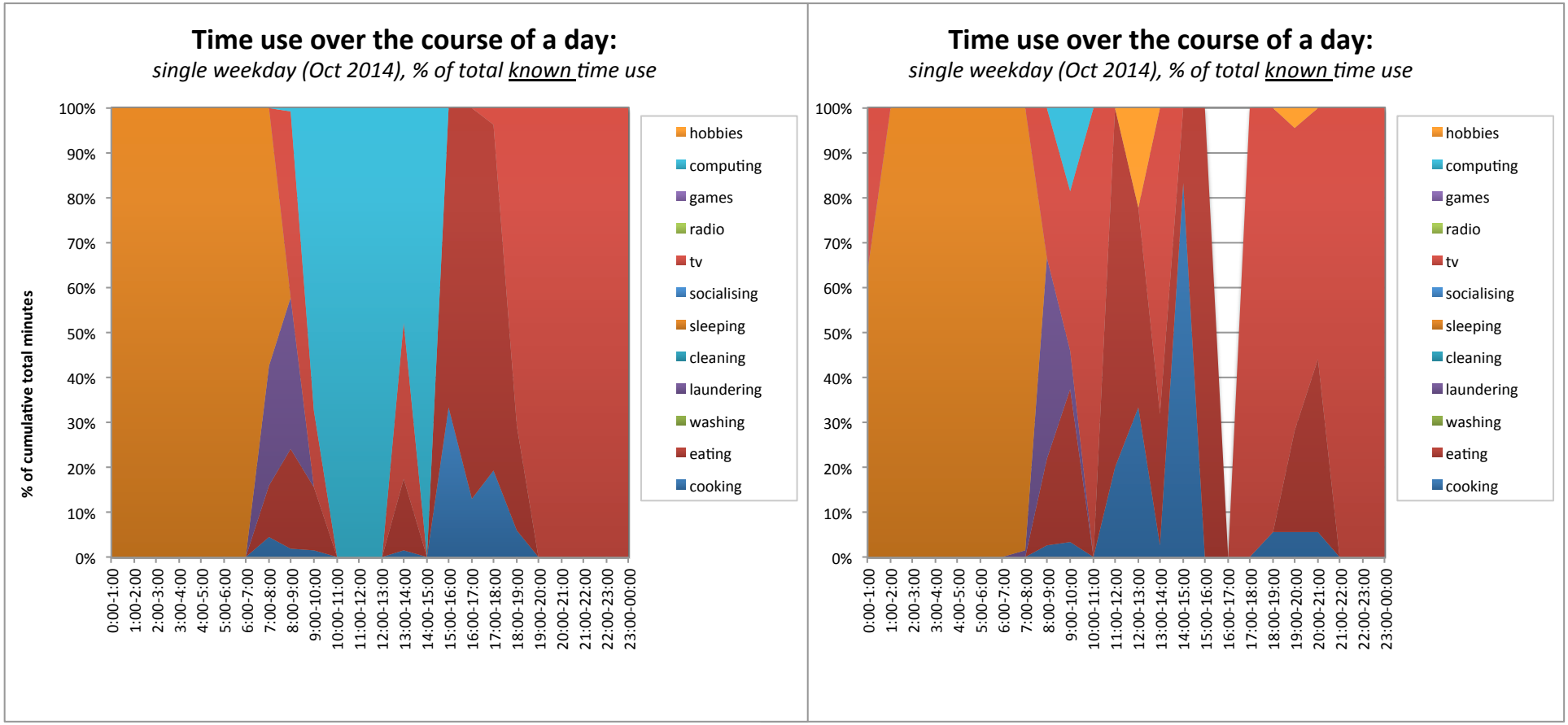
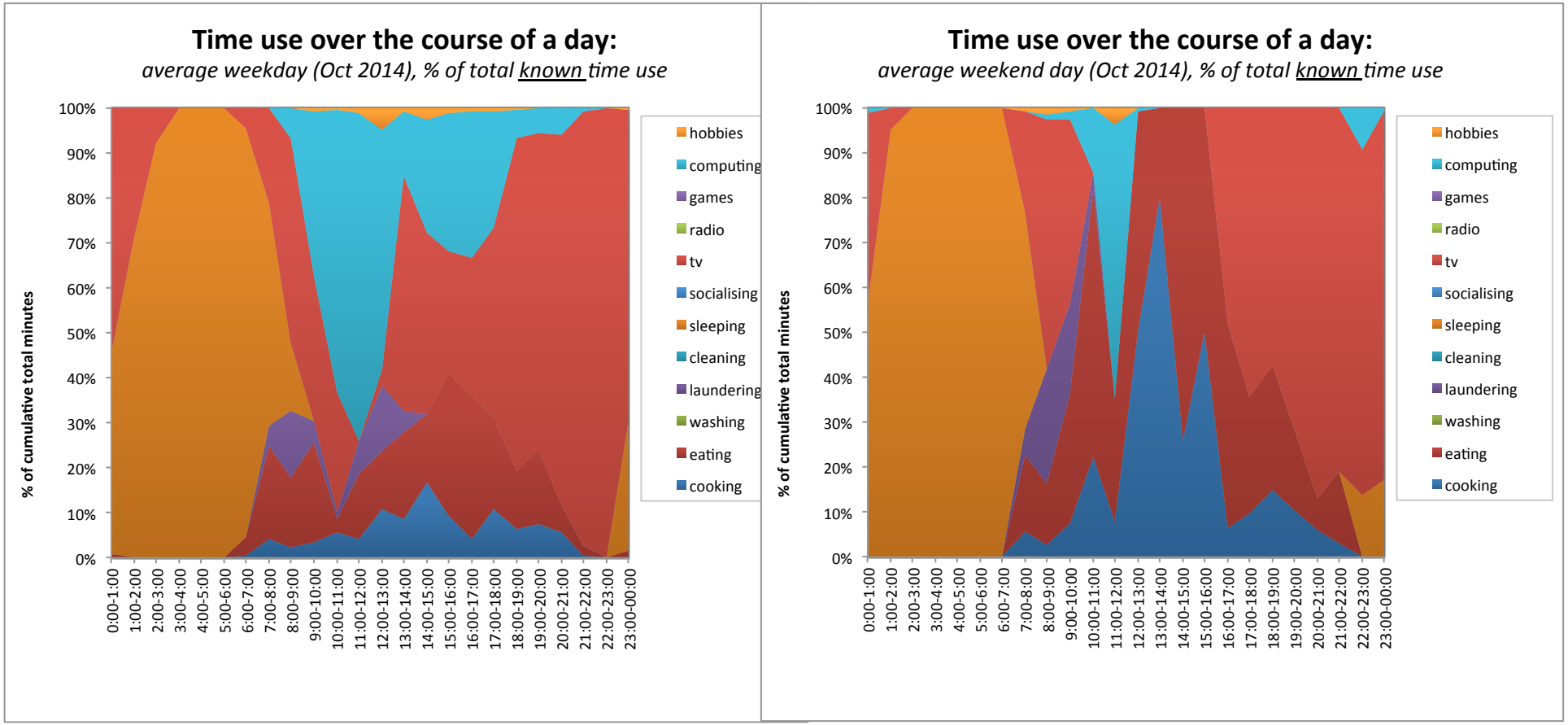


House 4. 2 retired adults

Results 2. Some … but not all activity time profiles varied markedly between **weekdays** and **weekends**.

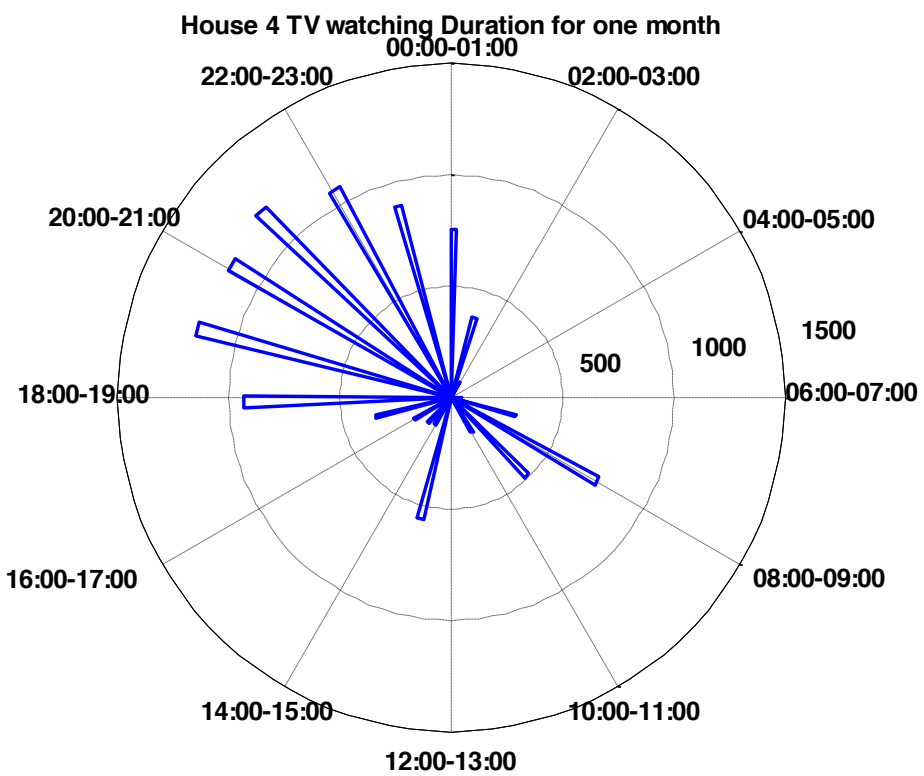


*** computing ***

*** cooking ***

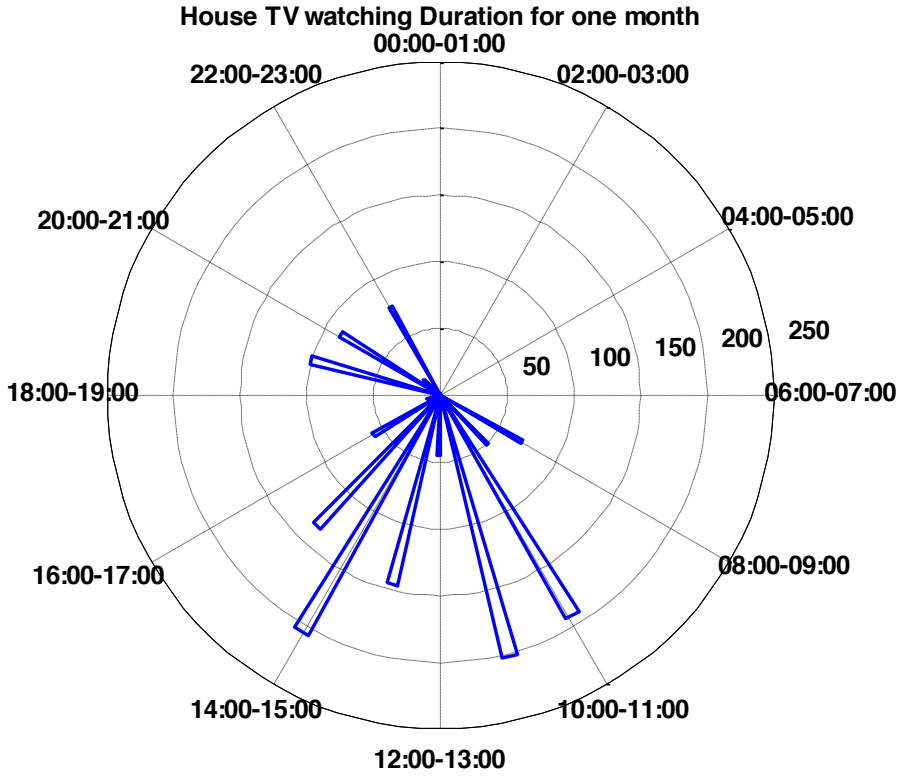
House 4. 2 retired adults

Results 2. Activity time profiles varied between households of **similar compositions**.



watching TV

House 4. 2 retired adults



watching TV

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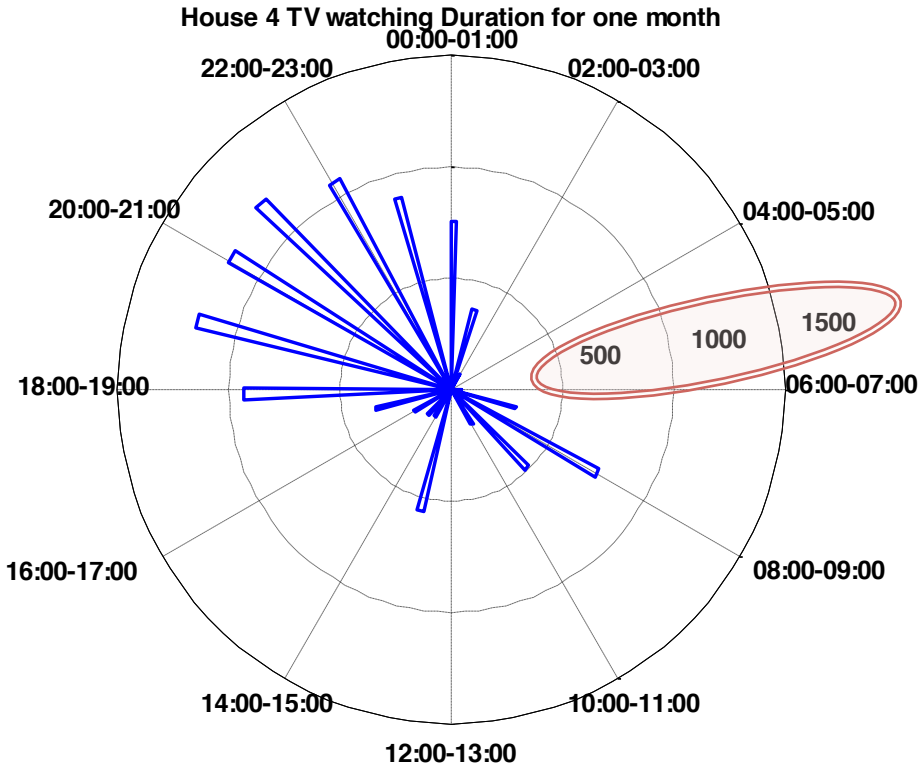

watching TV

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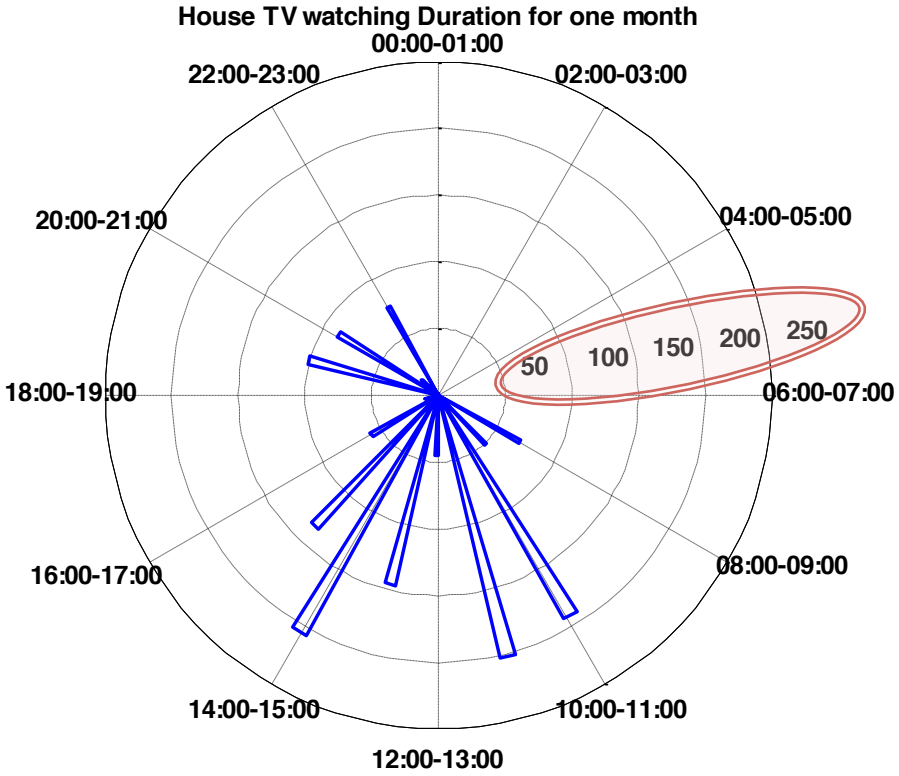
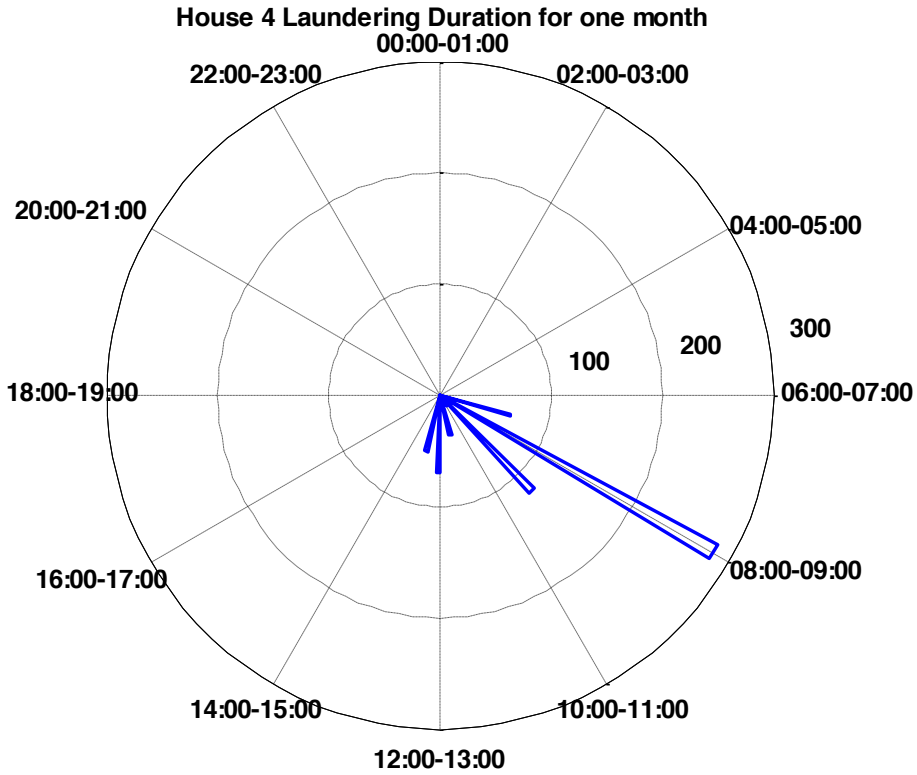


watching TV

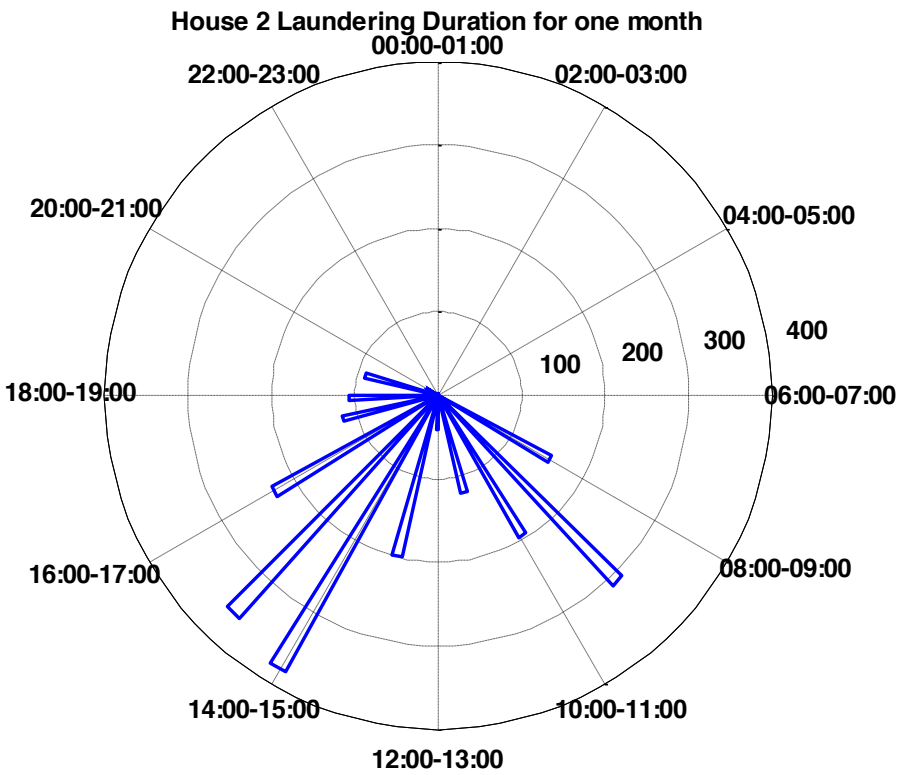
House 8. 2 retired adults

Results 2. Activity time profiles varied between households as a result of **different compositions**.



laundering

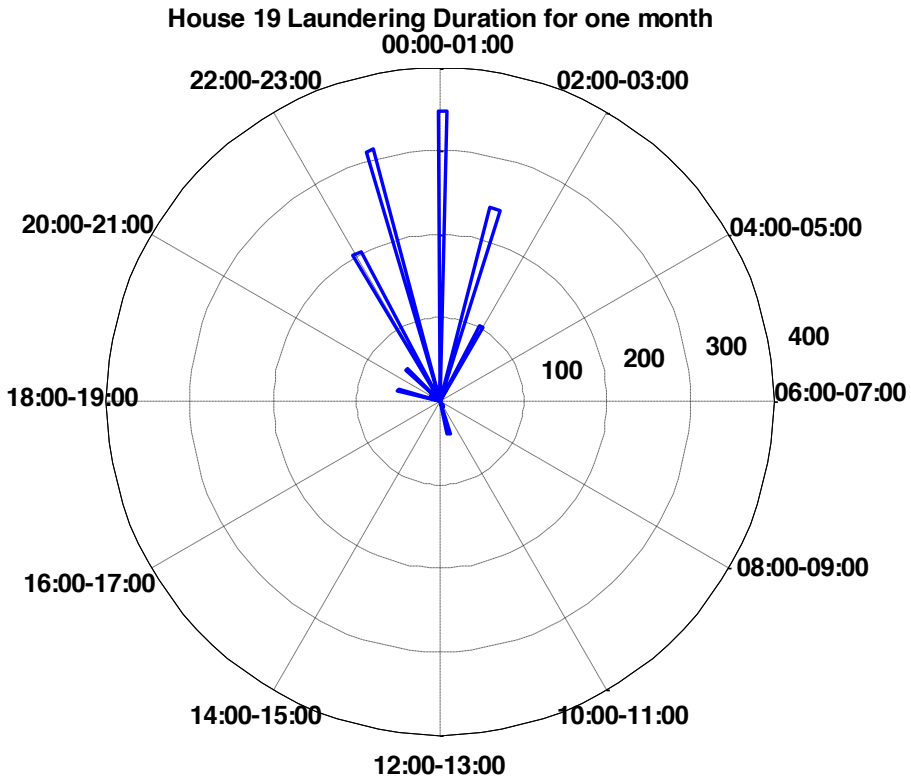
House 4. 2 retired adults



laundering

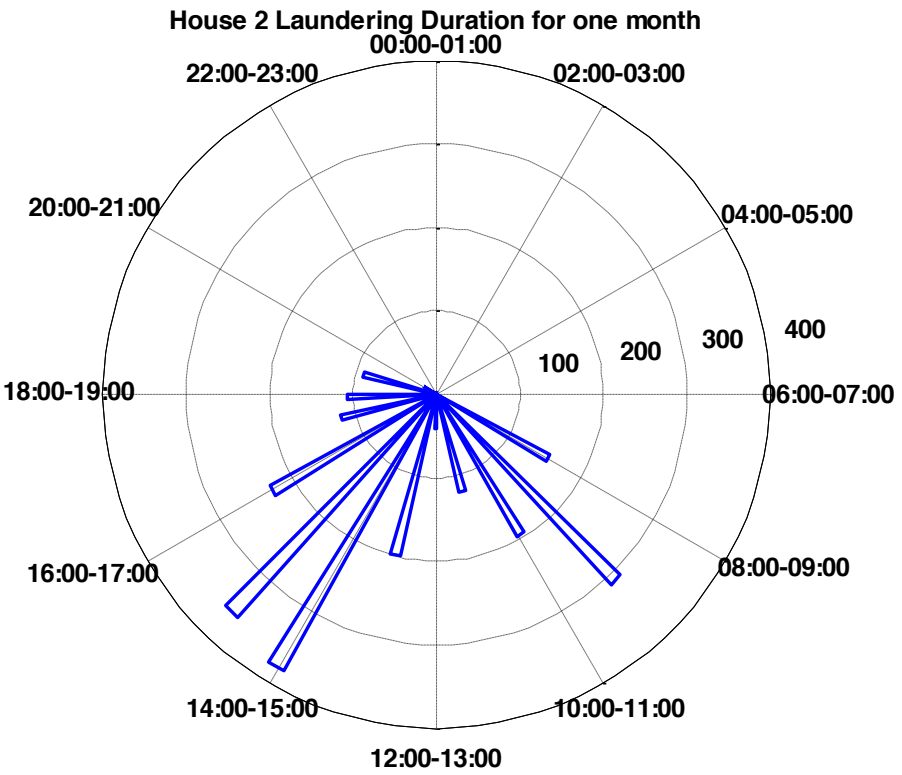
House 2. 2 adults + 2 pre-school children

Results 2. Activity time profiles varied between households with **different scheduling**.



laundering

House 19. 2 adults + 2 school children



laundering

House 2. 2 adults + 2 pre-school children

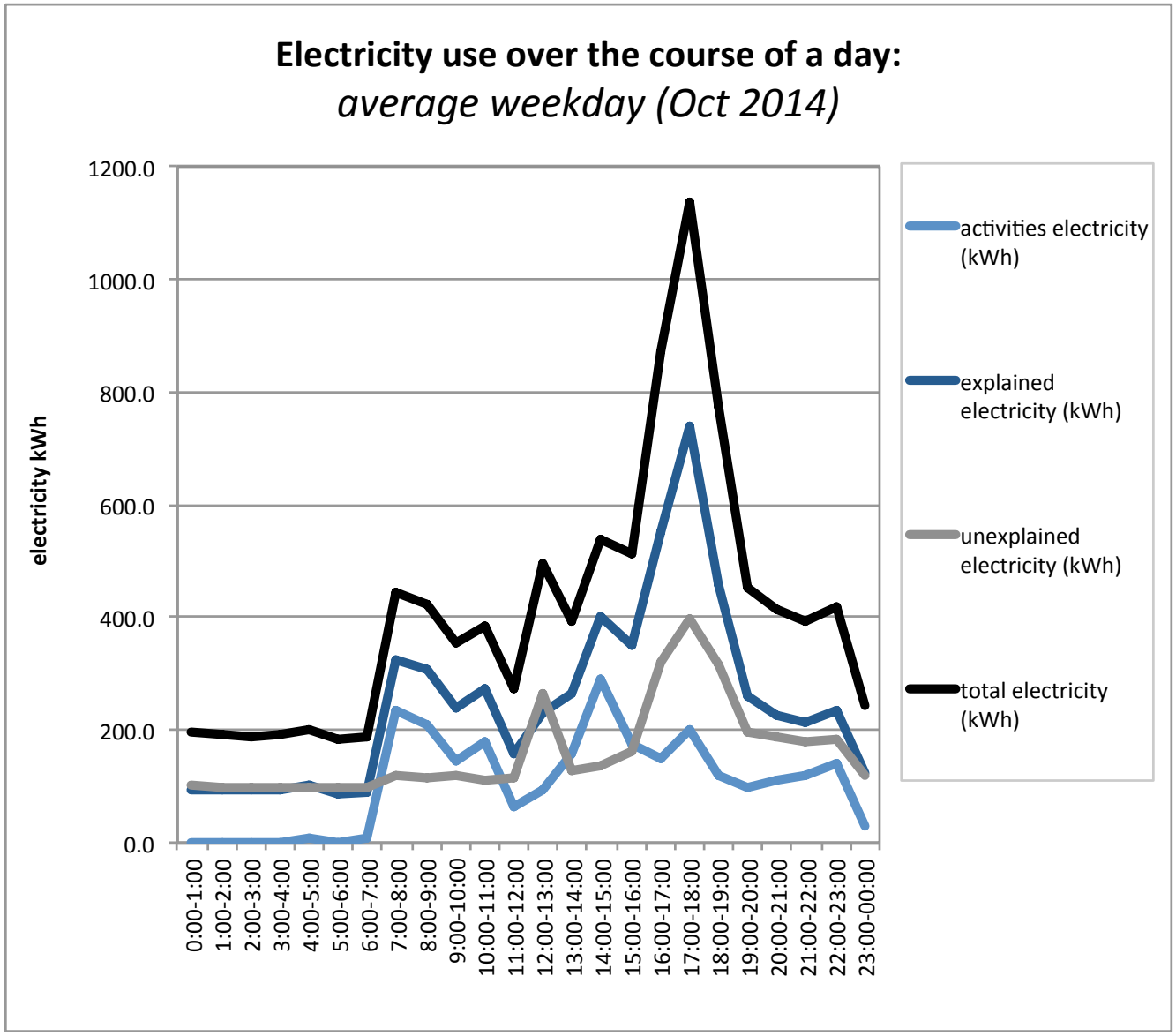
Results 3. Activity time profiles are **inter-linked temporally** to different extents.

correlations (time use): average weekday

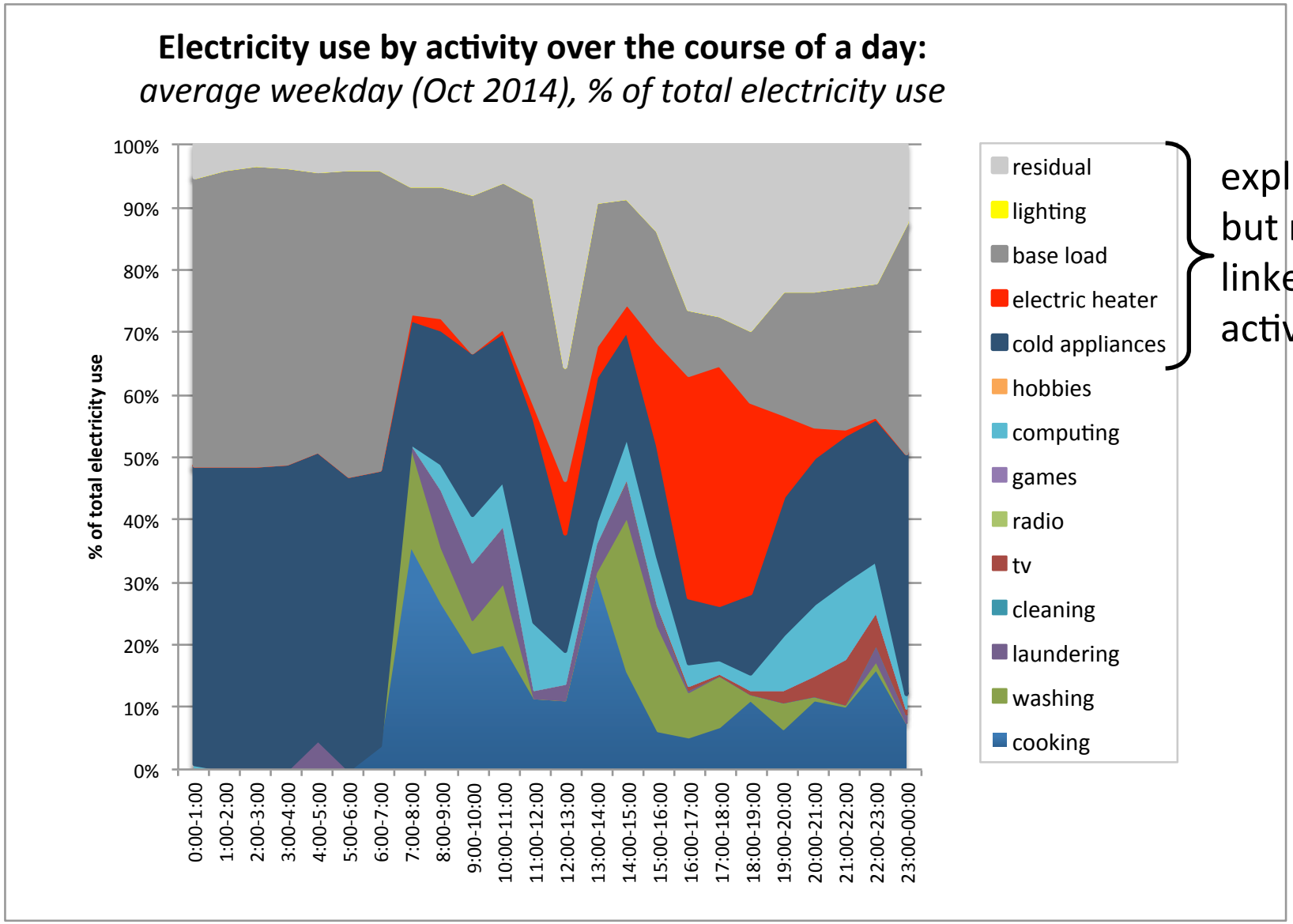
	cooking	eating	laundering	sleeping	watching tv	computing	hobbies
cooking	1.00						
eating	0.70	1.00					
laundering	0.17	0.46	1.00				
sleeping	-0.63	-0.51	-0.22	1.00			
tv	0.27	0.16	-0.03	-0.47	1.00		
computing	0.36	0.38	0.29	-0.56	-0.24	1.00	
hobbies	0.53	0.33	0.28	-0.50	-0.25	0.57	1.00

House 4. 2 retired adults

Results 4. **Energy use** can be apportioned among activities.



Results 4. Energy use can be linked to activities to provide **meaningful feedback** to households.



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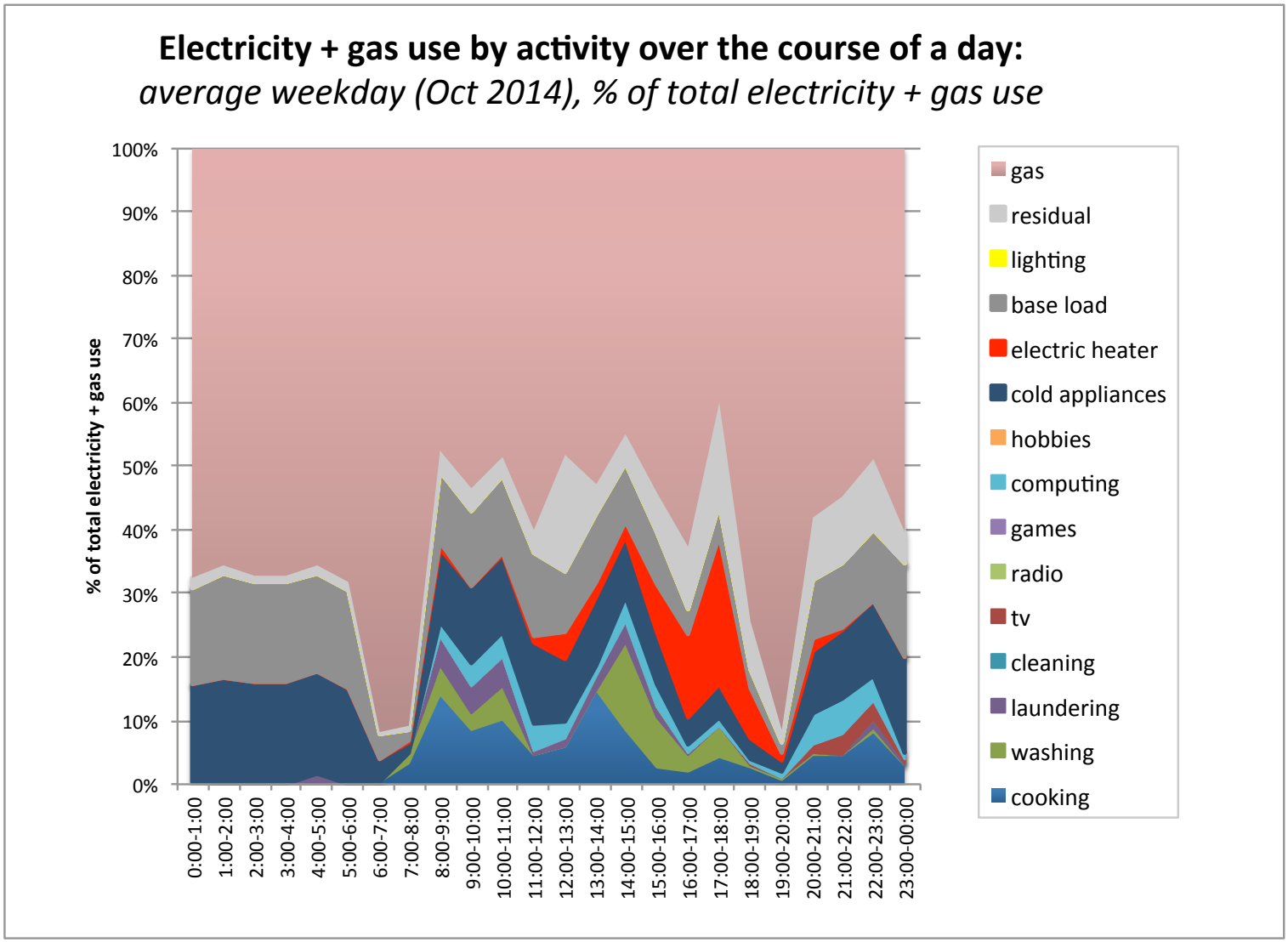

Method … Results … **Applications**

Applications

1. Comparison with time use statistics
   -> identification with national clusters

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   -> identification with national clusters
2. Temporal stability and sequencing of activities
   -> demand response

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3. Activity-based energy feedback
   -> retrofit & energy savings

Method … Results … **Applications**

Applications

1. Comparison with time use statistics
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4. Reduced methodology for smart meter rollout
   -> real-time activity time profiles nationwide!

Method … Results … Applications … **The End**

Applications

1. Comparison with time use statistics
   -> identification with national clusters
2. Temporal stability and sequencing of activities
   -> demand response
3. Activity-based energy feedback
   -> retrofit & energy savings
4. Reduced methodology for smart meter rollout
   -> real-time activity time profiles nationwide!

questions? suggestions? + informal session 2-3pm

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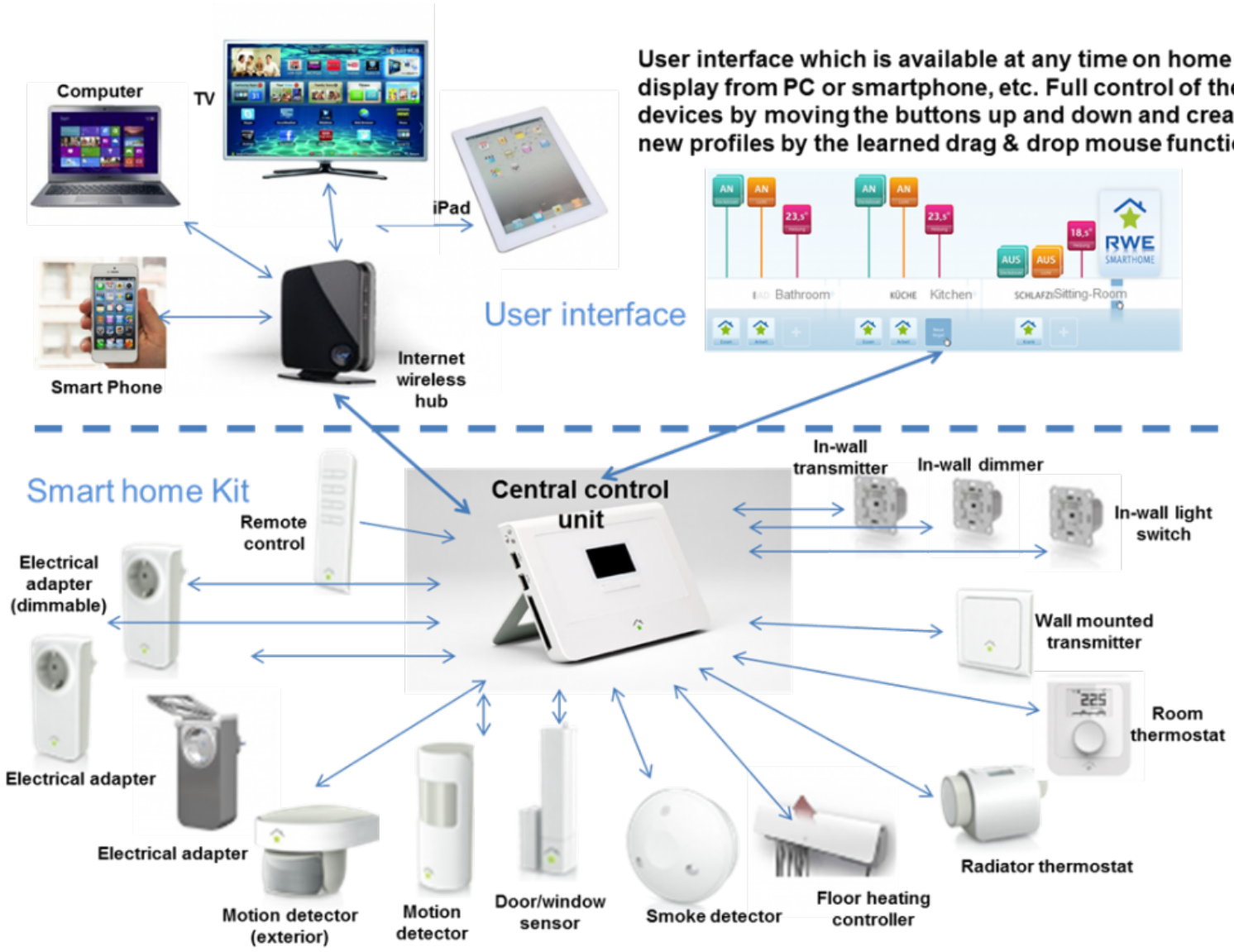
activities	practices	energy services
things people do, ways people describe their day or how they spend their time	*socially-shared bundles of doings and sayings constituted by technologies, skills, meanings and rules*	*useful functions provided by energy end-use technologies*
e.g. cooking, washing, resting, caring	e.g. cooking, washing, socialising	e.g. cooking, washing, heating, lighting
descriptive characterisation of everyday life in a way that is meaningful to households	theory-based analysis of constitutive elements of everyday life	ultimate purposes for which energy is consumed as part of everyday life

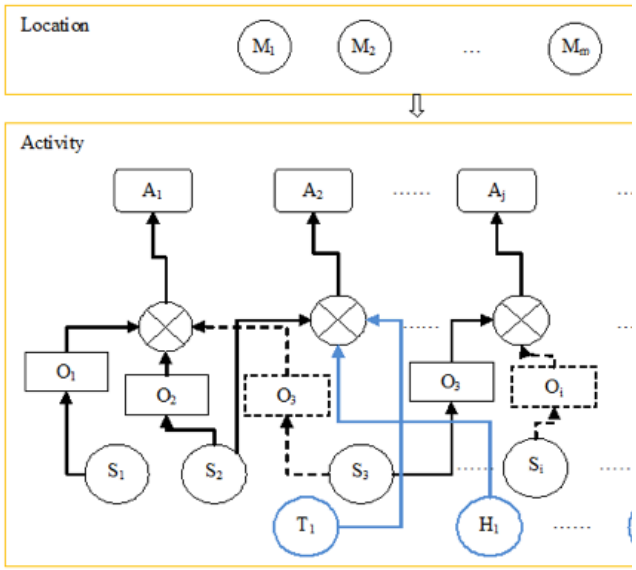
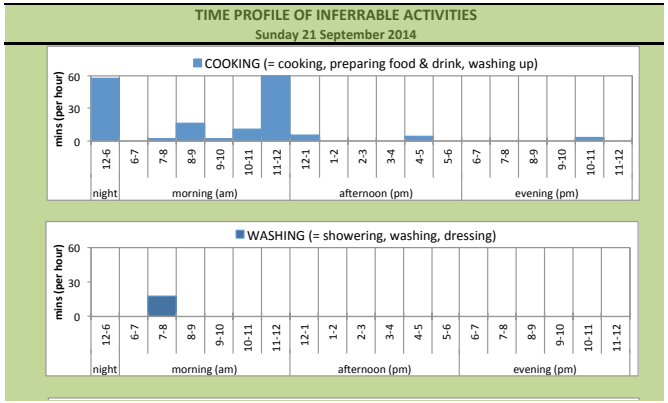
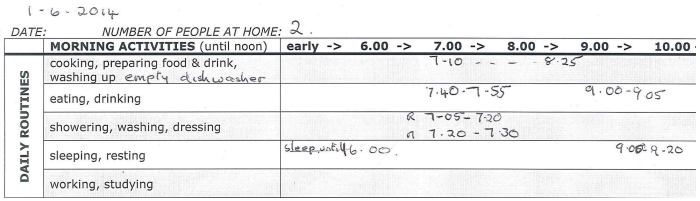
Method: Step 1. Develop a comprehensive set of activities to capture household life *and* energy use.

DAILY ROUTINES	
cooking	cooking, preparing food & drink, washing up
eating	eating, drinking
washing	showering, washing, dressing
laundering	doing laundry
cleaning	cleaning, housework, (other than laundry or washing up)
sleeping	sleeping, resting
INTERACTING	
communicating	communicating, interacting with people outside the home
socialising	entertaining, socialising, being with people at home
LEISURE & ICTs	
tv	watching tv, video, film or any audiovisual
radio	listening to radio, music or any audio
games	playing games on console, computer, tablet, smartphone
computing	using computer, tablet, smartphone, (other than for games or work)
OTHER ACTIVITIES	
hobbies	doing hobbies, sports
caring	looking after children, caring for household members
working	working, studying
other	other activities

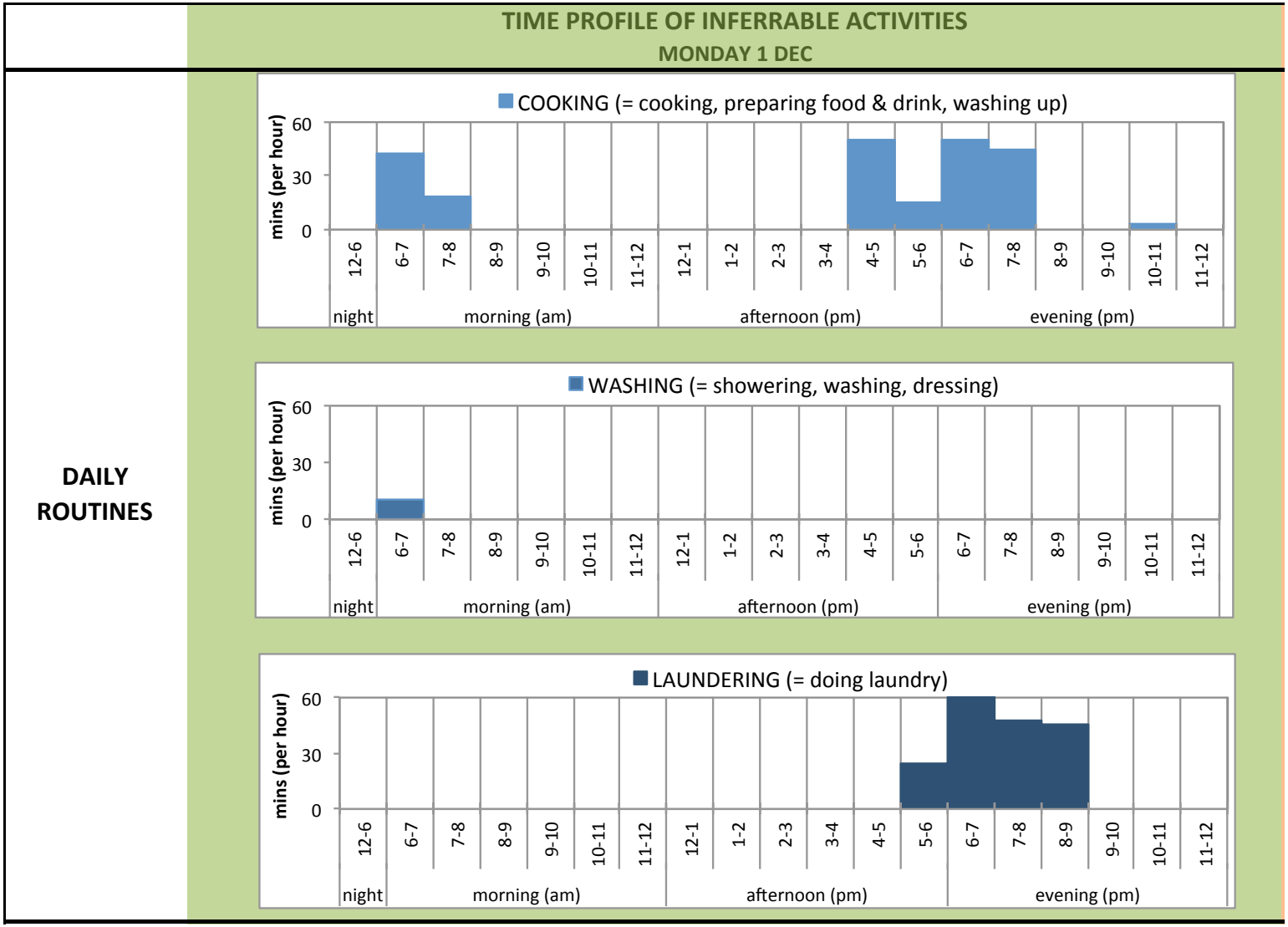
A smart home collects data from meters and sensors, and provides households with new control functions



quant. | qual. | mixed

Data requirements	Methodology, step-by-step	Illustrative examples
time use studies household interviews and video ethnography on activities and technologies	**1. Define activities** *comprehensive set of activities meaningful to households*	
household interviews and video ethnography house survey (appliances, rooms	**2. Build activity ontology** *map relationships between technologies and activities*	
electricity & gas smart meters appliance / plug monitor environmental sensors	**3. Collect real-time data** *collect & process energy and environmental data from homes*	
self-completion appliance time diaries	**4. Disaggregate data** **5. Infer activities** *process data using activity ontology and inference algorithms*	
self-completion activity time diaries	**6. Validate inferences** *compare inferences against time diary data & validate with household*	

Method: *Step 5*. Make **inferences** about time profile of activities (process energy data through ontology).



Method: *Step 6*. Validate activity inferences using activity **time diaries**.

1-6-2014

DATE: *NUMBER OF PEOPLE AT HOME:* 2.

	MORNING ACTIVITIES (until noon)	**early -> 6.00 -> 7.00 -> 8.00 -> 9.00 -> 10.00**
DAILY ROUTINES	cooking, preparing food & drink, washing up empty dishwasher	7-10 - - - 8.25
	eating, drinking	7.40-7-55 9.00-9 05
	showering, washing, dressing	R 7-05-7.20 n 7.20-7.30
	sleeping, resting	sleep until 6.00. 9.00-9.20
	working, studying	

Method: *Step 6*. **Validate** activity inferences using activity time diaries.

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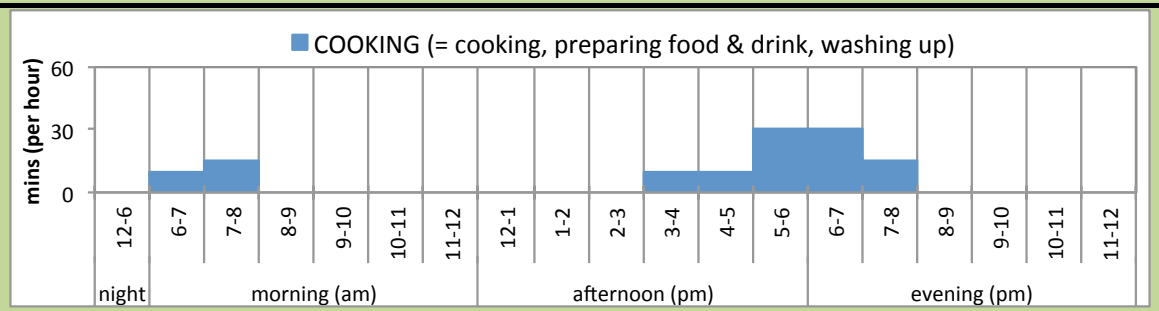
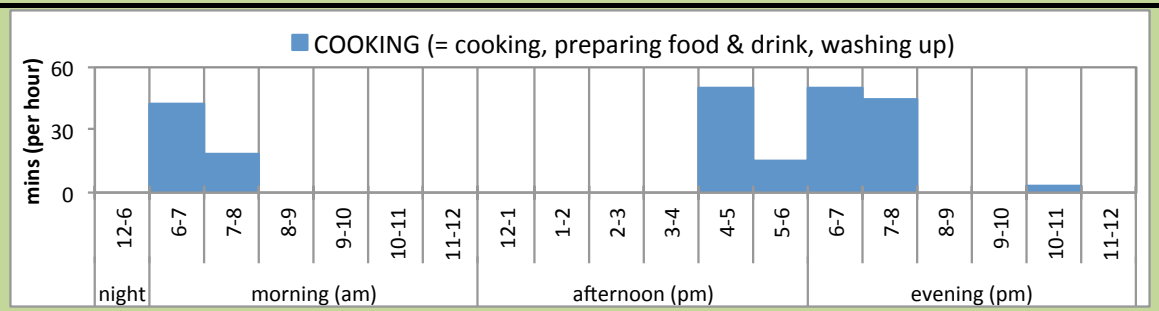
	s	
	s	9.00-9.20
	w	

TIME PROFILE OF ACTIVITIES RECORDED IN TIME DIARIES
MONDAY 1 Dec 2014

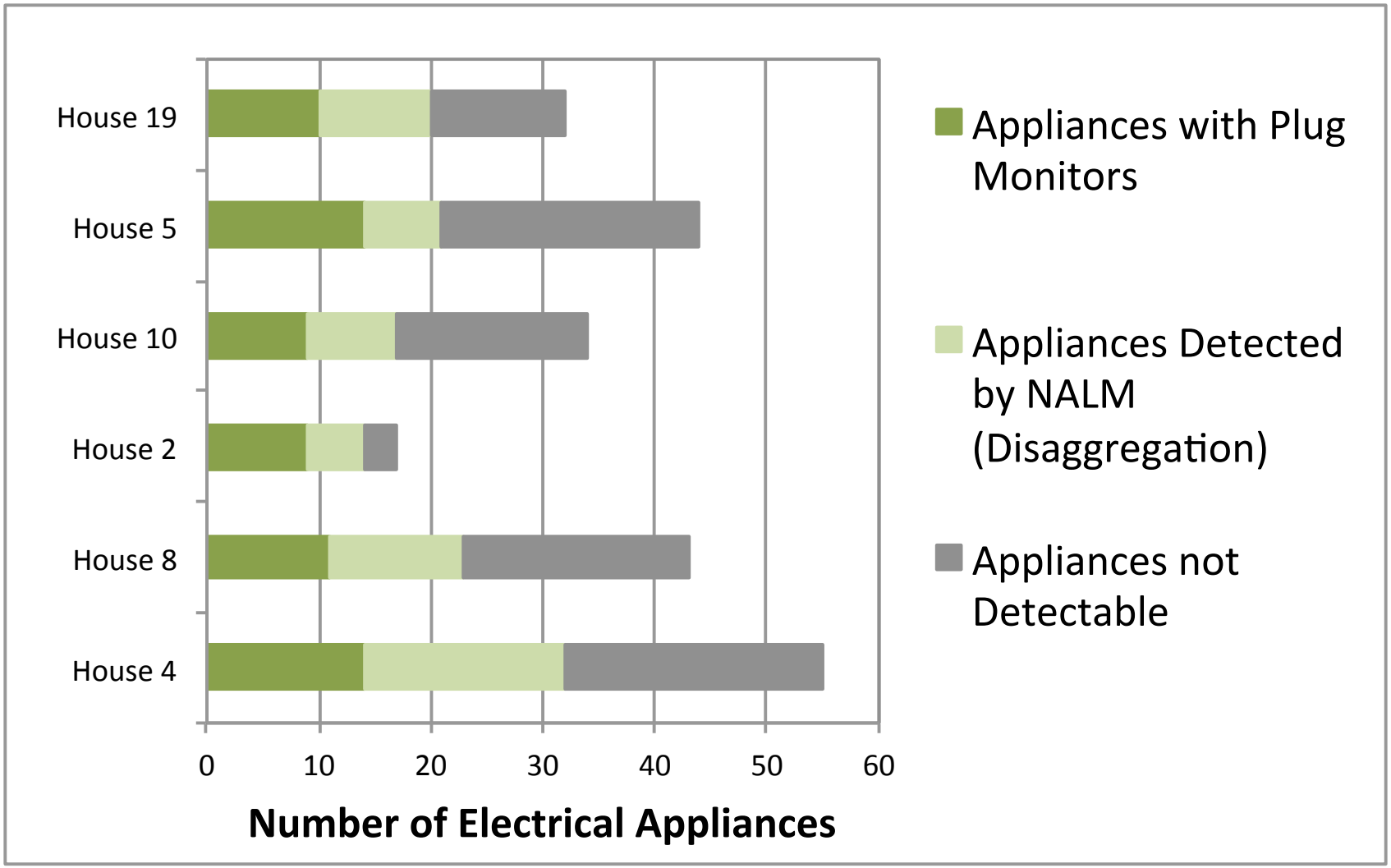


TIME PROFILE OF INFERRABLE ACTIVITIES
MONDAY 1 DEC



adjust ontology or appliance detection

Results 1. 50-80% of electrical appliances were **detectable** (exceptions: low power, battery/mobile).



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tv	0.27	0.16	-0.03	-0.47	1.00		
computing	0.36	0.38	0.29	-0.56	-0.24	1.00	
hobbies	0.53	0.33	0.28	-0.50	-0.25	0.57	1.00

correlations (time use): **average weekend day**

	cooking	eating	laundering	sleeping	watching tv	computing	hobbies
cooking	1.00						
eating	0.75	1.00					
laundering	0.07	0.43	1.00				
sleeping	-0.54	-0.60	-0.19	1.00			
tv	0.17	0.33	0.26	-0.42	1.00		
computing	-0.18	-0.12	0.01	-0.23	0.06	1.00	
hobbies	0.03	0.38	0.92	-0.20	0.19	0.24	1.00

House 4. 2 retired adults

Results 3. Activity time profiles are **inter-linked temporally** to different extents.

correlations (time use): average weekday

	cooking	eating	laundering	sleeping	watching tv	computing	hobbies
cooking	1.00						
eating	0.70	1.00					
laundering	0.17	0.46	1.00				
sleeping	-0.63	-0.51	-0.22	1.00			
tv	0.27	0.16	-0.03	-0.47	1.00		
computing	0.36	0.38	0.29	-0.56	-0.24	1.00	
hobbies	0.53	0.33	0.28	-0.50	-0.25	0.57	1.00

***correlations (time use):* average weekend day**

	cooking	eating	laundering	sleeping	watching tv	computing	hobbies
cooking	1.00						
eating	0.75	1.00					
laundering	0.07	0.43	1.00				
sleeping	-0.54	-0.60	-0.19	1.00			
tv	0.17	0.33	0.26	-0.42	1.00		
computing	-0.18	-0.12	0.01	-0.23	0.06	1.00	
hobbies	0.03	0.38	0.92	-0.20	0.19	0.24	1.00

House 4. 2 retired adults