

# SOONER OR LATER

## Shifting the timing of electricity demand

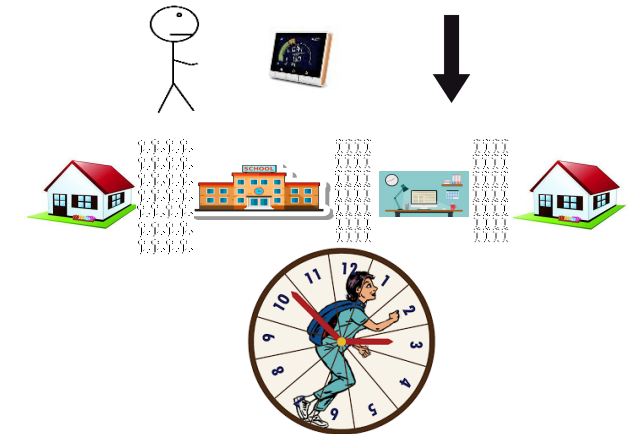
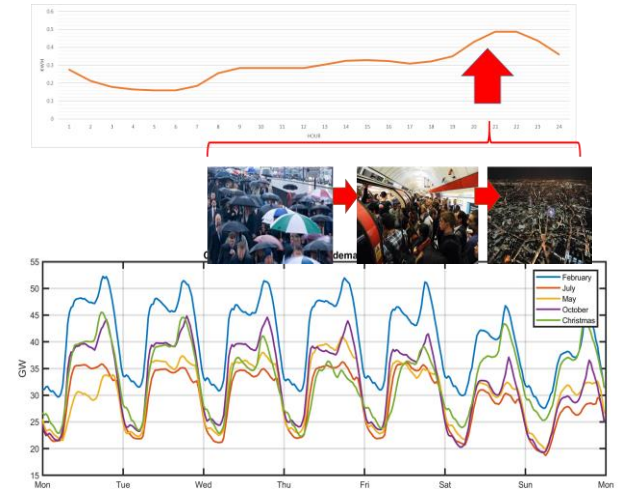


Professor Jacopo Torriti

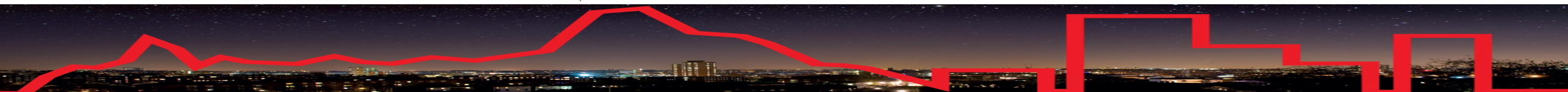
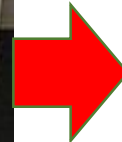
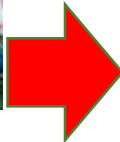
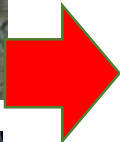
15<sup>th</sup> May 2019

# Outline

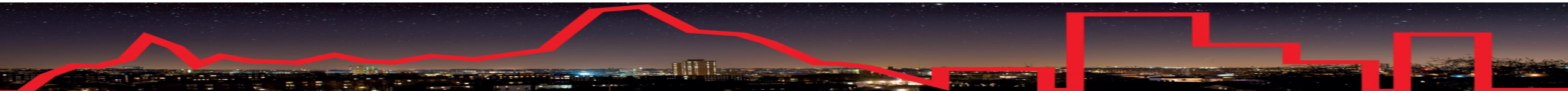
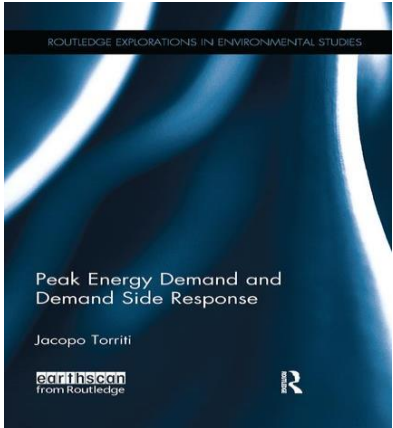
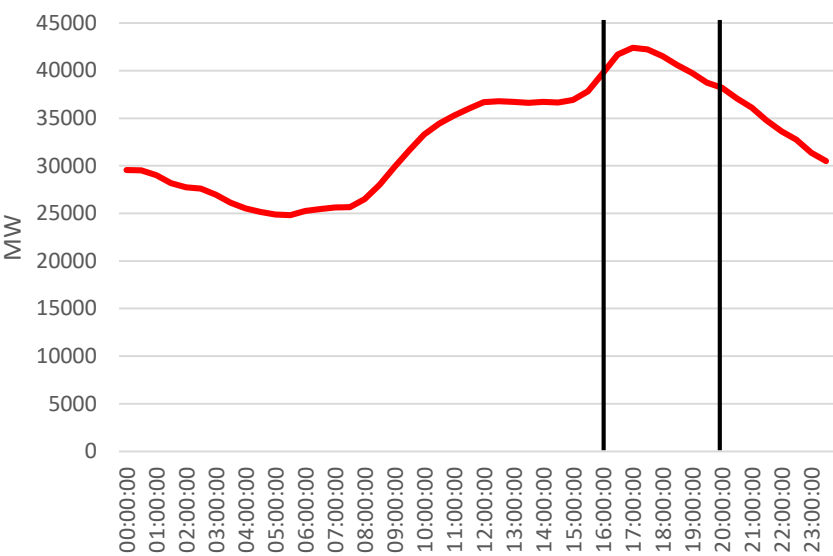
- Peaks
  - What they are
  - The peak problem
  - Understanding peaks
- Flexibility
  - Individuals
  - Activities
  - Winners and losers



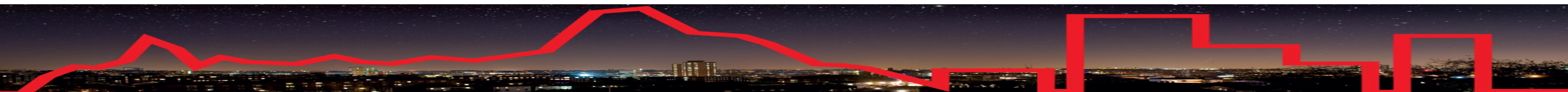
# When I tell people I do research on peak electricity demand...



...but it is about this:

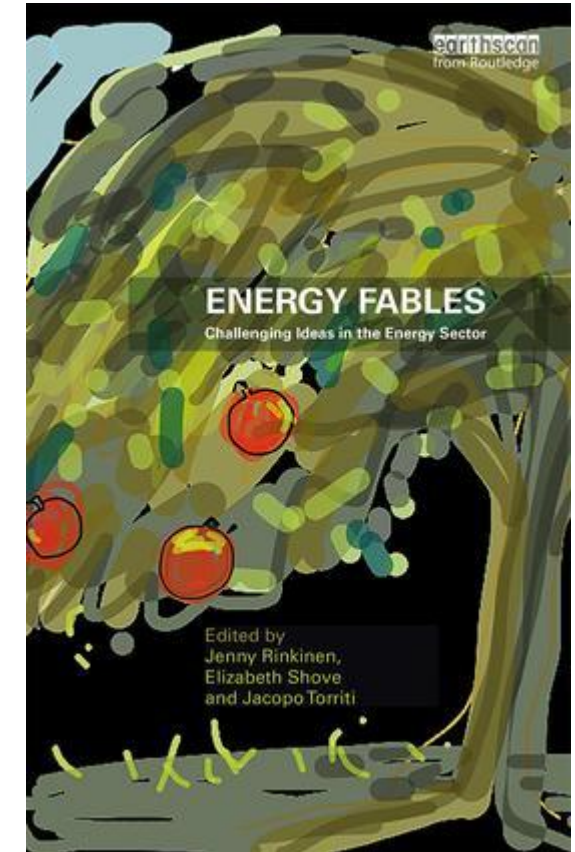


# THE PEAK PROBLEM





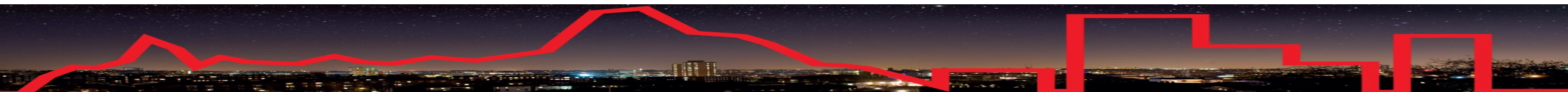
# The peak problem



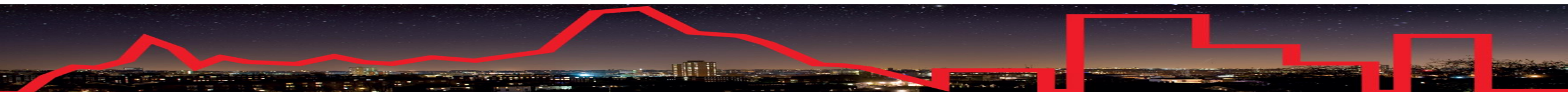
<https://www.routledge.com/Energy-Fables-Challenging-Ideas-in-the-Energy-Sector-1st-Edition/Rinkinen-Shove-Torriti/p/book/9780367027797>

# The peak problem

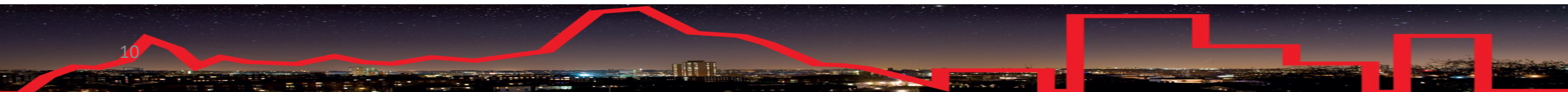
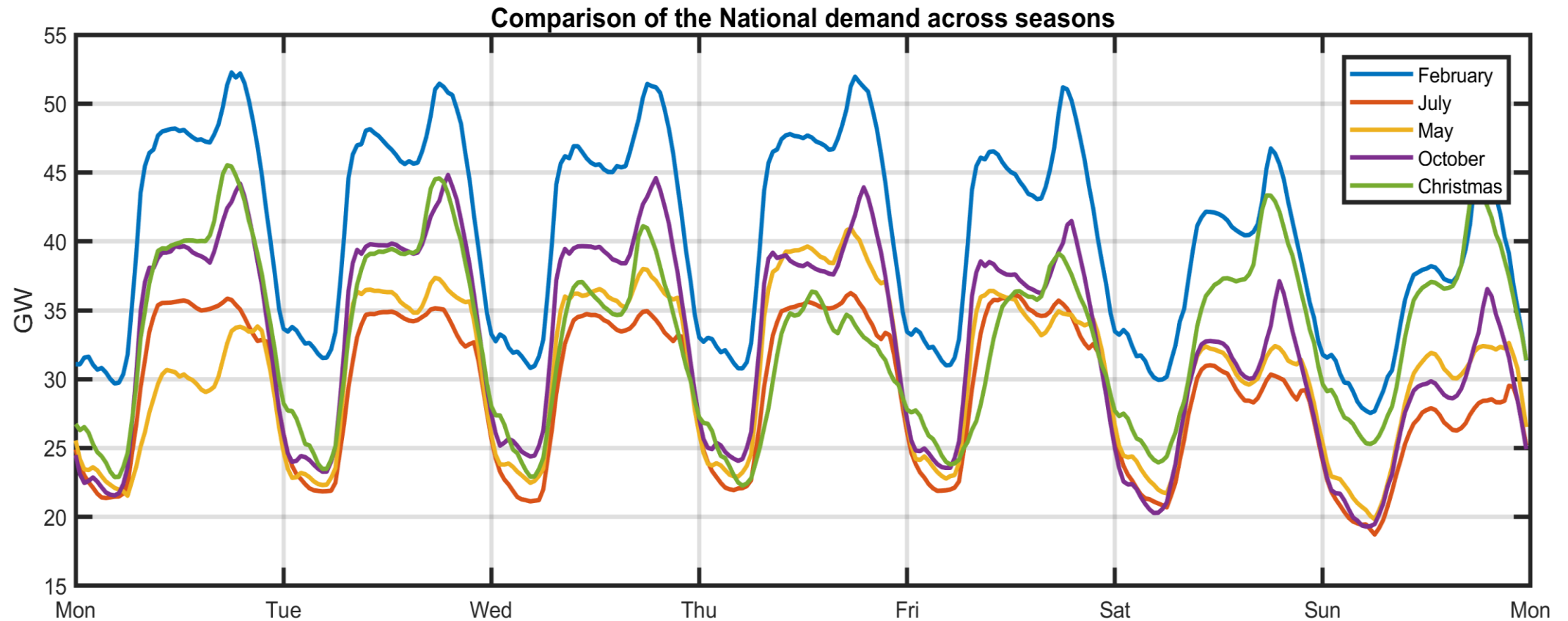
- Peaks in electricity demand bring about significantly negative environmental and economic impacts
- In the future:
  - intermittent renewables in the supply mix
  - electric vehicles and electric heat pumps



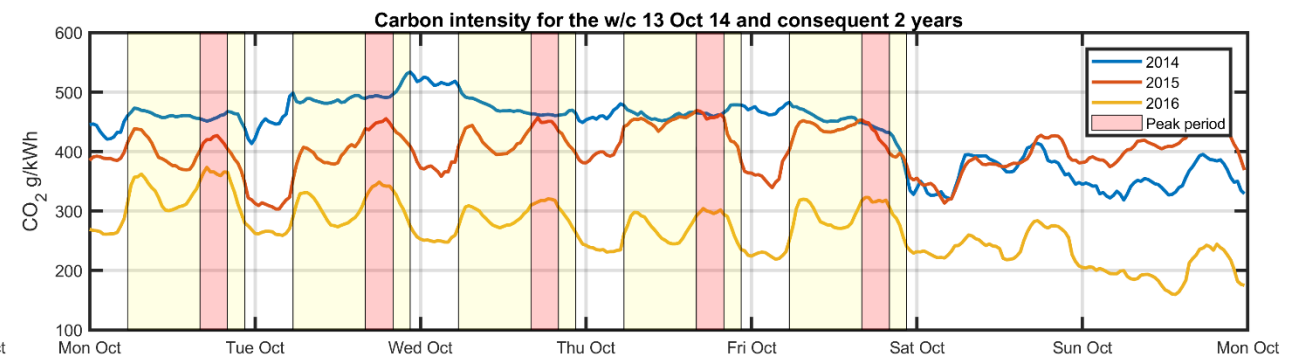
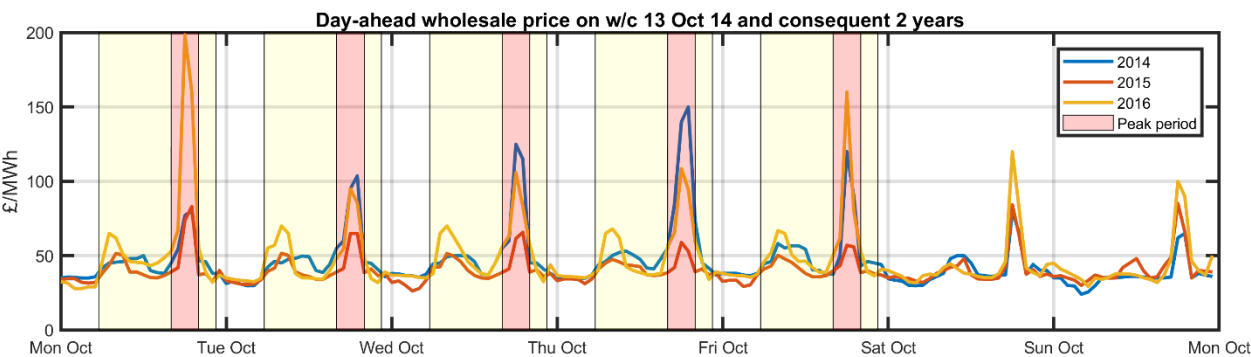
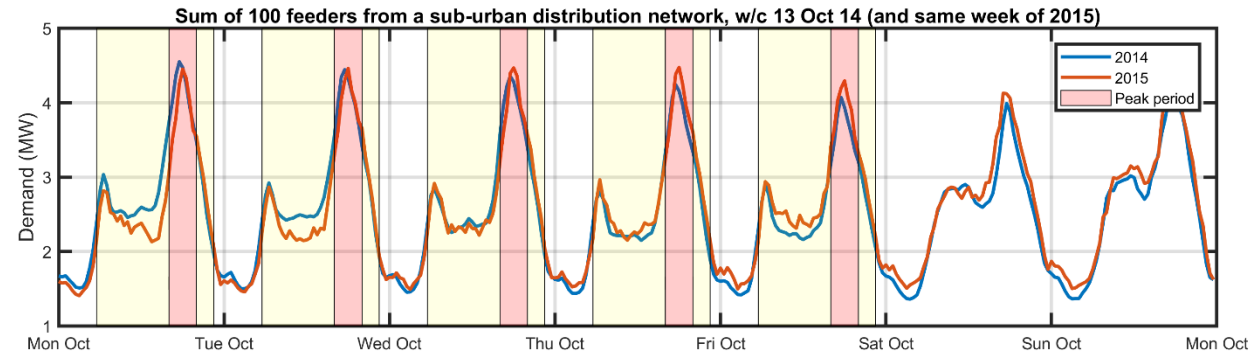
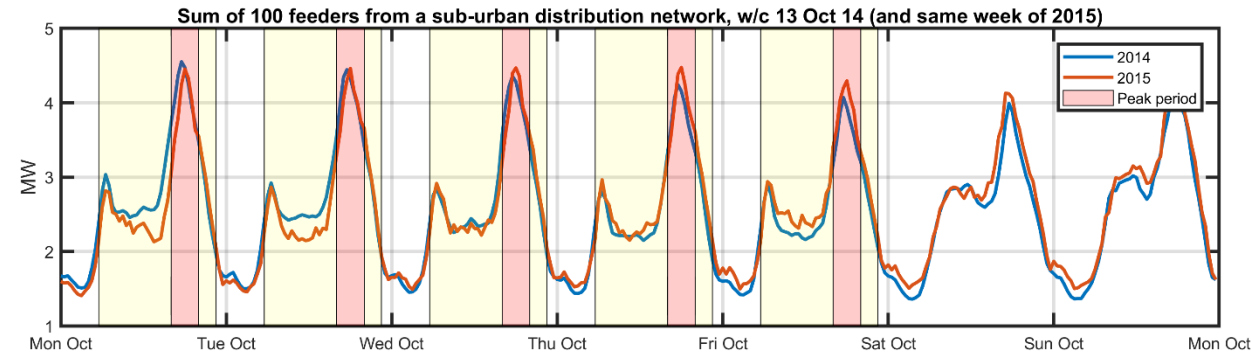
# UNDERSTANDING PEAKS



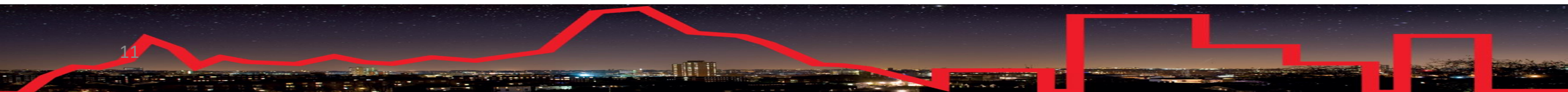
# Peaks every day



# Peaks: price and carbon intensity



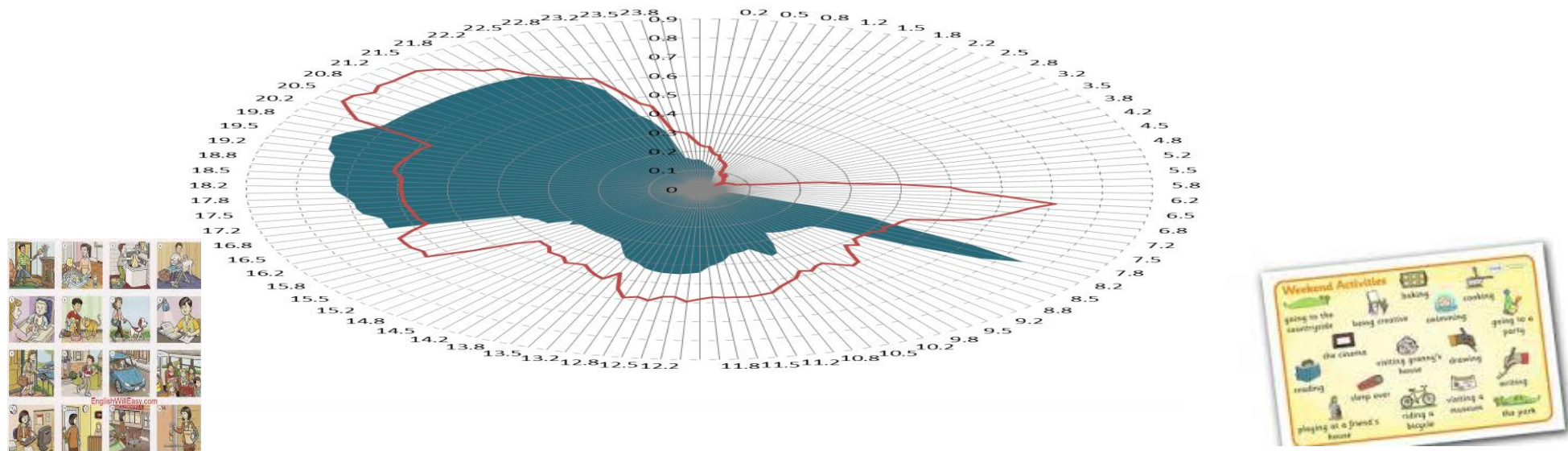
Source for Carbon intensity:



- Weekday



- Weekend



# Data on what people do



Diary/ person  id	Starting  Time	Ending  Time	Main activity	Parallel activity	Who with:				Where/mode of transport
					Alone	Spouse	Small child	Other pers.	
AA23	04:00	07:20	Sleep						At home
AA23	07:20	07:50	Shower						At home
AA23	7:50	08:30	Had breakfast	Read newspaper			Ch		At home
AA23	08:30	08:40	Walked to bus		A				By foot
AA23	08:40	09:00	Bus to job					OP	By bus

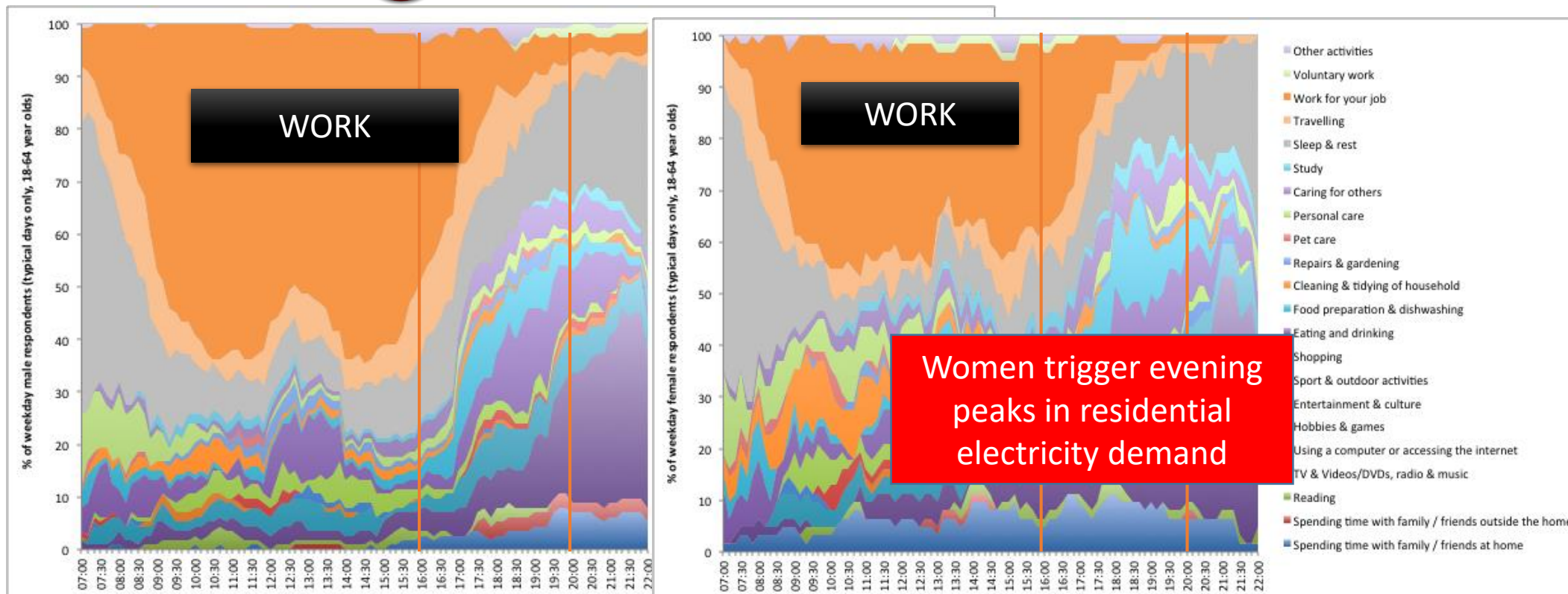
Country	StartTime	Work and study	Travel to/from work/study	Household work	Sleep and other personal care	Eating	Freetime	TV and video	Unspecified time
Belgium	04:00	1.04	0.07	0.16	97.16	0.15	1.01	0.17	0.24
Belgium	04:10	1.09	0.09	0.28	97.14	0.18	0.85	0.14	0.23
Belgium	04:20	1.09	0.15	0.18	96.94	0.4	0.81	0.17	0.25
Belgium	04:30	1.13	0.35	0.23	96.51	0.27	1.09	0.17	0.27
Belgium	04:40	1.23	0.34	0.36	96.46	0.2	0.97	0.15	0.29
Belgium	04:50	1.26	0.35	0.44	95.81	0.49	1.16	0.18	0.31
Belgium	05:00	1.53	0.34	0.61	94.76	0.49	1.78	0.21	0.27
Belgium	05:10	1.6	0.47	0.68	94.82	0.61	1.34	0.21	0.27
Belgium	05:20	1.71	0.64	0.61	94.54	0.65	1.25	0.24	0.36
Belgium	05:30	1.83	0.95	0.7	93.31	0.77	1.84	0.22	0.37
Belgium	05:40	1.94	1.26	0.99	92.77	0.74	1.74	0.24	0.3
Belgium	05:50	2.31	1.22	1.08	91.76	0.98	2.09	0.21	0.36
Belgium	06:00	3.08	1.06	1.39	88.08	1	4.81	0.23	0.34

# Peaks and gender

Men



Women

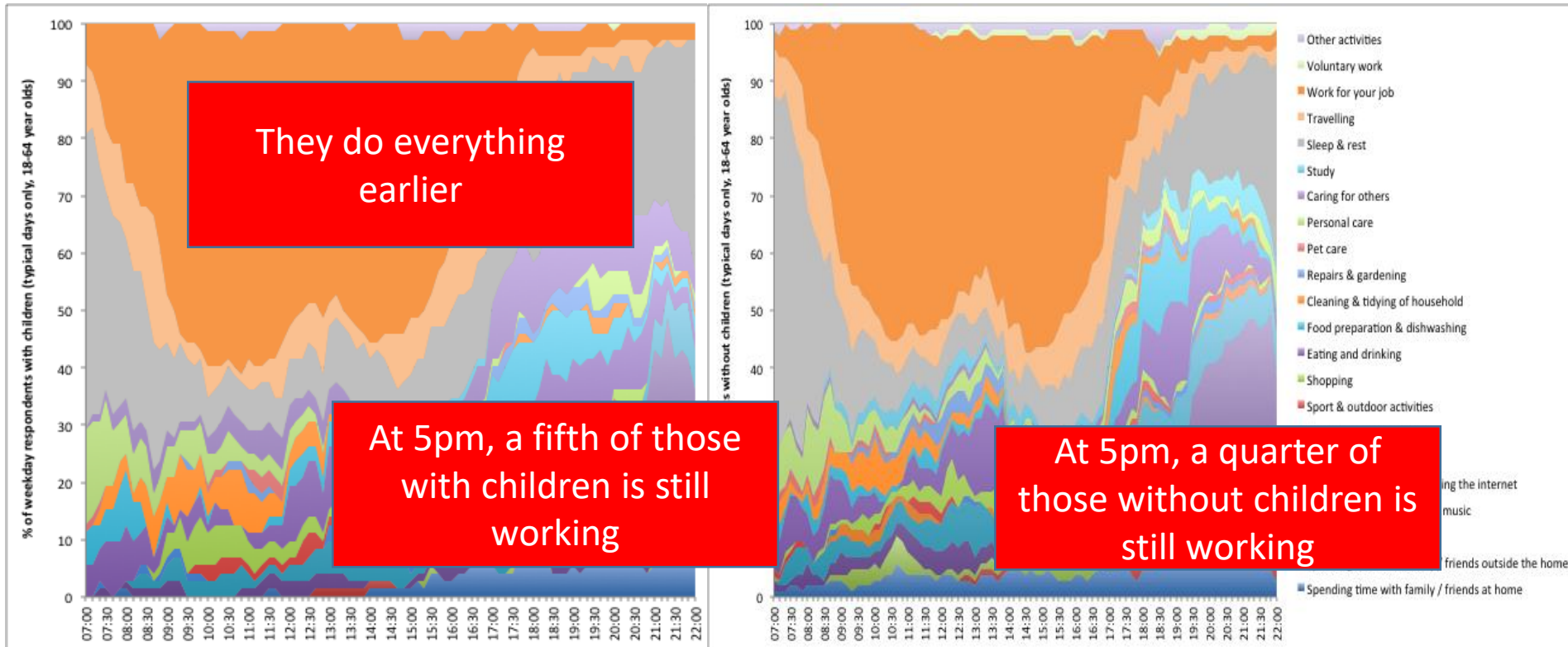


# Peaks and children

With Children  
children

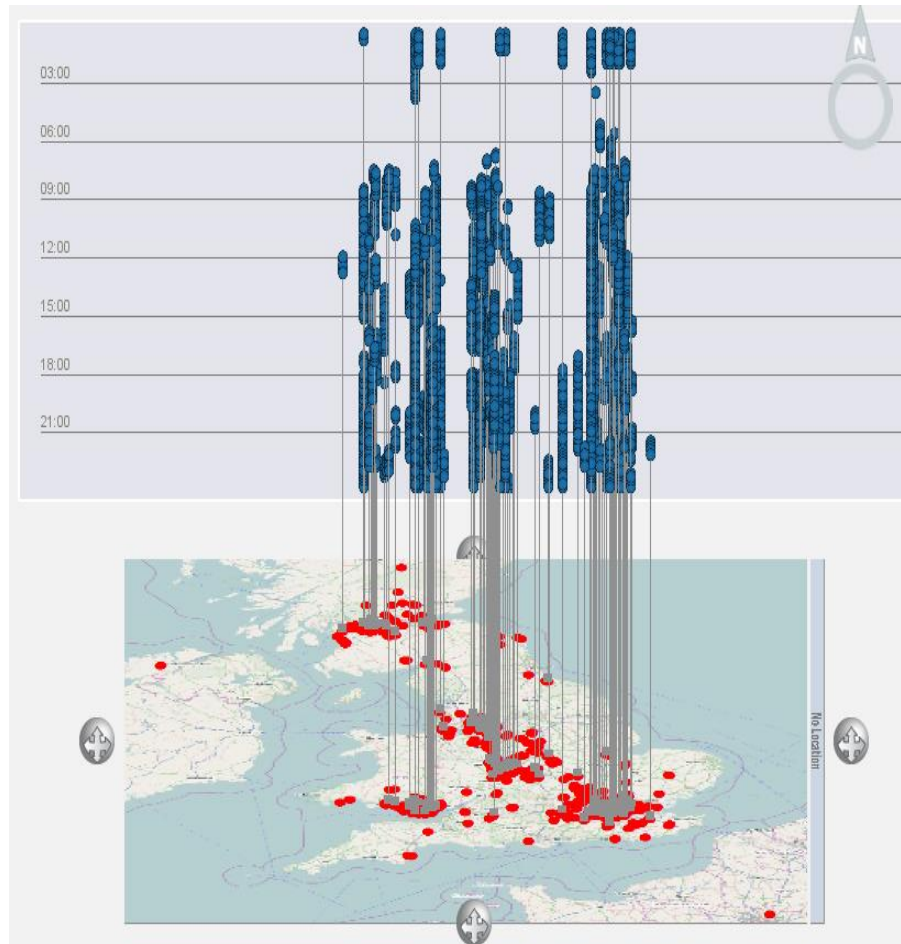


Without



# Knowing WHEN and WHERE

Computer use-UK



TV use-Spain



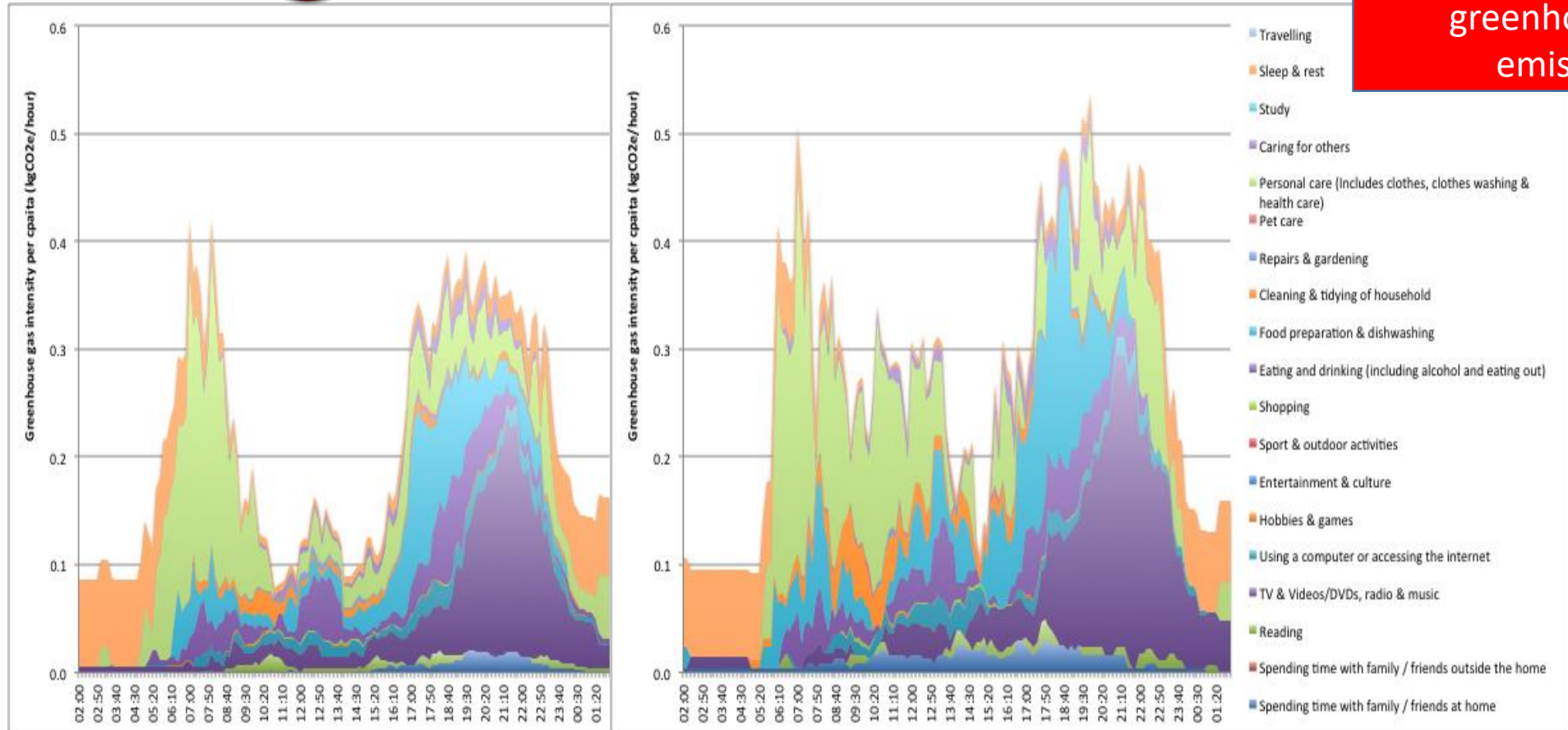
Average TV electricity consumption in Spain (MWh)

		Morning Peak	Evening Peak
Weekdays	Minimum	7,93	82,35
	Maximum	17,45	181,18
Weekends	Minimum	17,30	104,13
	Maximum	38,06	229,08

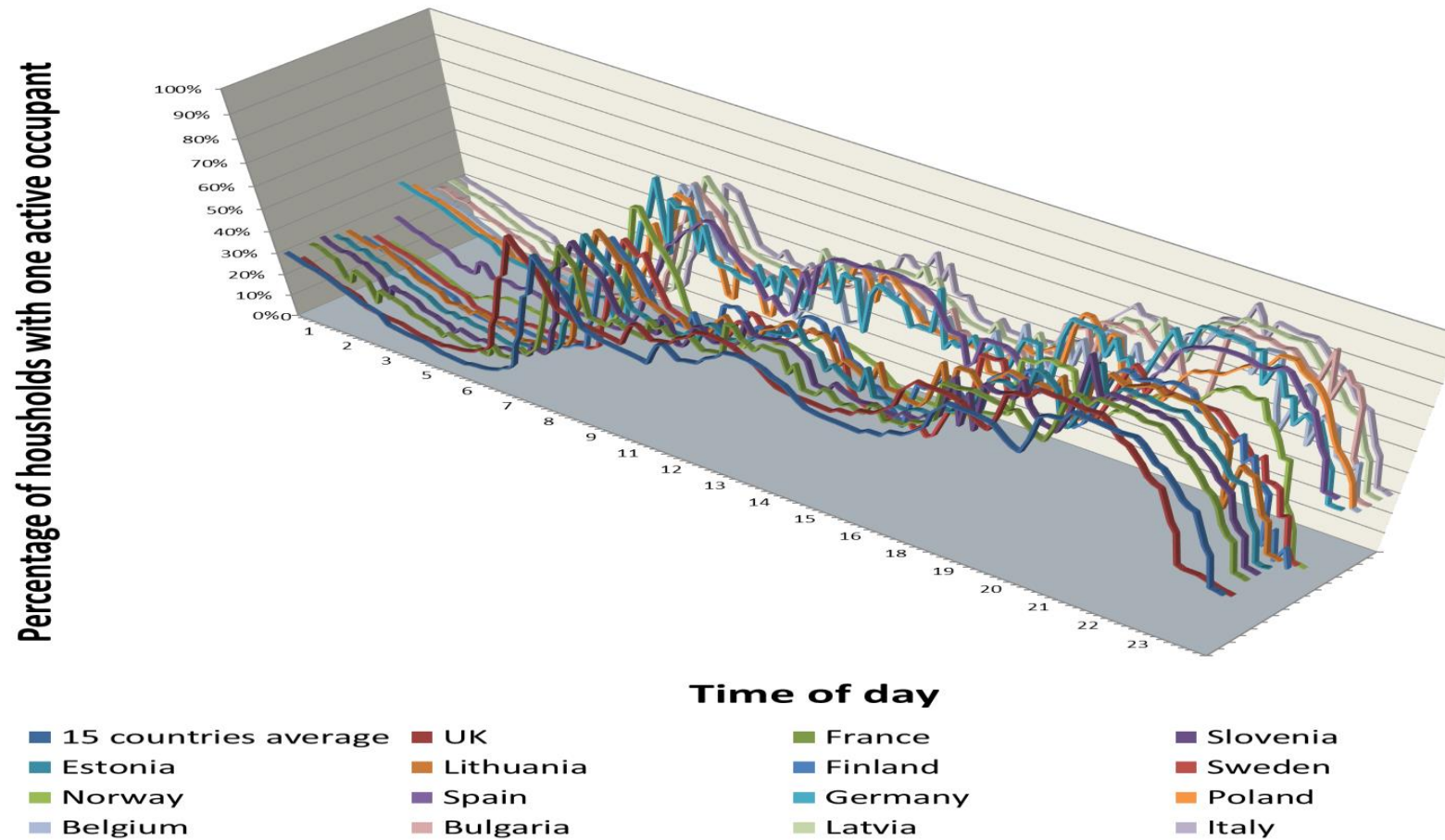
# Peaks and greenhouse gas emissions



Higher home occupancy  
reflects higher  
greenhouse gas  
emissions

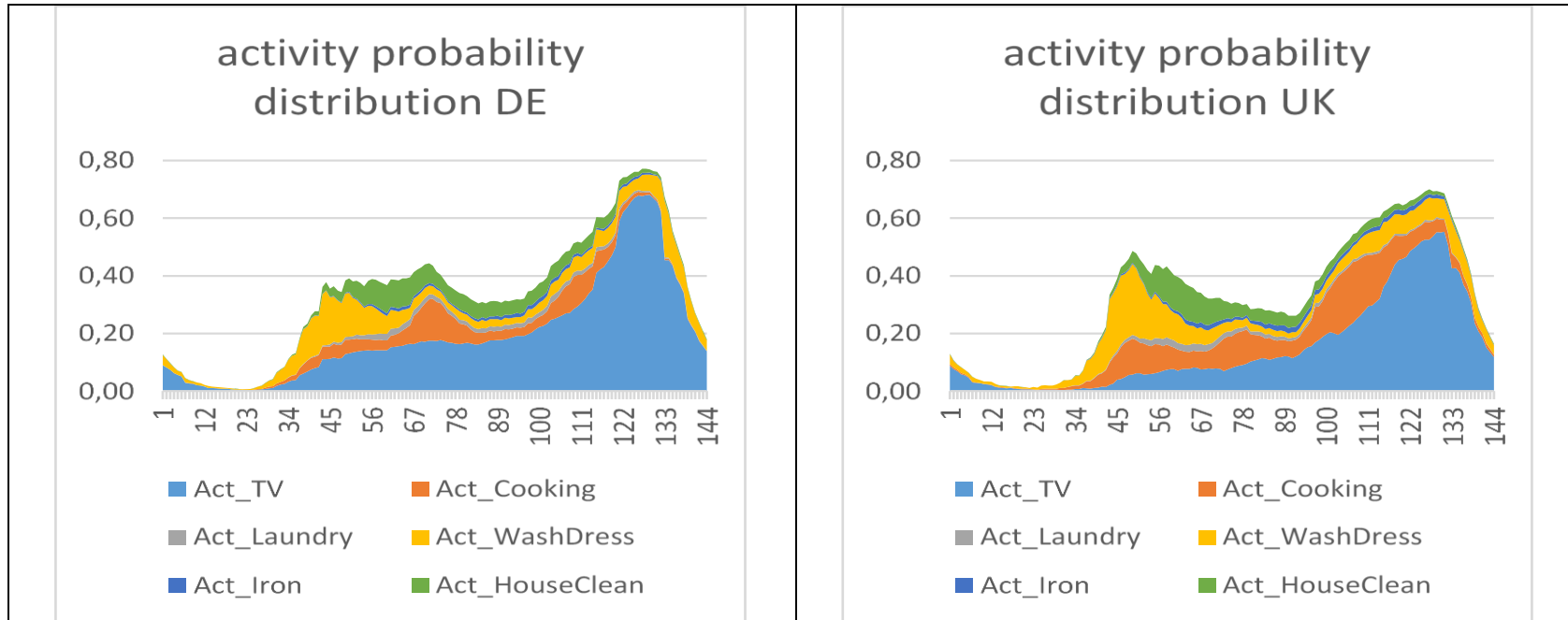


# Peaks and occupancy in different countries



# Peaks in Germany and the UK

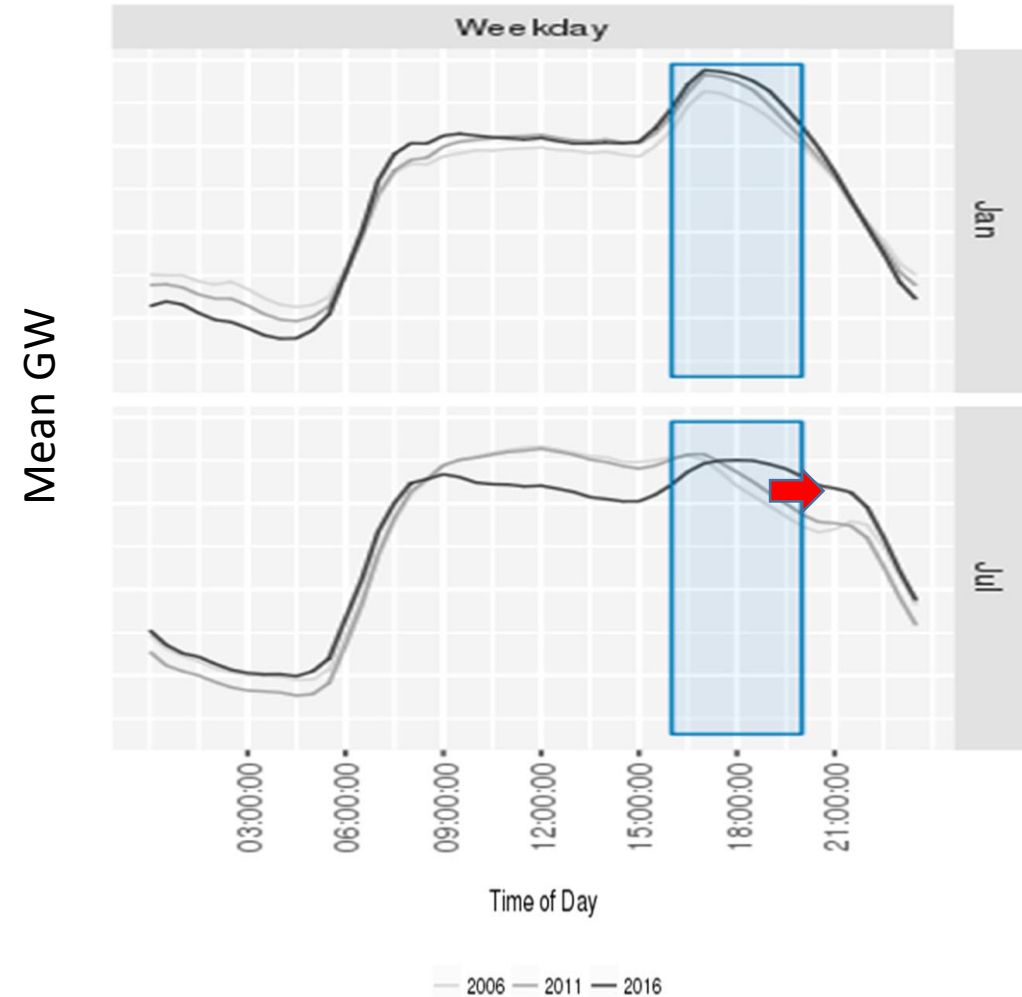
- Probability of  $\geq 1$  active person undertaking one of these six activities



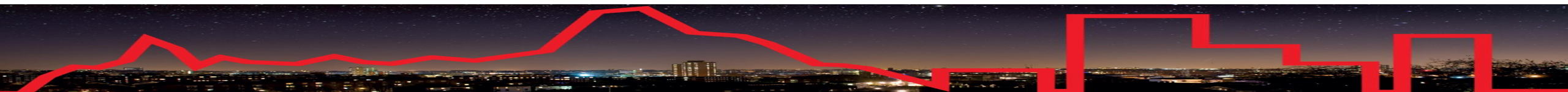
- Stronger midday peak in DE, morning peak more pronounced in UK
- Higher evening peak in DE, compared to flatter/broader one in UK
- Strong similarities in evening TV watching habits

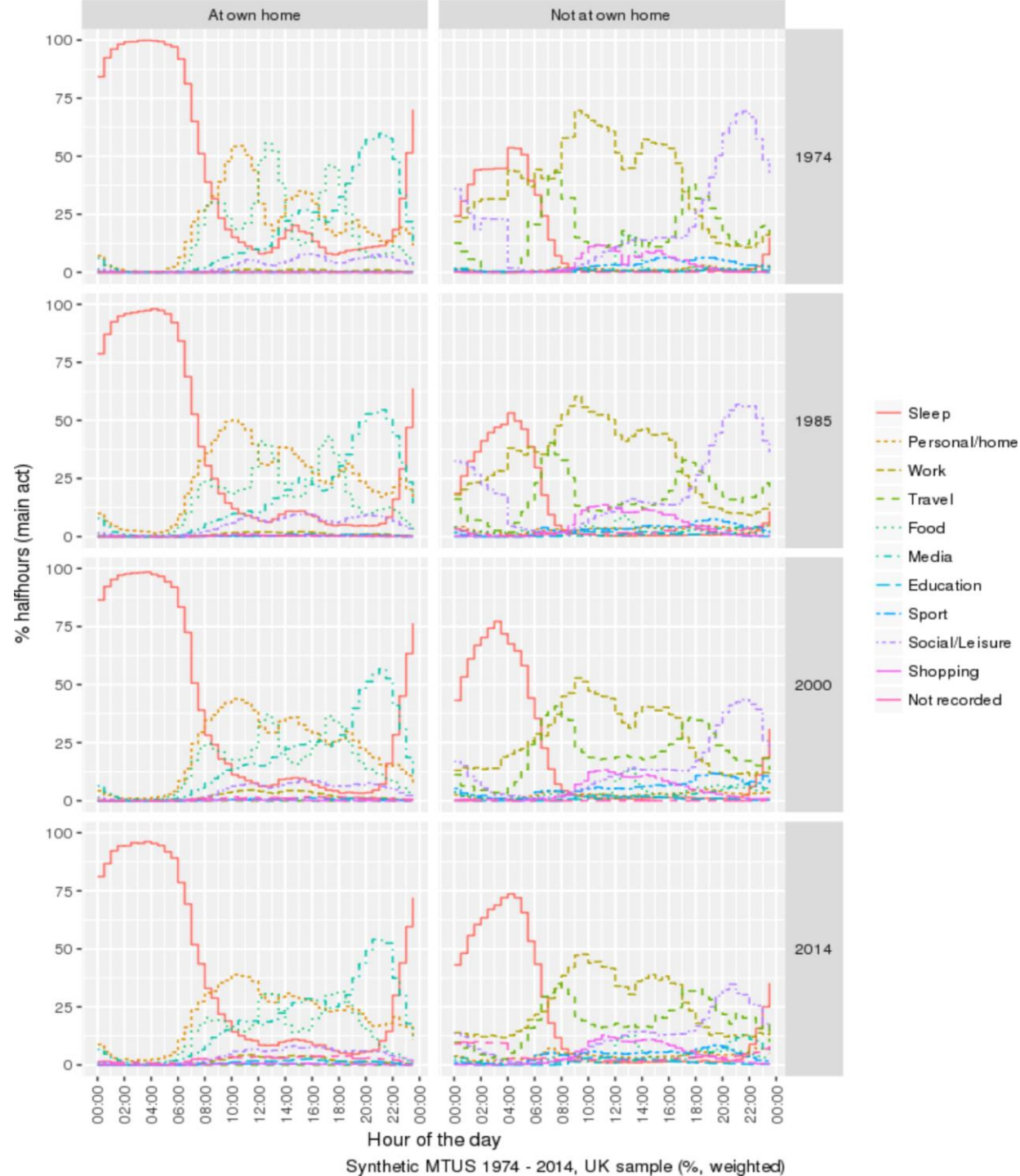
# Peaks across decades

- Relative decrease in mid-day demand
- Evening peak is later
- This is especially visible in July



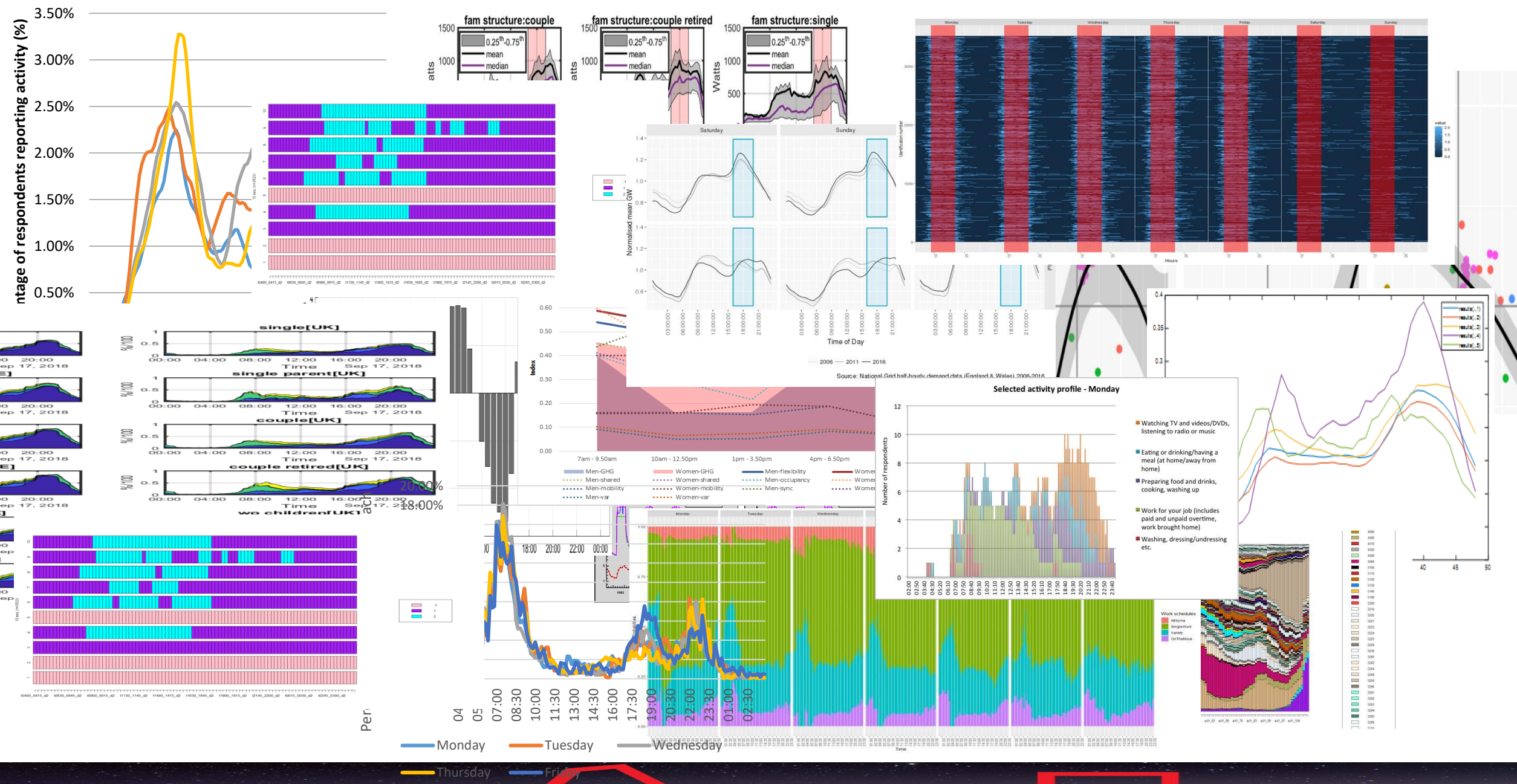
Source: National Grid half-hourly demand data (England & Wales) 2006-2016  
Peak demand period shown shaded





# Activities across decades

- Shift to later eating for all (especially working age)
- Reduced or shifted evening media use (squeezed between later eating and sleep)
- Reduction in morning weekday and Saturday 'personal/home care'
- Household care tasks have been shifted from weekdays to the evening peak period

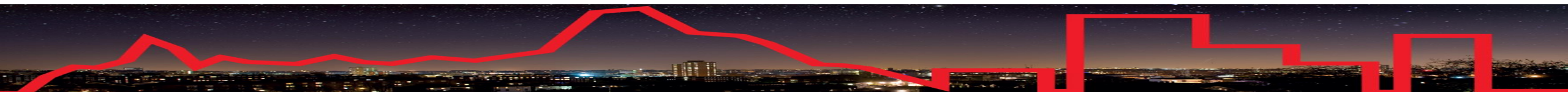




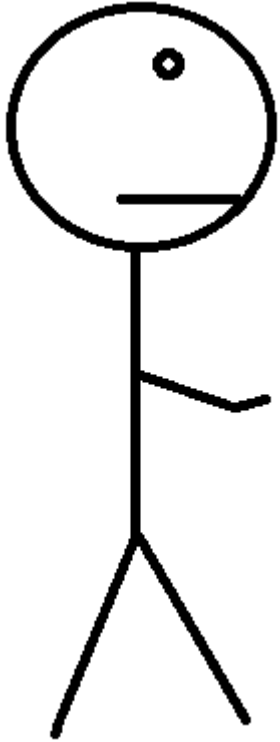
...AND THINK



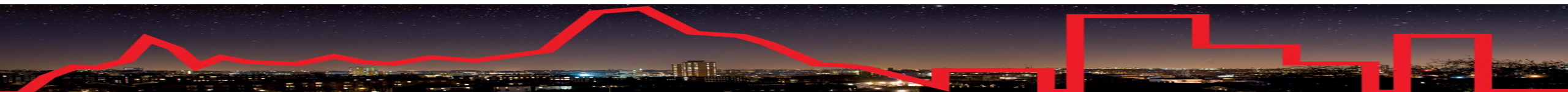
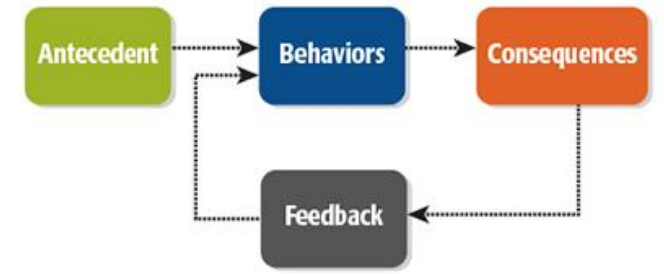
- What is energy demand for?
- Which concepts help explain the dynamics of energy demand?
- Why is there societal synchronisations?
- How can peaks be mitigated with non-energy arrangements?



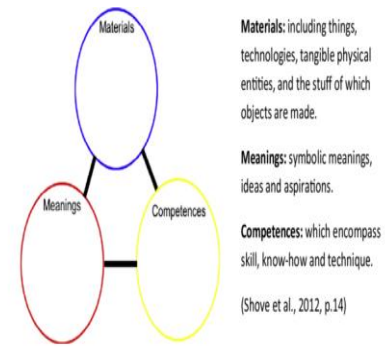
# Individual behaviour



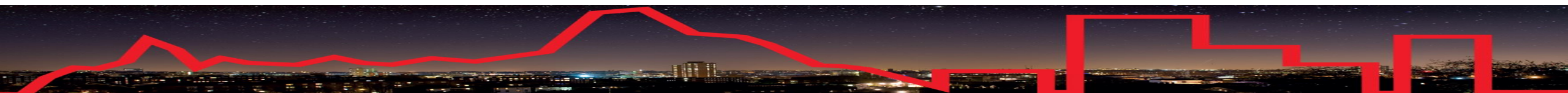
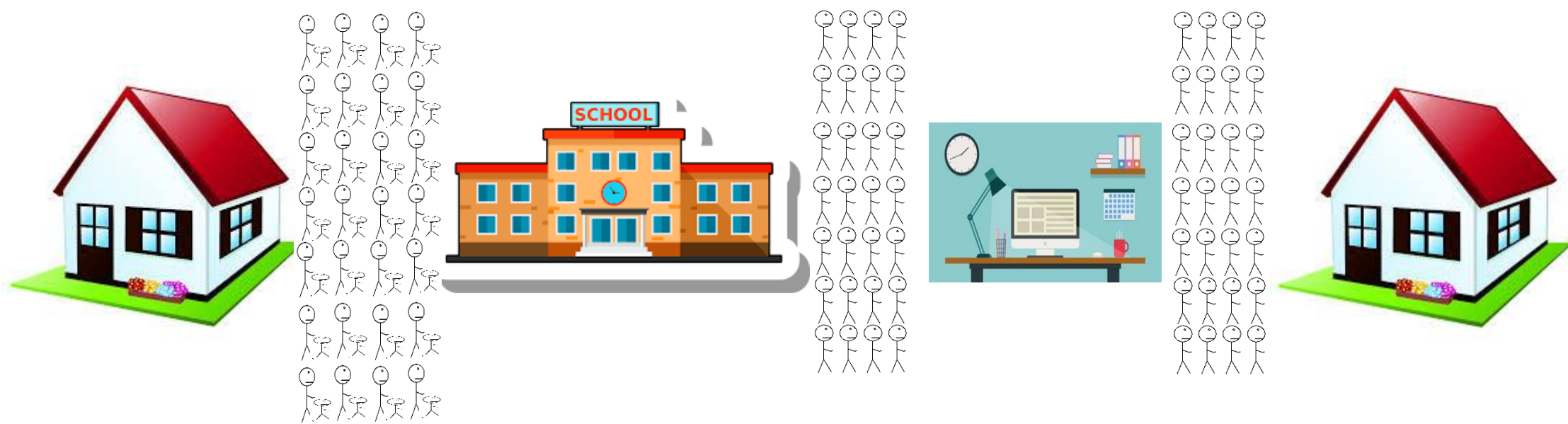
KWh € CO2



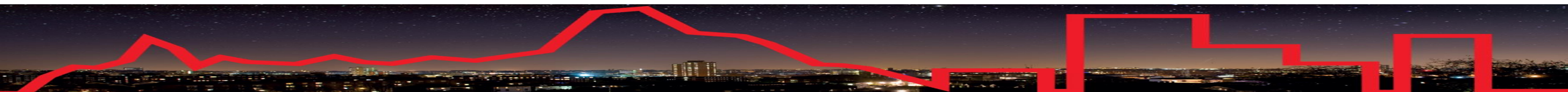
# Social practices



Shove, E., Pantzar, M., & Watson, M. (2012). *The dynamics of social practice: Everyday life and how it changes*. Sage.

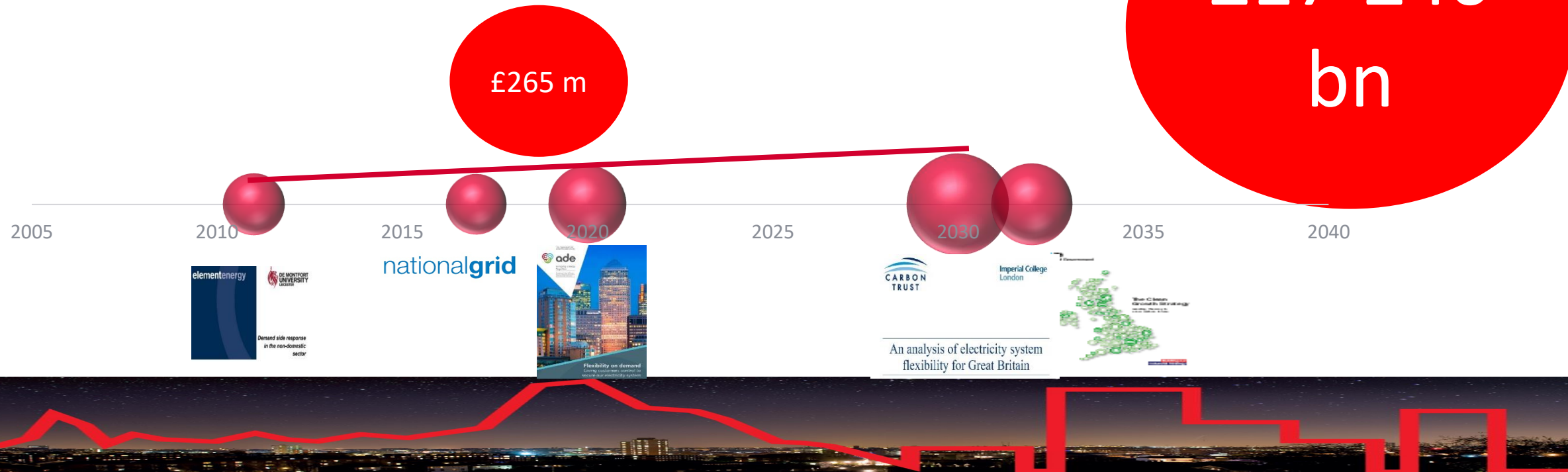


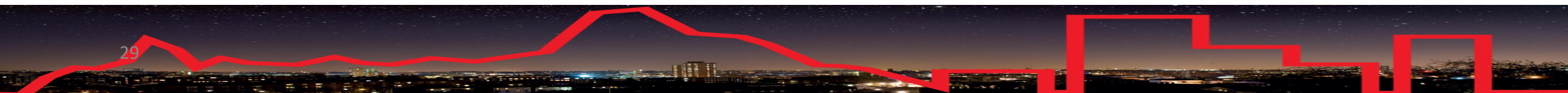
# FLEXIBILITY



# Flexibility: a win-win?

- Improving balancing with renewables
- Reducing costs of electricity generation
- Making the most of smart systems and battery storage

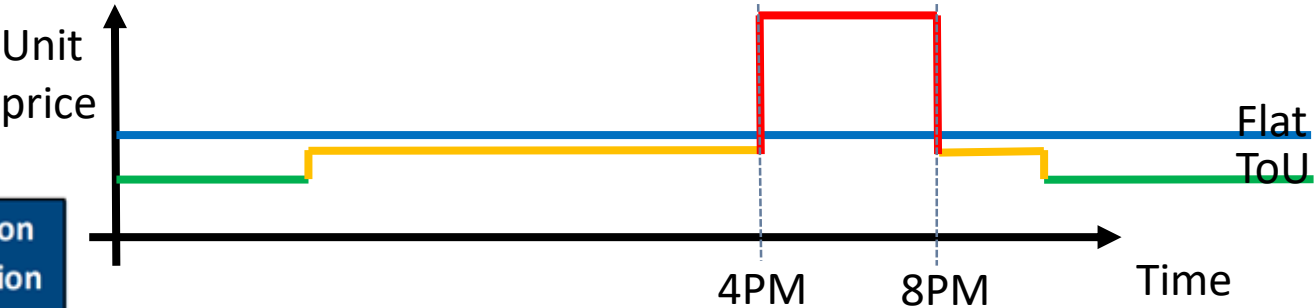




# Time of Use (ToU) tariffs

	Current Trends	High Renewables	Electrification	Electrification w/Automation [1]
Static TOU				
Opt-in	5%	5%	7%	8%
Opt-out	3%	3%	4%	N/A
iTOU				
Opt-in	N/A	10% [2]	N/A	N/A

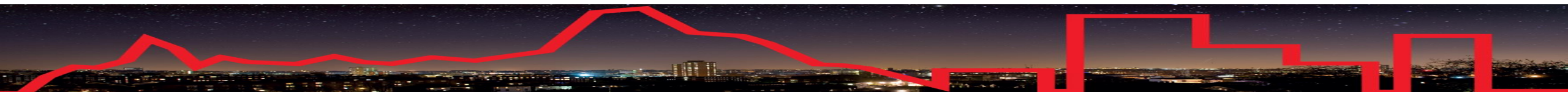
Source: Hledik et al (2017), “The Value of Time of Use Tariffs in Great Britain: Insights for Decision Makers: Final Report”, Report prepared for Citizens Advice. July 2017.

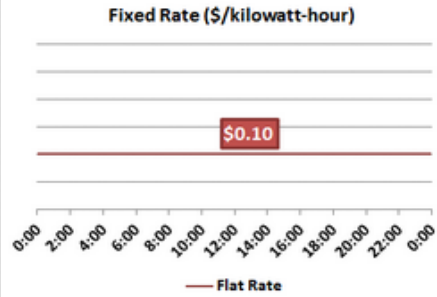
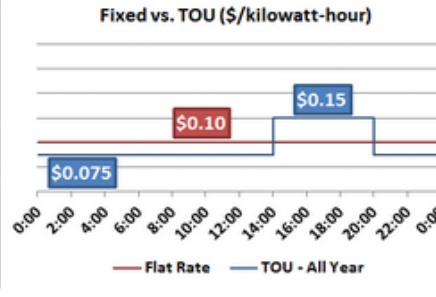
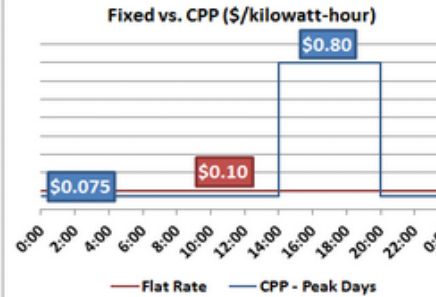


# APPROACH 1: Individual behaviour => price elasticity of demand



- Simple web-based choice experiment to elicit preferences for fixed tariffs and two dynamic tariffs (Time of Use and Critical Peak Pricing)
- The price attribute was framed as an electricity bill discount (i.e. a WTA format) to switch to the dynamic tariff
- Respondents were presented with four labelled choice cards
- Respondents were randomly divided into two sub-samples, with environmental and system benefits information presented to only one



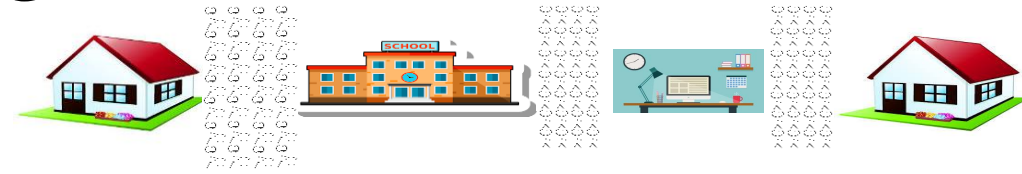
Tariff Type	Fixed	Time of Use (TOU)	Critical Peak Pricing (CPP)
Description	*Price stays the same throughout the day.	<p><b>*Cost:</b> Rate is 50% higher than your current fixed rate 6 hours of the day, every weekday, from 2pm until 8pm, during daily high demand.</p> <p><b>*Benefit:</b> Rate is 25% lower than your current fixed rate all other times.</p>	<p><b>*Cost:</b> On 10 weekdays selected by the electric company prices will raise 8x from your current fixed rate for 6 hours, from 2pm to 8pm, during emergency conditions. Your electric company notifies you one day in advance.</p> <p><b>*Benefit:</b> Rate is 25% lower than your current fixed rate all other times that day and all other days in the year.</p>
Environmental and Grid Benefits	*None	<p>*Less water and air pollution.</p> <p>*Aid the expansion of renewable energy.</p> <p>*Increased electricity reliability.</p> <p>*Slow the rate of electricity price increases.</p>	<p>*Less water and air pollution.</p> <p>*Aid the expansion of renewable energy.</p> <p>*Increased electricity reliability.</p> <p>*Slow the rate of electricity price increases.</p>
Graphic	 <p>Fixed Rate (\$/kilowatt-hour)</p> <p>Flat Rate</p>	 <p>Fixed vs. TOU (\$/kilowatt-hour)</p> <p>Flat Rate TOU - All Year</p>	 <p>Fixed vs. CPP (\$/kilowatt-hour)</p> <p>Flat Rate CPP - Peak Days</p>
Required Behavior Change to get Savings	*None - it's your current plan.	<p><b>Sustained, moderate changes during daily high priced times:</b></p> <p><b>*All regions:</b> Shift all listed appliances.</p> <p><b>*U.S.:</b> Adjust thermostat up by 2F (1C) from 75F (25C) during the summer.</p> <p><b>*Europe:</b> If you use electric heating, adjust your thermostat down by 2F (1C) from 68F (20C) during the winter. Use stand-alone electric room heaters at their lowest setting.</p>	<p><b>Oneoff, significant changes during 10 days' high priced times:</b></p> <p><b>*All regions:</b> Shift all listed appliances.</p> <p><b>*U.S.:</b> Adjust thermostat up by 5F (2.5C) from 75F (25C) during the summer. Turn off window and room air conditioning units, and all but essential lighting.</p> <p><b>*Europe:</b> If you use electric heating, adjust your thermostat down by 5F (2.5C) from 68F (20C) during the winter. Turn off stand-alone electric room heaters. Turn off all but essential lighting. Restrict use of electric cooking appliances by 50%.</p>
Potential Bill Increase with No Behavior Change	0%	0% to 5% \$0 to \$5.00 per month	0% to 5% \$0 to \$5.00 per month
Potential Bill Savings with Behavior Change  Note: the last 2 columns in this row change with each selection.	0%	10% Approximately \$10.00 per month	5% Approximately \$5.00 per month
Please Select One	Choice 1	Choice 2	Choice 3

# Discount needed for shifting electricity demand

	Coefficient	Std. Error	MWTA <sup>a</sup>	Std. Error <sup>b</sup>
DISCOUNT	0.163***	0.020		
TOU <sup>c</sup>	-1.993**	0.830	12.22%	4.91%
E&SxTOU	1.599***	0.622	-9.81%	3.87%
MALExTOU	-1.779***	0.627	10.91%	3.91%
HIBILLxTOU	1.255**	0.619	-7.70%	3.82%
STUDENTxTOU	-0.056	0.629	0.34%	3.86%
EASYxTOU	2.848***	0.657	-17.47%	4.19%
CPP <sup>c</sup>	-3.009***	1.039	18.45%	6.20%
E&SxCPP	2.086***	0.788	-12.80%	4.87%
MALExCPP	-1.437*	0.790	8.81%	4.88%
HIBILLxCPP	-0.390	0.793	2.39%	4.86%
STUDENTxCPP	-1.728**	0.804	10.60%	4.97%
EASYxCPP	1.981**	0.802	-12.15%	5.01%
Standard Deviations of Random Coeffs.				
TOU	2.776***	0.381		
CPP	3.365***	0.535		
Df			13	
Replications			1000	
Observations			1920	
Log likelihood			-438.380	
LR $\chi^2$		SDs (2)	205.56***	



# APPROACH 2: Activities as the unit of analysis

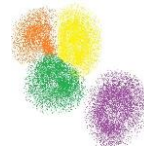


- Clustering based on what people do at peak time

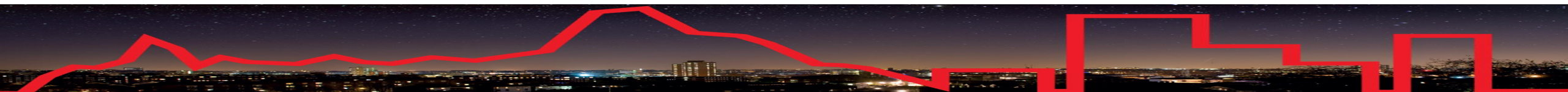


- Imposing Time of Use tariffs on different:

- Socio-demographic groups
- Clusters

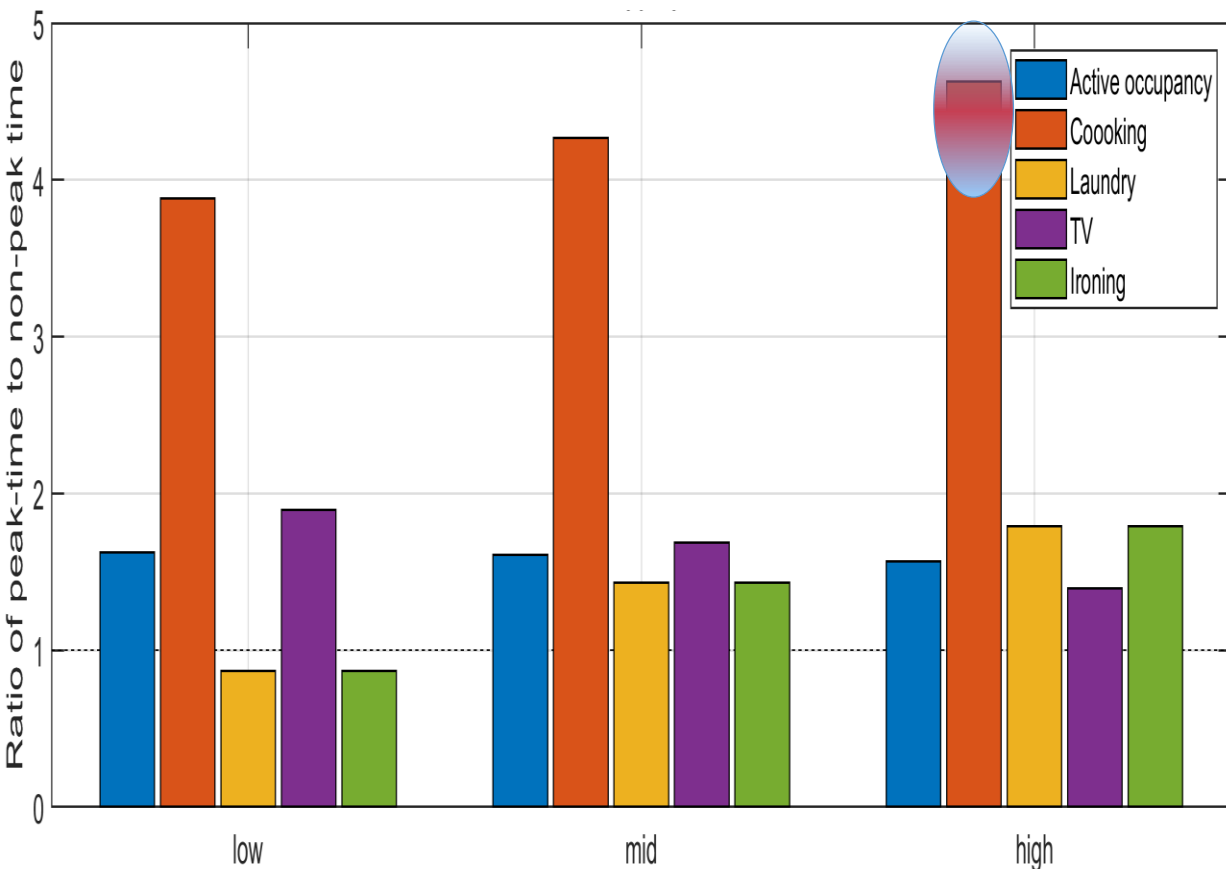


- Automation and everyday life

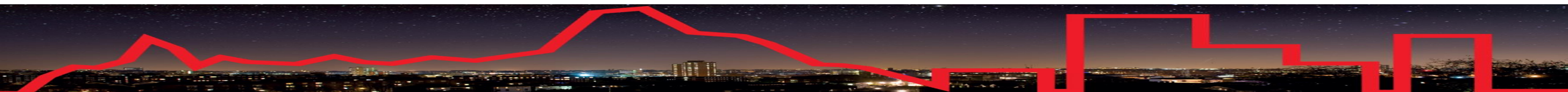
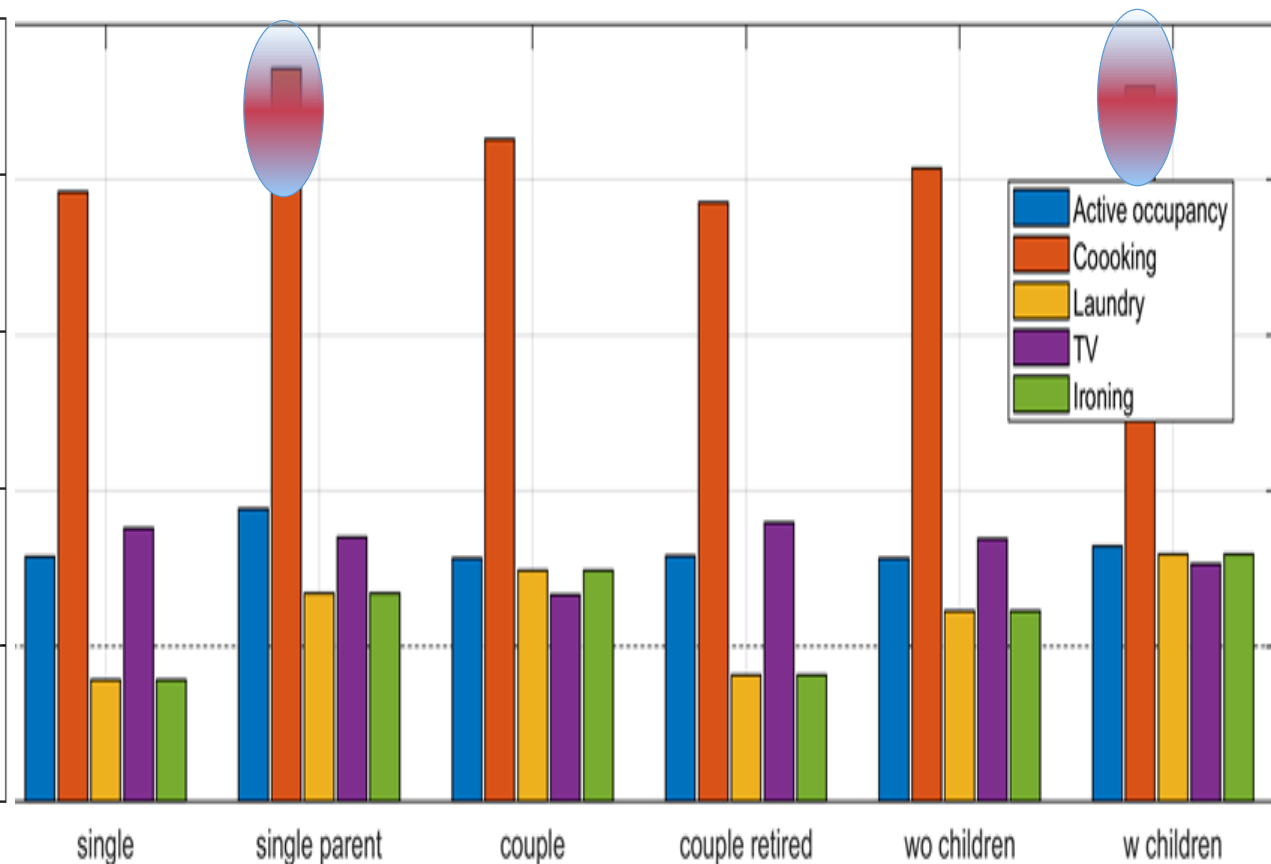




## Comparison peak and off-peak activities: income

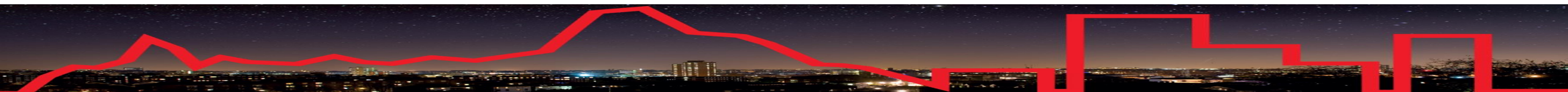
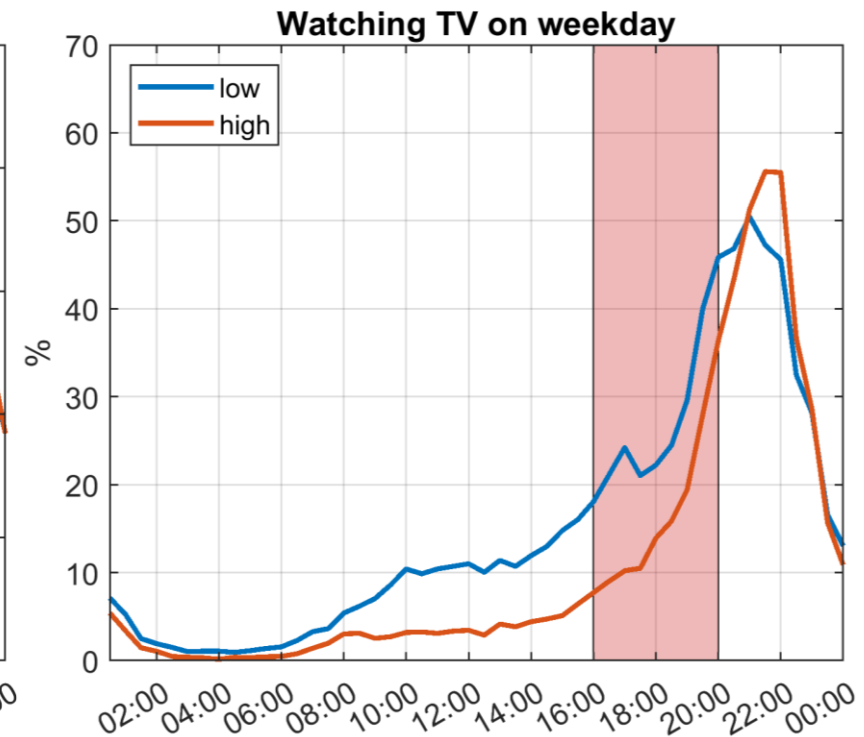
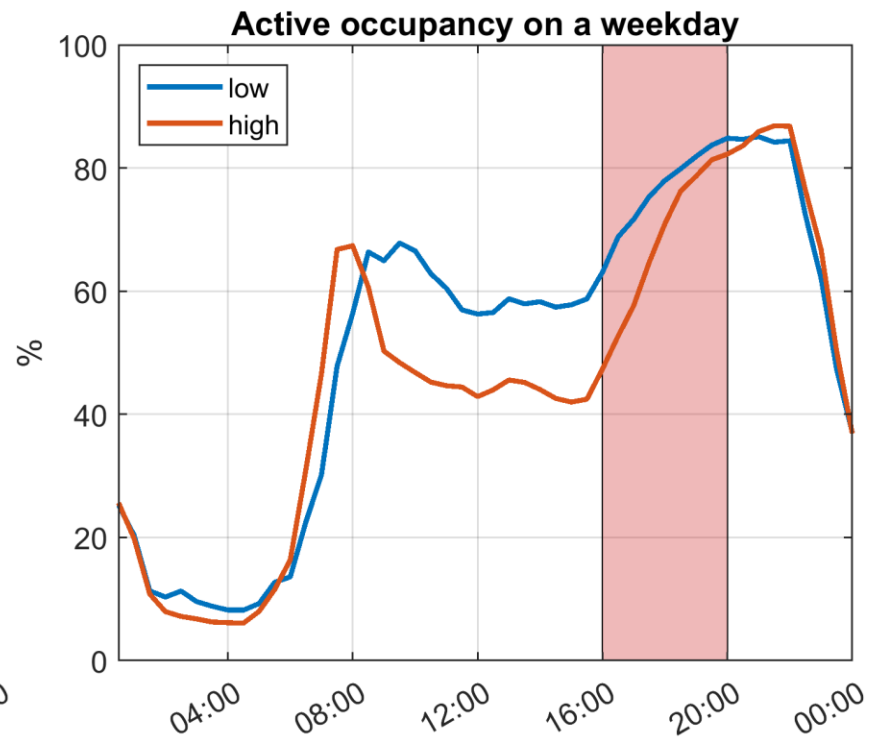
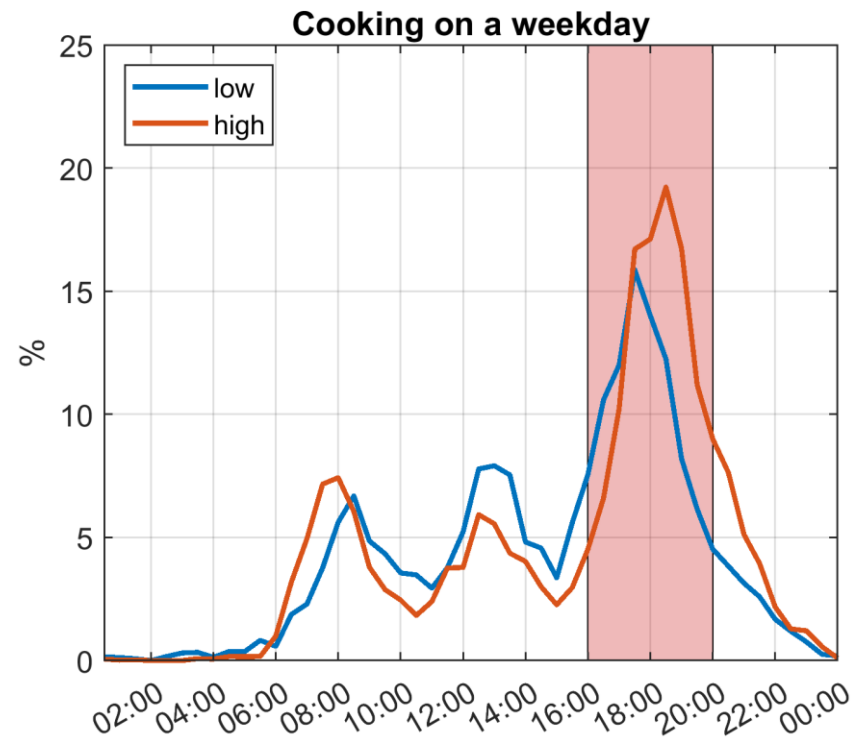


## Comparison peak and off-peak activities: household composition



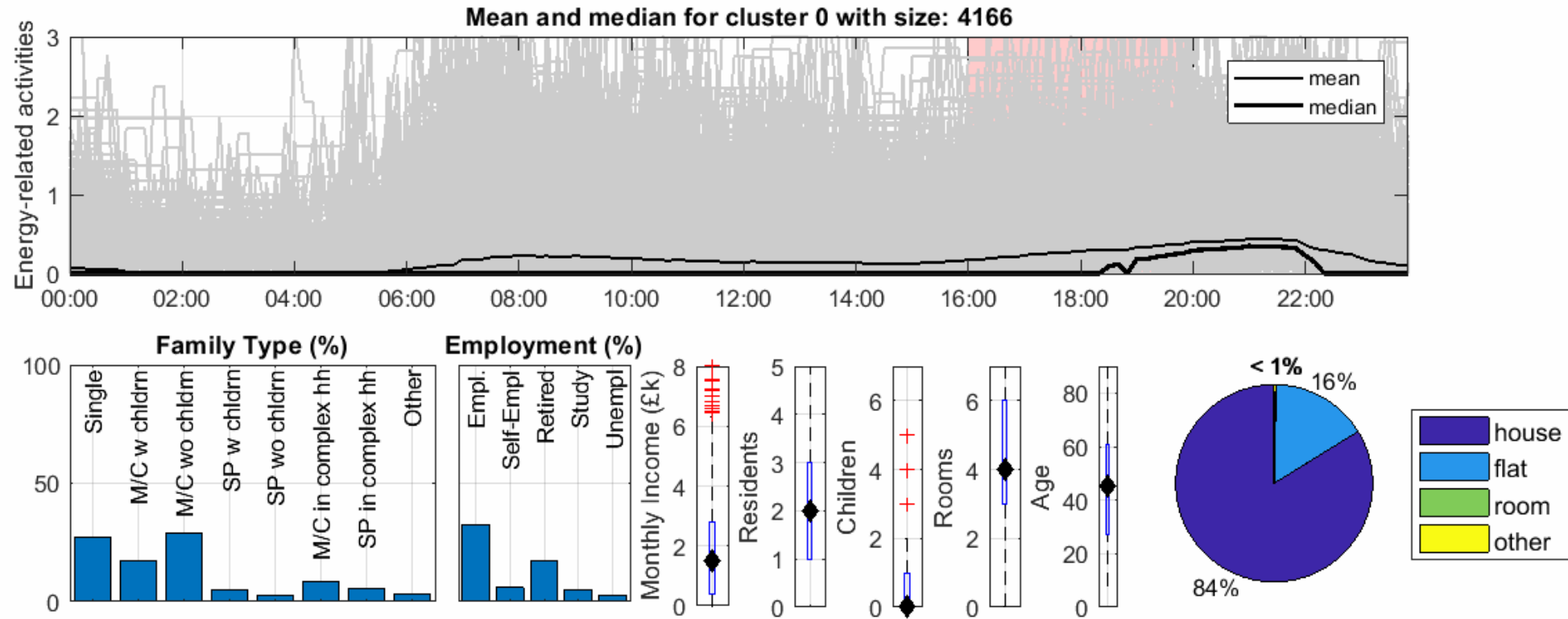


# Peak to off-peak ratio: Income





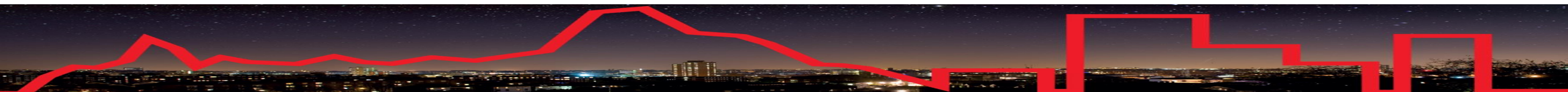
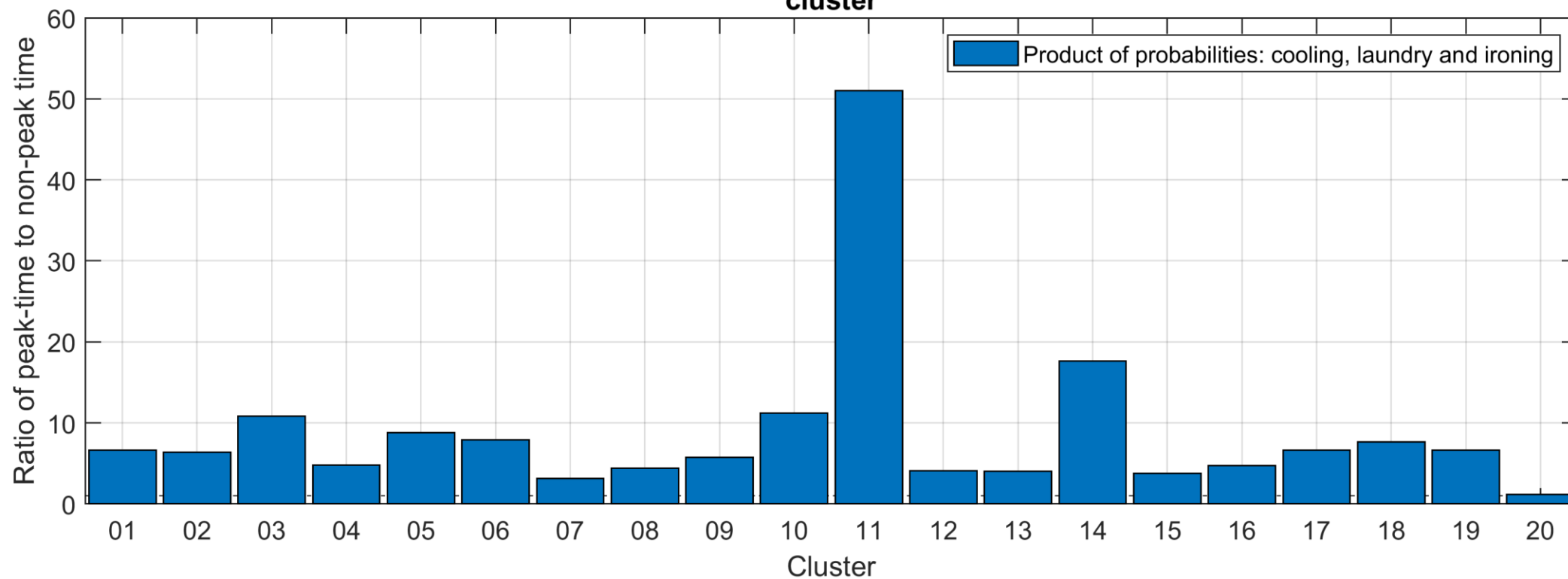
# Clustering households by activity

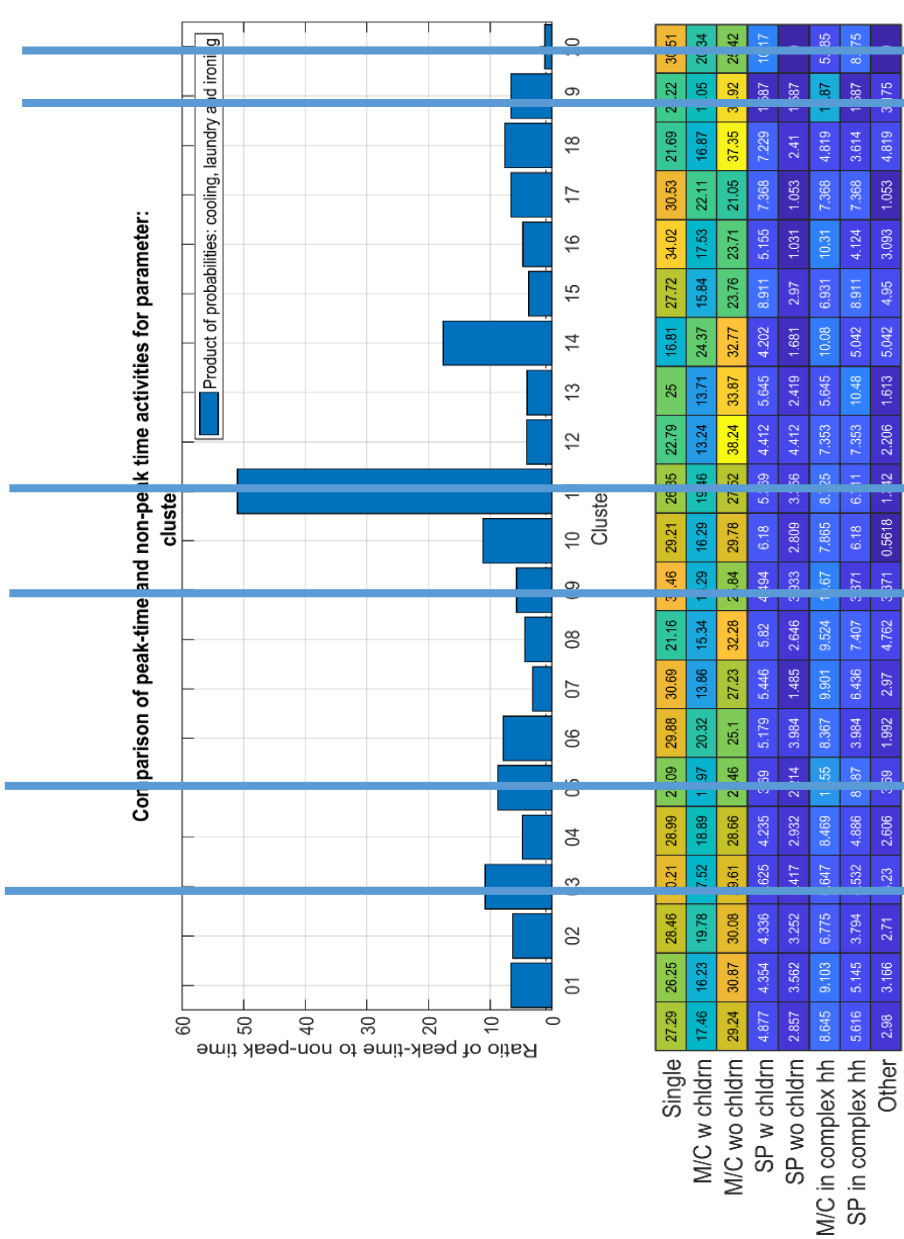




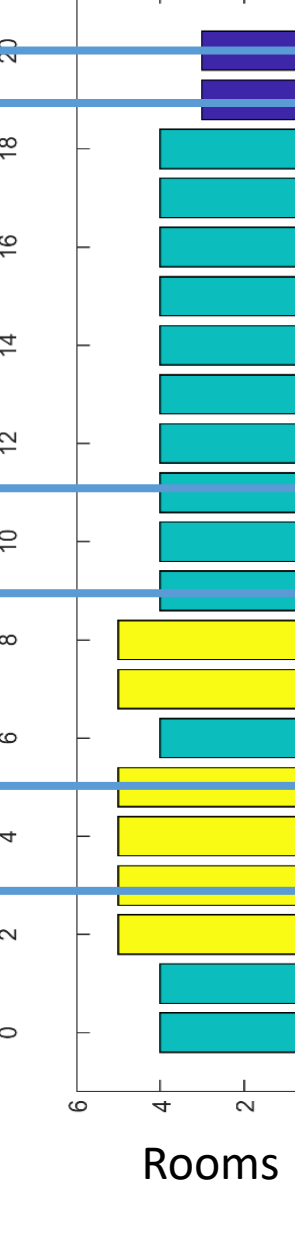
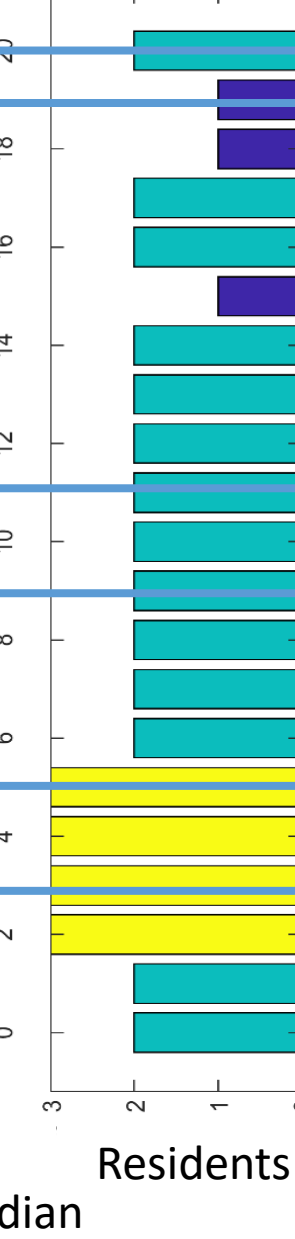
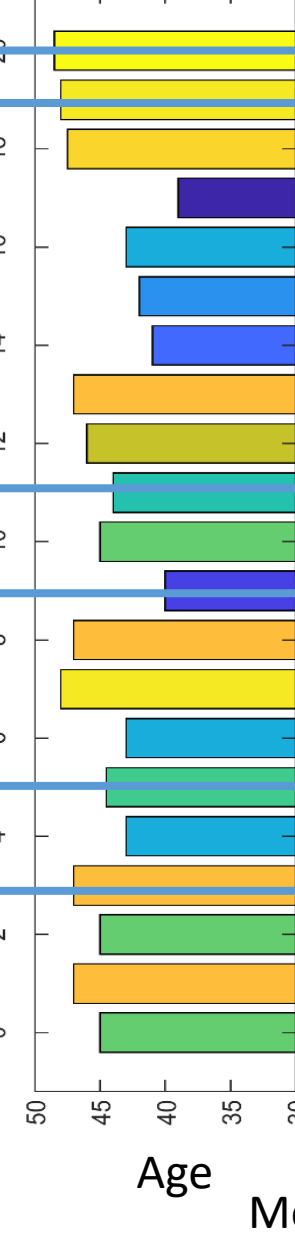
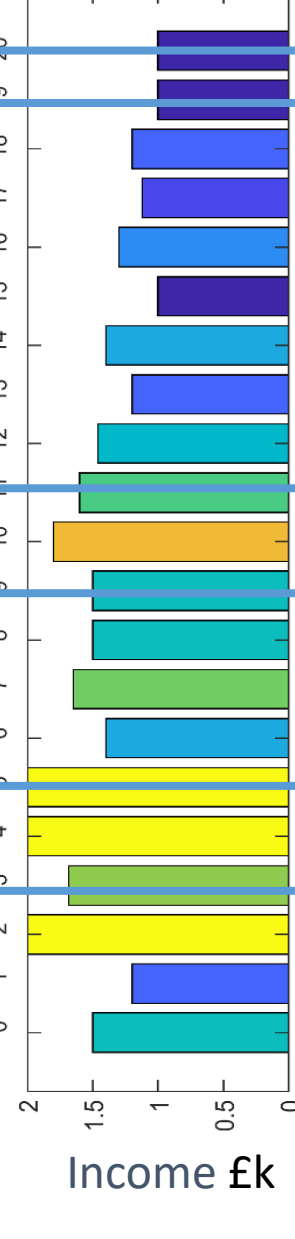
# Peak to off-peak ratio

Comparison of peak-time and non-peak time activities for parameter:  
cluster

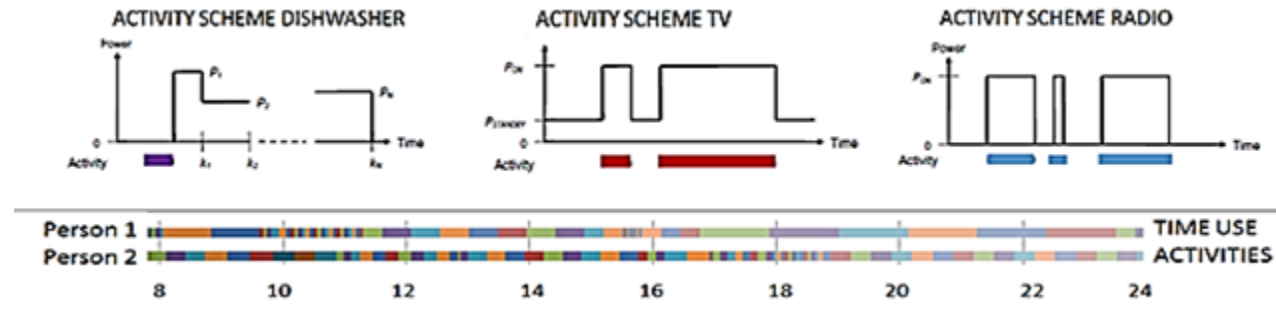




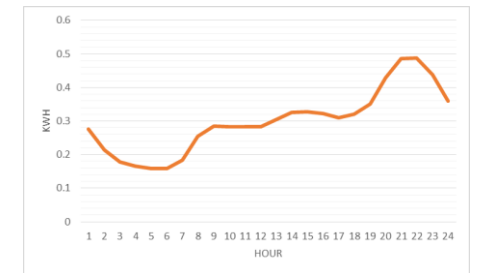
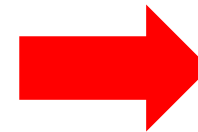
Single	27.29	26.25	28.46	0.21	28.99	2.09	29.88	30.69	21.16	3.46	29.21	26.35	22.79	25	16.81	27.72	34.02	30.53	21.69	2.22	31.51
M/C w chldrn	17.46	16.23	19.78	7.52	18.89	1.97	20.32	13.86	15.34	1.29	16.29	16.48	13.24	13.71	24.37	15.84	17.53	22.11	16.87	1.05	21.34
M/C wo chldrn	29.24	30.87	30.08	9.61	28.66	2.46	25.1	27.23	32.28	2.84	29.78	27.52	36.24	33.87	32.77	23.76	23.71	21.05	37.35	3.92	21.42
SP w chldrn	4.877	4.354	4.336	6.25	4.235	3.39	5.179	5.446	5.82	4.894	6.18	5.39	4.412	5.645	4.202	8.911	5.155	7.368	7.229	1.387	1.17
SP wo chldrn	2.857	3.562	3.252	4.17	2.932	2.14	3.984	1.485	2.846	3.333	2.809	3.36	4.412	2.419	1.681	2.97	1.031	1.053	2.41	1.387	
M/C in complex hh	8.645	9.103	6.775	6.47	8.469	1.55	6.367	9.901	9.524	1.67	7.865	8.26	7.353	5.645	10.08	6.931	10.31	7.368	4.819	1.37	5.35
SP in complex hh	5.616	5.145	3.794	5.52	4.886	8.37	3.984	6.438	7.407	3.71	6.18	6.11	7.353	10.48	5.042	8.911	4.124	7.368	3.614	1.387	8.75
Other	2.96	3.166	2.71	2.3	2.606	3.39	1.992	2.87	4.762	3.71	0.5616	1.42	2.206	1.613	5.042	4.96	3.093	1.053	4.819	3.75	



# From time use data to load profiles

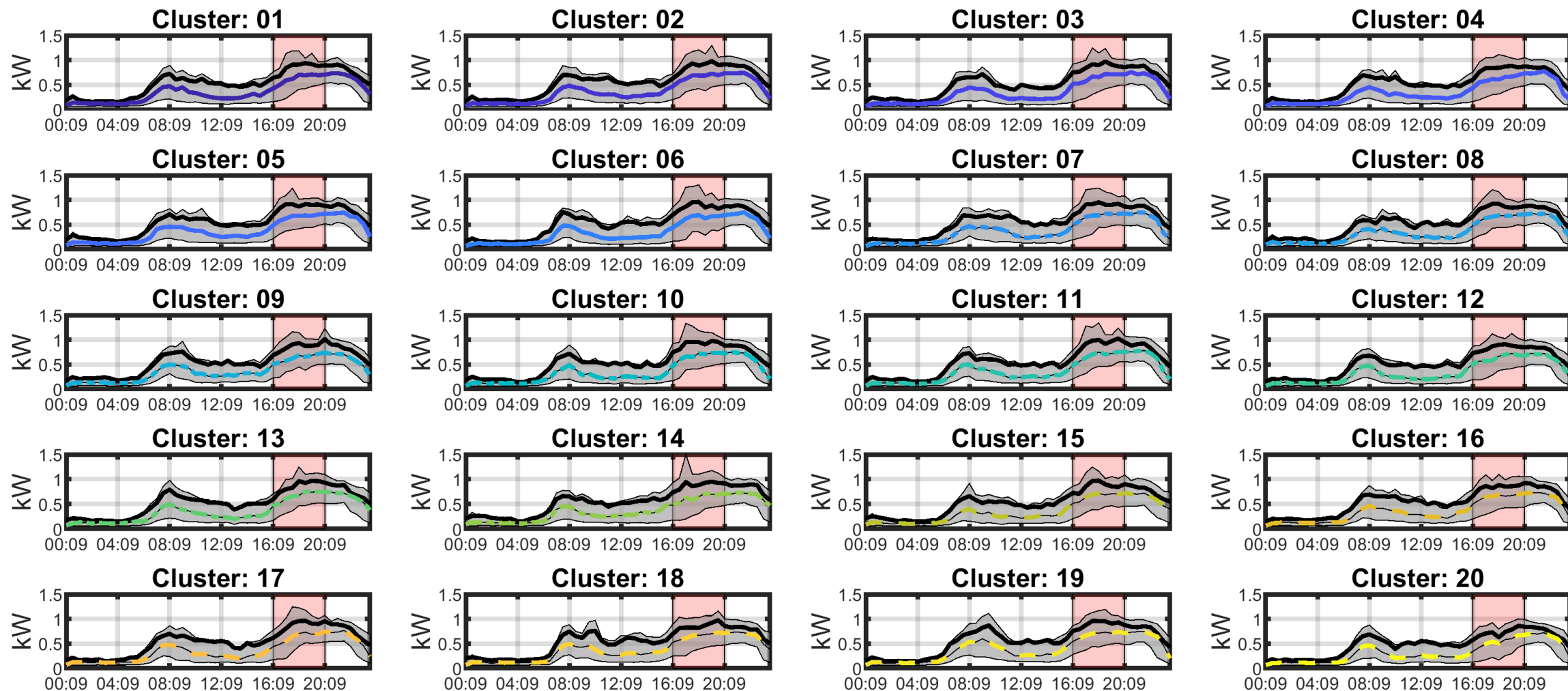


Activity schemes can enable to link time use activities with appliance and electricity use

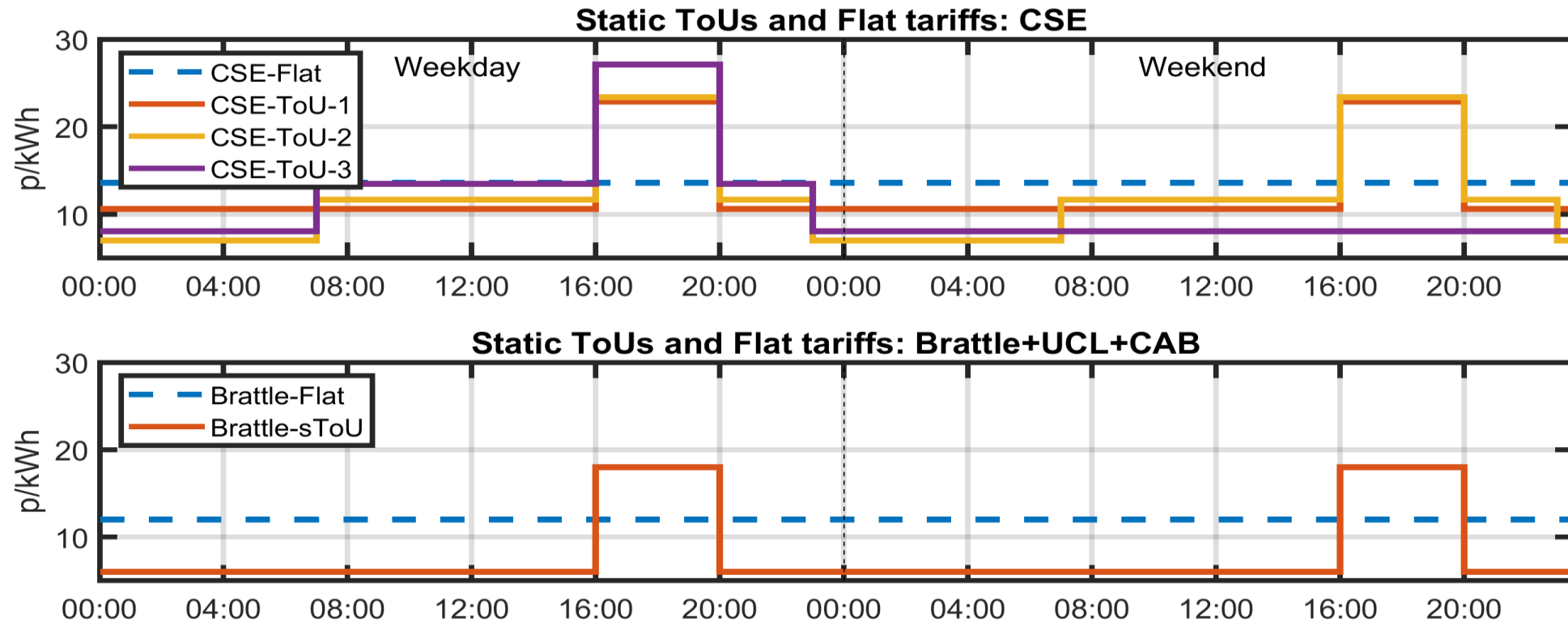




# Demand profiles



# Applying Time of Use tariffs



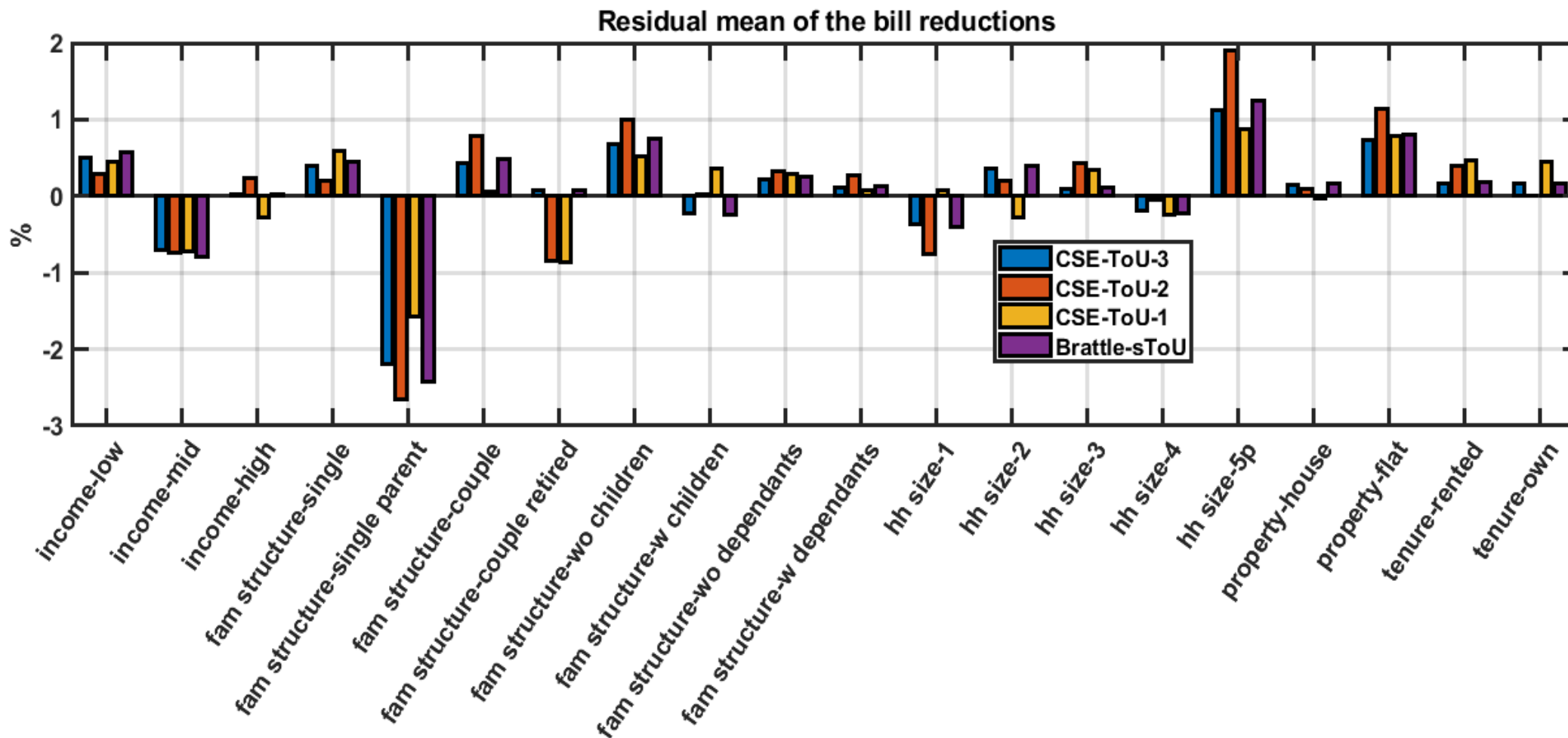
CSE - Centre for Sustainable Energy. 2014. "Investigating the Potential Impacts of Time of Use (ToU) Tariffs on Domestic Electricity Customers: Smarter Markets Programme."

Brattle +UCL - Hledik, Ryan, Will Gorman, Nicole Irwin, Michael Fell, Moira Nicolson, and Gesche Huebner. 2017. "The Value of TOU Tariffs in Great Britain : Insights for Decision-Makers." Vol. I.



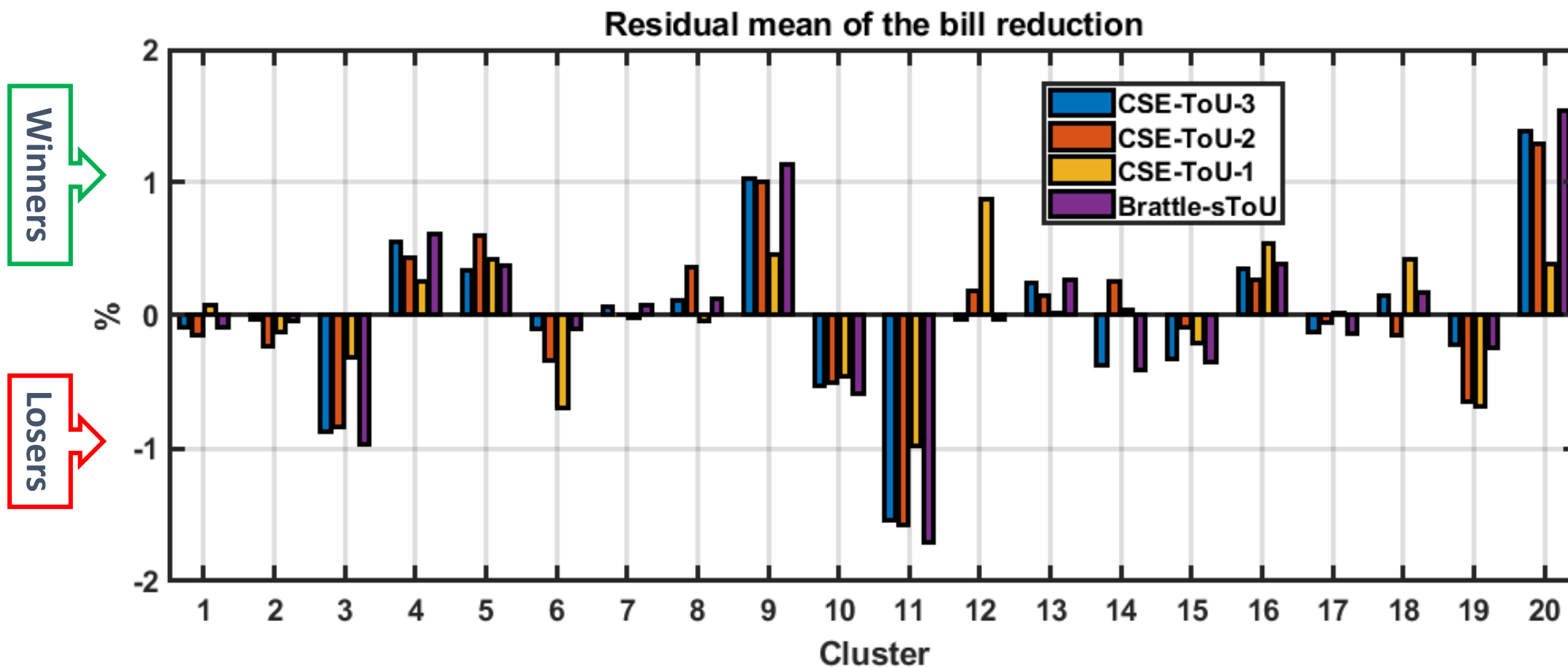
# Impact of Time of Use tariffs

Winners  
Losers





# Impact of Time of Use tariffs



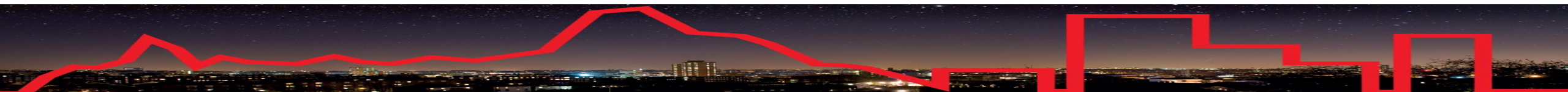
Power to the (flexible) people?

What happens to those who do not have the time and means for demand-side flexibility?

Time and non-energy arrangements

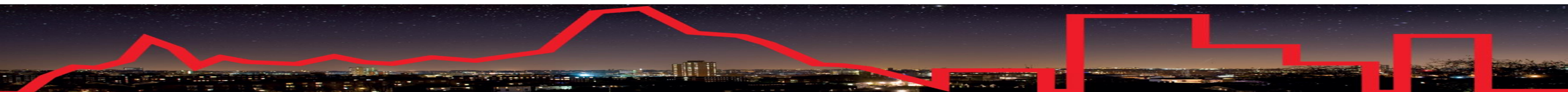
## The single mother nurse

- Protecting her from flexibility costs?
- Excluding her from flexibility opportunities?



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# THANKS

