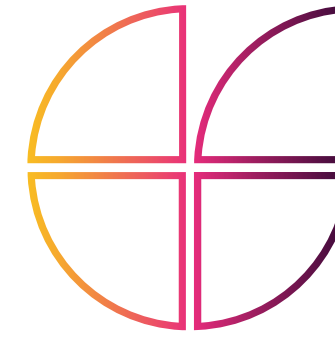




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SCIENCE**



people
~~technology~~
It's the ~~economy~~, stupid

Energy services, flexibility and data

Part I

Energy Systems MSc – Energy Demand – MT2025

Phil Grunewald

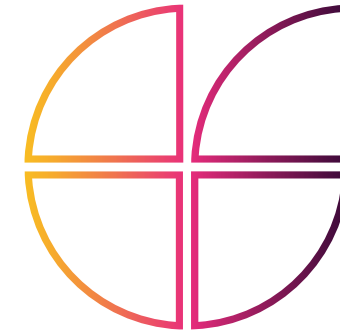
energy-use.org/slides

Part I

- System flexibility
- Energy needs and uses
- Feedback systems
- Causality

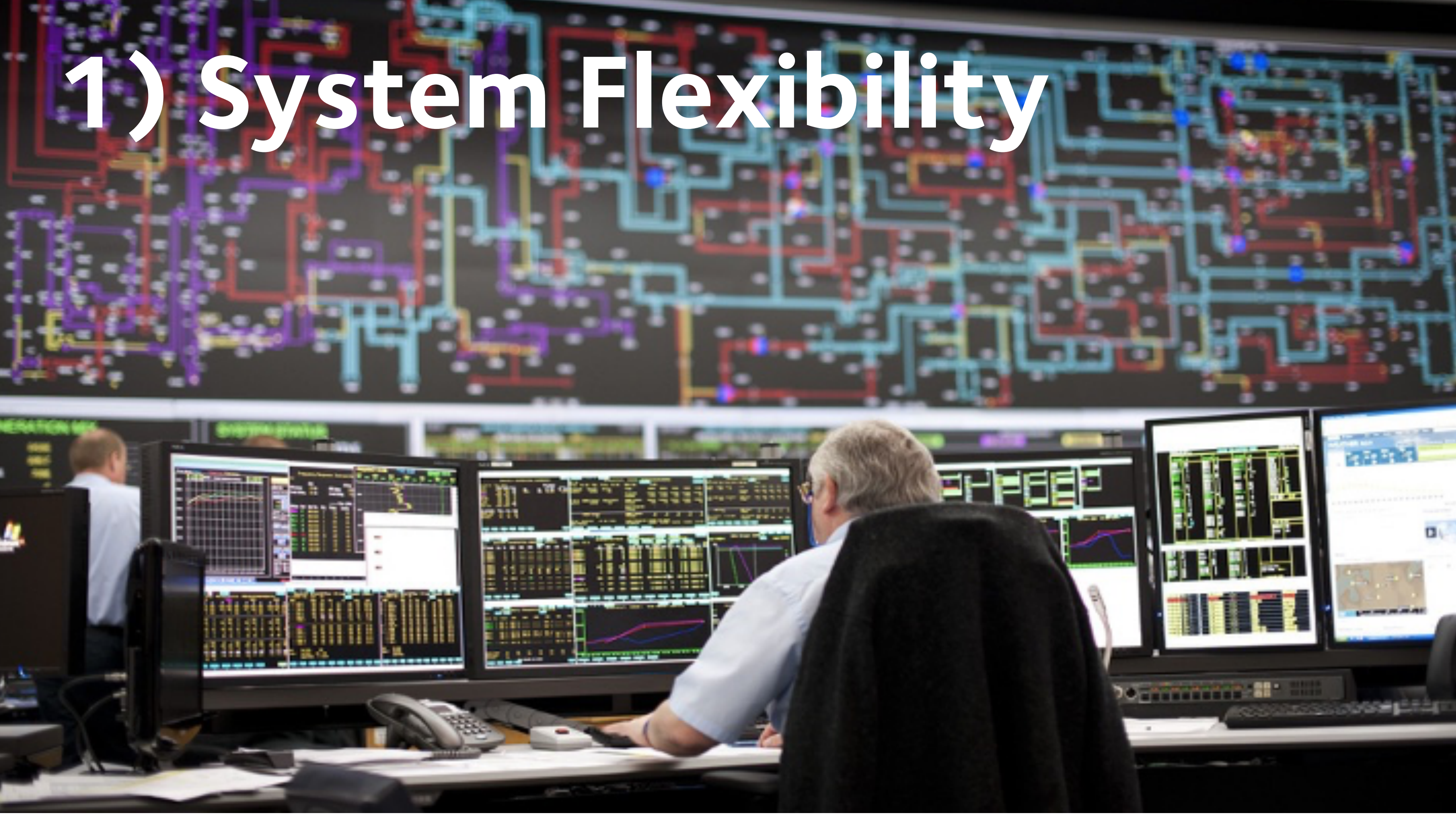
Part II

- Demand side flexibility
- Price elasticity
- Data and privacy
- Synthetic data



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SCIENCE**





1) System Flexibility

Team Demand



Charge car

Flexible



Oven

Evening



Tea

Daytime



Stand-by

Baseload

Each
Item
= 10 GW

Team Supply

Peaker
OCGT
£30 /MWh



Gas
CCGT
£20 /MWh



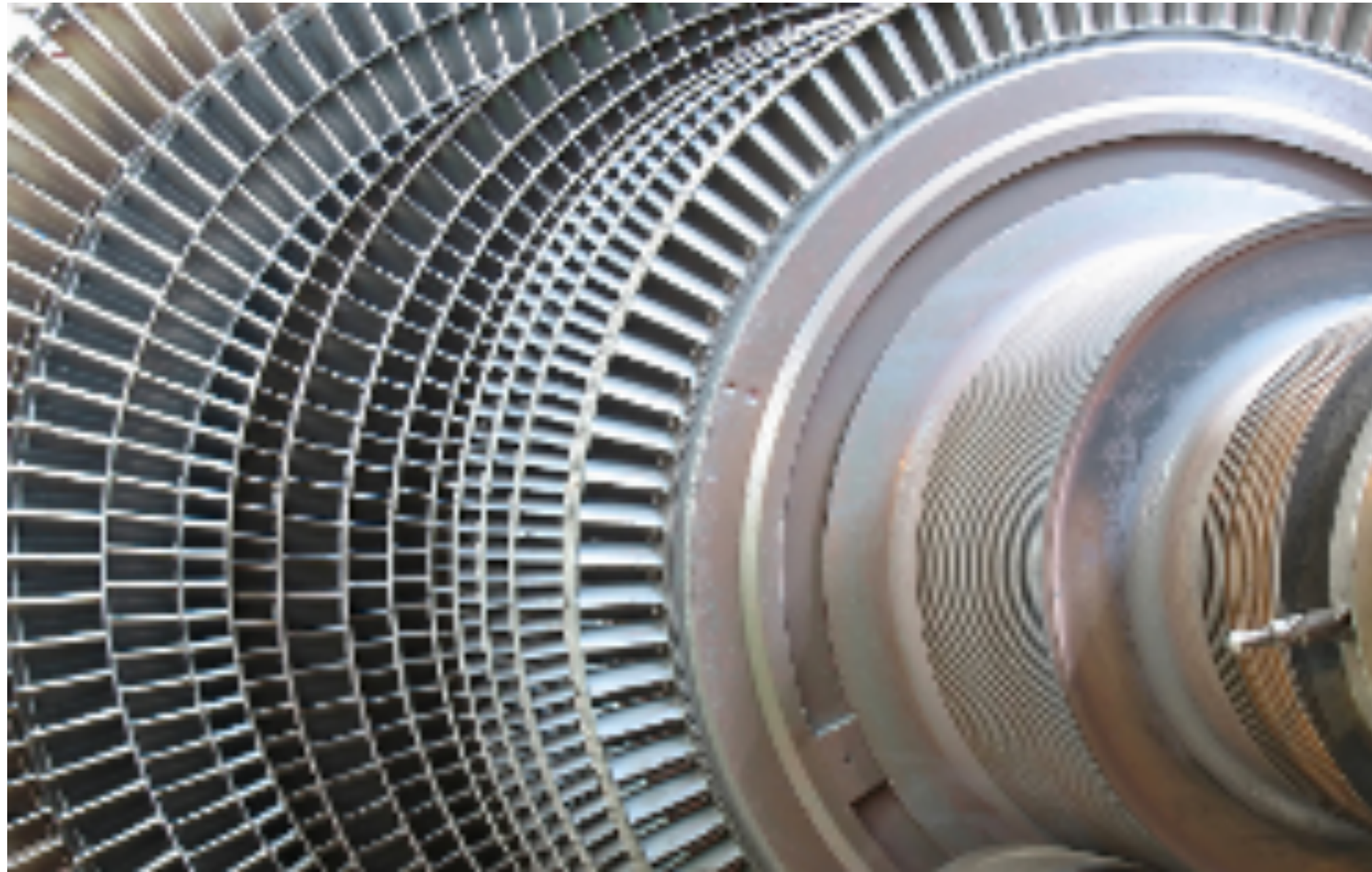
Nuclear
£1 /MWh



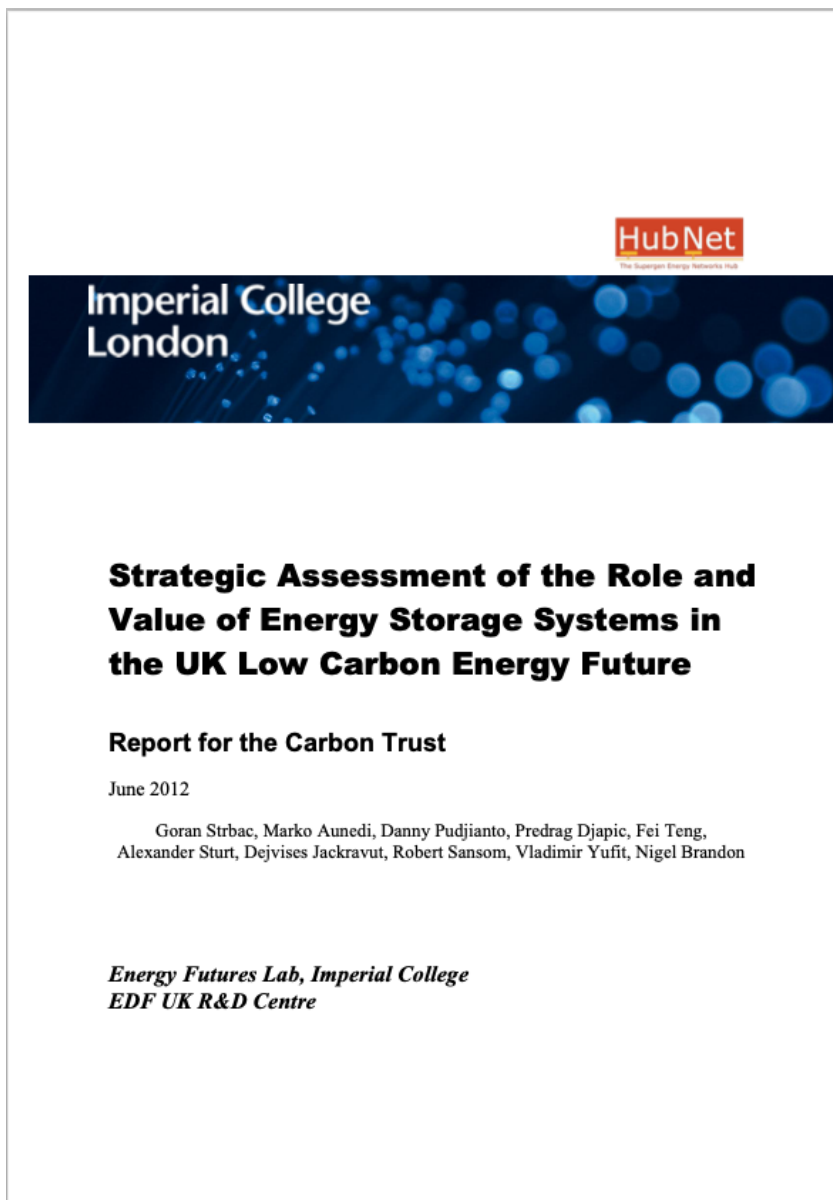
Renewables
£0 /MWh



Merit order
Peak pricing
Curtailment
Spinning reserve



The (passive) flexibility we will miss



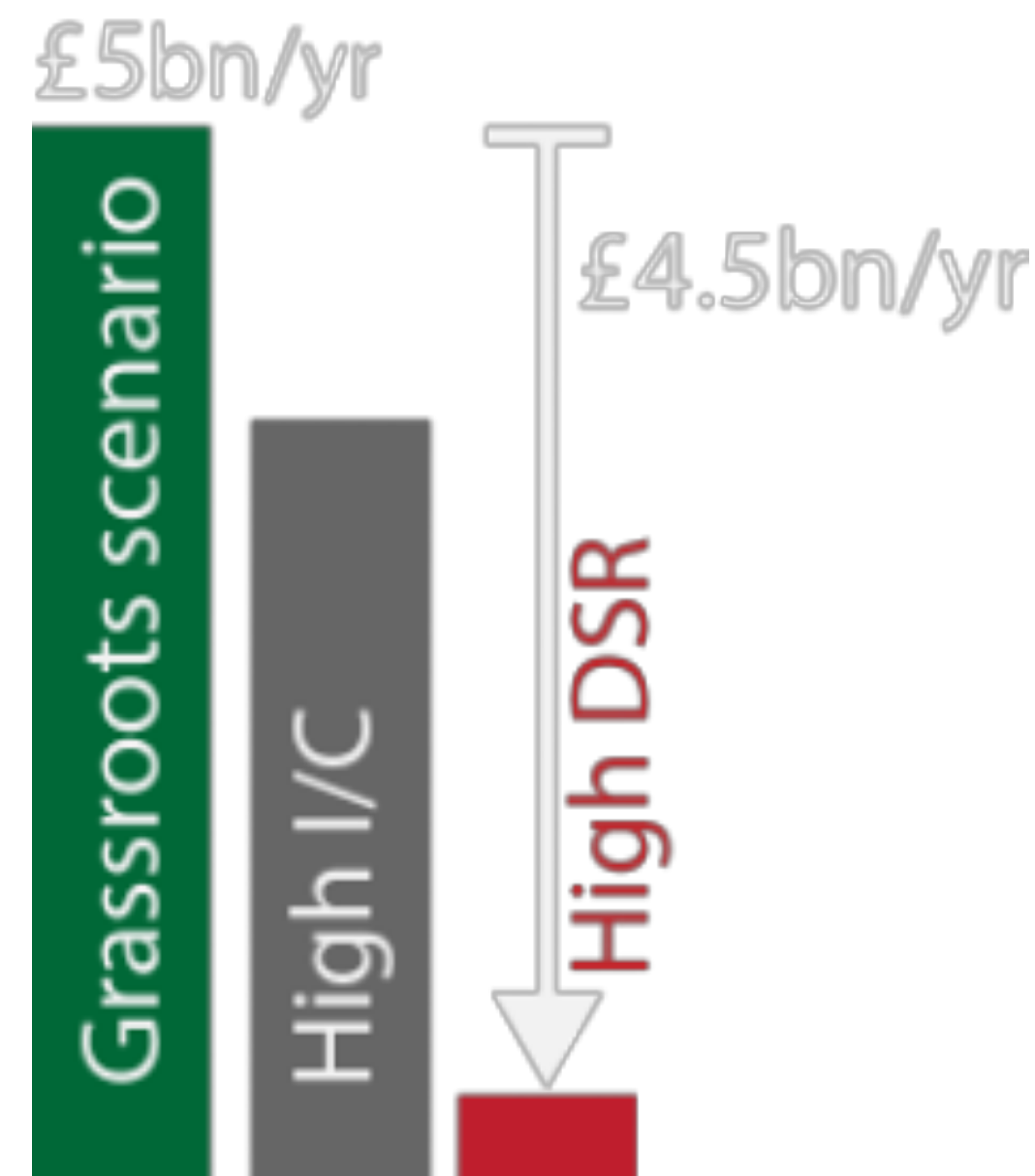
Estimated cost saving

£40 (up to)

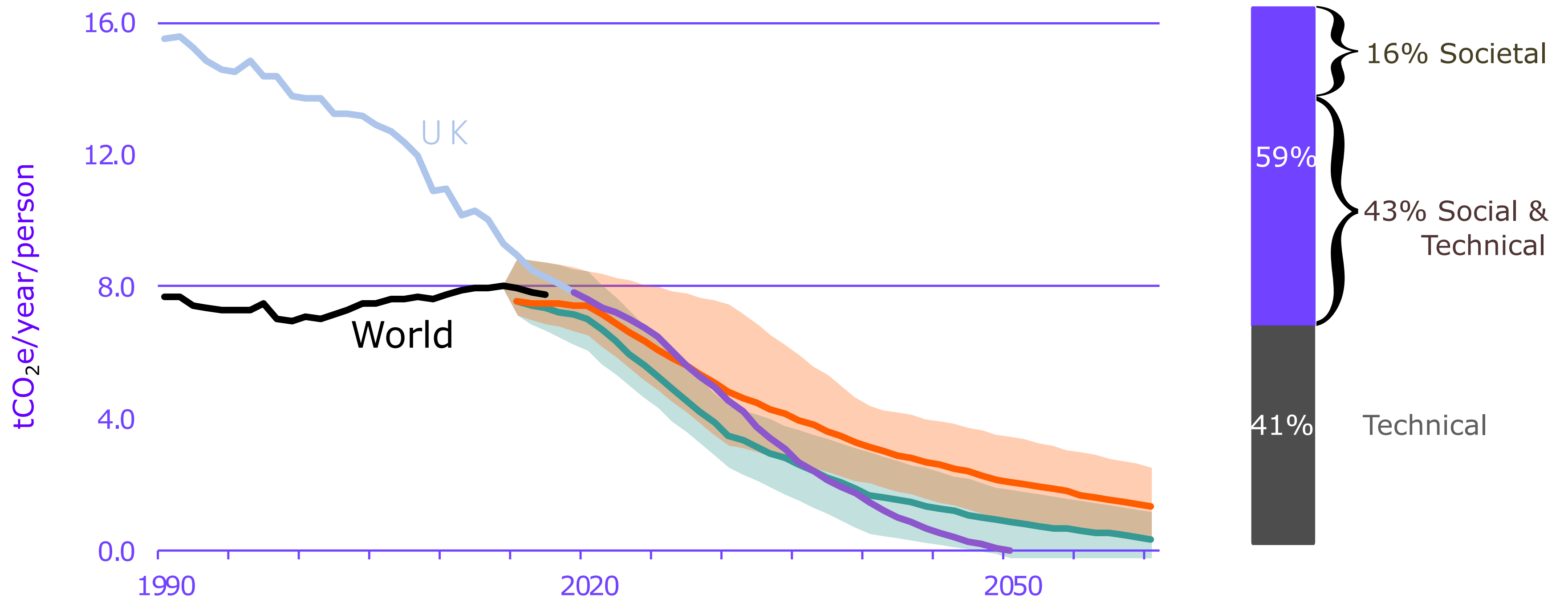
From savings on

- 1) Capacity
- 2) Operation
- 3) Networks, I/C

Demand matters



No demand measures - no net zero

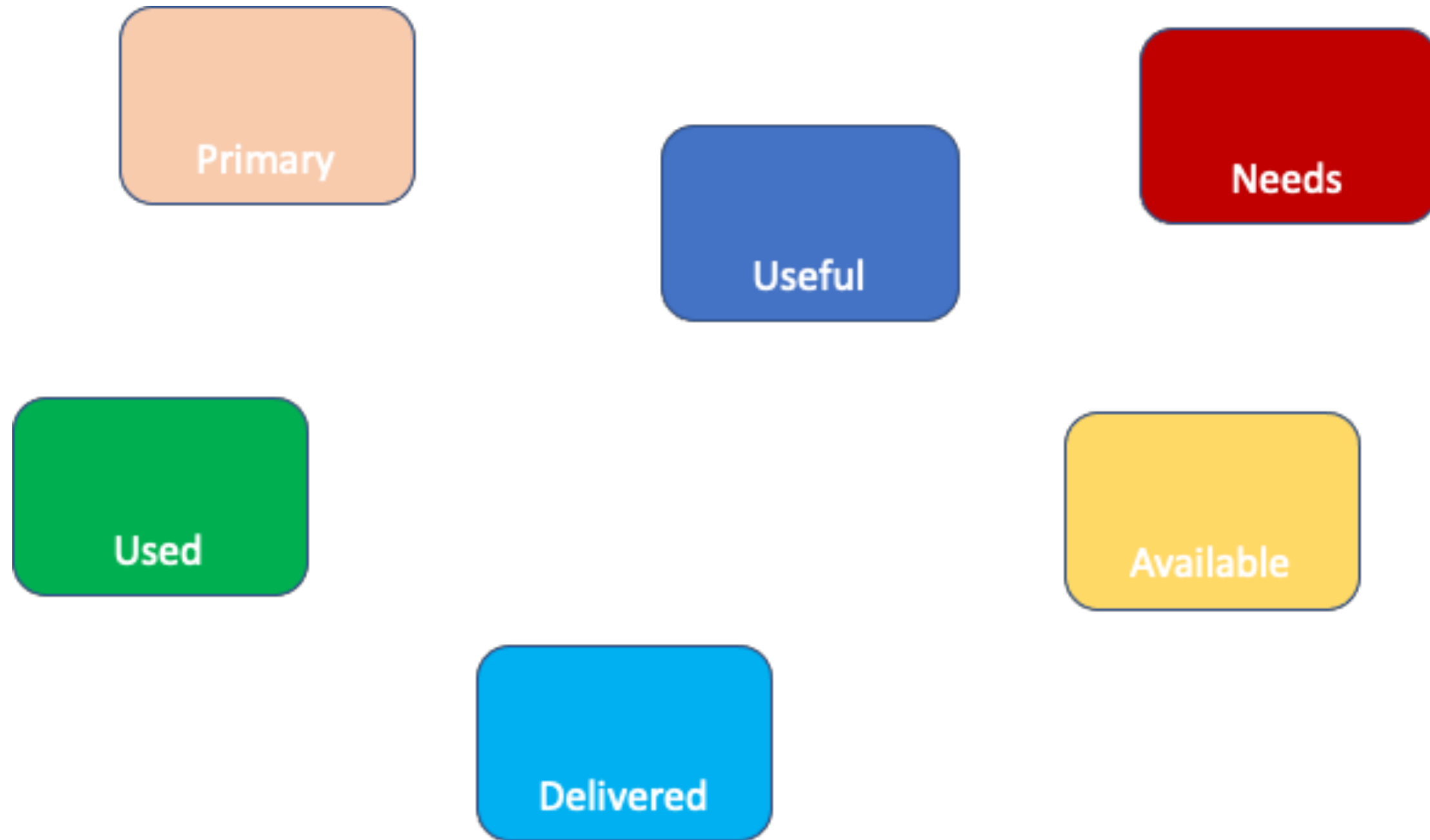


Source: Climate Change Committee. The UK's path to net zero.
The sixth carbon budget, Climate Change Committee, December 2020

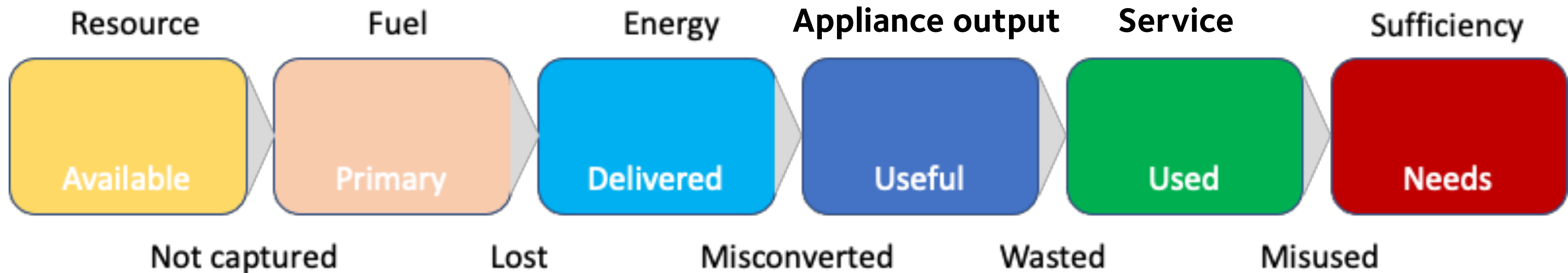


Energy needs and uses

Energy concepts



Meaning and order of different energy forms





Nowhere near to scale

The Sun

2.5**MW**/person

FF + Nuclear + RES

2.7**kW**/person

Metered

1.3**kW**/person

Appliance output

Service

Available

Primary

Delivered

Useful

Used

Needed

Well understood

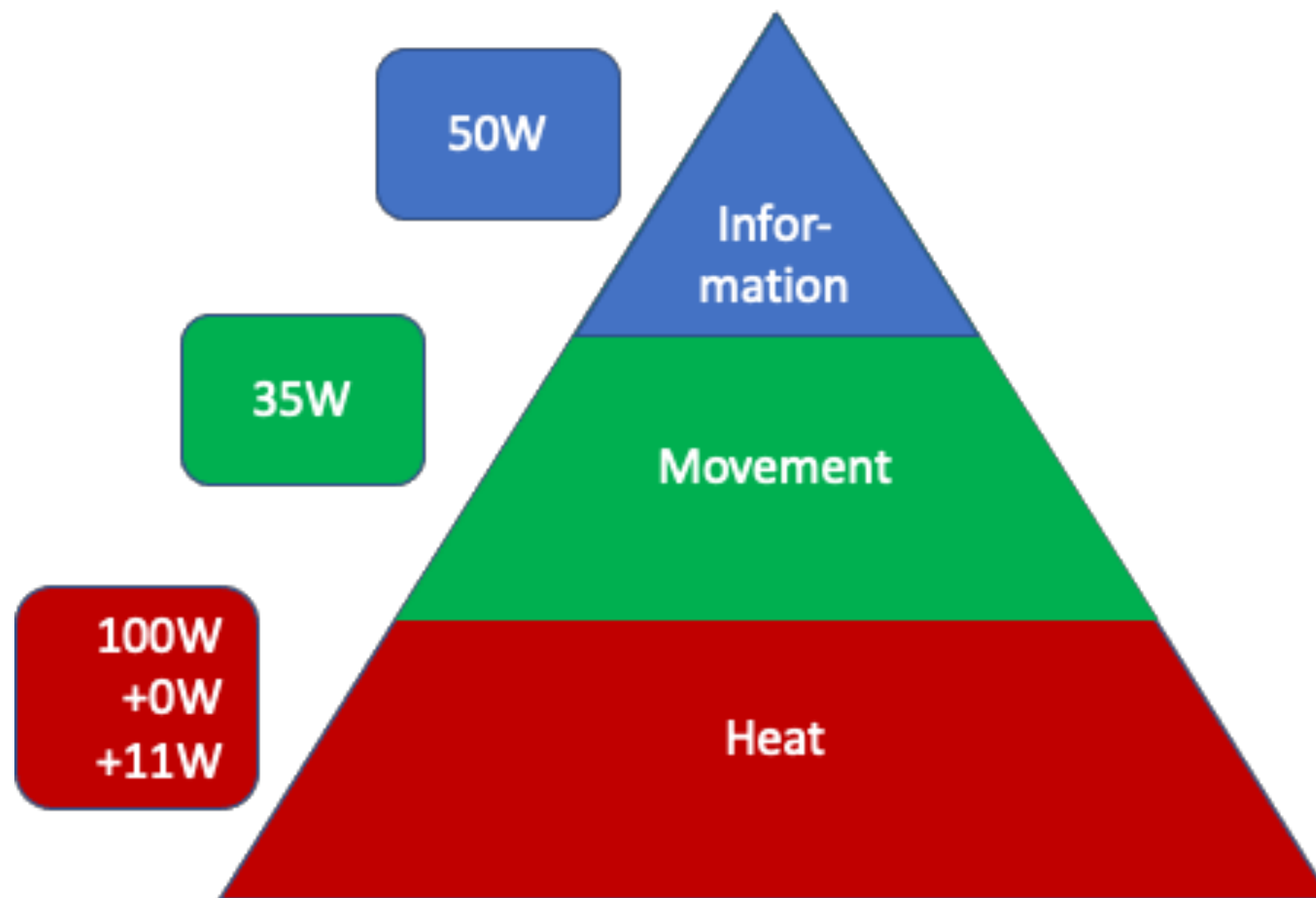
Poorly understood

data: worldbank.org, iea.org

Maslow's Hierarchy of Needs



Energy service needs



Information

- 60W / GB (IEA)
- Streaming at 1.25 GB 16 hours per day

Movement

- $E = m (v^2/2 + g h)$
- $m=100\text{kg}$, $v=100\text{km/h}$, $h=100\text{m}$
- 5 trips per day: 830Wh

Heat (100W ~2,000kcal)

- $E = -k \Delta T A$
- Inside 36°C, outside 0°C, surface 2m², $E=100\text{W}$
- $k = -1.4 \text{ W/mK}$

Coolth

- Inside 36°C, outside 40°C, $k = -1.4\text{W/mK}$

Energy service needs

2.5**MW**/person

Efficiency requirement ~1 in 10,000

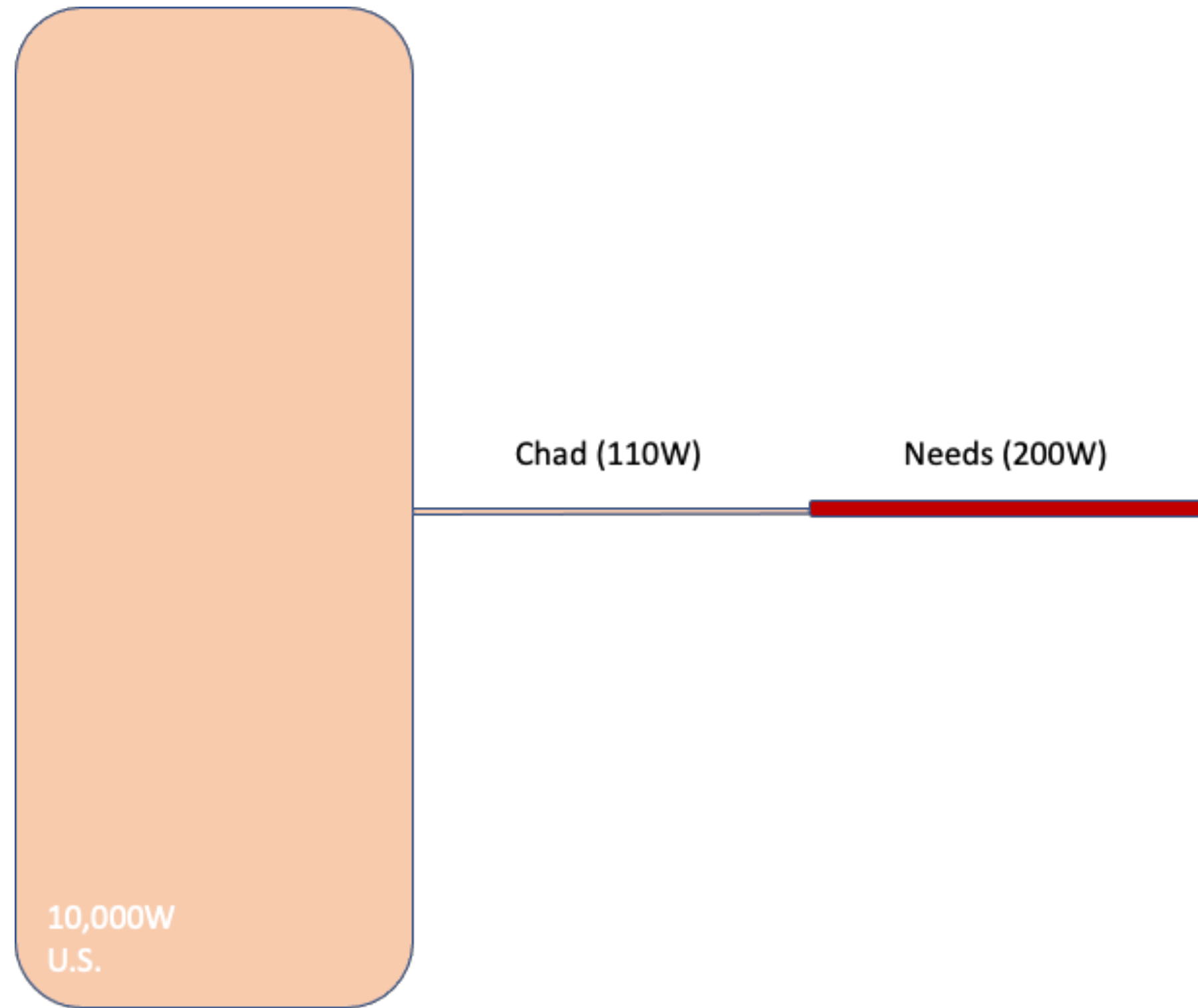
(Yes we can meet everyone's needs sustainably)



200 **W**/person

Nowhere near to scale

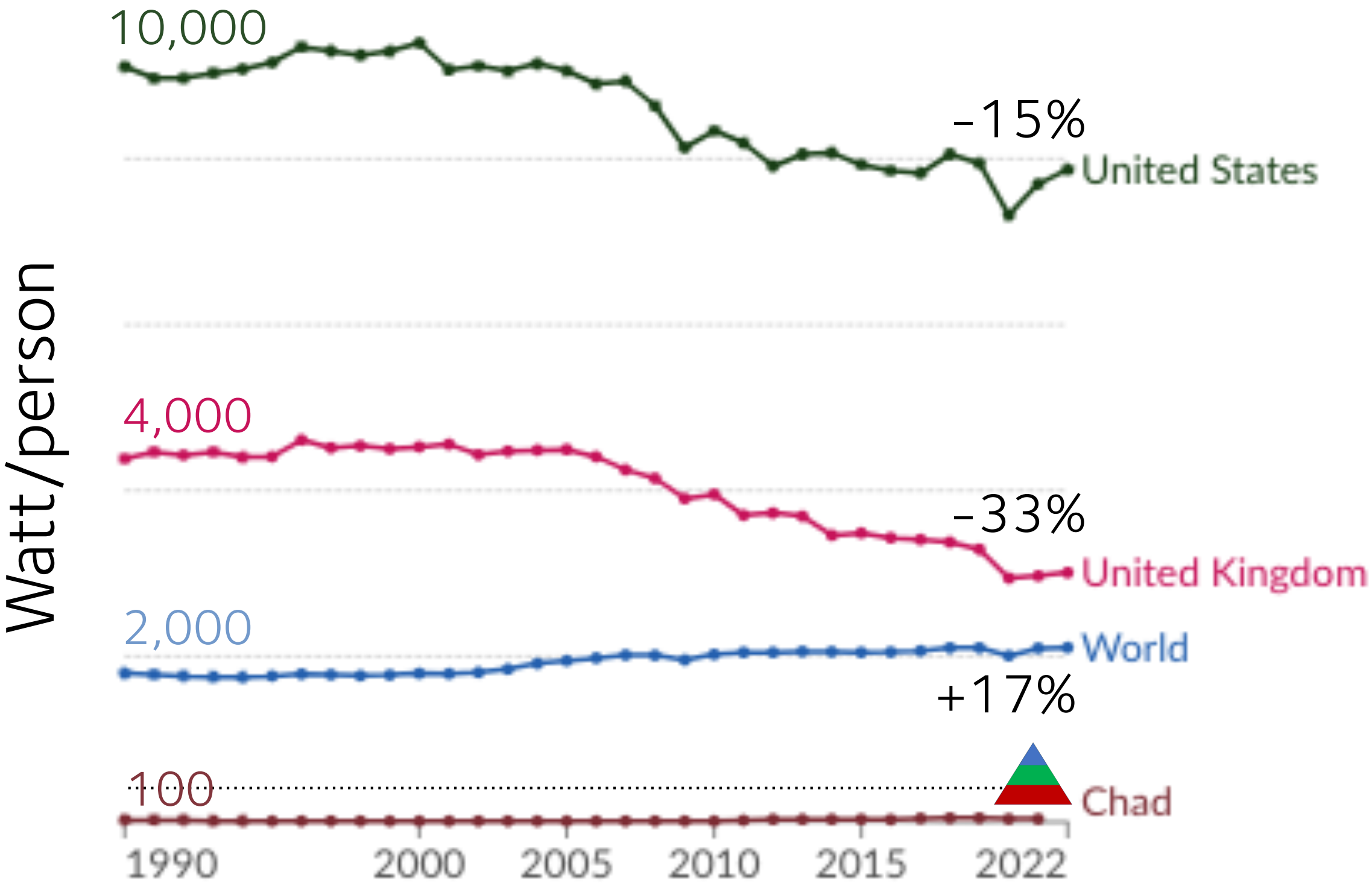
Energy service needs



Energy use

Over the past 30 years
Energy use in the UK

- a) Increased 50%
- b) Increased 20%
- c) stayed the same
- d) reduced by 20%



Feedback Systems

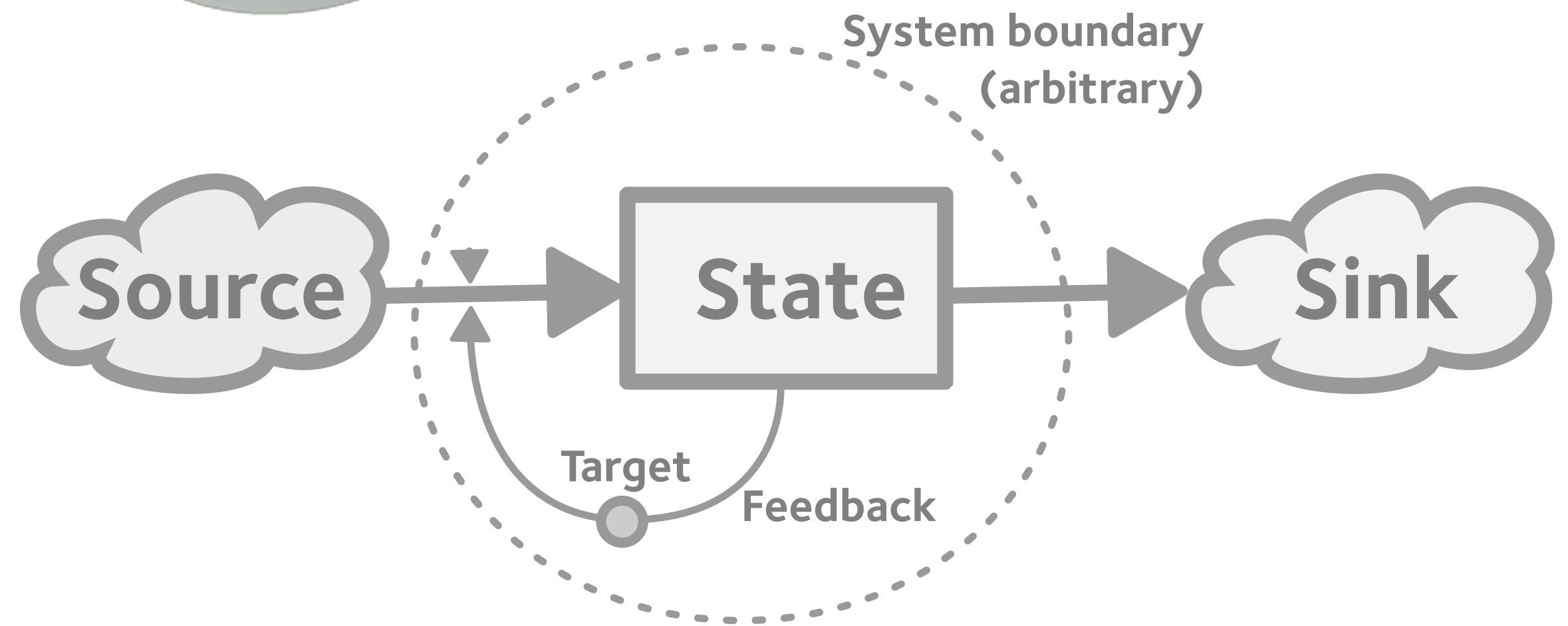
Thinking in Systems

A Primer

Donella H. Meadows

Edited by Diana Wright,

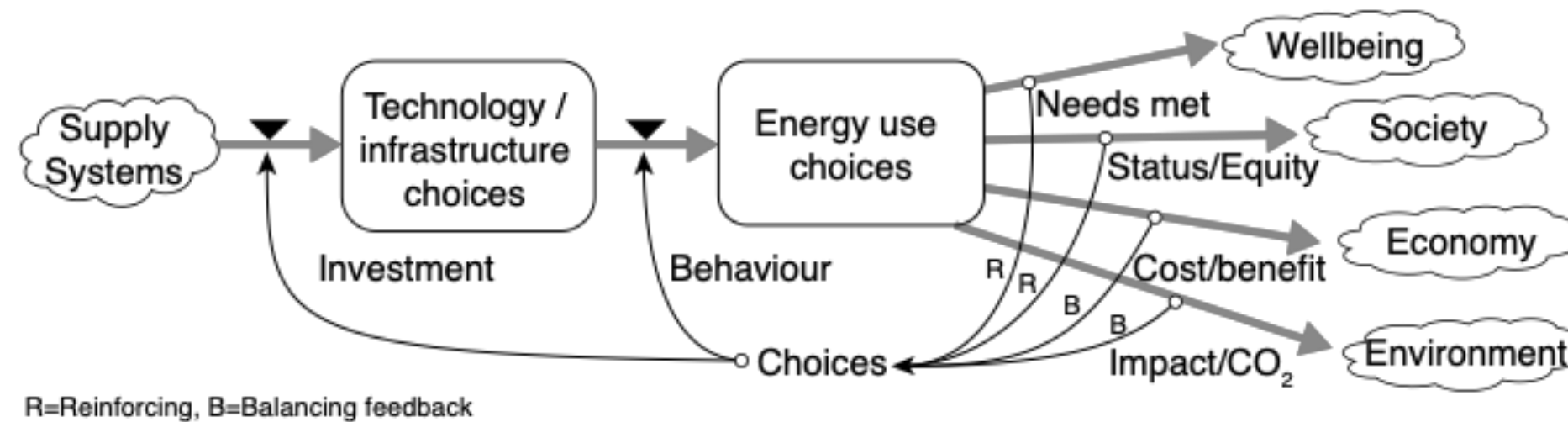
Sustainability Institute



Energy feedback

Good feedback is:

- Timely (not just fast)
- Accurate
- Relevant to system goals

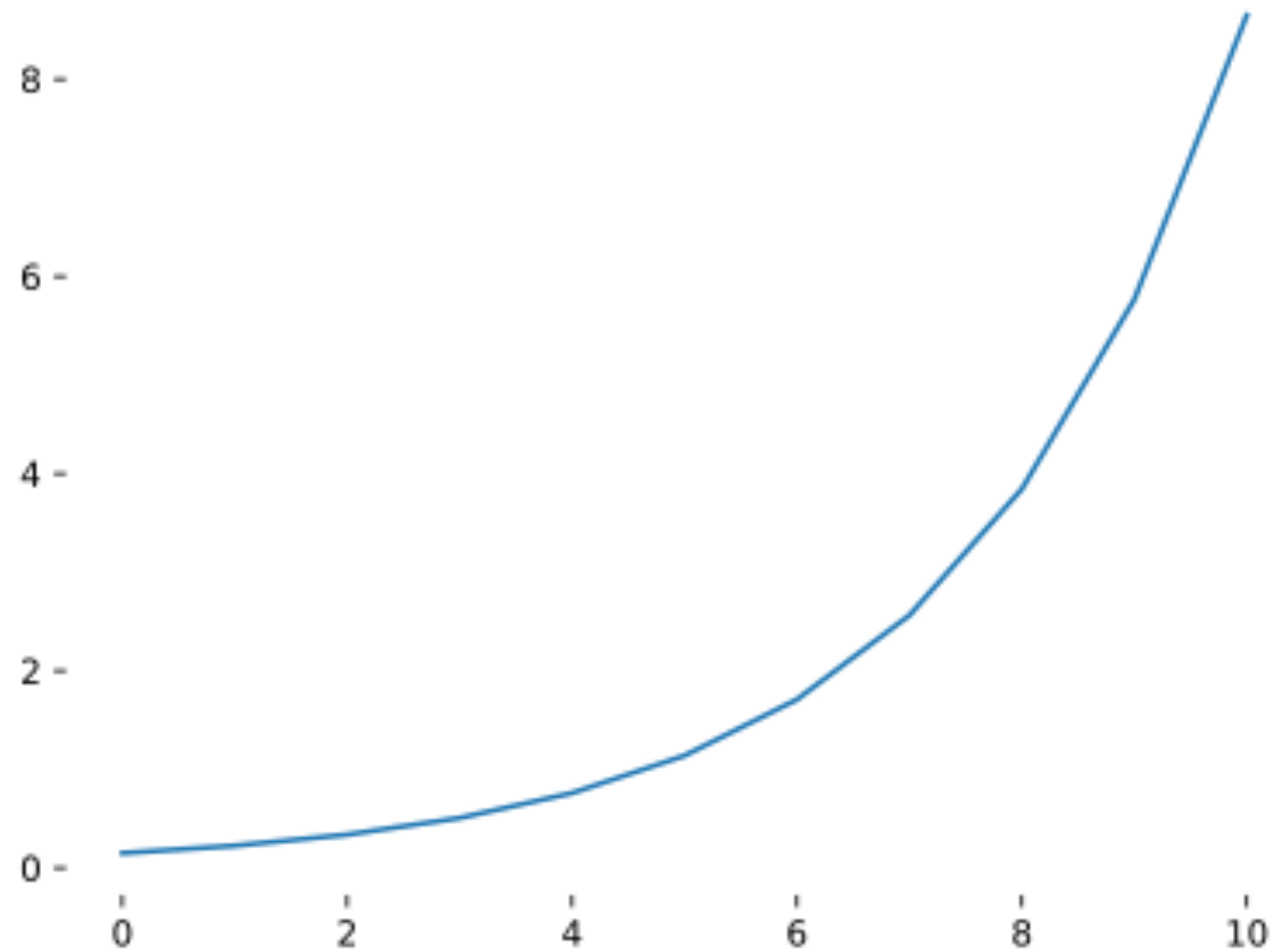


The power of feedback

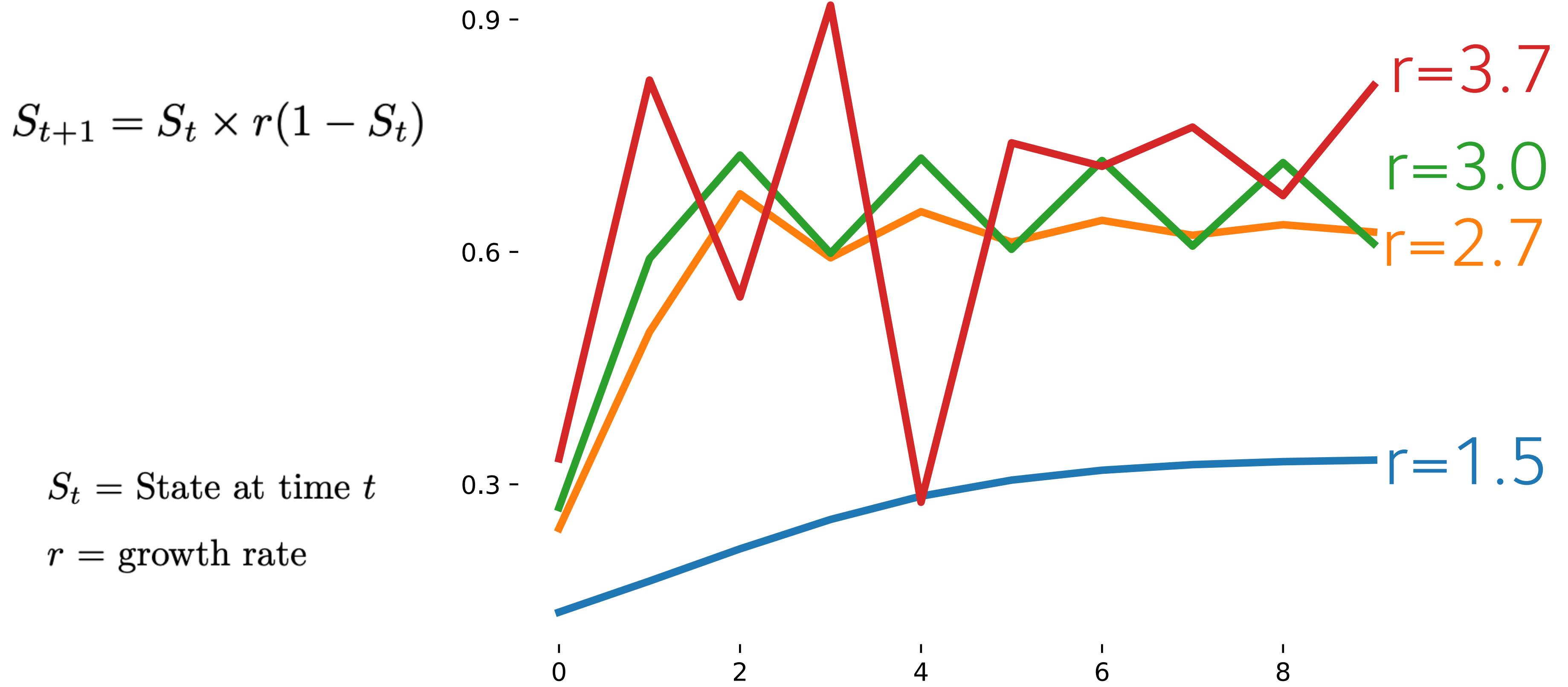
$$S_{t+1} = S_t \times r$$

S_t = State at time t

r = growth rate

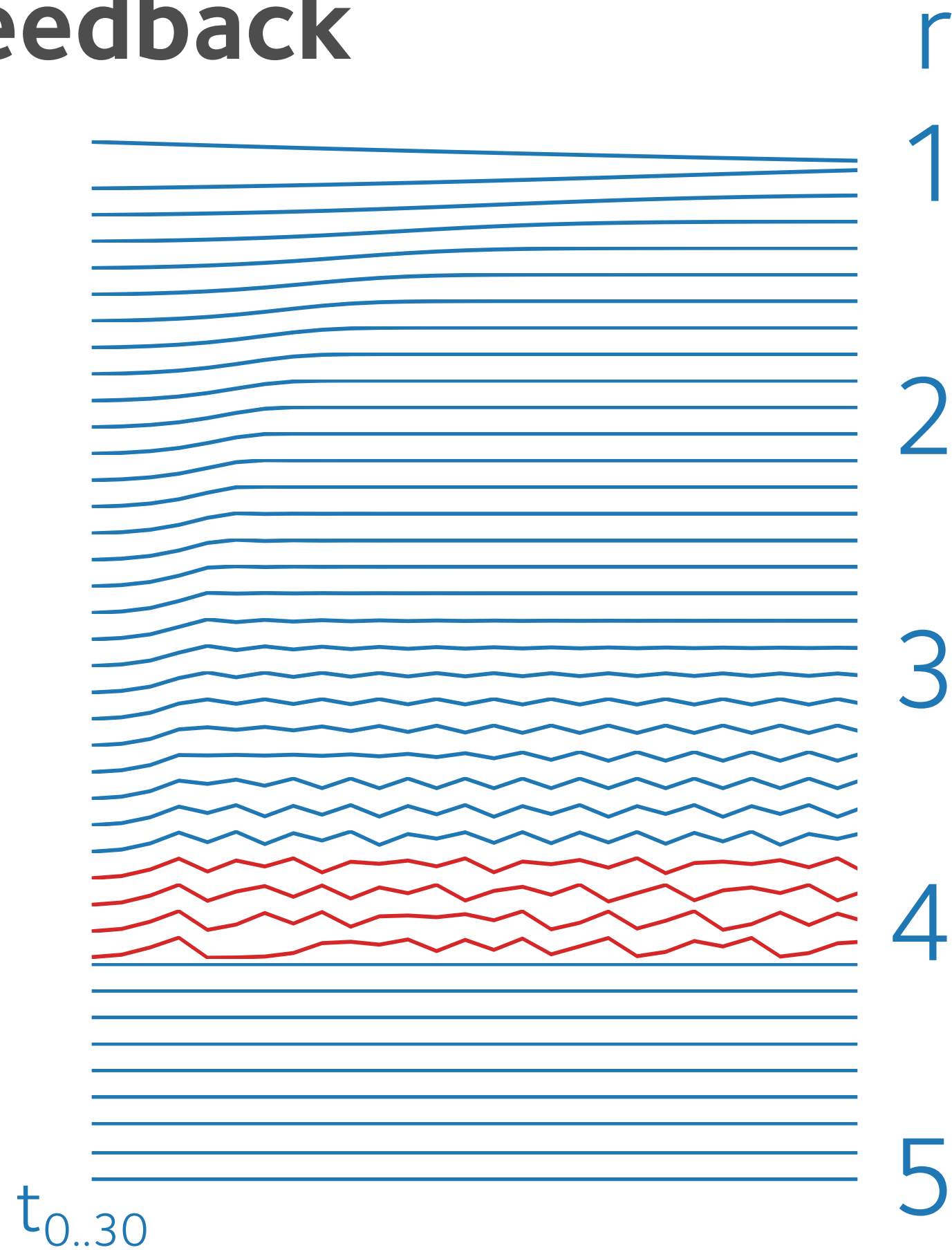


The power of feedback

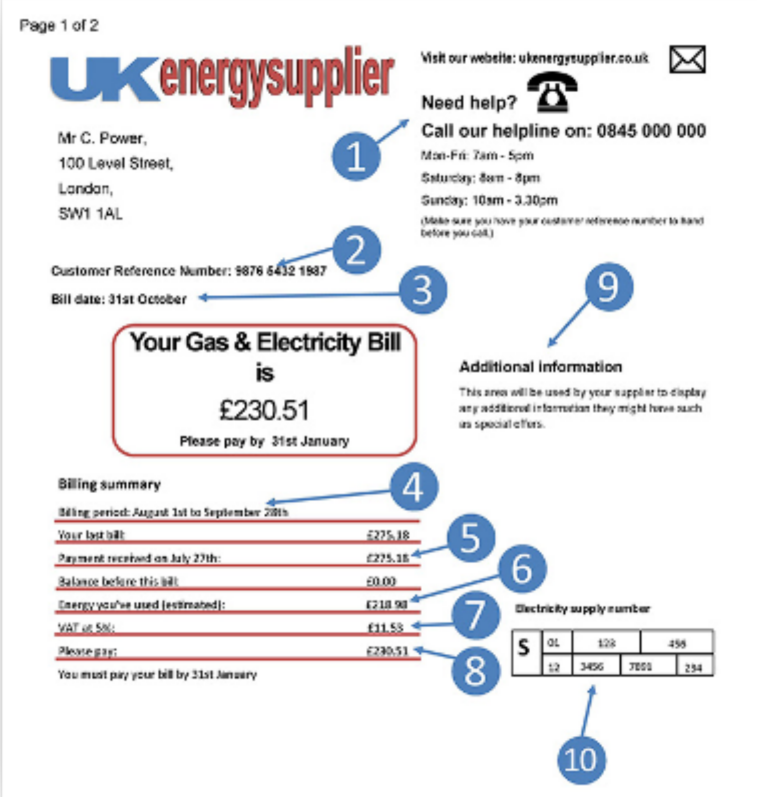


The power of feedback

$$S_{t+1} = S_t \times r(1 - S_t)$$



Good feedback?





Visit our website: ukenergysupplier.co.uk



Need help?



Call our helpline on: 0845 000 000

Mon-Fri: 7am - 5pm

Saturday: 8am - 8pm

Sunday: 10am - 3.30pm

(Make sure you have your customer reference number to hand before you call.)

Mr C. Power,
100 Level Street,
London,
SW1 1AL

Customer Reference Number: 9876 6432 1987

Bill date: 31st October

Your Gas & Electricity Bill
is
£230.51
Please pay by 31st January

Additional information

This area will be used by your supplier to display any additional information they might have such as special offers.

Billing summary

Billing period: August 1st to September 28th

Your last bill: £275.18

Payment received on July 27th: £275.18

Balance before this bill: £0.00

Energy you've used (estimated): £218.98

VAT at 5%: £11.53

Please pay: £230.51

You must pay your bill by 31st January

Electricity supply number

S	01	128	456
12	3456	7890	234

TESCO

MUSSELBURGH 0485 677 9479

LOTTO BOTH	4.00
CHOC DIGESTIVE *	0.25
CHOC DIGESTIVE *	0.25
BEETROOT	90.20
CHOPPED HAM	0.35
CHOPPED HAM	0.35
POTATOES	0.18
NEWSPAPER	0.35
BANANAS	0.79
TOTAL	96.72

Data for feedback

Data

1.7 kW

0.24 kgCO_{2e}

011000110

101111101

000000110

101011001

111010011

000010110



Information



Message

Fridge: €12 last month
Heating: €160 last month



A new 50l fridge suits your needs and pays for itself in 2 years.

options

do it

A 3kW heat pump is your best next carbon saving step for you

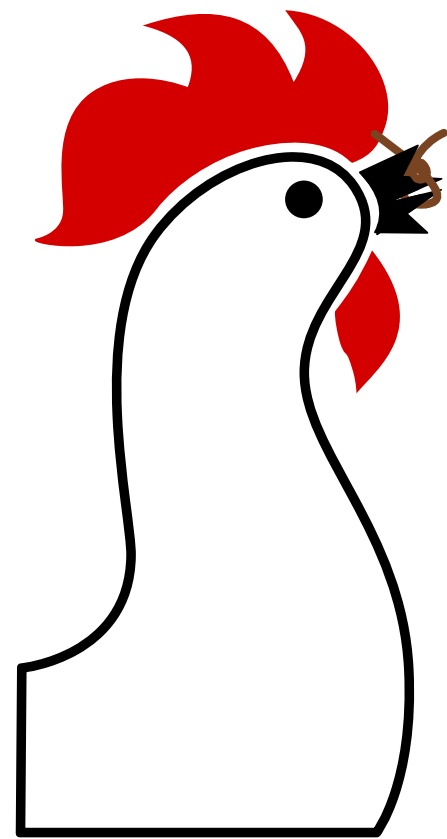
options

do it

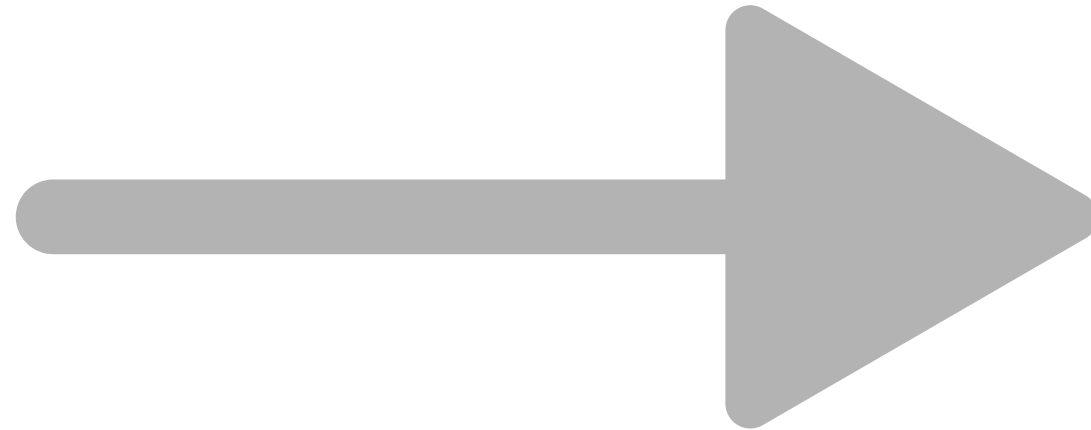


Judea Pearl

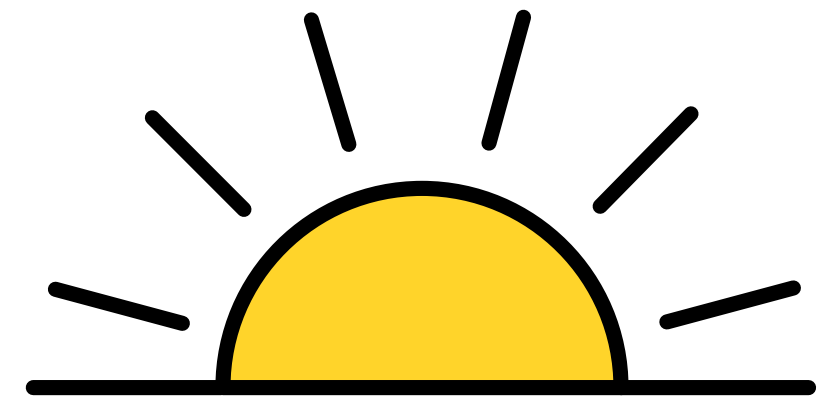
What **causes** the sun to rise?



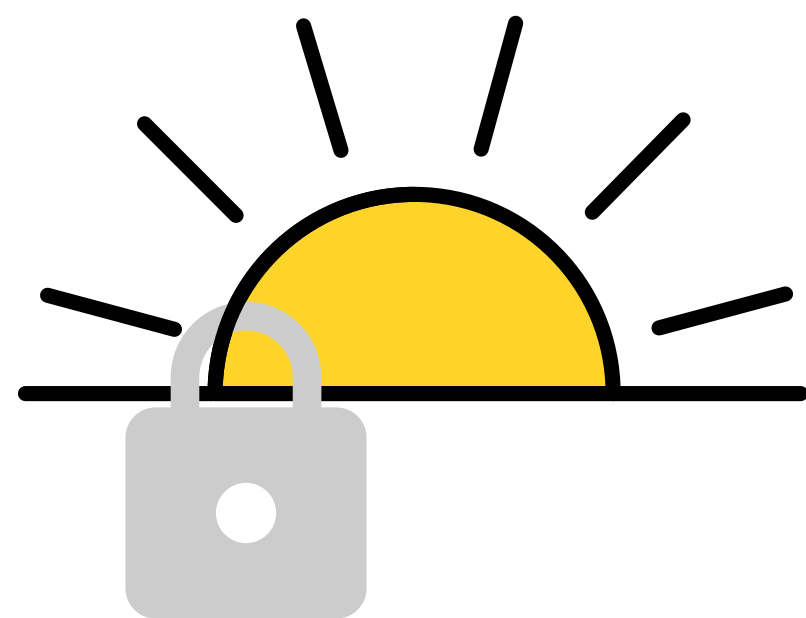
$P(\text{Sun} \mid \text{Crow})$



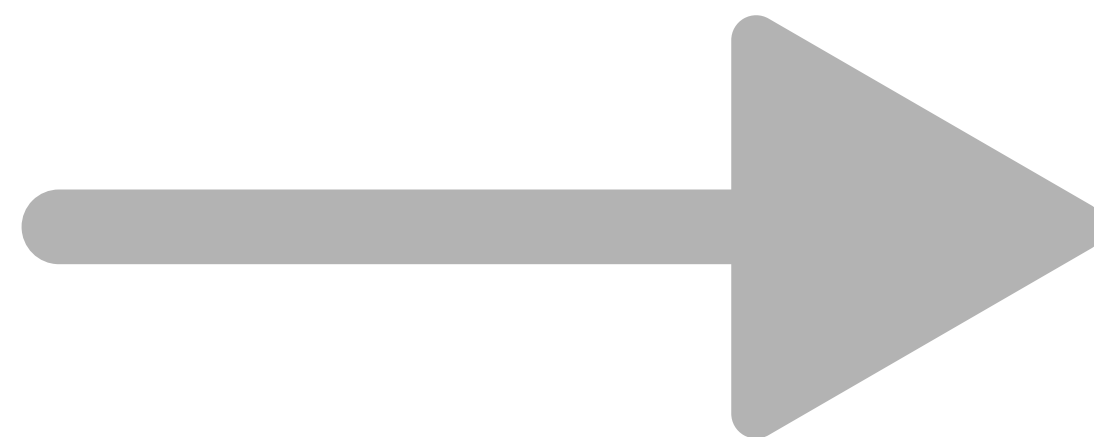
$P(\text{Sun} \mid \text{do not (Crow)})$



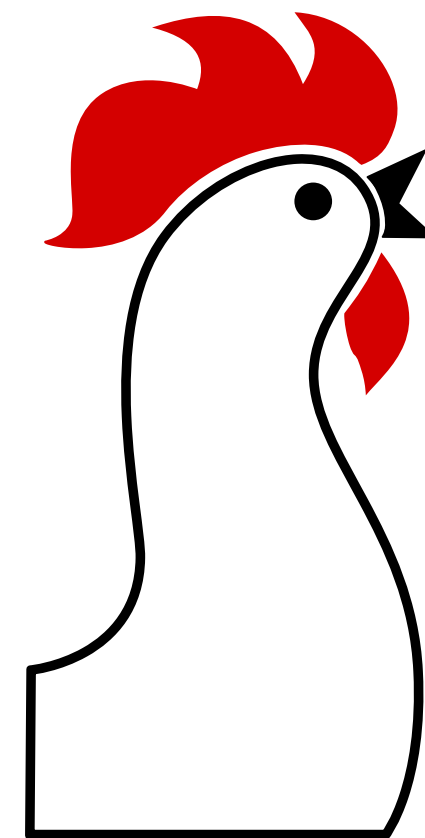
What **causes** the the cockerill to crow?



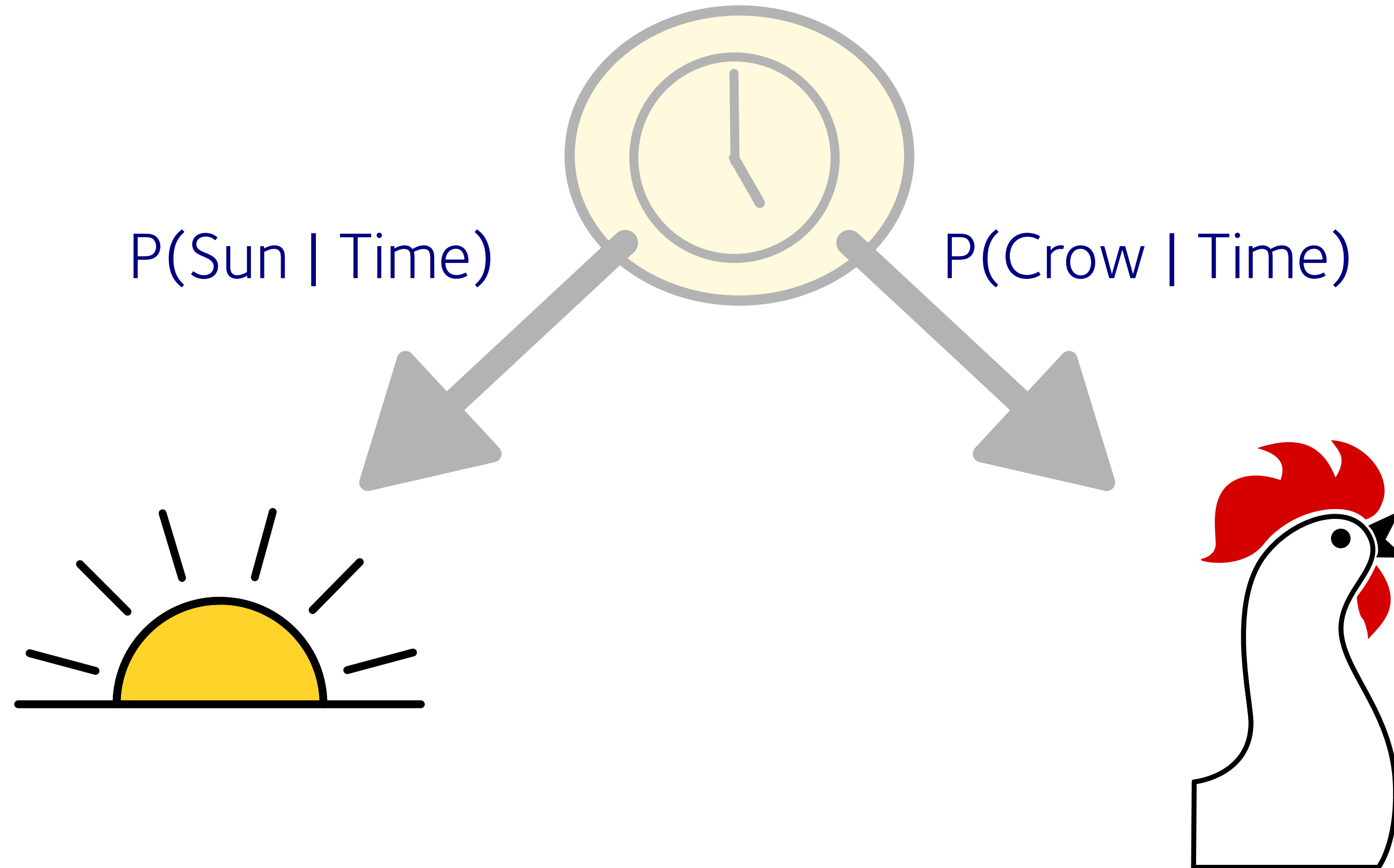
$P(\text{Crow} \mid \text{Sun})$



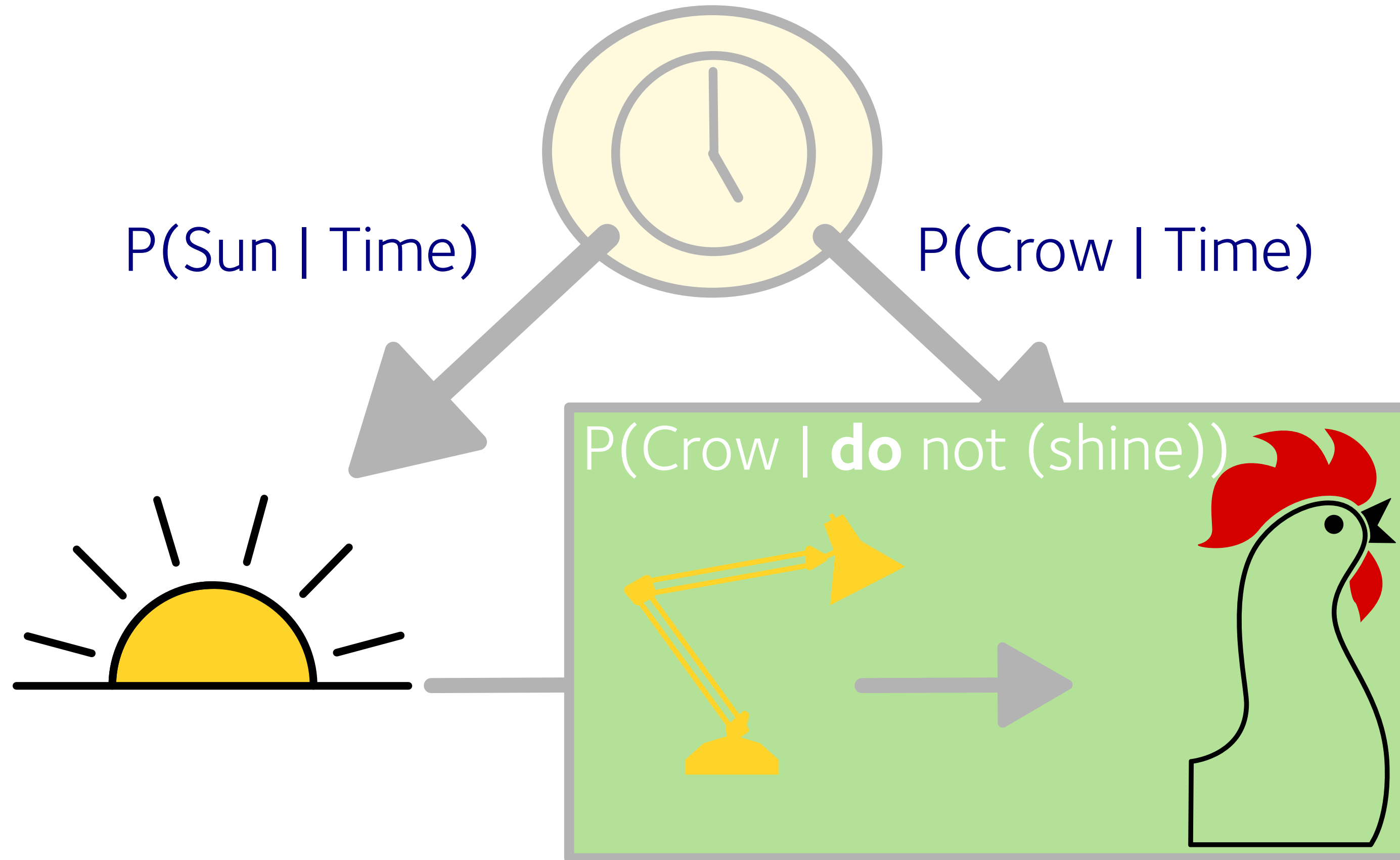
$P(\text{Crow} \mid \text{do not (Sun)})$



How to eliminate confounders?



How to eliminate confounders?



To understand causes we need (up to) three things

Causal model

Observation

Do something

Energy demand research is evolving

Understanding Demand

No data

Assume
& model

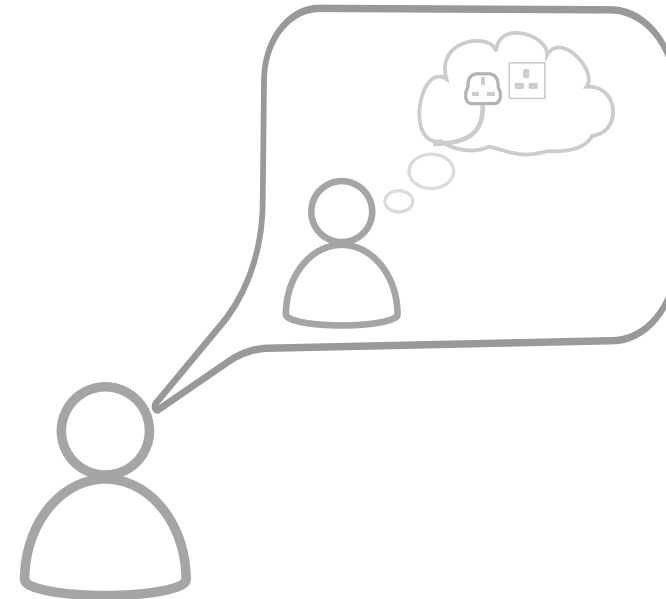
What **I think**
people do



Some data

Interpolate
& scale up

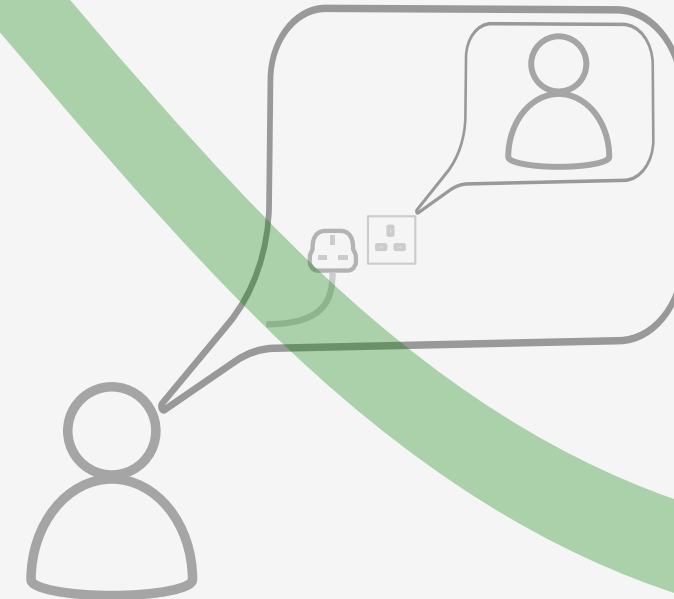
What **people** think
they do



Big data

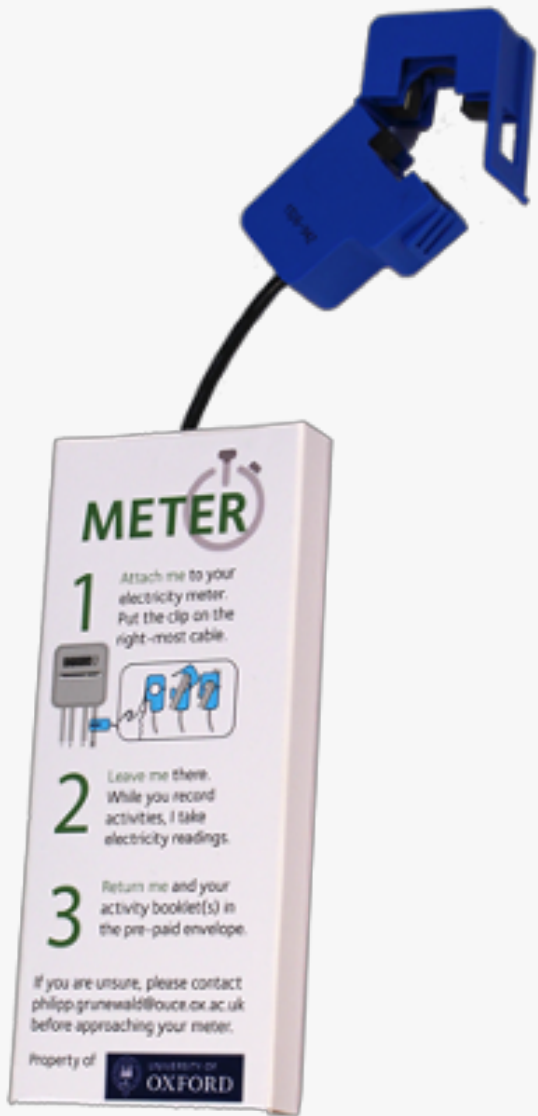
Train model
& analyse

What **data** says
people do



Understanding demand the hard way

JoyMeter.uk



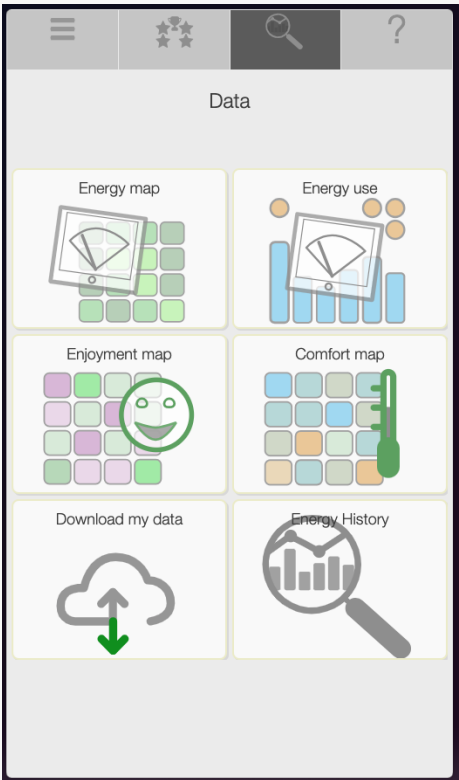
Current clamp



EDDI



App



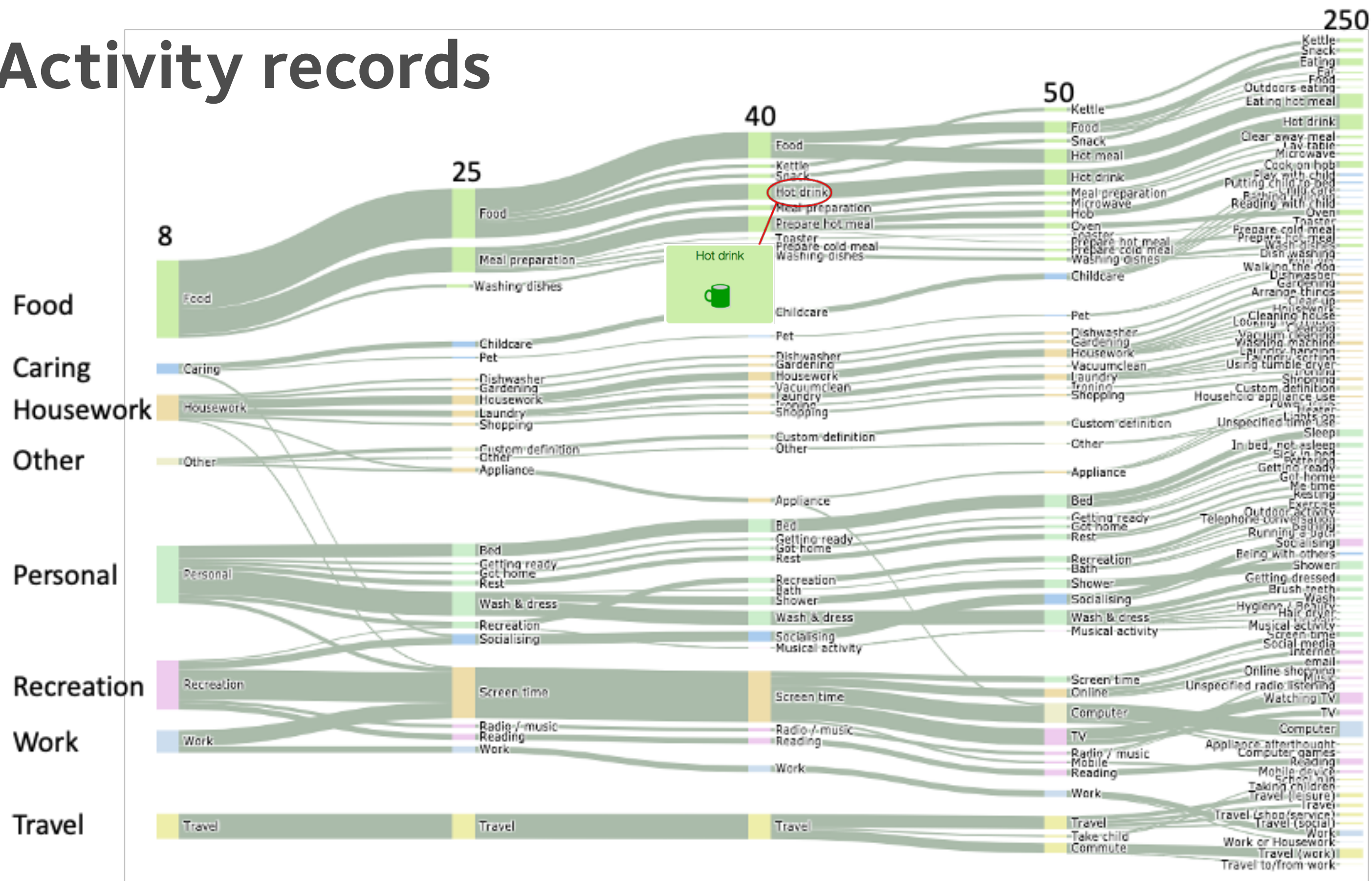
CAD (Consumer
Access Device)

Diary

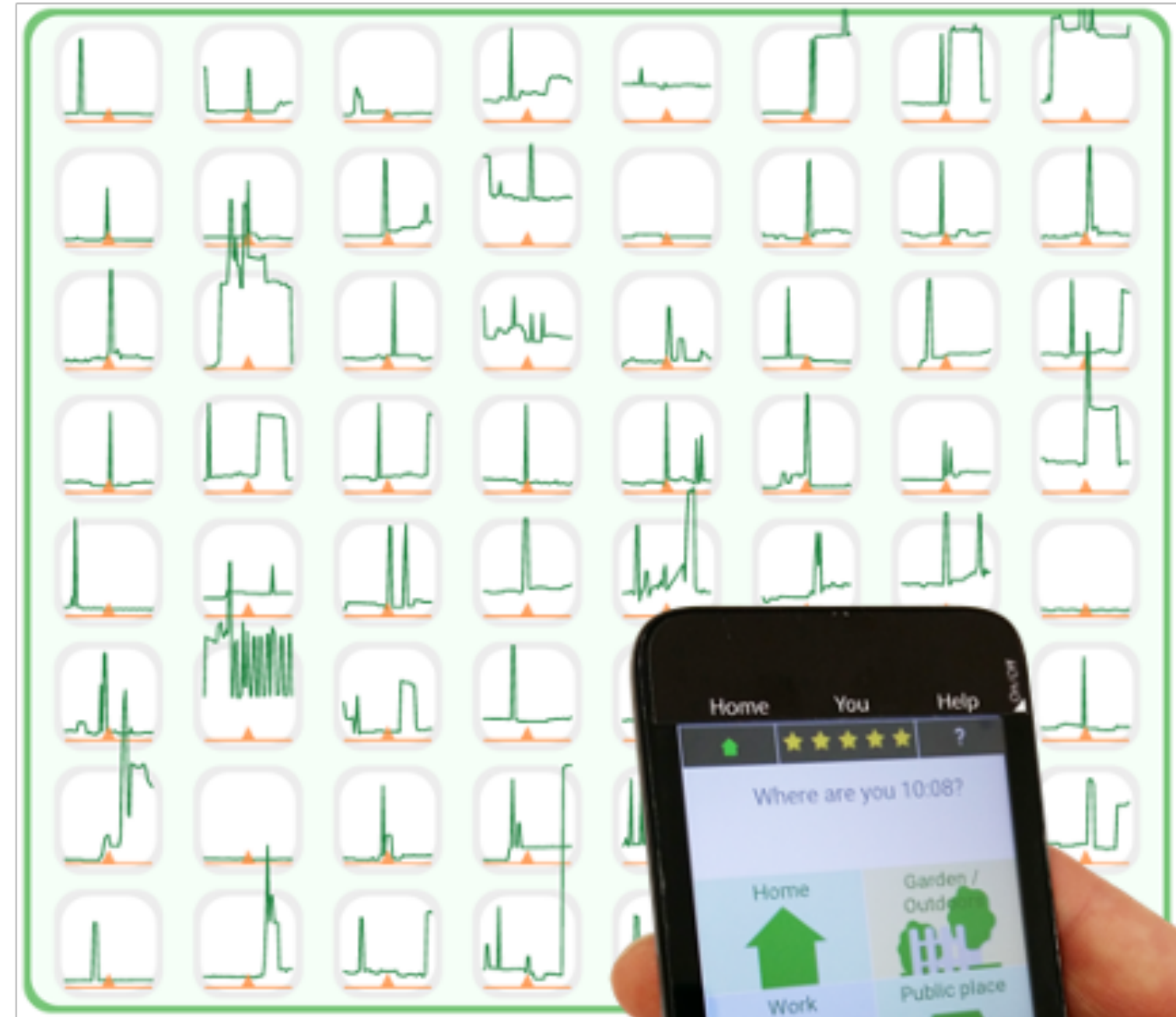
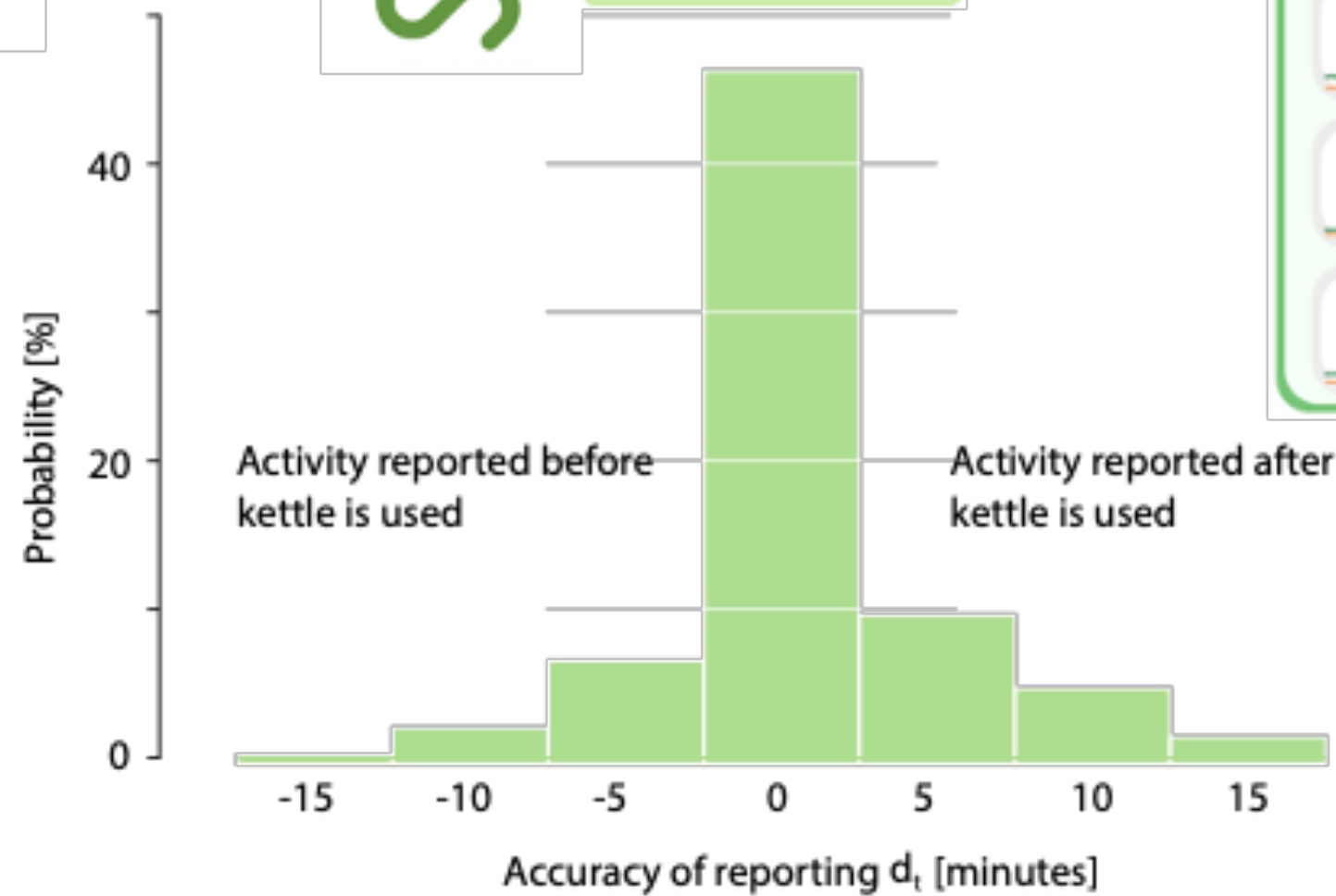


Time	What were you doing? Please write down your activities
5:00 p.m.	TV
5.40	prepare dinner
6.00	lay

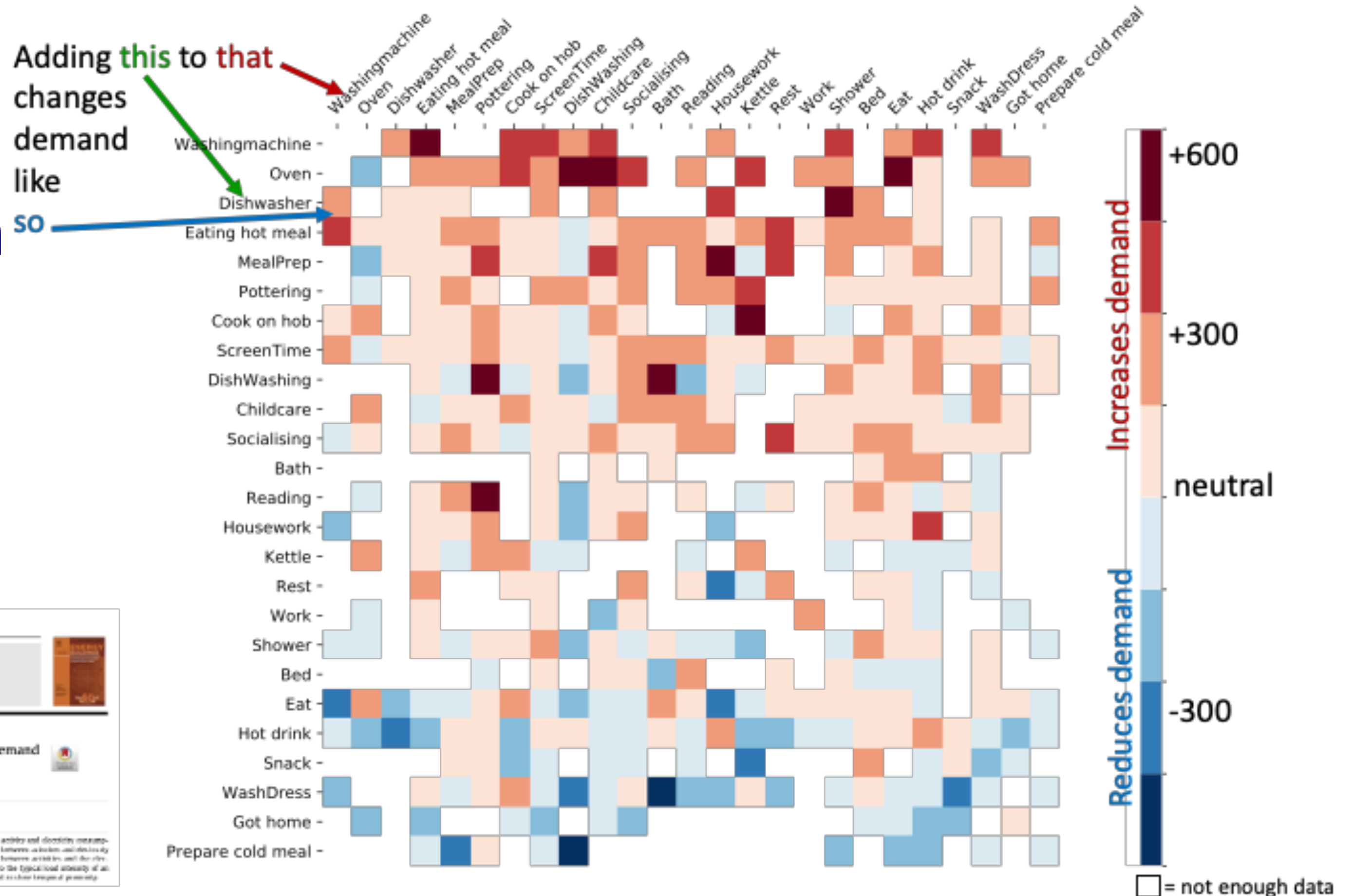
Activity records



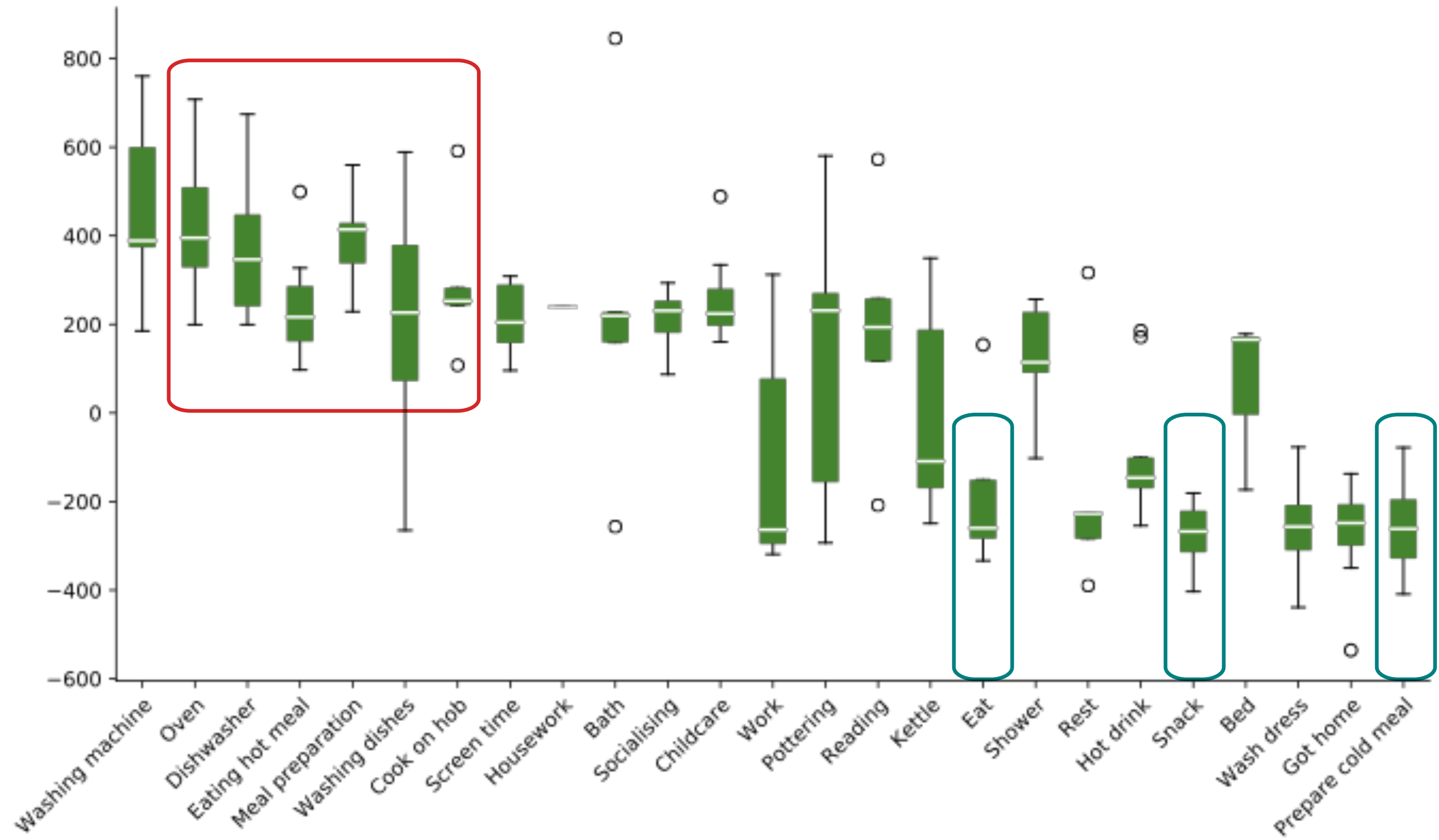
Tea-test



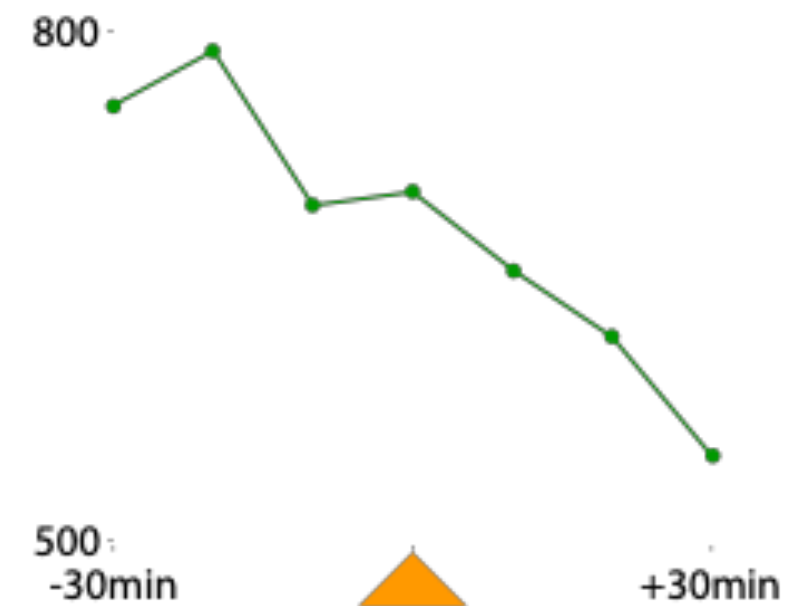
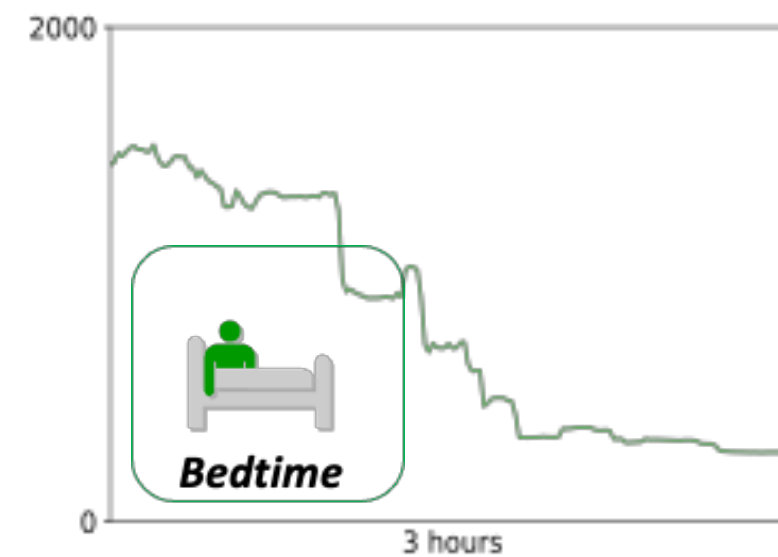
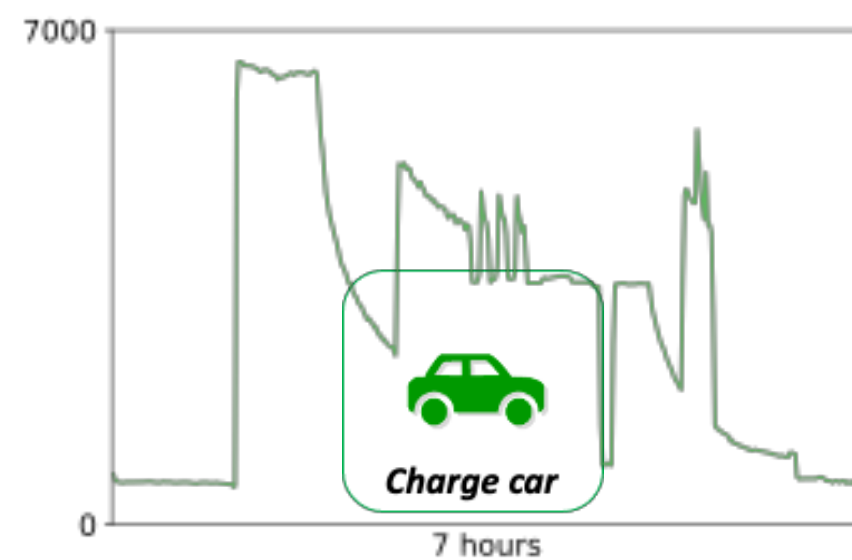
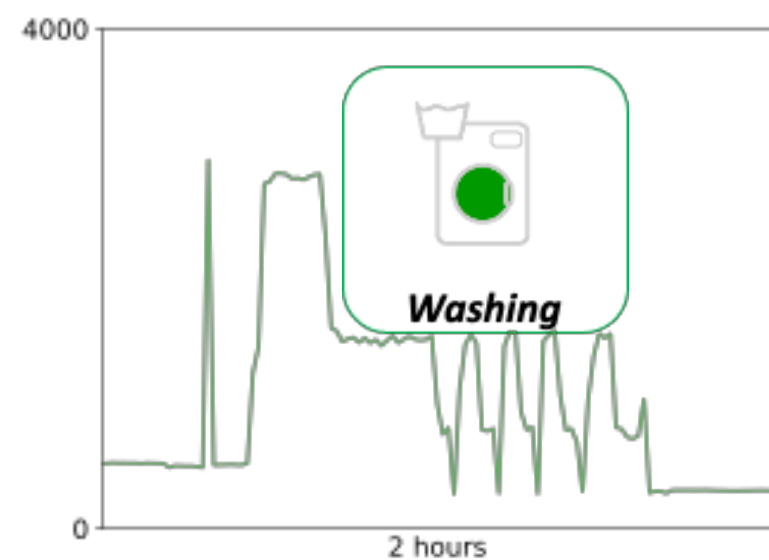
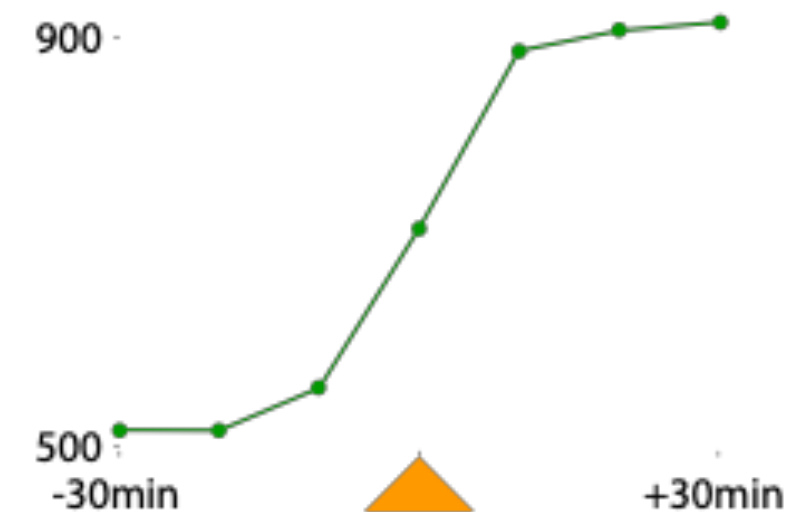
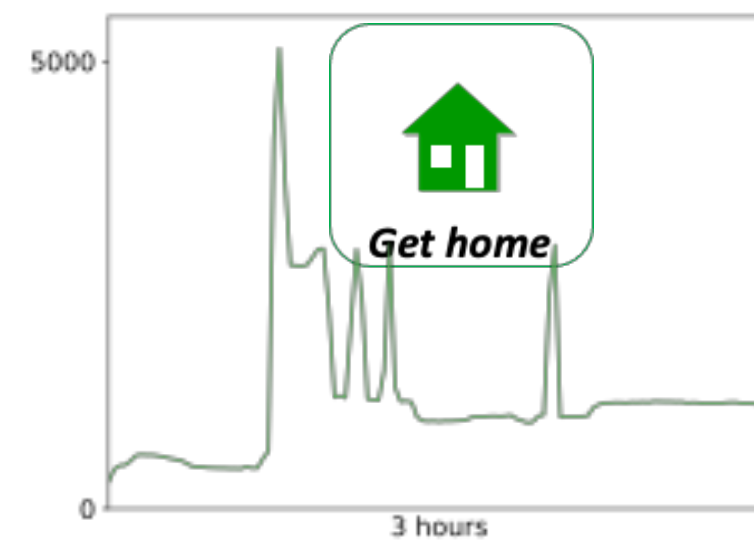
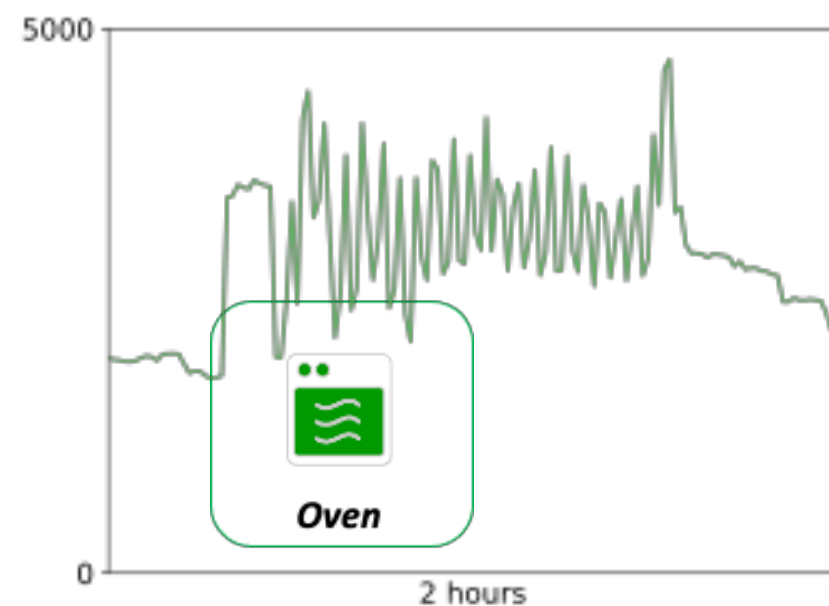
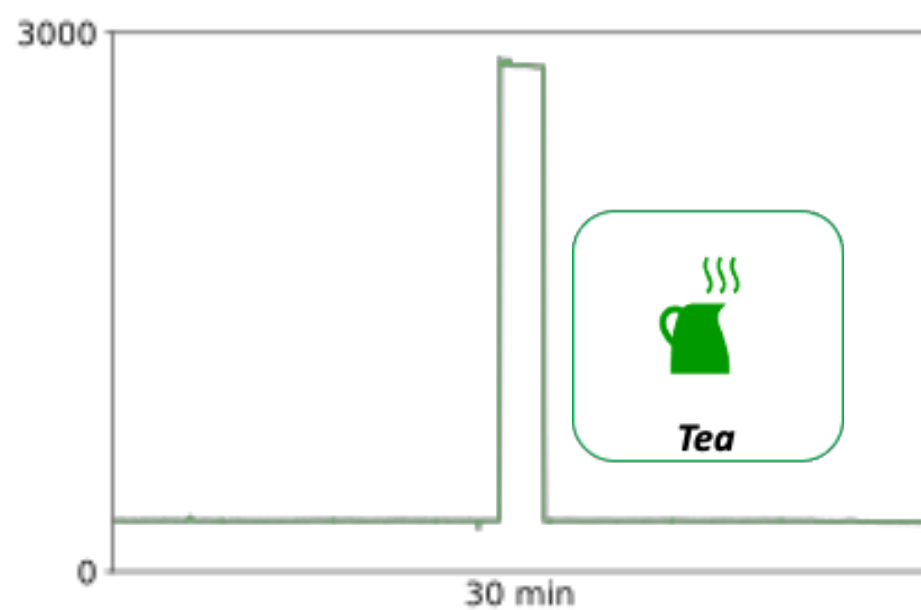
What is the 'marginal' contribution of activities to demand?



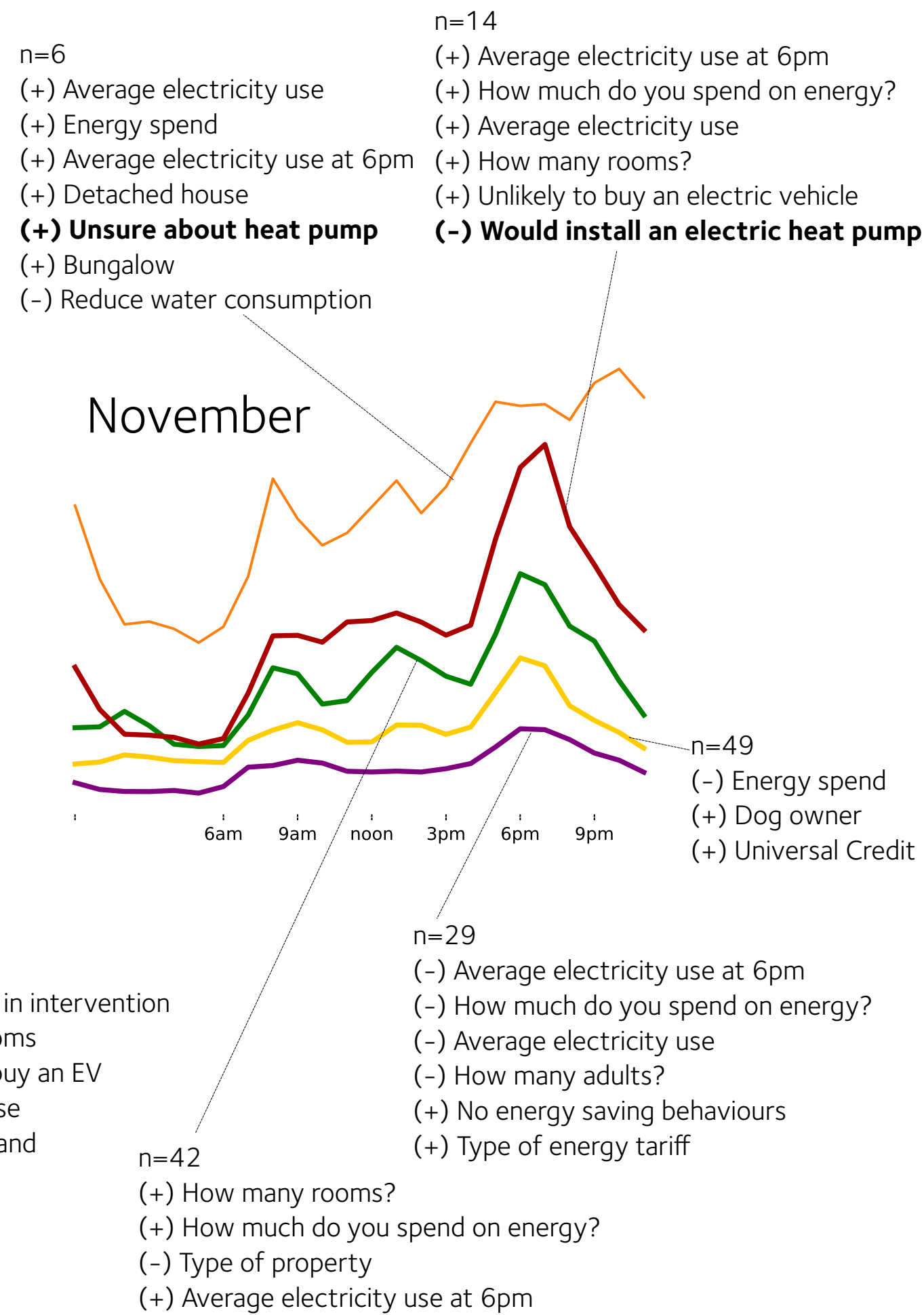
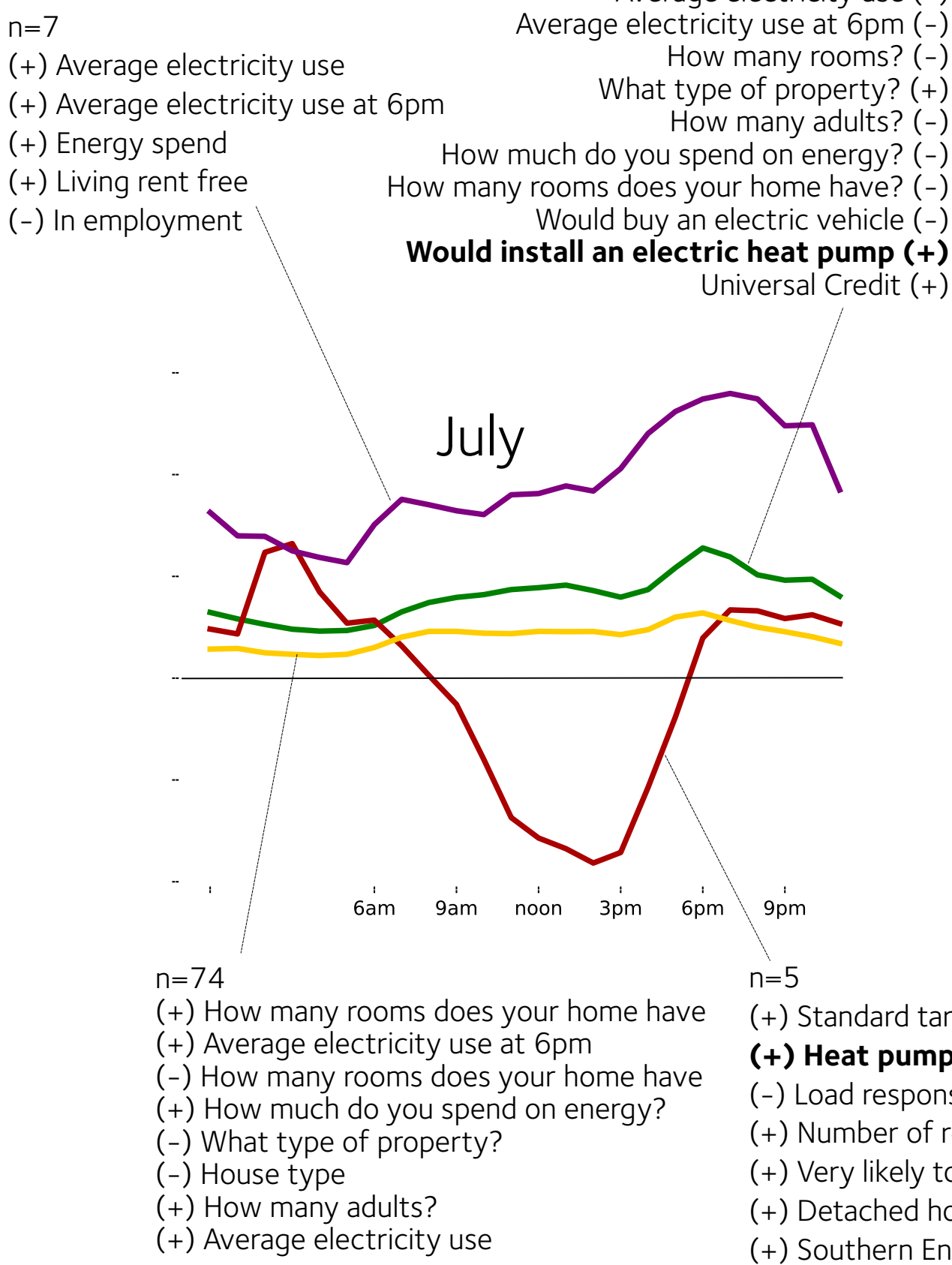
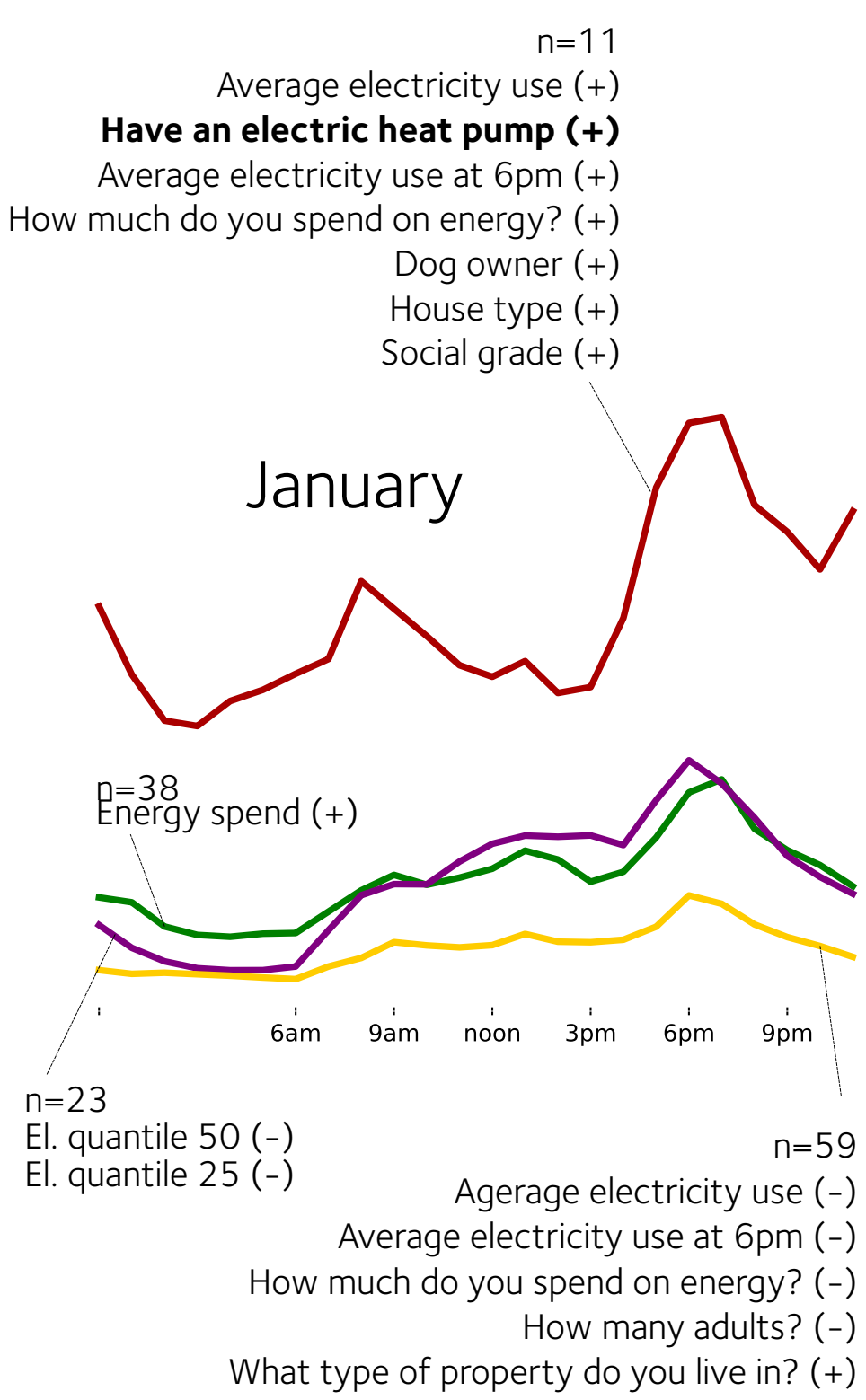
Marginal contribution of activities to demand



Watts this?



DTW clusters



Top 12 enjoyable activities

1. Socialising
2. Reading
3. Eating hot meal
4. Snack
5. Exercise
6. Sleep
7. Hot drink
8. TV
9. Got home
10. Eating
11. Me time
12. Gardening



1. Clear up
2. Wash dishes
3. Washing machine
4. Clear away meal
5. Wash
6. Travel (work)
7. Arrange things
8. Getting dressed
9. Brush teeth
10. Work
11. Computer
12. Travel (shop/service)



Enjoyment of activities and demand



Part I

- System flexibility
- Energy needs and uses
- Feedback systems
- Causality

Part II

- Demand side flexibility
- Price elasticity
- Data and privacy
- Synthetic data