DEPARTMENT OF ENGINEERING SCIENCE

UNIVERSITY OF OXFORD

people

~~technology~~

It's the ~~economy~~, stupid

# Energy services, flexibility and data

# Part I

Energy Systems MSc – Energy Demand – MT2024

Phil Grunewald

energy-use.org/slides

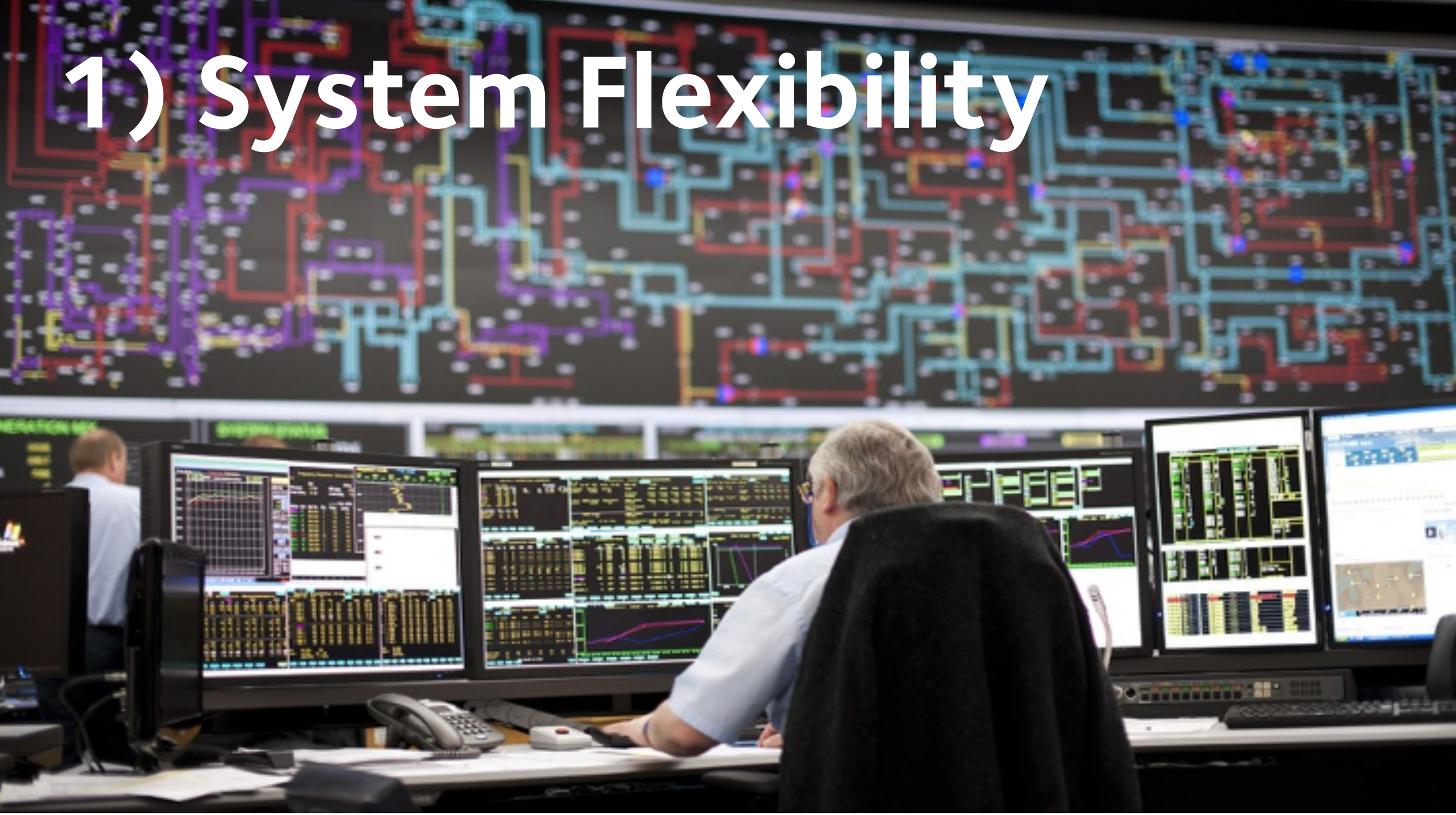
## Part I

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

## Part II

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

# 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

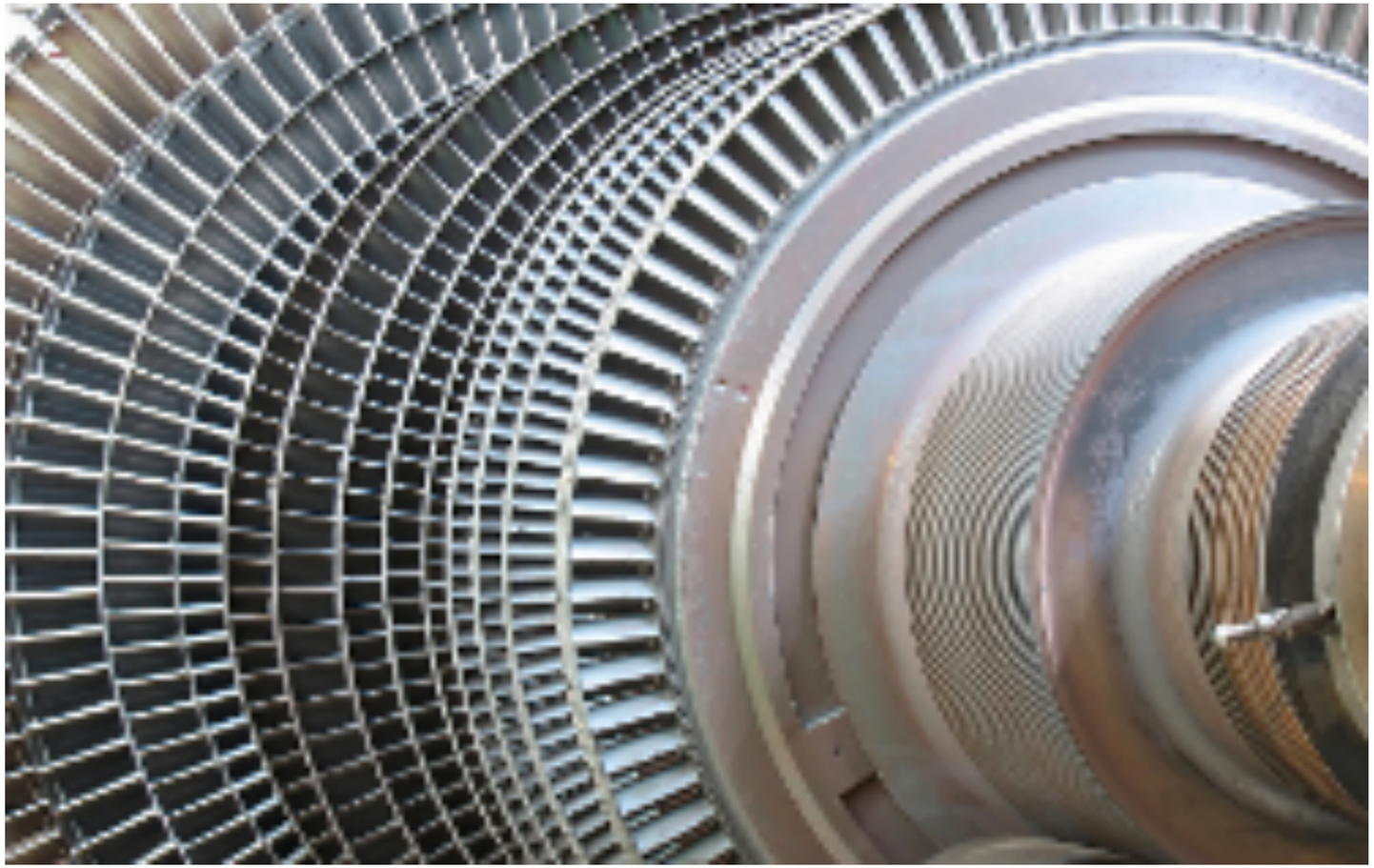
Renewables
£0 /MWh

Merit order

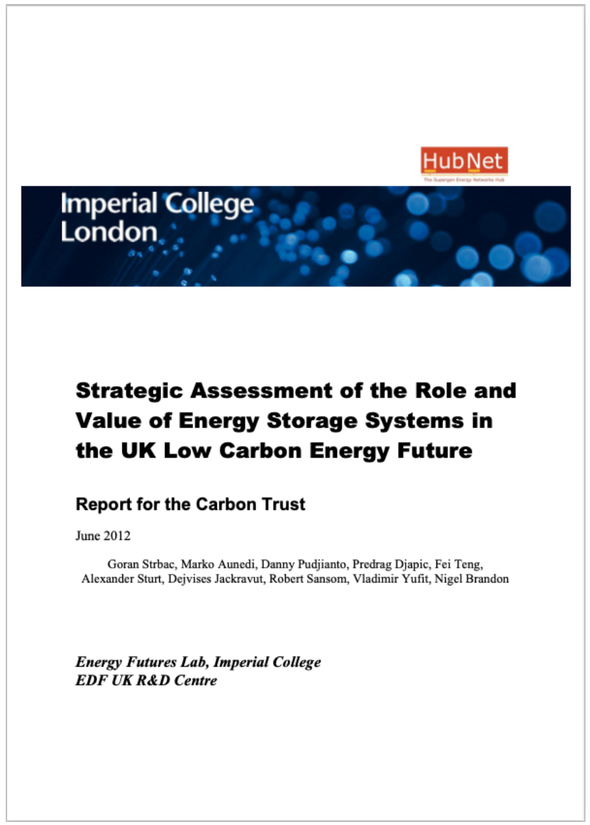
Peak pricing

Curtailment

Spinning reserve



# The (passive) flexibility we will miss

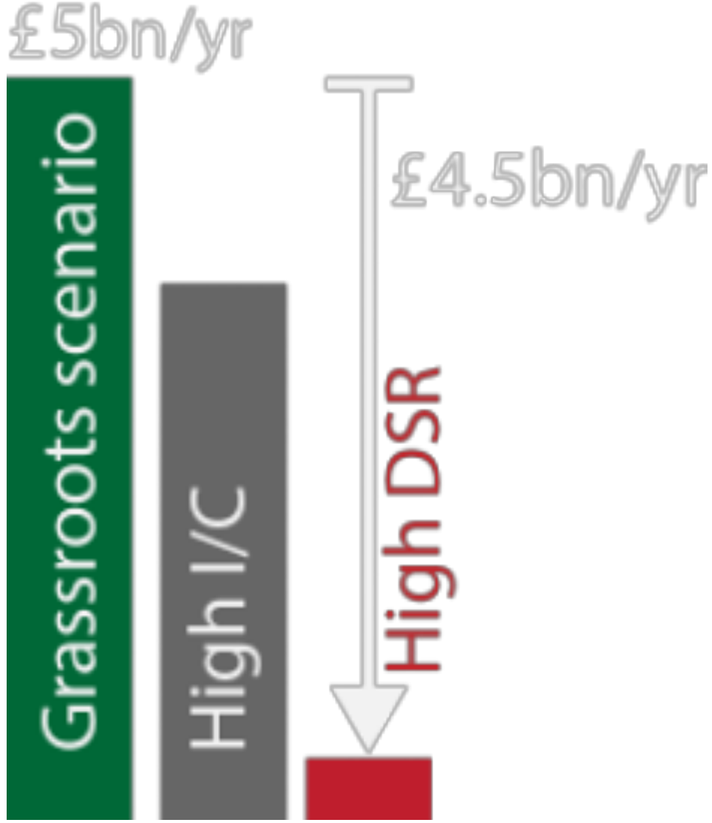

# Demand matters

## Estimated cost saving

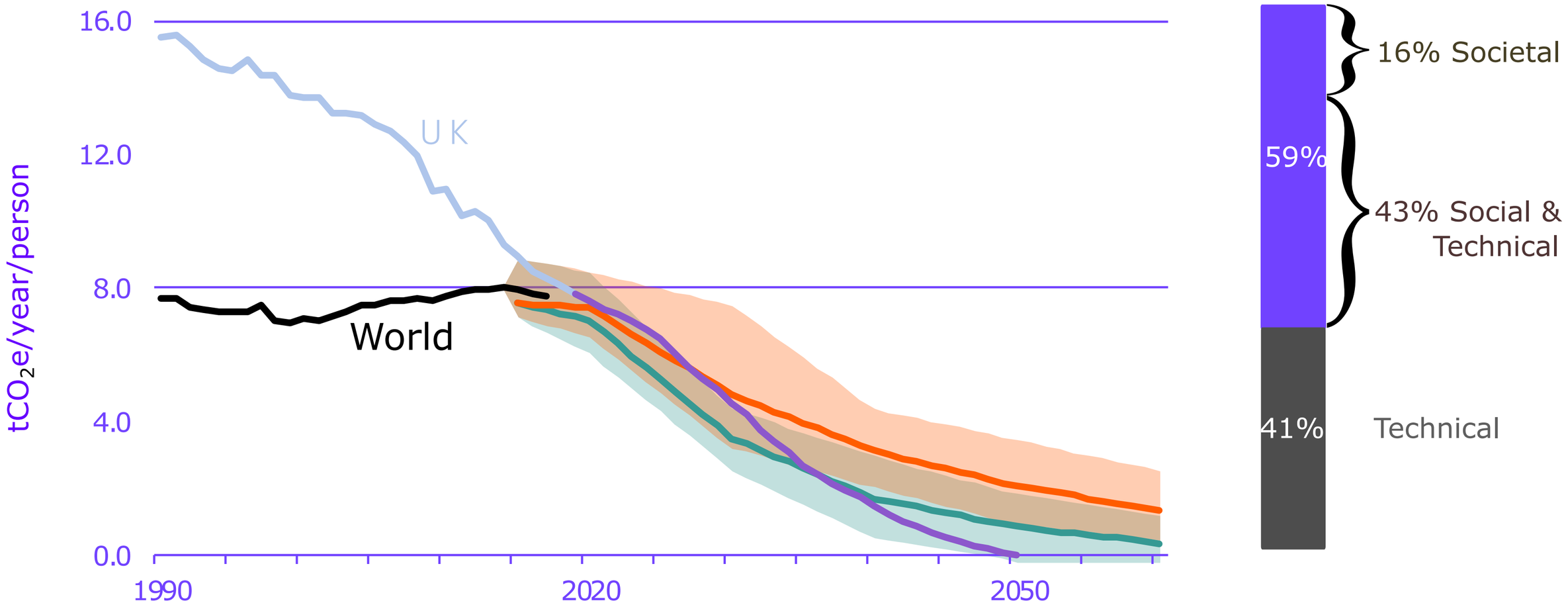
**£40** (up to)

From savings on

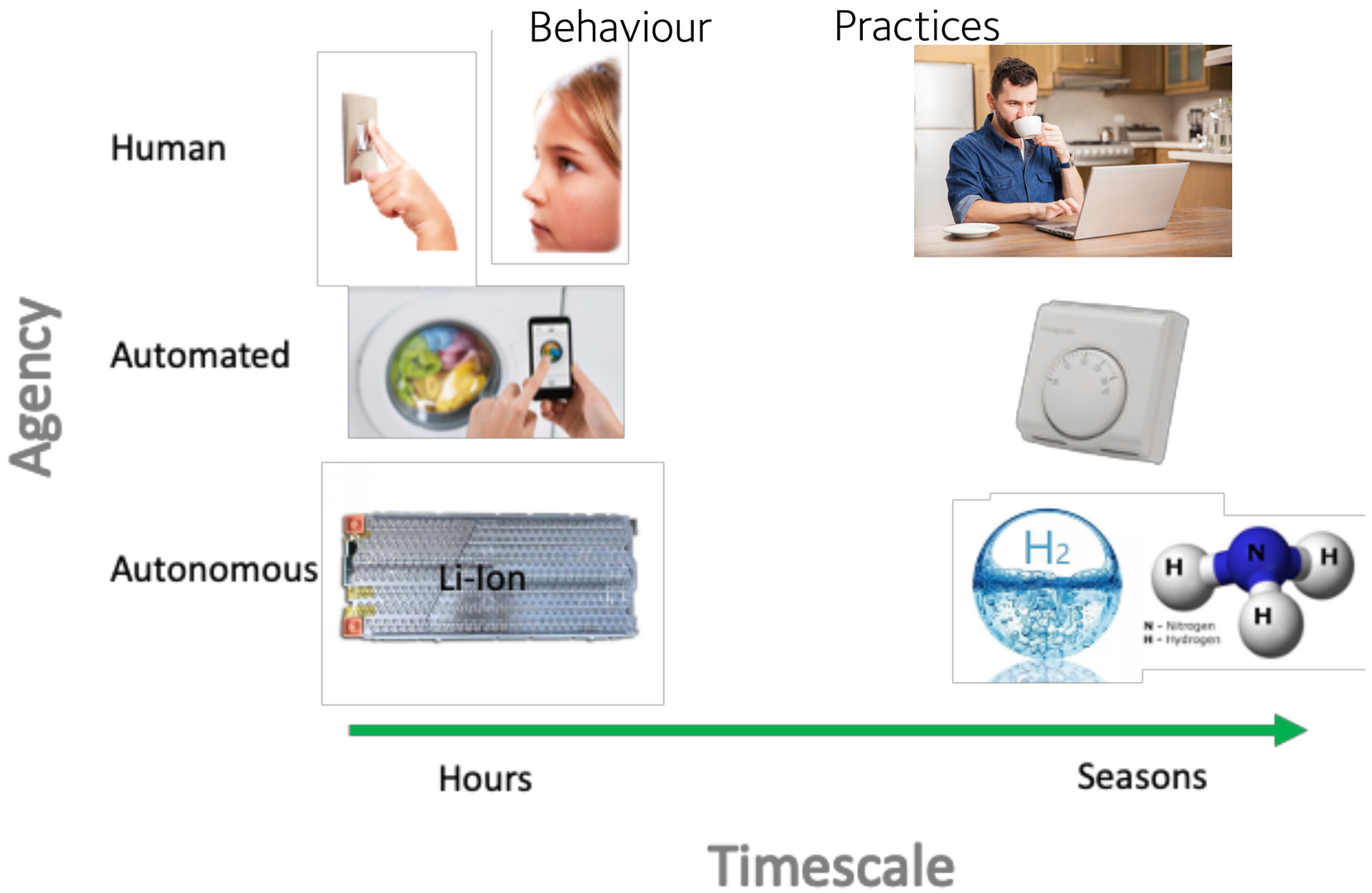
1) Capacity
2) Operation
3) Networks, I/C



# No demand measures – no net zero

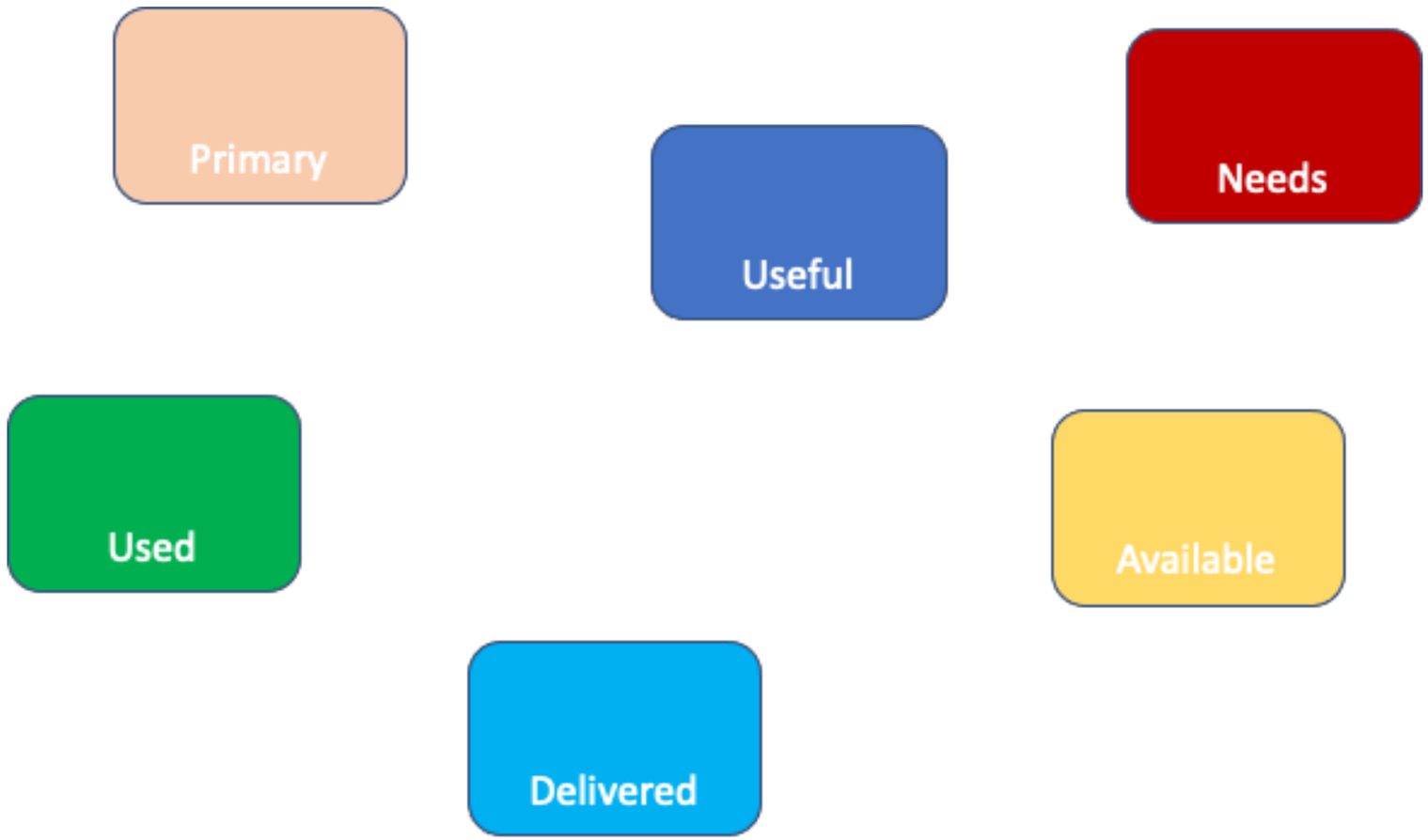



Source: Climate Change Committee. The UK's path to net zero. The sixth carbon budget, Climate Change Committee, December 2020

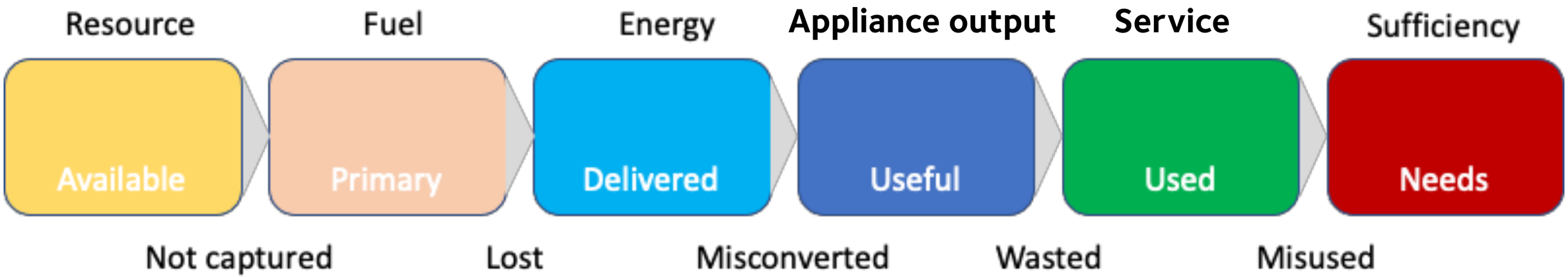

Behaviour
Practices
Human
Automated
Autonomous
Agency
Li-Ion
H2
H
N
H
H
N - Nitrogen
H - Hydrogen
Hours
Seasons
Timescale

# Energy needs and uses

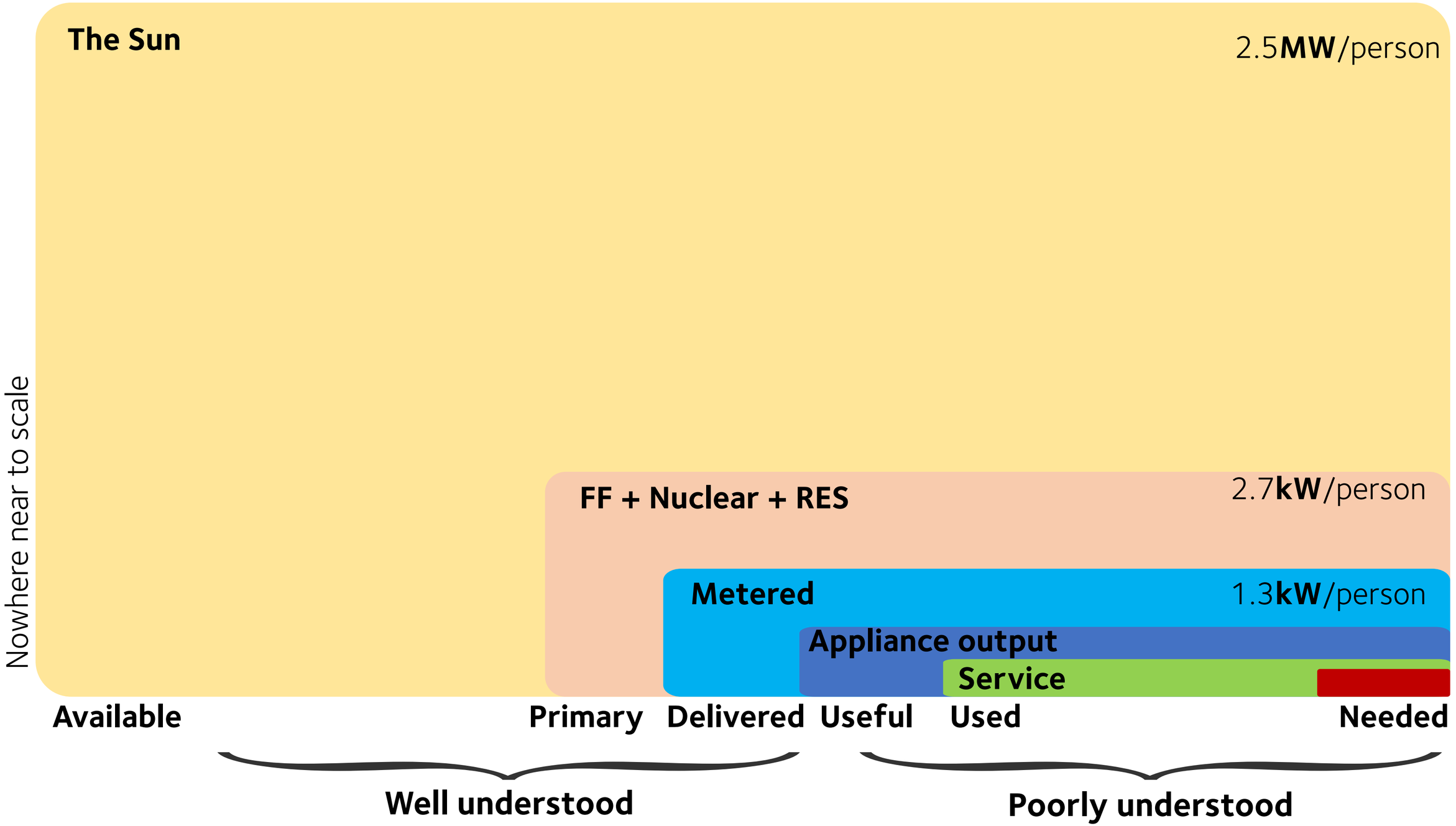
# Energy concepts



# Meaning and order of different energy forms



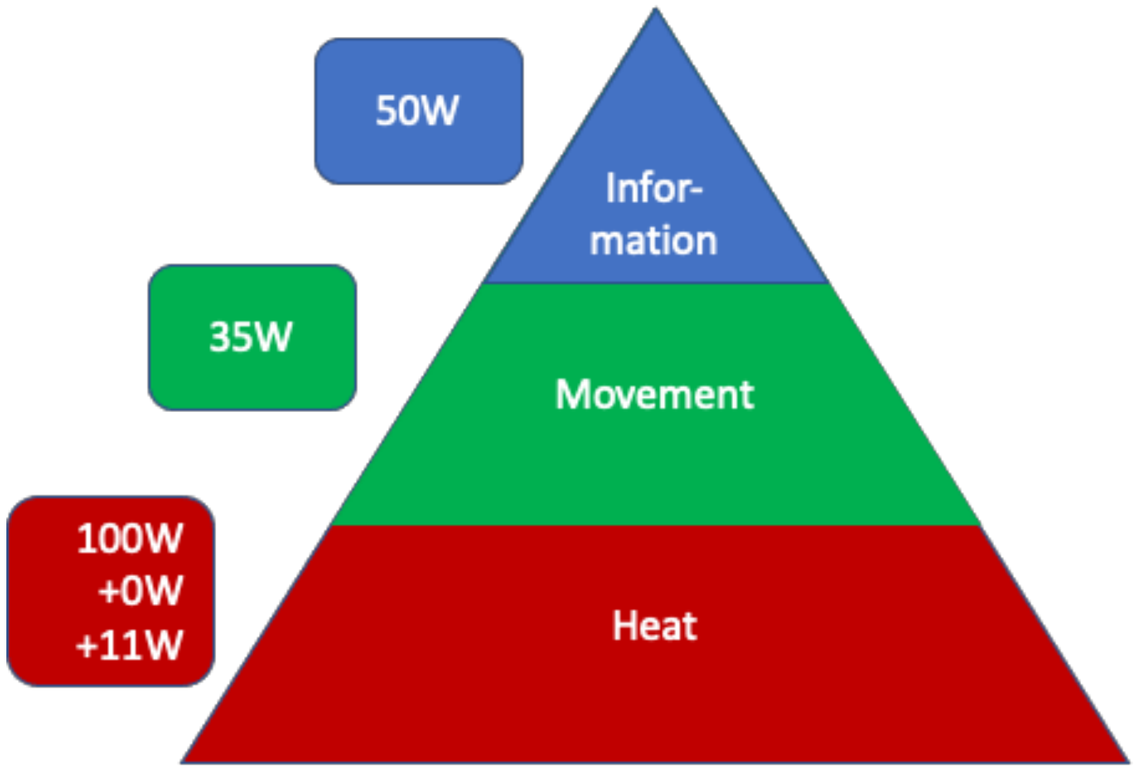

Pedal
Powered
Phone
Charging
£4 Per hour
£1.50 if you pedal!




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=100kg, v=100km/h, h=100m
- 5 trips per day: 830Wh

## Heat (100W ~2,000kcal)

- $E = -k\,\Delta T\,A$
- Inside 36°C, outside 0°C, surface $2m^2$, E=100W
- k = -1.4 W/mK

## Coolth

- Inside 36°C, outside 40°C, k = -1.4W/mK

# Energy service needs

2.5**MW**/person

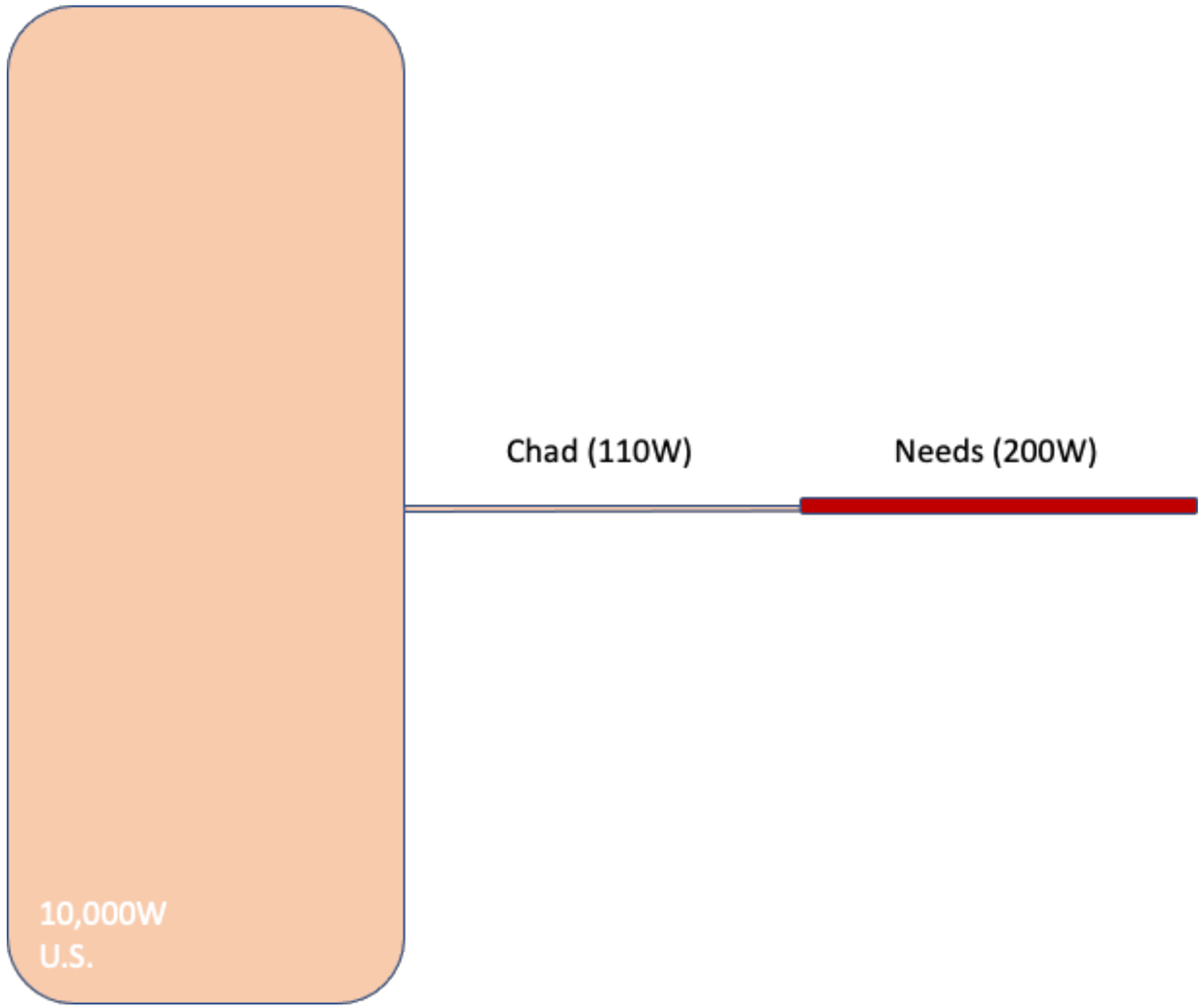
Efficiency requirement ~1 in 10,000

(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

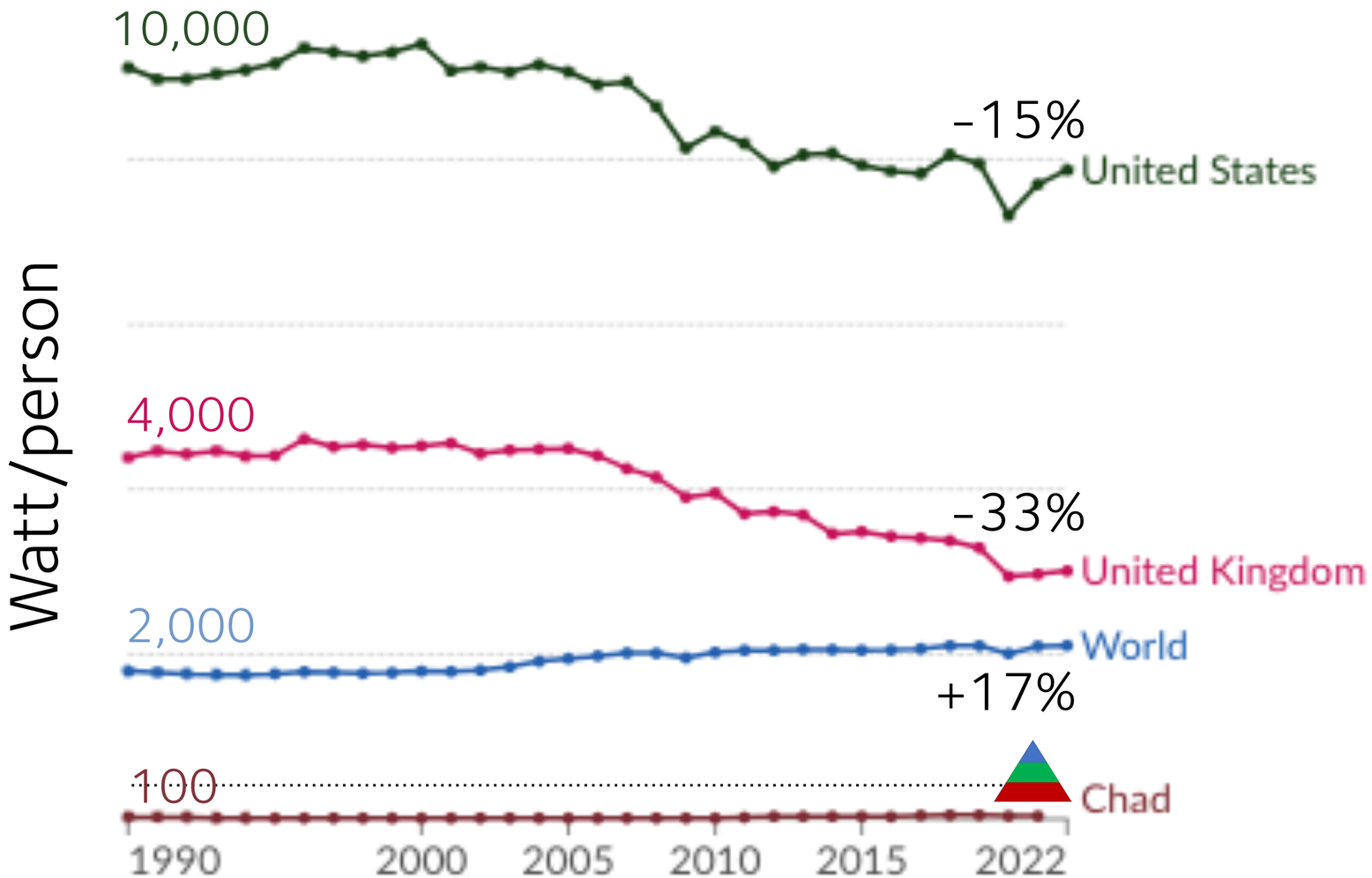
Energy use in the UK

a) Increased 50%

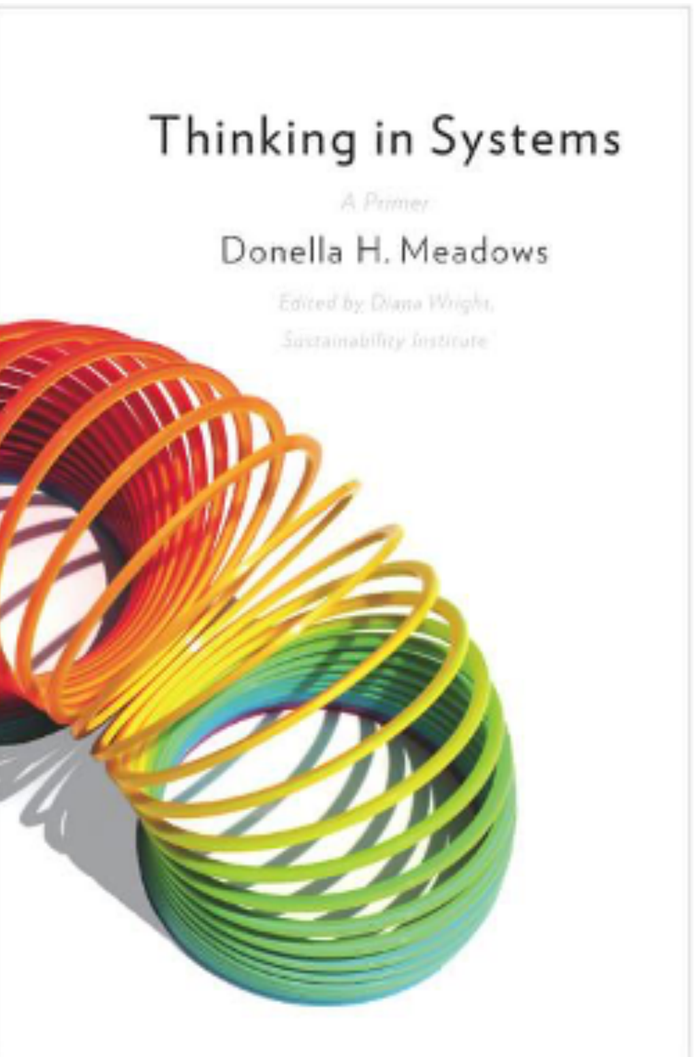
b) Increased 20%

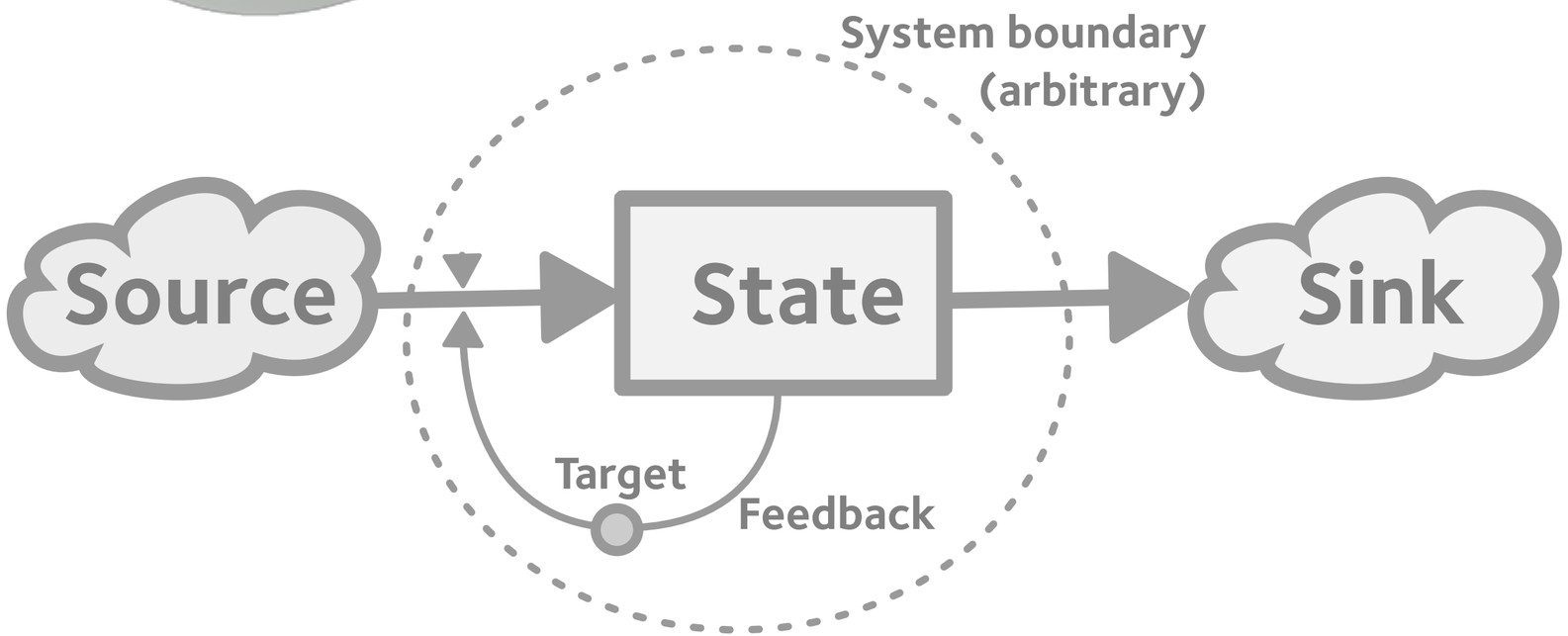
c) stayed the same

d) reduced by 20%



# Feedback Systems

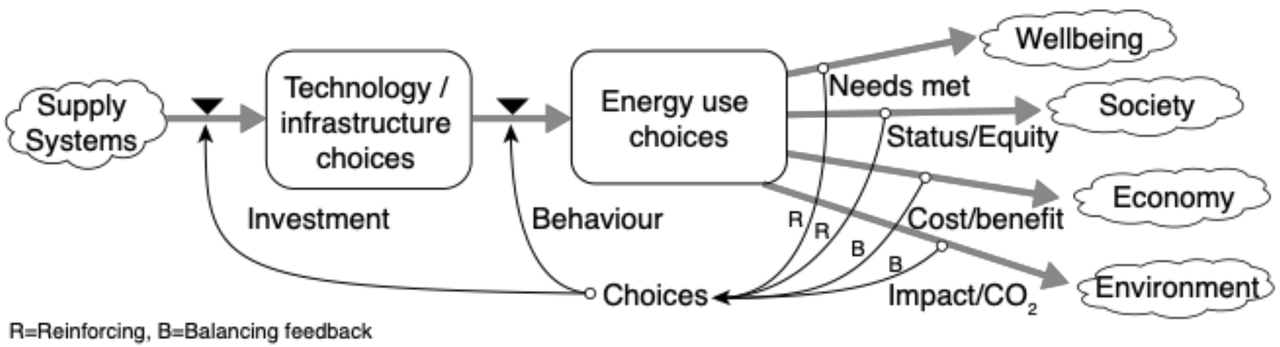

Thinking in Systems
A Primer
Donella H. Meadows
Edited by Diana Wright
Sustainability Institute


System boundary
(arbitrary)
Source
State
Sink
Target
Feedback

# Energy feedback

**Good feedback is:**

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

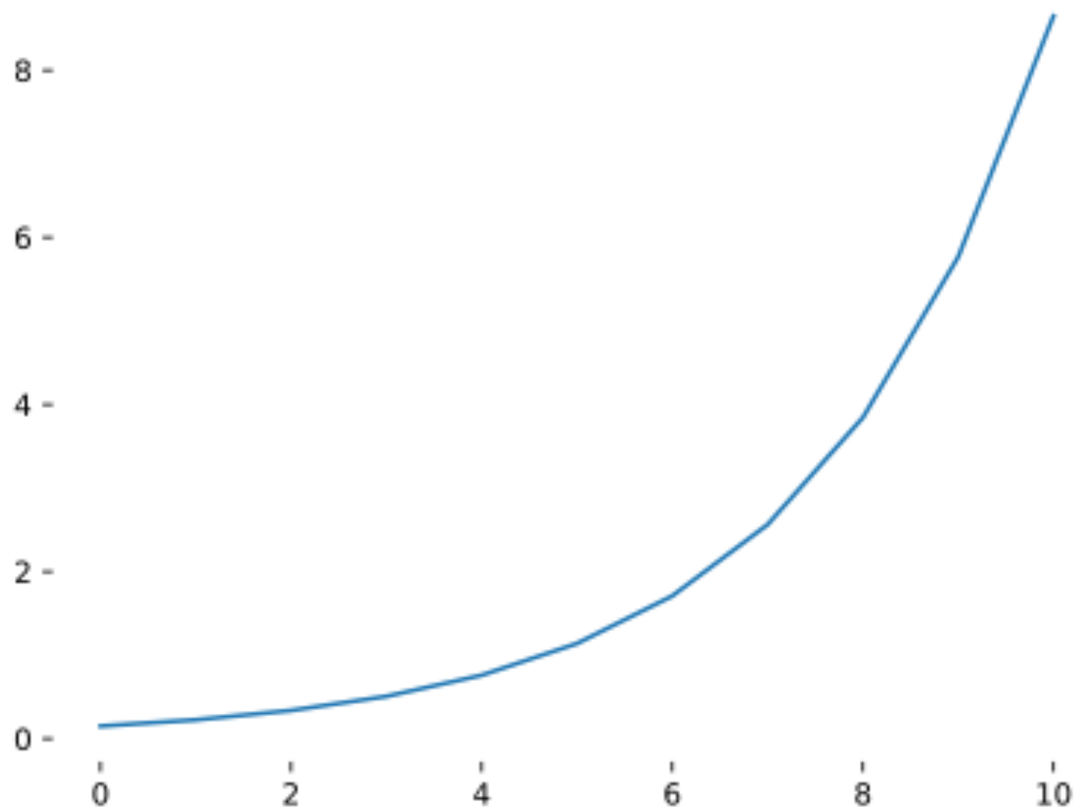


# The power of feedback

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

$S_t = \text{State at time } t$

$r = \text{growth rate}$

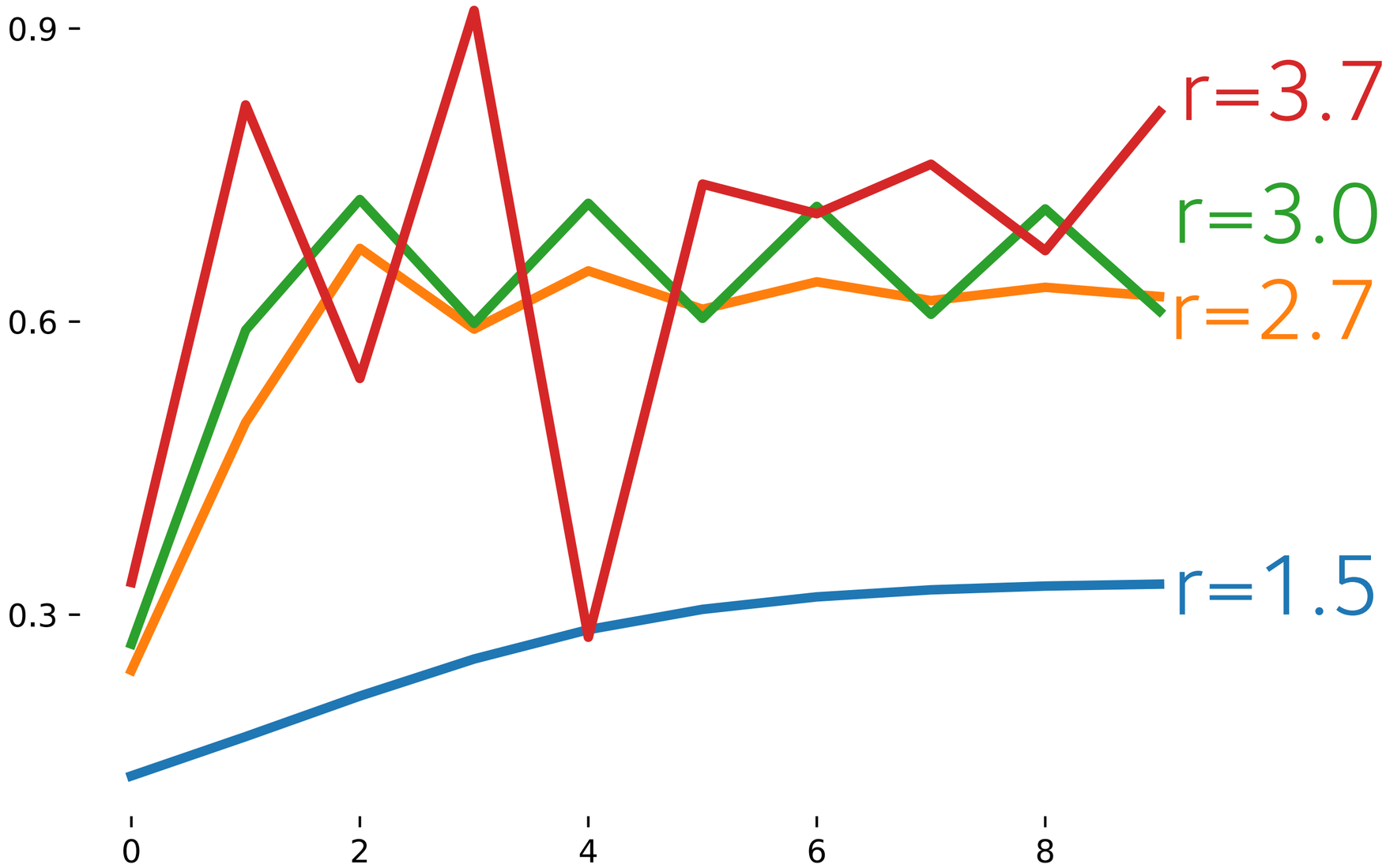


# The power of feedback

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

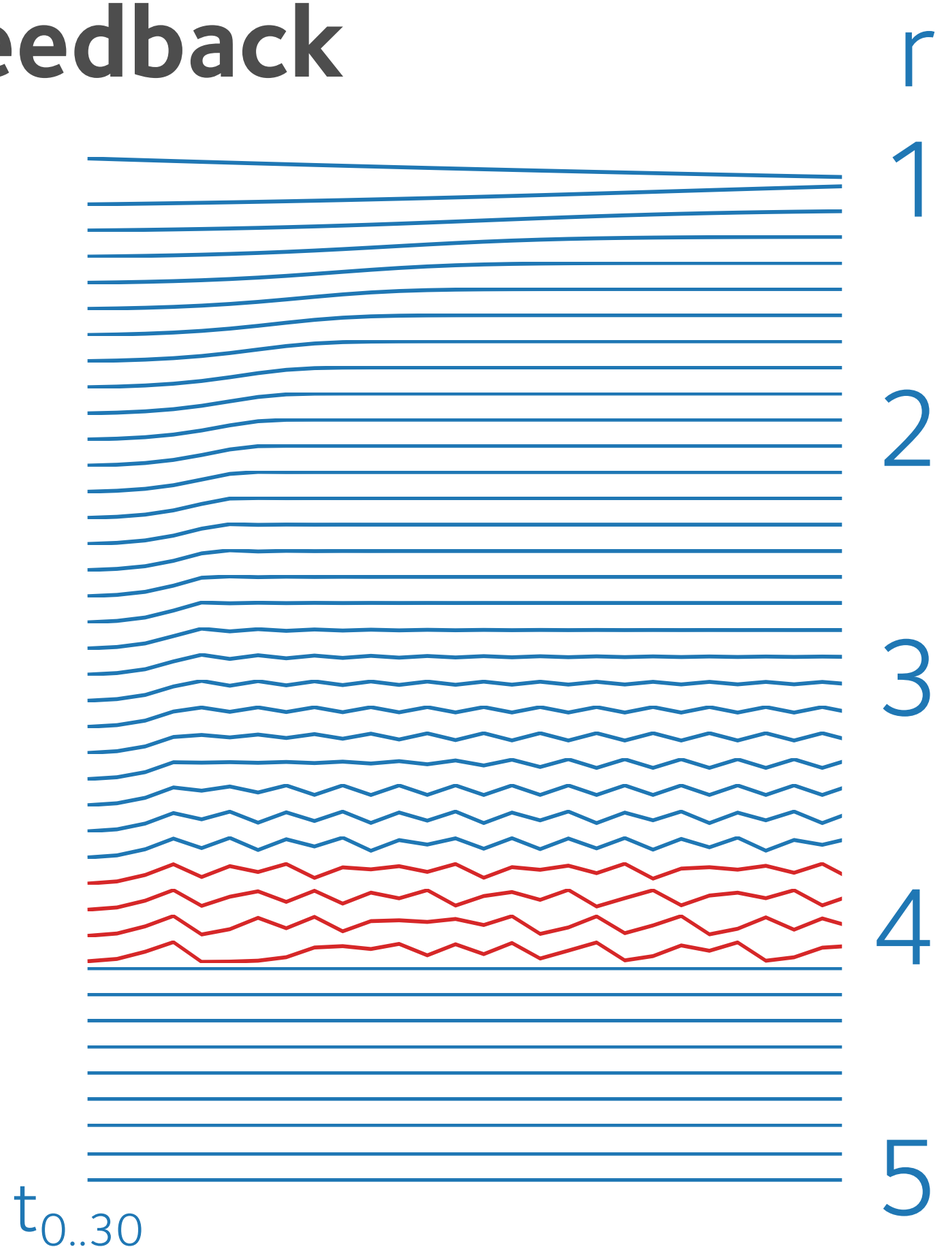
$S_t$ = State at time $t$

$r$ = growth rate



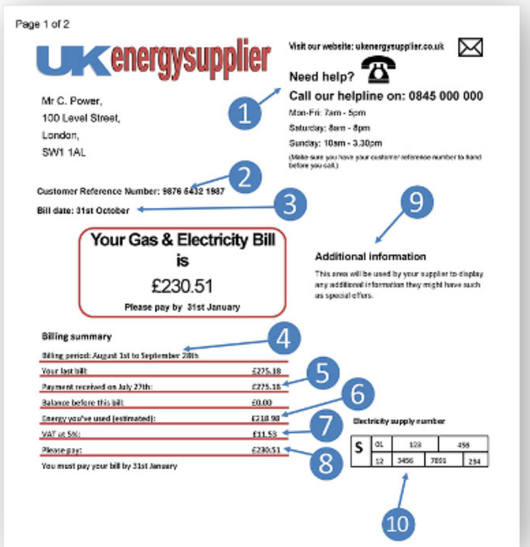
# The power of feedback

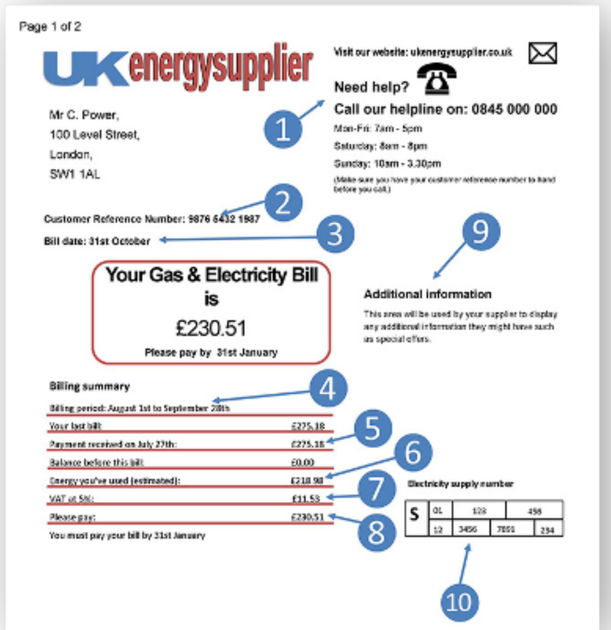
$$S_{t+1} = S_t \times r(1 - S_t)$$

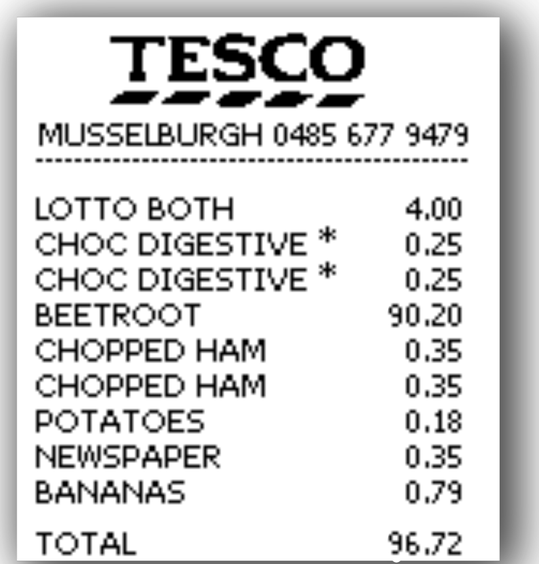


# Good feedback?

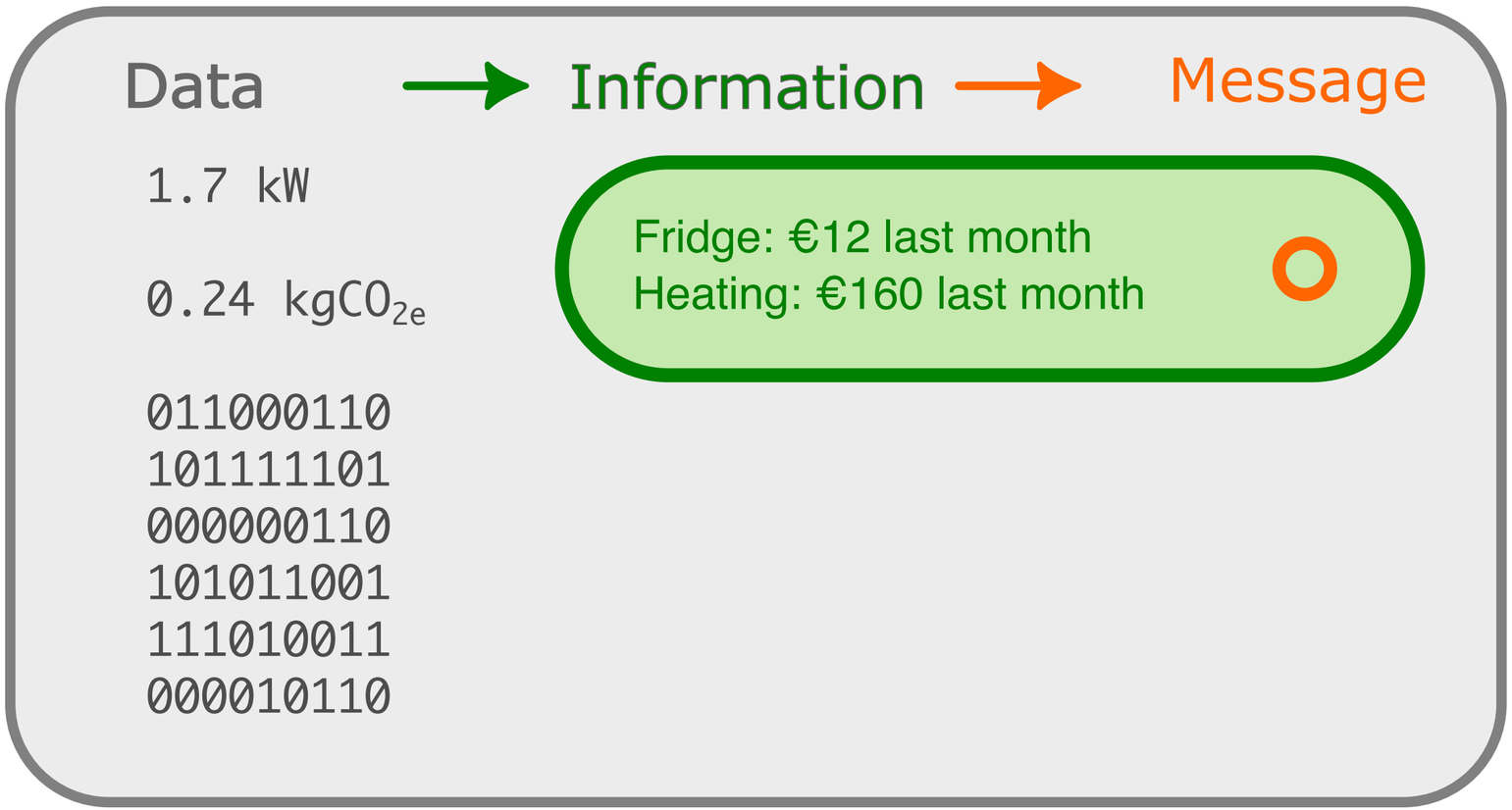





Page 1 of 2
UKenergysupplier
Visit our website: ukenergysupplier.co.uk
Need help?
Call our helpline on: 0845 000 000
Mon-Fri: 7am - 5pm
Saturday: 8am - 8pm
Sunday: 10am - 3.30pm
(Make sure you have your customer reference number to hand before you call.)
Mr C. Power,
100 Level Street,
London,
SW1 1AL
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): £218.90
VAT at 5%: £11.53
Please pay: £230.51
You must pay your bill by 31st January
Electricity supply number
S 01 123 456 12 3456 7891 234
1
2
3
4
5
6
7
8
9
10


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




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

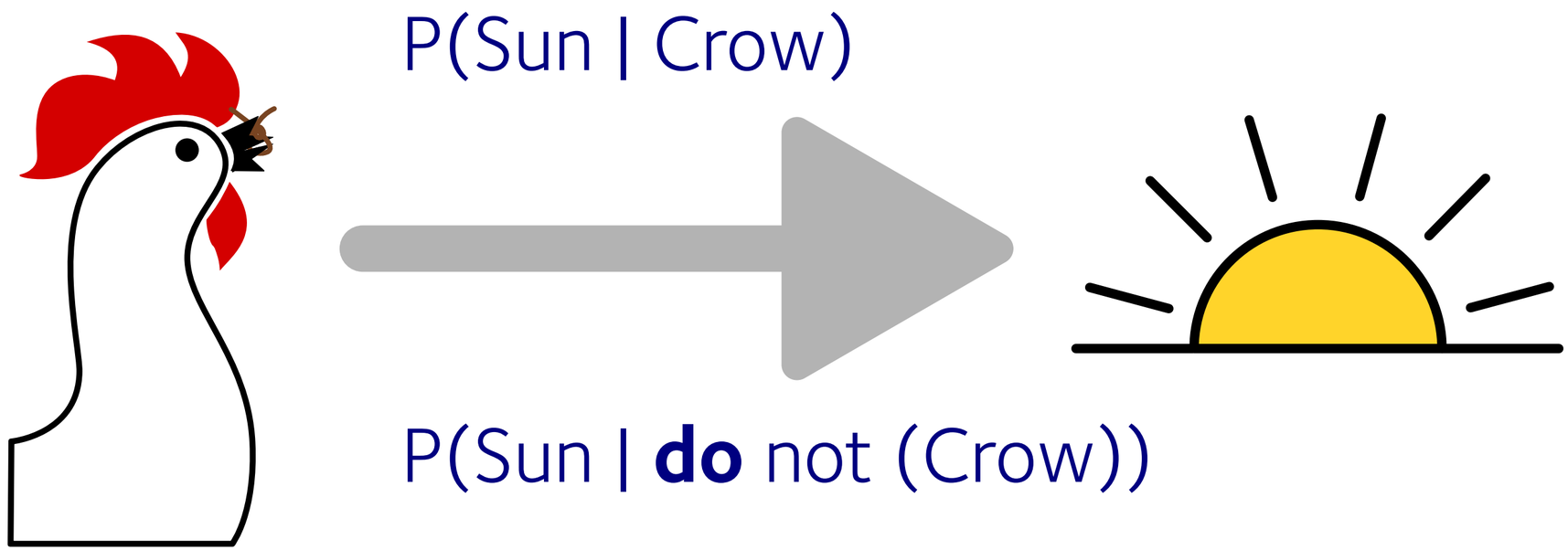
*options* *do it*

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

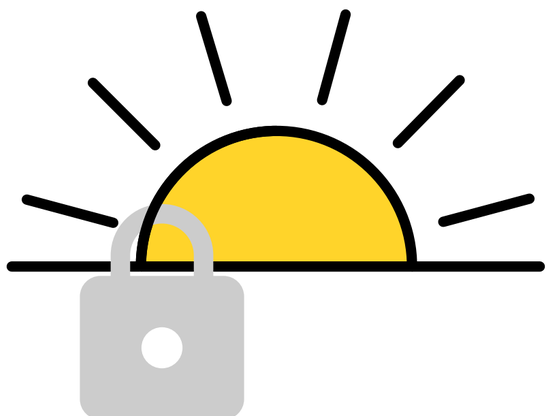
*options* *do it*

Judea Pearl

# What **causes** the sun to rise?

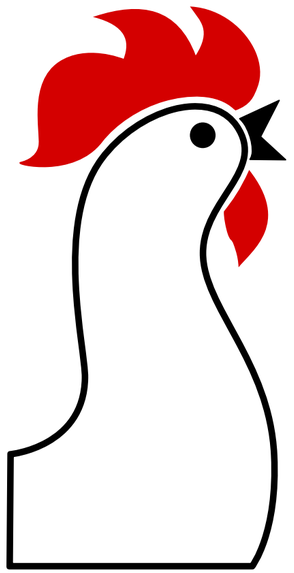


# What **causes** the the cockerill to crow?

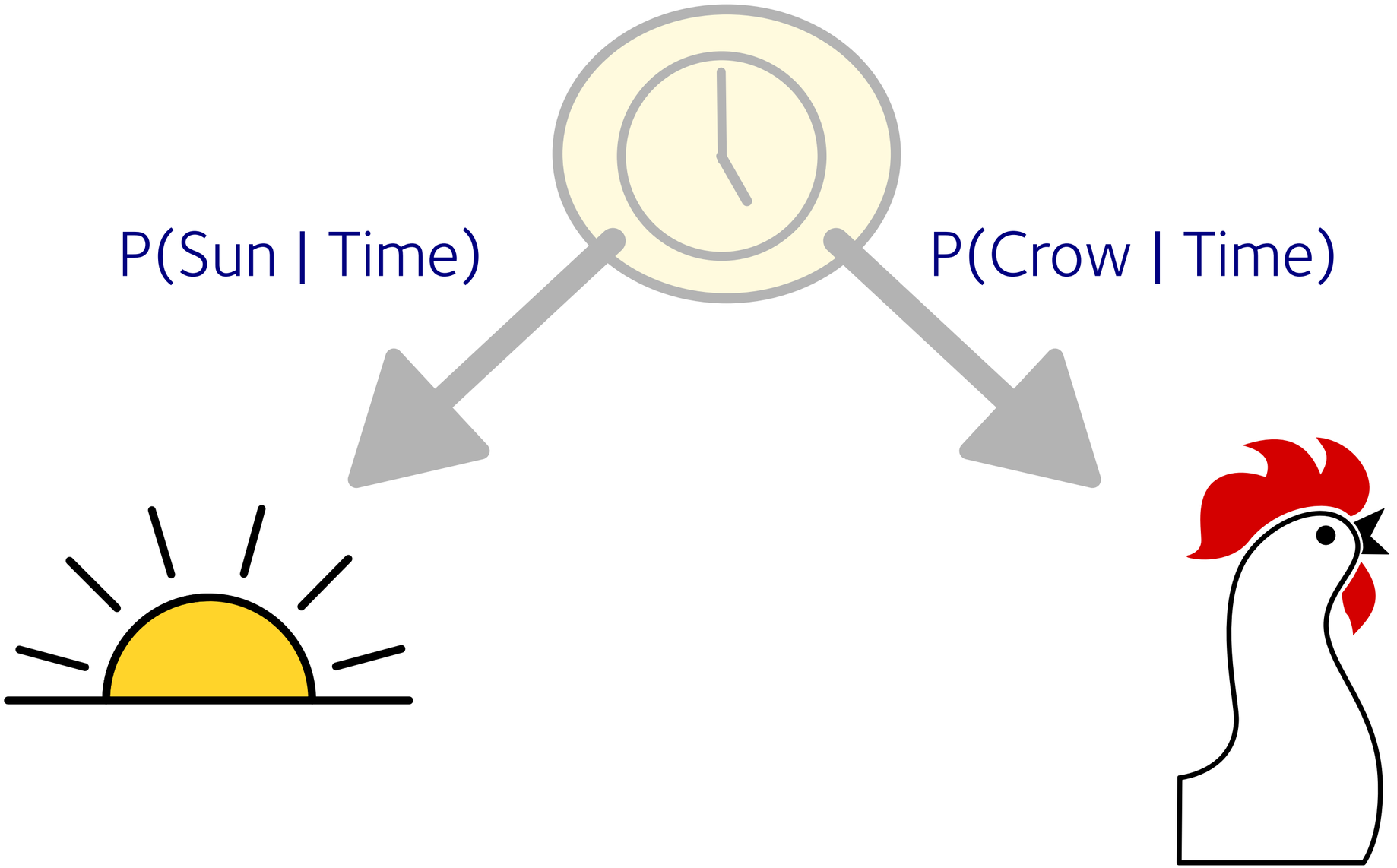


P(Crow | Sun)

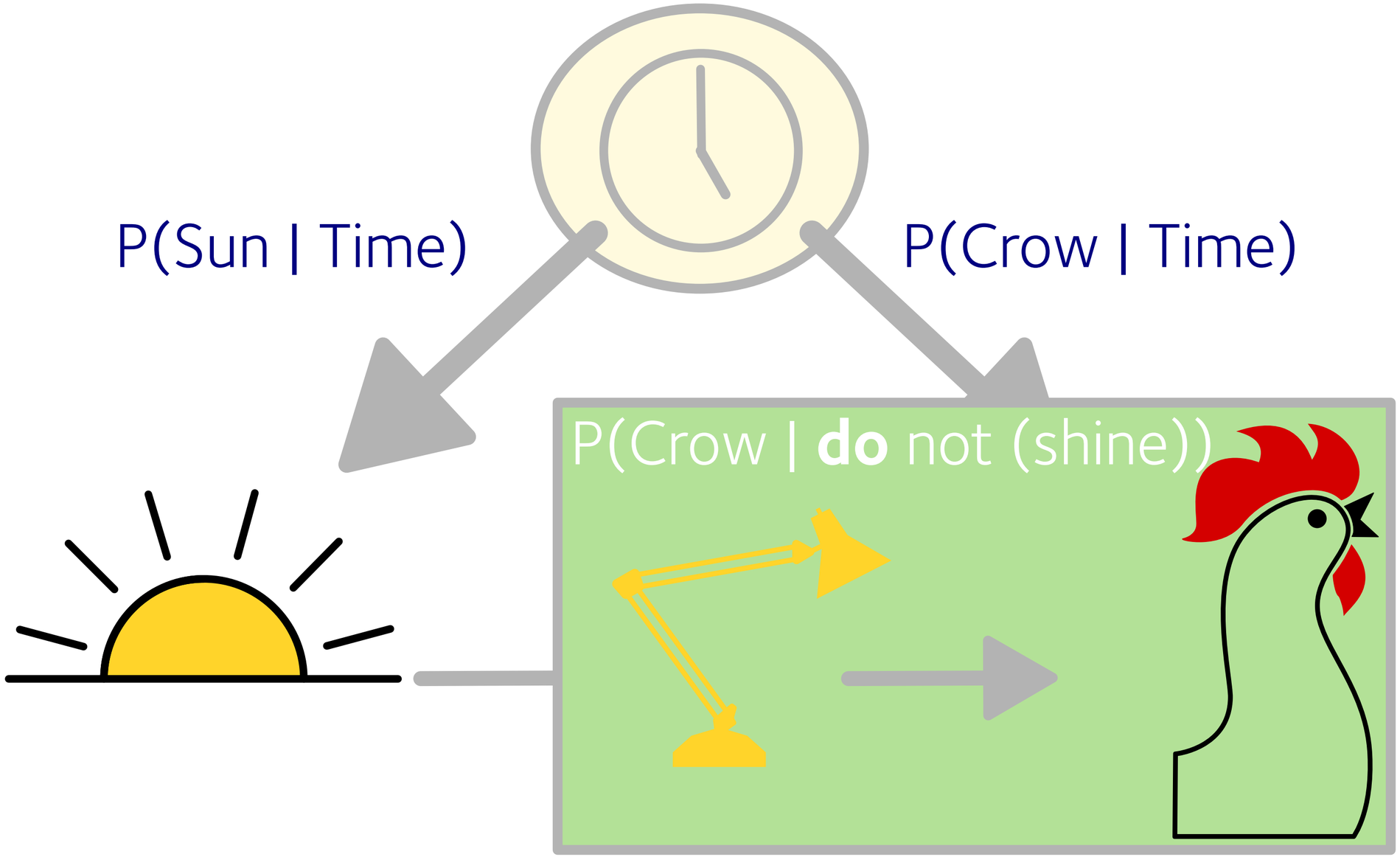
P(Crow | **do** not (Sun))



# 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

Effort

Understanding Demand

No data

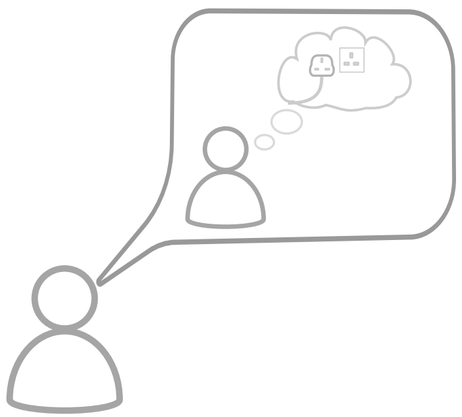
Assume & model

What **I think** people do

Some data

Interpolate & scale up

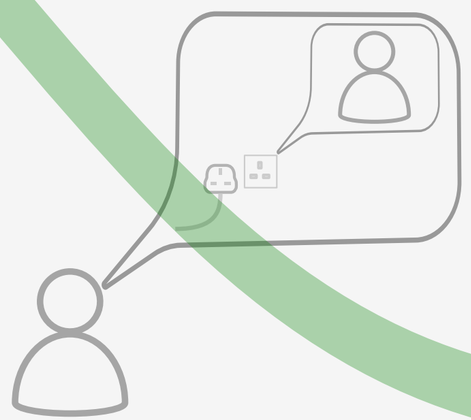
What **people** think they do



Big data

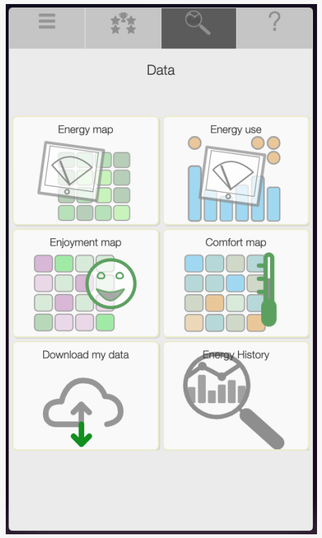
Train model & analyse

What **data** says people do



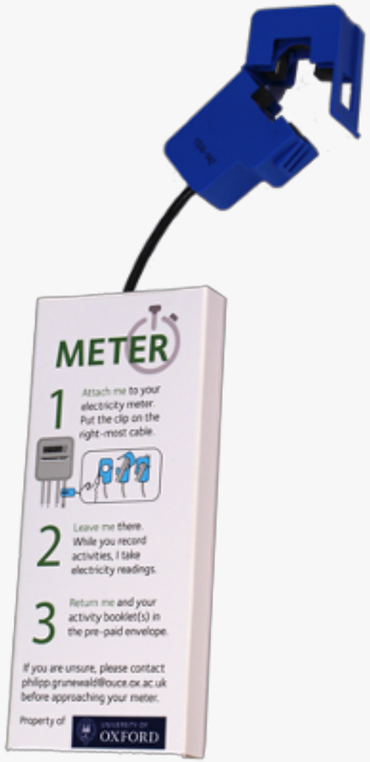
# Understanding demand the hard way

JoyMeter.uk




App


EDDI

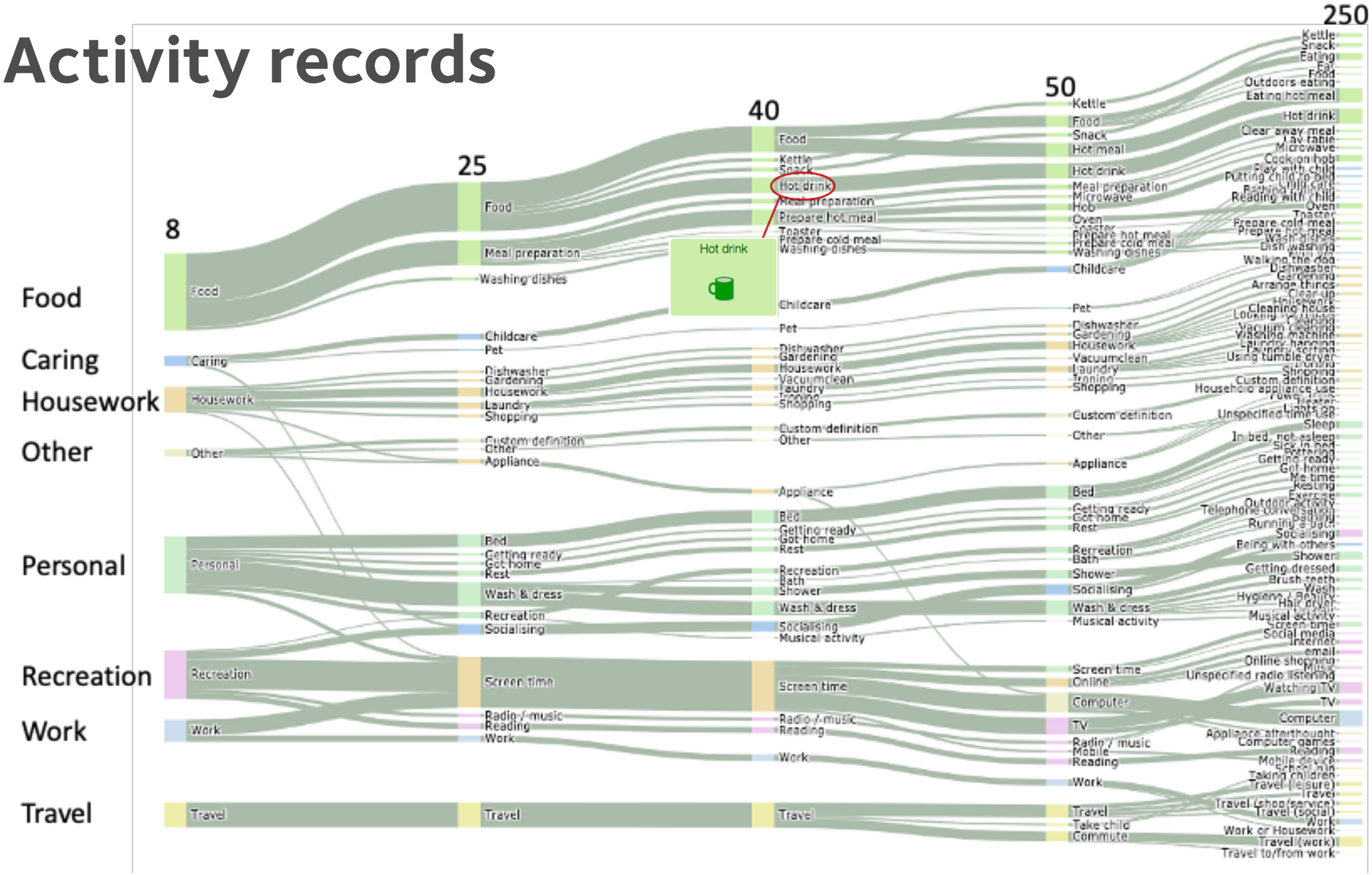




CAD (Consumer Access Device)

Current clamp

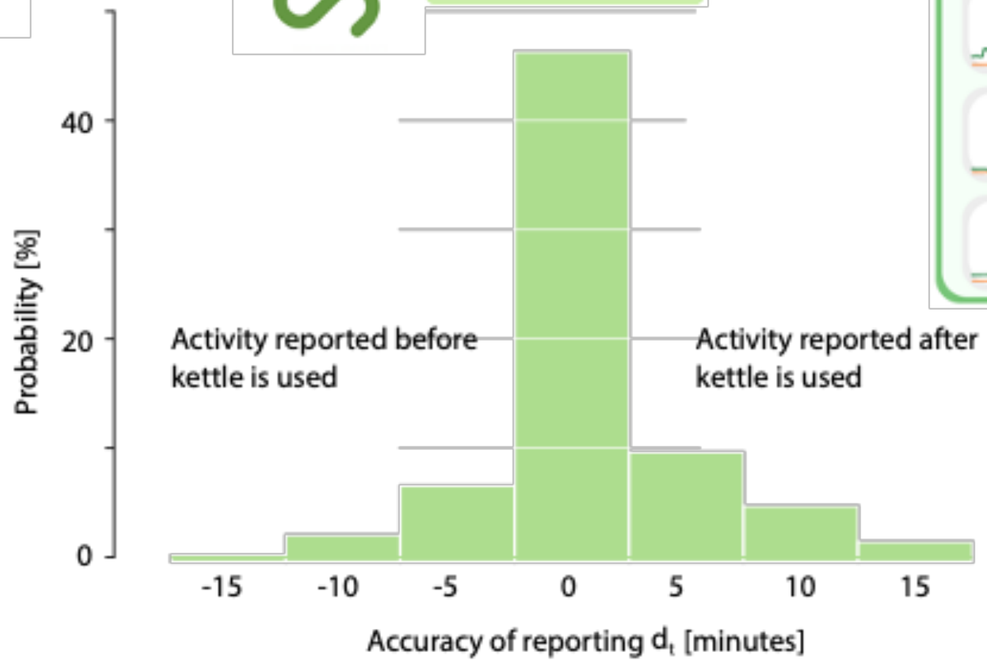

Diary

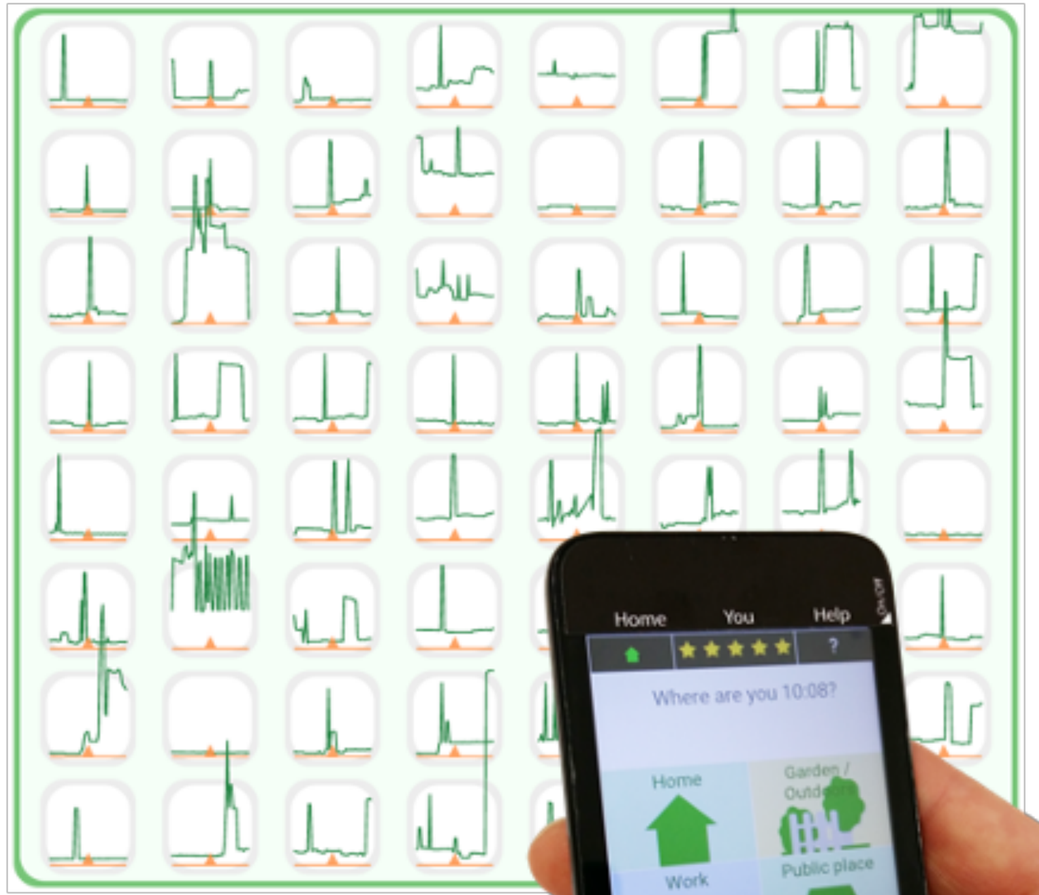
# Activity records



# Tea-test

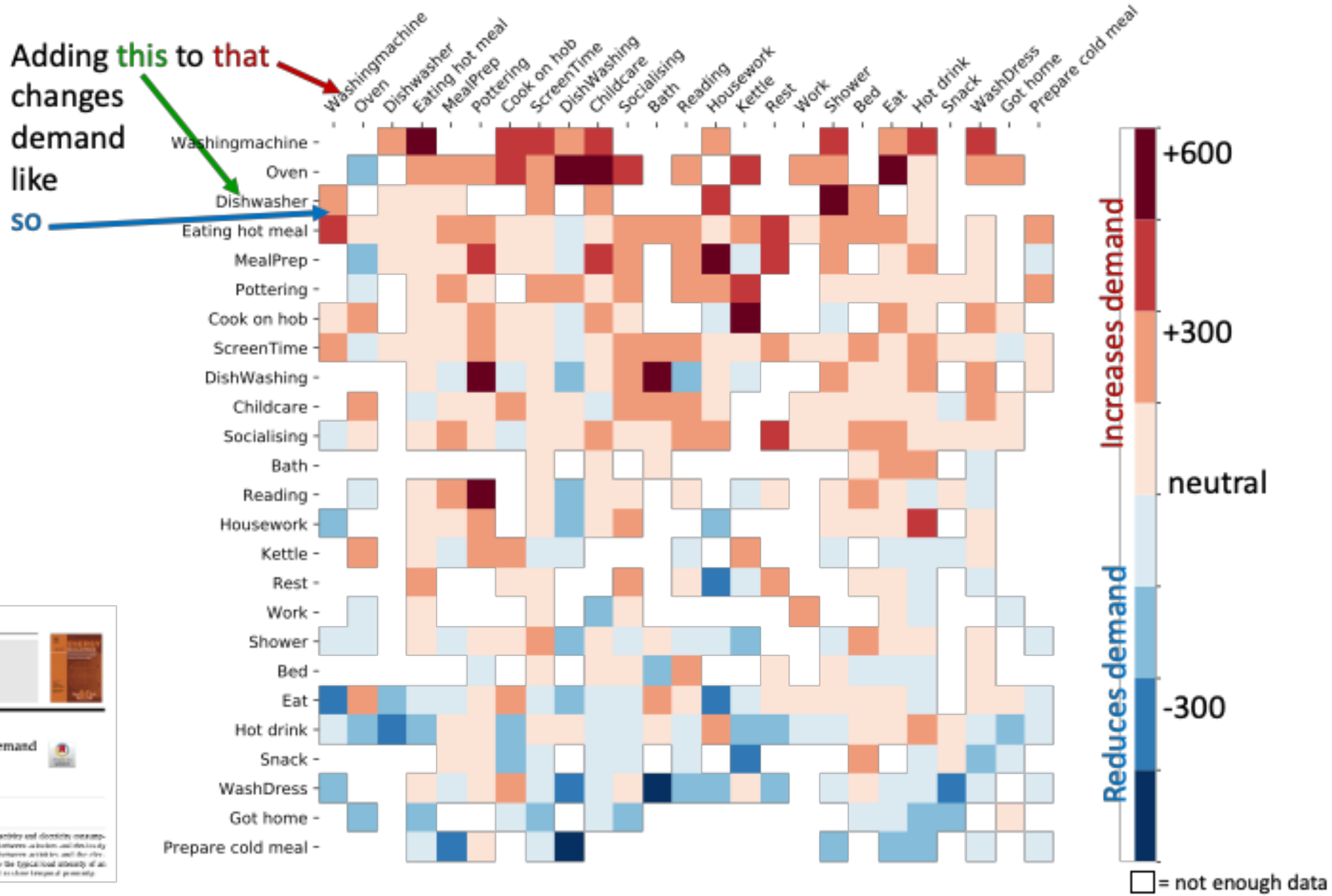

Hot drink

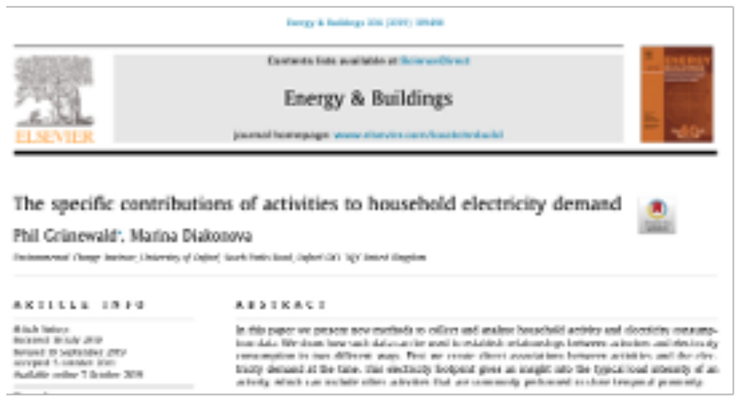

40
20
0
Probability [%]
Activity reported before kettle is used
Activity reported after kettle is used
-15
-10
-5
0
5
10
15
Accuracy of reporting $d_t$ [minutes]




Home
You
Help
Where are you 10:08?
Home
Work
Public place
Travel
Back
Home
METER

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



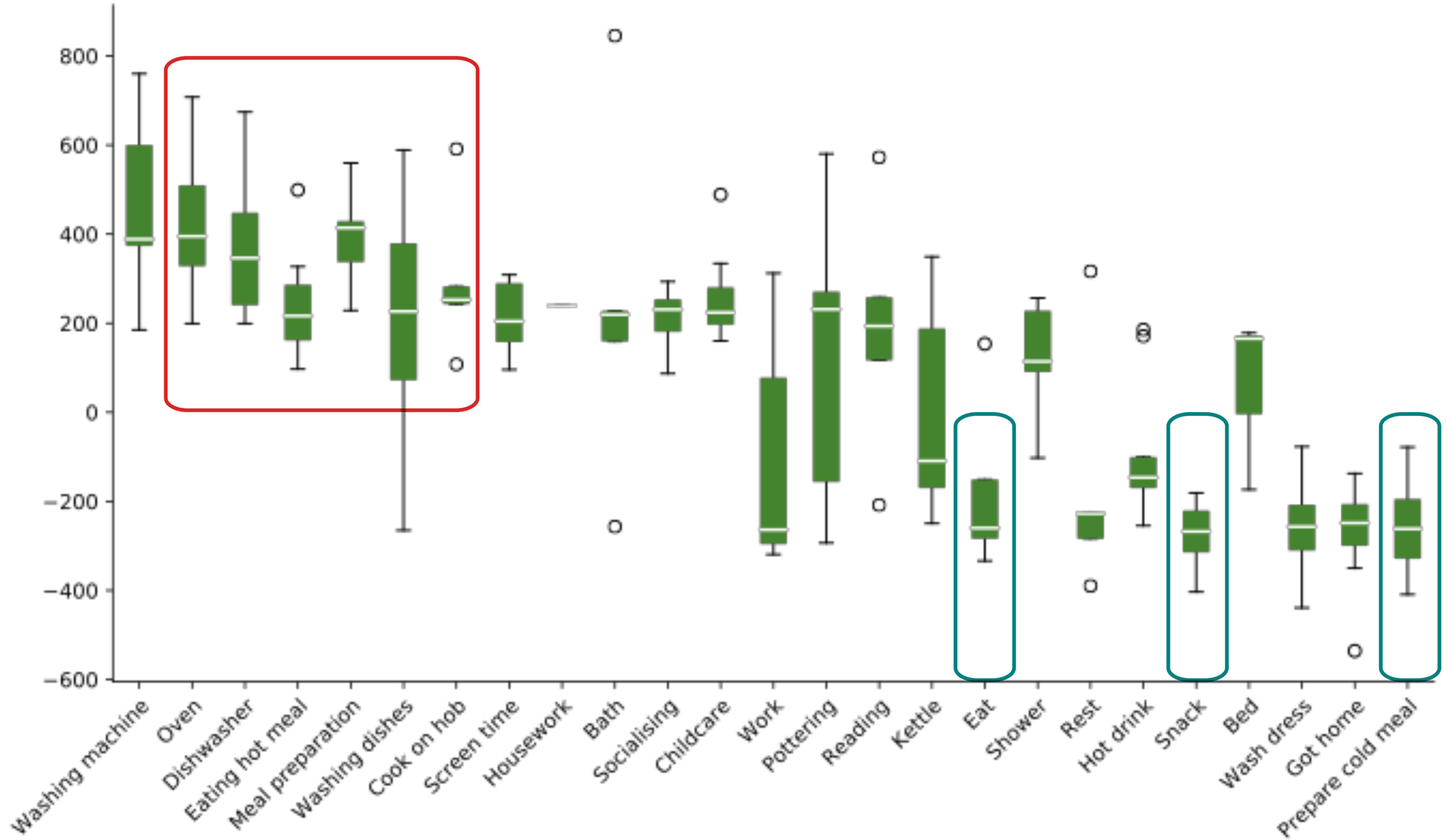



Energy & Buildings

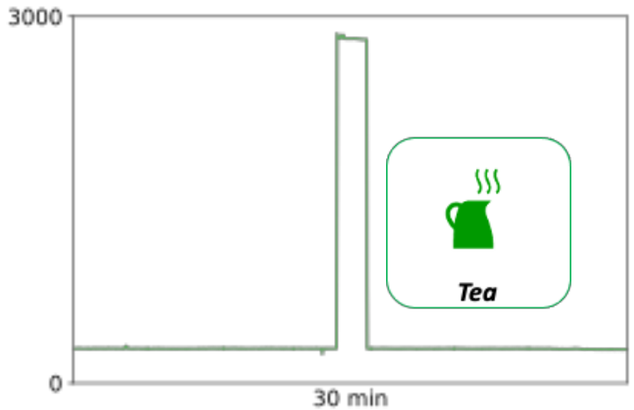
The specific contributions of activities to household electricity demand

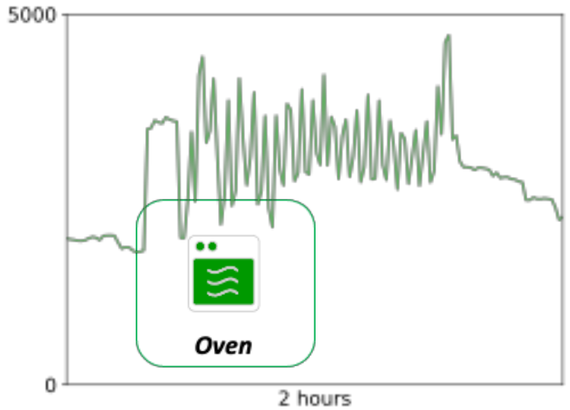
Phil Grünewald*, Marina Diakonova

# Marginal contribution of activities to demand

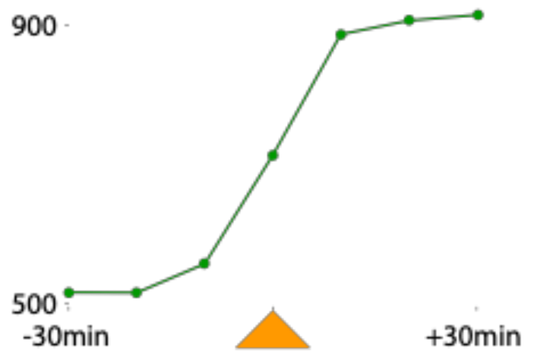


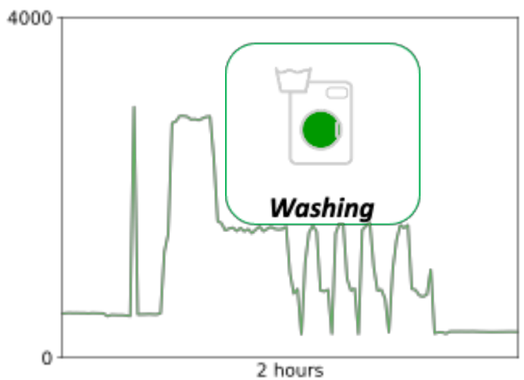
# Watts this?

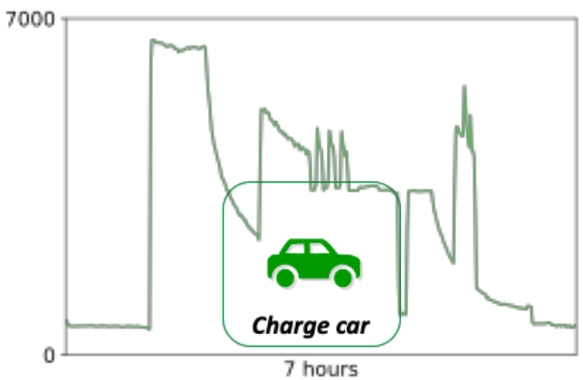

3000
0
Tea
30 min

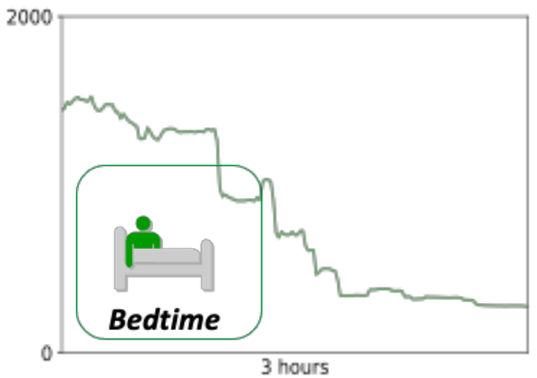

5000
0
Oven
2 hours

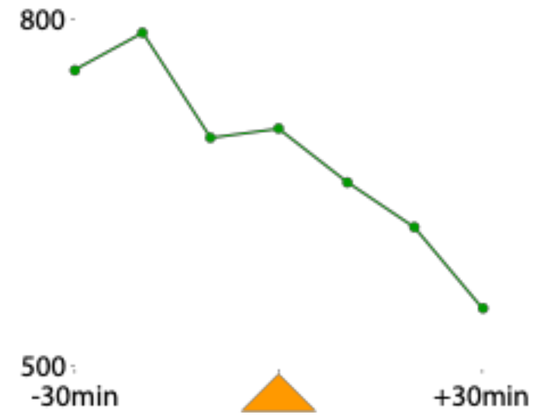

5000
0
Get home
3 hours


900
500
-30min
+30min


4000
0
Washing
2 hours


7000
0
Charge car
7 hours


2000
0
Bedtime
3 hours


800
500
-30min
+30min

# DTW clusters

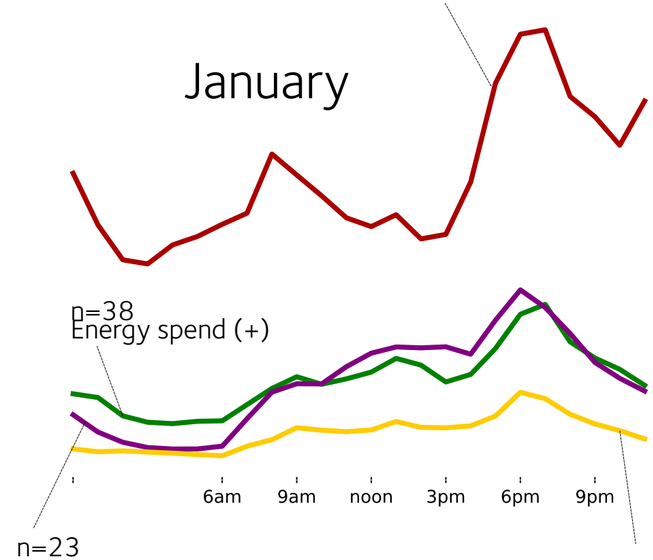
n=11
Average electricity use (+)
**Have an electric heat pump (+)**
Average electricity use at 6pm (+)
How much do you spend on energy? (+)
Dog owner (+)
House type (+)
Social grade (+)

n=7
(+) Average electricity use
(+) Average electricity use at 6pm
(+) Energy spend
(+) Living rent free
(-) In employment

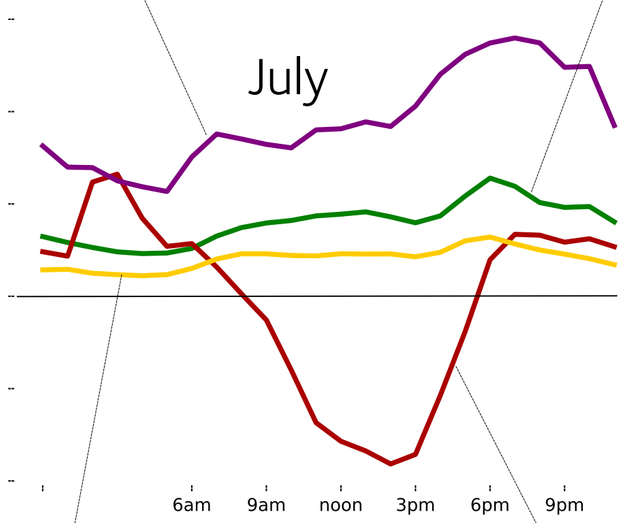
n=52
Average electricity use (-)
Average electricity use at 6pm (-)
How many rooms? (-)
What type of property? (+)
How many adults? (-)
How much do you spend on energy? (-)
How many rooms does your home have? (-)
Would buy an electric vehicle (-)
**Would install an electric heat pump (+)**
Universal Credit (+)

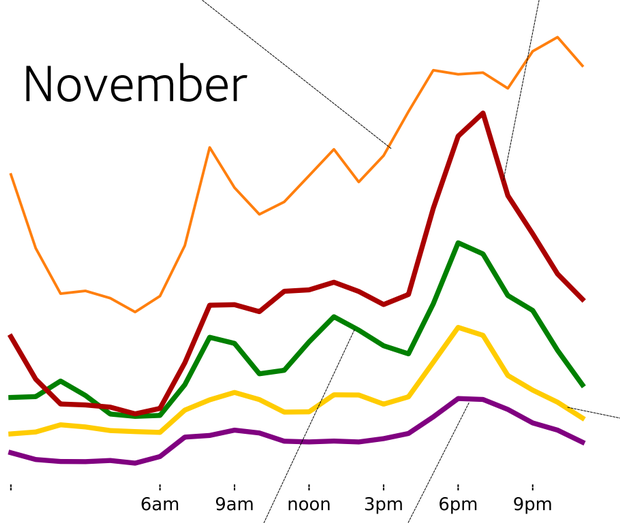
n=6
(+) Average electricity use
(+) Energy spend
(+) Average electricity use at 6pm
(+) Detached house
**(+) Unsure about heat pump**
(+) Bungalow
(-) Reduce water consumption

n=14
(+) Average electricity use at 6pm
(+) How much do you spend on energy?
(+) Average electricity use
(+) How many rooms?
(+) Unlikely to buy an electric vehicle
**(-) Would install an electric heat pump**




n=38
Energy spend (+)




n=49
(-) Energy spend
(+) Dog owner
(+) Universal Credit

n=23
El. quantile 50 (-)
El. quantile 25 (-)

n=59
Agerage electricity use (-)
Average electricity use at 6pm (-)
How much do you spend on energy? (-)
How many adults? (-)
What type of property do you live in? (+)

n=74
(+) How many rooms does your home have
(+) Average electricity use at 6pm
(-) How many rooms does your home have
(+) How much do you spend on energy?
(-) What type of property?
(-) House type
(+) How many adults?
(+) Average electricity use

n=5
(+) Standard tariff
**(+) Heat pump**
(-) Load response in intervention
(+) Number of rooms
(+) Very likely to buy an EV
(+) Detached house
(+) Southern England

n=29
(-) Average electricity use at 6pm
(-) How much do you spend on energy?
(-) Average electricity use
(-) How many adults?
(+) No energy saving behaviours
(+) Type of energy tariff

n=42
(+) How many rooms?
(+) How much do you spend on energy?
(-) Type of property
(+) Average electricity use at 6pm

# 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

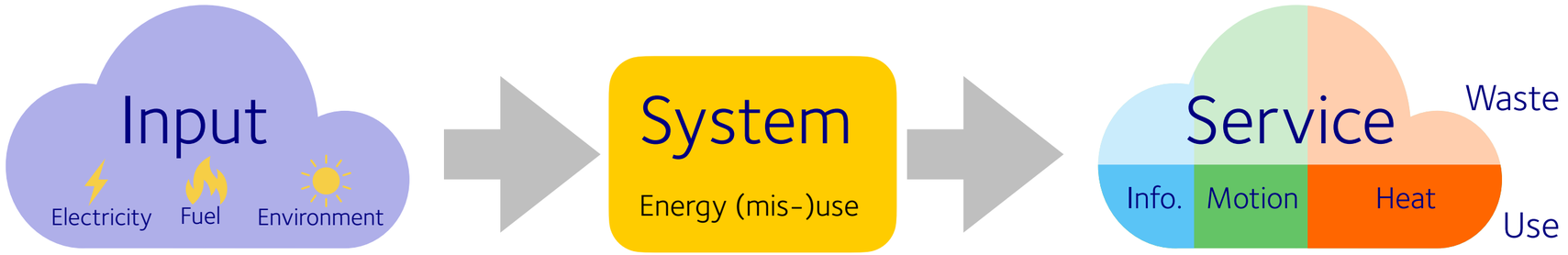
- Demand side flexibility
- Price elasticity
- Data and privacy
- Synthetic data

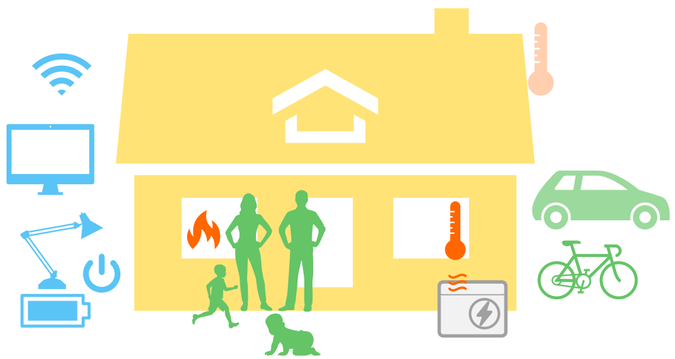
# To **change** energy use we need to **understand** energy use **(as a system)**

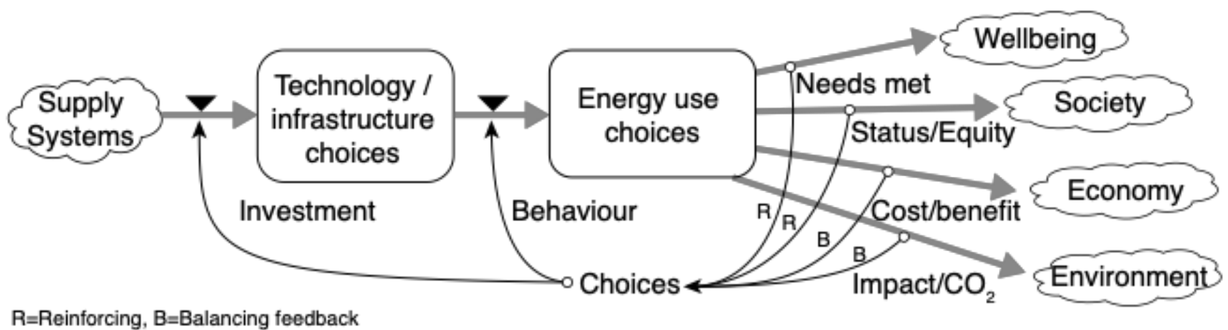
## How much?

## What?

## Why?






R=Reinforcing, B=Balancing feedback

**Good feedback is:**

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