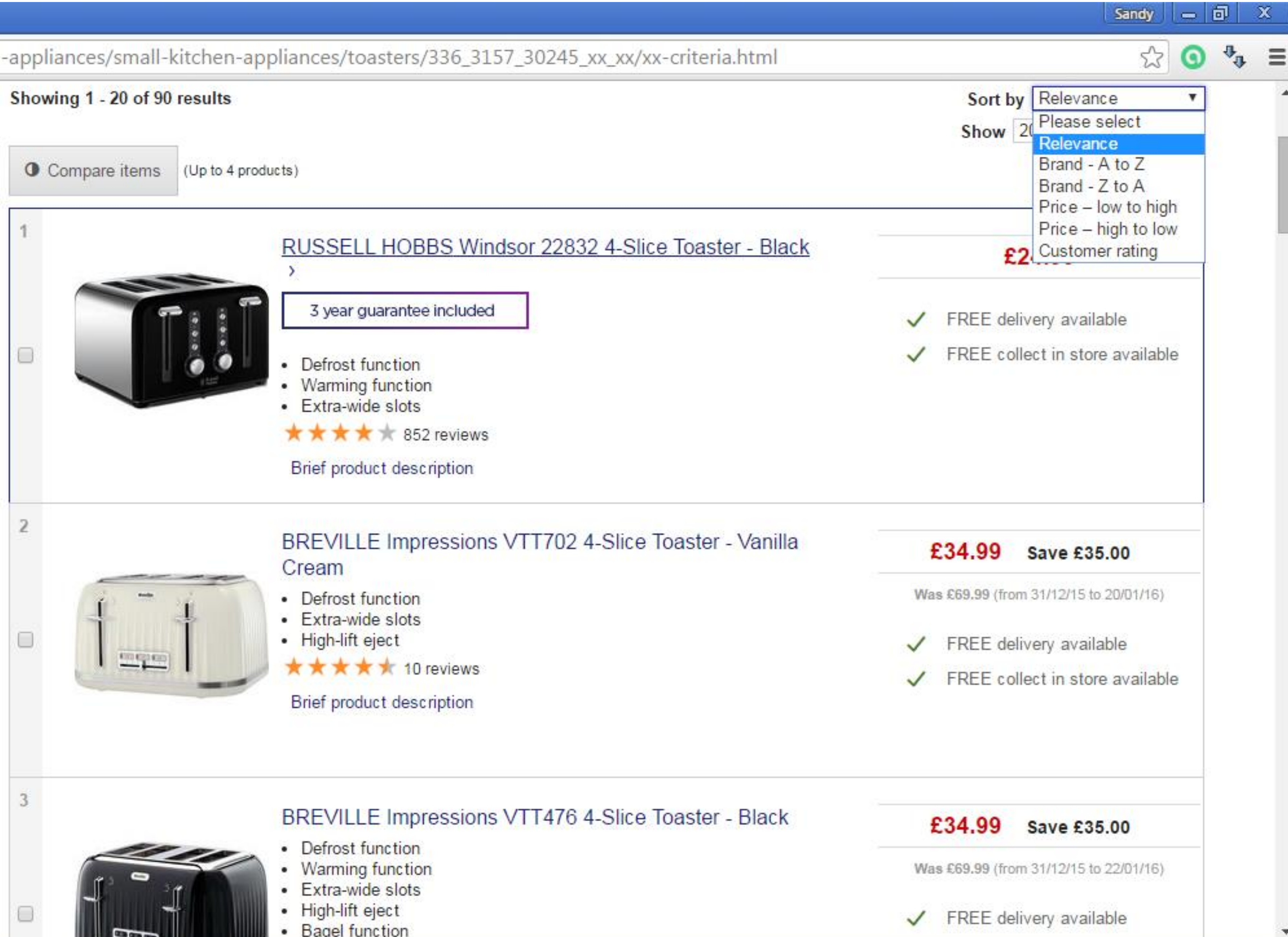
Weighing up the options: Finding the right solution when lots of things matter

Sandy Brownlee

Outline

- Decision making, multiple objectives
- Optimisation
- Building design
- Evolutionary algorithms
- Other real world applications



Sources: www.currys.co.uk

Sandy

d-appliances/small-kitchen-appliances/toasters/336_3157_30245_xx_xx/1_20/price-asc/xx-criteria.html

Showing 1 - 20 of 90 results

Sort by Price – low to high

Show 20 products per page

Compare items (Up to 4 products)

Show

1

ESSENTIALS C02TW13 2-Slice Toaster - White

★★★★☆ 30 reviews

Brief product description

£4.49

✓ FREE delivery available

✓ FREE collect in store available

2

LOGIK L02TBS13 2-Slice Toaster - Stainless Steel

- Defrost function
- Warming function
- Extra-wide slots
- High-lift eject

★★★★☆ 43 reviews

Brief product description

£12.49

✓ FREE delivery available

✓ FREE collect in store available

3

BREVILLE VTT375 2-Slice Toaster - Polished Stainless Steel

- Defrost function
- Warming function
- Extra-wide slots
- High-lift eject

£16.99

✓ FREE delivery available

✓ FREE collect in store available

Sandy

-appliances/small-kitchen-appliances/toasters/336_3157_30245_xx_xx/1_20/price-desc/xx-criteria.html

Showing 1 - 20 of 90 results

Sort by Price – high to low

Show 20 products per page

Compare items (Up to 4 products)

Show

1

KITCHENAID 5KMT4205BMS Artisan 4-Slice Toaster - Silver

- Defrost function
- Warming function

★★★★★ 3 reviews

Brief product description

£269.99

✓ FREE delivery available

✓ FREE collect in store available

2

KITCHENAID 5KMT4205BER Artisan 4-Slice Toaster - Empire Red

- Defrost function
- Warming function
- Extra-wide slots
- Bagel function

★★★★★ 3 reviews

Brief product description

£269.99

X Sorry this item is out of stock

Email me when back in stock

3

MORPHY RICHARDS Redefine 228000 2-Slice Toaster - Glass

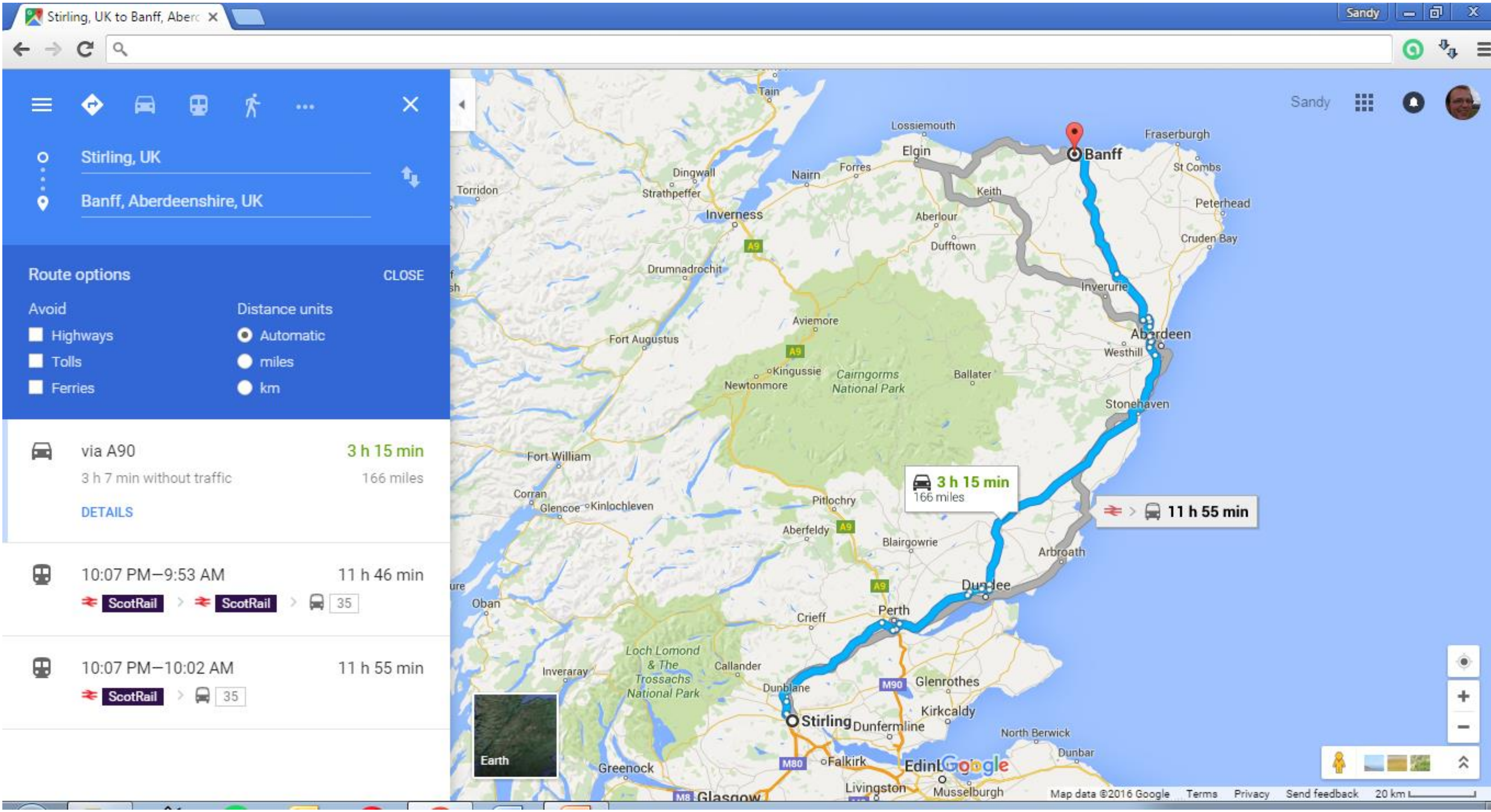
2 year guarantee included

- Defrost function

£199.99

✓ FREE delivery available

✓ FREE collect in store available


Stirling, UK to Banff, Aberc
Sandy
Stirling, UK
Banff, Aberdeenshire, UK
Route options
CLOSE
Avoid
Highways
Tolls
Ferries
Distance units
Automatic
miles
km
via A90
3 h 15 min
3 h 7 min without traffic
166 miles
DETAILS
10:07 PM—9:53 AM
11 h 46 min
ScotRail
ScotRail
35
10:07 PM—10:02 AM
11 h 55 min
ScotRail
35
Earth
3 h 15 min
166 miles
11 h 55 min
Banff
Fraserburgh
Lossiemouth
Elgin
Nairn
Forres
Keith
Inverness
Aberdeen
Stirling
Perth
Dundee
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Send feedback
20 km

Teenager flies from Sheffield to Essex via Berlin because it is cheaper than getting the train

Jordan Cox said the 1,017 mile round trip to Germany was £7.72 cheaper than a direct train home

Caroline Mortimer | @cjmortimer | Wednesday 27 January 2016 | 5

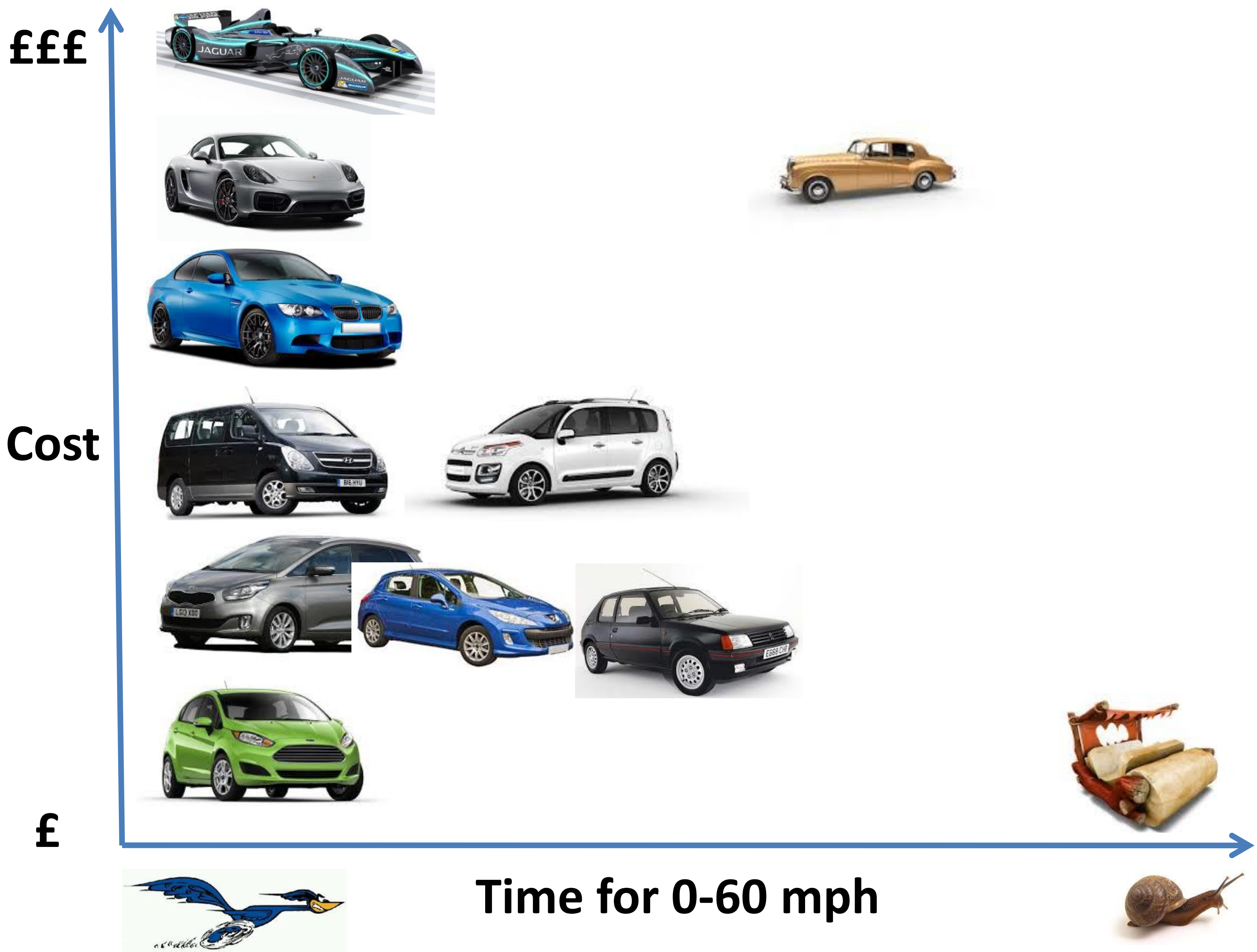
4K

Jordan Cox outside the Brandenburg Gate in Berlin as he details how he saved money on his adventure *Jordon Cox/Youtube*

A cost-conscious teenager found the perfect way to save on his journey home - by booking a flight via Berlin.

Jordon Cox, 18, realised it would cost him £50 to travel from Sheffield to Shenfield in Essex by train but if he "went the extra 1,017 miles" he could fly via the German capital and save £7.72.

- So what if we care about more than one thing?
- More than one *objective*?


£££
Cost
£
JAGUAR
Time for 0-60 mph

- Vilfredo Pareto
  - 1848 - 1923
  - Italian engineer, sociologist, economist, political scientist, and philosopher
- *Pareto optimal front:*
  - *The trade-off of optimal designs / options / solutions*

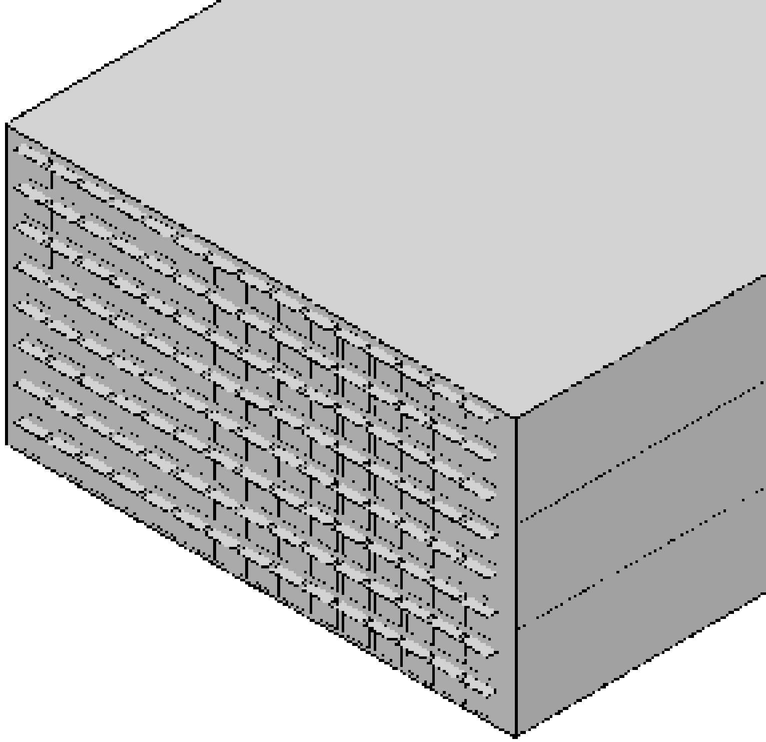

£££
Cost
£
Time for 0-60 mph

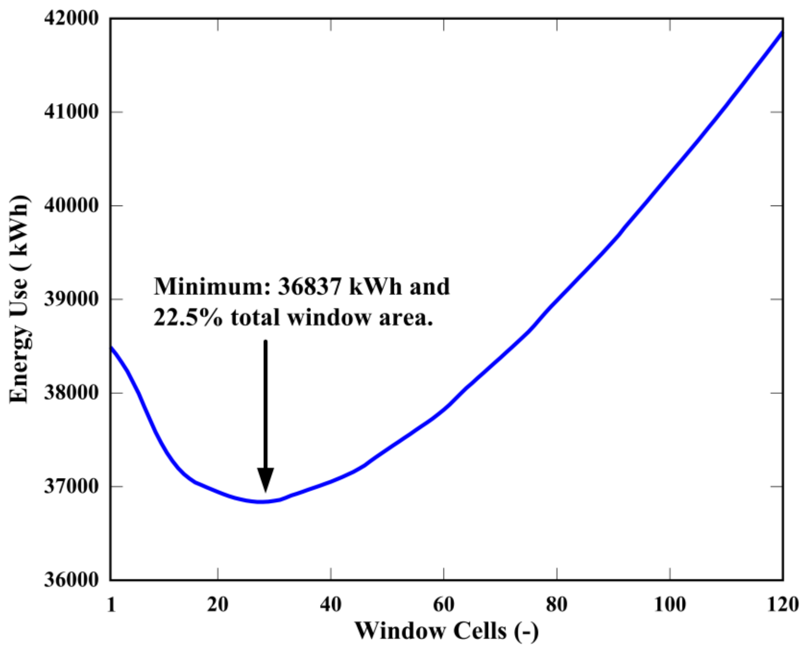
Optimisation

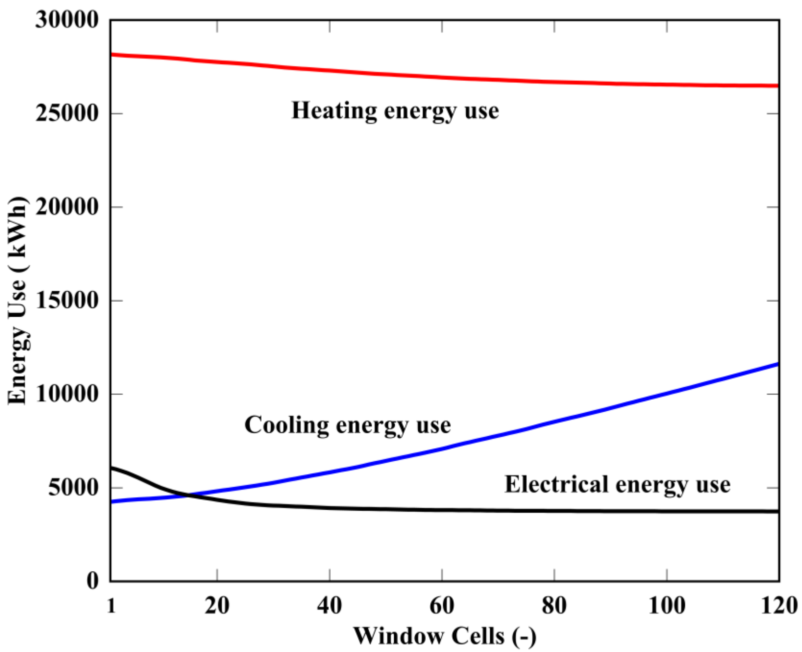
Variables → **Objectives**

Single-objective

- Minimal cost easy
- Minimal energy tricky!

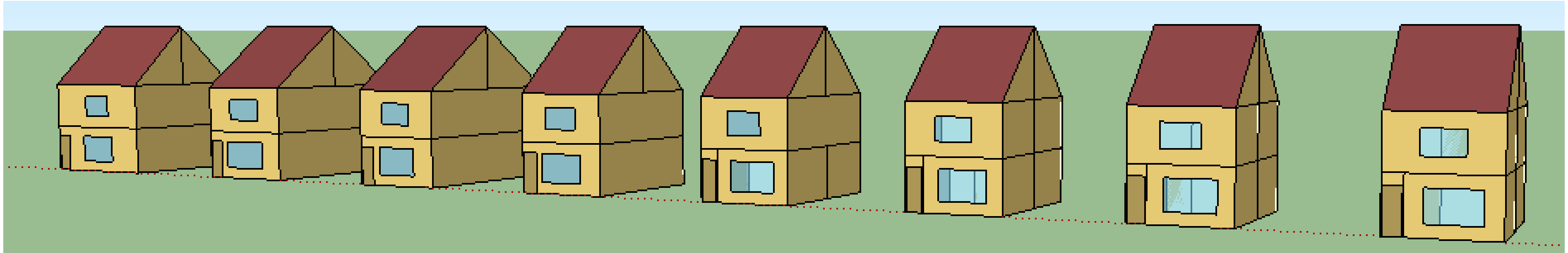


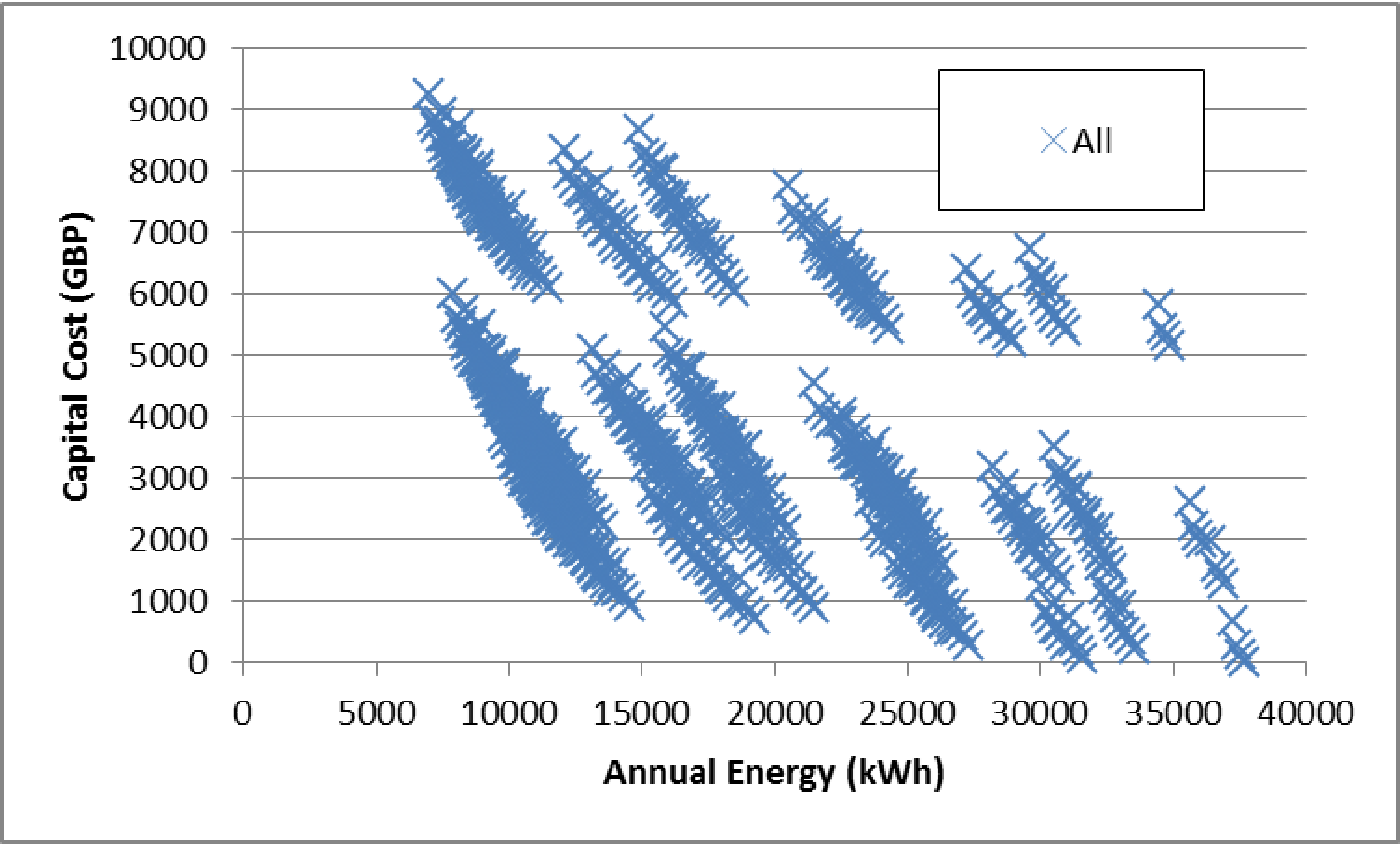




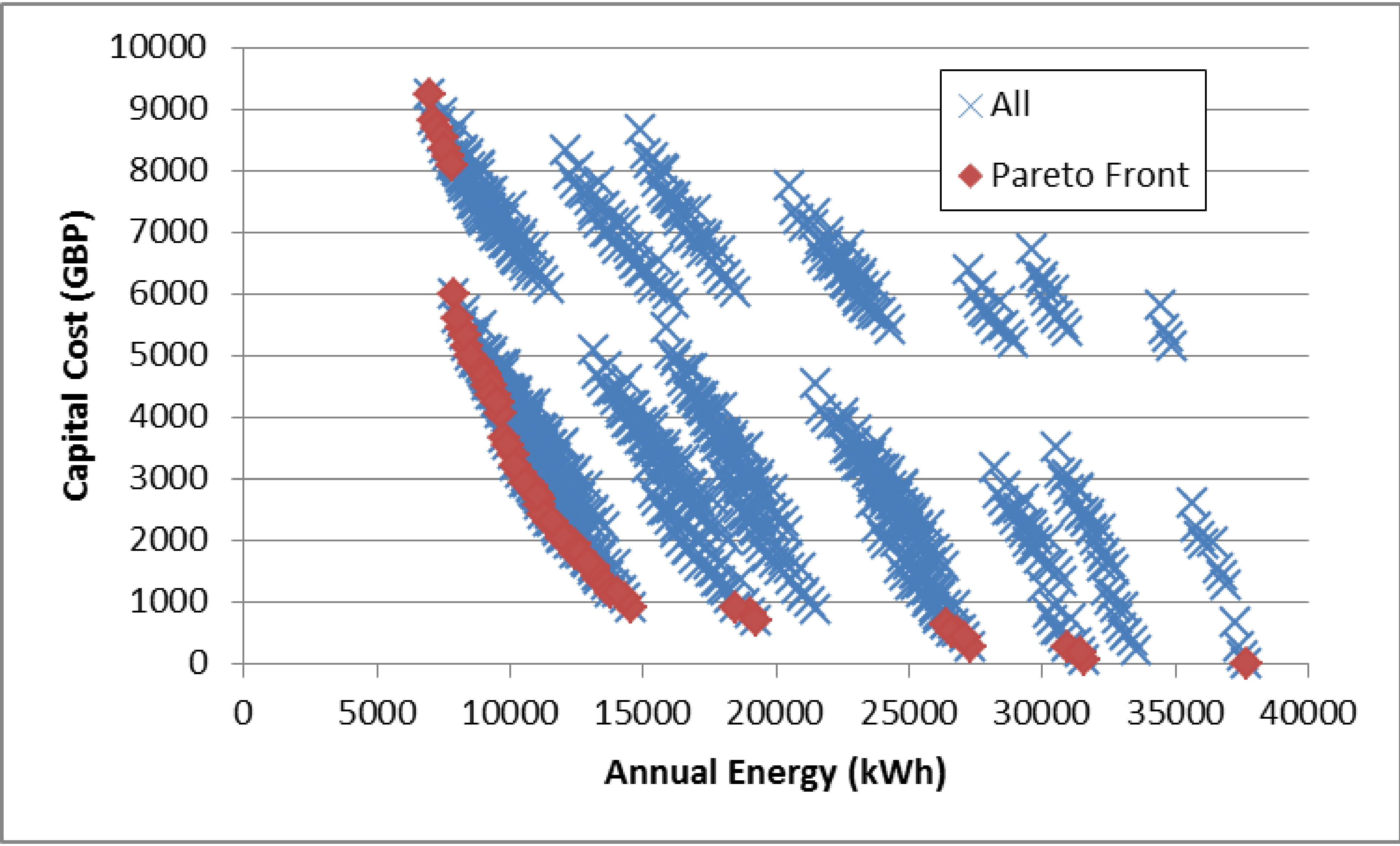
Multi-objective

- Minimise **cost** to improve house, and the **energy** required to run it
- 5 things to vary, 4 levels each
  - – Wall insulation
  - – Replace windows
  - – Replace door
  - – Floor insulation
  - – Roof insulation
- How many possible variations?





Capital Cost (GBP)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
5000
10000
15000
20000
25000
30000
35000
40000
Annual Energy (kWh)
All



10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
5000
10000
15000
20000
25000
30000
35000
40000
Capital Cost (GBP)
Annual Energy (kWh)
All
Pareto Front

Exhaustive search

- 5 variables, 4 values each:

  $4^5 = 4 \times 4 \times 4 \times 4 \times 4 = 1{,}024$

- 10 variables:

  $4^{10} = 1{,}048{,}576$

- 50 variables:

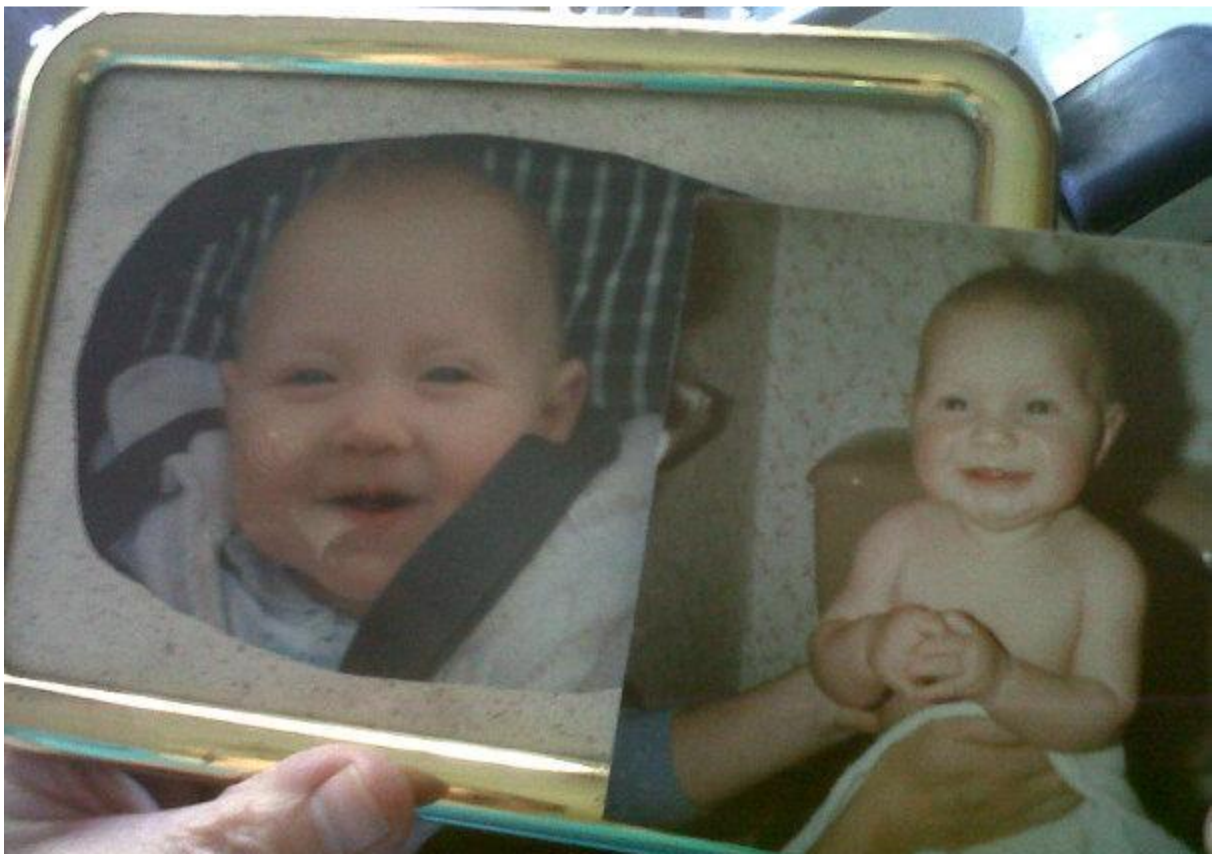
  $4^{50} = 1{,}267{,}650{,}600{,}228{,}229{,}401{,}496{,}703{,}205{,}376$

  or about 10^{30}

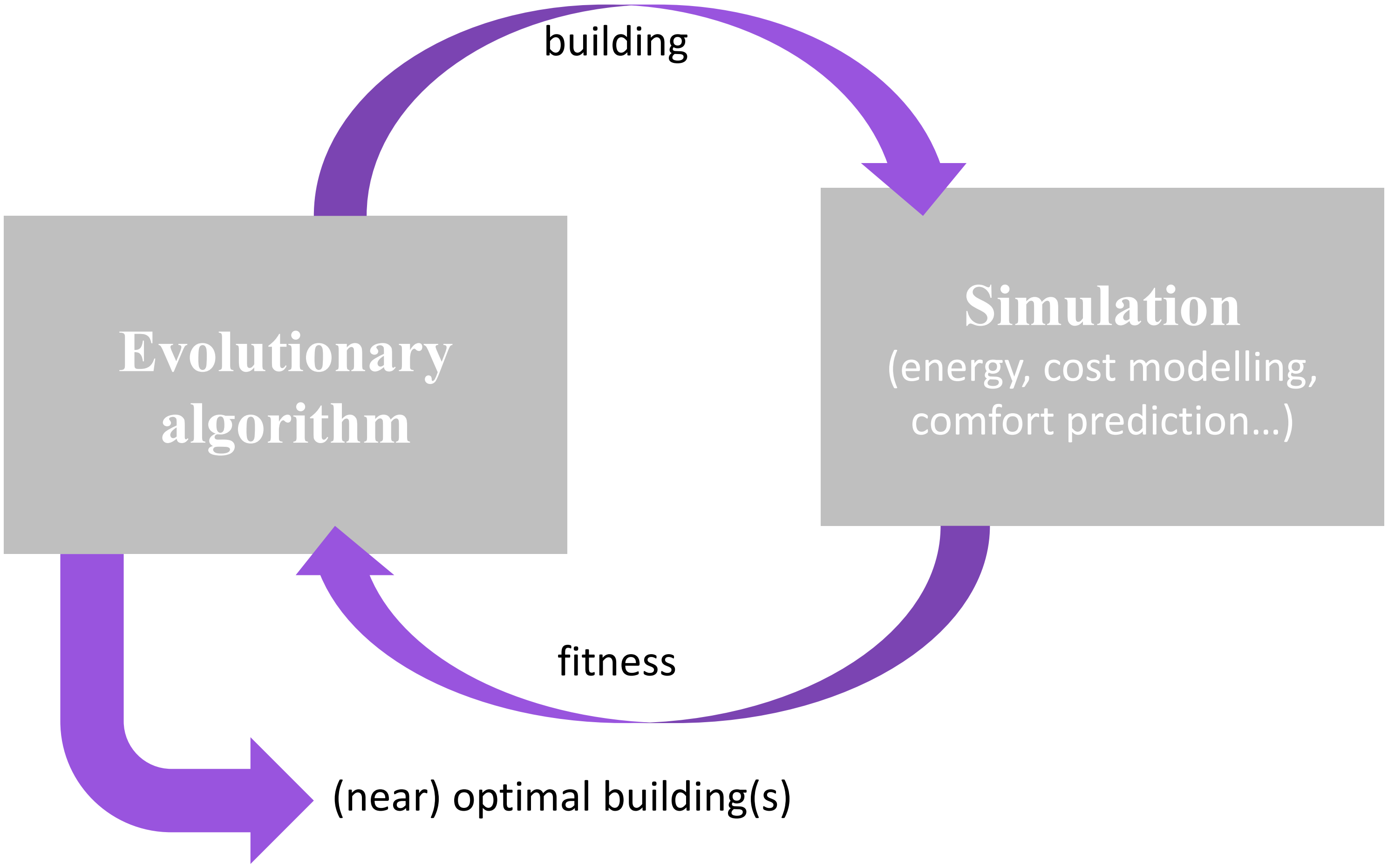
- *Combinatorial explosion*

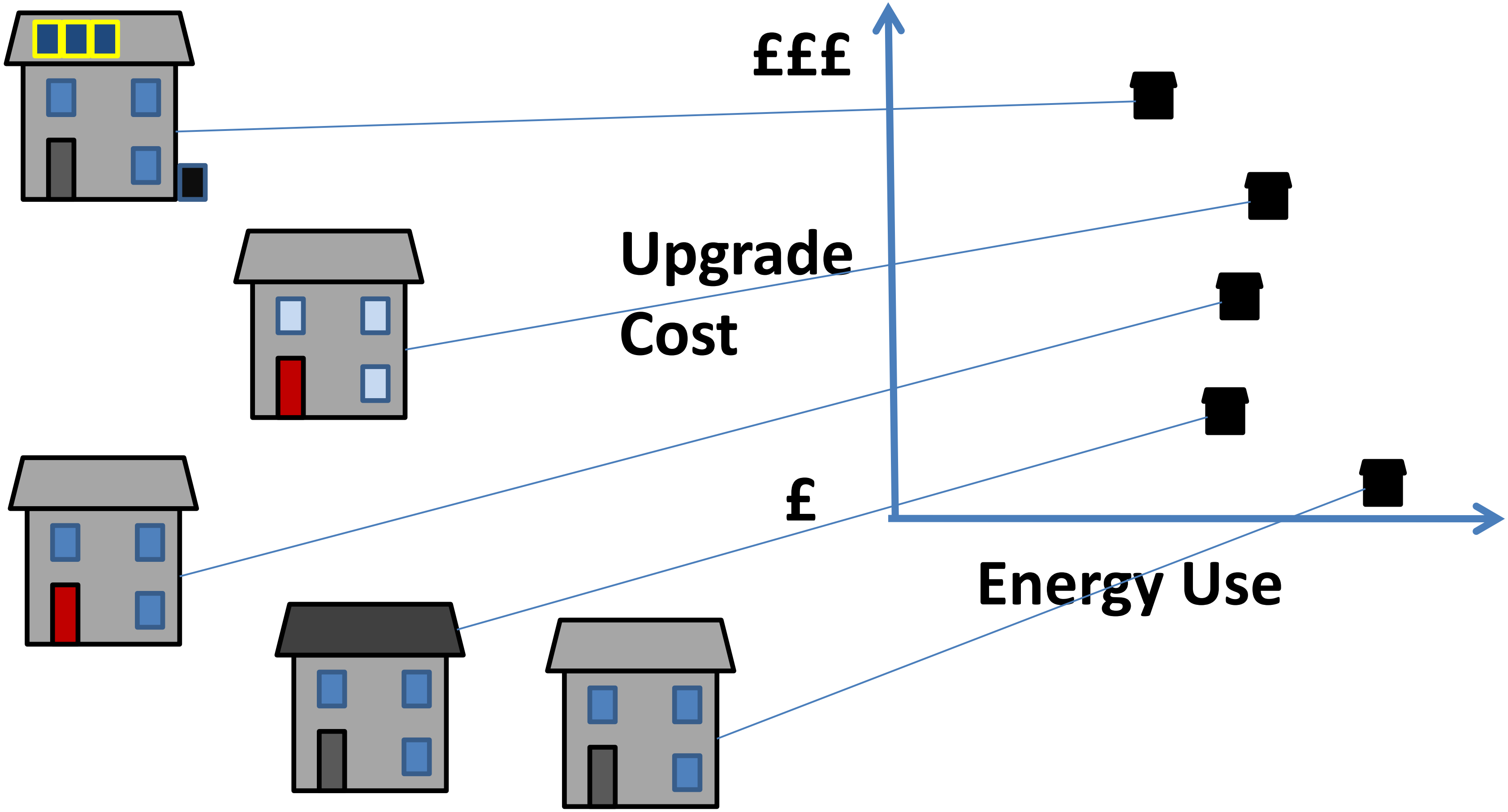
Evolutionary algorithms

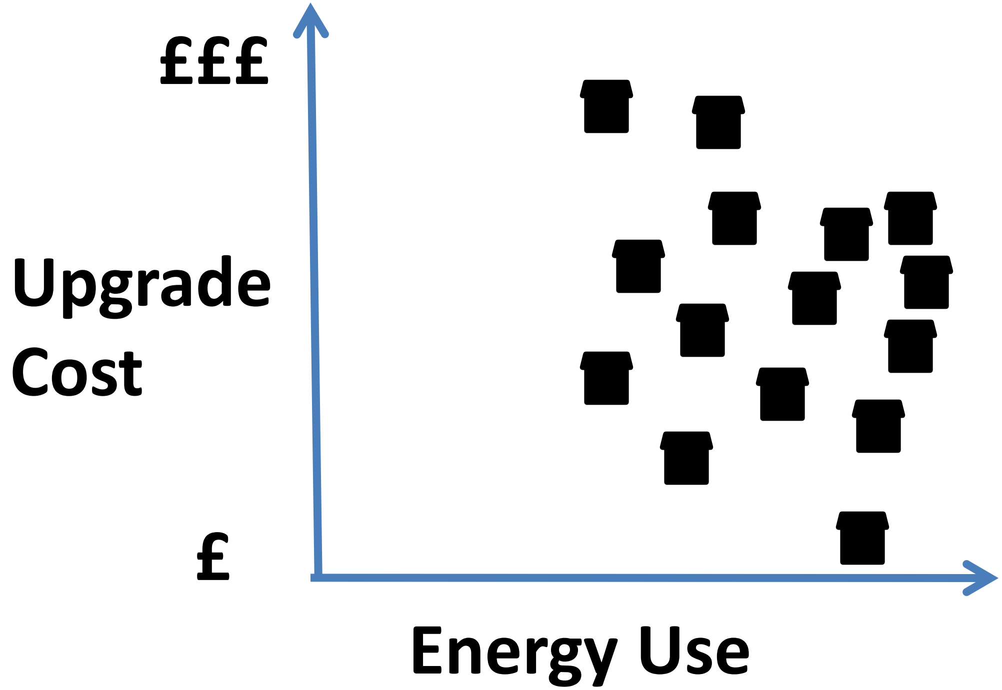
- Survival of the fittest
- Inheritance from parents to offspring

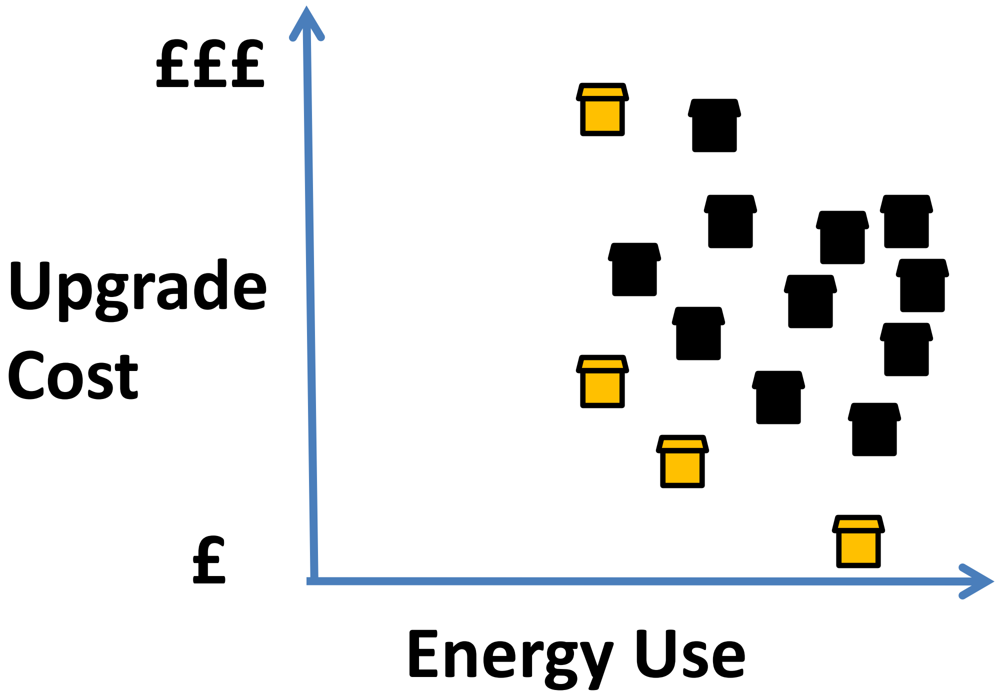


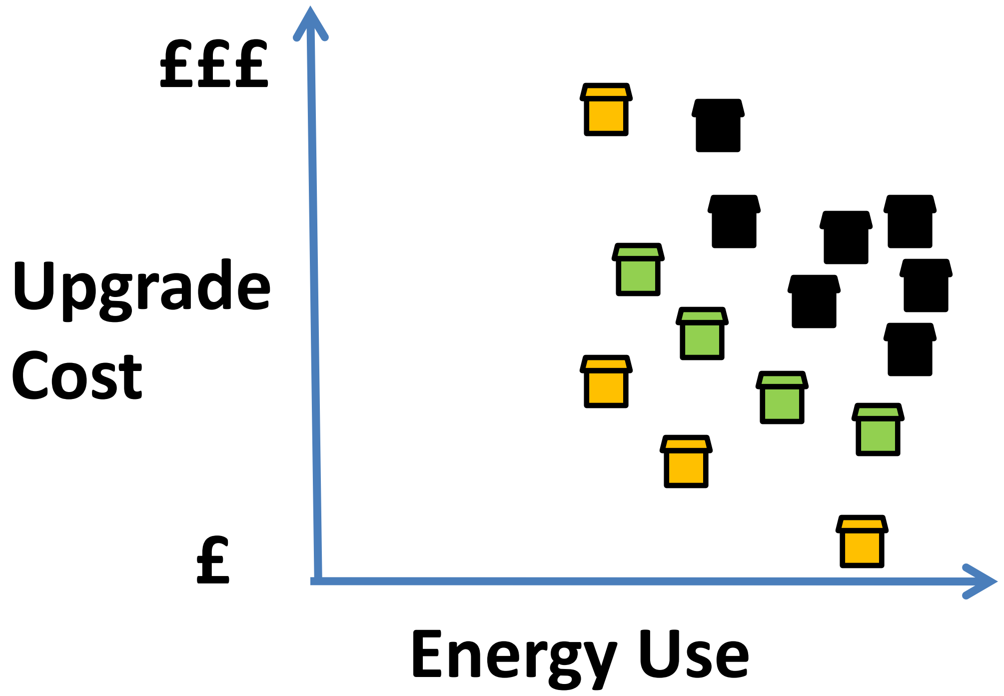
EAs for optimising buildings




£££
Upgrade
Cost
£
Energy Use


£££
Upgrade
Cost
£
Energy Use


£££
Upgrade
Cost
£
Energy Use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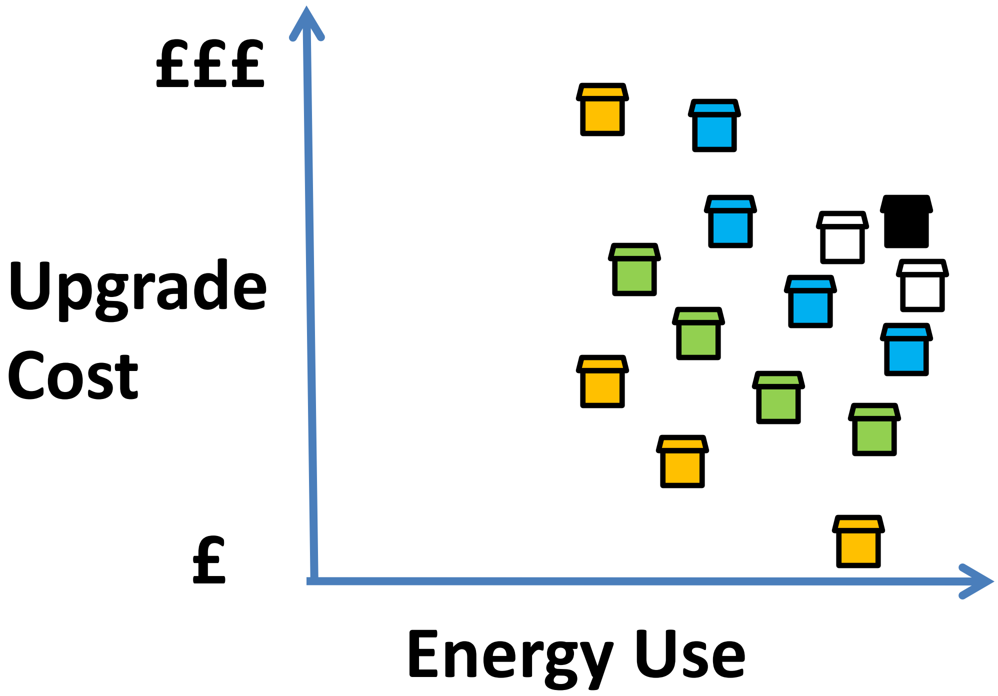
Upgrade
Cost
£
Energy Use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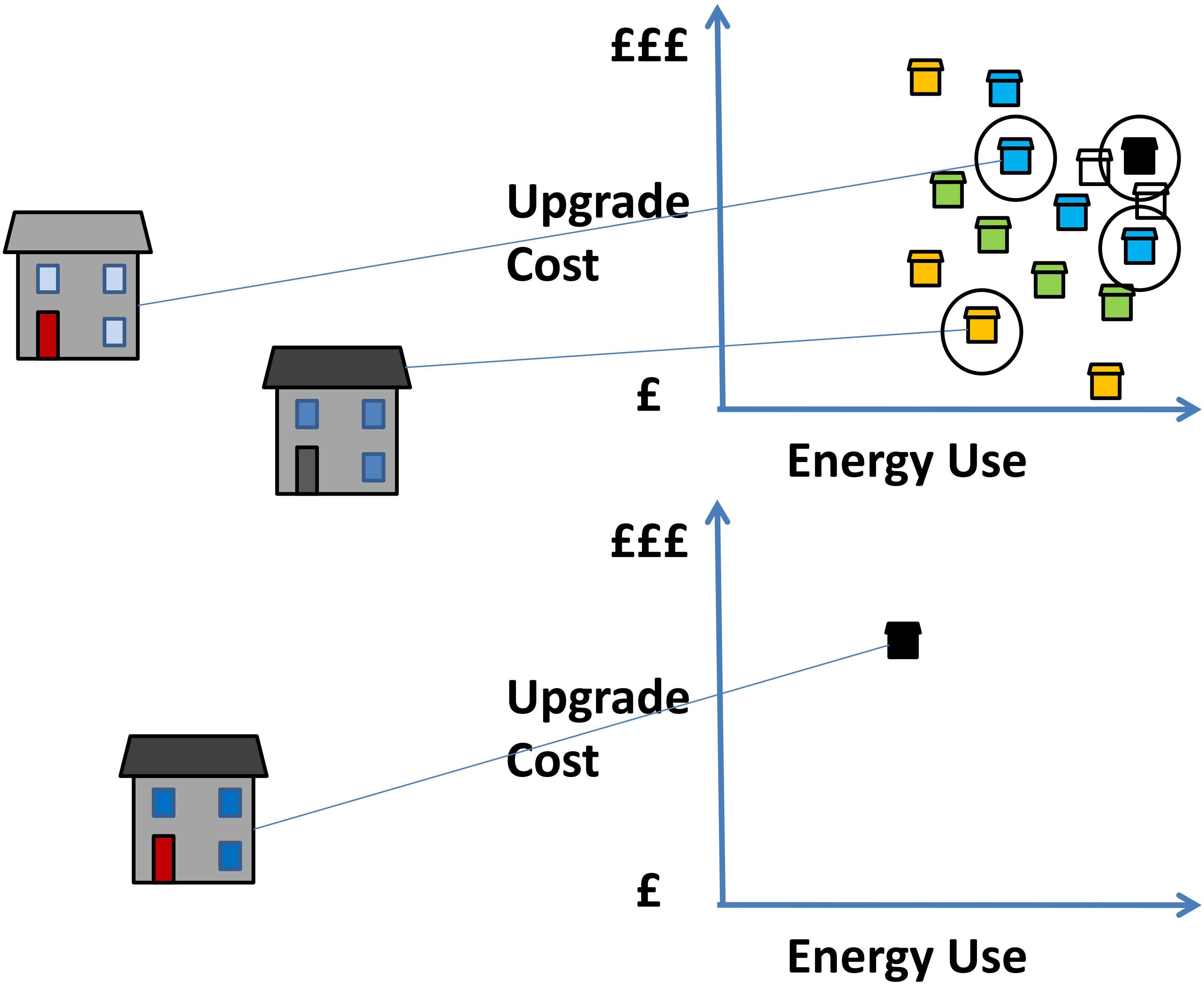
Upgrade
Cost
£
Energy Use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Cost
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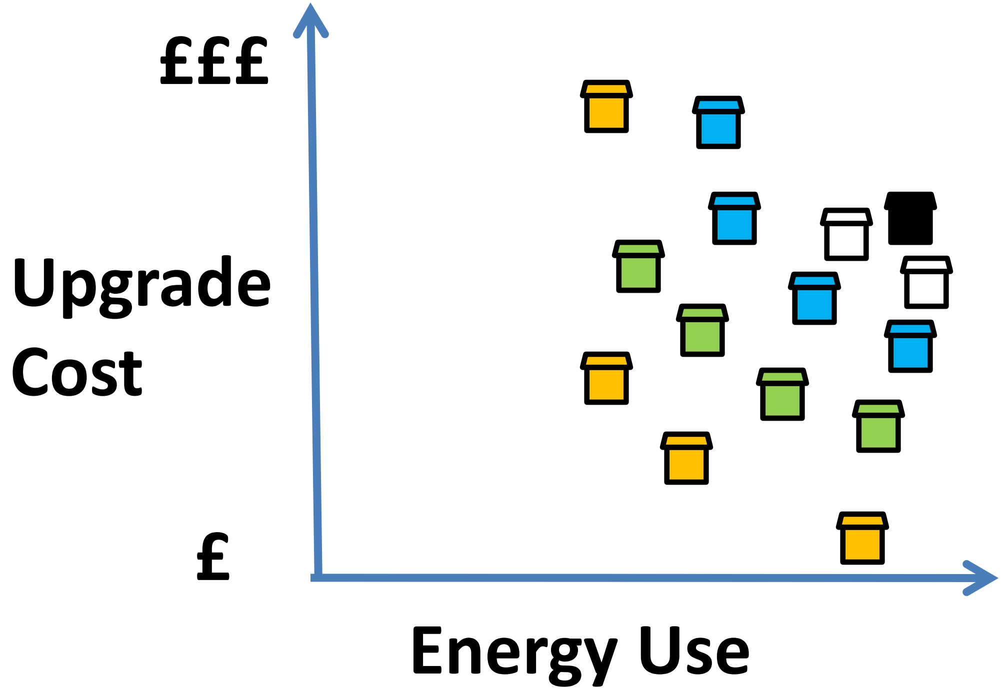
Energy Use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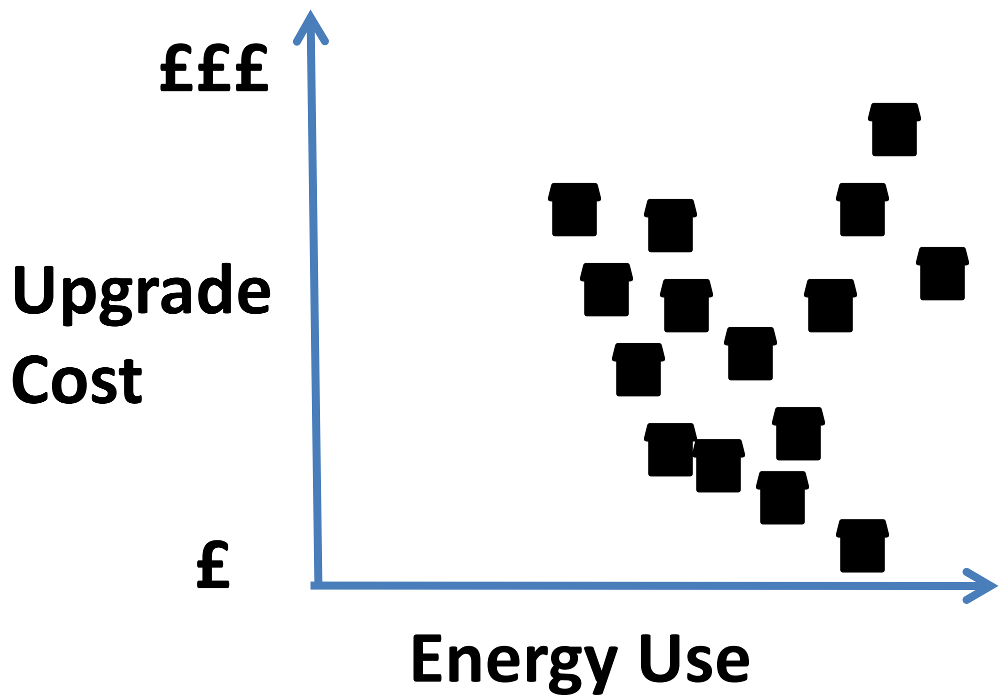
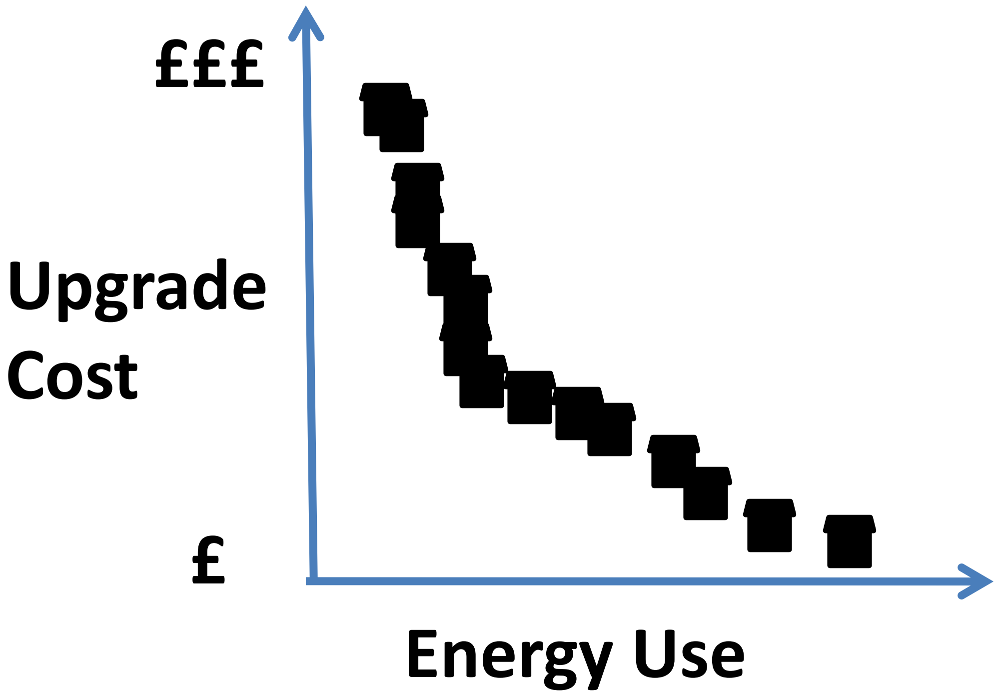
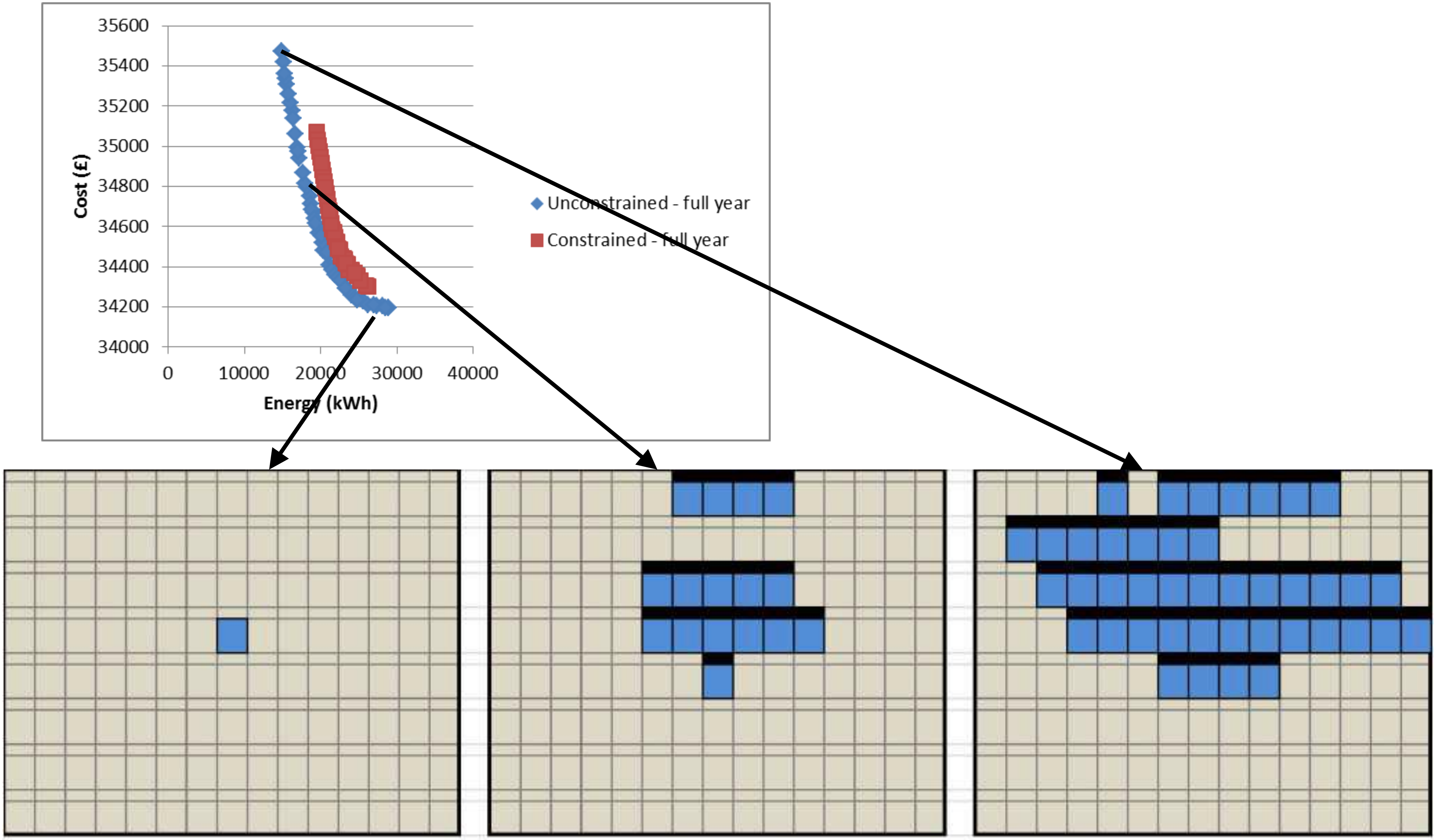
Upgrade Cost
£
Energy Use


£££
Upgrade Cost
£
Energy Use


£££
Upgrade
Cost
£
Energy Use

Example 1: Cellular Windows



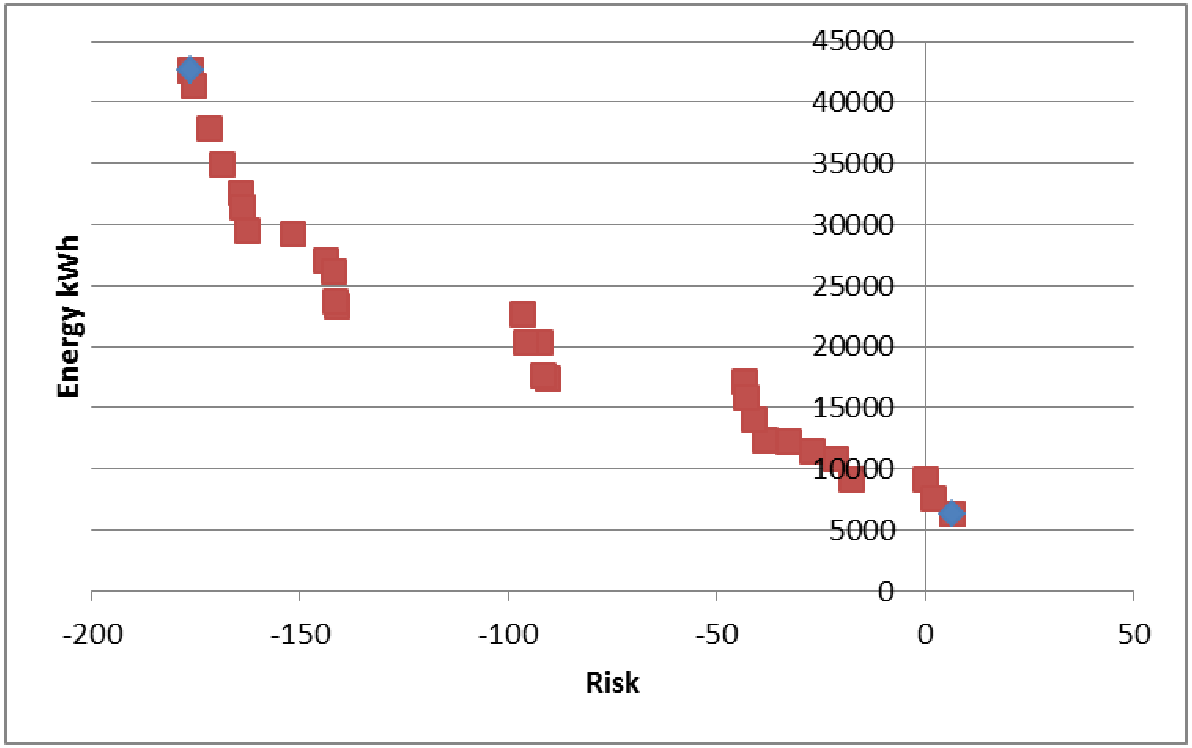
(a)
Lowest capital cost; highest energy use

(b)
Median capital cost and energy use

(c)
Highest capital cost and lowest energy use

Example 2: Risk of mould growth

- Hospital ward in Kuala Lumpur
- Optimise air conditioning / ventilation configuration to identify high risk conditions
- Risk related to long, warm, damp periods

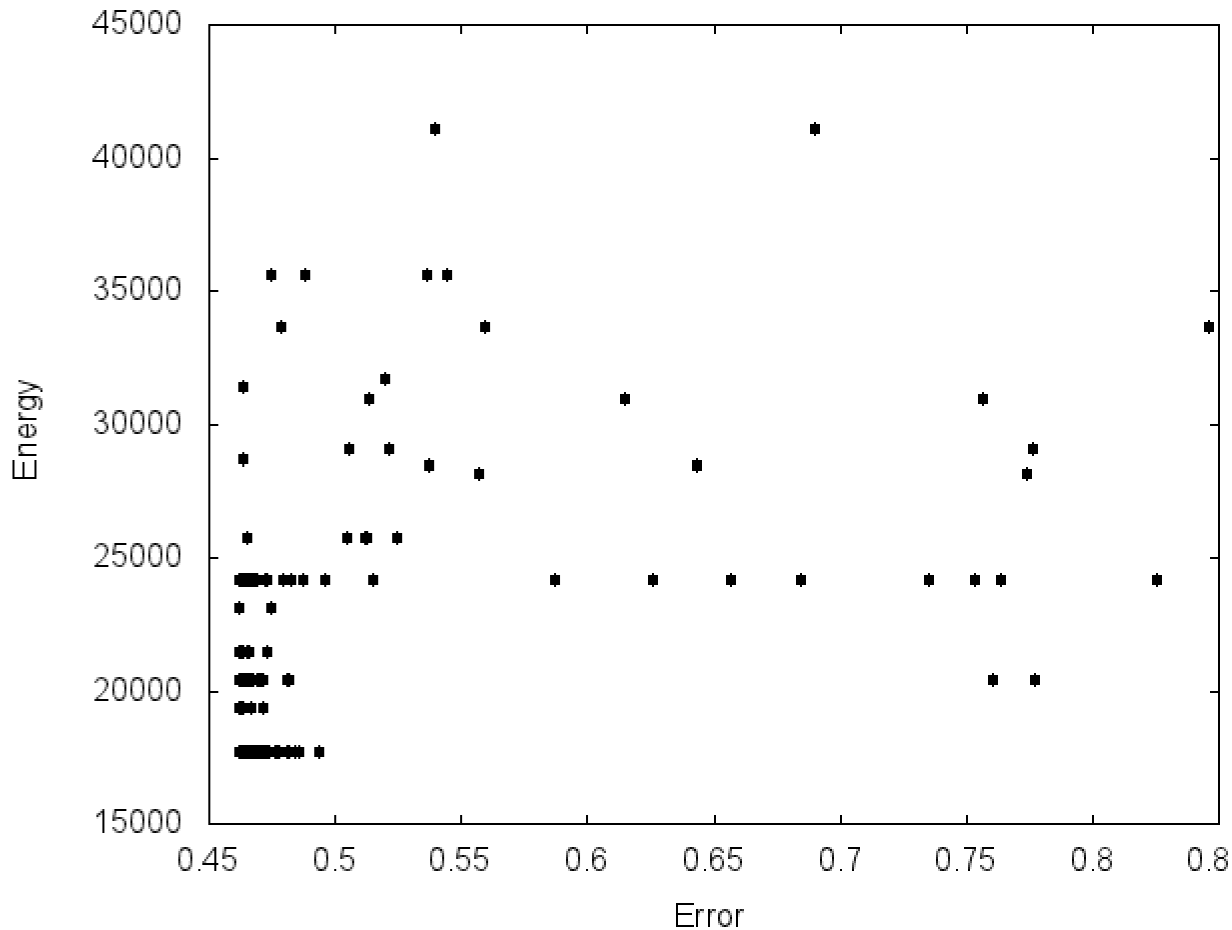


Some other applications…

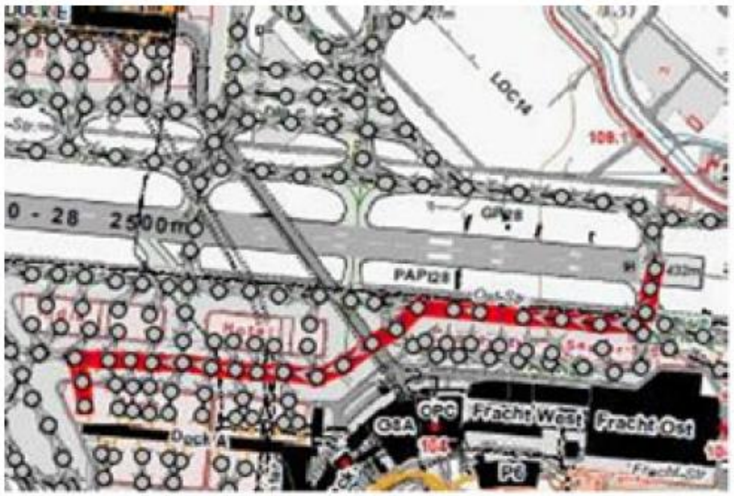
More efficient software

- What's more important?
  - Run faster
  - Better results
  - Longer on battery

- More on ANNs
  - for associative memory
  - 12 May
  - Bruce Graham

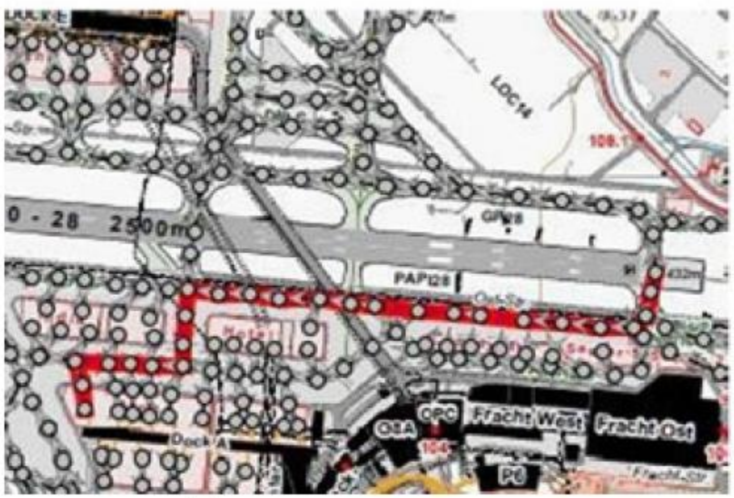


Greener Aircraft Taxiing

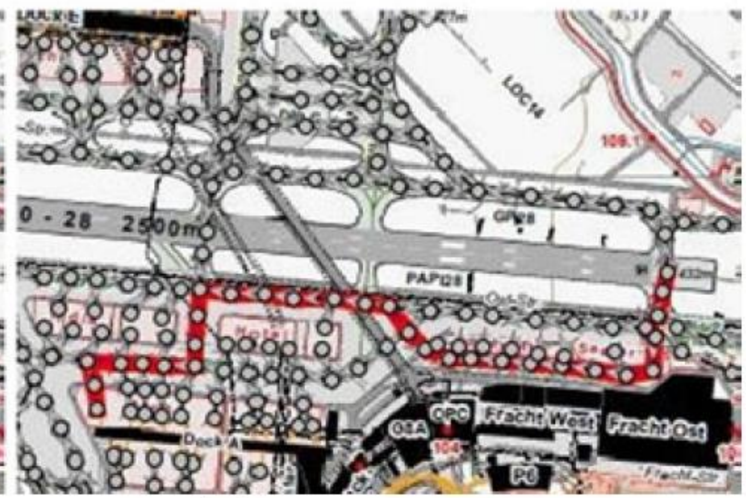


(a) Shortest route

(b) Alternative route



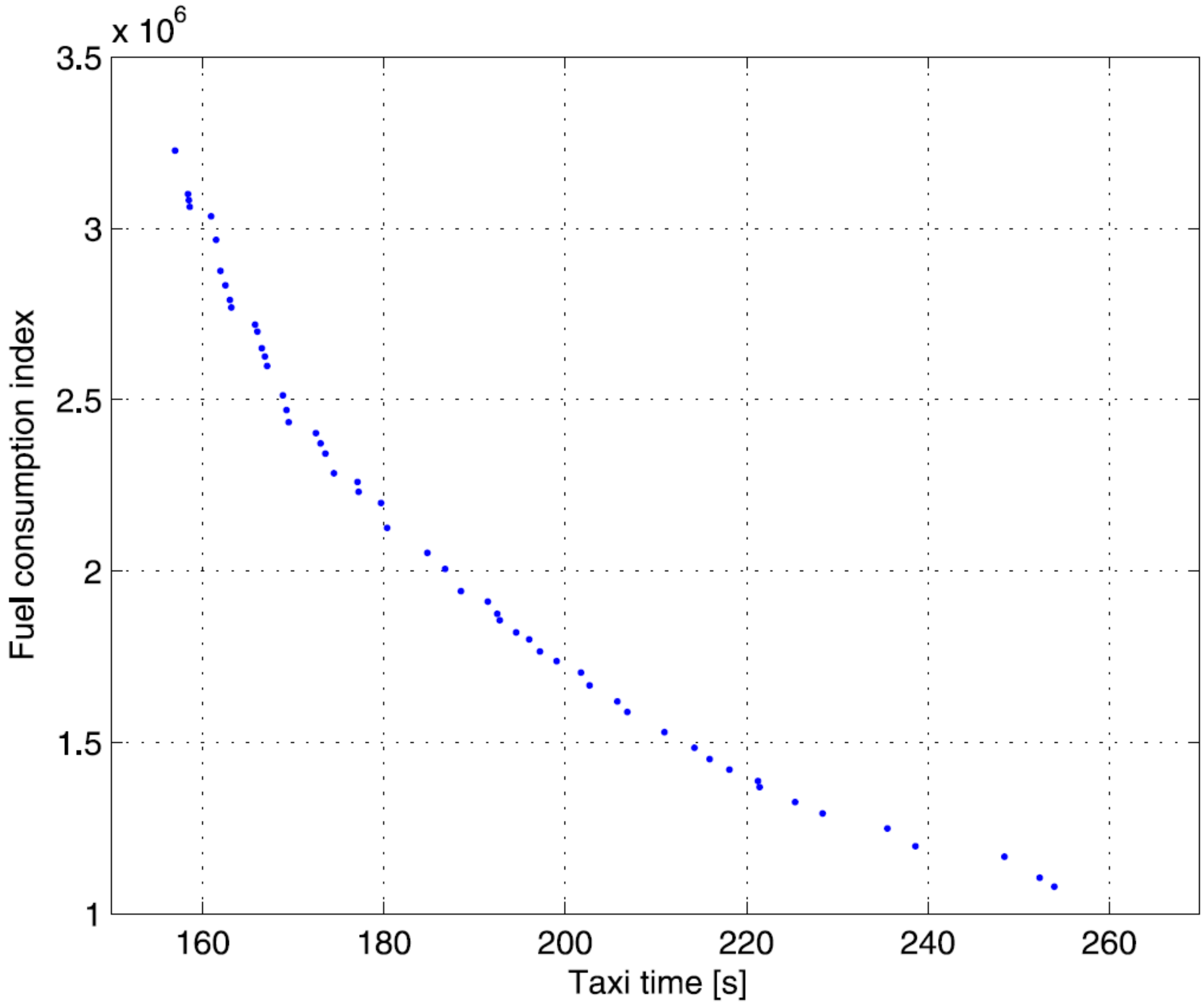
(c) Alternative route



(d) Alternative route

Figures from: Ravizza, S; Chen, J; Atkin J; Burke, E & Stewart, P. (2013) *The trade-off between taxi time and fuel consumption in airport ground movement.* Public Transp 5:25–40. DOI 10.1007/s12469-013-0060-1

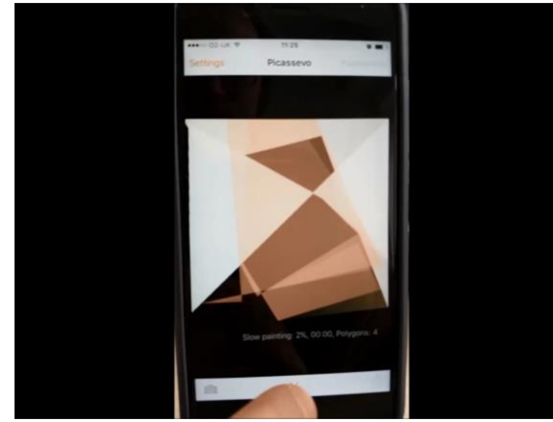
Greener Aircraft Taxiing

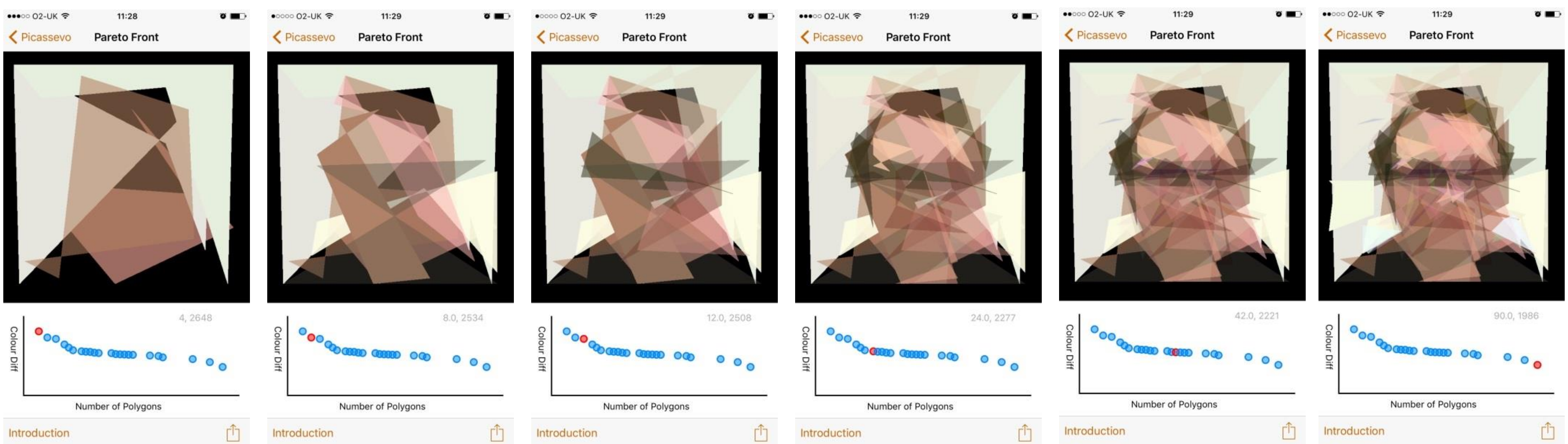


Figures from: Ravizza, S; Chen, J; Atkin J; Burke, E & Stewart, P. (2013) *The trade-off between taxi time and fuel consumption in airport ground movement.* Public Transp 5:25–40. DOI 10.1007/s12469-013-0060-1

Picassevo

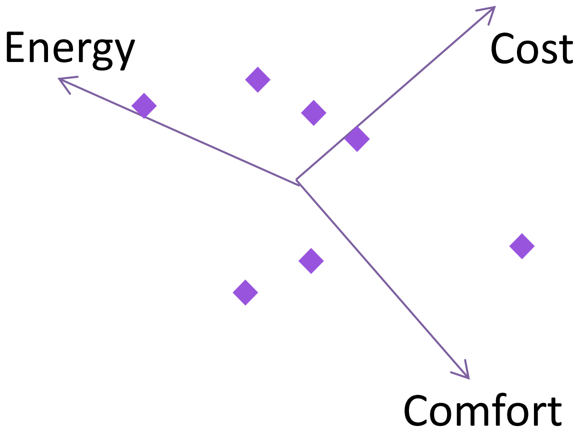
- Free from the iPhone app store
- https://appsto.re/gb/en1Nab.i
- Developed by our partners in the DAASE project at UCL:
  - http://daase.cs.ucl.ac.uk

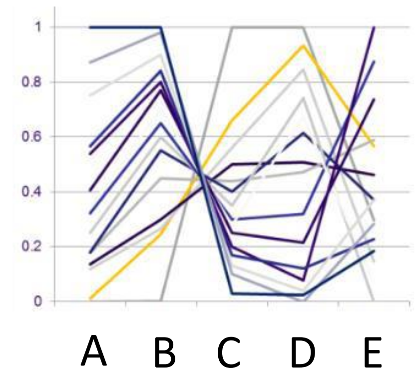




Ongoing research

- many objectives
  - how to optimise?
  - how to visualise?





- exploring the Pareto front

- more efficient search methods

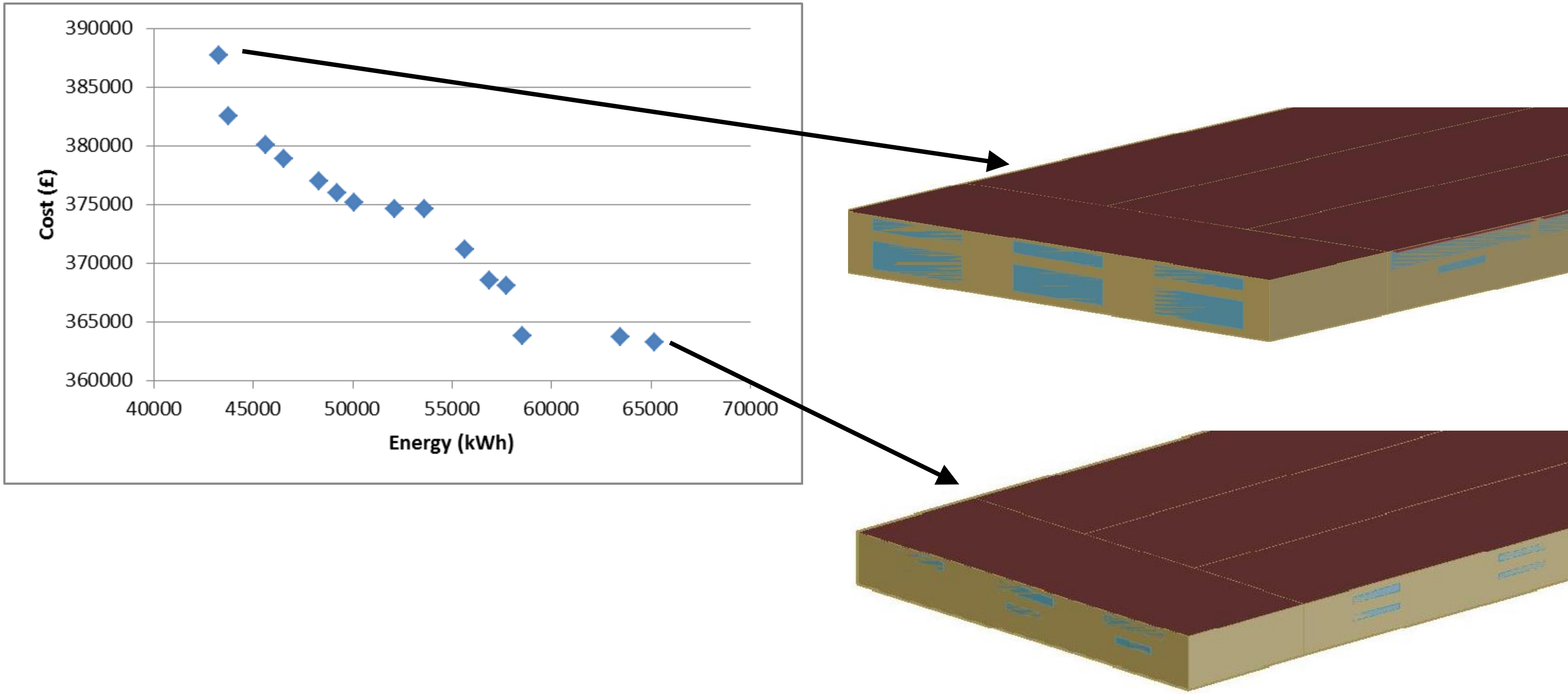
- human in the loop

Thanks!

- www.cs.stir.ac.uk/~sbr --- sbr@cs.stir.ac.uk
- Picassevo: https://appsto.re/gb/en1Nab.i
- Article on nature-inspired algorithms
  - "Why we fell out of love with algorithms inspired by nature" (link from homepage above)

- **Next Lecture: 31st March**
- **Zero: the history of an unappreciated number. Dr Anthony O'Hare**

Example 3: Office building



Exploring the Pareto front

A – heating set point

B – cooling set-point

C – temp for nat. vent

D – glazed area (N Upper)

E – glazed area (S Upper)

F – mech. ventilation rate

G – external wall type

H – ceiling and floor type

I – shading overhang (S)

Energy	CapCost	A	B	C	D	E	F	G	H	I
0.00	1.00	0.5	0.564516	0.98	0.65	0.82	0.11	0	1	1
0.01	0.90	0.5	0.564516	0.98	0.65	0.73	0.11	0	1	1
0.03	0.82	0.5	0.580645	0.98	0.57	0.73	0.11	0	1	1
0.04	0.76	0.5	0.580645	0.98	0.49	0.73	0.11	0	1	0
0.07	0.74	0.5	0.564516	0.98	0.49	0.73	0.11	0	1	0
0.07	0.70	0.5	0.564516	0.98	0.49	0.73	0.22	0	1	0
0.10	0.66	0.5	0.580645	0.98	0.41	0.73	0.11	0	1	0
0.10	0.62	0.5	0.564516	0.98	0.65	0.82	1.00	1	1	1
0.10	0.61	0.5	0.564516	0.98	0.65	0.82	0.11	1	1	1
0.10	0.61	0.5	0.564516	0.98	0.65	0.82	1.00	1	1	1
0.12	0.59	0.5	0.612903	0.98	0.65	0.82	0.67	1	1	1
0.14	0.57	0.5	0.548387	0.98	0.49	0.73	0.11	1	1	0
0.15	0.54	0.4	0.548387	0.98	0.57	0.73	0.67	1	1	0
0.17	0.53	0.4	0.548387	0.98	0.57	0.73	0.67	1	1	0
0.18	0.52	0.5	0.564516	0.98	0.49	0.73	0.11	1	1	0
0.18	0.49	0.4	0.548387	0.98	0.57	0.73	0.67	1	1	0
0.21	0.45	0.4	0.564516	0.98	0.41	0.43	0.11	0.5	1	0
0.21	0.43	0.5	0.564516	0.98	0.57	0.43	0.67	1	1	0
0.21	0.37	0.4	0.548387	0.98	0.49	0.43	0.67	1	1	0
0.24	0.35	0.4	0.548387	0.98	0.49	0.43	0.67	1	1	0
0.27	0.32	0.4	0.548387	0.98	0.41	0.43	0.11	1	1	0
0.32	0.30	0.4	0.548387	0.98	0.33	0.43	0.67	1	1	0
0.33	0.29	0.4	0.548387	0.98	0.33	0.43	0.11	1	1	0
0.35	0.27	0.4	0.580645	0.98	0.35	0.43	0.11	1	1	0
0.35	0.26	0.4	0.596774	0.98	0.24	0.43	0.11	1	1	0
0.36	0.25	0.4	0.548387	0.98	0.29	0.43	0.11	1	1	0
0.38	0.25	0.4	0.596774	0.98	0.33	0.33	0.11	1	1	0
0.39	0.25	0.4	0.596774	0.98	0.33	0.33	0.11	1	1	0
0.39	0.24	0.4	0.596774	0.98	0.33	0.33	0.11	1	1	0
0.41	0.20	0.4	0.596774	0.98	0.33	0.33	0.67	1	1	0
0.46	0.20	0.4	0.596774	0.98	0.33	0.33	0.11	1	1	0
0.46	0.20	0.4	0.596774	0.98	0.33	0.33	0.11	1	1	0
0.47	0.19	0.4	0.564516	0.98	0.24	0.33	0.11	1	1	0
0.49	0.18	0.4	0.596774	0.98	0.24	0.33	1.00	1	1	0
0.54	0.16	0.4	0.532258	1.00	0.24	0.33	0.11	1	1	0
0.55	0.14	0.4	0.596774	0.98	0.24	0.33	0.67	1	1	0
0.57	0.12	0.4	0.596774	0.98	0.24	0.33	0.11	1	1	0
0.64	0.11	0.4	0.612903	0.98	0.24	0.43	0.11	1	1	0
0.64	0.11	0.4	0.612903	0.98	0.33	0.33	0.00	1	1	0
0.65	0.09	0.4	0.596774	0.98	0.24	0.33	0.11	1	1	0
0.66	0.08	0.4	0.612903	0.98	0.24	0.33	0.11	1	1	0
0.67	0.08	0.4	0.612903	0.98	0.24	0.33	0.11	1	1	0
0.67	0.07	0.4	0.612903	0.98	0.24	0.33	0.11	1	1	0
0.70	0.07	0.4	0.612903	1.00	0.24	0.33	0.11	1	1	0
0.91	0.05	0.4	0.612903	0.98	0.33	0.04	0.11	1	1	0
0.92	0.04	0.4	0.596774	0.98	0.33	0.04	0.11	1	1	0
0.93	0.01	0.4	0.596774	0.98	0.29	0.04	0.11	1	1	0
0.97	0.01	0.4	0.612903	0.98	0.24	0.04	0.11	1	1	0
1.00	0.00	0.4	0.612903	1.00	0.24	0.04	0.11	1	1	0
Corr. with energy:		-0.76	0.63	0.32	-0.86	-0.93	-0.31	0.61	0.00	-0.54