CENTRE FOR RESEARCH INTO ENERGY DEMAND SOLUTIONS

The New Normal

Electricity demand and the potential for flexibility from EVs in a post-COVID, energy demand-conscious future

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ECEEE Summer Study 2022
Hyères, France

Government is (in theory) considering energy demand policies as a major lever for Net Zero

July 2018

HM Government

INDUSTRIAL STRATEGY

The Road to Zero

Next steps towards cleaner road transport and delivering our Industrial Strategy

- strategy sets out ambition for at least 50% — and as many as 70% — of new car sales to be ultra low emission by 2030, alongside up to 40% of new vans
- government will take ste... infrastructure to suppor[t] electric vehicle revolution
- strategy sets the stage ... hit UK roads since th[e] invention of the combustion engine

(early) March 2020

Department for Transport

Decarbonising Transport

Setting the Challenge

- Public transport and active travel will be the natural first choice for our daily activities. We ... public transport network.
- From motorcycles to HGV[s,] all road vehicles will be zero emission. Technological advances, including new ... will change the way vehicles are used.
- Our goods will be delivered through an integrate[d], efficient and sustainable delivery system.
- Clean, place-based solutions will meet the needs of local people. [C]hanges and leadership at a local level will make an important contribution to reducing national GHG emissions.
- The UK will be an internationally recognised leader in environmentally sustainable, [lo]w-carbon technology and innovation in transport.

CREDS has had significant impact in showing the role of energy demand policies in de-risking decarbonisation pathways

- "Energy demand reduction is a ***significant enabler*** of a cost-effective, timely and de-risked net-zero target"
- "The UK could ***more than halve its energy demand*** by 2050"
- "For mobility, ***the scale of reduction required cannot be achieved with electric vehicles alone but requires a reduction in distance travelled*** delivered through investment in active travel and not the further expansion of road networks"

https://low-energy.creds.ac.uk/wp-content/uploads/CREDS-Role-of-energy-demand-report-2021.pdf

Two of the CREDS low energy demand scenarios: Shift and Transform

SHIFT

- Significant shift in the attention given to energy demand strategies
- Ambitious programme of interventions across the whole economy describing what could be achieved with existing technologies and current social and political framings

TRANSFORM

- Transformative change in technologies, social practices, infrastructure and institutions
- Reductions in energy *and* numerous co-benefits: health, improved local environments, improved work practices, reduced investment needs and lower emissions

Low energy futures for mobility: a new normal?

A long (considerably longer than this) list of assumptions

Increase or decrease by 2030 and 2050 by scenario

Reasoning

Table 1: Passenger travel demand indicators, Shift demand and Transform demand scenarios

Type	Shift		Transform		Comment/source
	2030	2050	2030	2050	
Number of trips per person					
Commuting, reduction due to more in retirement	0%	5%	0%	5%	Proportion in working age or pensionable age will not increase substantially by 2030 (as pension age goes up) but the ratio does change by 2045 so that avg. number of working trips per person by then will go down. Of course, poorer pensions by then could mean that people would have to work into older age, but we have not assumed this.
Commuting, reduction due to working at home or teleworking	4%	7.5%	7.5%	13.5%	Industrial restructuring will have more impact on commuting than any policy, including telecommuting. The uptake in teleworking is reinforced by tax incentives, travel plans, gigabit/5G broadband-roll-out (by 2028 in HA, 2024 in TR), and road user charges and parking charges.
Commuting, increase due to gig and service economy	5%	15%	5%	15%	There are expectations that many more contingent and freelance workers will replace full time jobs, thus increasing trip rates per worker. (See trend data and evidence below.)
Commuting, reduction due to 4-day week	0%	0%	10%	15%	Only in Transform demand scenario: half of sectors introduce a 4-day week by 2030 (10% reduction in trips) and a further quarter by 2050 (15% reduction in trips).

The total change in each trip purpose, compiled from all the reasons in the LED scenarios

Consolidation

SHIFT SCENARIO, NUMBER OF TRIPS			
Trip type	**2019**	**2030**	**2050**
Commuting	1	1.01	1.025
Business	1	0.9	0.75
School travel	1	0.95	0.95
Shopping	1	0.8	0.7
Personal business	1	0.95	0.95
Local leisure	1	1.15	1.25
Distance leisure	1	1.1	1.2

TRANSFORM SCENARIO, NUMBER OF TRIPS			
Trip type	**2019**	**2030**	**2050**
Commuting	1	0.875	0.815
Business	1	0.85	0.65
School travel	1	0.95	0.95
Shopping	1	0.7	0.6
Personal business	1	0.9	0.9
Local leisure	1	1.15	1.3
Distance leisure	1	1.15	1.22

SHIFT SCENARIO, TRIP DISTANCE			
Trip type	**2019**	**2030**	**2050**
Commuting	1	0.92	0.75
Business	1	0.95	0.85
School travel	1	0.9	0.85
Shopping	1	0.9	0.9
Personal business	1	0.95	0.9
Local leisure	1	0.95	0.9
Distance leisure	1	0.95	0.9

TRANSFORM SCENARIO, TRIP DISTANCE			
Trip type	**2019**	**2030**	**2050**
Commuting	1	0.85	0.65
Business	1	0.9	0.83
School travel	1	0.85	0.75
Shopping	1	0.85	0.85
Personal business	1	0.9	0.85
Local leisure	1	0.9	0.85
Distance leisure	1	0.95	0.9

We want to look at the effect of these scenarios on the temporal variation in energy demand from transport

Objectives:

- To apply the LED scenarios to **travel diaries** (from the UK National Travel Survey)

- To analyse the impacts for the **energy system and potential flexibility from electric vehicle charging**

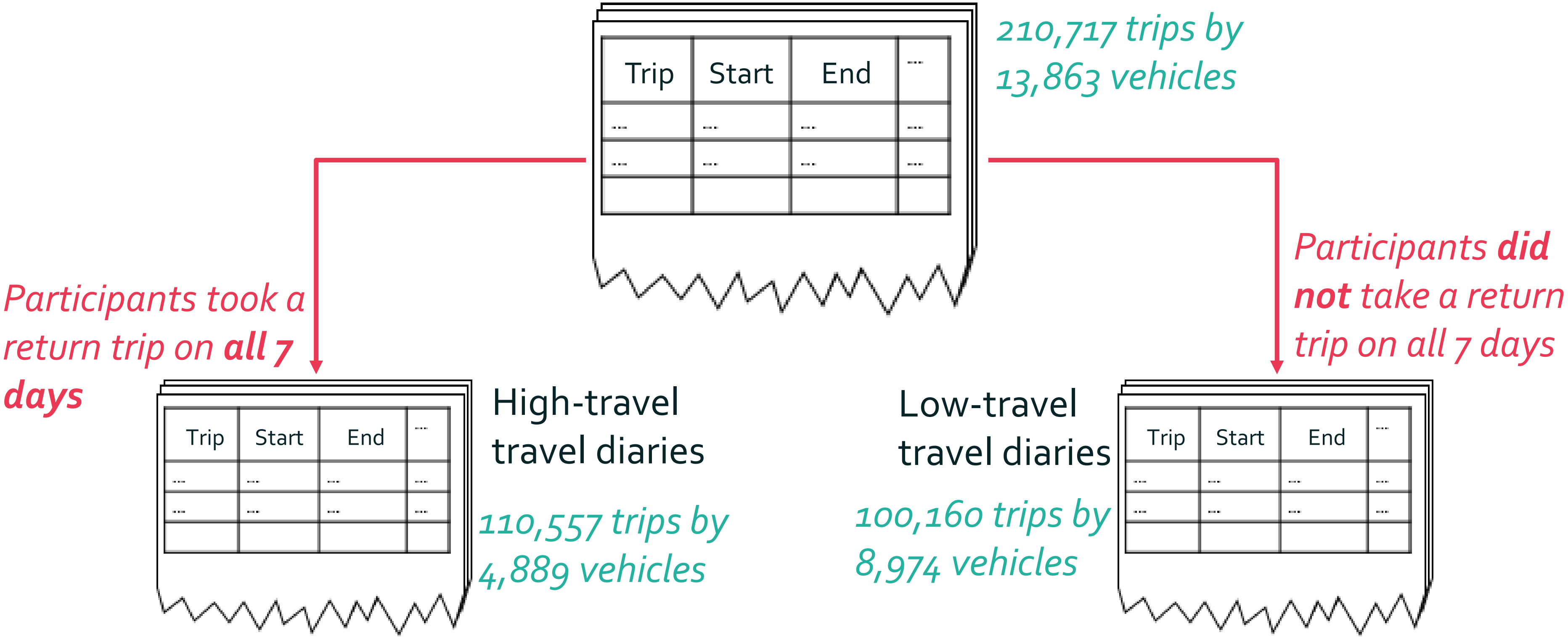
UK National Travel Survey (NTS) → vehicle-based travel diaries

- Annual survey conducted on behalf of the UK Department for Transport (DfT)
- ~15,000 respondents per year fill out a week-long travel diary
- One year → ~200,000 trips

Trip #	Origin	Destination	Trip Start	Trip End	Distance (miles)
1	Home	Food shop	Tu 09:30	Tu 09:50	3
2	Food shop	Home	Tu 10:40	Tu 11:00	3
3	Home	Other escort	Tu 18:15	Tu 18:20	0.25
4	Other escort	Home	Tu 18:20	Tu 18:25	0.25
5	Home	Other escort	Tu 19:40	Tu 19:45	0.25
6	Other escort	Home	Tu 19:50	Tu 19:55	0.25
7	Home	Food shop	W 09:30	W 09:50	3
8	Food shop	Home	W 10:30	W 10:45	3
9	Home	Work	Su 07:40	Su 08:00	7
10	Work	Home	Su 17:00	Su 17:20	7

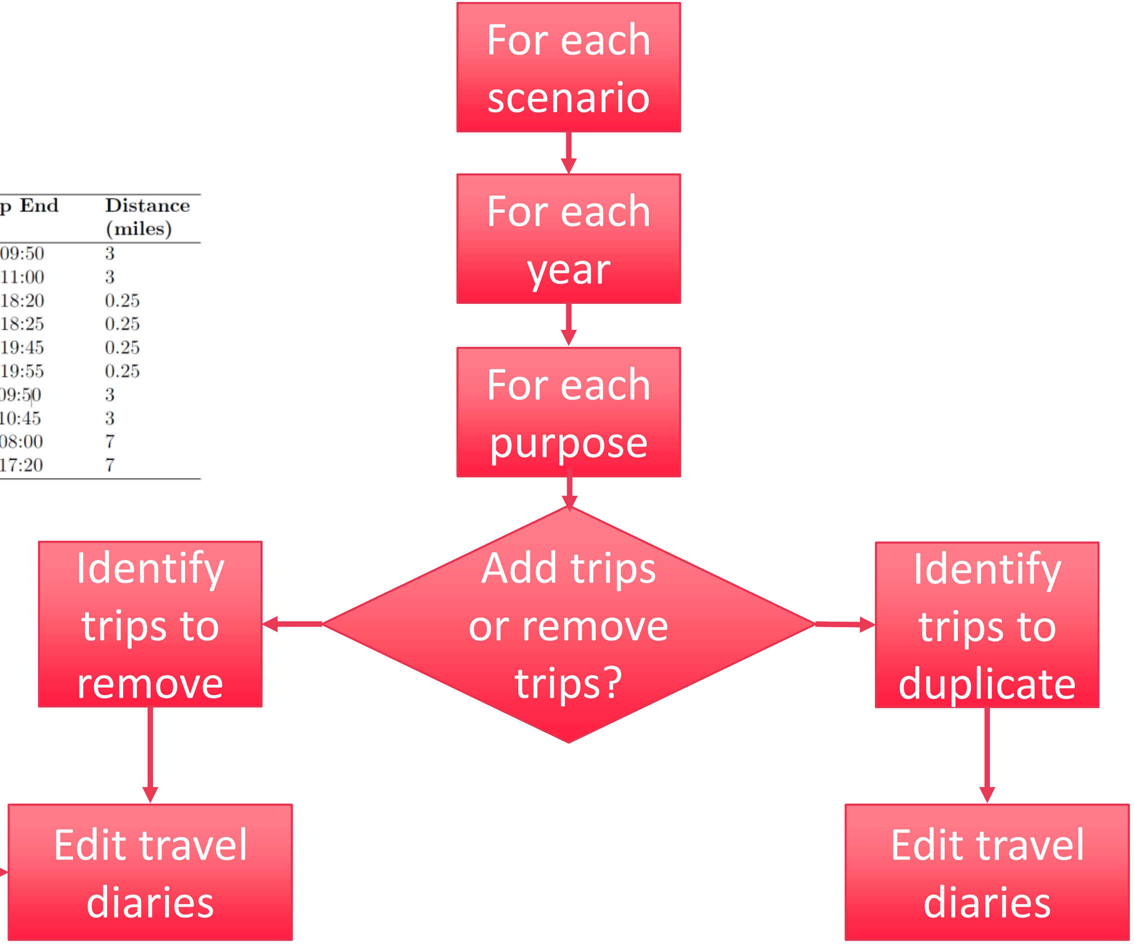
*Step 1: re-configure NTS data so that it's broken up into **vehicle-based** travel diaries (e.g. above)*

We split the NTS diaries into high-travel and low-travel diaries to enable analysis



Trip #	Origin	Destination	Trip Start	Trip End	Distance (miles)
1	Home	Food shop	Tu 09:30	Tu 09:50	3
2	Food shop	Home	Tu 10:40	Tu 11:00	3
3	Home	Other escort	Tu 18:15	Tu 18:20	0.25
4	Other escort	Home	Tu 18:20	Tu 18:25	0.25
5	Home	Other escort	Tu 19:40	Tu 19:45	0.25
6	Other escort	Home	Tu 19:50	Tu 19:55	0.25
7	Home	Food shop	W 09:30	W 09:50	3
8	Food shop	Home	W 10:30	W 10:45	3
9	Home	Work	Su 07:40	Su 08:00	7
10	Work	Home	Su 17:00	Su 17:20	7

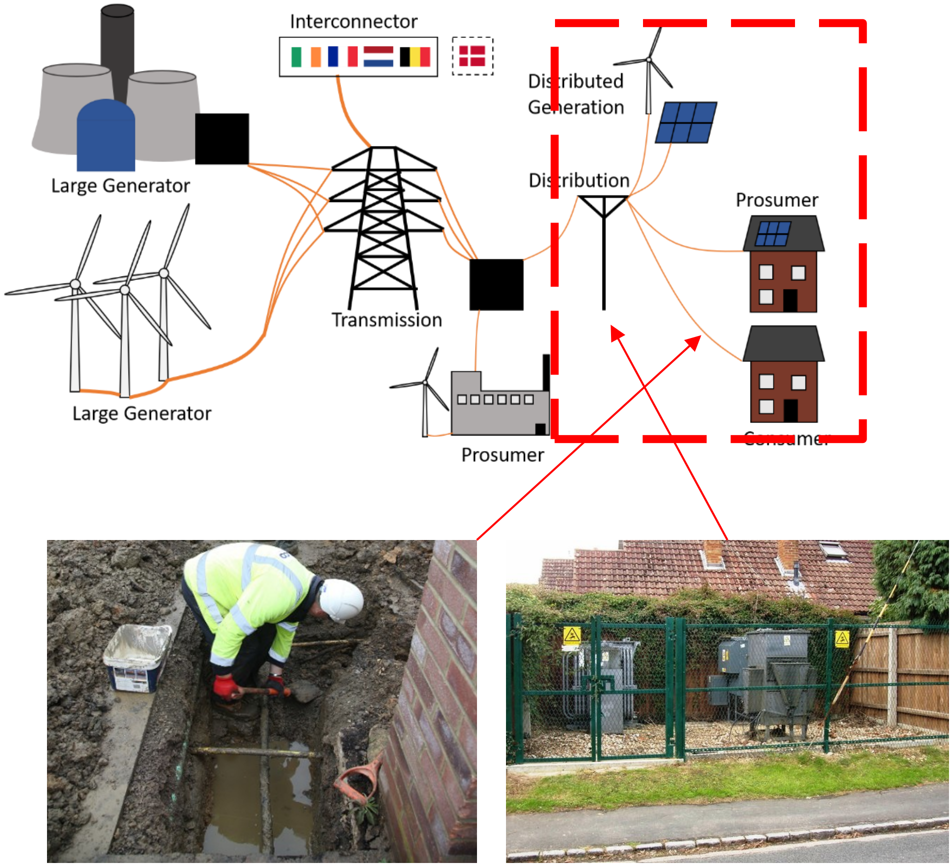
- Calculate number of trips to remove/add
- Randomly sample trips to add/remove
- For adding trips – ensure that duplicate trip can ‘fit’ into travel diary



Implications for Energy

- The ***magnitude*** of energy demand is only part of the story

- The ***timing*** of energy demand influences the ***peak consumption rate***, which sets the rate at which infrastructure must be developed



Travel Diaries are converted to Charging Schedules

Table 1: Example UK NTS travel diary (car-based trips)

Trip #	Origin	Destination	Trip Start	Trip End	Distance (miles)
1	Home	Food shop	Tu 09:30	Tu 09:50	3
2	Food shop	Home	Tu 10:40	Tu 11:00	3
3	Home	Other escort	Tu 18:15	Tu 18:20	0.25
4	Other escort	Home	Tu 18:20	Tu 18:25	0.25
5	Home	Other escort	Tu 19:40	Tu 19:45	0.25
6	Other escort	Home	Tu 19:50	Tu 19:55	0.25
7	Home	Food shop	W 09:30	W 09:50	3
8	Food shop	Home	W 10:30	W 10:45	3
9	Home	Work	Su 07:40	Su 08:00	7
10	Work	Home	Su 17:00	Su 17:20	7

Table 2: Minimal charging schedule derived from NTS travel diary in Table 1 for an EV with a battery capacity of 24 kWh and a home charger rated at 3.7 kW AC, 88% efficiency

Trip #	Charge Type	Plug-in	Plug-out	E_{start} (kWh)	E_{end} (kWh)	P^{max} (kW)
8	home	W 10:45	Su 07:40	8.44	24	3.26

Dixon, J., Andersen, P.B., Bell, K. and Træholt, C., 2020. On the ease of being green: An investigation of the inconvenience of electric vehicle charging. *Applied Energy*, *258*, p.114090.
Dixon, J. and Bell, K., 2020. Electric vehicles: Battery capacity, charger power, access to charging and the impacts on distribution networks. *ETransportation*, *4*, p.100059.
Dixon, J., Bukhsh, W., Edmunds, C. and Bell, K., 2020. Scheduling electric vehicle charging to minimise carbon emissions and wind curtailment. *Renewable Energy*, *161*, pp.1072-1091.

https://github.com/jamesjhdixon/evcharging

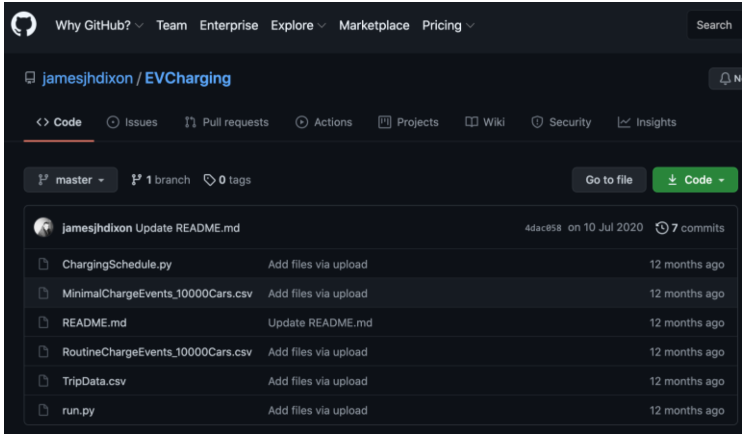


Table 3: Routine charging schedule derived from NTS travel diary in Table 1 for an EV with a battery capacity of 24 kWh and a home charger rated at 3.7 kW AC, 88% efficiency

Trip #	Charge Type	Plug-in	Plug-out	E_{start} (kWh)	E_{end} (kWh)	P^{max} (kW)
2	home	Tu 11:00	Tu 18:15	10.36	24	3.26
4	home	Tu 18:25	Tu 19:40	23.86	24	3.26
6	home	Tu 19:55	W 09:30	23.86	24	3.26
8	home	W 10:45	Su 07:40	22.36	24	3.26

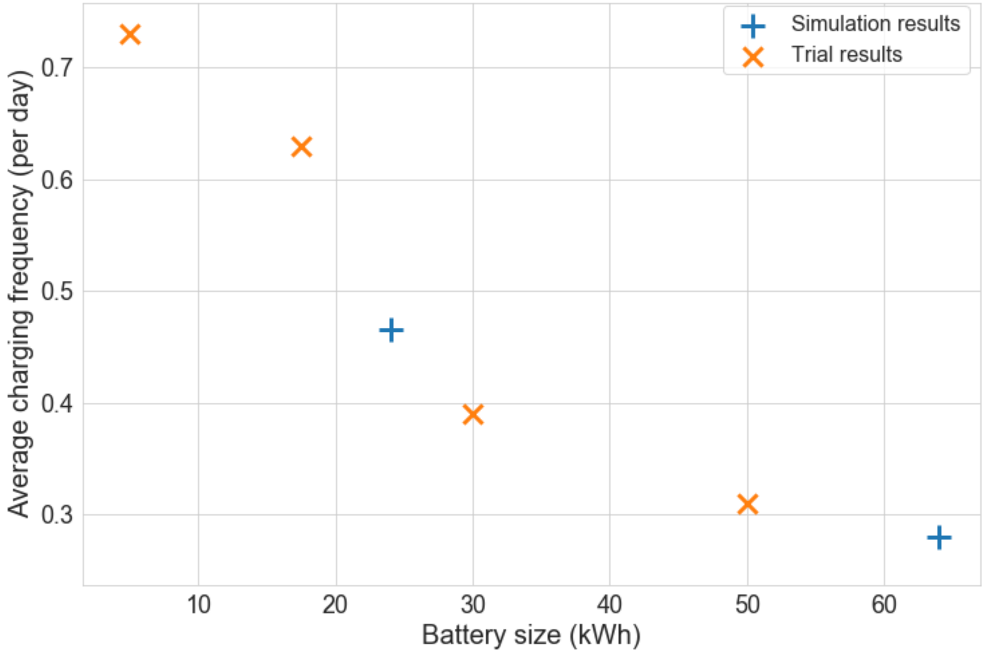
Charging frequency is validated against real trial data (Electric Nation)

FIGURE 6

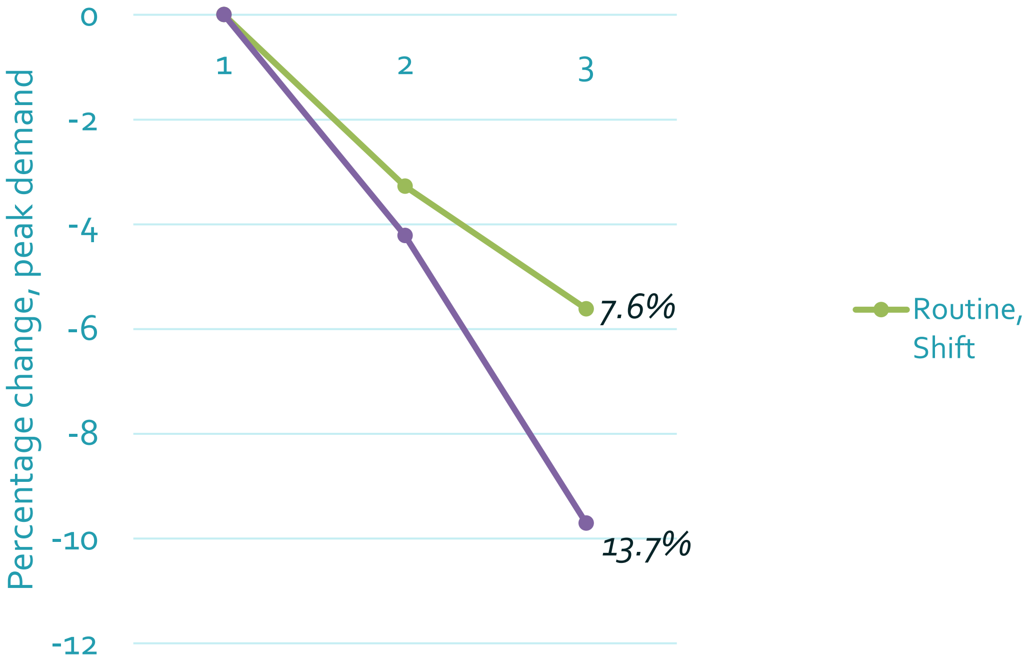
Charging Frequency for Different Vehicle Types

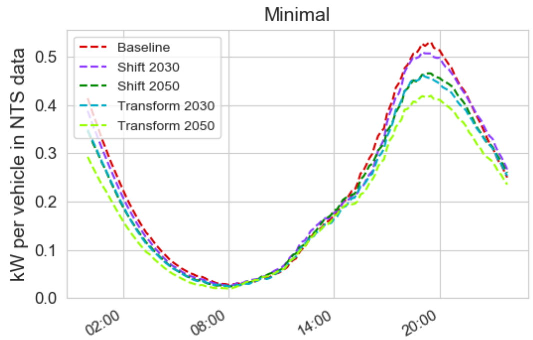
Category		Median Charging Frequency (Charge Sessions per Day)
All Participants		0.52
P/V Type	PHEV	0.76
	REX	0.45
	BEV	0.39
Battery Capacity	Less than 10kWh	0.73
	10 to 25kWh	0.63
	25 ro 35kWh	0.39
	35kWh +	0.31

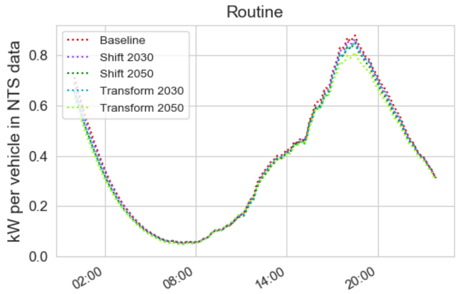
https://www.electricnation.org.uk/wp-content/uploads/2019/07/Electric-Nation-Trial-Summary-A4.pdf

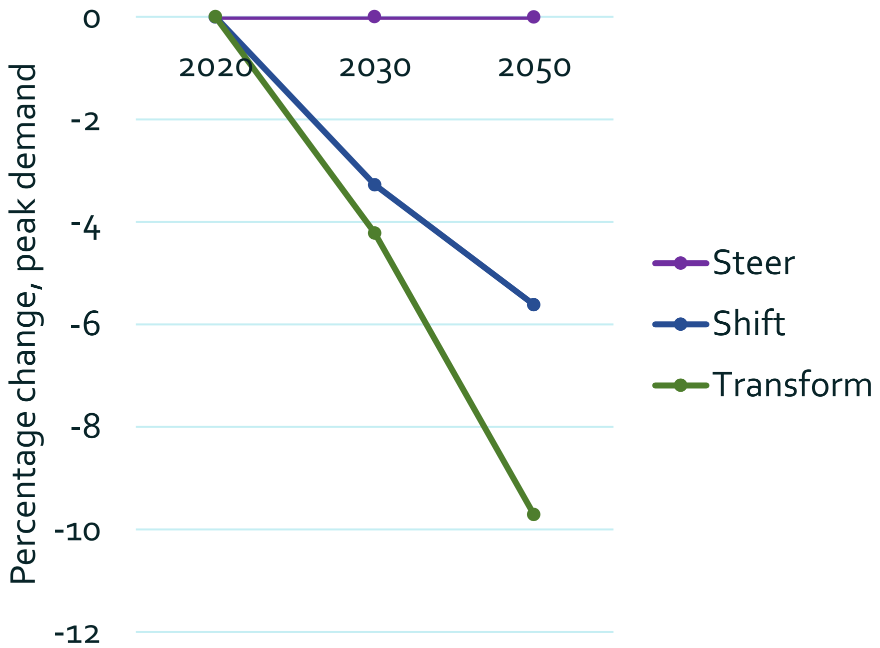


Peak charging demand can be reduced up to 14%

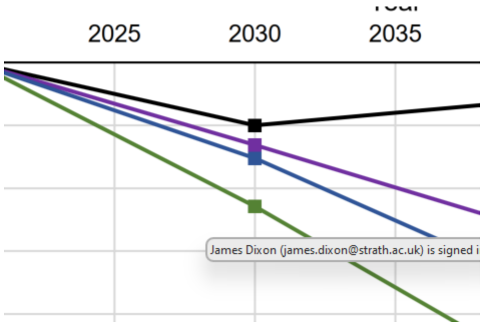




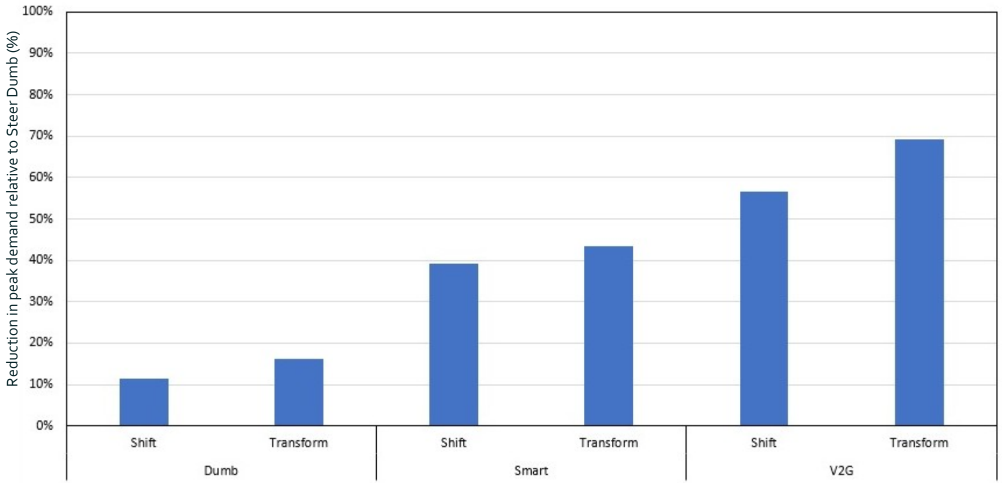




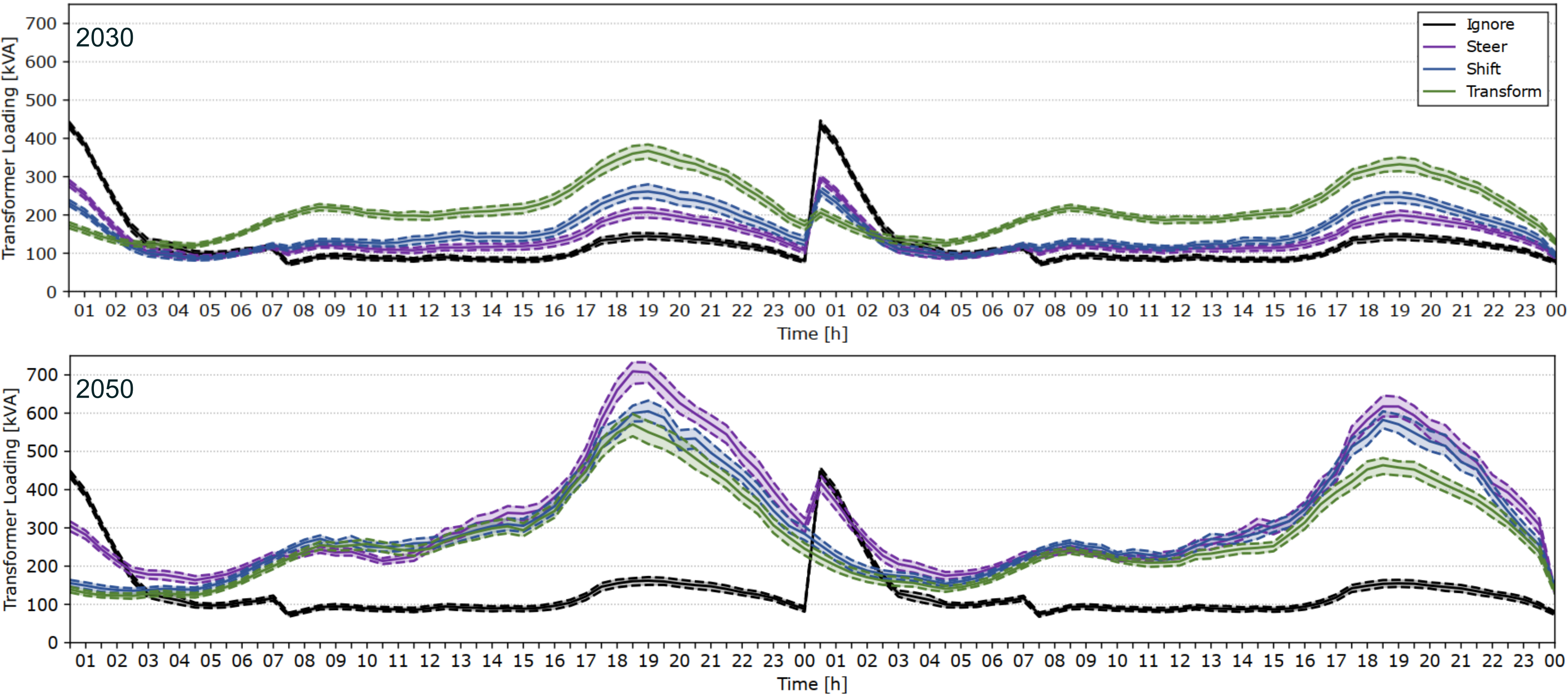
Percentage change, peak demand
0
-2
-4
-6
-8
-10
-12
2020
2030
2050
Steer
Shift
Transform

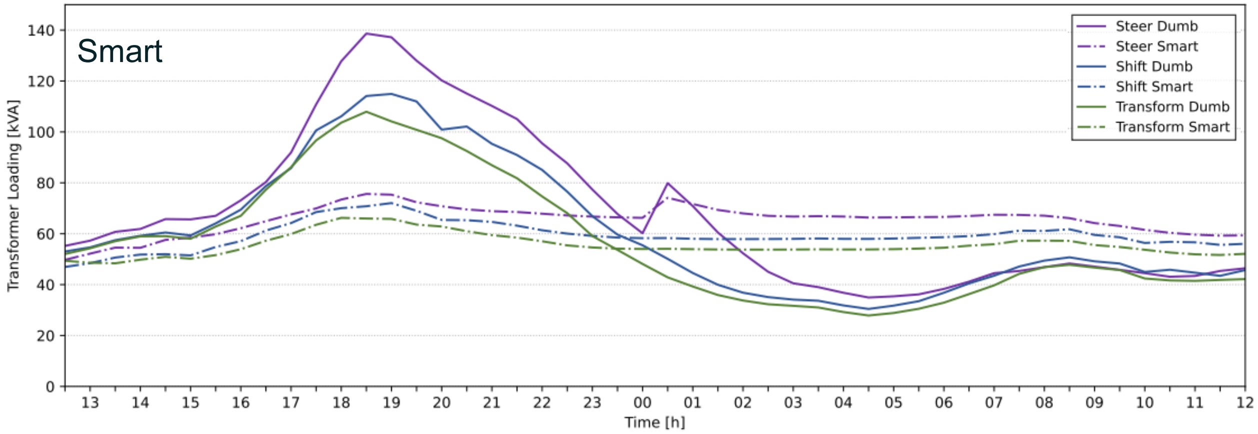


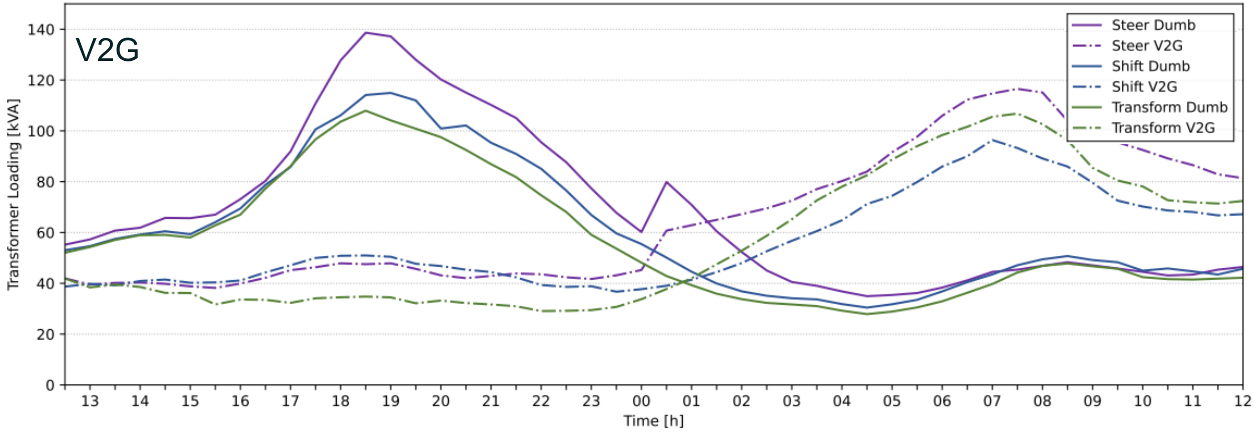
2025
2030
2035
James Dixon (james.dixon@strath.ac.uk) is signed i



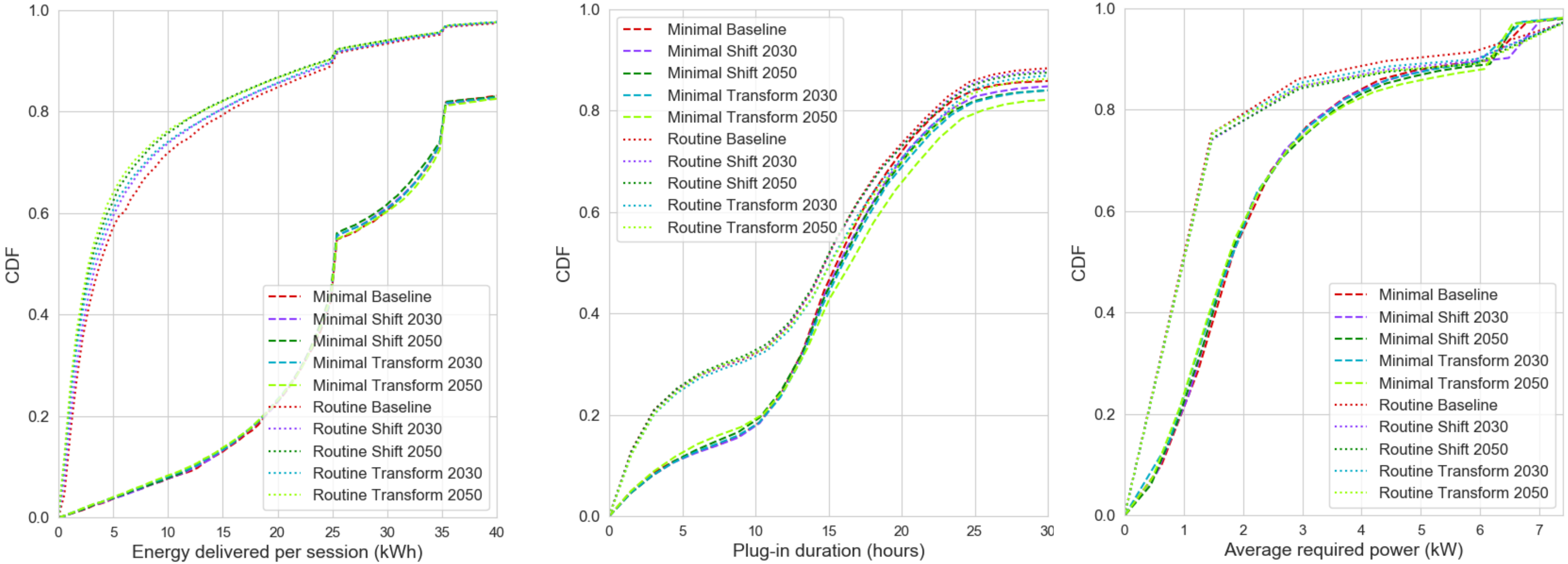
Reduction in peak demand relative to Steer Dumb (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Shift
Transform
Shift
Transform
Shift
Transform
Dumb
Smart
V2G


2030
Ignore
Steer
Shift
Transform
Transformer Loading [kVA]
0
100
200
300
400
500
600
700
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 00
Time [h]
2050
Transformer Loading [kVA]
0
100
200
300
400
500
600
700
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 00
Time [h]


Smart
Transformer Loading [kVA]
0
20
40
60
80
100
120
140
13
14
15
16
17
18
19
20
21
22
23
00
01
02
03
04
05
06
07
08
09
10
11
12
Time [h]
Steer Dumb
Steer Smart
Shift Dumb
Shift Smart
Transform Dumb
Transform Smart


V2G
Transformer Loading [kVA]
0
20
40
60
80
100
120
140
13
14
15
16
17
18
19
20
21
22
23
00
01
02
03
04
05
06
07
08
09
10
11
12
Time [h]
Steer Dumb
Steer V2G
Shift Dumb
Shift V2G
Transform Dumb
Transform V2G

Flexibility is generally greater but the effect is small- but there is a *much* greater effect from charging behaviour



Key takeaways

- Energy demand-focussed policies can reduce peak demand from EV charging, reducing required spend on infrastructure
  - Up to **14% reduction in peak kW per vehicle** if ‘Transform’ policies are pursued

- Flexibility of charging demand can be measured by the **plug-in duration** and the **energy that must be delivered**

- The effect on flexibility in these terms from demand-focussed policies is **small** – but there is significant effect from charging behaviour (i.e. how often people plug in)

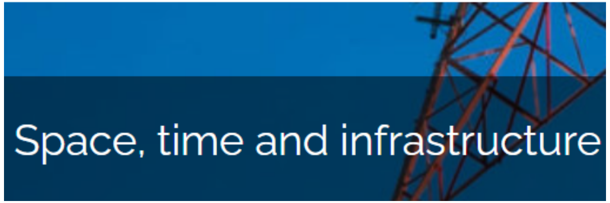
Further work

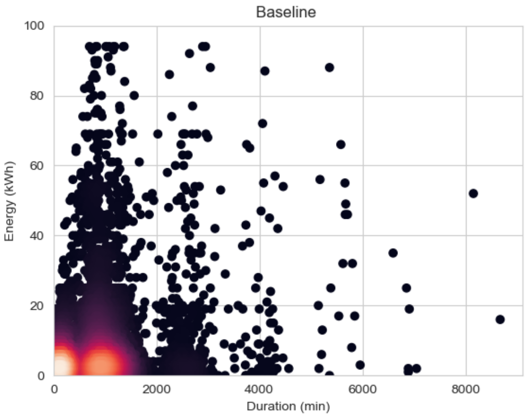
- Include longitudinal survey data on post-lockdown travel behaviour to inform future scenarios

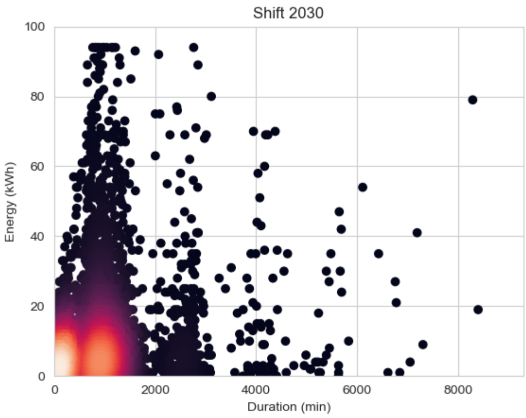
- Extend flexibility modelling – potential for smart charging & V2X

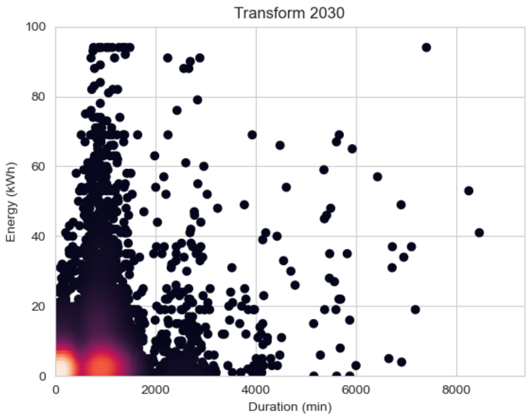
- Combine electricity demand for EV charging with electricity demand for heating (and effects since COVID)

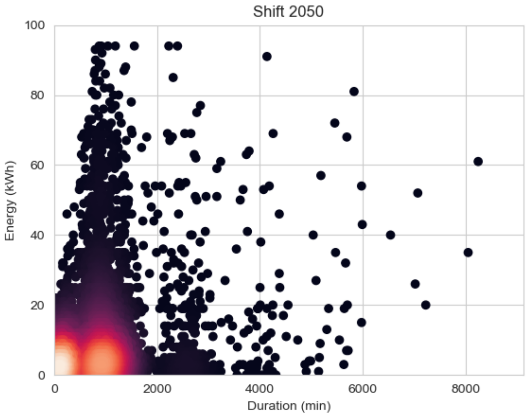
https://www.creds.ac.uk/uk-electricity-supply-infrastructure/

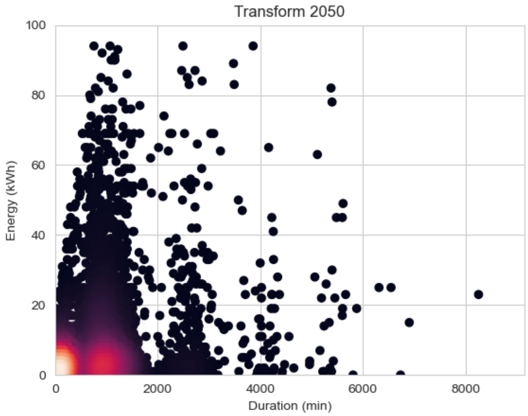



Baseline
Energy (kWh)
100
80
60
40
20
0
0
2000
4000
6000
8000
Duration (min)


Shift 2030
Energy (kWh)
100
80
60
40
20
0
0
2000
4000
6000
8000
Duration (min)


Transform 2030
Energy (kWh)
100
80
60
40
20
0
0
2000
4000
6000
8000
Duration (min)


Shift 2050
Energy (kWh)
100
80
60
40
20
0
0
2000
4000
6000
8000
Duration (min)


Transform 2050
Energy (kWh)
100
80
60
40
20
0
0
2000
4000
6000
8000
Duration (min)

ENERGY DEMAND PER CHARGE EVENT, kWh			
Scenario	**2019**	**2030**	**2050**
Shift	9.71	8.26	9.43
Transform		8.90	8.15