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The Impact of the Weather on Electric Vehicle Fleet Demand

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1. Evidence for how EV energy consumption is impacted by the weather
2. Two methods to model this relationship
3. Case study: German fleet
4. Case study: UK fleet

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Weather has an increasing impact on electricity supply and demand

- *Staffell & Pfenninger (2018)*
  - Electricity supply and demand are becoming **increasingly weather-dependent**
  - Heat electrification could see **peak demand increase by 20% in 15 years**
  - Additional weather driven loads may worsen this issue, **increasing cost or risk security of supply**

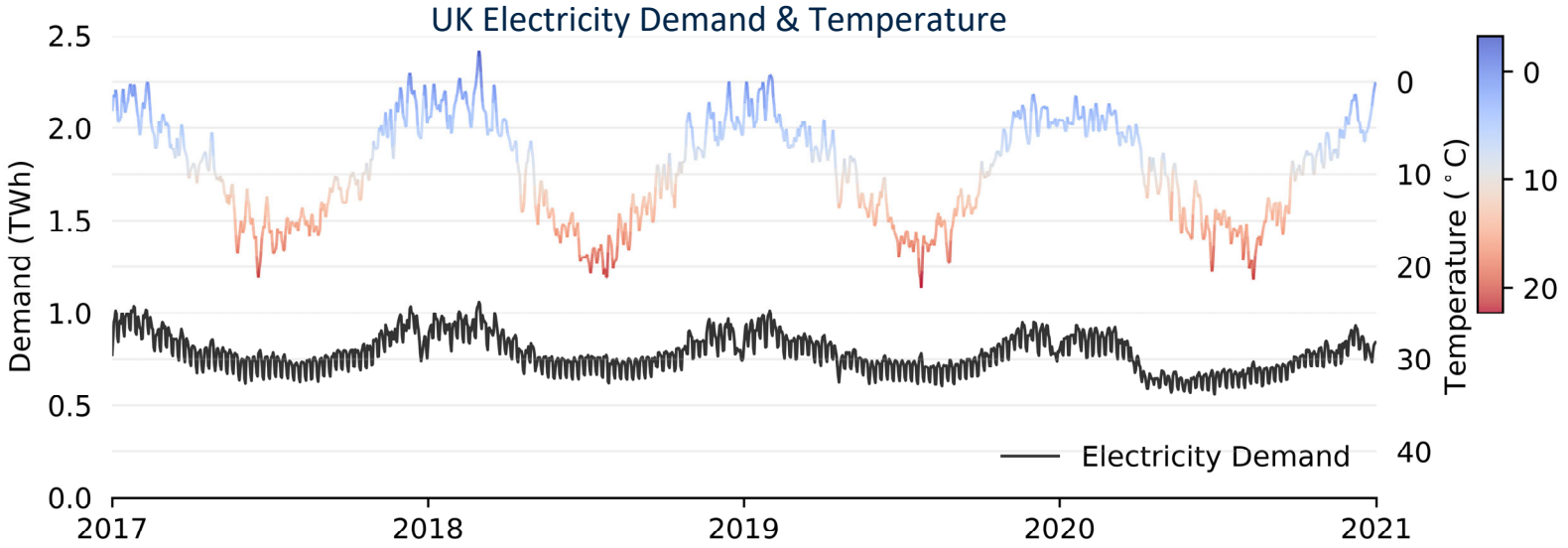

Figure reproduced from Mehlig et al. (2021)

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There is only limited data of how weather impacts EV demand

- Anecdotal evidence

- NAF (2020) *Twenty popular EVs tested in Norwegian winter conditions*
  - EVs on average lose **20 percent** of their range in colder climate
  - EVs **charge more slowly** in cold temperatures

1. **Yuksel & Michalek (2015)** *Effects of Regional **Temperature** on Electric Vehicle Efficiency, Range, and Emissions in the United States; **and 7 additional sources**.*

2. ***National Grid & Element Energy (2019) EV charging data;** 8 million UK charging events in 2017.*

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EV demand can be modelled as a function of the weather

1. Fleet demand as a function of **ambient temperature**
   - **Yuksel & Michalek (2015)** *Effects of Regional **Temperature** on Electric Vehicle Efficiency, Range, and Emissions in the United States; **and 7 additional sources**.*

2. Fleet demand as a function of **multiple weather variables**
   - ***National Grid & Element Energy (2019) EV charging data;** 8 million UK charging events in 2017.*

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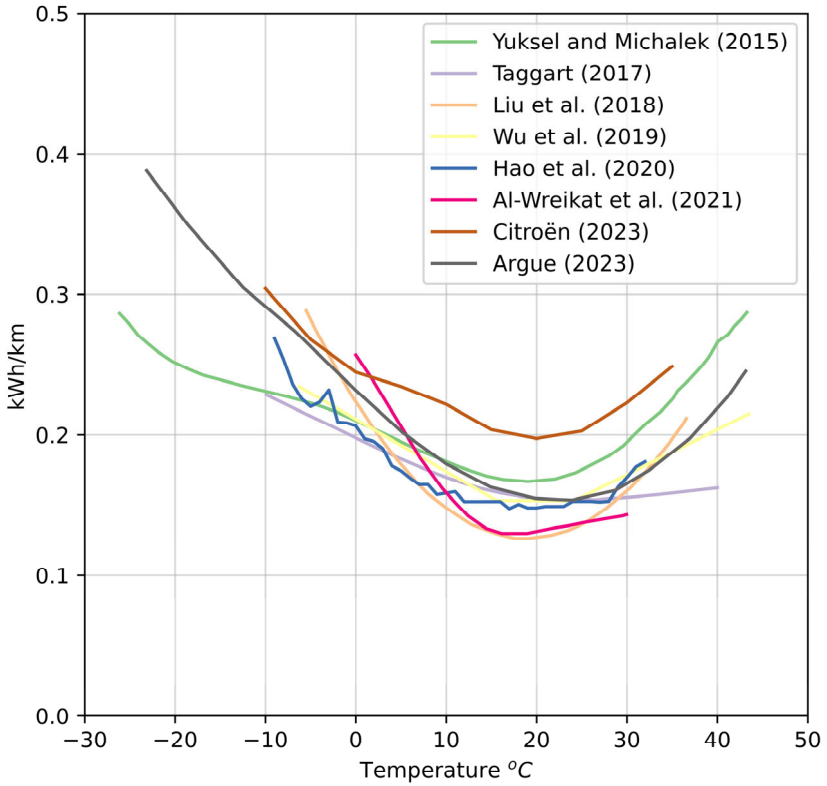
1. Fleet demand as a function of ambient temperature

We standardise these relationships of EV energy consumption and temperature using **changepoint regression**



Below 15 °C or above 25 °C **energy consumption consistently increases**

These relationships with temperature are often **not included in studies of national-scale charging demand**

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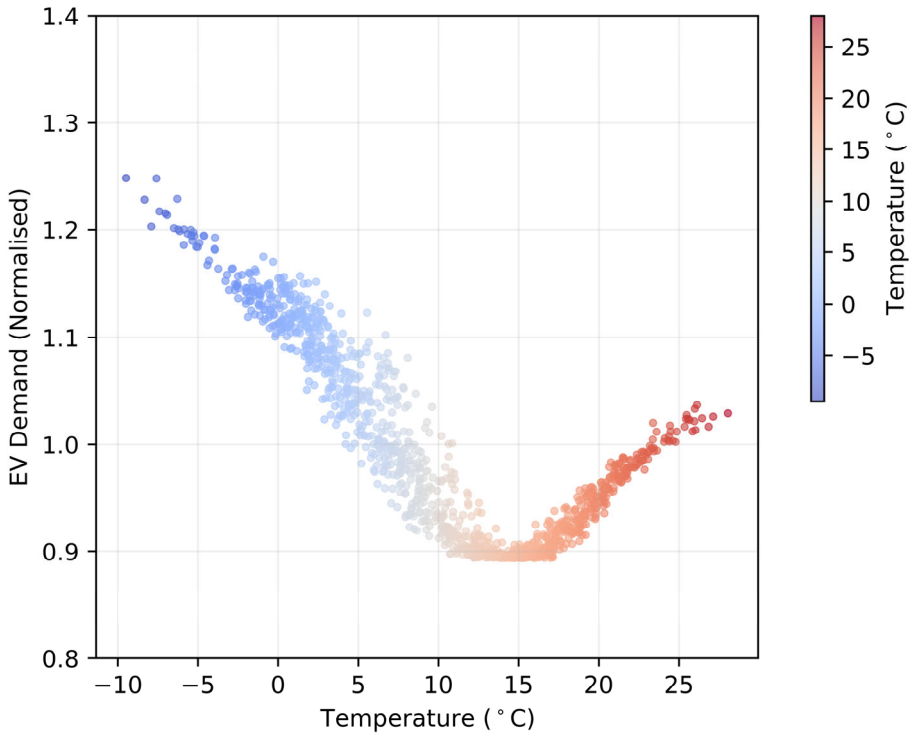
1. Fleet demand as a function of ambient temperature

We standardise these relationships of EV energy consumption and temperature using **changepoint regression.**



We use the *www.demand.ninja* model to **generate national-scale estimates of EV charging** demand covering many historical weather years.

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2. Fleet demand as a function of multiple weather variables

- We use the National Grid data to **correlate fleet-wide EV consumption to other weather variables:**

	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	**45.270**	**0.595**	**76.050**	**(***) < 2e-16**
Temperature	**-0.513**	**0.076**	**-6.769**	**(***) 5.51e-11**
Solar Irradiance	**-0.014**	**0.002**	**0.795**	**(***) < 2e-16**
Wind Speed	0.040	0.051	-0.772	0.441
Humidity	-0.116	0.151	-9.322	0.427
Weekend	**-9.727**	**0.189**	**-51.470**	**(***) < 2 e-16**

Residual standard error: 1.622 on 348 degrees of freedom;
Multiple R-squared: 0.9258, adjusted R-squared: 0.9248, F-statistic: 8686.6 on 5 and 348 DF, p-value: <2.2e-16.

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2. Fleet demand as a function of multiple weather variables

- We use the National Grid data to **correlate fleet-wide EV consumption to other weather variables:**
  - Intercept: Baseline demand of 45.3 MW
  - Weekends: On weekends demand drops by 21.4%
  - Temperature: Demand increases by 1.1% for every 1 °C drop
  - Solar Irradiance: Demand increases by 3.1% for every 100 W/m^{2*} drop

*(annual UK range is ±300 W/m^2)

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EV demand can be modelled as a function of the weather

1. Fleet demand as a function of **ambient temperature -> German case study**

2. Fleet demand as a function of **multiple weather variables -> UK case study**

- We use the *www.demand.ninja* model to **generate national-scale estimates of EV charging** demand covering many historical weather years.

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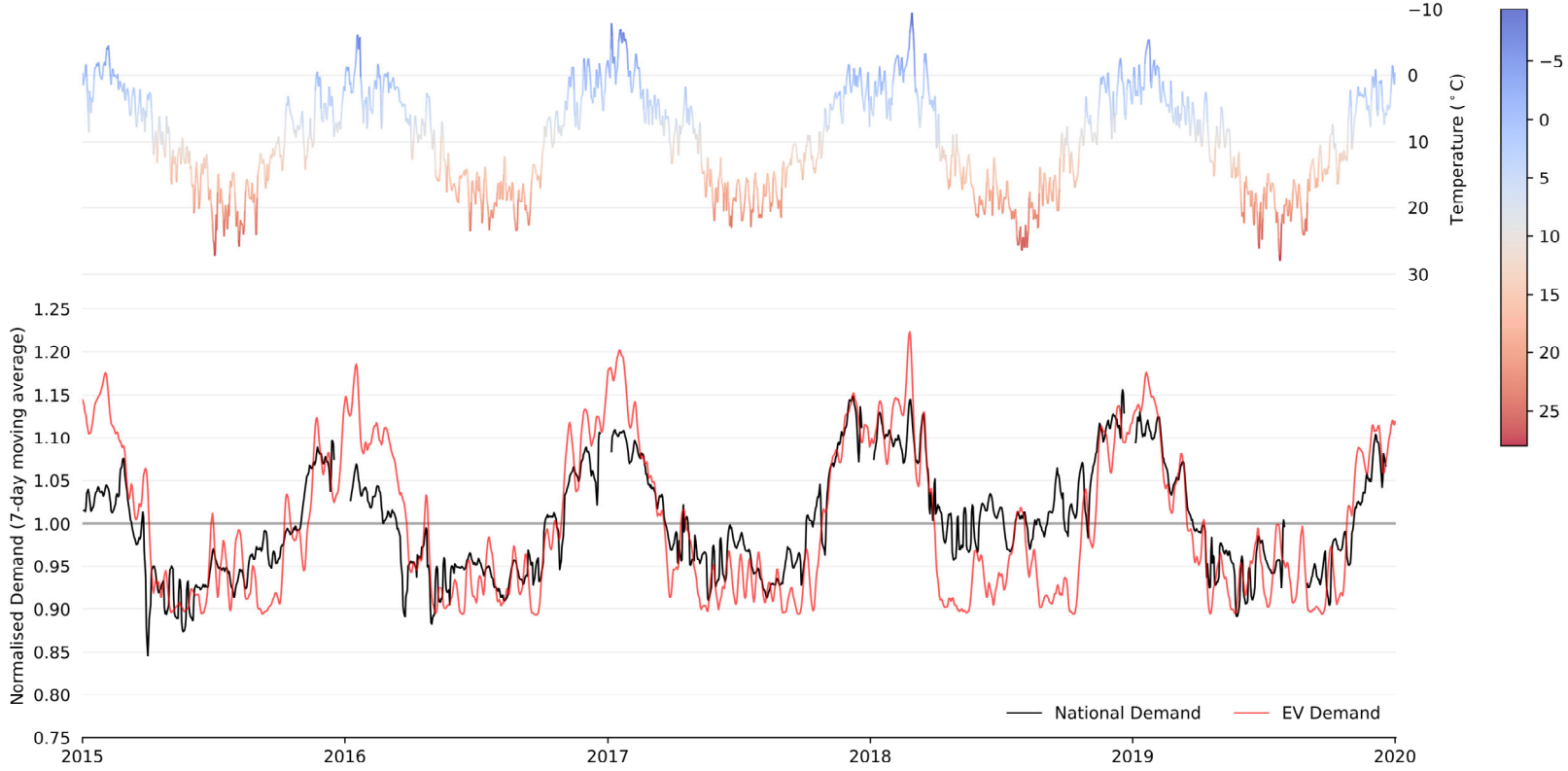
Case study: German fleet



National demand for Germany taken from www.entsoe.eu

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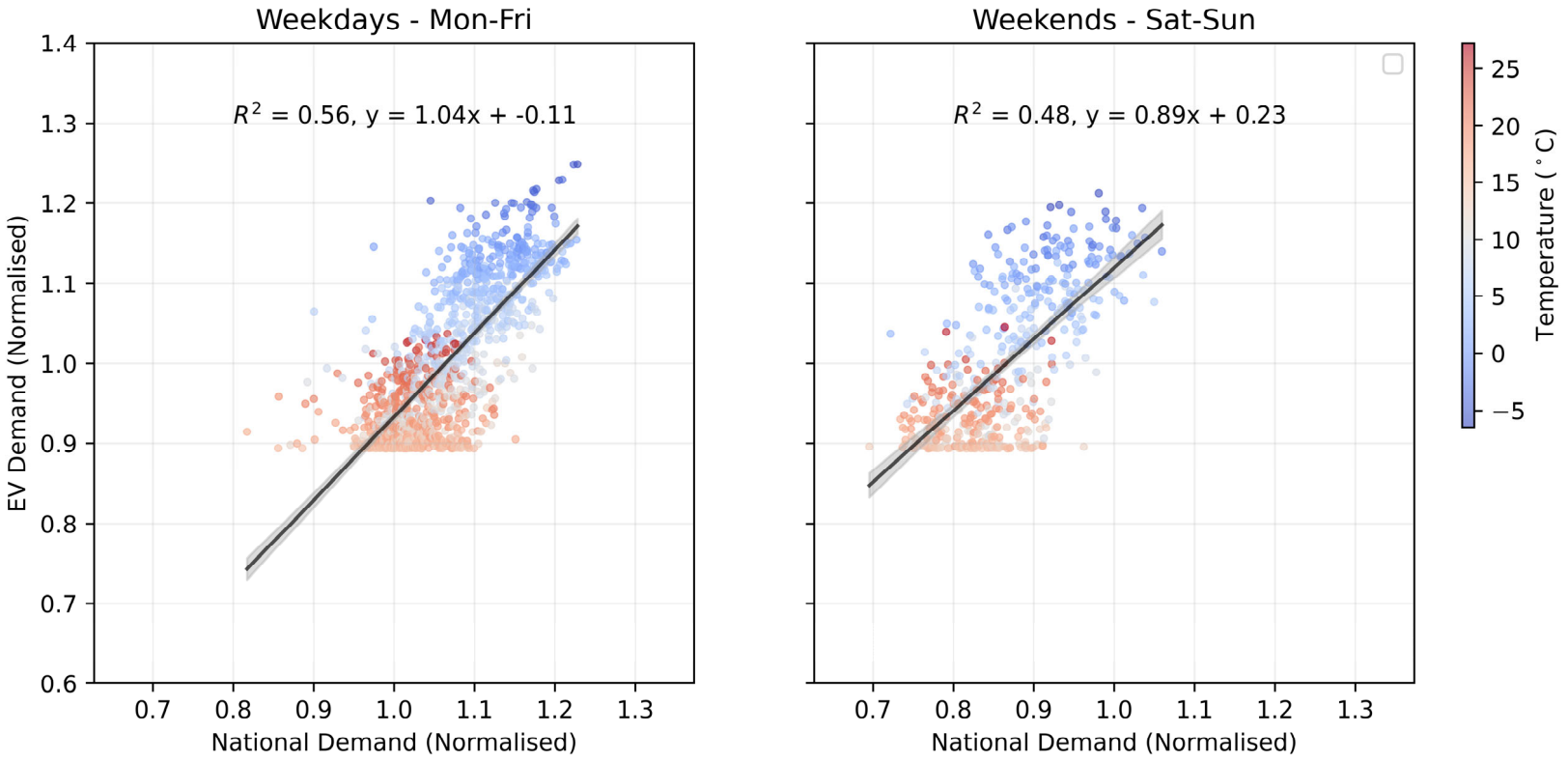
Case study: German fleet



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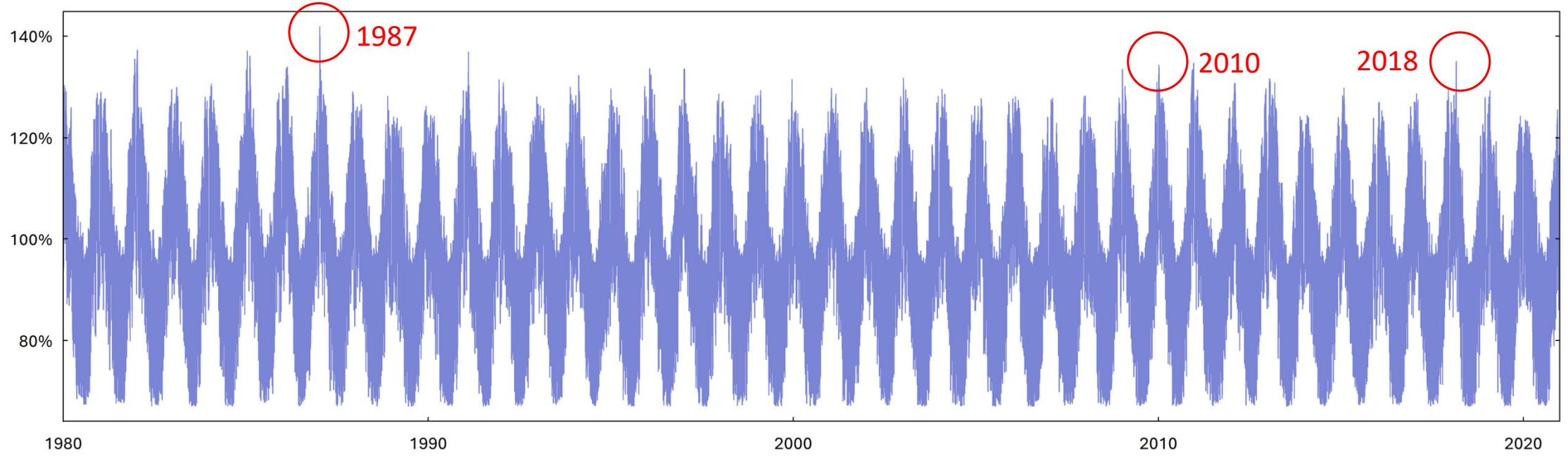
Case study: UK Fleet



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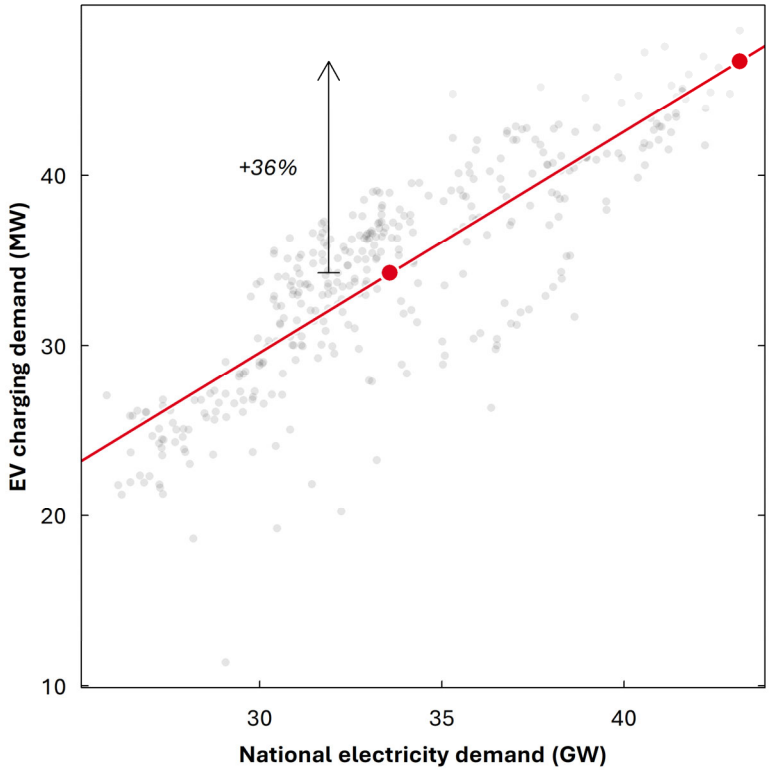
Case study: UK Fleet



Charging demand **was 36% higher on the day of peak electricity demand** than the annual-mean.

Diapositiva 14

MDN0 Iain could you confirm if it was 36% higher than the annual mean for EVs or National demand?
Mehlig, Daniel N; 2023-07-21T11:12:33.939

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Case studies summary

- **EV demand varied seasonally**, on average increasing by 12% in winter and decreasing by 6% in summer for Germany, compared to the annual average.
- During highest day of peak demand, **EV demand increased by 25% and 36%** compared to the annual average for Germany and the UK, respectively.
- **Correlation between EV demand and national demand**, suggesting demand from **EVs will contribute to peak conditions.**

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Conclusions

- Evidence **EV energy consumption is impacted by the weather,** therefore future models should include this relationship.
- EV fleet demand will follow **seasonal, weekly, and daily, weather patterns** that will need to be balanced with corresponding supply.
- Demand from future EV fleets is likely to **contribute to peak conditions.**
- Likely to **increase system cost** and if not addressed **may risk security of supply.**

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Next Steps

- Global modelling – apply these methods to different regions.
- EV Ninja – online webtool to generate EV charging profiles for different locations.

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Thank you

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