Planning of electric vehicle charging infrastructure using the Voronoi diagram

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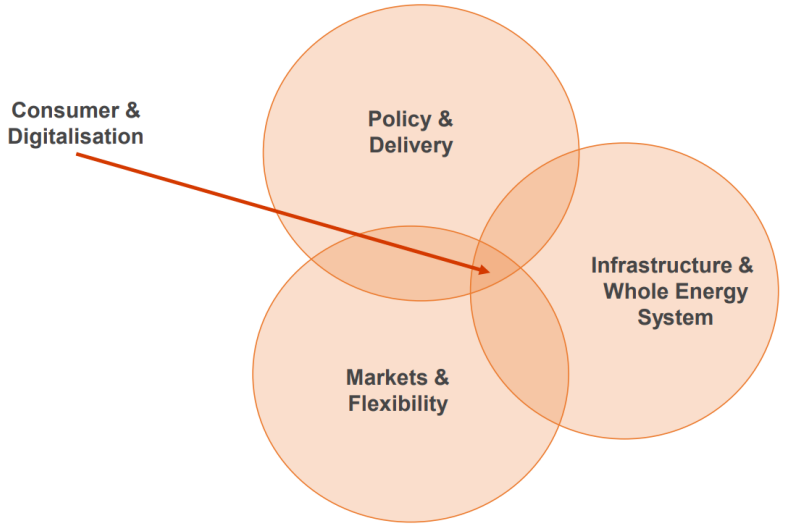
Overview

1. Background
2. EV adoption in the UK
3. Charging infrastructure
4. Spatial displacement of power via EVs
5. Planning of chargepoints
6. Discussion

Energy market in the UK

Climate change and energy transition

- UK emission target
  - Net zero emissions by 2050.
- **UK's strategy includes:**
  - Energy supply to be entirely powered by clean energy by 2035
  - Secure a 40GW installed capacity of offshore wind by 2030,
  - No new petrol or diesel car or vans, nor gas boilers to be sold by 2035.
  - Significant investment in a scale nuclear plant, hydrogen production facilities and carbon capture technology.
  - Support programs for low-carbon farming and reforestation.

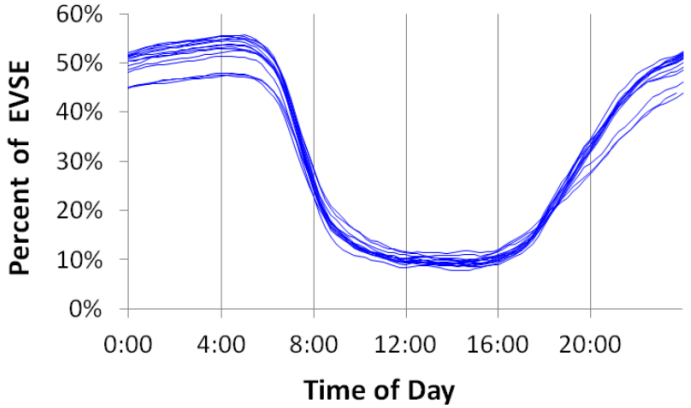


Key aspects of energy transition (FES 2022, National Grid)

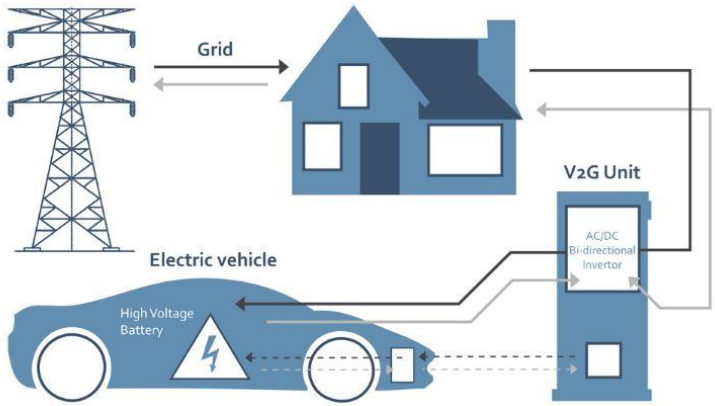
The path to net zero

Energy flexibility and EVs

- Energy systems need balancing supply and demand, then, flexibility is the ability to shift spatio-temporally supply and demand through signals (i.e. change in energy price).
- **Benefits of energy flexibility**:
  - It has been demonstrated that demand side response can help shifting such demand to off-peak periods (Finn, Fitzpatricka, Connolly, 2012).
  - Such demand side respond strategy works with the temporal dimension, yet, the spatial element of EV charging and flexibility still understudied.
  - Therefore, because of the mobile nature of EVs as energy storage, the demand side response strategies could not only shift demand but supply.

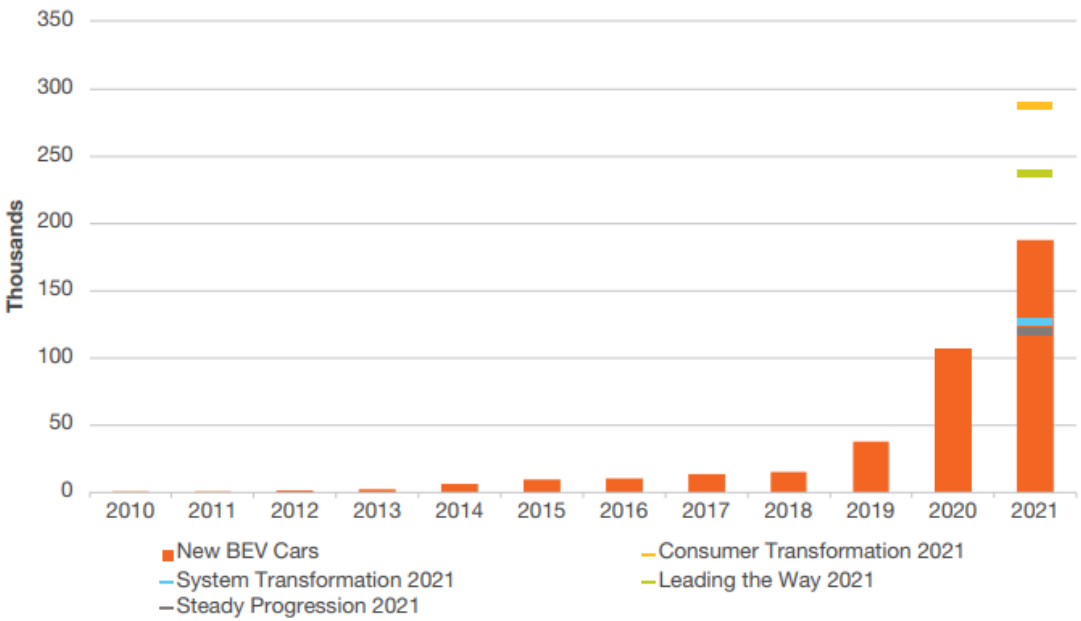


Intraday domestic EV charging profile (Schey, Scoffield, Smart, 2012)



Electric vehicles in the UK

EV adoption

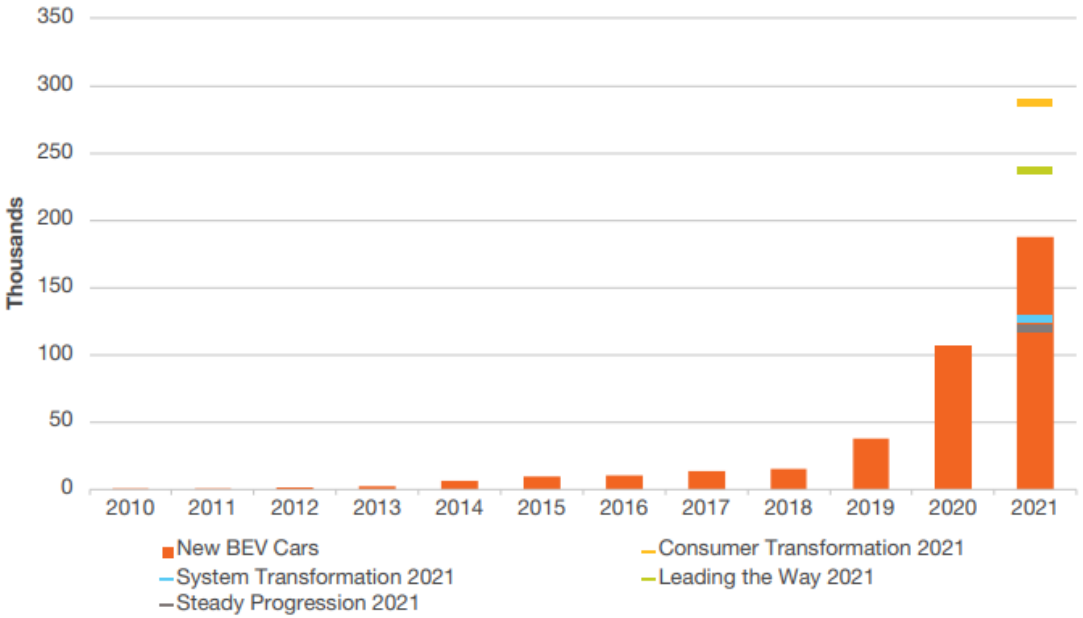


Sales of BEVs against FES 2021 forecasts (FES 2022, National Grid)

- The government aims for at least 300,000 public chargepoints by 2030, which is a 10x versus 12x-32x increase of EVs.
  - National Grid has highlighted that the locations of these chargepoints is also relevant, as demand and network characteristics present spatial regularities
  - Moreover, technologies such as V2G or V2B have the potential to increase the efficiency of demand side response strategies (Huang and Infield, 2009).
- **Challenges to V2G**
  - Higher cost than conventional chargepoint
  - Technology perception and acceptance
  - Battery degradation
  - Lack of attractive business models or incentives

Electric vehicles in the UK

EV adoption



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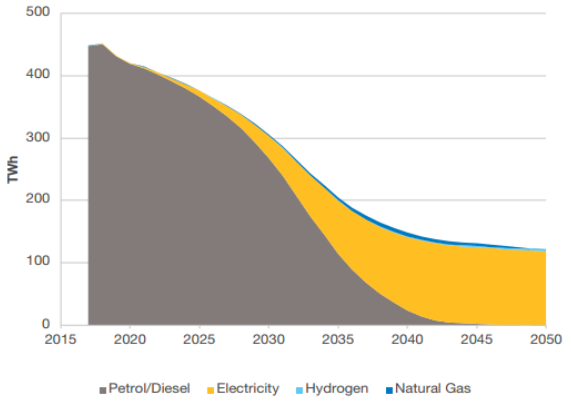
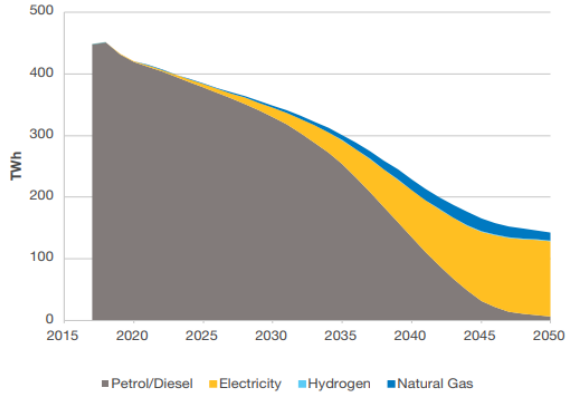


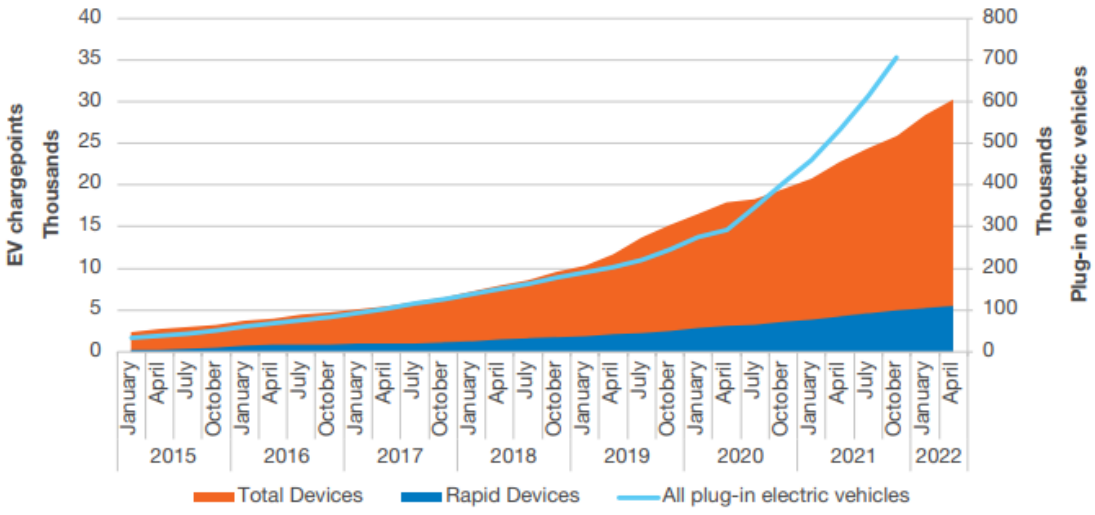
Annual energy demand for road transport in Leading the Way (FES 2022, National Grid)



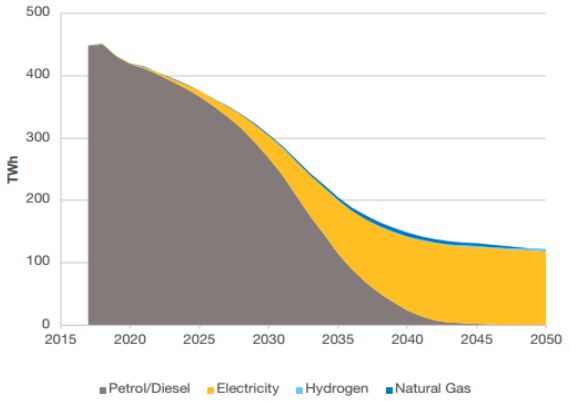
Annual energy demand for road transport in Falling short (FES 2022, National Grid)

Electric vehicles in the UK

Charging infrastructure



EV public chargepoints installed across the UK (FES 2022, National Grid)



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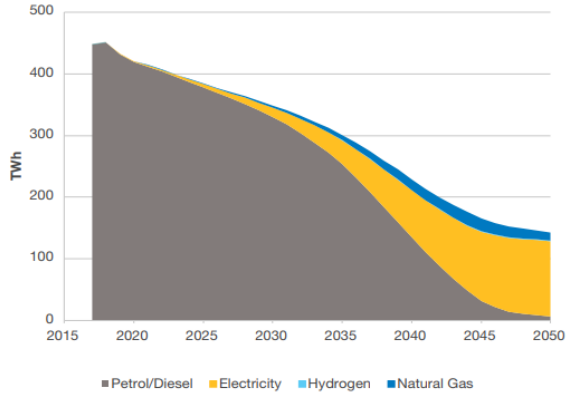
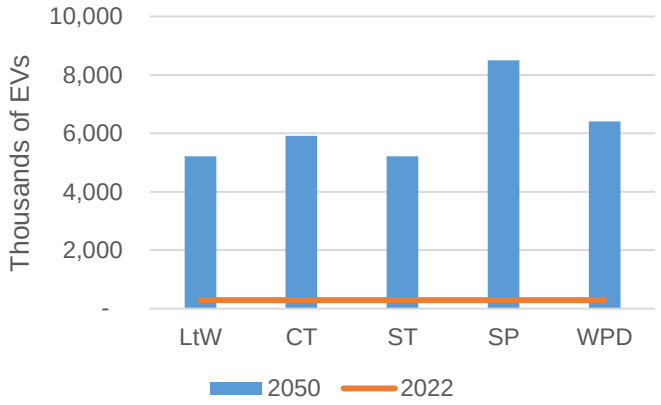


Annual energy demand for road transport in Falling short (FES 2022, National Grid)

Electric vehicles in the UK

UK midlands and southwest

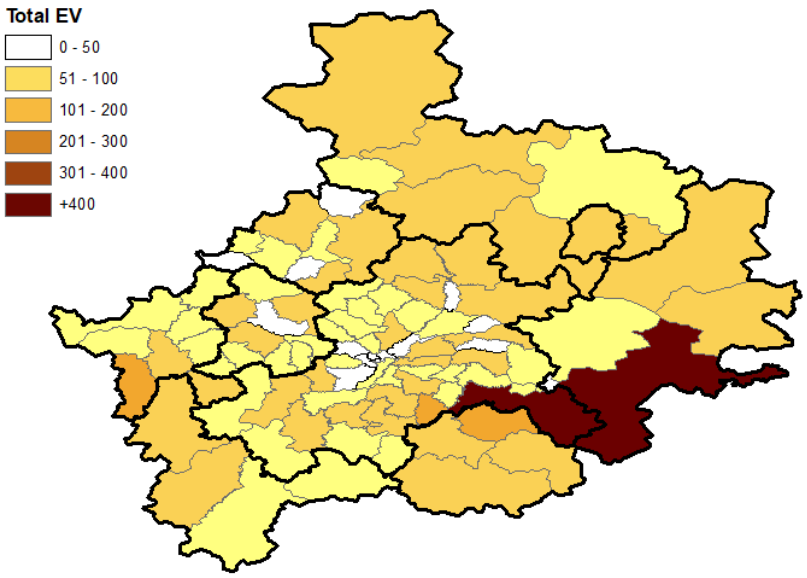
- Western Power Distribution delivers electricity to more than 8 million customers
  - Birmingham city has the largest GDP and GVA in England out of Greater London



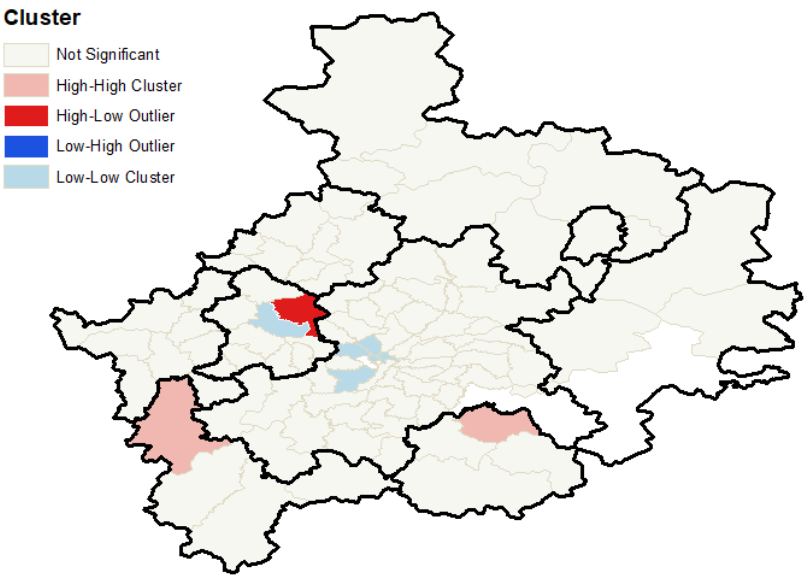
Total EVs in the WPD area by September 2050.

Electric vehicles in the UK

EV adoption – spatial dependence



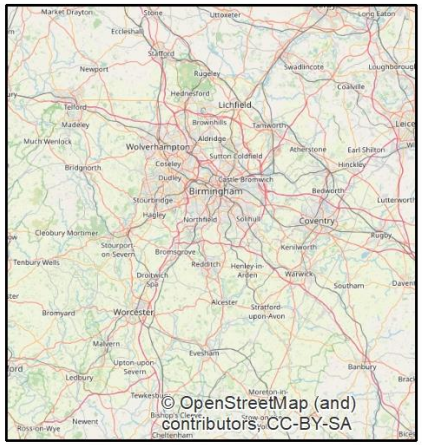
Spatial distribution of the EV registrations by September 2018.



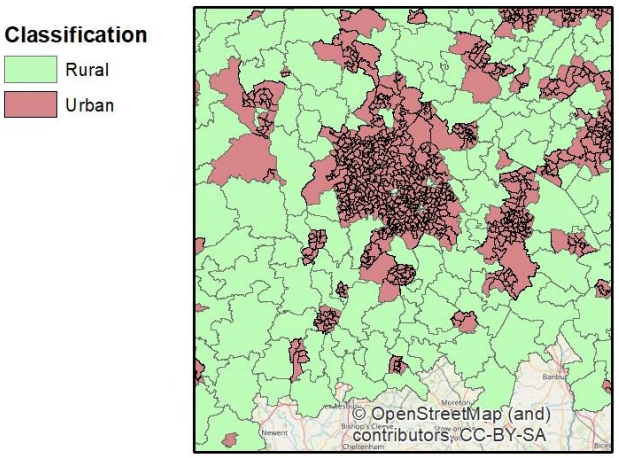
Hot spot analysis of the EV registration by Sept 2018

Electric vehicles in the UK

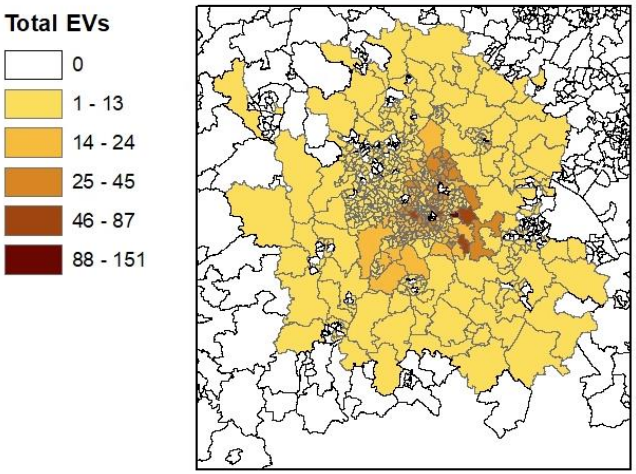
Birmingham city- travel patterns and urban/rural differences



Birmingham city and surrounding areas.



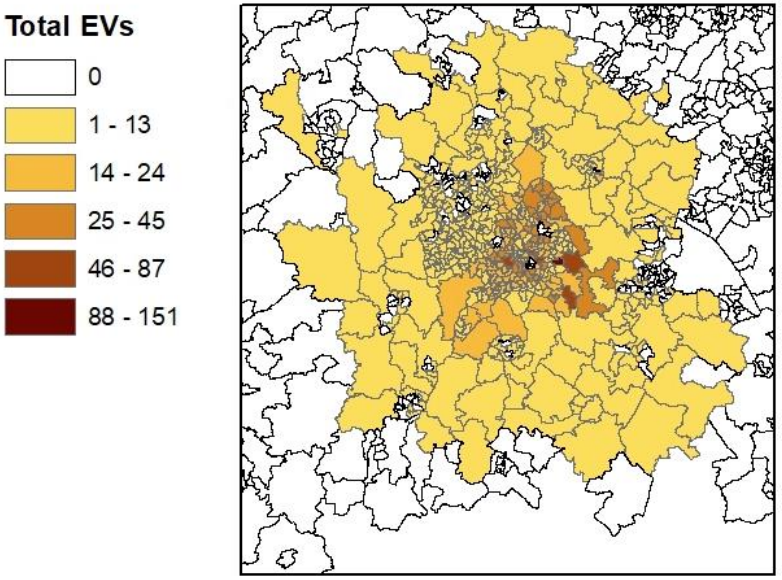
Rural and urban classification of census units (< NUTS 3)



Total EVs travelling into Birmingham city

Electric vehicles in the UK

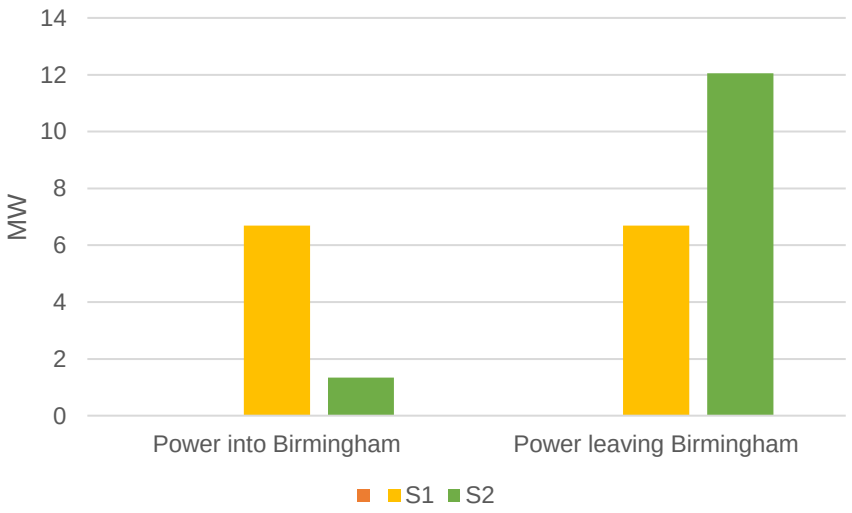
Birmingham city- travel patterns and urban/rural differences



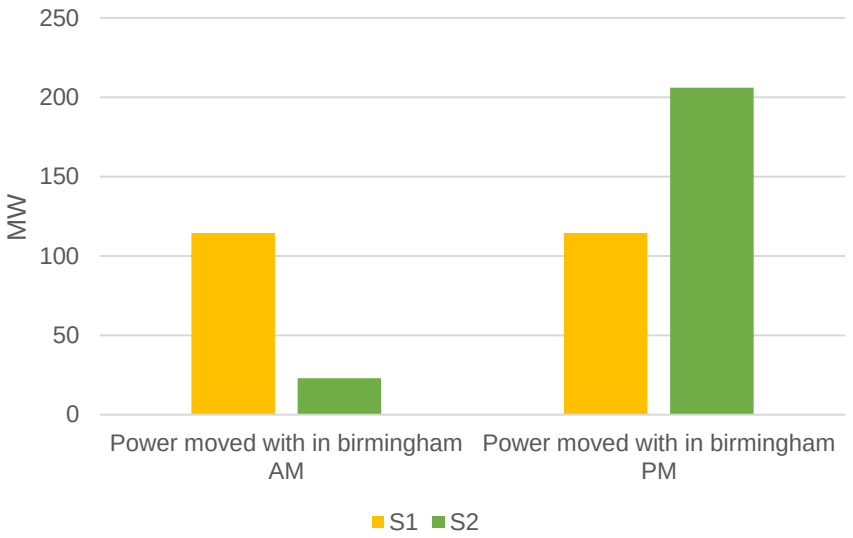
Total EVs travelling into Birmingham city 2022 and 2050

Spatial displacement of power via EVs

Total EVs commuting into Birmingham



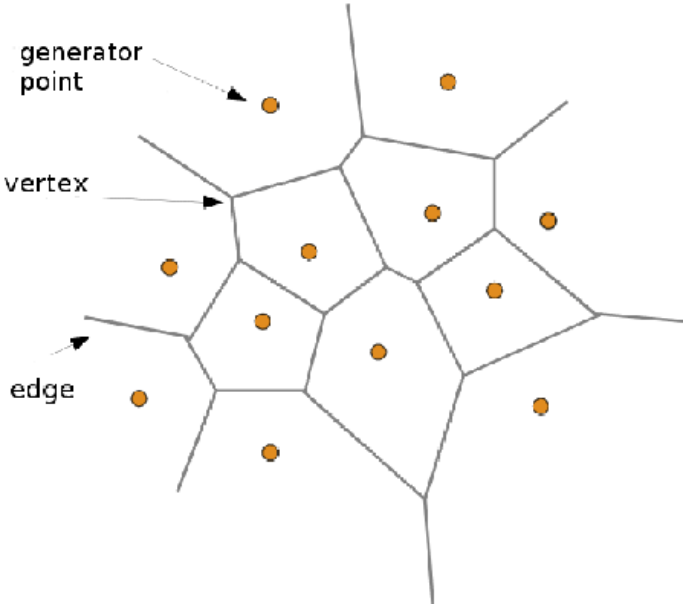
Potential power displaced via EV storage – Rural/Urban (2022)



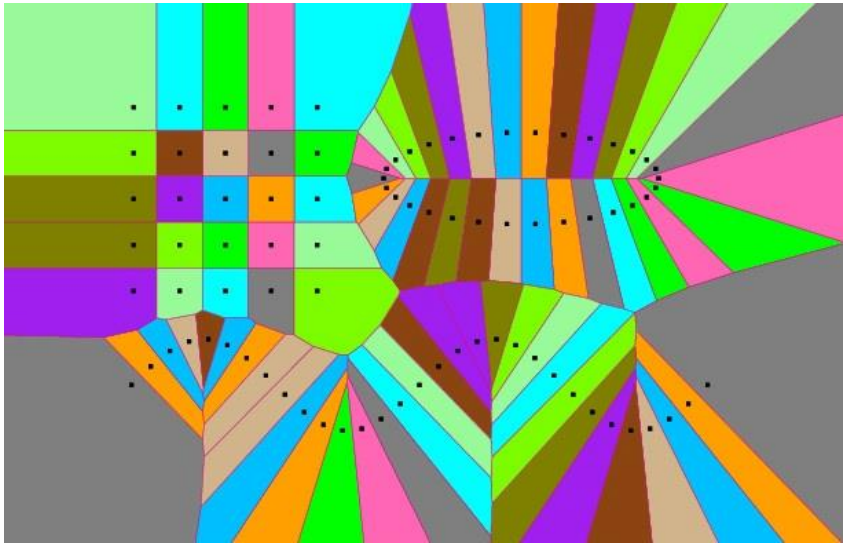
Potential power displaced via EV storage – Urban/Urban (2022)

Planning of chargepoints

The Voronoi diagram



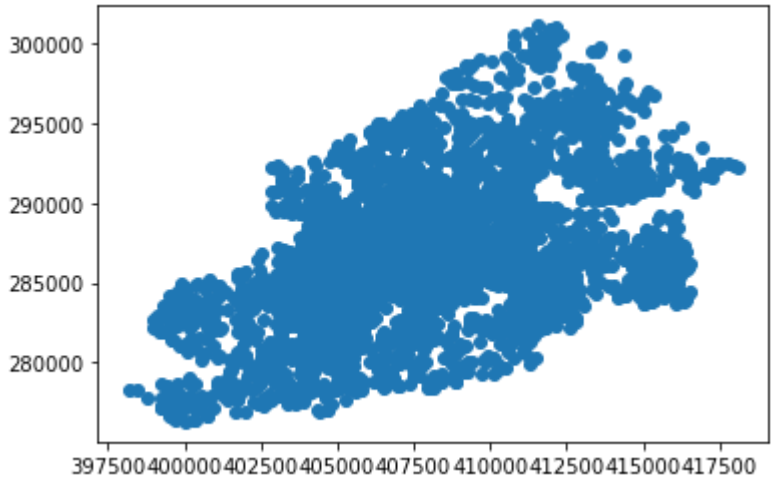
Voronoi diagram generation



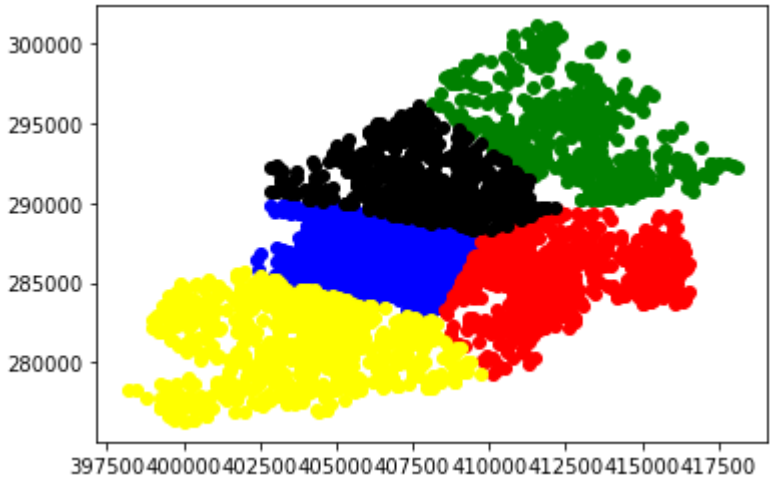
Voronoi diagram example

Planning of chargepoints

Total EVs commuting into Birmingham



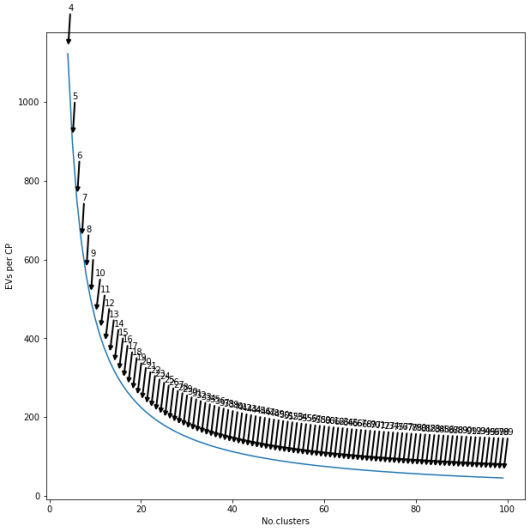
Spatial distribution of EVs travelling into Birmingham City (2022)



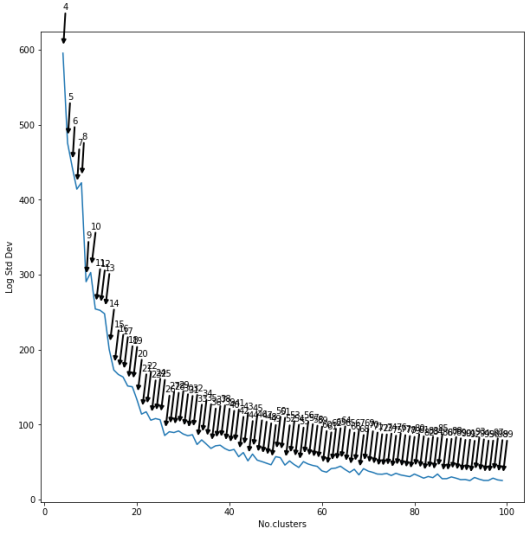
K-means classification (k=5)

Planning of chargepoints

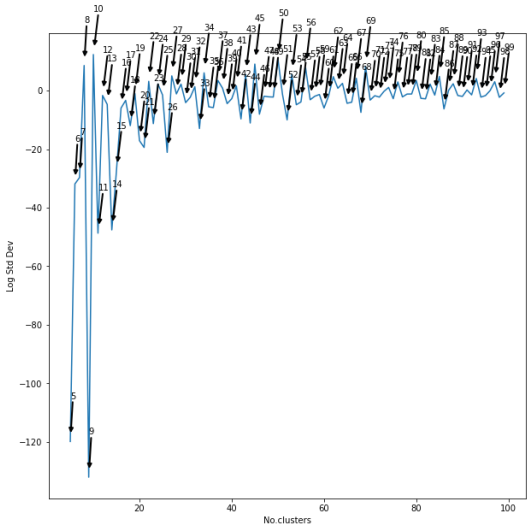
The elbow method



Total EVs per class



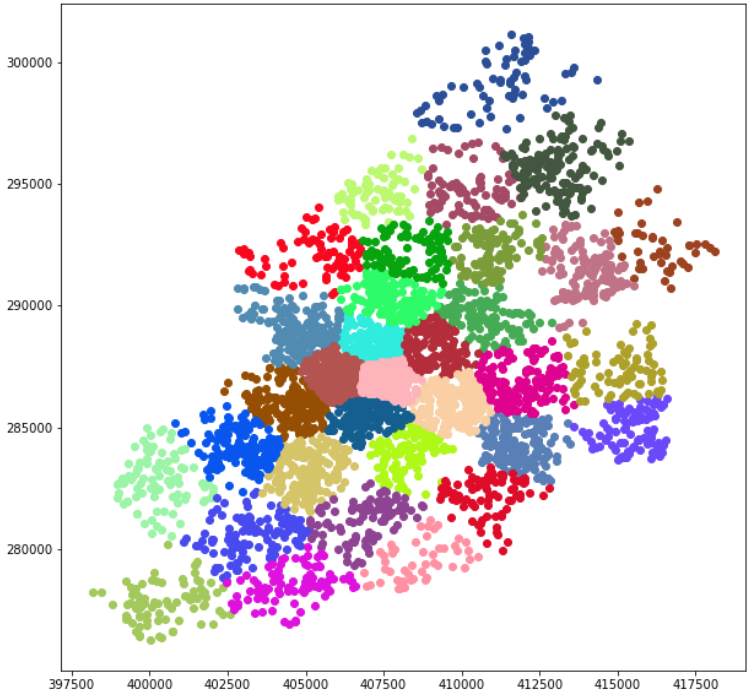
Standard deviation per class



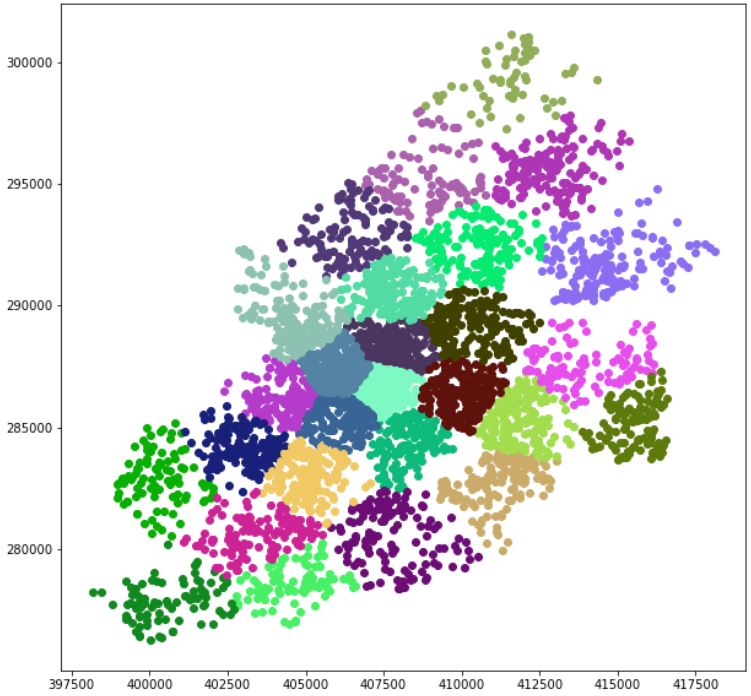
Standard deviation per class – first difference

Planning of chargepoints

Total EVs commuting into Birmingham



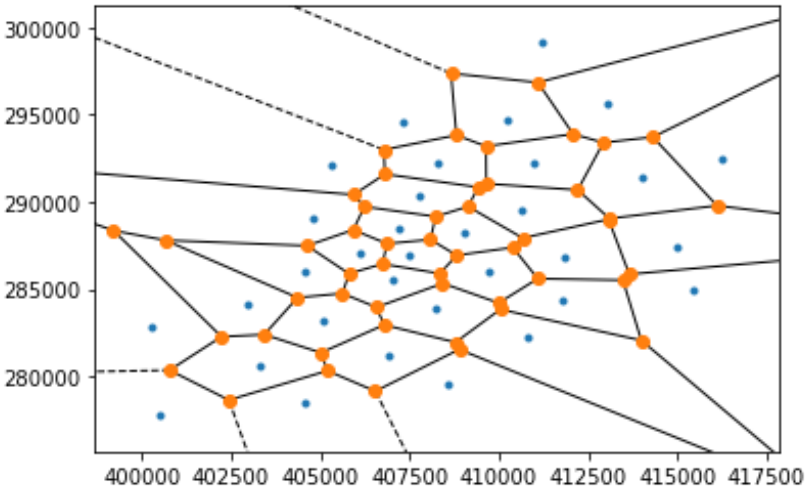
K-means classification (k=33)



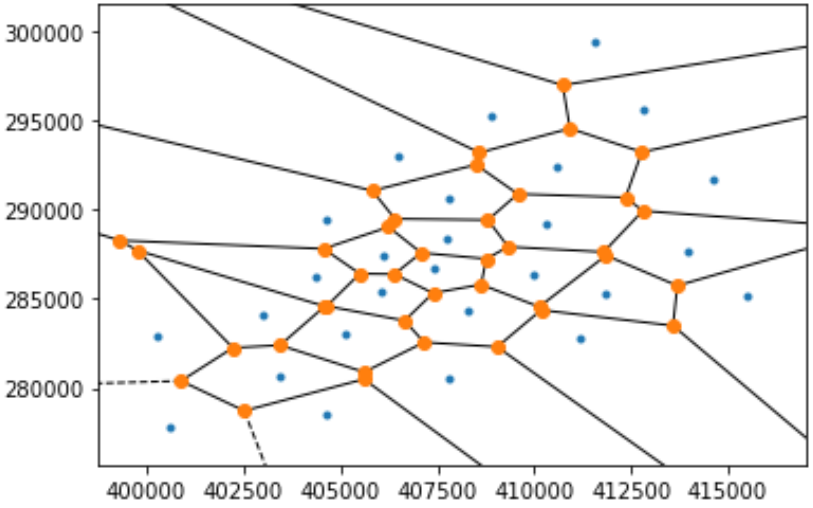
K-means classification (k=27)

Planning of chargepoints

Total EVs commuting into Birmingham (2022)



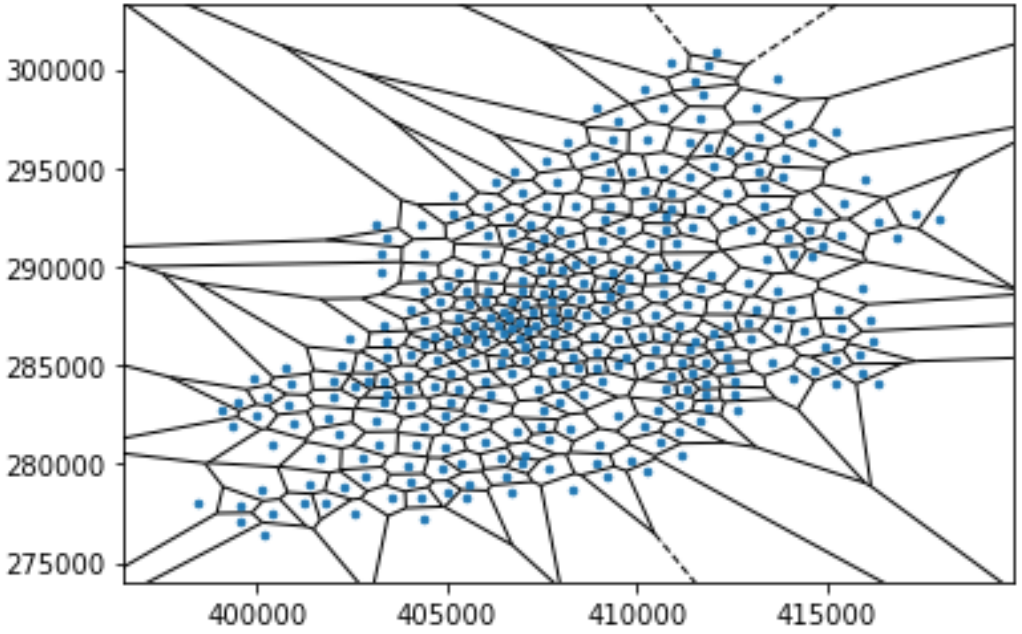
Voronoi diagram (k=33)



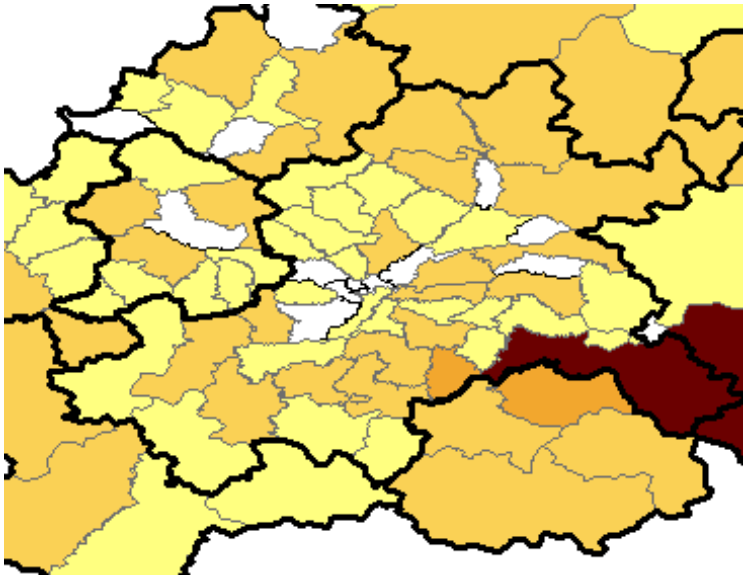
Voronoi diagram (k=27)

Planning of chargepoints

Total EVs commuting into Birmingham (20%)



Voronoi diagram (k=330)



Spatial distribution of the EV registrations by September 2018.

Discussion

- **Spatial dimension of EV adoption**
  - Include EV spatial regularities in current forecast models
  - DSR strategies can potentially shift demand across areas
- **Origin-Destination patterns and travel behaviour**
  - Bottom-up approaches may inform about current and future travel behaviour
    - More accurate models are required to understand actual power displacement
- **Spatial planning of chargepoints**
  - Mathematic approaches can inform local policymaking
  - EV spatial regularities are needed to be included along with the context of the data

Thank you

- Do you have any questions?