Written evidence submitted by the Energy and Power Group, Department of Engineering Science at the University of Oxford (GRD0024)

Welsh Affairs Committee—Call for Evidence: Grid capacity in Wales

Executive summary

Q4.

- In the next decade, rapid electric vehicle (EV) adoption threatens to increase grid congestion in Wales. By 2030, EVs belonging to residents of Wales could add up to 1.7 GW of demand[1] to the Welsh electricity system, which had an average demand of 1.6 GW in 2020[2]. The latter is expected to nearly quadruple to 6 GW by 2030.
- This increase in EVs also offers an opportunity for flexibility from vehicle to grid or smart charging technology. Welsh residents' EVs will store enough energy when half-charged to power 436,000 Welsh households[3] for one day in 2030. By 2035, this figure is expected to exceed the number of households in Wales.
- However, the challenges and opportunities of EV growth will not be evenly distributed across different regions of Wales. In 2030, areas in southeast Wales, the Isle of Anglesey, and Wrexham are expected to have EV-related power demand increases that are 5 to 10 times larger than other areas of the country .
- Pilot flexibility projects should be targeted in areas with many EVs expected by 2030. Lessons learned from these trials can ensure that all of Wales can benefit from EV flexibility and reduce grid congestion in the coming decades.
- Key considerations for consumer flexibility programmes include:
  - Frictionless start-up and ongoing convenience for consumer participation
  - Sufficient temporal and locational specificity to enable flexibility to reduce grid congestion
- Another potential approach for reducing grid congestion from EV deployment involves adding power capacity limits for domestic consumers to their contracts—that is, customers would pay to have a limit on how much electricity they can use at once. Such a programme is already implemented in Italy and Spain and could help to incentivize smart charging and other flexibility measures.

Q5.

- In rural areas of Wales, tourists driving EVs are likely to increase seasonal peak demand significantly and could overwhelm the grid even when residential EV adoption in those areas is low.
- Tourists and other long-distance drivers are less likely than residential users to participate in flexibility because of their desire for immediate charging upon arrival to a charging station.

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[1] Based on simultaneous 7 kW slow charging of all projected EVs.

[2] Subnational electricity consumption, Great Britain, 2005-2020. Department for Business, Energy & Industrial Strategy.

[3] Average daily domestic electricity use per Welsh household was 9.9 kWh in 2019, according to InfoBase Cymru Domestic energy consumption. We assume a typical EV battery size of 35 kWh.

- Achieving the Electric Vehicle Charging Strategy for Wales goal of installing rapid (43+ kW) EV charging points every 20 miles on the strategic trunk road network by 2025 is likely to cause grid congestion in rural areas and other areas with low grid capacity.
- We recommend a detailed study exploring options for managing grid congestion caused by tourists driving EVs during the holiday season, including:
  - Anticipatory investment in network upgrades along motorways
  - Developing signals on motorways to encourage tourists to use rapid chargers at times and locations that reduce grid congestion
  - Incentivizing tourist attractions and lodging to provide low-cost fast (7 to 22 kW) charging, that allow tourists to charge their EVs overnight or while visiting an attraction
  - Facilitate and incentivize co-location of renewable generation and rapid chargers
  - Partnering with charger providers to implement time-of-use charges based on the level of local renewable generation

About the authors
This submission has been prepared by the following members of the Energy and Power Group, Department of Engineering Science at the University of Oxford.

- Claire Halloran, doctoral candidate, specialising in spatial and temporal analysis of energy storage and demand flexibility.
- Dr Elnaz Azizi, specialising in demand-side response schemes through data analysis and system modelling
- Dr Filiberto Fele, specialising in enabling the flexibility of the future grid for the integration of low carbon technologies.
- Dr Jesús Lizana, specializing in thermal engineering in buildings.
- Dr Scot Wheeler, specialising in smart local energy systems and the integration of flexible energy technologies.
- Professor Malcolm McCulloch, specialising in leading research projects that span developed and developing countries and range across all aspects of power generation and distribution.

The Energy and Power Group research sustainable energy systems which accelerate universal access and a net-zero future. Within the authorship team we have extensive practitioner and researcher experience in transforming energy systems, including the following projects of relevance:

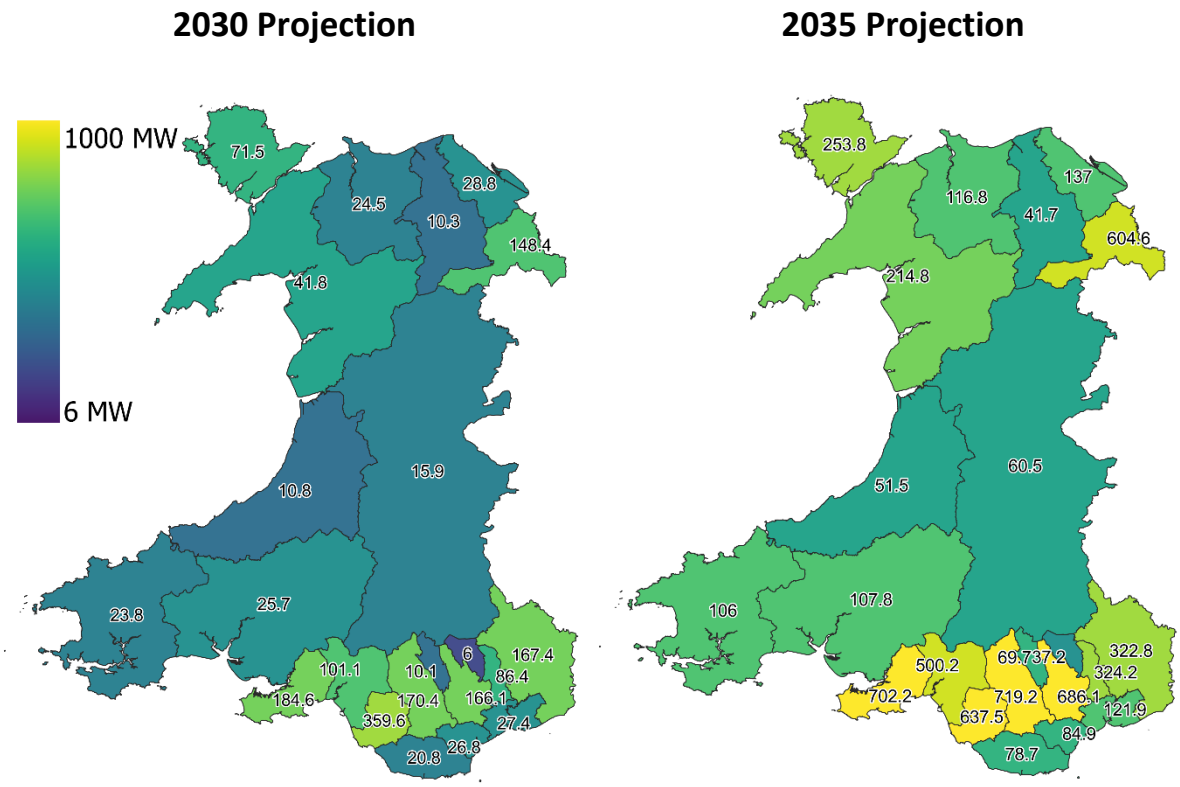
- Project Local Energy Oxfordshire (LEO) (UKRI-funded) is one of the most ambitious, wide-ranging, innovative, and holistic smart grid trials ever conducted in the UK. Project LEO aims to improve understanding of how opportunities can be maximised and unlocked from the transition to a smarter, flexible electricity system and how households, businesses and communities can realise its benefits.
- The Oxford Martin Programme on Integrating Renewable Energy brings together researchers on energy issues from different Oxford University departments to conduct interdisciplinary studies on the technical, market, social, and policy challenges for integrating renewables across a wide range of scales, resource types and contexts.

Question 4: What can be done to incentivise investment in grid flexibility, in particular vehicle to grid technology and 'smart' charging?

1 In the coming decade, we expect rapid electric vehicle (EV) adoption in Wales. If not properly managed, this change will increase grid congestion problems. If properly managed, this change can create the opportunity for grid support services from vehicle to grid and smart charging. By 2030, EVs belonging to residents of Wales could add up to 1.7 GW of demand to the Welsh

electricity system, which had an average demand of 1.6 GW in 2020. This number is expected to nearly quadruple to 6 GW by 2030. For comparison, the Hinkley Point C reactor will be able to provide up to 3.26 GW of electric power once completed.

2 However, this rapid growth in EV adoption will be unevenly distributed across different geographic regions of Wales. Areas with large shares of EVs will experience an increase in electricity demand for charging, which can exacerbate grid congestion in those areas. Unless flexibility measures are implemented, these early EV adopter areas are likely to experience grid congestion problems soon. Figure 1 shows the maximum charging demand from EVs by Local Authority in 2030 and 2035. Areas in South East Wales, along with the Isle of Anglesey and Wrexham, will lead Wales in EV adoption. These areas are expected to have EV-related power demand increases that are 5 to 10 times larger than other areas of the country: for example, in 2030, Bridgend could have up to 360 MW of extra demand from EV charging, and by 2035, this figure could nearly double to 638 MW. By comparison, 1 MW of power is how much 300-500 kettles would draw when turned on simultaneously. Our projections for EV adoption in Wales are created using the S-Curve Adoption Tool for EVs (SCATE)[4,5].



[4] Collett, K. A., Bhagavathy, S. M., & McCulloch, M. D. (2021). Forecast of electric vehicle uptake across counties in England: Dataset from S-curve analysis. *Data in Brief*, *39*.

[5] This tool uses an S-curve model of technology adoption, which represents the acceleration from slow initial uptake of a technology to widespread adoption and slowdown as market saturation is reached. This model allows us to project how small differences in the share of EVs between local authorities are likely to grow in the next 13 years. However, this model assumes a business-as-usual growth in EV adoption across the local authorities and does not account for policies that could accelerate this transition. This model also does not account for diffusion of EV adoption across the boundaries of local authorities, that is, we do not account for how the number of EVs in one local authority could affect the growth in EV adoption in neighbouring local authorities.

Figure 1. The potential increase in electricity demand from EVs could be 5 to 10 times higher in some Welsh local authorites than in others. Areas with large increases in electricity demand for charging are likely to face grid congestion. Figures are given in megawatts (MW)-- 1 MW of power is how much 300-500 kettles would draw when turned on simultaneously.

3 The number of EVs in an area determines the potential for smart charging and vehicle to grid flexibility. Smart charging can reduce grid congestion and provide other benefits by strategically shifting the time of day when EVs use electricity. Vehicle to grid technology allows electricity to flow from the EV battery back to the grid and can improve the grid resilience in case of extreme weather or network outages. By 2030, Welsh residents' EVs will store enough energy when half-charged to power 436,000 Welsh households for one day. By 2035, this figure is expected to exceed the number of households in Wales. For comparison, the Dinorwig Power Station in Gwynedd can store enough energy to power 467,000 Welsh households for a day.

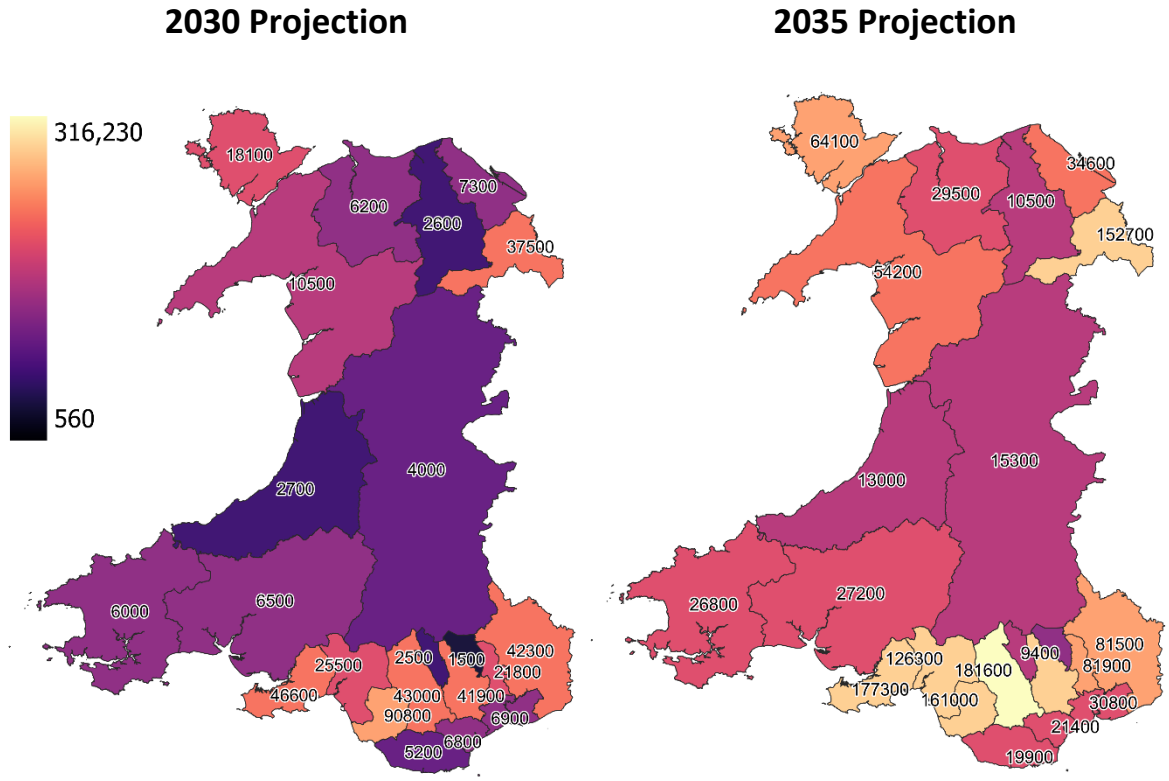


Figure 2. Vehicle to grid potential represented as the number of Welsh households that could be powered for a day using half the energy stored in electric vehicle batteries, per local authority. By 2030, each local authority is projected to have enough EVs to power thousands of households for one day, but vehicle to grid potential is distributed unevenly across local authorities.

4 In Figure 2, we show the potential for the vehicle to grid technology in Welsh local authorities as the number of households that could be powered for one day using half the energy stored in residents' EV batteries. These maps were created assuming the total number of vehicles in Wales remains unchanged from now to 2035. By 2030, all local authorities are projected to have enough EVs to power thousands of households for one day using vehicle to grid technology: Blaenau Gwent can power the fewest at 1,500 households, and Bridgend can power the power at 90,800 households. By 2035, local authorities have enough EVs to power a number of households ranging from 9,400 in Blaenau Gwent to 181,600 in Rhondda Cynon Taf—a number that exceeds the number of households in the local authority.

5 We measured the potential for energy storage under a vehicle-to-grid scheme in terms of households' energy consumption for illustrative purposes; however, the flexibility potential we identified could be used for any electric load. For example, flexibility from the large number of EVs projected around Neath Port Talbot could help reduce grid congestion caused by additional electric loads from the Port Talbot Steelworks, possibly following the envisioned emission-reducing measures involving electrification and carbon capture and storage.

Recommendation 1

6 The different paces of predicted EV adoption across Wales in the coming decade offer an opportunity to develop flexibility schemes trials in the coming years. Deployment of vehicle to grid and smart charging should be targeted to areas that are expected to lead Wales in EV adoption. Early learning from programmes in areas with a large number of EVs can benefit electricity systems throughout Wales as EV uptake increases across the country.

Recommendation 2

7 To incentivize flexibility in early adopter areas, we recommend focusing on creating programmes that enable convenient and frictionless customers participation. For flexibility programmes like smart charging and vehicle to grid, which involve many assets each contributing a small amount to flexibility, monetary compensation for each customer may be very little. This means that a low barrier to entry can be crucial for increasing customer participation in flexibility schemes. Aggregators, actors that represent many flexible customers in an electricity market, can help to simplify market participation for customers; however, aggregators lose the locational specificity of flexibility necessary to relieve grid congestion if they aggregate over too large an area.

Recommendation 3

8 A more extreme measure would entail limiting the maximum power consumption for each domestic consumer. Under such a scheme, customers would pay for a maximum power consumption limit specified in their contract. Such a strategy is already implemented in other countries such as Spain and Italy. This measure could promote deep deployment of flexibility measures to reduce grid congestion and need for network reinforcement.

Question 5: What should be done to ensure that the grid, particularly in rural areas, can cope with the extra demand that will be generated from the transition to electric vehicles?

9 In rural areas, tourists driving electric vehicles (EVs) are likely to increase electricity demand significantly and have the potential to overwhelm the grid in some areas. Tourist destinations in North East and Mid Wales could drive significant EV traffic in the coming years. Compared to residential EV users discussed in the previous question, tourists are more likely to prefer rapid charging and be inflexible about when they charge, making them more likely to strain the grid and less likely to contribute to flexibility. Despite projections of slow EV adoption in rural areas, these areas are likely to face increased demand from tourists driving EVs, particularly during the holiday season. Achieving the Electric Vehicle Charging Strategy goal of installing rapid (43+ kW)

EV charging points every 20 miles on the strategic trunk road network, including the A55 and M4, by 2025 may be a challenge with current grid capacity.

Recommendation 4

10 We recommend a detailed study of required grid reinforcement for managing the charging requirements of tourists, as well as non-grid alternatives given the long timescale for network upgrades. Non-grid solutions may include:

- Developing signals on motorways to encourage tourists to use rapid chargers at times and locations that reduce grid congestion
- Incentivizing tourist attractions and lodging to provide low-cost fast (7 to 22 kW) charging, that allow tourists to charge their EVs overnight or while visiting an attraction
- Facilitate and incentivize co-location of renewable generation and rapid chargers
- Partnering with charger providers to implement time-of-use charges based on the level of local renewable generation

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