Date of Submission

September 2020

# Project Closedown Report Document

*Notes on Completion:* Please refer to the **NIA Governance Document** to assist in the completion of this form. Please use the default font (Calibri font size 10) in your submission. Please ensure all content is contained within the boundaries of the text areas.

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|---|---|---|
| **Project Title** | | **Project Reference** |
| Electric Vehicle Uptake Modelling (EV-Up) | | **NIA_SPEN_0037** |
| **Funding Licensee(s)** | **Project Start Date** | **Project Duration** |
| SP Distribution and SP Energy Networks | January 2019 | 1 year and 1 month |
| **Nominated Project Contact(s)** | | **Year** |
| Nicol Gray, Ruairidh Chalmers | | February 2020 |

Scope

The transition to electrified transport along with greater penetration of other Low Carbon Technologies such as heat pumps will put increasing pressure on the low voltage networks as demand increases in the future. To ensure that the network continues to provide the level of service required for customers, there is an increasing need to improve forecasting to enable investment decisions to be made at the lowest overall cost, whilst at the same time minimising network risk.

Currently however, with immature EV market conditions and rapid technology change, accurate forecasting is extremely challenging and there is a need to model a range of adoption scenarios over an extended timeframe which increases this complexity. The EV market is new, evolving quickly and is driven by multiple unpredictable factors. Consumers are only just starting to decide what sort of vehicle they want and how they want to use them. Equally, suppliers of vehicles and services are inconsistent in what they offer and how well they match the developing consumer appetite. The result of these clashing variables is that meaningful predications can be extremely difficult to model.

Electric Vehicle Uptake Modelling (EV-Up) will contribute to the development of data sets to improve our understanding of customers' ability to transition to EVs based on off-street parking opportunities and customer demographics. This will enable improved understanding on the likely network areas which will see increased domestic demand and better inform and prioritise future investment programmes.

The project investigated the following areas;

- Probability of a household being able to park and charge at home
- Demographics, including income and behaviours

- Household mileage and the resulting charge demand

Combining these data sets together in a transparent methodology, will enable improved understanding as to the likely assets and network areas expected to experience increased domestic demand. This will better inform and enable prioritization of future investment programmes.

Objective(s)

Project objectives are;

- the development of data sets and methodologies to improve our understanding of customers' ability to transition to Electric Vehicles (EVs) based on off-street parking opportunity and customer demographics.

- enable improved understanding on the likely network areas where increased domestic demand may be experienced and therefore better inform future investment programmes.

- In addition, the dataset will complement existing work being carried out in core work programmes.

Success Criteria

The project will be considered a success if the learning provides the required level of information to make an informed decision on the viability of the solution to become business as usual.

Performance Compared to the Original Project Aims, Objectives and Success Criteria

The project has successfully delivered the following;

1. A robust methodology and model have been developed to better understanding customers' ability to transition to EV which has been validated through onsite and virtual audits.
2. Identification where increasing domestic demand as a result of EV adoption may be expected along with expected magnitude; based on user defined uptake scenarios and assumptions
3. Output data with common reference points to enable adoption by corporate systems and programmes of work.

The following section describes how the project delivered the aims of the project.

The project's key focus was the development of a clear and transparent methodology which combined together the inherent value in a number of disparate datasets to work at a household level in a scalable way.

## 1. Methodology

### *1.1 Parking Propensity*

At the foundation level the project assumed that the ability to park off-street will be a key enabler for EV uptake. Mapping this ability and identifying opportunities to park and charge at domestic premises provides an initial matrix of where increasing domestic electrical demand could be expected.

Using OS MasterMap, domestic properties were identified and tagged with the corresponding available parking area established as shown in Fig. 1. Detailed spatial analysis was conducted to determine a parking opportunity score based on several measurements such as proximity to road, ability to park multiple vehicles and type of property.

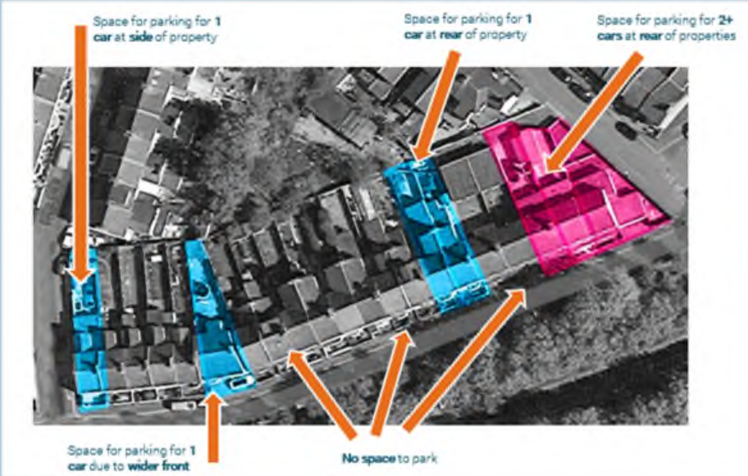


Fig. 1 Example parking space validation

### 2.2 Customer Demographics

Whilst the physical ability to park provides an indication of the opportunity, it does not differentiate between different social groups or provide meaningful insight into the magnitude or timeline of the impact required to fully model the impact of EVs on the distribution network. EV-Up combined the physical ability of consumers to park off street with key demographic information derived from Experian Mosaic data; which provides a pin-sharp picture of today's UK consumer, reflecting consumer and societal trends. By obtaining a deep understanding at the household level of the geodemographic group and type, the household can be linked to a probability to own a type of vehicle. This approach delivered:

- Improved understanding of ownership likelihood of EVs according to income and lifestyle
- Improved understanding of charging behaviours according to lifestyle

### 2.3 Household mileage

The allocation of the foundation data set was developed based on UK statistics of mileage, EV efficiency and average domestic demand based on the demographic groups identified. In addition, several foundation assumptions were used which are borne out by current evidence.

- EV ownership will consistently increase
- EV ownership will not fundamentally change job roles or behaviours
- Early EV adoption will be dominated by owners who live in properties with off-street parking where they can park their EV and charge using their own electricity supply

This baseline methodology enabled daily local energy demand to be calculated based on average mileage for each property. In addition, as EV adoption increases, diversification will mean the concept of a peak day is unlikely to exist and therefore daily demand is likely to be even. The introduction of EV adoption scenarios into the EV-Up model provides a robust estimation of the location and magnitude of increased demand on local networks which can be seen in Fig. 2.

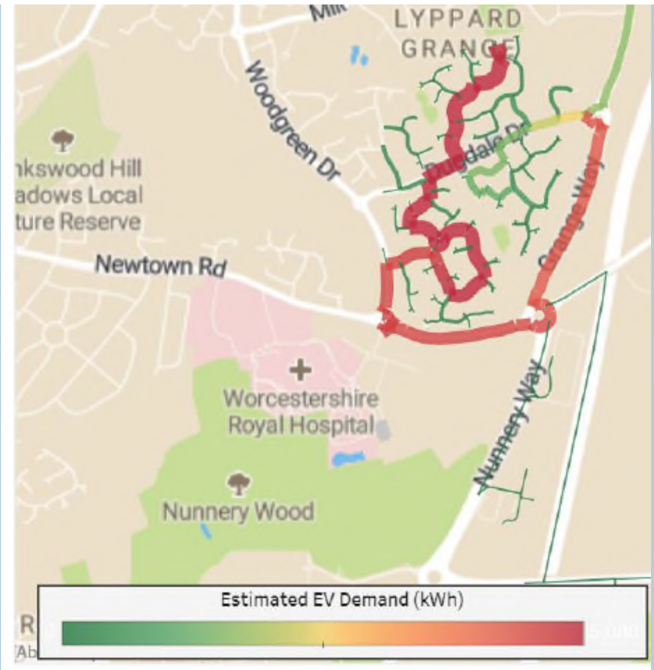

Fig. 2 Increased demand on local LV networks

## 3. Model methodology

The granular approach adopted has modelled increasing EV ownership and corresponding electric demand increases in two distinct ways; Rising Tide and Crashing Wave.

### *1.2 Rising Tide – a slow and steady increase in demand*

There will be local variance, but this gradual increase will require DNOs to steadily increase resilience of their network in advance of the rising tide. There will be enough notice to avoid significant surprises. The methodology enables modelling of scenarios to forecast the pace and location of this tide line, providing the ability to accelerate or decelerate the rise dependent on how the market is predicted to evolve. To deliver this model the following rules were established based on several iterative workshops with subject matter experts within the project team;

- Identify households which have off-street parking and assign the number of EVs they could accommodate
- Exclude households which are unlikely to own a car or who would be dependent on the second-hand market (for early years adoption)
- Assign an expected mileage to each household based on demographic architype
- Calculate the EV daily demand per household
- Derive an EV fraction, which is calculated as a ratio of forecast EVs to total vehicles in the area, and which meet the criteria listed above.

### *1.2 Crashing Wave*

The second growth profile is much more like a high impact Crashing Wave. This will be driven by single (high consumption) groups adopting EVs very rapidly and increasing their charging demand at a much faster rate. Predicting the timing of these crashing waves will be much harder, but it will be possible to identify areas where those waves are likely to crash. Crucially identifying locations that could be at risk of a more sudden and overwhelming rise in demand.  In addition to the rules established for the Rising Tide approach, this model incorporated the following;

- Identify high mileage households who will drive in excess of 20,000 miles per annum, and who can park and charge at home.
- Flag these households in the rising tide dataset to identify high risk areas

## 4. Project Output

### *4.1 Parking Propensity*

A key part of the input into EV UP has been the refinement of a dataset to help determine whether there is parkable space for 0, 1 or 2+ cars at the front, side or rear of a property. It was assumed that as it is cheaper to charge a vehicle from a domestic charger, more households would do this if possible rather than use on-street or hub charging where a higher kWh charge would be likely.

The creation of this dataset required the development of a number of business rules to ensure that there was both an acceptable level of accuracy and consistency when profiling different types of urbanity, property and development type. It defined the parkable space as being an area greater than 20.25 sq. m (the same area as a small family hatchback with all the doors open).

The methodology calculates the potential parkable space rather than attempting to view whether there was a car present on the driveway from other sources such as satellite data. It did not account for any planning constraints or other issues such as gardens or trees in front of properties. This was due to the core assumption that planning legislation and market forces might in the future dictate changes in behavior relating to use of space.

It has been previously assumed that approximately a third of UK households have no off-street parking, equivalent to the model's 0 space assignment. Using the parking propensity methodology the national percentage of the 27 million Great British households with no space to park was calculated to be 24.6%. It is likely that this is lower because as mentioned above, the model looks only at available space and not current usage or other restrictions.

EV-Up has demonstrated that a greater proportion of households in certain locations could have the ability to park off-street depending on willingness to convert usable space into off-street parking. The parking opportunity score (0, 1 or 2 vehicles) for selected areas is presented in Fig 3. This is further linked with the demographic information to assess the likelihood of the household's financial ability to allow this.

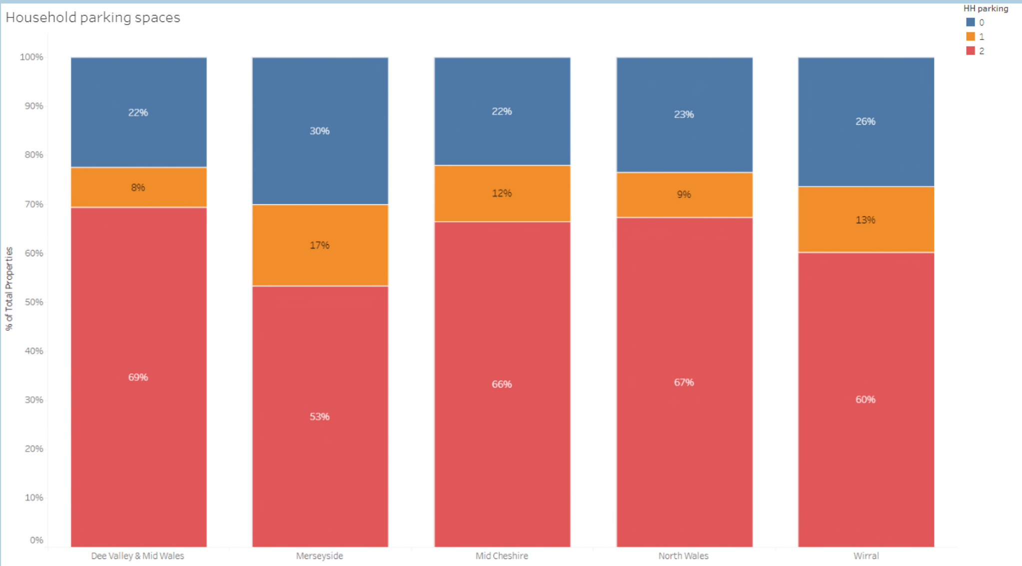


Fig. 3 Domestic off-street parking opportunity scores

Validation analysis concluded that accuracy was at 86% with a number of false positives and false negatives as a result of the methodology accounting for any issues.

### *4.2 EV adoption impact analysis*

On a macro level EV-Up has developed a unique dataset which has been designed to complement and enhance existing electrical network mapping.

Using the model to run specific EV adoption scenarios, the output provides increased understanding and visibility, clearly identifying specific areas of interest. When comparing EV ownership today with expected ownership in the future it is possible to identify the magnitude and impact of EV domestic charging on the distribution network. An example of this is shown in Fig. 4. This will be key in enabling UK DNOs to manage the impact of widespread EV adoption, preventing network constraints from impeding the progress of the transition to electrified transportation.

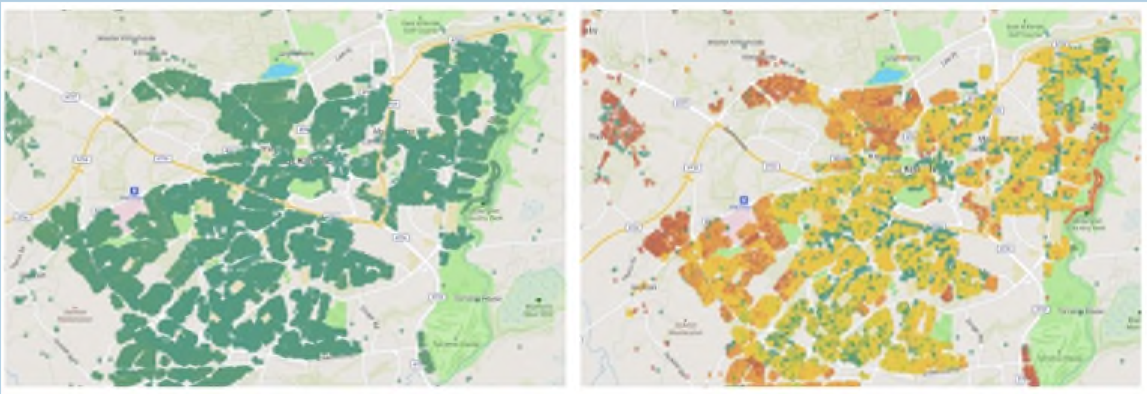

Fig. 4 EV adoption in East Kilbride 2020 compared with East Kilbride 2030 (20% EV Adoption)

A large part of this impact assessment was helping to focus the analysis at each individual household. By combining a number of factors such as the parkable space, property type and the socio-demographic classification of the property, a far more localised view of incremental charging demand was possible.

The development of two core models for EV adoption also assisted in helping to clearly define the potential adoption behaviours of two core demographics that impact the LV Network. At a high level there is general adoption, which will largely impact the network consistently.  In this model, specifying aspects such as exact EV vehicle models, availability, ownership and behaviours would be too hypothetical. In addition to general adoption a further cohort was identified that could more significantly impact the network with a demand surge. High mileage car owners such as field sales representatives and van drivers would need to charge their EV's on a regular basis.

Concentrations of these cohorts are best described as a crashing wave, and identifying these areas in relation to the LV network would be extremely useful.


Fig. 5 Increase in demand was modelled by users specifying a number of EV's for single or multiple year(s). This allowed a number of forecast scenarios to be modelled

It was also acknowledged in the project that although the EV marketplace is new, with the majority of owners buying (or having bought for them) an EV that is new, there is inevitably the development in time of a second hand car market, which will make EV's more affordable to a different demographic.

The model also looked to cater for properties of multiple occupancy, where a series of business rules were developed to help assign EV ownership where it was possible.

### *4.3 Locational Factors*

The granular bottom-up approach of EV-Up has enabled more focused impact assessment of EV adoption to be established. This is clearly demonstrated in St Andrews (Fig. 6) where clear difference has been shown to exist in different parts of the town.


Fig. 6 EV-Up output, St Andrews, UK

The outputs for St Andrews have enabled a more focused review of current and future network development plans, indicating the magnitude and location of increasing EV demand at residential properties. This localised approach is key for assessing future network development providing greater opportunity and data required for each local LV supply, rather than simply substation loading; as outlined in fig 6 above. The model has enabled:

- different uptake scenarios to be compared either at a Local, District or Regional level. This included the creation of a map-based selection including business specific boundaries such as primary substations.
- granular outputs for individual households linked with a unique reference to enable seamless integration into corporate system or other core work programmes

In addition, the outputs also indicate where increased provision of public charging may be required to enable the full transition to electrified transportation.

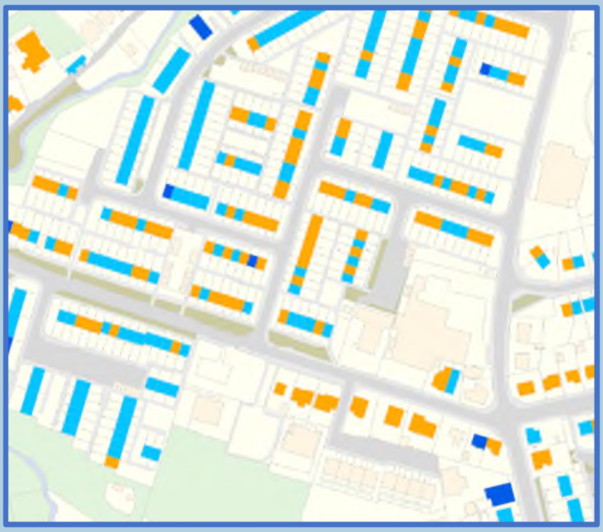

Fig 7. Example output at a household level with representative status of EV adoption probability

Users of EV Up were provided with an online user interface to set up, configure and run a number of scenarios. This meant that previous model runs could be accessed, adapted and re-run as part of ongoing projects. Users could first define their geography and area of interest, followed by options to label years with proposed EV volumes and specific flex assumptions around aspects such as the growth of the 2nd hand car market (see figure 8).

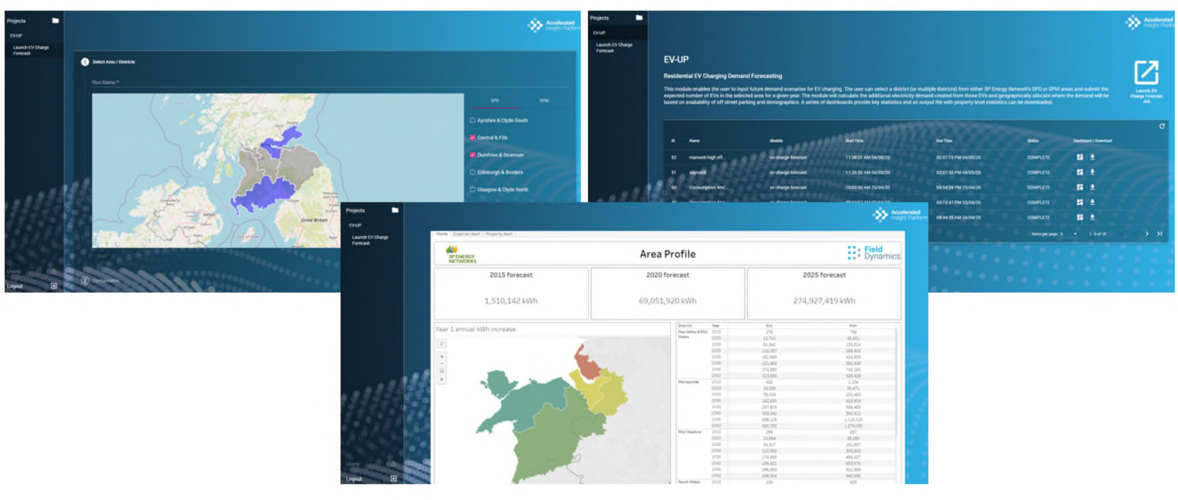

Fig 8. EV Up User Interface

## *5. Validating approach*

As part of the development of the model, a number of validation activities were undertaken to help refine and improve the parking propensity data. This included:

- Linking all business logic in the model to be strictly no more than one step away from a known 'fact' such as government office statistics.
- Use of additional data sources which provided an indication of how many vehicles a particular socio-demographic group is likely to own.
- This process meant that the assumptions in the logical flow of the model could be clearly articulated and business logic for the attribution of each household to any incremental usage was clear, rather than being either random, heavily caveated or developed from multiple assumptions.
- A number of on-street surveys to develop and refine business rules. Work done found that there were a number of scenarios where it was more difficult to obtain the correct value than others. In the case of those scenarios identified, additional business rules were developed to enhance the model further. Examples included relationships between the property and surrounding land parcels, through to other issues with underlying datasets. This led to the development and classification of a number of false positives and false negatives, which could explain the vast majority of mismatches between model results and surveys.
- Desktop surveys where results from the model were compared to Google Street View using external and internal review to determine how the model was affecting parking propensity scores. A number of surveys were undertaken arriving at 84% of accuracy in terms of results.


Fig 9. Validation results from a survey undertaken to improve parking propensity model

This helped to improve the accuracy of the 0,1,2 dataset, which was refreshed into the EV Up database a number of times throughout the project lifecycle.

Details of how the Project is investigating/solving the issue described in the NIA Project Registration Pro-forma. Details of how the Project is performing/performed relative to its aims, objectives and success criteria.

**Required Modifications to the Planned Approach During the Course of the Project**

There were two core modifications made to the approach which improved the methodology of the project.

**The balance of micro-segment analysis vs general trends.**

Wider research has proven that EV adoption has not followed the standard technology adoption curve across the whole market. Recent history demonstrates this clearly with the more conservative or older segments of society, such as suburban retirees and middle age executives driving the uptake in contrast to the adoption curve expected for other disruptive technologies such as mobile phones, which was primarily driven by the urban young. Therefore, the original approach to the project was to create a series of micro market segments, assigning available and applicable vehicle models to each micro-segment. This would create several micro segment adoption curves driven by the fit and availability of specific models to meet the consumer requirements within each segment. However, given the fluctuation in vehicle demand and lack of hard data, it was decided to switch the focus on the adoption model across the two core growth profile methodologies of rising tide and crashing wave.

The objective of the project was to more accurately forecast where additional domestic demand from new EVs will come from as consumers continue to replace conventional internal combustion engine (ICE) vehicles. However, it is important to ensure that these forecasting models are built on the correct balance of assumption vs. fact. Whilst this approach will reduce the sophistication and range of modelling, it will ensure that the results can be justified and backed up with credible evidence rather than a series of subjective assumptions; which in turn may inadvertently reduce the accuracy of the model.

**Project Roll Out**

The initial consideration of the project approach was to create a model for the SP Distribution Area and then roll out to the SP Manweb area. In practice, the model was updated across both distribution areas at the same time, ensuring that any changes to approach and methodology were consistent.

The Network Licensee should state any changes to its planned methodology and describe why the planned approach proved to be inappropriate.

**Lessons Learnt for Future Projects**

There were three areas which will be useful lessons learnt for any future exercise.

*Assumption development and formulation.*

The importance of using clear, referenceable assumptions from a range of secondary research sources and papers was crucial in the development of the EV Up methodology. There is always a risk with forecasting and projection modelling that layering multiple assumptions together mean that errors are amplified through aggregation. The production of a transparent methodology meant that results could be clearly communicated to stakeholders. This avoided a project where the outcomes would have been theoretical in nature.

*Visualisations*

Whilst the core output was a detailed data feed into a network model, the visualisations and mapping outputs created from the results of the forecast have been incredibly powerful in wider communications and stakeholder engagement exercises. These types of outputs should also be considered more widely in energy forecasting and scenario modelling innovation projects.

*Working with data at scale and the hyper-granular approach*

The Hyper-granular approach leads to a high degree of confidence in the aggregated results derived from it. When validating the aggregated results, the project has been able to justify its high level of confidence in the numbers. However, working in this way also presents some challenges.

Firstly, the practical challenge of working with large datasets meant that complex merging and joining of the data is time consuming. Ensuring that the methodology is fully confirmed, tested and validated before attempting to apply to the entire dataset is important to reduce time lost re-running significant data transformations or loads.

Secondly, when working with millions of datapoints, there will always be the risk of individual outliers. At this scale, no methodology will catch every scenario or there may be anomalies in the data. As a result, detailed and thorough validation exercises, individually checking thousands of properties were carried out to identify and document the causes of misclassifications. This enabled those working with the data at a granular level to understand why a misclassification occurs when they see one, but also enabled detailed statistical analysis of the overall results which proved that the number of misclassifications is small and does not materially impact the aggregated output used for forecasting purposes.

Recommendations on how the learning from the Project could be exploited further. This may include recommendations on what form of trialling will be required to move the Method to the next TRL. The Network Licensee should also state if the Project discovered significant problems with the trialled Methods. The Network Licensee should comment on the likelihood that the Method will be deployed on a large scale in future. The Network Licensee should discuss the effectiveness of any Research, Development or Demonstration undertaken.

**The Outcomes of the Project**

The project has delivered on the objective of using data to more accurately model future impacts on the distribution network as a result of the transition to EVs. EV-Up has established a robust methodology and model to understand and identify where EV adoption will occur across the SPEN distribution networks. The bottom-up approach has delivered an innovative approach to this problem, leveraging new data sets to model EV adoption. The project has contributed significantly to our understanding of customers' ability to transition to EVs and importantly has enabled this information to be absorbed into corporate systems.

EV-Up has delivered a new data set and methodology to better predict future network impact as a result of domestic charging – the results have clearly identified where clustering effects will greatly increase electrical demand as EV adoption increases.

As the project progressed several further opportunities have been identified which may lead to improved accuracy or increased scope.

- The EV-Up model did not differentiate the rate of adoption of one EV group verses another, rather it used the demographic groups to align car ownership and usage. However, it is recognised as EV adoption increases and consumer behaviour becomes more understood it may be possible to further improve the model by adopting a variable uptake rate for different demographic groups
- The objective of EV-Up was to focus on domestic charging, however, expanding the scope to incorporate commercial or public charging provisions may allow for a whole systems approach to be developed.
- EV-Up uses standard referencing to ensure data can be easily incorporated. This layering of data sets could be further expanded to improve accuracy; for example, locational factors or EV ownership clustering.
- There are clear synergies with the transition to low carbon heating which could leverage the housing and social demographic methodology to better understand customers' needs and willingness to accept new technologies such as heat pumps.
- Quantifying the latent ability of domestic consumers to participate in future flexibility opportunities.
- Quantifying the impact of local policy or planning on EV adoption.

When available, comprehensive details of the Project's outcomes are to be reported. Where quantitative data is available to describe these outcomes it should be included in the report. Wherever possible, the performance improvement attributable to the Project should be described. If the TRL of the Method has changed as a result of the Project this should be reported. The Network Licensee should highlight any opportunities for future Projects to develop learning further.

**Data Access Details**

SP Energy Networks has been leading various innovation projects to provide solutions to the challenges which our electricity network is facing due to the changes in the way we consume and generate energy. The projects are to support the UK government targets for low carbon economy and are predominately funded by Ofgem innovation fund mechanisms. The learnings and outcomes of the projects are typically disseminated through workshops, conferences and the SP Energy Networks innovation website, to allow knowledge sharing in wider UK applications. Our innovation website provides access to the key documents on the projects.

In addition to this, there may be data generated and collected as part of these innovation projects. It is our intention to share said data with relevant and interested parties who can demonstrate that their use of this is in the best interest of UK electricity customers. The provision of data is subject to anonymisation and/or redaction for reasons of commercial confidentiality or other sensitivity.

Access to this data must be requested by contacting SPInnovation@spenergynetworks.com. Please provide the following information in your request:

- Affiliation, position and contact details of requesting party
- Relevant project and type of data required
- Reasons for requesting this data and evidence that this data will be used in the interest of the UK network electricity customers
- How data will be shared internally and externally by the requesting party

Any data request deemed unsuitable for sharing will be highlighted to the appropriate requesting party. After receiving the request, we will provide the estimated date for completing the data provision based on other requests and our team workload at that time. All requested data remains the property of SP Energy Networks.

A description of how any network or consumption data (anonymised where necessary) gathered in the course of the Project can be requested by interested parties. This requirement may be met by including a link to the publicly available data sharing policy.

**Foreground IPR**

The following documents have been produced and will be made available.

- NIA close-down report
- High level Methodology report
- CIRED 2020 paper: DATA DRIVEN EV UPTAKE MODELLING

Further information can be requested for the SP Energy Networks Future Networks team;

A description of any foreground IPR that have been developed by the project and how this will be owned.

**Planned Implementation**

EV-Up has delivered a new and highly granular approach to network modelling and has delivered significant benefit and improved understanding for a range of core work streams. The project has delivered a new and innovative data set which has greatly improved LCT network modelling in a repeatable and transparent manner. Although the initial focus of the project was looking at EV adoption modelling it was recognised early in the project that the same methodology, leveraging the learning and data sets developed, could be used for other LCT technologies such as domestic heat.

Key work streams which have benefited from the outputs and continued work include;

**Project Charge** – A transport and electricity network planning project to create an over-arching map of where EV charge points will be required for the SPM area. Aggregated output from EV Up was supplied to provide more granular data source, complimenting the transport and network integration work.

**Distributed Future Energy Scenario (DFES)** modelling analysis and stakeholder engagement. Output from EV Up was fed to further the creation of a supply and demand model at primary substation level

**LV network modelling:** Data has been incorporated to improve understanding of average demand profiles for groups of houses types – improving network design studies and delivering real benefits for connected and future customers

**Strategic Partnership with Scot Government:** Project PACE is trailing an innovative delivery model for the roll out of critical EV charging infrastructure in areas where the market may not deliver. EV-Ip output has been used to identify areas where critical infrastructure will be essential to enable customers to transition to EVs

**Other Comments**

EV-Up was nominated as a finalist for the 2020 Network Awards data project of the year

EV-Up will be utilized as suggested above to complete a similar project looking at the forecasting of decarbonised heat uptake and customers ability to transition to these new Low Carbon Technologies, named Heat-Up. The results from Heat-Up will be combined with those from EV-Up to give a solid picture of effect that both EVs and Heat pumps will have on the network simultaneously.

**Standards Documents (Electricity projects only)**