Mobility demand profiles in Euro-Calliope

This document outlines the methods and assumptions associated with the computation of mobility demand profiles in Euro-Calliope.

Methodology

Mobility demand profiles are generated adopting the stochastic approach implemented in the open-source RAMP-mobility model (Mangipinto et al. 2022), accessible at: https://github.com/RAMP-project/RAMP-mobility and validated by the developers against a large dataset of charging profiles from the Netherlands.

RAMP-mobility allows users to generate mobility (i.e. fleet battery consumption) and charging demand time series for 28 European countries. It is grounded on country-specific, easy-to-gather data about population and vehicle fleet composition, user habits, weather and festivities. There are two main steps to the approach. First, it simulates individual vehicle mobility and battery consumption for several user categories and vehicle types, which are then aggregated to obtain the fleet power demand time series. Second, it simulates, for each vehicle, a charging time series that allows the pre-simulated mobility time series to be respected. This second step can be undertaken assuming different charging logics from a user perspective, ranging from 'uncontrolled' to 'smart' ones.

For the present study, we adopt the so-called 'perfect foresight' charging logic, which reflects the behaviour of users participating in vehicle-to-grid mechanisms and which has been conceived by the developers precisely for a functional integration with power system models in which the charging process of vehicle fleets is endogenously optimised. In addition, we modify the type of output produced by RAMP-Mobility to also obtain additional information regarding the state of each vehicle in each time step in terms of its connection to the charging infrastructure (i.e. the electricity grid). We this information to compute the ratio of 'real-time connected aggregate battery capacity' to 'maximum aggregate battery capacity that could be theoretically connected if all vehicles were to be simultaneously plugged in'. This time series allows the actual charge and discharge of the 'connected' fraction of battery capacity in each time step to be optimised as part of running the Euro-Calliope model. At the same time, additional, ad-hoc constraints in the Calliope energy system modelling framework (Pfenninger and Pickering 2018) ensure that the endogenously optimised charge/discharge does not violate the need to meet overall mobility demand on a monthly basis. This monthly demand is based on aggregating the hourly data of fleet battery consumption.

Results

Figure 1 and Figure 2 show results from some representative countries, from different macro-regions of Europe. The bottom-up approach of RAMP-mobility, which is grounded on country-specific input datasets and weather conditions, allows us to capture the differences that exist across European countries and that would have been missed if relying on the common practice of using a single, standard profile.

For instance, countries with a relatively high share of workers and students in their pool of users, such as Norway, exhibit steeper morning and evening peaks. Conversely, countries with relatively low shares of such users, such as Italy and Spain, exhibit substantially flatter profiles. Similarly, particularly hot or particularly cold weather in certain seasons can lead, in some countries, to non-negligible increases of battery consumption. For instance, the peak in Norway can be almost two twice as high as the peak in Spain in winter (Figure 1), due to the combined effect of higher active user shares and colder weather in Norway; the extent of the difference is not as pronounced in summer. Such changes are captured in the Calliope energy system modelling framework by enforcing monthly mobility demand constraints. Moreover, as shown in both Figures, peaks of mobility demand entail troughs in the plug-in profile (fraction of aggregate battery capacity that is connected to the grid in each time step). Mobility profiles characterised by steeper fluctuations in demand produce similarly steep fluctuations in the plug-in profile, which are accounted for on an hourly basis in Calliope.

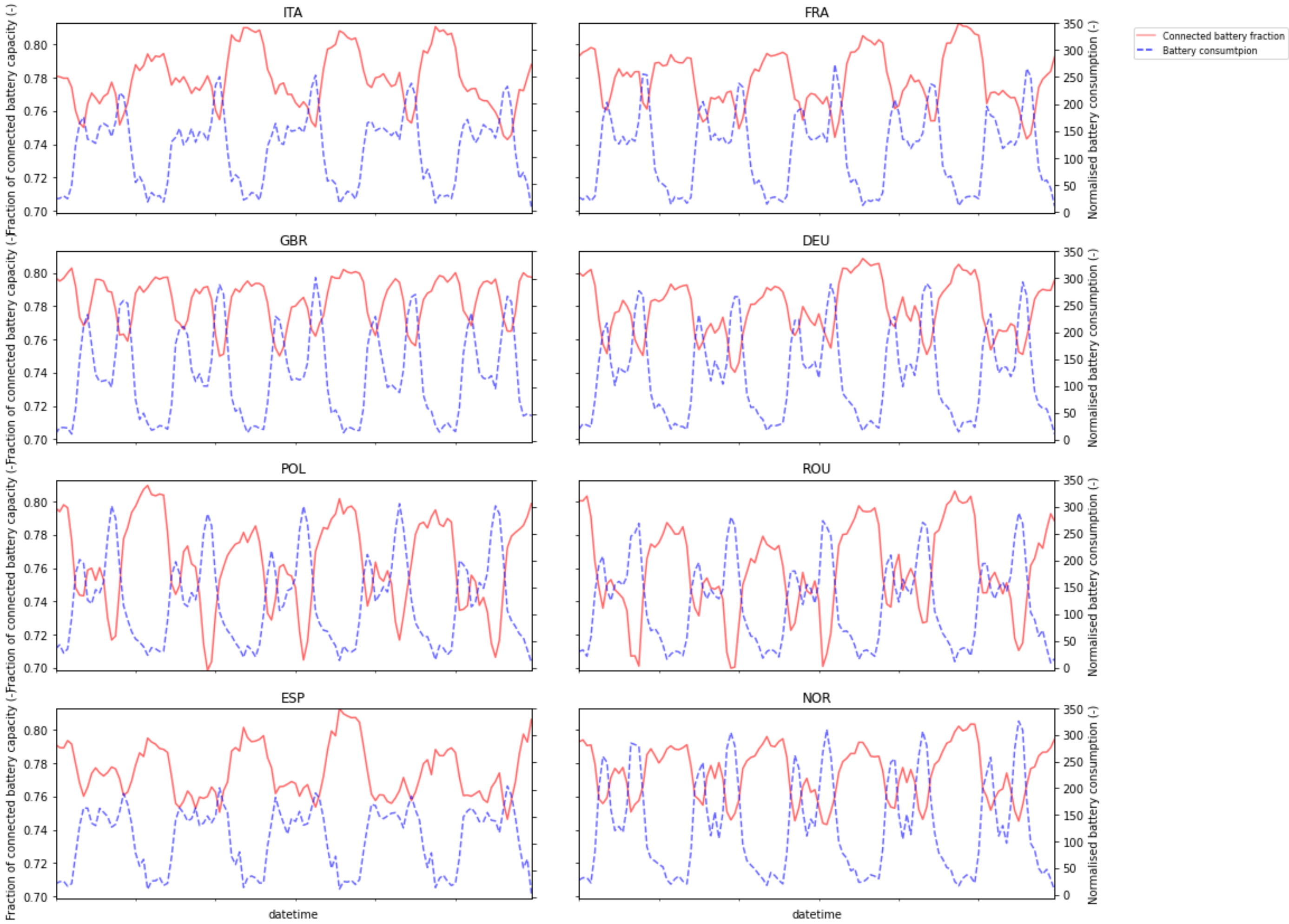

*Figure 1: Comparison of **winter** plug-in profiles (connected battery fraction; red line; left-hand y-axis) and electric vehicle electricity consumption (battery consumption; blue dashed line; right-hand y-axis) for eight countries in Europe. Countries have been selected to demonstrate the distinct differences between different countries, caused by both the composition of driver types and the weather.*

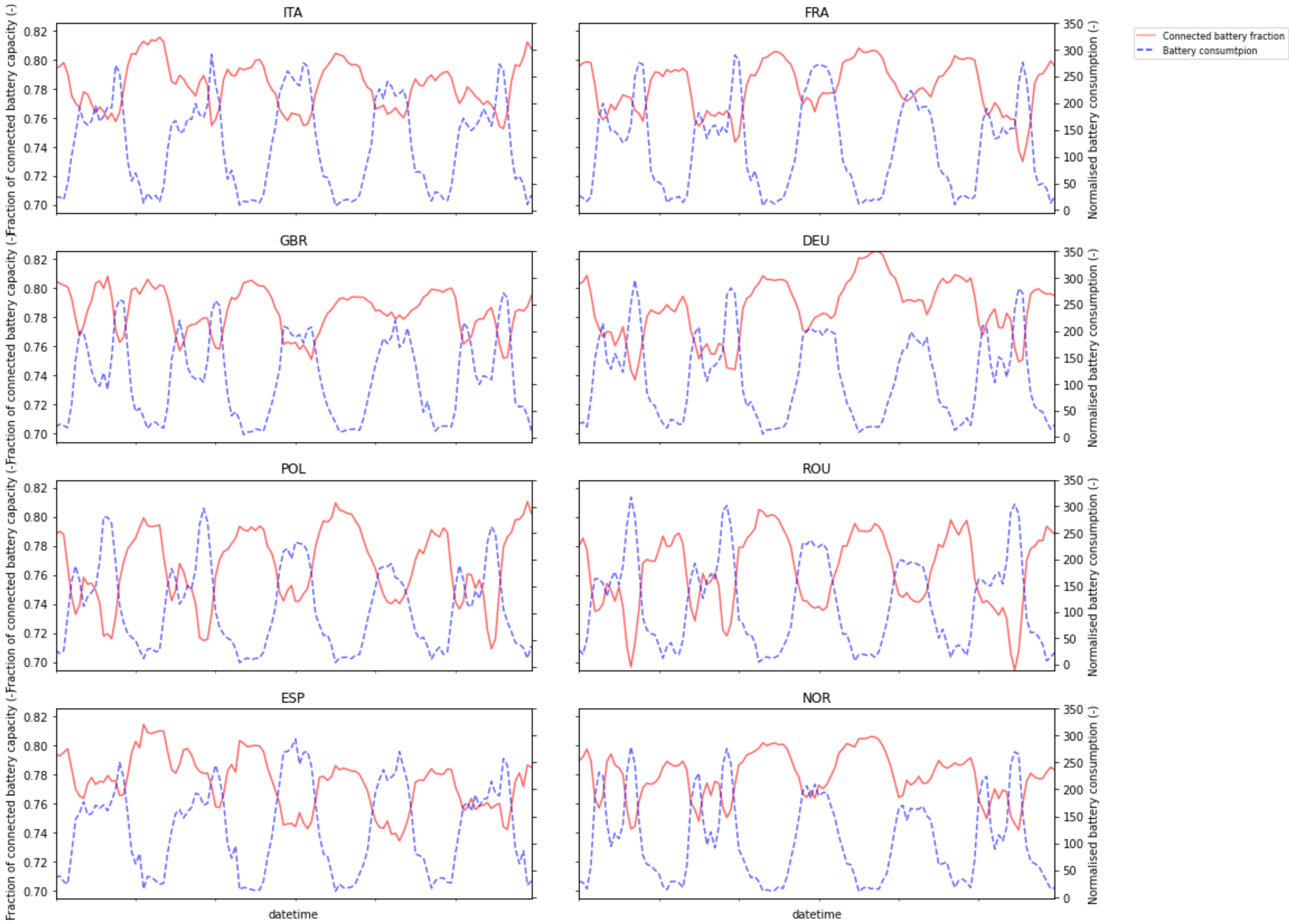

*Figure 2: Comparison of **summer** plug-in profiles (connected battery fraction; red line; left-hand y-axis) and electric vehicle electricity consumption (battery consumption; blue dashed line; right-hand y-axis) for eight countries in Europe. Countries have been selected to demonstrate the distinct differences between different countries, caused by both the composition of driver types and the weather.*

References

Mangipinto, Andrea, Francesco Lombardi, Francesco Davide Sanvito, Matija Pavičević, Sylvain Quoilin, and Emanuela Colombo. 2022. 'Impact of Mass-Scale Deployment of Electric Vehicles and Benefits of Smart Charging across All European Countries'. *Applied Energy* 312 (April): 118676. https://doi.org/10.1016/j.apenergy.2022.118676.

Pfenninger, Stefan, and Bryn Pickering. 2018. 'Calliope: A Multi-Scale Energy Systems Modelling Framework'. *The Journal of Open Source Software* 3 (29): 825. https://doi.org/10.21105/joss.00825.