Alignment requirements and justification: focus on time-series profiles

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Introduction

About ENA

Energy Networks Association (ENA) represents the owners and operators of licenses for the transmission and/or distribution of energy in the UK and Ireland. Our members control and maintain the critical national infrastructure that delivers these vital services into customers' homes and businesses.

ENA's overriding goals are to promote UK and Ireland energy networks ensuring our networks are the safest, most reliable, most efficient and sustainable in the world. We influence decision-makers on issues that are important to our members. These include:

- Regulation and the wider representation in UK, Ireland and the rest of Europe
- Cost-efficient engineering services and related businesses for the benefit of members
- Safety, health and environment across the gas and electricity industries
- The development and deployment of smart technology
- Innovation strategy, reporting and collaboration in GB

As the voice of the energy networks sector, ENA acts as a strategic focus and channel of communication for the industry. We promote interests and good standing of the industry and provide a forum of discussion among company members.

About Open Networks

Britain's energy landscape is changing, and new smart technologies are changing the way we interact with the energy system. Our Open Networks programme is transforming the way our energy networks operate. New smart technologies are challenging the traditional way we generate, consume and manage electricity, and the energy networks are making sure that these changes benefit everyone.

ENA's Open Networks programme is key to enabling the delivery of Net Zero by:

- opening local flexibility markets to demand response, renewable energy and new low-carbon technology and removing barriers to participation
- providing opportunities for these flexible resources to connect to our networks faster
- opening data to allow these flexible resources to identify the best locations to invest
- delivering efficiencies between the network companies to plan and operate secure efficient networks

We're helping transition to a smart, flexible system that connects large-scale energy generation right down to the solar panels and electric vehicles installed in homes, businesses and communities right across the country. This is often referred to as the smart grid.

The Open Networks programme has brought together the nine electricity grid operators in the UK and Ireland to work together to standardise customer experiences and align processes to make connecting to the networks as easy as possible and bring record amounts of renewable distributed energy resources, like wind and solar panels, to the local electricity grid.

The pace of change Open Networks is delivering is unprecedented in the industry, and to make sure the transformation of the networks becomes a reality, we have created six workstreams under Open Networks to progress the delivery of the smart grid.

2022 Open Networks programme Workstreams

- WS1A: Flexibility Services
- WS1B: Whole Electricity System Planning and T/D Data Exchange
- WS2: Customer Information Provision and Connections
- WS3: DSO Transition
- WS4: Whole Energy Systems
- WS5: Communications and Stakeholder Engagement

Our members and associates

Membership of Energy Networks Association is open to all owners and operators of energy networks in the UK.

- Companies which operate smaller networks or are licence holders in the islands around the UK and Ireland can be associates of ENA too. This gives them access to the expertise and knowledge available through ENA.
- Companies and organisations with an interest in the UK transmission and distribution market are now able to directly benefit from the work of ENA through associate status.

ENA members

ENA associates

- Chubu
- EEA
- Guernsey Electricity Ltd
- Heathrow Airport
- Jersey Electricity
- Manx Electricity Authority
- Network Rail
- TEPCO

Executive Summary

Energy scenarios are produced as part of the annual long-term forecasting activities undertaken by all GB Distribution Network Operators (DNOs) and the GB Electricity System Operator (ESO). The GB DNOs produce their Distribution Future Energy Scenarios (DFES), which are granular scenario projections for electricity demand, distributed generation and storage that incorporate regional factors. The ESO produces their Future Energy Scenarios (FES), which provide a set of scenario projections for Great Britain and focuses on the whole energy system through the lens of how the energy system can be decarbonised.

This report focuses on time-series (e.g., half hourly) profiles of demand and generation that are modelled in DFES and FES. This paper explains and justifies that time-series profiles for electricity demand and generation can vary across locations and voltages. The profiles should not be numerically aligned as this would not only result in inaccuracies in network and system planning, but it would also foreclose the use of smart meter data and other Low Carbon Technology (LCT) measurements to enhance profiles by reflecting local behaviours.

Focusing on local characteristics and the way these affect the profiles, the report explains that these effects are different between technologies. For example, it is the different irradiance levels between locations that need to be considered for PV profiles, whereas for EV charging profiles it is the local mix of charging types (domestic overnight slow charging vs en-route rapid charging and destination charging) and typical driving distances that affect the profiles.

In addition to local characteristics affecting individual customer demand and generation or substation profiles, the different levels of diversification, an average LCT can contribute with less demand at higher voltages compared to lower voltages. Using historical demand data across substations at different voltage levels, it is also shown that the diversified nature of demand at higher voltage levels does not allow the aggregation of individual substation peak demand to quantify peak demand across wider areas.

The paper proposes how the agreed "*initial alignment & feedback loop model*" for the DFES-FES alignment can be enhanced focusing on information and data exchanges around the annual energy forecasts to converge, where appropriate, assumptions between DFES and FES. Moving forward, profiles need to capture through granular measurements the local characteristics, as well as the dynamic changes in their shapes from the effects of time of use tariffs and the provision of flexibility services to transmission and distribution systems. It also highlights the need for more information and data sharing aiming to increase transparency in time-series profile assumptions used in DFES and FES to capture both granular/local and national/diversified characteristics.

Introduction

Overview of DFES and FES

Through the Open Networks programme run by the Energy Networks Association (ENA), networks have been working closely to align process and provide clarity on the purpose of the Distribution Future Energy Scenarios (DFES) and Future Energy Scenarios (FES) activities to stakeholders.

The DFES is an annual forecasting activity undertaken by Distribution Network Operators (DNOs) across Great Britain. They provide granular scenario projections that incorporate regional factors and can be used at a local level for strategic planning of electricity distribution systems and networks. These projections are informed by local stakeholder engagement to understand the needs, plans and delivery progress of local authorities and other stakeholders. The DFES provides an evidence base for DNOs to develop the business case necessary to support future investment, including regulated business plans.

The FES is an annual process undertaken by National Grid Electricity System Operator (ESO). It provides a set of scenario projections for Great Britain and focuses on the whole energy system, through the lens of how the energy system can be decarbonised. FES utilises information, insight and data from all sectors of the energy industry and is used as a fundamental part of the annual transmission network planning and national system operability analysis. It also provides insight to members of the energy industry and beyond.

Use of time-series profiles in DFES and FES

Both DFES and FES use time-series profiles – typically half-hourly averages – of electricity demand and generation. These profiles are used as both inputs and outputs of DFES and FES forecasting processes.

Typical inputs of the DFES forecasting processes are a) substation measurements, b) time-series profiles of modelled and measured low carbon technologies (LCTs); and b) half-hourly profiles of modelled and measured generation. Time-series substation profiles are currently available from the primary substations (typ. 33/11 or 6.6 kV) and upstream to the transmission-distribution (T-D) interfaces (GSP, typ. 400 or 275/132kV). Moving forward all DNOs will expand their visibility downstream of the primary substation using permanent measurements from smart meters and/or monitoring at distribution substations (typ. 11/0.4kV).

For the ESO FES, the electricity demand aggregation model estimates annual demand from the summation of its input sector-based demand forecasts (e.g. residential, appliances, etc). The product of these demands and the ratio of annual to peak demand are used to estimate peak demands. Thus, the ratio of annual to peak demand is a driving factor in estimating peak demand for residential, commercial and industrial demand (excluding heat and transport peak demand). This ratio is derived from historical half hourly metered demand for 2 thousand homes from 2008 onwards (supplied by Elexon). Using this extensive history, the uncertainty around peak forecasting can also be quantified. Within the aggregation modelling process, transmission losses data determined at half hourly intervals allow for variations in losses to be determined and forecasted with quantifiable uncertainty. This distribution of losses is then scaled using Week 24 submission data for losses to estimate losses for the distribution system, without time series data for distribution losses this is currently the best estimate.

The increasing availability of highly granular data has enabled the ESO to explore options for greater sophistication in modelling methods, yielding deeper insights and enabling customers to interpret information appropriate to them based on their appetite for risk. Current obstacles to realising these desired enhancements is the availability of granular data for specific sectors of demand. Should smart meter data be available either as a statistical summary of demand by region and sector or in a near raw form, the capacity for regionalised stochastic modelling would be greatly improved.

Focusing on demand LCTs, two common technologies modelled using profiles in DFES and FES are electric vehicles (EVs) and heat pumps. These two technologies are dominant and critical in the decarbonisation of the transport and heating sectors. However, time-series profiles can be also modelled for other forecasting components such as for the baseline demand of domestic and non-domestic customers. DNOs at the moment use annual electricity consumption data, e.g. for domestic demand, to produce time-series demand using typical profiles. Focusing on generation and storage, the most common technologies modelled using half-hourly profiles are solar generation (PV), wind farms, gas fuelled flexible generators and battery storage. The FES also capture the transmission connected generation that includes nuclear and thermal power stations.

Time-series profiles for demand and generation are required in energy scenarios for various reasons that exhibit similarities and differences between DFES and FES, as presented in Table I. This table summarises the DFES and FES outputs that require the use of time-series demand and generation profiles.

Table I: Justification of the use of time-series profiles of demand and generation in energy scenarios

Scenarios	Forecasting output that requires time-series modelling

Distribution Future Energy Scenarios (DFES).	• distribution network planning:
	  ○ assessment of true peak demand (ER P2/7)
	  ○ identification of thermal rating (continuous/cyclic)
	  ○ flexibility service requirements
	• compliance reporting & data sharing
	  ○ half-hourly measured demand excluding large generators at interface with transmission (Week 24 submission)
	  ○ assessment of true peak demand (LTDS, LI)
	  ○ description of LCT profiles (DFES)

Future Energy Scenarios (FES)	• transmission network planning:
	  ○ gas and electricity transmission network planning
	  ○ Network Options Assessment (NOA) process to ensure security of supply
	  ○ application of National Electricity Transmission System Security and Quality of Supply Standard (NETS SQSS) – use of BID3 constraint cost model
	• national system operability:
	  ○ System Operability Framework (SOF) technical assessments for operability

Starting from DFES, half-hourly modelled EV charging and heat pump demand is superposed on a substation's half-hourly demand to accurately reflect the local behaviours and characteristics captured in both the baseline demand and the incremental LCT demand. For example, a substation supplying a predominantly residential area could already exhibit a peak winter demand around early evening hours when people are at home and in future the additional demand from EV charging could be limited as they would mainly charge their EVs overnight using smart charging. On the contrary a substation supplying a predominantly commercial load could exhibit a peak winter demand around midday, which could coincide with destination EV charging in the same area. Therefore, only by modelling the time-series load for both baseline and the incremental LCT demand is it possible to have an accurate and well informed forecast of true peak demand that can be used in distribution network planning (e.g., following minimum requirements standard ER P2/7).

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As outlined in the above table, time series profiles are used in both transmission network planning and national system operability analysis. Central to this are the profiles and assumptions contained within the constraint cost modelling tool (BID3). This is a pan-European electricity dispatch model capable of simulating the electricity market in GB and other countries. BID3 works by seeking to find the optimised way to meet demand using available generation, based on minimising total cost. It can analyse the impact of different weather conditions using profiles based on historic actual demand. BID3 creates an hourly time series of demand using the annual value from FES and the relevant historic hourly profile. Other reasons that time-series modelling using profiles is required in energy scenarios are:

- the need to define half-hourly and at high resolution (i.e., weekly, monthly etc) requirements for flexibility services to the DSO and ESO;
- the identification of continuous vs cyclic type of loading across distribution networks, which defines the associated network asset ratings and available capacity headroom;
- compliance reporting for DNOs that requires a) half-hourly and at specific times active and reactive power forecasts in Week 24 submissions to the ESO; and, b) reporting of true peak demand in other reporting processes (LIs, LTDS)

Objectives of the report

The objectives of this paper are:

- to explain and justify that time-series profiles for electricity demand and generation can vary based on location specific and network voltage related factors;
- to propose how the agreed "*initial alignment & feedback loop model*" for the DFES-FES alignment can be enhanced focusing on information and data exchanges around the annual energy forecasts to converge, where appropriate, assumptions between DFES and FES; and,
- to highlight the need for more information and data sharing aiming to increase transparency in time-series profile assumptions used in DFES and FES to capture both granular/local and national/diversified characteristics.

Section 2 describes why time-series profiles of electricity demand and generation can vary across different DNO license areas and between distribution and transmission networks. Next, in section 3 the recommendation to further enhance profiles and improve alignment and standardisation are presented. In addition, the benefit to DNO and ESO stakeholders from increased transparency in modelling assumptions is also highlighted.

Variations in profiles

Currently energy scenarios use time-series profiles produced by learnings from innovation projects and real-life measurements. This is an evolving process and with access to smart meter data and higher penetration of LCTs time-series profiles used in energy scenarios will be able to better reflect local behaviours.

This section describes the variations in time-series profiles of electricity demand and generation due to a) local factors and b) differences based on voltage level. It also highlights the requirement for continuous updating of the profiles by reflecting local behaviours using more measurements including smart meter data.

Variations due to local factors

Location can affect the time-series profile of both demand and generation. Local factors can result in smaller and larger variations across profiles that model among others in energy scenarios:

- the EV charging;
- the heat pump demand;
- the distributed generation for renewables including solar (PV) and wind generation.

EV charging

EV charging is an area with significant uncertainties around future customer behaviours. However, depending on the supplied area of a distribution or even transmission based substation the modelled EV charging profile characteristics can different significantly. More specifically, these differences can be due to the local potential for overnight charging as opposed to destination or rapid en-route charging during the day, typical distances travelled by vehicles in that location and the mix of vehicle types in the location

Heat pumps

Similarly to the EV charging, the heat pump demand can also exhibit significant differences between different locations. For example, the types of customers based on their building stock in an area might require the use of different profiles to accurately reflect the expected impact on distribution network and national system demand. Areas with access to gas grid can also have more hybrid heat pumps that switch to gas/hydrogen/electric resistive during extremely cold weather. This can affect the profile shape compared to areas where all heat pumps are not hybrids. Other local factors that can affect these variations include differences on building stock composition[1] that impacts heating demand requirements, the availability of hot water storage at a property and the amount of energy efficiency measures that are assumed to be deployed.

Distributed Generation

Focusing on generation, the PV profiles are highly dependent on the local irradiance levels. The same installed PV capacity in the south of the country is expected to generate more compared to the north. This is due to different irradiance levels.

Similarly to PV, onshore wind generation can exhibit very different time-series profiles at different locations. This is mainly due to the very local differences of wind speed profiles. These differences can be observed from half-

[1] Table 5 of UK Power Networks Heat Street report (UKPN_Heat_Street_DRAFT_250121 (ukpowernetworks.co.uk)) details the space heating requirements of different housing types i.e. detached, terraced, flat etc.

hourly measurements of existing installations, where differences can be higher between adjacent wind farms compared to PV.

Profile differences based on voltage level

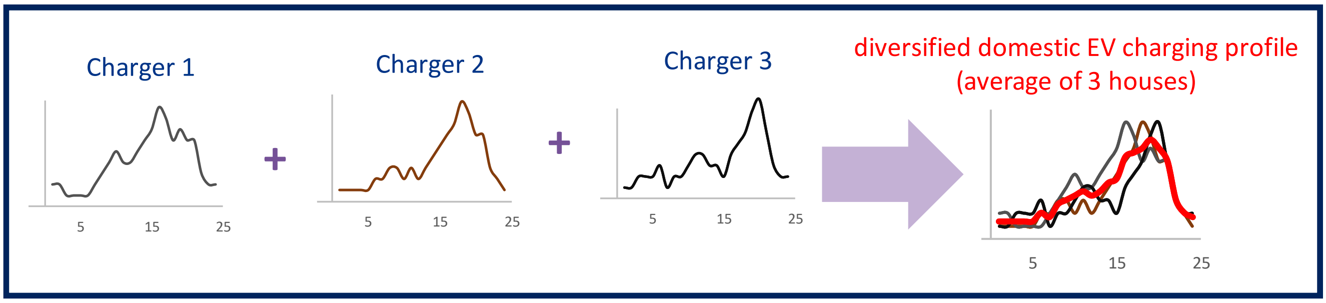
The variations in profiles are not only based on different local geographic and network characteristics. Demand and generation are more diversified as we move from the connection point of domestic and non-domestic demand and generation customers at lower voltages in distribution networks towards the transmission level voltages.

Demand diversification at low voltage

This can be better understood with both practical examples and measurements across different voltage levels. A visual illustration of demand diversification across three domestic EV chargers (e.g., 7kW installed capacity each) is shown on Fig. 1. Assuming that these three customers are supplied at low voltage by a rural pole mounted secondary substation, then the mean value per half-hourly period of the three domestic EV charging profiles can show the average contribution of a single EV charger on the demand of the secondary substation. This average contribution would be a well-informed EV profile per domestic customer to represent the EV charging demand at a sparsely populated pole mounted secondary substation.

As we move towards higher voltages, demand is further diversified and this average per customer contribution to peak demand becomes lower. For LV network planning the non-diversified nature of demand needs to be taken into account to secure supply (e.g., using ACE49 technical report).

Fig. 1. Demand diversification illustration for three domestic customers.



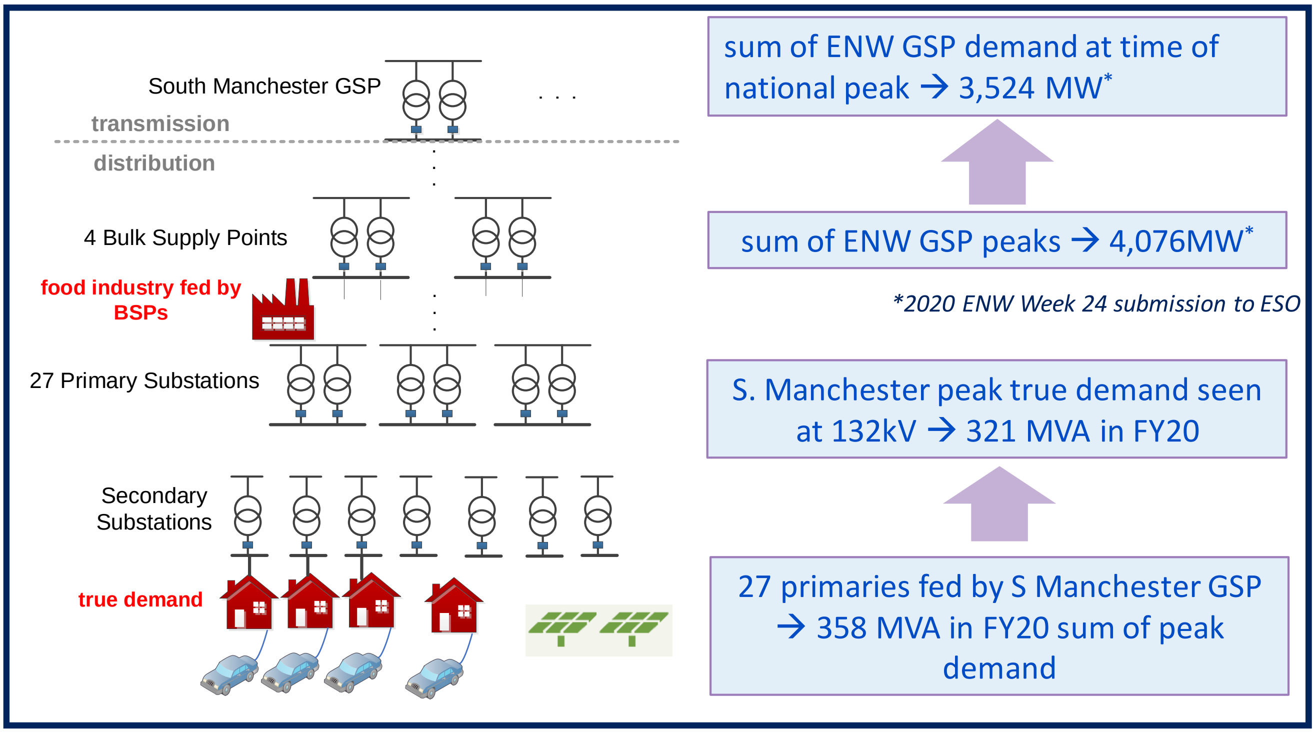
Demand diversification at higher voltages

The demand diversification can be also observed through measurements. An example is illustrated in Fig. 2 for the South Manchester GSP in Electricity North West's license area. South Manchester is supplying a pre-dominantly residential and small/medium sized commercial customer area. Most of the demand is supplied by a group of 27 primary substations, whereas only a large customer is supplied at 33kV by BSPs. Just before the pandemic the aggregated, annual and weather corrected peak demand across all primary substations was identified to be around 12% higher than the corresponding GSP peak demand. Regarding the whole license area, the aggregated annual peak demand of individual GSPs was found to be around 16% higher than the contribution of these GSPs on the time of national system peak.

In an oversimplified explanation where we could assume that each primary substation under South Manchester GSP has a similar mix of customers and the same applies for the whole license area, then this average group of customers under a primary substation has contributed in average:

- well over 12% more on the primary substation's peak compared to the peak of the T-D interface (GSP); and,
- around 16% more on the peak of the T-D interface compared to the national system peak.

Fig. 2. Demand diversification – the pre-pandemic South Manchester GSP example.



Similarly to the local variations of profiles, any numerical alignment of profiles across different voltage levels would neglect the diversified nature of demand and generation as we move towards higher voltage levels. As highlighted in the following subsection, the continuous improvement of profiles using local measurements is key to accurately reflect the effect of customer behaviour, LCT and renewable operations on distribution and transmission network loading.

Moving towards higher voltage levels, thus the average contribution of a domestic EV charger is expected in general to be lower than 1kW for transmission and sub-transmission voltages.

Continuous profile improvement

Capturing local behaviours using local time-series measurements

As more customers adopt LCTs and more time-series measurements become available through smart meters and DNO LV monitoring systems, time-series profiles for demand and generation can be further enhanced to capture local behaviours. Access to local/granular measurements will require the use of this data to inform time-series profiles in energy scenarios, as any numerical alignment would neglect real life behaviours.

The value of a competitive innovation framework

During the last decade the DNOs and the ESO have enhanced their time-series demand and generation profiles not only using local and aggregated measurements, but also using and sharing learnings and data from innovation projects. This was feasible due to the existing competitive innovation framework (incl. LCNF, NIA, NIC projects), which promotes the sharing of learnings and data across the DNOs and the ESO.

Moving forward, time-series profiles can be further enhanced and benefit from a competitive innovation framework. It should be highlighted that a numerical alignment of profiles between DNOs and the ESO will not only neglect important parameters such as local factors, demand diversification and real life behaviours informed by local measurements, but importantly will also foreclose the benefits from data and sharing learnings in the existing competitive innovation framework.

Recommendations

The previous section explained the various reasons that time-series demand and generation profiles are different depending on location and voltage level. Importantly as the penetration of various LCT types increases and further access to local measurements is available including smart meter data, profiles will need to capture local behaviours and inform local trends of demand and generation.

This section highlights next steps that can be taken by DNOs and the ESO to enhance the profiles used in energy scenarios. This does not only include areas where further standardisation and alignment across energy scenarios is feasible, but also information from the energy scenarios that is shared with stakeholders.

Focus on energy consumption comparison

As described in the previous section, alignment of time-series profiles across different locations and voltage levels will reduce the credibility and accuracy of load modelling. However, the DNOs and the ESO exchange forecasts of annual electricity consumption (energy) for the common scenarios as part of the established whole system FES building block process, which is part of the "*initial alignment and feedback loop*" model for the DFES-FES alignment and standardisation. Provided that the same definition of energy is used, energy demand values can allow a direct comparison between DFES and FES for key forecasting components, such as EV charging, heat pump demand and renewable generation.

The direct comparison and identification of differences between DFES and FES building blocks can show areas of divergence, e.g. for EV charging annual electricity consumption across a DNO license area. Observed differences should require further relevant information sharing from both DNOs and the ESO. For example, for EV charging the relevant information could be:

- behavioural and customer choice assumptions, e.g. forecasted EV volumes, average mileage assumptions, charging location assumptions
- technology assumptions, e.g. vehicle battery size, forecasts of battery cost
- local stakeholder inputs, e.g. local plans for EV chargers in connections pipeline and longer-term energy planning, air quality zones,

The information sharing around building blocks with significant differences would allow DNOs and ESO to understand assumption differences. Consequently, this would allow them, where appropriate, to further enhance the energy scenarios using a) well justified assumptions; b) wider data inputs to their forecasting processes and c) further insights from the DNO and ESO stakeholder engagement and planning processes.

Capturing behaviours using local measurements

Energy alignment as described in the previous subsection using the *initial alignment & feedback loop* model between DFES and FES can enhance profiles in the sense of them corresponding to closer differences in the associated annual electricity consumption.

Focusing on the intraday and seasonal differences of demand and generation, the recommended approach is to capture local behaviours using time-series measurements. The DNOs and ESO currently build their demand and generation profiles using measurements. However, for LCTs such as EVs and heat pumps the measurements at the moment correspond to first adopters. As access to smart meter data and other LV measurements increases in parallel with uptakes in LCT volumes, this will allow DNOs and ESO to capture the local behaviours in time-series demand and generation. Importantly, access to measurements across different voltage levels will allow energy scenarios to be built taking into account not only representative local behaviours but also proper levels of diversification across voltage levels.

Capturing the dynamic evolution of profiles

The DFES and FES adopt assumptions around future effects on the shape of time-series demand profiles from time of use tariffs, e.g. as part of smart EV charging and operation of heat pumps with hot water storage. The DNOs and the ESO need to continuously update their assumptions capturing the latest updates, taking into account the local behaviours as highlighted in the previous subsection, e.g. understanding how time of use tariffs affect local and national demand.

They also need to improve their understanding and reflect the effects on time-series demand and generation profiles from the provision of flexibility services to the transmission and distribution systems. More specifically, DNOs need to reflect the effects of flexibility services to the ESO on the local demand profiles, whereas the ESO needs to reflect the corresponding effects of DSO flexibility services on demand seen across transmission-distribution interfaces.

The value of transparency in profiles

Given that both DFES and FES are used for planning purposes, transparency in all their forecasting components is required to both justify decision making and enhance information sharing with DNO and ESO stakeholders.

Through Open Networks the DNOs and the ESO had previously agreed to investigate what profiles for EV charging and heat pump demand could be published for the benefit of their stakeholders. To further improve transparency it is recommended that this is expanded to:

- include explanations around the modelling and assumptions for EV charging and heat pump profiles;
- include typical profiles and explanations around the modelling and assumptions for solar and wind generation;

It should be also highlighted that the Network Development Plans (NDP) that all DNOs have started publishing from May 2022 will further improve transparency through explaining how forecasts are considered in distribution network planning processes.

Glossary

DFES	Distribution Future Energy Scenarios
DNO	Distribution Network Operator
DSO	Distribution System Operation
ENA	Energy Networks Association
ESO	Electricity System Operator
EV	Electric vehicle
FES	Future Energy Scenarios
LA	Local Authority
LAEP	Local Area Energy Plans
LI	Load Index reporting
LTDS	Long Term Development Statement
NETS	National Electricity Transmission System
NIA	Network Innovation Allowance
NIC	Network Innovation Competition
NOA	Network Options Assessment
SQSS	Security and Quality of Supply Standard

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