In partnership with

Smart Charging Architecture Roadmap

(SmartCAR)

December 2018

Smart Strategy Architecture Roadmap (SmartCAR)

Revision History

Version	Revision Date	Summary of changes (author)
0.1	22nd July 2018	First draft structure and smart charging models content for team review
1.0	8th August 2018	First draft report released to internal team for review
2.0	31st August 2018	Final draft for Sotiris/Ian/exec review
3.0	17th October 2018	Final version updated with all comments
3.3	7th November 2018	Review following trials scoping and finalization of smart charging strategy

Project Details

Name	Comments
Project Name	Smart Charging Architecture Roadmap (SmartCAR)
Sponsoring Directorate	Asset Management
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Distribution & Sign Off

Name	Role	Key changes incorporated
Tim Manandhar	DSO technology lead	Updates on existing delivery timeframes as well as other minor updates
Joseph Johnson / Tim Manandhar	SmartCAR project architect / Smartgrids IS lead	Clarifications to requirements Updates to architecture diagrams and flows Updates to delivery timelines and scope
Sam Do	DSO markets team representative	General clarifications in the CBA
Thanos Zargiannis	EVolution programme manager	General comments throughout Inclusion of “minimum viable product” for trials in roadmap and trials section
Sotiris Georgiopoulos	Head of Smartgrids	Feedback on CBA method and validation
Ian Cameron	Head of Innovation	Clarifications and further explanations

Contents

1 Executive summary

On 19th July 2018 the Government published its Road to Zero Strategy, which confirms an ambition to see at least half of new cars to be ultra low emission by 2030. This ambition is set out as part of the Industrial Strategy, in order to drive forward the UK's decarbonisation commitments and to deliver against the Air Quality Plan.

UK Power Networks is launching this report into Smart Charging Architecture in order to support the Government's ambitions, provide input into industry design and decision processes, and support a faster uptake of electric vehicles.

A number of projects have demonstrated the impact that electric vehicle uptake will have on the network in the coming years, and the potential for the coordination of charging sessions to reduce the overall peak demand impact, reduce reinforcement needs, and therefore provide the most efficient means to facilitate electric vehicle uptake at lowest cost.

The purpose of the Smart Charging Architecture Roadmap (SmartCAR) project

The UK's two notable smart charging projects – Scottish & Southern Electricity Network's 'My Electric Avenue' and Western Power Distribution's 'Electric Nation' – have conducted successful trials to understand consumer behaviour in relation to smart charging. These projects have been enabled by a technical solution in which the DNO controls network access via DNO-owned assets. This approach has been termed the "interim solution", acknowledging that in the longer-term an industry-wide solution is required that allows for market participants to facilitate smart charging.

It is in this context that we launched our Smart Charging Architecture Roadmap project (SmartCAR), to investigate longer-term potential approaches for smart charging in which the market can take the lead in managing EV loads.

Through this project we have:

- Worked with a **stakeholder steering group** throughout the project, to shape initial research and to develop and test emerging thinking and conclusions;
- Investigated **international case studies** to understand the leading smart charging models being trialed and implemented around the world;
- Identified an underlying **hierarchy of mechanisms for smart charging**, and a likely evolution of the UK industry as it progresses through development and implementation of the models;
- Developed **high-level designs for the industry architecture** required to support each potential smart charging approach, focusing on key functions, system requirements, data flows, use cases, and commercial arrangements;
- Investigated **communications standards and equipment standards** that could be employed for smart charging;
- Investigated the **costs and benefits** to determine the **value of EV flexibility**; and
- Set out a **roadmap for delivery of the core architecture**, including the evolution of functions and systems capabilities in the market and for DNOs.

Stakeholder engagement

To assist in shaping our strategy we have engaged a variety of stakeholders. This engagement was not intended as a formal consultation, but rather as a means to testing our thinking across a range of relevant stakeholders and seek challenge from different viewpoints. Electric vehicles (EVs) are a challenge that impact not just on networks about also suppliers, car manufacturers, digital businesses, and more, and as a result we engaged a diverse cross-industry group.

The stakeholder group comprised of charge point operators (pod-point, Chargepoint, and ChargeMaster), energy suppliers (OVO and Octopus Energy), car manufacturers (Ford and Nissan), industry bodies (OLEV, BEAMA, Energy UK and the SMMT), electricity networks (National Grid, SSE and WPD) and academia (Imperial College).

The feedback received from participants has been immensely valuable, and has helped to shape our focus and direction to ensure the findings are acceptable to as wide a range of stakeholders as possible. In general, all stakeholders support a similar approach to Smart Charging, in which customers and/or service providers coordinate charging (and discharging) of EV batteries in response to network price signals, as well as wholesale market and balancing services opportunities.

There is uncertainty regarding the level of "emergency control" that may be needed for DNOs, and how long it may take to establish market price signals, and we investigate this through the research set out in this report.

Summary of our smart charging strategy

Our international research identified four mechanisms to consider as means to facilitate smart charging – constraint price signals (via DUoS reform), flexibility procurement, capacity allocation and management, and DNO load management (i.e. where the DNO has a unilateral load-limiting option, enacted via 3rd party or DNO-owned control infrastructure). These mechanisms can be thought of as a hierarchy of mechanisms with increasing "DNO action", should market mechanisms be unable to fully manage emerging EV constraints.

Figure 1 below illustrates this potential hierarchy of operating regimes:

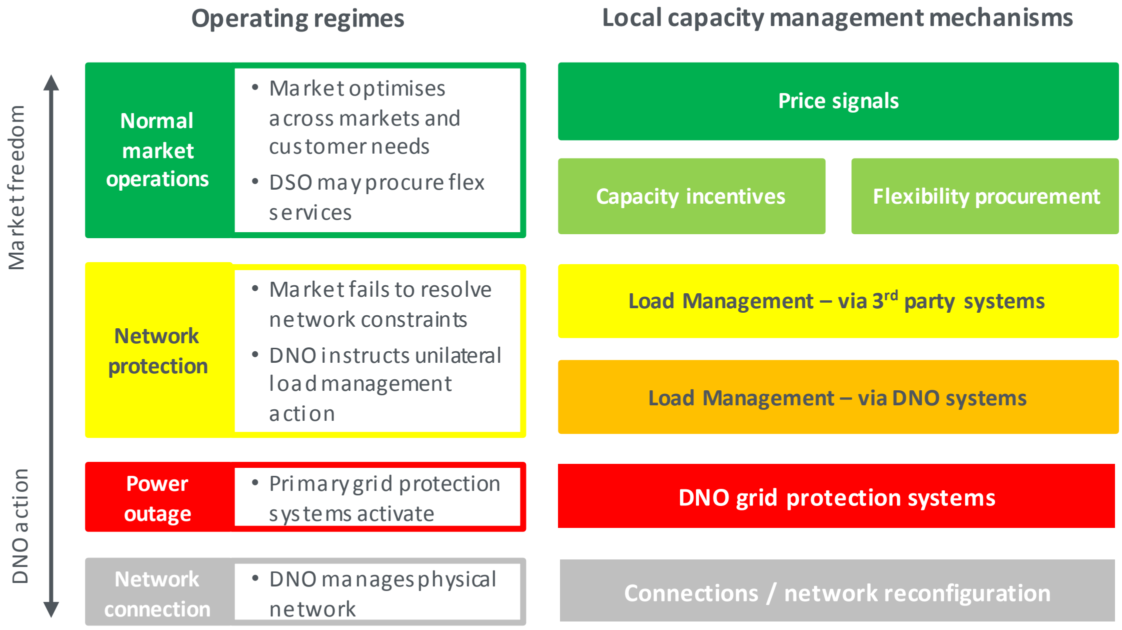


Figure 1: Illustration of hierarchy of smart charging approaches

UK Power Networks' strategy for smart charging is to pursue market-based approaches, in which 3rd parties deliver propositions that enable customers to mitigate their impact on the network and share in the benefits.

We believe that the end-state model in the UK should be based on reformed network price signals (i.e. reformed DUoS charging). This would enable customers to have the ultimate choice as to whether to charge at peak times, would serve to recoup network costs from the customers driving the increased costs, and is the method preferred by stakeholders.

However, this approach will need to be tested, and it may take some time to establish. Other methods may be required in an "interim" period, and we believe alternative market mechanisms, such as flexibility procurement or load management via 3rd parties (if compensated and opt-in) could also be effective and may prove quicker to implement.

We therefore intend to investigate the various "interim pricing" approaches with market participants through trials. This will help to test the efficacy of these market-based mechanisms in managing network constraints, will stimulate the market to develop propositions, will help to inform Ofgem's pricing reform, will help us to develop the capabilities we will need for the future, and may enable reinforcement deferral in the remainder of ED1.

Architecture assessment

Following on from the definition of our smart charging strategy, we set out the high-level architecture required to enable each of the possible smart charging mechanisms. Section 4 ('Smart charging architecture') sets out this assessment in detail, and Figure 2 below illustrates some of the outputs.

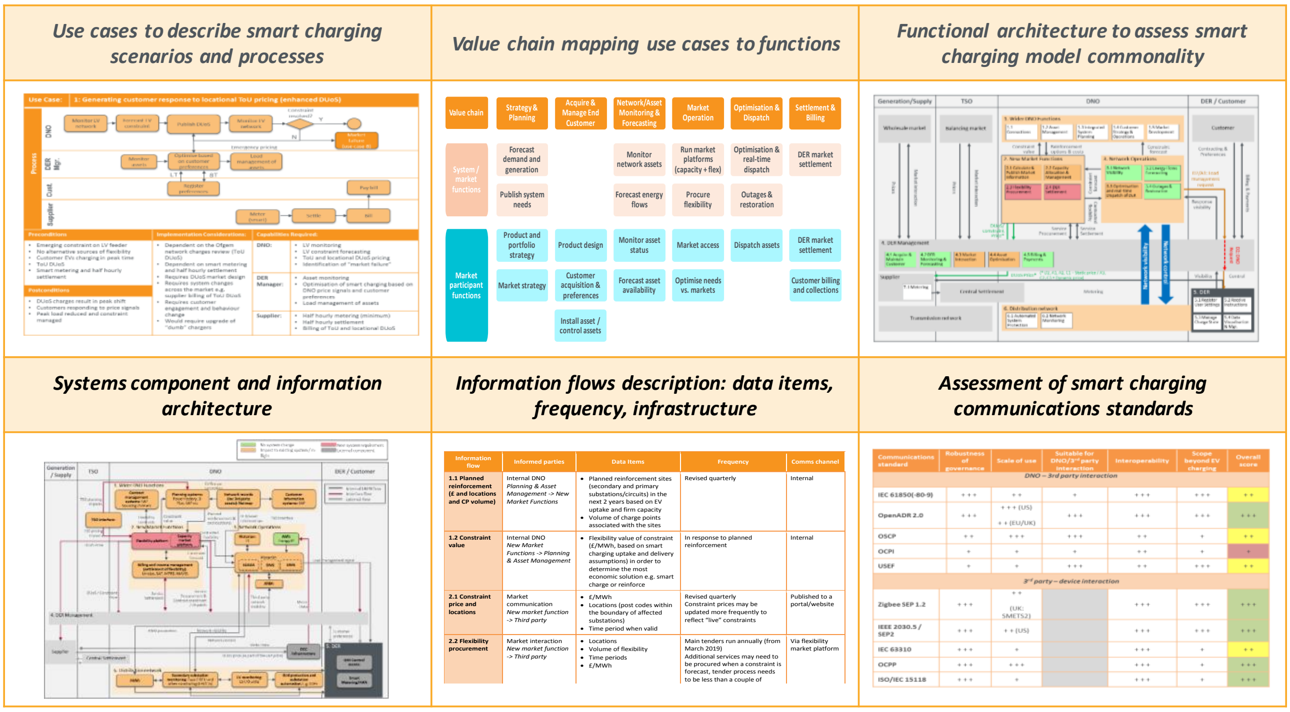


Figure 2: Illustration of outputs from the architecture assessment

Our architecture assessment identified "core" functions which are common to all of the possible smart charging approaches, and so are "no-regrets" areas that DNOs can start to invest. These are:

- Network visibility – *Substation telemetry (including low voltage) and associated central systems to enable real-time monitoring of the network*
- Energy flows forecasting – *Ability to forecast both long and short-term network constraints (including at low voltage substations and feeders)*
- Outages and restoration – *Management of planned and unplanned events and restoration of supply*

Other DNO functions, such as Calculating & Publishing Market Information, Flexibility Procurement and DER Settlement have requirements specific to the different smart charging approaches. The need and definitions of these "non-core" functions will be further determined through future smart charging trials.

Facilitating the various Smart Charging mechanisms identified will involve impacts to existing business and systems functions, and developing new functions. New "network operations" functions will be required to monitor conditions on the LV network with greater granularity and real-time visibility than today, in order to support improved visibility of constraints. New "market functions" would be required to generate constraint prices, interface with market participants in order to facilitate flexibility response, and potentially settle flexibility contracts. These kinds of functions could be required to manage all forms of DER, and not just EVs, and form part of the transition to a more active DSO model.

In between the DNO and the electric vehicle, we have defined a layer of "DER Management" functions. These would be carried out by 3rd parties, such as suppliers, aggregators or charge point operators, or by the customers themselves. These functions would have the role of interacting with electric vehicles and the markets (i.e. wholesale market, balancing mechanism, and new DNO market mechanisms), and optimising the charging (and discharging) schedule accordingly.

Our systems assessment suggests that there are candidate systems in UKPNs estate to support many of the functions for smart charging, albeit that enhancements will be required. In addition, it is likely that entirely new systems may be required in some areas. However, many of these required enhancements and new systems are also required for managing other DER, and so there are significant overlaps with other ongoing or planned projects. The requirements for electric vehicles therefore often add to the business case of existing projects, rather than requiring entirely new delivery projects.

A review of international communications standards in use has provided detail on the available standards, and suggests that Open ADR 2.0 may be the most appropriate candidate for UKPN to consider when developing a smart charging market interface. This standard covers the most comprehensive spread of information requirements across the smart charging models, including pricing. However, it is a more complex standard, and others may be more appropriate if we were to restrict the scope of smart charging to a simpler set of use cases.

The value of flexibility

In this publicly available document, we are unable to publish the full outputs of out cost/benefit assessment, but focus instead on the method followed and key conclusions. We conclude that there is a positive benefits case in UK Power Network's licence areas to pursue a smart solution to enable a rapid and lowest-cost uptake of electric vehicles.

Our modelling work has provided insight into the impacts electric vehicle uptake will have on our network, and highlights that LV impacts are likely to begin within the next 5 year horizon as clusters of EVs form. Our Recharge the Future project has developed a granular peak load forecast, which reveals that load is expected to increase by 30% by 2031, largely driven by EVs. If we were to cope with this through traditional reinforcement, the annual volume of substation and circuit reinforcement could increase by 30 times (from today's volumes) by 2031.

From this load forecast we have developed a view of the cost of traditional reinforcement that would be required to cope with this growth, and subsequently estimated the potential reduction in cost from utilising smart charging to reduce the impact of peaks. We have also determined the costs required to implement smart charging – both for the central systems capabilities required and the increased level of substation monitoring required in the field. This assessment has revealed that there is a positive business case for smart charging, and in addition we believe there may be potential to drive net benefits in RIIO-ED1 in the next 5 year timeframe, if we can mobilise solutions rapidly.

We are therefore satisfied that smart charging will be the most economic solution to managing electric vehicle uptake at lowest cost for consumers, and so we would be justified in investing in the required capabilities.

Architecture roadmap

Based on our understanding of the required architecture for smart charging, we have developed a roadmap of when the identified capabilities would be required. The timeline has been informed by both the level of opportunity for smart charging, and also by considering wider industry changes.

Ofgem's Network Access & Forward Looking Charges review is looking to drive reform to the access and charging regime, and the Open Networks project is progressing the design of the future DSO role – each of which aim to assist in realising the value of DER flexibility. Both of these projects suggest that large scale changes could be expected to be implemented by 2023, alongside the new ED2 regulatory framework.

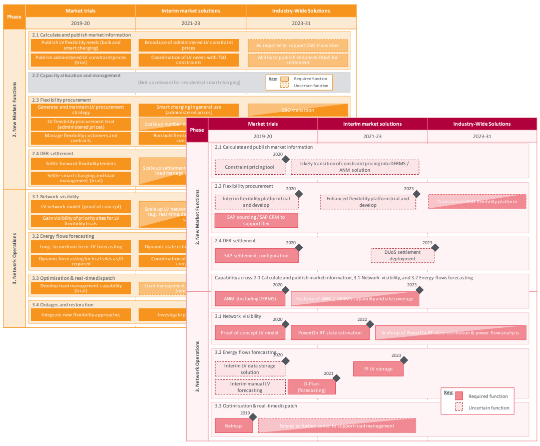
However, we believe we will need to develop an "interim solution" ahead of this timescale, though as outlined above we intend to investigate market-led "interim pricing" approaches. Our modelling suggests that smart charging will be the most economic way to facilitate electric vehicle uptake at lowest cost to consumers, and can drive benefits within the RIIO-ED1 timeframe. We also believe that developing an interim pricing solution will help to generate learning and insights which will help to inform longer-term reform, and will help UKPN to develop skills and capabilities that will be required to operate in the DSO role.

We are therefore setting out a roadmap with three broad phases:

- Phase 1: Market trials to develop and deploy interim solutions (2019-2021)
- Phase 2: Drive benefits from interim market solutions (2021-2023)

- Phase 3: Transition to mature market solutions (from 2023 and the start of ED2)

Based on these timeline assumptions, we have developed roadmaps to understand when we require specific functions defined in our architecture work, and the systems delivery timelines required to support the functions. Figure 3 below provides an illustrative view of these roadmaps, the full detail of which can be found in Section 6 ('Smart charging architecture roadmap').



The roadmaps plot first the functions required by when, and then the systems required to support them.

The functional roadmap illustrates the minimum requirements for a trial (2019/20), a required ability to scale up the volume of sites and transactions to drive ED1 benefits (2021-23), and uncertainty post 2023 based on charging reform and the DSO transition.

The systems roadmap identifies candidate existing systems and delivery programmes that could support functions in the required timelines, as well as areas where no existing systems or programmes could support the new requirements within the timescales

Figure 3: Illustration of functional and systems delivery roadmaps

Key next steps

There are four key actions following on from this work:

1) **Communications strategy and stakeholder alignment** – Insight developed through this project will need to be disseminated to the relevant stakeholders, as required for NIA funded projects. We will also consider sharing a more detailed view of the outputs with the Electricity Networks Association, to provide input to other licensees, and could take the opportunity to engage wider stakeholder group regarding the positions set out in this document. In addition, we will share our position with stakeholders such as Ofgem, OLEV and BEIS to support wider design thinking, as well others to support our brand awareness.

2) **Scope and mobilise the LV residential smart charging trial** – A priority action is to mobilise UKPN's response to the need for residential smart charging, and begin to develop our interim pricing solution. This will require scoping and mobilisation of the proposed trial, as part of the wider flexibility strategy and roadmap. An initial scoping of this trial is set out in Section 6.2.

3) **Feed architecture design work into systems delivery strategy** – The insight developed in this report can be used to inform UKPNs systems delivery programmes. In some areas this may entail incorporation of requirements and delivery timelines into existing projects, and in others this may require scoping and mobilisation of new projects. This will be assessed and taken forward by the relevant internal stakeholders.

4) **Support industry design work** – The insight developed in this report will serve to provide a basis for UKPNs input into industry design processes in relation to smart charging – for instance the LowCVP Taskforce (which will inform Government on secondary legislation) and wider related consultations. The UKPN teams responding (such as Innovation, Smartgrids and Regulation) can refer to this work in future when responding to consultations and requests for information on this topic.

2 Introduction

2.1 The purpose and structure of this document

This document is the final report developed through our "Smart Charging Architecture Roadmap" (SmartCAR) project. It sets out our research into residential smart charging approaches, and UK Power Network's strategy and roadmap for supporting the development of smart charging in the UK.

The document is structured into the following sections:

- **Introduction** – recapping on projects to date in the UK and the direction of travel of the industry debate, and setting out the subsequent objectives of the SmartCAR project
- **The value of residential smart charging** – setting out an overview of when electric vehicle uptake will begin to impact our network, and modelling on what value can be captured through smart charging to inform how it might be incentivised
- **Our smart charging strategy** – setting out our research into international smart charging approaches, the views of a range of industry stakeholders, and UKPN's subsequent strategy for smart charging
- **Smart charging architecture** – setting out the use cases that would deliver the strategy, the functions that we will require to support the use cases, an impact assessment against our current systems, and a spotlight on the current state of equipment standards and communications protocols in the industry
- **Smart charging architecture roadmap** – setting out the proposed roadmap for implementing different forms of smart charging capabilities, our view on the required trials and learning to be mobilised, and our recommendation regarding industry-wide coordination and decision making to support smart charging

2.2 Smart charging industry direction of travel

2.2.1 The Road to Zero

On 9th July 2018 the Government published its Road to Zero Strategy, which confirms an ambition to see at least half of new cars to be ultra low emission by 2030. This ambition is set out as part of the Industrial Strategy, in order to drive forward the UK's decarbonisation commitments and to improve air quality as part of the Air Quality Plan.

According to the Government's launch press release:

"The government has already committed to investing £1.5 billion in ultra low emission vehicles by 2020 and the Road to Zero Strategy outlines a number of ambitious measures including:

- A push for charge points to be installed in newly built homes, where appropriate, and new lampposts to include charging points, potentially providing a massive expansion of the plug-in network
- The launch of a £400 million Charging Infrastructure Investment Fund to help accelerate the roll-out of charging infrastructure by providing funding to new and existing companies that produce and install charge points
- Creating a new £40 million programme to develop and trial innovative, low cost wireless and on-street charging technology
- Providing up to £500 for electric vehicle owners to put in a charge point in their home through the Electric Vehicle Homecharge Scheme, and an increase in the value of grants available to workplaces to install charge points so people can charge when they are at work
- The extension of the Plug-In Car and Van Grants, allowing consumers to continue to make significant savings when purchasing a new electric vehicle
- The launch of an Electric Vehicle Energy Taskforce to bring together the energy and automotive industries to plan for the increase in demand on energy infrastructure that will result from a rise in the use of electric vehicles

The initiatives will set the stage for the mass uptake of ultra low emission vehicles. The government is also taking powers through the Automated and Electric Vehicles Bill (which received Royal Assent on 19th July 2018) to ensure charge points are easily accessed and used across the UK, available at motorway service areas and large fuel retailers and will be smart ready[1]. The government expects the transition to be led by industry and consumers and a review of the uptake of ultra low emission vehicles will take place in 2025 to consider what interventions are required if not enough progress is being made."

UK Power Networks (UKPN) is launching this report into Smart Charging Architecture in order to support the Government's ambitions, to provide input into industry design and decision processes, and ultimately to support a faster uptake of electric vehicles.

2.2.2 Overview of relevant related projects

There are a large number of recent and ongoing projects in the industry relating to electric vehicles and to smart charging, and in developing the scope of this project we considered how we could help to build on this existing work. The following section provides a brief overview of some of the key projects and industry design/decision processes that we are aware of and seeking to align with, and that have helped to shape our views.

DNO Innovation Projects

There are various innovation projects being carried out by DNOs in the UK looking into smart charging approaches – including Electric Nation (WPD), My Electric Avenue (SSEN), Low Cost Monitoring (SSEN), V2G (NPG), Recharge the Future (UKPN), Black Cab Green (UKPN), and LV Engine (SPEN).

The most relevant projects for this work are WPD's Electric Nation and SSEN's My Electric Avenue, which are briefly described in Section 2.3.1 below. These two projects have developed important insights into consumer behaviour and the technologies required to monitor the network and identify emerging constraints. To do this they have focussed on a specific scenario for smart charging in which the DNO limits EV charging at times to protect the network from overload.

This scenario is one of a broader set of possible approaches to smart charging, and so our SmartCAR project aims to build on this work by investigating the full range of potential approaches, including approaches in which market participants play a more active role in coordinating charging with respect to network and wider electricity system conditions.

Smart EV Project (2016 / 2018)

The Smart EV project is funded by SSEN through it***s*** Network Innovation Allowance, and delivered by EA Technology. It has carried out two rounds of consultation – one in 2016/17, and one in 2018 which published outputs in August 2018.

The first consultation focussed on managed EV charging, and sought input regarding whether managed charging was acceptable, what situations and safeguards would be acceptable, what level of choice and reward customers should experience, and views as to the technical approach. This initial consultation concluded that there was strong consensus for coordinating charging, but that there was a divergence of views as to how this should be achieved. This was the first time this question had been investigated in detail, and set the context for much of the debate that has followed. In particular, it set the scene for the debate regarding whether the DNO should have a role in managing charging, or whether this should be left to the market to deliver as part of a wider customer proposition.

The second consultation focussed on technical solutions for both an "interim solution" for managing charging (which is based on the DNO-led managed charging scenario) and a longer-term option of using smart meters to control charging. The outputs of the consultation have revealed that opinion is still divided as to how appropriate a DNO-led solution would be, though with recognition that it would be preferable to outages, and would be a robust solution that would be available

[1] The government will be further defining "smart ready" through secondary legislation following the Automated and Electric Vehicles Bill

in the required timeframes. Only 53% felt that the solution would be appropriate, with the rest either against or undecided, and a majority thought that any use of such a solution should be optional for the customer, subject to safeguards and compensated.

The SmartCAR project aims to build on the progress made through these consultations by investigating the broader strategic context for smart charging approaches, and by setting out the DNO capabilities that would be required to support the broader set of scenarios, including market-led options.

Energy UK Consultation on Smart Charging Equipment Standards

Energy UK published a paper in March 2018 setting out its members' views on the desired principles for smart charging, including the use of any DNO-operated managed charging solution and enabling the market for customer-focussed smart charging propositions. It sets out the required capabilities of smart charging equipment at a high-level. Energy UK has requested feedback on this, and is in the process of collecting and reviewing responses ahead of publishing its update.

UK Power Networks has responded to this consultation, and engaged with Energy UK in the development of our strategy, and we believe our approach is consistent with Energy UK's position. Our work builds on this by investigating the DNO capabilities required to support the market-side propositions for smart charging.

The Automated & Electric Vehicles Bill

The Automated & Electric Vehicles Bill passed through Parliament this year and received Royal Assent on 19^{th} July 2018. The bill makes provisions in relation to requirements and prohibitions for public charging points, information and data requirements, and smart charge points. This bill does not prescribe specific requirements and standards, but sets the framework for regulations to be developed and set via secondary legislation. Our work will help to provide input and evidence into the process of development of secondary legislation.

The Electric Vehicle Energy Taskforce

The Office for Low Emission Vehicles (OLEV), the Energy Systems Catapult and the Low Carbon Vehicle Partnership (LowCVP) have recently launched a new 'Electric Vehicle Energy Taskforce', in order to engage stakeholders in defining an approach to delivering the Government's Road to Zero strategy, and in particular how we might deal with a rapid uptake of electric vehicles. This group will inform the government's definition of secondary legislation for smart charging.

The group is in the process of forming and defining its work programme and it is likely that smart charging will form a core part of its remit and scope. UK Power Networks has attended one of the scoping sessions, and intends to support this process as a vehicle for coordinating industry debate and agreement regarding a national smart charging approach.

Mayor of London's EV infrastructure taskforce

The Mayor of London, Sadiq Khan, has created a new 'taskforce' to help increase infrastructure for electric vehicles in London, bringing together representatives from businesses, the energy industry, infrastructure firms, government and London boroughs. The taskforce has recently formed, and will publish recommendations and a delivery plan in 2019 regarding how, when and where to increase London's electric vehicle infrastructure up until 2025.

UK Power Networks has a key interest in this process, given that the initiative will impact one of our DNOs. We have attended initial launch and scoping events, and will continue to support the process going forward.

Energy Technologies Institute – Consumers, Vehicles and Energy Integration (CVEI) Project

This project aims to understand the required changes to existing infrastructure, as well as consumer response to a wider introduction of plug-in hybrid and electric vehicles in the UK. The first stage focussed on detailed analysis and design of market, policy and regulatory frameworks, business models and customer offerings, electricity and liquid fuel infrastructure and technologies throughout the energy system as well as at charging and refuelling points and on-vehicle. The second stage, is currently delivering a trial involving approximately 250 mass-market users to validate the impact of solutions identified in stage one and understand consumer and fleet responses to the vehicles and to managed charging.

With regards to smart charging, the initial analysis concluded that under modest levels of consumer response smart charging could lead to a sizeable reduction in costs compared to unmanaged charging, and put forward recommendations regarding the market frameworks and infrastructure that would need to be in place to facilitate this. Our work has drawn on this initial report, and looks in greater detail at the specific topic of smart charging to add detail to the findings. In addition, we focus on the implications for DNOs, and the services they will need to provide to enable the market.

Ofgem's Network Access & Forward-Looking Charges Review

Ofgem are currently engaged in a review of network access and forward-looking charges. This review is a response to the transformation of how we use the electricity networks, and in particular the potential for electrification of heat and transport to increase peak demands on the system, leading to constraints in some areas.

There is a risk that limits on network capacity could hinder the ability for the system to accommodate new low carbon technologies and changing usage patterns. Whilst traditional solutions to this would involve network reinforcement, the emergence of smart technologies and innovative business models offer opportunities to adjust demand and supply at times and places where there are constraints, to defer or reduce the network reinforcement which might be needed.

These trends and drivers mean that it is increasingly important that network capacity is allocated and used in a way which reduces the potential costs to consumers as a whole. To support this aim, it is important that users are provided with appropriate signals about the costs and benefits they confer on the network at a given time and place is a priority area, and the current access and charging arrangements do not provide these signals. This review therefore focusses on options to define more explicitly arrangements for access to the networks, and to improve the "forward-looking" elements of network charging – i.e. the element of network charges that looks to provide signals to users about how their behaviours can increase or reduce future costs on the network.

These reforms may have a significant impact on smart charging, and have the potential to provide industry-wide pricing signals that equitably recoup the costs of the network from the customers generating those costs, and therefore provide incentives for efficient network use. At present, the outcomes and timescales of the review are uncertain, although it is expected that implementation of reforms are unlikely ahead of the RIIO-ED2 price control period, starting in 2023.

We have attempted to take on board the direction of travel of this work, and in particular expect that the outcome will look to address the time-of-use and locational granularity of the current DUoS charging regime. We therefore assume a potential planning milestone of a reform to DUoS to be implemented by 2023, and examine the need for alternative solutions in the interim, as well as provisions for solutions if this reform does not go as far as expected in the timescale.

We intend for the insight generated through this report to provide input and evidence to Ofgem in the course of their review. In addition, as set out in Section 6.2 we are proposing a new trial looking at the impact of flexibility procurement at LV levels of the network, to provide incentives to market participants and consumers to engage in smart charging, and intend for this project to provide further input and evidence to support the review.

Ofgem's Future Insights Paper 5 – Implications of the transition to electric vehicles

Ofgem recently released an insights paper outlining their research into the challenges and opportunities associated with the electric vehicle transition. In this paper they provide evidence for the case for "flexible charging", in which smart systems communicate wth the wider system to understand the optimal times to charge – e.g. when there is an excess of generation on the system, or in order to alleviate network constraints by shifting charging to to time when there is excess capacity. Ofgem's findings in this paper have been considered in the course of this research, and we believe our findings are in line with, as support, their recommendations.

2.3 Electric vehicle uptake and the case for smart charging

The Office for Low Emission Vehicles (OLEV) has estimated a range of between 2.5m to 10m EVs to be on the road by 2030, and UKPN estimates a range of 1.9m to 4.1m will be connected to our network in this timeframe.

A number of projects have been carried out to understand the impact of EV uptake on the networks. UKPN's Low Carbon London project demonstrated that unmanaged EV charging aligns with the peak domestic demand. Scottish & Southern

Electricity Network's (SSEN's) My Electric Avenue project estimated that approximately one third of low voltage networks could need upgrading when 40-70% of customers have an electric vehicle, which may happen as soon as 2030. Aside from the expense, this also implies a good deal of disruption in digging up roads to reinforce the network, and may lead to delays in the connection of charge points – potentially impacting the speed of EV uptake.

One way to mitigate the impact of EVs on the network, reducing the need for reinforcement and associated costs and delays, is to coordinate charging sessions in order to reduce the overall peaks in demand – in other words, for customers to take it in turns to charge their cars. Most customers do not need their car 100% charged for typical week day use, and so long as their car is sufficiently charged when they need it, could be flexible regarding what time charging takes place. However, at present there are no incentives on EV owners to mitigate their impact on the network, as for the majority of customers the current network charging regime does not vary with time of use, and no technical solution in place.

Coordinating charging has the potential to deliver significant benefits for customers. SSEN's My Electric Avenue project estimated that coordinating charging could save around £2.2bn to UK customers out to 2050 based on deferred network reinforcement costs. In section 5, we set out our estimates of the benefits of avoided reinforcement in UKPN's own areas.

2.3.1 "Smart" vs. "managed" charging

The potential for this coordination of charging has become known as "smart charging" or "managed charging" – with an important distinction between the two terms.

SSEN's My Electric Avenue project and WPD's Electric Nation project have both shown that customers are open to changing their charging patterns when required, so long as their mobility requirements are met. To deliver these trials the DNOs installed control assets at the point of charging, and occasionally administered a pause to customers' charging sessions in response to network needs, balancing customer requirements. This has become known as "managed charging" – i.e. where the DNO has the ability to take unilateral action and curtail a charging session. This approach is consistent with a number of international projects, set out in section 3.3.1International case studies. Neither DNO proposes their "managed charging" arrangement as a long-term solution, but rather as a means to conduct consumer trials, and as an "interim" approach to help facilitate EV uptake ahead of wider industry design of an enduring approach.

Some industry participants in the UK have expressed concerns with the DNO assuming monopoly control of residential EV battery flexibility, highlighting that this may impact the customer experience, stifle competition, and restrict the ability to utilise the flexibility elsewhere on the system. An alternative vision – "smart charging" – includes the possibility for market actors to offer innovative services to EV owners, taking control of their charging patterns and working out when it is cheapest for them to charge their cars, with respect to local network conditions and wholesale market prices, and in some cases potentially offering balancing services back to the grid to generate more value for the consumer.

The European Committee for Standardisation (CEN) and the European Committee for Electrotechnical Standardisation (CENELEC) defined Smart Charging as "the charging of an EV controlled by bidirectional communication between two or more actors to optimise all customer requirements, as well as grid management and energy production including renewables with respect to system limitations, reliability, security and safety."[2]

In this report we will consider Smart Charging in this broadest sense, with "managed charging" (i.e. a DNO-only solution) considered as a sub-set of the possible ways to coordinate charging.

[2] ftp://ftp.cen.eu/EN/EuropeanStandardization/HotTopics/ElectricVehicles/SmartChargingReport.pdf

2.4 The scope and objectives of the SmartCAR project

2.4.1 Scope

At present, there is little understanding and interaction between DNOs and EV stakeholders on the solution architecture needed to support mass management of EV charging (Smart Charging). Consequently, DNOs do not fully understand the capabilities they need to establish to facilitate this crucial aspect of the Government's decarbonisation plan.

If DNOs are not able to plan the solution investments that enable Smart Charging, this could lead to customers having to wait to connect EV charging points until reinforcement is undertaken, frustrating the Government's policy objectives. Therefore, in order for DNOs to be able to continue delivering great customer service and providing timely charge point connections (in timescales aligned to customer and regulatory expectations), and if they are to enable rapid EV uptake whilst avoiding costly reinforcement where possible, then they must understand how best to plan for and deliver Smart Charging and flexible connection propositions.

This project therefore focussed on defining the architecture required (such as technology, assets, information flows, standards, business functions and commercial arrangements) to facilitate Smart Charging for residential customers, and helping DNOs to understand what they need to provide to enable the market. To do this, the project identified a range of possible industry approaches for Smart Charging, in order to understand the architecture requirements needed to support each of those approaches. This review covered the broad spectrum of options, including for example time of use tariffs, DNO/aggregator controlled charging points, and capacity management using market based solutions. By determining an architecture that details the full Smart Charging landscape, this project builds upon the findings of existing projects that have focussed on specific Smart Charging solutions, such as the link between charge points and substations.

2.4.2 Objectives

The objectives of the project when initiated were to:

1) Identify the range of smart charging approaches which could be used (building on international experience);
2) Establish and work with a Stakeholder Group to identify the most relevant EV charging approaches for the UK;
3) Develop our strategy for residential smart charging;
4) Define the core solution architecture required to support the majority of relevant EV charging approaches;
5) Investigate the cost/benefit case for smart charging and determine the value of EV flexibility; and
6) Develop a roadmap that describes how to deliver the core architecture needed under all planning scenarios.

3 Our smart charging strategy

3.1 Our approach to defining our smart charging strategy

To enable an investigation into the required functional and systems architecture to support Smart Charging, we first needed to define UK Power Network's strategy for Smart Charging. To inform this strategy we carried out an investigation into Smart Charging approaches, and engaged a range of industry stakeholders to seek their views.

Where other research into Smart Charging in the UK has focussed on a specific approach to Smart Charging or on developing a specific technology application, in this research we have tried to look more broadly at the full range of potential approaches, in order to understand the various options and reach a rationale for why any given approach may or may not be appropriate for the UK.

Our initial investigation focussed on identifying a range of Smart Charging industry models (i.e. industry-wide approaches to coordinating Smart Charging between parties) that might be possible in the UK. This was done by:

- Investigating international case studies to understand the leading models being trialled and implemented;
- Defining a set of "Design Principles" for the UK, articulating the requirements of Smart Charging in the UK;
- Defining a framework of options drawn from the case studies that characterise Smart Charging models;
- Forming a view of which models would and would not be suitable in view of the Design Principles; and,
- Testing the assessment and draft conclusions with stakeholders.

In this assessment, we are not trying to select a single recommended model for Smart Charging for the UK, but rather set out a range of potential models which may all be viable approaches for the UK. From this range of models, we then draw out conclusions regarding the key enablers that we believe will be required to support the evolution of Smart Charging, and set out our resulting strategy.

From this range of models, in subsequent sections we then set out the functional and systems architecture elements that are common across all scenarios, in order to identify capabilities which can be invested in with reasonable certainty that they will be relevant whatever credible Smart Charging models emerge, and a roadmap for development and delivery of those capabilities.

3.2 Stakeholder engagement

To assist in shaping our research and our strategy we engaged a variety of stakeholders across the industry. This engagement was not intended as a formal consultation, but rather as a means to testing our thinking across a range of relevant stakeholders to seek challenge from different industry viewpoints. This engagement took the form of a series of one-to-one meetings to gain input into our emerging research, and a group workshop to review our initial conclusions.

The stakeholder group we engaged with included the following representatives:

- Charge point operators (CPOs) – pod-point, Chargepoint, and ChargeMaster
- Energy suppliers – OVO and Octopus Energy
- Car manufacturers – Ford and Nissan
- Industry bodies – OLEV, BEAMA, Energy UK and the SMMT
- Academia – Imperial College
- Networks – National Grid, SSE and WPD

The feedback received from participants throughout this work has been immensely valuable, and has helped to shape our focus and direction to ensure the findings are acceptable to as wide a range of stakeholders as possible.

It should be highlighted that – whilst we may have expected to find some considerable divergence of views across stakeholders – we found a good deal of alignment. We believe there is a perception of some conflicts of opinion, driven by the "managed" vs. "smart" charging debate as highlighted in Section 2.3.1, but that this is largely resulting from stakeholders "playing their role" in feeding in to this debate. In general, all stakeholders all support a similar approach to Smart Charging, in which customers and/or service providers coordinate charging (and discharging) of EV batteries in response to local network price signals, as well as wholesale market and balancing services opportunities. There is uncertainty regarding the level of "emergency control" that the DNO may need, and how long it may take to establish market price signals, and we investigate this through the research set out in this report.

We do not set out a separate section here to detail the input received, but instead refer to stakeholder feedback throughout the document in order to highlight where views have helped to shape our findings and strategy. Fuller details of the stakeholder inputs can be found in Appendix B.

3.3 Investigation into smart charging approaches

3.3.1 International case studies

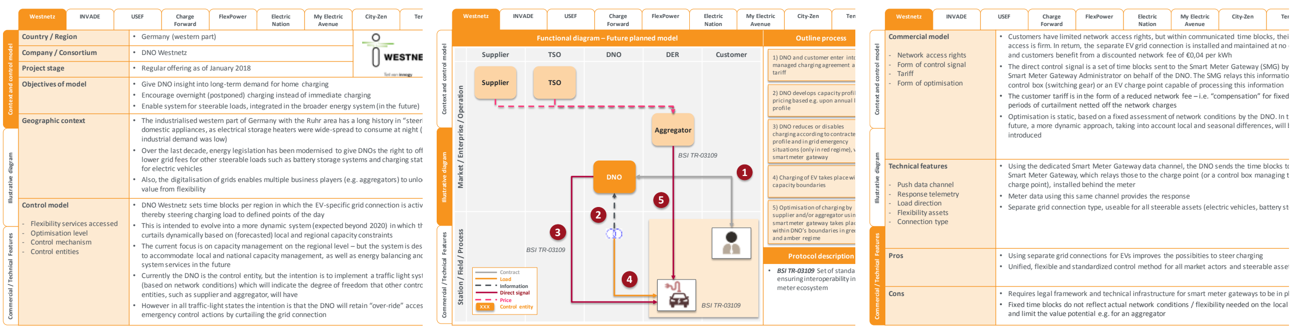
Case studies investigated

Our review of international case studies focussed on gathering insight into trials around the world in order to understand what others are doing, and what can be learned. Research was conducted utilising publicly available data, as well as input in some cases from subject matter experts who had specific experience of the trials involved.

The range of case studies were selected in order to understand specific differences in the approaches, including simple DNO-facilitated trials (including the main UK-based trials) as well as more complex approaches involving e.g. aggregators, connected cars, forward flexibility markets and provision of system services.

Content of the case studies

Figure 4 below provides an example of the outputs created as part of the case studies, the full detail of which is presented in Appendix A: International case studies.



Context and a description of the "control model"… **…an illustrative diagram of who's doing what, and…** **…a description of the commercial and technical features, plus pro's and con's.**

Figure 4: Example case study output

Table 1 below sets out headlines from each case study in order to provide the reader with an overview of these models.

#	Project	Country	Description
1	Westnetz	Germany	***Dedicated timed grid connection for controllable loads, such as EV*** • The DNO sets time blocks per region in which a customer's EV-specific connection is active, enacted via the Smart Meter gateway, steering charging load to defined points of the day • This is intended to evolve into a more dynamic system (expected beyond 2020) in which the DNO curtails dynamically based on (forecasted) local and regional capacity constraints • Currently the DNO controls access based on local network needs, but the intention is to implement a traffic light system (based on network conditions) which will indicate the degree of freedom that other entities, such as suppliers and aggregators, will have
2	INVADE	Norway	***Aggregator optimizes home based on DNO price publication*** • Home-optimisation using EV, home battery and other DER • The aggregator controls a local controller in the customers' home, optimising consumption or feed-in to the grid, based on flexible supplier/wholesale energy tariffs, and a peak DNO tariff • The DNO is able to control network access in the pilot based on capacity publication to the aggregator. In the near future, it is intended to limit this to price publication only.
3	USEF	NL / Utrecht	***Aggregator offers flexibility to DNO with flexible pricing*** • The DNO Stedin, as well as the aggregator, perform a daily forecast on the load within a local area (substation / feeder), and based on this, the DNO may procure flexibility from the aggregator, to shift load and reduce / prevent grid congestion • The aggregator also optimises against ToU wholesale supply prices and TSO services • The DNO has ultimate control within a 'red regime', when the bid/offer mechanism failed and/or demand is higher than forecasted – For this, curtailment options have been contracted.
4	Charge Forward	US / California	***Aggregator offers flexibility to vertically integrated utility*** • PG&E (in the role of TSO and DNO) asks BMW (acting as an aggregator) to lower demand in response to network congestion – currently at the regional level • BMW controls a fleet of electric cars (with customers opted-in), for which an algorithm decides which cars to reduce power or postpone charging (by up to one hour), with an opt-out option for the customers for any given session • The cars themselves can be in any location, with telemetry to the car itself. If it is plugged in to a public charge point, it can be used in the response. • The trial is accessing TSO congestion management services and enabling self-balancing portfolio optimisation for the balance responsible party
5	FlexPower	NL / Amsterdam	***Flexible power profile provided by DNO applied by Charge Point Operator*** • The DNO sends a neighbourhood-specific profile of time blocks, with additional and reduced capacity to the charge point management system operated by the CPO (Charge Point Operator), • The CPO sets this profile as maximum capacity at the charge points in the area (i.e. there is no dynamic capacity allocation between charge points based on occupancy) via its own systems • Local level optimisation for network capacity only
6	Electric Nation	UK / WPD	***Flexible power profile provided by DNO applied by Charge Point Operator*** • Local optimisation of 700 EVs in clusters

			• Constraint management applied via a capacity profile, adjusting the rate of charging, rather than just via a binary on/off curtailment • Capacity profile controlled by the DNO, via a customer-owned smart charger
7	**My Electric Avenue**	**UK / SSEN**	***Temporary curtailment of recharging with direct substation/charge point communication*** • Local optimisation of 100 EVs in clusters • Network constraint management only, managed by switching off the power to the charge point for 15 minutes at a time • Controlled by the DNO via 'Direct Line Communication' between the substation and the charge points
8	**City-ZEN**	**NL / Amsterdam**	***Aggregator handles bidirectional charging within dynamic capacity profile of DNO*** • Dense inner-city district means limited options to increase grid connection or LV capacity in the short term. Trial focusses on technical experiments into grid congestion management, V2G, and use of locally produced solar energy • The aggregator optimises the charging/discharging based on available grid connection capacity, capacity at substation as provided by DNO and the solar power forecast; as well as wholesale and system services markets • The aggregator directly controls a small number of charge points
9	**TenneT**	**Germany & NL**	***TSO ancillary services provided by home batteries and EVs with response stored in blockchain*** • Trial focusses on the possibilities of accessing TSO ancillary services provided by home batteries and electric vehicles with response stored in the blockchain • Regional and national optimisation takes place, with the aggregators providing flexibility response dynamically to the TSO in response to signals calling off pre-contracted response • Both the availability of an asset as well as the response are stored in the blockchain

Table 1: List of international case studies investigated

Key findings from the case studies

Figure 5 below illustrates these case studies on a spectrum of "DNO influence" vs. the "complexity of the model" in terms of services accessed and entities involved.

Most of the case study models are trials at an early stage, typically with the aim of investigating and enabling:

- The ability of managed charging to offset peak loads, enable connections, and mitigate reinforcement;
- The effectiveness of demand response via aggregators/ customers to manage grid constraints; and,
- The design of commercial mechanisms and technical solutions to support managed charging.

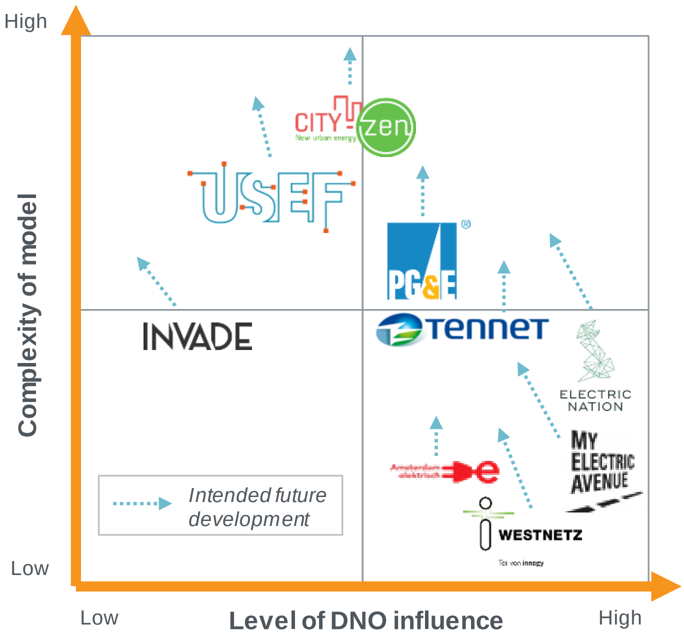


Figure 5: Overview of case studies

There are a variety of approaches being tested, and looking across the case studies has provided valuable learning into different aspects of Smart Charging, and has helped to shape our thinking. However, whilst most trials are aiming to develop into more complex iterations, at present no particular instance can yet be seen as the mature model to be followed, and so our thinking will need to look beyond the case studies.

Across the case studies we see a variety of different entities managing the EV charging process, and optimising across system needs – DNOs, aggregators and to some extent OEMs ('original equipment manufacturers', such as car manufacturers) and the customers themselves. Some of these models lead to a lower level of direct control of the network for the DNO, but still with indirect access to customer demand response, and with the onus on other parties to manage grid constraints.

The general picture is of trials beginning with models in which the DNO controls network access, driving toward models in which market actors take a greater role in managing grid constraints in response to price signals. In addition, some early-stage trials are beginning to explore intelligent and connected vehicles, home energy management systems (HEMS), Vehicle-to-grid technologies, and blockchain-enabled solutions, which will need to be considered when setting out our planning scenario for the UK.

3.3.2 'Design Principles' for the UK

In order to define suitable approaches for the UK we first set out a series of "Design Principles" to test with stakeholders. These principles are intended to capture what is important for the UK, and were defined with reference to wider industry design work such as Ofgem's Smart Systems & Flexibility Plan, the Network Access & Forward Looking Charges review, the ENA's Open Networks programme, and the various papers and consultations looking specifically into the definition of Smart Charging approaches.

The purpose of the Design Principles is not to try to determine which possible model satisfies them "the best", but rather to inform a validation of model options, and help draw out the rationale for viable options, and for those options that we deem not viable. All options that satisfy the Design Principles could then be seen as viable models for the UK.

Following stakeholder engagement, our Design Principles for residential smart charging are that any approach should:

1. Deliver consumer requirements in terms of access to mobility, value for money and choice
2. Ensure network access is not a barrier to electric vehicle uptake
3. Allow DNOs to maintain the operational integrity and safety of the networks, acting in a transparent and non-discriminatory manner
4. Minimise the risk of regret investment in DNO assets
5. Be consistent with the DNO's risk profile (financial, technical, reputational, cyber security)
6. Protect customer privacy
7. Ensure that the flexibility value of EV batteries can be realised where it is most valued to the customer

8. Enable competition between different business models and technologies (through interoperability)
9. Be equitable for all network users (including non-EV adopters and other forms of DER)
10. Be compatible with upcoming regulatory led change to network access and charging, and the DSO transition

Stakeholder feedback on the Design Principles

In the next paragraphs we summarise some of the key points of feedback from stakeholders on the Design Principles. The full feedback is set out in Appendix B.

"This set of principles is reflective of what we'd like to see"

Stakeholders agreed with the Design Principles put forward; none were requested to be removed, and no entirely new topics were put forward – though the principles generated good discussion and several enhancements were made. Generally they were felt to be in line with the direction of travel of the industry debate, with a good balance between the needs of the customer, the market, and the DNO.

Several stakeholders specifically commented that it was right to start with the principle on customer needs. "Customer choice" was seen as key, with any Smart Charging or emergency response approach needing to be understood and accepted by the customer.

There is general agreement that DNOs will need to be able to protect the network, though differing views as to how this should be implemented. Stakeholders appreciate that the network must be safe, and are aware that loss of supply is a customer experience risk. One stakeholder raised a clarification that any action by the DNO to protect the network where markets had failed would be seen as valid so long as the DNO acted in a transparent and non-discriminatory manner, leading to an amendment to Principle 3.

Some stakeholders raised a concern that in this fast-moving space, the future is uncertain and requires innovation, which involves risk. It is possible therefore that if it is incumbent on the DNO to drive innovation in some areas, and they are too risk averse, then they may become a blocker to progress. We understand that concern, and we will continue to support enhancements to the regulatory framework that reward DNOs for facilitating the uptake of EVs, and encourage them to promote market-based solutions.

Several stakeholders highlighted the need for interoperability to enable competition and switching, though some clarifications were raised – specifically in relation to charge points. Whilst there was appreciation that suppliers should be able to interact with any Charge Point Operator (CPO) to enable customers to switch, a caution was raised that it did not necessarily follow that the charge point assets should be interoperable between CPOs. This was raised on the basis that the CPO proposition is comprised of more than just the asset, and that interoperability would require each CPO to technically support a wide range of assets. Mandating interoperability of the charge points may therefore stifle innovation and erode the quality of the customer propositions available in the market.

Most stakeholders agreed that the solution should be equitable, with some specifically highlighting that the principles should apply not just to EVs but all types of load and Distributed Energy Resource (DER), leading to an expansion of the principle. This principle has arisen from the observation that the current network access and charging regime does not distribute the costs of the network fairly across EV users and non-EV users. In the short-term, EV users may be paid incentives to shift charging times in order to avert costly reinforcement, leading to a situation in which EV users would in fact be putting more strain on the network, and yet be paying proportionally less than non-EV users. We see a risk of an unfair distribution of costs, particularly in the near-term, and so propose this principle as a key aim to deliver in any Smart Charging approach.

Stakeholders are aware of Ofgem's Network Access & Forward Looking Charges review and highlight the difficulties in progressing the approach to Smart Charging ahead of clarity on the direction of travel of this work. However, there is general agreement that progress must be made, given that it may be several years before the review is completed and/or implemented. Some stakeholders raised the importance of also aligning with the direction of travel of the DSO transition, leading to an adjustment to Principle 10.

3.3.3 Factors that make up a Smart Charging approach

Drawing on the case study research, we defined a framework of factors and options that characterise the smart charging approaches observed. The purpose of this exercise is to attempt to capture the broad and general scope of potential options, in order to set any particular approach into the full strategic context.

These factors fall into three broad categories:

- **"Control model" factors** – which characterise the physical aspects of what the models are setting out to achieve in relation to the system, such as the services accessed, the level (local/regional/national) of system optimisation, the entity who is controlling the charging session and the means for enacting that control;
- **"Commercial model" factors** – which characterise the commercial approach that underpins the various control model variants, covering aspects such as network access rights, the "firmness" of the control signal, the form of tariffs, mode of settlement and degree of real-time optimisation taking place; and,
- **"Technical features"** – which encompass the various technical approaches that are observed to implement any given control model / commercial model, covering aspects such as the type of network connection involved, the data channels used for control and response signals, and the type of DER in scope

Figure 6: Smart charging models framework below sets out the factors as well as a set of options for each factor. Many of these options have been observed across the case studies, and indeed all of the case studies can be plotted on the framework. However, we have also added additional options that have not yet been observed, which are nevertheless feasible.

We have defined this framework in order to identify the range of considerations that need to be taken into account in determining an approach to Smart Charging, to aid the debate. Whilst this framework does not necessarily capture every possible nuance in potential approaches, it has served to ensure completeness of our thinking.

Control model	Primary system driver	Network capacity	System services	Wholesale energy	
	Optimisation level	Local	Regional	National	
	Control mechanism	Network connection	Asset		
	Control entity	DSO	TSO	3rd Party	Customer
	Primary control signal	Direct control	Contracted services	Price signals	
Commercial model	Network access rights	Non-firm	Hybrid	Firm	
	Tariff	Flat (access based)	Rising block	Static ToU	Dynamic ToU
	Settlement	Existing	Local/Regional	Central	Distributed ledger
	Form of influence	Real-time	Ex-ante		
Technical features	Push data channel	Specific channel	Generic internet	Secure network	
	Response telemetry	Specific channel	Meter data	LV telemetry	
	Power flow direction	Load only	Bidirectional (V2G)		
	DER Scope	EV only	All distributed energy		
	Connection type	General connection	Dedicated CP connection		

Figure 6: Smart charging models framework

Definition of factors and options

The factors and options illustrated in Figure 6 above are described below:

- **Control model factors**
  - **Primary system driver** – whether the main driver for smart charging is the availability of network capacity, offering system services (e.g. fast frequency response) or price differentials in the wholesale market
  - **Optimisation level** – whether system optimisation in relation to EVs is taking place at the local LV level only, regional DNO level, or includes elements of national optimisation for the TSO or wider wholesale market
  - **Control mechanism** – whether load is managed by restricting network access/curtailing the connection, or by directly controlling the asset to modulate its charge rate
  - **Control entity** – whether the EV charging intervention is ultimately controlled by the DNO, the TSO, a 3rd party, or the customer themselves. (Note that given a number of commercial entities may wish to take on e.g. aggregator or supplier roles – e.g. BMW in the PG&E case study – we do not make exhaustive reference to various business types here, but refer generally to "3rd Parties").
  - **Primary control signal** – whether the control signal to elicit an EV charging response is a direct signal, a price signal to incentivise a response, or a contracted service (e.g. under a bid/offer price acceptance)
- **Commercial model factors**
  - **Network access rights** – whether a customer has firm network access rights, non-firm access rights or a hybrid model in which access is firm under some conditions and non-firm under others
  - **Tariff** – whether the customer is exposed to a Flat access-based tariff, or to a Static ToU, Dynamic ToU, or Rising Block tariff
  - **Settlement** – whether no additional settlement is required to support the model, whether it is integrated into central settlements, whether bespoke local/regional platforms are used, or a Blockchain distributed ledger type approach is adopted
  - **Form of influence** – whether the optimisation is performed ex-ante (e.g. at the day-ahead stage against fixed forward signals) or in real-time (e.g. in response to dynamic signals representing current system conditions)
- **Technical features**
  - **Push data channel** – whether the data channel sending signals to the EV is a specific channel (e.g. PLC), via generic internet connection, or via a dedicated secure network such as the DCC
  - **Response telemetry** – whether the confirmation of EV response is transmitted via a specific channel, via meter data, or via LV telemetry at the substation
  - **Power flow direction** – whether the power flow direction is charging load only, or includes V2G
  - **DER Scope** – whether the scope of flexibility assets in question are just EVs, or include wider DER
  - **Connection type** – whether the connection to the EV is simply the general connection only, or a dedicated charge point connection

In general, stakeholders who were familiar with the different facets of Smart Charging were engaged in the framework, and felt that we had identified the majority of the relevant factors. No significant change to the factors and options were put forward; there was general agreement with all options on the list, none were flagged as impossible, and few new concepts were raised. Additional feedback is set out below and in Appendix B.

"This is really useful! You've captured a lot of concepts here"

Control model factors

- **Stakeholder feedback** – All primary system drivers were seen as viable, with one stakeholder commenting that perhaps the customer should also be mentioned as an option against this factor. Several raised the point that there were concerns as to whether the DNO or TSO should have any role in residential Smart Charging – which we return to at several points in this report. All stakeholders agreed that various types of entity/business may seek to take up a role in Smart Charging as a control entity. All stakeholders would prefer to see price signals used as the primary control signal, rather than direct control, though there was some divergence as to the feasibility of this. Several mentioned that thinking about the "control model" factors first was important, and cautioned that some parties may be pushing ahead with technical solutions, without first having a rationale within a holistic picture of what we are trying to achieve.
- **Initial conclusions** – The control model factors, relating to physically what we are trying to achieve on the system, appear to be the primary drivers that should determine the smart charging approach, with commercial model factors defined to support the control model. Following stakeholder engagement we believe that all system drivers should be included for consideration, as should all levels of system operation, as we have seen in the case studies. In addition we believe that there are no clear reasons at this stage to exclude either of the control mechanisms, as they have each been observed in current case studies. However, several stakeholders suggested that the National Electricity System Operator (ESO) acting as control entity of residential EVs would not be appropriate. Whilst the ESO may at some stage wish to access the flexibility of residential EV batteries, this service would perhaps be more appropriate via an aggregator. For this reason ESO-led models have been excluded from consideration.

Commercial model factors

- **Stakeholder feedback** – Some stakeholders suggested that it would be appropriate to ensure compensation for customers if they are curtailed (i.e. firm access rights). This was on the basis that it would help to make the new arrangements acceptable to customers, and avoid a negative reaction in the short term. Most stakeholders believe that a time-of-use tariff (ToU) is critical to make Smart Charging work. However, there are varying views as to what form that should take (e.g. static DUoS, dynamic DUoS, rising-block tariffs, etc.) and most stakeholders felt that this would need careful consideration and potentially some trials to determine. Some concerns were raised that static ToU tariffs might lead to secondary peaks, with aggregator algorithms shifting large numbers of customers from the current evening peak and creating a new peak at a different time. Two stakeholders suggested that Blockchain settlement and P2P trading were seen as the ultimate end goal for local Smart Charging (and wider Smartgrid coordination), but was seen as years away from being possible.
- **Initial conclusions** – Through consideration of these options, and consultation with stakeholders, it is clear that there are no obvious answers to the design of the commercial model for Smart Charging. In addition, much is linked to the outcome of Ofgem's Network Access & Forward-Looking Charges review. As such, at this stage we do not believe any of the options can be ignored, and all should be taken forward for consideration.

Technical features

- **Stakeholder feedback** – Two stakeholders saw the SMETS2[3] smart meter roll-out as a necessary enabler of market business models for Smart Charging, in order to allow for validated settlement of wholesale (and potentially distribution level) ToU tariffs, and also potentially as the 'push' data channel, as per the Smart EV Project consultation. As a result, a DNO interim solution was seen as required ahead of the Smart Meter roll-out. Not all stakeholders were of this view, and believed that other Smart technologies are able to provide

[3] Smart Meter Equipment Technical Specification 2 (SMETS2) smart meters (as opposed to SMETS1) are the "second generation" of smart meters, which integrate with the DCC (Data Communications Company, central industry architecture), therefore allowing consumer switching without the need for meter replacement. Rollout of SMETS2 meters started in 2018 and is expected to be at scale by early 2019.

adequate and secure metering and control channels. One stakeholder commented that focus should be on bi-directional load, rather than load only, as technology is moving in that direction.

- **Initial conclusions** – The technical features are largely independent of the overall Smart Charging model design, and there are various ways to implement any given Smart Charging approach. As such, we will not focus on the technical features as drivers of the strategic model options. Some technical elements – such as the power flow direction or the DER scope – may be areas that the industry would want to incorporate, though doing so would not drastically change the fundamentals of the approach to the control model and commercial model factors.

3.3.4 Products accessed via smart charging

In our Flexibility Roadmap, which can be found on our FutureSmart web page[4], we set out the flexibility products that we are tendering at EHV and HV level, and our emerging view on the future products that might be required on the LV network. In general, from EVs this will likely involve demand turn-down, demand turn-up, or even export from V2G, in response to network needs such as capacity constraints, voltage management, frequency response, or outage management.

In this report we are not looking in detail at service and product specification, but rather on the mechanisms for accessing services in general. For the CBA we have focussed on the deferral of reinforcement due to peak load growth and subsequent capacity constraints, as we believe this area is the key challenge to overcome in enabling EV uptake. This will largely translate to demand turn-down services, or provision of forward certainty of demand profiles – however detailed product and service design will be addressed in later phases of work.

3.3.5 Strategic assessment of smart charging models

Despite the exclusions we can make from the smart charging models framework, there are still a large number of permutations possible across the factors. As such, our next step in the development of the approach was to define a spectrum of notional models, covering all the factors, setting out the range of possibilities, and enabling stakeholder engagement regarding which would be feasible and appropriate for the UK.

Figure 7 below illustrates this spectrum of models. In this diagram, the X-axis illustrates that the spread of options ranges from “DNO facilitation” through to “Market participation”, with some models that imply a mix of DNO and Market action (for instance, models in which the DNO actively purchases flexibility response from market participants). The Y-axis illustrates a notional “complexity” of the model, with those at the bottom being perhaps simpler to execute, though not necessarily therefore more appropriate.

When reviewing this diagram it is important to note that:

- This is not intended as an exhaustive set of models representing all possible nuances, but is intended to illustrate a spread of the fundamental options drawn from the smart charging models framework, and highlight key exclusion areas.
- These models are not intended to be mutually exclusive, and – as set out in subsequent sections – it is likely that hybrids will emerge, and/or that different models would be applied for different situations.
- The focus of the mechanisms outlined in Figure 7 is the management of **local network capacity**. It assumed that in all models (except for model “D1”) market actors and the customer would have the ability to optimise the charging (and discharging) of the EV battery with respect to the wholesale market and balancing mechanism.
- The abbreviation “DNO” refers to the Distribution Network Operator, and whilst facilitation of such market mechanisms may more accurately be seen as a Distribution System Operator (DSO) role, we have not used this

[4] http://futuresmart.ukpowernetworks.co.uk/

term as it is not yet clear what this role will entail, pending conclusion of the Open Networks project. In addition, the term "ESO" has been used to refer to the National Electricity System Operator run by National Grid.

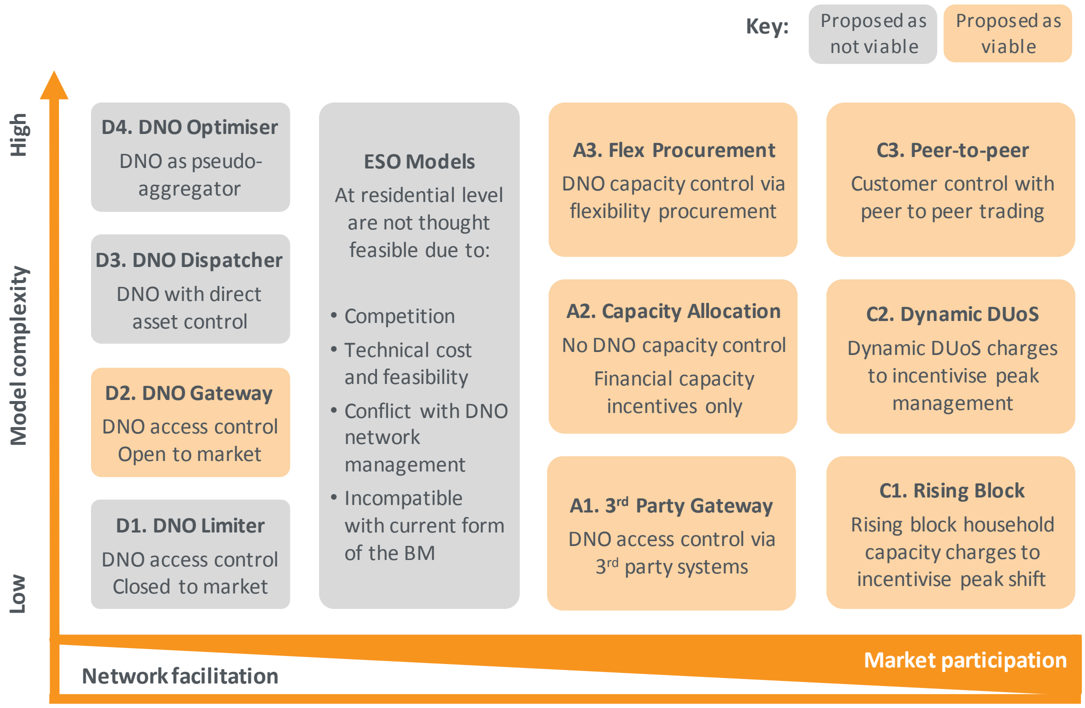


Figure 7: Spectrum of smart charging models

Description of the models

- **D1: DNO Limiter** – The DNO is the primary control agent of network access, with the ability to curtail the network connection in order to manage network capacity. In this scenario, the DNO does so with no coordination with other parties. The customer is likely to pay a flat tariff and have non-firm network access – i.e. not be further compensated for curtailment. The approach trialled in My Electric Avenue is similar to this approach.
- **D2: DNO Gateway** – The DNO is the primary control agent of network access, with the ability to curtail or limit the load at the network connection via the DNOs own systems in order to manage network capacity, potentially with firm access rights and compensation for the customer. Other parties are able to manage charging within the DNO capacity conditions, and optimise across wider markets, including distribution constraint prices via an enhanced DUoS or other incentive mechanism. Examples of this model include the Westnetz case study, whereby customers currently pay a static ToU tariff based on set periods of network access, and the Electric Nation trial. (Note that this model is equivalent to the model used in SSENs My Electric Avenue and WPDs Electric Nation trials).
- **D3: DNO Dispatcher** – The DNO has access to the assets themselves, with the ability to "dispatch down" EVs at times of network congestion. This activity is carried out with reference to network capacity only and does not optimise across wider markets. The customer is likely to pay a flat tariff and have non-firm network access – i.e. will not be further compensated for curtailment. There are no examples of this model in the International case studies.
- **D4: DNO Optimiser** – The DNO acts as a pseudo aggregator and controls flexibility (EV + DER) to manage network constraints, as well as access to additional revenue streams through wholesale arbitrage and, balancing services. The customer is more likely to have firm access where they are compensated for curtailment or benefit from load shifting through a dynamic ToU tariff. There are no examples of this model in the International case studies.

- **ESO Models** – This refers to any given model in which the ESO assumes control of individual residential EVs. No detailed definition has been put into these options, as our initial hypothesis was that these models would not be desirable – as set out in the stakeholder engagement section below.
- **A1: 3rd Party Gateway** – The 3rd party has freedom to optimise assets on behalf of its customers to maximise value in wholesale and balancing services markets, whilst the network connection has capacity, but the DNO can intervene and restrict network access at any moment if necessary, potentially with compensation for the customer. The DNO has access via 3rd party systems to curtail charging unilaterally to protect the network – requiring standardisation and interoperability.
- **A2: Capacity Allocation** – DNO allocates firm capacity rights via a market mechanism (e,g. auctions), and capacity holders are free to optimise assets to maximise value within limits of this allocated capacity right. No direct control is possible for the DNO at times of network stress, but parties are penalised for breaching capacity allocations. If capacity breaches are risking outages the DNO might consider additional measures to protect network integrity.
- **A3: Flexibility Procurement** –Ahead of congestion, the DNO procures flexibility services ex-ante from 3rd parties, similar to the current flexibility tenders on the EHV/HV networks that UKPN is running. The 3rd parties are able to optimise assets across alternative value streams, although it is likely that during the availability windows for the DNO flexibility service exclusivity will be required in order to maintain network integrity.
- **C1: Rising Block** – The customer has firm network access and a rising block tariff, with a core access right and an increased ‘premium’ rate once they exceed this capacity. These premium rates may vary by location, depending on network loading. The customer can optimise EV charging taking into consideration the network charge, energy price and potentially balancing services offered through an aggregator. There is no direct control for the DNO at times of network stress. If capacity breaches are risking outages the DNO might consider additional measures to protect network integrity.
- **C2: Dynamic DUoS** – The customer has firm network access and a dynamic ToU distribution price signal, whereby the rate varies according to live network conditions. The customer can optimise charging taking into consideration these dynamic network charges. There is no direct control for the DNO at times of network stress. If capacity breaches are risking outages the DNO might consider additional measures to protect network integrity.
- **C3: Peer-to-peer** – The evolution of blockchain technology may allow customers to trade energy locally, comparing the wholesale energy price against a local energy price to best meet their charging needs. How this would work is uncertain, though local network capacity would still need to be managed, potentially as per the Rising Block or Dynamic DUoS models above. There may be potential for varying network charges should customers only utilise the local network and not the broader regional or national network – although such considerations are purely speculative and cannot be included in a planning scenario at this stage.

Stakeholder feedback and key conclusions

Stakeholders did not put forward any major additions or amendments to the spectrum of models, and saw it as a comprehensive spread of options. Most agreed with all options as being viable, and with the models marked as unlikely to be viable, though with preferences for different models as outlined below. Many felt that the end state may not be a ‘one-size-fits-all’ solution, and that different models might be more appropriate for different network situations and customer types. It was also recognised that there may need to be an evolution through the models, as the industry tries different approaches, learns and matures. Additional feedback is set out below and in Appendix B.

DNO control entity models (D1-D4)

- **Stakeholder feedback** – All stakeholders agreed that the DNO models proposed as out of scope (i.e. D1, D3 and D4) would most likely not be appropriate, on the grounds that they would stifle competition and market access. Most stakeholders agreed that the D2 model could be a viable option, though many had reservations and a preference against this model. Many stakeholders assumed that the DNOs would require a form of ‘network protection’ action option in some circumstances, and believed that individual instances of curtailment of charging sessions should be quite rare. Some highlighted that a D2 model with a static set of rules or a timed connection would not be able to keep pace with customer behaviour, which is dynamic, and would therefore frustrate customer needs. It was also pointed out that the D2 model would create a bottleneck between sources of flexibility and other markets – such as the wholesale market or balancing services – and would therefore prevent market signals from taking all factors into account and making the optimal decision in a transparent manner, and as such should not be the preferred solution longer term.

- **Our recommendation** – in our view, most potential DNO-led models would not be appropriate for the UK, in view of the Design Principles. Models D1, D3 and D4 do not allow for wider market players to access the asset, inhibiting competition (Principle 8); models D1 and D3 may limit the additional benefits to the customer of accessing the wholesale energy and balancing services markets, which violates Principle 7 (enabling the value of flexibility); finally, all DNO control models would require investment in control technologies for the DNO, potentially leading to regret spend, which is in tension with Principle 3. Model D2 allows for an open market under defined conditions, thus enabling competition but with a level of certainty for the DNO, and is observed in a number of international approaches and the Electric Nation trial. As such we consider D2 to be a viable model, although with concerns regarding investment in DNO control assets.

ESO control entity models

- **Stakeholder feedback** – All stakeholders agreed with the exclusion of models in which the TSO would be the direct control entity, and the rationale set out. However, some stakeholders underlined the importance of close DNO/ESO coordination and highlighted that the ESO may in future wish to procure flexibility from residential customers (likely via aggregators).
- **Our recommendation** – following stakeholder engagement we believe that the ESO acting as control entity of residential EVs would not be appropriate. It would require technical control assets owned by the ESO to be installed at customer properties; would stifle competition; would cause complexities in how to coordinate with DNO network needs. Whilst the ESO may at some stage wish to access the flexibility of residential EV batteries, this service would be more appropriate via an aggregator. For this reason ESO-led models have been excluded from consideration.

3rd party control entity models (A1-A3)

- **Stakeholder feedback** – Many stakeholders saw the 3rd party models as the ultimate goal, with a spread of views across the three options (A1, A2 and A3). Some believed that A2/A3 were the ultimate goal, with no emergency action functionality required for the DNO, and with a general belief that a flexibility market could be designed such that the benefits would outweigh the costs and complexity – though recognising that this is as yet unproven. However, others (including market-side participants) were concerned regarding moving into the A2/A3 models in which there was no form of emergency response functionality for the DNO – i.e. there was an assumption that the DNO would need some form of emergency control, even if enacted via 3rd party systems – and some felt that the complexities and level of engagement required for the A3 model would outweigh the incremental benefits, and potentially put customers off. Several stakeholders commented that they were cognizant that aggregator solutions were as yet unproven, and that the DNOs rightly will need to be "convinced" that 3rd party models work, and that this will need to be done quickly in order to avoid any wide deployment of DNO-led solutions.

> "We can understand why the DNOs are nervous – the aggregator approach is currently unproven"

- **Our recommendation** – We believe that all 3rd party models in the spectrum could feasibly comply with all design principles, if implemented in the correct way, and so all were considered for architecture assessment. In particular, utilising 3rd party systems for flexibility response may provide some potential to manage the risk of regret investment. However, 3rd party models are as yet untested at scale, and work is needed to understand the level of certainty that the DNO can expect – both in terms of certainty of forward demand profiles, and potentially the response that could be expected following any real-time request or emergency signal. This present a risk to the ability of the DNO to maintain the integrity of the network (Principle 3), and so may inhibit EV uptake (Principle 2) in the short term. A model with no emergency request facility for the DNO (such as A2 or A3) may further add to this uncertainty until proven.

3rd Party and/or Customer control entity models (C1-C3)

- **Stakeholder feedback** – Some stakeholders saw the Customer models C1 and C2 as providing a higher degree of customer control, and as the more likely options. For others, the 3rd party and Customer models were ultimately seen as the same, as the 3rd party models would still need customer acceptance of terms and rules, and Customer models would still need some form of control technology services. Doubts were raised regarding the level of customer effort required, and it was suggested that customers would likely preference to work through 3rd parties. One stakeholder questioned the Customer models, and underlined the need to think about wider factors that might impact model variants, such as car sharing, mobility as a service, and autonomous vehicles.

"We must design around the consumer, and be mindful of the amount they have to act"

- **Our recommendation** – All customer-led models could feasibly comply with all design principles, if implemented in the correct way, and so all will be considered for architecture assessment. In these models the customer has maximum choice of when to charge, although may need to make choices more often. Similar to the 3rd party models, the customer models may lead to uncertainty in the level of response that could be expected in response to price signals, and so present a risk to the ability of the DNO to maintain the integrity of the network (Principle 3). This would need to be tested in early trials.

We therefore recommend that 7 models from the spectrum are viable, as highlighted in Figure 7: Spectrum of smart charging models above. Conceptual illustrations of these models can be found in Appendix C.

In the following sections, we examine these models in order to draw out the fundamental enablers and determine our strategy for supporting the development of the UK approach to Smart Charging.

3.4 Key enablers for residential smart charging

Across the spectrum of viable models there are four key mechanisms which are responsible for coordinating charging to optimise network utilisation and manage the capacity of the network:

- LV constraint pricing reflective of local network conditions (models C1-C3)
- Flexibility procurement (model A3)
- Explicit capacity allocations and incentives (model A2)
- DNO unilateral load-management action (models D2 and A1)

The first three of these are market mechanisms, whereas the last typically relates to a non-market mechanism, in which the DNO takes a unilateral action to limit or curtail charging at a given charge point. However, if this mechanism is designed to provide compensation for the customer and is on an 'opt-in' basis, load management actions begin to take on some characteristics of market mechanisms. We explore this further below.

In the following sections we will outline the options for each of these four mechanisms to inform our strategy and understand the implications for architecture development.

3.4.1 LV constraint pricing

Low-voltage (LV) network constraint pricing (models C1-C3) is stakeholders' preferred market means to manage the use of the local network. In these models, it is anticipated that at times of low network utilisation market actors would be coordinating charging with respect to wholesale market and balancing services opportunities, and would be taking into account LV network capacity based on price signals, to select the optimal times to charge (and discharge). This would help to keep the network operating within capacity limits, by incentivising customers to move their consumption away from times of congestion (or predicted congestion) to reduce demand.

Such price signals do not yet exist, and would most likely need to be enacted via the Distribution Use of System (DUoS) charging regime, which recoups the costs of the network from consumers, and is a regulated mechanism that the DNOs cannot adjust. Ofgem's Network Access & Forward Looking Charging reform will examine the nature of the capacity rights and charging regime for residential customers, and a potential outcome may be to deliver greater locational and time-of-use granularity into the charging regime, which would assist in providing price signals for smart charging.

It is possible that even once implemented, an LV constraint price may not always be able to fully protect the network. This could be for a variety of reasons, such as the pricing signal not being strong enough, customers not responding due to their immediate needs or simply not having the opportunity, or if a large number of customers moved their charging to a new peak. The other three mechanisms – i.e. explicit capacity allocation and incentives, flexibility procurement and load management actions – offer additional protection against these kinds of circumstances.

3.4.2 Flexibility procurement

In our Flexibility Roadmap[5] we have set out our plan for the next 2.5 years for the procurement of flexibility services to assist in managing the operation of the network. In this roadmap we set out our current flexibility needs, our product strategy and current flexibility products, with a focus on Extra High Voltage (EHV) and High Voltage (HV) levels of the network. In addition, we highlight that we anticipate future flexibility needs to include low voltage flexibility products, driven by the uptake of electric vehicles and electrification of heating.

Flexibility procurement is an approach currently in use in several DNOs at higher-voltage areas of the network, and is also well established as the basis for the national balancing mechanism. The current DNO mechanism takes the form of tenders for flexibility services, in which providers of flexibility response will contract with the DNO to then provide services in response to a real-time dispatch signal. It is possible that this mechanism could be used to mitigate LV constraints, if for example storage providers, distributed generators or demand-side response providers were able to submit proposals for installing (or utilising existing) assets within specific localised constrained areas of the network. It may also be possible to utilise more dynamic flexibility procurement to manage electric vehicles – for example procuring day-ahead flexibility on the basis of forecast constraints (as per the USEF case study), or even via a dynamic real-time flexibility market platform similar to the national balancing mechanism.

However, as outlined in our Flexibility Roadmap the way we engage the market in these existing approaches may not be possible for future LV flexibility needs. Firstly, our needs will be highly locational, which means that the total market size for potential flexibility providers may be limited to a few consumers in urban areas and even fewer in rural areas. There is a question on whether there will be sufficient participants (or liquidity) at this local level to run open market tenders for flexibility services. Secondly, due to the potential for sudden clustering of electric vehicles and heat pumps, the time we will have to proactively respond to emerging network developments at LV is far less than for primary substations, where there is a clearer line of sight of load growth. Given that the cycle times for open tenders can take multiple months, these approaches may not be suitable. Finally, the cost of reinforcement of a single LV substation is far lower than a primary substation. This means that the value of individual flexibility services will be lower – albeit that there could be high volumes required (depending on how DER take-up drives reinforcement needs). There are obviously costs involved in participating and running a tender process, and it may not be efficient to do this for individual LV assets.

These factors mean that we may need to consider how an 'administered price' approach could work for LV flexibility (at least initially). This would involve determining an appropriate incentive to provide to the market for flexibility response via smart charging – for instance a single static payment across our whole network, one that varies by LV zone, one that is specific per asset or even a dynamic utilisation payment which can vary by time of day or season. Whilst this approach will not enable price discovery via a dynamic market mechanism, it could still be employed to enable a lower cost alternative to reinforcement in some cases.

It should be noted that there will be many complexities in designing a workable approach that is acceptable to all parties and provides an effective means of managing the network. The role of the DNO should perhaps be limited to providing clarity and guidance to the market on the services required and their value, with market participants (such as suppliers) given the freedom to innovate customer propositions as they see fit. The appropriate market framework, transparency

[5] Which can be found at http://futuresmart.ukpowernetworks.co.uk/

and governance arrangements for this approach will need to be explored as part of our ongoing Flexibility Roadmap programme.

Finally, any method that takes place in a targeted way will require additional incentives for participants. Funding any incentives through avoided reinforcement costs would not be an equitable arrangement between electric vehicle users and non-electric vehicle users, due to the fact that the electric vehicle users would effectively be causing an issue on the network but be paying less than non- electric vehicle users for network access (i.e. due to the receipt of an incentive payment, leading to net lower costs). This issue can only be addressed through reform of the DUoS regime.

3.4.3 Capacity allocation and incentives

Capacity allocations are a market mechanism currently in use on higher-voltage areas of the network and with larger participants. For example, in our Flex DG project, a continuation of our Flexible Plug n Play project , developers of distributed generation assets in constrained areas are able to access faster and cheaper connections, by connecting ahead of reinforcement and committing to capacity restrictions. In these areas, known as ‘constraint managed zones’, we are investigating the ability for market participants to trade their capacity allocations bilaterally, thus enabling network capacity to be efficiently allocated to participants who will most value it. Participants are currently restricted from stepping outside their capacity allowance by an Active Network Management (ANM) system which can control the connection – though it would also be possible to simply meter the connection and provide financial incentives (i.e. penalties) to operate within agreed capacity limits.

This method is the basis for Model A2 in our initial research, and it is clear how it may be applicable for instance for large fleet customers, service station charger banks, or airport/supermarket carparks – who may already have existing connections in place or for whom they could be applied in the event of new connections applications.

However, at LV a capacity charging mechanism may also provide a simple way to implement time of use incentives for customers. Ofgem are investigating this as part of the Network Access & Forward-Looking Charges review, in which they have outlined a ‘core capacity allowance’ (i.e. a specific KW load level) for household consumers, with options on charges for use above that core allowance. This might include for instance additional charges for customers wishing to draw a higher load to power a fast charger, or different charges for additional load depending on the time of day.

3.4.4 DNO load management

Market mechanisms are the preferred means to manage network capacity, as they promote competition and innovation, enable the most efficient allocation of capacity, and enable customer choice. However, it is possible that market mechanisms may not always be able to fully protect the network, and in some circumstances it may be appropriate for the DNO to be able to restrict capacity – through curtailment or partial load-limiting – to avert outages.

This form of action is seen in a number of the case studies, either through applying a timed profile to the connections in advance, or by applying a real-time curtailment signal. In some trials these actions are carried out via DNO-owned control assets installed at the point of charging, and in other cases via 3rd party infrastructure and smart chargers.

Circumstances in which this might be appropriate include:

- If customers in an area are being subjected to repeated outages caused by EV load;
- In areas of the network with high-risk or vulnerable customers, to prevent any outages;
- In areas where customers are disengaged and market mechanisms are not able to manage the constraint; or
- If market mechanisms do not emerge quickly enough to cope with the speed of uptake of EVs.

Our preference is to utilise market mechanisms. DNO Load management carries several risks for the DNO, including customer experience issues, reputational issues, and regret spend on control assets. However, another option would be a more market-led variation of a load management approach, which is enacted via 3rd party smart charging infrastructure, rather than via DNO-owned assets, is offered to customers on an opt-in basis (i.e. they can refuse to sign up), is compensated when curtailment events occur (i.e. customers receive a pre-agreed incentive), is enacted transparently, according to rules, and provides customers with an opt-out facility to any given curtailment event.

In effect, this form of load management is a form of flexibility procurement via administered prices, as set out in Section 3.4.2. The key differences include the need for the DNO to have knowledge of specific EVs mapped to LV network feeders, and the fact that the instruction would be facilitated with an instruction generated by DNO systems and passed via 3rd party systems, rather than a price signal.

3.4.5 The need for transparency

All of the models described require transparency of information to be shared across participants. In order to be able to respond to network needs, market participants need to have visibility of data from the DNO that reveals the location of constraints, and also the value that the DNO can pay to manage them. This will require the DNO to deploy new monitoring equipment at LV levels of the network, as well as systems to generate requirements, prices and interfaces to the market.

In addition, the market will need to notify the DNO of all electric vehicle charge point installations, to enable constraint mapping. At present, the DNOs are not receiving suitable levels of visibility of installations, and this will inhibit the ability to provide visibility of, and manage, constraints if not improved. At present it is not mandatory for charge point installers to notify the DNO of new installations, and we aim to ensure this is changed.

3.4.6 The need for variety and evolution

The mechanisms described in the previous section have different strengths, and are suitable in different situations – for instance in different areas and voltage levels on the network, or for different customer types. In addition, these mechanisms could be seen as part of a hierarchy of options to manage different near- or real-time network conditions.

Figure 8 below illustrates how the mechanisms could co-exist in a hierarchy of options. In this figure, we have set out a series of 'operating regimes' in a traffic light system, with market mechanisms free to operate in the 'green' regime, and an 'amber' regime signifying times of network stress where a load management action may be enacted by the DNO.

Price signals (as per our C1-C3 models in Section 3.3.5) are seen as the preferred means to manage network constraints, with the other mechanisms representing an increasing level of DNO facilitation – i.e. flexibility procurement (model A3) capacity limits (model A2), and finally load management actions (models A1 and D2). Further trials and design processes (as outlined in Section 6.2) are required to understand to what extent there may be a need for the models that imply a higher degree of DNO facilitation.

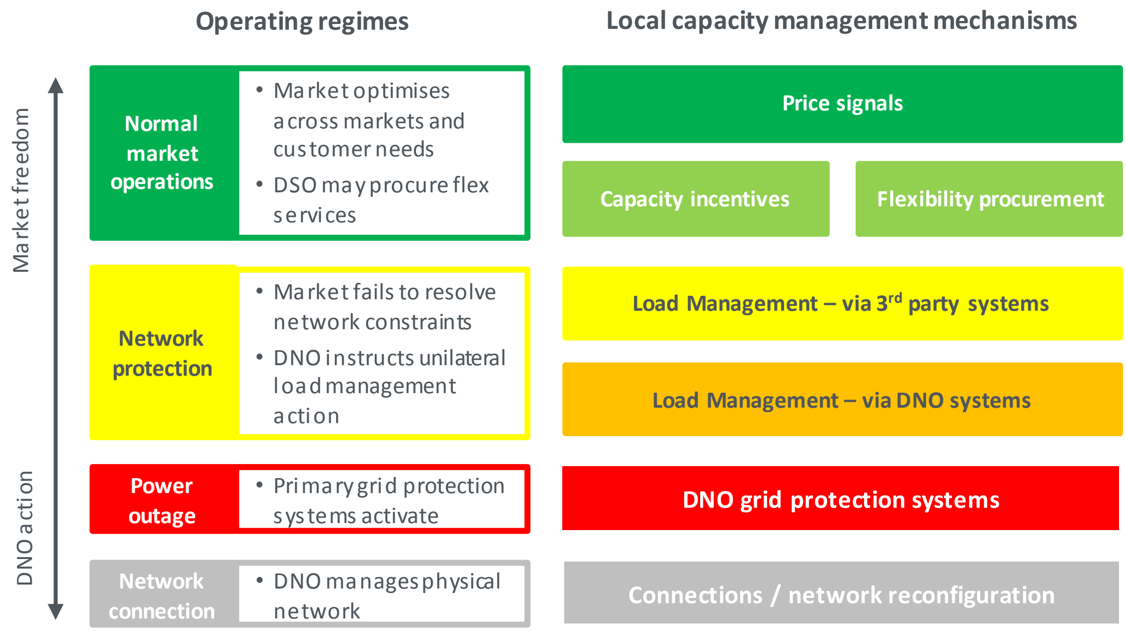


Figure 8: Illustrative hierarchy of 'operatimg regimes'

Rather than a single approach emerging, it is possible that a number of these mechanisms may be used at the same time. In addition, it is likely that the industry approach will evolve over time, as different methods are trialled and developed. As such it is likely that the DNO will need to support all elements at some point.

Figure 9 below sets out our view of the likely evolution of smart charging over time. In the initial "interim" phase, we will work with market participants to stimulate market approaches for smart charging. In particular, we will examine the examine the use of price signals, and the potential to utilise flexibility procurement ahead of any DUoS reform.

UK Power Network's strategy for smart charging is to avoid the need for or use of "load management" mechanisms. This strategy is set out below, and further evidence of our direction can be found in Section 6.2 where we set out our intent to mobilise trials for pricing-based approaches. However, we cannot rule out other DNOs utilising load management solutions, nor the potential need for such approaches in short-term emergency situations (such as where customers are subject to outages), and so we have illustrated these solutions as a likely part of the evolution of the market in the illustration below.

In the transition phase we may see implementation of an enhanced DUoS charge, and maturing of other market mechanisms, alongside a reducing use of load management as the market becomes more able to manage constraints. Finally, in a mature state the market would be managing most constraints on the network, with only occasional load management in specific circumstances.

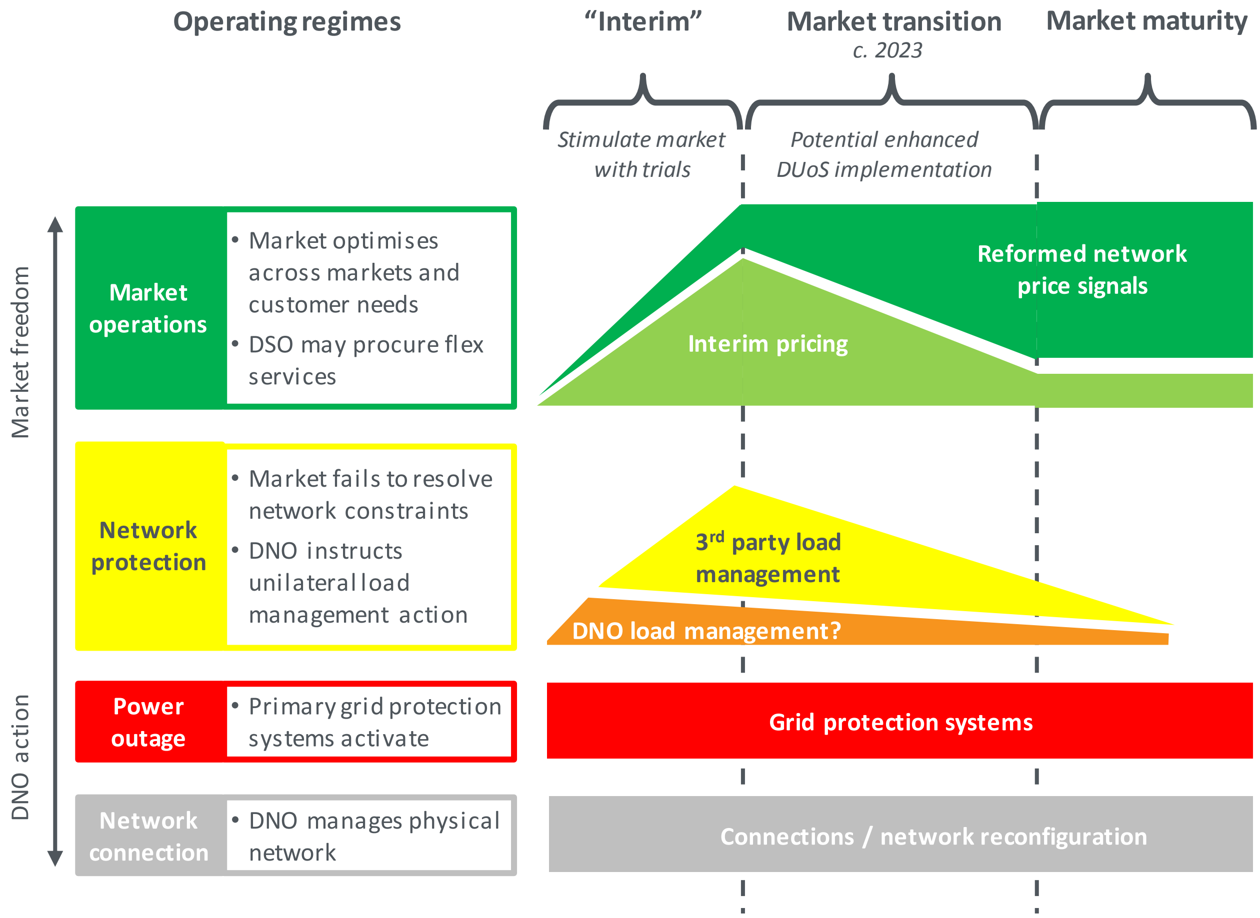


Figure 9: Evolution of smart charging approach

3.5 Summary of our smart charging strategy

3.5.1 Our smart charging strategy

We will pursue a hierarchy of options to manage constraints:

1) **We will promote transparency of customer and network needs**
   - Publishing emerging constraints data regularly and at a granular level, and
   - Lobbying for mandatory notification of charge point installations
2) **We will maximise the capacity available to the market through network reconfiguration where possible**
3) **We will facilitate the market to manage emerging constraints, through:**
   - Advocating a regulatory framework that rewards DNOs for facilitating the uptake of EVs, and encourages them to promote market-based solutions for smart charging
   - Providing a market for flexibility procurement to access technologies that can mitigate EV constraints
   - Supporting market participants in the development of smart charging propositions based on price signals:
     – Supporting Ofgem in developing charging arrangements which create appropriate incentives through DUoS, as a long-term solution
     – In the interim, pursuing an interim pricing approach to stimulate the market, via LV flexibility procurement and broader trials
4) **Where necessary, we will approach customers or 3rd parties to request a load-management option for the DNO, but on an opt-in basis for the customer, with compensation, and enacted via 3rd party infrastructure**
5) **Where economic to do so, we will reinforce the network**

3.5.2 Smart charging use cases

‘Use cases’ are typically defined to describe scenarios and processes that would be needed to deliver a given service strategy. They are used to help clarify the service strategy and begin to identify process steps and business capabilities that would be needed to deliver them. Table 2 below sets out the Use Cases that we investigated in order to define the required architecture to support our smart charging strategy. These use cases are set out in more detail in Appendix D, and form the basis for the architecture assessment set out in the following section. Please note that other Use Cases may be appropriate for variants of the Smart Charging approaches identified, and so this is not meant to be a full and final list, rather is intended to inform our architecture approach.

In this table we have highlighted whether the Use Cases are relevant for residential smart charging, which are relevant at HV vs. LV, and which are relevant in the short-term vs. the longer-term. Use Cases relevant for Capacity Allocation & Incentives (Use Cases 6 and 7) have been highlighted as not relevant for smart charging, as set out in Section 3.4.3 above. Those highlighted as relevant in the short-term are either associated with our related Flexibility Roadmap (Use Cases 4 and 5), or are required as part of our interim solution for managing LV constraints ahead of an industry-wide solution, as set out in Section 3.4.2 above (Use Cases 2, 3 and 8).

Key enabler	Use case		Relevant for smart charging?	Voltage		Timescale	
				HV	LV	Short term	Long term
Price signals	1	Generating customer response to locational ToU pricing (enhanced DUoS and/or capacity charges)	✓		✓		✓
Flexibility procurement	2	DNO identifies and publishes LV constraint pricing, and 3rd parties sign-up customers to smart charging tariffs	✓		✓	✓	✓
	3	Generating customer response to locational flex procurement via DNO administered prices	✓		✓	✓	
	4	DNO or market participant procurement of aggregated flexibility via a 3rd party utilising residential EVs under HV constraint – e.g. – Procurement of service to deliver emergency load shedding in response to real-time signals – Residential EV demand turn-up service to offtake excess generation in constraint managed zone	✓	✓		✓	✓
	5	DNO flexibility service procurement from bulk DER provider (e.g. storage) to mitigate LV EV cluster	✓		✓	✓	✓
Explicit capacity allocation & incentives	6	DNO allocation of capacity, management via ANM, and facilitation of secondary capacity trading	**n/a**				
	7	DNO allocation of capacity, management via financial penalties, and facilitation of secondary capacity trading	**n/a**				
DNO load management	8	DNO request for and use of “opt-in” load-management facility	✓		✓	✓	

Table 2: Smart charging 'Use Cases'

4 Smart charging architecture

4.1 Our approach to architecture development

In this section we set out a definition of the capabilities and solutions required to deliver our smart charging strategy. This work builds on the spectrum of smart charging models and the use cases set out in the previous section, which set out the relationships between different parties, the information flows, and the process steps required.

Building on this work we now set out:

- **An over-arching smart charging functional architecture** – a high-level value chain to support the Use Cases, that illustrate the logical flow of activities across the industry on both the network and market side, and a functional architecture map setting out the functions and information flows required
- **Definition of the core DNO functions** – identifying DNO functions that are core to all of the smart charging models and setting out requirements which describe the capabilities required
- **Key scenario stress tests** – in which we examine some key potentially disruptive smart charging trends and understand whether the architecture would need to change markedly to support these potential developments
- **Component and information architecture** – carrying out an assessment of changes required to UKPN's systems, and setting out component and information architecture layers to support the functional architecture
- **Equipment and information standards** – examining the communication standards in use internationally and their potential relevance for the UK, as well as the equipment standards that would be required

4.2 Smart charging functional architecture

4.2.1 Functional architecture

Figure 10 below sets out a smart charging value chain drawn from the Use Cases set out in Section 0. This defines a series of high-level activities, which is then used to inform the map of functions and information flows required. This is intended as a high-level and illustrative exercise, as a means to help identify key groupings of activities to be supported by the architecture, rather than a full and detailed capture of the processes required across the industry. The definitions are therefore kept generic and at a high-level at this stage, with subsequent sections defining functions in greater detail.

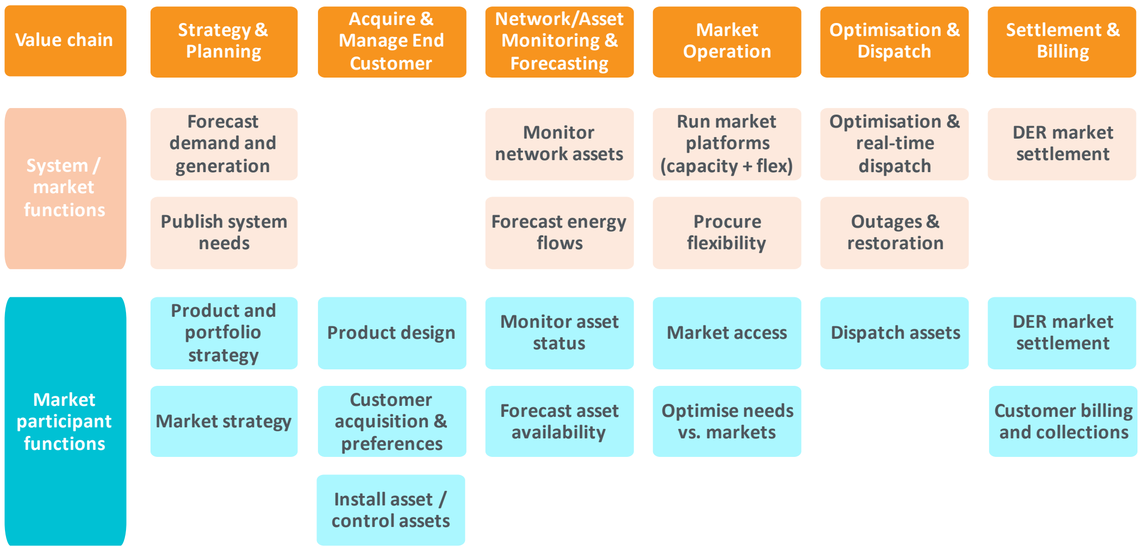


Figure 10: Smart charging illustrative value chain

Figure 11 below depicts the same functions in a functional map, setting out the high-level capabilities required for both the DNO and other parties to enable smart charging. The information flows both within the DNO and to external parties are detailed, as well as the specific flows which differentiate the smart charging models. This set of functions enables each of the use cases, and the process steps for smart charging flow through the functions in the order of the value chain above. Note that these functions are also aligned to the capabilities we previously laid out in our Future Smart Consultation Report[6].

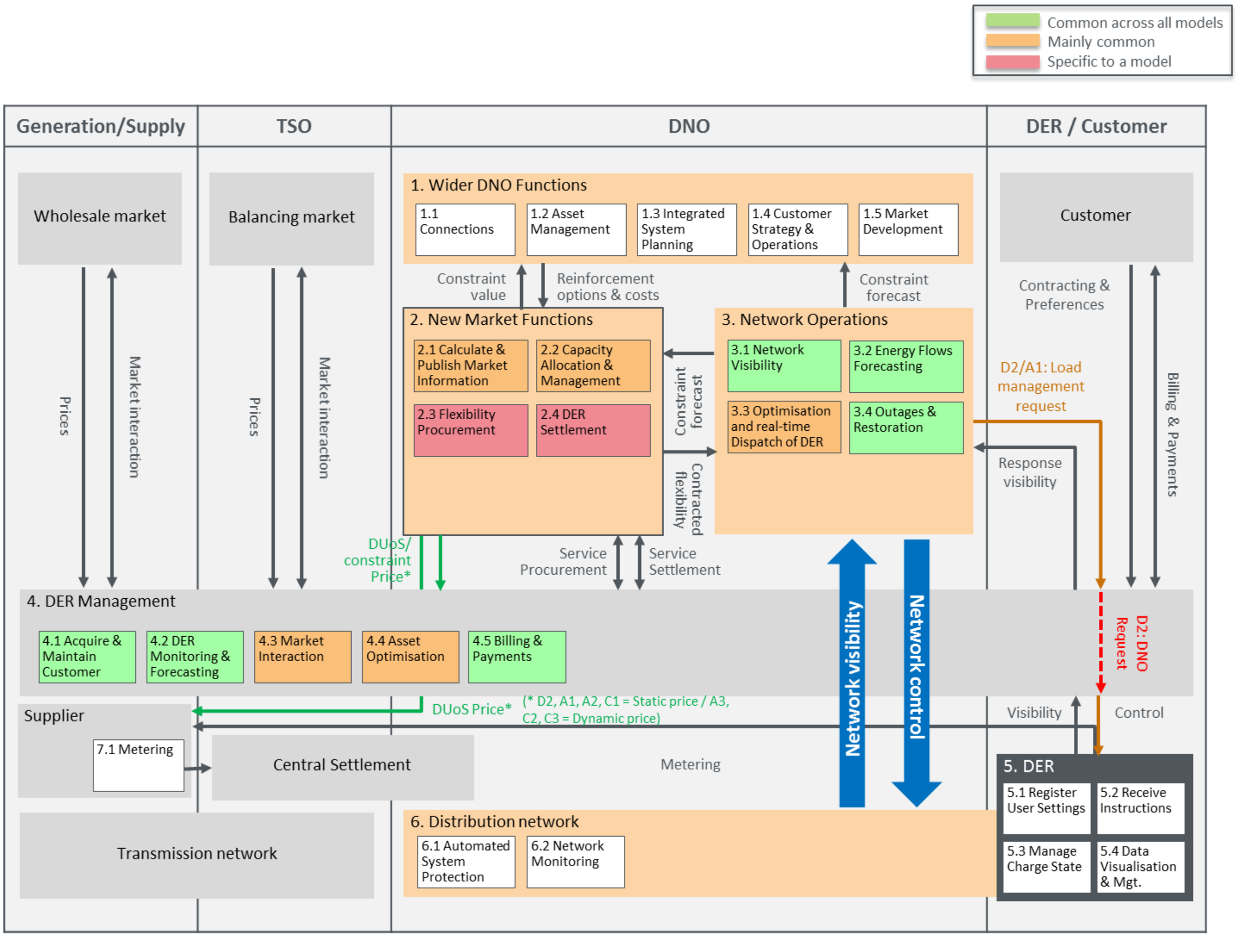


Figure 11: Smart Charging Functional Architecture

This diagram illustrates 6 key functional areas. Within the DNO, the 'Network Operations' functions will be monitoring the conditions on the network, forecasting energy flows (short and longer term), potentially carrying out load management requests, and managing outages and restorations as normal. The 'New Market Functions' refer to emerging capabilities which would be engaged in interfacing with the market to gain access to flexibility. These functions would for instance be publishing market information, such as locational constraint prices, and managing longer-term flexibility procurement.

In between the DNO and the electric vehicle/charging infrastructure, we have defined a layer of "DER Management" functions, that would be carried out by 3rd parties (such as suppliers, aggregators or Charge Point Operators) or by the customers themselves. These functions would have the role of interacting with the wholesale market, the balancing

[6] http://futuresmart.ukpowernetworks.co.uk/

mechanism, receiving local network constraint information from the DNO, and optimising the charging (and discharging) schedule of the electric vehicles.

In this functional map, we have illustrated via the red/amber/green colour-code whether functions are common across the spectrum of models set out in Section 3.3.5 (which we have termed “core” functions), or whether they are specific to only one or two possible models (which we have termed “non-core”). The purpose of this is to highlight which functions are highly likely to be required, regardless of the future smart charging approach, and which are more uncertain. The core functions (marked in green) are capabilities which the DNOs/DER Managers can begin to invest in, with confidence that they will be required in the long term. The non-core functions (marked in red) are areas in which there is so much uncertainty that we cannot yet begin to specify how they might work, or even be sure that they will be required.

We have also marked certain functions as amber, where there may be a series of sub-functions that are common across the various possible models, and others that are not. Some areas have also been marked amber if there are sub-functions that may be required in the short-term, but which might not be required in the longer-term – such as to support use case #5: DNO request for and use of “opt-in” load-management facility. Whilst investment in these areas might become redundant in the longer-term, they are areas which are required to support the transition to market-led approaches.

The coloured flows relate to specific smart charging models (as labelled), whilst the grey flows are common to all smart charging models.

Further details on the definition of core and non-core functions and sub-functions can be found in Appendix E.

4.2.2 Functional requirements

The following section sets out a high-level description of the functions illustrated in Figure 11. This is supported by a detailed definition and requirements for the core functions highlighted in the New Market Functions and Network Operations areas, which can be found in Appendix F.

1. Wider DNO Functions

(Note that given the focus of the project, we have not assessed requirements in the wider DNO functions in detail, but have provided a high-level description of the functions below).

- **1.1 Connections** – The connections function will need the capability to manage the processes and connection agreements for all charge point installations, as well as wider DER, LCT and non-linear load installations. The process will need to include capacity assessments, an understanding of current and forecast constraints, the level of LV visibility and existing DER installations. It will also need to develop and articulate connection propositions for different customer segments, and manage non-firm connections within constrained areas.
- **1.2 Asset management** – The asset management function will need the capability to register all EV charging points and their profiles for load forecasting (this also applies to wider DER). They will need new capabilities to carry out LV strategic planning, including condition based risk modelling at LV network levels to inform criticality assessments. There is likely to be a need for asset strategies and analysis that focus on managing linear assets (in particular HV circuits and LV feeders and service cables) in addition to point assets (distribution transformers, link boxes and similar assets)
- **1.3 Integrated system planning** – The integrated system planning function will need to identify and plan for longer term constraints and assess their associated reinforcement costs at all network levels, including LV. These costs will inform the suitability of specific market products to resolve a particular constraint. This function will also need to incorporate wider data sources, such as smart metering data and data provided by third parties e.g. Charge Point Operators. There will also be a need for coordination with the TSO regarding constraint planning.
- **1.4 Customer strategy & operations** – The customer strategy & operations function will need to manage the whole lifecycle of DER customers. Customers’ needs and products will require segmentation (as they will range from individuals to larger aggregators), their contracts managed and products defined.
- **1.5 Market development** – The market development function will need the capability to carry out market analysis and market sizing, as well as defining the communication with the markets.

2. DNO New Market Functions

- **2.1 Calculate & publish market information** – This function is illustrated as amber in the functional architecture map, as some sub-functions may not be needed in all future smart charging models. The generation and publication of future flexibility needs is considered core to all smart charging models and applies for all DER, not specifically to EVs. The granularity and frequency of this publication will need to be determined as part of a future trial. This information will be used to indicate to third parties particular network locations where there are emerging constraints and a need for flexibility services. Subject to our trial of LV constraint incentives, this function may also be required to generate and publish LV constraint incentives, on an occasional or potentially more dynamic basis. Testing of LV flexibility markets is required to determine the details for this function, and in future pricing may become more dynamic to reflect real-time network status and testing of market liquidity in response to bids/offers. Dependent on the outcomes of Ofgem's Network Access and Forward Looking Charges Review, time of use and locational DUoS may eventually need to be calculated and published in place of any interim incentive approach.
- **2.2 Capacity allocation & management** – The functions associated with capacity allocation & management are illustrated as red in the architecture map, as they are only required in one form of smart charging approach, and so are non-core functions (see Appendix E). At a high level, the purpose of these functions would be to manage explicit capacity allocations to parties, potentially facilitate secondary trading, and then either interact with Network Operations to enforce capacity limits under an Active Network Management scheme, or to interface with a settlement function to enable penalties for any capacity breach where appropriate. This function is being investigated as part of our Flex DG project and learnings will be disseminated separately.
- **2.3 Flexibility procurement** – This function is illustrated as amber in the architecture map, as some sub-functions may not be needed in future smart charging models (Appendix E). Management of the flexibility procurement strategy and the procurement of forward flexibility are considered core functions. However, this function applies for all DER, not specifically to EVs. This is generally focussed on HV with a minimum threshold on flexibility volume. The design of flexibility propositions and products sits within the Customer Strategy and Operations function described above. The procurement of LV flexibility is considered non-core as it applies to a single smart charging model, and is subject to our proposed LV trial. Testing of LV flexibility markets are required to determine the details for this function, though this is likely to include interaction with the market to provide incentives that effectively procure forward or perhaps more real-time flexibility via residential smart charging.
- **2.4 DER settlement** – This function is illustrated as red in the architecture map, as settlement is only required in a subset of smart charging models. In addition, we have little insight into what this might entail at this point, as there may be requirements for flexibility settlement across HV and new LV flexibility procurement, and/or potentially settlement of capacity incentives. Development of this function will be dependent on progressing the agreed industry approach to smart charging, as well as the Open Networks project's DSO design.

3. Network Operations

- **3.1 Network visibility** – This function is illustrated as green in the architecture map, as most sub-functions would be needed across all future smart charging models. Network visibility would be required to enable real-time monitoring of network constraints at constrained secondary substations and LV ways, in order to facilitate any form of smart charging. Active power, reactive power, voltage, current and neutral current would need to be measured for each LV way providing data to forecast future constraints and monitor the impact of smart charging interventions on identified constraints. For models where the DNO sends load management signals specifying the turn down of specific EVs/Charge Points, visibility of specific EVs/Charge Points on a LV way may also be required, although this is considered a non-core requirement.
- **3.2 Energy flows forecasting** – This function is illustrated as green in the architecture map, as most sub-functions would be needed across all future models. Energy flows forecasting provides the ability to forecast both long-term and short-term LV network constraints, which would be required at constrained secondary substations and LV feeders, in order to facilitate any form of smart charging.

- **3.3 Optimisation & real time dispatch of DER** – This function is illustrated as amber in the architecture map, as there is uncertainty whether some functions will be required in all future models. Elements of this capability would be required in the opt-in load management use case, in order to determine when the market over-ride may be necessary, and then to determine which specific assets are attached to a feeder and select assets for load management. The assets who have opted in to load management and are associated with the specific constraint will need to be identified and issued with a load management instruction. This instruction is likely to be published to third parties and initiated by their systems/assets. In certain scenarios involving flexibility procurement, ESO coordination may also need to be considered when determining which assets to dispatch, in case the ESO is also seeking flexibility response from aggregators managing specific electric vehicle/charge Pont clusters.
- **3.4 Outages & restoration** – Management of planned and unplanned events and restoration of supply are considered core to all smart charging models. Smart charging will have minimal impact, however, there will be process changes required in relation to communication of outages to third parties. Charging infrastructure equipment standards are further discussed in Section 4.5.2 regarding functionality following an outage. The introduction of vehicle-to-grid functionality may mean that EVs can play a further role in supply restoration. However, the future of this technology is still uncertain and there are wider ongoing projects looking at vehicle-to-grid more specifically. This is further discussed in Section 4.3.

Market Participant Functions (DER Manager)

(Note that given the focus of the project on DNO functions we have not investigated the market-side capabilities in detail. As such, here we provide a brief overview of potential functions to help illustrate the overall industry architecture).

- **4.1 Acquire & maintain customer** – defining propositions and acquiring customers, capturing and storing their preferences, managing in-life communications and retention
- **4.2 DER monitoring & forecasting** – monitoring EV charging patterns and live charge states, and forecasting expected demand (long and short term), this data may then need to be shared with the DNO for forecasting purposes
- **4.3 Market interaction** – interaction with the energy markets, including the wholesale market and balancing mechanism, as well as interacting/interfacing with new DNO market functions
- **4.4 Asset optimisation** – calculation of the optimal deployment schedule for assets based on price signals for all markets, location and customer preferences, and dispatch of assets to deliver the schedule
- **4.5 Billing & payments** – interaction with market settlement functions and clearing of market positions, calculation of customer billing requirements, customer billing and collections

DER Functions

- **5.1 Register user settings** – capture and storage of data relating to customer preferences regarding their EV charging patterns and mobility needs
- **5.2 Receive instructions** – maintenance of network connectivity and receipt of smart charging instructions
- **5.3 Manage charge state** – monitoring of charge state and alteration of charge/discharge states based on the smart charging instruction
- **5.4 Data visualisation** – storage and management of data related to smart charging, and the ability to display data locally to the consumer

Supplier Functions

- **7.1 Metering** – supplier metering of demand via the smart meter, however, in a smart world the DNO will have access to data via the DCC (TBC frequency of available readings).

The core functions most impacted by smart charging (New Market Functions and Network Operations) were expanded in further detail and high level data, system and process requirements were captured. These were mapped to existing UK Power Networks project scopes to identify any smart charging requirements which were specific to electric vehicles, and not captured within other projects. The majority of the requirements were encompassed within requirements for LV Monitoring & Visibility, Active Response, Active Network Management, the Flexibility Roadmap, Recharge the Future, and Power Potential. The key additional requirements specific to smart charging relate to the "opt-in" load management functionality, identification of DER assets which could contribute towards resolving a specific constraint, constraint pricing and settlement of these contracts. Full detail of the requirements can be found in Appendix F.

4.3 Key scenario "stress tests"

In this section we have reviewed three key technology trends – Vehicle to Grid (V2G), Home Energy Management Systems (HEMS) and Connected Car (CC) – to understand the risk that they may significantly impact on the architecture definition. A definition of each of these technology variants is set out below.

Vehicle to Grid (V2G)

This technology is more generally referred to as vehicle-to-everything (V2X), which has the potential to fully utilise the EV battery by allowing energy to also be fed back to the grid, home or building. This means that the grid can 'borrow' energy from the vehicle at peak times when constrained, and then later recharge the vehicle for mobility purposes. As a result V2G has the potential to double[7] the flexible power capacity in comparison to smart charging. This flexibility can be accessed the entire time the vehicle is plugged in, whereas smart charging can only be carried out whilst actively charging.

V2G is scaling up from an early pilot phase (~100 chargers worldwide) to larger scale implementation (>1000 chargers in the UK) over the next three years, with the help of the Innovate UK funding, with which OLEV and BEIS are providing almost £30 million to fund industry-led collaborative R&D in electric vehicle-to-grid technology[8]. There is a growing number of V2G-capable charge point suppliers, but at the moment only 3 car models are 'V2G-ready'. Other barriers to overcome include customer awareness and, uncertainty regarding battery degradation.

UKPN have set up the TransPower portfolio, under which they are working on V2G projects with several consortia, which will include assessing new architectures for flexibility. As part of this programme of work, UKPN have released their first report on the key learnings from 50 global V2G projects. This is the most comprehensive study on V2G to date and includes takeaways from all projects to date.

Home Energy Management Systems (HEMS)

Home Energy Management Systems (HEMS) are capable of receiving signals and controlling various household loads, and could be used to control the EV charge process potentially through the home area network (HAN). Currently most HEMS are not yet capable of controlling EV charge points. However, there are examples where preliminary connective functions have been rolled out, such as the collaboration between Nest and ChargePoint[9].

There are a number of factors which suggest that HEMS may take some time to achieve mass adoption, however, it is likely that EV users will be HEMS early adopters. Standardisation of an EV data model within the Internet of Things (IoT) standard will be required. In addition, the rollout of HEMS will need to follow the implementation of smart meters in

[7] California Energy CommissionEnergy Research and Development DivisionEPC 14-086 Project Final Report

[8] GovUK - https://www.gov.uk/government/news/30-million-investment-in-revolutionary-v2g-technologies

[9] http://www.neep.org/sites/default/files/StorageEVPV.pdf

relation to measuring the response to flexibility requests and ToU tariffs, however, HEMS could exist in parallel for control signals and (non-DUoS) pricing.

Connected Cars (CC)

The connected car can be defined as a car that is connected to the internet over a cellular or tethered connection. It is expected that in future this connectivity will enable a smart charging variant where the car can directly communicate with the CPO, aggregator, supplier or DNO, wherever it may be, and as a result could bypass the need for a smart charger. Companies like Jedlix[10] have trialled remote smart charging (for Tesla, BMW and Renault) with Elaad and in return repay the EV owner for their flexibility in the form of reduced energy bills. Consumers are adopting the connected car faster than expected, and in 2021 it is expected that 82% of total cars shipped in 2021 are expected to be a connected car[11]. For this connectivity to be leveraged for smart charging, agreements between market participants and network companies will need to be made regarding how these assets are managed.

4.3.1 Potential impacts of technology variants on functions

Figure 12 below sets out an impact assessment of the technology variants on the core functions and sub-functions.

Capability	Function	V2G Impact	HEMS Impact	Connected Car Impact	Description of Impact
3. Network Operations	3.1 Network visibility	L	L	L	N/A
	3.2 Energy flows forecasting	M	M	H	There will be an impact to forecasting, as more detailed data may be available and charging behaviours are likely to change as a result of V2G etc. It is expected that connected cars will provide more detailed data for forecasting due to the locational elements.
	3.3 Optimisation and real time dispatch of DER	M	M	M	There will be different business rules that may need to be applied when determining which assets to load manage (in the scenario where load management is used), and different services may be able to be offered e.g. turn up as well as turn down.
	3.4 Outages and restoration	H	L	L	V2G will be able to support supply restoration following an outage.
2. New Market Functions	2.1 Calculate and publish market information	L	L	L	N/A
	2.2 Capacity allocation	L	L	L	N/A
	2.3 Flexibility procurement	L	L	L	Potentially wider flexibility products relating to V2G.
	2.4 DER settlement	L	L	L	N/A

[10] Jedlix - https://www.slideshare.net/JorgvanHeesbeen/jedlix-presentation

[11] http://www.businessinsider.com/the-transformation-of-the-automobile-2016-forecasts-trends-and-analyses-on-the-disruption-of-the-automotive-industry-2016-4?international=true&r=US&IR=T

Figure 12: Potential impacts of technology trends

The most significant impacts relate to changes in the control asset, forecasting changes and for V2G the potential for outage restoration support. Whilst there may be significant impacts to third party systems, it is likely that the incremental impact on the DNO functions (i.e. over and above the required functionality to support smart charging) would be minimal.

As such we do not believe that any major additional requirements should be taken into account as core DNO functions for smart charging for these technology trends at this stage, though the uptake of these trends should be monitored and taken into account as appropriate.

4.4 Component and information architecture

In this section we set out our impact assessment of UK Power Network's solutions in view of the functional requirements for smart charging (Appendix F). This has allowed us to understand the readiness of the current solutions to deliver the smart charging requirements, the additional functionality that is required, and the order of magnitude of investment required. This has also enabled us to understand what current in-flight projects can deliver the requirements, whether additional requirements need to be added to existing or new projects, and to construct a delivery roadmap. In this publicly available report, we have removed references to UKPN's specific solutions, retaining generic names for solutions which support the various identified functions.

To conduct this impact assessment, we first defined a systems component architecture map, shown in Figure 13 below, mirroring the functional map previously defined, and capturing the relevant systems components and information flows to support the functions. The requirements matrix (Appendix F) was used to allocate the smart charging requirements to UKPN's systems in detail, and to highlight systems gaps, which have been illustrated via a red/amber/green colour code.

As can be seen on this diagram (Figure 13), few impacted systems have the required functionality to support smart charging, and many will require increased functionality. In addition, it is likely that entirely new systems may be required – for instance to support market functionality. However, much of this functionality is also required for managing other distributed energy resources, and so there are significant overlaps with wider in-flight projects.

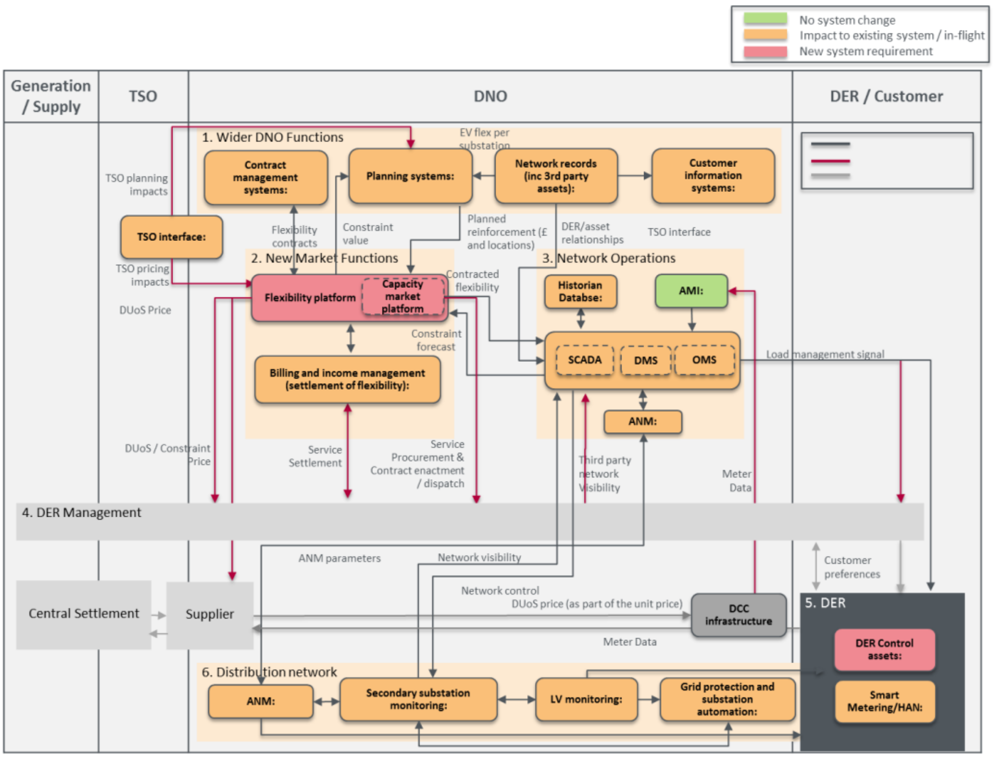


Figure 13: Component Architecture for Smart Charging

Based on the requirements, for each of the systems we have specified the high-level changes required to support smart charging, any relevant project delivering the change, the level of change from current functionality and the estimated cost of delivery. Where required, both an interim and longer-term change were documented, and this will be further discussed in the roadmap in section 6.

We have estimated costs for these impacts, based on subject-matter expert input from within UK Power Networks and our project partners Baringa. These costs are intended as 'order of magnitude' estimates only in order to provide an initial view to support the cost/benefit analysis. Only changes specific to smart charging were costed, as wider project costs have not yet been documented and smart charging is just one of the capabilities to benefit from their delivery.

Table 3 below captures details of the system impacts and approximate cost magnitudes.

System Capability	Headline Change Required	Relevant Project	Level of Change
DMS / SCADA / OMS	• LV network model and visualisation	LV model proof of concept	**H**
	• Real-time LV forecasting (power flow analysis and state estimation)	ANM / Active Response	**H**
	• Outage management: Visibility of CPs and visibility of outages on third party assets	N/A	**L**
ANM (inc. DERMS)	• Identification of "market failure" and unresolved constraints • Identify assets related to LV constraint • DER dispatch signals (and via third parties)	ANM *(some additional requirements)*	**H**
Storage	• An interim time series data storage solution would be viable	N/A	**H**
	• (Longer term) LV data storage	LV monitoring & visibility	**L**
Network records (inc. 3rd party assets)	• Associating charging infrastructure & MPANs with specific LV feeders (& phases) • Register "load management" information against assets	Evolution / ANM	**L**
Planning systems	• Longer term forecasting (inc. data capture and cleansing) • Constraint planning (incl. LV) • Reinforcement cost calculation (offline)	Active Response, Recharge the Future	**M**
Flexibility market platform(s)	• Publish future flex needs (location and magnitude) • Run flexibility tenders • Real time flexibility procurement • Notify third parties of load mgt. signals • Constraint pricing (via administered prices and/or DUoS – could also sit within ANM • Commercial modelling of dispatch – could also sit within ANM	Flexibility roadmap	**H**
Capacity market platform	• Network capacity allocation	N/A (to be further explored in FDG)	**H**
Billing and income management	• Interim: Pay market participants administered prices • Potential longer-term settlement of flexibility procurement and capacity	N/A	**L**
	• Bill suppliers for "enhanced DUoS"	N/A	**H**
Contract management	• Hold flexibility contracts	N/A	**M**
Customer information management	• Interim: Linking of customers to CP assets (via MPANs)	Power Potential / Evolution	**L**
	• Longer term: Closer integration of customers and contracts	N/A	**M**

Table 3: System impacts

The delivery timelines associated with the above system changes can be found in the roadmap in section 6.

In the short term, the system changes required to support smart charging are likely to cost £3.2m-£6.2m (as detailed for interim solutions / trials above and excluding wider system changes which are already associated with other projects).

In the longer term, as the market matures and LV monitoring is more widely spread, there is likely to be additional development required of £5m-£14m (excluding the unknown cost of DUoS billing and settlement, as well as the cost of the LV telemetry assets). These costs have been included as part of the cost/benefit assessment in section 5, in which the cost of LV telemetry has also been included.

4.5 Communications and equipment standards

4.5.1 Communications standards

In this section we examine the communication flows between system components and market entities, and review the communication standards that are being used in international markets to understand their suitability for the UK models.

The information flows between the DNO and third parties were detailed in the previous section in Figure 13, based on the smart charging models investigation and use cases set out in Appendix D. We collated insight into the communications standards utilised in the Case Studies (set out in Appendix A), and assessed these standards for suitability to deliver the required communications flows, by ranking their performance against five criteria – which are:

1. **Robustness of governance** – i.e. is the standard managed by a recognised and wide-spread body, such that it is likely to be a stable and enduring standard?
2. **Scale of use** – i.e. which countries is the standard in use in, and how many trials?
3. **Suitability for DNO/3rd party interaction** – i.e. how well does the particular communication standard fit with the requirements we have set out for the communications flows in the potential UK models?
4. **Interoperability** – i.e. to what extent can the standard be used across multiple flows and between multiple parties, thus easing the burden of implementation/adoption of standards?
5. **Scope beyond EV charging** – i.e. can the standard be used for further likely DER, such that its adoption might enable a more efficient standardisation across multiple technologies?

Table 4 below summarises the output of this assessment:

Communications standard	Level of governance	Scale of use	DNO/3rd party interaction	Interoperability	Scope beyond EVs	Overall score
DNO – 3rd party interaction						
IEC 61850(-80-9)	+ + +	+ +	+	+ + +	+ + +	+ +
OpenADR 2.0	+ + +	+ + + (US) / + + (EU)	+ + +	+ + +	+ + +	+ + +
OSCP	+ +	+ + +	+ + +	+ +	+	+ +
OCPI	+	+	+	+ +	+	+
USEF	+	+	+ + +	+ +	+ + +	+ +
3rd party – device interaction						
Zigbee SEP 1.2	+ + +	+ + (UK: SMETS2)		+ + +	+ + +	+ + +
IEEE 2030.5/ SEP2	+ + +	+ + (US)		+ + +	+ + +	+ + +
IEC 63310	+ + +	+		+ + +	+	+ +
OCPP	+ + +	+ + +		+ + +	+	+ + +
ISO/IEC 15118	+ + +	+		+ + +	+	+ + +

Table 4: Evaluation of communication standards

Next, the standards were assessed against the use cases (from section 0), both for flows to/from the DNO perspective and for third parties and the market. Table 5 specifies the information flows within each use case and the communications standards which are capable of transferring that information.

Use case	Market information flows	Suitable communications standards
DNO/third party interaction		
Flexibility procurement	Publication of flexibility needs	OSCP / Open ADR / USEF
	Bids & offers	Open ADR / USEF
	Calling on flexibility	OSCP / Open ADR / USEF / IEC 61850(-80-9)
	Settlement	*Separate process*
Capacity allocation	Allocation of capacity	OSCP / Open ADR / USEF / IEC 61850(-80-9)
	Financial penalties	*Separate process*
Third parties offering smart charging propositions	Asset registration	N/A – Requires addressing
	Publication of constraints and incentives	Open ADR / USEF
	Notification of assets with “load management” capability	USEF
ToU and locational DUoS	DUoS publication to market	Open ADR / USEF
	DUoS publication to meter	Separate process
Administered prices for smart charging	Publication of constraints and incentives	Open ADR / USEF
	Settlement	*Separate process*
Opt-in load management	Asset registration	N/A – Requires addressing
	Publish capacity profile/dispatch instruction	OSCP / Open ADR / USEF / IEC 61850(-80-9)
	DER dispatch (if applicable)	OCPP / OSCP / OCPI / IEC 63310 / SEP 1.2 / SEP 2.0 / Open ADR / IEC 61850(-80-9)
	Settlement	*Separate process*
Third party / market interaction		
Flexibility procurement	Flexibility availability	OCPP / OSCP / OCPI / IEC 63310 / SEP 1.2 / SEP 2.0 / Open ADR / IEC 61850(-80-9)
	DER dispatch	OCPP / OSCP / OCPI / IEC 63310 / SEP 1.2 / SEP 2.0 / Open ADR / IEC 61850(-80-9)
Capacity allocation	Capacity trading	Open ADR / USEF / other market processes
3rd parties offering smart propositions	N/A	OCPP / OSCP / OCPI / IEC 63310 / SEP 1.2 / SEP 2.0 / Open ADR / IEC 61850(-80-9)
ToU and locational DUoS	DER dispatch	OCPP / OSCP / OCPI / IEC 63310 / SEP 1.2 / SEP 2.0 / Open ADR / IEC 61850(-80-9)
Administered prices for smart charging	DER dispatch	OCPP / OSCP / OCPI / IEC 63310 / SEP 1.2 / SEP 2.0 / Open ADR / IEC 61850(-80-9)
Opt-in load management	DER dispatch	OCPP / OSCP / OCPI / IEC 63310 / SEP 1.2 / SEP 2.0 / Open ADR / IEC 61850(-80-9)

Table 5: Communications standards relevant to each use case

Figure 14 depicts the internal DNO, market interaction and external information flows, as well as the communications standards suitable for the particular flow.

Note that we have adopted a numbering convention in the below diagram in which “1.X” denotes an internal DNO information flow, “2.X” denotes a flow from DNOs to 3rd parties, and “3.X” denotes an external flow in the market domain. This numbering is then repeated in the accompanying table that describes the information flows. The numbering also follows the order of the steps in the processes set out in the use cases.

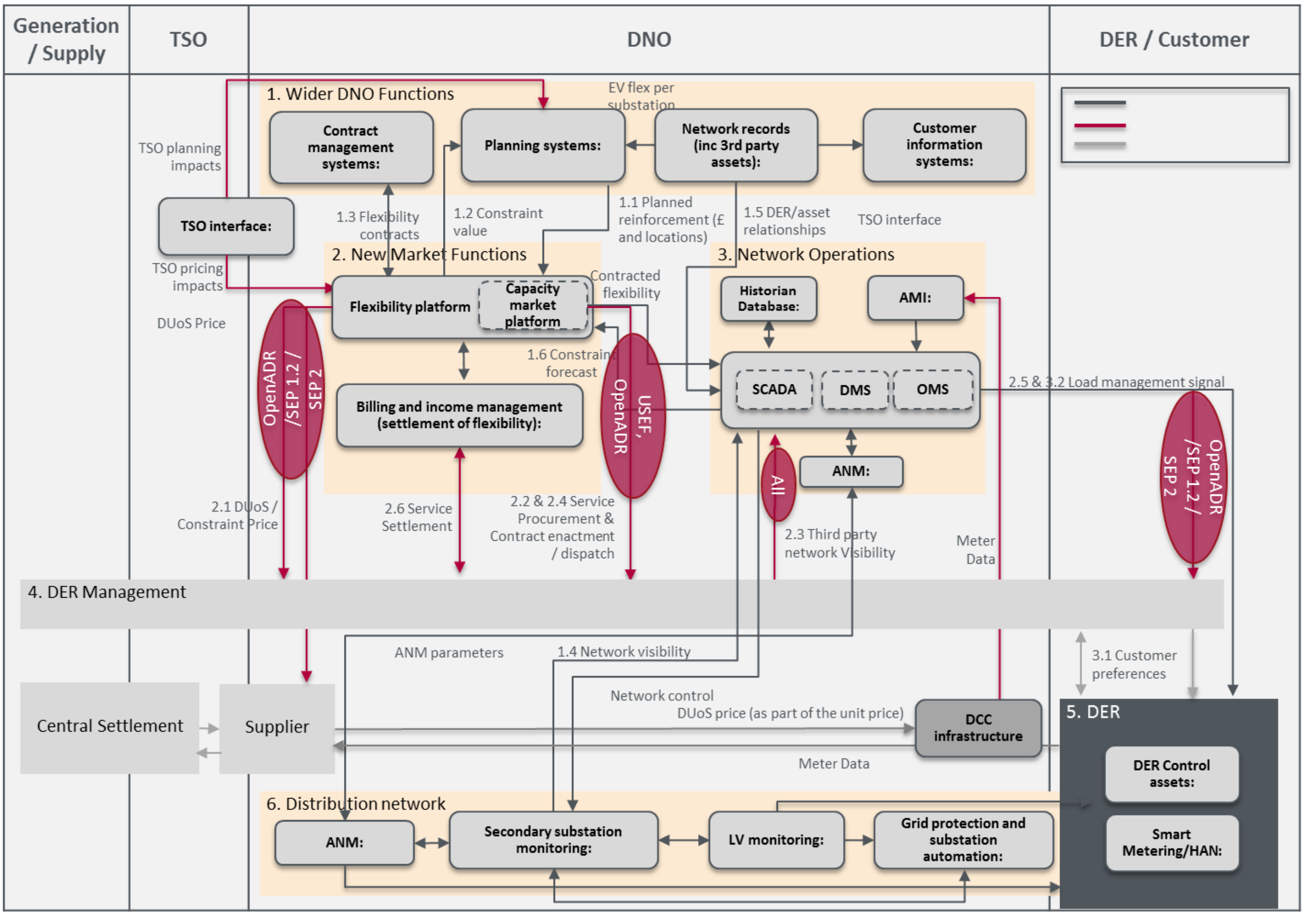


Figure 14: Information architecture for smart charging

Table 6 provides further information on each of the key information flows – the data items within that flow, a proposed frequency, communications channel and relevant standards – and has been used to help assess the validity of specific communications standards for each particular flow.

Information flow	Informed parties	Data Items	Frequency	Comms channel	Standards
1.1 Planned reinforcement (£ and locations and CP volume)	Internal DNO *Planning & Asset Management -> New Market Functions*	• Planned reinforcement sites (secondary and primary substations/circuits) in the next 2 years based on EV uptake and firm capacity • Volume of charge points associated with the sites	Revised quarterly	Internal	N/A
1.2 Constraint value	Internal DNO *New Market Functions -> Planning & Asset Management*	• Flexibility value of constraint (£/MWh, based on smart charging uptake and delivery assumptions) in order to determine the most economic	In response to planned reinforcement	Internal	N/A

		solution e.g. smart charge or reinforce			
2.1 Constraint price and locations	Market communication *New market function -> Third party*	• £/MWh • Locations (post codes within the boundary of affected substations) • Time period when valid	Revised quarterly Constraint prices may be updated more frequently to reflect "live" constraints	Published to a portal/website	OpenADR, SEP 1.2, SEP 2
2.2 Flexibility procurement	Market interaction *New market function -> Third party*	• Locations • Volume of flexibility • Time periods • £/MWh	Main tenders run annually (from March 2019) Additional services may need to be procured when a constraint is forecast, tender process needs to be less than a couple of weeks in this scenario	Via flexibility market platform	USEF, OpenADR
1.3 Flexibility contracts	Internal DNO *New Market Functions -> Contract Management*	• Participants • Flexibility contract details	Revised annually New contracts may be added in between when constraints emerge	Internal	N/A
1.4 DNO network visibility	Internal DNO *LV monitoring equipment -> Network ops function*	Measurements for each phase of each LV way: • Voltage • Active power • Reactive power • Current and neutral current	Half hourly averaged data required for historian Real-time data required when set thresholds exceeded	Connected to the Type E RTU as an IED via an Ethernet comms bus	DNP3/IP
2.3 Third party network visibility	Internal DNO *Third party -> Network Ops*	Asset information (MPAN, rating, phase) - > *potential data quality risk* • Voltage • Current • Active power • Reactive power	One off set up information (outside of interface) Typically sent at start of charging session, followed by Information sent every 15 minutes	Internet / data channel dependent on provider	OCPP / OSCP / OCPI / IEC 63310 / SEP 1.2 / SEP 2.0 / Open ADR / IEC 61850(-80-9)
1.6 Constraint forecast / monitoring	Internal DNO *Network Ops -> New Market Functions*	Updated information on constraints • Specific substation • Volume of MW reduction required • Time period	When required due to emerging constraint, >15 mins ahead	Internal	N/A
2.4 Contract enactment / dispatch	Market interaction *New Market Functions -> Third party*	• Specific substation (this may need to be a postcode) • Volume of MW reduction required • Time period	When required due to emerging constraint, >15 mins ahead	Via flexibility market platform	USEF, OpenADR

3.1 Customer preferences	External flow	• Customer charging preferences to optimize dispatch	Initial set up Updated when required	External	N/A
2.5 Load mgt. signal	Market interaction *New Market Functions -> Third party*	• MPANs affected • Curtailment duration • Rate of charge • Compensation	15-30 minutes ahead of curtailment	Internet / data channel dependent on provider	OCPP / OSCP / OCPI / IEC 63310 / SEP 1.2 / SEP 2.0 / Open ADR / IEC 61850(-80-9)
3.2 Load mgt. signal	External flow	DNO signal passed on to assets • Curtailment duration • Rate of charge • Compensation	Within 5 minutes of receiving DNO instruction	External	N/A
2.6 Service settlement	Market interaction *New Market Functions -> Third party*	• £ • Record of when flex was called on • Evidence of contract delivery	Monthly	TBC	TBC

Table 6: Key information flows

Recommendations for communications standards

There is one existing communications standard that meets the requirements for all of the use cases: Open ADR 2.0[12]. It is recommended that Open ADR 2.0 is considered for the interim solution as it the only communication standard which covers both the administered pricing and load management use cases (the proposed interim solution is further detailed in Section 6.2). However, there are other standards which can be used for a sub-set of the use cases (as specified in Figure 14).

Open Automated Demand Response (OpenADR) provides a non-proprietary, open standardized interface that allows electricity providers to communicate demand response signals directly to existing customers using a common language and existing communications infrastructure such as the Internet, utilising an XML data model which can be transported across a variety of mediums and interfaces. It is governed by the OpenADR Alliance, which is a member based organisation with 130 current member companies, and is therefore a well-supported open standard for Demand-Response. It has a strong support base in the US, and starting support in the EU and UK, and is already in use with EVs (both EV supply equipment as well as connected car).

We also believe there may be a longer term a standard for interaction between a charge point and the SMETS1/2 meter is developed (SMETS2 meters support Zigbee 1.2), as this could allow for the possible scenario where smart meters are used as control assets as well as granular charge point metering.

Two data flows within our use cases are not currently supported by any existing communications standard:

- **Asset registration**: notification to the DNO of asset installation and whether it is a “load managed” asset
- **MPAN to (technical) node mapping**: this information should be consistent and available to multiple market participants

[12] https://openadr.memberclicks.net/

Market interface infrastructure

We have not conducted a detailed assessment of the optimal infrastructure to select to manage the DNO's interface with the market for smart charging. There are a number of options which could be considered:

- **Internet** – Sending market requests via the internet would be quick to mobilise with high ease of access for all types of market participants. However, this information is then widely accessible, this is likely not suitable for sharing information linked to specific MPANs, there could also be issues around reliability as traffic bandwidth is not guaranteed.
- **IoT infrastructure** – The use of IoT infrastructure is likely more secure than the open internet. Conversely, it may take longer to mobilise within UKPN. There is a lack of maturity within networks to support an IoT approach and there will also be assurances required of reliance and security which are currently unproven.
- **SCADA infrastructure** – SCADA infrastructure would provide a very robust and fast communications infrastructure. However, this would be expensive to implement, and difficult for market participants to access. This type of infrastructure is more suited to incoming network visibility data, rather than sharing data with wider market participants.
- **DTN (Data Transfer Network)** – ElectraLink's Data Transfer Network (DTN) is a messaging and communications network, developed to underpin and support regulated data transfer in the electricity and gas industry. New data items could be added to allow for relevant smart charging communications. However, wider market participants such as charge point operators would need to gain access. This would then be a secure and governed communications channel which is not a proprietary approach by a single DNO.

The appropriate infrastructure should be investigated as part of a more detailed design phase of this work. In Section 6.2 we set out our intent to conduct a trial phase to design and deliver a minimum viable product to further refine the architecture designs, and propose to return to this question at that stage.

4.5.2 Equipment standards

There is currently limited consensus on smart charging equipment standards in the UK. This is an area set to be addressed under secondary legislation supporting the EV bill, as the primary legislation states the need for chargers to be "smart". It is also stated in the Road to Zero document that by 2018 all government supported chargepoint installations will have to have smart functionality[13]. There are a number of equipment standards already adopted, for example IEC 61851, which defines the rate of charge an EV can accept. However, a full set of smart charging equipment standards are yet to be defined.

Energy UK launched a smart charging consultation which closed in April 2018, which also encompassed a section on smart charger equipment standards. Respondents were asked for their opinions on what standards they would expect in terms of communication, interoperability, monitoring, accessibility, controllability and safety. At the time of writing, the window for responses had closed, but the results are yet to be published. It is not expected that this process will define the future specifications for smart chargers, but the insight generated will aid the government in the development of secondary legislation on smart charging standards.

In parallel to this, the Energy Network's Association (ENA) are in the process of developing an agreed position on the networks companies' recommendations for smart charging standards. This position will be used to consult, respond and advise relevant governmental bodies, such as OLEV, as well as industry, e.g. the British Electrotechnical and Allied Manufacturers Association (BEAMA), to advise the inclusion of these specifications in EV charge points going forward.

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[13] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/724391/road-to-zero.pdf

UKPN have also been developing documentation to feed into the ENA on the required characteristics and functions of smart chargers. A summary of those functions is provided below in Table 7, and the table of specifications submitted to the ENA can be found in Appendix G.

Category	System Capability	Use Cases associated with requirement for smart charger communication			
		2. Sign-up customers	3. Respond to ToU pricing	4. Flexibility procurement	8. DNO load-management
Safety	Power quality standards (if these can be mandated then DNO procurement of these services will be minimized)	✓	✓	✓	✓
	Safety: manual overrides, stochastic re-start following an outage	✓	✓	✓	✓
Communication	Robust (and user configurable) and reliable communication via secure channels	✓	✓	✓	✓
	Real time data exchange with a back-end system (system and control entity agnostic)	✓	✓	✓	✓
Network monitoring	Asset monitoring and measurement of current / voltage (this could also be via the smart meter)		✓	✓	
EV Comms	Send information on car charging state, i.e. connected / charging / discharging / standby / available		✓	✓	✓
	Indicate car's battery State-of-Charge (SoC)		✓	✓	✓
Charging data	Send near real-time smart charger operational data during charge cycle including current, voltage, bandwidth of charge rate (due to limitations set by cable/car) with low latency		✓	✓	
Control demands	Receive demands to change charge/discharge current		✓	✓	✓
	Ability for control by multiple entities – i.e. >1 interface				?
	Accept charge profile / charging limit		✓	✓	✓
	Log and transfer response to control request		✓	✓	✓

Table 7: Use case specific smart charger functionalities

In future, it may be necessary for the smart charger to interface with the smart meter for prices for ToU/locational DUoS in order to adjust the charge state based on price and customer preferences (if ToU/locational DUoS forms part of the network access reform). This interface may also be necessary in the scenario when the smart meter is used as the control device (as set out in SSEN's proposed SEC change[14]). More than one interface to the charge point would be necessary in the scenario where DNOs could send "opt-in" load management signals directly to charge points, however, this is not required if the signal is sent via the third party.

[14] https://smartenergycodecompany.co.uk/modifications/allow-dnos-to-control-electric-vehicle-chargers-connected-to-smart-meter-infrastructure/

Lastly, there are a number of functions which may be required in future, dependent on how the technology evolves over time. These options may include:

- Exchange information with other DER (PV, HEMS, home storage, etc.)
- Support 15118 to provide higher level of detail (useful for forecasting detail)
- Bi-directional charging (V2G) for ancillary services (incl. restore during outage)

UKPN's position on smart charger standards will be fed into the EV Energy Taskforce in order to inform secondary legislation to ensure all chargers are "smart" from 2019 (as set out in the Road to Zero).

5 The value of residential smart charging

5.1 Approach to determining the value of residential smart charging

In this publicly available document, we are unable to publish the full outputs of out cost/benefit assessment, but focus on the method followed and key conclusions. We conclude that there is a positive benefits case in UK Power Network's licence areas to pursue a smart solution to enable a rapid and lowest-cost uptake of electric vehicles. This section covers:

- **The impact of electric vehicle uptake on our network** – outlining our electric vehicle volume forecast, the resulting load growth required from our networks, the resulting network reinforcement required and the cost of that reinforcement, splitting out electric vehicles demand to estimate the cost of uptake in an "unmanaged" charging scenario (i.e. imagining what would happen if we do not pursue smart charging), and
- **The benefits of residential smart charging** – outlining how electric vehicle flexibility can be used to defer reinforcement by reducing the impact of charging on the network at peak times, setting out the benefits of that deferred reinforcement in terms of savings for the customer, and factoring in the approximate deployment costs to assess whether there is a cost/benefits case for smart charging when compared to traditional reinforcement.

5.2 The impact of electric vehicle uptake on our network

5.2.1 Electric vehicle volume forecast

UK Power Networks have worked in conjunction with Element Energy to define our load forecasts, through our 'Recharge the Future' project. As part of this work, we model electric vehicle take-up, from which EV peak load demands are derived.

This forecast creates a "Baseline" and "High" scenario for the volume of EVs in each MSOA[15], based on a number of factors including the current EV volumes in each MSOA, the percentage of vehicle sales which are EVs by 2030, and locational economic factors. These volumes are mapped to the specific primary and secondary substations in the MSOA areas, to create a volume of EVs forecast per substation. An uncertainty arises from the fact that the primary and secondary substations do not exactly match the MSOA boundaries, though the impact of this is expected to be small.

The forecast is currently being updated to align with the Road to Zero strategy, which will increase the EV volumes in the "High" scenario. For the purposes of our analysis the "High" scenario uses the EV volumes which would meet the Committee on Climate Change targets, representing 60% of vehicle sales by 2030, as set out in Figure 15 below.

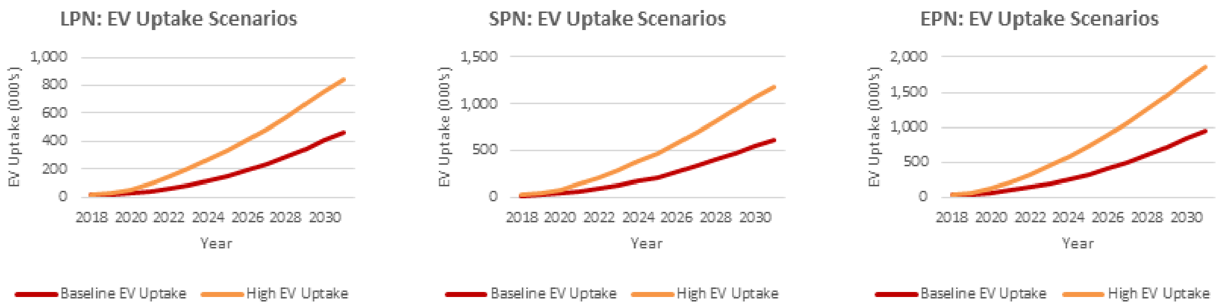


Figure 15: Element Energy EV uptake forecast

[15] MSOA stands for 'Middle Layer Super Output Area' – geographical areas defined by the Office of National Statistics for planning purposes, with populations of 5,000 – 15,000 people

This forecast is being developed as part of a related initiative, Recharge the Future, which will begin to publish flexibility needs to the market. The forecast generates graphical outputs to visualise EV uptake, as illustrated in Figure 16 below.

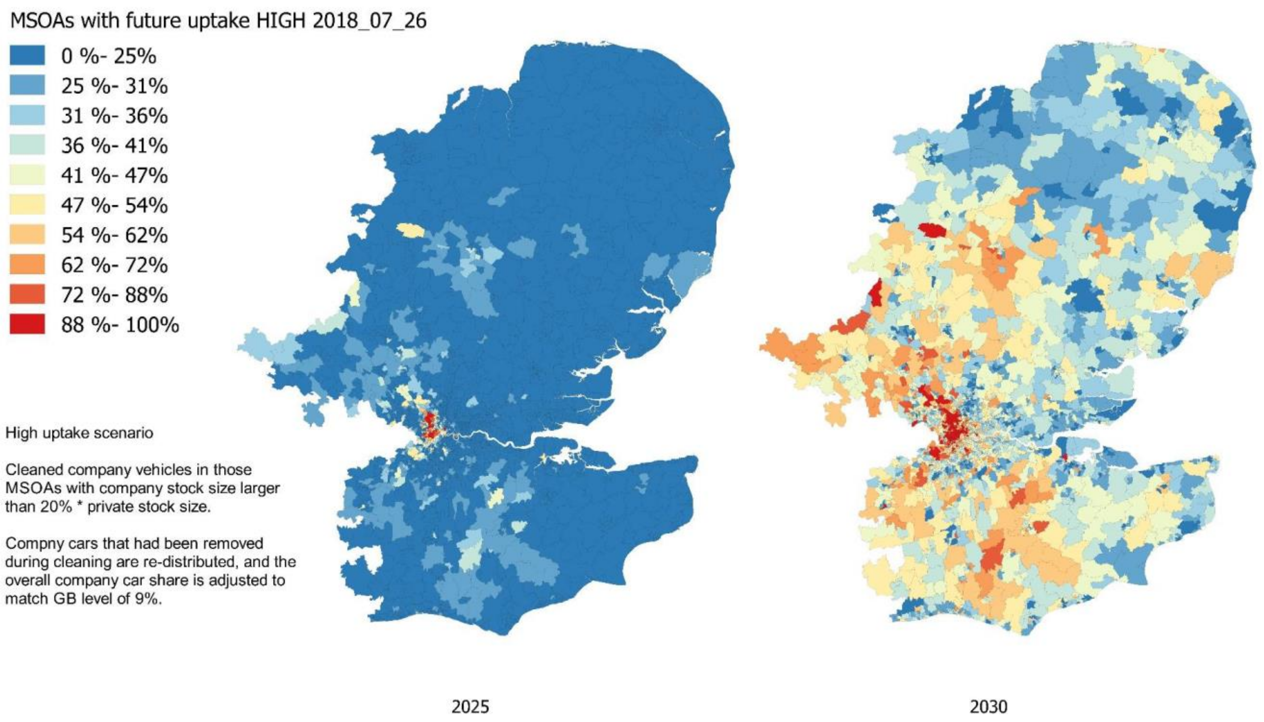


Figure 16: Element Energy modelling of geographical variance in EV uptake (percent of stock)

5.2.2 Electric vehicle load forecast

We have also calculated a peak load forecast associated with each substation, which is made up of domestic, I&C, heat pump and EV demand. The EV peak demand used in our modelling includes all cars, both private and commercial, but excludes vans and HGVs. The forecast accounts for all types of charging, including home, work place and rapid. The following pie chart shows the national charging split across vehicles and locations[16]. The SmartCAR project focusses on smart charging solutions for residential customers as residential charging currently makes up >72% of all charging, and this value could be higher if commercial residential cars follow similar charging patterns. There remain uncertainties about how charging behaviours will adapt in future, but this supports the case for smart charging at present as an alternative to reinforcement whilst the end state is still unclear.

"Residential car charging currently accounts for more than 72% of all charging"

[16] Private EV charging activity by location is taken from Ofgem's Future Insights on the Implications of the transition to Electric Vehicles. Vehicle numbers and types are from SMMT data. These two sources have been collated to produce the below pie chart.

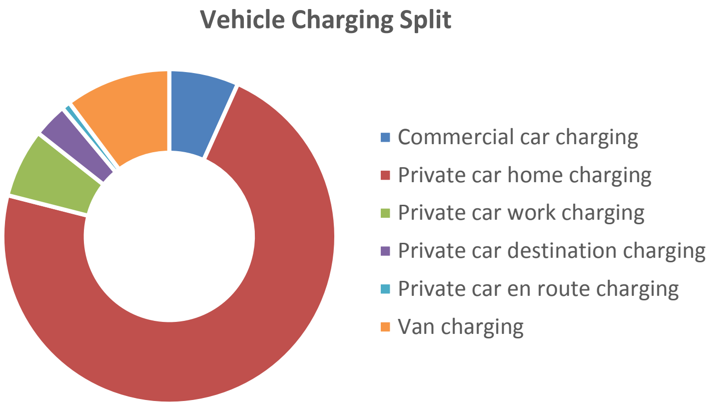


Figure 17: Split of charging across vehicle types and locations

Figure 18 below shows the proportion of peak load which is due to EVs for each DNO in order to examine their incremental impact. The charts show that on the LV network there is a slight increase in domestic and I&C demand from 2018-2031, however, the majority of the peak load growth is due to EVs with some contribution from heat pumps. The top line of charts show the peak load growth for the EV baseline scenario and the bottom line for a high uptake scenario. In the high EV uptake scenario peak load on secondary substations grows by approximately 30% by 2031.

Figure 18: EV vs. non-EV peak load forecast

> ***"In the high EV uptake scenario overall peak load on secondary substations grows by approximately 30% by 2031."***

We have then used the overall network proportion of peak load due to EVs to attribute an equivalent proportion to each primary and secondary substation, according to their respective forecast number of EVs. This EV peak load per substation is then scaled to account for load diversity based on the number of EVs. This peak load diversity curve has been derived from 377 EVs in WPD's Electric Nation trial, which reveals a natural variance in charging behaviour giving rise to a diversity relationship – i.e. the larger the number of EVs in an area, the lower the average peak load per EV, given that they naturally charge at different times. A minimum value of 1 has also been applied to the diversity scaling curve to ensure the peak load per EV at individual substations is not lower than the derived top-down network level peak.

Figure 19 below shows how the peak demand per EV reduces with increased number of EVs due to this behavioural diversity, and Figure 20 illustrates the diversity curve derived from Electric Nation. This diversity is associated with residential "unmanaged charging" prior to any coordination through smart charging, and will therefore be used to calculate reinforcement needs in an unmanaged charging scenario.

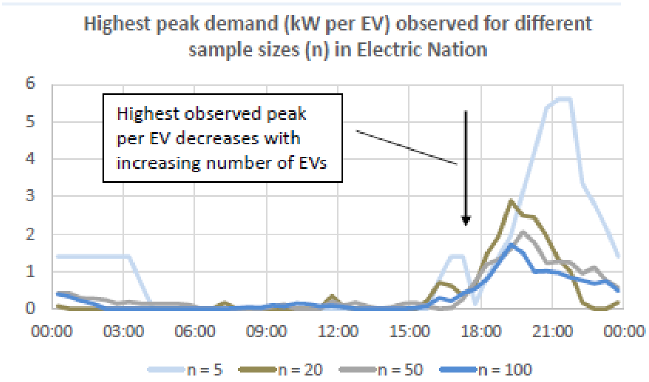


Figure 19: Peak load per EV with increasing EV numbers[17]

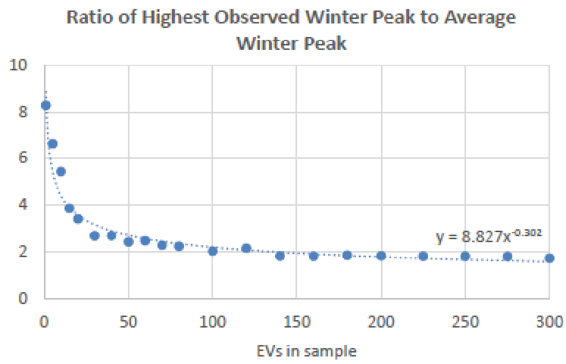


Figure 20: Diversity curve of peak load vs. # of EVs[18]

5.2.3 Network reinforcement volumes

The peak load forecasts discussed above were generated at substation level (both primary and secondary) and have been used to determine network reinforcement requirements. This has been assessed by comparing the peak load growth at each substation against the substation firm capacity rating (load limit of a substation).

When peak load forecast reaches 110% of firm capacity, we assume a reinforcement action will take place on the substation and surrounding infrastructure (for example this could include a new transformer and in some cases the switchgear replacement, surrounding circuit and cabling, land purchase etc.). The 110% of firm capacity reinforcement trigger accounts for the fact that the firm capacity of a substation will typically be exceeded for some time before reinforcement takes place, as a one off load exceeding the limit would not require reinforcement. This allowed us to calculate both secondary and primary substation reinforcement volumes.

The modelling showed that there was a significant increase in the volume of secondary substations requiring reinforcement before 2031. The annual volume of secondary substations requiring reinforcement increased in earnest from 2021 and continued to increase year on year. The impact on the primary substations is felt later than for secondary substations, although there is an increase in primary substation reinforcement volumes from 2025. Across all levels of the network EVs are the primary driver for reinforcement.

[17] Highest peak demand per EV observed during WPD's Electric Nation trial

[18] Unmanaged diversity curve derived from 377 residential EVs in WPD's Electric Nation trial

The difference in the volume of substations requiring reinforcement as a result of other peak load growth varies between the baseline and high EV uptake scenarios. This is due to the fact that the peak load forecast data is different for each of these scenarios.

A sensitivity analysis was also carried out to assess the impact of altering the reinforcement "trigger point". The modelling detailed in this report used a trigger of 110% of firm capacity. If this trigger was reduced to 80% of firm capacity, reinforcement volumes increased by 55%. A lower trigger may be necessary for radial network configurations as more headroom is required for diverting load. Furthermore, the trigger point may need to reduce in future as substations are run "hotter" overnight due to shifted demand; this will mean that they are less able to exceed their capacity at peak. A higher reinforcement trigger of 120% was also tested as in some circumstances substations are allowed to exceed capacity for short periods of time; this reduced reinforcement volumes by 19%.

This sensitivity analysis showed that reinforcement volumes were very sensitive to the "trigger point", so it is recommended that a range of scenarios are assessed as part of any future modelling and investment planning.

5.2.4 Key implications for customers and the network

The above modelling has shown that EV uptake will have an impact at LV network levels ahead of HV, this is due to the effects of clustering. EV clusters are as a result of a number of drivers:

- Natural variance leads to an uneven EV uptake per feeder (and phase), which is less pronounced at HV levels due to the larger boundary
- Affluence tends to be regionalised and is contributing factor to EV uptake
- Initial EV uptake promotes further local uptake
- EV uptake increases where there is existing charging infrastructure

Our modelling has shown that (under a traditional reinforcement case) for an example secondary substation with a current peak load of 91% of firm capacity (500kVA, approximated using transformer ratings), a cluster of 55 EVs (evenly distributed across LV ways) will trigger reinforcement. At LV feeder level this is even more pronounced, as 11 EVs will exceed the firm capacity (assuming 5 ways/secondary substation), this could be as little as 5-10% of people on a street owning an EV. The number that triggers reinforcement would be lower if EVs were not evenly distributed amongst phases.

The impact of EVs will vary for different customers, dependent on their local substation headroom and the volume of other EVs under their corresponding LV feeder and secondary substation. The problem is localised, as there is higher load diversity under a primary substation, due to the larger catchment area and industrial loads which may be connected. The above analysis shows that in the shorter term EV uptake is primarily a low voltage issue.

5.2.5 Cost of "unmanaged" charging

Based on the reinforcement volumes (as detailed above), we calculated an estimated cost of unmanaged charging – i.e. what it would cost to reinforce the network to facilitate the uptake of EVs, without deploying smart charging.

Representative reinforcement costs for each licence area have been taken from UKPN's annual regulatory reporting on ED1 costs and reinforcement volumes. The data was taken from the 2016, 2017 and 2018 submission of the CV1 (primary reinforcement) and CV2 (secondary reinforcement) RIGs tables. An average value of £/MVA released was calculated over the past 3 years. These costs include the direct costs associated with a reinforcement scheme, including substation upgrades, circuit reinforcement and power quality measures. The scheme level data was also analysed for both primary and secondary reinforcement to validate these figures.

We anticipate that EV uptake will trigger circuit reinforcement as well as substation upgrades as the cabling surrounding LV feeders will also need upgrading, so for cost modelling purposes we have assumed a triggered reinforcement scheme would also involve circuit reinforcement. As a result the £/MVA values for secondary reinforcement appear high, as they also account for circuit reinforcement which is not related to MVA release from a regulatory reporting perspective.

Through this method we calculated the counter-factual from which we could estimate the benefits of smart charging, and the value of flexibility on the LV network. We are not able to publish these value at this time, as we will need to undertake significant further modelling to validate this initial work. In addition, such values are commercially sensitive, and we will need to determine the best way to engage with the market to reveal the value of flexibility in the market.

5.3 The benefits of residential smart charging

5.3.1 Financial benefit drivers

The primary financial benefit of residential smart charging is delivered through deferred network reinforcement. Reinforcement deferral gives rise to cost of capital savings in present value terms. The implementation of smart charging means that peak load can be reduced, and as result reinforcement can often be delayed by a number of years. The benefits derived as part of this modelling are based on the current value of reinforcement deferral.

Smart charging can reduce overall peak load as the proportion of peak load attributed to EVs can be decreased by shifting demand away from peak. As the number of EVs increases, so does the benefit of smart charging, as a larger proportion of the peak load is due to EVs. Figure 21 below shows an illustrative diagram of how smart charging can defer reinforcement.

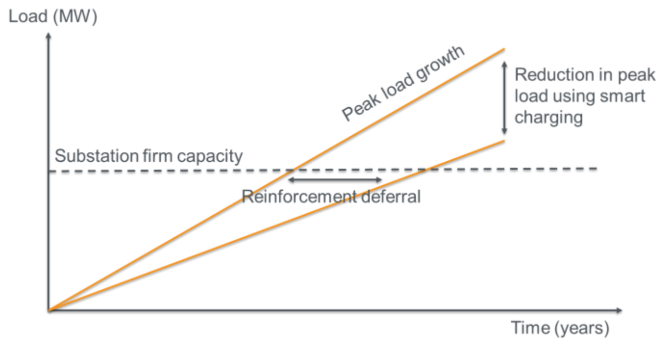


Figure 21: Illustrative diagram of reinforcement deferral via smart charging

There are also further potential benefits in the form of:

- Optionality value, in terms of not having to carry out reinforcement which in future is rendered unnecessary, for example if home charging does not develop as expected. The option value associated with uncertain load growth has been previously explored by Imperial College as part of UKPN's "FUN-LV" project. Based on selected case studies their analysis showed that option value could be significant in association with flexible assets. This has not been modelled in detail as part of this project, as the focus has been predominantly on reinforcement deferral. However, it is important to note there could be further benefits via optionality value due to the uncertainty of EV uptake.
- Increased connection speeds, as flexible options can be offered with smart charging, connection costs should also be lower. This is a benefit in terms of customer experience, particularly as 100k new connections are completed in UKPN's area each year[19].
- Improved resource management for network reinforcement, as reinforcement can be spread over more years, reducing the need to increase the size of the workforce.

For the purposes of this analysis we will focus on the benefits with reinforcement deferral only.

[19] https://www.ukpowernetworks.co.uk/internet/en/about-us/documents/our-networks-your-power.pdf

5.3.2 Key inputs and assumptions

Table 8 below lists the key modelling data inputs and their sources that have been used to build up the cost/benefit assessment.

Data Item	Description	Source
Peak load forecast	Baseline and high scenarios (to meet Committee on Climate Change targets) for total peak load growth associated to each primary and secondary substation (MW)	Element Energy – June 2018
EV peak load forecast	Baseline and high scenarios (to meet Committee on Climate Change targets) for EV peak load forecast associated to each primary and secondary substation (MW)	Element Energy – June 2018
Firm capacity (primary)	Firm capacity of each primary substation (MW)	PLE – September 2017
Firm capacity (secondary)	Transformer ratings for each secondary substation used as proxy for firm capacity (MW)	Transformer ratings from UKPN Asset Register
Discount rate	Used to calculate net present value of cost of capital (3.4%)	The Green Book
Primary reinforcement step up	Incremental primary reinforcement step up (30 MVA)	RIIO-ED1 reporting – Load related expenditure, 2014
Secondary reinforcement step up	Incremental secondary reinforcement step up (250 kVA). Secondary reinforcement transformer upgrades are generally 100kVA to 1000kVA.	RIIO-ED1 reporting – Load related expenditure, 2014
Reinforcement costs	Cost of reinforcement (£/MVA) as detailed in section 4.4.	ED1 submission

Table 8: Modelling data inputs

There are also a number of variable inputs which affect the net benefits. In order to understand the impact of these variables we have run a number of scenarios through our modelling:

- *Baseline EV uptake scenario*: Baseline EV uptake data and 50% of EV customers take up smart charging propositions
- *High EV uptake scenario*: High EV uptake data and 80% of EV customers take up smart charging propositions
- *ED1*: Models the baseline EV uptake scenario over the next 5 years

A description of the variable data items within the scenarios is detailed in Table 9:

Data Item	Description	Baseline Scenario	High Scenario	Source
Smart charging uptake	The proportion of EV customers who take up a smart charging proposition with a third party	50%	80%	Assumption, this needs to be tested via market trials
Smart charging EV peak load reduction	EV peak load reduction for those customers partaking in smart charging	90%	90%	Observed in WPD's Electric Nation project, see Figure 22.

Consolidation: Input into model	EV peak load reduction due to smart charging (compared to unmanaged) based on the proportion of consumer uptake	55%	28%	Consolidation of the above

Table 9: Variable model inputs

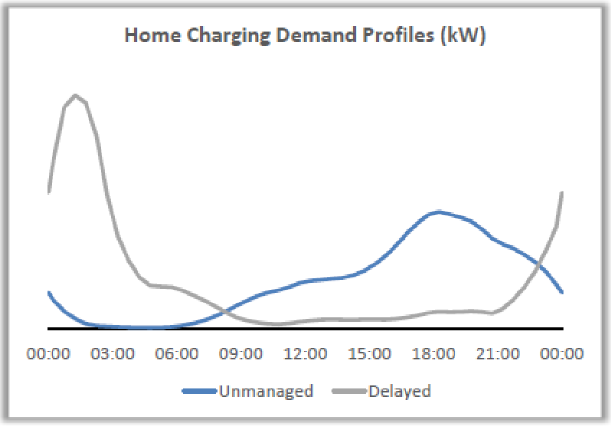


Figure 22: WPD's Electric Nation charging profiles

The reduction in EV peak load as a result of smart charging has been informed by WPD's Electric Nation trial. The change in charging profile as a result of incentives[20] within the Electric Nation trail has been detailed in Figure 22 on the left, in which the 18:00 – 20:00 peak has been reduced by 90%.

A range in smart charging proposition uptake has been modelled to understand the impact on benefits. This value will need to be further validated through trials to assess interest in customer propositions.

5.3.3 Cost of smart charging implementation

In order to determine the net benefits of smart charging, we have carried out an assessment of the implementation costs, these are made up of the following:

- **Central system changes**: These include the system changes associated with smart charging, but exclude the wider costs which are already attributed to other projects (e.g. ANM implementation). The central costs are assumed to be shared equally across the three DNOs, half of each of the DNO's cost are attributed to secondary substations and the other half to primaries. The majority of the central systems development is required regardless of which smart charging model is implemented (e.g. the systems required for load management systems are not specific to that use case), and as a result a single central system cost has been modelled.
- **Asset telemetry**: These are the costs associated with LV monitoring, and it is assumed that LV monitoring is required in order to implement smart charging. This is a variable cost which scales with the number of secondary substations where smart charging is required.
- **Customer incentive cost**: There will be a cost associated with a customer incentive in order to shift their demand away from peak. This cost has not been included as an input, so as to understand the total "pot" available for flexibility incentives. Therefore we will output the maximum value of the flexibility "pot" if all net benefits were to be passed on to consumers.

[20] Electric Nation participants were paid an £150 contribution to a smart charger, to be topped up by the OLEV home charge grant scheme, as well as £35 worth of vouchers for completing surveys.

Data Item	Description	Source
Central system upgrade costs	Central costs of systems upgrades associated with smart charging as discussed in section 4.4, excludes wider projects which smart charging will benefit from e.g. ANM. £9m total (mid-point long term cost assumptions), assumed £3m per licence area	See section 4.4
LV monitoring cost/secondary substation	[Redacted]	LV Network Use Case Options (UKPN's LV monitoring project)

5.3.4 Modelling the Benefits of Smart Charging

Smart charging will not deliver benefits at every substation, as the net benefits are dependent on the reinforcement cost inputs and the number of EVs per substation, as this affects the reduction in peak load smart charging can deliver. Smart charging is only considered beneficial once the reinforcement deferral savings exceed the cost of implementation. Smart charging needs to deliver at least one year's reinforcement deferral to cover the cost of implementing LV telemetry (central system costs are not considered on a per asset basis). Therefore reinforcement deferral of less than a year through smart charging is not considered suitable for implementation.

Figure 23 shows a schematic of the input data sets, variable inputs and model outputs:

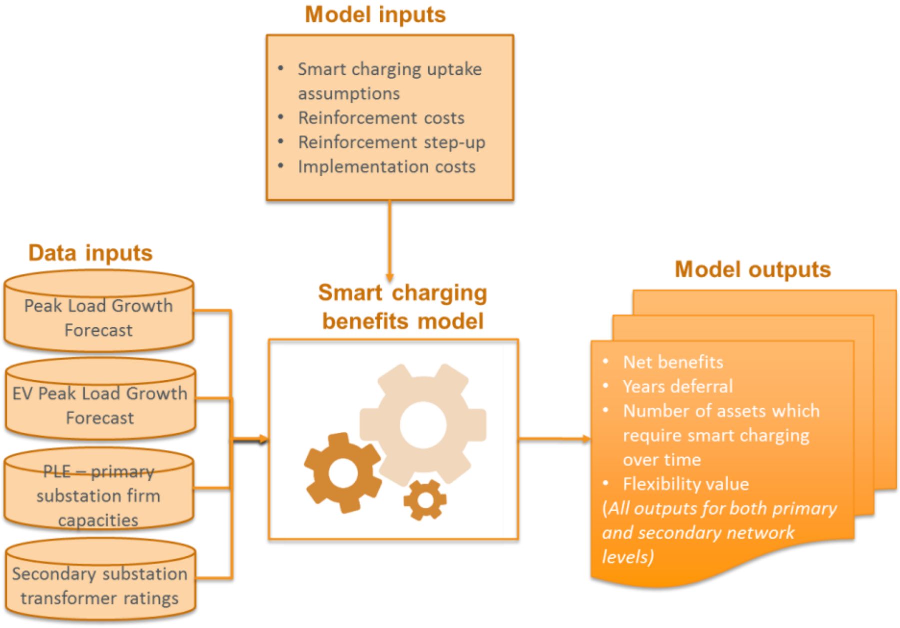


Figure 23: Schematic of the smart charging benefits model

The following methodology was employed to calculate the net benefit of implementing smart charging:

- The reinforcement trigger date was calculated for each primary and secondary substation in an unmanaged charging scenario. Reinforcement is triggered once the forecast peak load for the individual substation exceeds 110% of firm capacity.
- The reinforcement trigger date is calculated for each substation in a smart charging scenario, where the proportion of peak load due to EVs can be reduced according to smart charging input assumptions.
- The difference between reinforcement trigger dates for unmanaged and smart charging were calculated for each primary and secondary substation. As mentioned above, the length of reinforcement deferral for an

individual substation must be at least one year to cover telemetry implementation costs. If smart charging defers reinforcement by less than one year, the individual substation is not considered a suitable asset for smart charging.

- The model outputs the volume of substations where smart charging could deliver deferral for every year to 2031, this was also assessed as a proportion of the total asset base. It is also possible to assess which substations require reinforcement in any given year as well as the volume of EVs which has triggered the reinforcement.
- The total average reinforcement deferral was calculated for both primary and secondary substations
- The benefit of the deferral at each substation was calculated based on the reinforcement cost inputs, and this was then aggregated for each DNO.
- The volume of assets which were not suitable for smart charging were also assessed e.g. the reinforcement deferral was less than one year and therefore implementation costs could not be covered, or there were insufficient volumes of EVs to reduce peak load below the reinforcement trigger point.

5.3.5 Modelling the Value of Flexibility

The value of flexibility (i.e. the benefits per MWh) has also been estimated to help understand the potential value of incentive payments, and to assess whether they are sufficient to encourage consumers to shift their demand.

The flexibility value (£/MWh) was calculated by dividing the total benefits of smart charging for a given substation (and associated circuits) by the estimated total number of MWh that would need to be 'bought' to avoid reinforcement. This estimate of MWh has been constructed using broad assumptions, and so should be treated as an indicative assessment at this stage. The assumptions used are illustrated in Figure 24 below.

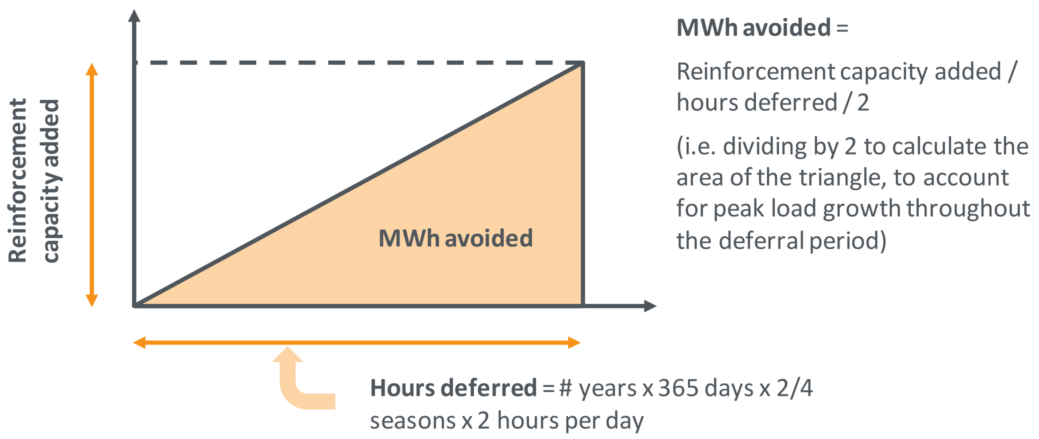


Figure 24: Value of flexibility

This assumes that flexibility would be called on every day for 2 seasons of the year, to avoid a 2 hour peak, based on WPD's Electric Nation finding (18:00-20:00). We also assume that load growth would continue throughout the deferral period, which would end when the reinforcement is eventually triggered at a later date. We therefore calculate the area of the triangle illustrated above as an estimate for the MWh that would need to be "bought" with the flexibility pot.

There is significant variance in the reinforcement costs (reported for the ED1 submission) between the 3 DNOs, and as this is directly proportional to the flexibility value (£/MWh), this will affect how appealing smart charging propositions are to customers. For example, the average £/MWh for secondary substation flexibility in LPN is more than twice that of SPN and EPN, reflecting the increased cost of more urban reinforcement.

There is further work to do to assess whether the flexibility values detailed above are sufficient to drive customer behaviour and to meet the inputted smart charging uptake assumptions. Proposed trials are discussed in section 6.2.

5.4 Recommendations

The preliminary SmartCAR CBA suggests there is a business case for smart charging, and implies that low voltage load growth will drive a significant increase in LV reinforcement needs throughout the 2020s.

The reinforcement volume modelling follows a similar approach to that used for the PLEs (as currently applied for primary reinforcement modelling). However, this approach utilises some approximations (such as modelling based on substation capacities and not assessing associated circuit capacities), and there is limited live LV load data to calibrate the forecasts against due to the lack of LV visibility and monitoring.

The £/MVA cost allocations (particularly for secondary substations) appear high to the business due to the treatment of circuit reinforcement costs. In addition, the data used in this modelling is based on a reactive historic spend profile, which may not be representative of future actions. However, this does tally with the estimated £/MVA for new connections and aligns with SPEN's methodology used within the 'LV engine' project.

As such we recommend that a strategic plan for ED2 LV reinforcement is developed to understand the scale of the challenge as a result of LV load growth via EVs. This will also enable and improve any further projects which involve an LV CBA. Lastly, smart charging trials should be mobilised based on the business case developed to date and this is further discussed in Section 6.2.

6 Smart charging architecture roadmap

The capabilities set out in Section 4 describe the functions that are likely to be required in the long-term to support smart charging. In this section, we investigate the required timeline for deployment of these capabilities, by examining external triggers such as the rate of electric vehicle uptake and related industry milestones.

Based on this roadmap of capabilities, we also set out the timeline of required solutions deployment, the minimum viable product that UK Power Networks will need to deploy in the short-term to support an 'interim solution', and our view of required trials and design work required across the industry to move the smart charging debate forward.

6.1 Smart charging architecture roadmap

6.1.1 Industry milestones and three broad phases of development

As set out in section 5.2.3, in the next 5 years we expect to see uptake of electric vehicles trigger reinforcement needs at c.100-200 secondary substations, or 0.5% of the total population, and associated circuit reinforcement works. There is an opportunity in this timeframe to achieve NPV benefits of £22m through smart charging, including the costs of system development, with further benefits of £250-900m in following 8 years.

There is activity across the industry geared toward enabling this uptake, and progress is expected for instance in smart charging standards development and infrastructure delivery. However, there are two key design milestones which will influence our timelines for developing smart charging capabilities:

- The timescales of the Energy Networks Association's (ENA's) Open Networks programme, and evolution of the design and implementation for the future Distribution System Operator role; and,
- Ofgem's Network Access & Forward-Looking Charges review, and the timescales for potential design and implementation of changes to the DUoS charging regime.

The ENA's Open Networks Programme and Ofgem's Network Access & Forward-Looking Charges review are both investigating reforms that may interact with and enable smart charging. However, we expect that the timescale for any major changes that arise from these programmes will likely extend beyond this 5-year horizon in which electric vehicle impacts begin to arise on our network. It is also likely that changes to the role of the DNO or to the DUoS charging regime will need to be consulted on and enacted via the RIIO-ED2 framework, which will not be in place before April 2023. It should be noted that at present the scope of any such reforms is also uncertain, and so it is not clear whether initial reforms would go far enough to enable smart charging.

We are therefore treating 2023 and the beginning of RIIO-ED2 as a planning milestone, and believe there is the potential for industry-wide change to take place at this point which may assist in supporting smart charging. However, we believe we will also need to begin developing an interim solution ahead of this timescale, for a number of reasons: Firstly, modelling suggests that smart charging will be the most economic way to facilitate electric vehicle uptake in some areas, and so presents an opportunity to develop flexibility solutions at the LV level; secondly, we believe there is a positive NPV benefit to implementing smart charging within ED1 timeframes, and to do so requires mobilising trials now to develop a solution capable of driving benefits at scale after 2020; thirdly, developing an interim solution will help to generate learning and insights which will help to inform longer-term reform, and finally it will also help UKPN to develop skills and capabilities that will be required to operate in the DSO role, and hedge against the risk that reforms do not go far enough.

We therefore propose a roadmap with three broad phases:

- Phase 1: Market trials for interim solutions (2018-2021)
- Phase 2: Interim market solutions (2021-2023)
- Phase 3: Transition to mature market solutions (from 2023 and the start of ED2)

These phases are illustrated in Figure 25 below.

Phase	Market trials	Interim market solutions	Industry-Wide Solutions
	2019-20	2021-23	2023-31
Smart charging opportunity	**0.2%** of secondary substations	**0.5%** of secondary substations **c.£20m NPV***	**5%-13%** of secondary substations **7%-20%** of primary substations **£250m-£900m NPV***
Evolution of market mechanisms	Flexibility tenders and framework contracts Develop LV flexibility mechanisms – e.g. interim pricing smart charging	Increase use of flexibility (HV and LV) as an alternative to reinforcement and drive NPV benefits in ED1, develop capabilities and inform reform	Transition to ED2 incentive framework Earliest anticipated DUoS reform Transition to new DSO model?

Figure 25: Broad phases of smart charging development

6.1.2 Roadmap of capabilities required

Figure 26 below illustrates the evolution of capabilities required to support smart charging. The diagram summarises broad elements of capabilities required at different times, based on the more detailed requirements developed through the architecture phase of this project. Appendix F sets out the requirements in a detailed matrix, with a cross-reference to identify which requirements are relevant at each of the broad three phases.

Phase		Market trials	Interim market solutions	Industry-Wide Solutions
		2019-20	2021-23	2023-31
2. New Market Functions	2.1 Calculate and publish market information	Publish LV flexibility needs (bulk and smart charging) Publish administered LV constraint prices (trial)	Broad use of administered LV constraint prices Coordination of LV needs with TSO constraints	As required to support DSO transition Ability to publish enhanced DUoS for settlement
	2.2 Capacity allocation and management	(Not as relevant for residential smart charging)		Key: Required function; Uncertain function
	2.3 Flexibility procurement	Generate and maintain LV procurement strategy LV flexibility procurement trial (administered prices) Manage flexibility customers and contracts	Smart charging in general use (administered prices) Scale up number of smart charging sites Run bulk flexibility tenders for LV constraints	DSO transition Continuation of interim procurement as required Potential to procure smart response for HV
	2.4 DER settlement	Settle forward flexibility tenders Settle smart charging and load management (trial)	Scale up settlement of smart charging and load management (automated)	Transition to DSO settlement arrangements Continuation of interim settlement as required
3. Network Operations	3.1 Network visibility	LV network model (proof of concept) Gain visibility of priority sites for LV flexibility trials	Scale up LV network model functionality (e.g. real-time, data items, number of sites)	Real-time network model (full network)
	3.2 Energy flows forecasting	Long- to medium-term LV forecasting Dynamic forecasting for trial sites as/if required	Dynamic state estimation (priority sites) Coordination of LV needs with TSO constraints	As required to support DSO transition Ability to publish enhanced DUoS for settlement
	3.3 Optimisation & real-time dispatch	Develop load management capability (trial)	Load management to support EV uptake (minimised)	Reduce load management as smart charging matures
	3.4 Outages and restoration	Integrate new flexibility approaches	Investigate potential for V2G	Potential use of V2G for outage management

Figure 26: Required evolution of capabilities to support smart charging

Broadly, the roadmap illustrates the need to conduct trials and market development in the 2019-2020 timeframe in order to develop the basic capabilities for smart charging via the interim administered pricing approach and load management, ahead of a broader deployment in the 2021-23 timeframe. Within this second phase, smart charging, and other flexibility sources) would need to be operational on some sites in order to manage electric vehicle uptake ahead of reinforcement as the most efficient solution. There is some uncertainty in relation to this phase, as the exact nature, scale, and cost/benefit, of some of the detailed capabilities will need to be determined through trials.

The third phase becomes much more uncertain, and is dependent on the outcome of industry design processes looking into the reform of network access and charging, and DSO models. In this phase we would look to transition to industry-wide approaches as the needs for flexibility increase, although the capabilities developed in phase 2 would serve to inform this design work and also serve as an established solution to assist in managing the transition, and likely to form the basis of enduring solutions.

6.2 Our proposed interim pricing trial

As set out in Section 6.1.1 we believe there is a need for an interim smart charging solution, based on price signals, ahead of proposed wider reform in 2023. We are therefore mobilising a trial to access LV flexibility from EV smart charging, in order to develop and deploy a viable solution ahead of 2021, to drive benefit in the period 2021-2023. These trials will investigate new forms of smart charging – in which the DNO enables the market to manage smart charging in response to price signals and other market mechanisms.

The objectives of this trial will be to:

1) Stimulate the development of market-led smart charging solutions, working with market participants to develop, enable and trial customer propositions – including:
    - Price-based mechanisms – i.e. testing a constraint price signal (to inform DUoS reform) as well as alternative pricing mechanisms, such as flexibility procurement and capacity allocation/management
    - DNO load management on an opt-in basis, compensated and enacted via 3rd party infrastructure.
2) Develop and test processes, systems components and commercial arrangements to enable these propositions
3) Understand customer response to these propositions and network impacts in a controlled environment
4) Develop a scalable solution that can be expanded to a large volume of customers ahead of broader reform
5) Inform Ofgem’s longer-term access and network charging reform

We will be engaging the market further in the development of these trials, and will be publishing details as part of the next stages of our Flexibility Roadmap.

7 Conclusions

Summary of our smart charging strategy

Following a broad assessment of possible smart charging approaches we identified four key mechanisms to consider as means to facilitate smart charging – constraint pricing (via DUoS reform), flexibility procurement, capacity allocation and management, and DNO load management. These mechanisms are spread across a spectrum from "market freedom" to "DNO action", and are likely to draw a corresponding divergence of views across stakeholders. These approaches were summarised in the following diagram:

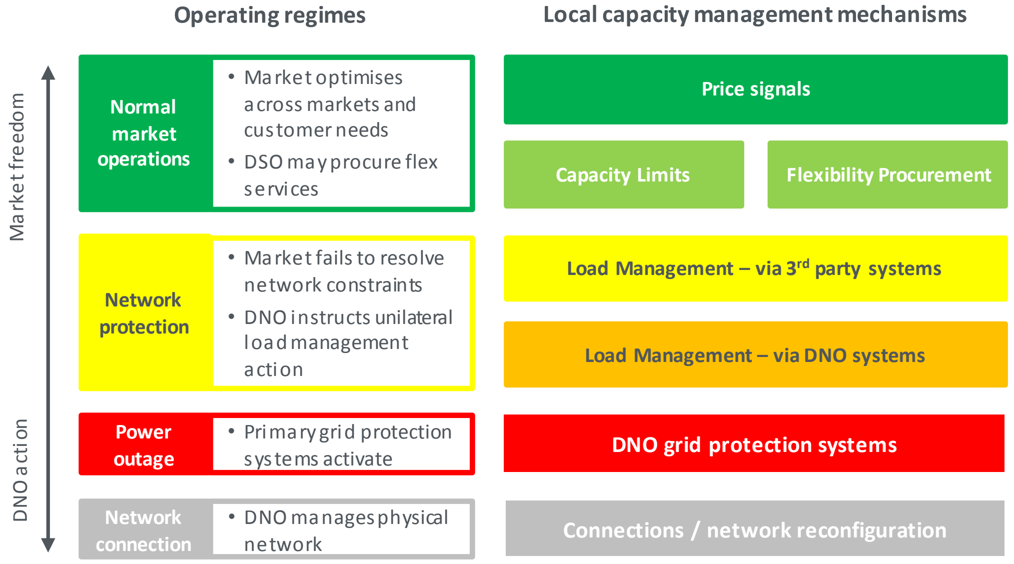


Figure 27: Hierarchy of smart charging mechanisms

UK Power Networks' strategy for smart charging is to pursue market-based approaches, in which 3rd parties deliver propositions that enable customers to mitigate their impact on the network and share in the benefits.

We believe that the end-state model in the UK should be based on reformed network price signals (i.e. reformed DUoS charging). This would enable customers to have the ultimate choice as to whether to charge at peak times, would serve to recoup network costs from the customers driving the increased costs, and is the method preferred by stakeholders.

However, this approach will need to be tested, and it may take some time to establish. Other methods may be required in an "interim" period, and we believe alternative market mechanisms, such as flexibility procurement or load management via 3rd parties (if compensated and opt-in) could also be effective and may prove quicker to implement.

We therefore intend to investigate the various "interim pricing" approaches with market participants through trials. This will help to test the efficacy of these market-based mechanisms in managing network constraints, will stimulate the market to develop propositions, will help to inform Ofgem's pricing reform, will help us to develop the capabilities we will need for the future, and may enable reinforcement deferral in the remainder of ED1.

Architecture assessment and roadmap

Following on from the definition of our smart charging strategy, we set out the high-level architecture required – including use cases, a value chain, a functional architecture map and requirements, a systems component and communications map, a systems impact assessment, and a review of the required communication and equipment standards.

An architecture roadmap has been developed that specifies when particular capabilities will be required, driven by EV uptake and wider industry change milestones. This phasing has also been mapped to the existing systems delivery schedule, to understand whether requirements are being (or can be) delivered by existing systems and existing projects, or whether new systems or projects might be required.

The value of flexibility

Our modelling work has provided insight into the impacts electric vehicle uptake will have on our network, and highlights that LV impacts are likely to begin to be seen within the next 5 year horizon as clusters of EVs begin to form.

We have confirmed that smart charging will be the most economic solution to managing electric vehicle uptake in some circumstances, with a positive NPV benefit, and have identified candidate sites and circuits that will begin to experience constraints first. It has not been possible to separate out the benefits of the different viable approaches (i.e. constraint pricing, flexibility procurement and DNO load management) but our strategic roadmap suggests that all of these approaches should be part of the future approach in some way, and so all should be pursued. In addition, the costs of pursuing all approaches still yield a positive NPV.

It is possible that DNO load management as a solution will not be required, if the market can deliver sufficient smart charging response when provided with visibility of constraints and incentives via administered price flexibility procurement. This will be reassessed as part of our LV trial.

Key next steps

There are four key groups of actions arising from this work:

1) **Communications strategy and stakeholder alignment** – Insight developed through this project will be disseminated to the relevant stakeholders, as required for NIA funded projects. This includes sharing outputs with the Electricity Networks Association, to provide input to other DNOs, and also to seek alignment with the wider stakeholder group regarding the positions set out in this document. In addition, we may need to share our position with Ofgem, OLEV and BEIS to support wider design thinking. A communications plan should be drawn up following sign-off of the strategy and this report.
2) **Scope and mobilise the LV residential smart charging trial** – A priority action is to mobilise UKPN’s response to the need for residential smart charging and begin to develop our interim pricing solution. This will require scoping and mobilisation of the proposed trial, as part of the wider flexibility strategy and roadmap.
3) **Feed architecture design work into systems delivery strategy** – The insight developed in this report can be used to inform UKPNs systems delivery programmes. In some areas this may entail incorporation of requirements and delivery timelines into existing projects, and in others this may require scoping and mobilisation of new projects. This should be assessed and taken forward by the relevant internal stakeholders.
4) **Support industry design work** – The insight developed in this report will serve to provide a basis for UKPNs input into industry design processes in relation to smart charging – for instance the LowCVP Taskforce (which will inform Government on secondary legislation) and wider related consultations. The UKPN teams responding (such as Innovation, Smartgrids and Regulation) can refer back to this work in future when responding to consultations and requests for information on this topic.

8 Glossary

Term	Definition
ANM	Active Network Management – Control systems that manage generation and load for specific purposes, keeping system parameters within limits based on automated actions to near real-time measurements
BEAMA	British Electrotechnical and Allied Manufacturers Association
BEIS	Department for Business, Energy and Industrial Strategy
BM	Balancing Mechanism – National Grid's mechanism for balancing supply and demand
CC	Connected Car – Equipped with internet access
CP	Charge Point
CPO	Charge Point Operator
CT	Current Transformer
DCC	Data Communications Company – Central infrastructure for SMETS2 meter communications
DER	Distributed Energy Resources
DERMS	Distributed Energy Resource Management System – Monitoring, optimizing and dispatching DERs to meet grid and market needs
"DER Manager"	A term used to define third parties a DNO could interact with to carry out smart charging e.g. CPOs, aggregators, suppliers etc.
DMS	Distribution Management System
DNO	Distribution Network Operator
DSO	Distribution System Operator
DTN	Data Transfer Network
DUoS	Distribution Use of System charges
ED1	RIIO-ED1 network price control (2015-2023)
ED2	RIIO-ED2 network price control (2023 – end date to be defined)
EHV	Extra High Voltage
ENA	Energy Networks Association
EPN	Eastern Power Networks (one of UKPN's 3 DNOs)

ESO	National Electricity Systems Operator
EV	Electric Vehicle
FDG	Flexible DG (UKPN innovation project)
FFR	Fast Frequency Response
FPI	Fault Passage Indicator
HAN	Home Area Network
HEMS	Home Energy Management System
HGV	Heavy Goods Vehicle
HV	High Voltage
IoT	Internet of Things
LCT	Low Carbon Technologies
LowCVP	Low Carbon Vehicle Partnership
LPN	London Power Networks (one of UKPN's 3 DNOs)
LV	Low Voltage
MSO	'Middle Layer Super Output Area' – geographical areas defined by the Office of National Statistics for planning purposes, with populations of 5,000 – 15,000 people
OEM	Original Equipment Manufacturer
OLEV	Office for Low Emission Vehicles
OMS	Outage Management System
PLC	Power Line Communications
PLE	Planning Load Estimate – A model used by UKPN to forecast future load growth for primary substations
PV	Photo Voltaic
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
SEC	Smart Energy Code
SMETS	Smart Metering Equipment Technical Specifications

SMMT	Society of Motor Manufacturing and Traders
SoC	State of Charge
SOP	Soft Open Point – used for network reconfiguration
SPN	Southern Power Networks (one of UKPN's 3 DNOs)
ToU	Time of Use
TSO	Transmission System Operator
V2G	Vehicle to Grid

Appendix A International case studies

#	Project	Country / Region	Description
1	Westnetz	Germany	• Dedicated grid connection for controllable loads, such as EV. Smart Meter used as control channel
2	INVADE	Norway	• Aggregator optimizes home based on DNO price publication
3	USEF	NL / Utrecht	• Aggregator offers flexibility to DNO with flexible pricing
4	ChargeForward	US / California	• Aggregator offers flexibility to vertically integrated utility
5	FlexPower	NL / Amsterdam	• Flexible power profile provided by DNO applied by Charge Point Operator
6	Electric Nation	UK / WPD	• Flexible power profile provided by DNO applied by Charge Point Operator
7	My Electric Avenue	UK / SSEN	• Temporary curtailment of recharging with direct substation – charge point communication
8	City-ZEN	NL / Amsterdam	• Aggregator handles bidirectional charging within dynamic capacity profile of DNO
9	TenneT	Germany & NL	• TSO ancillary services provided by home batteries and electric vehicles with response stored in the blockchain
10	Flex DG	UK / UKPN	• *(Potential to include to explore curtailment trading and dynamic capacity allocation)*

Westnetz | INVADE | USEF | Charge Forward | FlexPower | Electric Nation | My Electric Avenue | City-Zen | Tennet

Context and control model | Illustrative diagram | Commercial / Technical Features

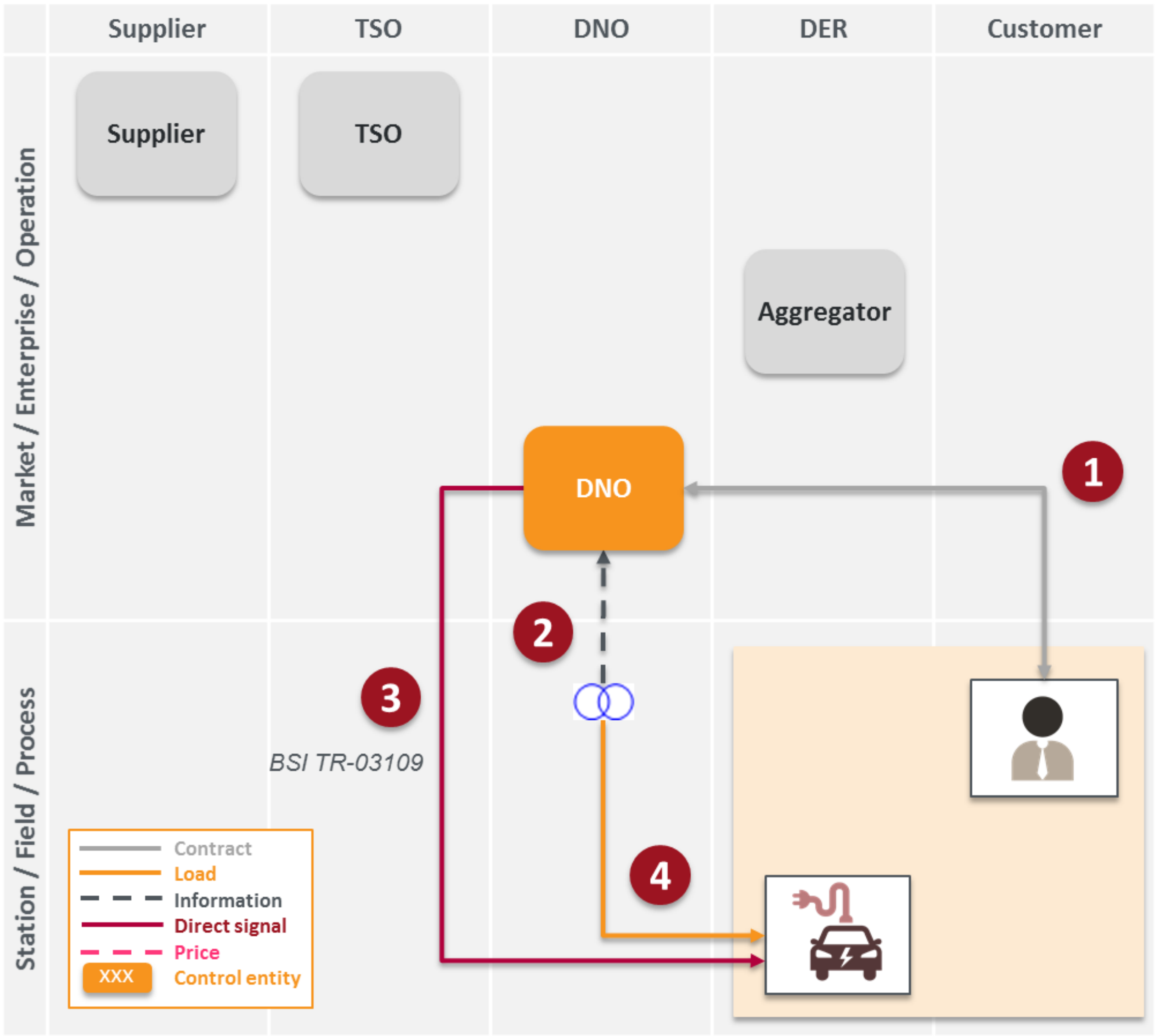
Country / Region	• Germany (western part)
Company / Consortium	• DNO Westnetz
Project stage	• Regular offering as of January 2018
Objectives of model	• Give DNO insight into long-term demand for home charging • Encourage overnight (postponed) charging instead of immediate charging • Enable system for steerable loads, integrated in the broader energy system (in the future)
Geographic context	• The industrialised western part of Germany with the Ruhr area has a long history in "steering" domestic appliances, as electrical storage heaters were wide-spread to consume at night (when industrial demand was low) • Over the last decade, energy legislation has been modernised to give DNOs the right to offer lower grid fees for other steerable loads such as battery storage systems and charging stations for electric vehicles • Also, the digitalisation of grids enables multiple business players (e.g. aggregators) to unlock value from flexibility
Control model - Flexibility services accessed - Optimisation level - Control mechanism - Control entities	• DNO Westnetz sets time blocks per region in which the EV-specific grid connection is active, thereby steering charging load to defined points of the day • This is intended to evolve into a more dynamic system (expected beyond 2020) in which the DNO curtails dynamically based on (forecasted) local and regional capacity constraints • The current focus is on capacity management on the regional level – but the system is designed to accommodate local and national capacity management, as well as energy balancing and system services in the future • Currently the DNO is the control entity, but the intention is to implement a traffic light system (based on network conditions) which will indicate the degree of freedom that other control entities, such as supplier and aggregator, will have • However in all traffic-light states the intention is that the DNO will retain "over-ride" access for emergency control actions by curtailing the grid connection

Smart Strategy Architecture Roadmap (SmartCAR)

Westnetz | INVADE | USEF | Charge Forward | FlexPower | Electric Nation | My Electric Avenue | City-Zen | Tennet

Context and control model | Illustrative diagram | Commercial / Technical Features

Functional diagram – Current model



Outline process

1) DNO and customer enter into timed capacity agreement and tariff

2) DNO develops capacity profile & pricing based e.g. upon annual load profile

3) DNO disconnects charge point outside of capacity boundaries via smart meter gateway

4) Charging of EV takes place within capacity boundaries

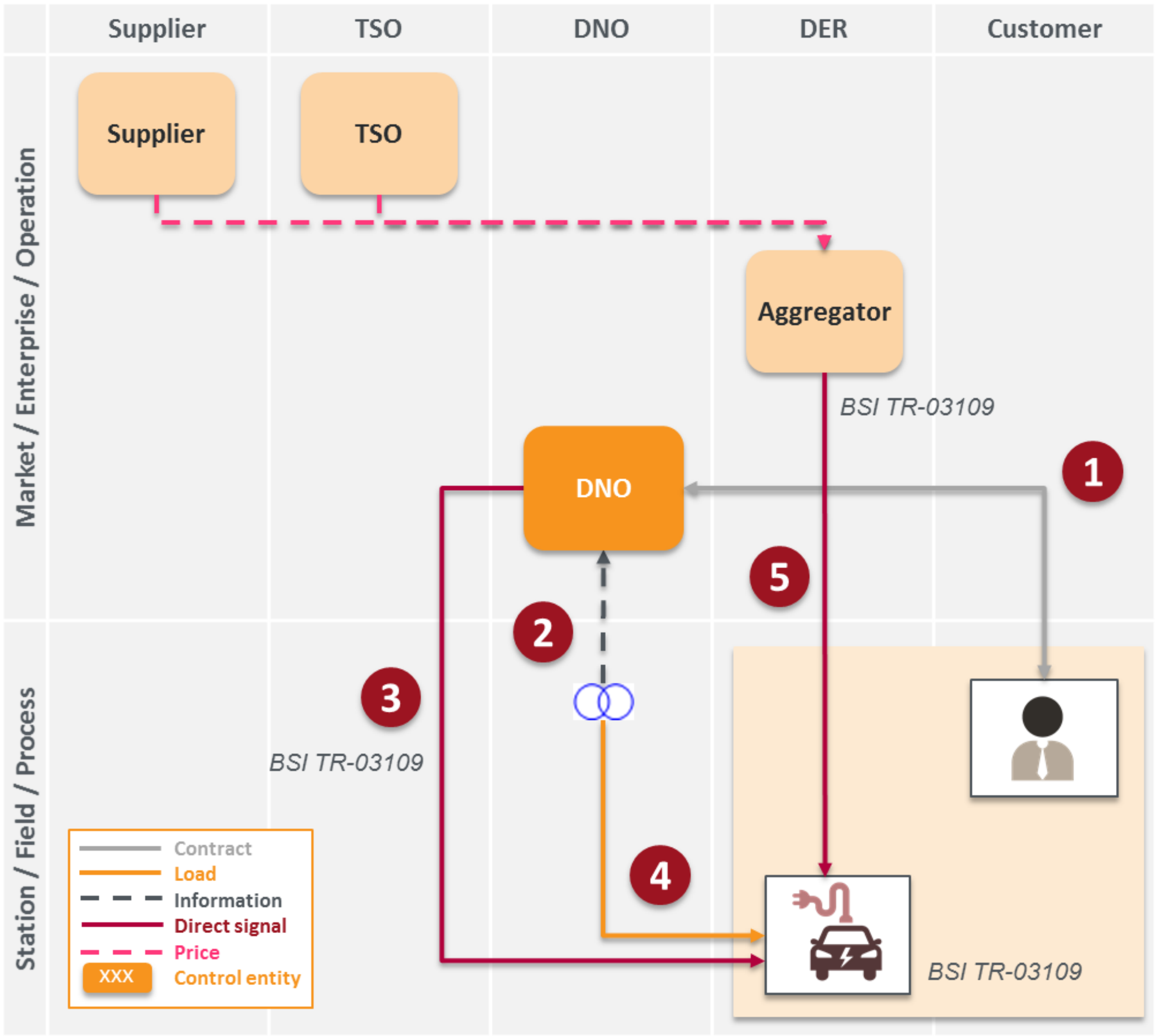
Protocol description

- ***BSI TR-03109*** Set of standards ensuring interoperability in smart meter ecosystem

Westnetz | INVADE | USEF | Charge Forward | FlexPower | Electric Nation | My Electric Avenue | City-Zen | Tennet

Context and control model | Illustrative diagram | Commercial / Technical Features

Functional diagram – Future planned model



Outline process

1) DNO and customer enter into managed charging agreement and tariff

2) DNO develops capacity profile & pricing based e.g. upon annual load profile

3) DNO reduces or disables charging according to contracted profile and in grid emergency situations (only in red regime), via smart meter gateway

4) Charging of EV takes place within capacity boundaries

5) Optimisation of charging by supplier and/or aggregator using smart meter gateway takes place within DNO's boundaries in green and amber regime

Protocol description

- ***BSI TR-03109*** Set of standards ensuring interoperability in smart meter ecosystem

Westnetz | INVADE | USEF | Charge Forward | FlexPower | Electric Nation | My Electric Avenue | City-Zen | Tennet

Context and control model | Illustrative diagram | Commercial / Technical Features

Commercial model - Network access rights - Form of control signal - Tariff - Form of optimisation	• Customers have limited network access rights, but within communicated time blocks, their access is firm. In return, the separate EV grid connection is installed and maintained at no cost and customers benefit from a discounted network fee of €0,04 per kWh • The direct control signal is a set of time blocks sent to the Smart Meter Gateway (SMG) by the Smart Meter Gateway Administrator on behalf of the DNO. The SMG relays this information to a control box (switching gear) or an EV charge point capable of processing this information • The customer tariff is in the form of a reduced network fee – i.e. "compensation" for fixed periods of curtailment netted off the network charges • Optimisation is static, based on a fixed assessment of network conditions by the DNO. In the future, a more dynamic approach, taking into account local and seasonal differences, will be introduced
Technical features - Push data channel - Response telemetry - Load direction - Flexibility assets - Connection type	• Using the dedicated Smart Meter Gateway data channel, the DNO sends the time blocks to the Smart Meter Gateway, which relays those to the charge point (or a control box managing the charge point), installed behind the meter • Meter data using this same channel provides the response • Separate grid connection type, useable for all steerable assets (electric vehicles, battery storage)
Pros	• Using separate grid connections for EVs improves the possibities to steer charging • Unified, flexible and standardized control method for all market actors and steerable assets
Cons	• Requires legal framework and technical infrastructure for smart meter gateways to be in place • Fixed time blocks do not reflect actual network conditions / flexibility needed on the local level and limit the value potential e.g. for an aggregator

Westnetz	**INVADE**	USEF	Charge Forward	FlexPower	Electric Nation	My Electric Avenue	City-Zen	Tennet

Context and control model

Country / Region	• Norway, Stavanger area
Company / Consortium	• DNO Lyse Elnett
Project stage	• Pilot 2017 – 2020 (with change to reg. framework 2019-2020)
Objectives of model	• Provide both the DNO and the end-customers with information, feedback and interaction to promote behavioural change • Exploit new opportunities arising in the EV/battery domain • Test interoperability of flexibility platform with existing ANM system / smart meter infrastructure
Geographic context	• Area with an increased uptake of PV solar and electric vehicles poses a challenge for the DNO • In Norway, peak pricing based tariffs are emerging and will be implemented during the next 2-3 years. End users can save money if they can avoid high loads in the high tariff periods
Control model - Optimisation level - Flexibility services accessed - Control entities	• Home-optimisation using EV, battery and other DER • The aggregator controls a local controller in the customers' home, optimizing consumption or feed-in to the grid, based on flexible energy tariffs (supplier and wholesale) and peak-based DNO tariff • The DNO control is in the pilot based on capacity publication to the aggregator. In the near future, it is limited to price publication only

INVADE

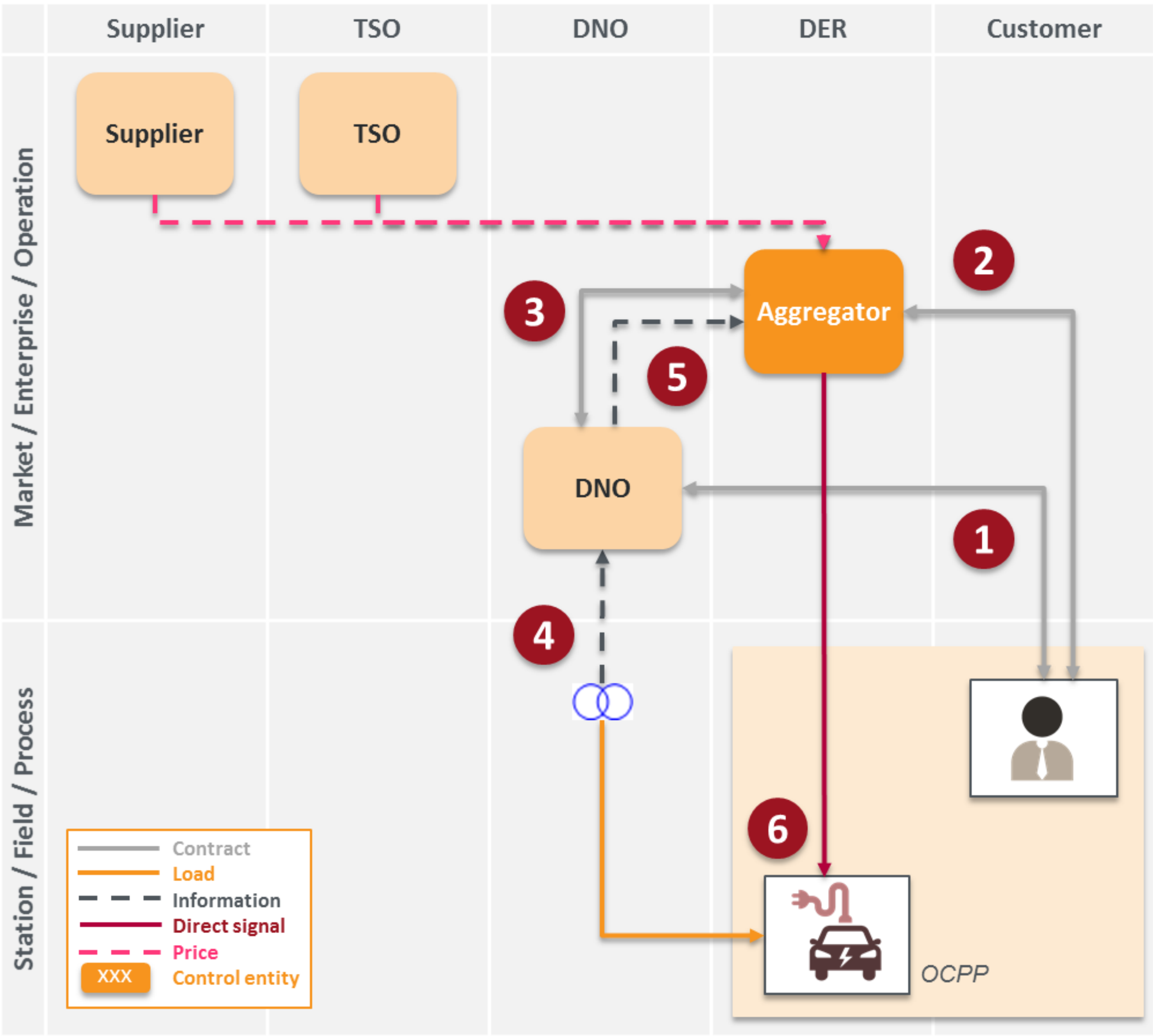
Illustrative diagram

Commercial / Technical Features

Westnetz | **INVADE** | USEF | Charge Forward | FlexPower | Electric Nation | My Electric Avenue | City-Zen | Tennet

Context and control model | **Illustrative diagram** | Commercial / Technical Features

Functional diagram – Current model



Outline process

1) DNO and customer enter into firm capacity agreement and tariff

2) Aggregator and customer enter into managed charging agreement and tariff

3) DNO and aggregator enter into contract for capacity allocation

4) DNO develops capacity profile based e.g. upon annual load profile and/or reflecting near-real-time constraints

5) DNO publishes this capacity to aggregator

6) Aggregator selects suitable charging sessions and adapts EV charging, optimising with the wider system and for the customer using on-site DER

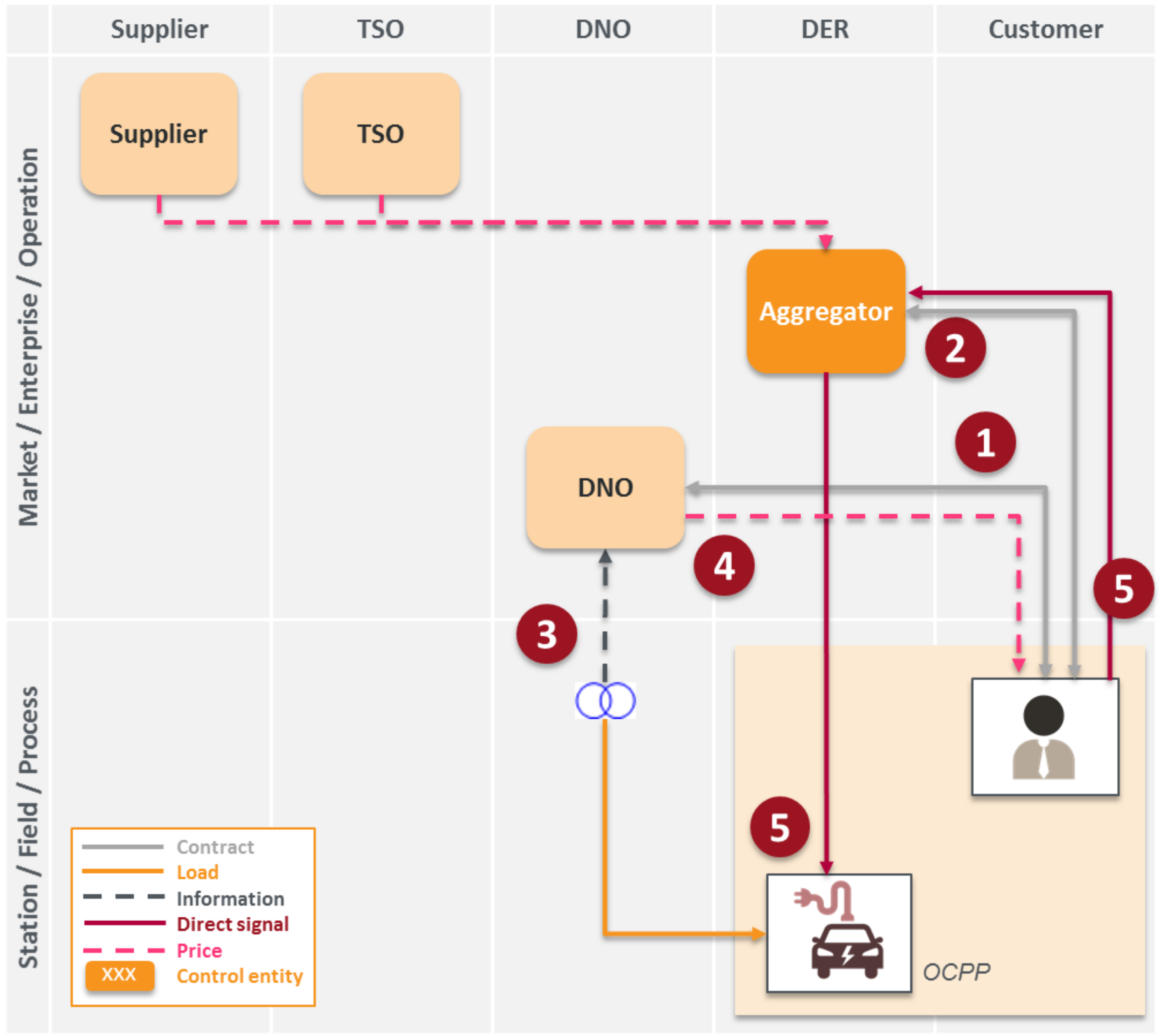
Protocol description

- ***OCPP*** Open Charge Point Protocol, for communications between EVSE and CPO
- Other interactions un-standardised

Westnetz | INVADE | USEF | Charge Forward | FlexPower | Electric Nation | My Electric Avenue | City-Zen | Tennet

Context and control model | Illustrative diagram | Commercial / Technical Features

Functional diagram – Future planned model



Outline process

1) DNO and customer enter into rising block agreement with ToU elements

2) Aggregator and customer might enter into managed charging agreement and tariff

3) DNO develops pricing based e.g. upon annual load profile

4) DNO publishes prices

5) Customer provides aggregator with (real-time) information on consumption, preferences, supplier and DNO tariffs etc.

5) Aggregator adapts EV charging, optimising with the wider system and for the customer using on-site DER

Architectural implications

- Norway is transitioning grid charging to a rising block tariff for consumers, with ToU elements
- The role of the aggregator could be performed by a customer-owned appliance (e.g. HEMS) instead of by a 3rd party

Westnetz | **INVADE** | USEF | Charge Forward | FlexPower | Electric Nation | My Electric Avenue | City-Zen | Tennet

		INVADE
Context and control model	**Commercial model** - Network access rights - Form of control signal - Tariff - Form of optimisation	• Customer has firm network access rights • The DNO provides available capacity to the aggregator, though the intention is to move to price publication for response offers • Currently, the customer tariff is static • With the introduction of new DNO tariffs in Norway (2019-2020) peak pricing will be introduced, which will likely be a mix of a minimum contracted capacity and ToU pricing for the extra capacity used • Optimisation is dynamic
Illustrative diagram	**Technical features** - Push data channel - Response telemetry - Load direction - Flexibility assets - Connection type	• Secure API between DNO and aggregator for available capacity (to change in: price) • Aggregator controls the charge point from the local controller, which is connected to the aggregator's platform • Meter data from substation for real-time measurements, meter data from customer's grid connection for verification • Bidirectional loads (from battery storage) are tested as well • Regular domestic grid connection, used with household/EV-mix. Useable with other DERs.
Commercial / Technical Features	**Pros**	• DNO focus on maintaining grid, flexibility managed from user side • Dynamic energy supply prices already fit in existing legal framework, DNO tariff will follow 2019-2020
	Cons	• DNO has limited control on demand side with uncertain response to price publication • Flexibility operator (aggregator) needed to manage the flexibility

Westnetz | INVADE | **USEF** | Charge Forward | FlexPower | Electric Nation | My Electric Avenue | City-Zen | Tennet

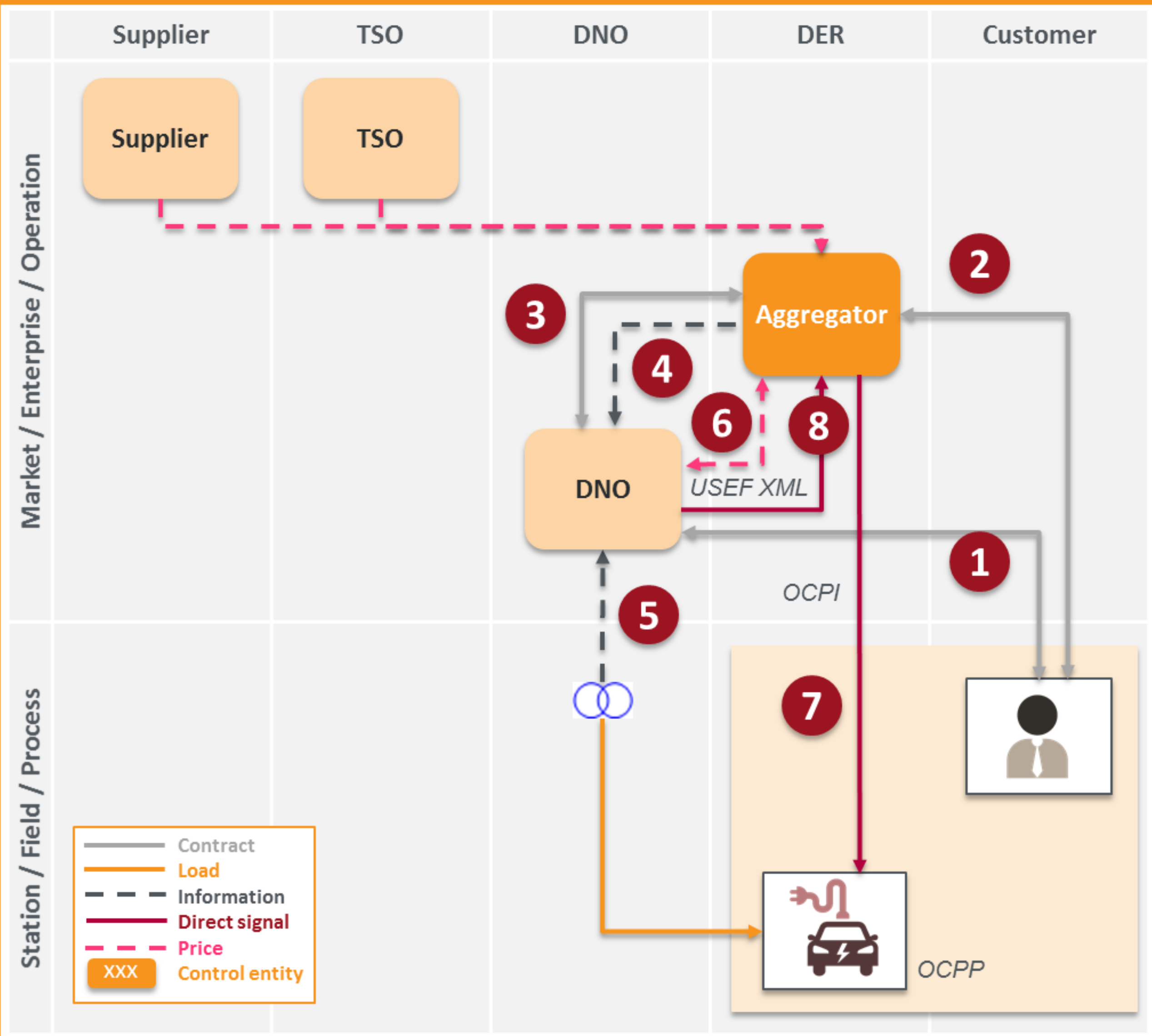
Context and control model | Illustrative diagram | Commercial / Technical Features

Country / Region	• The Netherlands, Lombok district of Utrecht
Company / Consortium	• DNO Stedin, aggregator Jedlix & others
Project stage	• Pilot 2017 - 2021
Objectives of model	• Prevent expected network constraints as a result of EVs • Central role for aggregator with the aim to increase flexibility for the DNO as well as more benefits / fewer constraints for the customer
Geographic context	• Densely populated area with an increased uptake of PV solar and electric vehicles poses a challenge for the DNO • The project utilises the "Universal Smart Energy Framework" (USEF), developed by a consortium of DNOs, Suppliers, Software Providers to improve the usage of flexibility on consumer level • Using USEF, bids and settlement common to the wholesale market are applied to the local level as well
Control model - Optimisation level - Flexibility services accessed - Control entities	• Primary optimisation is at a local level – i.e. LV cable and substation: ○ The DNO Stedin, as well as the aggregator, perform a daily forecast on the load within a local area (substation / feeder) ○ Based on this, the DNO might ask the aggregator for a flexibility offer ○ If accepted by the DNO, the aggregator will shift load to reduce / prevent grid congestion • The aggregator also optimises for the BRP and TSO • The DNO has ultimate control within a 'red regime', when the bid/offer mechanism failed and/or demand is higher than forecasted – For this, curtailment options have been contracted

Westnetz | INVADE | **USEF** | Charge Forward | FlexPower | Electric Nation | My Electric Avenue | City-Zen | Tennet

Context and control model | **Illustrative diagram** | Commercial / Technical Features

Functional diagram



Outline process

1) DNO and customer enter into firm capacity agreement and tariff

2) Aggregator and customer enter into managed charging agreement

3) DNO and aggregator enter into contract for response services

4) Aggregator sends forecast to DNO

5) DNO identifies likely constraint

6) DNO asks aggregator for bid for load shift / aggregator responds

7) After DNO offer, aggregator selects suitable charging sessions and adapts EV charging

8) If bid/offer market fails, and/or in the case of a near/real-time emergency situation, the DNO contracts capacity (either directly or through the aggregator) over which it has unilateral access

Protocol description

- ***USEF XML*** set of messages using XML or ebXML (ISO15000) format
- ***OCPI*** Open Charge Point Information Protocol, used for transfer of charging profile
- ***OCPP*** (see previous case study)

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		USEF
Context and control model	**Commercial model** - Network access rights - Form of control signal - Tariff - Form of optimisation	• Customer has firm network access rights, unless otherwise agreed / contracted with aggregator to provide emergency flexibility in 'red regime' • The control signal is an exchange of bids and offers. Once an offer from the aggregator is accepted by the DNO, the demand shift is fixed • The customer tariff is dynamic ToU through the aggregator • Optimisation is dynamic, based on a forecast and real-time metering data from the substation
Illustrative diagram	**Technical features** - Push data channel - Response telemetry - Load direction - Flexibility assets - Connection type	• Secure API between DNO and aggregator for flexibility bids / offers and response • Aggregator uses OCPI to set charging profile on the charge point (via the charge point operator's system) • Meter data from substation for real-time measurements, smart meter data from customer's grid connection for verification • Regular domestic grid connection, used with public charge points and with household/EV-mix. Useable with other DERs.
Commercial / Technical Features	**Pros**	• Unified, flexible and standardized control method for all market actors and steerable assets • DNO interacts with aggregator(s) with sufficient flexibility to relieve grid congestion (instead of interacting with individual systems)
	Cons	• Grid usage / congestion prevention has to be priced • If flex bid/offer-mechanism fails, DNO needs a fall-back solution

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Context and control model | Illustrative diagram | Commercial / Technical Features

Country / Region	• USA North-California
Company / Consortium	• Utility PG&E (not unbundled), aggregator BMW
Project stage	• 1st phase pilot 2015 – 2016, 2nd phase pilot 2017 - 2018
Objectives of model	• Use a distributed and aggregated fleet of electric vehicles combined with stationary battery storage to reduce demand
Geographic context	• California suffers from imbalance problems, especially during heat waves • In this trial, electric vehicles and or the stationary battery storage reduce charging when required to prevent imbalance and or grid congestion • As PG&E is a vertically integrated utility, whereas in Europe DNOs are unbundled, the division as to whether a demand-response event is triggered by local grid congestion, generation or imbalance is unclear
Control model - Optimisation level - Flexibility services accessed - Control entities	• PG&E (in the role of TSO and DNO) asks BMW (acting as an aggregator) to lower demand in response to congestion – currently at the regional level • BMW controls a fleet of approx. 100 (in the first phase) – 250 (in the second phase) electric cars (with customers opted-in), for which a smart algorithm decides on which cars to reduce power or postpone (by up to one hour), with the addition of stationary battery storage consisting of second-life batteries • The level of response currently available is approximately 100 kW • Currently the trial is accessing TSO congestion management services and enabling self-balancing portfolio optimisation for the BRP • However, plans are underway to include further services, namely day-ahead and intra-day portfolio optimisation, TSO frequency response, DNO level congestion management and voltage / reactive power services – this is to be trialled • The control entity in this case is an aggregator (BMW)

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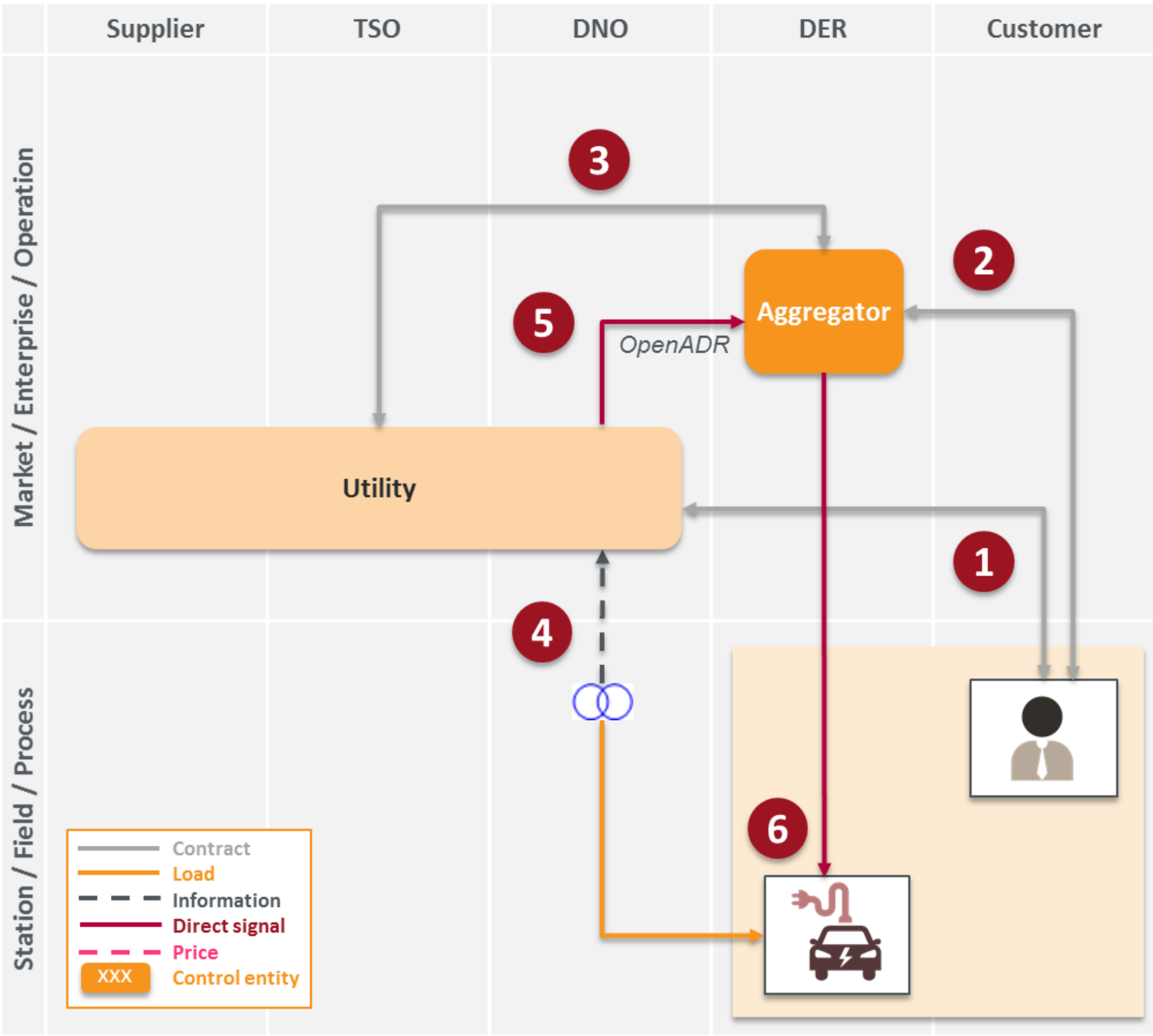
Context and control model | Illustrative diagram | Commercial / Technical Features

Functional diagram



Outline process

1) Utility and customer enter into firm capacity agreement and tariff

2) Aggregator and customer enter into managed charging agreement and tariff for participation

3) Utility and aggregator enter into contract for response services

4) Utility identifies emerging constraint via local substation / feeder telemetry / wider energy system

5) DNO sends out signal to aggregator to temporarily reduce load

6) Aggregator selects suitable charging sessions and adapts EV charging

Protocol Description

OpenADR Open Automated Demand Response, generic demand response protocol

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Context and control model / Illustrative diagram / Commercial / Technical Features

Commercial model - Network access rights - Form of control signal - Tariff - Form of optimisation	• Customers have firm network access rights and are paid a participation fee in compensation for curtailment. There is no additional payment per DR-event • Customers are notified of curtailment events and can opt-out of individual instances • The signal is a request from the utility to the aggregator, followed by a firm control signal instruction from the aggregator to individual vehicles via a proprietary platform (the system is agnostic to who owns/controls charge points) • The customer tariff is in the form of a "participation fee" – i.e. works on a static basis. However, opt-outs reduce the participation fee • Optimisation is based on a dynamic assessment of network conditions by the TSO which pushes requests to the aggregator
Technical features - Push data channel - Response telemetry - Load direction - Flexibility assets - Connection type	• OpenADR is used to trigger demand-response by the utility to the aggregator and vice versa for the response. The aggregator (BMW) uses a proprietary channel to interact with the vehicles • Aggregator selects suitable vehicles, and asks users to opt-out • Electric vehicles in combination with stationary battery storage (providing ultimate backup if all users opt-out) • Using smart meters at customers' homes or work locations, or at a public charge point, the drop in demand is measured. In the second phase, the use of the car's telemetry will also be trialled for reliability as an alternative
Pros	• Can quickly scale by using connected car platform (no additional hardware / software needed for customer) • If all users opt-out, a backup solution is needed (in this case: stationary battery storage)
Cons	• No geogrpahic certainty on specific substations / LV cables

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Context and control model / Illustrative diagram / Commercial / Technical Features

Country / Region	• The Netherlands, Amsterdam	Amsterdam elektrisch
Company / Consortium	• DNO Liander, Charge Point Operator Nuon/Heijmans	
Project stage	• Pilot started 2017, extension in 2018 (no end date)	
Objectives of model	• Maximize the available power on individual public chargers in a neighbourhood based on local static smart charging profiles • Understand the impact of smart charging on three different user groups of EV drivers • Verify the theoretical calculations with actual pilot data	
Geographic context	• Dense inner-city district means limited options to increase grid capacity in the short term • For each neighbourhood (three in the trial) a different capacity profile is used to reflect local differences	
Control model - Optimisation level - Flexibility services accessed - Control entities	• Local level optimization for network capacity only • The DNO sends the neighbourhood-specific profile of time blocks with additional and reduced capacity to the charge point management system operated by the CPO (Charge Point Operator), which sets this profile as maximum capacity at the charge points in the area (e.g. there is no dynamic capacity allocation between charge points based on occupancy)	

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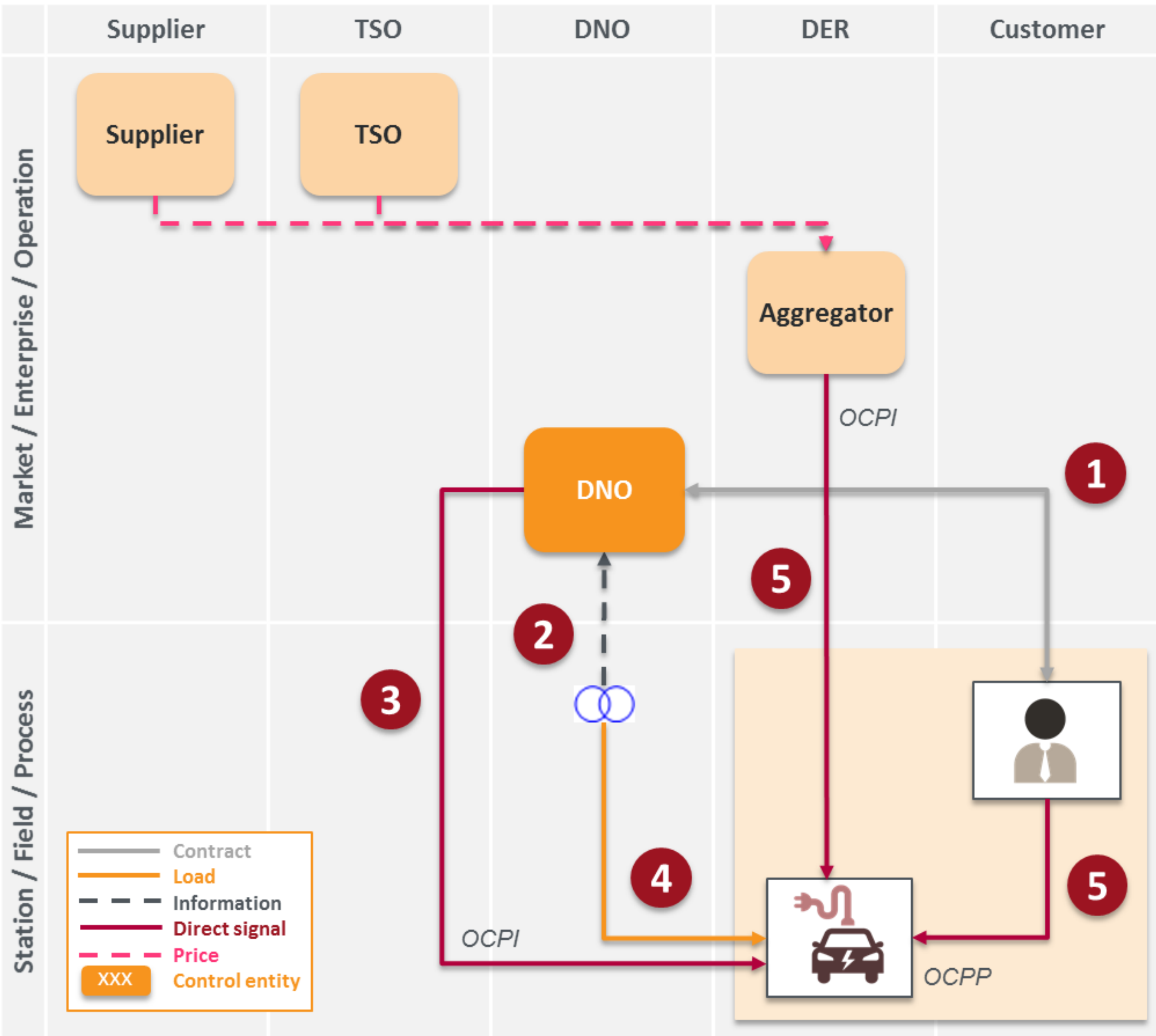
Context and control model | **Illustrative diagram** | Commercial / Technical Features

Functional diagram



Outline process

1) DNO and customer (for public charging: the CPO) enter into timed capacity agreement and tariff

2) DNO develops capacity profile per grid connection based e.g. upon annual load profile of local grid

3) DNO sets capacity profile via the charge point operator

4) Charging of EV takes place within capacity boundaries

5) Optimisation of charging process by customer/supplier/aggregator can take place within DNO's boundaries

Protocol description

- ***OCPI*** Open Charge Point Information Protocol, used for transfer of charging profile
- ***OCPP*** Open Charge Point Protocol, for communications between EVSE and CPO

Westnetz | INVADE | USEF | Charge Forward | **FlexPower** | Electric Nation | My Electric Avenue | City-Zen | Tennet

		FlexPower
Context and control model	**Commercial model** - Network access rights - Form of control signal - Tariff - Form of optimisation	• Customer has tiered access rights: reduced capacity is always available • The DNO provides available capacity to the charge point operator, which sets this as maximum capacity at the charge point. Typically, capacity is lower between 4 – 8 PM • The customer tariff is static (end customers pay per kWh for charging) • The customer's advantage is to be able to charge faster during most hours of the day • Optimisation is static for now based on analysis of grid data, but dynamic profiles will be trialled in the next phase
Illustrative diagram	**Technical features** - Push data channel - Response telemetry - Load direction - Flexibility assets - Connection type	• API between DNO and CPO for available capacity using OCPI. From CPO management system to charge point using OCPP • Meter data from substation for real-time measurements, meter data from charge point's grid connection for verification • Dedicated grid connection for EV charging only • The FlexPower connection being trialled could be used for other controllable DER assets as well
Commercial / Technical Features	**Pros**	• Direct DNO control • Faster EV charging available as well, which benefits most users
	Cons	• No customer interaction or override function • Currently only static profiles

Westnetz	INVADE	USEF	Charge Forward	FlexPower	**Electric Nation**	My Electric Avenue	City-Zen	Tennet

Context and control model | Illustrative diagram | Commercial / Technical Features

Country / Region	• UK
Company / Consortium	• WPD (with support from EA Technology)
Project stage	• Trial underway (2016 – 2019)
Objectives of model	• The project will develop a tool that will allow local network operators to identify which parts of their network (non-meshed) are likely to be affected by the future adoption of EVs and recommend the most economical solution to solve any issues this could cause • Develop an algorithm deployable on an existing substation monitoring facility that will enable the effect of PIVs on a LV network to be retrospectively analysed and allow the measureable impact to be compared against the modelling tool output. • 700 participants involved to gain understanding of customer acceptance of smart charging and whether customer incentives are required • Testing of an app which allows customers to enter information about their journey preferences and receive information about when they've charged their car and demand management they've been involved in
Geographic context	• This innovation project is taking place from 2016 – 2019 funded by NIA
Control model - Optimisation level - Flexibility services accessed - Control entities	• Local optimisation of 700 EVs in clusters, this also could be pushing towards regional optimisation dependent on the locations of the EVs. • Constraint management, adjusting rate of charging, rather than just binary (as in My Electric Avenue) • Controlled by the DNO, via the charge point operator

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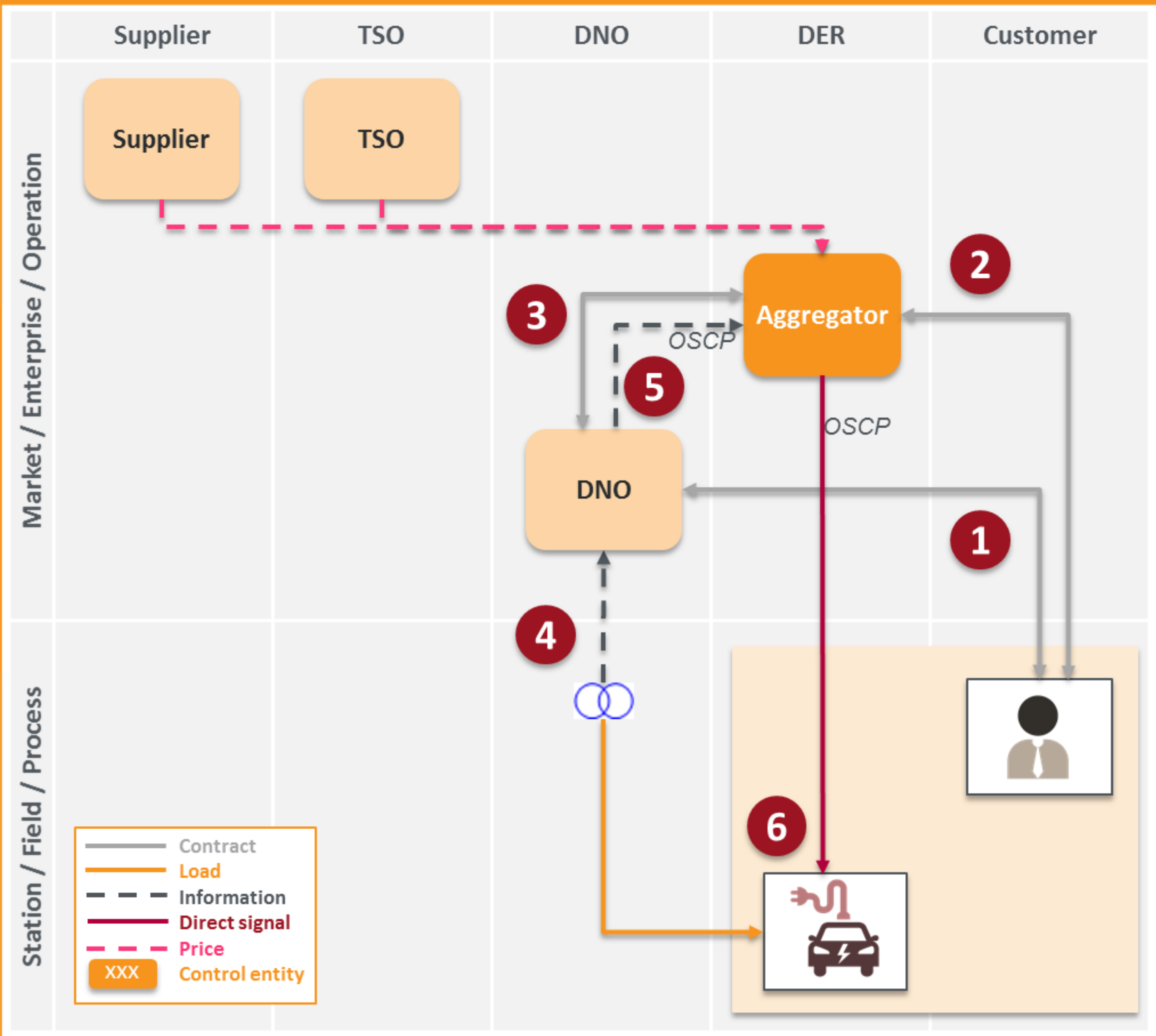
Context and control model | **Illustrative diagram** | Commercial / Technical Features

Functional diagram – Current model



Outline process

1) DNO and customer enter into firm capacity agreement and tariff

2) Aggregator and customer enter into managed charging agreement and tariff

3) DNO and aggregator enter into contract for capacity allocation

4) DNO identifies emerging constraint via local substation / feeder telemetry

5) DNO publishes capacity profile to aggregator

6) Aggregator selects suitable charging sessions and adapts EV charging

Protocol description

- ***OSCP*** Open Smart Charging Protocol: Provides forecast of the available capacity of the grid in the next 24 hours, can get updated with real time information

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Commercial model - Network access rights - Form of control signal - Tariff - Form of optimisation	• Non-firm connections, where an EV CP may be switched off or the rate of charging adjusted • Direct signal control from the DNO, via the CPO • Uncompensated for curtailment • Dynamic optimisation based on HV (11kV) forecast
Technical features - Push data channel - Response telemetry - Load direction - Flexibility assets - Connection type	• Generic network e.g. dual connectivity of GSM in combination with fixed internet (as GSM is not sufficiently reliable and there is not always good enough coverage). Some issues experienced with connection between smart charger and home broadband router. • Response received by LV telemetry (smart charging controller in the CP itself, provided by Greenflux and CrowdCharge) • Majority load only with some later V2G trials once CPs are available (working with Nichion) • EV only • Dedicated CP connection, trialled a range of power chargers
Pros	• This trial looks to build on the My Electric Avenue trial to test a range of EVs (as MEA trialed a single model) with different batteries and rates of charging. • The project is developing a tool to help DNOs understand which parts of their network are most likely to be affected by EV uptake • The algorithm to measure the effect of EVs on the network by analyzing existing substation data will help determine the LV telemetry requirements • Allows the customer to input their charge preferences
Cons	• The model still is only testing DNO control

Context and control model | Illustrative diagram | Commercial / Technical Features

Westnetz | INVADE | USEF | Charge Forward | FlexPower | Electric Nation | **My Electric Avenue** | City-Zen | Tennet

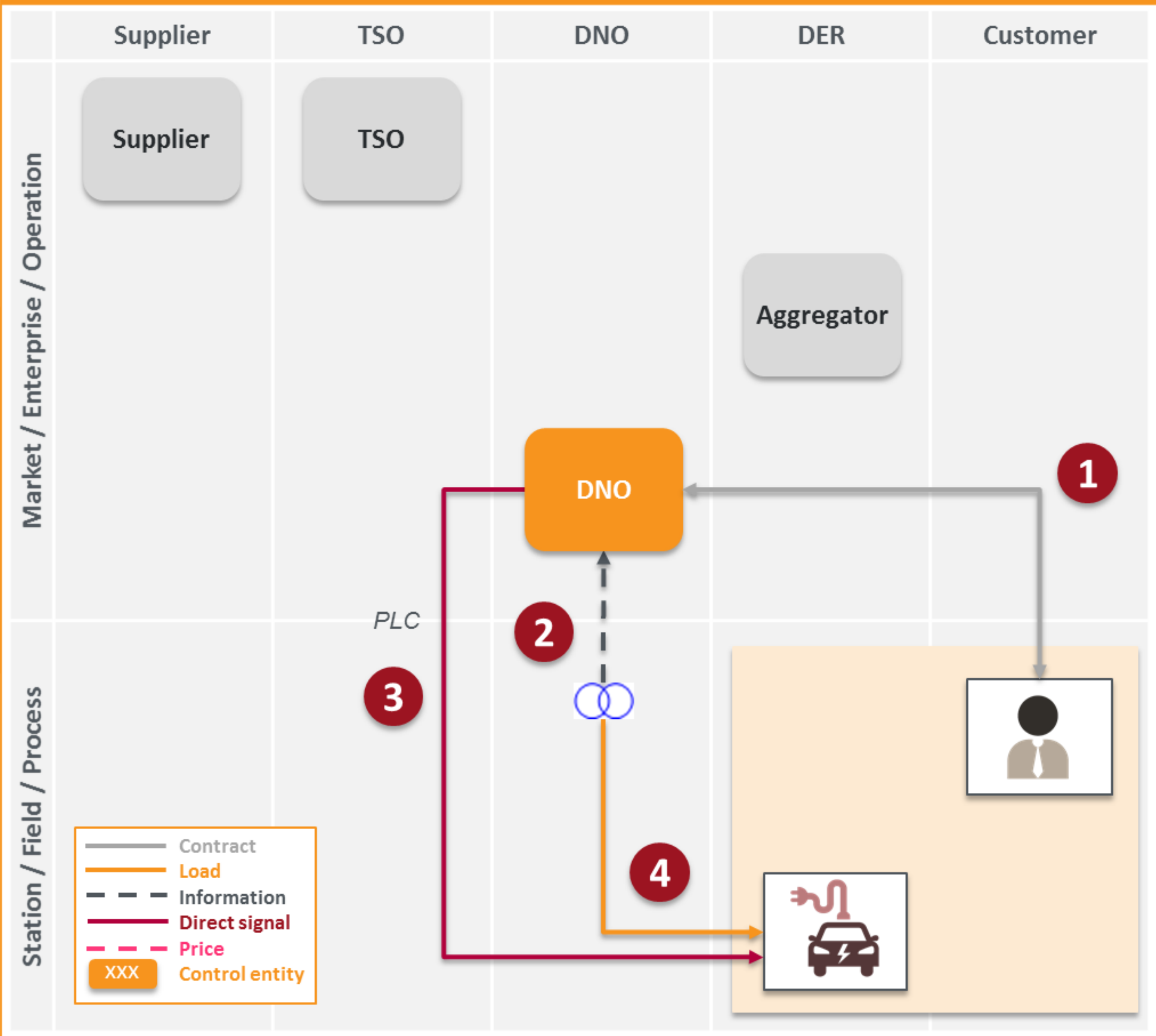
Context and control model | Illustrative diagram | Commercial / Technical Features

Country / Region	• UK
Company / Consortium	• SSEN (with support from EA Technology)
Project stage	• Completed 2015 – Extended via the Smart EV project
Objectives of model	• Demonstrate the benefits of smart charging and how curtailment of load can help reduce expected network constraints as a result of EVs • Trialling the Espirit system which employs demand-side management techniques to protect power networks from potential overload that might be caused by the simultaneous charging of numerous EVs on the same substation feeder • It does so by instigating temporary curtailment of recharging on a rolling basis (typically, in this trial, for 15 minutes each) across the local cluster of EVs
Geographic context	• This innovation project took place from 2013 – 2015 and was funded by LNCF, the Smart EV Project is now following on from the original trial • There may be a scenario where this model is not viable in future (dependent on the outputs of the Ofgem network access and future charging consultation) as it involves DNO control at a very local level
Control model - Optimisation level - Flexibility services accessed - Control entities	• Local optimisation of 100 EVs in clusters • Network constraint management only, managed by switching off the power to the charge point for 15 minutes at a time • Controlled by the DNO using the Espirit system

Westnetz | INVADE | USEF | Charge Forward | FlexPower | Electric Nation | **My Electric Avenue** | City-Zen | Tennet

Context and control model | Illustrative diagram | Commercial / Technical Features

Functional diagram – Current model



Outline process

1) DNO and customer enter into managed charging agreement and tariff

2) DNO identifies emerging constraint via local substation / feeder telemetry

3) DNO sends out signal to to temporarily reduce load

4) Charging of EV takes place whilst unconstrained

5) Optimisation by customer/ supplier/aggregator with other network assets is not carried out

Protocol description

- ***PLC*** Powerline Communications provides a technology to set up a TCP/IP connection over powerline

Westnetz | INVADE | USEF | Charge Forward | FlexPower | Electric Nation | **My Electric Avenue** | City-Zen | Tennet

Context and control model | Illustrative diagram | **Commercial / Technical Features**

Commercial model - Network access rights - Form of control signal - Tariff - Form of optimisation	• Non-firm connections, where an EV CP may be switched off for 15 minutes at a time • Direct signal control from the DNO, which switches off power to the CP • Uncompensated for curtailment • Dynamic optimisation based on response to live constraints, e.g. curtailment introduced once a pre-determined threshold was exceeded
Technical features - Push data channel - Response telemetry - Load direction - Flexibility assets - Connection type	• Specific push signal channel using power line channel communications. (PLC) communications were 65% reliable, over the air communications (e.g. GSM) would be preferable in future, but more expensive. The trial removed power from the entire charge point, in future, output to the vehicle should be restricted whilst power maintained to other functions • Response received by ICB (Intelligent Control Box) connected to the CP via the Monitor Controller at the LV substation • Load only, the Espirit algorithm was found to be unsuitable for flat load profiles (e.g. work place charging), further controls would be required for load sharing in these circumstances • EV only • Dedicated CP connection, trialled using 3.5kW charging, likely to be 7kW in future.
Pros	• Model proved the ability to reduce peak load to minimize reinforcement requirements.
Cons	• Some of the technical features used in this trial were found to be unsuitable e.g. the PLC communications were not reliable enough, the Espirit algorithm was unsuitable for flat load profiles e.g. workplace charging, the direct signal meant power was lost to the whole CP and the power of CPs are likely to be higher in reality that what was trialled. • As a result, significant changes would need to be made to this technical features of this model before it could be rolled out more widely. • From a customer perspective, the connection was non-firm and their charging preferences were not taken into account, therefore the state of charge was uncertain. As a result, the current model is likely to be unsuitable for wider rollout.

Westnetz	INVADE	USEF	Charge Forward	FlexPower	Electric Nation	My Electric Avenue	**City-Zen**	Tennet

Context and control model

Country / Region	• The Netherlands, Amsterdam	CITY-zen New urban energy
Company / Consortium	• DNO Alliander, aggregator Enervalis, CPO NewMotion	
Project stage	• Pilot 2018 – End 2019	
Objectives of model	• Understand the potential impact of V2G charging on the grid • Perform technical experiments into grid congestion/capacity management, evaluate the power quality issues that might arise with V2G, and increase use of locally produced solar energy in the neighbourhood. But also social experiments to find user requirements such as the minimal battery 'reserve' is that user would want to maintain, and the state of charge at time of leave. • Make a first estimation of the value of this technology for the customer, the charge point operator and the DNO	
Geographic context	• 2 chargers at public locations, 1 at office location and 1 at sporting facility, all in Amsterdam. • Dense inner-city district means limited options to increase grid connection and/or LV capacity in the short term	
Control model - Optimisation level - Flexibility services accessed - Control entities	• The aggregator optimises the (dis)charging process based on the local level (available grid connection capacity, capacity at substation as provided by DNO and the solar power forecast) as well as the wholesale markets (BRP / TSO). • The control entity in this case is an aggregator (Enervalis)	

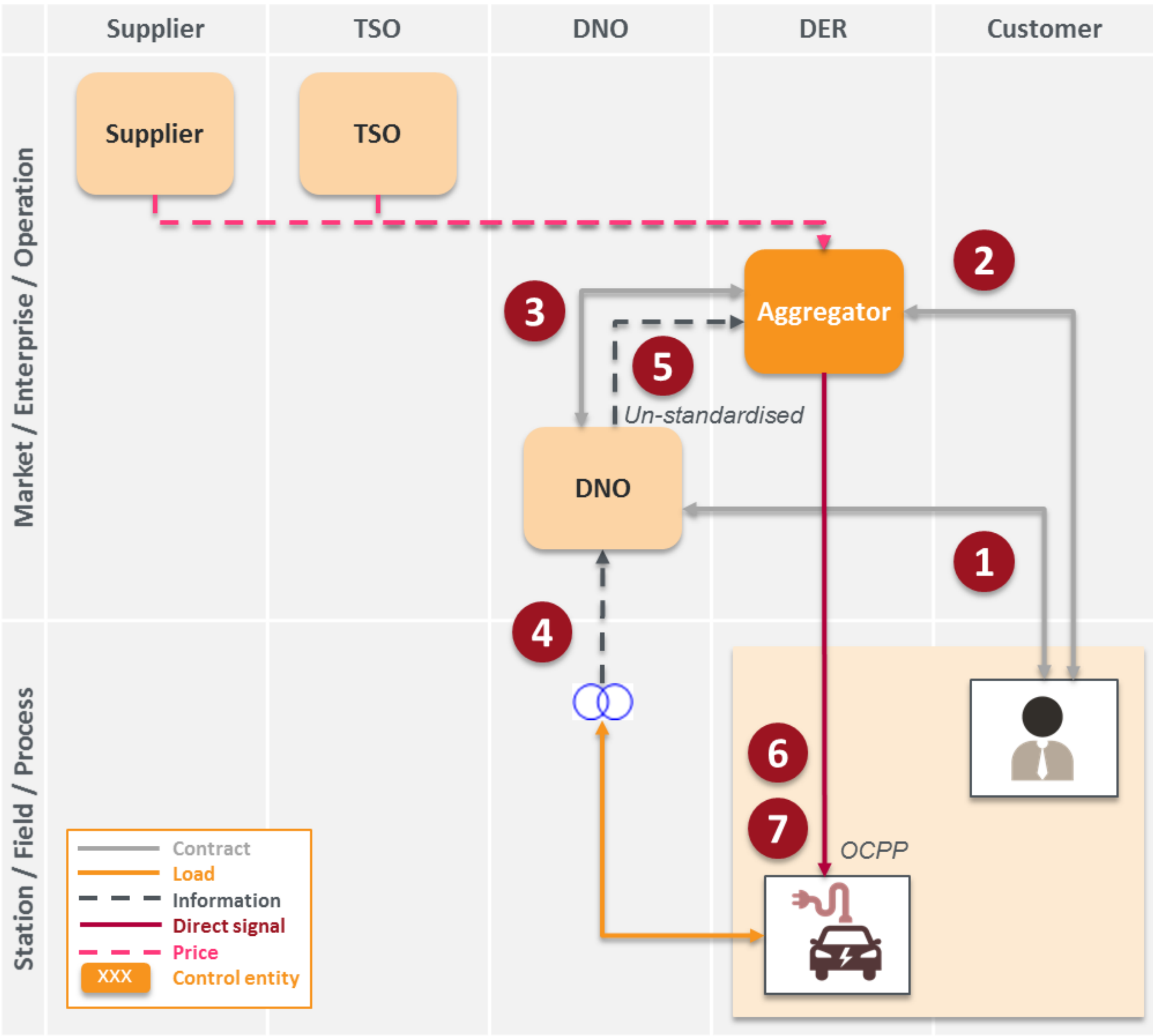
Illustrative diagram

Commercial / Technical Features

Westnetz | INVADE | USEF | Charge Forward | FlexPower | Electric Nation | My Electric Avenue | **City-Zen** | Tennet

Context and control model | Illustrative diagram | Commercial / Technical Features

Functional diagram



Outline process

1) DNO and customer (for public charging: the CPO) enter into non-firm capacity agreement and tariff

2) Aggregator and customer enter into managed charging agreement and tariff

3) DNO and aggregator enter into contract for flexible capacity

4) DNO identifies emerging constraint via local substation / feeder telemetry

5) DNO publishes capacity profile to aggregator

6) Aggregator adapts EV bidirectional charging, optimising with the wider system

7) Optimisation of charging process by aggregator takes place within DNO's boundaries

Protocol description

- ***OCPP*** Open Charge Point Protocol, for communications between EVSE and CPO

Westnetz | INVADE | USEF | Charge Forward | FlexPower | Electric Nation | My Electric Avenue | **City-Zen** | Tennet

		City-Zen
Context and control model	**Commercial model** - Network access rights - Form of control signal - Tariff - Form of optimisation	• Customers have non-firm network access rights and are compensated with a participation fee for the duration of the pilot and per charging session • The signal is real-time local capacity information from the utility to the aggregator. Estimation of time-of-leave is provided as input by driver to the aggregator, which takes this into account for optimisation. • The customer tariff is currently static (fixed fee per session) with a participation fee for the pilot, but will reflect more accurately network conditions in the future • Optimisation will be based on a combination of a dynamic assessment of network conditions by the aggregator and BRP/TSO optimisation
Illustrative diagram	**Technical features** - Push data channel - Response telemetry - Load direction - Flexibility assets - Connection type	• DNO provides a capacity curve to the aggregator. Aggregator selects suitable charging sessions and discharging moments • Using an extra smart meter on site, events (TSO, BRP, DNO) are measured • Bi-directional: EV charging & discharging (V2G) is tested in this pilot • EV only • Separate grid connections for public chargers, regular grid connections for office locations.
Commercial / Technical Features	**Pros**	• Using V2G, electric vehicles can provide additional support in relieving grid congestion caused by other (i.e. non-EV) loads • Combining BRP, TSO and DNO services improves value for the aggregator and driver
Commercial / Technical Features	**Cons**	• Costly hardware • No guaranteed availability of vehicle / battery capacity

Westnetz | INVADE | USEF | Charge Forward | FlexPower | Electric Nation | My Electric Avenue | City-Zen | **Tennet**

Context and control model | Illustrative diagram | Commercial / Technical Features

Country / Region	• The Netherlands & Germany (central)
Company / Consortium	• TSO TenneT, supplier Vandebron (in NL) and Sonnen (in Germany)
Project stage	• Pilot 2017 – 2019
Objectives of model	• TSO TenneT is exploring options that foster the participation of smaller decentralised assets in the imbalance markets to provide ancillary services • To test the possibilities of providing balancing services with electric vehicle charging and home battery load by making use of Blockchain technology • In The Netherlands, approx. 100 Tesla electric vehicles, in Germany approx. 100 home battery systems are participating
Geographic context	• The Netherlands has a growing number of electric vehicles on the road – especially Tesla for full EV, Germany has a rising amount of home battery systems that increase solar self-consumption • Energy transition is increasing the need for new methods of balancing services • TenneT is the TSO for The Netherlands and the central part of Germany
Control model - Optimisation level - Flexibility services accessed - Control entities	• Regional and national level • Suppliers acts as aggregator, providing capacity dynamically to the TSO • In The Netherlands: TSO signals need for balancing by Secondary Reserve and sends signal to the aggregator, that sends signal to connected vehicle to interrupt charging • In Germany, the TSO sends a re-dispatch request to the aggregator, that controls the home batteries • Both the availability of an asset as well as the response are stored in the blockchain

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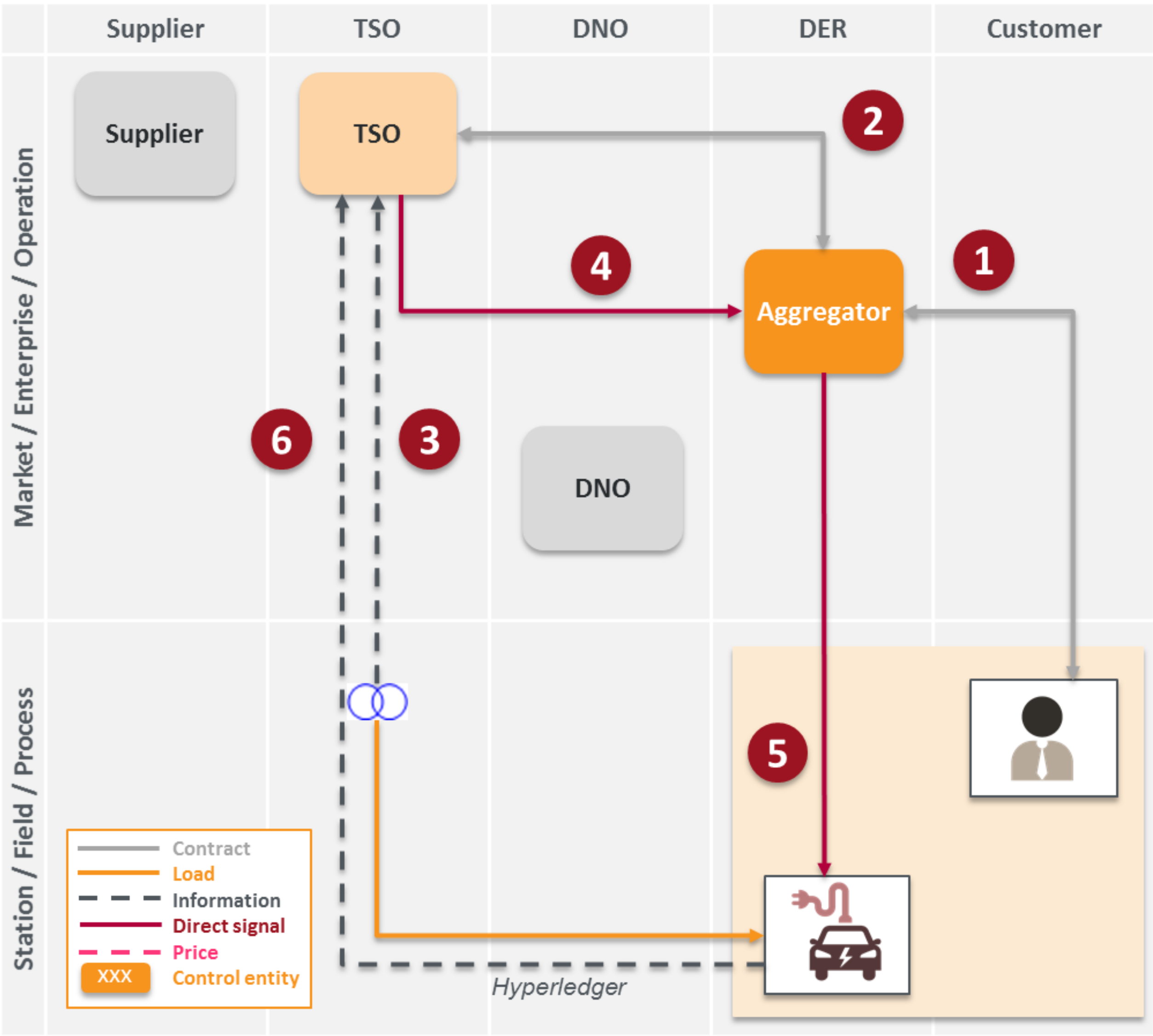
Context and control model | **Illustrative diagram** | Commercial / Technical Features

Functional diagram



Outline process

1) Aggregator and customer enter into managed charging agreement and tariff

2) TSO and aggregator enter into contract for response services

3) TSO identifies emerging constraint / balance need

4) TSO asks aggregator for response

5) Aggregator selects suitable charging sessions and adapts EV charging

6) Response is stored in the Blockchain

Protocol description

- ***Hyperledger*** a distributed ledger technology (blockchain) developed by a.o. IBM

Westnetz | INVADE | USEF | Charge Forward | FlexPower | Electric Nation | My Electric Avenue | City-Zen | **Tennet**

		Tennet
Context and control model	**Commercial model** - Network access rights - Form of control signal - Tariff - Form of optimisation	• Customers will have non-firm grid access: charging is stopped and started based on the request of TenneT. • Direct request signal from TenneT (TSO) to aggregator • Aggregator uses proprietary system to control assets • Customers are compensated with a participation fee (providing availability) and per event (delivered response)
Illustrative diagram	**Technical features** - Push data channel - Response telemetry - Load direction - Flexibility assets - Connection type	• Communication from TSO to aggregator using market standards • Blockchain for verification is provided by IBM, on the basis of their Hyperledger software • Response telemetry used is the electric vehicle or home battery itself • Load only with electric vehicles, bidirectional with home batteries • Electric vehicles and home batteries • Regular household connection
Commercial / Technical Features	**Pros**	• Use of decentralised assets, with blockchain technology and new methods for response telemetry is expected to reduce overall balancing costs
	Cons	• Volume of capacity subject to change as vehicles are not always charging • Regulatory framework not yet fit for decentralised methods and / or blockchain verification

Appendix B Stakeholder feedback

B.1 Overview of engagement approach

Our initial round of stakeholder engagement sought input to our research into smart charging model approaches. Draft materials were produced to support the stakeholder sessions, with questions covering the following areas:

- The current state of the industry debate on Smart Charging
- The Design Principles – what's important in a charging model for the UK?
- The smart charging models framework – what are the possible features and elements of a charging model?
- A spectrum of models – what models are likely in the UK?
- A series of general industry model questions

The following sections set out some of the commentary from those engagement meetings, though comments have remained anonymised to protect confidentiality. This feedback has also been incorporated in the thinking in the main body of the document.

B.2 The current state of the industry debate

Stakeholder questions

Within this section, we asked stakeholders the following questions:

- What are your general perceptions about UK EV charging industry current state?
- What's working well / what could be improved regarding industry evolution?
- What ongoing trials and projects do you think we should be linking up with?

A need for coordination

Stakeholders felt that there is a good level of activity and progress being made in the market from all parties – industry bodies, networks and market participants – who are contributing positively to the debate and driving innovation. Technologies and business models are seen to be emerging that can manage constraints, and this is driving down costs, but many felt that the next step requires integrating a number of disparate solutions into a coherent whole, and that this would require coordinated action.

"There is no current state – the debate is finding its feet"

Whilst there are a number of design processes ongoing in the industry, it is not yet clear to stakeholders which entity will facilitate the decision making process. Some stakeholders felt that the new LowCVP/OLEV/BEIS EV Taskforce could be the vehicle to take this role, and would welcome that. Participants highlighted that there is a pressing need to gain some certainty as to the timescales for action and for clarifying the standards around smart charging, in order to provide sufficient lead-time for development and manufacture of products.

However, many stakeholders reported that it seems that this 'joining-up' is beginning to happen, and are positive about the outlook. Many believe that it is a matter of only one or two years before we see a very healthy market and clear standards emerging.

Caution regarding early trials

Many participants raised the topic of the "managed charging" trials, in response to an open question about the state of the industry debate. This may in part be driven by the fact that they were meeting UK Power Networks – a DNO – for this discussion; however, the topic of "managed" vs. "Smart" charging (see section 2.3.1) is clearly one that all stakeholders would like to address.

"The interim solution is a slippery slope – once invested it will be hard to change course"

Stakeholders agree that the My Electric Avenue and Electric Nation projects have shown that customers will respond positively to managed charging in a way that can mitigate the network issues and enable connections ahead of reinforcement. There is also general appreciation of the need for the DNOs to be able to protect their network, though the "interim solution" provokes some concerns regarding openness and competition. Many believe that market participants will be able to manage constraints in response to price signals, and see an interim solution as potentially an expensive distraction. This topic is covered in greater detail in subsequent sections.

A need for transparency

"We need to see evidence-based decisions"

Some stakeholders felt that this area of debate was suffering from a lack of clarity of data to support arguments and decisions. There is a desire from market participants to see more data from DNOs regarding where and when constraints will happen, and the value that they could pay for mitigation of constraints through flexibility services, in order to stimulate the market. Some raised the question as to whether DNOs had proved the need for the "interim solution", or Smart Charging in general.

The DNOs in turn have related concerns regarding the level of adherence to the notifications process, and the installation code of practice. A key concern is that DNOs frequently are not given visibility of new connections, and so are unable to proactively spot potential clustering issues. In addition, charge points are often installed without respecting the service capacity of the home connection, leading to customer satisfaction issues for which the network is blamed.

More needs to be done by DNOs to give visibility of data to the market, and by market participants to participate in a controlled roll-out of EV connections and smart chargers, in order to avert escalating issues as the numbers of installs begins to ramp-up.

B.3 Review of the Design Principles

Stakeholder questions

Within this section, we asked stakeholders the following questions:

- This section is to understand you views on our draft Design Principles. For a model to be viable, it should be able to satisfy all of the below principles.
- Do you disagree with any of the below statements? Are there any missing?
- In what order would you prioritise them? What are your top three – why is that factor important, what benefit will it bring, what challenges?

Stakeholder responses

Stakeholders broadly agreed with the Design Principles put forward; none were requested to be removed, and no entirely new topics were put forward to be added – though the principles generated good discussion and several enhancements were made. Generally they were felt to be in line with the direction of travel of the industry debate, and stakeholders commented on the balance between the needs of the customer, the market, and the DNO.

"This set of principles is reflective of what we'd like to see"

Principle 1: Deliver consumer requirements in terms of access to mobility, value for money and choice

Several stakeholders specifically commented that it was right to start with the principle on customer needs. "Customer choice" was seen as key, with any Smart Charging or emergency response approach needing to be understood and accepted by the customer.

Principle 2: Ensure network access is not a barrier to electric vehicle uptake

Stakeholders agree that network access should not be a barrier to electric vehicle uptake (though comments were typically directed more toward principles relating to how DNOs and the market should ensure that this is not the case).

Principle 3: Allow DNOs to maintain the operational integrity and safety of the networks, acting in a transparent and non-discriminatory manner

There is general agreement that DNOs will need to be able to protect the network. Stakeholders appreciate that the network must be run safely, and are aware that loss of supply itself constitutes a customer experience risk, and consequently a risk to EV uptake.

No stakeholders disagreed with this principle, though there are different views as to how this should be implemented. One stakeholder raised a clarification that any action by the DNO to protect the network where markets had failed would be seen as valid so long as the DNO acted in a transparent and non-discriminatory manner, leading to the amendment in red above.

Many assumed that the DNO would need to have the ability to over-ride charging at times of overload, though highlighted that this should be done in a transparent and non-discriminatory manner, and preferably should be enacted via 3rd party control infrastructure. All feel that the use of any such mechanism should be minimised, such that we maximise the opportunity of the market to access the flexibility value of the battery, whilst managing network constraints.

This topic is covered in detail in the strategy presented in this report.

Principle 4: Minimise the risk of regret investment in DNO assets

Stakeholders agree that the DNO should seek to minimise regret investment, where this might concern smart charging control assets. There were some clarification questions raised and so we have updated the wording as highlighted in red above.

Principle 5: Be consistent with the DNO's risk profile (financial, technical, reputational, cyber security)

Some stakeholders raised a concern that in this fast-moving space, the future is uncertain and requires innovation, which involves risk. It is possible therefore that if it is incumbent on the DNO to drive innovation in some areas, and they are too risk averse, then they may become a blocker to progress. We understand that concern, though believe that the Totex incentives within the RIIO framework provide some incentive for the DNO to deploy Opex vs. Capex solutions, and we will continue to support enhancements to the regulatory framework that reward DNOs for facilitating the uptake of EVs, and encourage them to promote market-based solutions for smart charging.

One stakeholder commented that additional control assets on the network, as per the "interim solution", would increase the level of decentralisation and digitisation, and hence increase cyber security risk for the DNO. The "interim solution" would also drive higher reputational risks than a price-driven model; in a price-driven model the customers always have a choice whether to consume or not, where-as in a DNO controlled model there is a risk of curtailing a customer at the "wrong" time, leading to customer experience issues and potentially reputational impacts.

Principle 6: Protect customer privacy

Stakeholders agreed that customer privacy would be an increasing risk and should be protected.

Principle 7: Ensure that the flexibility value of EV batteries can be realised where it is most valued to the customer

Stakeholders agreed that the market should be able to access EV batteries in order to utilise the flexibility value on the wider system, such as in the wholesale market and balancing mechanism.

Principle 8: Enable competition between different business models and technologies (through interoperability)

Several stakeholders highlighted the need for interoperability to enable competition and switching, though some clarifications were raised regarding which elements of the value chain should be open to interoperability – specifically in relation to charge points and CPO back-end systems and support processes.

Whilst there was appreciation that charge points, when combined with their CPO offering, should be interoperable between suppliers to enable customers to switch, a caution was raised that it did not necessarily follow that the charge point assets themselves should be interoperable between CPO's. This was raised on the basis that the CPO proposition is comprised of more than just the asset, and that interoperability would require each CPO to technically support a wide range of assets.

Charge points are designed and manufactured to integrate with the CPO's back-end systems. As a result the technical feature set is specific, with for example a defined approach to firmware updates, a specific approach to security, etc. In addition, CPO's provide warranties, maintenance and customer support for their assets, which would become much more difficult with other companies' assets. Finally, key areas of the competitive propositions may be eroded, such as guarantees of accuracy of metering. In such circumstances, mandating interoperability of the charge points may in fact stifle innovation between CPO's and erode the quality of the customer propositions available in the market.

A compounding factor in this consideration is the current state of the charge point asset base in the UK, which some suggest may include a large proportion of "dumb" charge points at present, which some CPO's would struggle to support.

The general point (i.e. beyond the charge point areas outlined above) is that whilst interoperability and competition is universally seen as important, it should be recognised that in setting the boundaries we must avoid inhibiting or creating barriers to entry for innovative propositions, or creating policy and legislation that may need to be changed in the years to come.

Principle 9: Be equitable for all network users (including non-EV adopters)

Most stakeholders agreed with this principle, with some specifically highlighting through the conversation that many of the prior principles should apply not just to EV's but all types of load and DER.

Some however suggested the opposite, in that given EVs were giving rise to these issues and considerations, should we not manage EVs in a different way in order to resolve their own constraints? Whilst we agree that some aspects of EV integration are unique – such as the need to being market mechanisms to low voltage parts of the network, or the increased relevance of the asset to general consumers – the general issue of integrating a new technology and customer set into the network is not new (for example, recent developments integrating mid-scale distributed generation (DG) developers onto the network). In addition, the load driven by EVs is of course not the only load on the impacted areas of the network, which will include general customer load as well as DG and industrial loads, as well as other providers of flexibility who can assist in managing the EV load, and so should be considered alongside other assets and customer types on an equal basis.

This principle has arisen from the observation that the current network access and charging regime does not distribute the costs of the network fairly across EV users and non-EV users. Under the present regime, and as EV uptake increases, EV users will drive peaks in demand and trigger either reinforcement. The costs of this reinforcement will then be distributed (via the DUoS charges) to all consumers. As such, EV users will be driving increased costs on the network, but will not be paying more than non-EV users for the increased use of the network. Perversely, we see a risk that in the short-term, EV users may be paid flexibility incentives in order to shift their charging times and mitigate costs on the network. In this way, EV users would in fact be putting more strain on the network, and then be paying less than non-EV users.

We see a risk of an unfair distribution of costs, particularly in the near-term, and so propose this principle as a key aim to deliver in any Smart Charging approach.

Principle 10: Be compatible with upcoming regulatory led change to network access and charging, and the DSO transition

Stakeholders are aware of Ofgem's Network Access & Forward Looking Charges review and highlight the difficulties in progressing the approach to Smart Charging whilst there is little clarity on the direction of travel of this work. However, there is general agreement that progress must be made in any case, given that it may be several years before the review is completed and/or implemented.

B.4 Smart charging models framework

Stakeholder questions

Within this section, we asked stakeholders the following questions:

- This section is to understand you views on our draft Design Principles. For a model to be viable, it should be able to satisfy all of the below principles.
- Do you disagree with any of the below statements? Are there any missing?
- In what order would you prioritise them? What are your top three – why is that factor important, what benefit will it bring, what challenges?

Stakeholder responses

"This is really useful! You've captured a lot of concepts here"

In general, stakeholders who were familiar with the different facets of Smart Charging were engaged in the framework, and felt that we had identified the majority of the relevant factors. No significant change to the factors and options were put forward; there was general agreement with all options on the list, none were flagged as impossible, and few new concepts were raised.

Several mentioned that thinking about the "control model" factors as the primary drivers was a good approach, and cautioned that some parties may be pushing ahead with technical solutions, without first having a strong rationale within a holistic picture of what we are trying to achieve.

Stakeholders also put forward views regarding individual factors in the framework:

- **Primary system driver** – All primary system drivers were seen as viable, with one stakeholder commenting that perhaps the customer should also be mentioned as an option against this factor, and so this has been added.
- **Optimisation level** – There was little commentary on this factor, and it was implied that all options would be viable and the level of optimisation tied to the primary system driver.
- **Control mechanism** – Some raised the point that curtailment of the network connection should be a temporary solution only and in specific circumstances, and with guidelines/restrictions on how it is used. This point gets to heart of the "managed" vs. "smart" charging debate, which we return to at several points in this report.
- **Control entity** – Several raised the point that there were concerns as to whether the DNO or TSO should have any role in residential Smart Charging. In addition, one stakeholder suggested that "DNO" should potentially be labelled as "DSO", given that currently ownership or control of storage assets is outside of a DNO's licenced activities. Whilst we recognise this point, we believe that formally recognising the DNOs operating in this capacity as DSOs is premature, given the stage of design in the ENA's ongoing Open Networks programme. Some stakeholders raised the possibility of other types of entity/business also taking up a role in Smart Charging as a control entity. Our position on this is to remain "business model agnostic", and recognise that various types of entity could potentially take on a role as aggregator, but refrain from listing them all out as options on the framework, for simplicity. Stakeholders were on board with this approach.
- **Network access rights** – Some stakeholders suggested that it would be appropriate to ensure compensation for customers if they are curtailed (i.e. firm access rights). This was on the basis that it would help to make the new arrangements acceptable to customers, and avoid a negative reaction in the short term. This will need to be investigated in detail, given that (a) customers do not currently have explicit capacity rights enshrined in a capacity allowance, and there is not enough capacity for everyone to charge an electric vehicle, and (b) such an arrangement would be non-equitable to non-EV users without reform of the distribution charging regime.
- **Primary control signal** – All stakeholders would prefer to see price signals used as the primary control signal, rather than direct control, though there is some divergence regarding when this would be feasible. One stakeholder raised the concern that direct control presents a risk that customer needs may not be met, if the controlling entity (i.e. the DNO) was not able to fully account for customer preferences, whereas with price signals the final decision always rests with the customer.
- **Tariffs** – most stakeholders believe that a time-of-use tariff (ToU) is critical to make Smart Charging work. However, there are varying views as to what form that should take (e.g. static DUoS, dynamic DUoS, rising-block

capacity charges, etc.) and most stakeholders felt that this would need careful consideration and potentially some trials to determine. Some concerns were raised that static ToU tariffs might lead to secondary peaks, with aggregator algorithms shifting large numbers of customers from the current evening peak and creating a new peak at a different time. One stakeholder suggested that there may also need to be differences across load and supply tariffs, though due to the scope of this project as not yet looking to encompass V2G, we have not separated out load and supply tariffs.

- **Settlement** – Two stakeholders suggested that Blockchain settlement and P2P trading was seen as the ultimate end goal for local Smart Charging (and wider Smartgrid coordination), but was seen as years away from being possible. No stakeholders had strong views as to the form of settlement and saw it as connected with Ofgem's Network Access & Forward Looking Charges review.
- **Push data channel / response telemetry** – Two stakeholders saw the SMETS2 smart meter roll-out as a necessary enabler of market business models for Smart Charging, in order to allow for validated settlement of wholesale (and potentially distribution level) ToU tariffs, and also potentially as the 'push' data channel, as per the Smart EV Project consultation. As a result the DNO interim solution was seen as required ahead of the Smart Meter roll-out. Not all stakeholders were of this view, and believed that other Smart technologies are able to provide adequate and secure metering and control channels.
- **Power flow direction** – One stakeholder commented that the focus should be on bi-directional load, rather than load only, because the technology is rapidly moving in that direction. We intend for the approach set out in this report to be flexible to account for bi-directional load, though will not be designing for V2G in detail in this project.

B.5 Spectrum of models for the UK

Stakeholder questions

Within this section, we asked stakeholders the following questions:

- This section is to discuss a "spectrum" of models and gain your views as to what would be appropriate for the UK industry (we will provide "voiceover" in the session)
- Do you agree with the spread of model options and the groupings?
- Are any models missing?
- Do you agree with the models that have been excluded and the rationale?

Stakeholder responses

Stakeholders did not put forward any significant additions or amendments to the spectrum of models, and saw it as a comprehensive spread of options. Most agreed with all options on the spectrum as being viable, and with the models marked as unlikely to be viable, though with preferences for different models as outlined below.

Some stakeholders felt that the market concepts outlined in relation to networks were complex, and would need careful consideration. Many felt that the end state may not be a 'one-size-fits-all' solution, and that different models might be more appropriate for different network situations and customer types. It was also generally recognised that there may need to be an evolution through the models, as the industry tries different approaches, learns and matures.

Many stakeholders assumed that the DNOs would require a form of emergency action option, such as in the D2 and A1 models, and were surprised to see other options put forward without this feature. A general belief was that this option would be required, at least in the short-term, and that individual instances of 'managed charging' (i.e. where the DNO takes a unilateral curtailment action) should be quite rare.

A number of specific viewpoints were fed back in relation to the specific groups of models, as outlined below:

- **DNO models** – All stakeholders agreed that the DNO models proposed as out of scope (i.e. D1, D3 and D4) would most likely not be appropriate, on the grounds that they would stifle competition and market access. Most stakeholders agreed that the D2 model could be a viable option, though many had reservations and a preference against this model. Some highlighted that a D2 model with a static set of rules or a timed connection would not be able to keep pace with customer behaviour, which is dynamic, and would therefore frustrate customer needs. It was also pointed out that the D2 model would create a bottleneck between sources of flexibility and other markets – such as the wholesale market or balancing mechanism – and would therefore prevent market signals from taking all factors into account and making the optimal decision in a transparent manner, and as such should not be the preferred solution longer term.

- **TSO models** – All stakeholders agreed with the exclusion of models in which the TSO would be the direct control entity, and the rationale set out. However, some stakeholders underlined the importance of close DNO/ESO coordination and highlighted that the ESO may in future wish to procure flexibility from residential customers (likely via aggregators)
- **3rd party models** – Many stakeholders saw the 3rd party models as the ultimate goal, with a spread of views across the three options (A1, A2 and A3). Some believed that A2/A3 were the ultimate goal, with no emergency action functionality required for the DNO, and with a general belief that a flexibility market could be designed such that the benefits would outweigh the costs and complexity – though recognising that this is as yet unproven. However, others (including market-side participants) were concerned regarding moving into the A2/A3 models in which there was no form of emergency response functionality for the DNO – i.e. there was an assumption that the DNO would need some form of emergency control, even if enacted via 3rd party systems – and some felt that the complexities and level of engagement required for the A3 model would outweigh the incremental benefits, and potentially put customers off.
- Some complexities were foreseen with 3rd party models regarding knowing which customers are with which 3rd parties on which part of the network, in order to enable market models. Two stakeholders raised the point that if a constraint is identified at LV level, then for the emergency response in model A1 to work, the DNO would need to know which 3rd parties correspond to the relevant customers. Others, however, saw this as simply an implementation issue, and one that could be overcome with systems. Another concern raised was that the number of customers on any given part of the low voltage network would be low, and this reduces the level of liquidity for any market solution to work at that level, and may therefore lead to inadequate response. Several stakeholders therefore commented that they were cognizant that aggregator solutions were as yet unproven, and that the DNOs rightly will need to be "convinced" that 3rd party models work, and that this will need to be done quickly in order to avoid any wide deployment of DNO-led solutions.

"We can understand why the DNOs are nervous – the aggregator approach is currently unproven"

- **Customer models** – Some stakeholders saw the Customer models C1 and C2, with a higher degree of customer control, as more likely. For others, the 3rd party and Customer models were ultimately seen as the same, as the 3rd party models would still need customer acceptance of terms and rules, and Customer models would still need some form of control technology services. Doubts were raised regarding the level of customer effort required, and it was suggested that customers would likely preference to work through 3rd parties. One stakeholder questioned the Customer models, and underlined the need to think about wider factors that might impact model variants, such as car sharing, mobility as a service, and autonomous vehicles.

"We must design around the consumer, and be mindful of the amount they have to act"

B.6 Answers to key industry model questions

Stakeholder questions

Within this section, we asked stakeholders the following questions:

- What system driver will take primacy – i.e. what is the relative importance of network capacity vs. systems services vs. wholesale energy, and would this influence the most appropriate model?

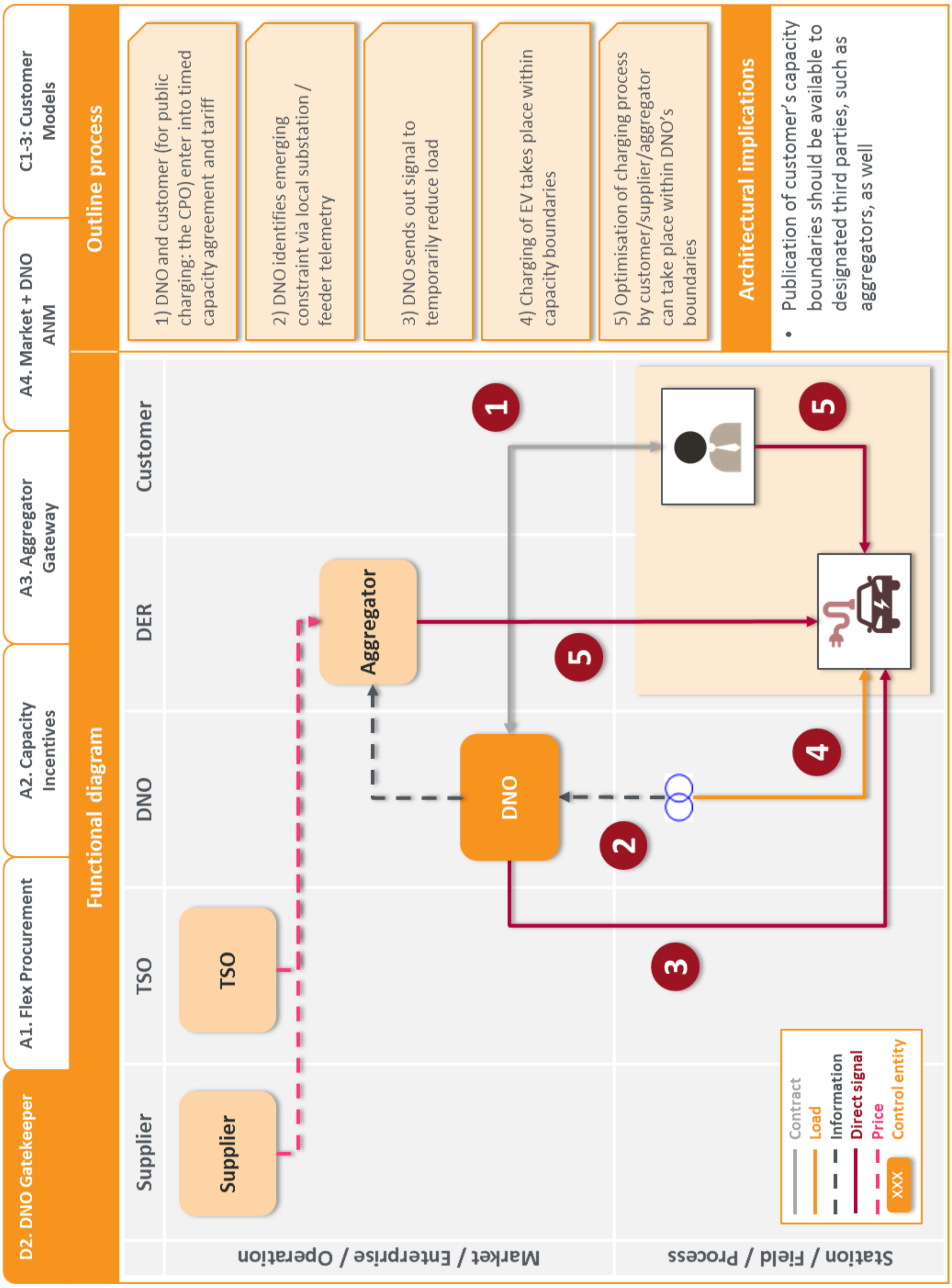
- What is the appropriate means for the DNO to maintain the integrity of its network? Will this be via a real-time curtailment mechanism, that does not inhibit market models, or should the DNO utilize other means (e.g. connections process, outages, manage via other DER?)
- What level of "firmness" of flexibility response can a DNO expect to get from an aggregator or customer, and will this be sufficient to maintain the integrity of the network?
- How quickly could we expect market business models to emerge, and is "regret spend" in interim DNO control systems acceptable to avoid inhibiting EV uptake in the short term if they do not emerge quickly enough?

Stakeholder responses

- **Primary system driver** – This was generally seen to be a complex question, and some pointed out that the solution would likely be dynamic, with rules and changes in one market area likely to have impacts on the others, and so the value would be revealed by the markets over time. Many felt that ultimately local network capacity should take primacy, as it is an enabler of the value in other markets – i.e. if the local network fails the assets in question would not access value in any markets. Some also pointed out that outages will provoke customer backlash, and that there would be reputational issues for parties to consider. However, some felt that the wholesale market opportunities would probably drive the most value in money terms to the customer, but that local network constraints would also need to be managed to enable this.
- **Maintaining integrity of the network** – Many stakeholders assume that some form of emergency control for the DNO will be needed, but stipulate that they would expect limited use, clear rules, and customer compensation. However, most also believe that the DNO should first use all other tools available where possible – i.e. maximising available capacity, flexibility procurement, constraint pricing, and then finally real-time tools.
- Most stakeholders had a preference for any emergency action to be enacted via 3rd party smart charging infrastructure and systems, as this would save cost for the DNO, which is passed on to customers. One stakeholder highlighted that costs for 3rd parties for smart charger solutions would be recovered from the specific customers causing constraints, rather than spreading the costs across all customers, which would be more equitable. In addition, 3rd parties could seek to recover these costs via the wider markets and services – i.e. the service could be net gain for the customer, even accounting for the costs of any control kit.
- Some stakeholders pointed out that outages would be a customer experience impact (one that the DNOs have a licence condition to look to avoid), and that given we have such high levels of reliability it is possible that customers could be very concerned if exposed to security of supply issues. As such the impact of occasional managed charging events should be considered as compared to this alternative. In addition, the current WPD and SSEN trials have demonstrated that customers are open to changing their charging patterns, and so we perhaps should not be too concerned about the customer impacts of managed charging events.
- Finally, one stakeholder raised the potential for safety issues, highlighting that any public safety incidents would be very damaging, and that any smart charging model adopted should have a 100% reliable safety mechanism.
- **Firmness of response from market models** – Some stakeholders claimed that their current systems and customer groups can deliver demand response with a high reliability. However, there is an appreciation that with any model in which a customer response is required or pre-agreed, there will likely be a drop-out rate, due to customer opt-outs and failure of communication signals. This is observed in the current DNO trials, and was also reported as a factor by market participants experimenting with demand response.
- **Speed of emergence of market business models** – Several stakeholders believe that the technology to deliver smart charging exists today, but that the barrier now is enabling coordination and communication across all parties and DNOs. Several raised the need for central coordination of design work to enable market business models, and so were pleased to see this project progressing, though also feel that an industry-facilitated approach is required.
- Some stakeholders felt that they did not have the information needed to understand what they should be doing to help manage the network impacts, and would value advice and examples of the services required. One stakeholder raised the point that a number of existing players in the DER Coordination space were focussed

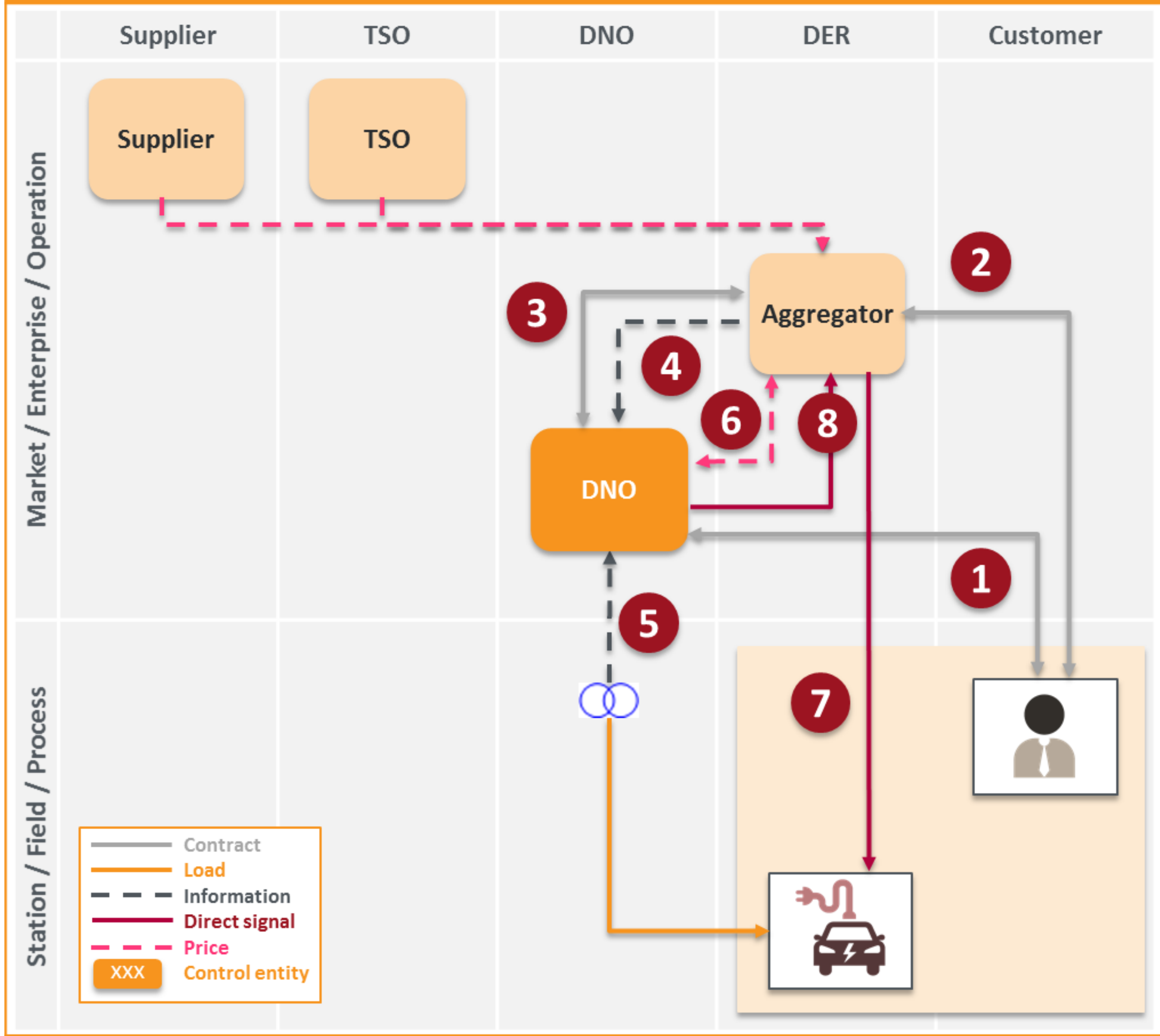
more on wholesale market and balancing mechanism opportunities, and were less ready to offer services to the DNOs. Some stakeholders felt more ready to begin developing services, and suggested that all the DNO would need to do to stimulate the market would be to clarify the value of response by revealing a price signal. It was felt that a simple proposition to offer the DNO day-ahead certainty could be enacted in a matter of weeks, with a real-time price mechanism not seen as particularly complex to achieve.

Appendix C Viable smart charging models



D2. DNO Gatekeeper | **A1. Flex Procurement** | A2. Capacity Incentives | A3. Aggregator Gateway | A4. Market + DNO ANM | C1-3: Customer Models

Functional diagram



Outline process

1) DNO and customer enter into firm capacity agreement and tariff

2) Aggregator and customer enter into managed charging agreement

3) DNO and aggregator enter into contract for response services

4) Aggregator sends forecast to DNO

5) DNO identifies likely constraint

6) DNO asks aggregator for bid for load shift / aggregator responds

7) After DNO offer, aggregator selects suitable charging sessions and adapts EV charging

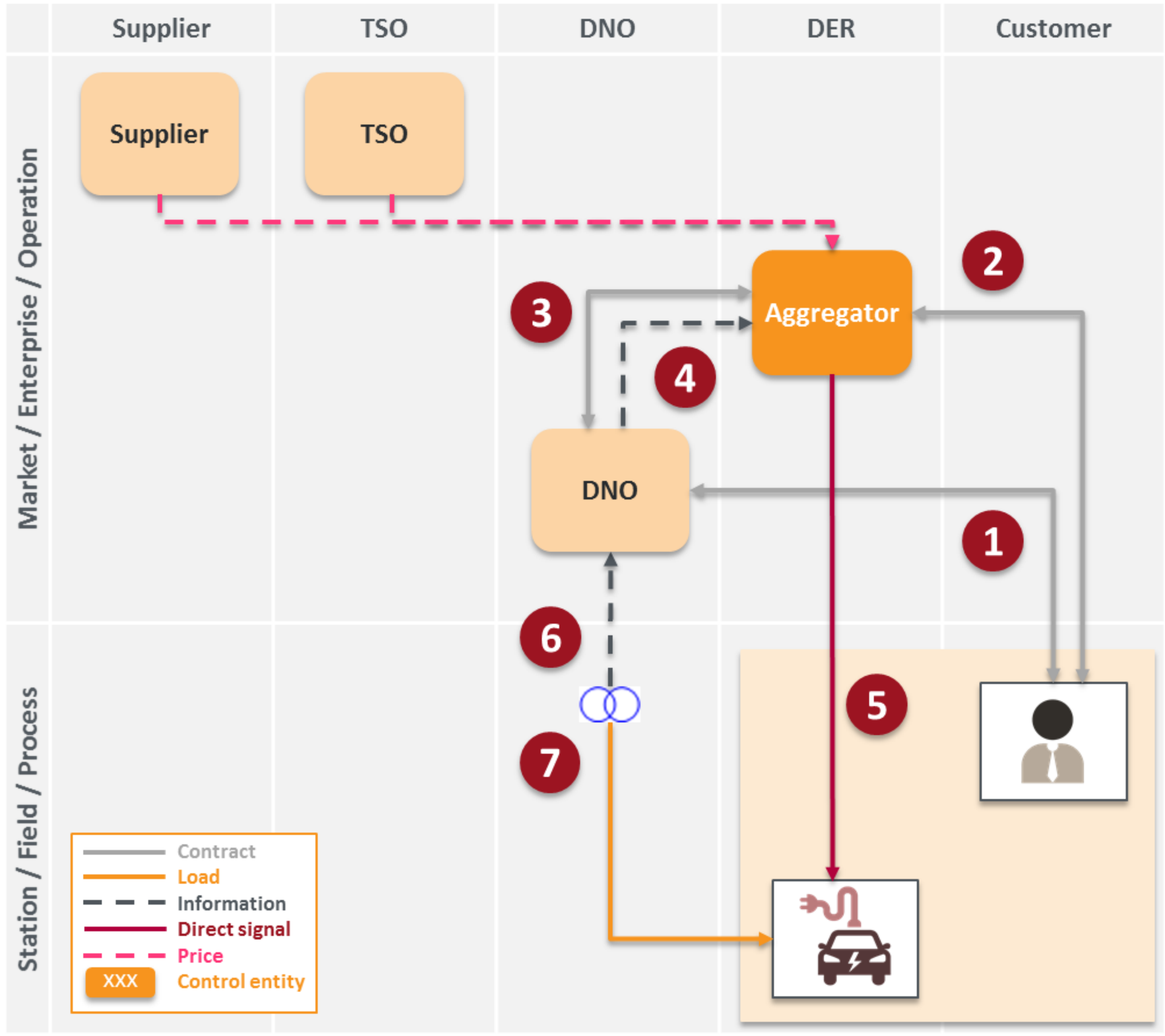
8) If bid/offer market fails, and/or in the case of a near/real-time emergency situation, the DNO contracts capacity (either directly or through the aggregator) over which it has unilateral access

Architectural implications

- Aggregators need to contract diverse portfolio of assets to be able to provide flexibility at all times
- Likely requires a more mature aggregator market

D2. DNO Gatekeeper | A1. Flex Procurement | **A2. Capacity Incentives** | A3. Aggregator Gateway | A4. Market + DNO ANM | C1-3: Customer Models

Functional diagram



Outline process

1) DNO and customer enter into firm capacity agreement and tariff

2) Aggregator and customer enter into managed charging agreement and tariff

3) DNO and aggregator enter into contract for capacity allocation

4) DNO publishes capacity profile to aggregator (potentially dynamically)

5) Aggregator selects suitable charging sessions and adapts EV charging

6) DNO identifies emerging unmanaged constraint in need of emergency action

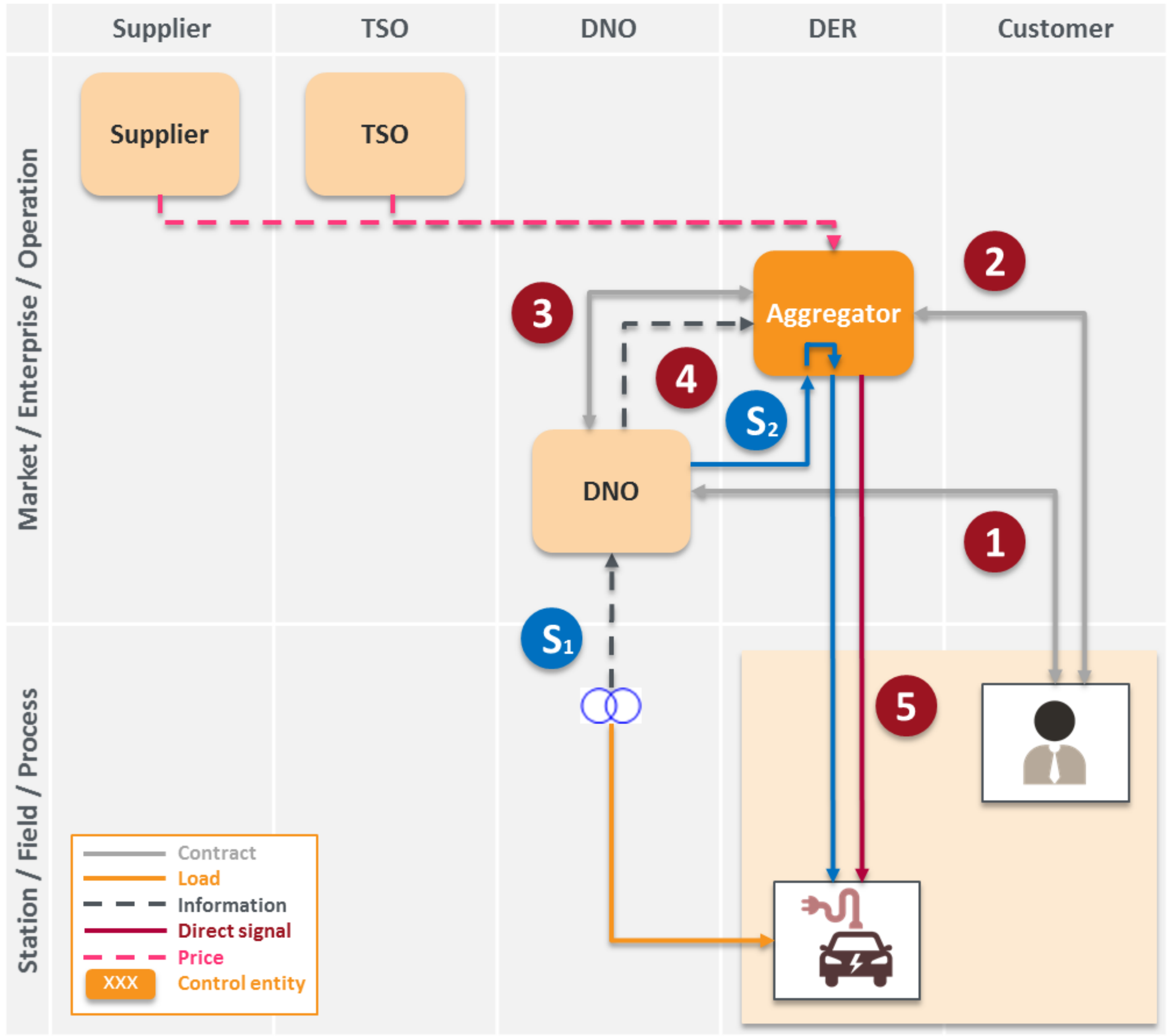
7) DNO takes emergency action as today – e.g. outage at feeder level

Architectural implications

- Similar architecture in place in various projects, such as FlexPower Amsterdam and Electric Nation

D2. DNO Gatekeeper | A1. Flex Procurement | A2. Capacity Incentives | **A3. Aggregator Gateway** | A4. Market + DNO ANM | C1-3: Customer Models

Functional diagram



Outline process

1) DNO and customer enter into firm capacity agreement and tariff

2) Aggregator and customer enter into managed charging agreement and tariff

3) DNO and aggregator enter into contract for capacity allocation

4) DNO publishes capacity profile to aggregator (potentially dynamically)

5) Aggregator selects suitable charging sessions and adapts EV charging process

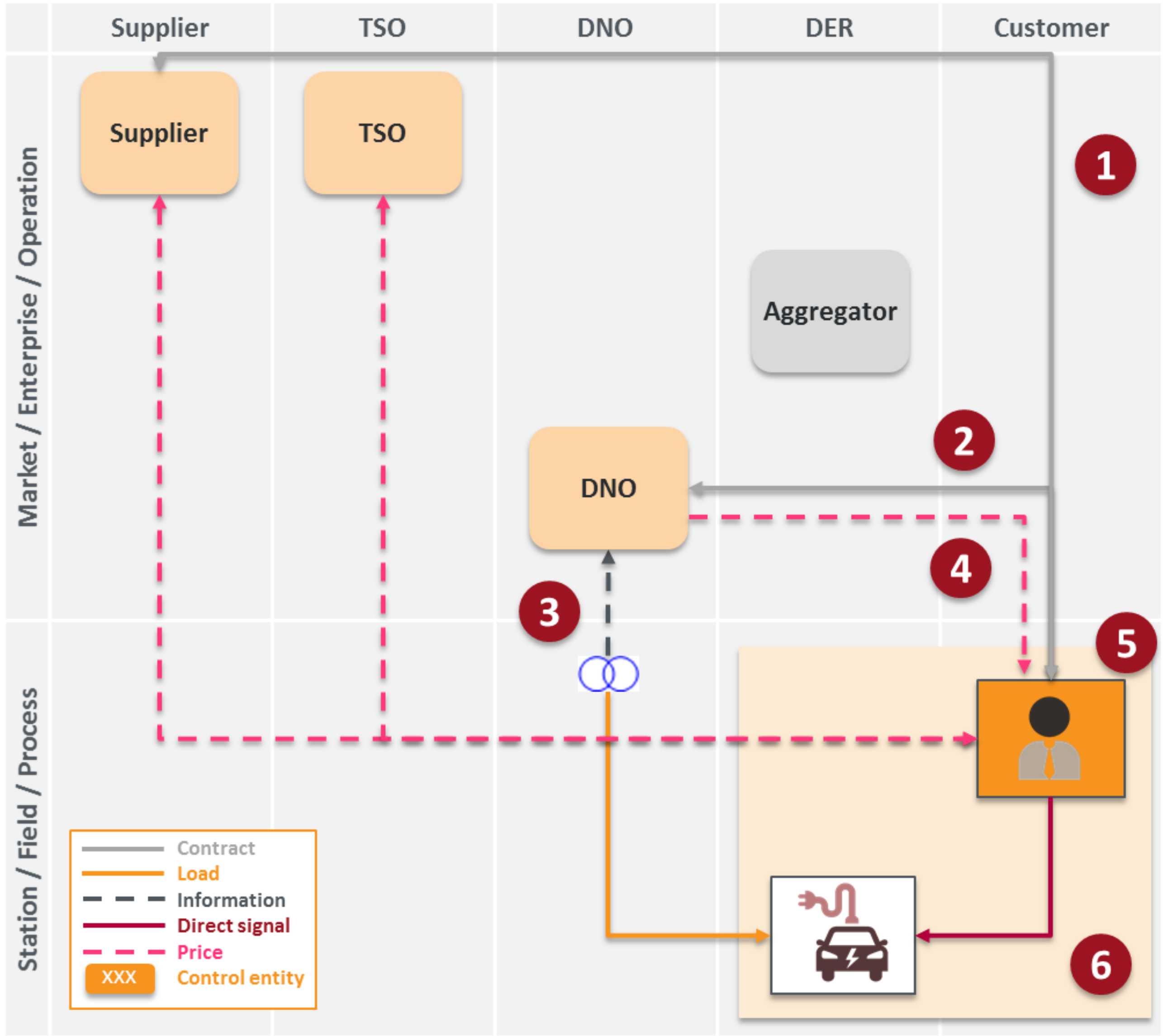
Safeguard:
S1) If market fails to manage constraint and DNO identifies emerging unmanaged constraint
S2) DNO selects charging sessions and curtails connection via ANM

Architectural implications

- Safeguard mechanism requires deep integration of DNO ANM system with aggregator's platform

D2. DNO Gatekeeper | A1. Flex Procurement | A2. Capacity Incentives | A3. Aggregator Gateway | A4. Market + DNO ANM | **C1-3: Customer Models**

Functional diagram



Outline process

1) Supplier and customer enter into energy supply and sale agreement

2) DNO and customer enter into capacity agreement with static or dynamic pricing

3) DNO monitors network and develops constraint pricing (static or dynamic)

4) DNO publishes access prices

5) Customer optimises response vs. wider markets, home DER and potentially the local area via P2P

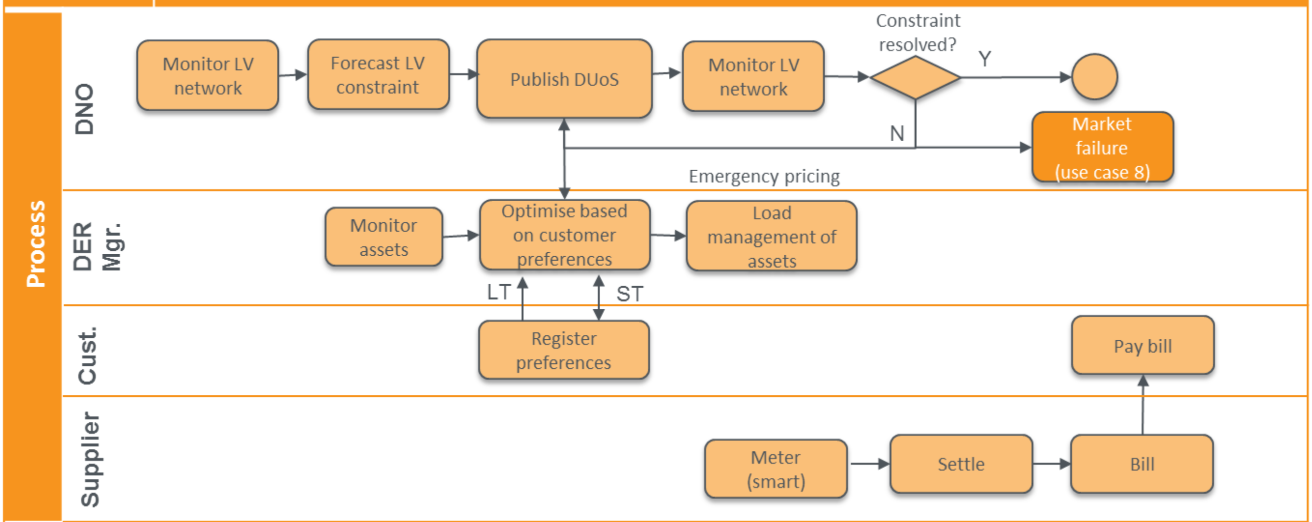
6) Customer manages charging

Architectural implications

- Rise of connected vehicles and chargers will increase the potential of response to dynamic pricing, though publication of price signals needs to be open to such platforms / devices

Appendix D Smart charging use cases

Use Case: **1: Generating customer response to locational ToU pricing (enhanced DUoS)**



Preconditions

- Emerging constraint on LV feeder
- No alternative sources of flexibility
- Customer EVs charging in peak time
- ToU DUoS
- Smart metering and half hourly settlement

Postconditions

- DUoS charges result in peak shift
- Customers responding to price signals
- Peak load reduced and constraint managed

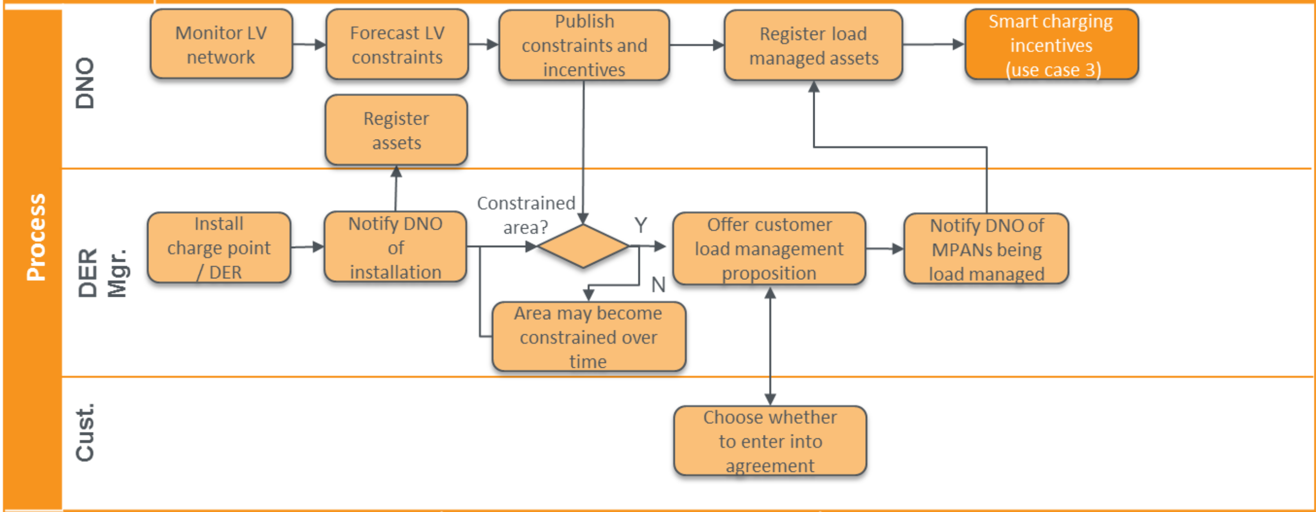
Implementation Considerations:

- Dependent on the Ofgem network charges review (ToU DUoS)
- Dependent on smart metering and half hourly settlement
- Requires DUoS market design
- Requires system changes across the market e.g. supplier billing of ToU DUoS
- Requires customer engagement and behaviour change
- Would require upgrade of "dumb" chargers

Capabilities Required:

DNO:	• LV monitoring • LV constraint forecasting • ToU and locational DUoS pricing • Identification of "market failure"
DER Manager:	• Asset monitoring • Optimisation of smart charging based on DNO price signals and customer preferences • Load management of assets
Supplier:	• Half hourly metering (minimum) • Half hourly settlement • Billing of ToU and locational DUoS

Use Case:	2: DNO identified and publishes LV constraint pricing, and 3rd parties sign-up customers to smart charging tariffs



Preconditions

- Emerging constraints on network
- No alternative sources of flexibility
- Customer EVs charging in peak time

Postconditions

- Consumers opt-in to have their load managed to prevent outages
- Peak load reduced and constraint managed

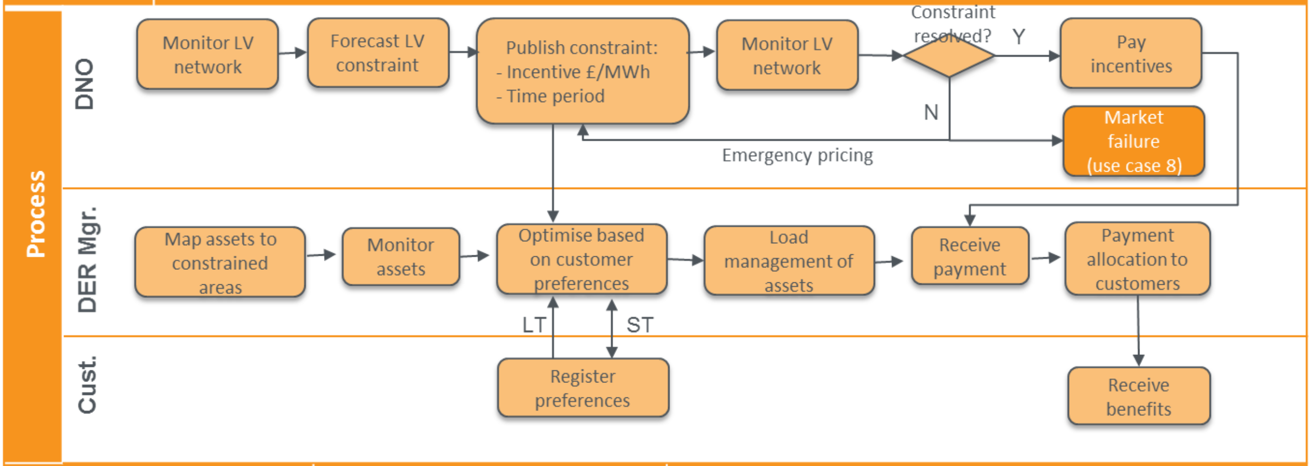
Implementation Considerations:

- Requires commercial incentive design
- Suppliers / DER coordinators able to access constraint prices and offer propositions
- Requires customer engagement and behaviour change
- Would require upgrade of "dumb" chargers
- Legislative change to ensure DNOs are notified of CP installations
- Technical solution largely exists today (via CPOs)

Capabilities Required:

DNO:	• LV monitoring • LV constraint forecasting • Constraint pricing • Asset register of CPs (mapped to LV feeders) and load managed assets logged
DER Manager:	• Notification capabilities following installation of CPs/load management propositions • Identification of assets in a constrained area • Customer acquisition with smart charging propositions

Use Case:	3: Generating customer response to locational ToU pricing (DNO administered prices for flex procurement)



Preconditions

- Emerging constraint on LV feeder
- No alternative sources of flexibility
- Customer EVs charging in peak time

Postconditions

- Incentive payments offered for peak shift
- Customers responding to voluntary incentives
- Peak load reduced and constraint managed

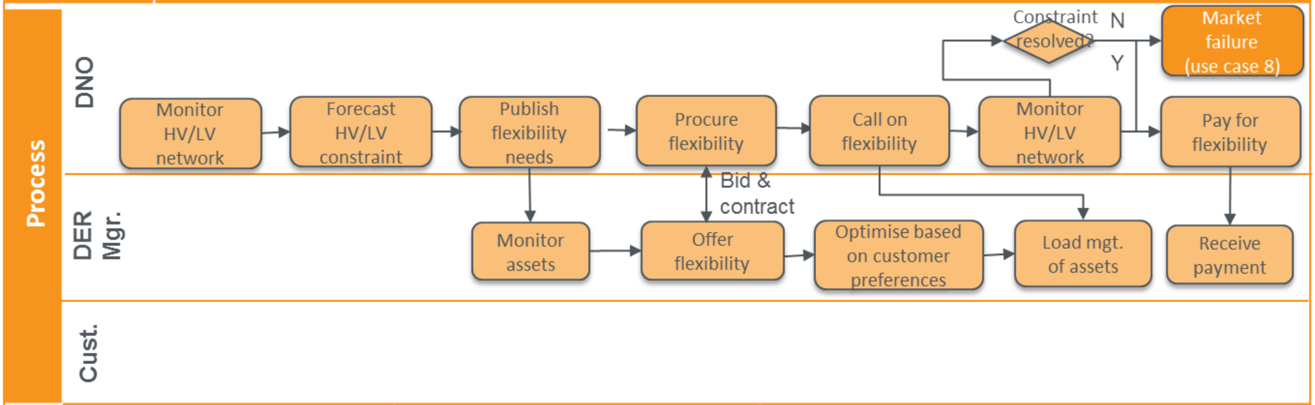
Implementation Considerations:

- Requires commercial incentive design
- Suppliers / DER coordinators able to access constraint prices and offer propositions
- Requires customer engagement and behaviour change
- Would require upgrade of “dumb” chargers
- Limited legislative change
- Technical solution largely exists today (via CPOs)

Capabilities Required:

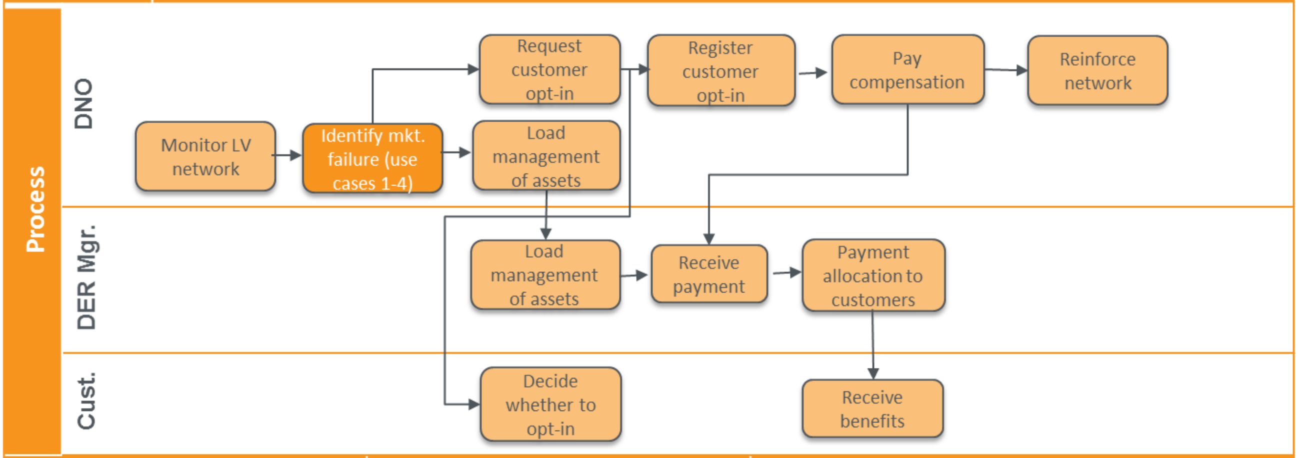
DNO:	• LV monitoring • LV constraint forecasting • Constraint pricing • Incentive payments • Identification of “market failure”
DER Manager:	• Mapping of assets to constrained zones • Asset monitoring • Optimisation of smart charging based on DNO price signals and customer preferences • Load management of assets • Incentive payment allocation

Use Case:	5: DNO flexibility service procurement from bulk DER provider (e.g. battery) to mitigate LV EV cluster



Preconditions	Implementation Considerations:	Capabilities Required:	
• Emerging constraint on network • Sources of bulk flexibility available and more cost effective than constraint pricing/DUoS	• Requires design of commercial flexibility products • Requires DNO to assess costs of flexibility vs. constraint pricing • Requires engagement of flex providers who can provide assets at a lower cost than smart charging • Limited legislative change	**DNO:**	• LV/HV monitoring • LV/HV constraint forecasting • Publication of locational flexibility needs • Procurement of flexibility • Valuing flexibility (vs. constraint pricing) • Monitoring delivery of flexibility • Payment for flexibility • Identification of “market failure”
Postconditions		**DER Manager:**	• Asset monitoring • Offering of flexibility • Optimisation of asset based on DNO price signals and customer preferences • Load management of assets • Payment allocation
• Need for larger connection alleviated • Additional flexibility means that the peak load can be managed			

Use Case:	8: DNO request for and use of "opt-in" load-management facility



Preconditions	Implementation Considerations:	Capabilities Required:	
• Third parties are not offering consumers attractive smart charging propositions • Incentives are not sufficient to manage constraints • Customers continue to charge EVs in peak times • No alternative sources of flexibility	• Requires design of commercial compensation • Requires customer engagement • Potentially requires DNO control asset design and installation journey (or open standards/third party control) • Would require upgrade of "dumb" chargers if control was via third parties / open standards • Requires charge point standardisation if "open standards" used • Limited legislative change, whilst solution remains "opt-in"	**DNO:**	• LV monitoring • LV constraint forecasting • Identification of "market failure" • Customer engagement for "opt-in" of load management • Load management (potentially via third party systems) • Compensation payments
Postconditions		**DER Manager:**	• Mapping of assets to constrained zones • Asset monitoring • Load management of assets based on DNO signals • Compensation payment allocation
• Consumers opt-in to have their load managed to prevent outages • Peak load reduced and constraint managed			

Appendix E Core functionality identification

L0 Capability	L1 Function	L2 Sub-Function	Interim (D1)	D2	A1	A2	A3	C1	C2	C3	RAG	Core
Network Operations	Network Visibility	Real-time network visibility - primary,	✓	✓	✓	✓	✓	✓	✓	✓	G	Y
		Power quality monitoring and health checks	✓	✓	✓	✓	✓	✓	✓	✓	G	Y
		LV network modelling	✓	✓	✓	✓	✓	✓	✓	✓	G	Y
		Visibility of Evs on feeder	✓	✓	✓						A	Y
	Energy Flows Forecasting	Day ahead energy forecasting (inc.	✓	✓	✓	✓	✓	✓	✓	✓	G	Y
		Analysis of historian data	✓	✓	✓	✓	✓	✓	✓	✓	G	Y
	Optimisation and Real-time Dispatch of DER	Failsafe monitoring and trigger	✓	✓	✓						A	Y
		TSO coordination					✓				R	N
		DER dispatch identification	✓	✓	✓		✓				A	Y
		Issue DER dispatch instruction	✓	✓	✓		✓				A	Y
	Outages & Restoration (BAU not EV related)	Manage unplanned events and incidents	✓	✓	✓	✓	✓	✓	✓	✓	G	Y
		Manage planned events	✓	✓	✓	✓	✓	✓	✓	✓	G	Y
		Restoration of supply	✓	✓	✓	✓	✓	✓	✓	✓	G	Y
New Market Functions	Calculate & Publish Market Information	Generate and publish future flexibility needs		✓	✓	✓	✓	✓	✓	✓	G	Y
		Generate and publish network capacity		✓	✓	✓	✓	✓	✓	✓	G	Y
		Calculate and publish enhanced DUoS charges		✓	✓	✓	✓	✓	✓	✓	G	Y
		Calculate and publish short-term dynamic DUoS		?	?	?	?	?	✓	✓	A	?
		Publish real-time network status				✓	✓				R	N
	Capacity Allocation & Management	Long and short term capacity allocation				✓				✓	R	N
		Run secondary capacity market				✓				✓	R	N
	Flexibility Procurement	Procurement strategy	✓	✓	✓	✓	✓	✓	✓	✓	G	Y
		Procure forward flexibility	✓	✓	✓	✓	✓	✓	✓	✓	G	Y
		Procure LV flexibility					✓				R	N
	DER Settlement	Settlement of capacity				✓					R	N
		Settlement of flexibility					✓				R	N

Appendix F Smart charging requirements

Requirements matrix v0.7.xlsx

Appendix G Equipment standards

The following table was submitted to the Energy Networks Association in response to a request for input into a joint paper setting out an agreed view on smart charging equipment standards.

Specification category	Description	Reason for incorporating such functionality	Details on implementation
Communication	Robust (and user configurable) communication via safe comms mediums	This is to ensure reliability of comms between the EV charge point and backend system / DNO control centre.[21]	EV charge points should communicate through secure comms that are resilient to cyber-attack, ensuring data privacy where applicable
	Real-time data exchange with a backend system (backend system agnostic)	Smart meters roll out is progressing slowly, therefore it is important EV charge points have the ability for live data exchange directly with a backend system (backend system agnostic)	Backend system and EV charge points should have bi-directional comms that allow exchange of data and control signals (a full-duplex communications channels protocol such as webSocket could be one technological solution). Also, internal time of EV charge points should be able to synchronise with all other components to have a common reference.
Network monitoring	Measure current/voltage accurately	Accurate energy measurement is required to allow for smart charging services to be provided through a market function	If smart charge point is not connected to a smart meter, a Measuring Instruments Directive (MID) approved meter / accurate to MID approved levels on-

[21] Reliability of comms in the Electric Nation NIA Innovation project has fluctuated between 50% and 90%. As such, imposing the maximum possible resilience of comms is essential

			board measurement device should be used
Interoperability	Interoperability in a market based environment and in an electricity network emergency case (post-fail)	EV charge points should support communication protocols that are able to operate with various backend end systems (backend system agnostic) or under different market architectures	
	Exchange information with any home/building energy management system (system agnostic)	Coordination between PV/battery, loads and EV charge points is required, thus control of charging can be done at an energy management system level in the future, where such infrastructure exists	
EV comms	Send information on car charging state, i.e. connected / charging / discharging / standby / available	This information will be used by the smart charging service provider to stay always informed about the availability of assets to control	
	Indicate car's battery State-of-Charge (SoC)	This information will inform the smart charging service provider about the flexibility of the asset and willingness/opportunity to provide such services. It also allows networks to interface with dynamic response solutions and aides forecasting load requirements	Availability of such information would require the OEM's involvement
Charging data	Send near real-time smart charger operational data during charge cycle including current, voltage, bandwidth of charge rate (due to limitations set by cable/car) with low latency	This is the main set of data received and assessed by smart charging service provider to decide on response to any requests for service provision	Send sub-minute detail/granularity at intervals of up to every 5 minutes
Control demands	Receive demands to change charge/discharge current	This is how any smart charging service provider can increase/reduce demand by EV charging	

	Control charge rate with managed blocks of flow	Current flowing into the EV can be changed in given steps	
Safety	Failsafe functionality	Such functionality would be required to cater for cases when smart charging functionalities do not operate correctly (e.g. due to lack of communication signal).	
	Manual override and visibility of this manual override back to the energy management system	Customers should have the option to manually override smart charging settings to allow for undisrupted charging under certain circumstances. This would allow DNOs to quantify the charging done outside of the smart charging schemes.	
	Remain in an idle state immediately after power restoration following a fault on the network.	During power restoration, if there are large load uptake steps there is a risk that the restoration sequence could be affected causing the network to sit down again.	