Programme Area: Energy Storage and Distribution

Project: Consumers, Vehicles and Energy Integration (CVEI)

Title: D4.2. Final Analysis of Technology, Commercial and Market Building Blocks for Energy Infrastructure

Abstract:

This report represents Deliverable D4.2, Final Analysis of Technology, Commercial and Market Building Blocks for Energy Infrastructure. The purpose of this report is to provide:

• A 'first principles' view of the key components or Building Blocks (BB) that are considered as part of understanding what technology/physical, actors/commercial, market/policy, and Customer Proposition structures are most effective in enabling mass deployment and use of ULEVs, and their relative importance.

• A systematic allocation of the BBs to the Narratives, in such a way as to focus the framework on the areas of highest materiality, providing the basis for the analysis reported in the separate D1.3 Market Design and System Integration Report.

The separate spreadsheet (accompanying this report) provides more details of the building blocks themselves.

Context:

The objective of the Consumers, Vehicles and Energy Integration project is to inform UK Government and European policy and to help shape energy and automotive industry products, propositions and investment strategies. Additionally, it aims to develop an integrated set of analytical tools that models future market scenarios in order to test the impact of future policy, industry and societal choices. The project is made up of two stages:

• Stage 1 aims to characterize market and policy frameworks, business propositions, and the integrated vehicle and energy infrastructure system and technologies best suited to enabling a cost-effective UK energy system for low-carbon vehicles, using the amalgamated analytical toolset.

• Stage 2 aims to fill knowledge gaps and validate assumptions from Stage 1 through scientifically robust research, including real world trials with private vehicle consumers and case studies with business fleets. A mainstream consumer uptake trial will be carried out to measure attitudes to PiVs after direct experience of them, and consumer charging trials will measure mainstream consumer PiV charging behaviours and responses to managed harging options.

Consumers, Vehicles and Energy Integration Project: TR1006_D4.2. Final Analysis of Technology, Commercial and Market Building Blocks for Energy Infrastructure

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Version History

Version	Date	Description	Prepared by	Approved by
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0 Glossary and acronyms

A list of key acronyms and glossary of key terms used across the project are provided in Table 1 and Table 2 respectively.

Table 1 List of acronyms

Item	Description
BB	Building Blocks
BEV	Battery Electric Vehicle
BMS	Battery Management System
CCS	Carbon Capture and Storage
CP	Customer Proposition
CPAT	Commercial and Policy Accounting Tool
CVC	Commercial Value Chain
DNO	Distribution Network Operator
DM	Demand Management
ECCo	Electric Car Consumer choice model
ESME	Energy System Modelling Environment
ETI	Energy Technologies Institute
EV	Electric Vehicle
FCV	Fuel Cell Vehicle
HRS	Hydrogen Refuelling Station
ICEV	Internal Combustion Engine Vehicle
LDN	Local Distribution Network
MC	Managed Charging
MCA	Multi Criteria Analysis
MCPT	Macro Charging Point Tool
MEDT	Macro Electricity Distribution Tool
MHDT	Macro Hydrogen Distribution Tool
MLDT	Macro Liquid Distribution Tool
MPF	Market and Policy Framework
PiV	Plug-in Vehicle
PHEV	Plug-in Hybrid Electric Vehicle
PSC	Physical Supply Chain
SGR	Stage Gate Review
SMR	Steam Methane Reforming
TCO	Total Cost of Ownership
TNO	Transmission Network Operator

ToU	Static Time of Use
TSO	Transmission System Operator
ULEV	Ultra-Low Emission Vehicle
WP	Work Package
V2B	Vehicle to Building
V2G	Vehicle to Grid

Table 2 Glossary of terms

Item	Description
Analytical Tools	The quantitative part of the *D1.2 Analytical Framework*, used to calculate values for the quantitative Success Metrics.
Analytical Framework	Overarching Multi-Criteria Assessment (MCA) framework applied to each narrative to help understand what 'good looks like' for mass-market deployment and use of ULEVs and the potential trade-offs, via the assessment of the Success Metrics. This framework comprises the Analytical Tools which are used to help inform the quantitative assessment as well as a set of supporting qualitative assessment metrics.
Building Blocks (or BBs)	Individual components that influence ULEV deployment and use within each Dimension. A selected subset of BBs and their respective values or states (e.g. technology costs) constitute the tangible components of each Narrative.
Dimensions	4 highest level areas categorising the BBs impact ULEV deployment and use covering: Customer Proposition (CP), Physical Supply Chain (PSC), Commercial Value Chain (CVC), and Market and Policy Framework (MPF).
Narrative	An internally consistent set of Building Blocks covering *all* Dimensions and collectively characterising a rational and distinctive model for facilitating mass deployment and use of ULEVs in the UK.
Success Metrics	Metrics used to determine what 'good' looks like for each Dimension as part of the assessment of a Narrative. These are divided into quantitative metrics, which are quantifiable via the Analytical Tools, and qualitative metrics.
User-Managed Charging	User-Managed Charging is represented by an assumed consumer response to static ToU tariffs, whereby the consumer shifts their load to cheaper periods, changing their charging profile.
Supplier-Managed Charging	Supplier-Managed Charging is represented by more complete load shifting, partly controlled by a third-party. The term 'Supplier'-Managed Charging refers to charging that is managed by any third-party acting as a Demand Management (DM) provider – the supplier, a standalone DM aggregator, Distributed System Operator (DSO) or other third-party.
Mainstream	'Mainstream' consumers refer to a large, diverse group of consumers – in the Diffusion Model, non-Innovators encompass all those in the Early adopter, Early majority, Late majority, and Laggard segments: for the purposes of this report, they shall be referred to as 'mainstream' consumers.

Pathway	The time horizon used in the Analytical Framework: 2015 to 2050.

1 Executive summary

The Consumers, Vehicles and Energy Integration (CVEI) Project, commissioned and funded by the Energy Technologies Institute (ETI), has been established to examine how to deliver mass deployment and use of Ultra-Low Emission Vehicles (ULEVs) in the UK, focused on cars and light vans over the period from now to 2050, and address the challenges and opportunities of integration with the full energy system (including plug-in hybrid and battery electric vehicles, and hydrogen fuel-cell vehicles).

The project is comprised of two Stages:

- **Stage 1:** aims to characterise: the market and policy frameworks; business propositions; and the integrated vehicle and infrastructure system and technologies; best suited to enabling a cost-effective UK energy system for low-carbon vehicles from now through to 2050.
- **Stage 2:** aims to validate key elements of the above through a trial with mainstream users (both consumers and fleets).

This document is part of Stage 1 and is focused on the individual factors – or *Building Blocks (BBs)* - identified as potentially impacting the future take up and use of ULEVs. To provide a holistic assessment of potential factors four key areas of interest have been explored:

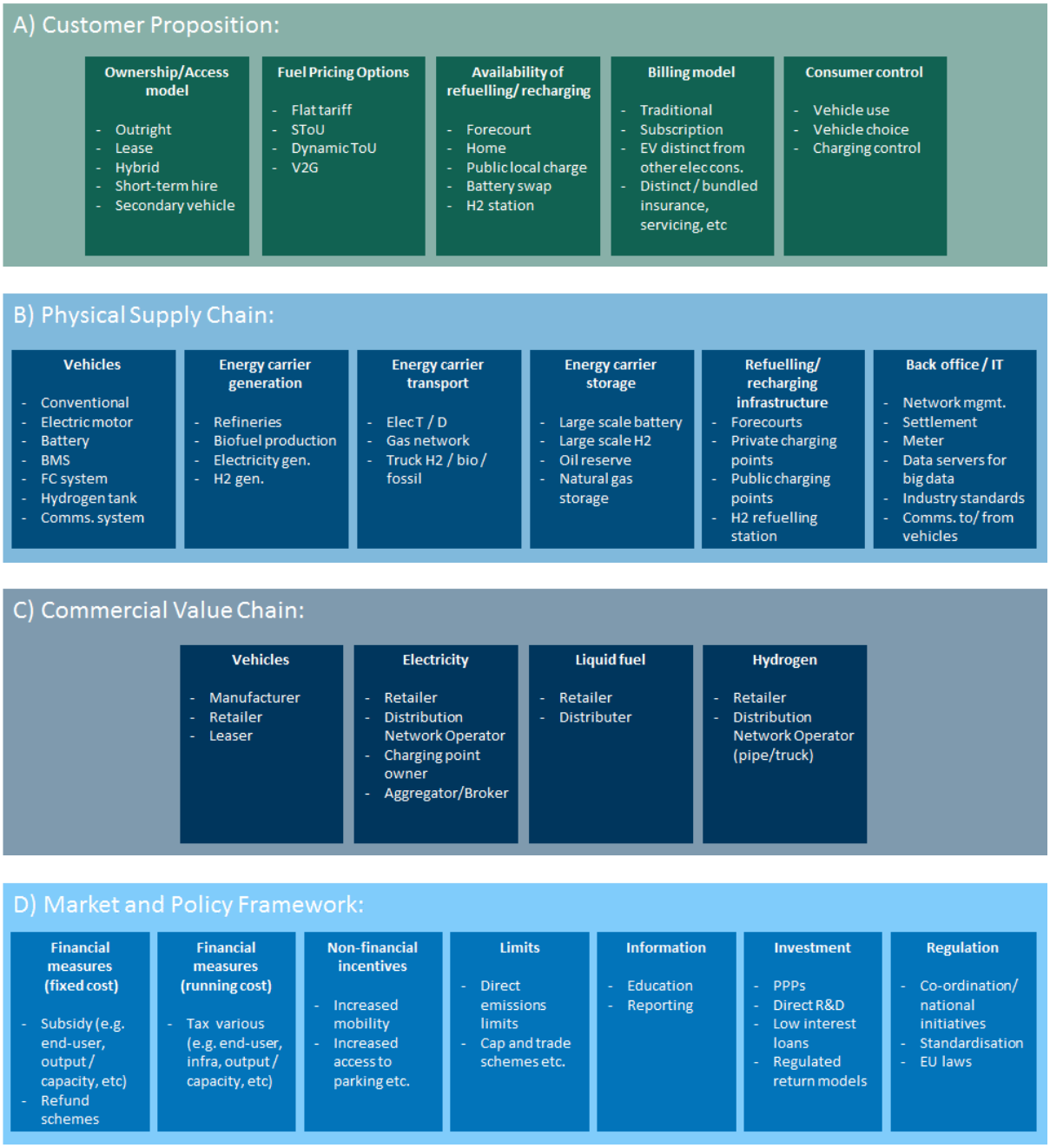
- **A) the Customer Proposition**
- **B) the Physical Supply Chain**
- **C) the Commercial Value Chain**, and
- **D) the Market and Policy Framework**.

The analysis in this document provides a key source of supporting material for the separate *D1.3 Market Design and System Integration Report*. This *D4.2 Final Analysis of Technology, Commercial and Market Building Blocks for Energy Infrastructure Report* describes the BBs in each of the four areas, including the synthesis of literature and evidence, areas for further research and key focus areas for the *D1.2 Analytical Framework.*

It is accompanied by the *D4.2 Building Blocks Catalogue* spreadsheet, which records the full details of each BB. Ultimately, the BBs are mapped on to *Narratives* – the primary purpose of this deliverable being to determine the specific aspects in each of the four areas that are material and should be included in the modelling, as part of the holistic analysis, and others that should be considered qualitatively.

Examples of the types of BB considered are outlined in Figure 1.

Figure 1 Examples of Building Blocks considered



For each key area of interest the issues most pertinent to ULEV uptake and use identified in the available evidence and literature were highlighted and reviewed. These are summarised below.

- **Customer Proposition:** the cost of ULEV ownership, the availability of infrastructure and the behaviour adopted by Plug in Vehicle (PiV) users in charging their vehicles.
- **Physical Supply Chain:** the evolution in performance and cost of vehicles with alternative powertrain technologies relative to conventional vehicles, the means of producing the energy carriers used in road transport, the options for distributing those energy carriers

from their place of production to the point of embarkation to the vehicle and the IT / communications infrastructure associated with innovative means of achieving efficient integration of the energy and transport systems.

- **Commercial Value Chain:** alternative modes for consumer access to vehicles from conventional upfront purchase to shared vehicle access on demand, the commercial case for deployment of charging and hydrogen infrastructure and the case for and implementation of Demand Management.
- **Market and Policy Framework:** the effectiveness of different interventions in efficiently stimulating uptake and use of ULEVs, how these interventions might be combined, the potential interaction of different levels of Government with the Commercial Value Chain in delivering investment in infrastructure and the role of information and education.

Accounting for uncertainty and limitations in knowledge surrounding these issues gives rise to the selection of the following key BBs. These represent the major themes and alternatives which have been applied (via a detailed mapping) to the forward looking *Narratives*, which quantitatively explore future worlds for ULEV uptake and use in the *D1.3 Market Design and System Integration Report*:

- **Customer Proposition:** alternative vehicle access models (including upfront purchase, leasing and vehicle sharing), electricity pricing options (including User-Managed and Supplier-Managed Charging), and the availability and access to different types of charging infrastructure.
- **Physical Supply Chain:** different modes of energy carrier production (particularly centralised and localised production of hydrogen), different modes of energy carrier transport recharging (particularly pipe and tanker transport of hydrogen), and emphasis on different locations for charging infrastructure (including home, work and public locations, and rapid charging on trunk roads).
- **Commercial Value Chain:** choices here reflect those made in the Customer Proposition and Physical Supply Chain. The consideration is primarily of the viability of different business models in different circumstances, particularly investment in new electricity charging and hydrogen distribution infrastructure. In addition, a representation of a Demand Management aggregator, to implement Supplier-Managed Charging of PiVs, has also been considered. Although Supplier-Managed Charging is referred to, this means charging that is managed by a third-party, which could be a supplier, an aggregator or DSO.
- **Market and Policy Framework:** measures to mitigate upfront costs (for example grants of different levels, or reduction in VAT), measures to reduce ongoing operating costs (including VAT reductions, fuel subsidies) and perks (including access to congestion or low emission zones).

Finally, the analysis of the BBs has identified a number of gaps in understanding, or areas for further research, particularly with respect to their quantitative impact on future ULEV uptake and use (for example the value consumers assign to non-monetised 'perks' such as bus lane access). These have helped to inform the Stage 2 trial design, which is described in detail in the *D1.4 Trial Design, Methodology and Business Case Report*.

2 Introduction

2.1 Background and context

The Consumers, Vehicles and Energy Integration (**CVEI**) Project, commissioned and funded by the Energy Technologies Institute (**ETI**), has been established to examine how to deliver mass deployment and use of Ultra-Low Emission Vehicles (ULEVs) in the UK, and address the challenges and opportunities of integration with the full energy system (including plug-in hybrid and battery electric vehicles, and hydrogen fuel-cell vehicles).

The project is comprised of two Stages:

- **Stage 1:** aims to characterise: the Market and Policy Frameworks; business propositions; and the integrated vehicle and infrastructure system and technologies; best suited to enabling a cost-effective UK energy system for low-carbon vehicles.
- **Stage 2:** aims to validate key elements of the above through a mass-market trial with real users.

Within **Stage 1** there are five Work Packages (WP):

- **WP1a:** Market Design and System Integration
- **WP1b:** Trial Design, Methodology and Business Case
- **WP2:** Consumer and fleet usage behaviours and attitudes to adoption
- **WP3:** Vehicle energy management systems and technologies, and
- **WP4:** Energy infrastructure management systems and technologies.

This report represents the *D4.2 Final Analysis of Technology, Commercial and Market Building Blocks for Energy Infrastructure Report* submitted as part of *WP4* within *Stage 1*.

The purpose of this deliverable is to provide:

- A 'first principles' view of the key components or Building Blocks (**BB**) that are considered as part of understanding what technology/physical, actors/commercial, market/policy, and Customer Proposition structures are most effective in enabling mass deployment and use of ULEVs, and their relative importance.
- A systematic allocation of the BBs to the Narratives, in such a way as to focus the framework on the areas of highest materiality, providing the basis for the analysis reported in the separate *D1.3 Market Design and System Integration Report*.

2.2 Structure of this document

This document is structured as follows (with the supporting *D4.2 Building Blocks Catalogue* spreadsheet providing further information):

- Section 3 describes the overall approach to developing the catalogue of Building Blocks.

- Sections 4 to 7 provide a more detailed description of the information for the Building Blocks related, respectively, to the:
  - Customer Proposition (CP)
  - Physical Supply Chain (PSC)
  - Commercial Value Chain (CVC), and
  - Market and Policy Framework (MPF).
- Section 8 describes how the underlying Building Blocks are used to inform the Narratives.
- Appendix A provides further information on the business models associated with the generic commercial entities on the CVC described in section 5.

3 Approach

3.1 Overview and high level categorisation

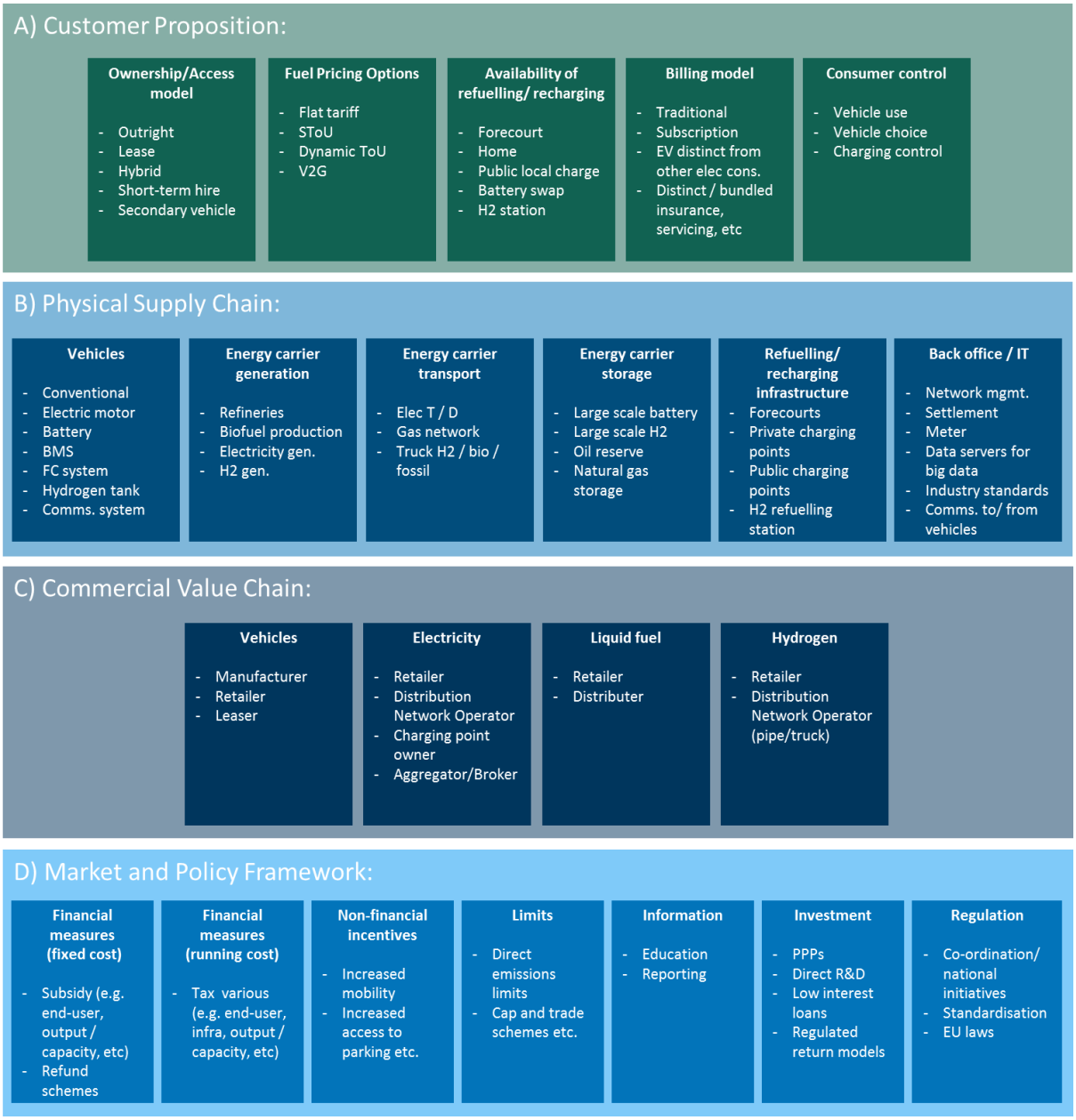
The core purpose of the BBs is to provide a bottom-up, first principles view of the core components which could impact mass-market deployment and use of ULEVs. This covers a potentially large number of BBs and the first step was to provide a MECE[1] grouping structure for them split into:

- **Dimensions** – four key overarching areas which collectively define the scope of assessment of the conditions for ULEV deployment and use. These are the:
  - **Customer Proposition (CP)** – what the consumer sees at the point of interacting with a ULEV (e.g. is the consumer buying or leasing the vehicle)
  - **Physical Supply Chain (PSC)** – the technologies and infrastructure required to deliver the vehicles and their energy requirements (e.g. hydrogen production or distribution)
  - **Commercial Value Chain (CVC)** – the commercial entities (and their business models) that sit across one or more parts of the PSC to collectively deliver the CP that the consumer sees (e.g. an electricity retail supplier or vehicle leaser), and
  - **Market and Policy Framework (MPF)** – Government intervention in the form of setting the overarching market framework for commercial entities (e.g. regulated monopolies for network infrastructure) or more direct policy intervention (e.g. in terms of taxes or subsidies on commercial entities or directly at the point of the consumer).
- **Categories** within each Dimension to help group similar types of BBs (e.g. under the PSC the category 'Vehicles' includes the BBs battery, battery management systems, fuel cell system, other components with a high technology-readiness level, electric motors for hybrids, hydrogen tanks and communication systems, whereas the category 'Refuelling / Recharging Infrastructure' includes BBs private charging infrastructure, public charging infrastructure, hydrogen refuelling stations and diesel / petrol forecourts).

Figure 2 provides an overview of the Dimensions and their specific categories along with a number of illustrative examples of the types of BBs that exist within each of these.

[1] Mutually Exclusive, Collectively Exhaustive

Figure 2 Overview of Dimensions and categories used to define example BBs



The supporting *D4.2 Building Blocks Catalogue* spreadsheet contains a wide range of more detailed information for each BB. The structure of the spreadsheet is described in more detail in section 3.2 of this report, but at a high level focuses on:

- Describing the core features of the BB
- Identifying examples that exist today or have been proposed (both in the UK and internationally), and

- Providing supporting evidence on the materiality of the BBs – i.e. to help assess and filter which BBs are likely to be more important to consider in detail as part of the overarching assessment framework (or to better understand current gaps in the knowledge base).

As part of the BB assessment the Project Team has undertaken a review of the available public and academic literature and drawn on the expertise its members, through a dedicated workshop and various bilateral conversations.

The final step of this analysis was to map the set of BBs assessed as most material onto each of the Narratives described in the *D1.3 Market Design and System Integration Report* in an internally consistent manner. These form the foundation of the assessment undertaken in the *D1.2 Analytical Framework*, the results of which are also described in the *D1.3 Market Design and System Integration Report.*

3.2 Structure of supporting *D4.2 Building Blocks Catalogue* spreadsheet

Accompanying this document is a supporting the *D4.2 Building Blocks Catalogue* spreadsheet, which contains more detail on each BB.

3.2.1 Customer Proposition (CP)

The Customer Proposition is comprised of five categories: ownership / access model, fuel pricing options, availability of refuelling / recharging, billing model and consumer control. Each category addresses a different aspect of the offering to the consumer, or the consumer need.

- The summary sheet sets out all of the BBs under the categories and identifies the overarching 'states' that the BB can take. For example, under the availability of refuelling / recharging category sits 'H_2 refuelling stations', a BB that could vary in terms the extent of the network and the ease with which a consumer can refuel their ULEV. BBs are classified by materiality.
- The detailed sheet is comprised of the following for each BB:
  - Explanation of BB
  - Current use in the UK, examples
  - Extent of current deployment
  - Data gaps
  - Current use internationally
  - Overall materiality, informed by the above
  - Information required in order to quantify the BB within the *D1.2 Analytical Framework*, including potential data sources or tools in which this is used; this links closely with the 'states' in the summarised version, and
  - Data sources, where applicable.

3.2.2 Physical Supply Chain (PSC)

The Physical Supply Chain is comprised of six categories: vehicles, energy carrier generation, energy carrier transport, energy carrier storage, refuelling / recharging infrastructure and back office / IT. The BBs represent different physical assets on the supply chain, with the exception of 'Industry Standards' which is particularly pertinent for the PSC and also appears in the MPF.

- The summary sheet sets out all of the BBs under the categories and identifies the underlying factors that are particularly relevant in defining each BB. For example, under the energy carrier generation category sits electricity generators, a BB that depends on the cost of new plants to meet demand, electricity generation cost, grid carbon intensity, and the generation mix. BBs are classified by materiality.
- The detailed sheet is comprised of the following for each BB:
  - Explanation of the BB
  - Level of technology development
  - Current use in the UK, examples
  - Initial assessment of the potential for emissions and cost reduction relative to other BBs
  - Initial assessment of the technology readiness and cost for each BB
  - Overall materiality, informed by the above
  - Information required in order to quantify the BB within the *D1.2 Analytical Framework*, including potential data sources or tools in which this is used, and
  - Data sources, where applicable.

3.2.3 Commercial Value Chain (CVC)

The Commercial Value Chain is defined in a different manner to the other Dimensions. This is because there are multiple ways in which an entity can create value, and hence many subtly or distinctly different business models exist along the value chain, as well as ideas for novel or new models. An added layer of complexity is that one entity will often form partnerships or mergers with other entities.

As per the other Dimensions, an extensive list of BBs has been identified together with some short-listing, taking into account the relative materiality of each BB. Examples of use in the UK and elsewhere have been used to understand what constitutes a 'generic' model for each entity, and where key variations exist.

The overall CVC is comprised of four categories, each of which have their own value chains: vehicles, electricity, liquid fuels, and hydrogen.

- The overall summary sheet sets out all of the BBs under the categories, identifying for each BB name, whether it is a stand-alone entity (or a combination).
- The summary sheet for each type of entity is the business model framework, which at a high level gives information about each element of the business model.
- The detailed sheets discuss the elements in greater depth and identify ways in which particular aspects may vary.

3.2.4 Market and Policy Framework (MPF)

The Market and Policy Framework is comprised of seven categories: financial measures (fixed cost), financial measures (running cost), non-financial incentives, limits, information, investment and regulation.

Some BBs are tangible in monetary terms, others are not. Most BBs described have already been implemented in some form (in the UK or elsewhere) although 'novel' measures have also been considered.

- The summary sheet sets out all of the BBs under the categories and gives a brief explanation, including existing examples where applicable. BBs are classified by materiality.
- The detailed sheet is comprised of the following for each BB:
  - Explanation of the BB
  - Current use in the UK, examples and success of these
  - Approximate value, extent of buyers covered, importance to the consumer
  - Current use elsewhere and success of these: in particular countries with high EV share and especially those with high share for relatively less financial incentive; countries where ULEVs were not well received despite market and policy support; and countries that have seen relatively high adoption of FCVs
  - Overall materiality, informed by the above
  - Information required in order to quantify the BB within the *D1.2 Analytical Framework*, including potential data sources or tools in which this is used, and
  - Data sources, where applicable.

4 Customer Proposition (CP)

4.1 Overview

The Customer Proposition (CP) Dimension covers all of the aspects faced by private and fleet buyers and users of cars and vans in the transport sector.

A summary of the BBs and their materiality is shown in Table 3. Materiality has been assessed through considering how each BB might impact on the total ULEV vehicle km travelled (consistent with the quantitative Success Metric outlined in the *D1.3 Market Design and System Integration Report*).

Table 3 Summary of BBs included in the Customer Proposition

Materiality for framework
High
Medium
Low

ACCESS MODEL	FUEL PRICING OPTIONS	REFUELLING AVAILABILITY	BILLILNG MODEL	CONSUMER CONTROL
1. Outright purchase	10. Static ToU	15. Private charging	24. Subscription model	29. Sole vs shared use
2. Contract purchase	11. Dynamic ToU	16. Public charging in motorways and A-roads (rapid)	25. Support for price certainty	30. Charging control
3. Hybrid (battery lease)	12. Demand Management payment	17. Public charging in local points (mid-level)	26. Traditional pay per unit model	31. Vehicle choice
4. Contract hire	13. Flat tariff	18. Workplace charging	27. Multi-modal	
5. Short-term hire/car club	14. Vehicle to Grid/Building (V2G/B)	19. H_2 refuelling stations	28. Own account	
6. Secondary market		20. Battery swapping		
7. Bundled installation of charge points		21. Electrolyte charge		
8. Maintenance, servicing and insurance		22. Dynamic/novel charging methods		
9. Access to other vehicles when ULEV unsuitable		23. Forecourt		

Note that perks (i.e. congestion charge exemptions or parking benefits), which are a part of the Customer Proposition, have been captured in the Market and Policy Dimension. A more detailed description of each BB is included within the supporting *D4.2 Building Blocks Catalogue* spreadsheet, and Figure 3 represents this for one of the BBs.

Figure 3 Example of detailed BB view in the supporting spreadsheet for the CP

Category		Access model
Building block number		**1**
Building block name		**Outright Purchase**
Explanation		Vehicle purchase through own finance directly from manufacturer or dealerships; vehicle usually counted as a fixed asset for accounting purposes. The consumer captures indirectly any government subsidies provided to the manufacturer (e.g. the plug-in car grant)

Currently used in UK?		**Yes**
Explanation/ examples		Outright purchase constitutes a third of total new car sales and a half of new vans sales

Impact on ULEV vkm (High / Med / Low, based on literature review experience)		**High -** the premium of PiVs capex over ICEVs is one of the most critical factors for private car purchase decision making, together with an 'anti-EV' bias. **Highly critical for economically rational fleet manager decision making**

Data gaps		**The relative depreciation of PiVs in comparison with ICEVs is not well understood and it is critical for outright purchase deals, as it is a popular ownership model among fleets. There is little evidence on PiV owner experience on battery life and resale value** Depreciation is as critical parameter for fleet, but not for private purchasers. Fleet managers base their decisions on rational TCO assessments, for which depreciation is a significant parameter. However, for the private purchasers, other attributes such as capex, fuel economy, availability of charging infrastructure, range or brand are the ones on which the consumer bases his or her purchase decision
Extent of current deployment, across: (% of new sales for 'Access model'; % of PiV users with access to each type of charging for 'Availability of recharging')	a1. private cars	30% (ca. 350k cars pa)
	a2. fleet cars	25% (ca. 320k cars pa)
	b2. fleet vans	50% (ca. 160k vans pa)
International examples of commercial propositions		Figenbaum et al (2014) found that 56% of owners in **Norway** cited uncertainty over the resale value of their EV as a disadvantage (being the third most cited element, behind range and uncertainty over continuation of incentives)

Information Required: **States** - they are ranked in order of importance. The first(s) one(s) are be used for the quantitative assessment, above	1	**Finance model prevalence:** - dependent on the Narrative traditional or new finance models
	2	**Pricing strategy:** Manufacturers selling at a reduced margin/at a loss to support early deployments, cross-subsidising from other models etc. (unlikely to persist in long-term)
	3	**Depreciation :** 'Business as Usual' (ULEVs higher depreciation than conventional cars) or same for both
	4	**Indirect subsidy**

4.2 Synthesis of evidence and literature

As part of the review of available evidence and literature for the BBs, insights were also drawn upon from the separate literature review undertaken for Work Package 2, which focuses largely on aspects of the consumer proposition for consumers and fleets.

The research questions that have been explored are:

- *What is the relative importance of purchase cost, price, maintenance, insurance, depreciation, tax incentives / grants / subsidies on the uptake of ULEVs?*
- *What is the relative importance of access to bus lanes, access to high occupancy vehicle lanes, parking incentives, road user charging incentives on the uptake of ULEVs?*
- *What is the role of access models on the uptake of ULEVs?*
- *What is the relative importance of the availability of different refuelling / charging propositions in the uptake of EVs?*
- *What is the relative importance of fuel pricing / payment / demand management options in the uptake of EVs?*

These questions were used to frame the literature review – answers were incorporated into the *D4.2 Building Block Catalogue* spreadsheet, together with more specific research on individual BBs.

The literature review exercise provided evidence on what the most critical parameters for the Customer Proposition are and highlighted those elements of the Customer Proposition in which there is no evidence on their impact to ULEV uptake.

- *Costs of ownership*
  - Purchase price is more critical to the Customer Proposition than running costs; recharging and driving range are also important (as these are the two most important 'anti-bias' factors putting-off potential purchasers of buying a PiV).
  - Other incentives, such as parking fee exemptions / rebates, congestion charge, or high occupancy vehicle lanes, appear likely to be less important than purchase price incentives and are highly context-dependent. However, despite the lower impact on their own, evidence suggests that a package of well-designed financial incentives plus non-financial incentives may be the most effective means of increasing PiV uptake.
- *Infrastructure availability*
  - Regarding charging infrastructure, home charging is seen as a pre-requisite of PiV ownership at this stage of the market development, and a combination of home and public charging is more valued than home and work charging infrastructure. Rapid chargers enabling longer trips (e.g. on motorways and A-roads), are highly valued by PiV owners, particularly BEVs, and they are regarded as the most efficient way to complement overnight charging and key for mass uptake of ULEVs.
  - Infrastructure availability or range 'anxiety' remains an important factor for many prospective ULEV drivers who often anticipate higher usage of charging points away from their home than actually transpires. This is compounded in some cases by lack of interoperability between public charging schemes (e.g. via 'roaming billing' models

or standardisation of charging connections) which is flagged as a current source of frustration for some PiV owners.

- *Charging behaviour*
  - There is no clear evidence in the literature of the impact of electricity pricing structures (e.g. time of use tariffs) and controllability of charging (i.e. control options and extent of direct control – User-Managed Charging – vs delegated control – Supplier-Managed Charging) on the uptake of ULEVs, as the focus has been on understanding how those parameters affect electricity consumption behaviour on ULEVs and the acceptability of those tariffs.
  - A recent UK survey (sample of 4,000) to measure consumer demand in Great Britain for a range of demand-side response tariffs[2], shows that EV owners are more likely to switch to static ToU tariffs and that Supplier-Managed Charging was the most popular, provided that it does not compromise end-user satisfaction[3] and that overriding facilities are offered.
  - *My Electric Avenue*, an eighteen month trial investigating the impact of PiV uptake on electricity distribution networks funded under the Low Carbon Network Fund scheme, made use of a device giving the Distribution Network Operator (DNO) the ability to temporarily curtail charging. The results indicated that this external control (i.e. Supplier-Managed Charging – here the DNO is in place of the supplier) did not cause significant inconvenience or unacceptable loss of service to the trial participants, with most declaring themselves comfortable with the DNO having ability to curtail their charging. Further research in *WP2* of the *CVEI Project* did not replicate this finding, which perhaps reinforces the need for clearer thinking and communication about the consumer offerings[4].

4.2.1 Combined Customer Propositions

Whilst the CP BBs reflect individual components of a CP it is also important to understand what is likely to be effective in terms of a combined proposition. Table 4 presents a summary of currently available commercial propositions.

Indicative examples present the interactions between entities and benefits for the end-users arising from the Customer Propositions. For each CP, some supporting facts are presented to illustrate the plausibility of the proposition.

Table 4 Examples of combined Customer Propositions

Description	Proposition
Fleet electric van in	A fleet manager purchases the Nissan eNV200 through **outright purchase**

[2] Is it time? Consumers and time of use tariffs. Trialling the effect of tariff design and marketing on consumer demand for demand-side response tariffs; UCL Energy Institute for Smart Energy GB, 2015

[3] In terms of maintaining acceptable temperature thresholds

[4] However, it should be noted that My Electric Avenue's findings were based on early adopters with direct experience of a DNO managed charging regime, via the trial itself, whereas the WP2 research findings were from a broader range of consumers without direct experience of such charging management.

London	benefiting from the Plug-in Van Grant. British Gas, the charging point partner of Nissan, installs **charging points at central van locations**, which have been supplied by the manufacturer ChargeMaster. They benefit from the Electric Vehicle Homecharge scheme. The van also has access to **Polar Network's public charging points**, owned by ChargeMaster. The user has to register online with the charging point network operator and then has access to all of the charging points in that network; billing is smart (e.g. via an app) and fees are **pay as you go**, dependent on the site. The user benefits from the congestion charge exemption, lower Vehicle Excise Duty (VED), and access to (Ultra) Low Emission Zones. *Facts: 50% of vans are purchased outright; pay as you go is one of the most popular billing models for charging infrastructure*
Private BEV, contract purchase	A private owner uses **personal contract purchase**[5] to acquire an electric vehicle, which allows him / her to spread the cost of the vehicle over monthly payments and provides an opportunity to own the vehicle at the end of the contract. The user has their own charge point at home, and benefits from a **discount in his / her electricity tariff**, provided by Ecotricity. In some cases the discount and the car purchase could be linked (e.g. Tesla cars using free Tesla supercharger network). They also have access to free electricity from Ecotricity's Electric Highway **rapid charge points**, through a swipe card that can also be used in other charge networks. *Facts: Personal Contract Purchase is the most popular access model among private cars (40% of new sales)*
Private BEV, with battery leasing	A private owner uses a **hybrid access model (battery leasing)**, in which they buy the vehicle but lease the battery from the same entity. The battery is paid for monthly, and rates depend on the length of the contract and on the agreed annual mileage. The OEM offers a battery performance guarantee. The user is registered to the Charge Your Car network, which operates charging points and collects the payments; **billing is done through an application or through a swipe card.** The owner primarily charges at home and overnight, but benefits from cheaper prices through EDF's **Eco20:20 time of use tariff.** Suppliers start to offer tariffs directly tied to EV ownership. *Facts: battery leasing is offered as the unique access model by some OEMs (e.g. Renault ZOE), or as one access model option by others (e.g. Nissan). In the UK time of use tariffs specific to EVs are not widespread. However, several national ToU trials have recently been carried out*[6]*, and EV-specific ToU tariffs*

[5] Essentially leasing the vehicle over several years before buying outright

[6] Customer-Led Network Revolution static ToU trial reported in February 2015, Low Carbon London Energising Change dynamic ToU trial reported in March 2015. DECC published its Electricity Price Signals and Demand

	are already on offer in other countries (e.g. Spain)
Company car PHEV chosen by user	An employee chooses a Mitsubishi Outlander PHEV as a **Benefit In Kind** from their company, which has acquired the car through **contract hire,** and remains its owner. Being a PHEV, the user benefits from lower **Company Car Tax** rates than petrol and diesel cars, maintenance and insurance are paid for by the company, and the employee benefits from lower Vehicle Excise Duty. The user can charge via the company's **charging infrastructure, located at the workplace, which is leased** on a three-year basis and paid for monthly, and benefits from access to (Ultra) Low Emission Zones. *Facts: ca. 40% of company car buyers are 'user-choosers'; POD Point launched an option last year to lease fast charging points to businesses*
Electric car club	A user of **E-car club**, in Milton Keynes, has access to the vehicles through the payment of **a membership fee plus an hourly or daily fee**. The booking is online, and can be done last minute. The car is collected and returned at a central bay *Facts: London is the second largest market for car clubs globally (ca. 160,000 members), with an industry commitment to include at least 50% ULEVs in fleet by 2025 (London ultra-low emission future)*

4.3 Areas for further research and known gaps

Gaps identified in the literature include:

- Analysis and demonstrations currently in progress aim to understand the **impact of different billing models (pay as you go, subscription)** and how important this is within the Customer Proposition.
- **The relative depreciation of PiVs in comparison with ICEVs** is not well understood and is particularly critical among fleets. There is a suggestion that purchase price subsidies are depressing the residual value of PiVs, and the impact could remain even once the subsidy is removed. Similar aspects include **impact of the battery life and resale value** on the owner experience, the potential impact that the **secondary market** could have on ULEV uptake, and the **potential success of battery leasing** in the UK (which is not well understood).
- The potential penetration of **solutions to provide overnight charging to households without off-street parking** (e.g. socket network / street furniture connections, shared charge points installed in residential areas) needs to be understood further (i.e. do they have the same value / provide as much certainty of access as 'home charging' for consumers).

Response report in 2014, examining insights from ToU trials from 2003 to 2014. Other trials in the US include the San Diego Gas & Electric's Plug-in Vehicle ToU Pricing and Technology Study (2014), SMUD's EV Innovators Pilot (2014) and Southern California Edison Company's Load Research Report (2013).

- There is uncertainty around the **mass take-up potential of car clubs in cities**.
- **The monetised value attributed by ULEV consumers to perks** (e.g. access to bus / high occupancy vehicle lanes, free parking, etc.) is not well understood, particularly in terms of the extent to which consumers heavily discount these benefits at the point of purchase, particularly where there is the potential for this value to diminish in future with significant ULEV uptake (e.g. the time saved from bus lane access with many users). This could include consumer attitudes to car ownership and the value of 'status' associated with owning a ULEV.
- **The monetised value attributed to having access to a secondary vehicle** (either permanently / temporarily) or e.g. via alternative transport services (e.g. longer distance journeys via rail).

A number of these gaps will be addressed in the Stage 2 trials, which aim to develop understanding of the attitudes and behaviours of mass-market consumers and fleets towards ULEV uptake and energy demand management.

In particular, these will be explored in relation to **the impact of fuel pricing options** (e.g. static Time of Use tariffs) **and related charging control options** (e.g. manual, automatic) on the uptake of PiVs.

4.4 Key focus areas for the *D1.2 Analytical Framework*

This section, and the equivalent sections 5.4, 6.4 and 7.4 for other Dimensions, highlight a number of aspects that were considered important in the D1.2 Analytical Framework considered within the D1.3 Market Design and System Integration Report, in some cases with reference to specific Narratives.

In the CP, those BBs categorised as high and medium[7] materiality are:

- **Purchase methods** in the access model are outright purchase, contract purchase, hybrid - battery leasing only, contract hire, short-term hire / car clubs and the secondary market. It is important to reflect the impact of leasing, such as spreading costs over time through contract purchase, as distinct from outright purchase, in the *D1.2 Analytical Framework*.
  - The secondary market for ULEVs is negligible in the UK currently, but is viewed as an important determinant of the economics of ULEV ownership in fleets. The depreciation of ULEVs may be higher than ICEVs particularly when the battery life is less than the vehicle life and especially in the 'Organic Action' Narratives (as there is less of coordinated push to standardise around ULEVs).
  - Bundled installation of charging points, (i.e. provided with the vehicle) is classified as medium materiality. For home and fleet charging points this could be added to the cost of the vehicle; the use of public charging points, together with the bundling of other services such as O&M, insurance and fuel, is described qualitatively.
- **Electricity pricing options** such as static ToU with User-Managed Charging are reflected through exogenous charging profile assumptions, adjusted in relation to estimates of consumer response to electricity price shapes from the Analytical Tools. Demand

[7] The levels of materiality are shown in Table 3.

Management payments appear in two of the Narratives where Supplier-Managed Charging is assumed – an explanation of User-Managed and Supplier-Managed Charging is given in section 4.4.1.

- **Hydrogen and liquid fossil fuel pricing** are variable, although to a lesser degree of granularity than electricity, and charged in a pay as you go manner, as per current pricing of liquid fossil fuels.
- **Recharging availability** reflects, in particular, private (home), workplace, public (non-rapid) and rapid charging. For the latter, the access to charging and the extent of the network is important.
- **The billing models** that the consumer sees vary between Narratives, such as the subscription model, and support for price certainty (e.g. real time data on current charging costs, at public locations for instance, to allow the consumer to take informed decisions on where it is more economically sensible to charge). However, this is qualitative in nature as it is not practical to model differences directly within the *D1.2 Analytical Framework*.
  - The variations in billing models by Narrative could be tested, or simulated, in the Stage 2 trials.
- The extent of **consumer control:** sole vs. shared vehicle use (i.e. extent of asset sharing), charging control (indirectly captured through User-Managed Charging in response to ToU tariffs, or Supplier-Managed Charging) and the vehicle choice. Shared use is investigated through the 'Mobility as a Service' based Narratives
  - Customer Propositions relating to 'Mobility as a Service' could be wide-ranging, for example, an Uber-style service with the vehicle arriving at the consumers home, a Zip Car-style service where the consumer picks up the vehicle from where it is parked (akin to London's Santander Cycles), car-pooling or, over the medium to longer term, a variation based on autonomous vehicles.
  - For the purpose of the modelling in the *D1.2 Analytical Framework* the exact proposition is not specified – rather it is assumed that fleets of vehicles are notionally accessed by consumers hour-by-hour as required, such that vehicles are driven by multiple users throughout the day. The underlying journey pattern requirements of the users are maintained (i.e. no modal shifting is assumed), however, there is some accounting for 'dead mileage' to reflect that the vehicles may need to cover more miles to enable access by multiple users. More optimal routing in the future and modal shifts may lead to reduced consumer mileage overall – this is not reflected in Stage 1. There is limited evidence on how consumers would engage with the concept of vehicles as shared assets and the response is presupposed for the purposes of the relevant Narratives. The focus of the Analytical Framework is therefore to help understand the potential economics, energy system impacts and carbon savings from a significant increase in the delivery of consumer requirements through asset sharing.

Other cost / subsidy elements that are part of the CP are for instance VED and Company Car Tax. These are factored in to the uptake tool (ECCo) and are discussed further as part of the MPF.

The CP BBs have been applied in a manner consistent with the description of the Narratives.

In terms of BBs that are not considered explicitly or tackled more qualitatively across the Narratives the rationale for these is as follows:

- Hybrid models – these are unlikely to show sufficient variation compared to the other purchase models which span the range from outright purchase, leasing and 'on-demand / hire'.
- Access to other vehicles – there is limited evidence to quantify the monetised value consumers place on this and it is deemed of secondary importance given that this issue is considered more explicitly in the *D1.2 Analytical Framework* via consideration of access to charging infrastructure and physical sufficiency of the ULEVs to meet the desired driving range in their role as the primary vehicle.
- Whilst dedicated V2G could be used for flexibility services, such as providing power back to the grid during a shortfall, it is assumed that consumers would not normally enact V2G themselves (i.e. as a reaction to price signals for energy arbitrage) without automated controls to facilitate this process. The focus of the literature is also predominantly around DNO / DM aggregator led demand management (CP BB12/ BB29), which is considered in some Narratives and would restrict the ability of the consumer to manage their own charging or export back to the grid. V2G/ V2B is also dependent on the level of battery degradation that might be experienced under more extensive charging cycles, which will be explored further as part of WP3.
- There is limited evidence to understand the extent to which consumers value different forms of billing models (as opposed to the actual costs of the energy or transport service) and hence these BBs are more illustrative examples of what might sensibly exist given the broader Narratives, rather than an integral part of the success of each Narrative.
- More novel forms of PiV charging have been excluded either due to early evidence that they are likely to be less effective (e.g. a move away from attempts to commercialise battery swapping) or a high degree of uncertainty over the long-term prospects for others such as electrolyte or dynamic charging (at least for mainstream consumers). Given the number of BB permutations associated with more standard charging infrastructure (availability, locations, pricing, etc.) these have been the focus for differentiation across the Narratives.

4.4.1 User-Managed and Supplier-Managed Charging

Several of the Narratives consider a managed approach to charging, whereby the consumer shifts their charging, or their charging is shifted by a third-party. In both cases this results in changes to the consumer's charging profile, compared to the profile assumed when the consumer sees a flat priced tariff – the currently prevailing norm, featured in BaU as a counterfactual.

- **User-Managed Charging** is represented by an assumed consumer response to static ToU tariffs, whereby the consumer pays peak and off-peak rates for their electricity, leading them to charge less at peak times and producing some load shifting.
- **Supplier-Managed Charging** is represented by more complete load shifting, partly controlled by a third-party. The term 'Supplier'-Managed Charging refers to charging that is managed by any third-party acting as a 'DM provider' – the supplier, DM aggregator, DSO or other third-party.

There is very limited evidence for how mainstream PiV consumers would engage with either of the overarching charging approaches and this is a key focus of the Stage 2 trial. Engagement is crucial as it is highly likely that the competitive retail market which exists at present in GB will continue into the future, restricting the ability to impose certain types of tariff structure across all consumers. The level of engagement is further complicated by the myriad of ways that the final features of the proposition could be presented to the consumer, some of which are described further below. For the purposes of the Analytical Framework in Stage 1 it is assumed that Supplier-Managed Charging provides a more optimal route to shaping consumer load given the interests of the wider energy system, whilst still providing the underlying consumer requirements. User-Managed Charging is assumed to provide a more limited response – in terms of changing the shape of charging to benefit the wider system - given the inability and/or disinclination of consumers to respond rapidly to changes in prices. However, it is assumed that there would still be some broad degree of economic rationality on behalf of consumers, such that they are at least no worse off than they would have been by maintaining their original charging profile in the face of static ToU tariffs.

The Narratives featuring Supplier-Managed Charging could also be interpreted as a DNO expanding to become a DSO, for instance aggregating individual loads and providing balancing services to the Transmission System Operator (TSO). However, for the purposes of the analysis this is represented as a separate DNO and separate DM aggregator[8]. Note that active network management is assumed to be through network automation algorithms, rather than via instructions to individual users as per a traditional system operator role – e.g. SSE's Orkney Active Network Management approach, which issues instructions to generators to control their output, in real time.

The provider of Supplier-Managed Charging schedules the vehicle charging optimally with the resulting benefits, to be further investigated through the *D1.2 Analytical Framework* and the *Stage 2* trials:

- Overall reduced balancing costs for the TSO, passed indirectly to the user through lower electricity prices. It is assumed that the electricity shifted is traded on the wholesale market and the affect is captured in the wholesale price, however, a DM aggregator may be able to accrue further revenues from participation in balancing services.
  - With regards balancing costs, there are well established competitive markets for the SO to procure balancing services from demand reduction and generation. The Balancing Services Incentive Scheme incentivises the SO to minimise the cost it incurs in doing so, and so should support adoption of services provided by management of PiV charging demand if this is cost effective.
- Avoided reinforcement cost for the DNO/ TNO, which are passed indirectly to the user through a lowered use of system cost component of the retail electricity price.
  - There remain key regulatory barriers to the deployment and utilisation of DM for network constraint management and investment deferral (e.g. there is no mechanism to direct account for and redistribute the avoided reinforcement cost resulting from DM). However, the recently updated DNO price control framework does reflect savings expected to arise from smart grids, smart meters and innovation

[8] As the DSO model is much broader than PiV charging and considers e.g. connection and management of various types of embedded generation

- described in more detail in section 7.2.5 in the *D1.3 Market Design and System Integration Report* - and the 'Smart Power' report published by the National Infrastructure Commission in 2016[9] recommends that "network owners should be incentivised by Ofgem to use sources of flexibility to improve the capacity and resilience of their networks as part of a more actively managed systems".

The final proposition that the consumer is presented with under Supplier-Managed Charging regime could take many forms. Some examples are given below.

- The consumer may be required to specify certain limits or constraints (e.g. specify their desired departure time and required state of charge on departure) or to accept certain limits or constraints specified by the DM provider.
- The specification of these preferences could be one-off (fixed for a certain length of time), daily (variable) or ad hoc (i.e. the DM provider manages the charging unless the consumer overrides this). For example, under BMW's Charge Forward scheme, BMW receives instructions from a utility to reduce load and it effects this load reduction by switching off a number of EVs on an hour-by-hour basis, accounting for the desired departure time as stated by the consumer. The consumer is able to override this.
- The interface with the consumer could be via an app on their phone or a smart display in the vehicle (e.g. BMW's iRemote App or My Electric Nations mobile device app, or an equivalent of an Energy Orb - a type of in-home display which glows different colours to signal which tariff periods are in place, and may also change colour to notify consumers in advance of a peak period).
- The consumer may or may not have visibility of the tariffs. Real-time pricing and a pricing forecast (i.e. for charging 'ahead of need' could be shown to the user through a smart device or website) and tracking showing when their vehicle has charged and the amount of avoided charging cost. At the opposite end of the spectrum, the user may have no visibility of prices and simply receives a reward for allowing the DM provider to take control.
- A Supplier could use periods of cheaper electricity to pass on savings to consumers, with additional components of the offering as required (e.g. 'reward payments') to make the proposition to consumers strong enough.
- Potential reward payments to consumers – an 'inconvenience' cost for allowing a third-party to manage their charging. The amount of reward could vary with the limits that are specified by the consumer or DM provider. The incentives could be provided as an:
  - Upfront – payment (e.g. the BMW Charge Forward trial offers a $1000 gift card per vehicle for participation) or other incentive (e.g. the My Electric Nation trial gives EV users a free charger for allowing their vehicle to participate in demand control events).
  - Ongoing – payment (e.g. BMW Charge Forward scheme offers an ongoing gift card payment for participation, which depends on the level of participation but could be up to $540 over the 18 month trial).

[9] https://www.gov.uk/government/publications/smart-power-a-national-infrastructure-commission-report

- Ad-hoc – small one-time or ad-hoc rewards for participation to foster positive word-of-mouth and encourage consumers to join.
- Penalty mechanisms – if load control becomes 'the norm' in future, in which case participation may be accepted and expected. At this stage, penalties could be introduced for lack of participation. However, this is likely to be challenging given the competitive retail market environment mentioned above.

Demand Management is discussed in detail in section 7.2 of the *D1.3 Market Design and System Integration Report*, including how to deliver it in practice and the risks and barriers that could affect the CP, PSC, CVC and MPF.

5 Physical Supply Chain (PSC)

5.1 Overview

The Physical Supply Chain (PSC) Dimension covers all of the supply chain components relevant to the transport sector and ULEVs in particular, including those associated with the energy supply chain.

The materiality for the *D1.2 Analytical Framework* and Research and Development (R&D) needs for each BB have been identified. To support an *a priori* view of materiality, two types of high level assessment were carried out:

- *Comparative assessments (e.g. change in Scenario compared to BaU)*: indicative impact of changing key parameters of each BB in terms of the costs or CO_2 emissions (e.g. the difference in battery costs comparing a BaU vs. rapid cost reduction Scenario).
- *Absolute assessments (e.g. stand-alone materiality within Scenario)*: capture the relevance of each BB within its category (e.g. what percentage of the vehicle capex does the battery or the electric motor constitute), or the relevance of the BB at the system level (e.g. investment required by 2050 in distribution network reinforcements).

A summary of key R&D gaps, a specific deliverable requirement for this Dimension, is captured in section 5.3.1, and a summary of the BBs and their materiality is shown in Table 5. A more detailed description of each BB is included within the supporting *D4.2 Building Blocks Catalogue* spreadsheet, with an example in Figure 4.

Table 5 Summary of BBs included in the Physical Supply Chain

Materiality for framework
High
Medium
Low

VEHICLES	ENERGY GENERATION	ENERGY TRANSPORT	ENERGY STORAGE	REFUELLING INFRASTRUCTURE	BACK OFFICE/IT
1. Battery	8. Electricity generators	12. Electricity distribution network	17. Large batteries	21. Private charging	25. Industry standards
2. Battery Management System	9. H_2 generation plants	13. Electricity transmission network	18, Large underground H_2 storage	22. Public charging	26. Assets for settlement (e.g. smart meters)
3. Fuel cell system (incl. range extenders)	10. Biofuel plants	14. H_2 distribution	19. Oil strategic reserves	23. H_2 refuelling stations	27. Assets for comms.
4. Generic high technology readiness components (e.g. chassis, engine)	11. Refineries	15. Trucks for liquid fuels	20. Natural gas storage	24. Forecourts	28. Data servers for big data
5. Electric motor		16. Gas network			29. Assets for comms. from/ to vehicles
6. Vehicle H_2 tank					

7. Comms. systems

Figure 4 Example of detailed BB view in the supporting spreadsheet for the PSC

Category		Vehicles
Building block number		**1**
Building block name		**Battery**
Explanation		Electricity storage component in plug-in electric vehicles. Primary influence on the cost and performance of all plug-in vehicles, as well as ability to provide Managed Charging Scenarios

Currently in the UK?		**Yes**
Explanation/ examples		Most cars in the market have Li-ion batteries (i.e. Nissan Leaf, Mitsubishi Outlander)

Quantification of impact - A1, A2, A3) COMPARATIVE ASSESSMENTS - how does changing the most material(s) state(s) across its different levels affects the analytical framework (i.e. comparing high/low with BaU Scenarios, in terms of costs for the system, CO2 emissions, etc.)	A1) CO2 emissions reduction potential (as % of total 2012 car CO2 emissions; Low: <5%, High: >20%)	
	A2) Cost reduction potential (as % of difference between Scenarios; Low: <5%, High: >20% difference)	High (battery cost differ 15-20% between the 'extreme Scenarios', all along 2020 towards 2050) 'Extreme Scenarios': comparing low battery cost, low range and high battery cost, high range Scenarios. The materiality of changing the state from a low to a high cost case is high, as this could determine whether PiVs are viable or not
	A3) Others (specified when relevant)	High (BEVs premiums over ICEVs differ ca. 10 and 5 % respectively, in 2020 and 2050, between extreme Scenarios) 'Extreme Scenarios': comparing low battery cost, low range and high battery cost, high range Scenarios
B1,B2,B3,B4) ABSOLUTE ASSESSMENTS - what is the importance of a particular state for the analytical framework; i.e. what % of a BEV capex constitutes the battery	B1) Technology development (high: technology development critical for mass deployment and use of ULEVs)	High - battery cost reduction is an important factor underpinning ULEV uptake, among other factors
	B2) Costs (as % of capex; low <10%, high: >20%)	High (BEVs: 25-30% and ca.20% of capex in 2020 and 2050, respectively) Today: 40% of costs *(ca. £9k for a C-segment car; initial modelling with ECCo's cost and performance database)*
	B3) System costs, i.e. associated to infrastructure investment, (cumulative values; Low: <100million; high: >1billion)	
	B4) Others (specified when relevant)	

Overall Materiality		**High** Battery costs and performance are a critical influence on uptake of ULEVs and hence overall opportunity for Managed Charging

Information Required: States - they are ranked in order of importance. The first(s) one(s) are be used for the quantitative assessment	1	**Battery cost:**- dependant on states below **LOW** (from 160 £/kWh in 2020 to 89 in 2050; 25-35kWh band, 2010£) or **BaU** (from 208 £/kWh in 2020 to 89 in 2050) i.e. cost differences between Scenarios of 25%, 10%, 5% and 0% in 2020, 30, 40 and 50 *(values from ECCo's cost and performance database with HIGH range, LOW energy density, Li-ion batteries)* **This state is based on assumptions on the states below (range, energy density, type of batteries)** Values will be based on Scenarios developed in battery cost modelling in WP3
	2	**Electric range (underlying assumption of battery cost):** - output from WP3 **HIGH** e.g. OEMs 'spend' battery improvements on increasing pack sizes and vehicle range **LOW** e.g. OEMs favour cost reductions rather than significant range increases, reflecting a world where consumers become comfortable with limited range EVs as infrastructure increases
	3	**Battery technology development (energy density) (underlying assumption of battery cost): -** output from WP3 **HIGH** (ca. 0.28kWh/kg, 2050) or **BaU** (0.14kWh/kg, 2050 as per today state-of-the-art); *Values from ECCo's cost and performance database*
	4	**Battery technology development (degradation) (underlying assumption of battery cost):** - output from WP3 **HIGH** e.g. lifetime less than vehicle lifetime, some Managed Charging configurations increase degradation or **LOW** - e.g. little or no impact of charging configurations on degradation, battery life exceeds vehicle design life
	5	**Battery type (underlying assumption of battery cost):** - output from WP3 Lithium-ion (variants and combinations of LMO, NMC, NCA) or Lithium-sulphur (post 2030)

5.2 Synthesis of evidence and literature

The Physical Supply Chain (PSC) Dimension covers all of the supply chain components relevant to the transport sector and ULEVs in particular, including those associated with the energy supply chain.

The research questions for the literature review have focused primarily on:

- *What is the availability of different technology BBs?*
- *How significant are the BBs expected to be in terms of driving ULEV-related costs both now and in the future?*

These questions were used to frame the literature review – answers were incorporated into the *D4.2 Building Block Catalogue* spreadsheet, together with more specific research on individual BBs.

In contrast to the Customer Proposition dimension, most PSC BBs exist across multiple Narratives, but the extent to which they are used – i.e. their materiality – depends significantly on the uptake and utilisation of different types of vehicles in the analysis of the Narratives. However, key insights from the review of literature are as follows:

- *Vehicles*
  - Battery costs will continue to comprise a significant portion of the costs of PiVs in the near term (~40% in 2016, ~25-30% in 2020), but they are dropping steadily coupled with more gradual improvements in range. A variety of more novel battery chemistries (e.g. lithium-sulphur) exist, but their cost is subject to significant uncertainty. *A more detailed assessment of battery technologies has been undertaken as part of D3.1 Battery Cost and Performance and Battery Management System Capability Report and Battery Database and costs and performance data is included within the D1.2 Analytical Framework.* In contrast to PiVs there is significantly higher uncertainty over the long-term costs of FCVs.
  - Continued, but more incremental improvements, are expected in conventional vehicle components through weight reduction and improved energy efficiency, but many of these will benefit ULEVs as well as conventional vehicles.
  - The extended time for which liquid fuels may be stored in the tank of PHEVs, especially in the context of an assumed increasing proportion of electrically delivered miles, has been identified as possibly leading to issues. These may arise due to winter grade liquid fuel being used in summer or vice versa, the ageing degradation of the fuel tank or fuel injection equipment, or stressed duty patterns for the ICE. These issues have been explored in detail in a paper prepared by Shell for the CVEI project[10]. This found that risks are of an operational rather than safety nature and there is scope for mitigation measures in fuel formulation and adaptations to vehicle hardware and software. The paper concluded that the currently available evidence is that the risks are minimal, but determining this conclusively will depend on the availability of greater operational data.
- *Energy carriers*

[10] The Nature of Potential Operability Risks from Longer Term On-board Fuel Storage in PHEVs, Shell, May 2016

- Hydrogen production is well established at small and medium scales via existing industrial processes such as Steam Methane Reforming (SMR). The key challenge moving forwards is production at larger scale for ULEVs in a manner that has low carbon intensity and at reasonable cost. To reduce carbon intensity sufficiently this is generally dependent on Carbon Capture and Storage (CCS)-based production routes (SMR plus CCS or coal / biomass gasification plus CCS) or large quantities of cheap, low carbon electricity (e.g. from new nuclear). Localised production (typically via small scale electrolysers) tends to be more expensive and the value of this route needs to be contrasted with the additional costs of distribution from centralised production.
- Second generation biofuel production routes offer potentially significant CO_2 reductions (e.g. 70%+ on a well-to-wheels basis compared to petrol and diesel).

- *Distribution of energy*
  - Management of the electrification of vehicles (both scale of supply and balancing) on the wider energy system and associated carbon reduction will benefit from broader activity associated with, for example, integration of increasing levels of intermittent generation and electrification of heat (which are likely to place higher absolute demands on the electricity system than electrification of transport).
  - Individual components of hydrogen distribution technologies are generally already established and the costs of distribution are generally small compared to the overall fuel selling price (potentially <10%). The choice of pipeline based distribution versus truck based distribution will depend on the volume of use, potentially linked to the role of hydrogen in other sectors of the economy, such as power generation.
- *IT / communications*
  - Adequate communications technology is a prerequisite for greater management of PiV charging (either by the consumer or more directly by an external party), such as control systems for Active Network Management. These are already being driven however by other factors of which PiVs are only one aspect (mandated roll-out in the case of smart meters and the requirement for more active management of all supply / demand by DNOs).
  - Interoperability and standards, e.g. with respect to charging infrastructure, are seen as an important enabler of PiVs from the consumer perspective and are primarily a matter of coordination as opposed to technology development.

5.3 Areas for further research and known gaps

5.3.1 Key R&D needs

For the PSC, key R&D needs for each BB have been identified, and a summary presented in Table 6.

Table 6 Summary of R&D needs for the Physical Supply Chain

Materiality for framework
High
Medium
Low

VEHICLES	ENERGY GENERATION	ENERGY TRANSPORT	ENERGY STORAGE	REFUELLING INFRASTRUCTURE	BACK OFFICE/ IT
Battery*: Li-on energy density, post-lithium-ion batteries and their degradation rates, battery pack manufacture	**Electricity generators:** conventional, mature. R&D for most renewables	**Electricity distribution network:** low voltage control technology (i.e. solid state transformer)	**Large batteries:** technically proven. R&D specific to technology type	**Private charging:** inductive charging, cost and performance (i.e. higher power ratings)	**Industry standards:** several under development
BMS*: state-of-charge, state-of-health and control algorithms for central management	**H_2 generation:** 'Brown H_2' production roll-out ready	**Electricity transmission network:** HVDC cables, better deep-water foundations	**Large underground H_2 storage:** large scale salt caverns, interaction with intermittent renewables	**Public charging:** inductive & dynamic charge, street furniture, electrolyte refuelling	**Assets for settlement:** Smart meters - capabilities, data exchange protocols
Fuel cell system: industrialisation of initial FCEV volume manufacturing processes	**Biofuel plants:** next generation fuels e.g. from gasification of solid biomass	**H_2 distribution:** mature. Increase mass stored per truck	**Oil strategic reserves** mature	**H_2 refuelling stations (HRS):** demonstrate 'roll-out ready' HRS, compressor reliability, maintenance cost	**Assets for comms.:** demonstration of Active Network Management
Generic high technology readiness level components: novel materials and efficiency measures	**Refineries:** mature. Introduction of drop-in biofuels (Hydrotreated Vegetable Oil)	**Trucks for liquid fuels:** mature. Improved efficiency	**Natural gas storage** mature	**Forecourts** mature	**Assets for comms. from/to vehicles:** navigation software, apps
Electric motor: low voltage and cheap, no rare earth metal motors		**Gas network:** mature			**Data servers for big data:** mature
Vehicle H_2 tank: novel materials for lower costs, higher capacity-to-weight and capacity-to-volume					
Communication systems: standards					

Note: *These BBs have been studied in more detail in WP3 (Vehicle energy supply management systems and technologies), see 5.3.3 for a summary of findings.

Table 7 summarises the main sources used to address the R&D needs within each BB, where a more detailed description can be found. Those where the technology is fully mature, have been excluded from Table 7.

Table 7 Summary of sources for key R&D needs

Source	Battery	BMS	Fuel Cell	Generic High TRL comp.	Elec. motor	H2 tank	Comms	Elect. generation	H2 generation	Elect. Transmission	Elec. Distribution	H2 distribution	Large batteries	Large und. H2 storage	Private charging	Public charging	H2 refuelling stations	Industry standards	Assets for settlement	Assets for comms	Comms from/to vehicles
1				x	x		x							x	X	x		x	x	x	x
2	x	x					x														
3			x			x			x			x					x				
4							x														x
5								x													
6								x													
7								x													
8								X													
9										x	x		x								

Sources:

1) Various websites (indicated as a comments in 'Level of technology development', in the *D4.2 Building Blocks Catalogue* spreadsheet)
2) Element Energy for ETI, '*D3.1 Battery Cost and Performance and Battery Management System Capability Report and Battery Database*', 2016. Element Energy for ETI, '*D3.2 Battery State of Health Model*', 2016
3) Technology Innovation Needs Assessment (TINA) Hydrogen for Transport Summary Report, Low Carbon Innovation Coordination Group, November 2014
4) Intelligent Mobility Technology Roadmap, Automotive Council, 2013
5) Technology Innovation Needs Assessment (TINA) Offshore wind Power Summary Report, Low Carbon Innovation Coordination Group, February 2012
6) Technology Innovation Needs Assessment (TINA) Bioenergy Summary Report, Low Carbon Innovation Coordination Group, September 2012 (covered under 'biopower')
7) Technology Innovation Needs Assessment (TINA) Marine energy Summary Report, Low Carbon Innovation Coordination Group, August 2012
8) Technology Innovation Needs Assessment (TINA) Carbon Capture and Storage in the Power sector Report, Low Carbon Innovation Coordination Group, August 2012
9) Technology Innovation Needs Assessment (TINA) Electricity Networks and Storage (EN&S) Summary Report, Low Carbon Innovation Coordination Group, August 2012

5.3.2 Outputs of other Work Packages for the *D1.2 Analytical Framework*

Information about the **battery pack** has been provided as part of WP3 and incorporated into the *D1.2 Analytical Framework* (e.g. updated cost and energy density data).

5.3.3 Gaps in the literature

Gaps identified in the literature include:

- More research may be required on the potential role **of low voltage motors for PiVs** and to quantify the impact on the total cost (e.g. there may be a trade-off between cheaper batteries and more expensive motor / electronics controls). However, this is considered to be a low materiality BB based on the low R&D impetus vs. improvement of high voltage battery packs.
- **Industry standards:** a more detailed understanding of the impact of different levels of industry standards (e.g. strict standards to guarantee the interoperability of ULEVs with the charging infrastructure).
- A significant volume of research is on-going, but more is needed, on the topic of **battery ageing / state of health**, in particular to generate more data on real-world degradation in different uses cases. Not all degradation mechanisms are understood yet and accelerated test procedures are also needed to simulate heavily used packs that are not yet available from vehicles in services given the average age of current PiVs.

Regarding battery packs[11], key findings related to R&D from WP3 are:

- **For lithium-ion batteries** (current technology), a transition in cathode material (from manganese oxide to nickel based oxides) is on-going and there is still scope for improvement in the energy density of these cathodes. R&D is also on-going to improve the energy density through an improvement of the anode (integration of silicon in the graphite anode). These improvements in electrode materials have been captured through the development of an R&D roadmap[12] and they are factored in the cost and energy density projections.

  Battery pack lifetime was found to depend on a number of parameters, particularly temperature. Assuming the temperature profile of London, a typical lithium-ion battery will see ca. 1% calendar degradation (the degradation happening over time) per year almost irrespective of the usage profile. The cycling ageing (the degradation happening when using the battery) comes on top of calendar degradation and is heavily dependent on specific battery chemistry and cycling conditions. Assuming a typical travel distance of ca. 15,000 km per year, the cycling ageing can range from less than 0.1% per year for a PHEV used in charge sustain mode only to ca. 10% for a BEV. Thus, the lifetime of a typical BEV battery is close to 10 years (but can be substantially lower or higher depending on the

[11] Battery with the integration of a BMS and other packing components such as power electronics, wiring harness and connectors, internal cell support, housing and a thermal management system.

[12] Two variants of the R&D roadmap were developed ('Baseline R&D path' and 'Slow R&D path'), refer to section 5 of the D3.1 Battery Cost and Performance and Battery Management System Capability Report and Battery Database.

specific usage profile and the battery chemistry) and the lifetime of a PHEV battery can easily exceed 10 years if the PHEV is not used exclusively in full electric mode.

There are uncertainties on life characteristics of future batteries based on new / future electrode materials, as a short lifetime is typically one of the impediments to their wider use.

Interestingly, based on the battery state of health model developed in WP3 it was found that Managed Charging could decrease or *increase* the lifetime of batteries – depending on how it is implemented (specifically, this depends on whether the Managed Charging leads to an increase or decrease in the average state of charge). This in turn depends to some extend to how consumers accept DM – a topic never studied at scale on mainstream consumers. This will be studied in Stage 2 through the trial, when the usage profile of the battery will be monitored, allowing greater understanding of the potential of DM on both the energy system and life of the battery.

- The Battery Management System (BMS)[13] is an important component (as a source of battery parameters used to inform the decisions on specific charging routines) for the integration of EVs in the electricity system / to support DM strategies. The three main BMS capability developments that have been identified for the integration of PiVs in the energy system are:
  - real-time reporting of state of health to optimise charging and usage of PiVs
  - advanced state of health estimating to allow prediction of availability for Demand Management, and
  - advanced functionality (e.g. to enable the identification of unusual aging trends) relying on new algorithms.

  The lack of these capabilities do not prevent the integration of PiVs through Managed Charging but they would improve this integration, in terms of battery protection and state of charge window available for grid services. Further improvements in state of health estimation will help minimise the impact of additional charging cycles on the battery lifetime, and improve understanding and evaluation of second life PiV battery applications (both technical and commercial/economic).
- **For post lithium ion batteries**, current R&D efforts were reviewed. It was found that the most advanced technologies and/or those which are promising in terms of theoretical energy density are lithium-sulphur and metal-air batteries. Both would benefit from the development of solid electrolytes (on-going) as these would bring increased safety. However, they all have remaining challenges to overcome to become viable automotive cells, typically in terms of cycle life, efficiency, (dis)charge rate, volumetric density and/or scalability.

The separate deliverables provided under Work Package 3 - *D3.1 Battery Cost and Performance and Battery Management System Capability Report* and *Battery Database and D3.2 Battery State of Health Model* - cover these topics and should be referred to for more detail.

[13] The set of electronic components that monitors and controls the battery. Its main functions are to protect battery and cells from damage, to prolong the battery lifetime, to ensure that battery state is fit for the application purpose and to interface with the host application (e.g. a car).

5.4 Key focus areas for the *D1.2 Analytical Framework*

The high and medium materiality BBs in the PSC are discussed below:

- For the **vehicles** the material components are the battery and BMS (studied under WP3) and the fuel cell system.
- The electricity generators and H_2 generation plants are an important part of the **energy generation** category and will be accounted for in the system modelling. The price of electricity and H_2 will vary under different Narratives depending on the generation mix (including types and capacities of H_2 generation technology deployed). A distinction will need to be made between localised H_2 generation (i.e. on-site, via electrolysis) and centralised generation and the cost differences between these.
- **Energy carrier transport** needs to be considered, in particular the electricity distribution network, H_2 distribution network and to a lesser extent the electricity transmission network. The investment requirements for the networks depend on demand for energy vectors which varies by Narrative. In most Narratives it is assumed that H_2 distribution is carried out by trailers as this is generally more cost effective at lower volumes. However, the H2P and ULEV Narratives include pipelines at varying scales.
- The focus of the **recharging / refuelling infrastructure** should be on private charging, public charging, hydrogen refuelling stations and petrol / diesel forecourts – the demand for infrastructure will vary between the Narratives.

The PSC BBs have been applied in a manner consistent with the description of the Narratives.

In contrast to the CP dimension, most PSC BBs exist across multiple Narratives, but it is the extent to which they are used which will depend on the uptake and utilisation of different types of vehicles in the analysis of the Narratives. The rationale for excluding specific BBs or treating them more qualitatively is as follows:

- Measures such as industry standards and other back office/ IT form a part of the relevant overarching Narrative but their impact cannot be quantified explicitly and hence they can only be explored qualitatively.
- Biofuel plants, refineries and large underground H_2 storage are included in the *D1.2 Analytical Framework* as part of the existing tools used, but are modelled only at a relatively high level (e.g. large scale batteries in the ESME model) or treated as a boundary condition (e.g. Refineries via exogenous assumptions for petrol / diesel wholesale costs).
- The gas network, oil strategic reserves and natural gas storage are not modelled explicitly as part of the *D1.2 Analytical Framework* tools, but their direct impact on ULEV uptake is deemed to be very limited (as they have limited impact on the cost or availability of infrastructure from the perspective of the ULEV owner) and hence there is negligible value of including them in the analysis.

6 Commercial Value Chain (CVC)

6.1 Overview

The CVC consists of the entities that exist in the value chain, together with the underlying business models that define how each of these creates value.

Given the myriad of potential commercial entities across the value chain these have been simplified to focus on generic commercial entities (and variants of these) which are closest to the consumer or more material in terms of ULEV-specific investments. This section describes the approach taken in doing so and the final list of entities that are incorporated within the *D1.2 Analytical Framework*, whereas the logic for how the commercial viability of the entities has been assessed is described within the *D1.3 Market Design and System Integration Report*, as part of the discussion on the tools used in the *D1.2 Analytical Framework*.

6.2 Synthesis of evidence and literature

The approach taken was to first identify all entities on the value chain, categorised in a matrix by:

1. **Category:** e.g. transport (vehicles, batteries, fuel cells) or fuel & infrastructure (electricity & charging points, hydrogen & pipelines / trucks / trailers, liquid fuels & trailers).
2. **Position:** along the value chain, in terms of 'classic' business models (manufacturer, broker / exchange operator, installer, site developer, owner, operator, distributor, retailer, service provider and secondary services).

An initial assessment of materiality for the *D1.2 Analytical Framework* was undertaken and partnerships/ mergers already in existence were noted, together with those that may make commercial sense in the future. This raised several key challenges that commercial entities might need to meet in order to efficiently achieve high ULEV uptake (aside from the commercial viability of the business model, which will be assessed using the *D1.2 Analytical Framework*):

- **How can the impact of plug-in vehicles on electricity distribution networks be managed?**
  - How can network management be structured? How can efficient reinforcement be incentivised?
- **How would hydrogen be delivered to the consumer?**
  - How could a hydrogen network be financed?
  - What drives the viability of pipeline versus truck-based distribution?
- **How might integration of vehicle provision, energy provision and other bundled services be achieved?**
  - What constructs efficiently achieve this integration?
- **How can fossil fuel business models be sustained?**
  - As volumes decline, can a fossil fuel distribution business be made viable?
- **How will deployment of charging infrastructure be financed?**

- Public finance, private businesses, individual installation?

Targeted research was undertaken by E3 and Baringa, to provide information on how these questions might be answered by the CVC, and to understand the roles of each entity and relevant business models already in existence in the UK and elsewhere (this information has been incorporated into the descriptions of the business models in the supporting *D4.2 Building Blocks Catalogue* spreadsheet). Key insights include:

- *Vehicle-related propositions*
  - Vehicle manufacturers / retailers are already beginning to offer a range of financing / leasing packages to PiV consumers mirroring the Customer Proposition Building Blocks and this is expected to increase in future helping to overcome the barrier of high upfront cost of ownership for ULEVs.
  - PiV-based car hire / sharing is still in its relative infancy, particularly in the UK. There are however, more developed examples in other countries, such as Car2Go in the US, which also includes bundling of additional services including energy. This is facilitated via free charging at a number of points in San Diego owned by partner charging point operator ECOtality.
- *Charging infrastructure and propositions*
  - A wide range of entities are involved in the development of non-home charging point infrastructure from dedicated charging point providers (e.g. Chargemaster), OEMs such as Tesla to retail suppliers such as Ecotricity in the UK. However, the deployment of such infrastructure is still at relatively small scale and many charging points are either free or heavily cross-subsidised to serve other purposes (e.g. promote consumer loyalty, advertising) and a question mark remains over the viability of these approaches at larger levels of infrastructure deployment and use.
  - Other more novel forms of charging infrastructure have proven less successful commercially. 'Better Places' battery swapping businesses in Denmark and Israel went into administration in 2013. Tesla have recently dropped plans to commercialise battery swapping stations, instead focusing on their rapid charging network.
- *Enabling demand management*
  - Demand management of PiV charging in the UK has been delivered through DNO-led innovation trials under Ofgem's Low Carbon Network Fund, such as SSEPD's My Electric Avenue project and UKPN's Low Carbon London project. To date the focus has been on the technical and economic issues associated with Supplier-Managed Charging at the DNO level and less on new commercial arrangements.
  - Whilst aggregators could at present monetise PiV demand management services and sell these to the TSO (e.g. as part of National Grid's Short Term Operating Reserve programme) commercial routes to monetise these services at the DNO level are still in their relative infancy. This is driven in large part by the clear separation of network ownership from supply of energy in the GB market, which does not exist universally (for example some utilities in California are vertically integrated) and hence these markets are often more developed in terms of their commercial structures to facilitate demand management.

- At the distribution level active management of PiV demand is closely tied into the broader evolution of the DNO in the UK to more actively manage both supply (e.g. distributed generation) and demand as part of a move to a DSO model).

- *Facilitating new hydrogen infrastructure*
  - Large-scale hydrogen network development for transport is not necessarily contingent on significant Government intervention and bodies of work such as the H_2Mobility project in the UK have illustrated how such a network could be developed organically through coordinated private sector activity.
  - This does have implications for how such infrastructure may be developed as it tends to favour e.g. truck and trailer distribution to facilitate more incremental roll-out and avoid the potential for significant lumpy investments in larger scale pipeline infrastructure. These could be more economic with larger volumes of hydrogen in later years, but have a higher risk of asset stranding.

Using the targeted research, a core list of generic entities was created that are considered to be material, along with variations to these that are novel, or that could be particularly important for ULEVs. The specific entities (BBs) on the CVC vary to some extent by Narrative.

6.2.1 Framing the business models

Using the list of core commercial entities, the business models have been defined using a framework. This gives high level information about the elements that collectively represent each specific model: partner network, key activities and resources, offer, consumer relationships and distribution channels, consumer segments, and revenues and costs.

'Generic' models have been used as a basis, either drawing on traditional models, or existing examples (in the UK or elsewhere) that are starting to gain traction. **Variations to these generic models are included** on each framework as either:

- **Changes to the activities assumed within one model**, e.g.:
  - a **Charging Point Operator** may vary through its use or not of distributed generation on-site, tariffs used for cost recovery, payment to host (e.g. host sites the stations for free or a fee / rent), and ownership models (charging points owned by Charging Point Operator itself, by an OEM, a utility, or the host).
  - **Vehicle sharing schemes** might provide different offerings to their consumers; for instance, manufacturer or third-party led (BMW DriveNow uses BMW cars, whereas Car2Go buys cars from local dealerships), the range of operation (ZipCar uses range extender vehicles, whereas other operators may be city-led and offer BEVs only), incentivised charging, cost of parking, and the extent of associated apps / digital offerings.

- **Closely-linked or very similar types of business models that can be described on the same framework**, e.g.:
  - a **hydrogen network operator** may typically operate at least in the short-medium term by delivering hydrogen gas in high pressure tube trailers or canisters; variants may be building new pipelines, re-purposing of existing gas pipelines (through

injection and recovery of hydrogen in the natural gas stream) or delivery as a liquid in tankers.

- a **vehicle leaser** is described as a generic business model; a battery leaser is similar enough to be described as a variant to this and would probably be combined with the vehicle leaser. Vehicle sharing schemes have been described separately as their focus is on shorter-term mobility and in some cases these could also be used as an advertising tool to encourage uptake of ULEVs.

Appendix A of this document shows the business model framework for each core commercial entity. Detailed descriptions of the business models are provided in the supporting *D4.2 Building Blocks Catalogue* spreadsheet. The entities which are represented in the *D1.2 Analytical Framework* are described in the Appendix to the separate *D1.3 Market Design and System Integration Report.*

6.2.2 Example business model

An example of the business model on the framework for the vehicle manufacturer is shown in Figure 5.

Table 8 provides the detailed description of this example, taken from the supporting *D4.2 Building Blocks Catalogue* spreadsheet.

Figure 5 Business model of the vehicle manufacturer described using the framework

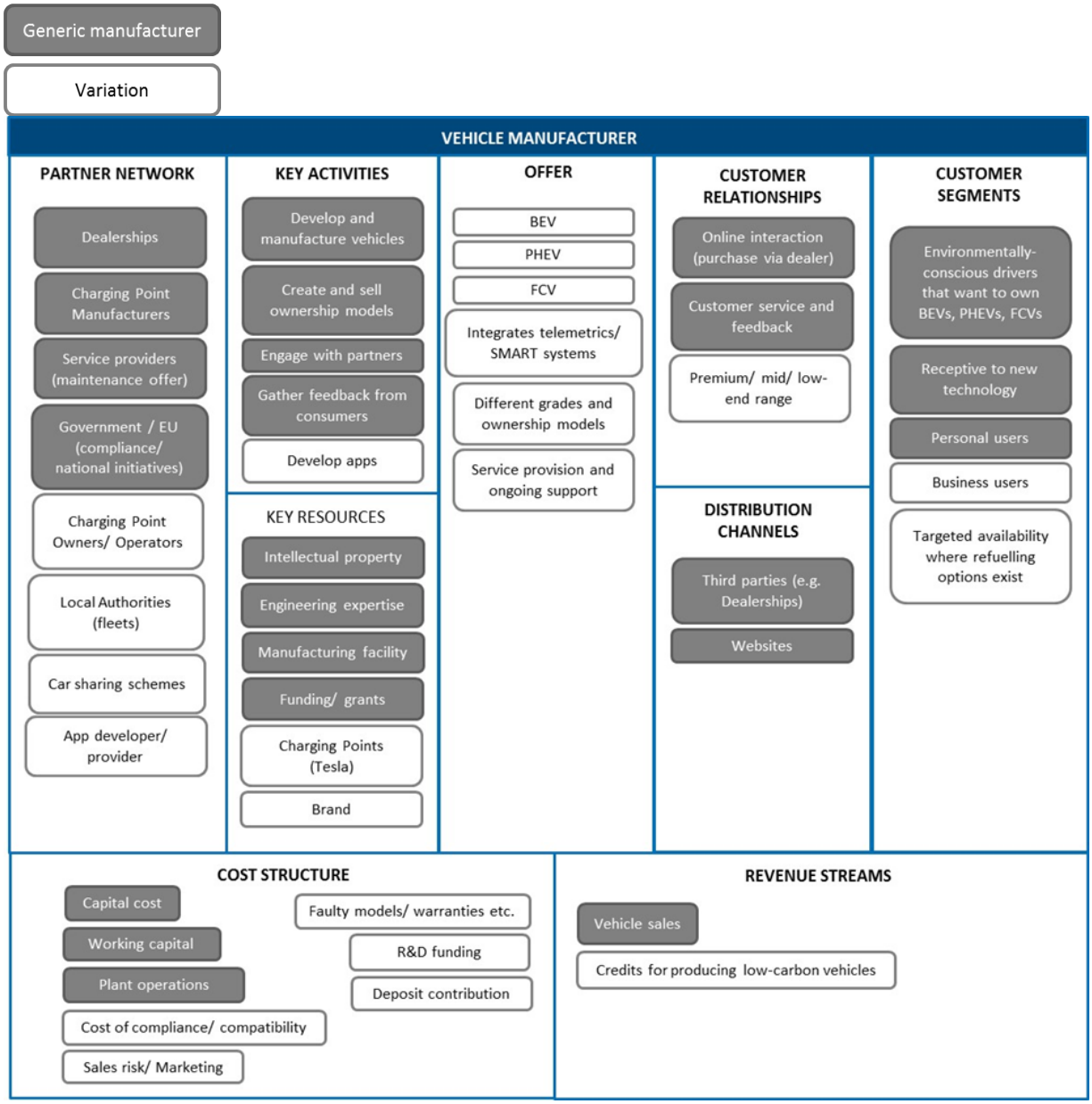


Table 8 Business model of the vehicle manufacturer described in detail

Vehicle manufacturer	
Known examples	Nissan LEAF, Mitsubishi Outlander PHEV, Tesla Model S, Chevrolet Volt, Toyota Prius Honda FCV Concept (US, 2017), Toyota FCV Mirai (US 2015-16), Hyundai FCV Tucson (US, 2014)

Generic vehicle manufacturer (e.g. Nissan LEAF)	
Proposition Offer	• **Manufacture of ultra-low emissions vehicles (<75 gCO_2/km) at cost appropriate to the target market, once accounting for any tax exemptions and credits.** Ideally cost-competitive with conventional vehicles. • **Service provision and ongoing support** (providing warranties e.g. 3-year or 60,000-miles vehicle warranty/ 5-year warranty on the battery) • **Information about mobility/ ChargePoint Partners/ Smart systems:** Nissan provides tools to manage range: 'Eco' driving mode option, option to specify reaching certain internal car temperature during car charging, and option to maximise range by choosing the most energy-efficient route • **Lower maintenance cost for EVs:** engines have less moving parts, which translates to fewer visits to a garage for repairs over the life of the car. Servicing costs of an EV are about £350 less than a petrol or diesel car. • **Range of mileage depending on model but in general low relative to conventional vehicles** (Nissan LEAF = 95-155 miles depending on Scenario, Tesla Model S = 330miles) • **Optional add-ons for high-end ULEVS:** such as acceleration upgrades, packages for sub-zero weather package or towing
Who is the consumer? Consumer segments etc.	• **Consumer is typically environmentally-conscious** (or corporate fleet user that wishes to improve their brand) • **Mid-range user** (Nissan c.£20,000); **low-end** (Toyota Prius); **high-end** (Tesla £95,000 Model X, GM, Fiat-Chrysler).
How is value creation organized? Activities/ Resources/ Partners/ Costs	**Activities**: • **Develop and manufacture low-emissions vehicles** at various grades (entry level, mid, top-of-the-range) and **create ownership models** (outright purchase, battery leasing based on three different annual mileages), **recommends charging options** [1) cable allowing recharging using a standard household socket, which can also be used at many public charging stations throughout the UK, 2) manufacturer's home chargers], **manage risk** (mitigate problem around stranding risk by focusing all engineering efforts on using the same basic parts in multiple cars), **marketing** (branding at charge stations, other advertising materials, cross-country excursions, partner with car-sharing scheme so consumers essentially test drive the cars without realising) **Resources:** • **IP, engineering skills**, **manufacturing facilities,** as well as **credits** for manufacturing ULEVs (super credits from EU), **grants/ funding** (Nissan LEAF factory supported by a £21 mn Grant for Business Investment from the UK Government and a proposed finance package from the European Investment Bank of up to £197 mn), **brand** (increased take-up has only happened with more well-known brands and models, sales only began to increase significantly with the availability of 4-5 seaters as there were concerns around safety of 2 seater models) **Partners:** • **Government/ EU** (lobbying/ influencing and compliance - in 2009, technology-neutral CO2 emission sales targets for new passenger cars were adopted, each manufacturer required to achieve at least a fleet-average CO_2 target of 130g/km by 2015 and 95g/km by 2020 and, for vans, the corresponding CO_2 target is 175g/km from 2016 and provisionally 147g/km from 2020) • **Industry bodies** (with the objective of supporting UK production of ULEVs, five key agencies

have been established by the UK government and DECC established Local Carbon Economic Areas across the UK to support low carbon specialisation within the UK economy; the North East is designated as the provider of EV expertise, while the Midlands region is linked more generally to advanced automotive technology, which includes EV design)
• **Dealerships** to display and sell cars on forecourts
• **Charging point manufacturers and owners**
Costs:
• Manufacturing (Nissan shifted production from Japan to the UK to reduce retail prices). GM and Fiat were reporting losses on EVs as over-engineered and over-priced.

Variation: Vehicle manufacturer and Charging Point owner/ Operator (partnership or merger)	
What makes this business model similar?	Vehicle manufacturer as per stand-alone manufacturer, partnered or merged with charging point owners/ operators
What makes this business model different?	In the stand-alone model the vehicle manufacturer may provide some information about the availability of charging point (e.g. this could be incorporated into the dashboard), however, there are extended options in a partnership/ merger arrangement: • **Charging points installed in dealerships associated with the manufacturer** (rapid charging in Nissan Dealerships; charging in Toyota dealerships in US) • **Partnerships with charging point owners** (Nissan recommend the use of the Ecotricity Electric Highway as it's currently free, in the USA they offer complimentary charging for 2 years, estimating the value at 500 $ p.a., and Toyota offer free fuel on their FCV for the first 3 years, estimating the value at 1250 $ p.a) • **Roll-out of own charging point stations to incentivise take-up of cars:** Tesla US and European Supercharger network – its Supercharger stations are free to use for Tesla owners, and by using a hugely powerful 120kW DC supply they can take the Model S from empty to 50% in 20 minutes. The 120kW DC supply only works with the Model S for now, but Tesla has said that if rivals build electric cars that can handle this current, it will help develop an adapter – so long as these makers agree to let their consumers use the Supercharger network for free, too. • **Only make ULEVs available where refuelling stations exist:** e.g. targeted roll-out in the USA of the Honda FCV, which is only available to consumers who live in Southern California where fast-fill hydrogen stations are available

6.3 Areas for further research and known gaps

Many of the business models on the CVC are traditional and therefore well-understood. There is less information available on the potential success and commercial viability of novel business models, such as those that do not yet exist at scale, including:

- The **DNO becoming a DSO**, which is at the early stages of discussion within the GB market and covers a wide range of potential roles[14] including more active management of both supply and demand – the latter is of more direct relevance in terms of demand management of PiVs, potentially via aggregators.
  - For example UKPN's Low Carbon London trials focused primarily on the technical and economic implications of integrating a range of low carbon technologies at the distribution level, with some initial exploration of possible commercial arrangements[15].
- **Battery leasing** models.
- **Battery swapping** (this has been trialled internationally but not in the UK).
- **The IT / data provider** (especially the appetite of the consumer for smart, consumer-oriented apps and bundling).

6.4 Key focus areas for the *D1.2 Analytical Framework*

The core generic commercial entities on the CVC are shown in Table 9 and are broadly categorised into:

- **Electricity:** retail suppliers, network operators, aggregators and Charging Point Operators
- **Liquid fossil fuels (including biofuels):** distributers (to forecourt) and retailers (at forecourt)
- **Hydrogen**: retailers (either forecourt or to home / depot[16]), distribution (road, pipeline network, gas distribution network repurposing), localised H_2 producers, and
- **Vehicles:** retailers, leasers, sharing business models (e.g. car clubs). Table 9 also identifies those commercial entities that are stand-alone (i.e. represented as a single entity on the *D1.2 Analytical Framework*) and those that are a merger of two or more commercial entities (i.e. where a combined offering creates value). Partnerships between entities are used in some Narratives, although there is no intent to quantify the value associated with partnerships via the *D1.2 Analytical Framework*.

[14] https://www.ofgem.gov.uk/sites/default/files/docs/2014/02/role_of_the_dso_slides.pdf

[15] Such as contract templates for the provision of demand management from direct consumers or via aggregators http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Low-Carbon-London-(LCL)/Project-Documents/LCL%20Learning%20Report%20-%20D1%20-%20Development%20of%20new%20network%20design%20and%20operation%20practices.pdf

[16] I.e. via pipeline network and potentially separating ownership and operation of the network from sale of the product flowing through it; analogous to the overarching market structure for gas and electricity today.

Table 9 Summary of BBs included in the Commercial Value Chain

Described by business model framework
Described as variant on framework
Not described/ limited notes in supporting spreadsheet

Category	Business model	Stand-alone Entity	Building Block Name	Sheet with Further Information
Vehicles	Manufacturer	×	1. Vehicle manufacturer	Vehicle Manufacturer
		×	2. Vehicle manufacturer and Charging Point owner/ Operator	Vehicle Manufacturer
	Retailer	✓	3. Vehicle retailer (retail arm of manufacturer)	Vehicle Sales
	Leaser	✓	4. Vehicle leaser	Vehicle Sales
		×	5. Battery leaser	Vehicle Sales
		✓	6. Vehicle sharing scheme	Vehicle Sharing
Electricity	Retailer	✓	7. Electricity supplier	Electricity Supplier
		×	8. Electricity supplier with vehicle manufacturer	Electricity Supplier
	Distribution Network Operator	✓	9. Electricity DNO	Electricity Network Operator
		×	10. Electricity DNO as DSO	Electricity Network Operator
		✓	11. Electricity DNO/ DSO with charging point network	Electricity Network Operator
	Charging Point Owner	✓	12. Charging Point Operator / network/ owner	Charging Point Operator
		×	13. Charging Point Operator/ network/ owner with electricity supplier	Charging Point Operator
		×	14. Battery swapping	Charging Point Operator
	Aggregator	✓	15. DM aggregator	Aggregator
		✓	16. IT/ data provider	Aggregator
Liquid Fuel	Retailer	✓	17. Liquid forecourt retailer	Liquid Fuel & H2 Retailer
	Distribution Network Operator	×	18. Liquid fuel road distributor	Liquid Fuel & H2 Network Operator
Hydrogen	Retailer	✓	19. Hydrogen retailer (at forecourt)	Liquid Fuel & H2 Retailer
	Producer	✓	20. Localised hydrogen producer	Liquid Fuel & H2 Retailer
		×	21. Localised hydrogen producer with forecourt retailer	Liquid Fuel & H2 Retailer
	Network Operator	✓	22. Hydrogen network operator (pipe)	Liquid Fuel & H2 Network Operator
		✓	23. Hydrogen road distributor	Liquid Fuel & H2 Network Operator
	Centralised Producer	✓	24. Centralised hydrogen producer	Not described – boundary condition

The entities in Table 9 are the Building Blocks that are represented in the *D1.2 Analytical Framework* and are, by definition, the focus for the framework.

The CVC Building Blocks have been applied in a manner consistent with the description of the Narratives.

Several simplifying assumptions that have been made, including putting in place defined boundary conditions (these conditions are described in the *D1.3 Market Design and System Integration Report Appendix C.2.1*) as part of the way the CVC BBs have been applied to the Narratives.

These are described below for each of the categories.

- **Electricity:**
  - Large-scale generation and transmission are treated as part of the boundary conditions reflecting a 'wholesale price'.
  - Potential changes to the risk premium and hedging strategies, or differences due to economies of scale, for the electricity supplier in different Narratives will not be modelled[17], therefore changes are considered qualitatively. Similarly it is assumed that in general, electricity suppliers continue to exist in their current format.
  - The DNO model for electricity is assumed to be a regulated 'natural monopoly'; independent DNOs could exist but for simplicity are not considered.
  - Alternative commercial arrangements for implementing DM are not directly considered. The aggregator is assumed to provide DM and / or ancillary services from control of ULEV charging directly to the DNO and other users. The use of managed ULEV charging / discharging for energy arbitrage revenues is considered to be less material and is considered qualitatively.
  - There are various permutations of the Charging Point Operator / network / owner in existence today. However, in general the Charging Point Operator / network / owner will be set up in a generic configuration. A partial exception is the Charging Point Operator / network / owner partnered with the DNO, which is represented through applying a regulatory return to the Charging Point Operator / network / owner, and is representative in general of regulated provision of charging infrastructure.
- **Liquid fossil:**
  - Production and supply is treated as part of the boundary conditions reflecting a 'wholesale price' – the forecourt retailer and distributor are accounted for because any changes to ULEV uptake will naturally have an impact on the liquid fuel value chain in terms of its ongoing commercial viability.
- **Hydrogen**:
  - Large-scale generation and transmission are treated as part of the boundary conditions reflecting a "wholesale price".

[17] Consistent with the key simplifying assumptions in the *D1.3 Market Design and System Integration Report*

- Repurposing of the gas network for H_2 delivered direct to the household / depot is not considered as part of the Narratives. The business case for doing so would not be ULEV specific and as such would need to include the costs of e.g. repurposing all heat, cooking and small scale industrial appliances to either hydrogen or electricity. The options for distribution and production have been somewhat simplified and it is the timescales of transition that are particularly important (e.g. from trailers to pipeline distribution, from localised methane reformation to electrolysis or large scale hydrogen production).

- **Vehicles:**
  - Manufacturers and the secondary vehicle market for ULEVs are treated as part of the boundary conditions. However, the price of the vehicles from the vehicle retailer contains the margin required by both the manufacturer and retailer itself**.**
  - For simplification, the battery leaser is only used in instances when the vehicle leaser applies.
  - Battery swapping is not considered explicitly. It is not clear how successful this would be in the UK – Denmark and China are examples of countries that have battery swapping stations. However, these also have a relatively low PiV market share for a relatively high degree of incentives. Battery swapping relies on a high degree of standardisation and hence may be more suited to fleets that use standardised battery packs.

- **The IT / data provider will be described qualitatively where applicable.** This entity collects data and converts it into products, such as apps showing charging station locations, apps giving the ability to choose, reserve and locate the vehicle, remote temperature control, state of charge monitoring, advanced services such as modelling the battery life, and information provision on the electricity prices / tariffs to encourage smart charging.

7 Market and Policy Framework (MPF)

7.1 Overview

The MPF has been divided into various BBs, grouped into the following categories: financial measures (fixed cost), financial measures (running cost), non-financial incentives, limits, information, investment, and regulation. The BBs reflect a mix of those which cover the market as a whole and those that are specific and targeted policy interventions.

- Overarching **market** rules by which *all* commercial entities and / or consumers must operate. This includes energy sector regulation in general, i.e. one of the most significant examples in the UK is the clear separation of monopoly ownership of electricity and gas network assets (via regulated return business models) and the supply of energy through them.
  - This separation is not mandated for liquid fossil road distribution to forecourts (as there exists the potential for meaningful competition), but it is not yet clear what the long-term market structure might be for pipeline (as opposed to road-based) hydrogen networks[18].
- **Targeted policy options** which are specific interventions enacted within the overarching market framework, such as a tax or subsidy, and which may be targeted or differentiated by entities operating in the same part of the market.

Each category has defined BBs within it that are either currently in use in the UK, in use elsewhere, or have not yet been implemented but could be used as a new method to incentivise ULEV uptake or dis-incentivise the use of conventional vehicles.

A level of materiality is assigned to each BB, either high, medium or low, and this defines its relative importance in the *D1.2 Analytical Framework*. For the MPF, the materiality is dependent on four underlying factors; approximate value to the end consumer (absolute £, % of vehicle cost or qualitative assessment), buyers covered (all vehicle buyers including fleets and individual users, cars and vans vs. specific target consumers), importance to the consumer (i.e. factors widely reported as a primary or secondary reason to buy a ULEV) and the use and success in the UK and elsewhere. A summary of the BBs is provided in Table 10.

A more detailed description of each BB is included within the supporting *D4.2 Building Blocks Catalogue* spreadsheet, and Figure 6 provides an example for one of the BBs.

[18] And similarly district heat networks, the commercial entities for which can currently exist on a merchant basis vertically integrated with supply to the point of the consumer.

Table 10 Summary of BBs included in the Market and Policy Framework

Materiality for framework
High
Medium
Low

FINANCIAL MEASURES: FIXED COST	FINANCIAL MEASURES: RUNNING COST	NON-FINANCIAL INCENTIVES	LIMITS	INFORMATION	INVESTMENT	REGULATION
1. Gov. grants to consumers	7. Fuel price subsidies	18. Increased mobility	22. Direct CO2 tax	26. Education/ marketing	28. Government funding/ investment	33. Adequate access to infrastructure
2. Private grants to consumers	8. Vehicle excise duty (annual road tax)	19. Simplification	23. Direct emissions limit incl. EC car/van regulation	27. Mandatory/ voluntary reporting	29. Leveraging Private investment	34. Other laws/ wider energy sector regulations including EC
3. VAT on assets	9. Company car tax	20. Status	24. Emissions cap and trade scheme		30. Investment in R&D	35. Commitment
4. Purchase/ registration tax	10. Fuel duty	21. Increased access to parking	25. Emissions credits scheme		31. Capital allowances	36. Role of local authorities
5. Refund schemes	11. VAT on fuel				32. Government guarantees	37. Standard-isation
6. Subsidies for other fixed costs	12. Cheaper mobility					38. Co-ordination/ National initiatives
	13. Cheaper access to parking					39. Planning regulations
	14. National insurance					
	15. Subsidies for other running costs					
	16. Road pricing – congestion / CO2 / revenue objectives					
	17. Weight tax					

Figure 6 Example of detailed BB view in the supporting spreadsheet for the MPF

Category	Financial measures: fixed cost
Building block number	**1**
Building block name	**Direct grants to consumers**
Explanation	• Upfront payment given to the consumer towards the cost of the vehicles/ infrastructure.

Currently used in UK	**Yes**
Explanation/ examples	• Plug-in Car Grant. This was introduced in 2011. From 1st April 2015, the grant was raised from 25% to 35% of the vehicle's RRP, (maximum of £5,000) and three grant categories introduced. This level will remain until at least 50,000 cars have been sold or until 2017, whichever is the sooner. Government committed to providing at least £200m in the period 2015-2020 to bridge the additional cost of ultra-low emission cars. • Plug-in Van Grant. • The Electric Vehicle Homecharge scheme. This was introduced in 2013 to enable ULEV owners to receive a grant towards the installation of a domestic charge point of 75% (maximum £1000 including VAT) and the Gov. has seen that a number of vehicle manufacturers and charge point suppliers will supply the remaining 25%. • Public Sector Workplace Grant.
How successful have these been in UK?	• Over 90% of responses to 2013 the Call for Evidence by the Office for Low Emission Vehicles suggested Government should continue to provide upfront consumer grants for cars and vans and reduce emission threshold from 75 gCO2/km (other definitions suggest 50 gCO2/km more appropriate). • The Plug-in Van Grant has had low uptake due to limited product availability so Government stated in 2014 it would consider whether to widen the scope.
Approximate value (abs) Rule of thumb: Low (~<£1000)/ Med (~£1000-3000,~10%)/ High (~>£3000,>10%)	• Up to £5000 per car (max £200m to 2020) or 35% RRP • Up to £8000 per van (max £30m) or 20% RRP
Buyers covered Rule of thumb: All (Fleet, Private, Car, Van)/ Most (some focus)/ Min (very targeted, e.g. ~<25% market) **(or otherwise other parties)**	• Private and fleet, car and van
Importance to consumer Rule of thumb: High (key reason) Med (considered a reason) Low (not important) **(or otherwise to parties involved)**	• UK fleets account for 75% of those that have claimed Plug-in Car Grant. • The Plug-in Car Grant was considered an important factor in the purchase decision of 85% of ULEV purchasers. • 89% of respondents to one survey said that the Plug-in Car Grant was very/fairly important in their decision to buy an EV.

Current policies elsewhere	• Direct grants and feebates
Estonia	• The deal between Government and Mitsubishi included subsidies from Mitsubishi for the first 500 private buyers of any electric car approved by the European Union
Norway	• Government set up a £5.6m fund allowing municipalities and companies to apply for grants to cover the installation costs up to around £4000 per charging point.
Japan	• EV purchasers in Japan are given a grant on the purchase of a new EV, capped at about €6,300. Representative BEV would receive €4600 and PHEV €3400. • The current formula is complicated but is basically: two thirds of the price difference between the EV and a comparable gasoline car.
Netherlands	• Subsidy for vans c.€3000 plus local grant (€2000 in cities for companies). • Home charging has also been supported, with some local municipalities giving grants of up to €1,000 towards the installation of home charging points. • Furthermore, some EVs were sold with one or more charging stations included, mostly free of charge including installation at home or office locations.

	• The city of Amsterdam will also grant up to €1,000 towards the cost of a charging point in a public parking space.
France	• A feebate on the purchase of new cars, the 'Bonus/Malus', was introduced in France in 2008. The system was neutral for cars emitting between 130 and 160 g/km. The less polluting cars benefited from a price reduction of up to €1,000, while the most polluting ones were subject to a taxation of €2,600. • Bonus cannot exceed 30% of purchase price. €7000 for BEV, €5000 for representative PHEV. • The policy appears to enhance the total sales of new cars by around 13%, despite the slowing down of the economy observed at this period. Planned to be neutral for the State budget, the measure turned out to cost €285m in 2008 because of its overwhelming success. • Buyers shifted their purchase option to cars benefiting from rebates but with hardly lower emissions. For more notes about effectiveness of feebates see 'Pathways to high penetration of EVs', p97
US	• Representative BEV: $7,500 federal (~€5400) and $2,500 (~€1800) state rebate. • Representative PHEV: $5,400 federal (~€3900) and $1,500 (~€1100) state rebate.
Germany - example for FCVs	
Denmark - example of unsuccessful MPF	• The case of Denmark, where tax exemptions lead to significant rebate, is an example showing that addressing the cost barrier does not necessarily lead to high uptake. • Despite a more generous tax exemption for BEVs in Denmark as compared to Norway, the uptake was only 0.3% in 2012 (vs.3.3% in Norway)
China - example of unsuccessful MPF	• China is another example of high purchase incentive not delivering uptake in comparison to the results obtained in leading countries (grant of 60,000 yuan [ca. £6.3k] in 2012 and 0.08% uptake) • One-time bonus €4200-7200 for BEVs based on battery range and around €4200 for PHEVs.
How successful have these been?	• Feebates have been very successful in France, appearing to enhance the total sales of new cars by around 13%. However, buyers shifted their purchase option to cars benefiting from rebates but with hardly lower emissions. A self-financing feebate scheme may not be sustainable beyond when EV sales match or exceed ICEV sales. • Upfront incentives are very important; but alone they may not lead to significant uptake (as was the case in Denmark and China)

Overall Materiality	**High:** • Upfront incentives viewed as important - likely to be a barrier until ~2030 • Often supplemented by local authorities and manufacturers/ vehicles suppliers (in the case of charging points). • Are not enough alone to result in significant uptake (as was the case in Denmark and China). • In Norway, the aim is to make ULEVs competitive or near-competitive with conventional vehicles; in Japan, roughly two-thirds of the price difference is captured.

Information Required	Car type, Van type, Charging Point type, H2 infrastructure type
	Total value
	Absolute or % of total cost
	Payment frequency
	Capped
	National or locational
	Differences for private users, leasing, and business users
	Differences for fleets/ non-fleet company cars
	Changes with emissions rate
	Difference for new vs. retrofit
	Forecast changes over time

7.2 Synthesis of evidence and literature

The MPF Dimension covers all market and policy components relevant to the transport sector and ULEVs in particular. The literature review focussed on understanding the current market for ULEVs in the UK and for other targeted countries, the strategies taken in different countries together with the government policies that underpin these, and the use of incentives, dis-incentives and laws / regulations. The review aimed to address the following questions:

- ***Which market and policy instruments have been applied,*** *either currently or historically, and how successful have these been at promoting high ULEV uptake?*
  - *In the UK, and for targeted countries (those that have been particularly successful or unsuccessful)*
  - *Have pre-determined **strategies** been developed and used? What did these contain? Do these address the primary concerns of the consumer e.g. range anxiety?*
- *Are there are **novel instruments** that have not yet been implemented in the UK or have had limited use elsewhere but that have the potential to be particularly effective?*
- *What value does the consumer place on **financial measures** targeting fixed costs compared to those targeting running costs, **or non-financial incentives**?*
  - *How can these be grouped effectively into a suite of complementary measures?*
- *How can **regulation be targeted at entities on the supply chain** to incentivise the production, marketing and sale of ULEVs?*
  - *For instance, enforced limits on emissions, requirements to provide and disseminate information, common standards for equipment and planning regulations*
- *Who should invest in ULEVs and supporting infrastructure?*
  - *What is the **role of the government and local authorities in both investing** in the physical supply chain directly **and in providing information** and educating others?*
  - *How can **private financing** be supported?*

These questions were used to frame the literature review – answers were incorporated into the *D4.2 Building Block Catalogue* spreadsheet, together with more specific research on individual BBs.

For the MPF it is both the value and the combination of measures (BBs) that is important. An equivalent level of subsidy or value to the consumer can be established using various combinations of different BBs. Key initial insights from the review of literature are:

- *Current measures*
  - In the UK, most of the instruments identified are already used, or have been used to varying extents.
  - The Government's current activities are aimed at supporting the early market, shaping the required infrastructure, securing the right regulatory and fiscal measures (strong, clear, lasting tax incentives to at least 2020 and making funding available to cities that commit to supporting a step change in ULEV adoption), investing in UK automotive capability and preparing the energy sector (e.g. ensure smart meters

have the technical capability to support Supplier-Managed Charging, such as incorporating the ability to send information on the current state of charge from the BMS to the supplier, which is not currently included as part of the standard smart meter specifications[19], or develop another way of sending information on the state of charge data to the Supplier).

- *Strategies*
  - Different countries have aimed to encourage high uptake of ULEVs in different ways and further detail is given on the specific approaches that countries have taken in the supporting *D4.2 Building Blocks Catalogue* spreadsheet.
  - In delivering its current vision for the ULEV sector in the UK, the Government's goals are: helping support the purchase of ULEVs through direct grants, incentives and advice; facilitating the provision of recharging infrastructure through provision where consumers would use it most (primarily homes and workplaces), with some provision of public recharging where needed; preparing for hydrogen fuel cell electric vehicles in the UK following Government's technology neutral approach; encouraging and investing in R&D; lowering emissions from other vehicles.
  - The primary barriers to purchasing an electric vehicle are range, certainty of access, cost and lack of knowledge, and for a hydrogen vehicle are availability of hydrogen, cost and supply of FCVs.
- *Financial incentives versus 'perks'*
  - Upfront incentives are viewed as important and likely to be a barrier until at least 2030. However, these may not be enough alone to result in significant uptake (e.g. as was the case in China). It is primarily the overall value of the upfront incentives that is important; these have been applied as tax exemptions in the Netherlands, grants in Norway and fee-bates in France, whereby vehicles with low emissions are rewarded whilst those with higher emissions are penalised[20].
  - Refund / buyback schemes may also be material; particularly for fleet users, which may be more concerned about residual value and battery replacement (Nissan addressed these concerns in 2015 by introducing a scheme through which buyers receive cashback for their old battery).
  - Access to high occupancy vehicle lanes is also considered to be important in California, and in Norway bus lane access is considered to be as important in EV uptake as main financial incentives in regions with high rush-hour traffic.
- *Combining measures*
  - A country that has been particularly successful in incentivising ULEV uptake through a combination of measures is Norway. Incentives in Norway are focused on tax exemptions rather than subsidies, and making the electric car purchase price competitive with, or at a small premium to, conventional cars. Growth in the market

[19] See section 7.2.3 in the *D1.3 Market Design and System Integration Report.*

[20] A fee-bate on the purchase of new cars, the 'Bonus/Malus', was introduced in France in 2008. The system was neutral for cars emitting between 130 and 160 g/km. The less polluting cars benefited from a price reduction of up to €1,000, while the most polluting ones were subject to a taxation of €2,600.

has been organic and sales increased significantly once models were available from major OEMs. Incentives such as road toll exemptions and access to bus lanes are viewed as important. Many incentives either have no cost, or are covered by those who pay more or over a longer period, and support measures are guaranteed for relatively long periods of time. Commitment is demonstrated by public procurement for municipal vehicles and the provision of public charge points with free charging and parking, and awareness of ULEVs is raised via the Norwegian Electric Vehicle Association.

- *Role of government and local authorities in investment*
  - The importance of anticipatory investment is still an unknown. It is argued that in Norway, growth in PiVs was organic and did not require anticipatory investment in a public charging network. However, it has been shown that high proportions of some consumer segments believe a rapid public charging infrastructure needs to be in place before they would adopt vehicles.
  - In the UK, the Government has awarded £35 mn available to four cities (Nottingham, Bristol, Milton Keynes and London) that have committed to supporting a step change in ULEV adoption in their areas and also intends to make £20 mn available to local authorities who commit to introducing ULEV taxis. In addition, the Government has set aside £5 mn for specific initiatives in Dundee, Oxford, York and the North East region.
- *Information and education*
  - Measures such as *education / marketing,* and *mandatory / voluntary reporting* may increase awareness and, consequently, uptake. Other than range concerns and purchase price, lack of knowledge / familiarity with PiVs is one of the most commonly cited barriers to uptake; various schemes have been used in the past, currently or are planned to try and meet this need – the Go Ultra Low Government website, various trials such as the Ultra-Low Carbon Vehicle Demonstrator Programme, the Green Bus Fund, Plugged-in-Places and Plugged-in-Fleets initiatives, a National Consumer Campaign with manufacturers and various apps. In particular, it is thought that direct user experience (e.g. test drives for fleet users) is important.

The role of DM is discussed as part of the CVC in section 6.2.

7.3 Areas for further research and known gaps

The majority of the market and policy instruments identified have been applied either in the UK or internationally, and studies have assessed the success of some of these measures.

Aspects that are less well understood and that have a direct impact on the consumer are:

- market and policy instruments used to introduce 'perks', such as **cheaper mobility** (road tolls) and **cheaper access to parking**
- the impact of **resale value and the secondary market** on ULEV uptake is unclear; measures that support the secondary market and maximise the residual value may therefore be interesting to explore, and

- the impact of novel taxation / incentive schemes such **as road pricing** which can be designed to address a combination of congestion, CO_2, air quality and tax revenue objectives. The most complicated aspects are the quantifiable impact on driving patterns / modal shift as a result of different forms of road pricing and their subsequent effect on congestion / CO_2 / air quality.

7.4 Key focus areas for the *D1.2 Analytical Framework*

This section focuses on those BBs that have been identified as high or medium materiality for the MPF. These are considered to be:

- Financial measures aimed at reducing fixed costs are **direct and private grants to consumers** (e.g. for cars, vans and home charging points)**, VAT on assets** (reclaimable if used for business, and in part if leasing) and **purchase / registration taxes** (these are particularly low in the UK).
- BBs targeted at running costs and considered material are **fuel price, VED** ('road tax', currently varies in the UK according to emissions), **fuel duty** (electricity and hydrogen are currently exempt), **VAT on fuel** (electricity has a reduced rate). **Company car tax** is currently lower for ULEVs than for petrol / diesel cars and means that the individual user benefits from paying less tax; this could be important – low uptake of ULEVs in Denmark is thought to be due to lower incentives for company cars vs. individual purchase.
- Differentiated **road pricing** could be used to recover loss of revenue from fuel duty due to the reduction in the proportion of cars that are fossil-fuelled as the uptake of ULEVs increases.
- 'Perks' such as **cheaper mobility** (e.g. congestion charge exemptions for ULEVs in the near term) and **cheaper access to parking** could be important, although likely to be valued more in urban areas, affecting a smaller number of overall users. Currently in the UK, Local Authorities operate a range of schemes to provide discounted or free parking or resident's parking permits.
- Potentially important non-financial incentives are focused on **increased mobility** (e.g. local low-emissions zones in cities) and intangible measures such as **simplification** (e.g. of taxes for ULEV users, badge schemes to simplify the identification of ULEVs, interoperability, removal of Vehicle Special Orders for hydrogen vehicles) and **status** (i.e. in Norway users have reserved number plates, and in France eco-labels) – whilst they are difficult to quantify these measures are considered qualitatively.
- A **direct CO_2 tax** is applied in some Narratives to account for the cost of meeting EU and national carbon targets. The level of carbon tax will be informed by the whole energy system element of the *D1.2 Analytical Framework* and importantly reflects the most cost-effective level of abatement from transport as part of the system as a whole. This is applied as a price on emissions in transport (e.g. as fuel duty to ICEV users) and is used to offset the implementation of 'subsidy' BBs when tracking an acceptable level of Government spending applied to transport abatement.

- **Direct emissions limits,** on manufacturers - currently there are limits imposed on vehicle manufacturers at EU level, requiring them to achieve specific fleet-average emissions targets by 2015 and 2020/21 for cars and vans[21] and, for instance, car manufacturers in California need to sell a set number of EVs each year. As part of the EU regulation there are also various adjustments applied to calculating compliance with these targets, including super-credits for ULEVs with CO_2 emissions of 50g or less, aimed at encouraging the development of breakthrough technologies. Other potential measures could be applied which focus directly on emissions such as emissions cap-and-trade schemes (vehicle owners / fuel suppliers get certificates depending on emissions rate of vehicle / emissions of fuel and can trade these).
- Measures such as **education / marketing,** and **mandatory / voluntary reporting** may increase awareness and, consequently, uptake. Other than range concerns and purchase price, lack of knowledge / familiarity with EVs is one of the most commonly cited barriers to uptake; various schemes have been used in the past, currently or are planned to try and meet this need – the Go Ultra Low Government website, various trials such as the Ultra-Low Carbon Vehicle Demonstrator Programme, the Green Bus Fund, Plugged-in-Places and Plugged-in-Fleets initiatives, a National Consumer Campaign with manufacturers and various apps.

Some of the material BBs are based on direct investment at some point along the value chain, such as:

- **Government funding** (e.g. funding to local authorities, to public-private partnerships such as match funding, and to private companies such as funding of charging infrastructure and vehicle manufacturing facilities)**.**
- **Private investment** leveraged by direct or indirect Government 'support' (e.g. low interest loans or guaranteed / regulated returns), particularly with respect to network infrastructure (including charging points).
- **Capital allowances** (for instance write-downs in the first year for ULEVs, which Element Energy has previously estimated to be worth around 7-10% of the value of the vehicle over four years), are also thought to be important. Note that this benefit no longer applies to rental companies, including car clubs; it has been suggested that it would be highly advantageous to re-instate enhanced capital allowances for leased and rental fleets to support ULEV uptake.
- **Investment in R&D** could also be important; the current focus is on improving the range of the battery, battery management systems and novel technologies such as dynamic charging.

There are also more **novel taxation / incentive schemes** for transport that should be considered, such as **road pricing** – these are not necessarily ULEV specific but can be designed to address multiple policy objectives simultaneously. For example, road pricing designed primarily to address congestion (via static or dynamic pricing strategies), but with secondary objectives to replace lost revenue from liquid fuel duty and / or reduce CO_2 / air quality emissions (e.g. via more efficient

[21] Fleet average values for new sales of cars of 95gCO2/km by 2021 and 147gCO2/km by 2020 for vans.

driving patterns or modal shift). In addition, congestion charging could alter PiV charging patterns indirectly by shifting the pattern of when vehicles need to be charged.

Aside from this, there are highly material elements of the overarching policy framework such as **other laws and regulations** (e.g. compliance with EU directives) and adequate **access to infrastructure** (extent of coverage, whether investment is anticipatory, organic, led by public authorities or private companies, perceived versus actual access requirements). Organic investment is reflected in the Organic Narratives, whereas investing somewhat more ahead of need (in order to increase consumer awareness or reduce perceived barriers such as lack of access to refuelling infrastructure) is reflected in the Co-ordinated Narratives.

There are other aspects of the overarching policy framework for which it is harder to quantify the impact but that are still important, such as:

- **commitment** (e.g. Government commitment to a strategy – for instance leading by example by using ULEVs in Government fleets, and Government commitment to industry – for instance through grandfathering[22] of subsidies and timely announcements of changes)
- the **role of local authorities** (e.g. mandates for a certain number of charging points or parking spaces), and
- **standardisation** (e.g. Government only funding public charge points with a certain type of sockets, standards for autonomous vehicles), all of which are described qualitatively rather than quantitatively.

The MPF BBs have been applied in a manner consistent with the description of the Narratives.

In terms of BBs that are not considered explicitly, or are tackled more qualitatively across the Narratives, the rationale for these is as follows:

- Private grants are not considered directly, as one of the key simplifying assumptions within the Commercial and Policy Accounting Tool (CPAT) in the *D1.2 Analytical Framework* is that commercial entities set prices to be as reflective of underlying costs as possible rather than undertake strategic pricing or use cross-subsidies in a wider business to achieve market share.
- Subsidies for other fixed / running costs are likely to have limited impact in relation to the upfront vehicle grants for example.
- Cheaper/ increased access to parking could be particularly valuable in urban areas, however, this may have limited influence on the total number of EVs unless parking spaces are converted to EV parking on a larger scale.
- Weight tax does not differentiate between ULEVs and conventional vehicles and the value of including it in the analysis is thought to be negligible.

[22] Grandfathering of subsidies means that the subsidy as originally granted will continue to apply, even if the levels of subsidy are subsequently changed for new agreements i.e. the original entity/ asset is exempt from future rule or regulatory changes. Grandfathering is usually granted for a set period of time.

- Simplification (e.g. of all taxes for ULEVs or of access methods for charging points) and status (e.g. different number plates or status symbols for ULEVs) can be assessed qualitatively if needed. However, the value of including them in the analysis is thought to be negligible.
- Other emission schemes are not modelled because a carbon tax is already accounted for in defining the overall amount of tax that is recovered by Government and can be distributed through subsidies.

8 Mapping Building Blocks to Narratives

8.1 Factors common to all Narratives

A number of Building Blocks will be common to all the Narratives, describing the following features.

- **Liquid fuel system:** the system of production of liquid fuels and its distribution to forecourts (i.e. the current dominant system of providing energy for automotive use), will exist in all Narratives. In general, volumes in this system will be expected to decline, though the forecourt system may be partially sustained through providing hydrogen.
- **Conventional vehicles:** conventional vehicles will continue to be used and be available for at least part of the modelled pathway, in all Narratives. Existing regulations applying to conventional vehicles are assumed to continue.
- **Policy programmes in related energy systems:** known programmes elsewhere in the energy system with relevance to ULEV deployment and use, for example smart meter roll out, will also be assumed.
- **Impact of EU vehicle standards:** proposed to reflect a linear improvement in the current EU targets from 2020/21 to 2030, of 75 gCO2/km for cars and 120gCO2/km for vans, but hold these constant from 2030 to 2050.

In addition, some themes, as identified in the *D1.3 Market Design and System Integration Report*, are independent and will be relevant to all Narratives.

- **Timing:** the rate at which ULEV deployment and use occurs, and the extent of ULEV deployment earlier in the pathway. This will be largely a function of the Market and Policy Framework, and the budget available.
- **Urban-rural split:** the drivers determining vehicle choice for consumers will differ depending on whether they live in an urban or rural area. In some Narratives this difference will be more pronounced than in others. In general where different drivers exist, the Building Blocks will accommodate different choices.

8.2 Overview of Narratives

Six core Narratives have been developed, including a Business as Usual (**BaU**) case, focused around active choices or strategies that can be delivered by the various actors involved (such as Government, industry, or indirectly by consumers). A brief description of the Narratives is provided below and more detail is given in *D1.3 Market Design and System Integration Report*.

- **Guided OEMs[23] – 'OEM'** *(organic action / mobility as an asset)*: vehicle OEMs make ULEVs attractive to consumers, by increasing desirability and enhancing functionality through integrated digital services which facilitate use of the vehicle (e.g. real-time access to maps

[23] Original Equipment Manufacturer

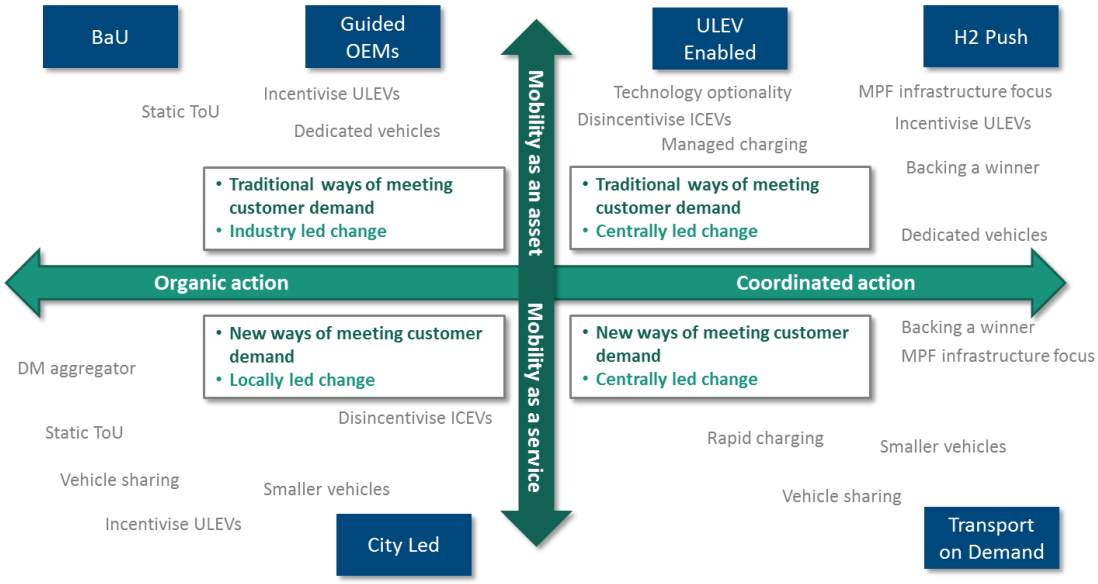
of public charging stations and electricity prices at these stations[24]). Proprietary motorway charging networks complement the dominant mode of home charging. To some extent this Narrative may be seen as an extension of current trends (a form of BaU+), where a number of manufacturers and technology developers are creating new and distinctive vehicles and offering a range of services around them. Policy at a central Government level is directed at a limited ongoing pull towards ULEVs, for example through differential rates of VAT, rather than a fully co-ordinated, heavily subsidised approach, and consumers receive some grant towards the capital cost of their vehicle or charging point but less so than in other Narratives.

- **City Led – 'City'** *(organic action / mobility as a service)*: city regions drive the transport agenda, focussing on local environmental issues such as air and noise pollution and congestion. Consumers use multiple modes of transport as an integrated service including cars, but these are provided more through short-term rental and car clubs. Urban car rental fleets are charged at public / work locations. Outside of urban areas vehicles are still owned predominantly as assets by their users.
- **ULEV Enabled – 'ULEV'** *(coordinated action / mobility as an asset)*: Government provides a supportive regulatory environment for charging and hydrogen infrastructure, reducing consumer anxiety in choosing a ULEV, and enabling a free choice between hydrogen and electrical energy sources.
- **Hydrogen Push – 'H2P'** *(coordinated action / mobility as an asset)*: central Government makes a decision to promote mass transition to hydrogen, through supporting both infrastructure deployment, and consumers purchasing hydrogen vehicles.
- **Transport on Demand – 'ToD'** *(coordinated action / mobility as a service)*: central Government identifies widespread social benefits in a smaller, more intensively used vehicle parc. Intervention provides common standards and widespread infrastructure enabling vehicle fleets to offer an on demand transport service to consumers.

The structure used to frame the Narratives is summarised in **Figure 7**.

[24] Particularly as part of any move to more dynamic electricity pricing.

Figure 7 Narrative summary



8.3 Summary of Building Block use

Table 11 to Table 14 set out the application of Building Blocks to different Narratives.

Note that the Building Blocks are also shown in the tables in sections 3.1.2 'Building Blocks' and 3.4 'Summary of key quantitative Building Blocks used' in the *D1.3 Market Design and System Integration Report.*

Key for Building Block use

✓	Captured quantitatively
✓	Belongs to this Narrative in particular but is not quantified

Key for Building Blocks – in CP, MPF and PSC

Materiality for framework
High
Medium
Low

Table 11 Summary of BBs to Narrative mapping for the Customer Proposition

Building Block Name	BaU	OEM	City	ULEV	H2P	ToD
Ownership/ access model						
1. Outright purchase	✓			✓	✓	
2. Contract purchase						
3. Hybrid (battery lease)[25]	✓	✓	✓	✓	✓	✓
4. Contract hire[26]	✓	✓	✓	✓	✓	✓
5. Short-term hire/car club[27]			✓			✓
6. Secondary market[28]	✓	✓	✓	✓	✓	✓
7. Bundled installation of charge points[29]		✓				
8. Maintenance, servicing and insurance	✓	✓	✓	✓	✓	✓
9. Access to other vehicles or forms of transport when ULEV unsuitable						
Fuel pricing options						
10. Static ToU (User-Managed)		✓	✓			
11. Dynamic ToU (Supplier-Managed)				✓		✓
12. Demand Management payment				✓		✓
13. Flat tariff	✓				✓	
14. Vehicle to Grid/Building (V2G/B)						
Availability of refuelling/ charging						
15. Private charging	✓	✓	✓	✓	✓	✓
16. Public charging in motorways and A-roads (rapid)	✓	✓	✓	✓	✓	✓
17. Public charging in local points (mid-level)	✓	✓	✓	✓	✓	✓
18. Workplace charging	✓	✓	✓	✓	✓	✓
19. H_2 refuelling stations	✓	✓	✓	✓	✓	✓

[25] Follows the same access model as the vehicles

[26] Only contract hire is modelled so that the Narratives are sufficiently distinct. Fleets always use contract hire.

[27] In this representation fleets are making the vehicle purchase decision and consumers are indirectly using the vehicles through the short-term hire/ car sharing scheme

[28] Vehicles that are leased by fleets are then sold to consumers in the secondary market

[29] Represented by bundled provision of services - not quantified in the *D1.2 Analytical Framework* as value small in comparison to other measures

Building Block Name	BaU	OEM	City	ULEV	H2P	ToD
20. Battery swapping						
21. Electrolyte charge						
22. Dynamic charging						
23. Forecourts (H2, liquid)	✓	✓	✓	✓	✓	✓
Billing model						
24. Subscription model[30]			✓			✓
25. Support for price certainty[31]		✓		✓		
26. Traditional pay per unit model	✓	✓		✓	✓	
27. Multi-modal[32]			✓			
28. Own account						
Consumer control						
29. Sole vs shared use	✓	✓	✓	✓	✓	✓
30. Charging control[33]				✓		✓
31. Vehicle choice[34]	✓	✓	✓	✓	✓	✓

Table 12 Summary of BBs to Narrative mapping for the Physical Supply Chain

Building Block Name	BaU	OEM	City	ULEV	H2P	ToD
Vehicles						
1. Battery	✓	✓	✓	✓	✓	✓
2. Battery Management System	✓	✓	✓	✓	✓	✓
3. Fuel cell system	✓	✓	✓	✓	✓	✓
4. Generic high technology readiness components (e.g. chassis, engine)	✓	✓	✓	✓	✓	✓
5. Electric motor	✓	✓	✓	✓	✓	✓
6. Vehicle H_2 tank	✓	✓	✓	✓	✓	✓
7. Communication systems[35]						✓
Energy carrier generation						
8. Electricity generators	✓	✓	✓	✓	✓	✓
9. H_2 generation plants	✓	✓	✓	✓	✓	✓
10. Biofuel plants	✓	✓	✓	✓	✓	✓
11. Refineries	✓	✓	✓	✓	✓	✓
Energy carrier transport						
12. Electricity distribution network	✓	✓	✓	✓	✓	✓
13. Electricity transmission network	✓	✓	✓	✓	✓	✓
14. H_2 distribution	✓	✓	✓	✓	✓	✓
15. Trucks for liquid fuels	✓	✓	✓	✓	✓	✓
16. Gas network						
Energy carrier storage						
17. Large batteries	✓	✓	✓	✓	✓	✓
18. Large underground H_2 storage	✓	✓	✓	✓	✓	✓
19. Oil strategic reserves						
20. Natural gas storage						
Refuelling/ charging infrastructure						
21. Private charging	✓	✓	✓	✓	✓	✓
22. Public charging	✓	✓	✓	✓	✓	✓

[30] Subscription based car clubs and multi modal tickets
[31] Support for users to understand available charging locations and prices given ToU tariffs
[32] Combined tickets across transport modes
[33] 'Supplier'-Managed Charging at home and work locations
[34] More small cars in car sharing Narratives
[35] To enable connected and autonomous vehicles

Building Block Name	BaU	OEM	City	ULEV	H2P	ToD
23. H_2 refuelling stations	✓	✓	✓	✓	✓	✓
24. Forecourts	✓	✓	✓	✓	✓	✓
Back office/ IT						
25. Industry standards[36]						✓
26. Assets for settlement (e.g. smart meters)						
27. Assets for comms.[37]				✓		✓
28. Data servers for big data						✓
29. Assets for comms. from/ to vehicles (e.g. autonomous vehicles)						✓

[36] For charging and data interoperability
[37] To enable managed charging

Table 13 Summary of BBs to Narrative mapping for the Commercial Value Chain

Described by business model framework
Described as variant on framework
Not described/ limited notes in supporting spreadsheet

Building Block Name	BaU	OEM	City	ULEV	H2P	ToD
Vehicles						
1. Vehicle manufacturer						
2. Vehicle manufacturer and Charging Point owner/ Operator		✓				
3. Vehicle retailer (retail arm of manufacturer)	✓ (private)	✓ (private)		✓ (private)	✓ (private)	
4. Vehicle leaser	✓ (fleet)	✓ (fleet)	✓	✓ (fleet)	✓ (fleet)	✓
5. Battery leaser[38]	✓	✓	✓	✓	✓	✓
6. Vehicle sharing scheme			✓			✓
Electricity						
7. Electricity supplier	✓	✓	✓	✓	✓	✓
8. Electricity supplier with vehicle manufacturer		✓				
9. Electricity DNO	✓	✓	✓	✓	✓	✓
10. Electricity DNO as DSO						
11. Electricity DNO/ DSO with charging point network				✓		✓
12. Charging Point Operator / network/ owner	✓	✓	✓	✓	✓	✓
13. Charging Point Operator/ network/ owner with electricity supplier						
14. Battery swapping						
15. DM aggregator				✓		✓
16. IT/ data provider			✓			✓
Liquid fuel						
17. Liquid fuel forecourt retailer	✓	✓	✓	✓	✓	✓
18. Liquid fuel road distributor						
Hydrogen						
19. Hydrogen retailer (at forecourt)	✓	✓	✓	✓	✓	✓
20. Localised hydrogen producer			✓			
21. Localised hydrogen producer with forecourt retailer			✓			
22. Hydrogen network operator (pipe)				✓	✓	
23. Hydrogen road distributor	✓	✓	✓	✓	✓	✓
24. Centralised hydrogen producer	✓	✓	✓	✓	✓	✓

[38] As per vehicle model

Table 14 Summary of BBs to Narrative mapping for the Market and Policy Framework

Building Block Name	BaU	OEM	City	ULEV	H2P	ToD
Financial – upfront/ fixed costs						
1. Gov. grants to consumers	✓	✓	✓	✓	✓	✓
2. Private grants to consumers[39]	✓	✓				
3. VAT on assets	✓	✓	✓	✓	✓	✓
4. Purchase/ registration tax	✓	✓	✓	✓	✓	✓
5. Refund schemes						
6. Subsidies for other fixed costs						
Financial – running costs						
7. Fuel price subsidies						✓
8. Vehicle excise duty	✓	✓	✓	✓	✓	✓
9. Company car tax	✓	✓	✓	✓	✓	✓
10. Fuel duty	✓	✓	✓	✓	✓	✓
11. VAT on fuel	✓	✓	✓	✓	✓	✓
12. Cheaper mobility[40]	✓	✓	✓	✓	✓	✓
13. Cheaper access to parking			✓			
14. National insurance						
15. Subsidies for other running costs						
16. Road pricing	✓	✓	✓	✓	✓	✓
17. Weight tax						
Non-financial incentives						
18. Increased mobility[41]			✓			✓
19. Simplification						
20. Status						
21. Increased access to parking			✓			
Emission limits						
22. Direct CO2 tax			✓	✓		
23. Direct emissions limit	✓	✓	✓	✓	✓	✓
24. Emissions cap and trade scheme						
25. Emissions credits scheme						
Information						
26. Education/ marketing[42]			✓	✓		
27. Mandatory/ voluntary reporting						
Investment						
28. Government funding/ investment	✓	✓	✓	✓	✓	✓
29. Private investment	✓	✓	✓	✓	✓	✓
30. Investment in R&D						
31. Capital allowances						
32. Government guarantees						
Other regulation						
33. Adequate access to infrastructure	✓	✓	✓	✓	✓	✓
34. Other laws/ wider energy sector regulations						
35. Commitment						
36. Role of local authorities			✓			
37. Standardisation						✓
38. Co-ordination/ National initiatives				✓		✓
39. Planning regulations			✓	✓		

[39] E.g. from the OEMs

[40] Congestion charging and exemption for ULEVs – all Narratives as BaU except City which has extended congestion charging to many cities

[41] E.g. access to high occupancy vehicle lanes (such as bus lanes)

[42] E.g. Government ULEV information services

Appendix A Business model overview

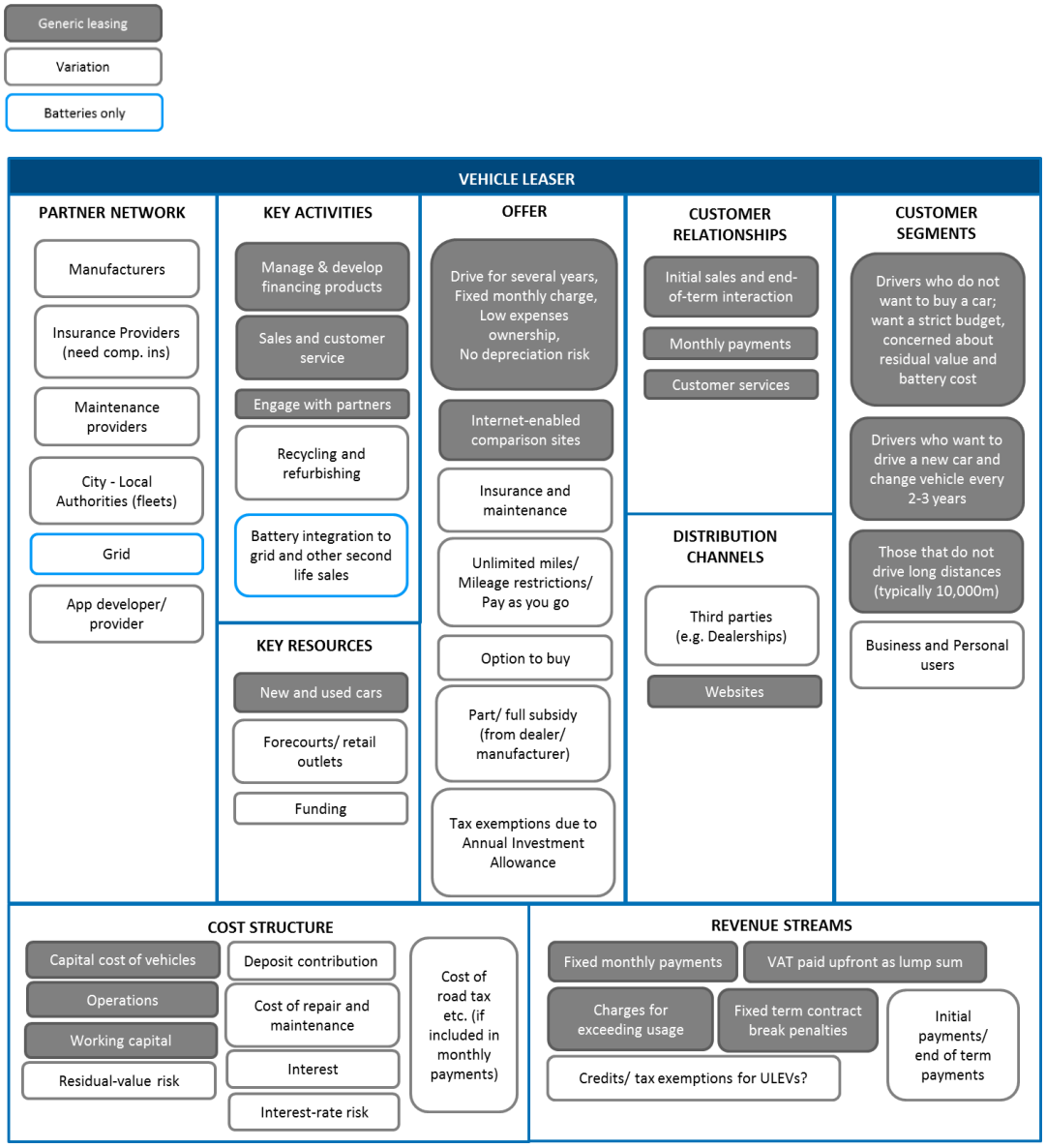
This section describes the key business model elements for each generic commercial entity on the value chain using the business model framework.

A.1 Vehicles

A.1.1 Vehicle leaser

The vehicle leasing model is used to describe the vehicle leaser, battery leaser (typically combined with the vehicle leaser). The vehicle retailer is a similar business model, with the exception that the consumer purchases the vehicle outright, rather than delaying purchase until the end of the contract (e.g. via a contract purchase scheme) or not purchasing at all (contract hire). It is outlined in Figure 8.

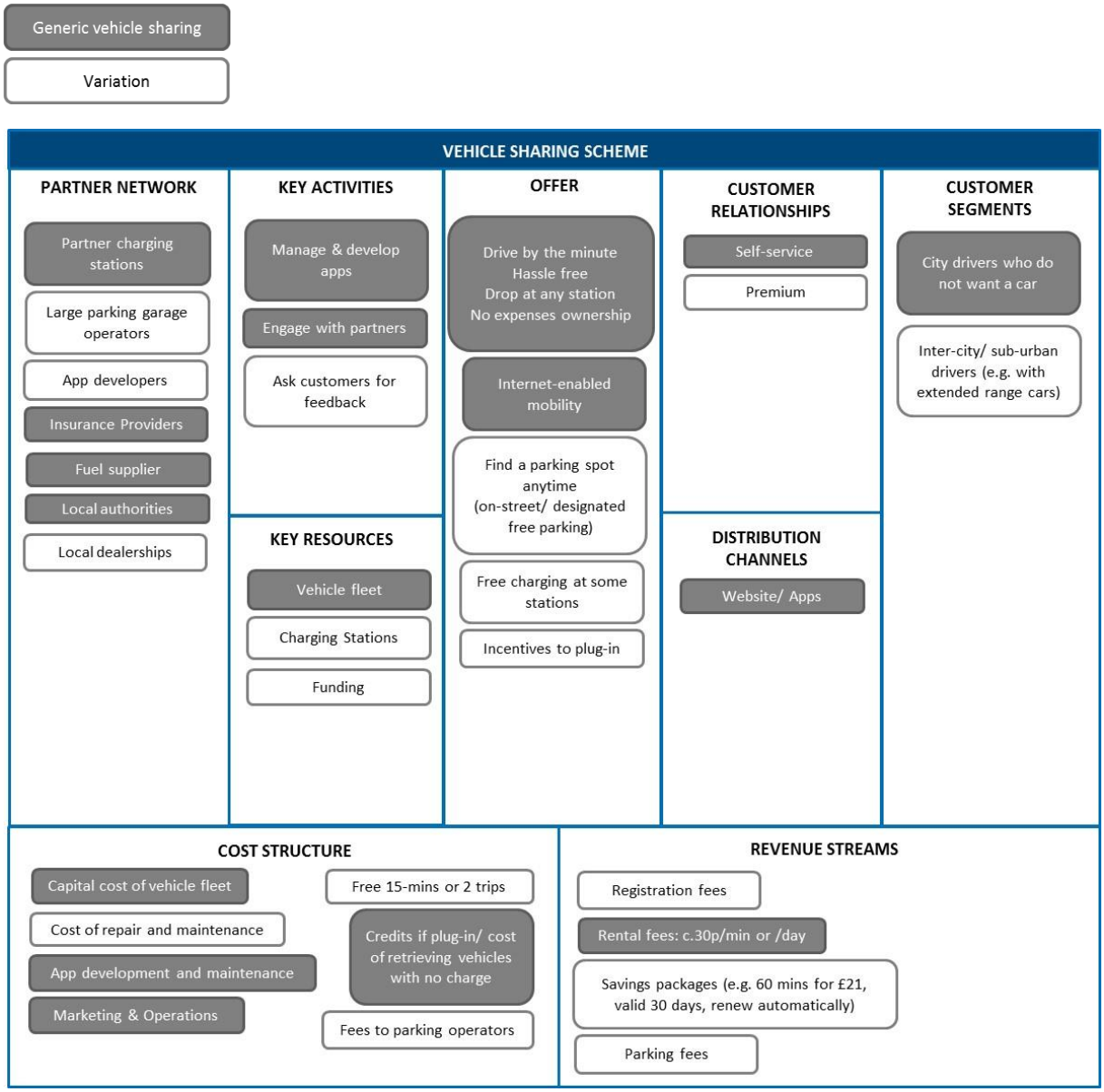
Figure 8 Business model of the vehicle leaser described using the framework



A.1.2 Vehicle sharing

Vehicle Sharing is a scheme whereby there is never an intent that the consumer will own the car; instead it is rented on a short-term per-minute or per-day basis. Three examples of these schemes are described in the supporting *D4.2 Building Blocks Catalogue* spreadsheet. The business model is outlined in Figure 9.

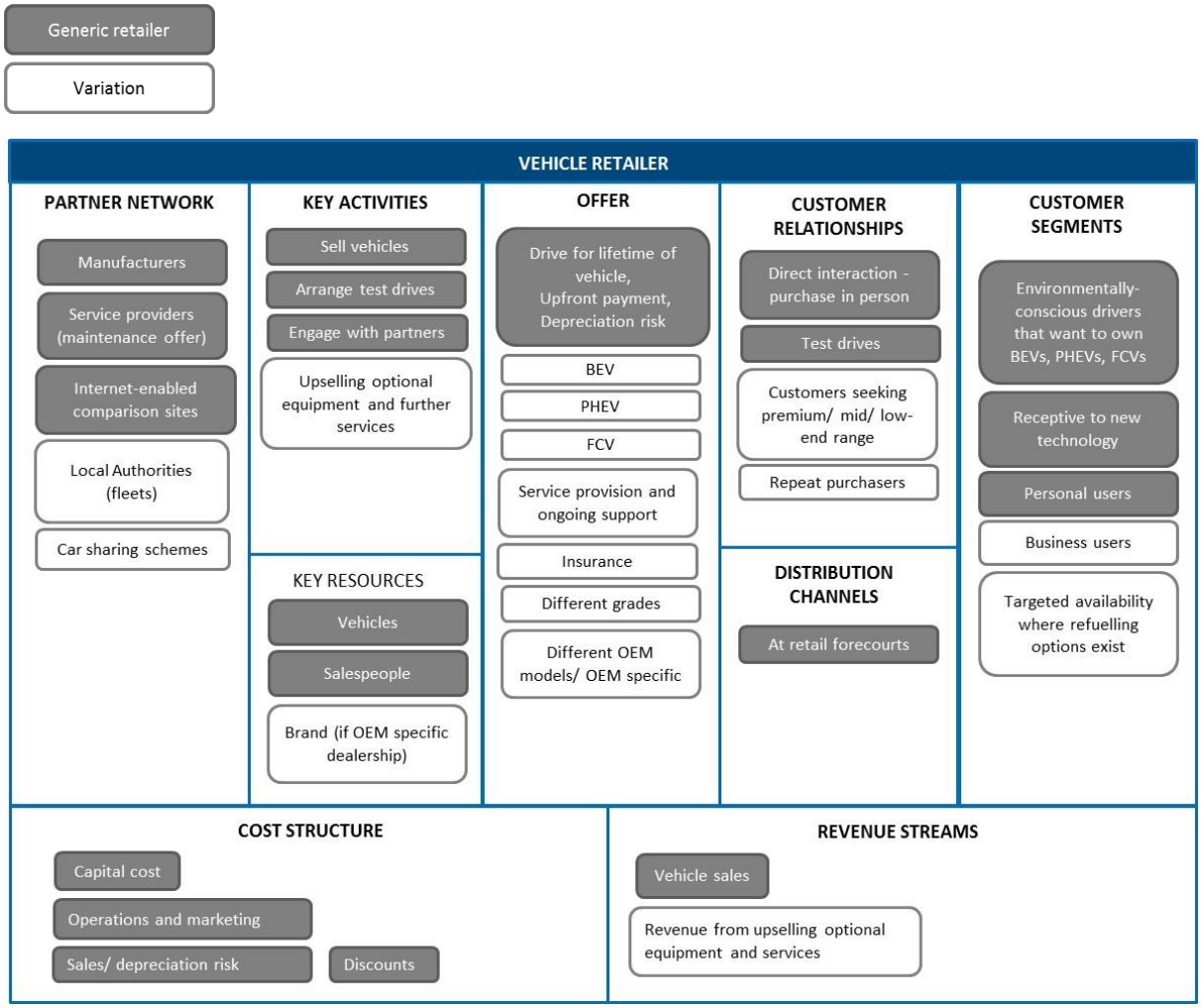
Figure 9 Business model of the vehicle sharing scheme described using the framework



A.1.3 Vehicle retailer

The vehicle retailer is a traditional commercial entity, with variations captured in the framework in Figure 10.

Figure 10 Business model of the vehicle retailer described using the framework



A.2 Electricity

A.2.1 Charging Point Operator and variants

As charging point infrastructure is currently being installed, a number of business models and combinations are being tested. The entities can be separately defined as:

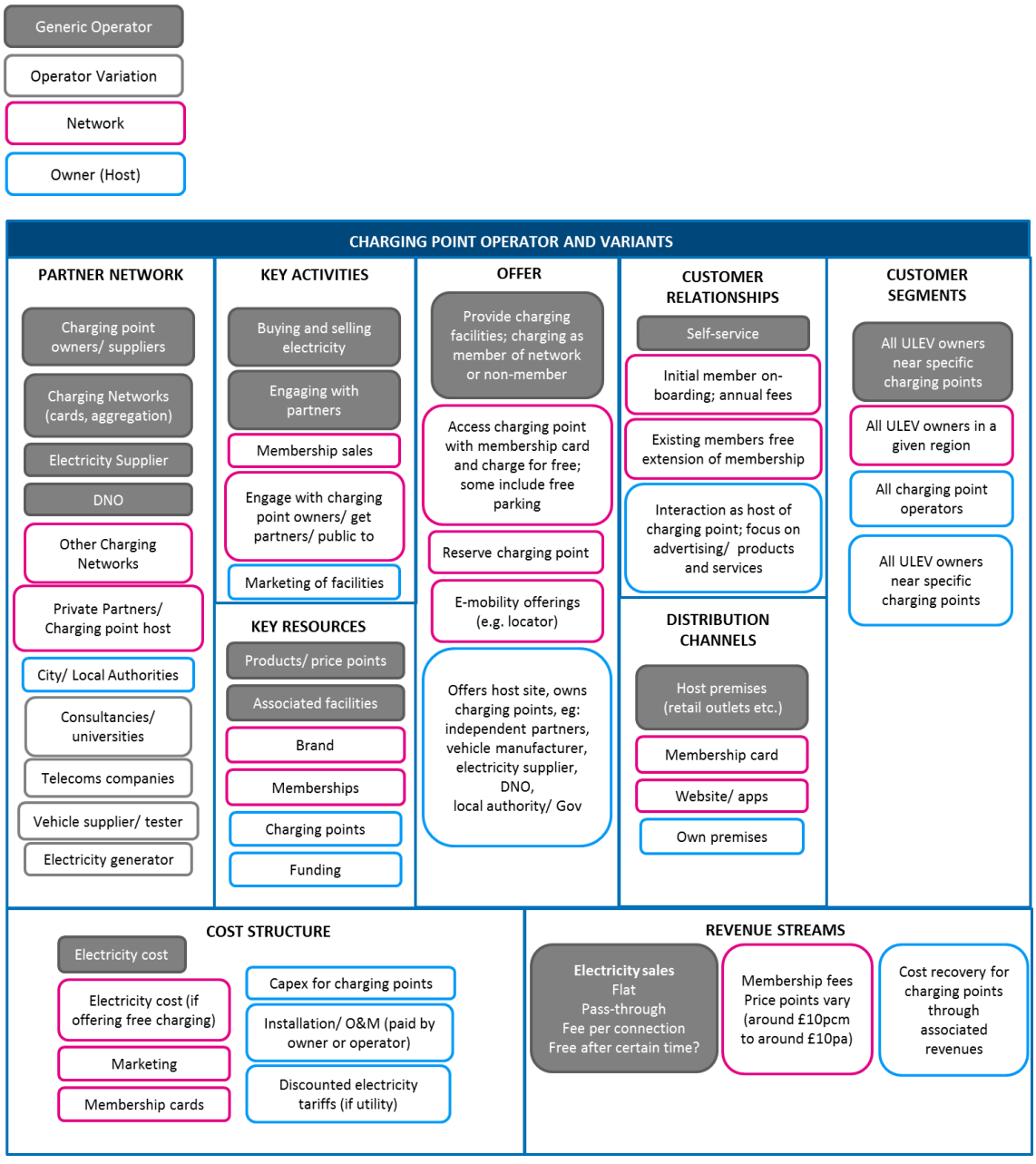
- **Operator:** buys and sells electricity - focuses on making margin from electricity. May/ may not own charging points. E.g. Source London, Source East, Plugged in Midlands, Charge Your Car, ChargeMaster
- **Network operator:** aggregator of charging points - focuses on membership fees. May/ may not own charging points. Can be network owner, or independent private partners, and
- **Owner:** host of charging points - focuses on associated revenues. May/ may not be the operator also. Retail outlets, home owners etc.

The 'generic' Charging Point Operator is described in the detailed supporting *D4.2 Building Blocks Catalogue* spreadsheet (as SourceLondon), and other known UK examples are set out, in addition to US examples.

Partnerships/ mergers of the electricity supplier with the Charging Point owner/ Operator have occurred (e.g. Ecotricity, British Gas, RWE). Battery swapping is another form of charging network and has been tested (e.g. BetterPlace in the US, Tesla). Both of these are depicted qualitatively in the supporting *D4.2 Building Blocks Catalogue* spreadsheet.

Example business models are outlined in Figure 11.

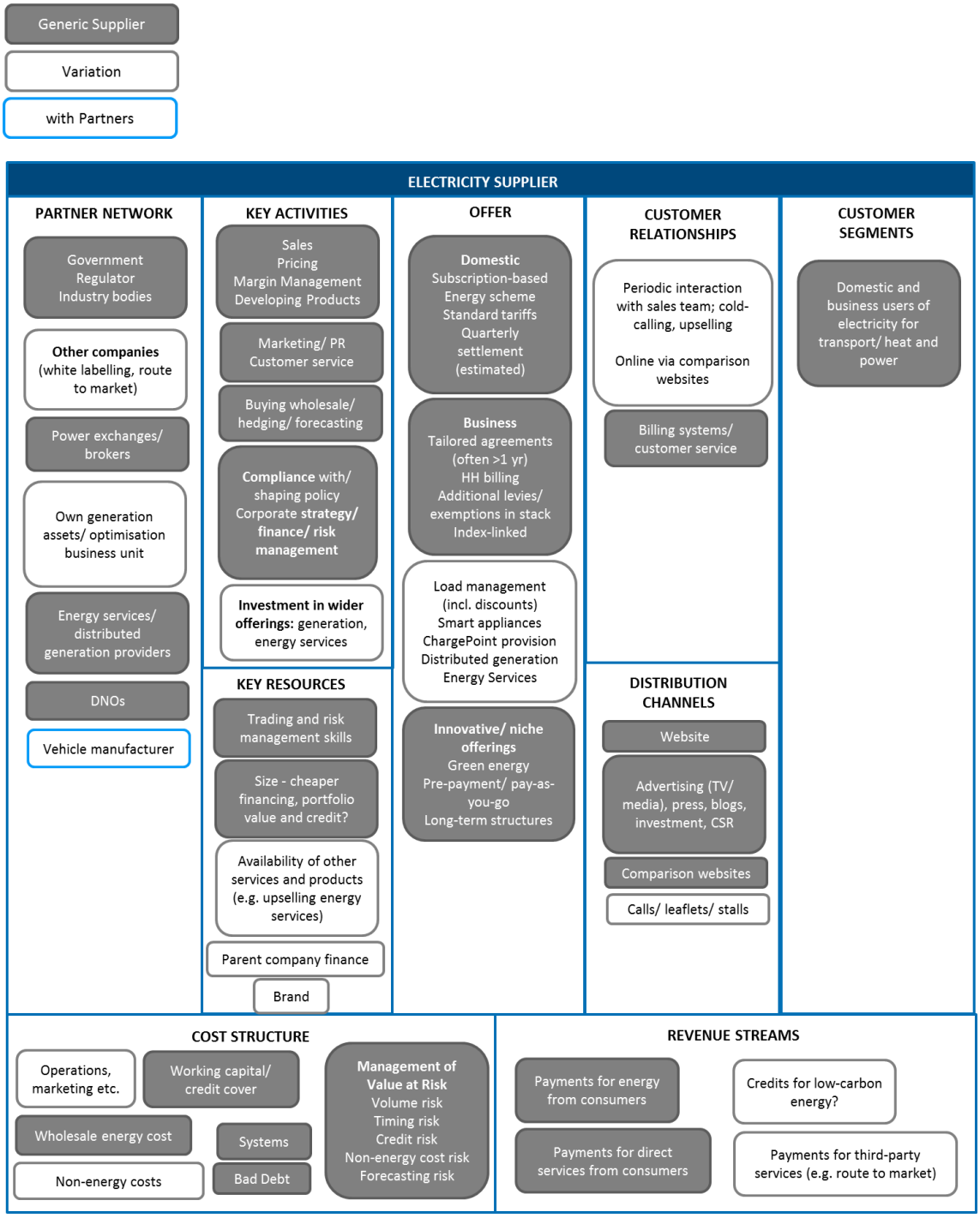
Figure 11 Business model of the Charging Point Operator/ owner/ network described using the framework



A.2.2 Supplier

The electricity supplier is a well-established business model. In the UK, electricity suppliers have partnered with vehicle manufacturers (British Gas, Ecotricity and RWE); shown on the framework. The business model is outlined in Figure 12.

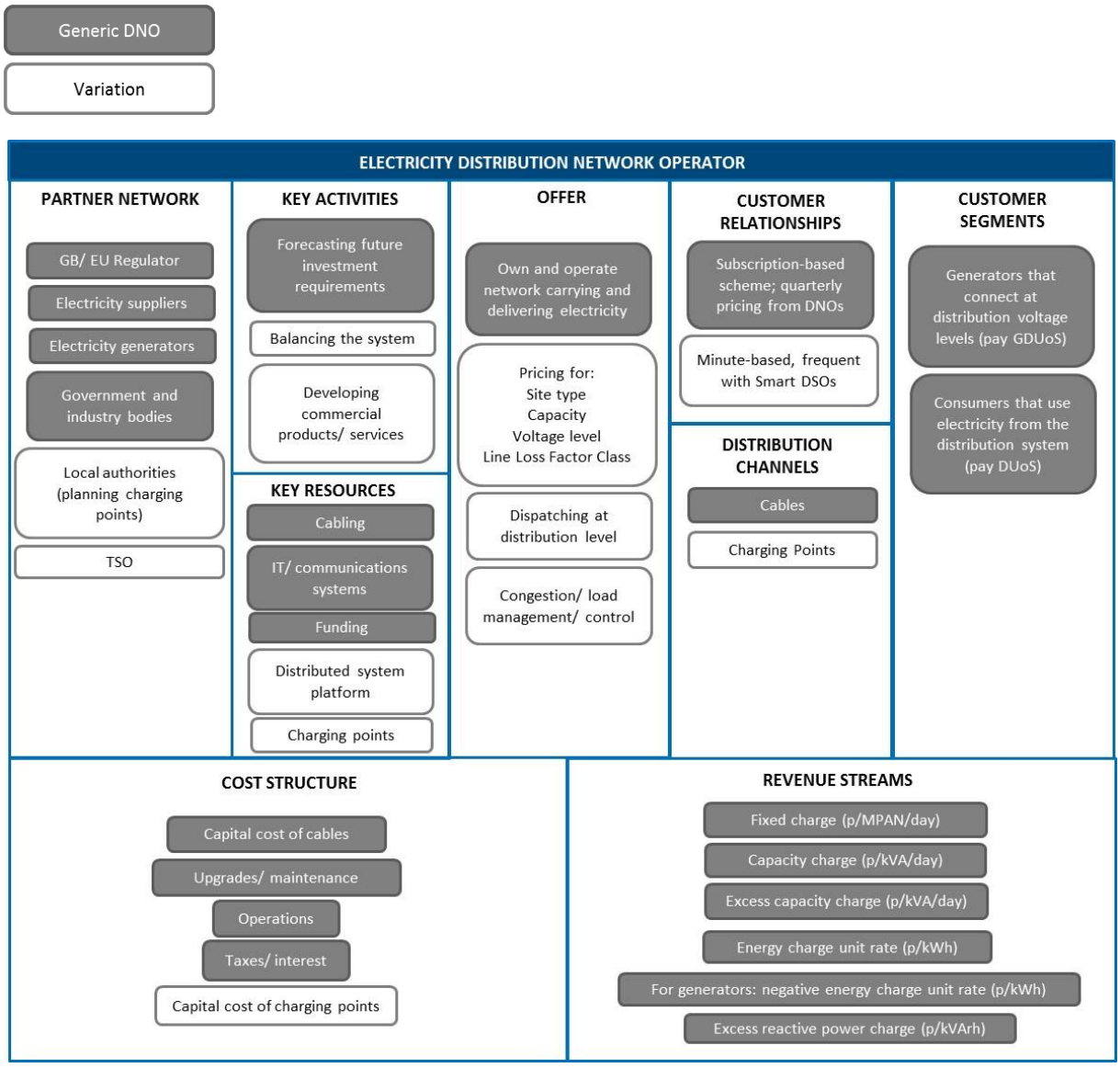
Figure 12 Business model of the electricity supplier described using the framework



A.2.3 Distribution Network Operator

The role of the Distribution Network Operator will likely need to evolve as the deployment and use of ULEVs increases. An account of the traditional business model is provided, and the associated changes were the Distribution Network Operator ('building and connecting') to transition to a Distribution System Operator ('connecting and managing'). Another existing model is the network operator also owning the charging point network (e.g. ESB Networks). These have been described as variations in Figure 13.

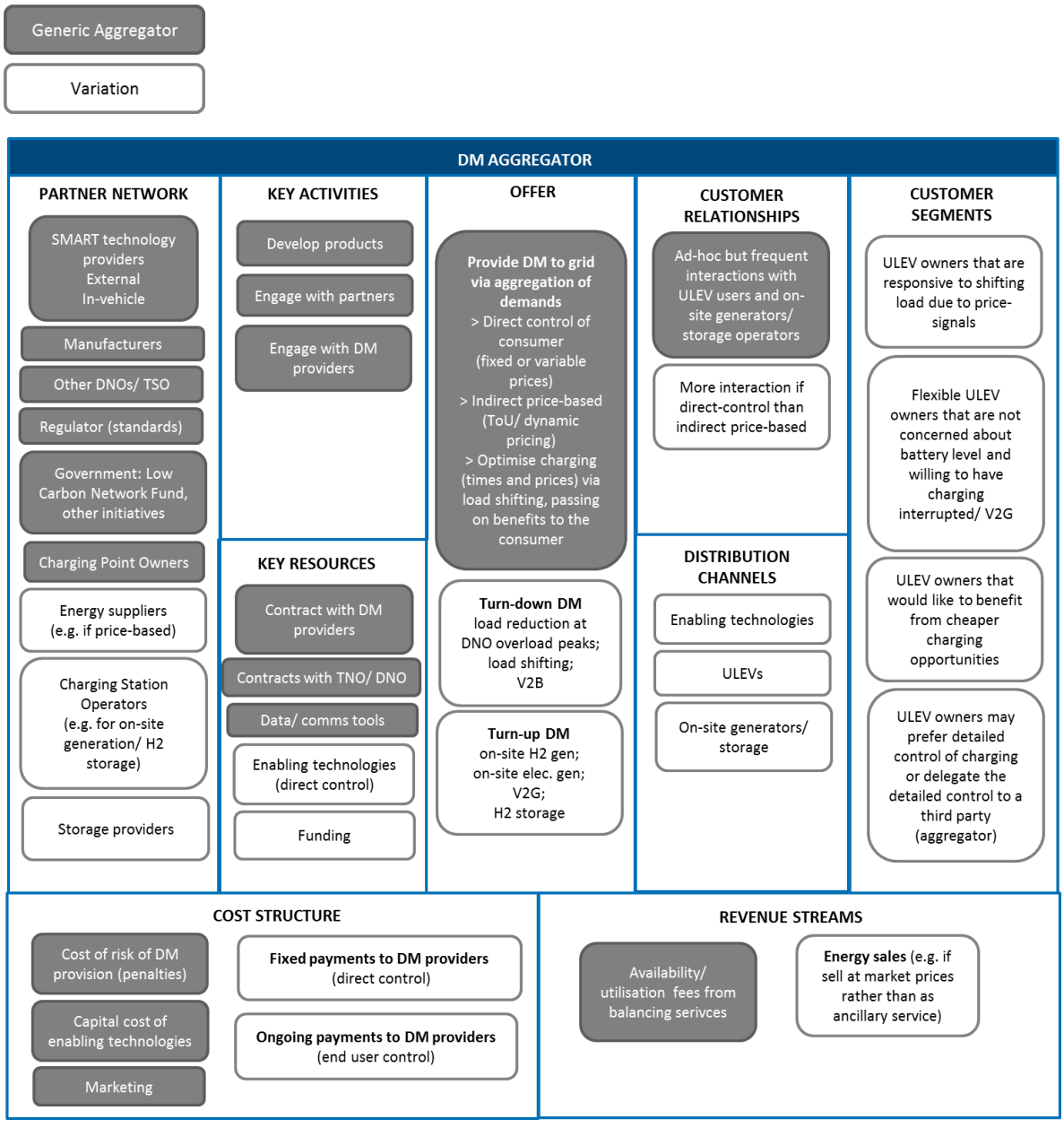
Figure 13 Business model of the electricity Distribution Network Operator described using the framework



A.2.4 DM aggregator

As ULEV uptake increases there will be more of a role for an entity that aggregates the load of the ULEVs and provides DM to the distribution network and/or System Operator. The role of IT/ data/ SMART services is similar in the sense that it requires a collection of data from individual users/ value chain entities and analyses it to produce useful insights or to optimise/ simplify a process. This is discussed in the supporting *D4.2 Building Blocks Catalogue* spreadsheet. The business model is outlined in Figure 14.

Figure 14 Business model of the DM aggregator described using the framework



A.3 Liquid fossil / biofuel

A.3.1 Retailer

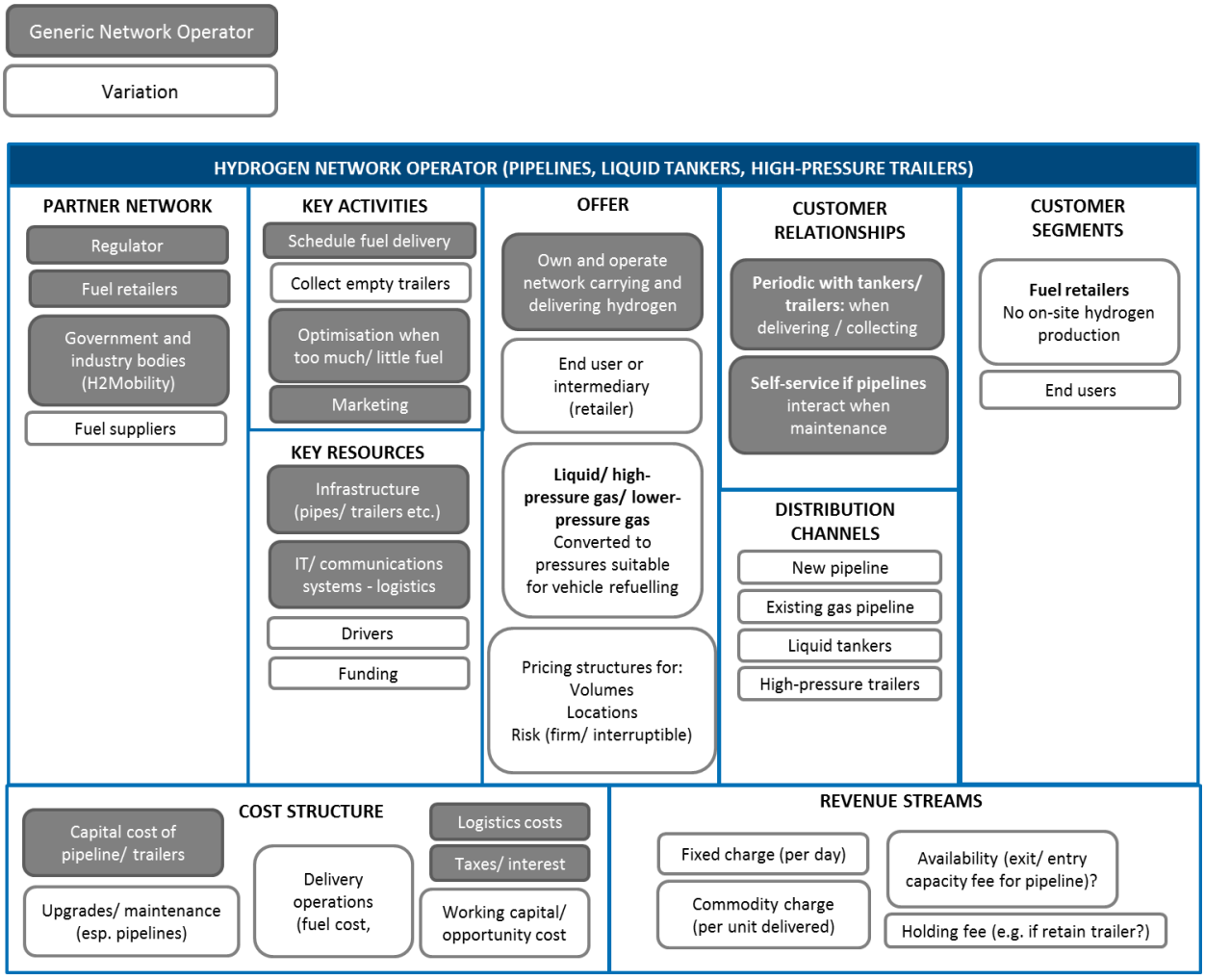
Liquid fuel retailer described as a variant in A.4.2.

A.4 Hydrogen

A.4.1 Network operator

There are various ways that the hydrogen network might evolve; in a more flexible way through high-pressure trailers, liquid tankers or through the use of static pipelines, either by re-purposing the existing gas pipelines or laying new pipelines. These are shown on the framework in Figure 15.

Figure 15 Business model of the hydrogen network operator described using the framework



A.4.2 Hydrogen retailer

The generic hydrogen retailer sells hydrogen to drivers of FCVs, via forecourts. Examples of this are Air Products, First Element, Air Liquide and LindeAir. This is in early stage development at the moment the hydrogen is primarily delivered as a gas in tankers. A variation is the use of on-site generation (electrolysis) such as ITM Power and Shell. Business models are outlined in Figure 16.

Figure 16 Business model of the liquid fuel/ hydrogen retailer described using the framework