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Programme Area: Light Duty Vehicles

Project: Economics and Carbon Benefits

Title: Generic Business Models for Plug-in Vehicle Environment

Abstract:

This project was undertaken and delivered prior to 2012, the results of this project were correct at the time of publication and may contain, or be based on, information or assumptions which have subsequently changed. This report provides an in-depth qualitative viability analysis (supported by initial quantitative estimates) of the generic business models which may be effective during the initial launch / take-off of a plug-in vehicle market in the UK. This report precedes the in-depth quantitative viability analysis in the Economics and Carbon Benefits project. The key insights and overarching conclusions are captured in the Executive Summary on pages 7 to 13.

Context:

A strategic level analysis of the potential size of the market for plug-in vehicles, the total level of investment needed and the total carbon offset for the UK.

ETI Plug-in vehicles project

WP 3.1.1 Generic business models

13 September 2010

Final Report

Deliverable number: WS3/ARUP/06

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Basis of Preparation

Our work has been a combination of desktop research and informational interviews.

- Desktop research has included review of research papers, industry journals, government reports and other PIV industry related publications.
- Informational interviews with stakeholders throughout the PIV industry have been conducted to verify and supplement information collected during the desktop study.

A complete list of publications reviewed is given in Appendix B and a list of interviews conducted during this study is given in Appendix C.

Publicly available data sources are referenced directly in this report. Interviews were conducted on the understanding that opinions, data or information obtained would not be directly referenced in this report.

Our analysis and opinions have been based on our technical knowledge and, where indicated, discussions with industry stakeholders.

We have not sought to establish the reliability of the sources of information used, but we have satisfied ourselves, so far as possible, that the information used is consistent with industry opinions.

This report takes into account the particular instructions and requirements of our client. It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

Glossary

Business Model	A collection of transactions that form part of the plug-in vehicle industry supply chain
Charge Post	A stationary unit that supplies electricity for the recharging of plug-in vehicles, also referred to as charge stations or charge points in the plug-in vehicle industry
Charging	Plug-in vehicle battery charging
Chassis	A vehicle without a battery
Consumer	The user of a vehicle, may be an individual or an organisation
Conventional Charging	Charging of plug-in vehicles using 3kW or 7kW plug-in charge posts (3-8 hour charge time)
BEV	Battery Electric Vehicle, a plug-in vehicle with no internal combustion engine
ICE	Internal Combustion Engine
ICEV	Internal Combustion Engine Vehicle
OEM	Original Equipment Manufacturer
PHEV	Plug-in Hybrid Electric Vehicle, a parallel hybrid
PIV	Plug-in vehicle, including battery electric vehicles, range extended electric vehicles and plug-in hybrid electric vehicles
R&D	Research and Development
Electric Range	Range of a plug-in vehicle on a single battery charge using only electric drive
REEV	Range Extended Electric Vehicle, a series hybrid
Rapid Charging	Charging of plug-in vehicles using 50kW plug in charge posts (10-30 minute charge time)
Running Costs	The annual costs of using a vehicle excluding depreciation, for the purpose of this report taken as maintenance and fuel
Total Cost of Ownership	The total cost of using a vehicle, for the purpose of this report taken as depreciation, maintenance and fuel

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Contents

Executive Summary

Introduction

This work considers **"the generic business models which may be effective during the initial launch / take-off of the [plug-in vehicle] market, in order to inform scenario development and system architecture definition"** in the UK.

14 business models have been considered: 12 from the vehicle provision, after sales service, and charging infrastructure sectors; and a further two that integrate vehicle provision and charging infrastructure provision. A scenario approach is used in the assessment of business model viability using four scenarios defined in terms of different levels of Plug-In Vehicle (PIV) take-up and charging infrastructure roll out in 2020. The business models are assessed for each scenario.

Overview of the PIV Market

The PIV market can be split into two interrelated components, vehicles and charging infrastructure, which must function together as a system. Developments in vehicles affect the requirements of charging infrastructure and vice versa.

PIVs are of three main types. Battery Electric Vehicles (BEVs), draw their power only from a battery and depend on publicly accessible charging infrastructure to extend their range. Range Extended Electric Vehicles (REEVs) and Plug-in Hybrid Electric Vehicles (PHEVs) carry an Internal Combustion Engine (ICE), which they can use to extend their range without relying on charging infrastructure. These differences mean demand for charging infrastructure depends not just on PIV take-up, but also on the proportions of BEVs, REEVs and PHEVs, bringing significant uncertainty to payback and return on investment in charging infrastructure.

It is useful to consider charging infrastructure in three categories: home, workplace, and publicly accessible. Most PIV charging is expected to take place overnight at home, some at workplaces and a small proportion at publicly accessible charge posts. All PIV owners with appropriate parking are expected to install a home charge post. Workplace car parks are expected to be appropriate locations for charge post and their provision can be matched to demand reasonably well. In contrast publicly accessible charging infrastructure is subject to significant uncertainty over demand, appropriate geographic distribution, and consumer willingness to pay, with implications on the risks involved in investment in businesses associated with this type of infrastructure.

Executive Summary

Deliverable Outline

This report is split into the following sections:

2. Methodology	this section describes the methodology, defines the business models considered, and outlines the scenarios used in the business model assessment.
3. Business viability summary	this section summarises the viability of the business models for each scenario highlighting the main reasons behind each assessment, taken from the more detailed analysis.
4. Business model analysis	this section gives detailed analysis of each business model in a consistent format that describes current and analogous experience, enablers, barriers, socio-economic benefits, strategic risk, political risk, subsidy, and legislation.
5. Appendices	appendices include take-up forecasts, sources, a list of interviewees, analysis of the differences between BEVs, REEVs and PHEVs, and a summary of relevant subsidy and legislation.

Executive Summary

Vehicle Provision

The success of PIVs depends on a combination of positive consumer attitudes, investment in developing vehicles by manufacturers and investment in charging infrastructure. Consumer attitudes towards PIVs are driven by vehicle cost, concerns about the reliability of the new technology, and, in the case of BEVs, range anxiety. In the early stages of the PIV market manufacturers are driven by emissions legislation and the need to develop technology.

European fleet average emissions legislation is a primary driver of PIV development. To avoid paying emissions premiums PIVs may be priced below cost by manufacturers in order to make them sufficiently attractive to consumers to achieve sales volumes that reduce their fleet average emissions below the target. However, in this case supply of PIVs is likely to be limited to that required to achieve the emissions target, to minimise incurred losses.

In scenarios where the cost of vehicles remains high in 2020 PIVs are not attractive to consumers, so the viability of vehicle provision is driven by manufacturers' strategic aims to establish brand, develop technology and meet emissions targets. In scenarios where PIV costs have reduced in 2020, in combination with extensive infrastructure roll out, PIVs are attractive to consumers and manufacturers have attractive opportunities to sell vehicles through their conventional channels.

Battery leasing is proposed as a way of making the cost structure and risk of PIVs more acceptable to consumers, by selling a chassis and leasing the battery, reducing the upfront vehicle cost and removing the main technology risk from the consumer. This model faces significant barriers to adoption, including unfamiliarity to consumers, and the complications in selling vehicles second hand. Although these barriers can be overcome, it is expected that in situations where this occurs the cost barriers to more conventional ownership models (buy or lease) will have been overcome, reducing the need for battery lease.

BEVs present operational problems for car clubs unless rapid charging infrastructure is widely available, but REEVs and PHEVs will be attractive to car clubs when their costs become competitive with ICEVs.

The interaction between consumer acceptance of business models and concern about technology risk is uncertain. For example, buying a PIV is familiar, but carries with it all the technology risk. Battery leasing is an unfamiliar business model, but helps to reduce exposure to technology risk. OEMs we have spoken to have questioned the willingness of consumers to accept novel business, but this should be tested.

Executive Summary

After Sales Service

PIVs are a new technology in mass market vehicles, which has a number of implications on maintenance. Consumers are likely to seek the reassurance of branded garages for their PIV maintenance needs. Garages will require a significant investment in training to become capable of servicing PIVs, but maintenance volumes are likely to be low because PIVs are predicted to require considerably less routine maintenance than ICEVs and during initial take-up they will only be present in small numbers. It is therefore uncertain who will make this investment.

In all scenarios main dealers will be able to leverage the value of their brands for competitive advantage in the maintenance market, but the low volumes and the need to keep overall PIV costs down to make them attractive to consumers will restrict profit maximising pricing policies.

At the end of their useful life, European legislation prevents PIV batteries being disposed of in landfill and places financial responsibility for recycling them on the organisations that brings them to market. Consequently battery recycling will be viable for any level of PIV take-up. Economies of scale are likely to be available from growth in portable battery recycling also required by European legislation, which in the UK must increase from 3% to 45% by 2016.

If a second life market for PIV batteries can be developed there may be greater opportunities for profit. The value of second life PIV batteries will be restricted by: the cost of reconfiguration; cheap alternative storage, such as lead-acid batteries; and the value of energy storage. It is only likely to be worth investing in developing the market and setting up reconfiguration facilities for scenarios where battery volumes are high.

Executive Summary

Charging Infrastructure

Alongside vehicles charging infrastructure is a critical part of the PIV system.

The rollout of charging infrastructure will be strongly affected by the mix of BEVs, REEVs and PHEVs and legislation governing whether DNOs can invest in charging infrastructure and include it in their regulated asset bases. Uncertainties in these areas mean there is currently considerable risk associated with charging infrastructure investment and this risk is likely to remain during the initial take-off of the PIV market.

BEVs, REEVs and PHEVs will all generally require a home charging facility, so demand is closely correlated with overall PIV take-up. Manufacturing such posts will be viable in all scenarios, but low barriers to entry mean profits will be low. It is expected that the consumer will own and operate their home charge post.

Workplace charge posts are likely to be important to a number of consumer groups. It will be essential to BEV drivers with a round trip commute further than their range. For PIV drivers without off-street parking at home it is likely to be the most convenient option for charging. For REEV and PHEV drivers keen to maximise their electric only miles workplace charging will provide an opportunity to top-up. The main business opportunities in this space are likely to be manufacture, installation and maintenance of posts. Operation is unlikely to generate significant revenue during initial take-off of the PIV market as it is expected that workplace charging will not require significant administration or billing.

Publicly accessible charging infrastructure is necessary for BEVs to extend their range beyond a single charge, so demand for it depends on the take-up of BEVs. Consumer willingness to pay for public recharging is likely to be restricted by the price of alternatives, such as REEVs, PHEVs and ICEVs, which do not need to charge to extend their range. Combined with the high cost of installing public charging infrastructure this presents significant challenges to operating profitably in this market. For all but the most optimistic scenario charging infrastructure is unlikely to be directly profitable and will be installed by local authorities for environmental reasons, or by private companies for indirect benefits, for example marketing.

Executive Summary

One proposed solution to this investment challenge is to change legislation to enable DNOs to invest in charging infrastructure and include it in their regulated asset base. DNOs could then adjust their network charges to earn a regulated return on this investment and electricity suppliers would sell electricity to PIV drivers through the charge posts. This change would affect workplace and publicly accessible charging infrastructure, but it is expected that home charge posts would continue to be installed by home owners. There are difficult practical issues with the regulated asset approach. For example where should charge posts be installed? Car parks of shopping centres and supermarkets may be suitable locations but there would then be issues of those businesses attracting indirect benefits, such as increased business from PIV drivers. A potentially complex regulatory framework would need to be established.

Integrated Business Models

In this report integrated business models are defined to be those that combine activities from the vehicle provision and charging infrastructure parts of the PIV system into a single business. Such business models are likely to appeal primarily to BEV drivers, as they are reliant on publicly accessible charging infrastructure to extend their range. Consequently the prices of vehicle and charging packages will be limited by substitutes such as REEVs, PHEVs or ICEVs that do not require access to public charging infrastructure.

The cost to the consumer of an integrated package is likely to be dominated by the cost of the vehicle, during initial take-off of the market. Therefore in scenarios where PIV costs remain high packages from integrated providers will remain unattractive to consumers in comparison to buying or leasing an ICEV.

In scenarios where PIV costs become competitive with ICEVs, integrated providers offer an innovative ownership model for consumers. Battery swap offers a differentiated service that could be attractive to consumers, but technical issues and barriers to battery standardisation by manufacturers make it unlikely to be viable. Without battery swapping stations, integrated models do not offer a sufficiently differentiated service to persuade consumers to risk a novel ownership model.

Executive Summary

Barriers and Enablers

During the initial take-off of the PIV market the main driver of vehicle rollout in Europe will be the European fleet average emissions legislation. Under this legislation OEMs will be fined if their average fleet emissions are above a target level. PIVs offer OEMs a means to reduce the average emissions of their fleets, particularly in the years to 2015 when the legislation incentivises such vehicles.

However, as PIVs are expensive to develop, require batteries that are expensive, and are produced in small volumes OEMs may have to price them below cost to make them attractive to consumers. Consequently there is a risk that the supply of PIVs will be restricted to that required for OEMs to achieve their fleet average emissions target to minimise losses.

With a restricted supply of PIVs, and BEVs in particular, it will take much longer for there to be sufficient demand to support a widespread charging infrastructure rollout. This will reduce the utility of BEVs to consumers and could be a vicious circle obstructing BEV take-up.

A further issue with charging infrastructure is the need for standards to enable PIV drivers to use any publicly accessible charge post. If standards are not set early in the launch of the PIV market, there is a risk of competing standards and under-specified charge posts, in particular charge posts with inadequate communications to facilitate billing and demand management (if required).

Many studies indicate that the main obstacles to consumers considering PIVs are the high cost of the vehicles, concern about the reliability of the new technology and, in the case of BEVs, range anxiety. Vehicle cost is expected to reduce as battery prices drop and vehicle production volumes increase. In the short term, government subsidies will help to mitigate the cost barrier, although initially even subsidised PIVs will be expensive compared to ICEVs. Technology concerns will be mitigated as PIVs driven by early adopters are proved in use. Range anxiety can be reduced by providing charging infrastructure, selling BEVs with larger batteries or consumers gaining experience of their true journey patterns.

For businesses considering entering the PIV market the main barrier is risk. Risk comes from a number of sources: the reliability of current technology; the rate at which technology will improve; government policy is changeable in timescales over which investment decisions must be made; and there is a great deal of uncertainty in demand, particularly for public charging infrastructure.

Recommendations on the impact of this study on future work within the ETI's Transport Programme

The business models work feeds into two other work packages:

- Infrastructure: conceptual business architecture (WP 2.4)
- Economic and carbon benefits: new revenue streams (WP 3.2.1)

Coordination with the conceptual business architecture of the infrastructure project was required to ensure the level of intelligence proposed for the charging infrastructure during the initial launch of the PIV market would be sufficient to support the associated generic business models. Regular teleconferences were held between Arup and IBM to discuss the business models work and to ensure compatibility.

The business models work informs the study of new revenue streams (and also the scenarios work) through:

- Understanding the interaction of vehicle and infrastructure business models;
- Understanding which business models are most viable and therefore most likely to dominate the PIV market.

The business models work has been coordinated with the development of the overall economic and carbon benefits model

Methodology

Business model definitions

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14 business models in four industry sectors have been considered

After Sales Services
- Vehicle Maintenance
- Battery Recycle

Vehicle Provision
- Vehicle Ownership
- Vehicle Lease
- Battery Lease
- PIV Car Club

Consumer

Charging Infrastructure
- Home Charge Post Manufacture
- Conventional Charge Post Manufacture
- Rapid Charge Post Manufacture
- Charging Infrastructure Operation
- Charging Infrastructure Ownership
- Billing Services

Integrated Models
- Battery Swap
- Complete System Integration

Each business model is defined by a subset of transactions in the PIV supply chain and considered fully in section 5

	Business Model	Summary Definition: further details in section 5
Vehicle Provision	Vehicle Ownership	Buy new vehicles from a manufacturer (or second hand vehicles) and sell them to consumers.
	Vehicle Lease	Buy new vehicles from a manufacturer and lease to consumers.
	Battery Lease	Buy new vehicles from a manufacturer, sell the chassis to consumers and lease them the batteries.
	PIV Car Club	Buy new vehicles from a manufacturer and charge consumers an hourly rental fee for use.
After Sales Service	Vehicle Maintenance	Charge vehicle owners a fee for garage services. Breakdown services are not included.
	Battery Recycle	Remove end-of-life batteries from vehicle and either repackage and sell for a second life use, or recover raw materials and sell to battery manufacturer.
Charging Infrastructure	Home Charge Post Manufacture	Manufacture and install charge posts suitable for domestic use to consumers.
	Conventional Charge Post Manufacture	Manufacture and install charge posts suitable for workplace or public use to organisations.
	Rapid Charge Post Manufacture	Manufacture and install rapid charge posts suitable for public use to organisations.
	Charging Infrastructure Operation	Operate charging infrastructure on behalf of the owner. Includes: maintenance, administration, billing and data collection. The requirements will broadly depend on charge post location (home, workplace or public).
	Charging Infrastructure Ownership	Buy charging infrastructure from a manufacturer. Value of charging infrastructure ownership depends primarily on location (home, workplace or public).
	Billing Services	Collect charging infrastructure usage data, bill consumers for their usage, arrange settlement with charging infrastructure operators.
Integrated Models	Battery Swap	Provide consumers with access to a vehicle for a monthly tariff inclusive of access to battery swap infrastructure and conventional charging infrastructure.
	Complete System Integration	Provide consumers with access to a vehicle for a monthly tariff inclusive of access to rapid and conventional charging infrastructure.

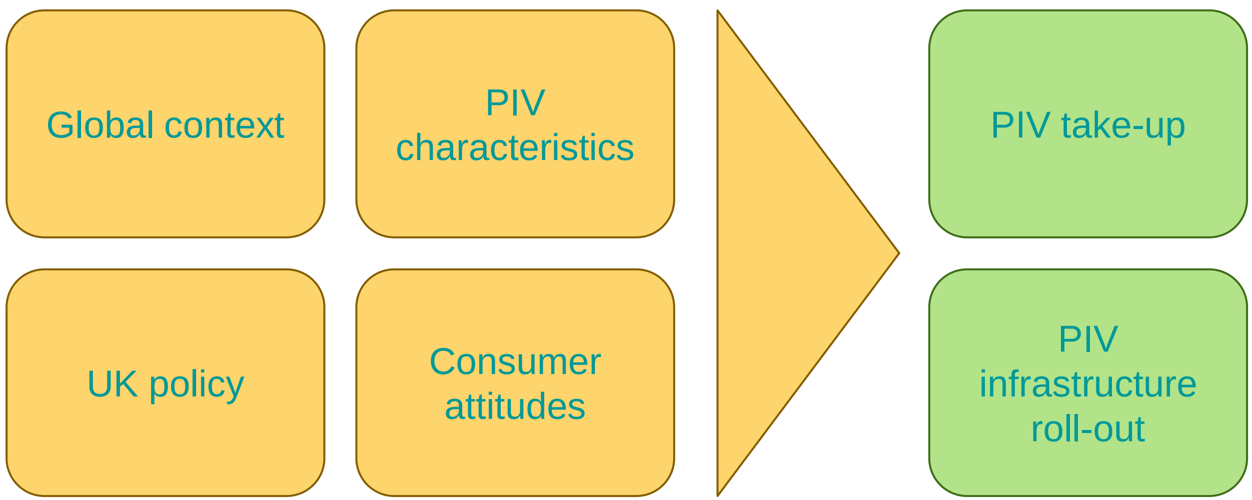
Scenario definition

A scenario approach is used in the assessment of business model viability

Business model viability is assessed to 2020. To provide a context within which to assess the business models and recognising that the future of the PIV market over the next 10 years is uncertain, a scenario approach is used.

Variables

Drivers of PIV take-up were used as variables, based on the outcomes of the variables workshop, and consistent with the early scenarios work. The underlying viability of PIV system business models is dependent primarily on the number of PIVs in the UK parc and on the quantity of charging infrastructure that is rolled out (although other factors, for example legislation, also have a significant effect). Consequently four scenarios were defined to explore the interaction of these two parameters.



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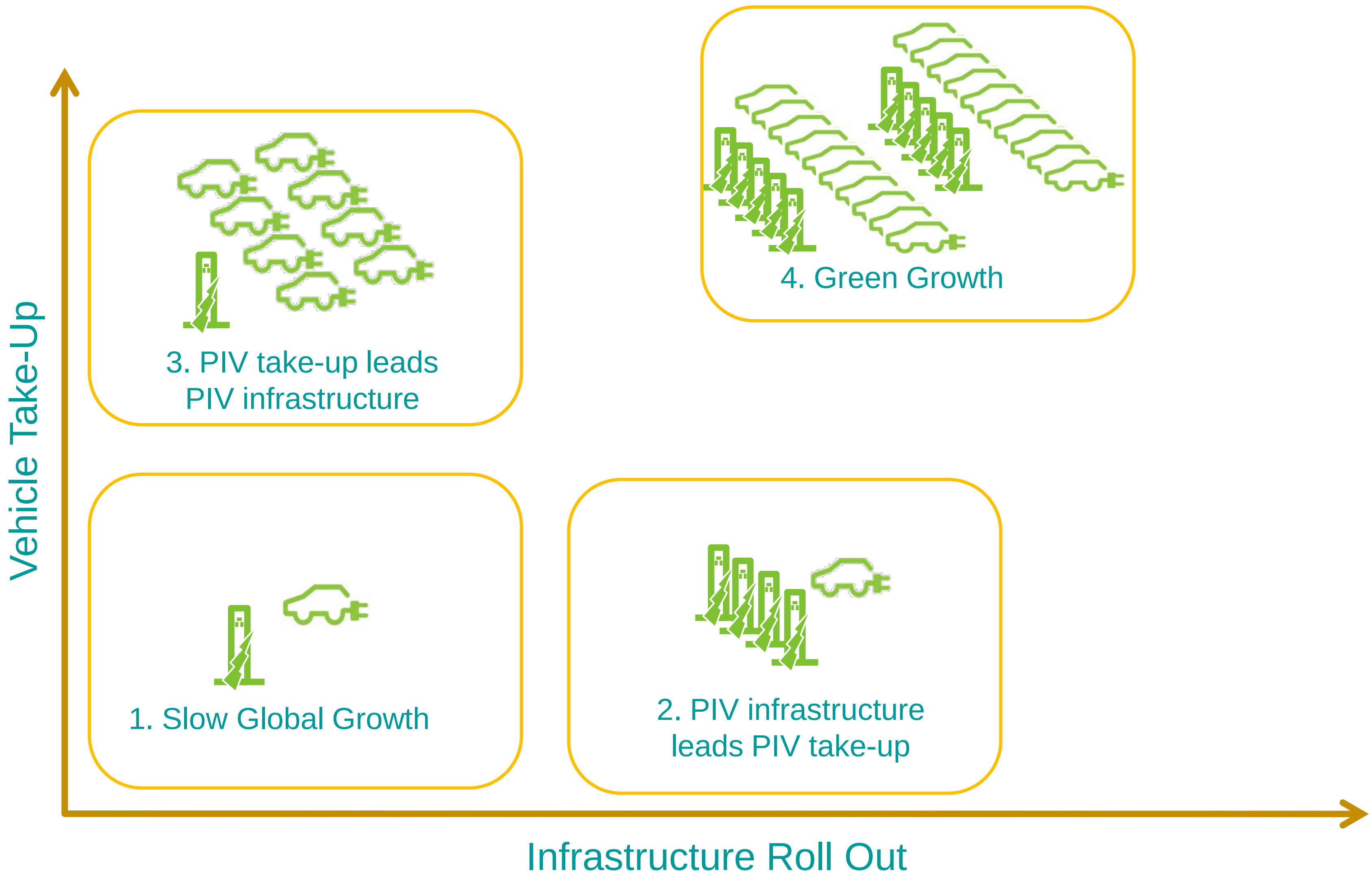
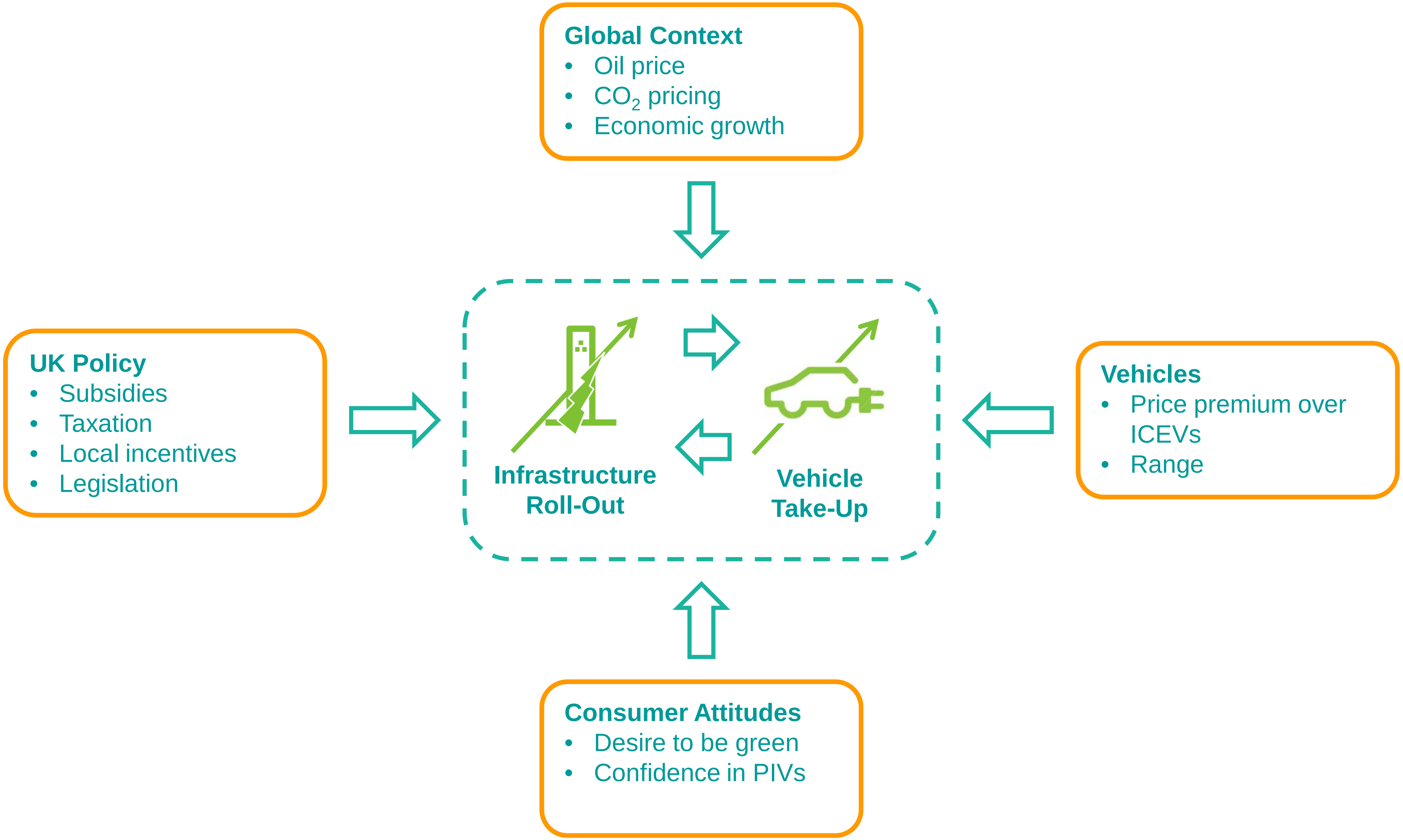
Four scenarios of different levels of vehicle take-up and infrastructure development were considered



Scenarios are described in terms of variables that will influence PIV take-up



Consistent trends characterise each scenario

Vehicle Take-Up

4. Green growth
- High investment in vehicle technology, PIV prices fall
- Rapid deployment of infrastructure
- Attractive investment opportunities due to high volumes and confidence
- Strong consumer appetite for PIVs

3. PIV take-up leads PIV infrastructure
- Significant global investment in PIV technology, PIV prices fall
- Low investment in UK infrastructure
- Consumer desire for PIVs but infrastructure limits take-up

1. Slow global growth
- Prolonged recession
- PIVs expensive, impractical and used by wealthy early adopters only

2. PIV infrastructure leads PIV take-up
- Some investment in infrastructure to encourage take-up
- Consumer reluctance to switch to PIVs
- OEMs supply minimum PIVs to achieve emissions target

Infrastructure Roll Out

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Further details for each scenario are used for business model assessment (1/2)

Variable	Slow Global Growth	PIV Infrastructure Leads PIV Takeup	PIV Takeup Leads PIV Infrastructure	Green Growth
Global Context	• Oil price returns to $50/barrel long term trend • Prolonged recession • ICEV running costs reduce relative to PIVs • No global agreement on CO_2 price	• Oil price remains at current levels • World and UK emerges from recession as expected • ICEV running costs unchanged relative to PIVs • No global agreement on CO_2 price	• Oil price remains at current levels • World emerges from recession faster than UK • ICE running costs increase relative to PIVs • Global CO_2 price agreement increases fuel cost	• Oil price rises quickly • ICE running costs increase relative to PIVs • Global CO_2 price agreement increases fuel cost
UK Policy	• Cost saving measures limit subsidies for PIV industry • Tax incentives and measures with little impact on government revenues for low uptake remain	• PIV industry subsidies limited, government focuses on PIV infrastructure investment which has a greater direct benefit to UK businesses and stimulating growth • Tax incentives and measures with little impact on government revenues for low take-up remain • UK expects to meet 2020 CO_2 targets	• Cost saving measures limit subsidies for PIV industry • Tax incentives and measures with little impact on government revenues for low uptake remain • UK unlikely to meet 2020 CO_2 targets	• Significant subsidies for PIV industry • Increased PIV uptake puts pressure on the government to limit tax incentives and other measures to maintain revenues • UK invests to meet 2020 CO_2 targets
UK Subsidy	• £250m to encourage low carbon vehicles reduced as part of cost cutting measures • Vehicle excise duty CO_2 bands remain constant enabling efficient diesels to achieve lowest band	• £250m to encourage low carbon vehicles reduced as part of cost cutting measures. • Vehicle excise duty CO_2 bands made more stringent to encourage PIV take up over efficient diesel	• £250m to encourage low carbon vehicles remains. • Vehicle excise duty CO_2 bands made more stringent to encourage PIV take up over efficient diesel	• £250m to encourage low carbon vehicles supplemented by additional government money to make PIV financially comparable to ICE from 2015 onwards and to encourage infrastructure installation. • Vehicle excise duty CO_2 bands made more stringent to encourage alternative fuel vehicles
UK Base Legislation[1]	• European emissions legislation incentivises OEMs to pursue super-credits via PIV, but supply capped to minimum necessary to meet target • Charging infrastructure not a regulated asset	• European emissions legislation incentivises OEMs to pursue super-credits via PIV, but supply capped to minimum necessary to meet target • Charging infrastructure not a regulated asset	• European emissions legislation incentivises OEMs to pursue super-credits via PIV • Charging infrastructure not a regulated asset	• European emissions legislation incentivises OEMs to pursue super-credits via PIV • Charging infrastructure not a regulated asset
UK Alternative Legislation[1]	• As for base legislation, except charging infrastructure is a regulated asset	• As for base legislation, except charging infrastructure is a regulated asset	• As for base legislation, except charging infrastructure is a regulated asset	• As for base legislation, except charging infrastructure is a regulated asset

[1] For each scenario business models where viability is affected by the alternative legislation are assessed twice, once for UK base legislation and once for UK alternative legislation.

Further details for each scenario are used for business model assessment (2/2)

Variable	Slow Global Growth	PIV Infrastructure Leads PIV Takeup	PIV Takeup Leads PIV Infrastructure	Green Growth
Vehicles	• OEMs and suppliers invest cautiously in R&D • PIV performance stagnates • Production volumes below efficient level • Vehicle prices remain high	• OEMs and suppliers invest cautiously in R&D • PIV performance stagnates • Production volumes below efficient level • Vehicle prices remain high	• OEMs and suppliers invest confidently in R&D • PIV performance improves significantly • Production volumes approach efficient level • Vehicle prices reduce	• OEMs and suppliers invest confidently in R&D • PIV performance improves significantly • Production volumes reach efficient level • Vehicle prices reduce
Consumer Attitudes	• Concern for CO_2 slips down consumer agenda due to financial pressures • Confidence in buying a PIV low due to cost of vehicles, range anxiety, unproven technology, low level of infrastructure	• Confidence in buying a PIV low due to cost of vehicles, range anxiety, unproven technology	• Concern for CO_2 significant among better off but generally moderated due to financial pressures • Confidence in buying a PIV restrained by low level of infrastructure • Incentive to buy a PIV increased by more favourable total cost of ownership vs ICEVs	• Consumer concern for CO_2 fashionable and an important purchasing criterion • Confidence in buying a PIV increased by familiarity and proven performance in use • Incentive to buy a PIV high due to subsidised costs, infrastructure availability, high cost of ICEV
Vehicle Usage Trends	• BEVs primarily used as second vehicles for short journeys due to range anxiety resulting from lack of infrastructure • REEVs and PHEVs used as main vehicle for all journey types	• BEVs primarily used as second vehicle for short journeys due to range anxiety and lack of experience of longer journeys • REEVs and PHEVs used as main vehicle for all journey types	• BEVs primarily used as second vehicles for short journeys due to range anxiety resulting from lack of infrastructure • REEVs and PHEVs used as main vehicle for all journey types	• BEVs primarily used as second vehicles but some use on longer journeys supported by appropriate charging infrastructure on trunk roads • REEVs and PHEVs used as main vehicle for all journey types
Infrastructure Deployment	• Limited or reduced government subsidy limits development and roll-out of infrastructure • Existing free government infrastructure disincentivises private investment	• Aggressive government subsidy facilitates roll out of charging infrastructure capable of supporting high levels of BEV uptake • Private investment in infrastructure limited due to low levels of BEV take-up	• Limited or reduced government subsidy limits development and roll-out of infrastructure • Existing free government infrastructure disincentivises private investment	• Aggressive government subsidy facilitates roll out of charging infrastructure capable of supporting high levels of BEV uptake • Private investment in infrastructure encouraged
Vehicle Take-Up	• Low (300,000) • Restricted to wealthy early adopters and those in areas with strong local incentives, eg London	• Low (300,000) • Restricted to wealthy early adopters and those in areas with strong local incentives, eg London	• Medium (600,000) • Fleet buyers purchase based on low total cost of ownership for high mileage, low range use, predictable usage pattern	• High (1,200,000) • Fleet buyers with suitable usage patterns buy PIVs for cost saving and PR reasons • Retail customers buy PIVs for cost saving and to demonstrate green credentials

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Context of business viability assessment

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Business model viability is assessed using a consistent scale

Not Viable	• No perceived current investment opportunity
Strategically Attractive	• Not currently profitable • Investment opportunities have insignificant (and potentially negative) net present value at conventional discount rates (<15%) • Potential strategic benefits for market entrants such as first mover advantage, early market share, brand credibility, technology development, ability to shape standards, possible access to third party funding
Viable	• Positive net present value investment opportunities with reasonable (less than five years) pay back periods • Marketplace may be competitive and not necessarily highly profitable • Viability may rely on access to third party funding or public subsidy
Attractive	• Attractive investment opportunities with significant net present value and high internal rate of return • Potentially low risk and highly scalable • Potential for high profitability, perhaps due to high barriers to entry or some other sustainable competitive advantage • Viability not dependent on third party funding or public subsidy

Business viability summary

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Business viability summary

	Business Model	Slow Growth	PIV Infrastructure Leads PIV Takeup	PIV Takeup Leads PIV Infrastructure	Green Growth
Vehicle Provision	Vehicle Ownership	Strategically Attractive	Strategically Attractive	Viable	Viable
	Vehicle Lease	Strategically Attractive	Strategically Attractive	Viable	Attractive
	Battery Lease	Not Viable	Not Viable	Not Viable	Not Viable
	PIV Car Club	Not Viable	Not Viable	Viable	Attractive
After Sales Service	Vehicle Maintenance	Strategically Attractive	Strategically Attractive	Strategically Attractive	Strategically Attractive
	Battery Recycle	Viable	Viable	Viable	Attractive
Charging Infrastructure (for base legislation)	Home Charge Post Manufacture	Strategically Attractive	Strategically Attractive	Strategically Attractive	Viable
	Conventional Charge Post Manufacture	Viable	Viable	Viable	Viable
	Rapid Charge Post Manufacture	Viable	Viable	Viable	Viable
	Charging Infrastructure Operation	Not Viable	Strategically Attractive	Strategically Attractive	Attractive
	Charging Infrastructure Ownership	Strategically Attractive	Strategically Attractive	Strategically Attractive	Attractive
	Billing Services	Not Viable	Not Viable	Not Viable	Viable
Integrated Models	Battery Swap	Not Viable	Not Viable	Not Viable	Not Viable
	Complete System Integration	Not Viable	Not Viable	Not Viable	Not Viable

Slow global growth scenario

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There are limited opportunities in the PIV supply chain in the 'slow global growth' scenario

Industry	Business Model	2010 → 2020	
Vehicle Provision	Vehicle Ownership	Strategically Attractive	
	Vehicle Lease	Strategically Attractive	
	Battery Lease	Not Viable	
	PIV Car Club	Not Viable	
Vehicle Service	Vehicle Maintenance	Strategically Attractive	
	Battery Recycle	Strategically Attractive	Viable
Infrastructure (for base legislation)	Home Charge Post Manufacture	Strategically Attractive	
	Conventional Charge Post Manufacture	Strategically Attractive	Viable
	Rapid Charge Post Manufacture	Strategically Attractive	Viable
	Charging Infrastructure Operation	Not Viable	
	Charging Infrastructure Ownership	Strategically Attractive	
	Billing Services	Not Viable	
Integrated Models	Battery Swap	Not Viable	
	Complete System Integration	Not Viable	

Conventional vehicle provision models may be pursued by some OEMs for strategic reasons

Business model	Summary of viability	Viability in 2020
Vehicle Ownership	• PIV costs are high due to low volumes and expensive batteries, but strategically important to OEMs to meet emissions targets, to establish brand and to develop technology in anticipation of future growth in the market. • OEMs price PIVs at a level to achieve sales volume necessary to meet European fleet average emissions target, but limit supply to this level to minimise losses. • Nevertheless, prices and lack of charging infrastructure make PIVs unattractive to most consumers, so take-up restricted to wealthy early adopters.	**Strategically Attractive**
Vehicle Lease	• In addition to the same issues associated with Vehicle Ownership, leases are priced conservatively due to uncertain residual values. Consequently volumes are low. • Lease is strategically attractive to OEMs, to access the fleet market, which judges vehicles on total cost of ownership, to establish brand and to develop technology in anticipation of future growth in the market.	**Strategically Attractive**
Battery Lease	• In addition to the same issues associated with Vehicle Ownership, battery leases are priced conservatively due to technology risk and uncertain residual values. • The necessary shift in consumer attitudes to vehicle ownership required for this model to be viable does not occur.	**Not Viable**
PIV Car Club	• High PIV cost makes them financially unviable for car club use • In addition lack of charging infrastructure makes BEVs operationally unviable.	**Not Viable**

Low volumes significantly limit after sales business opportunities if global growth is slow…

Business model	Summary of viability	Viability in 2020
Vehicle Maintenance	• Market will be driven by consumer need for reassurance, allowing main dealers to leverage brand to provide a competitive advantage. • Investment will be required to train staff to maintain new vehicle types. It is currently uncertain who will make this investment (dealers or OEMs). • Maintenance volume will be low, due to low take-up and reduced maintenance requirement of PIVs, but steady due to necessity of maintenance. • Pressure to keep total cost of ownership of PIVs down discourages profit maximising pricing policies.	**Strategically Attractive**
Battery Recycle	• European legislation requiring PIV batteries to be recycled and requiring the producer to pay makes recycling viable, but margins are low. • Low take-up combined with the 7-10yr expected life of batteries means second life battery volumes are very low. Cheap alternative storage technology (eg lead-acid) places cap on value of second life batteries. Second life uses of batteries not economic and reconfiguring volumes are inefficient.	**Viable**

...and viable infrastructure business models are limited to those associated with charge post manufacture

Business model	Summary of viability	Viability in 2020 Base Legislation	Viability in 2020 Alternative Legislation
Home Charge Post Manufacture	• Home charge post market strongly correlated with PIV take-up, so volumes will be low. • Low barriers to entry result in competitive industry with low profitability. • Home charge posts unlikely to be owned as regulated asset by DNOs, so business model is unaffected by legislation in this area. • Model is strategically attractive in anticipation of future growth.	**Strategically Attractive**	**Strategically Attractive**
Conventional Charge Post Manufacture	• Low level of infrastructure roll-out means market is small so only a small number of companies can occupy this space profitably. • Volume likely to be dominated by workplace charge posts. • Low barriers to entry and potential difficulty establishing a sustainable competitive advantage likely to limit profitability. • If charging infrastructure can be regulated asset, charge post roll out may be faster, enabling more firms to operate profitably in this space.	**Viable**	**Viable**
Rapid Charge Post Manufacture	• Low level of infrastructure roll-out means market is small so only a small number of companies can occupy this space profitably. • If charging infrastructure can be regulated asset public charging post roll out may be faster, increasing volumes and enabling more firms to operate profitably in this space. • Low barriers to entry (higher than for conventional charge post manufacture but little scope for IP ownership) and potential difficulty establishing a sustainable competitive advantage likely to limit profitability.	**Viable**	**Viable**

...and viable infrastructure business models are limited to those associated with charge post manufacture

Business model	Summary of viability	Viability in 2020 Base Legislation	Viability in 2020 Alternative Legislation
Charging Infrastructure Operation	• Home charge posts do not require operation services. • Workplace charge posts probably only require maintenance, as unlikely to be billed on a per use basis (this also applies to public charge posts provided free of charge). • Public charge posts billed on a per use basis could require full operation services. • Maintenance volumes will be closely correlated with infrastructure rollout as most non-domestic charge posts will require maintenance. Billing services and account management, which will be more prevalent in public charging, will have low volumes that are correlated primarily with the number of BEVs, as REEVs and PHEVs have less need to charge in public. • Charging infrastructure owners employ operators in some cases, but margins are squeezed due to overall lack of profitability in industry. • Under current legislation charging infrastructure operation is unprofitable. • If charging infrastructure can be regulated, charging infrastructure operation becomes necessary, not just convenient, and makes it strategically attractive, for example to electricity suppliers.	**Not Viable**	**Strategically Attractive**

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...and viable infrastructure business models are limited to those associated with charge post manufacture

Business model		Summary of viability	Viability in 2020 Base Legislation	Viability in 2020 Alternative Legislation
Charging Infrastructure Ownership	Home	• Home charge posts will be owned by the home owner for personal use. There will not be a business model in this space.	Not Applicable	Not Applicable
Charging Infrastructure Ownership	Work-place	• Under current legislation workplace charge posts will be owned by the building owners and provided as additional building facility for employees. • Charging posts unlikely to be operated for profit, so viability depends on perceived benefits to employers being worth the cost of charge posts. • If charging infrastructure can be regulated and an acceptable means to select workplaces for siting such infrastructure can be found, this change in legislation could significantly increase the rollout of workplace charge posts.	Strategically Attractive	Viable
Charging Infrastructure Ownership	Public	• Market for public charging is small due to low take-up of BEVs and is vulnerable to substitutes (REEVs, PHEVs, ICEVs). • Charging infrastructure owners derive indirect benefits (marketing; positioning or brand awareness benefits; differentiation from competitors in core business), so model is strategically attractive. • If charging infrastructure can be a regulated asset, ownership becomes viable for DNOs, but an acceptable means must be found for siting posts.	Strategically Attractive	Viable
Billing Services		• Viable when charging is billed on a per-use basis, which is likely to occur as the amount of infrastructure increases and the number of different owners increases. • If DNOs can install charging infrastructure as a regulated asset, a billing service will be essential to track usage and enable electricity cost to be billed to correct customer.	Not Viable	Viable

Consumer attitudes are slow to change, limiting viability of integrated models

Business model	Summary of viability	Viability in 2020 Base Legislation	Viability in 2020 Alternative Legislation
Battery Swap	• Barriers to this model make it unviable without significant change in consumer attitudes to vehicle ownership. • Low level of take-up leads to insufficient subscribers to support battery swap infrastructure.	**Not Viable**	**Not Viable**
Complete System Integrator	• This model is unviable without significant change in consumer attitudes to vehicle ownership. • Low level of take-up leads to insufficient subscribers to support an attractive level of charging infrastructure.	**Not Viable**	**Not Viable**

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PIV infrastructure leads PIV take-up scenario

Significant investment does not mitigate consumer doubt. Business model viability is similar to scenario 1

Industry	Business Model	2010 → 2020
Vehicle Provision	Vehicle Ownership	Strategically Attractive
	Vehicle Lease	Strategically Attractive
	Battery Lease	Not Viable
	PIV Car Club	Not Viable
Vehicle Service	Vehicle Maintenance	Strategically Attractive
	Battery Recycle	Strategically Attractive → Viable
Infrastructure (for base legislation)	Home Charge Post Manufacture	Strategically Attractive
	Conventional Charge Post Manufacture	Viable
	Rapid Charge Post Manufacture	Viable
	Charging Infrastructure Operation	Strategically Attractive
	Charging Infrastructure Ownership	Strategically Attractive
	Billing Services	Not Viable
Integrated Models	Battery Swap	Not Viable
	Complete System Integration	Not Viable

Conventional vehicle provision models strategically attractive for OEMs in ‘PIV infrastructure leads PIV take-up’ scenario

Business model	Summary of viability	Viability in 2020
Vehicle Ownership	• PIV costs are high due to low volumes and expensive batteries, but strategically important to OEMs to meet emissions targets, to establish brand and to develop technology in anticipation of future growth in the market. • OEMs price PIVs at a level to achieve sales volume necessary to meet European fleet average emissions target, but limit supply to minimise losses. • Prices make PIVs unattractive to most consumers, so take-up is restricted to early adopters.	**Strategically Attractive**
Vehicle Lease	• In addition to the same issues associated with Vehicle Ownership, leases are priced conservatively due to uncertain residual values. Consequently volumes are low. • Lease is strategically attractive to OEMs to meet emissions targets, to access the fleet market, which judges vehicles on total cost of ownership, to establish brand and to develop technology in anticipation of future growth in the market.	**Strategically Attractive**
Battery Lease	• In addition to the same issues associated with Vehicle Ownership, battery leases are priced conservatively due to technology risk and uncertain residual values. • The necessary shift in consumer attitudes to vehicle ownership required for this model to be viable does not occur.	**Not Viable**
PIV Car Club	• High PIV cost makes them financially unviable for car club use.	**Not Viable**

Low PIV volumes significantly limit after sales business opportunities if PIV infrastructure leads PIV take-up …

Business model	Summary of viability	Viability in 2020
Vehicle Maintenance	• Market will be driven by consumer need for reassurance, allowing main dealers to leverage brand to provide a competitive advantage. • Investment will be required to train staff to maintain new vehicle types. It is currently uncertain who will make this investment (dealers or OEMs). • Maintenance volume will be low, due to low take-up and reduced maintenance requirement of PIVs, but steady due to necessity of maintenance. • Pressure to keep total cost of ownership of PIVs down discourages profit maximising pricing policies.	**Strategically Attractive**
Battery Recycle	• European legislation requiring PIV batteries to be recycled and requiring the producer to pay makes recycling viable, but margins are low. • Low take-up combined with the 7-10yr expected life of batteries means second life battery volumes are very low. Cheap alternative storage technology (eg lead-acid) places cap on value of second life batteries. Second life uses of batteries not economic and reconfiguring volumes are inefficient.	**Viable**

...and viable infrastructure business models are again limited to those associated with charge post manufacture

Business model	Summary of viability	Viability in 2020 Base Legislation	Viability in 2020 Alternative Legislation
Home Charge Post Manufacture	• Home charge post market strongly correlated with PIV take-up, so volumes will be low. • Low barriers to entry result in competitive industry with low profitability. • Home charge posts unlikely to be owned as regulated asset by DNOs, so business model is unaffected by legislation in this area. • Model is strategically attractive in anticipation of future growth.	**Strategically Attractive**	**Strategically Attractive**
Conventional Charge Post Manufacture	• Higher level of infrastructure roll-out means market is larger so a larger number of companies can occupy this space profitably. • Volume likely to be mostly workplace charge posts. • Low barriers to entry and potential difficulty establishing a sustainable competitive advantage likely to limit profits on unit sales. • If charging infrastructure can be regulated asset, charge post rollout may be faster, providing a larger market, enabling more firms to operate profitably in this space.	**Viable**	**Viable**
Rapid Charge Post Manufacture	• Higher level of infrastructure roll-out means market is larger so a larger number of companies can occupy this space profitably. • If charging infrastructure can be regulated asset, public charge post rollout may be faster, increasing volumes and enabling more firms to operate profitably in this space. • Low barriers to entry (higher than for conventional charge post manufacture but little scope for IP ownership) and potential difficulty establishing a sustainable competitive advantage likely to limit profits on unit sales.	**Viable**	**Viable**

…and viable infrastructure business models are again limited to those associated with charge post manufacture

Business model	Summary of viability	Viability in 2020 Base Legislation	Viability in 2020 Alternative Legislation
Charging Infrastructure Operation	• Home charge posts do not require operation services. • Workplace charge posts probably only require maintenance, as unlikely to be billed on a per use basis (this also applies to public charge posts provided free of charge). • Public charge posts billed on a per use basis could require full operation services. • Maintenance volumes will be closely correlated with infrastructure rollout, as most non-domestic charge posts will require maintenance. Billing services and account management, which will be more prevalent in public charging, will have low volumes that are correlated primarily with the number of BEVs, as REEVs and PHEVs have less need to charge in public. • Charging infrastructure owners employ operators in some cases, but margins are squeezed due to overall lack of profitability in industry. • Under current legislation charging infrastructure operation is unprofitable. • If charging infrastructure can be regulated, charging infrastructure operation becomes necessary, not just convenient, and makes it strategically attractive, for example to electricity suppliers.	**Strategically Attractive**	**Strategically Attractive**

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...and viable infrastructure business models are again limited to those associated with charge post manufacture

Business model		Summary of viability	Viability in 2020 Base Legislation	Viability in 2020 Alternative Legislation
Infrastructure Ownership	Home	• Home charge posts will be owned by the home owner for personal use. There will not be a business model in this space.	**Not Applicable**	**Not Applicable**
	Work-place	• Under current legislation workplace charge posts will be owned by the building owners and provided as additional building facility for employees. • Charging posts unlikely to be operated for profit, so viability depends on perceived benefits to employers being worth the cost of charge posts. • If charging infrastructure can be regulated and an acceptable means to select workplaces for siting such infrastructure can be found, this change in legislation could significantly increase the rollout of workplace charge posts.	**Strategically Attractive**	**Viable**
	Public	• Market for public charging is small due to low take-up of BEVs and is vulnerable to substitutes (REEVs, PHEVs, ICEVs). • Charging infrastructure owners derive indirect benefits (marketing; positioning or brand awareness benefits; differentiation from competitors in core business), so model is strategically attractive. • If charging infrastructure can be a regulated asset, ownership becomes viable for DNOs, but an acceptable means must be found for siting posts.	**Strategically Attractive**	**Viable**

…and viable infrastructure business models are again limited to those associated with charge post manufacture

Business model	Summary of viability	Viability in 2020 Base Legislation	Viability in 2020 Alternative Legislation
Billing Services	• Viable when charging is billed on a per-use basis, which is likely to occur as the amount of infrastructure increases and the number of different owners increases. • If DNOs can install charging infrastructure as a regulated asset, a billing service will be essential to track usage and enable electricity cost to be billed to correct customer.	**Not Viable**	**Viable**

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Consumers are unwilling to adapt to integrated models

Business model	Summary of viability	Viability in 2020 Base Legislation	Viability in 2020 Alternative Legislation
Battery Swap	• Barriers to this model make it unviable without significant change in consumer attitudes to vehicle ownership. • Low level of take-up leads to insufficient subscribers to support battery swap infrastructure, which is not subsidised by government due to the significant barriers.	**Not Viable**	**Not Viable**
Complete System Integrator	• This model is unviable without significant change in consumer attitudes to vehicle ownership. • Low level of take-up leads to insufficient subscribers to support an attractive level of charging infrastructure and subsidised government infrastructure reduces price consumers are willing to accept for charging.	**Not Viable**	**Not Viable**

PIV take-up leads PIV infrastructure scenario

There are broader opportunities in the PIV supply chain in the 'PIV take-up leads PIV infrastructure' scenario

Industry	Business Model	2010 → 2020
Vehicle Provision	Vehicle Ownership	Viable
	Vehicle Lease	Viable
	Battery Lease	Not Viable
	PIV Car Club	Strategically Attractive → Viable
Vehicle Service	Vehicle Maintenance	Strategically Attractive
	Battery Recycle	Strategically Attractive → Viable
Infrastructure (for base legislation)	Home Charge Post Manufacture	Strategically Attractive
	Conventional Charge Post Manufacture	Strategically Attractive → Viable
	Rapid Charge Post Manufacture	Strategically Attractive → Viable
	Charging Infrastructure Operation	Strategically Attractive
	Charging Infrastructure Ownership	Strategically Attractive
	Billing Services	Not Viable
Integrated Models	Battery Swap	Not Viable
	Complete System Integration	Not Viable

Conventional vehicle provision models offer OEMs viable business opportunities

Business model	Summary of viability	Viability in 2020
Vehicle Ownership	• PIV costs are reduced due to battery cost reductions and some OEMs achieving efficient production volumes. PIVs remain important to OEMs to achieve emissions targets, to establish brand and to develop technology to capture future growth in market. • Some OEMs can achieve low profit level, others price PIVs to achieve necessary sales volume to meet European fleet average emissions target. Supply can meet demand. • Total cost of ownership of PIV is moderately attractive to consumers. Lack of charging infrastructure limits BEV take-up to those who can work around it (used as second car), with consumers requiring flexibility favouring REEVs and PHEVs.	**Viable**
Vehicle Lease	• In addition to issues associated with Vehicle Ownership, lease premiums are reduced due to greater global take-up providing more confidence in residual values. • Lease is particularly attractive to OEMs to target the fleet market, where buyers judge on total cost of ownership. • Volumes are moderate, leading to low profits, but expectation is of a long term shift towards PIVs.	**Viable**
Battery Lease	• In addition to issues associated with Vehicle Ownership, battery lease premiums are reduced due to greater global take-up providing more confidence in technology and residual values. • Battery lease not viable due to significant barriers to consumer acceptance of this new ownership model combined with the relatively high proportion of REEVs and PHEVs, which offer less potential to modify up-front vehicle costs, due to their smaller batteries.	**Not Viable**
PIV Car Club	• Lower PIV costs make them financially viable as car club vehicles in areas where local authority support is available to install charge posts at home locations. Where this support is not available, charge post costs make PIVs uneconomic. • Lack of rapid charge infrastructure makes achieving high utilisation with BEVs impossible due to long charge times.	**Viable**

Moderate PIV volumes present strategically attractive after sales opportunities

Business model	Summary of viability	Viability in 2020
Vehicle Maintenance	• Market will be driven by consumer need for reassurance, allowing main dealers to leverage brand to provide a competitive advantage. • Investment will be required to train staff to maintain new vehicle types. It is currently uncertain who will make this investment (dealers or OEMs). • Maintenance volume will be low, due to moderate take-up and reduced maintenance requirement of PIVs, but steady due to necessity of maintenance. • Pressure to keep total cost of ownership of PIVs down discourages profit maximising pricing policies.	**Strategically Attractive**
Battery Recycle	• European legislation requiring PIV batteries to be recycled and requiring the producer to pay makes recycling viable, but margins are low. • Moderate take-up of PIVs and consumer enthusiasm for them promises a growing supply of batteries in volumes that justify investment in reconfiguration capabilities and development of a 2nd life market. Cap on value of battery storage for non-vehicle applications due to cheap alternatives, eg lead-acid likely to prevent high margins.	**Viable**

Higher PIV take-up creates opportunities for profitable investment in charging infrastructure

Business model	Summary of viability	Viability in 2020 Base Legislation	Viability in 2020 Alternative Legislation
Home Charge Post Manufacture	• Home charge post market strongly correlated with PIV take-up, so volumes will be moderate. • Low barriers to entry result in competitive industry with low profitability. • Model is strategically attractive in anticipation of future growth.	**Strategically Attractive**	**Strategically Attractive**
Conventional Charge Post Manufacture	• Low level of infrastructure roll-out means market is small so only a small number of companies can occupy this space profitably. • Volume is likely to be dominated by workplace charge posts. • If charging infrastructure can be regulated asset, public charge post roll out may be faster, enabling more firms to occupy this space profitably. • Low barriers to entry and potential difficulty establishing a sustainable competitive advantage likely to limit profitability.	**Viable**	**Viable**
Rapid Charge Post Manufacture	• Low level of infrastructure roll-out means market is small so only a small number of companies can occupy this space profitably. • If charging infrastructure can be regulated asset, public charge post roll out may be faster, increasing volumes and enabling more firms to operate profitably in this space. • Low barriers to entry (higher than for conventional charge post manufacture but little scope for IP ownership) and potential difficulty establishing a sustainable competitive advantage likely to limit profitability	**Viable**	**Viable**

Higher PIV take-up creates opportunities for profitable investment in charging infrastructure

Business model	Summary of viability	Viability in 2020 Base Legislation	Viability in 2020 Alternative Legislation
Charging Infrastructure Operation	• Home charge posts do not require operation services. • Workplace charge posts probably only require maintenance, as unlikely to be billed on a per use basis (this also applies to public charge posts provided free of charge). • Public charge posts billed on a per use basis could require full operation services. • Maintenance volumes will be closely correlated with workplace and public infrastructure rollout, as most non-domestic charge posts will require maintenance. Billing services and account management, which will be more prevalent in public charging, will have low volumes that are correlated primarily with the number of BEVs, as REEVs and PHEVs have less need to charge in public. Lack of charging infrastructure means parc dominated by REEVs and PHEVs. • Operators are employed in some cases, and although margins are squeezed anticipation is of greater demand in future. • If DNOs can install charging infrastructure as a regulated asset, operation becomes necessary, not just convenient, and makes it viable.	**Strategically Attractive**	**Viable**

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Higher PIV take-up creates opportunities for profitable investment in charging infrastructure

Business model		Summary of viability	Viability in 2020 Base Legislation	Viability in 2020 Alternative Legislation
Infrastructure Ownership	Home	• Home charge posts will be owned by the home owner for personal use. There will not be a business model in this space.	**Not Applicable**	**Not Applicable**
	Work-place	• Under current legislation workplace charge posts will be owned by the site/building owners and provided as an additional facility of the building for employees. • Charging posts unlikely to be operated for profit, so viability depends on perceived benefits to employers being worth the cost of charge posts. • If charging infrastructure can be regulated and an acceptable means to select workplaces for siting such infrastructure can be found, this change in legislation could significantly increase the rollout of workplace charge posts.	**Strategically Attractive**	**Attractive**
	Public	• Market for public charging is moderate due to moderate take-up of BEVs but prices are restricted by substitutes (REEVs, PHEVs and ICEVs). • Charging infrastructure owners derive indirect benefits (marketing; positioning or brand awareness benefits; differentiation from competitors in core business) that are greater because there are more BEVs, so model is strategically attractive. • If charging infrastructure can be a regulated asset, the relatively large take-up of PIVs should enable a relatively large rollout of charging infrastructure to be justified resulting in greater revenues for the DNOs.	**Strategically Attractive**	**Attractive**

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Higher PIV take-up creates opportunities for profitable investment in charging infrastructure

Business model	Summary of viability	Viability in 2020 Base Legislation	Viability in 2020 Alternative Legislation
Billing Services	• Viable when charging is billed on a per-use basis, which is likely to occur as the amount of infrastructure increases and the number of different owners increases. • If DNOs can install charging infrastructure as a regulated asset, a billing service will be essential to track usage and enable electricity cost to be billed to correct customer.	**Not Viable**	**Viable**

Barriers make integrated model viability unlikely, but lack of charging infrastructure presents an opportunity

Business model	Summary of viability	Viability in 2020 Base Legislation	Viability in 2020 Alternative Legislation
Battery Swap	• Barriers to this model make it unviable without significant change in consumer attitudes to vehicle ownership. • Reduced cost of BEVs combined with lack of charging infrastructure may present an opportunity for a company willing to invest in charging infrastructure to differentiate itself.	**Not Viable**	**Not Viable**
Complete System Integrator	• This model is unviable without significant change in consumer attitudes to vehicle ownership. • Reduced cost of BEVs combined with lack of charging infrastructure may present an opportunity for a company willing to invest in charging infrastructure to differentiate itself.	**Not Viable**	**Not Viable**

Green growth scenario

There are attractive opportunities in the PIV supply chain in the 'green growth' scenario

Industry	Business Model	2010 → 2020	2010 → 2020
Vehicle Provision	Vehicle Ownership	Viable	Viable
Vehicle Provision	Vehicle Lease	Viable	Attractive
Vehicle Provision	Battery Lease	Not Viable	Not Viable
Vehicle Provision	PIV Car Club	Strategically Attractive	Attractive
Vehicle Service	Vehicle Maintenance	Strategically Attractive	Strategically Attractive
Vehicle Service	Battery Recycle	Strategically Attractive	Attractive
Infrastructure (for base legislation)	Home Charge Post Manufacture	Strategically Attractive	Viable
Infrastructure (for base legislation)	Conventional Charge Post Manufacture	Viable	Viable
Infrastructure (for base legislation)	Rapid Charge Post Manufacture	Viable	Viable
Infrastructure (for base legislation)	Charging Infrastructure Operation	Strategically Attractive	Attractive
Infrastructure (for base legislation)	Charging Infrastructure Ownership	Strategically Attractive	Attractive
Infrastructure (for base legislation)	Billing Services	Strategically Attractive	Viable
Integrated Models	Battery Swap	Not Viable	Not Viable
Integrated Models	Complete System Integration	Not Viable	Not Viable

High take-up and change in consumer attitudes leads to attractive opportunities for conventional and novel business models

Business model	Summary of viability	Viability in 2020
Vehicle Ownership	• PIV costs reduced due to cheaper batteries and some OEMs achieving efficient volumes. PIVs remain important to OEMs to achieve emissions targets, to establish brand and to develop technology to capture future growth in the market. • Some OEMs can achieve low profit level, others priced to achieve sales volume necessary to meet European fleet average emissions target, but confidence in long term profit level. Overall supply can meet demand. • Extensive availability of charging infrastructure largely addresses range anxiety. Relatively large number of global PIVs proves technology and removes much of this perceived risk. • Total cost of ownership of PIVs is attractive to many consumers compared to ICEVs resulting in strong UK demand. BEVs bought as second cars and in urban areas. REEVs and PHEVs bought for those requiring greater convenience on longer journeys.	**Viable**
Vehicle Lease	• In addition to issues associated with Vehicle Ownership, lease premiums are reduced due to greater global take-up providing more confidence in residual values. • Lease is particularly attractive to OEMs to target the fleet market, where more buyers judge on total cost of ownership. • Profits are attractive and model is highly scalable.	**Attractive**
Battery Lease	• Significant shift in consumer attitude to vehicle ownership removes main barrier to this model. However, technology risk and high proportional cost of batteries are essentially mitigated by 2020, eliminating the drivers for this model.	**Not Viable**
PIV Car Club	• Reduced PIV costs make them economic for car club use. • Availability of rapid charge infrastructure enables high utilisations of BEVs. • Consumer attitudes to vehicle ownership shift significantly resulting in high take-up. • Opportunities exist for developing sustainable competitive advantage through brand, relationships with stakeholders, and organisational learning.	**Attractive**

High take-up makes battery recycling attractive in green growth scenario

Business model	Summary of viability	Viability in 2020
Vehicle Maintenance	• As market matures maintenance will be dominated by that associated with wearing components. Kwik-fit models (characterised by economies of scale) will prevail. Vehicle maintenance services will be offered by others for strategic reasons only, eg maintaining customer relationships. • Investment will be required to train staff to maintain new vehicle types. It is currently uncertain who will make this investment (dealers or OEMs). • Pressure to keep total cost of ownership of PIVs down discourages profit maximising pricing policies.	**Strategically Attractive**
Battery Recycle	• European legislation requiring PIV batteries to be recycled and requiring the producer to pay makes recycling viable, but margins are low. • High take-up of PIVs provides a growing supply of batteries in volumes that justify investment in reconfiguration capabilities and development of a 2nd life market, although residual values are capped by substitutes, eg lead acid batteries. • The model is scalable and the 7-10yr life of batteries allows accurate forecasting of future volumes giving low risk investment opportunities.	**Attractive**

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High take-up and removal of subsidies allows charging infrastructure to be owned and operated profitably in green growth scenario

Business model	Summary of viability	Viability in 2020 Base Legislation	Viability in 2020 Alternative Legislation
Home Charge Post Manufacture	• Need for home charge posts strongly correlated with PIV take-up, so volumes will be high. • Low barriers to entry result in competitive industry with low profitability. • Home charge posts are unlikely to be owned as regulated assets by DNOs, so business model is unaffected by regulation in this area.	**Viable**	**Viable**
Conventional Charge Post Manufacture	• High level of infrastructure rollout means market is large so a large number of companies can occupy this space profitably. • Volume likely to be dominated by workplace charge posts. • If charging infrastructure can be regulated asset, charge post rollout may be faster resulting in bigger market. • Low barriers to entry and potential difficulty establishing a sustainable competitive advantage likely to limit profits on unit sales.	**Viable**	**Viable**
Rapid Charge Post Manufacture	• High level of infrastructure rollout means market is relatively large so a large number of companies can occupy this space profitably. • If charging infrastructure can be regulated asset, charge post rollout may be faster resulting in bigger market. • Low barriers to entry (higher than for conventional charge post manufacture but little scope for IP ownership) and potential difficulty establishing a sustainable competitive advantage likely to limit profits on unit sales.	**Viable**	**Viable**

High take-up and removal of subsidies allows charging infrastructure to be owned and operated profitably in green growth scenario

Business model	Summary of viability	Viability in 2020 Base Legislation	Viability in 2020 Alternative Legislation
Charging Infrastructure Operation	• Home charge posts do not require operation services. • Workplace charge posts probably only require maintenance, as unlikely to be billed on a per use basis (this also applies to public charge posts provided free of charge). • Public charge posts billed on a per use basis could require full operation services. • Maintenance volumes will be closely correlated with take-up, as workplace charge posts may be used by all types of PIV. Billing services and account management, which will be more prevalent in public charging, will have volumes that are correlated with the number of BEVs, as REEVs and PHEVs have less need to charge in public. • Charging infrastructure owners employ operators in many cases and can make profits through scale efficiencies. • If DNOs can install charging infrastructure as a regulated asset, charging infrastructure operation becomes particularly attractive as DNO revenues are limited, so operators may be able to retain more profit.	**Attractive**	**Attractive**

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High take-up and removal of subsidies allows charging infrastructure to be owned and operated profitably in green growth scenario

Business model		Summary of viability	Viability in 2020 Base Legislation	Viability in 2020 Alternative Legislation
Infrastructure Ownership	Home	• Home charge posts will be owned by the home owner for personal use. There will not be a business model in this space.	Not Applicable	Not Applicable
	Work-place	• Workplace charge posts will be owned by the site/building owners and provided as an additional facility of the building for employees. • Charge posts unlikely to be operated for profit, so viability depends on perceived benefits to employers being worth the cost of charge posts. • If charging infrastructure can be regulated asset and an acceptable means to select workplaces for siting such infrastructure can be found, this change in legislation could significantly increase the rollout of workplace charge posts.	Strategically Attractive	Attractive
	Public	• Market for public charging is potentially large due to high take-up of PIVs, but depends on split between BEVs, which will charge in public, and REEVs & PHEVs, which are unlikely to charge in public. • Per usage payment is commonplace so organisations owning premium charge post locations have the potential to position themselves to operate with attractive profits, although prices will be capped by available substitutes to public charging, eg buying a REEV, PHEV or ICEV instead of a BEV. • If DNOs can install charging infrastructure as a regulated asset, the level of take-up should enable relatively large rollouts to be justified resulting in greater revenues making ownership attractive.	Attractive	Attractive

High take-up and removal of subsidies allows charging infrastructure to be owned and operated profitably in green growth scenario

Business model	Summary of viability	Viability in 2020 Base Legislation	Viability in 2020 Alternative Legislation
Billing Services	• Increased consumer confidence in BEVs and widespread infrastructure results in inter-city and inter-regional use, providing an opportunity for billing service providers to offer BEV users a common interface for multiple charging networks. • If DNOs can install charging infrastructure as a regulated asset, a billing service will be essential to track usage and enable electricity cost to be billed to correct customer.	**Viable**	**Viable**

Profitability of charging infrastructure in green growth provides significant competition to integrators trying to roll out attractive networks

Business model	Summary of viability	Viability in 2020 Base Legislation	Viability in 2020 Alternative Legislation
Battery Swap	• Despite a significant shift in consumer attitudes to vehicle ownership that removes one of the main barriers to this model, technical barriers in vehicle design make this model unlikely to be viable. • Profitable opportunities in charging infrastructure make it more difficult for a battery swapper to access premium charging locations.	**Not Viable**	**Not Viable**
Complete System Integrator	• Despite a significant shift in consumer attitudes to vehicle ownership that removes one of the main barriers to this model profitable opportunities in charging infrastructure make it more difficult for a complete system integrator to access premium charging locations.	**Not Viable**	**Not Viable**

Business model analysis

ARUP

Business model analysis:
Quantitative analysis assumptions 1/2

Some business model analyses include indicative quantitative analysis. Assumptions common to all these business models are summarised below. The following points should be noted:

- BEV data is based on published information about the Nissan Leaf, which will be available from 2011
- For comparison of BEV costs with ICEV costs an entry level Ford Focus has been considered. Small ICE hatchbacks are available for significantly less than the cost of a Ford Focus and if these are perceived as being comparable by consumers, this would impact on the cost comparisons
- Given the uncertainty in the parameters used in the calculations the cost of money is neglected for all but the most capital intensive and high risk investments, eg battery lease

BEV Data (based on Nissan Leaf)	2010	2015	
Performance			
Range (a)	**100**	**100**	miles
Battery capacity (b)	**24**	**24**	kWhr
Purchase Costs			
Vehicle cost (c)	**28,350**	**19,950**	£
Specific battery cost (d)	**700**	**350**	£/kWhr
Battery cost (e) = b x d	**16,800**	**8,400**	£
Chassis cost[1] (f) = c – e	**11,550**	**11,550**	£
Fuel Costs			
Wall to battery efficiency (g)	**85**	**85**	%
Charging energy required (h) = b / g	**28.2**	**28.2**	kWhr
Overnight electricity cost (i)	**0.06**	**0.06**	£/kWhr
Daytime electricity cost (j)	**0.15**	**0.15**	£/kWhr
Overnight charge cost (k) = h x I	**1.69**	**1.69**	£/charge
Daytime charge cost (l) = h x j	**4.24**	**4.24**	£/charge
Maintenance Costs			
Annual maintenance cost	**150**	**150**	£/yr

[1] The calculated chassis cost for the BEV appears to be low compared to the cost of the ICEV minus an expected engine and gearbox cost of around £2,500. BEV chassis are unlikely to be lower cost than ICEV chassis initially as scale efficiencies will not initially be achieved in BEV chassis production

Sources: 4, 17

Business model analysis:
Quantitative analysis assumptions 2/2

ICEV Data (based on Ford Focus)		
Performance		
Fuel efficiency (a)	**9.3**	miles/l
Purchase Costs		
Vehicle cost	**17,710**	£
Fuel Costs		
Fuel cost (b)	**1.20**	£/l
Fuel cost per mile (c) = b / a	**0.13**	£/mile
Maintenance Costs		
Annual maintenance cost	**400**	£/yr

Usage Data		
Average annual mileage	**10,000**	miles
% of trips over 100 miles	**13**	%

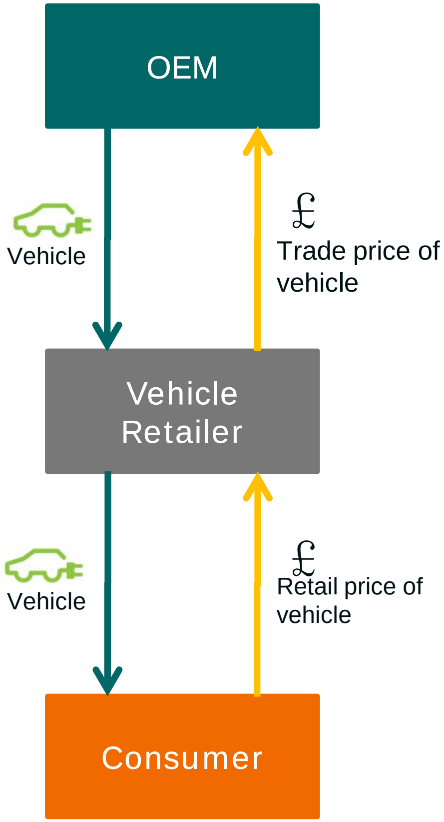
Residual Value at 4yrs Data		
BEV[2]	**16**	%
ICEV [55]	**30**	%

[2] BEV residual value estimated to be 10% at 5yrs [16]. Residual value at 4yrs estimated by applying same shape of depreciation curve as that for ICEV.

Sources: 4, 17

Business model analysis:
Vehicle Ownership 1/3

The vehicle retailer buys new vehicles from the manufacturer or second hand vehicles from the market then sells them to consumers at a profit. Vehicle retailers can be divided into manufacturers' dealerships, usually run on a franchise model, and independent dealerships.



Current and Analogous Experience

- In the UK vehicle ownership is one of the dominant models, with around 50% of new cars purchased outright [36].
- Currently available PIVs are provided using conventional business models, for example the G-Wiz is sold directly by Goin'Green.
- In 2007 and 2008 (2009 was distorted by the car scrappage scheme) private buyers accounted for around 43% of new car sales with fleets and businesses accounting for the remainder [39].

Enablers

- Vehicle ownership is a simple model for the consumer to understand, directly analogous to that for ICEVs.
- European consumers prefer vehicle ownership.
- Vehicle ownership is compatible with the current supply chain.

Barriers

- Purchase cost of PIVs will initially be high relative to equivalent ICEVs, which is one of the most important factors in the buying decision [5].
- Reliability of PIVs has not been proved in mass usage, so technology risk is high, which is an important factor in vehicle purchasing decisions [5].
- Residual values of PIVs are uncertain and this risk is carried by the consumer [16].
- Given the likely low level of sales, PIVs will be expensive to keep in stock and as demonstration vehicles.

Socio-Economic Benefits

- Replacing ICEVs with PIVs reduces local noise and air pollution.

Sources: 5, 16, 32, 36, 37, 38, 39, vii, viii

Business model analysis:
Vehicle Ownership 2/3

Strategic Risk

- The attractiveness of PIVs to consumers will depend on a number of factors subject to uncertainty:
    - Cost of running equivalent ICEVs (strongly correlated to price of oil if taxation is excluded) [5];
    - Technological developments;
    - Track record of PIVs in use [5];
- Second hand sales may require dealers to offer warranties on batteries, for which they will initially have little past experience (manufacturers are tending to offer long warranties on the electrical drive train [37]);
- Second hand value of PIVs will depend significantly on how quickly they become obsolete – subject to considerable uncertainty presently.

Political Risk

- The size of the PIV market will depend on a number of political factors:
    - Government subsidy of new PIVs;
    - Government policy, in particular taxation of liquid fuels and VED;
    - Government incentives and legislation to encourage the roll out of infrastructure;
    - Local authority incentives for PIVs, for example free parking, subsidised charging, congestion charge exemption.

Subsidy

- £230m has been proposed for subsidising the purchase cost of electric and plug-in hybrid cars, up to £5,000 per vehicle. £43m of the total has been confirmed for the first year of the scheme, running until March 2012 [38].
- At £5,000 per vehicle this is sufficient to subsidise 8,600 vehicles, which is compatible with forecast levels of take up in 2011 and 2012.

Legislation

- Manufacturers may produce and sell PIVs to help them meet the European fleet average emission target (see Appendix E). To sell the necessary volume of PIVs manufacturers may have to price them below cost, in which case they are likely to restrict supply to the minimum required to achieve the emissions target.
- Until 2015 the super-credits system will reduce the number of PIVs a manufacturer need sell to achieve the emissions target, which may exacerbate any restrictions on supply.
- Alternative approaches for manufacturers to achieve the emissions target include: developing small, efficient ICEVs; forming a pool with manufacturers with low emissions. The costs of bringing PIVs to market will be balanced against the costs of achieving the emission target by these (and other) alternative means.
- If the super-credit system is removed, as some environmental organisations are lobbying for [32], manufacturers using PIV sales to achieve the fleet average emissions target will have to sell more PIVs. In order to do this it may be necessary to reduce the price of PIVs.

Sources: 5, 16, 32, 36, 37, 38, 39, vii, viii

Business model analysis:
Vehicle Ownership 3/3

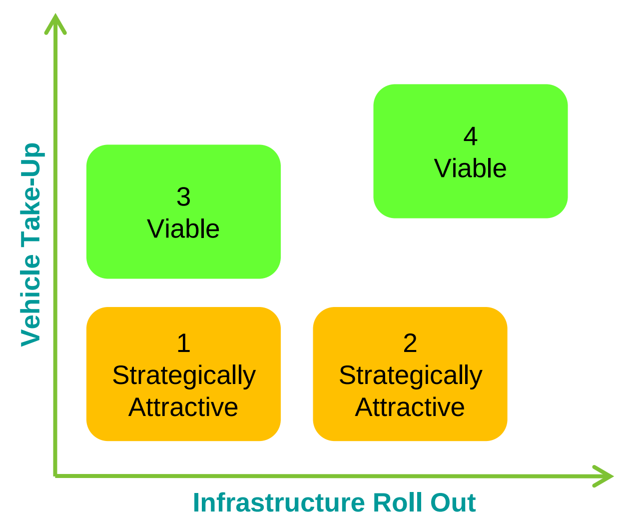
Business Opportunity and Quantitative Assessment

- Until such time as PIVs can be sold profitably by OEMs, supply and pricing is likely to be strongly driven by their strategies for meeting European fleet average emissions targets.
- Initially manufacturers' dealerships are likely to dominate the new and second hand market to provide consumer reassurance.
- The second hand market will rely on long OEM warranties or dealers to underwrite the condition of the battery.
- There is potential for main dealers to develop consumer relationships with a range of vehicles (PIV + ICEV, as many families have two cars).
- Business and fleet buyers are likely to be important during initial take-up of PIVs, giving opportunities for volume sales.
- £5,000 insufficient to make BEVs functionally or financially competitive with ICEVs.

	BEV (2011)	BEV (2020) by scenario		ICEV (by scenario)	
Purchase cost of vehicle	£28,350	3:£16,350	4:£16,350	£17,710	
		1:£28,350	2:£28,350		
Residual value at 4 years	16%	16%		30%	
Maintenance cost per year	£150	£150		£400	
Fuel cost per year	£169	£169		3:£1290	4:£2,585
				1:£1035	2:£1,290
4 year cost of ownership	£25,090	3:£15,010	4:15,010	3:£19,170	4:£24,340
		1:£25,090	2:25,090	1:£18,130	2:£19,170

- This is the default vehicle provision model and will therefore dominate for low vehicle take-up.
- PIV cost of ownership is attractive to consumers in green growth and PIV take-up leads PIV infrastructure scenarios, resulting in higher sales volumes making this business model more attractive in these scenarios.
- Green growth has highest volumes but also greatest associated change in consumer attitude. This is likely to make other vehicle provision business models more accessible in medium and long term.

Future Business Viability



Sources: 5, 16, 32, 36, 37, 38, 39, vii, viii

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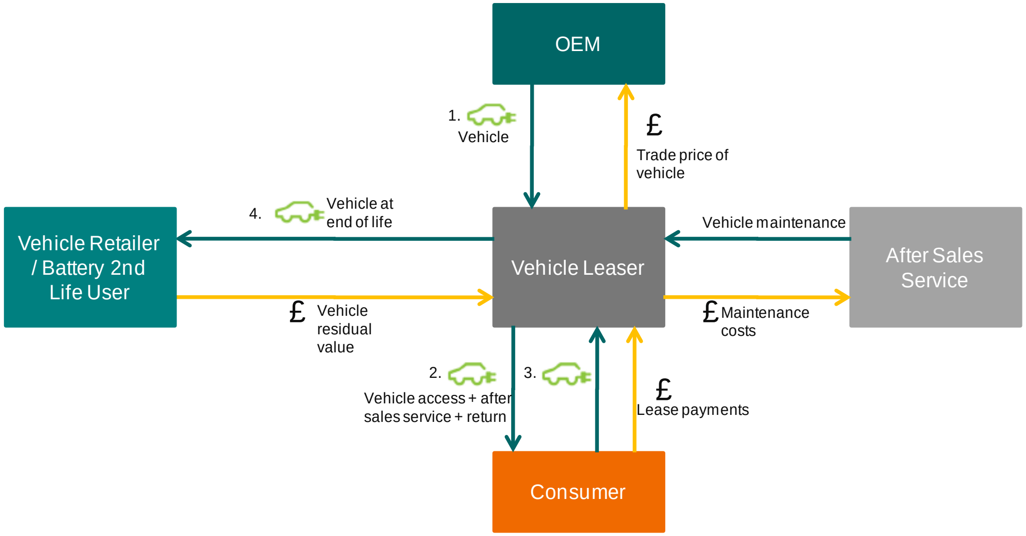
Business model analysis:
Vehicle Lease 1/3

The leaser buys a complete vehicle (chassis + battery) from a manufacturer and leases it to a consumer for a monthly fee. The lease fee includes maintenance costs, which the leaser pays to a main dealer. Once the vehicle reaches the end of its leasable life, the leaser recovers its residual value



Current and Analogous Experience

- Leasing is a planned business model for several forthcoming PIVs, for example the Mitsubishi i-MiEV and the Nissan Leaf.
- In 2007 and 2008 around 28% of new car sales were leased to fleets and businesses [39].

Enablers

- Reduces up-front cost that consumer must pay, which is an important factor in vehicle purchasing decisions [5].
- Familiar ownership model for consumers.
- Compatible with current supply chain.
- Favoured ownership model for business and fleet buyers, who are expected to be important in the initial take-up.
- Removes technology risk from consumer, which is an important factor in vehicle purchasing decisions [5].

Barriers

- Lease costs for PIVs will be significantly higher than for an equivalent ICEV.

Socio-Economic Benefits

- Replacing ICEVs with PIVs reduces local noise and air pollution.

Strategic Risk

- Technology risk, in particular lithium-ion batteries are unproven in power train application.

Sources: 5, 16, 32, 36, 38, 39, vii, viii

ARUP

Business model analysis:
Vehicle Lease 2/3

- Resale value of PIVs is difficult for leasers to assess:
  - Depends on rate at which cost of new PIVs reduces and the rate at which technology improves – subject to considerable uncertainty presently;
  - Depends on overall useful life of a PIV, which in turn depends on factors such as battery life;
  - Depends on future standardisation adopted, which is particularly critical for BEVs, which rely on public charging infrastructure for range extension. If battery swap becomes typical, only compatible BEVs will retain value;
  - Depends on second life uses for batteries;
  - Depends on external context such as oil price and consumer preferences when lease ends.

Political Risk

- The attractiveness of the PIV market and, crucially for leasing, the value of second hand PIVs will depend on a number of factors:
  - Government subsidy of new PIVs and whether this extends to leased PIVs;
  - Government policy, in particular taxation of liquid fuels and VED;
  - Government incentives and legislation to encourage the roll out of infrastructure;
  - Local authority incentives, for example free parking, subsidised charging;
  - The attractiveness of leasing vehicles for businesses is sensitive to government policy on vehicle lease related taxation and company car tax.

Subsidy

- The £230m consumer incentive programme for electric and plug-in hybrid cars, of which £43m has been confirmed [38], considered extending the subsidy to leased vehicles as well as owned vehicles [58]. Recent reports indicate that leased vehicles will not be eligible [57]. Full details of the scheme have not yet been released, so the eligibility of lease vehicles is unclear. This will have a significant impact on the attractiveness of leasing PIVs.
- At £5,000 per vehicle this is sufficient to subsidise 8,600 vehicles, which is compatible with forecast levels of take up in 2011 and 2012.

Legislation

- The main legislative issues are similar to Vehicle Ownership as they are driven by European fleet average emissions legislation.
- Company car taxation is based on vehicle CO_2 emissions (see Appendix E) and BEVs are taxed at the lowest rate of all vehicles (9%). This provides an incentive for company car drivers to select BEVs.

Sources: 5, 16, 32, 36, 38, 39, vii, viii

Business model analysis:
Vehicle Lease 3/3

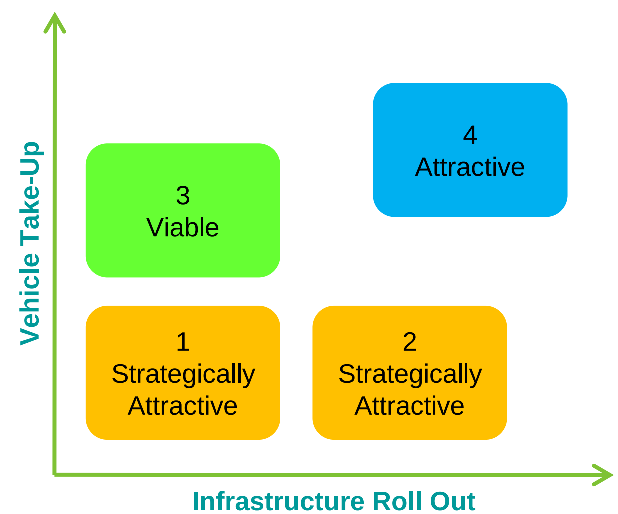
Business Opportunity and Quantitative Assessment

- Until such time as PIVs can be sold profitably by OEMs supply and pricing is likely to be strongly driven by their strategies for meeting European fleet average emissions targets.
- Business model considered to be attractive to consumers because it reduces the high up-front cost of PIVs; businesses and fleets likely to prefer lease model giving opportunities for volume.
- Significant and difficult to quantify commercial risk for the leaser will reduce once residual value data becomes available (around 5 years after significant volumes of PIVs first reach global market). Until then the multitude of unquantifiable risks likely to lead to very conservative pricing by the leaser.
- Meeting consumer drivers must be balanced against commercially quantifying the risks in PIV residual values and technology.

	BEV (2011)	BEV (2020 by scenario)		ICEV (by scenario)	
Purchase cost of vehicle	£28,350	3:£16,350	4:£16,350	£17,710	
		1:£28,350	2:£28,350		
Residual value after 4yrs	16%	16%		30%	
Lease premium on capital cost	100%	3:40%	4:30%	20%	
		1:60%	2:50%		
Lease cost per year	£13,040	3:£5,070	4:£4,660	£3,720	
		1:£10,210	2:£9,500		
Maintenance cost per year	£150	£150		£400	
Fuel cost per year	£169	£169		3:£1290	4:£2,585
				1:£1035	2:£1,290
4 year cost of ownership	£53,440	3:£21,550	4:£19,920	3:£21,650	4:£26,820
		1:£42,100	2:£39,270	1:£20,610	2:£21,650

- Business model is attractive to consumers relative to ICEV leasing in green growth scenario, although total cost of ownership is around 1/3rd greater than BEV ownership (because significant risk is transferred from the consumer to the leaser) or battery lease (because only the risk associated with the battery is transferred to the leaser).
- Green growth has highest volumes but also greatest associated change in consumer attitude. This is likely to make other vehicle provision business models more accessible in medium and long term.

Future Business Viability

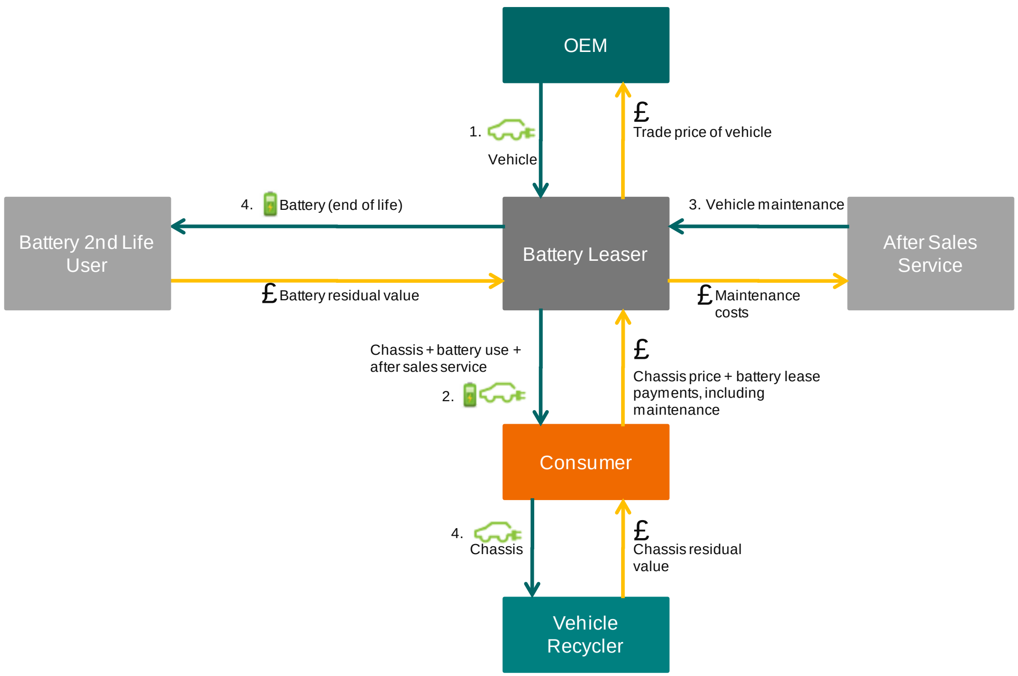


Sources: 5, 16, 32, 36, 38, 39, vii, viii

Business model analysis: Battery Lease 1/3

The battery leaser buys a complete vehicle (chassis + battery) from a manufacturer and then sells the chassis to a consumer and leases the battery for a monthly fee. The lease fee includes maintenance costs, which the battery leaser pays to a main dealer

Once the battery reaches the end of its leasable life, the leaser recovers its residual value. Ideally this would coincide with the termination of the battery lease contract. The consumer could then take out a new battery lease contract, in which case the battery leaser would purchase a replacement battery from the OEM, replace the battery themselves, or recover the residual value of the chassis



Current and Analogous Experience

- Battery leasing is a model offered by Modec, a commercial electric vehicle manufacturer. Customers can buy an electric van body and lease a battery for 4 or 5 year periods.
- Battery leasing does not yet exist in the consumer PIV market but is being proposed by Renault [40], although partner Nissan has decided against battery leasing [57].
- In a consumer context there is acceptance of the Calor Gas model where Calor Gas owns the bottle and the consumer buys gas by exchanging their empty bottle for a full one.
- In a commercial context airline engines can be leased separately from aircraft bodies. This is similar to the concept of leasing a vehicle battery separately from the vehicle chassis. Within this context the contractual issues with different ownership of different parts of a system have been resolved, albeit on a B2B rather than a B2C basis.

Enablers

- Reduces up-front cost of PIVs, which encourages take-up.
- Removes the most significant technology risk from consumer.
- Brings the cost structure of PIVs more in line with ICEVs.
- These enablers apply more strongly to PIVs where the battery makes up a large proportion of the vehicle cost. This is likely to be BEVs and some larger REEVs with longer electric range.

Barriers

- Ownership model is unfamiliar to consumers. OEM experience suggests consumers are uncomfortable with not owning the whole vehicle.

Sources: 5, 32, 38, 40, 41, vii, viii

Business model analysis:
Battery Lease 2/3

- Contractual issues for the battery leaser and the vehicle owner:
    - In case of the battery leaser terminating the service where would a consumer get a battery from and how much would it cost;
    - In case of default on battery lease payments, could the battery easily be recovered – this issue may have contributed to Nissan's decision not to go down a battery lease route [57];
    - CAP Monitor are influential and their opposition to this model is important [41].

Socio-Economic Benefits

- Replacing ICEVs with PIVs reduces local noise and air pollution.
- Newer batteries will be used in PIVs, resulting in more efficient use of electricity.

Strategic Risk

- Technology risk, in particular lithium-ion batteries are unproven in power train application.
- Residual value of batteries is difficult for leasers to assess:
    - Depends on rate of change of battery technology and price;
    - Depends on policy environment when lease ends;
    - Depends on second life use for batteries being found and cost of substitute technologies (eg power stations may use batteries, but cost would need to be competitive with hydro-electric storage).

Political Risk

- The attractiveness of the battery leasing within the PIV market will depend on a number of factors:
    - How government subsidy of new PIVs applies to battery leased vehicles;
    - Government policy, in particular taxation of liquid fuels and VED;
    - Government incentives and legislation to encourage the roll out of infrastructure;
    - Local authority incentives, for example free parking, subsidised charging;

Subsidy

- It is unclear how the £230m consumer incentive programme for electric and plug-in hybrid cars, of which £43m has been confirmed [38], would apply to PIVs provided under a battery lease model. The subsidy could apply to the whole vehicle cost, or just to that part of the vehicle that is bought outright, in which case this could affect the amount of the subsidy since it is more likely that the 25% value of the vehicle chassis would be lower than £5,000. This could have a significant effect on the attractiveness of battery lease.
- At £5,000 per vehicle this is sufficient to subsidise 8,600 vehicles, which is compatible with forecast levels of take up in 2011 and 2012.

Legislation

- The main legislative issues are similar to Vehicle Ownership as they are driven by European fleet average emissions legislation.
- Battery recycling legislation that makes battery producers liable for recycling costs may make it more attractive to OEMs to battery lease to retain greater control over the batteries, so they can minimise end of life costs, eg through second life uses.

Sources: 5, 32, 38, 40, 41, vii, viii

Business model analysis:
Battery Lease 3/3

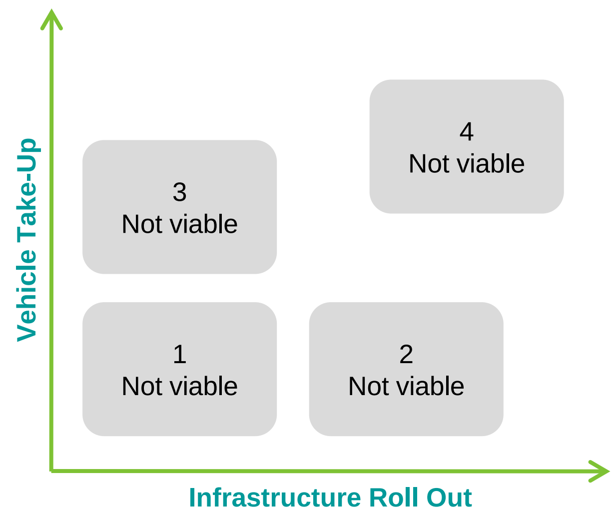
Business Opportunity and Quantitative Analysis

- Until such time as PIVs can be sold profitably by OEMs supply and pricing is likely to be strongly driven by their strategies for meeting European fleet average emissions targets.
- Model enables cost structure of PIV to be manipulated to encourage take-up, offering potential to capture larger portion of the market.
- Potential for long term relationship with consumer, as they will own the car for longer than a typical lease, and will need a battery for that period.

	BEV (2011)	BEV (2020 by scenario)		ICEV (by scenario)	
Purchase cost of vehicle				£17,710	
Purchase cost of chassis	£11,550	£11,550		N/A	
Purchase cost of battery	£16,800	3:£4,800	4:£4,800	N/A	
		1:£16,800	2:£16,800		
Lease premium on capital cost	100%	3:40%	4:30%	N/A	
		1:60%	2:50%		
Battery residual value at 4 yrs	£4,200	3:£1,200	4:£1,200	N/A	
		1:£4,200	2:£4,200		
Residual value after 4yrs	N/A	N/A		30%	
Lease cost per year	£6,300	3:£1,260	4:£1,170	N/A	
		1:£5,040	2:£4,730		
Maintenance cost per year	£150	£150		£400	
Fuel cost per year	£169	£169		3:£1290	4:£2,585
				1:£1035	2:£1,290
4 year cost of ownership	£36,180	3:£16,020	4:£15,660	3:£19,170	4:£24,340
		1:£31,140	2:£29,880	1:£18,130	2:£19,170

- Battery lease attractive to consumers relative to ICEV for PIV take-up leads PIV infrastructure and green growth scenarios.
- Battery lease 4 year cost of ownership close to vehicle ownership total cost of ownership for higher take-up scenarios, where residual value and technology risks are lower.
- Consumers expected to be reluctant unless expectations and behaviour changes significantly, ie green growth scenario. Yet green growth scenario is that in which technology risk and high proportional cost of batteries are essentially mitigated.

Future Business Viability

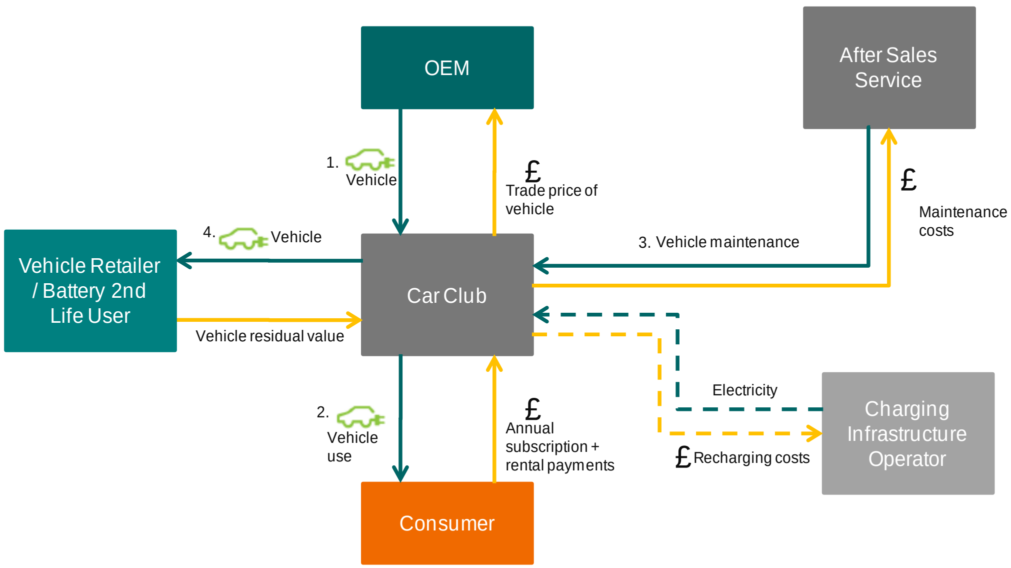


Sources: 5, 32, 38, 40, 41, vii, viii

Business model analysis:
PIV Car Club 1/3

The car club buys a PIV from the manufacturer and pays an after sales service organisation for maintenance of the vehicle. A consumer pays an annual membership fee for access to the car club then a per use rental fee for use of the car

This business model considers the feasibility of existing or new car clubs operating PIVs as part of a potentially mixed fleet of BEVs, REEVs, PHEVs and ICEVs.



Current and Analogous Experience

- Streetcar is the UK's largest car club. It started in 2004 and now has 80,000 members and 1,100 vehicles, which have replaced on average 26 privately owned vehicles each. 26x1,100 = 28,600, which is about 0.1% of the UK parc [11]. It hit profitability in 2008 [42].
- There are 127,000 members of car clubs in the UK [43].
- Car clubs are generally set-up with local authority backing to enable public parking spaces to be used.
- There have been some trials of PIVs by Zipcar and Streetcar with local authority backing [44].

Enablers

- Currently reduces the up front cost of accessing a PIV.
- Reduces the importance of range anxiety as most car club journeys are well within the range of current BEVs [45].
- Reduces the importance of widely distributed public infrastructure for same reason as above.
- Lower maintenance requirements of PIVs reduce running costs and down time for car club operator.

Barriers

- High cost of PIVs will be reflected in the per use charge and will make PIVs less attractive vs ICEVs – research shows that primary reason for joining a car club is cost saving [11].
- High capital cost, low running cost structure of PIVs is more difficult for car clubs to finance (they may lease vehicles instead).
- In addition to the cost of the PIV, car club must also ensure a charge post is installed at base location.

Sources: 11, 32, 38, 42, 43, 44, 45, 46

Business model analysis:
PIV Car Club 2/3

- Conventional charge time is up to 8hrs or more preventing high vehicle utilisation; rapid charging posts are expensive and there are concerns they have a detrimental effect on batteries.

Socio-Economic Benefits

- Replacing ICEVs with PIVs reduces local noise and air pollution.
- Reduces number of vehicles on the road, reducing land required for parking.
- Results in changed driver behaviour, reducing traffic volumes.
- Results in newer, cleaner vehicles on the streets.
- Provides an opportunity to expose a large number of people to PIVs encouraging further uptake.

Strategic Risk

- Running costs of PIV relative to ICEV depends on factors such as oil price, technology development.
- Residual value of PIV is dependent on factors that are unpredictable, for example oil price, technology development resulting in obsolescence.
- Residual value of PIVs depends on future PIV model adopted e.g. battery swap model - only vehicles that remain compatible will retain value.

Political Risk

- The viability of car clubs is significantly affected by local government policy as set out in Local Authority Transport Plans.
- The financial attractiveness of running a PIV as a car club vehicle depends on:
    - Cost of PIVs relative to ICEVs, which depends on government incentives such as vehicle subsidies and taxation.
    - Depreciation of PIVs, which depends partly on government policy at the time of resale.

Subsidy

- £230m has been proposed for subsidising the purchase cost of electric and plug-in hybrid cars, up to £5,000 per vehicle. £43m of the total has been confirmed for the first year of the scheme, running until March 2012 [38]. Business fleets will be eligible for the subsidy, so car clubs, if they purchase PIVs would be eligible.
- At £5,000 per vehicle this is sufficient to subsidise 8,600 vehicles, which is compatible with forecast levels of take up in 2011 and 2012.

Legislation

- The legislative issues described in Vehicle Ownership apply as they are driven by European fleet average emissions legislation.
- Many local authorities are introducing requirements for ultra low carbon vehicles and charging posts within the planning application process for new developments, which could provide a good opportunity for car clubs [46].

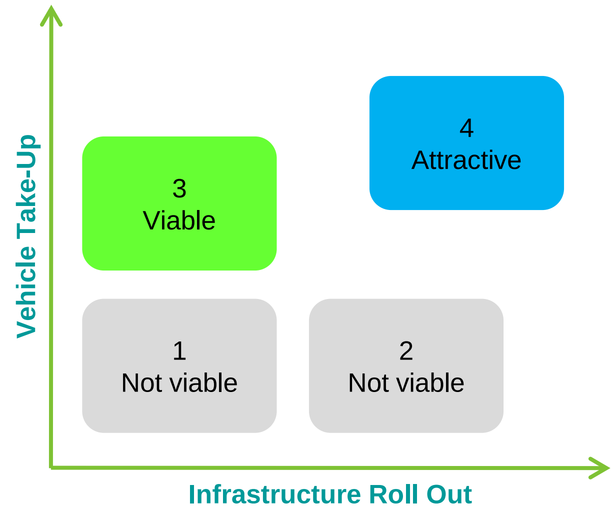
Sources: 11, 32, 38, 42, 43, 44, 45, 46

Business model analysis:
PIV Car Club 3/3

Business Opportunity and Quantitative Assessment

- Consumer appetite for car club model is driven primarily by cost savings over other forms of ownership, so economic viability of PIVs for car club operators depends on total cost of operation relative to ICEVs.
- To achieve low hourly rental fees, car club vehicles must achieve high utilisation. For BEVs this is not possible with conventional charging infrastructure but may be possible with rapid charging infrastructure.
- High take-up of car club membership depends on a significant shift in consumer attitudes toward vehicle ownership and mobility.
- PIV take-up leads infrastructure roll-out and green growth scenarios provide economically viable REEVs and PHEVs for car club operation.
- Only the green growth scenario provides the necessary conditions for attractive operation of BEVs by car clubs:
    - BEV cost of ownership attractive relative to ICEV
    - High levels of infrastructure assumed to include rapid charging
    - Significant shift in consumer attitudes toward vehicle ownership
- Operating BEVs in a car club model is likely to be more viable as part of a mixed fleet, rather than as a BEV only fleet, as vehicles with a broader range of capability can be offered – BEVs for short journeys, REEV, PHEV or ICEV for journeys beyond the range of a BEV.

Future Business Viability

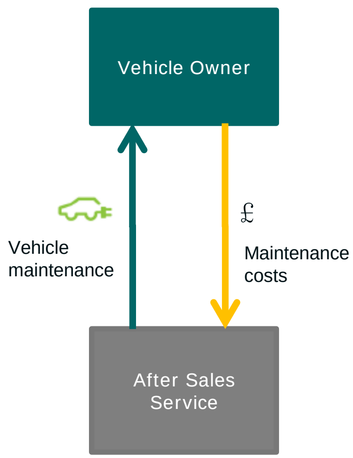


Sources: 11, 32, 38, 42, 43, 44, 45, 46

Business model analysis:
Vehicle Maintenance 1/2

The after sales service organisation maintains and services PIVs (and probably ICEVs too). Many of the business models suggested for the PIV market would result in the after sales service organisation dealing with fleet owners, rather than individuals.

Breakdown services are not considered within this model. PIVs are expected to be more reliable than ICEVs and therefore there will be less demand for breakdown services. There may be a niche opportunity for an 'emergency charging' service to provide reassurance to BEV drivers with range anxiety.



Current and Analogous Experience

- Existing hybrid vehicles can be maintained at main dealers and, due to removal of block exemptions for car maintenance, also at independents (see Appendix E). A number of independent garages now offer hybrid servicing.
- Maintenance costs of hybrids are currently similar to ICEVs.

Enablers

- This service is required for every PIV sold, so there is a guaranteed market, although its size depends on take-up.
- Main dealers are likely to have an advantage in terms of receiving support from OEMs to develop expertise in PIVs.
- Those parts of PIVs that are different from ICEVs (electric drive train) are expected to be very reliable [4], so most maintenance tasks will be familiar to existing mechanics.

Barriers

- Technology is new, so investment will be required in training and possibly equipment for maintenance.
- Volumes will be low in the short term.
- Maintenance requirements are expected to be significantly lower than for ICEVs [4].

Socio-Economic Benefits

- Supports the replacement of ICEVs with PIVs, which reduces local noise and air pollution.

Sources: 4, xii, xiii

Business model analysis:
Vehicle Maintenance 2/2

Strategic Risk

- As technology becomes better proven, PIV maintenance requirements may be reduced below their already low levels.
- Technology may change rapidly, resulting in high levels of investment to maintain expertise.

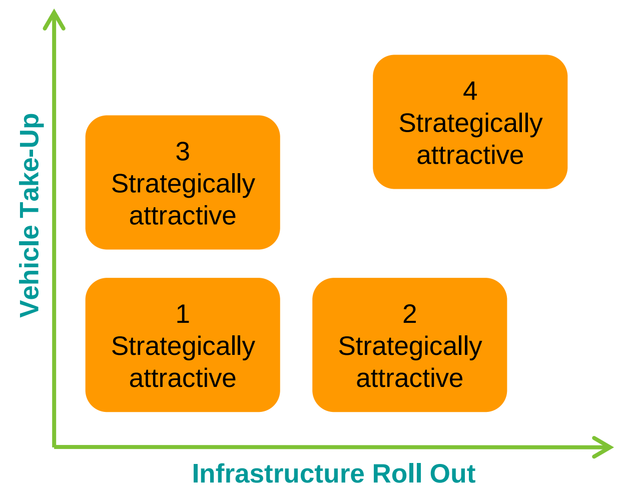
Political Risk

- No political risks have been identified.

Subsidy and Legislation

- European regulations that came into force on 1 June 2010 (see Appendix E) have reduced the extent to which manufacturers can protect their dealer networks' repair and maintenance business.
- From a legislative perspective independent repair and maintenance organisations should have reasonable access to the after sales market for PIVs.

Future Business Viability



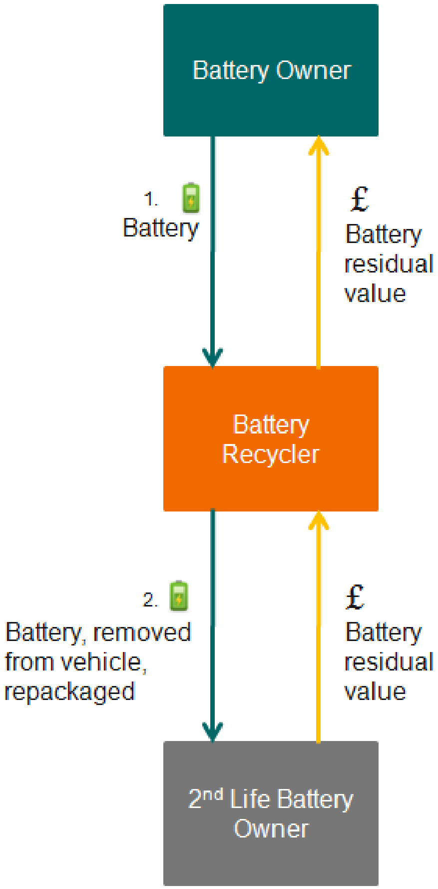
Business Opportunity

- For low take-up scenarios main dealers benefit from high barriers to entry and consequent competitive advantage. Potential for profit maximising is limited by the need to make PIV costs attractive to consumers.
- When market matures, most maintenance is expected to be on wearing components, eg brakes, tyres, etc, which may favour organisations such as Kwik Fit over the main dealers.
- Of strategic value only to maintain consumer relationship and confidence and support another core business.

Sources: 4, xii, xiii

Business model analysis:
Battery Recycle or Reuse 1/3

The battery recycler buys end of life batteries from battery owners, removes them from the vehicle and either recycles them for materials, or repackages them and sells them on for a second life use



Current and Analogous Experience

- Domestic battery recycling rates are low in the UK (3%). Increasing this rate is being driven by legislation placing responsibility on retailers and producers to pay costs [47]. Recycling rates for car batteries are much higher at around 90% [48].
- Producer compliance costs expected to be around 30p/kg [47].
- Toyota has a system in place to recycle batteries from old Prius cars, but lithium-ion batteries are less economic to recycle than the Prius nickel-metal hydride batteries due to lower material costs [8].

Enablers

- Batteries are expected to be unsuitable for power train, where power/charge to weight ratio is important, when their performance drops to 80% of their initial performance [4].
- For applications where power/charge to weight ratio is less important batteries with 80% performance may be of value, eg storage for wind farms [7].
- Most of the battery materials can be recycled, eg Toyota Prius batteries can be completely recycled [8, 9].
- There will be strong incentives for PIV batteries to be reused or recycled as this contributes to their sustainable image, which will be important to many consumers.

Barriers

- Lack of standardisation of batteries will make repackaging more difficult.
- Alternative battery types, eg lead-acid, likely to cap the value of PIV batteries in second life applications where energy and power density are not critical.

Sources: 4, 6, 7, 8, 9, 47, 48, xii

ARUP

Business model analysis:
Battery Recycle 2/3

Socio-Economic Benefits

- Supports the PIV market by reducing overall cost of ownership of PIVs, which reduces local noise and air pollution.
- Reduces waste.

Strategic Risk

- Second life application and value of batteries depends somewhat on:
  - Technology risk, until such time as battery technology is proven for long term use;
  - The reliability of battery performance characteristics.
- This business model relies on establishing strong relationships with OEMs as they are responsible for financing the costs of recycling waste batteries.

Political Risk

- Second life application for batteries is desirable, but depends somewhat on:
  - Political risks associated with government policy in the future.
- Second life value of batteries will depend on a number of factors:
  - Government legislation, for example on carbon cost;
  - The rate at which renewable generation is added to the grid.

Subsidy

- Battery recycling is unlikely to be affected by subsidies.

Legislation

- European batteries directive (see Appendix E), introduced in 2008:
  - Bans the landfilling and incineration of automotive batteries;
  - Makes the battery producer responsible for the costs of recycling waste batteries.
- This legislation guarantees a market for battery recyclers.

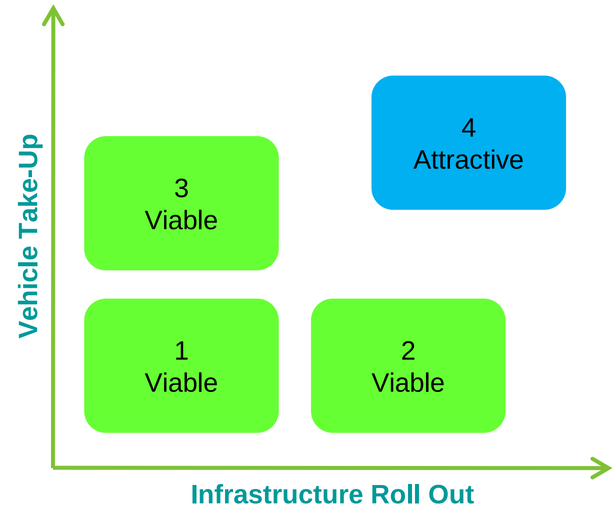
Sources: 4, 6, 7, 8, 9, 47, 48, xii

Business model analysis:
Battery Recycle 3/3

Business Opportunity Assessment

- The market for battery recycling is guaranteed through European legislation requiring automotive batteries to be recycled and placing the responsibility for financing this on the producers.
- A strong second life market for vehicle batteries will reduce the costs of ownership of PIVs, by enabling residual value to be recovered from batteries at the end of their automotive life.
- For all but the fastest take-up scenario there will be insufficient batteries reaching the end of their first life in the next 10 years to justify the investment associated with reconfiguring batteries for second life. However, in this scenario the risks and second hand value would be fully quantified by 2020; demand would be high; technological and logistical barriers would be overcome.

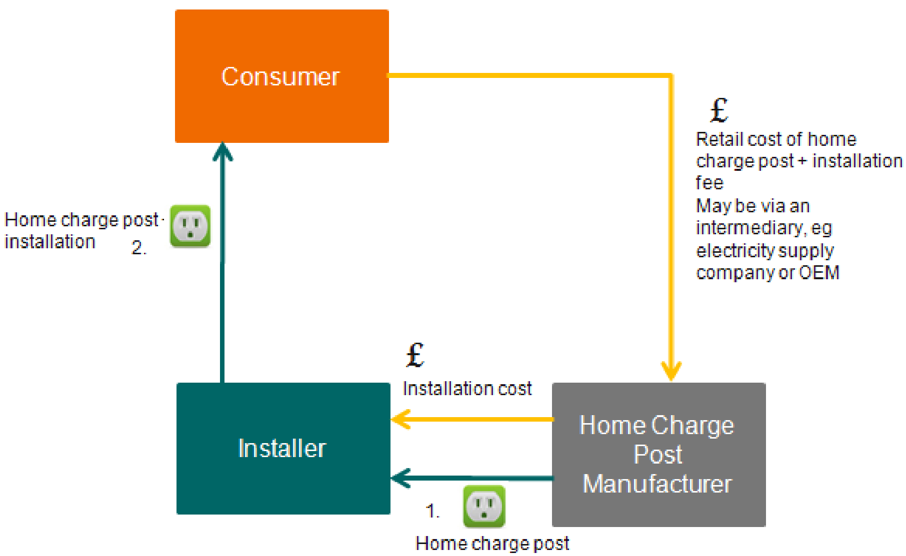
Future Business Viability



Sources: 4, 6, 7, 8, 9, 47, 48, xii

Business model analysis:
Home Charge Post Manufacture 1/3

The Home Charge Post Manufacturer manufactures and installs charge posts suitable for domestic use. These are a particular requirement for homes with off-street but no garage parking to facilitate overnight charging.



Current and Analogous Experience

- At present most drivers charge at home from a 13A supply.
- Sockets are generally standard 13A or 16A sockets, although domestic charge posts are available, eg from Charge Master [49].

Enablers

- Most PIV charging will occur at home [1],[18].
- Technology is currently quite basic (single phase power sockets), uses existing domestic power infrastructure and is easy to install.
- Smart metering in domestic residences may interface with charge posts and electricity supply companies to ensure electricity supply and demand for PIV charging matches (i.e. only allowing charging when there is sufficient electricity supply).
- Qualified electricians able to carry out installation at low cost, making route to market via domestic installers attractive. Also straightforward for manufacturer or other stakeholder to recruit in-house installation capability.
- Shared domestic charging networks, where PIV drivers join a club which allows them to charge at any other club members' domestic charge post, for example the EV Network UK, would be likely to increase demand for a domestic charge post over basic sockets.

Barriers

- Instead of installing a home charge post, consumers could install a conventional socket, in their garage, or a conventional exterior socket, on their driveway. This alternative will restrict the price that can be charged for more sophisticated home charging products.

Sources: 1, 18, 49, iv, vi

Business model analysis:
Home Charge Post Manufacture 2/3

Socio-Economic Benefits

- Home charging will tend to be overnight when the marginal CO_2 cost of electricity is low.
- Successful businesses in this space may make PIVs more viable helping to increase take-up, resulting in lower local noise and air pollution.
- Home charge posts could facilitate more convenient shared domestic charging networks, which could provide an extensive charging network very quickly and at low cost to the government.

Strategic Risk

- A shift to specialist charging technology such as inductive charging could be a risk to existing and potential new charge post businesses. Licensing and manufacture costs of inductive charge posts may be much greater than the current costs of plug-in charge posts due to strong IP.
- Low barriers to entry, difficult to establish and maintain a competitive advantage except through network effects that might come from smart metering and partnership with infrastructure operators.
- Domestic electricians and installers can purchase and install standard socket outlets (including weatherproof sockets). If data exchange via the charge point is required, this barrier may cease as consumers will have to buy from specialist charge point manufacturers.
- Limited repeat business or churn unless product features develop rapidly with onset of smart metering (high infrastructure deployment scenarios).

Political Risk

- Viability of home charge post manufacture closely correlated to PIV take-up, which depends on government incentives, eg purchase subsidy, taxation.

Subsidy and Legislation

- Home charge posts are unlikely to be directly influenced by subsidies or legislation, but will benefit or be adversely affected by subsidies and legislation that affect PIV take-up.
- The regulated asset status of charging infrastructure is considered unlikely to have a significant effect on the home charging market. Even if the inclusion of charging infrastructure on DNOs' regulated asset bases is facilitated, home charging infrastructure is likely to remain the responsibility of the home owner.

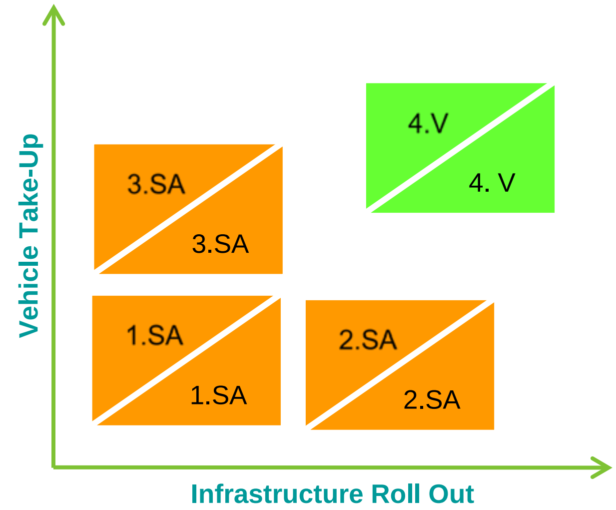
Sources: 1, 18, 49, iv, vi

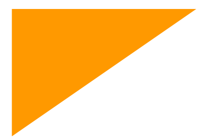
Business model analysis:
Home Charge Post Manufacture 3/3

Business Opportunity & Quantitative Assessment

- Currently revenues are limited to unit sales of charge posts.
- Growing demand for billing and data service requirements associated with charge posts will require integrated data/power charge post provision from specialist charge post providers [1].
- Need for home charge posts strongly correlated with take-up of PIVs but limited repeat business opportunity.
- Low barriers to entry result in competitive industry with low profitability.
- Business model only likely to be viable in high take-up scenarios or as part of a vertically integrated model with charging infrastructure operators.
- Legislation does not influence the final viability assessment for home charge post manufacture.

Future Business Viability





Assessment of viability for charging infrastructure not designated as a regulated asset

Assessment of viability for charging infrastructure designated as a regulated asset

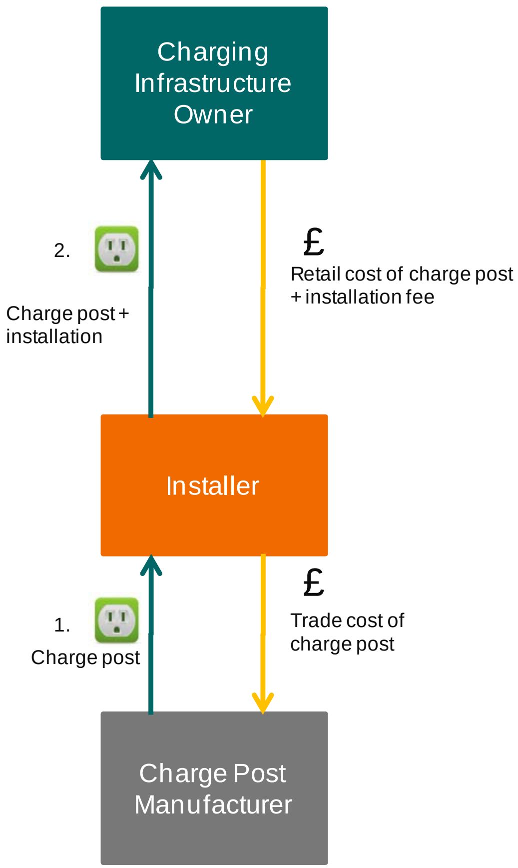
Sources: 1, 18, 49, iv, vi

ARUP

Business model analysis:

Conventional Charge Post Manufacture 1/3

The manufacturer sells, installs and potentially maintains charge posts suitable for non-domestic use, e.g. for workplaces, supermarkets, local authorities, etc.



Current and Analogous Experience

- There are 6-8 significant existing manufacturers offering conventional charge posts, for example Chargemaster, Pod Point, and Elektrobay.
- There are estimated to be 200 to 300 publically available charge points in the UK, so the current market is small [50].

Enablers

- Existing power infrastructure at a distribution level is sufficient to support workplace and public charge posts in all early market stage scenarios [1].
- Lack of charging infrastructure contributes to range anxiety which is a barrier to BEV take-up. Rapid charge post rollout is likely to be encouraged by the public sector if take-up acceleration is sought.
- Growing demand for billing and data service requirements associated with charge posts, provides a need for a specialist charge post provider that can handle charging, billing, and data information transfer services.
- Access to a number of qualified sub-contractors with ability to form cost effective strategic partnerships.

Barriers

- Some legislative uncertainty in relation to public charge posts and the associated cabling may limit demand.

Socio-Economic Benefits

- No specific benefits, but successful businesses in this space may make BEVs more viable helping to increase take-up, resulting in lower local noise and air pollution.
- Facilitating workplace charging enables some consumers without off-street parking to conveniently operate a PIV.

Sources: 1, 19, 50, iv, v, vi

Business model analysis:
Conventional Charge Post Manufacture 2/3

Strategic Risk

- There are a number of conventional charge post technologies using different powers (3.5kW and 7kW) and different connections (plug+cable and inductive). The success of different organisations may depend on which technologies become the industry standard.
- Conventional charge posts must compete with other forms of public charging, eg shared domestic charging networks, rapid charge posts and battery swap.
- Electricity distribution network capacity, may constrain investment in charging infrastructure in the long term.
- Business model viability requires cooperation and potentially significant investment from the public sector.

Political Risk

- Size of charge post market will depend on a number of factors:
  - PIV take-up, which in turn depends on government subsidy of vehicles, taxation;
  - Mix of BEVs, which have greater dependency on workplace and publicly accessible charging infrastructure, and REEVs & PHEVs, which can extend range using their ICE and the existing liquid fuel infrastructure.
  - Government subsidy of charging infrastructure;
  - Government legislation, in particular whether conventional charge posts can be considered as regulated assets by DNOs.

Subsidy

- The size of the conventional charge post market depends initially on the pace of charging infrastructure roll-out, which depends on expected requirements (based on expected BEV take-up) and on the total cost of installation.
- The cost to install charge posts is often subsidised, for example by the Plugged-in-Places scheme, which offers 50% government funding of charging infrastructure projects to successful applicants. These subsidies make infrastructure installation more attractive and should encourage faster infrastructure roll-out.

Legislation

- Designation of charge posts as a regulated asset could lead to earlier and more extensive infrastructure roll-out as DNOs would be able to guarantee a return on their investment and could potentially invest in anticipation of future demand (see Appendix E).
- In this case the charge post operator would pay an electricity supplier for energy usage and network usage charges and the electricity supplier would pay the DNO the network usage charges. The amount of the network usage charge would depend on how the DNO spread the cost of the charge posts over its users.

Sources: 1, 19, 50, iv, v, vi

Business model analysis:

Conventional Charge Post Manufacture 3/3

Business Opportunity and Quantitative Assessment

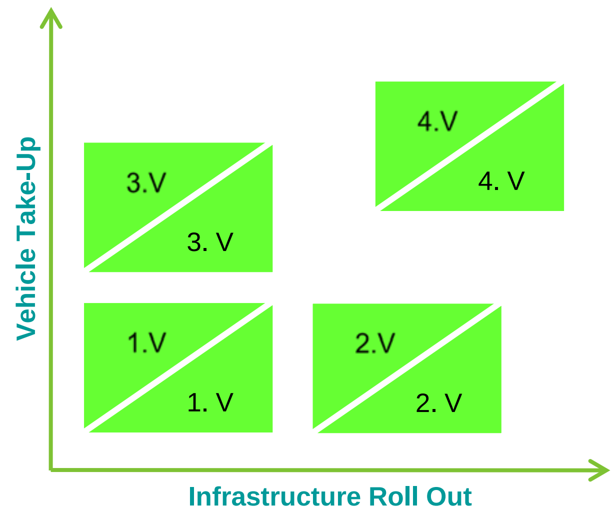
- Success is dependent on direct relationships with private / public sector commissioning rollout of charge posts, opportunities exist to become a preferred infrastructure supplier [19].
- Low barriers to entry and potential difficulty establishing a sustainable competitive advantage likely to limit viability of the business model if it is reliant on unit sales alone.

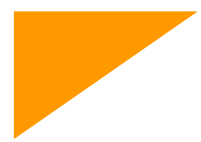
Conventional charge post	2010
Investment Costs	
Installed cost of charge post	£5,000
Assumed life of charge post (yrs)	5
Cost per year	£1,000
Operating Costs	
Price of electricity (£/kWhr)	£0.15
Battery charge required (kWhr)	28.2
Electricity cost per charge	£4.24
Operating / billing costs per charge	£1.00
Usage Assumptions	
Charges per year (approx. 2 per day)	700
Asset cost per charge	£1.43
Total	
Total cost of charge to break even	£6.66

- The combination of fixed and marginal costs are around £6 to £7 for a five year payback period. Consumer willingness to pay for public charging has not yet been tested but could conceivably be sufficiently high to allow profitable operation.
- Different scenarios do not directly influence viability, but do influence PIV infrastructure market size. Economies of scale will therefore determine how many companies can be successful in this space.

- Conventional charge post manufacture viability is not significantly affected by legislation. Legislation may affect who their customer will be and order sizes, but not the underlying model.

Future Business Viability





Assessment of viability for charging infrastructure not designated as a regulated asset

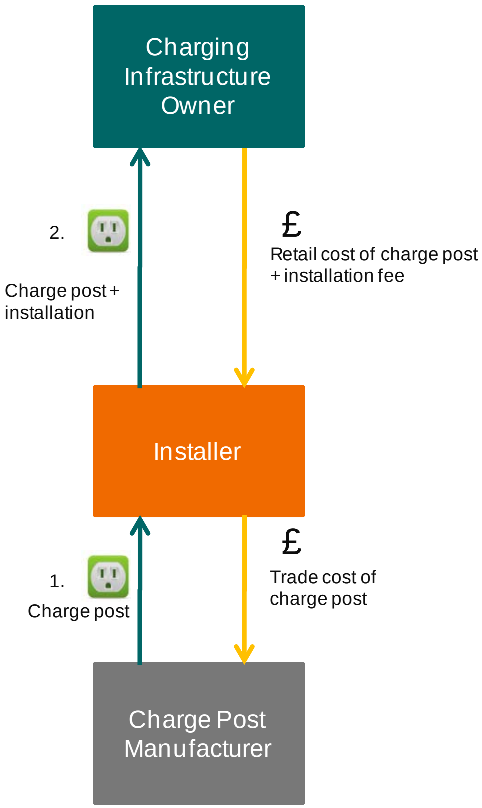
Assessment of viability for charging infrastructure designated as a regulated asset

Sources: 1, 19, 50, iv, v, vi

ARUP

Business model analysis:
Rapid Charge Post Manufacture 1/3

The rapid charge post manufacturer sells and installs charge posts suitable for public use, eg to supermarkets, service stations, show rooms



Current and Analogous Experience

- Rapid charging is supported by the Japanese government, which offers 50% subsidy of the charge post cost to organisations that install them.
- Trials by TEPCO suggest that installation of a rapid charge post can greatly reduce range anxiety resulting in drivers running their batteries down considerably more than in the absence of rapid charging [51].
- Around 200 rapid chargers are in service at businesses, shops, and petrol stations worldwide [52].

Enablers

- The existing power supply infrastructure is sufficient for a low level of rapid charge roll out [18].
- Rapid charge times are more compatible with current consumer refuelling behaviour than conventional charge times.
- The speed of rapid charging may increase consumer willingness to pay compared to public conventional charging.
- Rapid charging is being trialled in some cities, which will provide data for demand assessment. For example in Japan rapid charge posts are heavily subsidised as part of an aggressive government PIV infrastructure programme up until 2015.

Sources: 18, 51, 52, iii, iv, vi

Business model analysis:
Rapid Charge Post Manufacture 2/3

Barriers

- Rapid charging requires more specialist and costly technology than conventional charging, resulting in high costs per unit that will inevitably be passed on to consumers and might limit demand.
- The 50kW power requirements for rapid charge posts may require distribution network reinforcement.
- The large size of rapid charge posts likely to make them unpopular for on-street installation, due to the policy of local authorities to reduce street clutter. This would prevent access to a large segment of the charging infrastructure market.
- Greater health and safety risk than conventional charging posts due to higher voltages and currents.

Socio-Economic Benefits

- No specific benefits, but successful businesses in this space may make PIVs and particularly BEVs more viable helping to increase take-up, resulting in lower local noise and air pollution.

Strategic Risk

- Concern about the impact of rapid charging on battery life could affect acceptance of rapid charge posts. Battery manufacturers and OEMs do not recommend rapid charging as the primary charging method.
- Business model relies on OEMs manufacturing PIVs capable of rapid charging.

Political Risk

- Size of rapid charge post market will depend on a number of factors:
    - PIV and particularly BEV take-up, which in turn depends on government subsidy of vehicles, taxation;
    - Government subsidy of infrastructure and whether there are restrictions on what technologies are eligible for subsidy;
    - Government legislation, in particular whether rapid charge posts can be considered as regulated assets by DNOs.

Subsidy

- The size of the rapid charge post market depends initially on the pace of charging infrastructure roll-out, which depends on expected requirements (based on expected BEV take-up) and on the total cost of installation.
- The cost to install charge posts is often subsidised, for example by the Plugged-in-Places scheme, which offers 50% government funding of charging infrastructure projects to successful applicants. These subsidies make infrastructure installation more attractive and should encourage faster infrastructure roll-out. Plugged-in-Places applications have included provision of limited numbers of rapid charge posts.

Legislation

- Designation of rapid charge posts as a regulated asset could lead to earlier and more extensive infrastructure roll-out as DNOs would be able to guarantee a return on their investment and could potentially invest in anticipation of future demand (see Appendix E).
- In this case the charge post operator would pay an electricity supplier for energy usage and network usage charges and the electricity supplier would pay the DNO the network usage charges. The amount of the network usage charge would depend on how the DNO spread the cost of the charge posts over its users.

Sources: 18, 51, 52, iii, iv, vi

Business model analysis:
Rapid Charge Post Manufacture 3/3

Business Opportunity and Quantitative Assessment

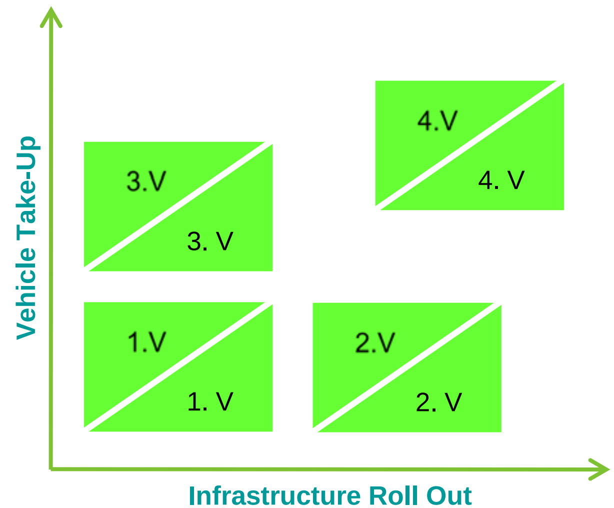
- Barriers to entry are low (higher than for conventional charge post manufacture but little scope for IP ownership). Combined with the potential difficulty of establishing a sustainable competitive advantage profitability may be limited if revenues are associated with units sales alone.
- Rapid charging technology is still in development and there is scope to realise economies of scope and scale as an early mover.

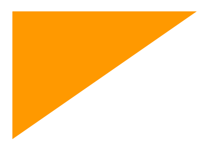
Rapid charge post	2010
Charge Post Costs	
Installed cost of charge post	£30,000
Assumed life of charge post (yrs)	5
Cost per year (£/yr)	£6,000
Electricity Costs	
Price of electricity (£/kWhr)	£0.15
Battery charge required (kWhr)	28.2
Electricity cost per charge	£4.24
Operating / billing costs per charge	£1.00
Usage Assumptions	
Number of charges per year (approx 12 per day)	4500
Asset cost per charge	£1.33
Total	
Total cost of charge to break even	£6.57

- Costs comparable to conventional charging and consumer willingness to pay will be significantly higher, so rapid charging is expected to dominate in most locations where high utilisation is guaranteed (other than homes and workplaces), if barriers can be overcome.
- Different scenarios do not directly influence viability, but do influence PIV infrastructure market size. Economies of scale will therefore determine how many companies can be successful in this space.

- Rapid charge post manufacture viability is not significantly affected by legislation. Legislation may affect who their customer will be and order sizes, but not the underlying model.

Future Business Viability





Assessment of viability for charging infrastructure not designated as a regulated asset

Assessment of viability for charging infrastructure designated as a regulated asset

Sources: 18, 51, 52, iii, iv, vi

ARUP

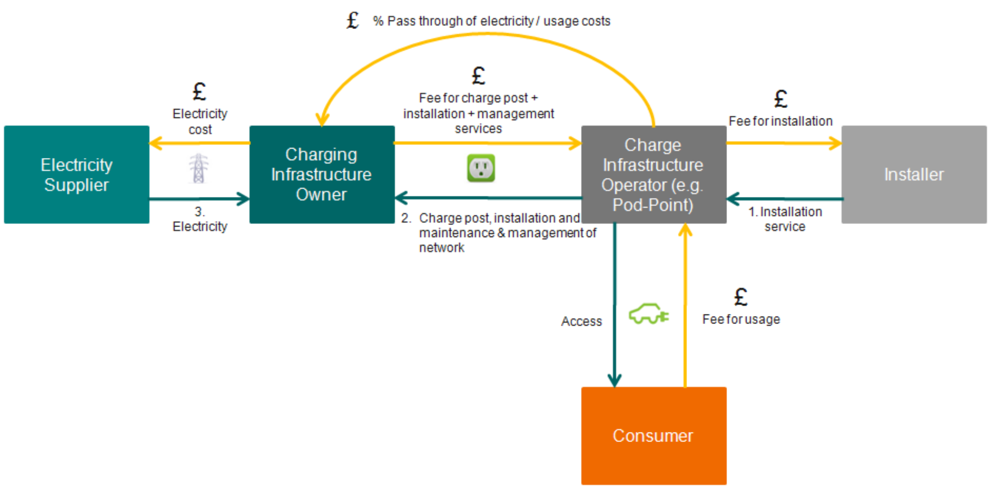
Business model analysis:
Charging Infrastructure Operation 1/3

The charging infrastructure operator manages a charging network on behalf of the owner. The charging infrastructure operator procures, arranges installation and maintenance of charge posts, manages data and payment collection. The charging infrastructure operator retains a percentage of the profit from each charge.

For home charge posts it is likely that all the functions of the charging infrastructure operator will be carried out by the home owner.

For workplace charge posts it is likely that a basic services will be required, primarily procurement and maintenance. Workplace charge posts are expected to be provided to employees for free, or for a fixed annual fee, so will not require data and payment collection.

Publicly accessible charge posts are likely to require the full range of operation services, from procurement through to data and payment collection. However, some owners may not charge for use, eg shopping centres providing free charging to encourage PIV drivers to visit, and could require a service similar to that for workplace charge posts.



Current and Analogous Experience

- Elektromotive have installed over 100 public charge posts for local authorities, shopping centres and Sainsburys [24].
- Elektromotive run the administration and maintenance of most of their charge posts for a fixed annual fee independent of the number of posts in the network [25].
- Other charge post manufacturers also offer maintenance and administration services for small fees, eg £25/annum/post.

Enablers

- The owners of workplaces and sites suitable for public charging infrastructure will generally not have the expertise to manage a charging infrastructure network.

Barriers

- Likely to require strategic partnerships with other PIV stakeholders.
- For workplace or publicly accessible charging infrastructure that is not charged on a per-use basis the required operation services are restricted (procurement and maintenance), so revenues will be smaller or owners may carry out their own charge post operation [20].
- Charging infrastructure operators can only charge consumers for electricity if they are registered as electricity suppliers. This may lead to simpler fixed parking charges which reduce the expertise required to operate charging infrastructure.

Sources: 20, 24, 25, i, iv, v, vi

Business model analysis:
Charging Infrastructure Operation 2/3

Socio-Economic Benefits

- No specific benefits, but successful businesses in this space may make PIVs more viable helping to increase take-up, resulting in lower local noise and air pollution.

Strategic Risk

- Whilst workplace charging is expected to be well utilised and can be more easily targeted at confirmed PIV drivers, demand for public charging infrastructure is uncertain (although currently expected to be a low proportion of overall charging).
- If charging infrastructure is designated as a regulated asset and therefore primarily owned and maintained by DNOs operation may be restricted to managing consumer accounts (administering access, billing, etc). This business model may be well suited to electricity suppliers who already have an established channel to consumers.

Political Risk

- Extent of workplace and public charging infrastructure will depend on a number of political factors:
    - PIV and particularly BEV take-up, which in turn depends on government subsidy of vehicles, taxation;
    - Government subsidy of charging infrastructure;
    - Government legislation, in particular whether charging infrastructure can be considered as regulated assets by DNOs.

Subsidy

- Charging infrastructure operation is unlikely to be a direct beneficiary of subsidy from the government but will benefit from any increased market size due to government incentivised charging infrastructure rollout.

Legislation

- Charging infrastructure operation is unlikely to be directly targeted by legislation.
- However, the size of the charging infrastructure operation market will be indirectly affected as it depends on the amount of workplace and public charging infrastructure and the utilisation of that infrastructure, which are both affected by subsidy and legislation (see Appendix E).
- If charging infrastructure is designated as a regulated asset maintenance of the regulated infrastructure will be carried out by DNOs, removing part of the charging infrastructure operation scope.
- The remaining scope of the charging infrastructure operator may become more attractive as it will be limited to consumer account management and billing, requiring less investment.

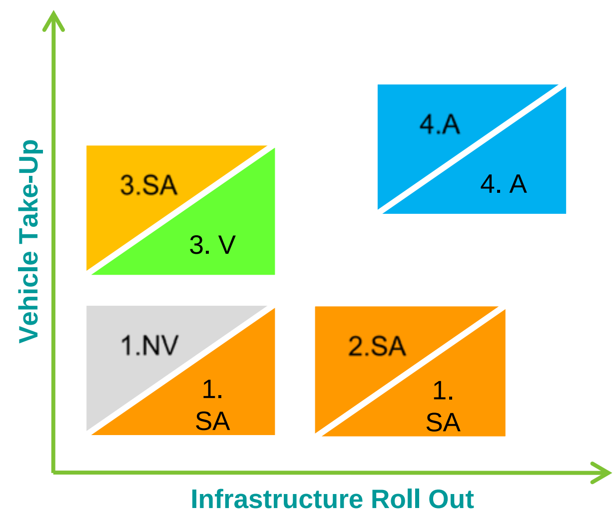
Sources: 20, 24, 25, i, iv, v, vi

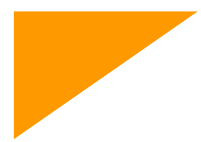
Business model analysis:
Charging Infrastructure Operation 3/3

Business Opportunity and Quantitative Assessment

- For non-regulated charging infrastructure:
  - Requirement for partnership with other PIV stakeholders raises barriers to entry;
  - As complexity of data transfer between PIVs and charge posts increases, outsourcing charging infrastructure operation likely to become more common;
  - There are early market opportunities to develop relationships with likely charging infrastructure owners.
- For charging infrastructure owned by DNOs as a regulated asset, operation of infrastructure must be separated, so opportunities for operators are greater.
- Market size for procurement and maintenance correlated to roll-out. Market size for data and payment collection more strongly correlated with BEV take-up than infrastructure roll-out.
- Few incumbent firms capable of manufacturing, operating and managing PIV charging infrastructure.
- Charging infrastructure operation offers charge post manufacturers a means to develop ongoing revenues.
- The combination of fixed and marginal costs for conventional and rapid charging infrastructure are around £6 to £7 for a five year payback period. Consumer willingness to pay for charging has not yet been tested but could conceivably be sufficiently high to allow profitable operation and therefore to provide an opportunity for a charging infrastructure operator.
- Economies of scale mean this business model is only viable for significant levels of public charging, which will only occur with a high level of BEV take-up, ie in the PIV take-up leads PIV infrastructure and green growth scenarios.

Future Business Viability





Assessment of viability for charging infrastructure not designated as a regulated asset

Assessment of viability for charging infrastructure designated as a regulated asset

Sources: 20, 24, 25, i, iv, v, vi

ARUP

Business model analysis:
Charging Infrastructure Ownership 1/3

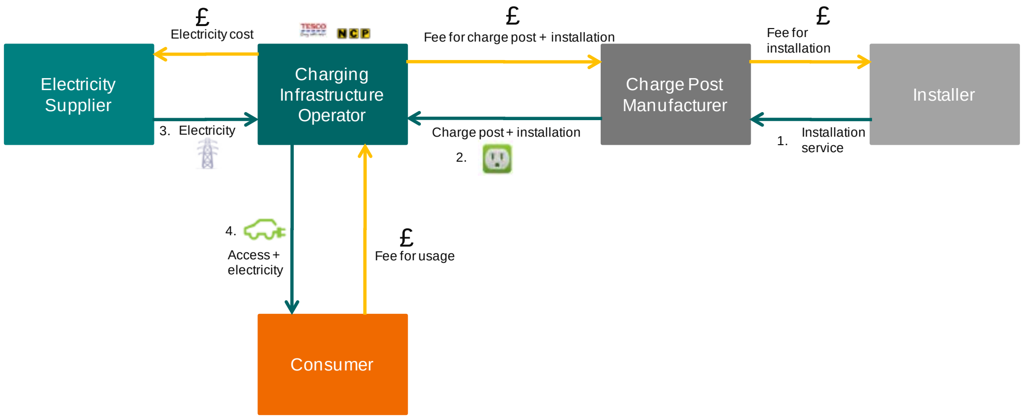
The charging infrastructure owner pays for installation of charge posts and charges consumers (directly or through a charging infrastructure operator) for use of the charge posts on a per use basis. The charging infrastructure owner pays an electricity supplier for the electricity consumed.

All forms of charging infrastructure must be owned.

Home charge posts will be owned by the home owner, so no business model for home charge post ownership is considered.

Workplace charge posts will be owned by the building owners and are likely to be provided as a facility for employees rather than for profit. Of course, buildings with charge posts may command some rental premium over buildings without.

Finally, organisations that might consider owning publicly accessible infrastructure include supermarkets, rail and airport operators, car park owners, councils. These charge posts may be owned for direct profit or for indirect benefits.



Current and Analogous Experience

- Current charge posts are generally owned by local authorities, shopping centres, car parks and other retailers [26].
- The purchase of charge posts is heavily subsidised by government grants, eg Plugged in Places (see Appendix E).
- Generally charging is offered free at point of use, eg Sainsburys, Lakeside, City of London [26, 27].
- Westminster charges PIV drivers a £75 annual fee for access to its charge post network [28].
- NCP has auctioned 12months' access to a parking space with a charge post to PIV drivers [27].
- Current numbers of charge posts are low [50] and it is unclear whether ownership is financially sustainable.

Enablers

- Existing power infrastructure at a distribution level is sufficient to support private/public shared charge posts in all early market stage scenarios [1].
- Lack of charging infrastructure contributes to range anxiety which is a barrier to BEV take-up. Rapid charge post rollout may be encouraged by government if BEV take-up acceleration is sought.
- The low number and limited development of data systems on charge posts being installed in public shared areas does not require a dedicated charging infrastructure operator, with infrastructure owners capable of operating and monitoring their posts [20].
- The use of free or annual subscription payment limits the need to actively manage charge posts at present, current usage charges generally cover parking fees rather than cost of electricity in the public areas [20].

Sources: 1, 20, 26, 27, 28, i, iv, v, vi

Business model analysis:
Charging Infrastructure Ownership 2/3

Barriers

- While public charging is available free of charge or on payment of a fixed annual fee there is little scope to recover costs of charging infrastructure directly. Only indirect revenues are available, eg additional sales while consumers wait for their PIV to recharge.
- Consumers can only be charged for electricity if the charging infrastructure owner / operator is registered as an electricity supplier.
- The price that can be charged for workplace and publicly accessible charging infrastructure depends on the cost and utility of the available alternatives:
    - Alternatives to charging away from home include using the ICE of a REEV or PHEV or driving an ICEV instead of a BEV, so cost of liquid fuel provides some kind of cap on public charging price;
    - Refuelling an ICEV, REEV or PHEV with liquid fuel will be quicker than recharging a PIV. This may discourage consumers from buying a BEV and discourage REEV and PHEV drivers from charging in public.

Socio-Economic Benefits

- No specific benefits, but successful businesses in this space may make PIVs more viable helping to increase take-up, resulting in lower local noise and air pollution.

Strategic Risk

- Investing in charging infrastructure before the consolidation of standards and protocols is a risk for the charging infrastructure owner.
- Demand for workplace and publicly accessible charging infrastructure likely to depend strongly on the mix of BEVs, REEVs and PHEVs in the PIV parc. This depends on technology development, price of BEVs relative to REEVs, PHEVs and ICEVs, and on the availability of BEVs.

Political Risk

- Viability of public charging infrastructure will depend on a number of political factors:
    - BEV take-up, which in turn depends on government subsidy of vehicles, taxation;
    - Government subsidy of infrastructure;
    - Government legislation, in particular whether charging infrastructure can be considered as regulated assets by DNOs.

Subsidy

- The cost of owning charging infrastructure is significantly affected by available subsidies, currently around 50% of the cost of an installed charge post. If these subsidies are removed the viability of infrastructure ownership is reduced.

Legislation

- If charging infrastructure is designated as a regulated asset (see Appendix E) this will significantly affect who is likely to own charging infrastructure.
    - DNOs can own infrastructure with a guaranteed return on capital and can access cheap finance.
    - Private companies would have to bear the risk that revenues are insufficient to provide an acceptable return on capital and are likely to have to rely on more expensive finance.
    - Consequently if charging infrastructure is made a regulated asset, charging infrastructure ownership is likely to be dominated by DNOs.
- If charging infrastructure is designated as a regulated asset ownership becomes viable to DNOs as they can guarantee a return on the capital employed in installing that infrastructure.

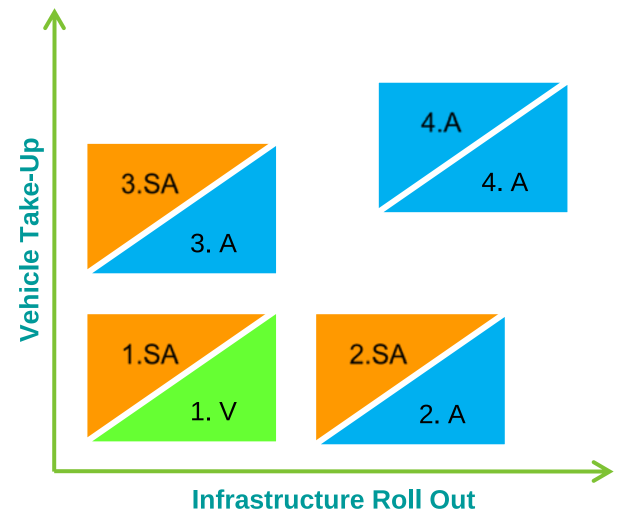
Sources: 1, 20, 26, 27, 28, i, iv, v, vi

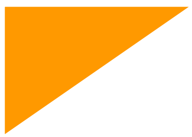
Business model analysis:
Charging Infrastructure Ownership 3/3

Business Opportunity and Quantitative Assessment

- Viability of privately owned charging infrastructure relies on the investment being returned through either one or a combination of:
  - Revenues earned directly from charging PIVs;
  - Increased revenues in core business, for example through differentiation from competitors in the core business or brand awareness benefits;
  - Indirect revenues, for example revenue from advertising on charge posts;
- Site owning organisations will control many of the premium charge post locations. As location will be a key consumer choice criterion there is potential for such organisations to position themselves to operate with attractive profits in the supply chain.
- Costs for conventional and rapid charging infrastructure are around £6 to £7 for a five year payback period (see calculations in conventional charge post manufacture and rapid charge post manufacture sections). Consumer willingness to pay for charging has not yet been tested but could conceivably be sufficiently high to allow profitable operation.
- The costs of installing charging infrastructure will reduce with increased production volumes, the potential revenues will increase with high levels of BEV take-up, consequently this business model will be viable under the green growth scenario
- In scenarios 1 to 3 much charging infrastructure is likely to be available to PIV drivers below cost, so only the indirect benefits discussed above will apply. In these scenarios this model will be strategically attractive. This model is only likely to be profitable once charging infrastructure subsidies are withdrawn and BEV volumes are high, ie in green growth scenario.
- Charging infrastructure included as part of a DNO regulated asset base has a guaranteed return on capital. If the need for a significant roll out of charging infrastructure can be justified by the DNOs and consequently receives regulator approval it will be an attractive opportunity to DNOs.

Future Business Viability





Assessment of viability for charging infrastructure not designated as a regulated asset

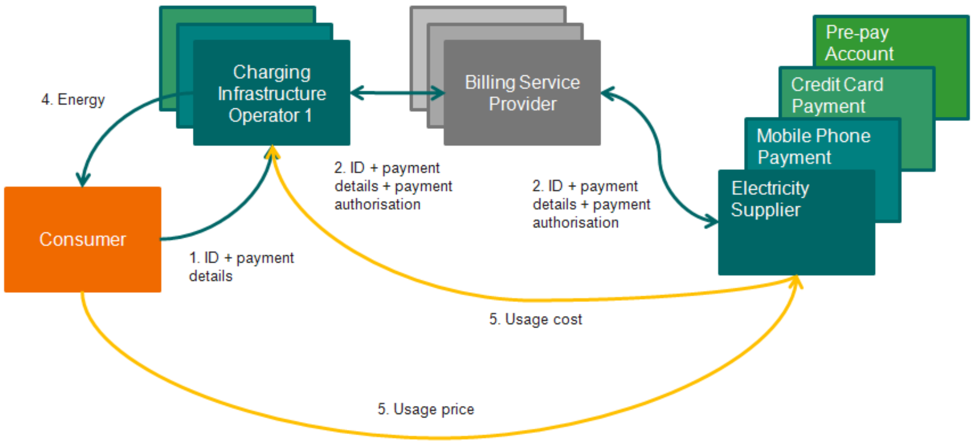
Assessment of viability for charging infrastructure designated as a regulated asset

Sources: 1, 20, 26, 27, 28, i, iv, v, vi

ARUP

Business model analysis:
Billing Services 1/3

In an environment where there are multiple charging infrastructure networks there would be benefit to consumers to be able to recharge at any network using a single account. To facilitate this one or more billing services would be required to manage the flow of data between the consumer and the various payment mechanisms.



Current and Analogous Experience

- Petrol stations facilitate paying at the pump using a credit or debit card. Charges are 2-6% for credit cards and a flat rate of a few pence for debit cards.
- Oyster card provides a means to prepay for travel. A similar system could be used for PIV charging – swipe a card to open the post, plug-in, swipe card to unlock the post again, at which point cost of recharge could be deducted from account.

Enablers

- Enabling consumers to easily access all charging infrastructure through a single account is likely to increase demand for public charging to the benefit of charging infrastructure owners and operators [1].
- Standardisation of charging, data and billing services would provide a common platform from which a single billing operator could act.

Barriers

- Charge post manufacturer standards, data systems, IT systems all differ, making it difficult to interface to all systems.
- Charge post manufacturers receive most of their revenues other than sales from billing, data services, and are unlikely to relinquish this revenue stream to third party billing organisations.

Socio-Economic Benefits

- Access to charge posts encourages use of PIVs which in turn contributes to lower CO_2 emissions, contributes to lower noise emissions and contributes to better air quality.

Sources: 1, vi

Business model analysis:
Billing Services 2/3

Strategic Risk

- Requirement for billing services depends on consumer willingness to pay for public charging. This may be undermined by:
    - Consumers opting for vehicles that do not require public charging, ie REEVs, PHEVs and ICEVs;
    - Free or subsidised charging offered by local authorities, organisations targeting indirect benefits;
    - Subscription based services, for example the Better Place model.
- Value of billing services depends on BEV owners using more than one charging infrastructure network. The likelihood of this happening depends on factors including:
    - Size of areas being covered by each network;
    - Distances BEV drivers travel, which depends on technology development and infrastructure roll out
- If market consolidation leads to only very few charging infrastructure operators these organisations will likely vertically integrate and form their own billing services organisation.

Political Risk

- The designation of charging infrastructure as a regulated asset could have significant effects on how infrastructure is owned and consequently the number of organisations a billing services organisation would need to interact with.

Subsidy

- Subsidy will only have an indirect effect on billing services in terms of increasing PIV take-up and infrastructure roll-out.

Legislation

- If charging infrastructure is designated as a regulated asset (see Appendix E) this may increase the viability of billing services.
    - The DNO would own and be responsible for maintenance of the charge post.
    - The DNO cannot directly charge consumers for use of the charge post, rather they charge electricity supply companies for the use of the network, so a billing service is required to collect data on charge post usage and arrange settlement of accounts.

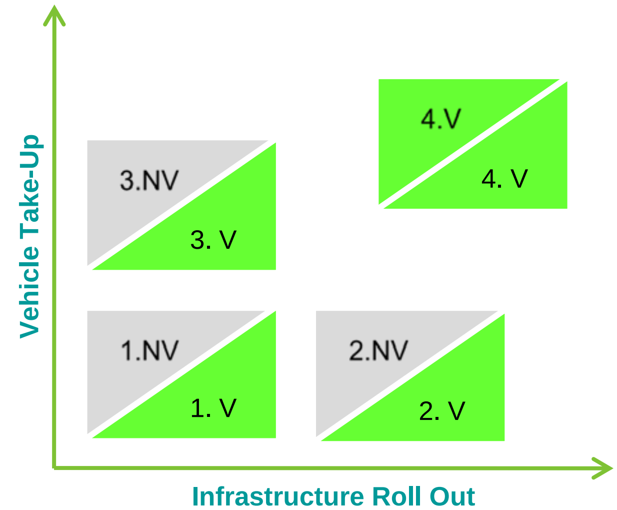
Sources: 1, vi

Business model analysis:
Billing Services 3/3

Business Opportunity

- Relationships with charging infrastructure owners / operators will be important to the success of billing services, so there is some first mover advantage.
- The billing service provider model will be attractive when consumer adoption of BEVs reaches scales where BEV users are charging vehicles in different regions – ie there is some correlation of viability with future BEV range.
- Billing services will only be viable if there are multiple, well established charging infrastructure owners / operators in the market. The viability of billing services will therefore follow that of charging infrastructure ownership and operation, which are only both attractive in the green growth scenario.
- If charging infrastructure is owned by DNOs as part of their regulated asset base, a billing service will be required (it will be very similar to the operator in the case where DNOs own charging infrastructure), so in this case it is viable.

Future Business Viability



Sources: 1, vi

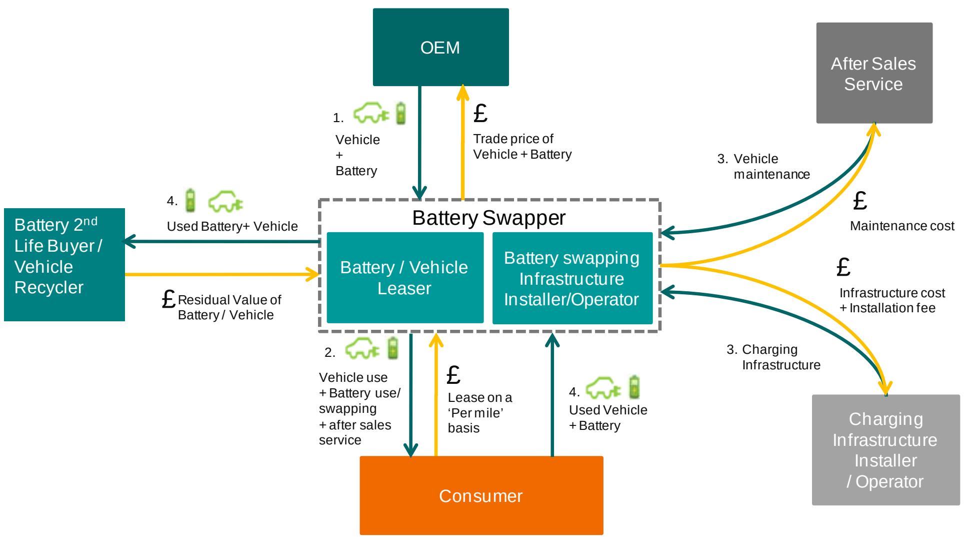
Business model analysis:
Battery Swap 1/3

The battery swapper buys a PIV from the OEM. The chassis may then be sold or leased to the consumer, while the battery swapper retains ownership of the battery. The battery swapper sells use of the battery to the consumer, eg on a per mile driven basis.

The battery swapper installs battery swapping infrastructure at locations across a coverage area where the consumer can quickly change the part charged or empty battery in their PIV for a fully charged battery.

The battery swapper also provides maintenance of the vehicle as part of the monthly contract and is likely to offer insurance, roadside assistance (through a third party), etc.

Battery swapping as a means of charging a PIV is only considered feasible as part of an integrated business model, ie one that combines vehicle provision (through battery lease or whole vehicle lease) and charging infrastructure provision (through battery swap infrastructure).



This is because vehicle owners would be unwilling to exchange a battery they owned for another of uncertain quality. Battery swap is also primarily of benefit to BEV drivers rather than REEV and PHEV drivers who have less need for access to public charging infrastructure and derive less benefit from battery leasing.

Current and Analogous Experience

- From a technology perspective, Betterplace has developed and demonstrated a prototype battery swap station in Japan [23, 29]. It is currently trialling battery swap with a fleet of three taxis in Tokyo [30].
- The business model of combining hardware ownership with network access is comparable to the mobile phone contract business model where the cost of the phone is recovered through network charges. There is widespread acceptance of this business model although 61% of mobile users opt for pay-as-you-go [31].

Enablers

- Reduces up-front cost that consumer must pay, which is an important purchase decision driver [5].
- Removes technology risk from consumer, which is an important factor in vehicle purchasing decisions [5].
- Battery swap infrastructure is compatible with current consumer expectations of vehicle use, because it has the potential to enable a BEV to be 'refuelled' as quickly as or more quickly than an ICEV [29].

Barriers

- Ownership model is unfamiliar to consumers. OEM experience suggests consumers are uncomfortable with not owning the whole vehicle.
- OEMs unlikely to quickly settle on a standard battery form and swapping process making it difficult to service more than one brand of vehicle at any one battery swap station.

Sources: 5, 21, 22, 23, 29, 30, 31, i, iii, iv, v, vi, xii, xiii, x

Business model analysis:
Battery Swap 2/3

Socio-Economic Benefits

- Replacing ICEVs with PIVs reduces local noise and air pollution.
- Battery swap enables the range of BEVs to be extended indefinitely, so a greater proportion of journeys could be low carbon.
- Batteries will be owned by businesses which may be better placed to deal responsibly with them at the end of their life.
- Newer batteries will be used in vehicles, resulting in more efficient use of electricity.

Strategic Risk

- Technology risk, lithium-ion batteries are unproven in power train application.
- Resale value of PIVs is difficult for leasers to assess
  - Depends on rate at which cost of new PIVs reduces and the rate at which technology improves – subject to considerable uncertainty presently;
  - Depends on overall useful life of a vehicle, which in turn depends on factors such as battery life;
  - Depends on second life uses for batteries.
- Large capital investment in infrastructure must be made ahead of subscriber take-up.
- Battery swap is currently differentiated from other charging technologies by its speed. Competing technologies (rapid charge, dynamic inductive charging) may mitigate this and become dominant.
- Price of battery swap must be competitive with alternative means of achieving the same consumer utility, for example using an ICEV, REEV or PHEV instead. This will depend on total cost of ownership of different vehicle types given a consumers journey patterns.

Political Risk

- Viability of battery swap business model will depend on a number of political factors:
  - PIV incentives, eg government subsidy of PIVs, taxation;
  - Government subsidy of charging infrastructure;
  - Government legislation, for example whether battery swap stations and rapid charge stations can be considered as regulated assets by DNOs.

Subsidy

- Battery swap is currently only being developed by Better Place and only Renault are currently planning battery swap compatible vehicles. Consequently battery swap is not currently likely to receive government subsidy, as it only covers a small part of the market. For battery swap to receive subsidy it is expected that greater adoption of the approach would be required, eg most BEVs being compatible.

Legislation

- It is also considered unlikely that battery swap stations would be considered to be a regulated asset.
  - Difficult for the battery swap operator to function in a system that must provide fair access to the network, ie swap station;
  - Battery swap stations are outside the area of expertise of DNOs as they are complex mechanical systems, so unlikely DNOs would be keen to install them.

Sources: 5, 21, 22, 23, 29, 30, 31, i, iii, iv, v, vi, xii, xiii, x

Business model analysis:
Battery Swap 3/3

Business Opportunity and Quantitative Assessment

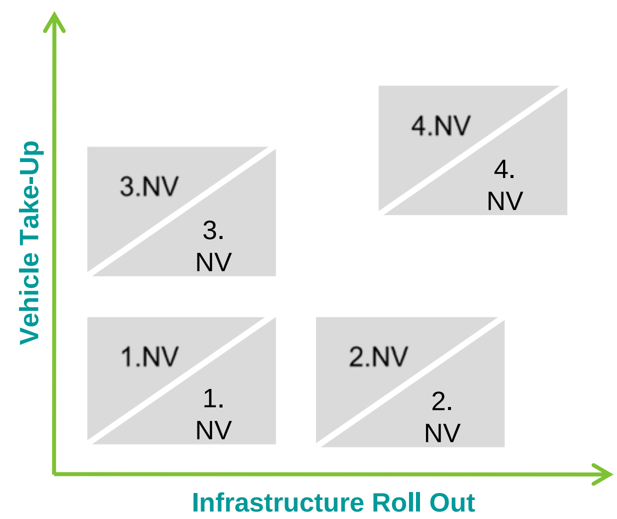
- Consumers expected to be reluctant to enter the type of ownership model required by battery swap unless expectations and behaviour change significantly, ie green growth scenario. Calculations are carried out for this scenario only.
- The 4 year breakeven cost of ownership for this model is around 5% more than that for vehicle lease, but includes access to infrastructure. It is conceivable that customer willingness to pay would be sufficiently high to enable this model to be profitable.

Battery Swap (green growth scenario)	2020
Subscriber Base	
Number of subscribers (10% of total PIV parc)	**120,000**
Battery swaps per vehicle per year[1]	**25**
Public charges per vehicle per year[2]	**15**
Battery Swap Station Costs	
Cost of battery swap station and batteries[3]	**£1,200,000**
Number of battery swap stations[4]	**37**
Total investment in battery swap stations	**£44,400,000**
Payback period (yrs)	**5**
Asset cost per charge	**£2.96**
Operating / billing costs per charge	**£1.00**
Electricity costs per charge	**£4.24**
Total cost per charge to breakeven	**£8.20**
Conventional Charging Post Costs	
Total cost per charge to breakeven	**£6.66**
Vehicle Costs	
Vehicle lease and maintenance cost per year[5]	**£4,810**
Monthly Breakeven Costs	
4 year breakeven cost of ownership	**£20,930**

[1] Assumes 1,500 miles/yr for long journeys (13% of miles in journeys over 100miles), battery swap every 60miles
[2] Assumes annual 10,000miles, 15% of charges at public charge posts, 100mile range
[3] Includes 100no. 24kWhr batteries at £200/kWhr
[4] Assumes one battery swap station every 60miles on all 2188miles of UK motorway trunk road
[5] Taken from vehicle lease calculation, includes 30% lease premium on vehicle cost

- Battery swap requires a large capital investment. The cost of capital is likely to be high, because the enduring value of battery swap infrastructure is highly uncertain.
- The barriers to this model are extremely high and unlikely to be overcome, so this model is not viable in all scenarios considered.

Future Business Viability



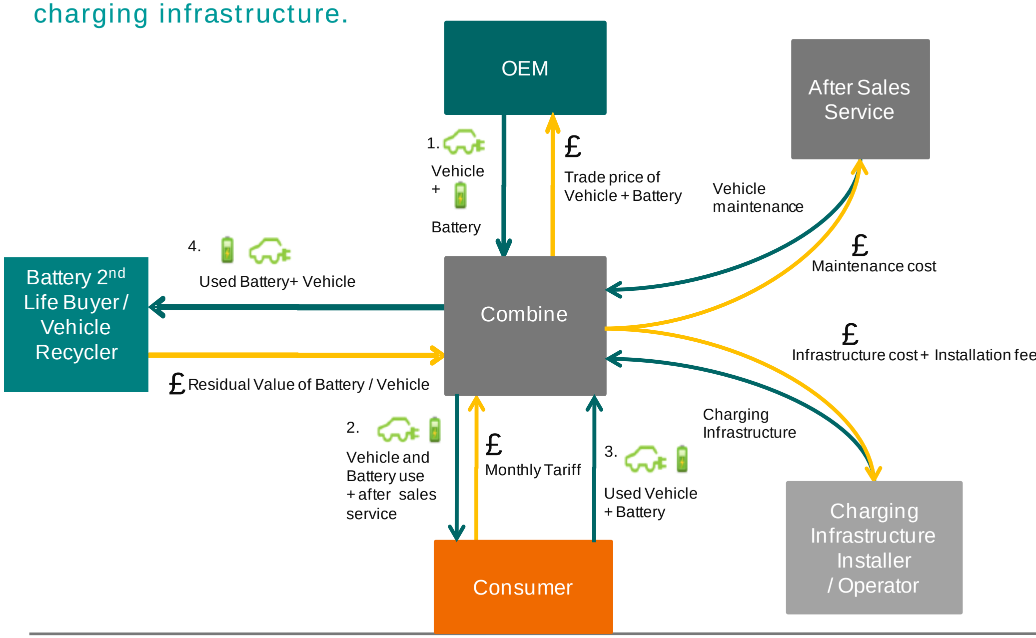
Business model analysis:
Complete System Integration 1/3

The Complete System Integration organisation buys a PIV from the OEM. Use of the vehicle is provided to the consumer for a monthly tariff.

The Complete System Integration organisation installs charging infrastructure at locations across a coverage area which the consumer has access to as part of their tariff.

The Complete System Integration organisation also provides maintenance of the vehicle as part of the monthly contract and is likely to offer insurance, roadside assistance (through a third party), etc. It is very similar to the Battery Swap model, but does not include battery swap stations, thus removing a major uncertainty from the business model.

This model is primarily of benefit to BEV drivers rather than REEV and PHEV drivers who do not have a requirement for access to public charging infrastructure.



Current and Analogous Experience

- The business model of combining hardware ownership with network access is comparable to the mobile phone contract business model where the cost of the phone is recovered through network charges. There is widespread acceptance of this business model although 61% of mobile users opt for pay-as-you-go [31].

Enablers

- Reduces up-front cost that consumer must pay, which is an important purchase decision driver [5].
- Removes technology risk from consumer, which is an important factor in vehicle purchasing decisions [5].
- Enables the cost structure of the vehicle to be adjusted to meet consumer preferences.
- Provides both vehicle and infrastructure resulting in a more attractive package for consumers.

Barriers

- Likely to require strategic partnerships with other PIV stakeholders, in particular with owners of premium charge post locations.
- Costs of PIVs will be significantly higher than for equivalent ICEVs.
- Ownership model is unfamiliar to consumers. OEM experience suggests consumers are uncomfortable with not owning the whole vehicle

Sources: 5, 21, 22, 31

Business model analysis:
Complete System Integration 2/3

Socio-Economic Benefits

- Replacing ICEVs with PIVs reduces local noise and air pollution.
- Batteries will be owned by businesses which may be better placed to deal responsibly with them at the end of their life
- Newer vehicles will result in more efficient use of electricity
- Charging infrastructure may be more rapidly rolled-out by private industry

Strategic Risk

- Depends on the take-up of BEVs, which depends on the supply from OEMs, which is driven strongly by European emissions legislation.
- Large capital investment in infrastructure must be made ahead of subscriber take-up.
- Technology risk, lithium-ion batteries are unproven in power train application.
- Resale value of PIVs is difficult for leasers to assess:
  - Depends on rate at which cost of new PIVs reduces and the rate at which technology improves – subject to considerable uncertainty presently;
  - Depends on overall useful life of a vehicle, which in turn depends on factors such as battery life;
  - Depends on second life uses for batteries.

Political Risk

- Viability of complete system integration business model will depend on a number of political factors:
  - BEV take-up, which in turn depends on government subsidy of vehicles, taxation;
  - Government subsidy of infrastructure;
  - Government legislation, in particular whether charging infrastructure can be considered as regulated assets by DNOs.

Subsidy

- A complete system integrator may receive subsidy from the government to install charging infrastructure, which would help to reduce the charges made to customers, making tariffs more attractive and increasing volumes.

Legislation

- If charging infrastructure is designated as a regulated asset (see Appendix E) a large proportion of charging infrastructure is likely to be installed by DNOs, who must provide fair access to that infrastructure.
- Complete system integration organisations will not have exclusive access to DNO charging infrastructure, which may reduce their competitive advantage, however, it will still be possible to offer integrated packages to consumers by acting as an operator of DNO infrastructure.

Sources: 5, 21, 22, 31

Business model analysis:
Complete System Integration 3/3

Business Opportunity and Quantitative Assessment

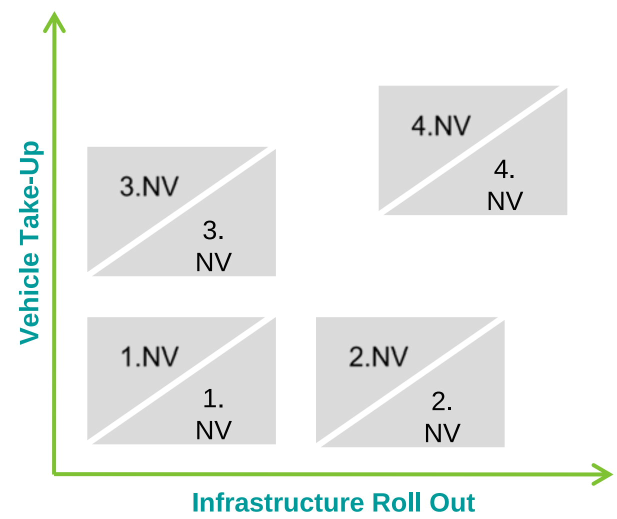
- Consumers expected to be reluctant to subscribe to this type of ownership model unless expectations and behaviour change significantly, ie green growth scenario. Calculations are carried out for this scenario only.

Complete System Integration	2020
Subscriber Base	
Number of subscribers (10% of total PIV parc)	**120,000**
Rapid charges per vehicle per year	**15**
Conventional charges per vehicle per year	**15**
Rapid Charge Costs	
Installed cost of rapid charge post	**£30,000**
Number of rapid charge posts[1]	**1000**
Total investment in rapid charge posts	**£30,000,000**
Payback period (yrs)	**5**
Asset cost per charge	**£3.33**
Operating / billing costs per charge	**£1.00**
Electricity costs per charge	**£4.24**
Total cost per charge to breakeven	**£8.57**
Conventional Charging Post Costs	
Total cost per charge to breakeven	**£6.66**
Vehicle Costs	
Vehicle lease and maintenance cost per year[2]	**£4,810**
Monthly Breakeven Costs	
4 year breakeven cost of ownership	**£20,152**

[1] There are approximately 1000 supermarket petrol stations in the UK, so this is taken as a reasonable distribution of infrastructure for rapid chargers
[2] Taken from vehicle lease calculation, includes 30% lease premium on vehicle cost

- Complete system integration requires a large capital investment. The enduring value of charging infrastructure is uncertain, but less so than for battery swap stations.
- Consumer barrier only overcome in green growth scenario. However, in this scenario owners of premium charge post sites are likely to find the charging infrastructure market attractive making it difficult for a complete system integrator to roll-out a network that will be attractive to consumers. Therefore model is unviable in all scenarios.

Future Business Viability



Appendices

ARUP

Appendix A: Take-Up

Forecasts of PIV take-up in the UK by 2020 provided by organisations and people Arup interviewed are summarised in the table below. Not all organisations interviewed had forecasts available.

Take-up	EV and PiHEV Parc 2020
Between the business-as-usual and the mid-level uptake scenarios in CENEX report	535,000
3.5% of new car sales by 2020[1]	495,000
600,000 EVs and PiHEVs by 2020	600,000
Single figure % of new car sales by 2020[2]	550,000
10% of new car sales by 2020[1]	1,100,000
Average	635,000

Notes:

[1] Assume PIV sales are 0% of new car sales in 2010 and x% of new car sales in 2020 with a linear increase in between. Assume new car sales of all types of car are 2,000,000 per year. Assume no cars reach end of life by 2020. PIV parc is sum of sales in each year between 2010 and 2020.

[2] Calculation procedure is as for [1]. Assume single figure % is 5%.

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Appendix C: Interviews

No.	Company	Sector	Name	Location	Date
i	Oxford City Council	Public	John Copley	Oxford	June 2010
ii	IBM	IT	Nigel Baker-Brian, Simon Parker	London	June 2010
iii	TEPCO (Tokyo electric Power Company)	Charging Infrastructure	Hiroshi Sasamoto	London	June 2010
iv	EDF Energy UK	Electricity Supply	Kate Armitage, Sebastien Pelissier	London	June 2010
v	HALO_IPT	Charging Infrastructure	Dick Stimpson	London	June 2010
vi	Chargemaster Ltd	Charging Infrastructure	David Martell CEO	London	June 2010
vii	Nissan	Vehicle Manufacture	Tim Disney	Cranfield	May 2010
viii	PSA Peugeot Citroen	Vehicle Manufacture	Phil Robson, Bob Grant, Alan Nicholson	Coventry	May 2010
ix	Transport for London	Public	Mark Poulton	London	June 2010
x	London Thames Gateway Development Corporation	Public	Mark Bradbury	London	June 2010

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Appendix D: Implications of hybrids

Introduction

PIVs include both BEVs, REEVs and PHEVs. The differences between these types of PIVs have implications for the viability of business models in the PIV market.

This appendix assesses the impact of REEVs and PHEVs on business model viability. It is split into three sections:

- Overview of the differences between BEVs and REEVs & PHEVs;
- Comparison of the barriers and enablers associated with BEVs with PHEVs;
- Assessment of the impact of the Plug-in Vehicle parc being made up of 50% FEVs and 50% PiHEVs.

Overview of BEVs, REEVs and PHEVs

Definitions of the three types of PIV are given below.

BEV

- Uses a battery to provide power to an electric motor to drive the vehicle
- Must be plugged in to recharge the battery from the grid

REEV and PHEV

- Combine an internal combustion engine and a battery to provide power
    - In a parallel configuration (PHEV) the electric motor and the ICE connect in parallel to the transmission
    - In a series configuration (REEV) only the electric motor drives the car, the ICE drives an alternator that recharges the battery and powers the electric motor
- The vehicle can be plugged in to recharge the battery from the grid

For the purposes of assessing business model viability there are significant differences between BEVs and REEVs & PHEVs. The differences between REEVs and PHEVs are less significant from the perspective of this study, although there are some considerations:

- Parallel hybrids are reasonably established in the market (eg Toyota Prius) and have built up a level of consumer confidence and familiarity, although PHEVs are new.
- PHEVs are more complex than REEVs and use their ICE in a different way that is likely to be more onerous for the engine which may result in lower maintenance costs for REEVs.

Appendix D: Comparison of enablers and barriers

	Full electric vehicle	Plug-in hybrid electric vehicle (parallel)	Plug-in hybrid electric vehicle (series)
Battery only range on a single electric charge	• Currently 80-100miles (eg Mitsubishi i-MiEV, Nissan Leaf)	• 12miles (eg Toyota Prius) • It is expected that parallel hybrids will have lower battery only range than series hybrids	• 40miles (eg Vauxhall Ampera) • It is expected that series hybrids will have higher battery only range than parallel hybrids
Extending range	• Range can only be extended beyond the battery only range by recharging the battery. • With a conventional charge post this will take around 6-8hrs. With a rapid charge post this will take around 15mins. • Infrastructure is currently sparse. Significant behavioural change is required from drivers to adjust to using an electric vehicle for longer journeys.	• Range can be extended beyond the battery only range by using the ICE, which can be refuelled using existing fuel infrastructure. • Little behavioural change is required by drivers to adjust to using a parallel hybrid.	• Range can be extended beyond the battery only range by recourse to the ICE, which can be refuelled using existing fuel infrastructure. • Little behavioural change is required by drivers to adjust to using a PiHEV.
Purchase cost	• Current cost around £30,000, of which 16kWhr battery is around £10,000	• Current cost around £20,000, of which battery is around £2,500	• Estimated cost around £35,000, of which 16kWhr battery is around £10,000

Appendix D: Comparison of enablers and barriers

	Full electric vehicle	Plug-in hybrid electric vehicle (parallel)	Plug-in hybrid electric vehicle (series)
Running costs	• Running costs are currently low, around 1-2p/mile and maintenance costs are expected to be lower than for ICE vehicles.	• Running costs depend on journey characteristics that affect how many miles are travelled using the ICE. • Fuel economy likely to be better than equivalent ICE vehicle. • Maintenance will be more expensive than for a full electric vehicle, due to the presence of an ICE.	• Running costs depend on journey characteristics that affect how many miles are travelled using the ICE. • Most journeys are likely to fall within the battery only range of a series hybrid. • Fuel economy will be better than equivalent ICE vehicle. • Maintenance will be more expensive than for a full electric vehicle, due to the presence of an ICE, but lower than a parallel hybrid as the ICE will be used in a less onerous regime, ie periods of constant running to recharge battery.
CO2 benefits	• CO2 benefits depend on generation mix and time of recharging. • With overnight conventional charging CO2 benefits are potentially significant.	• CO2 benefits depend on how many miles are travelled using the ICE, the generation mix and the time of recharging. • With low battery only range models fewer miles will be battery only, reducing the CO2 benefits compared to FEV.	• CO2 benefits depend on how many miles are travelled using the ICE, the generation mix and the time of recharging. • With 40mile battery only range most journeys can be made using the battery only.

Appendix D: Comparison of enablers and barriers

	Full electric vehicle	Plug-in hybrid electric vehicle (parallel)	Plug-in hybrid electric vehicle (series)
Emissions legislation	• Emissions count as 0g/km within the European emissions legislation. • FEVs qualify for super-credits until 2016.	• Emissions will be low for given size of car due to efficiency improvements as a result of hybridisation. • If 50g/km can be achieved then parallel hybrids will qualify for super-credits until 2016.	• Emissions will be low for given size of car due to efficiency improvements as a result of hybridisation. • If 50g/km can be achieved then series hybrids will qualify for super-credits until 2016.
Subsidy	• Eligible for government subsidy subject to vehicle meeting published standards.	• Eligible for government subsidy subject to vehicle meeting published standards.	• Eligible for government subsidy subject to vehicle meeting published standards.

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Appendix E: Legislation

Introduction

This appendix summarises legislation and government subsidy that could have a significant impact on the viability of business models in the electric car market.

The appendix is split into two sections:

- Legislative issues
- Subsidy issues

The impact of the legislation and subsidies that are summarised in this appendix on the business models is assessed in the main body of the report.

Appendix E: Legislation

Legislation	Overview
European emissions legislation	• Sets targets for OEM fleet average CO_2 emissions and imposes financial penalties on OEMs that do not meet those targets • Affects vehicle provision business models directly
Regulated asset status of charging infrastructure	• Affects whether or not DNOs and IDNOs can include charging infrastructure in their regulated asset base • Affects charging infrastructure ownership directly and consequently affects other charging infrastructure business models
Block exemption legislation	• Aims to prevent OEMs obstructing competition in sales and maintenance of vehicles • Affects vehicle maintenance business model
European battery legislation	• Prohibits landfill of automotive batteries and makes producer responsible for financing recycling of batteries • Affects battery recycle and reuse business model
Company car taxation	• Company car tax now varies depending on CO_2 emissions of vehicles • Affects vehicle provision business models
Local planning policy	• Local planning policy can be used to encourage car sharing • Affects car club business model
Congestion charge exemptions in London	• Exemptions likely to apply on a CO_2 emissions basis in the future • Affects vehicle provision business models

Appendix E: Legislation

European Emissions Regulation

- Fleet average CO_2 emissions are set at 130g/km, reducing to 95g/km from 2020 onwards, with an adjustment for vehicle mass meaning the emissions target for heavier vehicles is higher than for lighter vehicles [59].
- Average fleet emissions are calculated based on a manufacturer's new passenger cars registered in a year. In 2012 65% of these must be taken into account, in 2013 75%, in 2014 80% and from 2015 onwards 100% [59].
- Average fleet emissions are calculated on a Europe-wide basis, not at the level of individual member states [59, 60].
- Each passenger car with emissions below 50g/km will be given 'super-credits' until 2016, which means they will be counted as more than one car in the fleet average as follows: 3.5 cars in 2012 and 2013, 2.5 cars in 2014 and 1.5 cars in 2015 [59].
- Full electric vehicles will be classed as having zero emissions [59].
- Manufacturers that have fleet average emissions above 130g/km must pay an emissions premium. The premium for each car new registered car is €5 for the first g/km above 130g/km, €15 for the second, €25 for the third and €95 for subsequent excess g/km [59].

Issues

- The current volume weighted CO_2 emissions of the top 25 brands by volume are shown in the table on the following page [53]. Only Fiat and Mini currently achieve the target of 130g/km.
- For manufacturers excess emissions charged at €95/g/km, each electric vehicle sold will reduce the penalty by 130g/km x €95 = €12,350. With the super-credit taken into account this could rise to as much as €43,225 in 2012 and 2013.
- There is an incentive for manufacturers to encourage the sale of sufficient low emissions vehicles to achieve fleet average targets and avoid emissions premiums. This could lead to BEVs being sold at a loss, particularly while the super-credits system applies, with availability restricted to that required to achieve the fleet average emissions target.
- Nissan had fleet average emissions in the first half of 2009 of 159g/km [54]. The aggressive pricing of the Nissan Leaf electric car may be motivated by the objective of achieving sales volumes sufficient to achieve their emissions target.
- There are calls to abolish the 'super-credits' for low emission vehicles, as these enable manufacturers to sell cars that emit more CO_2 than are saved by the electric vehicles without incurring penalties [32].

Appendix E: Legislation

Make	H1, 2009 EU21 Sales Volume	Weighted Average CO2 (g/km)
FIAT	535,590	129.1
MINI	65,559	129.7
TOYOTA	358,982	132.9
LANCIA	61,776	134.1
PEUGEOT	500,880	134.5
CITROEN	437,781	138.8
HYUNDAI	168,260	138.8
RENAULT	517,783	138.9
FORD	664,582	140.4
CHEVROLET	95,564	141.6
SEAT	166,110	142.4
SUZUKI	134,014	144.9
HONDA	132,360	146.5
KIA	128,296	148.9
OPEL	434,218	149.5

Make	H1, 2009 EU21 Sales Volume	Weighted Average CO2 (g/km)
SKODA	245,471	149.9
MAZDA	108,429	151.2
VAUXHALL	122,019	152.3
DACIA	95,036	152.4
VOLKSWAGEN	838,117	152.5
BMW	285,023	158.4
NISSAN	159,311	158.9
AUDI	323,256	162.6
MERCEDES	298,491	178.8
VOLVO	99,726	179.0

Appendix E: Legislation

European Block Exemption Regulation

- Requires OEMs to provide reasonable access to technical information on their vehicles necessary for carrying our repairs and maintenance.
- Prevents OEMs making their warranties conditional upon maintenance and repair being carried out by their dealers.
- Reduces barriers to using alternative spare parts for repairs.

Issues

- This legislation should enable independent garages to compete on a more equal footing with main dealers for vehicle repair and maintenance.
- A number of independent garages offer repair and servicing of Toyota Prius cars, so this legislation has had an effect.
- Anecdotal evidence suggests consumers do not have a good awareness of this legislation particularly with regard to the effect on warranties. This being the case, main dealers still benefit from a competitive advantage in the repair and maintenance of vehicles that are within their warranty periods.
- The trend towards longer warranties offered by OEMs is partly motivated by a desire to retain repair and maintenance business within the main dealer network for longer.

Appendix E: Legislation

European Batteries Directive

- Bans landfilling or incineration of automotive and industrial batteries.
- Puts the financial responsibility for battery recycling costs onto producers.
- Puts targets on the proportion of portable batteries that are recycled (45% by 2016).

Issues

- OEMs, as producers of vehicles containing batteries, are responsible for the financial costs of recycling them.
- Consequently the market for automotive battery recycling is guaranteed.
- Battery recycling will be a growth market, as currently only around 3% of portable batteries are recycled, so to hit the 45% target a large increase in recycling is required.
- Although battery design and battery chemistry differ between portable batteries and electric vehicle batteries, there are likely to be economies to be gained for recyclers to deal with both types helping to improve the overall viability of the battery recycling market.

Appendix E: Legislation

Regulated Asset Status of Charging Infrastructure

- One approach to enabling the large investment required to roll out charging infrastructure that has been suggested is allowing DNOs to install charging infrastructure and recover the cost through network fees.

Issues

- The revenue of DNOs is regulated and based on depreciation of their regulated asset base, operating costs and return on capital.
- DNOs are responsible for maintenance of their regulated assets and investment in network upgrades that are not attributable to a particular user.
- DNOs are not permitted to invest in new assets that are attributable to a particular user. For example, if a development needs a new substation, the developer would be responsible for financing the substation and any network upgrades that become necessary as a result of the development.
- DNOs can take assets into their regulated asset base but are not permitted to pay for them. In the example above the developer could give the DNO the substation, in which case the DNO becomes responsible for its maintenance.
- Under current legislation, including charging infrastructure in the DNO regulated asset base does not solve the problem of recovering the investment cost, since the DNO cannot pay for it.
- If legislation was changed, it would be possible to enable DNOs to spread the asset cost across the complete user base, reducing the costs to electric vehicle users. This is likely to be extremely difficult.
- Independent DNOs are similar to DNOs but do not have responsibility for a particular geographical area and can operate anywhere.
- IDNOs are free to invest in network assets, so could either directly invest in charging infrastructure or purchase charging infrastructure from a private owner.
- IDNO revenue and return on capital are regulated, so typically they do not fully finance network assets, but buy them for a proportion of their installed cost.
- An IDNO cannot spread the cost of charging infrastructure across the whole network, because they only own small parts. Therefore they are only likely to invest in charging infrastructure if demand at a price that justifies their investment is reasonably certain.
- Under current legislation, allowing IDNOs to include charging infrastructure in their regulated asset base does not solve the problem of recovering the investment cost, since the costs of the charging infrastructure are likely to be directly charged to the charge post users.
- Designating charging infrastructure as a regulated asset forms part of the Conservative Party manifesto [35].
- Assessment of business models for the case where charging infrastructure is a regulated asset has assumed the case where legislation has changed to allow DNOs to recover their investment through network charges. Under the current legislation the regulated asset status of charging infrastructure does not significantly alter the economics of charge posts.

Appendix E: Legislation

Company Car Taxation

- Company car tax varies between 15% for cars emitting 121g/km CO_2 up to 35% for cars emitting 235g/km or more.
- Cars emitting less than 120g/km pay 10%, which includes hybrids.
- Electric cars pay 9%.

Issues

- Hybrids with low emissions and electric vehicles will benefit from advantageous company car taxation compared to petrol or diesel vehicles, which will encourage take up by business earlier than take up by consumers.

Appendix E: Subsidy

Subsidy	Notes
£230m for consumer incentives to encourage low carbon transport	• The funding for the first year of the scheme (£43m for 2011-12) has been confirmed by the new government, the remainder of the funding is yet to be confirmed • Subsidies of up to £5,000 on BEVs and PiHEVs • Puts requirements on vehicles including: 7 year electrical power train warranty, range of 70miles for BEVs and 10miles electric range for PiHEVs
£120m low carbon vehicles innovation platform funding	• Technology Strategy Board, DfT, Advantage West Midlands, One North East and EPSRC • To fund R&D
Vehicle excise duty	• Free for vehicles with CO2 emissions below 100g/km, ie BEVs, some PiHEVs but also some efficient diesel cars • Expectation that the threshold values will become more stringent as vehicle technology improves?
Plugged-in-Places	• Subsidy for three consortia, in phase 1, to install infrastructure.
Infrastructure Grant Programme	• Match funding to encourage organisations to install charge points (and other alternative fuel refuelling stations).