Markets, Barriers, Opportunities & Business Models for the ACCRA system

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Executive Summary

Introduction Autonomous & Connected vehicles for CleaneR Air (ACCRA) was an Innovate UK funded project. The ACCRA system allows hybrid internal combustion engine (ICE) vehicles to become part of a city's urban traffic management control system; monitoring the vehicles' location and operational state, and able to control the zero-emission (ZE) running strategy, ensuring ZE through areas of poor air quality (AQ).

The system was demonstrated in Leeds and the project findings used to assess the applicability and capability of the system to support the proposed 2020 Leeds Clean Air Zone (CAZ). This project was led by Dynniq who provide traffic management systems to cities, and supported by the *Transport Systems Catapult (TSC), Cenex, Earthsense, Tevva Motors and Leeds City Council.* The system has been designed, built and tested during a 12 month project (completing in July 2018) and is intended to work inside the Clean Air Zones mandated by the UK government.

This report was led by Cenex with the support of an industry advisory group and examines the Markets, Barriers, Opportunities and Business Models for the ACCRA System.

ITS Industry Analysis The ITS industry is predicted to grow by between 100% and 250% in the next 10 years, meaning systems like ACCRA will become more prevalent across the world. Most UK cities already have a system built on open-specification Urban Traffic Management Control (UTMC) standards and many more European cities are following suit, making them accessible to other suppliers and their products and not limiting the use of ACCRA to those cities already served by Dynniq. The number of "Connected" vehicles that would be able to interact with these systems is also rising, with KPMG predicting that 80% of cars will be connected by 2030, and this connectivity will be achieved through either the 5G (mobile network) or DSRC (WiFi) method, or a combination of both.

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Target Market: Air Quality Air quality is an increasingly important problem in the world, particularly in Europe and the UK where several UK cities are exceeding the statutory NO_2 annual average limit of 40µg/m^3. Five UK cities have been mandated to introduce a Clean Air Zone (CAZ) mainly targeting diesel vehicles, the largest source of NO_2. This consequently puts a stronger focus on restricting vehicles such as HGVs and buses, and a very small focus on restricting hybrid vehicles which mostly run on petrol. The CAZ cities are predicted to comply with the NO_2 limit by 2025 if enforcing the most strict, class D type of CAZ. However, air quality limits are expected to continue reducing beyond 2025, as indicated by the CAZ Framework and the impending Road to Zero consultation, so measures that support zero-emission running in cities, such as ACCRA, will inevitably hold more of a long term benefit to a city.

Target Market: Hybrid Vehicles Of the multiple types of hybrid available, only range extended electric, plug-in hybrid and full hybrids have enough ZE range to operate ACCRA. There is currently only a small percentage of hybrids on the road in the UK & Europe, approx. 4%, meaning ACCRA's immediate effect would be quite small. However, the hybrid market as a whole is growing quickly, particularly in the UK, due to drivers such as the Plug-in Vehicle grant & changes to vehicle excise duty. CAZs will also likely help this growth, as well as EU legislation on average fleet CO_2 levels & several country's pledges to stop non-hybrid sales, such as the UK's 2040 target. This will mean a much larger vehicle parc in the future for ACCRA to work with. In the meantime, retrofitting larger vehicles with hybrid drivetrains in order to use ACCRA could be a viable option for fleets who operate inside CAZs but don't have large capital funds to replace vehicles with.

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Competitive Analysis ACCRA has several indirect competitors for improving air quality in cities, whose main strengths are that they are likely to have a larger impact in a shorter space of time. ACCRA's key strength is its' longevity, low cost and compatibility with zero emission running, which means that those buying hybrids now are not necessarily punished later by lowering emission standards in cities. Early adopter locations for ACCRA are locations favourable to the three key factors; ITS, air quality and hybrids (for example the CAZ cities in the UK as well as large cities in Europe such as Amsterdam, Rotterdam, Barcelona & Paris). The geo-fencing technology and air quality modelling aspects of ACCRA also have potential future opportunities in automatic charging, building HVAC management, reducing noise pollution, alerting drivers of congestion, or information on available parking spaces and charge-points.

Business Models & Market Strategy ACCRA will be required to run larger trials in order to obtain accurate set-up and maintenance costs and develop a working business model. Principally, ACCRA is less well equipped to make large improvements to air quality than its' competitors in the short term, so it must rely on its strength to improve localised hotspots (e.g. around schools & hospitals) and to offer a retrofitting option in the HGV and bus markets where there are few/no low emission alternatives. Work must be done to overcome some key barriers, such as ensuring that vehicles can obtain the necessary connectivity and that the drivetrain switch is easy or preferably automatic. Liaising with local authorities is also key to ensure that there is a clear benefit for the user to have the ACCRA system. In the long term, with growing numbers of hybrids, it will be able to contribute significantly to improving air quality in cities and thus pay back by improving citizens' health. Also, with lowering air quality limits, it will avoid users having to replace non-compliant hybrids before their end-of-life, as is the current case with diesel vehicles bought in good faith for their lower CO_2 emissions.

Contents

Abbreviations

Abbreviation	Meaning	Abb.	Meaning	Abb.	Meaning
ACCRA	Autonomous and Connected vehicles for CleaneR Air	HEV	Hybrid Electric Vehicle	REEV	Range Extended Electric Vehicle
		HGV	Heavy Goods Vehicle	SMMT	Society of Manufacturers and Motor Traders
ADL	Alexander Dennis Limited	HVAC	Heating, Ventilation and Air Conditioning	TSC	Transport Systems Catapult
AFV	Alternatively Fuelled Vehicle	ICE	Internal Combustion Engine	TU	Telemetry Unit
ANPR	Automatic Number Plate Recognition	IHME	Institute for Health Metrics and Evaluation	UDG	UTMC Development Group
AQ	Air Quality	ITS	Intelligent Transportation System	UK	United Kingdom
AQMA	Air Quality Management Area	LA	Local Authority	ULEZ	Ultra Low Emission Zone
BEV	Battery Electric Vehicle	LEZ	Low Emission Zone	UN	United Nations
CAZ	Clean Air Zone	LGV	Light Goods Vehicle	UTMC	Urban Traffic Management and Control
CO_2	Carbon Dioxide	NEDC	New European Driving Cycle	V2I	Vehicle to Infrastructure
DEFRA	Department for Environment, Farming and Rural Affairs	NO_2	Nitrogen Dioxide	VED	Vehicle Excise Duty
		NO_x	Oxides of Nitrogen	VMS	Vehicle Management System
DfT	Department for Transport	OEM	Original Equipment Manufacturer	WHO	World Health Organisation
DME	Decision Making Engine	PAB	Project Advisory Board	WLTP	World harmonised Light vehicle Test Procedure
EU	European Union	PHV	Private hire Vehicle	ZE	Zero Emission
FMI	Future Market Insights	PM	Particulate Matter	ZEZ	Zero Emission Zone

Introduction

Introducing the project and the partners, what the ACCRA system is and how it will work, and the products that will be produced by the key partners as a result of the project

The Project and its' Partners

Autonomous & Connected vehicles for CleaneR Air (ACCRA) was an Innovate UK funded project, led by Dynniq who are specialists in mobility and energy technology solutions, specifically providing traffic management systems to cities. The project began on July 1st 2017 and is scheduled to run for 12 months. Dynniq are supported by:

- ***Transport Systems Catapult (TSC)*** *- UK's technology & innovation centre for Intelligent Mobility*
- ***Cenex*** *- Not-for-profit research & consultancy organisation specialising in low carbon transport*
- ***Earthsense*** *- Leading air quality measuring, modelling, monitoring and data specialists*
- ***Tevva Motors*** *- Manufacturer of range-extended, zero-emission freight vehicles*
- ***Leeds City Council*** *- One of five UK cities to be mandated with a Clean Air Zone, and providing the test bed for this project*

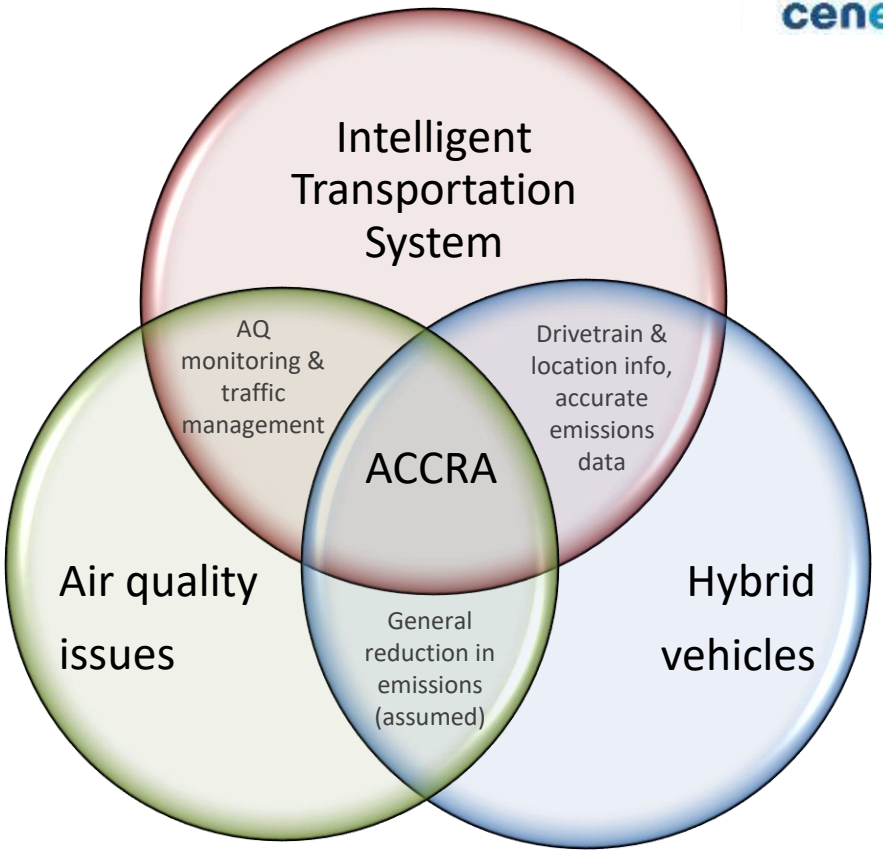
As part of this market study, a Project Advisory Board (PAB) was set up with the aim of getting input on the ACCRA solution from a wide variety of organisations outside of the project consortium, to better understand the marketplace, and the barriers or opportunities that the solution might face. The organisations that sat on the board are shown here (right), and the feedback gathered in these meetings was used to produce this market study.

The ACCRA System

The ACCRA system will allow hybrid internal combustion engine (ICE) vehicles to become part of a city's urban traffic management control system; monitoring the vehicles' location and operational state, and able to control the zero-emission (ZE) running strategy, ensuring ZE through areas of poor air quality (AQ).

The system was demonstrated in Leeds and the project findings used to assess the applicability and capability of the system to support the proposed 2020 Leeds Clean Air Zone (CAZ). Following the project, the partners will be able to exploit the developed technology as urban areas worldwide look to introduce zero emission zones.

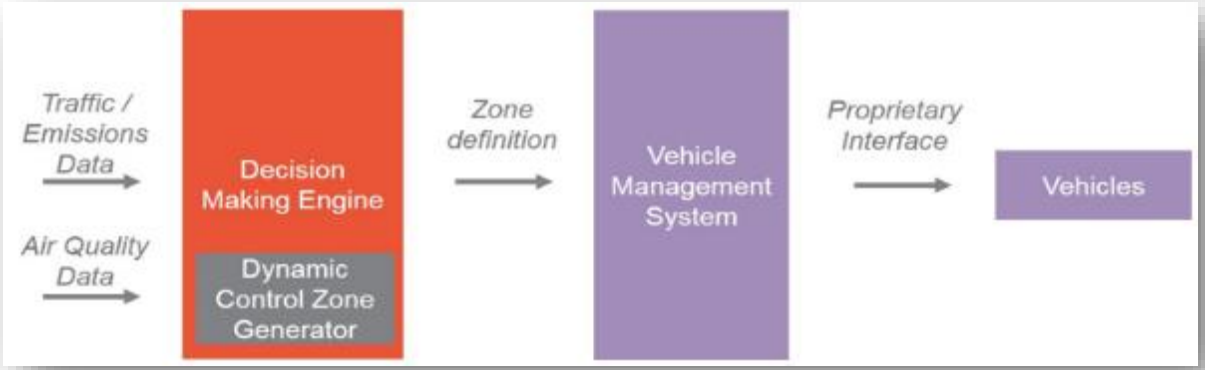
ACCRA presents itself as a viable solution when three key conditions are met; the existence of an intelligent transport system in a city, an air quality problem, and a number of hybrid vehicles. Each of these factors will be considered separately in this study to understand their prevalence, before considering where these markets intersect and therefore provide the best early adopter markets for the ACCRA system to succeed in.



The ACCRA System

ACCRA works by monitoring traffic and collecting air quality data from a variety of sensors around the city. The system will then identify any areas that are breaching, or are likely to breach, the air quality limits prescribed by the operator (usually the local authority), and create a “dynamic control zone” in that area. This process is known as “active geo-fencing”.

Any compatible hybrid vehicles entering this zone will then be requested by the urban traffic management system to switch their engine to “zero emission” mode whilst driving inside the zone, in order to reduce pollution in the area until air quality returns to an acceptable level, at which point the zone is removed and traffic is allowed to operate normally again.



The ACCRA system will sit inside the existing urban traffic management system of a city, as an added feature that can be offered to compatible vehicles at first, and in time possibly becoming a requirement of vehicles wanting to enter a city with air quality targets.

Products

As a result of the ACCRA project, four new products have been developed by various members of the consortium, which are as follows:

Decision Making Engine (DME) – A module integrated with the Intelligent Transportation System (ITS) of a city, capable of receiving a variety of data inputs, and using these to create dynamic geo-fenced zones and advise a city's ITS on actions required to improve air quality. This product will be developed by Dynniq.

Vehicle-to-City Interface – A module integrated with the ITS of a city that will translate data inputs from external sources, such as vehicles, into data compatible with the DME.

Vehicle Interface – Vehicle integrated module allowing the processing & transfer of data and control signals from a vehicle to a city's infrastructure. This product will be developed by Tevva.

Sensor Interface – A module integrated with an air quality sensor to enable the ITS to receive live, real-time air quality data from both mobile & static sensors.

These products will be offered as a package to prospective customers when purchasing the ACCRA system, but may also be offered individually by the respective partners.

Intelligent Transportation Systems Industry Analysis

Analysing the current size of the industry that ACCRA is intended for, how it is likely to grow in future, the key factors behind this potential growth, and the effects this may have on vehicle technology

What are Intelligent Transportation Systems?

Intelligent Transportation Systems (ITS) aim to enable the "smarter" and more efficient use of transport networks, allowing users to make more co-ordinated and safer choices when travelling, for the purposes of:

- improving the mobility of people and goods
- increasing safety, reducing traffic congestion and managing incidents effectively
- meeting transport policy goals and objectives – such as demand management or public transport priority measures

They do this by combining data from multiple different sources such as Automatic Number Plate Recognition (ANPR) cameras, speed cameras, CCTV, weather information, air quality sensors etc, interpreting the data and using it to improve the flow of traffic via car navigation systems, traffic signal control systems, variable message signs, variable speed limits and any other communication or control method at the ITS's disposal.

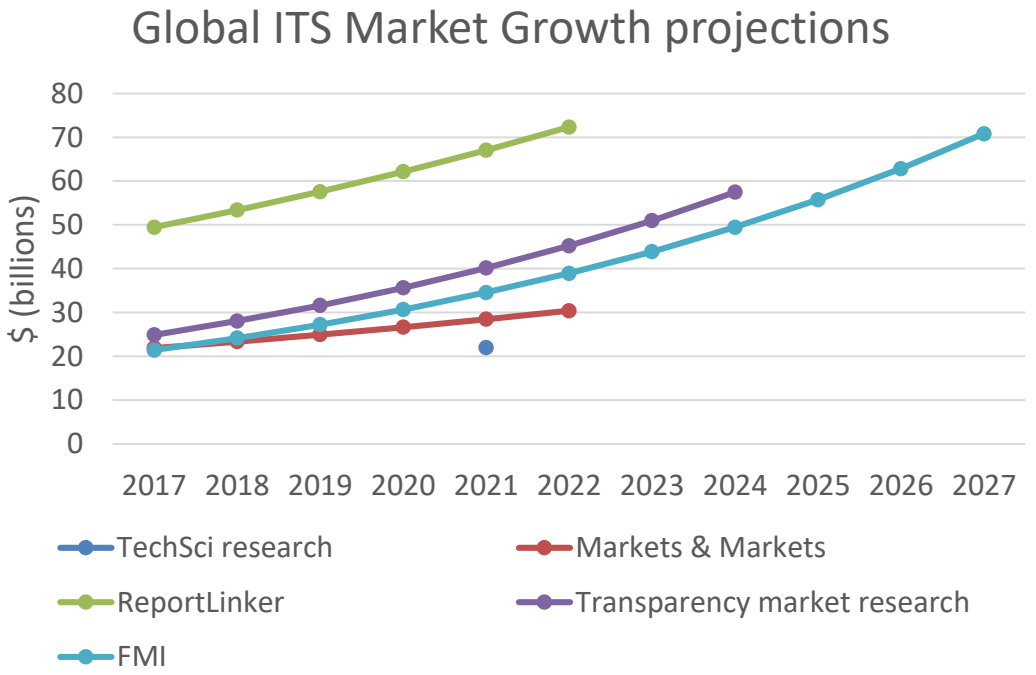
Activity and improvement on ITS technology is prevalent all over the world and is generally driven and co-ordinated by three international bodies; ERTICO (Europe), ITS America & ITS Asia-Pacific.

Global ITS Markets

The global value of ITS markets is currently at approximately $25 billion, and a majority of market research studies agree that this figure is likely to grow in the near future, approximately doubling by 2023 and, according to Future Market Insights (FMI), potentially trebling over the next 10 years.

Key markets around the globe that are pushing this growth are those in Europe, North America and South/East Asia, and predominantly in areas of high, dense population.

This growth bodes well for products such as ACCRA which will depend on these communication systems becoming more common-place and therefore being able to integrate into them.



Average current market value = $22.72 bil; average projected value in 2021 = $31.28 bil; Average growth in next 3 years = 37.6%

ITS in the UK

ITS has been standardised in the UK under the Urban Traffic Management Control (UTMC) initiative, which at its' core is a library of technical specifications that traffic managers can contribute to and use when building their own UTMC system. It was created in the early 1990s by the UK Department for Transport (DfT) and its aim was:

- *To make use of mainstream technology as far as practical: notably internet protocols*
- *To set standards where useful – but only where useful: we focus on interfaces, and leave functional innovation to the creativity of suppliers*
- *To be maintained by consensus: we want to foster practical systems suited to both suppliers and users, not to create a technical dictatorship*
- *To be open and readily available: UTMC specifications are free to access and free of charge*

Since then it has developed into the de facto national standard for traffic-related ITS, with the great majority of UK local authorities having a UTMC core to their traffic management systems. This ensures that systems can effectively speak to each other simply, quickly and cheaply, and avoids the dangers of a local authority using a bespoke system and becoming locked-in to a supplier.

All of the work is undertaken cooperatively with both the public highways community and the systems industry under the UTMC Development Group (UDG), which is always managed by up to 10 of its' members (7 local authorities & 3 suppliers).

UTMC aim to provide practical help, avoiding excessive complexity in favour of simple, agreed approaches. Backed by policymakers in the UK and Europe, UTMC is free for anyone to use, and there are implementations all across the globe.

UTMCs in the UK & Europe

UK market

The ACCRA system has been designed and developed by Dynniq, who develop and operate UTMC systems in the UK and Europe. Dynniq ran one of the first four UTMC demonstrator projects in York from 2001-2004 [1], and since then have expanded the number of cities they operate in to 15, including Sheffield, Rotherham, Doncaster, and Kirklees [2]. These 15 cities would provide the ideal conditions to be able to install the ACCRA system almost immediately.

ACCRA is designed to work with Dynniq's own systems which are built on a UTMC platform. ACCRA therefore is theoretically able to work with any system that is build on a UTMC platform, opening up opportunities all over the UK. Other major suppliers of UTMC systems in the UK include Siemens and Mott MacDonald, which expands the potential market of ACCRA to over 100 cities [3].

Europe

The UTMC group work with their European counterpart POLIS to expand the use of open access specifications, encouraging common standards between cities and avoiding supplier lock-in. POLIS is a large network of local authorities, suppliers and research facilities working together to develop innovative technology and policies for local transport [4].

One of POLIS's projects, Project POSSE, encourages the use of ITS for sustainable urban policies and supports the development of Europe-wide open ITS specifications and standards. Reading in the UK is leading the project which includes the cities of Klaipeda (Lithuania), Burgos (Spain), La Spezia (Italy), and Pisa, (Italy).

Other members of POLIS include Berlin, Barcelona, Amsterdam, Rotterdam, London & Southampton (CAZ cities), Paris, Rome, and Milan, which all represent potential future markets for ACCRA that could be early adopters in Europe. There is a potential opportunity to engage with the POLIS group and promote the use of ACCRA to its members.

Data Communication with Vehicles

The ability for cities, or infrastructure in general, to gather and act on traffic data has various uses that can improve transport in a number of ways, for instance managing traffic signals for better flow. However, to fully realise the potential of all the data available to a city it must be communicated with the vehicles travelling inside it, namely **Vehicle to Infrastructure (V2I) communication**.

For this to be possible, the vehicles must have a level of technology capable of collecting, sending and receiving data to and from the infrastructure around it. Vehicles with this capability are known as **Connected Vehicles:**

> *A connected vehicle is a vehicle with technology that enables it to communicate and exchange information wirelessly with other vehicles, infrastructure, other devices outside the vehicle and external networks [5]*

This connectivity is normally achieved by accessing the internet via a GSM digital network, the same used by over 90% of the mobile communications industry. This is done either through a SIM card embedded in the vehicle or tethering with the driver's smartphone, and this level of connection already exists in many of the vehicles we drive today, powering services such as satellite navigation (sat-nav) systems or e-Call (European wide initiative that allows the driver to call the emergency services in the event of a collision using a single button, pictured).

There are several other categories of vehicle communication including:

V2I – Vehicle to Infrastructure (e.g. traffic signals, traffic management centres)

V2D – Vehicle to Device (e.g. the driver's mobile phone)

V2V – Vehicle to Vehicle

V2X – Vehicle to everything

Example of an e-Call system fitted in the headliner of a car

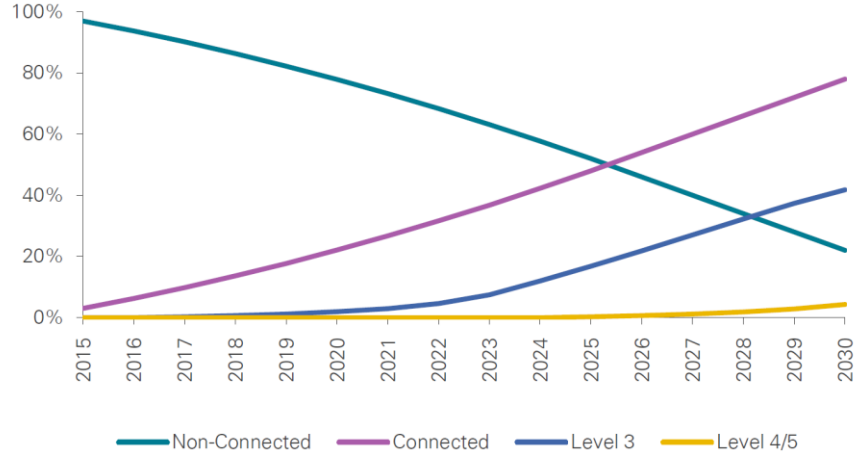
Growth of Connected Vehicles

For autonomous vehicles to navigate safely and efficiently, they will require a lot of data from their surrounding environment and as such will need to be “connected”.

The percentage of connected vehicles is currently quite low but predicted to grow to almost 80% of the total UK vehicle parc by 2030. Regulations are starting to promote this growth, such as the requirement that all cars sold in the EU are to have the e-Call system fitted from April 2018 [6].

There are two competing methods of connectivity; 5G is based on the expansion of the current mobile phone network, works over longer distances, is able to both send & receive signals, and is currently the favoured method by vehicle manufacturers (OEMs) in Japan & Europe. However, it is still in its development phase.

Technology take-up as a percentage of total UK vehicle fleet, based on KPMG analysis of IHS (2015) estimates



Source: KPMG analysis based on IHS (2015) estimates and publicly available information from GSMA (2014), Ofgem, MobileSquared and RAC Foundation (2008).

DSRC (or ITS-G5) is more akin to WiFi, sending out signals for vehicles to act on without the ability to respond. It works on shorter ranges but is already standardised and able to be fitted, hence it being favoured by many OEMs in the USA [7,8].

Many OEMs across the world are delaying decisions on vehicle development to see which system becomes more widely accepted, and many industry experts believe that the future of connectivity will see a combination of both standards. For those vehicles currently without connectivity, Tevva can potentially install a Tevva Link Telemetry Unit (TU) to enable a vehicle to operate ACCRA.

Target Market

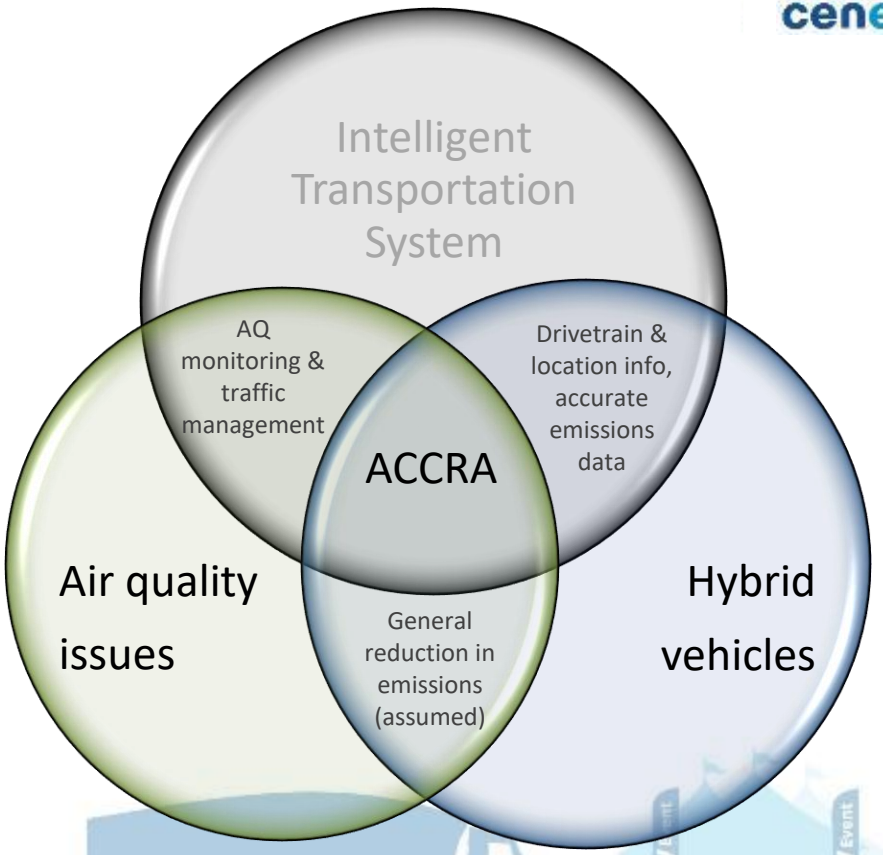
Project ACCRA: Target Markets

Introduction

Within the Intelligent Transport System industry there are many markets that can be exploited by a product or service, depending on the problem being solved, and ACCRA overlaps two of these markets.

ACCRA's goal is to improve air quality so this forms one of those key markets that we will look into further, understanding why air quality has become such an issue in recent times, how wide spread the issue is, what is currently being done to combat it, and what may happen in the future.

The system is specifically targeted at hybrid vehicles, so this is the second key market we will have to consider. Again we will look into the technology itself, how many vehicles are currently being sold and where, and how sales might change in the near and distant future.



UK & Global Activity for Emission Reduction

Understanding the drivers behind the recent concerns over air quality, particularly in cities, and the actions that are being taken to solve this problem, both in the UK and globally. Specific attention is paid to Clean Air Zones in the UK, how they may affect vehicles operating in cities, and how ACCRA can be integrated with them

Drivers Behind Improving Air Quality & Emissions

Air Quality Concerns

A World Health Organisation (WHO) air quality model (Sept 2016) shows that 92% of the world's population lives in places where air quality levels exceed WHO limits. The WHO estimates that in 2012 there were 6.5m deaths (11.6% of all global deaths) caused by air pollution. [9]

In Dec 2016 Paris hit record levels of air pollution causing severe smog. This provoked a vehicle ban based on license plate number for two days. [10]

The World Bank and the Institute for Health Metrics and Evaluation (IHME) jointly published a study that predicts the annual cost to the global economy is $5 trillion. [11]

In Nov 2016 ClientEarth, a group of environmental activist lawyers, won a court case against the UK government over its failure to tackle air pollution across the UK, noting that air quality plans had been watered down and highly inaccurate modelling was used to justify policy decisions. [12]

Climate Change

There is a vast and growing body of scientific evidence showing that climate change is already happening. Global average surface temperatures have risen higher than pre-industrial levels, global sea level has risen by 20m from melting ice sheets, and sea ice is decreasing.

Human activity is a significant contributor to the greenhouse gas effect, whereby carbon dioxide (CO_2) and other gases collectively create a warming effect in the atmosphere. Burning of fossil fuels has increased progressively since the industrial revolution, releasing huge quantities of greenhouse gases into the atmosphere. [13]

A number of international projects such as the UN Paris Agreement (2015) are designed to reduce emissions to levels which will limit the damage of global warming. [14]

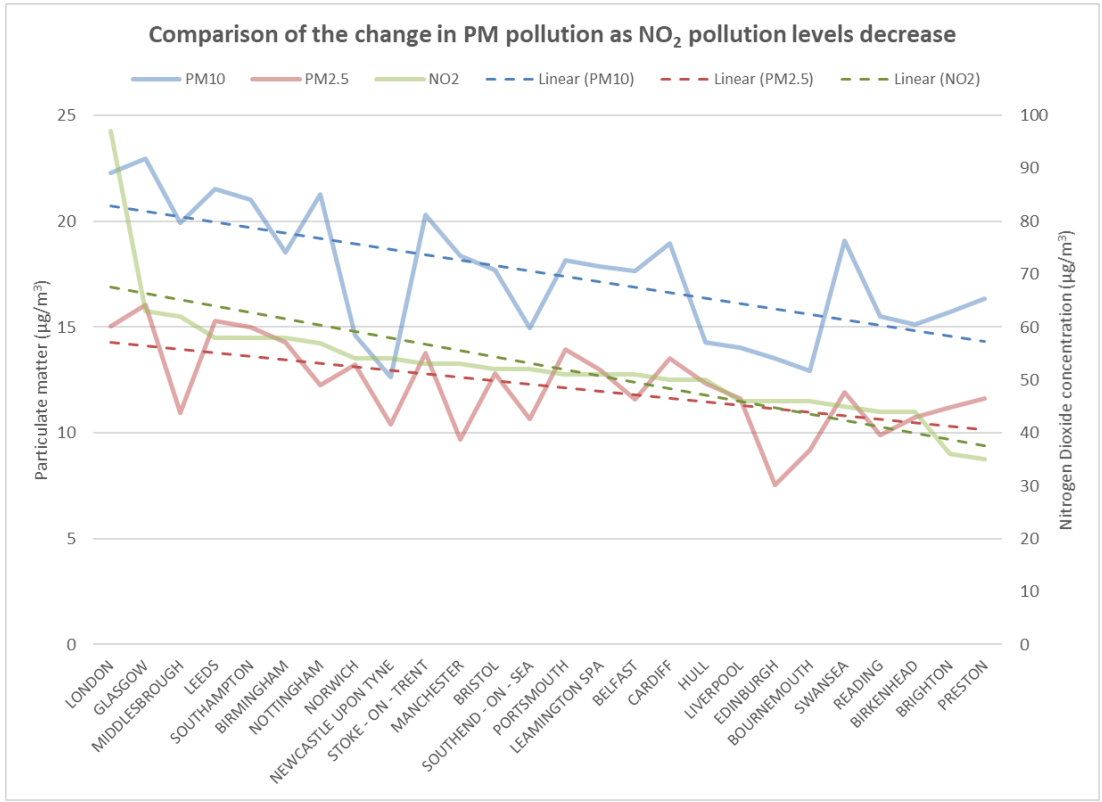
Global Air Quality Issues

The WHO monitor air quality across the world in almost 3000 different cities by measuring the levels of particulate matter (PM), as this is the most commonly used indicator to assess the health effects of air pollution. Despite the UK's desire to tackle NO_2 pollution, a correlation between the two can be derived.

The graph here shows the NO_2 values measured by the UK's Department for Environment, Farming and Rural Affairs (DEFRA), compared to the PM values measured by WHO for the same UK cities.

As shown by the graph, there is a correlation between the two showing that as NO_2 levels tend to decrease so do PM levels.

From this we can make the broad assumption that the two pollutants are related and that, if a city has high pollution levels of one, it is likely to have high pollution of the other too.

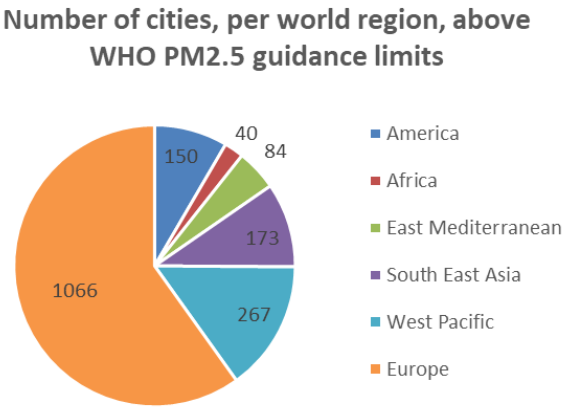


Global Air Quality Issues

City	PM2.5 (ug/m^3)	NO_2 (ug/m^3)
LONDON	15.0	97
GLASGOW	16.0	63
MIDDLESBROUGH	11.0	62
LEEDS	15.3	58
SOUTHAMPTON	15.0	58
BIRMINGHAM	14.3	58
NOTTINGHAM	12.2	57
NORWICH	13.2	54
NEWCASTLE UPON TYNE	10.4	54
STOKE - ON - TRENT	13.8	53
MANCHESTER	9.7	53
BRISTOL	12.8	52
SOUTHEND - ON - SEA	10.6	52
PORTSMOUTH	13.9	51
LEAMINGTON SPA	13.0	51
BELFAST	11.6	51
CARDIFF	13.5	50
HULL	12.4	50
LIVERPOOL	11.6	46
EDINBURGH	7.5	46
BOURNEMOUTH	9.2	46
SWANSEA	11.9	45
READING	9.9	44
BIRKENHEAD	10.8	44
BRIGHTON	11.2	36
PRESTON	11.6	35

WHO guideline values are set at levels in order to encourage the least harm to human health as possible. For NO_2 this limit is 40µg/m^3 while for PM2.5 (particulate matter less than 2.5µm in diameter) this limit is 10µg/m^3 [15]. From the table on the left we can see a strong correlation between cities that exceed both limits, with 20 of the 26 exceeding both and again demonstrating this correlation between PM and NO_2.

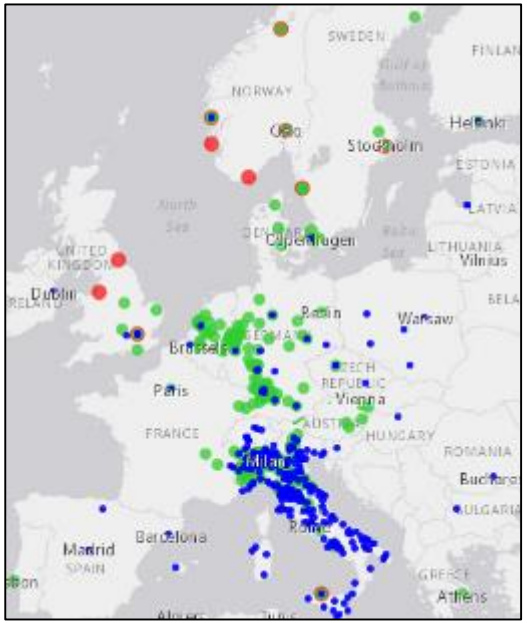
Therefore, if we apply the same assumption to the rest of the cities surveyed by WHO, and assume that any city exceeding the PM2.5 limit will also likely be exceeding the NO_2 limit, we can estimate the number of cities around the world that have a NO_2 air quality problem.



Here we can estimate that over 1000 cities in Europe have an air quality problem, with a further 714 outside of Europe [16]. This represents the potential size of the market for ACCRA.

Given the interest and focus within Europe currently around air quality, it would make this region the best market to penetrate initially, and this also happens to be the largest market.

Traffic Regulations & Restrictions



- Major access regulation scheme (e.g. permitted areas)
- Low Emission Zone
- Urban road charging scheme (e.g. tolls, congestion charge)

One way to combat poor air quality and climate change is through traffic regulations such as Low Emission Zones (LEZs). The map (left) shows that there are hundreds of LEZs / other access regulated zones (521 currently) in cities across Europe. [17]

Additionally, there are continued efforts to tighten regulations, e.g.:

- The ultra-low emission zone (ULEZ) in London to be implemented by September 2020 with proposals to bring that forward to April 2019. [18]
- Stuttgart plans to ban diesel vehicles that are not compliant with latest Euro 6 standards in central areas of the city on high pollution days. [19]

Few other areas of the world are implementing LEZs on the same scale as Europe. However, China has already put in place a number of traffic regulation schemes to limit traffic volume / production to curb emissions, particularly Beijing which has problems with smog.

China also has ongoing environmental policy development, e.g. Action Plan for Air Pollution Control - 1.7 trillion yuan ($230 billion) to be spent on air pollution controls (2013-2017). [20]

Many countries and regions are beginning to align their emissions standards and test requirements with those of the European Union (EU) making these sorts of regulations more likely across the world in the future, and make systems like ACCRA relevant and useful to many more locations.

UK Air Quality Activity

In July 2017, the UK government released the UK Plan for Tackling Roadside Nitrogen Dioxide Concentrations [21], which requires local authorities to take action to reduce the annual mean average measurements of Nitrogen Dioxide (NO_2) to under the 40µg/m^3 statutory limit. NO_2 is found in the NO_x (oxides of nitrogen) emissions from transport, so improving transport emissions is a major part of this plan.

In total, 29 local authorities have been mandated to produce a plan to reduce pollution; London has already begun steps with its LEZ and toxicity charge, Leeds, Nottingham, Derby, Birmingham & Southampton have all been mandated to introduce a CAZ, and 23 more local authorities are required to make actions plans.

Many other councils are already considering taking action such as Norwich (LEZ), Oxford (Zero Emission Zone, ZEZ), Liverpool (mass education scheme) and Cardiff (low emission transport strategy).

These councils all represent the potential early adopters for the ACCRA system.

Table 3: Local authorities with persistent exceedances required to undertake local action to consider the best option to achieve statutory NO_2 limit values within the shortest possible time[40]

Basildon District Council	Coventry City Council	Leeds City Council	Nottingham City Council	Southampton City Council
Bath and North East Somerset Council	Derby City Council	Manchester City Council	Rochford District Council	Stockport Metropolitan Borough Council
Birmingham City Council	Fareham Borough Council	Middlesbrough Borough Council	Rotherham Metropolitan Borough Council	Surrey Heath District Council
Bolton Metropolitan Borough Council	Gateshead Metropolitan Borough Council	New Forest District Council	Rushmoor Borough Council	Tameside Metropolitan Borough Council
Bristol City Council	Greater London Authority	Newcastle City Council	Salford Metropolitan Borough Council[41]	Trafford Metropolitan Borough Council[42]
Bury Metropolitan Borough Council	Guildford Borough Council	North Tyneside Council	Sheffield City Council	

Source: DEFRA / DfT, UK plan for tackling roadside nitrogen dioxide concentrations, July 2017

UK Traffic Regulations & LEZs

There are several types of area/zone that exist in the UK and relate to air pollution. They are as follows:

Acronym	Name	Definition	Location
AQMA	Air quality management area	Area designated by a local authority as being at risk of not achieving the National Air Quality Objectives, and therefore requiring some further management	UK, various (current total = 655)
CAZ	Clean air zone	A geographically defined area bringing together immediate action to improve air quality	London, Leeds, Derby, Nottingham, Birmingham, Southampton (all in planning)
LEZ	Low emission zone	A form of CAZ that only applies to the most polluting vehicle types or specific vehicles, as determined by the local authority	Greater London (heavy duty diesel vehicles only); Norwich, Nottingham, Oxford, Brighton (all buses only)
ULEZ	Ultra-low emission zone	A form of CAZ (class D) that applies to vehicles of all sizes and fuel types	Central London

The UK government has, alongside the UK NO_2 plan, released the Clean Air Zone Framework [22], a document that will guide local authorities on how to set up a CAZ and ensure schemes remain consistent between cities.

Clean Air Zones

The Clean Air Zone Framework contains the guiding principles by which local authorities should set up and run their CAZs. A key decision for the local authority (LA) will be whether drivers are asked to pay a charge to enter the zone or not, and which type of vehicles will be charged. London and other similar zones have had success with charging vehicles so this is seen as the most effective method of improving air quality quickly, but LAs must rule out all other alternatives before considering this option.

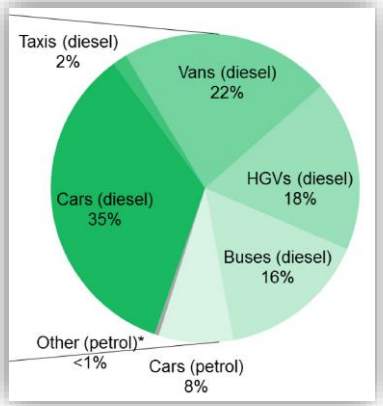
From the date that each emission standard came into force we can see that, for light duty vehicles (cars, vans etc), any petrol vehicle made after January 2005 and any diesel vehicle made after September 2014 will remain compliant. For heavy duty vehicles any bus, coach or heavy goods vehicle (HGV) made after January 2013 will also remain compliant.

The standards are intended to target diesel vehicles, particularly cars, as these are a much bigger contributor to the NO_2 pollution issue. HGVs and buses currently contribute ≈34% of roadside NO_x concentrations but only account for 1.75% of all vehicle registrations, so would be a key vehicle type to target as quite small improvements could yield quite large reductions in NO_2.

It is also worth noting that the framework states “Ultra low emission vehicles with significant zero emission range will never be charged for entering or moving through a Clean Air Zone”.

Class A	Class B	Class C	Class D
Buses, coaches, taxis and private hire vehicles (PHV’s)	Class A + Heavy goods vehicles (HGV’s)	Class B + Large/small vans (light goods vehicles, LGV’s) and minibuses	Class C + Cars and motorcycles/mopeds (optional)

UK national average NO_x concentrations from transport, 2015 [23]



Vehicle type	Emission standard
Bus, coach, HGV	Euro VI
Large/small van, minibus, car, taxi, PHV	Euro 6 (diesel) Euro 4 (petrol)
Motorcycles, mopeds	Euro 3

Clean Air Zones & Integrating ACCRA

ACCRA is intended to be a solution that works alongside CAZs in order to improve air quality, so to encourage its use there needs to be an incentive, whether that be a reduction in charges or the removal of restrictions that would apply to non-ACCRA vehicles.

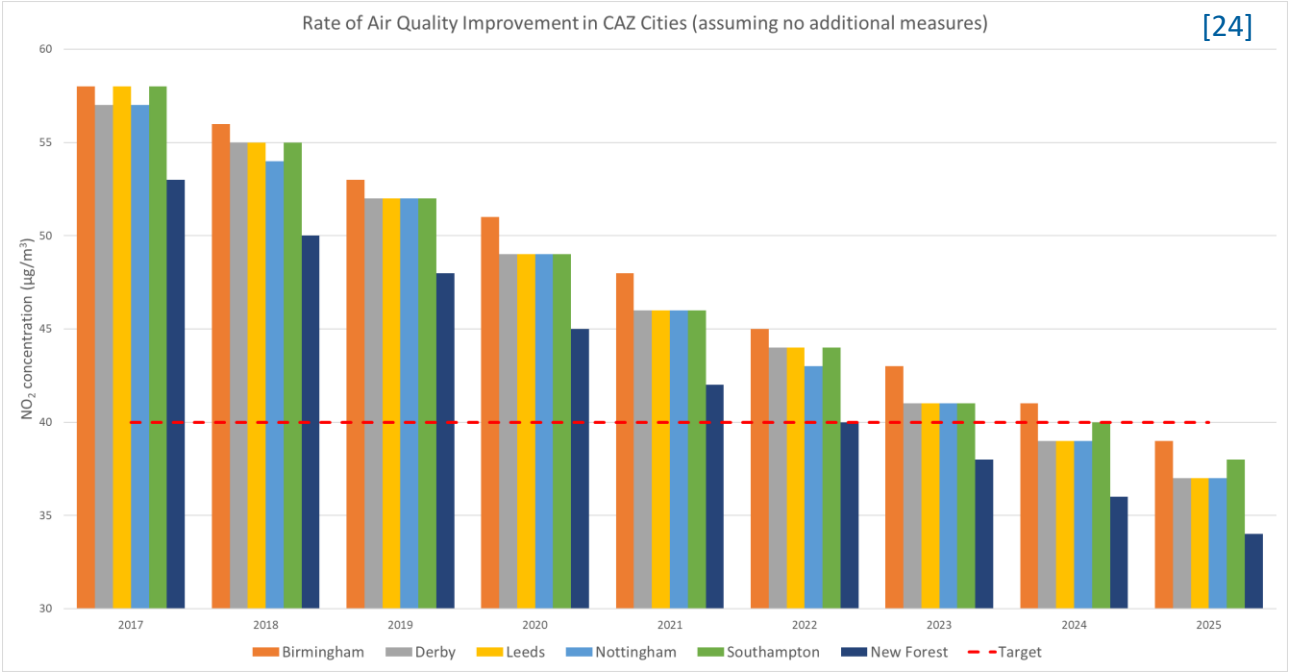
By analysing some of the tools at a local authority's disposal to create a CAZ, we can see that only small amount of these are relevant and could provide a concession to ACCRA vehicles (highlighted in bold below). These would also have to be above and beyond those concessions given to ULEVs which are already exempt from charges under the CAZ Framework.

Charging zone tools	
Access charge to enter CAZ for certain vehicles, determined by either age, Euro standard or type	
Non-charging zone tools	
Encourage ULEV uptake through preferential parking/delivery/taxi bays, lower parking fees, access to bus lanes or pedestrianised areas (at night), increased access to charge-points & alternative refuelling stations, and tax incentives for businesses	
Complete or time-dependant bans (variable by vehicle type/euro standard, e.g. Crit'Air)	Cooperation with businesses to encourage flexible working, consolidating deliveries, eliminating the need for travel by using technology more
Improving and promoting alternative public transport options such as buses and trains	AQ considerations built into standards for land use planning, public sector fleet procurement and operation, and taxi licensing
Optimising traffic management	Expansion of walking & cycling networks
Publicizing and demarcating	Communication & education campaigns

UK CAZ City Projections

The graph on the right shows the government's prediction of how levels of NO_2 will naturally decrease in the CAZ cities due to fleet turnover to more modern & cleaner vehicles.

By introducing a CAZ, the government has estimated this timeline could be brought forward to 2020, and as such sets the benchmark for achieving compliance "as soon as possible".



Cities such as Leeds and Southampton have already declared their intention not to charge passenger cars or motorbikes under a class D. These cities are therefore likely to introduce additional measures in order to achieve compliance within the timeframe suggested by the governments' modelling (~2020). Several other measures have been identified in the UK NO_2 Plan 2017, and ACCRA could be added to this list of potential additional measures

Global Air Quality Activity & Future Developments

Outside of the UK, according to http://urbanaccessregulations.eu/ there are 258 cities & locations with LEZs in the EU, including speed restricted areas, toll roads and full CAZs. Outside of Europe there is very little activity, the only notable additions being Hong Kong (3 small LEZs that apply to buses only) [25] & Singapore (operated as a Congestion Zone that has in-direct improvements in air quality) [26].

It should be noted that, while the WHO guidelines set a limit of 40µg/m^3 for NO_2 and 10µg/m^3 for PM2.5, scientific studies have yet to identify a "safe" limit of exposure to these substances [27], so until this can be determined it must be assumed that no amount of exposure to these substances is safe and there will always be a negative effect on a person's health.

From this we can also predict that WHO guidelines, and therefore statutory limits for these pollutants, are likely to decrease in future and this fact has already been taken into account in much of the UK legislation around air quality. The CAZ Framework states "To meet these needs the minimum vehicle standards… will be periodically updated" [28]; policy 7 from the London Mayor's Transport Strategy 2018 alludes to zero emissions and tighter air quality standards, and the Clean Air Strategy 2018 highlights the impending release of the Road to Zero strategy for exhaust emissions from road vehicles.

Therefore, while current CAZ guidelines provide exemptions for vehicles such as ULEVs or Euro 6 diesels, it is highly unlikely these vehicles will remain exempt in the long term, and thus a zero emission solution such as ACCRA will give a vehicle greater flexibility & longevity in an environment of ever more restrictive policies and air quality limits.

UK & Global Markets for Hybrid Vehicles

Understanding the UK and global markets for hybrid vehicles, how they are likely to change in future, and the drivers behind any change. Specific attention is given to those hybrid types that are compatible with ACCRA, and how this affects the size & class of vehicles that are compatible with ACCRA

What is a Hybrid?

A hybrid vehicle has at least two power sources that can provide propulsion to the vehicle (or work together to reduce the energy required for propulsion of the vehicle).

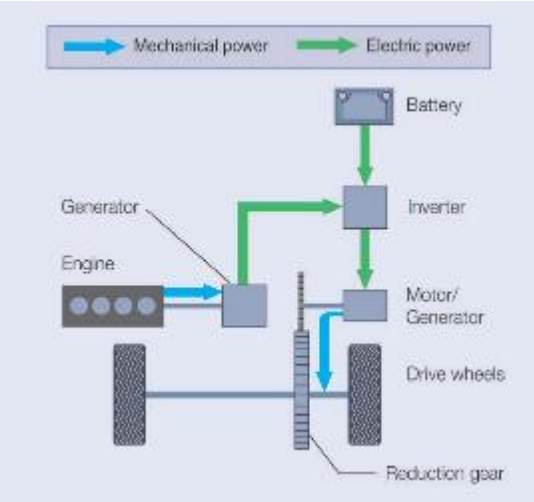
There are several different types of hybrid drivetrain available on vehicles that vary in there intended use. Some are designed to reduce the work needed to be done by the internal combustion engine, some to completely replace the engine where possible, and some to enhance vehicle performance (e.g. in supercars).

To work with the ACCRA system, a vehicle needs to be capable of running in zero emissions mode for at least a short distance (greater than 1 mile). Some hybrid vehicles are not capable of this, so we will first explore the different types and determine which variants of hybrid vehicle are potentially compatible with the ACCRA system.

Hybrid Types

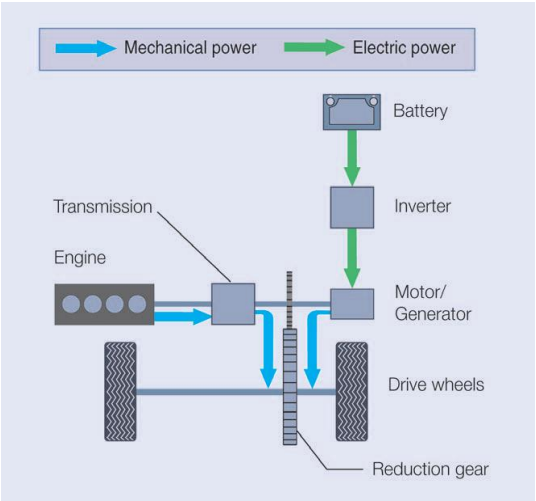
When considering road vehicles, hybrids appear in two main configurations; **series** and **parallel**.

Series



The wheels are powered by an electric motor, which derives its power from a battery. This battery is charged by an on-board power unit such as an internal combustion engine, but critically this power unit is not connected to the wheels and doesn't directly provide propulsion.

Parallel



The wheels can be powered by either the electric motor or the on-board power unit, or both simultaneously.

There are several forms of parallel hybrid, depending on the capacity of the installed battery and how much power the motor can supply to the wheels.

Series hybrids, often know as Range-Extended Electric Vehicles (REEVs), are always capable of running in zero-emission mode, so all of these type of vehicle are potentially capable of working with ACCRA.

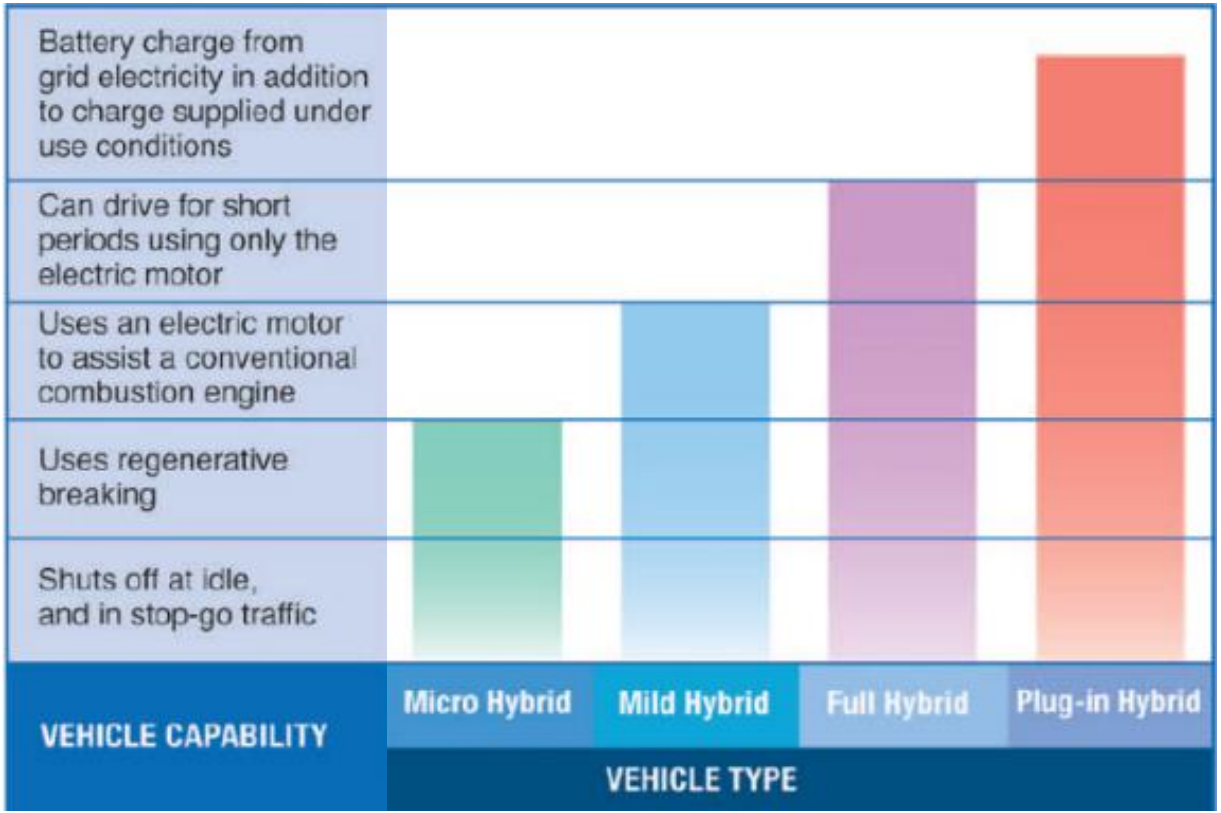
Due to the different nature of parallel hybrids, some are not compatible.

Hybrids Compatible with ACCRA

In general, there are four different types of parallel hybrid; micro, mild, full and plug-in.

The table (right) shows the main differences between each type.

There are only two types that are able to drive for at least short periods using only the electric motor, those being the **full hybrid** and the **plug-in hybrid (PHEV)**. It is only these types of parallel hybrid that are compatible with the ACCRA system, and therefore the market study will concentrate on these types, their current prevalence, and their projected increase in popularity over the next 10-15 years.



Hybrids Compatible with ACCRA

Below are typical examples of each of the hybrid types that are compatible with the ACCRA system, detailing their zero-emission (ZE) range and a number of other examples that all have similar characteristics.

Series hybrid (REEV)

BMW i3 Range Extender

ZE range ≈ 110 miles

Total range ≈ 205 miles (NEDC)

Other models include:

Vauxhall Ampera

Nissan Note e-Power (Japan only)

Parallel hybrid (Full)

Lexus CT200h

ZE range ≈ 2 miles

Total range ≈ 680 miles

Other models include:

Toyota Prius

Ford C-Max Hybrid

Parallel hybrid (Plug-in, PHEV)

Volkswagen Golf GTE

ZE range ≈ 30 miles

Total range ≈ 580 miles (NEDC)

Other models include:

BMW 330e

Volvo XC90 Twin Engine

The same variations also apply to other classes of vehicle such as buses, heavy goods vehicles (HGVs) and light goods vehicles (LGVs). We will analyse the compatibility of ACCRA with each of these vehicle classes separately in more detail.

Source: Go Ultra Low, manufacturer websites

Vehicle Markets for ACCRA – Cars & Taxis

Cars

There are almost no models of hybrid car available that use a diesel engine, so almost all hybrids on the roads have petrol hybrid powertrains. As we have discussed in the air quality section, the CAZ Framework advises an emission standard of Euro 4 for petrol engines, and also means that any petrol hybrid built since 2005 will automatically be compliant with CAZ restrictions.

The vast majority of hybrids on the roads today have been built since 2005 and thus there is an extremely small amount of hybrid cars that would be non-compliant. **Therefore, using the ACCRA system currently doesn't offer any further benefit to the user and means the passenger car segment is not a viable market.**

Taxis & Private Hire Vehicles (PHVs)

Despite most taxis and PHVs using the same type & size of vehicle as passenger cars, they are subject to taxi licensing rules imposed by the LA they work in, and as such have more stringent conditions to satisfy. They also tend to be diesel vehicles and are therefore a prime target for CAZs of all types, from A to D.

However, the simplest option for operators with non-compliant vehicles is still to replace them with a compliant vehicle such as a Euro 6 diesel, and as such **ACCRA currently offers no added incentive.**

Hackney Carriages are taxis that are given added benefits by a local authority (e.g. ability to take fares from locations without taxi ranks) in return for a higher specification of vehicle with a better turning circle and the ability to take disabled passengers.

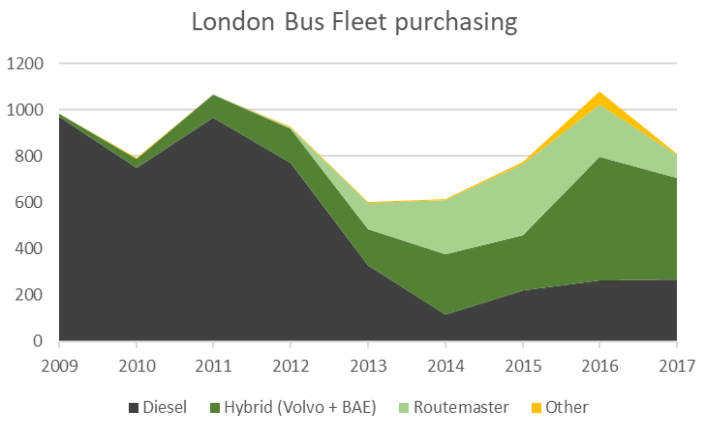
Several ULEV options for Hackney carriages are beginning to appear on the market, such as the Dynamo Evalia and LEVC Vista (pictured left), but as they are ULEVs they already comply with CAZ emission standards and, again, are **currently an unviable market for ACCRA.**

Vehicle Markets for ACCRA – Buses

Bus manufacturers are also beginning to develop hybrid versions of their existing models, and have already rolled many of them out across councils in the UK. There are two main manufacturers of hybrid buses:

Volvo – most of their hybrid models (7900H, B5LH, B5LHC) are configured as parallel, full hybrids with a very short ZE range. The 7900EH however is a plug-in hybrid meaning it is able to run for long distances on ZE mode.

Alexander Dennis (ADL) – these run a BAE designed hybrid system and are configured as a series hybrid, therefore giving them the potential to work with ACCRA.



There is a third hybrid model made by Wrightbus called the Routemaster, but this was made especially for London only and is also a mild hybrid with little ZE range. London currently has over 2900 hybrid buses [29] but approximately two thirds of these are mild hybrids that wouldn't be compatible with ACCRA.

ADL have sold more than 1000 of their series hybrid buses across the UK, with 500 in London and another 500 distributed across cities such as Reading, Oxford, Essex, Lincoln, Yorkshire, Manchester, Renfrewshire, Glasgow, Lothian, Perth and Dundee [30].

The amount of hybrid buses operating in London continues to grow, and given the air quality targets we can expect to see similar trends in other large cities, meaning buses of the ADL type would be a viable market for the ACCRA system.

Vehicle Markets for ACCRA – Goods Vehicles

Lights Goods Vehicles (LGVs; gross vehicle weight, GVW <3500kg)

Many Original Equipment Manufacturers (OEMs) are beginning to hybridise their LGV range, such as Vauxhall, Mercedes and Peugeot. Unfortunately these models are often micro hybrids, which incorporate start-stop technology, and don't have a ZE range. Ford have created a PHEV version of their Transit Custom van which is currently being trialled, and LEVC are also producing a van-version of their range-extended taxi, but both of these are not scheduled to be available until 2019.

At this vehicle size, OEMs have tended to jump straight to full electric vehicles, such as the Nissan eNV200, Renault Kangoo Z.E. and the Citroen Berlingo Electric L1 635 LX.

Heavy Goods Vehicles (HGVs; GVW >3500kg)

Larger vans and trucks are also beginning to be equipped with hybrid systems, although few of them currently have the capability to drive in ZE mode at speeds above 20km/h or for extended periods, and fall more into the category of mild hybrids (e.g. Iveco, Hino, Fuso & Volvo trucks).

This is however a step further on than their lighter counterparts and indicates it is more likely that HGVs will develop hybrids with a ZE range in the near future. Exceptions to this are Tevva (pictured here), who have developed a range of trucks between 7.5t and 14t that have up to 100 miles of ZE range.

Generally, commercial & goods vehicles do not have the zero-emission ranges capable of operating the ACCRA system and so are not currently a viable market to base the roll out of ACCRA on, although HGVs may become capable in the next 5 years. However, the ACCRA system could help drive sales and development of such vehicles if the business case is favourable.

Options for HGVs and Buses

As discussed in the air quality section, HGVs and buses comprise only 1.75% of all vehicle registrations [31] but are responsible for ≈34% of all roadside NO_x concentrations, making them a key early target to improving air quality. There are currently very few options for fleets operating HGVs or buses if they are to comply with the air quality legislation, and avoid the restrictions/charges of the CAZs being introduced into cities around the UK and Europe.

Depending on the size of the vehicle, replacing an HGV with a CAZ complaint, Euro VI standard vehicle would cost anywhere between £30,000 and £90,000. Assuming a daily charge of £100 for non-compliant vehicles and entering the zone every working day, payback on this would be relatively short (1.5-3.5 years), but the initial outlay may be too much for a fleet to cope with.

The same issue can be seen with buses and, while there may be slightly more options for purchasing new hybrid vehicles, the costs can be between £250,000 and £350,000 [32], far greater than for HGVs.

An alternative to replacing a vehicle may be to retrofit the vehicle with a hybrid system, which tends to require much lower capital cost outlay.

In the HGV market, Tevva Motors are able to retrofit a hybrid system to HGVs ranging in weight from 7.5t – 14t. For buses, Vantage Power is currently the only business able to retrofit a hybrid system, a process that is estimated to cost approximately one quarter of the cost of purchasing a new hybrid bus. In both circumstances, the hybrid system being fitted is a series system meaning that it has sufficient zero-emission range to mean that it would be compatible with ACCRA.

These options therefore present a potentially more cost effective opportunity to operators and fleet managers, who need to comply with legislation but do not have access to large amounts of capital funds to completely replace vehicles. It would also mean a larger market for the ACCRA system, which itself may prove an added bonus to an operator installing a hybrid system on their current vehicles, and in turn increase the number of retrofits carried out.

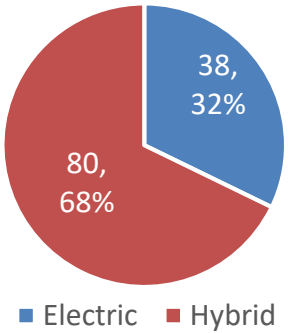
UK Market Size - Current

The market for hybrids vehicles in the UK is small but growing rapidly, especially with advent of plug-in vehicle grant in 2011 & continued support until at least March 2020 [33].

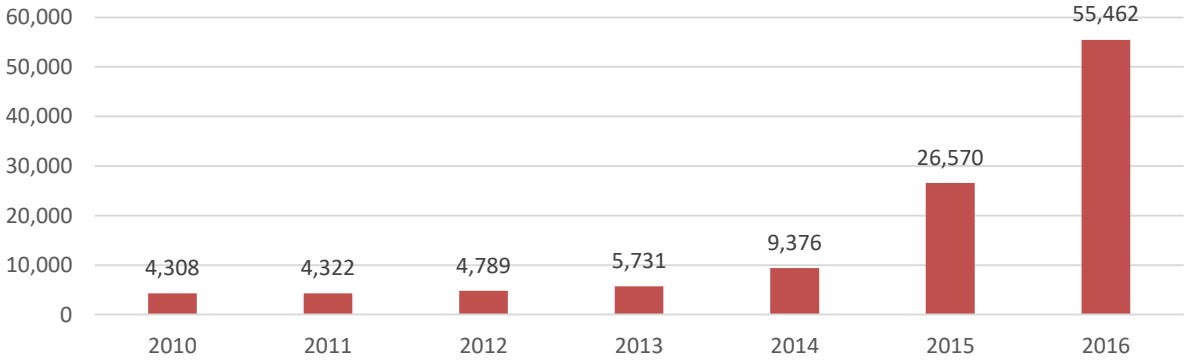
Market data published by the government and Society of Motor Manufacturers & Traders (SMMT) is limited in its stratification, making it difficult to identify how many ACCRA compatible hybrids (REEV, full and PHEV) are being registered. However, all of the hybrid models currently classified as ULEV have an available ZE range large enough for ACCRA, and data is available on the registration of Ultra Low Emission Vehicles (ULEVs) in the UK. Therefore, by counting the number of hybrid ULEVs registered we can at least derive a minimum figure for the current size of the market for ACCRA.

Data from the last 7 years shows their increased popularity and this interest is accelerating, with the number of ULEV hybrids on UK roads effectively doubling each year since 2013.

Vehicle models classified as ULEV [34]



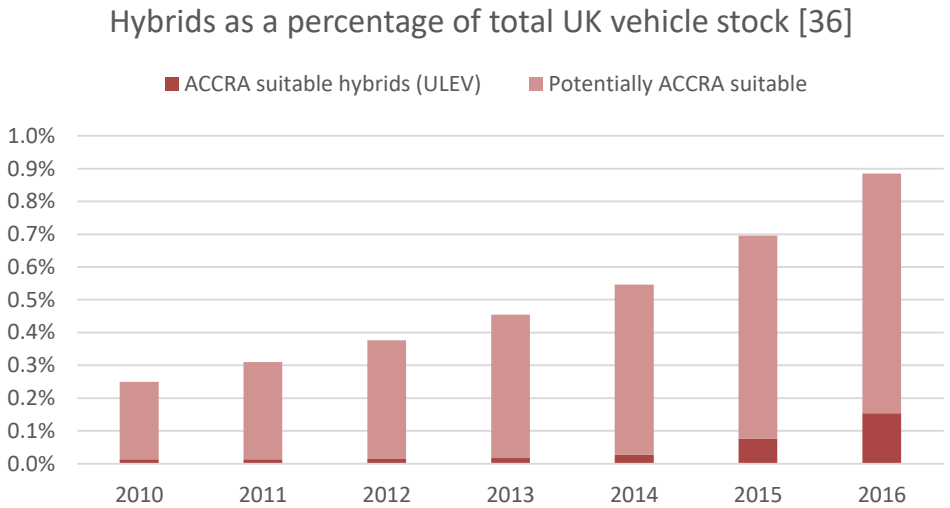
Total ULEV hybrids (minimum market for ACCRA) [35]



UK Market Size - Potential

Expressed as a percentage of the total vehicle stock in the UK shows that ULEV hybrids currently occupy a very small part of the market (~0.15%).

However, according to data from www.carpages.co.uk there are a further 137 hybrid vehicle models that are not classified as a ULEV, but many of which will be full or PHEVs and therefore still be ACCRA compatible. Examples of these vehicles would be the Kia Niro, Toyota Auris, and Ford Mondeo. Including these increases the *potential* market to over 300,000 vehicles and almost 0.9% of the UK vehicle stock, with the actual figure somewhere between 0.9% and 0.15%.



This group of vehicles would also include hybrid versions of heavy duty vehicles such as buses and HGVs, a classification of vehicle that are heavy polluters in city environments. These vehicles are also often operated by city councils making it easier for the city to make the necessary improvements to the vehicle fleet and control their engine operation.

For example, a Volvo Hybrid B5LH bus emits 951.6 gCO_2/km and is a relatively high polluting vehicle [37], but it has the capability to run in zero emissions mode for short periods. The hybrid drivetrain therefore enables even the most polluting of vehicles to contribute to improving the air quality in a city, when that ZE range can be controlled and targeted in the right places.

UK Market Drivers

The **Plug-in Grant** is a key driver behind the increase in hybrid vehicle sales in recent years. Depending on the size of vehicle being purchased, a consumer can expect to get either 20% or 35% of the cost of the vehicle paid for by the grant, up to a maximum figure (for cars this maximum is £4500). Due to its success and popularity, this scheme has been extended a number of times and is currently funded to run until March 2020 [38].

Clean Air Zones themselves will also likely drive buyers habits to shift to more low emission vehicles, in order to avoid the potential charges for entering these zones. Changes to **Vehicle Excise Duty** (VED, more commonly known as Car Tax) have also encouraged people to look at buying more low emission vehicles, with cars incurring a much larger tax cost in their first year depending on the CO_2 emissions, and only those under 50g/km being free of charge (previously all cars under 100g/km) [39].

Manufacturers themselves are also being pushed to develop much more clean and environmentally friendly vehicles. **EU regulation (EC) No 443/2009 (23 April 2009)** sets mandatory emissions targets for all new cars, meaning that OEMs have to ensure that the average emissions of all their cars sold in the EU are below a certain level. The next target for OEMs to reach is 95g CO_2/km by 2020, followed by a 15% reduction by 2025 and a further 15% by 2030 [40].

The new World Harmonised Light Vehicle Test Procedure (WLTP) will arrive in September 2018 so all current emissions figures for vehicles will likely change, but if the tests were to stay the same this would mean a CO_2 fleet target for OEMs of 66.5g/km in 2030. Given that there is not a single vehicle in the EU that achieves CO_2 figures this low without either being a hybrid or completely ZE, **it is likely that many OEMs will turn to hybridisation for a lot of their vehicles and much sooner than 2030.**

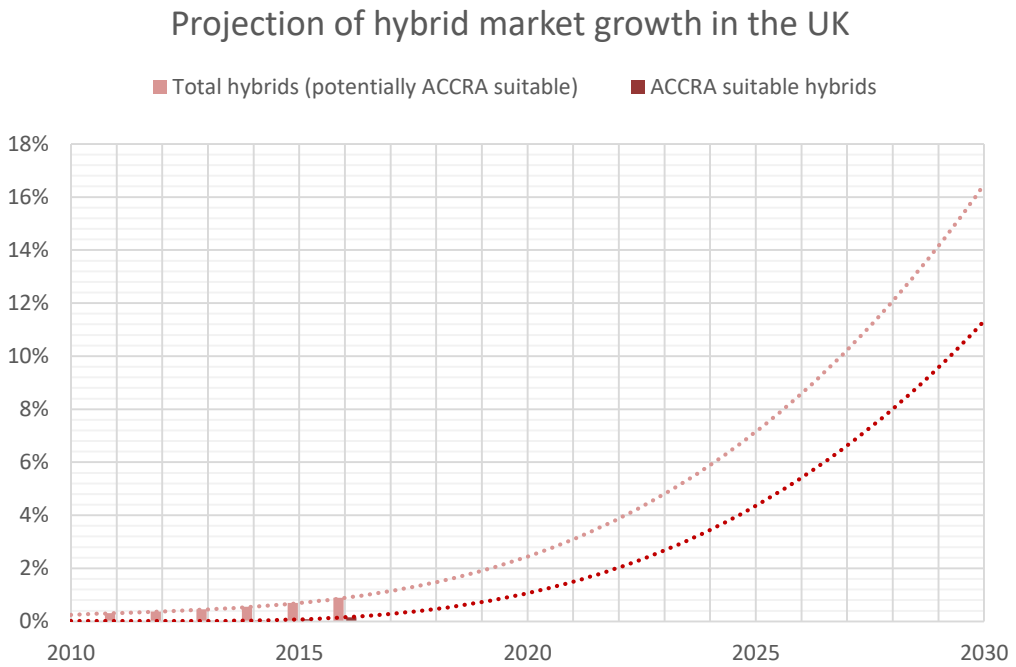
Source: International Council on Clean Transportation, European Parliament and of the Council

UK Market Size - Forecast

Extrapolating the registration data shows that hybrid vehicles could take up approximately 16.5% of the vehicle market by 2030, with at least 11% being ULEV and therefore compatible with ACCRA.

This projection assumes the same conditions remain in place under which the market is currently growing i.e. the plug-in grant. While this scheme will inevitably end, it is likely to be at a time when increasing hybrid sales are able to sustain themselves or be replaced by pressures that would also encourage hybrid/ULEV sales, such as charging schemes in CAZs, ensuring that the rise in sales continues.

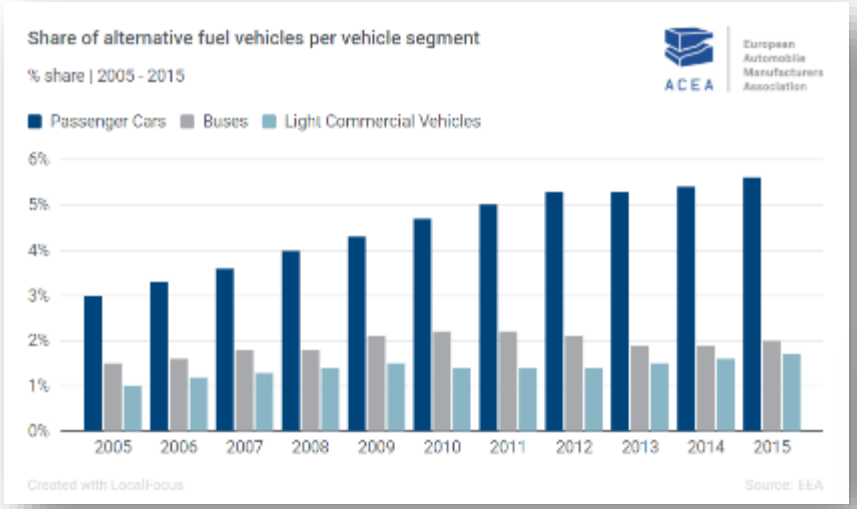
The number of models of hybrid vehicles available also continues to increase rapidly, with OEMs such as Volvo, Volkswagen, Toyota, JLR, Ford & Mercedes-Benz making pledges to invest heavily in electric vehicle research and hybridise many of the vehicles in their ranges.



The UK government has also pledged that from 2040 onwards the sale of petrol-only and diesel-only cars & vans will be banned [41], and EU legislation on OEM fleet emissions will continue to encourage the development of more low emission vehicles.

All of these factors make it very likely that hybrid vehicle sales will continue to rise rapidly, particularly those with longer ZE ranges and therefore capable of operating ACCRA, and quite possibly faster than is predicted here.

EU Sales Figures

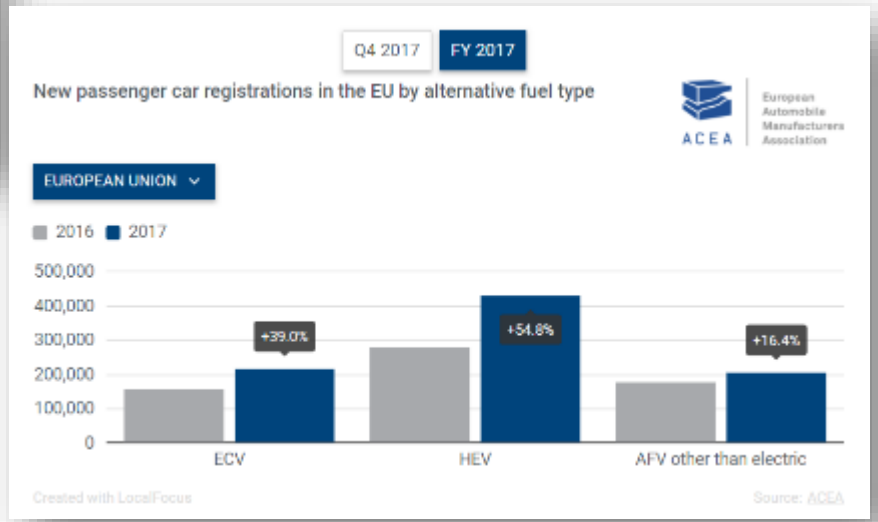


While data from the EU is less detailed, we can identify the same trends as seen in the UK. Overall the sales of Alternatively Fuelled Vehicles (AFVs) are growing, which includes battery electric vehicles (BEVs), all variants of Hybrid Electric Vehicle (HEVs) and several other fuels including hydrogen fuel cell and biogas.

The current share of the vehicle parc in Europe stands at 3.2%.

The passenger car segment enjoys a larger share of the AFV market than that of buses or LGVs, most likely due to the choice, or lack of choice, of vehicle available.

We can also see from the graph on the right that the majority of AFVs being purchased in the passenger car segment are HEVs and this figure is rising, from 278,729 cars in 2016 to 431,504 cars in 2017.



Competitive Analysis

Analysing the strengths & weaknesses of the ACCRA system and its competitors in improving air quality. Understanding the key barriers that will prevent ACCRA from being used and the opportunities that it can take advantage of. Highlighting the key locations that could be the early adopters of the system, and any potential future uses for the system or the technology developed by the project

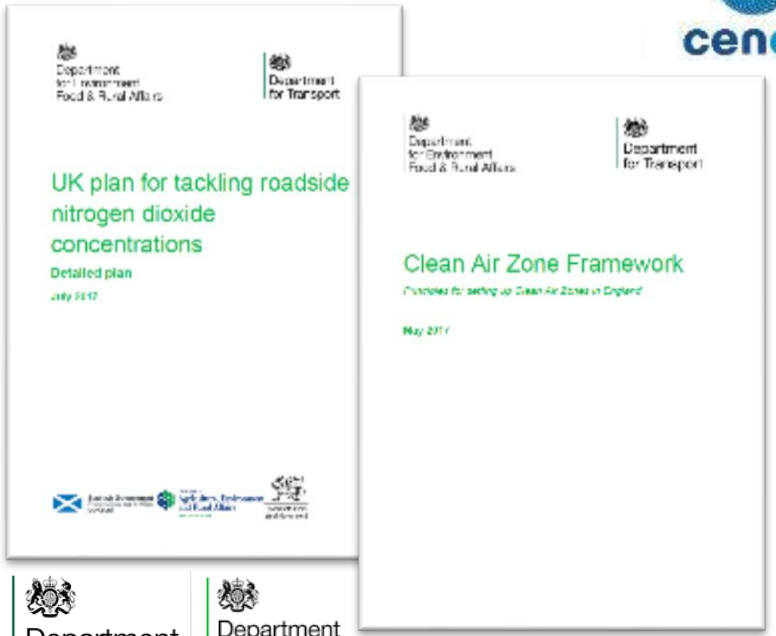
Project ACCRA: Competitive Analysis

The Solution & Competitors

The air quality problem in the UK is a relatively recent one and, as such, solutions to tackle the problem are quite new and extremely varied, with little evidence on which are the best methods to improve air quality as so few have been tried and tested.

Using the connectivity of vehicles and live air quality data to create geo-fenced zones is a unique method of trying to tackle the air quality problem, and therefore the ACCRA system currently does not have any direct competitors. However, there are a variety of different methods & solutions that have been proposed by both industry and by the government through the UK Plan for Tackling Roadside Nitrogen Dioxide Concentrations 2017, the Clean Air Zone Framework and the Clean Air Strategy 2018.

Also, as part of this project a Project Advisory Board (PAB) was set up including representatives from the vehicle and ITS industries, government, local authorities, academics and air quality experts. From the board and the policy documents described above, a list of indirect competitors was compiled. By analysing the strengths & weaknesses of these competitors, we will be able to better identify the opportunities open to ACCRA and how it might overcome some of the barriers it might have to market entry.



Project ACCRA: Competitive Analysis

Competition Strengths & Weaknesses

The following table lays out the main strengths and weaknesses of ACCRA and its' main competitors in improving air quality.

Method	Strengths	Weaknesses
ACCRA	Automatic - doesn't require manual enforcement, targets AQ improvements in worst areas, ability to charge those hybrids still using ICE engine, potential future uses & builds towards CAV eco system	Moves emissions rather than eliminates, reliant on hybrids which aren't very abundant, not necessary to avoid CAZ charges (euro VI)
City centre ban	Easy to implement & enforce (pedestrianize areas), completely removes emissions	More difficult for businesses, reduced access (e.g. for deliveries), extra strain on public transport, potentially create congestion outside city centre, moves emissions rather than eliminates
Odd-even number plate ban	Easy to implement & enforce, doesn't discriminate (e.g. richer vs poorer), targets a large amount of vehicles	Requires costly manpower to enforce, tried once and failed (people in Paris ignored it or bought more vehicles)
Crit'Air sticker system	Easy to implement & enforce, affects all vehicles, removes most polluting vehicles, easy to understand and comply with	Requires costly manpower to enforce, favours newer cars and therefore the richer, indirectly targets diesels which were previously bought in good faith
Improved traffic management	Utilises existing systems (cheap), quick to do	Limited effect on overall AQ, potential improvements quite small
ULEV roll out in captive/ commercial fleets	Easy to control and manage to ensure it happens, targets vehicles with traditionally higher emissions & higher mileage in cities	High cost, long time to replace all vehicles, not all vehicle classes have ULEVs available (particularly the most polluting, large vehicles)
Education schemes to encourage smarter behaviour	No enforcement required, applies to all, engages with citizens (can feel part of the solution, rather than imposed upon as part of the problem)	Difficult to engage a large amount of people, not required so no guarantee will turn into actions/improvements, difficult to measure
Charging CAZ	Similar schemes already in place and work well, clear standards, affects all vehicles, guaranteed AQ improvement	Costly to install necessary ANPR systems, penalizes the poorer and businesses, indirectly targets diesels which were previously bought in good faith
Natural fleet turnover	OEMs legislated to adopt tightening Euro standards	Will take a very long time!
Modal shift schemes (e.g. expand cycling networks)	Reduced traffic, improved traffic flow, effects will be long term, improves health of citizens	Costly and will take a long time, people may still choose not to use these schemes so AQ improvement not guaranteed
ULEV roll out to private owners	Targets majority of vehicles, likely to have a large impact on emissions	ULEVs are expensive & people can still choose not to buy (not enforced) so no improvements guaranteed, doesn't tackle biggest polluters (e.g. buses & lorries)
Bypasses / traffic redirection	Removes emissions from city centres, improves traffic flow and efficiency of engines (less stop-start)	Expensive and take a long time, moves emissions rather than eliminates them
Working from home	Reduced traffic, improved traffic flow	Controlled by local businesses not the council, need to convince them.
Reduce speed limits	Guaranteed to reduce emissions, easy to implement, impacts large amount of vehicles (depending on roads chosen)	Poorer traffic flow, unpopular with the public

Competition Strengths & Weaknesses

Method	ZEZ Complimentary
ACCRA	
City centre ban	
Odd-even number plate ban	
Crit'Air sticker system	
Improved traffic management	
ULEV roll out in captive/ commercial fleets	
Education schemes to encourage smarter behaviour	
Charging CAZ	
Natural fleet turnover	
Modal shift schemes (e.g. expand cycling networks)	
ULEV roll out to private owners	
Bypasses / traffic redirection	
Working from home	
Reduce speed limits	

Many of the alternative solutions to improve air quality involve restricting access to the city in some way, as in the charging CAZ or vehicle bans. These methods almost certainly reduce the amount of traffic entering a city and are therefore guaranteed to reduce emissions and improve air quality. However, this either increases costs for citizens or makes conditions more difficult for businesses that rely on vehicle access to make deliveries or provide transport services.

Solutions such as the roll out of ULEVs or modal shift schemes, supported by education schemes and/or government funding, are intended to maintain the current levels of travel but ensure that they are done in ways that produce a minimal amount of emissions. While they present a more idealistic, long term solution, they are much harder & slower to implement as they are encouraged rather than enforced.

High costs through the provision of government grants, investment in the public transport, installation of ANPR, or citizens and businesses buying new cars can also be a large barrier. ACCRA is likely to be a much lower cost solution as the system is simply a software upgrade to an existing ITS, and it takes advantage of hybrid vehicles that are already becoming common place and are rising in number naturally.

One key advantage that ACCRA holds over many of these solutions is its longevity; as standards tighten & Zero Emission Zones (ZEZs) become more widespread, ACCRA actually maintains the ability for people in hybrids to access these zones, and could even allow local authorities to introduce ZEZs sooner.

Barriers to Market Entry

Key Barrier	Mitigation
Low number of vehicles that are compatible, so will have little effect on current air quality problems	- Rising numbers of compatible hybrids, driven by government grants and changing public opinions - Investigate expansion of system to ICE vehicles with "cleaner" modes e.g. lean burn, reduced cylinders
Tevva TU currently has **no control of a non-Tevva vehicle's drivetrain**	- Initially in non-Tevva vehicles, Tevva TU would monitor drivetrain to confirm ZE running in CAZ (and avoid charge/restrictions) - To enable drivetrain control in future, Tevva will need to talk with OEMs to; a) allow access of Tevva's TU into their own vehicles software/communications, and; b) negotiate license agreement to fit TU at production - Future developments could be made to enable direct V2I communication
Lack of incentive for drivers to purchase/use system, even in charging CAZ as standard (Euro 6) is already set and vast majority of hybrids already satisfy this requirement	- Liaise with L.A's to negotiate incentives such as parking, use of bus lanes, company car tax reductions, access to restricted roads - Lobby schools & hospitals to highlight the benefits of "targeted" zero emission running around their buildings, and persuade councils to provide such incentives - Liaise with fleet operators to show how ACCRA opens up option of hybridising vehicles to achieve compliance, avoiding replacing the fleet - Highlight & communicate future benefits that system effectively future-proofs many hybrids against zero emission zones, reducing need to replace vehicles each time emission or air quality standards are tightened
Perception by L.A. or public that **emissions are moved rather than eliminated**	- Design system to be able to prevent charging the battery (and therefore running the ICE at its least efficient) in sensitive/built up areas immediately outside the dynamic zone

ACCRA's main challenge is that it currently targets a relatively small amount of vehicles. Given the immediate nature of the air quality problem in cities, many LAs are looking for solutions that will make quick, large improvements, something that ACCRA cannot currently provide. However, this is a temporary weakness as hybrid sales continue to rise and the aggregated effect of potential emission reductions will therefore continue increasing. The issue of connectivity can be seen in the same way, as this capability is already growing based on other drivers and ACCRA can only help to accelerate this.

In order to generate interest in the system then, it is therefore important to highlight the range of uses that the system has, or could be developed to have in the future. A key focus should be on the ACCRA's ability to be part of a ZE strategy in cities in the future, without forcing fleet operators and members of the public to incur large capital costs, a factor which may encourage LAs to provide the necessary incentives for ACCRA to thrive and thus help overcome the final barrier.

Market Opportunities

By cross-referencing the three key factors that make ACCRA a viable solution for a city (ITS, AQ issues, hybrid vehicles), we can identify the places that would benefit the most from introducing the system and would be the potential early adopters. In the list here we can see the ideal locations within Europe are highlighted in bold. Milan, Rome and Berlin also have the ideal conditions but their share of hybrid vehicles is lower than elsewhere.

While the **CAZ cities*** identified by the UK government are not part of POLIS, they also have ITSs and thus would also be ideal locations for ACCRA. Outside of Europe there is currently too little data available to be able to perform this type of analysis.

Given the small number of hybrids on the roads at present, in the short term (up to 2025) the main opportunity for ACCRA is its ability to target hotspots of pollution in sensitive areas, such as schools and hospitals. Any savings here would likely have a greater impact on health, both politically and also due to the greater vulnerability of the people concerned.

The key vehicle segments to target in these locations would be the buses and HGVs, predominantly by promoting the retrofit of these large, expensive vehicles with hybrid systems. Use of the system could also be promoted to those who already own compatible hybrids through additional incentives such as cheap parking, restricted area access & more charge-points.

Country	City	AQ issue	POLIS	Hybrid sales % (source: ACEA, mild, full and plug-in)
UK	**London**	o	o	4.1%
UK	Edinburgh		o	4.1%
UK	**Glasgow**	o	o	4.1%
UK	**Manchester**	o	o	4.1%
UK	**Newcastle**	o	o	4.1%
UK	Reading		o	4.1%
UK	**Southampton**	o	o	4.1%
UK	**Leeds**	o	*	4.1%
UK	**Nottingham**	o	*	4.1%
UK	**Derby**	o	*	4.1%
UK	**Birmingham**	o	*	4.1%
Spain	**Barcelona**	o	o	4.8%
Holland	**Rotterdam**	o	o	4.5%
Holland	**Amsterdam**	o	o	4.5%
France	**Paris**	o	o	3.9%
Switzerland	Basel	o		3.8%
Poland	Warsaw	o		3.6%
Denmark	Copenhagen	o		3.5%
Italy	Milan	o	o	3.4%
Italy	Rome	o	o	3.4%
Italy	Venice	o		3.4%
Greece	Athens	o		2.8%
Germany	Berlin	o	o	2.5%
Germany	Heidelberg	o		2.5%
Russia	Moscow	o		?
Turkey	Istanbul	o		?

Secondary Markets and Uses for ACCRA

The ACCRA solution can be broken down into the components that give the system its value. They are:

- A detailed model of air quality and emissions from traffic in the city
- The ability to create geo-fenced areas based on the input data (in ACCRA's case, air quality and traffic)
- A wireless, electronic connection between a city and the vehicles travelling inside/near it
- The ability to influence a vehicle's drivetrain

From the PAB meetings, several other uses and markets were identified for the ACCRA system and its components. The general conclusion was that, while air quality is the issue that has inspired the system, it is likely that in the future ACCRA will have a much wider range of uses.

Potential further uses and developments of the ACCRA system, or its' individual components	
Influencing the drivetrain of a non-hybrid (e.g. switching an ICE vehicle into lean burn mode)	Automatically charging vehicles for entering a zone, whether created by a geo-fence or not, using the V2I connectivity
Allowing buildings to have access to the air quality/geo-fence data so that they can better control their HVAC systems (to avoid replacing clean air with dirtier air from outside)	Replacing air quality data with noise data, using the geo-fencing technology to identify noise hotspots and advise appropriate vehicles/machines/buildings etc to run in quieter modes

Uses specifically of the V2I capability to pass a driver information that may affect their journey, and that the city collects or has access to		
The location of accidents, roadworks, major events, emergencies or natural disasters	Bus, train or plane timetable information and delays for making connections	Nearest available parking spaces or charge-points
Speed limit changes (e.g. for temporary roadworks), potentially integrating with on-board sat nav and speed warnings	The timing of traffic lights that the vehicle is approaching (and advised speed in order to coincide with green light)	

Business Model & Market Strategy

Identifying the viable markets for ACCRA and outlining a business model that shows the key activities that need to be done to make it a success, and the aspects of cost and revenue that need to be considered when deciding if the system represents value for money for a local authority

Key Conclusions on Viable Markets

The following table lays out the key conclusions that we can take from the market study, from both point of view of the operator of the system (e.g. local authority), and also the user of the system (e.g. drivers).

There is also a difference when considering the short and long term, given the impending changes in legislation & technology.

	Factors affecting the operator	Factors affecting the user
Short term (up to 2025)	Low numbers of hybrid vehicles – ACCRA won't significantly contribute to annual average air quality target (<40 µg/m^3) but will help target hotspots of pollution (>200 µg/m^3 – 1 hour mean) and reduce pollution around sensitive areas such as schools and hospitals	Vast majority of hybrid cars are already compliant with advised CAZ charging rules - currently no advantage to having the ACCRA system. For LGVs, hybrid retrofit not available & new vehicles jumping straight to ZE, so neither segment is currently viable
	ACCRA expands the options for fleet operators with HGVs & buses that currently have little/no choice of hybrid/zero emission alternatives to replace their fleet with	Retrofitting a hybrid system to larger vehicles (HGV's & buses) is a viable option, as this will likely cost less than replacing the vehicle. ACCRA therefore offers an alternative option and a chance to avoid CAZ restrictions (or take advantage of CAZ concessions)
Long term (beyond 2025)	CAZ emissions standards likely to tighten, and eventually move to zero (CAZ Framework, 2040 commitment, 2050 aspiration, Road to Zero). ACCRA potentially enables these plans to be brought forward	Vehicles, including hybrids, that are currently compliant would eventually fall below the required standards – ACCRA enables users to maintain their CAZ concessions or continue avoiding charges
	Hybrid vehicles will likely make up >5% of entire vehicle parc, meaning they can make a large, immediate difference to air quality if their efforts are coordinated and targeted	Reduces need to replace vehicles each time the standards tighten and therefore reduces capital expenditure (both for fleet operators and the general public alike)
	Maintains access to CAZs for a larger number of vehicles, avoiding problems for businesses (e.g. deliveries)	

Business Models

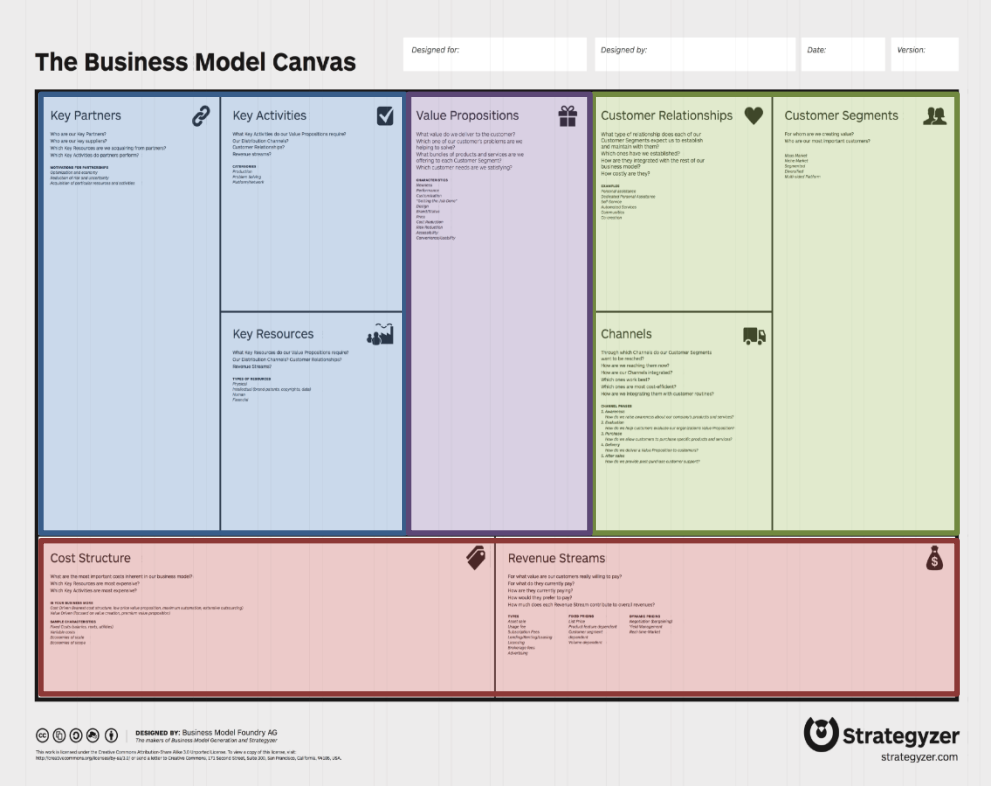
In order to visualise a potential business model for ACCRA, we will use a known template called the Business Model Canvas.

It divides a business into 9 key elements, that can be categorised as:

- Infrastructure – how is ACCRA built and run?
- Offering – what does ACCRA provide?
- Customer – who receives the offering and how?
- Finances – does it pay back?

We will create a business model for both the short term and the long term cases, and both will be written from the perspective of a local authority, who would be the owners and operators of the system, and the ones responsible for improving air quality.

The finances section shows purely qualitative items, as further work and wider trials are required to quantify the benefits and costs of the system.



Source: https://strategyzer.com/

Potential Business Models – Short Term (<2025)

Up to 2025, it is presumed that current CAZ emission standards will still be in place, so ACCRA will specifically target heavier vehicles.

Due to the low number of hybrids, the key offering is around reducing hotspots of pollution rather than city-wide average improvements.

If a local authority chooses to enforce a charging CAZ, then the items highlighted in red also become part of the business model.

Financially, apart from installing air quality sensors, the ACCRA system does not have a lot of associated costs so payback is a distinct possibility based on the revenues it creates.

Business Model Canvas – ACCRA

Key Partners

ITS operator (e.g. Dynniq)

Air quality sensor manufacturer (e.g. Earthsense)

Vehicle Management System operator (e.g. Tevva)

Hybrid vehicle manufacturers

Key Activities

Air quality sensor maintenance

Urban Traffic Centre operation

Tevva VMS management

Integration with ANPR system

Key Resources

Urban Traffic Centre (ITS)

Air quality sensors

Tevva VMS

ANPR system

Value Propositions

ACCRA will provide:

- Improved air quality around hotspots or sensitive areas of a city (e.g. schools & hospitals)

- Unrestricted vehicle access to a city's CAZ

- Avoidance of charges for entering a CAZ

Customer Relationships

Provide air quality information to customers

Automate the system to make it easy to use

Channels

Air quality improvements will be delivered through either:

- Tevva vehicles
- Hybrid vehicles with a retrofitted Tevva TU
- Hybrid vehicles with access to Tevva's Vehicle Management System

Customer Segments

School children, hospital patients, other vulnerable members of society

Drivers of any full, plug-in or range-extended hybrid vehicle entering the CAZ, specifically fleet operators with HGV's & buses

Cost Structure

Air quality sensor installation & maintenance

UTC software upgrade & maintenance

Revenue Streams

Reduction in healthcare costs

No loss in public transport performance, business performance or other services reliant on buses/HGVs

CAZ charges collected from capable vehicles not running in zero-emission mode

Potential Business Models – Long Term (>2025)

Beyond 2025, there are very few changes in the infrastructure and costs of the system.

One key difference will be the growing number of hybrids and the wider customer segments that ACCRA can serve. ACCRA's offering can then widen to city-wide average air quality improvements as well as hotspots.

With growing connectivity, ACCRA could also potentially become a requirement so that a city can monitor the drivetrains of all vehicles and charge them appropriately, making a charging CAZ smarter and changing driver's behaviours faster. This adds more to the revenue streams without any additional costs, improving any potential payback.

Business Model Canvas - ACCRA

Key Partners	Key Activities	Value Propositions	Customer Relationships	Customer Segments
ITS operator (e.g. Dynniq) Air quality sensor manufacturer (e.g. Earthsense) Vehicle Management System operator (e.g. Tevva) Hybrid vehicle manufacturers	Air quality sensor maintenance Urban Traffic Centre operation Tevva VMS management Integration with ANPR system **Key Resources** Urban Traffic Centre (ITS) Air quality sensors Tevva VMS ANPR system	**ACCRA will provide:** - Improved air quality around hotspots or sensitive areas of a city (e.g. schools & hospitals) - Improved overall air quality across the whole city - Unrestricted vehicle access to a city's CAZ - Avoidance of charges for entering a CAZ	Provide air quality information to customers Automate the system to make it easy to use **Channels** The air quality improvement will be delivered through hybrid vehicles	Citizens of a CAZ city Drivers of any full, plug-in or range-extended hybrid vehicle entering the CAZ

Cost Structure	Revenue Streams
Air quality sensor installation & maintenance UTC software upgrade & maintenance	Reduction in healthcare costs No loss in transport performance for businesses, councils, commuters or the public CAZ charges collected from all vehicles not running in zero-emission mode

Conclusions

- The initial aim of the project was to solve the problem of a city not being able to communicate with a hybrid vehicle, and utilise its ability to run in zero-emission mode where it is needed most – in areas of poor air quality. The system has been created and tested in just 12 months, proving that connecting vehicles to a city is possible and building on the capabilities of the Tevva truck, Earthsense's air quality monitoring & modelling, and Dynniq's own ITS offering.
- In the short term, the relatively low number of hybrid vehicles in the UK & Europe means ACCRA cannot have a large enough impact on reducing levels of NO_2 in a city to compete with other AQ improvement solutions available. However, provided an LA can be persuaded to offer concessions to ACCRA vehicles, then it becomes a viable option for fleets of HGVs or buses that operate in cities, who can choose to retrofit hybrid systems as they have little/no low emission alternatives to replace vehicles with.
- ACCRA's main strength comes in the long term, when AQ limits and therefore emission standards in CAZs are likely to reduce and eventually reach zero, meaning ZEZs will become more common. Hybrids themselves will also be far more common, so it will be imperative that they have a method of operating inside ZEZs without restriction, which is what ACCRA will allow them to do.
- Besides air quality, ACCRA has many other potential uses and therefore could be more valuable to a city than a purely air quality focussed solution, and can help drive the improvement of connectivity with vehicles to their surroundings.
- To fully prove the system, and obtain reliable costings for the system and its potential revenues, ACCRA would benefit from further funding in order to run a pilot project such as a small fleet trial.

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