UNIVERSITY OF BIRMINGHAM

BIRMINGHAM ENERGY INSTITUTE

Life in the Fast Lane: Evolving Paradigms for Mobility and Transportation Systems of the Future
A Workshop to Determine Research & Development Needs and Supporting Policies
Hosted by the U.S. Department of Energy, Washington D.C.
October 26-27th 2016
James V. Forrestal Building, 1000 Independence Avenue, SW

Business Models for Ultra Low Emission Vehicles & Sustainability

Gavin D. J. Harper
Birmingham Energy Institute

BHAMENERGY
WWW.BIRMINGHAM.AC.UK/ENERGY

Slide courtesy:

riversimple

VW Beetle

2008

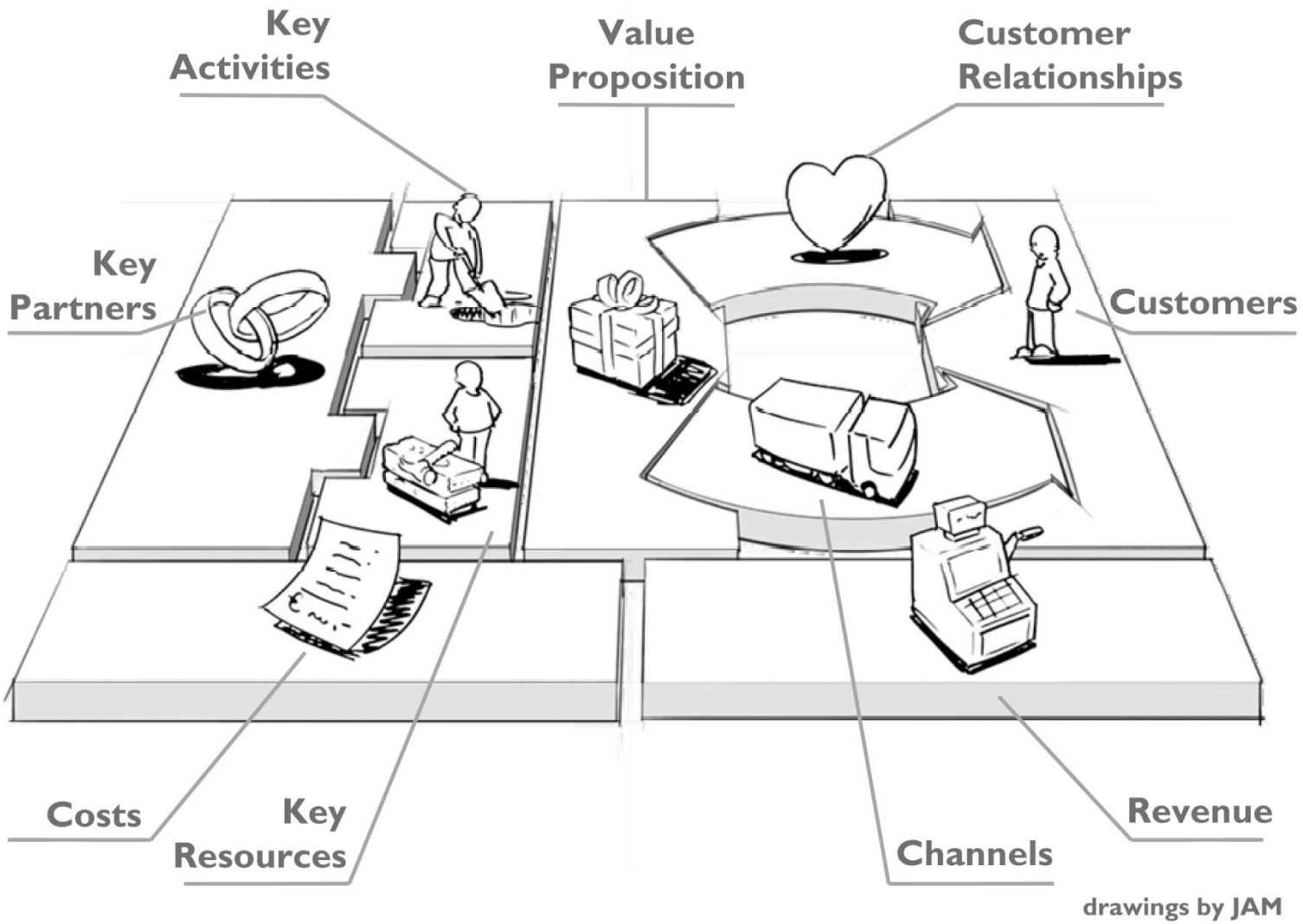
38mpg

1948

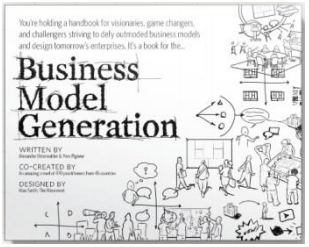
38mpg

The MINI E is a development vehicle, informing future market products, infrastructure, policy-making and business modelling.

The Business Model Mediates Between The Economic and Technical Domains
Chesborough & Rosenbloom (2002, p. 536)

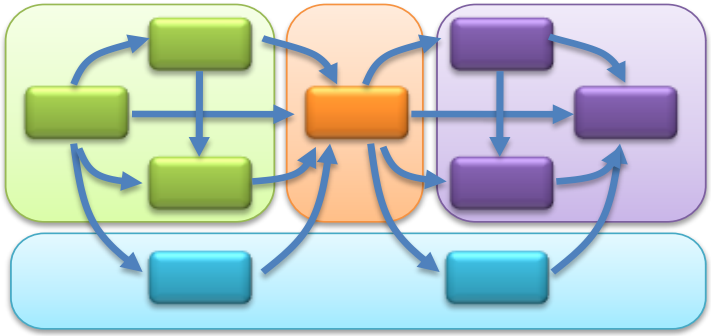


http://www.businessmodelgeneration.com/

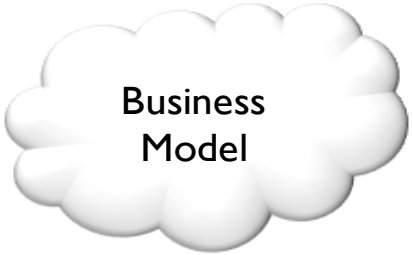


Level of Abstraction

The business model ontology is a *representation* of the business model.



Business models are an *abstract concept*



The physical business model is the *embodiment* of the business model.

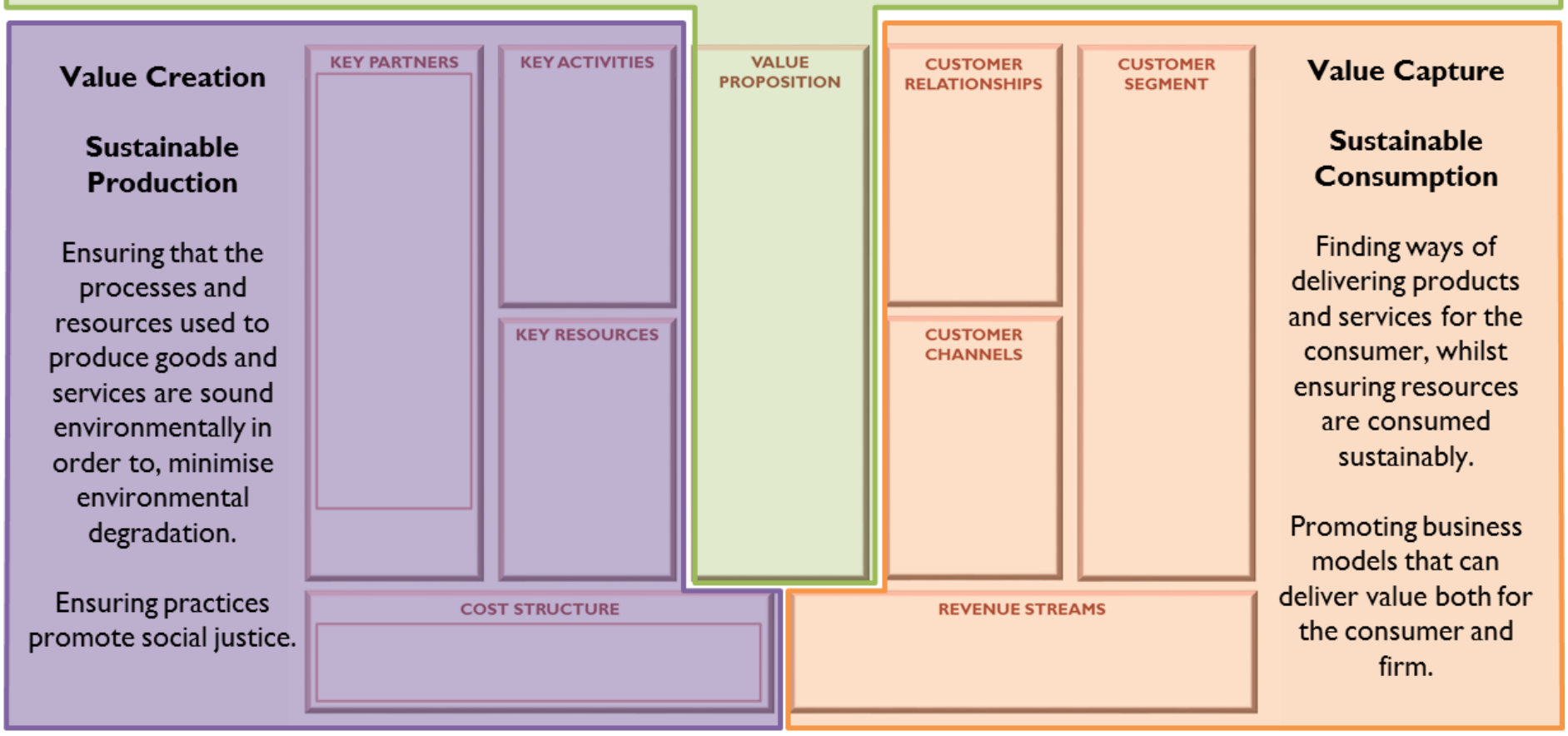
Harper, G.D.J., The role of business model innovation in transitioning ultra-low emission vehicles to market, PhD Thesis, Cardiff University http://orca.cf.ac.uk/71735/

Value Proposition

Sustainable value propositions may be about 'dematerialisation' converting products into services in order to promote better use of finite resources and pooling of goods.

The product or service provides the utility that the user seeks, with a value proposition that is appealing to the user.

For the value proposition to be sustainable, both the "value creation" side of the business and the "value capture" side of the business must focus on sustainable outcomes.

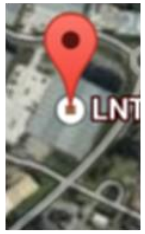


Nissan Motor Manufacturing UK

Morgan

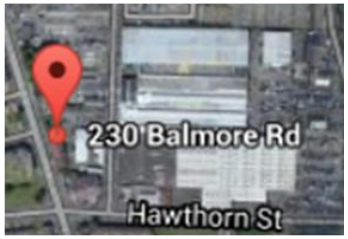
Lotus

Smith Electric Vehicles

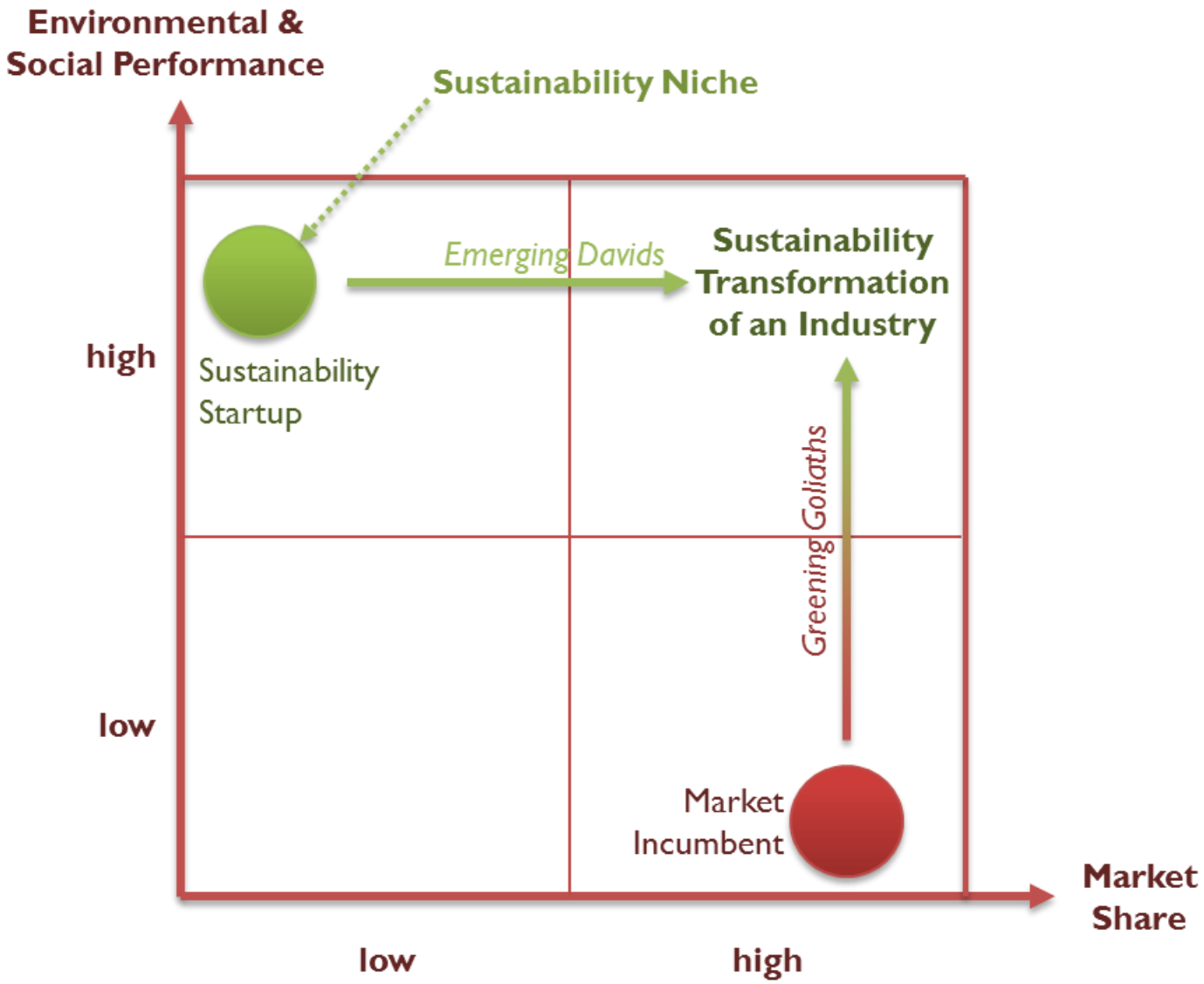


Ginetta

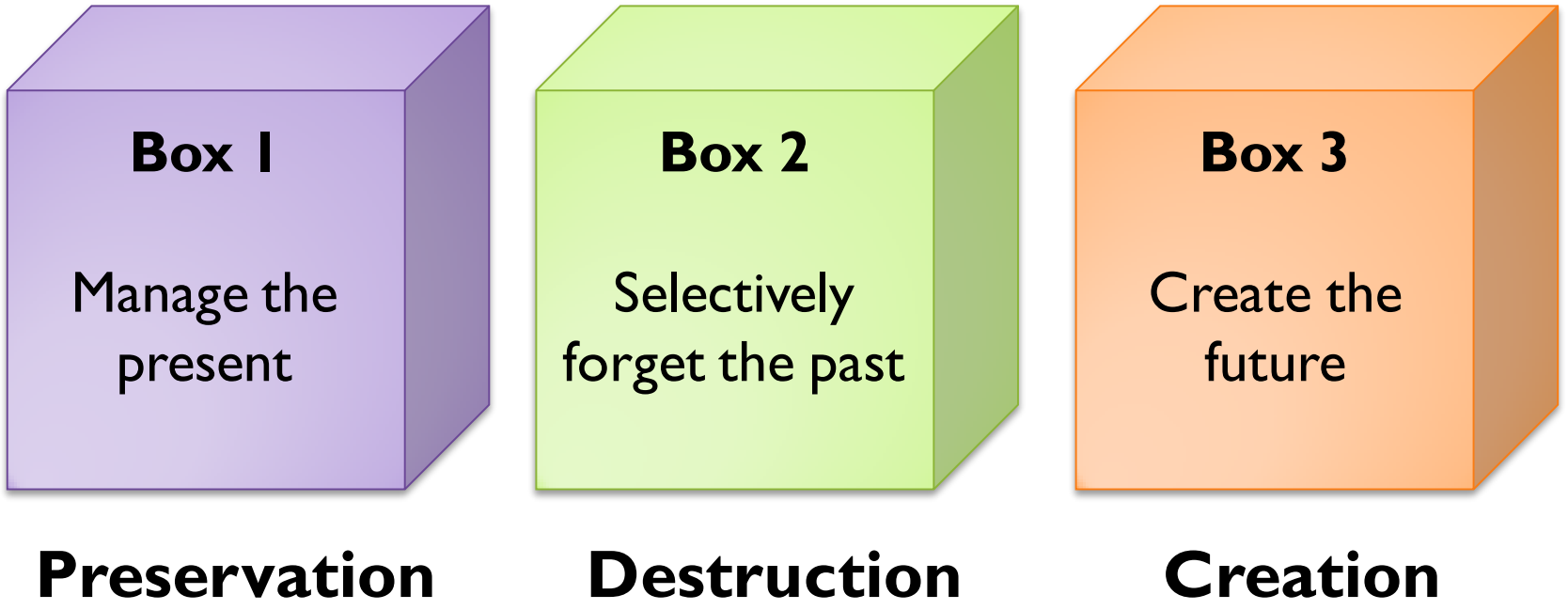
Modec



Allied Vehicles



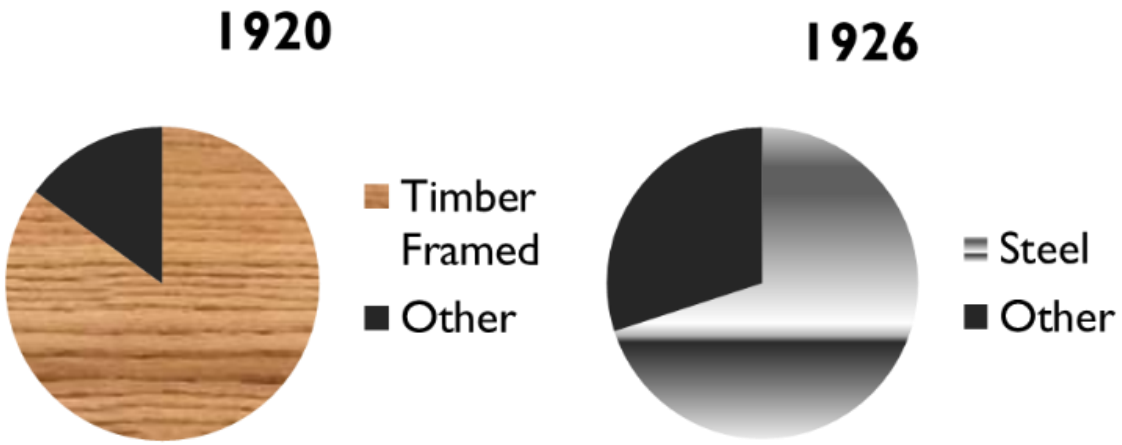
Co-evolution of sustainability start-ups and market incumbents towards the sustainability transformation of an industry (Hockerts & Wüstenhagen, 2010, p. 488)



"Three Boxes" Approach To Business Model Management proposed by (Govindarajan & Trimble, 2011)

Foundations of the present industry Business Model

- Ford – Moving assembly line production.
- Budd – Father of all steel press body work.
- Sloan – Paint, model cycles, market segmentation, finance, consumer choice.
- Toyota – "Japanisation" of the Auto Industry. Quality Control, Just in Time, Kaizen,



Budd's Transformation of the Vehicle Industry Nieuwenhuis & Wells, (2003)

Nieuwenhuis, P., & Wells. P. (2003) *Did Ford really invent mass production?*. Cardiff: The Centre For Business Relationships, Accountability, Sustainability and Society. Retrieved March 12, 2014, from: http://orca.cf.ac.uk/39703/

Nieuwenhuis, P., & Wells, P. E. (2007). The all-steel body as a cornerstone to the foundations of the mass production car industry. Industrial and Corporate Change, 16(2), 183-211, doi: http://dx.doi.org/10.1093/icc/dtm001

When is a Business Model Past it's Use-By Date?

The old business models have now reached the point at which they begin to see their marginal productivity drop inexorably. Their strategies, which focus on cost reduction procedures such as downsizing, restructuring, outsourcing, etc., have become indistinguishable from those used by their competitors. Initially, this process enabled margins to be improved but the time came when no progress could be made any longer.

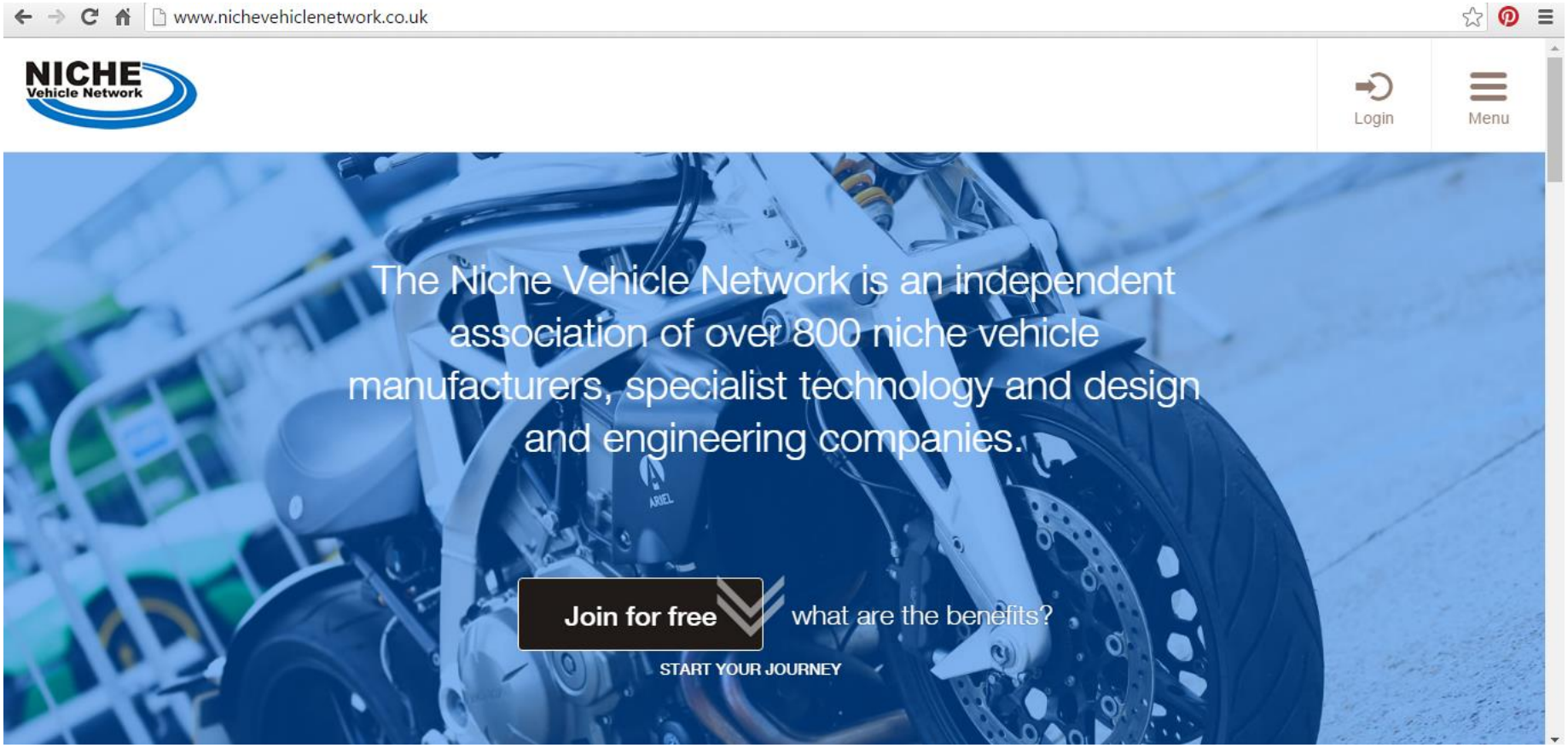
(Hamel, 2000)

They can produce a vehicle that they have spent millions of pounds to develop, for a price – because they have the volume – that competes with our product – which we haven't spent millions of pounds developing. Clearly then as a Value Proposition, you have to differentiate yourself by some other means.

Paul Faithfull, Westfield Sportscars Ltd. / Potenza Technology Ltd.

One of [the] key means [by which we differentiate our Value Proposition from volume car makers] is weight – we have put a lot of effort into differentiating ourselves by weight – and I don't believe that a large volume manufacturer can reach a weight of less than 700 kilos on a conventional car [because of pressed steel] They have to meet elements of legislation, and the demands of their marketing departments in terms of noise, vibration and harshness, that we don't.

~~Paul Faithfull, Westfield Sportscars Ltd. / Potenza Technology Ltd.~~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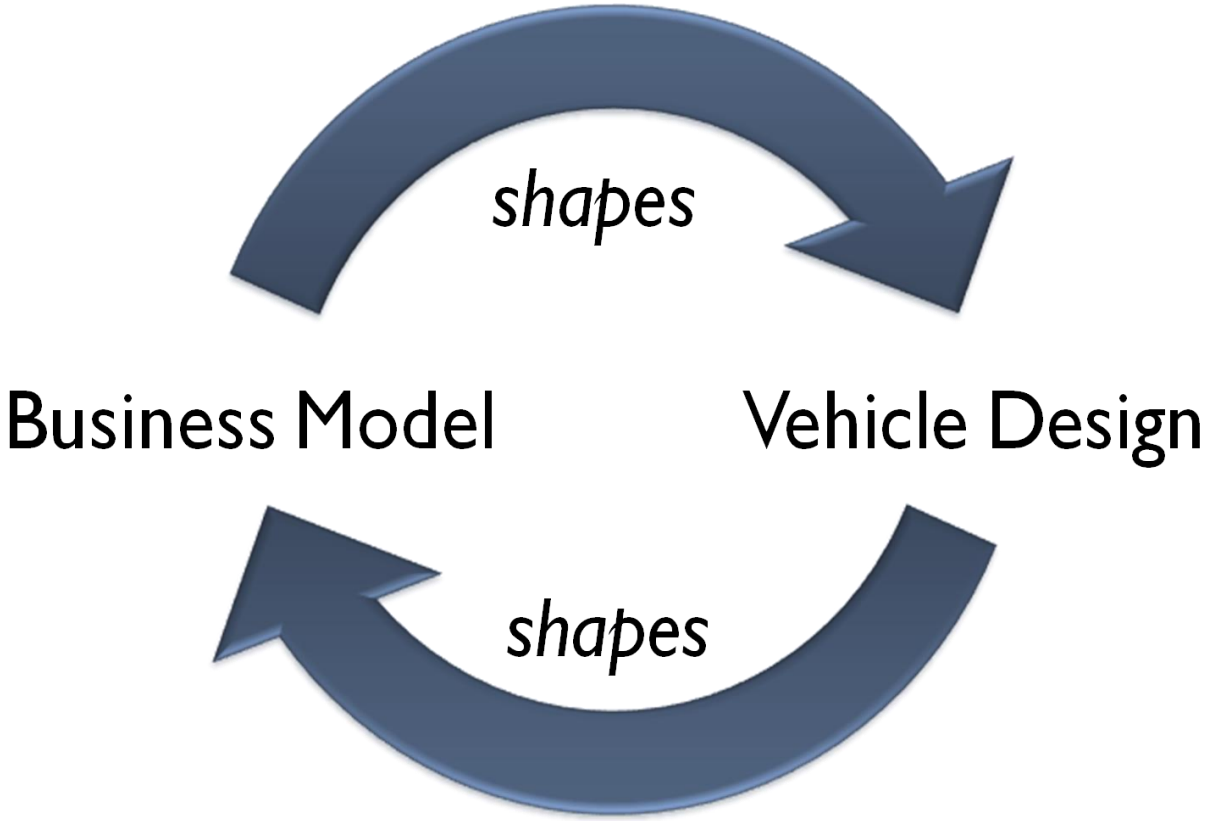
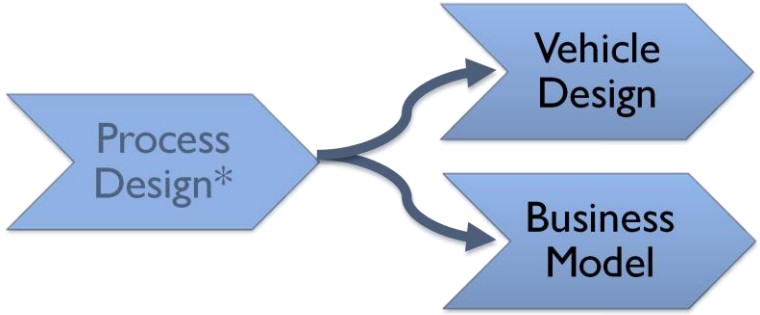
Business Model Design & Vehicle Design Co-Shape Each Other



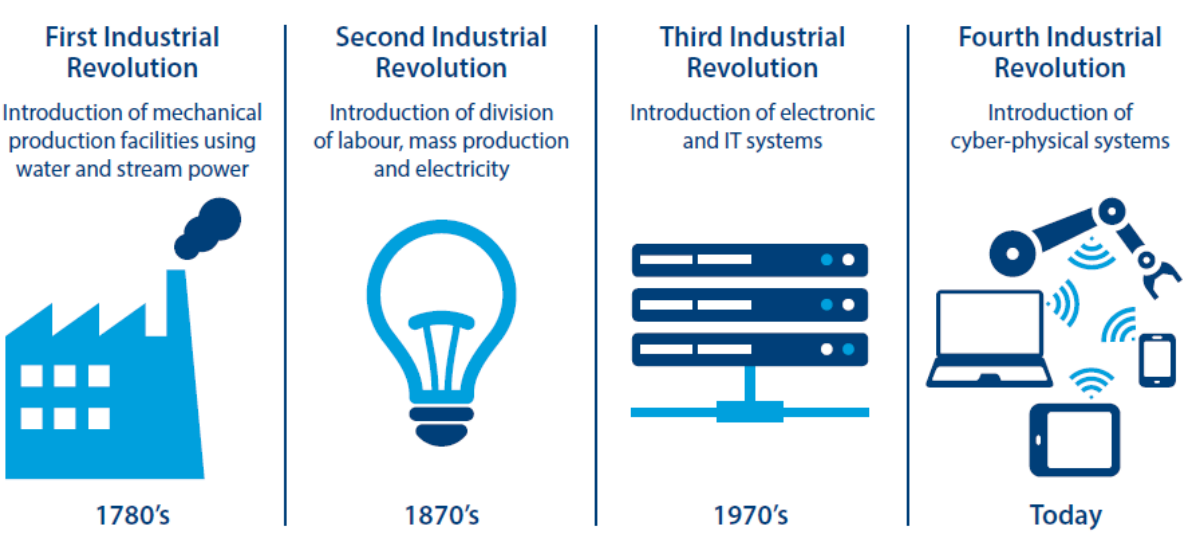


Traditional VM's – The process design Is largely defined. It constrains the vehicle design and many elements of mhe Business Model

There are some examples where the process design leads and this shapes the product – e.g. Gordon Murray Design.

In the example of Riversimple, the Business Model was designed first, shaping the product based on actual user requirements.
The process was then designed around the most efficient way of meeting these requirements.

Industry 4.0 & Factory in A Box



University of Birmingham, Loughborough University and the Manufacturing Technology Centres are partners in ITEMA the International Thermal Energy Manufacturing Accelerator.

www.era.ac.uk

Industry 4.0 & Factory in A Box

- Industry 4.0
  - Cyber-physical systems
  - Internet of Things / Services enabled manufacturing.
  - Heavily automated
  - Virtualisation of manufacturing plant
- Factory in a Box
  - Packaged component manufacturing
  - Designed to manufacture products for export close to source.

To meet growing demand, the number of refrigerated trucks on the road is going to increase

2013 | Previous estimate 2025 | Feasible estimate 2025 | Maximum estimate 2025

Many refrigerated trucks are kept cold by a separate engine that uses up to **20%** of the vehicle's diesel consumption

Diesel transport refrigeration units emit up to **6 x** as much NOx & **29 x** as much particulate matter as a modern HGV engine

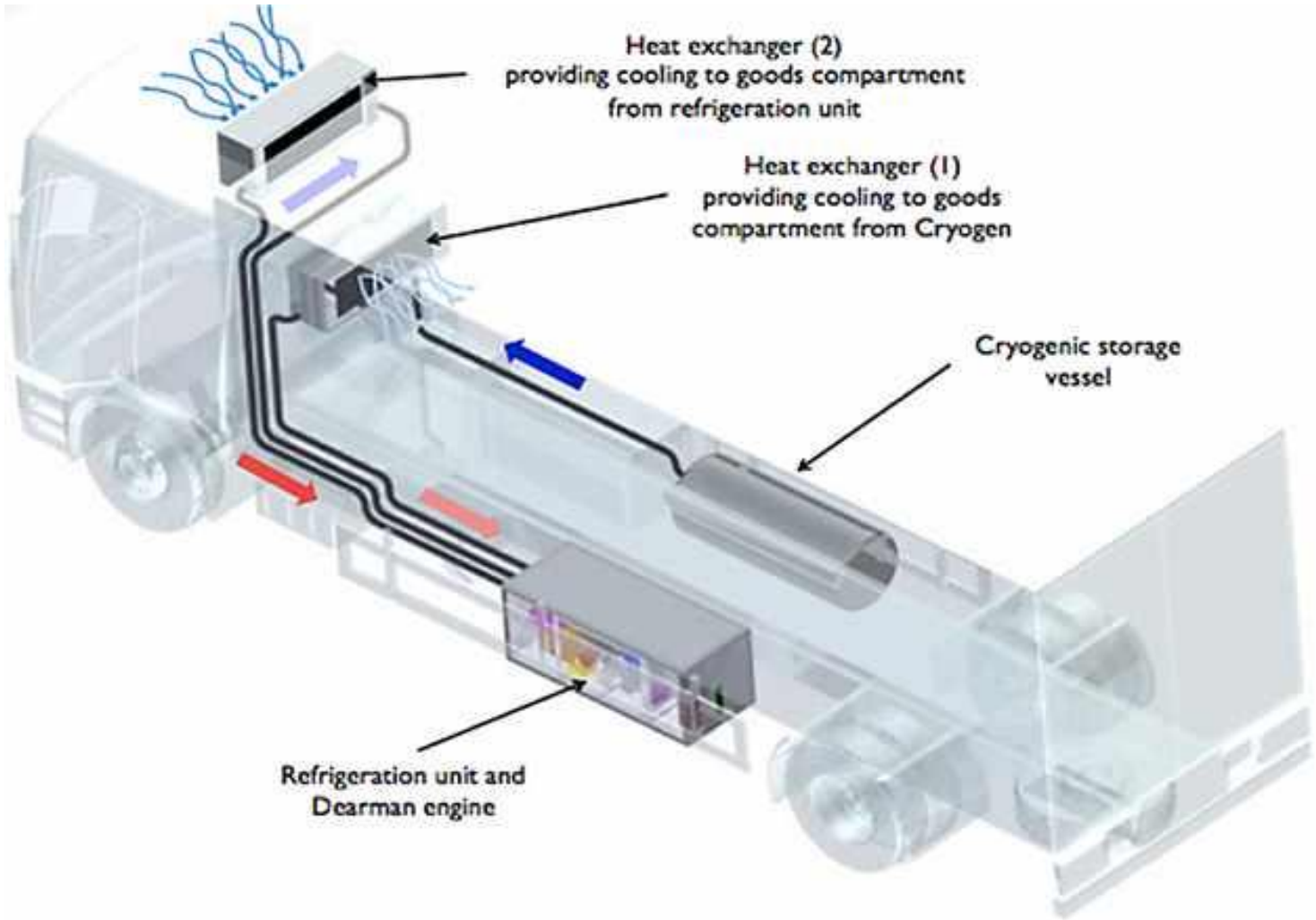
Air pollution currently causes

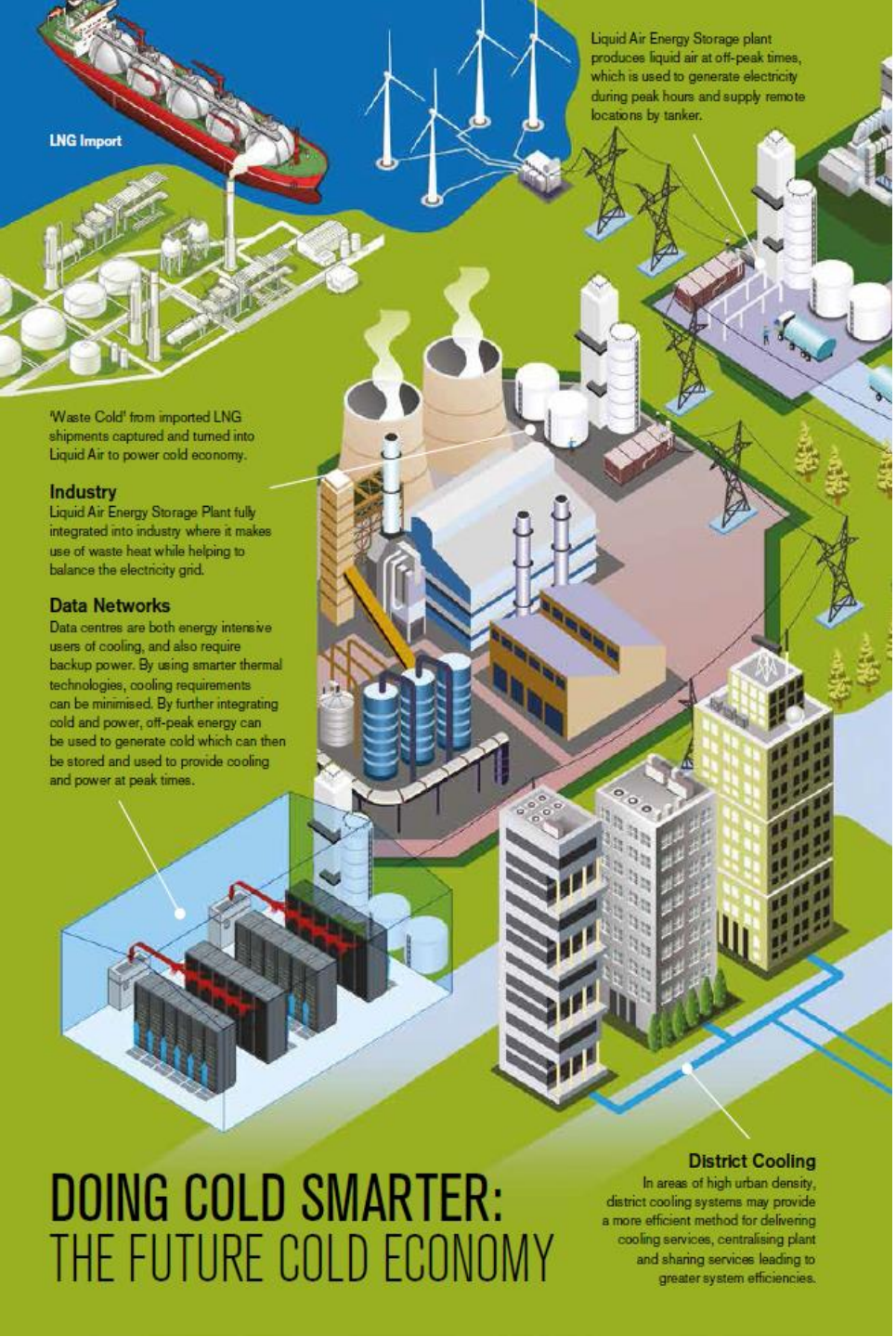
600,000

premature deaths each year in India and

1.2 million

in China

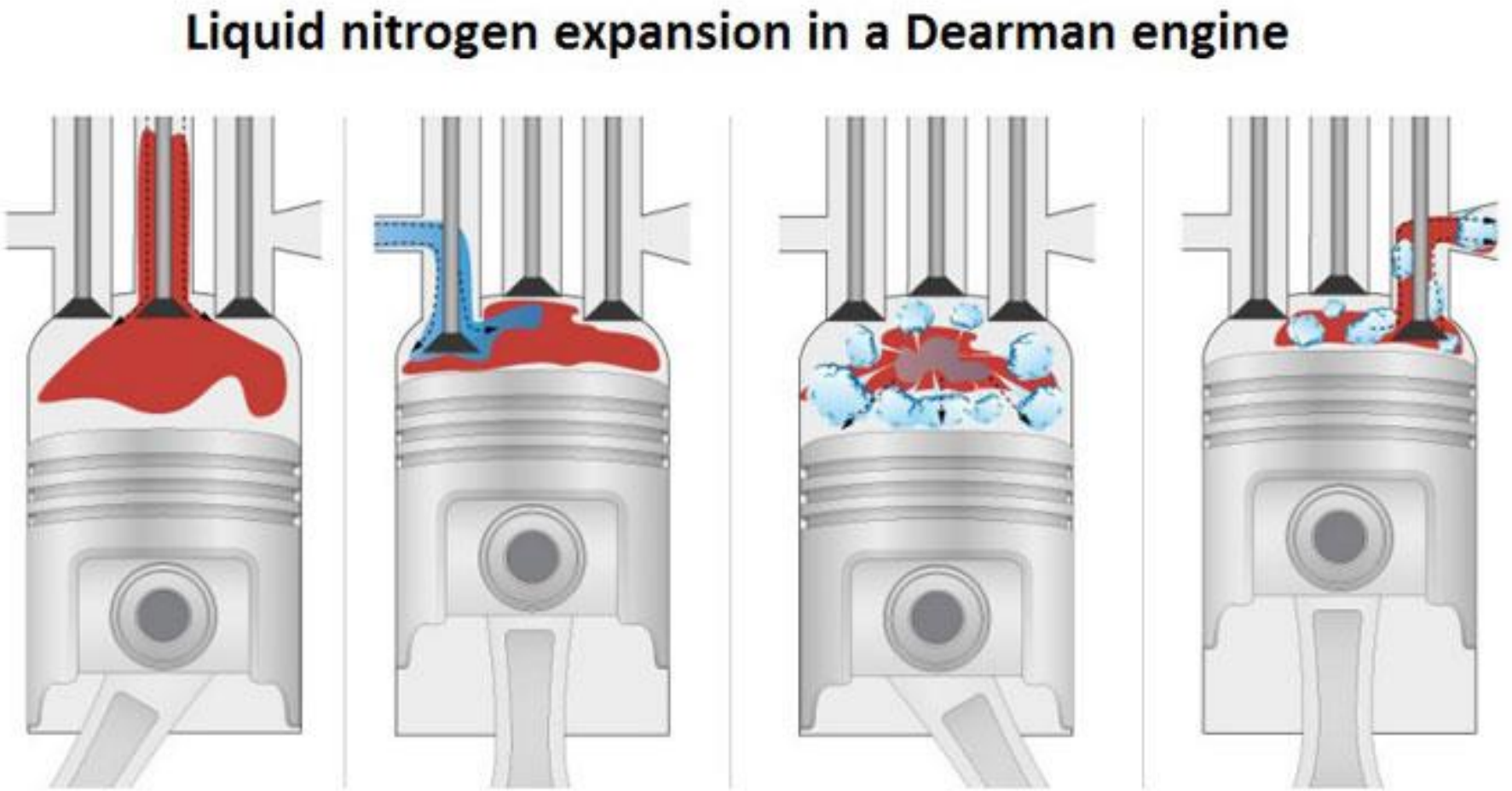

Heat exchanger (2)
providing cooling to goods compartment
from refrigeration unit
Heat exchanger (1)
providing cooling to goods
compartment from Cryogen
Cryogenic storage
vessel
Refrigeration unit and
Dearman engine



DOING COLD SMARTER:
THE FUTURE COLD ECONOMY

Dearman Engine

Dearman Engine



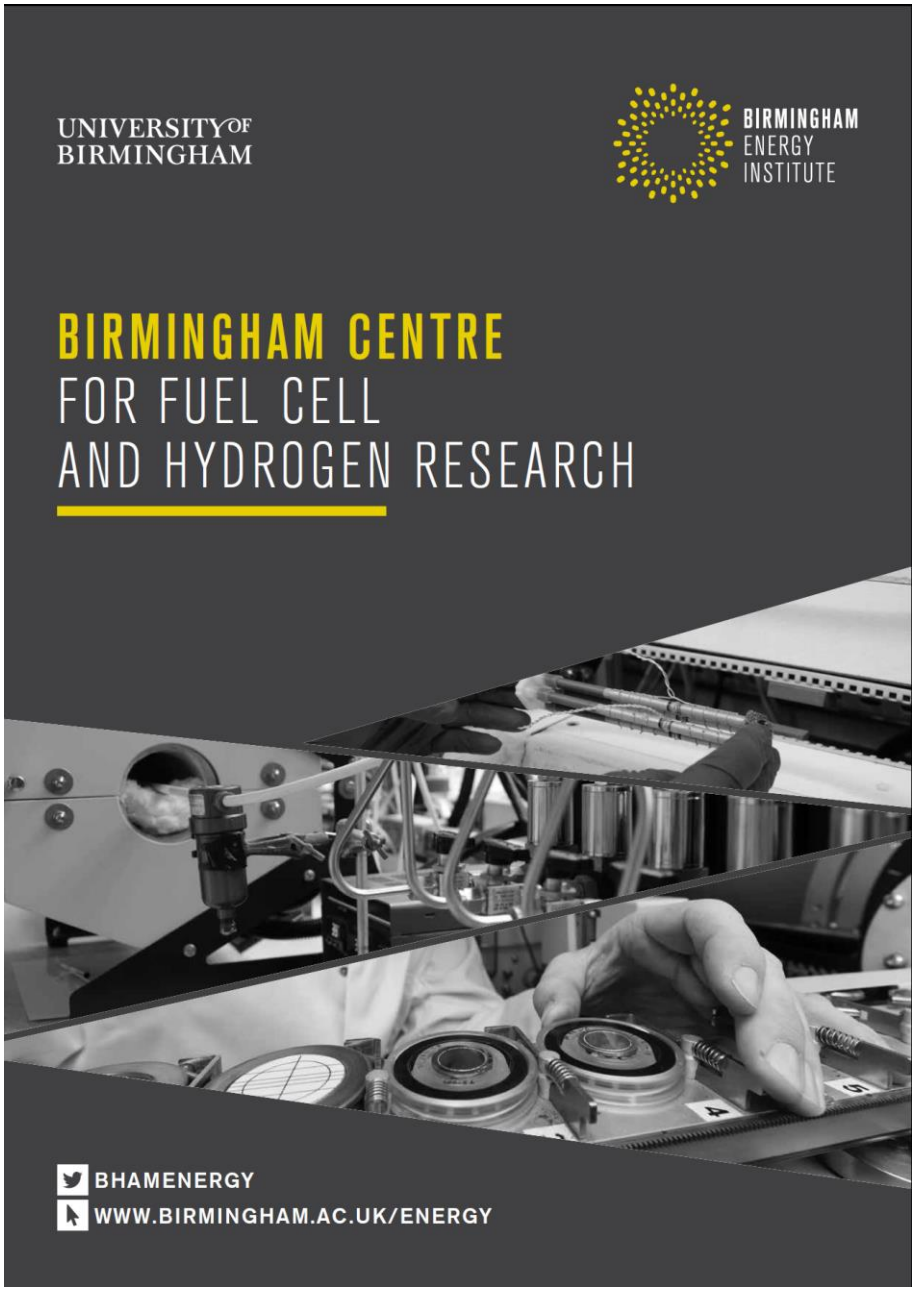
Dearman Engine

- Different business models for the delivery of cold as a service.
- Decouples provision of cold from hydrocarbon fuel.
  - Recovery of "Waste Cold" from LNG
  - Use of "Wrong-Time" Energy to produce liquid air as an energy vector.
- Cold as a 'service'?

SWARM

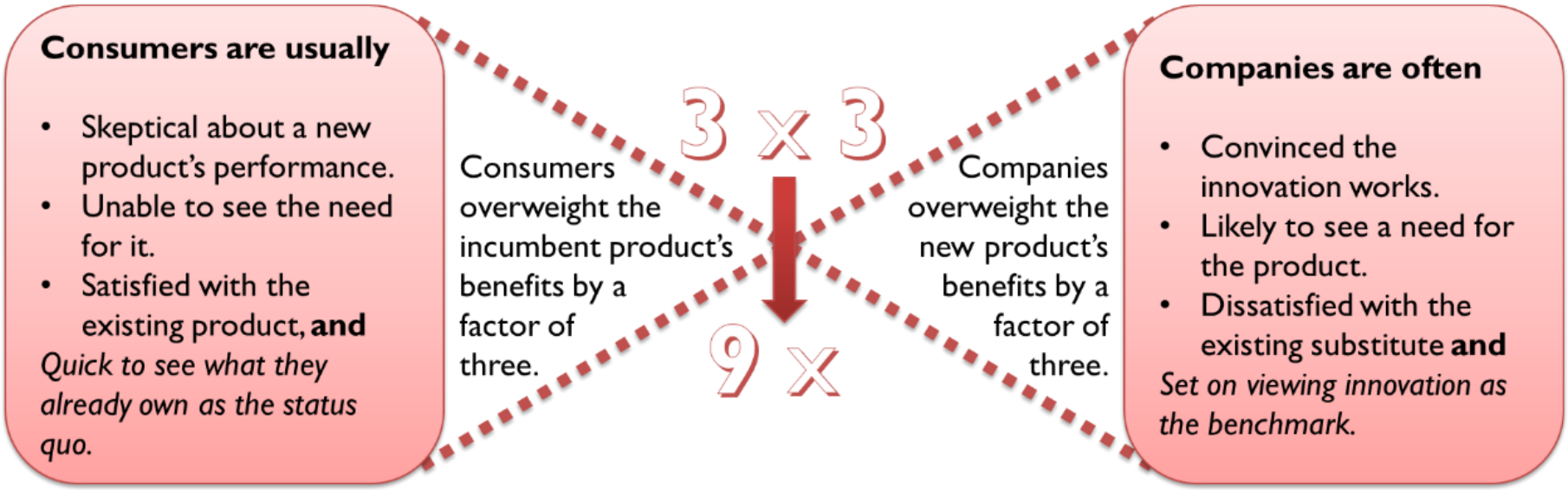
Birmingham Centre for Fuel Cell and Hydrogen research www.birmingham.ac.uk /fuelcells are partners in an EU funded project "SWARM" to deploy small lightweight fuel cell vehicles.

This project aims to optimise and build 100 low cost Fuel Cell Hybrid Vehicles. Our expertise will be leveraged to optimise the components and vehicles systems resulting in improved efficiency. There are five industrial partners: Air Liquide, Microcab, Riversimple, H2O e-mobile, and TUV.



If you make the vehicle significantly smaller and lighter, fuel cell costs decrease significantly, which affect the economics and viability of fuel cell vehicles.

The University of Birmingham was the first campus in the UK to have it's own hydrogen refuelling station and has been operating a fleet of microcabs on campus for a number of years.



There's a fundamental problem for companies that want consumers to embrace innovations: While developers are already sold on their products and see them as essential, consumers are reluctant to part with what they have. This conflict results in a mismatch of nine to one between what innovators believe consumers want and what consumers truly desire.

The 9x Effect (Gourville, 2006)

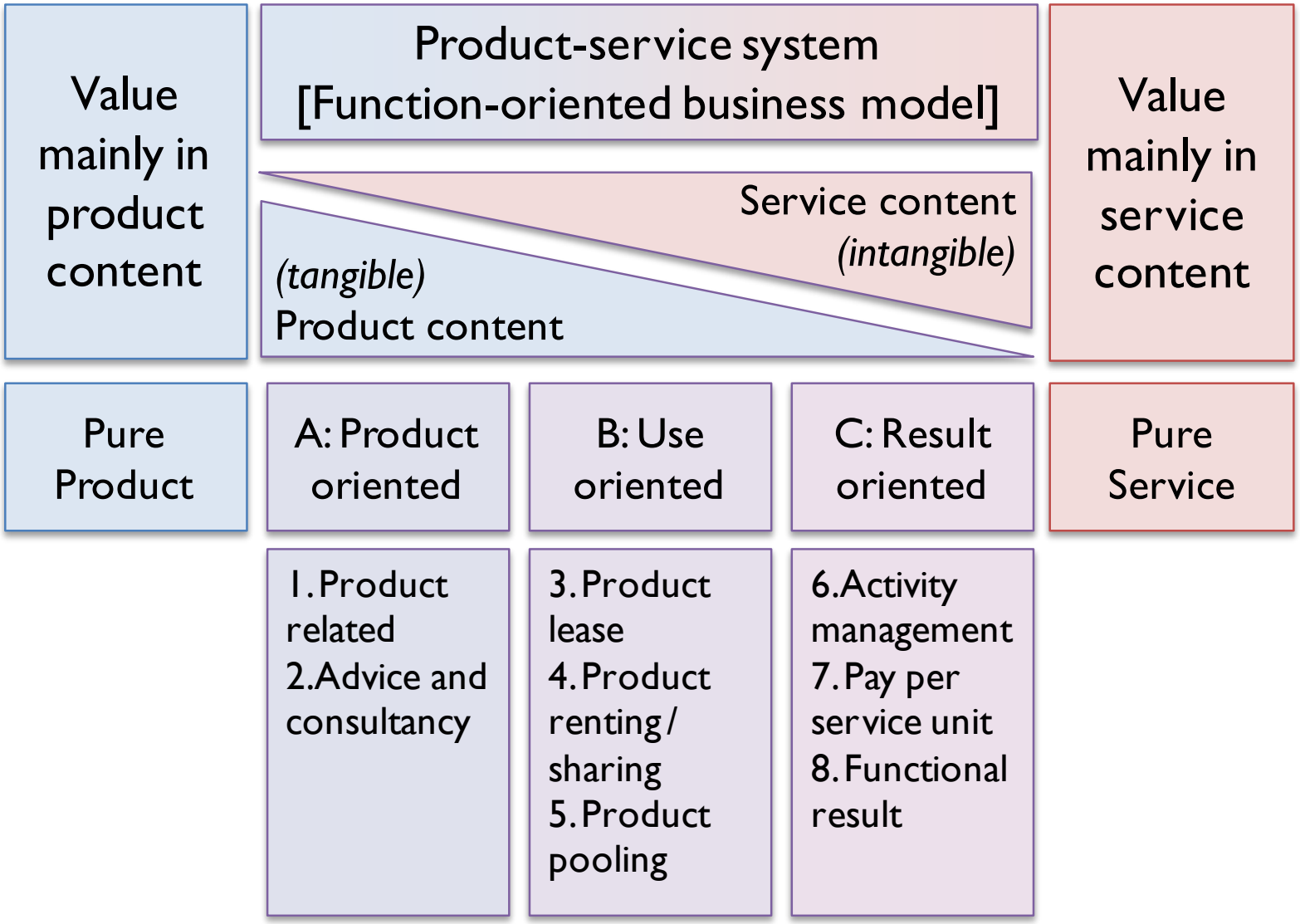
	Low-end BEV	High-end BEV
Vehicle	Nissan Leaf	Tesla Model S
Price	$29,000-35,000	$70,000-105,000
Range	75 miles	270 miles
Acceleration (0-60mph)	9.9 seconds	3.1 seconds
Top Speed	93mph	155mph
Fastest Charge Time	4 hours	1 hour 15 minutes

Hardman, S., Shiu, E. & Steinberger-Wilckens, R., 2016. **Comparing High-End and Low-End Early Adopters of Battery Electric Vehicles**. *Transportation Research Part A: Policy and Practice*, 88

Fuel Cell Vehicles

'Compared to an ICEV how does a FCV compare when considering the following?'

Hardman, S., Chandan, A., Shiu, E. & Steinberger-Wilckens, R., 2016. **Consumer attitudes to fuel cell vehicles post trial in the United Kingdom**. *International Journal of Hydrogen Energy*, 41 (15)



Main and subcategories of PSS
From (Tukker A. , Eight types of Product Service System: Eight ways to sustainability? Experiences from SUSPRONET, 2004)


MUSEUM
OPEN

Engineered for the future

Slide courtesy © Riversimple / Hugo Spowers

Designed from a 'clean slate' to deliver safety and aero-stability

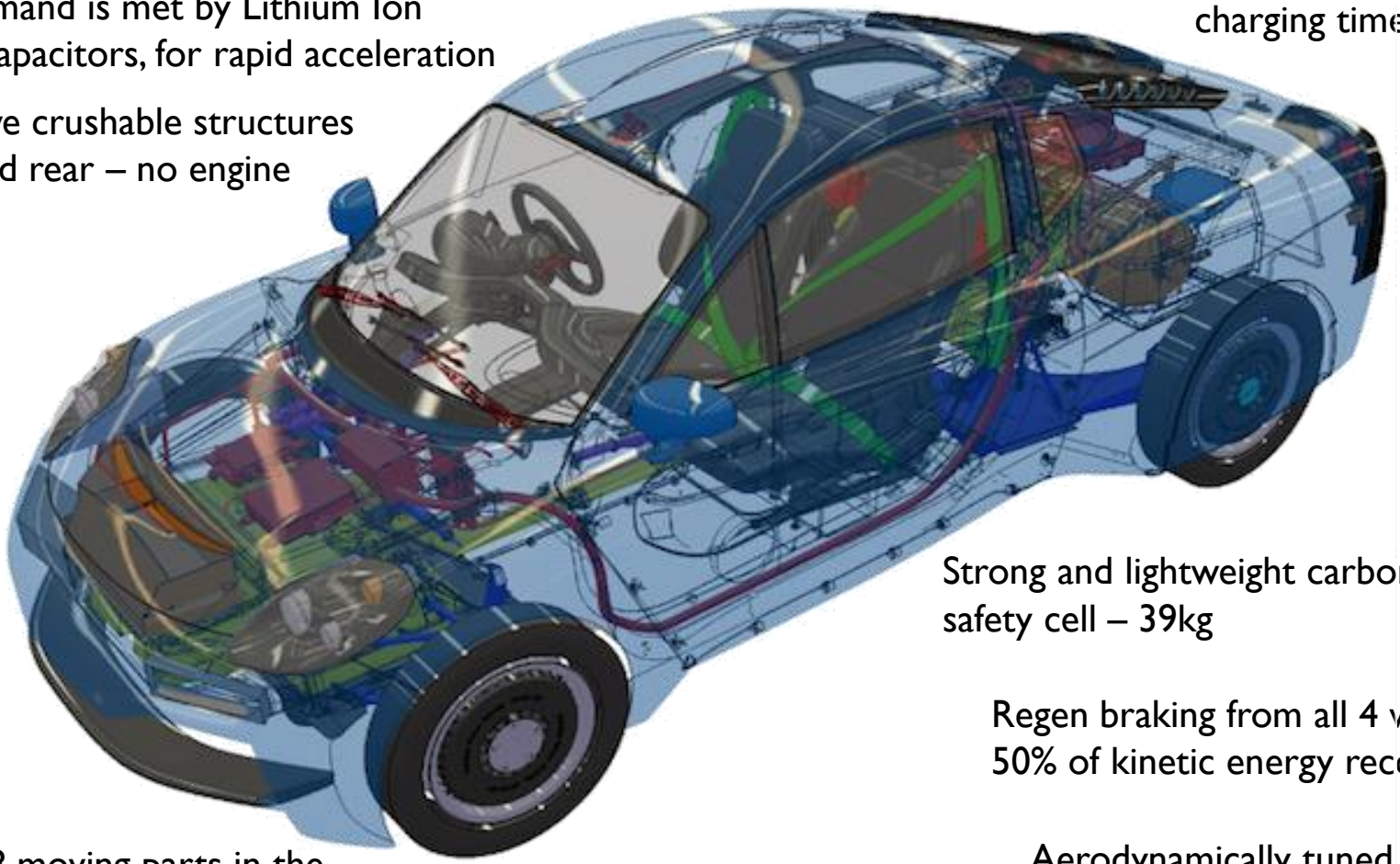
Carbon fibre doors, 200mm of energy absorbing structure to manage side impact

Carbon fibre tank to take H_2 at 350bar pressure

No battery weight or charging time

Peak demand is met by Lithium Ion Super-Capacitors, for rapid acceleration

Extensive crushable structures front and rear – no engine block



Strong and lightweight carbon fibre safety cell – 39kg

Regen braking from all 4 wheels – 50% of kinetic energy recovered

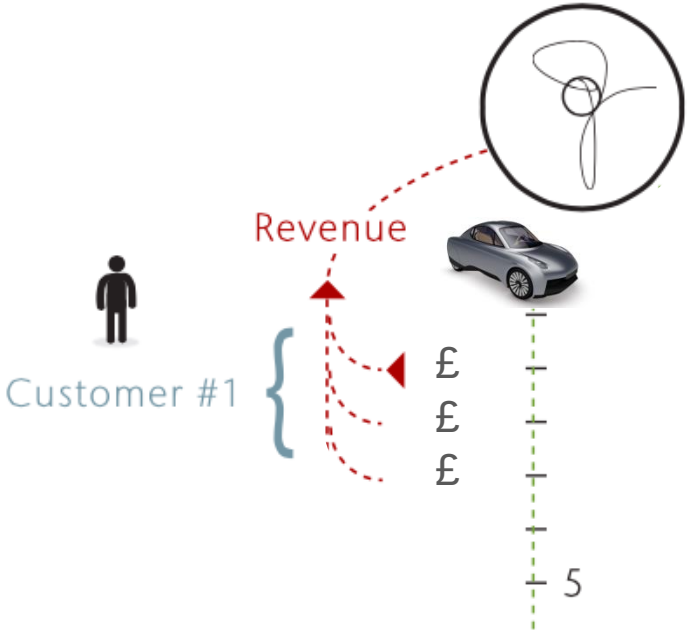
Only 18 moving parts in the powertrain – cleaner (no oil), lower cost to maintain

Aerodynamically tuned to eliminate rear lift in cross wind

Selling a car delivers

only 40%

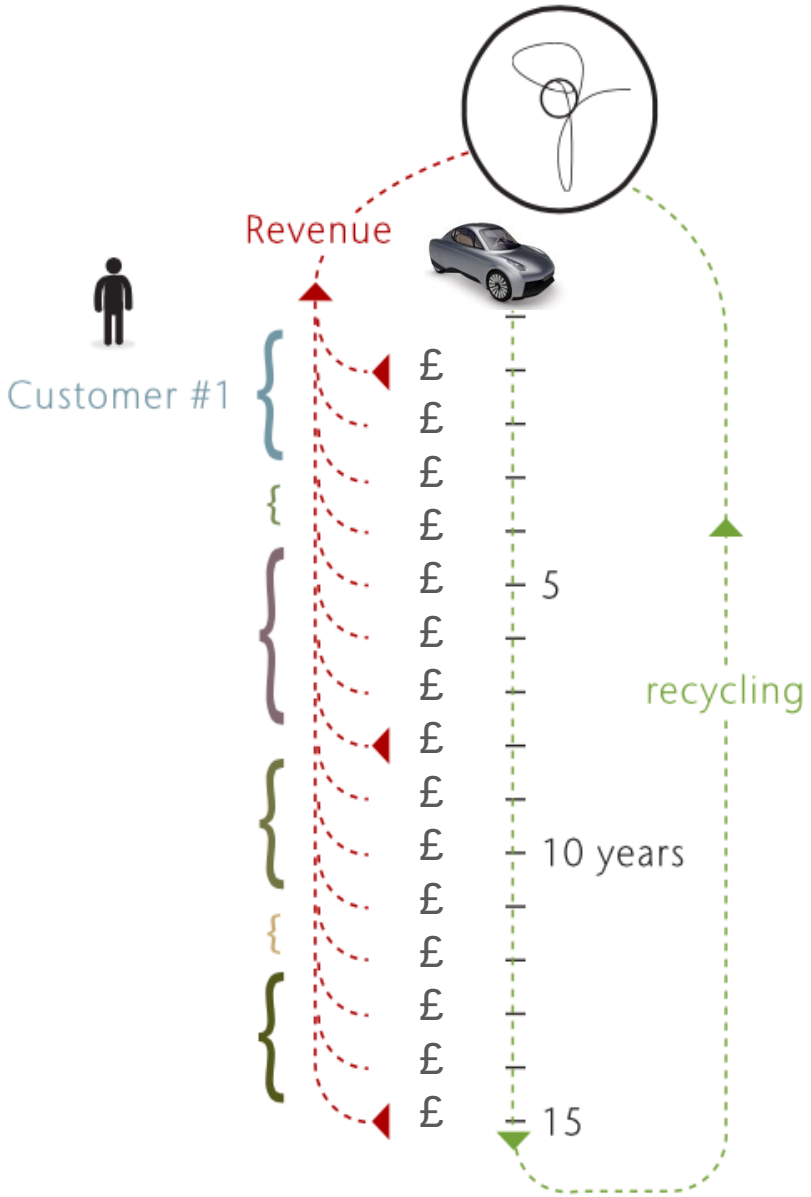
of the lifetime revenues
to the manufacturer



Riversimple offers mobility as a service and gains

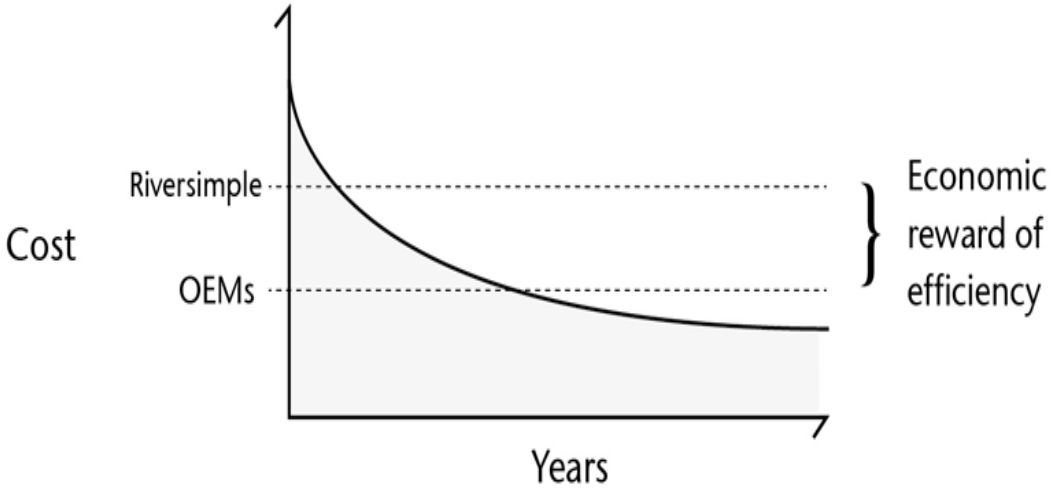
100%

of the revenues generated by the car over 15 years



Bringing new Low Carbon Vehicle technologies to market

riversimple



Typical supply chain cost curve

- **To sell a car competitively:**

LCV supply chain costs = ICE supply chain costs

- To sell a service **competitively**:

LCV lifetime operating costs = ICE lifetime operating costs

BUSINESS MODEL CANVAS: RIVERSIMPLE

KEY PARTNER

Partnership with BOC to install hydrogen gas stations in their prototype areas.

Riversimple hydrogen car, powered with motors from Horizon Fuel Cell. Collaborated with Amzel Ltd, Alan Docking Racing and Element Energy, as well as universities.

Partnered with Morgan for their hydrogen powered LIFEcar.

KEY ACTIVITIES

Design (and potentially manufacture) of small hydrogen vehicle.

Smaller plants upon rollout means that there are more of the plants, but they will be better suited to suit each demographics different need.

KEY RESOURCES

Innovative intellectual property relating the the novel drivetrain.

Innovative business model

VALUE PROPOSITION

Leasing of vehicle rather than buying it as a commodity. No maximum or minimum mileage allowance. Fully bundled service including road tax, maintenance, insurance and fuel.

Sell mobility as a service, rather than a car as a product. Customers able to lease

The ownership of the vehicle stays with Riversimple who also supply the hydrogen for the fuel cells. The customers pay for "mobility" as a service, therefore it is in Riversimple's best interests to constantly improve vehicle efficiency.

CUSTOMER RELATIONSHIPS

Customers can interact with Riversimple through their personalised digital interface in their car, on the web or mobile,

Aftersales care and support is key to maintaining the customer relationship

CUSTOMER CHANNELS

50 Fires foundation makes the vehicle "open source" and allows customers to interact with the firm to improve the performance of the vehicle or suggest alterations.

CUSTOMER SEGMENT

.Local authorities.

Small commercial fleets.

Car clubs to be major customers, due to leasing business model.

COST STRUCTURE

Low component count on each car and carbon composite bodies mean that smaller production plants will be used.

REVENUE STREAMS

Due to the fact that this model operates on a leasing format rather than a retail form, means that maintenance, fuel and the recycling of the car at the end of its life is all built into the contract, and is offered to the consumer at no extra cost.

Strategic Elements & Critical Materials
"Key Resources" for the Automotive Industry

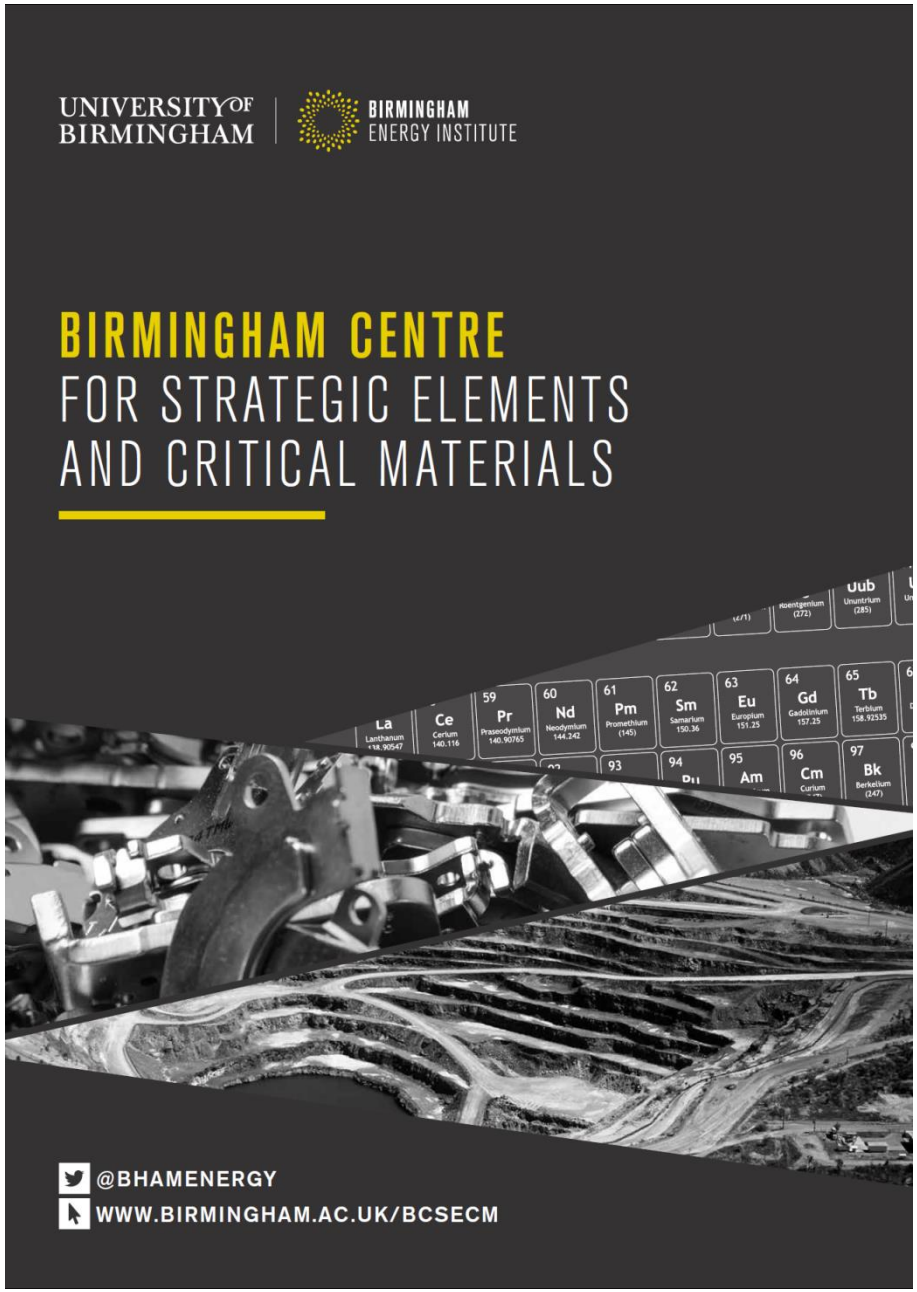
- The automotive industry has had a number of incidents that have highlighted how vulnerable supply chains are:
  - PA-12, German Chemical Factory Fire
  - Paint colours – Japan Tsunami
- With a transition to cleaner mobility solutions, new vulnerabilities will be introduced to automotive supply chains.
- It is important to understand constraints and challenges around Critical Materials for the clean energy transition.

The Birmingham Centre for Strategic Elements & Critical Materials is the first UK university research centre in the field.

www.birmingham.ac.uk/BCSECM

Our scientists are working on a number of technologies that could help alleviate some of the resource challenges around scarce materials in automotive applications:

- Mining platinum from road dust and storm water gullies using biological processes.
- Recycling of rare earth magnets and manufacture of new magnets suitable for vehicle drives.



Remanence Project

- University of Birmingham a partner in this EU project.
- Aim to develop new and innovative processes for the recovery and recycling of neodymium iron boron magnets (NdFeB) from a range of waste electronic and electrical equipment (WEEE).
- Advanced sensing and mechanical separation techniques used in combination with innovative processes to recover the rare earth magnets in the WEEE.
- Material recovered in a form that can easily re-enter the primary magnet manufacturing production route, so providing large energy savings and reduced production costs for European manufacturers.
- http://www.project-remanence.eu/

Graphic from: http://www.project-remanence.eu/

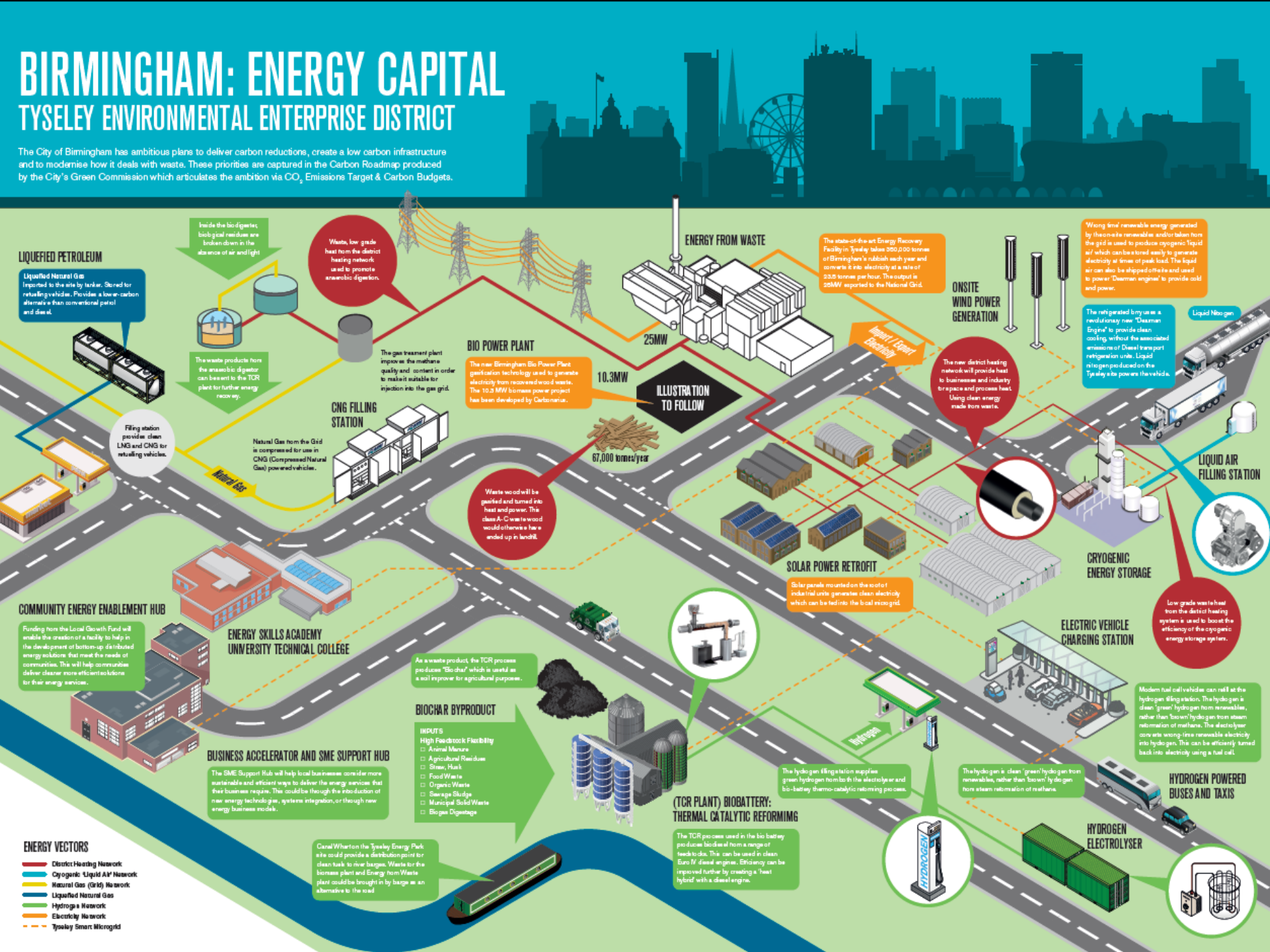
Energy Capital

- Triple Helix Demonstrator for a range of new energy technologies & vectors.
- EV Charging, Hydrogen, Liquid Air, CNG, LPG, Biodiesel planned for site.
- Truly multi-modal:
  - National Express looking at rolling out a fleet of hydrogen buses.
  - Liquid air hub for clean cold vehicles.
  - Birmingham – more canals than Venice 35 miles.
    - University of Birmingham has developed a "Hydrogen canal boat"

BIRMINGHAM: ENERGY CAPITAL

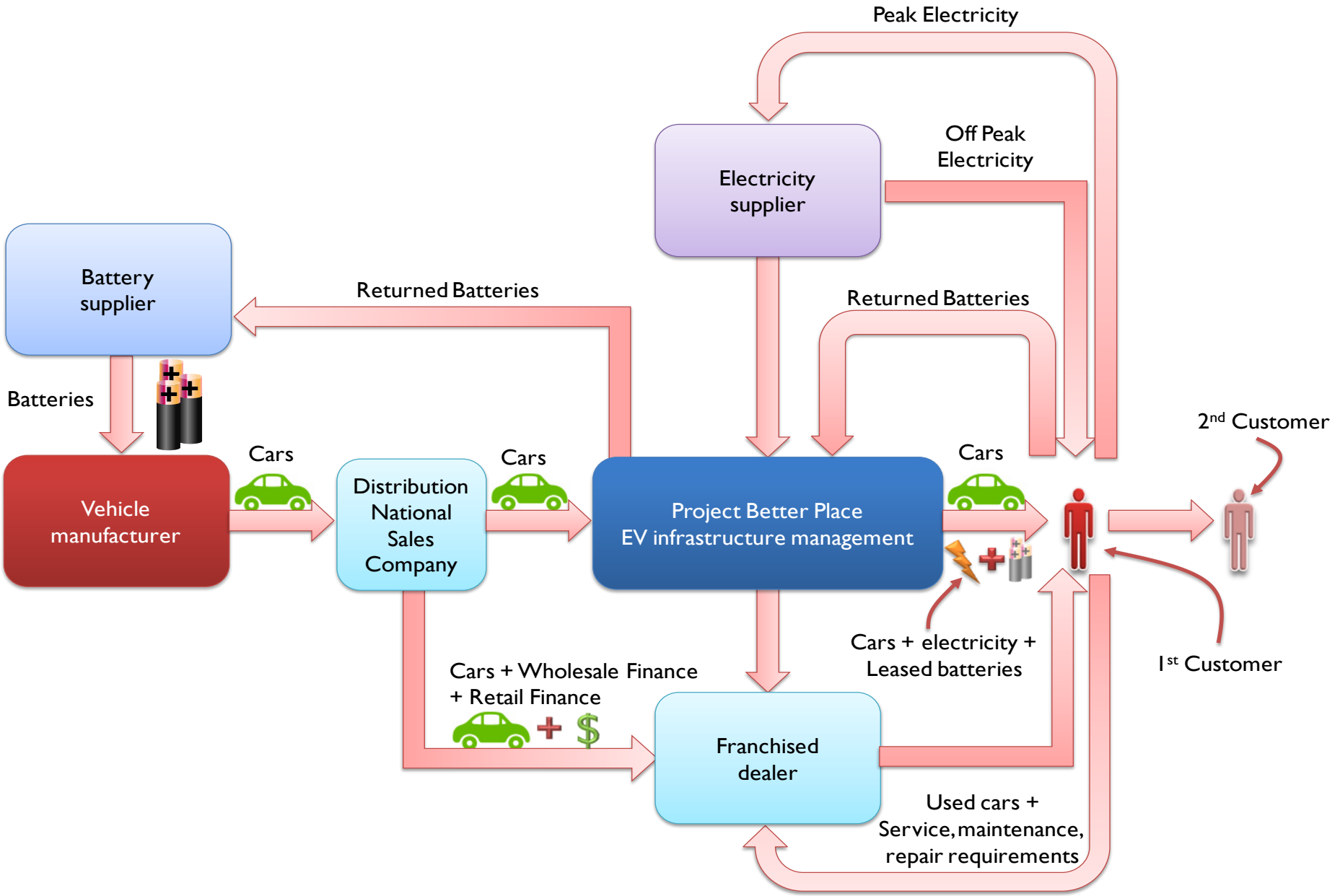
TYSELEY ENVIRONMENTAL ENTERPRISE DISTRICT

The City of Birmingham has ambitious plans to deliver carbon reductions, create a low carbon infrastructure and to modernise how it deals with waste. These priorities are captured in the Carbon Roadmap produced by the City's Green Commission which articulates the ambition via CO_2 Emissions Target & Carbon Budgets.

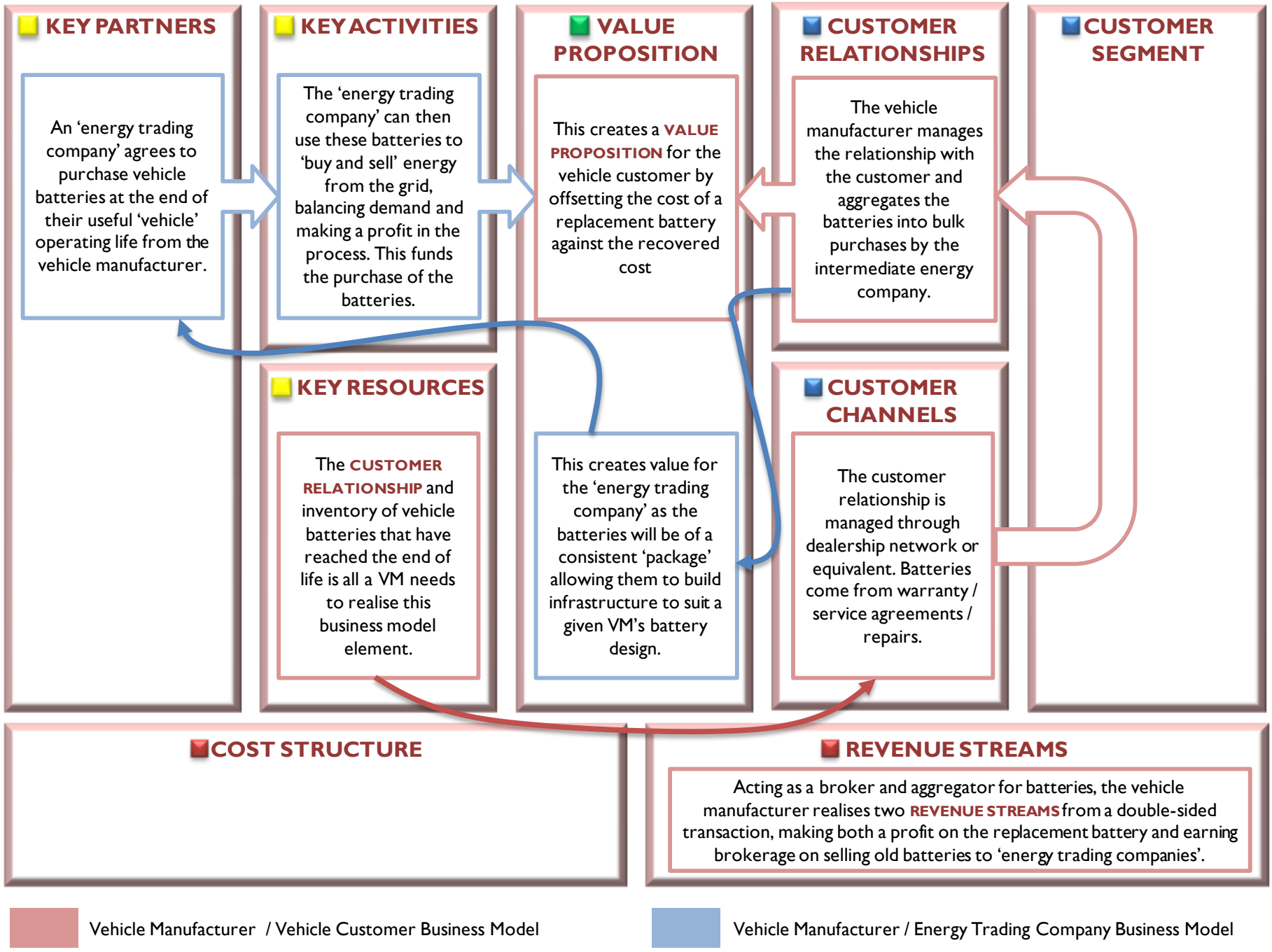


- National Low Carbon Mobility Centre: To enable collaboration between institutions and businesses to overcome challenges facing low carbon vehicles including grid connectivity and battery ageing.
- New battery chemistry: To develop the next generation of Lithium-ion batteries with radically improved performance.
- Electro mechanical behaviour: To research the mechanical properties of batteries to support a drive towards lighter-weight car batteries.
- Second life applications: To explore how retired batteries can be used to meet the need for greater energy storage in domestic and industrial applications.

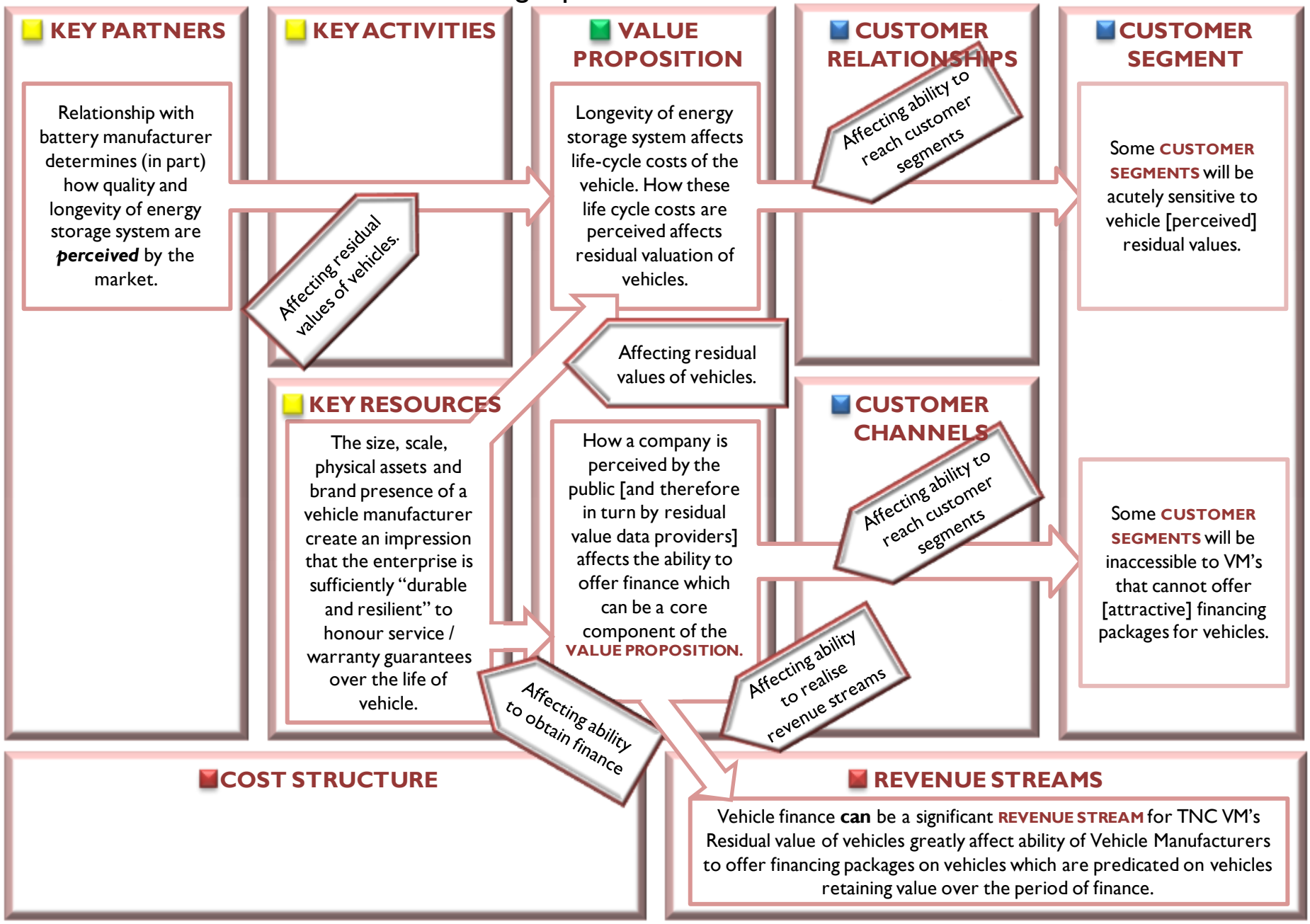
- www.era.ac.uk



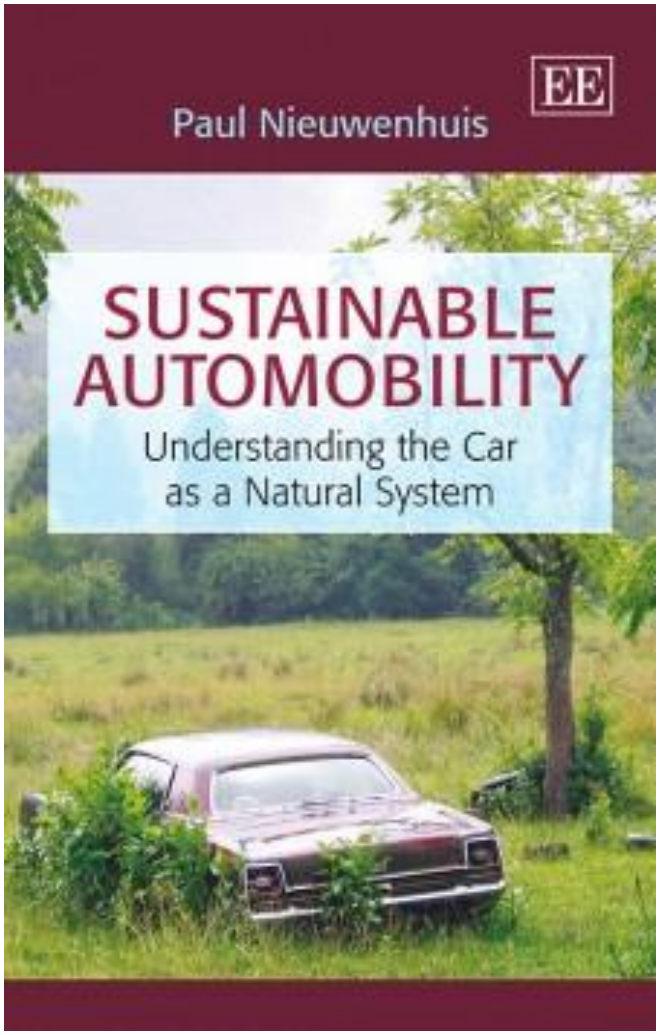
The Project Better Place Business Model as envisioned by (Wells P. E., 2010b, p. 127)

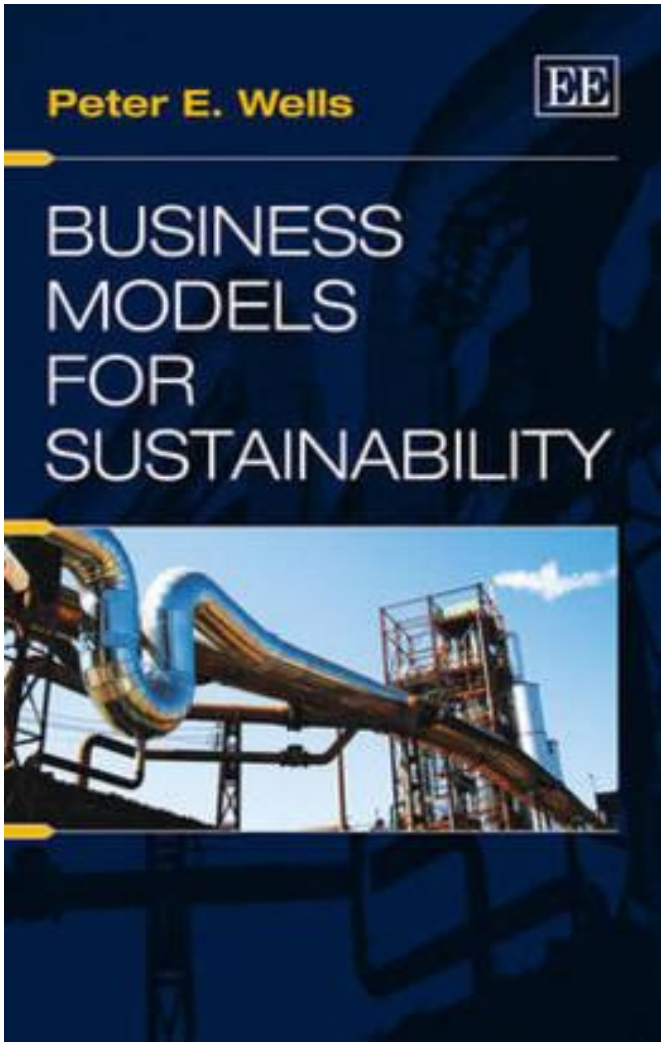

KEY PARTNERS
An 'energy trading company' agrees to purchase vehicle batteries at the end of their useful 'vehicle' operating life from the vehicle manufacturer.
KEY ACTIVITIES
The 'energy trading company' can then use these batteries to 'buy and sell' energy from the grid, balancing demand and making a profit in the process. This funds the purchase of the batteries.
VALUE PROPOSITION
This creates a VALUE PROPOSITION for the vehicle customer by offsetting the cost of a replacement battery against the recovered cost
CUSTOMER RELATIONSHIPS
The vehicle manufacturer manages the relationship with the customer and aggregates the batteries into bulk purchases by the intermediate energy company.
CUSTOMER SEGMENT
KEY RESOURCES
The CUSTOMER RELATIONSHIP and inventory of vehicle batteries that have reached the end of life is all a VM needs to realise this business model element.
This creates value for the 'energy trading company' as the batteries will be of a consistent 'package' allowing them to build infrastructure to suit a given VM's battery design.
CUSTOMER CHANNELS
The customer relationship is managed through dealership network or equivalent. Batteries come from warranty / service agreements / repairs.
COST STRUCTURE
REVENUE STREAMS
Acting as a broker and aggregator for batteries, the vehicle manufacturer realises two REVENUE STREAMS from a double-sided transaction, making both a profit on the replacement battery and earning brokerage on selling old batteries to 'energy trading companies'.
Vehicle Manufacturer / Vehicle Customer Business Model
Vehicle Manufacturer / Energy Trading Company Business Model

The relationship between 'Energy Storage Quality Perception', 'Residual Vehicles Values' and 'Vehicle Financing Options' shown on the Business Model



Suggested Reading





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