

Preparing for a Life Cycle CO₂ Measure

A report to inform the debate by identifying and establishing the viability of assessing a vehicle's life cycle CO₂e footprint

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Confidential Low Carbon Vehicle Partnership

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Accelerating the
Shift to Low Carbon
Vehicles and Fuels

Approved



Dave Greenwood

- **Introduction**
- Strengths and Limitations of the existing tailpipe CO₂ measure
- Elements and Boundaries for evaluating life cycle CO₂ emissions
- Impact of Regulations on life cycle CO₂ emissions
- Consequences of Technology Evolution on life cycle CO₂ emissions
- Gaps, Accuracy and Further Work
- Recommendations
- Conclusions
- Appendices

LowCVP commissioned a study to identify and establish the viability of assessing a vehicle's life cycle CO₂ footprint

Background

- The current metric for comparing the GHG emissions of European passenger cars is based on measuring the tailpipe CO₂ emissions over the New European Drive Cycle (NEDC)
- Legislative targets for reducing corporate fleet average CO₂ are driving the development of low carbon technologies and alternative fuels
- The tailpipe CO₂ metric is insufficient for comparing the environmental impact of zero and ultra-low emission vehicles, such as electric (EV) and fuel cell vehicles (FCV), since it does not consider CO₂ emissions resulting from the generation of the fuel, or those embedded within the vehicle production
- There is growing demand from consumers for information on the carbon footprint of the goods and services they purchase



Life cycle thinking is required to develop new measures for comparing the environmental impact of passenger cars

- The purpose of this report is inform the debate by examining the feasibility of considering a vehicle's whole life cycle, exploring the options for developing new metrics, and explaining how this could be taken forward

This report endeavours to answer a series of questions related to developing new CO₂ metrics

Report Objectives

1. What are the strengths and limitations of the current gCO₂/km metric for comparing the GHG-emissions of European passenger cars?
2. What elements contribute to a vehicle's life cycle CO₂ emissions?
3. What is an appropriate boundary for the evaluation of a vehicle's life cycle CO₂ emissions?
4. This question is in four parts:
 - a. What international regulations apply to light duty vehicles in Europe? How might these regulations impact the vehicle's life cycle CO₂ emissions?
 - b. What CO₂ emissions typically arise during the production, use and disposal of European passenger cars? How will evolving technologies, such as vehicle electrification, alter the balance of life cycle emissions between production, in-use and disposal?
 - c. What is an appropriate balance of focus between the production, in-use and disposal phases for relevant combinations of new technologies?
 - d. To what degree can the contributing elements currently be assessed?
5. What are the current gaps in understanding surrounding LCA of passenger cars? What is the present status of accuracy for assessing the elements contributing to a vehicle's life cycle emissions? What further work is required to achieve a fair life cycle CO₂ measure for vehicles?
6. In Ricardo's opinion, what are the most appropriate forms for a new measure of CO₂ emissions for European passenger vehicles? What timescales are desirable and practicable for transitioning to a new CO₂ emission measure?

- In accordance with the LowCVP's tender document, this study has not:
 - Assessed the suitability of existing drive cycles, but has reviewed the limitations already identified
 - Sought to define an improved test-cycle for determination of emissions arising from the in-use phase, but has identified and assessed the viability for measuring contributing elements for vehicle production, in-use and disposal
 - Considered metrics for different vehicle classes at this stage, but has focused on light duty vehicles
 - Considered individual components unless significantly relevant to life cycle emissions
 - Considered individual components unless causing a significant variation to life cycle emissions
 - Defined a metric to replace tailpipe CO₂, but has recommend elements of a life cycle CO₂ analysis for inclusion in a metric and define principles for determining which elements should be included and a gap analysis for determining them

Abbreviations



Abbr.	Explanation	Abbr.	Explanation	Abbr.	Explanation
AMT	Automated Manual Transmission	EREV	Extended Range Electric Vehicle	MPI	Multi-Point (fuel) Injection
Auto	Automatic Transmission	EV	Electric Vehicle	NEDC	New European Drive Cycle
B7	Diesel with up to 7%vol FAME	FAME	Fatty Acid Methyl Ester	NiMH	Nickel Metal Hydride
B10	Diesel with up to 10%vol FAME	FCV	Fuel Cell Vehicle	OEM	Original Equipment Manufacturer
B100	100% biodiesel	FQD	Fuel Quality Directive	PAS	Power Assisted Steering
BoM	Bill of materials	GDI	Gasoline Direct Injection	PEM	Proton Exchange Membrane
CO ₂	Carbon Dioxide	GHG	Greenhouse Gas	PFI	Port Fuel Injection
CO ₂ e	Carbon Dioxide equivalent	GWP	Greenhouse Gas Warming Potential	PHEV	Plug-In Hybrid Electric Vehicle
CVT	Continuously Variable Transmission	H&S	Health and Safety	TTW	Tank-to-Wheels
DCT	Dual Clutch Transmission	HC	Hydrocarbons	R&D	Research and Development
DECC	Department for Energy and Climate Change	HCCI	Homogeneous Charge Compression Ignition	RED	Renewable Energy Directive
DI	Direct Injection	HEV	Hybrid Electric Vehicle	UN ECE	United Nations Economic Commission for Europe
E10	Gasoline with up to 10%vol ethanol	HVAC	Heating Ventilation and Air Conditioning	V6	V 6-cylinder engine
E20	Gasoline with up to 20%vol ethanol	I4	In-line 4-cylinder engine	VCA	Executive Agency of the United Kingdom Department for Transport
E85	Gasoline with up to 85%vol ethanol	ICE	Internal Combustion Engine	VGT	Variable Geometry Turbocharger
EC	European Commission	ISO	International Organisation for Standardization	VVA	Variable Valve Actuation
ECU	Engine Control Unit	LCA	Life Cycle Assessment	VVT	Variable Valve Timing
EoL	End-of-Life	LCI	Life Cycle Inventory	WTT	Well-to-Tank
EPAS	Electric Power Assisted Steering	Li-Ion	Lithium Ion	WTW	Well-to-Wheels
				ZEV	Zero Emission Vehicle

Carbon dioxide, greenhouse gases and Global Warming Potential



Explanation of definitions

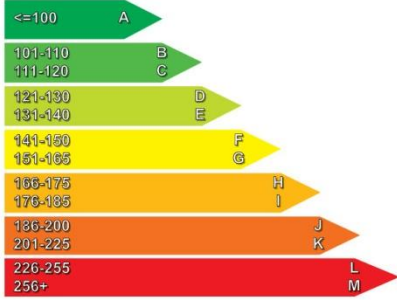



- Greenhouse gas (GHG) is the collective term for the gases which are considered to contribute to global warming
- Carbon dioxide (CO₂) is considered to be one of the main contributors to global warming
- However GHG also includes gases, such as methane (CH₄) and nitrous oxide (N₂O)
- Life cycle assessment studies frequently refer to carbon dioxide equivalent (CO₂e or CO₂eq), which is a metric for comparing the emissions from various greenhouse gases depending on their Global Warming Potential (GWP) for a specified time horizon. The quantity of the gas is multiplied by its GWP to obtain its CO₂e value
- Examples of GWP for common GHGs is provided in the table below

Greenhouse Gas	Global Warming Potential (100 years time horizon)
CO ₂	1
CH ₄	21
N ₂ O	310

- GWP is sometimes referred to as Climate Change Potential (CCP)
- This study has focused on the vehicle's life cycle impact in terms of CO₂ and GHG emissions. However a vehicle can also impact the environment in other ways, such as air acidification (SO₂ and NO_x), water footprint, depletion of resources, human toxicity and air quality

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The current CO₂ metric for comparing passenger cars is based on measuring tailpipe CO₂ emissions over the NEDC

Fuel Economy		VED band and CO ₂												
CO₂ emission figure (g/km) 														
Fuel cost (estimated) for 12,000 miles <small>A fuel cost figure indicates to the consumer a guide fuel price for comparison purposes. This figure is calculated by using the combined drive cycle (town centre and motorway) and average fuel price. Recalculated annually, the current cost per litre as at March 2009 is as follows: petrol 88p, diesel 100p and LPG 51p (VCA March 2009).</small> VED for 12 months <small>Vehicle excise duty (VED) or road tax varies according to the CO₂ emissions and fuel type of the vehicle.</small>														
Environmental Information A guide on fuel economy and CO ₂ emissions which contains data for all new passenger car models is available at any point of sale free of charge. In addition to the fuel efficiency of a car, driving behaviour as well as other non-technical factors play a role in determining a car's fuel consumption and CO ₂ emissions. CO ₂ is the main greenhouse gas responsible for global warming.														
Make/Model:	Engine Capacity (cc):													
Fuel Type:	Transmission:													
Fuel Consumption: <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th>Drive cycle</th> <th>Litres/100km</th> <th>Mpg</th> </tr> </thead> <tbody> <tr> <td>Urban</td> <td></td> <td></td> </tr> <tr> <td>Extra-urban</td> <td></td> <td></td> </tr> <tr> <td>Combined</td> <td></td> <td></td> </tr> </tbody> </table>			Drive cycle	Litres/100km	Mpg	Urban			Extra-urban			Combined		
Drive cycle	Litres/100km	Mpg												
Urban														
Extra-urban														
Combined														
Carbon dioxide emissions (g/km): Important note: Some specifications of this make/model may have lower CO ₂ emissions than this. Check with your dealer.														
 To compare fuel costs and CO ₂ emissions of new cars, visit www.vcacarfueldata.org.uk 														

- The current CO₂ metric for comparing passenger cars in Europe is based on measuring the tailpipe CO₂ emissions [gCO₂/km] (EU Directive 2003/76)
 - The tailpipe CO₂ test is based on the New European Drive Cycle (NEDC), which comprised of four ECE phases (urban driving) and one EUDC phase (extra-urban)
 - The test occurs in a controlled laboratory environment, using rolling road dynamometers for repeatability
 - The vehicle has to be ‘cold’ at the start of the test, requiring a soak period of at least 6 hours before the test. The ambient temperature during testing has to be within 20°C and 30°C
 - For validation purposes, the test is overseen by an authorised person from the Type Approval Agency (e.g. VCA)
- The EU is adopting a fleet average tailpipe CO₂ target for new passenger cars (M1), with non-compliance penalties and super-credits for low emission vehicles (EU Regulation No 443/2009)
 - The requirement for fleet average 130 gCO₂/km will phase in from 2012 to 2015
 - A further 10 gCO₂/km reduction is to come from additional measures such as gear shift indicators, more efficient air conditioning, low rolling resistance tyres, aerodynamics and biofuels
 - The long term target is fleet average 95 gCO₂/km by 2020

Strengths of the current CO₂ measure include the used of a defined drive cycle, test procedures and reference fuel

Strengths of the existing tailpipe CO₂ measure

Strengths	Comments
<ul style="list-style-type: none"> ➤ Fixed drive cycle 	<ul style="list-style-type: none"> ● The same drive cycle is used for all light duty vehicles, providing a common reference ● Historic data set exists from 1995 to present day – enabling tracking of overall reduction
<ul style="list-style-type: none"> ➤ Defined reference fuels 	<ul style="list-style-type: none"> ● Prevents differences in results due to different fuels
<ul style="list-style-type: none"> ➤ Defined test procedure 	<ul style="list-style-type: none"> ● Clearly defined and understood ● Covers all necessary requirements for a variety of vehicles ● Ensures each vehicle is tested using the same procedure
<ul style="list-style-type: none"> ➤ 'Cold' start emissions included 	<ul style="list-style-type: none"> ● Covers the warm-up period of vehicle
<ul style="list-style-type: none"> ➤ Level playing field 	<ul style="list-style-type: none"> ● All OEMs abide by same set of rules ● The results acquired are consistent and, therefore, create meaningful historical emissions trends

- These strengths conversely can be seen as limitations ...

Limitations of the existing tailpipe CO₂ measure revolve around the laboratory conditions not representing the real world conditions

Limitations of the existing tailpipe CO₂ measure

Limitations	Comments
<ul style="list-style-type: none"> • Tailpipe only 	<ul style="list-style-type: none"> • No consideration of well-to-tank CO₂ emissions, just tank-to-wheels • Under this condition, EVs have zero tailpipe emissions at point of use
<ul style="list-style-type: none"> • Constrained drive cycle 	<ul style="list-style-type: none"> • The current modal cycle (NEDC) is not representative of the range of real-world driving conditions • Focuses on lower speeds (urban and extra urban), without considering higher speeds • It does not consider gradients, does not account for cornering, or how driver behaviour effects driving performance
<ul style="list-style-type: none"> • Unrepresentative environment 	<ul style="list-style-type: none"> • The test ambient temperature (~25°C) is higher than average ambient temperature across Europe • There is no allowance for climatic variation between regional markets
<ul style="list-style-type: none"> • No ancillaries 	<ul style="list-style-type: none"> • Effect of ancillaries is not considered <ul style="list-style-type: none"> – No HVAC loading – No electrical loads (e.g. lights) – No PAS/EPAS loads from steering inputs
<ul style="list-style-type: none"> • Road load factors 	<ul style="list-style-type: none"> • Data is not publicly available • Scope for differing interpretation of rules when defining road load factors
<ul style="list-style-type: none"> • Powertrain 	<ul style="list-style-type: none"> • Little knowledge on effect of hybrids and electric vehicles • Range provided for EV not representative

Comparing the current tailpipe CO₂ measure with the real world experience suggests real world typically exceeds NEDC results

- In 2009 TNO analysed records of fuel-card usage in the Netherlands to understand the differences between real world driving and the test-based, published fuel consumption and tailpipe CO₂ data
 - In general, fuel consumption and tailpipe CO₂ was higher than the official, published fuel consumption from the NEDC test
 - Real world tailpipe CO₂ could be 15-40% higher, depending of fuel type, technology and usage pattern
 - In the Netherlands, the real world use is approximately 20% urban, 35% extra-urban and 40% motorway driving. The NEDC is split 35% urban and 65% extra-urban driving (by distance travelled)
 - Therefore, the differences between published and real world CO₂ can be attributed, in part, to the greater share of motorway driving in the real world experience
- AutoCar regularly review new passenger cars for the benefit of their readers. The vehicles are assessed by experienced drivers, who perform a similar set of driveability tests for each vehicle. AutoCar publish the average fuel consumption of the vehicle experienced during the test drive, along side the fuel consumption stated by the vehicle manufacturer. This data provides an indication of the difference between the published fuel consumption values and the “real world” experience. Tailpipe CO₂ can be calculated from the fuel consumption, depending on the fuel type
 - A comparison of NEDC results with AutoCar experience is provided in the next slide
 - For the selected examples, real-world vehicle CO₂ emissions appear to be ~20% worse than the certified figures

Real world tailpipe CO₂ could be 5-40% higher than the NEDC CO₂ measure for conventional passenger cars ...

SELECTED EXAMPLES

Segment	Vehicle	Fuel	Fuel Consumption		Tailpipe CO ₂		Difference [%]
			NEDC [L/100km]	AutoCar Test [L/100km]	NEDC [gCO ₂ /km]	AutoCar Test [gCO ₂ /km]	
A: Mini	Hyundai I10	Gasoline	5	7.5	120	180	33%
	Fiat Panda	Gasoline	4.3	5.5	103.2	132	22%
	Mini	Gasoline	6.9	9.5	165.6	228	27%
B: Small	Renault Clio	Gasoline	6.6	8	158.4	192	18%
	Seat Ibiza	Gasoline	6.2	7.9	148.8	189.6	22%
	Ford Fiesta	Gasoline	6.5	8.3	156	199.2	22%
C: Lower Medium	Audi A3	Gasoline	9.1	12.2	218.4	292.8	25%
	Ford Focus	Gasoline	6.4	8.4	153.6	201.6	24%
D: Upper Medium	BMW 3-series	Diesel	5.7	7.1	151.1	188.2	20%
	Ford Mondeo	Diesel	6.1	7.2	161.7	190.8	15%
E: Executive	BMW 5-series	Diesel	6.2	7.8	164.3	206.7	21%
	Mercedes C-class	Gasoline	6.1	8	146.4	192	24%
F: Luxury	Bentley Continental	Gasoline	17.1	20.3	410.4	487.2	16%
	Jaguar XJ	Gasoline	7.2	10.2	172.8	244.8	29%
	BMW 7-series	Gasoline	7.2	9.7	172.8	232.8	26%
G: Sports	Nissan 370Z	Gasoline	10.4	10.9	249.6	261.6	5%
	Mazda MX-5	Gasoline	8.2	11.8	196.8	283.2	31%
	Audi TT	Gasoline	10.3	12.6	247.2	302.4	18%
SUV	Land Rover Freelander	Diesel	7.5	10.1	198.8	267.7	26%
	BMW X5	Diesel	8.7	10.7	230.6	283.6	19%
	Suzuki Grand Vitara	Diesel	9.1	11.3	241.2	299.5	19%
MPV	Ford S-max	Diesel	6.4	9.1	169.6	241.2	30%
	Mazda 5	Diesel	5.2	8.1	137.8	214.7	36%
	Vauxhall Zafira	Gasoline	7.3	10.8	175.2	259.2	32%

... and for hybrids



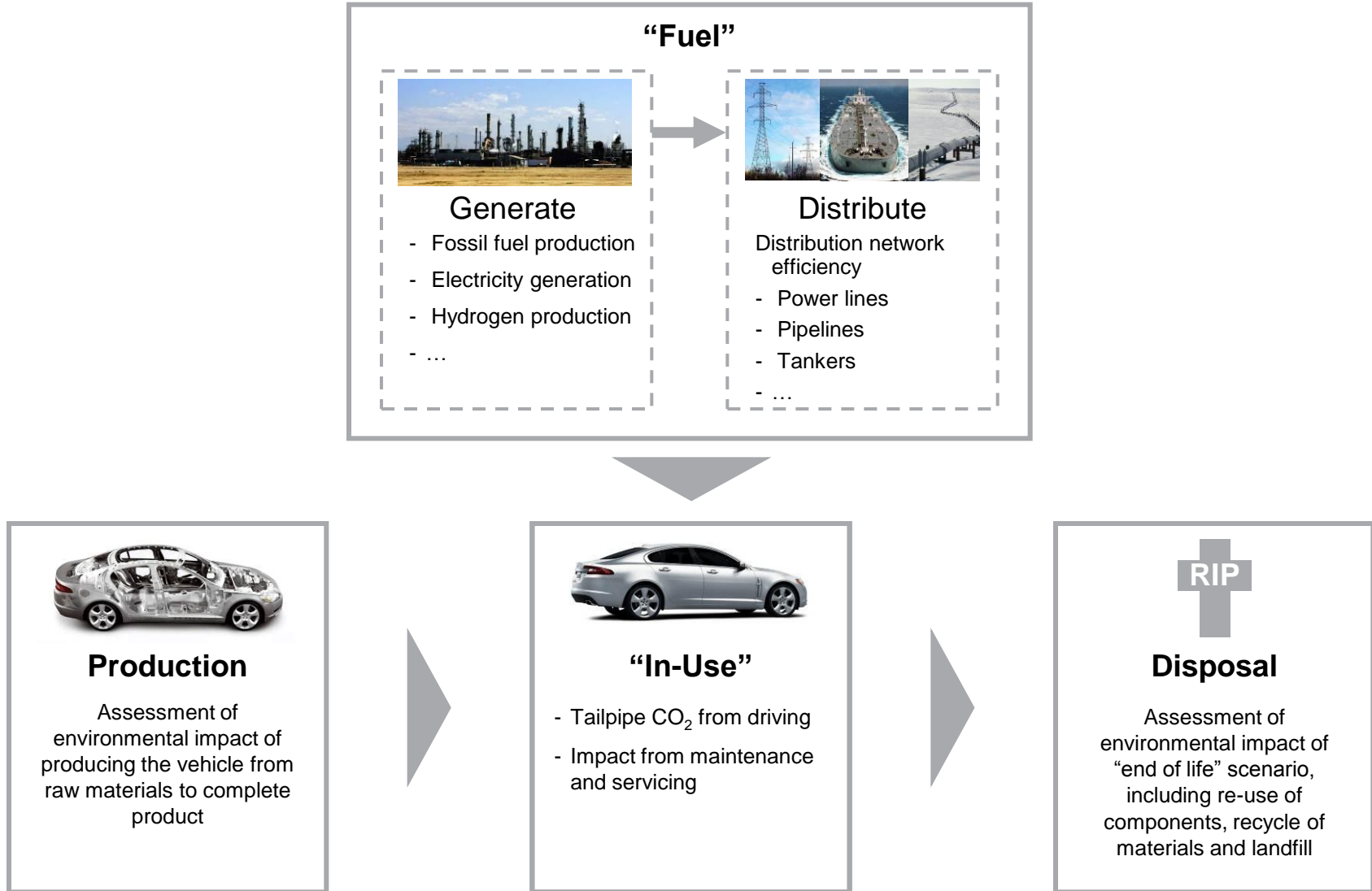
SELECTED EXAMPLES

Segment	Vehicle	Fuel	Fuel Consumption		Tailpipe CO ₂		Difference [%]
			NEDC [L/100km]	AutoCar Test [L/100km]	NEDC [gCO ₂ /km]	AutoCar Test [gCO ₂ /km]	
D: Upper Medium	Honda Insight	Gasoline Hybrid	4.6	7.1	110.4	170.4	35%
	Toyota Prius	Gasoline Hybrid	4	5.9	96	141.6	32%
SUV	Lexus RX450h	Gasoline Hybrid	6.3	9.7	151.2	232.8	35%

Segment	Vehicle	Fuel	Fuel Consumption		Tailpipe CO ₂		Consumption
			NEDC [kWh/100km]	AutoCar Test [kWh/100km]	NEDC [gCO ₂ /km]	AutoCar Test [gCO ₂ /km]	Difference [%]
D: Upper Medium	Nissan Leaf	Electricity	17.3	19.9	0	0	15%
G: Sports	Tesla Roadster	Electricity	17.4	26.7	0	0	54%

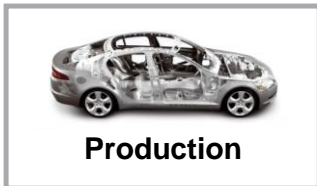
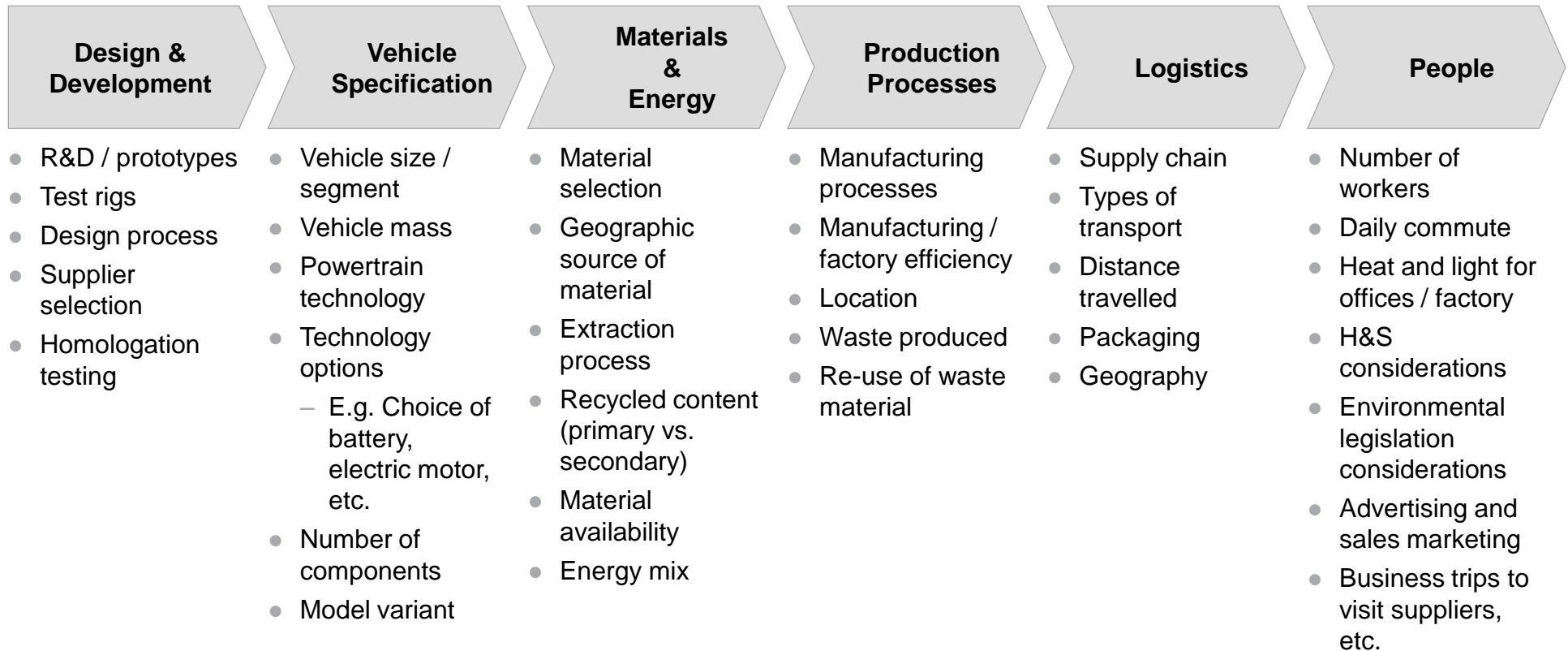
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A vehicle's life cycle can be divided into four "blocks" – production of the vehicle, production of the fuel, "in-use", and disposal



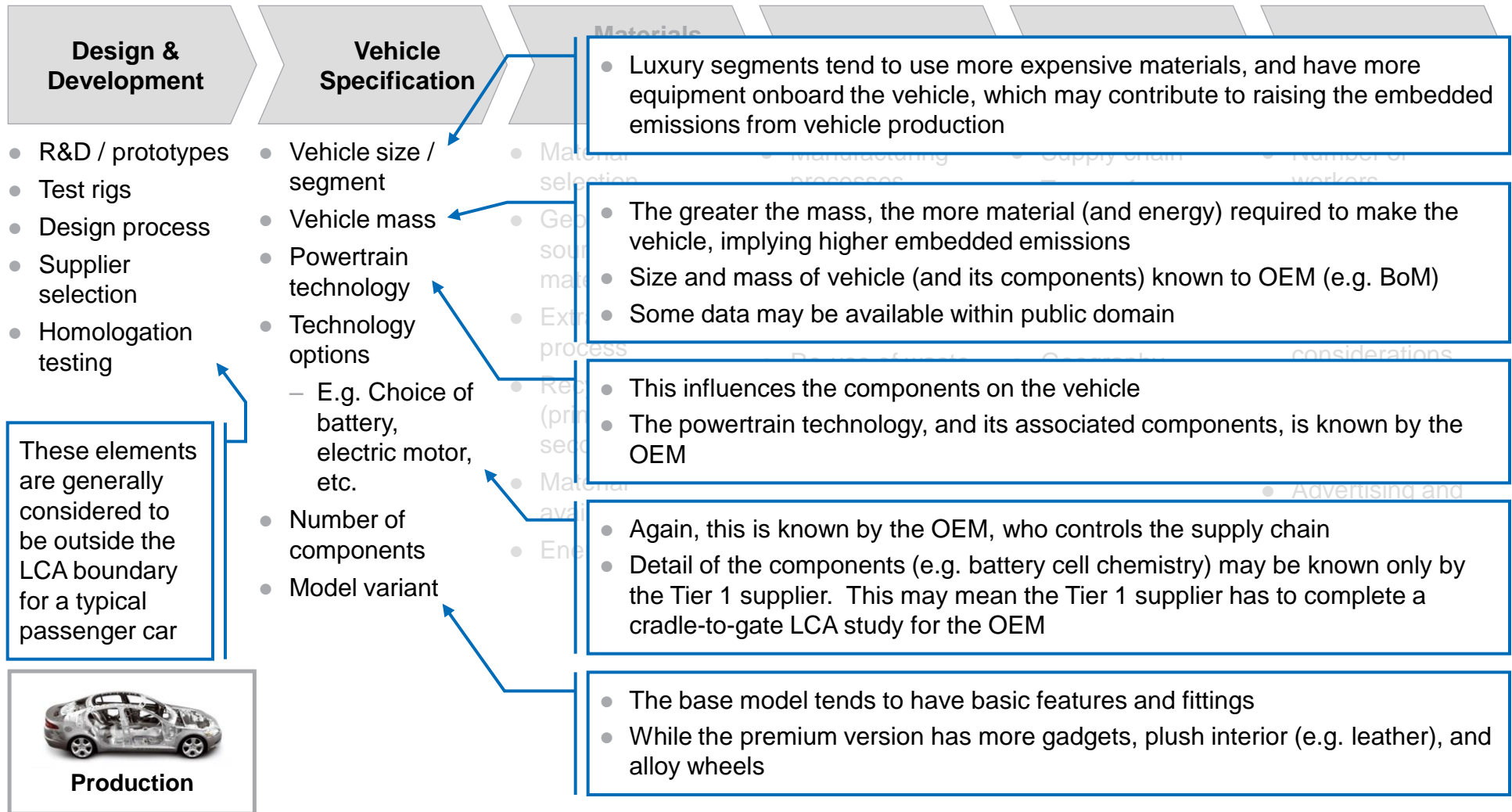
Material selection, energy use, production processes and supply chain logistics all contribute to the CO₂ emissions from production

Elements from vehicle production contributing to life cycle CO₂ emissions



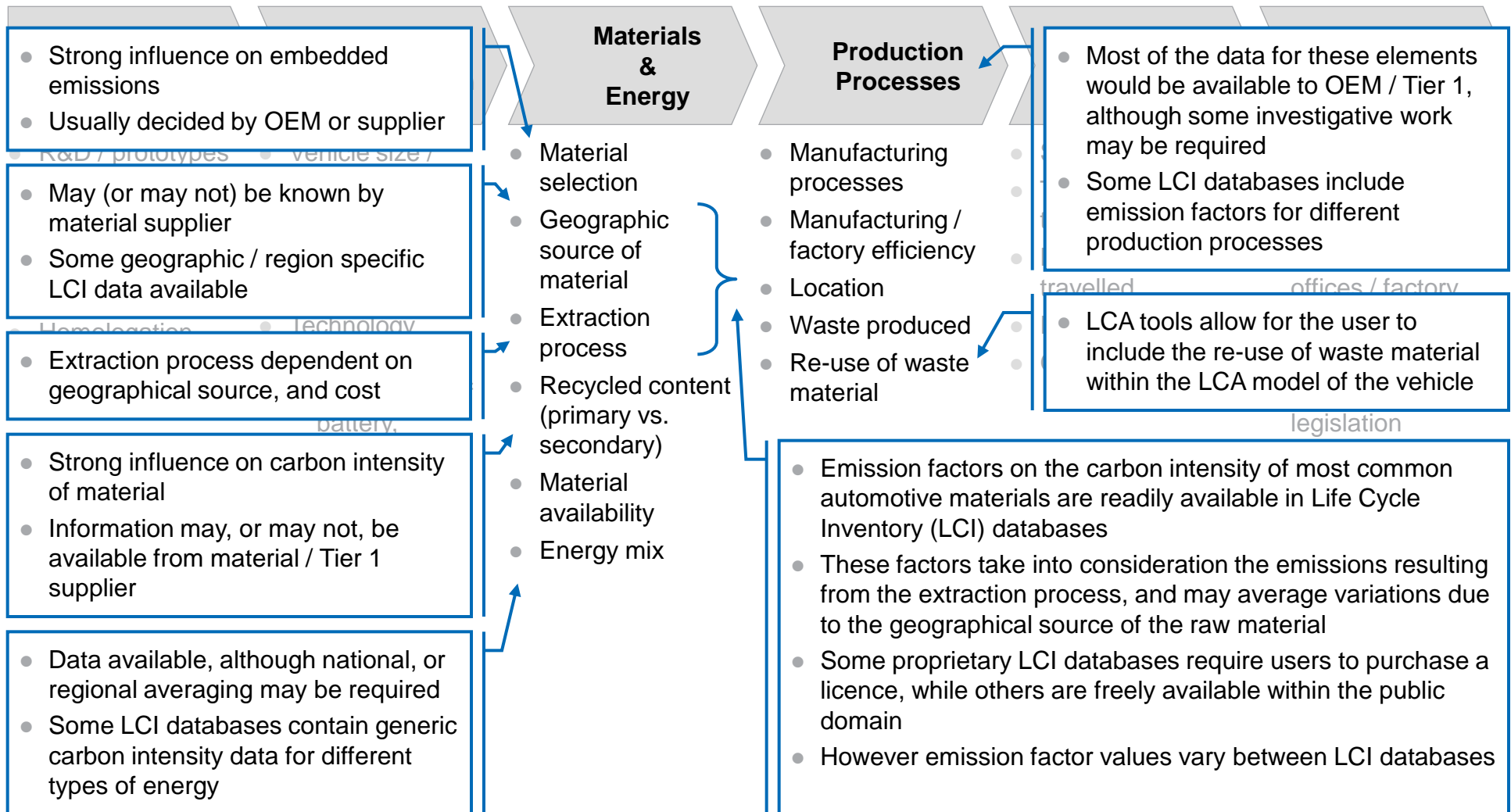
The vehicle specification determines the design of the vehicle, and its resulting embedded emissions

Elements from vehicle production contributing to life cycle CO₂ emissions



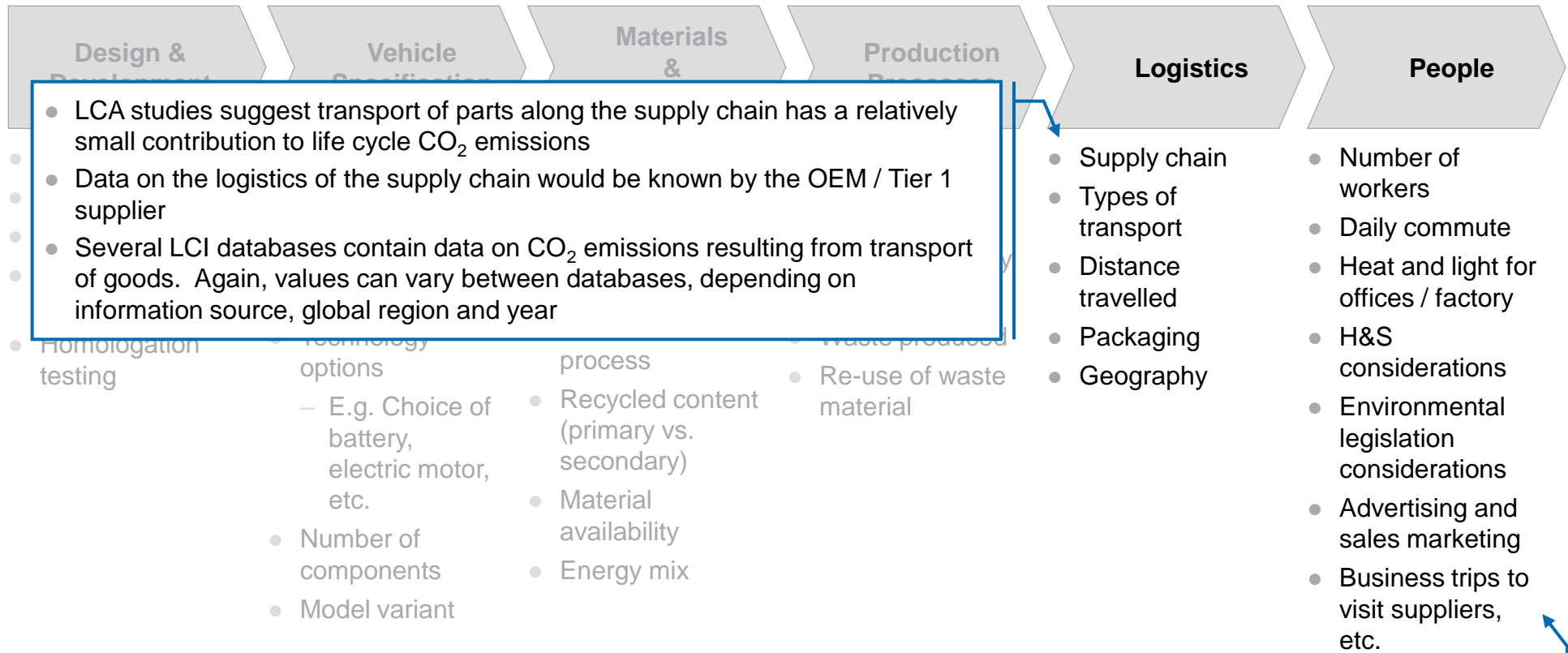
Selection of materials, production processes and location have a strong impact on the embedded CO₂ from vehicle production

Elements from vehicle production contributing to life cycle CO₂ emissions



The logistics of the supply chain can impact the embedded CO₂ emissions from vehicle production

Elements from vehicle production contributing to life cycle CO₂ emissions

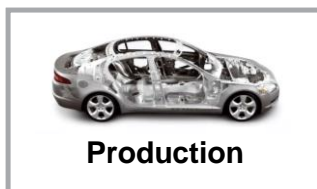
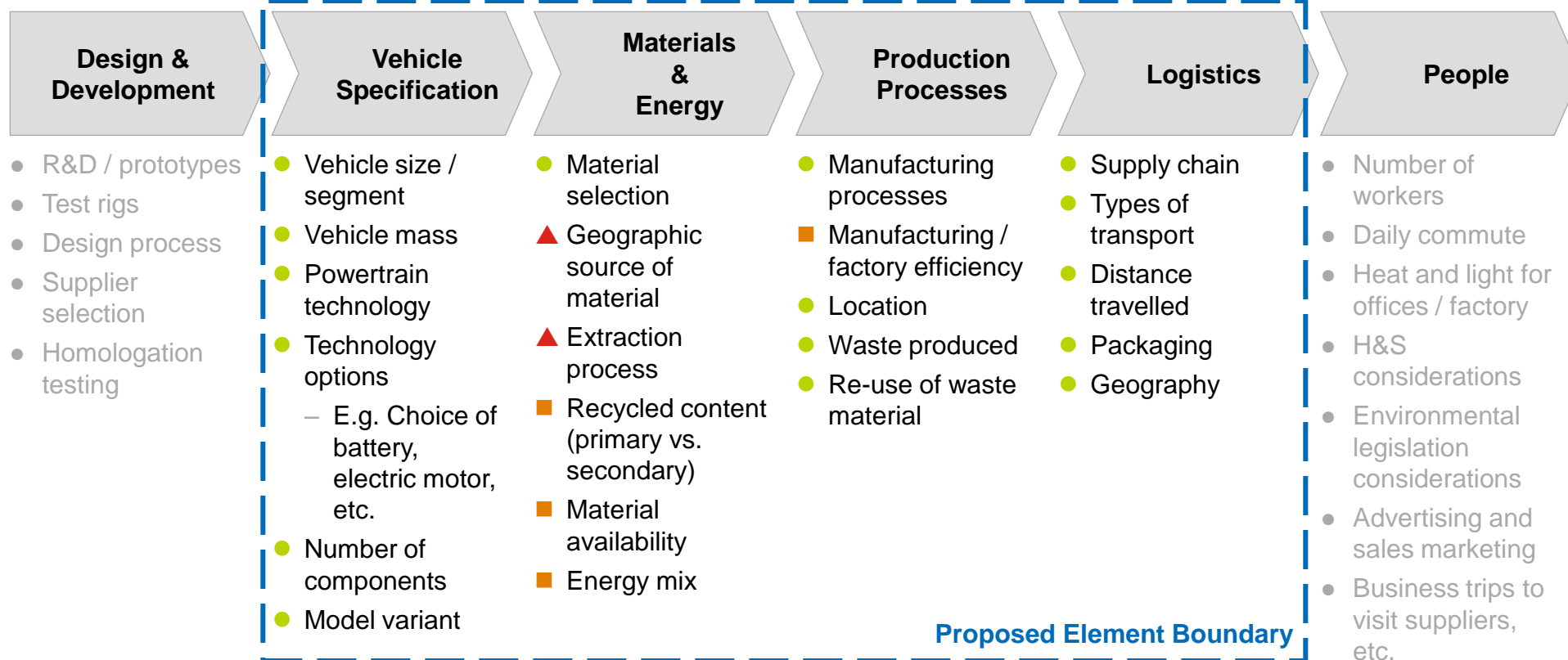


Production

These elements are generally considered to be outside the LCA boundary for a typical passenger car

The proposed element boundary for production includes vehicle specification, materials, energy, production processes and logistics

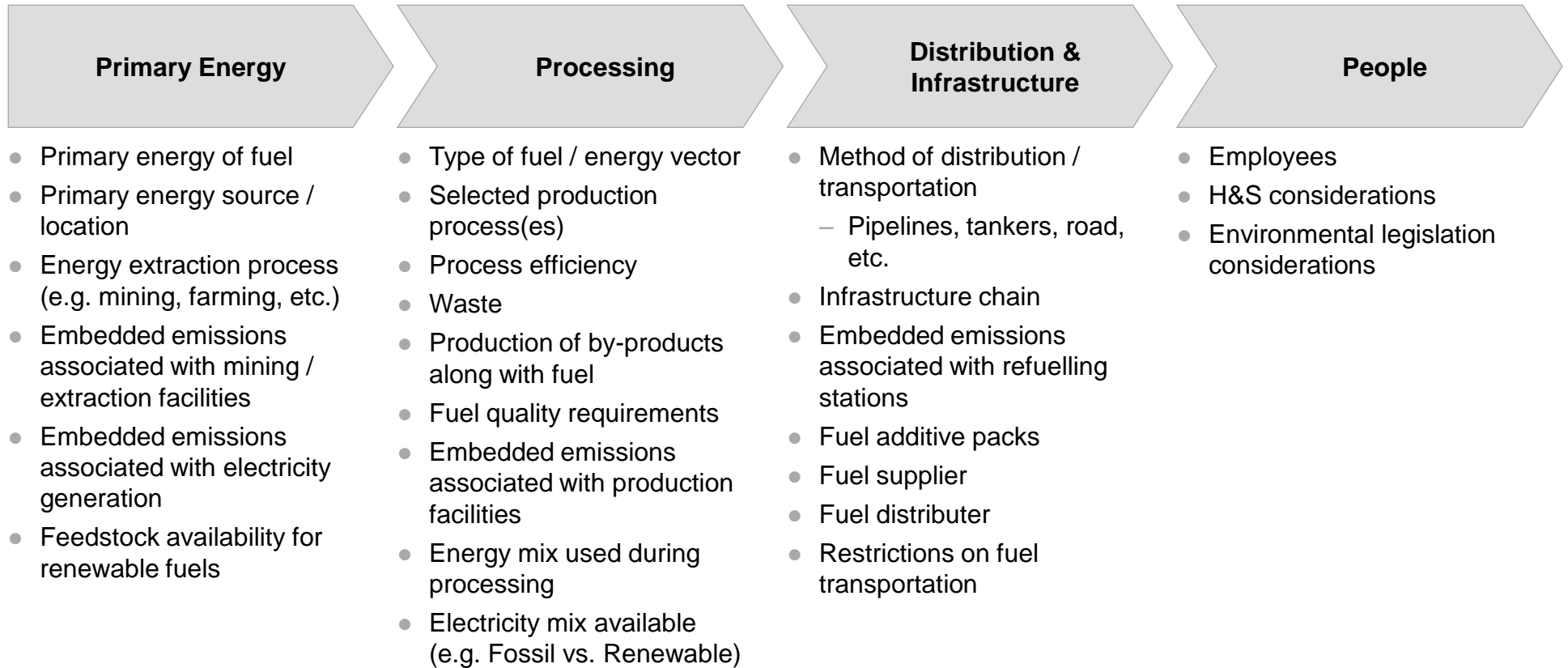
Elements from vehicle production contributing to life cycle CO₂ emissions



- Can be measured / known
- Could be measured / known
- ▲ Difficult to measure / has to be assumed

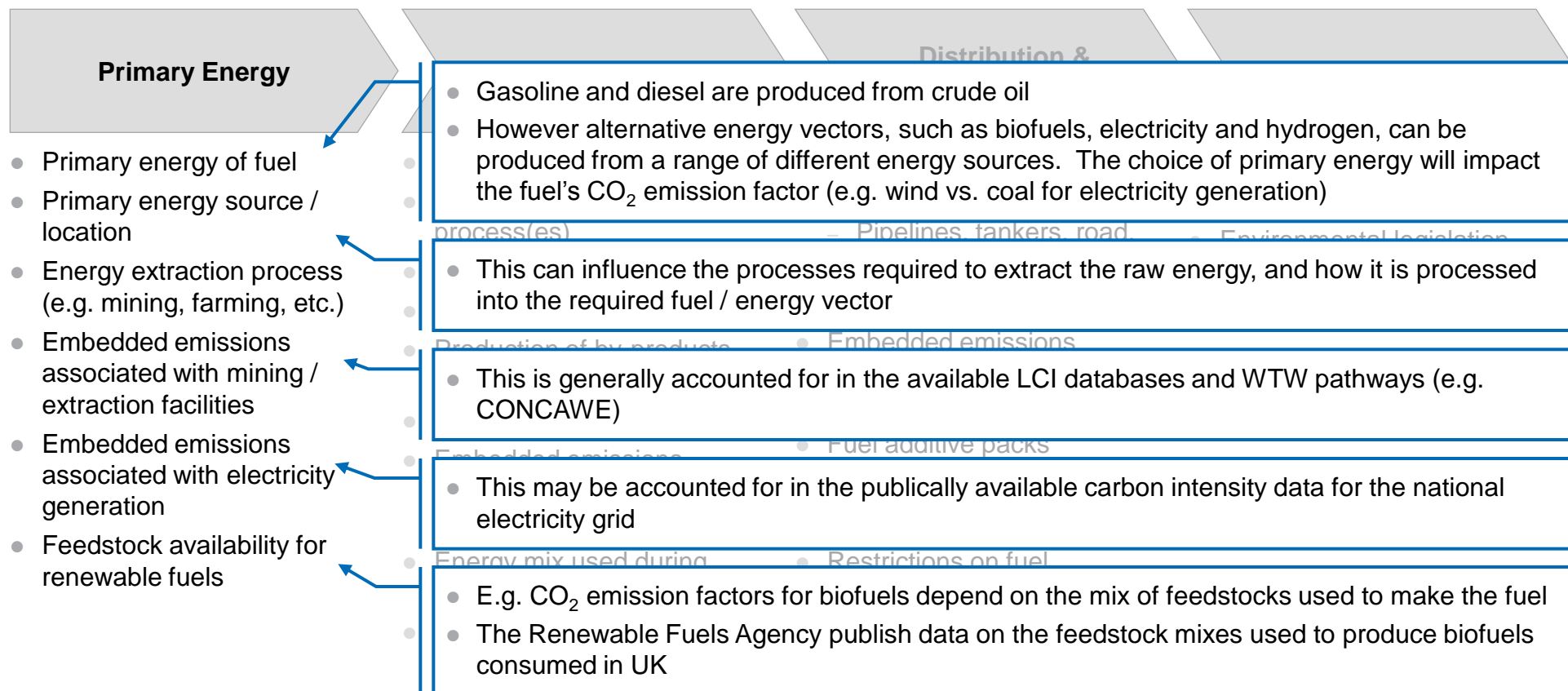
Well-to-tank CO₂ emissions from the fuel depend on the primary energy source, production process and the refuelling infrastructure

Elements from fuel well-to-tank contributing to life cycle CO₂ emissions



The choice of primary energy source has a strong influence on the fuel production process and associated WTW CO₂ emissions

Elements from fuel well-to-tank contributing to life cycle CO₂ emissions

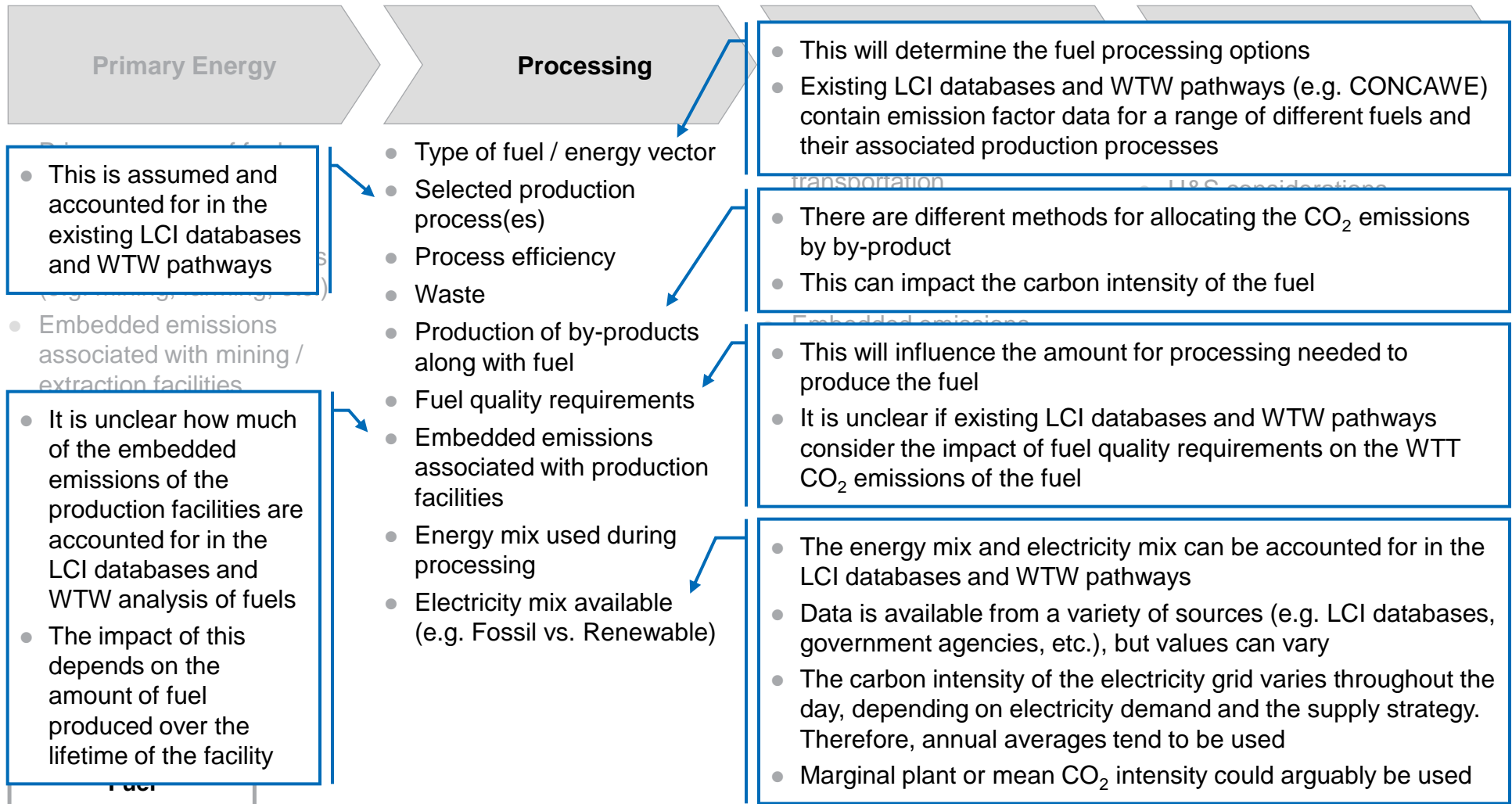


Fuel

- The impact of direct change in land use is already accounted for in several LCI datasets for biofuels
- However discussions are on-going nationally and internationally regarding how the impact of indirect land use change (iLUC) should be accounted for

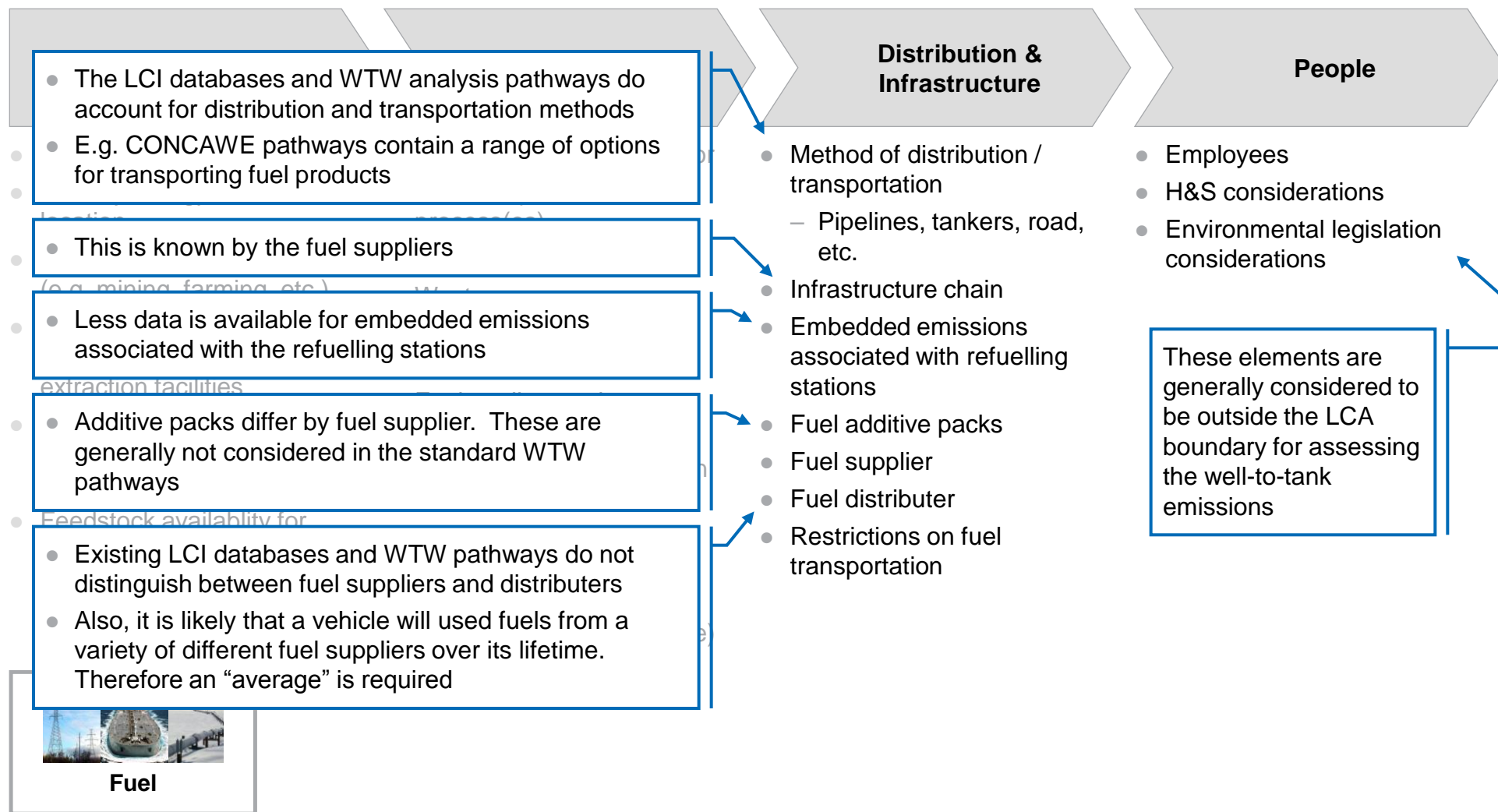
Different processes can be used to make the fuel / energy vector, which will impact the WTW CO₂ emissions

Elements from fuel well-to-tank contributing to life cycle CO₂ emissions



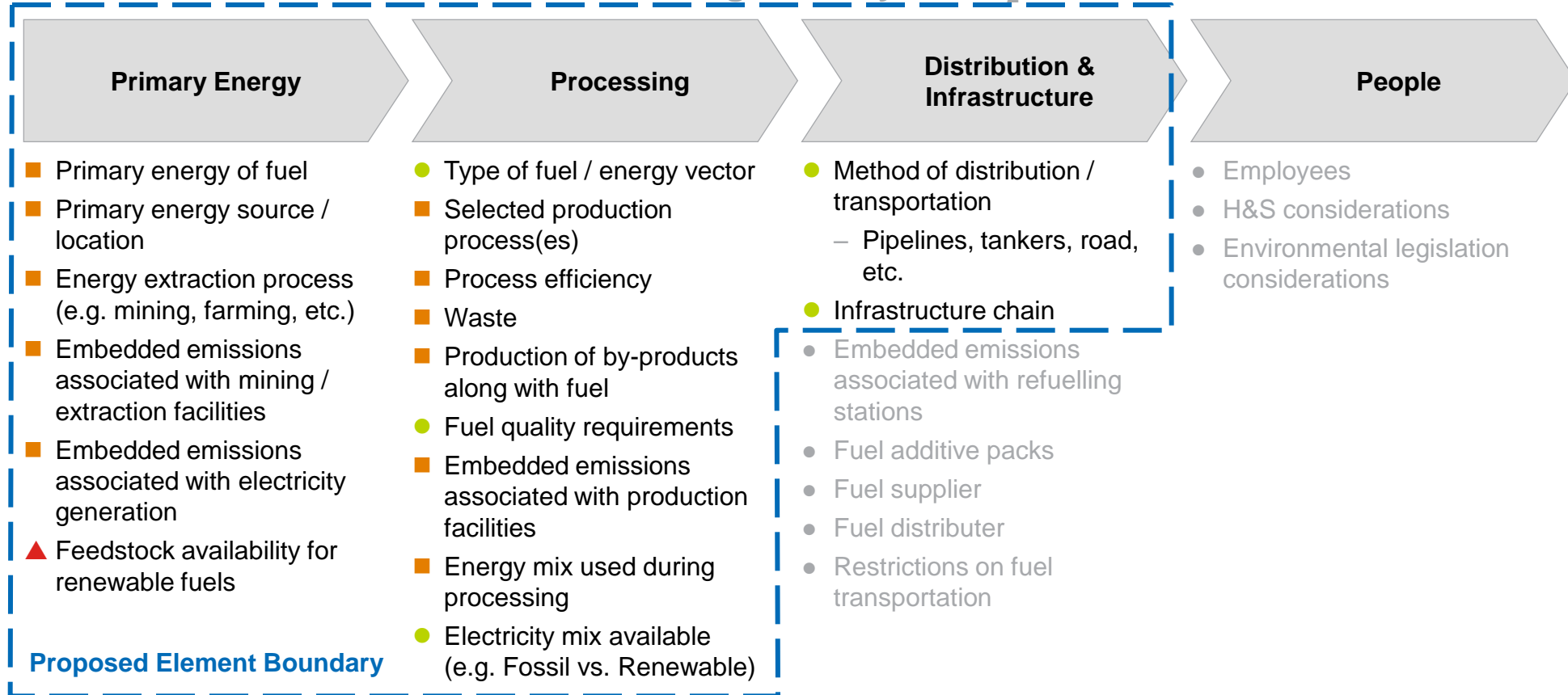
There are different methods for transporting the fuel from source of primary energy, through production, to the refuelling station

Elements from fuel well-to-tank contributing to life cycle CO₂ emissions



The proposed boundary for the fuel well-to-tank pathway includes elements regarding primary energy, processing and infrastructure

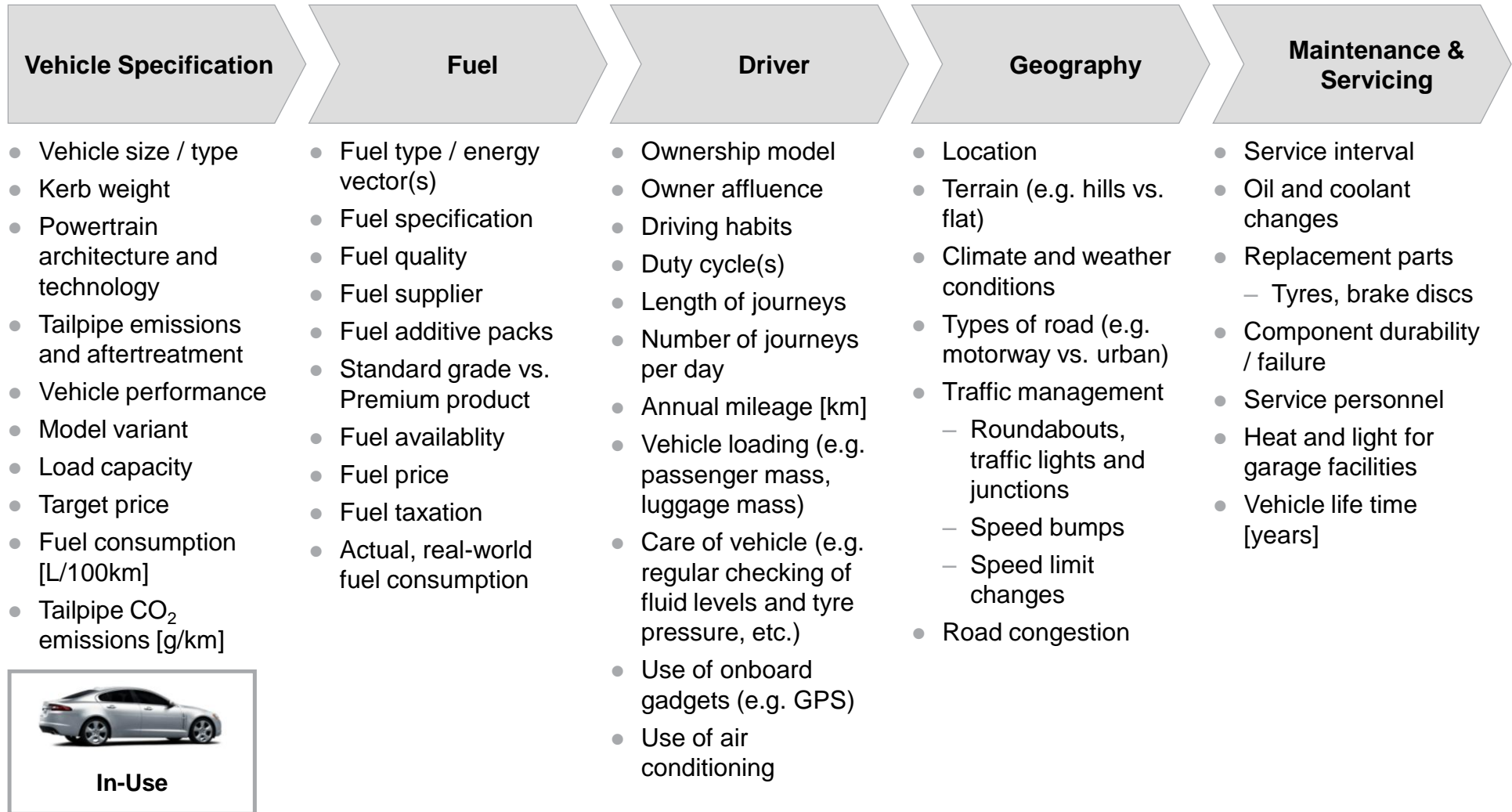
Elements from fuel well-to-tank contributing to life cycle CO₂ emissions



- Can be measured / known
- Could be measured / known
- ▲ Difficult to measure / has to be assumed

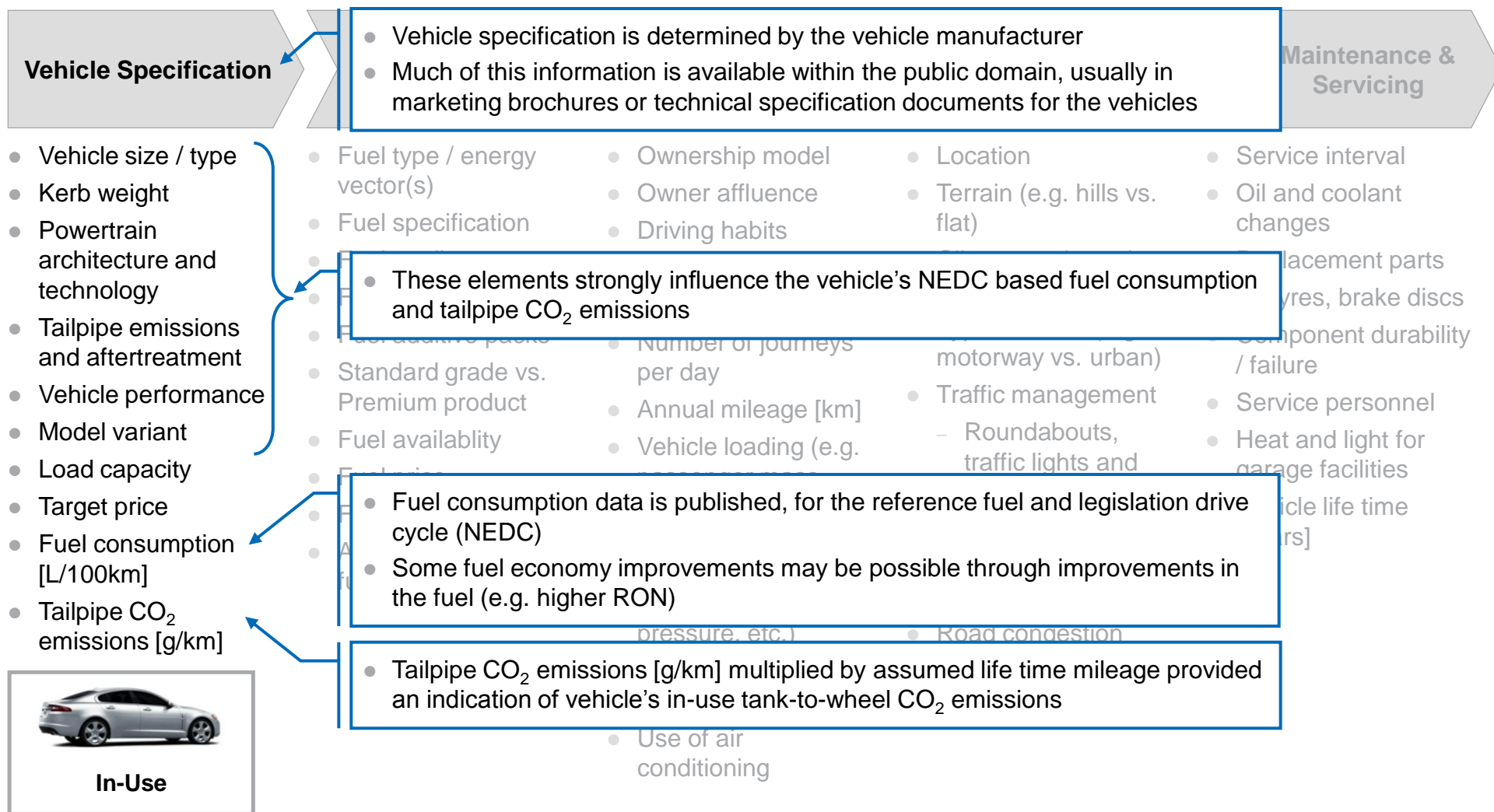
CO₂ emissions from the “in-use” phase depend on the vehicle technology, fuel, and how the vehicle is driven

Elements from use phase contributing to life cycle CO₂ emissions



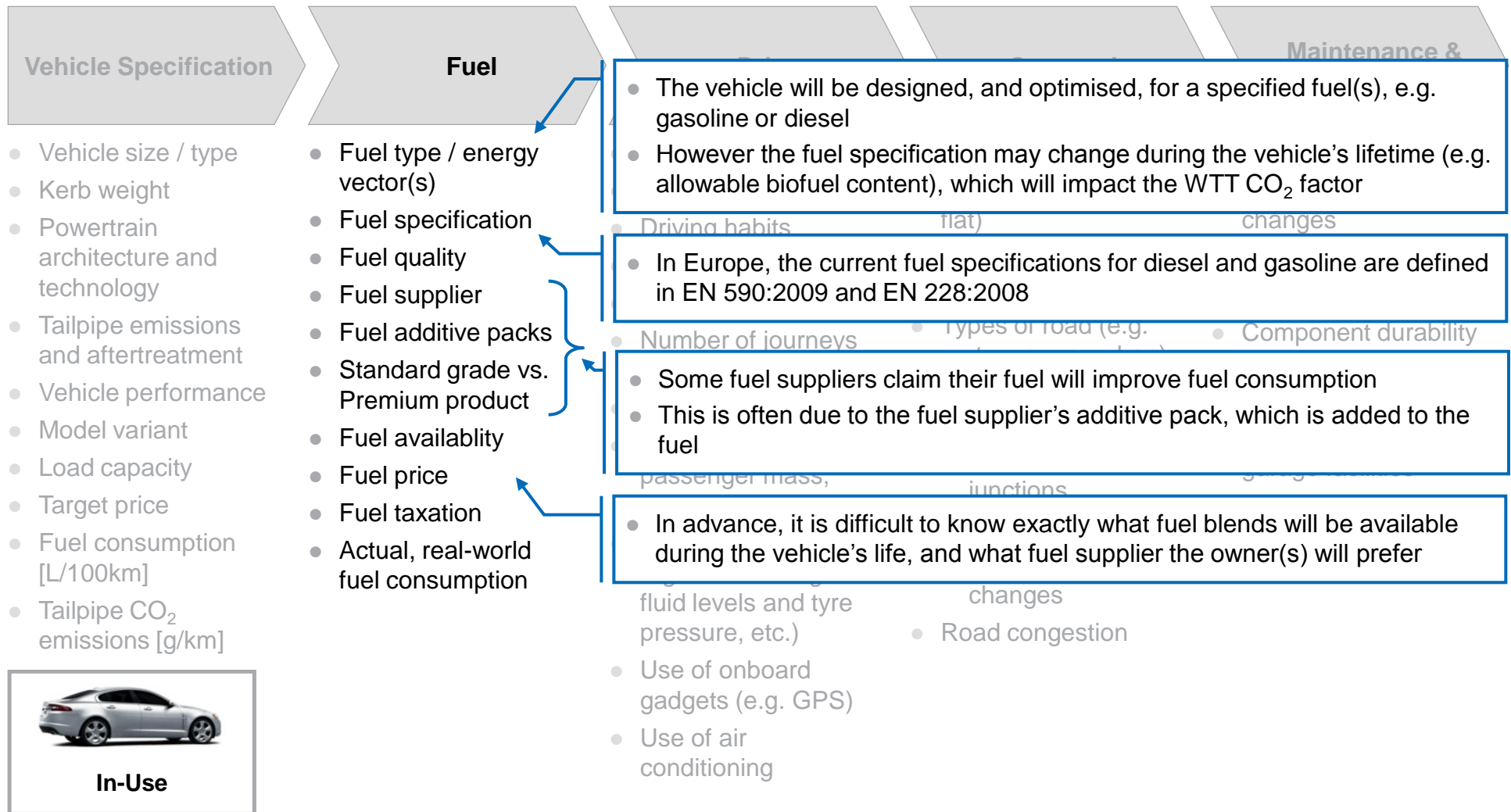
The manufacturer's vehicle specification has a strong influence on the published fuel consumption and tailpipe CO₂ data

Elements from use phase contributing to life cycle CO₂ emissions



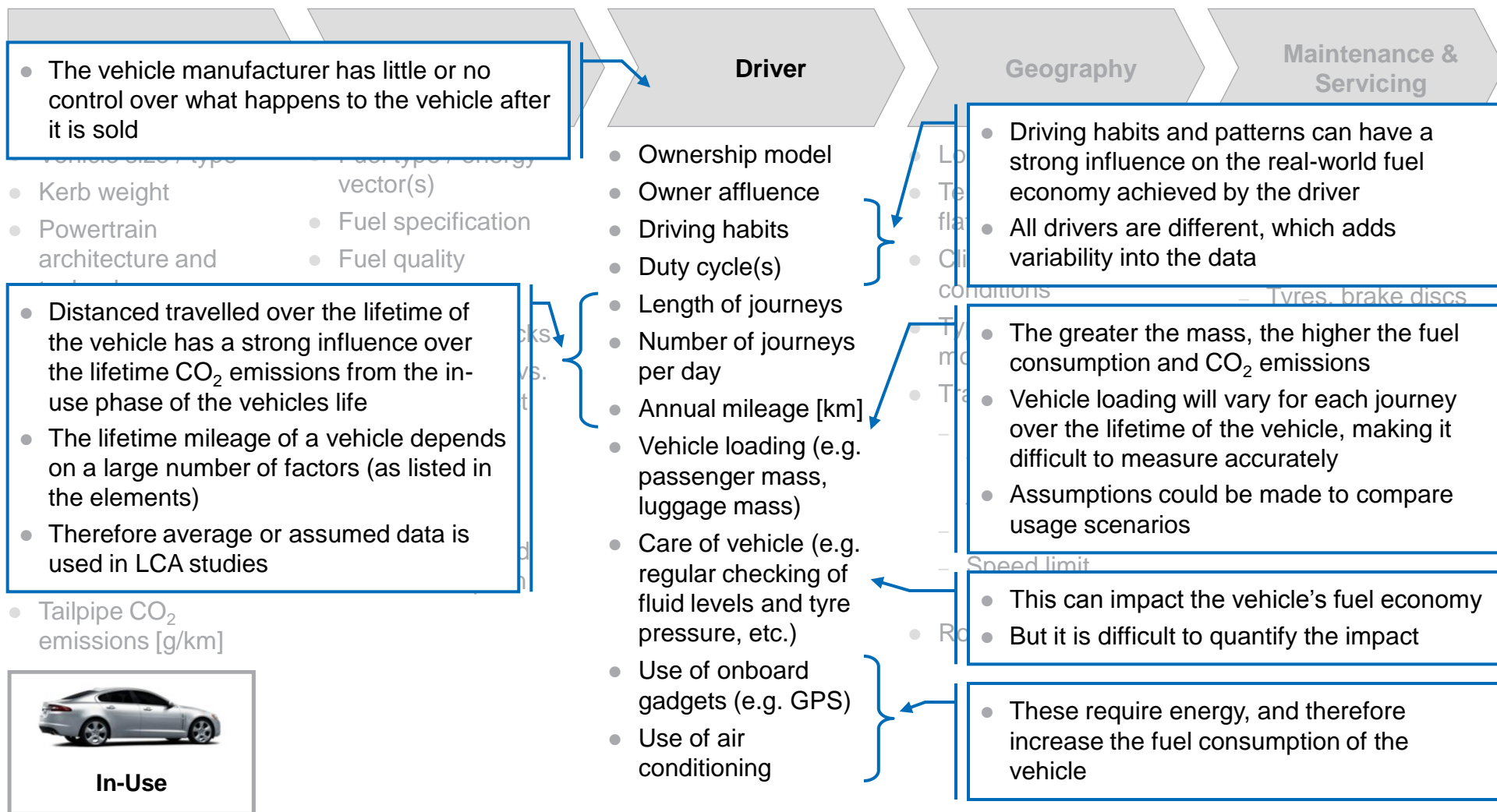
Variations in the fuel / energy vectors used by the vehicle may impact the real world results

Elements from use phase contributing to life cycle CO₂ emissions



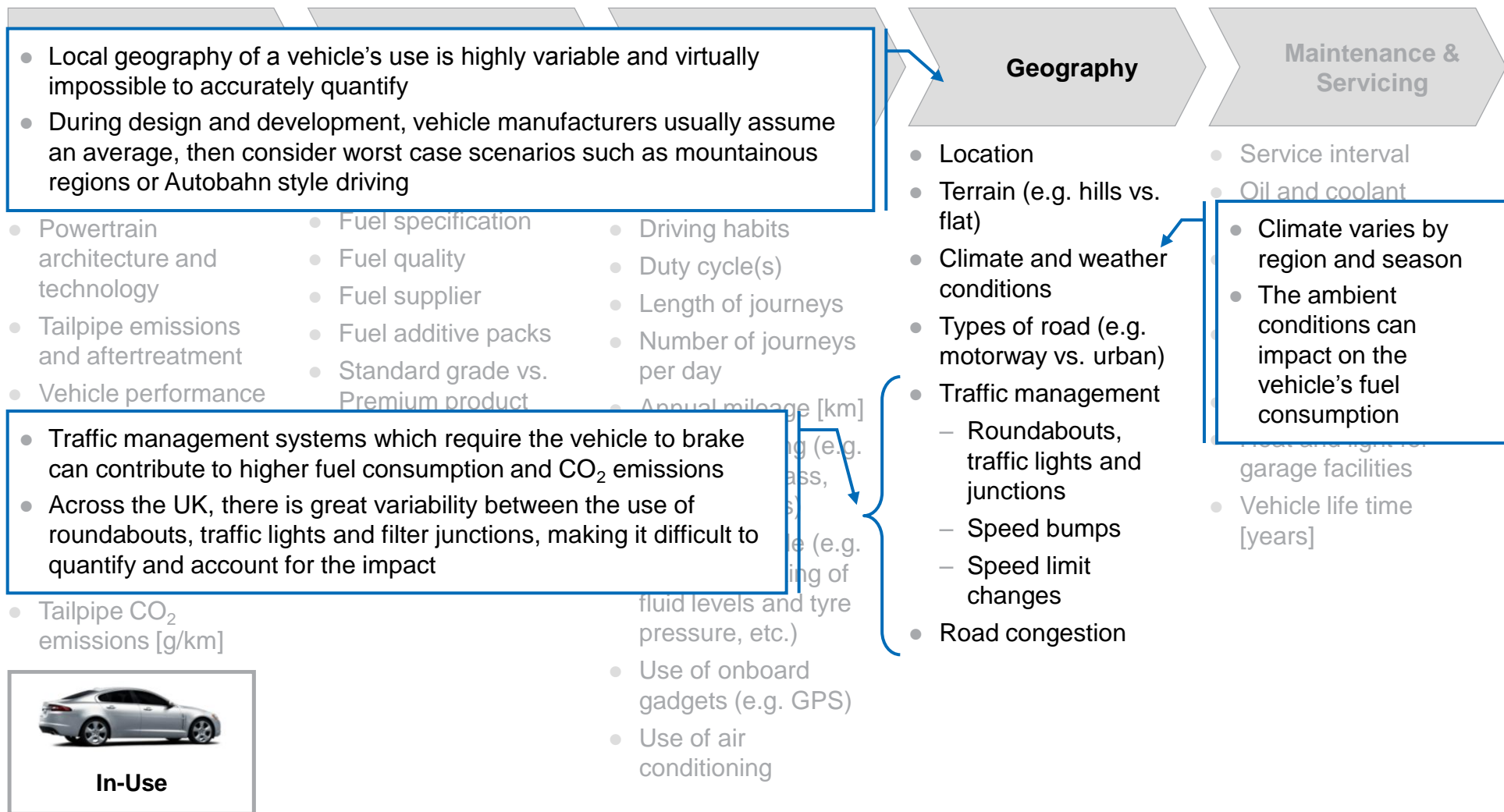
Driver behaviour adds variability into the in-use CO₂ results

Elements from use phase contributing to life cycle CO₂ emissions



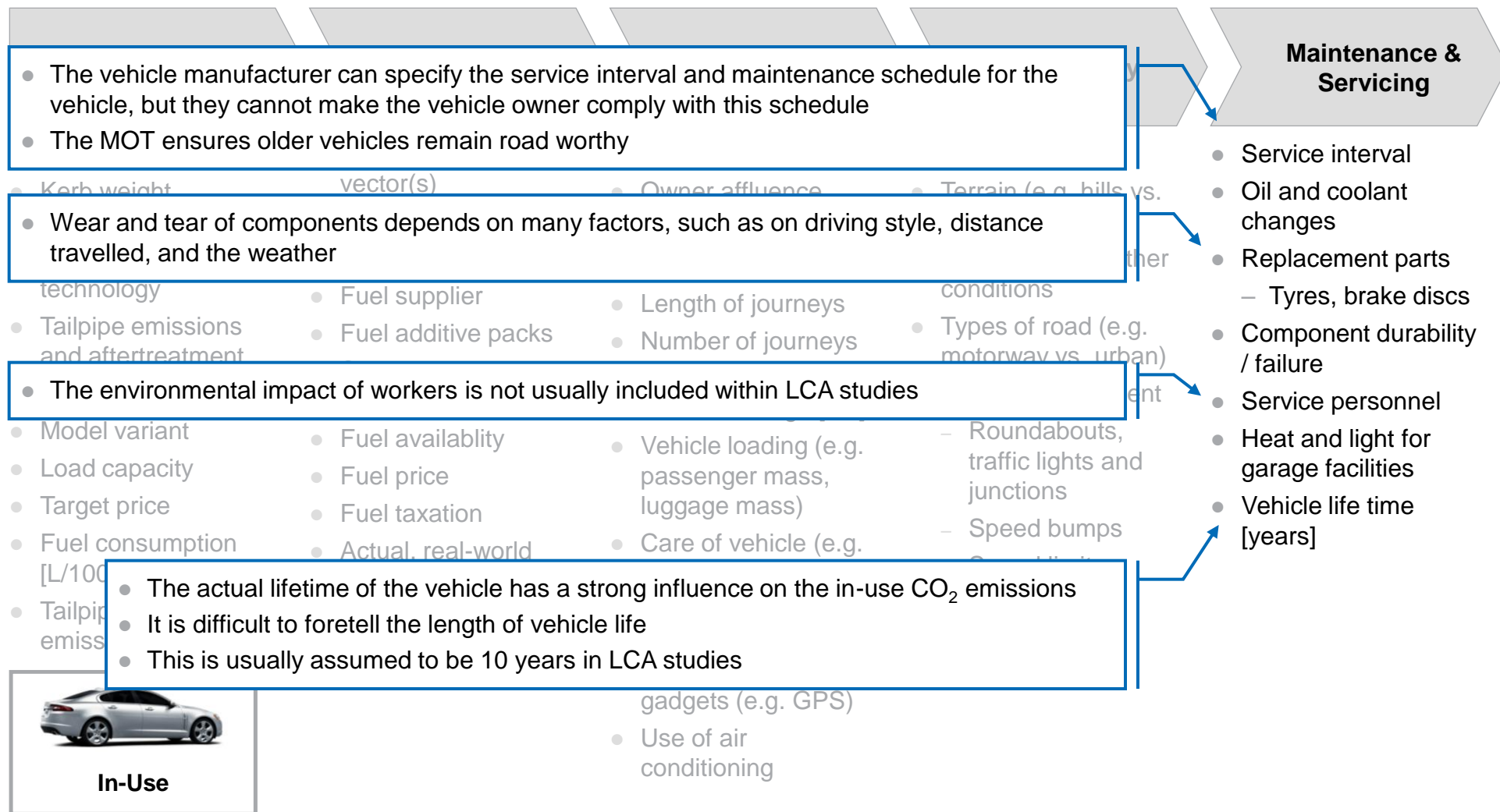
Gradients, weather conditions, road layout and traffic congestion can all impact in-use fuel consumption

Elements from use phase contributing to life cycle CO₂ emissions



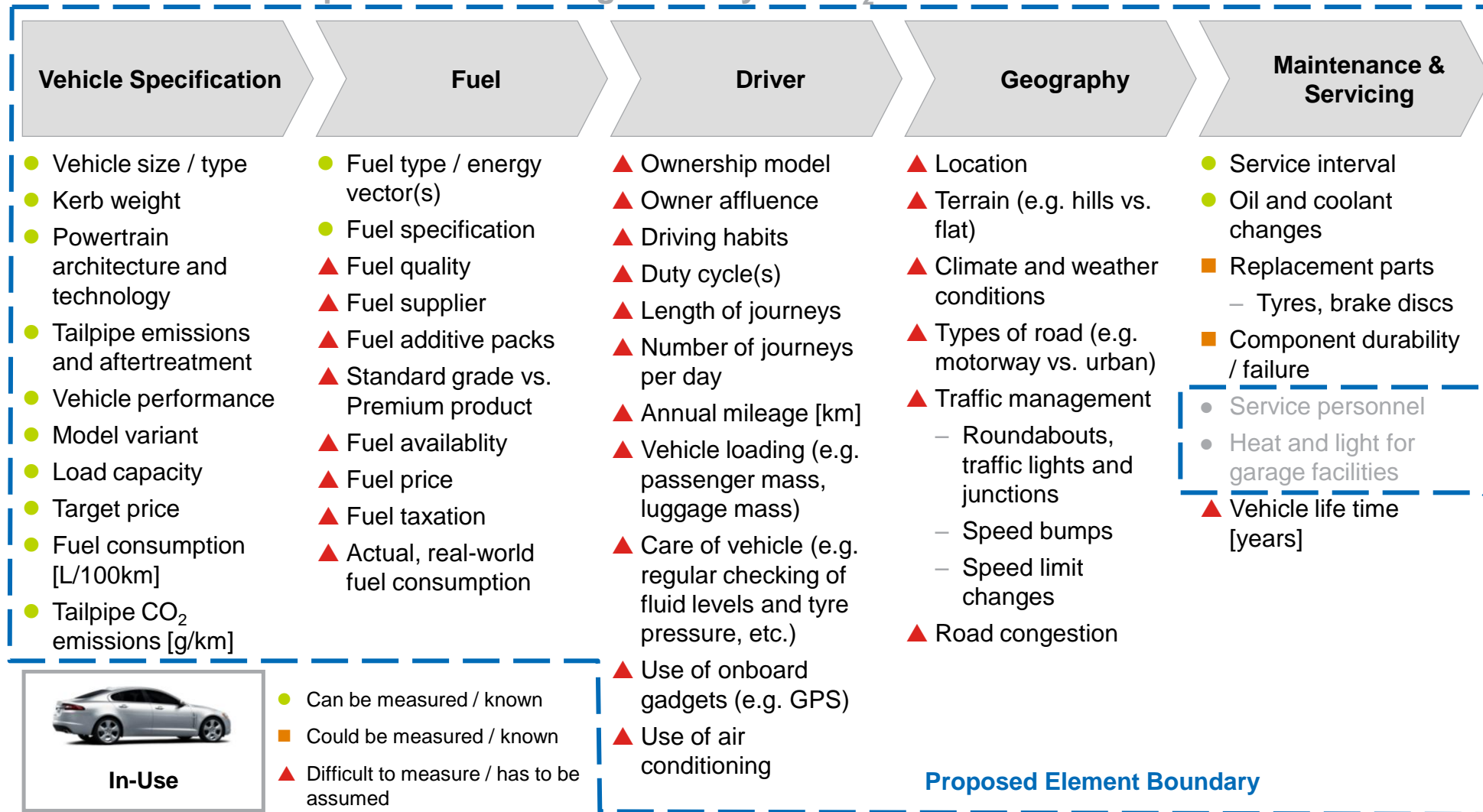
Maintenance and servicing could increase the embedded emissions of the vehicle, depending on what components are replaced

Elements from use phase contributing to life cycle CO₂ emissions



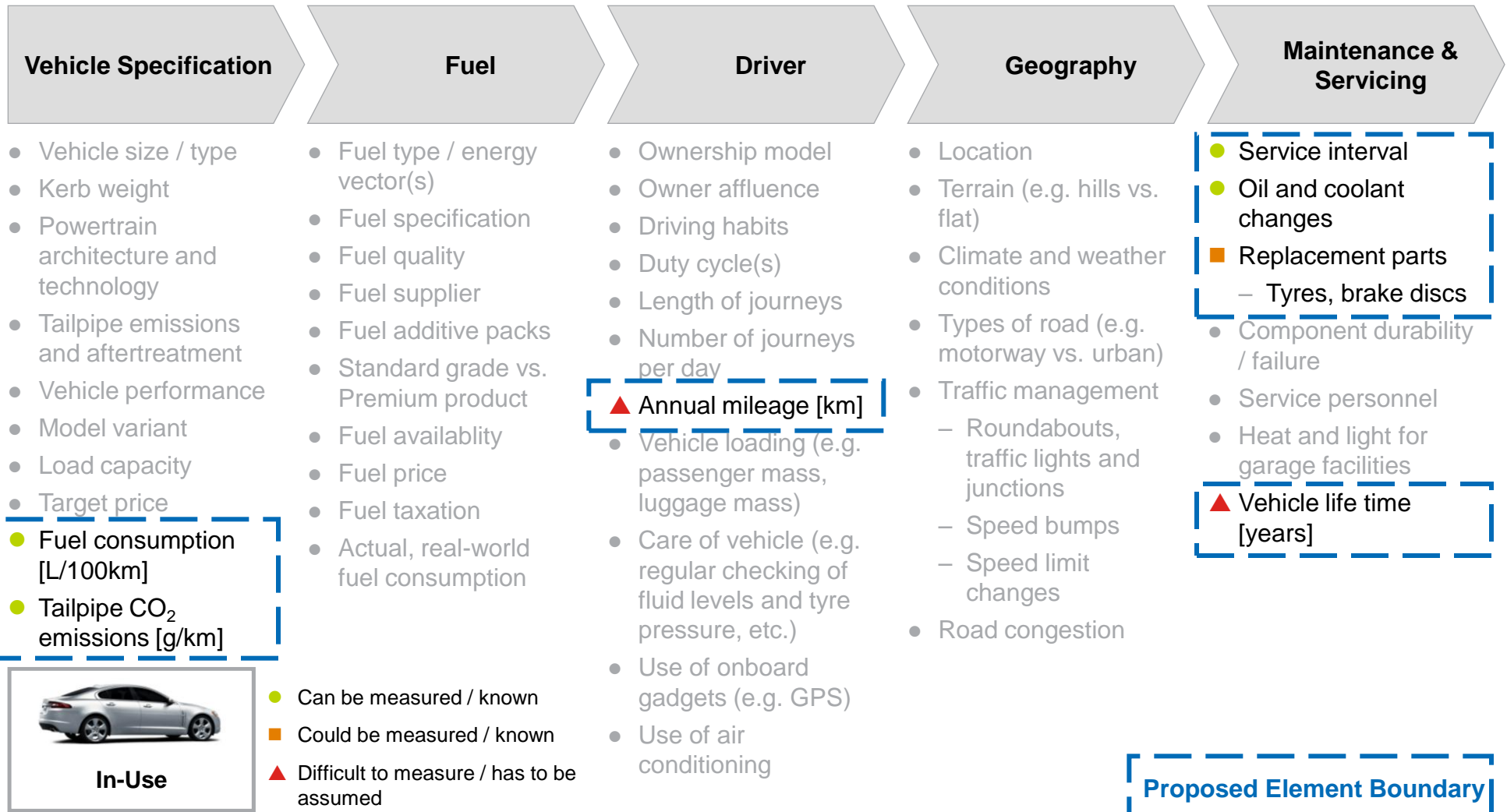
The proposed boundary for assessing in-use CO₂ could include all these elements, or ...

Elements from use phase contributing to life cycle CO₂ emissions



... focus on the NEDC results and Product Categorisation Rules for a common comparison

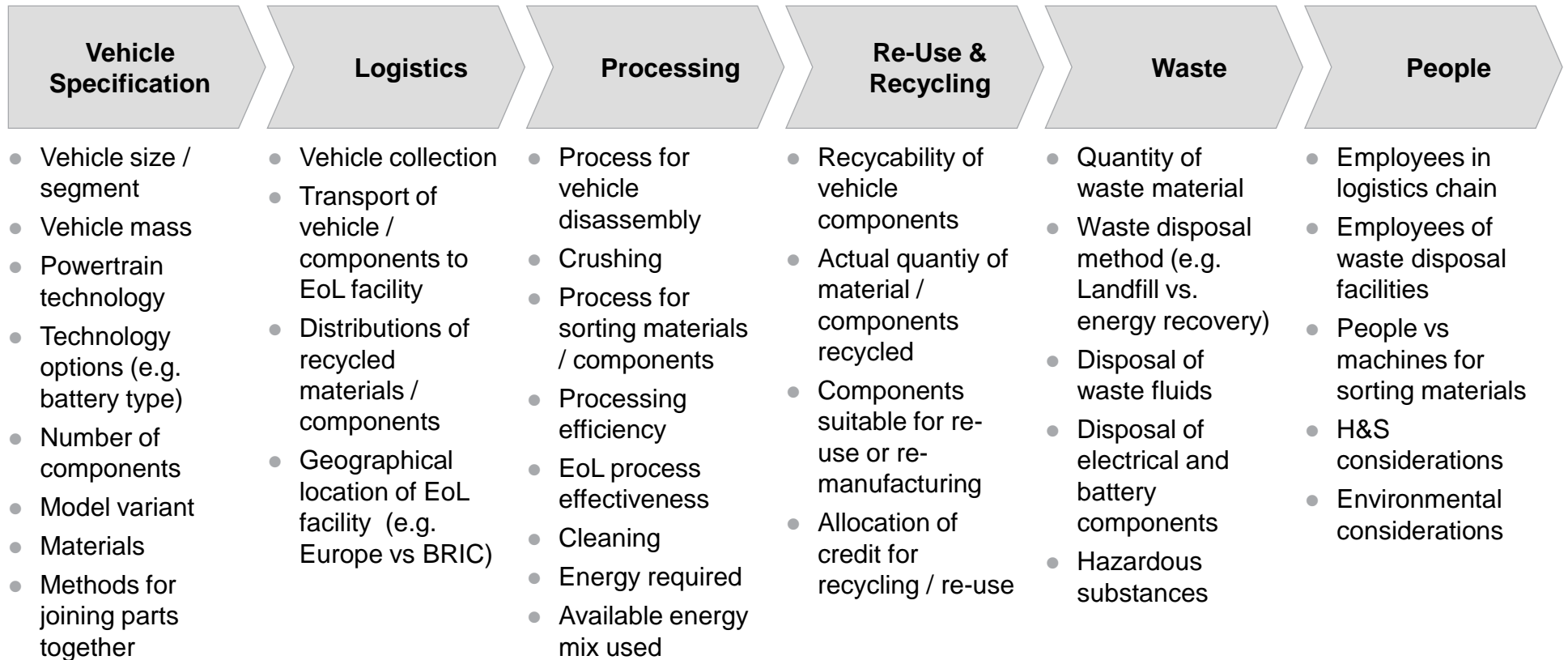
Elements from use phase contributing to life cycle CO₂ emissions



Proposed Element Boundary

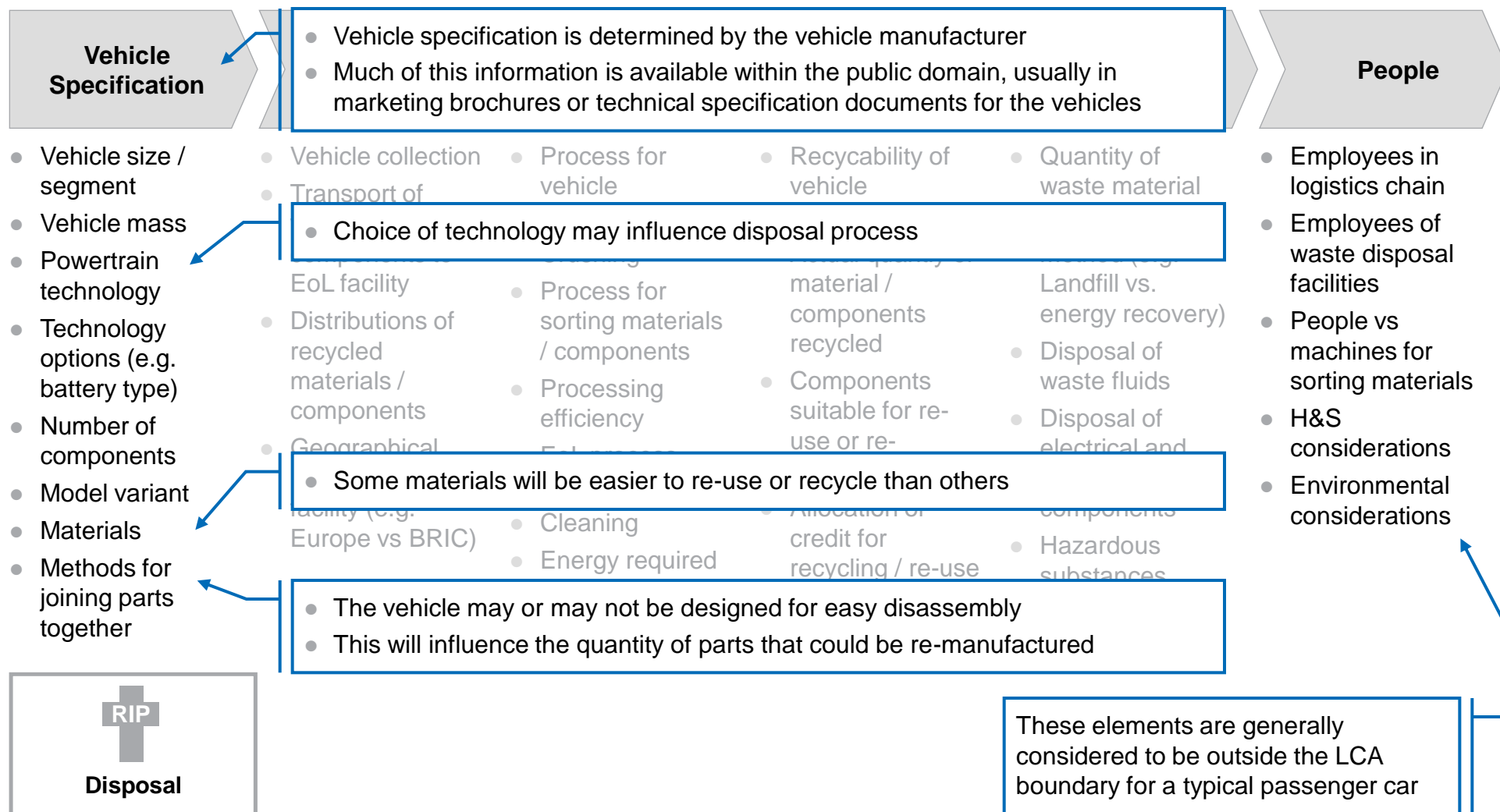
Emissions from vehicle end-of-life largely depend on what happens to the vehicle and its components

Elements from vehicle end-of-life contributing to life cycle CO₂ emissions



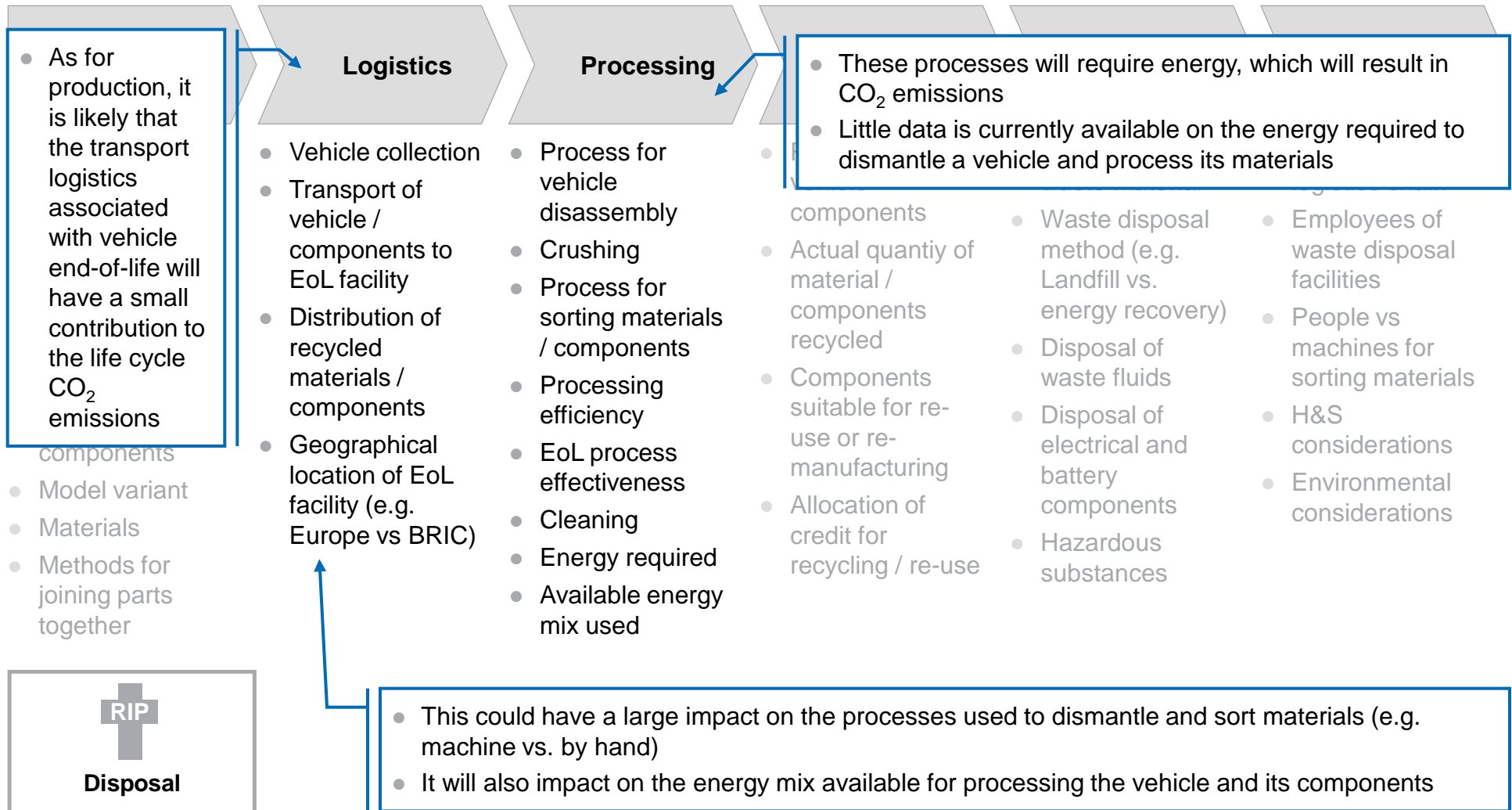
Elements related to the vehicle specification determine what could happen during the EoL phase

Elements from vehicle end-of-life contributing to life cycle CO₂ emissions



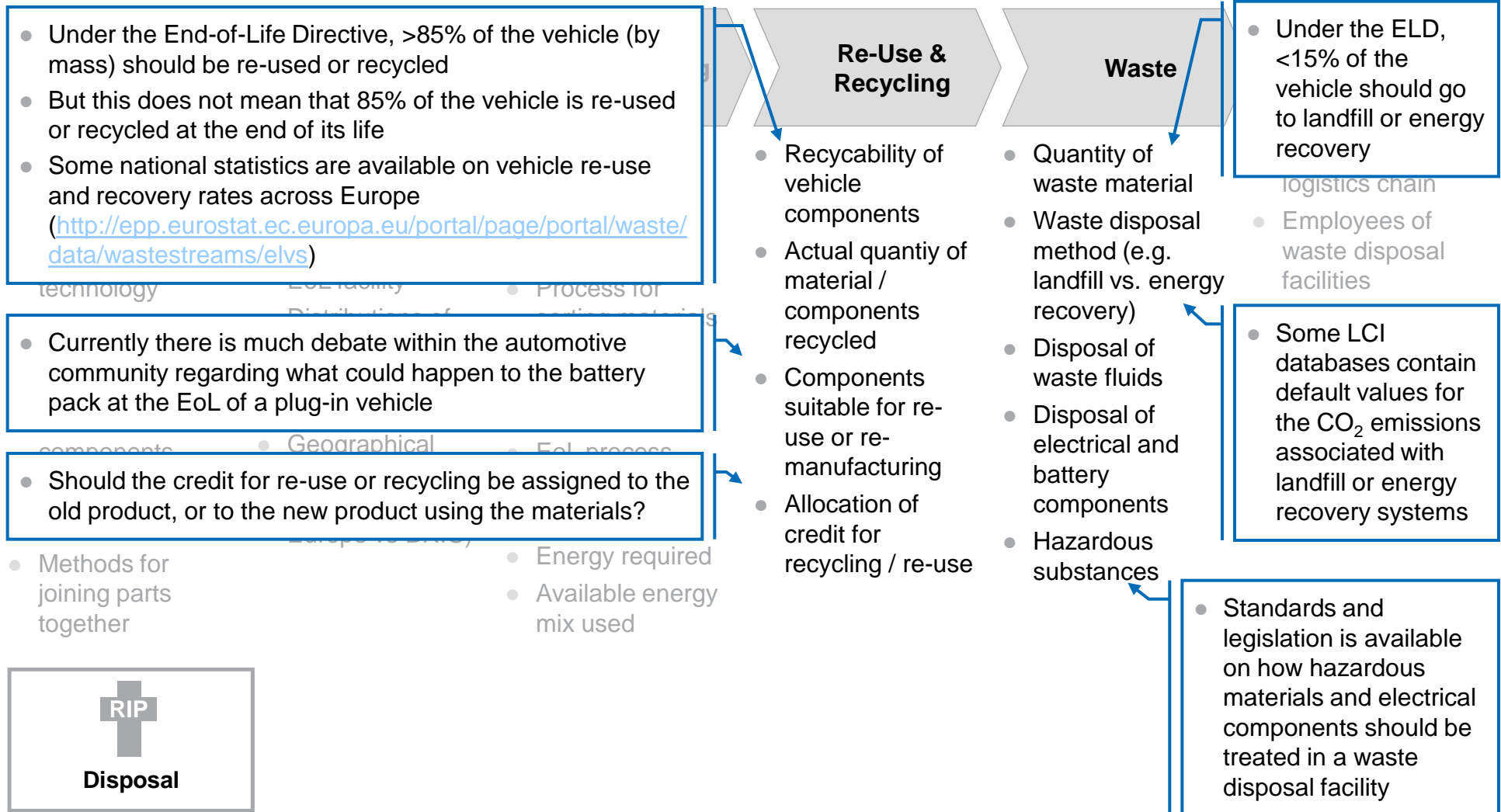
Geographical location and the processes used to dismantle and recycle the vehicle could have a large impact on EoL CO₂ emissions

Elements from vehicle end-of-life contributing to life cycle CO₂ emissions



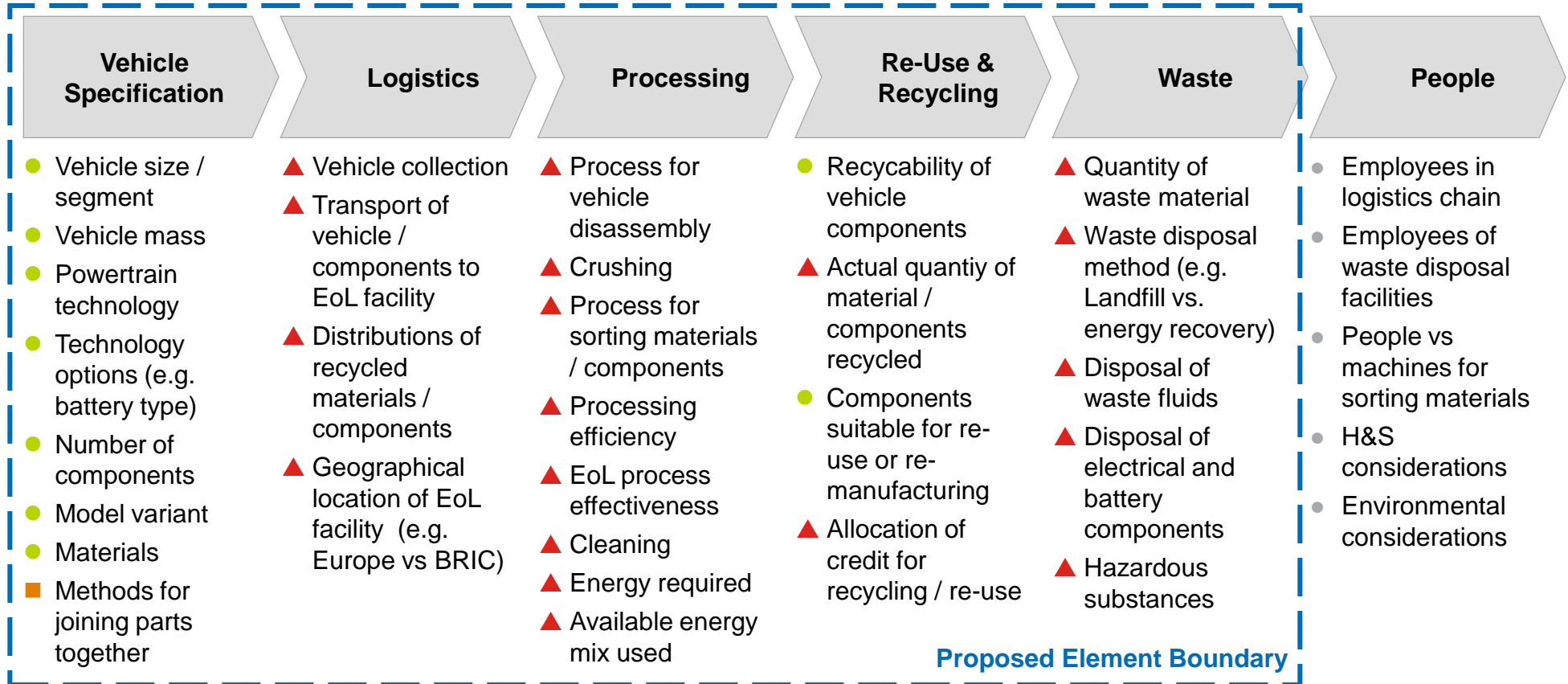
It is likely that most of the vehicle will be re-used or recycled, with a small quantity of waste material for landfill

Elements from vehicle end-of-life contributing to life cycle CO₂ emissions



Ideally, LCA of the vehicle end-of-life should consider the logistics, energy and processes required to dispose of the vehicle

Elements from vehicle end-of-life contributing to life cycle CO₂ emissions



Disposal

- Can be measured / known
- Could be measured / known
- ▲ Difficult to measure / has to be assumed

A vehicle LCA study is likely to be conducted during the pre-production or launch phase of a new vehicle model. There is some uncertainty regarding how well these EoL elements can be quantified ~10 years in advance

- Introduction
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Some legislation is directly designed to reduce a passenger car's environmental impact but with unintended consequences ...

Legislation	Relative effect on life cycle CO ₂ emissions				Commentary
	Production	In-use		Disposal	
		WTT	TTW		
Renewable Energy Directive (Directive 2009/28/EC) / Fuel Quality Directive (Directive 2009/30/EC)	-	★ ↓ ↓	?	-	<ul style="list-style-type: none"> Set European targets for increasing use of renewable energy in transport fuel, and for decreasing GHG emissions of fuels
Tailpipe CO ₂ (Regulation No 443/2009)	↑ ↑	-	★ ↓ ↓ ↓	↑	<ul style="list-style-type: none"> Driver for uptake of new "low carbon" technologies, e.g. hybridisation and electrification Many of these technologies increase the embedded emissions of the vehicle, while significantly decreasing tailpipe CO₂
Tailpipe Emissions (Directive 2003/76/EC)	↑	-	↑	↑	<ul style="list-style-type: none"> Driver for aftertreatment and advanced combustion technologies Often strategies compromise on fuel consumption to reduce tailpipe emissions of CO, HC, NOx and particulate
Other Type Approval legislation* (as defined by Directive 2007/46/EC)	↑	-	↑	↑	<ul style="list-style-type: none"> The objective of most Type Approval legislation is to improve safety This legislation can lead to increasing the number of components within the vehicle, which increases vehicle mass and embedded CO₂ emissions
End-of-Life Directive (Directive 2000/53/EC)	?	-	-	★ ↓ ↓	<ul style="list-style-type: none"> Driver for improving the re-usability and recyclability of automotive components

Legend: ↑ Increases CO₂ emissions ↓ Decreases CO₂ emissions - No significant impact on CO₂ emissions ? Unknown impact ★ Intended impact

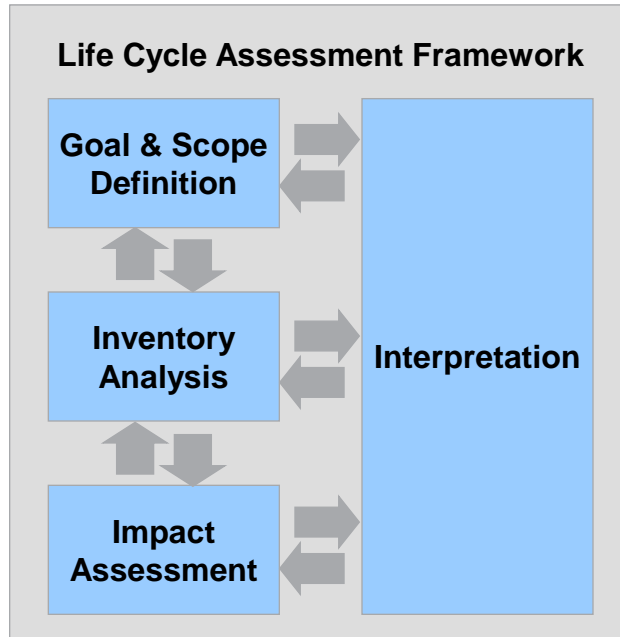
* A list of Type Approval legislation is supplied in the Appendices

... while other legislation, not aimed at vehicle CO₂, has an indirect effect on vehicle life cycle CO₂ emissions

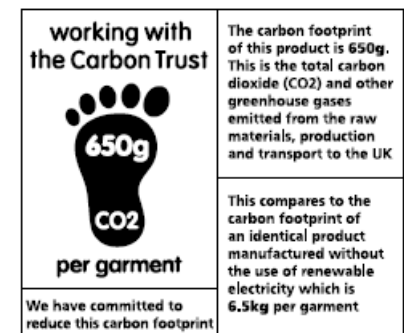
- Examples of legislation that may have a positive or negative effect on the life cycle CO₂ emissions of a passenger car:
 - Environmental Legislation applying to material extraction and processing, or manufacturing
 - Overall, likely to have a positive effect on environmental impact, but may compromise on CO₂ emissions to achieve targets
 - Health and Safety Legislation applying to material extract and processing, manufacturing, or handling and transport of materials and components
 - May restrict “best CO₂ reduction” option
 - Shipping restrictions on transport of potentially hazardous materials and components, such as battery cells
 - Emissions Trading Scheme (Directive 2009/29/EC)
 - State Aid Rules
 - May delay the market introduction of new and novel low CO₂ technologies due limited government capability to bridge the commercialisation valley of death / mountain of risk
 - Intellectual Property and Patents
 - May restrict the availability of good solutions depending on who owns the “rights”
 - Employment Law
 - Taxation and Incentives
 - Highway regulations, road restrictions and traffic management
 - E.g. Spain reducing national speed limit

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International Standards already exist for defining the Life Cycle Assessment (LCA) process

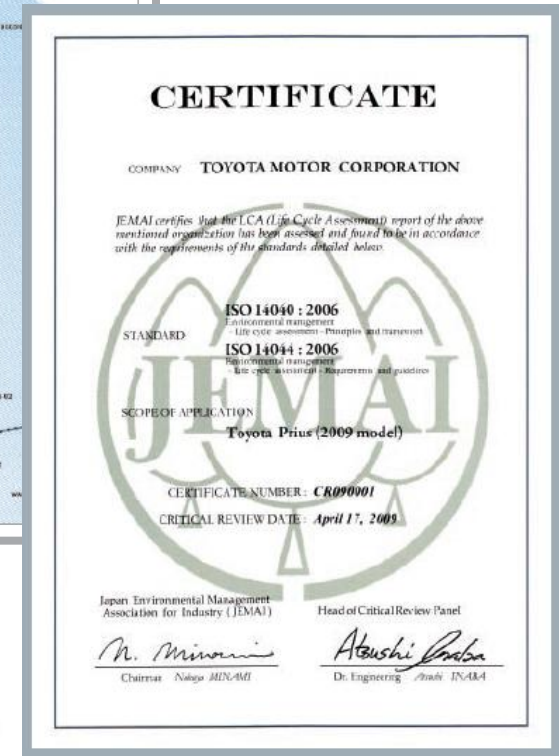


- The Life Cycle Assessment (LCA) process is outlined ISO 14040:2006 (general principles) and 14044:2006 (guide for practitioners)
 - LCA considers the entire life cycle of a product or service, from cradle-to-grave
 - It is a relative approach, structured around a functional unit, which defines what is being studied
 - LCA studies are inherently complex. Therefore transparency is important to ensure proper interpretation of the results
 - LCA considers many types of environmental impact, not just CO₂ emissions
 - Several databases are available containing Life Cycle Inventory (LCI) data on the environmental impact of different materials, energy sources and manufacturing processes
- Environmental Product Declarations (EPDs) are defined by ISO 14025. An EPD must be based on a product LCA, use Product Category Rules (PCR) for the relevant product type, and be verified by a third party
- In October 2008, BSI British Standards published PAS 2050, a Publicly Available Specification “for the assessment of life cycle greenhouse gas emissions of goods and services”. This process for using LCA techniques to calculate the “carbon footprint” (CO₂ equivalent) of a product or service was co-sponsored by the Carbon Trust and UK Department for Environment, Food and Rural Affairs (DEFRA)
- An international standard for carbon footprinting is currently under discussion (ISO 14067)



Many OEMs are already conducting Life Cycle Assessment studies of their vehicles that comply with ISO 14040 and ISO 14044

- Many OEMs conduct Life Cycle Assessment studies of their vehicles as part of their Environmental Management strategies
 - VW began investigating LCA in the early 1990s
 - Toyota started using LCA in 1997. Since 2004, LCA has been implemented for all new passenger car models, as well as those undergoing a model change
 - PE International's published customer list for their GaBi LCA tool includes Audi, Daimler, Fiat, Ford, GM, Honda, Renault, Mitsubishi, Nissan, Toyota, VW, Volvo Bosch, Continental, Delphi, Siemens, Valeo, and Anglo Platinum
- Several OEMs have published the results from their LCA studies to inform customers, shareholders and other stakeholders
 - Although certificates of validity show the LCA is based on reliable data and conforms to ISO 14040, it is not clear if different OEMs use the same set of assumptions or input data sets



Certificates from relevant technical inspection organisations show that the LCA has been based on reliable data, and conforms to the requirements of ISO standards 14040 and 14044

OEM LCA studies suggest passenger car life cycle CO₂ emissions are 20-80 tonnes, depending on segment and lifetime mileage

Life Cycle Assessment of Passenger Cars – Baseline Data from Literature

Vehicle	Description	Lifetime Mileage [km]	Life Cycle Total CO ₂ e [tonnes CO ₂]	Life Cycle [%]			Source
				Production	In-Use	Disposal	
VW Polo	Diesel 1.6L TDI, 55 kW (un-laden weight 1157 kg)	150,000	23	20.6%	79%	0.4%	VW (2009)
VW Polo	Gasoline 1.4L MPI, 63 kW (un-laden weight 1104 kg)		29.5	~17%	~83%	<1%	VW (2009)
VW Passat Estate B6	Diesel 2.0L TDI, 103 kW (un-laden weight 1510kg)		32.4	19%	80%	1%	VW
VW Passat Estate B6	Gasoline 1.6L FSI, 85 kW (un-laden weight 1403kg)		38.2	18%	81%	1%	VW
Toyota Prius	Hatchback 1.8L VVTi V (un-laden weight 1420kg)	150,000	-	26%	71%	3%	Toyota
Mercedes-Benz A-Class	A150 Gasoline 1.5L, 70 kW, with ECO start-stop system	300,000	32	16%	83%	<1%	Mercedes-Benz (2008)
Mercedes-Benz E-Class	E 220 CDI BlueEFFICIENCY Diesel 2.1L, 125 kW		48	18%	82%	1%	Mercedes-Benz (2009a)
Mercedes-Benz S400 Hybrid	Gasoline 3.5L V6 205 kW 15 kW motor, Li-ion battery		78	14%	85%	<1%	Mercedes-Benz (2009b)

Vehicle hybridisation and electrification can reduce life cycle CO₂ emissions, but this increases embedded emissions from production

- One of the main drivers for the development of automotive technology today is reducing the in-use CO₂ emissions. The trend is towards hybridisation and electrification
- The introduction of battery packs, electric motors and power electronics into a passenger car increases the embedded CO₂ emissions associated with the vehicle's production, while significantly reducing the tailpipe CO₂ emissions from the use phase
- This leads to a shift in the life cycle balance between production and use phases

SELECTED EXAMPLES

Vehicle	Description	Lifetime Mileage [km]	Life Cycle Total CO ₂ e [tonnes CO ₂]	Life Cycle [%]			Source
				Production	In-Use	Disposal	
Conventional	Based on Toyota Corolla type vehicle Li-Ion battery technology	240,000	64.6	13%	87%	Not considered	Samaras and Meisterling (2008)
HEV			46.1	18.8%	81.3%		
PHEV 30			43.9	20.8%	79.2%		
PHEV 60			43.4	23.2%	76.8%		
PHEV 90			43.9	24.6%	74.9%		
Standard Car	C-segment vehicle (e.g. VW Golf)	150,000	40.3	12.9%	87.1%	Not considered	Gauch et al. (2009)
EV	C-segment vehicle (e.g. VW Golf), with 300 kg, 30 kWh Li-Ion battery pack	150,000	19.5	34.7%	65.3%		

To investigate further, Ricardo has compared estimates of life cycle CO₂ emissions for a range of vehicle technologies and fuels

- Comparing results from different LCA studies can be difficult if the assumptions and input data are not the same
- Therefore, in order to evaluate how evolving technologies will alter the balance of emissions between production, in-use and disposal phases, Ricardo has produced high level estimates of life cycle CO₂ emissions for different vehicle architectures. Information on the methodology used is provided in the Appendices
- Three comparison sets have been prepared. In each set, the options are compared to a mid-size gasoline passenger car

Comparing Technologies

- Mid-size gasoline
- Mid-size plug-in hybrid vehicle (PHEV)
- Mid-size extended range electric vehicle (EREV)
- Mid-size pure electric vehicle (EV)
- Mid-size fuel cell vehicle (FCV)

Comparing Vehicle Size

- Mid-size gasoline
- Small gasoline
- Mid-size diesel
- Large diesel
- Large diesel, with downsized ICE

Comparing Biofuels

- Mid-size gasoline with E10
- Mid-size gasoline with E20
- Mid-size gasoline with E85
- Mid-size diesel with B7 (FAME)
- Mid-size diesel with B10 (FAME)
- Mid-size diesel with B100 (FAME)

- Vehicle specifications based on Ricardo roadmap projections for 2015
- Assumed lifetime mileage 150,000 km
- Baseline gasoline assumed to be E10 (10%vol ethanol), in line with current fuel specifications
- Baseline diesel assumed to be B7 (7%vol FAME), in line with current fuel specifications
- Electricity grid mix assumed to be 500 gCO₂e/kWh (2010 values published by DECC)
- Further information about vehicle and fuel specifications is provided in the Appendix 2

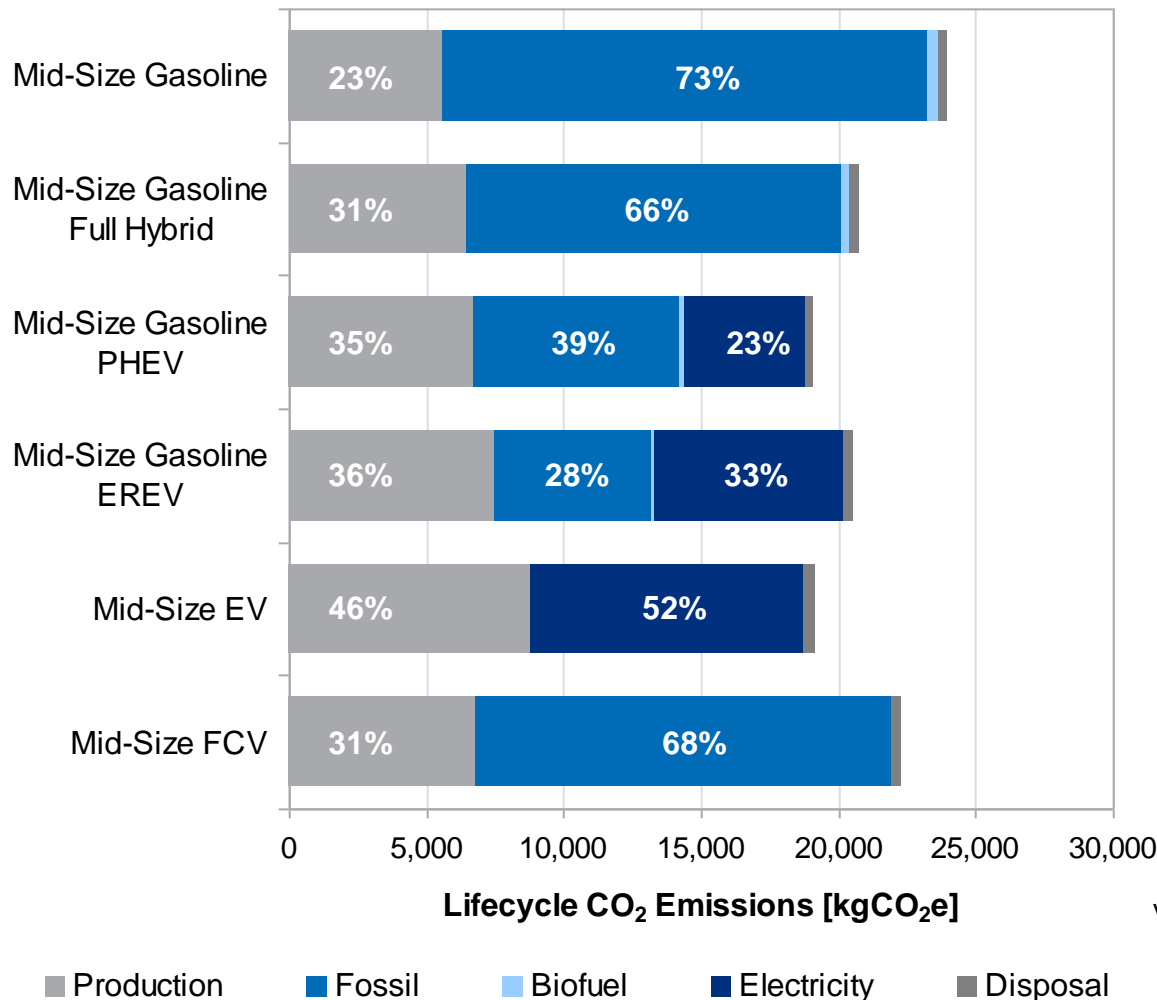
Health Warning

The charts on the following slides are based on high level estimates of life cycle CO₂, and provide an indication of expected future trends. The results do not come from detailed LCA studies conducted in accordance with ISO 14040



Ricardo results show hybrids and EVs will have lower life cycle CO₂ emissions, but embedded emissions will be more significant

Comparing Technologies

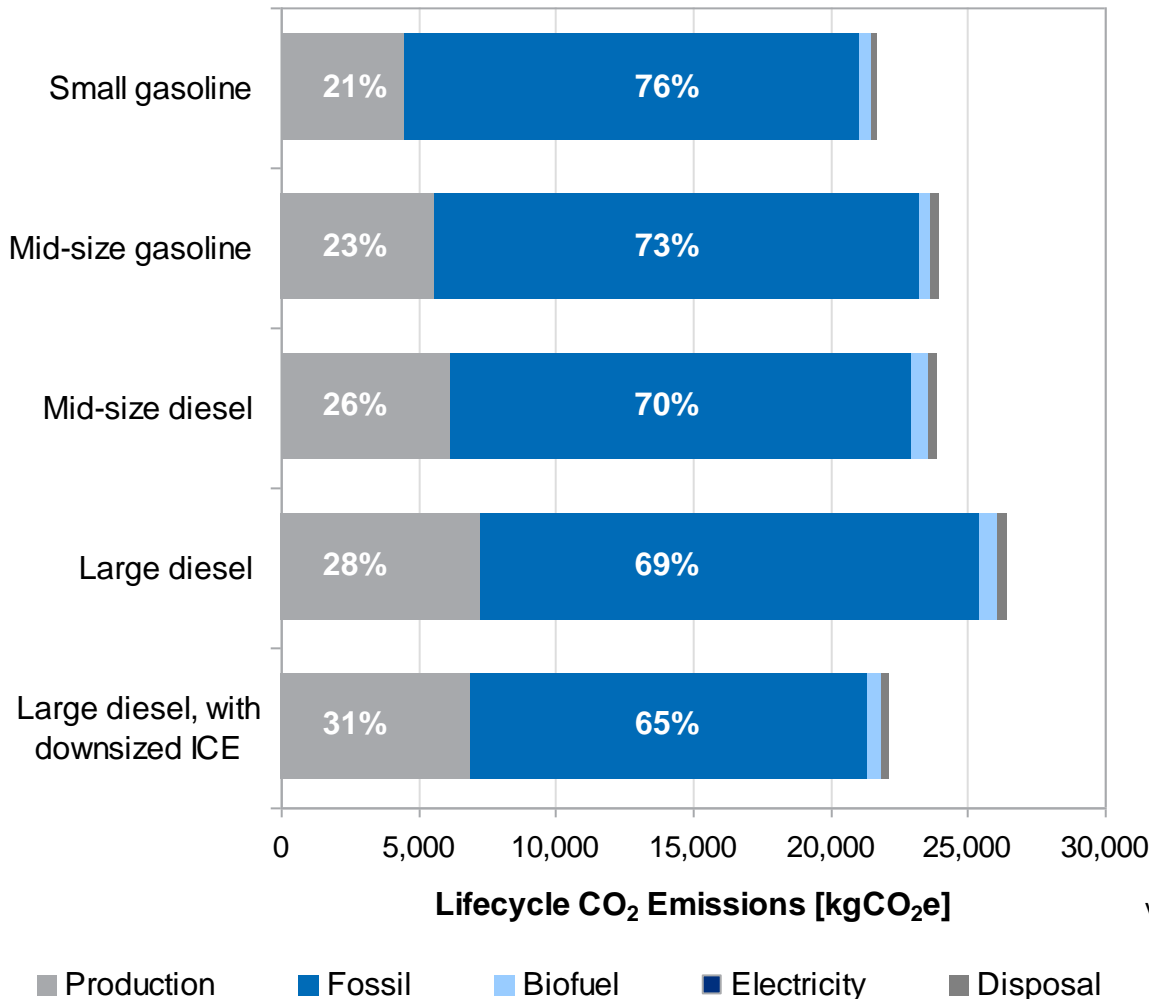


- Predicted improvements in the conventional ICE powertrain designed to reduce in-use tailpipe CO₂, will naturally help to lower the life cycle CO₂ emissions compared to current values
- Life cycle CO₂ reductions for hybridisation and electrification could be 10-20% (compared to a mid-size gasoline passenger car in 2015)
- However, embedded CO₂ from production will increase, due to the addition of components such as advanced battery packs, electronic motors and power electronics
 - For an EV, nearly half the life cycle CO₂ could result from production

Vehicle specifications based on roadmap projections for 2015. Assumed lifetime mileage 150,000 km. Fuels E10 and B7. Electricity carbon intensity assumed to be 500 gCO₂/kWh. Further details on assumptions is provided in the Appendix 2

Diesel and gasoline passenger cars have similar life cycle CO₂ emissions, which generally increase with vehicle size

Comparing Vehicle Size

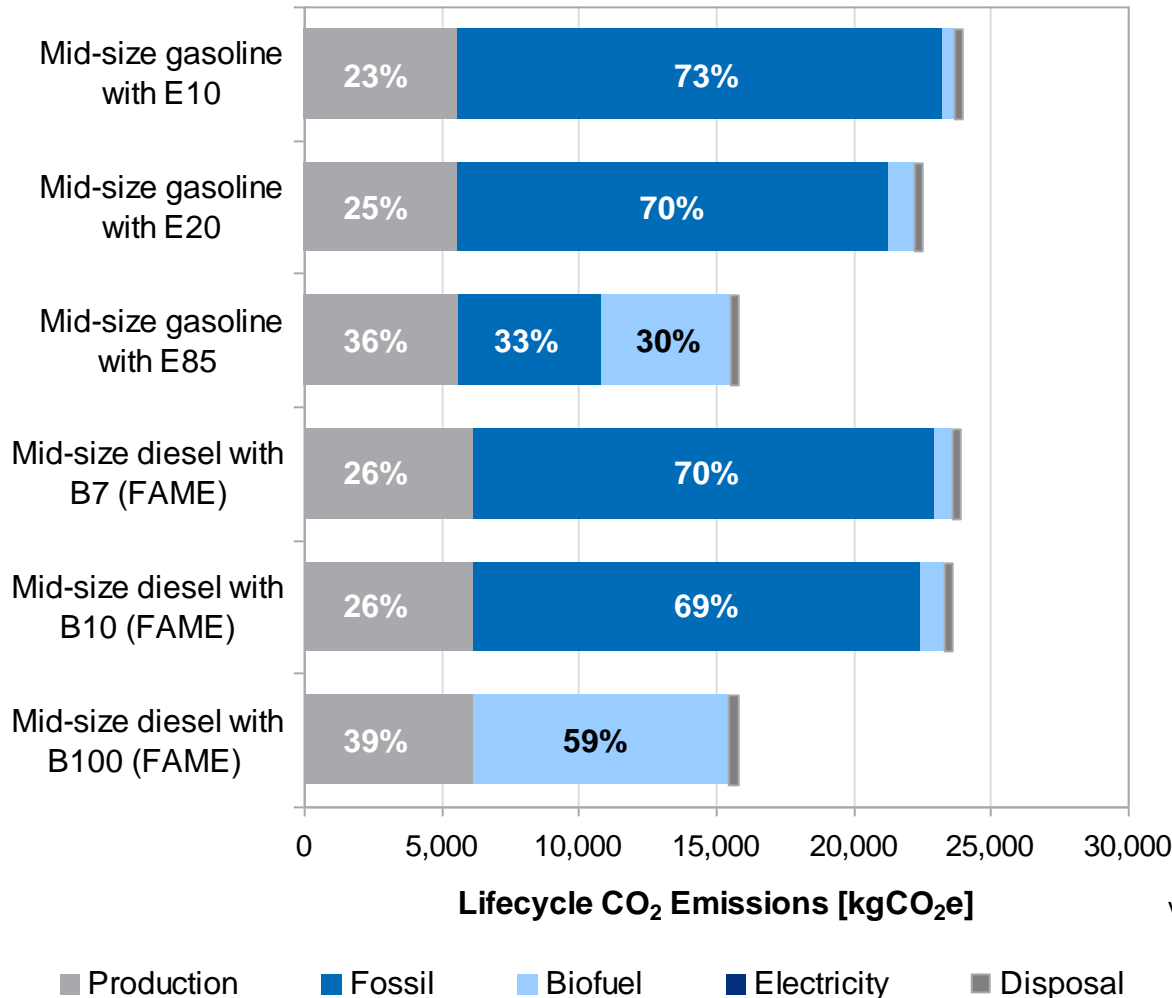


- As expected, larger cars have higher life cycle CO₂ emissions
- The embedded CO₂ for diesel vehicles is higher than the embedded CO₂ for gasoline vehicles. However, since tailpipe CO₂ emissions are generally lower, the life cycle CO₂ emissions for gasoline and diesel passenger cars are very similar (assuming lifetime mileage is 150,000 km)
- Adopting downsizing ICE technology will help to reduce life cycle CO₂ emissions, although this is mainly due to improvements in fuel economy leading to lower tailpipe CO₂

Vehicle specifications based on roadmap projections for 2015. Assumed lifetime mileage 150,000 km. Fuels E10 and B7. Electricity carbon intensity assumed to be 500 gCO₂/kWh. Further details on assumptions is provided in the Appendix 2

Increasing the biofuel content helps to reduce Well-to-Wheel CO₂ emissions ...

Comparing Alternative Fuels



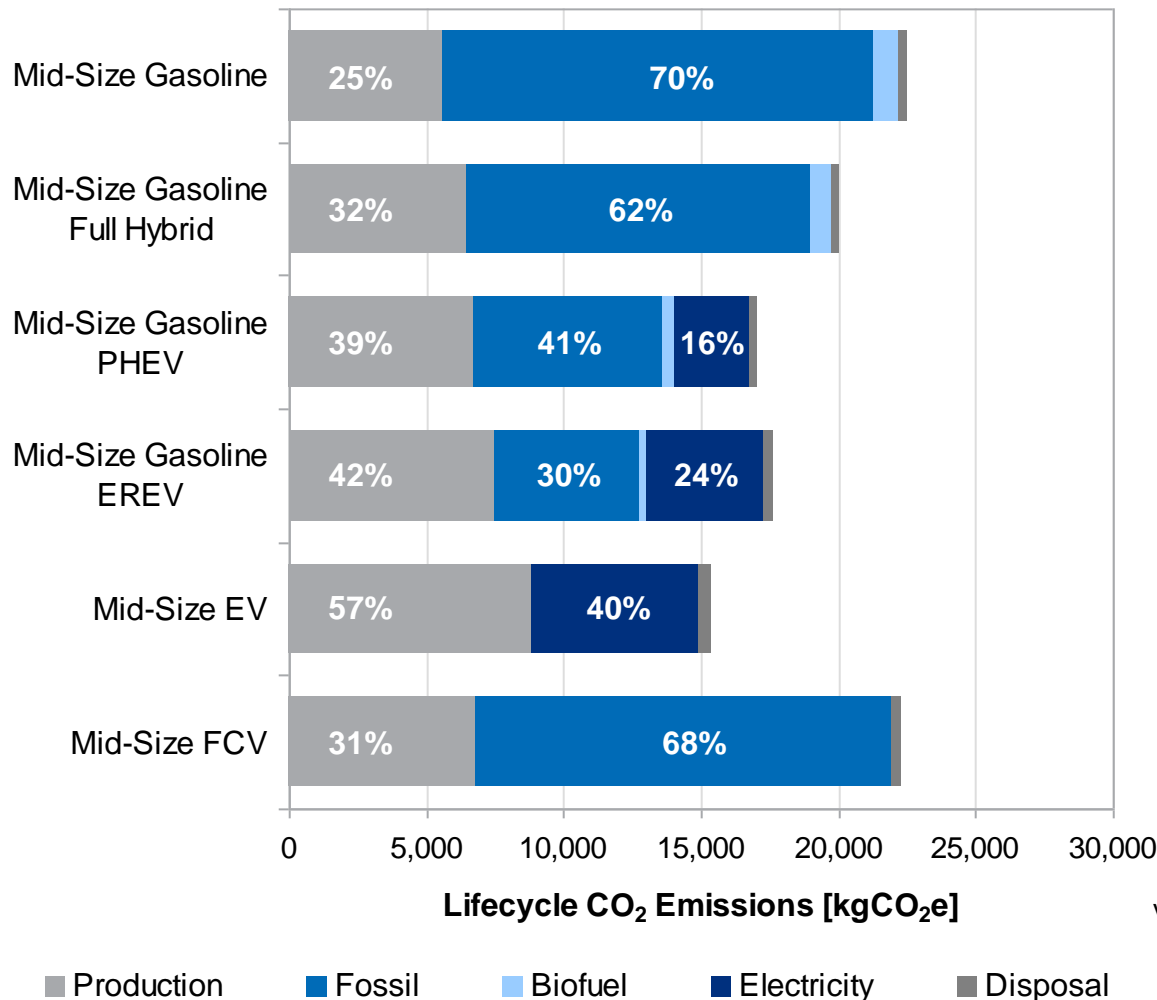
- The higher the biofuel content, the lower the WTW CO₂ emissions resulting from the use of fuel
- The actual level of saving is dependent on the feedstock and production processes used to make the biofuel
- As WTW CO₂ emissions reduce, the embedded CO₂ emissions from production and disposal become a more significant part of the whole life cycle CO₂ metric

Vehicle specifications based on roadmap projections for 2015. Assumed lifetime mileage 150,000 km. Fuels E10 and B7. Electricity carbon intensity assumed to be 500 gCO₂/kWh. Further details on assumptions is provided in the Appendix 2

... for conventional and alternative powertrain technologies



Comparing Technologies with Alternative Fuels

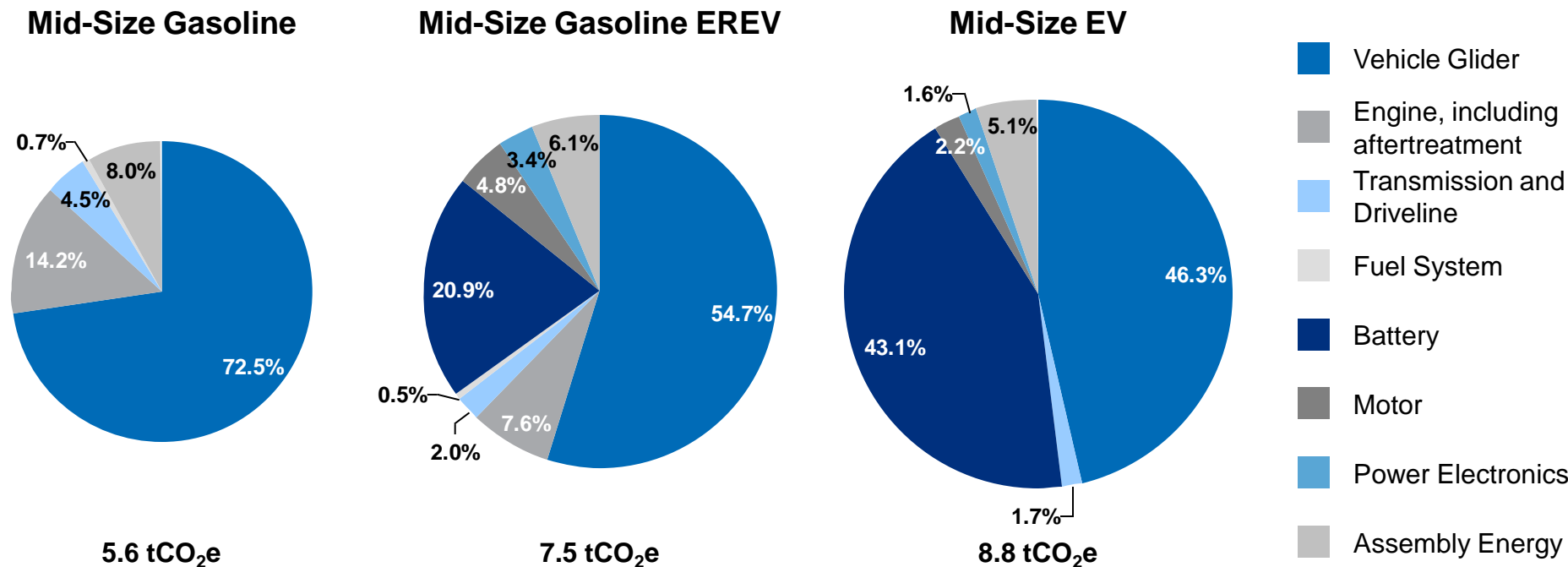


- The WTW CO₂ reductions achieved through increasing the use of biofuels also applies to other powertrain technologies
- Reducing the carbon intensity of the UK electricity mix also helps to reduce the WTW CO₂ emissions for plug-in vehicles
- But, as a consequence, CO₂ emissions from production become more significant
 - For an EV, >50% of life cycle CO₂ could result from production
- Note: In this study it has been assumed that hydrogen is produced by steam methane reforming of natural gas. If produced from renewable sources, its carbon intensity would be significantly reduced by ~90%

Vehicle specifications based on roadmap projections for 2015. Assumed lifetime mileage 150,000 km. Fuels E20. Electricity carbon intensity assumed to be 310 gCO₂/kWh. Further details on assumptions is provided in the Appendix 2

The technology evolution to plug-in vehicles will lead to higher embedded CO₂ emissions due to the addition of new components

Embedded CO₂ Emissions [kgCO₂e]



- For a standard family gasoline passenger car, >70% of the embedded CO₂ emissions result from the non-powertrain components (the vehicle glider)
- However this balance will change with the additional components required for hybridisation and electrification. For an extended range EV, the battery could account for >20% of the embedded CO₂ emissions. While for an EV, the battery could represent >40% of the embedded CO₂ emissions from production

Vehicle specifications based on roadmap projections for 2015. Further details on assumptions is provided in the Appendix 2

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Current gaps in understanding surrounding LCA revolve around the LCI data for materials, processes, fuels and energy

Life Cycle Inventory (LCI)

- Quantifying the difference in results due to different LCI datasets and LCA tools
- Assessing environmental impacts of new automotive materials, such as composites
- Assessing environmental impacts of advanced production processes
- In addition to CO₂, what other environmental impacts should be considered?
 - E.g. water footprint, toxicity, etc.

Real World Use

- What is the extent of the variability introduced by a population of different users?
 - E.g. Impact of using air conditioning, impact of low tyre pressures, etc.
- What is the realistic lifetime for a future vehicle?
 - How far will it travel?

Gaps in Understanding

Vehicle End-of-Life

- What really happens at the end of a vehicle's life?
- What will happen to new technologies (e.g. EV)?
 - What disposal processes will be required?
 - How can these be modelled within an LCA study?
- How should the environmental impact be allocated between old and new products?

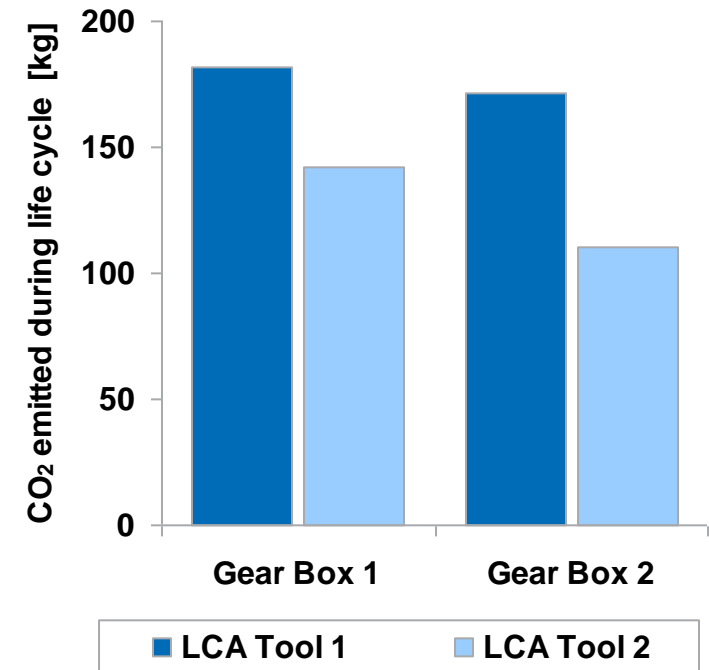
Future Fuels & Energy Vectors

- What will be the future biofuel content for gasoline and diesel?
 - What biofuel mix will be used?
 - What will be the feedstock mix?
 - What will be the carbon intensity of these fuels?
- What will be the future carbon intensity of the electricity grid?
 - Marginal vs. Mean?

The detail of the methodology employed by the LCA user can have a significant impact on the life cycle results

- It is possible to conduct two LCA studies of the same product, which both comply with the ISO 14040 standards, but have very different results
- Variability in LCA results can be a consequence of:
 - Functional unit definition (e.g. lifetime mileage)
 - LCA boundary, determining what has been included or excluded from the study
 - Assumptions employed
 - Life Cycle Inventory data set, and associated data quality
 - LCI databases define emission factors for materials, energy and processes
 - When selecting LCI data, the user should consider the geographical horizon, time horizon, precision, completeness and representativeness of the LCI data
 - Method for allocating environmental impact of co-products
 - If a process produces more than one product, the environmental impact can be split between the products produced
 - Choice of LCA software tool
 - Several commercial LCA tools available, in addition to in-house tools developed by vehicle manufacturers

Results from LCA study of two gear boxes, using two different LCA tools



In the above example, an LCA study was conducted of two gear boxes, one with an aluminium casing and the other with a steel casing. The study was repeated using two different LCA software tools, with the same bill of materials for the gear boxes. The differences in results is primarily due to the LCA tools using different LCI databases

Peer review and sensitivity analysis are recommended to ensure use of a rigorous process and to quantify variability of results

- ISO 14040 recommends that LCA studies are peer reviewed to ensure an appropriate methodology has been used
- Conducting sensitivity analysis can help to identify which elements could contribute most to result variability, and to understand the range
- Some LCI databases have data quality indexes to help users identify if the selected data is suitable for the application being investigated

A large, grey, downward-pointing arrow shape that tapers at both ends, pointing towards the text below.

***However even with peer review and sensitivity analysis
LCA results from different studies can still be significantly different
depending on input data sets and assumptions***

The LCA community is already active in initiatives to improve accuracy, data quality and use of consistent methodology

Existing LCA Initiatives

- There are several organisations engaged in activities to improve the accuracy of life cycle assessment and to establish common methodologies and data sets so products can be compared on a “like with like” basis

EXAMPLES



- **European Platform on Life Cycle Assessment** (<http://lct.jrc.ec.europa.eu>)
 - The aim is to support businesses and public authorities in the implementation of Sustainable Consumption and Production
 - In March 2010 the European Commission published their ILCD handbook
 - Their Life Cycle Thinking website and LCA Forum is hosted by the European Commission Joint Research Centre, Institute for the Environment and Sustainability (JRC-IES)



- **UNEP Life Cycle Initiative** (<http://lcinitiative.unep.fr>)
 - An international life cycle partnership set up by the United Nations Environment Programme (UNEP) and the Society for Environmental Toxicology and Chemistry (SETAC)
 - Their main mission is to bring science-based Life Cycle approaches into practice worldwide



- **The Carbon Label Company** (www.carbon-label.com)
 - Set up by the Carbon Trust in 2007
 - Primary objective is to help businesses to measure, certify, reduce and communicate the lifecycle greenhouse gas (GHG) emissions of their products and services

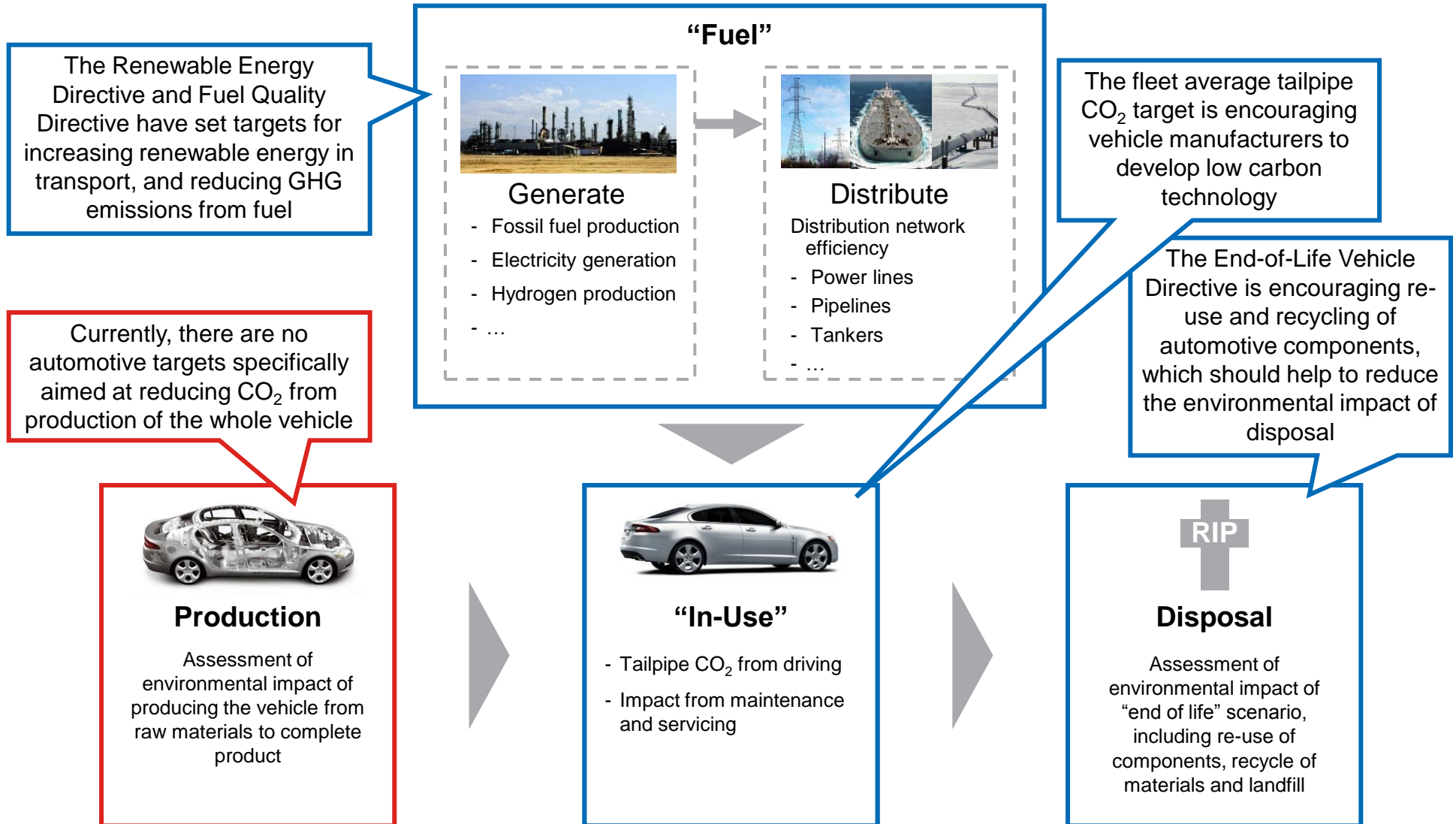
Further work is required, engaging with OEMs, LCA practitioners and vehicle drivers, to close the gaps in life cycle understanding

Suggestions to LowCVP for Future Work

- **Open the dialogue with vehicle manufacturers**
 - Encourage OEMs to publish the results (and their methodology/assumptions) from their LCA studies. This will provide a benchmark of the current life cycle CO₂ emissions of European passenger cars, split between production, in-use and disposal
- **Make contact with LCA networks and initiatives**
 - Many of these networks are already active in trying to improve the quality of life cycle inventory data
 - Work with the existing initiatives to develop a standard / default LCI dataset for the automotive industry
- **Investigate the variability of vehicle use to understand the range between extremes**
 - E.g. Consumer surveys to understand travel patterns, driver styles, typical vehicle loading, use of on-board heating and air conditioning
 - Conduct sensitivity studies to appreciate the impact of different use patterns on life cycle emissions
- **Research vehicle end-of-life to understand what really happens during vehicle disposal**
 - What will be the impact of new technologies, such as advanced battery packs?
 - How will new materials impact re-use and recyclability?
- **Make LCA part of the process**
 - Get life cycle thinking embedded within the design process
 - Allow LCA results to drive reduction in both cost and CO₂ footprint (“Clean ‘n’ Lean”)

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Europe currently has specific targets for reducing the environmental impact of a vehicle during the fuel, use and disposal phases, ...



... but there are no specific CO₂ targets for the production of the whole vehicle

Recommendations for a life cycle CO₂ measure

- Consider a new CO₂ metric based on the GHG emissions emitted during vehicle production [tCO₂e]
 - The vehicle's life cycle CO₂ can then be calculated for a defined use, fuel and disposal scenario
- Consider targets aimed at reducing the life cycle CO₂ [tCO₂e]. For example:
 - Cap on production CO₂, dependent on vehicle segment
 - Reduction target for production or life cycle CO₂, compared to an appropriate baseline
 - Maximum “pay back period” for trading increased embedded emissions against reductions in tailpipe / WTW CO₂ emissions
- Consider the fiscal and regulatory framework in which vehicles are sold, used and disposed
 - Allocation of incentives / regulation to best influence commercial and consumer behaviours for lowest life cycle CO₂

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Future CO₂ metrics will need to consider a vehicle's whole life cycle, but work is required to obtain common methodologies and data sets

Conclusions

- The vehicle's embedded CO₂ from production and disposal is becoming a greater portion of the life cycle CO₂ emissions
- Current regulatory frameworks do not recognise this
- Standards, guidelines and manuals already exist for conducting Life Cycle Assessment and Environmental Product Declarations of products such as passenger cars
 - However input data, boundary conditions and assumption can vary between LCA studies
- Life Cycle Inventory databases exist containing information on the carbon intensity of materials, energy, production processes and fuels
 - Some databases are freely available within the public domain, while other proprietary databases require users to purchase a licence
 - Values can vary between databases depending on the geographical horizon, time horizon, data source, completeness and representativeness of the LCI data
- For a life cycle CO₂ measure to be regulated, work will be required to standardise the process detail, life cycle boundary, and input data, such that results from different manufacturers are directly comparable
- Key areas for further investigation include:
 - Development of a common LCI dataset to be used by the automotive industry
 - Impact of different in-use assumptions, especially around drive cycles and use of ancillary functions
 - Obtain a better understanding and modelling of the environmental impact of vehicle end of life, especially for new technologies such as electric vehicles

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Appendix 1

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Appendix 2

Further information on Ricardo analysis of impact of technology evolution on life cycle CO₂ emissions

Ricardo derived a set of vehicle specifications designed to produce equivalent performance characteristics by vehicle size

Vehicle Specifications based on Technology Roadmap projections for 2015

Vehicle	Vehicle Description	Vehicle Mass [kg]	Tailpipe CO ₂ [gCO ₂ /km]	EV Driving Range * [km]
Mid-Size Gasoline	1.4L 91kW I4 DI engine with VVT and FGT	1340 kg	109 gCO ₂ /km	-
Mid-Size Gasoline Full Hybrid	1.4L 91kW I4 DI engine with VVT, 1.8 kWh NiMH battery pack, 56 kW Motor	1430 kg	84 gCO ₂ /km	-
Mid-Size Gasoline PHEV	1.4L 91kW I4 DI engine with VVT, 4.8 kWh Li-ion battery back, 56 kW Motor	1460 kg	47 gCO ₂ /km	20 km
Mid-Size Gasoline EREV	1.0L 44kW I3 PFI engine, 13.4 kWh Li-ion battery back, 72 kW Motor	1510 kg	35 gCO ₂ /km	55 km
Mid-Size EV	32.2 kWh Li-ion battery back, 71 kW Motor	1480 kg	0 gCO ₂ /km	180 km
Mid-Size FCV	73 kW PEM fuel cell system, 1.8 kWh Li-ion battery back, 67 kW Motor	1410 kg	0 gCO ₂ /km	-
Small Gasoline	1.0L 59kW I3 PFI engine with VVT	1080 kg	103 gCO ₂ /km	-
Mid-Size Diesel	2.0L 101kW I4 engine with VGT Turbo	1420 kg	105 gCO ₂ /km	-
Large Diesel	3.0L 123kW V6 engine with VGT Turbo	1720 kg	113 gCO ₂ /km	-
Large Diesel, with downsized ICE and reduced vehicle weight	2.0L 123kW I4 engine with 2 stage turbocharging	1680 kg	90 gCO ₂ /km	-

* Depth of battery discharge for calculating EV range assumed to be 50% for PHEV and EREV, and 70% for EV

Source: Ricardo

A variety of alternative fuels were considered ...

Fuel Specifications, and assumptions regarding Well-to-Tank CO₂ emissions (1/2)



- The study has considered three grades of gasoline:



E10 containing 10%_{vol}, 7%_{energy} ethanol



E20 containing 20%_{vol}, 14%_{energy} ethanol



E85 containing 80%_{vol}, 73%_{energy} ethanol, to allow for seasonal and regional variations

- Ethanol is assumed to be from a range of feedstocks (70% sugar cane, 20% sugar beet, 8% wheat, 2% corn)
- Carbon intensity of ethanol is assumed to be 28.7 gCO₂e/MJ_{fuel}, derived from RED typical values
- Carbon intensity of gasoline is assumed to be 83.8 gCO₂e/MJ_{fuel}, RED default value

- The study has considered three grades of diesel:



B7 containing 7%_{vol}, 6%_{energy} FAME



B10 containing 10%_{vol}, 9%_{energy} FAME



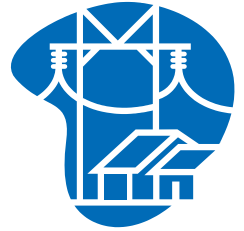
B100 containing 100%_{vol}, 100%_{energy} FAME

- FAME is assumed to be from a range of feedstocks (40% soy, 25% oilseed rape, 15% tallow, 10% palm, 10% other)
- Carbon intensity of FAME is assumed to be 43.4 gCO₂e/MJ_{fuel}, derived from RED typical values
- Carbon intensity of diesel is assumed to be 83.8 gCO₂e/MJ_{fuel}, RED default value

... including electricity and hydrogen

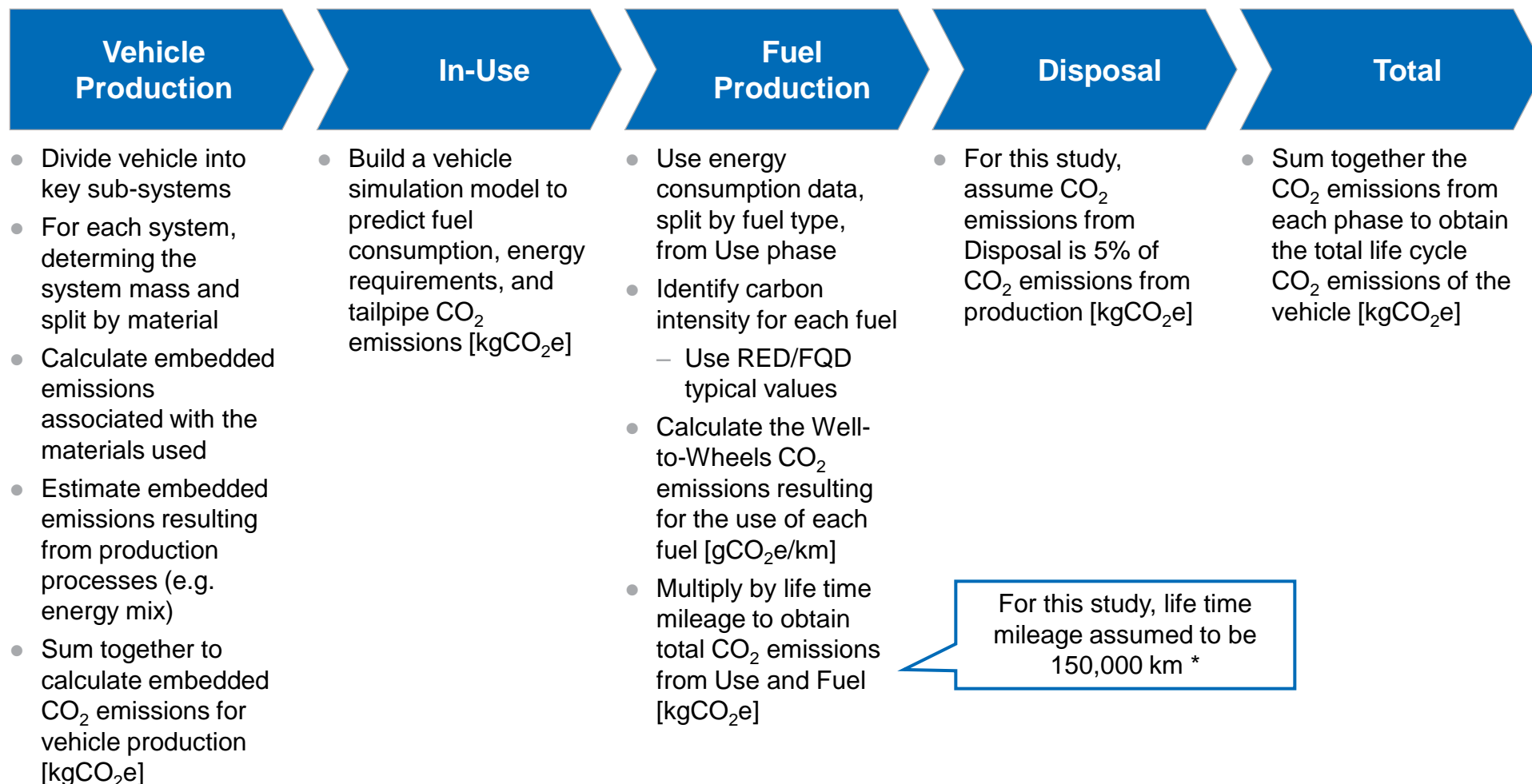
Fuel Specifications, and assumptions regarding Well-to-Tank CO₂ emissions (2/2)

- Electricity for plug-in vehicles assumed to be from UK National Grid
 - 2010 UK electricity carbon intensity assumed to be 500 gCO₂e/kWh, 139 gCO₂e/MJ (DECC)
 - 2020 UK electricity carbon intensity assumed to be 310 gCO₂e/kWh, 86 gCO₂e/MJ (CCC Scenario)
- Hydrogen was assumed to be from industrial sources, produced using steam methane reforming
 - Carbon intensity for hydrogen assumed to be 99.7 gCO₂e/MJ_{fuel}



Ricardo have developed a top-down methodology for estimating life cycle CO₂ emissions for a range of vehicle technologies

Ricardo's methodology for calculating high level estimates of life cycle CO₂ emissions



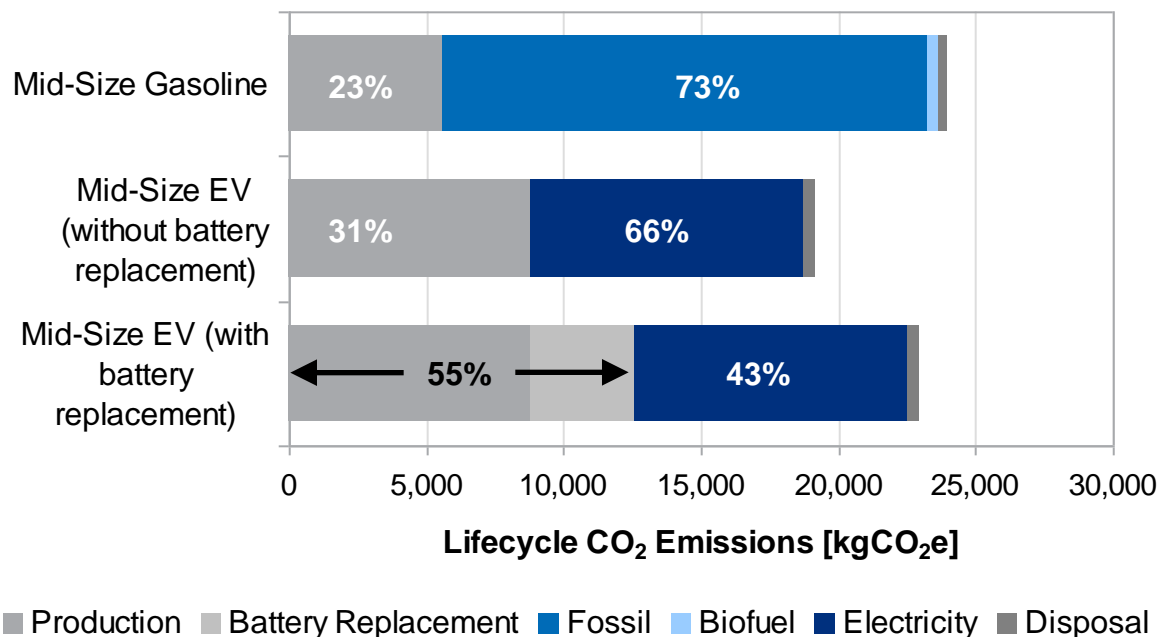
* The Product Category Rule for passenger cars currently states lifetime mileage as 150,000 km. This project has not assessed if this definition is appropriate for current and future passenger car technologies



Other assumptions used in Ricardo's high level analysis of life cycle CO₂ emissions from passenger cars

Other assumptions

- Ricardo's top-down methodology provides a high level estimate of the production, in-use and disposal CO₂ emissions of a generic vehicle, useful for providing an indication of future trends in life cycle CO₂. This process does not currently confirm with ISO 14040
- Assume tailpipe CO₂ is equal to tailpipe CO₂e, since tailpipe emissions other GHGs will be very small
- For EVs, EREVs and PHEVs, assume the battery does not need to be replaced during the vehicle lifetime
 - This study has not investigated the likelihood of a Li-ion or NiMH battery pack lasting the lifetime of a plug-in vehicle



- If the battery has to be replaced during the vehicle's life, then the embedded CO₂ emissions will increase, as illustrated in the chart left

Vehicle specifications based on roadmap projections for 2015. Assumed lifetime mileage 150,000 km. Fuels E10 and B7. Electricity carbon intensity assumed to be 500 gCO₂/kWh. Further details on assumptions is provided in the Appendices

Appendix 3

Vehicle Type Approval

Regulations are enforceable by law, while codes and standards tend to be voluntary unless referred to in regulations

Definitions

Directives

- A directive is a legislative act of the European Union, which requires member states to transport it into national law, without dictating the means of achieving that result

Regulations

- A regulation is a legislative act which becomes immediately enforceable as law. It is a statutory document, legally binding and has to be adhered to
- It is self-executing and do not require any implementing measures

Codes

- A code is a collection of laws or rules, specifying the minimum standard to adhere to
- Usually voluntary, but depends on its jurisdiction

Standards

- A Technical Standard is an establish norm or requirement, usually defined in a formal document
- Developed by Standards Organisations, with diverse input, usually voluntary, but might become mandatory if adopted by government
- Standards are not legally binding unless referred to in a regulation



Vehicle Type Approval is granted to a vehicle that meets a minimum set of regulatory, technical and safety requirements

What is European Vehicle Type Approval?

- Vehicle Type Approval is the procedure whereby a Member State certifies that a type of vehicle satisfies the relevant administrative provisions and technical requirements relating to:
 - Active and passive safety
 - Protection of the environment
 - Performance and other issues
- The objective of Vehicle Type Approval is:
 - To enable vehicles to be put on the market according to common requirements
 - To ensure the proper functioning of the internal market in the EU
- The concept is also applicable to components and systems
- Within the Europe Community, the framework for the type approval of motor vehicles is defined in **EC Directive 2007/46/EC**
- The **EC Whole Vehicle Type Approval system (ECWVTA)** means that if manufacturers can obtain approval for a vehicle type in one Member State, the vehicle can be marketed within the EU without further tests or checks, subject to presenting a **certificate of conformity**
- Automotive EC Directives and UN ECE Regulations require third party approval (e.g. UK VCA)

To obtain European Type Approval, a vehicle has to comply with ~50 EC Directives

Europe: Application Standards for Vehicle Type Approval



Environment

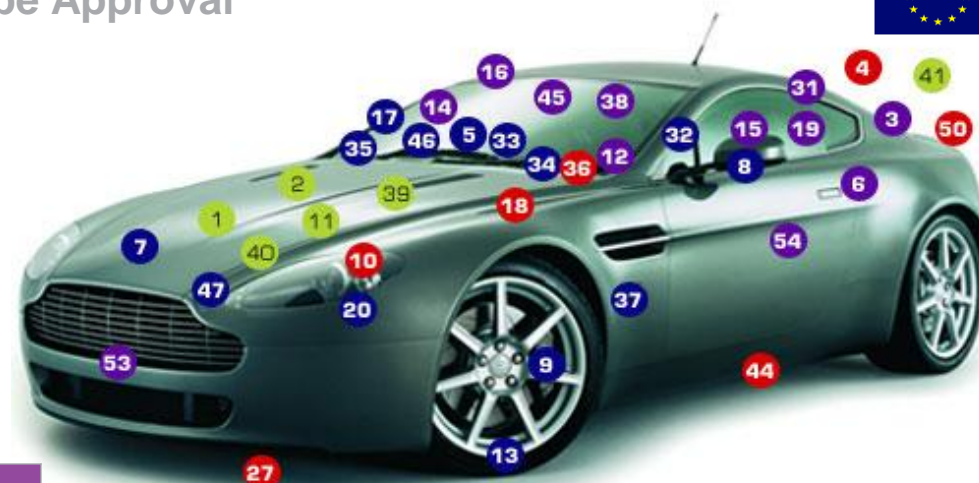
- 01. Sound Levels EC 2007/34
- 02. Emissions EC 2003/76
- 11. Diesel Smoke EC 2005/21
- 39. Fuel Consumption EC 2004/3
- 40. Engine Power EC 1999/99
- 41. Diesel Emissions EC 2008/74

Active Safety

- 05. Steering Equipment EC 1999/7
- 07. Audible Warning EC 70/388
- 35. Wash / Wipe EC 94/68
- 13. Antitheft EC 95/56
- 32. Forward Vision EC 90/630
- 08. Rear Visibility EC 2005/27
- 46. Tyres EC 2005/11
- 17. Speedometer and Reverse Gear EC 97/39
- 34. Defrost / Demist EC 78/317
- 09. Braking EC 2002/78
- 20. Lighting Installation EC 2008/89
- 33. Identification of Controls EC 94/53
- 37. Wheel Guards EC 94/78

Passive Safety

- 19. Safety Belt Anchorage EC 2005/41
- 16. Exterior Projections EC 2007/15
- 15. Seat Strength EC 2005/39
- 14. Protective Steering EC 91/662
- 03. Fuel Tank EC 2006/20
- 12. Interior Fittings EC 2000/4
- 31. Safety Belts EC 2005/40
- 06. Door Latches and hinges EC 2001/31
- 38. Head restraints EC 78/932
- 45. Safety glazing EC 2001/92
- 53. Frontal impact EC 1999/98
- 54. Side impact EC 96/27



21 22 23 24 25 26 28 29 30

Lighting Equipment

- 21. Reflex Reflectors EC 97/29
- 22. Side, Rear and Stop lamps EC 97/30
- 23. Direction indicator lamps EC 1999/15
- 24. Rear registration plate lamp EC 97/31
- 25. Headlamps (including bulbs) EC 1999/17
- 26. Front fog lamps EC 1999/18
- 28. Rear fog lamps EC 1999/14
- 29. Reversing Lamps EC 97/32
- 30. Parking Lamps EC 1999/16

Other Directives

- 27. Towing Hooks EC 96/64
- 04. Rear Registration Plate EC 70/222
- 18. Statutory Plates EC 78/507
- 36. Heating systems 2004/78
- 10. Radio Interference Suppression EC 2009/19
- 44. Masses and Dimensions EC 95/48
- 50. Mechanical Couplings EC 94/20