Objective

1-litre car

The most efficient car in the world

L1

Conceptual study

XL1

Safety and everyday practicality

XL1

Development to short production run readiness

2002 2009 2011 2013

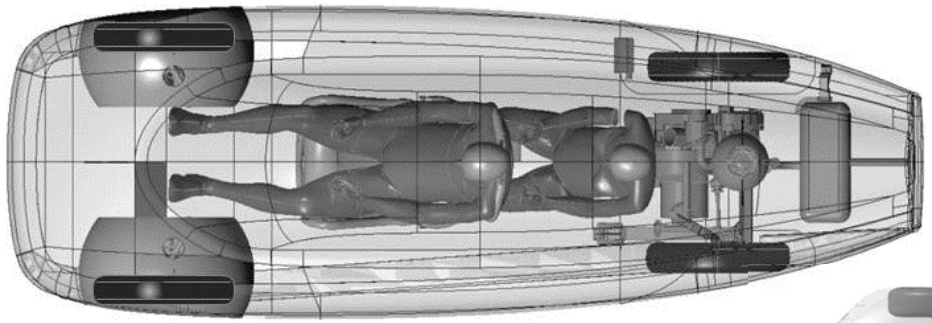
The concept of the 1-litre car in 2002

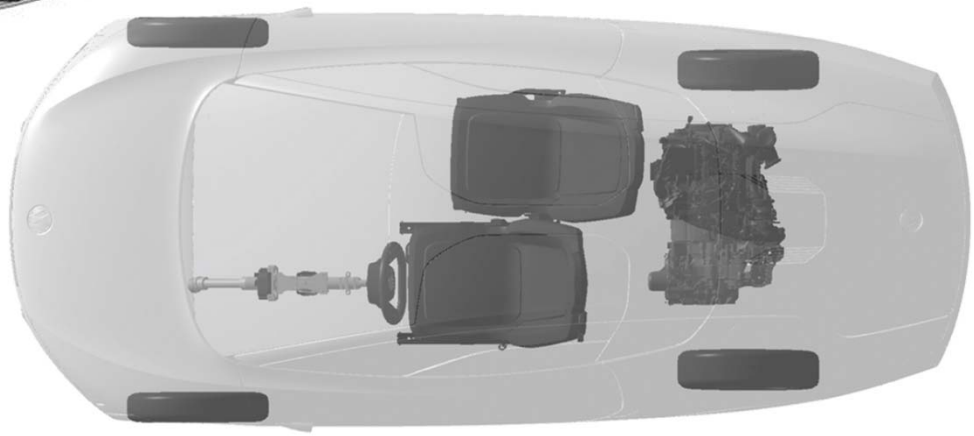
Engine
1-cyl. 0.3l 6.3 kW (8.5 PS)

Gearbox
ASG 6-speed with
pulse start / battery regeneration

Aerodynamic drag:	**0.159**
Top speed:	**120 km/h**
Fuel consump.:	**0.99 l/100 km**

Package: 1-litre car versus XL1





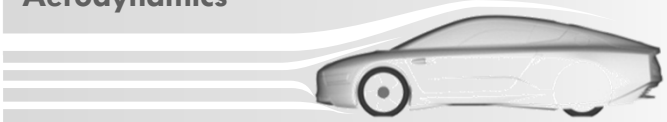
Ways to boost efficiency

Reducing resistance and drag

Lightweight design

Reversal of upward weight spiral

Aerodynamics



Optimising efficiencies

Highly efficient TDI engine

Downsizing

Plug-in hybrid: Electrification of the powertrain

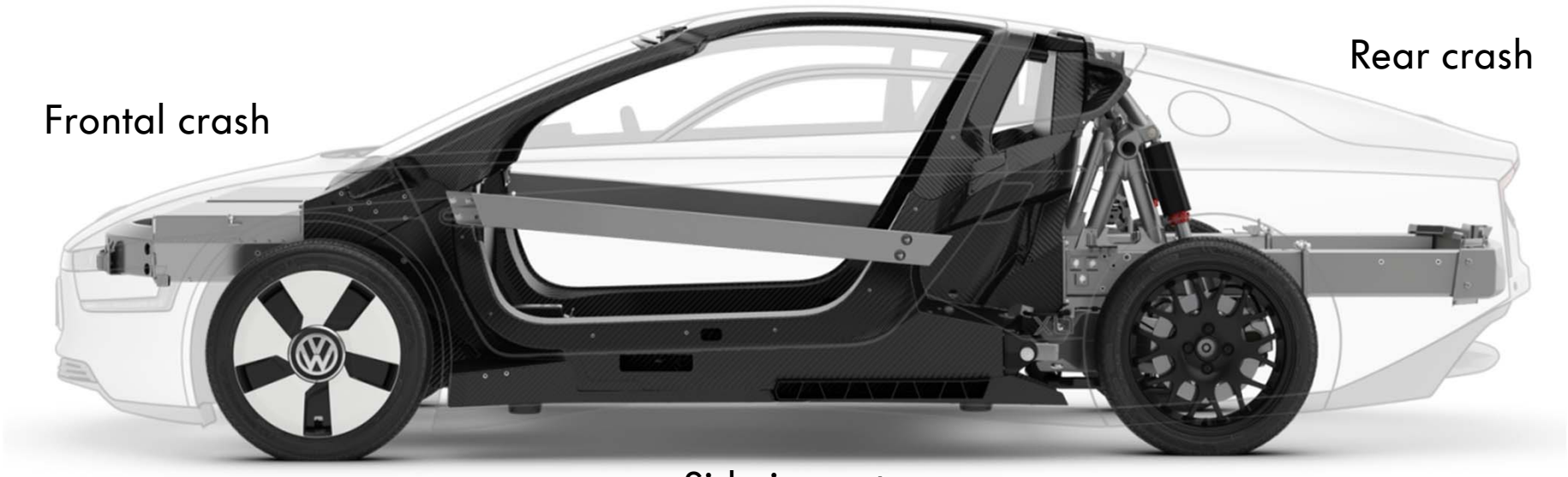
- All-electric share of driving
- Battery regeneration (braking energy)
- Highly effective hybrid operating strategy

Lightweight and safe

Rollover

Rear crash

Frontal crash



Side impact

Lightweight design in the XL1: CFRP monocoque

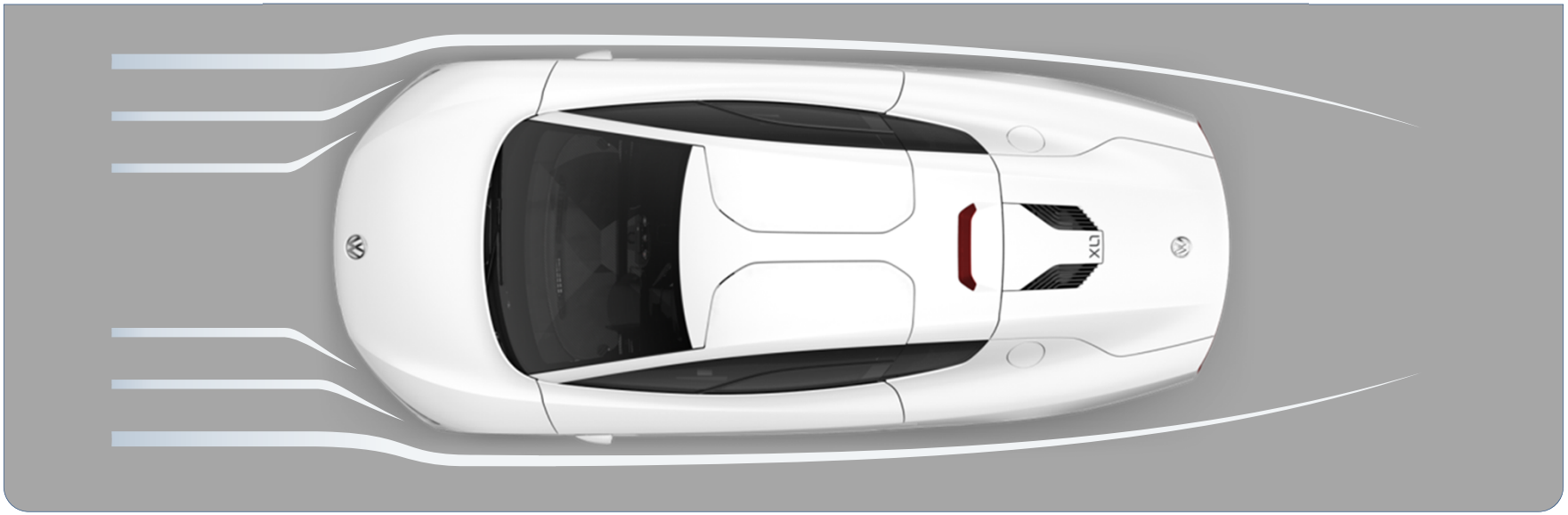
Reducing resistance and drag: Aerodynamics

Smooth surfaces

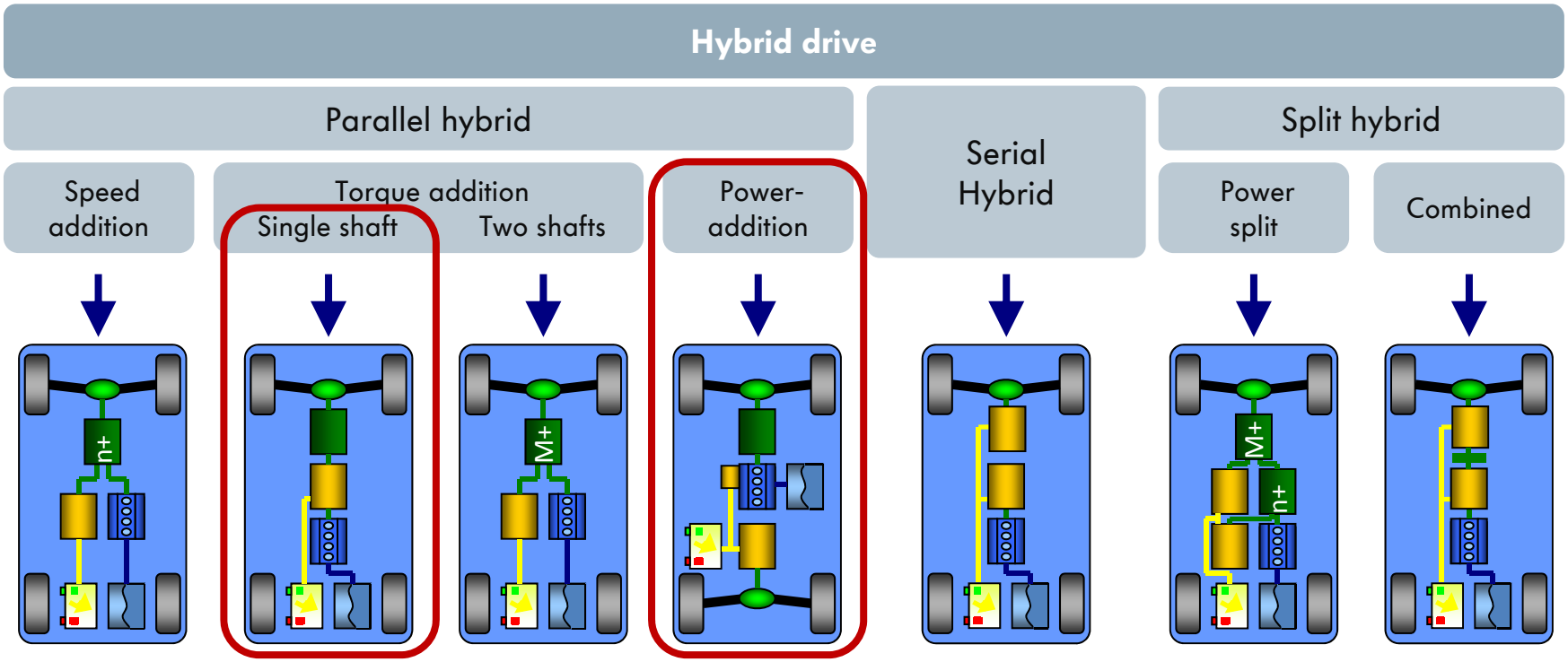
Aerodynamic basic body shape

Optimal tyre dimensions

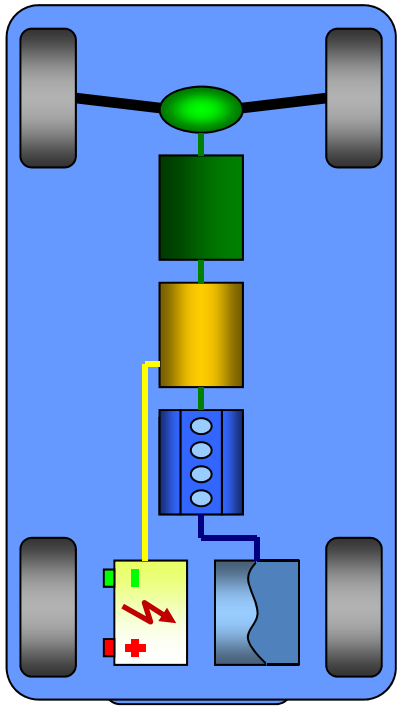
Aerodynamic optimisation of details

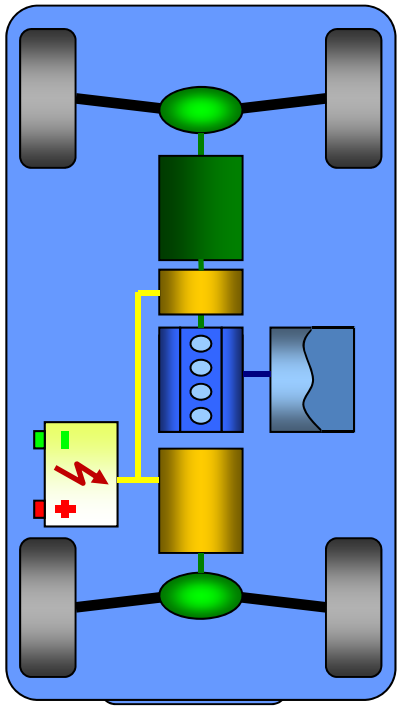


Hybrid vehicles – possible topologies



Hybrid vehicles at Volkswagen





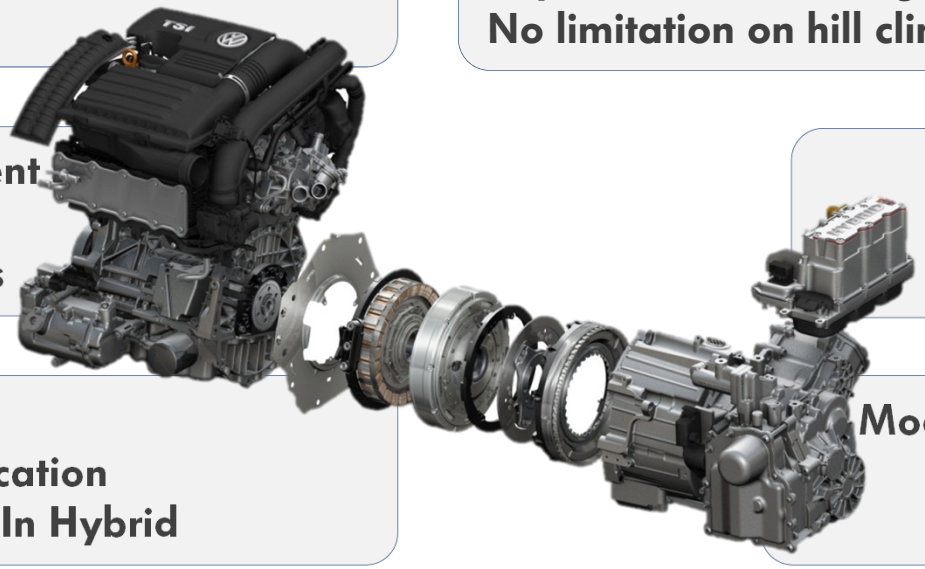
The single-shaft parallel hybrid – a modularly extendable approach

Advantages of the parallel hybrid concept

High fuel savings potential

Sporty driving performance
Reproducible handling properties
No limitation on hill climbing ability

Modular component systems capable
E traction modules

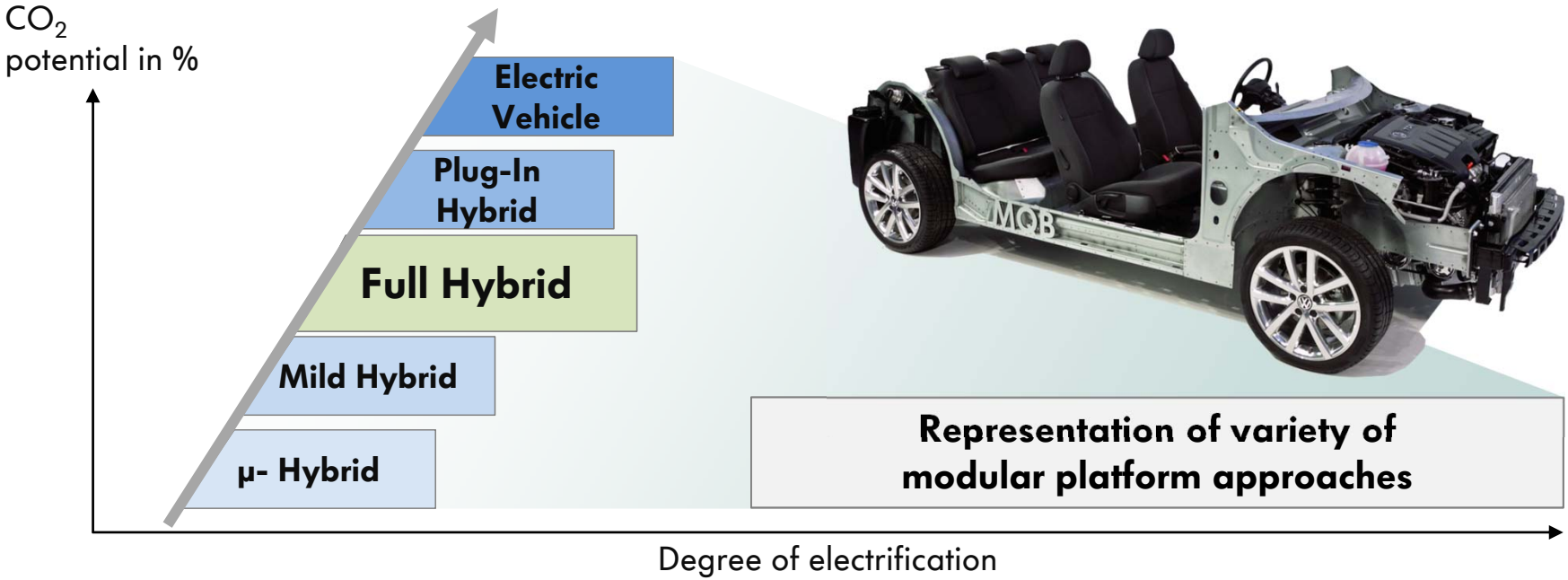


Use of Technology building blocks
TDI®, TSI®, DSG®

Scalability
Degree of electrification
Mild / Full / Plug-In Hybrid

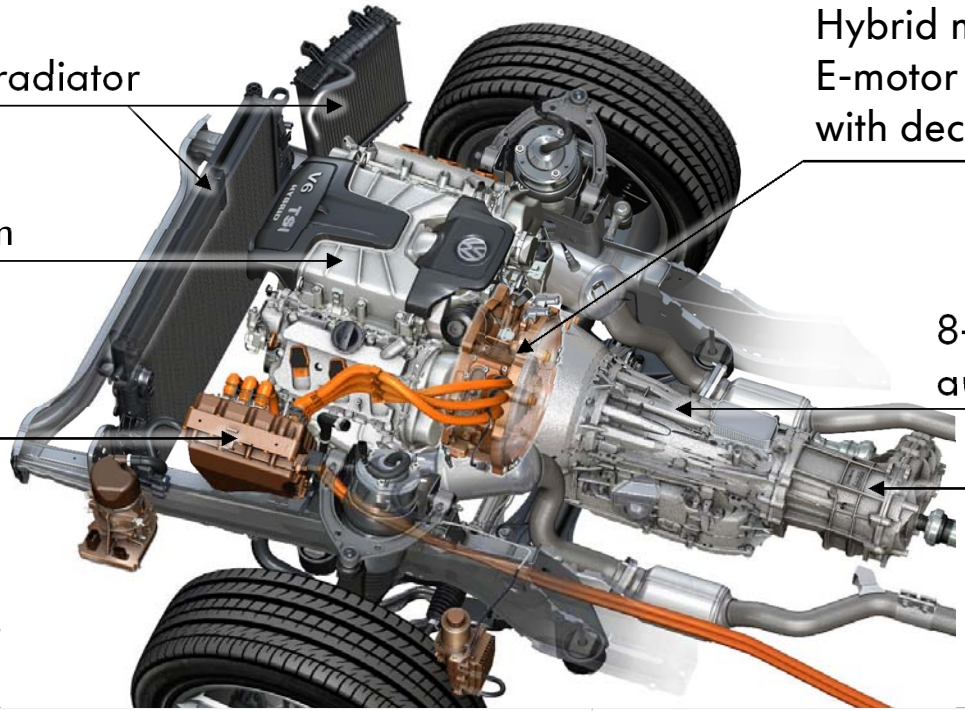
Modularity of powertrain components

Modular hybrid component system by Volkswagen



Touareg Hybrid –
the first hybrid from Volkswagen

Powertrain of the Touareg Hybrid



Low-temperature radiator

3.0l V6 TSI
245 kW / 440 Nm

Power electronics

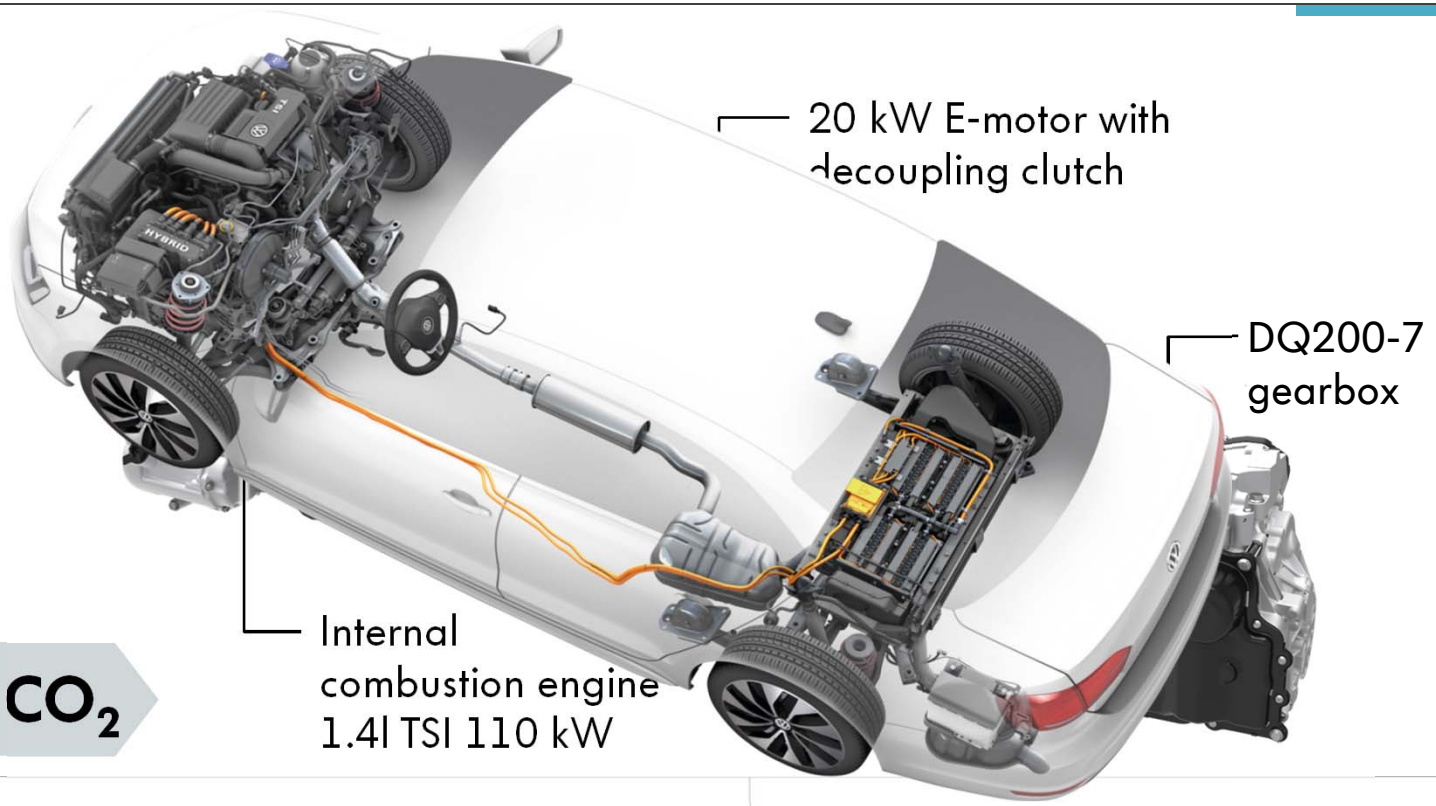
Hybrid module:
E-motor (34 kW / 300 Nm)
with decoupling clutch

8-speed torque converter
automatic gearbox

Torsen transfer
case

- 20 % CO_2

Powertrain of the Jetta Hybrid



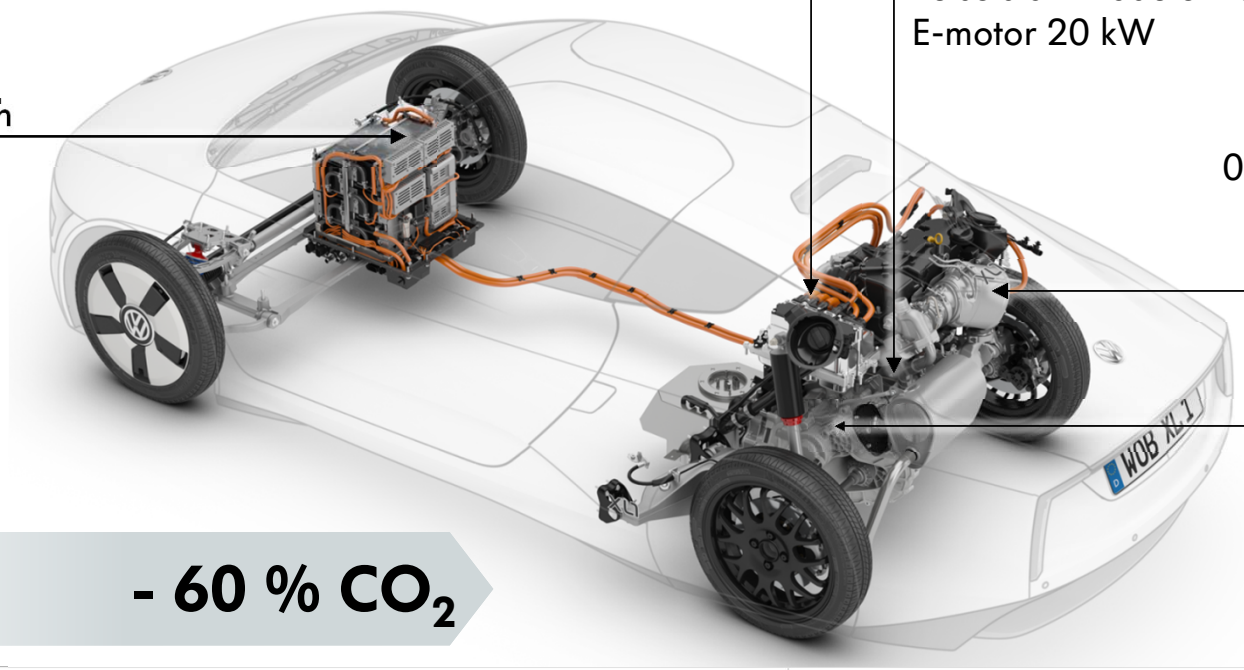
- 20 % CO_2

Layout of the hybrid system in the XL1

Lithium-ion battery
60 cells
230 V
5.5 kWh

Power electronics
incl. DC/DC convertor

Pulse start module incl.
E-motor 20 kW

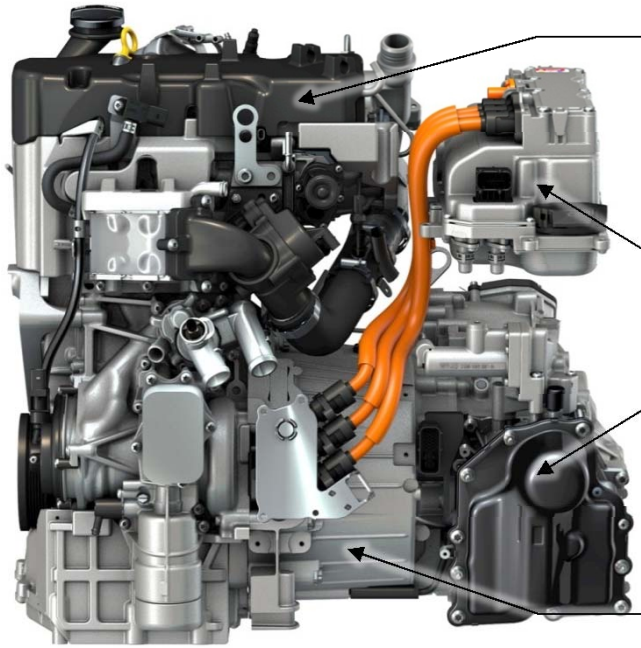


0.8l R2 TDI 35 kW with
engine block made
of aluminium

Weight-optimised
magnesium
dual clutch gearbox

- 60 % CO_2

Plug-in hybrid powertrain in the XL1



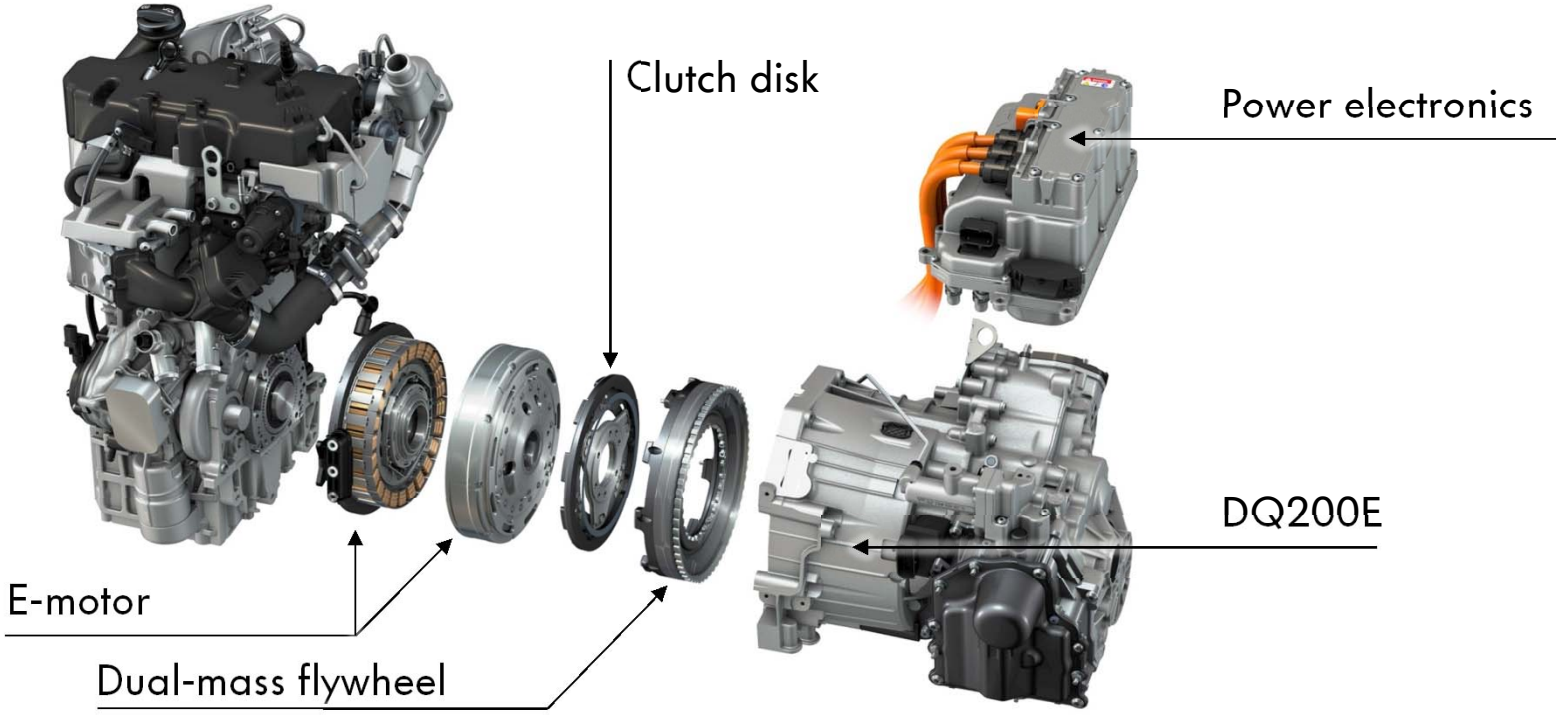
Internal combustion engine
- 2-cyl. 0.8l TDI®
- Pe = 35 kW, Md = 120 Nm

Power electronics
- integrated DC/DC converter

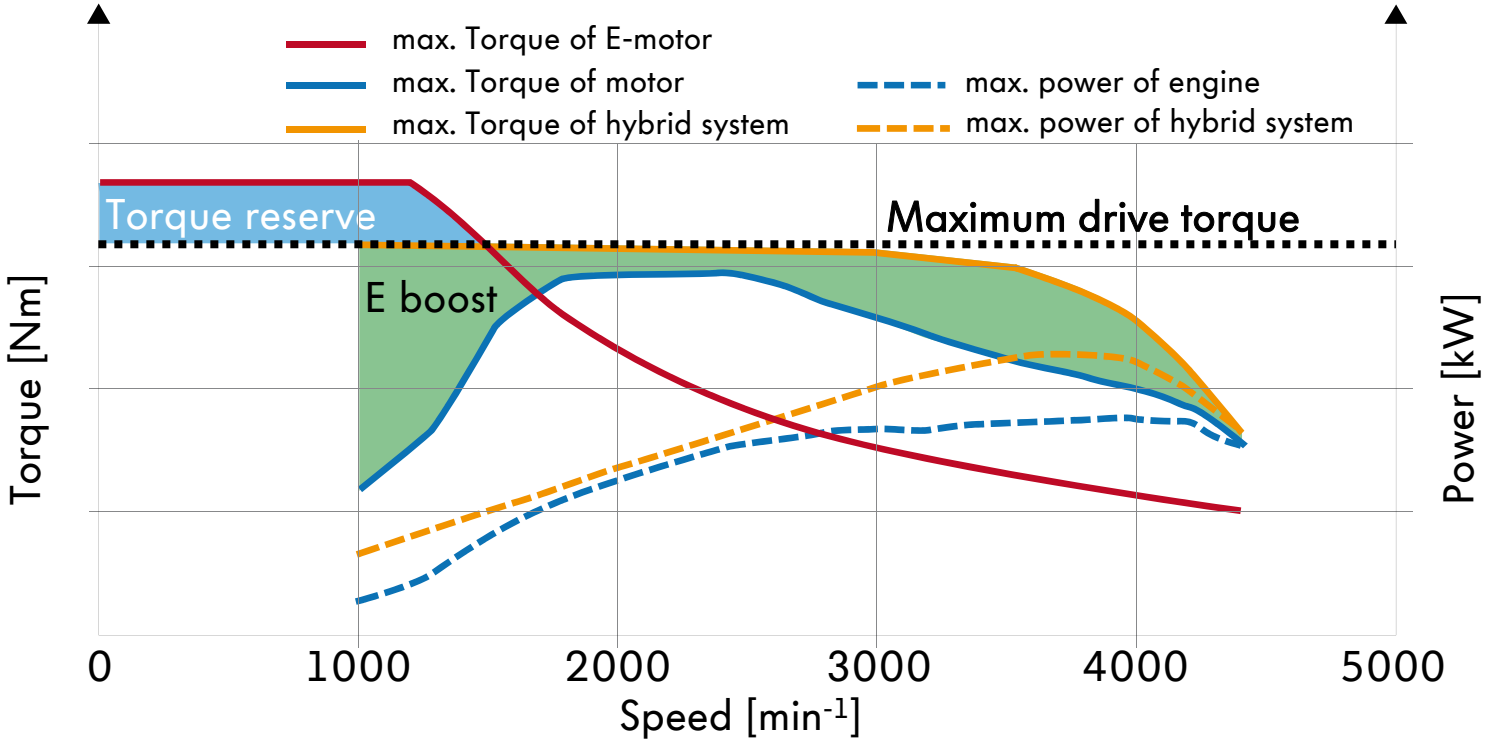
Dual clutch gearbox
- 7 speeds
- Dry clutches

Hybrid module
- Permanently excited synchronous motor 20 kW
- Driving clutches + K0 + dual-mass flywheel

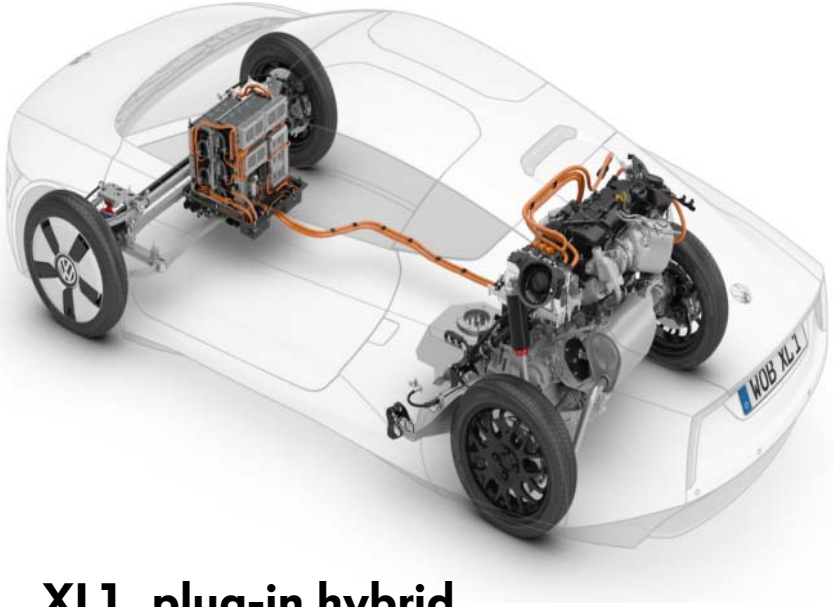
Plug-in hybrid powertrain in the XL1



Power and torque curves



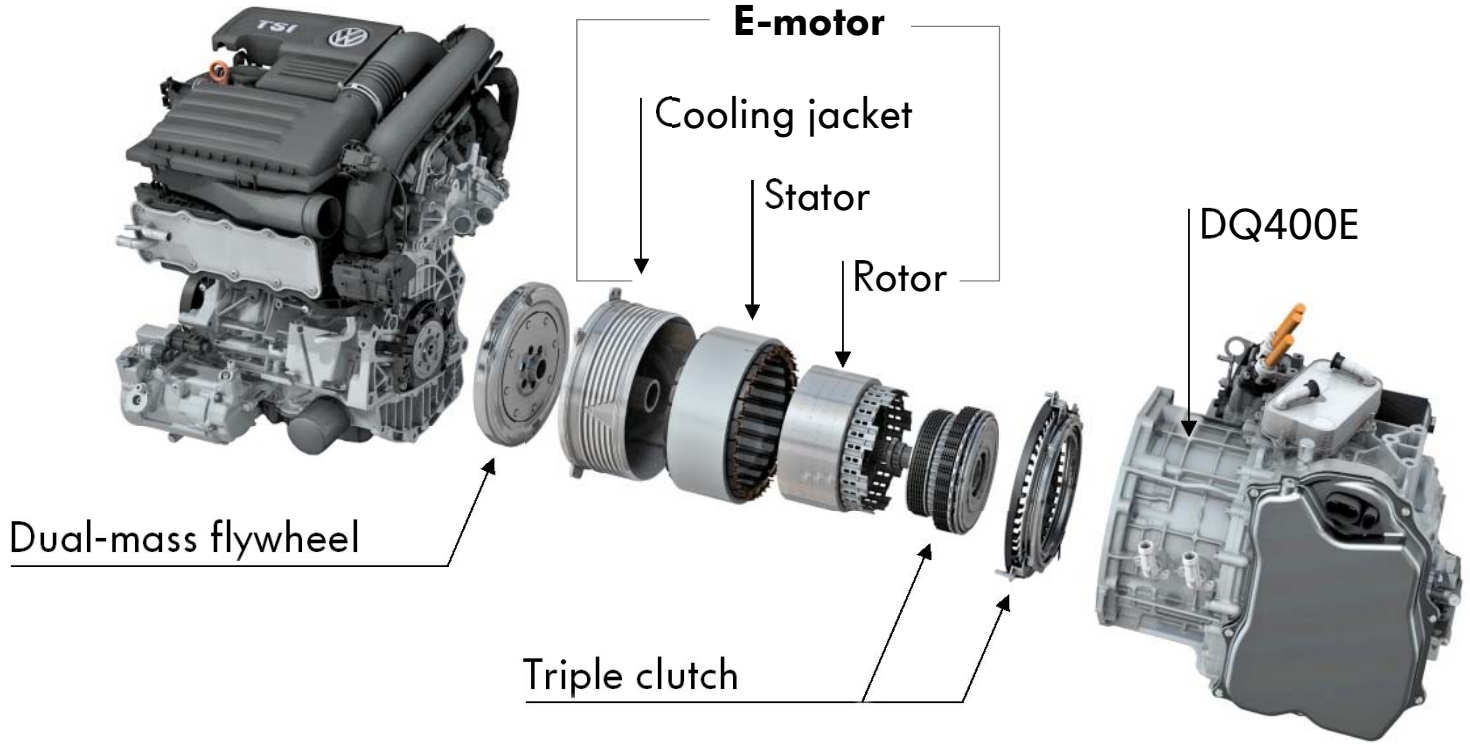
XL1 and MQB – comparison of two plug-in hybrid



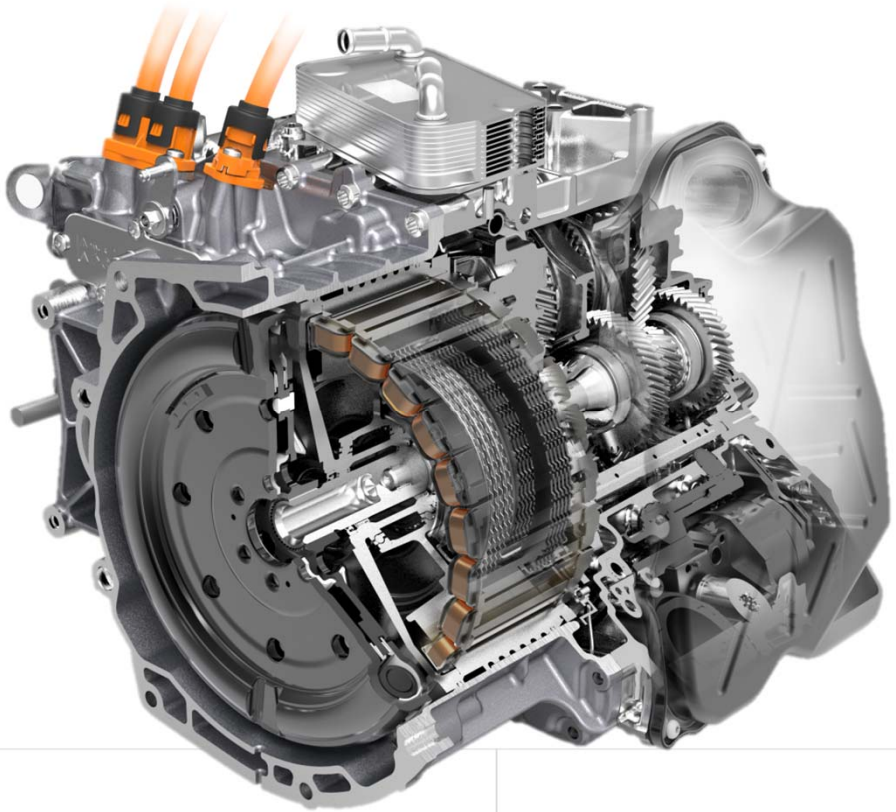
XL1 plug-in hybrid

MQB plug-in hybrid

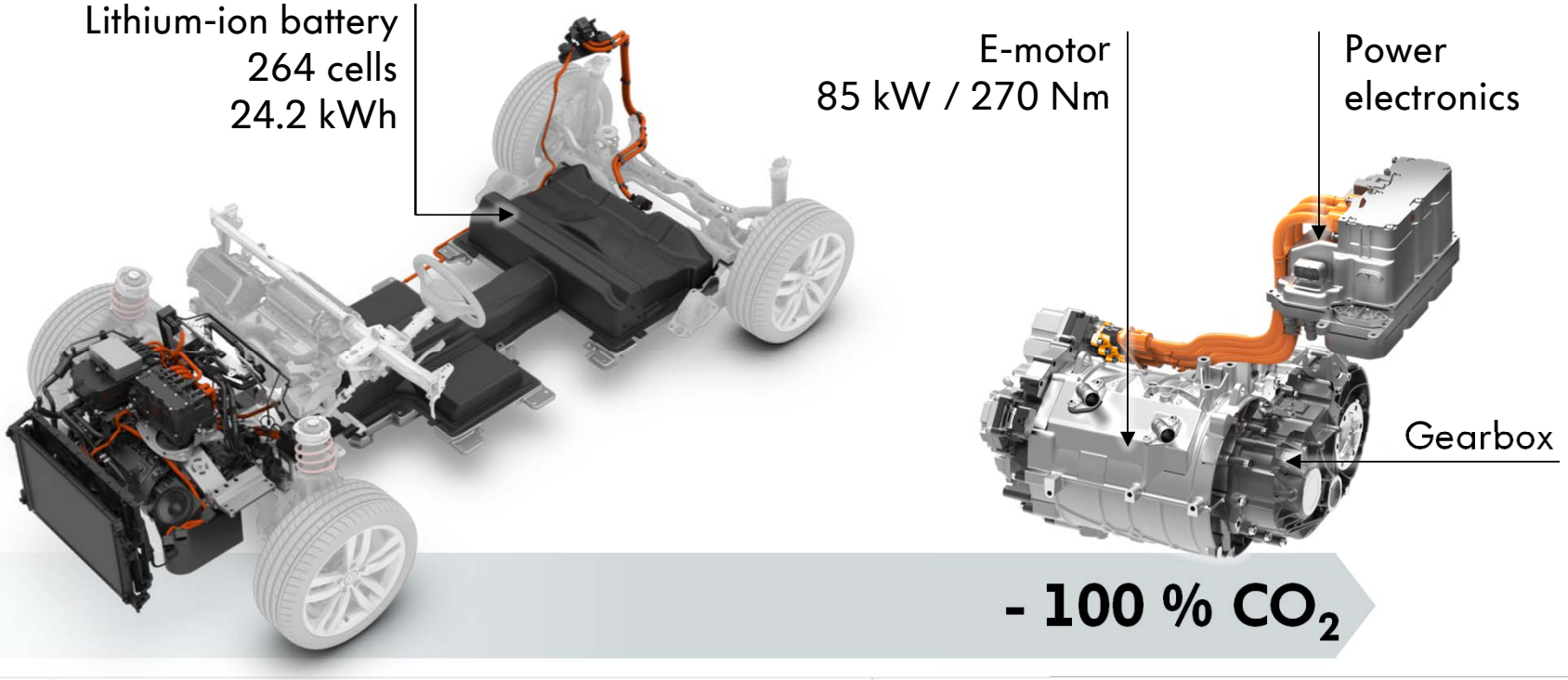
MQB plug-in powertrain -
The next generation of functional integration



New hybrid gearbox –
component of the modular hybrid component system



Electric powertrain in the MQB

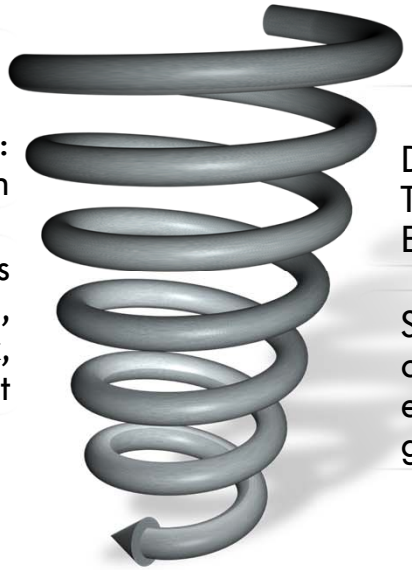


Reversal of the upward weight spiral

Requirements:
Comfort, safety, quality, legal requirements, interior

Starting point:
lightweight body design

Secondary effects
on other areas,
e.g. smaller fuel tank,
no steering assist



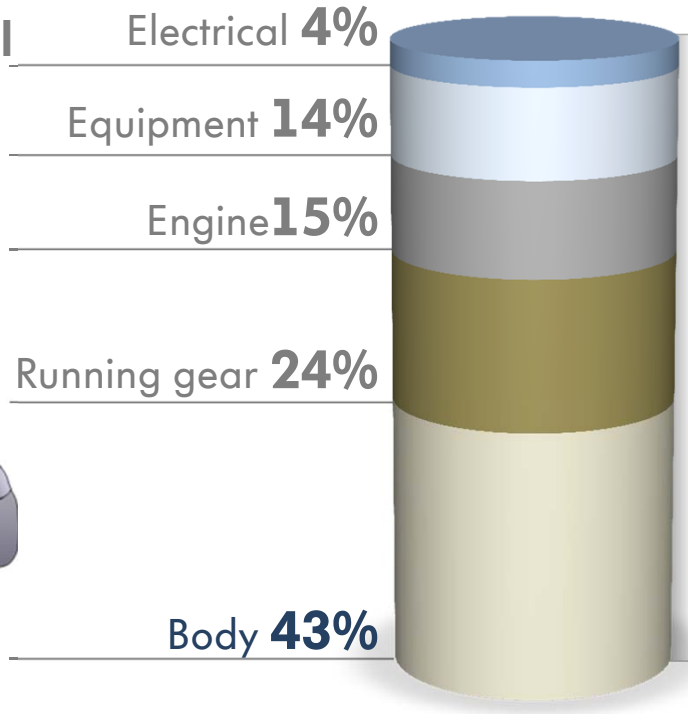
Downsizing of
TDI engine,
E-motor and HV battery

Secondary effects
on other areas
e.g. lightweight running
gear, narrow tyres

Results: **systematic weight reduction**

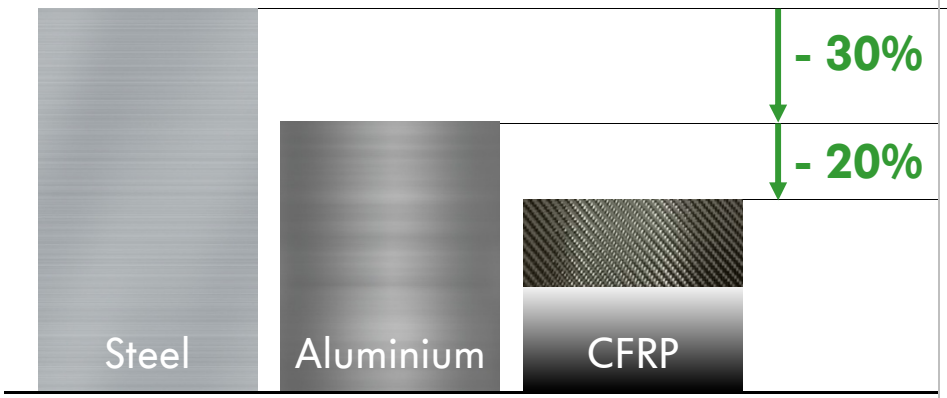
Weight share by subassemblies

Total weight of a typical passenger car in the compact class:



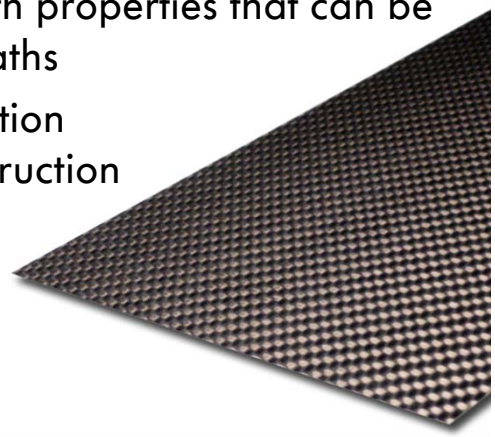
» **Conclusion: Optimisation of the body is necessary!**

Opportunities for reducing body weight



Advantage of CFRP – significant weight savings due to:

- High specific modulus of elasticity
- Directional strength properties that can be aligned to load paths
- Functional integration and integral construction



Reducing resistance and drag: Lightweight design

CFRP monocoque

- Safety cell
  and load-bearing vehicle structure
- Inner surface of monocoque used for some interior surfaces
- Direct mounting of running gear
- Total weight of monocoque
  approx. 89.5 kg

Reducing resistance and drag: Lightweight design

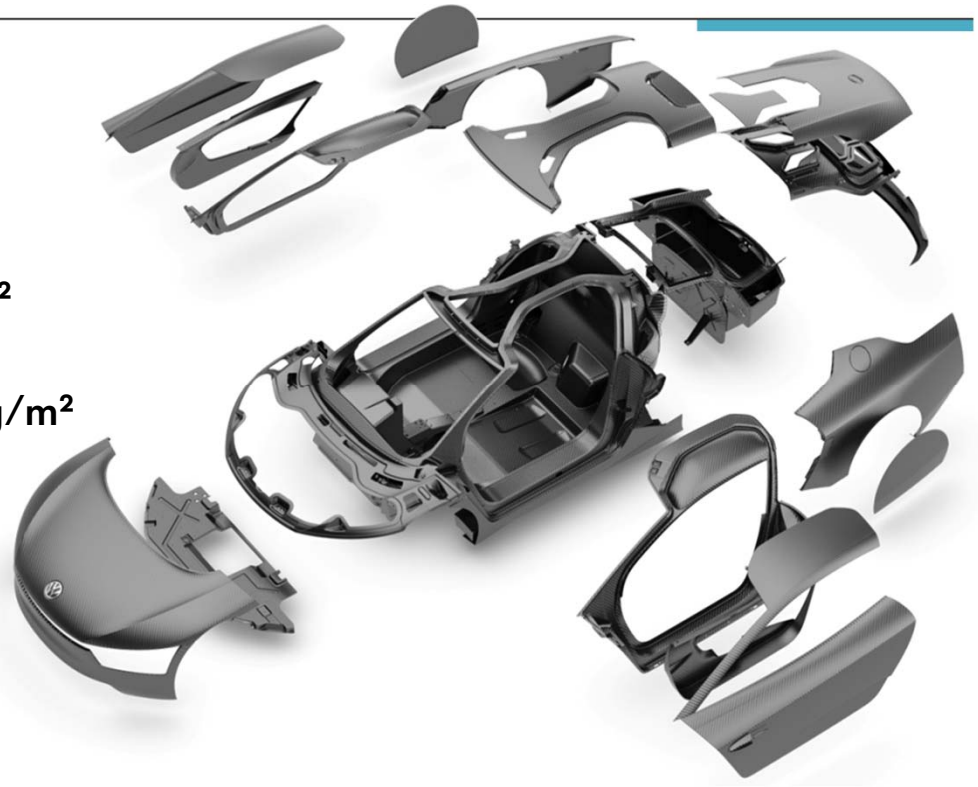
Complete exterior skin including structural parts of CFRP

Minimal weight: **CFRP approx. 1.8 kg/m²**

- By comparison:
  Production steel body is **approx. 5.1 kg/m²**

Ideal elastic deformation behaviour

- No permanent bumps or dents



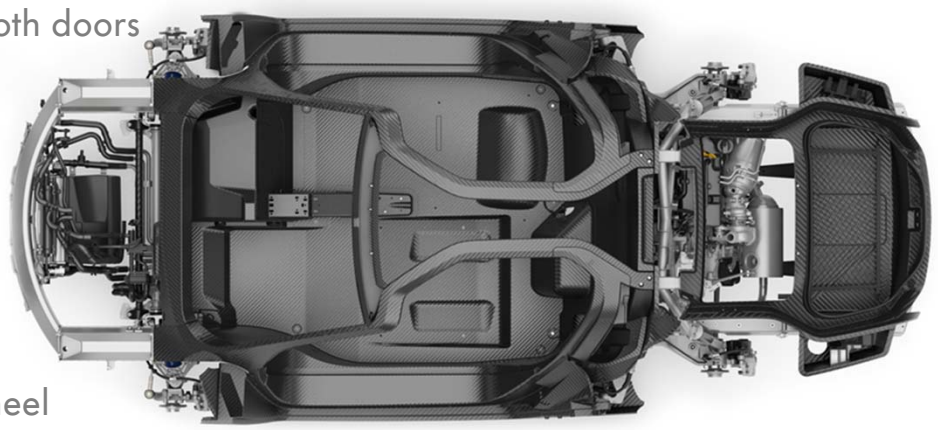
Lightweight and safe

Rollover

- Rollover protection integrated in CFRP monocoque
- Separating bolts in both doors for emergency exit

Rear crash

- Wheel capture claw, rear wheels
- Aluminium crash tubes with crossmembers



Frontal crash

- Airbag in steering wheel
- Aluminium crash tubes with crossmembers
- Sandwich structure (CFRP / PMI foam) in firewall
- Wheel capture claw, front wheels

Side crash

- Aluminium impact beams in the doors
- Capture claw in area of doors/sills
- CFRP crash element in floor area

Reducing resistance and drag: Lightweight design of running gear

CFRP anti-roll bars

Steering without need for steering assist

Narrow tyres, magnesium wheels

Shown:
front wheel

Ceramic brake discs

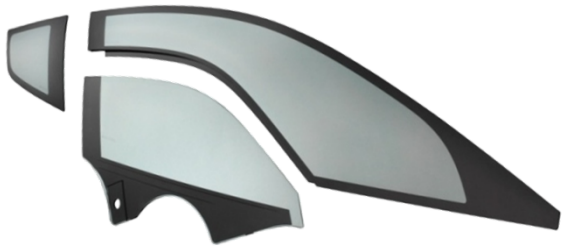
- CFRP engine bearing
- 10-litre fuel tank,
- Aluminium hollow casting of semi-trailing link
- Etc.

Reducing resistance and drag: Other lightweight design measures

Single-shell CFRP comfort seats

Polycarbonate side windows

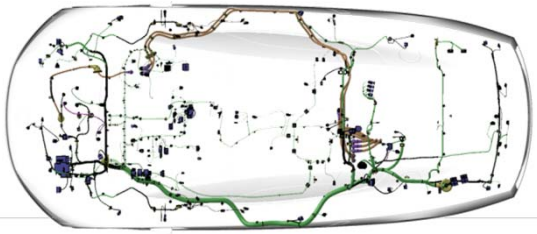
SABIC Lexan with Exatec coating method



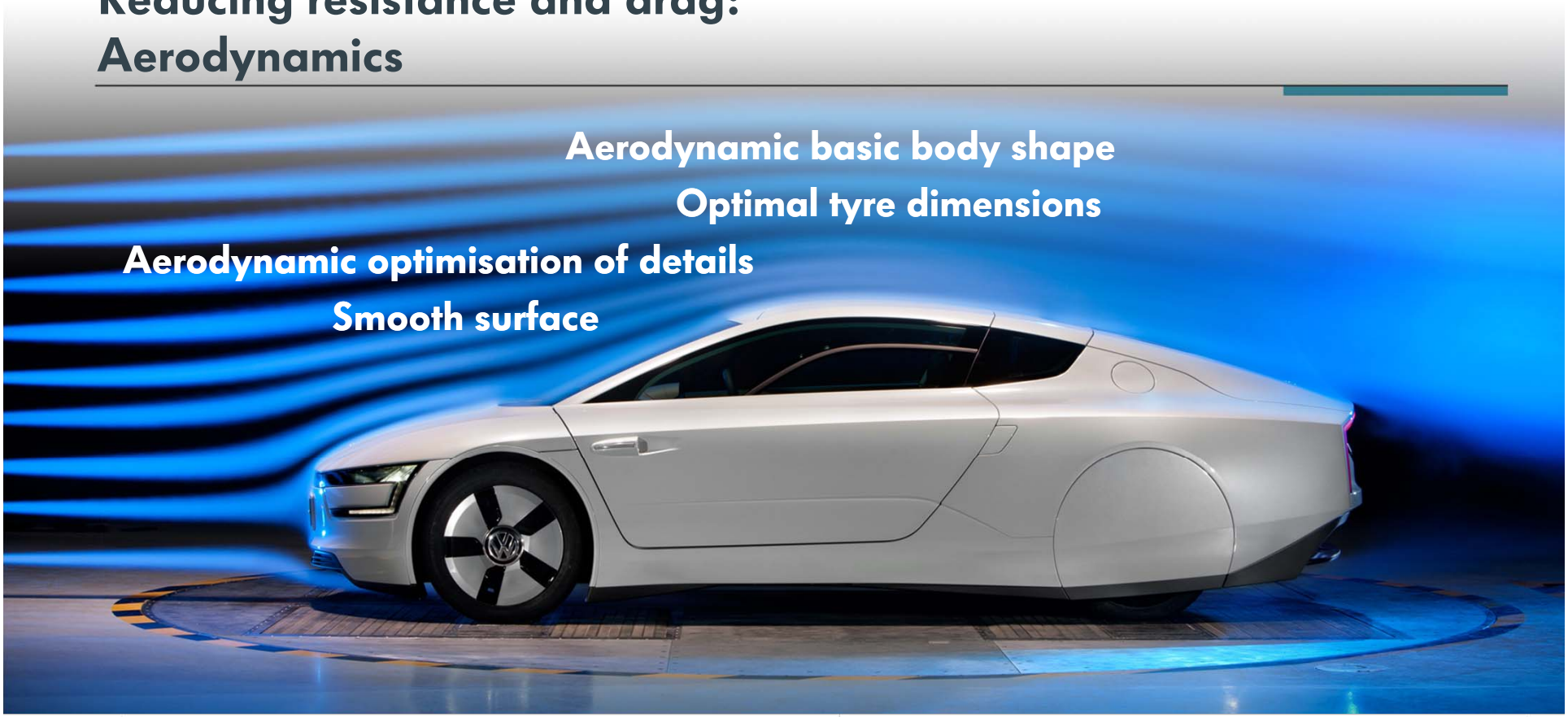
Natural fibre dashboard, Magnesium module crossmember

Lightweight electrical system

(Aluminum wiring, reduced wire gauges, decentralised fuse concept)



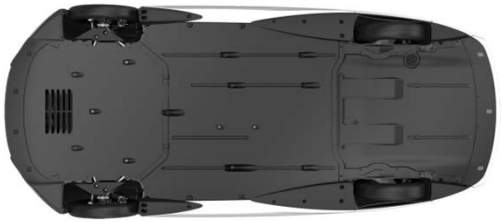
Reducing resistance and drag: Aerodynamics



Reducing resistance and drag: Aerodynamics

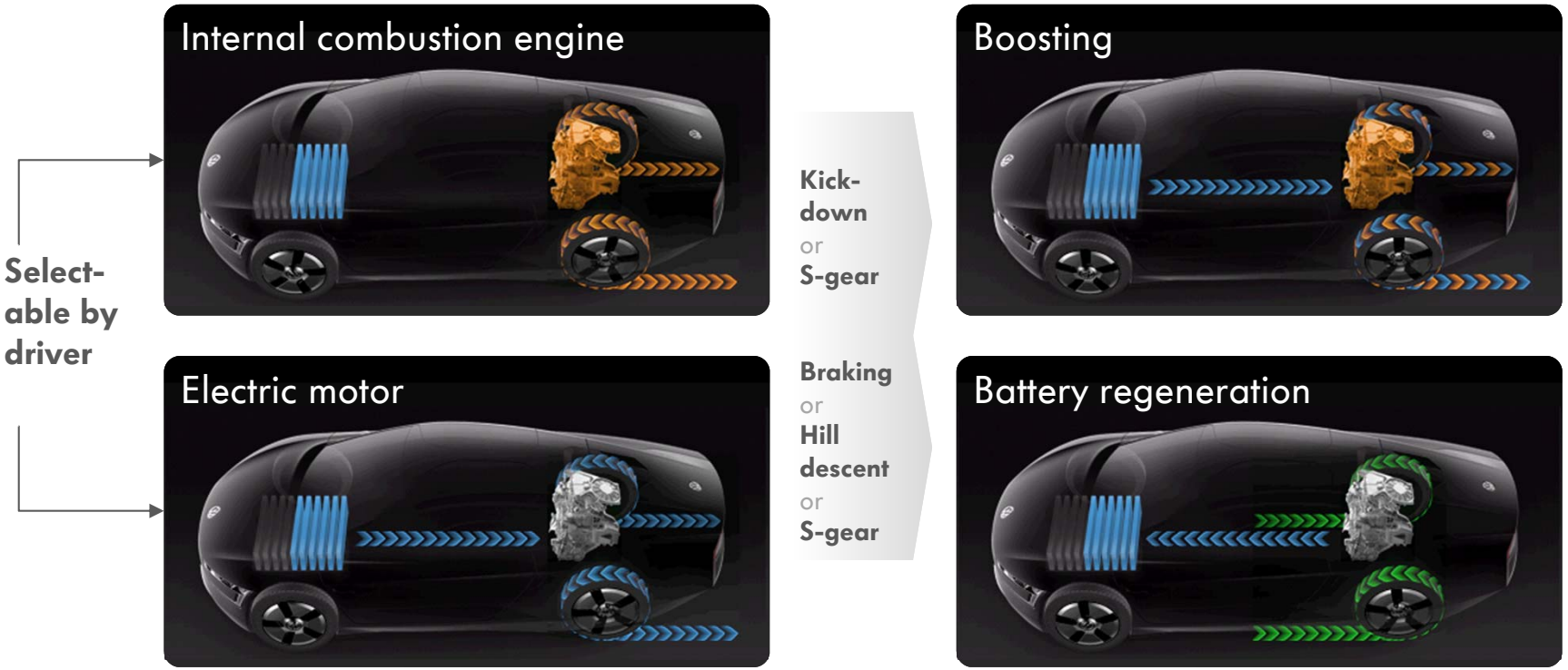
Aerodynamic basic body shape
- Small frontal area based on low overall height and narrower roof structure
- Wider front end, narrower at rear
- Low roof profile

Smooth surface
- Cooling air obtained without large air intakes
- e-Mirror system instead of door mirrors
- Underbody fully enclosed
- Rear wheels fully covered



Other aerodynamic measures
- Rear surface offset forward (“Attika”)
- Cooling air intake can be closed by louvres
- Leading and trailing aerodynamic shaping in front of and behind wheels

Operating strategies
Energy flows



Wide-ranging everyday practicality despite extreme efficiency

- Convenient entry due to large door openings despite low body
- Comfortable space provided for both occupants
- Adjustable driver‘s seat and steering wheel

- Dual clutch gearbox for high level of ride comfort
- Cruise control system
- Brake booster
- ABS and electronic stabilisation programme

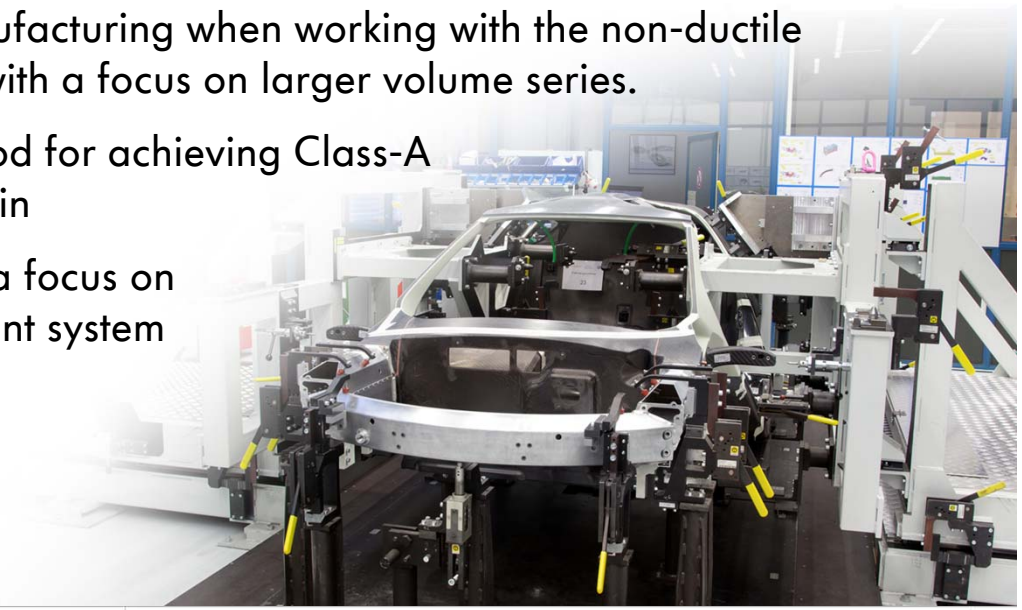
- Full range of multimedia devices with radio, navigation, Internet
- Air conditioning and PTC auxiliary heating
- Cargo capacity approx. 120 litres
- Parking assistant

Results designed for maximum efficiency

- Aerodynamics: **Cd = 0.189**
- Curb weight (without driver): **795 kg**
- Top speed (electronically controlled): **160 km/h**
- Fuel consumption (NEDC): **0.83 l/100 km**
- CO_2-emissions (NEDC): **21 g/km**
- Electrical range **50 km**
- Total range **approx. 500 km**

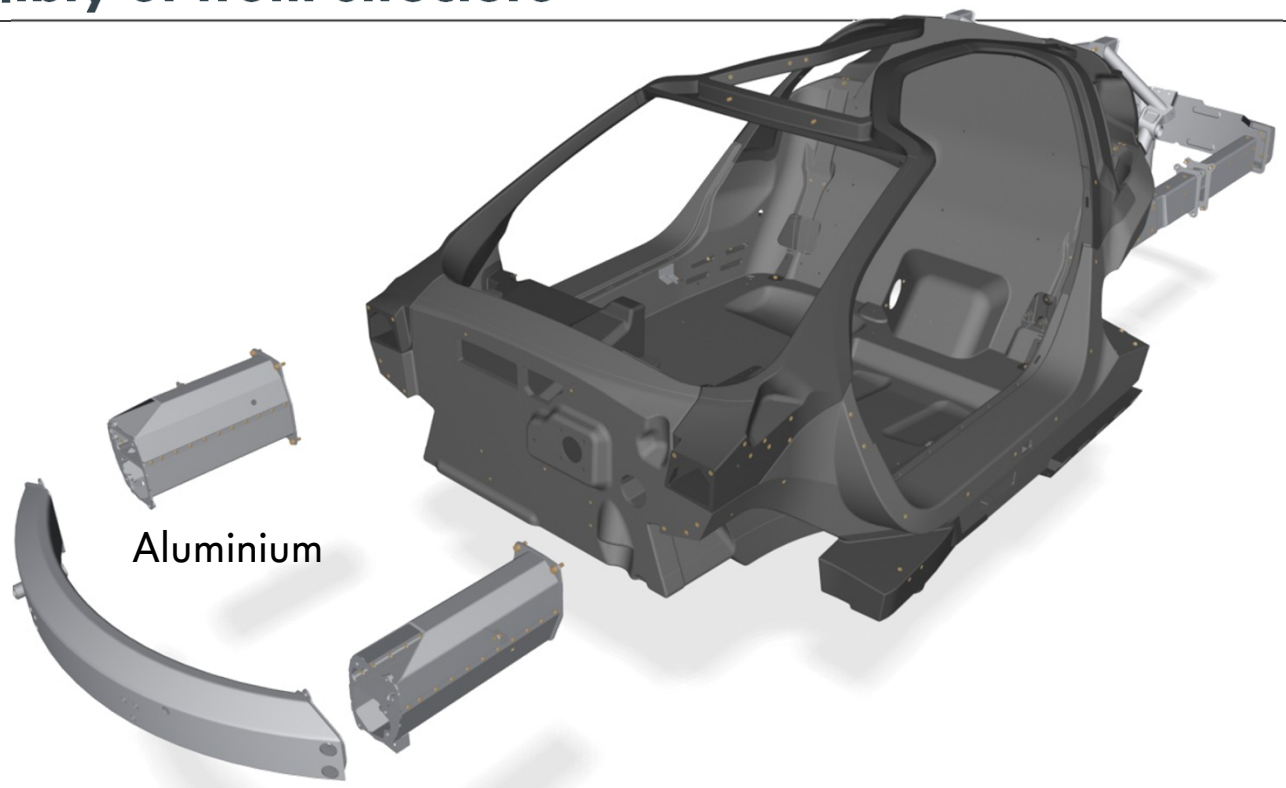
Tasks & challenges of XL1 production:

- Implement industrial processes in the manufacture of CFRP components (aRTM) and other parts/modules (PC windows, CFRP anti-roll bars, etc.)
- Achieve process assurance in body manufacturing when working with the non-ductile material CFRP together with aluminium with a focus on larger volume series.
- Implement a high-volume painting method for achieving Class-A paint buildup quality on CFRP exterior skin
- Modular, flexible vehicle assembly with a focus on future integration in a modular component system strategy.

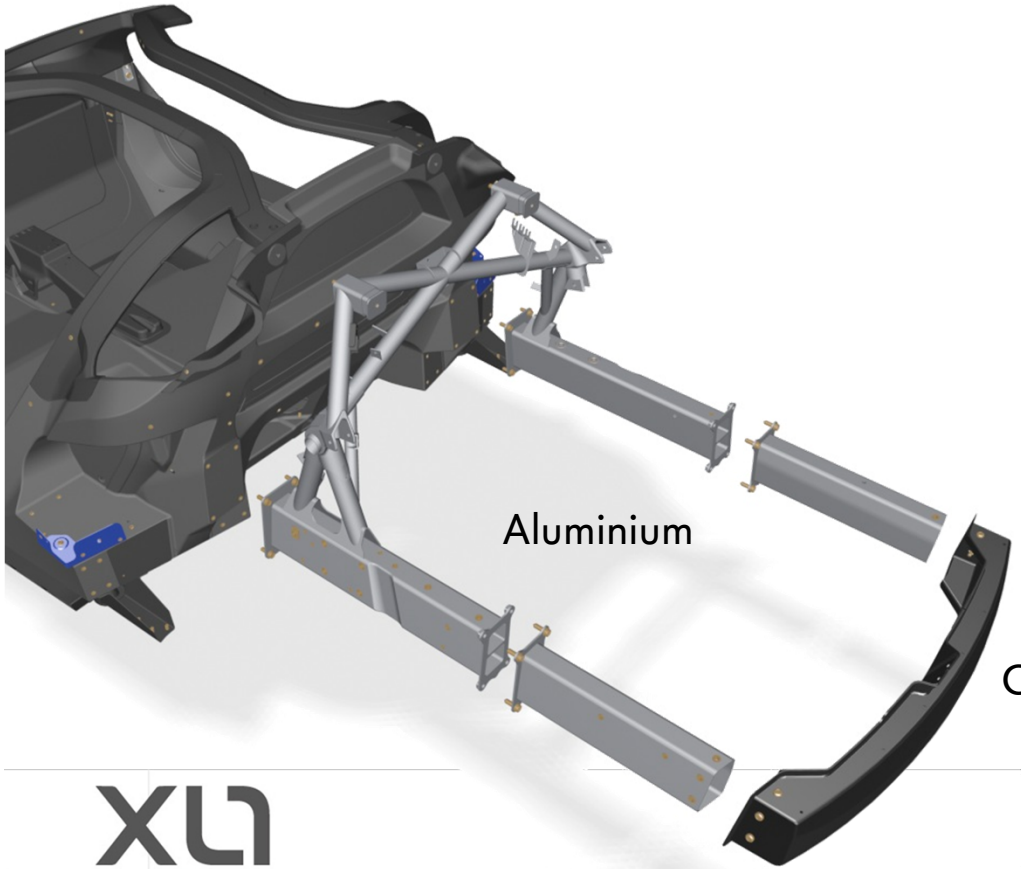


Finished CFRP monocoque

Assembly of front structure



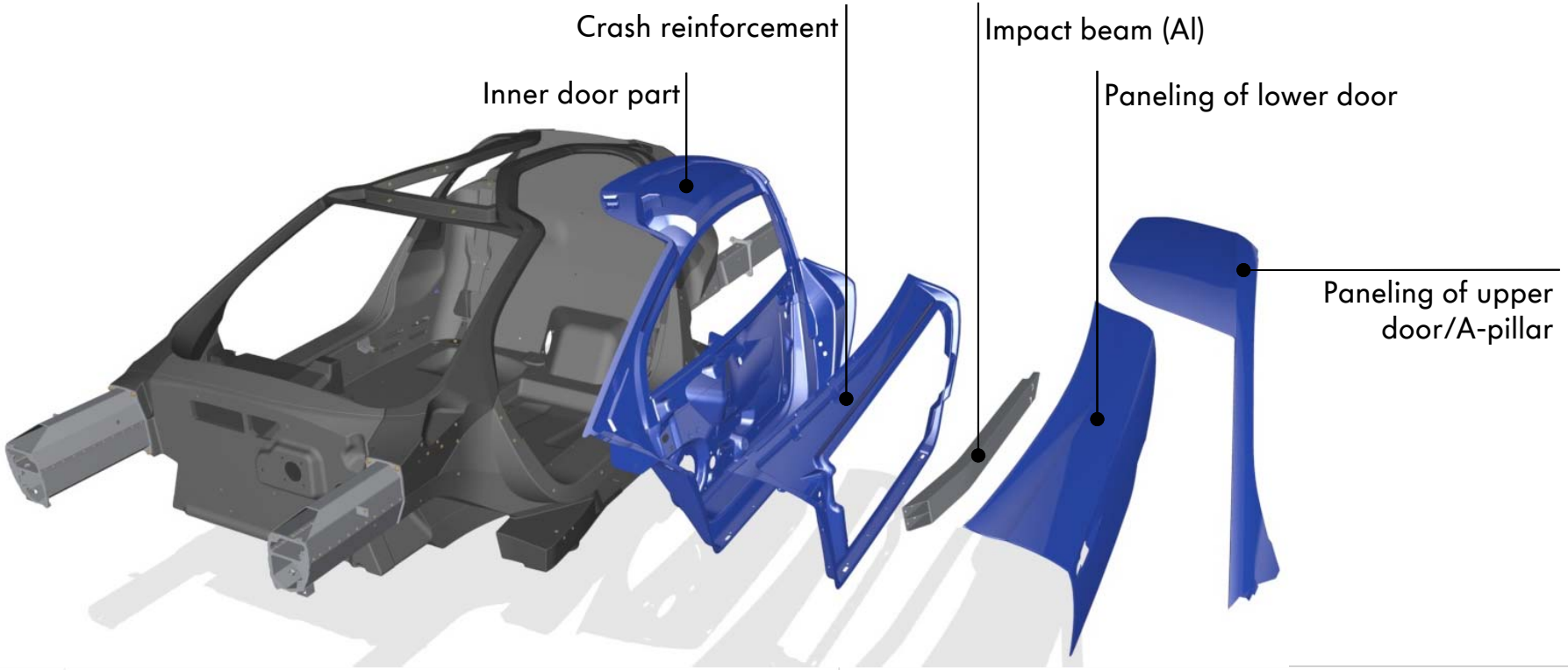
Assembly of rear structure



Assembly of body structure

- Precision geometry station (automatable) for joining monocoque, aluminium crash structures and exterior skin (roof)
- Use of specially developed adhesives

Manufacturing and installing swivel door



Body assembly with doors