Routes Towards Low Carbon Luxury Vehicles

Dr Mike Richardson 4th December 2014
Brand Requirements
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Showroom

2014
Global Sales Growth

- **Jaguar Land Rover Total**

<table>
<thead>
<tr>
<th>Year</th>
<th>Sales</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009/10</td>
<td>208,197</td>
<td>+ 16%</td>
</tr>
<tr>
<td>2010/11</td>
<td>240,905</td>
<td>+ 27%</td>
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<tr>
<td>2011/12</td>
<td>305,859</td>
<td>+ 22%</td>
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<tr>
<td>2012/13</td>
<td>374,636</td>
<td>+ 16%</td>
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<tr>
<td>2013/14</td>
<td>434,311</td>
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Jaguar Land Rover Total sales grew significantly from 2009/10 to 2013/14.
Sources of Energy: Timescales

- **Seconds**
  - Photovoltaic Electricity

- **Minutes**
  - Direct Solar Heating

- **Hours**
  - Wind

- **Days - Weeks**
  - Water Power

- **Months - Years**
  - Biomass

- **Millions of Years**
  - Fossil Fuel
    - Coal, N. Gas, Oil

http://www.apsenergyconservation.org/PDF/MS-FormationOfFossil.pdf
Worldwide Greenhouse Gas / CO2 / Fuel Economy Regulations to 2025

EU 2020: 95

China 2020: 117

US 2025: 109

[1] China's target reflects gasoline vehicles only. The target may be higher after new energy vehicles are considered.
In the medium term fossil fuels will predominate:

- Petrol/diesel falls gradually
  - 90% in 2030 to 50% in 2050
- EV / Hydrogen share will grow
- Liquid fuels continue to be majority with low to moderate uptake of biofuels
- 2nd generation biofuels will complement or replace 1st generation as land and food issues continue

Source: Ricardo-AEA analysis
Land Rover Carbon Reduction Philosophy

3 areas:

- Weight Reduction
- Powertrain Innovation
- Parasitic Loss Reduction
Life Cycle Design

- Power Supply
- Fuel Production
- Material Extraction
- Material Production
- Vehicle Manufacturing
- Vehicle Use
- Recycling
- Landfill
- Disposal
- Emissions to air & water
- Energy
- Production
- Raw material
- Waste

- Use
- Energy
- Emissions to air & water

- Disposal
- Energy
- Emissions to air & water
- Waste
Virtuous Circle of Weight Reduction

Achieved weight saving of 420kg – equivalent to the weight of five adults

Reduced weight improves vehicle dynamics and contributes to more agile and responsive handling

Every 100kg saved in the vehicle mass saves around 2% in fuel consumption

8% better fuel efficiency overall as a result of the weight saving
Whole Vehicle Efficiency

Intelligent Power Management & Smart Regenerative Charging
Optimised aerodynamic design and Active Vanes
Lightweight body construction

Uprated Auto Trans 8 Speed Transmission
Transmission Idle Control Torque converter lock-up strategy
Friction optimised common rail diesel engine
Electric cooling fan
Efficient Alternator and AC compressor
Electric Power Assisted Steering

Low Rolling Resistance Tyres Driveline optimisation Stop-Start technology
Down-sized turbo-charged engine
Individual manufacturers will prioritise certain technologies to fit with brand values, but OEMs share a common view of a high level Technology Roadmap.

- **Low Carbon Technology Roadmap**

  - **EU Fleet Average CO₂ Targets (g/km)**
  - **130**
  - **95**
  - **TBD**

  - **Fuel Cell Vehicle**
  - **H₂ Infrastructure**
  - **Mass Market EV Technology**
  - **Charging Infrastructure**
  - **Plug-In Hybrid**
  - **Energy Storage Breakthrough**
  - **Full Hybrid**
  - **Micro/Mild Hybrid**
  - **IC Engine and Transmission innovations (gasoline/diesel/gas/renewables/H₂)**
  - **Vehicle Weight and Drag Reduction**

  - Phase 1
  - Phase 2
  - Phase 3
Range Rover Hybrid Technology

- Power electronics
- Inverter & DC:DC converter
- Li-ion battery
- Permanent Magnet AC Synchronous Motor
- 3.0l V6 turbocharged Diesel
Performance vs Economy - Diesel

**Better**

- **13MY Range Rover TDV6**
  - 196g/km, 7.9s 0-100km/h

- **11MY Range Rover TDV8**
  - 254g/km, 7.8s 0-100km/h

- **15MY TDV6 Range Rover Hybrid**
  - 169g/km, 6.9s 0-100km/h

- **13MY Range Rover TDV8**
  - 229g/km, 6.8s 0-100km/h
Vehicle Energy Consumption

Energy required to drive vehicle over cycle. Powertrain independent - Wh/km

Powertrain efficiency, CO₂ g/Wh

Energy for tyres, aero and accelerating vehicle mass
Ancillary loss energy
Transmission and driveline loss energy
Coolant waste heat energy
Exhaust waste heat energy
Fuel Energy
Engine waste energy
Energy discussion

157Wh/km

Power Lines 92% Efficient

Battery Charger 89% Efficient

Li-ion Batteries 94% Efficient

Electric Drivetrain 80% Efficient

- Vehicle 129Wh/km

144Wh/km

Europe grid average 0.566g CO₂/Wh
Norway grid average 0.003g/Wh

Equivalent to
Eu 82gCO₂/km
Norway 0.432 g/km

22kWh battery needs ~10400kWh of energy to make.
10 years at average of 40km/day (95% population)
=146,000km.
Equivalent CO₂: Eu Grid 40g/km; Norway Grid 0.21g/km
Research Activities

- Leander
- REHEV
- CX75
- Range_e
- REEVolution
- Evoque_e
- Catapult
- Limo Green
Future Electrification

• Evoque_e project in conjunction with the Technology Strategy Board & partners is investigating several electrification options.

• 3 vehicles are being developed:
  • Full EV Battery Electric Vehicle
  • Plug-in Hybrid Electric Vehicle
  • Mild Hybrid Electric Vehicle.

• A broad range of additional technologies will be applied across these vehicles to further advance our experience in optimising the electrification of our vehicles.
Luxury customers are unlikely to compromise their requirements. This means that luxury vehicle manufacturers have some interesting challenges ahead.

Fossil fuels will be here for a while. We need to make the best possible use of these through improvements in vehicle and propulsion system efficiency.

JLR has plans to drive down CO₂ emissions in all areas of the business as well as lifetime CO₂.

Electrification is a key enabler, with many different architecture options available, however decarbonisation of the grid and reduction of the embedded energy in the battery are important requirements.
Paths to Low CO₂

Future vehicles’ technology will permit sourcing energy from lower carbon options and manage energy more frugally (thermal, kinetic and losses).

Courtesy ERTRAC - Energy Carriers for Powertrains 2014