Energy & Fuels Road Map
Technology Group 2015 activities

Neville Jackson
Chief Technology & Innovation Officer, Ricardo plc
Auto Council Technology Group priorities & activities are focused on delivery of the Automotive Industrial Strategy

1. Invest [up to £1 billion over 10 years] in a new **Advanced Propulsion Centre** (APC)
2. Enhance collaboration on innovation and technology between **motorsport** and mainstream automotive
3. Identify the future high value **manufacturing technologies** that are required to deliver the technology road maps
4. Create an **energy storage** roadmap which includes non-electric solutions
5. Create an **intelligent mobility** demonstration program in UK where effectiveness and the business case can be tested
6. Consider opportunities from **EU R&D funding** and how to improve collaboration/access
7. Improve coordination and collaboration with the **academic research** community to align research funding with industry challenges
8. Conduct analysis of **future technology** needs and **additional critical roadmaps** for the sector to support the prioritisation of collaborative technology work
9. Establish a **Design** specific workstream to focus and further build UK strength in the discipline
Roadmap for Light Duty, Commercial Vehicle and Off-Highway energy – background and objectives

- **Need:**
  - Future perspective of Transport Energy sources and vectors consistent with long term Green House Gas targets for UK

- **Objectives:**
  - To create a high level consensus view for the future of transport energy in the UK that is consistent with A/C passenger car and heavy duty/off highway roadmaps

- **Team:**
  
  Neville Jackson - Ricardo (Chair)  
  Richard Pearson - BP  
  Felix Balthazar - Shell  
  Jamie Turner - Jaguar LandRover  
  Steve Faulkner - Caterpillar  
  Jonathan Murray - LowCVP  
  Celine Cluzel - Element Energy  
  Adam Chase - E4tech  
  Richard Stark - Associated British Foods  
  Liam Lidstone - Energy Tech. Institute  
  Ed Bower - Ricardo (Facilitator)

- **Positive feedback from:**
Inputs to the roadmap included recent UK & EU studies and the Pass Car, Commercial Vehicle & ICE roadmaps

- ERTRAC roadmap “Energy Carriers for Powertrains”
- E4Tech “A Harmonised Auto-Fuel Biofuel Roadmap for the EU to 2030”
- Element Energy (LowCVP) “A Fuel Roadmap for the UK”
- Auto Council Passenger Car & Commercial/Off-Highway Vehicle Roadmaps
Energy Roadmap shows long term transition from gasoline & diesel fuels to a majority renewable energy portfolio

UK: Energy Roadmap for Passenger Cars, Commercial & Off-Highway Vehicles

Policy:
- RED/FQD/ Air Quality

Targets: Vehicle CO₂:
- “Tailpipe” CO₂ Requirements
- Well to Wheel CO₂
- Life Cycle based Requirements

UK GHG (ref 1990):
-29%
-35%
-50%
-80%

High level targets derived from fuels, renewable energy & air quality directives

Source: Automotive Council, ERTRAC, E4tech, Element Energy
Energy Roadmap shows long term transition from gasoline & diesel fuels to a majority renewable energy portfolio

UK: Energy Roadmap for Passenger Cars, Commercial & Off-Highway Vehicles

Indicative Energy Mix:
- Liquid Fossil
- Natural Gas Electricity Biofuels (including gas)
- Others

Main energy vectors colour coded to match energy mix indicators

Indicative energy mix highlights increased use of alternatives to liquid fossil fuels

UK GHG (ref 1990):
- Indicative Energy Mix:
  - Gasoline
  - Diesel
  - Electricity
  - Natural Gas
  - Hydrogen
  - Niche fuels

Policy:
- RED/FQD/Air Quality
- “Tailpipe” CO₂ Requirements
- Well to Wheel CO₂
- Life Cycle based Requirements

Targets: Vehicle CO₂:
- UK GHG (ref 1990):
  - -29%
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UK: Energy Roadmap for Passenger Cars, Commercial & Off-Highway Vehicles

Policy:
Targets: Vehicle CO₂:
UK GHG (ref 1990):
Indicative Energy Mix:

Subject to sustainable feedstock availability

Gasoline
Diesel
Electricity
Natural Gas
Hydrogen
Niche fuels

Key:
Introduction
Mainstream
Phasing out

Energy Roadmap shows long term transition from gasoline & diesel fuels to a majority renewable energy portfolio

Moving beyond E10 would require a sustainable mix of "food" and increasingly "non-food" crop biofuels – supply of the latter is a significant challenge

Next step from E5/E10 either E20 with backwards compatibility issues or more use of “drop-in” bio content to retain standard fuel specifications

Source: Automotive Council, ERTRAC, E4tech, Element Energy
Energy Roadmap shows long term transition from gasoline & diesel fuels to a majority renewable energy portfolio

UK: Energy Roadmap for Passenger Cars, Commercial & Off-Highway Vehicles

Policy:
Targets: Vehicle CO₂:
UK GHG (ref 1990):
Indicative Energy Mix:

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<thead>
<tr>
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<tbody>
<tr>
<td>-29%</td>
<td>Liquefied CO₂ correction</td>
</tr>
<tr>
<td>-35%</td>
<td>Natural Gas Liquid</td>
</tr>
<tr>
<td>-50%</td>
<td>Electricity Liquid</td>
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Subject to sustainable feedstock availability

- Liquid Fossil
- Natural Gas
- Electricity
- Biofuels (including gas)

- Protection grade for E10
- E10
- E20+ with ‘Drop-in’ bio-gasoline (EN228)
- Longer Term Protection Grade (if required)

Introduction of E10 most likely in 2017 - dependent on Renewable Transport Fuels Obligation target being raised by Government

E20 could also include butanol up to equivalent oxygenate levels

Assume that protection grade available as required to enable continued operation for older vehicles

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Energy Roadmap shows long term transition from gasoline & diesel fuels to a majority renewable energy portfolio

UK: Energy Roadmap for Passenger Cars, Commercial & Off-Highway Vehicles

Targets: Vehicle CO₂:
UK GHG (ref 1990):
Indicative Energy Mix:
Mix: Others

UK GHG (ref 1990):
-29%
-35%
-50%
-80%
-29%
-35%
-50%
-80%

“Tailpipe” CO₂ Requirements
Well to Wheel CO₂
Life Cycle based Requirements

Electricity (Inc Power to Gas: H₂+CH₄)
Biofuels (including gas)
Liquid Fossil
Nat Gas

Indicative Energy Mix:
-29%
-35%
-50%
-80%

2015 2020 2025 2030 2040 2050

Natural Gas
Hydrogen
Niche fuels

Electricity

Gasoline

Diesel

Unlikely to go beyond B7 blend wall unless vegetable oil availability increases or alternatives such as microbial or microalgal oils are successfully developed in volume

Potential growth in HVO production capacity to provide low carbon, sustainable drop-in biodiesel and bio-naphtha

HVO as “drop in” component already used in current fuels

Subject to sustainable feedstock availability

Source: Automotive Council, ERTRAC, E4tech, Element Energy
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UK: Energy Roadmap for Passenger Cars, Commercial & Off-Highway Vehicles

Policy:
Targets: Vehicle CO₂:
UK GHG (ref 1990):
Indicative Energy Mix:

RED/FQD/Air Quality
“Tailpipe” CO₂ Requirements
Well to Wheel CO₂
Life Cycle based Requirements

-29%
-35%
-50%

Natural Gas
Electricity
Biofuels
(including gas)

-80%

Electricity (Inc Power to Gas: H₂+CH₄)
Biofuels (including gas)

Gasoline
Diesel
Electricity
Natural Gas
Hydrogen
Niche fuels

Depending on GHG benefit/economics
LPG/CNG/LNG/H₂/B30/E85 etc

Wide range of “niche” fuels – only likely to move into mainstream if supported by policy drivers (GHG/Air Quality) and associated economics/availability/supply infrastructure and fiscal regimes

Source: Automotive Council, ERTRAC, E4tech, Element Energy
Energy Roadmap shows long term transition from gasoline & diesel fuels to a majority renewable energy portfolio

UK: Energy Roadmap for Passenger Cars, Commercial & Off-Highway Vehicles


Targets: Vehicle CO₂:
- UK GHG (ref 1990):
- Indicative Energy Mix:

Well to Wheel CO₂
- RED/FQD/Air Quality
- "Tailpipe" CO₂ Requirements
- LIFE Cycle based Requirements

-50%
-35%
-29%

Key:
Introduction ➔ Mainstream ➔ Phasing out

Direct use of electricity in transport in line with Auto Council Pass Car and Commercial Vehicle roadmaps

Power to Gas technology offers potential solution for renewable electricity “storage”

Increasing Decarbonisation (direct use dependent on EV/PHEV growth/battery breakthrough)

Power to Gas (H₂ & CH₄)

Renewable electricity to Hydrogen & Synthetic Methane dependent on success of H₂ Fuel Cell vehicles and economics of supply

Lower Carbon NG/LNG

'Green' H₂

Source: Automotive Council, ERTRAC, E4tech, Element Energy
Energy Roadmap shows long term transition from gasoline & diesel fuels to a majority renewable energy portfolio

**UK: Energy Roadmap for Passenger Cars, Commercial & Off-Highway Vehicles**

**Policy:**
- Targets: Vehicle CO₂:
  - UK GHG (ref 1990):

**Indicative Energy Mix:**
- Natural Gas
- Hydrogen
- Electricity
- Diesel
- Gasoline
- Others

**Key:**
- Introduction
- Mainstream
- Phasing out

**Energy Roadmap shows long term transition from gasoline & diesel fuels to a majority renewable energy portfolio**

- Gas to Liquids & Refining (replacing fossil Natural Gas)
- Gasoline
- Diesel
- Electricity
- Natural Gas
- Hydrogen
- Others

**Potential use for “green” H₂ and Synthetic Methane to substitute for fossil Natural Gas in refineries**

**Targets:**
- Vehicle CO₂: RED/FQD/Air Quality
- “Tailpipe” CO₂ Requirements
- Well to Wheel CO₂
- Life Cycle based Requirements

**RED/FQD/Air Quality:**

**UK GHG (ref 1990):**
- Gasoline
- Natural Gas
- Hydrogen

**Niche fuels**

**2015**
**2020**
**2025**
**2030**
**2040**
**2050**

Source: Automotive Council, ERTRAC, E4tech, Element Energy
Energy Roadmap shows long term transition from gasoline & diesel fuels to a majority renewable energy portfolio

UK: Energy Roadmap for Passenger Cars, Commercial & Off-Highway Vehicles

**Policy:**
- Life Cycle based Requirements

**UK GHG (ref 1990):**
- Gasoline
- Natural Gas
- Hydrogen
- Diesel

**Indicative Energy Mix:**
- Liquid Fossil
- Biofuels (including gas)
- Electricity

**Subject to sustainable feedstock availability:**
- 'Green' H₂
- Lower Carbon NG/LNG
- ‘Fossil’ NG/LNG

**‘Tailpipe’ CO₂ Requirements:**
- 29%
- 35%
- 50%

**Well to Wheel CO₂ Targets:**
- E5 + ‘Drop-in’ bio-gasoline (EN228)
- E10
- E20+
- -80%

**‘Tailpipe’ CO₂ Requirements:**
- Increasing Decarbonisation (direct use dependent on EV/PHEV growth/battery breakthrough)

**Security of Supply/Sustainability/Integrated Energy Policies:**
- Electricity (Inc Power to Gas: H₂ & CH₄)
- Biofuels (including gas)

**RED/FQD/Air Quality:**
- Subject to sustainable feedstock availability

**Life Cycle based Requirements:**
- Electricity (inc Power to Gas: H₂ + CH₄)
- Biofuels (including gas)

**Natural Gas:**
- Gas to Liquids & Refining (replacing fossil Natural Gas)

**Electricity:**
- Power to Gas (H₂ & CH₄)

**Hydrogen:**
- H₂ - Steam Reforming
- ‘Green’ H₂

**Niche fuels:**
- LPG/CNG/LNG/H₂/B30/E85 etc

Source: Automotive Council, ERTRAC, E4tech, Element Energy

Image credit: Automotive Council UK
The roadmap shows some complex interactions but provides some clear future messages

Key Roadmap messages:

- Roadmap shows long term (2050) transition from current gasoline & diesel fuels to a majority renewable energy portfolio
- Introduction of E10 most likely in 2017 - dependent on Renewable Transport Fuels Obligation target being raised by Government
- Auto & Oil Industry preference for any further increases in bio content should feature “drop-in” fuels that retain existing fuel specifications
- Increasing use of electricity in battery electric and plug-in vehicles but also potential for “power to gas” – electricity to Hydrogen & synthetic Methane – which can be stored
- Renewable gases may be best used in refinery processes rather than directly in transport to substitute for fossil Natural Gas – this reduces carbon content of liquid fuels
- “Niche” fuels (LPG/CNG/LNG/H2/B30/E85) only likely to move into mainstream if supported by policy drivers and associated economics/ availability/ supply infrastructure
- Fuel specifications and standards must be defined at EU level at a minimum and preferably on a global scale, sufficiently in advance of fuel & vehicle market introductions

The road map provides an insight into pathways to meet the UK 2050 80% GHG reduction target. It does not represent definitive pathways being pursued by Auto Council members