Lotus and global electric vehicles

By Jamie Turner
Chief Engineer – Powertrain Research

Lotus and global electric vehicles

- **Lotus, low carbon Vehicles and a green Ethos**
- Global Government Intervention
- Electric vehicle Technology Challenges & Trends

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Lotus - Today

Chapman's Philosophies remain Lotus Values:

- Innovation
- Performance through light weight
- Fun to drive
- Great ride & handling

Shareholder – PROTON (Perusahaan Otomobil Nasional Berhad)

Lotus Cars

- Manufactures & Sells 3,000 cars per annum
- Models: Elise, Exige, Europa, 2 Eleven and Evora

Lotus Engineering

- Engineering centres in UK, USA, China & Malaysia
- Global automotive OEM & Tier1 clients
- Engineering Services and Technologies, employing 400 globally
  - Powertrain - Efficient performance / Hybrid & Electric drives
  - Vehicle - Exciting niche vehicles / driving dynamics
  - Design - Concepts / full size models / show cars
  - Research and Technology

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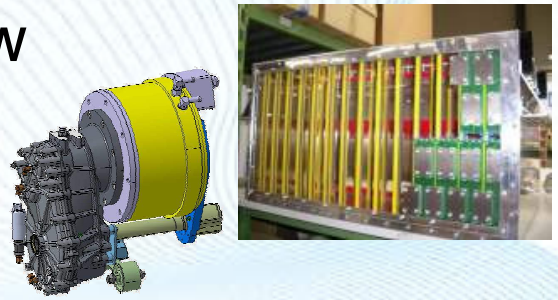
Lotus - A Green Ethos

- Business benefits / drivers;
  - Customer demand
  - Cost reduction
  - Corporate and social responsibility
- The three strands of going green;
  - Reduce - Waste materials (paint solvents, panel lamination process), energy consumption (lights, compressed air CMS, motor inverters, auto meter reading, building management systems)
  - Reuse – Stillage / Kanban system, Water recirculation, tyres (track crash protection)
  - Recyle – office paper, packaging, metals, plastics, oil absorbents and hazardous materials
- In 2006 Lotus HQ emitted over 9000 tonnes of CO_2, last year this was reduced to 7,500 tonnes.
- Waste recycling saved £21,000 pa in landfill
- Lotus will install 3 wind turbines on site saving >15,000 tonnes of CO_2 pa and providing 100% of the site electrical requirements

Hybrid & Electric Vehicle Group Overview

- ‘Holistic’ whole vehicle approach to H & EV systems integration
- Hybrid & Electric systems design
  - 17 years of H & EV experience
  - 30 years Active Controls experience
  - In house Vehicle & drivetrain simulation
  - Control strategies & hardware
  - High Voltage motor & inverter expertise
  - High voltage Battery integration experience
  - Active noise control
  - Mechanical / hydraulic / electrical capability
- Vehicle integration – Hydrogen / EV build areas, Battery build area
- Test facilities – E-motor Dyno, Rolling roads, Test track
- Production facilities



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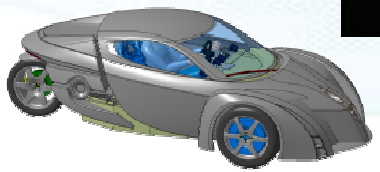
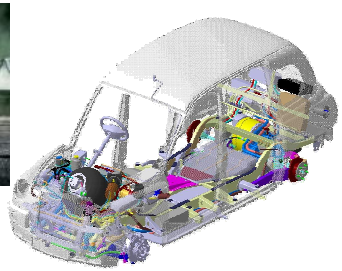
Lotus - Development Electric Vehicles

- 1996 onwards Th!nk Nordic - City car
- 2005 onwards Tesla Motors sports car
- 2007 3 wheel sports concept & series hybrid SUV for ZAP
- 2007 City car 55kW motor; 5-speed transmission
- 2008 City car – Hub motors
- 2008 Sports car x 3 - 190kW, 0-60mph <5s
- 2009 City & Family cars - 125kW motor, 20-40 kWh battery
- 2009 Executive saloon Range Extender engine – Limo Green
- 2009 Hybrid fuel cell taxi 75kW motor, 30 kW fuel cell







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Production Electric Vehicle

- Lotus Cars are assembling the Tesla Roadster under contract
- Lotus Engineering carried out certain design and engineering tasks
- Lotus Engineering supplied the initial chassis modified by Tesla engineers
- Styling developed in Lotus Design Studio

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Government intervention - USA

- US Government has already committed $80 Billion to the struggling automotive sector.
- The Obama administration has assigned $2.4 billion in EV grants for 48 projects :
  - $5.9 billion to Ford - Truck & small car production lines
  - $1.6 billion to Nissan - Battery assembly plant & electric car production line
  - $465 million to Tesla - Model S Sedan production development
  - $301 million to Johnson Controls - manufacturing base for advanced batteries
  - $300 million to Dow Kokam - for manufacturing battery cells and material
  - $249 million to A123 - build a prismatic battery plant
  - $49 million to Celgard - separator production capacity
  - $95.5 million to Saft America - manufacturing plant for lithium-ion cells
  - $10 million for Educational programs

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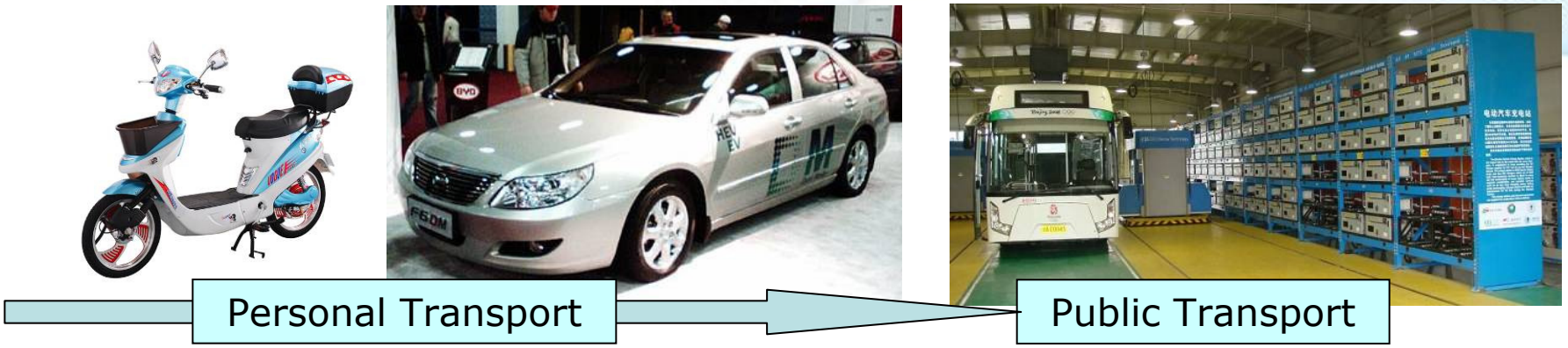
Government intervention - China

- China realize they can not easily close the technology gap in IC Engines and so are focusing incentives on start/stop, plug in hybrids and Electric Vehicles
  - RMB 10bn fund to support new energy cars and parts development
  - Preferential taxes, subsidy and penalty mechanism for vehicle fuel economy
  - Increased rewards to production & consumption of low displ. PHEV & EV's
- Chinese suppliers already have some competitive advantage
  - Li-ion batteries Lower raw materials costs and economies of scale –already has significant manufacturing base, putting resources into R&D and production ramp up and has the ability to drive down costs (investing in automation / quality)
  - Permanent-energized synchronised motors - Already has leading quality product at a low price and local materials resources (80% Neodymium global resource)



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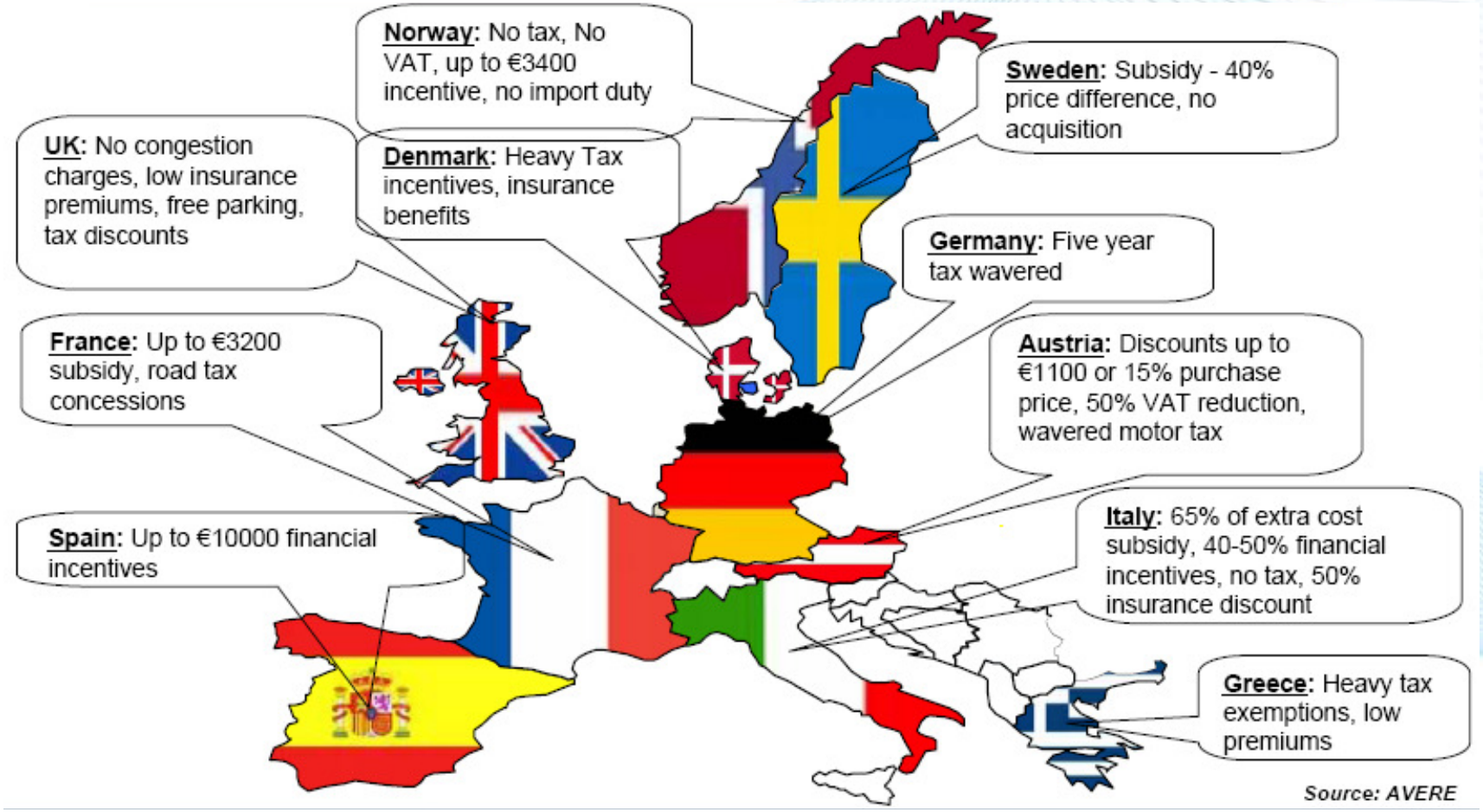
Government intervention – Europe



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Government intervention – UK

- Research and Development has been support through a variety of part funded initiatives through organisations such as;
  - EST - TSB - NAIGT - Low CVP - EPSRC - SMMT
  - ETI - DfT - DECC - Cenex - Mayor of London
  - Lotus consult with many of these organisations and would hope for initiatives to continue

- User and production manufacturing incentives important factors;
  - Clarity of benefit – should be based on M1 vehicle but will need modifying due to ICE centric
    - Vision angles, low speed / high speed crash
    - Concerns with M0 classification, over simplification of requirements (Quadra cycle)
  - Long term application - ref LPG example



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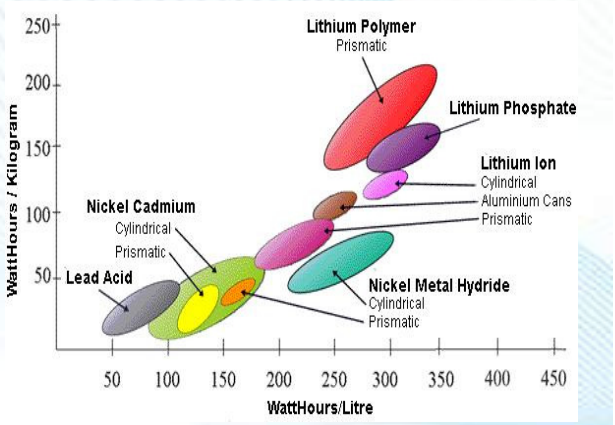
Pure Electric Vehicle – Challenges



- 'Family saloon', battery capacity Pure EV >100kWh: (~300mile range)
  - Battery pack weight (and size) ~ 600 to 1000kg
  - Battery pack cost > £20,000
  - Charge time using a domestic supply
- Technology Maturity / Market Awareness / Standardisation
- Motor power density
  - Continuous rating is typically half the peak rating (hill climbing ability, maximum speed)
- Wheel motors: - Regen braking replacing brakes, Legislation / Market demand
- EV Challenges will drive the requirement for Series HEV in the short to medium term

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Electric Vehicles Trends – Europe / USA

Small City Cars

- Small electric vehicles are developing from quirky niche vehicles into main stream product
- 10-45kW motor and lead acid / lithium batteries.
- G-Wiz, NICE, iMEV, Smart EV etc

Sports Cars

- 85-440kW, top speed of 80 - 130mph & 0-60 in 4s.
- Nickel zinc, Li ion battery, range 100 - 200 miles,
- Tesla roadster / Model S, Dodge EV, ZAP Alias, Fisker

Commercial Transport

- 100-150 mile range at 50mph (max) and 1-2 tonne load capacity
- 75-120kW motor and Sodium Nickel Chloride / Lithium phosphate batteries
  - Smith Edison Van (Sainsbury, TNT and Scottish & Southern Energy
  - Modec Urban Delivery Van (Tesco, Asda & local council fleets)

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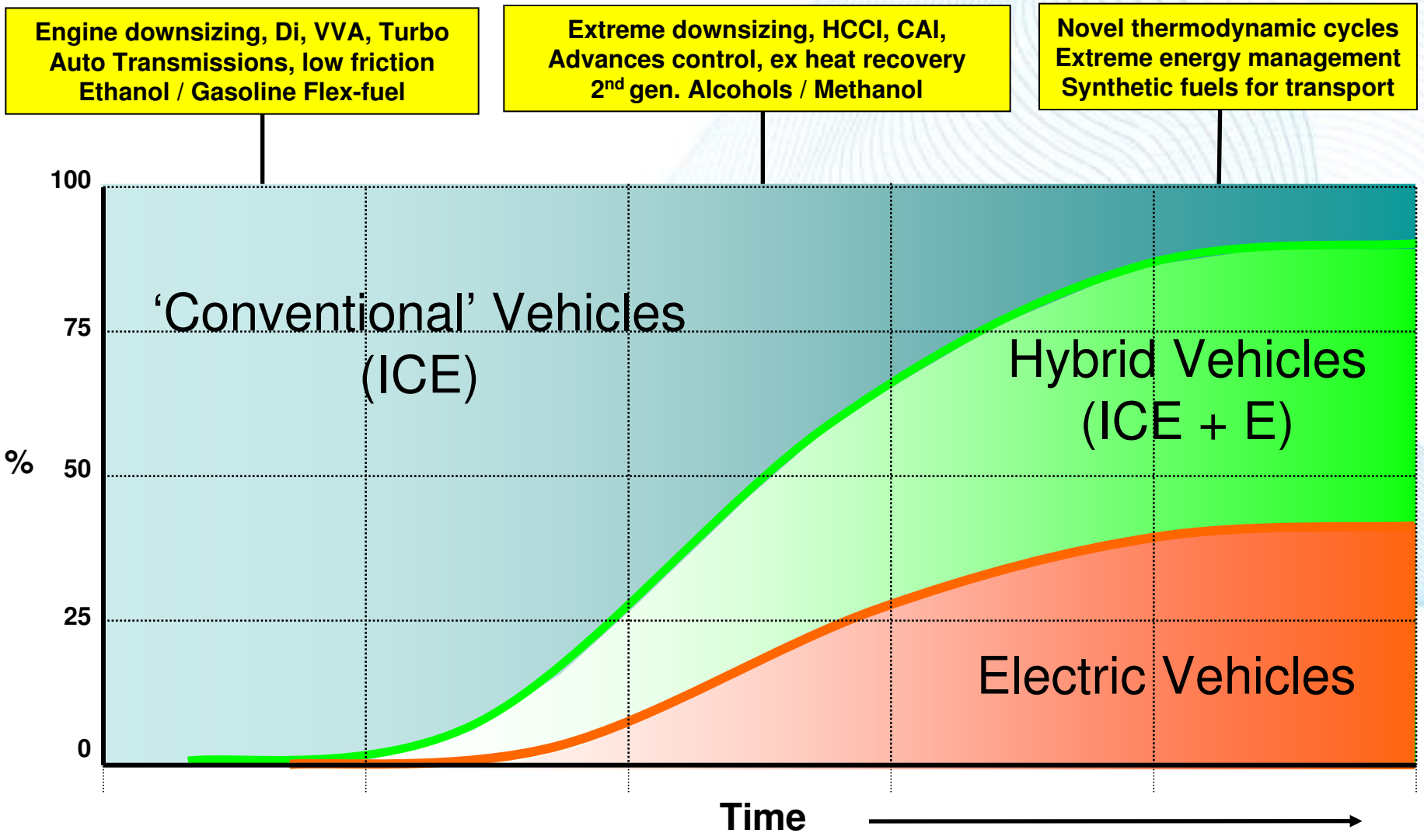
The move from ICE To EV



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Hybrid & Electric vehicles – Lotus View

- The challenge facing electric vehicles is how to make them cost effective and durable
  - Lithium ion cell technology, modular battery packs, Range enhancement, hub motors & BMS
- Lotus Cars Focus on third party manufacture, & keeping a watching brief on technology
  - Need a cost effective solution for niche electric sports car manufacture
- Engineering Focus on micro & mild start/stop systems and electric vehicles (plus REE)
  - Applications luxury car market, city cars & light commercial vehicles.
  - Range extender engines - new engine architecture – restricted speed / low cost
- Battery Electric hybridisation is not the whole picture
  - Flywheel & Ultra capacitors offer efficiency benefits
  - Hydraulic hybrids have potential in light and heavy duty commercial applications, without the disadvantages of electrical systems

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Thank you

If you require further information please contact:
Steve doyle Tel: +44 (0)1953 608561
E-mail: sdoyle@lotuscars.co.uk

www.grouplotus.com