ENGINEERING

HYBRID & ELECTRIC VEHICLE TRENDS

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Slide 1

A1 Titles should be in capitals

Administrator, 03/11/2010

AGENDA

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- Background
- Government Intervention
- Market trends
- Infra Structure
- Battery technologies
- Lotus View / Challenges

MARKET TRENDS –EV'S TO HYBRID AND BACK

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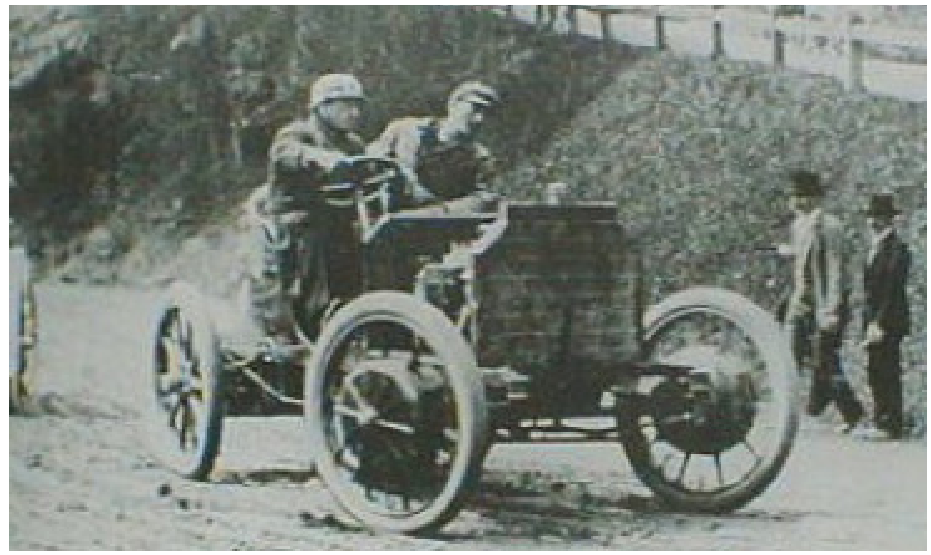
- First electric vehicle - Robert Anderson 1830's
- First hybrid vehicle – Ferdinand Porsche in 1900
  - Series hybrid, Wheel hub motors
  - 300Ah battery, 16hp engine
- Drive configurations / terminology
  - Micro hybrid - Start/stop technology
  - Mild hybrid - Start/stop technology plus torque assist
  - Parallel hybrid - Both IC engine & electric motor can drive the vehicle in Parallel
  - Series hybrid - IC engine drives a generator, wheels driven by electric motor
  - SHEV, EREV or REEV
  - Multi Mode / power split system - combine the above functionality
  - Battery Electric Vehicle - BEV
- Simpler systems offer less functionality & fuel efficiency, but are easier & cheaper to realise
- Hybrid types - Air, kinetic, hydraulic and electric



LOTUS BACKGROUND

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- Lotus involved with over 20 hybrid / electric vehicle projects since 1990
- Over 17 years of hybrid controls experience
- Utilising a range of alternative powertrain architectures
  - Full EV, micro hybrids, stop / start, series and parallel hybrids
- From drivetrain design and concept vehicle builds / technology demonstrators to full production vehicle programmes

INDUSTRY CHALLENGES

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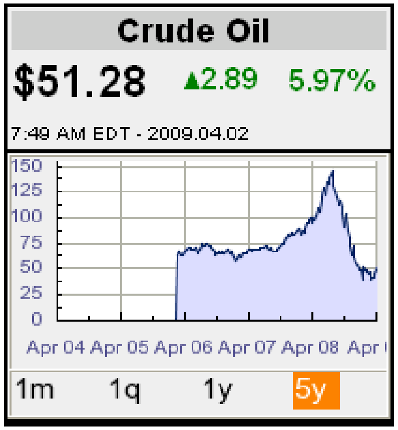
- Lower carbon footprint
  - Global warming and legislation
- Less reliance on fossil fuels
  - Fuel reserves and energy security.
- Affordable technologies for the consumer
  - Cost-effective solutions, economical to use.



THE REALITY – THE PREDICTED SITUATION IN 2020

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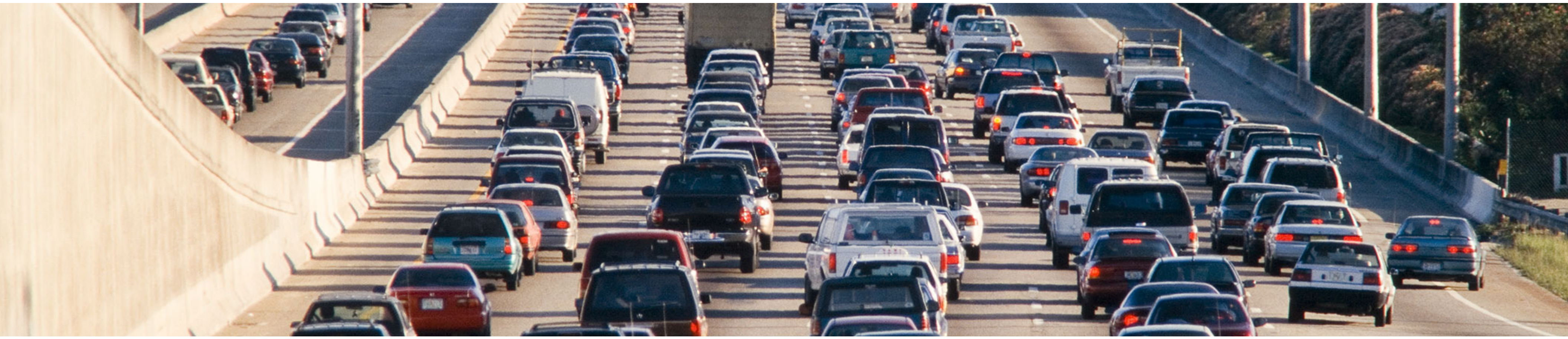

- The number of vehicles in worldwide use will have doubled to 1.2 billion*
- Only 7.3% of sales in 2020 are expected to be BEV / HEV vehicles
  - BEV @ 1.8%*
  - HEV @ 5.5%*
- Average CO_2 emissions per vehicles are expected to reduce by just 19%
- CO_2 emissions from vehicles will continue to rise at a significant rate (+60% by 2020?)
- *Source: J.D. Power : Drive Green 2010: More Hope than Reality?, November 2010

BARRIERS TO BEV / HEV GROWTH

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- Total cost of vehicle ownership
- Range Anxiety of EVs
- Recharging times
- Lack of Infrastructure
- Power and performance
- Battery life and costs
- Rapid rate of technology development may render new vehicle obsolete
- Uncertainty regarding residual values of EV.
- Lack of standardisation may render new vehicle obsolete (betamax video)

GOVERNMENT INTERVENTIONS

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- Emissions legislation (target is an average CO_2 level < 130grams/km)
  - Punitive charges for non compliance
- Increasing levels of Fuel duty taxation
  - In 2008 UK government claimed over £24billion in fuel duty
- Grants for companies developing technologies to support a low carbon economy
- Grants for the development of low carbon infrastructure
- Taxation of vehicles is based on their carbon emissions]
  - reduction and rebates for users of low Carbon vehicles
- Subsidised costs for users of low carbon vehicles
  - Government funded discounts
  - Congestion charge waiver
  - Parking fees
  - Insurance benefits

GOVERNMENT INTERVENTION – EUROPE

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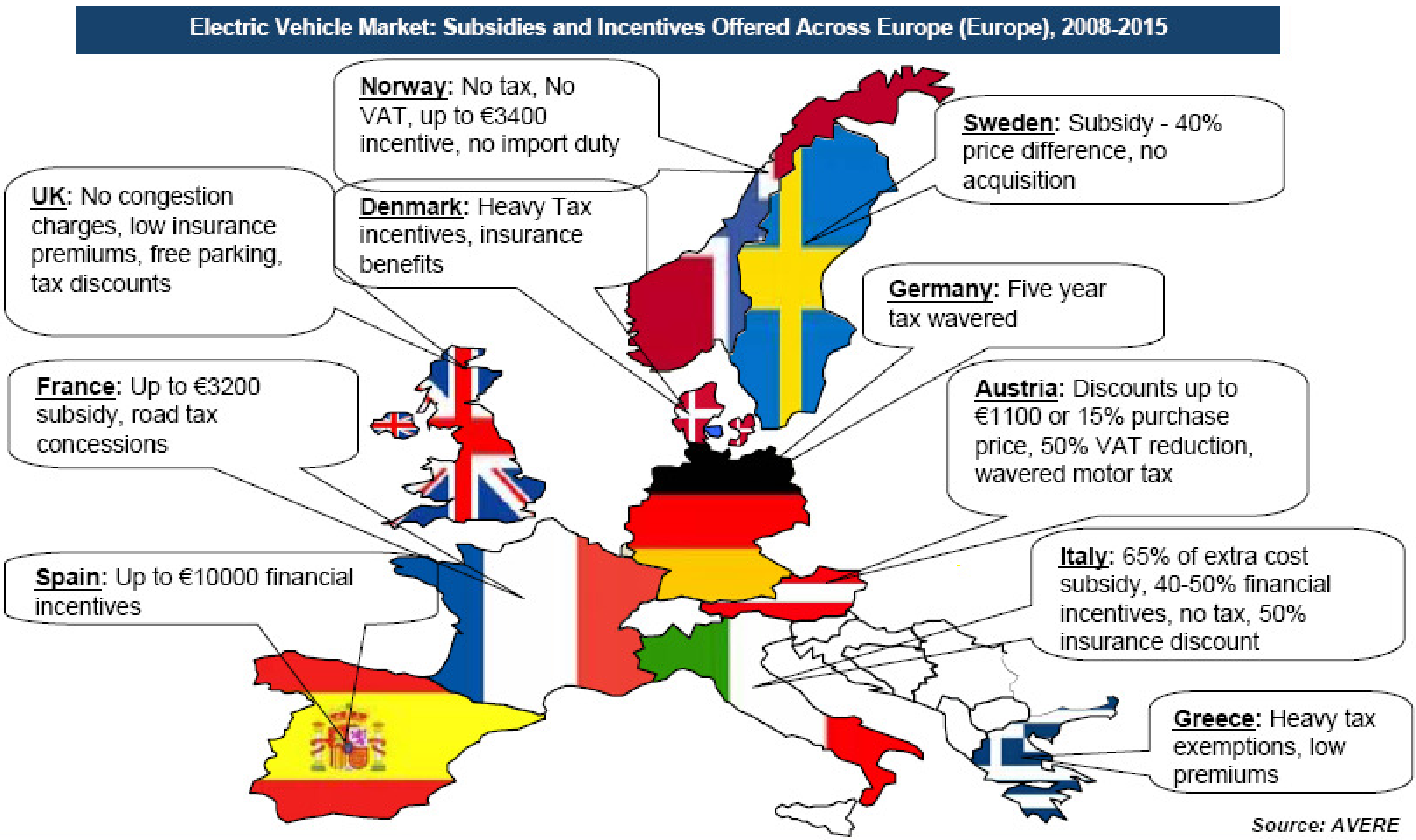

WHAT DOES THE UK MOTORIST CURRENTLY PAY?

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- Figures are 2007/2008 from HM Treasury Ev219
  - Fuel duty £24.9 billion
  - Vehicle Excise Duty £5.4 billion
  - Tolls & congestion charge £0.6 billion
  - VAT on Fuel £6.8 billion
  - VAT on vehicle sales £6.9 billion
  - Insurance premium tax £1.0 billion
  - Company car tax (& fuel benefit charge) £2.5 billion

TOTAL £48 billion / year

- Wholesale loss of this revenue with additional costs to subsidise green motoring is in the longer term not sustainable. It's only affordable when take up is at such a low level that it doesn't make a difference!

IF THE GOVERNMENT CAN'T AFFORD TO KEEP GIVING AWAY CARROTS THEY WILL END UP USING A MUCH BIGGER STICK.

PROFILE OF BUYERS OF HEV - USA

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- HEV drivers are on average*
  - 3-5 years older than buyer of a gasoline / diesel car
  - Generally have higher level of education (40% with a postgraduate degree)
  - Will have a higher income than a gasoline vehicle buyer (but lower than diesel)
- Of all prospective customers interested in buying an HEV the level of interest declines by 50% once they are advised of the price premium for an HEV*
- Green motoring is a lifestyle choice of the affluent or the very committed.

*Source: J.D. Power : Drive Green 2010: More Hope than Reality?, November 2010

PURCHASE CONSIDERATIONS

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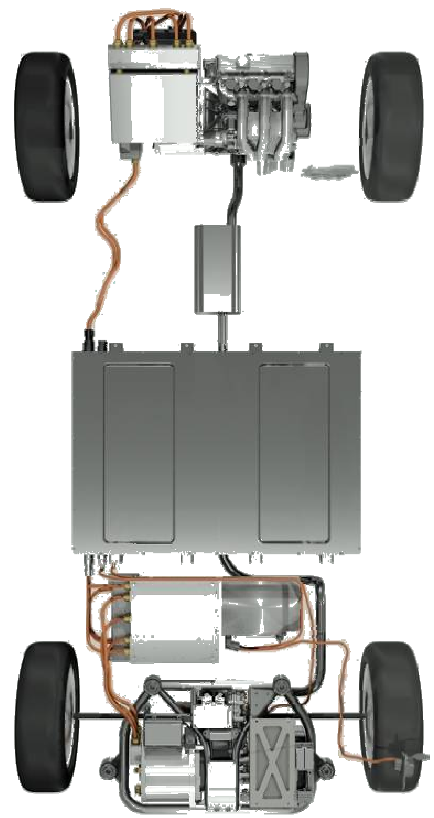
Buying considerations for “US HEV”owners compared to “All US vehicle” purchasers

Issue	HEV	All
Gas mileage	90%	40%
Environmental	70%	10%
Technology	70%	32%
Comfort	36%	50%
Styling	24%	47%
Reliability	57%	63%



HEV buyers

- Concern for environment
- See technology as solution
- Self thinkers
- Early adopters
- Life style choice

THE MOVE FROM ICE TO EV

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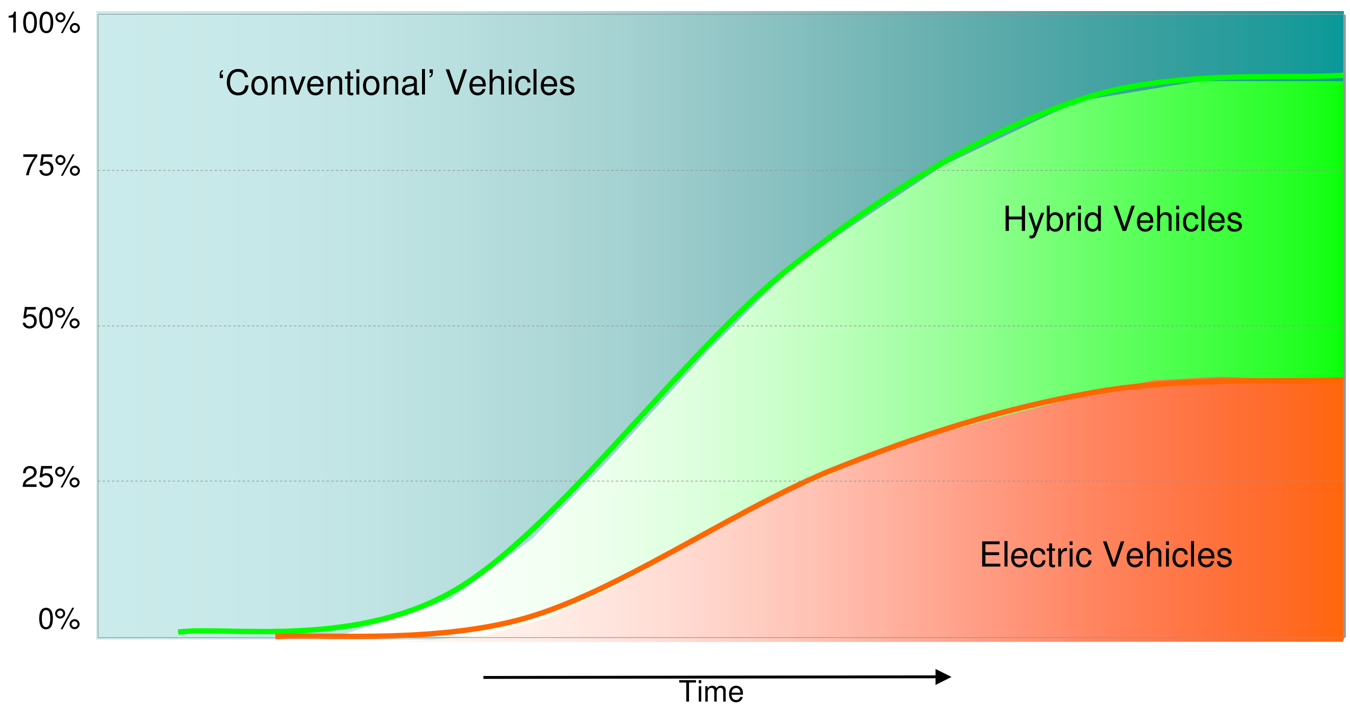
- Increased hybridisation of light duty vehicles
- Move to plug in multi mode hybrids and Series hybrid systems in the next 5 years
- Increase in City EVs in Europe and REEVs in North America
- Initial products have been niche products for high performance / city cars / commercial vehicles.



CITY CAR BEV

- Small electric vehicles developing from small niche vehicles (Neighbourhood Electric Vehicles) into main stream product City EVs
- Limited range and performance optimised for urban use
  - Small 10-45kW motors
  - Limited capacity lead acid / lithium batteries.
- Likely to be 2nd or 3rd car
- User Incentivised by taxation / cost subsidy
  - Free parking (£1.10- £4.40/hour)
  - No congestion charge (£8/day saving)
- Source London – charging Infrastucture
  - Launching spring 2011
  - 1,300 public charging points London by 2013
  - £100 annual membership fee for charging
- Gem e2, REVA G-Wiz, to NICE, iMEV, Smart EV, Think etc

PROTON EMAS WITH LOTUS SERIES HYBRID DRIVETRAIN

SPORTS CARS HEV/ BEV

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- Very high performance vehicles : 85-440kW, top speed of 80 - 130mph & 0-60 in 4s.
- Wealthy Early adopters –Technology driven - “Seen to be Green” - exclusivity
- Socially acceptable sports car – performance without guilt
- High price delivers exclusivity and status
- High end Nickel zinc, Li ion battery, range 100 - 200 miles,
- Tesla roadster / Model S, Dodge EV, ZAP Alias, Fiskar

EVORA 414E HYBRID

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COMMERCIAL TRANSPORT

- Limited range and speed suitable for fixed base operation – urban delivery/ service providers (supermarkets, mail , local councils, electricity companies …) - 100-150 mile range at 50mph (max) and 1-2 tonne load capacity
- PR corporate benefits – “seen to be Green”
- Incentives on tax / congestion charge makes it viable
- Low running & servicing costs – high utilisation (eg taxi)
- 75-120kW motor and Sodium Nickel Chloride / Lithium phosphate batteries

HYDROGEN FUEL CELL TAXI

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MAINSTREAM CARS

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- Most commercially successful products are those that do not compromise range & performance – currently dominated by parallel hybrid (Prius)
- Range extension of EV with specialised ICE generator engines
- Mild hybrid / stop start systems
- Initial pure EV passenger cars attempting to break though into mainstream.
  - Extending range on EV city car
  - Nissan leaf
  - Volt / Ampera
  - Focus EV (2012?)

HYBRID & ELECTRIC VEHICLES – LOTUS VIEW

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- 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
- Initial applications luxury car market, city cars (range is less important) & light commercial vehicles
- Focus on micro & mild start/stop systems and series hybrids
- Reduction of non propulsion systems energy usage
  - HVAC, Brakes, steering, infotainment, etc
- Range extender engines - new engine architecture – constant speed / low cost
- Battery Electric hybridisation is not the whole picture
  - Flywheels & super capacitors are potentially more efficient in Micro hybrids
  - Hydraulic hybrids have potential in light and heavy duty commercial applications, without the disadvantages of electrical systems

KEY AREAS OF ACTIVITY FOR LOTUS

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- Series hybrid technology (414e , Hydrogen taxi)
- EV vehicle development – City cars - system integration & control
- Low weight vehicle architectures for low carbon vehicles
- High efficiency range extender engine for REEV
- Torque vectoring system & Navigation based energy management strategies
- Low power consumption systems – Hotel loads
- Driving dynamic effects of EV/HEV (vehicle dynamics / comfort / NVH / driver feedback)
- External noise generation for EV pedestrian safety
- Stop / start micro hybrid

REDUCING CARBON FOOTPRINT – AN EXAMPLE

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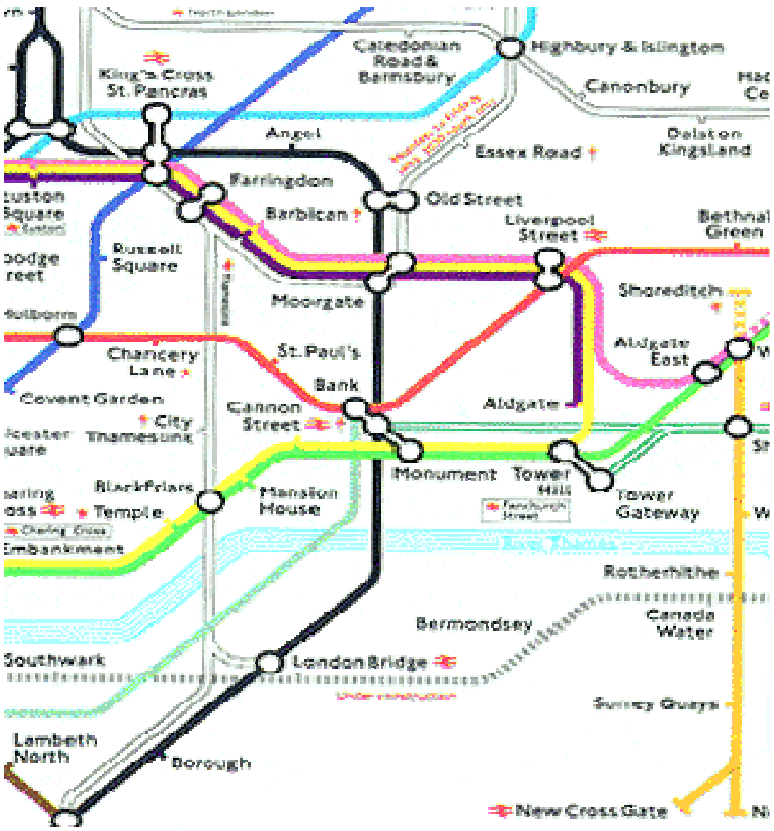
- Car driver who has 50 mile commute into London = 100 miles/day = 25,000 miles/year
- Plus 5,000 miles / year for leisure at weekends.
- 2.0litre Ford Focus @169gCO2/km for all travel.
- Overall tailpipe CO2 emissions = 6760 kg CO2/year
- Considering Changing to a Nissan Leaf for commuting 25000 miles @ 0gCo2/km and buying a 5.0litre Jaguar XK8 for weekend 5000 leisure miles@ 292gCO2/km
- New overall tailpipe CO2 = 2336 kg CO2/year a 66% reduction.
- A significant positive environmental change to his carbon footprint !

REDUCING CARBON FOOTPRINT ONE STAGE FURTHER!



- Now however he looks at the costs of the EV and decides he will use public transport instead.
- This is an **more** environmentally friendly solution
  - It saves the CO2 used to produce the EV in the first place
  - It saves electricity to run the EV*
  - It reduces overall congestion
  - *Note: Although full EVs have zero CO2 **tailpipe** emissions the generation of electricity in the UK will give these vehicles an equivalent level of around 90g CO2/km.
- BUT now if he wants to run his Jaguar at the weekend he is branded irresponsible and harming the environment.

WHAT SHOULD LEGISLATORS DO?

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- High CO2 cars does not consequently result in high CO2 production – CO2 production depends on usage.
- CO2 to build a conventional vehicle is often less than to produce an EV due to high energy use in producing the battery.
- WHEN THERE IS A HOSEPIPE BAN THE TARGET IS TO REDUCE WATER CONSUMPTION - IT DOESN'T MAKE IT ILLEGAL FOR B&Q TO SELL HOSEPIPES !
- To deliver the philosophy that the "polluter pays" the taxation on energy consuming devices should be based on the total release of additional (non renewable) CO2.
- Taxation of a product at point of sale can drive an attitude of –" I've paid for it – I may as well use it as much as possible".
- Ultimate scenarios of an individual carbon allowances (rationing) and individual carbon trading could be the ultimate result in a free market economy.

WHAT IS NEEDED?

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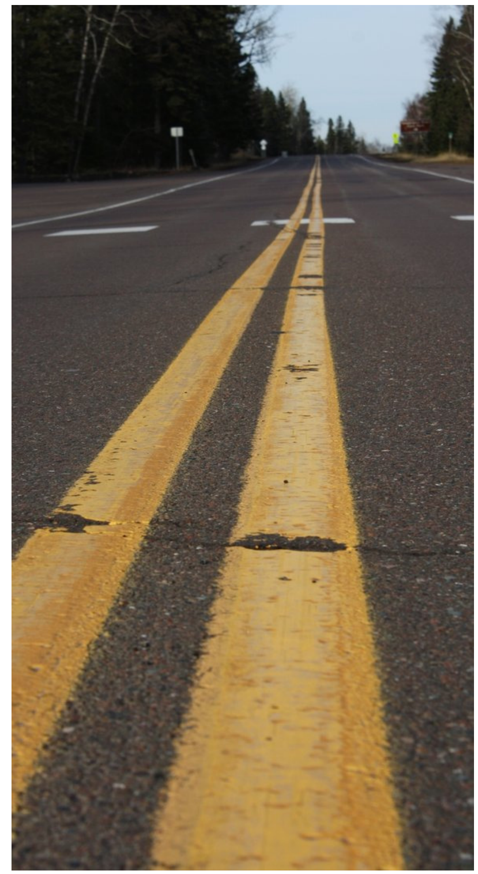
- Legislation and policies that reduces the production of CO_2
  - Low carbon transport promotion
  - Electricity is not zero emissions
  - Range extended EV's are strong condenders
  - Tax the Carbon in the fuel not the vehicle
  - Incentivise use of public transport
  - Affordable policies
- Breakthrough in battery technology
  - Lower costs
  - Reduce weight
  - Improve performance
- Charging Infrastructure development
  - Standardisation
  - Fast charging availability
  - Commercial models
- Low Carbon electricity production
  - Otherwise EV's are a CO_2 illusion



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THANK YOU

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