RUSTAT CONFERENCES

JESUS COLLEGE, CAMBRIDGE

Transport and Energy Conference Report

By Gerard Casey, Centre for Sustainable Development, University of Cambridge

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Transport and Energy

Thursday 27 November 2014

08.30 - 09.20
Registration and Refreshments - Prioress's Room, Cloister Court
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09.30 - 09.35
Welcome and Introduction - Upper Hall, Jesus College

Professor Ian White *Van Eck Professor of Engineering, Master of Jesus College, and Chair, Rustat Conferences*
Professor Robert Mair *Sir Kirby Laing Professor of Civil Engineering, University of Cambridge; former Master, Jesus College*

09.35-10.05
Keynote Overview and Scene Setting: Transport, Infrastructure and Energy Priorities
Identifying the Policy Challenges

Michael Hurwitz *Director, Energy, Technology, International, Department for Transport*
James Stewart *Chairman, Global Infrastructure, KPMG*

New Technology and Research in Transport and Energy
What are the new technologies and areas of advanced research? Which are the priority areas? What is the impact of new technologies on transport and energy policy?

10.05-11.00
New Technology: Nuclear & Aerospace
Flights of fancy, aircraft transport futures

Chair: Tony Roulstone *Cambridge Centre for Nuclear Energy*
Dr Phill Cartwright *Electrical Engineering Director, Engineering Excellence Group, Laing O'Rourke*
Dr Tim Coombs *Lecturer, Department of Engineering, University of Cambridge*

11.00-11.20
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11.20-12.20
New Technology: New Engine Concepts for Fuel Economy
Fuel efficiencies, biofuels and the decarbonisation of road freight; powertrain electrification – synergy between F1 and roadcars

Chair: Professor Nick Collings *Head of the Acoustics, Fluid Mechanics, Turbomachinery and Thermodynamics Division, Department of Engineering, University of Cambridge*

Professor David Cebon *Professor of Mechanical Engineering, University of Cambridge; Director of Cambridge Vehicle Dynamics Consortium and the Centre for Sustainable Road Freight*
Matthew Tipper *VP Alternative Energies, Shell*
Dr Sunoj George *Manager, Hybrid Systems, McLaren Automotive Ltd*

12.25-13.30
Lunch – Master's Lodge

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New Technology: The Electrification of Transport
Balancing with decreasing dependence on fossil fuels. Rail systems; aerodynamics and energy in rail tunnels; autonomous electric vehicles; current and future battery technologies and energy storage

Chair: Paul Stein *Chief Scientific Officer, Rolls Royce*
Professor Andrew McNaughton *Technical Director, HS2*
Professor Clare Grey *Department of Chemistry, University of Cambridge*
Martin Tugwell *Director, Transport Catapult Systems, Autonomous Electric Vehicles*

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Urban Development – the planning of transport and how it affects energy
Transport and energy inextricably are linked in planning cities and urban development; the economics of transport planning with reference to energy. Role of rail-led regeneration and redevelopment, and urban energy implications

Chair: Professor Koen Steemers *Professor of Sustainable Design, University of Cambridge, Fellow, Jesus College*
Dr Ying Jin *Senior University Lecturer, Department of Architecture, and Energy Efficient Cities Initiative EECi, University of Cambridge*
Richard Blyth *Head of Policy, Royal Town Planning Institute RTPI*
Neil Chadwick *Director, Steer Davies Gleave*

15.30-15.40
Break – Upper Hall

15.40-16.10
Policy Focused Panel Discussion
Following session talks and roundtables – a discussion of key policy challenges and opportunities for UK, Europe and beyond. Skills gaps and capacity building

Chair: Professor Robert Mair *Sir Kirby Laing Professor of Civil Engineering, University of Cambridge; former Master, Jesus College*
Dr Miles Elsden *Chief Scientific Adviser, Department for Transport*
James Stewart *Chairman, Global Infrastructure, KPMG*

16.10
Conference Close

Transport and Energy

Thursday 27 November 2014

Professor Ian White FREng
Van Eck Professor of Engineering and Deputy Vice-Chancellor, University of Cambridge, and Master, Jesus College, Cambridge.

Ian White opened the Rustat Conference on Transport & Energy and welcomed the participants to Jesus College.

The very location of Jesus College itself was chosen due to the access it afforded via boat. Since this time, transport and energy have changed significantly. In the early days of the Nunnery only 3 rooms were heated. This has changed dramatically since then. Transport has also expanded in terms of scale, function and range.

Robert Mair CBE FREng FRS
Sir Kirby Laing Professor of Civil Engineering, University of Cambridge
Former Master, Jesus College, Cambridge

Robert Mair joined in Ian White's welcome to Jesus College. Transport and energy are the defining problem of the coming decades. The Rustat Conference has always focused on topical subjects and this is no different. What does our future hold in store in terms of energy supply, energy demand and our ability to move? Will car ownership in cities become a thing of the past? How will we ensure secure, affordable and decarbonised electricity? These are some of the questions we will attempt to answer.

Keynote Overview and Scene Setting: Transport, Infrastructure and Energy Priorities: key policy challenges

Michael Hurwitz
Director, Energy, Technology, International, Department for Transport
James Stewart
Chairman, Global Infrastructure, KPMG

In the first session **Michael Hurwitz** opened with the following statistics from recent times:

- In October in the UK, 1 in 105 cars was a plug in (Ed - In November it was 1 in 92)
- A 40t heavy goods vehicle with a 400-mile range would on current technology require a 23t battery
- On 6th October, the UK exported 2GW energy to France. Could this have been utilised domestically if storage existed?
- In 2008, anthropogenic matter air pollution was estimated to have an effect on mortality equivalent to nearly 29,000 deaths in the UK
- Oil prices at a low of $77 per barrel, approaching a 5 year low

Some illustrate significant progress and others illustrate real tensions and challenges. Traditional thinking, which prefers to treat sectors as independent and separate, has been shown to longer hold true. These issues are dependent and require to be treated as such.

Michael Hurwitz moved on to outline four key reflections on policy challenges.

1. Policy resilience – There is a need to develop policies, which have longevity and stretch beyond different decision-making cycles – be that of administrations or businesses of different types. For example, the Low Emissions Vehicle Agenda, which has survived two Governments and has secured a budget beyond 2020. This policy was born in a time of climate change focus but has since shifted and fulfilled different, newer objectives – particularly around the economy. Its energy efficiency relationship has lower cost implications, especially useful in for government during times of austerity. Further to this, the huge costs associated with vehicle particulate emissions have been illustrated in terms of their public health impacts, thus adding more value to the agenda. A policy is more likely to be resilient if it can demonstrate it meets multiple objectives.
2. Trade-offs – There is a need to make strategic and consistent policies across sectors and government. For example, the incentives surrounding biomass – the use of bio-methane from waste, through the renewable heat incentive is worth £65MWh. Alternatively, the same energy if it is used for transport is worth £12-15MWh under the Renewable Transport Fuels Obligation (RTFO). Such a situation leads to bias and highlights the importance of bringing greater clarity in the policy position surrounding biomass' future strategic use and role. The DfT is revising the transport incentives upwards (doubling them), DECC are reviewing whether to bring the heat incentive down towards parity.
3. Consumer journey – Selling change is very hard, no matter the strength of macro economic justification. The reaction to proposals of fuel subsidy reduction in Nigeria is a poignant example of this. It is also important to consider how to distribute any burden

across society and avoid overly loading certain demographics. This is a political challenge, if not an analytical one.
4. Sustainability of subsidies/incentives – The creation of a market or a system, which is dependent on subsidies and incentives, is to be avoided. The Treasury are always eager to know when a subsidy can be removed as the market has become self-sustaining. There is a difference between priming a market and propping up a market indefinitely. The key is to unlock a situation where the new system pays for itself, but attractive to consumers and commercially viable.

James Stewart followed by moving to a higher-level perspective and started by commenting on the recent change in profile of infrastructure.

The topic of "Tackling global investment and infrastructure" was the first feature item, on the first page of the G20 leaders' Communiqué from the recent 2014 Brisbane Summit. Russia has planned $650B on transport by 2020 and the US has pledged $77B on energy this year alone. Such enormous investment is found within a backdrop of fundamental global change.

There are two key challenges:

1. *Prioritisation* - Considering the ambition, challenges faced and continued economic pressures, what do governments need to do and what do they want to do to avail of opportunities? There is a difference between power investments that are required for security of supply and those investments, such as HS2, which are to try and open up economic opportunities.

2. *Funding* – How can this infrastructure be paid for. There are two main sources of funding: taxation/borrowing and user charges. User charges have challenges -
   - Governments don't like them. For example, Northern Ireland continues to have no water charges, arguably as a result of a lack in political will.
   - In some cases user charges do not cover the capital cost. For example, fares from railways will, at best, likely only ever cover operational costs. Government therefore incurs the bulk of the capital cost.

There are two consequences of this funding challenge. First, there is a real need to find new ways to pay for infrastructure; i.e. incremental taxes ring fenced to infrastructure investment or value capture schemes. The rise of the middle-income group who can contribute more is a positive development but counteracted by the increasing demands of an ageing population.
Secondly, governments are increasingly required to account for the full economic and social benefits associated with new investments, as part of their justification for the capital contribution. Historically, methodologies for capturing this have proved to be far from robust. There is a real need for improvement here.

Four trends have been identified:

1. *Market reform*. The status quo is not fit for purpose. In the UK energy market reform and the changes to the Highways Agency are good examples of this.

Network Rail could be next. Public sector utilities moving to private sector is also expected, for example, as seen in Australia.

2. *Risk distribution*. The public sector will be required to take more risk, as the private sector has become much more conservative. Especially with regards to demand risk, political risk and currency risk. A direct ramification of this is the increasing need for direct Government interventions, as in the Hinkley Point C Nuclear Power Station and the new Battersea development. Multilaterals are also expected to increase their level of support.
3. *Skills deficit*. There is not sufficient technical ability to supply infrastructure. The emergence of new players in this market, such as from China and Japan will bring new skills and innovation into projects.
4. *Technology*. With the exception of telecoms, technology has had a limited impact on infrastructure. Will new methods of construction emerge? Can it reduce cost, time lines and environmental impacts? The HS2 timeline of 15 years is just too long. Investment in data analytics will improve the utilisation of information. Can we use data to better inform demand predictions? Can we use it to manage whole life costs and make better strategic maintenance decisions?

To conclude, there is more optimism that technology will play a greater role in the next 20 years, than there was for the past 20.

Discussion

Phillip Cartwright queried **James Stewart** on why he believed technology adaptation has been so low in infrastructure. **James Stewart** replied that it is primarily an issue of cost. There is not enough investment in research and development and the infrastructure market has not opened itself up to the technology market as others have done so. This may be explained by the degree of protectionism, fragmentation and orthodoxy associated with the industry. Laing O'Rourke being a notable exception.

Nick Collings commented that the privatisation of the railways resulted in events such as Potters Bar & Hatfield. **James Stewart** clarified that public sector reform can take place without privatisation.

Tony Roulstone pressed **Michael Hurwitz** on his point on variable geometry policy and being able to suit short-term political flavours. Is variable geometry policy another excuse for not having consistency of purpose, as you change direction to local winds? **Michael Hurwitz** replied that rather than having variable and constantly moving objectives, there is a need to find the golden, fundamental thread, which remains robust from a number of perspectives. The civil service is there to provide objective advice – part of this is to give ministers a steer on what to aspire to in the long term and then find ways of making it viable in the shorter term.

Andrew McNaughton remarked that resilient policies do not lend themselves to resilient work programmes. In response to the comments on the delivery of HS2, it will take 20 years to deliver 224km, in contrast to the 500km of HSR China delivers per year. Such a difference is not explained by simply having a larger work force, rather by the enormous technological development ongoing in China as a result of extraordinary investment. The UK is more developed in terms of public consultations, with 17 public consultations and ten judicial reviews in the past six years alone. Translating resilient policies to a resilient programme and resilient funding seems to be at the heart of the issue.

Ying Jin ends the session by querying what the trend may be regarding plug in electric vehicles in the UK. **Michael Hurwitz** replied that for the short to medium term there will be a focus on efficiency. There will be a range of electrical technologies in the 10/15-year period but there will still be a significant ICE sector for the foreseeable future.

New Technology and Research in Transport and Energy: What are the new technologies and areas of advanced research? Which are the priority areas? What is the impact of new technologies on transport and energy policy?

New Technology 1 - Nuclear & Aerospace: small scale nuclear for shipping; flights of fancy: aircraft transport futures

Chair: Tony Roulstone
Cambridge Centre for Nuclear Energy
Dr Phillip Cartwright
Director, Engineering Excellence Group, Laing O'Rourke
Dr Tim Coombs
Lecturer, Department of Engineering, University of Cambridge

In the second session, **Tony Roulstone** opened by highlighting the two ways in which nuclear can play a part in the transport system.

1. *Decarbonisation of the electricity system*

Carbon emission reduction has three elements. The first is energy saving through the reduction in demand and a shift from the direct linkage between energy and economic growth. The second is the cleaning up of the energy system, including specifically the electricity supply. This must occur before the widespread electrification of transport and heating can usefully occur. Lastly, the electrification of heating and rail and car transport replaces fossil fuels but also increases the electricity demand. Hence the size of electricity systems grows whilst reducing both carbon emissions and total energy demand.

The scale of this challenge is immense. For example, China, which is the largest carbon emitter in the world and is typical of developing countries that grow by depending on high carbon energy sources such as coal and oil. In China just to halt its increase in emissions it would need

- 1000GWe of renewable generation. For reference, the UK has around 10GWe and plans for around 30GWe.
- 400GWe of nuclear. For reference, China has 20 GWe of nuclear and plans for 50 GWe by 2020. This requirement is therefore 20 times the Chinese nuclear supply and more than the current total global nuclear capacity.

2. *Nuclear shipping*

More than half of the world's nuclear reactors are found in ships – military vessels such as submarines or aircraft carriers. There are over 700 nuclear reactors in ships worldwide and 30 reactors in UK submarines alone. Therefore we can say that nuclear propulsion of ships can be made to work.

About 3% of anthropogenic GHG emissions are associated with shipping, an amount similar to that produced by aviation. Ship emissions are growing at more than 3% pa in response to growth in global economy. Unless addressed, shipping emissions are likely to reach double, current level by 2050. Unlike many other types of GHG emissions there are very few ways of cutting those from shipping. Left untouched, shipping could account for 15-20% of our total emissions by 2050.

Efficiency savings through better hull, engine and propulsion design and slower steaming can give around 20-30% savings. This is far from the 80% required by the targets set for developed countries. Large ships, such as containers, bulk goods carriers and oil tankers require around 50-100MWe of propulsion power. This level of power is consistent with the output of small reactor systems.

Large ships dominate the market and are owned by a small number of nations. Greece, Japan, China, Germany, S Korea, US and Norway account for over 60% of global tonnage. The impact of nuclear adoption in large ships by just these seven countries would be large.

In 1960s several demonstrators were built using nuclear power for non-military ships. These showed that nuclear shipping is feasible, but it was not perceived as economic and had many institutional and legal barriers such as:

- Nuclear liability and Law of the Sea
- Safety regulation – no internationally agreed standards
- Routes and ports – regulating suitable routes and ports
- Nuclear proliferation concerns
- Operator standards and qualification
- Security – for example, against piracy
- Logistics for support – refuelling/refitting

There are several groups studying nuclear shipping now. This included BMT, Hyperion, Rolls-Royce, Hyundai and also US and Chinese consultancies.

All the studies make use of the well proven light water reactor technology, which is the mainstay of nuclear power generation. Also, newer technologies have been proposed– liquid metal fast reactors, gas turbine cycles and graphite-based fuels based on the potential to increase thermal efficiency. Despite this potential, it is important to remember we have 10,000 years of operational reactor experience that tells us PWRs work. The application of a new reactor technology in a new application would be costly and rarely works.

The three technological challenges for moving from military to commercial nuclear shipping will be:

- The use of low enrich uranium fuel, rather than highly enriched uranium employed in military system – for proliferation concerns
- Nuclear safety – the adoption of civil standards
- Economic – reduction of capital costs

The key economic issue is that nuclear reactor systems cost 20/30 times more than a similarly powered diesel. On the other hand, nuclear systems have very long periods between refuelling, (potentially 10 years) and have much lower fuel costs, which dominate the economics of diesel power.

The economic trade-off between nuclear and diesel is unclear, compounded by the dynamic nature of oil prices, carbon taxes and interest rates. Current modelling indicates that very high current fuel prices would be required. Heavy oil costs would have to increase by 50% from \$800 to \$1200/tne, or an equivalent carbon tax would need to be levied ~ \$120/tne CO_2.

The economics of reactor construction can be changed by using volume manufacture methods. These reduce the high capital cost of the nuclear power system. Capital cost may be reduced through standardisation, simplification and factory-based manufacturing learning. There seems to be scope for a 50% reduction in capital costs, which would transform the economic equation for nuclear power shipping.

To conclude, nuclear shipping is feasible, but:

- Where is the international will to address the institutional problems?
- Where is the investment to get the concept started?
- Will people be willing to pay the higher costs or apply large carbon taxes?

Dr Phillip Cartwright opened by going back to comments made by **James Stewart**. There is a critical requirement to adopt research, technology and manufacturing techniques from the automotive and aviation sectors. Why is it that companies such as GE, Rolls-Royce and car manufacturers have made such massive leaps in terms of efficiency and reliability while the construction and infrastructure sector has lagged behind?

As an example, commercial nuclear reactor power stations are of enormous scale. A generic case of a pressurised water reactor features the following:

- 3GW capacity reactor
- Capable of supplying 5 million homes
- Cost of £20B
- 10 years to build
- Employing 25,000 people
- 6,000 construction people on site at any one time
- Materials
    - 1.2million m^3 of concrete
    - 15,000t of structural steel
    - 1,000,000t of sand
    - 51 cranes

The scale and challenge of such an energy supply project is compounded by the critical domestic need to supply on time and on budget.

The construction industry in the past 20 years has been slow on the uptake of new technology. However, we have now begun to model energy projects in the same way that car manufacturers and the aviation sector have been modelling for many years. This has been shown to provide cost and time certainty on the programme.

And in further developments, in the same way that Rolls Royce knows where each engine is, how it is performing and what its future status will likely be, Laing O'Rourke are beginning to do the same with the performance of buildings and infrastructure. The application of such investments in large energy projects, such as reactors, can be applied to smaller manufacturing processes. We know how to make energy centres and data centres in factories. Why can't we make small modular reactors in factories? The capital cost is lower and the predictability is higher. There are challenges around containment, power dense electronics in machines, modular electronics and diagnostics and prognostics. However, given the right investment and encouragement, these can all be overcome.

Diagnostics and prognostics is a growing issue. Do we know how our buildings actually perform? The use of sensors in every building can be used to see how it *really* behaves and thus feed this information back to the design process. There are significant savings that could be made here.

Infrastructure and construction is starting to invest in research and technology. But not all in the sector are. And the question is, why is it not encouraged?

Dr Tim Coombs began by introducing Flight Path 2050, Europe's aviation targets. The focus of this talk was on those targets that relate to the protection of the environment.

The Flight Path 2050 targets:

1. 75% reduction in CO_2 emissions per passenger km, 90% reduction in NOx and perceived noise emissions by 65%
2. Aircraft movements emission free during taxing
3. Air vehicles are designed and manufactured to be recyclable
4. Europe is established a centre of excellence on sustainable alternative fuels
5. Europe is at the forefront of atmospheric research

The first two targets are technical, engineering challenges and the remaining, 3,4,5 are policy challenges. These targets are fairly stringent and yet they resemble quite closely those set by NASA, which are under even tighter time scales. Are these targets realistic? It is argued that they are not.

To place these targets in context, it is necessary to examine their historical development. By 2050, there is a requirement to reduce noise by 52dB. The past 50 years has seen noise reduction in the region of 20dB. Efficiency has improved by about 60% in the same time frame and yet another 60% is required to the 2050 targets. Can that be achieved with standard turbo fans? Turbo fans are more efficient the faster they are driven. However, the faster they are driven, the more noise they will make. This optimisation is reaching its technical plateau and there is a need to explore elsewhere.

The focus then moves to the configuration of the airframe. We have evolved from the standard Boeing 707, to the De Havilland Comet, with recessed engines, to the An-74, with engines above the wings and then to the Northrop YB-49, which featured multiple propulsion units. The use of more propulsion units has been identified as the most promising route forward.

Research by the Silent Aircraft Initiative in Cambridge has resulted in two key findings:

1. Delta wing shape
2. Embedment of multiple propulsion fans

The use of multiple fans is to separate the turbo fan from the propulsion fan. Power is generated by the turbo fan, which is used to power the electric fans. Thus the propulsion units can be situated in more suitable locations, reducing noise and improving aerodynamic efficiency.

However, a high bypass ratio turbo fan has an energy density requirement of 8kW/kg and currently a typical electric motor only provides 0.5 – 1 kW/kg. Therefore a standard electric motor, despite its efficiency, will not solve the problem.

The E Thrust Concept hybrid aircraft features energy storage, power generation in the form of a turbo fan and embedded electric fans in the wings. During the high power periods of take off and landing, energy is drawn from storage. During cruise, the lower energy requirement results in energy being stored, for its use during the higher demand periods.

More radical than this, Rolls Royce, Magnifye and EADS have been working on a superconducting turbo fan. The magnets are capable of providing around 17tesla and the superconductors can carry around 1500A of current. These two technologies combined provide an engine that could supply 8kW/kg. Despite the promise, there are issues with cooling, there is a need to monitor current and magnetic fields (to avoid quench), there are manufacturing problems and as such it currently isn't sufficiently mature for aeronautic application.

Discussion

Paul Stein commented on the conservatism of the aviation sector. Passenger growth expectations are high and there are very stringent safety requirements. Just based on statistics the average pilot starting their career today will never experience an engine in-flight shut down. New technology introduction requires a massive amount of proof of concept before acceptance into mainstream use. The recent issues with the Boeing 787 highlight the potential problems that can arise, and it must be remembered that this was a small technological step compared to those proposed here.

Distributed propulsion units may be possible with other approaches and may not need to wait for superconducting advancements. As was highlighted by a recent survey, which showed that electric aircraft was a practical proposition and could be in service by 2035. As a first step, superconducting may not be required. Superconducting has promised much but delivered little to date. There is general support but a need for caution. **Paul Stein** also added his support to Phillip Cartwright's thoughts on prefabrication of complex items in controlled environments. It can indeed reduce costs and improve performance.

Michael Hurwitz inquired Phillip Cartwright on how he thinks Government can, through regulatory frameworks, aid infrastructure and construction in its path to more innovative technologies. **Phillip Cartwright** responded that he felt Government should incentivise construction based research and development more. There has been a change in recent years, as for example, Laing O'Rourke have spent £17m in the past 2 years through partnerships with 3 leading Universities of its own investment. The procurement process and supply chain have been a big focus of Laing O'Rourke and they believe it is a barrier to innovation. **Andrew McNaughton** concurred that the procurement process can certainly not remain as it is. It requires strategic relationships over longer terms, with multi-nationals and not simple inclusive of tier 1 companies. There are smaller scale technology companies who can contribute so much, but who are currently excluded.

Matthew Tipper queried the economics and security issues surrounding nuclear shipping. **Tony Roulstone** emphasised the size of the potential market and the opportunities it could provide through volume and standardisation. Currently, reactors are in effect handcrafted on site individually. If most of the construction could be done in factories in a much more controlled environment, large savings could be made. The question is how to start this process? Who is going to be the first mover and make the key investments? Regarding security, the use of lower enrichment uranium reduces the scope for weapons use. The issue surrounding terrorism and accidents is about perception. Is a nuclear ship a higher level of hazard than an LNG powered ship? How does this compare to the hazardous loads such as Chlorine some ships carry? This is certainly a problem, but not something that cannot be overcome.

Nick Collings reinforced the point on the perception of nuclear risk. There is a significant amount of irrationality in international regulation. After Fukushima, the Japanese evacuated 100,000 people for 4 years and there were deaths associated with the evacuation itself. There was no rational need for the scale of evacuation carried out.

Regarding new energy technologies, **Paul Stein** stressed that Nuclear Fusion should not be forgotten and discounted. It is now an engineering problem and not a scientific one. It has the potential to solve many of these larger issues.

New Technology 2 - New engine concepts for fuel economy, fuel efficiencies, biofuels and the decarbonisation of road transport and road freight

Chair: Professor Nick Collings
Head of the Acoustics, Fluid Mechanics, Turbomachinery and Thermodynamics Division, Department of Engineering, University of Cambridge
Professor David Cebon
Professor of Mechanical Engineering, University of Cambridge; Director of Cambridge Vehicle Dynamics Consortium and the Centre for Sustainable Road Freight
Matthew Tipper
VP Alternative Energies, Shell
Dr Sunoj George
McLaren Automotive Ltd

Nick Collings opened the third session by emphasising the importance of not '*over-greening*.' Recent claims made on the new Milton Keynes bus service highlight the over-simplistic generalisations that can be made about new technologies such as EV. There is a need to consider the nuances and detail of all technologies in decision-making. Secondly, the regulatory environment is a critical consideration. Current incentives (which have been set with significant political interference) have created significant distortions. The supply of electric vehicles is largely seen by the vehicle manufacturers as a method of increasing/maintaining profit via a reduction of CO_2 exceedance fines, rather than actual CO_2 reduction. The need for robust policy, which doesn't over focus on one technology, is clear.

David Cebon began by introducing his thesis: "*Achieving major CO_2 reductions in road transport is not a technological issue, but a social and political issue. It is largely a problem of government policy and social engineering.*"

There are three examples:

1. *Out of hours deliveries* – traffic congestion doubles fuel consumption due to energy dumping during breaking. At present, truck curfews of 9pm-7am, acts to maximise consumption and congestion, by ensuring that trucks hit the roads at the same time as rush hour. This is easily solved, but requires social and political will.

2. *LCVs* – multiple trailer long haul transport vehicles use 30% less fuel and emit 30% less CO_2 per freight task. In contrast, aerodynamic improvements equate to 2-3% savings. There can be 40% less truck per km, reducing the transport costs by 30% and increasing the ratio of freight to truck. In terms of safety, there are 1/5th the amount of crashes per 100million km travelled compared to conventional road freight. There is adoption in Australia, Germany and Scandinavia. Yet, they are currently not permitted in the UK due to lobby group influence on Government. This can only happen when politicians become brave enough.

3. *Policy issues* - The average car currently emits 150-250 gCO_2/km, with the worst cars emitting close to 400gCO_2/km. The Nissan Leaf EV (on the current UK grid mix) would emit 100gCO_2/km, at a cost of £25,000 (including a £5k subsidy). In contrast a VW Polo Blue Motion emits 90gCO_2/km at an unsubsidised cost of £15,000. It is clear that the most effective thing to do would be to bring forward policies to move from 200gCO_2/km cars to 90gCO_2/km cars, such as the VW. This would instantly halve emissions with an existing, commercialised product.

Silver bullets are dangerous as they let politicians off the hook. There is no need for policy changes as an imminent technological solution can effectively solve the problem. This pushes us away from the behavioural change that is needed.

There is a need to focus on policies that can dramatically reduce fuel consumption and CO_2 emissions with what we have now. This is primarily about political will, sound policies, good marketing and social engineering. It isn't about technology.

Matthew Tipper commenced by emphasising the ramifications of the energy trilemma to the transport sector. The demand for road transport is moving towards 2 billion vehicles, this rising need is at odds with our need to reduce carbon emissions. Shell still envisages 50% liquid fuels to 2050 and a small proportion even by 2100. Despite this, countries such as the UK could make much more significant decarbonising moves locally.

There is a need to be pragmatic and look at the immediate alternatives. The first port of call should be to replace liquids with alternatives and thus leverage existent infrastructure. For example, using first generation bio fuels, such as sugar cane ethanol in Brazil, which offers 70% GHG savings. Gas production will continue to increase and new applications are emerging, such as for those in the marine sector.

There are 3 key factors that are required to align to commercialise these technologies:

1. Drive train and fuel alignment
2. Infrastructure
3. Customer value proposition

No one model is applicable globally. Sugar cane ethanol has worked in Brazil, but there is a need to understand what models suit where. The UK is driving for electrification, as it suits its small size and population density. However, there is a need to recognise that electric and hydrogen solutions are expensive. The internal combustion engine is not yet redundant and its use with low carbon bio fuels should be exhausted before there is the leap to expensive solutions such as electric and hydrogen.

There is a real need for private and public partnership, with improved communication and coordination. Regulatory risk is key concern for Shell and there is a requirement for more clarity here.

Although there is a strong temptation to shoot for big ideas, there is a need to be pragmatic too.

Sunoj George addressed how F1 racing technology has been applied to the OEM market. From this, how can it be applied in a cost efficient, commercial manner? How can we reduce our emissions and improve efficiency?

Kinetic Energy Recovery System (KERS) was introduced into F1 in 2009, allowing breaking energy to be harnessed and transformed into electrical energy. By 2014, this power has been doubled with a performance effect around ten times greater. This technology has led to the battery technology now being worked on in McLaren. Although there is a large focus on high-end performance, this is not to say the work of McLaren has no role in emissions reduction. The high performance McLaren P1 super car emits only 194gCO_2/km, roughly equivalent to that of a 2-litre Ford Mondeo. The P1 offers 4.5 kW/kg power density, in the F1 application it can achieve nearly 7 kW/kg and beyond this, to 2020, 10 – 15 kW/kg outputs are expected.

High voltage and mild (48V) hybrids have been flagged to be a technology of growing importance going into the future. These can achieve a 30% reduction in terms of CO_2 emissions in combination with improved fuel economy. German OEMs are pushing in the 48V sector and it is expected to become the mainstay.

Fundamentally, the overall transport issues are not about single solutions. The system solution is not something discussed in technology research. All of the technologies must be brought together, control systems, calibration and optimisation to bring about overall successes.

McLaren agrees that the ICE will continue for some time. Figure 1 illustrates the projected Powertrain electrification progression over the coming years.

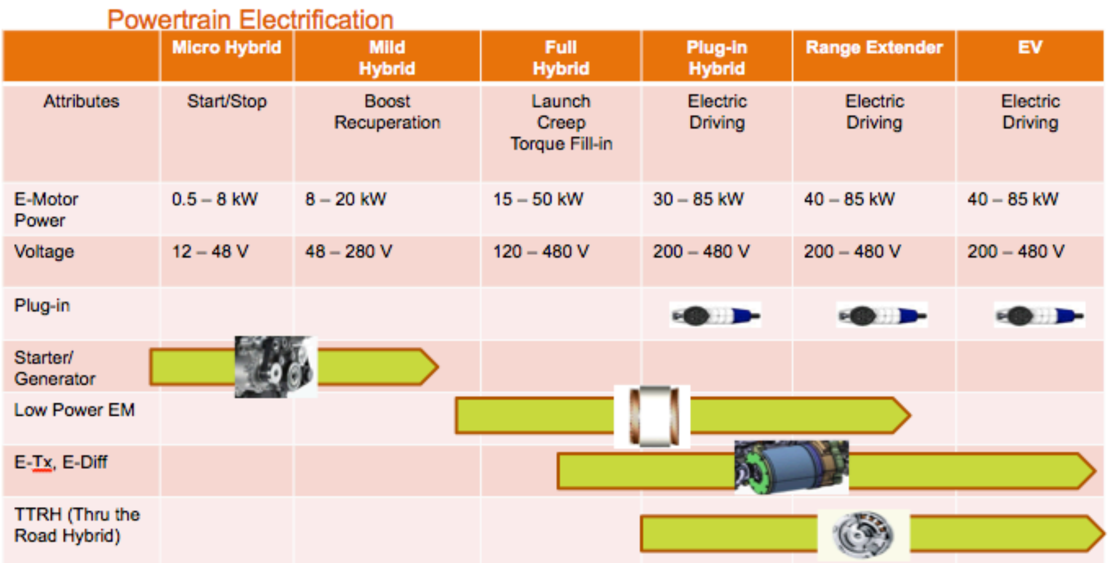

Figure 1 Projected General OEM Powertrain electrification evolution

There is a need to engage the public to bring about an understanding that is not just about technological silver bullets and that there is a degree of bigger picture, social change.

Discussion

Paul Stein concurred with **Matthew Tipper** that the utilisation of existing infrastructure is an easier sell. Beyond this, there is a need for real debate on bio fuels. Matthew responded that there is much more consensus on bio fuels in the US, thus giving certainty and providing policy stability. The UK debate features much more uncertainty and as a result, the US is where Shell is investing.

Richard Webb questioned the applicability of the Australian and German precedents of longer good vehicles to the UK context. The UK has more crowded and smaller roads. **David Cebon** agreed that there are context specific issues in the UK but that these are solvable. For example, there are technical changes needed to increase manoeuvrability. These issues are the focus of research abroad and in Cambridge. Beyond this, there is a need for policy focus, to cover the routes, maintenance and driving requirements. **Richard Blyth** commented that there appears to be a trend to localised shops. How do we move these proposed longer lorries to hubs, to then distribute locally? **David Cebon** responded that there are 3 aspects to this:

1. *Largest container* - the most efficient means of delivery is to use the largest container possible and avoid double handling. This is hugely advantageous as one larger truck is 40% less carbon than 2 small trucks.
2. *Urban consolidation points* – A consolidation centre can deliver to multiple shops along one road link.
3. *Home delivery* – The most inefficient mode is the family car. 50 full cars can be replaced by one van. This has congestion benefits too. This is a social and not technological issue.

Michael Hurwitz asked what robust empirical evidence could be used to convince vocal resisters. **Nick Collings** responded by considering the Electric Vehicle case in the UK. The policy, he argued, was as a result of a report by Arup. However, this report neglected the embodied carbon associated with the batteries themselves. If this had been included, the conclusions of the report would likely have changed. **Michael Hurwitz** responded that this report was not the sole basis for the DfT policy decision.

Robert Mair queried what the role of shale gas might be in the UK. **Matthew Tipper** emphasised the success in the US is related to access to capital, a highly skilled workforce, permit changes and land ownership differences. There is uncertainty if the rest of the world can unlock this potential, especially in relation to the skill shortage problem.

Shane Slater said the regulator will always have to make policy on the best available current science and explained that the need for policies which are applied at a much larger scale. The EU tailpipe emissions targets have made a tangible and quantifiable difference. [Ed - UK new car tailpipe was 164.9g CO_2/km in 2007; in 2014 it was 128.3 g CO_2/km – almost exclusively from improved ICE efficiency]. Globally there is a need to have multiple policies at multiple levels, each working over different time periods but all aimed at practically leading to the desired long-term outcome. On this basis, **David Cebon's** comments on the incentives of the VW Bluemotion versus Nissan Leaf are true but there must be a combination of such pragmatic decisions with longer term, much more ambitious targets if there is to be overall success.

Nick Collings suggested that this is fundamentally about human behaviour and our performance expectations. The demand for speed, range, price, acceleration and reliability is extremely high. **David Cebon** agreed and proposes that there is a need to change public perception of the value, perhaps along the lines of the cigarette educational advertising campaigns.

New Technology 3 - The Electrification of transport – balancing with decreasing dependence on fossil fuels. Rail systems; aerodynamics and energy in rail tunnels; autonomous electric vehicles; current and future battery technologies and energy storage

Chair: Paul Stein
Chief Scientific Officer, Rolls Royce
Professor Andrew McNaughton
Technical Director, HS2
Professor Clare Grey
Department of Chemistry, University of Cambridge
Martin Tugwell
Director, Transport Catapult Systems, Autonomous Electric Vehicles

Paul Stein began by setting the scene of world energy provision. At 9.55am (at the time of the conference), real time data showed that 2.6% of the UK's 40GW energy demand was met by wind, a large fraction of gas, some nuclear but the majority was coal. The application of electricity to transport could be significant. If we grow to 1million plug-in cars in the next 5-10 years, with each consuming 10kW while on charge, we would require 25% of the current energy demand alone. Have we prepared our infrastructure for such a shift? This is a simultaneously a great challenge and great opportunity. If the energy provision from wind, solar and other intermittent sources can move to 10/15% of total generation, the prospect of EV being used as energy storage for load balancing becomes very attractive. Thus, this initial problem could become a great virtue. There are many smart ways we can combine energy and transport to solve problems in both domains.

Andrew McNaughton commenced with the assertion that rail transport is a mass transport system and as such, is only efficient when there is a mass to be transited. Therefore, it is crucial to match demand with supply. Incremental technological efficiency developments are meaningless with low load factors. In terms of rail, the trend of urbanisation in the UK is advantageous and creates great potential. Rail transport must focus on high-density area. The current rail network was built in a very different time and for very different reasons. Currently, about 60% of the network has a good cost to benefit ratio for electrification.

There is a need to make better use of energy in rail. As 80% of energy is used in starting and stopping, there is much room for service optimisation. Tunnels are increasingly being adopted for visual reasons, primarily in response to public concerns. However, the energy requirements increase by 60-70% over full operational life.

Beyond this, rail is a young technology that has undergone little change. There is little research budget and historic trends have been poor. Since the 1980's, trains are 30% heavier, use 30% more energy and efficiency has dropped by 30%. The adoption of technology in the automobile industry sets a good example for rail to follow.

Martin Tugwell outlined the role of the Autonomous Electric Vehicles Catapult. The goal is to foster smarter travel with intelligent usage and a focus on end users. The mobility itself is the service and therefore it is the access and not the ownership of transport that is in focus.

The Autonomous Vehicle Catapult is delivering pods on behalf of the Automotive Council. The pods are constructed by RDM in collaboration with the Robotics Group at Oxford University. This technology provides a greater level of access than GPS based systems and can allow access within buildings, such as shopping centres.

Using pods in a dynamic real world environment, where there will be interactions with people, poses issues surrounding user safety and confidence.

Is it possible to use pods as storage to aid the balance of supply and demand of the electricity grid? With an ageing population, can they be used to give better mobility, for longer and thus increase the quality of life for a significant proportion of the population?

Technology is not the barrier, nor the silver bullet. Does it respond or does it shape the future? What does the user want? How does the technology influence that? What does Uber do that people like? Would Uber be as popular if they were public run?

Clare Grey outlined the chemistry challenges faced for energy storage in batteries. Intrinsically, a material can only hold a limited amount of electrons. Increasing the voltage is destabilising and can lead to the combustion of organic matter. We are approaching this technical ceiling.

The Toyota Prius uses a nickel metal hydride battery, allowing for fast charging at the compromise of a low capacity. The battery operates within a range of 18-20% to ensure this longevity. Lithium ion batteries have 3 times the capacity of lead acid batteries but at a much higher cost, although these have come down as a result of large investments in China. Lithium air has a similar capacity as gasoline. Super capacitors allow power surges and thus can be used to mix peaks and troughs in specific applications. The 2020 and 2050 targets will not be met via electrification alone.

Issues:

1. *Charging* - consumers expect charging at a similar rate as current gas filling. To charge a car in 20minutes would require a copper cable of 20cm diameter. Charging at such a rate would degrade batteries greatly and has the potential to destabilise to the point of combustion.
2. *Infrastructure* - many local roads do not have electricity supply to provide infrastructure.
3. *Safety* – batteries involve toxic materials and plastics. Although they are not as intrinsically dangerous as gasoline they have specific requirements.
4. *Resources* – wide scale use poses supply and demand issues. For example, the cobalt in lithium batteries is already expensive. There is a push towards the use of more abundant raw materials, such as sodium.
5. *Logbooks* – there is a need to keep detailed battery histories to maximise full life use.
6. *Remote charging* – Potential but low efficiencies, 85% at best. The aim of electrification is efficiency and so this undermines overall aims.

Discussion

Ying Jin queried what speed the pods will be capable of in Milton Keynes and whether people would require a license. **Martin Tugwell** responded that 14kmh is expected. Initially testing will occur offsite with a user. Insurance and licensing is something that is part of an ongoing discussion with other Government departments.

Tony Roulstone asked for more clarity on the concept of using pods as energy storage devices, which can be used for grid balancing. Is there potential for battery degradation due to energy pulling and pushing demands, beyond that of the user? If so, who would cover this cost? **Shane Slater** clarified that there is a difference between putting energy in, taking energy out and balancing. Capacity payments are very different from utilisation payments. This is all about scale and having a big fleet. It is concluded that this sounds a reasonable and advantageous idea but that there is a real need to carry out modelling to quantify if the magnitudes are balanceable. **Paul Stein** added that using domestic electric and plug-in hybrid vehicles for load balancing did not necessarily require energy pulling and pushing and hence battery degradation – most proponents of this approach were simply suggesting smart charging by time-shifting to when intermittent loads were available in return for a lower tariff.

Urban Development – The planning of transport and how it affects energy Transport and energy inextricably linked in planning cities and urban development; the economics of transport planning. Role of rail-led regeneration and redevelopment, and urban energy implications.

Chair: Professor Koen Steemers
Professor of Sustainable Design, University of Cambridge
Dr Ying Jin
Senior University Lecturer, Department of Architecture, and Energy Efficient Cities Initiative EECi, University of Cambridge
Neil Chadwick
Director, Steer Davies Gleave
Richard Blyth
Head of Policy, Royal Town Planning Institute RTPI

Koen Steemers commenced by introducing a perspective on the built development. More than half of the world's population lives in cities. This is not in an effort to reduce emissions, but rather due to economic, cultural and social interactions. Cities, however, provide us with many opportunities to reduce emissions as well as energy consumption. We must integrate our transport with the wider built environment.

Buildings emit 50% and transport emits 25% of our CO_2 emissions in the UK. It is the synergies and interactions between these sectors that is the focus of this session.

Ying Jin stated that the synergy between transport and buildings has been the focus of much debate. How much do planning and the built environment contribute to reducing energy demand? Using 10 years of DfT data from the UK National Travel Survey, structural equation modelling has been applied to relate the complex interdependencies in the built environment. This research has shown that the planning of the built environment has a stronger influence in some geographic areas but weaker in others.

The UK may be considered in 3 different types of areas. First, there are dense areas with good public transport. This accounts for around 20% of the population. Here, demographic and planning changes have significantly increased the influence of the built environment on travel modal choice, to the extent that it is now the dominating factor. These dense areas have had success in increasing connectivity along with a reduction in car emissions.

Second, at the other extreme there are the rural areas, which accounts for 30% of the population. The majority of this population live strategically close to the denser conurbation. Only 8% out of the 30% are truly rural. In these rural areas there has been continuing car ownership growth, if car ownership has not already saturated at around 80% of the households. This 30% of the population in the countryside areas have few practical alternatives other than car travel and so progress could only be made through engine fuel efficiency and hybrid/EV adoption over time.

Third, there are the suburban areas in between, of intermediate densities. In those areas, which account for 50% of the population. What can be done in using built environmental planning to influence travel behaviour is obviously important to the overall success of reducing transport energy use and emissions. The location of futures jobs and industry will influence how sustainable these areas will be. Currently, the preference is to locate development in brown field sites, as greenfield sites face environmental challenges and local resistance is a major factor. This is all occurring to a backdrop of difficult issues, such as infrastructure under-investment, shortage of business floor space in high growth areas and lack of affordable house supply.

In this context of how people travel and where new development can be accommodated, the areas within walking distance of stations deserve more attention. The UK has 25 national rail hubs, 66 regional interchanges and 274 main feeder stations. DECC data illustrates that compared to rail, diesel cars emit 15 times more energy and a bus 4 times than rail travel per person-km. By 2030, diesel cars are expected to improve to around 10 times that of train and buses 3 times. The younger generations have shown a willingness to adapt to denser areas, which afford more connectivity and are more socially attractive.

The land use around train stations is changing, as a result of the new ideas of planning and urban design. The perception of working and living near a rail station has changed dramatically in recent times, as for example, can be seen in the Kings Cross Central development in London. What will these new developments mean socially, environmentally and economically? Design has the potential to achieve a great deal in these contexts. Secondly to this, new financing has opened potential. Thirdly, the use of more space by stations for commercial use is building momentum but facing some barriers. One example of this challenge is displayed in comparing New York to London. The NYC subway can access 1.7million people within a 20minute walk of stations. However, London can only achieve a fraction of this. It remains a great challenge for us to set a standard and thus enable this to be rolled out appropriately across the UK.

Richard Blyth opened by commenting on the history of comparably small infrastructure investment in the UK to other developed nations. Despite recent capital expenditure plans of the Coalition Government, we are still behind cities such as Paris, who has recently announced EUR 30 Billion infrastructure spending. Within this, there is the ever-emerging paradox of rising demand and shortage for housing. This is not an issue of a land shortage but rather this is a lack of infrastructure to connect these housing sites. There is land available but there is not land with future access by at least one mode of transport.

There are two things here. There is inadequate funding for infrastructure and there is an extreme shortage of housing. We need to target these collectively. The RTPI have found a lack of coordinated thinking in government action, with little integrated thinking to find solutions, which tackle issues in multiple sectors. Some economists have proposed that instead of maintaining green belts, land use change should be dictated to by its character and if it is perceived as being ugly, it should be possible for it be built upon. There is no issue with this, but where is the transport connection considerations in this decision making? This idea can only work if there is sufficient future transport capacity to support it.

The appraisal of schemes is currently loaded in favour of journey time savings and neglects aspects such as the new housing potential created. There is a need to reconsider the weight attributed to different metrics. The Oxford to Cambridge link business case would be vastly improved by opening up housing developments along the route.

The RTPI advocate devolution in this context as it can enable land use and transport decisions to be made more easily if they are given to city and county level. The distinction between local and national decisions is not clear. For example, all of housing is treated locally and yet all of transport is treated nationally.

The current coalition government is targeting housing permissions at "all costs." However, one of the costs is urban sprawl due to the ease of gaining permissions in areas of poor transport and infrastructure. This development is not desirable.

It is interesting to note the scheme proposed by the URBED the recent winner of the Wolfson Prize Garden City Award. The winning plan was not a garden city, rather an extension to a pre existing area. It was transit lead and followed a snowflake shaped expansion.

In closing, is it time for a secretary of state for housing?

Neil Chadwick began by outlining the factors that explain why we want to live in towns and cities – social pulls, specialisation, dynamism and economic agglomeration. How do we make our cities more productive?

There are three externalities in transport:

1. Accidents - 25 years ago there were 10 deaths per day on UK roads. There are now 5 per day.
2. The environment – pollution, NOx, SOx and GHG emissions.
3. Congestion – there is simply more demand than supply.

In terms of financial cost, congestion is the greatest cost to the UK economy and this won't be changed by the adoption of EV. Cars can be improved to any extent but this distracts from the reality that society needs to change the way in which it travels.

It is important to remember than energy itself is cheap and it is the taxation that is responsible for the high user cost. The cost of motoring is not actually the determining factor in current traveller behaviour. The proposition for new services much be made in terms of its opportunities, the convenience, the connectivity and the higher level of service. Fundamentally, how do we make public transport more attractive to the public?

Discussion

Phillip Cartwright commented that the 150,000 houses per year deficit is significant when you consider there is land available. This is a supply chain limitation. Can this be opened up? **Koen Steemers** questioned if an assessment has been carried out to quantify what the consequences of this shortfall are.

Neil Chadwick mentioned the importance of precedent. Life style decisions are influenced at the beginning of exposure to a new environment. People will stick to what they know and behaviour can become fixed if policies do not target travel behaviour at the time of opportunity.

Tony Roulstone queried the role of high density living in the UK beyond London. British do not appear to like such provision, as there seems to be a social expectation of personal gardens for example. **Ying Jin** concurred that the UK is complex in this sense. There is a need for better-connected groups of cities, with each built around rail hubs. Japan offers an interesting precedent.

Richard Blyth commented that the unification of the Manchester councils to plan new housing together is a big development. It has the potential to act beyond the traditionally short-term political considerations. **Andrew McNaughton** added his voice to the issues surrounding the absence of coordinated land use and transport planning. Building is occurring in cheap areas. These very areas are cheap as they are underserved by infrastructure. **James Stewart** ended the session by questioning why it is the UK still talks of housing and not apartments. Government controlled land is poor and badly situated. There is a need to build up on what land is already in use. Fundamentally this requires a cultural change.

Policy Focused Panel Discussion
From session talks and roundtables – discussion of key policy challenges and opportunities for UK, Europe, and beyond. Skills gaps and capacity building.

Chair: Professor Robert Mair
Sir Kirby Laing Professor of Civil Engineering, University of Cambridge; former Master, Jesus College
Dr Miles Elsden
Chief Scientific Adviser, UK Government Department for Transport
James Stewart
Chairman, Global Infrastructure, KPMG

Miles Elsden began the final session with a reflection and roundup of the day. Regarding innovation, how and where will this come from? Infrastructure and construction are young in terms of innovation. Risk, where does the risk lie and who will take responsibility? Where do the boundaries lie between government, policy makers and the private sector? These are grey areas and there must be clarification to enable good management.

Is technology incremental or disruptive?

How do we reconcile the variation in data resolution?

- Data & Information technology at monthly cycles
- Cars at 5 year cycles
- Trains at 30 year cycles
- Planes at 50 year cycles
- Infrastructure at 100 year cycles

Liquid fuels are necessary until we can find alternatives with sufficient energy density. However, there has been no discussion on synthetic fuels? There is the potential to use nuclear energy to generate. What about third generation biofuels?

James Stewart commented that the prospects for energy are discouraging. Nuclear is expensive and slow, solar, tidal and wind are small and governments are struggling to have an impact.

Who is the master planner in terms of organising all these new technological ideas into a coordinated plan?

How do we genuinely change behaviour? Why do people need to own a house? Will people be commuting into work in 20 years time? How do we change transport behaviour? There has to be a cultural change before we use infrastructure in a different way.

Regarding infrastructure time scales, why does it take so long? It cannot continue at this rate.

The role of the government and the private sector is a continuing theme. In the case of Battersea, it took Government 30 years to eventually become involved. Development was stalled due to a lack of transport infrastructure.

Discussion

Thomas Briggs queried why, in the case of Battersea, did it take so long before government intervention. **James Stewart** responded that it was related to fiscal capacity concerns. Government was reluctant to borrow. Borrowing impacts negatively on capacity and so what government eventually did was offer a guarantee, which was off their balance sheet, which TFL could then borrow against. This was only possible as the UK held a AAA credit rating.

Richard Blythe commented on the evolution of government attitudes to infrastructure. It has taken the Treasury a significant period of time to recognise the value in infrastructure.

Nick Collings queried **Miles Elsden** on his experience of the scientific community within government. **Miles Elsden** highlighted that there is only one scientific voice in the House of Commons, but many more in the House of Lords. Judging by the greater number of economists in DfT it would appear that they have been more successful in influencing policy. There are recent examples of scientific research influencing policy in a tangible way. A notable example would be Robert Mair's recent fracking publication. Ultimately it is important to remember that the DfT are primarily focused on the delivery of many large-scale projects. With the demands of delivering a mega project such as HS2 it is often difficult to consider more than what is ongoing in the very short term.

Thomas Briggs felt there is a need in the UK to deregulate and allow market freedom, as has been successfully done for fracking in the US. In contrast to this, **Tony Roulstone** argues that the UK has been waiting for the market to solve many of these infrastructure wide problems. Although the market is a wonderful mechanism for many decisions, it is not for everything. There must be a market and a non-market case.

Tony Roulstone raised the difference in leadership of energy policy in the US and the UK. The Secretary of Energy in the US has been held by technical and academic figures. Currently held by Dr Ernest Moniz, an MIT Professor. In the UK, it remains a political position. It is also important to remember that the UK effectively abolished the scientific civil service in the 1980's. Is it possible to follow the US model in the UK? **Miles Elsden** recounted that Winston Churchill's science advisor was offered a post as the Minister of Science but he declined as he felt it was inappropriate. Such a setup is not inconceivable in the future. Beyond this, there is now a scientific fast stream in the civil service, which aims to attract Masters and PhD level candidates. This has great potential, but will face some time lag before it penetrates into more senior levels.

James Stewart closed the conference by commenting that the larger the project, the more political the decision-making appears to be.

Rustat Conferences Jesus College, Cambridge

The Rustat Conference is an initiative of Jesus College, Cambridge, and chaired by Professor Ian White FREng, Master of Jesus College. The Rustat Conferences provide an opportunity for decision-makers from the frontlines of politics, the civil service, business, the professions, the media, and education to exchange views on the vital issues of the day with leading academics. Since its founding in 2009, Rustat Conferences have covered a variety of themes including: *The Economic Crisis*; *The Future of Democracy*; *Cyber Security*; *Manufacturing in the UK; The Future of Research-Intensive Universities; The Geopolitics of Oil and Energy; Drugs Policy; Organisational Change in the Economic Crisis, Cyber Finance, The Understanding and Misunderstanding of Risk, and Food Security.*

In addition to acting as a forum for the exchange of views on a range of major and global concerns, the Rustat Conferences provide outreach to a wider professional, academic, student and alumni audience through the publication of reports. The conferences are held at Jesus College, Cambridge and are named after Tobias Rustat (d.1694), a benefactor of Jesus College and the University.

Rustat Conferences Foundation Members

The Rustat Conferences are supported through a mix of sponsorship and a membership scheme that was launched in 2013-14 - details of this can be found at www.Rustat.org We are very grateful to the Rustat Conferences Foundation Members for their generous support:

- **Dr James Dodd -** James's career has concentrated on the founding, financing and governance of companies in the areas of telecommunications and technology. He studied physics at the universities of London, Oxford and Cambridge, and began his career in the areas of scientific and financial analysis for both government and industry. He serves on a number of boards in these areas and is active in supporting a number of academic projects and charities in related fields.

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- **Maria and David Willetts**

Rustat Conferences

Speaker Biographies

Richard Blyth

Richard Blyth has been Head of Policy and Practice at the RTPI since September 2011. Since then he has established the RTPI's new policy paper series starting with Housing in 2013 and also the special RTPI Centenary Planning Horizons research programme with five projects being published in 2014. Prior to this he was an Associate Director at Capita Symonds where he worked on commissions for local authorities on infrastructure planning to support core strategies, and for a number of private clients on regeneration schemes. He spent more than four years in the Civil Service, including being responsible for Local Plans in England.

Dr Phillip Cartwright

Phillip Cartwright is the Electrical Engineering Director at Laing O'Rourke's Engineering Excellence Group. Previously, he was head of electrical power and control systems with Rolls-Royce, where he was responsible for the global function, business and associated corporate strategy for electrical power and control systems. Phillip started his career in the design of high-voltage power systems in the UK, India, China, Uruguay and Brazil. He has since designed and/or managed projects for safety critical systems (nuclear and aero) and many large turnkey power system applications, including HVDC, Flexible AC Transmission Systems and onshore and offshore wind farms. He was previously a senior engineering and commercial manager with the nuclear group AREVA, working with developers, manufacturers and network operators throughout the world to progress the development and implementation of enabling technologies for energy networks.

Professor David Cebon

David Cebon is a Professor of Mechanical Engineering at the University of Cambridge and a Fellow of the Royal Academy of Engineering. He is Director of the Cambridge Vehicle Dynamics Consortium and the Centre for Sustainable Road Freight. David leads the University Engineering Department's Transport Research Group and the Department's research theme 'Energy, Transport and Urban Infrastructure'. He serves on the Editorial Boards of three international journals. Professor Cebon's research covers the mechanical, civil, and materials aspects of road transport engineering. He has authored and co-authored numerous papers on dynamic loads of heavy vehicles, road and bridge response and damage, traffic information, advanced suspension design for heavy vehicles, heavy vehicle safety and mobility, heavy vehicle fuel consumption and the micromechanics of asphalt deformation and fracture. He has a Ph.D. in engineering from Cambridge University and a bachelor's degree from Melbourne University.

Neil Chadwick

Neil Chadwick is a Director with Steer Davies Gleave, an employee-owned consultancy specialising in the transport sector and which operates in the UK and internationally. Neil oversees the company's Strategy and Economics work in the UK. With 25 years' consultancy experience, Neil has undertaken a wide range of transport strategy and policy studies, as well as the development of business and investment cases. He has led the development of multi-modal transport strategies, as well as the strategic, economic and financial cases for major transport investments. In addition to working in the UK, he also has worked in Ireland, the Middle East and Australia. Neil has a Physics degree from Oxford University, a Transport Master's from London and a Master's in Public Administration and Public Policy from York.

Nick Chism
Nick Chism is the Global Chair of KPMG's Infrastructure, Government and Healthcare practice. He is a partner in KPMG Corporate Finance and sits on its global leadership team. Nick joined the company in 1996, working on numerous PPPs and concessions with public and private sector clients across the UK and Europe, principally in road and rail, while supporting the growth of a global network. He ran the UK team from 2004 and then devoted considerable time to developing new businesses in the United States and Middle East. He became KPMG's first head of global infrastructure in 2008, and has overseen a period of considerable growth worldwide since then – its activities now span more than 130 countries.

Professor Nick Collings
Nick Collings is head of the Acoustics, Fluid Mechanics, Turbomachinery and Thermodynamics Division of the Department of Engineering at the University of Cambridge. Nick's research interests are IC engine control, and emissions measurement and amelioration. His work in the IC Engine control group includes topics related to the measurement and control of pollution and the development of a series of very high performance emissions measurement systems, in particular, those with high frequency response, which have resulted in commercial devices, now marketed worldwide. New work is underway on sensors to measure particulates from IC engines. Nick is also working on exhaust after-treatment modelling and understanding of the heat transfer processes in the exhaust system and mechanisms of pollution conversion to benign products within the catalyst.

Dr Tim Coombs
Tim Coombs has 20 years' experience in superconducting engineering, covering both experimental and theoretical aspects. He leads one of the strongest superconducting groups in the world with an extensive portfolio of experimental techniques, mathematical analysis tools and machine designs. He has an internationally leading publication record which extends to more than 100 papers released in high impact scientific journals. He has worked on novel solutions to the Critical State, developing one of the first algorithms capable of calculating the critical state in two dimensions. Tim also pioneered the (now standard) use of the H-formulation. His group constructed the world's first all superconducting motor and he has achieved global recognition for his ideas on the magnetisation of superconductors which will provide a field strength an order of magnitude stronger than conventional magnetic materials, enabling smaller, lighter, more efficient motors and generators. Tim has authored more than ten patents.

Dr Miles Elsden
Miles Elsden joined the Department for Transport in May 2012. He is currently Chief Scientist and Acting Chief Scientific Advisor and is head of the Science and Engineering profession in the Department. Miles has a background in applied mathematics and computational fluid mechanics and spent a number of years as an academic in the UK, France and Germany before joining a software development company based in Brussels. He is a Chartered Mathematician, Chartered Scientist and Chartered IT Professional, a Fellow of the Institute of Mathematics and its Applications and a Cambridge Science and Policy Fellow and an Honorary Professor at University College London. He also holds an MBA from Cranfield University.

Dr Sunoj George

Sunoj George is Manager of Hybrid Systems at McLaren. He joined the company as Powertrain Control Systems Team Leader in 2012, initially taking on responsibility for a next generation ECU project. In the time since, Sunoj has worked on developing the hybrid system on the world renowned McLaren P1. In December 2013, Sunoj was appointed as Hybrid Systems Manager, taking on the responsibility of developing the next generation of hybrid supercars at McLaren**.**

Professor Clare Grey

Clare Grey is the Geoffrey Moorhouse-Gibson Professor of Chemistry at the University of Cambridge. Her current research interests include the use of solid state NMR and diffraction-based methods to determine structure-function relationships in materials for energy storage (batteries and supercapacitors), conversion (fuel cells) and carbon capture. She received a BA and DPhil in Chemistry from the Oxford University. Her recent honours and awards include the 2007 Research Award of the Battery Division of the Electrochemical Chemical Society, the 2010 Ampere and RSC John Jeyes Awards, the 2011 Royal Society Kavli Lecture and Medal for work relating to the Environment/Energy. She is a Fellow of the Royal Society.

Michael Hurwitz

Michael Hurwitz is the Director of Energy, Technology and International at the Department for Transport. His teams direct and deliver UK-wide policies and programmes on low and ultra-low emission vehicles, low carbon fuels, air quality, promoting innovative new technology on the roads (in particular the connected car and automation), overseeing related government R&D expenditure and international negotiation of regulations on vehicle safety and emissions. He also oversees development of the DfT's international relations, with the EU and wider world. From 2011 to 2014 he was Policy Fellow at the Energy Futures Lab, Imperial College London.

Dr Ying Jin

Ying Jin is a senior lecturer at the University of Cambridge's Department of Architecture. Through research and consultancy work he has led multi-disciplinary teams for strategic planning of London and surrounding regions, sub-regional and local planning in the English Midlands, transport and energy scenarios for the European Union and long term city region and transport studies in China and in South America. He is the urban modelling lead of Cambridge University's Energy Efficient Cities initiative, and a co-Investigator at the Cambridge Centre for Smart Infrastructure and Construction. Ying has been lead convenor for the annual Symposia on Applied Urban Modelling since 2011.

Professor Robert Mair

Robert Mair is the Sir Kirby Laing Professor of Civil Engineering at Cambridge University and head of civil and environmental engineering. He was Master of Jesus College between 2001 and 2011 and founding chair of the Rustat Conferences (2009-11). He is also one of the founding directors of the Geotechnical Consulting Group (GCG), an international consulting company based in London. He was appointed chief engineering adviser to the Laing O'Rourke Group in 2011. After graduating from Cambridge in 1971, he worked continuously in industry except for a three-year period when he returned to Cambridge to undertake a PhD on tunnelling in soft ground. Throughout his career he has specialised principally in underground construction, providing advice on numerous projects worldwide involving soft ground tunnelling, retaining structures, deep excavations and foundations. He has been a member of expert review panels on major international underground construction projects, including the current Crossrail project in London. He leads a major research group at Cambridge and is principal investigator for a recently-awarded Innovation and Knowledge Centre on Smart Infrastructure and Construction funded by EPSRC, TSB and industry. He chaired the Royal Society/Royal Academy of Engineering Review of Shale Gas Extraction in the UK in 2012. He has recently been appointed chairman of the Science Advisory Council of the Department of Transport.

Professor Andrew McNaughton
Since 2009, Andrew McNaughton has been Chief Engineer and Technical Director of High Speed Two Ltd, developing the principles, network and specific route design for high speed rail in Great Britain. From 2001, he was Chief Engineer of Network Rail responsible for the specification and development of the GB rail network, investment authorisation and overall system safety management. Andrew is a Fellow of the Royal Academy of Engineering, the Institution of Civil Engineers, the Royal Geographical Society and the Chartered Institute of Logistics and Transport. Andrew has been Vice Chair of the EU Transport Advisory Group, Chair of the UIC Infrastructure Commission and Chair of the EU Rail Research Council.

Jonathan Neale
Jonathan Neale is COO and acting CEO for McLaren Racing, having joined the company as Operations Director in 2001. In 2004, Jonathan was appointed Managing Director, which increased his responsibilities to include the engineering departments, enabling him to become more involved in the technical strategy and direction of McLaren Racing. Jonathan is an active supporter of the Foundation for Science and Technology and the Rustat Conferences.

Tony Roulstone
Tony Roulstone established and teaches on the Nuclear Energy Master's programme at the University of Cambridge with research interests in the economics and safety of nuclear power. He is also a visiting Professor of Nuclear Engineering at City University in Hong Kong. Tony received his degree from the University of Cambridge and has spent much of his career in the nuclear and aerospace industries, starting with UKAEA working on fast reactor systems and including 20 years at Rolls-Royce where he became Managing Director Nuclear Group in 1992. Also, he was the nuclear engineering director when the Vanguard nuclear submarines were being delivered. He has also held senior engineering and corporate transformation roles in Rolls-Royce plc.

Professor Koen Steemers
Koen Steemers is the Professor of Sustainable Design in the Department of Architecture at the University of Cambridge, where he has been Head of Department and Director of Research. He is an architectural and built environment academic and was recently named in Building Design's inaugural list of the "50 most influential people in UK sustainability". His PhD work at Cambridge developed new insights in to the links between urban design and energy consumption which generated a series of funded research projects and drew the attention of academics and practitioners. He was invited to act as consultant, notably to the Richard Rogers Partnership on numerous projects, and became a Director of Cambridge Architectural Research Limited in 1991. Koen is leading a research team undertaking research into energy demand, user behaviour and environmental performance of architectural and urban space. He coordinates the MPhil course in Architectural and Urban Studies, and has produced 170 publications, including 10 books.

Paul Stein
Paul Stein is Group Chief Scientific Officer at Rolls-Royce, where he helps set technological and business direction in view of market and technology trends, and examines areas where alternative technological and innovative approaches could lead to competitive advantage. In 2006, Paul joined the Ministry of Defence as the Director General of Science and Technology. Paul started his career at Philips Research Laboratories in Redhill, Surrey, developing technology and systems engineering techniques for early generation analogue cellular phone systems. Paul is a Fellow of the Royal Academy of Engineering, a Fellow of the Royal Aeronautical Society and a Fellow of the Institution of Engineering and Technology.

James Stewart
James Stewart joined KPMG in 2011 as the Chairman of KPMG's Global Infrastructure practice. He has been involved in the Infrastructure and PPP market for more than 20 years and has particular experience in the Rail, Road and Social Infrastructure sectors as well as advising government on delivering infrastructure investment programmes. Most recently, he has advised Amtrak and the State of California on their High Speed Rail projects and he has been working with the Sao Paulo Metropolitan Transportation Authority. James started his career at Hambros and Société Générale where he became Managing Director of Project Finance and the Global Head of Infrastructure and Environment. He then moved to Newcourt Capital as Head of European Project Finance followed by CEO of Partnerships UK and CEO of Infrastructure UK (IUK) before joining KPMG

Matthew Tipper
Matthew Tipper was appointed Vice President of Shell Alternative Energies in 2012. He joined Shell in 2009 as Commercial General Manager and has more than 25 years' commercial experience in the company, gained across various Downstream business roles, primarily in trading and supply. Matthew was previously responsible for leading Shell's global gasoline trading business, during which time he spent several years working in Houston and established a number of new trading ventures including a biofuels business centered upon the USA, Europe and Brazil. He spent much of his early career in a range of trading and supply operations in Africa, the Middle East, India and the UK. Matthew has a first degree in Geography and an MBA. He is a fellow of the Royal Geographical Society, and a patron of Mansfield College, Oxford.

Martin Tugwell
Martin Tugwell is Head of Business Development at Transport Systems Catapult, the UK's centre for innovation, technology and applied Research and Development in Intelligent Mobility. The Catapult's mission is to encourage emerging technologies to be harnessed to enable the efficient movement of people and goods and to drive forward innovation in the transport sector so as to support business growth. Martin has a track-record of championing new models of integrated delivery, playing a leading role in developing strong partnership working between the public, private and academic sectors.

Professor Ian White
Ian White is Van Eck Professor of Engineering, and the Master of Jesus College, Cambridge. He is also head of photonics research in the Electrical Division in Engineering, and chair of the Rustat Conferences. Ian White began his time at Cambridge by being awarded the BA in 1980, and the PhD in 1984. After being appointed a research fellow and assistant lecturer at Cambridge, he moved to the University of Bath to become professor of physics in 1990. In 1996, Professor White moved to the University of Bristol, becoming head of the Department of Electrical and Electronic Engineering in 1998. He returned to Cambridge in October 2001 as Van Eck Professor of Engineering. Ian's current research interests are in the area of high speed communication systems, optical datacommunications, laser diodes for communications and engineering applications and RF over fibre systems.

Rustat Conference on Transport & Energy
Jesus College Cambridge – Thursday, 27 November 2014
Participants List

Title	First Name	Surname	Position	Organisation
Professor	Jean	Bacon	Professor of Distributed Systems; Fellow, Jesus College	University of Cambridge
Professor	Alison	Bashford	Vere Harmsworth Professor of Imperial and Naval History	University of Cambridge
Mr	Richard	Blyth	Head of Policy	Royal Town Planning Institute RTPI
Mr	Thomas	Briggs	Head of Transportation Energy Policy	BP plc
Dr	Phillip	Cartwright	Electrical Engineering Director, Engineering Excellence Group	Laing O'Rourke
Mr	Gerard	Casey	Rustat Conference Rapporteur; PhD, Centre for Sustainable Devt	University of Cambridge
Professor	David	Cebon	Professor of Mechanical Engineering	University of Cambridge
Mr	Neil	Chadwick	Director	Steer Davies Gleave
Mr	Nick	Chism	Global Chair, Government & Infrastructure; Foundation Member, Rustat Conferences	KPMG
Dr	Stuart	Clarke	University Senior Lecturer in Chemistry, Fellow, Jesus College	University of Cambridge
Professor	Nick	Collings	Head of the Acoustics, Fluid Mechanics, Turbomachinery and Thermodynamics Division, Department of Engineering	University of Cambridge
Mr	Nick	Collins	Transport Correspondent	The Daily Telegraph
Dr	Tim	Coombs	Senior Lecturer Department of Engineering	University of Cambridge
Mr	John	Cornwell	Director, Science & Human Dimension Project	Jesus College, Cambridge
Dr	Heather	Cruickshank	University Lecturer, co-founder Centre for Sustainable Devt	University of Cambridge
Dr	James	Dodd	Director, Oriel Securities; Foundation Member, Rustat Conferences	Oriel Securities
Dr	Clare	Dyer-Smith	Coordinator, Cambridge Big Data Strategic Research Initiative	University of Cambridge
Dr	Miles	Elsden	Chief Scientific Adviser	Department for Transport
Ms	Carolina	Feijao	PhD, Department of Biochemistry	University of Cambridge
Dr	Sunoj	George	Manager, Hybrid Systems	McLaren Automotive Ltd
Professor	Clare	Grey	Department of Chemistry	University of Cambridge
Mr	Michael	Hurwitz	Director, Energy, Technology and International (ETI)	Department for Transport
Dr	Ying	Jin	Department of Architecture, Energy Efficient Cities Initiative - EECi	University of Cambridge
Mr	Eirian	Jones	Director; Foundation Member, Rustat Conferences	Lord North Street - SandAire

Title	First Name	Surname	Position	Organisation
Mr	Stephen	Joseph	CEO	Campaign for Better Transport
Mr	Terry	Macalister	Energy Editor	The Guardian
Professor	Robert	Mair	Sir Kirby Laing Professor of Civil Engineering	fmr Master, Jesus College University of Cambridge
Mr	Chris	Malins	Head, Fuels Programme	International Council on Clean Transport
Professor	Andrew	McNaughton	Technical Director	HS2
Mr	Jonathan	Neale	Chief Operating Officer and Acting CEO; Foundation Member, Rustat Conferences	McLaren Racing Ltd
Mr	Tony	Roulstone	Cambridge Nuclear Energy Centre	University of Cambridge
Mr	Clive	Savage	Downstream Strategy, Portfolio & Alternative Energies Comms	Shell
Mr	Adrian	Sington	Director	DCD Media
Dr	Shane	Slater	Director	Element Energy
Professor	Koen	Steemers	Professor of Sustainable Design, Fellow, Jesus College	University of Cambridge
Mr	Paul	Stein	Chief Scientific Officer	Rolls-Royce
Mr	James	Stewart	Chairman, Global Infrastructure; Foundation Member, Rustat Conferences	KPMG
Dr	Preti	Taneja	Jesus College	Cambridge
Mr	Corin	Taylor	Senior Adviser	UK Onshore Oil & Gas UKOOG
Mr	Giles	Thomas	Deputy Technical Director	HS2
Mr	Matthew	Tipper	VP Alternative Energies	Shell
Mr	Gwyn	Topham	Transport Correspondent	The Guardian
Mr	Martin	Tugwell	Director of Business Development	Transport Systems Catapult
Mr	Richard	Webb	Deputy Features Editor	New Scientist
Mr	Paul	Westbury	Group Technical Director	Laing O'Rourke
Professor	Ian	White	Master, Jesus College, Van Eck Professor of Engineering, Chair, the Rustat Conferences	University of Cambridge
Professor	Peter	Williamson	Professor of International Management, Fellow Jesus College	Cambridge Judge Business School, University of Cambridge
Professor	Andy	Woods	BP Professor, Head of BP Institute	University of Cambridge
Rustat Conferences, Jesus College				
Mr	Gerard	Casey	Rustat Conference Rapporteur; PhD, Centre for Sustainable Devt	University of Cambridge
Mr	Jonathan	Cornwell	Director, Media Symposia, and Rustat Conferences	Jesus College, Cambridge
Ms	Carolina	Feijao	PhD, Department of Biochemistry; assisting Rustat Conferences	University of Cambridge
Mr	Lee	Pearson	PhD, Centre for Environmental Policy; Jesus College member assisting Rustat Conferences	Imperial College London
Dr	Elisabeth	Schimpfossl	Leverhulme Early Career Fellow; assisting Rustat Conferences	University College London

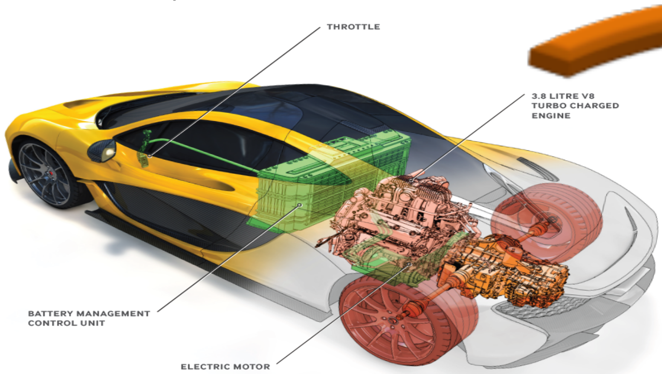
Presentation Slides – Dr Sunoj GerogeMcLaren Automotive

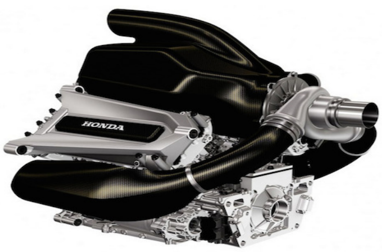
Powertrain Electrification – Synergy between F1 and Roadcars
‘The McLaren Insight’

Dr. Sunoj George
Manager, Hybrid Systems
McLaren Automotive Ltd.

Hybrid Technology Transfer
Motorsport - Automotive

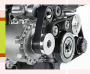
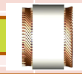
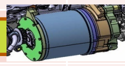
- ❖ Motor Control Unit
- ❖ Motor





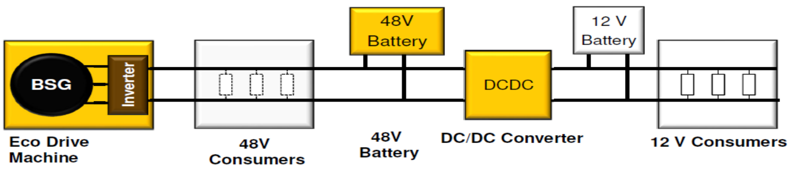
- ❖ Battery Cooling
- ❖ Motor Control Unit

Powertrain Electrification

	Micro Hybrid	Mild Hybrid	Full Hybrid	Plug-in Hybrid	Range Extender	EV
Attributes	Start/Stop	Boost Recuperation	Launch Creep Torque Fill-in	Electric Driving	Electric Driving	Electric Driving
E-Motor Power	0.5 – 8 kW	8 – 20 kW	15 – 50 kW	30 – 85 kW	40 – 85 kW	40 – 85 kW
Voltage	12 – 48 V	48 – 280 V	120 – 480 V	200 – 480 V	200 – 480 V	200 – 480 V
Plug-in						
Starter/ Generator						
Low Power EM						
E-Tx, E-Diff						
TTRH (Thru the Road Hybrid)						

Powertrain Electrification – Mild Hybrid to 48V Hybrids

- 48 V is a technology trend in Europe with numerous development activities ongoing on OEM and supplier level.
- 48 V improves stability of power supply, smooth engine starts and air conditioning improvements in engine off conditions
- CO_2 improvements (up to 30%) due to recuperation, extended Start/Stop (i.e. on the move, coasting conditions)
- Fuel efficiency benefits and torque fill-in characteristics available that can enable



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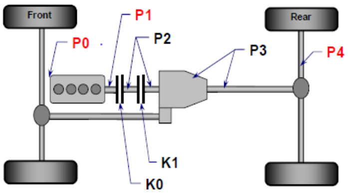
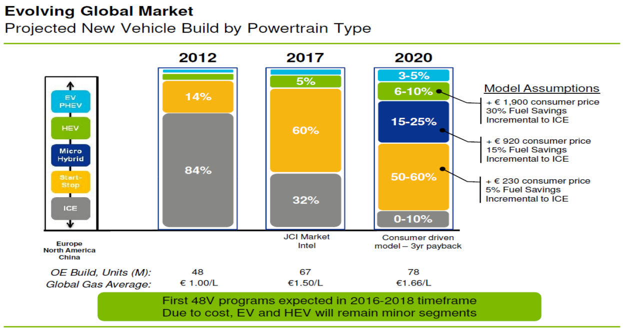
Powertrain Electrification – Full Hybrids/EVs



P0 = Belt driven Starter Generator (BSG)
P1 = Crankshaft mounted E-machine (CSG)
P2 = E-Machine on the gear input
P3 = E-Maschine on the gear output
P4 = Axle Drive

Reference: Continental AG

Reference: JCI



Powertrain Electrification – Challenges

- ❖ Motor Power Density – Roadmap from 4.5 kW/Kg to 10-15 kW/Kg
- ❖ Power Electronics – Roadmap to SiC and GaN devices.
- ❖ Battery Power Density
  - ➢ Current energy density of cells in the range of 140 to 170 Wh/kg
  - ➢ The best that battery packs will be able to achieve will be 200 Wh/kg. This energy density will be the focus of BEVs. For PHEVs, specifically for the sports car market, the energy density will be more around the region of 100 Wh/kg.
  - ➢ Current cost \$1000 to \$1200 per kWh.
  - ➢ OEM cost target of \$500 to \$600 per kWh is achievable by 2020.
  - ➢ Supercapacitor technology still under investigation – may be useful for transient torque delivery and crank conditions due to high power density. However, current control electronics and costs associated with this technology make it not applicable to McLaren usage conditions.
  - ➢ Technologies such as Lithium-air and Zinc-air batteries provide more opportunities and are being investigated.

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Powertrain Electrification – Challenges

- Downsizing and Electric Boosting
- Battery Technologies
- Charging Infrastructure
- Quicker route to bringing new technologies to the market
  - Government incentives to low volume/high technology value
  - UK manufacturing incentives for high power devices (Power Electronics, E-motors, Cell Manufacturing)

McLaren Hybrid Technology – Sunoj George 7