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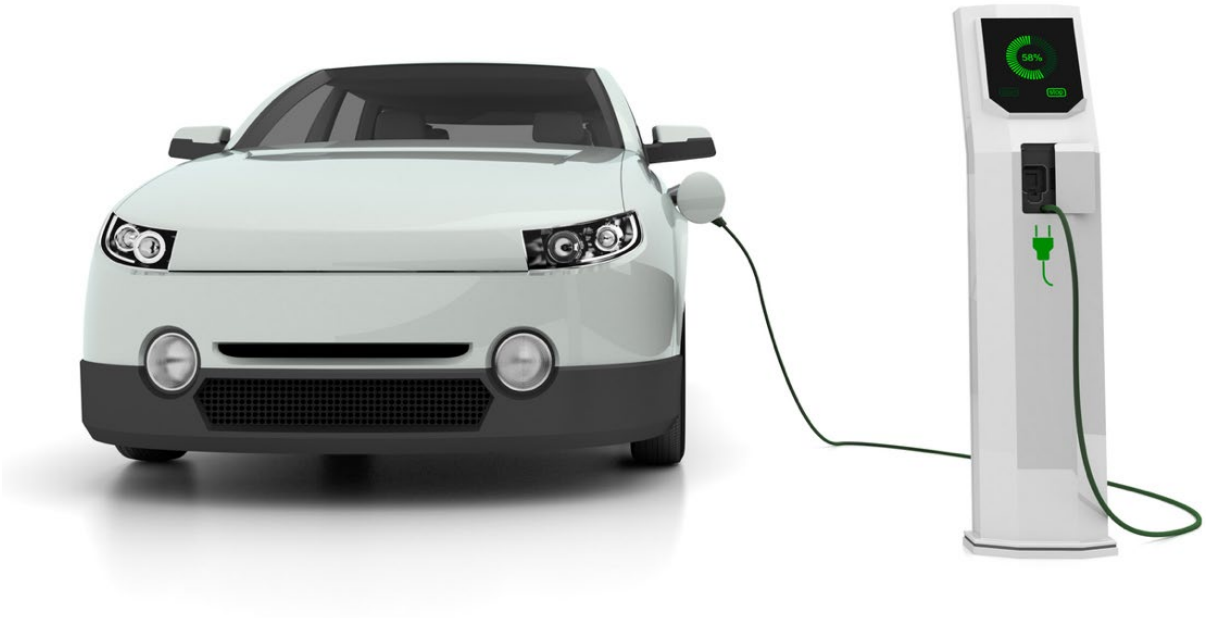
Accelerating Electromobility in the UK and Singapore:

a shared challenge

April 17-20, 2023

Symposium Report



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Introduction

Newcastle University (UK) in Singapore, in partnership with the Energy Research Institute at Nanyang Technological University, hosted the symposium *Accelerating Electromobility in the UK and Singapore: a shared challenge*. The event, funded by the UK Government's Department for Science, Innovation and Technology, aimed to identify areas for bilateral partnerships and research that will help to overcome the socio-economic, scientific and technical barriers to the mass uptake of electric vehicles (EV) and other modes of electromobility. Through these shared challenges, the symposium highlighted opportunities for joint academic and industry collaboration between the UK and Singapore in advanced electric transport research, development and onward commercialisation of solutions.

Over three days, speakers from industry, government and academic institutions, along with over 200 registered participants, shared insights from a technology, economics and policy framework point of view for accelerating electromobility in the UK and Singapore. Sessions were conducted in plenary with panel discussions, case study presentations and break-out sessions on day three.

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Nanyang Technological University	Charge+
Innovate UK	Envision Digital
Technical University of Munich in Singapore	Strides
Singapore Management University	Hyundai Singapore
University of Coventry	Arup
Strathclyde University	Engie Lab Singapore
Cranfield University	Keppel Infrastructure
Singapore Institute of Technology	Siemens Energy
Singapore University of Technology and Design	Jaguar Land Rover
University of Birmingham	Wearnes Automotive
Singapore Polytechnic	GogoX
Republic Polytechnic	Continental Corporation
National University of Singapore	PTV Group
Enterprise Singapore	Blue Line Taxis (UK)
NEU Battery Material	V Flow Tech
RSK Group	Bureau Veritas
Wiredbox Group	ACE Green Recycling
Keppel Volt	Durapower

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Executive Summary

The symposium consisted of three days of in-depth discussion about personal, public and private electromobility and transportation in urban settings. Topics included electric cars, infrastructure, batteries and energy supplies. Delegates also explored the latest alternative fuels, powering heavy vehicles, and powertrains.

- Day one included policy developments, for electromobility, the vehicles themselves, and the charging network developments.
- Day two focused on urban mobility, including fleets and trends in electrifying operations of large private and public transport operators, as well as developments in autonomous vehicles.
- Day three examined battery technology, charging networks, data science and bridging workforce skills gaps needed to support the infrastructure upgrades and charging networks roll-out to implement EV and other electromobility modes at scale. The environmental issues and complexities of battery recycling and repurposing were also addressed.

Panels and presenters discussed the importance of decarbonisation and sustainable solutions in future mobility. There was an emphasis on the need for collaboration and aligning industries on value chains, and the role of governments to set targets and align activity through policy planning and the academia-industry partnership opportunities to achieve net-zero emissions goals in the transport sector. The experts also highlighted collaboration between companies and institutions to develop new technologies and innovations for electrification and advanced manufacturing. The need to take decisions today that will be converted into actions that will lead to a more sustainable sector, consequently providing cleaner cities and reduction in climate changing emissions, was discussed.

The panellists also discussed the challenges of transitioning from petrol and diesel road transport to electromobility. One opportunity discussed is the need for more collaborative research between academia, industry and different countries to share knowledge and data.

Experts considered the challenges of electric vehicle charging infrastructure and its impact on energy demand. Different types of charging networks, such as fast/rapid and wireless, were discussed along with their potential impact on power grids. The need for smart solutions that balance convenience and cost-effectiveness is emphasized. The potential role of Vehicle to Grid (V2G) is viewed as a technology that will emerge later this decade at scale.

Various experts presented on topics related to autonomous vehicles, including driver behaviour, testing, insurance considerations, and public perception. The speakers discussed the challenges of implementing autonomous technology in transportation networks. They also touched on the importance of human factors and consider potential risks such as cyber-attacks. Overall, they remain optimistic about the future of autonomous vehicles but acknowledge that public acceptance will be key to success.

The challenges facing the expansion of charging networks, such as cost, space, and user behaviour were discussed and the panellists also addressed issues related to reliability and perceptions of electric vehicles. Despite these challenges, there is a need to push towards innovation in the industry to make EVs more accessible and convenient for users at scale.

The speakers discussed various challenges and solutions related to electric vehicle charging, including the need for collaboration between industry sectors and policymakers, the importance of building an ecosystem that supports innovation, and potential business models for mobile charging. They also touched on concerns around battery degradation and the need for real-world testing. The overall message is that while progress has been made in this field, there is still much work to be done to ensure a sustainable future for electric vehicles.

Two videos of the symposium were produced. They can be accessed using the following links:

Video 1

Video 2

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Recommendations

The symposium *Accelerating Electromobility in the UK and Singapore: a shared challenge* provided a unique opportunity for delegates from industry, government and research and education institutions to exchange perspectives on the policy, technical and research challenges in the transition to electric urban transport. An objective of discussions is to identify critical projects and research areas that need further investment to accelerate the transition to transport electrification. These are presented below as a list of recommended projects or key topics.

A recurrent theme of the symposium was the need for bilateral research between the UK and Singapore, which would draw on the research strengths and transport electrification experiences in each country. As well as joint research, panellists also emphasised the need for public and industry partnerships with the aim to channel R&D into commercial applications.

The funding agencies in the UK and Singapore are well positioned to support these collaborations. The availability of bilateral research grants that incentivise partnerships between research institutions and businesses to tackle the challenges of electromobility would have a significant positive impact on progress. Such grants could be offered using the model of the Innovate UK – Enterprise Singapore innovation funding competitions. They would be specifically aimed at transport electrification, given the importance of this sector in reducing carbon emissions and in urban planning.

As listed below, there are many aspects of electromobility for which funding support would incentivise partnerships to bring about solutions. This would ensure that government targets for uptake of electromobility are achieved in both countries and that this is done in a sustainable way.

We hope that funding agencies in the UK and Singapore, as well as industry partners, will commit to supporting the following projects and areas of research.

- Modelling is a key part of the decision-making process in determining the number, location and type of EV charging stations to deliver an appropriate infrastructure. The symposium discussed different types of modelling using different data sets, variables and assumptions. A project can be set up to review current models for EV charging networks to identify best modelling practices and tools, data availability, assumptions, accuracy and other parameters. This would help to improve modelling practices and lead to better decision-making in setting up networks of charging stations.
- An important discussion in the symposium was about consumer behaviour and perceptions about using EV's. This has an impact on the rate of uptake of EV's and

design of infrastructure. An important piece of research would be to compare public perceptions of EV's in the UK and Singapore and understand the significant drivers and influences that impact on consumer decision-making.

- The symposium highlighted different policy positions specifically the validity of targets, and incentive schemes offered by the UK and Singapore governments. A useful project would be to conduct a review of policies, incentives and targets for both countries and to compare this with other countries where strong progress has been made in the transition to electromobility.
- The updating of grid infrastructure to support the energy demands of electromobility was a recurring discussion across the three days of the symposium. This is clearly an area that requires further investigation. It includes the modelling of energy demands arising from electrification of transport, the technical aspects of how to connect charging stations to the grid and the optimisation of energy demand (to even out peaks and troughs of energy demand).
- Another important area of discussion related to the types and locations of charging stations. While modelling of transport routes and volumes may help to determine the best locations for charging stations, availability of charging sites, such as street parking areas, public carparks, shopping mall carparks and fast road services areas may depend on factors such as costs, space, land ownership and public convenience. Transport authorities may also delay decision-making about implementation of charging networks in anticipation of forthcoming new technologies. A study that reviews the factors that determine charging station location, how optimised these locations are and the types of charging facility they should support (slow or fast charging) would make an important contribution to the set-up of EV infrastructure.
- In one of the sessions there was a discussion about renewable energy and energy storage in charging infrastructure. The idea of battery exchange was also considered. These technologies may mitigate demands on grid supplies from electric transport. Further investigations can be undertaken to advance these technical solutions to energy demands.
- An interesting and critical area concerns the business modelling for private sector investors in EV infrastructure. There was a widespread view that partnerships between government, research institutions and industry are an essential ingredient for successful progress in the transition to electromobility. However, from an industry perspective, investments, for example in setting up charging stations, have to yield returns. A study that looks at possible business models, how they may work alongside public investment and the mechanics of public-private partnerships would help to provide confidence for growth in private sector investment.
- A key discussion on Day 2 was about transportation using alternative fuels. In particular the use of hydrogen as a fuel for heavy transport may be more viable than using batteries. However, rapidly changing technologies make it difficult to predict future dominant energy sources for public and heavy transportation. In formulating policy, governments in the UK and Singapore need to be up to date with these technologies and their trajectories. A research paper that provides this information would help to support good policy and decision making.
- Another immediate concern for the government agencies responsible for managing the transition to electromobility is the policy framework during the transition process. This includes questions such as the flexibility of timelines, incentives, hybrid technologies for transport, technical standards, safety and so on. An advice paper

about how transportation may be best managed over the next decade would provide policy makers with a useful reference point.

- In the first session on Day 2 the panellists presented some broader insights in the context of urban planning. Progress with electric transport may not reduce the transportation burden in cities, for example commuting, parking, accessing services such as education and health care, and incentivising use of public transport. Government policies can reduce the need for people to spend their time moving around cities, for example by creating self-contained suburban towns that offer workplaces and all amenities. Policy development for urban transport should draw on studies of how urban planning can minimise transport demands.
- Autonomous vehicles will become more common on public roads in Singapore and the UK, although there are still many technical, policy and safety issues to overcome. They will have an important role to play in transport electrification. Further studies may consider how AV systems can help to progress transport electrification, particularly for public transport, the built environment and fleet management.
- The third day of the symposium had a strong focus on battery technology. This is an area of critical scientific and technical research that will continue to need funding to ensure batteries can be produced on a large scale sustainably, they deliver the charging and storage capabilities needed for transport and that they can be recycled or disposed of also in a sustainable way. Battery research projects should consider the full life cycle of the battery and not just the battery performance features.
- The recycling of batteries is a nascent industry. It has yet to develop capabilities that will be required for the mass recycling of batteries once EV's are used by the majority of drivers. Priority should be given to funding research projects that advance the technologies that can be used to maximise battery life-cycle and recycling performance, as well as managing the disposal process sustainably without major damage to the environment. Such research projects will also help support industry investment in this area.
- Use of batteries in electromobility creates a range of engineering challenges such as how battery units are stacked and connected to the vehicle, monitoring and optimising battery performance, safety, corrosion and leakage, thermal management and other factors. All of these aspects play an important role in the large-scale deployment of batteries in personal and public transport. The challenges are best through programmes that support industry and research commercialisation and innovation partnerships.
- The final area of discussion at the symposium was about the training and skills needed to ensure there is a workforce that can support electromobility, including in the production of batteries and vehicles as well as in maintenance. Training may be in the form of new content and skills for technical, diploma and undergraduate programmes or reskilling through professional training for those who are already in work. The key area for investment and development is curriculum content. The relevant government agencies can consider supporting this area of work, which may be implemented by education institutions working in partnership with industry.

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Session Notes

This section includes a summary of the key actions and priorities and discussions arising from the panels and presentations.

Session 1: Opening remarks

Panellists:

Kara Owen, British High Commissioner to Singapore, British High Commission

Natalie Black, HM Trade Commissioner for Asia Pacific, UK Government

Richard Davies, Professor and Pro-Vice-Chancellor, Global and Sustainability, Newcastle University

The symposium aims to explore opportunities to foster collaboration between the public and private sector alongside academia to expedite progress in the mobility sector in both the UK and Singapore. Each speaker identified the issue of electromobility as a key factor in addressing climate change.

Tackling climate change is one of the UK Government's top priorities and climate, nature, and energy remain at the forefront of UK's international policy priorities. The UK is accelerating its net zero transition, including driving green transition to net zero, delivering just energy transition partnerships with Indonesia and Vietnam, and releasing a series of climate energy reports that demonstrate acceleration pathways for a net zero transition whilst highlighting the importance of energy security. Both governments are pulling the best of their sectors together to make progress.

The UK and Singapore has signed the Green Economy Framework, a hybrid framework that promotes a greener, growing economy. This is a first of its kind for the UK and aims to bring together elements of climate policy work and trade agreements. The initial scope of the framework will be on three core pillars: low carbon energy technologies, green transport, and sustainable finance.

The UK and Singapore will collaborate to achieve their decarbonisation targets under the Paris agreements and enhance energy security across the green economy. The two countries will collaborate with businesses, universities, and investors to align supply chains, promote research, conduct workshops, and partnerships, and regulate and standardise the developing green sectors.

Given the transport sector's high dependency on fossil fuels, electric mobility is key to meeting decarbonisation targets. The UK has decided to phase out the sale of new petrol and diesel cars and vans by 2030, with all new cars and vans being zero emissions from the tailpipe by 2035. The UK government has committed £2.5 billion since 2020 to support the

transition to zero-emission vehicles, including funding to accelerate the rollout of charging infrastructure.

Singapore has implemented policies to encourage the uptake of EVs, including tax rebates, grants for charging infrastructure, and purchasing cleaner public transport. The UK and Singapore will collaborate to share knowledge and learn from each other about regulations, smart charging functionality, battery recycling, and circular economy, and ensure workforces are ready for a sustainable future.

The collaboration between the UK and Singapore presents significant opportunities for the broader Southeast Asia region. The significance of the private sector and academia in driving the green transition was emphasised. The symposium underscored the substantial impact of UK investments to innovate multiple industries. The critical role of universities in research and training the workforce for the needs of new sustainable industries was also highlighted.

The private sector has been critical in driving the transition towards a greener and more sustainable future, with the UK securing the second-highest cumulative amount of low-carbon investment in Europe. UK investments have had a significant impact on various industries, such as renewables hydrogen, carbon capture, power, stable materials, and energy storage. Partnerships in the Asia Pacific including with Japanese and Australian investors have secured significant investments in UK green infrastructure projects.

The Northeast of England has a strong industry base for electric and autonomous vehicle production, as well as tackling the challenges to reduce greenhouse gas emissions in industrial clusters and throughout the supply chain. There are numerous partnerships and centres in the northeast of England working on transport electrification, EV production and battery technologies. Newcastle University plays a key role in research and training to support these developments both regionally and nationally.

Panel Discussion

In this first plenary panel the importance for governments to implement policies and frameworks that give direction to the green economy sectors was emphasised. Regulating and providing support for industry and academic research is highlighted as a means of creating and implementing technologies relevant to the sector’s ecosystem in the development of greener technologies.

Key technical challenges include the development of sustainable supply chains, standardisation of technical systems, managing energy supplies for EV charging alongside existing and smarter grids, development of battery technologies including their end of life and environmental and economic recycling .

There are many opportunities for collaboration and investment in Singapore's green economy sector. Innovate UK and Enterprise Singapore have launched joint calls for innovation partnerships between companies in the UK and Singapore. Universities also play a crucial role in reskilling and training and are becoming more agile by offering a range of ways of learning, such as degree apprenticeships and online courses. The focus is on

developing new ways of teaching students and understanding what future students will need, such as 24/7 access to advice and greater transnational education.

It is important to jointly address future skill gaps for example enabling a workforce that can support alternative fuels, batteries and electric vehicle production and maintenance.

Session 2: Trends in the electrification of urban transport

Panellists:

Colin Herron, Professor of Practice, Newcastle University

Niels De Boer, COO Future Mobility Solutions, Energy Research Institute

Bicky Bhangu, President APAC Region, Rolls Royce

Min Yih Tan, SVP Global Mobility Network, Shell

The panel discussed the major trends in the electrification of urban transport.

Transport decarbonisation is not just about electrification of transport; it requires decarbonisation of the entire supply chain including car components and battery materials, car manufacturing, power supplies, shipping and logistics. Measuring the true impact on the environment of the switch to EV's is complicated.

Battery production and disposal is another area where the environmental impacts are not fully measured. Battery disposal in particular has the potential to cause massive negative impact on the environment. It is important to plan the battery life cycle as part of the electrification of transport. Battery technology is changing rapidly; planning for recycling and making the economics of battery lifecycle viable requires significant research, which is best advanced through international collaborations.

The changing technology of batteries and charging facilities make it very hard to plan ahead, for example ultra-fast charging and solid-state batteries may mean the concept of slow overnight charging at home is not the primary means to keep EV's charged.

Continuing the trend in the uptake of EV's requires incentives for both consumers as well as support for business investments and research. The majority of drivers in both countries have no experience with EV technology. Technologies and policies need to be adopted that will cater for the mass market to enable a transition to electric transport for all drivers.

The transition to EV's still requires time, with estimates that 60% of vehicles would still use petrol by 2030. With the current changes in technology, it is difficult to forecast the benchmark standard of charging that can be scaled up.

The speakers emphasised the need for academic and industry collaboration and the importance of deep-diving into challenging problems through research programmes and knowledge-sharing initiatives. The session concluded by highlighting the significant challenges that still need to be addressed, including training and transitioning a workforce, decommissioning traditional car manufacturing plants, and understanding the impact of policy decisions on the transition to electric mobility.

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Session 3 – Modelling EV networks in the UK and Singapore

Panellists:

Colin Herron, Professor of Practice, Newcastle University

Tobias Massier, Principal Scientist, Technical University of Munich, Create Singapore

Muhamad Azfar Ramli, Deputy Department Director, Institute of High Performance Computing, Agency for Science, Technology and Research

Yangfang Helen Zhou, Associate Professor, Operations Management, SMU.

Planners tend to use models to evaluate best locations and charging types for EVs. However, these models can't predict consumer behaviour. Initially studies in the UK showed early EV adopters used overnight charging at home. With the availability of fast charging, work and public charging spaces, as well as improved battery range, currently around 50% of consumers charge at home.

The technology of fast charging has reduced the need to have large numbers of chargers. However, other considerations are important such as how to ensure use of chargers are optimised (by preventing the parking of EV's at charging locations after they are fully charged).

The charging infrastructure in Singapore is likely to be very different from the UK. It needs to reflect high density housing, the use of public spaces for parking, limited range requirements and greater use of public transport. In the UK, weather, long-distance driving and the use of on-street parking outside many homes are important factors.

Different types of vehicle may require different charging or battery technologies, for example small urban vehicles and larger ones used for distance driving or high performance. It is important to continually assess developments in charging and battery technologies and provide this information to help city and transport planners update policies and engineering works that support rollout of EV infrastructure.

<u>The Singapore Integrated Transport Energy Model</u>

Singapore has set a target of 60,000 charging stations by 2030 and aims to have all road vehicles running on clean energy by 2040. This is an ambitious target that requires extensive planning, policy and technical work. Modelling is used to work out how to deploy charging stations, but this is based on assumptions about trends in technology and consumer behaviours. UK modelling benefits from data that has been collected in the past but based on older technologies.

Modelling in Singapore includes 4 elements: consumer behaviour in relation to use of charging stations, geospatial planning of charger locations, taking into account charger and vehicle types, large scale mobility modelling that looks at population and transport movements across Singapore and modelling of grid impact. Other considerations include parking demands and traffic flow.

The City Mobility Simulator (CityMoS) from TUMCREATE Singapore was able to conduct large scale simulation with high level of details. The simulation looked at the movement of individual vehicles to determine charger placement. The tool was also able to incorporate all vehicle classes for better simulation. The simulation looked at the number of 'unable to

charge' scenarios and charger occupancy utilisation. It showed that if chargers were placed uniformly across Singapore, the number of 'unable to charge' scenarios was high, but there was a 72% reduction if the chargers were placed on a demand-based placement model (concentrating chargers in places of high use of vehicles). The distribution grid optimisation tool by TUMCREATE, Multi-Energy System Modelling and Optimisation (MESMO) was coupled with CItyMoS to provide a more realistic picture of grid impacts of EVs and to look at both the transport and power system at the same time.

Another aspect of modelling is to predict energy demand if a network of charging stations is fully utilised. It is important for energy providers to understand the impact on the grid and whether existing energy supplies are sufficient to power transport electrification. This is currently being assessed by the Science and Technology Policy and Planning Office in Singapore.

Session 4 – Implementing EV Charging Networks

Panellists:

Josey Wardle, ZEV Infrastructure Lead, Innovate UK

Arjun Raju KS, Head of e-Mobility APAC, Siemens Smart Infrastructure

Freddie Chew, General Manager, ComfortDelGro ENGIE

Darren Teo, Vice President Group Sustainability, CapitaLand Investment

The implementation of EV charging networks faces practical challenges from the perspective of land owners (where charging stations may be located) and changing station operators in the UK and Singapore. Users of EV charging networks include private and commercial drivers, and their usage patterns may change over time.

Changing the perception that EV vehicles are costly due to high electricity prices and poor charging infrastructure requires addressing issues such as reliability and misuse of charging infrastructure, developing better technology, reassuring drivers about range anxiety and educating the public on the benefits of EVs. For example, mobile solutions to charging (as opposed to fixed charging stations) require policy support to be feasible, as effectiveness may vary depending on the country and case. Implementing a mobile solution to charging faces challenges such as network problems, safety concerns, and the need for vehicle retrofitting. Another innovation is to optimise charging and discharging activities (vehicle to grid), which can help prolong battery life, offsetting some of the costs associated with battery degradation.

There is a need for monitoring behavioural change and understanding of the complexities of using electric vehicles (EVs) and charging infrastructure. A mixture of different types of charging infrastructure is required to cater to different use cases.

The implementation of EV charging networks requires a comprehensive approach that addresses different use cases and stakeholders, ensuring scalability and reliability. Collaboration among different industries and stakeholders is crucial for building a sustainable and efficient charging network. Authorities from the energy and transport sectors, as well as research institutes, should work together to identify potential challenges and develop solutions to overcome them.

The commercial organisation investing in charging infrastructure needs assurance of a return on investment. A mixture of different types of charging infrastructure is required to cater to different use cases. The commercial organization investing in charging infrastructure needs assurance of a return on investment. Car park availability and the installation of superchargers are identified as significant challenges.

Session 5: Infrastructure for electromobility

Panellists:

Goh Chee Kiong, CEO, Charge+

Akshay Rathore, Professor of Engineering, Singapore Institute of Technology

Yan Xu, Associate Professor, Nanyang Technological University

Monica Huang, Technical Principal, Envision Digital

The panellists discussed the challenges faced in the infrastructure planning and setup for electromobility.

Key technical challenges for implementing large numbers of EV chargers in Singapore include emissions management of energy supplies, holistic management (infrastructure to consumer), grid planning, and power supply optimisation. R&D and innovation are needed to support the installation of more EV chargers using smart energy electric systems and the adoption of new technology like fast and wireless charging. This will impact real-time operation of the power grid, national energy supplies and modelling grid demand.

By 2035, Singapore plans to import thirty percent of its energy, with a significant emphasis on renewable energy, and needs an appropriate storage system to maintain a constant power output to prevent any impact on the power grid. EVs may contribute to grid flexibility and act as a source of power reserves. Switch room upgrades for EV infrastructure are new technologies to manage energy use but they are expensive, and battery or energy storage solutions are being considered.

Private sector participation in charging infrastructure is encouraged, but government support is needed for power infrastructure upgrades. A shared infrastructure for charging, similar to internet optical fibre, could be explored for greater accessibility and cost-effectiveness.

Key issues to be discussed include sustainability in financing and the business models for charge station operators, greater knowledge sharing, and management of end-of-life batteries. Collaboration among stakeholders is crucial to addressing challenges and achieving a successful transition to electromobility.

Session 6: Research and business case studies

Panellists:

Farzaneh Farhadi, Researcher, Intelligent Transport Systems, Newcastle University

Safak Bayram, Lecturer, Strathclyde University

Richard Chin, General Manager, Strides

David Goh, Head of Hyundai Cradle, Hyundai Singapore

Law Chung Ming, Executive Director, Enterprise Singapore

Data-Driven Approach using Simulation and Optimisation for EV Charging Infrastructure

The presentation focuses on the challenges posed by the growth of electric vehicles (EVs) and the need for optimised and demand-driven charging infrastructure in the UK. Factors such as societal changes, policies, and the speed of uptake of EV's need to be taken into consideration when estimating the number of EVs that will be on the road in 2030.

The presentation further explores the use of a data-driven approach that incorporates simulation and optimisation techniques to design a charging infrastructure that is both cost-effective and robust. Sensitivity testing is used to assess the impact of different variables on the optimisation results, ensuring that the charging infrastructure can adapt to different circumstances.

Statistical Analysis of Public AC Chargers in the UK

EV sales in the UK have increased significantly, with over a million EVs sold. UK's charging network comprises over 42,000 connectors, 58% of which are AC chargers. However, infrastructure to support EVs is taking longer to develop, resulting in a PEV-to-charge ratio of 7 in 2022. The public charging infrastructure is underutilized as 76% of EV owners in the UK have a dedicated charger at home. At the same time lack of availability of charging stations in many locations (e.g. motorways and urban roads) is a disincentive for uptake of EV's.

There is a need to consider the methodology for deciding charging types and locations of chargers and the optimum ratio between fast and slow charging. Faster charging reduces overstay, which is significantly higher for level 2 chargers. The load profiles of public charging show two peaks at 8 am and 5 pm, except on weekends. International collaboration is necessary to tackle common problems and develop solutions for EV users globally.

Case study of electric taxis in Singapore

The presentation focuses on Strides, a taxi operator in Singapore that currently has over 300 electric taxis on the road and plans to deploy more over the next 2-3 years.

The percentage of EV sales in Singapore has significantly improved in 2022, accounting for 12% of total car sales compared to only 4% in 2021, but only 1% of the total car population in Singapore are EVs. Fleet owners, particularly taxi operators, play a significant role in the utilisation of EV chargers, typically requiring a full charge on a daily basis. The cost of electricity for charging is the most expensive component for operators, presenting a challenge for wider adoption of EVs.

Singapore has set a target to make HDB housing estates more EV-friendly by 2025, which will greatly accelerate e-mobility in the country. EV chargers in HDBs usually take six to eight hours to get a full charge, and electric taxi drivers prefer slow charging at the car park within

their own residential estate due to its convenience. Electric taxi drivers prefer locations that are convenient, sheltered, have food and beverage outlets, toilet facilities, and a dedicated rest area.

With supportive policies and infrastructure, electric taxis have the potential to become a prominent mode of transportation in Singapore.

Driving opportunities for innovation

Singapore is starting to follow the global trend of increased sales of electric vehicles (EVs). Affordability and high upfront costs are major concerns that hinder mass EV adoption in the country. Range anxiety, or concerns over the reliability of transportation, is a manifestation of deeper anxieties over transportation availability.

Lowering the price of the battery may impact of vehicle costs. New battery chemistry and repurposing could help overcome the cost challenges to EV adoption and accelerate the transition to a sustainable transport system. Stakeholders can collaborate to overcome technical and policy barriers. Start-up companies are very innovative in the EV sector but require significant investments to provide new solutions at scale.

Singapore's e-mobility business landscape

Singapore has ambitious goals for transport electrification and is working towards them. Enterprise SG is working with industry partners to develop standards for EVs, a business ecosystem and trial facilities. Singapore is a key market for electrification and is keen to partner with like-minded and capable partners.

Enterprise SG also supports industries in the electrification of heavy goods vehicles and other mobility technologies, including autonomous vehicles. Singapore is aiming to convert its entire public bus fleet to EVs. Enterprise SG is working with commercial operators, particularly start-up companies to commercialise and implement new technologies. For example, Singapore companies have recently launched an electric two-wheeler and a locally designed electric bus.

Supporting fleet owners is another area of focus for Enterprise Singapore. Important concerns for fleet operators include mass charging facilities, battery swop technologies and warranties and the resale value of fleet EV's. Standardising battery types across OEMs could benefit fleet operators by allowing for battery exchange in EV's. This would enable continual use of vehicles and help ensure business sustainability. The impact of electromobility on the business models for taxi companies is another important consideration.

Day 1 Round up

- Collaboration and knowledge-sharing between countries is important for the EV industry.
- Public-private partnerships are crucial for developing necessary EV infrastructure.
- Rapid increase in battery production is needed to meet large scale uptake of EV's.
- A whole-system approach considering the entire life cycle of EVs is required, particularly battery recycling or swoping to minimise the environmental impact of end-of-life batteries.

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Day 2

Session 7 – Urban Mobility and Innovation

Panellists:

Phil Blythe, Professor of Intelligent Transport Systems, Newcastle University

Jeff Obbard, Professor, Cranfield University

Josey Wardle, ZEV Infrastructure Lead, Innovate UK

Michael Chadney, Senior Transport Planner, Arup Singapore

The speakers discussed the future of mobility in urban areas and how it is impacted by technology and government policies, with a focus on the whole urban living environment and lifestyle changes, as well as the importance of considering electromobility in a holistic way to drive decarbonisation and address climate change.

The speakers also addressed changes in travel patterns, the challenges of urbanisation, and the potential impact of future developments in urban aviation. The concept of the five pillars of the Intelligent Transport System (ITS) was discussed, with road pricing in Singapore (through the gantry system) as an example of early traffic management measures.

Case studies were presented on rail innovation and automation, the use of autonomous vehicles in logistics, and R&D activities in electromobility, including the need for understanding driver behaviour to plan future charging infrastructure.

Decarbonisation in transport was highlighted as a priority due to the significant carbon emissions from road and domestic transport, with electric vehicles and hydrogen both playing potential roles in addressing heavy transport. The Press On Project developed an electric propulsion aircraft, which will be ready by 2024 for passenger transport around Scottish Orkney Islands. The project examined the potential for low carbon hydrogen aviation fuel and bulk hydrogen production using Sorbent enhanced steam to generate hydrogen fuels for actual testing in the real aircraft.

The UK's decarbonising transport strategy aims to not just replace petrol/fuel cars with clean zero emission cars but also to reduce the number of vehicles on the road. Initiatives are being undertaken to increase public transport use in different forms, introduce zero emission buses, increase active transport modes such as cycling and walking, and micro mobility solutions for last mile logistics and urban freight logistics. Efforts are also being taken to decarbonise rail services, maritime services, and aviation transport, and multi-modal solutions are being explored to improve transportation efficiency and widen choices for consumers.

The second talk as about the work of Innovate UK, which funds programs to improve EV charging technologies and energy storage, research software solutions to make accessibility of charging easier, and redesign electric mobility for those with disabilities. For example, the Vehicle to X Program focuses on research and development projects to use electric vehicles to help with broader energy challenges, for example by using vehicles for energy storage

and putting energy back into homes, businesses, other vehicles, other loads, and the grid. Innovate UK is also working in the maritime sector with the Zero Emissions and Infrastructure program to develop and demonstrate real-world clean maritime solutions.

The Department of UK has provided £200 million worth of funding to Innovate UK for the heavy freight sector, which includes running a five-year real-world demonstration of zero-emission heavy freight technologies, infrastructure development, and potential future interventions to support decarbonisation in the heavy freight sector. The Tees Valley Hydrogen Transport project aims to broaden the use cases for hydrogen in Teesside and Innovate UK has undertaken supply chain research and development to look at the challenges involved in using hydrogen as a fuel.

The third talk presented a global view on decarbonisation of the transport sector and highlighted the need to go beyond achieving net zero emissions. The Paris Agreement aimed to set the limit of increase to 1.5°C, but the United Nations and the World Meteorological Organisation have warned that this limit will be breached soon, as extreme weather events continue to occur.

The transportation sector is responsible for about 15% of emissions, with shipping and aviation being the most rapid source of growth. The Intergovernmental Panel on Climate Change (IPCC) warned that immediate and large-scale emission reductions are necessary to achieve the net zero emissions target. The IPCC also warned that based on the policies implemented to date, the expected increase in global warming would be 3.2°C, and net negative emission technologies are necessary to stay within 1.5°C.

The forth presentation was about future mobility, an area in which innovation is complex and continually evolving, and governments might be challenged in planning the future of their cities. The approach taken by the Arup Centre for Climate Action take a holistic view of the urban environment and living needs.

In planning for future mobility, one of the basic principles is to establish suburbs that are self-contained, thereby reducing the need for lengthy journeys for many people. This would include working, shopping and accessing all services within the one locality. Mobility hubs are strategically located integration points that allow for seamless journeys and fully integrated multimodal services, amenities and technologies. Place-based components of transportation hubs help integrate with local identity and connect different suburbs.

The speaker shared a project on urban integration component and looked into how autonomous vehicles could shape greener neighbourhoods that allow people to move around seamlessly and safely. The outcome-led framework looked into areas such as flexible streets and places, liveable communities, healthier environment, optimised operations and efficient network and to identify associated benefits in each area.

Questions and Answers

1. **Is there any key distribution network for hydrogen?**

   Teesside is a big industrial complex in UK, which is used to research the implementation of new fuel technologies such as hydrogen at a commercial scale. Different types of electrolyser facilities were installed in Teesside to provide green hydrogen for different activities and smaller ones were installed around a local air

force base to demonstrate that localised hydrogen economies could be built. The facility at the airport is looking into the use of hydrogen for ground transportation, particularly for the green fleet and also to explore using hydrogen for heating and cooking for the domestic properties of the air force personnel and their families. There are plans to build a hydrogen refuelling facility just outside the base, which the community could use for hydrogen refuelling.

2. **How do you plan to apply the multimodal solutions to reduce the number of vehicles in cities?**

   There are a number of multimodal transport hubs around UK which are aligned with renewable energy generation facilities. For example, one was built outside Oxford, where congestion was a serious concern in an historical city with many protected buildings with very narrow pavements. The transport hub was built just outside the Oxford. Electric buses operates from there to take people into the city centre, and are able to refuel from the hub. There are also charging facilities for taxi ranks and a large car park to encourage drivers to park and take decarbonised transport solutions to the city centre. This is a good example of multimodal solutions and micro mobility solutions for that last mile of the travellers in town are used. The idea is that by bringing together the energy solutions for that with the transport solution and moving it outside of the city. These solutions could be replicated to other parts of the UK but the investment cost would be high.

3. **Has the panel members thought about the battery swapping technology, where fleet users such as taxis could use lower specifications batteries?**

   There had been trials for a number of system in UK, Germany and Israel. Rapid chargers would be useful for fleet operations and freight logistics, where the mileage is high. Vehicles which do not run long distances do not need bulky high specification batteries to minimise waste of energy to carry batteries. Optimising battery weight and the flexibility to swop batteries would be part of managing a large transport fleet. Battery swop could be used by motorbike delivery companies.

4. **Is hydrogen a greenhouse gas? What about methane emissions? Are we making the problem worse?**

   It is now recognised by the UN and IPCC that methane has a much more significant impact on global warming than carbon dioxide, and stopping the release of methane should have priority. Hydrogen may also be considered as a greenhouse gas, and further studies are required to model the impact of the production of hydrogen as a fuel. The speaker questioned if there had been too much emphasis on reduction of CO2 at the expense of the emission of other greenhouse gases.

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Session 8 – AV Technology and Policy

Panellists:

Niels De Boer, COO Future Mobility Solutions, Energy Research Institute, Nanyang Technological University

Malilka Meghjar, Assistant Professor, Singapore University of Technology and Design

The Centre of Excellence for Testing and Research of AV (CETRAN) supports autonomous vehicles (AV) testing procedures and performs AV testing for Land Transport Authority (LTA) for AV authorisation in Singapore. CETRAN has a program to test AV technology and will progress to test AV services, with a focus on fixed schedule services like buses and shuttles.

A regulatory sandbox for AV trials has been implemented in Singapore since 2017, and is expected to conclude in 2027, allowing LTA to allow trials without legal constraints but with safety drivers. Trials are conducted with fully automated SAE Level 4 vehicles and a Stage-Gate R&D process is applied with milestones to assess AV before allowing subsequent trials on public roads. Simulation testing is used in dedicated facilities and is too dangerous to test in the real world.

In another example of research projects in this area, Singapore University of Technology and Design (SUTD) and Massachusetts Institute of Technology (MIT) Alliance for Research and Technology have done research on AV in mobility on-demand systems in mixed traffic condition and multimodal solutions for the first and last mile. The objective is to roll out the mobility on-demand systems at different stages, considering factors such as fleet size, vehicle mix, and integration into existing environments.

The speaker discussed a project relating to AV and congestion capture technology, which can dissipate traffic build-up in transport routes. Optimal transit points between different modes of transport are identified to improve network utilisation and reduce travel times. Trials and public rides were conducted in the one north region of Singapore to gather feedback on the autonomous driving experience. The milestone one test involves transitioning between autonomous and manual modes, familiarising the vehicle with the environment, obstacle detection, fault detection, and emergency braking. Understanding road context, intent, and driving styles are important for autonomous driving in complex environments. Results show matching decisions between the autonomous system and safety drivers in response to erratic behaviours.

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Session 9 – The role of AV in electromobility

Panellists:

Niel De Boer, COO Future Mobility Solutions, Energy Research Institute, Nanyang Technological University

Samuel Layton, Head of Singapore Operations, Aurrigo

Jeannie Lee, Associate Professor, Director of Programmes, Singapore Institute of Technology

Phil Blythe, Professor of intelligent Transport System, Newcastle University

The panellist discussed the role of autonomous vehicles (AV) in electromobility.

AV's operating in public places have to manage different public responses and behaviours. Educating pedestrians is key to increasing public confidence in AV technology, and educational materials could be used for different age groups to increase understanding of the technologies. In trials of autonomous buses at NTU, students were confident in the safety of automated buses on campus, but broader public perception and behaviour are still key areas of focus. Human acceptance and understanding of AVs are crucial, and policies need to consider cultural and environmental factors.

Trials in urban areas require more real-time management and sensors in the environment to support autonomy, due to high densities of traffic, while rural areas present other challenges, such as how to control vehicles, particularly those used for heavy goods and buses, on rural roads.

Public acceptance of autonomous vehicles may be affected by incidents involving fully automated cars, such as Tesla crashes and fatalities. Learning from the rail industry, which has successfully managed public perception, could help improve public acceptance of autonomous vehicles. Safety practices from the rail industry, with a strong focus on investment in safety measures, can be applied to autonomous vehicle operations.

The starting point in setting up AV networks is to cover the gaps in the current transportation network and to explore micro-services and to provide services with the highest impact. Niche use cases and controlled environments will likely be the starting point for autonomous vehicle deployment, gradually expanding to broader applications. The growth of autonomous vehicle technology will follow a similar trajectory to other technologies and initial applications of autonomous vehicles are likely to be in passenger shuttles and controlled operations.

Collaboration between the UK and Singapore can facilitate knowledge exchange, research, and trials to understand the differences and challenges of autonomous vehicle deployment in different environments and cultures. Understanding cultural and environmental differences is important for developing policies, standards, and ensuring the successful integration of autonomous vehicles.

Implementation of autonomous vehicles has been successful, leading to a significant increase in job opportunities. Traditional driving jobs such as bus drivers, truck drivers, and delivery drivers are becoming less desirable and harder to fill due to a lack of interest from younger generations. Reimagining these jobs to be done remotely or in more desirable

environments, such as from home or in air-conditioned control centres, can help attract younger generations.

Session 10: Infrastructure, technology and alternative fuels

Josey Wardle, ZEV Infrastructure Lead, Innovate UK

Phil Blythe, Professor of Intelligent Transport Systems, Newcastle University

Wang Zhenglin, Head, Marketing and Partnerships, Keppel Infrastructure

Peng Xiaoyang, R&D Programme Manager, Engie Lab

Sandeep Hadap, Regional Sales Manager (Asia), Siemens Energy Singapore

The UK aims to increase integrated electrification of transport with grid supplies and storage. The technology uses flexibility services to mitigate the expected increase in electricity demand by putting energy back into the grid and using as much renewable energy as possible. EVs are seen as a key way to provide distributed storage devices to reduce peak demands on the grid and maximize the use of renewable resources. The UK policy requires new public charging devices to be capable of smart charging interactions and deploying Vehicle to X charging technology. The UK is also looking at Vehicle-to-X (V2X) energy solutions to be a growing part of their electricity activity and is looking to make this everyday use by 2025. The UK Vehicle-to Grid (V2G) Programme ran for five years from 2018-2022, resulting in the rollout of 650 bi-directional charging points in homes and workplaces.

For example, a case study examined two home-use projects: Powerloop and Project Sciurius, which achieved a high success rate in incentivizing participants to engage in discharging activities. Concerns remain regarding battery degradation from domestic and fleet users, financial rewards for participating in V2G activities, and the need for commercial propositions. The study found that operators could save money using V2G technologies, but there is no one-size-fits-all solution for fleets.

The UK's approach to powering various trucks and building networks is still evolving, with a need to balance investment in electrification while exploring other fuel sources like hydrogen. While electrification may be suitable for some vehicles, it may not be the best option for all.

In the case of Singapore, the challenge of getting sixty thousand EV chargers into the grid is primarily due to the older buildings not designed to support the EV charging infrastructure. The use of solar panels and batteries is suggested as a solution, and grid stability is important to meet energy demands at peak and average times. The need to get the chargers out ahead of demand and ensuring the business model is right are also challenges. Policymakers must keep up with the changing trends in the EV industry and use the most up-to-date data available to make informed policy decisions. More data will be available for analysis with the increasing utilization rate of EVs, leading to better policy outcomes.

Siemens is actively involved in the research and development of alternative fuels for heavier vehicles, particularly hydrogen. The company believes that hydrogen fuel cells have the potential to significantly reduce the carbon footprint of the transport industry and lead to a more sustainable future. While electrification dominates in light vehicles, the Singapore government is also exploring other solutions such as bio and hydrogen fuels for heavier

vehicles. The government has plans for electrification for transport, and hydrogen is being explored as a viable option for heavier vehicles.

Although V2G and V2X are relatively new in Singapore, there is a growing interest in exploring these topics. Siemens is well-positioned to support such initiatives, starting with automation, followed by transmission and distribution, and smart infrastructure. The economics of such schemes need to be examined to ensure that they are beneficial for consumers.

Session 11: EV's, fleets and the business context

Panellists:

Alistair Scott, Managing Director APAC, Jaguar and Land Rover

Patrick Wong, Country Manager, GoGoX

Chen Xinwei, Deputy General Manager, Strides

Wong Zhonghao, Product & Sales Manager, Wearnes Automotive

Yossapong Laoonual, Associate Professor KMUTT, Electric Vehicle Association of Thailand

Singapore's supply of electric vehicles (EVs) can meet current demand but is impacted by a number of global supply chain factors. The adoption of EVs in Singapore is driven by sustainability, environmental concerns, lower cost of ownership, and government grants and emissions rebates. The Singapore government's current focus is on consumer transportation. Emission-free trucks are not yet available in Singapore.

The high cost of buying new vehicles in Singapore and the lack of charging infrastructure in public housing are major barriers to the adoption of EVs. Singapore's target of 60,000 charging points is intended to meet charging demand when the majority of drivers are using EV's. The market for second-hand EVs in Singapore exists but is relatively small. The criticism that EVs are too expensive is not necessarily true, as EVs have become price-competitive and the initial cost of purchasing an EV may be higher but the cost of ownership could be lower due to reduced maintenance and operating costs.

Policymakers should consider the behaviours and needs of different groups of EV drivers to design effective policies and infrastructure. EV drivers in Singapore prefer fast chargers in shopping malls but there is a risk of hogging parking spaces in shopping districts. The Singapore market is less challenging from a supply perspective, as there are no long distances for which long range batteries are required. However, for most people, home charging is not possible. Continued support for measures to encourage consumers to buy EV's is required.

Insurance premiums for EVs are generally higher than ICE vehicles due to uncertainties around repair costs, battery replacement, and accidents involving EVs. The cost of EVs is generally declining and the running cost is expected to be lower in the long run.

In relation to EV batteries, responsible management of end-of-like batteries is essential, and there is a need for regulatory frameworks to establish responsibility for end-of-life disposal of

EVs and their components. Proper disposal and recycling of EV batteries is a global concern, and governments, manufacturers, and consumers should work together to ensure proper disposal.

Session 12: Fleets and logistics case studies

Panellists:

Shruti Rathore, Senior Strategy Consultant, Arup

Lewis Hunter, Research Fellow, Strathclyde University

Tom Shanks, Chief Financial Officer, Blue Line Taxis UK

Kelvin Ng, Business Development, PTV Group Singapore

Aval Singh, Engineer, Intelligent Fleet, Continental Corporation

Arup UK has been working in the EV industry since 2008 to accelerate EV adoption. The company has worked with a local authority to transition around 100 government owned vehicles to EV with a phased implementation plan, recommending fleet reduction opportunities and how to be reimbursed for home charging and other change operations.

Collaboration between the government and private sector is needed to address significant challenges in the EV industry, including grid connection and land availability. Blueline, a UK taxi company, has proposed establishing a UK taxi taskforce to address challenges they face in implementing electric vehicles as an alternative to petrol vehicles. The profitability of EV taxis relies on technological advancements to manage downtime due to charging with EVs. Increasing range and decreasing vehicle cost are other important factors.

The Agile Street Project demonstrated smart EV charging using the UK smart metre network to accelerate EV adoption. Smart charging can be interpreted in different ways depending on the goals, such as working within grid constraints or enhancing efficiency and sustainability within smart cities. Agile Streets project showed user behaviour is crucial for success, but infrastructure and regulatory frameworks need improvement for smarter public charging facilities.

The practical challenge of converting 1,000 taxi to EV and developing a new business model with regard to operation and mobility as a service was presented.

Continental NTU Corporate Lab has 16 projects, including project A3 that focuses on smart and efficient fleet management. Project A3 aims to address fleet operators' pain points, such as low fleet utilisation by predicting gaps in utilising fleets efficiently. The team uses open-source New York taxi data to develop an optimisation model for fair supply distribution throughout the location to ensure that drivers get a fair share of the passengers to reduce profit disparity. The team also optimises charging and discharging of EVs to minimise battery degradation.

PTV is recognised for its expertise in traffic management software, modelling and simulations, traffic data analysis and has worked the Charge EV project to increase the adoption of EVs in Singapore. The Charge EV project created a predictive and dynamic

model to identify where and how many charging stations are needed and when they should be ready, resulting in better allocation of limited resources, increased adoption of EVs, and reduced idle times.

In Southeast Asia, electric 2-wheelers are a significant trend in EVs, with the majority of personal transport being 2-wheelers. A case study of swappable electric 2-wheelers in Taipei showed that the project helped improve the coverage of the charging network, increase utilisation of chargers, and reduce idle capacity. Another option is ridesharing, which can help reduce the overall number of vehicles on the road to reduce traffic consumption and carbon footprint.

Day 2 Round up

- Innovate UK funding and collaboration opportunities between UK and Singaporean partners, including the NetZero Resilience Transport Hub were discussed.
- Challenges for charging networks as the number of electric AVs increases and whether the energy system can cope with the demands of 60,000 chargers in Singapore were highlighted.
- Fleets were identified as a major driver for the adoption of EVs, but challenges arise due to different fleet operations and the need for cooperation across sectors was emphasised. Concerns about range and the type of vehicles needed for fleet ownership for logistics and taxi companies were also discussed.
- The importance of being clear about the use of smart technologies and how they may contribute to better transportation systems in cities was highlighted.

DAY 3

Session 13: Next generation EV technologies

Panellists:

Clive Ford, Innovation Lead, Institute of High Performance Computing, A*STAR)

Rohit Bhagat, Professor and CEO, Institute of Clean Growth and Future Mobility, Coventry University

Gavin Harper, Research Fellow, Birmingham University

Arjun Bhatterai, Chief Technology Officer, V-Flow Tech

The discussion focused on recent trends in lithium-ion battery cell formats and modelling and simulation for EV battery packs. There are three types of battery cells: cylindrical, pouch, and prismatic, with pouch cells being used in EVs. The Lucid Air and BYD blade are examples of new battery pack innovation that improve range performance in EV's.

Energy efficiency is an important design consideration when designing battery packs for EVs. Modelling and simulation are important tools used in the development of EV battery packs to save time and costs. Co-simulation is used to integrate different material properties with the energy that is put into the battery cells. Thermal modelling is an important aspect of battery pack modelling, which looks at how the battery heats up due to fast acceleration, rapid charging and discharging. A*STAR is working with stakeholders and research institutions on the next generation battery pack to improve battery pack design.

Energy storage is important to maximise the use of renewables. Lithium-ion batteries are good for medium to high power discharge but may not be suitable for certain applications. Redox flow batteries, made of vanadium, are introduced as a promising technology. Vanadium in the battery can be recycled, leaving only 15-20% plastic waste. Graphite used for the reaction does not get consumed, resulting in no degradation as long as it is not overcharged. Vanadium flow batteries are extremely safe and non-flammable, can be discharged up to 100%, and have longer discharging capability. Innovative applications include using them in carparks connected to solar panels to power chargers off the grid. V-flow Tech offers reliable, safe, and sustainable storage solutions.

Battery recycling should be approached as a key aspect of battery research, design and production, not just an end-of-life solution. There is a gap between battery production and their disposal, as not enough batteries have reached their end of their life yet. Greater automation and smart adhesives can be used to make disassembly easier and facilitate recycling. Digitalisation can simplify the recycling process and enable quick analysis of battery health. Designing batteries for circularity from the outset is important to achieve a more sustainable circular economy.

The Centre for Advanced Low-Carbon Propulsion Systems focuses on fuel cells and supercapacitors and works on modelling power electronics systems. The centre works closely with companies that are interested in producing new materials and is engaged in many projects related to cell formats. The centre is developing sensor arrays that can be embedded into various formats of batteries to provide real-time information about the cell's behaviour. The centre has a large battery testing facility and works with a modelling group to

obtain real-time data from the discharge/charge profiles and for aging of the battery. The centre is interested in using optical sensing to embed optical technology within cells, and is working on fast charge mapping networks. The centre is also developing techniques to understand the remaining value of battery modules, whether they can be repaired or repurposed.

LFP batteries offer another type of energy storage energy storage. LFP batteries have been widely adopted in the industry since 1985 for energy storage applications. Lithium-ion batteries like LFP are cost-effective for discharging over short periods of one to three hours compared to flow batteries. LFP batteries have a relatively long life span, making them more economical for energy storage applications.

The speaker envisions the future of EV technology as using onboard sensors and diagnostic methods to give service centres real-time information about an EV's battery, in order to delay recycling as long as possible. The amount of data required for battery analysis is a significant consideration for manufacturers and researchers. AI and other smart technologies can infer a lot of information with limited data, but manufacturers are reluctant to share their data with competitors or other parties. Collaboration between manufacturers and researchers is necessary to advance data analysis and processing in battery technology.

Session 14: Emerging Battery Technology

Panellists:

Ho Choon Lim, Deputy Group Manager, A*STAR

Amit Gupta, Head of Rolls-Royce Electrical Singapore

Elsa Feng, Assistant Professor, Singapore Institute of Technology

Arjun Bhatterai, Chief Technology Officer, V-Flow Tech

The session discussed emerging battery technology and its limitations, including mass employment and station storage. The challenge of repurposing batteries for different applications was highlighted, and the need for proper diagnosis and evaluation of energy storage and use. For example, batteries for light electric aircraft give rise to challenges such as safety, energy density, cycle life, high cost, technical challenges, and the need for backup energy. Research is ongoing to solve problems in backup processes and monitoring battery cell temperature, fast-charging stations, thermal management, and oversizing for extra engineering.

For general battery use, corrosion, leakage, and fire were raised as major challenges, and the importance of product design to prevent propagation of faults in battery packs and battery case rupture. Energy density in transportation and battery cost are significant issues, and the drawbacks of batteries include electrolytes being too close to the batteries and requiring huge amounts of storage, SOC and SOH installations, and system integrators. Opportunities to use materials that can adapt to different battery uses were discussed, as well as the need for diagnostics level in cell modelling and building a database.

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Session 15: Modelling, data and EV networks

Panellists:

Colin Herron, Professor of Practice, Newcastle University

Tom Shanks, CFO, Blue Line Taxis UK

Lewis Hunter, Research Fellow, University of Strathclyde

Eng Yew Yeoh, Director, Regional Institute for Sustainability and Energy Transition Bureau Veritas

Panellists discussed the issues in modelling and analysing data for the future transport infrastructure. They also discussed the importance of data in predicting demand for electric vehicles (EV) and placing infrastructure to support it. Further research is needed to understand the behaviours of slow EV adopters and their expectations

Fleet operators were identified as significant players in the EV ecosystem. Financing is a critical issue, and fleet operators have concerns about the economic viability of transitioning to electric vehicles and associated infrastructure. The panel highlighted the need to bring stakeholders together to address the financing business planning for electric vehicles and charging infrastructure. Data sharing needs to be developed to help EV fleet management.

Further research is needed on the complexities of managing data and applying modelling and analysis to maximise efficiency for EV fleet operations. It can also be used for profiling and forecasting their requirements to maximise the utilisation of charging points.

Local authorities in the UK play a significant role in determining the best places to put charging infrastructure, and a suitable platform is needed to update data regularly and facilitate sharing knowledge. Capturing different driver habits in different cities were identified as an important factor to consider in planning for EV charging facilities.

Another important area is to capture carbon emissions in the supply chain. The production and disposal of batteries, for example, may generate significant carbon emissions.

Session 16: Reimagining The Battery For The Circular Economy

Panellists:

Rohit Bhagit, Professor and CEO, Institute for Clean Growth and Future Mobility, Coventry University

Lidijia Siller, Professor Nanoscale Science, Newcastle University

Bryan Oh, CEO, NEU Battery Material

Gavin Harper, Research Fellow, Birmingham University

Song Ziyou, Associate Professor, National University of Singapore

The panel of experts discussed the technical aspects of reimagining the battery for the circular economy, its key pressure points and challenges in the recycling and reuse of batteries. The speakers highlighted the conflict between improving performance and downstream factors in the process of battery recycling.

The quality of graphite needed for good batteries is hard to achieve, making it difficult to retain the value back. Finding technical solutions to recycle batteries and obtaining acceptable battery performance is a significant challenge. The new wave of technology would make batteries more reliable and designed for recycling. Safety knowledge for handling batteries should also made available to everyone. New batches of batteries should also have new materials to reduce waste and hazardous levels.

Government regulations will play a crucial role in ensuring that batteries are designed with second life / recycling capabilities and that they have minimal fire and environmental risk and that it is cost-effective. The absence of these considerations in the current policies is a significant issue.

Session 17: Grid to Charging Stations

Panellists:

Wenyi Chew, Business Development, Keppel Volt

Kelvin Ng, Business Development, PTV Group

Parikshit Yadav, Co-Founder, Wired Box Company

Peter Gettinby, Land Director RSK

Limited grid capacity is a significant challenge for Singapore in supporting EV charging infrastructure. Within the range of different charging technologies available, the Singapore government has included slow charging in the evenings and overnight charging in housing estates to avoid charging spikes during peak hours. The government has changed local laws to require private condo developers to install EV chargers. Smart chargers can be used to dynamically balance loads and meet contracted capacity charge to address issues related to in-building spare capacity and power availability to install DC chargers.

Alternative energy sources that do not require the grid, such as batteries or hydrogen, can be used to deal with grid fragility. Singapore's newer housing estates can support large-scale charging, but older estates and current substations cannot. Upgrading infrastructure to support different type of charging facilities is ongoing, but expensive.

The government can also work with petroleum companies to install DC fast chargers in petrol stations and commercial buildings. Petroleum operators are reconfiguring their business infrastructure to offer fast charging at petrol stations and may also offer swappable electric batteries.

Public transport and sharing, such as electric buses and fleets with multiple charging stations, are also potential solutions. Solar energy generation from the city's buildings is limited, but distributed energy storage systems could be considered in the future. There is a

need to find solutions to implementing widespread charging networks to mitigate range anxiety. Excess electricity generated by renewable developers may be stored for charging electric vehicles. A hybrid charging solution using EC is proposed for cross-border charging between Singapore and Malaysia.

Battery swapping may become viable in some markets but requires long-term investment and evaluation of pay-off and return on investment. The asset life of current chargers is 10-15 years, but technology is advancing towards higher voltage chargers. Vehicle makers also need to consider models for EV's that permit battery swop.

Session 18: Recycling and Reuse Case Studies

Panellists:

Aaron Wee, VP Investments and Strategy, ACE Green Recycling

Simon Lambert, Senior Lecturer, Newcastle University

Gavin Harper, Research Fellow, Birmingham University

Aravind Muthiah, Stategic Product Specialist, Durapower

Tan Kai Liang, Section Manager, A*STAR

Panellists discussed battery recycling, repurposing, and remanufacturing in this session, and shared relevant insights on their respective projects and case studies.

Durapower presented two case studies involving energy supplies for fleet charging and grid support when supplying EV energy demands. The speaker discussed how batteries can be repurposed at the end of their life to extend battery packs and additionally provide energy back to the grid. To power an emission-free fleet of vehicles, Durapower developed a ground-up proof of concept covering every aspect of EV battery management —from custom-fitting battery modules to designing automatic battery charging & swapping stations.

One key pressure point is the difficulty in controlling chemical reactions and restoring the value of batteries when reaching the end of their lifespan. The grades of graphite needed for high-quality batteries pose a challenge for recycling processes, making it hard to retain their value. Concerns about materials and the amount of batteries being produced exist, requiring efforts to improve the recycling process and extract valuable components like plastics, metals, electrolytes, and graphite. The issue of what to do with batteries once they have been used and finding solutions for their recycling is a significant challenge.

The panellists also discussed battery remanufacturing in the aerospace industry and the potential for repurposing EV battery systems for a much longer usage life. Designing battery packs that could be used till their end of is important. However, they noted that disassembly is still tedious and time-consuming, leading to high costs. Repurposing batteries can be costly, and carbon roadblocks based on regulations can be an issue.

Waste management hierarchy and how it was applied to battery recycling was discussed. Recycling priorities are based on population centres and industrial demands in locations such as India, USA, and Singapore. Recycling may make more sense for smaller-scale usage (e.g. electric motorcycles), while repurposing may be more attractive to larger businesses.

There is a need for feasible standards, technological improvements, and community efforts to strengthen the second life of batteries. Regulations and legislation are needed to ensure transparency, proper declaration, and sharing of information among manufacturers, particularly in a second wave of the economy. Reimagining batteries for a circular economy in 10 years involves developing new technologies, designing batteries for easier recycling, and focusing on core technologies, information sharing, and reducing waste hazards.

Session 19: Training and Skills Case Studies

Panellists:

Goh Say Seng, Deputy Director (Technology Development), Singapore Polytechnic

Carl Perrin, CEO, Institute for Clean Growth And Future Mobility, Coventry University

The session discussed the importance of training and skills in Electromobility and highlighted the need for a holistic approach in developing skills and creating career pathways in the Electromobility industry. However, businesses are facing challenges in hiring workers with the right skills, so many are hiring and retraining people for specific e-mobility roles.

The Coventry University -JLR (Jaguar Land Rover) Electrification upskilling programme aims to offer a general transport electrification intermediate course in Aug 2023 and specialist courses thereafter.

The Scalable Delivery of Applied PEMD (power electronics, machines and drives) training aims to upskill workers to meet the employer demand for skills to support electric vehicles. The national electrification skills framework is being developed to guide the industry in creating career pathways. This requires a transformation roadmap involving driving technical development within schools, creating courses in the future of mobilities, and establishing partnerships with automotive and training partners.

Singapore Polytechnic is also driving tech developments within schools, including eight hubs for creating courses related to the future of mobilities. The speaker provided a history of electromobility training, traced back to the 1990s when there were already projects on conversions, business and development, such as developing an electric bus and solar car. The Polytechnic is currently developing a suite of diploma level courses that will provide s

Session 20: Training and Skills'

Panellists:

Quek Yang Thee, Programme Chair, Republic Polytechnic

Colin Herron, Professor of Practice, Newcastle University

Carl Perrin, Professor and CEO, Institute for Clean Growth and Future Mobility, Coventry University

The final session discussed training skills and a wrap-up of the symposium. There are currently no courses for battery or vehicle manufacturing in Singapore, but plans are in place to develop suitable courses. Existing courses offer some hands-on practical training, and collaborations with authorized dealers allow students to gain hands-on experience with the vehicles to learn the fundamentals. There are various levels of courses, and the importance

of exposure and hands-on experience was stressed as well as the need to increase gender diversity in the field.

The symposium covered policies, infrastructure, collaboration, and challenges in achieving sustainability. A multi-disciplinary approach to training was emphasised, and topics covered included batteries, sensors, data management, and design. Attendees appreciated the complexity of the topic and the need to attract more students to study the technologies of electric transport, as well as the policy and scientific aspects.

Round-up

In the round-up of the symposium, the speakers reflected on the breadth of the topic of transport electrification. The challenge of setting up policies, infrastructure, supply chains, energy systems to support the mass uptake of EV vehicles is immense. Additionally, the need to implement technologies, standards and regulations for maintenance of vehicles, safety and consumer protection, as well as vehicle and battery recycling and disposal amounts to a small industrial revolution.

Given the urgency of tackling climate change, all these changes need to take place in a short timescale. Policy-makers need to continually review funding and incentives, regulations, intermediate technologies, research priorities and energy supply considerations to support the desired pace of change. Achieving the targets for electromobility in the next 2 to 3 decades will require investments and collaborations between countries, research institutions and industry sectors on a large scale.

A critical aspect of the transition to electromobility is the availability of a workforce that has the skills to support the design, production and supplies of electromobility technology. For example, the establishment and operations of giga-factories to produce batteries cannot be achieved unless there is a workforce that is skilled to work in these settings. Large-scale training and retraining programmes provided by education and training organisations in partnership with industries are an essential part of the transition to electromobility.

While the purpose of electrification of transport is to reduce emissions generated vehicles, buses, trucks and so on, the hidden costs and impacts need to be addressed as part of the overall planning and regulations for transport. What is the carbon footprint arising from the manufacture of EV's? Are the supply chains sustainable? How do we manage the disposal of existing vehicles? And, critically, how is the life-cycle of batteries to be managed? If EV's are adopted on a large scale, regulations, technology and processes are needed to avoid creating battery landfill sites and the extreme environmental damage that would result.

While there are many challenges to overcome, technology is changing rapidly and giving rise to many exciting opportunities. Examples include the use of alternative fuels, such as hydrogen and synthetic substances, alongside battery technology; the use of AI and data modelling capabilities to manage urban transport and create new transport conveniences for people; the integration of different energy systems and energy storage systems, such as vehicle to grid technology, to maximise energy efficiency; the possibilities for healthy living environments that are focussed around people and communities rather than cars. If governments work in close partnership with research institutions and industry, many of these advancements can be achieved to create better living environments for everyone.

Department for Science, Innovation & Technology

Newcastle University

Feedback

Day 1

The insights from the feedback received for Day 1 of the symposium provide valuable information regarding the relevance and interests of the attendees. These insights can be linked to the recommendations identified in the following way:

The feedback indicates that the attendees were particularly interested in the theme of trends in electrification of transport, which aligns with the recommendation to conduct a review of policies, incentives, and targets for both the UK and Singapore. By comparing their policies and targets with other countries that have made progress in electromobility, both countries can stay updated with the latest advancements and insights in this field, as highlighted by the attendees' interest in staying up-to-date.

The feedback also highlights the strong interest in implementing EV charging networks, which correlates with the recommendation to review current models for EV charging networks and identify best practices and tools. This recommendation addresses the attendees' attraction to the challenges, strategies, and best practices involved in establishing effective and efficient charging networks.

Moreover, the feedback indicates an interest in research and business case studies related to electrification of transport and EV charging networks. The attendees' desire for empirical evidence and real-world case studies aligns with the recommendation to provide insights into the successful implementation of electrification initiatives and EV charging networks.

Although the feedback suggests that discussions on modeling EV networks and electromobility infrastructure were of relatively lower relevance to the attendees, it is worth noting that the recommendation to improve modeling practices for EV charging networks can indirectly address this aspect. By reviewing current models and identifying best practices, the modeling and planning of electric vehicle networks can be enhanced, even though it may not have resonated as strongly with the attendees.

Overall, the insights from the feedback for Day 1 of the symposium support and provide validation for the recommendations identified. They emphasize the importance of policy review, implementation of effective charging networks, supporting research and business case studies, and improving modeling practices, all of which are aligned with the interests and concerns expressed by the attendees.

Day 2

The insights from the feedback received for Day 2 of the symposium provide valuable information about the relevance and interests of the attendees. These insights can be linked to the recommendations identified earlier in the following way:

The feedback indicates that the attendees were particularly interested in the theme of EV energy supply in Singapore and the UK, particularly through case studies. This aligns with the recommendation to update grid infrastructure to support the energy demands of electromobility. By addressing the challenges and solutions related to providing adequate energy supply for electric vehicles, as highlighted in the case studies, the attendees' interests in energy supply are addressed.

The second most relevant theme identified in the feedback is urban mobility and innovation. This resonates with the recommendation to draw on studies of how urban planning can minimize transport demands. The discussions on innovative approaches to improving urban transportation, such as addressing congestion and promoting sustainable mobility solutions, align with the interest in exploring urban planning strategies that can support the transition to electromobility.

The interest in the business implications of electric vehicles, including fleet management and market dynamics, aligns with the recommendation to explore possible business models and the mechanics of public-private partnerships. The attendees' relatively lower interest in these themes suggests the need to further emphasize and communicate the potential benefits and opportunities for private sector investment in EV infrastructure.

Furthermore, the interest in AV technology and policy aligns with the recommendation to consider the technical, policy, and safety issues associated with autonomous vehicles. By addressing advancements, challenges, and regulations surrounding AV technology and its integration into the electromobility ecosystem, the attendees' concerns and interests in this area are acknowledged.

Overall, the insights from the feedback for Day 2 of the symposium support and provide validation for the recommendations identified in the report. They highlight the importance of updating grid infrastructure, exploring urban planning strategies, considering AV systems in transport electrification, exploring business models, and addressing AV technology and policy. These recommendations align with the attendees' interests and concerns expressed during the symposium.

Day 3

The insights from the feedback received for Day 3 of the symposium provide valuable information about the relevance and interests of the attendees. These insights can be linked to the recommendations identified earlier in the following way:

The top-ranked themes of the next generation of EV technologies, emerging battery technology, and battery for circular economy align with the recommendation to invest in research and development of advanced battery technologies. The attendees' strong focus on exploring future developments and innovations in the field of electric vehicles, particularly through battery technology, supports the recommendation to advance battery technology to enhance performance, range, and sustainability of electric vehicles.

The high relevance of battery recycling and reuse case studies connects with the recommendation to implement sustainable practices in battery management. The attendees' interest in learning about successful case studies and best practices in recycling and reusing batteries reinforces the need to minimize waste and maximize the lifespan and value of battery materials, as suggested in the recommendation.

The theme of grid to charging stations aligns with the recommendation to develop an integrated charging infrastructure. The attendees' interest in understanding the challenges and strategies for integrating charging stations into the electrical grid reflects the importance of ensuring reliable and efficient charging services for electric vehicles, as emphasized in the recommendation.

The relevance of modeling EV data and EV networks supports the recommendation to optimize the placement and utilization of charging infrastructure. The attendees' interest in data-driven approaches to predict charging demand, improve network efficiency, and enhance the overall performance of EV networks aligns with the recommendation to leverage modeling techniques for optimizing charging infrastructure.

The interest in EV training and skills case studies correlates with the recommendation to invest in training and skills development. The attendees' recognition of the importance of a skilled workforce in the growing electric vehicle industry aligns with the recommendation to develop training programs and initiatives that address the specific skills needed in the evolving field of electric mobility.

Overall, the insights from the feedback for Day 3 of the symposium align well with the recommendations identified. They emphasize the importance of investing in battery technology, implementing sustainable practices in battery management, developing an integrated charging infrastructure, optimizing charging infrastructure through data-driven approaches, and investing in training and skills development. These recommendations address the interests and concerns expressed by the attendees during the symposium.