Bus Decarbonisation Taskforce

Supply Chain and Draft Pathway Meeting

15 July 2021

Agenda

Item
1. Welcome
2. Supply Chain (paper 4.1, from page 3. Please note annex C and D have been provided as separate documents)
3. First draft pathway and next steps for the Taskforce (paper 4.2, from page 18)
5. Summary and conclusions from Chair

For ease of reference, the guiding vision previously agreed by the Taskforce is a future where:

Bus operators are exclusively running zero-emission battery-electric and hydrogen fuel-cell buses; The bus sector provides an excellent service meeting passengers' day-to-day needs; People enjoy travelling on buses and knowing that doing so is one of the most climate-friendly choices they can make; There are vibrant ownership and leasing markets for buses which benefits operators, manufacturers and the finance sector; The smart technology on buses enables them to be operated in the most energy efficient way; There is an even stronger and diverse domestic manufacturing sector and supply-chain comprised of high-quality skilled jobs with continued innovation reducing manufacturing and supply chain emissions; Energy networks, bus operators and Local Government are used to working together to ensure depots are powered/fuelled and all potential users are able to benefit from the energy provision centred at depots and on-route charging infrastructure; Buses and infrastructure are fully recycled at the end of asset life contributing to the circular economy, reducing waste and supporting further decarbonisation efforts; After an important period of support, the Government has ceased subsidising battery-electric and hydrogen fuel-cell buses, but continue to support innovation in new zero-emission fuels and technologies of the future; Scotland is recognised the world over as a leader in the design, manufacture and operation of high quality zero-emission buses and other large road vehicles, alongside associated green finance solutions.

Paper 4.1 Supply Chain

This paper considers actions which can be taken to bolster the Scottish manufacturing and supply chain sector, and the circular economy for zero-emission buses and component parts. It has the following sections:

The Scottish zero-emission bus market in context

Sustainable Mobility Innovation

Supply Chain Development

Demand

Driving down the cost of zero-emission buses

Batteries

Annex A: Enterprise support landscape

Annex B: Components of zero emission buses

Annex C: Driving down the cost of zero emission buses (provided as a separate document)

Annex D: Batteries mapping briefing note (provided as a separate document)

The taskforce are invited to:

a) commend the strides that the manufacturing sector has made in recent years to supply both battery-electric and hydrogen fuel-cell buses of ever increasing range and reliability into the Scottish market;

b) note the synergies in development of the zero-emission bus supply-chain with that of other vehicles, and the positive developments in Scotland's zero-emission mobility ecosystem;

c) agree that the primary opportunity for growing an even stronger and diverse domestic manufacturing sector, and for developing an increasingly circular economy, relates to vehicle batteries;

(d) agree that the development of fuel cells represents a further opportunity;

d) agree actions that all parties represented by Taskforce members can take in relation to the supply chain, to move towards the Taskforce's guiding vision. For example, these may include:

- development of closed-loop battery economy in Scotland;
- enhanced international marketing of Scotland's capacities and potential for growth;
- commitments from the bus industry to support nascent Scottish suppliers of zero-emission buses and their components.

The Scottish zero-emission bus market in context

The bus manufacturing sector has effectively shifted its focus from diesel to zero-emission vehicles in recent years. Both battery-electric and hydrogen fuel-cell buses are proven technologies that have been tested, demonstrated, and rolled-out to varying degrees across the world.

Globally, the zero-emission bus market is dominated by China, which produces over 90% of all buses, and deploys around 99% of all battery-electric buses. In 2017, Yutong's sales of large and medium-sized buses reached 67,268 units, of which 24,865 units are "new energy" buses[1].

One bus manufacturer, Alexander Dennis Ltd, has a plant in Falkirk, and is part of a wider ecosystem of zero-emission mobility in Scotland. Scottish Enterprise Foresighting (TNEI/Element Energy Report 2017[2]) identified several strong Scottish niche applications including vehicle retrofit, vehicle components, and biofuels. Combined turnover of 15 Scottish largest transport companies is over £2 billion per annum and they employ around 4,500 direct FTEs[3].

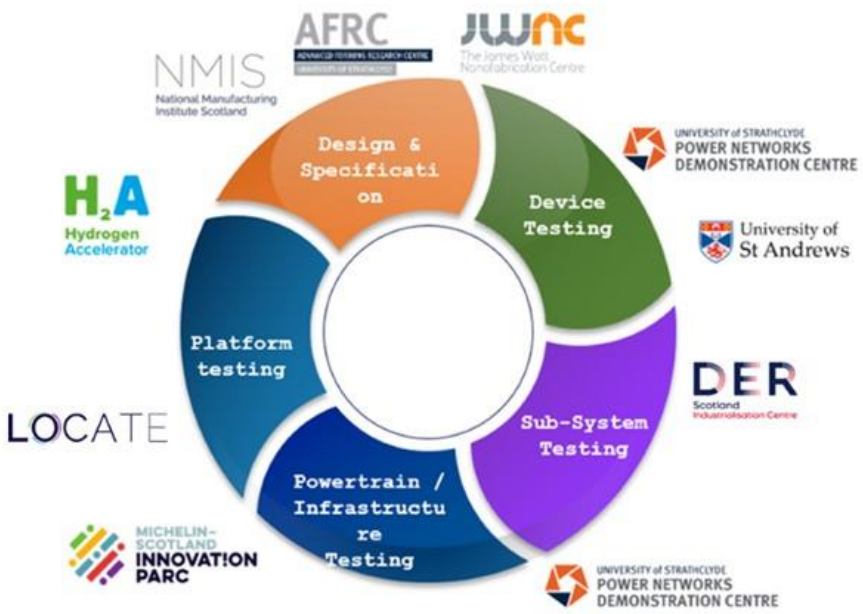
Company Themes	Company Sectors	Company Sub-Sectors	Identified number of Companies
Vehicle manufacturing	Vehicle manufacturers and retrofitters	Low carbon related	4
		Conventional	4
	Vehicle component manufacturers	Batteries	4
		Fuel cells	2
		Fuel saving technologies	2
		Conventional	5
Refuelling and fuels	Biofuels	Conventional	9
		Advanced	2
	Refuelling Infrastructure	Hydrogen	2
Recharging infrastructure and services	Grid Services		3
	Electric vehicle charge point installers		28
	Mobility services		1

TNEI/Element Energy Evaluation of Niche Transport Opportunities for Scotland (2017)

[1] Bloomberg Annual Electric Vehicle Outlook 2019; https://en.yutong.com
[2] TNEI/Element Energy Evaluation of Niche Transport Opportunities for Scotland (2017)
[3] TNEI/Element Energy Evaluation of Niche Transport Opportunities for Scotland (2017)

Sustainable Mobility Innovation

Building on Scotland's international reputation for research, Transport Scotland and Scottish Enterprise are supporting the development of an innovation ecosystem focusing on zero emission components and systems development, testing and verification for specialist and heavy duty vehicles across road, off-road, rail maritime and aviation. This is with a view to making Scotland a global destination for vehicle development, testing and demonstration, with resulting opportunities for Scotland's vehicle supply chain, including the bus supply chain.



This innovation ecosystem includes:

- the Future Electrical Machines Manufacturing Hub;
- the Driving the Electrical Revolution Scotland Industrialisation Centre at the University of Strathclyde;
- the University of St Andrew's Hydrogen Accelerator which facilitates the effective and efficient implementation of hydrogen technologies and delivers hydrogen projects;

- the LOCATE drive train testing facility being developed by the the Scottish Government in partnership with the Power Networks Demonstration Centre and the Hydrogen Accelerator; and
- and the Michelin Scotland Innovation Parc as a key innovation hub for emerging mobility technologies and skills development.

It also encompasses the Sustainable Mobility Cluster Builder[4], contracted to Urban Foresight, as a new programme to help Scottish companies capitalise on opportunities in zero emission mobility. In addition, Scottish Enteprise's Energy Market Expert Support programme (contracted to Cenex) provides heavily subsidised advice and consultancy to Scottish supply chain organisations involved in the decarbonisation of the transport sector.

Supply Chain Development

In alignment with aims of the Manufacturing Recovery Plan – Supply Chain Competitiveness, Scottish Enterprise has objectives to support the competitiveness of manufacturing companies of all sizes in their return to markets and rebuilding of their customer base; to continue to develop thriving & agile businesses; support manufacturers of all sizes to build stronger, more resilient supply chains; and identify opportunities to develop new supply chains and capability. Annex A provides more information.

Within the context of this broader, and growing, zero-emission vehicle and energy ecosystem, Scotland has particular strengths in the zero-emission bus manufacturing and supply chain, ranging from world-leading academic capabilities in chemistry to production of textiles for interiors to chassis manufacturing, as well as comparative advantage in the electric battery market.

[4] hello@urbanforesight.org

Furthermore, there is considerable scope for the learning and skills development (design, manufacture, maintenance, infrastructure and finance) in the bus sector to cross over in to other parts of zero emission mobility.

Demand

As demand shifts from diesel buses to zero-emission buses the supply chain will be bolstered, practical skills knowledge will be built up and businesses will have confidence to invest. The momentum in domestic demand needs to be maintained and international demand needs to be strengthened. Both the public and private sector in Scotland could consider further action to articulate Scotland's ambitions and strengths and potential for inward investment and growth. Such actions could range from strengthened strategic marketing of Scotland, further research to define Scotland's supply chain strengths and potential strengths, to commitments from the bus industry to support nascent Scottish suppliers.

Driving down cost of zero emission buses

Increased demand can create a virtuous circle with reduction in costs, which is vital for the Taskforce's vision to be fully realised.

The key components of both battery electric and fuel cell buses can be categorised as:

- glider and chassis
- electric drivetrain
- drivetrain integration
- drivetrain power system.

In a battery electric bus, the main components of the drivetrain power system include an AC-DC converter and battery pack, whereas in a hydrogen fuel cell bus, these are a battery pack, hydrogen storage tanks and a fuel cell system. (see Annex B – provided as a separate document)

Battery electric bus infrastructure comprises electric chargepoints and smart charging equipment/software. Hydrogen fuel cell infrastructure comprises electrolysers, fuel storage, compressors and hydrogen refuelling dispensers. On top of these specific requirements, both hydrogen fuel cell and battery electric buses require battery storage and grid connections.

As set out in research commissioned by Transport Scotland (Annex B) the largest cost components of zero-emission buses are:

(1) the glider and chassis (41% of battery electric bus cost, 48% fuel cell) and

(2) the drivetrain power system (36% and 28% respectively).

The key **cost drivers** of a **battery electric bus** include:

- Raw materials: The precious metals used in the battery pack are seen as the main cost driver in a battery electric bus. Given their limited supply and the lack of recycling/reuse capabilities, manufacturers expect that the cost of batteries could increase in the future.
- Customisation: Customisation of bus components based on differing operator needs (e.g. livery, in-vehicle systems/equipment, accessibility etc.) can add up to 10% of the overall cost. It is important that regulations on standards are as future-proofed as possible.
- Import duties: Import duties can add up to 10% of the overall cost.

The key cost drivers of an **electric bus depot** are:

- The grid connection costs (which can vary from £60k - £1.5m for an additional 1.5MW capacity depending on distance between a depot and the grid network, and local reinforcement requirements). The use of battery storage solutions could help to reduce these costs.
- The lack of interoperability of charging points may also add to future capital investments should an operator opt for a different manufacturer in future procurements.

The key cost drivers of a hydrogen fuel cell bus include:

- Integration of components: Relative to a battery electric bus, the higher cost of a hydrogen fuel cell bus can be attributed to the fact that there are more parts to integrate and as such more complex engineering work is often required.
- Platinum electrolyte membrane: This is the most expensive part of a hydrogen fuel cell (60% of cost). Although the use of platinum in a fuel cell may reduce its price, it was recently found out that such fuel cells may also need more frequent membrane replacements in the future (at present, this is estimated to be every 7 – 10 years for the platinum electrolyte membrane).
- Import duties: Hydrogen fuel cells are also as dependent on imports and subject to the prevailing tariffs (similar to battery electric buses, given the need to import fuel cells but also batteries for the overall fuel cell system).

The key cost drivers of hydrogen fuel infrastructure include:

- Similarly, grid connection costs are also significant. However, this can be addressed by strategically locating hydrogen re-fuelling sites at locations closer and more accessible to the existing grid network.
- Electrolysers are still a very costly component to the hydrogen infrastructure. The per unit cost of capacity (e.g. per MW) of an

electrolyser is expected to fall as the scale increases to accommodate for more use cases (e.g. lorries, etc.).

- Compressors and cooling equipment also make up a significant component of the infrastructure cost.

The table on the following page sets out the opportunities for driving down costs and the Taskforce are invited to discuss and agree which should be prioritised.

Area	Specific Opportunities
Infrastructure	Develop shared, multimodal refuelling facility/station for hydrogen vehicles (demand aggregation through expansion of use cases) Increase the supply of renewable energy by utilising the excess capacity of windfarms Assess the future demand for recycled batteries to develop plans to upscale the relevant capacity/infrastructure
Partnerships	Undertake trade and inward investment promotion activities to help increase local content and Scotland-based businesses to access international demand Establish a platform (trade shows, associations, etc.) where Scotland-based businesses can get more regular access to domestic and international markets, and build better relationships
Skills	Encourage industry and higher education institutions to develop relevant training programmes Provide training to operators' staff through Provide relevant education, training and upskilling opportunities and embed into necessary curricula or qualifications
Regulations	Analyse the impact of existing and future trade barriers on zero emission technologies Develop proposals addressing market failures, such as those caused by information asymmetry (e.g. grid connection costs) Product standards (e.g. interoperability of charge points, standardisation of batteries and buses)
Innovation and R&D	Support research initiatives to secure affordable domestic supply (e.g. for raw materials of batteries such as Lithium) R&D to improve the life of cells within batteries and develop methods for cell refurbishment R&D to improve the life, quality and reliability of fuel cells R&D to improve the efficiency of manufacturing and production processes

Batteries

Batteries are particular important component of zero emission buses (including hydrogen-fuel cell buses) because of their significant contribution to the overall cost, the lack of certainty about their residual value, the large number at play in an increasingly electric transport system, the finite natural resources that form their composition, and potential for their manufacture and remanufacture in Scotland.

Opportunities to attract battery manufacture to Scotland need to be grasped and encouraged. The major battery manufacturers are predominantly located in Asia, with the top four being: Korean LG Chem, the Chinese CATL and BYD, and the Japanese Panasonic. US car manufacturer Tesla is the fifth largest producer of batteries. Growth in this market is strong. On average, the global battery market increased by 9% per year between 2010 – 2017 with global capacity demand set to reach 2,600 Gigawatt hours (GWh) in 2030. The UK's Faraday Institution suggests that based on electric vehicle demand alone, the UK will need 140 GWh of battery production, equivalent to seven 'Gigafactories'.

Two British companies, AMTE Power and Britishvolt, are planning to build the first UK Gigafactories, which will have a combined capacity of up to 30GWh annually. It is estimated by Ricardo that the capacity of the EV batteries placed on the Scottish market could reach 10.1 GWh by 2025 and up to 42.9 GWh in 2030. Thus the conservative growth is over 300% growth from 2025-2030.

Scotland has a number of strengths which could give it an advantage in the growing global market for electric vehicle batteries: from the sustainable mobility ecosystem set out above, to its strong chemical/refinery expertise to cutting edge R&D in chemistry, design and innovation.

On top of this, there are already a small number of battery manufacturers based in Scotland, including manufacture of actual cells and import of cells to build bespoke battery applications. Examples of these include:

- AMTE Power Ltd: producing lithium-ion batteries for the automotive, aerospace, defence, oil & gas and energy storage sectors.
- Denchi Group Ltd: producing a range of battery chemistries and types for the security and defence sector, but also for oil and gas and medical industries.
- MEP Technologies: design and manufacture battery packs and system solutions for a diverse range of markets.

Aligned with battery manufacturing, there are significant opportunities for Scotland deriving from battery reuse and recycling, as part of a circular economy approach.

A new piece of research from Zero Waste Scotland (Annex D, attached separately) has assessed the current battery sector in Scotland and made projections about the future demand and waste arisings, in order to identify the potential for Scottish companies to improve sustainability and increase circularity within the supply and disposal chains.

Currently, raw materials are extracted from countries around the world to produce a variety of battery types which are imported to Scotland for use. Once they are no longer fit for their original purpose, they are either sent to landfill or collected via regulated schemes which export batteries to Europe for recycling. In both cases critical materials, representing significant value, are lost to the Scottish economy.

The modelling shows that the most significant growth in battery use in Scotland will be in electric vehicles (EV), with a smaller, concurrent, increase in portable batteries for products like mobile phones. By 2050 it is estimated that there will be up to 13,000 tonnes of waste arisings per year from EV batteries alone.

Projections show there may be sufficient future arisings of Li-ion battery waste in Scotland to consider investment in an appropriately sized recycling facility. The viability of such a plant would be likely dependent upon the availability of feedstock, whether it could be co-located with battery manufacturing, and the cost of electricity supply to the plant.

The immediate circular opportunities for Scotland are:

- Improving infrastructure to ensure maximum capture of waste batteries, with a grading, sorting and matching function to maximise reuse and onward value.
- Battery recycling targets and carbon footprint declarations to encourage the greatest use of valuable materials.
- Supporting the development of EV battery design and manufacturing.
- Decarbonisation of, and further improvements to, public transport and active travel to reduce the need for individual car ownership.

ANNEX A: **Enterprise support landscape**

SE Supply Chain Capability Activity

A pilot programme for the Scottish Government Manufacturing Action Plan was deployed between 2017 – 2020 which engaged with key manufacturers and supply chain firms seeking opportunities for Scottish manufacturers. Resultant activity can be categories as follows:-

1. Manufacturers sought assistance to improve internal Supply Chain processes and performance.
2. Manufacturers sought support to improve the performance of the companies within their Supply Chain
3. Supply Chain Development – support offered to identify suitable Scottish manufacturing partners for available contracts / opportunities

Key Learnings:-

- SME 's have a more agile approach than large companies to exploring working relationships with new manufacturing partners
- Large firms with global footprint governed by national / global procurement policies offer more complexities and longer lead times for entry into their Supply Chains.

The above activities have been adopted into the Scottish Government Manufacturing Recovery Plan – Supply Chain Competitiveness & are available to Scottish Government Supply Chain Development Programme

Manufacturing Recovery Plan

Supply chains and competitiveness – Actions

1. Deliver an Engagement programme to maximise opportunities to increase Scottish content, resilience and access new or existing supply chains.
2. Increase the economic impact of public sector procurement.
3. Support inward investors to help identify opportunities for Scottish manufacturers created by new and emerging supply chains.
4. Deliver webinars and provide remote support tools to ensure manufacturers stay competitive using recognised business improvement tools such as Lean through to supply chain excellence models.

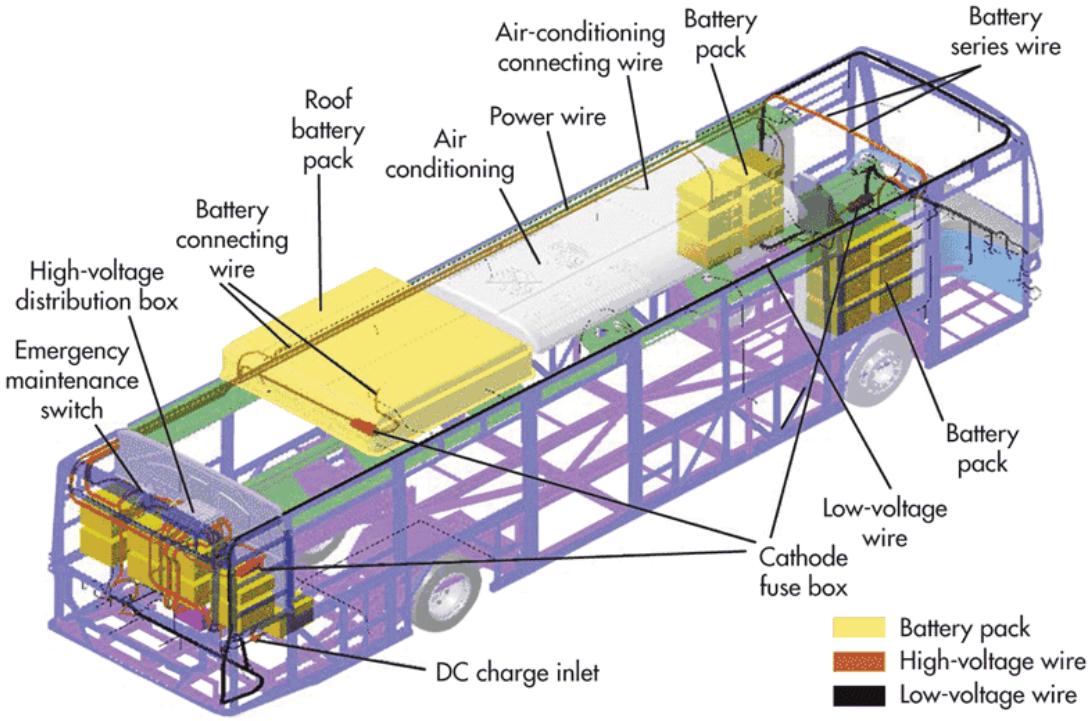
Integral to the success of the Manufacturing Recovery Plan is the Partnership approach incorporating e.g. NMIS, SG, SE, SDS, CENSIS, etc

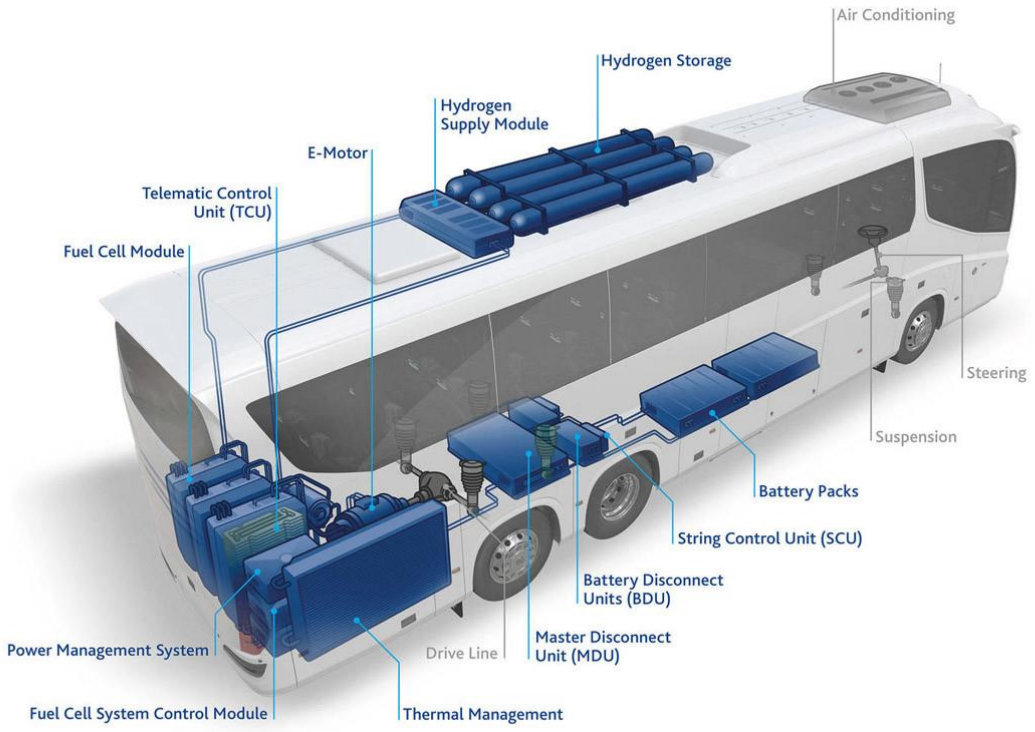
Supporting Supply Chain Development

The support landscape includes a variety of options for Supply Chain Development Support including:-

- Manufacturing & Supply Chain business improvement – Cost , Quality & Delivery improvement; performance and process improvement , people development via SMAS , NMIS etc
- Supply Chain Development – matching manufacturing opportunities to capability in the existing or emerging Scottish Supply Chain
- Business Excellence & Improvement support – meeting Tier 1 supply chain entry criteria
- Partnership Support – signposting companies to most relevant innovation support available
- SE Industry Directories – directories of companies and a source of areas of manufacturing capability
- Supply Chain Capability Mapping – identification of existing and emerging manufacturing capability
- NMIS Hydrogen Supply Chain Capability Mapping – in progress
- Battery Supply Chain Mapping – in progress

ANNEX B: **Components of zero-emission buses**





Paper 4.2 First Draft Pathway and next steps for the Taskforce

This paper provides a first draft pathway, based on the Taskforce's discussions to date, to enable the taskforce to consider whether it is on track to have co-designed a pathway to a zero-emission bus fleet by November 2021.

Please note both that the further steps needed in the manufacturing and supply-chain sector will be incorporated into the pathway following today's item on that subject.

The taskforce are invited to:

a) agree whether or not the "steps" on the pathway as set out in the draft are correct, necessary and sufficient to achieve the Taskforce's guiding vision, including whether planned UK Government regulation should be added;

b) note that the aspiration to remove the majority of diesel buses from public transport by 2023 has been included as a milestone in the draft pathway, and to discuss what bold and transformative steps can be incorporated into the pathway to achieve it;

c) agree what further work the Taskforce needs to undertake to fill any gaps or increase the comprehensiveness and/or quality of the pathway;

d) consider whether the pathway is agreeable ahead of November 2021, and if so whether a final meeting of the Taskforce to formalise the commitments of all members to deliver the steps could coincide with COP 26.

Draft pathway

The purpose of the Taskforce is to co-design a pathway to a fully zero-emission bus fleet within one year of its first meeting in November 2020.

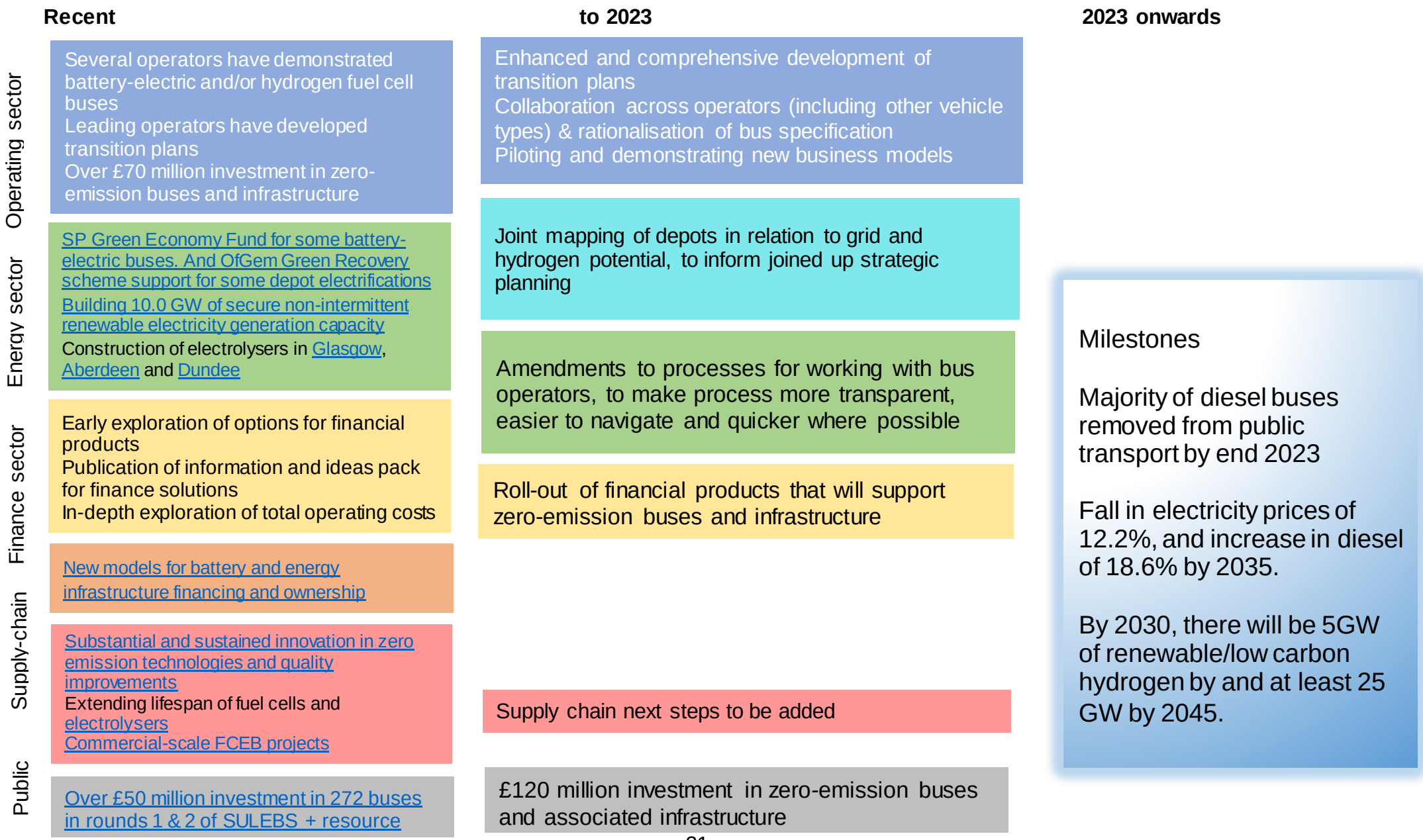
The first draft of the pathway steps is given on the following page. It aims to be clear that much progress has already been made, and that the pathway to a fully zero-emission bus sector requires actions within and between the finance, energy, operating, manufacturing and public sectors, with many of the steps required from now being increasingly multi-sector.

The pathway has been drafted based on the previous 3 taskforce meetings, setting out in one place the consensus reached on what is needed over the coming months and years to achieve the vision. Following the present meeting, steps agreed by the Taskforce relating to the supply-chain and circular economy will be added.

The Taskforce may wish to comment on the extent to which the steps agreed to date are necessary and sufficient to achieve the vision, whether planned UK Government regulations should be added and/or whether regulatory steps by the Scottish Parliament may be necessary.

No target date has been agreed as to when the entirety of Scotland's public service buses should be zero-emission and accordingly, few dates are given in the pathway. Some Scottish Government set milestones have been included (including the intention to remove the majority of diesel buses from public transport by the end of 2023).

The sector to whom the steps, or actions, relate are indicated in the pathway by virtue of positioning and colouring but lead responsibility and target dates are not given. The taskforce may wish to consider whether any of the steps could or should be more explicit about which parties represented around the table are taking forward the necessary work.


Recent
to 2023
2023 onwards
Operating sector
Several operators have demonstrated battery-electric and/or hydrogen fuel cell buses
Leading operators have developed transition plans
Over £70 million investment in zero-emission buses and infrastructure
Enhanced and comprehensive development of transition plans
Collaboration across operators (including other vehicle types) & rationalisation of bus specification
Piloting and demonstrating new business models
Energy sector
SP Green Economy Fund for some battery-electric buses. And OfGem Green Recovery scheme support for some depot electrifications
Building 10.0 GW of secure non-intermittent renewable electricity generation capacity
Construction of electrolysers in Glasgow, Aberdeen and Dundee
Joint mapping of depots in relation to grid and hydrogen potential, to inform joined up strategic planning
Finance sector
Early exploration of options for financial products
Publication of information and ideas pack for finance solutions
In-depth exploration of total operating costs
Amendments to processes for working with bus operators, to make process more transparent, easier to navigate and quicker where possible
Roll-out of financial products that will support zero-emission buses and infrastructure
Supply-chain
New models for battery and energy infrastructure financing and ownership
Substantial and sustained innovation in zero emission technologies and quality improvements
Extending lifespan of fuel cells and electrolysers
Commercial-scale FCEB projects
Supply chain next steps to be added
Public
Over £50 million investment in 272 buses in rounds 1 & 2 of SULEBS + resource
£120 million investment in zero-emission buses and associated infrastructure
Milestones
Majority of diesel buses removed from public transport by end 2023
Fall in electricity prices of 12.2%, and increase in diesel of 18.6% by 2035.
By 2030, there will be 5GW of renewable/low carbon hydrogen by and at least 25 GW by 2045.

Manifesto Commitment and next steps for the Taskforce

Following the Scottish elections in May, the Scottish Government has an aspiration to remove the majority of diesel buses from public transport by the end of 2023. The Taskforce are invited to consider additional steps that can be taken in the immediate future to help deliver that on the pathway to a fully decarbonised bus fleet, and whether the remit – or lifespan - of the Taskforce should be amended to support this.

Options for consideration include:

a) no change – the Taskforce agrees a pathway by November 2021 and all subsequent work to deliver the steps are taken forward by relevant parties in good faith that other steps are being progressed.

b) additional meetings and/or subgroups are arranged between now and November to focus specifically on the immediate-term actions needed to deliver the 2023 milestone.

c) extending the lifespan of the Taskforce until the end of 2023, and adjusting the remit towards delivering the Pathway as a programme until that point.

The originally intended end date for the Taskforce, November 2021, coincides with COP26 being hosted in Glasgow. This raises the possibility that the progress to date, and commitments by all parties on the Taskforce to deliver the steps on the pathway, could be championed publically at a point when media attention will be focussed on actions to tackle climate change.