ANNEX C – Workshop Outputs
SSAC Report - Environmental Impacts of the Scottish Manufacturing Industry

Information collected from stakeholders at workshop held 16th March 2020 and through post–workshop follow up conversations and emails.

Tables of information:

The questions put to the workshop covering each sector above were:

Q1 CLIMATE CHANGE IMPACTS
Consider impacts through-out whole of manufacturing process as well as from raw materials and processes undertaken abroad.
Q2 MITIGATION MEASURES
What are the current and future measures your sector is using to mitigate climate change and other environmental impacts of your manufacturing sector?
Q3 INNOVATIONS
What innovations is your sector embracing, or likely to develop in the future?
Q4 OTHER ENVIRONMENTAL IMPACTS
Other environmental impacts of your manufacturing sector.
Q5 SCENARIOS AND SOLUTIONS
Scenarios and solutions to reduce climate change emissions and other environmental impacts of your sector.
Q6 What are the challenges you face to meeting SG targets, net-zero emissions of all greenhouse gases by 2045, with interim targets for reductions of at least 56% by 2020, 75% by 2030, 90% by 2040?
Q7 What support is missing to meet the targets? For example, does your sector need information, training, financial help, or something else?

PRECISION MANUFACTURING (e.g. photonics; quantum; medical devices; satellites)
Q1 CLIMATE CHANGE IMPACTS
Consider impacts through-out whole of manufacturing process as well as from raw materials and processes undertaken abroad.
Raw materials and components usually obtained from elsewhere as there is no local supply chain.
Assembly is not most energy intensive. Transport of components is significantly more energy intensive.
Refrigeration and air conditioning required for precision engineering of components and to retain ambient conditions within large data centres.
Regulation of waste chemicals: the unequal allocation of carbon footprint to sectors for materials that may not have been produced within Scotland.
Scales of production and effects on energy efficiency.
Significant energy and materials required for environmental testing e.g. liquid Nitrogen for rapid cooling.
SATELLITES
Manufacturing and assembly of small satellites in Scotland. Industry trend from low volume to mass manufacture of small satellites
Increasing number of small satellites needs an increasing number of Lithium Ion batteries – further increasing demand for lithium and other rare elements
Battery production with respect to satellites is energy intensive and currently raw materials are not reused (allowed to burn up on re-entry).
Launch activities, either testing propellants or actual launches have an impact on the ozone layer and climate through greenhouse effect.
Launch (satellite/testing) activities: 1 vertical launch in advanced planning (Sutherland), Perhaps another 2 (Shetland and Western isles); Also, horizontal launch sites planned e.g. Prestwick
Q2 MITIGATION MEASURES
What are the current and future measures your sector is using to mitigate climate change and other environmental impacts of your manufacturing sector?
Some activity and plans underway.
New regulations regarding incineration of WEE waste and the need to find alternatives
SATELLITES
Satellite batteries thrown away. Opportunities in recovery?
Use of green propellants .However, some 'green' propellants such as hydrogen peroxide are potentially carcinogenic.
Work on mitigating ozone impact by injecting particles into ozone layer to reflect sunshine.
PHOTONICS
Sector has provided a sustainability study undertake in 2019 and this is to be included in the literature for this study.
Q3 INNOVATIONS
What innovations is your sector embracing, or likely to develop in the future?

Transition from electronics to photonics -will reduce the amount of power/energy used in telecoms / IT sector.
Move to digitalisation in the design and manufacture process will increase efficiency by allowing more control over processes and ability to gain more information at each step.
Use of digital twins reducing the need for early prototypes and optimising designs and manufacturing processes more efficiently. Model driven engineering means more optimisation work can be done before a prototype is made.
Digital suites mean lower movement of people and transport. Note also changes in skills required of workforce (opportunities)
Move to net shape manufacture through use of additive manufacturing processes.
IoT lends itself to remote monitoring and efficiency improvements across most sectors. IoT will have a growing positive impact as there is greater investment in it. It offers manufacturers the opportunity to make processes more efficient thereby often reducing both waste and energy use.
<SUB-SECTOR NAME>
Q4 OTHER ENVIRONMENTAL IMPACTS
Other environmental impacts of your manufacturing sector.
AIR
Aircraft and space vehicle impact - noise, gas emissions, space waste.
WATER
Need for increasing amounts of cobalt, lithium etc - need to source.
Leads to increase in mining activity. Opportunity as well as an environmental challenge.
LAND
<SUB-SECTOR NAME>
Q5 SCENARIOS AND SOLUTIONS
Scenarios and solutions to reduce climate change emissions and other environmental impacts of your sector.
Systems thinking across the full design/manufacture/use/ remanufacture spectrum. This point is applicable to all sectors and possibly the full eco-system.
<SUB-SECTOR NAME>
Q6 What are the challenges you face to meeting SG targets, net-zero emissions of all greenhouse gases by 2045, with interim targets for reductions of at least 56% by 2020, 75% by 2030, 90% by 2040?
<SUB-SECTOR NAME>
Q7 What support is missing to meet the targets? For example, does your sector need information, training, financial help, or something else?
<SUB-SECTOR NAME>

MEDIUM-SCALE / IN-FACTORY MANUFACTURING (e.g. Automotive / Aerospace)
Q1 CLIMATE CHANGE IMPACTS
Consider impacts through-out whole of manufacturing process as well as from raw materials and processes undertaken abroad.
GENERIC IMPACTS
Raw materials and components obtained from elsewhere as there is no local supply chain. Impact of transport and supply chain must therefore be considered.
This is a big enough sector to have significant emissions due to extraction predominantly out with Scotland.
It is important for Scotland to decide whether the environmental impacts from these items (especially the proportion which are used / consumed in Scotland) is part of its manufacturing impact.
A simple solution to reducing Scotland's environmental impact from manufacturing is to offshore more manufacturing, but this could be to less environmentally responsible sources and would have knock-on implications at a societal and economic level. This is not a responsible / viable solution. In fact, there is a strong net climate benefit in reshoring manufacturing to take advantage of Scotland's world leading low carbon energy system.
Forging and casting in factories is energy intensive.
Sustainability may be a negative rather than a positive for some products. Parts are engineered to last a long time, which is good for sustainability but perhaps not if products in use lag decades behind those in production in terms of their environmental impacts and technological advancement. The key point here is that manufacturing is about what is made as well as how things are made. Making great products that are sustainably produced should be the goal and the shift to a more sustainably focused consumer base must be an opportunity for Scotland.
SUB-SECTOR SPECIFIC IMPACTS
AEROSPACE
Metals required by the aerospace sector such as titanium are energy intensive to produce. The re-use impact is the least. Recycling (remelting) of metals requires much less energy cost than extraction does. Value could be assigned to the metals that are currently in circulation in the economy. We should see metals (and other energy intensive materials) as stored energy.
The scale is medium volume, and resource efficiency is not a driver, cost is. There is a policy opportunity here, if Scotland's support for manufacturing inward investment returned the maximum company funding for truly resource efficient manufacture - - establish a basis for company support whereby Scotland is THE PLACE to be supported on low environmental impact manufacture based on incentives
There is also a complex interplay between scale of production, requirement for product integrity and specification that leads to large amounts of waste as small parts are cut from large blocks.
Large percentages of expensively produced materials are currently turned into swarf (waste) which relatively little finding its way into the end product.

The shift to composites is significant, whilst driven by lower weight, higher performance in the end use, the inputs are all oil based – even the carbon fibre and require large amounts of energy to produce e.g. pyrolysis to form the fibre and to manufacture parts - epoxy/fibre composites being autoclaved.
Q2 MITIGATION MEASURES
What are the current and future measures your sector is using to mitigate climate change and other environmental impacts of your manufacturing sector?
GENERIC MITIGATION MEASURES
Some activity and plans.
Remanufacturing and repurposing of components and products
Increased durability leading to extending product life e.g. design trains to last 3x longer.
SUB-SECTOR MITIGATION MEASURES
AUTOMOTIVE / RAIL SECTOR
Electrification of vehicles becoming more widespread. Successes in public transport sector e.g. Buses
Electrification increasing focus on light weight structures where steel is being replaced by composite structures.
AEROSPACE
Production efficiencies being introduced – based on best practice in other sectors.
Q3 INNOVATIONS
What innovations is your sector embracing, or likely to develop in the future?
GENERIC INNOVATIONS
Digitalisation of factories and use of sensors to improve efficiency by allowing more control over processes and ability to gain more information at each step.
Take up of new innovations should be encouraged and decision-making ought to be based on efficiency. This requires that infrastructure developed in tandem to support these innovations.
SG backed programmes already exist e.g. OEMs (Original equipment manufacturer).
SUB-SECTOR INNOVATIONS
AUTOMOTIVE
Move to Hydrogen and Electric power and lack of electric infrastructure.
RAIL
2 major products expected next year from China so there is global competition but also opportunity
Q4 OTHER ENVIRONMENTAL IMPACTS
Other environmental impacts of your manufacturing sector.
AIR
WATER (QUANTITY AND QUALITY)
Water is recovered by evaporation or filtering. Automotive sector has made steps to reduce water use already.
However, it is unclear what risks there are to existing practice by changing technology.
LAND
Regulation on this in many areas. Disposal of waste not to landfill.
Chemical waste has its own regulations.
<SUB-SECTOR NAME>

Q5 SCENARIOS AND SOLUTIONS
Scenarios and solutions to reduce climate change emissions and other environmental impacts of your sector.
Considerations of Lifecycle of product from design through use and re-use
Important to consider when discussing incentives/ deterrents E.g. Aircraft manufacturers have to work in parallel on multiple technologies in order to bring them together before each product is released, as it takes years to release the final product. This is high risk so incentives from government need to consider this (see ALL). The point here is that in most industries, where the product development time is relatively short, many aspects of innovation (especially materials and manufacturing) are decoupled from the process of launching new products. This make the product launch low risk and provides certainty over the launch date (e.g. new models of car, new models of smart phones)
The nature of aerospace and some other similar industries means that they have to develop new technology within their product development programmes. As a result of this they have developed approaches which could be learned from – given that new technology will be key to meeting the zero carbon challenge
<SUB-SECTOR NAME>
Q6 What are the challenges you face to meeting SG targets, net-zero emissions of all greenhouse gases by 2045, with interim targets for reductions of at least 56% by 2020, 75% by 2030, 90% by 2040?
<SUB-SECTOR NAME>
Q7 What support is missing to meet the targets? For example, does your sector need information, training, financial help, or something else?
<SUB-SECTOR NAME>

LARGE-SCALE FABRICATION (e.g. Shipbuilding; Wind Turbines)
Q1 CLIMATE CHANGE IMPACTS
Consider impacts through-out whole of manufacturing process as well as from raw materials and processes undertaken abroad.
GENERIC IMPACTS
Raw materials obtained from elsewhere as there is no local supply chain. Assembly is not as energy intensive as transport.
The relative energy intensity of producing composite materials compared to standard forms. E.g. wind turbine blades.
Efficiency is sometimes not the driver for choice of material/manufacturing technique but instead it is often about readiness of a particular technique either through ability of a large company to drive it or similarity to well-known processes. Regulatory frameworks around certification of new technologies are the biggest issue here. This will only be countered by some form of regulatory control on environmental impact of the product and its manufacturing method. This is another policy opportunity.
There is a good parallel with aerospace where the combination of safety certification rules and ever tightening environmental standards ACARE have driven change. In shipbuilding and offshore industries the barriers to change through certification outweigh the incentives to change.
SUB-SECTOR SPECIFIC IMPACTS
SHIPBUILDING
Ships use a lot of diesel and there could be opportunity to move to a low carbon alternative if one was currently available.
WIND TURBINES
Discussion about the environmental effects of setting up large wind farms due to amount of shipping.
Blades are composite materials and therefore energy intensive to produce. See above comments on carbon fibre based composites.
The issue with composites is also about the fact that there is no viable mechanism for recycling at end of life and an increased amount of deployed composite will create waste issue in future
Q2 MITIGATION MEASURES
What are the current and future measures your sector is using to mitigate climate change and other environmental impacts of your manufacturing sector?
GENERIC MITIGATION MEASURES
Some activity and plans.
Potential for efficiency in industrial digitisation as this reduces waste and maximises output for given energy inputs. Data centres though are energy intensive due to need for air conditioning and electricity.
Regulation due to quality and safety standards may have to be balanced with need to mitigate environmental impacts.

SUB-SECTOR SPECIFIC MITIGATION MEASURES
WIND TURBINES
Wind Turbines life being extended by use of LIDAR to anticipate strong gusts reducing stress on blades and gearbox extending life of turbines. Also improves efficiency of turbine.
Q3 INNOVATIONS
What innovations is your sector embracing, or likely to develop in the future?
GENERIC INNOVATIONS
Enhanced consideration of life cycle implications, including how to measure product costs through lifecycle (including more than one cycle, re-use, recycle).
Recovery of waste materials to retrieve the value and extend the utility.
Passport for each asset - what it is and how it was made, and used through life. Digital manufacturing techniques will enable.
Sector have made efforts to characterise the life cycle and capitalise on it. Incentives could be important here
SUB-SECTOR SPECIFIC INNOVATIONS
none noted
Q4 OTHER ENVIRONMENTAL IMPACTS
Other environmental impacts of your manufacturing sector.
AIR
WATER
LAND
<SUB-SECTOR NAME>
Q5 SCENARIOS AND SOLUTIONS
Scenarios and solutions to reduce climate change emissions and other environmental impacts of your sector.
<SUB-SECTOR NAME>
Q6 What are the challenges you face to meeting SG targets, net-zero emissions of all greenhouse gases by 2045, with interim targets for reductions of at least 56% by 2020, 75% by 2030, 90% by 2040?
<SUB-SECTOR NAME>
Q7 What support is missing to meet the targets? For example, does your sector need information, training, financial help, or something else?
<SUB-SECTOR NAME>

FOOD AND DRINK
Q1 CLIMATE CHANGE IMPACTS
Consider impacts through-out whole of manufacturing process as well as from raw materials and processes undertaken abroad.
GENERIC CLIMATE CHANGE IMPACTS
General
FDF food and drink report to be published end April (UK level)
Sector is very diverse/includes lots of SME so difficult to determine generic impacts.
Also noted that groups of sectors in study are large and not same as standard classification. Related to another comment that often changes made on an individual basis have greatest impact and example given of company asking employees to consider how to be more environmentally conscious. Can be returned to under opportunities
Dominated by Scotch Whisky industry. Preference was expressed for the whisky industry to be considered as a separate sector
Raw Materials
Raw materials mainly (but not all) produced in Scotland and the impacts of that captured under Agriculture and Land Use and Land Use Change categories rather than manufacturing/industry.
Fertiliser use – production energy intensive (emissions likely elsewhere in UK/beyond)
Supply Chain
Packaging is generally imported. Regulations are strict for packaging and slow to change, for health and safety reasons. There is a need for standards of progressive improvement vs sustainability to go alongside those for safety which currently disincentivise change
Note made that imports will become more complex due to tariffs. Applies to all sectors.
Work underway to look at improving the efficiency of logistics.
Production
Processing, by-product impacts, and waste are significant impacts.
Consumer waste is greater than industrial.
Age of machinery may lead to greater volumes of waste and less efficiency (revisited under innovations)
SUB-SECTOR SPECIFIC IMPACTS
SCOTCH WHISKY
Scottish whisky industry looking at water and carbon footprint. Two pieces of work sponsored by SG on decarbonisation food and drink (one from CXC, one from element energy).
Biotech industry working closely with whisky sector (via Scotch Whisky Research Institute) to valorise co-products from the sector (circular economy). Some distilleries using anaerobic digestion to generate biogas from pot ale.co-product. Carbon capture technologies from fermentations also under investigation but several companies
Scotch Whisky Pathway to Net Zero: Report for Scotch Whisky Association (May 2020)
https://www.scotch-whisky.org.uk/newsroom/world-environment-day-industry-continues-to-take-steps-on-the-journey-to-net-zero/

Q2 MITIGATION MEASURES
What are the current and future measures your sector is using to mitigate climate change and other environmental impacts of your manufacturing sector?
GENERIC MITIGATION MEASURES
Extensive activity/advanced plans
Reducing impact of packaging is more challenging for food and drink than other industries due to legal/standard issues for food safety.
Consumer demand may help the shift to different materials for packaging and behavioural changes means less plastic is used as well as commodities like palm oil which are associated with deforestation.
Reducing packaging or making it/products lighter weight for transportation also minimises energy use and waste.
Refrigeration and heating currently requires a lot of energy and uses gas and oil so there is opportunity to make changes.
Minimising waste can also be achieved through innovative use of by-products e.g. CO2 from fermentation made into Spirulina (a high value product)
Sector highlighted difficulties in changing behaviour when diverse and numerous businesses in Scotland.
SUB-SECTOR SPECIFIC MITIGATION MEASURES
DRINK / SCOTCH WHISKY
Whisky industry reducing energy use and investing in biomass and CHB
FOOD
Food production made to be resource efficient and energy use could be further improved through efficiency improvements in manufacturing processes.
AGRITECH
Work underway to cut emissions associated with land management (e.g. soil/grassland management), reduce emissions from livestock (e.g. animal feed additives) and emissions from manure and slurry (e.g. anaerobic digestion)
Opportunity to make changes in energy efficiency of lighting for vertical farms as seen at JHI.
Q3 INNOVATIONS
What innovations is your sector embracing, or likely to develop in the future?
GENERIC INNOVATIONS
Opportunities in digitalisation as with other industries. Control over processes can be useful in complex manufacturing processes that require different temperatures and could lead to less waste and greater efficiency.
Upgrading of old equipment through digital technologies e.g.in biscuit making ovens, equipping of ovens with sensors could improve performance, efficiency and reduce waste. It could also provide data that could be useful in optimisation of processes. Potentially prohibitive costs of retrofitting old equipment should be examined and areas of opportunity prioritised.
Skills and training and ensuring managers are aware of new innovations and help increase their uptake.

Transport costs are an opportunity to address and Brexit may require this to be considered and planned for more efficiently which would also reduce energy consumption.
SUB-SECTOR SPECIFIC INNOVATIONS
Q4 OTHER ENVIRONMENTAL IMPACTS
Other environmental impacts of your manufacturing sector.
AIR
General comment that apparent environmental impacts and C footprint of industry is high, but it is a large sector.
WATER
Water usage is high but sectors taking steps individually e.g. Scotch Whisky. Opportunity for more integrated approach?
Many SMEs make a consistent approach more difficult and cost is a barrier.
LAND
Biodiversity risks.
Individual sectors taking steps but could be more integrated amongst all – note that this relates more to production i.e. supply chain than to processing
SUB-SECTOR
Q5 SCENARIOS AND SOLUTIONS
Scenarios and solutions to reduce climate change emissions and other environmental impacts of your sector.
SUB-SECTOR
Q6 What are the challenges you face to meeting SG targets, net-zero emissions of all greenhouse gases by 2045, with interim targets for reductions of at least 56% by 2020, 75% by 2030, 90% by 2040?
SUB-SECTOR
Q7 What support is missing to meet the targets? For example, does your sector need information, training, financial help, or something else?
SUB-SECTOR

CHEMICALS / PHARMACEUTICALS
Q1 CLIMATE CHANGE IMPACTS
Consider impacts through-out whole of manufacturing process as well as from raw materials and processes undertaken abroad.
GENERIC IMPACTS
Mainly imports of raw materials so manufacture and transport most energy intensive.
Transport and shipping emissions still high – focus on ship emissions improvements.
Opportunity for re-shoring of manufacture, especially with growing expertise in distributed manufacturing and growth in microfactory modules that are being developed (see below)
Also need to develop flexible, agile and "de-risked" supply chains. Will see a massive increase in this concept (e.g. COVID-19 pandemic effect). This will probably work against CO2 emissions with smaller less energy efficient plants rather than fewer, larger, more energy efficient / integrated plants.
Opportunity to switch to renewable energy sources is most obvious approach.
Opportunity for working circular economy – especially for biotechnology.
Scales of manufacturing and examples. For pharma, relatively low volumes and high regulatory burden means recycling of solvents etc. is not usually carried out.
Conversely, agrochemicals is a large area in Scotland and larger volumes mean heat and energy recycling in plant is much more common. Lean manufacturing heavily applied.
Move to modular flexible plants with hybrid batch and plant modules incorporated into microfactory units i.e. 'factories in box'.
Lots of accessible tools for monitoring and decision making. Recent H2020 project STYLE – green chemistry and American Chemical Society round tables provide some very useful accessible tools.
Impacts on air, water quality and land by potentially complex emissions from manufacturing operations, storage and transport of intermediates and the formulation, packaging and distribution of final products.
Greenhouse gas emissions from manufacturing processes and from the generation of heat and power.
SUB-SECTOR SPECIFIC IMPACTS
CHEMICALS
In the chemical sector in Scotland there is a wide range of manufacturing of active ingredients, intermediates and final product formulations.
Greenhouse gas emissions from the manufacturing sector in 2017 was 8.7 MtCO2e about 21.7% of Scotland's net emissions.[1] This includes chemicals manufacturing at approx. 1.4 MtCO2e and oil & gas refining at approx. 2.8 MtCO2e.
[1] https://www.gov.scot/publications/scottish-greenhouse-gas-emissions-2017/
PHARMA / FINISHED ARTICLES / AGROCHEMS
Some raw materials (petrochemicals). Manufacture of active chemical ingredients rather than final formulation is most common activity in Scotland in pharmaceutical.
Raw Materials
Impacts from making active chemical ingredients which is main activity in Scotland (various CMOs)

Mainly global as raw materials shipped from rest of world (usually Asia/Far East) and product often shipped on for further formulation and packaging Europe or USA.
Supply Chain
Long distance and time for (often 2 years) supply chain with multiple raw materials from Asia (some US or Europe).
Many imports and high levels of (mainly EU) regulation. For example, EpiPens are imported, and manufacture of this is very highly regulated.
Active Chemical ingredient usually shipped to different formulation + packing site before they are then shipped to distribution centres and finally pharmacy. This is driven by different regulatory requirements, so usually easier to have 2 different sites running different quality systems.
Last mile is the most expensive aspect of the whole supply chain for medicines in delivering to pharmacy / patients in the community.
Production
Raw materials are fixed, but there is opportunity to improve manufacturing processes or to do some processing close to the site of extraction or generation / sourcing of raw materials.
Methods of production and efficiency: Pharma are shrinking to small scale continuous which would be more efficient (lower energy and CO2 and other environmental impacts e.g. solvent waste etc.) than the current batch method.
CMAC at University of Strathclyde is conducting research into scaling down from existing batch production to continuous or hybrid batch and continuous of chemicals as well as digital modelling to improve efficiency as a strategic partnership of Medicines Manufacturing Innovation Centre (MMIC).
Secondary / formulation is area of focus as tabletting can be significantly streamlined – CMAC and MMIC work on direct compression.
Some areas will always struggle to change drastically – e.g. high potency compounds and some manufacturers currently run dedicated equipment for each process to avoid any cross-contamination, but could be more efficient with smaller continuous plants.
Lots of scope to reduce primary and secondary manufacturing unit operations / costs / emissions BUT slow to implement due to regulatory change.
High cost to implement regulatory changes (> £1million), so have to have significant financial benefits before filing for any changes. Quality by Design approach and now new guidance in ICH Q13 docs will help this, but still a conservative, slow to change industry.
Intermediates / raw materials / synth chemicals
Most focus in industry to date is on cost/use of energy in plants as this has direct impact on costs.
Lean manufacturing and energy re-use generally well implemented in larger manufacturing plants.
BIOTECHNOLOGY
Biotech offers some interesting opportunities for chemical industry decarbonisation. It's not a magic bullet by any means but for certain product-types it has huge potential for sustainable manufacturing.

As a broad, general comment bio-based chemicals manufacturing is almost certainly more sustainable in terms of raw materials supply (plants not oil) but far less adaptable in terms of products that can be made and life cycle assessments are important to ensure that energy costs are understood. Impact on emissions is really only significant for large scale processes – i.e. not biopharmaceuticals where the total demand is a few tonnes. But it becomes significant at larger volumes – e.g. antibiotic production and larger.
Opportunity to re-shore bioethanol production for petrol blend. Currently import 50M litres of ethanol mainly from France. All could be derived from locally grown sugar beet using ~1% of Scottish arable land. Feasibility assessment underway with farmers led by IBioIC and Rural Innovation Support Service. Other bio based manufacturing could develop around this supply chain (e.g. ethanol to ethylene, bioplastics production, protein for human consumption).
Q2 MITIGATION MEASURES
What are the current and future measures your sector is using to mitigate climate change and other environmental impacts of your manufacturing sector?
GENERIC MITIGATION MEASURES
Some activity/plans
Opportunity to increase activity and useful investigation could be made into barriers currently in place.
Energy efficiency – increased use of wind, solar and other green energy resources.
Use of greener e.g. (biologically derived) solvents.
There is a heat map of Scotland with hot spots for where electricity and heat is generated and where there is a demand which may be a useful resource.
Recycling of materials and solvents at larger scale.
Implementation of circular economy aspects for biotechnology - link waste materials from one industry to feedstock for another.
Optimisation of supply chain – balancing risks needing several suppliers, reshoring of some operations.
Reduction of transport also mentioned as area for exploration by the sector. Possibly involves re-shoring of manufacture – less transport miles and lower risk.
Novel manufacturing approaches to remove unit ops – continuous manufacturing, smaller scale, direct compression, microfactory units / modular plants.
Digitisation – predictive design, implementation into manufacturing, monitoring and process modelling. "Digital twins". More efficient manufacture, better design and efficacy of product.
Microfactories / flexible modular units / factory-in-a-box / smaller continuous units, technology to manufacture closer to point of need so less waste as manufacture to specific volume requirements, not large campaign manufactures in 1-2 sites worldwide.
Distributed manufacturing avoids large campaigning so enables more flexible manufacture on demand significantly reducing over-manufacturing in current paradigm.
Potential application / deployment of CCS e.g. through industrial cluster approach.
Training of people going into relevant sectors for awareness of how to impact on CO2 emissions and general environmental impact assessments schools, Universities, modern apprenticeships etc.
Also possible education of end user consumers to shop for more sustainable products.

Barriers to mitigation mechanisms:
Regulations
Local taxation rules
Countries wanting to move up the value chain of manufacturing so stipulation final formulation must be in country, otherwise has very high import tariff.
Labour and manufacturing costs in far east lower vs Scotland (although this is increasing in far east as salaries increase and environmental regulation tightened.
Products manufactured by chemical or biological means are regulated under the Pollution Prevention and Control (Scotland) Regulations 2012 (PPC Regulations) and policed by the Scottish Environmental Protection Agency (SEPA).[1] Permits set strict conditions to prevent or reduce impact on the environment. Operators are required to utilise "Best Available Techniques" for which mandatory emission levels are set in reference documents developed under the EU Industrial Emissions Directive (2010/75/EU), as well as to reduce consumption by continuing to improve their processes through innovation and efficiencies. SEPA undertakes regular inspections and reviews reported data to check compliance. Reported data includes resource use, waste arising, and emissions to air and liquid discharges all at a specified frequency. Operators are also required to report the mass release of specific pollutants to air, water and land and any offsite transfers of waste.
[1] https://consultation.sepa.org.uk/sector-plan/chemicals-manufacturing/
SUB-SECTOR MITIGATION MEASURES
PHARMA
Already uses wind and solar power (in some companies where they have larger sites – how to implement at smaller scale?)
New synthesis options – conditions, reagents, biocatalysts and operating windows.
CHEMICAL
Some agrochemical companies recycle heat and this may be an opportunity for others.
Opportunities at Grangemouth to reduce flaring and increase efficiency.
CHEMICALS
Due to the hazardous nature of chemicals, some manufacturing sites, depending on the quantities held, fall under the Control of Major Hazard Installations 2015 (COMAH) which transposes the EU Seveso III Directive (2012/18/EU). Operators of these sites must take all measures necessary to prevent major accidents and to protect human health and the environment. As of 2019 there were 20 sites in Scotland regulated by COMAH.
Chemical manufacturing sites may also be regulated under a number of other environmental regulations aimed at reducing Scotland's greenhouse gas emissions. This includes the EU Emissions Trading Scheme, Energy Savings Opportunities Scheme, and the Regulations for Fluorinated Greenhouse Gases and Ozone Depleting Substances. Again SEPA undertake regular audits under these regulations.
The marketing and use of chemicals is currently regulated by (EC) No. 1907/2006 on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH). This regulation will continue to apply after Brexit under UK legislation and requires suppliers and importers of chemicals to ensure their safe use with respect to human health and the environment throughout the supply chain. This requires the assessment of all risks by importers or suppliers in the chemical supply chain and the dissemination of safety

information to all downstream users. SEPA hold enforcement powers to check that operators are using the correct measures to prevent release of such chemicals.
BIOTECH
Circular economy / raw materials in biotech industry- uses could also be found for waste as a raw material e.g. for processes at the IBioIC.
Q3 INNOVATIONS
What innovations is your sector embracing, or likely to develop in the future?
GENERIC INNOVATIONS
Novel chemistries and catalysts.
Training – 3D or virtual environments – data visualisation and digitisation (behind compared some other industries).
Digital Twins – "Model based design and manufacturing" – similar concept to precision manufacturing topic. Still quite a way to go to be fully first principles modelling but mix of core research focus at CMAC at University of Strathclyde.
Supply chain innovations through 1. Re-shoring – to address current supply chain risks. May require changes in terms of tax breaks; 2. distributed manufacturing models allowing for manufacture on demand – much more agile.
Life Cycle assessment in data-light environments.
Five potential themes have been identified for the Scottish chemicals sector.[1] They all offer innovation driven opportunities and the potential for the chemicals sector to work closely with other key Scottish sectors particularly energy and life sciences. As such, they are strongly aligned with key sector and market trends, particularly and focus on the development of innovative high value chemical technologies in the established European chemical sector.
[1] CSS Strategy Review 2019 (Optimat)
SUB-SECTOR INNOVATIONS
PHARMA
Digital design + new designs for more efficient tablets.
Work underway on the move from batch to continuous pharma manufacture (e.g. CMAC, MMIC) is likely to result in a move to hybrid manufacture (both batch and continuous) with continuous used only where there are clear advantages.
Microfactories / flexible modular units / factory-in-a-box / smaller continuous units, technology to manufacture closer to point of need so less waste as manufacture to specific volume requirements, not large campaign manufactures in 1-2 sites worldwide.
Improved efficacy for drug delivery through tablets by understanding fundamental science e.g. controlled release rates, improved bioavailability of amorphous compounds.
3D printing of tablets on demand in pharmacy or hospital, especially for clinical trials.
Polypharmacy – multiple drugs in one tablet printed for personalised medicine.
Direct compression to make tablets – reduces number of unit operations.

Print drugs on demand, at point of use or in pharmacy.
CHEMICALS
Energy Storage and Distribution
Two potential focus areas have been identified in this area, namely:
1. New materials and chemistries for advanced Li-ion batteries (propulsion applications),
2. New and improved energy storage batteries for energy systems.
Beneath these strategic targets are a number of priorities and actions including:
• A focus on low carbon and renewable transport systems, with a particular emphasis on electrifying the sector using a range of options.
• Improving system security and flexibility through the development of innovative energy systems that combine renewable power generation with improved energy storage and distribution systems, building on the "global shift away from centralised generation and passive consumption".
This will require a wide range of innovative generation and storage technology solutions that industry and academia in Scotland could be well placed to exploit.
Energy storage and, in particular, batteries is viewed as the technology that will support the transition to a lower carbon energy system due to its broad application in the power industry and in transport. There is also potential for energy storage technologies to support the integration of these industries to increase cost efficiencies and bring emissions close to zero[1]. There is, however, still significant development of battery technologies required, especially in materials and chemistries, to increase energy and power density, improve recyclability, reduce charging times, improve safety and reduce cost. The development of new chemistries that remove the need for critical raw materials such as cobalt and graphite and reduce the amount of Li required are, currently, of particular interest. There is also significant research being undertaken into new, safer electrolytes that are, for example, aqueous rather than solvent based or are solid state rather than liquid.
Market growth is expected to be significant with conservative estimates suggesting that there will be around 50 million electric vehicles, globally, by 2030. Similarly, Li-ion batteries based energy storage is expected to grow from about 3-4 GWh in 2017 to 100GWh in 2025.
There is a small company base in this technology field in Scotland but it is noted that these companies would not be considered as chemical companies, in the traditional sense. Rather, they sit at the interface between chemistry and energy storage. Based on the description of their activities, these companies do, however, appear to be actively innovating across the battery development, manufacture and end-user supply chain.
There is a particular strength in Scotland's academic institutions, within individual universities and the Energy Technology Partnership research pool. St Andrews University, in particular, is recognised as world leading in the field of energy materials and chemistries but there is also capability at the Universities of Glasgow, Strathclyde and Edinburgh as well as at Heriot Watt University.
The bulk of battery manufacture, currently, is carried out in Asia and the Far East and that is unlikely to change in the near future, due to the level of capital investment required for a new battery manufacturing plant. The fact that Scotland already has an established,

large manufacturer that is actively innovating in the fields of materials and chemistries is an asset.
There is need to support the emerging supply chain in Scotland, as part of the strategy to establish a wider UK supply chain, by continuing to encourage innovation in this area, develop collaboration with the energy sector and, in particular, support collaboration between companies and between companies and academia to support technology commercialisation for exploitation in Scotland or for export markets.
[1] Li-ion Batteries for Mobility and Stationary Storage Applications: Scenarios for Costs and Market Growth, JRC Science for Policy Report, 2018
Low Carbon Energy / Hydrogen Economy
The opportunity in this area is focused on the production, storage and distribution of hydrogen for energy generation, heating and propulsion applications.
The hydrogen economy will also have an important role to play in helping Scotland to achieve it strategic energy objectives.[1]
Hydrogen can be produced using processes that have low greenhouse gas emissions and can be utilised as an energy carrier or be converted to electricity in a fuel cell for applications including transport, power and heating.
The global hydrogen generation market was valued at $103.2 billion in 2017 and is expected to reach a value of almost $207.5 billion by 2026, a CAGR of 8.1% over the period although the lack of proper distribution and transportation infrastructure is restraining market growth[2]. Most hydrogen is made by steam reformation of methane, which is relatively energy intensive and results in CO2 emissions, unless it is combined with carbon capture, storage and utilisation. It is also produced by electrolysing water, a process that is less efficient and traditionally more expensive than steam reforming[3], unless energy from renewables is used and can be considered cheap or free.
Scotland has a relatively strong company base, relative to its size, which is supported by the Scottish Hydrogen and Fuel Cell Association (SHFCA).
Scotland, and the UK as a whole, is really only starting to make progress in the development of a hydrogen economy and there is significant potential to develop new and improved technologies in the areas highlighted in the UK Hydrogen and Fuel Cells Roadmap.
In terms of capabilities, Scotland has world-leading physical and materials chemistry academic expertise at St Andrew's University. There is also capability at the Universities of Edinburgh, Glasgow, Herriot Watt and through the Energy Technology Partnership.
The Scottish Government has already invested in a number of projects including the Aberdeen Hydrogen Fuel Cell Bus Project (Scotland is an early adopter of this technology, although the fuel cells are provided by a Canadian company); 'Surf n Turf', a project in Orkney to convert and store energy as hydrogen; and 'H100' a feasibility study into the construction of a hydrogen distribution network.
In addition, a European consortium, led by St Andrews University and including Orkney Islands Council was successful in securing €9.3 million through the European Commission's Horizon 2020 programme to develop, build and demonstrate the world's first sea-going car and passenger ferry fuelled by hydrogen.

Scotland already has a small but active industrial, public sector and academic base in this area but, as noted above, there are still significant opportunities to exploit chemical sciences and, in particular, materials chemistry, to support the further development of the hydrogen economy in Scotland.
[1] https://www.scottishcities.org.uk/media/case-studies/building-the-hydrogen-economy-in-scotland
[2] Hydrogen Generation – Global Market Outlook (2017-2026), Statistics Market Research Consulting Pvt Ltd, Nov 2018
[3] Hydrogen: Still the Fuel of the Future?, Angeli Mehta, July 2018, https://www.chemistryworld.com/features/hydrogen-still-the-fuel-of-the-future/3009235.article
Alternative Feedstocks
Scotland has strength in bio feedstocks and land-based crops and internationally recognised Industrial Biotechnology Innovation Centre (IBioIC) and a growing number of Industrial Biotechnology (IB) companies. The National Plan for Industrial Biotechnology defines an ambitious plan for growth.[1]
In Chemical Sciences three additional focus areas have been identified in this area, namely:
1. Derivation and processing of hydrogen as a feedstock
2. CO2 capture, storage, transportation and utilisation
3. Biogas (from anaerobic digestion) / biomethane.
Hydrogen has potential to be used as an alternative feedstock for the chemicals industry, particularly in combination with CO2 captured from industrial emissions as discussed below.
CO2 and biomethane can be subjected to chemical and IB processes to generate commercially valuable chemicals and other products, as well as sequestering carbon. When done in conjunction with hydrogen, this can result in the production of various short chain hydrocarbons that can be used directly, such as butanol for fuel, or can undergo further chemical synthesis to produce alcohols or olefins, for example.
CCS and CCU are, increasingly, being considered in an integrated way and the 2017 Clean Growth Strategy emphasised the UK Government's ambition to become a leader in carbon capture, utilisation and storage (CCUS) technology with a view to deploying scaled up technologies during the 2030s[2].
There are a few examples of commercial scale plant using chemical catalysts to manufacture methanol and biofuels from captured CO2 and H2 generated from the electrolysis of water; converting CO2 to solid carbonates to be used in the construction industry to replace aggregates and cement; and converting CO2 to polymeric materials to substitute petrochemical derived plastics. IB processes offer more flexibility and adaptability but are at an earlier stage of development.
Scotland has a strength in CCUS research particularly through Scottish Carbon Capture and Storage (SCCS) in Edinburgh, one of the UK's largest CCS research groups and the UK Industrial Decarbonisation Research and Innovation Centre (IDRIC) was established at Herriot Watt university in 2020.[3]
The CCUS company base in Scotland is developing, in line with the rest of the UK. A company based in Scotland, is recognised as a leader in the field, providing support to CCUS projects in the UK and supporting the development of the regulatory and

commercial framework. Additionally, an industry led alliance called NECCUS has recently formed to promote and encourage Scottish commercial activity in CCUS.
There are also a number of Scottish chemicals companies that could use the products manufactured from circular carbon.
There is already motivation to pursue developments and opportunities in this area through the Northern Connections Living Lab project and work is being done to scope out a CCU Living Lab project for Scotland, which will incorporate a number of innovation challenges that need to be addressed. Scottish companies with relevant technologies would be given the opportunity to participate in this project.
CCS, CCU and Hydrogen will require a collaborative approach, both company to company and company to academia, to deliver progress further along the TRL scale towards commercialisation. There is a need to develop collaborative partnerships between organisations, both academic and industrial, with the relevant capabilities in IB and traditional chemical sciences (e.g. catalysis) to participate in multi-disciplinary innovation activities. This could build on the early successes already demonstrated through Project Acorn and, potentially, The Northern Connections CCU Hub project.
[1] https://www.sdi.co.uk/media/1673/national-plan-for-ib-2019-pdf
[2] Carbon Capture and Usage, POSTbrief Number 30, October 2018, Houses of Parliament Parliamentary Office of Science and Technology
[3] https://idric.org/
Circular Economy
Developing circularity in the chemicals sector is extremely wide reaching and encompasses many of the areas already identified. In addition, from a chemical sciences perspective, circularity can be achieved through the flow of biological materials e.g. biomass feedstocks for chemicals manufacture.
Two further potential focus areas have been identified:
1. The use of waste and by-products as feedstocks
2. The development of advanced chemical recycling technologies (modifying materials' molecular bonds to recover hydrocarbons utilising catalytic cracking, for example)
The Scottish Government's Circular Economy Strategy sets out strategic objectives, priorities and actions for Scotland, recognising that the global economy and, therefore, the Scottish economy is at an early stage of transition towards full circularity. The strategy is being delivered in partnership with Zero Waste Scotland, the Enterprise Agencies and SEPA. Although, in the first instance, Chemical Sciences is not included within the initial priority areas (which are food and drink and the broader bio-economy; remanufacture; construction and the built environment; and energy infrastructure), discussions with Zero Waste Scotland have revealed a willingness to support initiatives in this area. More generally, a move towards a more circular economy supports Scotland's Economic Strategy and its four priorities (Innovation Inclusive Growth, Internationalisation and Investment) and the Manufacturing Action Plan, all of which are very relevant to Chemical Sciences.
The Chemical Sciences Scotland Strategic Plan 2025 [1] also recognises the impact that the Circular Economy will have and specifically highlights:
• Resource efficiency and emissions reductions

- Enabling recycling and reuse.

The chemical industry will contribute to the circular economy in two key ways:

- By enabling the circular economy in downstream industries
- Circulating molecules to close the loop.

This will require the development of new business models, products and process technologies that go beyond the concept of using a product just once[2].

Much of the focus of chemical recycling, to date, has been on plastics, breaking it down into constituent components to be used as a fuel or a feedstock to create new plastic. Initially, this has been at demonstration scale due to the high energy intensity of the processes and the poor economic returns but development of processes to deal with 'easier' types of material are now becoming commercially viable. Subsequently, work is being done to deal with more difficult plastics, such as laminated, multi-polymer material[3].

Increasing competitive pressures from chemical companies operating internationally has led to significant focus on reducing cost and becoming more efficient. This has led to efforts to minimise material input, process energy consumption, water consumption etc. The principles of 'green chemistry' also focus on the use of synthetic design methods to minimise waste products and, specifically, minimise toxicity of substances produced. Whilst these principles result in economic benefits they also address increasing environmental protection regulation and pressure from end consumers for producers to operate more sustainably (e.g. in the cosmetics market).

The conversion of feedstock materials, such as oil, natural gas, bio-based inputs and minerals, into organic and inorganic chemicals can often involve complex international supply chains. Throughout these conversion processes a range of side products arise from the chemical reactions used to produce the primary product streams. Obtaining value from these side products (and hence minimising material leakage from the system) is a very well established part of the industry.

Some Scottish chemical sciences companies are already deploying circular economy practices in their day to day activities, albeit, they may not recognise them as such. For example, recycling of solvents (80% to 90%) results in significant cost savings, and leasing of catalysts rather than purchasing them outright can also result in cost savings.

Considering, specifically, the potential focus areas noted in this area (the use of waste and by-products as feedstock; and the development of advanced chemical recycling technologies), no strong capability in chemical recycling has been identified. The development of these technologies would require a multi-disciplinary, collaborative approach encompassing many of the chemical sciences capabilities already discussed, plus enabling technologies such as catalysis and formulation, as well as capability in process engineering. These are all capabilities that exist in Scotland, within academia and within industry.

The global trend towards the adoption of circular practices cannot be ignored and the key will be to identify specific opportunities and begin to address these individually as part of a wider move towards circularity.

[1] https://www.lifesciencesscotland.com/news/new-strategy-scotlands-chemical-sciences-sector-chemical-sciences-scotland-unveils-new-strategic-plan

[2] ChemistryCan – Accelerating Europe towards a Sustainable Future, CEFIC Sustainability Report, 2017

[3] https://www.mrw.co.uk/knowledge-centre/chemical-recycling-heats-up-with-plants-at-scale/10037348.article
Advanced Materials and Molecules
Two potential focus areas were identified in this theme, namely:
1. Advanced products for health and well-being (medicinal chemistry)
2. Multi-functional materials.
The Industry Leadership Group for Life Sciences has developed a strategic plan for item 1.[1]
With regard to the second area, the emphasis here is on multi-functional materials, rather than materials in general. This includes for example; engineering polymers based on advanced formulation and additives, advanced high temperature coatings, self-healing composites, smart glazing solutions, smart drug eluting materials, carbon nanotube and graphene based materials for electronics, batteries and super-capacitors, and new electronic chemical formulations for optical materials and functional thin films.
There is a small but strongly growing market for multi-functional materials and very strong research capability in Scotland's universities. There are, however at this time, very few companies active in the development, commercialisation and use of multi-functional materials. Significant investment is currently being made in the development of a Lightweight Manufacturing Centre, which is part of the National Manufacturing Institute of Scotland (NMIS) and which will focus on delivering research and development projects involving lightweight materials, such as light alloys, polymer matrix composites, metal matrix composites, ceramic matrix composites and hybrid materials.
The capabilities will include:
• Process optimisation; helping companies to better understand and control their processes with a view to achieving an increase in production with improved repeatability,
• Integrity analysis; the team is working with companies to help them produce components with superior integrity and improved performance capability helping to reduce failure rates,
• End-of-life recycling; developing enhanced recycling techniques to enable companies to use recycled materials to produce components that compare favourably to those manufactured with virgin materials.
The development of new and improved composite materials and the development of recycling techniques will require chemical sciences capabilities but, at this stage, it is not possible to be definitive about what these capabilities will be. Chemical sciences in Scotland has an important contribution to make in the new Lightweight Manufacturing Centre.
[1] Life Sciences Strategy for Scotland 2025 Vision, Accelerating Growth, Driving Innovation, Life Sciences in Scotland, 2017
Q4 OTHER ENVIRONMENTAL IMPACTS
Other environmental impacts of your manufacturing sector.
AIR
WATER
Chemical degradants in water. Significant water treatment plants required.
What happened to discarded medicines – often ends up in landfill and then into water course – can have significant impacts e.g. oestrogen levels.

Water (river or sea) often used as coolants on large plants.
Requires systems thinking e.g. Dutch publication in bio-mass production.
For large molecules (biological based) medicines which will be a growth industry for Scotland – high potency but will have larger waste streams, but mainly aqueous/organic so requires suitable containment and waste treatment.
LAND
Land use for feedstock for bio-refineries or bio-based solvents … tensions and conflict.
CHEMICALS -The carriage of dangerous goods by road or rail is regulated by the HSE, and covered by the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2014 (CDG), which aim to protect anyone that might be directly (or inadvertently) involved with the movement of hazardous substances.
WASTE
Other areas of Waste - Patient compliance, clinical trials waste.
Fate of unused/discarded pharmaceuticals in the environment Eg. Manufacturing campaign paradigm – often forecasting amounts of drug that will be required 2 years ahead of time to get supply chain fully in place so volumes are usually not correct (too high, or low) when finished product actually gets to hospital or pharmacy… so companies often over-produce to ensure no shortage of medicines supply.
Materials with limited lifetime.
CHEMICALS - The majority of intermediates, along with some final packaging, is covered by the Regulation (EC) No 1272/2008 on the classification, labelling and packaging of substances and mixtures (CLP Regulations). This seeks to ensure the safe use and supply of chemicals and covers aspects from labelling, through the safe packaging of chemicals and products. Waste packaging requires to be assessed to determine if there are any remaining hazardous components.
CHEMICALS - Under The Producer Responsibility Obligations (Packaging Waste) Regulations 2007, an obligated company is defined as a producer (i.e. companies who have a turnover of more than £2 million and have handled packaging materials weighing more than 50 tonnes in a year). They have an obligation to register with SEPA and to fulfil prescribed recovery and recycling targets. This is a market driven system to encourage minimisation of packaging waste as well as increased recycling where the producers take financial or physical responsibility.
BARRIERS AND OPPORTUNITIES
Regulatory burdens.
Social uptake/use, increased patient compliance taking course of medicines?
Training + equipment requirements to make tablets in pharmacy or hospital.
Increase in recycling of catalysts as costs increase.
CHEMICALS - play an intrinsic part in modern living. The benefits of chemicals are significant but the unintended environmental consequences of chemical use in society are apparent. Some impacts are more visible than others, and general awareness on issues vary accordingly. The effects of plastic pollution, anti-microbial resistance and the harmful effects of hazardous chemicals (for example, endocrine disruption) on ecosystems will continue to pose significant challenges.
Q5 SCENARIOS AND SOLUTIONS
Scenarios and solutions to reduce climate change emissions and other environmental impacts of your sector.

CHEMICALS / PHARMA
Holistic approach to environmental impacts- example from EU (SPIRE) could be considered as a roadmap to helping the processing industries improve efficiency and reduce environmental impact.
Incentives must carefully consider global nature of manufacturing sector and be applied consistently and fairly.
See innovation section above.
Increase in pre-competitive manufacturing research – especially increase in digital twins and process modelling to improve processes reducing development costs, time and impact.
CHEMICALS
Scotland hosts one of the largest and most significant offshore CO_2 Storage resource bases in Europe. Along with England and Norway, these resources represent a strategic resource of European significance enabling the safe sequestration of CO_2 in deep sub-surface geological formations during the transition to a Net Zero GHG emissions economy. The technology to develop this resource is available now and is based upon proven industry practice developed through the exploitation of oil and gas resources.
Scotland has a huge role to play in this new sector which has the potential to grow to a size comparable with the oil and gas industry.
In fact, this potentially provides a much needed way of transitioning jobs and repurposing infrastructure as the use of fossil fuels declines. Delivering clean energy from the combustion of natural gas resources as well as hydrogen from steam methane reforming and putting the resulting CO_2 back underground is central to this response. Work by Strathclyde University in 2019 has suggested that the development of a CCUS industry could support up to 105,000 jobs within the Scottish economy by 2050 enabling a just transition to a Net Zero emissions economy. Future technologies that could support delivery of our net zero aspirations include Direct Air Capture and Bioenergy with CCS (BECCS).
Scotland has skills, capability, technology, commercial, infrastructure and natural resource advantages in this sector. Through this advantage, Scotland will be in a strong position to support other regions decarbonise through the export of storage resource, and industrial, scientific and commercial know how, engineering and services.
The Scottish chemicals and oil & gas refining industries are part of the newly formed alliance. The NECCUS alliance is a "not for profit" industry led company whose sole purpose is to support Scottish Industry meet the clean industrial growth challenge and Net Zero greenhouse gas (GHG) targets announced by both Scottish and UK Governments. It will achieve this through the support, promoting and advocacy of an accelerated deployment of Carbon Capture, Usage and Storage **(CCUS)** technologies in Scotland and the further development of the Scottish Supply chain to meet the demands of this new sector.
The aim of NECCUS is to prepare industry and other stakeholders for an effective transition to Net Zero through deployment of CCUS, production of hydrogen through SMR with CCS, promoting clean industrial growth zones and to ensure that CCUS plays an active role alongside other low and zero emission technologies to deliver Net Zero targets.

NECCUS will work closely with industry, Scottish Government, the development agencies, academia and trade organisations such as the Scottish Carbon Capture and Storage, Scottish Hydrogen Fuel Cell Association and Chemical Sciences Scotland and the Oil and Gas Technology Centre to promote and encourage Scottish commercial activity in CCUS and a growth pathway towards Net Zero. The NECCUS ambition will include the development in Scotland of the first net zero industrial cluster in the UK by 2045. It will complement and build on existing CCUS initiatives in the region including the Acorn CCS infrastructure project, the Aberdeen Vision project (hydrogen production through steam methane reforming with CCS) and prepare the Scottish industrial sector for future decarbonisation activity.
Q6 What are the challenges you face to meeting SG targets, net-zero emissions of all greenhouse gases by 2045, with interim targets for reductions of at least 56% by 2020, 75% by 2030, 90% by 2040?
CHEMICALS
Response to Q3 Innovations gives a comprehensive picture of key challenges and opportunities the Scottish Chemicals sector has in driving towards a Net Zero emissions future.
Q7 What support is missing to meet the targets? For example, does your sector need information, training, financial help, or something else?

MATERIALS
Q1 CLIMATE CHANGE IMPACTS
Consider impacts through-out whole of manufacturing process as well as from raw materials and processes undertaken abroad.
GENERIC IMPACTS
Mostly production. Raw materials can be imported long distances (e.g. Aluminium ore from Canada).
SUB-SECTOR SPECIFIC IMPACTS
ALUMINIUM
Aluminium production uses hydropower, however the ore is shipped from Canada. NB the large hydro scheme for the aluminium smelter is a significant part of the renewable energy smart grid – can reverse and act as a pump storage facility of surplus grid capacity.
Energy cost of extraction is 7 times higher than that of reuse (recycling is different as it involves smelting).
CEMENT
Cement production - energy intensive industry. Opportunity at policy level to mandate use of alternative to Portland cement in concrete, and/or to re-use or re-purpose existing buildings
Q2 MITIGATION MEASURES
What are the current and future measures your sector is using to mitigate climate change and other environmental impacts of your manufacturing sector?
GENERIC MITIGATION MEASURES
Extensive activity/advanced plans
Electrification is an opportunity to drive the change in use of materials, to light weight alternatives.
Composite materials can be more energy intensive to produce and there are re-use and recycle issues with these.
Tax benefits for low carbon, asset value of materials would present useful incentive for industry. Suggestion of tax benefits if companies demonstrate carbon footprint impacts including recyclable nature of products and raw materials.
Recycling rates can be improved and converted to high value products as demonstrated by Glasgow double glazing company that uses 100% recycled products and has been successful in influencing its supply chain to go “greener”
Some energy intensive aspects covered by EU ETS.
SUB-SECTOR SPECIFIC MITIGATION MEASURES
Q3 INNOVATIONS
What innovations is your sector embracing, or likely to develop in the future?
GENERIC INNOVATIONS
Innovations around re-use of materials.
Opportunity with quantity of materials already in Scotland to invest in recovery and reuse which adds value.
Can extend the lifecycle of materials especially base metals

SUB-SECTOR SPECIFIC INNOVATIONS
Q4 OTHER ENVIRONMENTAL IMPACTS
Other environmental impacts of your manufacturing sector.
AIR
WATER
LAND
SUB-SECTOR SPECIFIC
Q5 SCENARIOS AND SOLUTIONS
Scenarios and solutions to reduce climate change emissions and other environmental impacts of your sector.
GENERIC SCENARIOS AND SOLUTIONS
SUB-SECTOR SPECIFIC SCENARIOS AND SOLUTIONS
Q6 What are the challenges you face to meeting SG targets, net-zero emissions of all greenhouse gases by 2045, with interim targets for reductions of at least 56% by 2020, 75% by 2030, 90% by 2040?
GENERIC CHALLENGES
SUB-SECTOR SPECIFIC CHALLENGES
Q7 What support is missing to meet the targets? For example, does your sector need information, training, financial help, or something else?
GENERIC SUPPORT
SUB-SECTOR SPECIFIC SUPPORT

TEXTILES
Q1 CLIMATE CHANGE IMPACTS
Consider impacts through-out whole of manufacturing process as well as from raw materials and processes undertaken abroad.
GENERIC IMPACTS
80% of manufacturers are micro SMEs (under 10 employees)
88% of manufacturers use 'sustainable manufacturing methods'.
Lots of small enterprises (less than 10 people) in this sector mean they can be versatile and use sustainable manufacturing methods
Complex international supply chains and many products/raw materials are imported and exported (sometimes both) e.g. wool is exported and imported.
Supply chains are not transparent, and is mainly imported cashmere, wool, cotton and synthetics.
There is a tool to assess the impact, used by larger companies but the smaller SMEs cannot afford it.
May be consumer driver for sustainability (repeated under opportunities)
SUB-SECTOR SPECIFIC IMPACTS
Q2 MITIGATION MEASURES
What are the current and future measures your sector is using to mitigate climate change and other environmental impacts of your manufacturing sector?
GENERIC MITIGATION MEASURES
Extensive activity/advanced plans
Large number of small micro-companies means they can respond quicker to market trends.
Consumer behaviour means market for responsible products.
Sustainable manufacturing methods developed and in use, eg. efforts to lower water use, care label impact.
Traditional methods use manual labour and are low energy intensive.
Scotland is a premium quality brand with a long life of product, and zero waste design and assembly focus i.e. Scottish products are more sustainable. Need to enhance awareness of this in an increasing world demand for responsible products.
Design is often outsourced and is proactive in reducing waste in the design stage.
Manufacturing outsourced internationally, following Brexit may bring back to UK but there may be a skills issue. (See point below)
Many textiles exported (approx. 50%)
Movement towards dual flow of products, i.e. to return items for repair, clothing as a service. There are emerging business models e.g. garment rental.
Skills deficit in UK for production and repair/refurbishment, exacerbated by Brexit and points-based immigration system
SUB-SECTOR SPECIFIC MITIGATION MEASURES
Q3 INNOVATIONS
What innovations is your sector embracing, or likely to develop in the future?

GENERIC INNOVATIONS
Connectivity in supply chains improved with virtual reality to address remoteness of workforce and training needs.
Use of digital technology in heritage equipment – reduces waste and down-time whilst maintaining 'craft' value add.
Smart fibres and textiles are innovations with potential for growth.
Reuse of high value waste e.g. Cashmere can also be capitalised on
High consumer demand for sustainable textile products – Scotland well placed to respond to this
SUB-SECTOR SPECIFIC INNOVATIONS
Q4 OTHER ENVIRONMENTAL IMPACTS
Other environmental impacts of your manufacturing sector.
AIR
WATER
LAND
Growth in use of natural fibres (market driven).
Potential for land use conflict e.g. food v fibre production
SUB-SECTOR SPECIFIC
Q5 SCENARIOS AND SOLUTIONS
Scenarios and solutions to reduce climate change emissions and other environmental impacts of your sector.
GENERIC SCENARIOS AND SOLUTIONS
Consideration of social aspects – move away from centralised activity to more localised, individually focused (agile, customised)
SUB-SECTOR SPECIFIC SCENARIOS AND SOLUTIONS
Q6 What are the challenges you face to meeting SG targets, net-zero emissions of all greenhouse gases by 2045, with interim targets for reductions of at least 56% by 2020, 75% by 2030, 90% by 2040?
GENERIC CHALLENGES
SUB-SECTOR SPECIFIC CHALLENGES
Q7 What support is missing to meet the targets? For example, does your sector need information, training, financial help, or something else?
GENERIC SUPPORT
SUB-SECTOR SPECIFIC SUPPORT

ALL SECTORS (GENERIC) **Q5 SCENARIOS AND SOLUTIONS - to reduce climate change emissions and other environmental impacts**
SYSTEMS THINKING AND ENGINEERING
Examples from other countries / EU could help design Scotland's approach (i.e. look at other countries as exemplars).
Need a good example of a systems approach to communicate what is meant. Aircraft construction was one suggestion. Need to consider cases where Scotland really can operate at a full system level. Mainly possible in cases where a full vertical supply chain operates in Scotland, or where products are developed here.
Could be driven by 'grand challenges' which is a mission driven solution to a problem.
Deadlines important for progress to zero carbon. Difficult to match up Scottish Government high level targets (e.g. 2030 reduction 75%) to efforts of individual companies and sectors.
INCENTIVES
Need to consider life-cycle and complexity of manufacturing process.
Carbon tax taking into account carbon emissions internationally, embedded tax system.
Need for positive incentives or rewards.
BUT local country carbon taxation on its own will harm those areas where it is applied. Must be a global, regional, or universal on an industry-specific basis for it to be fair. Chemical manufacturing is so global, can't be applied at a regional level. Pharma manufacturing location is almost totally driven by local taxation rules (e.g. Ireland, Singapore, Puerto Rico) so unless it is used as a carrot it will be detrimental to Scotland.
Changes to public sector procurement can have an influence - e.g. make environmental considerations a key point in the buying decision.
Tax incentives or even investments like the previous programmes to encourage the take-up of renewable energy could also have a positive impact.
BUY-IN FROM STAKEHOLDERS
Workers within the companies on the ground are the best placed to know what innovations could help so could ask them and tailor approaches.
Consumer buy in and power should be considered. Education of the public.
In general, most sectors / businesses of scale are actively involved in understanding and reducing their GHG emissions, driven by internal corporate objectives and/or stakeholder & client expectations, and also regulation (e.g. EU ETS).
Resource efficiency has largely been the focus of activity across sectors, as lean thinking and efficiency objectives have been more involved in driving general operational improvement.
Scottish engineering / manufacturing, as a hub in many international supply chains, has the opportunity to be at the forefront in key aspects of the global campaign on reducing carbon emissions if we can support the sector with the optimal blend of fiscal measures, skills pipeline, and R&D support.
From a recent survey of our (Scottish Engineering) members in manufacturing and engineering
• Well over 90% recognise that the declared climate emergency is real and requires an active and urgent response.

- 66% are actively pursuing operational changes that will support reduction in climate impacts.
- 53% are actively pursuing product/service design changes or diversification that will support reduced climate impact.

This would indicate that the issue is understood and that the challenge is in encouraging industry to innovate in materials, processes and end products, and where necessary to seek diversified opportunities where core skills can be redeployed.

We (Scottish Engineering) would be happy to repeat and share this survey with you, for example annually, to help gauge industry attitude towards these key issues.

SUPPORT NETWORKS AND KNOWLEDGE SHARING

There is an active and mature support network in place for businesses e.g. Scottish Enterprise (SE), Zero Waste Scotland (ZWS), Renewable Energy Systems (RES), Scottish Environmental Protection Agency (SEPA), Energy Skills Partnership (ESP), that provides a wide range of knowledge, experience, technical and financial support to all sizes and sectors. Scot Gov't should continue to support these agencies to deliver general and tailored support – experience suggests "hand holding" businesses results in higher implementation of efficiency projects as these are de-risked through knowledge based support and identification of funding schemes where appropriate.

Knowledge sharing across sectors is valuable e.g. the whisky sector generally shares knowledge widely on environmental improvement, as its sees this as a non-competitive aspect; enabling and facilitating knowledge sharing (what does and doesn't work) would be a valuable part of the net zero ambition.

ALL SECTORS (GENERIC)
Q6 What are the CHALLENGES you face to meeting SG targets, net-zero emissions of all greenhouse gases by 2045, with interim targets for reductions of at least 56% by 2020, 75% by 2030, 90% by 2040?

Need for a structured Scottish Roadmap to achieve Net Zero Emissions targets.

The main challenge is likely to be the financial cost of step change investment projects; resource efficiency improvement will only impact so much, and across sectors, investment in new technology will be the next stage in cutting emissions. An example would be the glass sector where the most efficient technology could mean additional investment of £25m for a typical furnace. This may be a more extreme case, but the principle is the same in many technologies. While regulation (PPC) has an input – Best Available Technology – mandating the most expensive solutions could drive businesses elsewhere resulting in carbon leakage. The other challenge that goes hand in hand is understanding of new technology and confidence in it to perform as promised – it's a real business risk to invest in a new/different technology – support wise, how can this be de-risked to provide comfort? See comments above on business support.

With respect to renewable energy the capital cost difference vs fossil fuel technology is still significant, and in many cases requires a very long term outlook and acceptance that ROI will be >7 years. Can businesses realistically look that far ahead? Some are willing to do this where corporate policy allows, but others are not.

COVID-19: there's no doubt this will delay or cancel investment in low carbon solutions where businesses are acutely financially challenged.

The challenges to the engineering / manufacturing sector of supporting the achievement of the Scot Gov't targets are significant and complex. They include:

• Growing the technical skills base and enhancing mechanisms for industry-academic co-operation.
• Financing the research, development and application of new production methods, materials, technologies, and products and services
• Reducing logistical / supply chain emissions, re-shoring where possible, whilst maintaining Scotland's position in international supply chains.
• Maintaining competitiveness for a sector which operates in global markets.
• Supporting businesses through transition / diversification from carbon intensive industries.
• Creating measurement and reporting frameworks which are meaningful, fair and do not impose significant administrative costs on business.
ALL SECTORS (GENERIC) **Q7 What SUPPORT is missing to meet the targets? For example, does your sector need information, training, financial help, or something else?**
NMIS is inspired by, and follows on from, a UK project with the focus of the economy. It could have a stronger focus on sustainability and circular economy. Holistic thinking required.
Discussion around understanding that successful innovations result from either luck or forcing and that the pathway is different in Scotland from UK. Geography but also how to enable SMEs to step up to the mark. Often not enough time in SMEs to make major transitions.
General discussion on need for holistic approach was the lesson from wind turbines which was assuming electrification ignoring the potential of Hydrogen
Need for a focal point for the activity.
Businesses appreciate a broad range of support to help realise emissions reduction e.g. knowledge based technical support, best practice guidance, sharing good practice with other businesses. There is still a need for financial support in the right circumstances to incentivise uptake of state of the art technology. It's acknowledged that gov't funding will continue to be a challenging aspect, but support will help projects get over the line. There is also an element of risk sharing when gov't funding is available and support can give confidence to businesses that the public sector is "buying in" to projects.
The support should include targeted fiscal measures such as new or additional tax credits in relevant R&D / Investment. International experience indicates that such measures can be highly effective in incentivising industry to move in the desired direction where market forces alone may not yet have responded to the extent required, without the off-putting bureaucracy of a grants based incentive.
At the same time it will be important to avoid further taxation, levies or other penal approaches which risk rendering Scottish industry uncompetitive and displacing production overseas.
Support should be targeted at key sectors. Scotland can't be world leaders in everything but there are specific fields where Scotland has the opportunity to take a leading position e.g. in renewable energy, energy storage, aerospace, space, transport, life sciences. The concept of critical mass is vital here in terms of building national and regional hubs, supported in partnership with Government and academia by shared centres of excellence in developing and applying leading edge manufacturing and engineering techniques.

FURTHER INFORMATION SOURCES
Q1 CLIMATE CHANGE IMPACTS
Consider impacts through-out whole of manufacturing process as well as from raw materials and processes undertaken abroad.
FURTHER INFORMATION SOURCES
J Srai. Cambridge Uni work
Settanni, E and Harrington, TS and Srai, JS (2017) Pharmaceutical supply chain models: A synthesis from a systems view of operations research. Operations Research Perspectives, 4. pp. 74-95.
Harrington, TS and Phillips, MA and Srai, JS (2016) Reconfiguring global pharmaceutical value networks through targeted technology interventions. International Journal of Production Research. pp. 1-17.
Tsolakis, Naoum, and Jag Srai. "Modelling 'Green' Paracetamol Supply Chain Operations Defined by Renewable Chemical Feedstocks in England: A System Dynamics Analysis." (2016).
Phillips, Wendy, Nick Medcalf, Kenny Dalgarno, Harris Makatoris, Sarah Sharples, Jag Srai, Paul Hourd, and Dharm Kapletia. "Redistributed manufacturing in healthcare: Creating new value through disruptive innovation." (2020). https://uwe-repository.worktribe.com/output/999236
Recent H2020 project STYLE - https://www.spire2030.eu/style/
POST-WORKSHOP ADDITIONS
An Assessment of the Opportunities for Re-establishing Sugar Beet Production and Processing in Scotland, National Non-Food Crop Centre
https://www.brydenwood.co.uk/projects/glaxosmithkline-beta-building-prototype/s1317/
Pfizer/GCon Pods systems
https://www.pharmaceutical-technology.com/contractors/cleanroom/g-con-manufacturing/
Q2 MITIGATION MEASURES
What are the current and future measures your sector is using to mitigate climate change and other environmental impacts of your manufacturing sector?
FURTHER INFORMATION SOURCES
Factory in a box
https://smartmanufacturingaccelerator.co.uk/what-is-factory-in-a-box
POST-WORKSHOP ADDITIONS
Q3 INNOVATIONS
What innovations is your sector embracing, or likely to develop in the future?
FURTHER INFORMATION SOURCES
Discussion of 'Pharma 4.0' as being the future of manufacturing within this industry Pharma 4.0

https://ispe.org/initiatives/pharma-4.0
Life Cycle assessment in data light environments – STYLE H2020 project – UK contact is Amy Peace at Britest Ltd.UK https://www.spire2030.eu/style/
POST-WORKSHOP ADDITIONS
Q4 OTHER ENVIRONMENTAL IMPACTS
Other environmental impacts of your manufacturing sector.
FURTHER INFORMATION SOURCES
POST-WORKSHOP ADDITIONS
Q5 SCENARIOS AND SOLUTIONS
Scenarios and solutions to reduce climate change emissions and other environmental impacts of your sector.
FURTHER INFORMATION SOURCES
https://www.gov.uk/government/publications/industrial-strategy-the-grand-challenges/missions
https://marianamazzucato.com/
Horizon 2020 spire (5 years), sustainable process industry roadmap
https://www.spire2030.eu/intro
David Mackay's book
https://www.withouthotair.com/download.html
POST-WORKSHOP ADDITIONS
Strategic Insights Unit commissioned Frost & Sullivan to produce a major report.
https://es.catapult.org.uk/reports/innovating-to-net-zero/
http://www.energy-transitions.org/sites/default/files/ETC_MissionPossible_FullReport.pdf
https://www.ogauthority.co.uk/news-publications/publications/2019/ukcs-energy-integration-interim-findings/
https://www.scottishfuturestrust.org.uk/storage/uploads/sftassessingdemandforcommercialdevelopment.pdf