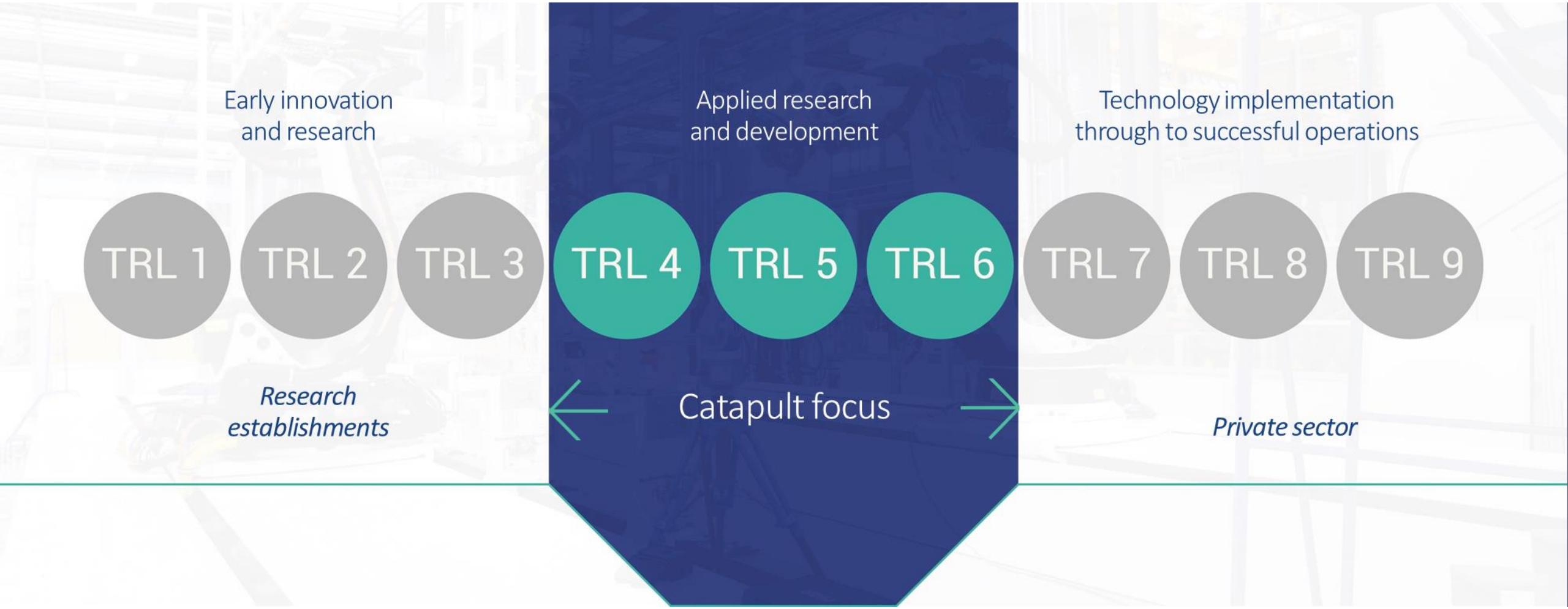
NATIONAL COMPOSITES CENTRE

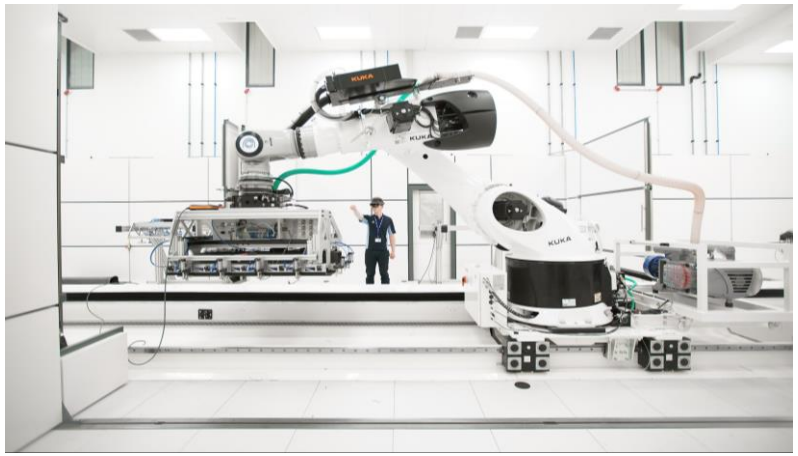
Composites Role in Delivering Net Zero

June 2022

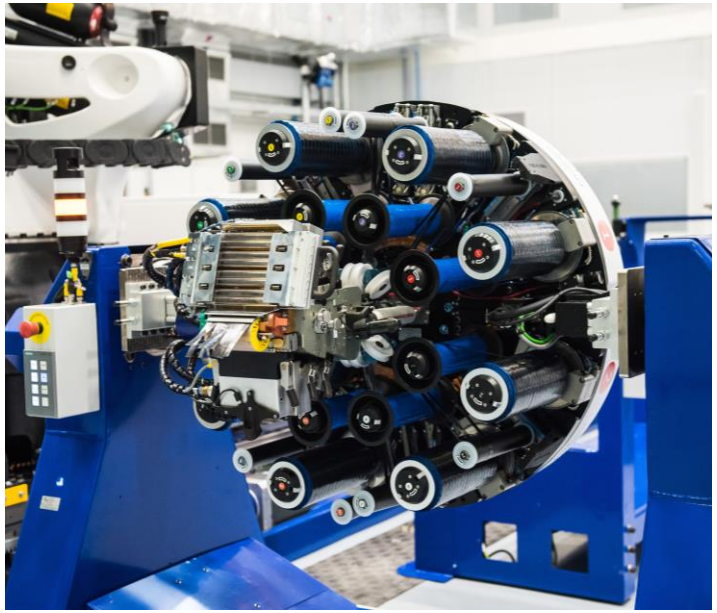
Part of University of Bristol & HVMC

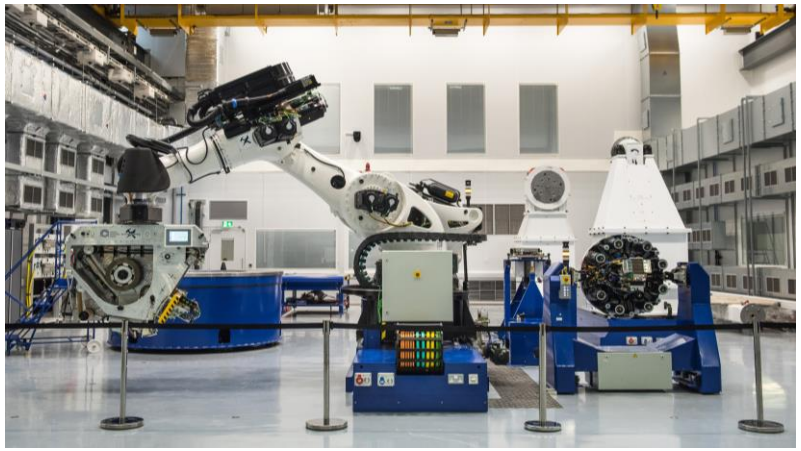
Catapults mission:
Translating Research into Application – bridging the 'valley of death'





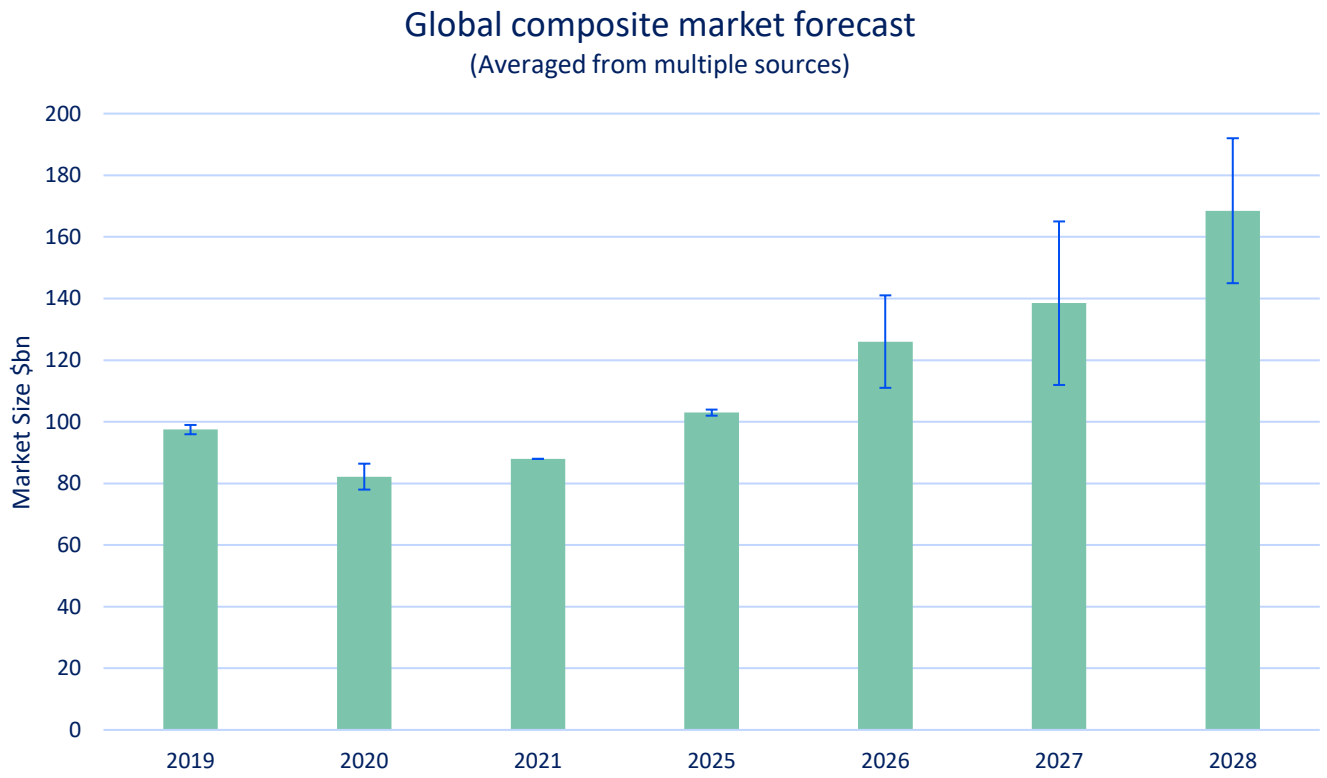
Europe's leading composite innovation capability





NATIONAL COMPOSITES CENTRE

Future demand for composites is strong



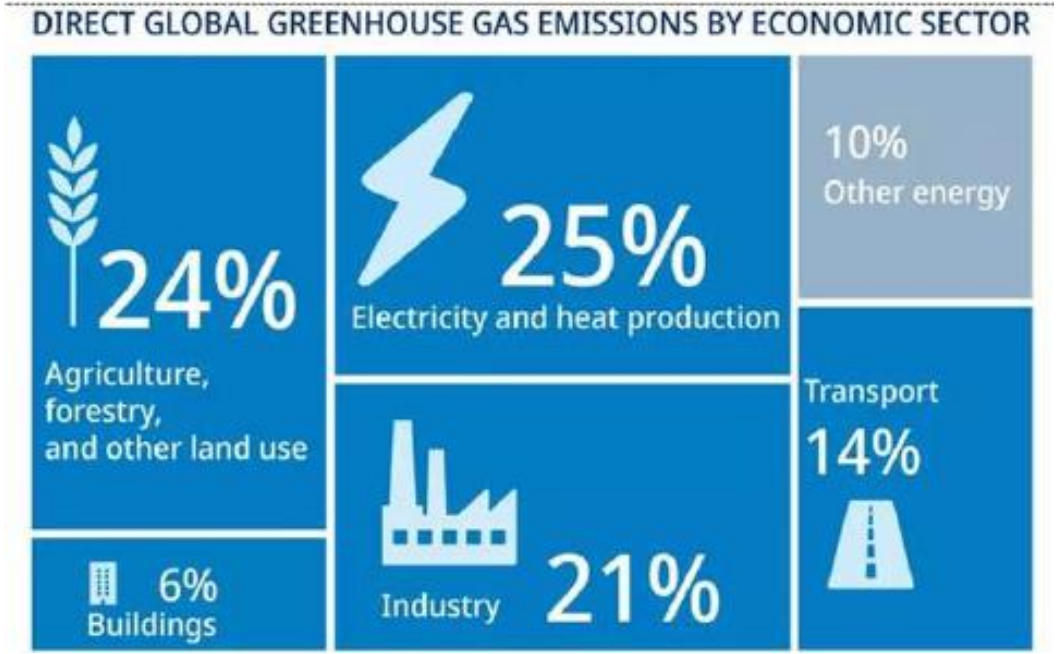
Composites forecast to **grow faster** than global economy (6-9% per annum)

Designated a **critical material** by US

Driven by enabling the Net Zero Transformation

‘Net Zero requires transformational technology to deliver a step change in product and system level performance – composites can enable this transformation’

- **Light-weighting** to **accelerate electric mobility**
- **Storage and distribution** technology to **enable hydrogen**
- **Performance step-change** to **scale wind energy**
- **Zero emission aircraft** to achieve **‘jet zero’**
- **Energy efficient infrastructure** and **buildings**
- **High temperature, lightweight** materials to **unlock nuclear**



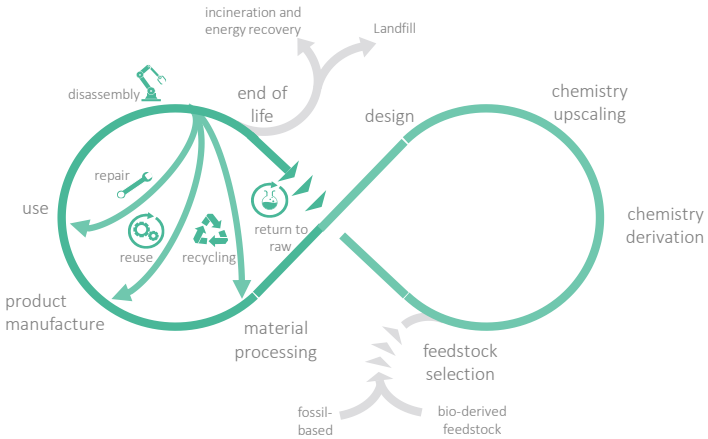
… but relies on solving 4 key problems

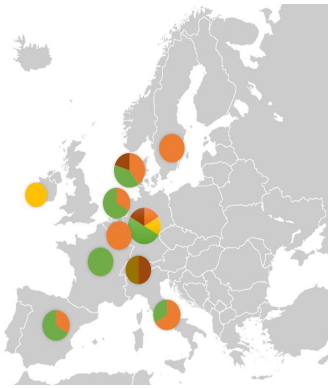
Bringing new products to market quickly

Reducing embodied emissions

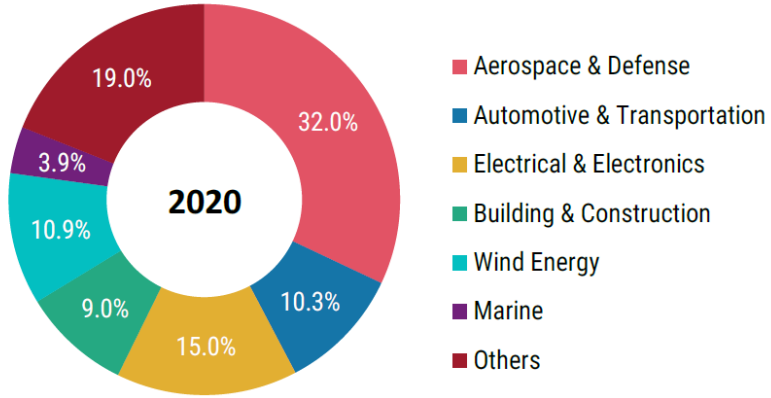
Solving the sustainability of composite materials

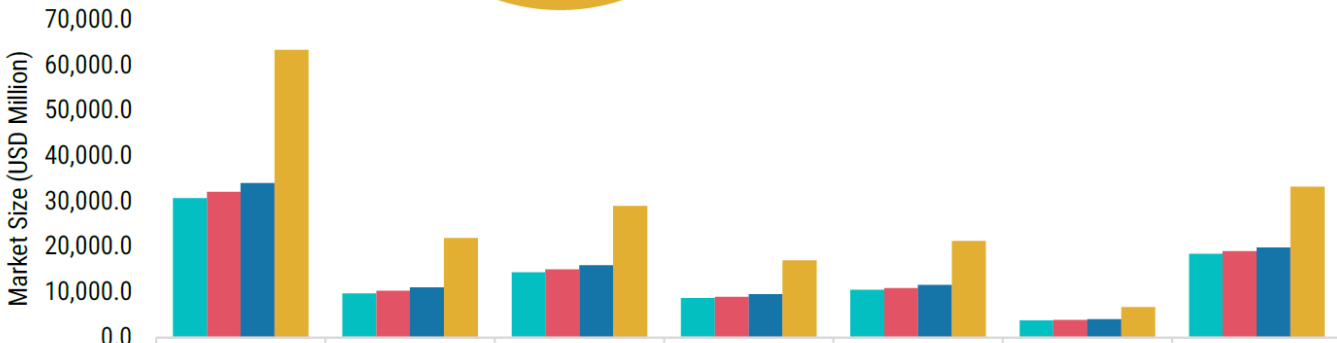
Securing a supply chain for the complete value chain





Where are composites used?



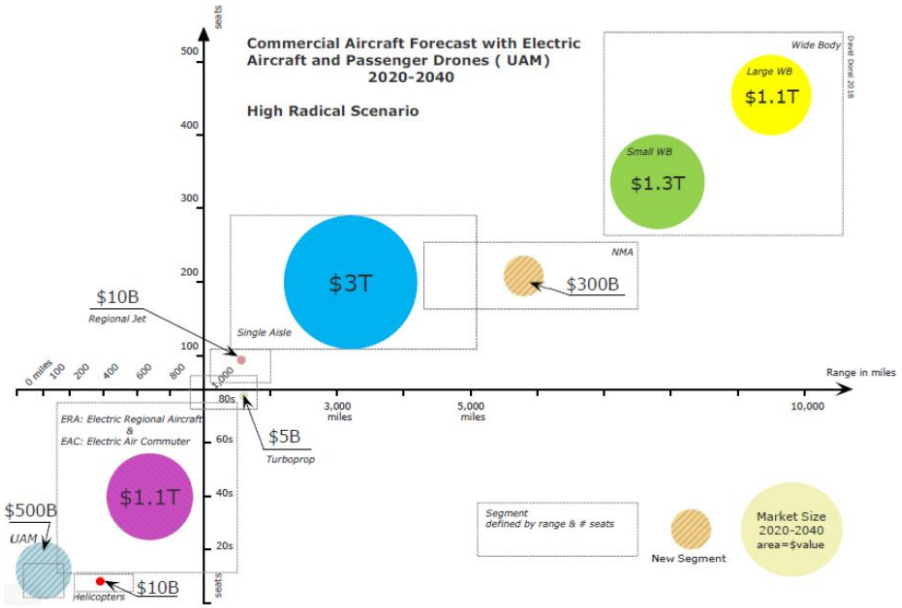


	Aerospace & Defense	Automotive & Transportation	Electrical & Electronics	Building & Construction	Wind Energy	Marine	Others
2019	30,716.81	9,760.68	14,395.12	8,666.84	10,480.36	3,762.02	18,457.17
2020	32,073.50	10,297.05	14,990.51	9,000.39	10,926.58	3,865.40	18,992.98
2021	34,021.19	11,033.24	15,858.28	9,495.05	11,572.53	4,034.00	19,851.97
2028	63,328.13	21,943.89	28,980.37	17,015.57	21,318.64	6,670.29	33,217.30

Global Composite Market Research Report

Aerospace

Aerospace market expected to recover to pre-pandemic levels by 2025
Use of composite materials is linked to development of Zero Emissions flight and growth will be predicated on introduction of new platforms



Aerostructures

- **Lightweight structures** will continue to be important in the transition to sustainable flight
- New **high-volume platforms** will see significant rise in use of composites

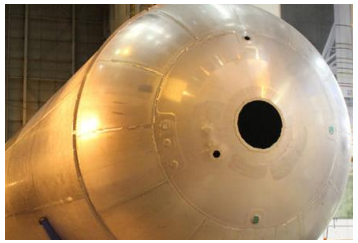
Propulsion

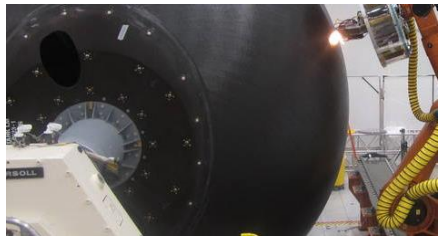
- Composites will play a key role in future **propulsion systems**

Urban Air Mobility

- composites will be fundamental to the design of future **UAM vehicles**

Hydrogen Aircraft - The Future?





Relies on solving critical issues for low weight cryogenic storage

Comparison of climate impact from H_2 propulsion and synfuel

Compared to kerosene-powered aircraft, timeframe until 2100

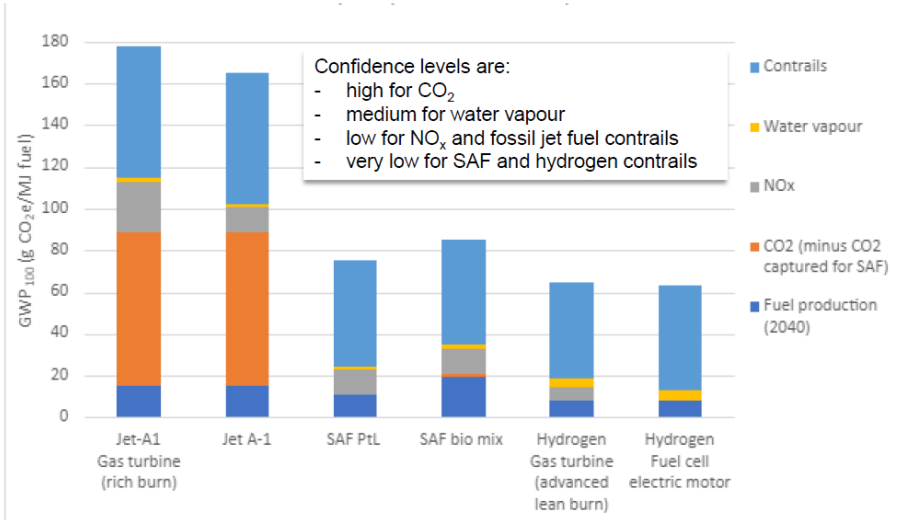
FLY ZERO AEROSPACE TECHNOLOGY INSTITUTE

Source: CleanSky2, 2020. Hydrogen powered aviation

Ongoing scientific debate about **full climate** impact, in particular:
- Contrail/cirrus formation
- Aggregate measure

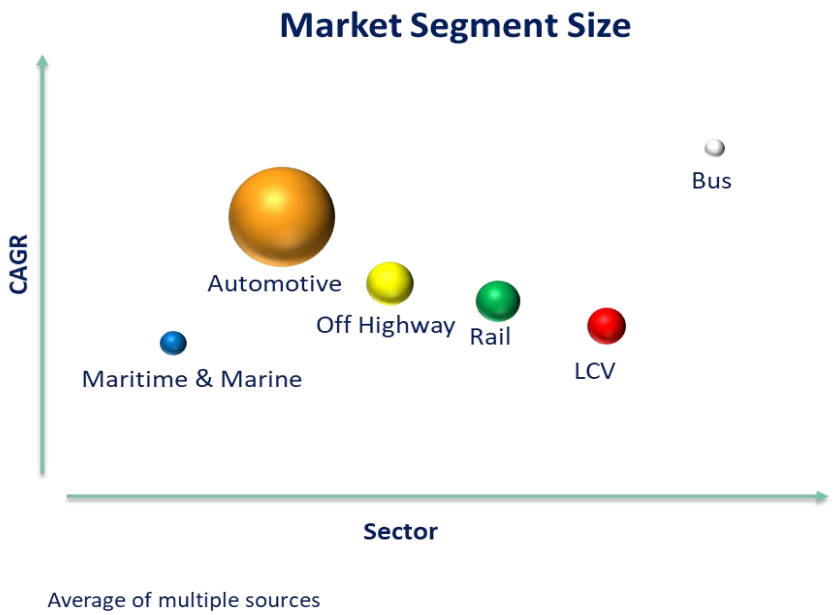
Total climate impact could be 2 to 4 times compared to CO_2 emissions alone

	Change of in-flight emissions and emission related effects[1]				Climate impact reduction potential[4]
	Direct CO_2	NO_x	Water vapor[2]	Contrails, cirrus	
Synfuel	-0% / -100% (Net)[3]	-0%	-0%	-10-40%	-30-60%[3]
Hydrogen turbine	-100%	-50-80%	+150%	-30-50%	-50-75%
Hydrogen fuel cell	-100%	-100%	+150%	-60-80%	-75-90%



Surface Transport

The demand for composites within Surface Transport applications is expected to grow significantly as vehicles transition to zero emission technology



Average of multiple sources

- All surface transport sectors transitioning to electric, or hydrogen powered solutions
- Transition to zero emission propulsion will increase the need for lightweight structures – to drive vehicle efficiency and to offset weight increases from batteries
- Hydrogen will drive significant new demand for composites - 2030 Pressure vessel demand forecasts range from 60k tonnes to 250k pa (current global Carbon Fibre production capacity c.150k tonnes pa)
- Recycling/sustainable solutions will be a pre-requisite
- Materials for fire propagation in Marine and Light Commercial Rail is key to unlock market opportunity

Hydrogen Tanks

?

2020

- 87kg tanks for 5kg hydrogen ≈5wt%
- 85°C max temperature
- ≈30kg Carbon fibre
- Routine inspection
- Unknown end of life

2030

- Reduced carbon content/cost
- Increased operating temperature
- Performance monitoring
- Solutions for end of life

UK's first recycled hydrogen tank

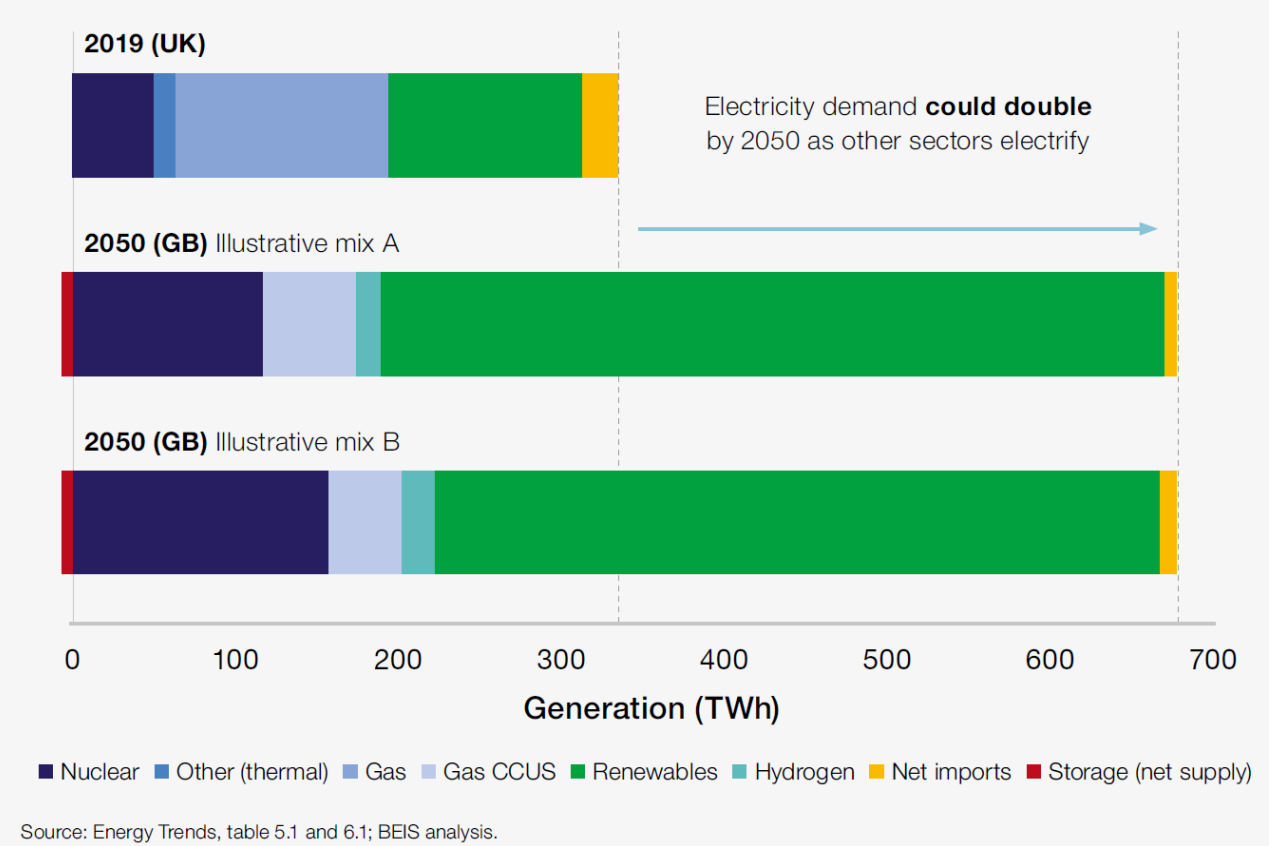
With partners B&M Longworth and Cygnet Texkimp, the NCC successfully reclaimed continuous carbon fibres from an existing whole pressure vessel and re-used them to manufacture a new pressure vessel.

Energy

The major shift in the Energy landscape provides further opportunities for Composites

- Wind – significant growth in size and volume
- Oil and gas - rebranding to sustainable technologies
- Nuclear - developments in both Fission and Fusion technology
- Hydrogen – new opportunity

UK Electricity Mix (BEIS Energy White Paper)



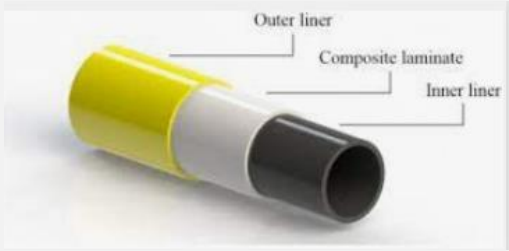
Source: Energy Trends, table 5.1 and 6.1; BEIS analysis.

Hydrogen Distribution & CCUS

Market opportunity

- Strong market interest in H2 export from offshore generation 100+km of 8” pipeline per 800MW H_2 generation.
- Onshore pipe network connecting ‘backbone’ with industrial hubs. 25+km of per hub
- H2 generation offshore is expected to offer cost benefits compared to onshore
- Composite pipes offer lower cost deployment and maintenance than metallic’s.

Technical opportunity



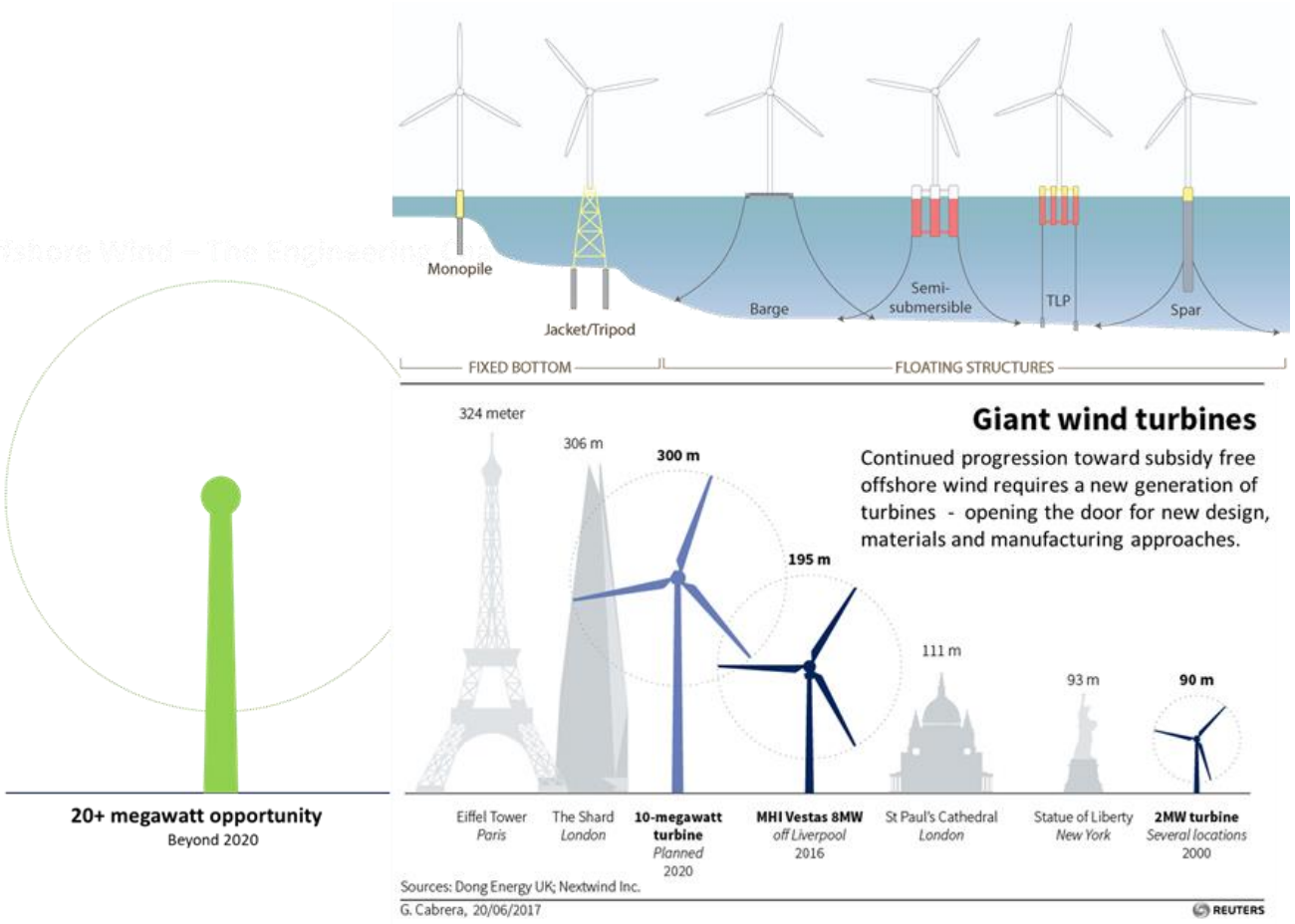
2022

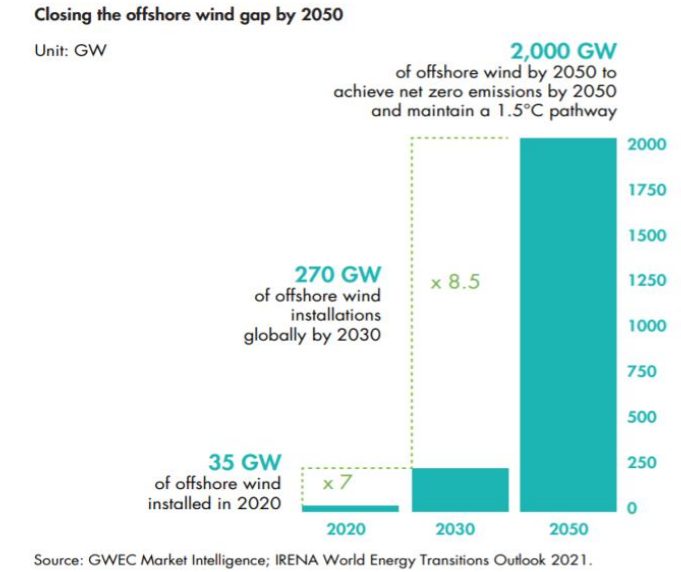
- Uncertain suitability of existing metallic pipe infrastructure for H2
- Limited application of composite pipes in off-shore applications due to costly certification process and deployment limitations

2026

- Accessible and cost-competitive certification of composite offshore pipes to export energy as H_2
- Unlocking new pipes application through health monitoring
- Minimising TOTEX through deployment of asset management (in-service lifeing)

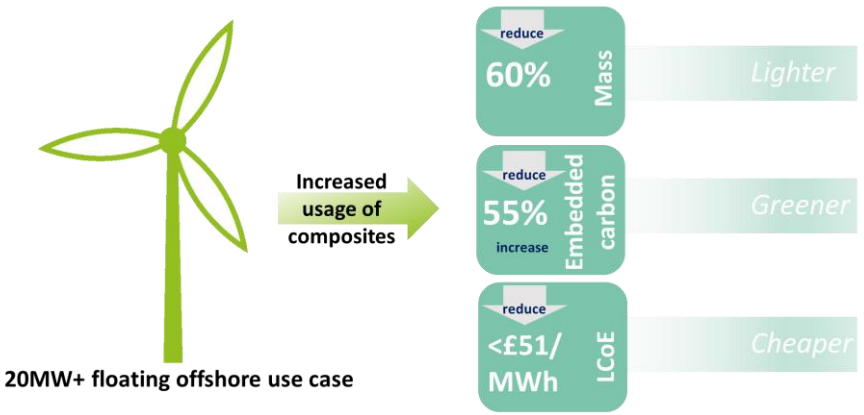
Offshore wind of the Future





Joule Challenge:

Securing UK design and manufacturing for the next generation offshore wind



Construction & Infrastructure

Global Construction 2030 – forecasts the volume of construction output will grow by 85% to $15.5 trillion worldwide by 2030.

The construction industry accounts for 39 per cent of the world's greenhouse gas emissions - 28% from energy consumption and 11% from construction materials (20 billion tonnes of concrete per year)

Lower Emissions

New Build - Lower Costs & Faster Delivery

Lower Costs - Existing Assets

- Thermal bridging - buildings
- Upgrading with lightweight materials
- Low carbon solutions
- Upcycling waste stream materials
- Reduced operational carbon
- Reduced weight components & sub-assemblies
- Offsite assembly mfg
- Multi-functionality
- Reduced maintenance
- Corrosion / durability
- Life extension / Risk Reduction
- Corroded structures
- Repurposing (offices to flats)
- Existing asset integrity – sensors and SHM

TRANSPORT INFRASTRUCTURE | UTILITIES INFRASTRUCTURE | OTHER INFRASTRUCTURE | MINOR BUILDINGS | MAJOR BUILDINGS

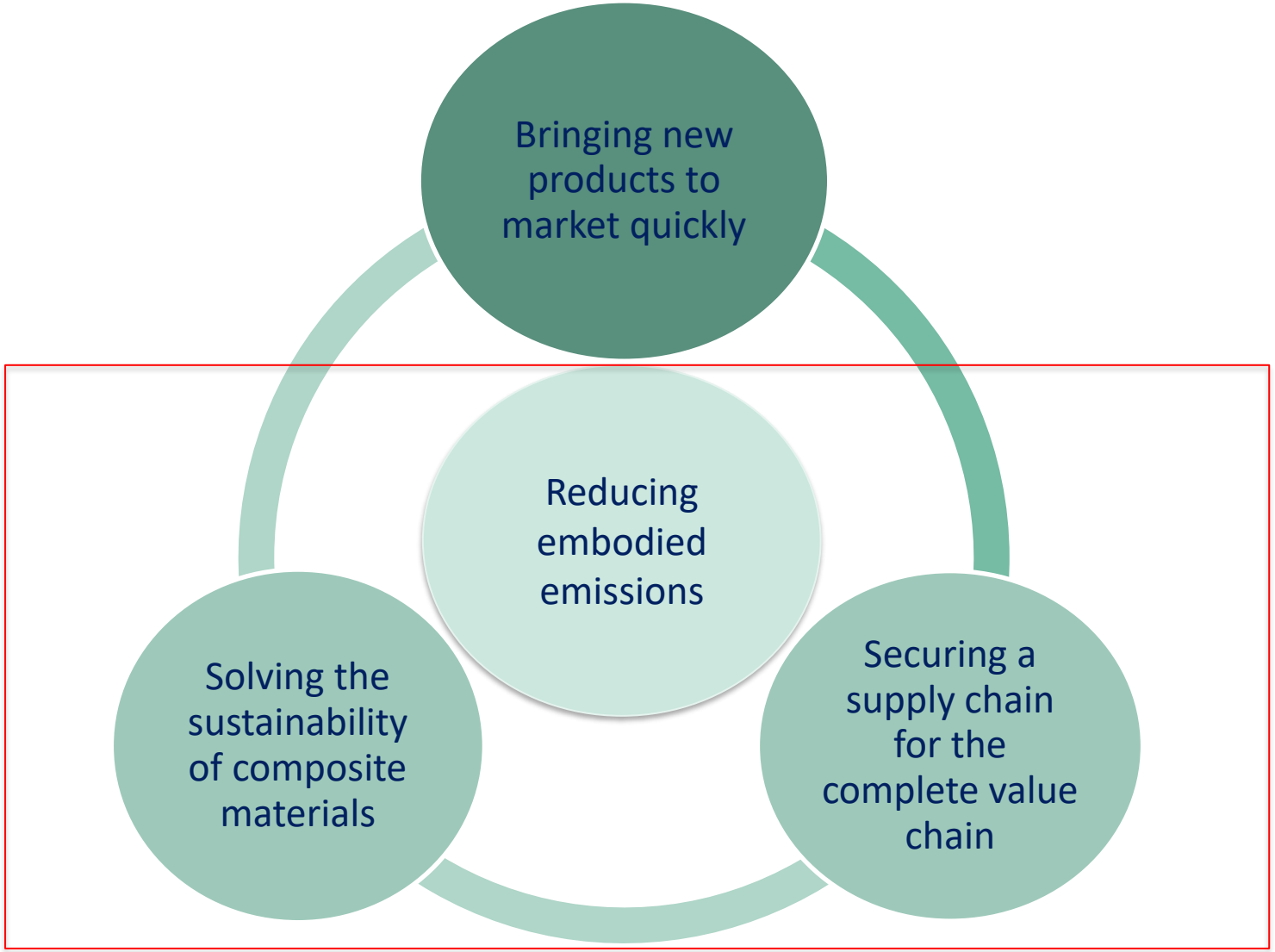
Low Carbon Buildings & Infrastructure

Seismic II - platform-based construction demonstrator building. Designed in line with the government's Construction 2025 targets, it exceeds them in every way, delivering a building that is 75% faster to complete, **70% lower in carbon impact** and 47% better value than traditional construction.

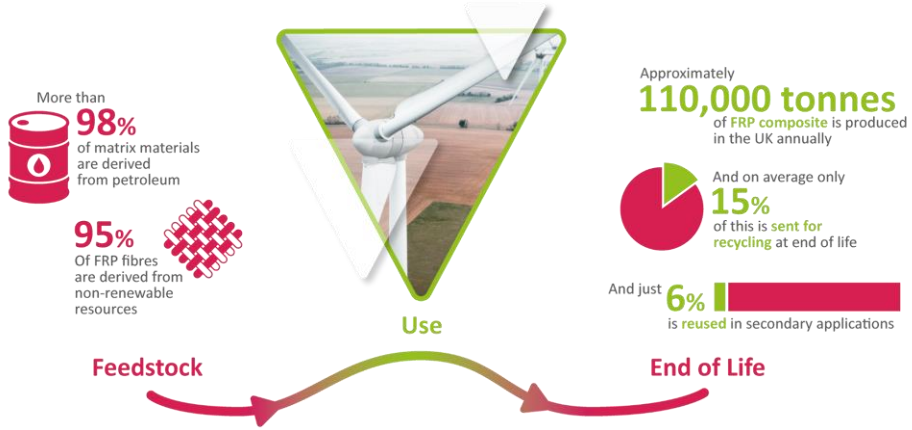
Futura Bridge - The NCC has partnered with Network Rail to investigate, design and build a composite footbridge. The project will specifically target key metrics of reduced cost and reduced greenhouse gas emission in line with Construction 2025.

Low Carbon Concrete - National Highways M42 Junction 6 improvement scheme comparing traditional steel reinforced concrete with a low carbon concrete reinforced with basalt fibre. Basalt is 4-5x lighter than steel, 62 per cent less CO2 that does not corrode.

… focussing on the other 3 challenges



Solving the sustainability of composite materials



Automotive:
- Average Lifespan of a car in UK → 14.2 years
- End-of-Life Vehicles (EU 2017) → ~5.3million vehicles
- Composites used in Automotive (Mainly GFRP 2020) → 14,000 tonnes
- EoL vehicles → Shredded & Polymers are forwarded to Energy recovery

Electronics:
- Electronics Waste (Global 2014) → ~41.8M tonnes
- Printed Circuit Board Waste (~3% of Global total) → ~1.25M tonnes

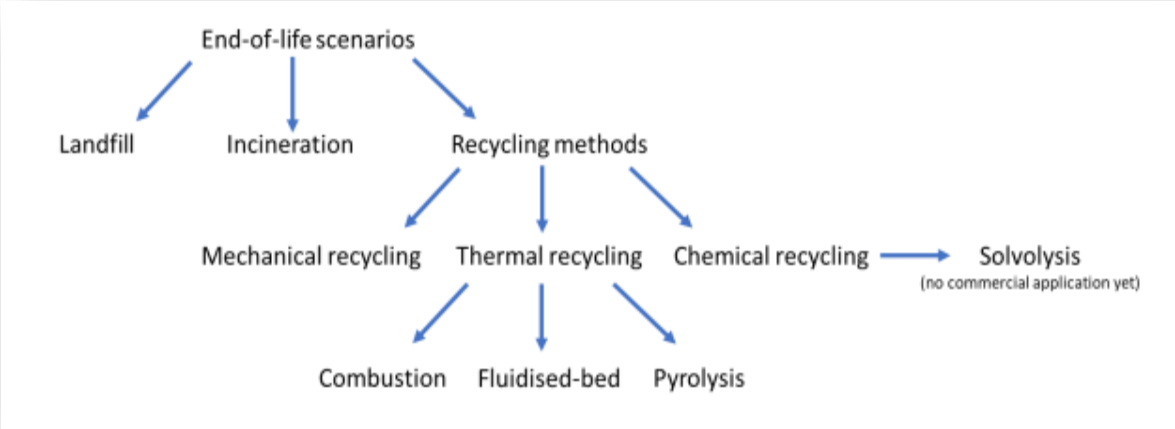
Aerospace – Modern Aircraft:
- Lifespan → 25 years
- Proportion of Composite Materials → up to 53%
- Estimated CFRP Waste (Global by 2050) → up to 500,000 tonnes

Renewable Energy - Wind Turbines:
- Lifespan → 16 - 25 years
- Estimated Waste (Global by 2050) → ~43M tonnes
- Estimated CFRP Waste (Europe by 2050) → ~179,000 tonnes

The challenge common to all sectors is the need for sustainable composites

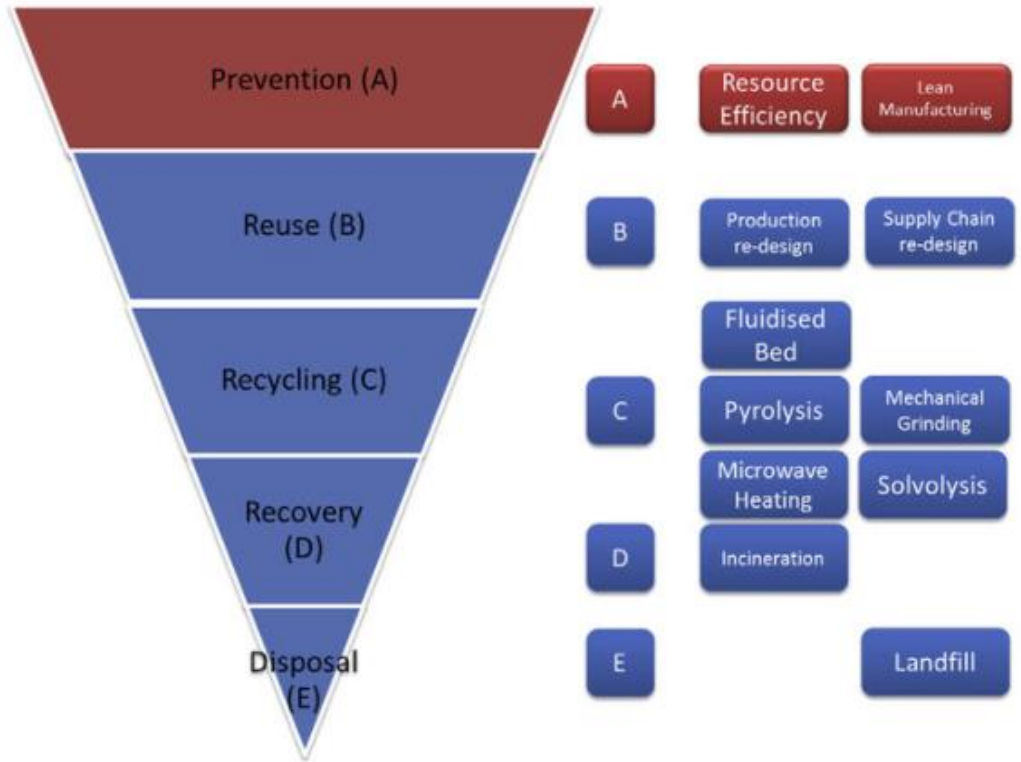
End of Life Options for Composites

EoL Composites Scenarios for CFRP & GFRP:



- Mechanical Techniques
  - Milling / grinding / shredding / chopping
- Thermal Techniques
  - Pyrolysis
  - Fluidised Bed
  - Microwave pyrolysis
- Chemical Techniques
  - Solvolysis
- Novel Techniques
  - Steam Explosion
  - High Voltage Fragmentation

Composites waste management strategies allocated on the Waste Management Hierarchy.

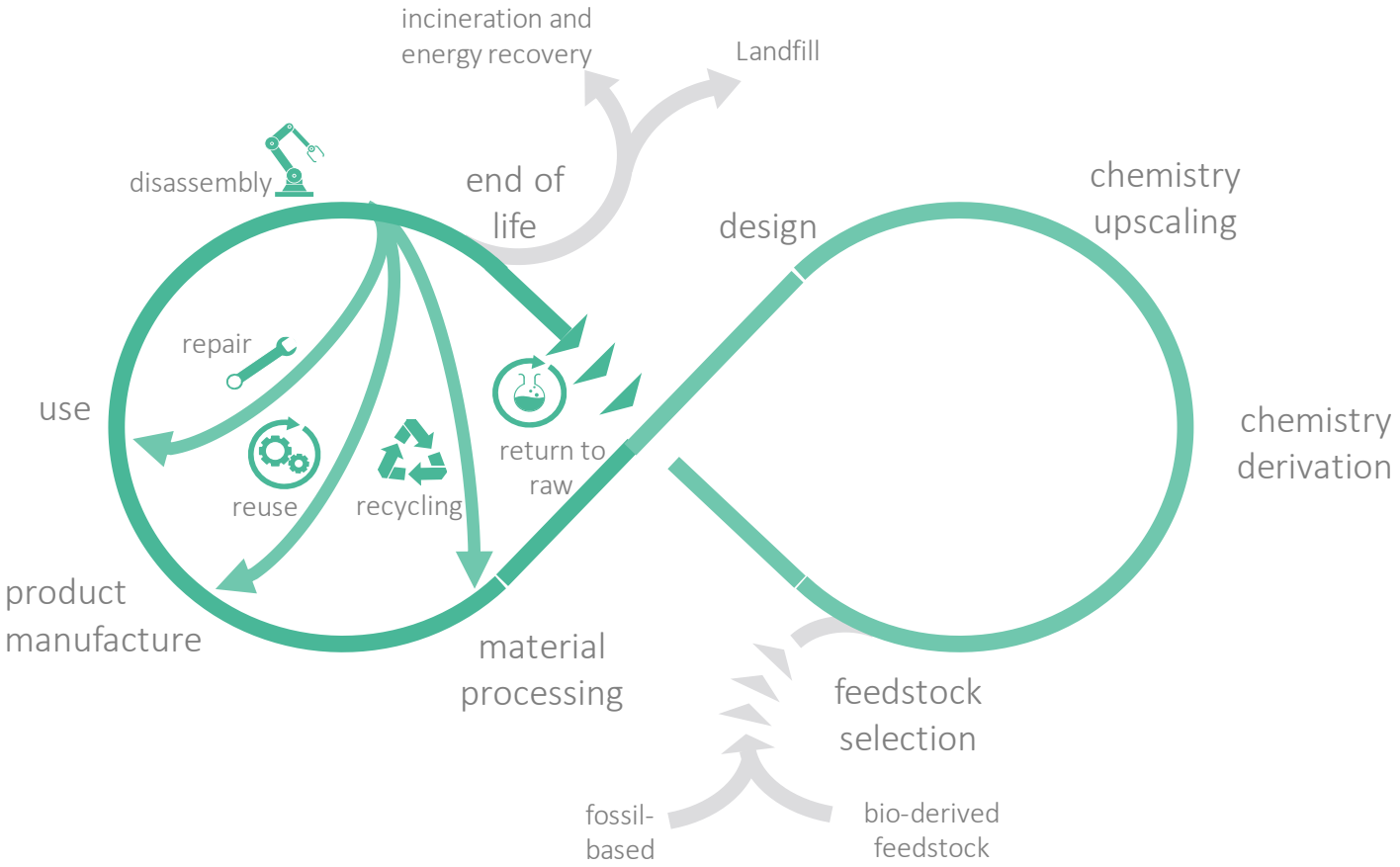


Waste Framework Directive: "Preventing waste is the preferred option and sending waste to landfill should be the last resort."

Krauklis, A.E.; Karl, C.W.; Gagani, A.I.; Jørgensen, J.K. Composite Material Recycling Technology—State-of-the-Art and Sustainable Development for the 2020s. J. Compos. Sci. 2021, 5, 28. https://doi.org/10.3390/jcs5010028

Technology readiness level assessment of composites recycling technologies DOI: 10.1016/j.jclepro.2015.08.104 January 2016 Journal of Cleaner Production 112(1):1001 Justyna Rybicka, Ashutosh Tiwari, Gary A. Leeke

Sustainable Composites

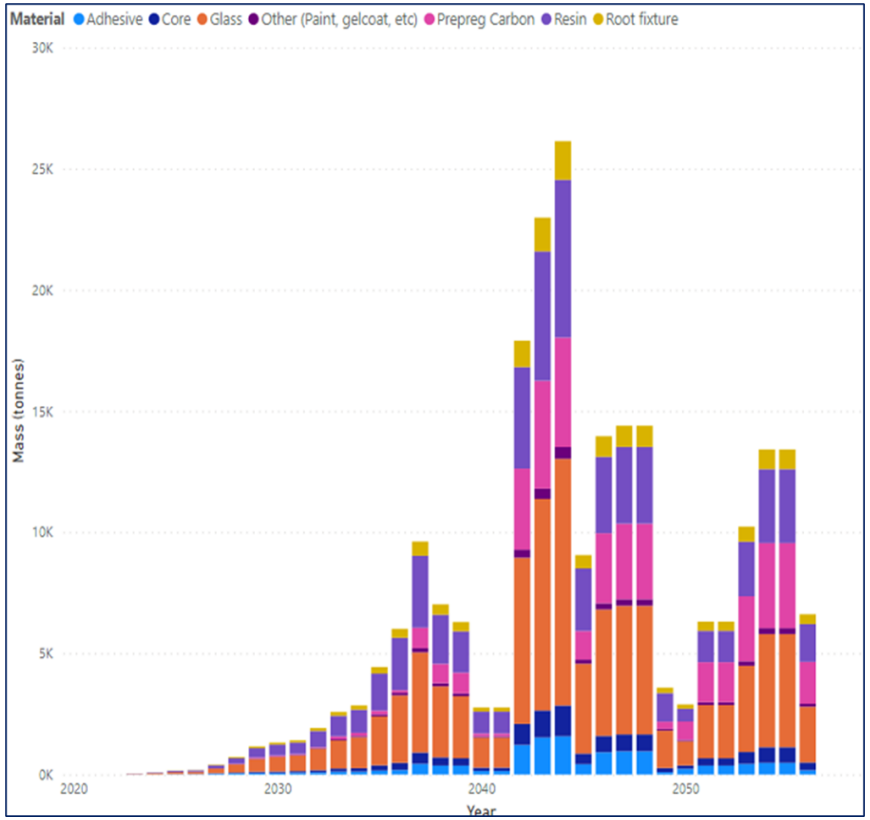


Sustainable Composites

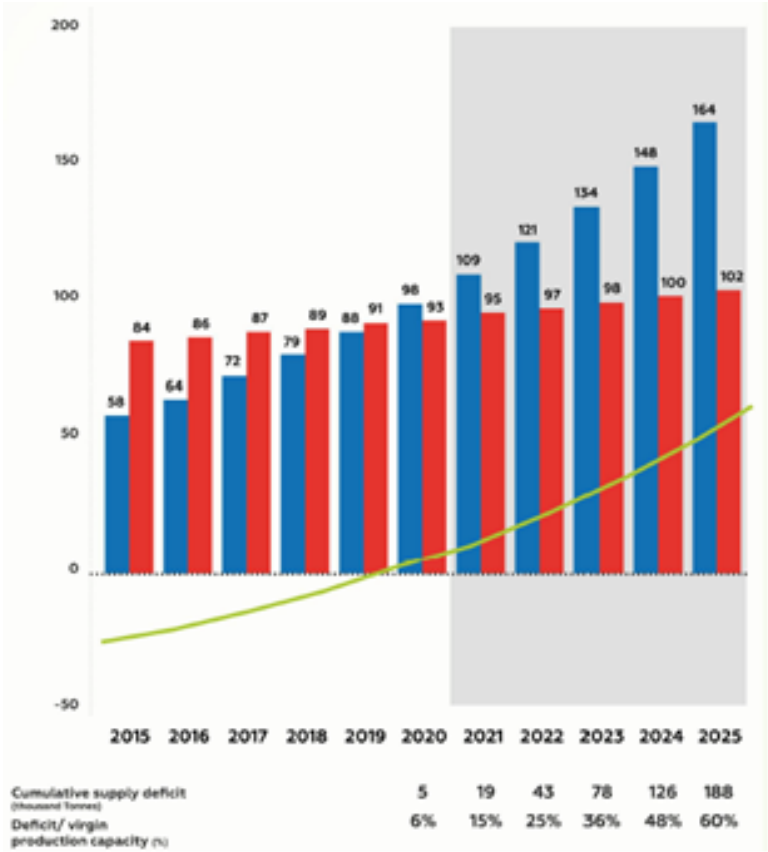
A PARTNERSHIP BETWEEN THE NCC AND CPI

Wind Energy Example

Forecasted growth of UK wind turbine waste 2020-2060 - SusWind

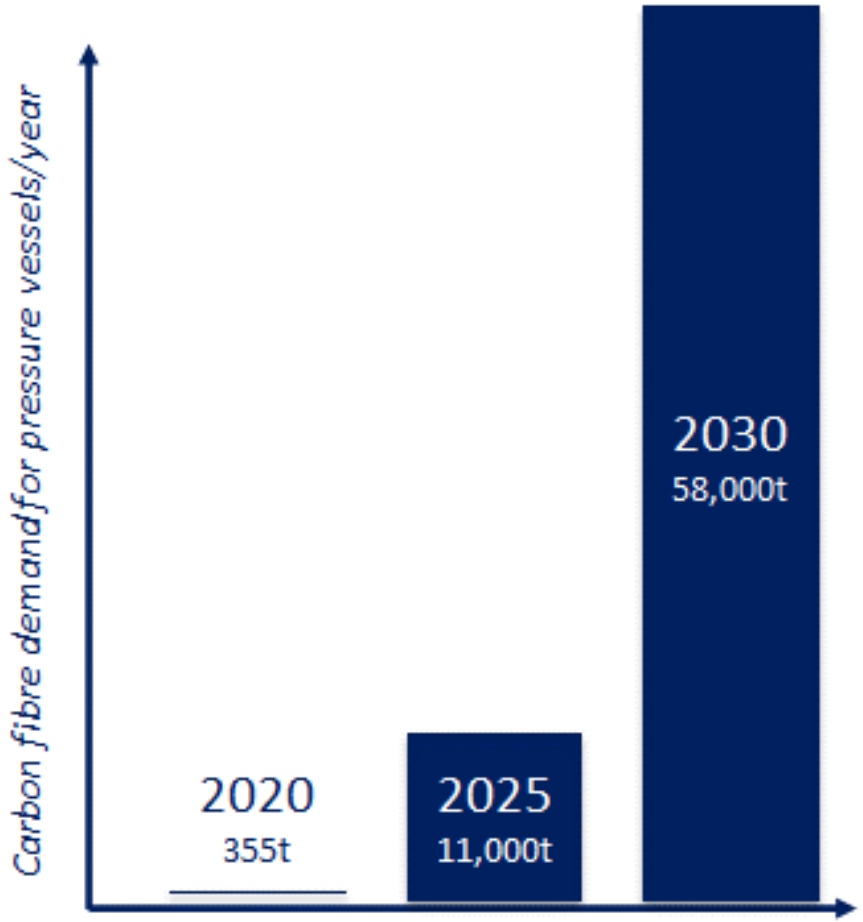


Securing supply chains – CF demand out stripping supply



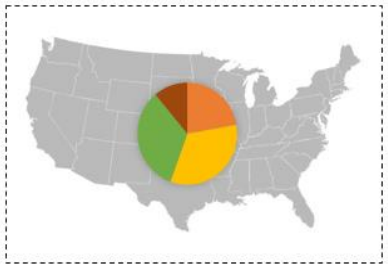
JEC forecasts a shortage of CF of between 15%- 60% within 5 years

New product supply chains – hydrogen storage example

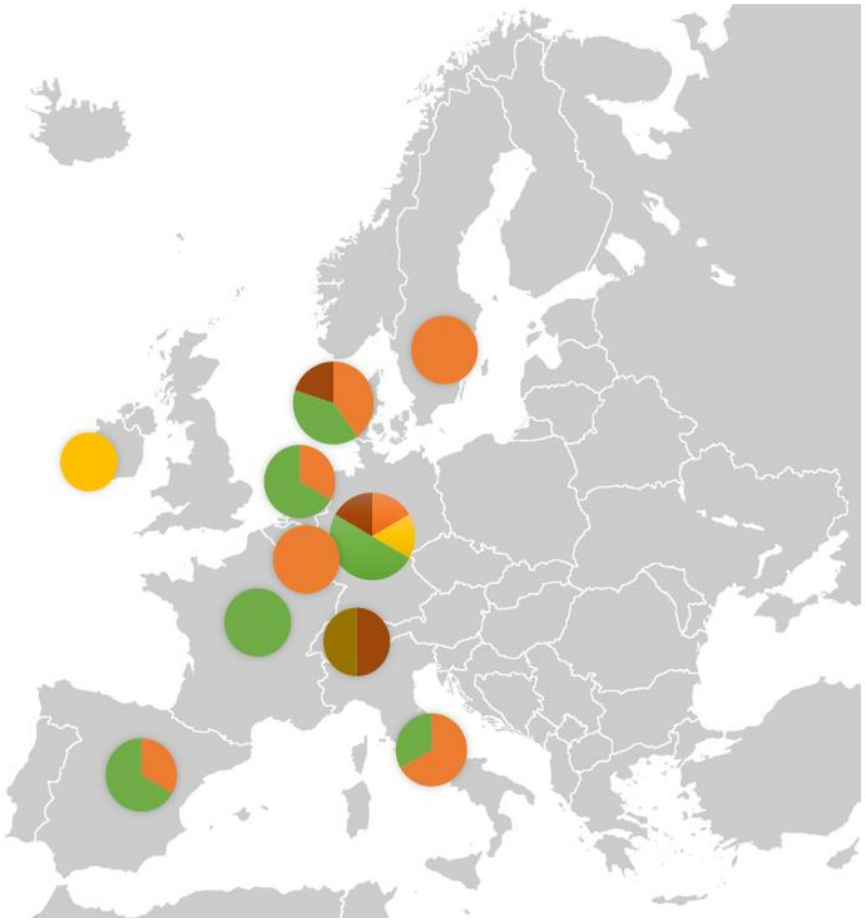


Establishing a recycling supply chain

USA



South Korea



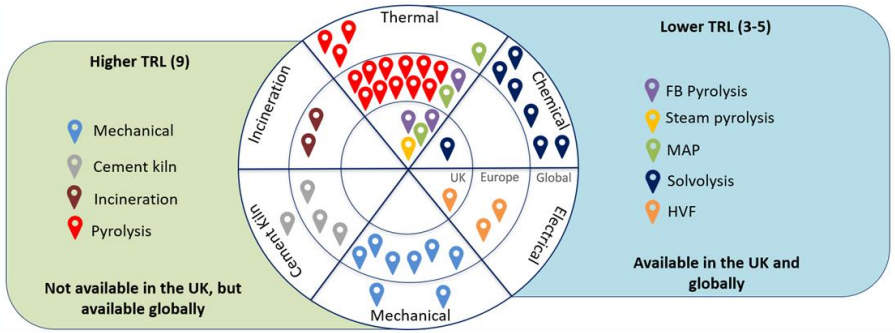
Technology maturity

Large TRL gap in available technologies

TRL 9	Cement kiln, Pyrolysis, Incineration, Mechanical
TRL 8	
TRL 7	
TRL 6	
TRL 5	Steam pyrolysis
TRL 4	Solvolysis
TRL 3	High voltage fragmentation, Fluidised bed pyrolysis, MAP
TRL 2	
TRL 1	

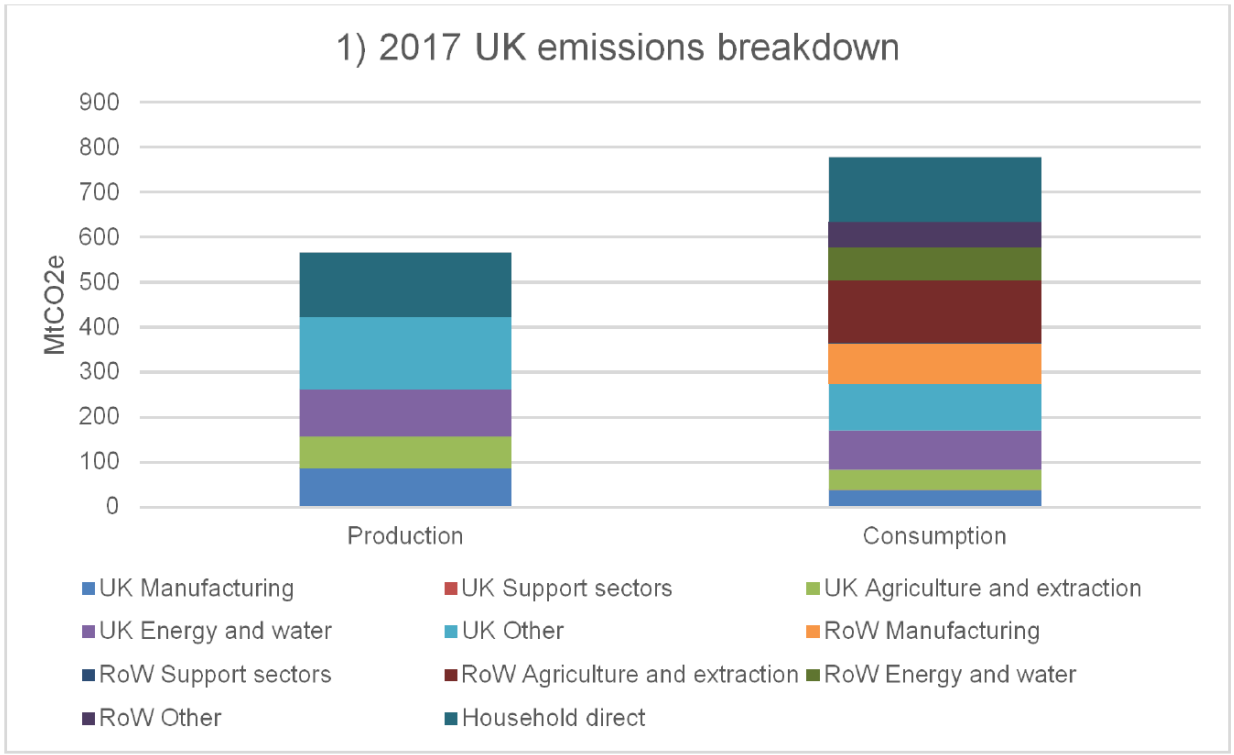
Geographical location

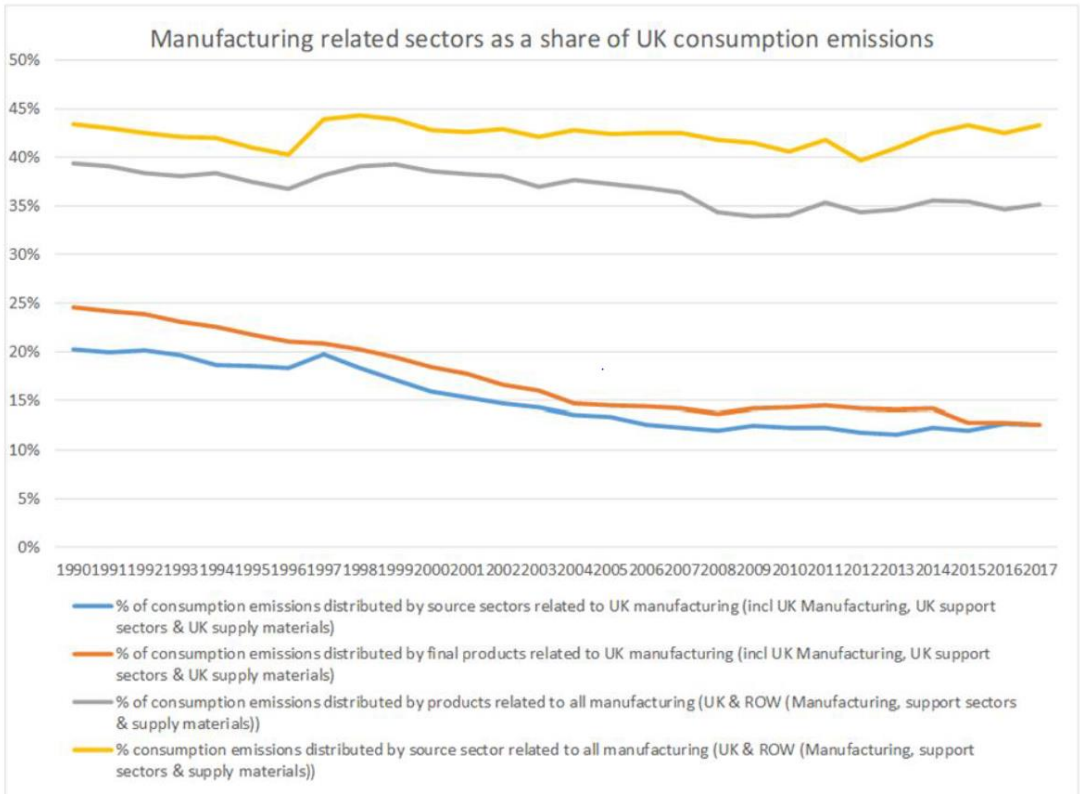
Commercially available (TRL 9) technologies are not currently available in the UK



UK based technologies are at lower, more developmental stages (TRL 3-5)

Addressing Emissions



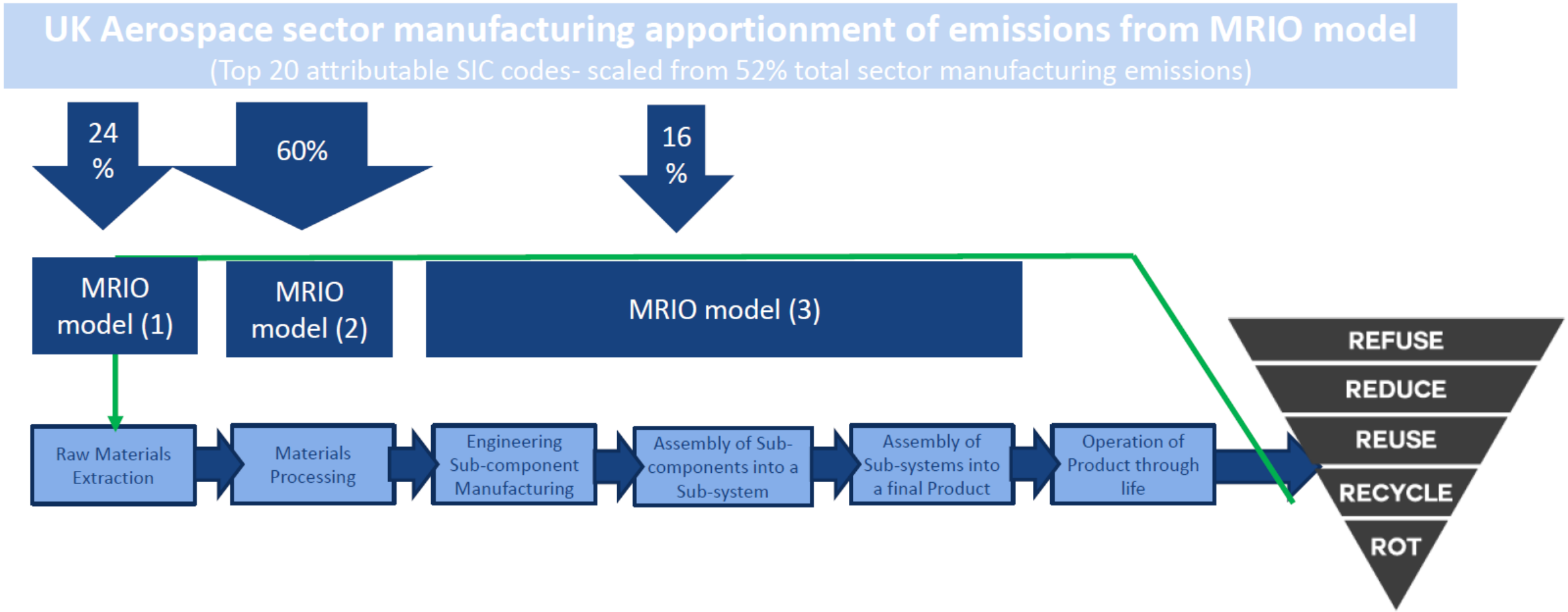


UK consumes more emissions than it produces

UK manufacturing emissions declined over past 30 years due to offshoring

89% of the emissions associated with UK's demand for manufactured product occur outside UK

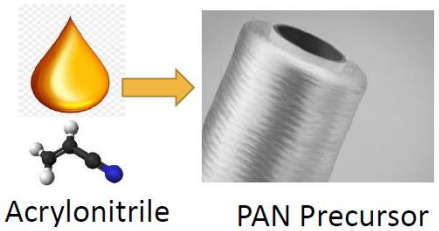
Consider full supply chain – Aerospace example



>80% of aerospace manufacturing emissions in raw material & materials processing

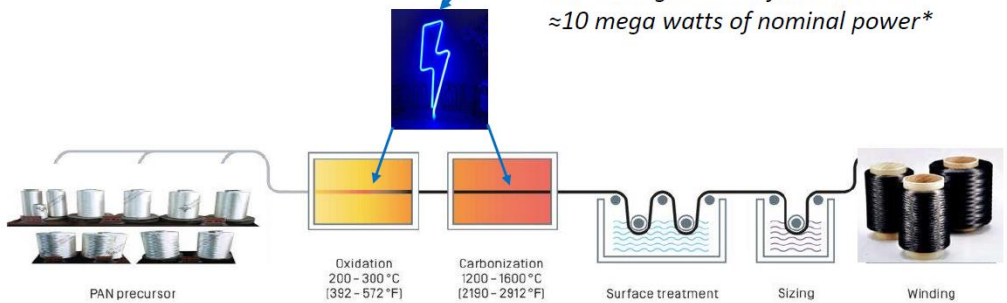
Carbon Fibre's greatest challenge

The primary raw material is an oil derivative



The production process requires large amounts of electricity

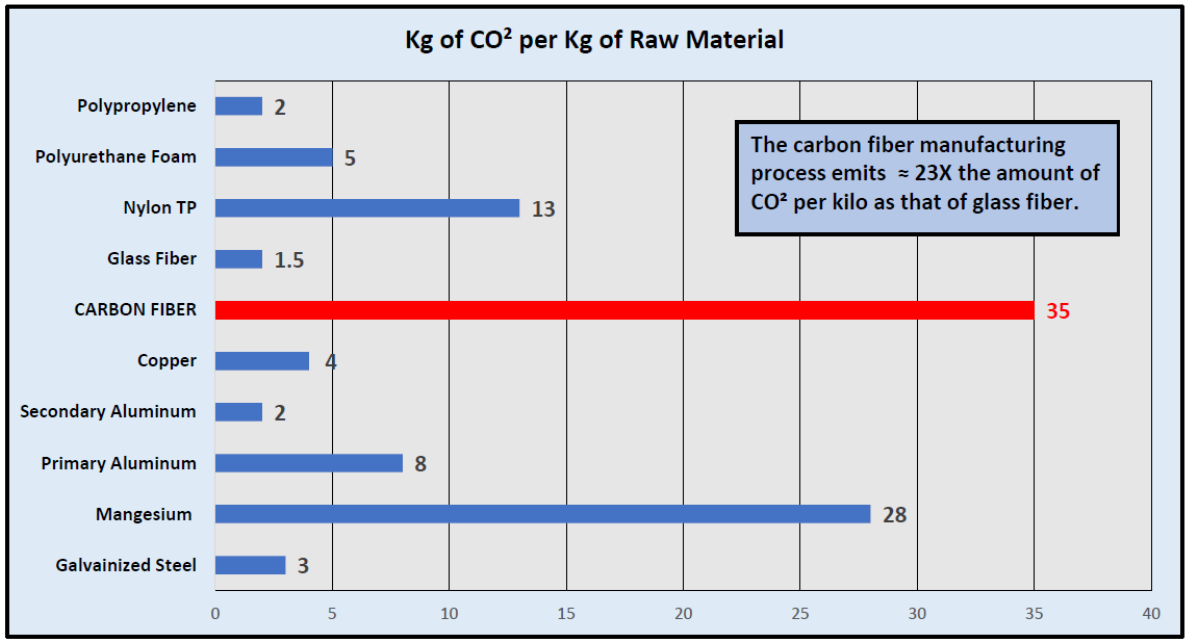
*The average carbon fiber line uses ≈10 mega watts of nominal power**



Carbon Fiber Manufacturing Process

*Source: Oxidation & carbonization equipment suppliers for a 1500 mt line

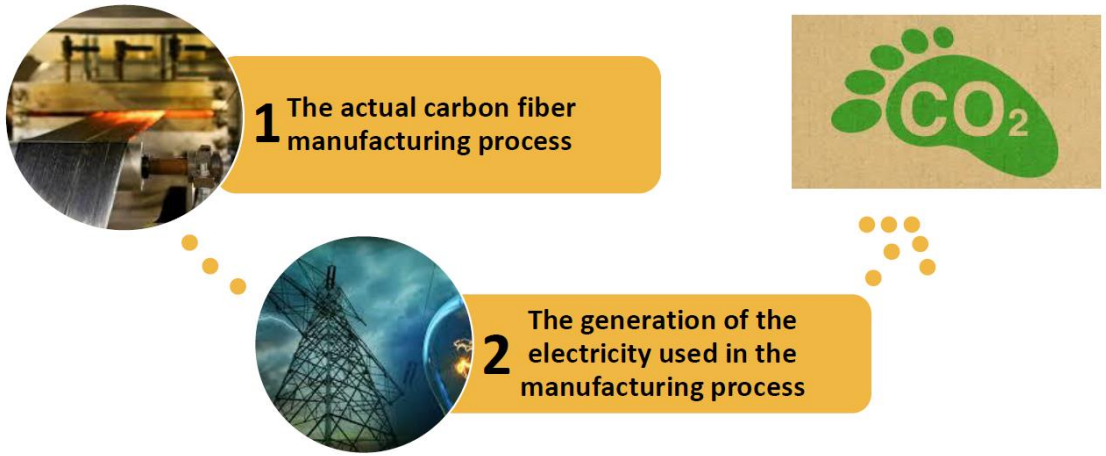
Direct CO^2 emissions generated by the production of one kilo of raw material



Source: BMW AG, 2019 - Toolbox Sustainability – Greenhouse potential in Kilograms of CO^2 per kilo of raw material

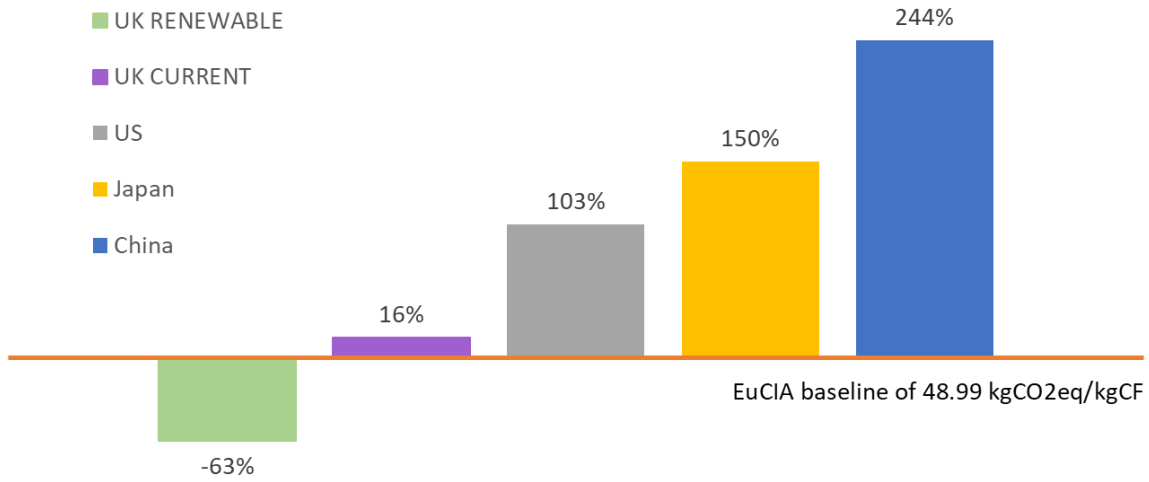
Potential of ‘Green-shoring’ Carbon Fibre

2 primary sources of CO_2 & greenhouse gas emissions from CF production



Potential reduction in CO_2 per kg of CF produced

(vs the European average energy mix – orange line)



*Source: The European Composites Industry Association (EuCIA) dataset for carbon fibre production, 2019

- ‘Green shoring’ opportunities to reduce the environmental impact of CF production
  - Use of high % renewable energy
  - New ‘lower energy’ manufacturing processes (oxidation) e.g LeMond
  - Local production to limit transportation emissions

  - ……coupled with a local recycling/reuse supply chain

Summary

- Future market opportunity for composites is very strong
- Significant role to play delivering net zero
- But…..it relies on solving the 4 major challenges