COMPOSITES AUSTRALIA INC.

# SCOPING STUDY
# THE AUSTRALIAN CARBON FIBRE COMPOSITES SECTOR

Composites Australia

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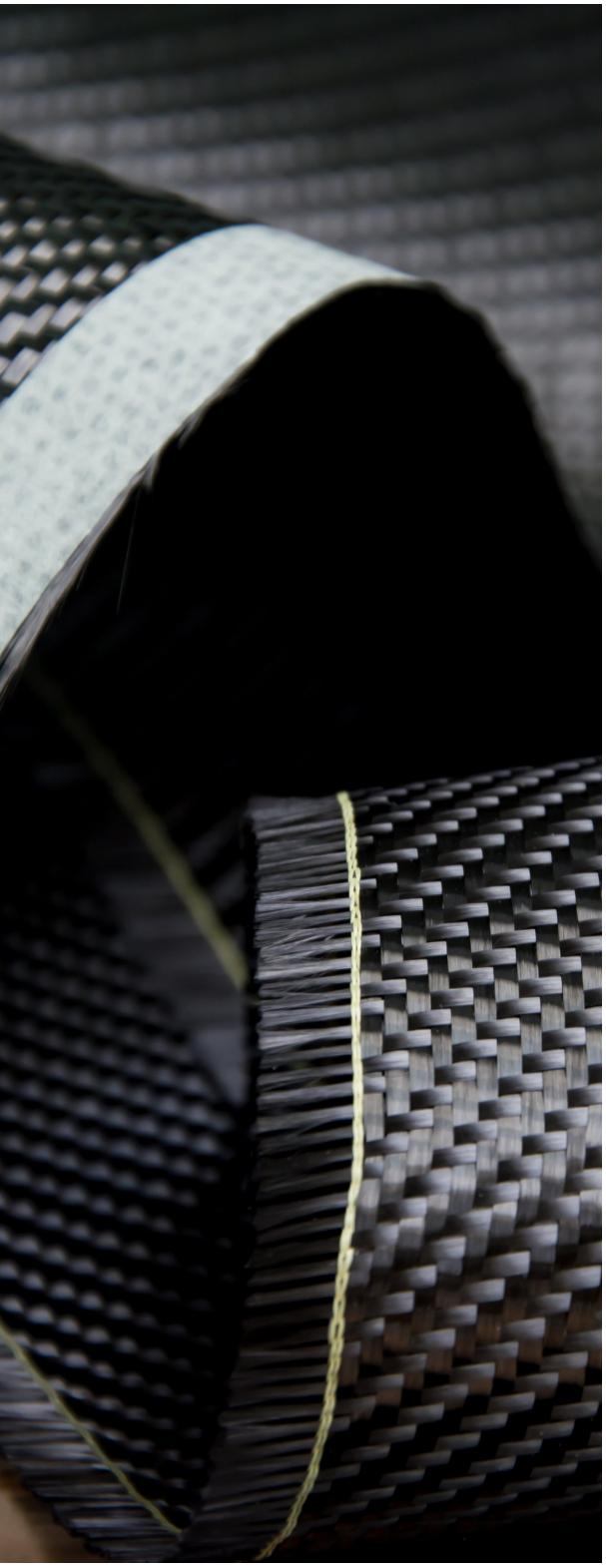




Front cover image: Spanda, Elizabeth Quay Perth. Designed by Christian de Vietri, made by ShapeShift Design Technologies using carbon fibre

# ABOUT THIS REPORT

Image: Partington CC - credited to Ron Nott

As a raw material for manufacturing, the properties of carbon fibre enable impressive performance and aesthetic results for a plethora of end use applications, many of which are yet to be identified.

As an imported raw material with no definitive tariff code to track volumes, measuring the sector is limited to researching the sector and interviewing the hundreds of companies that operate within the Australian composites industry. To that end, we used the lockdown time caused by the COVID-19 restrictions to interview selected stakeholders, marshal previous research and industry studies that have gone before this one and studied over 600 websites - all to map the capabilities of Australian companies, enterprises and institutions and their specific capabilities with carbon fibre composites.

For the purpose of commercial discretion, prices and usage volumes of carbon fibre as well as employment numbers are suppressed in this public document.

Our experience is that industry personnel are overwhelmingly open and accommodating in sharing their knowledge, professional experience and perspectives on future industry directions.

Kerryn J Caulfield

**KERRYN CAULFIELD**
CEO

## FINDINGS

*a: Our research identified 111 enterprises that have an interest in carbon fibre across six states and the ACT. This includes companies that "make things", companies that supply raw materials, and sometimes machinery, into the carbon fibre manufacturing economy as well as agencies that supply engineering, industrial design, research, development and innovation services.*

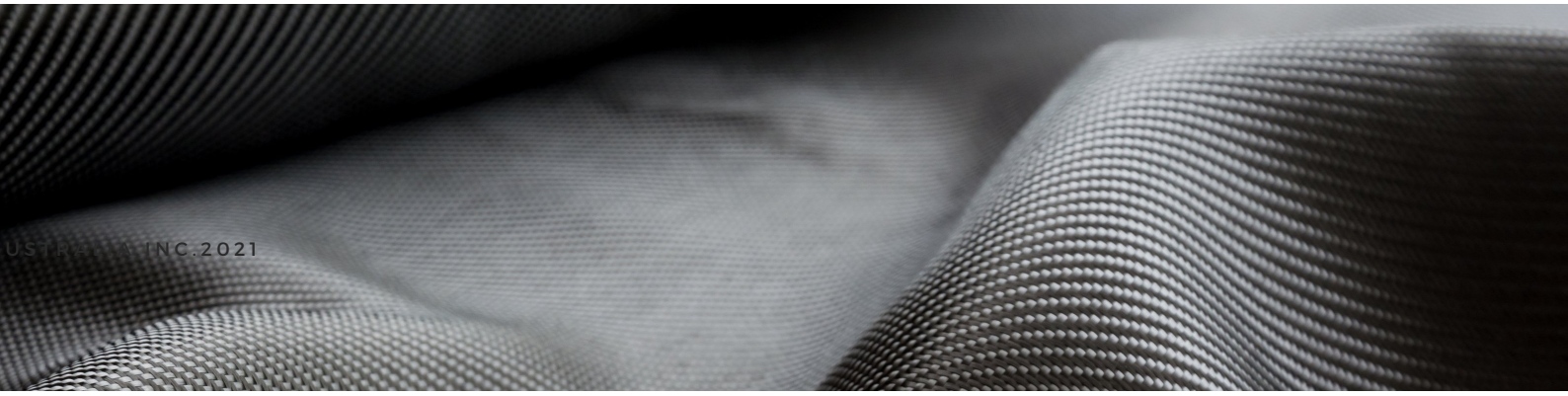
*b: State and Federal investment in carbon fibre R&D through Universities, and carbon fibre capability development by way of grants directly to companies has largely been successful in priming the development of a state-of-the-art industrial sector.*

*c: Investment in manufacturing carbon fibre inputs such as roll-goods will fortify the sector against trade disruptions.*

*d: There are perceived opportunities to grow the carbon fibre composite sector through industrial sovereign capability in the Defence sector.*

*e: New mining ventures, such as lithium and rare earths are also likely to provide opportunities to grow the carbon fibre composites sector. So too in hydrogen energy and exotic materials linked to the growing aerospace industry.*

*f: Investment is required to develop learning materials to boost the trade skills shortage.*




## 1: CARBON FIBRE - THE MATERIAL

Carbon fibre reinforced composites (CFRP) are about ten times stronger and five times lighter than steel and also eight times stronger, while two times lighter than aluminium. Carbon fibre is heralded as defining the “new industrial landscape” especially in key markets such as aerospace, automotive, wind energy, marine, oil and gas, infrastructure and transport and various industrial applications.

The need to reduce fuel use, invest in alternative sources of energy and develop materials that have a lower environmental impact will hasten carbon fibre research and increase use in broader industrial sectors. The technology is particularly suited for highly corrosive environments in the mining, defence and the oil and gas industries.

Carbon fibre can be 10 times more costly than glass fibre which is the traditional workhorse of the composites sector.

Value adding by way of further manufacturing carbon fibre tow or roll-goods (see section 5.6..1) using state-of-the-art technology into componentry therefore has a much higher net economic output which is ultimately beneficial for Australia’s economy. This is more so when the components are for export markets.

*"Carbon fibre is used to make a thermoset composite, also known as carbon fibre reinforced polymer or CFRP"*

Composites can be known as FRP (Fibre-Reinforced Polymer) composites which are made from a polymer matrix in the form of a resin that is reinforced with an engineered, man-made or natural fibre or other reinforcing material. Fibreglass, carbon fibre, polypropylene, aramid, boron, basalt and flax fibres can be used as reinforcement.

The matrix protects the fibres from environmental and external damage and transfers the load between the fibres. The fibres, in turn, provide strength and stiffness to reinforce the matrix.

The most common form is a polyester resin matrix combined with a glass fibre reinforcement which is known as GFRP.

The choice of fibre and resins is an engineered process by which materials are specified considering manufacturing processes and available equipment, performance requirements, internal and external conditions and end-use be it marine, aerospace, industrial, defence, automotive, construction or architectural applications.

## 2: CARBON FIBRE IN THE GLOBAL ECONOMY

Between 2009 and the end of 2019, the carbon fibre industry experienced a decade of uninterrupted growth. Global carbon fibre consultant, Daniel Pichler, reported in May 2021 that "... demand for, and supply of, carbon fibre increased by, on average, 11% a year. During this time, the industry more than doubled in size, from producing 40 kt of carbon fibre a year in 2010 to over 100 kt a year in 2019."

While growth was subsequently stymied by the global pandemic and a slump in new commercial aircraft production, other markets such as the sporting goods and marine leisure market; wind energy as well as pressure vessels for the hydrogen economy and construction and infrastructure are ramping up.

According to Daniel, “Carbon fibre is still an industry in its early development phase. Despite the events of this extraordinary year, the future is promising for carbon fibre.” 1

## 3: SOVEREIGN INDUSTRIAL CAPABILITY

As a policy, sovereign industrial capability is a nation’s access to, or control over, the skills, technology, intellectual property, financial resources and infrastructure that are critical to achieving a country's objectives. The term is commonly used for defence priorities, although in recent times, closed borders as a result of the global pandemic have caused governments to reassess sovereign industrial capability associated with national health priorities.

Given the unique technical advantages of advanced materials and the role that carbon fibre composites play in defence related components and products, countries around the world are investing in carbon fibre research and development and products. For example, in 2019 the South Korean conglomerate Hyosung announced that it will spend 1 trillion won ($825 million) to boost its carbon fibre production capacity from 2,000 to 24,000 tonnes by 2028. The move is said to reduce the country's dependence on external suppliers, notably Japan. See case study at Appendix 3.

For Australia, the Government’s commitment to the safety of the Australian people and to the defence of our territory and national interests were outlined in the Defence Whitepaper in 2016. Subsequent documents have identified carbon fibre as a capability critical to defence. See footnote.

1: https://www.innovationintextiles.com/carbon-fibre-after-covid19/
2: Advanced Materials & Manufacturing - Insights Paper (November 2017), Defence Science & Technology Group: www.dst.defence.gov.au
3: Sovereign Industrial Capability Priority Plan - Dec 2019:
https://www.defence.gov.au/SPI/Industry/CapabilityPlan/Docs/Combat%20Clothing%20Industry%20Plan.pdf

## 4: MEASURING THE SECTOR

Defining the Australian carbon fibre composites sector according to existing statistical definition can be challenging as there is not a distinct civil subsector in the Australian standard industrial classifications. Furthermore, unlike fibreglass, the tariff codes under which carbon fibre is traded include other materials which obscure volumes. And for defence and aerospace related applications, its use and associated volumes are more than often confidential.

The best measure of the sector comes from raw material usage for which we are reliant on advice from industry.

## 5: AUSTRALIA'S CARBON FIBRE SECTOR

### 5.1: SIZE AND SCOPE

Our research identified **111 enterprises** that have an interest in carbon fibre across six states and the ACT. This includes companies that "make things" (fabricators/manufacturers), companies that supply raw materials, and sometimes machinery, into the carbon fibre making economy as well as agencies (including Universities) that supply engineering, industrial design, research, development and innovation services.

Of the enterprises that have an interest in carbon fibre, **69 are companies that "make things"** (fabricators/manufacturers). A further 12 provide R&D services, eight provide engineering services, seven provide education services and six are suppliers into the carbon fibre composites economy.

Most companies serve more than one market sector. End use markets and applications are spread almost **equally across the sectors of aerospace & defence, transport, industrial, marine as well as repairs** for all four sectors - a further 20 per cent is 'other end-use applications.'

- The majority of companies using carbon fibre to 'make things,' are fabricators/manufacturers that **use multi materials** and for which carbon fibre or hybrid carbon fibre products and components is part of a broader offering. This could include boat builders that use carbon fibre in bespoke applications, through to tank and pipe manufacturers that use carbon fibre as a material solution to meet engineering and/or performance specifications.

- There is a lesser amount of fabricators/manufacturers that use **carbon fibre exclusively** in one or more of its available forms - including tow, woven or non-crimp fabric form - as a composite reinforcement. This group includes large employers such as Carbon Revolution (500+) through to micro companies making unique products such as Unmanned Aerial Systems or archery bows. This group uses the greatest volumes of carbon fibre.

## 5.2.DEFINING THE AUSTRALIAN COMPOSITES SECTOR

The Australian composites industry is uniquely dominated by SMEs and is incomparable to offshore markets. Companies predominantly have entrepreneurial origins which is always a consideration in scoping exercises. The sector has grown out of a material technology and engineering capability, rather than being contained within a more traditional market vertical of very large companies as is the case in Europe and the US.

Companies can supply services and/or manufacture for a breadth of end-use sectors. But there are many that have thrived by being generalists supplying a number of end markets. Some companies can produce a single product such as a boat or a caravan - often under one brand. Others produce components that are commissioned by manufacturers closer to the end-user. The diversity in the manufacturing business models across a vast range of products covering the many end use market segments is a consideration when profiling the market.

Carbon Revolution, carbon fibre wheels

## 5.3: WHAT AUSTRALIANS MAKE

Carbon fibre tow, braid, tape, woven and stitched (multiaxial) fabrics are fabricated/manufactured into an array of components and products including but not limited to the following:

- Architectural components
- Automotive components for defence vehicles, motorsports including V8 supercars, luxury and classic cars
- Concrete reinforcement
- Conductive welding brushes
- Conveyor rollers
- Fashion accessories
- Fabrics - braid, tape, woven and stitched (multiaxial)
- Helicopter repair and components
- Helmets - ballistic and sports
- Industrial products for the mining sector including rock bolts, piping, vent tubes and mine ducts
- Industrial storage tanks and tank linings for mineral and rare earth storage
- Marine components including propellers, oars, cleats, heads, rigs and spas
- Medical equipment components
- Musical instruments and instrument cases
- Pre pregs, core and sandwich materials
- Remotely operated vehicles (subsea ROVs)
- Repairs of infrastructure (bridges), aircraft, ships and submarines
- Small vessels including canoes, racing boats and paddle boards
- Solar technology
- Sporting equipment including croquet mallets and archery bows
- Storage vessels for hydrogen
- Subsea infrastructure
- Surfcraft and surfcraft components such as fins
- Unmanned aerial vehicles UAV's
- Urban art
- Wheels – both automotive, aerospace and bicycle

*News articles on carbon fibre composite manufacturing can be found on the Composites Australia website at: https://www.compositesaustralia.com.au/news/*

## 5.4: PROCESSING CARBON FIBRE COMPOSITES

There are three main processing groups that are employed to make carbon fibre components and parts.

- **Intermediate processing,** which converts the carbon fibre tow into semi-usable product such as textiles and prepregs. Additional mould processing is required to convert textiles and prepregs into a composite.

- **Direct conversion**, which converts carbon fibre tow and also chopped carbon fibre directly into a finished composite. This includes filament winding, radial braiding and pultrusion technologies.

- **Moulding processes,** which is the group of production technologies that convert the carbon fibre and a resin matrix to a final composite. These can include wet hand lay-up, vacuum bagging, resin transfer moulding, compression moulding and autoclave moulding.

See Appendix 1 for model of the composites processing.

## 5.5:AUTOMATION

The conventional method of hand layup of dry or pre-impregnated woven materials is a large part of the carbon fibre composite component fabrication industry.

Hand layup requires the skills and experience of workers to manipulate flat sheets of composite material into shape during layup. This dexterous process is capable of producing high performance and complex parts and is still the standard of aerospace composites fabrication processes; so too for large components such as wind turbine blades and boat hulls. Bespoke applications such as the strengthening of the Westgate Bridge with carbon fibre and the  subsphere for the Deepsea Challenger will require hand layup skills for the foreseeable future.



BMW i3 automated production

## 5.5: AUTOMATION CONT.

While automation of manufacturing processes ensures repeatability, consistency, time savings and quality control, investing in automation is a pragmatic decision between cost and assured volumes in Australia's generally slim markets.

One exception is Geelong-based Carbon Revolution which is investing in tooling and robotics to lift its production from 10,000 carbon fibre wheels a year to half a million in the long term.

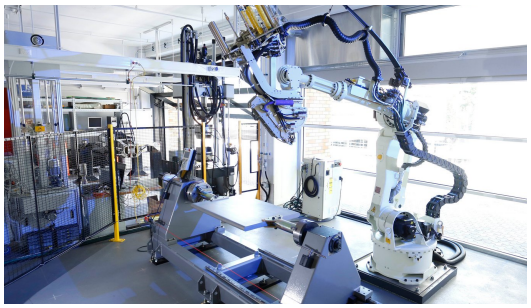
University of NSW is also currently leading a bid for a Cooperative Research Centre for automated composite manufacturing. The centre already features a multi-axis robot and spindle system for maximum control over fibre trajectories and part geometry as well as heads for laying parallel prepreg carbon fibre tows.

The University of Southern Queensland has invested in a radial braider allowing for automated dry fibre placement to produce complex lightweight preforms on an industrial scale.

Composites manufacturers were early adapters and are engaged users of computer-aided processes that enhance quality and productivity, such as CNC machines, Computer Aided Design (CAD), 3D printing and similar enabling technologies.

Carbon Revolution automated manufacturing - Waurn Ponds facility

AIRBUS helicopter hand layup of carbon fibre



Robotics at UNSW

## 5.6: SUPPLY OF CARBON FIBRE INPUTS

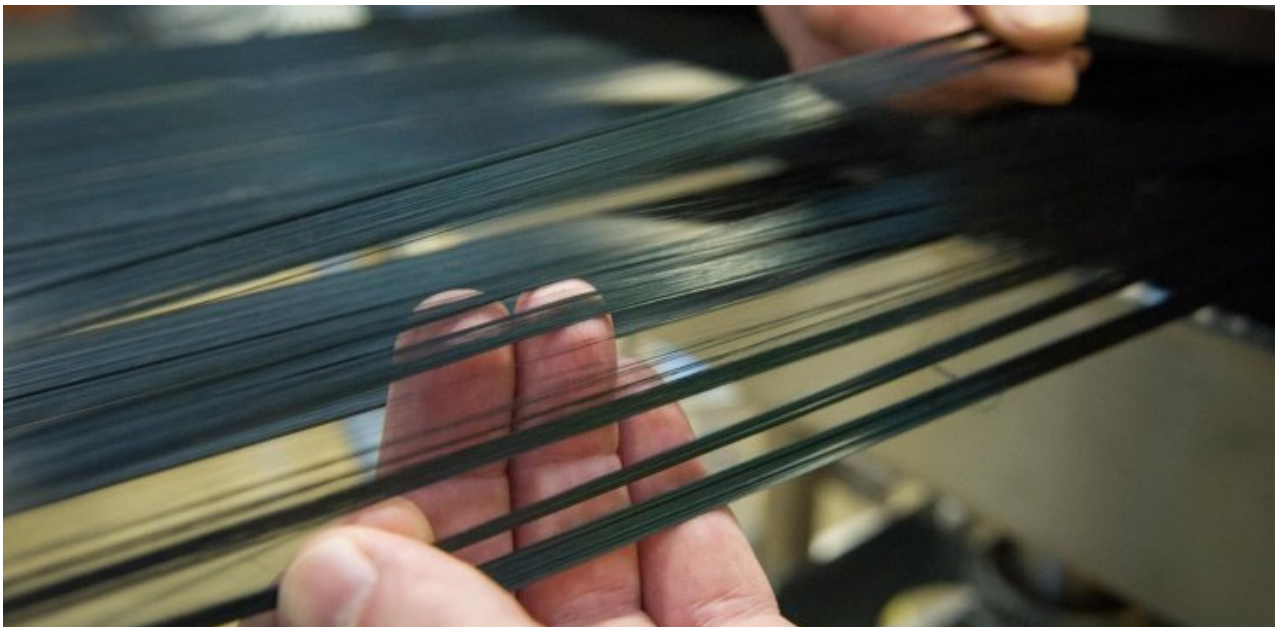
For **carbon fibre,** Australian fabricators/manufacturers are largely reliant on imported raw material mainly from the United States, Japan, Europe, and China. Product is imported in a number of forms, including milled, chopped, tow and roll-goods. The latter two are explained below:

### 5.6.1: CARBON FIBRE TOW

**Carbon fibre tow** is the primary form of carbon fibre. Tow is formed by bundles of untwisted filaments of carbon fibre - each filament can be from five to 10 microns in diameter. A bundle can nominally contain from 500 to 48,000 carbon fibre filaments.

Carbon fibre tow is limited to a few manufacturing processes included filament winding and pultrusion technology for pressure vessels, pipes and profiles (to name a few).

Geelong based Carbon Nexus has a R&D scale single tow line as well as a pilot line capable of producing approximately 80 tonnes, which is not considered commercial scale. To that end, there is no commercial production of tow in Australia.



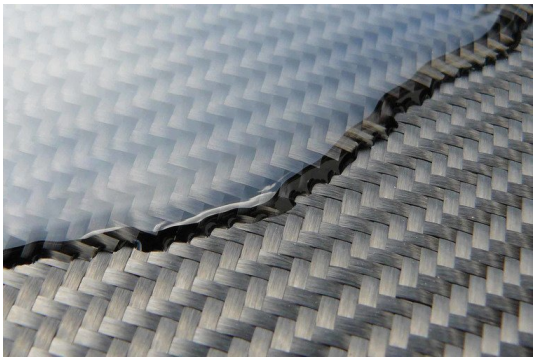
### 5.6.2: CARBON FIBRE ROLL-GOODS

Further processing of carbon fibre tow is in the manufacture of yarns, textiles and pre-pregs by spinning, weaving and/or braiding that are subsequently used to produce carbon fibre reinforced composite components. Multiaxial fabrics reinforcements – sometimes known as non-crimp fabrics (NCF) or carbon fibre warp knits - are multiple layers of unidirectional fibres, with each ply placed in a different orientation or axis. These layers are then typically stitchbonded to form a fabric.

Like traditional textile technology, carbon fibre fabrics made into many different patterns (weaves) that are dictated by the engineering specifications of a given end use be it a F1 Front Bumper Face Bar or a racing oar. For example, 2/2 twill weave fabric at the 200gsm weight is the most commonly used carbon fabric of all. It is suitable for use in wet-lay, vacuum bagging and resin infusion manufacture as well as for use as a single surface layer.

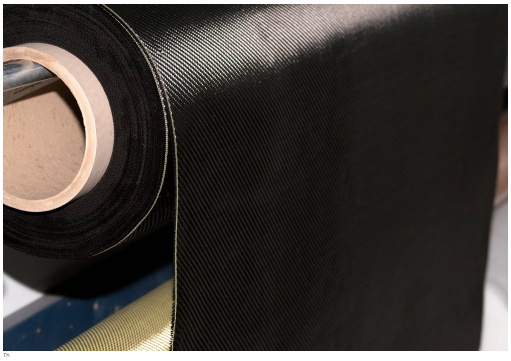
## 5.6.3: RESINS

Of equal importance to the carbon fibre reinforcement is the bonding matrix which is usually an **epoxy resin** that contributes to the strength, durability and chemical resistance to a composite. Epoxies use a hardener - also called a curing agent. The hardener (part B) and the base resin (part A) co-react in an "addition reaction," according to a fixed ratio. The properties of the final CFRP product can be affected by the type of additives introduced to the resin system. Epoxy resin feedstocks and base resins are imported and blended in Australia.



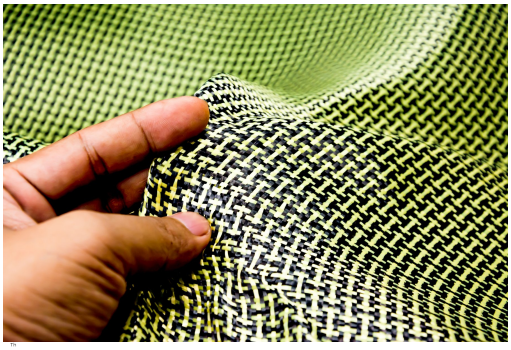
## 5.6.4: DOMESTIC PRODUCTION OF CARBON FIBRE

**For roll-goods,** Sydney-based high performance industrial textile manufacturer, Colan Australia, is the only mill in Australia with carbon fibre weaving capability which it has been processing for over 30 years. However, while Colan continues to manufacture a modest carbon fibre range, its technology doesn't match future needs of carbon fibre component fabricators and manufacturers. Nonetheless, Colan is the only Australian company with a significant body of Intellectual Property in the process of manufacturing carbon fibre.



Carbon fibre fabric - Colan Australia

**For pre-pregs,** GMS Composites which is based south east of Melbourne, pre-impregnates carbon fibre roll-goods and fibres with a resin system. The company's portfolio also includes resin films, low-temperature prepregs, tooling, and ballistic, fire retardant and toughened high impact prepregs.



Carbon fibre and aramid blend

## 6: SKILLS AND TRAINING

For composites manufacturing trade workers, formal Vocational Education and Training (VET) qualifications are generally a three to four-year Certificate III apprenticeship, which combines 'off-the-job' training with practical industry experience. Within the Australian Qualification framework (AQF), the training packages are:

- MEM31119 Certificate III in Engineering – Composites Trade
- MEM30719 Certificate III in Marine Craft Construction
- PMB Plastics, Rubber & Cablemaking - Cert II, III, IV, Diploma & Advanced Dip

A recent analysis of enrolment and completion numbers for the above qualifications shows an unsettling decline in numbers since 2008. While training is delivered in composite trade skills by PARTEC in QLD, GOTAFE in Victoria and NSW, SM TAFE in W.A. and TAFE NSW, there are no TAFEs offering training in South Australia or Tasmania - all of which is an ominous indication that the skills shortage is likely to continue for the foreseeable future.

## 7: UNDERGRADUATE AND POST GRADUATE

Australian universities are increasingly offering undergraduates courses that incorporate composite materials, engineering and design,

- ANU – Research School of Engineering: Composite Materials
- Monash University – Depart. of Mechanical & Aerospace Engineering: Composite Structures
- Monash University – Depart. of Materials Science & Engineering: Polymer and Composite Processing and Engineering.
- University of NSW – School of Materials Science & Engineering
- Swinburn University
- University of Southern Queensland
- University of Queensland – School of Engineering
- The University of Melbourne – School of Engineering



Dr Jasjeet Kaur, Research Scientist CSIRO

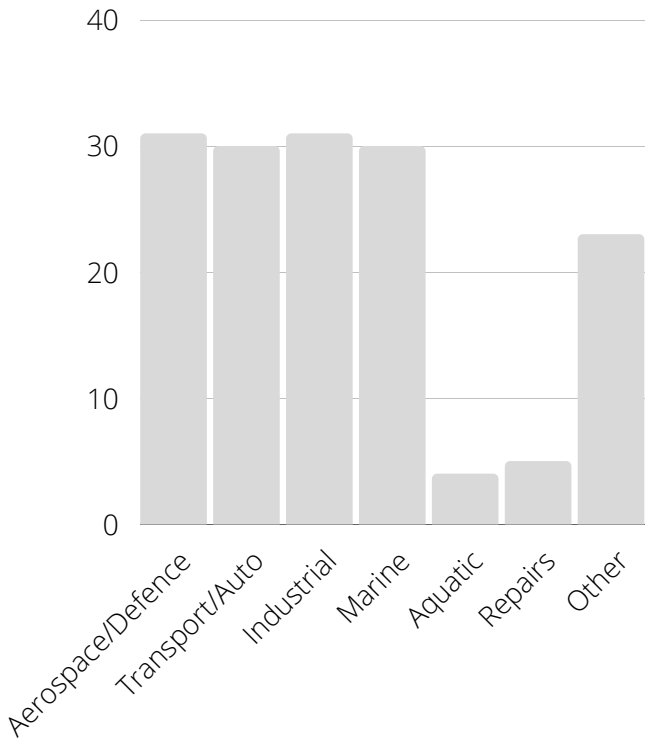
## 8: RESEARCH AND DEVELOPMENT

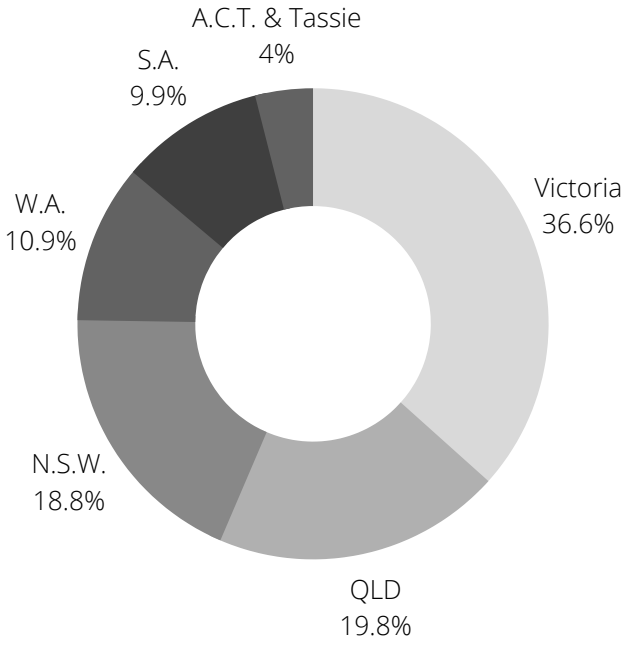
Australia universities and government research agencies – a number of which are defence related – initiate, fund and conduct a significant portfolio of research and development projects around carbon fibre composites.

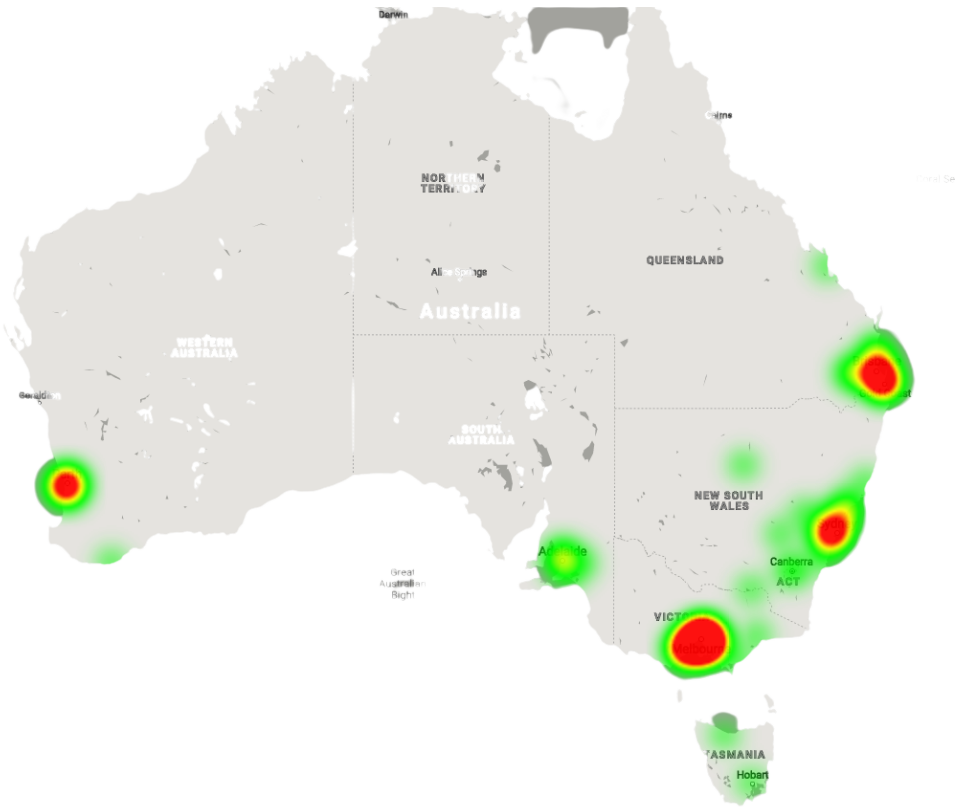
Research and development initiated and funded by CSIRO is centred around the early stages of carbon fibre production, including the polymerization of acrylonitrile into polyacrylonitrile and then spinning and further processing PAN to produce a higher-quality and cheaper precursor fibre.

## 9: GEOGRAPHIC LOCATIONS OF CF COMPOSITE SUPPLY CHAIN

The geographic locations are shown in the following heat map. Suffice to say that 37 per cent of the enterprises that have an interest in carbon fibre are located in Victoria; 20 per cent in Queensland; 19 per cent in NSW; 11 and 10 per cent in Western Australia and South Australia respectively; and a further two per cent in each the ACT and Tasmania.




Heatmap showing the locations of companies and enterprises using carbon fibre

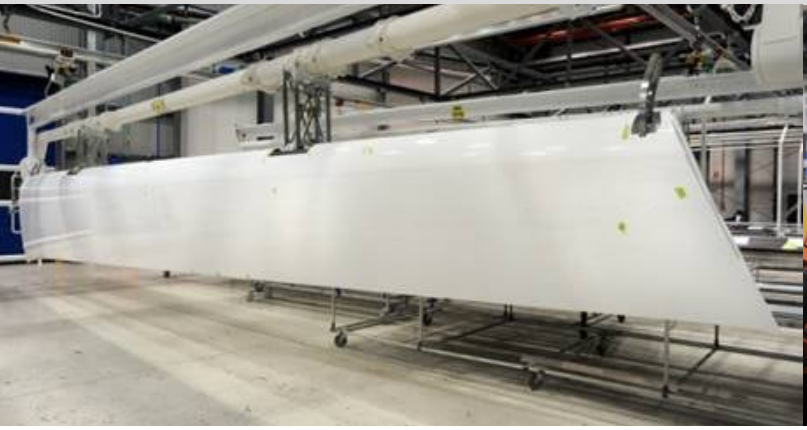
## 10. STEP CHANGE INITIATIVES

State and Federal investment in carbon fibre R&D through Universities, and carbon fibre capability development by way of grants directly to companies has largely been successful in priming the development of a state-of-the-art industrial sector. All the clusters covered in section 5.1 have been primed with significant government investments. For the Geelong region, the Victorian state government and Federal government have invested over $150 million since 2010 through Deakin University and enterprises in which the university has financial interests.

Further grants of lesser value have been awarded to The ARC Training Centre for Automated Manufacture of Advanced Composites at the University of NSW for robotic fibre placement technology. So too, in selected programs through Monash, Swinburne, University of Newcastle, University of Southern Queensland and the University of Queensland.

For the future, there are perceived opportunities in carbon fibre composites for storage tanks and pipes for new mining ventures, such as lithium and rare earths, and industries such as hydrogen energy and exotic materials linked to the growing aerospace and space sectors.

The Government's commitment to the safety of the Australian people and to the defence of our territory and national interests were outlined in the Defence Whitepaper in 2016. Subsequent documents have identified carbon fibre as a capability critical to Defence.



Boeing 787 Outboard flap


Boeing robotics

### 10.1: BOEING AUSTRALIA

Boeing Australia is manufacturing the carbon fibre critical control surfaces for the 787 Dreamliner at Fishermans Bend in Victoria. The production line brings together advanced composites technology, robotics and technical and engineering expertise to take the raw carbon fibre from lay-up for each of the four moveable trailing edge wing components, through the resin infusion process and curing ovens and on to assembly.

While most manufacturers were using pre-preg composites, the Melbourne-based team developed, tested, certified to strict aviation standards, and then put into production its innovative resin infusion composite technology. This process removes the need for a traditional autoclave oven process, significantly reducing the capital facilitation costs. The breakthrough is the culmination of many years of refinement and development of work undertaken some 15 years ago in collaboration with the Cooperative Research Centre for Advanced Composites Structures (CRC-ACS see 5.2) which was funded through the CRC program for 20 years.

## 10.2. THE CRC FOR ADVANCED COMPOSITES STRUCTURES

Cooperative Research Centre -ACS operated from 1991 to 2015. Over 24 years of industry, university and government laboratory collaboration produced highly practical and valuable technology and capability outcomes that helped Australia's composites industry to move forward competitively.

At its core, the CRC-ACS showed that coordinated teamwork was a productive approach for Australia's composites industry, helping it to achieve international market share and prominence. The state-of-the-art manufacturing facilities and world-class engineers are still all under the one roof at Fishermans Bend in Victoria, now operating as the for-profit enterprise, ACS Australia.

## 10.3. THE GEELONG FUTURE ECONOMY PRECINCT

Deakin University, together with the Victorian State Government and Federal Government, made the initial strategic investment of $34 million to establish the Australian Carbon Fibre Research Facility located within the Geelong Future Economy Precinct. Officially opened in early 2014, the Carbon Nexus research facility now lies at the heart of a carbon fibre and composites manufacturing cluster. The open-access carbon fibre/composite research facility consists of an 80 tonne carbon fibre production line and a research and development scale single tow line scaled down from the pilot line.

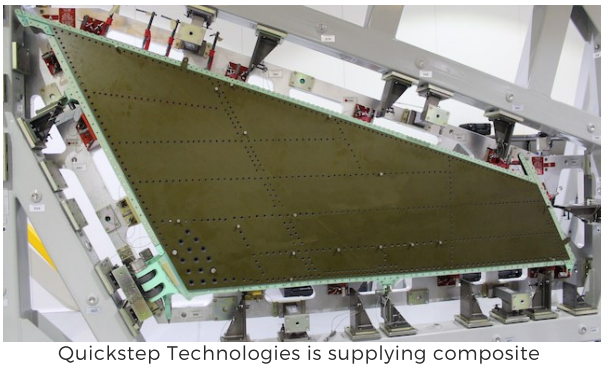
The precinct includes manufacturing operations for several companies that manufacture carbon fibre composites products including Carbon Revolution Ltd, Partington CC, which produces high performance bicycle wheels, and The Smart Think which produces ballistic helmets.

Also located at the elite precinct is the CSIRO and Deakin patented wet spinning line, which enables invaluable research into the raw materials for carbon fibre production and which was largely funded by the Science and Industry Endowment Fund.

## 10.3. DEFENCE SPENDING - JOINT STRIKE FIGHTER

The F-35 Lightning II joint strike fighter (JSF) is a stealthy, supersonic multirole fighter developed by Lockheed Martin.

Through a partnership with the RAAF, the agreement with Lockheed Martin for F-35 production and sustainment capability in Australia enables more than 50 Australian companies to be awarded service and production contracts for the F-35, valued at AU$2.7 billion.



Quickstep Technologies is supplying composite components to Marand for the F-35 tail. (Lockheed Martin)

Quickstep Holdings with Marand Precision Engineering supply about 700 sets of carbon fibre composite parts for F-35 JSF vertical tails over 14 years. The commission comprises 18 individual parts including skins, spars and fairings.

The 2018 Defence Industrial Capability Plan, which aims to boost sovereign industry and military capability has the ability to enable similar production opportunities.

## 11: THE CLUSTER PERSPECTIVE

The economic framework of 'clusters' was introduced by Michael Porter in his book 'The Competitive Advantage of Nations' published in 1990. His findings on how nations gain industrial advantage were based on studying existing organically formed European and US geographic clusters of inter-dependent companies. The economic model has since matured to include 'niche clusters' that are nationally spread and which rely on a collective interest.

### 11.1:GEOGRAPHIC CLUSTERS

- The Coomera Marine cluster on the Gold Coast in Queensland, which is home to global luxury boat builders Riviera and Maritimo, evolved from its proximity to an extensive network of waterways, protected anchorages and generations of passionate boaties.

- The Henderson cluster in WA on the edge of the Indian Ocean was also born from the Port's vital role in providing support to defence, commercial shipbuilding and repair, the resource sector, and offshore oil and gas.

- The Toowoomba composite cluster evolved from entrepreneurial endeavours and investment by the Queensland State Government in its regional research capability at the University of Southern Queensland.

- The Geelong Future Economy Precinct on the Deakin University campus was co-funded between the Victorian State Government and Federal Government as part of a suite of strategic government investments to transform heavy industry-based regional economies into advanced manufacturing powerhouses.

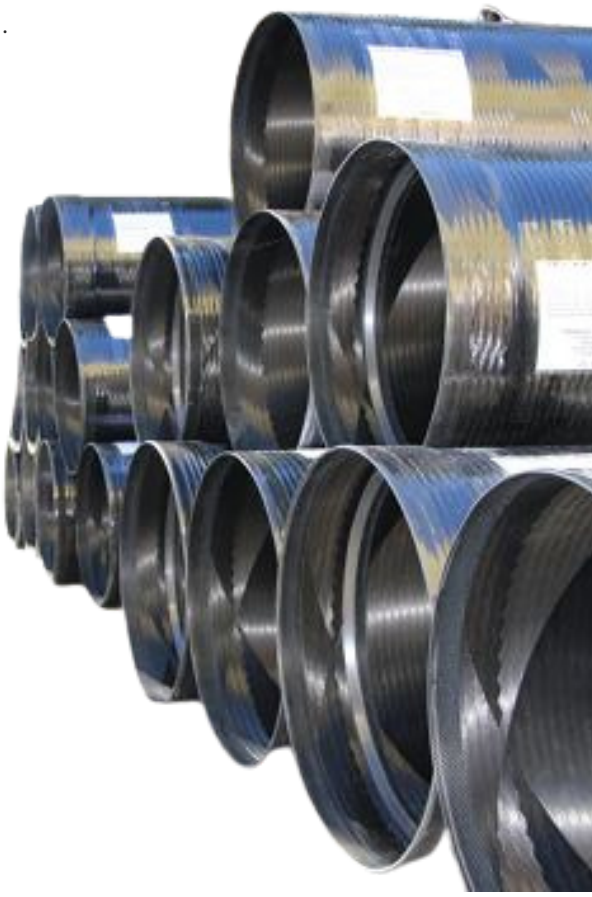
  The Carbon Nexus research facility now lies at the heart of a carbon fibre and composites manufacturing cluster that includes Carbon Revolution Pty Ltd (see following case study), Partington CC which produces high performance bicycle wheels and The Smart Think which produces ballistic helmets.

Deepsea Challenger carbon fibre subsphere made by LSM Advanced Composites, Toowoomba

Ron Allum in the Deepsea Challenger pilot sphere

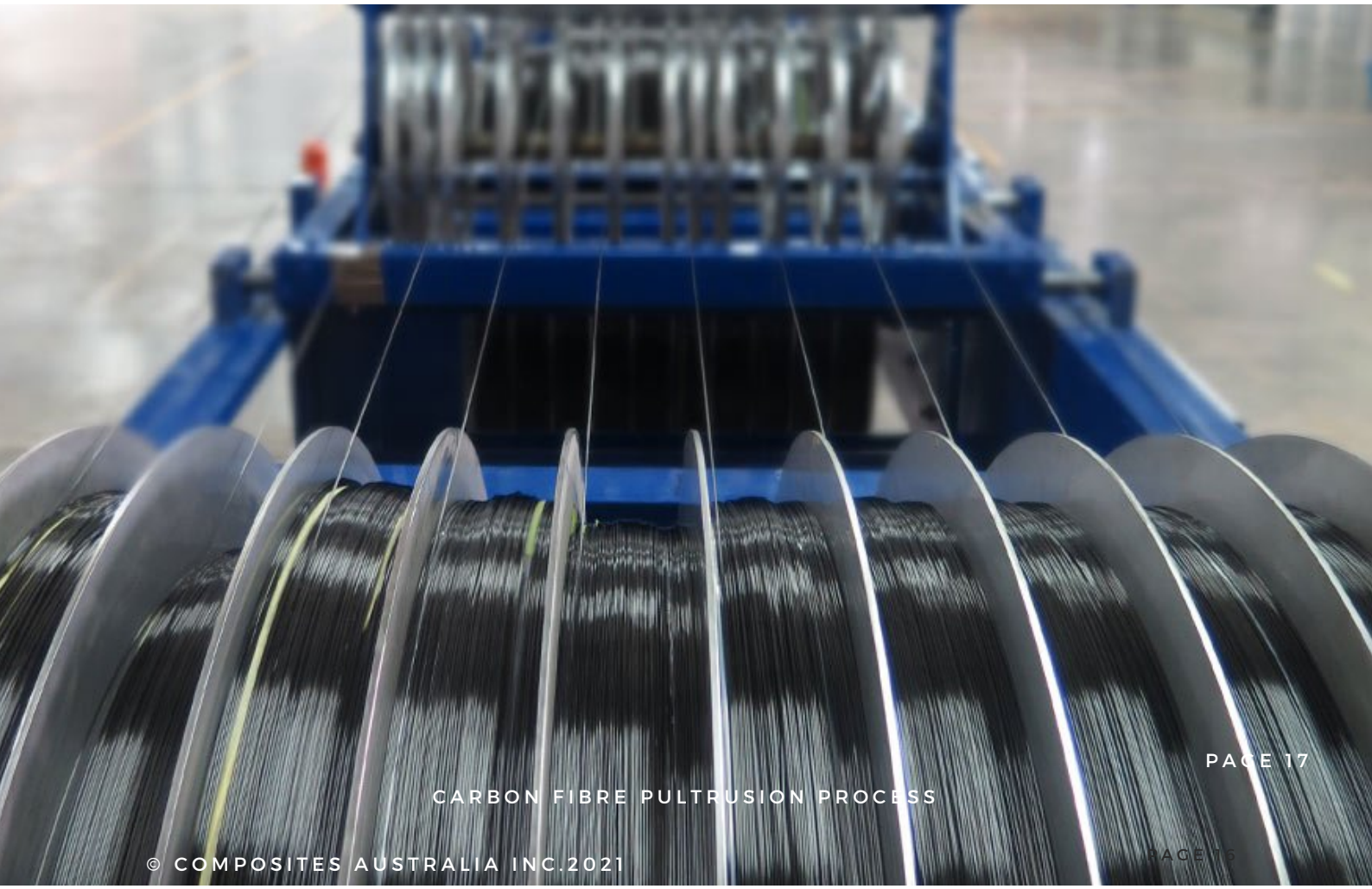
*"An industrial cluster is formed where a foundation of locational advantages exists and entrepreneurs, who - on a wing and a prayer - overcome their own unique challenges and become the next generation of employers reshaping the future of manufacturing. " Kerryn Caulfield*

## 11.2: NATIONAL CLUSTERS



- The Australian industrial mining sector is globally unique. Mainly located in regional areas across the country, Australia's cluster of composite manufacturers that supply the sector use the material science of composites – often using carbon fibre or carbon fibre hybrid combination - to produce tanks, mining ducts and piping that withstand the harshest of climates and corrosive elements.

- The Australian motorsport and V8 Touring Car Racing Series sector is also uniquely Australian. It is a cluster of proud and aligned partners, race teams and employees that provides exhilarating and accessible motorsports-led entertainment to engaged and passionate fans across Australia and beyond. While the 'collective cluster' of forty odd teams is geographically spread, common to all is a need for lightweighting by way of carbon fibre componentry provided by a national sector.



CARBON FIBRE PULTRUSION PROCESS

## APPENDIX 1: LEADING COMPANIES MANUFACTURING WITH CARBON FIBRE

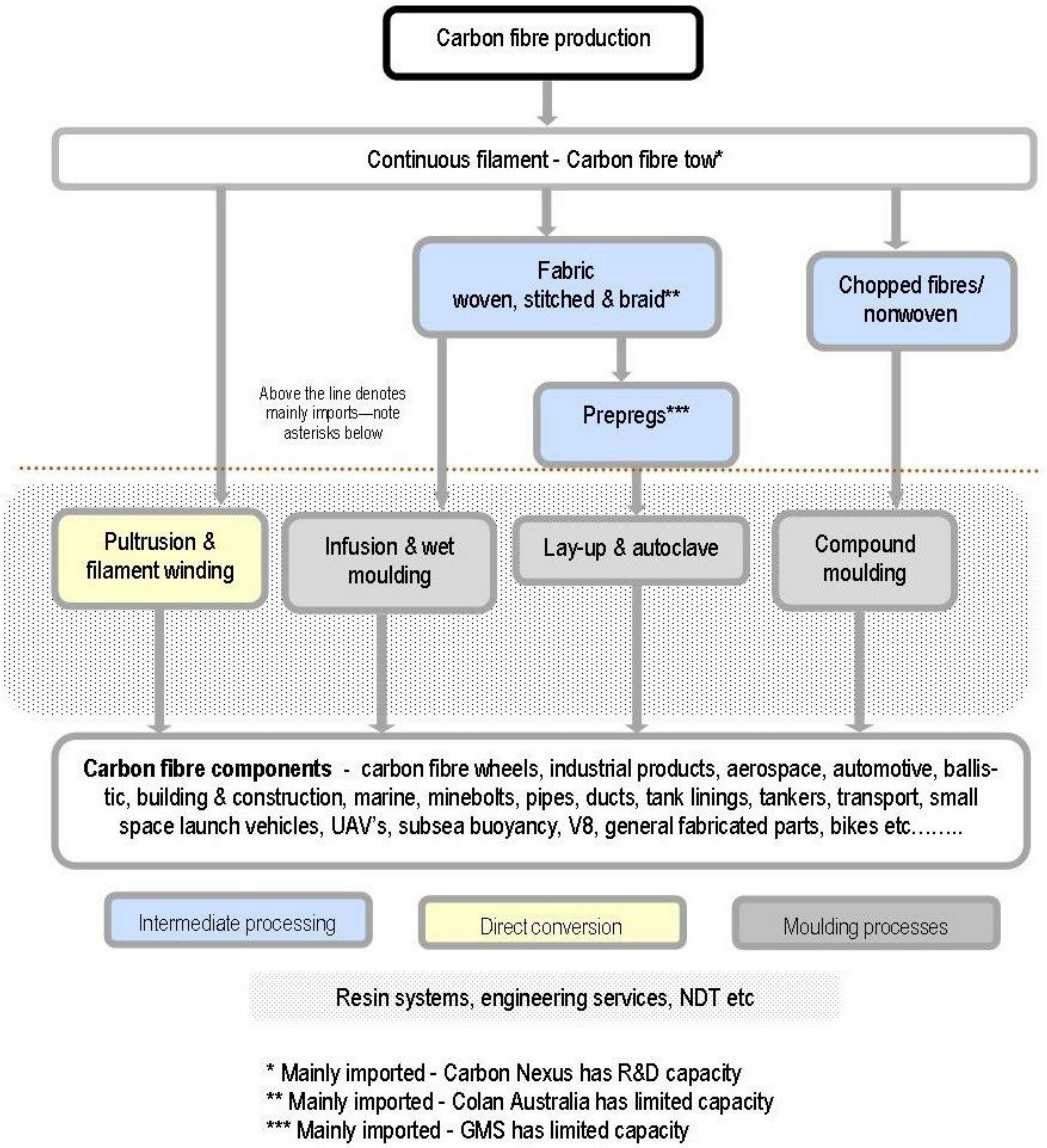
Our research identified 111 enterprises that have an interest in carbon fibre across six states and the ACT. Though not measured by volumes or technology, the following companies remain significant to carbon fibre usage in Australia.

- Boeing Australia (VIC)
- Carbon Revolution Ltd (VIC)
- Colan Australia (NSW)
- Croker Oars (NSW)
- CST Composites (NSW)
- GMS Composites (VIC)
- LSM Composites (QLD)
- Matrix Composites & Engineering (WA)
- NOVAFAST (SA)
- Omnitanker (NSW)
- Poletec (NSW)
- Quickstep (NSW & VIC)
- RPC Technologies (NSW)
- Xtek (ACT)

The following images aren't directly related to the above companies

## APPENDIX 2: CARBON FIBRE COMPOSITES MANUFACTURING SUPPLY CHAIN

Carbon fibre composite components are produced by way of a number of processing technology pathways.



## APPENDIX 3: 1.CARBON FIBRE CASE STUDY – KOREA

South Korea is said to be one of the top five consumers of carbon materials but it has traditionally relied primarily on imports from Japan, the United States and the European Union to meet its demand.

In mid-2019, the South Korean conglomerate Hyosung announced that it will spend 1 trillion Won ($825 million) to boost its carbon fibre production capacity from 2,000 to 24,000 tonnes by 2028. The additional capacity will increase Hyosung's market share in carbon fibre from 2% to 10%, making it the third highest producer of carbon fibre globally. The move is said to reduce the country's dependence on external suppliers, notably Japan.

The Jeollabuk-do Province in the southwest of the Korean Peninsula is home to Korea's own Carbon Valley after an initial substantial investment by the South Korean Ministry of Knowledge Economy (MKE) in 2010. The strategy was to turn traditional farming communities into high tech areas engaged in developing carbon materials to supply the country's advanced manufacturing industries of defence, automotive, aerospace, electronics, wind energy, and other renewable energy industries.

Carbon Valleys around the world, including 'Carbon Nexus" in Geelong, Victoria are modeled around Michael Porter's cluster theory (see section 11) and the dynamics of "Silicon Valley - the US global centre for high technology. The initial "Valley" was "CFK-Valley" e.V. in Stade in Germany which evolved from the cluster of companies, R&D agencies, and higher education institutions in and around Airbus where the vertical tail planes, pressure bulkheads and upper-wing shells for Airbus aircraft are produced.

Co-located in the Jeollabuk-do Province carbon fibre precinct are the Korea Institute of Carbon Convergence Technology (KCTech), the Korean Advanced Nano Fab Center, the Korean Institute of Science and Technology (KIST); Hanwha Nanotech Corporation, and Vinatech, a company specializing in carbon electrodes. Major Korean automobile-related companies such as Hyundai, Daewoo, Mobis and Kia also have established manufacturing facilities in this area. Carbon fibre manufacturers and/or their suppliers in the area include Hyosung, Taekwang, GS Caltex, Samsung General Chemicals and SK Chemicals.

Composites Australia

Composites Australia is the peak industry body for the Australian composites sector. It exists to increase awareness of the capabilities of the Australian composites industry and the adoption of composites technologies by Australian manufacturers, engineers and designers.

A member-based organisation, we connect and support the development of the industry and facilitate collaboration with researchers.