Queensland Department of State Development

Sustainable Manufacturing –
a literature review with case studies

An initiative of the Queensland Advanced Manufacturing 10-Year Roadmap and Action Plan

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Executive Summary

The Queensland manufacturing sector is diverse and dominated by small to medium enterprises which make up over 90% of the 16,400 businesses that employ almost 170,000 people and which contributes over $20 billion to the Queensland economy.

The Queensland Government has identified a number of priority industries that it believes can be supported to build on competitive strengths and create the knowledge-based jobs of the future. Under the *Advanced Manufacturing 10-Year Roadmap and Action Plan*, priority industries to be targeted include manufacturers in the sectors of food and beverage processing; aerospace, automotive and transport; defence; industrial biotechnology; biomedical; mining; precision agriculture and renewable energy. Sustainability plays an integral role in each of these areas.

As with all Australian states, there is no regulatory incentive for SMEs to consider or report on resource use or greenhouse gas emissions, however Queensland manufacturers have an opportunity to improve their competitiveness through adopting more sustainable business models and approaches. Sustainable manufacturing employs processes that are non-polluting, conserve energy and natural resources, and are economically sound and safe for employees, communities and consumers. In order to be more sustainable, manufacturers will need to utilise renewable resources and identify efficiencies across supply chains in order to reduce resource consumption, emissions and costs. This will inevitably involve greater R&D and the utilisation of innovative technologies and advanced materials, not just in product manufacturing but also in product design. There is also increasing customer demand for products that are affordable and which reduce their environmental footprint. Social corporate responsibility is also becoming increasingly important along with the transparency to assist consumers to make informed decisions relating to the sustainability of the products they purchase.

While it is not uncommon for manufacturing companies to improving resource efficiency within the bounds of their own manufacturing sites, a more integrated approach is required which includes customers, suppliers, employees and other stakeholders. Overarching frameworks such as The Circular Economy and Value Chain, which are further developed than the older approaches of Cleaner Production and Ecoefficiency, provide methodologies for applying practices that consider all three pillars of sustainability (economic, environmental and social). These are underpinned by the seventeen United Nations Sustainable Development Goals. Other more specific methodologies such as life cycle thinking, product stewardship and cradle to cradle product design can also be adopted throughout the value chain.

The following literature review examines key issues for Queensland manufacturers and current drivers and barriers impacting on the adoption of sustainable manufacturing. It includes numerous case studies and examples of how manufacturers in Australia and around the world are becoming more sustainable.

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1 Introduction

The State of Queensland is host to over 16,000 manufacturers, with capability in the sub-sectors of defence, biomedical, biotechnology, aerospace, precision agriculture, food processing, transport, renewable energy and more. Many of these are already or moving towards being considered as Advanced Manufacturers utilising cutting edge technologies and processes (see Box 1). As with any manufacturer, those companies that can be described as being 'advanced' also must make a conscious decision to adopt practices that are more sustainable – those which reduce their environmental footprint while also considering the social and economic impacts of their decisions. It is common for manufacturers to undertake initiatives that reduce resource consumption e.g. via energy or water efficiency projects, however, many manufacturers do not have a broader sustainability program integrated into their business operations that considers environmental, social and economic factors.

Improved sustainability is an ongoing process and provides many benefits for manufacturers from reduced resource use, better relationships along the supply chain, improved marketing opportunities and new markets and better work conditions for both direct employees and those within the supply chain.

There are numerous opportunities along the value chain of a manufactured product where companies can improve sustainability. This can begin with considering some overarching frameworks and how sustainability can be integrated into business models and strategies and through improved product design and stewardship. The following literature review examines some of the many opportunities available to manufacturers, with particular focus on Advanced Manufacturers. Examples and case studies from Australia and internationally are provided. The approaches discussed are applicable to manufacturers of all types and sizes. All manufacturers contend with drivers and barriers and it is acknowledged that small to medium enterprises face their own set of challenges. These are discussed in the light of manufacturing companies situated in Queensland, Australia.

Box 1: Advanced Manufacturing

Advanced manufacturing incorporates niche market products and a range of activities from design and research and development (R&D), to production, distribution and after-sales services. It focuses not only on products but also on value-adding across the entire value chain and includes:

- collaborative R&D and design-led thinking,
- innovative business models and effective supply chain capabilities,
- the effective use of disruptive technologies and systems and cutting-edge materials,
- a focus on customisation and exports,
- world-best practices and processes,
- new ways to manufacture existing products and the manufacture of new products, and
- the provision of high value-added services and innovative solutions (DSD, 2016).

2 Sustainable Manufacturing – an overview

Key Messages:

- There are a number of voluntary broad-based frameworks for implementing practises that consider economic, social and environmental sustainability. The most recent and well-known frameworks are the Value Chain and the Circular Economy.
- The 17 Sustainable Development Goals are global goals that have been developed by United Nation member states and can be incorporated into sustainability plans at a company level.
- Value Chain and Circular Economy frameworks are focussed towards manufacturers and include full life cycle analysis of products and services and require multi-stakeholder collaboration.
- Cleaner Production and Ecoefficiency are established frameworks for minimising impacts of manufacturing. They are less explicit about working across supply chains compared with Value Chain and Circular Economy.
- Global Reporting Initiative (GRI) is the most widely used reporting framework in Australia.
- The Institute of Chemical Engineers and other organisations have developed sets of sustainability indicators suitable for manufacturers to use to measure progress.

There is no single or formal definition of Sustainable Manufacturing (SM), however it is well summed up as “the creation of manufactured products that use processes that are non-polluting, conserve energy and natural resources, and are economically sound and safe for employees, communities and consumers” (USDC, 2010). Businesses often see water, energy and waste bills as just the cost of doing business. As a first step, many companies often focus on resource efficiency within the bounds of their manufacturing sites. During the drought in mid-2000s Queensland businesses were forced to look at and take measures to reduce water consumption. This was driven from government pressure in the form of Water Efficiency Management Plans for large water consumers as well as community pressure to save water. Electricity bills are currently the concern to most businesses with increasing costs forcing businesses to analyse energy consumption and energy efficiency measures. Many manufacturing companies have also adopted lean manufacturing as one approach for evaluating value added processes and reducing physical and time related wastes.

Resource efficiency and waste reduction is a useful start in striving to be more sustainable. However, focussing on just resource use within the boundary of a manufacturing site, is incremental. To achieve maximum effect from sustainable practices an ongoing integrated approach through the business and across the supply chain is required.

The following section provides an overview of some of the overarching frameworks that manufacturers can consider in striving to be more sustainability. The frameworks presented consider sustainability across whole supply chains and which require a high level of collaboration between suppliers, customers and stakeholders.

2.1 Sustainable Development Goals

On a world scale, the overarching framework for Sustainable Development is represented by the seventeen Sustainable Development Goals (SDGs) driven by the United Nations (Figure 1). The SDGs are the result of multi-stakeholder negotiations with UN member states and involve a wide range of sectors, including business. The seventeen goals have been developed to tackle the world’s most pressing social, economic, and environmental challenges in the lead-up to 2030. They are strongly supported by the World Business Council for Sustainable Development (WBDSD) which have produced the ‘CEOs Guide to the Sustainable Development Goals’ (WBCSD, 2017a). An evaluation of the business case and opportunities in achieving the SDGs is provided in the ‘Better Business, Better World’ Report (BSDC, 2017).

Figure 1: Sustainable Development Goals (UN, 2017)

The SDGs include 169 targets which encompass a full range of economic, environmental and social factors (UN, 2017). UN member states' achievement of the SDGs by 2030 will require intergovernmental cooperation/support as well as the support of business and the community with far-reaching policies to encourage their implementation. These can be easy to disregard as goals that should be driven by government or 'other' organisations. However, for small to medium advanced manufacturers that are based in Queensland, the following goals (adapted from the SDGs) could be considered and aspired to as best practice if not already incorporated into a company's business plan:

SDG Goal No. 12: Responsible Consumption and Production

- Achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil.
- Substantially reduce waste generation through prevention, reduction, recycling and reuse.
- Adopt sustainable practices and integrate sustainability information into their reporting cycle.
- Adopt sustainable procurement practices.

SDG Goal No. 13: Climate Change

- Evaluate energy consumption and set targets for reducing greenhouse emissions

SDG Goal No. 9: Industry, Innovation and Infrastructure

- Seek to retrofit processes to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes.

SDG Goal No. 8: Decent work and economic growth

- Endeavour to decouple economic growth from environmental degradation.

SDG Goal No. 10: Reduce inequalities

- Promote the inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion, economic or other status.

SDG Goal No. 5: Gender Equality

- Encourage equal opportunity for employment and leadership at all levels of the organisation.

Section 2.6 on Sustainability Reporting includes suggestions for indicators which are suited to manufacturers.

2.2 Value Chain

A useful framework for manufacturers to consider is that of the value chain which examines the sustainability of a service or product across the entire supply chain. Opportunities to reduce environmental and social impacts are built in from product design and raw material sourcing through to manufacture, end use and end of product life. An important aspect of considering the complete supply chain is collaboration between all parties (suppliers, distributers, retailers). A full analysis of an entire supply chain by all stakeholders can yield excellent results and build the foundation for ongoing improvement. Figure 2 shows themes across a value chain. This approach has been adopted by the European Union Programme on Sustainable Consumption and Production in Asia (Switch Asia, 2017) and is also acknowledged as contributing to the future of Queensland manufacturing (DSD, 2017b).

Designing for sustainability Eco-design Product improvement	Ethical supply Green procurement	Resource efficiency Emission reduction Technical innovation Corporate Social Responsibility Environmental Management Systems Industrial ecology	Creating demand for better products Consumer awareness raising Promote sustainable life-style Marketing for eco-products	Eco-labelling Product information disclosure	Green public procurement Product stewardship
Design	**Raw material**	**Manufacture**	**Retail**	**End use**	**End of life**

Value Chain

Greening supply chain/ Sustainability criteria/ Knowledge sharing/ Collaboration

Figure 2: Value Chain (Adapted from (Switch Asia, 2017))

2.3 Circular Economy

The idea of the value chain is taken a step further with the adoption of the Circular Economy. The Circular Economy model seeks to replicate natural ecosystems whereby there is no build-up of material waste as it is simply broken down or transferred into 'nutrients' (raw materials) which promote the growth of other 'organisms' (new products).

'*A circular economy is a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and* *recycling*' (Geissdoerfer, 2017). This is in contrast to a linear economy which is a 'take, make, dispose' model of production (Macarthur, 2017).

The aim of the Circular Economy model is not to have it applied on an adhoc basis to individual supply chains but to see it fully developed and integrated across all value chains and production systems so that all resources are used sustainably. Industrial ecology applies the circular economy model on a smaller scale (refer to Box 2).

Box 2: Industrial Ecology

Industrial Ecology promotes the circular economy within an industrial setting. It approaches man-made eco-systems with natural eco-system thinking where the waste or by-product from one process becomes the input to another whether within a company or between companies.

Industrial ecology estates locate companies in close range so that they can benefit from the other's material or energy flows thus reducing the impact to the environment of both companies. An example is the Kalundborg Industrial Park in Denmark (www.symbiosis.dk/en).

2.4 Cleaner Production and Ecoefficiency

Cleaner Production and Ecoefficiency are an aspect of the broader sustainability frameworks of the Value Chain and Circular Economy as they generally do not explicitly focus on supply chains or social sustainability aspects and are often implemented with a narrow scope to address resource use within manufacturing facilities or businesses.

The concept of cleaner production was introduced in by UNEP in 1989. Cleaner production is defined as "the continuous application of an integrated preventive environmental strategy applied to processes, products and services to increase overall efficiency, and reduce risks to humans and the environment. Cleaner production can be applied to the processes used in any industry, to products themselves and to various services provided in society" (UNEP, 2004).

Key concepts include:

- housekeeping to improve work practices, methods and proper maintenance of equipment,
- process optimization,
- raw material substitution,
- new technology to reduce resource consumption and minimise wastes while increasing productivity,
- product redesign.

The concept of eco-efficiency was first introduced in 1992 by the World Business Council for Sustainable Development (WBCSD, 2017b) which defined eco-efficiency as being achieved by *"the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life-cycle to a level at least in line with the Earth's estimated carrying capacity."* Its prime focus is creating more value with less impact.

The WBCSD has identified seven success factors for eco-efficiency:

- reduce the material intensity of goods and services,
- reduce the energy intensity of goods and services,
- reduce toxic dispersion,
- enhance material recyclability,
- maximise sustainable use of renewable resources reduce material durability, and
- increase the service intensity of goods and services.

Both approaches are similar and the key to both these strategies is that they combine environmental protection and productivity.

Implementing Cleaner Production or ecoefficiency involves a number of steps:

- measure use and establish as baseline,

- identify opportunities,
- estimate savings,
- evaluate opportunities for business suitability,
- develop an implementation plan,
- execute the plan,
- measure savings, and
- track and/or monitor and report on efficiency savings (PIMA, n.d.).

2.5 Corporate Social Responsibility

It is important that businesses achieve and maintain a social license to operate. A business needs to continually demonstrate that '*it pays taxes where revenue is earned; abides by environmental and labour standards; respects the national politics and customs where it operates; integrates social and environmental factors in its investment decisions; and, above all, engages as a partner with others to build an economy that is more just*' (BSDC, 2017). The Australian Centre for Corporate Social Responsibility undertakes an annual review of the status of CSR amongst Australian and New Zealand companies (ACCSR, 2017). An on-line survey was completed by 1215 professionals from about 16 sectors with around 50 responses from the manufacturing sector. The focus of the 2017 survey was the Sustainable Development Goals and non-financial reporting. Among the key findings was that:

- 43% of all respondents reported a behaviour change in their organisation as a result of mapping the SDGs to reporting or strategy.
- 53% said that sustainability reporting should be mandatory.
- 57% of respondents mapped the SDGs against the business strategy, however these were mostly foreign owned companies with Australian listed companies amongst the lowest proportion to map the SDGs to their business strategy.
- 83% of respondents rated 'Building stronger relationships with stakeholders' as a high or very high priority for the year ahead which was the highest rating of all listed priorities.
- The manufacturing sector said it was mapping value chains against SDGs. (The survey results did not specify which of the SDGs the manufacturing sector was focussing most efforts.)

2.6 Sustainability Reporting

Sustainability Reports are an excellent opportunity for a company to demonstrate its commitment to the implementation of sustainability measures and initiatives. These reports are separate to the SDGs but may incorporate them. Though sustainability reporting is voluntary in Australia, there is a steady increase in mandatory sustainability reporting around the world with a regular review indicating governments in over 80 per cent of 71 countries studied had introduced some form of regulatory sustainability reporting instrument (KPMG, 2016). Descriptions of some common international reporting frameworks are shown in Box 3.

The voluntary Global Reporting Initiative (GRI) G4 remains the most widely used reporting framework in Australia (ACCSR, 2017). It is applicable to any size company, however it is generally only followed by medium to large companies. In 2016, there were 191 Sustainability Reports registered with the GRI by Australian companies (GRI, 2017a). As an indication of size, 68% of the companies reporting had greater than 1000 employees and 7% had less than 50. There is a plethora of information that could be reported and companies often undertake a materiality assessment to help prioritise what is important. Materiality is the threshold at which aspects become sufficiently important that they should be reported (GRI, 2017b).

While most small to medium Australian companies do not have formal sustainability reports, depending on size, they are still faced with some mandatory and voluntary requirements to report some aspects which are related to sustainability, for example, energy consumption. These reporting measures are often not made public and can also have thresholds which only capture medium to large manufacturers as indicated in Table 1.

Box 3: Common sustainability reporting frameworks

Global Reporting Initiative – GRI is an international independent organization that helps businesses, governments and other organizations understand and communicate the impact of business on critical sustainability issues such as climate change, human rights, corruption and many others. It has pioneered sustainability reporting since the late 1990s. In October 2016, GRI launched the first global standards for sustainability reporting. The GRI Standards are a trusted reference for policy makers and regulators, and have a modular structure so they can be kept up-to-date and relevant. Of the world's largest 250 corporations, 92% report on their sustainability performance and 74% of these use GRI's Standards to do so. See www.globalreporting.org

UN Global Compact - The United Nations Global Compact is a United Nations initiative to encourage businesses worldwide to adopt sustainable and socially responsible policies, and to report on their implementation. The Global Compact is strongly linked with the Sustainable Development Goals and incorporates ten principles. The Global Compact Network Australia discusses how the principles apply within an Australian context. This includes four leadership groups focussed on human rights, environment, anti-corruption and sustainable development. *It defines supply chain sustainability as the management of environmental, social and economic impacts, and the encouragement of good governance practices, throughout the lifecycles of goods and services. The objective of supply chain sustainability is to create, protect and grow long-term environmental, social and economic value for all stakeholders involved in bringing products and services to market.* See www.unglobalcompact.org/about

Integrated Reporting (IR) Framework – Originating in Europe, this is a voluntary framework focused on bringing greater cohesion and efficiency to the reporting process. The purpose of the framework is to establish Guiding Principles and Content Elements that govern the overall content of an integrated report, and to explain the fundamental concepts that underpin them. See www.integratedreporting.org/

ISO26000:2010 – is an international standard which provides guidance on what is social responsibility and helps organizations translate principles into effective actions and share best practices. It is aimed at all types of organizations regardless of their activity, size or location. As it is a guideline, organizations do not become certified to this standard. See www.iso.org/iso-26000-social-responsibility.html

Eco-Management and Audit Scheme and ISO14001 – a voluntary program developed by the European Union. EMAS incorporates ISO14001 (Environmental Management Systems) and includes a set of environmental indicators and the requirement for public reporting on structures and programs.

Table 1: Reporting instruments in Australia

(GRI, 2017a)

Reporting instrument	Type	M/V[1]	Metric[2]	Scope/ Business size
Carbon Credits (Carbon Farming Initiative) Act, 2011	Legislation	V	E	All participants
Australian Water Accounting Standard 1 & 2	Standard	V	E	Generally large organisations
Regulatory Guide 247 on operating and financial review (OFR), 2013	Guideline	M	G	ASX listed companies
The Australian Securities and Investments Commission (ASIC) Socially Responsible Investing Section 1013DA Disclosure Guidelines, 2003	Guideline	M	E/S	Sellers of investment products
National Pollutant Inventory, 1998.	Program	M	E	Required where pollutant threshold is exceeded
Corporations Act – Sect 299, 2001	Legislation	M	E	Any registered company
Reconciliation Action Plan, 2006	Strategy	V	S	Any organisation
National Greenhouse and Energy Reporting Regulations 2008	Legislation	M	E	Generally large organisations emitting greater than threshold

Reporting instrument	Type	M/V[1]	Metric[2]	Scope/ Business size
Requirements under the Financial Services Reform Act (FSRA), 2010	Legislation	M	E/S	Financial services only
Renewable Energy (Electricity) Act 2000	Legislation	M	E	Electricity providers
Corporate Governance Principles and Recommendations, 3rd Edition, ASX Corporate Governance Council, 2014	Guideline	V	E/S/G	ASX listed companies
Listing Rule 4.10.3, Australian Stock Exchange (ASX)	Rule	M	E/S/G	ASX listed companies
Workplace Gender Equality Act	Legislation	M	S	Companies with > 100 employees

1. Mandatory or voluntary
2. Environment, Social, Governance

2.6.1 Sustainability Indicators

Manufacturing sustainability can be measured via key performance indicators. While there are no mandatory schemes for Queensland manufacturers, measuring resource use and other indicators provides manufacturers with a basis for improvement.

The OECD Sustainable Manufacturing Toolkit suggests a selection of 18 indicators, which include the use of non-renewable materials, resource intensity (materials, energy, water), greenhouse gas emissions, recyclability of products and more (OECD, 2011). However, each of these is focussed on environmental sustainability and does not include any social sustainability indicators.

In contrast, the GRI includes a detailed list of potential economic, social and environmental indicators which companies can choose to base their reports. Companies generally undertake a 'materiality assessment' to help prioritise what is important. (See Box 3).

The Institute of Chemical Engineers has a set of Sustainability Metrics specifically for Process Industries which include environmental, social and economic factors (IChemE, un.d). Table 2 shows a sample of typical indicators.

Garbie suggests a method for assessing sustainability practices and implementation which revolves around four main themes of awareness, drivers, barriers and the relevance of sustainability indicators (social, environmental and economic) which are categorised as short term, long term and continuous (Garbie, 2015). Awareness, drivers and barriers are evaluated across various operational levels using survey questions. These results are combined along with the weighted sustainability indicators to arrive at a single value for the company. This methodology can be used to compare with other like companies or benchmark between industries.

Table 2: Sample of Sustainable Indicators useful for Manufacturers

Description	Unit	Description	Unit
Environment		**Economic**	
Total Net Primary Energy Usage per kg product	kJ/kg	Gross margin per direct employee	$/person
Percentage Total Net Primary Energy sourced from renewables %	%	R&D expenditure as % of sales	$/$
Total raw material used per kg product	kg/kg	Investment in education/employee training expense	$/$
Net Water use per kg product	kL/kg	**Social**	
Global warming burden per unit value add	kg CO_{2e} /$	Employee turnover	%
Hazardous solid waste per unit value add	Tonne/$	Promotion rate	%
		Indirect community benefit per value add	$/$

3 The Business Case

There is a strong business case for manufacturers to improve sustainability through integrating sustainable business models, programs and initiatives to develop a long-term strategy. '*Executives are often reluctant to place sustainability core to their company's business strategy in the mistaken belief that the costs outweigh the benefits. On the contrary, academic research and business experience point to quite the opposite*' (Whelan, 2016). There are numerous examples and case studies included in this literature review which point to the benefits of sustainable manufacturing. Some of these benefits are raised below:

Driving competitive advantage

Resource and production costs are reduced through improving efficiencies. Inherent in sustainable manufacturing is looking for ways to reduce environmental impacts through reduced resource consumption. Opportunities range from being no and low cost with quick returns on investment (12-18 months) through to medium to high costs with longer returns (> 2 years). Manufacturing companies can reduce resource and production costs by tens of thousands of dollars per year as demonstrated in Section 6.

Improving risk management

Addressing social and environmental issues and making these integral to how a company operates reduces business risk. Such companies are viewed more favourably by the community, stakeholders and investors. An example is the lending policies and position on sustainability taken by leading Australian banks such as Westpac and National Australia Bank (Westpac, 2017). Such companies also have a greater chance of being successful in government bids for tenders and grants.

Reduced costs of compliance

In Queensland, companies that are involved with the state funded ecoBiz program (See Section 5.3), are eligible for a 10% discount on their environmentally relevant activity fees. Companies which have a certified Environmental Management System can gain a further 20% reduction (DEHP, 2016a). Further reduction of 20% can be made when a lower emission score is met. This can save Queensland companies in the order of thousands of dollars per year. Other examples include reductions in trade waste or solid waste disposal fees through improved resource efficiency.

Fostering innovation

Investment in research and development in manufacturing can lead to new, improved and more cost-effective ways of operating as well as opening up potential new markets for services and products. Examples of new and improved methods of manufacturing are discussed throughout Section 7. Manufacturers are not simply selling a stand-alone product but an item that is fulfilling an overall service requirement. Offering additional services which support the use of a base product is one way of increasing competitiveness and market share. This is discussed further in Section 8.

Building customer loyalty

A recent survey of 20,000 adults from five countries found that a third of consumers are now choosing to buy from brands they believe are doing social or environmental good (Unilever, 2017). Of its hundreds of brands owned by Unilever, those such as Dove, Hellmann's and Ben & Jerry's, that have integrated sustainability into both their purpose and products delivered nearly half the company's global growth in 2015 (Unilever, 2017). Companies that can demonstrate that they are working towards reducing environmental impacts and that are supporting their staff and communities will have an improved chance of building customer loyalty.

Attracting and engaging employees

A company that supports and encourages staff and fosters an environment which welcomes suggestions for making improvements also leads to a happier, more productive workforce. Companies that are 'walking the talk' also attract committed and loyal employees. Examples of how companies can be more socially sustainability are given in Section 7.

4 Key issues for Queensland manufacturers

Key Messages:

- Queensland manufacturers compete in a global market which presents many opportunities and challenges.
- Australian manufacturers are ranked 26th for Global Competitiveness after countries including Switzerland, Singapore, United States, Netherlands, Germany and New Zealand.
- Energy and water security and pricing as well as climate policy creates uncertainty.
- Advancements in the digital economy are poised to change the way manufacturers currently go about business.

4.1 Industry Snapshot

Queensland manufacturers are competing in a global market which present a range of challenges and opportunities. A snapshot of the Queensland sector is shown in Figure 4. It is the 6th largest industry in Queensland by employment, offering almost 170,000 jobs, 88% of which are full time. It is a sector that is dominated by small to medium sized companies with 93% of companies having fewer than 20 staff. The sector's percentage share of total real production output for the state has declined over the past 15 years (1999-2000 to 2013-14), from over 10% to about 7%—a trend seen nationally and internationally (QPC, 2016). The sector had enjoyed steady growth from 1990 to 2006, however, as a result of the Global Financial Crisis, after 2006-07 it shrank, with real output in 2014-15 around 17% lower than that in 2006-07 (Figure 3) (QPC, 2016). Key factors impacting on the industry and its ability to compete at a global scale are discussed in a recent review of the manufacturing sector, conducted by the Queensland Productivity Commission (QPC, 2016). Such factors include:

- Australia's exposure to Chinese markets, the impact on the resources sector and flow on effect to manufacturers;
- the impact of the global financial crisis;
- high Australian labour costs impacting on overall operating costs; and
- rises in energy and electricity prices.

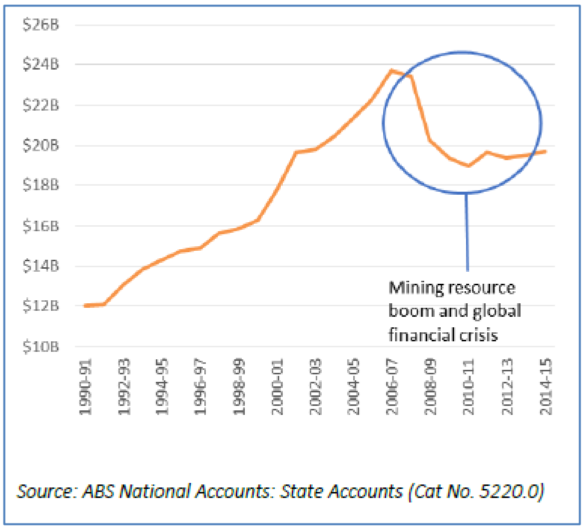

Figure 3: Queensland real manufacturing output ($billion)

These factors and a range of suggested policy instruments and support measures are discussed in the issues document and various company submissions (CCIQ, 2017a). Amongst these are a range of opportunities which also have the potential to improve sustainability credentials. These include:

- stable energy policy and frameworks,
- increased service focus of manufactured goods,
- digitisation and improved efficiency of processes,
- investing in enabling infrastructure. This should be sustainable e.g. sustainable building.
- investment in research and development.

These factors are discussed further below throughout this literature review.

The Australian manufacturing sector should see an increased demand for Australian goods from Asian markets, especially China, due to the rising Asian middle-class and demand for products of higher quality, reliability and trustworthiness than may be available locally (AIG, 2017).

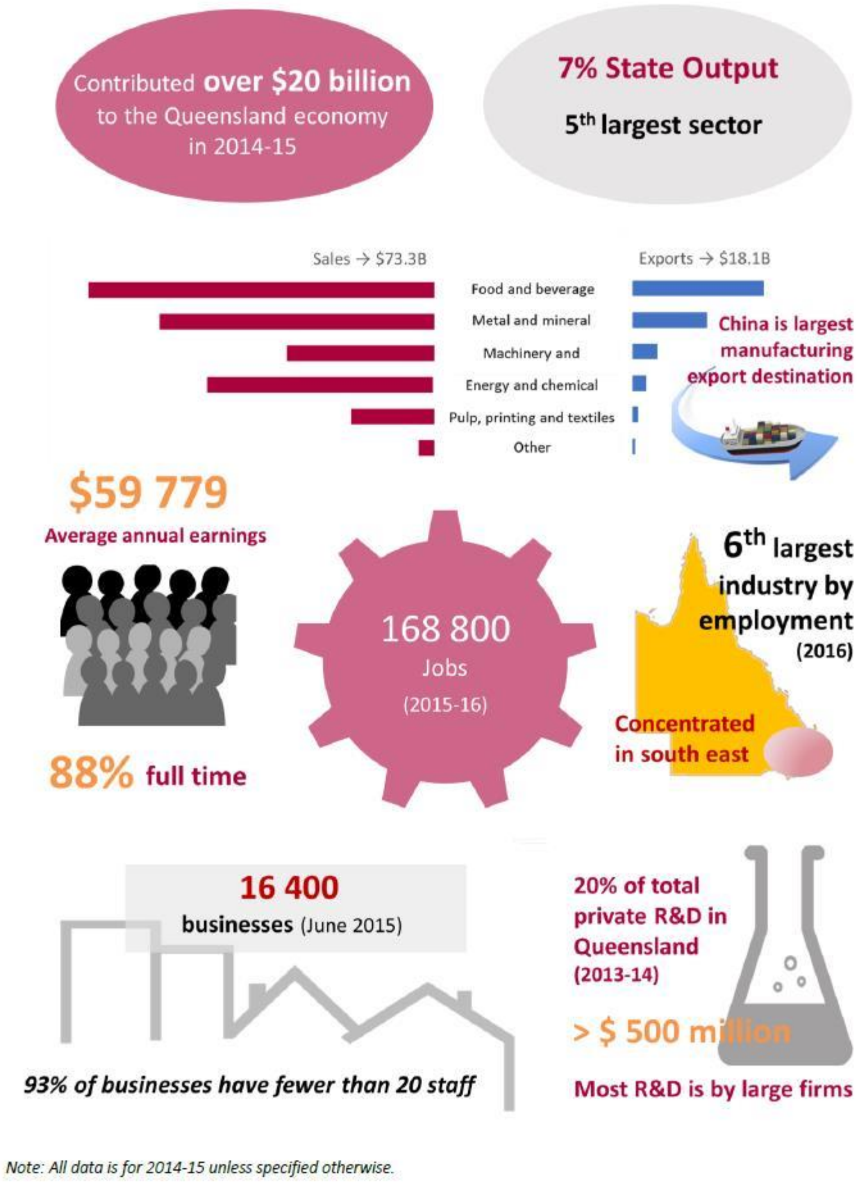

Figure 4: Snapshot of Queensland Manufacturing (QPC, 2016)

4.2 Global Competitiveness

The Global Competitiveness Index assesses the competitiveness landscape of 138 economies, providing insight into the drivers of their productivity and prosperity. The Australian Industry Group undertakes surveys and collects data for the Australian contribution into this global research. The results of the 2016/17 GCI show Australia as ranking 26th in the world, slipping 3 places from the previous year. The top 5 ranked countries are Switzerland, Singapore, United States, Netherlands and Germany, with New Zealand ranking 13th and China 28th. Ongoing deficiencies for Australia are government procurement of advanced technology (63rd), lower company spending on R&D (24th) and university-industry collaboration in R&D (33rd), although Australia does better on the quality of our scientific research (12th) (Manufacturers Monthly, 2016). These relatively low-ranking factors indicate limitations to the capacity for manufacturers to make improvements to their competitiveness that are also sustainable.

The Australian Manufacturing Growth Centre Sector Competitiveness Plan (AMGC, 2017) discusses these issues with recommendations for a way forward. The plan identified 'knowledge priorities' via industry analysis and consultation, a literature review and surveys. The research identified knowledge gaps in the fields of robotics and automated production processes; advanced materials and composites; digital design and rapid prototyping; sustainable manufacturing and life cycle engineering; additive manufacturing; sensors and data analysis; materials resilience and repair; and precision manufacturing; among several others. Further information on these fields and how some companies have addressed them is included throughout this literature review.

4.3 Energy Security and Pricing

Queensland manufacturers source their energy from natural gas (28%), petroleum products (23%), electricity (19%), black coal (16%) and the remaining 14% from a mix of LPG, diesel oil, fuel oil and wood / wood waste (Figure 5). Ninety two percent of Queensland electricity is generated from non-renewable energy sources of coal (65%) and gas (27%) (DIIS, 2016a). Energy security and pricing is particularly pertinent with respect to encouraging sustainable use of energy resources.

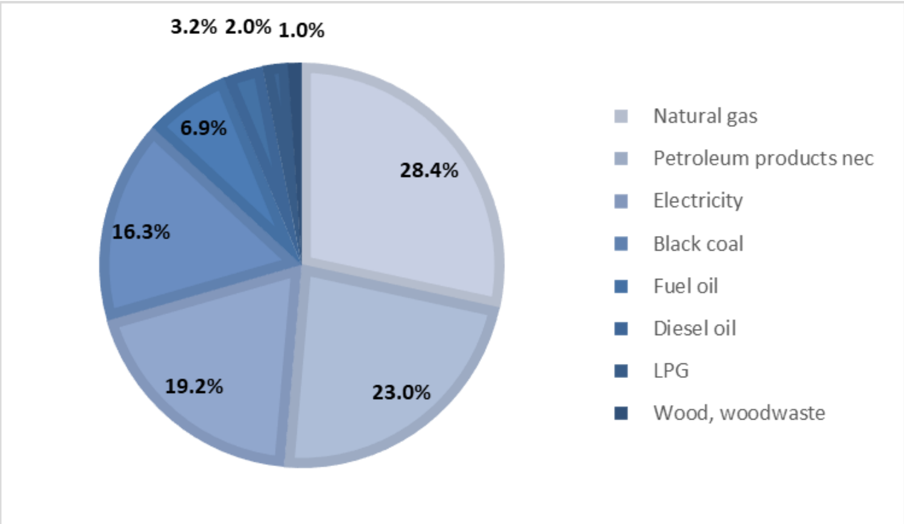

Figure 5: Energy sources – Qld Manufacturers, 2014-15 (DIIS, 2016b)

Australian manufacturers, including those in Queensland, have seen their electricity supply cost doubled in the seven years from 2007-08 to 2014-15 (Figure 6) with expectation of continued price increases (Wood, 2017) (CCIQ, 2017a). Contributing factors to the rise in electricity prices are decreasing demand in grid electricity (which increases fixed and variable supply costs for a smaller pool of customers), increase in electricity sourced from renewables and closure of a number of coal-fired power generators which has impacted on the capacity to supply power to the national energy market (Wood, 2017). Wholesale gas prices have also tripled over the last 5 years (Figure 7) due to LNG exports impacting on domestic supply.

In addition, energy security is a serious concern with the ability of the National Energy Market to consistently supply power being in question, along with many manufacturers being unable to confirm future gas contracts (Wood, 2017). There is a chicken and egg scenario impacting on demand and pricing with small businesses indicating that, as a result of high electricity prices, they are investigating alternative energy options (CCIQ, 2017a). Australia has a national renewable energy target of 20% by 2030, and this will also help drive growth in sustainable energy supply in manufacturing (CEC, 2017). Queensland has a state based target of 50% renewables by 2030 (DEWS, 2017).

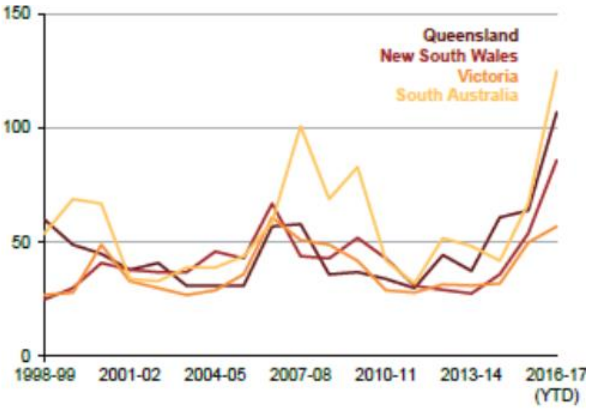

Figure 6: Annual volume weighted average spot electricity prices $/MWh

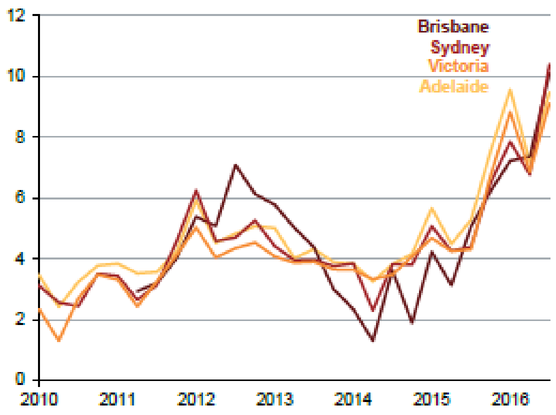

Figure 7: Quarterly gas prices, $/GJ (Wood, 2017)

4.4 Climate Policy

In 2015, greenhouse gas emissions from the manufacturing sector accounted for 20.4% (109.8 Mt CO_{2-e}) of Australia's total emissions (538.2 Mt CO_{2-e}). In Queensland, manufacturing accounted for 17.6% (26.7 Mt CO_{2-e}) of Queensland's total emissions (152.1 Mt CO_{2-e}) (DEE, 2017b).This excludes transport. Manufacturers are keen to see stable Climate Policy with uncertainty impacting their business decisions (CMI, 2016). In a recent survey of 208 large emitters, 78% of respondents agreed or strongly agreed that consideration should be given to expanding the threshold of coverage for entities under the mechanism (CMI, 2016).

The Australian Government is currently conducting a review of Climate Policy (DEE, 2017c). The associated discussion paper lists emission reduction policies applicable to industrial sectors. Many of these are only applicable to large scale emitters and are out of reach of small to medium businesses. Voluntary policies and programs applicable to Queensland SME are shown in Box 4.

Box 4: Voluntary Climate Programs applicable to small to medium business

National Energy Productivity Plan – The NEPP committed to develop further measures to improve energy productivity in the industrial and resources sectors. Measures in early-stage development promote voluntary action and support research, for example, helping businesses self-manage energy costs through information, capacity building and improved services, recognising and promoting business leadership and best practice and voluntary commitment programs. The NEPP includes a target of a 40% improvement in energy productivity by 2030. www.environment.gov.au/energy/national-energy-productivity-plan

Clean Energy Innovation Support - The CEFC is working with the private sector to deliver capital investment solutions to reduce emissions from industrial processes. ARENA can fund research and development to assist with reducing emissions from the industrial sectors from renewable energy. See www.cleanenergyfinancecorp.com.au/ and www.arena.gov.au/about-arena/

National Carbon Offset Standard - A National Carbon Offset Standard is available for manufactured products to demonstrate climate leadership. Carbon neutral products can create brand differentiation and gain a competitive edge, for example through carbon-smart procurement chains. www.environment.gov.au/climate-change/carbon-neutral

CCIQ ecoBiz – The Chamber of Commerce and Industry Queensland (CCIQ) is the provider for the state funded program, ecoBiz. This program is aimed at assisting businesses to reduce their electricity, water and waste costs. The program provides one on one coaching, worksite audits, webinars and benchmarking. www.cciqecobiz.com.au

In a response to the Climate Policy review, CCIQ believes that a barrier for small businesses to reduce their emissions is the initial capital expenditure required to implement emissions and cost reducing initiatives and so financial support should be made available in the form of grants, rebates and/or tax deductions for emission reducing investment (CCIQ, 2017b). Section 5.3 lists some of the government based sustainability programs available in Australia which include various forms of industry assistance.

4.5 Water security and pricing

Water security can be a significant issue for Queensland manufacturers, particularly those in regional areas. As at 25 May 2017 there were a total of 32 out of about 78 councils and 3 part council areas drought declared, with 52 Individually Droughted Properties in a further 7 council areas (Figure 8) (DSITI, 2017). In Brisbane, water supply prices have increased more than three-fold since 2008 from $1.27/kL (Warnecke, 2008) to $4.29/kL (QUU, 2017). Arguably, water security, rather than pricing is a more significant driver for water conservation by manufacturers (Case Study 1).

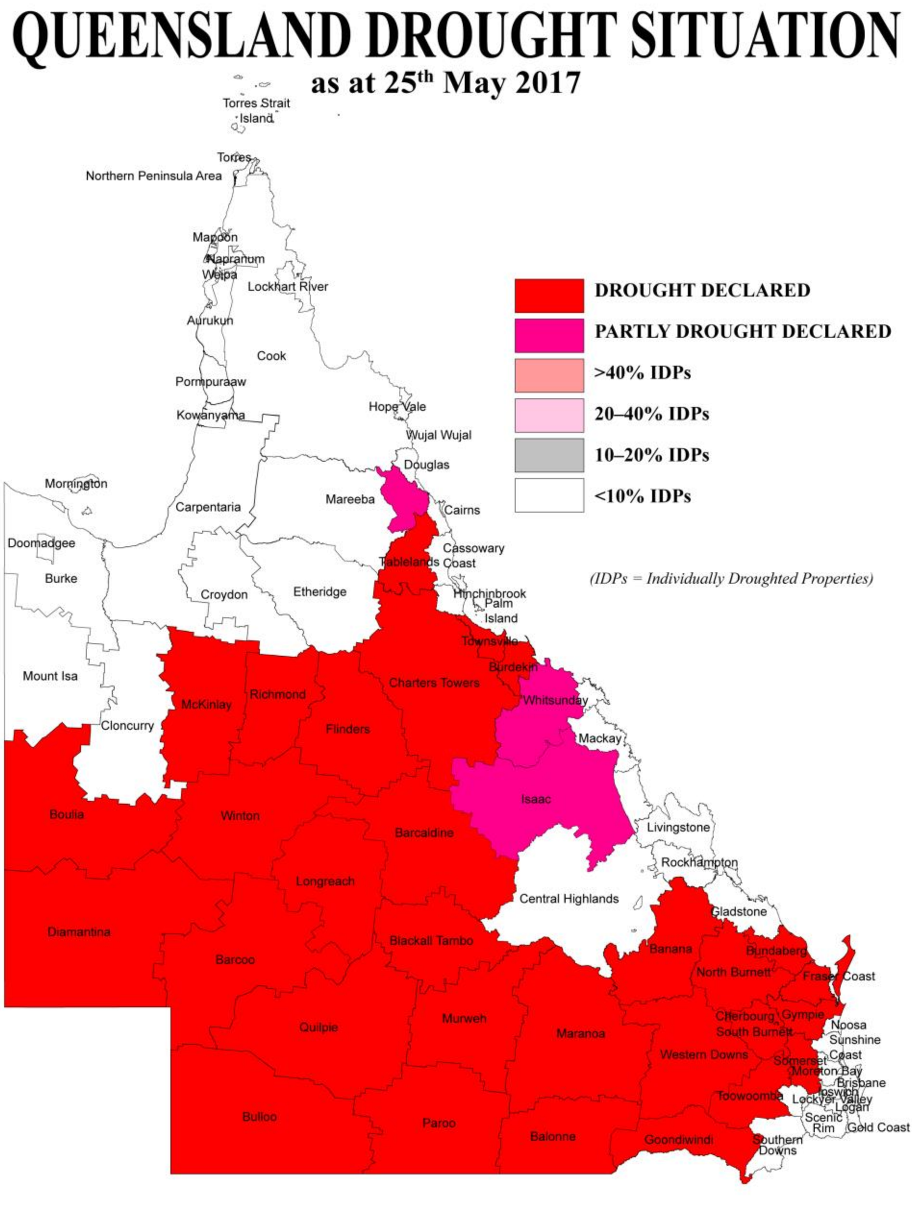

Figure 8: Drought affected areas in Queensland (DSITI, 2017)

In 2014/15, Queensland manufacturers used 5% (187 GL) of the total water consumption for the state with the largest consumer being the agriculture sector (60%). Water consumption by the manufacturing sector has increased by 48% since 2012/13 (Figure 9). There is insufficient information provided in the literature to explain the variation in water consumption since 2009/10 and what has contributed to this trend. Water consumption figures include self-extracted (e.g. rivers, lakes), distributed, regulated discharge and reuse (includes stormwater) (ABS, 2016b).

Case Study 1: Water security concerns trigger action for Dalby Bio-Refinery Ltd (DBRL)

In 2010, due to water supply concerns in the Dalby region, DBRL switched from using mains potable water to Class A+ recycled water. The Dalby township's wastewater treatment plant was upgraded to supply this water in a project jointly funded by the state government, the council, and the bio-refinery. DBRL now receives around 1ML of recycled water daily. This has also enabled 20% of Dalby's potable water supply to be returned to town's residents to help it deal with future growth and extended drought periods (DSD, 2017h).

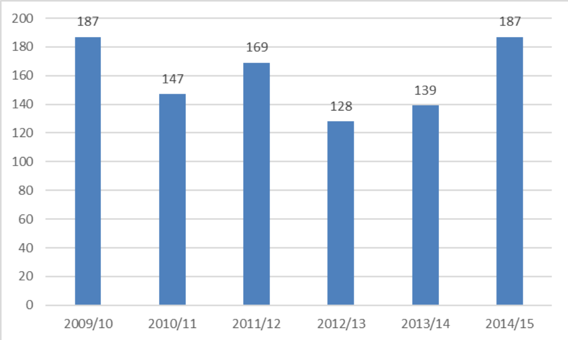

Figure 9: Water consumption – Qld Manufacturers (ABS, 2016b)

4.6 The digital economy

The digital economy and its impact on manufacturing is known as the 'Fourth Industrial Revolution' or Industry 4.0 (Box 5). It is a trend that is permeating and impacting all areas of business including financial transactions, business operating processes and advanced manufacturing processes. As cited by (Stock, 2016), 'it is based on the establishment of smart factories, smart products and smart services embedded in an internet of things and of services (Box 6) also called 'industrial internet'.

The Queensland Government has produced the Queensland Digital Economy Strategy and Action Plan (DSITIA, 2014) which sets strategic objectives for Queensland to uptake digital technologies and skills across the community and in business.

The digitisation of manufacturing and business processes will revolutionise the way manufacturers do business with great potential to improve efficiencies. Sustainable manufacturers are those which will embrace and capitalise on the digital economy from simple measures such as digital accounting systems which can reduce office paper use to more advanced examples such as real time monitoring to reduce energy peak demand and resource use or the use of 3D printers block chain and smart contracts (See Section 8.2). Table 3 shows examples of how digitisation can help the move towards more sustainable manufacturing.

Box 5: Industry 4.0

Industry 4.0 (the 'fourth industrial revolution') refers to the current trend of improved automation, machine-to-machine and human-to-machine communication, artificial intelligence, continued technological improvements and digitalisation in manufacturing. This trend is enabled by four key drivers:

1. Rising data volumes, computational power and connectivity.
2. The emergence of analytics and business-intelligence capabilities.
3. New forms of human-machine interaction, such as touch interfaces and augmented-reality systems.
4. Improvements in transferring digital instructions to the physical world, such as robotics and 3D printing (DIIS, 2017).

Box 6: The Internet of Things

Internet of things (IoT) is the inter-networking of physical devices, vehicles (also referred to as "connected devices" and "smart devices"), buildings, and other items embedded with electronics, software, sensors, actuators, and network connectivity which enable these objects to collect and exchange data.

Table 3: Example sustainability impacts of Industry 4.0

Sustainable Manufacturing Elements	Example of digitisation	Environmental/Social Impact
Value Chain	• Smart grids, micro grids, smart meters leading to greater uptake of renewable energy and improved monitoring of resource use. • Solar trading. • Smart logistics. • Product labelling (QR codes) showing product history.	• Reduced carbon emissions. • Reduced losses e.g. quicker response to water leaks and excessive use. • Reduction in food waste due to reduced stocktake/order error. • Reduced transport emissions. • Labelling leads to greater consumer power and ability to make green choices.
Circular economy	• Waste databases and websites which efficiently link and track wastes and potential users. • Digital tracking of hazardous wastes • Improved knowledge of waste quantity, type and location.	• Faster development of the circular economy model. • Reduced resource intensity through greater recycling. • Reduced waste, beneficial reuse.
Product design	• Improved process modelling software capability, costs and access. • Improved 3D printing capability, costs and access.	• Reduced energy, water and waste through improved design.
Manufacturing process	• Energy and water management systems utilising smart meters. • Human-machine interfaces and apps which feature real time monitoring and operator alerts. • Machine sensors which alert of wear and possible breakdowns. • Use of robots.	• Real time monitoring of resource use. • Alerts which prompt quicker corrective action to issues. • Reduced resource use through vastly more efficient manufacture.
Organisation	• Digitised training modules. • Social media with instant connection to customers and suppliers.	• Increased capability of staff minimising resource use. • Greater ability for customers to make green choices.

5 Drivers and Barriers

Key Messages:

- There are common drivers and barriers of sustainable manufacturing many of which are applicable/experienced by Qld manufacturers.
- Unlike large business, Queensland SMEs have no compulsory requirement to consider or report on energy use, greenhouse emissions or other resource consumption.
- There is low incentive to encourage waste reduction and recycling amongst Qld business. Queensland is the only other state (next to Northern Territory) that has not introduced a landfill levy to drive recycling.
- There are fewer sustainability programs and/or financial incentives for SMEs in Queensland compared with other Australian states.

There are many well documented drivers and barriers for achieving sustainable practices and some common themes are raised below. Many of these are dependent on company location and the existing support that is available. For example, there is different support provided to companies in regional or metropolitan areas and in different states of Australia. The identification of these barriers and drivers can assist in the development of programs, policies and other instruments by governments, industry groups or manufacturers themselves in order to best promote sustainable practices.

5.1 Common themes

Manufacturers, by their nature, utilise significant amounts of resources and are capable of generating significant amounts of waste and pollutants. While not always water intensive, advanced manufacturers are generally energy intensive industries often employing state of the art precision equipment and technologies. Developing new markets and products via advanced manufacturing can also mean greater consumption of potentially scarce resources which may be exacerbated by trading in a global economy. What is important for the sector is to strive towards decoupling economic growth from environmental degradation. The drivers and barriers for sustainable manufacturing are well researched. Typical themes cited in literature for advanced manufacturers are shown in Table 4.

Table 4: Drivers and barriers for Sustainable Manufacturing

(Bhanot, 2015) (Nordin, 2015) (ACCSR, 2017)

Drivers	Barriers
• Market pressure • Government Regulation • Government assistance such as grants and subsidies • Management Commitment • Economic benefits • Lower manufacturing cost • Environmental and Corporate Social Responsibility • Investment in innovation/technology • Stakeholder pressure • Reduced risk	• High capital cost for environmental improvements • Competing needs for investment of funds • Prioritisation of more pressing business issues • High cost of meeting regulations • Lack of awareness of sustainability concepts • Lack of ideas/knowledge of what to do • Lack of customer/consumer demand • Lack of employee and management commitment • Cost of training • Lack of funds • Lack of government regulation or assistance • Lack of community and/or shareholder demand • Incompatibility between management and manufacturing system • Negative attitude/scepticism towards concepts • Scepticism towards new technologies

The size of SMEs is also considered to have a significant effect on the adoption of environmental practices with larger businesses more likely to be proactive due to greater resource availability (Bos-Brouwers, 2010) (Salimzadeh, 2013). Barriers for SMEs include lack of capital, lack of technical skill (e.g. no specialist staff), insufficient information to confidently make informed decisions, lack of human resources; and the prioritisation of more pressing business issues (Meath, 2016). These barriers, all of which are identified in Table 3 are compounded by the size of SMEs. Meath et al also reports an overlap in SMEs capability for organisational change and the ability to adopt technological innovations with similar sets of challenges to adoption of environmental practices. Another point raised is the importance of identifying barriers early in the design of any programs, discussed further in Section 6.1.

While the drivers and barriers listed in Table 4 are frequently identified in literature, a number of more recent research papers have attempted to analyse and rank these in order to inform strategies for addressing them. Three such papers are discussed below:

In order to compare and analyse ideas on the drivers for sustainable manufacture, Bhanot et al, 2015, analysed survey results of 106 researchers from around the world, including Australia, Germany, the USA and India along with 99 predominantly Indian industry professionals (Bhanot, 2015). Statistical analysis was undertaken on the results indicating a close consensus for the top 3 drivers of 'lowering manufacturing cost’; 'investment in innovation & technology' and 'market pressure' and top 2 barriers of 'lack of awareness of sustainability concepts' and 'costs too high'. Interestingly, perhaps unsurprisingly, there was lower consensus regarding government promotions and regulations with researchers considering it to be an important aspect of for effective implementation of policies and rules whereas industry felt burdened with rules and regulations and did not believe they were of any help in improving their performance.

Research undertaken by Fargani et al also identified the themes shown in Table 4, with the top five drivers being:

- Competitiveness - better process performances, higher product quality, higher efficiency, competing with best practices in sector.
- Incentives - investment subsidies, awards, R&D support, tax exemptions, duty free imports.
- Organizational resources - availability of financial resources and skilled staff to implement programs.
- Technology - opportunities, advantages and performance of available green and efficient technology.
- Cost savings - reduction of energy consumption, reduction in virgin material use, less waste (Fargani, 2016).

The study goes further to undertake statistical analysis of selected factors that underlie the drivers and determined that the level of implementation of six sigma (a disciplined and methodical, statistical approach to process improvement); the level of supply chain integration; and the level of implementation of lean manufacturing; each coupled with additional environmental impact tools, deserved special attention.

In a third study, Shankar et al researched the drivers for combining advanced manufacturing

Case Study 2: Identification and ranking of sustainable manufacturing drivers in a tyre manufacturer

Shankar et al applied their methodology of AHP and MCDM to a leading South Indian tyre manufacturer that has begun to lose market share and wanted to improve organisational culture to realise more intangible benefits rather than just fiscal performance. The results indicated that, the top 3 drivers for sustainable manufacture were:

1. achieving and maintaining product quality,
2. market capability
3. financial benefit.

Environmental and social related factors were given a lower ranking e.g. green purchasing (ranked no. 7), optimising resource use (8), green innovation (9) employee welfare (13) with customer expectations rated the lowest (15). The higher rankings of fiscal factors indicate that, in this example, these are still a major focus (Shankar, 2016).

with sustainable strategies (Shankar, 2016). The paper describes a method to identify and rank sustainable manufacturing drivers using an analytical hierarchy process (AHP), which is a multi-criteria decision making (MCDM) approach. The application of this method is shown in Case Study 2. A useful outcome from this paper is the methodology for identifying and ranking the drivers which can vary according to geographical location and industry sector and which could be adopted at a company or government level e.g. as part of the design of sustainability programs (See Section 5.3).

5.2 The Queensland Context

There are a number of items, not all of which are specific to Queensland, which arguably hinder small to medium manufacturers from becoming more sustainable. These are to do with government policy and encouraging industry to be involved in government programs. It is acknowledged that industry generally does not welcome additional layers of regulation and so encouraging sustainability is a balance of push and pull factors.

Reporting Resource Consumption and Waste

A first step in improving resource efficiency is to establish a baseline of resource consumption. Many manufacturers fail even to do this. As in all Australian states, there is no formal requirement for SMEs to consider or report the level of resource consumption or to develop key performance indicators or set targets and it is purely a voluntary measure.

The National Greenhouse and Energy Reporting scheme (NGERS) requires that organisations that meet a facility threshold or corporate group threshold must annually report their energy consumption, generation and greenhouse emissions. There is also a threshold for which companies must undertake public reporting. However, the NGERs scheme is a requirement for larger energy users and emitters and generally does not capture the many small to medium enterprises which make up over 90% of the total number of Queensland businesses.

Even for large enterprises, there is no requirement to report on water consumption or waste generation. During the drought period of the mid-2000, there was a requirement for large Queensland water users (over 10ML per annum) to develop Water Efficiency Management Plans to outline how a 25% water reduction would be achieved. However, this scheme has ended and there is no further regulatory requirement. The Victorian Environment and Resource Efficiency Plans (EREP) (Vic. EPA, 2013) ran from 2008 to 2013 and required large water and energy users to identify and implement resource efficiency actions. The program was discontinued due to duplication with the NGERs program.

Drivers to minimise waste

There is essentially a lack of a driver to encourage Queensland manufacturers to increase the level of recycling. This is illustrated in in a review by (Ritchie, 2016) in discussing a landfill levy as a proven driver in other states (Box 7).

Box 7: State of Waste 2016 – current and future Australian trends

(Ritchie, 2016) describes current and future trends for recycling in Queensland:
'*Aside from the Northern Territory (which generates 1% of Australia's waste), Queensland is the only other state that has not introduced a landfill levy to drive recycling. Figure 10 shows landfill levy prices for all states except ACT, Tas and NT.*
A levy was introduced temporarily for 18 months over 2010/2011. The effect of SE QLD's low landfill price has been 477,000 tonnes of waste (2014) and 398,000 (2015) travelling (by road and rail) from NSW and VIC, to QLD.

The NSW Government needed to introduce the "Proximity Rule" to try to slow the flow of waste to cheap QLD landfills. In NSW, the landfill levy raises more than $600 million per year and the government has used these funds to establish the $465.7 million infrastructure and recycling grants program. These funds are granted to private companies and Councils (up to $5 and $10 million respectively) for new or improved recycling infrastructure.

In addition, the Clean Energy Finance Corporation (2015), estimated that new Energy from Waste and biogas projects "could avoid 9 million tonnes of CO_{2-e} each year by 2020, potentially contributing 12% of Australia's national carbon abatement".

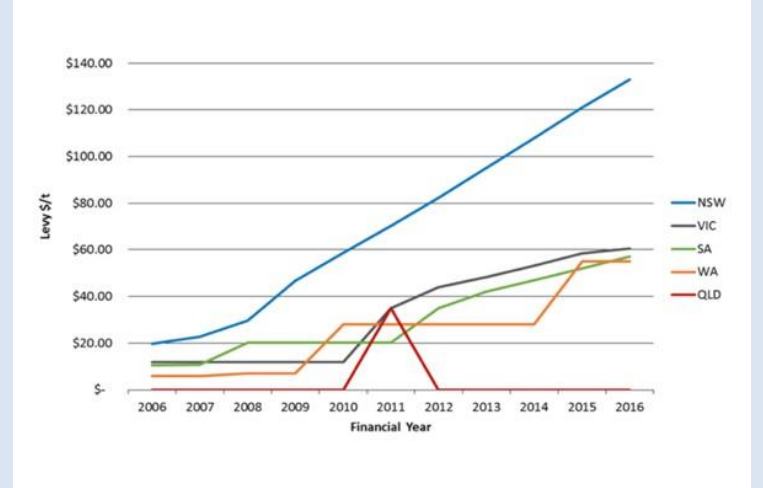

Figure 10: National Landfill Levies (excluding ACT, TAS and NT). Cited by (Ritchie, 2016).

No state based drivers for energy productivity for SMEs

Australia's energy productivity is 14% lower than the Group of 20 world economies (G20) average, and is the second lowest amongst the developed nations in the Group. There is a National Energy Productivity Plan which has a target of a 40% improvement in energy productivity by 2030 (COAG, 2016). Energy Productivity for the country is measured as a ratio of Economic Output (GDP) and energy used (PJ). For a manufacturing company, it could be measured as energy used per unit of production output.

The industry-led Doubling Australia's Energy Productivity (2xEP) Steering Committee has developed and published collaborative roadmaps on how to double energy productivity in the manufacturing, agriculture, mining, built environment and passenger transport sectors. The manufacturing sector has a voluntary target of doubling its energy productivity by 2030 and the roadmap document has a range of policy and program recommendations including establishing a voluntary commitment (2xEP Challenge), building business capacity and accelerating investment in energy productivity technologies through an Energy Efficiency Certificate Trading Scheme (See Box 8) (A2EP, 2016). It is noted that there are no similar schemes operating in Queensland.

Box 8: Energy Efficiency Certificate Trading Scheme

From A2EP:
Currently there are separate energy efficiency white certificate schemes operating in NSW (ESS), VIC (VEET), ACT and SA (REES). These schemes allow energy users to generate tradable certificates for verified energy saving activities, which they can sell to energy retailers with energy saving obligations. The schemes are currently inconsistent with varying rules and methodologies. While there have been recent efforts to achieve some consistency between some states, there are serious limits within some schemes preventing recognition of a range of meaningful energy reduction initiatives. 2xEP recommends the establishment of a nationally available white certificate scheme based on the following principles:

- Individual states may still administer the programs and decide whether to join, but the rules and methodologies would be the same regardless of location.
- The scheme would be available to anyone that contributes to them.
- The scheme would be based on the NSW model, but further enhanced to ensure they deliver effective market transformation in all the market sectors they impact.
- Exemption arrangements will be needed, based on those in NSW and Victoria, for energy intensive trade exposed industries and large energy users (A2EP, 2016).

Investment in enabling, green infrastructure

Investment in enabling infrastructure is highlighted as a priority in securing a future for Queensland's manufacturing industry (CCIQ, 2017a). Sustainability aspects should be considered in the investment of such infrastructure, for example, development of green buildings and facilities (Case Study 3), ICT capability (see Section 0) and transport infrastructure that supports new generation transport e.g. electric vehicles (Case Study 4).

Case Study 3: First Green Star Rated Manufacturing Facility in Australia

The Kingspan Manufacturing Facility in Somerton, Victoria, is Australia's first Green Star Rated Manufacturing plant. The 14,000 m^2 facility was designed using sustainably sourced building materials, a 750kW solar system, a rainwater harvesting system and energy renewing ventilators providing double the minimum fresh air requirement.

The facility also utilises Kingspan technology, including a smart lighting system and high-performance insulation.

Kingspan places a high priority on net zero energy manufacturing and aims to meet the energy needs of its 100-plus factories around the world through renewable energy by 2020. It currently meets 60 per cent of energy requirements. The plant construction was awarded a $3 million grant from Melbourne's North Innovation and Investment Fund, set up by the Victorian Government in partnership with the Federal Government and Ford Australia (Stefanovic, 2017).

Case Study 4: Tritium car charging station

Australia's first commercial electric vehicle (EV) charging stations are being rolled across five sites in Queensland, using the state's home-grown Veefil fast charger technology by Brisbane company Tritium. The stations are being developed by energy retailer Locality Planning Energy with drivers only paying for the electricity they use making them as cost effective as home charging. The stations offer recharging EV batteries at a rate 25 times faster than a home charger. This is the first time in Australia stations will sell electricity for a rate cheaper on a km by km basis than fuel for a traditional combustion engine vehicle.

Drivers can check availability and book online. With a station going in at Noosa Heads it is possible for EVs to travel between Brisbane and Noosa (140km) with further journeys possible when stations are developed. Tritium is currently developing an even higher powered Veefil unit that will give EVs a 150km range for 10 mins of charging. (Vorrath, 2016). .

5.3 Sustainability Programs

Sustainability programs (policies and instruments) are generally developed by government as either a carrot or stick method to assist companies to become more sustainable. Successful programs developed for large company often do not translate well to the SME environment and therefore, tailoring of programs or developing programs specifically for SMEs is necessary (Bos-Brouwers, 2010). In the review of the Queensland based, ClimateSmart Cluster Program, (Meath, 2016), indicated that drivers and barriers need to be identified at the program design stage and, where possible, individual and flexible solutions provided for each. Barriers can arise at various stages of a program, for example, as a result of staff changes and loss of a 'champion' or due to other business priorities that might arise in the duration of a project. (Meath, 2016) presents a model for improving the adoption of energy efficiency measures in small- and medium-sized enterprise (SME) energy efficiency programs (Figure 11). This model could be adopted for sustainability programs generally.

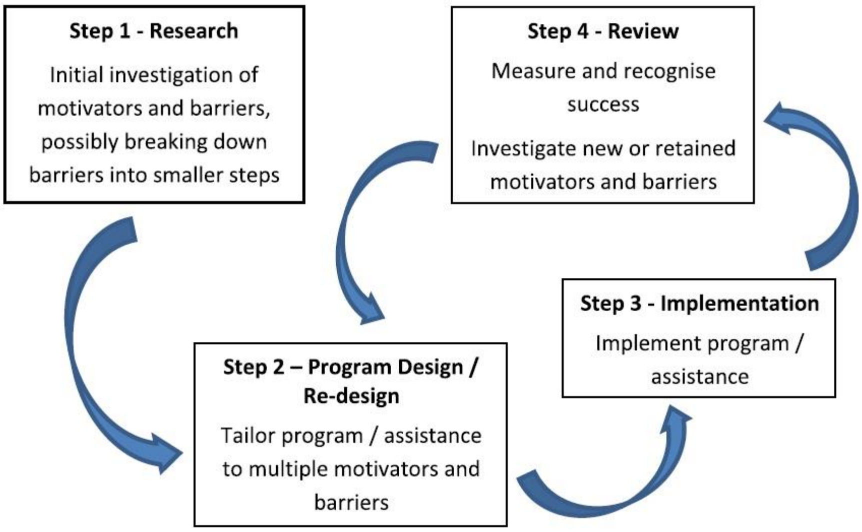

Figure 11: Improving the adoption of energy efficiency measures in SME energy efficiency programs (Meath, 2016).

A 2012 study by Carter et al investigated the effectiveness of different government sustainability policies. They found (Carter, 2012):

- Government rebate systems such as on rainwater tanks or solar hot water systems do encourage uptake of technologies which lead to improved water and energy efficiency. However, these schemes can undermine a polluter-pays principle and create inefficiencies if the scheme encourages consumers to opt for the cheapest system rather than a more expensive yet more efficient system which could lead to better environmental outcomes in the long run. It also found that if schemes are developed and implemented too hastily unintended and serious consequences may result so time to consider all consequences of a scheme should be taken before they are implemented.
- Tightly focussed small scale programs can be very effective. A state-wide approach to ZeroWaste by the South Australian government (now called Green Industries SA) has brought results by working with local councils, businesses and industry to support projects that improve infrastructure, technology, waste management systems and subsequently, resource efficiency, recovery and recycling. Although strongly committed to recycling, ZeroWaste focusses on improving waste management by adopting a preferred method of reuse, reduce and avoid in preference to recycling. South Australia currently diverts 79% of their waste from landfill compared with Queensland which recovered on average 48% of general waste (SOE, 2017). For Queensland, this is made up of municipal (33%), commercial and industrial (47%) and construction and demolition (50%) (DEHP, 2016b).
- Local governments and councils are proactively engaged in implementing sustainability programs and are an important resource in rolling out state or federal sustainability policies. However, they also need the funding back up to roll out these policies or they are likely to fail or be a weaker version.
- Governments have embraced sustainability without really understanding the concept and rarely releasing a definitive statement of what it means or how it can be implemented effectively.
- Traditional reliance of market-driven, economic-centred approaches to government result in chronic disproportionality between sustainability pillars. There is a strong lean towards environmental pillar as long as it also shows a strong economic benefit, often with the social impact ignored or not seen as relevant.

- Policy can be effectively implemented when there is a common goal and operating within a well-documented and cooperative funding model.

Germany is at the forefront of environmental implementation whilst retaining economic growth. This has been achieved over several decades of targeted policy design and implementation. Environmental protection policy has been adopted as mainstream in all areas of economic activity. They have (Buehler, 2011):

- Adopted an Energy Concept document in September 2010 defining ambitious medium and long-term targets with renewable energy accounting for at least 80% of electricity consumption by 2050. Increased taxation on energy (electricity and fuel) has resulted in overall greater efficiency through the economy leading to lower energy costs for households and industry. In addition, export of energy efficient technology has increased and the incentive to reduce energy use has helped the German economy to become more resilient.
- Promoting renewable energy has led to an increase in renewable-energy-related jobs employing around 340,000 people in biomass, wind and solar power. A feed-in tariff promotes renewable energy and efficiency technologies including combined-heat-and-power plants, cap and trade system and energy tax reform. The strong environmental policies drive modernisation and create new market opportunities through export of energy efficiency technological solutions leading to a strong industry sector.
- Encouraging Green infrastructure such as green roofs, green facades and permeable pavements have led to the development of new technologies through the support of a range of incentives and requirements at multiple levels of government.

A list of some of the current Australian national and state based programs is provided (Appendix A) all of which are available to SMEs. Each of the programs is voluntary and they are generally focussed on a mixture of energy and water efficiency and waste reduction. Several programs in NSW, Victoria and South Australia provide financial incentive i.e. grants/matched funding ranging from a few thousand dollars to up to $300,000, to undertake resource assessments and implement efficiency projects.

Several of the states also offer some interesting financial models to encourage resource efficiency as follows:

Environmental Upgrade Agreements (EUA)

EUAs have been adopted by a number of local governments including the City of Melbourne and City of Sydney. The EUA allows for building retrofits which reduce resource use in buildings, particularly energy. Environmental Upgrade Agreements are a method of financing environmental upgrades for older buildings. Loans are provided by financial institutions. The loan is repaid via resource savings (typically energy) and repayments are made via a levy on council rates. The council then repays the financial institution. Retrofits have been made to over 540 buildings in Melbourne since 2010 (Blundell. L, 2014) (City of Melbourne, 2017). This method could potentially be adopted to encourage upgrade of manufacturing facilities.

Energy efficiency schemes (energy certificates)

Energy efficiency/saver schemes are being offered by NSW, Victoria and South Australian state governments. For the Victorian Energy Efficiency Target (VEET) scheme, a liability is placed on large energy retailers to surrender a specified number of energy efficiency certificates each year. Certificates are created through abating one tonne of greenhouse emissions. Abatement activities relevant to manufacturers include building retrofits, lighting upgrades, air conditioning upgrades, trigger and spray nozzle upgrades and installation of efficient motors. A list of registered products and prescribed activities is provided on the VEET website (VEET, 2017). Box 8 discusses recommendations for the rollout of a national scheme.

6 Environmental Sustainability in Action

Key Messages:

- To improve sustainability of products, manufacturers need to analyse the whole of the supply chain to find opportunities rather than just the boundary of their manufacturing facility.
- Strategies such as Life Cycle Assessment, Product Certification, Green Chemistry and Design for Remanufacture can be used to improve product design and reduce environmental impacts by focussing on the whole of product life.
- Many Advanced Manufacturing methods and technologies, e.g. forming, subtractive and additive processes, are significantly more energy intensive than conventional processes such as conventional bulk-forming. However, there are many opportunities to reduce energy consumption.
- There are opportunities for all manufacturers to reduce resource consumption through improving water, energy, material and waste efficiency.
- There are various co-regulatory, accredited and non-accredited Product Stewardship Schemes operating throughout Australia and manufacturers can participate in and learn from these.

Manufacturers have opportunities to improve their environmental performance throughout a product lifecycle through analysing design, inputs, manufacturing processes, end uses and disposal (OECD, 2011). These stages are discussed below.

6.1 Product Design

Sustainability starts during product design. Consideration of embodied energy, greenhouse gas, water and material parameters at the design stage can help reduce the use of:

- materials
- hazardous materials
- non-renewable materials, and even
- difficult to source or expensive materials.

Benefits to the manufacturer include (OECD, 2011):

- reduced expenditure on materials,
- reduced costs related to handling, storage and treating harmful substances, and improved worker safety,
- a lower regulatory compliance burden, and
- reduced waste disposal requirements.

There are numerous approaches and frameworks for incorporating sustainability into product design. Many have common principles as discussed in the following sections.

6.1.1 Product Life Cycle Assessment (LCA)

LCA (or cradle to grave) is a systematic approach that assesses the environmental aspects and potential impacts of a product, process or service throughout its life cycle (ALCAS, 2015). LCAs quantify various resource use and impact indicators including greenhouse emissions, energy and water consumption, eutrophication potential, land use and more.

Life Cycle Assessments are rigorous and useful where a high level of accuracy is required. They are however, time-consuming and expensive. LCA's are typically conducted by experienced practitioners and findings may be peer-reviewed. There are a number of LCA software tools which are available to assist practitioners (refer to Box 9). Tools often use publicly available inventory data or otherwise product-specific data or a combination. The two most commonly used tools in Australia are SimaPro and GaBi. GaBi is suitable for beginners as well as experienced practitioners. It also integrates social and economic impacts (Sustainability Victoria and PACIA, 2008).

In some cases, the manufacturer's design objectives may be to only make a quick comparison of environmental impacts across the life cycle. In this case simpler methods such as Life Cycle Maps, Sustainability Matrix and other streamlined LCA tools may be more suitable (Case Study 5). Streamlined LCA tools have been specifically developed, usually with a specific purpose in mind. In Australia, the Packaging Impact Quick Evaluation Tool (PIQET)™ is an on-line life cycle evaluation tool used for designing packaging systems. Greenfly is an on-line life cycle modelling and eco-design tool that also provides suggestions on how to reduce the environmental impacts of the product being assessed (Sustainability Victoria and PACIA, 2008).

Box 9: Directory of LCA tools

The International Society of Sustainability Professionals and American Centre for Life Cycle Assessment have developed a Directory of Sustainability Life Cycle Assessment Tools that addresses the best application of a wide range of tools (industry type, product, or geographical area), type (modelling or a database) and features.

The directory also includes information such as available support available, operating system (PC/Windows, Mac, web-based, or mainframe), tool language, focus (environmental, social or economic performance) and cost (Hitchcock, 2011).

Case Study 5: Use of Life Cycle Assessment and Costing Tool, Toyota Motor Corporation

Toyota used the LCA tool EPIC determine if changing the packaging of floor mats during shipping would result in environmental and economic savings. EPIC is a full Life Cycle Assessment and Costing tool that produced results that Toyota's engineers could incorporate into the packaging design process.

The new packaging change involved replacing expendable shipping modules made of cardboard, wood, and nails with reusable shipping modules made of high density polyethylene plastic which were shipped back to the supplier after use.

The results indicated that the new packaging system reduced natural resource depletion by 54%, and global warming by 41%. The system also reduced costs by 55%, saving $0.72 per floor mat (Early, 2009).

In 2009, the EU Eco-design directive established a framework for energy-using and energy-related products (such as windows and insulation) manufactured or imported and sold in its 28 Member States which collectively are responsible for around 40% of all EU greenhouse gas emissions. The European Commission estimates that around 80% of a product's impacts are decided during the design phase (Conformance, 2016). The directive is a framework which focuses on reducing energy consumption throughout the lifecycle of the product and other negative environmental impacts of products such as the water, emissions and embodied waste during the design stage (European Comission, 2017).

The approach involves:

- Definition and scoping the boundaries of what is and is not included in the assessment.
- Creating an inventory that quantifies the energy and raw material inputs and environmental releases associated with each stage of a product's manufacture, retail sale, use and disposal.
- Assessing the impacts on human health and the environment associated with the inputs and environmental releases.
- Analysis to evaluate opportunities to reduce energy, material inputs, or environmental impacts at each stage of the product life-cycle including the design stage.

6.1.2 Product certification

There are numerous product and industry specific certification systems which provide third party certification and assurance to consumers of the sustainability credentials of the product or process. Manufacturers can use labels as a means of distinguishing their products from competitors or for sourcing resources from certified providers.

Examples include:

- Global Green Tag which is an Australian certification system using LCA (see Box 10),
- Cradle to cradle which is a design concept using biomimicry (see Box 11 and Case Study 6),
- FairTrade which is a social sustainability tag,
- Nordic Swan ecolabel (product label for Nordic countries),
- Blue Angel ecolabel (German certification for products and services),
- Australian Carpet Environmental Classification Scheme,
- Australian Furnishing Research and Development Institute (AFRDI) Green Tick program for furniture,
- Good Environmental Choice Australia (GECA) which has a focus more on health and environmental aspects.
- Australian Government Energy and Water ratings for products made or imported into Australia
- GreenPower for Australian Renewable Energy
- Smart Approved Watermark (certifies water efficient products and services in Europe and Australia)
- EnergyStar - a US certification program which also applies to most electric equipment (www.energystar.gov)
- Epeat – An American product rating system for electronic equipment

Box 10: Global Green Tag certification system

Global Green Tag is a Queensland based product certification system that is recognised in over 70 countries. It uses LCA processes to independently certify that each product meets certain criteria before they are given a rating.

Where applicable, Green Tag Certified Products are:

- Externally certified to ISO 9001 for Quality Management
- Externally verified as compliant to:
    - ISO 14024 for Type 1 (Third Party) Eco-labels and
    - ISO 17065 for Conformance Assessment Bodies
- Compliant with:
    - ISO 14040 & ISO 14044 for LCA
    - ISO 14067 for Greenhouse Gas Emission calculations
    - ISO 14025 for Environmental Product Declarations and
    - ISO 21930 and EN 15804 for specific Environmental Product Declarations
- Australian Competition and Consumer Commission (ACCC) and US Trade Marks & Patents Office Approved (Global GreenTag, 2017).

Case Study 6: C2C designed carpet tile gives $2.5 million savings, Shaw Contract Group, Georgia, US

Due to competitive pressure and health-related problems EcoWorx applied the C2C design principles to develop a durable, flexible and recyclable carpet tile with:

- 5 times more tensile strength,
- 8 times the tear strength, and
- 2 times the delamination strength than traditional PVC-backed tiles.

The product uses 40% less energy to produce than a traditional carpet tile and weighs 40% less, also reducing transport costs. The tiles are free of chemicals identified on a 'red list'. An environmental guarantee for a global program to reclaim and recycle old tiles is also provided (GECA, 2017).

The improved design saves the Shaw Contract Group around $2.5 million annually in water and energy savings (Godelnik, 2014).

The Ecolabel index is an independent global directory of ecolabels and environmental certification schemes, while the Ecospecifier is an Australian based company which provides a free database of already verified and certified products.

Industry specific certifications include:

- National Australian Built Environment Rating System (NABERS), GreenStar and Leadership in Energy and Environmental Design (LEED) for building certification
- EarthCheck for the tourism industry
- Forest Stewardship Council for sustainable forestry
- Australian Certified Organic
- Rainforest Alliance

- Telecommunications Certification Organisation (TCO) for IT products
- Marine Stewardship Council
- National Association for Sustainable Agriculture Australia (NASAA) for agricultural products and certified organics

Box 11: Cradle to Cradle ®

Cradle to Cradle® (C2C) is a certification system which uses at a design concept that was developed in the 1990s and is a whole of life biomimetic approach to the design of products. Biomimicry is the process of looking to nature for innovative solutions.

The three principles that form the basis of C2C are that:

- material inputs (nutrients) to a product should be safe and continuously cycling in the environment. Nutrients at the end of their life (waste) should benefit another organism (i.e. another industrial or natural process),
- products should grow (be produced) using renewable energies, and
- a variety of approaches should be used to reduce impacts (natural diversity).

The use of this approach is believed to shift design thinking from eco-efficiency (or reducing negative impacts) to eco-effectiveness in that it improves positive impacts and mimics natural processes. Products can be certified by meeting the criteria of a Cradle to Cradle Certified™ Program (EPEA, 2017).

A review of the approach and certification by a global environmental data and insight company found the C2C approach to product design resulted in significant environmental and economic benefits including cost reduction, improved product value, innovation promotion and risk avoidance. The cost of certification is seen as an issue; however, companies are able to adopt the approach without certification (Godelnik, 2014).

6.1.3 Green chemistry

Green chemistry focuses on design of products and processes that minimize the generation and use of hazardous chemicals.

The approach is based on a series of 12 principles to achieve the design goal of being at the highest level of the following hierarchy:

1. Source Reduction/Prevention of Chemical Hazards
2. Reuse or Recycle Chemicals
3. Treat Chemicals to Render Them Less Hazardous
4. Dispose of Chemicals Properly.

Case Study 7: Hazardous chemical removal from medical drug reduces waste by 75%, GlaxoSmithKline.

Pharmaceutical company GlaxoSmithKline (Verona, Italy) redesigned a chemical used to treat chemotherapy induced nausea and vomiting by removing a number of hazardous substances. By doing so, the method for making the chemical no longer relied upon subfreezing temperatures during production.

The initiative saved energy, reduced waste by 75%, and lowered the cost of raw materials by 50% (GlaxoSmithKline, 2005).

Benefits to the business include higher yields for chemical reactions (reduced inputs); fewer synthetic steps saving energy and water; reduced waste and remediation or disposal costs; costs savings of replacing an input with a waste product; and improved competitiveness e.g. able to demonstrate safe credentials of the product (Case Study 7 and Case Study 8) (US EPA, 2017).

Case Study 8: Elimination of hexavalent chrome, Digga Australia, Qld

Digga Australia specialise in earthmoving machinery attachments for skid steer loaders, excavators, telehandlers, tractors and backhoes including augers. Previously the various machinery wear components were chrome plated with a hexavalent chrome based coating which is a known human carcinogen and a priority pollutant in various state and international Environmental Acts. Digga have recently switched to a more environmentally friendly organically based polyurethane coat for the wear parts (TEG, 2017).

6.1.4 Design for Remanufacture

Remanufacturing is the process of returning a used product to like new condition i.e. the new product is a combination of old and new products (Hatcher, 2011). Remanufactured parts differ from repaired and reconditioned parts in that they come with a warranty and in some cases, have been upgraded. The price of a remanufactured item is generally 30%–40% of a new one (Ilgin, 2012).

To be successful the product needs to be designed to achieve a long useful life and typically the value-added costs, such as labour and energy, are incorporated into the products total cost. Manufacturers must provide a collection and recovery system that collects items in significant numbers and a distribution network and transportation system for used and new remanufactured products.

The upfront costs of products that are designed for remanufacture are typically greater than for those that cannot be remanufactured. However, customers will realise savings over the life of the product through avoiding the cost of full product replacement (Case Study 9).

Case Study 9: Xerox saves 2 million by redesigning part to enable remanufacturing, Oklahoma, US

The plant manufactures a variety of parts for Xerox's black and white and colour printer lines. Design teams work to maximize easy disassembly, durability, reusability, and recyclability to reduce the need for virgin materials. Product are returned at the end of leasing agreements. By 2000, Xerox had already saved 200 million in remanufacturing.

One significant product redesign for remanufacturing involved increasing the durability of the corotron devices (used to add an electrostatic charge to the printer drum). By strengthening the aluminium housing to facilitate disassembly, the device could be remanufactured. This improvement has saved more than $10 per part in service (saving $US 2 million annually) and a 58% reduction of corotrons sent to the landfill (US EPA, 2009).

6.1.5 Design for Disassembly (DfD)

This approach focuses on designing products so they can be easily recovered at the end of their life (Case Study 10 and Case Study 11). This type of design criteria also enables easy disassembling for repair.

The approach involves:

- choosing recycling-compatible materials,
- avoiding materials which require separating before recycling,
- fewer components and fasteners and fewer types,
- integrating components related to the same function,
- standardised components,
- ensuring components are accessible and easily separated, and
- use of non-polluting markings or coatings.

Case Study 10: Innovative LED lights DfD, Sotek - CobaltNiche, Australia

LEX is a slimline LED exit sign that uses revolutionary optical waveguide technology that reduces energy consumption from 2.4W (standard LED) to 0.5W.

To aid recycling CobaltNiche has designed the product from only two types of plastic. The assembly clips together so no mechanical fasteners are needed. This reduces assembly and disassembly time. The reduced product size not only lowers raw material consumption but also improves efficiency of transport (Good Designs Australia, 2010).

The light is RoHS compliant and heavy metals free. With a life span of 40 000hrs, maintenance and source replacement is also greatly reduced.

Design for Disassembly can also encompass Design for Modularity (DfMo) which promotes modular design to ease upgrading so as to delay replacement, and improve serviceability and disassembly. Design for Serviceability (DfS) focuses on design for ease of repairs including simplification (fewer items to fail / wear out, diagnose, disassemble/reassemble) and standardization.

Case Study 11: Technology: Active Disassembly using Smart Materials

This technology adds shape memory material (metal alloy or polymer) components into products. The material holds it shape until it reaches a trigger temperature when it then develops a second shape. This means all the components and fastenings of a batch of electrical or electronic equipment can be separated at the same time. Smart materials are however currently more expensive than conventional fastenings (Harrison, 2009).

The Nokia 5510 prototype mobile phone uses Shape Memory Alloy (SMA) actuators with curve-to-open snap fits that hold the cover, display and display window in place. The screws and screw bosses are also made out of a Shape Memory Polymer (SMP) (Bhamra, 2016).

EU legislation is increasingly stringent with the introduction of the Waste Electronics and Electrical Equipment (WEEE) Directive in 2000 and the End of Life Vehicle (ELV) Directive in 2003. The 2006 Restriction of Hazardous Substances (RoHS) EU directive bans six substances that have a history of posing risks to human health. Design for disassembly and remanufacturing are proving profitable approaches for companies which meet this legislation (Hatcher, 2011).

6.1.6 Advanced Materials

The development of advanced materials will support more efficient and sustainable manufacturing practices. An assessment of innovative clean energy technologies in advanced manufacturing by the US Department of Energy focused on next generation materials. These materials hold promise both economically and in terms of engineering as well as offering better environmental performance across entire life cycles from extraction to end-of-life (US DOE, 2015d). Examples of advanced materials include:

High performance structural materials such as:

- low carbon cement that reduce greenhouse gas emissions from cement calcining processes by using substitute materials such as magnesium silicates or carbonates and/or carbon-cycling processes (IEA, 2009).
- lightweight but high tensile metals such as magnesium and aluminium alloys and high strength steels, and polymer matrix composites. These contribute to increased vehicle fuel-efficiency e.g. a 10% reduction in vehicle mass can lead to 6-8% improvement in vehicle fuel economy (US DOE, 2015c).
- phase-stable materials that are stable at high temperatures and pressures to advanced manufacturing reliant on advanced ultra-supercritical steam turbines.
- high strength multi-material used for joining dissimilar materials such as composites and lightweight metals (Case Study 12 and Case Study 13).

Case Study 12: Rotor manufacturer using advanced materials, Airwork Helicopters, Queensland

Airworks in Caboolture have designed advanced rotor blades with the help of US engineers and tested by CSIRO. The tail rotor blades for Bell 206 helicopters are made from carbon fibre and kevlar, with an electroformed nickel edge to increase durability. The AH rotor has double the 2500 hr life of the original part and is 30% cheaper. It is also quieter and repairable. Most of the materials are sourced from Australian suppliers (Roberts, 2015).

Case Study 13: Sustainable Wood Alternative, Innowood, New South Wales

INNOWOOD have developed an advanced composite material that uses extrusion technology to convert recycled waste wood powder and resin material to produce a durable, non-toxic wood composite that is termite, mildew and water resistant and 100% recyclable. The lighter composite wood profile can reduce the weight of facades by up to 70% while still preserving the natural hardwood timber look. The composite can be designed and extruded into different profiles (Innowood, 2017).

Materials for efficient energy conversion such as:

- Catalysts for fuel cells which have long-term durability (>5,000 hours) in fuel cell vehicles (U.S. DRIVE, 2013) and for more efficient conversions in bioprocesses.
- High thermoelectric materials that convert waste heat into electricity.
- Wide bandgap semiconductor devices that lead to weight, volume, and cost savings for manufacturers. The devices have higher switching frequencies than their silicon-based equivalents so smaller inductors and capacitors in power circuits can be used while also having reduced energy requirements (Technology Assessment 6N, 2015)
- Photovoltaic materials to generate electricity to reduce carbon emissions and consumption of non-renewable energy sources.

Improved surface coatings including

- improvements in scale and flux for ceramic, metallic, polymeric, and composite membranes.
- improved coatings to reduce corrosion and durability.
- surface treatments and coatings for reduced friction losses.
- surface morphologies that reduce drag in solid-liquid interactions for marine transport and harvesting of water from fog.

Materials that improve chemical separation e.g. for fuel cells, batteries, water purification such as porous materials for hydrogen storage and carbon capture.

6.2 Manufacturing and process efficiencies

The manufacturing sector is diverse with wide variation in processes to produce items such as composite plastic products, high strength steel components, value-added food products and also biomedical products. Advanced manufacturers typically use energy intensive technologies, particularly those that transform metal or plastics into precision products and parts. Processes used by many advanced manufacturers in sectors such as defence, aerospace, transport and mining include:

- Deformation – includes bulk forming (rolling, forging, extrusion) or sheet forming (stretching, bending, contouring).
- Subtractive – three dimensional objects are constructed by successively cutting material away from a solid block of material.
- Additive – three dimensional objects are constructed by successively adding layers of material e.g. via 3D printing.

The following section discusses manufacturing and process efficiencies, mostly in relation to manufacturers that undertake forming, subtractive or additive processes.

6.2.1 Energy intensity and efficiency

- There are a number of key factors which impact on the energy demand and efficiency of manufacturers. These are: The increasing electrical energy intensity of manufacturing technology.
- The need for intensive thermal energy (heating and cooling) by some manufacturers.
- Managing the introduction of new digital technology and increased availability of real-time data including access to excessive data.
- The extensive use of motor driven systems.
- Energy supply affordability, including managing peak demand and power factor charges.

These factors are discussed in the following sections.

Energy intensive technology

A growing demand for energy, depletion of fossil fuels and the impact of carbon emissions has seen a shift to more environmentally responsible manufacturing practices. In many cases, this has been accompanied with new environmental legislation, particularly in European countries. Conversely, there has been an increase in the use of energy intensive advanced manufacturing technologies (AMTs) including information networks, robots, computer numerically controlled (CNC) machines and computer-aided design and manufacture. Reducing energy costs is an important driver for manufacturers and energy efficiency is recognised as one of the most effective methods of reducing costs and carbon emissions. The use of energy cost accounting also provides transparency on the cost-, material- and energy-efficiency of a new technology which is an important aspect of advanced sustainable manufacturing (Steinhilper, 2013).

A 2014 study compared bulk-forming, subtractive, and additive processes and found the energy consumption of additive processes was approximately 100-fold higher than that of conventional bulk-forming processes. Subtractive processes were found to be between one and one hundred times more energy intensive than conventional processes. Of the subtractive processes, grinding consumed the largest amount of energy compared with conventional milling techniques (Hae-Sung Yoon, 2014).

More recently however, LCA studies suggest that advanced additive manufacturing may have lower environmental impacts of conventional manufacturing.

Kafara et al undertook four cradle to grave LCA studies of different manufacturing processes of mould cores

- (i) casting with low-melting alloy (MCP in Figure 12);
- (ii) milling from plaster-like material (Aquapour),
- (iii) additive manufacturing with High Impact Polystyrene (HIPS) and
- (iv) additive manufacturing with powder materials (like salt).

The findings (Figure 12) showed additive manufacturing processes have a lower environmental impact than the conventional manufacturing processes (Kafara, 2017).

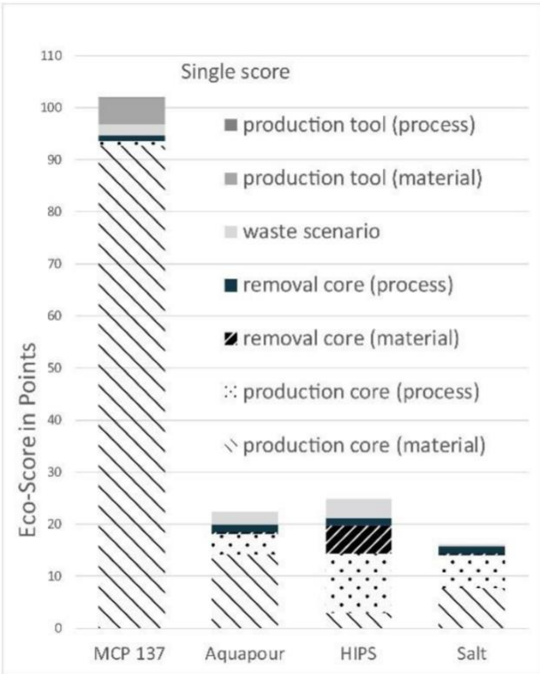

Figure 12: Comparison of single score LCA results (Kafara, 2017).

Another 2015 LCA study found the sustainability of additive manufacturing verses CNC machining depended primarily on the per cent utilization of each machine (Faludi J. B., 2015). The study shows the importance of also considering efficiency measures of machinery utilisation and idle time. The Fused Deposition Modelling (FDM) additive manufacturing was found to have the lowest ecological impacts with the authors recommending the use of FDM machines over CNC mills or polyjet machines, if they provide sufficient quality of surface finish. They also suggest manufacturers share high-utilization machines. The impacts of the ink jet machine compared with the CNC machine was variable depending on idle times and process parameters (Faludi J. B., 2015).

Digital technology and real-time data

The introduction of new digital technology and increased availability of real-time data allows manufacturers to:

- access diagnostics to inform decision-making,
- enable more targeted optimisation of processes, and
- provide improved performance metrics.

Advanced networked data and information technologies is commonly referred to as (ASCPMM) which includes:

- **Advanced Sensors** which collect and transmit real time data,
- **Controls** for response and process optimisation,
- **Platforms** to process the data and computations,
- **Modelling** for predictive control and to assess the impact of optimisation initiatives, and
- applying the above to **Manufacturing** (US DOE, 2015b).

It has been estimated that investments in ASCPMM over the next 20 years could lead to savings of $15 billion in annual electricity costs for the manufacturing sector, with average company energy demand reducing by 20% (Rogers, 2013). Table 5 provides a summary of the benefits and barriers to ASCPMM. These digital technologies form part of the Internet of Things (refer to section 0).

Table 5: Summation of benefits and barriers of ASCPMM (US DOE, 2015b)

Benefits	Barriers
Smart energy management system (EMS) to cost-effectively measure and manage energy consumption. Smart systems allow energy load management. Integration into existing wired/wireless communication technologies.	Low or underdeveloped value proposition.
The ability to integrate digital control systems with automated process controls and information systems to collect and analyse large amounts of data to better understand and predict the relationship between operations and their energy use.	Actual or perceived interference with operations.
Allows algorithms to analyse manufacturing systems to meet and anticipate production demand and how best to optimise energy use.	Technological limitations.
Ability to track items from across supply chains using advanced inventory tags and Global Positioning System to optimise manufacturing, delivery processes, inventory management, maintenance, compliance and safety.	Hardware/software incompatibility and technology "lock-in".
Ability to electronically communicate digital designs, creating shorter or disrupted supply chains e.g. for additive manufacturing (3D printing).	Cybersecurity and risk concerns.
Effective predictive maintenance.	-
Distributed rather than centralized control to localise and reduce burden of individual controllers	-
Greater flexibility to react to operational changes (predicted or unpredicted)	-
Cloud-based platforms for centralised management to maximize energy productivity and process energy efficiency.	-
Achieving maximum benefit from the deployment of state-of-the-art (SOTA) manufacturing technologies and possibly longer-term opportunities.	-

Some challenges identified by the US Advanced Manufacturing Partnership for the update of ASCPMM technology include:

- Standardization and interoperability need to be assured so that data can be readily interpreted between devices and systems and services (Case Study 14). This will avoid vendor lock-in where products from different service providers are incompatible. As Case Study 15 from Simplicity Australia suggests manufacturing to ISO standards is important.

- The need for reliable and cost-effective techniques with some manufacturers suffering due to unaffordability of new methods.
- Service architecture and need for effective cyber-security.
- The model-based control and optimization paradigm is widely and successfully used in some manufacturing sectors but has had limited application in many others.

Case Study 14: 3D faxing reducing transport and paper carbon emissions

Queensland company, RedEye, has developed a cloud-based platform that collates engineering plans and data in one convenient location. This means large paper records for meetings on and off site are significantly reduced. As well as reducing the carbon emissions related to paper consumption the company has solved a global problem recording a 706% growth in its company over the last three years (Rickert, 2015).

As well as enabling clients to upload and share engineering designs, files can be faxed to any 3D printer on the network. This eliminates the costs and environmental impacts associated with transporting parts locally and globally (Hanson, 2013).

Case Study 15: Manufacturing to ISO standards, Simplicity Australia, Queensland

Simplicity Australia specialises in the design and manufacture of cutting edge air seeders and cultivators. The variable rate (VR) electronics on Simplicity's seeders and cultivators meet the requirements of the 2014 international *ISO 11783 standard – Tractors and machinery for agriculture and forestry - Serial control and communications data network* (ISOBUS).

ISOBUS sets the standard for agriculture electronics and works to reduce the wastage related to product incompatibility. By doing so growers are not limited to using a specific precision display and controlling system to operate individual machinery items. By using ISOBUS compliant electronics Simplicity is helping to ensure electronics are not rendered obsolete when the grower buys new farm attachments. (DSD, 2017a)

Energy Management Systems

Energy efficiency enables manufacturers to use less energy for the same, or in some cases greater output. The International Energy Agency reports energy efficiency has the technical potential to reduce industrial energy use by about 20% (IEA, 2013). It is also an important and cost-effective means for reducing greenhouse gas (GHG) emissions.

Implementing an energy management system can help manufacturers benefit from the full potential of energy efficiency in terms of continuously identifying and prioritising opportunities (Case Study 16). An energy management system can be implemented according to the ISO 50001 energy management standard or a customised approach. As with other recognised management systems involvement at all levels is essential (OECD, 2014). A recent review of energy saving effects of energy management system found (Lee, 2016):

- Building Energy Management Systems (based on 105 cases) had an average saving effect of 16%.

Case Study 16: Energy Optimisation System, Heat Treatment Australia, Queensland

An Energy Optimisation System monitors the real-time energy consumption of about 15 equipment items to help reduce costly peaks in consumption. The system works on a decision hierarchy where automated load shedding occurs when set peak levels are approached. Operators are notified via a light system, with green, amber or red, indicating that load shedding is occurring.

The system has reduced peak demand by about 30% with additional savings in reduced electricity consumption (measured as energy per kg of customer parts heat treated) through identifying and targeting inefficient equipment items such as pumps and air compressors. Since installation, the EOS has saved in the order of 60,000 kWh and $24,000 per year (DSD, 2017d).

- Energy management systems for industrial, company and factory (based on 103 cases) had an average saving effect of 10%.
- Energy Management System for equipment (based on 97 cases) had an average saving effect of 39% for artificial lighting systems, 14% for HVAC using smart controls and 16% for motors (variable frequency controls).

Energy supply affordability, including managing peak electricity load and power factor charges

Peak demand charges compensate for electricity suppliers guaranteeing sufficient electricity supply for peak events. In addition to improving the efficiency of equipment there are a number of ways manufacturers can reduce these charges. These include:

- Load shedding - can be undertaken manually or automatically with an energy demand management system that uses electronic sensors and submeters to turn off or ramp down non-essential high consumption circuits to reduce the total demand.
- Use of alternative fuels/fuel switching - involves using alternative fuels or renewables to reduce the need for electricity during high-load periods e.g. solar PV systems (Case Study 17), natural gas heat pumps and natural gas-fired absorption chillers.
- Power factor is a measure of efficient power usage and is expressed as a numerical value between 0 and 1. The closer the power factor is to 1, the more efficiently electricity is being consumed. A poor power factor below 0.8 can negatively impact electricity bills. Installing power factor correction equipment (capacitors) can help improve this efficiency (Case Study 18).
- Energy storage - uses batteries to store electrical energy during periods of low demand in a chemical form which can then be converted back into an electrical form during periods of high demand (Case Study 19).

Case Study 17: Renewables to reduce peak demand, Simplicity Australia, Queensland

Simplicity installed a 150kW solar photovoltaic system (PV) across two of the company's commercial properties. As well as generating renewable electricity that can be consumed immediately for daily operations, the PV system has helped to reduce the business's peak demand charges. The solar PV panels generate around 232 MWh annually and offset around 60% of the businesses general electricity consumption and peak demand charges (DSD, 2017a).

Case Study 18: Power Factor Correction. Priestley's Gourmet Delights, Queensland

Since installing a custom designed Power Factor Correction Solution Priestley's increased their Power Factor from 0.764 to 0.996 and were able to save $6,000 in just three months in avoided penalty charges (ecoBiz, 2017).

Case Study 19: Battery storage to reduce peak demand, Century Yuasa, Queensland

The process of manufacturing batteries especially vehicle batteries is energy intensive. Century Yuasa consumes around 1MW of electricity per day costing $1.5 million annually with $900,000 used in the charging room alone.

Peak demand charges significantly add to the cost of electricity and for this reason the charging of the batteries is staged. Century Yuasa have also installed an industrial Battery Energy Storage System (BESS) to mitigate daily load spikes and reduce peak demand tariffs. The batteries allow Century Yuasa to capture electrical energy during periods of low demand to be stored in a chemical form and then converted back into electrical form during periods of high demand. The system is composed of a 76kWh battery bank which feeds a 110kVA inverter. The system includes a large screen LCD interface at the battery bank and potential web interfaces that allows Century Yuasa to log-on and view energy consumption and real-time levels of peak demand. Efficiency initiatives have reduced energy consumption by 23% over the last eight years (DSD, 2017f).

6.2.2 Additive manufacturing (AM)

Additive manufacturing fabricates products layer-by-layer to produce three-dimensional objects printed on demand. The EU believe AM technology has the ability to shift manufacturing from mass-production to mass-customisation and to a more local level (European Commission, 2014). Similarly, research undertaken by Pacific Consulting Group on the current use of 3D printing in the Australian manufacturing industry estimate the technology will profoundly transform manufacturing, especially for advanced manufacturers producing complex, low unit volume parts (Pacific Consulting Group, n.d.). AM is particularly relevant to advanced manufacturers producing:

- intricate customized designs,
- parts or products needing a variety of small variations,
- multipart assemblies,
- low numbers of end-use parts or products (including spare parts),
- moulds or mould templates needed for mass production, and
- light weight parts.

Advanced manufacturers who have embraced the technology include aerospace and automotive sectors (Case Study 20), medical and healthcare, logistics and consumer products (BSR, 2015). Refer to Box 12 for information on printing materials.

Case Study 20: 3D Printing increases durability of gun mounts and reduces costs

EOIR Technology (US) was contracted to create a camera and mount for gun sights but found traditional manufacturing methods were failing performance tests. Left with a tight budget and contract deadline the company invested in a Solid Edge® CAD software package, Dimension 3D Printer, and thermoplastic modelling materials.

Sturdy plastic parts proved tough without having to go through a costly, time-consuming process of machining them in aircraft-grade aluminium.

Manufacturing costs for these components would normally have exceeded $100,000. Instead, the company produced 40 quality gun mounts for less than $40,000 (Stratasys, 2013).

AM technology can significantly improve manufacturing efficiencies by:

- reducing traditional machining requirements (i.e. tools, moulds or punches),
- enabling rapid prototyping and testing (faster design cycles) prior to full scale production,
- enabling the rapid production of manufacturing aids e.g. jigs
- reducing inventory levels and shortening the supply chain,
- reduction in human error,
- driving innovations, and
- time-to-market reduction. (BSR, 2015) (McAlister, 2014)

Box 12: 3D printing materials

3D printing materials include plastics, ceramics, food, glass and even human tissue. They generally work in one of two ways. They are melted, extruded and then solidified or via a powdered material that fuses into solid form.

In some cases, research has been able to improve on the characteristics of the traditionally used material for example, development of 3D printed wood composites that have the same properties of wood but do not warp.

In the case of metals, researchers have looked at their underlying molecular arrangements so as to improve their physical, electrical and mechanical properties. Some lighter-weight structures, recyclable and some polymers are even self-healing (Anderson, n.d.).

McAlister and Woods suggest a number of opportunities to reduce resource energy, materials and waste including (McAlister, 2014):

Energy

- Reducing active print time per part by producing hollow parts and supports rather than solid parts
- Optimising layer thickness
- Enabling short productions of customised products or parts,
- Printing the maximum number of parts per print (Box 13)
- Reducing idle/standby time
- Optimise the melting point of the material against strength requirements of the part.

Materials

- Considering the embodied energy e.g. plastics from renewable sources or biodegradable sources or recycled plastics
- Using materials that will not shrink
- Using less toxic materials
- Using materials that require less finishing where possible
- Reducing material inputs through lower number of parts and light weighting. Raw material is reduced by up to 40% when compared with subtractive technologies (Reeves, 2008),

Box 13: Life cycle impacts of printing the maximum number of parts per 3D print

Print the maximum number of parts per print (no benefit for small-scale FDM machines)

- 50% reduction in lifecycle impacts per part for an inkjet style 3D printer (Faludi J. , 2013)
- 3 to 98 % reduction in energy per-part for metal sintering, printing multiple parts (Wolfson School of Mechanical and Manufacturing Engineering, 2011)

Waste

- Using low waste generating printers and those that have the flexibility to use recycled feedstock
- Purchasing feedstock from suppliers that offer cartridge and/or waste return
- Use of a shredding and extrusion devices to create recycled feedstock from failed prints and support structures

Sustainability concerns around 3D printing include the possibility of frivolous printing and the high electricity consumption of printers. Social issues include potential job losses, ethics and consumer rights (Gebler. M, 2014).

6.2.3 CNC Machining

Computer Numerical Controlled (CNC) machine tools are mostly subtractive technologies. They commonly include sawing, cutting, grinding, drilling, turning and milling machines. CNC machines have been used extensively over the last two decades for prototyping, form and fit testing, the creation of jig and fixture creation and the production of parts. They are compatible with a wide range of plastic and metal materials. They also include non-conventional machining tools that rely more on thermal processes such as electro-discharge or spark erosion machining, laser beam machining, plasma arc machining and electron beam machining. CNC machines can reduce material waste by:

- Producing parts with a high level of accuracy and repeatability.
- Analysing the parts dimensions to determine how to best fit shapes for maximum sheet utilisation. CNC machine use what is known as nestling software for this purpose (Case Study 21).
- Lower tooling costs as there is less of a need for complex jigs and fixtures.
- Minimal inspection due to accurate part repeatability (little rework).
- Less operator failure waste.

Case Study 21: Nesting software reduces waste, B&R Enclosures, Queensland

B&R Enclosures manufacture electric enclosures, racks and cabinets for all sectors including Telecommunications, Mining, Oil & Gas, Construction and Agriculture. Rolled steel sheets, used to make the enclosures, are cut to varying lengths according to the type and size of enclosures to be produced. The lengths of sheet are then processed in either a laser cutter and/or punching/shearing machine to produce the various enclosure components.

B&R uses 'nesting' software which analyses the pattern dimensions of the various enclosures and uses an algorithm to determine how best to fit and cut the shapes to ensure maximum utilisation of the steel sheet. The software is used on a daily basis with inputs modified according to production schedules. Around 100 labour hours per week are saved as a result of utilising this software, allowing engineers to focus on other tasks (DSD, 2017g).

The level of automation in a CNC machine varies however they increasingly have more automated auxiliary functions. Advanced machine control and programming not only enables complex machining operations but also reduces production times and streamlines production and production planning as they can often perform work at one setting that would normally require several conventional machines.

However, increasing automation also increases energy consumption with a computer-controlled milling machine requiring 2.5 to 60 times more power than a hand-controlled milling machine (Figure 13) (De Decker, n.d.)

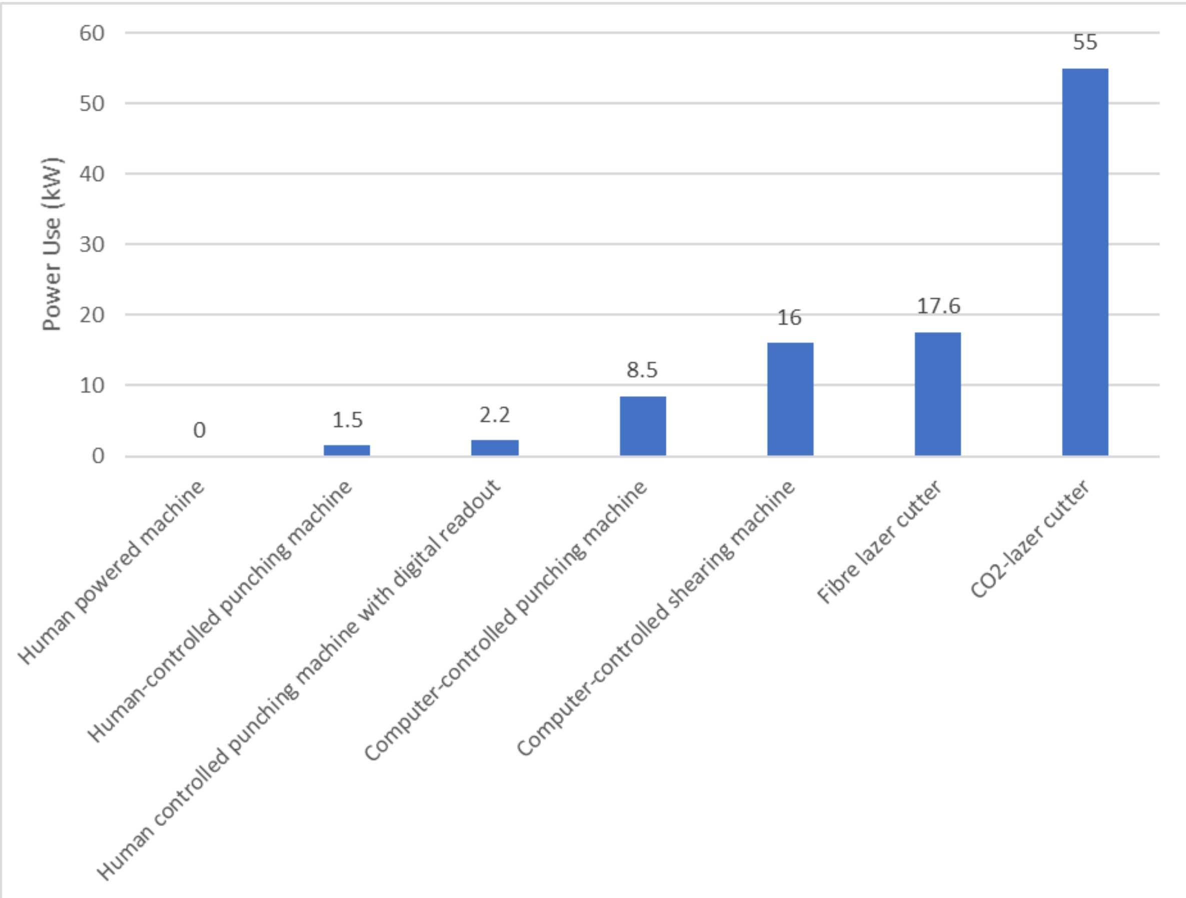

Figure 13: Power use of different generations of metal cutting machines (De Decker, n.d.)

Analyses of metal-cutting processes show that the power consumption of a CNC control with feed-axis and spindle motors frequently only comprises 25 to 30 % of the total energy consumption with auxiliary components such as fans and motors (peripherals) consuming the remainder (Heidenhain, 2011). Green suggests a number of initiatives to reduce the energy consumption of CNC machinery (Green, 2015):

For machine tool users:

- Select tools and machines sized to suit needs (i.e. don't oversize).
- Use specialized machines for large series production runs.
- Optimise cutting conditions - tool, parameters, cooling lubricant (Case Study 22).
- Reducing the time, the machine is left on.

For machine tool manufacturers (eco design)

- **Main drive:** use efficient motors, transmission and bearings for the milling spindle / turning spindle.
- **Peripherals:** ensure they are not oversized and suited to various types of machining processes and conditions e.g. cooling lubricant quantity, cooling power of chillers. Use frequency controlled fluid-air fan cooling units, pumps and compressors where appropriate.
- **Fluid circuits (compressed air, cooling lubricant and hydraulic oil):** replace compressed air purges with advanced seals or replace hydraulic systems with electro-mechanical components. If a machine has particularly efficient pump motors this alone can save significant amounts of energy (Heidenhain, 2011).
- **Machine control:** Adaptive feed rate and control that automatically adjusts according to material being worked. Use of hibernation modes which set in after a specified time period. Compressed air supply which automatically turns off after the machine is stopped and the spindle cools down. Advanced compensation of thermal errors used to reduce warm-up time. Automatic adjustment of peripherals according to variable minimal process needs.

Case Study 22: Initiatives reduce CNC machining energy use by 73%, GKN Aerospace, US

Researchers with GKN Aerospace found strategic choices related to tools, coolant, programming and parameters could reduce the level of energy use by 73%. The research focused on a titanium sample part.

Coolant recycling by connecting the machining cell to a coolant recycling system with centrifuge also saved $45,000 per year in coolant and cut water use by 11 % (Zelinski, 2013).

6.2.4 Process heat

Process heat is used by manufacturers to produce process hot water or steam; to heat fluids or to transform materials such as metals, plastic, rubber, glass and biomass into a wide variety of products. Process heat is typically produced using electricity, natural gas, coal, biomass, and fuel oils. Equipment used for process heating includes furnaces and kilns, dryers, evaporators, and heat exchangers. Process heating accounts for approximately 61% of manufacturing energy use annually (US OEERE, 2010). Considerable energy savings can be gained through process optimisation, reducing heat loss, heat recovery and co-generation (Case Study 23). As part of the US Department of Energy four yearly review of manufacturing technologies, the following recommendations were made to improve the efficiency of process heating (US DOE, 2015a):

Optimise heat generation systems

- Pre-heat combustion air.
- Pre-heat fuel (not recommended for natural gas).
- Use of turbine and combustion systems capable of utilising alternate fuels e.g.
    - fuel-flexible gas turbines that can utilise off-gas and waste streams with low energy content.
    - fluidized bed combustion systems that have high combustion efficiency and reduced emissions (sulphur- and nitrogen-oxides) and which can also use alternative fuels such as biomass and waste products.
    - multi-fuel burners that can use a range of fuel including natural gas and landfill gas.
- Oxygen-enriched combustion which can reduce the energy loss in the exhaust gases and increase heating system efficiency.

- Use of an electric process heating system as a booster element to preheat the work pieces before they are processed with a fuel-based heating system.
- Computational optimization to adjust variables such as the percentage of excess air, oxygen concentration, and material flow temperatures for optimal energy efficiency.

Case Study 23: World's best practice Swiss Combi's ecodry™ drying system, Dalby Bio-Refinery

Dalby Biorefinery converts red sorghum grain into fuel-grade ethanol and high value animal feed products. The company uses a world's best practise drying process to produce Distiller's Grain, used as animal feed. Except for the product entrance and outlets, the system's circuit is completely sealed. Features of the technology are:

- The ability to dry with superheated steam reducing primary energy consumption by up to 11% while still achieving the same amount of product output. Superheated steam also provides a gentler drying process retaining more of the nutritional value, in particular the proteins of the grain is retained.
- Drying can be undertaken at a lower temperature because semi-dried product is recirculated back to the initial heat zone for additional drying and dispersion. The recycling of a portion of the stillage improves drying efficiency and reduces variations in quality.
- Energy savings by recovering heat from the furnace flue gases (outlet gases) to reheat steam that is then recirculated back into the drum.
- Energy savings through eliminating the need for a separate thermal oxidiser to destroy air pollutants and odour by burning exhaust gases at a high temperature. Instead, water and other substances evaporated from the product are drained from the sealed circuit and the dehumidified air is introduced into the furnace as combustion secondary air. Energy released in destroying the air pollutants (oxidation) provides additional combustion energy for the drying process (DSD, 2017h).

Typical emission reductions from. Ecodry compared to conventional drum dryers	
Flue gas	48% lower
Nitrous oxides	14% lower
Total Organic Compounds	100% lower (almost 0)
Particulate matter	100% lower (almost 0)
Carbon Monoxide	86% lower

Optimise electrotechnology heat generation systems

- Use of high-frequency electro-technologies such as microwave, radio frequency, and induction. As well as higher energy efficiency, these technologies can often process products that cannot be done using conventional thermal processing methods. For example, microwave energy has been shown to sinter ceramics, alter grain structure in sintered metals, and accelerate chemical reactions (USDT, 2015).

Reduce heat loss

- Use of seals, furnace curtains, liners, and heat shields.
- Insulation to reduce radiation losses.

Sensors and Process Controls

- Use of robust sensors suitable for harsh, high-temperature environments including direct process measurement sensors, and accurate and reliable thermocouples to optimize heat transfer and containment systems.
- Use of furnace control sensors and control technologies for better fuel utilization. These can accurately measure compositional characteristics of fuels and oxidant, control flame quality and stability and provide continuous flue gas analysis. Pressure controllers can eliminate cold air infiltration, maintain uniform temperatures, and reduce wear saving in maintenance costs.
- Optical laser-based sensors have the potential to provide for more accurate and real-time measurement of temperatures and physical properties e.g. image-based sensing to monitor surfaces and capacitive sensors to monitor moisture content.

Optimise waste heat management

- Use heat recovery and heat integration systems to recovery waste heat from combustion exhaust gases, cooling water, belts and product etc (Case Study 24).
- Improve design of heat exchangers for low-temperature waste heat recovery e.g. ceramic inserts, dimpled/finned heat exchangers, and heat pipes.
- Optimise design of heat exchanger networks e.g. pinch analysis.
- Combined Heat and Power (CHP) system that generate power while producing hot water or steam from the waste heat Use advanced high-temperature materials to make equipment strong and resilient
- Use of high-temperature materials for heat exchanger and equipment design for improved heat containment and heat exchange e.g. ceramics and ceramic matrix composites (CMCs). Advanced manufacturing methods like additive manufacturing may enable optimized designs that were not achievable by conventional manufacturing methods.
- Use of corrosion-resistant coatings for furnace components to reduce maintenance requirements and improve the service life of equipment e.g. ceramic coating for a recuperator proved to lessen the impact of high-temperature (1204°C) corrosive flue gases on the recuperator in an aluminium melting furnace.

Case Study 24: Cogen saves money and increases productivity by 20%, Adelaide Malting, South Australia

Adelaide Malting produces malted barley for national and international beer brewing companies. The company replaced the electrical fans on its gas engines with natural gas-powered fans. The heat recovered from the gas engines is then used to heat air for drying the malt. The initiative has boosted productivity by 20% and saves the plant $70,000 - $75,000 annually. The payback period was 2 years (Environment Australia, 2001)

6.2.5 Motor driven systems

Motor-driven systems include compressors, machining and forming tools, robots, pumps, fans, air handling and ventilation conditioner, refrigeration systems and material handling systems such as conveyors.

When selecting a motor, it is important to remember the motor uses 4-10 times its purchase price in electricity (DTRDI, 2010b) Thus, while all three phase electric motors are subject to Minimum Energy Performance Standards (MEPS) requirements in Australia and New Zealand, manufacturers should consider not just the initial purchase price but operating costs as well (Energy Ratings, 2017). MEPs legislation was introduced in October 2001 (MEPS1) and updated in April 2006 (MEPS2) so motors purchased today are likely to be more efficient than most motors over ten years old. Motors should also be sized appropriately. Motors are often sized to handle peak demand and consequently may be inefficient for the majority of operation (Pagan, 2004).

Variable Speed Drives (VSD) can dramatically improve energy consumption by adjusting the motor speed to continually match the load of the equipment. They are suitable for manufacturing processes that operate at variable loads or are oversized. Future motors will benefit from improved wide bandgap (WBG) semiconductors which are expected to enable even more cost-effective and higher efficiency systems (US OEERE, 2015).

6.2.6 Water efficiency

Water security is a real issue for Queensland manufacturers with over 50% of the state being drought declared in May 2017 (Section 4.5). To alleviate the risk of diminishing supply, manufacturers should look for opportunities to improve water efficiency and, where viable, look for alternate supplies such as internal water recycling/reuse (Case Study 25), captured rainwater (Case Study 26) or even the use of recycled town water (Case Study 27). A first step in improving water efficiency is to have adequate metering, including sub-meters and to regularly monitor trends in water use. This enables any issues, such as leaks or poorly operating equipment, to be quickly identified. The use of smart water networks including smart meters, leakage sensors, pressure sensors, flow meters, and water quality sensors are becoming increasingly common with water supply companies (Utility Magazine, 2017) and this technology will also become more viable for manufacturers.

For processes that require extensive cleaning, such as in food processing, having water efficient fittings and encouraging staff to conserve water as part of everyday practises can lead to significant savings. Other initiatives include:

- Good workplace design and layout for easy cleaning and scheduling to reduce cleaning requirements.
- Operator training and access to dry cleaning equipment.
- Use low flow / high pressure hoses where aerosols are not a problem and triggers on hoses.
- Install electrical sensors to shut off water when not required.
- Optimising flow rates.
- Reuse final rinse water for pre-rinses cycles.

Utilises such as boilers or cooling towers which provide a supply of chilled water for air conditioning or other process cooling systems can also consume significant quantities of water. In the case of boilers, it is important that water consumption is minimised by ensuring all condensate is captured and returned to the boiler. Steam traps and condensate lines should be inspected and maintain regularly. For cooling towers and boilers, water consumption can be minimised by optimising their cycles of concentration and finding uses for bleed water. Refer to Queensland Government Fact Sheets on Boiler Efficiency, Cooling Towers and Cleaning Methods and Practises for further information (DTRDI, 2010c).

Case Study 25: B&R Enclosures, Brisbane, Queensland

B&R Enclosures is Australia's largest manufacturer of electric enclosures, racks and cabinets. The company provides non-metallic, stainless steel, aluminium and steel enclosures of various shapes, sizes and ratings.

Once the steel components are formed, they are powder coated to produce a high-quality rust resistant finish. This involves several stages of surface cleaning and preparation requiring the use of alkali and acid chemicals, town water and reverse osmosis (RO) treated water.

The powder coating process was optimised to reduce water consumption by increasing the level of recirculation of initial rinse water and reducing the once-through final rinse water. This process reduced annual water consumption by around 24% saving 2.4 ML and $12,000 per year and additional energy related savings in producing RO treated water (DSD, 2017g).

It is easy for manufacturers to underestimate the cost of water and wastewater treatment. In addition to purchase price, the full cost of water includes any incoming treatment, heating, pumping and then final treatment and disposal.

Case Study 26: Water efficiency, Beard & Brau Farmhouse Brewery, Queensland

B&B capture all the water they require in rainwater tanks. Water is a vital ingredient in beer and consumes around 45% of all the water entering the brewery. The remaining water is used predominantly for cleaning.

B&B has reduced its overall water consumption by 40% and is now at world's best practice, using 1.8-2L of water for every litre of beer they produce. Initiatives have included:

- Changing the breweries cleaning regime to reduce water consumption and use biodegradable chemicals that do not harm the wastewater treatment process. The biodegradable chemicals developed and tested by B&B and AIRD Chemistry have reduced the breweries water consumption by 24% in addition to significant energy savings in hot water use and better cleaning results
- A new automatic keg washer that reduces LPG gas usage and water use from 200L/hr down to 130L/hr whilst also reducing the risk of Repetitive Strain Injuries (DSD, 2017c).

Case Study 27: Alternate water supply, Dalby Biorefinery Ltd, Dalby, Queensland

Dalby Biorefinery is one of three commercial bio-refineries currently operating in Queensland and is Australia's first grain-to-ethanol facility. First commissioned in 2008, the plant converts red sorghum grain into fuel-grade ethanol and high value animal feed products. In 2010, due to water supply concerns in the region, Dalby Biorefinery Ltd switched from using mains potable water to Class A+ recycled water. The Dalby township's wastewater treatment plant was upgraded to supply this water in a project jointly funded by the state government, the council, and the bio-refinery. The plant now receives around 1ML of recycled water daily. This has also enabled 20% of Dalby's potable water supply to be returned to town's residents to help it deal with future growth and extended drought periods (DSD, 2017h).

6.2.7 Waste efficiency

Waste intensity in the manufacturing industry has increased 31% between 1996-97 and 2013-14 (CSIRO, 2016b). The value of waste supplied to the Australian economy (e.g. waste with value) increased 18% in the year to 2010-11 to reach $5.4 billion. Manufacturing waste accounted for approximately 14% or $741 million (ABS, 2016a).

The need to compete with developing countries with relatively cheap labour costs has meant many industrialised countries are increasingly looking to produce high quality products using innovative and lean techniques to maintain a competitive advantage (Narkhede, 2017). Manufacturing approaches such as lean or flexible manufacturing aim to provide consumers with an affordable product without forfeiting customization (Krar, 2003).

Lean manufacturing is a team-based approach to continuous improvement that focuses on eliminating non-value-added activities or "waste" from the viewpoint of the customer. The concept has been promoted by the Queensland Manufacturing Institute (QMI Solutions) for over a decade (QMI, 2008).

The first part of the lean manufacturing process is to consider what aspects of the product add real value for the customer. For example, if a customer is buying a computer, they might be looking for quality, durability, affordability and recyclability. Thus, lean manufacturing investigates if every step in the production process is adding the values that the customer wants. This could mean designing and using high-quality parts to improve durability. Wang reports product development determines 80% of the manufacturing cost and thus significant cost reductions can be achieved in the design phase (Wang, 2010). In addition to design concepts covered in section 6.1 of this review manufacturers can use Design for Six Sigma (Identify-Design-Optimize-Validate). Design for Six Sigma seeks to design products, services or manufacturing processes carefully in the first instance so less time is needed downstream improving the product or service (Cudney, 2012).

The second part is based on the management philosophy derived from the Toyota Production System (TPS) that focuses on reducing wastes in the manufacturing process. The seven wastes that do not add customer value include: unnecessary motions, waiting for work and materials, transportations, overproduction, excessive processing, excessive inventories and corrective operations i.e. rework and scrap. For example, "just in time" inventory management where inventory stock is kept low and ordered 'just-in-time' to meet customer requirements (Case Study 28). As the manufacturer learns more about what customers really want they are better able

Case Study 28: Lean Supply Chains, Zara, Spain

Spanish clothing manufacturer Zara has actively sort to reduce its levels of overproduction and waste developing lean manufacturing and supply chains. By using **Just in time inventory management** new designs can arrive in store within fifteen days (traditionally this takes 2-5 months).

Twice a week, at precise times, store managers enter customers buying habits into a computer. This information is then sent to a design team who make immediate improvements. Twice a week, on schedule, the retailers then receive new garments. Zara has close to 6500 stores across 88 countries around the world (Robison, 2015).

to create a product at the lowest price with minimal waste. There are many tools available to manufacturers interested in reducing manufacturing waste. These include (Wang, 2010):

- The 5S system which is designed to improve workplace organization and standardization. The 5s' are: Sort, Straighten, Shine, Standardize and Sustain.
- Cellular manufacturing where workstations and equipment are closely located allowing work to be completed on one piece at a time to meet specific customer demands and minimize part movements.
- Kanban to visualize work flows and to identify and eliminate bottlenecks
- Kaizen for continuing improvement involving everyone finding and eliminating waste in equipment, labour or production methods.
- Total Preventative Maintenance to minimize downtime.
- Value Stream Mapping to better understand the flow of the material and information as a product makes its way through the value stream.
- Six sigma that seeks to identify and remove the causes of defects and minimize variability. It defines a sequence of steps in a process and has specific value targets such as process cycle time. It then uses statistical methods to measure the level of deviation away from the set target (Case Study 29).

Case Study 29: Six Sigma reduces wasted time and resources, B&B Farmhouse Brewery, Queensland

Beard & Brau brews over 28 different types of beer per year. The ability to maintain consistency and to track each batch for quality purposes is critical. B&B applies a Six Sigma approach to each batch to identify and quickly resolve any defects in the process. Six Sigma is a data driven methodology that involves undertaking frequent measurements during the process and then statistically analysing the results to ensure they are within six standard deviations between the mean and the nearest specification limit. Data is then stored as part of B&B's document quality control system and linked to a batch code that is labelled on every bottle or keg leaving the brewery.

The Six Sigma process identified that bottling was the bottle neck in the process. A review at the design stage resulted in a move from using 330ml bottles to 500ml bottles. Because 500ml bottles only contain 10% more glass than their 330ml counterparts the business can now bottle the same amount of beer per cartoon whilst reducing the number of bottles from 24 to 15. The initiative significant reduces labour times while also reducing material resource consumption per carton by 33%. It also reduces carbon emissions from transport as the weight of the new cartons are less than that of the old (DSD, 2017c).

Lean manufacturing has also been extended out into the supply change as a way to reduce unnecessary waste. Initiatives include ensuring delivery at the correct time, appropriate packaging, effective and minimal inventory systems, minimising warehousing space and correct storage and handling. A key aspect of lean supply chains are the supplier partnerships and strategic alliances that focus on being mutually-beneficial and transparent. Companies within lean supply chains realised that by transferring costs either upstream or downstream does not increasing their competitiveness as ultimately the consumer pays. Coordination is driven by a focus on achieving efficiency, eliminating waste and creating value in products (Daud, 2011).

Ecoefficiency can add to a lean manufacturing approach by not only considering how to reduce waste but also considering beneficial uses for unavoidable waste. These include (Pagan, 2004):

- Onsite reuse of waste,
- Reuse of waste by other businesses (Section 2.3, Case Study 30 and Case Study 31),
- Donations (see section 7.4),

Case Study 30: Reuse of waste, Fibrelogic, South Australia

Fibrelogic produces glass reinforced plastic (GRP) pipes using advanced manufacturing technology. Previously non-conforming pipes were downgraded and destined for landfill. After looking for alternative markets the pipes today are now used for dog kennels, boat pontoons, linings for old wells, water storage and feeding troughs. This initiative saved 200 tonnes per year of waste going to landfill, 2000m^2 of yard space and approximately $75,000 per year in landfill fees (ZeroWaste SA, n.d.).

- Using waste as a potential fuel source e.g. pyrolysis, gasification or anaerobic digestion,
- Product recovery during processing,
- Extraction of valuable products (Case Study 32),
- Recycling, and
- Development of new products from by-products.

Case Study 31: New product from waste, Aximill, Victorian

Aximill manufactures commercial grinders. Recently they saw an opportunity to start a new business using paper and plasterboard waste from Boral and coffee grinds from MacDonald's using their own technology. By reprocessing the paper and broken plasterboard, Aximill can produce kitty litter while the coffee component reduces dust and also assists the composting process. The initiative will divert up to 11.5 tonnes/yr of coffee grounds and 1 000 tonnes/yr of waste paper, saving Boral and MacDonald's $130 000 per year in disposal fees (CSIRO, 2016a).

Case Study 32: Turning seafood waste into a high-grade product, Biomedical Chitosan, Qld

Biomedical Chitosan are manufacturers and suppliers of high-grade biomedical chitosan. The chitosan is derived from crustacean waste from aquaculture and sustainable wild fisheries in Australia. Developing chitosan for use in thin film surgical adhesive, nerve and corneal repair is of particular interest. After 3 years of experimentation the company is in the process of scaling up the plant which is capable of manufacturing high quality chitosan of various specifications. This will result in thousands of tonnes of seafood waste that is turned into a highly value-added product and which is prevented from reaching landfill.

6.3 Product Use

Manufacturers can influence the way their products are used and disposed of. This section outlines some ways manufacturers can contribute to the sustainable use and disposal of their products.

6.3.1 Product Stewardship

Product Stewardship or Extended Producer Responsibility (EPR) is an approach that there is a shared responsibility of those who design, manufacture, sell, use or dispose of a product towards the way the product is managed throughout its lifecycle to minimise its impact on the environment, safety and human health (DEE, 2016). All people involved in a product and its packaging from design and manufacture, through the sale and use to the end-of-life should take responsibility to reduce the impact on the environment, safety and human health. Although Product Stewardship often focuses on end-of-life collection and recycling components it should consider minimising energy, water and resource consumption through production, use and disposal phases and also includes:

- product design to ensure the longevity of a product and the ability to easily reuse or recycle the product (refer to Section 6.1),
- material selection to replace hazardous materials with less hazardous material,
- consumer usage and education to ensure proper use, repair and disposal of the product,
- product durability and reparability to extend the working life of the product and ease and cost of repair,
- product longevity by ensuring component upgrade (particularly electronic goods) is easily facilitated,
- Opportunities to reuse the products where possible before the need to pull apart and recycle (e.g. refillable cartridges).

Product stewardship also has the potential to support new jobs with many collection and reprocessing companies operating as social enterprise operations that create jobs and training for local people who may have experienced barriers to gaining lasting employment such as Soft Landing (refer to Appendix B).

There are several policy instruments on how Product Stewardship can be achieved. Table 6 provides a list of some examples of the types of policy instruments that can be used.

Policies that apply directly to manufacturing include (Gupt, 2015):

- Product take back mandates and recycle rate targets which make it compulsory for manufacturers or retailers to take back end-of-life (EOL) products with penalties if these targets are not met (Case Study 33 and Case Study 34). This is often achieved through a collective effort by industry.
- Voluntary take back schemes (most prevalent type of extended producer responsibility (EPR) in Australia) involve no penalties for not meeting targets. These are often arranged through industry groups.

Table 6: Types of policy instruments (Gupt, 2015)

Types of policy instruments	Examples
Administrative instruments	• Collection and / or take-back (mandatory or voluntary) • Reuse and recycling targets • Setting emission limits • Recovery obligation • Product standards • Technical standards
Economic instruments	• Material / product taxes • Subsidies • Advance disposal fee systems • Deposit-refund system • Upstream combined tax / subsidies
Informative instruments	• Environmental reports / labelling • Information provision with recyclers • Consultation with authorities about collection network
Agreements	• Social contracts • Gentlemen's agreement

Case Study 33: Management of White and Brown Goods Decree in the Netherlands

In 1998 the Netherlands made it mandatory for retailers to take back old electronic and electrical goods in exchange for new ones. Manufacturers had to accept their products from the retailers and arrange transport and recycling. Targets for recycling were set at various levels ranging from 75% for refrigerators to 45% for small appliances. Recycling costs were covered by upfront fees charged on products. Municipalities ended up collecting 80% of goods with retailers reducing their storage and handling difficulties by offering discounts if consumers did not return their old appliance. The program was successful in achieving the EU target of 4kg of waste electrical and electronic equipment (WEEE) per person per year since 2001 (Gupt, 2015).

Case Study 34: Legislation leads to re-design in Japan

Japan has implemented legislation for the recycling of e-waste. The recycling of batteries and computers is covered through an internalised cost added to the purchase price with consumers transferring the old products directly to the manufacturer or through post offices. Consumers are responsible for the cost of transport of larger goods such as TVs, refrigerators and washing machines back to retailers who then convey them to collection locations designated by the manufacturers. Manufacturers are responsible for providing their own recycling facilities or outsourcing to commercial companies. Heavy penalties are applied for non-compliance.

This system has had a significant impact on product re-design. It has led to electronic products free from hazardous materials such as lead and bromine.

Japan also has an EPR scheme for packaging wastes where consumes are responsible for sorting their waste packaging and municipalities are responsible for collecting and forwarding waste to registered recyclers. Producers are responsible for recycling the properly sorted packaging waste. Heavy penalties are applied if the packaging is not properly recycled. The scheme has resulted in a design change to reduce waste containers and packaging through light weighting products and change in materials. Between 1996-2009 the total quantity of packaging was reduced by 16% (Gupt, 2015).

- Mandatory take-back and recycling with tradable recycling schemes allow trading of credits among producers to meet the required targets.
- Advanced recycling fee applies a tax on the sale of the products to cover the cost of recycling.
- Deposit refund system applied a tax that can be refunded when the product is returned for recycling.

- Upstream taxes may be applied to the manufacturer such as material taxes on specific materials that are harmful or difficult to recycle with the tax level set to cover treatment costs. This encourages manufacturers to substitute less harmful materials. Similarly, upstream combination tax/subsidy can be applied to the producer to cover the waste treatment costs.

The focus on recycling of components of products at the end of their life is more energy intensive then options to extend the life of products and to reuse. A European study found approximately one third of materials entering a recycling centre or civic amenity site could be re-used and at least 25% of electronic waste has a significant re-use value. However, recycling, landfilling or incineration are easier options to re-use under current legislation. (RREUSE, 2015a) The low price of new products compared with the high cost and difficulty of repairing products can make repair uneconomically viable.

Studies in Europe have found that while 77% of EU consumers preferred to repair their products the high cost of repair meant they replaced or disposed of their products instead. (RREUSE, 2015b) In addition the number of repair specialist firms has decreased reducing the availability of people capable of repairing products despite the rise in consumption. For example, in the USA television and radio repairmen decreased from 110,000 people in 1963 to approximately 80,000 people in 2006 despite the rise in population by 90 million over that period. Similar statistics in Europe show a decline in repair service providers. (RREUSE, 2015b)

Several strategies that manufacturers can implement to make repair more economically viable include:

- Designing products to allow easy repair reducing time and cost of the repair,
- Providing access to manufacturing repair and service manuals to independent service providers.
- Providing access to replacement parts for a minimum of 10 years at reasonable prices. (RREUSE, 2015a)

In Massachusetts (US) the state made a legislative change to allow independent automotive repair and service technicians full access to up-to-date repair and diagnostic information for all makes and models of vehicles using a universal system. The EU implemented a similar campaign which has resulted in a number of successes. (RREUSE, 2015b) In 2013 The Repair Association was formed in America to advocate for anyone associated with repairing products to have access to the information and parts they require to fix their own products. (Repair, 2017)

Consumer Rights legislation can also be used to increase the reparability of products by having minimum guaranteed lifespan on products. This can result in manufacturers providing products with longer lifespans to reduce economic loss from forced repair. (RREUSE, 2015b) In addition, providing additional labelling on the durability of a product will allow consumers to choose a product based on lifespan.

6.3.2 Australian Product Stewardship

The Australian Government's *Product Stewardship Act 2011* was developed out of the National Waste Policy to provide a framework to manage the environmental, health and safety aspects of products with a particular focus on waste disposal. The legislation covers voluntary, co-regulatory and mandatory schemes.

The objective is to reduce landfill particularly of products harmful to human health and environment by increasing the reuse and recycling of valuable materials from products. To achieve this a product stewardship approach looks for manufacturers to replace more harmful components of their products with less toxic or more easily recyclable components.

While there is provision under the *Product Stewardship Act* for mandatory schemes to be developed which place a legal obligation on parties to take a certain action there are no currently no mandatory schemes in place. Mandatory schemes may include labelling, making arrangements for recycling product at the end of life or requiring a deposit or refund applied to a product.

Co-regulatory approach are schemes delivered by industry and regulated by the Australian Government. These schemes have specific requirements placed on industry such as meeting a certain recycling target or avoiding, reducing or eliminating waste from a product. Table 7 provides details on the one current co-regulatory scheme.

Table 7: Co-regulatory Product Stewardship programs

Program	Description
National Television and Computer Recycling Scheme (Australia wide)	National Television and Computer Recycling Scheme established in 2011 to provide an industry funded collection and recycle services for televisions and computers. The scheme provides progressively increasing recycling targets to remove hazardous television and computer waste from landfill and increase the recovery of useable materials with a target of 30% by weight of the amount of televisions and computers discarded in 2012-13 to 80% in 2026-27. 90% of the material of the televisions and computers recycled must be reused or manufactured into new products to be classified as recycled. (DEE, 2015). www.environment.gov.au/protection/national-waste-policy/television-and-computer-recycling-scheme

The voluntary schemes are developed within the industry itself but are accredited under the act to meet specific requirements to ensure transparency and accountability. Many industries already undertake some level of product stewardship and this method allows them to provide the community with some certainty of their activities. (DSEWPC, n.d.) There are two Voluntary Schemes that have been accredited by the Australian Government under the *Product Stewardship Act 2011* as shown in Table 8.

Table 8: Accredited Voluntary Schemes

Program	Description
Mobile Muster (Australia wide)	MobileMuster is the official mobile recycling program for the industry to collect and recycle phone components including handsets, batteries and accessories. Since the program started in 1998 over 1,244 tonnes of mobile phone components have been collected and recycled or approximately 10.86million individual handsets and batteries. (Mobile Muster, n.d.) www.mobilemuster.com.au/
FluoroCycle (Australia wide)	FluoroCycle seeks to increase the national recycle rate of waste mercury containing lamps to reduce the amount of mercury ending up in landfill. Currently it is estimated that 95% of all mercury containing lamps including CFLs or fluorescent tubes are sent to landfill. (Lighting Council Australia, 2017) The accumulation of mercury in landfills is a concern as it converts to toxic methylmercury and can spread in the environment through air, water and soil. FluoroCycle is open to any Australian organisation who will commit to recycle all their waste mercury-containing lamps. www.fluorocycle.org.au/.

There are several other voluntary industry driven schemes which have not yet been accredited by the Australian Government under the *Product Stewardship Act 2011*. These are shown in Appendix B.

The Minister for the Environment produces an annual list of products that will be considered whether there is benefit in accreditation or mandatory action under the act. The *Production Stewardship Act 2011* is currently undergoing review.

The National Waste Policy Knowledge Store has been developed to showcase innovations and initiatives taken by Australian industry, government jurisdictions, business and the community to recycle, reuse avoid and reduce waste. These case studies highlight situations where small business, local governments, industry or community groups are benefiting and profiting from these initiatives (DEE, n.d.).

6.3.3 International Product Stewardship

Product Stewardship and Extended Producer Responsibility is an international concept with programs being run for years in Europe and the United States of America and around with world with a mix of mandatory programs such as the EU directives on Ecodesign, Waste Electrical and Electronic Equipment (WEEE) and EU labelling and industry based programs such as Product stewardship program for fertilisers through the Fertilisers Europe. The WEEE promotes repair and preparation for re-use of products to extend the life of products.

There are also industry groups targeting product stewardship and zero waste such as Zero Waste Europe which assist community groups at a local level to implement zero waste initiatives but also work at a higher level to influence EU policy (Zero Waste Europe, 2017).

The United States of America have no national legislation on Product Stewardship or EPR however, several states have taken on measures such as the Strategic Directives from the State of California on Extended Product Responsibility (CalRecycle, 2017). The USA have similar groups such as the Product Stewardship Society which facilities the spread of information and resources about Product Stewardship (Product Stewardship Society, 2017) and the Product Stewardship Institute which assists in voluntary product stewardship programs for industries including (Product Stewardship Institute, 2016):

- Appliances containing refrigerants
- Auto Switches
- Batteries
- Carpet
- Electronics
- Fluorescent Lighting
- Gas Cylinders
- Household Hazardous Waste
- Junk Mail
- Mattresses
- Medical Sharps
- Packaging
- Paint
- Pesticides
- Pharmaceuticals
- Phone Books
- Radioactive Devices
- Thermostats
- Tyres.

The Global Product Stewardship Council is an Australian based not for profit forum to assist in the global development of product stewardship. It provides online resources for information on product stewardship and information on policies and programs across the world. They currently have members from 12 countries around the world (Global Product Stewardship Council, 2017).

6.3.4 Australian Packaging Covenant

The Australian Packaging Covenant is the principle national instrument to reduce the environmental impacts of consumer packaging established in 1999. It aims to optimise resource recovery of consumer packaging through the supply chain and prevent the impacts of fugitive packaging on the environment (Case Study 35 and Case Study 36). The Covenant is the industry led component of the co-regulatory arrangements under the *National Environment Protection (Used Packaging Materials) Measure 2011* (NEPM) (DEE, 2017a).

Under the Covenant businesses in the supply chain that are consumers of packaging or packaged products with an annual turnover of $5m or more are required to choose between becoming a Signatory to the Covenant or meet individual compliance obligations under the NEPM. The Covenant currently has over 900 signatories. Obligations under the Covenant include (APC, n.d.):

- designing packaging that is more resource efficient and more recyclable.
- increasing the recovery and recycling of used packaging from households and away from home sources.
- Taking action to reduce the incidence and impacts of litter.

While the APC recognises that packaging is necessary, it recommends a lifecycle approach and provides tools to the industry for sustainable packaging design.

The Queensland Government is a signatory to the Covenant.

Case Study 35: Bundaberg Brewed Drinks engage supply chain for savings

Bundaberg Brewed Drinks (Bundaberg) holds Blue Sky innovation days where suppliers and staff come together to develop new ideas on how to improve business delivery. These innovation events develop trust along the supply chain partnership and allow both sides to use the expertise of each other to develop better solutions.

The Bundaberg Engineering team and the bottle suppliers worked together to reduce the weight of each glass bottle by 15g without compromising the integrity of the bottle particularly when pressurised. Reduced weight of the bottles leads to reduced glass use and freight costs.

The collaborative partnership between Bundaberg and their packaging supplier was highlighted by the assistance provided by Bundaberg to the supplier to get their production up and running after the factory was flooded in 2011.

Similarly, Bundaberg received a "Non-Conformance" notice from their supermarket customer for packaging that was tearing during shelf stacking. This led to broken bottles producing not only lost merchandise but also safety hazard from broken glass. Bundaberg worked directly with shelf stackers to determine the problems and inform the redesign process.

This led to a packaging product that:

- could be opened without a knife and placed directly on the shelf within the outer packaging improving safety;
- was thinner to reduce material use
- improved display and marketing. (APC, 2014a)

Case Study 36: Bristol-Myers Squibb and DHL partner for success.

Bristol-Myers Squibb Australia (BMS) is a biopharmaceutical company which supplies medicines to pharmacies, doctors' surgeries and hospitals within Australia. They had an aim to reduce packaging waste by 5% from a 2009 baseline.

Due to the nature of their medicines transport must be strictly temperature controlled. For this they were importing ready-made boxes (flat pack was not an option) to be used. These boxes were also providing their customers with disposal problems.

BMS worked closely with a third party logistic supplier DHL to develop a reusable packaging. Frequent innovation brainstorming meetings between BMS and DHL led to the development of Cool Green Cell – a reusable coolbox made of high quality polyurethane design specifically to deliver pharmaceutical and medical products between +2^{o}C and +8^{o}C. DHL own and lease the box to BMS with the customers returning the box to DHL.

To improve return rates to 90% success DHL:

- Have a team to arrange returns.
- Run daily reports to identify customers receiving boxes the day before.
- Call the hospital or pharmacy to confirm collection details.
- Wait for customers to unpack on the spot and returning boxes on delivery.

BMS saved 108 tonnes of waste and 900 m^3 of packaging materials in 2013. They save the purchase of 15,000 cool boxes and related ice/gel packs. Customers save in disposal costs of single-use boxes and time spent on waste management (APC, 2014b).

6.3.5 Sustainable Procurement

Sustainable or Green Procurement aims to minimise the adverse environmental, social and economic impacts of goods and services across the life of these products. (DEE, 2013) Sustainable Procurement looks beyond the upfront cost of the item to the broader environmental and social impacts such as cost of disposal and conditions of labour (ECO-Buy Limited, 2013).

The benefits to manufacturers from sustainable procurement include: (CCIQ/USQ, 2016a)

- Reduced cost over the life of the product due to the consideration of operating and disposal costs as well as upfront costs. (Hollos, 2012)
- Reduced environmental impact due to the consideration of resource requirements over the life of the product including manufacture, operation and disposal.
- Reduced social costs over the life of the product through consideration of social conditions of those involved throughout the supply chain and by supporting programs that improve social equity such as fair trade or other social enterprises.
- Improved company image through product certification (e.g. green labelling) and promotion of environmental improvements.
- Improved productivity through a healthier workforce due to reduction of chemicals and hazardous material on site and in the air environment leading to fewer sick days and higher productivity.
- Risk reduction by removing hazardous materials from products and associated workplace health and safety risk with handling hazardous materials. In addition, risk to customers and for disposal is reduced.
- Staff retention through improved job satisfaction and attraction of high performing staff that want to work in a sustainable workplace.
- Increased supply of sustainable products as the demand for them increases.
- Improved supply chain collaborations.

A study undertaken of 70 companies in Europe indicates that sustainable supply chain collaborations can lead to improved social and environmental performance of companies involved which in turn can lead to reduced costs and improved productivity (Hollos, 2012). A similar study in South Africa of 312 SME Manufacturing companies found that those involved in green procurement, green logistics and/or green manufacturing benefited from better environmental collaboration. In addition, those with higher environmental collaboration had improved financial performance (Mafini, 2017).

6.3.6 Transport

Environmental impacts of transport include greenhouse gas emissions as well as use of resources i.e. fuel, wear and tear on tyres and other vehicle components. The weight, packaging and the size of goods transported has an impact on resource use. Similarly, driving efficiency also impacts on fuel efficiency. Initiatives to achieve more sustainable transport should include (CCIQ/USQ, 2016b):

- Where possible, choosing alternate fuel sources e.g. biofuel or use of electric/hybrid vehicles.
- Reducing transport of goods through scheduling to reduce the number of trips and to only transport full loads. Better flexibility on delivery times through good supply chain relationships help to improve scheduling to minimise mileage and allow route planning.
- Choosing a fleet that is sized appropriate for the majority of trips (e.g. not oversized) and has a high fuel efficiency. Also, ensuring the fleet is aerodynamic by removing roof racks and bull bars that disrupt flow and adding aerodynamic features such as air deflectors improve fuel efficiency.
- Providing driving efficiency training to improve driving habits such as avoiding hard acceleration or braking.
- Undertaking frequent maintenance of the vehicles including the tyres improve fuel efficiency. Monitoring fuel efficiency as a drop-in efficiency can indicate a maintenance problem.

Ensuring tyres are keep at the appropriate pressure reduces wear and tear, improve fuel efficiency and improve safety.

- Include forklifts in fleet maintenance. Providing streamlined, clear paths for forklift runs will improve fuel efficiency. Switching off forklifts instead of idling reduces fuel consumption.

7 Social Sustainability in Action

Key Messages:

- Digital technology is revolutionising workplace health and safety via the use of wearable devices which can monitor movements and help to train employees.
- Engaged staff are significantly more productive, work more safely, generally happier and more likely to participate in company cultural change or sustainability programs.
- Manufacturing companies can be more socially sustainable through adopting ethical procurement practises and supporting social enterprises and local communities.

Social sustainability for manufacturers can include both issues within the company and how the company interacts with its community. Social aspects of sustainability are often overlooked as they are more challenging to quantify and qualify compared with environmental or economic sustainability issues (Sutherland, 2016). Manufacturing plays a key part in meeting society's needs through both providing goods, services and systems but also providing employment and hence financial support to families and individuals. Manufacturing companies are increasingly interested in their social impact whilst considering issues such as Corporate Social Responsibility (Section 2.4), triple bottom line reporting, brand reputation, product stewardship (Section 6.3.1), transparency and responsibility towards workers. Social impacts from a manufacturing perspective include the direct and indirect effects felt by a stakeholder due to the manufacturing enterprise (Sutherland, 2016). Stakeholders include staff and their families, supply chain, customers, industry groups, owners and the community in general. All stakeholders should be considered when aiming to be more socially sustainable.

7.1 Automation and digital technology improving OHS

Replacement of human workforce with robot and other technologies. such as driverless trucks, can reduce workplace injuries improving the welfare of workers. Case Study 37 shows how a mining company reduced driving injuries through automation.

Wearable devices are being developed to reduce workplace accidents. Wearable advances include:

- Systems to monitor staff in remote or dangerous locations.
- Watches that detect the presence of noxious gases
- Hats that can monitor brain activity to detect conditions that may lead to accidents or injuries such as fatigue or heat exhaustion.
- Helmet and iPad that allow 2-way communication between a field worker and supervisors to provide remote assistance.
- Virtual simulation to provide realistic safety training of high-risk tasks.

Barriers that may slow down uptake include:

- The need for good Wi-Fi connectivity.
- Ability to interpret a potentially overwhelming amount of data.
- Data storage with security.
- Concern over worker privacy (Twentyman, 2016).

Worker health and safety is a social sustainability indicator and it also has an impact on economic sustainability, for example lost time injury or accidents (Nguyen, 2017). Workplace or Occupational

Case Study 37: Rio Tinto Autonomous Trucks reduce injuries

Complete automation provides improvements to worker safety by removing the human error factor. Rio Tinto has the largest fleet of autonomous trucks in the world. They are controlled remotely by operators and have resulted in:

- 100% reduction in injuries over 10 years through automated train, truck and haulage system.
- 14% improvement in truck utilisation through enhanced operational performance through analysing and visualising data.
- 3 times drill labour productivity improvement through cab-less drill and computer controlled mineral recovery. (DIIS, n.d.)

Musculoskeletal disorders (WMSD) which can affect worker's muscles, skeleton, cartilage, vascular system, ligaments and nerves and can have a significant impact on the sustainability of the workplace. These injuries can include pain to the back, knees, neck and shoulders caused by incorrect positioning and movement of the body. The cost of WMSD in the European Union has been estimated to be 240€ billion which is approximately 2% of the EU GDP (Bevan, 2015).

Human-Centred Automation (HCA) has been developed as an alternative to fully automated lines which remove human input altogether to provide a system that integrates machines to support the workers rather than replace them. Ergonomic measures such as workplace layout design, process design or special equipment to support the worker can be enhanced through the use of Digital Human Models to simulate worker posture during use (Sanchez-Lite, 2013). Similarly, technical equipment such as lifting aids or human robot collaborations can reduce the physically demanding tasks for the workers. Alert systems can also be installed which let users know when ergonomically unfavourable situation arise (Nguyen, 2017).

Digital programs can be used to develop job rotation schedules to prevent injuries such as Repetitive Strain Injury. These schedules rotate the worker through a series of required tasks to ensure that loads are alternated through multiple regions of the body rather than straining one part of the worker's body (Nguyen, 2017).

7.2 Staff awareness and engagement

When staff leave a manufacturing company there is significant cost to the employers such as recruitment and retraining costs. Increasing retention rates, particularly of highly skilled workers can eliminate these costs. Increasing payrates is often not feasible especially for small to medium manufacturers. Staff engagement can be a more effective method of retention. There are many benefits for both manufacturers and for staff from increasing staff engagement. A recent UK study compared engaged staff with non-engaged staff and found up to:

- 70% improved productivity,
- 78% improved safety,
- 70% lower employee turnover,
- 86% greater customer satisfaction, and
- 40% greater profitability (Pickering, 2016).

Methods to increase engagement include (Pickering, 2016) (Taylor, 2016):

- Listening to employee ideas and feedback which can help them to feel more valued. Giving staff ownership of their own job can help them to engage with their business. As they typically know the production operation in most detail they can often find solutions to problems. Employee surveys, toolbox talks, brainstorming sessions or just providing suggestion boxes can allow staff to bring their ideas forward (Case Study 38).
- Improve change management by keeping staff informed on changes being made (Case Study 39).

Case Study 38: Staff engagement brings savings

Keystone Foods (then trading as Australian Food Corporation) encourages innovation and ownership of environmental responsibility from all staff. They provide rewards for the best environmental innovations, provide staff training and awareness. This encouraged more than 50 suggestions in a single year. One of the best suggestions was to use rechargeable batteries for equipment such as inspection torches and probes, saving approximately $4000 in twelve months. (DTRDI, 2010a)

Case Study 39: Information helps engagement

Staff engagement and morale was low at a manufacturing site. Focus groups were run and determined the problem was a lack of understanding of the new corporate structure after a restructure. The CEO became more involved in communicating the changes which resulted in a better understanding and acceptance by employees and a higher engagement (Employee Engagement Surveys, n.d.).

- Providing a flexible workplace to take employees preferences into account when scheduling work hours. This can significantly increase workplace satisfaction.
- Fostering career development and professional growth and keep employees challenged and motivated. Well managed training programs can also help employers develop the required skills to replace those employees who retire, thereby maintaining quality levels and competitive advantage. These programs can be on-the-job training or external training such as university and TAFE / industry certificate training.
- Provide an in-house mentoring program for more experienced staff to help share their knowledge and skills with less experienced staff. This can boost morale and can deepen core values that the company has developed.
- Providing company stock ownership or profit sharing can increase engagement as staff can benefit directly from a profitable business.
- Providing wellness benefits program to help staff stay healthy can boost employee happiness. This could include on-site programs such as nutritional support or walking programs or off-site programs such as discounts with a local gym or other wellness centre. Other support can be financial wellness programs which help staff manage their money and take control of debt.
- Celebration of hard work and contributions can assist employee satisfaction. These may be onsite celebrations such as an end of month BBQ or annual off-site celebrations. Providing some of the profits gained from employee improvement initiatives towards staff celebrations can be a great way to promote suggestions. Acknowledgement of specific staff involvement can increase job satisfaction as employees know that their contribution is appreciated.
- Supporting employee community-based programs (refer to section 7.3) or achievements outside the workplace can boost employee morale.

7.3 Ethical sourcing and social enterprise

Ethical sourcing is a subset of sustainable procurement where companies aim to work with suppliers to improve their social and environmental practices, particularly when suppliers come from developing countries. Purchasing from these regions assist in their economic development however, companies should consider the possible risk of human rights violations such as child and forced labour. Organisations such as Fairtrade that focus on fair prices, working conditions and support for empowerment of farmers can assist other businesses to ensure their products are sourced ethically. (Fairtrade, 2016)

Social enterprise involves a business operating for social benefits. Often the business will have:

- Social objectives as a core focus,
- Limited or reinvested profits for social benefit,
- Capital from a mixture of sources including income, philanthropy or grants, and
- Social as well as financial returns (QSEC, 2017).

Case Study 40: Social enterprise for collection/recycle of electronic waste, Substation 33

As a not-for-profit, social enterprise initiative, Substation33 provides a safe and supported work environment for work for the dole participants, special needs youth, and at-risk community members. The centre accepts electronic waste from the local community, council and businesses providing an outlet for the recycle of computers, monitors, servers, office equipment, televisions, household appliances and any other obsolete or unwanted electronic equipment. The organisation diverts around 100 tonnes of e-waste from landfill per year and, in 2015, provided over 9000 hours of paid employment and over 25,000 hours of work experience and volunteering during 2015. Source: (CCIQ, 2016a)

While it may not be possible for manufacturers to operate as social enterprises they can adopt some of the practices of social enterprises which may include:

- providing opportunities for employment or upskilling of people who may be struggling to find employment such as those with a disability or long-term unemployed (Case Study 40).
- Supporting local communities.

- Offering flexible work conditions to promote work/life balance and other support such as family friendly policies or childcare subsidies (Lalle, 2012) (Case Study 41).
- including social enterprises within their supply chains (refer to Product Stewardship 6.3.1).

Case Study 41: Social enterprise for clothing manufacturer

Clothing manufacturing Southwest Creations Collaboration started in 1994 with the objective of alleviating poverty by providing dignified, living wage employment to women from low-income communities. Over the past 20 years they have employed over 125 people, created 35 living wage jobs and provide a college-readiness program for employee's children. This schooling program has had a success rate of 98% high school graduations and 86% college attendance rates.

The enterprise is also financially viable, growing from an early revenue of $US30,000 to over $US1m leaving the company 100% self-sufficient and able to contribute $US100,000 annually to support social impact programs (Southwest Creations Collaboration, 2015).

7.4 Supporting the local community

Supporting the local community strengthens both the manufacturing company and the community. Examples of ways manufacturers can be involved in their community include:

- Providing sponsorship such as to the local children's sports team.
- Providing grants, donations or in-kind support through products and services. This may include matched donations for those raised by staff.
- Allowing staff to lend their skills and work time to causes they support.
- Providing cause-related marketing where a portion of the sales goes to support a social cause.
- Providing mentoring or expert advice to local groups or other businesses.
- Working with local suppliers which can increase their ability to respond to just in time supplying (Case Study 42).
- Employment of marginalised workers (refer to Social Enterprise in Section7.3)

There are many benefits to manufacturers for supporting their local community. Such benefits include:

- Improved staff morale, job satisfaction and workplace commitment (improved staff retention) to be allowed to spend work time supporting a cause.
- Increase in the skills of staff such as project management, sense of responsibility or capacity to get on with a wider range of people.
- Improved teamwork when staff work together on community projects leading to better cohesion within the workplace.
- Improved company reputation within the community which may lead to better promotional opportunities within the traditional and social media. This may also reduce the marketing budget by providing free publicity and more word-of-mouth sales.
- Stronger local network which may result in new customers and suppliers.
- Recruitment of more loyal employees as people want to work for socially responsible companies. Recruitment costs may also reduce as potential employees seek out companies with a social agenda.

Case Study 42: Sourcing locally to support the community

Beard & Brau Farmhouse Brewery (B&B) is an independent brewery located on acreage in South East Queensland's Tamborine Mountains. As a craft brewer, B&B primary mission is to value-add to the brewing process to produce uniquely flavoured beers of the highest quality. Passionate about revitalising the community values of a village brewery and conscious of their carbon footprint B&B use natural ingredients they can procure locally. The brewery's malt, grains, cocoa and vanilla are all sourced from Queensland producers, only their hops are sourced from Tasmania. Botanicals such as nettles and elderflower are grown on site while lemon myrtle and finger limes are supplied by nearby farms (DSD, 2017c).

- Increased sales from socially aware consumers.
- Stronger position to attract investors by having a social agenda. (ICAEW, 2009)

Manufacturers need to make sure that the companies or causes they support have similar core values to their own business. In addition, it can be detrimental to manufacturers to only want to support these groups for what they can get out of it as this can be seen as lip service to both staff and community. Generally, community support is more effective when staff have some choice or ownership in the support provided leading to a far more integrated relationship (Our community, n.d.).

8 Economic Sustainability in Action

Key Messages:

- Sustainability is best implemented by integrating it into corporate strategy and conventional business models e.g. the business canvass.
- Investment in research and development is key to driving innovation in manufacturing.
- Blockchain and 3D printing are disruptive technologies that are currently driving innovation in manufacturing.
- The implementation of sustainable business models provides an excellent opportunity for value creation.
- Manufacturing companies can add value to their products through increasing service provision. Manufacturing industries that have created non-production capabilities exhibit the strongest export performance.

Though in decline, Queensland manufacturing companies continue to make a significant and important contribution to the local and national economy through the provision of over 160,000 jobs and around $20 billion of output (see Section 4.1). The following describes how the adoption of sustainable business models can help drive innovation and create further value for the sector.

8.1 Sustainable business models

Business models provide a visual perspective of a company's structure which include factors such as value proposition, customers and key resources. Lüdeke-Freund defines a sustainable business model as one that "creates competitive advantage through superior customer value and contributes to the sustainable development of the company and society" (Lüdeke-Freund, 2010). Sustainable business models regard society and the natural environment as primary stakeholders alongside shareholders, customers and suppliers.

There is an increase in literature regarding the integration of sustainability into conventional business models. Joyce and Paquin have adapted the Business Model Canvass (a visual representation of a company's value proposition, key activities, resources, customers, cost structure etc (Osterwalder, 2010) and developed a triple layered business model canvass (TLBMC) that represents economic, environmental and social aspects (Joyce, 2016). The TLBMC (Figure 14) provides a high-level summary analysis and 'is meant for developing an integrated and holistic perspective of the entire business model, which may, in turn, shed light on where deeper and more focused analysis may need to be done'. Oertwig et al describe business models and methods for integrating sustainability into the corporate strategy, which include the concepts of natural and human capital alongside financial capital (Oertwig, 2017). A framework for management of corporate sustainability performance is shown in Figure 15.

The business models are an important first step for broad scale integration of sustainability. However, there can be a gap between having a business model and putting it into practise. Oertwig et al raises an important factor regarding such enterprise models in that 'the implementation of a sustainable development strategy requires not only an excellent knowledge of the internal processes and structures, but also, for example, of relationships with customers and partners' (Oertwig, 2017). Transforming the business model into an effective strategy as well as having a business culture open to adaptation and all driven by strong leadership are crucial factors. This is discussed further in the following sections.

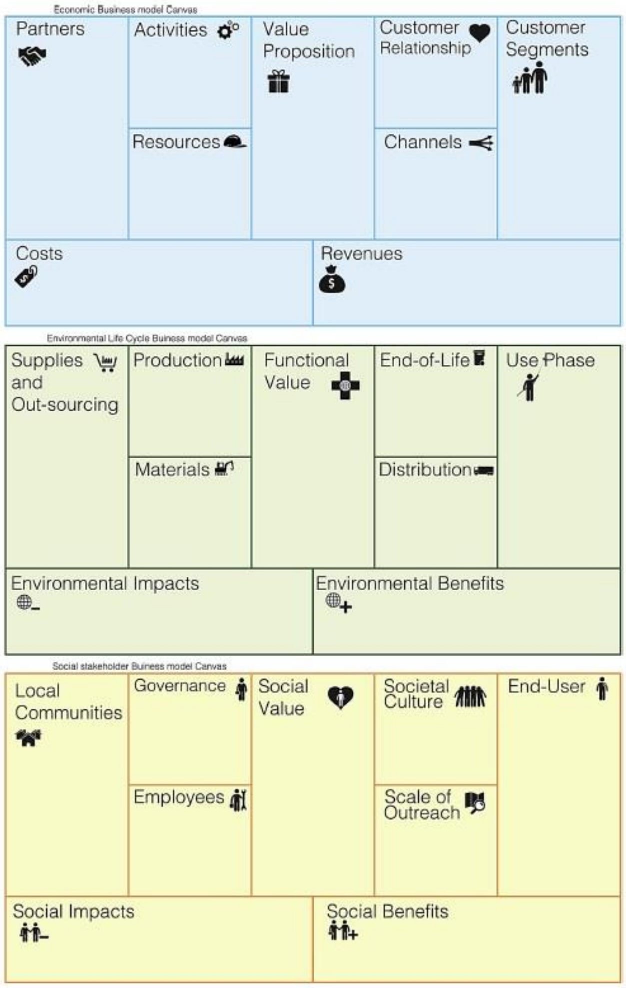

Figure 14: Triple layers business canvass model (Joyce, 2016)

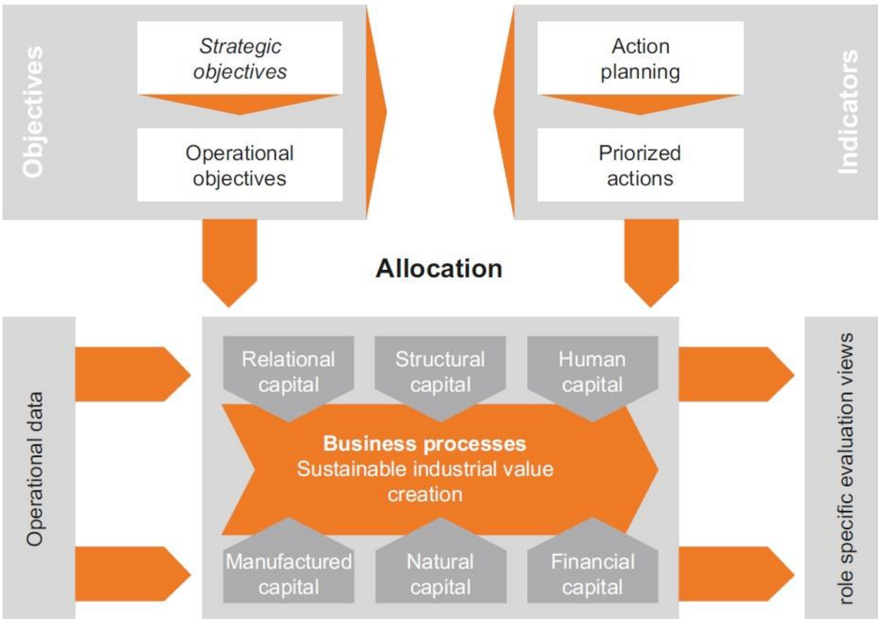

Figure 15: Model-based framework the management of corporate sustainability performance (Oertwig, 2017)

8.2 Driving innovation

Innovation generally refers to changing processes or creating more effective processes, products and ideas. It is commonly assumed that innovation is the main driver for economic growth. With respect to size of companies and their capacity to innovate, 'the question is not whether large companies are more innovative than SMEs; of more importance is the conclusion that SMEs innovate differently from large companies with particular importance given to 'informal and entrepreneurial leadership style, flexible organization capacities and motivated personnel' (Bos-Brouwers, 2010).

O'Regan et al explored the innovation process associated with high and low performing firms within the context of strategy (encouraging staff creativity), organizational culture (empowerment) and leadership styles (transformational/human resource) in SMEs (O'Regan, 2005). The study analysed 194 survey responses of SMEs in the UK and undertook statistical analysis of the survey results. The results indicate that high performance firms place a greater emphasis on all these attributes compared with low performance firms. The differences in emphasis were statistically significant with respect to the majority of the attributes.

Innovation cannot occur without research and development (an example of this is illustrated in Case Study 43). Australian business expenditure on R&D is weaker than that of many key OECD competitors which is potentially hindering the capacity for innovation. For example, in 2013, Australian businesses' expenditure on R&D was the equivalent of 1.19% of GDP, while in Germany it was 1.90%, US 1.94%, Japan 2.65% and South Korea 3.26% (AMGC, 2017).

A study of 50 successful Australian aerospace and medical technology companies reported that five key ingredients have helped to create technology leadership in Australia's top firms - public research funding, commercial R&D support, university collaboration, capability transfer from another industries, and strategic government demand. The mix of direct /funding) versus indirect (tax incentives) government support is raised as another outlier compared to other OECD countries with approximately 90% of support for Australian businesses coming from indirect channels. This is compared to countries such as the United States (27% indirect channels) and Germany (100% direct channels). The Australian Manufacturing Growth Centre therefore is recommending to improve the design of Australian Government support for business-led R&D (AMGC, 2017).

Case Study 43: Simplicity Australia, Maintaining competitiveness through R&D

Simplicity Australia, based in Dalby, Queensland, specialises in the design and manufacture of cutting edge air seeders and cultivators. To compete and thrive Simplicity has had to continuously invest in product development. This has meant constantly integrating new and innovative manufacturing process or advanced technologies into either altered or new machinery. To remain competitive and to ensure Simplicity has the capacity to respond to new demands and the constantly changing operating environment it has:

- Invested heavily in the research and development
- Increased its capacity by using state-of-the-art technology
- Developed a highly skilled and diverse workforce including fostering in-house mentoring
- Ensured that all forms of waste that do not value add to a product have been eliminated (DSD, 2017a).

With respect to education and provision of useful tools and resources for business an example is InnoSupport which is a European consortium to support innovation (see Box 14).

Box 14: InnoSupport: Supporting Innovations in SMEs

InnoSupport is an extensive twelve-part innovation guide/web platform which has been developed by a European consortium of universities, research organisations, technology and incubation centres and other technology transfer organisations. The guide describes processes for identifying, evaluating, financing and marketing innovations and includes case studies, tools and various other support measures. See www.innosupport.net/.

8.2.1 Blockchain and 3D technology

An emerging disruptive innovation which is set to drastically change the way many manufacturers do business is that of 3D printing and blockchain (See Case Study 44). Blockchain technology is derived from bitcoin and is a distributed ledger which stores a digitally encrypted record (database) of the history of a product or service and all related transactions. The information is replicated, shared and synchronised across multiple sites, countries or institutions.

In manufacturing, blockchain technology can be used to protect print files that describe high-value, high-margin, precision-manufactured parts, such as components in jet engines or power generation equipment (Cognizant, 2017). The intellectual property surrounding the design of such parts means that they can command purchase prices that are hundreds or thousands of times higher than their printing cost. 'These design files are the crown jewels of 3D manufacturing value chains, and must be extremely well-protected against theft or tampering when shared among a global network of printing facilities' (Cognizant, 2017).

3D printing combined with blockchain has the capability to drastically change business models, in that manufacturers of all sizes can 'borrow' or lease printing capacity on an as needs basis, so that the printing service and protection of IP related to designs becomes the new business model. Another feature is the use of 'smart' business contracts which digitally facilitate, verify, or enforce the negotiation or performance of a contract and allow business to be conducted between non-trusted parties, without the need for a middleman. Smart contracts can reduce or even eliminate the need for 'trusted' intermediaries including banks and lawyers. Risks and opportunities of blockchain technology are discussed by CSIRO (CSIRO, 2017).

In the previous example provided, smart contracts can be used to automatically locate the most appropriate printer (based on attributes such as availability, price, quality and location) and automatically negotiate terms, such as price, quality level and delivery date.

Case Study 44: Blockchain and 3D printed driving: Innovative manufacture of Cufflinks

IT Consulting Company, Cognizant and partners demonstrate how 3D printing and blockchain is innovating manufacturing, through developing a prototype of a block-chain-based shared 3D printing factory. In this case, the company is manufacturing custom designed cufflinks. The process works as follows:

- Print orders are executed – 3D printers are used by the customer on demand.
- Designers register their design on the blockchain – this enables designers to receive royalties once an order is received for a product they have designed.
- The digital product memory provides information about the material used e.g. titanium cufflinks, material history and quality.
- Trade finance processes and document processing is digitized eliminating many checking and verification processes normally associated with trade financing.
- Mass customization is enabled, as each cufflink includes a serial number in its design, printed on the side.
- Each cufflink box is tagged to a QR code, which connects the cufflink's identity to its digital product memory (Cognizant, 2017).

8.3 Value adding (extending service provision)

Value added can be considered as 'anything that changes the shape or character of the product' (Miles, 2008). In lean manufacturing, value adding is a step which:

- transforms the item toward completion (something changes)
- is done right the first time (not a rework step)
- the customer values and is willing to pay for.

A non-value adding activity achieves none of these things and effort should be taken to remove such activities from the manufacturing process. Importantly, these descriptions refer to the provision of a product and the surrounding service. There is opportunity for manufacturers to add value through increasing the services related to their products. Taking advantage of digitised processes and selling the functionality and accessibility of products instead of only selling the tangible products is a leading concept in how businesses will operate (Stock, 2016).

The Australian Manufacturing Growth Centre Sector Competitiveness Plan (AMGC, 2017) discusses increased levels of service provision surrounding existing products including providing a capability or solution rather than selling a piece of equipment; and bundling services that are typically conducted by the customer or third parties in the outbound supply chain e.g. training, support, repairs, data monitoring and analytics. Relevant examples include many of the approaches discussed in Product Design (Section 6.1) and Product Stewardship (Section 6.3.1) e.g. providing access and promoting take back and recycling avenues and providing consumer information to enable them to carry out their own repairs on products. It is noted that Australian manufacturing industries that have created non-production capabilities i.e. higher numbers of service based occupations, exhibit the strongest export performance for example, the aerospace industry, pharmaceutical and medical/surgical equipment (AMGC, 2017).

8.4 Value creation

As opposed to value adding, value creation is about creating value from something which did not exist before. An organisation's business model provides the basis for creating value. The implementation of a sustainable business model therefore provides an excellent opportunity for value creation (Case Study 45). Sustainable value creation requires companies to have systems thinking when making business decisions and to consider value creation opportunities across supply chains and from multi-stakeholders, including customers, suppliers, employees, society and planet ((Stock, 2016) and (Evans, 2017)).

Evans et al present tools for mapping and analysing value creation (Evans, 2017). The tools 'provide a structured way of helping companies identify opportunities for business model innovations that result in more sustainable businesses'. The first of these is the Cambridge Value Mapping Tool which provides a process to identify 'captured, missed, destroyed, surplus/absence and opportunity' to create value.

Case Study 45: Value Creation through Sustainability Branding, The Butterfly Mark - Positive Luxury

Positive Luxury has awarded the butterfly mark to over 300 high quality luxury brands that have sustainability as an integral part of their business. The butterfly mark tells a brand's sustainability story by revealing its social, environmental and philanthropic efforts on a website. A growing band of consumers want luxury goods, but prefer to buy from brands that are striving to have a positive impact on people and the planet.

Transparency at the point of sale promotes informed choices. Each brand awarded the butterfly mark has to meet stringent requirements: brands need to demonstrate how they make sustainability part of their business model. All brands featured take great care over sourcing raw materials, manufacturing and marketing. Positive Luxury hopes its community of brands will become industry leaders, showing other brands how to offer luxury goods in a sustainable way (The Guardian, 2014).

A second tool is the Sustainable Value Analysis Tool which help manufacturers identify opportunities to create sustainable value by analysing the captured and uncaptured value throughout the entire life cycle of products. The tool consists of a poster and a set of cards. Yang provides an excellent example of the tool being applied in practise to a Chinese company that manufactures gas generators (Yang, 2014). Rather than simply selling one-off generators, the tool helps identify further opportunities for value creation including operator training, leasing arrangements, rare waste gases being used in new markets and the utilisation of waste heat produced by the generator.

9 Conclusion

The Queensland manufacturing sector contributes over $20 billion to the Queensland economy, with 90% of the 16,400 businesses being SMEs that employ around 170,000 people. Manufacturers compete in a global market which present a range of challenges and opportunities. Embracing sustainable manufacturing is one way for Queensland manufacturers to improve competitiveness.

There are a number of voluntary broad-based frameworks for implementing practices that consider all three pillars of sustainability (economic, environmental and social). These include The Circular Economy and Value Chain which are further developed than the older approaches of Cleaner Production and Ecoefficiency. These are underpinned by the seventeen United Nations Sustainable Development Goals.

There are many advantages to the uptake of sustainability including reduced cost of manufacture and compliance; fostering innovation; and building customer and employee loyalty. However, Queensland manufacturers face many challenges such as energy and water security and pricing, higher labour costs (compared with international competitors), lack of capital and the increasing need for a highly skilled workforce that is capable of embracing the opportunities presented by manufacturing in a global economy and digital age.

All sustainability approaches begin with establishing a baseline on resource use and impact. As in all Australian states, there is no regulatory incentive for SMEs to consider or report on resource use or greenhouse gas emissions.

However, there are a multitude of opportunities for Queensland Manufacturers to improve their competitiveness through adopting more sustainable business models, approaches and initiatives within manufacturing plants and across supply chains. Examples of these are presented in this literature review.

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Appendix A Prominent national and state based business sustainability programs, 2017

Program	Organisation	Focus	Description/targets	Financial incentive
National				
NEPP	Federal Government - COAG	Energy	The NEPP includes a target of a 40% improvement in energy productivity by 2030. Roadmaps prepared for manufacturing, agriculture, mining, built environment and passenger transport sectors. Target to double manufacturing energy productivity by 2030. www.environment.gov.au/energy/national-energy-productivity-plan	Some financial incentive and tax breaks proposed.
NABERS and Greenstar Ratings	National Government Program	Efficient Buildings	NABERS is a national rating system that measures the environmental performance of Australian buildings, tenancies and homes. NABERS measures the energy efficiency, water usage, waste management and indoor environment quality of a building or tenancy and its impact on the environment. nabers.gov.au/public/webpages/home.aspx	No
Greenstar	Green Building Council of Australia	Efficient Buildings	For the design, construction and operation of sustainable buildings, fit outs and communities. new.gbca.org.au/green-star/	No
Queensland				
ecoBiz	Chamber of Commerce and Industry Queensland on behalf of Qld State Government.	Energy/water/ waste	No specific targets. Program offering ecoefficiency assessments, workshops, webinars to SMEs. www.cciqecobiz.com.au	Free assessments and provision of resources.
New South Wales				
Sustainability Advantage	NSW Office of Environment and Heritage	All resources	Business commits to a 12 month program including sustainability diagnostic and modules. Businesses are recognised for achieving resource reductions. www.environment.nsw.gov.au/sustainabilityadvantage/	Small financial contribution to participate. Approximately $4000 p.a.

Program	Organisation	Focus	Description/targets	Financial incentive
Energy Saver Program	NSW Office of Environment and Heritage	Energy	Provision of energy audits, training, loans and project implementation for business. www.environment.nsw.gov.au/business/energy-saver.htm	Resources free of charge
Energy Savings Scheme	NSW Office of Environment and Heritage	Energy	Generation of energy saving certificates for energy efficiency projects. Certificates are sold back to energy retailers which reduces implementation costs. www.ess.nsw.gov.au/Home	Financial incentives through selling energy saving certificates to energy providers
Environmental Upgrade Agreements	NSW Office of Environment and Heritage	Energy/water/ waste	Energy, water, waste efficiency projects and building upgrades www.environment.nsw.gov.au/business/upgrade-agreements.htm	Government backed and subsidised loans with repayments made via project savings
Industrial Ecology Program	NSW EPA	Energy, water, waste	Funds Industrial Ecology facilitators to work with organisations in NSW to help them identify and implement projects that will reduce waste or provide them with resources to create new material.	Funds Industrial Ecology Facilitators
Victoria				
Materials efficiency grants	Sustainability VIC	All resources	Material efficiency/waste reduction projects www.sustainability.vic.gov.au/services-and-advice/business/energy-and-materials-efficiency-for-business/boosting-productivity	Grants up to $13,000
Energy assessments grants	Sustainability VIC	Energy	Energy assessments with implementation bonus www.sustainability.vic.gov.au/services-and-advice/funding	50% of assessment costs up to $6,000 plus $3000 implementation bonus
Environmental upgrade service	City of Melbourne	Energy/water/ waste	Energy, water, waste efficiency of building works (non-residential buildings on rateable land across Victoria) www.energy.vic.gov.au/energy-efficiency/environmental-upgrade-agreements	Access to loans with council as intermediary

Program South Australia	Organisation	Focus	Description/targets	Financial incentive
Energy Productivity Program	Department of the Premier and Cabinet	Energy	For businesses using > 160 MWh p.a. for audits and project implementation dpc.sa.gov.au/what-we-do/services-for-business-and-the-community/energy-efficiency/south-australian-energy-productivity-program#sthash.L0D4WGzg.dpuf	75% of the cost of a level 2 energy audit up to $15000 plus implementation grants
Energy Retailer Energy Efficiency Scheme (REES)	Department of the Premier and Cabinet	Energy/water	Requires energy retailers to assist household and business on energy use and cost. Audits and free or subsidised energy efficiency upgrades e.g. lights/ showerheads. dpc.sa.gov.au/what-we-do/services-for-business-and-the-community/energy-efficiency/retailer-energy-efficiency-scheme	Subsidised energy efficiency upgrades
Water efficiency audits	SA Water	Water	Free audits www.sawater.com.au/business/products-and-services/water-efficiency-audits	Provision of general resources (checklists etc) on water efficiency
Resource Productivity Assessments	Green Industries SA	Any resource discharged via trade waste	Grants to help identify opportunities for improving the way trade waste (commercial and industrial wastewater) is managed to reduce volume and/or improve the quality discharged. www.greenindustries.sa.gov.au/resource-productivity-assessment-program	Up to $10,000 grant to 50% max of assessment costs
Food and Beverage Implementation Grants	Green Industries SA	Trade Waste	Up to $300,000 (plus GST) in matched (1:1) grant funding for trade waste implementation activities, such as design and installation of new, or upgrades and additions to, infrastructure that will reduce trade waste volume/load	Up to $300,000 (plus GST) in matched (1:1) grant funding
Recycling Infrastructure Grants Program	Green Industries SA (govt organisation)	Waste	For projects that will: • improve efficiency of recycling facilities; • improve the recycling of materials banned from landfill; • establish or upgrade a resource recovery facility	Up to $300,000 per grant

Program	Organisation	Focus	Description/targets	Financial incentive
Western Australia				
Low Emissions Energy Development (LEED) Fund projects	Department of Environment Regulation	Energy	Innovative technology projects at the commercial demonstration, commercialisation and local adaptation stages in Western Australia.	Up to 25% of project costs
Waterwise Office Program	City of Perth	Water	Free program which provides resources and recognition to owners and managers of office buildings that commit to improving water efficiency.	Provision of resources
CitySwitch	City of Perth	Energy	CitySwitch Green Office engages with individual building tenants to assist them reduce energy use.	Provision of resources

Appendix B Unaccredited Voluntary product stewardship Schemes

The following table provides a list of the voluntary product stewardship schemes within Australia as provided by the Australian Government (2017).

Table 9: Unaccredited Voluntary Schemes

Program	Description
Tyre Stewardship Australia (Australia wide)	This end of life tyres product stewardship scheme was established in 2014 is authorised by the Australian Competition and Consumer Commission for five years until 3 May 2018 and funded by the industry. Tyre Stewardship Australia (TSA) has been established by tyre importers to administer the scheme which aims to increase domestic tyre recycling, expand the market for tyre-derived products and reduce the number of tyres sent to landfill, exported as baled tyres or illegally dumped. It is a voluntary scheme which allows any stakeholder in the supply chain including tyre manufacturers and importers, retailers, fleet operators, collectors, recyclers and local governments to apply to participate. Participants commit to ensuring an environmentally sound end of use for the tyres. (DEE, 2014). www.tyrestewardship.org.au/
Paintback (Australia wide)	Paintback is a voluntary product stewardship scheme run by a not-for-profit organisation (Paintback Ltd) which raises funds through a waste levy using local governments and waste service providers to collect and safely dispose of waste paint and packaging. (Paintback Ltd, 2016) www.paintback.com.au/
PVC Product Stewardship (Australia wide)	Vinyl Council of Australia runs the PVC Product Stewardship program aims to reduce the environmental and health and safety impacts of PVC throughout the lifecycle. Improvements have included management of Vinyl Chloride Monomer (VCM) emissions on site, 99.8% reduction of lead additives by members from 2002 to 2014 with the remaining lead coming from old stock that is being phased out. 70% of signatories have phased out mercury from the supply chain. (Vinyl Council of Australia, n.d.) www.vinyl.org.au/sustainability/pvc-stewardship
drumMUSTER (Australia wide)	AgSafe delivers the drumMUSTER voluntary program on behalf of the AgStewardship Australia Limited. The drumMUSTER program collects empty plastic and metal farming chemical containers across rural Australia which are then reprocessed into a new range of products. Chemical manufacturers are involved in the process by applying a logo on their products that have the levy applied to them and are included in the program. Farmers participate by thoroughly rinsing the containers and taking them to the muster locations. The plastic products made from the recycled drums including wheelie bins, fence posts, irrigation pipes, bollards and barstools (concrete supports). They replace products that were being made from virgin materials meaning that not only fewer containers going into landfill but fewer natural resources are required to produce these plastic and metal items. Since it started in 1998 more than 29 million agvet chemical containers have been recycled. (AgSafe, 2017) www.drummuster.org.au/
ChemClear (Australia wide)	AgSafe also deliver the ChemClear program which provides a safe disposal method of left-over agvet chemicals as no extra cost. One of the aims is to reduce the amount of stored chemicals on properties and in businesses around Australia thereby reducing the potential environmental impact of these chemicals might cause in the future through events such as illegal dumping, incorrect disposal to landfill or through natural disasters such as bush fires or floods. It uses a waste levy placed on the sale of participating manufacturer's products. Approximately 98% of the collected chemicals are reused as alternative fuel sources to fire cement kilns while the remaining are Schedule X chemicals such as organochlorides, arsenics and cyanides are treated by Plasma Arc technology, or stabilised and fixed for secure landfill depending on the regulations in each state. (AgSafe, n.db) All the drums collected through the program are recycled through the drumMUSTER program. Since 2003 the program collected and safely disposed for more than 587 tonnes of obsolete, inherited and unknown agvet chemicals. (AgSafe, n.d.a) www.chemclear.org.au/
Cartridges 4 PlanetArk (Australia wide)	Cartridges 4 Planet Ark is a multi-vendor program operated in Australia to collect and divert printer cartridges from landfill. It has been operating since 2003 with collections, recycling and materials recovery undertaken of 35 million cartridges in 12 years. The program is supported by manufacturers of the cartridges and toners who take on end-of-life responsibility for their used cartridges. They cover the costs involved in the take-back program offering Extended Producer Responsibility (EPR) to all their customers. Close the Loop provide the collection and recycle of the products some components such as clean plastic being returned to manufacturers to be turned into new cartridges or other products or turned into eWood. Metal is separated and sold as scrap. Other products include Enviroliner pens and rulers made from waste plastic cartridges with post-consumer recycled ink. Waste toner is used in an asphalt product. The program is open to the public through collection points in businesses or through participating retailers providing drop-off points. www.closetheloop.com.au

Program	Description
Battery Recycling (Australia wide)	The Australian Battery Recycling Initiative (ABRI) is establishing a national stewardship program for handheld batteries. Recycling batteries can prevent many hazardous materials entering landfills. The Queensland Department of Environment and Heritage Protection is leading negotiations for the ABRI. There are several battery collection programs around Australia. Battery World Community Recycling Program collects and recycles domestic use batteries through their retail outlets. It has collected and recycled over 8,000 tonnes of lead acid and other types of batteries. It also runs a schools program to provide collection services and an education program. www.batteryworld.com.au/Recycling Century Yuasa collect car batteries through a network of service stations across Australia. It reclaims 98% of lead acid batteries by separating the components and re-processing into new products. www.cyb.com.au/our-priorities/environment/recycling The Victorian BatteryBack program is run by Close the Loop. Batteries are returned to participating retailers by the consumers. Close the Loop collects then sorts the batteries before forwarding them to the appropriate recycler. The Queensland Government have run PowerTool BatteryBack and emergency and exit lighting battery recycling pilot programs in 2015/2016. www.ehp.qld.gov.au/waste/power-tool-battery-recycling.html and exitcycle.org.au/about/
SoftLanding (mattress Recycling) (NSW, ACT, WA)	Soft Landing is a national social enterprise operating across NSW, ACT and WA that collects and recycles mattresses. SoftLanding partner with TIC Mattress Recycling to recycle over 90% of the mattress components including steel springs for scrap metal, foam for carpet underlay, husk for weed matting and mulch, felt pad and fabric for boxing bags and timber for kindling, mulch and animal bedding. Soft Landing operates as a social enterprise providing training and employment opportunities to people who have experienced barriers to employment providing benefits to individuals and the community as a whole. www.softlanding.com.au/
Plastic Police Partnerships (NSW)	Plastic Police Partnerships is run by Cross Connections to engages local communities, including schools, businesses, councils and other program partners to convert waste soft plastic into furniture and equipment that can go back into the community. It is a NSW program. crossconnections.com.au/plastic-police-partnerships/
REDcycle Program (Australia wide)	REDcycle is a collaborative program to collect and recycle domestic soft plastic. It is run by the RED Group in conjunction with retailers such as Coles and Woolworths and many food manufacturers and the Australian Manufacturer Replas who processes the soft plastic into products such as from fitness circuits to sturdy outdoor furniture, to bollards, signage. They have collected over 263 million pieces of plastic since the program launched. www.redcycle.net.au/