Your Country's National Welding Capability (NWC) and its Significance to the UN Sustainable Development Goals (SDGs)

By

Chris Smallbone

IIW Fellow IIW President 2005-2008 Honorary Member ASR

allbones@iinet.net.au

Abstract

As an outcome of a meeting with UNIDO in 1994 in Vienna, the International Institute of Welding (IIW) through its IIW Board of Directors Working Group Regional Activities and Liaison with Developing Countries (WGRA) introduced the unique IIW WeldCare Programme to assist developing countries to improve their national welding capabilities particularly through the establishment and/or growth of a not-for-profit national welding organisation.

Since then, IIW WGRA has assisted many countries freely through the holding of IIW technology innovation workshops, governance workshops and International Congresses as well as providing them with information, experiences and documentation on successful activities particularly from experiences in South Africa, Australia and globally. The Chapter entitled "*Emerging Nations*" in the IIW history book "*linking people, joining nations*" shows many of these activities. https**://cld.bz/Uz1rh1w**

In 2013, as an extension and expansion of the IIW WeldCare Programme through IIW WGRA, a project "Establishing a National Welding Capability (NWC)" was created and managed by the author. Several very successful NWC workshops have been held since then to assist not only developing countries but also developed countries which could utilise them to improve their national welding capabilities. These have included Romania, Bulgaria, Serbia, Greece, Hungary, South Africa, India, New Zealand, and Thailand amongst others [1].

Based on feedback from the workshops and International Congresses held, the need for 11 comprehensive guidance notes with links to a knowledge resource bank were identified and are nearing completion. Further feedback has also indicated that some countries may possibly need some direct assistance in implementing improvements to their national welding capabilities.

The Guidance Notes outline recommendations on strategies which could be implemented by a country including implementing a Flagship Programme with the Goal "To Assist the Country to Establish, Sustain and Improve Its National Welding Capability".

Furthermore, the United Nations (UN), has 194 countries as members and with the challenges of improving the quality of life in countries, the UN has implemented 17 Sustainable Development Goals (SDGs) aimed at low and middle income countries.

Improving a country's National Welding Capability can make a significant contribution to, and have a very positive effect on, many national and international programmes including the SDGs.

When one considers the networks which the IIW, its 50 Member countries, universities, colleges, research organisations and companies involved in welding have, bringing all the

available welding resources to assist in achieving the SDGs can have a remarkable positive effect globally on all countries.

On 4th March 2021, UNESCO published a report titled “Engineering for Sustainable Development: Delivering on the Sustainable Development Goals” [2]. There is no reason why a similar initiative could not be undertaken for the welding field. This paper, even with the relatively few examples shown, can serve as a catalyst, and the National Welding Capability Project as the basis, for such a report.

It is hoped that this paper will stimulate ideas amongst the international welding community for feedback to the author and propagation into countries to improve their SDGs.

1. Introduction to IIW National Welding Capability Project and UN Sustainability Development Goals

The original concept of the NWC Project was to assist developing countries to create an optimal NWC in their countries.

Imagine, if you will, a person sitting at a desk in such a developing country with a blank piece of paper and being given the challenge to create a plan to implement and grow the NWC of the country. This would be a herculean task but with the assistance of people around the world with the experience and knowledge on implementing the NWC building blocks, such a person, with the right culture, drive and enthusiasm, could build the NWC Project up at a much faster rate than on their own. This will also involve coming up with a national plan.

In line with fundamental humanitarian principles, any national plan must have as a main objective, the improvement of the quality of life of people in the country and its biodiversity. Most people simply want a job, personal security and health for their family, a decent roof over their heads, education for their children, food in their stomachs and a sustainable positive environment around them benefitting biodiversity.

The IIW NWC project therefore aims to assist a country’s industry, government or IIW Members to achieve the following objectives:

- to identify the welding related needs in the country and provide solutions to ensure the country’s future sustainability in relation to these needs;
- to implement its own National Welding Capability(NWC) Project;
- to identify the country’s existing capability and consolidate the existing welding related ‘building blocks’ in the country to create the basis for a NWC;
- to analyse, and identify the improvements required in the existing welding related ‘building blocks’ as well as what additional ‘building blocks’ are required in the country; and
- to create the mechanisms and processes, to establish and maintain the country’s sustainable NWC including the possible establishment or improvement of a national organisation(s) responsible for the promotion of welding and related disciplines.

The welding industry is taken as those organisations and people:

- involved with the total life cycle of welded products/structures including design, manufacture, conformity assessment, inspection and testing, operation, maintenance, repair and decommissioning including recycling and other environmental conditions
- engaged in, or employing, any of the organisations or people involved above;
- supplying welding equipment or consumables or materials to be welded; and /or

- involved with education, training, qualification, certification, research and development, work health and safety (WHS), standards and industrial relations aspects of welding.

In the IIW NWC Project, 10 Guidance Notes (GNs) are presently being produced to cover each NWC Building Block, each containing a Plan-on-a-Page with a Goal, five Objectives and 30 Strategies, and the start of an Operational Plan for each Strategy.

The concept of each IIW Guidance Note is that the user can link through each strategy to an IIW NWC Knowledge Resource Bank with information pertinent to that particular strategy. The information obtained through the links, documents, references, reports etc in the IIW NWC Knowledge Resource Bank will have been gathered from the experiences of organisations and individuals who are prepared to share their successes and lessons, including challenges and failures, with the global community.

The user of the IIW Guidance Notes will then decide which strategies (those shown in the GNs or amended or new ones) and information to use to meet the outcomes required in their own country's National Welding Capability Project business plan.

The 17 UN Sustainable Development Goals (SDGs) agreed upon in 2015 by world leaders are the blueprint to achieve a better and more sustainable future for all. They address the global challenges we face, including those of poverty, inequality, climate change, environmental degradation, peace and justice. The 17 Goals are all interconnected, and in order to leave no one behind, it is important that we achieve them all by 2030.

- Each SDG has a clear Goal with targets to be achieved by 2030 and indicators for measuring, monitoring and evaluating progress against the Goal. It is not just countries which are being asked to implement the SDGs but also companies, organisations of all types and even individuals. Since the Goals are interconnected, contributions into one Goal can have a positive effect on other Goals.
- There are many examples of how IIW Members have cooperated and collaborated with developing countries to assist in improving their national welding capabilities [3]. Such examples include amongst others, Germany-China, France-Thailand, UK-Malaysia, USA-Trinidad and Tobago, Japan-Vietnam, Portugal-Angola, Japan-Egypt, Austria-Indonesia, Germany-Vietnam, South Africa-Africa (IAEA), USA-Nigeria, Holland and Canada-South Africa, Germany-Indonesia. The main emphasis in all of the examples mentioned was on education and training and transfer of appropriate technologies.
- Even though these examples happened over the past three decades, the experiences and results achieved can be used to introduce new projects today. For example, the UN has had a range of programmes which countries benefitted from. Reference [4] gives examples in a number of countries of UNIDO's programme of direct support to industry under trust fund arrangements, Reference [5] shows how UNIDO visited Vietnam to study the status of welding in Vietnam and the requirements for improvements and welding training development and Reference [6] shows many of the programmes available within UNIDO to help developing countries.

Today, improving a country's National Welding Capability will have a significant effect on improving all its UN Sustainability Development Goals.

- With the assistance of people around the world with the experience and knowledge on implementing the NWC Project building blocks, a person, with the right team, culture, drive and enthusiasm, could build the optimal NWC for the country and help improve all the SDGs in that country.
- The role of engineering in achieving each of the 17 SDGs is also highlighted in the UNESCO Engineering Report titled "Engineering for Sustainable Development: Delivering on the Sustainable Development Goals" published on 4th March 2021 [2].

- When one considers the networks which the IIW, its 50 Member countries, universities, colleges, research organisations and companies involved in welding have, bringing all the available welding resources to assist in achieving the SDGs can have a remarkable positive effect globally on all countries.
- There is no reason why a similar initiative could not be undertaken for the welding field. This paper can serve as a catalyst for such a report and the National Welding Capability Project as the basis for the report
- The Covid-19 Pandemic has brought major challenges to all countries in particular the poorer developing countries. To achieve the optimal NWC in each country as well as contribute to the SDGs, it is becoming even more important on how to assist countries with both concrete ideas and support.

Shown below under each SDG are a few examples for each of the 17 SDGs on how welding can make positive contributions both in a country and globally.

2. Welding Influences on UN Sustainable Development Goals (SDGs)

The title of each SDG has been used together with the number of targets and indicators for each SDG. The volume of information and activities related to welding which can have a positive effect upon the SDGs is immense so only a few examples are shown under each SDG below.

2.1 End poverty in all its forms everywhere-Seven Targets, 13 Indicators

Welding technology is an enabling technology used across almost all industries and a wide range of materials and applications, from micro-joining of medical devices, electronics and photonics, to larger scale applications such as bridges, buildings, ships, rail, road transport, pressure equipment and pipelines.

- It encompasses the total life cycle of welded products/structures including design, manufacture, conformity assessment, inspection and testing, operation, maintenance, repair and decommissioning including recycling and other environmental conditions. It is critical to the infrastructure of any country;
- History shows many examples of the importance of welding to the world. The formation of the International Institute of Welding (IIW) itself illustrates this. After the devastation created through World War 2, Europe in particular, was in a terrible mess but countries got together in 1947 and formed ISO and IIW amongst other organisations to somehow build up the quality of life again. 13 countries formed IIW (11 European, USA and South Africa). This number has grown to 50 illustrating the importance countries give to welding;
- Examples of the value of welding to economies of countries and its contribution to improving quality of life have been shown over many decades;
- Federal, State and Local Government and industry initiatives in different countries, results of these initiatives and success stories from local and overseas sources can all be used to show the importance of welding to a country and its effect on alleviating poverty;
- One comprehensive study in the USA (2002) surveyed the manufacturing, construction and mining industries in which welding was a critical enabling technology [7];
- It found their combined revenue totaled some US$3.1 trillion, or about one-third of that country's gross domestic product. Direct welding costs were $34.1B, 70% of which was labour costs. The labour costs for welding activities was in fact about 4% of the total labour costs for those industries. The true value added by welding technology in this example is probably at least ten times the direct welding costs due to the added value to the economy after the implementation and use of the technology;

- The German Welding Society, (DVS) has regularly arranged for the economic significance of various joining technologies to be investigated and quantified in scientific expert reports (in 2001, 2005, 2009, 2013 and 2017).These originally applied to the value added and employment connected with the production and application of welding in Germany and were then progressively expanded for other joining technologies and for various other countries in Europe and the EU. References [8], [9], [10].
- Such information has been used by the European Union (EU) to establish a Joining Sub-Platform within the Technology Platform "Manufuture". The Manufuture Technology Platform was implemented to create a strategy regarding research and innovation in manufacturing. Part of the justification for the Joining Sub-Platform is that joining is a core element of innovative and sustainable manufacturing and will have its own strategic research agenda funded by the EU [11].
- Welding contributes positively to all human endeavour and the quality of life of all. It does this in numerous ways, whether through creating power for lighting and cooking; potable water and safe sanitation; national infrastructure; efficient, safe and effective transportation; accommodation both for living and working, a multitude of machines for different industrial applications, medical, health and safety devices and by many other ways. All of these are also linked to job creation.
- Without welding, people around the world could not switch on a light, turn a tap to access water, travel by train, road, sea or air, or use a computer or a multitude of other applications which improve the quality of life.
- In short, welding contributes to improving the national and global quality of life including the mental health and physical wellbeing of current and future populations and makes a major contribution to alleviating poverty.

2.2 End hunger, achieve food security and improved nutrition, and promote sustainable agriculture-Eight Targets, 14 Indicators

- Probably 97% of the world's farmers are in developing countries so agriculture is the primary source of employment, income and food in such countries. With the share of the agricultural population being 67% of the total global population, so many basic needs are met by agriculture. It recorded 39.4% of the GDP and in that 43% of all exports includes agriculture commodities.
- Unfortunately, many developing agricultural producing countries depend on agricultural imports and food certainty and many emerging countries will not refine without a significant increase in local production. Farming throughout history has had good times and lean times and even with periods of healthy animals and crops the risk of flooding, pestilence and war, are always present.
- Food production throughout the world is seeing new methods implemented through the introduction of technologies such as AI, IoT, Automation, Urban agriculture with Smart design and vertical farms, use of drones amongst others.
- On the other hand however, some predictions on major issues affecting food production in 2020 included

    - Climate change.
    - The ongoing trade war between the United States and China.
    - Rapidly depleting reserves of freshwater around the world.
    - The looming food crisis.
    - Economic insecurity in the United States.
    - Ongoing closures of food processing facilities and local businesses due to the COVID-19 pandemic.
    - Depletion of natural resources due to widespread industrial agricultural practices.

- High rates of food waste, which threaten to intensify food insecurity around the globe
- Disruptions in trade networks and fluctuations in global demand for agricultural products.
- Economic strife and crippling debt for individual farmers.

- Although there are many factors which can produce hunger in the population in a country, if one considers some of the elements required to assist a country to be able to grow, harvest, store, process and distribute food, welding can assist at each stage in ensuring success and add value to a country's food production needs and hence reduce the probability of hunger.
- At the planting, growing, irrigating and harvesting stages there will always be a need to assemble, install and repair equipment such as tractors, tilling equipment, planters, balers, combines, ploughs, mowers, harvesters, grain and feed handling, dams, sprayers and irrigation equipment. Similarly, with storage and distribution, storage and drying equipment, boiler and boiler components, scrubbers, fans, pumps, conveyors, gear boxes and turbines as well as forklift trucks, pallets, lorries.
- Even if one is in a region of subsistence farming, collective farming or individual large farms, access to skilled people and equipment is essential both to make components and perform repair and maintenance using welding.
- In developed countries, many farmers call on companies to perform such work which could add considerable costs to food production, or the farmer or employee attend training courses at colleges to obtain the required skills to perform such work. A key objective should be to train as many people as possible in the area in the appropriate welding skills for any eventuality which may arise. Such people can also use the skills for non-agricultural purposes as well and develop other businesses.
- In many developing countries however, opportunities to attend such colleges are often not readily available. The challenge, therefore, is to assist farmers often in remote rural areas to be able to access such training and obtain the necessary skills. Some innovative ideas over the past four decades in countries such as Australia and the US have involved mobile welder training centres which can be driven to all areas accessible by road. The availability of welding supply companies to offer technical advice and welding supplies to such farmers is also critical. Timing is very important since the farmer cannot wait in the middle of planting or harvesting to fix machinery. Transfer of appropriate technology to farmers is much easier today due to the more acceptable forms of communication such as the latest welding news, blogs, podcasts, virtual conferences, online courses, and digital tools designed to help people grow and succeed
- With respect to food processing the hygienic requirements of for example, the food and beverage industry place high demands on the welds that hold tanks, pipes and vessels together.
- The requirements specified in codes and standards for a high-quality weld and weld surface finish are paramount in the dairy and other food and beverage industries, as the consequences of poor surface and weld quality can be costly and dangerous.
- Contamination scares in the dairy sector provide some examples of the consequence of not getting things right. In effect, every metre of weld inside a storage or process tank or vessel represents a risk to be managed. Fabricators must make significant efforts to ensure that both the weld integrity is adequate and that the surface finish meets the specified requirement for hygiene.
- In developing countries, it is therefore imperative that the country builds up a competent welding workforce to be able to build, repair and maintain the relevant plant for such food processing and agricultural equipment using appropriate technologies.

2.3 Ensure healthy lives and promote well-being for all at all ages-Thirteen Targets, 28 Indicators

With respect to linking welding to assisting people to have healthy lives and well-being, probable good examples are those related to equipment and medical devices. Such equipment could be the more mundane examples such as medical gas distribution and piping systems which are critical for use in hospital operations and patient care to the more exotic examples involving a wider range of materials and process challenges as well as operating conditions.

To ensure the continuous well-being of people in a country and continued accessibility to health systems to increase life expectancy therefore, welding and joining technology transfers are needed and contribute to meeting various medical objectives including examples such as the following:

- Design, materials selection, joining of exotic materials, surface coatings;
- Replacement or augmentation of body parts (e.g. hip implants);
- Malfunction assist devices (e.g. heart pacemaker, hearing implant);
- Control over regeneration (e.g. stents);
- Transient devices (e.g. pins or screws in broken bones)
- Methods during assembly fundamentally influencing design, performance and cost.

In the past, specific challenges have included,

- Medical devices involving welding and allied processes, have been increasingly in demand. Not only does interconnection and packaging technology dictate the electrical, optical, mechanical, reliability and service life performance of a medical device, but it often accounts for over 65% of its added value;
- Microjoining technology, involving welding and allied processes, is fundamental to the cost effective assembly of sensors and medical device based products;
- Joining issues can be traced to over 80% of failures in devices;
- Design, FEA, simulation, animated modeling for virtual visualisation of products;
- Size reduction to minimize intrusive surgical procedures;
- Materials with long-term stress corrosion cracking resistance;
- Surface engineering for in-vitro and in-vivo acceptance;
- New materials such as shape-memory alloys capable of surviving hostile environments;
- Bio-compatibility;
- Hermetic and environmentally sealed assemblies;

Different countries, depending on their needs and existing expertise, may have had general outcomes including technology transfer related to:

- Fine laser welding and cutting;
- Laser welding of plastics;
- Laser micromachining e.g. fine hole drilling, sieve and fine filter manufacture;
- Laser soldering;
- Laser surface modification for implants;
- Electronic bonding of ceramic composites;
- Titanium performance in medical applications evaluation;
- Improved knowledge of materials selection and application;
- Improved knowledge of design principles for manufacturing;
- Increased use of modelling techniques to improve efficiency, reduce costs and increase profitability.
- Improved surface coatings via novel coating and spraying techniques;
- Improved awareness of adhesive bonding technology and capabilities;
- Industry awareness of global issues (Pb-free solder and removal of toxic fluxes);
- Industry awareness and uptake of state of art technology such as lasers.
- Availability of improved tools for surgery and non-invasive procedures;

- Increased incidence of bone and joint replacements;
- Increased incidence of implanted devices;
- Increased availability of artificial parts used in maxillofacial and craniofacial treatments;
- Increased use of titanium alloys in external prostheses and implanted devices;
- Improved surgical instruments made from titanium alloys;
- Improved life for implantable devices.

In terms of improving this SDG, results from the above might include assisting countries by

- Enabling technologies made available to innovative manufacturers seeking to push the boundaries of existing medical device technology;
- Specialist training courses for engineers and technicians involved in medical device manufacture;
- Medical specifications for bio-medical materials, e.g. titanium alloys;
- Improved life for implantable devices;
- Reduction in premature failures;
- Improved quality of life for post-operative patients
- Ensuring high reliability in all types of medical gas distribution and use.

2.4 Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all-Ten Targets, 11 Indicators

Results of Federal, State and Local Government education and training (E&T) initiatives in different countries, as well as success stories from local and overseas sources, can all be used to show the importance of education, training, skills and careers paths to a country.

To be successful, winning nations must have a number of cultures. These include a skills respect culture, a quality culture, innovation culture and a productivity culture [13].

Linking the above will lead to improving this SDG in a country.

- Linked to this also, technology innovation is a necessity for a country to be globally competitive. Innovation can be defined as ‘To bring in something new, make changes (ideas, methods etc.) whether in simple or complex forms’. It includes applying inventions and the adoption of research and development (R&D) outcomes.
- Whether a country’s economy is considered developed, developing or an economy in transition, innovation is constantly required to meet the growing needs of its population. Innovation includes new products and processes, significant changes to existing products and processes and significant changes to management and organisational structures.
- Understanding the need for innovation, the availability of technology receptors in companies, effective technology transfer mechanisms and appropriate research and development (R&D) are all dependent, to a large extent, on the education, training and related skills of the people in the industry.
- None of the above can occur if the correct human resources are not available. Many countries are in the position of having a dearth of well-qualified and experienced personnel in the welding-related fields. Education and training therefore underpins so many other factors influencing an industry’s performance and competitiveness.
- It is incumbent upon both government and industry in a country to investigate, recommend and implement measures that will ensure that the optimum E&T is performed to produce outcomes to meet the needs of the different welding-related industry sectors in the country including skills levels and career paths and routes for people [14], [15], [16], [17] [18], [19], [20], [21].This will help ensure lifelong learning opportunities.

- Highly skilled employees, who generally feel more valued, are more flexible and better able to adapt to changes in processes and product design than their lower skilled counterparts and can respond more rapidly to changes in market demand.
- High level skills will become more important to a country's industry as its economy moves towards a reliance on greater skills intensity and knowledge-based industries.
- Economies with lower skills levels might well be at a disadvantage in a global knowledge-based economy where rewards for firms and individuals will flow increasingly to the technologically skilled and innovative, that is with broadly based skills and abilities.
- There must also be sufficient competent researchers in the country to be able to perform the R&D to deliver optimum outcomes in the optimum time so that the technology can be delivered (by technology deliverers) to people to receive it (technology receptors), assimilate it, develop it further if necessary, and apply it.
- There are excellent examples of networks successfully established to bring industry and all levels of government together to supply the E&T, skills and career paths to create viable industry sectors and overcome constraints as well as fostering partnerships between Small, Medium Enterprises (SMEs), larger firms and training providers [19],[20],[21].
- The development of the International Institute of Welding (IIW) E,T,Q and C programmes and their implementation in 47 countries worldwide illustrates the importance and need for world class personnel to be available in the welding industry in a country [18].
- The vast majority of developed economies also have well established sustainable programmes for the recruitment, training and qualifying of practical welding personnel of all types and levels to meet its industry's needs. Similar programmes need to be implemented in medium to low income countries with the assistance of the developed countries and examples of this do exist.

Consider the different types of personnel who may need E&T to acquire the necessary skills and knowledge to perform their work competently: These could include:

- Research and Development: researchers [21];
- Technology Diffusion: technology deliverers, technology receptors [18];
- Education and Training: lecturers, teachers, instructors [18],[22],[23],[24];
- Qualification and Certification: examiners, auditors;
- Industry Personnel: designers, specifiers, engineering personnel, welding engineers, technologists, specialists, practitioners, welders, artisans and apprentices using welding, inspectors, hobbyists and handymen, maintenance and repair personnel, and stores personnel amongst others.
- Personnel using specific techniques such as additive manufacturing, adhesive bonding, rail welding, thermal spraying and Thermit welding.

All these personnel will require career paths and career routes available to them to achieve success [14], [16], [17]. Many developed countries are in the position of being able to assist less developed countries improve their SDGs. Such assistance could include:

- Upgrading competency levels of welding instructors at training centres and companies to world's best practice to improve efficiencies as well as ensuring the latest and best training resources and facilities are available to them [22], [23], [24]
- Implementing programmes to assist secondary schools to develop and support educational programming, capital equipment, consumables and protective equipment that create and upgrade quality learning environments in school technology programs [25], [26].
- Giving people opportunities to earn qualifications and certification, offering better opportunities for employment at all levels including upper level management, research and technology innovation.
- Promoting education and training which results in credible personnel qualifications and certifications, which should also be portable both within a country and overseas, as well

as being recognised on an international basis, is important to help retain work in the country [18].

- Assisting Industry to create new employment opportunities by making the best of a country's and international employment practices thus improving industry performance and give people incentives and career opportunities to develop and master new fields.
- Promoting policies with Governments which enable the re-training of job leavers and older workers for re-employment for sustained employment and supporting industry in its ability to attract and bring in expert overseas personnel where required.
- Linking in with the Government initiatives to provide secondary students with improved career paths from school to work; such initiatives could include part-time apprenticeships and traineeships; training of school teachers to teach welding, provision of training resources [25],[26].
- Helping establish closer partnerships between higher education institutions and industry and the development of an effective, affordable research and research training system to contribute to national economic development, international competitiveness and the attainment of social goals

2.5 Achieve gender equality and empower all women and girls-Nine Targets, 15 Indicators

During the WWII, in some countries such as the US, Canada, USSR and UK, due to sheer necessity, women and girls were employed in a wide range of employment situations normally fulfilled by men. Similarly, in many developed countries today, due to women and girls showing that they are competent to fulfil the employment roles, they are employed on an equal basis to men. Unfortunately, there may be countries where due to a variety of reasons, this does not apply. There may therefore be a need to change a number of cultures in a country to achieve equality and empowerment.

One of the best ways to enable women and girls to show that they are competent to perform any type of work is to show that they have achieved the required qualification and certification criteria specified for a particular type of work or application. At the same time, if one can change the culture which might be having a negative effect on this approach, then it might achieve positive results.

- This becomes easier to achieve when a country has developed and implemented a number of cultures including a skills respect culture.

A skills respect culture is a national way of life which is characterised by:

- support of, and value placed on, a willingness to learn;
- respect for people who acquire skills; and,
- tangible rewards for individuals who acquire skills
- This means that people at all levels irrespective of gender and in all disciplines within organisations will have a willingness to adapt or learn new skills. They will also be seen to deliver excellent work results. Organisations will be seen to promote skills development and will be highly productive and competitive.
- All of the above will lead to a thriving national economy since a culture of skills development is encouraged nationally [27], [28].
- There has been excellent work carried out by the National Productivity Institute (NPI) and Skills SA Foundation in South Africa to show how a country could identify the key issues detracting from having a national skills respect culture and ideas on how such a culture could be implemented [27],[28].
- Ideas on infrastructure and conditions to be created to facilitate the development of a national skills culture include:
    - reshaping the role of schools;
    - refocusing training systems;

    - improving the image and competence of trainers;
    - improving the image and competence of employers and,
    - designing attractive training incentives for organisations.
- Ideas on refocusing the skills development processes to establish a national skills culture include:
    - developing the 'whole employee'; and
    - developing a national sense of work pride.
- Learning from other countries is very important. For example, a review of the 'Winning Nations' report by Lindeque and Verster of Eskom in South Africa in 1992 revealed after a group visited such nations that these nations use various tools for creating a skills respect and work pride/work ethic culture as a means of developing skilled workers/professionals who can deliver excellent goods and services.
- Various countries, for example Germany, Singapore and the USA, have used activities to improve the image of welding as a strategy to create a skills respect culture in their countries.
- Many countries have projects which they have implemented and the experiences and lessons learnt including successes and failures are invaluable. The Australian Federal and State Governments as examples, have been quite proactive in promoting skills on both a national and regional basis [29], [30].
- Today, digital technologies such as artificial intelligence, robotics and automation are transforming the world of work. Developing the appropriate digital skills in the workforce is an important component in industry's effort to compete in this rapidly emerging global digital economy. Reference [31], a research report on skilling the Australian workforce for the digital economy is excellent with a significant number of further references from across the world for additional information. As the welding industry embraces more of Industry 4.0.then the challenges of training the general workforce in digital technology grow.

2.6 Ensure availability and sustainability management of water and sanitation for all-eight Targets, 11 Indicators

Clean Water Management is a key issue in any Government's strategic policy. A sustainable water environment is critical to all stakeholders in a country and hence its national interest. Major restructuring is normally required and strategic challenges could include drinking water quality, water wastage eg, leaking pipes, environmental issues related to effluent discharge and irrigation issues and for industry to meet these challenges in a productive and competitive manner.

Welding and joining technology transfers could contribute to meeting the national objectives in the following ways:

- Urgent need for a country to upgrade its water catchment, storage, treatment and distribution and waste water infrastructure in both urban and rural applications;
- Minimisation of resource wastage and the risks of serious health and supply breakdown due to failing pipes/distribution;
- Maintenance of aging infrastructure.

Examples of specific applications and welding technology solutions that could be analysed, prioritised, developed, demonstrated and disseminated with relevant stakeholders to help meet the management of water and sanitation in the country include:

- Manufacture and construction of mainstream pipelines;
- Manufacture of pipework and structures in water and waste water treatment facilities;
- Manufacture and construction of desalination plant involving materials such as titanium alloys;

- The growing use of different materials such as stainless steels, titanium alloys, PVC, polyethylene, polypropylene and polybutylene, ABS and Glass Reinforced Plastic (GRP), as against existing materials such as grey cast iron and steel;
- Installation and maintenance of water storage liners and floating covers;
- Repair and maintenance of aging infrastructure

Developed countries can assist with these by providing expertise in areas such as

- Joining and NDT testing techniques for liners and covers;
- Avoidance of failures due to poor structural integrity through better design and inspection technology;
- New methods of repair and maintenance including the use of composites;
- In-line inspection of butt fusion welded plastic pipe;
- Mechanised welding of external and internal joints on mainstream pipelines;
- High-pressure water-jet cutting of damaged concrete support structures for low cost maintenance of in-service pipelines;

General outcomes leading to increased quality of life and the SDG could include:

- Joints in pipes/pipelines of a range of different materials having high integrity and reliability;
- High integrity joints in liners and covers;
- More economical longer pipelines for transferring water over long distances;
- More efficient water distribution;
- More efficient tankage and filtration systems;
- Efficient operating desalination plants;
- Life extension for aging infrastructure.
- Reduced overall project costs;
- Reduced maintenance, repair and inspection costs;
- Less failures and lower environmental damage;
- Longer working life of plant;

These can all help with improving the water and sanitation management issues in this SDG by having:

- Cleaner better quality drinking water;
- More efficient irrigation;
- Less water wastage;
- More efficient waste water treatment;
- Less pollution;
- Increased water resources.

2.7 Ensure access to affordable, reliable, sustainable and modern energy for all-Five Targets 6 Indicators

For a country to develop affordable, reliable, sustainable and clean modern energy for its people, this often means developing industries competent to manufacture and maintain the appropriate equipment. Although one tends to think of “clean energy” as renewable energies such as solar, wind, hydro etc, these and other types of energy sources require high quality design, manufacture, maintenance etc.to ensure their reliability. In the foreseeable future up to 2030, even with a determined effort to move to cleaner energy sources, energy sources such as coal, gas, nuclear will still be in existence and will require the same attention to reliability in service.

- Although there are many types of equipment applications covering areas such as structural, rotating, corrosion resistance etc, pressure equipment is shown here as just one example of the approach for optimal reliability
- The types of pressure equipment employed in such energy sources could cover items such as boilers, pressure vessels, pressure piping, gas cylinders and tanks. Such equipment is used in power stations, petro/chemical, process plants, general industry, energy, food, cryogenics, LPG, mineral processing and for public gas cylinders etc as well as being linked to numerous structural related equipment.
- The number of pressure equipment items installed/used in a country is immense with an enormous asset value matched by the number of people directly involved in industry using pressure equipment.
- This sector is vital for any country's power and energy supply and the strategic challenge is to improve performance and avoid failures. Fortunately in developed countries, codes, standards and regulations exist and compliance rigorously enforced.
- The specific aspects of the energy industry where welding and joining technology transfers are needed and contribute to meeting the national objectives may include the following in a developing country:

  - Local manufacturing and repair companies developing unique areas of competitive advantage in the pressure equipment industry on a global level;
  - Optimisation of strategies and practices to handle aging plant and equipment.

  Examples of specific applications and welding technology solutions that could be analysed, prioritised, developed, demonstrated and disseminated with relevant stakeholders to help meet the energy challenges in the developing country could include:

  - Manufacture of boilers, pressure vessels, pressure piping, air receivers, gas cylinders, etc;
  - Maintenance, repair and rehabilitation of the above equipment;
  - Maintenance of good quality, reliability and safety, yet reduction of costs by better technology – hard and soft technologies;
  - Improvement of fabricators/welding technology skills (competency at all levels including top management).

  This will be achieved through solutions, amongst others such as:

  - Extend the use of advanced technologies in design, joining and testing;
  - Provide guides to industry such as diffusion of latest best equipment and practices which also helps governments regulators and insurance;
  - Help a country with conformity assessment aspects such as risk based inspection, design verification, fabrication verification, In-service inspection verification;
  - Development of a national mark to identify pressure equipment confirming to standards and comparable with EU = "CE", USA = "U" Stamp);
  - Risk assessment and management guide to manufacturers and users;
  - Commentaries on codes, on design, on training (covering two previous points), welding procedures (ASME, EU and ISO) and documentation simplification;
  - Harness industry capabilities regarding technology, facilities, equipment by having a full record of capabilities and creating networks and alliances to maximise use of the capabilities.
  - Rationalise critical equipment eg, heavy roll, heavy presses and spinning for heads, forging facilities and large heat treatment furnaces;
  - Laser welding for large numbers – water heaters and gas cylinders;
  - Greater use of plastics for pressure piping.

One could expect general outcomes leading to more affordable energy to include

- Reduced manufacturing costs;
- Reduced inspection and maintenance costs;
- Less failures.
- Improved weld quality in pressure equipment manufacture;
- Extended service life of equipment;
- Reduced maintenance costs;
- Less unplanned shutdowns;
- Extended duration between shutdowns.

Thus helping improve this SDG with

- Increased turnover for SMEs;
- Safer operating environments;
- Prevention of catastrophic failures and major losses to the economy;
- Less environmental damage;
- Import replacement and increased exports

2.8 Promote sustained, inclusive and sustainable economic growth-Twelve Targets, 17 Indicators

There are many factors which can have a positive effect on the growth of a country's economy. Some of these involve creating the correct cultures within the country. For example, ethics, skills respect, productivity, quality, work, health and safety, environmental, innovation and service excellence amongst others [32].Examples of how these can contribute to an excellent national welding capability are shown in the "winning nations".

People in the "welding industry" can have a positive effect on economic growth. Innovation and the need to have competent people to play their part in innovation also places emphasis on the importance of education, training, qualification and certification of people as well as certification of companies in the country to improve this SDG.

- As a simple example, according to an American Welding Society (AWS) report, by employing a qualified welding supervisor, a company can save up to US$17,044 per welder per year as follows: reduced weld metal volume $3,319; reduced arc time per weldment $4,281; reduced rework, scrap and rejects $3,244; reduced work effort, motion and delay time, $6,200 [12].
- Qualification can be defined as: Evidence of education, training, and knowledge gained. A qualification is valid for life and cannot be withdrawn if earned correctly e.g. a degree or IIW Diploma or some certificates.
- As with every amount of learning achieved, knowledge is ever evolving and changing as society changes and technologies improve, so the need to keep pace with change requires the need for ongoing education to remain valid and have some currency.
- Certification can be defined as: The procedure by which a certification body gives written assurance that a person is competent for a specified class of work. The document issued is a Certificate of Competency. Continued ongoing certification is valid for a set period of time, and proof of continued ongoing competence is required for regular re-certification and continued registration. Certification can be withdrawn if it has been proven that the person has dropped below the competency level required.
- Competency can be defined as: Having the training, qualification and skill to apply knowledge and experience to satisfactorily perform the required level of work required.
- Certification has the benefit of giving both the person and the industry in which they work increased confidence that the person can carry out their work professionally, in line with

current regulations, standards and requirements, and that they continue to enhance their knowledge and skills.

- The inclusion of mandatory qualifications and certifications for different types of welding personnel in national and international standards as well as customer specifications shows the importance of personnel education, training and skills levels to the quality and reliability of welded products/structures.
- Appropriate Q&C arrangements are essential if companies are to achieve and maintain international competitiveness in a global economy.
- There is a growing trend that companies in industry see the value of putting in systems in compliance with standards such as ISO 9000 and ISO 3834, and bodies qualifying and certifying personnel complying with ISO 17024 and ISO 9712 or bodies certifying products, processes and services complying with ISO/IEC 17065:2012- Requirements for bodies certifying products, processes and services as well as WHS and environmental standards such as ISO 45011:2018 *Occupational health, safety management systems* and ISO 14001:2015 *Environmental Management Systems Standard*
- There is also greater emphasis on ensuring that the relevant organisations comply with ISO/IEC 17021:2011- Conformity assessment-Requirements for bodies providing audits and certification of management systems.
- The qualification and certification of welding related personnel has not just given greater assurance to users of such personnel with respect to their competence but has increased the work pride, and quality culture, of the individuals in achieving such status and professional recognition.
- In developing countries however, there are probably large numbers of personnel who have not been exposed to such processes or cultures and strategies need to be implemented to assist such people achieve their optimum performance and a quality culture.
- There is a need to show developing countries the value and benefits of introducing a quality culture through improved productivity and greater prosperity in the country. There have been good examples of Expert Technology Tools available to assist companies implement ISO 3834 and ISO 14731 [33]
- The ongoing development and implementation of ISO 3834 Quality requirements for welding-Fusion welding of metallic materials and ISO 14731 Welding coordination-tasks and responsibilities throughout the world, is leading to an improved quality culture in many countries and companies including greater recognition of the image and importance of competent welding related personnel [32].
- In all the above, investment in skills is a key way in which industry can adjust to the changing market environment. Increased skills levels in firms and meeting the required standards above are likely to lead to improved international competitiveness and an improved market share in domestic and international markets for medium to poor countries.
- Marketing should promote the benefits of education, training, qualification, certification, R&D, technology and innovation at the same time.
- The development of the International Institute of Welding (IIW) Education, Training, Qualification and Certification programmes and their implementation including the IIW Manufacturers Certification Scheme according to ISO 3834 (IIW MCS ISO 3834) in 47 countries worldwide illustrates the importance and need for world class personnel and companies to be available in the welding industry in a country [18].
- A key objective in a developing country is to provide jobs for local people and improve their quality of life. Having the various welding related personnel and companies acknowledged as meeting International and National Standards is a means of achieving this, hence the importance of recognised qualification and certification.
- Ideally, all companies no matter how small, can institute ‘on-the-job’ training to equip human resources with greater knowledge and skill and in turn, develop a learning culture. This philosophy will add value to the individual, the company and to national prosperity.

- Persuading governments and industry to support the upliftment of disadvantaged people through improved skills and knowledge of welding and NDT can also be a positive approach to be adopted in a NWC Project in a developing country.
- For example IIW WGRA/COM, Success Story No 1 illustrates how the Canadian, Dutch and South African Governments were persuaded to provide the funding to train and qualify 65 disadvantaged people in NDT. As the Success Story states “This wonderful team effort, between three national governments, industry bodies, national welding institutes and South African industry resulted in an outstanding outcome in improving the quality of life and ongoing opportunities for young people”[34].
- Such a success story can lead to further support. For example, the Australian Federal Government later supported SAIW in the training of disadvantaged people in South Africa as welders and through the South African Fabrication and Construction Training Trust Fund (SAFCTF) 100s of disadvantaged people were also trained at SAIW as welding inspectors, welding supervisors and NDT personnel.

2.9 Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation-Eight Targets, 12 Indicators

An innovation culture is where everybody and every effort contributes to bringing in something new, to making changes (ideas, methods etc.) whether in simple or complex forms and includes applying inventions and the adoption of R&D outcomes.

- Innovation is now much more of an incremental process, in which research, entrepreneurship, creativity, customer demand and customer service all play their part and greater innovation spurs higher productivity helping the industry and economy to prosper.
- Implementation of innovative ideas and processes especially for smaller firms requires an effective link between the firms themselves and sources of technology. Research and development must therefore link in well with what technology diffusion provides but there must be market awareness of the R&D outcomes if technology diffusion mechanisms are to be effective and increase innovation.
- Companies themselves must recognise the importance of new technology to their business, and hence R&D, so that the market demand for new technologies continually improves and the level of technology uptake at the individual company level increases.
- To optimise the benefits of welding to a country’s economy, innovation must play a significant role and this will require a major cultural change in many companies and individuals particularly in consciousness raising of the importance of innovation to company competitiveness and industry survival.
- The development of sufficient people as both technology deliverers and technology receptors is critical to ensure that innovation can take place
- ISO Technical Committee 279 (ISO/TC 279) Innovation management documents has completed very good work, in assisting countries improve the innovation culture, by introducing ISO Guidelines in this area. These include:

    - ISO 56002, Innovation Management-Innovation management system-Guidance
    - ISO 56003:2019 Innovation management-Tools and methods for innovation partnership-Guidance
    - ISO/TR 56004:2019 Innovation Management Assessment-Guidance

ISO has also planned to introduce additional standards as follows:

- ISO 56000, Innovation management-Fundamentals and vocabulary
- ISO 56005, Innovation management-Tools and methods for intellectual property management-Guidance
- ISO 56006, Innovation management-Strategic intelligence management-Guidance
- ISO 56007, Innovation management-Idea management

2.10 Reduce inequality within and among countries-Ten Targets, 11 Indicators

It is important to conduct a needs analysis in a country to establish exactly what is required to improve the quality of life in that country and have solutions to improve equality. In the welding related field there are examples of how such needs analyses have been conducted and then used to put in place appropriate strategies and action plans [35],[36],[37],[38],[57]. The results which will be achieved through the country's National Welding Capability (NWC) Project and help improve the SDG could include amongst others:

- The country establishing its own not-for-profit National Welding Institute/Society/Association which will become the National Welding Capability (NWC) Project Lead Organisation as well as become the country's representative in the 50 Member country International Institute of Welding (IIW).
- The National Welding Institute/Society/Association having a full range of membership categories and membership system to accommodate all appropriate parties in the country and their involvement in the National Welding Capability (NWC) Project.
- The country having a not-for-profit organisation achieving full recognition as an International Institute of Welding (IIW) Authorised Nominated Body (ANB).
- The country's educational institutions including universities, colleges and practical welding training centres having their instructors trained and qualified to the required standard to train the full range of qualified and certified personnel required by its industry.
- A programme of upgrading all training resources required by the country's educational institutions prioritised and implemented.
- A network of IIW Approved Training Bodies (ATBs) established in the country.
- The country's personnel trained, qualified and certified in the country as IIW welding engineers, technologists, specialists, practitioners, welders, supervisors and inspectors and where applicable, to other national and international standards and specifications such as those in Canada, South Africa, USA, EU and ISO.
- The country having an organisation achieving full recognition as an IIW Authorised Nominated Body for Company Certification (ANBCC) and a programme of auditing and certifying companies in the country.
- The country's companies certified to ISO 3834 and/or other national programmes such as that of the Canadian Welding Bureau if required.
- A comprehensive study of the country's needs in terms of welding related personnel and companies.
- The creation of required networks to make the NWC Project a success.
- These results will enable the country to be independent and self-sufficient in various welding related personnel and company needs in terms of International and National Standards.
- To implement how this can be achieved, the NWC Guidance Notes would be used and appropriate Goals, Objectives, Strategies, Outcomes, Action Plans including Timelines would be implemented.
- All the above will help put a country on an equal footing with many other countries.

2.11 Make cities and human settlements inclusive, safe, resilient, and sustainable-Ten Targets, 15 Indicators

There has been an unprecedented growth of cities over the past seven decades with the need to create safe and affordable buildings including housing as well as safe and efficient public transport. There has also been a growing trend to make such structures resilient to disasters such as earthquakes, fires, floods as well as failures due to shoddy quality.

Some examples are given below on how countries have met these challenges and developing countries could learn from such experiences.

- After WWII, the Canadian Welding Bureau (CWB) was formed in 1947 with the main objective of giving government and industry greater confidence and assurance in the

design, fabrication, construction and erection of welded steel, particularly in high rise structures. There had been a number of expensive and potentially disastrous welding jobs on bridges built under the interstate highway program.

- The Canadian Standards Association (CSA) had been given the mandate in the 1930s to start welding standards development and the creation of a national body to administer them.
- Two key standards, W59 and W47.1 were put in place and the formation and role of CWB (now known as the CWB Group) was to act as the official administering body to ensure the uniform rollout and enforcement of the standards across Canada, including embedding the requirement for adherence to these standards in the National Building Code [39].
- The CWB thus became the organisation, supported by industry and government bodies, to ensure the integrity of welded steel, and later aluminium and rebar structures, welding inspection companies and inspectors and welding consumables through the certification of fabricators, construction companies, inspection and test centres, welding consumables as well as personnel, and the continuing provision of appropriate standards through one of the national standards organisations.
- Such stable and sustainable activities enabled the CWB to grow to an organisation with considerable financial reserves and a staff complement in excess of 200 people across all the provinces in Canada and with over 7000 CWB certificated companies worldwide, such experiences can be transferred to other countries to make their welded structures safer and more resilient to failures.
- In the US and New Zealand, due to having parts of their countries on severe earthquake zones as well as suffering a number of major earthquakes, new improved design codes, fabrication and erection techniques were introduced to improve the resistance to failure in earthquake conditions.
- In Australia, due to many parts of the country being subjected to severe bushfire situations, new design and building codes have been introduced to again make buildings safer and more resilient to failure.
- Countries also need good, safe and efficient local and cross-country public rail transport systems to ensure sustainable cities and communities. There are many examples of countries which have established the codes and standards for the welding design, fabrication and manufacture of all the components required for such railway systems.
- EN 15085 is a standard now extensively used for the certification of companies involved with railway applications for the welding of railway vehicles and components. Together with standards for the welding of rail, with the correct technology transfer processes in place, there is no reason why a country's public rail system cannot be built and maintained correctly and operated safely.

2.12 Ensure sustainable consumption and production patterns-Eleven Targets, 13 Indicators

There are many examples of sound environmental and Work, Health and Safety {WHS} management practices around the world to assist in control of many wastes related to welding.

An environmental culture of an organisation could be defined as the product of individual and group values, attitudes, perceptions, competencies and patterns of behaviour that determine the commitment to, and the style and proficiency of, an organisation's environmental management.

- Similarly, organisations with a positive environmental culture are characterised by communications founded on mutual trust, by shared perceptions of the importance of welding related activities to the environment and by confidence in the efficacy of preventive measures.

- The introduction of ISO 14001, *Environmental management systems - Specification with guidance for use*, is designed to help organisations manage, control, and report on their environmental performance. It therefore specifies the requirements for an effective environmental management system (EMS), providing a framework that an organisation can follow rather than establishing environmental performance requirements.
- The role of an Environmental Welding Coordinator (EnvWC), to be responsible in a company for all the welding related environmental activities, is also growing in some areas of the world and increasingly companies are having to comply with national and/or regional laws and regulations [40].
- Experience has shown that even with the introduction of such measures, this culture is one of the most difficult to get industry to implement, particularly with the large number of SME operatives in this sector. With the fast growing awareness of environmental problems in the world however, it is anticipated that adoption of this culture in countries will improve.
- In Australia, through a Federal Government programme known as the Industry Cooperative Innovation Project (ICIP), in 2012, WTIA completed a project titled ICIP DS 6: Expert Technology Tools (ETTs) on Welding WHS and Environmental Management Systems, Audit Tools and World's Best Practice for the Shipbuilding Industry. These ETTs were subsequently released publically for anybody to use as a basis for their own environmental management system manuals and self-assessment tools in their particular industry.

    - Welding in the Shipbuilding Industry: An Environmental Management System (EMS) Manual [41].
    - Welding in the Shipbuilding Industry: An Environmental Management Self-Assessment Tool [42].

- In parallel, WTIA Technical Note TN23 Environmental Improvement Guidelines [43] and WTIA Guidance Note GN04-Environmental Aspects and Impacts of the Activities Health and Safety [44] are complementary to this work.
- A document entitled *Environmental management systems - Requirements with guidance for use in the fabrication by welding* gives essential interpretation of the criteria in ISO 14001 in the field of welding fabrication [45].
- The role of the EnvWC can be promoted both for the benefit of individual companies, and the advancement of careers in welding. The concept builds upon the role of the Responsible Welding Coordinator (based on Standards ISO 3834 and ISO 14731) which has been successfully introduced into industry around the world to promote improved welding management and productivity [16],[33].
- A Work, Health and Safety (WHS) culture of an organisation, as used by the Health and Safety Executive (HSE) in the UK, is the ‘product of individual and group values, attitudes, perceptions, competencies and patterns of behaviour that determine the commitment to, and the style and proficiency of, an organisation’s health and safety management’.
- Organisations with a positive work health and safety culture are characterised by communications founded on mutual trust, by shared perceptions of the importance of health and safety and by confidence in the efficacy of preventive measures.
- One of the most effective ways to improve the work health and safety culture is through the effective application of the laws and regulations which exist in many countries. This will automatically reduce waste by less people being negatively affected by poor WHS.
- Unfortunately, where such enforcements do not take place, many accidents and health problems related to welding activities do occur.
- The key to development and continuous improvement in a WHS culture is to change attitudes and behaviours at all levels. The mantra “all injuries are preventable” is not a utopian ideal but should be the basis for development and implementation of WHS management systems.

- Hazard identification, risk assessment and implementation of appropriate risk management protocols are essential. This requires identification of and understanding of potentially hazardous processes, development and use of better equipment and raising the awareness and competency of individuals to work safely.
- IIW and its members have been very active in creating awareness through education, training and technology diffusion throughout the world but unfortunately, particularly in developing countries, numerous examples of widespread routine procedural violations occur where people, not just management, put cost or production before health and safety.
- In any organisation, senior management must commit to produce higher levels of motivation and concern for health and safety throughout the organisation. Managers need to lead by example and appear regularly on the 'shop floor', talk about health and safety and visibly demonstrate their commitment by their actions, for example stopping production to resolve issues.
- Good communications between all levels of employees should be part of everyday work conversations with ownership at all levels. The unique knowledge of employees with their own jobs, their involvement in workshops, risk assessments, plant design etc. all lead to a positive culture.
- The introduction of ISO 45011*Occupational health, safety management systems* can be a significant aid to improving the culture in many countries and organisations.
- There is so much information available on these subjects that such information and technology can be transferred into developing countries to assist them in this Goal. Part of this technology transfer would be the education and training of personnel in companies accompanied by the establishment of company environmental, WHS and quality management systems and their certification [46].

2.13 Take urgent action to combat climate change and its impacts by regulating emissions and promoting developments in renewable energy-Five Targets, 8 Indicators

Energy resources power both domestic and industry needs, and are a key contributor to a country's economic prosperity. The demand for energy increases as a country's economy and population grow. Fossil fuels such as oil, natural gas and coal are examples of non-renewable resources and they cannot be replaced as quickly as they are being used. In contrast, resources that are referred to as renewable energy sources can be used again and again, without depletion, or can be replenished in a short time frame. The wind, sun (solar) and waves are all sources of renewable energy.

- Countries will vary as to the amount of renewable and non-renewable energy sources including fossil fuels which they have as well as the speed at which they can move to a fully renewable energy situation.
- In many countries, energy needs are still mostly met by fossil fuels. Coal resources are used to generate high percentages of domestic electricity; natural gas is found in many homes and is increasingly used in industry; and the transport system may be heavily dependent on oil, some of which may be imported. Nuclear energy is favoured in many countries.
- Although the use of renewables is increasing, they still only account for a relatively small proportion of primary energy consumption and electricity generation. Hydro energy resources were developed early in some countries and are currently the largest renewable source of electricity in some countries. Hydro energy is derived from water within areas of high rainfall and elevation. The wind and solar energy industries are growing rapidly, with wind and solar farms becoming more common. There has also been significant investment in research and development aimed at increasing the efficiency and cost-effectiveness of wind and solar power, including the development of solar thermal power stations.

- In addition, a country could also have geothermal, wave and tidal resources. Geothermal energy can be in the form of buried, high-heat producing rocks. For countries with coastlines there could be world-class wave energy and tidal resources. Bioenergy is another significant potential energy resource. Organic matter (e.g. landfill or sugar cane waste) can be used to generate electricity and heat, as well as for the production of liquid fuels (biofuels) for transport. There is also growing interest in the use of hydrogen by industry and as fuel in cars.
- This is leading to greater cooperation and collaboration between various countries. Germany and Australia is a good example. German and European strategies focus on developing so-called "green hydrogen" – hydrogen produced from renewable energy sources. The Australian strategy uses the broader term of "clean hydrogen" that includes both green and blue hydrogen (hydrogen produced from natural gas which captures emissions using carbon capture and storage).
- In addition to other energy-related activities such as energy efficiency measures and the expansion of renewable energy production, green and clean hydrogen offer significant opportunities to decarbonise industry and a potentially massive new export industry can be developed, either in the form of hydrogen or ammonia as this is easier to store and transport. Through hydrogen, there is also the possibility to produce Green Steel. Of course, Australian exports would not necessarily go to Germany, but there are also large regional markets in countries like Japan, South Korea, or Singapore. Developing countries can also investigate such models for their own country.
- Irrespective of the type of energy source used either now or in the future, welding and joining will be employed to varying degrees in the manufacture, repair and maintenance of the structures producing the energy or components using the energy source. Coal, gas and nuclear power stations will still function for many years ahead so it is important that the appropriate welding related technologies are available in a country to ensure the optimum life cycle is obtained. Similarly with oil and gas pipelines and structures, both onshore and off-shore. With renewables such as wind and solar energy, the components have their own challenges not just in manufacture but also in service ensuring that premature failures do not occur.
- With the advent of transport vehicles fuelled by energy sources such as electricity and hydrogen, the efficiencies of manufacture, repair and maintenance by welding and joining will still be required.
- Whether the use of energy from ocean and tidal waves or from storage dams is to be used, the infrastructure required will still need the high quality design, manufacture and operation as similar structures required for renewables.
- Promoting the developments in renewable energy, will still require all the benefits of an improving national welding capability. A goal of development will be to reduce life cycle costs to achieve a cost per kilowatt hour of electricity which is attractive to consumers. Lowering fabrication costs, increasing production rates, enhancing durability and reducing maintenance will all contribute to this.

2.14 Conserve and sustainably use the oceans, seas and marine resources for sustainable development. Ten Targets, 10 Indicators

In terms of challenges below the water, there are many concerns about the whole range of pollution taking place which can have a major significant effect on the marine ecosystems. Since welding is used in numerous applications which will be used in water, the integrity of the welds becomes paramount.

If one considers the range of applications covering ships, boats, oil and gas carrying pipelines and tankers, failures can result for example in fires and oil pollution from small spills to catastrophic damage.

- As areas such as the Arctic are being increasingly targeted for use such as for oil and gas exploration, oil and gas production, shipyards and naval bases amongst others, the risk of

weld failures in operation increases due to the more demanding conditions existing. At the extremely low temperatures, the chances of weld failures due to brittle fracture and fatigue increase significantly. The conditions for performing repair and maintenance involving welding become far more onerous and give rise to greater possibility of poor quality welds and hence failures.

- The importance of the integrity of welding is illustrated by the Alexander L Kielland platform in the North Sea in March 1980 which capsized with the loss of 123 people. The official investigations concluded that the root cause of the accident was an undetected fatigue crack in the weld of an instrument connection on the bracing. It was reported that there was no pollution due to this accident.
- When catastrophic accidents have occurred related to oil production platforms and tankers, the effects can be disastrous on animals, birds and marine life. For example, the spill from BP's Deepwater Horizon rig in the Gulf of Mexico in 2010, covered 68000 square miles of sea surface and killed approximately one million coastal and seabirds, 5000 marine mammals and 1000 sea turtles. The long term effects on the environment and animals' health are immense.
- The high integrity and reliability of welded structures in marine applications to this SDG is essential.

2.15 Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss. Twelve Targets, 14 Indicators

In terms of this Goal, welding can have a positive influence in a number of ways. In all the issues mentioned, water management plays a significant role in their success. As mentioned in section 2.6, water sources whether dams, rivers, desalination plants etc, need to be built and maintained. Pipelines need to be constructed, laid and maintained to carry the water to the points where distribution can take place to where the water is required with minimum waste.

- In terms of combatting desertification and using the reclaimed land for agriculture as happens successfully in various countries, efficient storage and irrigation methods are essential and the integrity of welding can have an effect on this.
- With forest management and remediating land which has been degraded, similar challenges with ensuring reliable efficient water supplies exist. Storage tanks, pipelines, piping systems will all require competent people to apply appropriate welding and inspection technologies.
- In addition, reliable heavy moving equipment and other types of vehicles will be required on an ongoing basis. This will require competent welding maintenance workers with the abilities not only to apply the appropriate technologies but also to develop the necessary procedures and application processes often for difficult-to-weld materials.
- In all these cases including biodiversity loss, it is often required to fence-off and protect the land enclosed against feral animals killing off rewilding attempts and damaging the habitat being remediated. Although fencing is one step along the rewilding path, again welding plays a significant role in ensuring the integrity of such fencing. In Australia for example, there are major moves not just to conserve existing and often quite degraded land areas but to revitalise it. Rewilding is a complex issue.
- Concerns do exist in countries where pristine land could be degraded or degraded land degraded even further. Examples of the types of catastrophic failures which can occur and dramatically affect numerous people, animals and land include the Bhopal disaster in India and the Chernobyl nuclear power plant failure in Ukraine in 1986.
- On December 3 1984, more than 40 tons of methyl isocyanate gas leaked from a pesticide plant in Bhopal, India, immediately killing at least 3,800 people and causing significant morbidity and premature death for many thousands more.
- However, the organisations fighting for the victims claim the tragedy has killed at least 25,000 people. A report released in April, 2019, by International Labour Organisation (ILO) dubbed

the 1984 Bhopal Gas Tragedy as one among the world's 'major industrial accidents' of the 20th century.

- Apart from the dreadful human toll, we also cannot ignore the environmental impacts of the disaster. Over 2,000 animals were killed by the gas that night, most of them livestock that people relied on for food.
- 34 years later, Chernobyl radioactivity is still circulating. The long-lived radionuclides released by the accident mean the disaster continues decades on. ... They have now had the biggest fires ever recorded in the Chernobyl exclusion zone. What is one of the largest wildlife areas in Europe will take years to recover. Heavy gas was absorbed into local rivers, making the water undrinkable and poisoning the fish.
- Chernobyl has become a byword for catastrophe. When it comes to vegetation, all but the most vulnerable and exposed plant life never died in the first place, and even in the most radioactive areas of the zone, vegetation was recovering within three years.
- Welding is used in many critical applications which if failure occurs, varying degrees of contamination and destruction can take place. These can range from catastrophes similar to those mentioned above through to issues such as sewerage spillages onto land and into rivers.
- The great benefits of welding can be realised however with the proper design, materials, procedures, manufacture, conformity assessment, operations including repair and maintenance as well as decommissioning leading to positive contributions to improving this SDG.

2.16 Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective accountable and inclusive institutions at all levels-Twelve Targets, 23 Indicators

An ethics culture is probably one of the most important cultures that needs improving throughout the world. Prof. Phil Hopkins, an international authority on integrity of pipelines, relates ethics and engineering in his excellent paper [47]. One definition of ethics is a synonym for ordinary morality – 'Morality' refers to those standards of conduct everyone (every rational person at his rational best) wants every other to follow even if everyone else's following them would mean having to follow them too. Morality (in this sense) is the same for everyone, engineers included. The golden rule 'Do to others as you would have them do to you' is an excellent model.

- Throughout the world, unfortunately, a culture of corruption exists in many countries whether developing or developed. There are many examples of different types of corruption and the welding related industry has tried to implement ways of obviating these. In some examples of corruption, the culture is so prevalent that to overcome it is a major constraint.
- In creating a NWC, it is critical to ensure that the organisations involved all comply with the applicable legal and statutory obligations covering aspects such as financial, tax, governance, law, industrial relations etc. as well as ensuring that Directors, employees, suppliers, etc. do not have conflicts of interest. This is critical since credibility of the organisations and their employees will be paramount in being successful in both establishing and sustaining a NWC.
- It is also important that the organisations in the NWC team and the NWC Lead organisation have policies for their organisational corporate cultures. A good example of such a policy is given by Geoff Carter in reference [48]. The Board of a company needs to acknowledge that the organisation's culture is formed by the way people, on the whole, behave-what they believe, the values they hold, the attitudes they adopt-without thinking about any of it. The Board must ensure that an appropriate set of behaviours, beliefs, values and attitudes is embedded in the way things are done in the organisation. These behaviours, beliefs, values and attitudes should then be passed through the organisation via communication and imitation, from one employee, volunteer or even director to the next.

- There are many examples of things going wrong ethically and industry and governments attempting to prevent such occurrences in the future. For example:
    - In industry, employees can be tempted to pass non-conforming work in a variety of ways for financial gain, so employers and law makers introduce strict penalties for such people if found guilty - the Alaska Pipeline scandal over 40 years ago is a prime example.
    - Qualification and certification (Q&C) of personnel are methods used by industry through Q&C issuing bodies to show that a person is competent to perform a particular function. Prior to issue, the recipient can be requested to sign a code of ethics and if at some future time the person is not complying then the Q&C can be withdrawn. It is hoped that the application and strict adherence to the code of ethics creates an ethical culture in the industry-numerous examples exist of individuals pretending to have Q&C documentation which they do not have.
    - There are many examples across the world of students, examination bodies, certification bodies abusing the system so strict governance and quality management systems are implemented to prevent corrupt practices-cheating in examinations is a common occurrence.

- A useful approach is to look for 'ethical leadership' in people at all levels. The most successful leaders inspire others to embrace a common goal through recognition of shared values. They build and maintain effective relationships by living and leading with integrity.
- ISO has also introduced standards which involve ethical behaviour. ISO 19600:2014-Compliance Management Systems-Guidelines and ISO 26000 Social Responsibility Guidance Document.
- ISO 19600:2014 covers establishing, developing, implementing, evaluating, maintaining and improving an effective and responsive compliance management system within an organisation. They are guidelines and the extent to which they are used depends on the size, structure, nature and complexity of the organisation. The Standard falls under ISO Technical Committee 309, Governance of organisations.
- Some countries such as Australia had introduced a range of national standards to cover different aspects of controlling the risk of fraud and corruption. In particular it is necessary to keep up to date with revisions made necessary because of fraud and corruption in the Australian economy due to technological advancement and the way business is conducted. A corporate governance series comprising AS 8000 Good Governance principles, AS 8001 Fraud and corruption control, AS 8002 Organisational codes of conduct, AS 8003 Corporate social responsibility and AS 8004 Whistleblower protection program for entities. To ensure that the National Welding Capability Project is a great success, standards such as these should be implemented. Additional guidance on applying these standards can be found in a Securities Industry Research Centre of Asia-Pacific (SIRCA) document [49].
- Based on the agreement that ISO/TC 309 Governance of Organisations, together with its working committees, would establish and implement a series of ISO Standards covering subjects related to good governance of organisations, Standards Australia withdrew the above standards including amendments in 2007. They are worthwhile consulting since the need for the subject matter is continuously growing.

2.17 Strengthen the means of implementation and revitalise the global partnership for sustainable development- Seventeen Targets 25 Indicators

Many people and organisations think of networking as being the meeting of people at events such as conferences, cocktail parties, social networks etc. or those linked to personal or professional computer networks. Although these are very useful and can contribute in various ways to the success of achieving an optimum NWC, the more useful networks however, are

the more formal networks established closely associated in most instances with the welding industry.

- Such networks help in producing a multitude of partnerships, both large and small, ready to work together on appropriate activities to assist in meeting SDG Targets in a country.
- A general definition of a network is that it consists of a variety of entities (e.g. organisations and people) which are largely autonomous, geographically distributed and heterogeneous in terms of their operating environment, culture, social capital and goals, but that cooperate and/or collaborate to better achieve common or compatible goals.
- Companies in industry need to continually innovate to remain competitive. Innovation includes new products and processes, significant changes to existing products and processes and significant changes to management and organisational structures;
- Implementation of innovative ideas and processes especially for smaller firms requires an effective link between the firms themselves and sources of technology, knowledge and information. Networks are a crucial fundamental requirement for this.
- A strong NWC Project Lead Organisation can be the catalyst to establish and sustain such networks with most of the organisations in the networks considering themselves as partners if the team achieving the NWC and giving their ongoing commitment to establishing the NWC.
- Since all the different building blocks to create a successful NWC are essential, networks and the partnerships which evolve are therefore of great importance in the areas covering funding, government, industry, R&D, technology transfer, education and training, qualification and certification (Q&C), skills and career development, cultures, standards and communications which will all contribute positively to the SDGs.
- There are many examples of such networks around the world but the challenge is to resource, build up and sustain such networks. Whether a country's economy is considered developed, developing or an economy in transition, such networks are essential but obviously countries in different stages of development will have varying challenges and difficulties to succeed in establishing and maintaining the networks.
- There are excellent examples of networks successfully established to bring industry and all levels of government together to supply the R&D, technologies, technology deliverers and technology receptors to create viable industry sectors and overcome constraints as well as fostering partnerships between Small, Medium, Enterprises (SMEs), larger firms and Multinational Enterprises (MNEs) which play a leading role in technological innovation, R&D investing and patenting [19], [20].

International networks have many benefits across all the activities in a NWC. For example, such networks include amongst many others, those shown below and can all contribute to the NWC Project and SDGs:

- IIW with 50 Member countries[18];
- International Organisation for Standardisation (ISO) with 162 Member countries [50];
- WorldSkills International with 79 member countries [51];
- International Committee for Non-Destructive Testing (ICNDT) with 66 Full Members and 9 Associate Members[52];
- IIW Authorised Nominated Bodies (ANBs) in over 46 countries [18];
- IIW Approved Training Bodies (ATBs) in each country with an IIW ANB;
- Welding equipment/consumable suppliers [53],[54];
- NDT equipment suppliers [55], [56].

Similarly with networks within the NWC Lead Organisation or NWC Project Team:

- NWC Project Lead Organisation Technology and Research Board;
- NWC Project Lead Organisation Education and Training Board;

- NWC Project Lead Organisation Qualification and Certification Board;
- NWC Project Divisional or Professional Membership Committees;
- NWC Project User/Asset Owner Groups;
- NWC Project Industry Specific Groups (ISGs);
- NWC Project Technical Panels;
- NWC Project Technology Expert Groups (TEGs);
- NWC Project Technology Support Centres (TSCs) Network – Local;
- NWC Project Technology Support Centres (TSCs) Network – International;
- Federal, State and Local Governments;
- Professional Associations/Institutes;
- Industry Groups for Specific Business Needs;
- Standards Developing Organisations;
- Vocational Education and Training Organisations;
- International Government Organisations
- International Technical Organisations
- Individual Experts

3. Some General Examples of Beneficial Outcomes of the NWC on the SDGs

The NWC Project and the welding industry's contribution to the UN SDGs can be immense and helps to:

- develop short, medium and long term strategies to meet the needs of a country including the SDG Targets;
- ensure that the needs and solutions are appropriate and relevant and help minimise waste of money and effort;
- assist in identifying and securing both local and international funding for the required activities, ensure its proper use and control of the finances and maximise the value of the investment by all parties;
- assist in being able to see how different government funding and innovation programmes work in other countries and hence learn from these experiences when seeking new programmes and funding in one's own country;
- bring forward how different and/or comparable countries are achieving their optimum NWCs and their SDGs;
- implement appropriate solutions to ensure that the required numbers of personnel of all types and categories are available to achieve the optimal NWC and SDG Targets;
- create the appropriate links, culture and teamwork necessary to achieve the challenges in the NWC Project;
- improve the cooperation and collaboration between all NWC Project groups;
- in a relatively short time period, grow the number of people involved in a national association of welding related personnel to extraordinary levels;
- make it easier for the exchange of people, ideas, facilities and equipment;
- ensure that the competent personnel are available at all levels to identify the problems, find the solutions, deliver these to industry and assist in the receiving, adopting, adapting and implementing of the solutions to increase company and industry performance and hence a successful NWC and hence SDGs;
- continually improve the credibility of the NWC Project groups to governments, industry, sponsors, investors etc.;
- create a culture for governments and industry to recognise the benefits of investing in welding related activities which normally do not have the same star appeal as say biomedical, information technology and other activities;
- maximise the promotion, marketing and communication of all NWC Project activities both nationally and internationally;

- act as the catalyst for bringing individuals as experts to the country to assist in the various NWC Project activities appropriate to their expertise;
- provide opportunities to 'showcase' success as well as give recognition to individuals at all levels who have contributed to building up a successful NWC.

4. References

[1] Establishing a National Welding Capability (NWC) in a Country. Chris Smallbone, IIW International Welding Congress-Weld India, Mumbai,India,6-9 February 2020

[2] UNESCO Engineering Report, Engineering for Sustainable Development Delivering on the Sustainable Development Goals, Published 4th March 2021

https://en.unesco.org/reports/engineering

https://unesdoc.unesco.org/ark:/48223/pf0000375644.locale=en

[3] Welding in the World and the Future, Chris Smallbone, IIW International Congress, Hammamet, Tunisia, 28-30 May 2010

[4] United Nations Industrial Development Organisation (UNIDO) Service to Industry, UNIDO's Programme of Direct Support to Industry under Trust Fund Arrangements, Some Recent Examples. 29 January 1993

[5] United Nations Industrial Development Organisation (UNIDO), Vienna, Report on the Status of Welding in Vietnam and on the Requirement for Improvements and for Welding Training Development.NC/VIE/92/046. Technical Report of the Joint Mission of: Mr H. Strauss and Mr A.P. Buckle, February 1993.

[6] UNIDO Programme. In support to Enhancing the Productivity through Technology Transfer, Commercialisation and Diffusion for Sustained Growth and Poverty Alleviation, Vladimir Kozharnovich, Programme Manager, Industrial Promotion and Technology Branch, UNIDO,1st IIW South East European Welding Congress 24-26 May 2006,Timisoara,Romania.

[7] "Welding-related Expenditure Investments and Productivity Measurement in U.S. Manufacturing, Construction and Mining Industries" Published by American Welding Society (AWS) and Edison Welding Institute (EWI) The Bureau of Export Administration, U.S. Department of Commerce May 2002.

[8] Macroeconomic and sectoral value added by the production and application of joining technology in Germany, in selected countries in Europe as well as the EU as a whole. Short version of the expert report, Michael Kersting, Waike Moos and Anna Werbeck Ruhr Research Institute, Bochum 2017

[9] Trends in Joining Technology-Value Added by Welding Technology. K.Middeldorf. German Welding Society (DVS).International Conference - Innovative Technologies for Joining Advanced Materials, Timisoara, Romania 2009.

[10] Smallbone, C. and Kocak M., "IIW White Paper: Improving Global Quality of Life Through Optimum Use and Innovation of Welding and Joining Technologies" Published by IIW 2012

[11] European Welding Federation (EWF) Employment, training and qualification needs of the European industry-a perspective from the joining sector.19th May 2015

[12] Final Report, Welding Supervisor Training and Certification, July 31, 2003, National Shipbuilding Research Program, Bender Shipbuilding and Repair Company, Barchoff and Associates, Inc and American Welding Society.

[13] Cultures for Success - Does the Fabrication Industry have them? Chris Smallbone 1996 Asia Pacific IIW International Congress, Auckland, New Zealand

[14] DVS German Welding Society, Research/Technology/Education. IN FOCUS. Welding Qualification in the DVS. Companies-Procedures-Personnel. www.dvs-ev.de https://www.die-verbindungs-spezialisten.de/index.php?id=2740

[15] 1982 Fred. L. Plummer Lecture Award. Education and Training in Welding Technology in a Developing Country, The Republic of South Africa Chris Smallbone, Executive Director, South African Institute of Welding

[16] WTIA GN 14 Rev 0, 28th May 2014, Guidance Note on Your Career as a Responsible Welding Coordinator (RWC).

[17] WTIA GN 13 Rev 0, 26th May 2014, Guidance Note on WTIA and IIW Career Paths from Apprentice to Welding Engineer.

[18] International Institute of Welding (IIW), Technical Management Board (TMB), International Authorisation Board (IAB) et al. http://iiwelding.org/iiw-members

[19] "The OzWeld Technology Support Centres Network: A Unique Model for Technology Innovation by Industry" ASM/AWS 6th International Conference on Trends in Welding Research 15 – 19 April 2002. Pine Mountain, Georgia, USA. Chris Smallbone, Chief Executive Officer, Welding Technology Institute of Australia

[20] Australian Federal Government Department of Education, Science and Training. Report 'Knowledge exchange networks in Australia's innovation system; overview and strategic analyses' Howard Partners, June 2005

[21] National Structural Integrity Research Centre (NSIRC) www.twi-global.com>nsirc

[22] CWB Welding Foundation Train the Trainer Workshops www.cwbweldingfoundation.org/programs

[23] AWS Certified Welding Educator Program (CWE), www.aws.org>certification.detail.certified welding educator program.

[24] CSWIP Welding Instructor, CSWIP Specialist Welding Instructor, Certification Scheme for Welder Training Organisations (CSWTO), www.cswip.com/certification/welding-instruction

[25] CWB Group, CWBiacorn Connecting Education and Industry and Prospective Acorn Partner Information Sheet Trent.konrad@cwbgroup.org

[26] AWS SENSE program, www.senseonline

[27] A Discussion Document on Creating a culture of Respect for Skills in South Africa. P.J.J. Dorfling, National Productivity Institute, August 1994.

[28] Report on "Think Tank" on the Formation of a Strategy for a National Skills Culture, Skills SA Foundation, Tuesday, 13th July, 1993, Chris Smallbone, President: Skills SA Foundation.

[29] Australian Government, Department of Education, Employment and Workplace Relations. Targeting Skills Needs in Regions Program Evaluation. August 2011 ISBN 978-0-642-78081-2. WTIA pages 29-30 and 103 https://www.voced.edu.au/content/ngv%3A49526

[30] New South Wales, Department of Education and Training. End of Project Report: Targeting Skills in the Regions (TSNR). Upskilling and Expansion of Regional Welding Personnel and Industries in NSW 13-01-09

[31] Research Report. Skilling the Australian workforce for the digital economy. Victor Gekara, Darryn Snell, Alemayehu Molla and Stan Karanasios, RMIT University, Amanda Thomas, Australian Industry Standards, Published by National Centre for Vocational Education Research(NCVER), 2019

[32] Establishing a National Welding Culture, Guidance Note 10 - Implementing the Necessary Cultures Building block. (Still to be published)

[33] WTIA Expert Technology Tool ISO 3834:2005 Quality requirements for fusion welding of metallic materials - Benefits and Implementation revision 1- 1 August 2008. National Library of Australia card number and ISBN 1 92076131 4 https://weldaustralia.com.au/wp-content/uploads/2015/02/tgn-3834-full-set-rev-1.pdf

[34] IIW WGRA-Com Success Story Number 1 *A team effort between three national governments, industry bodies, national welding institutes and South African industry gives hope to new welding inspectors and a model for the future.*

[35] Welding Industry Technology Needs Study-Cooperative Research Centre for Materials Welding and Joining (CRC-MWJ), Planning & Managing Projects Pty Ltd, 30 November 1995

[36] Welding Industry Vision Workshop Results Summary, June 30-July 1 1998, U.S. department of Energy, Office of Industrial Technologies and American Welding Society

[37] European Joining Platform to Manufuture. Joining Sub-Platform Strategic Research Agenda (SRA)-results of the Industrial Survey and the new SRA 2018-2020. Kristian Martinsen (Sintef)-Industrial Chairman, 7th European Joining Platform General Assembly Meeting, Portugal 16 November 2017

[38] A Technology Roadmap for Welding and Joining in Canada-2006 to 2016, Suthey Holler Associates, February 2006

[39] The Canadian Welding Bureau. D.E.H. Reynolds President-Canadian Welding Bureau, IIW Annual Assembly 23-27 July 1990, Montreal Canada

[40] WTIA Environmental Welding Coordinator WTIA OzWeld School of Welding Technology, Training Courses 2013

[41] Welding in the Shipbuilding Industry: An Environmental Management System (EMS) Manual. Industry Cooperative Innovation Project, Optimum Welded Plant in the Heavy Engineering and Infrastructure Industry. WTIA. 2012

[42] Welding in the Shipbuilding Industry: An Environmental Management Self-Assessment Tool. Industry Cooperative Innovation Project, Optimum Welded Plant in the Heavy Engineering and Infrastructure Industry. WTIA.2012

[43] WTIA TN 23 Environmental Improvement Guidelines 2002. National Library of Australia card number and ISBN1-920761-00-4

[44] WTIA GN 04 Environment Hazards, Impact and Control in Fabrication of Welded Products 2002

[45] The Environmental Management of Fabrication by Welding. Welding in the World 46, 22-31 (2002) Published 16 January 2013 Springer Link. https://doi.org/10.1007/BF03263387

[46] Greater Confidence Through Integration of Welding Quality, Work, Health and Safety, and Environmental Management in Mines and Their Suppliers, Smallbone C IIW International Congress, Cairns, Australia 2011.

[47] Pipeline Engineers: Ethics, Responsibilities, and Competency. Phil Hopkins, Technical Director, Penspen Integrity, UK.(now retired),WTIA International Pipeline Integrity Conference,Wollongong,Australia,7-9 March 2005.

[48] Organisational Corporate Culture Policy. G, Carter, Managing Director, Strategic Governance Group. Curtin, ACT 2605, Australia

[49] Fraud Resistance: A Practical Guide. Securities Industry Research Centre of Asia-Pacific (SIRCA) Martin Samociuk and Nigel Iyer Business Excellence Australia, A Division of Standards Australia International.2003.

[50] International Organisation for Standardisation (ISO) www.iso.org

[51] WorldSkills International www.worldskills.org

[52] The International Committee for Non-Destructive Testing (ICNDT) http://www.icndt.org

[53] European Welding Association (EWA) http://european-welding.org

[54] WEMCO A Standing Committee of AWS www.aws.org>wemco

[55] Nondestructive Testing Management Association (NDTMA) https://www.ndtma.org

[56] The British Institute of Non-Destructive Testing (BINDT) https://www.bindt.org/Buyers-Guide/NDT-Equipment-Providers

[57] A Comprehensive Advanced Materials Joining and Forming Technology Roadmap-Final Report, Prepared by Tom McGaughy, Hyunok Kim and Harvey Castner, EWI, Columbus, Ohio, 28 April 2017.