ENGINEERS AUSTRALIA

Our FLNG Future

Engineering Opportunities and Challenges

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About Engineers Australia

Engineers Australia is the peak body for the engineering profession in Australia, representing all disciplines and branches of engineering. With membership of over 100,000 Australia wide, Engineers Australia is represented in every state and territory of Australia and overseas through chapters in the UK, Singapore, Malaysia and Hong Kong. All Engineers Australia members are bound by a common commitment to promote engineering and to facilitate its practice for the common good.

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1. Executive Summary

The introduction of Floating Liquefied Natural Gas facilities (FLNG) into the Western Australian gas industry marks a major step change in the way natural gas fields can be developed. The first large scale FLNG in the world will be the Prelude facility that will operate in the Browse Basin off the Kimberley coast. Prelude is potentially going to be followed by several other such facilities in the area and there is growing global interest in the use of FLNG for similar fields.

FLNG and associated subsea systems bring a number of changes to the way LNG developments are undertaken, moving from a large onshore facilities fed from offshore fields to one where the facility is stationed directly at the field. These changes are reflected in changing demands for engineering skills and services. To understand how the effects of these changes on the Western Australian engineering sector could be best managed, Engineers Australia held a series of facilitated workshops with operators, engineering companies, researchers and industry representative bodies to solicit understandings and identify both the opportunities and challenges for the industry.

The workshops identified a number of themes, which are discussed in the following paper, namely:

- The engineering workforce in Western Australia has a large number of skills directly relevant to support the installation, commissioning, operations, maintenance, ongoing development and eventual decommissioning of FLNG facilities. These skills are spread across industry and academia.
- There is a strong desire among all parties for the local engineering workforce to be as heavily engaged in FLNG as possible.
- There is a real appetite for close and meaningful collaboration among all parties: for operators to work together across project boundaries to rationalise and optimise the sharing of information; for engineering companies to collaborate in supporting the operations of the facilities; and for academia to collaborate on impactful research.
- With Western Australia being the first location for the deployment at scale of FLNG, the state has the opportunity to establish itself as a centre of knowledge and excellence in the operations and maintenance of the technology. If properly managed, these skills could then be marketed to organisations deploying FLNG into other regions of the world.

Leveraging the opportunities offered by FLNG will not be straightforward. However, there is work to be done to ensure this once in a decade opportunity is grasped fully. The collaboration opportunities need to be explored, developed, fostered and supported by all parties. Organisations need to be given opportunities by operators to fill some knowledge gaps and enable them to offer the best services possible to the operators. Engineering companies need to be honest and open about their actual skills but also prepared to invest in developing the skills needed, and academia needs to produce both graduates and research that is relevant, wherever possible.

If these hurdles can be overcome, it is considered that Western Australian engineering will be able to position itself to grow with the adoption of FLNG, including key world class R&D niche areas and responses to local challenges such as metocean conditions and remote operations. If these opportunities are not grasped, however, the window of opportunity will close and the centre for knowledge of the technology would move elsewhere. Already, Singapore is providing $5m to its national university for FLNG and seeking to become the regional centre more broadly.

2. Acknowledgements

Engineers Australia would like to acknowledge the following organisations whose work has contributed directly or indirectly to this report:

- The operators, engineering companies, academic and research institutions, industry bodies and individuals who participated in the workshops and/or provided individual input during the preparation process.
- The Economics and Industry Standing Committee of the Western Australian Parliament for its work in producing the report “The economic impact of floating LNG on Western Australia”.

3. Introduction

3.1 Discussion process

To prepare this report, the Western Australia division of Engineers Australia initiated and chaired a series of meetings to solicit the views and perceptions of as many organisations involved in the lifecycle of FLNG as possible. Meetings were held with:

- a number of operators of potential facilities;
- engineering companies which have a history of involvement in natural gas production and operation of LNG facilities in Western Australia;
- tertiary education providers, both at the university and vocational training level;
- research bodies which have been involved in developing and researching offshore technologies, working with operators and engineering companies to better understand current and future challenges and proposing potential solutions, and
- industry representative bodies.

The first meetings were held with the operators of potential FLNG facilities to understand their needs, both current, imminent and future, their perceptions of the capability of the current domestic engineering workforce to support and supply their needs and to identify the perceived gaps between what they need and what could be available. Following the meetings with operators, a meeting was held with the engineering organisations. At this meeting the data collected from the operators was shared and discussed, along with soliciting the views of the engineering companies as to what they believe they could offer and how they would like to see the industry evolve to support FLNG.

A final meeting was held between the operators, engineering companies, tertiary institutions, research bodies and industry bodies to gather a holistic group view of the needs and opportunities and to arrive at some commonly held views and desires for the future.

All meetings were held in confidence (Chatham House rules) and as such individuals and organisations will remain anonymous in this report.

3.2 Background

Gas production, and the export of Liquefied Natural Gas (LNG) has been a major part of the Western Australian, and indeed the Australian economy for decades. Production started with small onshore production facilities and rapidly moved into the offshore world. Western Australia has had the benefits of onshore processing of offshore gas from the North West Shelf at Karratha for around 25 years, with the recent addition of the Pluto facility and the impending production from both Gorgon and Wheatstone (and the Ichthys project pipeline to Darwin). The next generation of exploitable gas reserves, which are being found further offshore in increasingly deep water, are also very remote from current onshore processing facilities, making commercial development of the reserves more complex.

In parallel with the new fields being more remote, technology involved in production of LNG has been developed that will allow the entire production train for processing of natural gas into LNG to be performed offshore, this production will be performed on purpose built floating facilities known as FLNG. The first such facility to be planned for production in Western Australian waters is Shell's Prelude facility which is due to start operation in 2017.

Prelude is likely to be the first such facility, but with the opportunity for a number of other similar facilities in the future it is appropriate to consider:

- how the lifecycle of a FLNG facility could be supported by the Western Australian engineering workforce;
- what the advent of such facilities will mean to the current work opportunities;
- where new opportunities may present themselves, and
- what the local engineering workforce can and should do to best position themselves for the arrival of the facility;

It was against this background:

- of the definite arrival of FLNG into Western Australia;
- uncertainty about the level of opportunities that may be available to the local engineering workforce following the arrival of FLNG;
- the rapidly changing engineering landscape from the resultant offshoring of much of the technically demanding engineering design associated with the development of FLNG (and LNG generally), and
- the knowledge that there were a number of different initiatives under way or being planned to prepare for the arrival of FLNG;

that the Western Australian division of Engineers Australia decided to prepare this report.

Changing environment

Western Australia has a history stretching back around 25 years of production of LNG, running from the development of Woodside's first production train at the Karratha gas plant which shipped its first cargo in 1989 through the development of subsequent trains at Karratha, the Pluto facility and the facilities under construction at Wheatstone and Gorgon. Each of these onshore processing facilities is fed by offshore natural gas. As a result of a combination of the discoveries of natural gas being located further offshore, the increasing costs of new onshore developments and the evolution of new technologies, operators are looking increasingly toward offshore processing of natural gas to LNG (via FLNG) facilities.

While there are currently no FLNG facilities operating in Australian waters, the first such facility, Shell's Prelude, is under construction in Korea with an anticipated arrival in the Browse Basin off Western Australia's Kimberly coast and production in 2017. It is possible that the Prelude facility will be joined in coming years by Woodside's proposed multiple FLNG Browse development and an Exxon-Mobil/BHP Billiton FLNG in the Scarborough field, giving a total of five possible facilities currently under consideration, with the potential for others in future years.

The current fleet of FLNG's is being designed and constructed outside of Australia with, for example, Prelude designed by Technip and built by Samsung, resulting in a loss of potential design engineering and construction jobs to the Australian labour market and a lost opportunity for the Australian workforce to learn the fundamentals of the design and construction of these facilities. However, once the facilities are operating off Australia, there are many opportunities for local engineering engagement over the facility lifecycles.

Recent onshore LNG trains such as Train Five of the Karratha gas plant, Pluto, Gorgon and Wheatstone have been largely designed in modular form overseas. The move to design and fabricate the process plant overseas has been driven by a combination of factors. On the design side, the companies which have been awarded the engineering work and which hold the technology licenses, have their design centres located internationally in locations such as London, Paris and Yokohama, from where they have designed similar plants for other parts of the world such as Qatar, giving them a stable workload and the ability to establish and maintain a core skill set. Another factor against the work being performed in Australia has been the relatively high cost and low quantities of skilled and LNG-experienced Australian engineering personnel.

Fabrication of the large modules has also gravitated to lower cost yards located in the Asia-Pacific region where the fabrication yards have been established and developed over decades of corporate and government investment to be able to produce multiple multi-thousand tonne modules per year.

This combination of the major LNG plant design companies having their knowledge centres located outside of Australia, the subsequent lower levels of exposure of Australian engineers to the design of LNG trains, higher Australian engineering costs and smaller pool of skilled personnel makes it extremely difficult for Australia to be competitive in the greenfield design of new LNG trains. Likewise the limited number of suitable fabrication yards in Australia capable of producing modules of suitable size for a new greenfield LNG facility have also limited Australia's ability to compete.

The advent of FLNG has added a further order of magnitude to the scale of new build facilities. They are the largest floating structures ever to be constructed, with the Prelude facility for instance measuring 488m long, 74m wide and weighing over 600,000 tonnes. There is simply nowhere in Australia such a facility could be constructed. Additionally, the skills needed to design such facilities are distributed across the globe, with no single geographic location having all of the skills.

With the globalisation of engineering design, it has become difficult for single countries to claim a competitive edge over others. Instead the expertise is held by the global engineering companies who execute the design of specific forms of process plant, with these companies sharing the work around their global skill pool in a way that gives them the best commercial outcome for themselves and their clients. Despite Australia's track record in significant oil and gas facilities (e.g. Bayu Undan, Angel, NR2, Pluto offshore, ROC Oil, Apache), our relatively small local engineering skill pool has meant Australia has struggled to establish itself as a centre for large scale LNG engineering design of any forms of process plant. The local focus has been on smaller areas of overall facilities and more "commodity" forms of engineering such as infrastructure for remote facilities as required for LNG plants, gas processing plants and mine sites alike.

Boom and bust economy

Over recent decades, Australia as a whole and Western Australia specifically have experienced a number of booms and busts in the industrial engineering and heavy industry construction. The two most recent booms, running from approximately 2004/5 to 2007 and 2008/9 to 2013 have seen unprecedented demand for engineering skills across projects from Oil & Gas to mining. This has driven up project design costs, with commensurate shortages of field labour having similar effects on the costs for construction and commissioning of these plants. As the current wave of LNG projects come to their conclusion with the completion of construction over the next 2 to 3 years of Gorgon and Wheatstone in WA, Ichthys in the Northern Territory and the three LNG facilities on Curtis island in Queensland, the local oil and gas engineering workforce needs to find an alternate point of demand for their skills, or the engineering industry risks losing the skills through personnel moving to other areas of engineering, leaving the profession or leaving Australia to seek opportunities overseas.

Being a remote population centre, Perth has a relatively small locally based pool of skilled engineering personnel. Migrant workers from domestic and international sources then supplement this skill pool. Typically during the boom times this migrant workforce swells, then shrinks back as the work finishes, likewise members of the local engineering workforce will follow the work, either to other domestic locations or overseas. This small overall volume and migratory aspect to the local workforce therefore makes it hard to build depth of knowledge during the boom and bust cycles. Without a stable, balanced workload employers will not commit to long-term investment in staff development and employees will not remain with employers for the length of time needed to develop these skills. Instead, employees take responsibility for their own careers and do so by pursuing the work wherever it may be.

As the engineering industry moves out of its most recent boom phase, it is undergoing a major structural change, from greenfield projects to brownfield, from major new capital expenditure to sustaining capital where projects are measured in thousands to millions of dollars and weeks to months from the previous tens of billions of dollars and multiple years to execute. These structural changes present both challenges and opportunities for the engineering profession in Western Australia if it is able to reconfigure and position itself to make the most of them.

The arrival of FLNG is just one facet of this structural change, but it is one that is not just a local but also a global phenomenon. WA will be host to the first full scale FLNG facility which may, over the coming decade be joined by a number of additional facilities. The arrival of FLNG facilities such as Prelude in Australian waters brings with it a whole set of new opportunities and challenges for the profession. Operating and maintaining a huge and extremely complex process plant, in a tropical marine environment, subject to category 5 cyclones, located over 200km from the coastline and thousands of kilometres from major population centres will open up many areas for engineering personnel to address as they learn how to optimise the process and operate the plant over the decades of operation.

Current local strengths and opportunities

There are potentially 5 FLNG facilities to be installed off the Western Australian coastline over the next 10 or so years. As a result, Western Australia has the opportunity to become an internationally recognised centre of knowledge in the deployment, operation and maintenance of FLNG technology. Assuming each facility needs more than a few hundred locally based engineers to support operations and maintenance, the experience gained by these personnel will create a strong pool of valuable engineering skills unique to Western Australia. This opportunity is of great benefit to WA and will happen naturally. However, there is much more that could be achieved with a proactive approach to collaboration.

The operation and maintenance expenditure (Opex) over the life of an FLNG facility is anticipated to be at least as large as the initial capital cost of the facility. These FLNG facilities will therefore each need significant installation, operations and maintenance engineering support, which can be locally based if the skills and the desire is here to provide it. As the engineering expertise in these phases develops and as new facilities are considered, the local engineering workforce will be ideally positioned to assist in future design work (whether carried out in Western Australia or internationally). The opportunity to participate in the development of these unique FLNG operations will provide substantial career opportunities for both early career and experienced engineering and operations personnel.

With its history of offshore exploration and operation and its long history of LNG production, Western Australia is already well positioned to support the planned developments in FLNG in WA and beyond. WA already offers:

- 25 years of LNG experience locally;
- Extensive fixed and floating oil and gas experience (design and operation) based locally, both greenfield and brownfield;
- local engineering capability (that has been attracted to WA and built by recent mining and oil and gas projects);
- Extensive knowledge of the local regulatory and environmental requirements;
- Strong database of the metocean and geotechnical conditions;
- Strong understanding of the Australian Standards;
- Strong local understanding of the interface between subsea and topsides development;
- Information technology, collaborative work environments;
- Pleasant and geopolitically stable local environment;
- Attractive location to recruit personnel;
- Strong links between operators, engineering and academia, and
- Extensive operating and brownfield experience in LNG and in offshore operation.

There will be some areas of expertise that either require local knowledge or niche expertise where the skills or knowledge may not be as strong as desired. Some may include:

- Anchoring system design specific to FLNG challenges;
- Corrosion and asset management;
- Remote Operations, and
- Metocean data and analysis.

However, gaps such as these are, in many cases, already being addressed by the work of both local research facilities such as the Centre for Offshore Foundation Systems (COFS) and by research being undertaken locally and internationally by engineering and equipment supply companies, many of whom have existing offices in Western Australia.

Specialist (rather than generalist) skills are also likely to be needed. Examples may include:

- Mooring systems for FLNG;
- Naval architecture;
- Corrosion protection for such large stationary marine facilities;
- Asset Integrity specific to large floating production facilities;
- Locally based procurement;
- Advanced materials (possibly a skills gap in WA but available in Australia);
- Extreme weather event prediction (globally immature technology), and
- Supply Chain / Logistics;

As FLNG begins to be deployed into Western Australian waters some of these potential knowledge gaps may prove to be already filled and new, previously unconsidered requirements are likely to appear. However, on balance it is believed that most of the skills are either available in WA now or capable of being rapidly developed by local personnel once the physical assets are here to be learnt from.

Some areas of potential opportunity include:

- Insurance costs, financing constraints and the need for certainty of production typically leads to a conservative and potentially expensive design approach. There may be opportunities to further develop some niche technology solutions to prove them for use on FLNG facilities.
- Most of the current tranche of design is to be performed outside Australia. Non-local design companies will typically specify equipment types that they are familiar with and this may further reduce the likelihood of selecting locally manufactured equipment items. There may be opportunities to input to approved vendor lists that increase the opportunity for local content and encourage the sharing of spares between Operators. However, this is a task that would be outside the remit of this initiative.
- Some of the technologies that will be developed in the FLNG industry will be able to be applied in the general oil and gas and LNG industry to assist with monetising associated gas and smaller fields. FLNG will "miniaturise" some technology that will then be available to smaller onshore fields.
- The Centre for Offshore Foundation Systems is a successful model that has brought together university research skills (through access to PhD students and research capability), Operators (such as Woodside) and private industry (Advanced Geomechanics). It was initiated out of the need to solve a problem (rather than capitalise on an opportunity such as FLNG). However, many of the principles may apply to creating either a physical or virtual Centre of Excellence for FLNG.

3.3 Current research initiatives

Presently, there are a number of research initiatives being pursued by various entities in the engineering space aimed at preparing for the arrival of FLNG. These bodies include the Western Australian Energy Research Alliance (WA:ERA), the UWA Centre for Offshore Foundation Systems (COFS), and the CSIRO. There are further relevant research projects and courses such as Curtin University's recently established Master of subsea engineering, which is one of only six such courses offered worldwide.

- **WA:ERA** — An unincorporated joint venture established in September 2003 between CSIRO and academic partners, The University of Western Australia and Curtin University. Core industry partners are Woodside and Chevron and there is increasing collaboration with Shell. WA:ERA has a mission of fostering collaboration and resourcing for petroleum and geosequestration related research that provides innovative, safe and sustainable solutions.
- **COFS** — Located within UWA, COFS carries out fundamental and applied research at an internationally recognised standard of excellence in the areas of the mechanics of seabed sediments, offshore foundation systems, pipeline and deep water offshore engineering and geohazards, and uses its expertise to service the offshore petroleum industry at a national and international level. This centre is internationally recognised as expert in difficult subsea geomechanics such as WA's North West Shelf calcareous soils.
- **Floating LNG training centre** — located at the Australian Centre for Energy Process Training (ACEPT) facilities at Henderson to provide training to operators for Shell's Prelude facility and the potential to provide training for future FLNG facilities based on experiences from assisting Shell.
- **Global Centre for Floating Liquefied Natural Gas (FLNG) Learning and Research** — Established in 2011 between Shell, Curtin University, Challenger Institute of Technology with its ACEPT facility and with funding from the WA and federal government

Each of these initiatives or groups will provide benefits to their participants and give some opportunities to those involved. However, by working closely together they may well deliver a much greater overall benefit to the Western Australian engineering profession as a fully coordinated and planned suite of initiatives. For instance, while Shell and Woodside as two of the major FLNG players are involved, other potential FLNG operators are not part of the alliances. Likewise, the University of Western Australia (UWA), Curtin University and Challenger Institute are involved but other universities such as Murdoch and Edith Cowan University (ECU) and Charles Darwin University (CDU) are not, potentially leaving some opportunities for greater synergy unexplored.

Led by UWA, since 2013 WA:ERA has been developing a new Floating Systems Centre (FSC) to leverage Australia and WA's first mover advantage in FLNG and associated subsea systems. However, there has been no State Government financial support and funding promised by the former Federal Government was withdrawn and not proceeded with in the May 2014 Budget. In scoping the FSC, WA:ERA found broad industry support but without funding, the FSC can only commence in a modest manner through initial engagement and project funding through Woodside and Shell.

4. Vision for the future

Through holding the series of workshops with operators, engineering companies, academia and other industry bodies, Engineers Australia was able to solicit the views and beliefs held by industry as to where the future opportunities exist in the development of FLNG in Western Australia, these can be described as a series of themes.

- Firstly, these is a strong desire from all parties for the Western Australian industry to participate as fully as possible in the development of FLNG as not just a local technology but as a world wide step change in the way LNG is produced.
- Secondly, that there should be as deep a level of collaboration between entities as possible to ensure the arrival, deployment, start up and operation and eventual abandonment of FLNG facilities in Western Australian waters is as efficient, safe and productive as possible.
- Thirdly, that there is a strong existing capability in Western Australia, spread across both engineering and research, with experience in Oil & Gas and strong experience in designing and operating facilities in Western Australian waters, and that while this skill pool may need some strengthening in specific areas to support FLNG, it is in place and proven.

Historically there is a strong history of operators collaborating in fields where they all have equity stakes; a strong example of this is the North West Shelf Venture (http://www.nwsg.com.au) where multiple operators have collaborated for around 25 years in the successful development and operation of the facility. Collaboration between facilities is less common and where it occurs is more tightly controlled, yet there are many ways that more open collaboration could bring substantial benefits in both knowledge and savings to all involved. Likewise, it is very common for engineering companies to partner in the tendering and execution of major developments, though outside of such partnerships collaboration gives way to competition. Equally, universities frequently collaborate on some research undertakings such as the collaboration in WA:ERA (that includes the CSIRO) discussed earlier in this report. However, many of these collaborations, like those of operators and engineering companies are limited to the participants in a specific agreement. As will be discussed further below, it was felt that a greater level of collaboration for all parties could be of great benefit.

The second theme to emerge was associated with Western Australia's likely involvement in supporting the life cycle of FLNG facilities. There was a general agreement that the first "wave" of FLNG, commencing with the Prelude facility and including many of the potential facilities currently being considered for development are unlikely to be designed in Western Australia and that aside from some specific and specialised equipment, the supply of the facilities is unlikely to be undertaken domestically, this view was driven by a number of factors:

- Western Australia is not presently a significant design centre for either LNG or large floating facilities. Such centres are currently located around the headquarters of a number of major engineering companies in major cities such as Paris, London, Houston and Yokohama.
- Western Australia specifically, and Australia as a whole, does not have shipyard and dock facilities capable of the construction of a FLNG facility up to the size of Prelude. Only a few such facilities exist and they are all located in Korea and China.

Thirdly, there was a belief that the current local workforce is capable of supplying virtually all of the skills needed to support the commissioning, operation, modification and eventual abandonment of these facilities using:

- currently available skills;
- supplemented where necessary by either the development of new skills not readily available worldwide;
- educating the current local workforce in skills not presently available in WA, and
- importing some skilled specialists where needed to fill gaps.

As the local workforce develops their knowledge of the operation of FLNG, it is believed by all parties that these skills will then become increasingly in demand for FLNG in other parts of the world and as such, WA has the opportunity to become regarded as a knowledge centre for the operation of FLNG. This opportunity will only present itself for the time that FLNG is new on the world stage. However, as the technology is deployed in other countries there is a chance that the opportunity will be lost if it is not fully embraced in WA.

FLNG will have the potential to bring real benefit to WA and Australia.

- Government (both state and federal) will directly benefit from:
  - Export revenues derived from the sale of the LNG produced;
  - New globally valued engineering expertise will be developed in Australia;
  - Further development of the North West of WA and the Northern Territory;
  - Increased productivity as the new technology is fully understood, and
  - Attracting foreign students to the universities who are participating in the research involved with FLNG facilities to learn skills that can then be taken back to their home countries.

The engineering community will benefit from:

- Interesting and challenging career opportunities, at home. However many facilities are eventually deployed along with opportunities to be part of developments for outer regions.
- Universities and the CSIRO will be able to play a strong research based and educational role.
- Vocational training centres will benefit from the opportunity to train operators and maintenance personnel to support these new facilities, and could potentially be in a position to provide this training to the global FLNG workforce, not just the domestic one.

Some additional opportunities were also considered, such as metocean, corrosion, remote operations, asset management and the management of data produced by these facilities. The FLNG industry will produce a massive amount of data and much of this data will require various forms of analysis to be able to optimise the operations of the facilities. Western Australia has access to the computing power at the Pawsey Centre. There may be opportunities to use the Pawsey Centre's capability to assist with processing of this data (so called "big data"). Infrastructure such as the Pawsey centre, which is already in place, could also be emphasized to help to attract other operators to Western Australia.

At the meetings, current local strengths and gaps were discussed, these are outlined in Appendix A.

5. Hurdles to overcome

Establishing a truly collaborative environment in industry in general and in the emerging FLNG sector specifically will not be without its challenges. For various commercial and legal reasons, many involved parties have histories of going alone and developing similar solutions to problems rather than pooling their resources and developing common solutions. However, any additional collaboration beyond that currently occurring was felt to be an opportunity to improve the overall productivity and capability of industry. As such, the following areas deserve strong consideration.

There has been a strong willingness to share safety initiatives. However, there has been an historic lack of willingness to share in other areas (e.g. shared operating practices, shared insurance spares, shared marine or aviation logistics support, etc.).

Providing appropriate incentives to academia such that their research is industry focussed, wherever possible, and the results are made available to all parties was seen as a hurdle, as was competition for funding amongst the universities.

Any engineering research facility should run in parallel to the WA Centre for Offshore Foundation Systems and the associated proposed WA:ERA Floating Systems Centre and not be in competition with it. The feeling in the meeting was that the current research initiatives are working well and any new FLNG research should not interfere with what is already in place but should be complementary.

Some questions to be answered remain around how IP would be managed between operators, between engineering houses and within the research community. The issue of IP and confidentiality and commercial advantage is a real one for many participants. The representatives from the engineering organisations noted that there are often strong restrictions placed on them by operators regarding confidentiality and IP, which add to the overall complexity of the issue.

Cost increases in recent years for performing engineering in Australia have been driven by a combination of the resources boom's upward pressure on wages and the shifting exchange rate between the Australian and US dollar. These have had the effect of making Australian

engineering appear more expensive, particularly in US$ terms, which is the industry norm for costing, than other parts of the world where work has been scarcer and exchange rates have remained more stable. While the effect of these cost changes is acknowledged, they are felt to be somewhat transient and largely outside of the control of both the projects and the engineering profession.

The relatively high cost of living in Perth, the complexity and changes to working visas and the activity in other attractive markets such as London and Paris makes attracting technical specialists to Perth challenging.

6. What would we like from each of the main stakeholders?

Operators

- Define the areas of technology and process areas that are available for local engineering participation, and those that are not, due to issues such as ownership of technology;
- More clearly define what opportunities exist for the local engineering sector and where possible quantify them (or work with the engineering sector to quantify them). The engineering sector can better supply a service if the future need is more clearly defined;
- Continue to support and collaborate strongly with local universities and research bodies, and
- Develop deeper levels of collaboration with other operators in WA, the NT and the Asia-Pacific region.

Governments

- Encourage Operators to buy locally and support R&D capability building and impactful industry-relevant R&D projects;
- Provide financial support, potentially in the form of a grant, to help utilise and develop the engineering and research capability that is available in WA to the FLNG Operators and more widely;
- Support in marketing the engineering capability in Western Australia. This could be undertaken through the efforts of organisations such as Austrade at international trade events;
- Financial and tax incentives for organisations undertaking R&D and development of technologies, and
- Continue the drive to reduce the complexity of red and green tape.

Researchers and Higher Education

- Collaborate with Operators to address key challenges with expertise of a world class standard;
- Work with industry to translate academic research into "industry speak" and produce industry relevant outcomes;
- Find ways to share the research that is being done as broadly as possible with industry, and
- Produce industry relevant graduates and post-graduates.

Engineering Houses

- Increase engagement with academia;
- Initiate research projects with local academic institutions;
- Be honest about real capability;
- Market their local capabilities better, both locally and internationally, and
- Proactively develop new capability of relevance to FLNG.

Engineers Australia

- Engineers Australia, as an independent body, should facilitate ongoing interaction between operators, government, engineering, academia and other research bodies and industry bodies relevant to the development of FLNG in Western Australia.

7. Recommendations

1. That all operators of FLNG in Australian waters, regardless of the state or territory in which they may be based (WA and NT), collaborate as openly as possible in the sharing of knowledge, facilities and experience.
2. That the industry as a whole works to identify deficiencies and opportunities in the current skills pool and to find ways to fill those gaps through development of local personnel, through focussed education and where necessary through targeted importation of skills.
3. That a regular (annual) researcher and industry conference be held to allow academia to showcase research to industry and industry to advise researchers of their current needs. That the conference be mindful of competition such as from Singapore, Norway and Scotland but be open to organisations wishing to attend.
4. That Industry, in the form of both operators and engineering companies contribute both financially and in kind (for example through the provision of time for personnel) to support the coordination efforts of Engineers Australia.
5. That the Federal and WA State governments provide grants, tax incentives and marketing support to stimulate the involvement and growth of the Western Australian engineering sector in FLNG.
6. That methods are found to include all Western Australian universities in the research work being undertaken around FLNG. This could be by specific activities that leverage the skills of each university or by groups such as WA:ERA (or the new Floating Systems Centre) expanding to potentially include CDU, Murdoch and ECU.

Appendix A

Areas of potential cooperation

Throughout the meetings, various ideas were raised where the operators felt there were opportunities for them to work more closely together (and with the other industry partners) to develop capability, conduct research or test ideas to help improve the capability of the industry as a whole. This will help to build the engineering capability within the FLNG industry in WA.

Ideas included:

- Building shared met-ocean capability – Operators such as Woodside have strong met-ocean capabilities and experience from years of offshore work in WA waters whereas new entrants such as Shell do not have this strength locally. Collaborating on the development of ongoing knowledge in this area could be beneficial to all parties.
- Building Naval Architecture capability – naval architecture skills were felt to be somewhat lacking in WA in general. There are a few consultancies offering naval architecture services and each of the operators and some large consultancies also have capability in this area. However, there is little in the way of naval architecture taught in WA universities so the skills must be imported from interstate universities (e.g. Australian Maritime College, in Tasmania) and overseas.
- Building Flow Assurance capability
  - There was a common feeling that current designs are leaning toward traditional solutions such as a heavy reliance on the use of mono ethylene glycol (MEG).
  - The offshore production industry in WA places a significant demand on global MEG supply. This reliance poses a risk to operations should supply of MEG be interrupted through changes of global demand or manufacturing issues.
  - There may be significant benefits in exploring alternative treatment solutions in place of reliance on MEG e.g. electrically based solutions using surplus on-board power.
  - There is a contrasting view held by some of the engineering organisations that there is quite a strong pool of flow assurance engineers available in WA. This skill pool may need to be more strongly marketed or enhanced to offer the services expected by clients.
- Operations
  - Reliability modelling and engineering was felt to be a collaboration opportunity. With FLNG being new technology there is a need for end to end reliability modelling of the whole production chain from reservoir to facility, and some of this data could be shared between operators to improve productivity. (Note, it is recognised that there will be proprietary technology in each FLNG facility that cannot be shared in modelling of any kind).
  - Process optimisation through building comprehensive computer models of the entire production chain from reservoir to export.
  - Development of operations and maintenance documentation, potentially creating a shared data set of generic operations and maintenance documentation that can be used as the basis for any new project in WA or elsewhere. It was felt that, while each facility will be different in a number of ways, there will equally be a large degree of commonality, and if template operating manuals captured 50 to 70 percent of a facility that would represent a huge saving for each subsequent operator.
  - Shared training of operations and maintenance personnel (e.g. permitry, operator training, maintenance training, etc.)
  - Shared generic inductions.
  - Development of an “Operations Tool Kit” of common practices and knowledge to benefit all operators.
  - On the same basis as “design one, build many” comes “operate one, operate many.”
  - A central operating facility where, potentially, multiple operators could gather in a campus like environment to house the remote operational support for their facilities. Such a facility, should it be deemed possible, would allow for deeper sharing of experience and coordination of activities such as safety exercises and extreme weather event responses.
  - A physical asset to use for carrying out testing of FLNG concepts.

- Predictive weather forecasting and sharing of knowledge and experience.
- Marine operations simulation and training (e.g. dual body motion, berthing and decoupling).
- Shared safety engineering
  - Explosion exceedence modelling and the associated layout development to safely place a LNG train onto a space constrained hull.
  - Operational safety case development and studies (e.g. a framework could be developed that could be shared with subsequent developments streamlining the development of such documents and allowing the lessons learnt from earlier facilities to be incorporated in future facilities).
- Maintenance engineering
  - A different maintenance philosophy is required for FLNG as opposed to onshore, with equipment selected and designed to be maintained without major campaigns. As such, experiences gained during maintenance of facilities could and should be shared to assist the overall industry.
  - The possibility to hold shared insurance spares should be explored such that large common items could be held centrally or as a minimum operators could be aware of the spares held by others in case of major equipment failures.
  - Shared maintenance philosophy development.
- Simulation
  - Real time simulation (such as could be potentially made available to operations engineers on an Ipad) to allow process optimisation and modelling in situ and enable on board operations and maintenance personnel to more readily optimise the facility.
  - Shared simulators where feasible.
- Shared research

Additional research could also be performed and shared in the areas of personnel support and management; potential areas for such work are;

  - The effect of various shift patterns and rotations employed on these new FLNG facilities to provide the optimum worker well being.
  - Research into the technology used to support remote offshore operations and how such technology could benefit FLNG.
  - Ongoing research into collaboration between virtual teams formed by offshore and onshore based personnel.
- Remote operations – opportunities to learn from the experiences of current offshore operators such as Woodside and onshore operations of BHP, Rio Tinto etc.
- A coordinated emergency response program including sharing procedures, knowledge, facilities and resources for de-manning during cyclones — it is possible for instance that de-manning could be staged via adjacent facilities or helicopter flights and capacity could be shared between operations.
- Corrosion protection
- Shutdown and maintenance planning
- Subsea technology
- Control Systems (onshore monitoring)
- Shared supply bases and shared logistics support
- Sharing of marine resources and in particular “spreads”
- Shared helicopter operation
- Shared marine facilities (e.g. tug boats and tug boat pens)
- Shared research and resources between the universities

A number of major equipment suppliers have established centres in Western Australia to support their current installed base of equipment, as these organisations become directly involved in FLNG it is logical that their support for the FLNG technology will also be undertaken in Western Australia, a sample of such organisations are:

- GE – Turbines – have a large supply and maintenance facility located at Jandakot;
- FMC – FMC are supplying arm loaders to the Prelude facility and have a strong local presence;
- Turrets – It is unlikely that turrets will be fabricated here due to the size; however, the supply companies may at some stage establish support facilities in Western Australia;
- LNG pumps, and
- Subsea equipment manufacturers – FMC, Aker etc.

Commissioning and handover to Operations (including operator training) will be an important part of each project. Some Operators are considering sending their operations personnel to Korea for training and to participate in commissioning on a FIFO rotation similar

to the rotation they will be part of during operations. This is a hugely expensive undertaking. With the large number of facilities potentially to be commissioned for WA, there may be an opportunity to set up a near shore commissioning and training facility in WA that can provide gas for live commissioning and lead to considerable cost savings. This facility could be used by various Operators as needed. In future this could be linked to a WA based facility for training of FLNG operations personnel from around the world (similar to the Challenger TAFE facility that is potentially space constrained). Cooperation between the Operators may allow operations personnel to be trained or at least gain on-site experience on another Operator's existing facility before taking charge of their own facility.

Qualification programs for hardware may provide an opportunity. Joint Industry Projects (JIPs) could be set up so that particular equipment can be qualified to suit more than one Operator. This may have the added advantage of enabling shared insurance spares if like-equipment is ultimately chosen.

It was noted that JIPs either already exist or could be set up in the areas of:

- Naval architecture
- Cyclone response
- Mooring system development
- Safety in design
- Logistics (particularly if focused on an "inter-company" perspective)

Another suggestion was that consideration be given to the units of some of the university engineering courses to focus on specific LNG/FLNG issues (such as cryogenic engineering to give industry ready graduates a more industry focussed research potential and support the growth of FLNG engineering expertise locally). Other areas may include:

- Naval architecture
- Logistics
- Safety and risk.