WE SHAPE A BETTER WORLD

Delivering successful LNG programmes

arup.com/energy
**THE LNG MARKET IS CHANGING**

Prices are being driven down - even renegotiated - and buyers are seeking shorter term, more flexible contracts. The supply market is growing at an extraordinary rate. In the last decade, the LNG supply market has doubled to 301.5 million metric tons per annum (MMPTA) and is predicted to grow by up to 46% over the next decade.

Arup’s specialist LNG team works with developers, operators, investors and buyers on a range of solutions from technical due diligence to full scale design and project delivery.

We have a strong global track record in delivering a wide range of LNG export and import terminal projects for both developers and contractors. We provide world class technical solutions to the energy market, including steel and concrete storage tanks, jetties and associated site infrastructures. We provide comprehensive solutions for every step of LNG developments.

**STORAGE SOLUTIONS FOR LNG PROJECTS ACROSS THE WORLD**

We have the skills available in-house to undertake the design of the concrete outer containment for a variety of tank design systems to all national and international codes and standards for single, double and full containment tanks including those utilising a traditional 9% Nickel steel inner container or a membrane liner. We incorporate the latest developments in code requirements and the findings of theoretical and experimental research into our methods of analysis and designs, thus delivering rational, reliable and cost-effective solutions to our clients.

- Tank design is standardised by volume based on site-specific seismic isolation
- Tanks prefabricated offshore in parallel with foundation construction
- Dedicated fabrication yard, leading to improved productivity and higher quality
- Tanks pre-commissioned offshore
- Reduced man-hours on site results in lower project costs.

**LNG TO POWER**

LNG to power is a relatively rapid way of adding significant capacity to the grid. We work with clients to provide technical and advisory services on various side programmes including small to midscale. We’ve worked on numerous commissions across Asia and the US including scoping works, detailed design and funding advisory.

**NEAR SHORE AND OFFSHORE**

Arup is experienced in evaluating FSRU for near shore and deep water environments as well as fixed onshore facilities. We have also undertaken the development of conceptual and detailed designs for offshore liquefaction facilities and FPSOs.

We have a multi-disciplinary team comprising of structural, mechanical and naval architectural experts to develop floating LNG facilities from concept to build. We have carried out feasibility and project lifecycle studies to help clients choose the right option to develop facilities.

Arup has a good working relationship with world’s leading offshore and shipyards to deliver new-built or converted floating assets to tight time schedules. Our considerable experience and skills allows us to respond to projects in developing economies to reduce time between the contract date and first gas. Our specialist LNG teams collectively assess various development stages of assets to assist a wide range of clients from developers, regulators, investors and government institutions.

**ONSORE LNG**

Onshore facilities compromise of a number of complex factors from pipelines, to storage and transportation. Our experienced global LNG team have worked on a number of innovative programmes of work for clients including small to midscale. We work with clients to deliver low risk solutions whilst being cost efficient.
Delivering LNG programmes across the supply chain

This supply chain snapshot looks at the LNG market as a whole from generating the supply to meeting the demand. We have the capabilities to support programmes of varying size with numerous skills such as infrastructure design and technical due diligence.
Supporting LNG programmes with our skills

We support clients across a range of different LNG infrastructure markets and deliver a range of technical and commercial services. We have LNG teams in the key market areas across the world and cross-share knowledge and skills to deliver programmes of various sizes for clients. Arup focuses on delivering high value, low risk cost effective solutions whether that be tank design or transaction advice.

**PROGRAMME MANAGEMENT**
We provide specialist services on a wide range of complex LNG portfolios, programmes and projects. As professional project managers, we draw on our diverse backgrounds, which include design, construction, time and cost control, to drive sustainable results that consistently save our clients time and money, and minimise risk for both their projects and reputation. This allows us to lead the project effectively, identifying the best solutions to client issues by tailoring our approach, and forging partnerships with clients to understand and achieve their aims.

**MECHANICAL ENGINEERING (MEICA)**
We have a detailed appreciation of the design elements that are needed to ensure the integrity of mechanical systems associated with LNG facilities. In particular, the containment of cryogenic liquids requires expertise in material selection, insulation system design, stress analysis and plant/piping layout. The specific issues around LNG storage tanks include the limited space available on the tank for the required equipment along with the need to route large diameter boil off gas lines and accommodate pump retrieval systems. Our experience encompasses conceptual design, detailed design and post construction operator support.

**CIVIL STRUCTURAL ENGINEERING**
Arup offers a full range of expertise for the structural design of new onshore facilities as well as maintenance and upgrade design services for existing facilities to achieve optimal operational and capital cost efficiency.

**GEOTECHNICS**
Hidden dangers in the ground are a source of risk for any construction project. We identify and understand the geotechnical hazards present in the ground, and help our clients to avoid or control the risks. Major offshore and marine project experience includes static, cyclic and seismic assessments for capacity of mud mats, suction anchors, piled, gravity and skirted foundations. Our main onshore services include ground investigations, pipeline routing, design of deep and shallow foundations, retaining structures as well as ground seismicity analysis.

**PROCESS ENGINEERING**
Our LNG specialists have the skills to assist project developers and operators in the role of owners engineer. This includes reviewing and commenting on contractor deliverables for the pre-FEED, FEED and EPC phases. We provide independent technical due diligence reviews for project developers and JV partners at certain critical project stages e.g. pre-FID reviews. Our experience allows us to provide independent lenders technical advice for the lead bank or banking consortium prior to financial close and independent review of engineering progress, construction progress, schedule risk, etc. during the execution phase.

Because of our wide range of in-house skills, Arup is able to put together integrated project teams of engineers and specialists in order to provide a complete package. We offer integrated design capability for onshore structures of all varieties including but not limited to jetties, quays, berthing and mooring structures, LNG tanks, ro-ro and ferry piers.
Supporting LNG programmes with our skills

**MARITIME**
Our specialist maritime experts bring an understanding of metocean and ship-shore interfaces to ensure berth availability could be maximised and interruptions to safe-operations are minimised. We undertake the design, review, inspection and construction management of marine facilities for LNG projects including the loading / unloading platforms, trestle structures, mooring and berthing dolphins and seawater pipelines. Beyond the product jetty, we also have experience with the wider harbourside infrastructure works. Design of the physical infrastructure will balance the demands for:

- Shipping logistics and balance between storage, send-out and shutdowns.
- Behavioural dynamics in relation to vessel response and structural integrity
- Ensuring appropriate support from ground consistent with overall structural performance
- Design for constructability using techniques and methodologies suited to local conditions, international experience and schedule constraints

**ADVANCED DIGITAL ENGINEERING**
We’re a world industry leader in the advanced analysis of offshore and onshore facilities. Our expertise has been developed from working on Arup designed new-build structures as well as performing assessments and life-extension designs on existing structures. Our experience covers steel, concrete, or hybrid fixed platforms, storage tanks and FPSOs situated in oil fields throughout the world - it includes structural, foundation and mechanical assessment. Our expertise coupled with our approach to engineering enables the most challenging of problems to be tackled, from the best method to extend the life of an ageing platform, to developing the best value solution for a structure in an earthquake prone region.

**OWNERS ENGINEER**
Our professional experts can be seamlessly integrated within the client’s Owners Team for Major Capital Projects, enabling them to manage the FEED or Execution phase of the project. Our skills allow us to:

- Review and shape the deliverables during the FEED phase to ensure that the client will be receiving a fit for purpose facility
- Review the Execution phase deliverables to ensure that the FEED intent is met
- Monitoring and evaluating the perform of the Execution phase contractor/s
- Assisting the client to make the necessary organizational changes in a timely fashion prior to handover and operation of the facilities
- Client team Commissioning Support
- Ongoing Operational Support, Troubleshooting and Debottlenecking

**BUSINESS INVESTOR ADVISORY**
By combining technical, operational and financial expertise our advisory services help clients manage risk and maximise their return on investment. Our approach is designed to integrate technical, financial, economic and commercial expertise to enable our clients to fully evaluate opportunities and assess the potential risks. Our broad range of skills enables us to seamlessly work across the full project lifecycle:

- Completing accurate, independent technical evaluations and feasibility studies
- Performing detailed engineering studies, documentation and construction phase services
- Assessing the business case for greenfield projects
- Structuring and securing appropriate financing
- Allocating risk and commercial contracts
- Identifying performance improvement opportunities.
DELIVERING SUCCESSFUL LNG PROGRAMMES

Can FSRUs live up to the hype?

With floating storage and regasification units (FSRUs) seen as part of the answer to the LNG industry’s supply-demand imbalance, we take a closer look at whether, and how, this solution can fulfil its potential.

**The Availability Factor**

FSRUs are seen as a solution for cost-effective receiving infrastructure. They’re held up as the right answer for the growing number of LNG-to-power projects that could help areas move away from more expensive and polluting fossil fuels. But diving straight into cost-effectiveness misses a vital issue: availability.

An FSRU can only deliver natural gas when it’s on station – and it can’t guarantee to be on station all the time because of the sea conditions during events such as hurricanes. If the FSRU is putting gas into a network, this is fine – there is redundancy. But what if it’s supplying an oil-fired power station that has been converted to gas and is not part of a larger grid? Can the FSRU really deliver the uptime that this requires?

**Weighing up the Costs**

Where an FSRU can deliver the uptime required, there can be cost benefits. Would there be a premium for building onshore – for example in or around a major city, or in a remote location? If there is, then an FSRU starts to look like an attractive option, even though it doesn’t necessarily eliminate challenges over issues such as permitting.

FSRUs don’t have to be built at the often-remote locations where they’ll eventually be used. They can be built offshore, benefitting from the productivity and cost savings from offsite fabrication. Build a hull cheaply, add a storage tank and vaporizers, then sail the FSRU to where it’s needed. Alternatively, well maintained used LNG carriers are also considered for converting into FSRUs, reducing capital costs and construction time.

Ultimately, the industry has got to bring down costs of getting LNG to shore for smaller-scale projects otherwise opportunities will disappear. If the roadblocks disappear, FSRUs may finally get the chance to live up to the hype.

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**Curtis Island LNG**

Client: John Holland Group

Together with John Holland Group (JHG), Arup completed the detailed design and construction phase supervision of three LNG jetties consented on Curtis Island in Gladstone, Australia. Bechtel was the common EPC contractor for the separate projects delivered for three different owner consortia (QCLNG, GLNG, APLNG).

Arup provided engineering services including marine, structural, geotechnical, MEICA and oil & gas as well as construction supervision support for each jetty. Each structure was comprised of concrete post-tensioned deck units, pipe rack modules, mooring and berthing dolphins, jetty trestle piles, loading platform, and catwalks.

As a result of having three different owners, each jetty structure contained a number of unique details which were developed to suit preferred construction methods from JHG.

In addition to the export jetty works, Arup also designed seven berths of the materials offloading facility for GLNG. This facility included berthing and mooring dolphins connected by catwalks and a tied soldier-pile wall platform suitable for modules and materials to be either rolled or lifted off delivery vessels. The facility included two berths for passengers to be transferred to/from the remote Curtis Island site.
Delivering world class LNG infrastructure

PRE-FEASIBILITY ASSESSMENTS FOR LNG IMPORT FACILITIES IN EAST ASIA

Client: World Bank

Arup undertook a technical and commercial feasibility study for the development of LNG Terminal and power station projects in the Philippines and Vietnam.
- Identified current and emerging LNG transportation, receiving, storage, and regasification approaches
- Conducted pre-feasibility analysis, including field work on two specific sites
- Assessed disaster and marine factors that influenced technical configuration, CAPEX and OPEX, and environmental impact
- Arup also provided framework for the development of the LNG industry in the Philippines and Vietnam

PRE-FEASIBILITY ASSESSMENTS FOR LNG IMPORT FACILITIES IN EAST ASIA

Client: Energy World International

Arup undertook the overall planning and development which included siting, layout and detailed design for both the export terminal in Indonesia and the import terminal in Philippines for this project.
Effective siting analysis and layout planning of the receiving terminal and power station was completed to efficiently utilise the prevailing conditions to limit the potential risks from geological, seismic and metocean environment.

PAGBILAO LNG TERMINAL, PHILIPPINES

Client: Confidential

Arup is assisting the client with the planning and development of an onshore receiving terminal and associated power station development. This involves an overall assessment of the site conditions to determine the most appropriate layout for the terminal in particular the siting for the storage tanks, jetty and regasification plant in order to make best use of the prevailing conditions and to limit the potential risks from geological, seismic and metocean environment.

DELFIN LNG, USA

Client: Fairwood Peninsula Energy Corporation

Arup was commissioned to provide project management services including development and maintaining of project schedule, budget and information management. The project management team will also work with Delfin LNG to procure engineering, environmental consulting and other required services, as well as manage the design and regulatory processes. The project includes a pipeline retrofit, subsea pipeline tie-in manifold, yoke mooring, and high-pressure gas transfer system. The project will connect with a floating liquefied natural gas (LNG) production, storage and offloading (FLSO) vessel.

PILBARA LNG OFFSHORE TANKS

Client: BHP Billiton

Arup prepared pre-feasibility concepts to advise on the feasibility and likely range of cost for locating two 150,000m³ liquefied natural gas (LNG) storage tanks offshore between Onslow and Thevenard Island as an alternative to onshore storage, which is being considered as the base case. Two studies were used as reference material for the comparative analysis: Firstly, a series of studies for storage tanks off the Gorgon LNG liquefaction project, offshore Barrow Island. Secondly, storage tank design studies on the Compass Port Regasification terminal, located in the Gulf of Mexico, 18km south of Mobile Bay, Alabama.
About Arup

Arup is an independent firm of designers, planners, engineers, consultants and technical specialists, working across every aspect of today’s built environment. Together we help our clients solve their most complex challenges – turning exciting ideas into tangible reality as we strive to find a better way and shape a better world. We are truly global. From our 84 offices worldwide more than 14,000 planners, designers, engineers and consultants deliver innovative projects around the globe.
Shaping a better world

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