

Aucerna
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The efficiency challenge of LNG production

Planning and scheduling in a global
industry coming of age



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Executive summary

Liquid Natural Gas production volume is set to hit a new global height between 2015 and 2020.

In order to be competitive, companies need to shift from bringing massive facility construction projects in on budget, to large-scale production of natural gas in a volatile price environment. In this white paper we will explore what opportunities LNG operators have for capital efficiency in one of the world's most cost-intensive industries as it comes of age.

Industry analysts, including Accenture and KPMG, have put forward integrated planning and scheduling technology as one of several high-impact methods for oil and gas companies to manage and reduce the risk of the complex and cost-intensive factors of LNG production.

KPMG, in its 2014 analysis [Major LNG projects: Navigating the New Terrain](#)¹, found that successful LNG projects worldwide were defined by their ability to deliver on drivers under their control including capital efficiency, timely project delivery and disciplined and robust processes and systems. KPMG went on to report that among the key means operators have to achieve capital efficient and timely delivery of LNG to market is comprehensive planning and scheduling.

In this analysis we will assess:

- **How does integrated planning and scheduling play a role in capital efficient LNG production?**
- **What critical impact can integrated planning and scheduling have on hitting production deadlines and targets?**
- **What have emerged as critical capabilities for integrated planning technology?**
- **What are the opportunities and challenges ahead?**

Working with global LNG producers, including QGC and energy consultants at Accenture, Aucerna has observed three capabilities of integrated planning and scheduling technology that global energy companies require to best compete:

- **Comprehensive planning model that provides accurate forecasts and plan adaptability** – ability to forecast accurately and rapidly make decisions based on what-if scenarios run on a comprehensive plan model.
- **Integrated activity scheduling** – development plan models must incorporate all of the complex factors of production and tie in the interdependencies of scheduling.
- **Company-wide visibility of continuous evolving plans** – immediate access to revised plans and schedules across corporate planning, asset planning and operations teams.

With such a significant role ahead for Australia in global LNG production, we will examine a use case where the core capabilities of the Aucerna petroleum planning technology contributes to high performance by Coal Seam Gas (CSG) to LNG producers.



Industry context

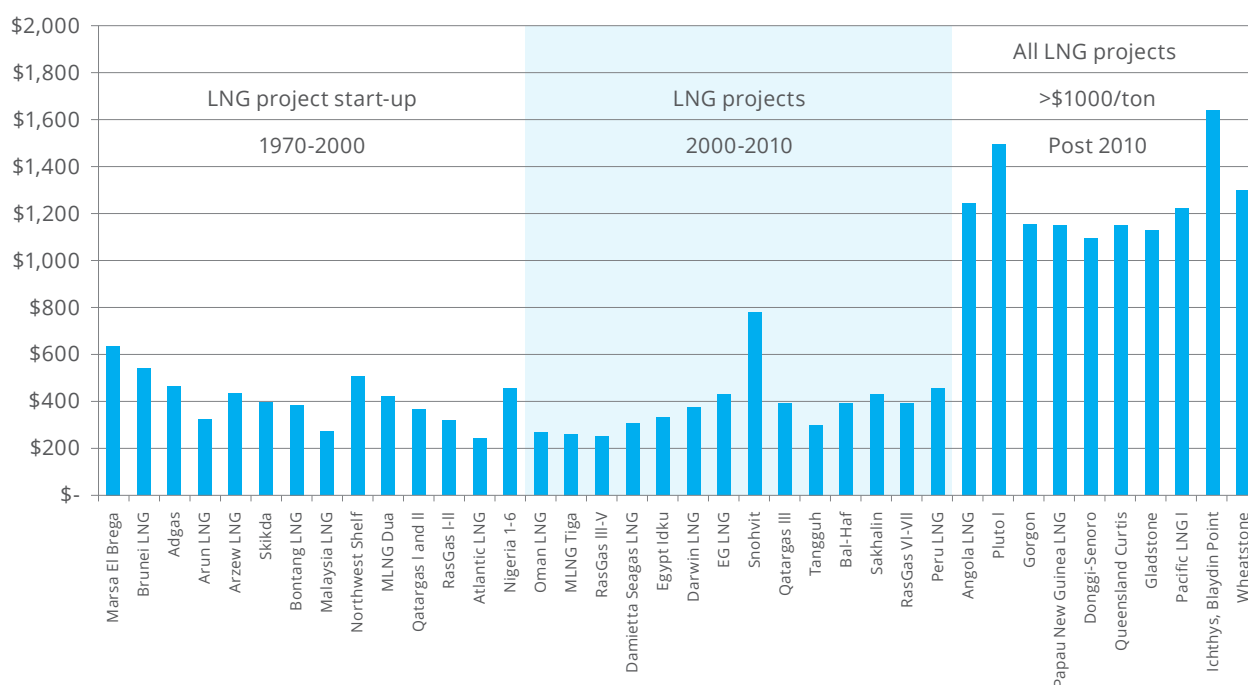
LNG reputation for high costs

The track record isn't great for the LNG industry in terms of schedule delays and cost overruns setting up global LNG plants to create the means of LNG production. Of the twelve most recent LNG projects, ten went over time

and/or budget – many by 40 to 50 percent (Deutsche Bank¹).

As the chart indicates below, the costs are also systematically rising over time.

LNG export plant cost trends



Note: CAPEX (\$/ton in 2012 dollars) of LNG Capacity Source: Apache Corp based on Public Data

LNG projects are challenged by their sheer size, increasing technical complexity, labour issues and environmental issues. Upstream supply regions have also become more complex, requiring drilling programs and infrastructure plans that have a time horizon that spans decades.

Location is another costs driver. Australia is an exceptionally high cost geography and market. During the recent construction of Australia's CSG to LNG

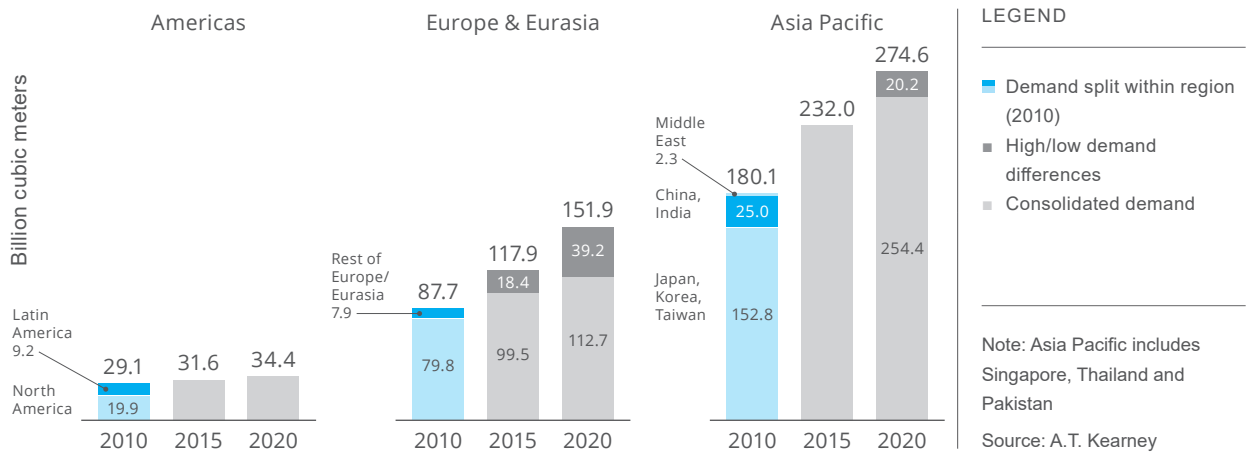
facilities, three projects were sanctioned at almost exactly the same time, creating a spike in demand for specialized labour. This was exacerbated by the coincidental boom in the mining industry on the West Coast of Australia. These two factors combined to create the perfect storm of high labour costs. Situations like these have led most Australian LNG projects to exceed their original budgets by 30%.²

Growing LNG demand & supply

With costs so high in LNG and daunting competition – why the continuing interest in getting into the high-stakes game? Because worldwide LNG demand is rising as conventional oil sources are in decline.

Ernst & Young forecasts that “Global LNG demand by 2030 could be almost double that of the estimated 2012 level of about 250 million metric tonnes.”³

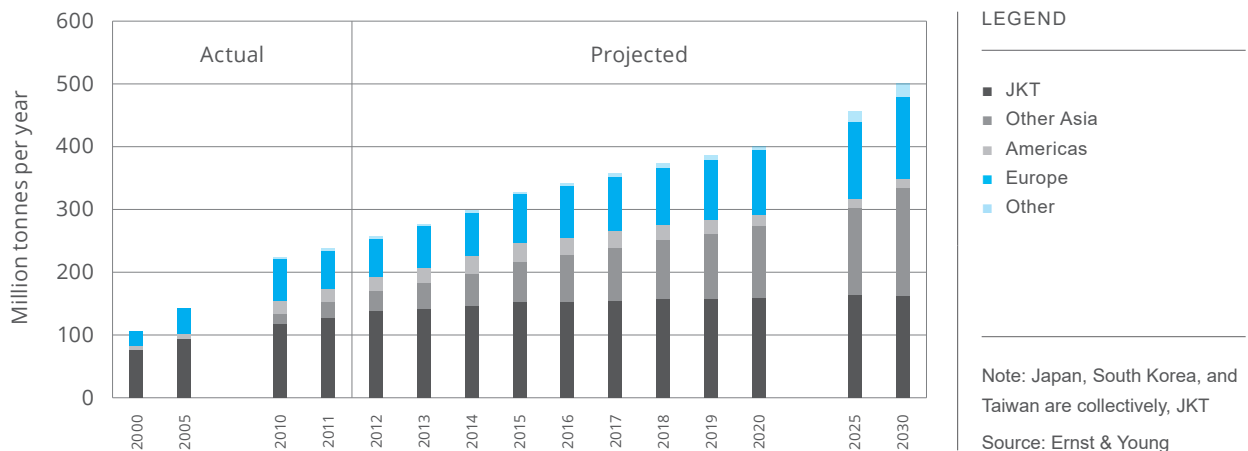
Projected LNG demand by region, through 2020



Worldwide growth in production is running parallel to increasing global demand. The first wave of LNG producers to enter the market was dominated by Asia, then Qatar and Australia dominated the second wave

and now North America is leading the third wave of new entrants to LNG production - along with dozens of other new entrants set to join in the next 10 years or more.

Global LNG production



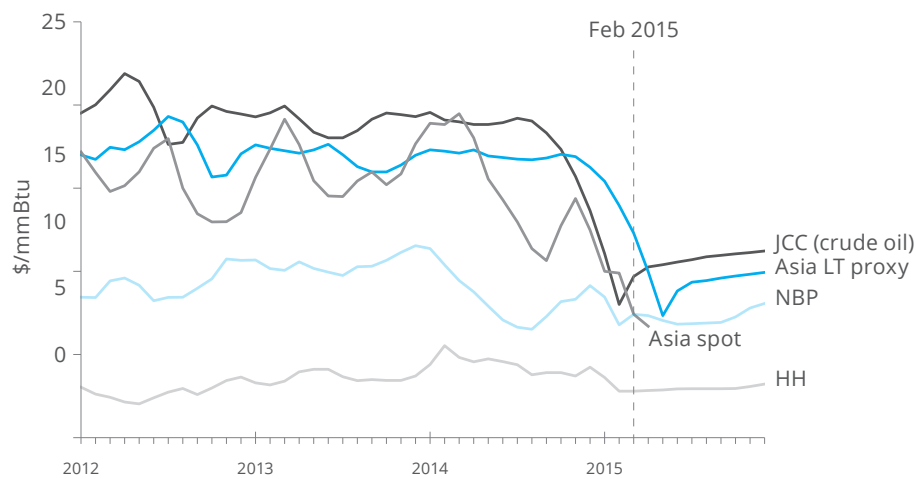
Pricing uncertainty

While customers continue to line up, there are many unanswered questions around the future of LNG pricing. Will it continue to be linked to oil pricing? Will consensus build around spot pricing? Will disparate regional gas prices converge?

LNG pricing has traditionally been fixed under long-term contracts and tied to crude pricing such as the JCC (Japan Crude Cocktail). This long term pricing meant that suppliers could lock in a rate of return on a mega project without being exposed to wild fluctuations in

the LNG price. There has been talk recently of hub based pricing, where price would be exposed to the instantaneous fluctuations of price. A number of LNG contracts have been signed on a “Henry Hub Plus” basis. Clearly the industry is a long way away from a true spot market as the size of the volume of LNG ships is considerably below the volume of crude on the seas. In addition, in the current price and cost environment, there has not been a new LNG project sanctioned in Australia since 2012.

Gas & LNG prices (2014)



Note: Asian spot prices have generally traded between crude oil (JCC) and European market price (NBP) levels. Asia long-term proxy = $14.85\%JCC (-3) + 0.50$. Long-term prices (Asian LT proxy shown) are generally indexed to crude oil, with a three-month lag. Henry Hub (HH) price is North American market.

Source: Platts, Petroleum Association of Japan and Bloomberg

The core challenge of how to produce LNG while avoiding high costs and delays is amplified against a backdrop of uncertain market prices. Worldwide, producers face increasing pressure to predict, manage and make profitable amid rising global supply.



Capex challenge as LNG production ramps up

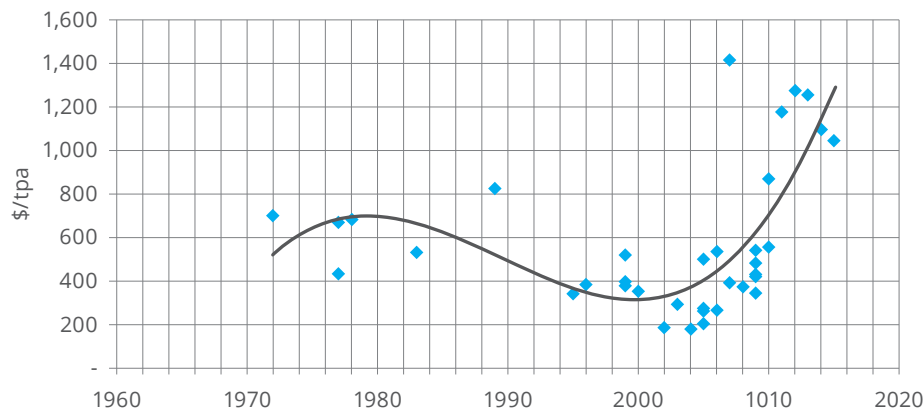
Competition ahead between LNG producers will be increasingly focused on which companies can best achieve the production they forecast with enough capital efficiency to make a capital return in the modern LNG market.

The curve in the chart below shows the trend of the LNG metric cost by year, based on data from Wood Mackenzie. The year stated is the start-up date. Liquefaction plants typically take 10 years to develop from concept to production, including 4 years for site construction.

The curve shows that the metric cost for the early plants in the period 1970-1990 averaged \$600/tpa, dropping to an average of \$400/tpa in the period 1990-2008 as the plants increased in size, reflecting economy of scale and learning by the industry.

However, from 2008 the metric cost increased dramatically to an average of \$1200/tpa for projects executed in the period 2011-2015. Over the period 2000 to 2012 this represents a 300% increase compared with an average of 100% for the upstream oil and gas industry.

Liquefaction Capex – Historical trend in 2008 dollars



Source: Wood Mackenzie

LNG operators have particularly complex operations to manage, loaded with risks to achieving forecasts. In order to deliver LNG profitably to market, producers must first:

- Discover and appraise a large and accessible natural gas field
- Plan a ten year project for the field development, plant design and cargo fleet
- Arrange financing for the 20 billion dollars in capital required
- Secure a 20-30 year contract (or contracts for the gas)
- Manage the project and schedule costs to complete it on time and on budget
- Rapidly ramp-up production to meet first gas commitment.
- Worldwide, LNG producers face the same capex challenge: How to get LNG to market amid a myriad of ever-shifting and costly production variables along a complex LNG chain?



Integrated planning and scheduling

Industry analysis of operator opportunity for LNG efficiency

With such high complexity and risk, LNG has attracted significant industry analysis on methods for oil and gas companies to manage the cost-intensive factors of LNG production.

KPMG, in its 2014 analysis Major LNG projects: Navigating the New Terrain⁴, found that successful LNG projects worldwide were defined by their ability to deliver on drivers under their control including capital efficiency, timely project delivery, and disciplined and robust processes and systems.

KPMG went on to report that comprehensive planning and scheduling is one of the key means operators have to achieve capital efficiency and timely delivery of LNG to market.

Global analysts share the perspective that integrated planning and scheduling technology has emerged as a critical means for global energy companies to compete in the price-sensitive worldwide LNG market.

Analyst perspective on integrated planning and scheduling

Accenture, in its 2015 analysis of methods to achieve high performance in unconventional operations⁵, singled out three levels of planning and the differentiating technology capabilities exhibited by the best performing

companies. They also calculated the impact of integrated planning and scheduling on an oil and gas producers' business.



Differentiating technology capabilities in three critical planning areas

1 Field-level integrated planning

Field-level planning focuses on activities such as facilities capacity analysis, production forecasting and field constraint analysis to determine the optimal well-delivery plan. The output from field-level planning is then delineated to create a more detailed well and facilities schedule.

Value chain integration

- technology incorporates all factors that can impact plans included for realistic model and scenario planning

Systematic approach

- cloud-based system for high-speed analysis integrated with data from other systems

Link with actual performance and drilling schedule

- integration with actual performance and schedule data
- easily updatable planning parameters
- easy-to-use interface for both planning and scheduling groups for frequent and consistent updates to plan

2 Integrated schedule

Well scheduling and facilities construction shifts from a high-level plan to establishing a 12-month activity schedule identifying the wells to be drilled and the activities required to progress them from geology to production. To coordinate activities across several departments, operators need to view well-level scheduling as an integration tool to facilitate quick decision-making and cross-functional collaboration.

Fully integrated well – delivery scheduling

- Integrate timing requirements for all the functional groups including pad construction, drilling, completions, well-site facilities

Intuitive and interactive

- user-friendly interface should link all the activities
- visually display inventory locations and consumption triggers provide data analytics and report on KPIs

Manufacturing approach

- Well-delivery process tools to manage rapid product delivery as an assembly line
- critical path dependencies between activities are built in

Actual performance feedback loop

- continuous cross-department reporting of actual performance data
- well scheduling results provide feedback to field-level planning to drive the right decisions

3 Integrated supply chain

Incorporating the integrated schedule, supply chain integration aligns supply chain activities such as material management and logistics, service company scheduling and coordination.

Supplier visibility to supply chain

- give suppliers a mechanism to provide feedback on the demand forecast and identify optimization opportunities

Mobility solutions for efficient scheduling and coordination

- increase visibility into the overall supply chain with mobile applications supported by cloud infrastructure that allow operators to view the status of deliveries and service equipment, as well as track material movements more accurately, reducing phone call outs and transportation costs

Source: Aucerna interpretation of Accenture analysis

Integrated planning - impact on cost and cycle time

Integrated planning can reduce cycle time and well cost and improve recovery per well through standardization, measurement, analytics and performance management. Continuous improvement extends to all aspects of the well, from origination and geological prognosis through to drilling operations and handover to production. Integrated planning also has the following effects on process and costs.

Process

- Integrated planning and scheduling across functions
- Agile, flexible scheduling that allows for 'what if' scenarios
- Efficient process management and workflows
- Analytics that support decision making and continuous improvement

Costs

- Improved capital efficiency
- Reduction in cycle time of up to 10% to 15%
- Predictable, repetitive and effective execution
- Improved communications and organizational effectiveness in the use of people, materials and oil field services

Source: Accenture analysis



Integrated planning and scheduling technology requirements

Based on more than 10 years of experience working directly with oil and gas companies on some of the most complex and capital intensive development projects worldwide, Aucerna has observed three critical capabilities of integrated planning and scheduling technology to equip global energy companies to best compete:

- **Comprehensive planning model that provides accurate forecasts and plan adaptability** – ability to forecast accurately and rapidly make decisions based on what-if scenarios run on a comprehensive plan model.

- **Integrated activity scheduling** – development plan models must incorporate all complex factors of production and tie in interdependencies of scheduling.
- **Company-wide visibility of continuous evolving plans** – immediate access to revised plans and schedules across corporate planning, asset planning and operations teams.

Given the manufacturing-style complexity and risks of LNG production, companies that possess these capabilities have certain advantage.

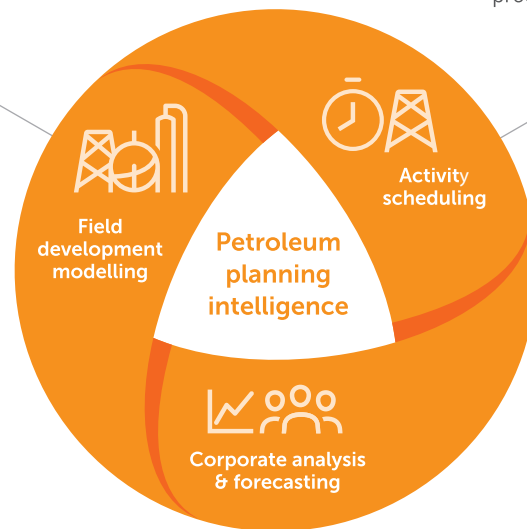
enersight™ Software—Petroleum planning intelligence for high performance decisions

Asset planners

Quickly evaluate your development options to reach asset goals

Operations teams

Integrate timing and operations constraints into plans to meet production and capital targets



Executive teams

Align asset development decisions with corporate objectives

Aucerna is the petroleum industry's most comprehensive, integrated planning software enabling upstream producers to make the most competitive and cost-effective decisions at every stage of their business. Enersight software brings together the critical capabilities of field development modeling, activity scheduling and cor-

porate analysis and forecasting to provide continuous forecasts and accurate corporate plans. Cloud-based, enersight™ petroleum planning software connects asset teams, corporate planners and operational teams all over the world.



INTEGRATED PLANNING FOR COAL SEAM GAS TO LNG IN AUSTRALIA

Australia opportunity and challenge



By 2018, Australia is positioned to be the world's largest LNG exporter.⁶ The nation already has seven LNG operations now constructed and three export facilities.

The challenge for Australia ahead becomes how to produce LNG with enough capital efficiently to realize returns on the massive investment in plant infrastructure and upstream gathering systems. To date, Australia's costs are estimated to be 40 percent greater than US LNG capex costs.⁷

Twenty-nine percent of Australia's LNG production is forecast to use conventional coal seam gas as feedstock.⁸ CSG to LNG production is an industrial process with infrastructure for compression, gas gathering and water treatment.

While conventional LNG projects are challenging already, coal seam gas LNG projects have additional operational and cost efficiency challenges:

- Relatively low production rates of the wells require large number of wells to be drilled to meet the ramp up and to continue to fill the plant into the future
- Rapid production ramp-up required to fill the LNG plant
- Production drawn from a large number of wells across huge basin areas in order to meet the deliverability requirements of multiple LNG trains
- CSG wells initially create large volumes of water resulting large water volumes to be managed
- Variable nature of CSG reservoirs - notoriously difficult to model

Aucerna integrated planning technology applied

In this case study, we will examine a coal seam to LNG development in Queensland, Australia. A typical project in Queensland supplies an LNG plant with 1.5 bcf per day from five thousand to seven thousand producing gas wells in a basin producing for more than 25 years.

We will look at how Aucerna integrated planning and scheduling technology can be applied to help most profitably develop, adapt and execute an on-target development plan.

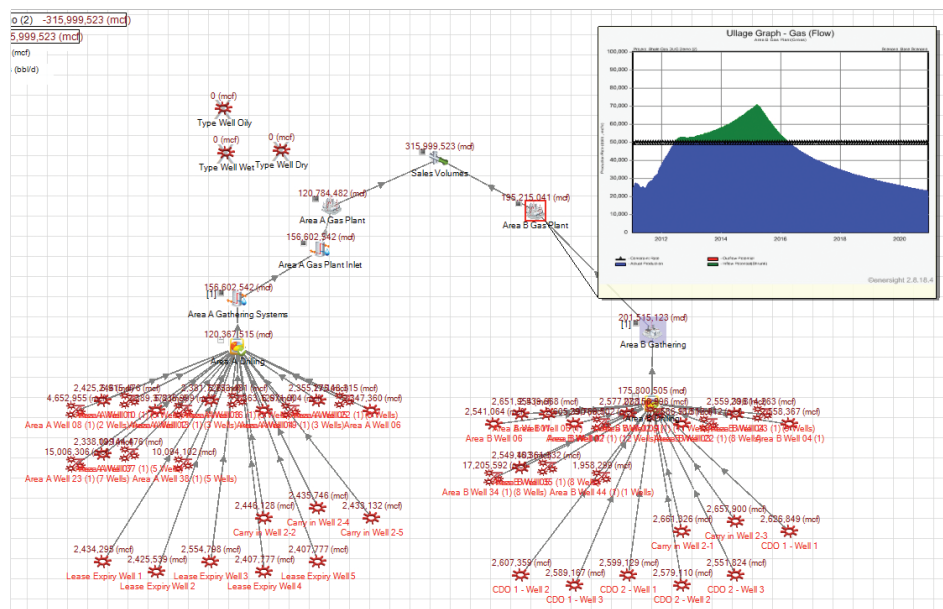
Comprehensive planning for accurate forecasts

To be reliable and achievable, the CSG to LNG corporate plan needs to factor in all of the complexity of production and capital investment. The planning model must incorporate workflows including individual well forecasts, surface flow model, constrained surface network, drilling scheduling including constraints and downtime, and economics.

modelling plus integrated activity scheduling to provide LNG producers intelligence for making good development decisions and provides continuous, accurate capital forecasting and corporate plans.

A large CSG development has multiple gathering areas feeding to field compression and a central processing facility before being sent to a large export pipeline. A typical example of this nodal network structure modelled in Enersight is shown below.

enersight™ petroleum planning software incorporates the industry's most comprehensive field development

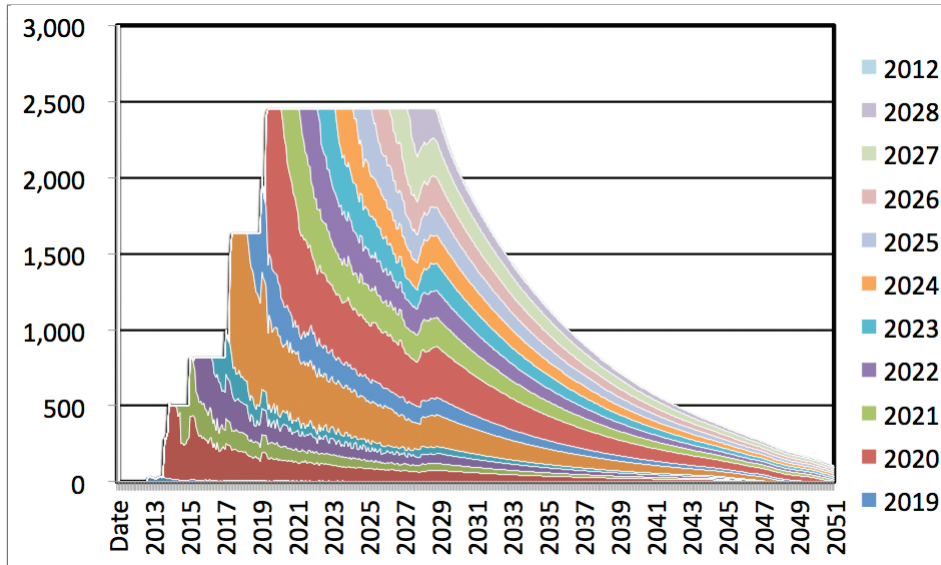


Source: enersight™ – Nodal Network Diagram showing constraints and interdependencies

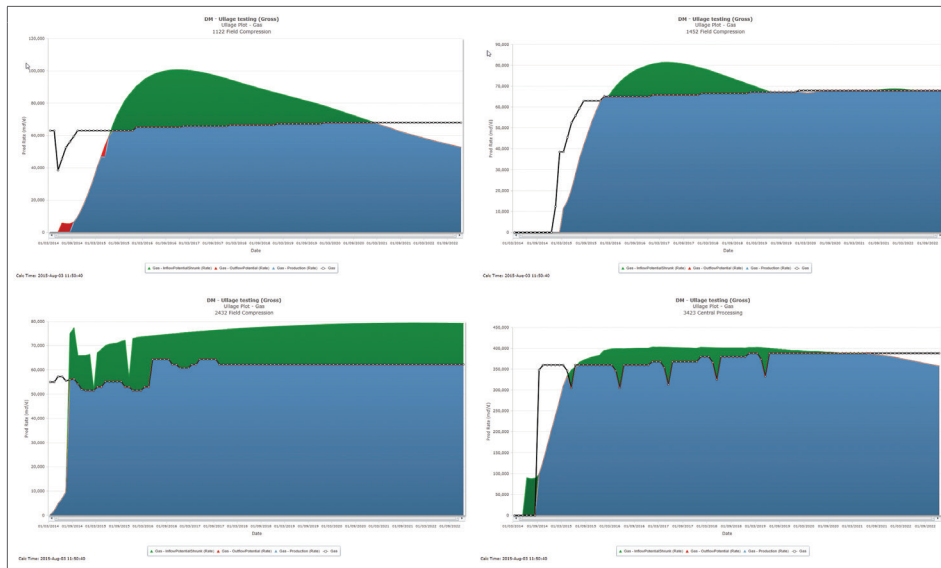
Key development planning capabilities:

- Network flow insight – see available and excess capacity by well
- Forecast dewatering phases and correlating gas production over phases
- Analyze well phasing, facility timing, capacity utilization
- Import production forecasts type curves and reservoir simulations.





One of the key results from the model is the ability to see the available as well as the excess capacity of every facility in the flow network. The vehicle to illustrate this in the model is the ullage graphs.



The enersight™ development planning model can be used to run multiple realisations of a project in order to establish the development schedule, size the gas and water facilities and pipelines as well as test value drivers for the project.

Plan adaptability

In addition to accurate corporate planning, capital efficient LNG production requires ongoing, intelligent decisions on how to best realize the project as development factors shift including schedule, water and pipeline facility capacity and value drivers such as fluctuating global pricing.

With the corporate plan in place, enersight™ allows producers to perform what-if analysis, such as pricing or timing, and to evaluate specific investment decisions, such as expanding facility capacity. What-if scenarios can be run within a few hours to evaluate new plans and make the best use of capital.

Integrated activity scheduling

In order to achieve the steep ramp up profile required for the LNG plant, it is necessary to drill hundreds of wells per year, then de-water and produce those wells into the plant. The LNG drilling schedule is complex yet must be simple to update and integrate into forecasts and estimates.

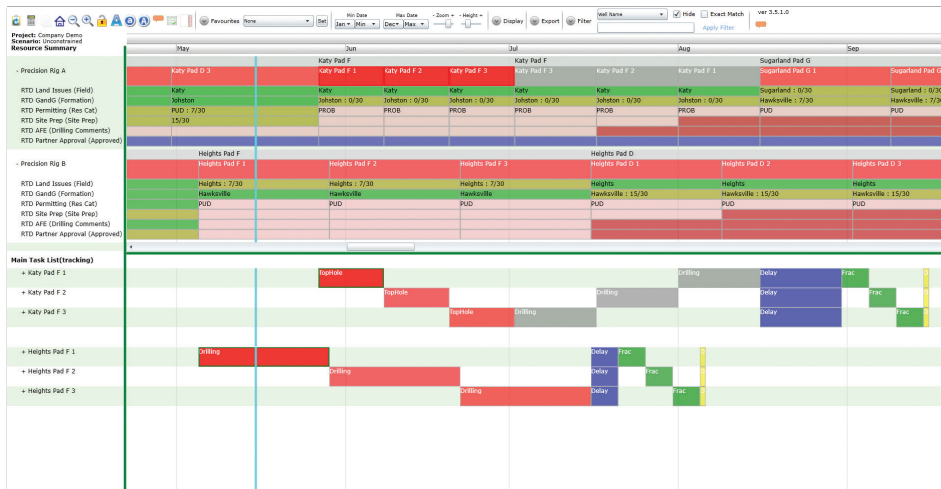
In enersight™, a producer's hundreds of wells are integrated into one cohesive activity schedule for operations teams to use to meet production and capital targets.

Key capabilities for ongoing development decisions:

- Quantify the economic and production metrics of each development option
- Assess detailed capital expenditure profiles and development schedules
- Rapidly compare various development decisions

Key integrated activity scheduling capabilities:

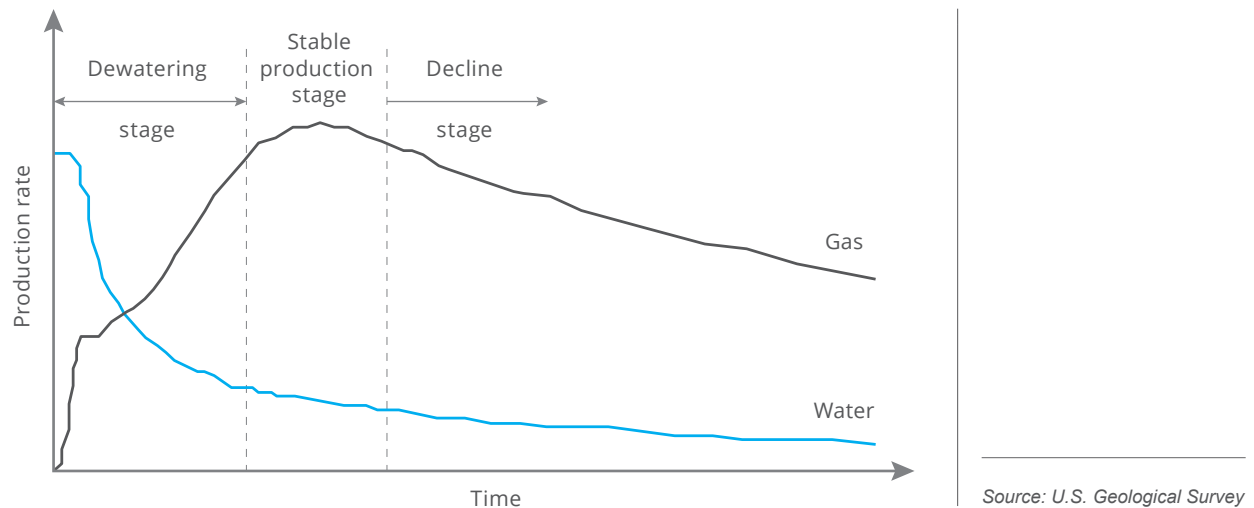
- Drilling schedules can be made at a high level as a number of wells per year, or at detailed level with rig availability, well construction steps and activity durations
- Drag-n-drop updates simplify updates to Gantt chart schedules
- Readiness-to-drill tracking



Source: enersight™ Drag n' Drop Gantt Chart Schedule



CSG wells in Queensland can produce at a peak rate from several hundred thousand mcf/day to two million mcf/day depending on depth and reservoir quality. The plot below shows an example of a CSG/CBM production forecast.



The type curve shows how production management for CSG production is challenging, with high initial rates for water treatment or disposal, and risking gas production. To operate a field at peak efficiency, enersight™ can import the production forecast of an entire field and

compute the production of individual wells, taking into account any bottlenecks in the gathering system. The activity scheduler can model all of the steps for constructing wells and managing drilling rigs.

Company-wide visibility of continuous evolving plans

Given the long-term capital requirements of LNG to CSG projects, continuous visibility into production and forecasts is essential for economic decisions and to demonstrate capital efficiency to partners, shareholders and investors.

As operations are underway, enersight™ provides daily iterations of the production forecast together with the well phasing, facility timing, capacities and capacity utilization across a total resource base of wells. After development decisions are evaluated in Enersight, the development choices made immediately impact and update schedule and corporate plan and forecasts. With Enersight accessible across corporate, asset planning and operations teams, updated plans is continuously seen and shared.

Key capabilities of corporate analysis and forecasting:

- Continuous access to actuals versus budget versus forecast
- Daily production forecasts, up to date with drilling schedule
- Consolidated latest estimates
- Yearly-review of drilling
- Evaluate portfolio options.

In the years ahead, CSG to LNG producers in Australia must demonstrate the capital efficiency of an LNG production process loaded with operational challenge. Integrated planning and scheduling technology presents demonstrated opportunities to more profitably develop, adapt and execute an on-target development plan.

Summary

The next five years are forecasting certain growth in global LNG demand. With the recent drop in oil prices, the market is witnessing the inherent conflict of producers, with increasing project costs, selling to buyers that are more price sensitive.⁹ While no one can fully predict the future of global LNG pricing, it seems inevitable that pricing pressure will continue, and with it the pressure on global LNG producers to constrain costs of production.

As new LNG production comes online, the risk for global LNG producers has shifted from managing the costs and schedules of facility construction projects to producing large-scale field development projects.

While integrated planning and scheduling technology is only one aspect of the solution to achieve efficiency in LNG production, it will be a considerable factor in determining which energy producers gain mastery of the manufacturing variables of LNG, and gain visibility into the opportunities and avoidable issues of profitable LNG production.

About the author – Don Merritt

Vice-President, Australian Operation

Don heads Aucerna's Australia operation, focusing on consulting and business development. A mechanical engineer by training, Don began his career as a reservoir engineer with Petro-Canada.

He gained experience in developing international oil and gas fiscal models through his leadership positions with Merak's Asian office and Schlumberger in Australia, Indonesia and Canada.

About Aucerna

Aucerna is the world leading provider of solutions for integrated strategy, planning and execution in upstream oil and gas.

From the field, to the boardroom, in operations across 6 continents, Aucerna is empowering E&P organizations to maximize the value of their upstream portfolios and stay ahead of the competition. Our solutions help customers work more efficiently across teams and functions and make better strategy and planning decisions based on data they can trust.

Visit us at www.aucerna.com.

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Aucerna is a global source of technology and expertise for the energy industry, with nearly 400 employees in 12 global offices. We proudly serve the industry's largest base of customers, from super-majors and emerging operators to energy investors, consultants and education institutions. Aucerna solutions are deployed in every region of the globe, helping companies make better investment decisions by connecting the people and the data of the modern energy industry.

