LNG and the Great Reformation

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ABSTRACT

In the wake of the global economic changes to the energy markets that began in 2014, the LNG industry has seen changes in pricing that were unfathomable just months earlier. In parallel, the capital cost (CAPEX) of LNG projects nearing completion was viewed to be radically expensive; as a result, proposed projects were viewed to be economically unsustainable. In the expectation of lower than usual LNG prices for many years, there is a deep rooted demand for dramatically low cost LNG production facilities. The rhetoric is so strong; it is as if there is a Great Reformation at work.

The issue with a reformation, referendum, or revolution, is that there are two sides to every story. Some see the need for drastic reform and some just pray for the application of common sense within the current set of rules or laws. In the world of LNG, the reformers carry signs displaying low $US/tonne, demanding these CAPEX metrics regardless of plant size, location, or proper engineering definition. Engineering, Procurement, and Construction (EPC) companies, deeply affected by the reformists, look for practicality in the world; simply following the rules, strategies, and lessons developed over decades of experience (traditional execution planning) will yield results that meet economic expectations and lead projects to sanction.

This paper will review public expectations on LNG CAPEX, contractor experience and lessons learned, and principles taught in even basic Project Management courses and common Value Improvement Practice workshops. In the future, will the rhetoric result in incredible reductions in the cost of LNG plants or will simply abiding by well-defined plans, robust procedures, pertinent experience, and lessons learned result in the new projects needed to continue growth in the LNG industry?
Introduction

As a result of the number of LNG project sanctions or final investment decisions (FIDs) since 2010, the market is awash in new LNG production capacity. In addition, more projects in EPC are slated to come on-stream in the next few years. Simultaneously, North America has a plentiful amount of low cost natural gas with flat regional demand and no specific export destination for sale. This combination of events results in a drastic change from the historically predictable increase in LNG demand growth year on year. Many call this period an “LNG glut”.

Forecasters look to the years beyond 2022 as the time when the LNG glut has been absorbed by the market and future demand growth returns to positive and predictable levels. Therefore, it may be only after 2022 when the world requires new LNG production capacity. While plant expansions are normally the lowest cost of incremental supply, natural gas owners, pipeline companies, and LNG project developers look for opportunities to implement grassroots projects in this era of uncertain gas and LNG economics.

To startup a new facility as early as 2022, new FIDs should occur at least four years earlier (e.g. 2018). The challenges facing grassroots project opportunities is that the most recent slate of projects have been characterized as being high capital cost (CAPEX) and being longer than expected in duration. For many developers reviewing project economics, building new projects at these recent CAPEX and schedule trends makes future projects economically unfeasible.

The reaction to the most recent project cost and schedule results is often polarized. New project developers, operating on the tolling model, must have low cost facilities when they don’t control the gas supply. Experienced project developers desire the previous rates of return when project costs were low and LNG sales prices were high. Banks require cost certainty and often lump sum turnkey (LSTK) EPC contracts while EPC contractors must evaluate the pricing risk associated with multi-billion dollar projects which have a recent tendency to overrun their estimates. The points of view from different stakeholders of the project development community lead to many questions:

- Are the costs of today’s LNG projects expensive or are they reasonable?
- Does the cost have more to do with where we locate the projects and how we develop and execute them, or are they inherently “good or bad”?
- Will recent project results become the new cost and schedule benchmarks?
- Can CAPEX, and/or $US/tonne, go significantly down in the foreseeable future?

KBR’s recent LNG publications focus on both technology and execution. A common theme when comparing one project to another is: Not All LNG Plants are Created Equal. In short, the site-specific elements of every project (technical, commercial, and execution-related) most influence project CAPEX and schedule. When reviewed over time, comparing recent project results to historic project results, leads to the misleading use of $US/tonne (unit cost) as a means to judge the past as well as the feasibility of future LNG projects.

In reality, projects in the earliest stage of development may not know their site-specific impacts to CAPEX and schedule. This paper will touch on concepts from both sides of this discussion to see the argument from each side. Regardless of what side you favor, the continuing dialogue over what an LNG project should cost leads to an implacable position with those on the opposite side.
Will Implacable Positions Lead to a Great Reformation?

An implacable position is simply where each side of an issue or argument is unable to be appeased or placated through the process of discussion. In the context of technical or commercial LNG issues, implacable positions result in an awkward stalemate on how to best develop a project. Stepping back from the context of LNG projects, society is filled with implacable positions in the areas of politics and religion; the premise of this paper is that a continued stalemate on an overly sensitive issue may trigger an LNG Reformation to move past this stalemate.

In LNG design and execution, there are many decision points that often form polarizing positions. In some cases, the positions are based on core beliefs (religion) or on the interpretation of limited data (politics). Taking the political view, there simply aren’t enough project data points to know the best possible way of configuring an LNG plant in every location without detailed study. The lack of data leads to logical ways of arriving at different conclusions. Even with detailed study, the data is mostly site specific and often cannot be used as a universal answer for subsequent projects.

To discuss these implacable positions without detailed study, we use strategies seen in politics and religion to make our case. For many of the decision points shown in Table 1, it is easy to fall one way or another based on core beliefs or interpretation of limited data to support each side. For further review, the pros and cons of these arguments are often found in technical papers at major gas and LNG conferences.

<table>
<thead>
<tr>
<th>A “2 in 1” vs. &quot;1 in 1&quot; train design</th>
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<tr>
<td>Few large drivers vs. many small drivers</td>
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<td>Compressors at grade vs. elevated deck</td>
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<td>Facility capacity: Large vs. Small trains</td>
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<td>Cryogenic hydraulic turbines: include or avoid?</td>
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<td>Multi-loop refrigerant technologies vs. single loop</td>
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<td>Heat exchangers: Coil wound vs. Plate Fin</td>
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<td>Heavies removal: Front end NGL vs. Scrub column</td>
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<td>Site preferences: Industrial vs Remote</td>
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<tr>
<td>Heating medium: Hot oil vs. Steam vs. Water</td>
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<tr>
<td>Cooling medium: Air vs. Water</td>
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</table>

Table 1. Decision Points that may lead to Implacable Positions

In addition to the examples in Table 1, the public debate about LNG project unit cost continues to escalate. With the current LNG glut and the lack of project FIDs, the debate is reactionary and completely natural; project CAPEX when viewed over time is seen as too high – the reaction is that project cost must come down or new projects cannot be sanctioned. If we can all agree that lower costs are good for projects, how does CAPEX or $US/tonne simply “come down”? As stated, there are often two sides to every viewpoint. Let’s call the two sides of this debate the Reformers and the Traditionalists.

Reformers see recently delivered project costs (as well as projects nearing completion) trending quite high since 2000. These projects, many over $2,000/tonne, are not seen as economically feasible in the current natural gas sales market. In their eyes, new
projects must have drastic cost reductions from current levels in order to support sanction. New targets are often set well below projects currently in EPC as a higher benchmark cost based on recent events cannot be tolerated; change must be visionary and occur now. Another way to categorize this view is "top-down" thinking.

The Traditionalists are also keen to reduce project costs, but interpret project history and its impact on the future differently than the Reformists. The Traditionalists see projects as site-specific data points and do not attribute a permanent shift in unit cost based on recent project history. Traditionalists believe that all CAPEX estimates are a direct function of reliable project data, sequential engineering, and project execution; in their eyes, unrealistic targets derail the project development process. In other words, Traditionalists view every project on its own merit, where the best of the best will make it to sanction. This view is referred to as "bottom-up" thinking.

While pursuing cost reduction and racking and stacking projects based on $US/tonne is not new, the concept of an “aspirational cost” is now seen in the project development queue. While the concept of “aspirational cost” will be discussed in a subsequent section, it is a key element in whether or not this debate escalates to higher proportions.

Although many have experiences with polarized feelings on design and execution issues, the recent CAPEX and schedule outcomes have led to this lively debate on the future of LNG projects. The possibility of a Great Reformation will continue as long as there is a wide gap between the two sides of this argument. In order to temper the debate, the industry needs to openly discuss issues and experience that will make future projects technically and commercially successful. This paper will address how cost is reported in the public domain, the cost viewpoints from both sides of project development, a view on “aspirational cost”, and the lessons learned from both independent parties and the contracting community.

How Cost is reported in the Public Domain

When researching CAPEX exclusively using public domain data, it is difficult to discern what is included or excluded in reported costs. For projects that have made FID, the reported costs are often the EPC contract value of the liquefaction plant and not the total cost of diverting gas from any source through an LNG export plant. Even these reported EPC costs may not include owner’s costs, pipeline costs, provisional sums or scope outside of EPC costs. In addition to the ambiguity of reported cost, CAPEX growth is often not updated during the EPC phase. Therefore, there is no certainty that previously reported costs at time of sanction reflect the owner’s expected final cost when EPC is completed. This ambiguity in the publicity reported data leads to a wide range of $US/tonne for completed projects.

For projects prior to sanction, reporting cost in terms of $US/tonne has the potential to add ambiguity to the true cost of the project. Nevertheless, projects seeking equity investors, LNG offtakers, or project financing use $US/tonne as a way to benchmark their project against all others; when grouped together, these estimates beat nearly all projects in EPC or recently completed. Regardless of the stage of front end development, it can be unclear if a reported low $US/tonne represents the initial phase of development or the final facility capacity which may take the completion of several expansion projects. Even after sanction (especially in high cost labor locations), comparisons will still be made to show projects that are “better or worse” than each other.

The difficulties in using $US/tonne to rack and stack project opportunities is that the cost metric does not take into account the scope and site specific differences in each project. There are only two components to the benchmark, CAPEX and LNG production rate; any
cost that does not influence the LNG production rate results in a negative perception on the project economics. These scope and site-specific elements are fundamental in determining both the numerator and denominator of this simple benchmark. Some site-specific decisions that influence $US/tonne are shown in Table 2. Note that some of these items can be implacable positions as shown in Table 1.

| Large facility size vs. small facility size | "Outside the fence" (pipelines, power plant, camps) |
| Remote locations vs. industrial locations | Total product slate (LPG and condensate) |
| Modular projects vs. stick build projects | Environmental (CO2 sequestration, carbon tax) |
| Large train vs. small train philosophy | Local content (labor and material) |
| Marine (water depth, current, dredging) | Sustainable development (regional infrastructure) |
| Labor pool (skill, availability, retention, cost) | Onshore, offshore, or at-shore |

Table 2. Site-specific Decisions that Heavily Influence $US/tonne

In the end, the decisions from Table 2 result in scope differences as well as technical and execution risks when comparing one project to the next. These risks may not be accurately priced pre-FID and may be excluded in the conceptual phase due to lack of data or limits in work scope. In reviewing the $US/tonne for projects in the development queue, a range should be given to illustrate the reliability of the data. Some of this inaccuracy can be due to the project state of development (pre-FEED, FEED, or near FID), or simply influenced based on the site specific characteristics known to the study team. To take advantage of the sense of ambiguity, some projects aspire to be a certain threshold of cost, regardless of the level of development in their project. These aspirations often zero in on $US 500/tonne.

The Sponsor Perspective: CAPEX Must be Lower than it is Today! A Qualitative Top-Down Approach

The LNG project sponsor of today takes on many forms. While the traditional international oil companies (IOC), National Oil Companies (NOC), regional energy companies, and corporate conglomerates remain the backbone of the project sponsor pool; there is a significant new field of independent project developers sponsoring LNG projects. These new LNG developers need their LNG projects to be commercially attractive on their own merit as they are unlikely to participate in the upstream gas exploration or the downstream LNG and gas distribution business. From any sponsor perspective, an attractive project is low CAPEX and high reliability; the conundrum is how to guarantee LNG delivery at a lower cost than projects currently being built.

Many publications often refer to the “LNG value chain”: the series of links of project infrastructure connecting a natural gas source to natural gas market a significant distance away. One key concept of the LNG value chain was that each link was meant to be developed in parallel with each other, as every piece of infrastructure was needed at the same time to develop transportation of LNG by sea. In history, LNG infrastructure was not built on speculation, but underpinned by reliable gas supply and long term contracts with established LNG markets. The traditional project sponsors often had interest in several links of the LNG value chain; for example, pairing liquefaction with natural gas supply or receiving terminals with downstream consumption markets. The highly integrated companies could leverage the entire chain if they had the resources to support it.
With natural gas currently in abundant supply and expected low cost in areas like North America, the liquefaction plant link of the LNG value chain has become more competitive than ever. In a period of high LNG demand, these projects could be built on speculation for sales to LNG traders or the spot market. Therefore, the new project sponsors, developing a single link of the chain, must be cost competitive to stand out from the traditional sponsors; the new sponsors do not have the balance sheets to carry a project that does not meet its financing obligations, gas supply and LNG sales contracts, or satisfy its equity shareholders.

In order to differentiate these projects, the developer companies have banded together as Reformers to push the industry to achieve lower CAPEX. This position is a natural reaction in distancing themselves from large projects in challenging locations with complicated logistics (i.e. high CAPEX and unit cost). The movement is in a qualitative way, pushing the vision from the top-down.

It is difficult for the developer to capture the value of low cost gas to support grassroots liquefaction projects. Developers looking to showcase their projects will need to show a unique advantage to its project, such as a willingness to accept a lower tolling fee, progress in long term sales agreements, or prior LNG development experience. Since developers tend not to have prior LNG development experience or inroads to the traditional LNG sales markets, the touted advantage is often low project CAPEX, reflected in the commercial tolling fee. When scrutinizing the cost estimates, successful projects will likely have a site advantage to justify a reduction in unit cost.

Even some of the experienced LNG sponsors have aligned with this new top-down vision. In 2016, an IOC called off its plans for a floating LNG project in SE Asia and is aiming to bring CAPEX for LNG plants down to $US 500 per tonne, down from as high as $US 2,400 per tonne two years ago, and wants to construct plants in half the time. While these are stretch goals regardless of the economic environment, these types of requirements put the industry on notice to find better ways of delivering projects and/or securing project outcomes based on the pre-FID cost estimate.

Without a unique project advantage, it is difficult for a project developer to stand out from the pack of peer opportunities and recently completed projects. However, it seems odd that several project opportunities, regardless of size and scale, have targeted the same cost benchmark. Developers have embraced this stretch goal of low $US / tonne, which in today’s market is referred to as an “aspirational” cost.

The “Aspirational” Benchmark of $US 500/tonne

In light of how costs are reported, projects that have not entered the later stages of engineering and development approaching EPC (a.k.a. Front End Engineering Design [FEED], Define Stage, or FEL-3) cannot estimate their capital costs with any significant degree of accuracy. According to well-known benchmarks such as Independent Project Analysis (IPA), the Construction Industry Institute (CII), and AACE (formerly the Association for the Advancement of Cost Engineering), projects that have not entered FEED have a cost estimate accuracy of no better than +/- 25%. Most projects that are
conceptual in nature cannot accurately capture the site-specific aspects of their CAPEX and therefore assume an “aspirational” CAPEX of $US 500/tonne. Figuring in recent project outcomes (which may have deviated from the recommendations of these independent agencies), the estimate uncertainty could be significantly higher.

This aspirational benchmark of exactly $US 500/tonne actually highlights the lack of progress in engineering and site-specific development while publicly displaying a cost target that appears to significantly beat the results of projects in regions such as Australia and Asia. In addition, the target is more aggressive than brownfield receiving terminal conversion projects. The problem with the aspirational benchmark is that it gives a false sense of confidence in EPC costs, where there is little to no site-specific substantiation to support such a low cost metric. In sum, only unique site-specific features will lead to CAPEX estimates that meet or beat the current benchmarks.

This premise of aspirational cost is not a harsh critique of projects that think they can be built for $US 500/tonne, but more a challenge to the belief that the current project execution model is broken and that costs can be artificially reduced because we deem it to be so. When comparing one project to another, cost differences are often determined by scope variances or distinct site advantages. Even the smartest project teams with the smartest people cannot guarantee low CAPEX projects on challenging sites with onerous scopes of work without extensive and rigorous strategic execution planning. Lessons learned from the contracting industry and publications by IPA are consistent with the difficulties of executing against unrealistic FEED and EPC targets for both cost and schedule. What we do not want is good project opportunities supported by people with good intentions to have bad cost, schedule, or operability outcomes.

The Universal Components of CAPEX for LNG Projects

Regardless of whether an LNG project is located in the North America, Africa, Australia, or elsewhere, there are common cost categories that can provide insight as to why every LNG project is unique. These buckets of cost allocations are often broken down by plant area. If done in this fashion, these areas are commonly:

The LNG Plant:
- Gas treating,
- NGL recovery or Fractionation,
- Liquefaction and Refrigeration, and

Utilities and Infrastructure:
- Utilities and offsites,
- Material offloading infrastructure, and
- LNG storage and marine offloading

The cost categories associated with the LNG plant will not have as much variability as utilities and infrastructure. From KBR design and EPC experience, site-related infrastructure costs have the largest influence to grassroots CAPEX. If $US/tonne is the only means of economic judgment, every project must balance the LNG plant capacity (i.e. LNG plant costs) to match the utilization of the costly infrastructure. However, new LNG developments are built in incremental phases and it is not often that the base infrastructure is perfectly optimized to the first phase of LNG capacity. In fact, many projects are designed for a modest LNG capacity (to limit the magnitude of CAPEX) with allowances for pre-investment to accommodate expansion and utilize the installed infrastructure. In history, projects often begin with a two train grassroots plant followed by a single train expansion that requires a minimal increase in LNG storage or marine infrastructure. However, in the eyes of $US/tonne, any plant where infrastructure isn’t
fully utilized is a costly plant. The only way to hide these infrastructure costs is to claim the ultimate facility size when comparing a prospect to an operating project.

In order to conceptualize grassroots project CAPEX based on the target of $US 500/tonne, some ranges of facility sizes and the resulting CAPEX if based on $US 500/tonne is shown in Table 3. This table includes a range of prospects, projects in EPC, and recently completed projects to show the magnitude of suggested CAPEX for small, medium, and large facilities based only on $US 500/tonne. The actual and projected CAPEX for these projects can be found in the public domain to evaluate if the “aspirational cost” is realistic.

Table 3 illustrates the difficulties in building grassroots facilities to $US 500/tonne without distinct site advantages or pursuing economies of scale. The benchmark is made up of only two variables, CAPEX (numerator) and the facility size (denominator). To hit the suggested benchmark, you need to bring the cost significantly down or bring the facility size up. Of the potential facility sizes shown in Table 3, only the largest projects have a realistic chance of being built to $US 500/tonne; these projects may benefit from both site advantages and classic economies of scale.

<table>
<thead>
<tr>
<th>Proposed Facility Capacity</th>
<th>Projected CAPEX @ $US 500/tonne</th>
<th>Similar Capacity Existing or Proposed Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Mt/a</td>
<td>$1 Billion</td>
<td>Donggi Senoro LNG</td>
</tr>
<tr>
<td>4 - 6 Mt/a</td>
<td>$2 - 3 Billion</td>
<td>Annova LNG, Texas LNG, Jordan Cove LNG</td>
</tr>
<tr>
<td>7 - 8 Mt/a</td>
<td>$3.5 - 4 Billion</td>
<td>PNG LNG, Magnolia LNG</td>
</tr>
<tr>
<td>9 Mt/a</td>
<td>$4.5 Billion</td>
<td>Wheatstone LNG, Ichthys LNG, Corpus Christi LNG</td>
</tr>
<tr>
<td>10 Mt/a</td>
<td>$5 Billion</td>
<td>Calcasieu Pass LNG</td>
</tr>
<tr>
<td>12 Mt/a</td>
<td>$6 Billion</td>
<td>SCT&amp;E LNG, Mozambique LNG</td>
</tr>
<tr>
<td>15 Mt/a</td>
<td>$7.5 Billion</td>
<td>Gorgon LNG</td>
</tr>
<tr>
<td>16.5 Mt/a</td>
<td>$9 Billion</td>
<td>Yamal LNG</td>
</tr>
<tr>
<td>24 - 26 Mt/a</td>
<td>$12 - 13 Billion</td>
<td>Rio Grande LNG, Driftwood LNG</td>
</tr>
</tbody>
</table>

Table 3. Example of Facility Size and CAPEX at $US 500/tonne Target

Listing LNG prospects in the same table with actual operating projects is a bit unfair based on what is known about the cost of recently completed projects. However, it is exactly this divisiveness, where $US/tonne says projects are either good or bad, that needs to play out before the next wave of project sanctions. When a potential project is advertised or delivered at $US 1,000/tonne, is it really a bad project?

The Execution Perspective: Costs are a Direct Function of Your Estimate! A Quantitative Bottom-Up Approach

Companies that design, build, and deliver LNG projects (EPC contractors, subcontractors, equipment and material suppliers, and other skill-based suppliers) are engaged in heavy competition to reduce costs. In any era, these companies need to be cost competitive in order to have projects to design and deliver. However, when bound to lump sum turnkey contracts, these companies build their cost estimates from the bottom-up, using a quantitative approach, not the top-down. Any shortcuts in building an estimate from the
details-up will result in risk and contingency that will be added to the bid price for the project – exactly the opposite expectation when trying to reduce project CAPEX. Using the naming convention from the previous section, we will call these companies the Traditionalists.

The Traditionalists are deeply affected by the new vision from the Reformers as the Reformers hold the leverage in developing the next wave of LNG projects. In fact, the traditional sponsor companies mentioned previously (IOCs, NOCs, etc.) may align with either the Reformers or the Traditionalists; regardless of that alignment, it is the new sponsor companies that are keen to develop projects now. To compound matters, the Traditionalists are afraid that they will have difficulty competing for these projects using unit cost benchmarks that have not been proven in many years. The bottom-up view of estimating CAPEX is that a quantitative view is a reliable view; attention paid to details results in estimate reliability moving forward. What good is signing on to an estimate of $US 500/tonne if it is not reliable or supported by quantitative details?

In order to search for cost savings, the Traditionalists look for FEED schedules long enough to do the detail type of work to support a bottom-up philosophy and assure the accuracy of the data for the respective phase of development. This methodical front end planning is aligned with the Traditionalist’s decades of experience that site-specific factors influence the uncertainty and risk in today’s CAPEX estimates.

In general, there are many design and site-specific factors that influence the cost of an LNG facility, some of these factors include those shown in Table 4 and discussed in detail in other publications. Low project CAPEX that is a reliable project CAPEX must look at each of the configuration and execution characteristics in Table 4 and determine the proper functionality and cost for the project.

<table>
<thead>
<tr>
<th>Targeted Total Plant Capacity</th>
<th>Labor Availability &amp; Retention</th>
<th>Plant Layout</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of LNG Trains</td>
<td>Labor Cost &amp; Productivity</td>
<td>Soils &amp; Earthquake Factors</td>
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<tr>
<td>Large vs. Small Train Philosophy</td>
<td>Power Generation Philosophy</td>
<td>Design &amp; Engineering Specifications</td>
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<td>Performance Guarantees</td>
<td>Design Margins</td>
<td>Local or National Regulations</td>
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<tr>
<td>Modularization Concepts</td>
<td>Availability &amp; Reliability</td>
<td>Environmental Considerations</td>
</tr>
<tr>
<td>Site Selection</td>
<td>Sparing &amp; Maintenance</td>
<td>Schedule Risk and Guarantees</td>
</tr>
<tr>
<td>Site Preparation &amp; Constructability</td>
<td>Shifting CAPEX to OPEX</td>
<td>Marine Design</td>
</tr>
</tbody>
</table>

Table 4. Design and Site-specific Factors that Influence CAPEX

After discussing the views of both the Reformers and the Traditionalists, it is clear there is still a gap in how much costs can come down in the near term. In order to bridge this gap, there must be an understanding of how to develop new projects in a way to improve the overall sponsor economics while having a well-developed design basis to ensure the results in execution. One of the ways to increase the probability of executing to plan is by acting on past experience, lessons learned, and the insight from organizations like Independent Project Analysis (IPA).
Sample of Recent Contractor Experience and Lessons Learned

While many project-specific papers may touch on lessons learned, this section highlights a few areas that affect the ability to develop projects both before and after sanction.

Contractor and Owner/Sponsor Project Teams

LNG project size and scope is getting bigger (classified by IPA as megaprojects) while the depth of resources from owner and contractor teams continues to decrease. In addition to retirements, the proliferation of developer companies and the increased competition in the contracting industry contributes to the dilution of the LNG and megaproject talent pool. This shift has been consistent, but rarely addressed\(^3\), since the 1980s but is accentuated by the LNG glut, the downturn in LNG sales prices, and the rise of the developer community. When looking for immediate improvement, the average age of the hydrocarbon industry workforce does not help this ongoing issue for staffing competent owner and contractor teams.

The contracting community wants experienced owner teams. The integrated project team, where the sponsor and the contractor are working together in the project organization, and no key project roles are vacant, has proven to be successful for megaprojects. While contractors can "go it alone" in EPC, project execution works best with full alignment on the project goals, the cost and schedule basis, the project success metrics, and reasonable sharing of the project risk.

Cutting Corners in FEED

Any project management course will likely state that cutting corners in the front end of a project will have a negative consequence in the project results. If this adage is true, why do we continue to cut corners in the phases prior to sanction? If today is the period of the LNG glut, project teams should be making extra efforts to justify project costs; hopefully teams are not sitting idle waiting for the global gas demand to improve. Cutting corners in FEED is adding risk to future results. From contractor experience, the only way to cut corners (e.g. faster or cheaper FEED) is to delete FEED scope and defer it to EPC. Deferral of FEED scope will always result in greater uncertainty in EPC.

Modularization

Recently completed projects as well as new opportunities continue to explore the benefits and best use of modularization. As stated in other publications\(^8\), modularization is a useful execution strategy, but it is just as important to know why you modularize as how and what you modularize. The mega-module concept still has merit in remote locations, areas with climate challenges, or projects that have restrictions on the source, cost, or amount of construction labor. Newer projects are embracing the small and mid-scale train philosophy to look for repeatability in manufacturing which may lead to economic gains. In short, one type of modular strategy does not fit all projects and it is unwise to overlook a stick-build strategy until proven otherwise.

Reliable Project Data

Project data, called Basic Data by the IPA, is the fundamental data needed to turn a concept into a project. LNG plants have fixed parameters (power, heat exchanger area, and refrigerant flow) that cannot be increased at will. A plant with production constraints due to failure to acquire accurate project data may forever have production shortfalls.

For LNG, project data includes the feed gas composition, ambient air and water temperatures, wind data, soils data, etc. Changes to the project data at any time will...
have knock-on effects to the project design which can be significant if they affect material that has already been purchased. An example is a change in feed gas composition or contaminants after the project has been sanctioned. Project data sourced by third parties needs to be verified, as early as possible, because inaccuracies in project data can have detrimental performance effects on production.

As an example, most LNG projects are air cooled (heat of compression rejected to ambient air). A contractor must rely on wind and ambient temperature data provided in the basis of design for plot layout and to design for hot air recirculation. If that data is unreliable, the plant may exhibit permanent performance issues if the dominant wind speed or direction differs greatly from the predicted data. If annual ambient temperature profiles do not match their predictions (e.g. in a case where the plant may have disturbed the ambient climate in some way), similar problems occur. In the case of wind data, there are often limited ways to mitigate a production shortfall. By the way, you can’t overcome all errors simply with design margin – trust, but verify.

*Design Margins*

In the pressure of reducing CAPEX, nearly every project confronts the issue of design margins, the cost of such margins, and the possible elimination of these margins. In the design and construction of a megaproject, where production shortfalls are catastrophic to rates of return, are margins the source of low hanging fruit to reduce CAPEX? With the exception of extreme conservatism, design margins allow the contractor teams, who assume the plant performance risk, an allowance for operating the facility outside the single point at which it was designed and to operate at design rates with nominal wear and fouling.

Since all the heat exchangers have been built and the compressors and drivers have been installed, there is very little one can do to change the performance of an LNG plant. Design margins on the remaining elements allow for a degree of variability with fixed mechanical equipment in order to meet the performance obligations of the contractor and meet the delivery obligations of the owner. Trimming these margins will only result in added contingencies and risk on the contractors, unless plant performance liabilities are reduced to mitigate contractor risk.

Lost in the discussion of design margins is the functionality of the plant outside the design point. The behavior of the plant during off-design conditions (high ambient temperature, feed gas variation, turndown, machinery trip, etc.) requires the use of robust controls and margins in order to provide stability over the entire expected operating range. Lastly, adequate design margins allow for the variations that are expected from key equipment supplied by third parties (turbines, motors, compressors, heat exchangers, pumps, etc.). These suppliers are critical to the technical success of a project, but must have allowances for variation in performance based on their track record and experience.

*Allowance for Oversight*

It may seem counterintuitive for companies with a long history in LNG, but the allowance for technical and execution oversight during FEED and even EPC is a key lesson to assure that projects are focused on controlling CAPEX while also assuring design integrity, constructability, and operability. This oversight is especially beneficial if it can be conducted within the owner and contractor organizations to capture lessons learned from similar projects and region-specific experience. These actions are often a combination of “cold eyes reviews” and assigned oversight from subject matter experts who cover multiple projects.
The nature of project teams is such that every project will be made up of different individuals with different historical experiences. In addition, the inevitable attrition in all project organizations should remind teams not to overlook routine design and execution quality; overlooking “the simple stuff” may cause rework, issues in construction, or even worse, an impact to production. Oversight can be conducted by third parties (especially for owner companies with limits in resources), but care should be taken to hire firms with both design and operation experience. In addition, oversight (internal or external) should not jeopardize the project by making changes and recommendations that have no positive impact to CAPEX, production rate, safety, operability, or maintainability.

**Insight from Independent Project Analysis (IPA)**

Many books, papers and presentations have been delivered by IPA on the execution of megaprojects and the reasons behind project outcomes. Instead of recreating work already well documented, this section refers to key themes found in the book *Industrial Megaprojects, Concepts, Strategies, and Practices for Success* by Edward Merrow. This book is a reflection on the project history from many industries (which includes LNG) while also providing the practices and strategies of project development that lead to the opportunity for project success.

Some of the key themes from *Industrial Megaprojects* include:

- 65% of industrial projects over $US 1 Billion fail to meet business objectives
- Schedule pressure dooms more megaprojects than any other single factor
- Projects routinely skimp on the front end – “speed kills projects”
- Taking risks with megaproject schedules is a fool’s game
- Contractors cannot do owners’ work
- The outsourcing of technical expertise began in the 1980s
- Integrated teams generate better projects
- Contractors tend to do good projects well and bad projects poorly
- Lump sum contracts are not a ceiling on project cost – they are a floor
- Losses for contractors do not translate into gains for the sponsors
- Schedule incentives are ineffective
- Beware the low bid……and finally
- By the time the shovel goes in the ground, the outcomes of almost every project are already determined

Published in 2011, the themes from *Industrial Megaprojects* are consistently relevant in today’s world of LNG megaproject execution. Even though these themes have held for decades, the changes since 2011 such as the drop in LNG commodity pricing, the current LNG production glut, and the proliferation of the developer community, will be interesting case studies for the next edition.

**Conclusion**

While considering aspects of both sides of this story, this paper won’t immediately change the position from either side. However, this discussion may help those searching for clarity among the daily news published about LNG projects or those seeking advice on developing their own LNG endeavors. As with most human behavior, those deeply set in their ways will be difficult to change.

As with many other industries, the LNG industry has the potential to be the victim of its own success. After decades of successful projects, many regions are now awash in low cost natural gas; in order to grow the LNG industry, there is a widespread push for changes in project CAPEX in order to develop new projects in the current economic
climate. The Reformers have a new vision on LNG unit cost and are leading the push for change. While Reformers believe that their vision will set the path for change, change does not come easily.

Recent history has shown that project costs are increasing without insight as to how to revert the trend. Based on analysis from groups such as IPA, projects are shown not only to have cost growth, but many other flaws which lead to undesirable outcomes. The Traditionalists look back to history and rigorous project development planning in order to get back to predictable results. Traditionalists see predictability as the key to keeping projects on track from the feasibility phase through the execute phase.

Is there really a Great Reformation on the horizon? No, there is not. A Great Reformation will cause undue discomfort to one side of the discussion, and history indicates it will be the Traditionalists who feel the discomfort. The signals from both sides indicate that a correction is necessary, but an immediate or radical correction is impossible based on recent history and the natural behavior of thousands of people on project teams executing megaprojects.

What we have today is a turning point in the LNG timeline. Lower unit costs will lead to more projects in the future, but a higher assurance of outcome would be an equally positive correction in LNG megaproject delivery. The sustained growth of the industry depends on fully developing projects pre-FID and reliably estimating costs and schedule in order to gain assurance on the project outcome.

In order to make a correction, top-down and bottom-up thinking must meet in the middle. Projects should start with stretch goals and a top-down vision, but one that is supported by economic analysis of what range of costs can make a project viable. After project feasibility is assured, strive for low CAPEX for a given site, but pay attention to the site-specific details, seriously take on the lessons from recent projects (and the people who executed them) and evaluate site factors during FEED. While in FEED, develop project estimates with a bottom-up collaborative approach and allow the proper time for contractors and suppliers to provide the necessary estimate and schedule information without adding unnecessary cost risk or contingency.

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