Arthur D Little

Energy & Utilities

Nuclear New Build Unveiled

Managing the Complexity Challenge

Contents

Authors

Dr. Matthias von Bechtolsheim
bechtolsheim.matthias@adlittle.com

Michael Kruse
kruse.michael@adlittle.com

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Executive Summary

Nuclear power is undergoing a tremendous renaissance, with 61 units currently under construction and about 500 further reactors already under contract or planned within the next two decades. More than 150 different projects, many of them joint ventures, are competing against each other to attract technology suppliers. If projects are implemented as their owners intend, global investment volumes will be in the range of the annual gross domestic product of leading European countries and will exceed thousands of billions of euro.

Typically, owners run their projects to very tight time schedules but in many cases the project team is new to the nuclear sector or has only limited nuclear new build experience. The Arthur D. Little study, "Nuclear New Build Unveiled", analyzes trends and challenges in the nuclear industry with regard to new build projects as well as providing insights into the approach of owners and project companies towards their projects. The study concludes that, besides its technical complexity, the management challenges posed by a nuclear new build are often underestimated and call for professional management of nuclear new build ventures. This publication is a summary of the study.

Nuclear New Build Today: A Snapshot

While the political debate continues in some countries regarding the benefits and risks of nuclear power, a snapshot of the status of nuclear new build shows that currently 49 countries intend to implement a nuclear program within the next two decades.

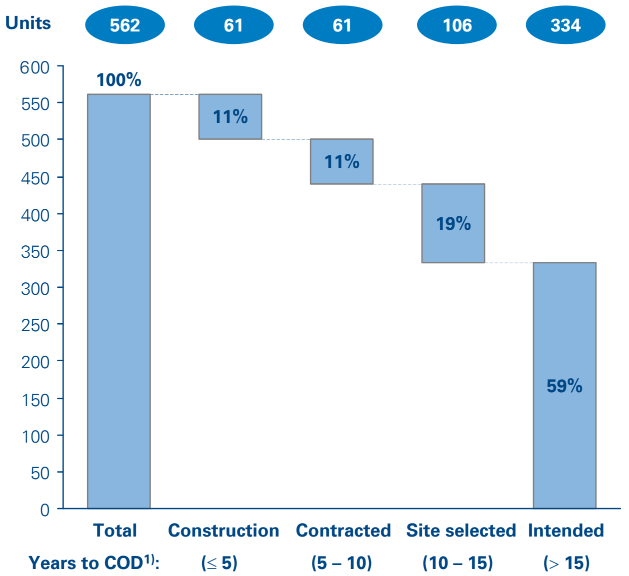
Sweden, for example, is considering reversing its strategy to abandon nuclear power and Italy is planning the return of nuclear power with 13GW third-generation (GEN III) technology. Many more nuclear newcomer countries are participating in workshops with the International Atomic Energy Agency and evaluating their options for establishing a national nuclear program.

Within the next ten years a first wave of 122 units is expected to start commercial operation in several countries around the world. A further 106 units could be commissioned in the following decade if current plans come to fruition. Owners and governments have announced their intention to build another 334 units in the long term (see figure 1).

Of course, these statistics do not define tomorrow's nuclear landscape. Nuclear new build involves too many uncertainties to provide a reliable picture of future developments. Still, the ambitions of more than 150 new build projects globally to build at least one plant show that nuclear new build has a significant position in the portfolio of carbon-free electricity-generation technologies.

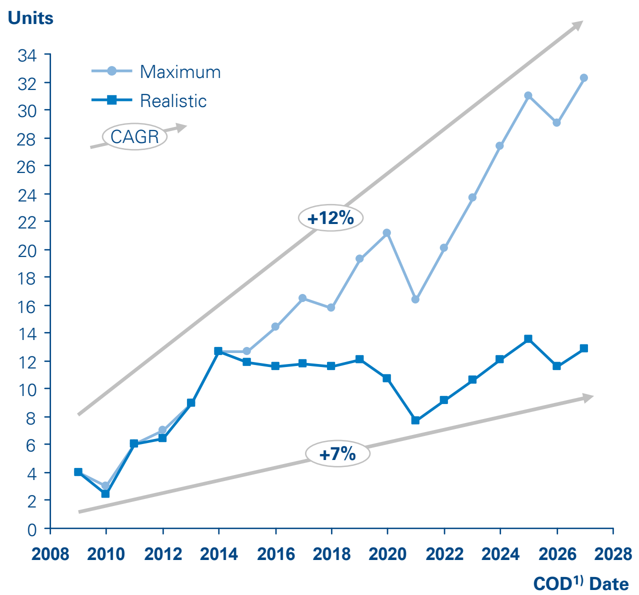
In the most optimistic scenario, the number of commissioned nuclear power plants (units) is expected to increase steadily until 2030 by a compound annual growth rate of 12% (see figure 2) and reach a first peak in 2020 with 21 units starting commercial operation. Even when the current challenges involved in financing nuclear power plants are taken into account as well as the tendency for some governments to exaggerate their nuclear new build ambitions for political reasons, a more realistic scenario still shows a compound annual growth rate of 7% over the next 20 years. In this scenario, a first peak will occur in 2014 assuming that several units that are already under construction are completed. Following this, a slight decline in growth will occur due to the postponement of some projects by their owners.

Figure 1. Expected number of nuclear new build units (status June 2010)



1) COD = Commercial Operation Date
Source: World Nuclear Association, Arthur D. Little Analysis

Figure 2. Expected commercial operation dates (status June 2010)



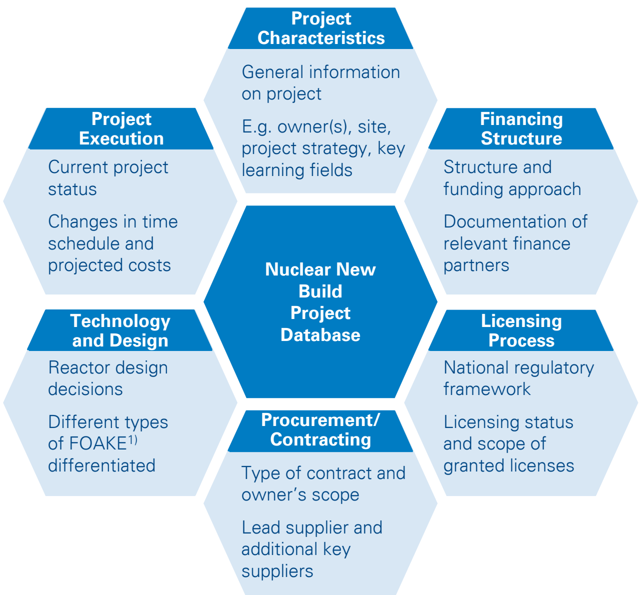
1) COD = Commercial Operation Date
Source: World Nuclear Association, Arthur D. Little Analysis

Characteristics of New Build Projects

In order to provide detailed insights into the approach and existing challenges of owners towards their nuclear new build projects, Arthur D. Little has developed a nuclear new build database. The database includes – in addition to comprehensive statistical data – in-depth interviews with market participants from the entire nuclear new build value chain (e.g. reactor vendors, Architect Engineers, financing institutions, utilities and project companies, etc.) and serves as a central analytical tool.

The database includes all nuclear new build projects and their units that are currently under construction or being planned, along with a number of information areas including general project characteristics, technology, licensing, financing and procurement (see figure 3).

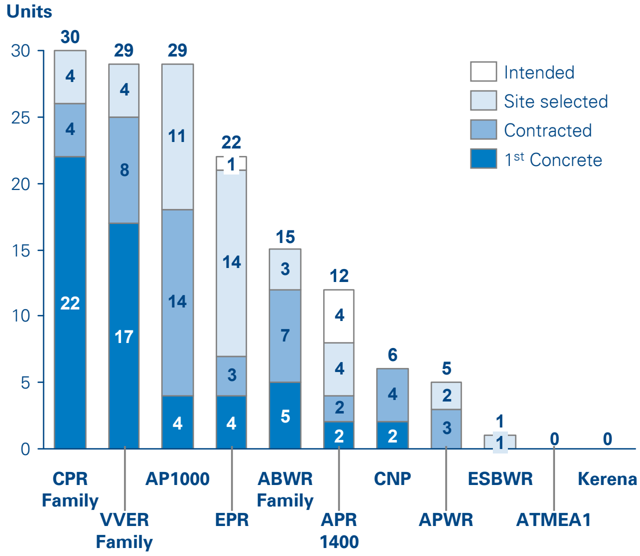
Figure 3. Information areas on the nuclear new build database



1) FOAKE = First of a Kind Engineering
Source: Arthur D. Little

The technology dimension of the database, for example, which includes the status of the widely favoured light water reactor (LWR) technology, shows that currently, a decision on the supplier of the nuclear steam supply system (nuclear vendor) has been taken for 149 units (see figure 4).

Figure 4. Lightwater reactors already formally chosen by owner (status June 2010)



Note: The ATMEA1 and Kerena reactors (both Areva) are being considered by certain owners, but have not yet been finally selected. Toshiba's AB-1600 is not included due to unclear design status.
Source: Arthur D. Little Analysis

The current spectrum of light water reactor designs includes 12 different reactor types or families of design, which are marketed by vendors as competitive standard designs. Some proprietary reactor designs exist but these are not considered here. They are included in the database alongside heavy water reactors.

Selected for 30 units, the most common light water reactor designs are the Chinese pressurized water reactors of the CPR family. At present, they are under construction only in China and they reflect China's ambition to establish a strong domestic nuclear industry. It is China's national strategy to become a global exporter of its two nuclear third-generation designs in the future. The country is developing knowledge rapidly by collaborating with well-established foreign partners and through its own extensive research program.

The Russian VVER reactor design family, developed by nuclear vendor Rosatom, has also been chosen for various nuclear new build projects, mainly in Asia, Russia and Eastern Europe. Currently, there are 17 units with this design under construction and the decision has been taken to use this technology for an additional 12 units.

The design most commonly marketed by nuclear vendors in the western hemisphere is Westinghouse's AP-1000 (selected for 29 units), followed by Areva's EPR reactor (selected for 22 units). The ABWR reactor design family, which is marketed by several nuclear vendors (GE/Hitachi, Toshiba and its subsidiary Westinghouse), is less popular in terms of units. At present, globally, there are plans to implement 15 units of the ABWR design.

Other reactors in the market are at an earlier design phase. These reactors have not yet reached a degree of design maturity that is broadly accepted by the market or licensed by regulators. Among them are Areva's ATMEA1 and Kerena reactors as well as General Electric's ESBWR. Whereas the Kerena is under close consideration by some new build projects but has not yet been formally selected, the ESBWR has already been selected for one project to be implemented some time in the future.

Summarizing this snapshot, the technology analysis reveals two key considerations for owners who plan to implement a nuclear program:

1. Given that "first of a kind" engineering imposes tremendous challenges on the suppliers and owners from a technology point of view, reactor types that have already been constructed several times have an advantage due to design maturity. The analysis identifies those designs that are most popular.
2. At the same time, depending on the timeline of the projects that have already selected a certain type of reactor, other (competing) projects might have a disadvantage in terms of labor provision by the supplier as well as reduced negotiating power if engineering and construction schedules collide.

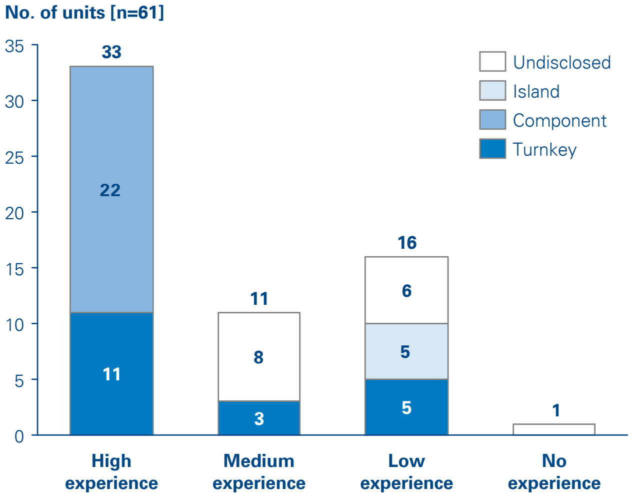
A detailed look at the procurement and contracting approach of nuclear new build projects reveals a correlation between the contract approach chosen and the degree of experience owners have. In general three broad contract approaches can be identified. They are:

- **Component (or multiple-package):** The owner, possibly with the help of an engineering consultancy, assumes overall responsibility for design, procurement and construction of the plant. A large number of contracts (e.g. for pipes) are issued to various contractors who carry out parts of the project.
- **Island (or split-package):** Overall responsibility for design, procurement and construction of the plant is divided among a relatively small number of contractors, who are responsible for the functionally integrated systems of the overall plant (i.e. nuclear island, conventional island and balance of plant).
- **Turnkey (or EPC):** The supply of the complete nuclear power plant, ready for commercial operation, is the responsibility of one general contractor (EPC contractor) or a consortium, which acts as general contractor. Nowadays a turnkey approach does not necessarily have to be fixed price.

The analysis of the 61 units currently under construction shows that only owners (or their project team) with a high level of experience implement their new build using a component approach. Less-experienced owners currently building a plant tend to choose either a turnkey or an island approach (see figure 5 overleaf).

This analysis reveals a clear tendency among owners that do not have much experience to shift as much responsibility as possible for design, interface management and overall risk exposure to suppliers even though these suppliers demand a turnkey premium.

Figure 5. Owner's experience and contract approach of units under construction (status June 2010)



Definition: Owner's experience defined by owner's new build projects finished during last 10 years (and projects currently in progress):
- No: Neither new build nor nuclear operating experience
- Low: Only operating experience and no new builds prior to current project
- Medium: Already started construction of one or two plants (excl. current project)
- High: Three or more new build projects implemented (excl. current project)

Source: Arthur D. Little Analysis

Although not shown in this summary report, a similar analysis for those projects that are currently at an advanced planning stage but not yet under construction produces an even clearer picture. Here, owners without any new build experience opt overwhelmingly for a turnkey approach. A component or island approach has been chosen for only a single project.

In summary this snapshot of the procurement and contracting approaches reveals two key insights, which need to be understood by the owner:

1. Actual market behavior shows that inexperienced owners are aware of the inherent risks of island or component approaches. They do not overestimate their own capabilities and have a realistic view of the complexity and risks of nuclear new build.
2. Prior to deciding on the contractual approach and level of responsibility to be assumed by the owner's project team, owners need to undertake a detailed assessment of their own competences in order to be able to develop a comprehensive procurement/contracting strategy.

As the examples discussed here show, a detailed analysis of the market landscape and project environment provides an additional perspective on the strategic planning of a nuclear venture and should be completed early on in the project by the owner's new build project team to ensure that decision-making is as objective as possible.

Supply Chain: Still an Issue?

For suppliers and owners alike, it is important to understand critical issues associated with the nuclear new build supply chain. These include existing global problems with the availability of critical components, insufficient willingness on the part of the financial markets to support nuclear new build, the availability of skilled labor and many more.

Data from Arthur D. Little's nuclear new build project database together with data provided by technology suppliers offers a number of insights into critical areas of the supply chain, including heavy forgings (i.e. long-lead items) and skilled labor. In addition to the current tight situation on the financial markets, it is crucial that owners address these two issues in order to avoid delays and/or price escalation. Resolving the issues of long-lead items and skilled labor will help ensure all work is of excellent quality, something that is central to the success of a new build.

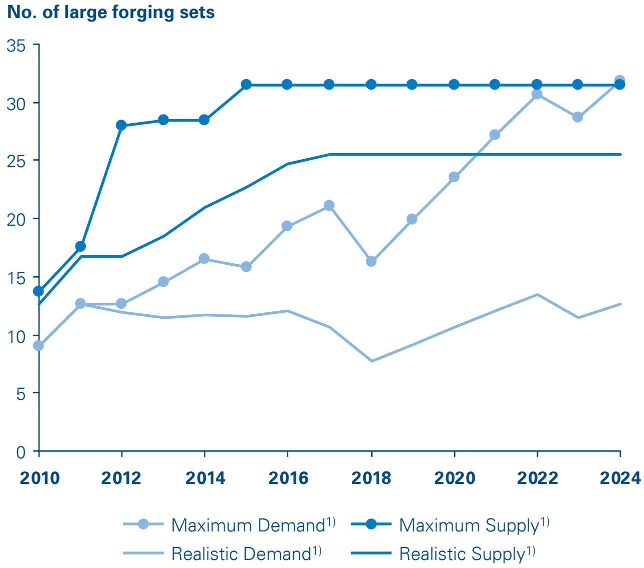
Long-lead items

Analysis of demand and supply with regard to typical long-lead items (e.g. nozzle shell flange for reactor pressure vessel) shows that the issue of bottlenecks for heavy forgings has been largely resolved. This holds true at an overall level (see figure 6) and on a reactor-design-specific level as well, as explained in the study.

An assessment of demand and supply for large forgings for the first wave of nuclear new build until the year 2024 indicates that sufficient forging capacity will be available in time. This means project delays caused by non-availability of forging components can be avoided and timely slot reservation is no longer that critical. This projection includes the capacity of the 14,000-ton presses needed to manufacture ultra-large forgings from heavy steel ingots for the different reactor types. These have been a key concern in the recent past. According to capacity projections from suppliers such as Japan Steel Works, Sheffield Forgemasters, Areva/SFARSteel and others, sufficient capacity will be available by the time nuclear new build projects require the manufacture of large forgings to begin.

Owners should be aware that expanded or new production lines carry with them the risk of lower quality in the period immediately after start-up, and must monitor carefully whether suppliers will be able to produce components to nuclear-grade quality. Proof is still required that problems with quality do not effectively negate newly expanded capacity.

Figure 6. Global demand and supply in large forgings (status June 2010)



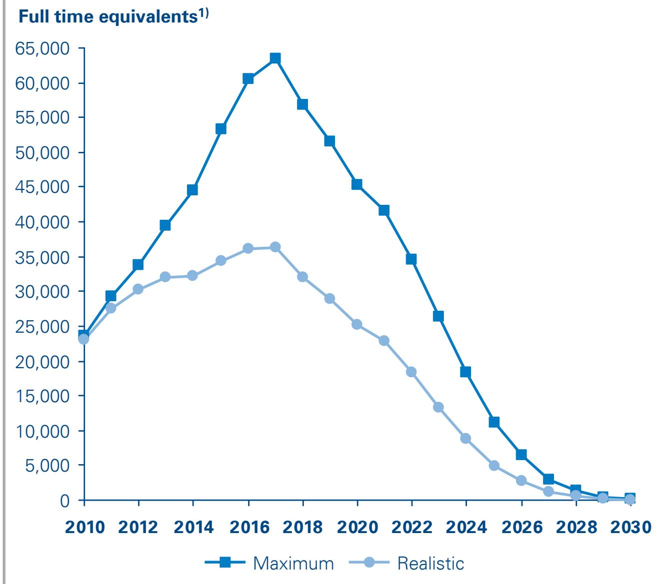
1) VVER design and CPR design not included in this analysis
Source: Arthur D. Little Analysis

The Arthur D. Little study shows that bottlenecks could arise in other areas of the nuclear new build supply chain as well. In total the study examined 153 key plant components; 25 were considered potentially critical. In Central Europe, for example, there are only a few suppliers of heavy lifting and transport equipment. Depending on overlaps in projects' time schedules, this could be a source of unexpected risk; although not excessively critical, it could still delay the project.

Skilled labor

In contrast with the issue of long-lead items, a highly critical issue – and one that is already prevalent – is the lack of suitably qualified and experienced personnel. This situation is especially critical in Central Europe and among member states of the European Union. Here regulatory requirements, even though they are less prescriptive than those in the US, for example, demand considerably more skilled staff.

Figure 7. Overall labor demand in Europe for nuclear new build (status June 2010)



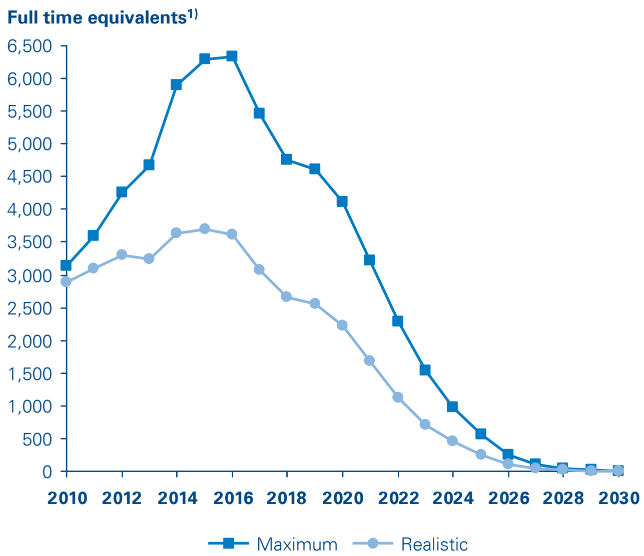
1) Upstream component manufacturing (e.g. pumps) not included
Source: Arthur D. Little Analysis

Based on different labor-demand scenarios, the Arthur D. Little study indicates likely shortages in a number of labor categories. If project schedules achieve their current projections, more than 65,000 people will be needed to work on nuclear new build throughout Europe by the year 2018 (see figure 7). A more realistic scenario, which takes into account the fact that not all planned new builds will be implemented, still estimates a labor-demand peak of 35,000 people. This number does not even take into account upstream supply chain labor involved in the manufacture of equipment and components.

Closely linked to the issue of overall labor shortages, is the specific challenge of having enough suitably qualified and experienced engineers. The high number of new build projects undertaken by owners with only low or moderate levels of experience typically necessitates the integration of a strong Owner's Engineer into the owner's project team. The engineer's role is to represent the owner's interest with suppliers and to act as an extension of the owner's project team. At the same time, the project team itself needs a sufficient number of people with the required competences to act as intelligent customers. Nuclear regulators today typically adhere to the intelligent customer principle, requiring the owner's project team to retain sufficient technical knowledge of the services being provided by a third party to specify requirements competently and manage quality delivery of the services.

In an optimistic scenario, a peak of 6,500 nuclear, conventional and civil engineers will be needed by engineering consultancies, suppliers and owners in Europe within the next decade. Even in a more realistic scenario, the Arthur D. Little study estimates that over 3,000 people will be required (see figure 8).

Figure 8. Engineering labor demand in Europe for nuclear new build (status June 2010)



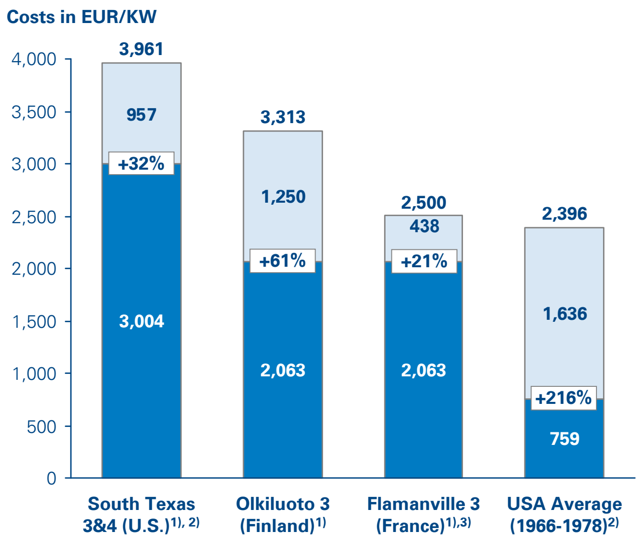
1) Suppliers, Owner's Engineers, owners and project teams themselves
Source: Arthur D. Little Analysis

As a consequence of the labor situation in the nuclear new build field, there is a general need for the nuclear industry to attract young professionals and to invest in education, training and convincing career prospects. At a project level, owners facing tight labor supply need to achieve a good understanding of the resources and skills they require over time and the skills they already have within their own domain. It is clear that the issue of labor needs to move up the strategic agenda for project owners.

Nuclear New Build Challenges

As building new nuclear power plants is one of the most complex technical undertakings that currently exist due to extremely high quality requirements and standards, owners frequently face tremendous financial risks (see figure 9).

Figure 9. Cost overrun per KW of selected nuclear new build projects (status June 2010)



1) Estimates, project in progress (South Texas construction not started, yet)
2) In EUR (conversion date 2010, May 20th)
3) Initial overnight estimate 2005, cost update in 2008
Source: Arthur D. Little Analysis

Typical investment of €5bn per unit and long project-execution times of around 12–15 years from first feasibility studies to the start of commercial operations impose a high degree of uncertainty. Tight regulation in many countries, including rigid safety requirements, challenging financing requirements and public reluctance, add further complexity that needs to be handled professionally.

The Arthur D. Little study reveals that inaccurate understanding of project risks and inaccurate prioritization of critical activities often lead to significant delays and budget overruns. Projects in Finland (Olkiluoto 3), the US (South Texas 3&4) and France (Flamanville 3) have demonstrated these risks dramatically.

Detailed assessment of several past and current nuclear new build ventures and in-depth discussions with more than 30 industry members across the nuclear supply chain indicate several factors that led to cost overruns. These could have been mitigated by the owner and/or suppliers if proper management had been applied. They are:

- start of construction before design completion (including changes imposed by owner)
- insufficient incorporation of regulatory requirements into design and lack of reliability of licensing process
- insufficient schedule integration and communication between suppliers and owner
- lack of strategic and operational planning by the owner (processes, activities, milestones)
- insufficient control and progression of the new build project (time, costs, quality)
- poor interface definition and management between involved parties (including language handling)
- hesitant implementation of countermeasures for identified risks and constraints
- lack of timely provision of suitably qualified and experienced staff (owner and suppliers)

In addition to these key challenges, discussions with members of the different functional areas of new build projects, such as engineering, commercial, licensing and legal, reveal that a lack of understanding of other departments' requirements and the natural interdependencies between the different tasks of a project's subject areas often delay decision-making. This is amplified by an unspoken reluctance among project members to deal with the high degree of uncertainty involved in nuclear new build, which sometimes impedes progression of the project.

All these issues show that, while the technical complexity of nuclear new build is widely recognised, the management challenges are often underestimated and call for professional management of nuclear new build ventures.

Practitioners' Lessons Learned

The Arthur D. Little study reveals that countries and utility companies planning a nuclear new build should heed the following lessons:

1. The first requirement for a nuclear new build project is a well-structured and thoroughly organized approach specifying activities, roles and responsibilities, the organizational structure over time, and a master plan in order to avoid surprises and speed up project execution.
2. Especially for joint-venture new build projects, owners need to define effective decision-making, steering and governance mechanisms. These mechanisms must ensure a transparent, reliable but still flexible and broadly accepted decision-making process by owners and the project team alike. Within this approach, a criteria-based stage-gate process should give guidance to the joint venture's shareholders regarding their role in verifying and signing off major decisions.
3. Owners should not overestimate their own skills and management capabilities and their ambitions should be realistic. For owners with only limited or moderate experience, for example, an EPC (turnkey) approach with a limited owner's scope and contractual structure based on a hybrid-pricing model is often the best solution to balance risks and price.
4. Deciding on the reactor technology too early cuts negotiating power and strategic flexibility. Procurement needs to be subject to as much competition as possible while closely considering technology selection and licensing needs. This calls for the development of an optimal procurement approach for the plant, often including pre-qualification of suppliers.
5. Just signing one or more delivery contracts for the plant (e.g. EPC contracts) is not sufficient. Achieving a high degree of design maturity (nuclear, conventional and balance of plant) prior to contract fixing is needed as a baseline for achieving a well-structured contract. Here, early works contracts with more than one nuclear supplier help to establish this baseline.
6. Nuclear new build is not only about selecting the right technology and signing a contract with a consortium. The matter of financing the nuclear power plant, including financial engineering, needs to be handled with the same care. It needs to be addressed early during project development to secure a reliable financing scheme.

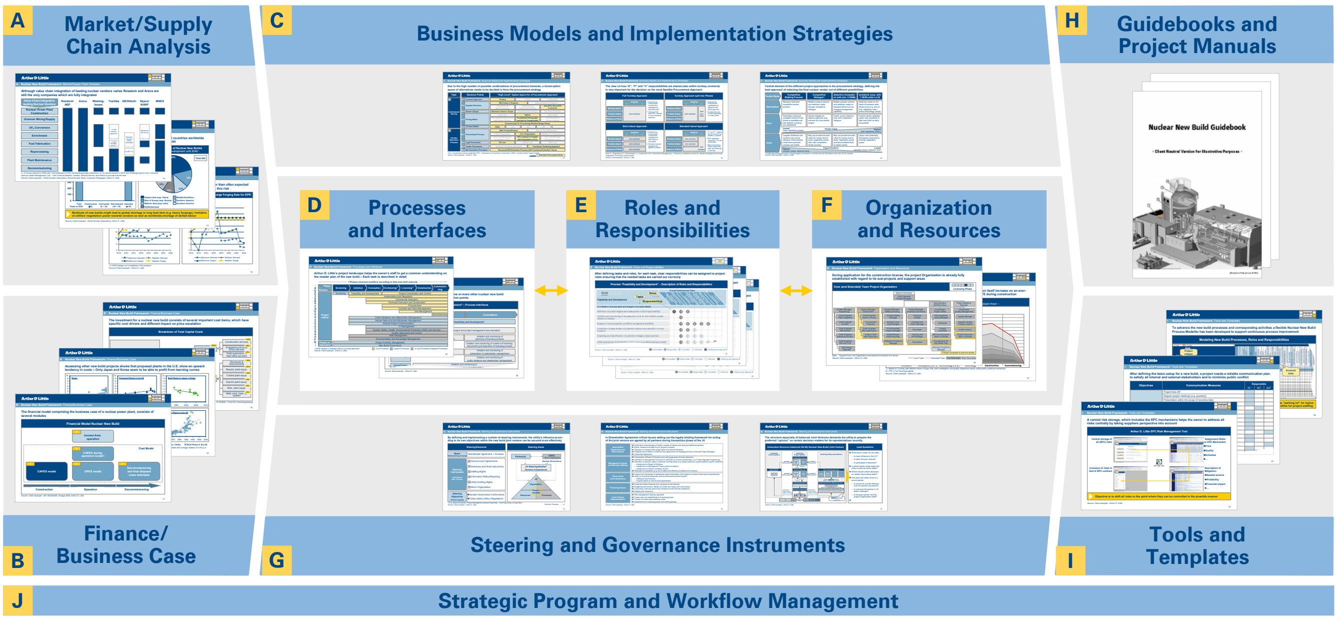
These lessons and others from ongoing nuclear new builds show that project success depends on a combination of factors. However, project decision-makers rarely manage projects from a holistic perspective and underestimate the interdependencies that exists between important project activities. Again, the lessons learned provide evidence that the management challenge of nuclear new build must not be underestimated.

Nuclear New Build Framework

Based on the results of the nuclear new build study and project experience from several engagements in the nuclear field, Arthur D. Little has developed a comprehensive framework to help owners establish and define a well-structured approach to developing and managing their new build ventures from a strategically relevant and holistic perspective (see figure 10).

The framework covers all the elements that need to be addressed from a strategic and management perspective. The framework helps owners set a clear baseline for the project, reducing the inherent risks of nuclear new build and empowering the project team to develop and implement nuclear new build according to quality, cost and schedule.

Figure 10. Arthur D. Little nuclear new build framework



Source: Arthur D. Little

Contacts

If you would like more information or to arrange an informal discussion on the issues raised here and how they affect your business, please contact:

Austria
Dr. Matthias von Bechtolsheim
bechtolsheim.m@adlittle.com

Belgium
Kurt Baes
baes.kurt@adlittle.com

Czech Republic
Dean Brabec
brabec.dean@adlittle.com

France
Franck Herbaux
herbaux.franck@adlittle.com

Germany
Dr. Matthias von Bechtolsheim
bechtolsheim.m@adlittle.com

Italy
Saverio Caldani
caldani.saverio@adlittle.com

Japan
Hiroshi Shimizu
shimizu.hiroshi@adlittle.com

Korea
Daesoon Hong
hong.daesoon@adlittle.com

Middle East
Thomas Kuruvilla
kuruvilla.thomas@adlittle.com

The Netherlands
Martijn Eikelenboom
eikelenboom.martijn@adlittle.com

Portugal
Grant Greatrex
greatrex.grant@adlittle.com

Spain
Jesus Portal
portal.jesus@adlittle.com

Sweden
Bo Lenerius
lenerius.bo@adlittle.com

Switzerland
Dr. Matthias von Bechtolsheim
bechtolsheim.m@adlittle.com

UK
Stephen J. Rogers
rogers.stephen@adlittle.com

USA
Rodolfo Guzman
guzman.r@adlittle.com

Nuclear Power Station Grohnde, Germany

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