Arthur D Little

Viewpoint

Nuclear failures

Risks, uncertainties and future potential

In 2011 the tragic events at Fukushima called the nuclear industry to a sudden halt. In the months after the accident, several nuclear programs for example in Switzerland, Thailand, The Netherlands and to some extent also in the U.S., were put on hold or stopped entirely. Now, seven years later, it is evident that the global nuclear industry has recovered from this shock and is back to speed, albeit with a slower pace. In the beginning of 2018 about 450 reactors had been under operation and more than 55 new reactors are under construction at the moment. With varying level of maturity several countries around the world plan to enter into nuclear as newcomers. In total, globally more than 600 nuclear reactors, mostly in Middle East and Asia, are intended to be built within the next 25 years; large commercial nuclear power plants as well as small modular reactors. This shows a clear path forward to the nuclear industry and justifies having a critical look at the deployment success factors.

The large number of proposed reactors reveals a remarkable fact: It is expected that the number of operated nuclear power plants will increase until 2030 compared to today's status-quo despite contradicting indications from some media.

This positive scenario however, does not show the number of nuclear programs which "failed" to continue with their project development or construction activities and have either stopped entirely or been put on hold indefinitely.

A recent Arthur D. Little study identifies more than 10 nuclear programs totalling 45 planned reactors which have ceased existence during the last five years, several of them already before Fukushima. Another 25 nuclear programs with about 70 reactors have put their plans on hold. If and when these programs continue is uncertain. On the other hand, countries like Turkey and the Kingom of Saudi Arabia push to advance their programs rapidly and China will match the number of installed reactors with those of France in less than ten years, becoming the world's second largest nuclear power producer after the United States by 2025.

There are two main reasons why a nuclear new build program fails. The most obvious reason is to a large extent exogenous to the owner and originates in a country's nuclear policy and state or public opinion to nuclear power as an energy source. In Switzerland for example, despite an expected electricity demand supply gap within the next decades and a low carbon energy policy, the Swiss Bundesrat decided to abandon nuclear power as an option in the wake of Fukushima, due to a wave of public opposition. As a consequence, three Swiss energy companies stopped their nuclear new build plans only few months after Fukushima.

Similarly, in Lithuania, the Social Democrats forced a non-binding public referendum on whether Lithuania should build a nuclear reactor. The referendum was held in conjunction with the national election. About 63% of those voting in the referendum said they did not want additional nuclear power.

These examples show, unless there is an exceptionally strong link between the country's ambition to establish a self-sustainable nuclear industry – meaning jobs to the people – and the nuclear program, earning public trust and confidence is crucial for the program's success. This is a major reason why the nuclear programs in countries like China, India, Russia and Turkey progress well.

The other reason for failure originates in economic realities. Investment costs for several nuclear power plant new builds averaged around € 3,900 per kilowatt. In contrast, the investment cost for one of the world's most advanced Combined Cycle Gas Turbine (CCGT), Irsching 5 in Germany (860 megawatt), was less than € 500 per kilowatt. As long-term prices for gas are expected to continue to be comparably cheap, the nuclear option is also less attractive from a fuel perspective and hardly reaches its required return on investment. If only one-dimensional indicators such as net present value (NPV) or levelized cost of energy (LCOE) are considered, the nuclear option is a difficult one. Only if other indicators such as Value Chain Localization and Economic Impact, Human Capital Development as well as Security of Supply aspects are integrated into the "calculation", nuclear becomes a real option.

The rationale of economic viability is not new to the nuclear industry. Even before the tragedy of Fukushima, sceptics of nuclear energy argued that the nuclear industry's prospects were dimmed by delays and escalating costs long undermining the economic viability, and hence competitiveness, of nuclear energy. Since Fukushima, this view has received even stronger justification, especially in liberalized energy markets where increasingly volatile electricity prices put the high number of reactors - which are still proposed - at a certain risk.

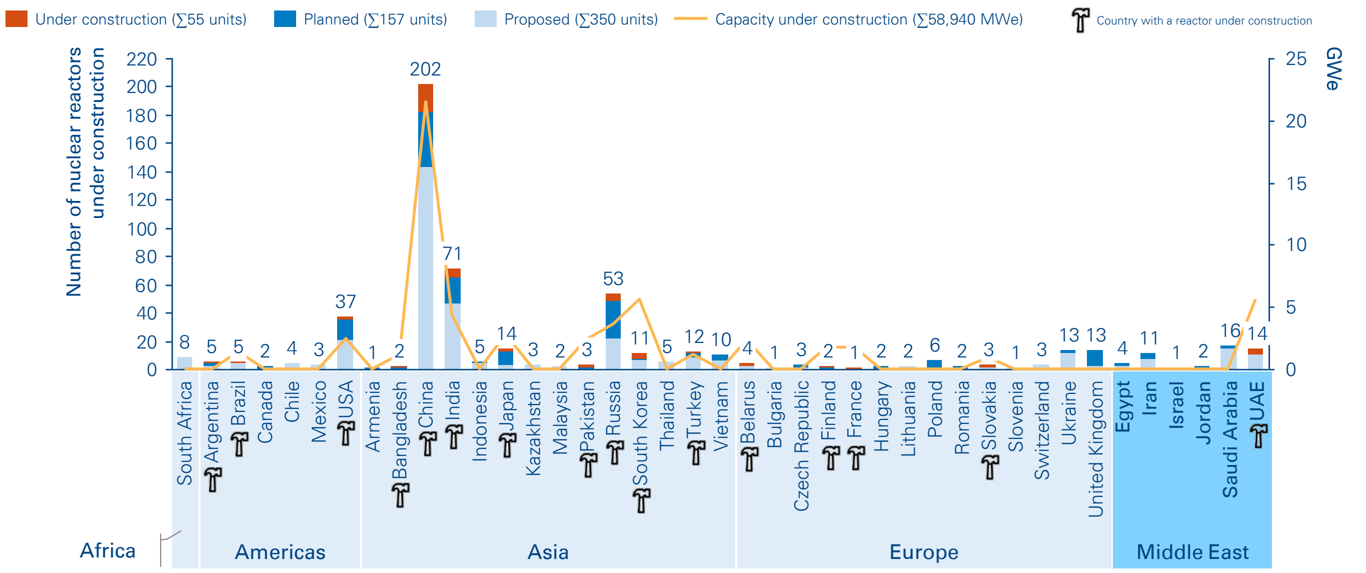
The first wave of commercial nuclear reactor programs in the U.S. for example, which were introduced during the late 60s and 70s of the last century, faced on average three years delay and a remarkable 300 per cent cost overrun relative to the original estimated investment cost. However, at that time, in many industrialized countries including the U.S., nuclear energy was viewed as a state industry vehicle driving economic advancement, and overall cost was less of an issue as energy market prices were regulated.

Nowadays however, several nuclear programs are facing significant challenges to meet their envisaged return on investment due to schedule delays and exceeding cost projections. This also makes it hard to argue with other benefits such as the overall Economic Impact from such a program as well as localization.

Hence, a major driver avoiding failure of a nuclear new build program is to maximize the plant's economic viability by limiting cost escalations and schedule delays. Interestingly, this premise is well-known to owners of nuclear new build programs, however remarkably few projects, notably Chinese and South Korean ones, seem to be able to execute their venture within the limits of this premise. Nevertheless, the hidden costs of these nuclear players are rarely made public and are rather unknown. Hence also this performance can be challenged to a certain extent.

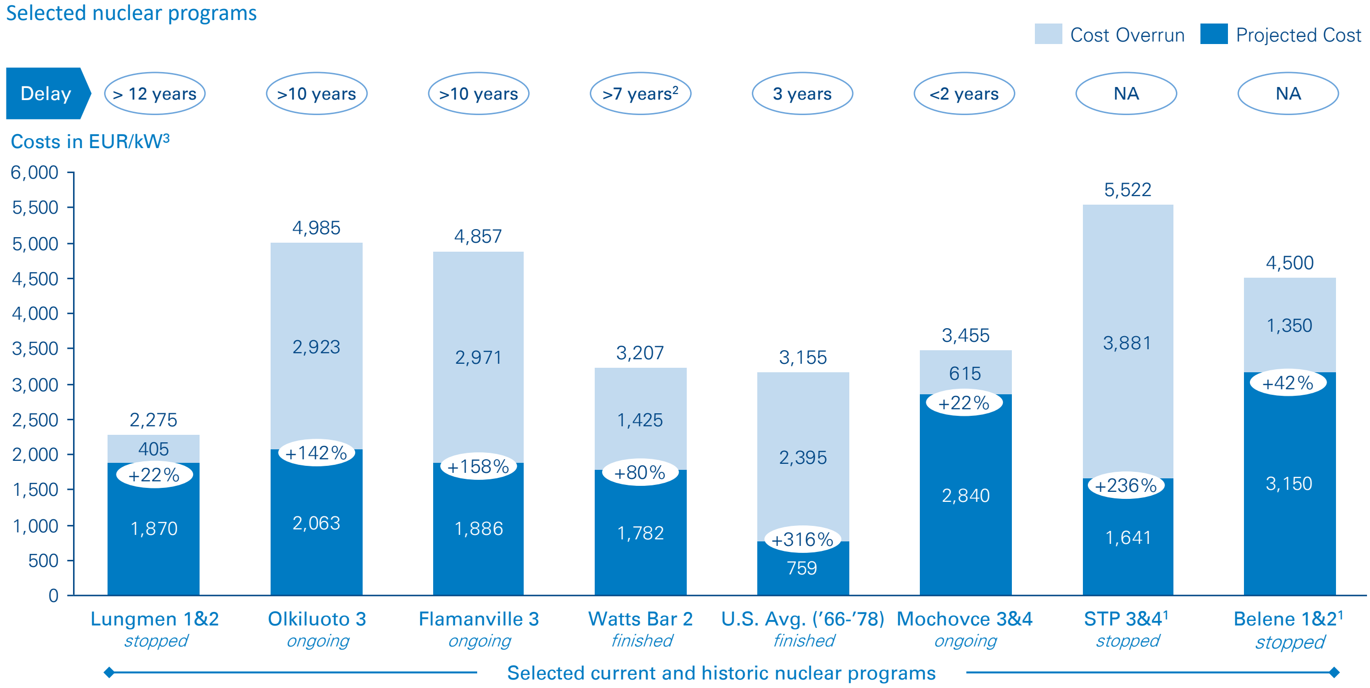
At the root of the failure often lies an inaccurate understanding of project risks. In addition, inaccurate prioritization of critical activities and lacking capabilities of the project organization and suppliers, has led to significant delays and budget overruns.

Currently there are 55 reactors under construction in 16 countries with a total capacity of ~59GW with 507 more planned or proposed



Comment: Under construction = First concrete for reactor poured, or major refurbishment underway; Planned = Approvals, funding or commitment in place, mostly expected in operation within 8-10 years; Proposed = Specific programme or site proposals, timing of start of operation very uncertain. Figure does not include Small modular Reactors (SMR
Source: WNA (April 2018), Arthur D. Little analysis

Selected nuclear programs



1 Projects canceled or under revision, construction not started, yet; 2 Projects are restarts, time before restart not included; 3 Cost values with 15-12-15 F/X rates
Source: Arthur D. Little Analysis (2016-12-15)

In the past, several projects tended not to be ready for this challenge. Projects in Finland (Olkiluoto 3), the U.S. (South Texas 3 & 4), France (Flamanville 3) and Russia (Kursk 5) have demonstrated these risks dramatically. Historically, several factors have led to cost overruns, including:

- Start of construction before design completion and inability of the owner to communicate its utility requirements in a comprehensible manner
- Lacking ability to incorporate regulatory requirements into the plant's design and lack of reliability of the licensing process
- Insufficient schedule integration (starting by having the end in mind) and communication between first tier suppliers, sub-suppliers and owner
- Lack of strategic and operational planning by the owner (governance, milestones and so on)
- Insufficient project management capabilities including controlling progression of the new build project (time, costs, quality), across all key suppliers
- Poor interface definition and management between involved parties (including the regulator)
- Non-transparency of major project risks and hesitant implementation of counter-measures for identified risks and constraints
- Lack of understanding of needed capabilities over time and hence lack of timely provision of suitably qualified and experienced staff.

A tangible example: During project development some owners, especially in countries with weak grid infrastructure, tend to underestimate the effort and time needed to provide sufficient grid infrastructure for the plant. Instead, they focus their efforts entirely on the technology choice of the plant, not considering the impact the plant will have on the entire electricity system of the country.

These challenges of not understanding the interdependencies of a nuclear venture are 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 further.

All these issues show that, while the technical complexity of nuclear new build is widely recognized, root-cause for ultimate failure of a nuclear new build are the inherent management challenges. These are often underestimated and call for professional management of new build ventures, which goes far beyond methodical proper program management. Deep understanding of the nuclear program itself (of all technical and non-technical elements as well as their interdependencies) is needed. Remarkably, on a theoretical level many owners are quite aware of these factors which determine cost overruns to a large extent. However, they fail in building the needed capacity within their own organization to address these existing challenges.

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Arthur D. Little

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