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Current status and emerging trends in financing nuclear power projects

Nadira Barkatullah [a,*], Ali Ahmad [b]

[a] AECOM, Sydney, Australia
[b] Issam Fares Institute for Public Policy and International Affairs, American University of Beirut, Beirut, Lebanon

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A B S T R A C T

Traditionally, governments have used domestic public sector funds to finance nuclear power projects. However, a recent trend shows that governments, world-wide, are increasingly looking towards the private sector for new financing approaches with different risk and ownership structures that mitigate risk, and new contractual arrangements that aim to lower the fiscal burden associated with nuclear power projects. This paper gives an overview of the major challenges related to financing nuclear power plants such as the high upfront capital cost, sensitivity to interest rate and long construction time. The paper then discuses existing and emerging financing strategies and contractual arrangements for both, government and private investors. The analysis eventually evaluates the potential of the emerging financing approaches to resolve some of the challenges associated with the deployment of nuclear power but there is no one-answer, as each project is unique and requires careful review regarding the applicability of the financing model, as some of these approaches may have their own challenges.

1. Introduction

The next decade is critical for nuclear power. Proponents of nuclear power believe that the shift away from carbon-producing energy sources represents an opportunity for expanding global capacity of nuclear electricity. However, the nuclear industry is struggling with internal and external challenges that could hinder such prospects. At the 2015 United Nations Climate Change Conference, known as COP21,[1] in a historic stance, the world agreed that climate change is a major issue, with 196 countries signed an agreement to abate the rise in global temperature to 2C (3.6F) by century's end.[2] A mix of technologies including nuclear and renewable is perceived by many as the most effective way to tackle climate change [1,2]. In addition to global warming, which is rated as one of the top risk at the Annual World Economic Forum 2016 [3], many competing factors are likely to influence future energy investments. Improving energy security, innovative financing, reducing costs, deregulating electricity markets and supply chain backlog are probably the most important factors that governments consider when shaping their energy policies. The weight assigned to these factors, however, could differ substantially from one country to another, based on the country's economic climate and the type of project and technology under consideration.

One major challenge associated with the deployment of nuclear power is financing, which, regardless of its mechanism or source, remains a barrier due to the large-scale of funds required and long tenor, in line with the economic life of the nuclear assets.[3] The diverse and exclusive set of risks involved and the waning economic competitiveness of nuclear electricity, due to high investment costs and the despatch risk in deregulated electricity markets. Furthermore, there is also fierce competition from alternative investment proposals (e.g. power generation projects using different technologies such as gas, hydro, wind and solar), which are less contentious from a reputational point of view and more in tune

* Corresponding author.
E-mail addresses: nbarkatullah@gmail.com (N. Barkatullah), ali.ahmad@cantab.net (A. Ahmad).

[1] COP stands for "Conference of Parties", said parties being the countries that ratified the UN Framework Convention on Climate Change in 1992 at the Earth Summit in Rio de Janeiro, Brazil.

[2] The first time in over 20 years of UN negotiations, to achieve a legally binding agreement on climate, with the aim of keeping global warming below 2C. http://newsroom.unfccc.int/unfccc-newsroom/finale-cop21/.

[3] Up to 80 years in case of license renewal(s) [4].

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with the political and general public mood. In that context, investors from the private sector, appear to be struggling to find "good reasons" to support nuclear power versus other technologies.

In this paper, we present a holistic view of financing nuclear power projects, from outlining the economic and fiscal challenges faced by project developers and investors to examining the existing financing strategies and contractual arrangements available when considering nuclear power projects. The paper also evaluates the potential of emerging financing approaches to resolve some of the challenges associated with the deployment of nuclear power. Section 2 outlines key economic features of nuclear power and the basics of financing. Section 3 highlights the challenges and risks of financing nuclear power projects, while the different types of financing approaches of nuclear power projects are discussed in Section 4 and 5. Next, Section 6 discusses contractual and ownership arrangements, employed for the infrastructure projects and finally, Section 7 concludes the main findings.

2. Background

2.1. Overview of key economic features

Compared to other energy sources, nuclear power is highly capital-intensive, which brings in higher sensitivity to interest rates. Although the cost of building nuclear power plants generally varies with geographic location and the unique circumstances of each project, its per kilo-watt (electric – kWe) cost range is substantially higher than that of traditional sources of energy such as natural gas, and is becoming increasingly less competitive against renewables.

The last decade has seen a further decline in the relative economics of nuclear power in most of the OECD countries.[4] From operations point of view, the main challenge is the risk of not being despatched, specifically in the deregulated electricity market. For new investments, it will be imperative to have Government support.[5]

Cost uncertainty during the construction phase is a major challenge, like in the case of the Vogtle project in U.S., for example, two AP1000 reactors are under construction with the actual unit capital costs increased to $6100/kWe in 2012, roughly 2.5 times the cost estimate assumed in a Massachusetts Institute of Technology (MIT) study in 2001 [8]. Since then cost estimates for Vogtle have further increased, due to delays and difficulty in meeting quality standards [10].[6] The recent cost estimates are more than $7000/kWe, see Fig. 1. Likewise, the estimated costs of constructing a European Pressurized Reactor (EPR) in Western Europe or North America range from around $5000 to $7300/kWe, or about $6100/kWe on average [11–13]. These numbers are consistent with the revised estimates for nuclear power plants that are recently constructed or under construction across the globe. Initial cost estimates, have generally been revised, in some instances more than twice, as shown in Fig. 1.

Fig. 2 shows the overnight cost data compilation in different regions (US, Europe, Asia and Middle East) and its standard deviation.[7] The range is from $3500–$5000/kWe, for all regions, except Asia, which is very daunting for newcomer countries. The costs for Asia are lower, given low input costs and very high localization rates. The standard deviation around the mean is $2000–$2700/kWe. Asian countries (Japan, South Korea and China) have maintained a momentum of nuclear power plant construction, whereas, most "Western" projects are 'first-of-a-kind' (FOAK), resulting in significant construction delays.

The outlook for future investment costs in Europe and the United States is not very encouraging. The findings from a study based on 30 U.S. and 30 European nuclear technology experts shows that on average, under a business as usual scenario, the current (Gen. III/III+) designs are expected to be somewhat more expensive in the year 2030, than they were in 2010, with the expectation that next generation of designs (Gen. IV) to be even more expensive [14].

In addition to the capital-intensive nature, nuclear energy possesses some exclusive risks, further discussed in Section 3. Collectively, these features contribute to the challenge of financing nuclear power plants. Despite these challenges, nuclear reactors are being built across the world, though at different pace and efficiency. Table 1 shows the 60 reactors that are currently under construction [15], in 15 countries, with 22 reactors in China alone. Though China's interest in investing in low carbon technologies also extends to solar and wind energy projects.

The United Arab Emirates (UAE) and Belarus are the only newcomer countries on the list, having started the construction of their reactors in 2012 and 2016, respectively. It is interesting to note that almost all nuclear power plants that are currently under construction will operate in regulated electricity markets, with substantial government support. The support may be in the form of long-term power purchasing contracts (PPA) or high electricity tariffs, in the absence of government subsidy. As shown in Table 1, Government financing and support still dominate the industry, as the leading source of finance.[8]

Government support is also looked at favourably by the financiers, whether it is in the form of PPA, government equity or government guarantee. Examples of different forms of government support include the U.S. Department of Energy's loan guarantee, for Vogtle nuclear power project of $6.5 billion [16], the UK Government's 35-year CfD for Hinkley Point C and the cooperation agreement with Hitachi and Horizon Nuclear Power to promote external financing for Wylfa nuclear power project [17].

On the other hand, nuclear power has low fuel and operational costs. According to the costs estimates of the U.S. Energy Information Administration (EIA), the variable operational and maintenance (O& M) costs of advanced nuclear are about 13% of the total levelized cost, based on 2020 costs projections [18].

2.2. The impact of Fukushima

Prior to Fukushima, the global financial crisis of 2008 had a significant impact on all large-scale infrastructure projects. The lack of liquidity in the financial markets made financing difficult for

[4] In the United States, for example, several reactors have been prematurely shut down because they cannot compete with the low natural gas prices [5]. A former staff of the U.S. Nuclear Regulatory Commission has argued that nuclear power has become so uncompetitive that market forces will phase out the US nuclear fleet by mid-century [6].

[5] Like the UK's Contract for Difference (CfD) system which provides price guarantee (eg., like Hinkley Point C price guarantee of £92.5/MWh, for 35 years), which is vital for the financial viability of the project [7]. Government support is required because of the current design of the electricity market in the UK, where short-term price signals prevail, with no new base load asset been built in the UK for many years.

[6] Westinghouse, and the operator, Georgia Power, have sued each other for nearly a billion dollars, with each blaming the other for delays and cost escalations.

[7] The term "overnight" capital cost generally includes the Engineering, Procurement, and Construction (EPC) costs, owner's and contingency costs but excludes interest during construction cost, escalation and inflation cost, as if the plant was being built overnight.

[8] Government Financing can take various form, including, State Budget (like, tax revenue), Export Credit agency Finance (ECA), Government Equity (Direct equity or Independent Public Offering), Government loan, PPA (Power Purchase Agreement) and Issuance of Government Infrastructure bonds. Vendor financing can be either equity or debt.

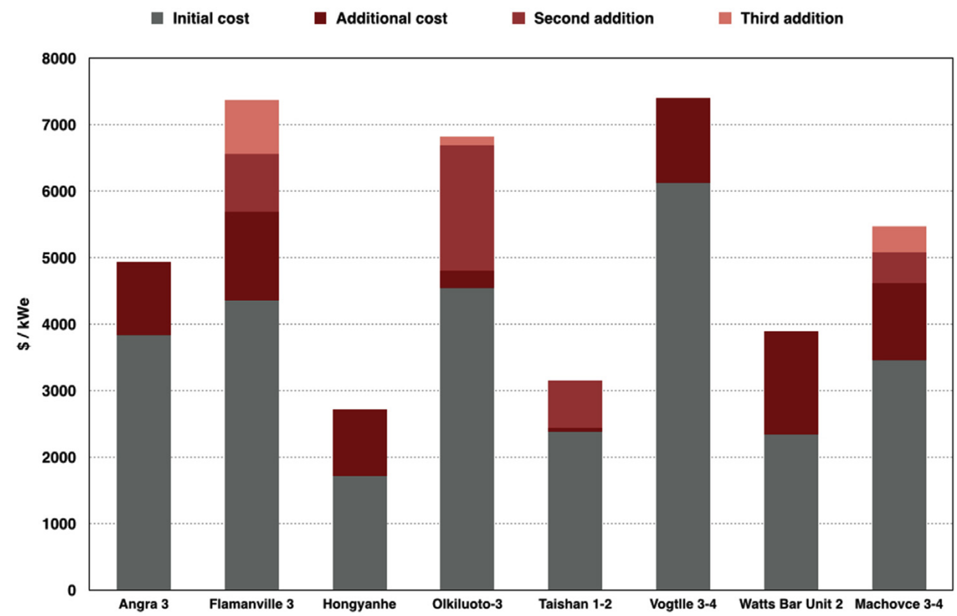

Fig. 1. Revised investment cost estimates, $/kWe.
Source: World Nuclear News, Nucleonics and other publications, 2008–2015.

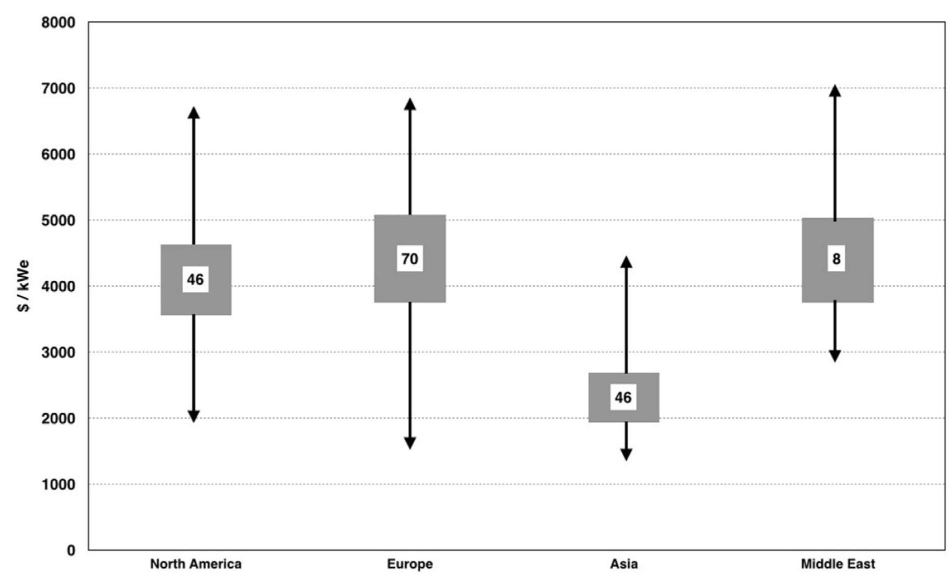

Fig. 2. Overnight cost range, by region, $/kWe.
Source: Source: Various publications, 2008–2015.

most capital-intensive projects. This, along with fears of another recession, austerity measures, sovereign debt crisis, slow global growth and low electricity demand, coupled with low gas prices, made the economic case of nuclear very challenging.

The Fukushima disaster was another major setback to the nuclear industry. Not only affecting public acceptance of nuclear power negatively, but also increasing investment costs due to additional safety enhancement [19]. A subsequent result was pushing for higher emphasis on nuclear safety systems, particularly the potential effects of external factors. Consequently, some countries scaled down and postponed nuclear power projects. Other countries decided to exit their nuclear programs (Germany, for example). While others like China, Republic of Korea, India, UK, Belarus, Russia, UAE and Pakistan, decided to proceed with their plans to build nuclear power reactors.

In some countries, Fukushima also had an impact on the economics of nuclear power. Revising licensing procedures and adopting more stringent safety measures such as conducting more tests [20], led to increased capital and operational costs. In countries where building nuclear remains an option, governments shifted their interest completely to Generation III or Generation III+ reactor as a result of seeking designs that offer better safety features. In some respects, Fukushima was also a stark reminder that nuclear safety is very important and such events in one country would have an impact on the industry as whole.

Table 1
Reactors currently under construction and their financing mechanisms, as of 5 March 2017.

Country	Units	MWe (net)	Construction Start	Financing Type/Model
China	22	20,500	2009–2015	Government/Vendor
Russia	7	5520	1983–2010	Government
India	5	2990	2002–2011	Government/Vendor
USA	4	4468	1972–2013	Government/Private sector
UAE	4	5380	2012–2016	Government/Vendor
South Korea	3	4020	2008–2013	Government
Pakistan	3	2343	2011	Government/Vendor
Belarus	2	2218	2013–2014	Government/Vendor
Japan	2	2683	2007–2010	Government/Other
Slovakia	2	880	1985	Government/Corporate Finance
Ukraine	2	2068	1986–1987	In process
Argentina	1	25	2014	Government
Brazil	1	1245	2010	Government/Vendor
Finland	1	1600	2005	Government/corporate Finance/Project Finance (Mankala Model)
France	1	1600	2007	Corporate Finance

Source: IAEA-PRIS for construction data. The data on financing mechanism are from various publications, World Nuclear News, Nucleonics, Reuters, WNA country profiles, and authors' opinion

2.3. Basics of financing: equity and debt

Nuclear power projects can be either financed though debt and or equity. Generally, financing involves a combination of both with varying proportions, depending on project's circumstances and the risk profile. Debt financing involves obtaining loans from financial institutions for the project.[9] In this case, lenders would receive regular payments with interest, which would depend on the project structure, owner risk profile, including credit rating of project owner and/or developers. On the other hand, equity financing involves investing in return for a share of the project's profits. In this case, equity holders would obtain the return on their investments through the sale of electricity when the reactors are operational. The cost of equity is higher as investors are exposed to higher risks than lenders. However, if the business was not generating sufficient cash, lenders could also miss debt service.

Since nuclear power projects use a combination of debt and equity financing, the investment cost of these projects can be calculated using the weighted average cost of capital (WACC), defined as:

$$WACC = \frac{Debt}{Debt + Equity} Rd + \frac{Equity}{Debt + Equity} Re$$

where Rd is the cost of debt finance; and Re is the cost of equity finance.

If the Capital Asset Pricing Model (CAPM) is used to calculate WACC, the risk free rate and the risk premium determine the cost of debt (Rd), whereas the risk free rate, risk relative to the market (beta) and the market rate of return (also known as equity risk premium) determines the cost of equity(Re).

WACC represents an appropriate discount rate, which can be used to calculate the net present value (NPV) of cash flows.[10] By definition, the WACC is the weighted sum of the interest rate paid or the cost of debt to lenders and the expected return on investments (the cost of equity) to equity holders in the project. Because of the capital-intensive nature of nuclear power, project costs are sensitive to interest rate. Consequently, a small change in the debt and equity balance, i.e. in the WACC of the proposed project, would have a significant impact on the levelized cost of electricity (LCOE).[11]

Due to capital markets risk perception of nuclear power, its cost of finance is higher. Consequently, with risk premium of x percent above other power generation assets added to the interest rate, the WACC for nuclear can be expressed as:

$$WACC_{nuclear} = WACC_{other\ power\ generation} + x\%$$

3. Major risks and financial risk management

3.1. Complexity and capital cost

The enormous scale of overnight capital cost quoted for nuclear power plants, ranging from $2 billion to $9 billion, is a significant investment commitment. It is very challenging for the 45% of the countries reporting their Gross Domestic Product (GDP) to the International Monetary Fund (IMF), with GDP below $20 billion, to invest in a project worth one third of their GDP. Financing nuclear projects becomes even more challenging for governments with gross debt to GDP of more than 50%, as it may affect their credit rating and the cost of finance.

The LCOE of nuclear power plants is thus influenced by the initial high up front capital cost, which could account for 70 to 80% of the total annual levelized cost. The remaining costs are fuel cost (including uranium enrichment), operation and maintenance cost, and decommissioning and waste disposal cost. There are multiple reasons for nuclear power plants to have high overnight capital costs: first, they are very complex structures with many hundred thousands of components that have to be designed and manufactured with very high standards to cope with sensitive and difficult operational conditions, such as high pressure and irradiation. Second, accidents at nuclear facilities, particularly those of far-reaching impact such as Three Mile Island, Chernobyl and, more recently, Fukushima, have contributed to enhancing safety systems by adding another layer of defense or complexity, leading to further increase in cost. For example, EPR designs rely on the concept of “redundancy” where multiple identical “trains” of critical components exist to reduce risk of failure [21]. This results in increased

[9] Debt can also be raised through capital markets through the issuance of long-term infrastructure bonds.

[10] From an investor's point of view, one would want the internal rate of return (IRR) of a project to be higher than WACC to invest.

[11] LCOE is a conventional way to compare the cost of electricity generated by different sources. It follows from the standard discounted cash flow methodology, which accounts for the time-value of money. LCOE is used to calculate the life cycle cost of producing electricity, and is the ratio of the total cost to the benefits (in this case the electricity produced) with all figures being discounted to the same baseline year.

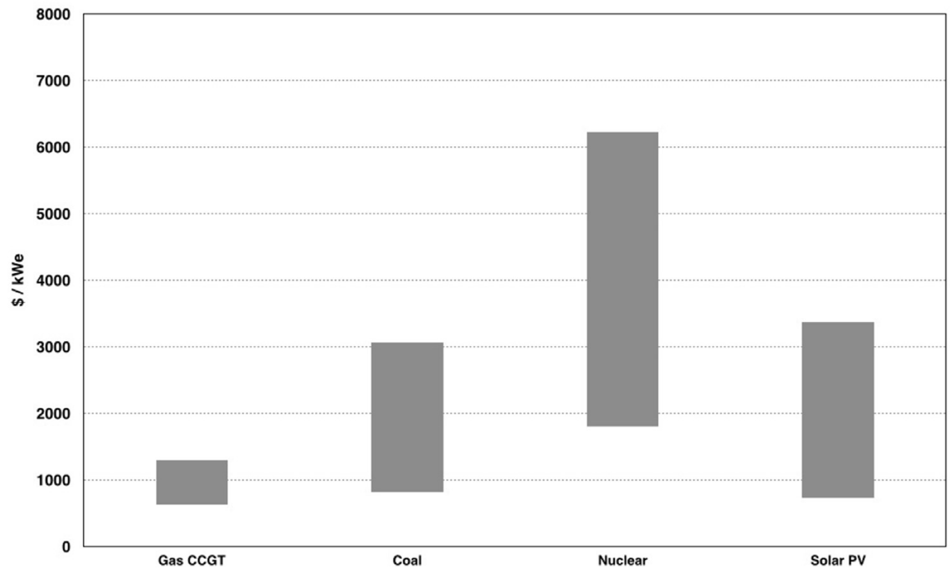

Fig. 3. Overnight capital cost range, by technology, $/kWe.
Source: OECD overnight capital cost range for capital costs of natural gas combined-cycle (CCGT), coal, nuclear and solar PV and power plants, refer to OECD Projected Cost of Generating Electricity, 2015.

number of components, complexity and, eventually, capital costs.

The lower range of nuclear power costs, as discussed earlier, are reflective of the Asian region, mainly depictive of China's nuclear power plant projects ranging from $1800-$2600/kWe. As shown in Fig. 2, China appears to be a global leader in nuclear new build, with nuclear power projects built at significantly lower costs than those built elsewhere in the world, particularly in Europe or in the U.S. Some of the main reasons for China's ability to build nuclear power plants at relatively lower cost include high level of localization, i.e. heavy and complex reactor components being manufactured domestically, lower input cost (materials, equipment and labor costs), lower foreign exchange exposure and (recent) consistent experience. One should be cautious when the overnight costs are compared across different regions and countries, as differences prevail, because each project is unique and the cost differ by the type of technology, the size, site, known technology, FOAK, localization rate, etc. In addition to this there are definitional issues: are overnight costs quoted consistently? Do they entail EPC, contingency and owners cost? or only include some ingredients of the overnight cost.

On a per kilowatt basis, the capital cost of advanced nuclear power plants, according to the U.S. EIA, is $4646/kWe. While solar PV plants and advanced gas combined-cycle have capital costs of $3123/kWe and $942/kWe, respectively. These numbers are consistent with the overnight capital costs range of nuclear, gas (CCGT), coal and solar PV that are shown in Fig. 3, and based on 181 plants across the globe [22].

3.2. Sensitivity to discount rates

As a direct result of being capital intensive, nuclear power projects are sensitive to discount rates. Although other energy sources such as utility-scale solar or wind are also capital intensive, investors may request higher returns when considering nuclear power projects due to the higher risks involved. Specifically, construction delay, which is rated as the highest risk in the industry. For the risk premium to be revised downwards, the nuclear industry needs to build more projects on time and within budget.

Due to the high upfront capital cost for nuclear, as shown in Fig. 4, the total LCOE generated by nuclear power increased by about 90% when the discount rate increased from 5 to 10%, while that of natural gas increased by 38%. The various assumptions used to estimate the costs are listed in Table 2.

Factors that could affect interest rates include credit rating of the borrower, be it a governmental entity or a private utility, as well as country and project-specific risks. Countries with credit ratings below investment grade rating of BBB-, BBB- and Baa3, according to Fitch, Standards & Poors and Moody's, respectively, would find it more difficult to borrow funds i.e. are likely to pay higher interest rates and consequently suffer a higher cost of finance.[12]

3.3. Long lead times

Lengthy lead-time is one of the main drivers of cost escalations in nuclear power projects. In addition to construction time, lead-time includes the time required for the complex technical and financial planning as well as the time needed to complete licensing procedures. According to the World Nuclear Industry Status Report, the reactors currently being built have been under construction for an average of 7.6 years, as of July 2015 [23]. Historically, experts argued that learning has generally led to building bigger and more complex nuclear reactors, increasing lead-time [24]. This is more applicable in the case of FOAK designs that can add up to 35% to the overnight cost [25].

In a recent empirical study based on data from the U.S. and France's nuclear reactor programs between 1966 and 2002, M. Berthlem and L. E. Rangel concluded that lead-time is linked to the degree of heterogeneity of the reactor fleet. High level of standardization seems to reduce lead-time, and consequently, capital costs [26]. However, the effect of learning in nuclear power projects, particularly that of France, in the 1970s and 1980s is debatable. A. Grubler presented a case of “negative learning” where specific costs increase with accumulated knowledge [27]. The reason for such a trend was new safety and quality standards,

[12] Investment grade depicts that the country or company has manageable debt and is able to meet its future obligations to repay debt.

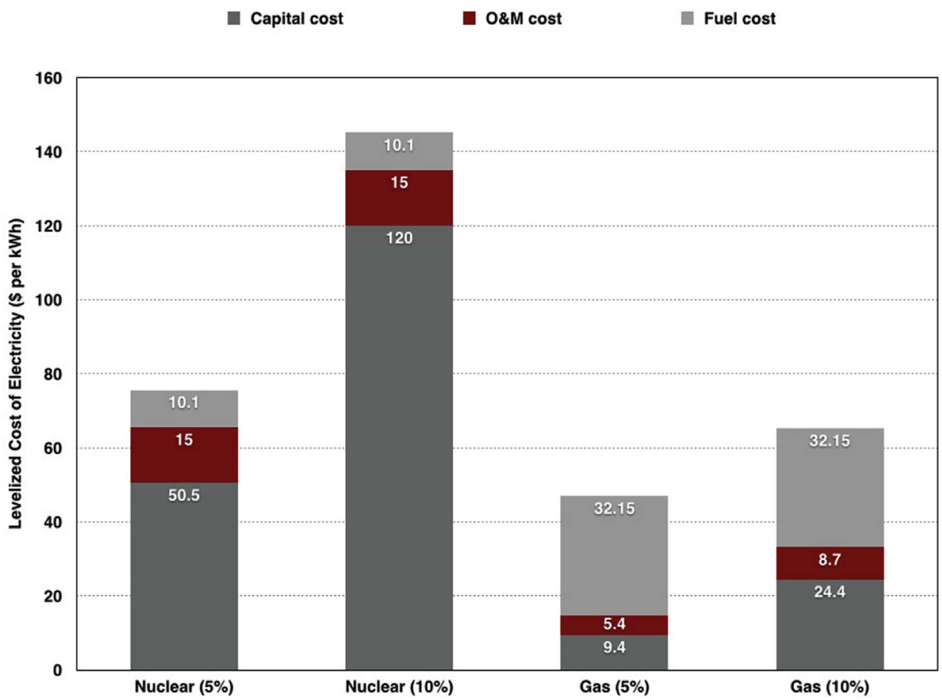

Fig. 4. Effect of varying discount rate on the LCOE for nuclear and gas-fired power plants.

Table 2
Assumed parameters used to estimate LCOE.

	Nuclear	Natural Gas
Unit Capital Cost ($/kW)	$4646	$910
Fixed O&M ($/kW-y)	$93.28	$15.37
Variable O&M ($/MWh)	$2.14	$3.27
Heat rate (BTU/kWh)	10458	6430
Gas used (mmBTU/MWh)		6.43
Gas cost ($/mmBTU)		$5.00
LEU Fuel Cost ($/kg)	$3211	
Fuel consumption (kg/kWh)	3.15E-06	
Economic life (years)	60	40
Capacity Factor	90%	90%
Auxiliary Consumption	8%	8%
Discount Rate	5 and 10%	5 and 10%

integrated retroactively in ongoing projects. Regardless of the type of relationship between learning rate and the lead-times, the financial impact of long lead-time is higher in deregulated markets, where private investors do not have the financial strength to bind their capital for such long periods.

3.4. Other risks

In addition to the aforementioned economic challenges of nuclear power there are some other risks that also affect the economic competitiveness of nuclear power against other energy sources. Decades—long payback periods, for example, add extra disincentive for investors as they would increase likelihood of exposure to unfavourable market conditions and policy shifts over a prolonged period of time.

Hence, investors would either have to assume a lower availability and/or ask for higher returns, due to the despatch risk, or request long-term electricity contractual arrangement, such as CfD, as a risk mitigation measure due to the volatility in the wholesale electricity market. The price volatility increases with growing shares of intermittent renewable generation, as has been the case in Germany.

In some countries, investors are trying to request for market reform or lobbying for green credit for nuclear to provide a "level playing field" with other subsidised carbon-free technologies and make it more competitive with fossil power generation. In regulated markets, long-term electricity purchase guarantees provide a risk mitigation measure to curtail despatch risk.

Another issue is the risk associated with volatile foreign exchange rates. This is of particular importance when governments seek foreign investments and/or when large and expensive equipments are imported such as the case with many parts of a nuclear power plant. Put simply, the foreign exchange risk results due to unfavourable variations in the exchange rate. Since the electricity generated by nuclear power plants is sold domestically, the major foreign exchange risk emerges from financing rather than the project itself [28]. For example, loans in foreign currency carry such risks in case domestic currency depreciates against the reference foreign currency.

3.5. Risk mitigation management

A robust financial risk management strategy is imperative for nuclear financing. Well-structured nuclear projects, where risks identified upfront, allocated, with proper risk mitigation strategy, pose less uncertainty to financiers and are relatively easier to finance. Tables 3 and 4 below provide examples of major risks involved in nuclear power projects during planning, construction and operation phases, respectively. The table shows a simple formulation of a financial risk management matrix, which, first, identifies the risk (name of the risk), second, states the nature of the risk (pure or speculative),[13] third assesses the risk (high, medium

[13] Pure risk is an absolute risk, while speculative risk is something that may or may not happen.

Table 3
Financial Risk Management Matrix: Planning and construction phase risks.

Name of Risk	Nature of Risk	Risk Assessment	Risk Allocation	Risk Mitigation
Construction delay/Project Manag't	Pure	High	Owner/Main contractor	Qualified third party contractors/PMC
Construction delay/Licensing	Speculative	Medium – High	Owner	Independent Regulatory Body and have good communication with the Regulatory
Non Delivery or delay due to low capacity of the vendor to supply equipment	Pure	High	Main contractor	Selection of qualified supplier with good track record/contract clause liquidation damages/Third party monitoring
Credit risk (Loan disbursement schedule)	Speculative	Medium	Owner/Lenders	Well defined loan agreement
Credit risk/foreign exchange (currency)	Speculative	High	Owner/Lenders	FX hedging strategy
Interest rate risk	Pure	High	Owner/Lenders	Fixed rate loan
Escalation cost	Pure	Medium	Owner/Main contractor	Vendor contractual agreement – cap the cost/detailed sources by country
Commodity price	Speculative	Low	Owner	Hedging strategy/Target pricing with contractor
Lack of skilled staff	Speculative	Low	Main contractor	Fixed Price Turnkey Contract
Technology changes to design	Speculative	Medium	Owner/ contractor	Contractual arrangement with vendor

Table 4
Financial Risk Management Matrix: Operations phase risks.

Name of Risk	Nature of Risk	Risk Assessment	Risk Allocation	Risk Mitigation
Performance	Speculative	High	Operator	Qualified operators agreement at a certain performance rate
Electricity price	Speculative	Low	Owner	PPA
Fuel Supply	Speculative	Medium	Fuel Supplier/contractor	Long term fuel supply contract/agreement
Safety	Speculative	Medium	Operator/Owner	Tested design
Spent Fuel Management	Pure	Low	Owner/Fuel Supplier	Govt. TBD after the bid approval process is complete
Regulatory Compliance	Speculative	Medium	Owner/operator	Agreement with operator
Foreign Exchange	Speculative	Medium	Owner/Off-taker	PPA linked to Foreign currency
Third party Force Majeure	Speculative	Medium	Owner/All contractual parties	Agreement with third party

Note: Electricity price risk is low for regulated utility environment with PPA and high for deregulated market.

and low), fourth, allocates risk (who takes the ownership of the risk) and finally, possible risk mitigation strategy (how the risk could be managed). In the planning and construction phase, one of the most highly rated risks is construction delay. Cost increases (not only due to delays, but also due to increase in cost of materials, staff, etc.) are also a major source of risk. The most highly rated risks are: construction delay due to poor project management; supply chain risk; credit risk due to foreign exchange exposure; and interest rate risk. Risk allocation is based on the type of risk. For example, construction delay risk is shared between the owner and the contractor, with mitigation measure to employ a contractor that is experienced, and with a good track record of delivering projects on time.

Table 4 lists some examples of operational phase risk, where the most highly rated risk is the performance risk, which concerns the despatchability of the plant, ensuring the generation of electricity as per the agreement to contribute to generating cash flow. This risk is allocated to the operator, depending on the contractual arrangement in place. The other risks like fuel supply, spent fuel management, and regulatory compliance risk are also listed.

4. Government financing

Traditionally, governments have invested public sector funds from the tax revenue and electricity tariff charges to finance nuclear power projects. Governments may also have equity ownership, as an equity owner in Joint Venture (JV) agreements. One example is the Taishan nuclear power project in China, a JV between China General Nuclear (CGN), a China Government owned company, with an equity stake of 70% and the French Government owned company EDF (Électricité de France), with 30% share, to co-own and operate two EPR. This cooperation has been extended to the UK Hinkley Point C project, where EDF and CGN have 66.5% and 33.5% shares, respectievly [29].

In both cases, the main suppliers are French and Chinese government owned companies (Areva CGNPC,[14] others), where debt is provided by international banks and ECA, with the overall support provided by the UK, French and the Chinese governments. EDF and CGN have also agreed on a wider UK partnership for the joint development of new nuclear power stations, at Sizewell in Suffolk and Bradwell in Essex, to promote their respective technologies in the UK market. At this stage, the form of government support is not known for these future projects.

In case of lack of national budget resources available to build nuclear power plants, governments may opt to build equity. There are many ways that a government can create equity, for example, it can pledge receivables from creditable government-owned industries. Other examples of possible government funding mechanisms may include:

- Additional cost recovery rates (to fund nuclear projects) or surcharges on electricity sales;
- Use of national funds (for example infrastructure funds or postal savings);
- Creation of a government-run private bank to help finance “clean energy projects” (including nuclear);
- Banks to finance infrastructure; and
- Asset pooling (in countries or by utilities with other significant power generation assets).

Governments can also provide support and incentives to

[14] China General Nuclear Power Corporation.

support energy projects. Examples of such incentives and support are discussed below:

4.1. Loan guarantee

Examples of governments providing loan guarantee include the U.S. Department of Energy's loan guarantee for Vogtle nuclear power project of $6.5 billion and UK's guarantee scheme for infrastructure projects. Other examples of UK Government's support are: the loan guarantee for the Wylfa nuclear power project, an agreement between the UK Government with Hitachi and Horizon Nuclear Power to promote external financing; and also initial UK Government's guarantee for Hinkley Point C of £2 billion [30]. However, the British loan guarantees need certain conditions to be met, and these reportedly include seeing Flamanville operate by 2020 [31]. EDF, however, has decided not to take the 2 billion loan guarantee [32].

4.2. Guaranteed long term electricity contractual agreements

These are generally host government-backed power agreements like the PPA, where the host country utility enters into a long term agreement (based on the life of the asset) to purchase electricity from the nuclear power project developer/owner, at an agreed price. This aims to provide revenue stability and long term commitment. Like in the case of Akkuyu nuclear power project in Turkey, the Turkish Electricity Trade & Contract Corporation (TETAS) has an obligation under a 15-year contract to buy a fixed proportion of power at a fixed price of US$ 12.35 cents/kWh from the project company. This pertains to the 70% of the output of the first two units and 30% from units three and four. The non-contracted power will be sold by the project company in the open market. The revenue from the PPA will pay for the project cost (expected to be paid off in 15 years), after which the project company will pay 20% of the profits to the Turkish government [33]. In Canada, in the case of Bruce Power nuclear plant, the secure long-term cash flow from the PPA will allow Bruce Power to proceed with its long-term refurbishment program, like investing in life-extension activities for Units 3–8 [34].

In the case of the UK's Hinckley Point C, a long-term electricity contractual agreement (Contract for Difference (CfD)[15] for 35 years) at £92.50/MWh, between EDF Energy and the UK Government, will also guarantee cash flow for the project [35]. The agreed CfD is very important for the financial viability of the project. The long-term electricity price purchase contractual arrangement reduces the electricity market risk, in terms of both price and volume, specifically in deregulated electricity markets, which is vital for risk averse investors. Since most of the previous nuclear plants were built in regulated markets with long-term contracts and price stability (like the nuclear new build in China, Pakistan, India, Russia or the UAE), the change in the structure of electricity markets to semi or fully deregulated markets, with competition among power generations, has amounted to regulatory market risk. Investors want long-term electricity price guarantees, as it plays a decisive role in the commercial and financial sustainability of nuclear power [36].

4.3. Export credit agency (ECA) financing

ECA, also known as trade finance, it provides financing services such as guarantees, loans and insurance to support domestic companies for their activities overseas, in order to promote exports in the domestic country. This type of finance has been generally very important for nuclear power projects as it is a key long term financing debt instrument, with attractive fixed interest rates. Fig. 5 shows the ECA mechanism, where a local bank[16] provides loan to the foreign buyer, under the ECA cover, and makes payment on delivery to the exporter. The foreign buyer makes loan repayments to the bank over time, based on the agreed term and loan amount. Examples include the France-Coface loan to Finnish utility TeollisuudenVoima (TVO), for the Olkiluto-3 project in Finland. Another example is the Government-to-Government loan, an export credit of $10 billion given by the Russian Government to support the Belorussian VVER (Russian technology) to finance the nuclear power project [37].

5. Private financing

Government financing and/or support, in both the developed and developing countries, is one of the leading financing approaches. However, restrictive funds and the sovereign credit pressure after the global financial crisis has put more burden on government resources. Governments are increasingly looking to the private sector to co-finance new infrastructure investments, including large scale capital intensive asset like nuclear power plants. Why?

- A recognition that public funds are insufficient to meet the capital intensive infrastructure requirements like nuclear power as governments are under severe fiscal pressures to use the resources for high priority social sector programs, like health and education;
- Increasing acceptance of the principle that the beneficiaries of a project should pay for it rather than taxpayers as a whole; and
- A recognition of the greater incentives for efficiency and expertise in innovation, design, construction and operation that the private sector can bring based on the market demand, The principle of “best value for money” is assumed to be embedded in private sector participation.

Private sector finance can take various forms, ranging from corporate finance to project finance, but pure project finance or non-recourse finance is still not available for nuclear. Project finance or non-recourse financing has been increasingly used to finance large scale non-nuclear energy power projects, where a special purpose vehicle (SPV) entity is formed to build the power plant. As the SPV entity does not have a credit track record, lenders only have limited recourse and hold the pledged project assets and rely on the future cash flows generated by the project company, for the loan payments.

The private financing models that have been employed or that are emerging in the nuclear industry are discussed below, these span from corporate finance models to risk diversification financing models. It should be noted, however, that these models only reflect some signs of the shift towards more private sector participation; project finance remains unavailable for nuclear power projects due to the various risks mentioned earlier.

5.1. Corporate finance

Utilities with robust balance sheet have employed corporate

[15] A CfD is simply an agreement between two parties – the investor and the CfD provider – to pay each other the change in the price of an underlying asset. Depending on which way the price moves, one party pays the other the difference from the time the contract was agreed to the point where it ends.

[16] In general, the lender(s) is (are) a commercial bank(s) which has (have) a strong relationship with the exporter, rather than a local bank (e.g. a bank from the host country).

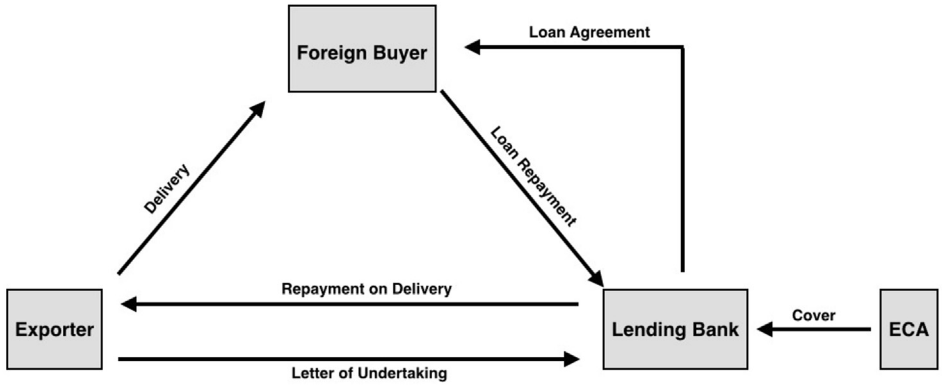

Fig. 5. Government Financing: ECA financing mechanism.

finance or balance sheet finance, where a company borrows or raises financing (through debt and/or equity) against the assets of the company, as a whole. The bank or the bond holder provides funds to the company, and it has a claim against the company's whole cash flows, unless the loan is secured against a particular asset, as is common for mortgages. The risk of the investment is then borne by all providers of the capital to the company. An example is Flamanville 3 project where EDF, the French electric utility company, largely owned by the French Government, using corporate financing, has financed the construction of Areva's third-generation EPR, with 1650 MW capacity, in France. The original cost estimate reported in 2007 was €3.3 billion (in 2005 values). However, cost overruns of more than €4 billion, with revised project cost estimates of €10.5b (September 2015) and excessive project delays, have been a big setback for the project.[17]

The industry is cognizant that even a company like EDF needs to utilize a risk diversification strategy, specifically when it is venturing into a FOAK technology, which can add up to 30% to the cost of a nuclear power plant [25]. The credit rating agencies have pointed towards risk diversification, advising companies that if they want to avoid any downgrades, it is important that they change their financial policies, have partnerships, and/or strengthen their balance sheet to curtail any credit pressure. Some companies have taken on the credit rating agencies advise, like Duke Energy, merging with Progress Energy in July 2012, thus strengthening its (Duke Energy) balance sheet to form the largest US utility, with a market capitalization of more than $50 billion [39].

Cognizant of this fact, the utility industry and the financial sector have devised some alternatives to invest in nuclear projects to diversify risk. Some of these financing models are discussed in the following subsection.

5.2. Mankala financing model

Generally when a group of investors jointly invest in a project to raise debt and equity to fund a project, it can be categorized as investor financing model. Debt can be raised as a loan from commercial banks, and/or ECAs or by issuing bonds by tapping into the capital markets, etc. Investors also provide equity, as shareholders, or raise equity by issuing shares (initial public offering).

One example of investor financing is the Mankala Model. This type of model is also called cooperative model and is popular in Finland's electricity sector. In the case of the Mankala Model [40], there are several interacting parties that share the risk, this includes the Mankala Company (or the nuclear developer), lenders, shareholders and the Engineering, Procurement, and Construction (EPC) contractor, see Fig. 6.

The lenders provide the Mankala Company the loan for the construction of the nuclear project and in return, receive debt service payments, by the shareholders. Portion of the project equity and loans are provided by the large power customers, who have long-term power purchase agreements with the project company, which ensures a stable future revenue stream from the project. The Mankala Company does not aim to make a profit, and the shareholders do not receive dividends. The Company owners benefit by using the electricity or selling it forward, in the electricity market.

In Finland, the Mankala model is applied in the case of Olkiluoto-3 project, which is currently under construction. The financing model has the characteristics of hybrid financing (corporate finance and project finance). The project is financed partly through the balance sheet of TVO with leverage characteristics similar to project finance, 75% debt financing and 25%, equity financing. Some equity is provided by the large electricity customers, that have long-term PPAs with the project company, and receive the rights to the electricity produced. The construction risk is shared between the Mankala company and the EPC contractor, who is assigned to construct the nuclear power plant and signs construction contract with the Mankala company. In addition to this, the project also has export credit guarantee by the French and Swedish Governments to support the company by providing funding at very attractive interest rates, reducing the cost of financing. Hence, in general the Mankala Model, with multiple investors is a good model to diversity project's risks.

Another example is Fennovoima, in Finland, with Shareholders Rosatom (34%) and a consortium of Finnish power and industrial companies (66%) with 69 shareholders (mostly small regional and municipal utilities and also industry, like trade, mining and steel manufacturing), to construct and finance the Hanhikivi nuclear power plant. An agreement with the Russian state nuclear company, Rosatom, is signed to build the AES-2006 VVER Russian technology, initially funding more than $2 billion using ECA financing, along with other loan to support its technology [41].

The Mankala model is so far implemented in Finland, however countries in Europe have expressed interest in adopting the

[17] The cost overruns and construction delay has led to some serious financial stress for the company, having an impact on the company credit rating, as Moody's downgraded EDF to A1 from Aa3, with negative outlook [38]. Other reasons that contributed to EDF's downgrade include the need for EDF to spend between €55 billion and €100 billion, for an upgrade of their nuclear fleet within the next 10–15 years. The credit downgrade has led to further fueling of investors' negative sentiment, with a sell-off of EDF shares, resulting in a share price plunge of 50%, since January 2015 and decline in the company market capitalization. (Reuters, 15 January 2016).

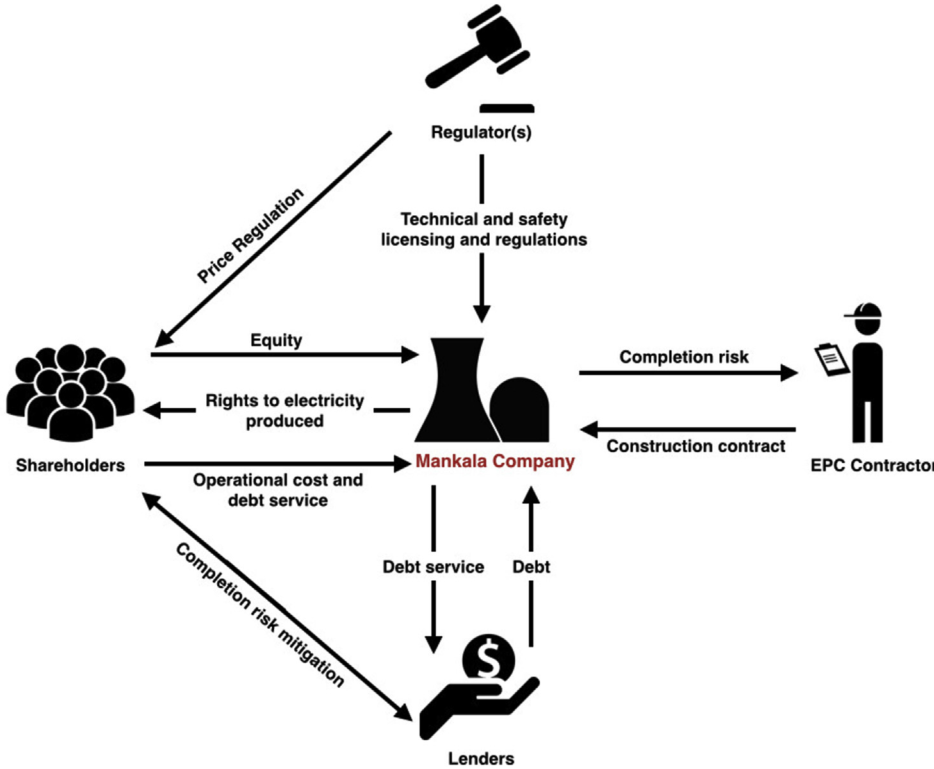

Fig. 6. Investor Finance Model: Mankala Model and risk diversification.

Mankala model, as a risk diversification strategy.

5.3. Vendor financing

Owners are increasingly perceived to be more inclined to build nuclear power technology backed by vendor financing. Having recognized owners' sentiment and the market trend, most of the vendors are considering this possibility. Vendor financing is based on vendor's financial standing and market demands. It can be achieved either through debt financing, where vendors provide credit by borrowing from the banks (generally as a liability on its balance sheet) or arranging for the loan or credit, through the lenders or banks to fund the project. An example is Rosatom 30 year interstate loan of €10 billion, for the Hungary New Paks project, to builds two units of Russian VVER units, adding 2400 MW capacity at Paks plant. The loan covers 80% of the anticipated project cost, with a loan repayment plan, spanned over 21 years of plant operation.

Another example of vendor financing are: China National Nuclear Cooperation loan of $9–10 billion to the Pakistan Government (Pakistan Atomic Energy Commission) to build two ACP1000 reactors (Chinese technology reactors) to add 2200 MW capacity to the Karachi Coastal nuclear power project [42]. In most of these projects, the governments of the exporter of the technology are very much involved in the transactions, hence requires government support. In some instances the borderline between "vendor financing" and "government-to-government financing" is very fine. Vendors have also put a direct stake in the nuclear power projects, by providing equity. As a shareholder, this can be expensive, as the cost of equity is higher than the cost of debt, so can add to the financing cost of the project. An example is a potential Bulgarian, Kozloduy-7 nuclear power project, with 30% equity by Westinghouse and 70%, by the Bulgarian Energy Holding [43].

Some vendors are termed as strategic partners, like in the case of Jordan, where Russia's Rosatom Overseas will be a strategic partner and operator of the plant, financing $10 billion of the project. The strategic partnership structure, Rosatom 49% and the Jordanian government 51% [44].

Given that vendors have limited balance sheets, some vendors are opting for further risk diversification strategy, by forming consortia. An example is the potential Turkey Sinop project, where a group of vendors (Mitsubishi and Itochu, and France's Areva and GDF Suez) are to provide 70% debt financing and 30% equity finance for the Sinop Atmea-1 reactors. The Atmea-1 is a FOAK designed for load-following and using the same steam generators as that of Areva's large EPR. Of the total equity, the consortia will take an equity stake of 65% and the rest (35%) by EÜA, the Turkish Electricity Generation Company [33].

5.4. Raising finance through capital markets

Owners and investors are also tapping into the capital markets to raise financing to fund nuclear power plants. These have been either raising debt by the issuance of bonds or issuing shares and raising equity. Like State-owned China Guangdong Nuclear Power Holding, offshore yuan bond, raising CNY1.5bn ($240m) via a three-year bond at 3.75%, rated as A+/A3 by Fitch & Moody's [45]. Other examples are Tepco raising $2 billion in private-placement bonds from lenders [46], Korea Hydro and Nuclear Power issuing $750 million in bonds in September 2012, $500 million in September 2013 and $300 million in June 2015; and China General Nuclear Power Corp issuing $600 million in bonds, in January 2016 [47].

To raise equity, some utilities, owners and vendors are issuing share through Initial Public Offering (IPOs), like Romania's Nuclearelectrica listing, raising €63 million [48], China Nuclear Construction Company to raise $289 million as IPO [49] or in the course

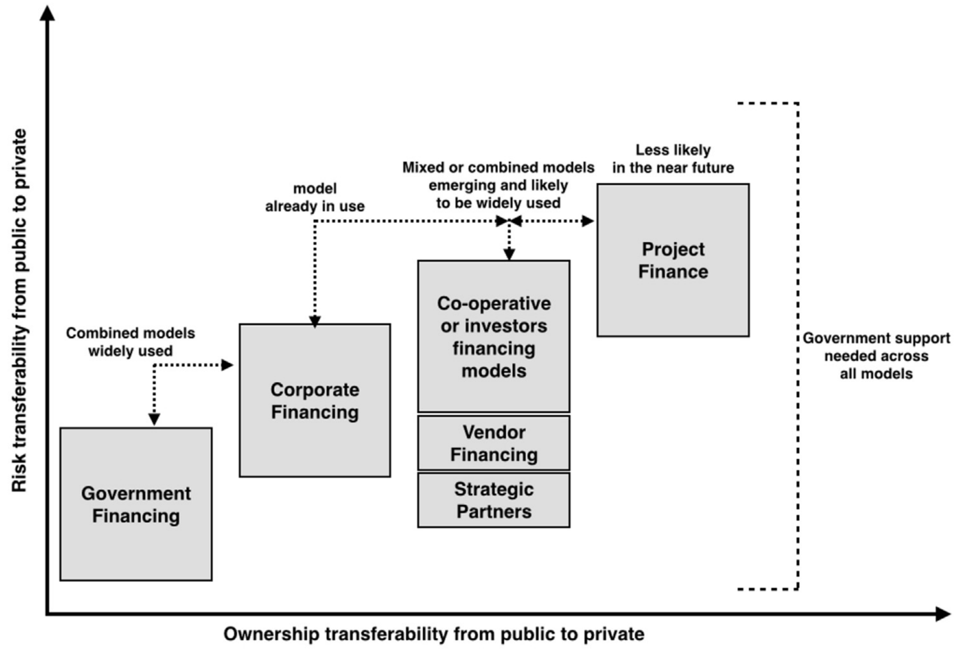

Fig. 7. Emerging trends of nuclear financing models.

of privatisation of state companies like China National Nuclear Power, to raise $3.89 billion of IPO.

Every model varies in risk allocation and ownership transfer ability across the public and private sectors (See Fig. 7). It is envisaged that over time as new plants are build, the combination of investor style financing models might become more apparent in the nuclear industry, where multiple equity partners share the risk. Tapping into the capital markets is another risk mitigation option, either through issuance of corporate bond or offering ownership to strategic and industrial partners through Initial Public Stock Offering.

As stated earlier pure project finance is still not available for nuclear. There were some attempts of project financing in 2009, when new project companies were formed, like Nuclear Innovations North America (NINA), a partnership between NRG Energy and Toshiba to invest in new nuclear projects, in South Texas [50], but NRG withdrew from the project in April 2011, after the Fukushima disaster of March 2011. As the financial industry, started to re-assess the financial impact of the Fukushima event, it looked less favourably towards large scale high risk infrastructure projects like nuclear power projects.

5.5. Phased financing

Phased financing, as shown in Fig. 8, is a mechanism that can be applied to any financing model, discussed above. It may be applicable to the different phases of nuclear power projects, spanning from development and construction to the decommissioning phase. For a nuclear power project, the initial financing phase occurs during the development and construction, which is deemed most risky and has a high cost of finance.

Phased financing pertains to revisiting the financing terms once the nuclear power plant is constructed. Refinancing can take place during the plant's operation and decommissioning, when there is lower risk, and thus, a lower risk premium, associated with the project. The lower risk, after successful commercial operation of the nuclear power project, provides better refinancing opportunities, on better terms and conditions that lowers the financing costs and provides more financing option, as a broader pool of investors could also be tapped. Thus phased financing, can lower the project overall cost of financing in case of successful completion of the nuclear power project.

6. Contractual and ownership arrangements

6.1. Existing contractual approaches

There is a wide range of contracting structures that are available, which can be considered for building nuclear power plants. The selection of the most appropriate contract structure depends on the circumstances, the experience and the capability of the owner/developer when initiating the project. This section discusses the main types of contractual approach applied for nuclear power projects.

6.1.1. Turnkey contract

Under this contractual arrangement, most of the risk and responsibilities are taken by the supplier, which maybe OEM (vendor of the nuclear power project), or a specialised Architect Engineer company, depending on who is best placed to take on the risk. As it has the necessary experience and knowledge about any potential issues that may arise during the construction phase. It can be a single contractor or a consortium of contractors that takes the technical responsibility for the whole nuclear power project. The responsibility of the vendor includes, but is not limited to, engineering, design, procurement, licensing, supply of all equipment, all on-site and off-site fabrication, assembly, fuel loading, testing of all system and final commissioning of the plant. Hence, the lead contractor would be responsible for the performance of the whole scope of the project, from the time the first concrete is poured to the nuclear power plant testing and commercial operation, when the nuclear power plant is tuned over to the operator.

There can be some variants of this type of contract, like some minor works or supply of equipment is provided by local suppliers, but the overall responsibility rests with the lead contactor or vendor. An important distinction is whether the contract is firm fixed price or “open book” (or usually a combination). In the firm

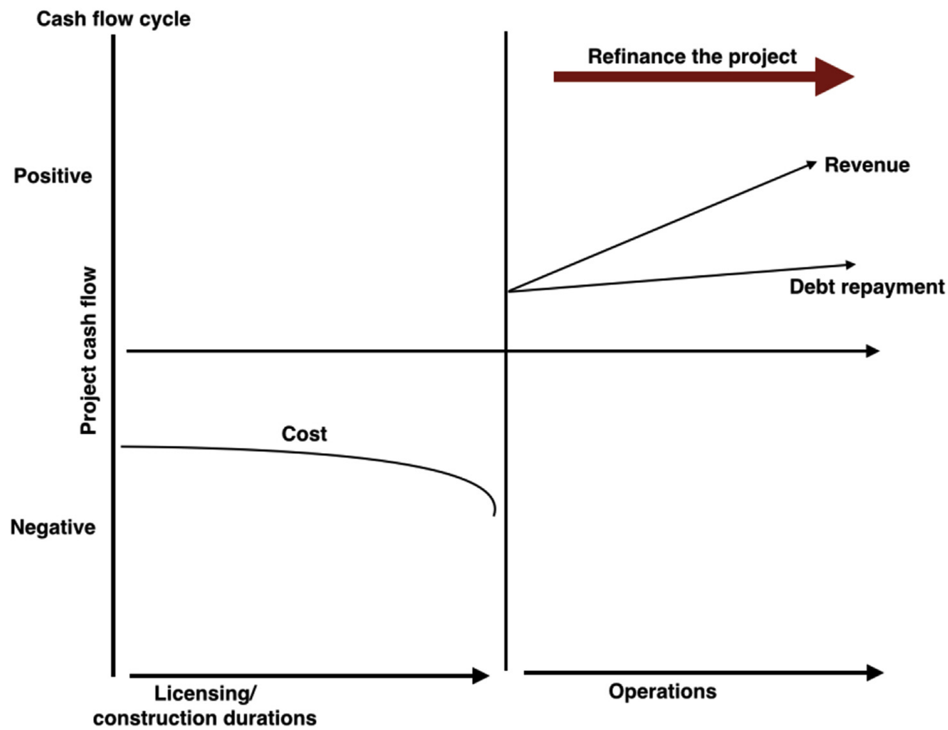

Fig. 8. Phased financing [40].

fixed price case, this type of contract is generally more expensive, as the risk premium of any project contingency is priced-in the cost of the nuclear power plant. The contractor should also have the capability to deliver the project. An extreme example is the case of Olkiluoto-3 project in Finland, where the main contractor is Areva, which, in 2004, agreed to an extremely aggressive schedule and low firm fixed price. The project is behind schedule by several years and has exceeded the budget by several billion Euros. The French Government has already recapitalised Areva with additional funds to survive this situation. Areva being the lead contractor has prime responsibility for the project delivery, it has been disputing partial construction delays and cost overruns with the TVO, asking for compensation, which is not accepted by TVO, who has stated that the contract was agreed as fixed price turnkey contract. TVO has also filed claims for delay. The matter is still unresolved [51], as arbitration is still in progress.

6.1.2. Split-package contract

Under his type of contract, the responsibility to deliver the nuclear power project is divided among few contractors, each delivering a large section of the work. However, the overall responsibility to deliver the nuclear power project rests with the plant owner, which is expected to have experience in the project management of such large scale projects and with nuclear requirements. Usually, the owner will hire experienced Architect Engineer as EPC/M (EPC including management) contractor and or an Owners Engineer to provide the extensive human resources and systems to organise such a complex undertaking (project management, procurement, interface design, etc). The procurement process entails separate procurement of the main parts of the nuclear power plant, typically separate contracts, which are divided into nuclear island, turbine island and balance of the nuclear power plant related investments. These contracts are managed and signed by the owner who is also responsible for coordination among the contractors to deliver and install the nuclear island, the turbine or generator and the balance of the plant. Hence, the key risk is the interface risk, e.g. the management of the interface between many complex contractual arrangements. This type of contract is termed as a split-package contract, as the owner might work with different entities or vendors, based on perceived strength of the contractor.

Under this contract, the owner of the plant can possibly mix parts delivered from overseas (generally nuclear island and turbine generator) and those that can be manufactured in the country, locally produced (like construction works and perhaps balance of plant). This gives the owner more control and the opportunity to optimize between competitive suppliers. However, the owner or a contract manger appointed by the owner, would be required to manage simultaneously, all the contacts and oversee the work, thus seen as more of a managerial role (as opposed to the more monitoring role under the EPC Turnkey structure), in order to ensure the successful completion of the project.

6.1.3. Multi-contract

Under this contract, construction of new nuclear power plant is organised by the owner of the project. The owner is also the architect-engineer, whereby it enters into multiple contracts for various services (engineering, design, and construction) and equipment. There are numerous (hundreds) separate smaller contracts which are managed and signed by the owner, who is also responsible for coordination during preparation and construction. Under this approach, the owner needs to be experienced and have the capability to manage multiple contract. Hence, like the split-package contract one of the key risk is the interface risk, e.g. the management of the interface between many complex contractual arrangements.

The main advantage of this contractual arrangement is that it gives the owner more control of managing the procurement of all equipment. This transparency, may lead to significant cost efficiencies, given the owner knowledge of the supply chain. However, all the risks are borne by the owner, so requires a robust risk

Table 5
Contractual arrangements.

Broad Category	Main variants	Ownership of capital assets	Responsibility of investments	Assumption of risk	Duration of contract (years)
Supply and Management Contracts	Operational/Maintenance Management	Public	Public (O) Public/Private (M)	Public (O) Public/Private (M)	1–5
Lease	Lease	Public	Public	Public/Private	3–20
Concession**	BOT*	Public/Private	Public/Private	Public/Private	15–30
Private Ownership of Assets	BOO	Private	Private	Private	Indefinite

*) Build-Own-Operate (BOT) has many other variants such as Build-Transfer-Operate (BTO), Build-Own-Operate-Transfer (BOOT) and Build-Rehabilitate-Operate-Transfer (BROT). **) Franchise contracts are also a type of concession arrangements with 3-7 years of durations.

management strategy.

This type of contractual arrangement is more suitable for large experienced utilities, with large new built programs. In France, it has been utilized by the French utility EDF for the Flamaville project because it had vast nuclear engineering resources (for managing its operating fleet), prior experience in managing such large-scale nuclear projects.[18] Another example is the United States, where TVA (USA Tennessee Valley Authority), has been responsible for project development and construction, as well as owner and operator role, following the completion of the construction of the nuclear power project. Successful examples are KEPCO and CGN, who have used this approach, but over time have split off some of their competences into specialised engineering and construction subsidiaries.

It is not likely that this approach could be used by an owner who is looking to develop its first nuclear power plant project, since it would lack the necessary expertise. A special scenario is where the newcomer partners with an experienced third party utility, like in Alternative Contracting, discussed below.

6.2. Alternative Contracting and ownership practices

There are also alternative contractual arrangements emerging in the nuclear industry, these are classified as public private partnership (PPP) arrangements. Where, PPPs are a “cooperative venture between the public and private sectors, built on the expertise of each partner, that best meets clearly defined public needs through the appropriate allocation of resources, risks and rewards.” [52] The PPP can take various form, like supply management, lease, concession and private ownership of assets. The concession contracts are generally Build-Operate-Transfer (BOT) and the ownership of assets can be Built Own Operate (BOO), see Table 5.

The BOT and BOO contracts have been very common across a spectrum of industries (water, energy, transport, health, communication, education, etc.) and have been employed across the world. In the case of BOT contract, the project company undertakes the construction, including financing, of a given infrastructure facility, the operation and maintenance. The project company operates the facility over a fixed term and charges facility users (customers) appropriate rates, fees, rentals, etc. The charges are fixed and do not exceed those proposed in the bid or as negotiated to recover the company's investment, operating and maintenance expenses, there is an inflation and escalation factor included and agreed at the time of negotiation of the contract. At the end of the fixed term, the contractor or developer transfers the facility to the government, generally at a pre-agreed price.

Under the BOO scheme the project company is authorized to finance, construct, own, operate and maintain an infrastructure. The project company is allowed to recover its total investment, operating and maintenance costs plus a reasonable return thereon by collecting rate, fees, rentals or other charges from facility users. This type of model is requested by newcomers with limited financial resources, as the nuclear power plant is built, financed, owned and operate by the contractor or vendor. The local content depends on the level of maturity of the industry in the country. Mostly local companies can participate as subcontractors for civil construction part. The operating personnel are provided by the contractor, who must be financially very sound because the investment costs are enormous and the return of capital investment might take more than a decade. Profit by the contractor/vendor is made through purchasing electricity, through a long-term PPA, after connection to the grid.

The BOT/BOO arrangements are becoming more popular among countries that lack the funds to construct nuclear power plants, as one of the attractive features of such arrangement is that the contractor also arranges the financing, which is part of the BOT/BOO arrangement, hence delivers the whole package. Generally, multiple investors, financiers, vendors, etc., form a consortia to BOO/BOT a project for large-scale infrastructure projects, which is important for risk diversification.

The Akkuyu project in Turkey, which started in 2008 with the Russian supplier consortium, is an example of the first BOO project in the nuclear industry (discussed earlier). Another potential example is the Jordan project, to build two 1000 MWe VVER units in Az-Zarqa where the Russian government is providing partial funding. A joint project company is to be established that will own and operate the plant. This will be the first nuclear power plant of this technology in the Middle East region. Through it is early to state, but the agreement appears to have similar characteristics as of BOO arrangement [44].

7. Conclusion and policy implications

The traditional financing methods of government financing still dominate the industry but governments are increasingly looking for private sector participation to initiate new innovative financial structures for the nuclear industry. However, initial government support is imperative to finance new nuclear power plant projects, under all financing options.

As a risk diversification strategy, new models have emerged to increase the number of equity partners to diversify the risk. Like the Finnish Mankala Model, or investor financing where a consortium formed by the large industrial consumers and municipal utility companies are contributing to the project investment, who share the risk and eventually the reward once the project is completed and starts to generate revenues. In addition to this, vendor financing has really picked up in recent years, as the market demands, where single vendor or consortia of vendors are joining to finance nuclear power projects.

As new plants are built, hybrid style financing models might

[18] In the case of Flamanville 3 project, EdF has failed to implement this approach successfully and has suffered in credibility with investors, with considerable construction delay and cost overrun.

become more apparent in the nuclear industry where multiple equity partners share the risk. Investors are also tapping into the capital markets as risk mitigation option by issuance of corporate bonds, and raising equity by offering ownership to strategic and industrial partners or through IPO.

Under current conditions, there are some signs of a shift away from traditional government financing, but project sponsors are still looking towards some support or guarantee from governments, as sponsors of new nuclear power plants may not be able to pay the yield needed to attract equity holders. For commercial investors and lenders, concern about delays and cost overruns in the face of the industry past performance has always been a major factor. Design readiness and construction duration is still the key influencing factor to impact the total investment cost, where construction risk is still rated number one, hence to gain confidence of investors more projects on “Schedule and within Budget,” are becoming a priority.

The financial industry is going through some restructuring after the global financial crisis of 2008, with stringent regulation to avoid similar future crises, such as increased capital requirements for banks (Basel III), US Financial Regulatory Bill, the change in trading rules in Germany, stern banking liquidity rules in China and the Bank Levy in the UK. These are intended to protect investors but may also add to project financing costs and impact on market liquidity. In the short-term it will make financing for investors very challenging, especially for large scale infrastructure projects like nuclear power plants. Regulators are also going to be excessively vigilant regarding new risky investment projects. The financial institutions are going to be very cautious with any new investment venture.

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