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Nuclear New Build – How to Move Forward

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Hinkley Point C (Courtesy of EDF)

Nuclear New Build – How to Move Forward

Ruediger Koenig and Edward Kee

This article is part of a 3-part series on challenges, opportunities and lessons-learned related to nuclear in the circular economy. Topics:
I Nuclear New Build – How to Move Forward
II Nuclear Plant Decommissioning – How to Prepare for Closure
III Circular Economy – Lessons Learned, from and for Nuclear

Situation Many governments, international organizations and experts consider nuclear energy an important part of the future global energy system, especially in the context of electricity industry decarbonization. In November 2020, the UK Government included nuclear in its Ten Point Plan for a Green Industrial Revolution.[1] In the United States, the current administration and newly elected administration have expressed support for nuclear energy.

However, global nuclear power is not growing, with strong growth in some countries, such as China and Russia, offset by declines in other countries, such as the US.

After an optimistic "nuclear renaissance" period between approximately 2004 and 2011, few nuclear new build projects have moved forward in market economies. The few new nuclear projects that moved to construction experienced delays and cost overruns. Nuclear power struggles with low public acceptance and political resistance, as seen in the failure of the EU to include nuclear energy in its Taxonomy for Sustainable Finance Activities so far.[2] In the US, operating nuclear power plants with decades of remaining useful life are being closed early due to financial losses.

This paper looks at some of the reasons why nuclear new build has not made more progress and what might be necessary for it to attain its potential.

Two key factors are (1) how to deal with completion risk during development and construction and (2) how to overcome market failure to enable reliable and competitive power supply in future, decarbonized energy markets. Of course, the nuclear industry must also become more successful delivering projects in quality, schedule, and budget at reasonable cost.

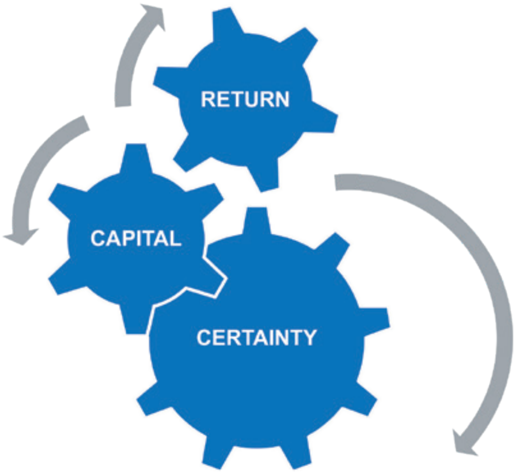

Figure 1
Challenges for new infrastructure investments.

Problems Facing New Nuclear

Recent experience in the United Kingdom serves as an example to discuss the problems facing new nuclear power plant investments.

UK Example

The UK offers particularly favorable conditions for nuclear new build. The UK has a large economy, well-established nuclear experience, strong public support for nuclear power, and Government nuclear strategy and policy positions favoring nuclear power for many years.

Since establishing its nuclear new build vision with the 2006/08 White Paper, the UK has made a series of policy enhancements (e.g., Energy Market Reform 2010, Nuclear Industry Strategy 2012, Clean Growth Strategy 2017) to set a favorable framework for new nuclear build. Although this has attracted substantial nuclear power project development activity by various international parties, nearly all these new nuclear projects have been cancelled, suspended, or remain in very early stages of development.[3] Only Hinkley Point C, with foreign government owned nuclear industry owners and supply chain that operate with unique strategic and financial objectives, and a guaranteed future power offtake price at an extremely high level, is under construction.

When electricity markets, such as those in the UK, do not provide adequate financial incentives for new generation investment without substantial out-of-market subsidies and other support from government, this is market failure.[4] The necessary financial and human capital needs for such large infrastructure megaprojects do not find sufficient returns at sufficient certainty.

Besides broader aspects, which we will discuss later in this article,[5] for nuclear this is due to five interrelated reasons:

- **Nuclear power provides public goods (e.g., emission-free electricity, energy security, energy diversity, grid stability and frequency control) that have**

1 See https://www.gov.uk/government/news/pm-outlines-his-ten-point-plan-for-a-green-industrial-revolution-for-250000-jobs
2 See https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/eu-taxonomy-sustainable-activities_en
3 In addition, EdF's decision not to utilize the UK Guarantees Scheme shows the need for a rethink of risk allocation structure in certain financial tools.
4 See https://nuclear-economics.com/21-market-failure/
5 Also see http://www.world-nuclear-news.org/V-Can-nuclear-succeed-in-liberalized-power-markets-0420152.html

little recognized or realized value in the current, liberalized electricity market and that are not included in most Levelized Cost of Electricity (LCOE) estimates. Electricity markets with high levels of intermittent and volatile power supply from renewables result in significant offtake volume risk for baseload plants, like nuclear power. Electricity spot market prices and futures may not be high enough to cover annual cash generating costs for baseload plant, such as NPPs, let alone depreciation and financing.[6]

- **The track record of nuclear new build projects in Western countries since the 1980s has been consistently bad.** This has been due to many reasons, including supplier performance issues and the complexity, cost, tenor, and uncertainty of nuclear safety regulation. This has not just led to loss of trust by investors, financial institutions, and the public, but has also caused the entire nuclear value chain to internalize contingency and risk. Taken together, this has resulted in high cost estimates for new nuclear power projects that destroy the commercial business case.
- **Straight commercial finance or corporate finance is not available nor viable to fund the development and construction of a new nuclear power plant.** Few investors have the required capital capacity to fund the equity in these new nuclear projects – this is true not only for corporate investors but has also proven to be a problem for government projects in smaller countries. Financial markets do not treat favorably (private) investment in megaprojects with the time, size, and risk profile seen in nuclear power projects. After the 2008 financial crisis, stricter regulation reinforced prudential requirements and the finance industry shifted to less capital-intensive activities, developed new financing strategies based on shorter bank debt funding cycles, and instituted aggressive asset rotation policies. Most new nuclear power plant investments, with high capital-intensity and long operating life, are not "bankable" and to the extent they are, exposure to nuclear projects can be bad for credit ratings and brand reputation for the relevant parties.
- **Even when Government addresses future revenue risk (e.g. through post-construction power contracts as in the UK), substantial project completion risk remains for the long, initial development and construction period.** The magnitude of nuclear power project completion risk exceeds the financial capacity of most potential investors. In addition, the long asset life of modern reactor designs (licensed for 60 years; possible life extensions to up to 100 years) are not captured by discounted cash flow analyses that place little value on cash flows more than 30 years in the future.
- All these challenges could likely be overcome in a suitable energy market regulatory framework, in OECD countries and other large economic compacts. **However, there is substantial, growing uncertainty over future energy systems and electricity market designs.** Electricity industry structures and market designs are developed with a public goal to be technology-neutral, but decision-makers must interact with politically-driven preferences for certain forms of generation or choose opportunities which provide "quick wins" in a known context.

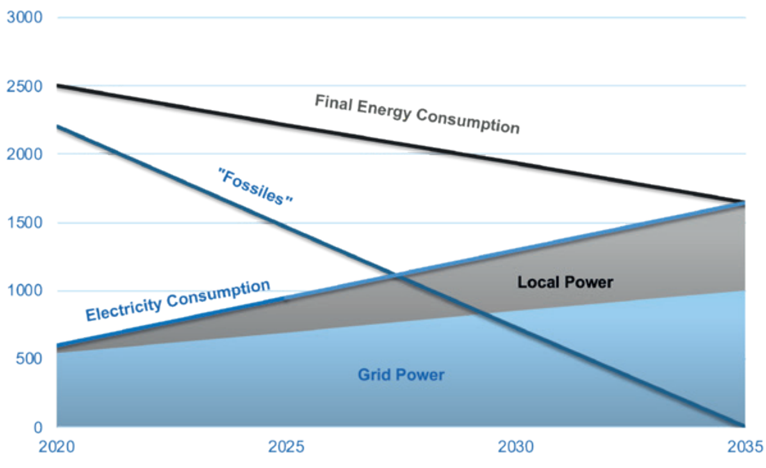

Figure 2
Typical scenario for changes in energy supply (Germany, in TWh).

Market Barriers

In the old 20th Century electricity industry, vertically-integrated electric utilities provide electricity service to end-use customers. Utilities provide this service by planning, investing in, operating, and maintaining an electricity system to meet customer demand with a high degree of reliability. The electricity system includes power plants, transmission lines, local distribution lines, and other infrastructure. The cost of building and operating this electricity system is recovered from electricity users in rates (i.e., prices) for electricity service. These utilities include regulated investor-owned utilities, government-owned utilities, and public power utilities[7]. This approach remains in place in several countries, including China, thereby enabling an active nuclear new build program.

Electricity industry reforms, starting in the 1990s, involved the de-integration of traditional electric utilities, splitting vertically-integrated utilities into separate power plant companies, regulated transmission and distribution companies, and retail electricity suppliers. Importantly, electricity reform required new wholesale electricity markets and new independent entities to operate electricity markets and wholesale power systems (i.e., Independent System Operators).

The switch to the new market-based electricity industry raised few issues when there was an established, large energy infrastructure where electricity has an important but limited role, with sufficient, dispatchable generating capacity and grids, and providing inherent services (e.g. frequency control); and where most energy needs have been covered by readily transportable and storable fuels. But this system is now being de-constructed, at an ambitious rate.

By contrast a future, decarbonized energy system will rely substantially on electricity from volatile generation. Besides huge investment in renewables generating capacity, this creates additional needs for back-up energy which require storage and transport solutions as well as additional services e.g. for conversion to heat and for grid controls. It will also require substantial demand-side

6 See http://nuclear-economics.com/wp-content/uploads/2014/08/2014-04-EJ-Merchant-nuclear-rescue-article-Kee-Zoli.pdf

7 Regulated investor-owned electric utilities are shareholder-owned firms with a monopoly electricity service area and an obligation to serve all customers in this service area. An economic regulator oversees regulated utility rates, investment decisions, and other matters. Government-owned electric utilities (e.g., municipal utilities) are similar, with the government overseeing rates and investment decisions.

investment (more efficient and more flexible processes and active/passive load management).

Delivering these technologies and the investment to create the needed infrastructure in time to meet political decarbonization targets will require a different electricity industry design, Government involvement, and technology at the required scale and cost.

As the UK Ten Points Plan recognizes, nuclear offers several benefits in this regard, as it is (i) a proven and low-carbon dispatchable technology, (ii) that performs well within the existing grid infrastructure, and (iii) can be designed and operated to complement volatile renewables generation. Furthermore, new designs such as Small Modular Reactors (SMRs) can offer additional flexibilities.

But, under what conditions can nuclear participate in the future market environment?

Revenue Certainty versus Completion Risk

The 20th Century electricity industry structure led to investment in most of the existing electricity infrastructure including nuclear power plants. In this model, revenue risk (i.e., the risk that project operating cash flow will not be sufficient to cover plant generating costs) as well as project completion risk (i.e., the risk that a project can encounter delays and cost-overruns or even complete write-offs in case of cancellation) were shifted to governments or to the ratepayers of regulated investor-owned utilities. In a market-based electricity industry, market players are expected to absorb both risks.

The 20th Century approach has utilities and economic regulators that consider a range of public-good power plant attributes and system outcomes when making power plant investment decisions. In the new market-based electricity industry, wholesale electricity generated by deregulated or merchant power plants is sold into a wholesale electricity market. It focuses on power plant cash flow from commodity bulk electricity sales that do not reflect public goods.

In this context, nuclear investments are unique compared to other investments in low-carbon electricity generation:[8]

- The greatest cost and risk for nuclear is in the development and construction period. Once the plant is in operation, it provides reliable power at low operating cost for 60 or more years and operates within the existing energy infrastructure *(i.e., risks are internalized and the benefits externalized)*.
- By comparison, renewables also have high construction and low operating cost, but with a shorter construction period and at relatively low development and construction risk. Once renewable generation is in operation, it provides intermittent power needing additional electricity industry infrastructure (e.g., energy storage and/or backup and transportation and distribution grid extensions). While renewables also have (very) low operating costs, they have substantially shorter productive lifetimes. A renewable project investor is insulated from these risks *(i.e., benefits are internalized but the risks externalized)*.

Revenue adequacy and certainty with NPP commercial operation provides financial benefits, but it does not directly address completion risk issues.[9] This is the key issue preventing more nuclear investment.

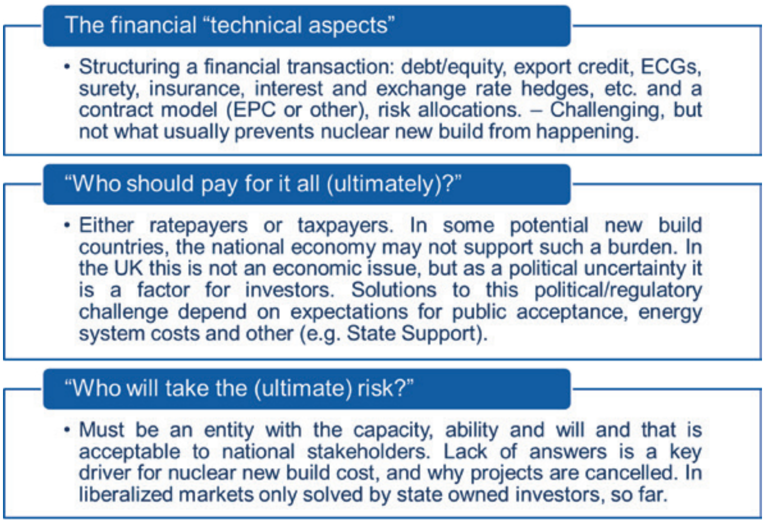

Figure 3
Three key questions for nuclear new build, from a financial perspective.

Barriers to Investment

Nuclear projects involve long and capital-intensive development and construction periods. Discounting of future cash flows lead to project net present value dominated by the capital expenditures in the first ten years. This puts a high level of quantitative risk on the nuclear project developer which results in higher risk markups for CAPEX and discount rates. Furthermore, the developer will proceed more cautiously, leading to extended schedules, i.e. even longer lead periods.

This has three effects:

- First, from a financial perspective, it raises the required future revenue in a power contract to uncompetitive and/or politically unacceptable levels, leading to revenue risk that must be reflected in discount rates.
- Second, regardless how high promised future revenue or profits may be, few if any investors have the capacity to absorb the financial risk, they will have to carry for 10+ years before the nuclear power plant generates revenue. Only limited parts of that risk can be allocated to their supply chain, whether for cause or for credit capacity.
- Third, from a strategic perspective, it raises corporate decision hurdles for project development related to ratings, stock prices, risk governance, portfolio prioritization, and other factors. This can lead to project cancellations when the time and cost required to reach a Final Investment Decision (FID – the "point of no return") exceed the development budget capacity of potential investors.[10]
- Another unique limiting factor for nuclear investments is the requirement for special nuclear power owner/operator qualifications, technology export restrictions, and non-proliferation issues. This either restricts the potential number of investors or requires the project to address these requirements by incurring additional risks and costs (e.g., hiring a contract operator).

8 It would likely be similar for CCS/CCUS.

9 See https://nuclear-economics.com/30-uk-rab-model/

10 Typical project development cost of 10-20% of CAPEX, in case of a project size greater €10 billion, adds up to €2 billion write-off if project cannot reach FID.

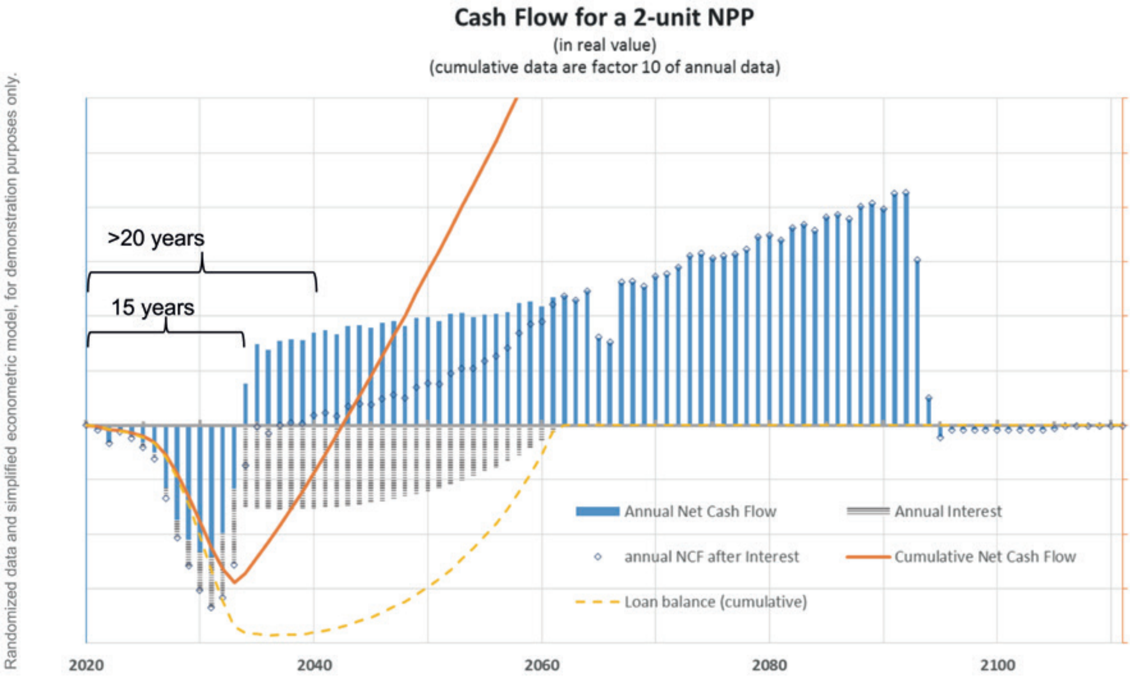

Figure 4
Indicative, typical financial schedule for nuclear new build. 15 years negative cash flow.

- Finally, awareness of and sensitivity to the back-end challenges and cost of nuclear plants (i.e., decommissioning and disposition of high-level waste) is higher both in public opinion and policy/legislation compared to renewables. **This is an aspect we will return to in a later article in this series.**

Taken together, these issues raise the hurdles for nuclear investment so high that there are few potential investors with the technical and financial capability to enable a significant, effective, and competitive nuclear new build program in Western countries.

One Proposed Solution

There is an urgent need for a large amount of new nuclear capacity to replace the combustion-based power plants that will be closed to meet electricity decarbonization goals. This need is even more urgent due to the closure of existing nuclear power plants for technical and economic reasons.

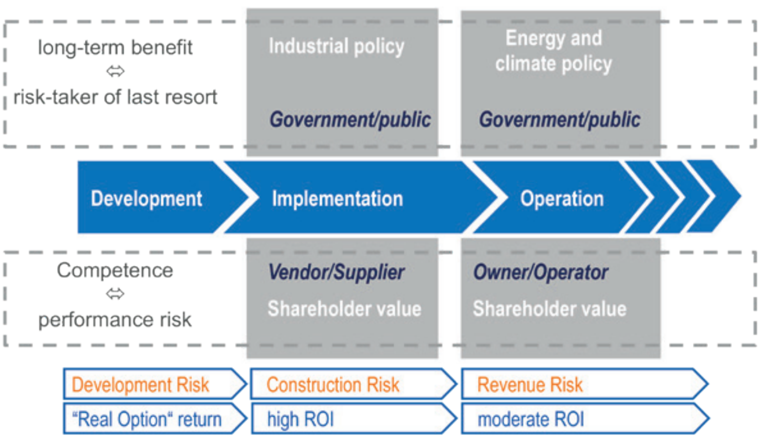

Figure 5
Balancing benefits and risks.

In the absence of a feasible market approach to electricity that will deliver new nuclear power investments, governments must take a leading role. This could be established as a Government funded nuclear new build program that is privatized once it is in operation.[11]
Such an approach could be implemented quickly and would consist of two segments:

1. **Government would take nuclear power project completion risk.** This is the risk that new nuclear power plants will be built at the required quality, on budget, on schedule and have an assigned role in the future energy market. Only limited financial exposure would be re-allocated to the commercial supply chain.
2. **Government would transfer the plants and operating risk to the private sector once completion is assured and the plants have their assigned role in the future energy system.** This could be secured by power contracts, a Regulated Asset Base ("RAB") scheme, or in innovative new market designs being discussed in the industry: solutions can be developed over time, approximately 10 years during development and construction, with significant additional information on the future new energy system.

There would be different ways to implement such an approach. Implementation details should be discussed with global nuclear power participants and potential new energy market players, the financial industry, and project stakeholders. To achieve economies of scale and benefit from learning curves, efforts should be made to develop an approach for a fleet of several new nuclear power plants – perhaps even across country borders.

There should however be a well-designed strategy for risk-sharing between host Government and supplier Governments that could be agreed and implemented in various ways (including export credit or political guarantees) but needs to bear in mind the likely attached "geo-political price".

11 In these cases, as with any other major energy infrastructure measure, close attention must be given to State Aid limitations: e.g. in the EU, while the proposed solution addresses clear market failure, the model must be designed in a way compliant with relevant EU Directives.

Initial Agenda for Public New Build Organization

- Develop a resource and governance plan, to manage the new build programme:
  - Engage experienced programme management providers to operate the NHC/PBO
  - Hire suitably qualified personnel to fulfill the "intelligent customer" role
  - Define programme baseline for the new nuclear fleet (including planned capacity, number of plants, unit sizes, phasing over time, etc.)
  - Agree decision making strategies for the investors and other stakeholders
- Acquire approved nuclear sites (including rights to relevant existing site license information)
- Develop a regulatory and licensing strategy (if this is not already established, as e.g. in the UK)
- Develop a financing model for the required construction programme, presumably in the order of EUR 50 billion with a 20-year tenor
- Develop a contract model which:
  - Limits liability for suppliers but maintains skin in the game
  - Retains economies-of-scale and efficiency across the entire new build programme
- Perform a preliminary procurement process (e.g. via an RFI) to evaluate different options for the design, consenting, building, and commissioning of the plants, in particular:
  - How many reactor vendors and designs should be engaged?
  - Should nuclear operations know-how be included in vendor consortia or be contracted from (which?) consultants? If the latter, should there be one for the entire fleet or one per reactor design/vendor or one per plant?
  - How will the required operator know-how be secured for the purposes of the site license application and for the future (post operation) private owners?
- Develop an auction strategy to achieve maximum value when privatizing the new plants: e.g. based on real-options and game-theory, should this be put to market as early as with vendor selection, or as late as after proven successful operation?
- Develop an ownership spin-off model for the future privatized operating nuclear power plants, enabling a construction debt refinancing and a transition to longer-term equity players and suitable operators.
- Establish a compliance grid for State Aid and Competition rules as well as political (legislative/executive as well as public participation) requirements for:
  - the management and oversight of the development and construction programme
  - the future transfer of the completed assets to the private sector

Figure 6
Strawman – point of reference for discussions for NHC/PBO.

The Government role could be carried out by a national Government body, a trans-national body such as the EU, or other types of multi-country regional power compacts via a special purpose vehicle[12] (Nuclear Holding Company – NHC and/or Parent Body Organization – PBO). While Government certainly isn't the "better entrepreneur" there are good examples of outstanding infrastructure projects in the public sector when professional programme management is applied (London Olympics, Gotthard Base Tunnel), as well as other examples where mitigation of problems that did occur was simplified due to public ownership.

The advantages of this approach are:

- Significantly lower cost of capital during construction, due to Government debt ratings and capital returns requirements.
- A programmatic approach to an infrastructure building programme that can lead to economies of scale and learning curve benefits, streamlined decision-making and more efficient implementation.
- Lower risk factors to be considered by supply chain, leading to lower procurement cost and greater competition.
- Lower cost to completion enables lower cost of carbon free baseload energy (i.e., this could be lower by a factor of more than 2, compared to private investment).
- Gain time, during development and construction to create conditions to overcome market failure for nuclear investment.
- A transfer of operating nuclear power plants to the private sector, at a profit to the public, when completion risk and uncertainty over future energy system and market design are eliminated.

Insights

It is increasingly clear that a market approach to the electricity industry will not deliver new nuclear plant investment and may not even support the continued operation of existing nuclear power plants.

The recent UK experience also makes it clear that new nuclear power plant investments may not be delivered by providing private investors with a set of out-of-market incentives.

To deliver the investment in energy infrastructure, including nuclear, in the manner and magnitude necessary for a successful transition to a zero-carbon electricity sector, a greater role of government is needed – albeit for a limited time. The approach described above presents a way to do this.

In future opinion pieces for **atw**, we will discuss how nuclear can participate in a circular economy by addressing its unique back-end challenges and what general lessons can be learned from the nuclear experience for the electricity industry and energy markets more broadly. We will be happy to reflect comments there which we may receive to this article.

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12 This is a large step beyond the "NEPIO" as per IAEA development models in terms of structure, resources, mandate, and budget.

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