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Nuclear Energy Agency

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Unlocking Reductions in the Construction Costs of Nuclear:

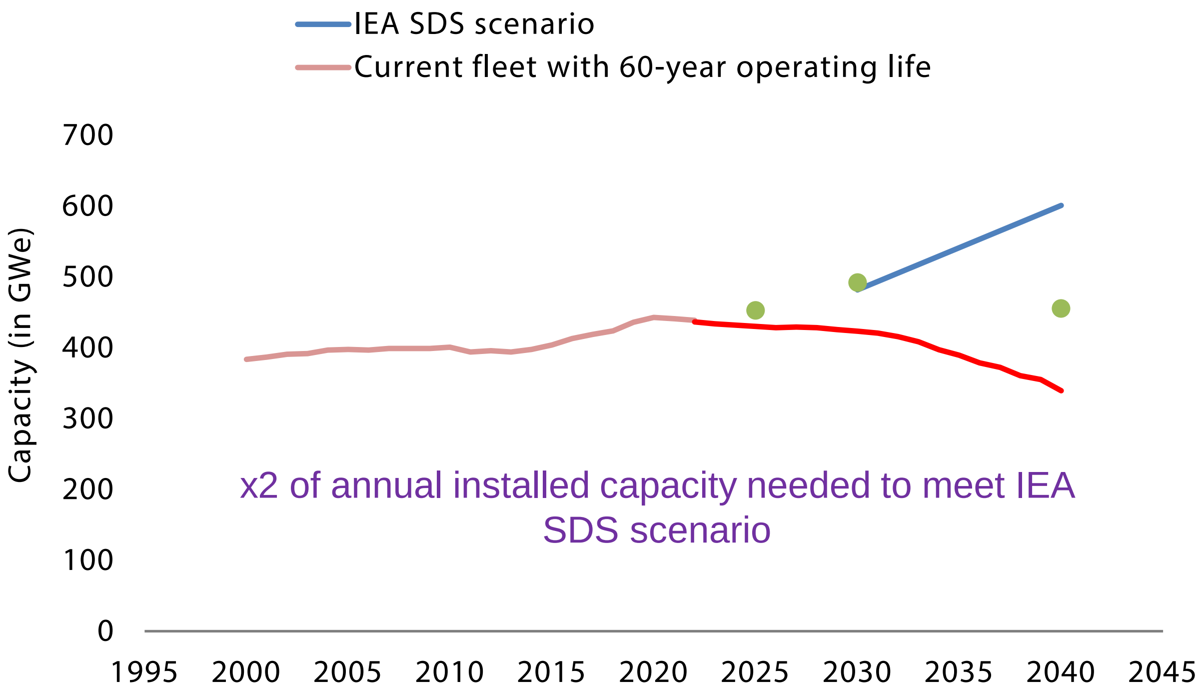
A Practical Guide for Stakeholders

IEEJ webinar – 14 September 2020

Motivation of the study: nuclear power at a critical juncture

- Need to ramp-up nuclear new build in order to meet **2050 decarbonisation objectives**
- **FOAK projects near completion** in several OECD and non-OECD countries
- Today, nuclear **new build projects are perceived as risky**: importance of driving down both costs and risk perception

Global nuclear capacity by scenario 2010-2040



Source: IEA

Primary focus on short term (<2030) investment cost reduction opportunities of large Gen-III light water reactors

Content of the Report

Overview of the costs of nuclear power

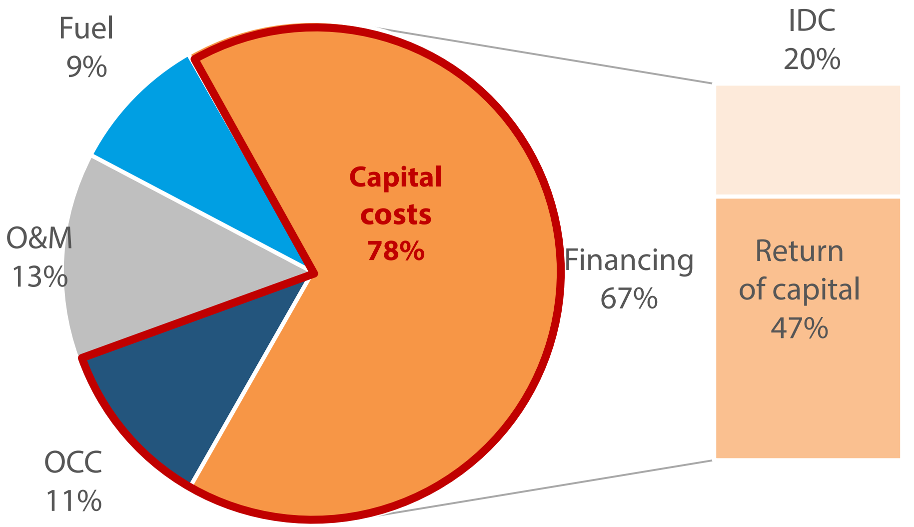
Core drivers of nuclear construction costs: lessons from historical and recent projects

Short- and longer- term opportunities to reduce nuclear construction costs

Policy frameworks to deliver competitive nuclear projects and policy recommendations

Nuclear production costs breakdown

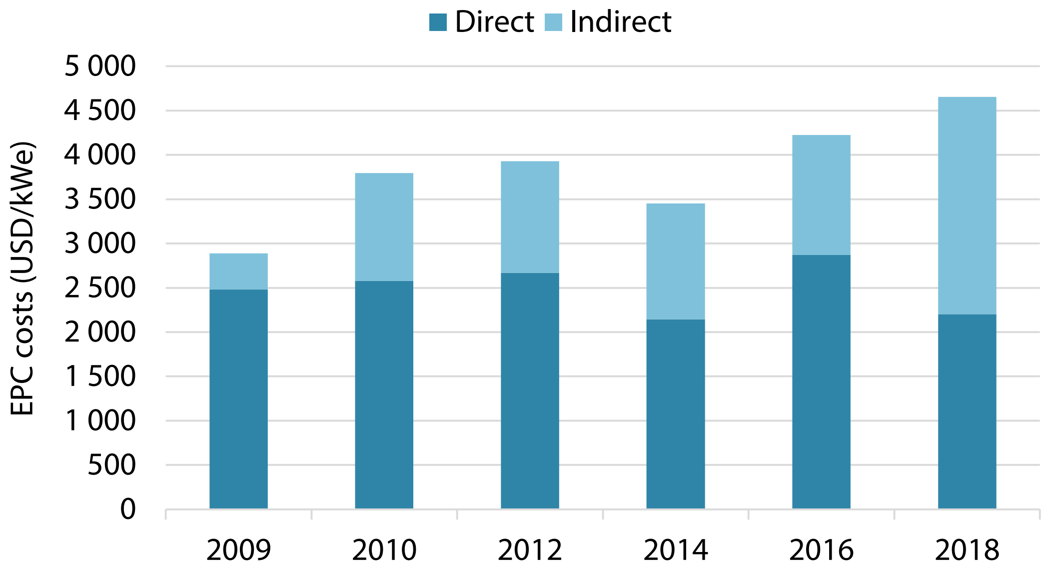
Typical capital costs represent 78% of nuclear production costs (LCOE)



Note: With discount rate at 7%, Return of capital refers to interest during operation, OCC: Overnight construction cost, IDC: Interest during construction

Source: NEA

Indirect costs explain in large part the trend in construction costs

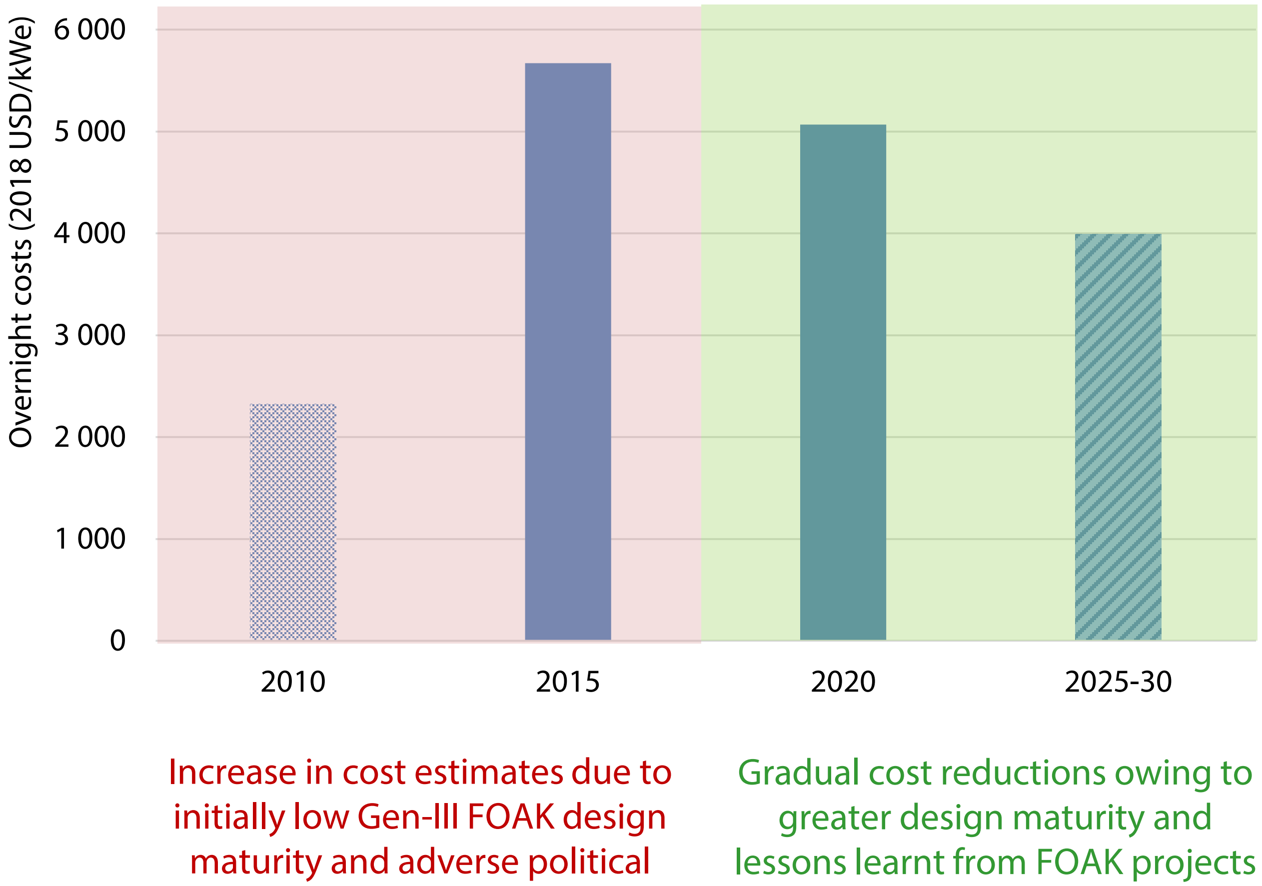


Source: NEA

Recent construction cost increases are due largely to **indirect costs** and reflect the **non-recurring costs** of deploying a new generation of reactors

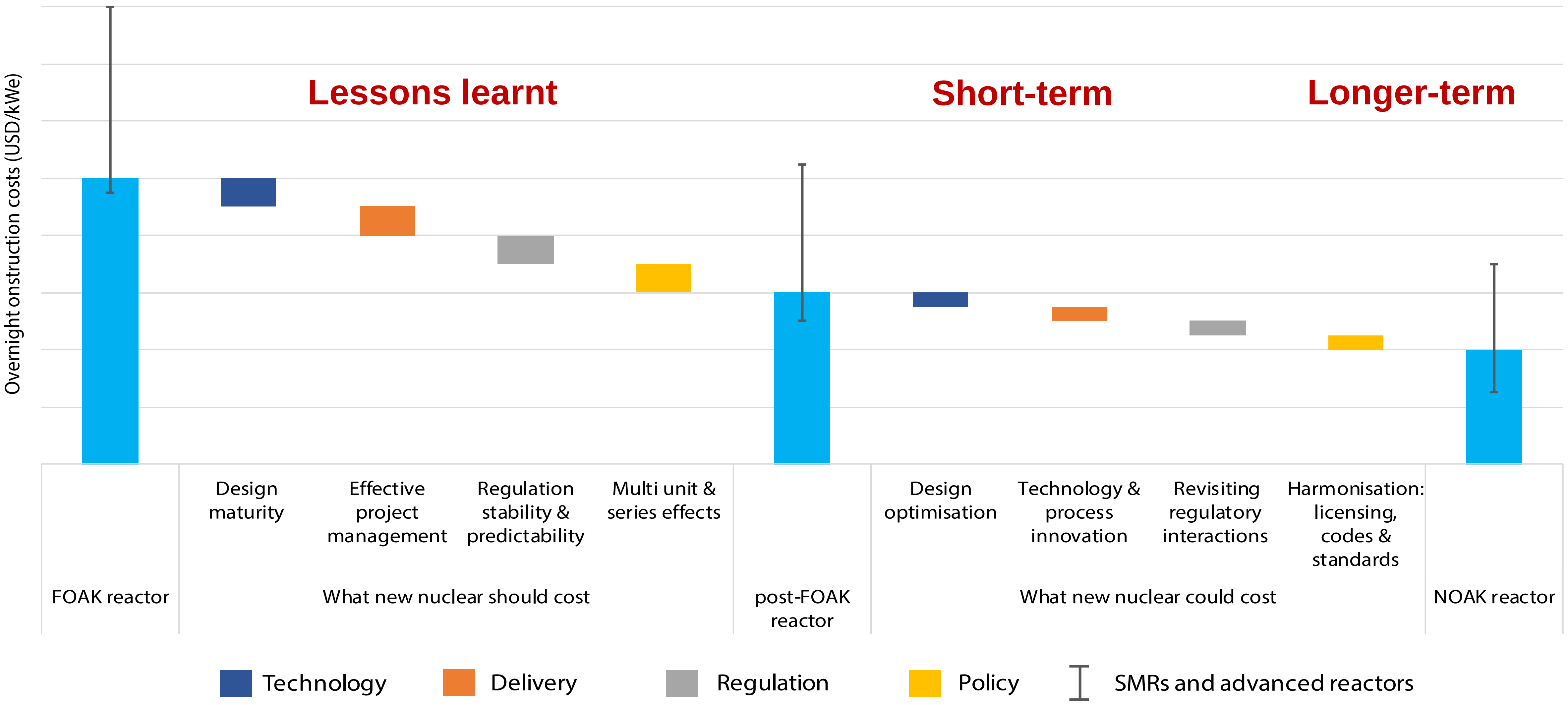
Average trend in the *projected* costs of nuclear new build in OECD countries

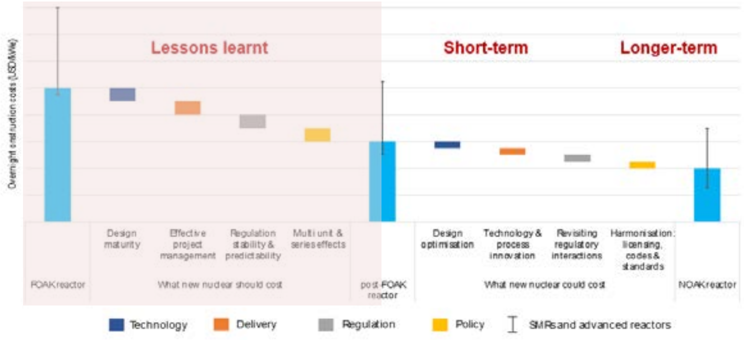
- Gen-III initial costs estimates driven by **low level of design maturity** and the **specific political context** of announced budgets
- Recent trend in projected costs reflects **increased design maturity** and **lessons learned** for post-FOAK projects
- Gap between two sets of projections has impacted overall **perceived investment risks** has potential to impact **public acceptance**



Notes: 2010, 2015 and 2020 OECD average overnight construction cost data based on 2005, 2010 and 2015 NEA/IEA projected cost reports, adjusted for USD inflation using OECD statistics. NEA average estimate for 2025 based on preliminary data from the forthcoming NEA/IEA Projected Costs of Generating Electricity 2020 report.

Eight priorities to unlock nuclear construction costs reduction





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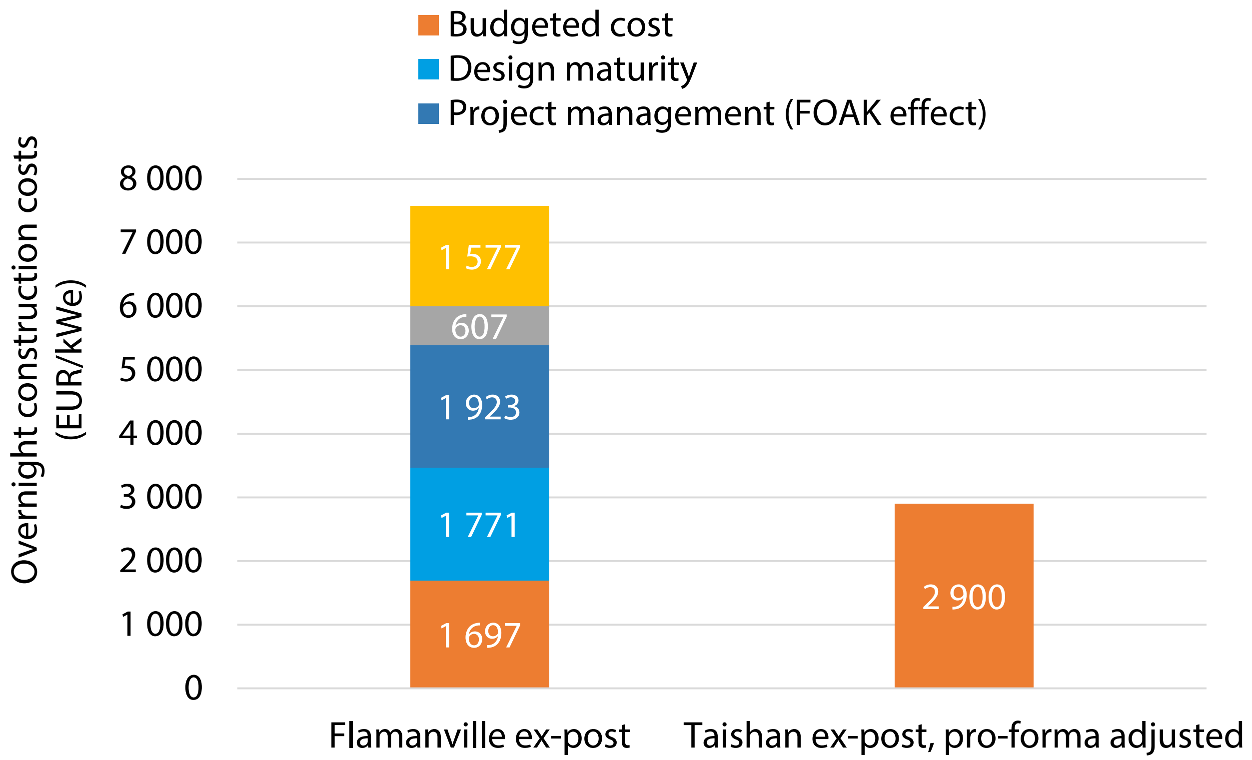
Learning from FOAK projects: EPR lessons

Key drivers of Flamanville cost out-turn compared with Taishan



Source: based on Folz (2019)

Comparison between EPRs Flamanville & Taishan

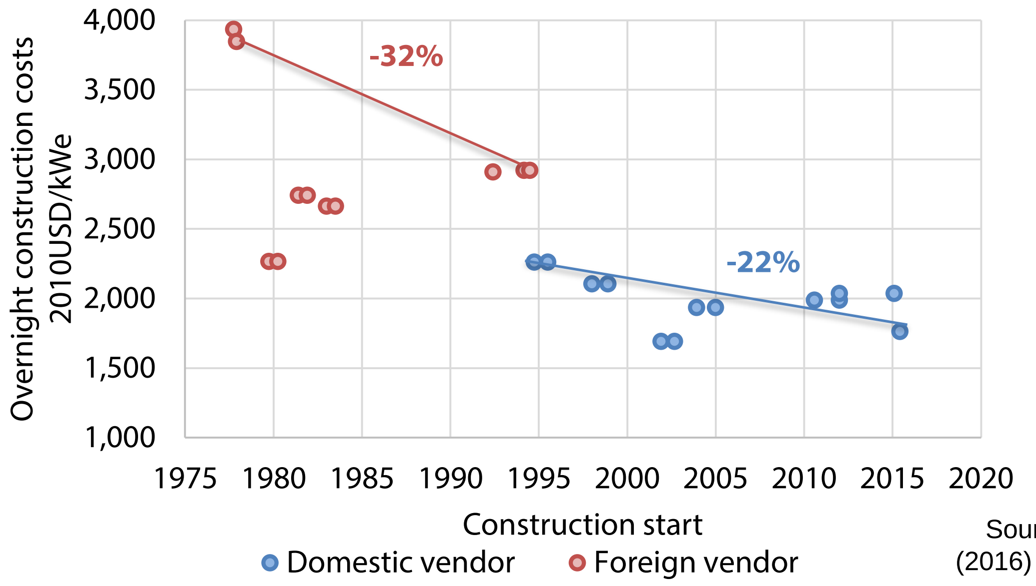
	Flamanville 3	Taishan 1 & 2
Site	Single unit project & difficult site conditions	Twin project, with perspective for 2 additional twin units
Design maturity	No lessons learnt from OL3	Lessons learnt from FA3
Supply chain capabilities	Challenges following 16-y without new build	Ongoing large-scale new build program
Project management	No dedicated project team at construction start	Integrated project team
Political leadership	Uncertainties regarding political commitment	Strong political leadership

In addition to **design maturity** and **project management**, **political leadership** is a key factor to foster mobilization and integration of the nuclear supply chain

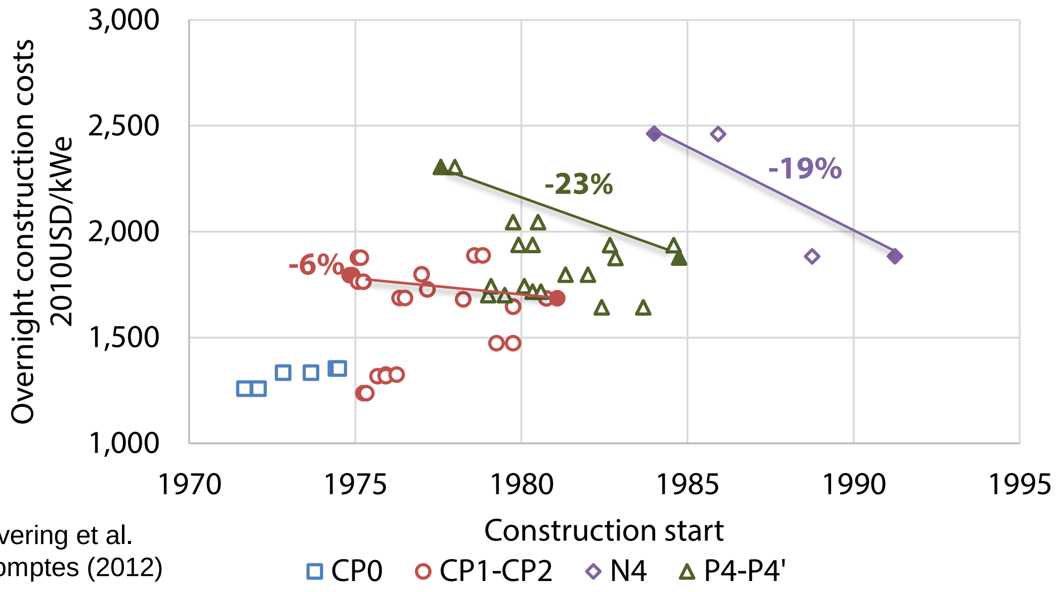
Historical and recent projects have demonstrated learning with serial construction

- Serial construction of nuclear reactors can yield a reduction in construction costs :
  - ✓ **Program effect**: reduction of nonrecurring / indirect costs
  - ✓ **Productivity effect**: learning by doing through mobilization of the supply chain
- Not universal but observed in: France (80s), Japan (90s), Korea (00s), Russia/China (today)

Historical construction costs in Korea



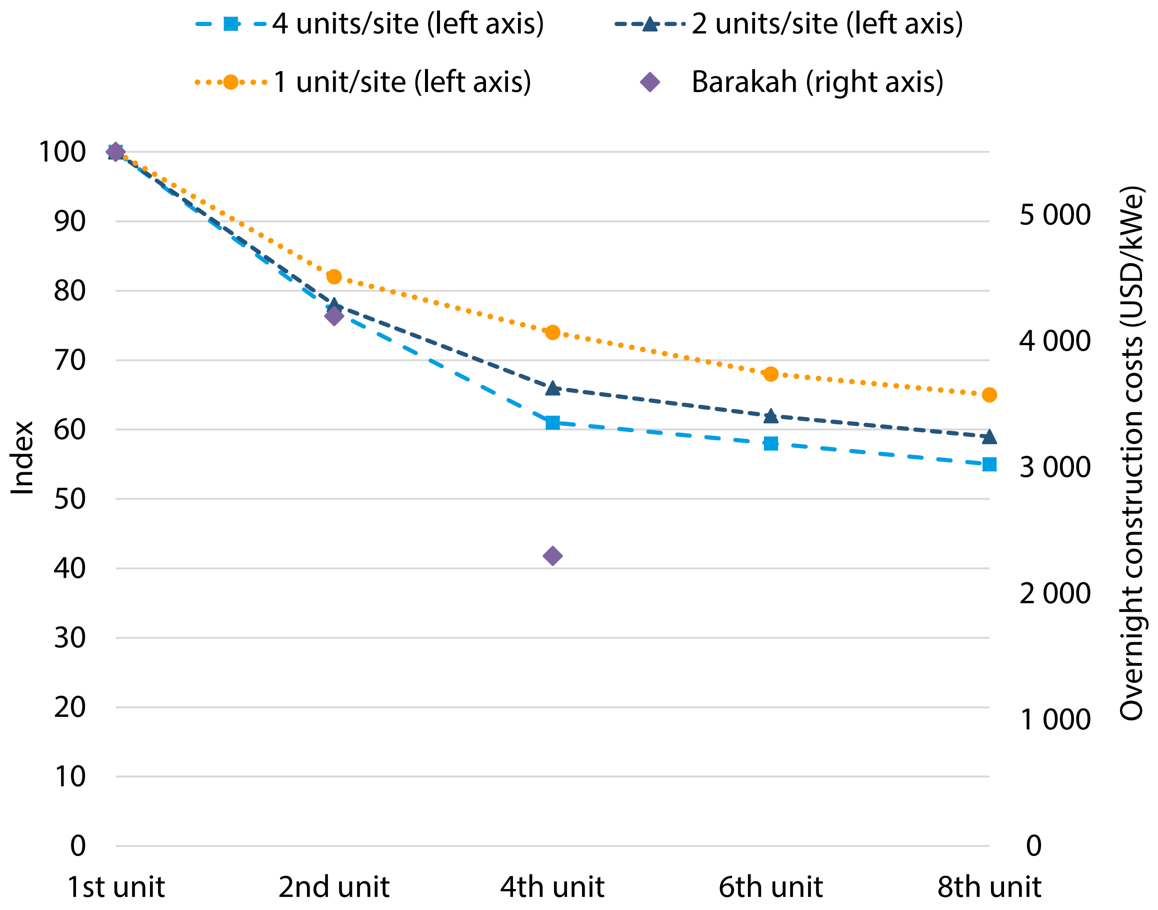
Historical construction costs in France



Source: based on Lovering et al. (2016) and Cour des Comptes (2012)

Multi-unit construction reduces the non-recurrent costs of infrastructure development per reactor

- Multi-unit projects further facilitate the **allocation of resources** between units, reducing risks and impacts of delays
- NEA (2000) estimated that constructing reactors in pairs **reduces the cost of the second reactor by about 15%,** and 5% for the 2nd pair
- **Barakah 4-unit project** in the United Arab Emirates demonstrates that such cost reductions can be even more rapid for the most successful projects



Source: based on NEA (2000) and Gogan (2019)

Nuclear safety regulation can enable cost reductions

Lessons learned

Core conditions for successful regulatory interactions

Regulatory stability

- *Important to understand and anticipate any safety or environmental changes to avoid retroactive design activity or re-work in construction*
- E.g. Impact of changes during construction post-TMI on new build in the US during the 70s/80s

Regulatory predictability

- *Introducing new rules without the associated clear technical requirements needed for engineering studies*
- E.g. regulation for pressurized equipment in France on FLA3: 10-year for the translation of the new rules into technical requirements

Short-term (<2030)

Innovative approaches to revisit regulatory interactions

- An increased **awareness** within regulators of the impact of their activities on cost, and **willingness** to understand implication of regulatory decision on technology performance
- Identification of **mutually beneficial situations** suitable for co-operation (*see Horizon case study*)
- Clear and transparent communication to **avoid misinterpretation**
- **Alignment on the objectives and outcomes** of both regulators and licensees

Cost optimization with regulator involvement: lessons from the Horizon project

- In 2016, **Hitachi-GE and ONR cooperated on a review of the ABWR to identify costs reduction opportunities**. Several factors identified, notably to adapt GDA generic assumptions to local site conditions and plant layout.
- The **design optimization phase pursued realized expected overnight capital cost reductions in excess of 20%** for a twin unit deployment vs. two single units. Key factors for success included:
  - ✓ Regulators engagement at executive level
  - ✓ The process benefitted from the capability and experience in both the project team and regulators
  - ✓ Benefits realised from challenging initial design assumptions associated with the co-location of units on the same site
- Further significant **cost reductions expected from a commitment at the outset to four units at the same site** vs. twin unit with potential for a second twin unit at the same location.

Horizon project post design optimization

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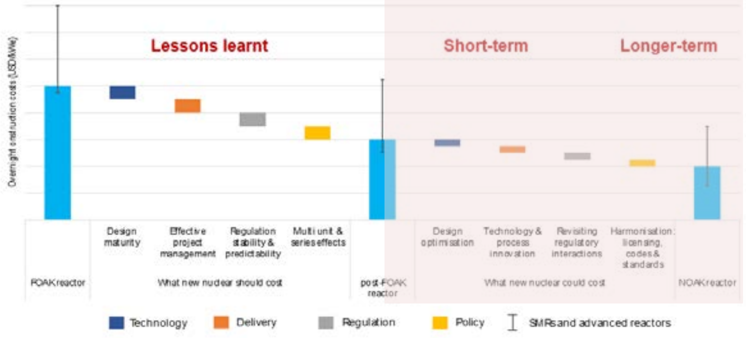

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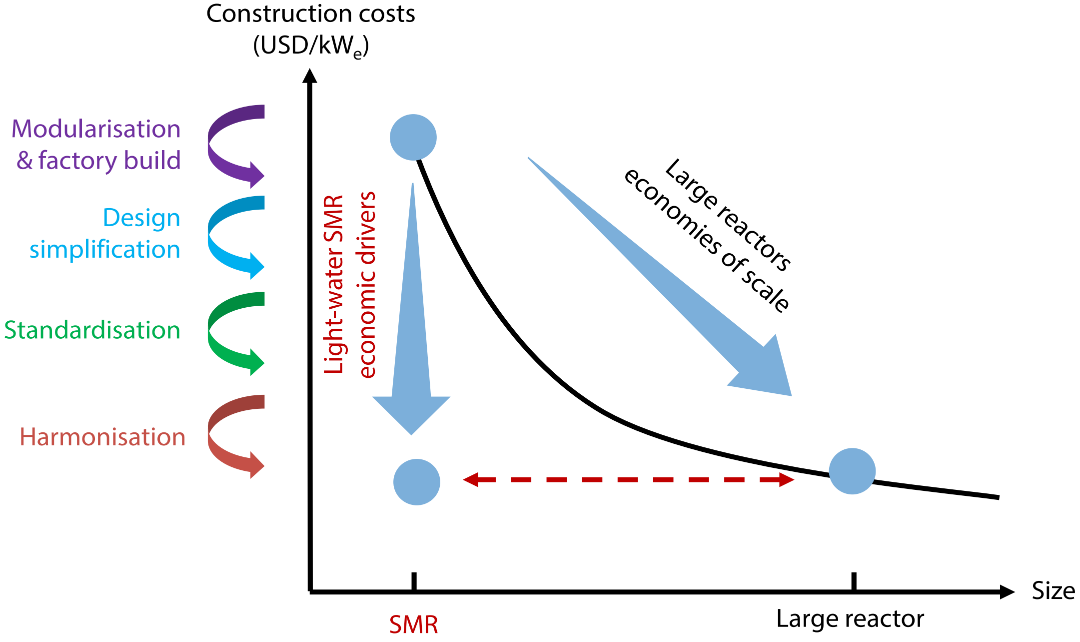
Long-term continuous improvement can be achieved through the interplay between processes and product design

	Enabling processes	Product design	Construction processes
Short-term (<2030)	Design to cost Systems engineering Digital transformation (e.g. PLM) Knowledge management Quality management & control Revised regulatory processes	Simplification Standardisation Reclassification of safety components Improved seismic design	Modular construction Advanced concrete & rebar solutions Risk-informed inspection Early advanced manufacturing
Longer-term (>2030)	Harmonisation Qualification Continuous improvement	SMR features Gen-IV features Advanced materials	Factory-based fabrication Mature advanced manufacturing

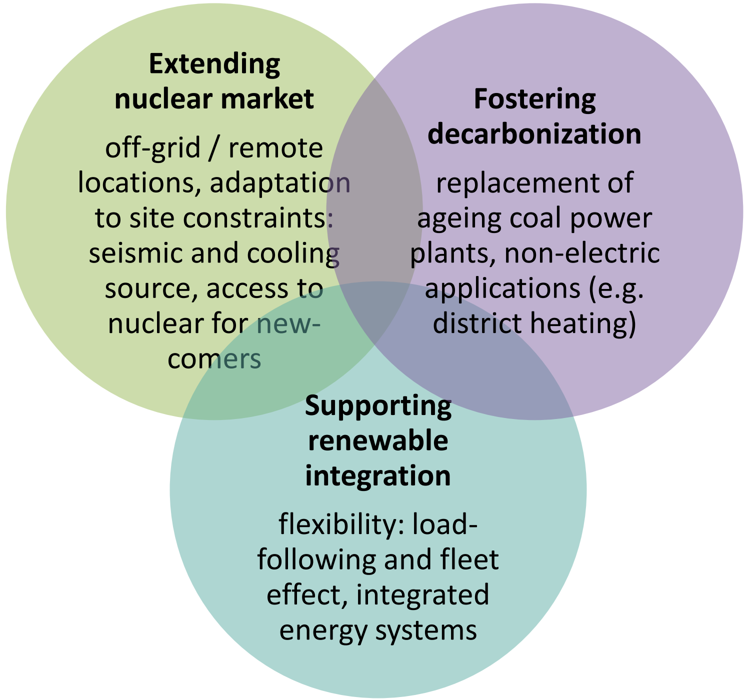
Complementarity between technologies

SMR construction cost will take advantage of specific cost reduction drivers and from progress made with large reactors

SMR economic drivers that help compensate for diseconomies of scale



SMR market applications



Large reactors and SMRs target **different markets and applications**. Industrial capabilities achieved with near-term (early-2020s) investments in large reactors will support SMR development. To counterbalance the lack of economies of scale, SMR rely more on **serial construction** with specific cost reduction strategies proven in other industries

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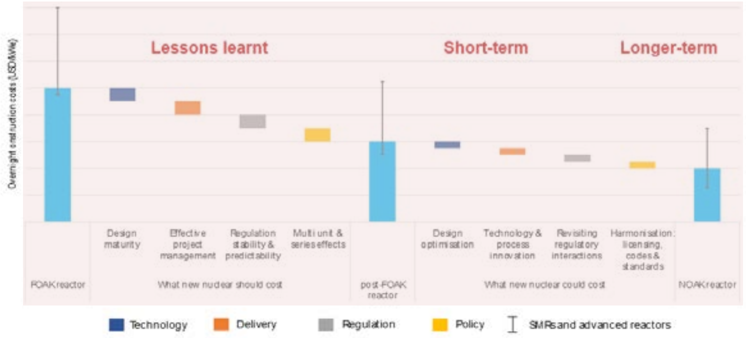

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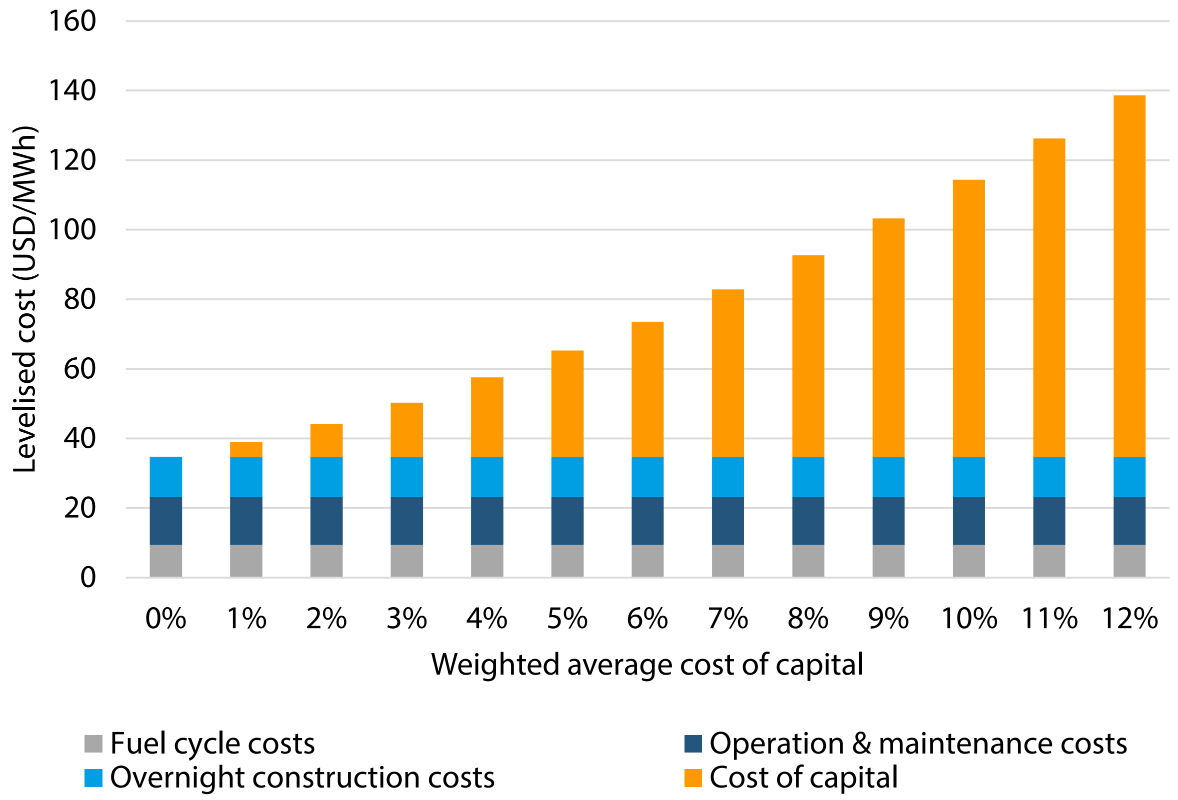
The role of government: the need for long term planning

- Nuclear new build requires long term planning: **commitment** and specific **regulation**
- Clear rationale for further **government intervention on financing**:
  - ✓ Social and environmental **externalities**: climate, clean air, fuel diversity, …
  - ✓ Electricity **market failures**: lack of long term price signals to mitigate market risks
  - ✓ **Macroeconomic context**: weakening monetary policy and growth in private equity funds, but with continued high expectation in terms of risk premium. Opportunity for new-nuclear to contribute to **post-COVID-19 recovery**.

Affordable financing is key for the economic performance of nuclear (1/2)

- Cost of capital reflects **risk allocation and mitigation decisions**
- Many of the **cost reduction opportunities identified in this study will support risk mitigation** during the post-FOAK phase
- Strong **rationale for direct/indirect government involvement** to lower the cost of capital and therefore the cost for the final consumers. This implies some transfer of risk

LCOE of a new nuclear power plant project according to the cost of capital



Note: Overnight cost of 4500 USD/kWe, a load factor 85%, 60-year lifetime and 7-year construction time

Affordable financing is key for the economic performance of nuclear (2/2)

Nota: x: risk owner, x: other key stakeholders for risk mitigation

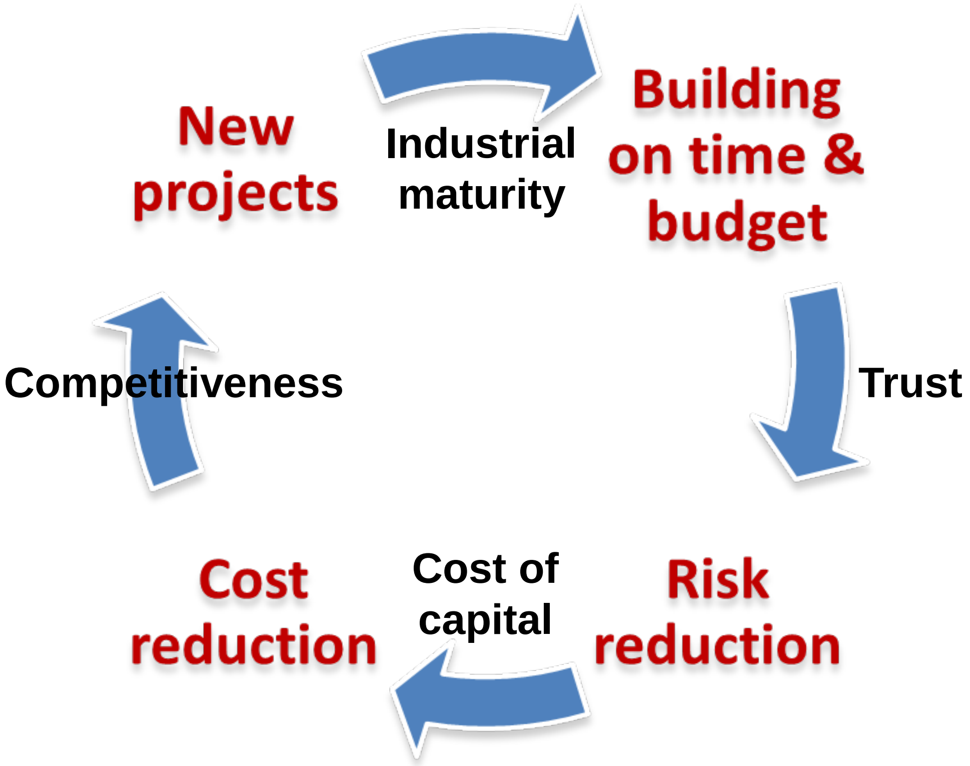
		Industry				Other stakeholders			
		Plant owner	Vendor	Project team	Supply chain	Government	Society	Safety auth.	Financiers
Technology	Design	x	x	x					
	Integration of new technologies		x	x	x				
	Nuclear quality assurance standards	x	x	x	x			x	
Organisational	Project management	x	x	x					
	Supply chain capabilities		x	x	x	x			
Policy framework	Political support	x				x	x		
	Licensing framework	x				x	x	x	
	Financing	x				x			x

Effective risk allocation and mitigation requires concerted efforts among industry, government and society

Governments can support financing through a range of financial mechanisms depending on country and projects conditions

Direct Financial support	Indirect financial support	
	Power purchasing agreements	Regulated assets
Equity, debt, ECAs, loan guarantee	**Contract-for-difference (UK), Mankala model (Finland)**	**Rate-of-return (US), Regulated Asset Base (UK)**
Equity stake can be transitional as additional sources of financing should become available once the plant is operational	PPAs focus on market risks but often do not address explicitly construction risks, which impact risk premium	Specific conditions can be specified for the allocation of certain risks (e.g. cost sharing and cap with hybrid RAB model)

While government support is essential to start or restart a nuclear program, it should be transitional as improvement in industrial maturity will drive both risk and costs down



Conclusions and policy recommendations

The nuclear sector is transitioning from FOAK and could rapidly deliver more competitive Gen-III reactors

- **Capitalize on lessons learned from recent Gen-III reactors:** Building on these designs, governments have a window of opportunity for cost reductions in the early 2020s. :
- **Prioritize maturity of design and regulatory stability:** Policies play a significant role to ensure that new build projects start with the right conditions.
- **Consider committing to a standardised nuclear programme:** For countries considering multiple new-build projects, commitment to a standardised nuclear programme is the most promising route to realise cost reductions.

Construction cost reduction opportunities are available at several levels

- **Enable and sustain supply chain development and industrial performance:** Industrial and energy strategies for new nuclear plants need to be carefully articulated.
- **Foster innovation, talent development and collaboration at all levels:** Governments can support cost reductions with SMR and advanced reactors by ensuring timely licensing and construction of demonstrators.

The governance framework is essential to support competitive new nuclear construction

- **Support robust and predictable market and financing frameworks:** (Transitional) targeted financial support is currently essential in Western OECD countries to deliver cost-competitive new nuclear.
- **Encourage concerted stakeholder efforts:** Governments should foster a social contract with industry and society.
- **Tailor government involvement to programme needs:** Countries restarting a nuclear programme or considering only a single-plant project are likely to require further government support.

Report launch and follow-up

- **High-level launch webinar on July 2nd**
  - Panel moderated by NEA DG
  - Over 600 registered participants
  - Recording available online
  - Several press articles

- **Next steps**
  - Financing of new nuclear and the interplay with electricity market regulation
  - Advanced technology for nuclear costs reduction (digital transformation, modular construction, improved seismic PSA)
  - SMR

Download: oe.cd/nea-redcost-2020

Contact: email