DE LA RECHERCHE À L'INDUSTRIE

HOW TO REDUCE THE COSTS OF NEW NUCLEAR?

Dr. Michel BERTHELEMY

CEA/I-tésé

&

Chair, OECD/NEA Expert Group on the reduction of nuclear construction costs

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INTRODUCTION

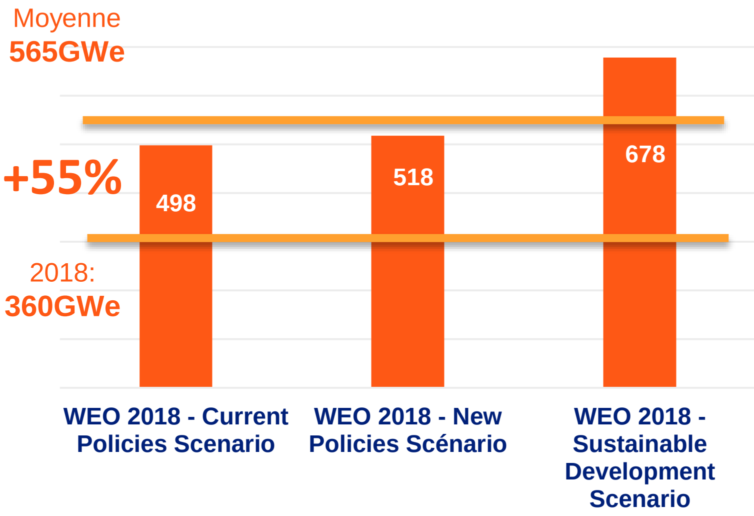
Not a new topic …

- OECD/NEA (2000) already looked at construction costs reduction
- OECD/NEA (2015) focused on supply chain issues
- Recurrent projects costs studies (CGE) with IEA

.. But important time to revisit the issue

- Many FOAK reactors commissioned in 2018/2019
- LCOE challenges with reduction of levelized costs of renewables
- Need to ramp-up nuclear new build to meet role in decarbonisation scenarios

Installed nuclear capacity in 2040 (GWe)



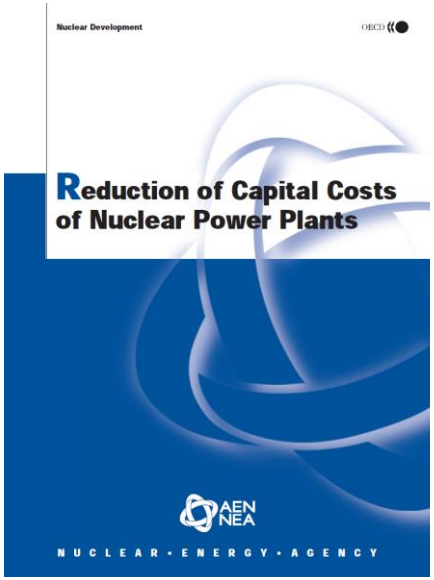
Primary focus on near term (2030s) costs reductions for Gen-III as we move from FOAK to NOAK

BACK TO THE FUTURE: 2000 NEA STUDY « *REDUCTION OF CAPITAL COSTS OF NUCLEAR POWER PLANTS* »

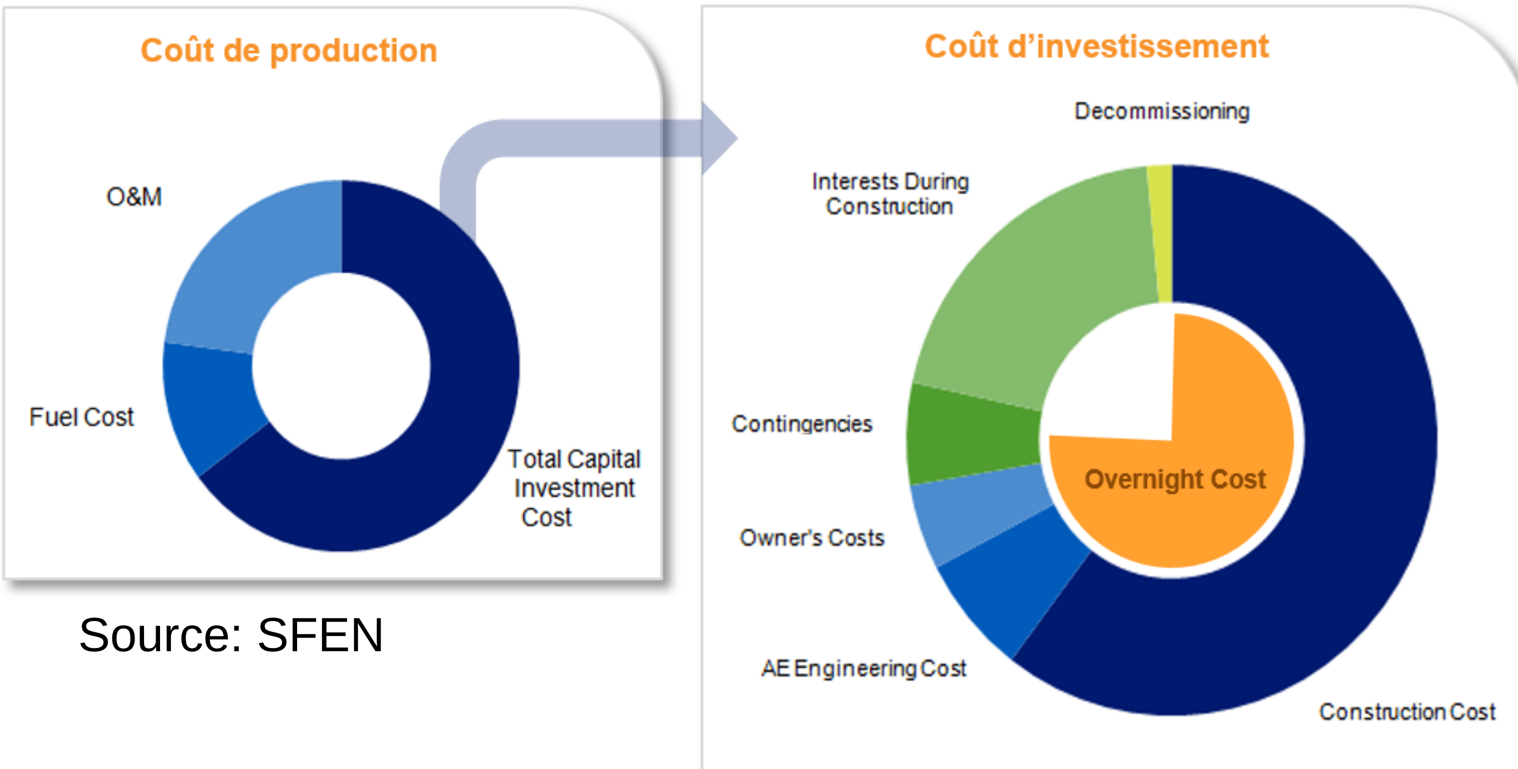
… Follows 1988 Expert Group study on the *"Means to Reduce the Capital Cost of Nuclear Power Stations"*

Key areas covered:

- Increased plant size
- Improved construction methods
- Reduced construction schedule
- Design improvement
- Improved procurement, organisation and contractual aspects
- Standardisation and construction in series
- Multiple unit construction
- Regulation and policy measures



BACK TO BASICS: NUCLEAR PRODUCTION COSTS BREAKDOWN



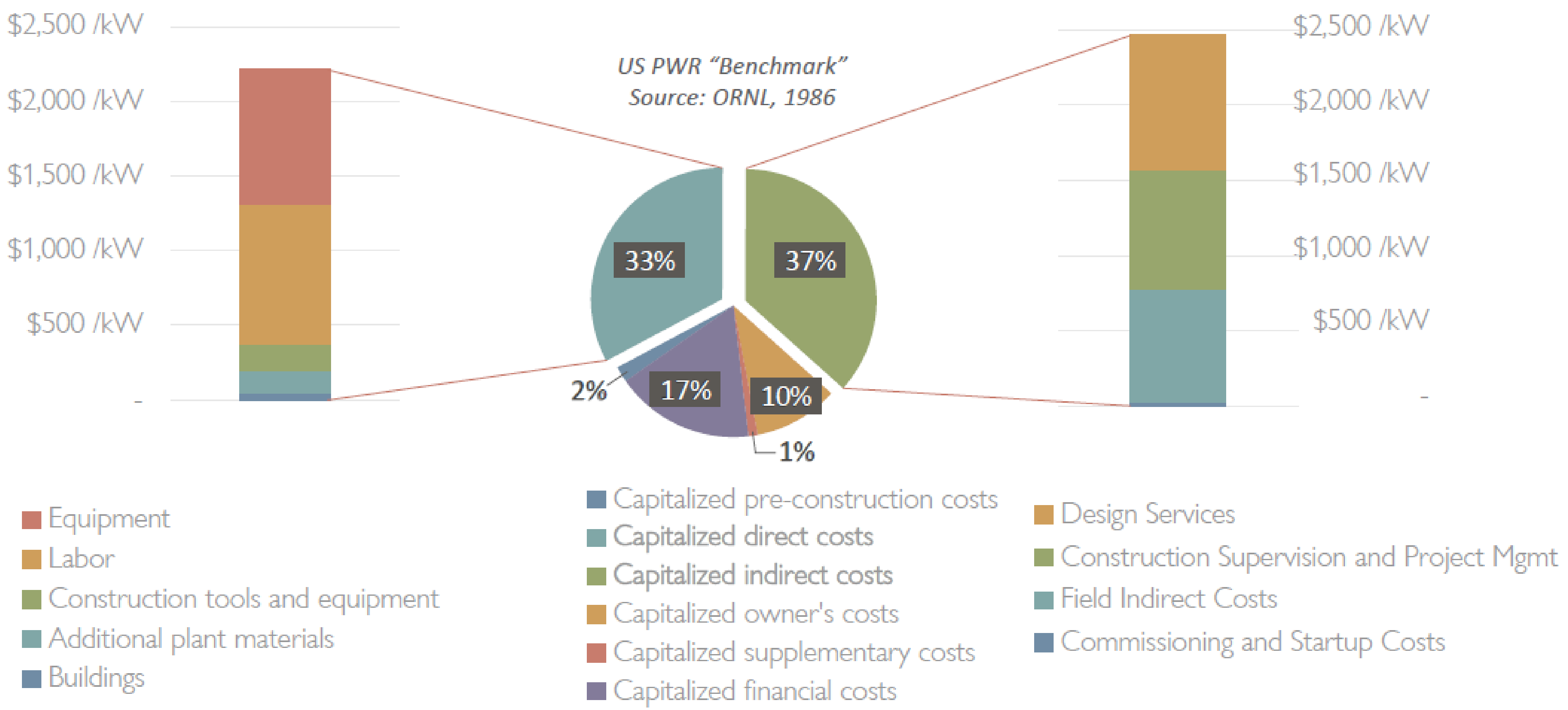
Source: SFEN

At a 7% discount rate → investment costs = about 2/3rd of the levelized costs of nuclear power
(source: SFEN, 2018)

NUCLEAR INVESTMENT COSTS BREAKDOWN

Direct costs

Indirect costs

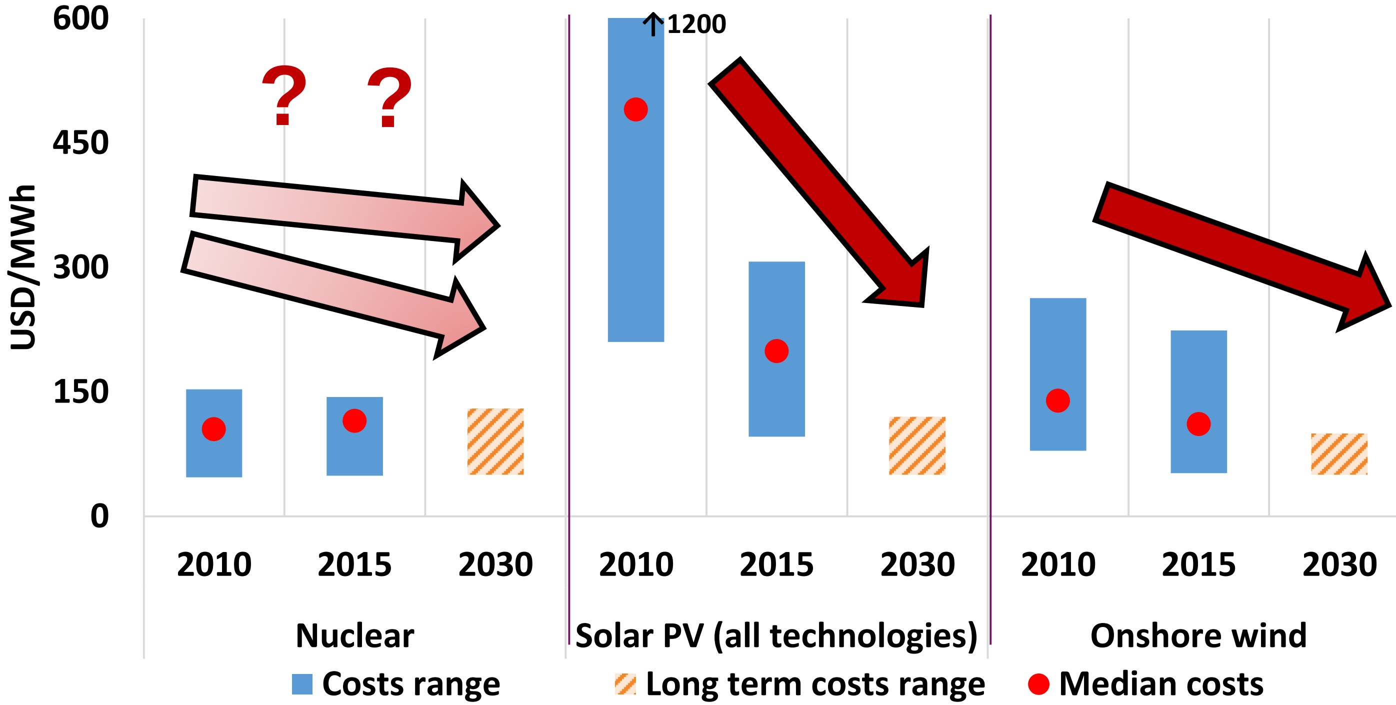


Direct v. indirect construction costs (source: ETI, 2018)

RECENT ESTIMATES ON THE COMPETITIVENESS OF NUCLEAR NEW BUILD (POST-FOAK)

Rapid reduction in the costs of renewables, but **nuclear expected to remain in competitiveness range in many parts of the world** on a LCOE basis

Role of the **cost of capital** (nuclear, solar PV and wind are all capital intensive)



International trend in levelized costs for Nuclear, Solar PV & onshore wind, 10% discount factor
(Source: IEA/NEA, 2010 & 2015 + projections for 2030)

CONSTRUCTION TIME OF RECENT FOAK GEN-III PROJECTS

				Construction time (years)			
	Design	Decision	Construction start	Initial	Delay	Final	Construction completed
OL3	EPR	2003	août-05	4	11	15	2020
FLA 3	EPR	2005	déc-07	5	7	12	2019
NovoV 2.1	VVER1200	2006	juin-08	7	1	8	2016
Leningr 2.1	VVER1200	2006	oct-08	5	3	8	2018
Sanmen 1	AP1000	2007	avr-09	6	3	9	2018
Hayiang 1	AP1000	2007	sept-09	5	4	9	2018
Shin Kori 3	APR1400	2007	oct-08	5	3	8	2016
Taishan1	EPR	2007	oct-09	5	4	9	2018
Vogtle 3	AP1000	2008	mars-13	4	2	6	2019
Fuqing 5,6	HUALONG 1	2014	mai-15	5	?	?	?

Source: SFEN, 2018

CONSTRUCTION COSTS OF RECENT FOAK GEN-III PROJECTS

	Country	Reactor	Start	MWe	Ex-ante construction cost USD/kWe	Ex-post construction costs USD/kWe
Olkiluoto 3	Finland	EPR	2005	1 x 1630	2430	> 6260 (*)
Flamanville 3	France	EPR	2007	1 x 1600	2475	7800 (*)
Leningrad 2	Russia	VVER1200	2008	2 x 1085	2673	3040
Sanmen 1,2	China	AP 1000	2009	2 x 1000	2650	2800
Taishan 1,2	China	EPR	2009	2 x 1660	1960	3150
Shin Hanul 1,2	South Korea	APR1400	2012	2 x 1325	2300(**)	2645
Vogtle 3,4	United States	AP 1000	2013	2 x 1117	5565	6800
Fuqing 5,6	China	HUALONG 1	2015	2 x 1090	2800	3500

Source: SFEN, 2018

(*) 1€ =1,2 USD (**) = Shin Kori 3,4

DIFFERENT WAYS TO LOOK AT THE POTENTIAL FOR COSTS REDUCTIONS

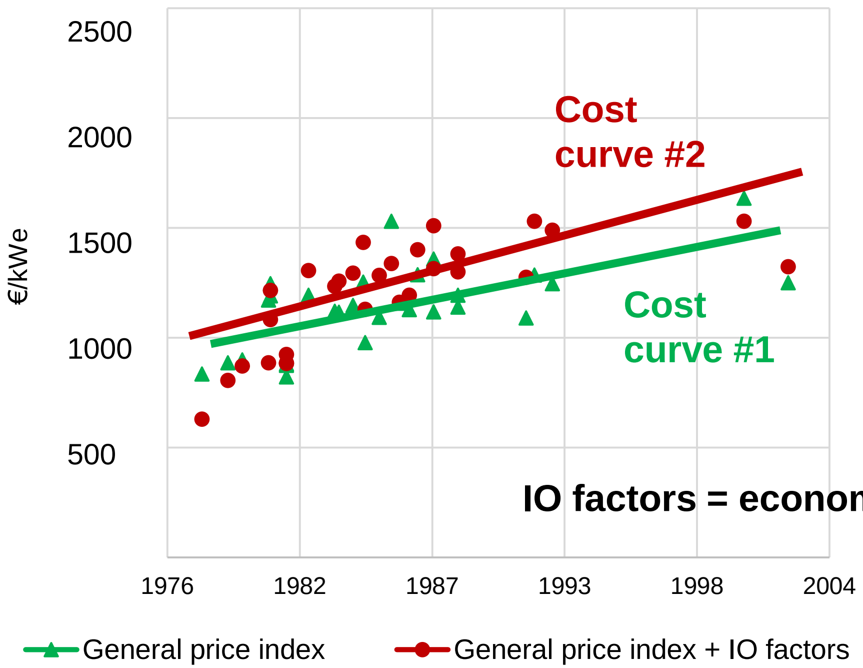
- ❖ Historical costs trends
- ❖ Evidence of learning by doing (econometrics)
- ❖ Lessons learnt from other industries
- ❖ Lessons learnt from recent FOAK projects

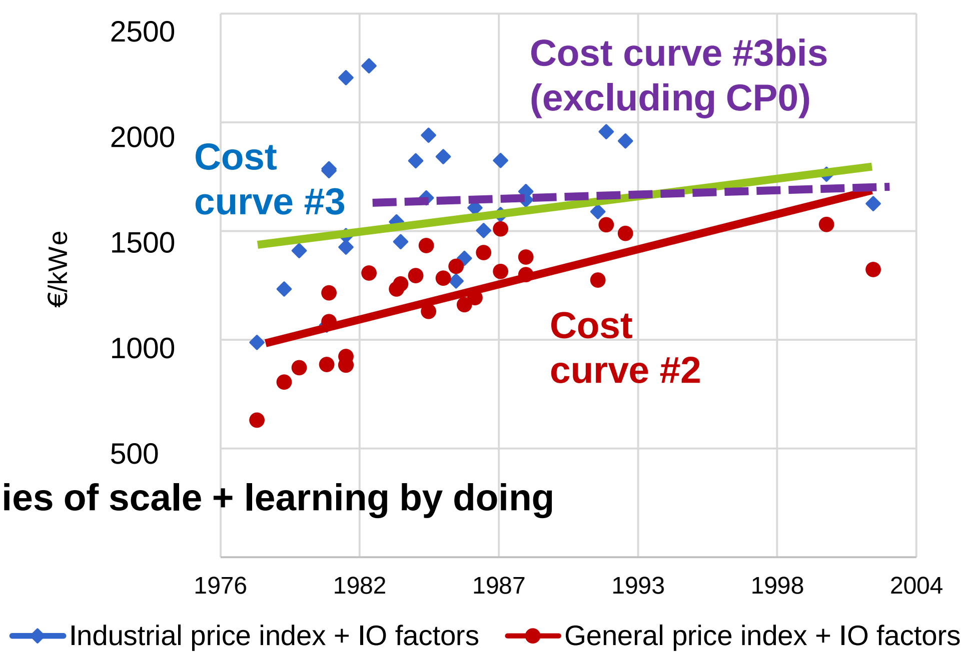
CONSTRUCTION COSTS TREND: HISTORICAL EVIDENCE FROM FRANCE

Difficulties for comparison of (international) construction costs data

❖ Eg. Choice of deflator

Case of France: **limited construction costs increase overtime** if control for economies of scale + learning using industrial price index





IO factors = economies of scale + learning by doing

Construction costs data in France: defining and interpreting overnight costs…

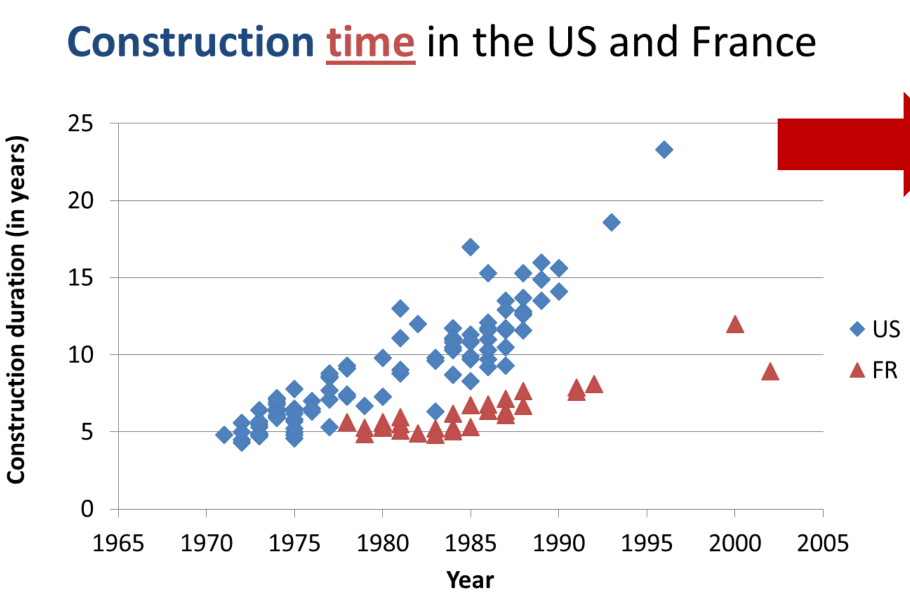
Source: Cour des comptes, 2012 + own interpretation

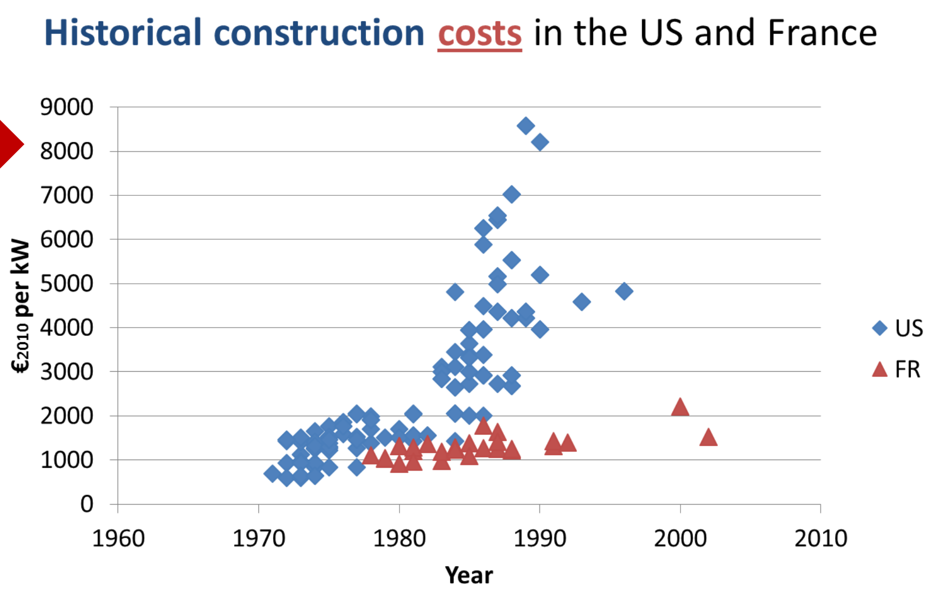
CONSTRUCTION COSTS DRIVERS: CONSTRUCTION TIME & LEARNING BY DOING

Recent econometric studies

(Berthelemy and Escobar, 2015; Escobar and Lévêque, 2016)

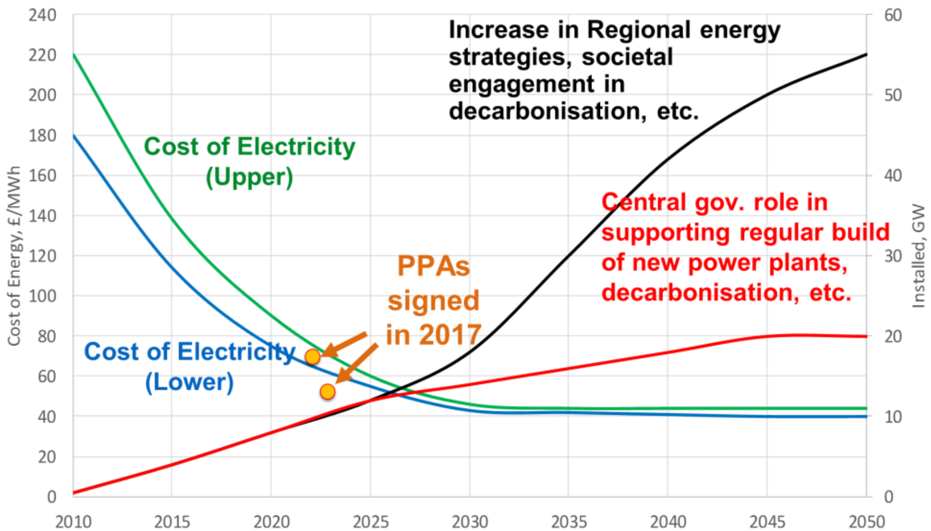
- ❖Role of construction time
- ❖**Learning by doing conditional on standardization…**
- ❖… but trade-off between reductions in costs enabled by standardization and potential gains from adopting new technologies





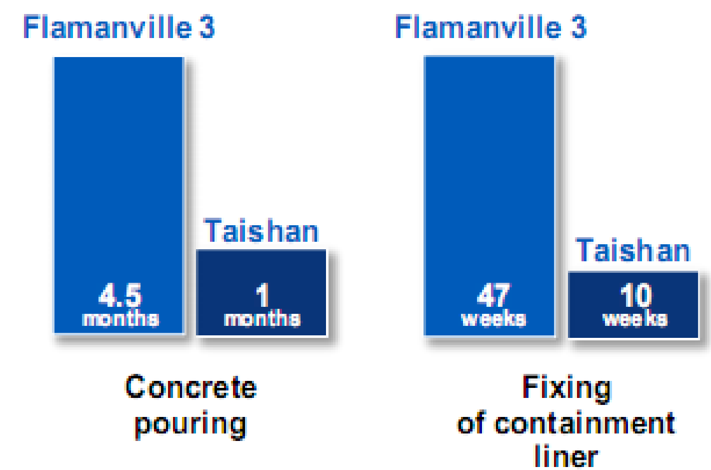
CONSTRUCTION COSTS DRIVERS: GETTING TO THE LEARNING CURVE

Fast learning in the UK offshore wind industry



* The CFDs were half the price of contracts awarded in the last UK offshore wind tender in February 2015.

Significant improvement for key construction stages between Flamanville v. Taishan EPRs



CONSTRUCTION COSTS DRIVERS: PARALLEL WITH OTHER INDUSTRIES

McKinsey, “A risk-management approach to a successful infrastructure project”

https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/a-risk-management-approach-to-a-successful-infrastructure-project

Large, complex, long-term projects.

Involve a large number of stakeholders (e.g. contractors) entering the project at different stages with different roles and responsibilities.

Significant interface risks.

Poor project structuring and risk management.

Planned
Actual

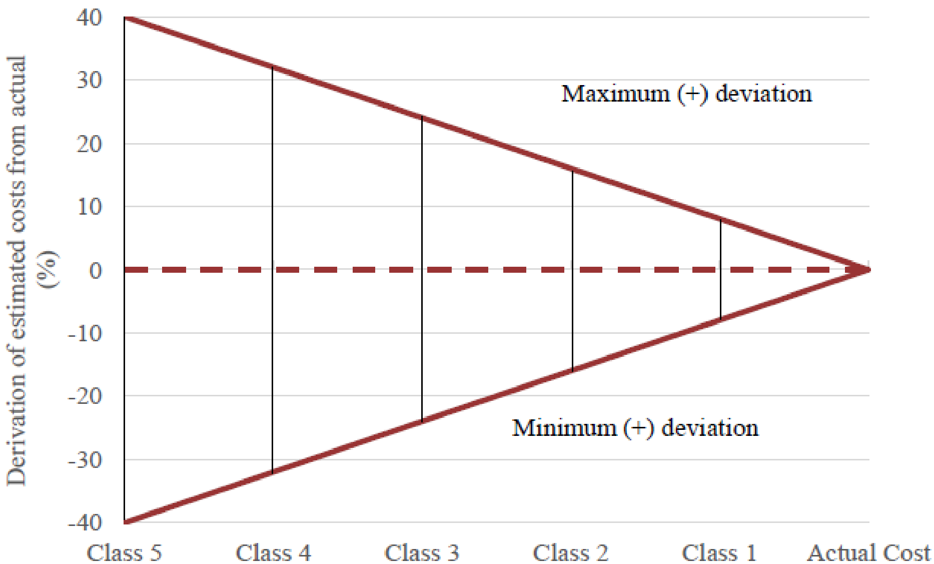
Example	Budget vs actual, € billion	Delays and start-up problems	Incorrect capacity and revenue plans	Total value lost vs plan, € billion
Eurotunnel	Planned 7.5; Actual 15.0	• 6-month delay • 18 months of unreliable service after opening	• Overestimated market-share gain in freight and passengers by 200%	~7.5
High-speed rail Frankfurt-Cologne	Planned 4.5; Actual 6.0	• 1-year delay of construction • Legal and technical issues	• Unforeseen capped government funding	~1.5
Betuwe Line NL (cargo rail)	Planned 2.3; Actual >5.0	• 1.5-year[1] delay of construction • Technology choices still not finalized	• Annual revenue shortfall of €20 million	~3.0
Kuala Lumpur Airport	Planned 2.0; Actual 3.5	• Initial issues with connectivity to downtown area • Complaints about facility hygiene levels	• Handles only ~60% of current capacity • Losing market share to Singapore	~1.5

[1]Project still not finalized and costs could go even higher.

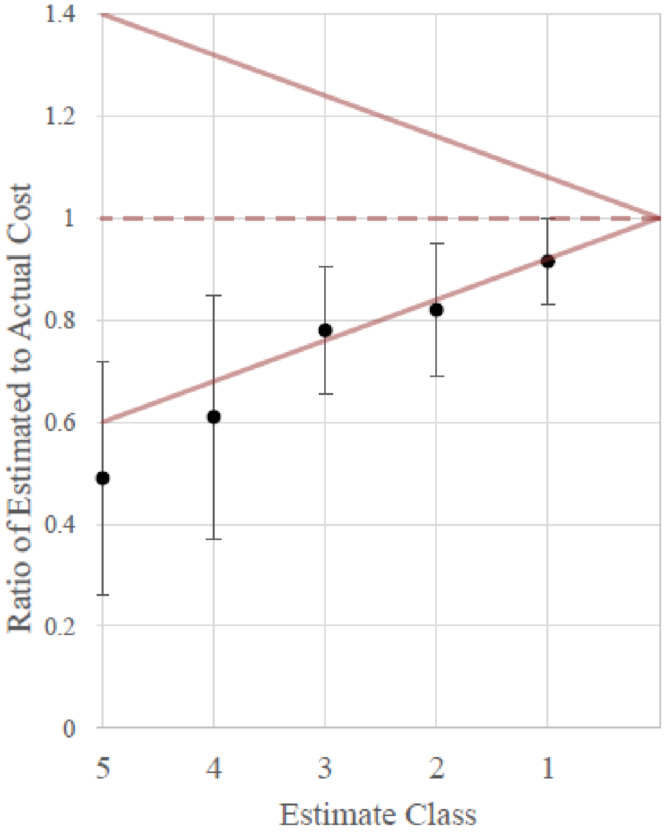
Source: Annual reports; Jane's Airport Review; McKinsey analysis; Reuters

CONSTRUCTION COSTS DRIVERS: LESSONS FROM RECENT GEN-III FOAK (1/3)

Ex-ante



Ex-post

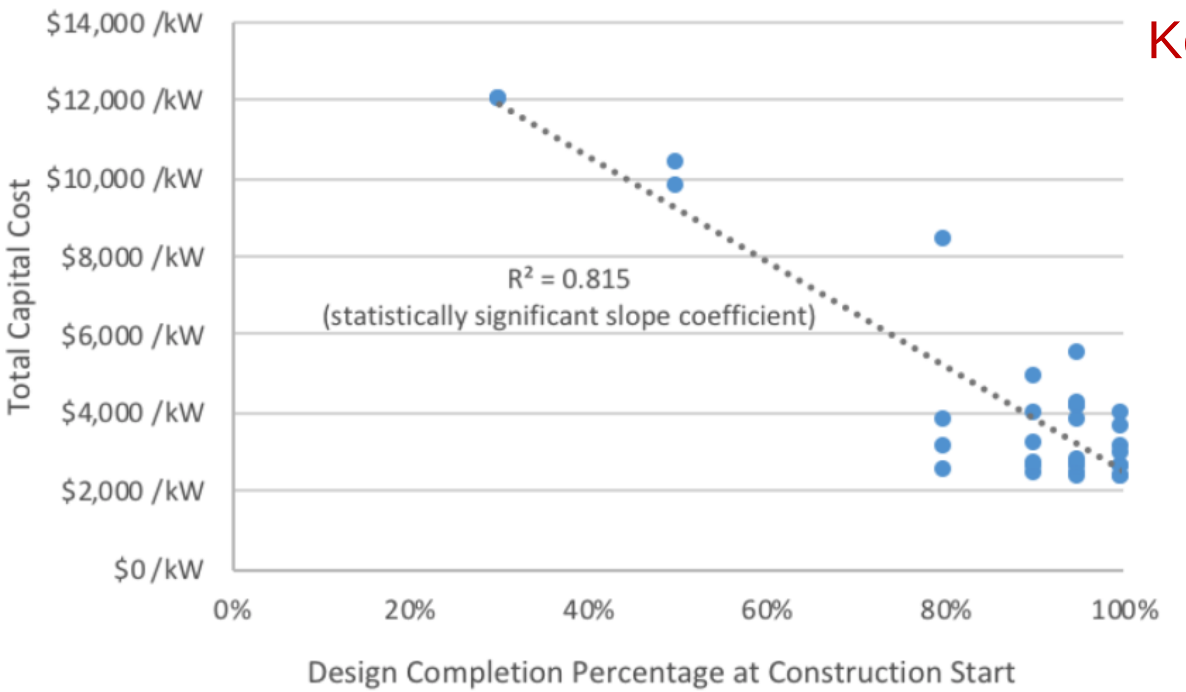


Optimisitic bias: Early estimates of projects costs are underpredicted a majority of the time

Source: Rand (1981!!!)

CONSTRUCTION COSTS DRIVERS: LESSONS FROM RECENT GEN-III FOAK (2/3)

Figure 6. Design Completion Percentage and Total Capital Cost

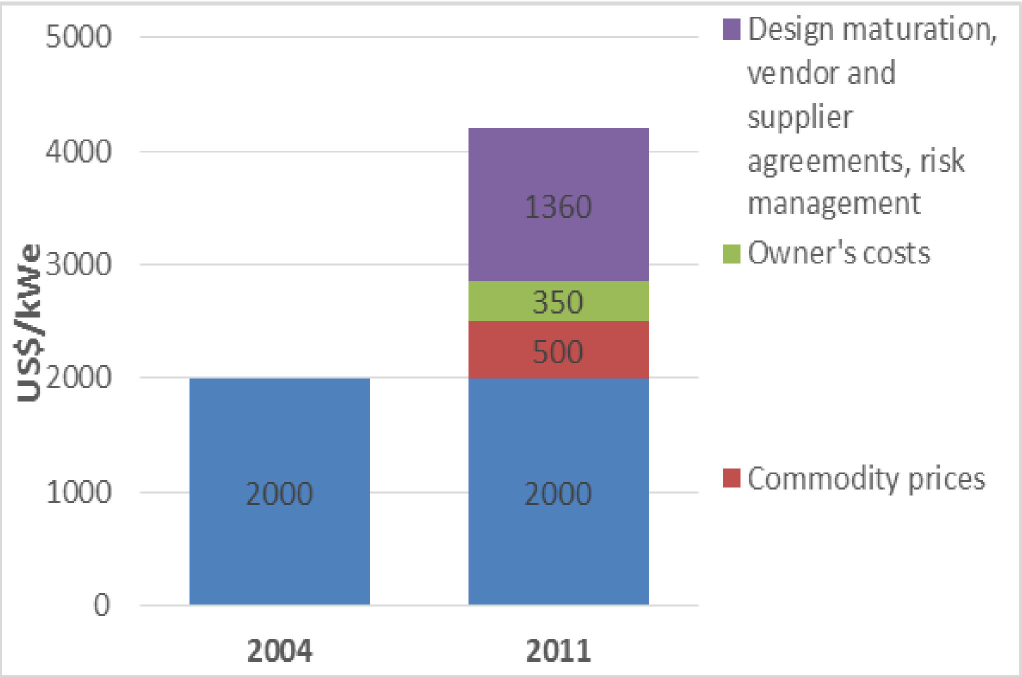


Source: ETI (2018)

Key role of **design maturity**

- Partly to do with optimistic bias to benefit from first-mover advantage
- Misalignment of incentives (e.g. push construction start in order to secure funding at Vogtle)

CONSTRUCTION COSTS DRIVERS: LESSONS FROM RECENT GEN-III FOAK (3/3)



Factor for increases in overnight construction costs in the US *(Source: Univ. of Chicago, 2011)*

Importance of **regulatory framework and industrial policy on soft costs:**

- Regulatory uncertainty
- Issues with risk allocation
  → "margins on margins effect"
- Asymmetric information and transaction costs
  → "hold up" problem

Post-Fukushima safety regulations indirect impact on construction costs through delays (?)

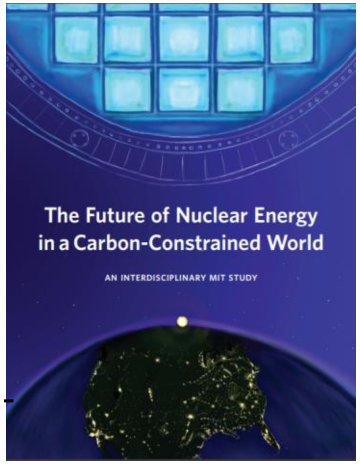
CONSTRUCTION COSTS DRIVERS: VIEW OF MIT ON THE ROLE OF NEW TECHNOLOGIES

Innovation to reduce costs, boost revenues and thermal efficiency

Reduce Capital Cost		Reduce O&M	Boost Revenues	Boost Efficiency
Modular Construction	Advanced Concrete	Robotics	Energy Storage	Hydro-phobic/hydro-philic Coatings
Seismic Isolation, Embeddment	Accident Tolerant Fuels	Advanced Informatics and I&C (AI, machine learning)	Brayton Cycles	
3D Printing	Advanced Decommissioning	Oxide Dispersion-Strengthened Alloys	Chemicals Production	Supercritical CO2

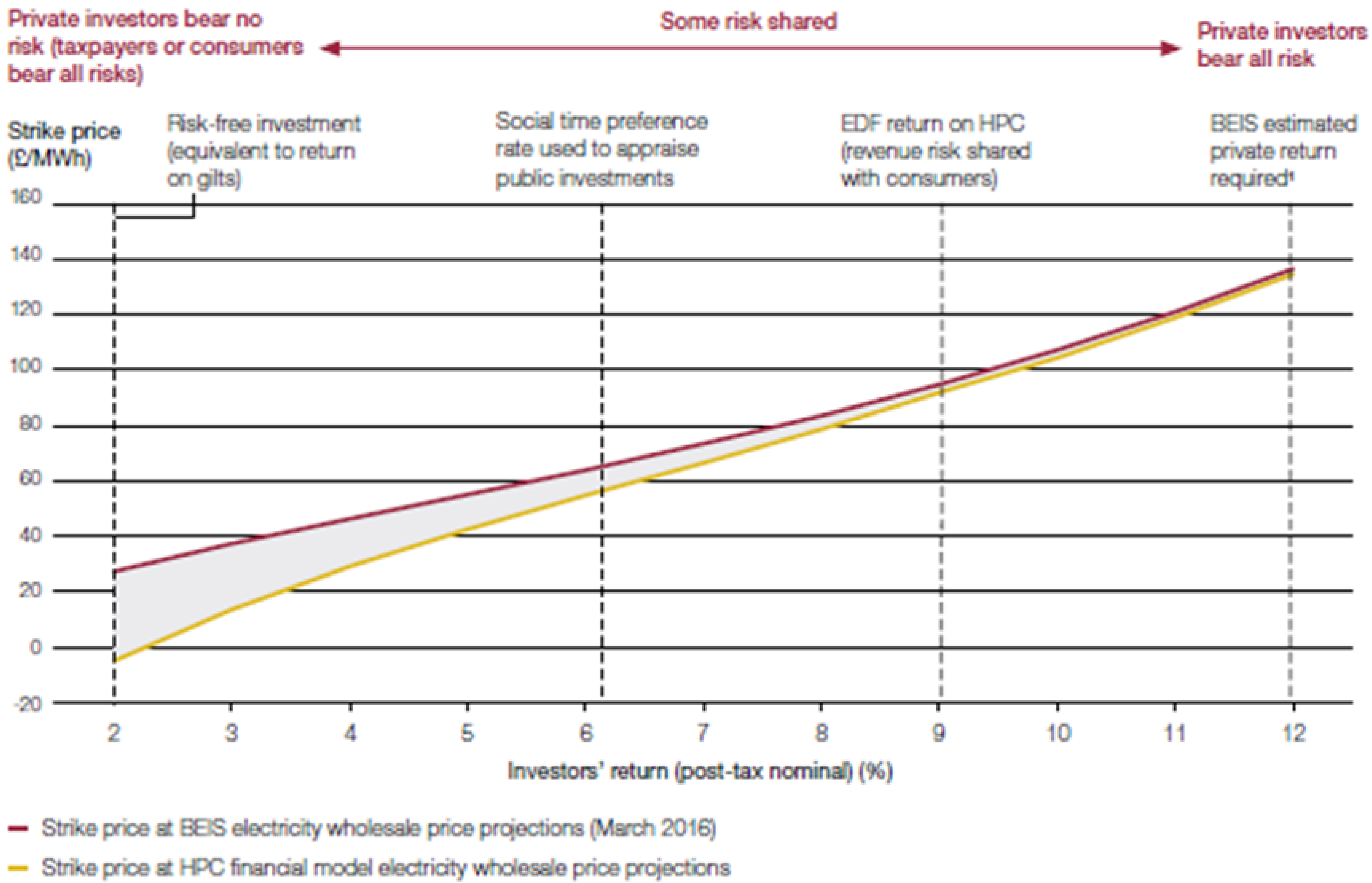
blue font = most promising

Emphasis to be put on **cross-cutting technologies** that can reduce the **indirect costs**



http://energy.mit.edu/wp-content/uploads/2018/09/The-Future-of-Nuclear-Energy-in-a-Carbon-Constrained-World.pdf

THE ROLE OF PUBLIC INTERVENTION FOR REDUCING THE COST OF CAPITAL



Department for Business, Energy & Industrial Strategy, “Hinkley Point C”, National Audit Office, HC 40 SESSION 2017-18 23 JUNE 2017

KEY FACTORS FOR REDUCING CONSTRUCTION COSTS: CONCLUSIONS FROM SFEN STUDY

1) Design **maturity** & **simplification** (EPR2 project)

2) **Procurement** & risk management practices

3) **Policy framework**, in particular for reducing **financing** costs

4) **New technologies** (digital, HP concrete, modular construction, ...)

5) **Learning by doing** + **twin** effect through **standardization**

Conclusion SFEN study: **- 30 % construction costs** reduction achievable for future projects

DIFFERENT CATEGORIES OF RISK FOR NUCLEAR PROJECTS

A nuclear projects covers a range of risks in a single multi-billion project

- Market risks: In Europe, electricity prices divided by 2 over the last 10 years (60 to 30 €/MWh)
- Politicial risks: energy policy reversal with changes in political majority
- Technical risks: costs overruns & delays

➡ **Need to balance risks between investors, final consumer and the State**

Two keys energy policy enablers:

- Support low carbon investments → **credible & robust CO_2 price**
- Some form of **long term contract** → RAB, CfD, ..

➡ Conclusion SFEN study: **up to -50 % financial costs** reduction achievable for future project

CONCLUDING REMARKS

New nuclear needed to meet our **2050 CO2 objectives** (IEA, EU, IPCC)

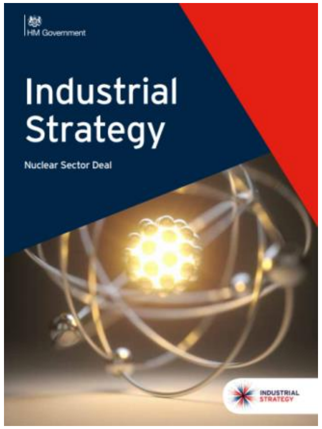
The nuclear industry is moving from FOAK and could deliver ‘rapidly’ more competitive Gen-III/III+ series reactors

- Important to capitalize on the **lessons learnt + supply chain competencies**

Need to consider together construction costs reduction and financing as key levers to reduce overall LCOE

- **Better risk allocation** between public and private stakeholders to mitigate project risks and avoid misalignment of incentives
- New nuclear = infrastructure project

(New) nuclear requires a concerted effort between the industry and policy makers



THANK YOU FOR YOUR ATTENTION

michel.berthelemy@cea.fr