Achieving large-scale deployment of SMRs:

The role of design engineering, manufacturing and codes and standards

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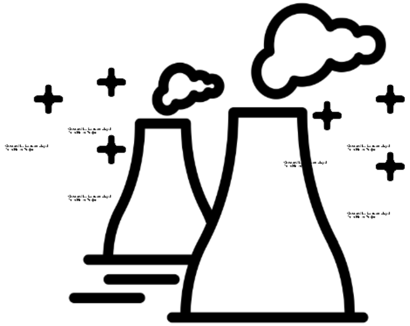
Outline

1. **The Context – SMRs in Net Zero pathways**
2. **SMR competiveness – Supporting a global market**
   - ***The role of engineering design, manufacturing and codes and standards***
   - ***Some challenges***
   - ***Conditions for success***
3. **Key takeaways**

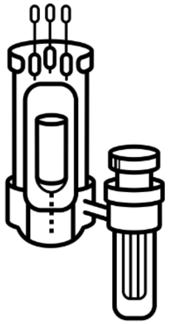
1. Context – SMRs in Net Zero Pathways

The Full Potential of Nuclear Energy in Net Zero Pathways

Long Term Operation



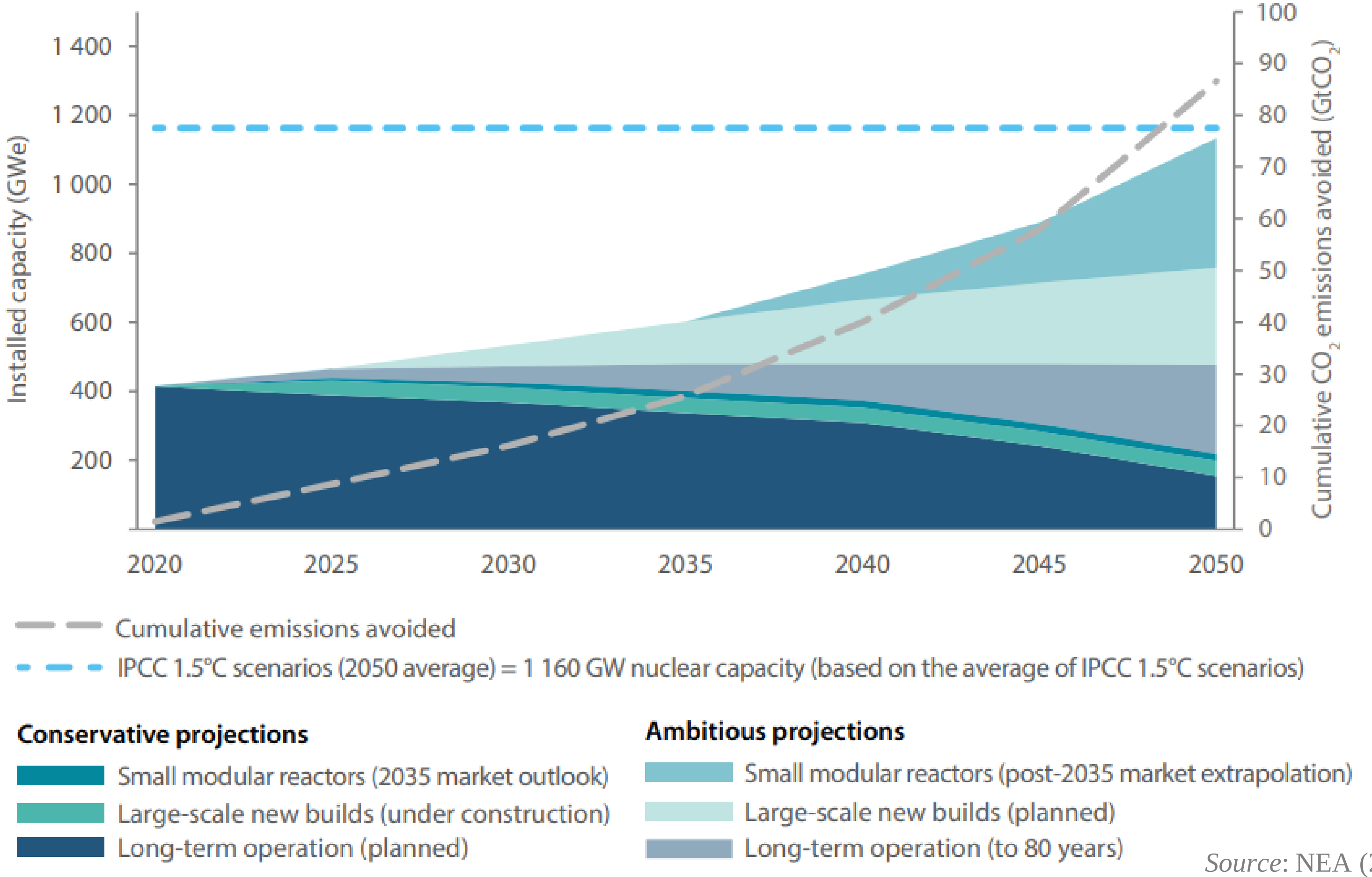
Gen-III Reactors



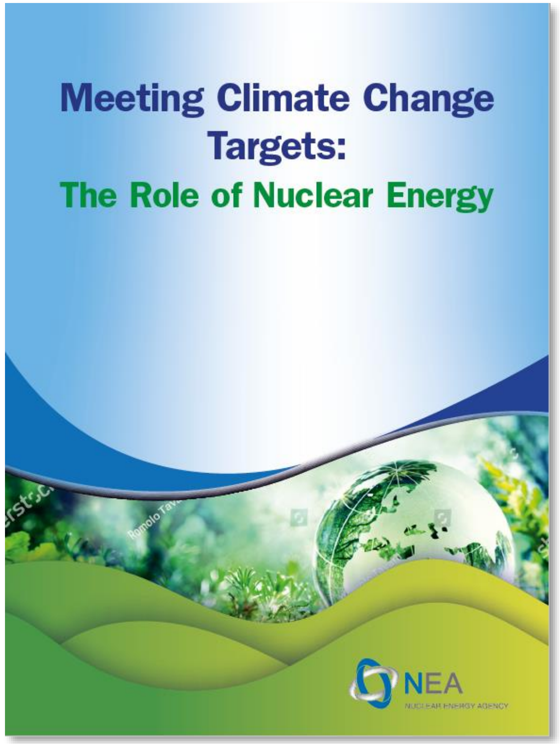
Small Modular Reactors

Non-Electrical applications

SMRs could represent around 30% of the installed capacity by 2050



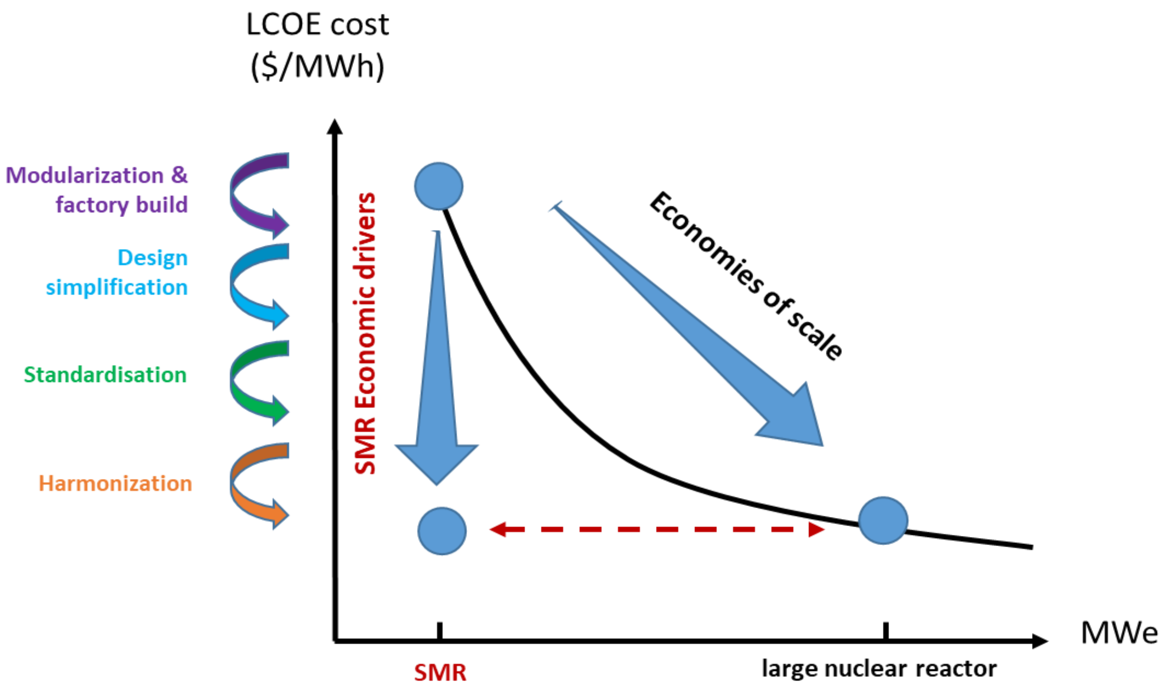
Source: NEA (2022)

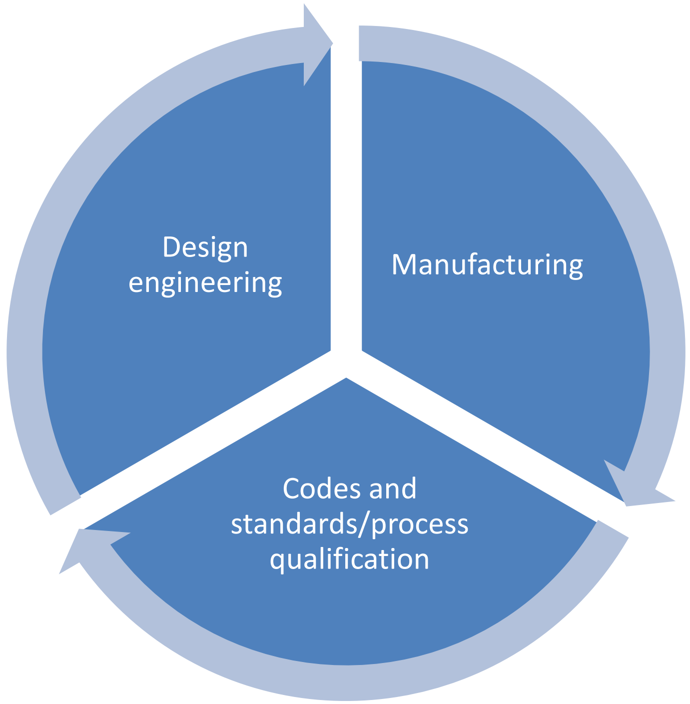


Link: https://www.oecd-nea.org/jcms/pl_69396/meeting-climate-change-targets-the-role-of-nuclear-energy

2. SMR competiveness – Supporting a global market

Economies of series are at the core of SMRs competiveness

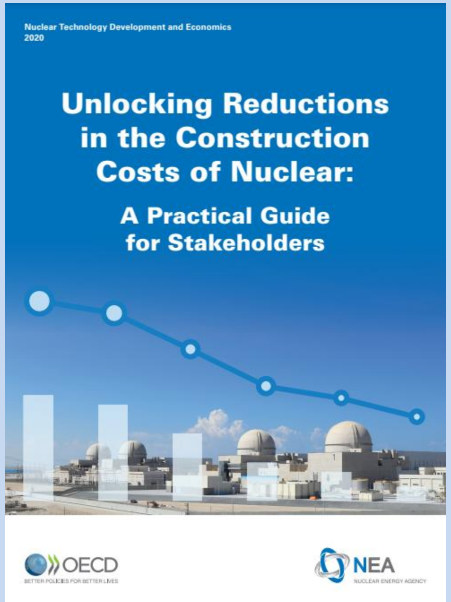




To balance **diseconomies of scale,** SMRs aim to foster **economies of series** through a number of specific drivers. These economic drivers have already been **proven in other industries** (e.g. shipbuilding, aircraft) but will require a **global market**

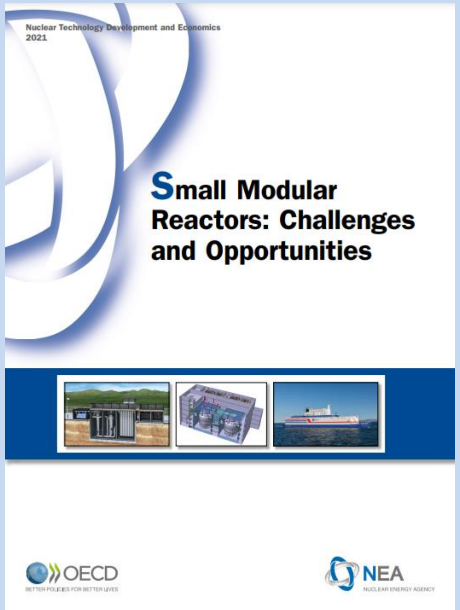
Recent NEA Products and Initiatives related to SMRs

Unlocking Reductions in the Construction Costs of Nuclear (2020)



Report: https://www.oecd-nea.org/jcms/pl_30653/unlocking-reductions-in-the-construction-costs-of-nuclear?details=true

Small Modular Reactors: Challenges and Opportunities (2021)



Report: https://www.oecd-nea.org/upload/docs/application/pdf/2021-03/7560_smr_report.pdf

Workshop on Advanced Construction and Manufacturing methodologies for New Build

Objective:

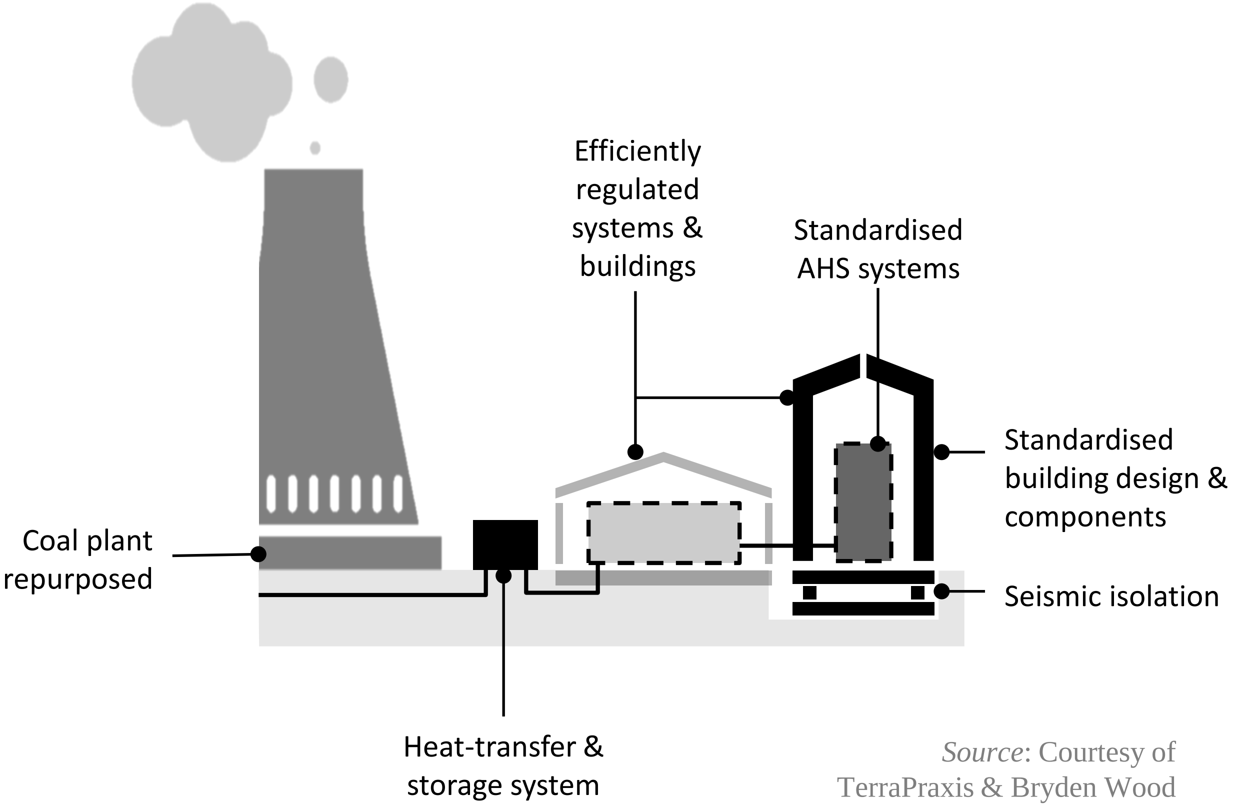
- Assess how new construction and manufacturing techniques, along with new design and project management approaches, can reduce overall construction risk and costs

Link: https://www.oecd-nea.org/jcms/pl_64903/advanced-construction-and-manufacturing-methodologies-for-new-nuclear-build

Design engineering: Design to achieve scale and speed of the built systems, processes and stakeholders' interactions

- **Simplification:**
  - Risk-informed approaches to minimize the nuclear scope, reduce the number active components and enable COTS
  - Shared infrastructure across modules
- **Improved standardization:**
  - Optimal levels of modularity with reduced site-specific work
  - Do not forget the deliver chain
- **Fit to requirements**
  - Design for manufacturing, assembly, cost and end-user requirements

Illustrative example of standardized coal-plant repowering with a SMR



Source: Courtesy of TerraPraxis & Bryden Wood

Manufacturing: a new whole set of techniques is available with SMRs

- The reduced size and weight as well as simple geometries enable the adoption of new manufacturing techniques not suitable for large reactors
- Most promising techniques include: Hot isostatic pressing, electron beam welding, additive manufacturing, laser diode cladding, etc.
- Main advantages include: speed, lower costs, reduced inspection needs, and lower commodity usage
- Possibility to combine manufacturing techniques with other innovations (e.g. digital solutions) to achieve higher levels of automation and accuracy

Main characteristics of reactor pressure vessel welding techniques

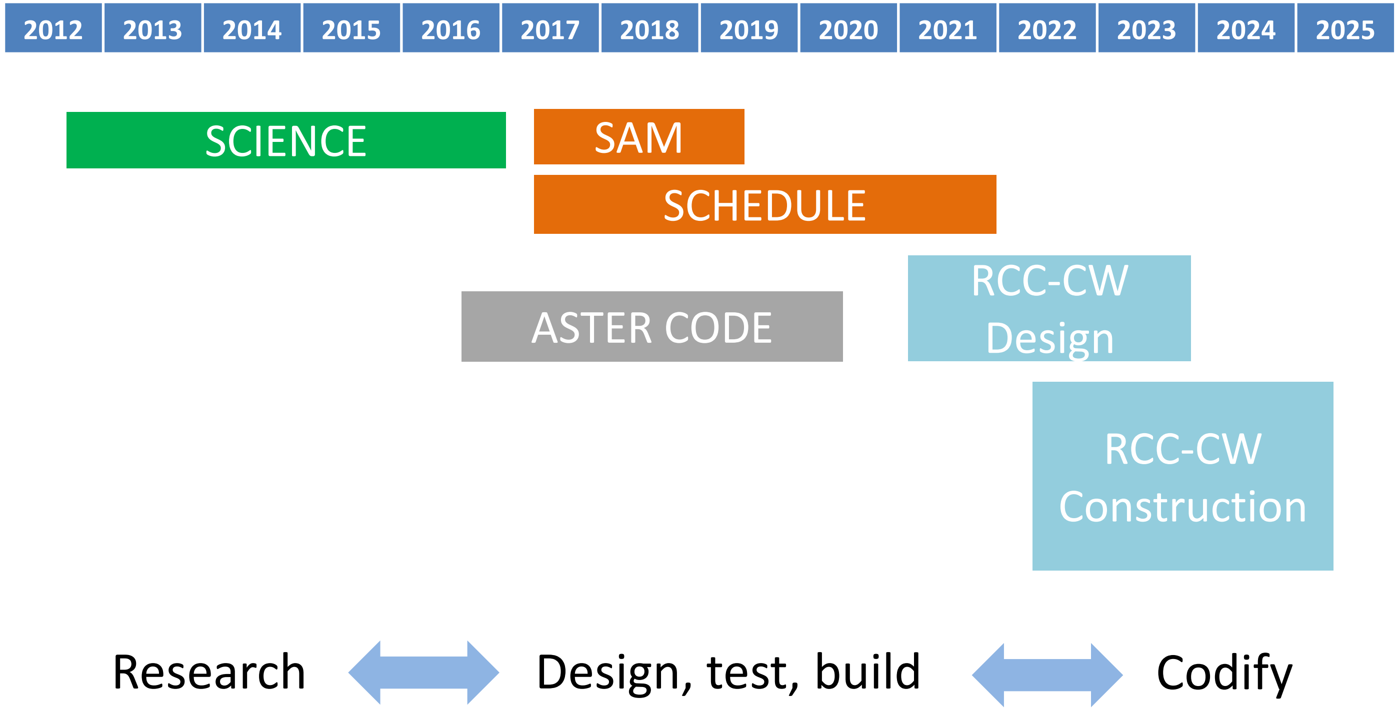
Welding technique	Estimated duration (Days)	Mass of the filler (kg)	Carbon footprint (kg of CO2)
Gas tungsten arc welding	99	1932	1820
Submerged arc welding	26		
Narrow-groove gas tungsten arc welding	38	1535	686
Electron beam welding	**1.2**	**0**	**9**

Source: Adapted from NARMC

Codes & Standards: Leverage on existing codes while maximizing harmonization from the outset

- New approaches requires new standards to ensure reproducibility, volume and reduce cost through keener competition
- Standards already exist in most cases but adaptation to nuclear requirements are needed. The developing new standards can be quite lengthy (more than a decade)
- Trades-off between the use of existing standards and new one should be sought
- Harmonisation is possible in certain common areas and remains a major driver to build a truly global market. The development of new standards brings opportunities to maximize harmonisation.

Qualification process of steel plate-concrete structures for nuclear construction (European case)

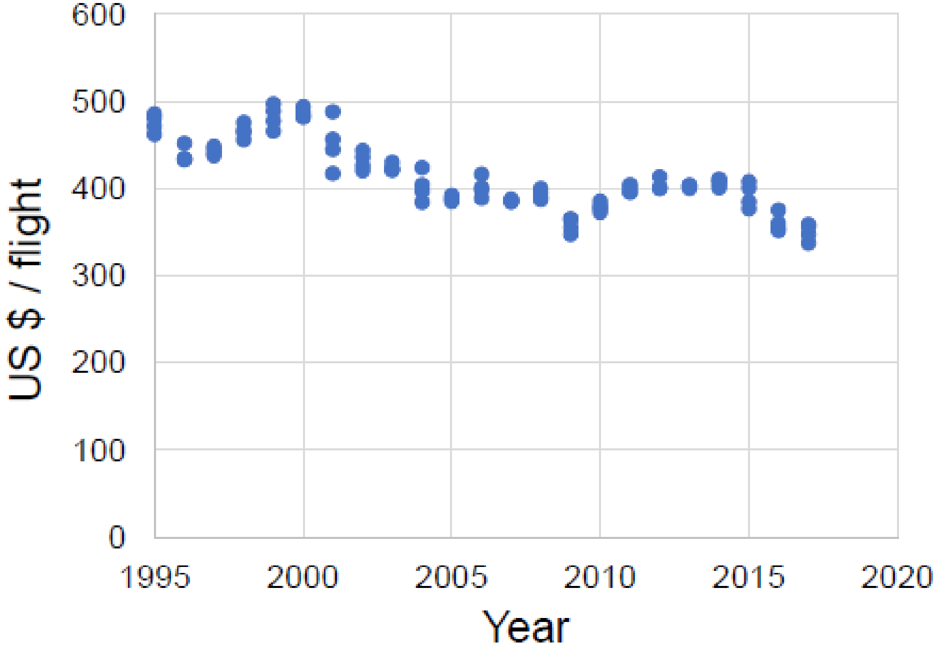


Source: Adapted from EDF

Measuring the benefits of standards harmonization

The case of the aviation industry

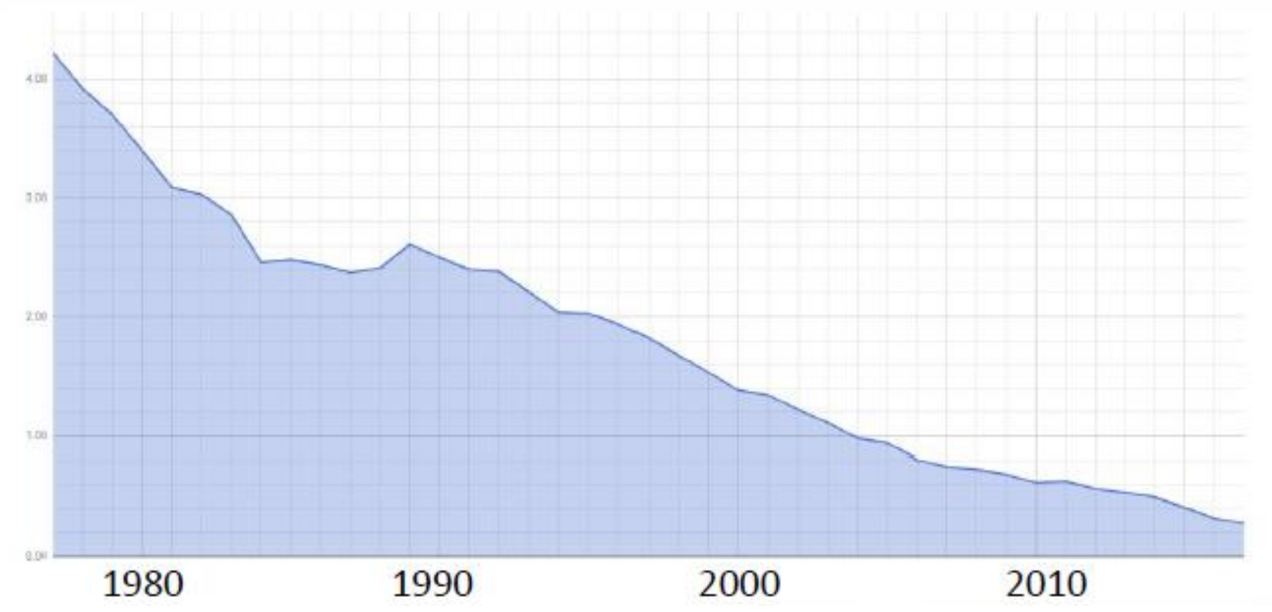
US Average Domestic Air Fares, inflation adjusted



Lower costs due to keener competition

Source: Bureau of Transportation Statistics
https://www.transtats.bts.gov/AIRFARES/

Airliner Accident Per 1 Million Flights 1977-2017



Increased quality and safety

Source: https://www.aviation-safety.net/statistics/

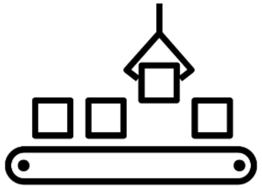
Some challenges…

- Some design approaches represent **a significant departure** from existing methodologies which requires training, new skills and could also **face change resistance** in organization.
- The maturity level of some advanced manufacturing techniques for nuclear designs is still low and **further efforts are needed for full industrialization**
- The development of new code and standards is a **lengthy and expensive process** that not all suppliers can afford. Most of the codification efforts are carried out **in a voluntary basis** which could face some limitations
- Harmonization efforts are limited by the need to **protect national sovereignty of regulators and political considerations**
- Promote innovation is not the core activity of regulators. Some regulators may be reluctant to the adoption of new approaches and lack the **ability to regulate innovation**

More projects needed to align stakeholders and put all these new engineering and manufacturing techniques into practice and refine code and standards

Conditions for Success – *beyond technical feasibility…*

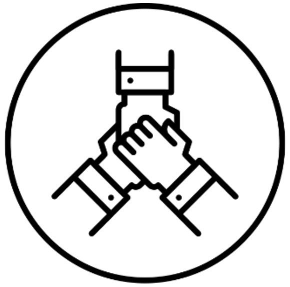
Regulatory and Policy Enabling Frameworks



Ramped up Supply Chains and Talent Pipeline

Market Demand and Good Fit

Public Confidence and Community Support



Strategic Partnerships – Public-Private, Indigenous, International

Public-Private Financing

Conditions for Success – *beyond technical feasibility…*

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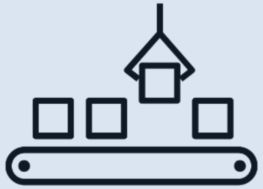

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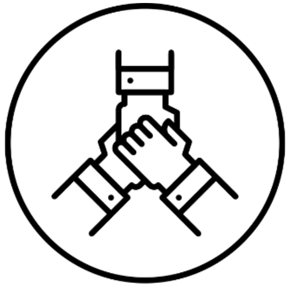

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Creating enabling regulatory framework

The US NRC Action Plan for Advanced Manufacturing Technologies (AMT)

- In June 2020, the NRC published the Revision 1 of its AMT Action Plan in order to prepare the organisation to the increasing appetite of nuclear industry to adopt new manufacturing techniques
- The Action plan has three main tasks:
  - **Technical preparedness:** prepare NRC staff to review AMT applications
  - **Regulatory preparedness:** guidance to support the effective review of AMT applications
  - **Communications and Knowledge management:** collection and integration of information and engagement with external partners.
- **Non-safety related**, additively manufactured components already installed in two US reactors

Westinghouse produces 3D-printed component for US nuclear plant

7 May 2020

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Print Email

US-based Westinghouse Electric Company announced on 4 May that a 3D-printed thimble plugging device was successfully installed Exelon's Byron 1 during their spring refuelling outage.

The thimble plugging device is used in nuclear reactors to help lower fuel assemblies into nuclear reactor cores. It is a first-of-a-kind installation for the nuclear industry.

"Our additive manufacturing programme offers customers enhanced component designs that help increase performance and reduce costs, as well as provide access to components that may not be available using traditional manufacturing methods," said Ken Canavan, Westinghouse's chief technology

Source: https://www.neimagazine.com/news/newswestinghouse-produces-3d-printed-component-for-us-nuclear-plant-7911951

Building up capabilities through targeted, pilot projects

US National Reactor Innovation Center - Advanced Construction Technology (ACT)

- ACT utilizes expertise from industry, academia, research institutes, as well as existing infrastructure, to demonstrate construction technologies not being yet used in the nuclear industry
- Several promising technologies have been selected for specific demonstration projects. The objective is to build confidence but also reduce regulatory risks:
  - Steel Bricks
  - Vertical Shaft Construction
  - Digital Twin and advanced monitoring technology

Building up capabilities by supporting non-nuclear manufacturers

UK Fit 4 Nuclear Initiative

- Fit For Nuclear (F4N) is a unique service to help UK manufacturing companies get ready to bid for work in the nuclear supply chain
- It builds on the success of similar initiatives in other low-carbon sectors such as Fit For Offshore Renewables
- More than 950 companies have now completed the online F4N assessment, with most receiving ongoing support and development from the team. Around 110 are currently granted F4N after putting their action plan into practice

F4N Fit For Nuclear

3. Key Takeaways

Demonstration is key to prove to refine the design engineering, manufacturing and codes and standards for SMRs that will support a truly global market

- **SMRs are part of the nuclear power solutions** to achieve (and remain) in net zero pathways
- The success of SMRs will rely on **the creation of a truly global market** that will foster learning effects**. Design engineering, manufacturing and codes and standards are key levers** to achieve the necessary scale that will support a global market
- The theory, techniques and processes are well known but they **need to be put into practice and at scale**. This requires a set of enabling conditions that go beyond pure technical feasibility: conducive policy and regulatory framework, robust supply capabilities and new build decisions, among others.
- Examples exist on how regulators and governments can support these enabling conditions. International harmonization efforts are also taking place. **Joint, pilot demonstration projects that bring all key stakeholders together** can be particularly useful to build trust and accelerate deployment.

Thank you!