Enabling Maritime Decarbonization by Using Nuclear Technology

European Tugowners Association
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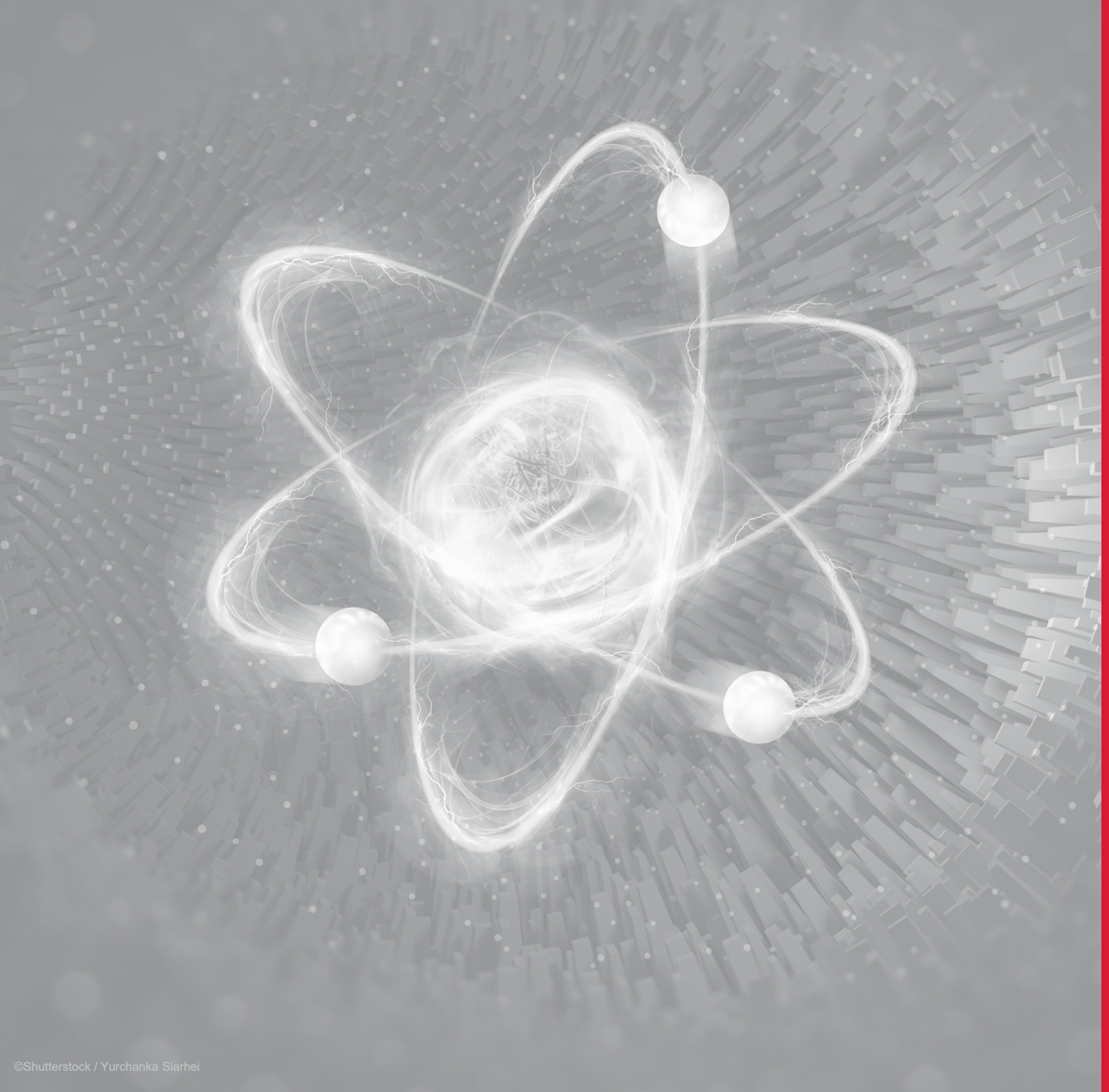

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Contents

Nuclear Maritime Applications

- United States
  - 1940: Research on marine nuclear propulsion
  - 1953: 1st naval test reactor, Mark 1
  - 1955: 1st nuclear submarine, USS Nautilus
  - 1962: U.S. Navy 26 nuclear submarines, 30 under construction
  - 1959: 1st nuclear-powered merchant vessel, N.S. Savannah

Current Military Use of Nuclear Power	
US Navy	• 73 Submarines • 11 Aircraft Carriers
Russian Navy	• 21 Submarines • 1 Battlecruiser
China	• 14 Submarines
British Navy	• 10 Submarines
France	• 9 Submarines • 1 Aircraft Carrier
Indian Navy	• 1 Submarine

NS (Nuclear Ship) Savannah, enroute to the World's Fair in Seattle, 1962
Credit: US Government - NARA

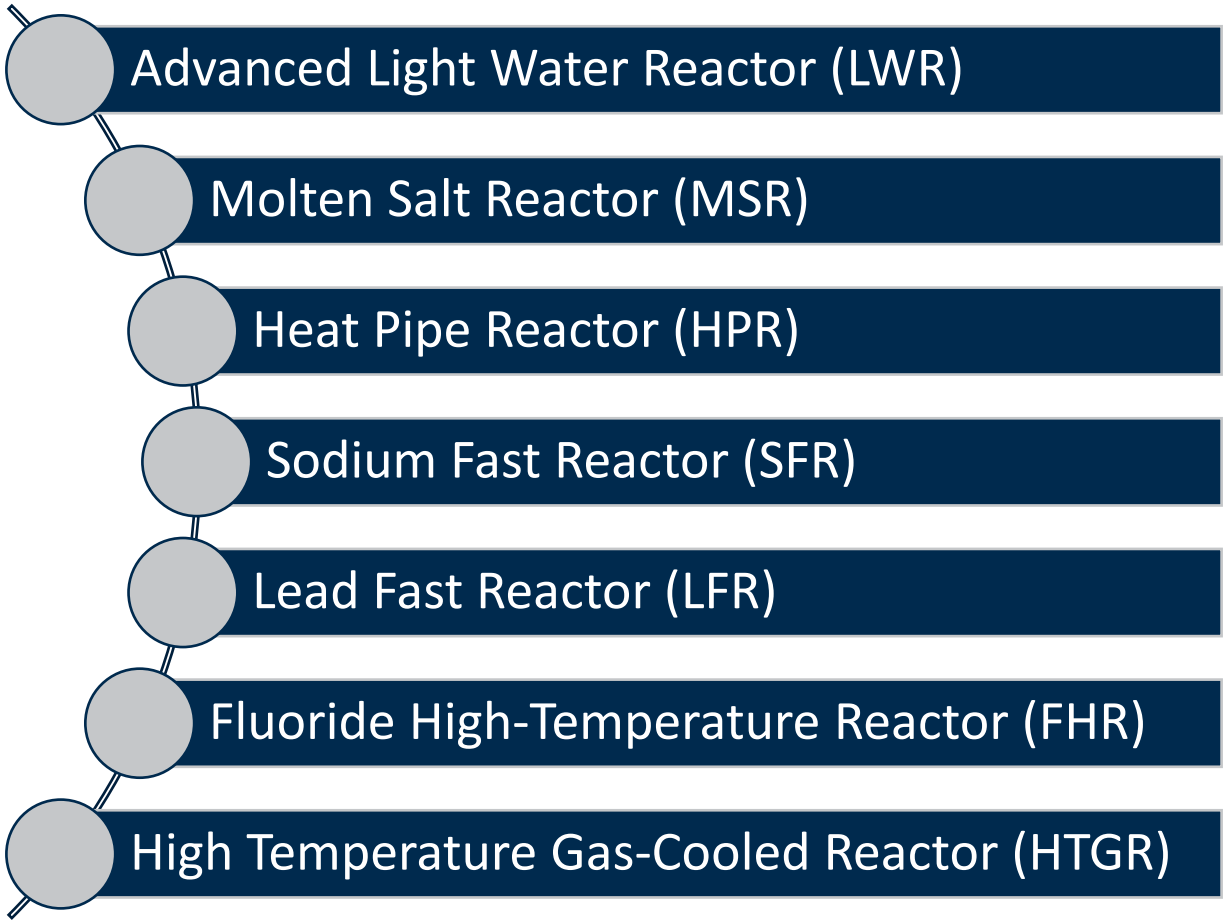
Advanced Reactors

Improved designs of conventional reactors are expected to reduce economic, security, technical, safety and regulatory barriers.

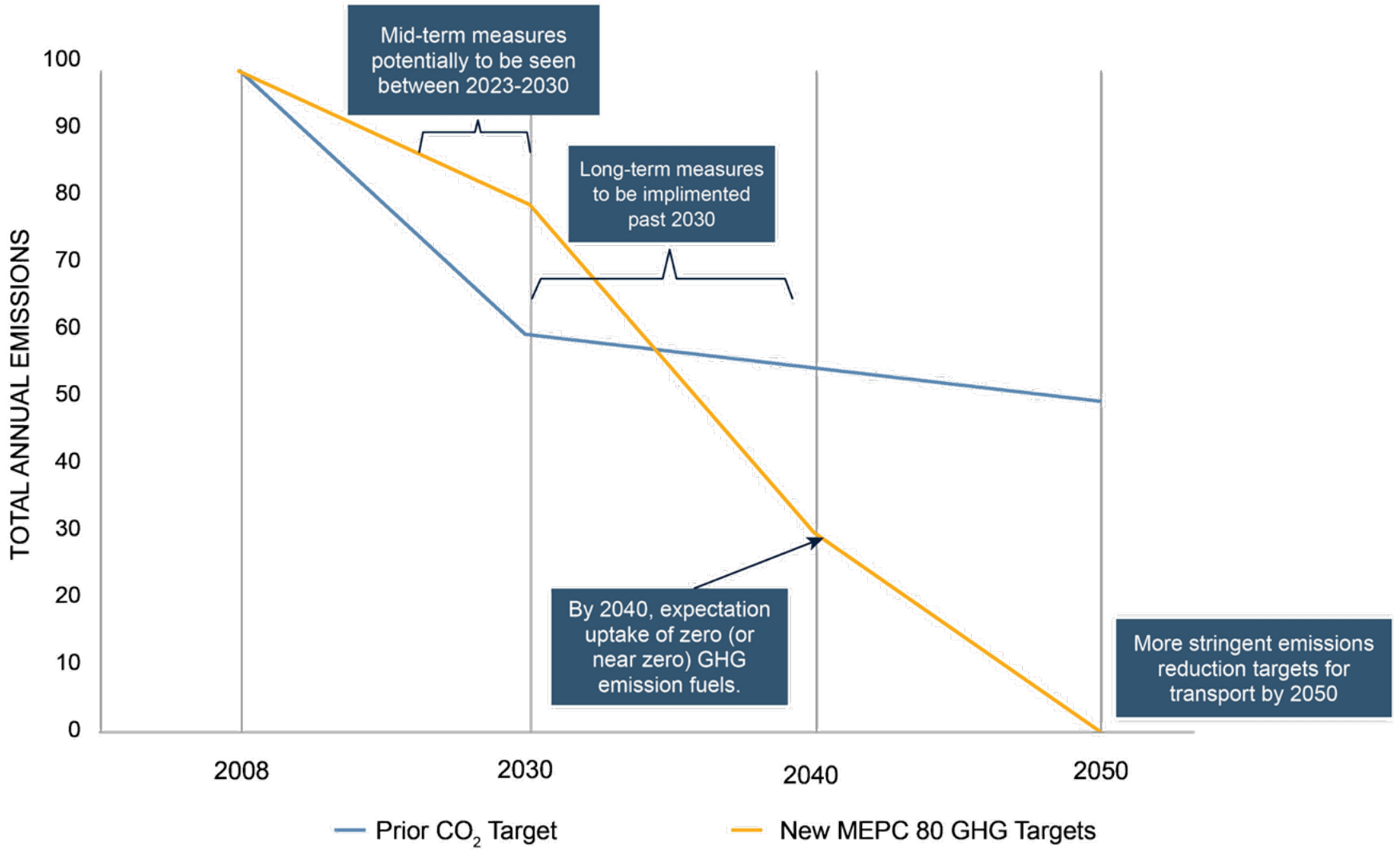
Advanced reactors may have:

- Inherent safety features
- Greater fuel utilization
- Lower waste yields from conventional nuclear applications
- Superior reliability
- Resistance to proliferation
- Increased thermal efficiency
- Integration with electric and non-electric applications

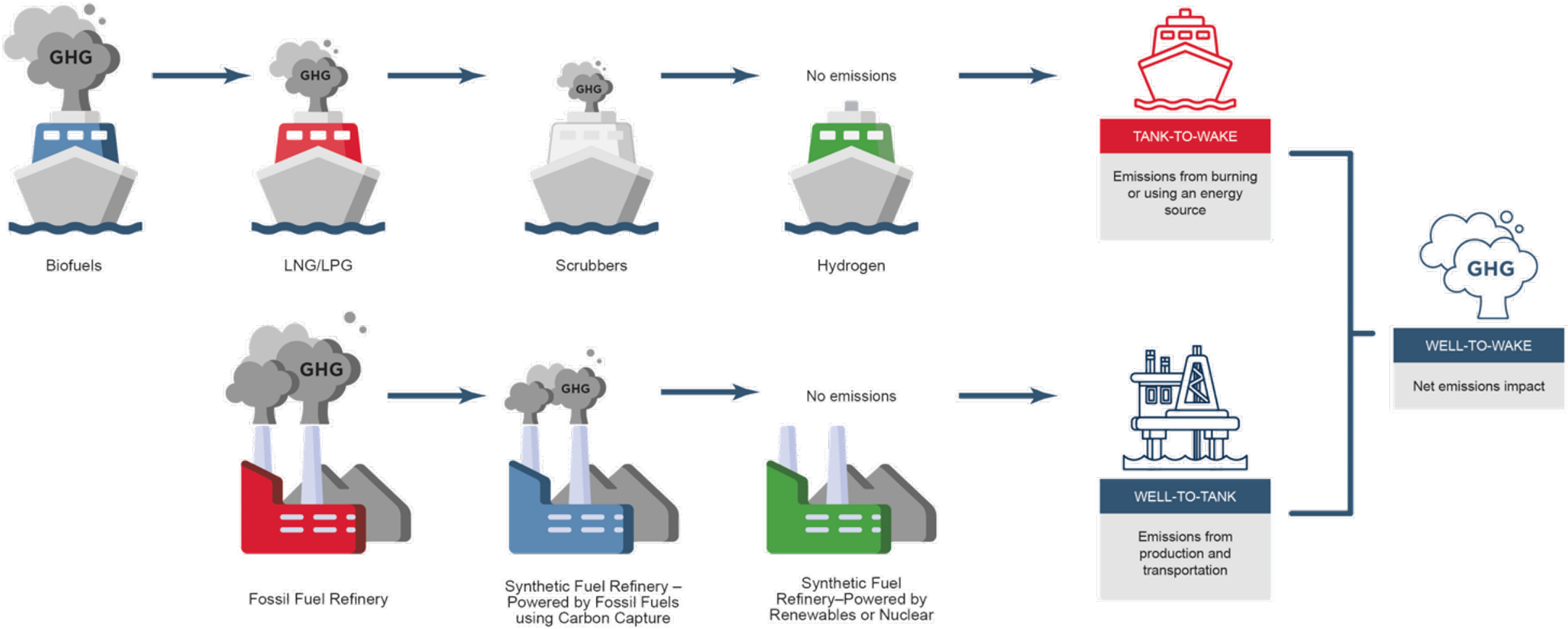
Advanced Reactor Types



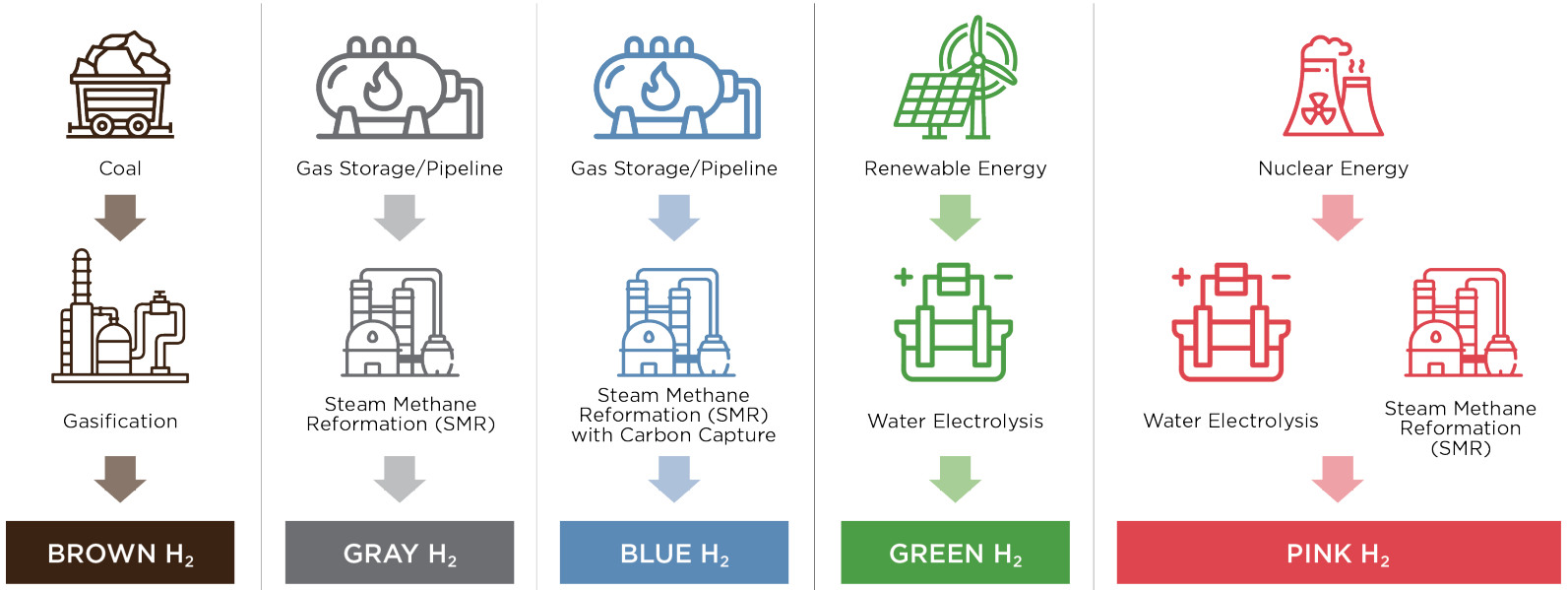
Impact of MEPC 80



Eliminating Emissions from Fuels



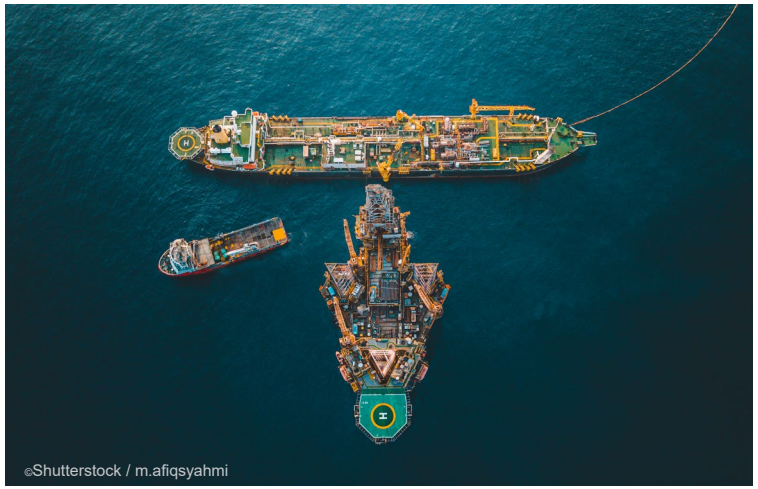
Future Fuels



Nuclear – Maritime Use Cases

Land-Based Support

- Electricity for Onshore Power Supply (OPS) to other vessels
- Produce marine fuels
- Power marine support infrastructure, shipyards, and ports



Coastal and Offshore Industry

- Floating power barge for grid electricity
- Zero-carbon power for oil and exploration
- Suitable for arrays of microreactors or small modular reactors

Nuclear-Electric Propulsion

- Reactors fitted for high power
- Zero-carbon switch
- Reduce or eliminate bunkering

Commercial Nuclear Benefits

The Blue Economy is Suited for Nuclear

- Available space away from population centers or areas with land restrictions
- Readily available water as a heat sink
- Seismic Isolation
- Desalinated/pure water available for hydrogen production from steam methane reforming or electrolysis

Commercial Nuclear Challenges

Safety

- Risk Management
- Safety Management Considerations

Regulatory

- International (IAEA,IMO).
- Flag State.
- Coastal State

Operational

- Nuclear maintenance at shipyards.
- Terminal considerations.
- Crew training requirements.
- End of life considerations.

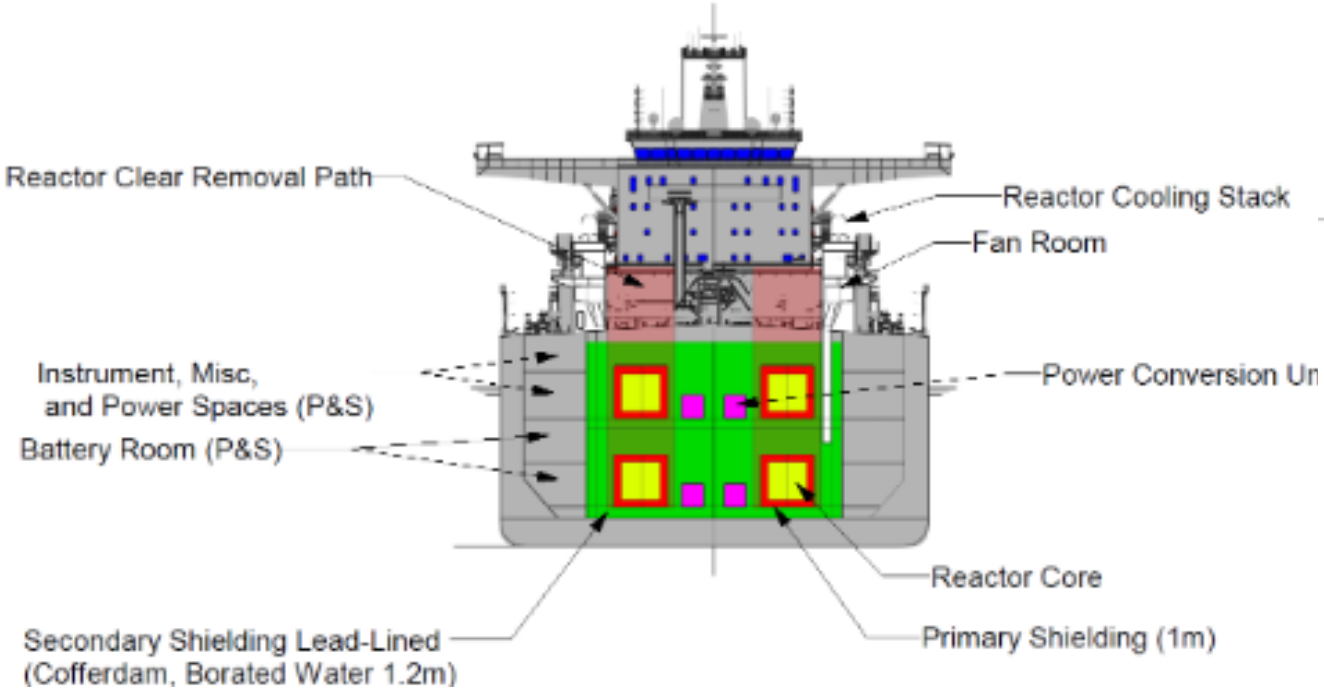
Commercial/Social

- Capex requirements for construction.
- Trade location limitations.
- Public perception and acceptance.
- Public/private partnerships.

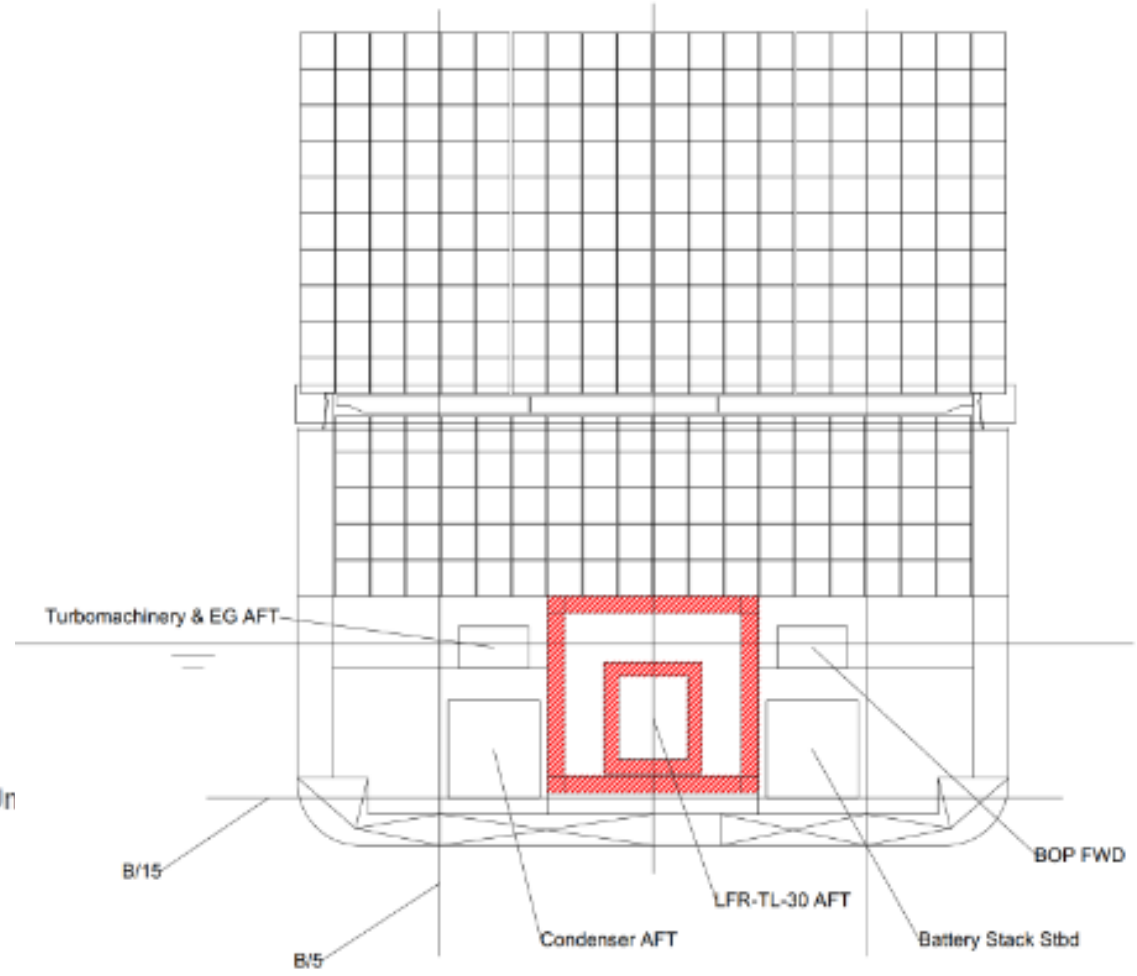
ABS

Nuclear Vessels Concept Study (Herbert Study)

- Advanced Reactors integrated with ship systems for propulsion
- Showcasing early possibilities of arrangements for reactors on vessels
- Considering the operational benefits for commercial vessels



Suezmax Tanker

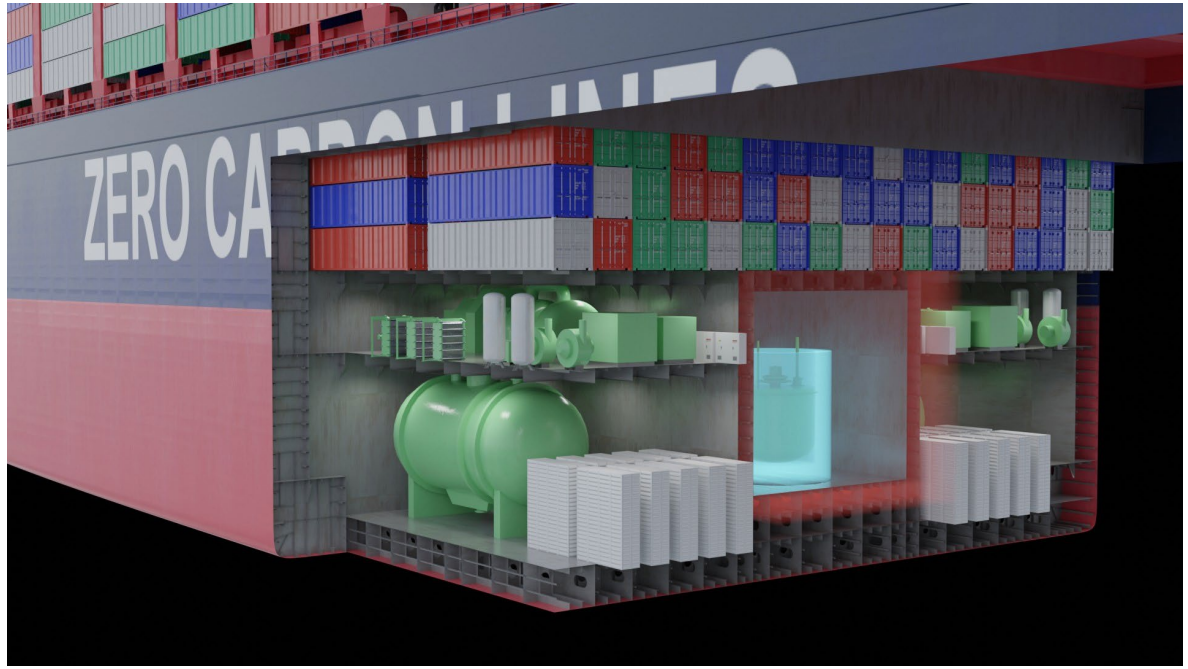


14K TEU Container carrier

Herbert Study Findings

Ship Considerations

- **Nuclear-Electric Plant** is the preferred arrangement
- **The position of the nuclear reactor likely at mid-ships**
- **Battery location** needs to account for risks
- **Turbomachinery and electrical generation plant** need to be designed with reactor type



Reactor Considerations

- **Reduce size & weight**: optimize per operational requirements
- **Maintainability** during short periods of drydocking
- **Minimize the need for re-fuelling**
- **Flexible power** to support variable load requirements typical of time at sea

New Technology Qualification

- New Technology Qualification for a Compact Molten Salt Reactor to power a commercial power barge
- December 2020: New Technology Qualification Feasibility Statement issued

IN THE SPOTLIGHT: ABS completes feasibility study on Molten Salt Reactor Technology

THU, DEC 17, 2020 15:36 CET

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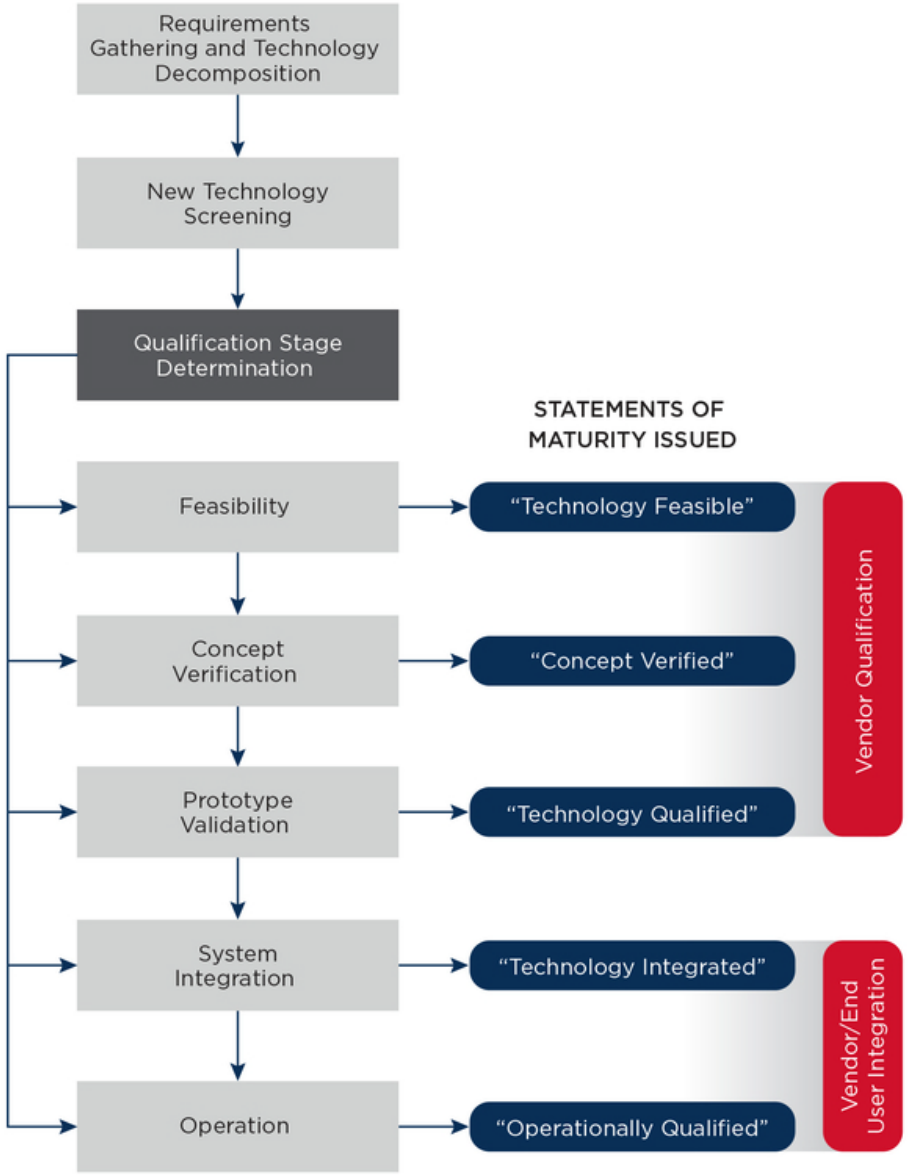
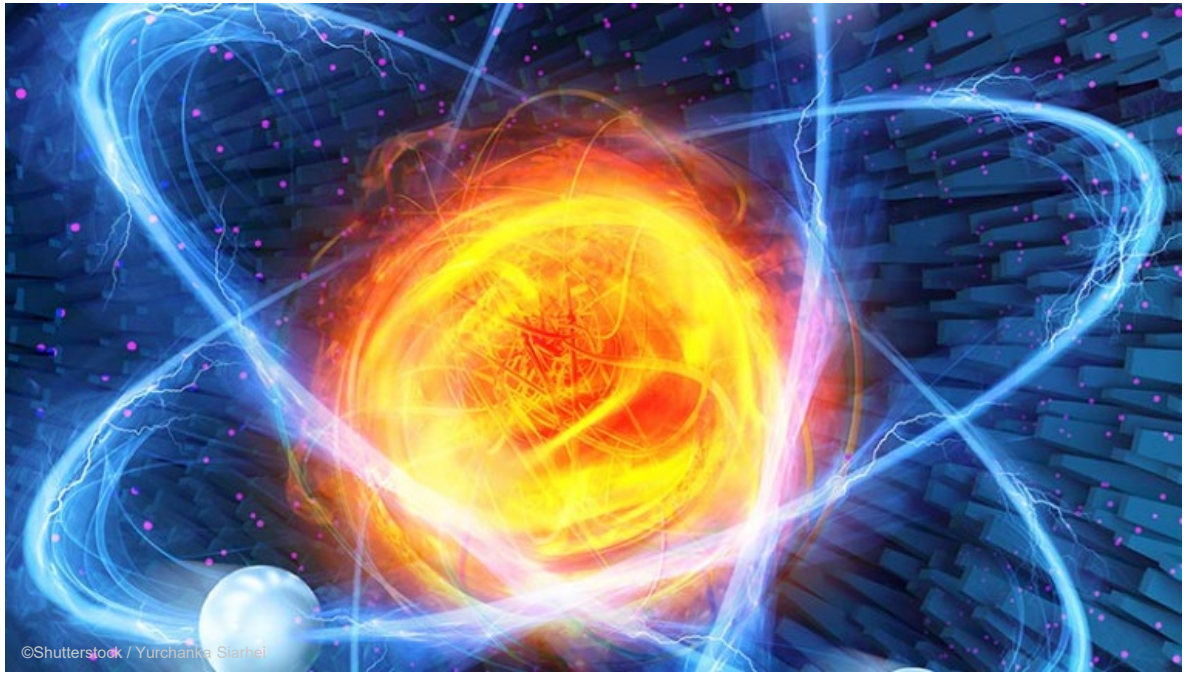


Future Collaboration

- ABS can assist shipowners and operators researching alternative fuels, like nuclear power, through:
  - Risk assessments
  - Modeling and simulation
  - Techno-economic analysis
  - Joint projects
  - Qualification of New Technologies
  - Approvals in Principle



Thank You

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