Extraordinary Innovation Project 109IN206

Nuclear Powered Ships – Is it feasible?

Political, Societal, Technical, and Commercial Aspects

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Courtesy of DNV

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MANAGING RISK

Question?

- Do you believe ***nuclear power shipping*** will be a reality 20-30 years from now?

- Do you really want to have it?

Objective of the DNV feasibility study

- Evaluate feasibility of nuclear powered ships with regard to;
  - *Technical*
  - *Commercial*
  - *Societal, political and regulatory aspects*

- Explore benefit or business opportunity for DNV, and

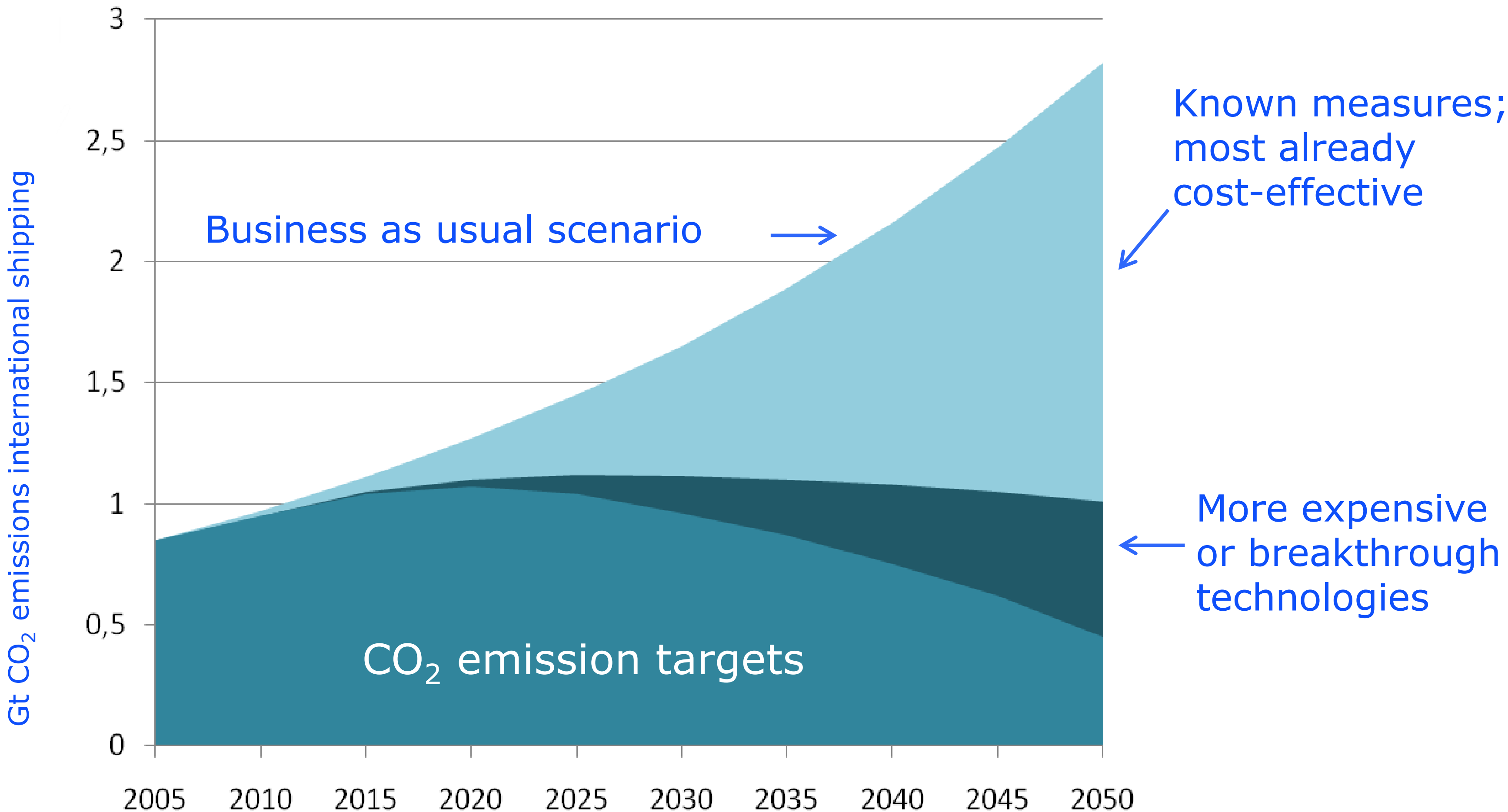
- Recommend further actions

Conclusion: Feasibility of nuclear powered ships

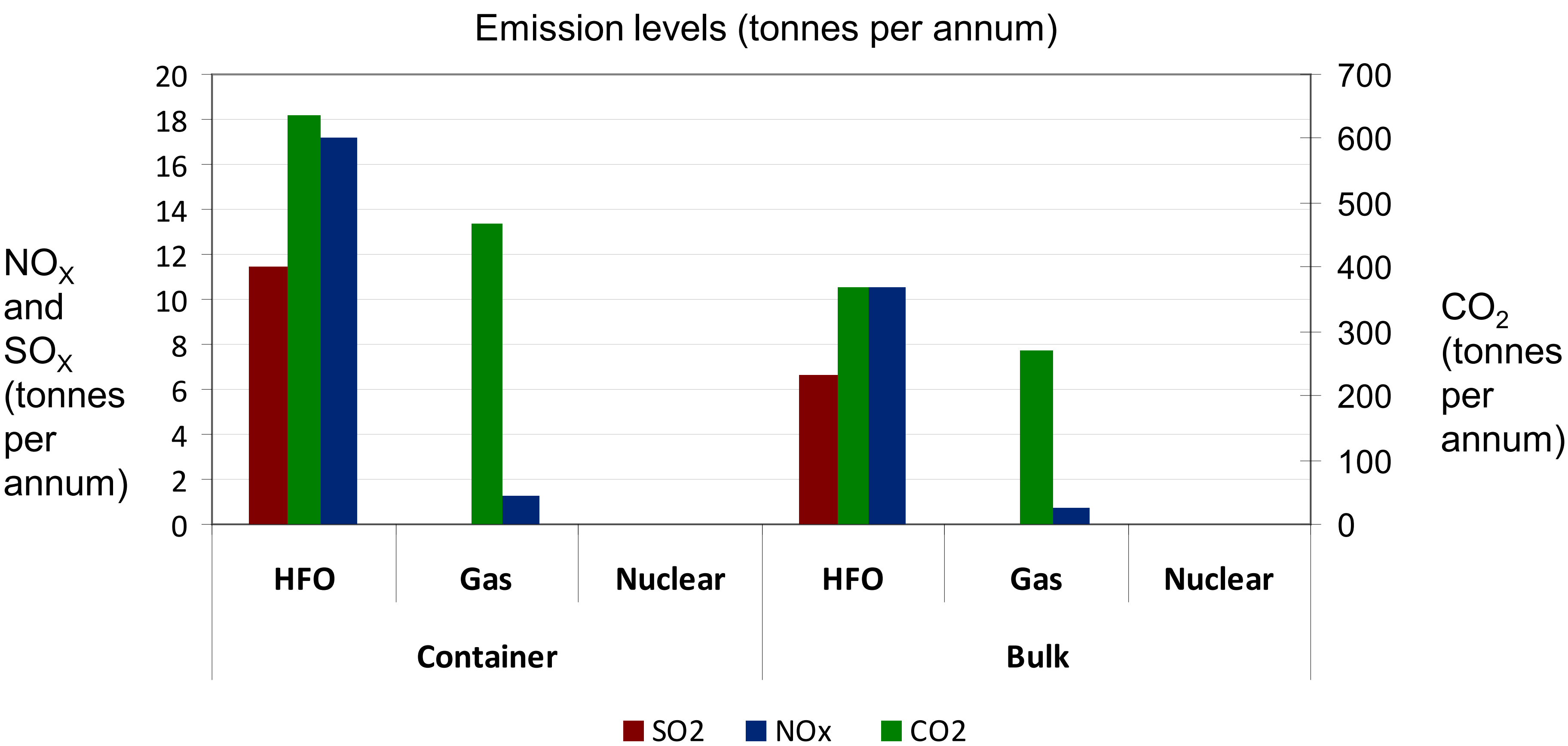
- Technically: **Feasible**
- Commercially: **Feasible, but …**
- Politically: **Possibly feasible, but …**

WHY this study?

Cutting CO_2 emissions from baseline scenario

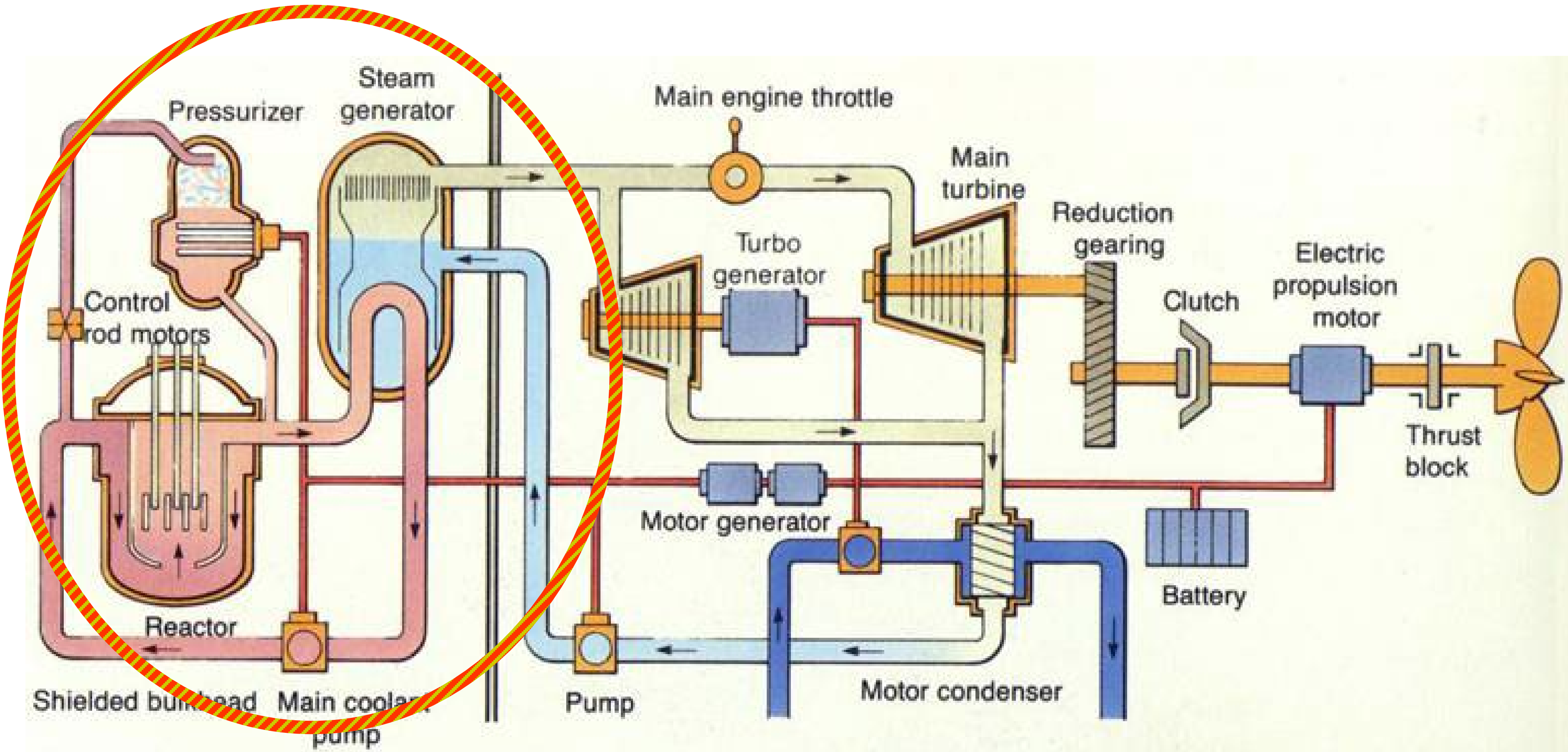


Environmental performance



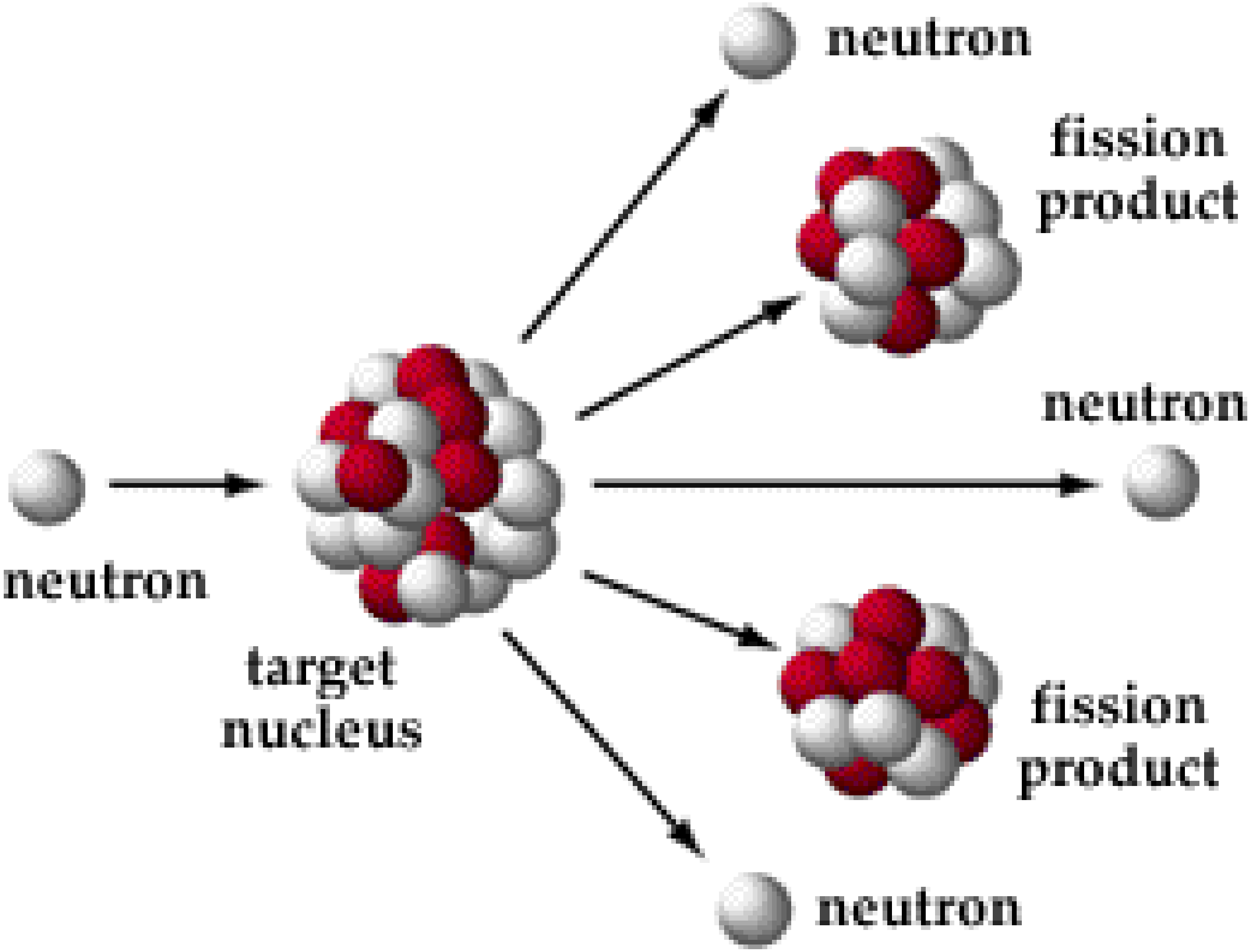
Emissions calculated based on two case studies

What is nuclear shipping?



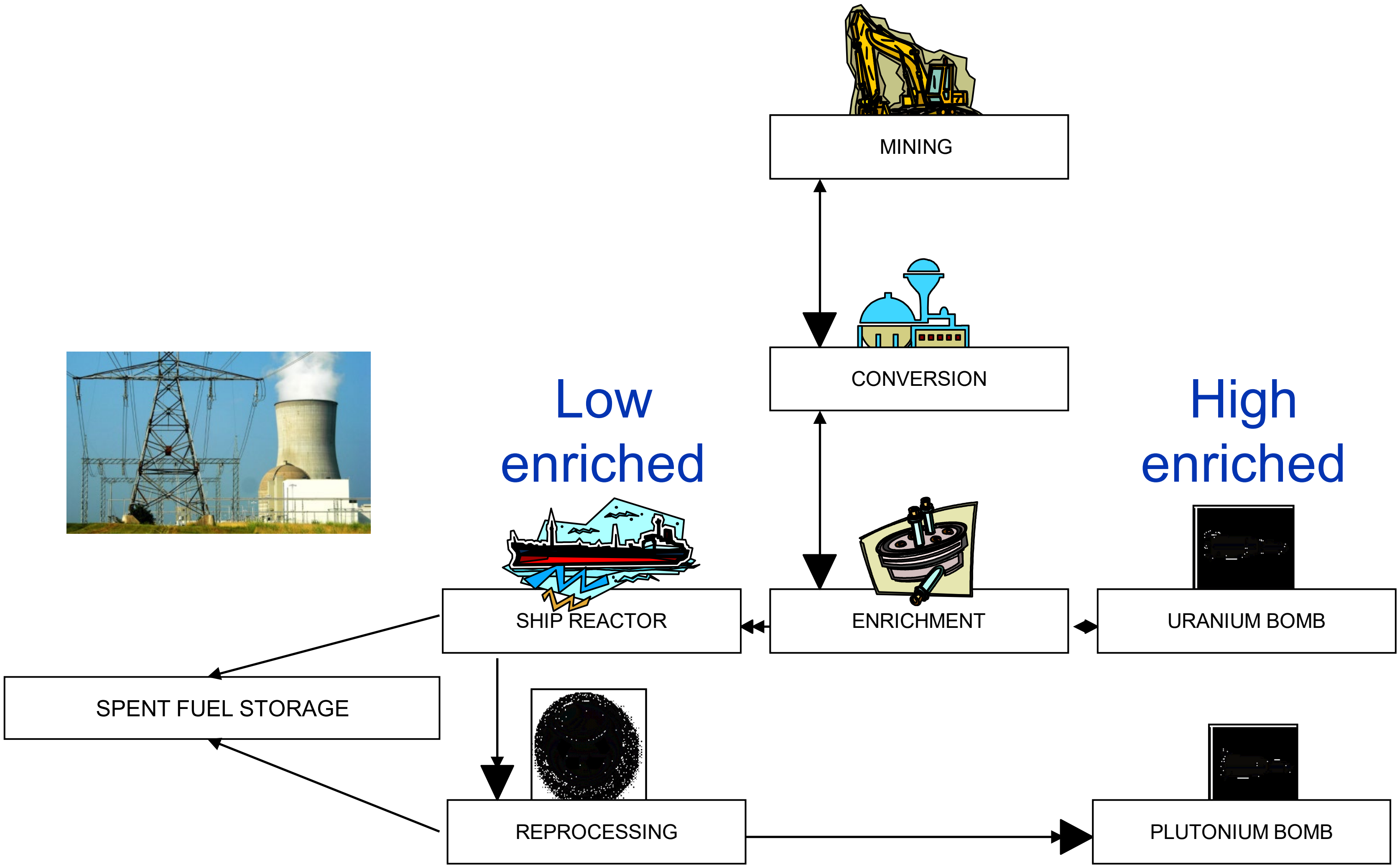
http://www.subadventures.net/Sub_04_719_files/image018.jpg

Nuclear fission: Splitting of uranium atoms in fuel

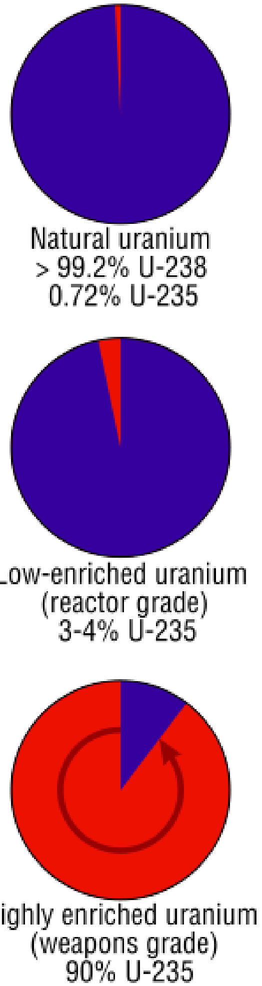


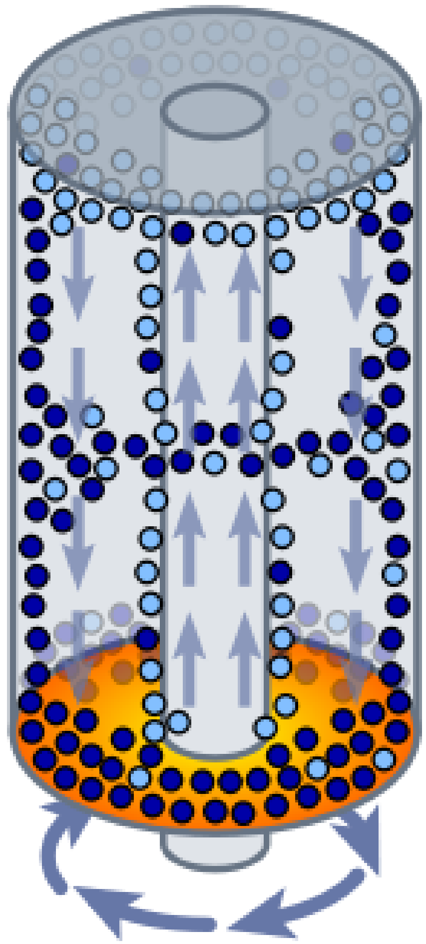
http://people.moreheadstate.edu/students/alsimp01/files/technology.html

Peaceful versus non-peaceful uses



Enrichment lower than 20% (non-weapon grade)

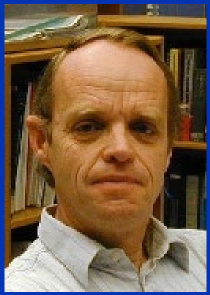




http://commons.wikimedia.org/wiki/File:Uranium_enrichment_proportions.svg

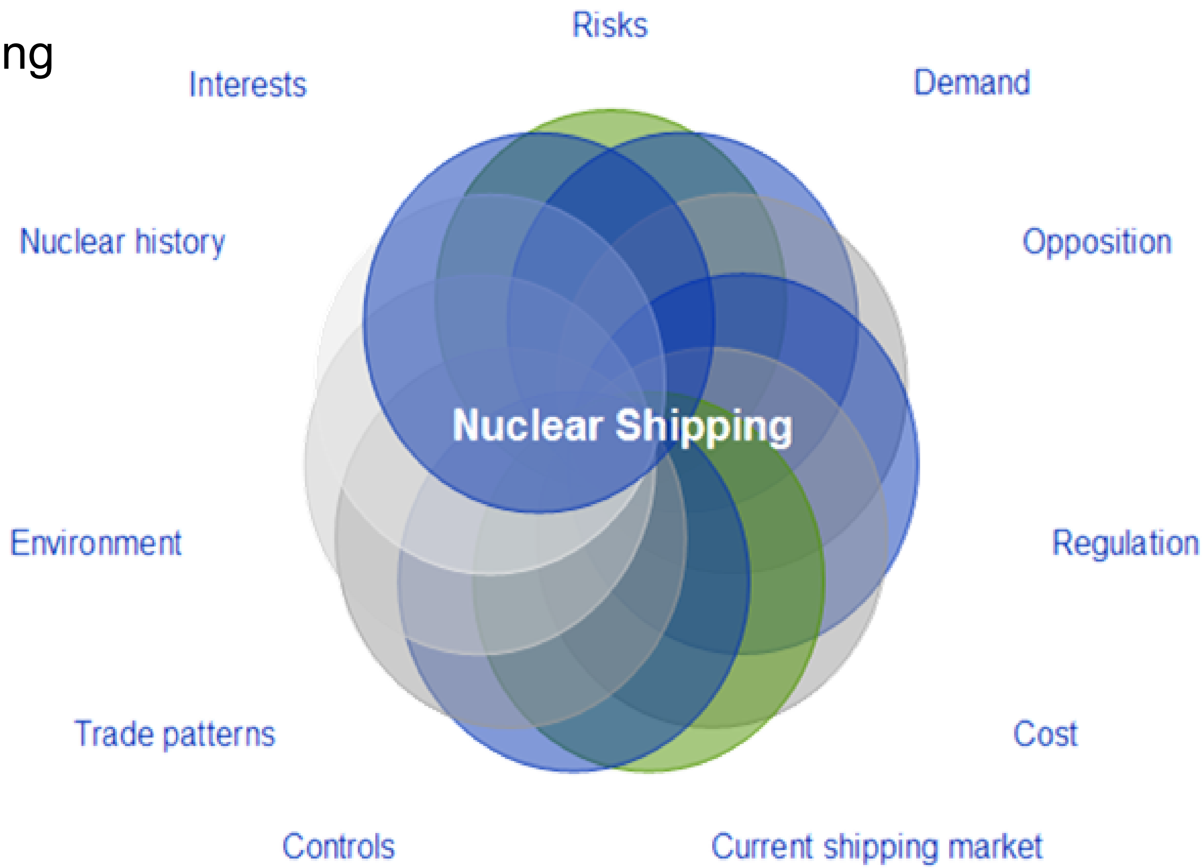
How did we work?

Project team

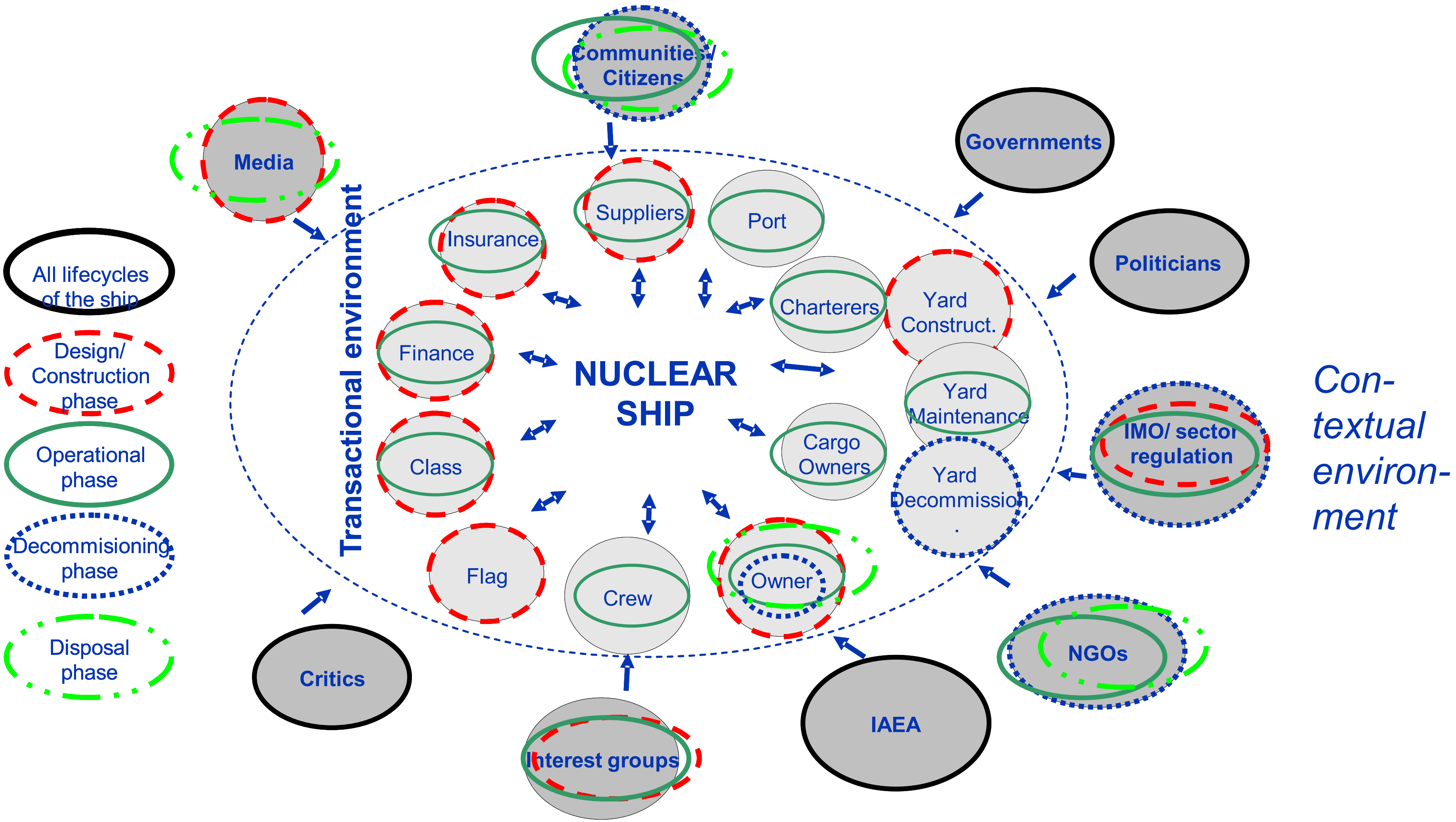


Holistic assessment of …

- All aspects of nuclear shipping
- Risks unique to nuclear shipping
- Stages of nuclear shipping
- Stakeholders in nuclear shipping



Stakeholders in nuclear shipping



Safety and Security Risks during nuclear shipping phases

	SAFETY (unintentional)				**SECURITY (intentional)**			
	RELEASE		*EXPOSURE*		*EXPLOSIVE*		*ATTACK*	
PHASE	**SEA/ LAND**	**AIR**	**1. PARTY**	**3. PARTY**	**RADIO- LOGICAL**	**NUCLEAR**	**HIT**	**TAKE- OVER**
DESIGN AND CONSTRUCTION			X			X		
OPERATION	X	X	X	X	X		X	X
DECOMMISSIONING	X	X	X	X	X	X		
DISPOSAL	X		X	X	X	X		

Findings

Factors unique to nuclear shipping …

Compared to on-shore facilities

- Reactor is compact
- Subject to ship motion
- Variable power-output to adapt to operational modes
- New stakeholders

Compared to conventional ships

- No emissions to air during operations
- Nuclear fuel fabrication, refuelling, spent fuel handling
- Nuclear safeguards; dedicated control regime
- Design considerations on reactor safety, security, refuelling
- High initial investments and low fuel expenses
- New stakeholders

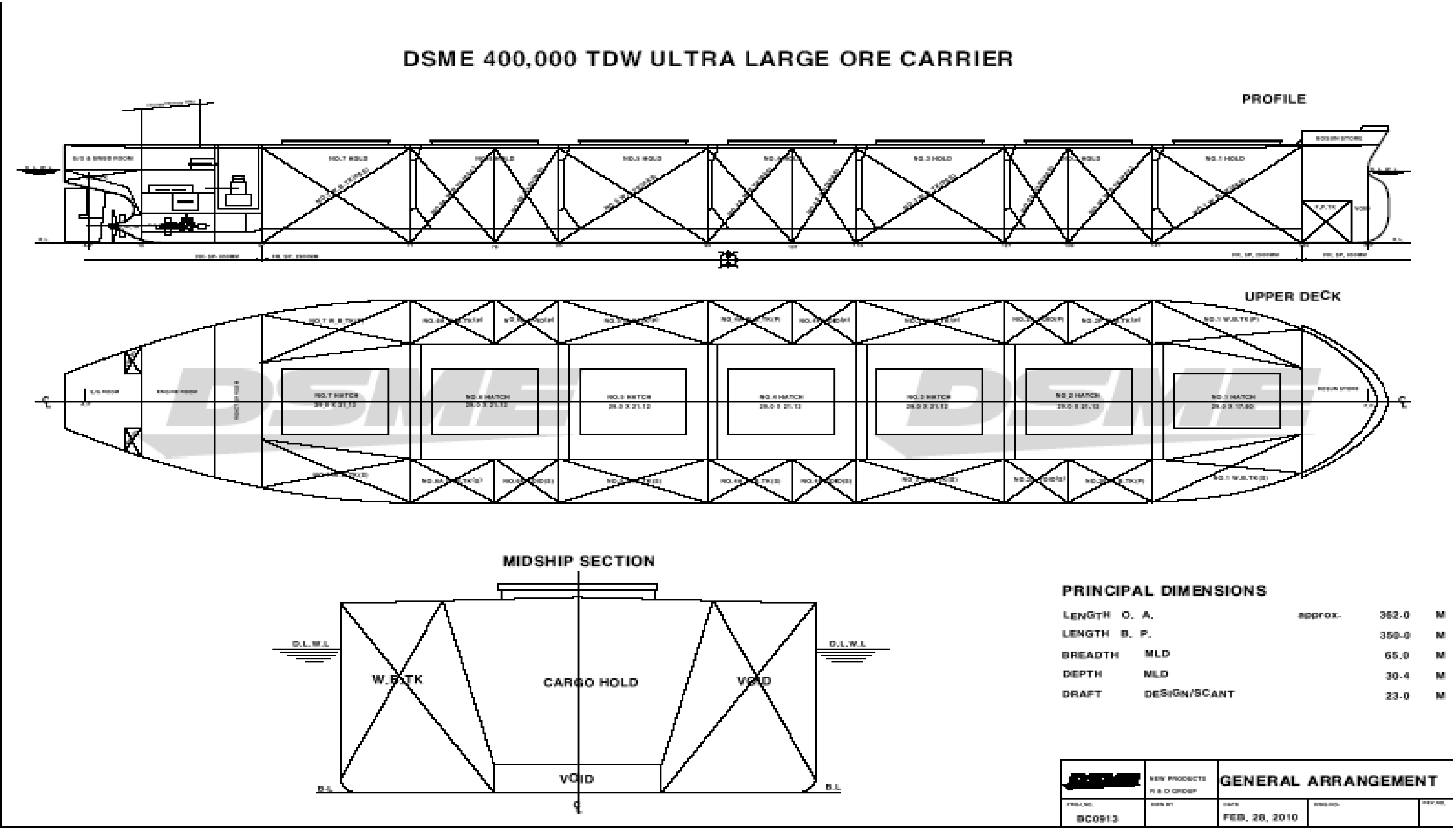
Candidate Reactors for shipping

Reactor Model	Power (MWe)	H x B (m)	Enrichment	Maturity
KLT – 40 (Russia)	35	3.9 x 2.2	Probably < 20%	High
KAERI SMART-P (Korea)	32.5	7.2 x 3.3	19,5 %	Low
Toshiba 4S (Japan)	10 (or 50)	24 x 3.5	17-19 %	Low
Hyperion (USA)	25	2.5 x 1.5	?	Very low

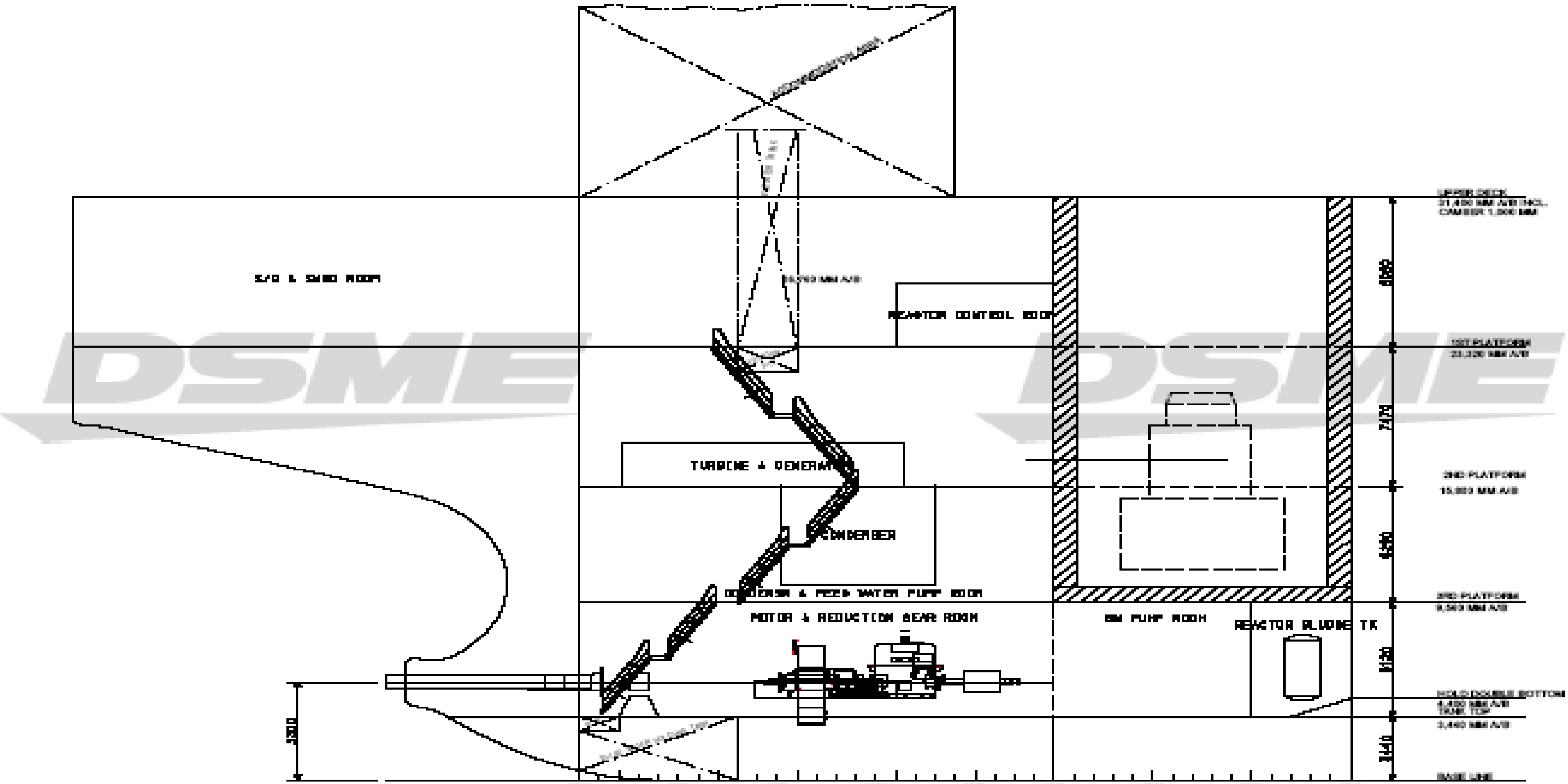

РАДИОАКТИВНОСТЬ

KLT-40 (Russian Floating Nuclear Power Plant, under construction)

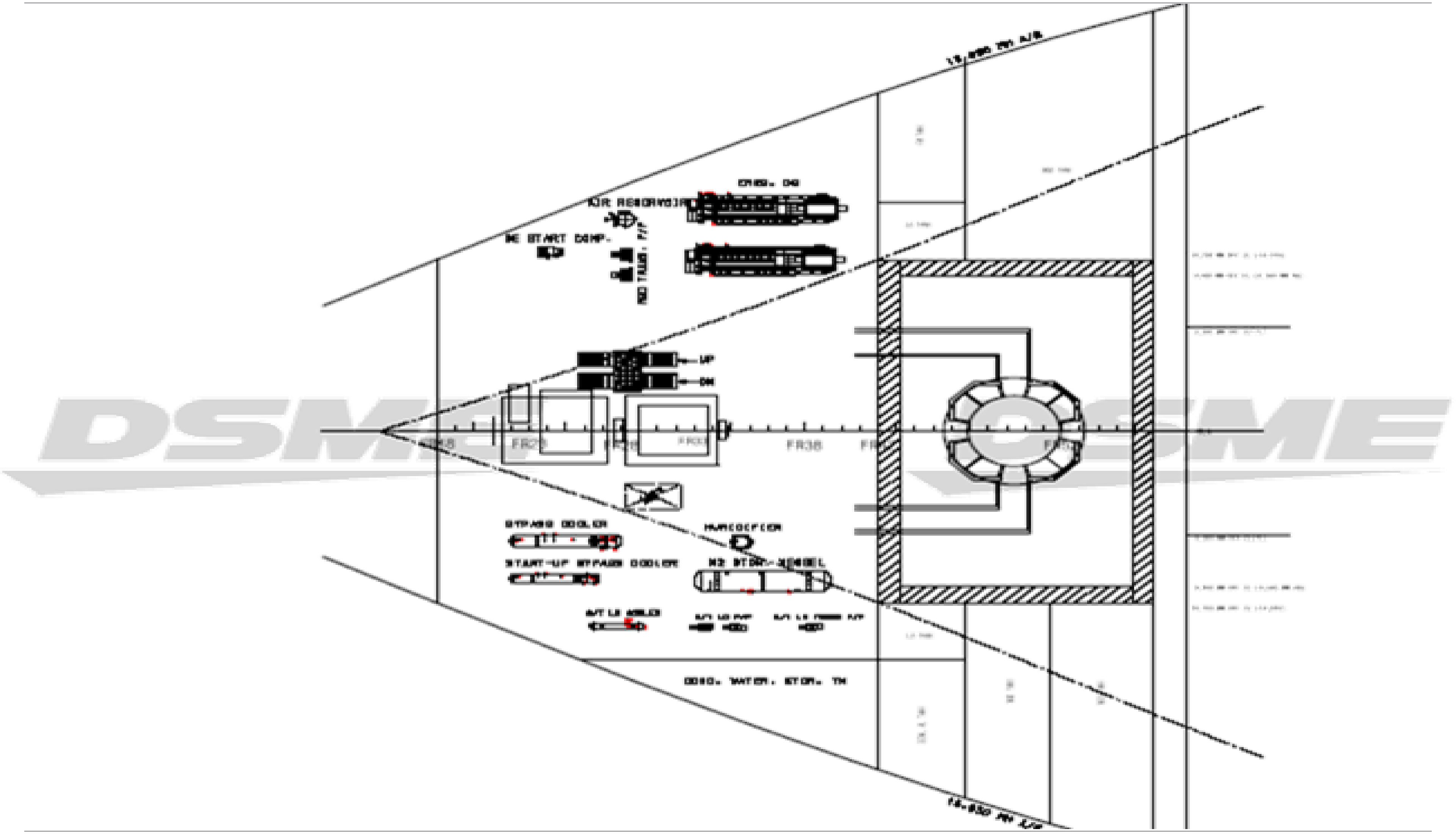
400,000 DWT Ore Carrier

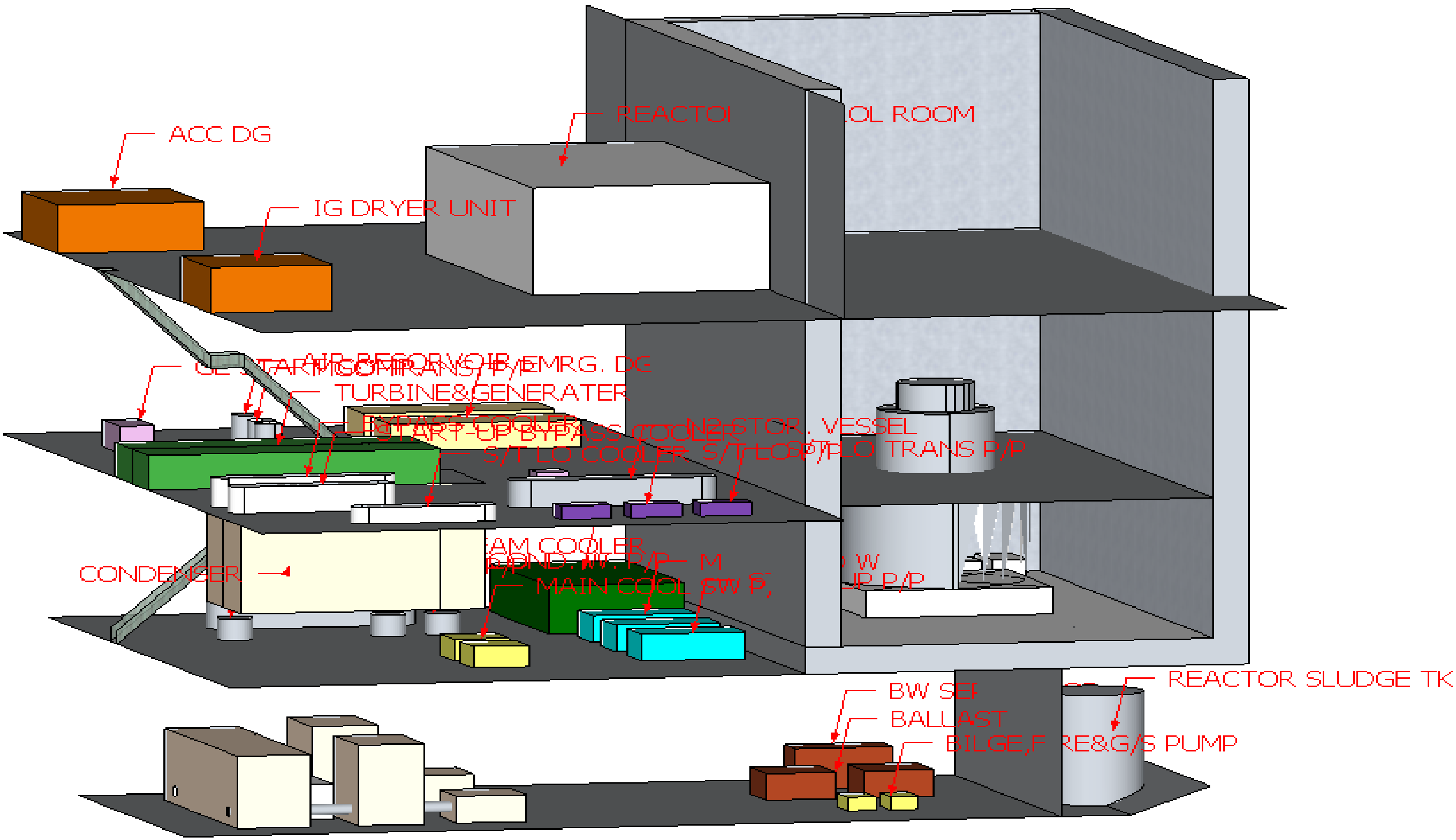


Machinery Room – Elevation



2nd Platform



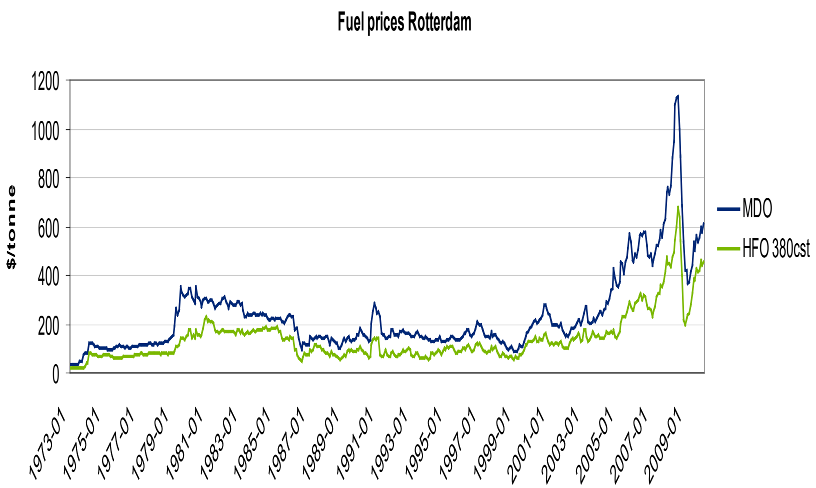

ACC DG
IG DRYER UNIT
EMRG. DG
TURBINE&GENERATER
N2 STOR. VESSEL
S/T LO COOLER
CONDENSER
MAIN COOL SW P,
BALLAST
REACTOR SLUDGE TK

Mr. Stephen Pan

- Chairman
  World-Wide Shipping Agency
- Chairman
  DNV Greater China Committe

Two main drivers for lifecycle costs have high uncertainty

Fossil fuel prices



Nuclear reactor cost

- Estimates ranges from $2500 per kW to $4000 propulsion power installed.
- Cost of nuclear fuel and refuelling is also uncertain

Baseline assumptions

Fuel price

- $450 per tonne oil
- $450 per tonne gas

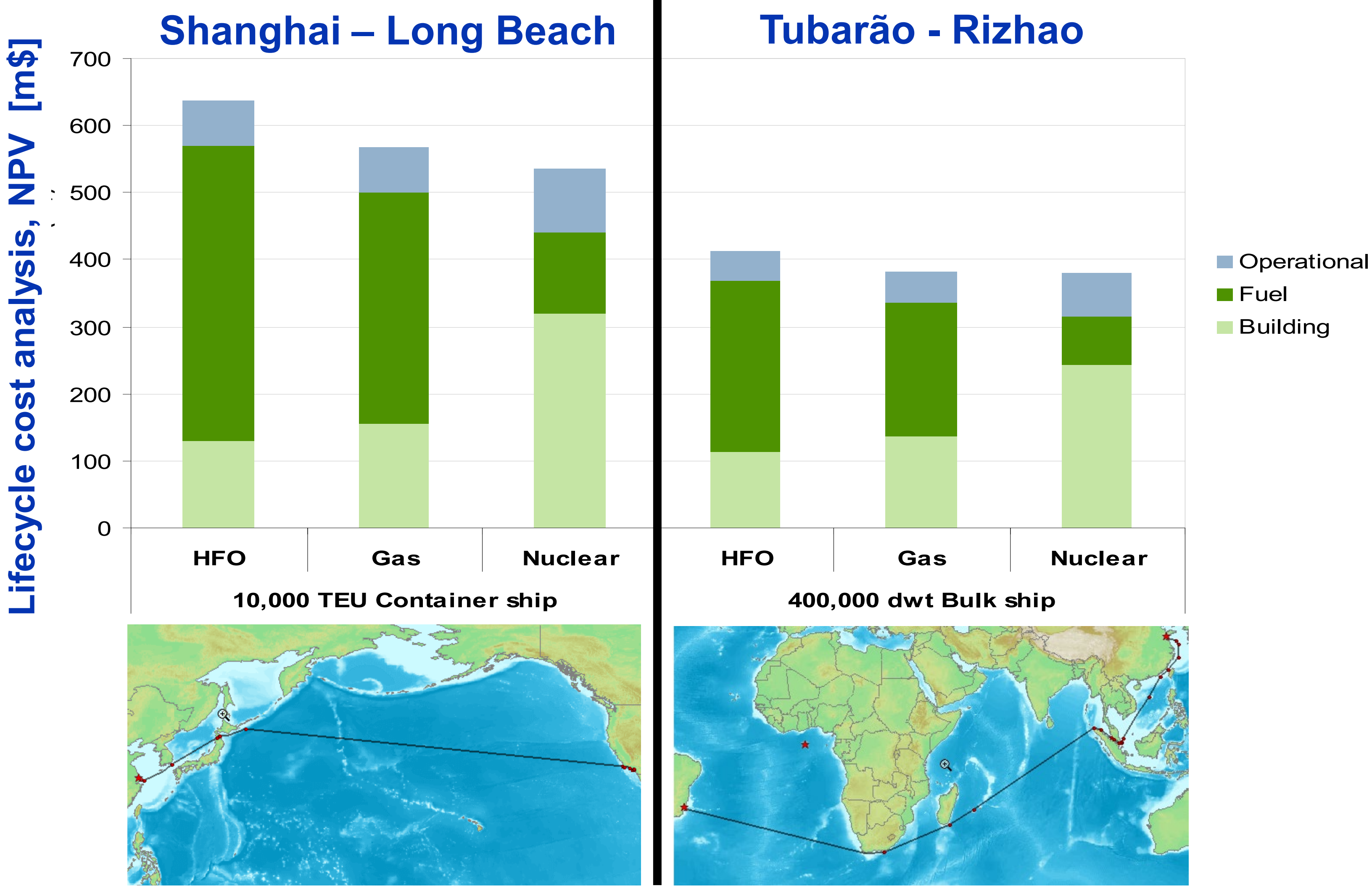
Lifecycle analysis

- 25 years operation
- 8 % discount rate
- 2 % inflation on all costs

Reactor cost

- $2500 per kW output (container ship)
- $3500 per kW (bulk ship)

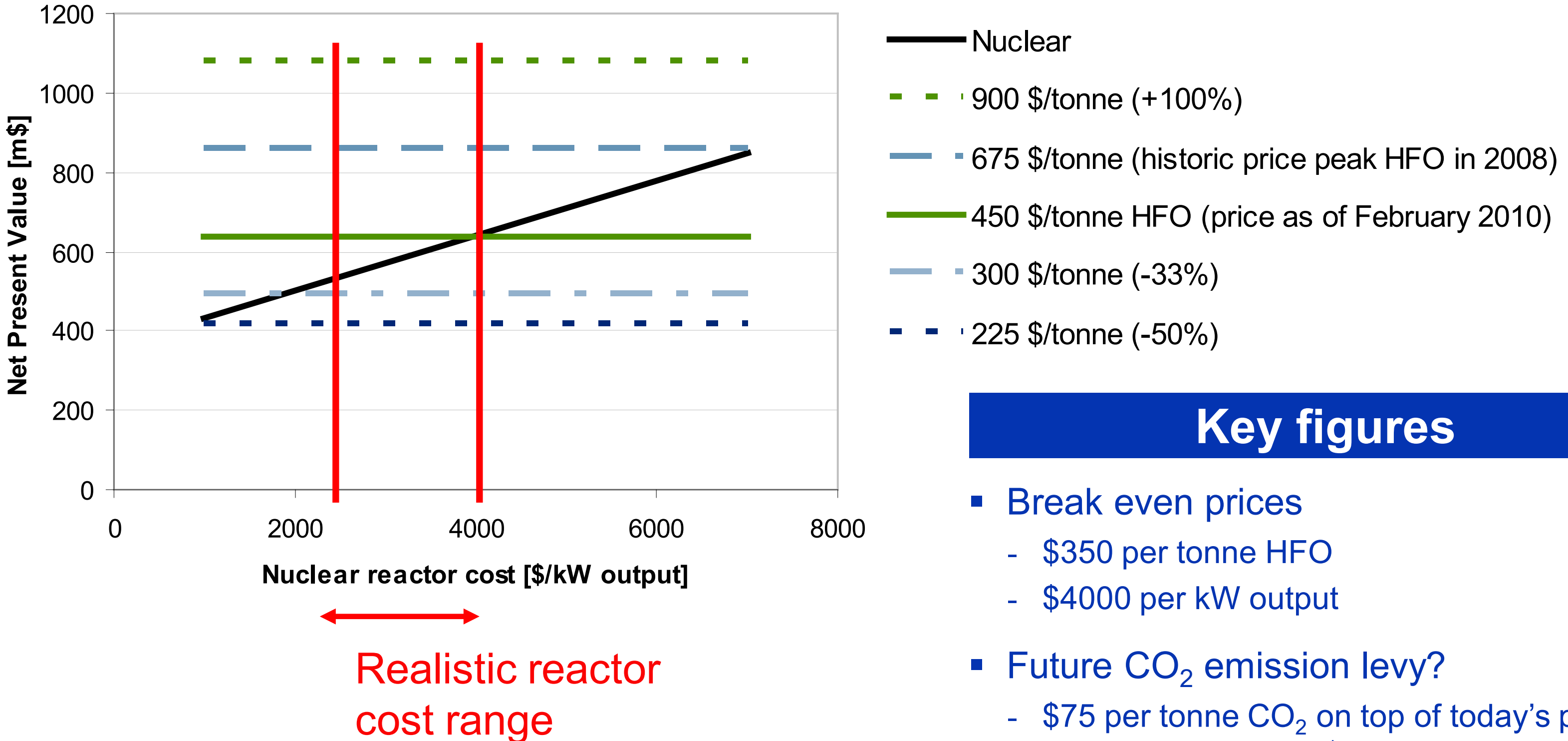
Nuclear shipping may be profitable with today's fuel prices



Cost of oil versus nuclear fuel

With increased costs of fuel oil nuclear powered ships becomes financially superior to ships with conventional propulsion

Transpacific container shipping



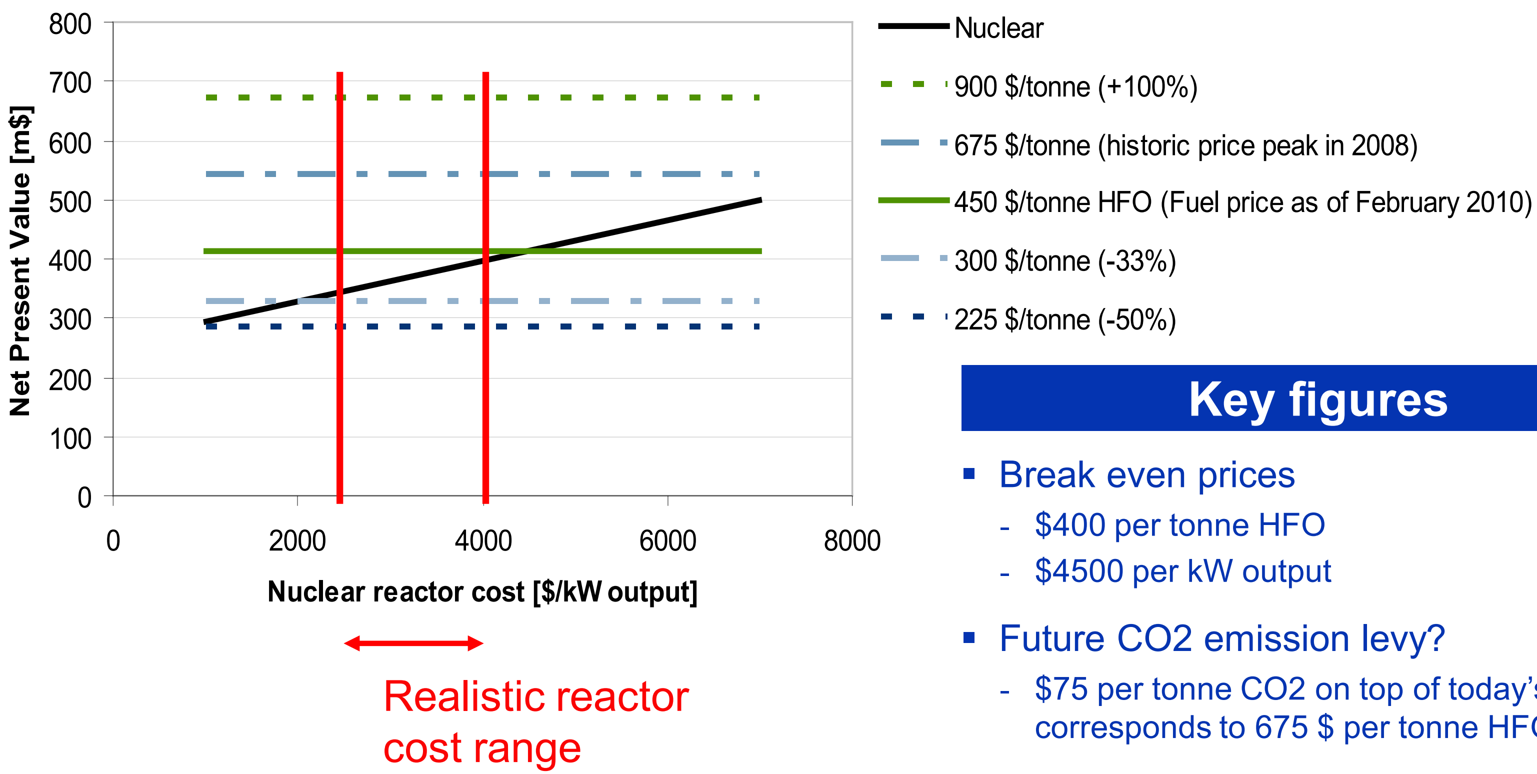
Key figures

- Break even prices
  - $350 per tonne HFO
  - $4000 per kW output
- Future CO_2 emission levy?
  - $75 per tonne CO_2 on top of today's price corresponds to 675 $ per tonne HFO

Cost of oil versus nuclear fuel

With increased costs of fuel oil nuclear powered ships becomes financially superior to ships with conventional propulsion

Brazil – China bulk shipping



Key figures

- Break even prices
  - $400 per tonne HFO
  - $4500 per kW output
- Future CO2 emission levy?
  - $75 per tonne CO2 on top of today's price corresponds to 675 $ per tonne HFO

Regulatory framework insufficient

- IMO, and others, will need time to develop competence and resources required
- IAEA may see a need for more appropriate safeguards for nuclear shipping
- For most Flag States, as well as Port Authorities, the introduction of nuclear shipping will be demanding
- Development of appropriate national regulations, norms, and standards will take time, licensing and approval processes as well
- A unified code, standard, or practices for safe, secure and efficient operation should be established. This could reduce risks to investors and improve financial incentives

The shipping industry should engage itself in all these activities as soon as possible

Question?

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Conclusion: Feasibility of nuclear powered ships

- Technically: **Feasible**
  - Currently some 150 vessels in operation, most military
  - 12,000 reactor years in service
  - Several designs/concepts under development for merchant ships; marinization and miniaturization
- Commercially: **Feasible, but subject to …**
  - Oil price
  - Reactor cost
  - Market potential
  - Strong 1st mover
- Politically: **Possibly feasible, but highly dependent on …**
  - Safety and Security issues be well under control
  - Development of currently insufficient regulation
  - Public perception, and impact of nuclear power revival

Thank you for your contributions

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