CHALLENGES FOR USING LNG FUELED SHIPS FOR ARCTIC ROUTES

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Agenda

- ARCTIC ENVIRONMENT
- DESIGN ASPECTS OF SHIPS OPERATING IN ARCTIC ENVIRONMENTS
- LNG AS CLEANER FUEL OPTION
- CHALLENGES IN ICE PERFORMANCE IN VIEW OF PROPULSION
- LIFECYCLE MODEL PROPOSITION FOR LNG FUELED SHIPS OPERATING IN THE ARCTIC
- CONCLUDING REMARKS

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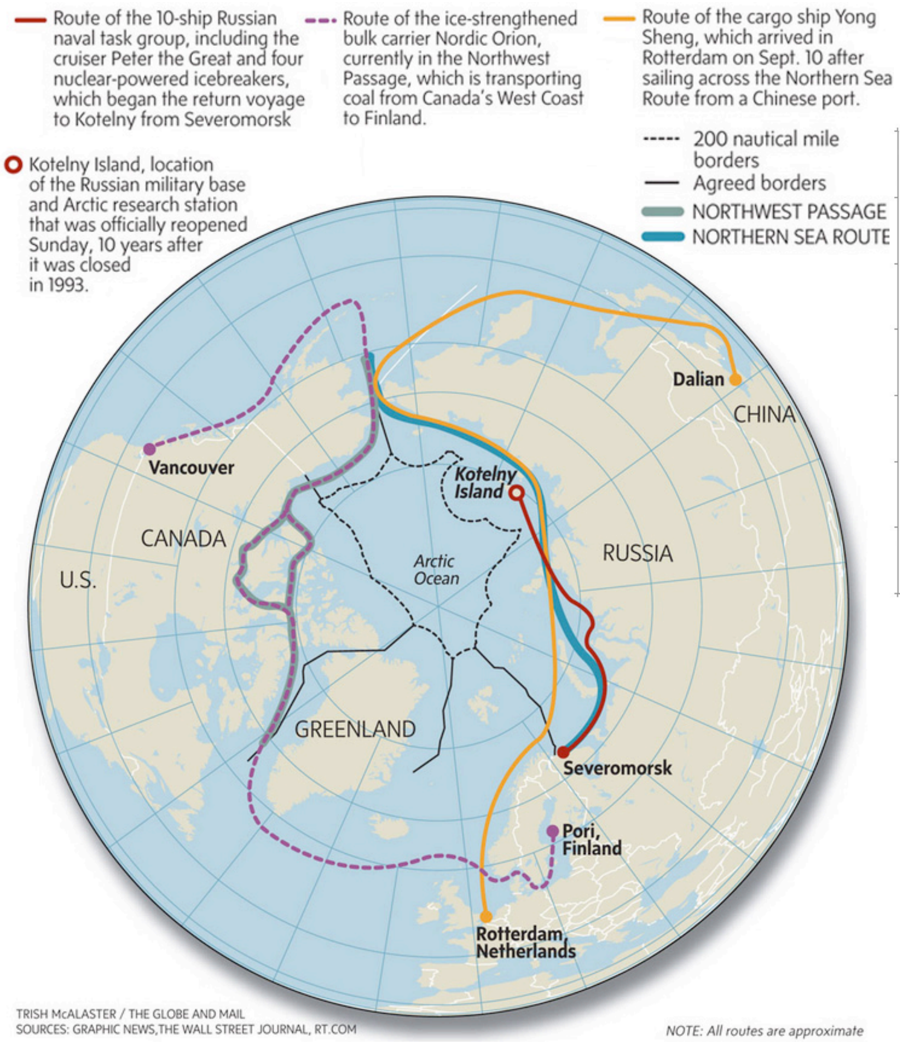
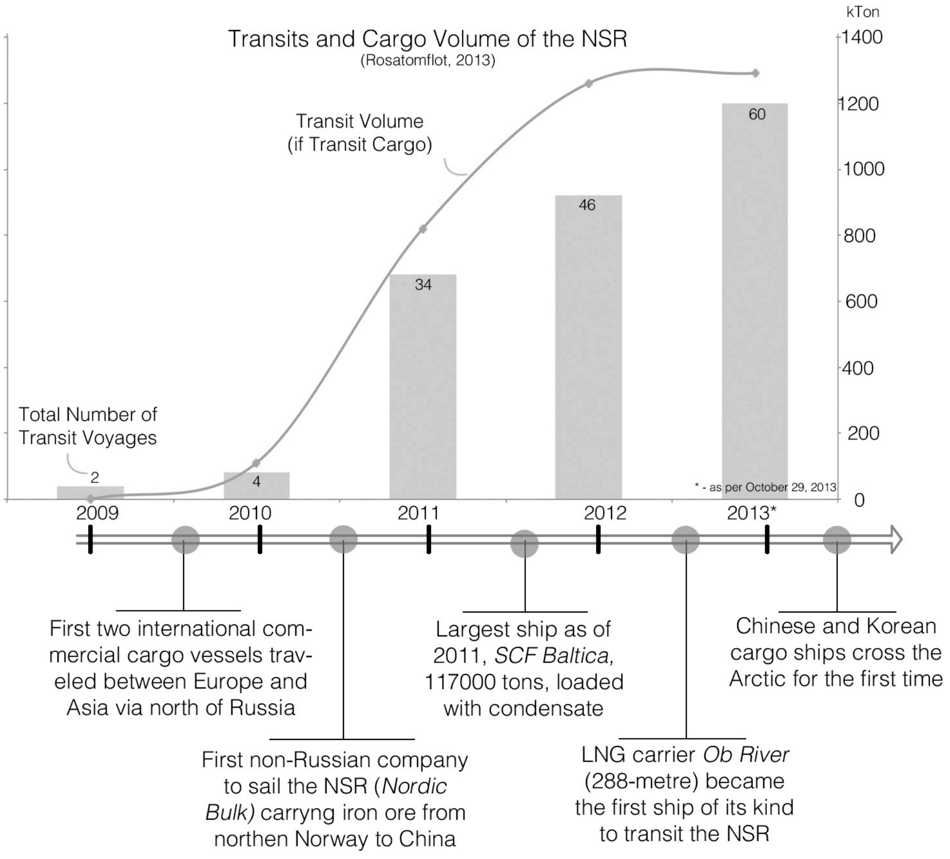
Arctic Environment





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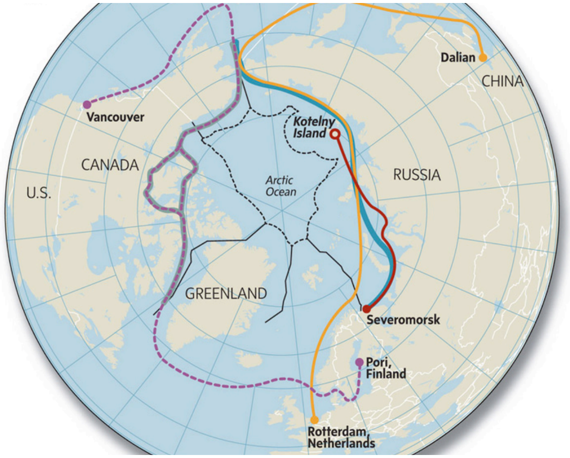
Arctic Challenges

- Ice free season
- Site specific conditions (polar low, drifting ice masses)
- Uncertain prediction models
- Limited visibility (dark winter, foggy simmer)
- Required safety level – unwanted pollution
- Polar code as consensus



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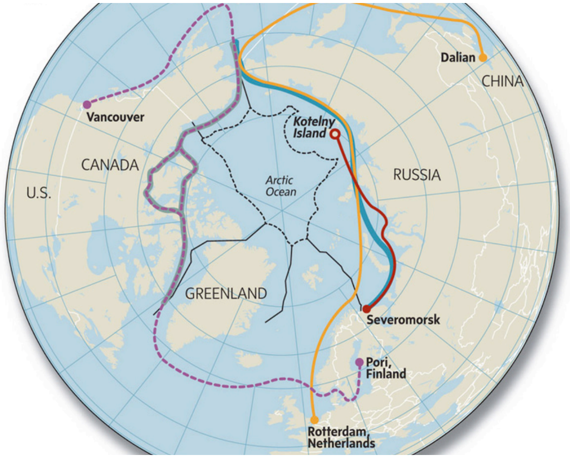
Arctic and LNG

- Environmental concerns
- LNG as LNG is now introduced as a very clean alternative fuel
- Meet IMO tier III regulations and EEDI
- Design concerns (ice)
- Infrastructure
- Propulsion system
- Ice scenario



Design Aspects for Ships in the Arctic

- Finnish-Swedish Ice Class Rules (FSICR, 2008) – Baltic Sea
- Concern related to hull form, propulsion machinery, ship systems, stability, navigation and communication equipment, supplies and emergency facilities
- Compromise between a classical ice-strengthened merchant vessel and an icebreaker
- Feasible domain usually by adding ice-features to an existing open-water concept rather than modifying an existing icebreaker

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Design Aspects for Ships in the Arctic

Table 1. Arctic ship design considerations

Item	Considerations
Structure (hull, forecastle, poop, deckhouse)	Ice-breaking bow, ice knife at the rudder for conventional rudders, sheltered forecastle to prevent icing, deckhouse allowing a close-range view
Crew facilities (crew spaces, service spaces, stairs and corridors)	Additional insulation of the superstructure and crew area, crew spaces located in areas of low vibrations
Machinery (engine and pump rooms, engine casing, funnel, steering and thrusters)	Inlets for cooling must be placed well stern
Tanks (fuel oil, lube oil, water, sewage, ballast, voids)	Additional capacity required, waste- and bilgewater-collecting tanks with capacity for 30 days or a cleaning system for sewage and domestic water. Ballast tank heating system No tanks containing environmental risk located towards outer hull, Tank heating systems
Comfort systems (air condition, water and sewage)	Additional heating
Exterior decks (mooring, lifeboat, etc.)	Additional heating
Cargo spaces	Additional heating if needed
Cargo handling (hatches, ramps, cranes, pumps)	Must comply with cold climate to prevent icing or fracture
Trim and stability	Stability must take ice interactions into account and specific trim requirements must be met
Resistance	Requirements according to target ice class to satisfy performance criteria
Propulsion	Ice class determines propeller design and material as well as main machinery output
Hull scantlings	Strengthening according to ice class

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LNG Machinery Arrangement

- In general the same machinery arrangement can be applied with LNG fueled engines as for traditional diesel engines.
- Gas fueled engines are designed to “replace” the diesel engines, or as retrofit solutions, where the main differences are related to fuel system.
- The main question is whether the ship shall be 100% LNG fueled, or have a dual fuel (DF)
- DF means that it can be operated on LNG, marine diesel oil (MDO) or heavy fuel oil (HFO) or in a combination
- DF gives more operational flexibility, while pure LNG operation is the most environmental friendly solution.
- For propulsion machinery systems, we find LNG engines mainly in three different machinery configurations: Gas–Mechanical propulsion, Gas-Electric propulsion and Hybrid propulsion systems.

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LNG as Cleaner Option

Table 2. Best available technology emission reduction in % compared to MDO

Reduction factors compared to diesel	Pure Gas LBSI	Dual Fuel* Low pressure	Dual Fuel High pressure
CO2	25-30%	20-30%	20-26%
NOx	80-90%	75-90%	30-50%
SOx	>99%	95-99%	95-97%
Particulates	>99%	95-99%	90-95%

* Highest reduction factors for DF obtained with micro pilot ignition

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LNG Infrastructure

- Limited infrastructure
- LNG bunkering for ships is currently only available in Norway, Sweden, Korea, and Argentina
- Along the Arctic, the only currently planned bunkering station is in Hammerfest, Norway
- LNG is still not easily accessible as fuel for ships
- The missing link is the development of break bulk facilities, small-scale liquefaction plants and small scale distribution infrastructure

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LNG Drivers and Barriers

- LNG as fuel for ships is now a proven and available solution
- There are currently 45 LNG fueled ships, non-LNG carriers or inland waterway vessels, in operation worldwide while another 47 are approved for building (as of 02.01.14)

Table 3. Drivers, barriers and uncertainties for LNG fueled ships

Drivers	**Barriers**	**Uncertainties**
Reduces NOx, SOx, PM, CO2	High system costs	Rate of bunker grid expansion
Comply with EEDI	Inadequate LNG bunkering grid	Future LNG fuel prices
Proven and available solution	Difficult retrofit	
Competitive LNG price	Size of fuel tanks	

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Propulsion Challenges for Ice

- Higher Speed - Higher Thrust – Higher ice-loads
- Sufficient hull strengthening, and adequate strength of the propulsion machinery elements
- Proper design of the hull shape, that is, by reducing ice resistance, in combination with the adequate arrangement of the propeller
- Ice-induced loads acting on the propeller, along with increased hydrodynamic loads due to the disturbed wake field, are transmitted to the other elements of the propulsion machinery system led by the main engine
- Efficient propulsion for open water as well

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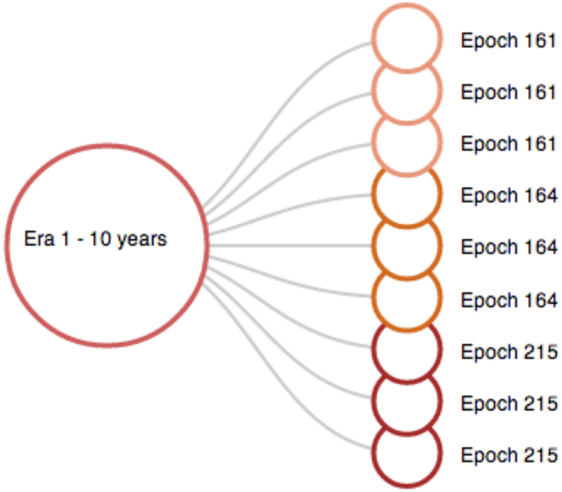
Simulating Future Scenarios for Missions at the Arctic via Epoch-Era



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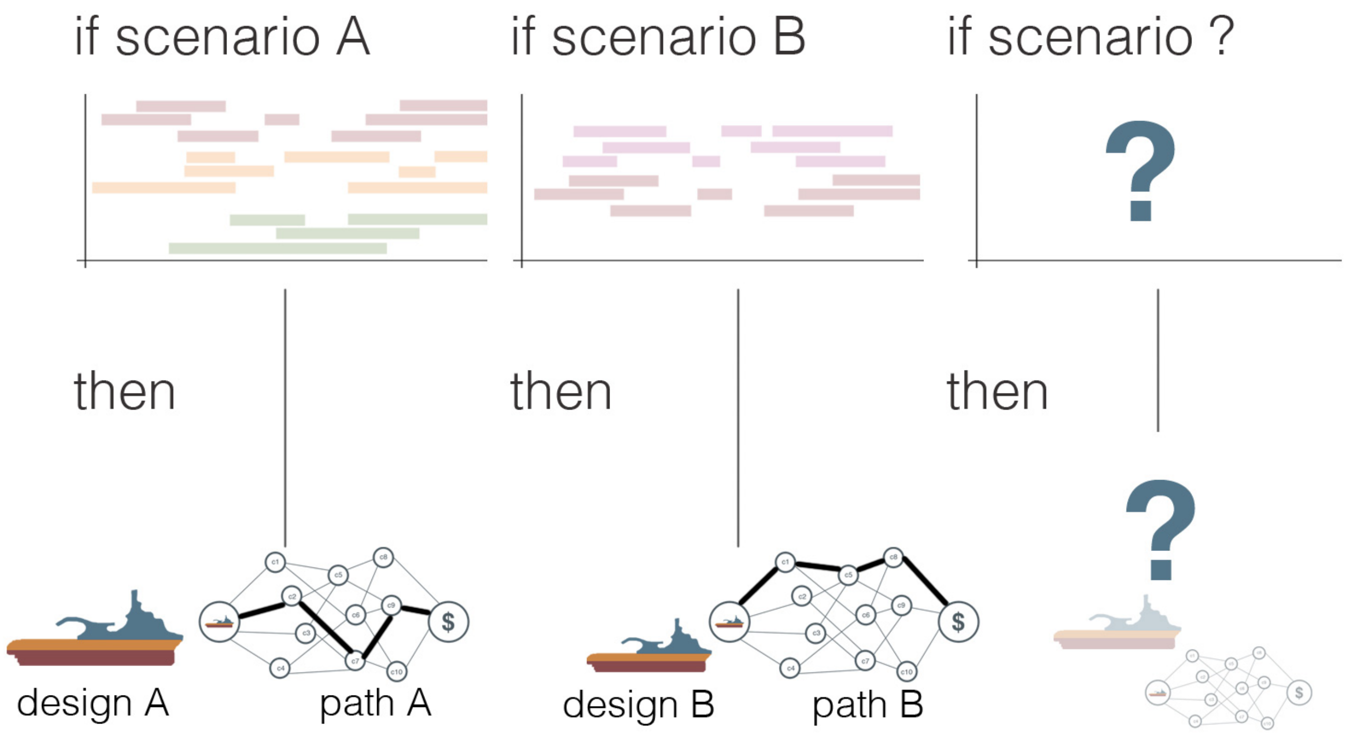
Handling Uncertain Future

scenario uncertainties:

field development
new technology
market
policy / regulations



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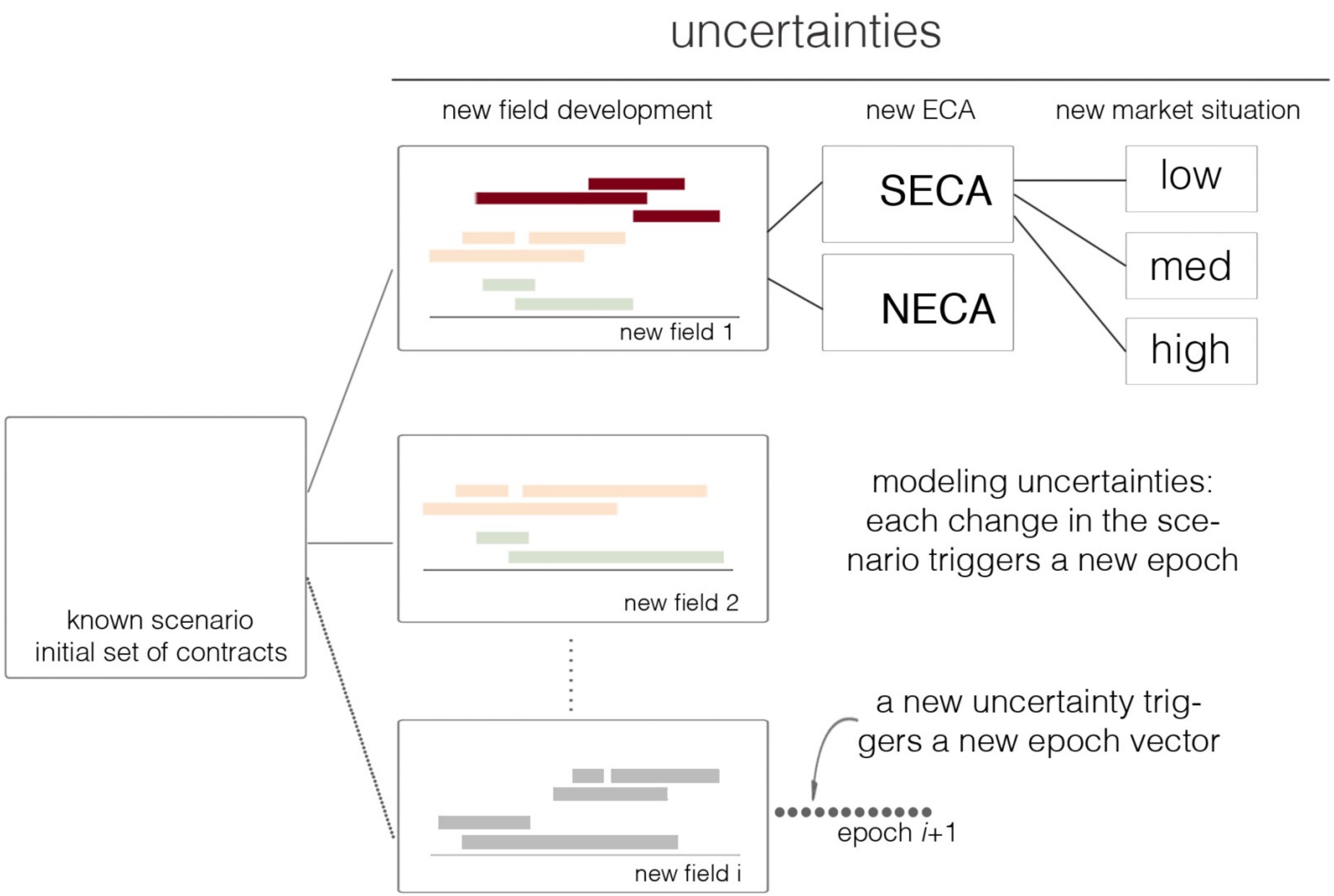
Decomposing Context



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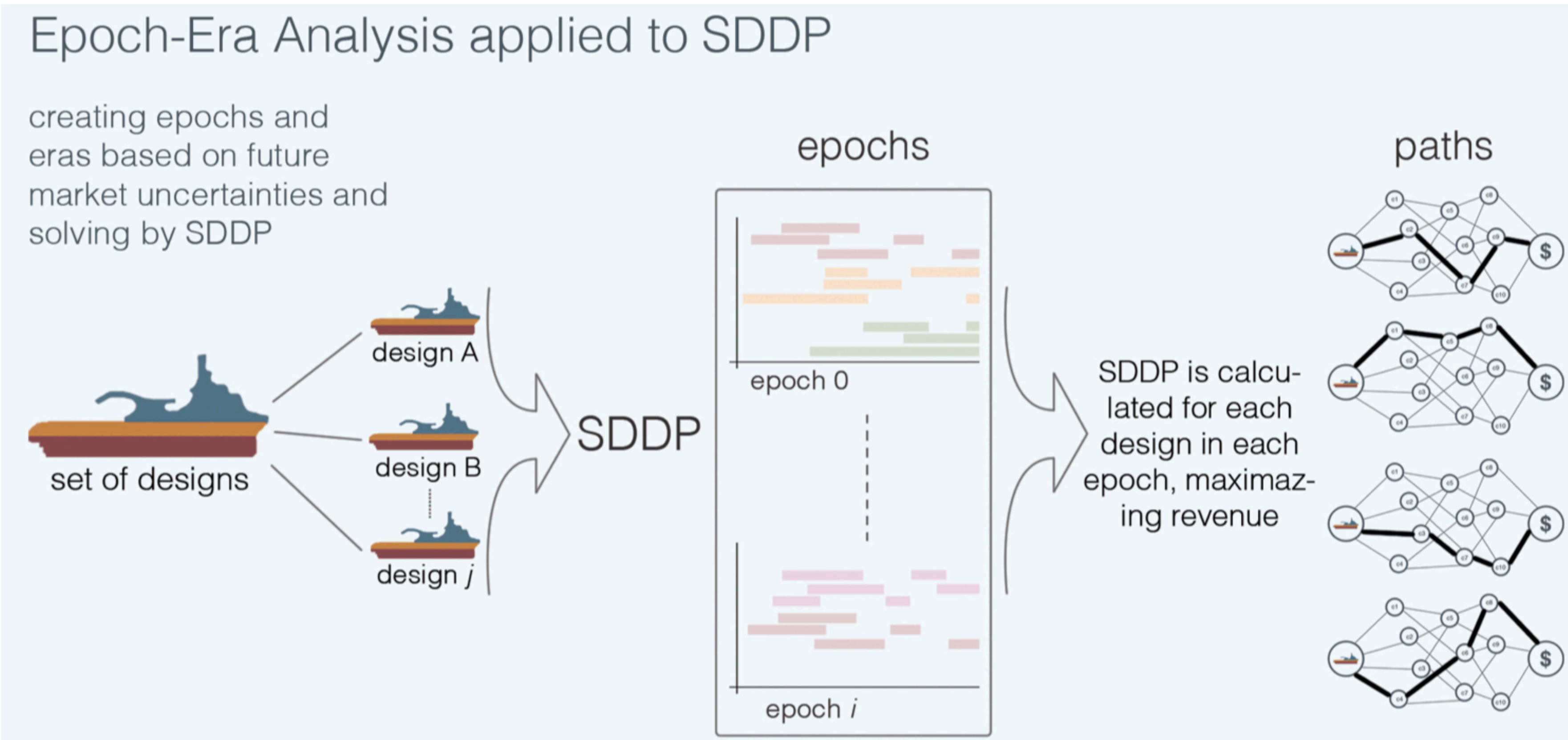
Decomposing Designs



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Arctic – Contextual Factors

- **Environmental Conditions**: weather and ice conditions, as well as the consequences to operability caused by icing, darkness, fog.
- **Technology Development**: Improve behavior in ice, with advancements in hull structure and propulsion; Improvements in maintenance and reliability of LNG machinery.
- **Infrastructure:** LNG bunkering installations along the arctic; Support and emergency infrastructure within acceptable range/response time, as well as wider ice-breakers available (breadth limitation).

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Arctic – Contextual Factors

- **Policy/Regulations**: Future regulations may create a new ECA; new rules connect to regional agreements, political factors or instability. LNG regulations towards…
- **Market/Risk:** Market situation can affect both the use of Arctic routes and LNG fuelled ships. A stronger demand would increase the activity (risky-prone behavior), whilst a weaker demand would lead to more conservative solutions.

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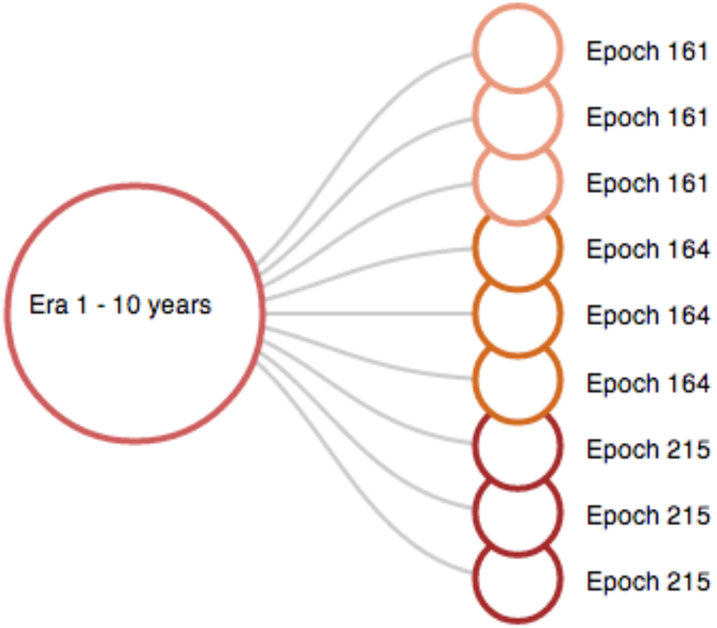
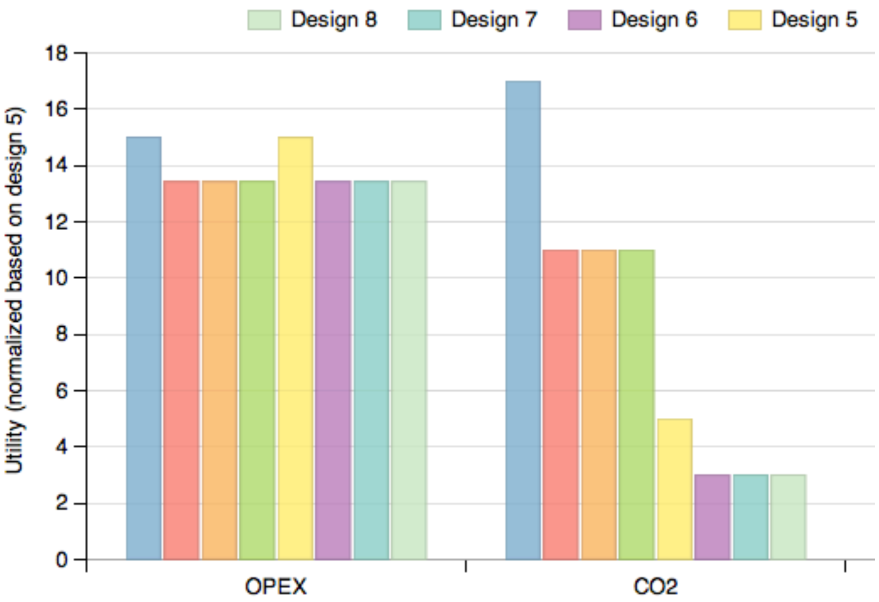
Arctic – LNG Case





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Epoch Variables

Category	Epoch Variable	Unit	Range	Steps
Season Open	Months Open	months	0-6	7
Environmental	Ice Conditions	Ice Class	none - 1C	4
Regulations	HFO Ban	no/yes	no-yes	2
Regulations	ECA	no/yes	no-yes	2
Risk	Risk Level	Level	low-high	3
			Epoch space (total):	336 epochs

Each epoch variable represents a possible categorial change in a contextual factor, and is used as instrument to the mapping between context parameters and vessel performance.

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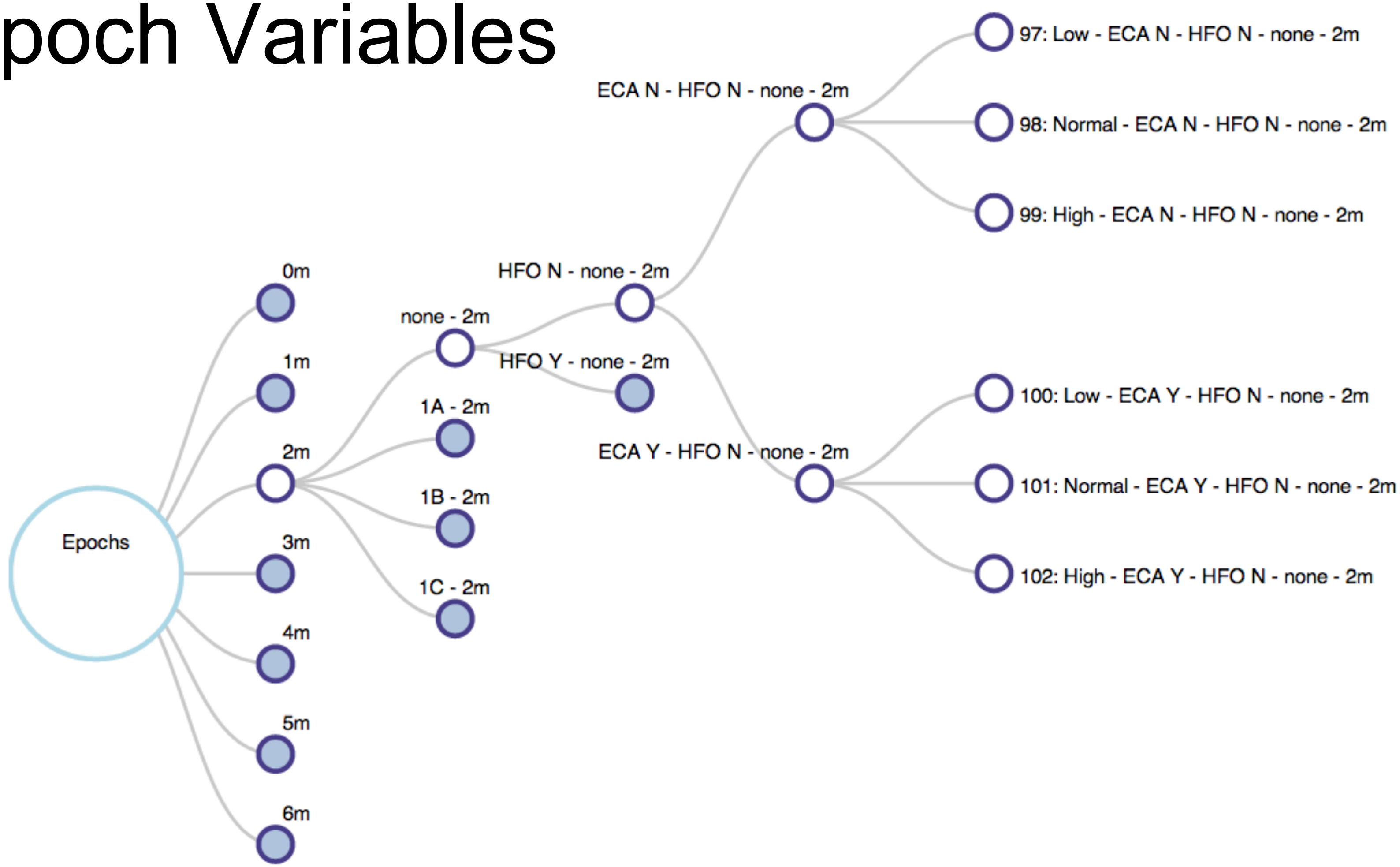
Epoch Variables



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Design Variables and Attributes

Category	Design Variable	Unit	Range	Steps
Propulsion	Type	Machinery Type	LNG - Conventional	2
Class	Ice Class	Class	none-1C	4
			Design space (total):	8 designs

Attrbute Name	Units
CO_2	ton/year
NO_X	ton/year
SO_X	ton/year
$CAPEX_{Machinery}$	$
$OPEX_{Machinery}$	$/year

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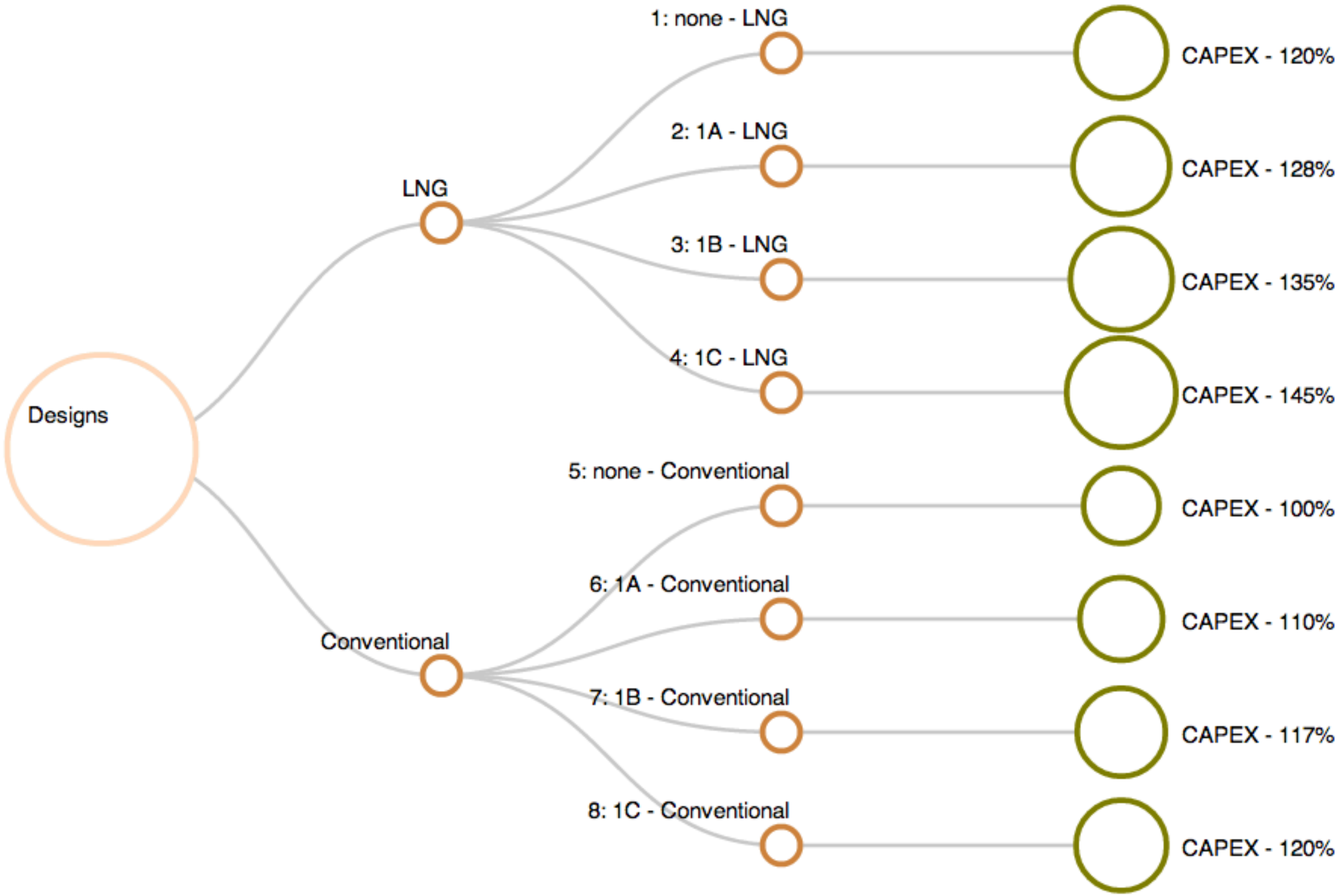
Design Variables and Attributes



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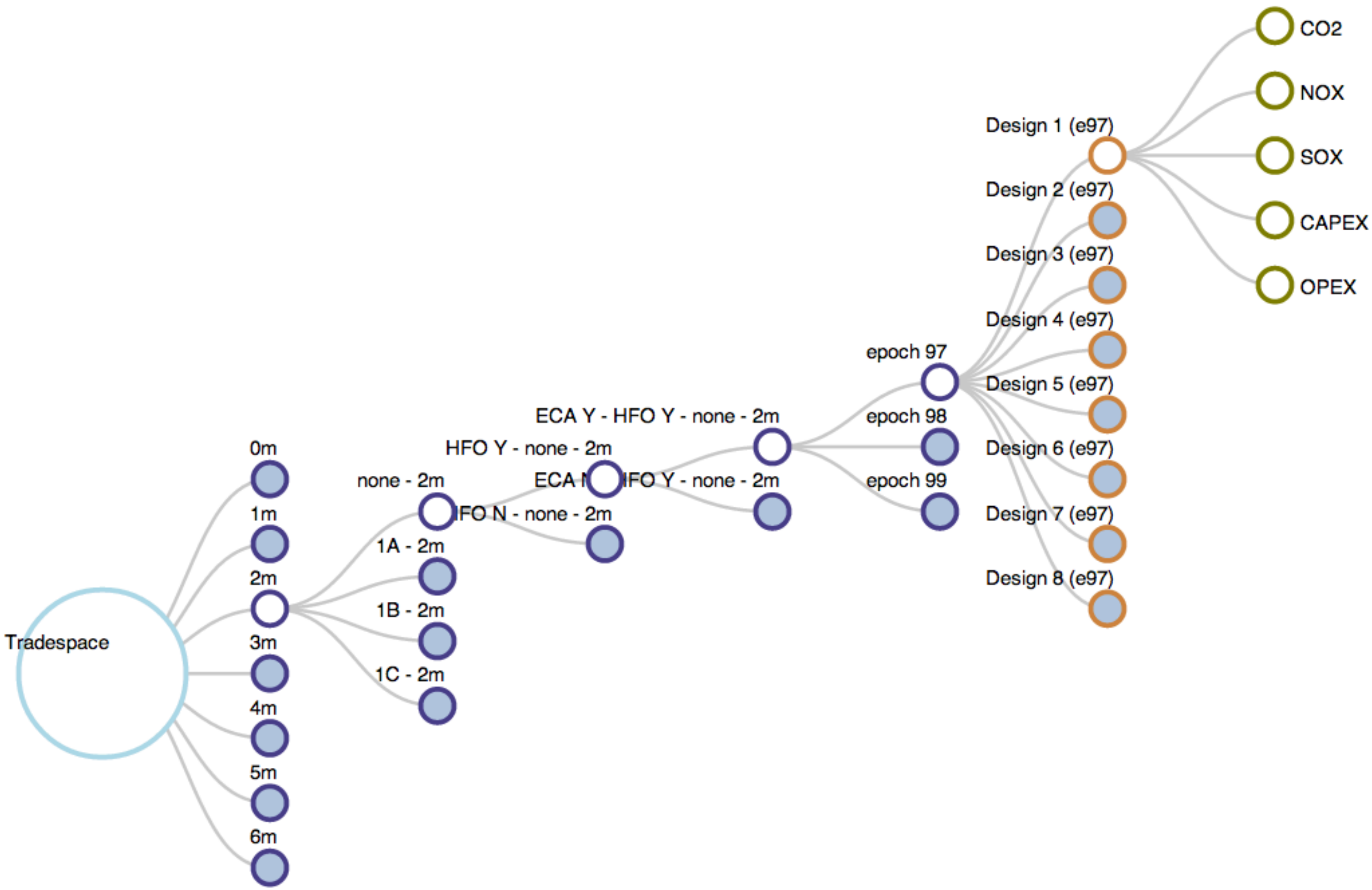
Tradespace Evaluation



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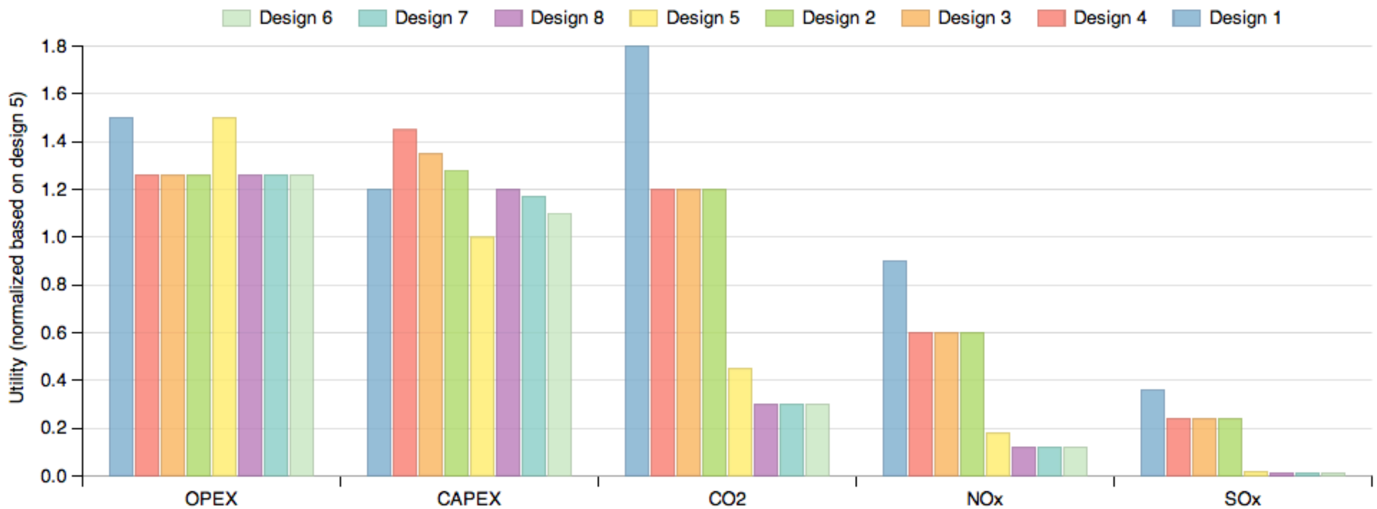
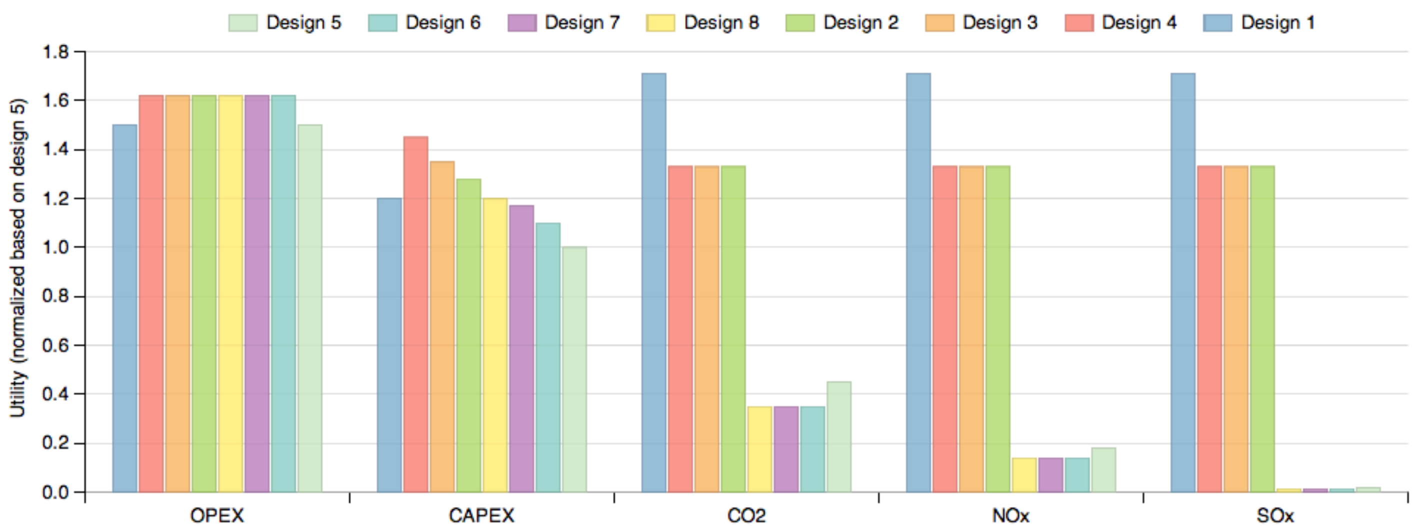
Epoch Analysis

Epoch 161



Epoch 20



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Era Construction

Each era is one possible lifecycle simulated

Era	Epoch	Years
Era 1		
Open 3 Months, yes Ice Class, no HFO/ECA, normal risk	161	3
Open 3 Months, yes Ice Class, yes HFO, no ECA, normal risk	164	3
Open 4 Months, yes Ice Class, yes HFO/ECA, normal risk	215	4
	Total	**10**

Other methods to construct eras can be based on probailistic distribution of the uncertainties, tunned by stakeholder's stylistic preferences.

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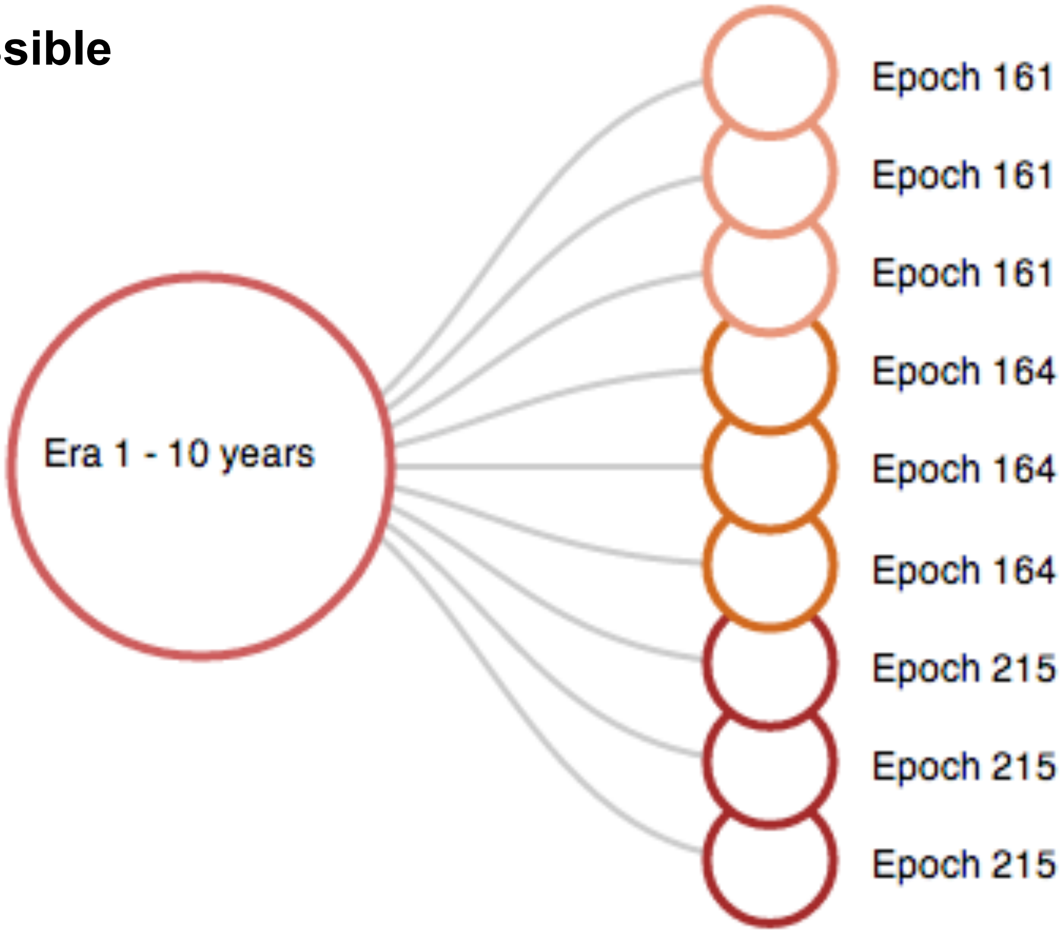
Era Construction

Each era is one possible lifecycle simulated



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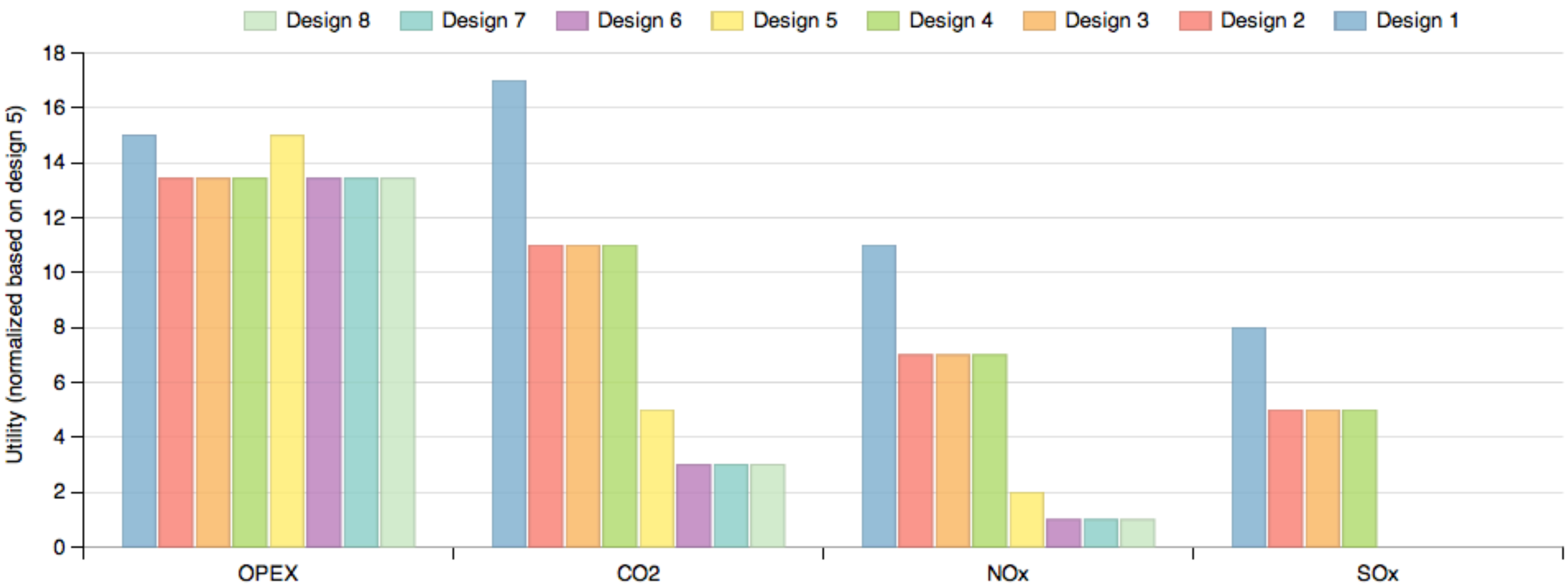
Era Analysis



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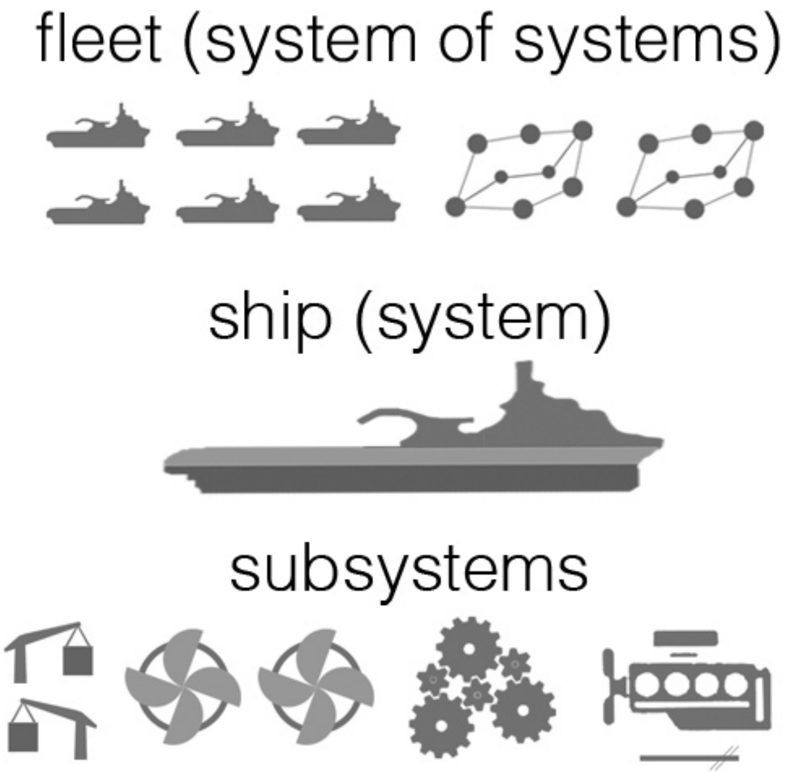
Next Steps

- Challenges in three levels:
  - Key dimensioning parameters for fleet development: LNG and Arctic transportation (ice-free season, LNG bunker availability, regulations)
  - Ship design characteristics (hull strength , systems integration, propulsion interaction)
  - Propulsion system: dual fuel, technology developments



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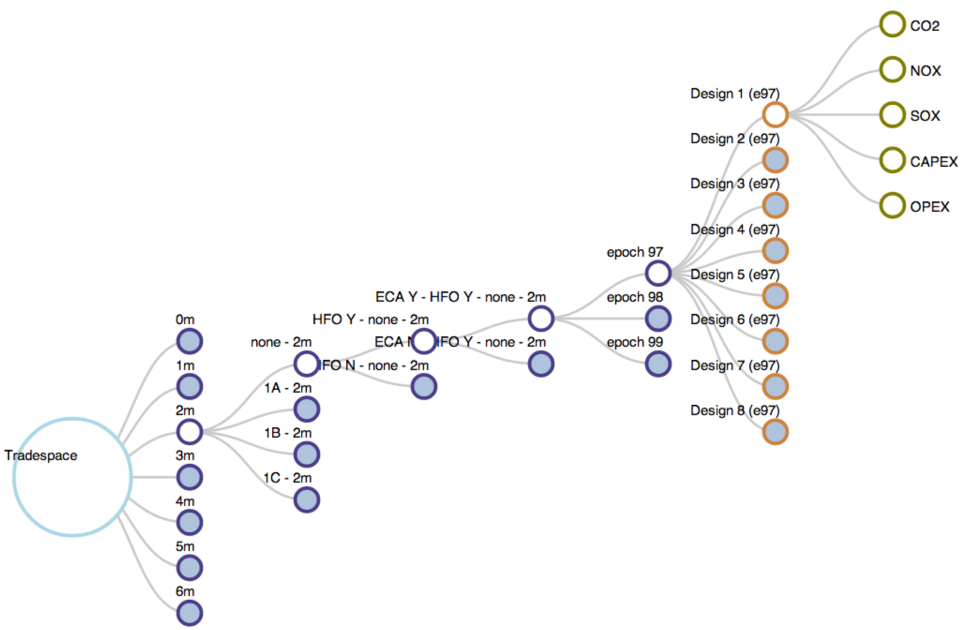
CHALLENGES FOR USING LNG FUELED SHIPS FOR ARCTIC ROUTES

Questions?



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