Zero-emission hydrogen power for research vessels

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Presentation Overview

- Research vessels at Scripps
- Why zero-emission ships?
- Feasibility of zero emissions
- Zero-emission hybrid vessel

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Acknowledgments: We are grateful for our visionary sponsors

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Zero-emission feasibility studies have been supported by the U.S Department of Transportation **Maritime Administration** (MARAD) Maritime Environmental and Technical Assistance (META) program.

Ship Tracks 1956-2021

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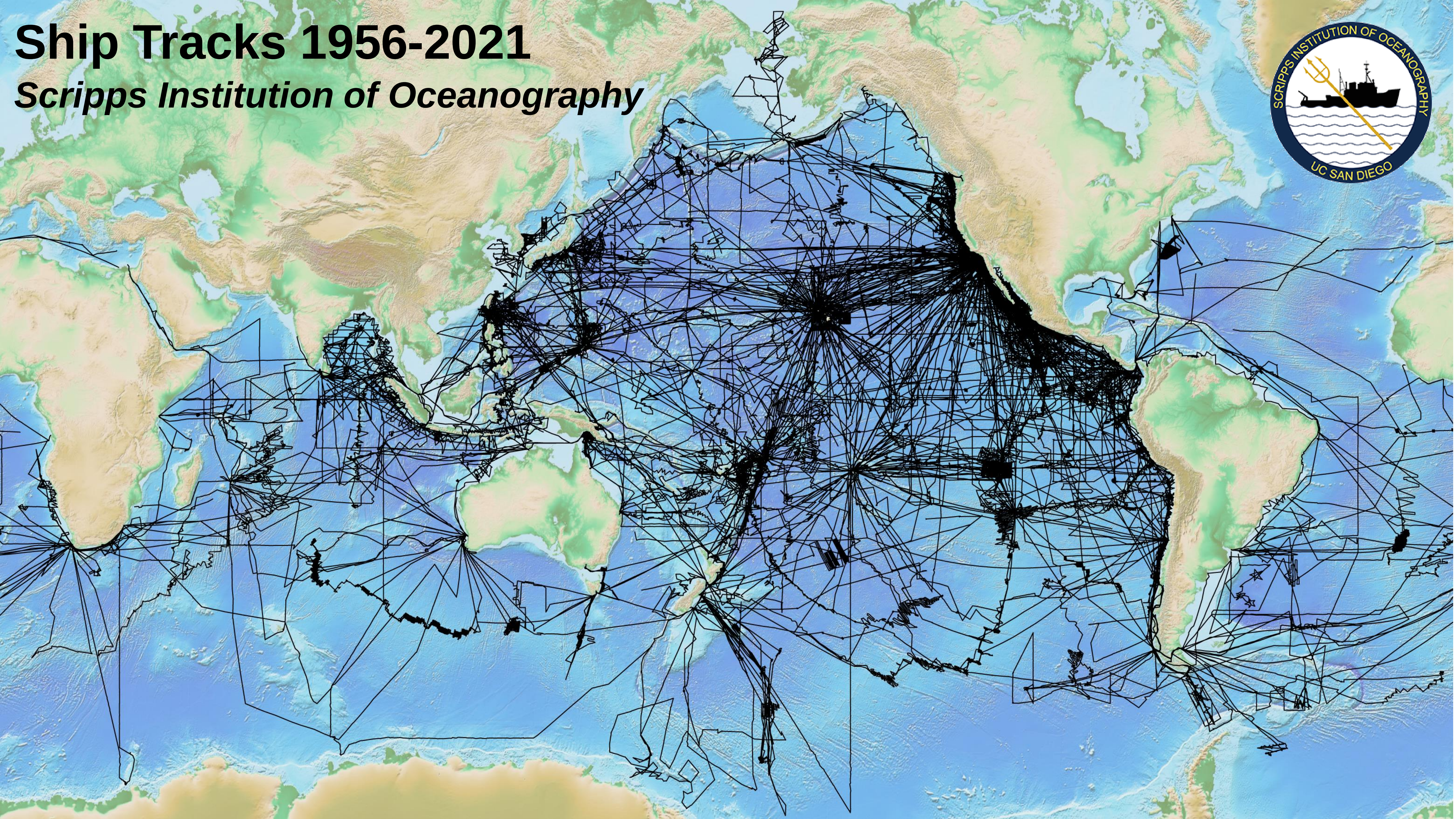


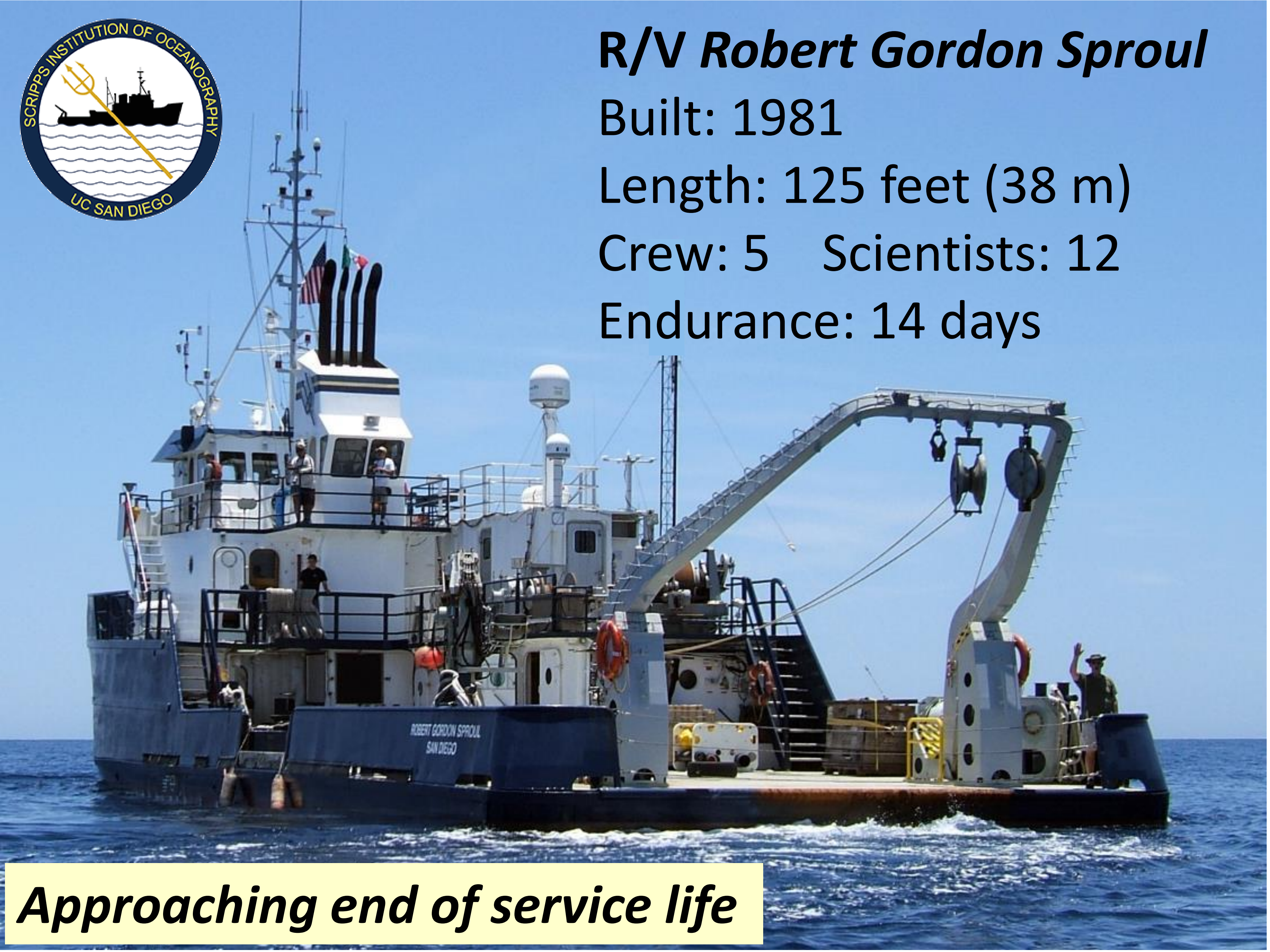
R/V *Robert Gordon Sproul*

Built: 1981

Length: 125 feet (38 m)

Crew: 5   Scientists: 12

Endurance: 14 days



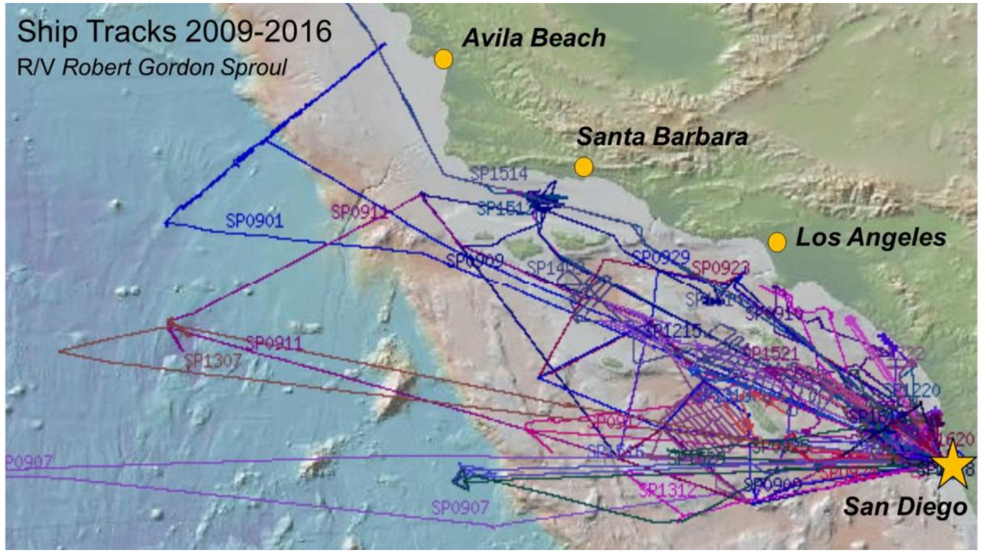
Approaching end of service life

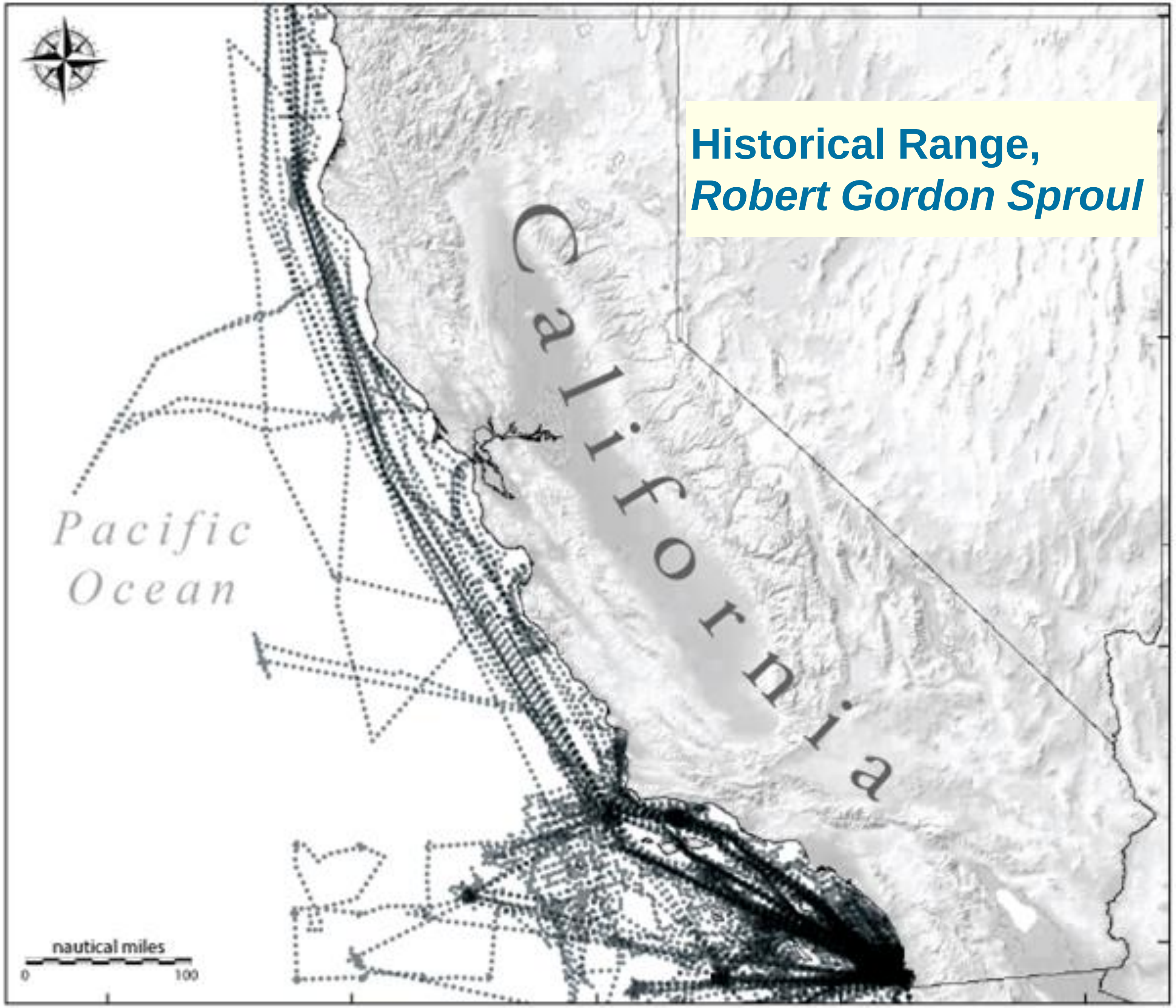
Sally Ride

Roger Revelle

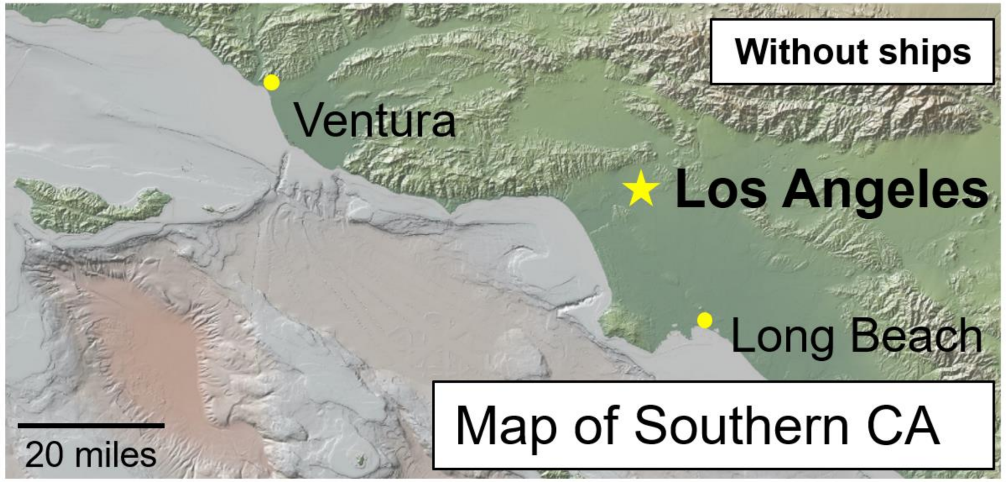
Beyster

California's ocean
...is our office





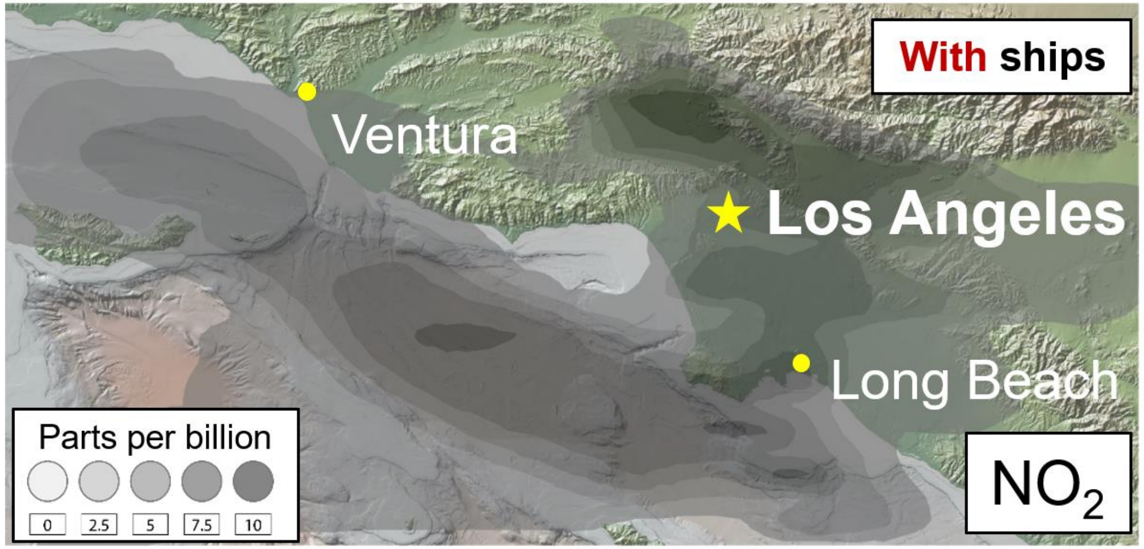
Ship Emissions Pollute Southern California

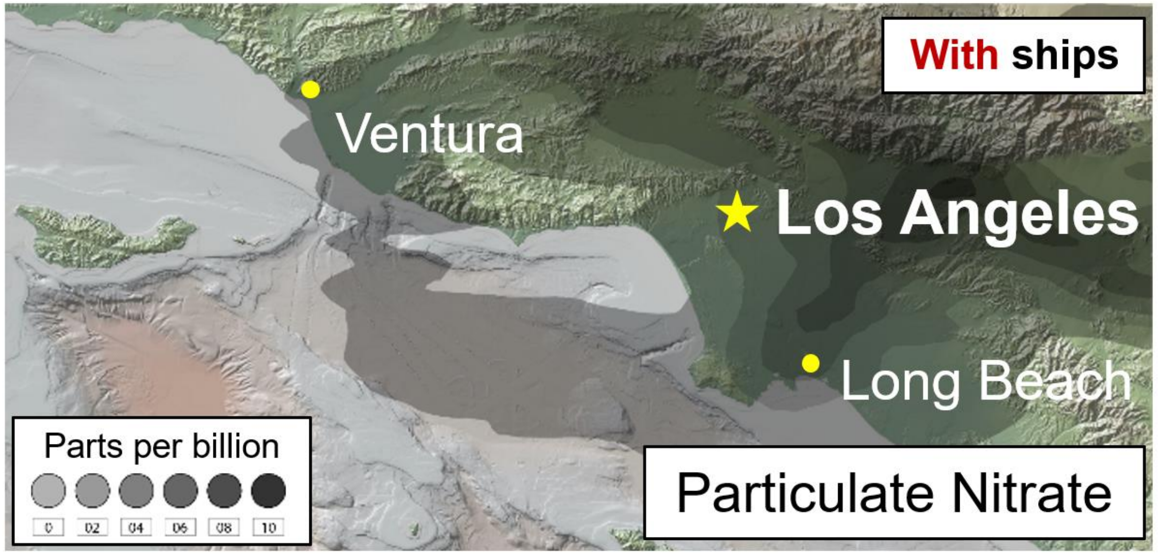


CARB recognizes diesel particulate matter as a **toxic air contaminant.**

"…diesel exhaust still poses substantial risks to public health and the environment."

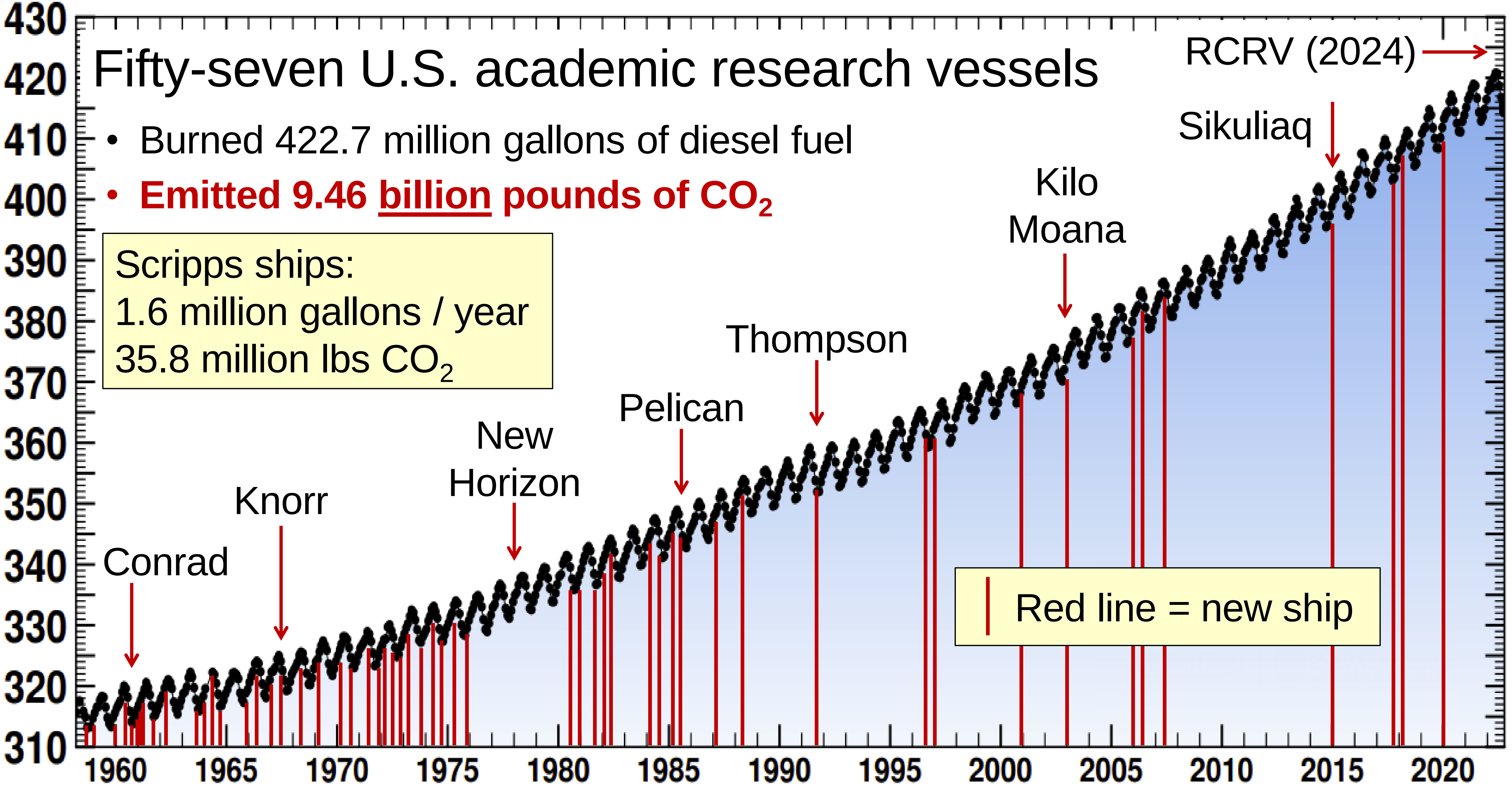
Positive (dark) values show higher concentration due to ship emissions





Dabdub et al., 2008, Air Quality Impacts of Ship Emissions in the South Coast Air Basin of California

Ships pollute the Earth with CO_2 (a greenhouse gas)



Maritime industry must decarbonize

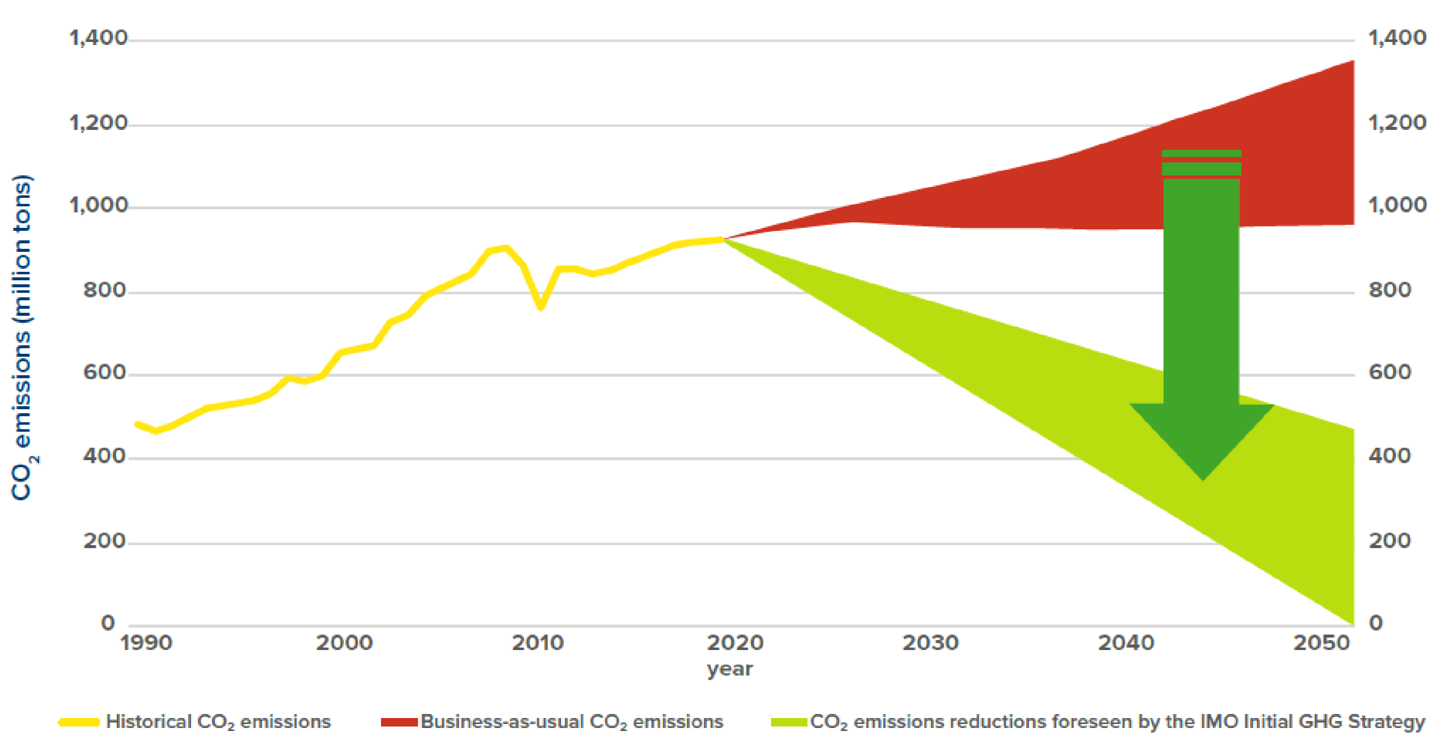
Represents ~3% of global CO_2 emissions (would be 6th-highest GHG emitter, if a country)

Represents 13% and 15% of global NOx and SOx pollution, respectively

Without action, emissions will grow by 90% - 130% by 2050

- Dominant maritime fuel is heavy fuel oil
- Maritime industry is difficult to abate, and new fuels will involve hydrogen or hydrogen-derived fuels produced from renewable resources.
- Zero-carbon fuels are entering the global fleet and must scale rapidly to achieve IMO's 2050 climate target.

FIGURE 1: HISTORICAL AND PROJECTED CO_2 EMISSIONS FROM INTERNATIONAL SHIPPING



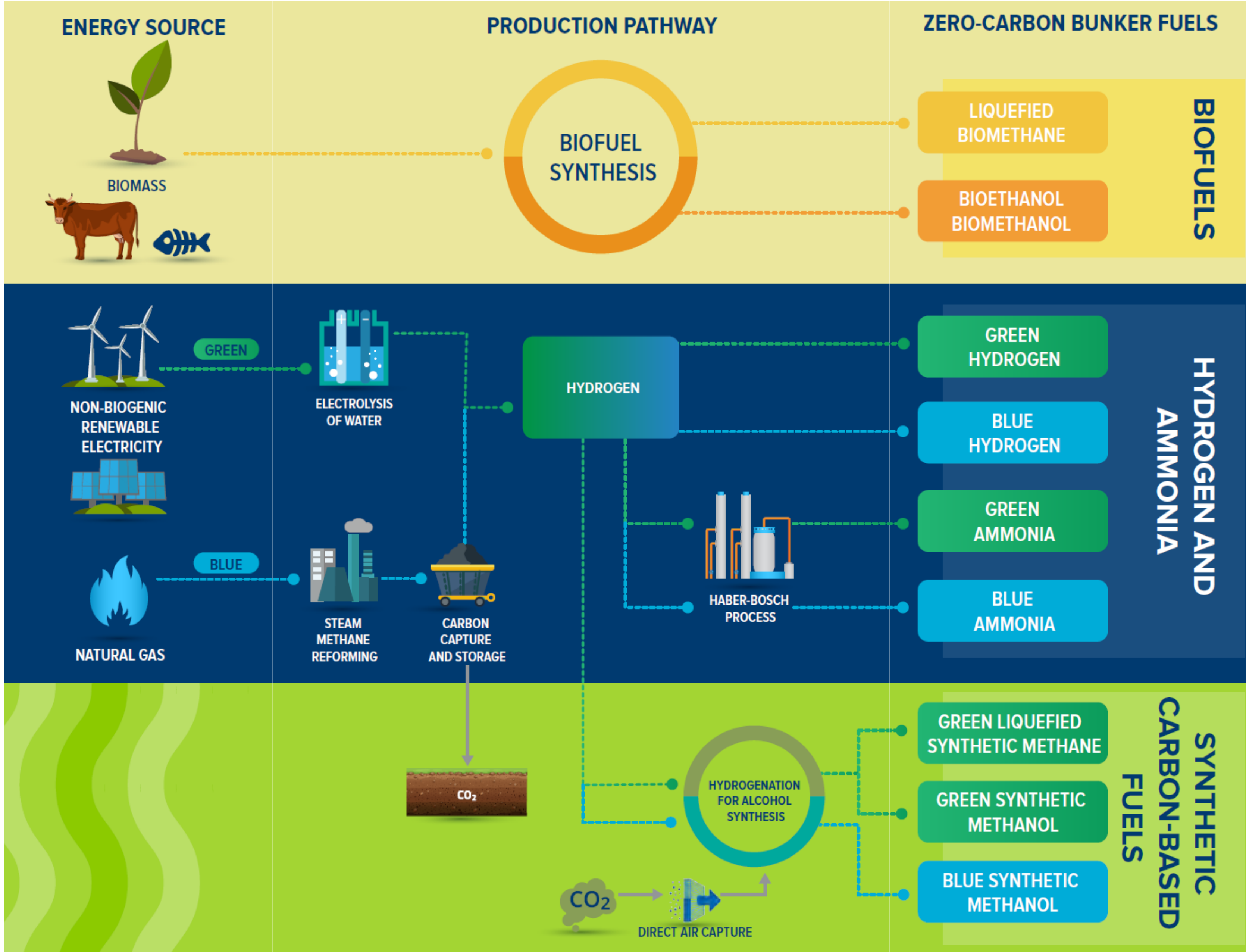
Source: IMO (2020), IMO (2018b)

World Bank, 2021, Summary for Policymakers and Industry: Charting a Course for Decarbonizing Maritime Transport

2023 IMO strategy to reduce GHG emissions from ships

July 15 2023: International Maritime Organization (IMO) adopted revised strategy to reduce greenhouse gas emissions

- Ensure an uptake of alternative zero and near-zero GHG fuels by 2030
- Goal-based marine fuel standard regulating the phased reduction of fuel GHG intensity
- Net-zero GHG emissions from international shipping close to 2050



World Bank, 2021, Summary for Policymakers and Industry: Charting a Course for Decarbonizing Maritime Transport

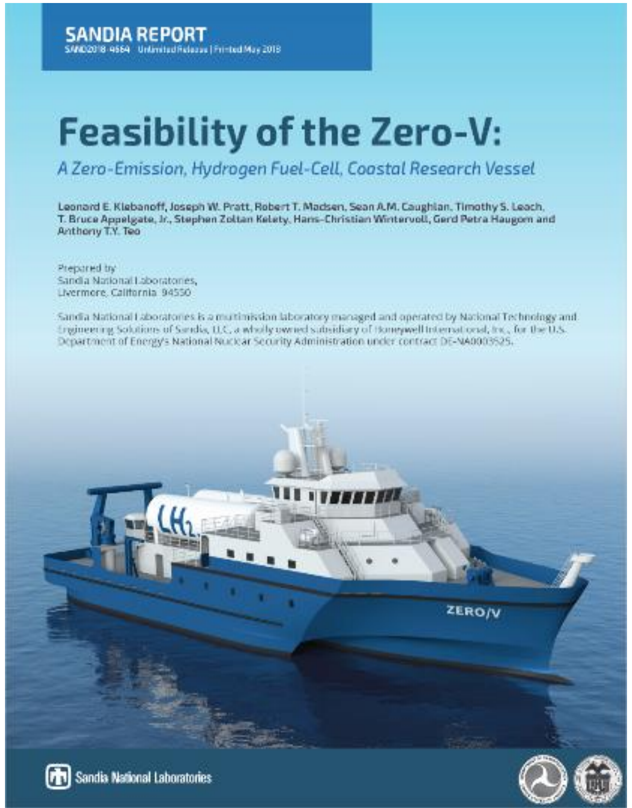
Feasibility Study: Can We Eliminate Ship Emissions?

2018 Study:

Is it possible to build a capable non-polluting coastal research vessel that does not use fossil fuels, with existing technology that is available commercially now?

2020 Study:

Can a coastal research vessel use a hybrid approach to achieve zero emissions using hydrogen fuel cells or batteries, coupled with conventional propulsion?



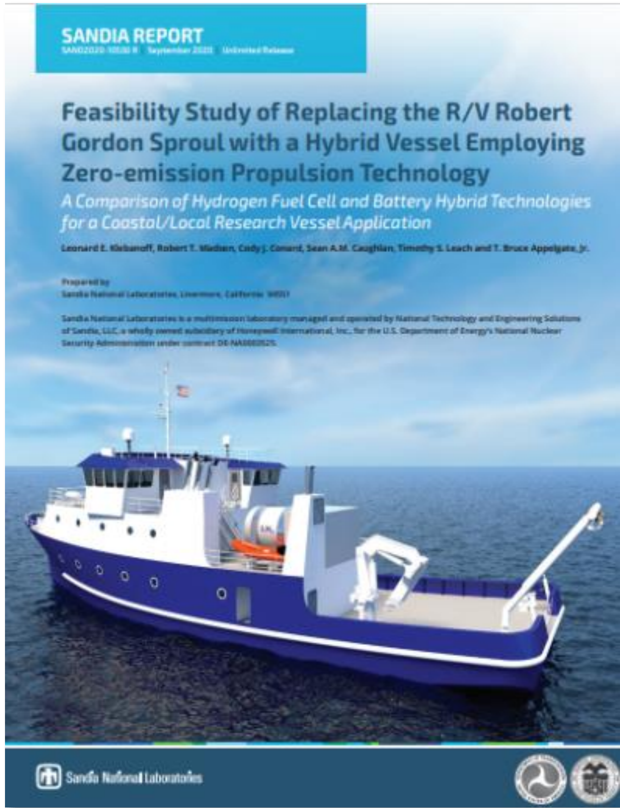
Answer: Yes

Answer: Yes

Download the full reports:

maritime.sandia.gov

This work was supported by the U.S. Department of Transportation, Maritime Administration



Benefits of a zero-emission vessel

University of California mission: Carbon neutrality by 2025

Environmental benefits

- Reduce/eliminate CO_2 emissions
- H_2 and derivative fuels from renewable (non-fossil) sources
- Reduce/eliminate criteria pollutant emissions
- Hydrogen fuel spill cleans itself up in < 30 seconds
- Quiet operations = low impact on marine wildlife

Scientific advantages

- Quiet: low underwater radiated sound = better acoustics
- Uncontaminated air and water samples
- Minimizes harm to physical & biological systems
- Makes own ultrapure water

Hydrogen-hybrid zero-emission research vessel

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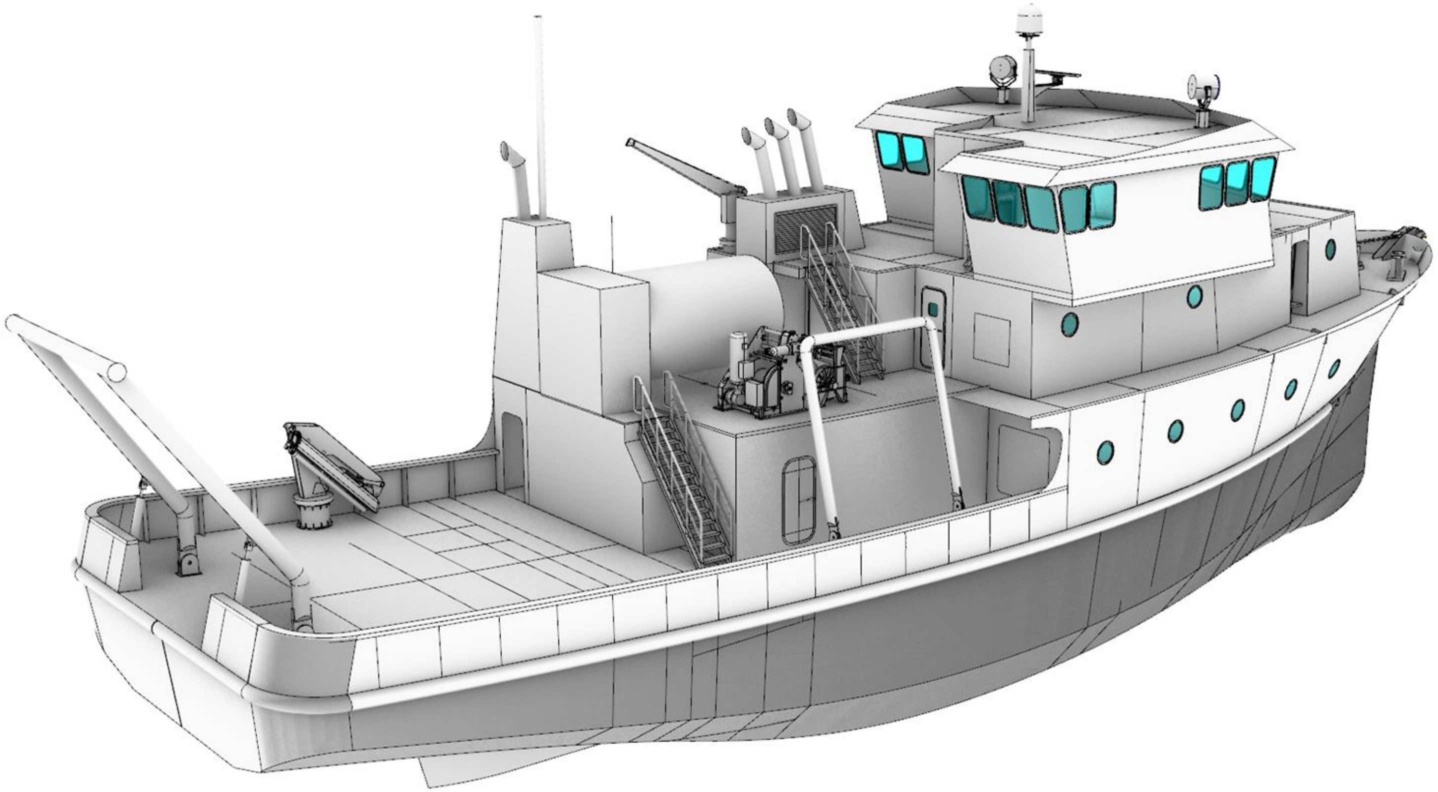
The San Diego Union-Tribune

UC SAN DIEGO RECEIVES $35 MILLION IN STATE FUNDING FOR NEW CALIFORNIA COASTAL RESEARCH VESSEL

First-of-its-kind hydrogen-hybrid vessel will be vital to education and research



California Budget Act of 2021, $35M

On 12 July 2021, California SB 129 funded Scripps to build a hydrogen hybrid research vessel

Office of Naval Research, 2022, Award N00014-22-1-2765, $4M

Design of an Oceanographic Research Vessel of Interest to the Office of Naval Research

Hydrogen-hybrid zero-emission research vessel

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Construction timeline

Phase I: Detailed engineering and design, review, and construction preparation

- 2021: Establish project office at Scripps, issue RFI and RFP for design (complete)
- 2022: Development of detailed vessel engineering and design
- 2023: Final engineering review

Phase II: Construction

- 2024: Shipyard selection
- 2024: Keel laying and construction

Phase III: Commission for service

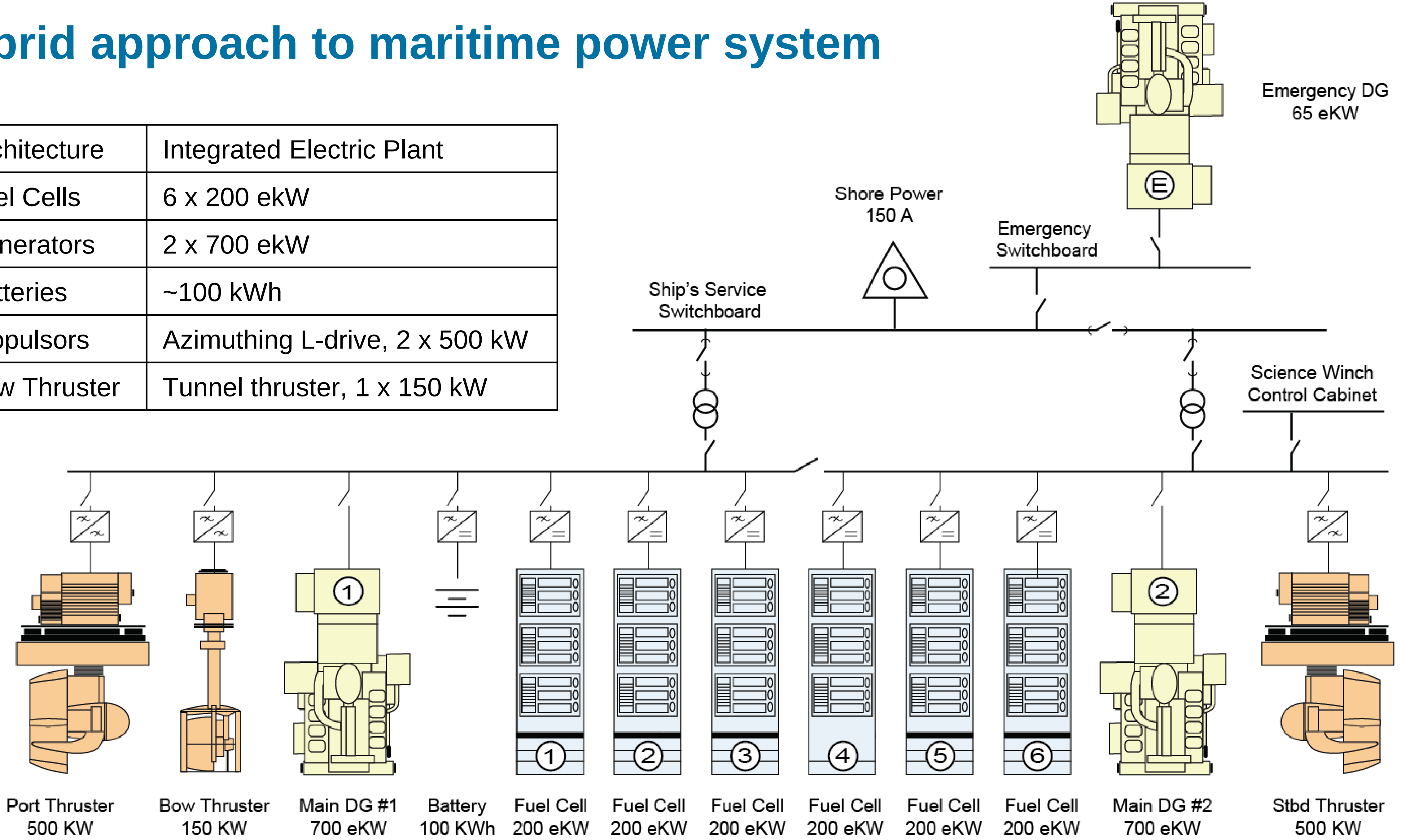
- 2025: Christening, sea trials, delivery
- 2026: Science verification trials
- 2027: Operational for science

Vessel characteristics

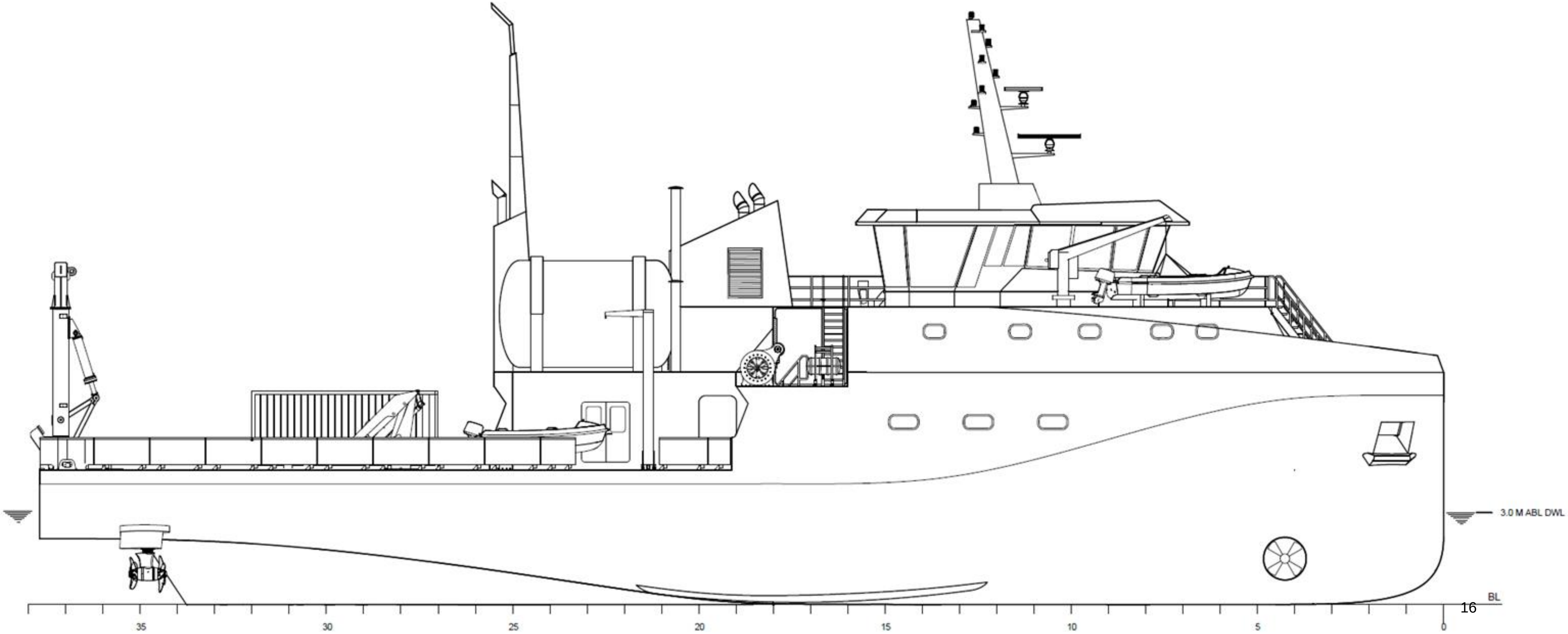
Length overall	49.9 m (164 feet)
Beam	11.0 m (36 feet)
Range (hydrogen)	400 nm
Range (diesel)	6,500 nm
Range (methanol)	2,400 nm
Endurance	11 days
Cruising speed	10 knots
Azimuthing thruster power	Two L-Drives, 500 kW each
Crew berths	7
Scientist berths	16 (on overnight trips)
Students	40 (on day trips)
Stationkeeping	Dynamic positioning
Main crane	2,400 lbs SWL
Stern A-Frame	21,000 lbs SWL
Side Frame	10,000 lbs SWL
Winches	Trawl, CTD/Hydro
Scientific instrumentation: sonar suite, GPS, motion reference, satcom broadband, network	

Hybrid approach to maritime power system

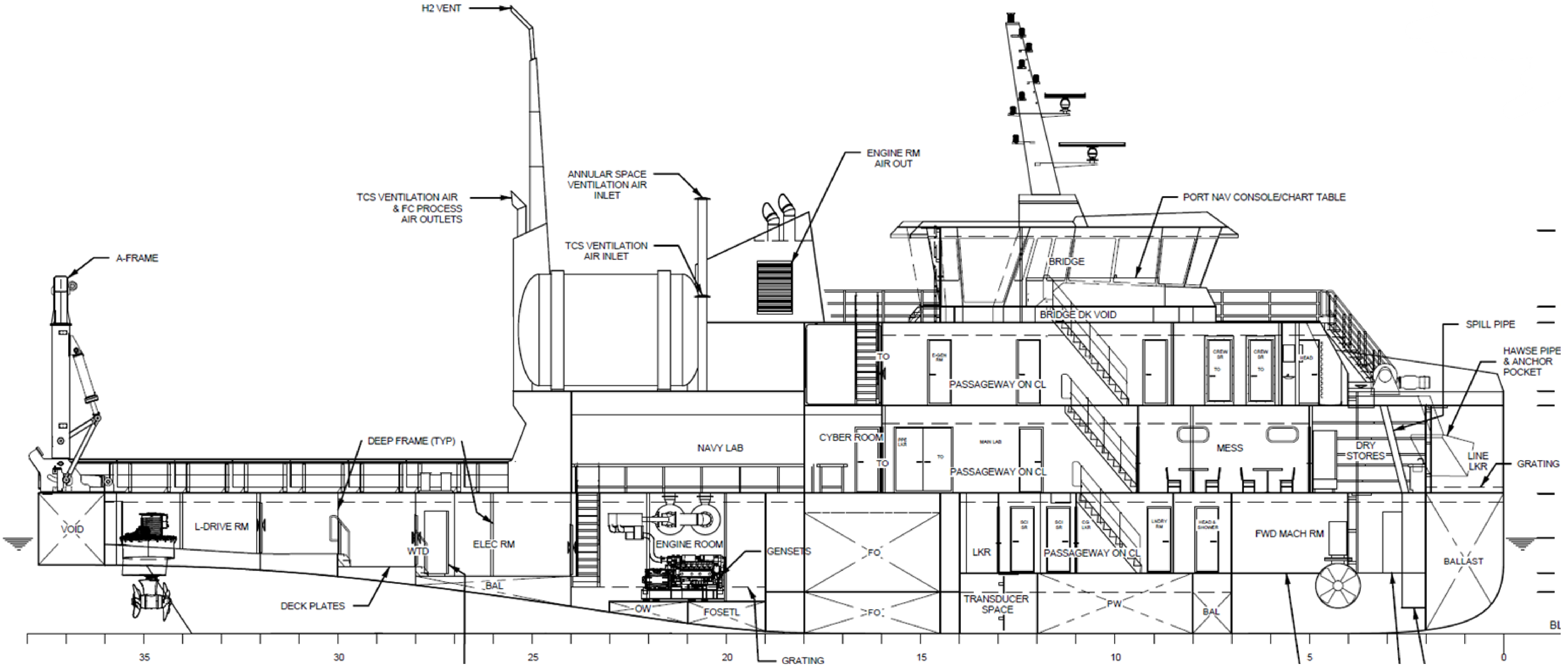
Architecture	Integrated Electric Plant
Fuel Cells	6 x 200 ekW
Generators	2 x 700 ekW
Batteries	~100 kWh
Propulsors	Azimuthing L-drive, 2 x 500 kW
Bow Thruster	Tunnel thruster, 1 x 150 kW



Outboard profile



Inboard profile



Methanol convertible concept

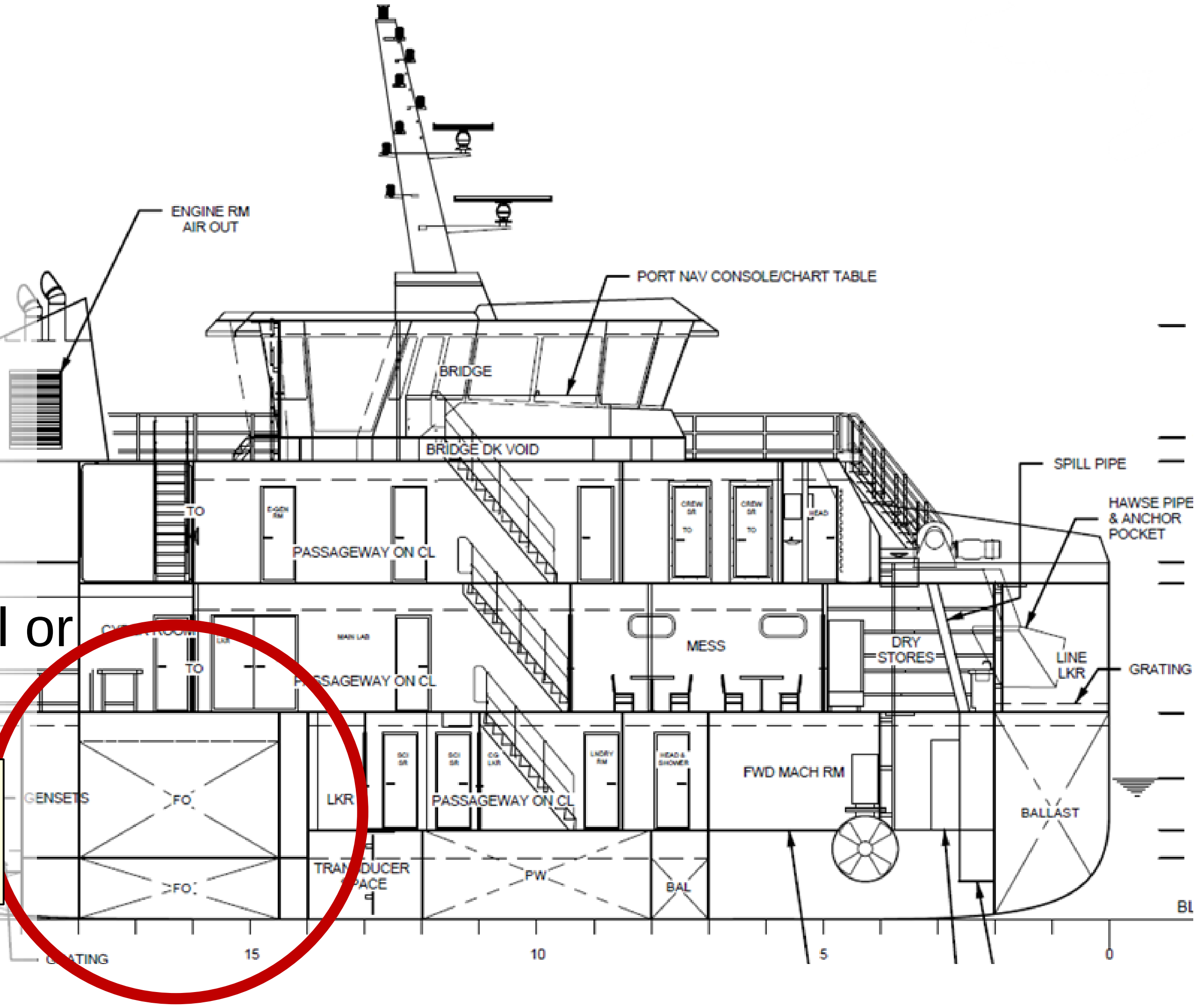
Designed with future conversion to methanol in consideration

- Limit invasiveness of conversion
- Confirm feasibility of arrangements
- Ensure adequate stability

Elements incorporated into the design

- Cofferdams around fuel oil tanks
- Space for future methanol prep room
- Fuel oil tanks sized to meet endurance requirement after conversion to methanol

Repower or retrofit gensets to pure methanol or methanol-diesel dual-fuel engines



The initial design is for a hydrogen/diesel fueled hybrid. It will not be reviewed for, or approved for, carriage of methanol fuel or as a methanol-ready vessel. This reduces technical and regulatory risk.

PRELIMINARY

ARCHES Maritime Working Group

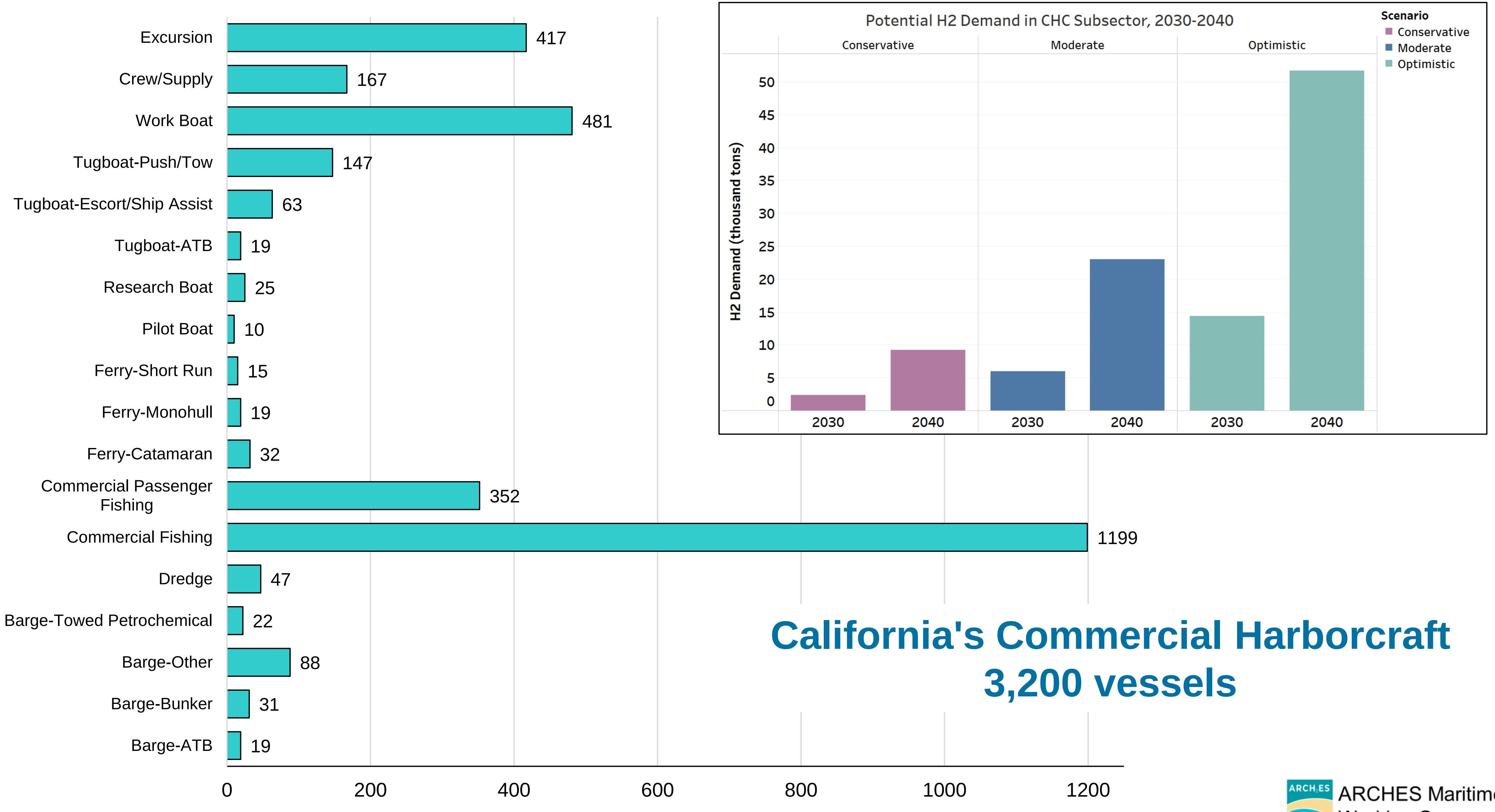
- Maritime vessels currently do not use hydrogen or hydrogen-derived fuels
- The scale of hydrogen demand in the maritime sector is large enough to underpin California's overall hydrogen strategy, catalyzing hydrogen production and driving down costs for all hydrogen users -- at sea and ashore.

Ocean-going vessels, including container ships, tankers, and passenger cruise ships: These vessels are now largely powered by bunker oil, and decarbonization will likely come from switching fuels to methanol or ammonia made from hydrogen

Commercial harbor craft, including ferries, tug boats, and fishing and research vessels: Such craft are likely to decarbonize through either batteries or direct use of hydrogen, depending on circumstances.

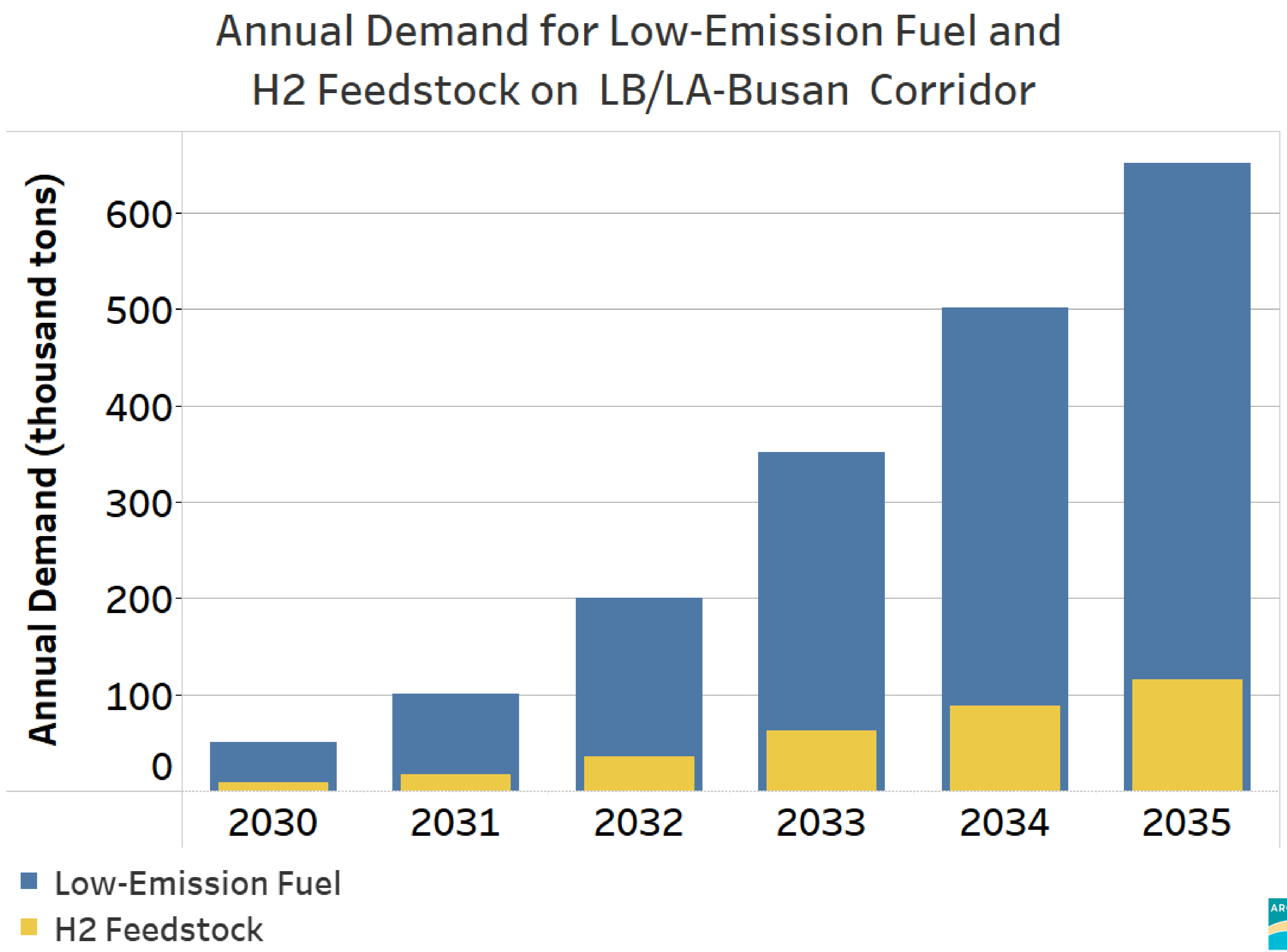
- A single transpacific green shipping corridor will provide offtake for large-scale production—more than 100,000 tons of hydrogen per year before 2035.

Context: 100,000 tons of hydrogen is roughly equivalent to the annual fuel demand of approximately 20,000 long-haul trucks (using hydrogen fuel cells)



California's Commercial Harborcraft
3,200 vessels

ARCHES Maritime Working Group



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How much will emissions be reduced?

	Baseline: *Sproul* diesel generators		Baseline: Tier 4 diesel generators	
Reductions	**30-year life**	**45-year life**	**30-year life**	**45-year life**
Green House Gases ($MTCO_2e$)	50,077	75,115	40,740	61,111
NOx (lbs)	4,833,524	7,250,286	500,478	750,716
Reactive organic gases (lbs)	483,285	724,927	21,503	32,255
Diesel particulate matter (lbs)	235,496	353,243	2,402	3,602
$PM_{2.5}$ (lbs)	225,134	337,701	2,296	3,444
Fossil Fuels (gal)	6,091,200	9,136,800	8,370,432	12,555,648

What are the costs -- really?

	Two years	Ten years	Twenty years	Thirty years	Forty-five years
GHG cost effectiveness ($ / $MTCO_2e$)	$ 5,649	$ 1,179	$ 612	$ 276	< $ 1
Criteria emissions cost effectiveness ($ / lbs)	$ 807,538	$ 168,502	$ 87,430	$ 39,485	< $ 1

Coastal Class Research Vessel (CCRV)

A hydrogen-hybrid ship with zero-emission capability

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