UC San Diego

HYDROGEN ENERGY TOWN HALL
DECEMBER 5, 2022

Resource Management & Planning

UC San Diego

SETTING THE STAGE

STEPHEN JACKSON

ASSOCIATE VICE CHANCELLOR, RESOURCE MANAGEMENT & PLANNING

WELCOME

- Jen Bowser, Sustainability Engagement Manager, UC San Diego Sustainability
- Nguyen Minh, Research Scientist, Center for Energy Research
- John Dilliott, Director, Utilities & Sustainability
- Melanie Davidson, Hydrogen Commercial Development Manager, SDG&E
- Zoltan Kelety, Research Vessel Construction Manager, Scripps Institution of Oceanography

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WELCOME

JEN BOWSER

SUSTAINABILITY ENGAGEMENT MANAGER

LAND ACKNOWLEDGEMENT

The UC San Diego community holds great respect for the land and the original people of the area where our campus is located. The university is built on the unceded territory of the Kumeyaay Nation. Today, the Kumeyaay people continue to maintain their political sovereignty and cultural traditions as vital members of the San Diego community. We acknowledge their tremendous contributions to our region and thank them for their stewardship.

BEFORE WE BEGIN

This webinar is being recorded.

Recordings and Q&A can be viewed on the Climate & Sustainability Town Halls webpage: https://sustain.ucsd.edu/about/town-halls.html

QUESTIONS

- Were submitted during registration
- Can be submitted in the Zoom Q&A feature

We'll answer as many questions live as time allows.

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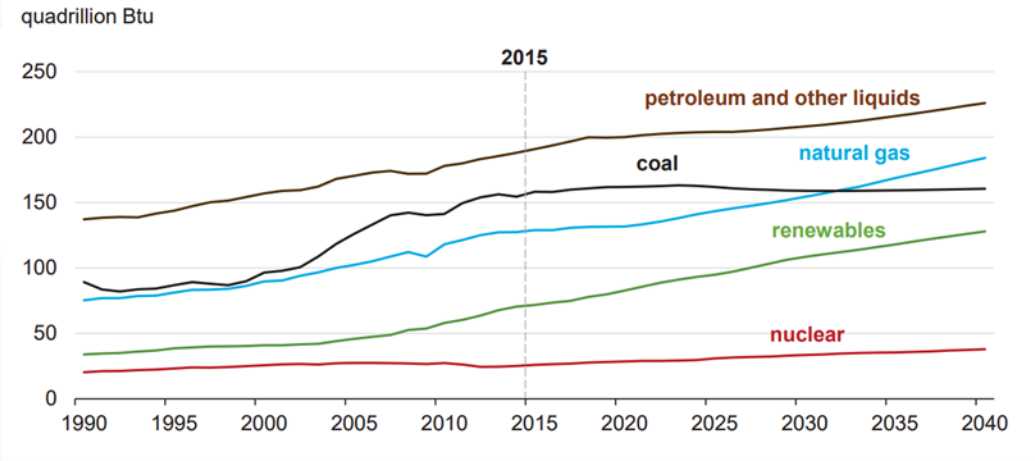
HYDROGEN AND FUEL CELL TECHNOLOGIES FOR CLEAN AND EFFICIENT ENERGY FOR THE FUTURE

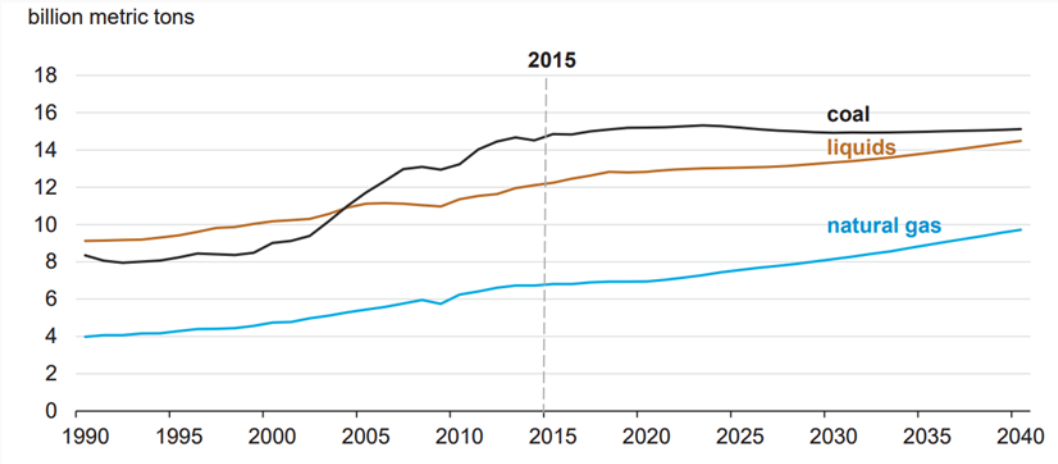
NGUYEN MINH
RESEARCH SCIENTIST/PRINCIPAL INVESTIGATOR
UC SAN DIEGO CENTER FOR ENERGY RESEARCH

WORLD ENERGY CONSUMPTION AND CARBON DIOXIDE EMISSIONS

WORLD ENERGY CONSUMPTION



WORLD ENERGY-RELATED CARBON DIOXIDE EMISSIONS



International Energy Outlook 2017
U.S. Energy Information Administration

POTENTIAL APPROACHES TO MEET ENERGY GROWTH WHILE LIMITING CARBON DIOXIDE EMISSIONS

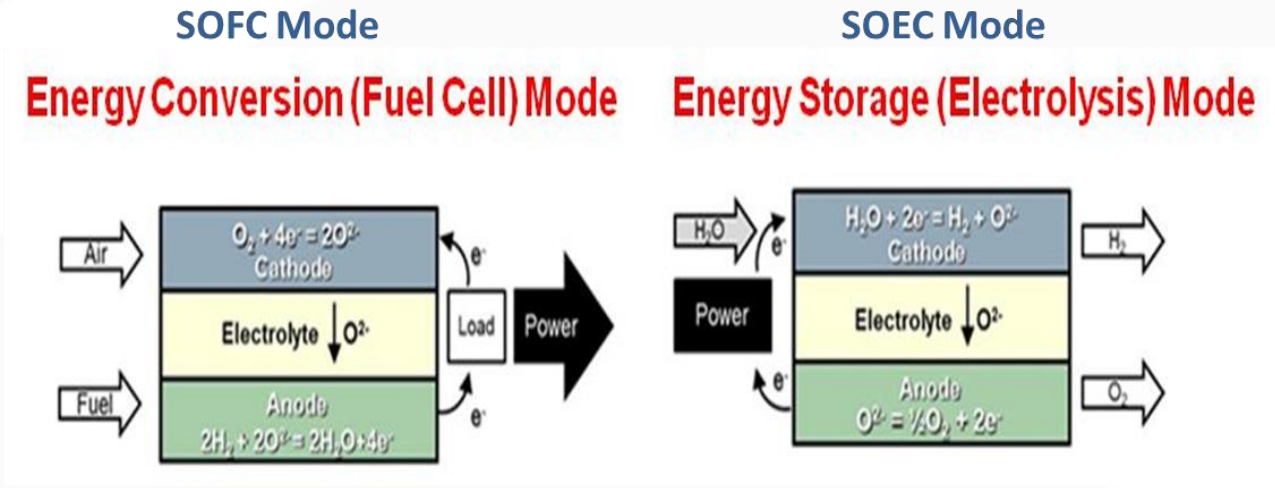
- Development of clean and more efficient energy systems (e.g., fuel cell systems)
- Expansion of sustainable energy technologies (e.g., solar, wind, etc.)
- Use of clean fuels (e.g., hydrogen, especially clean hydrogen such as hydrogen produced from water using sustainable energy)

HYDROGEN AND FUEL CELLS

- The primary fuel for fuel cells is hydrogen.
- Fuel cells with hydrogen fuel can be used for clean and efficient power generation (fuel cell mode).
- Fuel cells in reverse operation can be used to split water to produce hydrogen (electrolysis mode).
- Fuel cells can operate on fossil and renewable fuels.

HYDROGEN AND FUEL CELL R&D AT UC SAN DIEGO

- Solid oxide cell technology – all solid-state cell operating at 600-800C
- Solid oxide cell: solid oxide fuel cell (SOFC) for power generation, solid oxide electrolysis cell/reversed SOFC (SOEC) for hydrogen production and reversible solid oxide cell (RSOC) for both power and hydrogen production



Methane fuel

Anode: $CH_4 + 4O^{2-} = CO_2 + 2H_2O + 8e$ (fuel/hydrogen electrode)

Cathode: $2O_2 + 8e = 4O^{2-}$ (oxygen electrode)

Mixture of water and carbon dioxide

Anode: $2O^{2-} = O_2 + 4e$ (oxygen electrode)

Cathode: $H_2O + 2e = 2O^{2-} + H_2$ (hydrogen/fuel electrode)

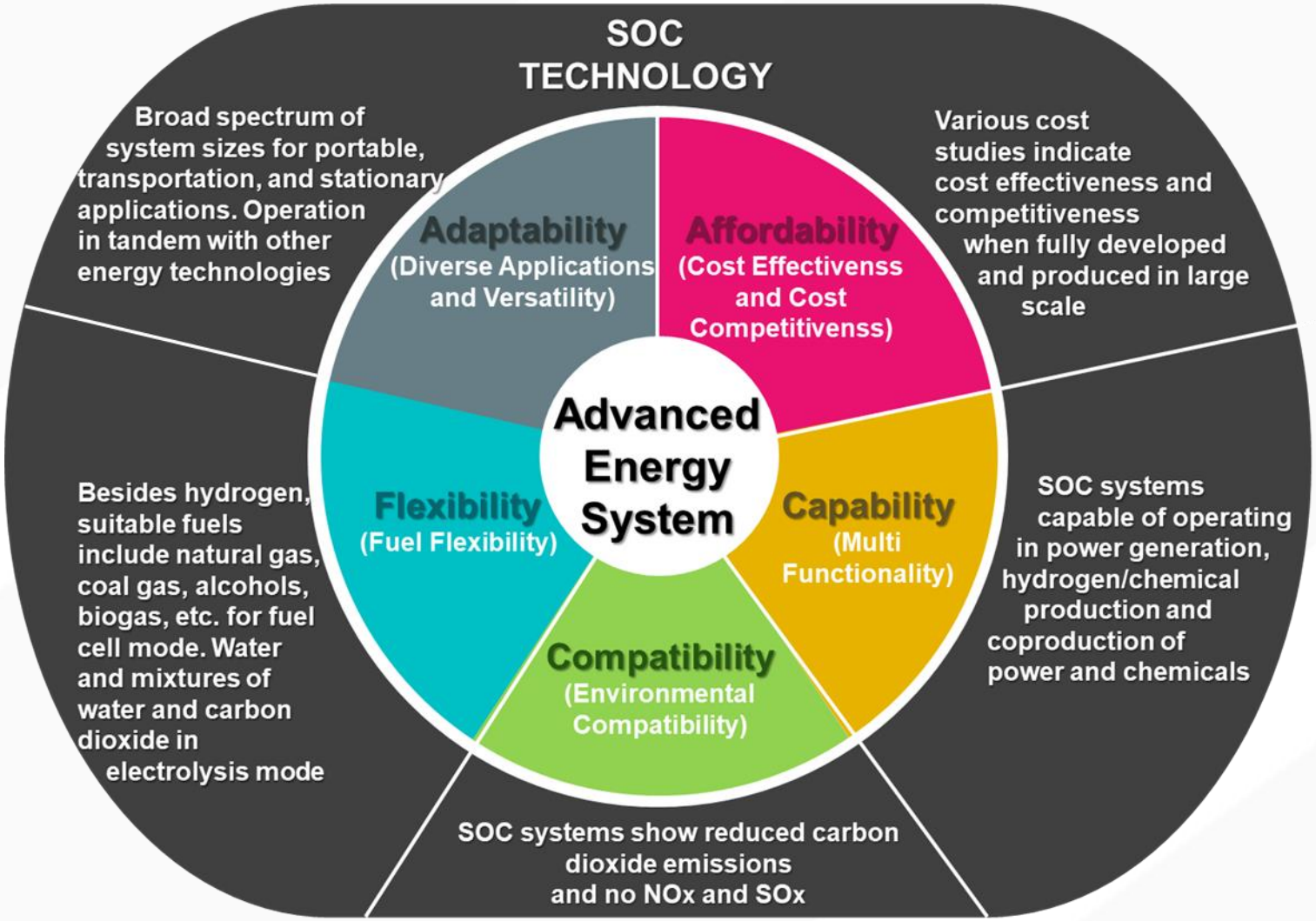
$CO_2 + 2e = CO + O^{2-}$

HYDROGEN AND FUEL CELL R&D AT UC SAN DIEGO

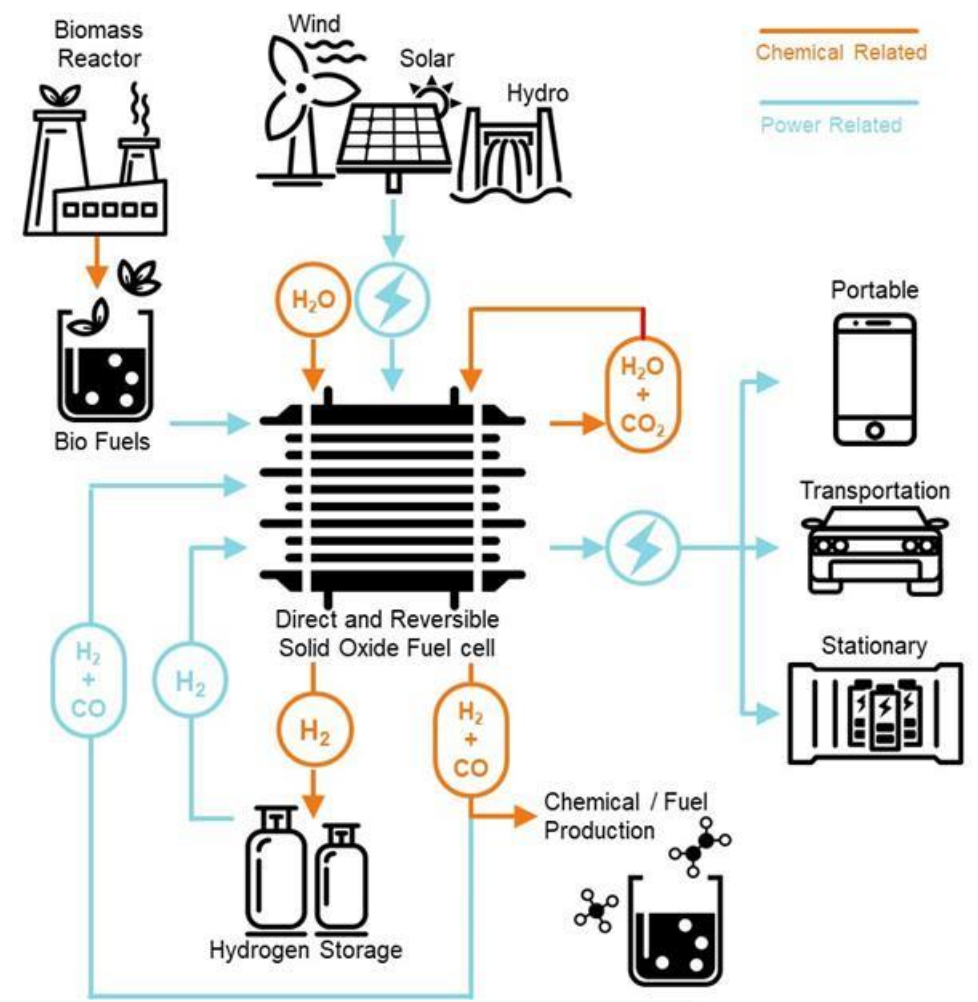
- Solid oxide cell technology: all solid-state cell operating at 600-800C
- Solid oxide cell: solid oxide fuel cell (SOFC) for power generation, solid oxide electrolysis cell/reversed SOFC (SOEC) for hydrogen production and reversible solid oxide cell (RSOC) for both power and hydrogen production

FUTURE ENERGY SYSTEMS

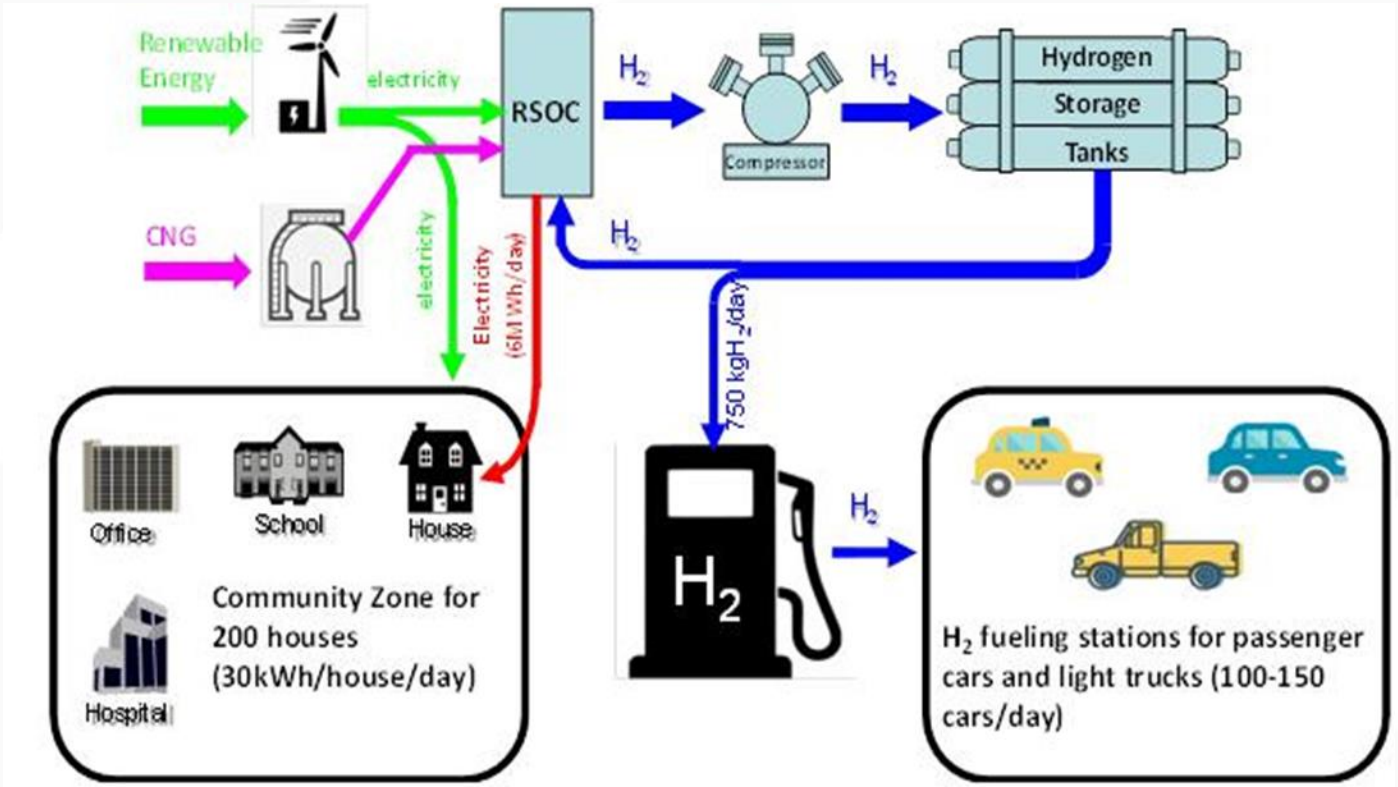
SOC TECHNOLOGY – A POTENTIAL FOR FUTURE ENERGY SYSTEMS



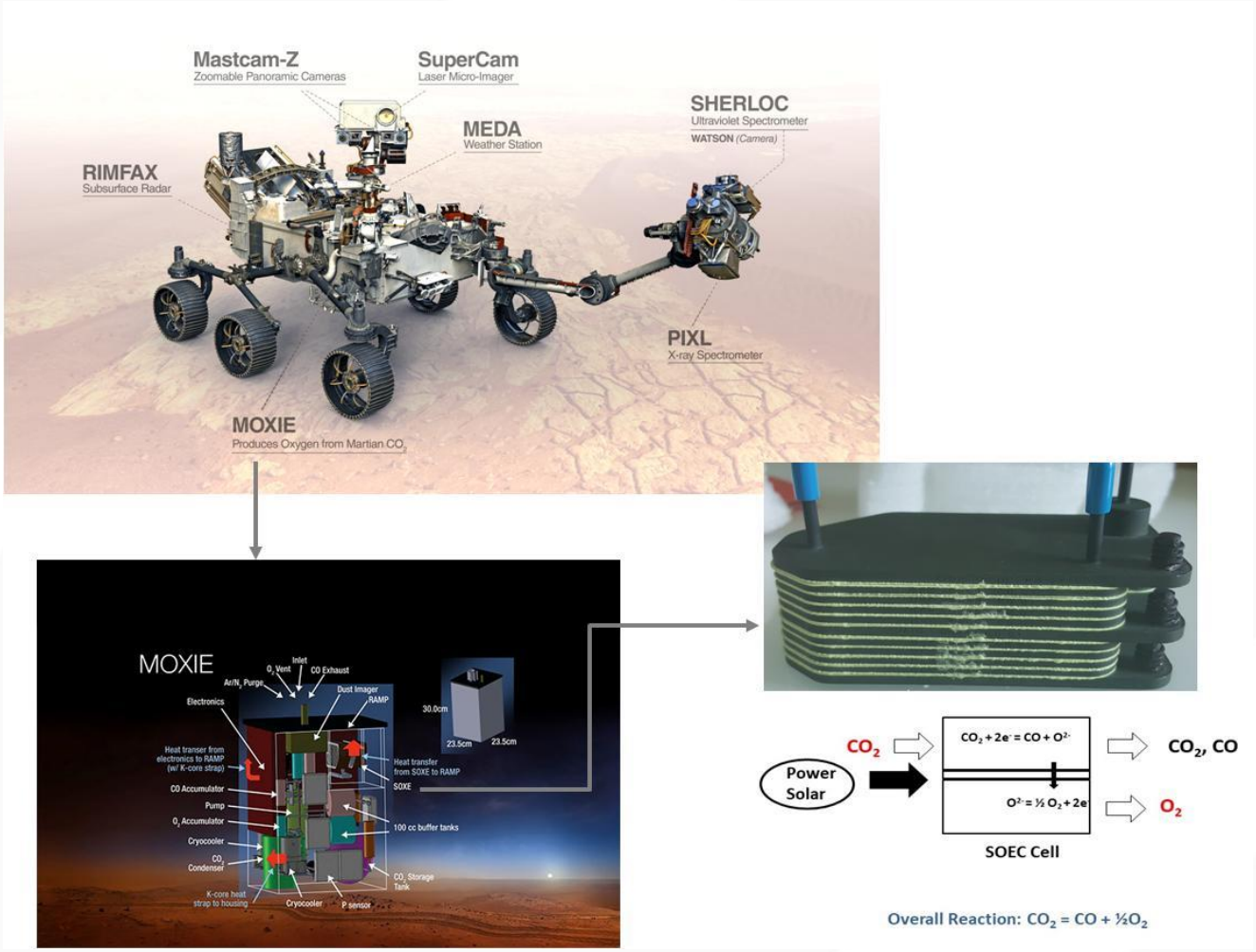
CLEAN, EFFICIENT AND SUSTAINABLE RSOC-BASED ENERGY SYSTEM



EXAMPLE OF DISTRIBUTED HYDROGEN/POWER SYSTEM



SOLID OXIDE CELL TECHNOLOGY IN NASA MARS PERSEVERANCE ROVER



CONCLUDING REMARKS

- Hydrogen and fuel cells are clean, efficient and versatile technologies.
- Fuel cells, along with hydrogen fuel, could play a significant role in energy systems for the future.
- Enhanced durability and reduced cost for fuel cells, improved hydrogen storage and distribution, and reduced cost for hydrogen production are required for widespread adoption and applications.

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UPDATE ON STRATEGIC ENERGY PLAN

JOHN DILLIOTT
DIRECTOR, UTILITIES & SUSTAINABILITY

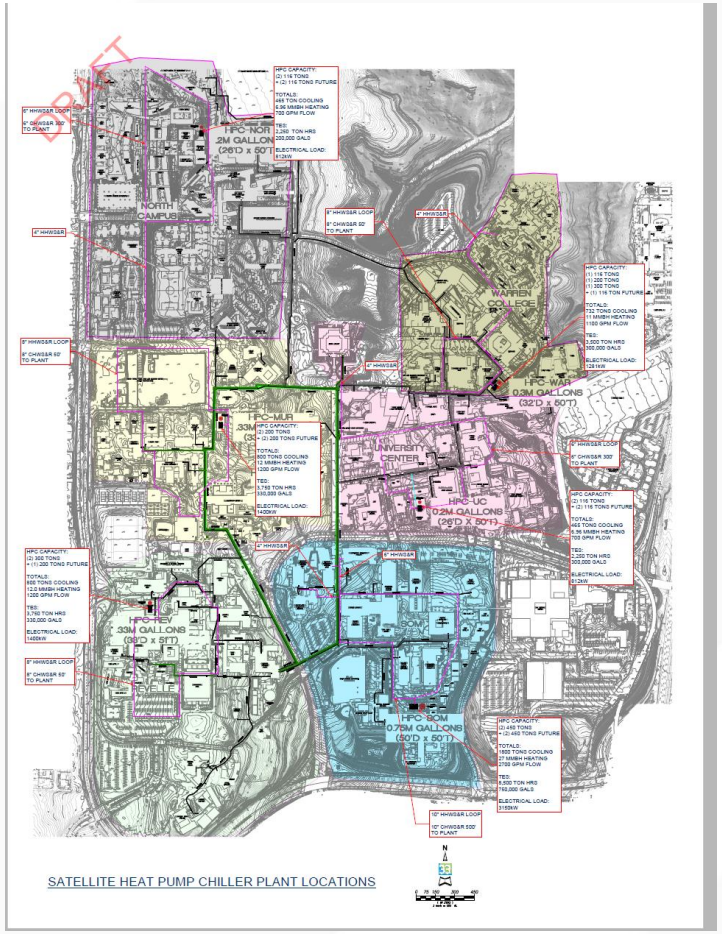
DECARBONIZATION STRATEGY

Campus Energy Profile

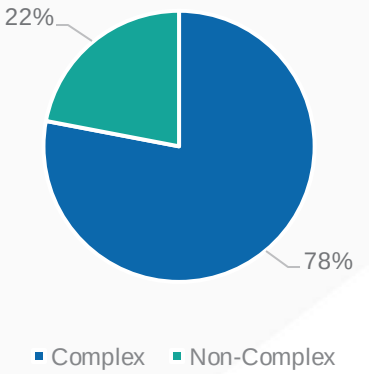
- 78% complex space – Research, medical/clinical, supercomputing
- 22% non-complex space – Housing, classrooms, administrative

~65% of comfort heating load can be served with electric heat recovery chilling technology.

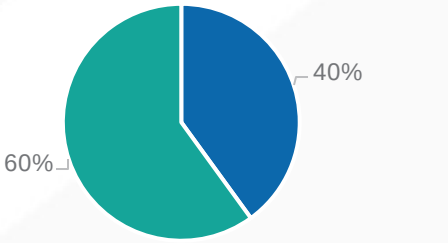
~65% of comfort heating load is ~40% of overall load.



Campus Energy End Use



Campus Energy Demand



ACTIVE CARBON REDUCTION PROJECTS

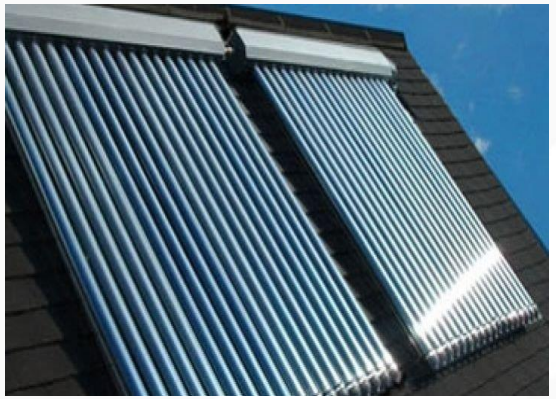
Biogas and Hydrogen

Delivered via SDGE System

- UCOP Program has secured ~20% of supply with goal of 40% by 2025
- Potential of 20% H2

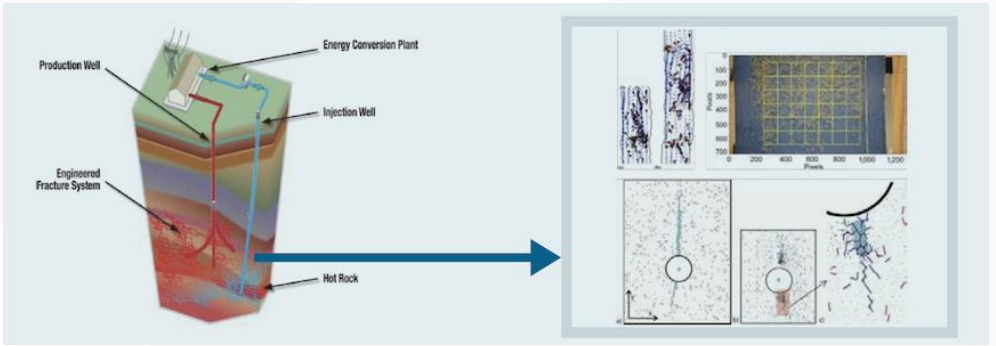
Solar Thermal

- UC San Diego Researcher – Dr. Carlos Coimbra



Geothermal – Energy Geotechnics

- UC San Diego Researcher – Dr. Ingrid Tomac



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SDG&E HYDROGEN INITIATIVES AND HYDROGEN DECARBONIZATION

MELANIE DAVIDSON

HYDROGEN COMMERCIAL DEVELOPMENT MANAGER, SDG&E

Hydrogen at SDG&E

We are at the beginning of re-imagining our energy systems to be 100% clean energy by 2045; hydrogen is a key component.

Melanie Davidson
Hydrogen Commercial Development Manager
San Diego Gas & Electric
UC San Diego Town Hall, December 5, 2022

Agenda

1. Policy and Market Updates for Hydrogen
    - California and Federal
2. SDG&E Path to Net Zero Study
3. SDG&E Hydrogen Projects

California Leads in Climate & Clean Energy Policy

Governing Law – SB100

By 2045, obtain

100%

of electricity from renewable sources

Governing Law – SB1383

By 2030, reduce methane emissions

40%

below 2013 levels

Executive Order B-55-18

By 2045, economy-wide, become

Carbon Neutral

Governing Law – SB 1075

State agencies must consider

Green H2

in decarbonization strategies

Recent Federal Laws Enhance Pathways for Clean Hydrogen

Bipartisan Infrastructure Law, 2021

- **$8 BN** for H2 hubs
- **$1 BN** for electrolysis RD&D
- **$500 MM** for H2 manufacturing and recycling RD&D
- Develop National H2 Roadmap
- Defines “Clean Hydrogen”

Inflation Reduction Act 2022

- 10 Year Production Tax Credit for Clean Hydrogen facilities up to $3/kg

SDG&E, Carbon Neutrality and Hydrogen

SDG&E's Commitment to Sustainability

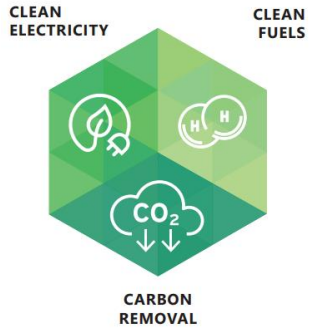
Net Zero by 2045

The Path to Net Zero

A DECARBONIZATION ROADMAP FOR CALIFORNIA

SDG&E BCG BLACK & VEATCH

https://www.sdge.com/netzero



Technological **diversification**

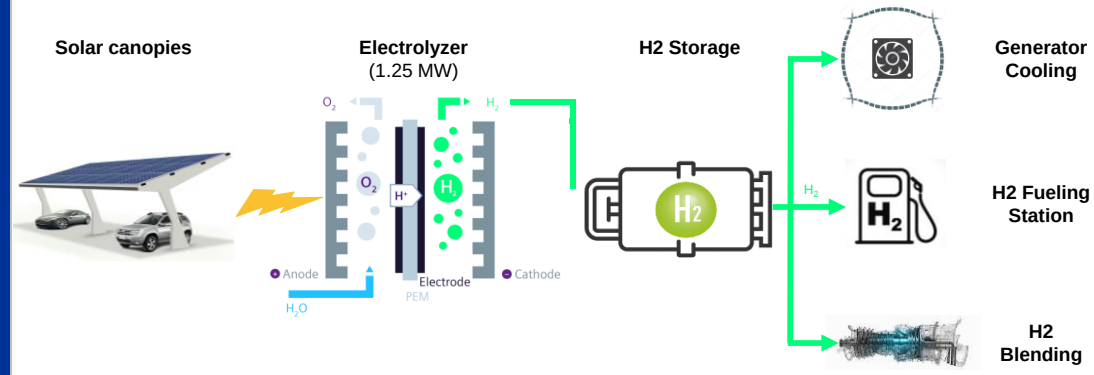
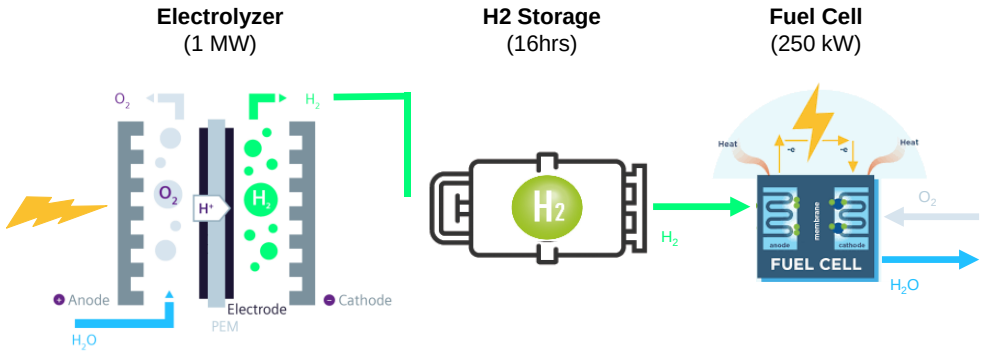
20 GW

2045 clean hydrogen **generation**

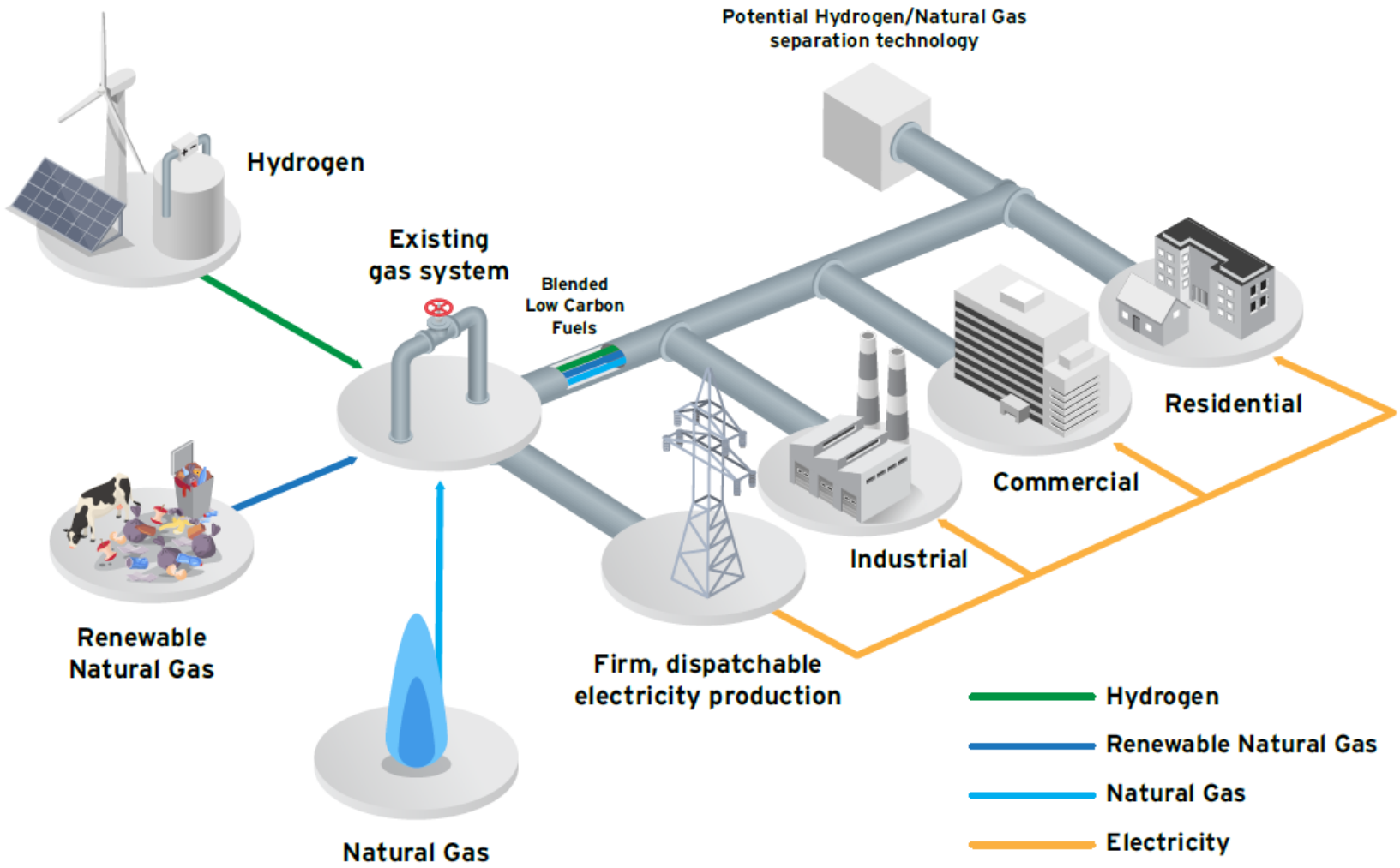
6.5 MMT

2045 total clean hydrogen **demand**

SDG&E Hydrogen Pilots Underway, 2023 Delivery

	Multi-Use H2 Demonstration @ Palomar Energy Center	Long Duration Energy Storage w/H2 @ Borrego Springs Microgrid
Completion	2023	2023
Use cases	• Power-to-gas H2 fuel blending • Generator H2 cooling • Light-duty vehicle H2 fueling	• Long duration H2 storage demonstration • H2 as a CAISO market participant • H2 as a resiliency asset
Equipment	• Solar canopies • Electrolyzer with H2 compressors • H2 storage • H2 vehicle fueling system • Fuel blending skid	• Electrolyzer with H2 compressors • H2 storage • Fuel cell
Conceptual layout		

Hydrogen blending for decarbonized gas network



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Hydrogen Blending Pilot with UC San Diego – Planning Phase

WHY?

- Support carbon neutrality in the gas system
- Help inform our regulator, the CPUC, on safe hydrogen blending standards

WHAT?

- Blend clean hydrogen with natural gas up to 20% by volume to evaluate pipeline impacts
- Partner with fuel cell researchers at UCSD CER

WHERE and WHEN?

- Campus location TBD
- Project would likely kick off no sooner than 2024

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HYDROGEN SEA VESSEL

STEPHEN ZOLTAN KELETY

RESEARCH VESSEL CONSTRUCTION MANAGER,
SCRIPPS INSTITUTION OF OCEANOGRAPHY

Scripps zero-emission hydrogen hybrid research vessel

Zoltan Kelety
RV Construction Manager
Scripps Institution of Oceanography
skelety@ucsd.edu

Presentation Overview

- Why zero-emission ships?
- Feasibility of zero emissions
- Zero-emission hybrid power
- Coastal class research vessel

Acknowledgments: We are grateful for support and collaboration

Research vessels operated by Scripps Institution of Oceanography are part of the US Academic Research Fleet, a major facility supported by the National Science Foundation under awards that include OCE-1827444, OCE-1827415, OCE-1827383, OCE-1923051, and OCE-1823600.

This material presented here is based upon work supported by the Office of Naval Research under Awards N00014-22-1-2765 and N00014-16-1-2745. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the author and do not necessarily reflect the views of the Office of Naval Research.

This material is based upon work supported by the U.S Department of Transportation Maritime Administration (MARAD) Maritime Environmental and Technical Assistance (META) program.

Download the full reports:
maritime.sandia.gov

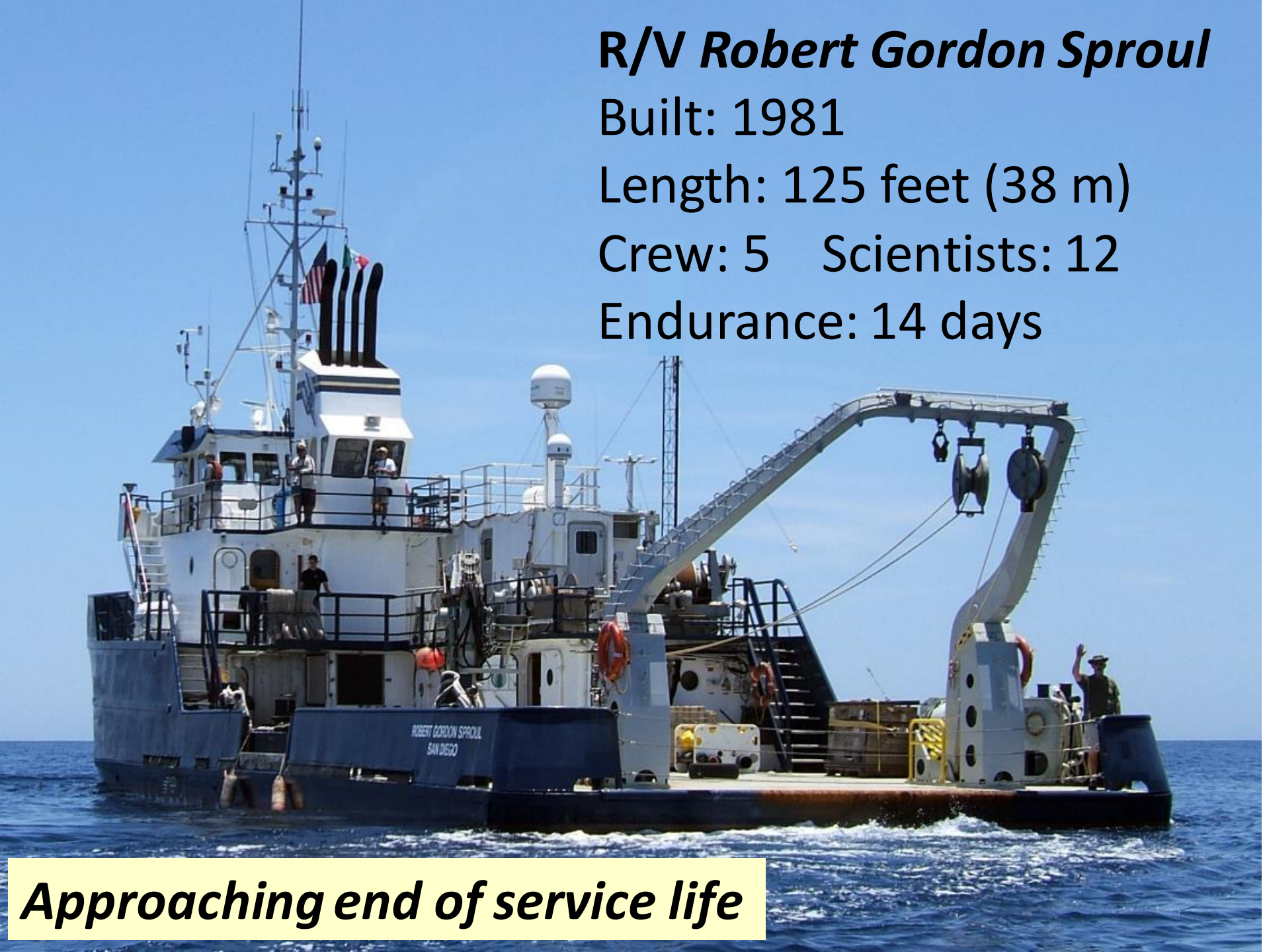
R/V *Robert Gordon Sproul*

Built: 1981

Length: 125 feet (38 m)

Crew: 5 Scientists: 12

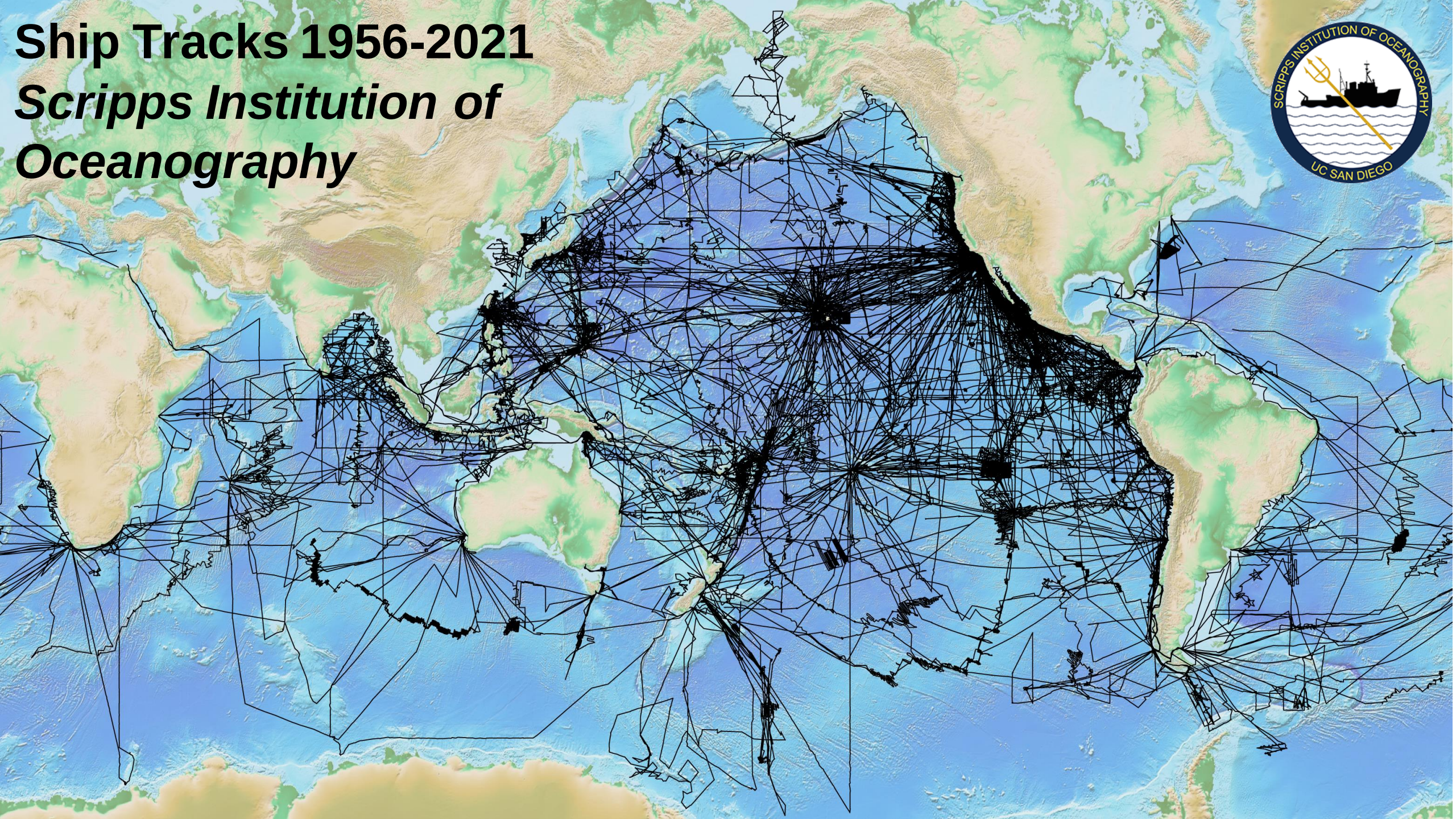
Endurance: 14 days



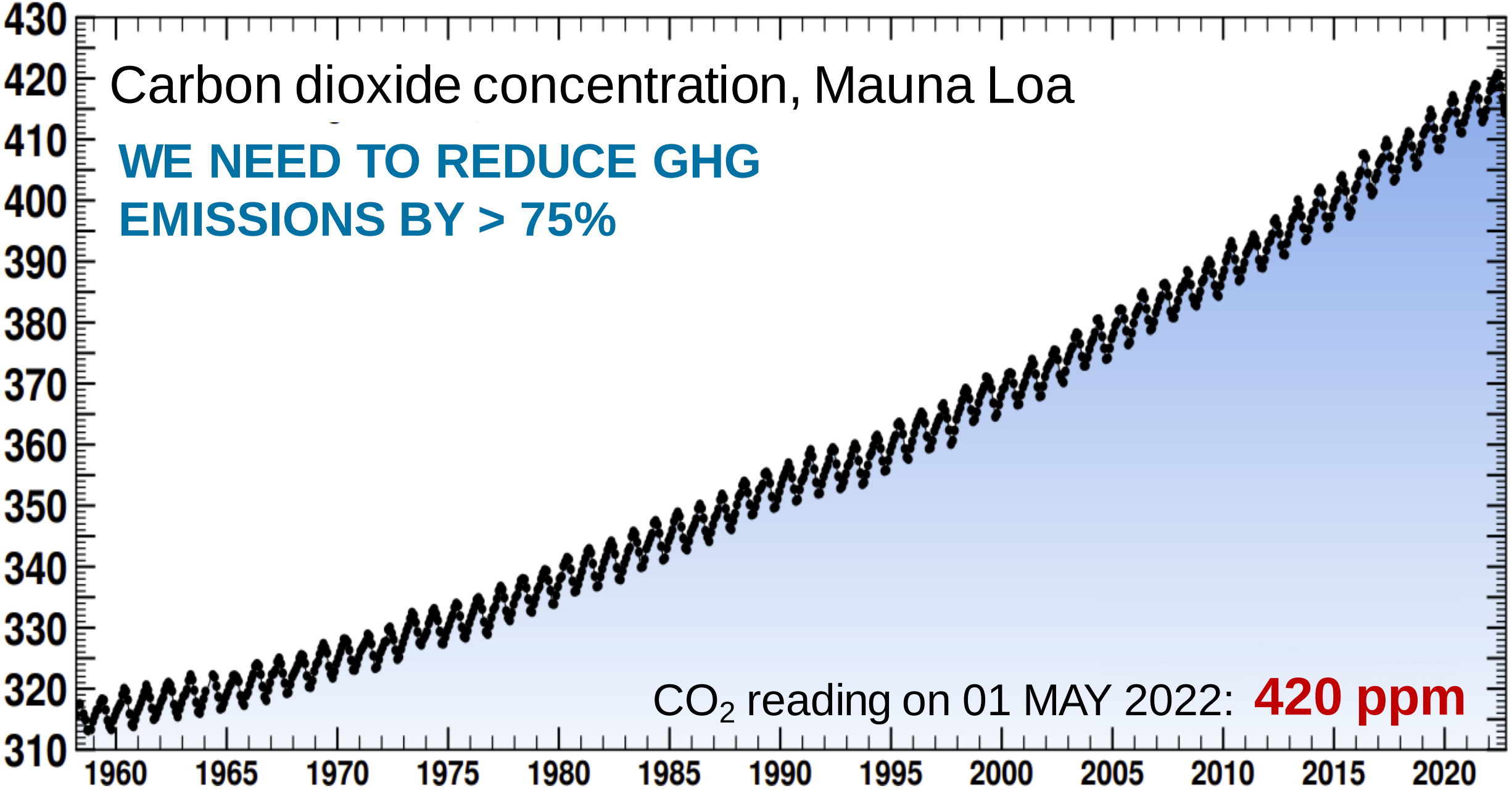
Approaching end of service life

Ship Tracks 1956-2021

Scripps Institution of Oceanography



Ships pollute the Earth with CO_2 (a greenhouse gas)



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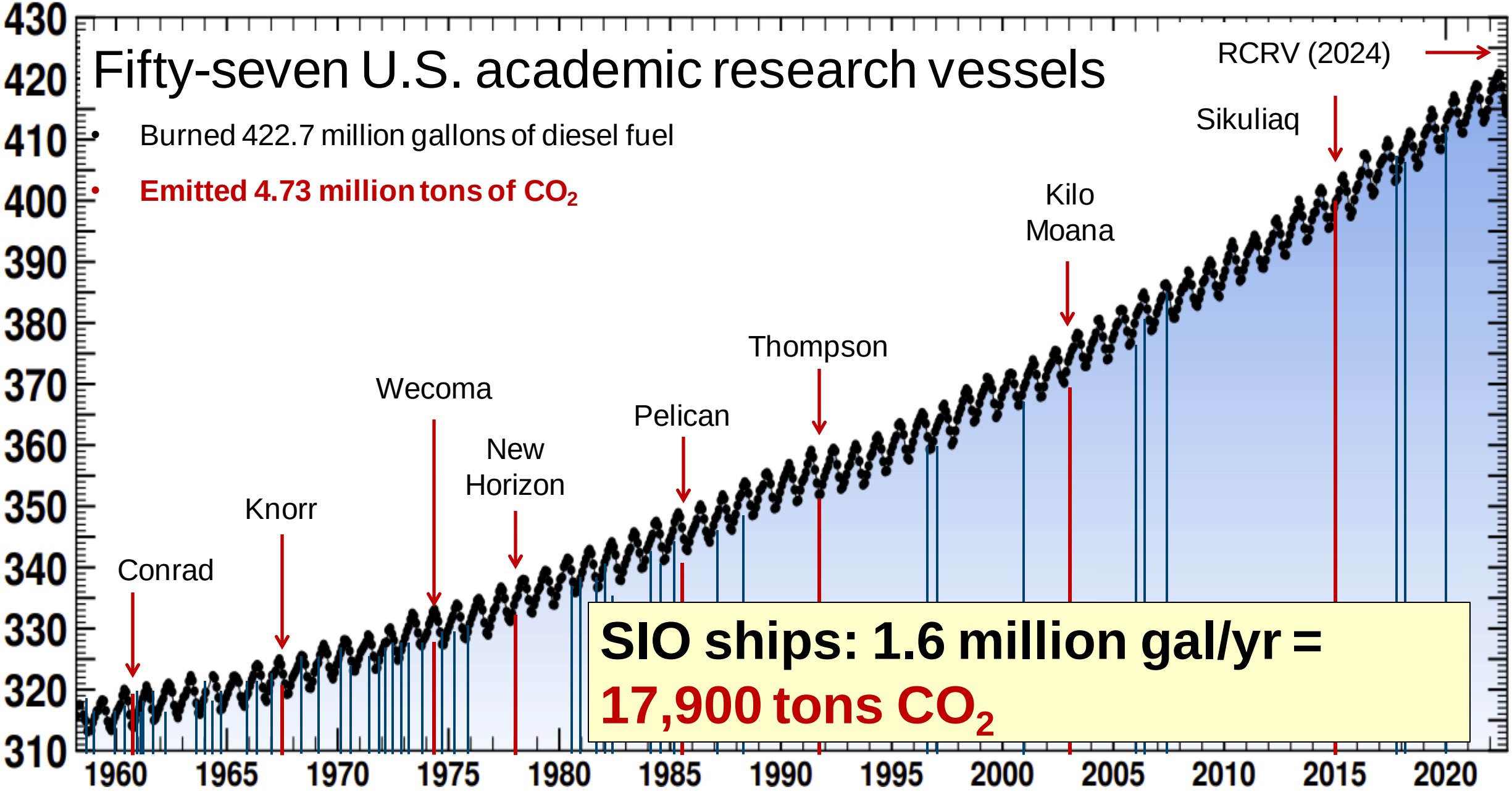
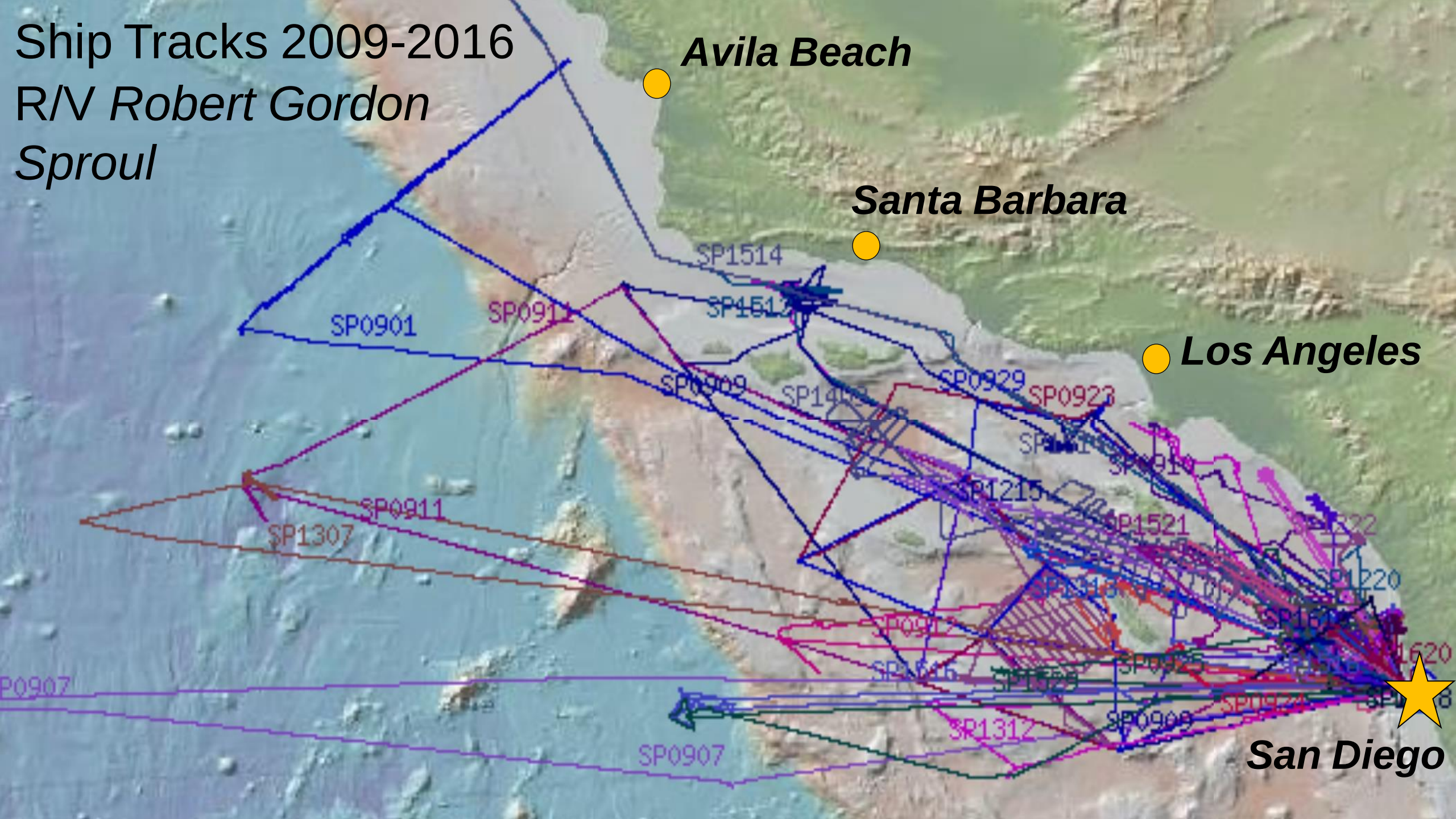
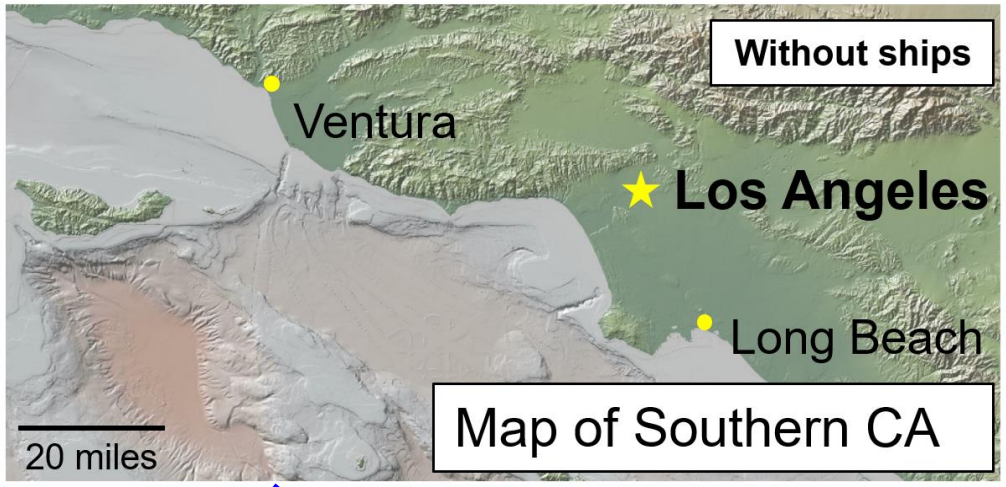



Ship Tracks 2009-2016
R/V *Robert Gordon Sproul*
Avila Beach
Santa Barbara
Los Angeles
San Diego
SP1514
SP1512
SP0901
SP0911
SP0909
SP0929
SP0923
SP1215
SP1521
SP0911
SP1307
SP0907
SP0925
SP0924
SP0909
SP1312
SP0907

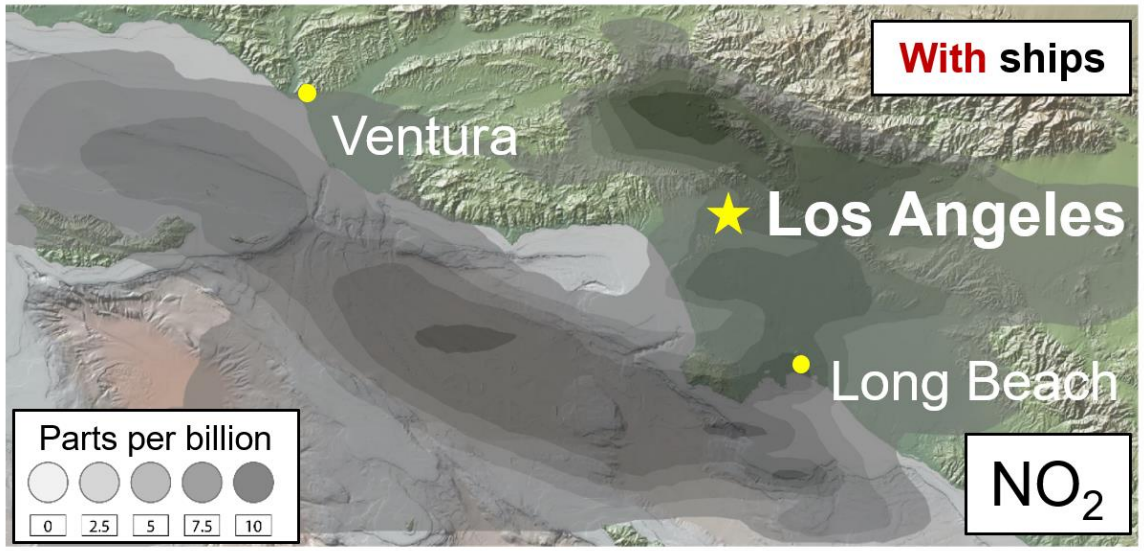
Ship Emissions Pollute All of Southern California

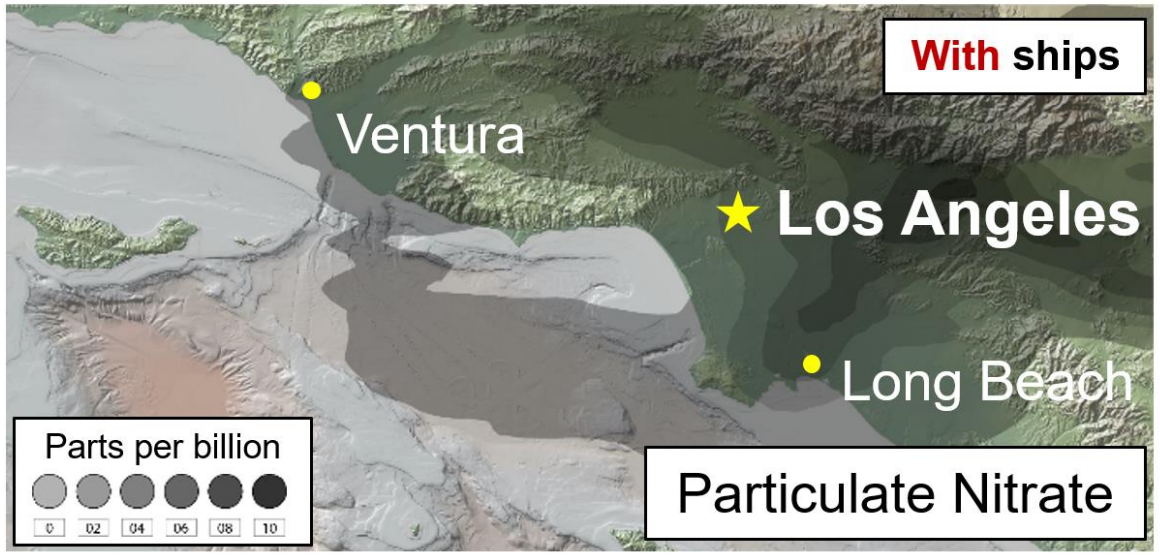


CARB recognizes diesel particulate matter as a **toxic air contaminant.**

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

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





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

WHY A ZERO-EMISSION VESSEL?

University of California mission: Carbon neutrality by 2025

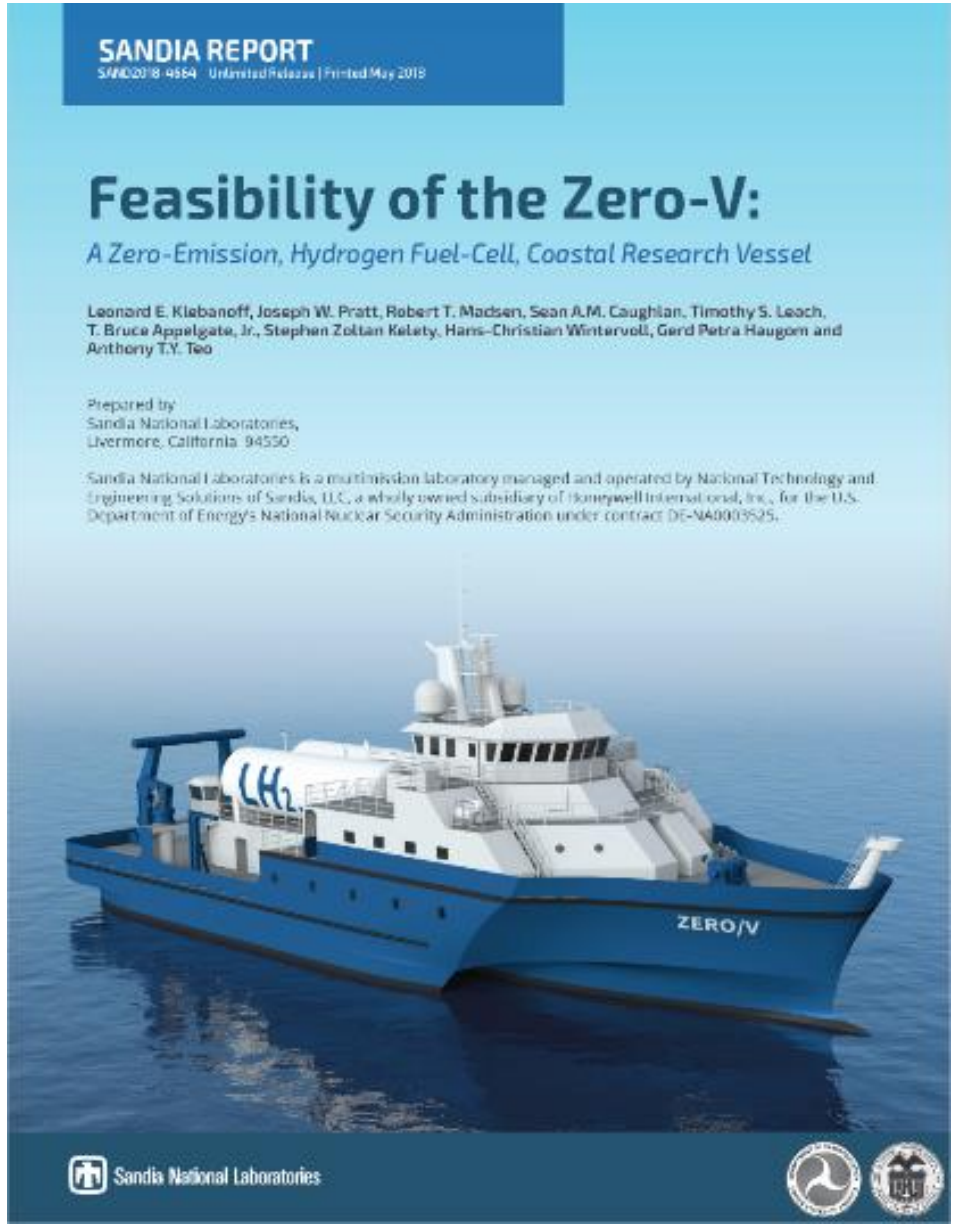
Scientific advantages

- Quiet: low underwater radiated sound = better acoustics
- Sample uncontaminated air and water
- Protects physical / biological systems
- Makes own ultrapure water

Environmental benefits relative to fossil fuels

- H2 will be derived from renewable sources
- No criteria pollutants, no greenhouse gas emissions
- Hydrogen fuel spill cleans itself up in < 30 seconds
- Quiet operations = low impact on marine wildlife (also better for humans!)

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?

Answer: Yes

Download the full report:
maritime.sandia.gov

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

MARAD Maritime Administration

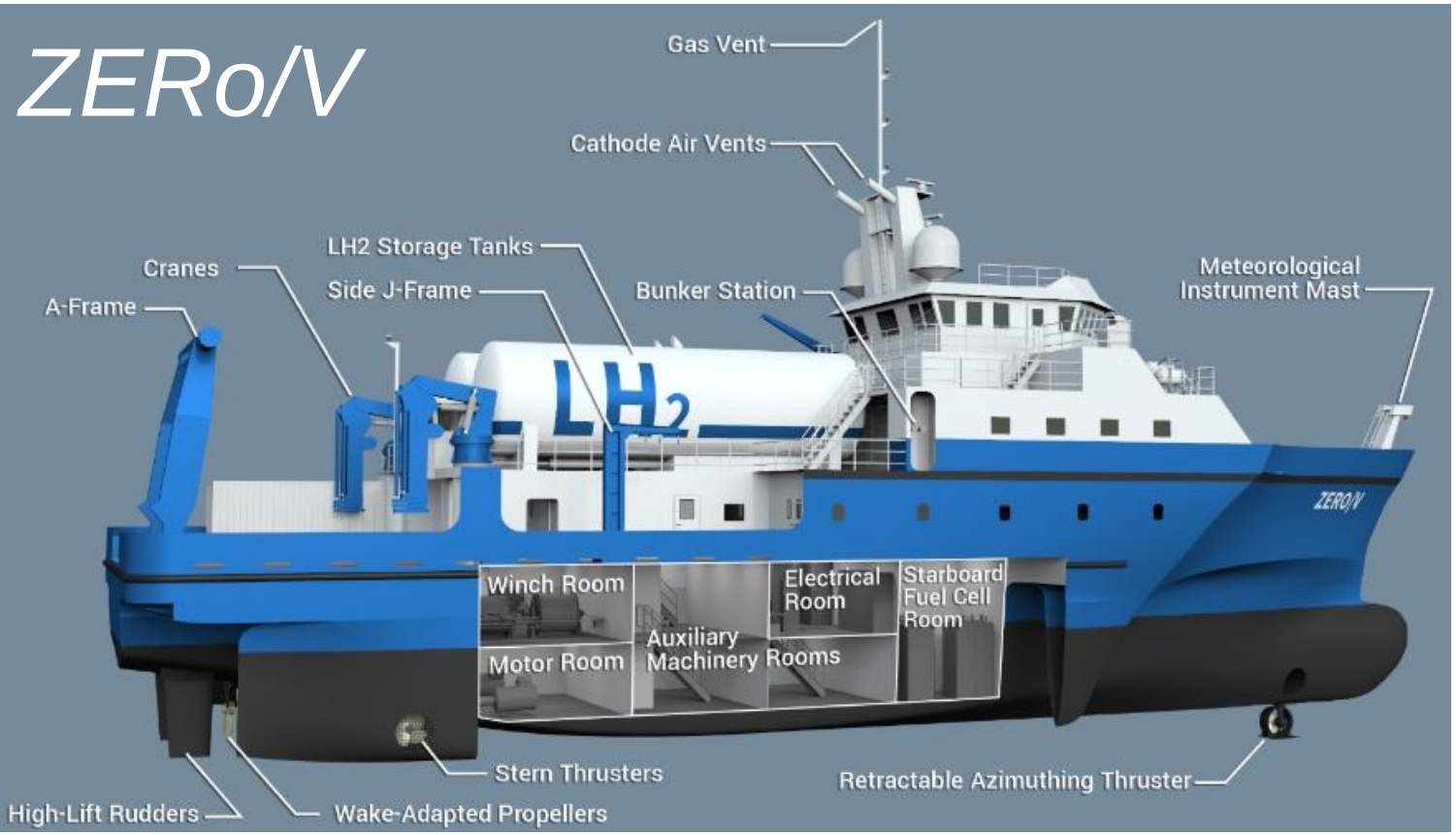
Glosten

Sandia National Laboratories

Scripps Institution of Oceanography

DNV·GL

A zero-emission research vessel is feasible NOW using existing technology



- Oceanographic research vessel for coastal / regional operations
- Uses clean hydrogen: **No fossil fuels!**
- Zero emissions: **Clean / no GHGs!**
- Carries no diesel: **No oil spills!**
- All-electric propulsion: **Quiet!**
- **FEASIBLE** with existing technology
- Outstanding scientific capabilities
- Advanced instrumentation
- Designed for California's educational and R&D needs

A bold, transformative game-changer

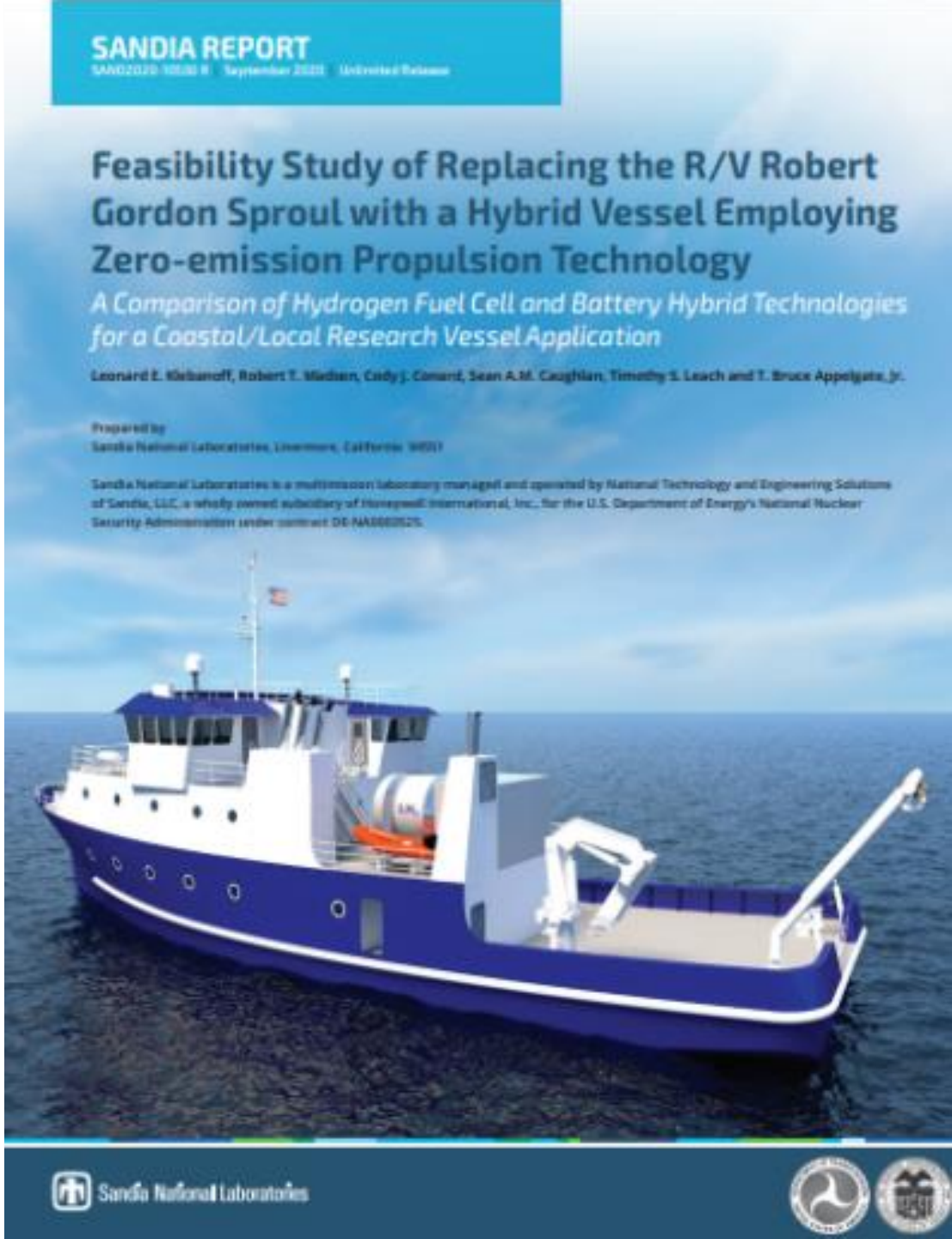
The zero-emission research vessel (ZERo/V) concept vessel has a range of 2,400 nm with berths for up to 20 scientists, supporting general-purpose missions.

What about a coastal vessel?

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

power systems:

- **Baseline Vessel:** conventional diesel-electric propulsion.
- **Battery Hybrid Vessel:** diesel-electric plus lithium-ion battery bank.
- **H_2 Hybrid Vessel:** diesel-electric plus H_2/Fuel Cell
- **All Hydrogen Vessel:** 100% H_2/Fuel Cell propulsion



Science mission requirements, along the entire CA Coast

Cruise speed	10 knots
Max speed	11 knots
Range	2,400 nm
Endurance	10 days
Students	30 (min) 40 (desired)
Crew berths	5 (singles preferred)
Science berths	12 (min)
Stationkeeping	Dynamic positioning
Lab area	340 ft2 (min)
Deck sockets	UNOLS compliant
Main crane	2,400 lbs SWL
Stern A-Frame	21,000 lbs SWL
Side Frame	10,000 lbs SWL
Winches	Trawl, CTD/Hydro
Sewage holding	2,000 gal (min)
Portable vans	2 (min)
Scientific instrumentation: sonar suite, GPS, motion reference, satcom broadband, network	

Historical Range

Science instrumentation

General multi-purpose research vessel

- High frequency ADCP
- Medium frequency ADCP
- 12kHz transducer
- Expendable bathythermograph
- GPS/GNSS x2
- Multibeam sonar
- Sub-bottom profiler
- Sonar synchronization unit
- Fisheries imaging sonar
- USBL positioning system
- Metorological system sensors
- Underway seawater system sensors
- Portable transducer pipe string
- Universal acoustic deck box
- Computing cluster & storage array
- Network security (switches, firewalls)
- Scientific system display array
- SatComs: Dual GX100 HP NX systems
- Cellular internet integration
- AIS antenna
- Radio direction finder / receiver

Hybrid Variants: Battery vs Hydrogen

Hydrogen hybrid is better than batteries

Cruise Speed	Zero Emissions Range (NM)	
	Battery Hybrid	Hydrogen Hybrid
9 knots	37	330
10 knots	25	234

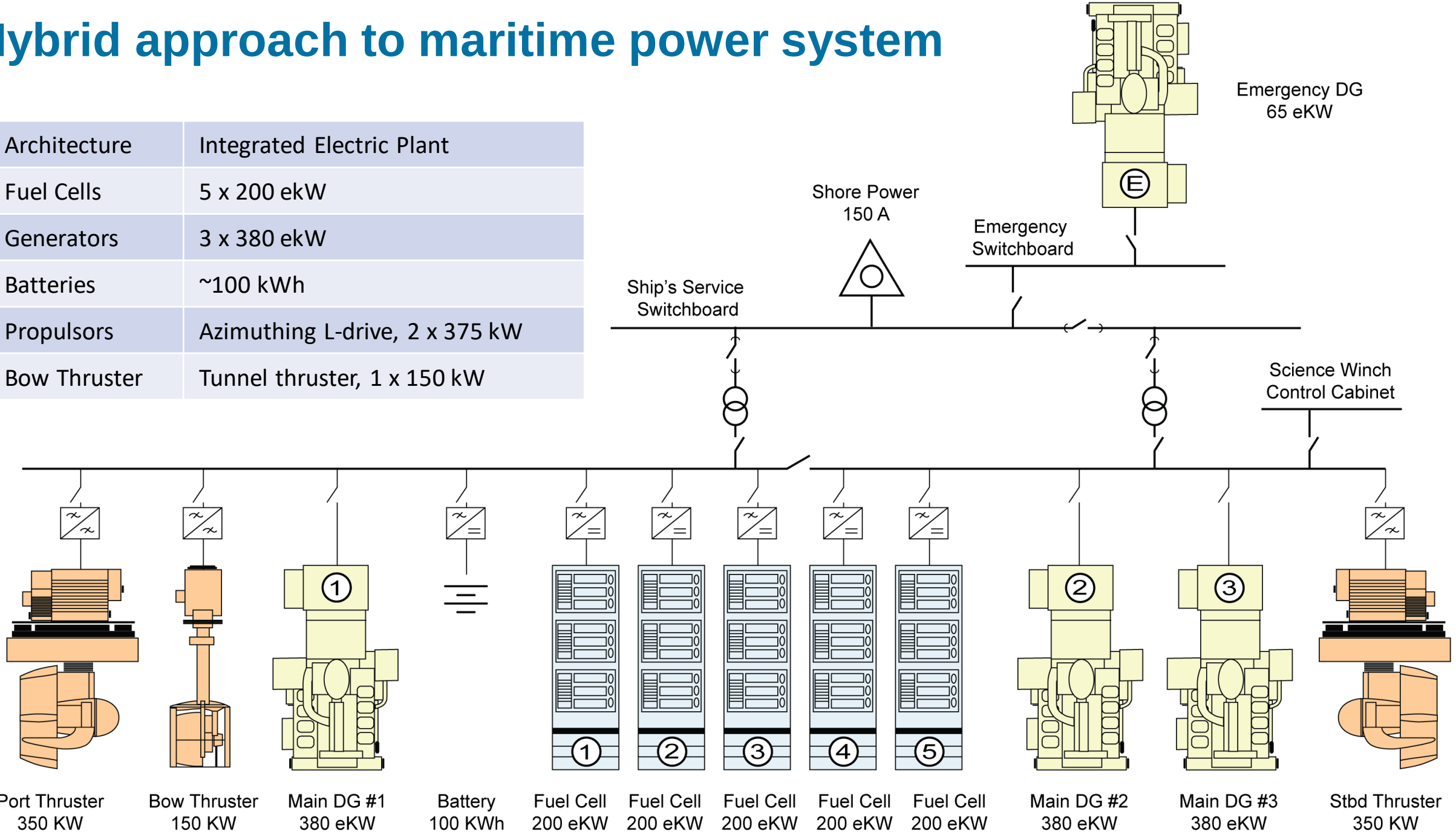
Compared to batteries, the Hydrogen Hybrid offers:

- ✓ 9x better zero-emission range & endurance
- ✓ Commensurate reductions in NOx, HC, PM and GHGs
- ✓ Better suited for ocean-going ships with long missions

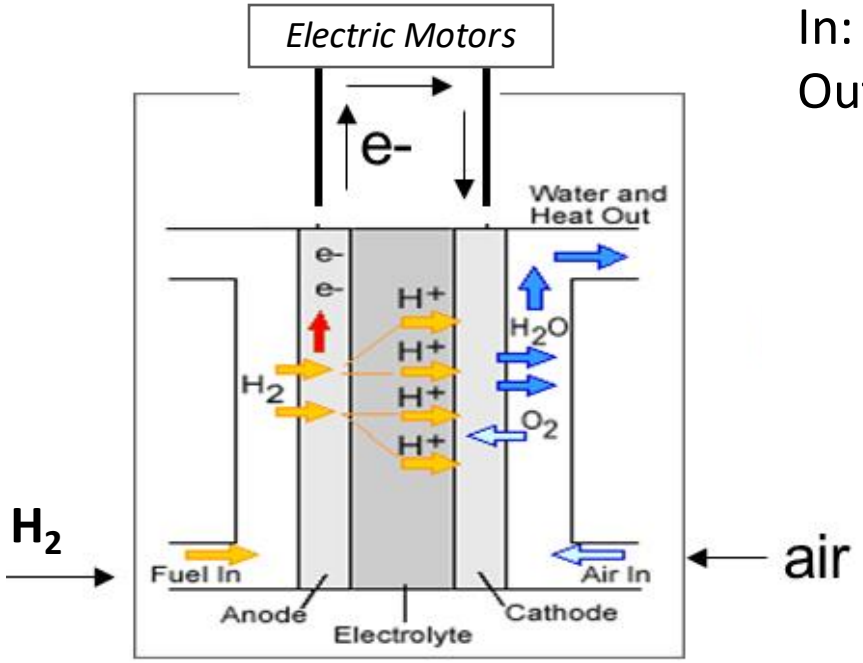
75% of missions can be zero-emissions using hydrogen --- **fossil free**

Hybrid approach to maritime power system

Architecture	Integrated Electric Plant
Fuel Cells	5 x 200 ekW
Generators	3 x 380 ekW
Batteries	~100 kWh
Propulsors	Azimuthing L-drive, 2 x 375 kW
Bow Thruster	Tunnel thruster, 1 x 150 kW



Hydrogen fuel cells produce ZERO GHG or criteria emissions

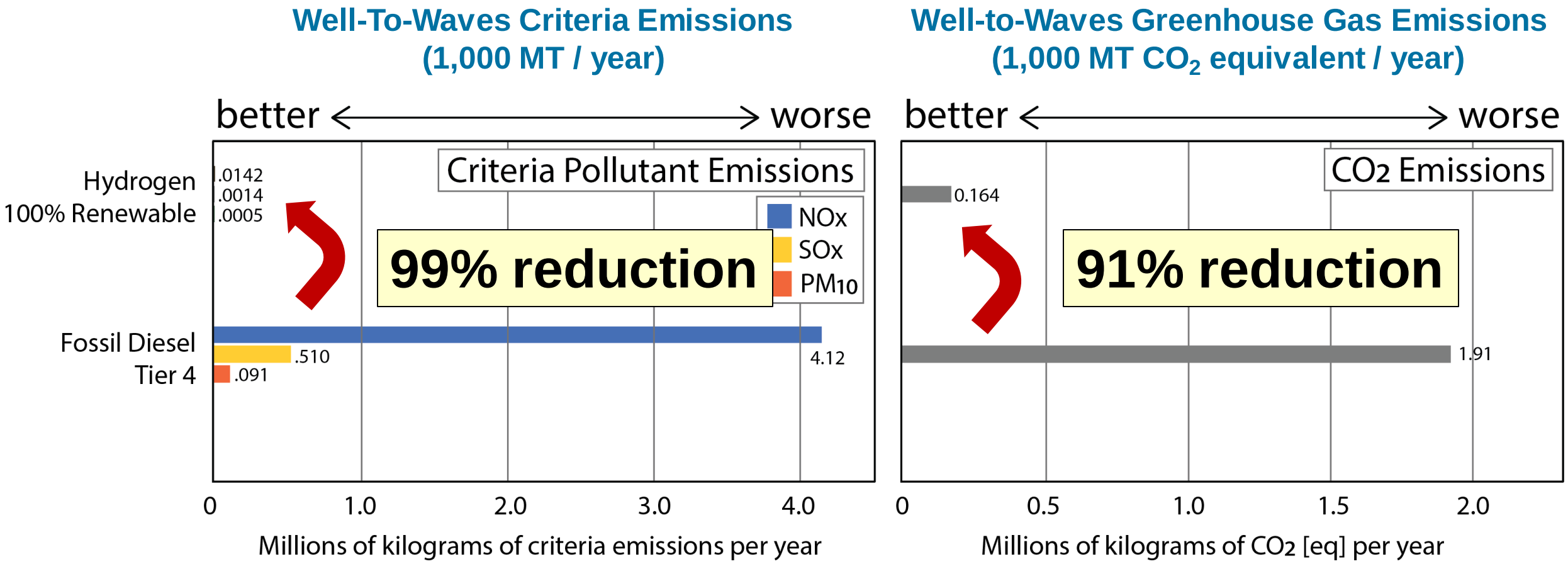


In: H_2 and air
Out: Electricity
Waste Heat
Warm humidified air

$2\ H_2 + O_2 \rightarrow 2\ H_2O$

- Commercially available
- More energy efficient than diesel generators
- No emissions at the point of use
- Eliminates fuel spills, greatly reduces noise
- Emissions only arise from H_2 production/delivery

Emissions: Total impact from H_2 production and delivery



Criteria pollutant emissions can be reduced using LH_2. Dramatic reductions in GHG can be achieved with ***renewable*** LH_2. Renewable LH_2 is available now from commercial gas suppliers.

Fuel and bunkering: Safe and available at scale

Existing methods of LH_2 delivery

- Safe, proven practices
- Applicable to ship bunkering
- No major new shore infrastructure needed

Liquid hydrogen delivery at Emeryville, CA H_2 Station

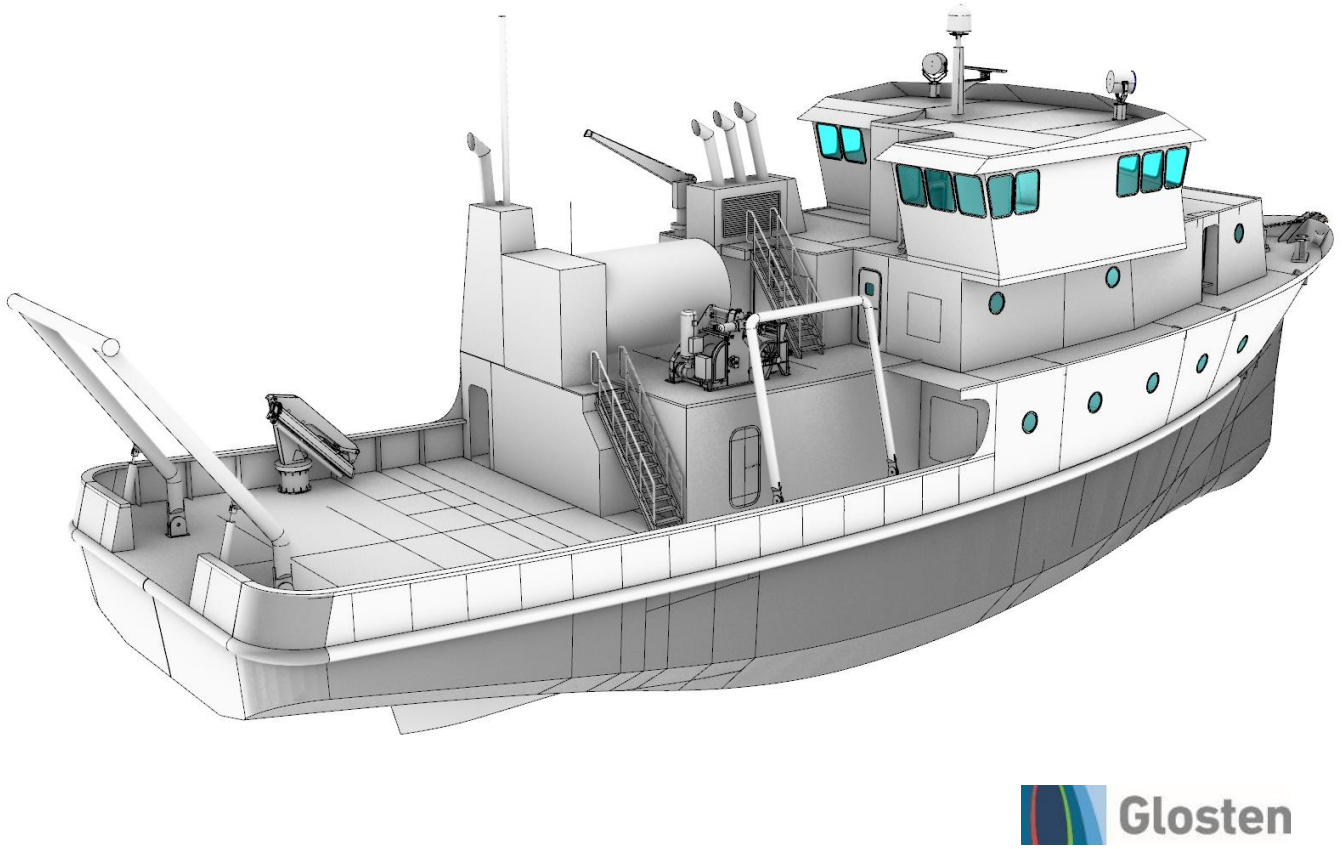
Hydrogen is readily available at scale

- Mature supply chain
- LH2 bunkering will require one trailer
- Full fuel transfer in < 4 hours

Decarbonizing requires clean hydrogen

- New green hydrogen production facility near San Diego coming on line 2023
- Electrolysis from solar, wind and nuclear electricity – no fossil fuels involved

The San Diego Union-Tribune



Glosten

Jul 23, 2021

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

On 12 July 2021, Governor Newsom signed SB 129, which contained one-time appropriations to Scripps, for a hydrogen hybrid research vessel

Design & Construction Timeline

Phase I: Detailed engineering, design, review, and prep

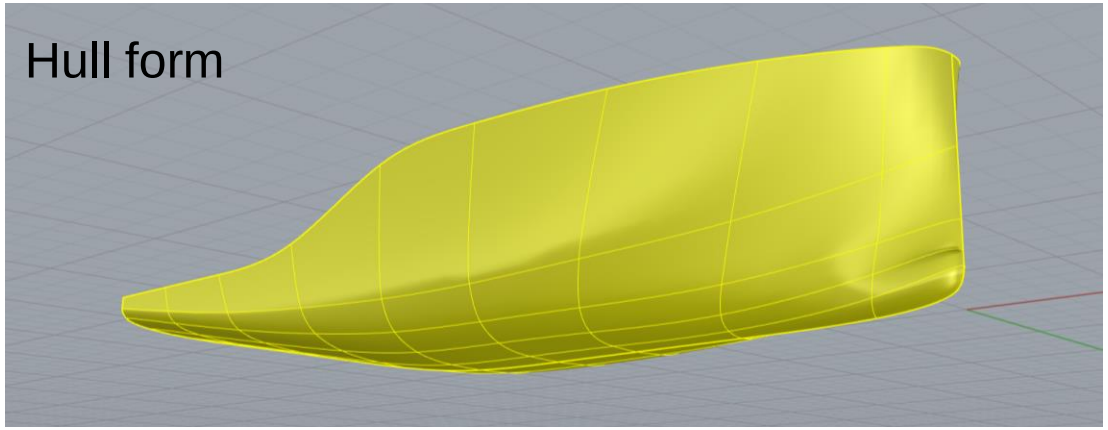
- 2021: Establish project office at Scripps, issue RFI and RFP for design (complete)
- 2022: Development of detailed vessel engineering and design (underway)
- 2023: Final engineering review and construction prep

Phase II: Construction

- 2024: Keel laying and construction

Phase III: Commission for service

- 2026: Christening, sea trials, delivery, verification
- 2027: Begin regular operations in Q1



UC San Diego