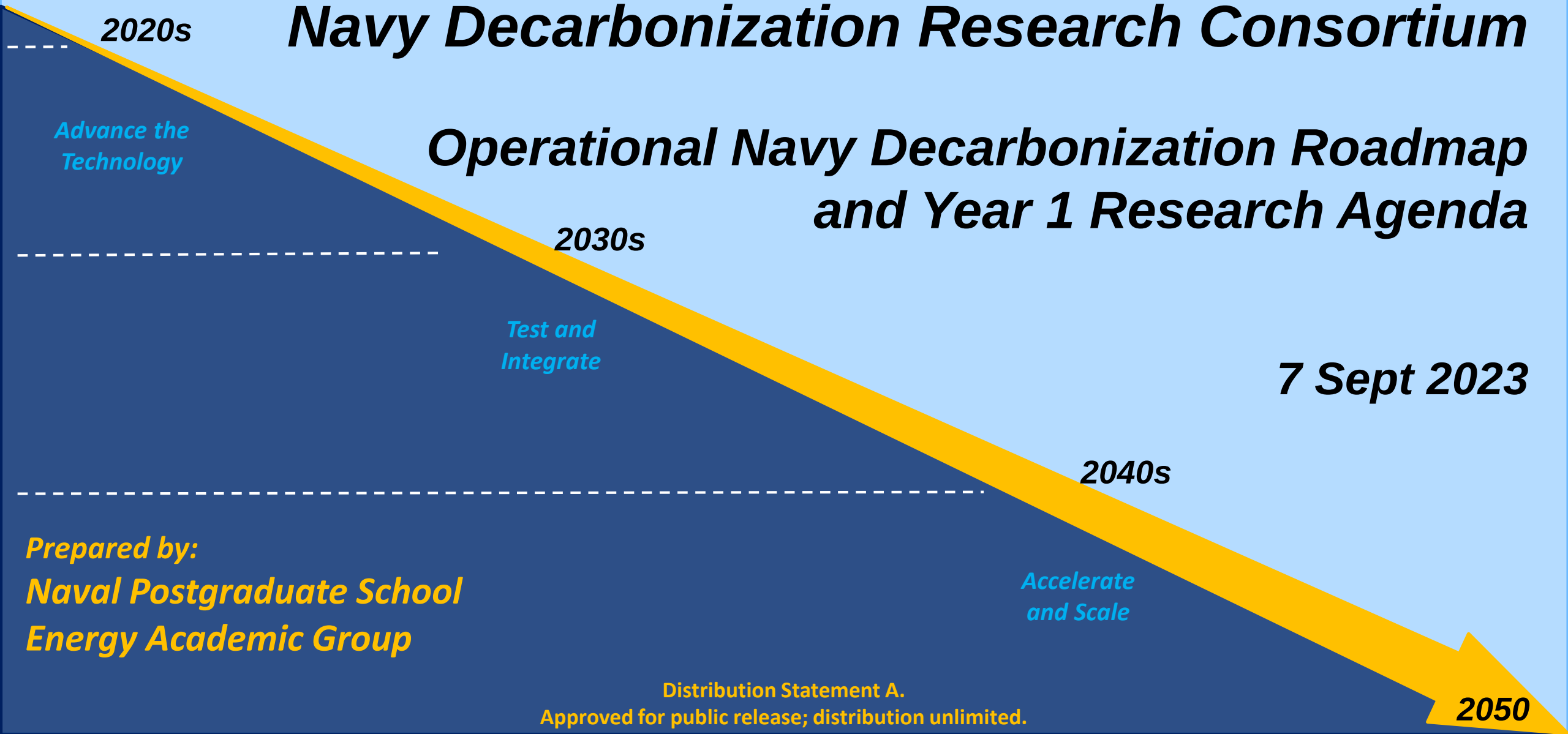
Navy Decarbonization Research Consortium

Operational Navy Decarbonization Roadmap and Year 1 Research Agenda

7 Sept 2023



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Executive Summary

- ***Navy will only pursue decarbonization measures that maintain or enhance warfighting capability and mission effectiveness***
- Decarbonizing Navy ships requires R&D to enable integration of: 1) lower carbon fuels, 2) alternative propulsion systems, 3) efficiency enhancing technologies, and 4) carbon capture and storage processes
- Continued emphasis on demand reduction and efficiency technologies are crucial to early emission reduction efforts
- ***Increased and ongoing collaboration with DOE, DOT and across the Navy is critical to meeting the decarbonization challenge***

- Key objectives of this initial effort:
  - Assessed and identified research focus areas for highest potential to enable *Navy ship* decarbonization
  - Solicited and accepted proposals for Year 1 Research Agenda
  - Developed decarbonization roadmap structure and initial roadmap to guide research and lay the foundation for future efforts
  - Identified key next steps required to advance the research agenda and develop potential technology transition

- Other key points:
  - Majority of current Navy investment supporting decarbonization objectives has been with the goal of increasing combat capability and addressing contested logistics challenges
  - Integrating new technologies on naval platforms is a challenge; ***decarbonization is a unique challenge***

Decarbonization Roadmap

Background

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Mission Statement & Objective

- Mission Statement
  - The Navy Decarbonization Research Consortium is a public-private collaboration with the goal to advance interdisciplinary research to help the Navy meet the ***complex challenges of platform decarbonization***, with a focus on ***ships and aircraft***
  - The Consortium will evaluate and identify technologies that show ***promise for adaptation*** on naval platforms and ***accelerate adoption*** as appropriate

- Objective
  - Establish a consortium of individuals, institutions and companies to address the Navy platform decarbonization challenge, whose membership and structure is adaptable over time
  - Develop a Decarbonization Research Agenda for ONR that includes interdisciplinary research and analysis, and identify areas for potential research opportunity
  - Continue the Consortium collaboration addressing the complex problems of platform decarbonization, evolve the Roadmap as technologies and new research avenues are identified, and identify technology transition opportunities

Why Decarbonize?

IPCC Reporting

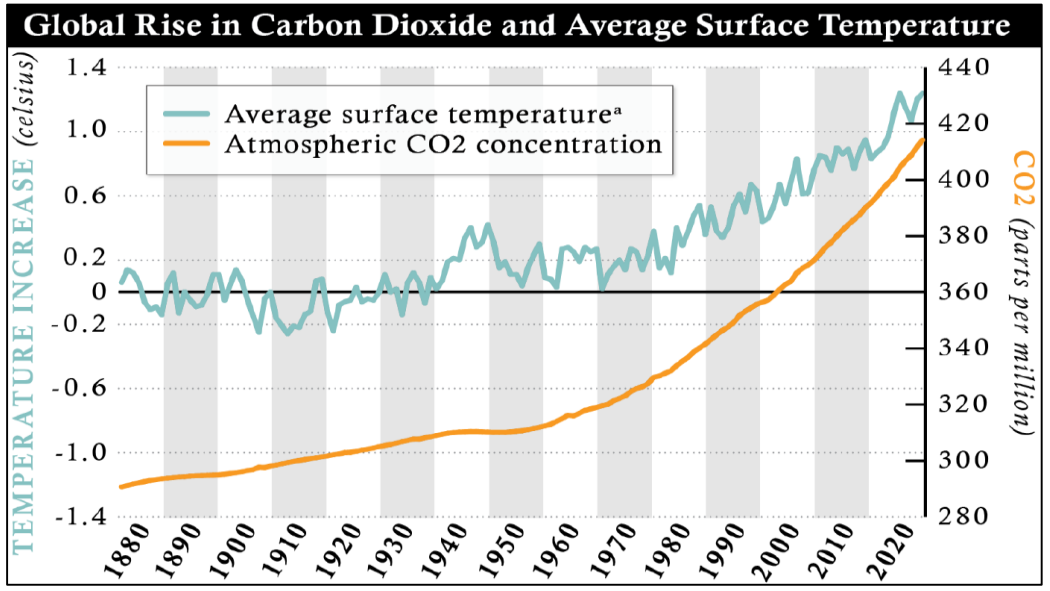
- Human activities, principally through emissions of greenhouse gases, have unequivocally caused global warming, with global surface temperature reaching 1.1°C above 1850-1900 in 2011-2020
- The likelihood of abrupt and irreversible changes and the severity of their impacts increases with higher global warming levels
- Limiting human-caused global warming requires net zero CO_2 emissions

US Intelligence Reporting (US Annual Threat Assessment)

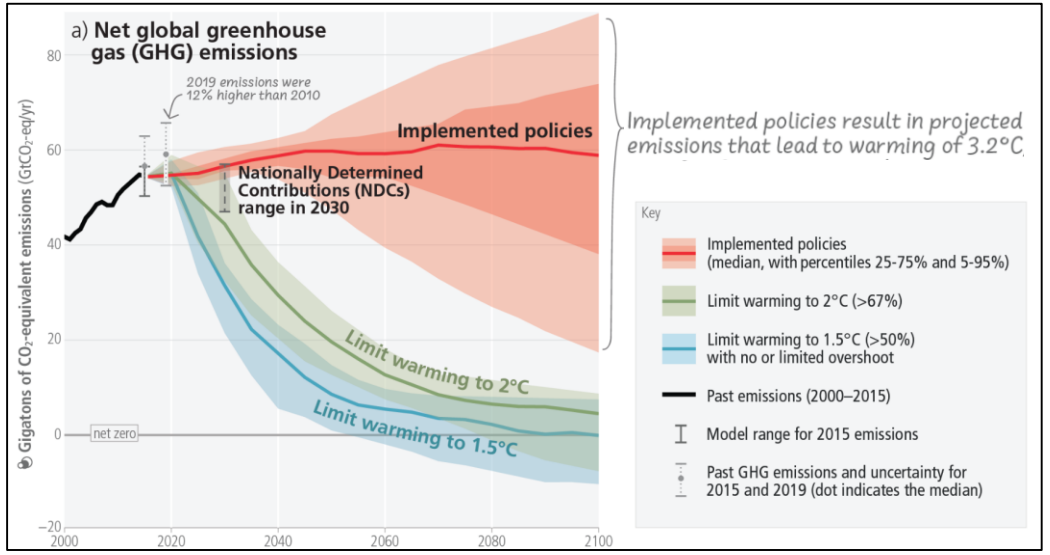
- Climate change will increasingly ***exacerbate risks to U.S. national security*** interests as the physical impacts increase and geopolitical tensions mount regarding the global response

DoD Climate Risk Analysis

- ***Climate change presents serious risks***, but DoD, along with the entire U.S. government, as well as our allies and partners, is determined to address this common threat
- DoD will work to prevent, mitigate, and respond to the defense and security risks associated with climate change

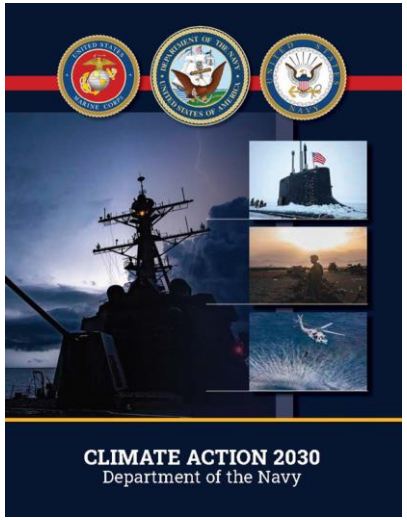


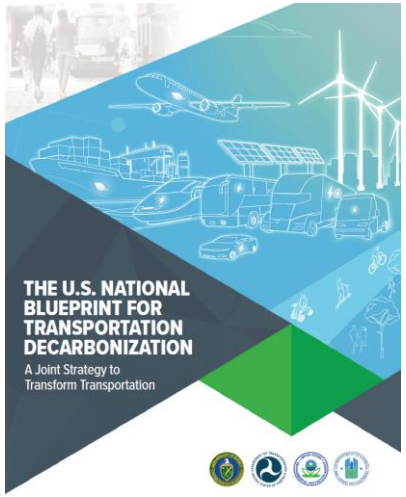
National Intelligence Council report, *Climate Change and International Responses Increasing Challenges to US National Security Through 2040*, 2021



IPCC AR6 Synthesis Report (SYR), 2023

Directives & Key Guidance Documents





Primary References

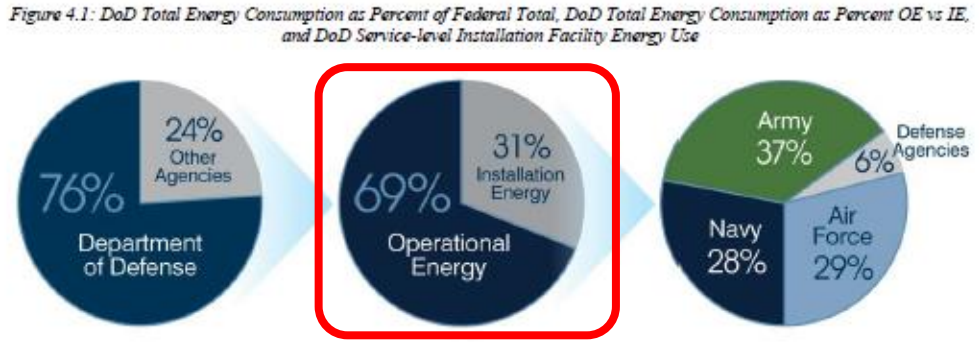
- EO 14008 – Tackling the Climate Crisis at Home and Abroad (*Jan 2021*)
- DoD Climate Adaptation Plan (*Sept 2021*)
- DoD Climate Risk Analysis (*Oct 2021*)
- EO 14057 – Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability (*Dec 2021*)
- Federal Sustainability Plan (*Dec 2021*)
- **DoN Climate Action 2030 (*May 2022*)**

Secondary References

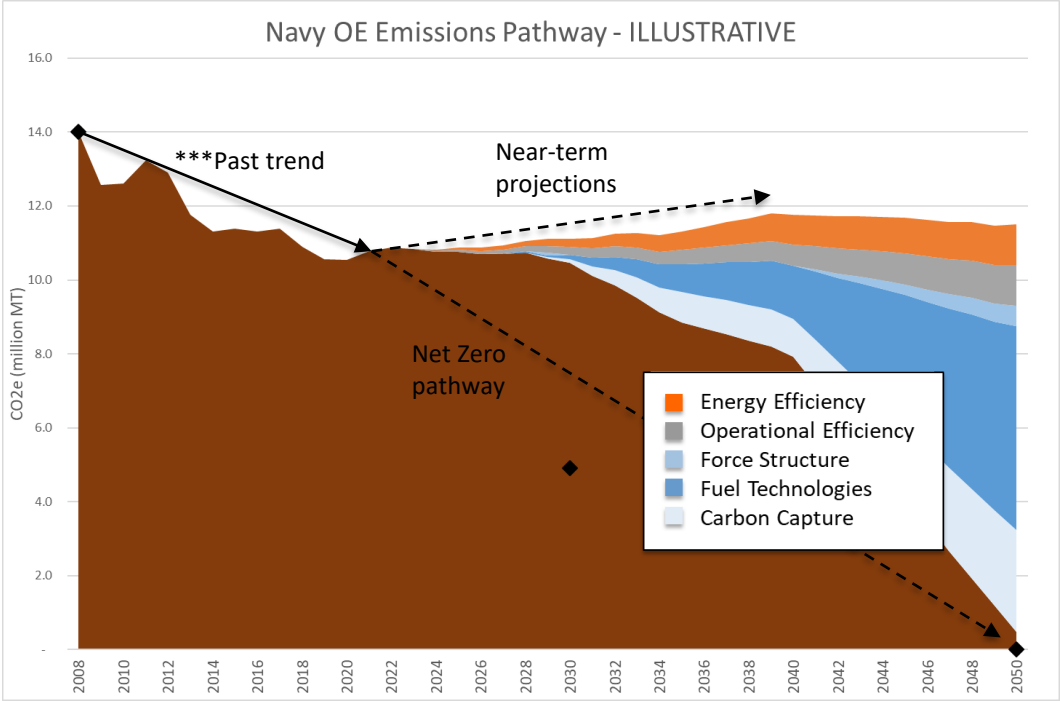
- **US National Blueprint for Transportation Decarbonization (*Jan 2023*)**
- FAA Aviation Climate Action Plan (*2021*)
- IMO GHG Strategy (*2023*)
- DOE Hydrogen Shot (*June 2021*)
- U.S. National Clean Hydrogen Strategy & Roadmap (*June 2023*)
- Clean Fuels & Products Earthshot (*June 2023*)
- DOE SAF Grand Challenge (*Sept 2022*)
- USAF Climate Action Plan (*Oct 2022*)
- US Army Climate Strategy (*Feb 2022*)
- USCG Climate Framework (*Jan 2023*)
- Net Zero Efforts Across World Militaries (*NPS – 2023*)

Navy Emissions

- FY21 DON emissions were ~16.7M metric tons CO2e
  - ~70% operational, ~30% installations
  - Operational emissions ~50/50 split between jet fuel (JP-5) & ship fuel (F-76)



- ***Significant reductions in energy use have been realized since FY08
  - Majority of reduction is attributable to reduced operating hours & lower speed
  - Energy demand is expected to increase going forward
  - ***Past trendline is not indicative of future trajectory***

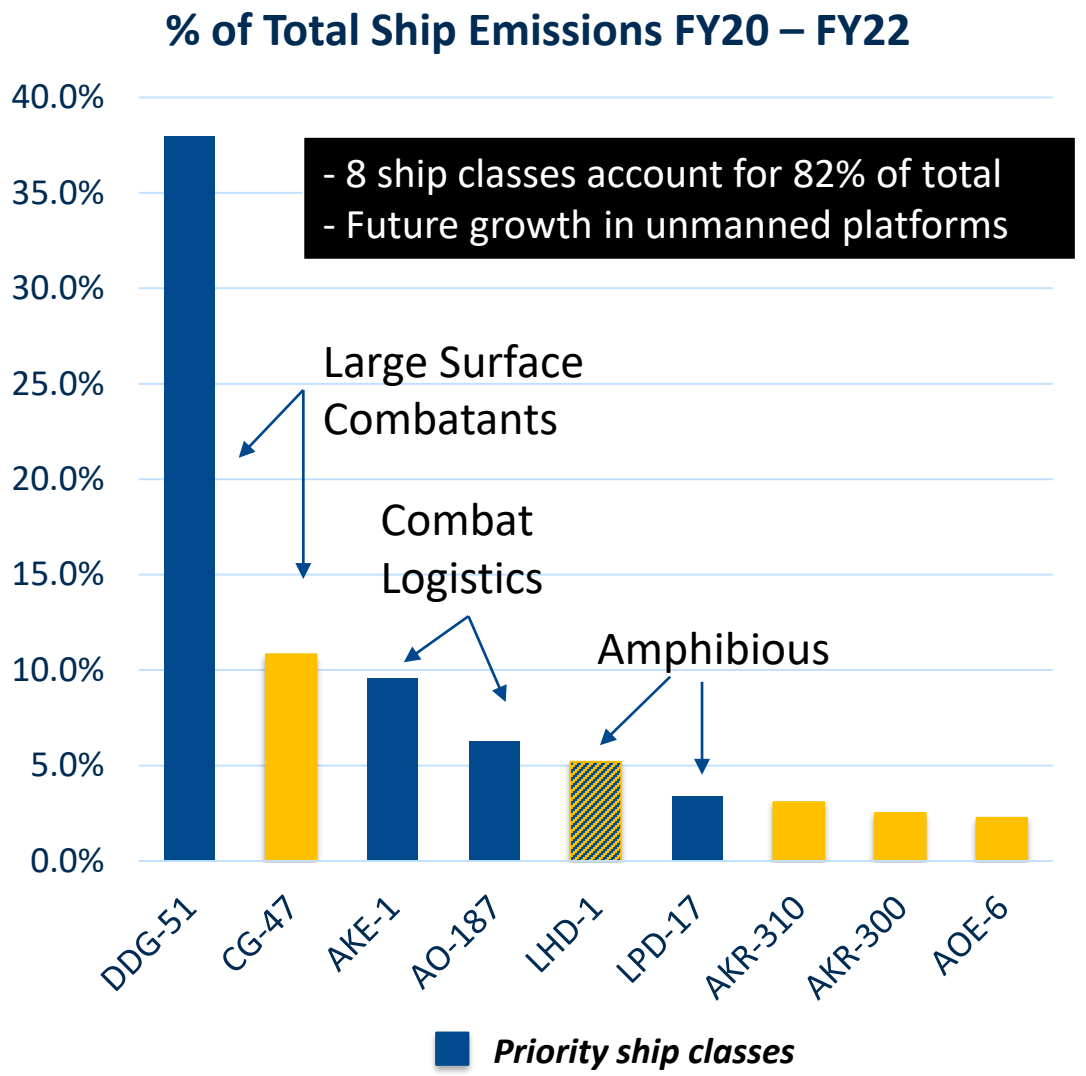


- ***A portfolio of technologies and solutions will be required to address this problem – no single approach will do***

Navy Unique Challenge

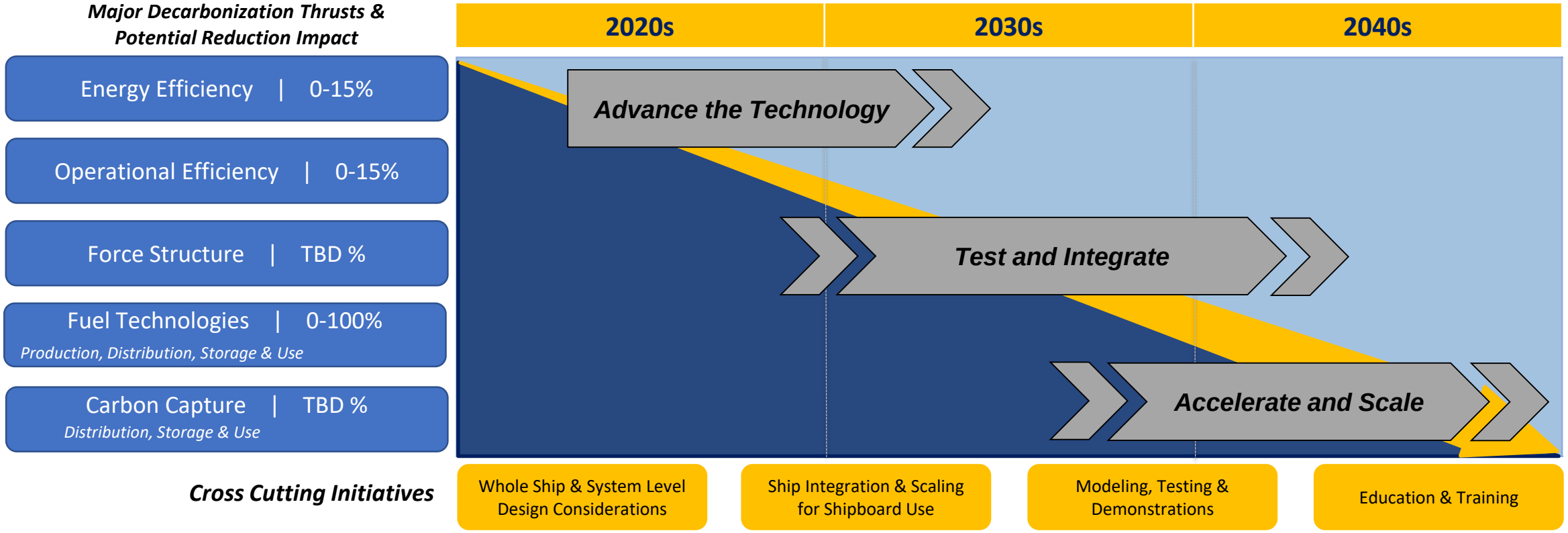
- Platforms in-service/in-design today will be in the fleet ***past 2050***, with conventional diesel and gas turbine engines
- ***Energy demand is increasing***, due to growth in new platforms (including ***unmanned*** vessels) and increased onboard energy demand
- Navy ships must maintain ability to ***refuel underway*** and at ***remote*** locations – we operate ***forward***, ***distributed***, and in ***contested*** environments
- Must maintain ***interoperability*** with partners and allies
- Space, weight, power, and cooling ***margins are limited***
- Integration of technologies on new and existing ships must meet ***strict standards*** (MIL-STD and Technical Warrant Reviews)

- ***Must focus on retrofitting the current fleet and informing future platform design and construction***



Decarbonization Thrusts for Navy Operations

- Roadmap structure developed to potentially serve as a ***framework*** for broader Navy decarbonization efforts
  - Informed by numerous decarbonization and Net Zero products, to ensure alignment with Navy, other government and commercial strategies
  - Current efforts focused on ***maritime platform decarbonization***
- Consortium identified ***five (5) major decarbonization thrust areas***, supported by four (4) cross-cutting initiatives
  - Also developed Rough Order of Magnitude (ROM) levels of potential emissions reduction impact for Navy platforms



Decarbonization Thrusts – Detail

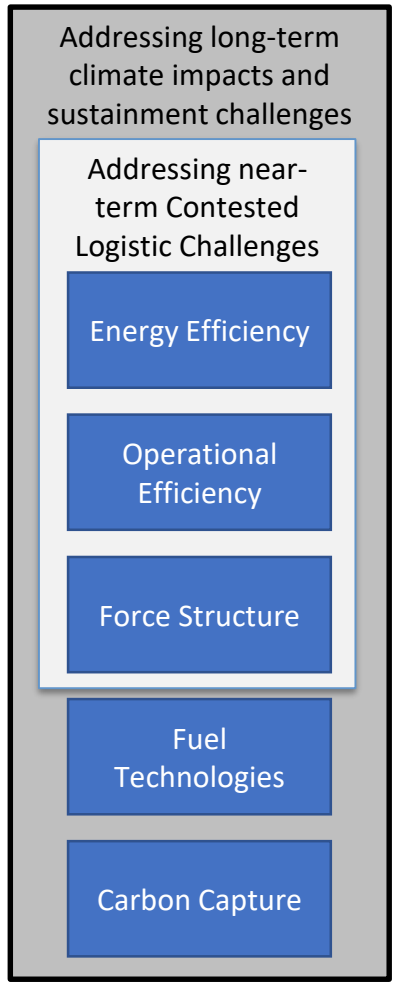
	Approx Impact to Operational Navy Decarbonization (%)	Category	Sub-Category
Major Thrust Areas	0% - 15%	Energy Efficiency	Propulsive efficiency improvements & direct drag reduction
			Propulsion & power generation improvements
			Electrification, hybridization & energy storage
			Waste Heat Recovery (WHR)
			Electric load reduction
			Lightweight materials
	0% - 15%	Operational Efficiency Improvements	Route optimization
			Plant line-up & speed optimization (single generator ops, etc.)
			Trim optimization
	TBD	Force Structure	New/emerging CONOPS (to include manned/unmanned teaming)
			Mission optimized future platforms (including unmanned, attritable, single-use assets, etc.)
	0% - 100%	Fuel Technologies: Production, Distribution, Storage and/or Use	Blended or drop-in fuels (bio-, renewable-)
			Non drop-in liquid fuels (ammonia, methanol, etc.)
			Hydrogen
			Nuclear
			Renewable energy
	TBD	Carbon Capture: Distribution, Use and Storage	Shipboard
			Terrestrial
			Other emissions capture/reduction (high GWP refrigerants, etc.)

Assessment of Current Activities & Research Focus Areas

- Assessment of Current Activities
  - Navy prioritizes investment in efficiency, electrification, and force structure enabling employment and sustainment of combat capabilities
    - Navy investment in lower carbon fuels and carbon capture technologies are primarily focused on 1) fuel generation in theater and 2) qualification of new alternative fuel pathways
  - DOE active across all relevant sectors, funding fuels R&D under several focused projects:
    - SAF Grand Challenge
    - Energy Earthshot – Clean Fuels and Production
    - Zero-Emissions Shipping Mission (ZESM)
  - DOT partnered with DOE on ZESM and is active in maritime decarbonization with a focus on Low Carbon Fuels, Electrification, Energy Efficiency, Carbon Capture, and Green Shipping Corridors

- Year 1 Research Agenda Focus Areas
  - ***Use*** of lower carbon fuels in Navy relevant prime movers
  - Shipboard carbon capture technologies
  - Energy efficiency technologies
  - Modelling and analysis of energy systems, ship design process and systems architecture
  - *Operational Efficiency and Force Structure were not prioritized for Year 1 efforts*

Major Decarbonization Thrusts



Year 1 Research Agenda

Fuel Technologies & Carbon Capture

- Collaboration of USC, CSU, PSU, USNA
  - University of South Carolina: Fuel Flexible Gas Turbine Technology Integrated with Exhaust Gas Recirculation and Hydrogen Carrier Fuels
  - Colorado State University: Liquid-Fueled Solar Centaur 40 Gas Turbine Testing with High EGR Fraction to Support Carbon Capture System Integration
  - Penn State University: Fuel Flexible Gas Turbine Technology Integrated with Carbon Capture and Utilization
  - USNA: Working Towards Zero-Carbon Naval Energy Technologies with Midshipmen at the USNA
- University of Wisconsin: Enabling mixing-controlled combustion of low carbon fuels in naval reciprocating engines
- University of Illinois: Sustainable Power for Decarbonization of Naval Vessels

Energy Efficiency: Electrification & Hybridization

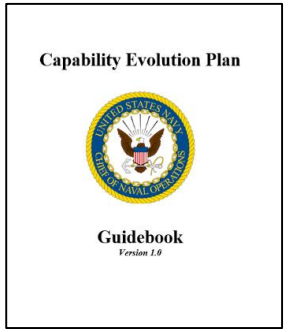
- NSWC Philadelphia: Evaluation of Propulsion Derived Ship Service and Weapons Power to Support Decarbonization

Cross-Cutting: Modeling - Energy Systems, Ship Design, System Architecture

- Collaboration of GWU, NPS, ABS, USNA
  - George Washington University: Energy Systems Modeling, Prediction, and Planning Tool for Navy Decarbonization Technologies
- NPS: Trade space exploration for climate impact and quality attributes for Navy ships
- NPS: High-level system architecture, modeling and performance evaluation of a fleet of green-energy ships producing hydroelectric energy and hydrogen at sea

Advance the Technology – S&T Evolution

- Take initial steps towards transitioning solutions onto Navy platforms
  - Identify transition/integration pathway(s) and begin to document as evolution plan
  - Assess and elevate technology readiness level (TRL)
  - Continually assess impacts to decarbonization objectives



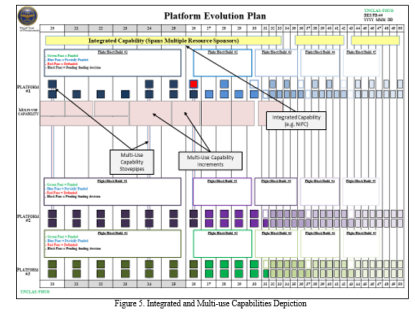


Figure 5: Integrated and Multi-use Capabilities Depiction

Major Decarbonization Thrusts & Potential Reduction Impact

- Energy Efficiency | 0-15%
- Operational Efficiency | 0-15%
- Force Structure | TBD %
- Fuel Technologies | 0-100%
  Production, Distribution, Storage & Use
- Carbon Capture | TBD %
  Distribution, Storage & Use

2020s	2030s	2040s

Advance the Technology

Applied Research in maritime decarbonization
- ❑ Feasibility assessments
- ❑ Concept Development
- ❑ Technology Development
- ❑ Component Testing

Prioritizing:
- **Large Surface Combatants**
- **Large Combat Logistics**
- **Large Amphibious Ships**
- **Future propulsion systems**

Test and Integrate

Integration and demonstrate in operational environment
- ❑ Navy and MIL-STD Testing
- ❑ Ship Integration
- ❑ Measurement & Validation (M&V)
- ❑ Tech Warrant Approval
- ❑ Engage industry reps

Accelerate and Scale

Integrate across all intended applications
- ❑ Increase production
- ❑ Accelerate integration
- ❑ Measure performance

Cross Cutting Initiatives

- Whole Ship & System Level Design Considerations
- Ship Integration & Scaling for Shipboard Use
- Modeling, Testing & Demonstrations
- Education & Training

Collaboration Strategy

- Develop and mature a robust collaboration strategy, with ***six*** core communities
  - Current Consortium group – foster increased collaboration amongst Consortium members
  - Internal Navy and other DoD – operational energy, climate and resilience constituencies
  - Other USG Agencies – DOE/ARPA-E, DOT, and others (e.g. NASA, EPA, NOAA, etc.)
  - International partners – NATO, TTCP*, Pacific Islands Partnership, etc.
  - Industry – potentially via the DOT/MARAD U.S. Center for Maritime Innovation (*in work*)
  - Academia – identify leading researchers in other technology areas

- Two major goals for collaboration activities are:
  - Better understand ongoing efforts and identify most impactful areas of research to guide and prioritize future years' research agenda
  - Identify appropriate Navy "role" in various thrust areas, considering:
    - Leverage government-wide approach and R&D portfolios of other partner entities
    - Navy unique requirements that may not otherwise be addressed

* TTCP – The Technical Cooperation Program (US, UK, Canada, Australia, New Zealand)

Roadmap – Key Actions

Major Decarbonization Thrusts

- Energy Efficiency
- Operational Efficiency
- Force Structure
- Fuel Technologies
- Carbon Capture

Cross Cutting Initiatives

2020s | **2030s** | **2040s**

Advance the Technology

Test and Integrate

Accelerate and Scale

Key Actions

1) ***Increase collaboration between Navy, DOE and DOT with specific focus on Navy decarbonization challenges (Whole of Government Approach)***
2) Expand collaboration to more fully include rest of DoD, private sector and international partners
3) Mature Year 1 Research Agenda into longer term roadmap through ongoing collaboration activities
4) Set realistic decarbonization targets for each major thrust area
5) Further develop S&T evolution pathways for each funded project and major thrust area
6) Start to assess potential transition timelines based upon future shipbuilding plan and development paths
7) Identify policies that constrain adoption of promising technologies and offer appropriate policy changes
8) Analyze and assess any safety-related issues that may hinder adoption
9) ***Execute Year 1 Research Agenda***

Key Actions

1) Identify specific target platforms for technology transition
2) Work directly with relevant Navy labs and/or Program Offices to transition technology onto platforms
3) Continue collaboration across government, industry and academia
4) Continue to assess new emerging technology with potential relevance to Navy platform decarbonization
5) ***Meet 2050 decarbonization goals***

Next Steps

- Develop and implement Collaboration Strategy with core partners
  - Continue potential research opportunity identification process
- Execute Year 1 Research Agenda
  - Support required Navy-project team collaboration and data collection
  - Develop project specific S&T evolution pathways with each funded research team
- Assess impact of Year 1 research concepts and technologies to overall Navy decarbonization objectives
  - Further develop Roadmap to include more specific targets, as needed
- Align with other roadmap and data collection efforts
  - Work with other efforts to develop methodology to synthesize R&D and project information across technical areas for efficiency, leverage and gap identification purposes
- Explore applying Consortium model and findings to Aircraft
  - Potentially extend to installations at a later date?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