Decarbonization Research Consortium

WELCOME

13 April 2023

nps.edu/decarb

Decarbonization Research Consortium Meeting
13 April 2023 / 12 – 2 ET / 9 – 11 PT
Agenda

12:00 – 12:15	Welcome/Introductions Welcome from Stanford University: Chuck Litchfield, Doerr School of Sustainability Follow-up from 24 March Meeting
12:15 – 12:45	Presentation: ONR Carbon Capture Program, Dr. Heather Willauer
12:45 – 1:15	Context: Net Zero Pathway Options Roadmap Discussion
1:15 – 1:45	Collaborative Research / White Paper Updates
1:45 – 2:00	Admin/Homework/Conclusion

Study:
Pathways to Net Zero for the Operational Navy

April 2023

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NAVAL POSTGRADUATE SCHOOL

Funded by the NPS Naval Research Program

Analyzing Pathways to Net Zero Emissions by 2050

Table 1. DoD Operational Energy Demand by Service

		FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21e	FY22e
Operational Energy Demand, Million Barrels	Army	10.1	7.3	7.1	7.6	9.2	9.0	8.1	9.3	9.3
	Navy	28.2	28.5	28.5	28.4	26.0	28.1	27.9	25.3	25.3
	Air Force	48.6	52.0	49.6	49	51.9	45.3	41.2	46.7	46.2
	Marines	0.2	0.2	0.2	0.2	0.5	.38	0.4	0.5	0.5
	Other DoD	0.3	0.5	0.4	0.3	0.9	.77	0.3	1.0	1.0
	Total Demand	**87.4**	**88.6**	**85.7**	**85.5**	**88.5**	**83.6**	**77.6**	**82.8**	**82.3**
	Expenditures (Billions)	**$14.0**	**$14.1**	**$8.7**	**$8.2**	**$9.1**	**$11.0**	**$9.20**	**$8.24**	**$8.40**

DRIVERS:
Naval Mission Readiness
Strategic Competitiveness / Contested Logistics
Emission Reduction to Reduce Conflict Exacerbation

APPROACH:

- **Understand Dept of Navy fuel/energy consumption**
- **Focus on Ships & Aircraft**
- **Study options for shifting to reduced emission energy sources**
- **Identify Multiple Pathways for Net Zero by 2050**

CLIMATE ACTION 2030

Department of the Navy

Climate-Ready Force

To remain the world's dominant maritime force, the Department of the Navy must adapt to climate change. ***A force that is resilient to climate impacts is more capable, agile and lethal***. We will enhance our operatio l capability, resilience, and reduce our climate impacts by aligning our climate actions to ***strengthen maritime dominance, empowe people, and strengthen strategic partnerships.***

Performance Goals

Build Climate Resilience

Ensure that our forces, systems, and facilities can continue to operate effectively and achieve the mission in the face of changing climate conditions, and worsening climate impacts.

Reduce Climate Threat

We must reduce our greenhouse gas emissions and draw greenhouse gases out of the atmosphere, stabilize ecosystems, and achieve, as an enterprise, the nation's commitment to net-zero emissions by 2050.

Ambitious Targets

To achieve net-zero emissions economy-wide by 2050, the Navy and Marine Corps commit to:

Reliance on Fossil Fuels:

- Vulnerable Supply Lines
- Contested Logistics
- Danger of Fuel Transport

- 1 million cars' worth of CO_2e drawn down by 2027 through nature-based solutions

Lines of Effort

Our ... are cons ... ase's (DoD)

1.
2.
3.
4.
5.

LOEs adapted to FORCE:

Facilities and Lands

Operations and Platforms

Resupply

Community

Energy Ashore

Focus on Resilience

Nature-Based Resilience: Mitigate shoreline erosion, protect mission-critical assets, and improve natural assets that are key to achieving resilient infrastructure and operations.

Energy Resilience: Install cyber-secure microgrids or comparable resilience technology that leverage carbon free power generation and long-duration battery storage.

Defining Net Zero Emissions

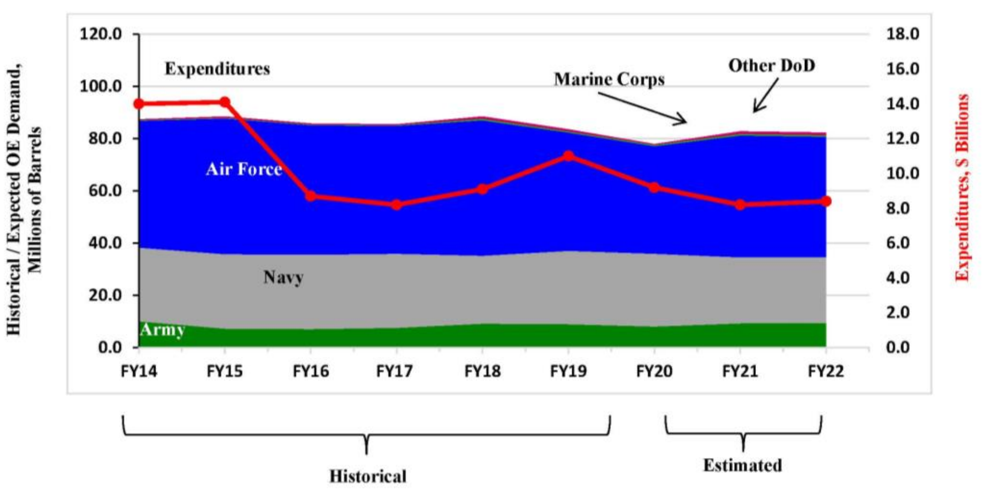
***Climate Action 2030* (Navy Climate Strategy): Net-Zero Emissions: negating the amount of greenhouse gases produced by human activity by reducing emissions and implementing methods of absorbing carbon dioxide from the atmosphere.** This removal of greenhouse gases could be done through land or natural resource management, and human pollution intervention (DON Climate, 2022).

***Army Climate Strategy*: Net-zero emissions. A condition achieved when anthropogenic emissions of greenhouse gases to the atmosphere are balanced by anthropogenic removals of those same gases over a specified period.** In this strategy, the “specified period” is a rolling 12 months generalized as, but not necessarily synchronized with, a given calendar year (Department of the Army, 2022).

Data Sources: Emissions and Assets

- **Dept of Navy/DOD Data**
- **Decarbonization Driver Tree / Advana Dashboard**
- **Private Sector Data**
- **Key Metrics:**
    - **DOD GHG Emissions: ~ 70% from operations**
    - **Energy Use By Domain: 71% Air; 14% sea**

Figure 1. DoD Operational Energy Demand, FY 2014 – FY 2022e[5]



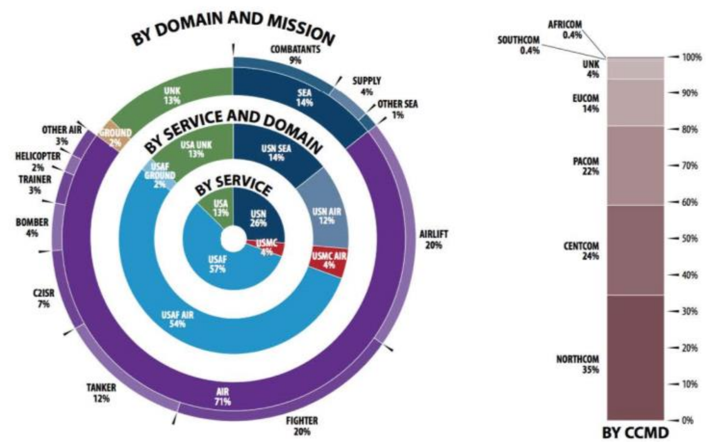


Figure 1: Operational Energy Use, FY 2014

Reduction Strategies

RMI
Regulatory Solutions for Building Decarbonization

- Alternative Fuels
- New Technologies
  - Hydrogen-based energy
  - Unmanned Systems
- Nuclear
- Batteries/Electrification
- Increased Efficiencies
- Renewable Energy Sources
- Carbon Offsets/Carbon Sequestration

Reduction Strategies: Alternative Fuels

CONTEXT	CHALLENGES	EMISSIONS REDUCTIONS
- Ships & Aircraft reliant on fossil fuels - Some "drop-ins" - A MUST for future decarbonization	- Single Fuel Concept - Specific needs of fuel type - Logistics/supply - Private Sector advancements applicable to military use	- Heavily reliant on changes within this strategy - Make up 20-25% of reductions

Reduction Strategies: New Technologies
Hydrogen-based energy

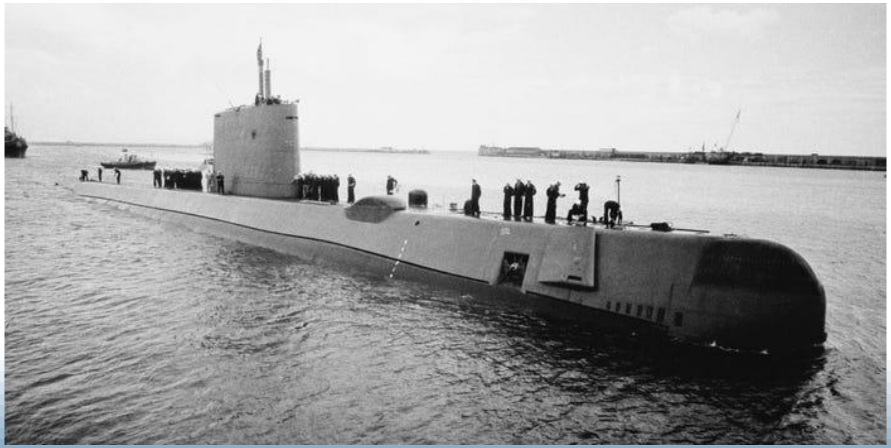
CONTEXT	CHALLENGES	EMISSIONS REDUCTIONS
- Historically used by military - Cutting edge technology development - Lower acoustic and heat signature - Carbon free emissions	- Emissions rely on how Hydrogen-based energy is created - Safety issues (perceived & real) - Ability to scale-up technology & apply to military context	- Conservative until ~ 2040 – 2045 - Counts for larger amount in Aspirational Pathway

Reduction Strategies: New Technologies
Unmanned Systems (UxS)

CONTEXT	CHALLENGES	EMISSIONS REDUCTIONS
- UxS have rapidly advancing technology that may be able to adapt quickly to new fuel source - Ability to supplement/partner with crewed systems	- Most are still reliant on fossil fuels - Gap in data showing whether UxS save fuel and emissions compared to crewed platforms - Even if electrified, rely on renewable or low-carbon grid to lower emissions	- Conservative approach because need to transition to low or no carbon emissions fuels - Larger part in Aspirational because of potential in alternative/renewable fuel and battery advancements

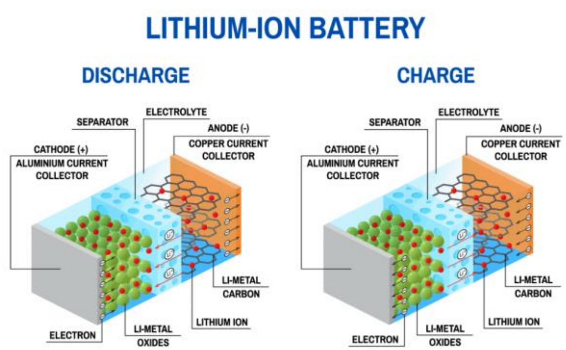
Reduction Strategies: Nuclear

CONTEXT	CHALLENGES	EMISSIONS REDUCTIONS
- Emit zero GHG during operations - Small Modular Reactors advancing & available for use onshore and shipboard - Navy accustomed to nuclear	- Long Acquisition process - Future investment by Navy in question - Costs may outweigh benefits - Nuclear waste + safety concerns - Legal issues	- Given lack of enthusiasm for Navy operational use (beyond current)… - Pathways show modest emissions reductions from Nuclear as investment is likely closer to 2050



Reduction Strategies: Batteries/Electrification

CONTEXT	CHALLENGES	EMISSIONS REDUCTIONS
- Small but quickly growing aspect of Navy energy - Hybridization on ships/aircraft possible - Batteries evolving - Effective for Marine Corps applications	- Less energy dense, range limitations - Safety/fire risks - Need better design and training - Supply chain & market challenges for rare earth minerals	- Anticipate inclusion in pathway but modest contribution - Larger part in aggressive and aspirational pathways because of ongoing advancements



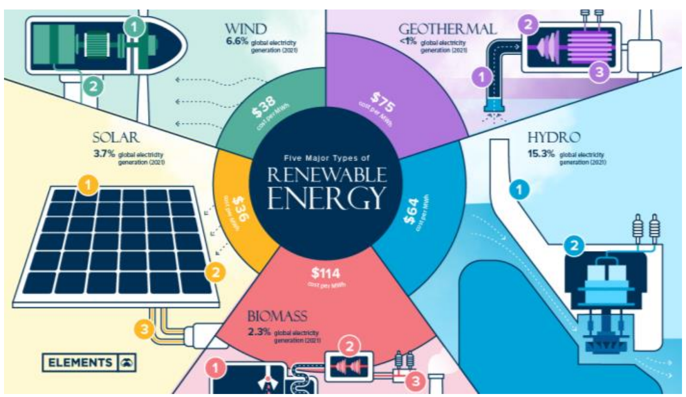
Reduction Strategies: Increased Efficiencies

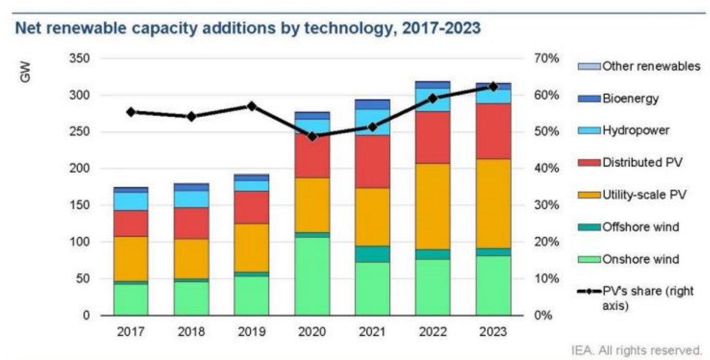
CONTEXT	CHALLENGES	EMISSIONS REDUCTIONS
- Increased efficiencies evolving and many able to incorporate quickly - Can see improvements in behavior, policies, practices & engineering - NPS is developing and refining tools to increase efficiencies	- Increase in operational tempo, new platforms/weapon systems can counteract efficiency savings - Questions regarding international availability of carbon-neutral fuels	- Modest estimates on role of efficiencies in emissions reduction

FUSED Model Results	Fuel Use in Gallons
Navy Ship Fuel Consumption 2022	379,260,924
Navy Ship Fuel Consumption 2030	396,189,852

Reduction Strategies: Renewable Energy Sources

CONTEXT	CHALLENGES	EMISSIONS REDUCTIONS
- Solar, wind and hydropower relevant to Navy operations - New technology - Cost competitive - Likely greater advantage for Marine Corps and installations	- Availability - Need to pair with battery storage - Private sector advances limited utility in military context	- Ability to reduce emissions likely to increase but may be modest - We use renewables in modest approach across 4 pathways





Reduction Strategies:
Carbon Sequestration ✦ Carbon Capture & Storage ✦ Carbon Offset Programs

CONTEXT	CHALLENGES	EMISSIONS REDUCTIONS
- Seen as fallback option when demand reduction/technology fails - Technology advancing - Navy opportunity in coastal wetlands sequestration and seawater carbon capture	- Many vulnerabilities - Relies on both future technology + changing behaviors - Kicks the can down the road (avoids real reductions)	- Part of equation because many pathways reliant - Recommend cautious approach - Less reliance on these strategies in Aspirational pathway

From Pew Report, Coastal "Blue Carbon" (Pew, 2021)	
Salt Marshes	1940 pounds of carbon/acre/year
Seagrasses	1230 pounds of carbon/acre/year
Mangroves	2016 pounds of carbon/acre/year

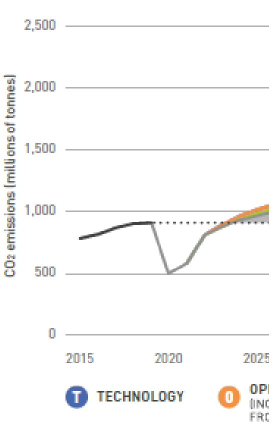
Model Pathways

Scenario 0: baseline / continuation of current trends

Traffic forecasts are in the 'central' range of around 3.1% per annum compound growth. Technology improvements are conservative (i.e., assuming no- shifting to unconventional platforms a continuation of the current rate of i another wave of new aircraft joining the fleet around 2030-2035. Despite

investments in operations and infrastructure result in some net improvements and CO₂ reductions. Sustainable aviation

Traffic growth	C
Technology developments	T
Operations and infrastructure improvements	O
Sustainable aviation fuel	F
Offsets (or other carbon mitigation options)	M



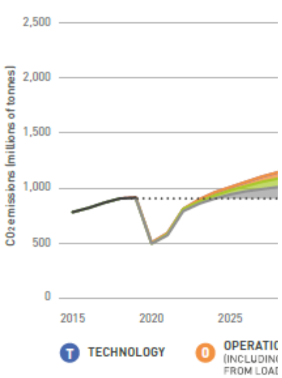
Comparison with industry -50
In order to meet the industry long
12% of emissions reductions. Op
show a low- to high-range contin
litres) of SAF with a 100% emissi
remainder required to meet goal
650 – 1,200 Mt in 2050.

Scenario 1: pushing technology and operations

Under this scenario, technology improvements are prioritised and ambitious with the expectation of the emergence of unconventional airframes and a transition of hybrid/electric aircraft from 2035/40. Signific operations and infrastructure improvements improvements and CO₂ reductions. The gap b emissions after technology and operations an

improvements and the 2050 carbon goal is fulfilled with the use of sustainable aviation fuels. This will require significant

Traffic growth	C
Technology developments	T_4
Operations and infrastructure improvements	O_3
Sustainable aviation fuel	F_2
Offsets (or other carbon mitigation options)	M_1

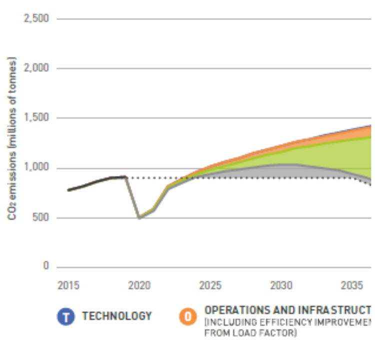


Comparison with industry -50% lor
In order to meet the industry long-term
26% of emissions reductions. Operatio
require 320 Mt (400 billion litres) with a
mix of SAF and offsets in the form of ca

Scenario 2: aggressive sustainable fuel deployment

Under this scenario, technology improvements are ambitious with new aircraft configurations such as blended wing body options, although those are based on current powerplant and technologies (not a significant shift to electric or hybrid, with the industry prioritising investment in sustainable fuels). Despite mid traffic growth, investments in operations and infrastructure result in some net improvements and CO₂ reductions. The gap between CO₂ emissions after technology

Traffic growth	C	Central scenario:
Technology developments	T_3	New airframe con performance such
Operations and infrastructure improvements	O_2	Mid-range improv
Sustainable aviation fuel	F_3	Backcast of what i 90% of convention emissions reducti
Offsets (or other carbon mitigation options)	M_2	Around 155 millio emissions gap to r

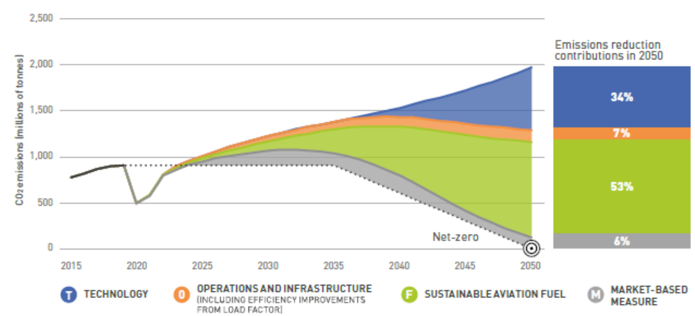


Comparison with industry -50% long-term goal set in
In order to meet the industry long-term goal of -50% by 20
14% of emissions reductions. Operations and infrastructur
require 390 Mt (490 billion litres) with a 100% emissions re
mix of SAF and offsets in the form of carbon removals.

Scenario 3: aspirational and aggressive technology perspective

Under this scenario, technology improvements are very ambitious with electric aircraft up to 100-seat, zero-emissions aircraft (powered by green hydrogen) for the 100-200 seat segment and hybrid-electric powered unconventional aircraft configuration for larger aircraft. Despite a mid-level of traffic growth, investments in operations and infrastructure result in some net improvements and CO₂ reductions. The gap between CO₂ emissions after technology and operations and infrastructure improvements and the 2050 carbon goal is fulfilled with sustainable aviation fuels (requiring significant amounts of SAF with high emissions reduction factor (ERF)). Under this scenario, offsets will be needed to clear up any residual emissions in 2050 but may be required during 2035-2050 as a transition mechanism.

Traffic growth	C	Central scenario: 3.1% CAGR 2020-2050
Technology developments	T_5	Very aggressive acceleration of the introduction of electric, hybrid and zero-emissions (hydrogen) aircraft in the 2035-2040 timeframe
Operations and infrastructure improvements	O_2	Mid-range improvements and airline load factor improvements
Sustainable aviation fuel	F_4	Backcast of what is required (around 1,000 Mt of CO₂) to replace 90% of conventional fuel: 330 Mt (410 billion litres) of SAF with a 100% emissions reduction factor by 2050
Offsets (or other carbon mitigation options)	M_3	Around 115 million tonnes worth of offsets may be required to close the emissions gap to net-zero



Comparison with industry -50% long-term goal set in 2009
In order to meet the industry long-term goal of -50% by 2050 compared to 2005 levels, Technology would contribute 41% of emissions reductions. Operations and infrastructure improvements 8%. A back-cast to meet the goal would require 260 Mt (330 billion litres) with a 100% emissions reduction factor by 2050 (51% of emissions reductions), or a mix of SAF and offsets in the form of carbon removals.

Reduction Estimates

Strategy	Estimated Reduction %			
	Base	#2	#3	#4
Energy Efficiency	5.0%	7.0%	8.0%	9.0%
Operational Efficiency	5.0%	7.0%	8.0%	8.0%
Force Structure	0.0%	0.0%	0.0%	0.0%
Low Carbon Fuels	20.0%	22.5%	25.0%	25.0%
Hydrogen	7.0%	7.0%	8.5%	15.0%
Unmanned Systems	4.0%	5.0%	8.0%	11.0%
Battery Storage	4.0%	7.5%	10.0%	10.0%
Renewables	5.0%	7.5%	10.0%	9.0%
CCS/CCUS	20.0%	22.5%	22.5%	13.0%
Remaining Emissions	3.31	1.54	-	-

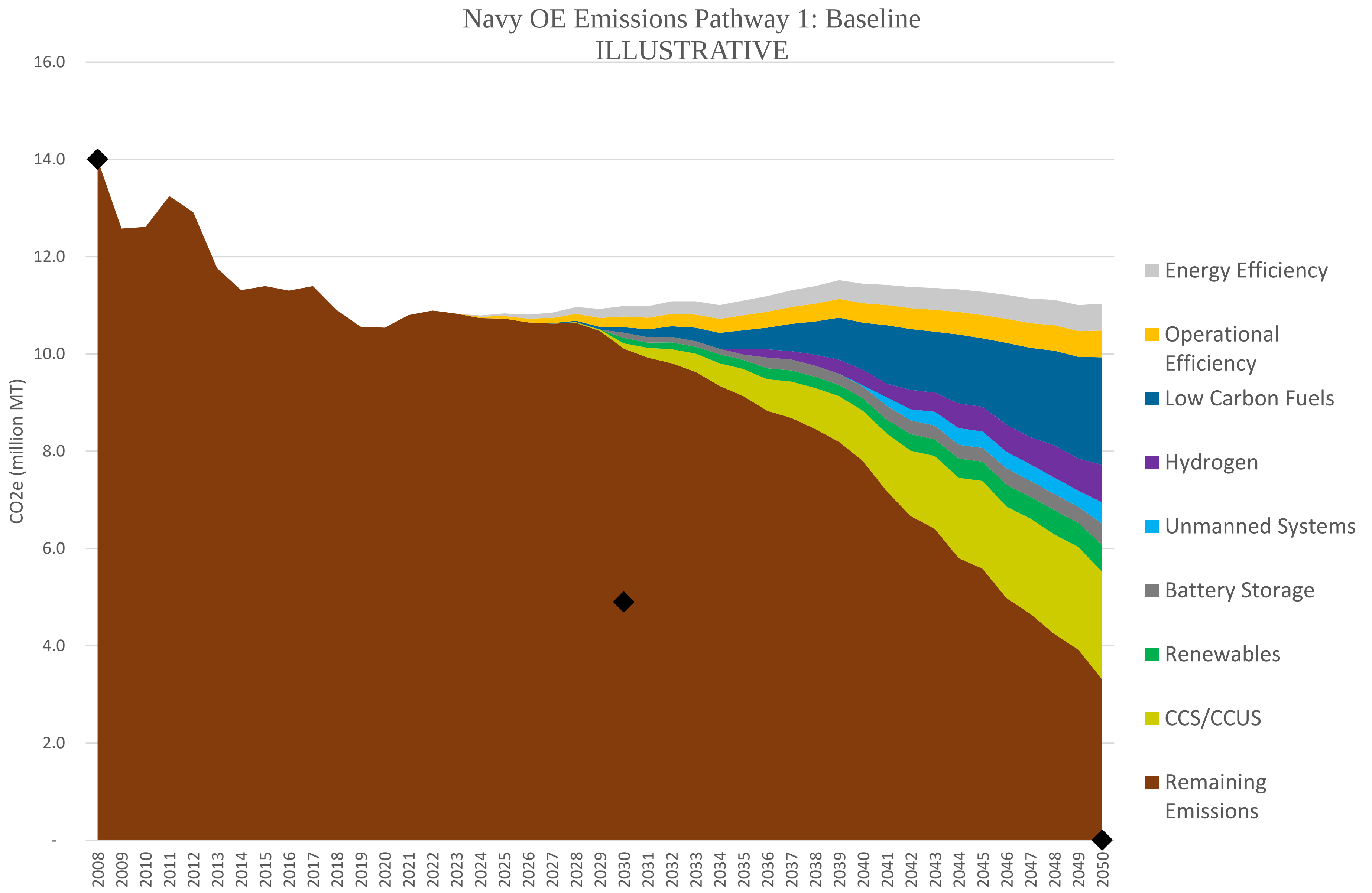


Figure 16. Pathway 1: Baseline

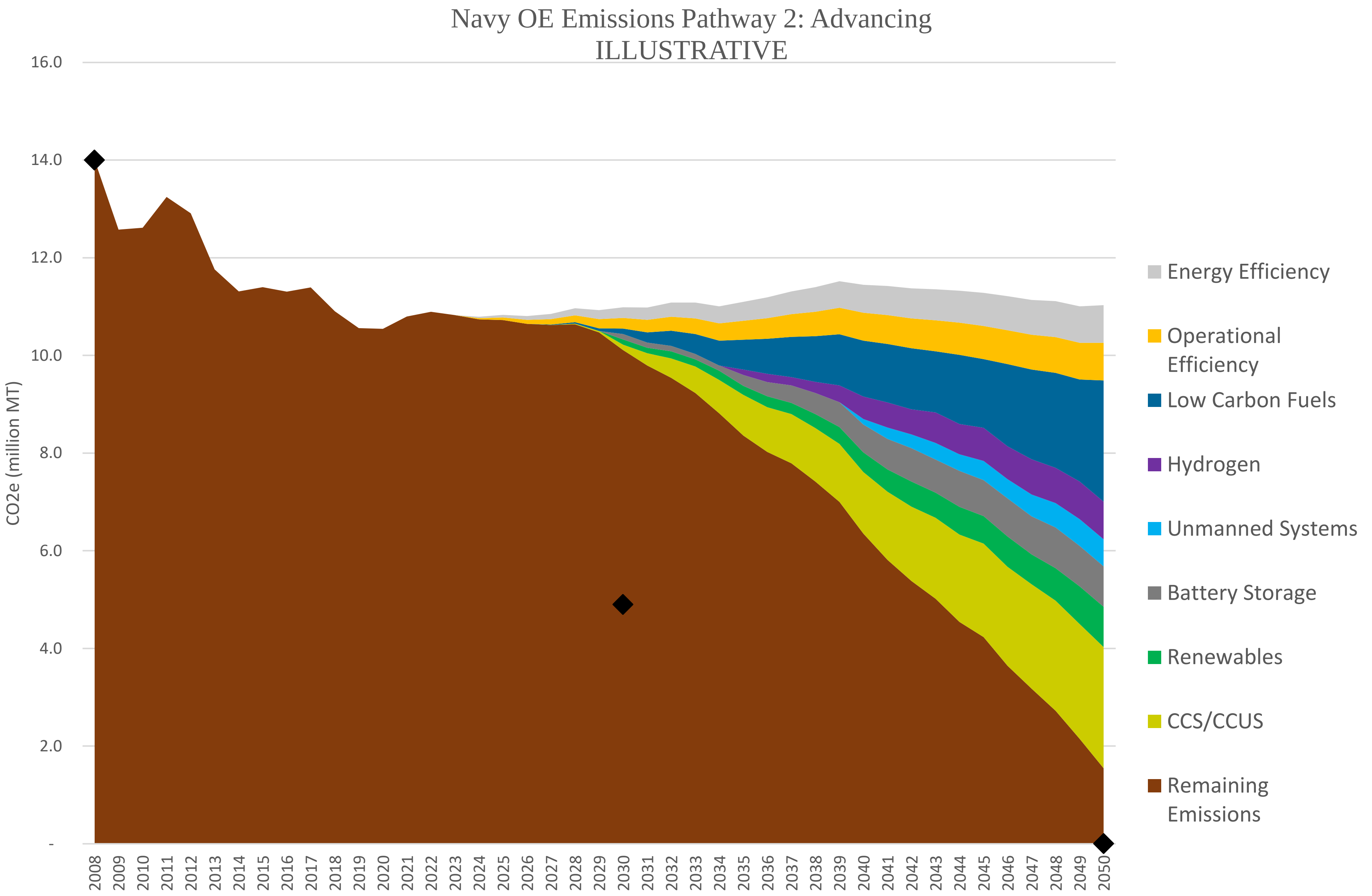


Figure 17. Pathway 2: Advancing

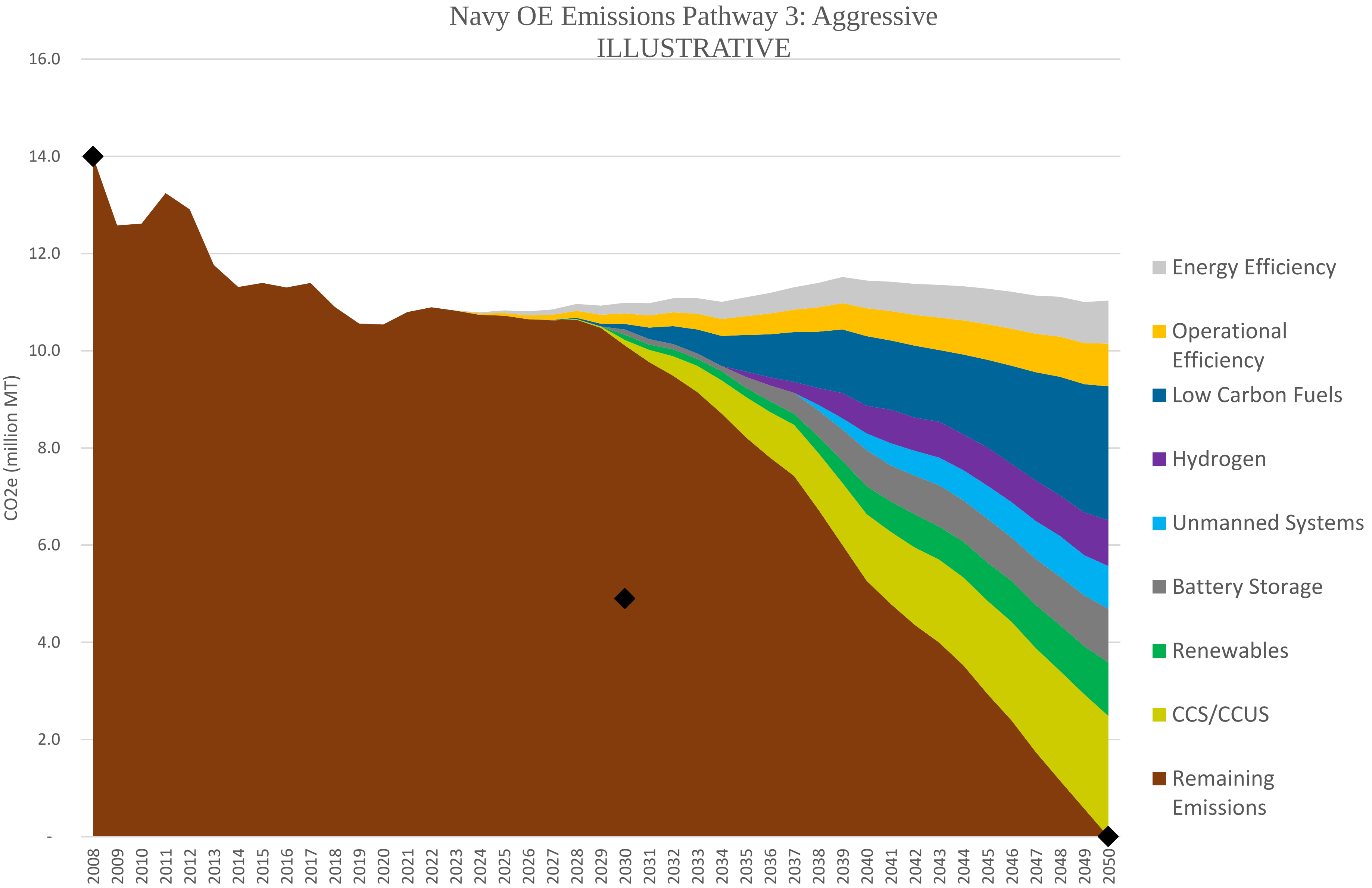


Figure 18. Pathway 3: Aggressive

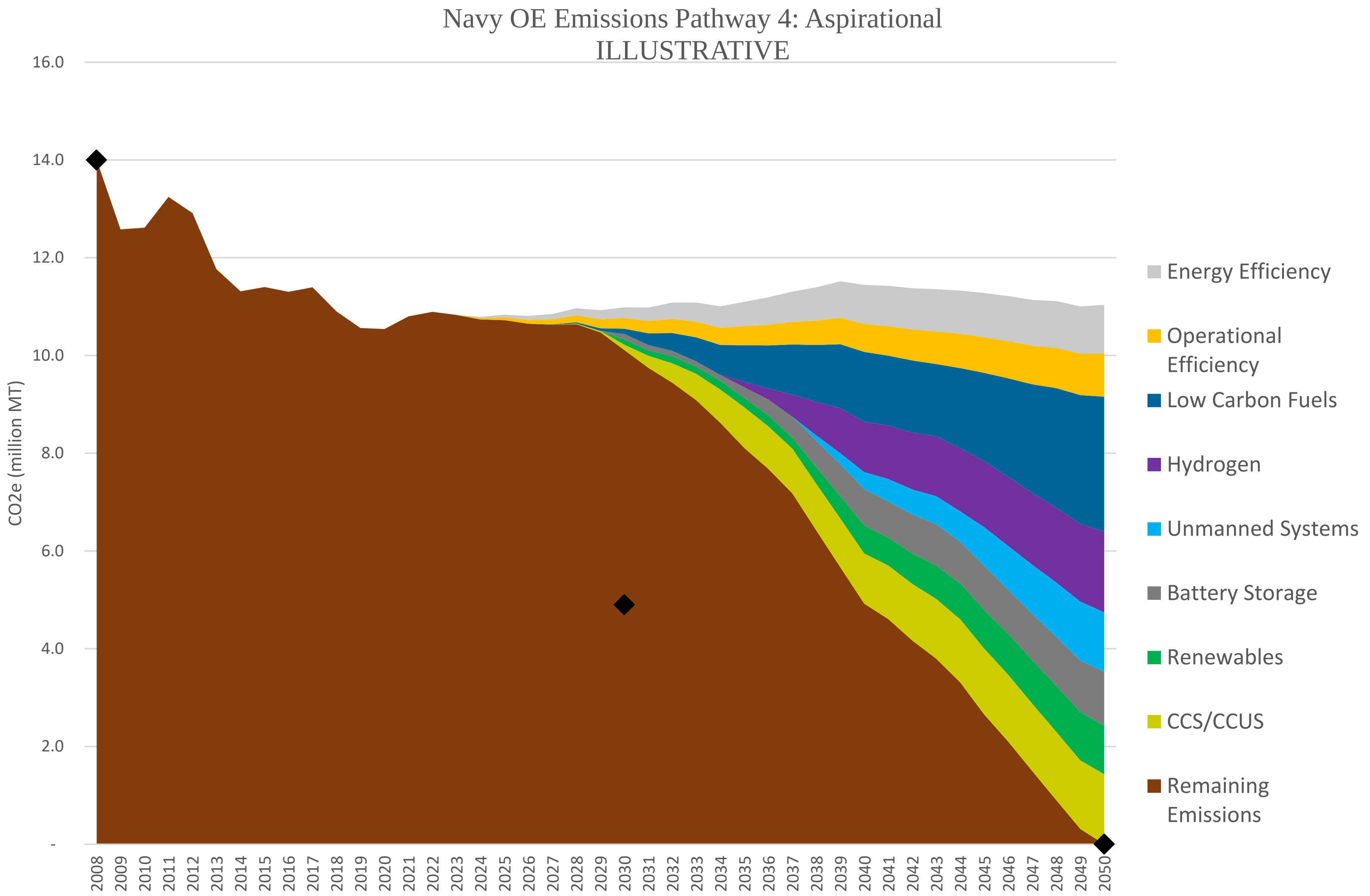


Figure 19. Pathway 4: Aspirational

Findings & Recommendations

- **A Whole of Government Approach**
- **Investing Now**
- **Promising Strategies**
- **Cautions**
- **Priorities for Research**
  - Creation of fuel/energy in-theatre
  - Demand reduction
  - Aircraft & shipboard decarbonization
  - UxS studies to show the impact of transitioning to uncrewed
- **Year 2 Research: Force Structure Analysis**

Decarbonization Research Roadmap

Roadmap – Next Steps

- *Finalize Key Thrust Areas and Cross-Cutting Initiatives*
- *Roughly categorize/align USG, DOD, DON activities to these Thrust Areas*
  - *Includes ~100 Navy S&T/R&D investment projects*
- *DRAFT Year 1 Research Agenda – Summarize White papers/proposals along these same Thrust Areas*
- DRAFT ONR Decarbonization Research Roadmap
  - Align Year 1 Research Agenda with other USG/DOD/DON activities to identify gaps and overlap
  - Goal: Develop "CEP-like" products for each Thrust Area and Cross-Cutting Initiative
- Solicit feedback from other stakeholders
  - What have we missed; Where else should we be focusing our efforts

In work
Future

Thrust Areas & Cross-Cutting Initiatives

Major Thrust Areas	NPS 2050 Net Zero Approx %age Impact (%)
Technology & Energy Efficiency *(includes propulsion effic, drag reduction, electrification & hybridization, thermal mgmt and storage, etc.)*	5% - 15%
Operational Efficiency Improvements *(includes route planning, optimum plant alignment, etc.)*	5% - 15%
Force Structure *(includes smaller "single mission"-focused platforms(?), unmanned systems, etc.)*	TBD
Lower Carbon Fuels *(includes SAF, renewable diesel, green ammonia, green methanol, hydrogen, nuclear(?), batteries(?), etc.)*	20% - 70%
Carbon Capture, Use and Storage *(includes shipboard CCS/CCUS, terrestrial-based CCS(?), etc.)*	TBD

Cross-Cutting Initiatives	
Whole ship and system level design considerations	
Ship integration and technology scaling for shipboard use	
Modeling, test sites and demonstration capability	
Education and Training	

Major Guidance Documents

Primary

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

Plus ~100 DoN S&T/R&D Projects

Secondary

- US National Blueprint for Transportation Decarbonization (*Jan 2023*)
- FAA Aviation Climate Action Plan (*2021*)
- IMO GHG Strategy (*2018*)
- DOE Hydrogen Shot (*June 2021*)
- DOE SAF Grand Challenge (*Sept 2022*)
- USAF Climate Action Plan (*Oct 2022*)
- US Army Climate Strategy (*Feb 2022*)
- Summary of World Military Activities (*NPS – 2023*)

Decarbonization Research Consortium

Path Forward

April 24 Meeting: Canceled; Switched to Individual Online Meetings

May Meeting: Focused on Research Roadmap
12 May 2023, Online

June Meeting: Research Roadmap + Federal Landscape
23 June 2023, Hybrid
In-person, Washington, DC & Online