Ocean Energy Carbon Removal

DE-FE0032409

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Ocean Energy Carbon Removal

Objectives, Funding & Dates

Project Objectives

- Recover CO2 from seawater using integration of renewable wave energy & a direct ocean capture process
- Fully evaluate the costs for the system with view to optimization
- Development of a path towards large scale commercial deployment
- Robust analysis of life cycle impacts with a deep commitment to environmental justice, and societal considerations and impacts (SCI)

Funding (DOE and Cost Share)

- Govt: $200,000 Cost Share: $50,000

Overall Project Performance Dates

- 12/20/2023 – 09/19/2025

Project Partners

Ocean Energy (OE) is developing technology which has been extensively tested and is now at a stage where it is now one of the most commercially viable technologies for harnessing the power of the oceans.

The US Naval Research Laboratory (NRL) is an important link in the Navy Research, Development, and Acquisition (RD&A) chain. Through NRL, the Navy has direct ties with sources of fundamental ideas in industry and the academic community throughout the world.

The National Renewable Energy Laboratory (NREL) is transforming energy through research, development, commercialization, and deployment of renewable energy and energy efficiency technologies.

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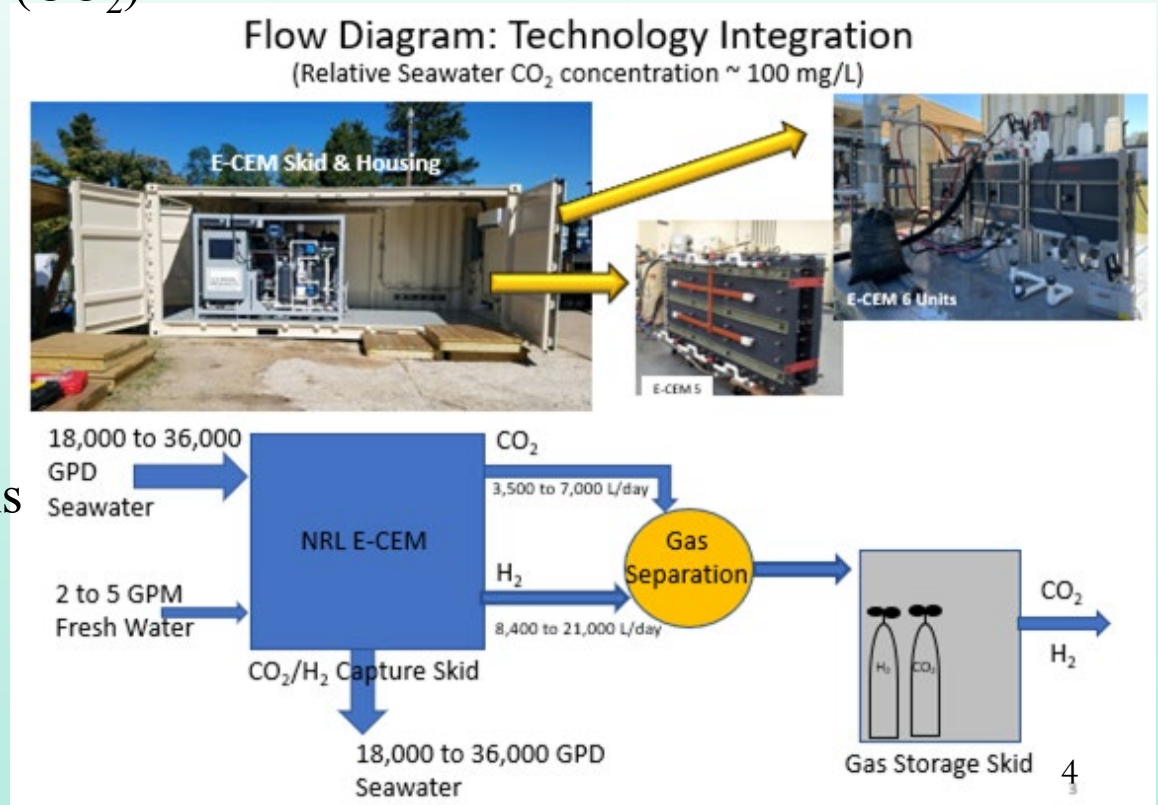
U.S. NAVAL RESEARCH LABORATORY

NREL
Transforming ENERGY

NRL Electrolytic Cation Exchange Module

- Electrolytic Cation Exchange Module (E-CEM) is made up of independent mobile skid with control logic plate form
- E-CEM 5 processes 25 gallons/min seawater
- 21,000 L/day hydrogen (H_2)
- 7,000 L/day of carbon dioxide (CO_2)
- 480 VAC, 3-phase, 60 Hz
- E-CEM 5 dimensions:
  9ft x 4ft x 0.33ft
- Skid dimensions:
  9ft x 6.2ft x 4.7ft
- Conex container dimensions:
  9.8ft x 8.5ft x 8ft
- Testing of new E-CEM designs
- E-CEM 6 dimensions:
- 2.4ft x 1.8ft x 0.33ft
- E-CEM 6 needs 12 cells
  - 25 gal/min sea water



Floating Oscillating Water Column (OWC) OE BUOY

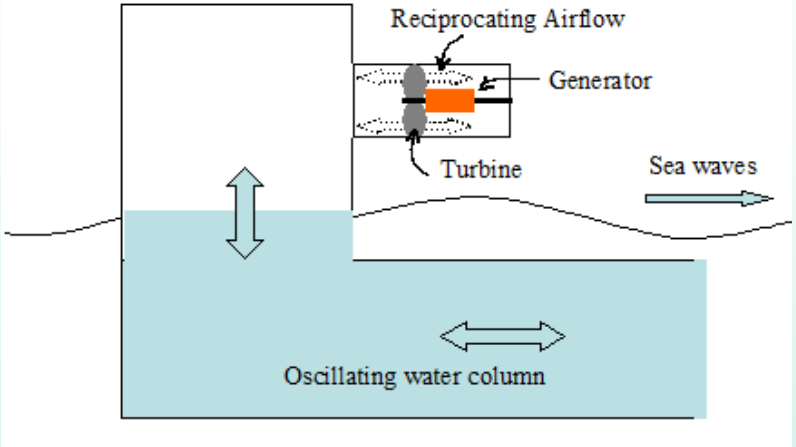
- Hydrodynamic interaction of device & waves generates reciprocating air flow

- Airflow drives unidirectional turbine that drives a rotary generator

- System has undergone many steps in TRL development process
  - Countless hours of tank testing
  - Over 2 years of ¼ scale deployment
  - Full scale testing at WETS in Hawaii to start later this month
  - Testing to last at least 12 months

- WETS unit 122.7 ft x 60.7 ft x 66.6 ft
- Rated power of 500 kW
- Average power output approximately 150-350 kW
- Max Power 800 kW

Floating Oscillating Water Column (OWC) OE BUOY



Benefits & Challenges of Merging Tech.

- Technical and economic advantages
  - Simple integration of the E-CEM into OE Buoy
  - Direct access to ocean water for decarbonization
  - No need for additional electrical infrastructure
    - Cost reductions
    - No transmission losses
    - Significantly increases potential deployment sites
  - Energy used produces no additional carbon

- Technical and economic challenges
  - Wave Energy Conversion power quality
  - Recovering generated CO_2 and H_2
  - Routine and emergency system maintenance

Project Scope

- Down select E-CEM Module to match 3.4 MWh/day
- Design mobile skid using off the equipment to fit within OE Buoy
- Determine method for capturing, storing and utilizing H_2 and CO_2 on the OE Buoy

Major milestones

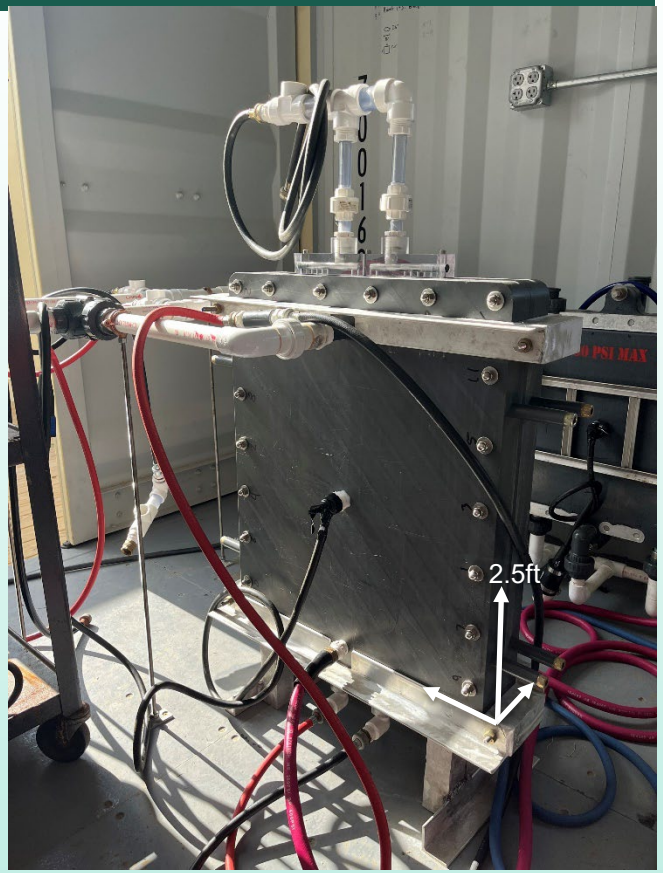
- Phase 2 Design Complete – M11
- For other milestones see CBP Overview

Project Success Criteria

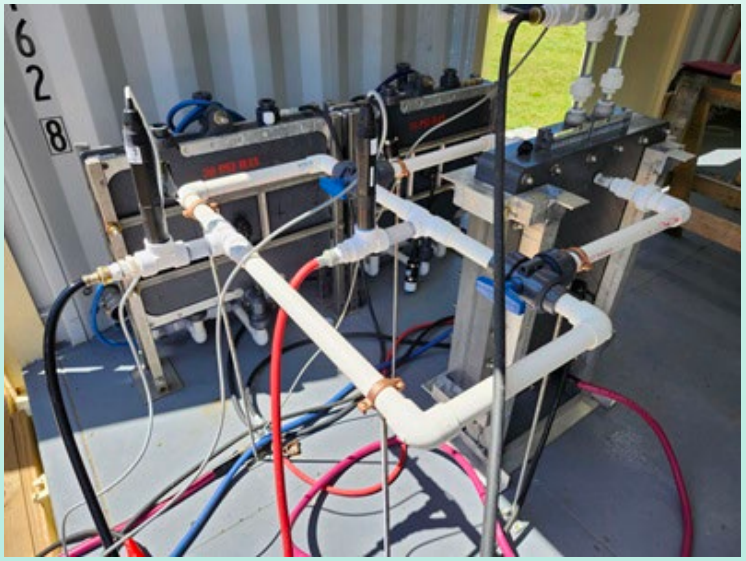
- Plotting reliable way forward for adding E-CEM to OE35 at WETS
- Secure Phase II Funding

NRL DOC E-CEM Technology Accomplishments

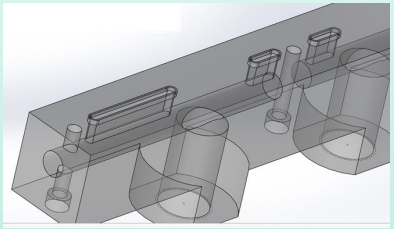
- Refined design to enable higher efficiency optimizing membranes, spacers, compartment volumes, endblocks, operational pressures, and electrodes)
- Fabricated and characterized new E-CEM design (E-CEM 6+)
- Demonstrated 50% reduction in number of modules to enable an equal throughput of seawater: from 12



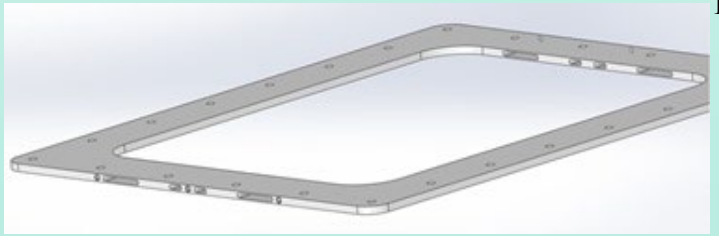
E-CEM 6 +



E-CEMs 6 and 6 +

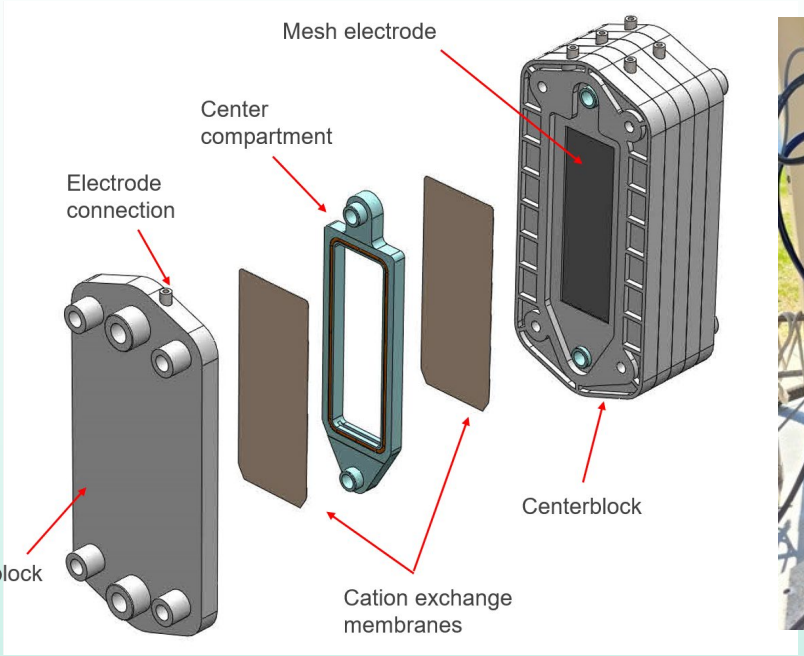


E-CEM Manifold



E-CEM Spacers

NRL E-CEM DOC Technology Accomplishments



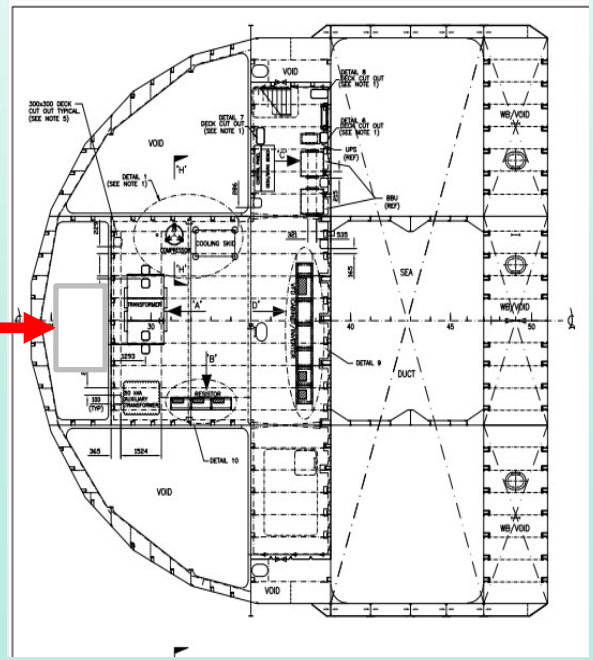
- E-CEM 8 processes ~8 gpm of seawater
- ~3 E-CEM 8 modules to make more than 1 gallon of fuel/day
- E-CEM 8B just delivered with updated O-rings

- NCRADA-NRL-23-833 with commercial entity to commercialize and transition NRL DOC technology
- E-CEM 8, 9, 10 transition to multi-compartment configurations to reduce size, weight, and number of modules to process 18 gal/min if seawater
- Novel module designs that have greater than three compartments that result in stacked devices
- A stacked module configuration is advantageous as a reduction in endblock pairs reduces overall weight, materials, and costs of the device.
- Identifying technologies for compressing hydrogen, a useful biproduct of the system, which could be used to power the buoy during steady sea state.

Feasibility Study Results

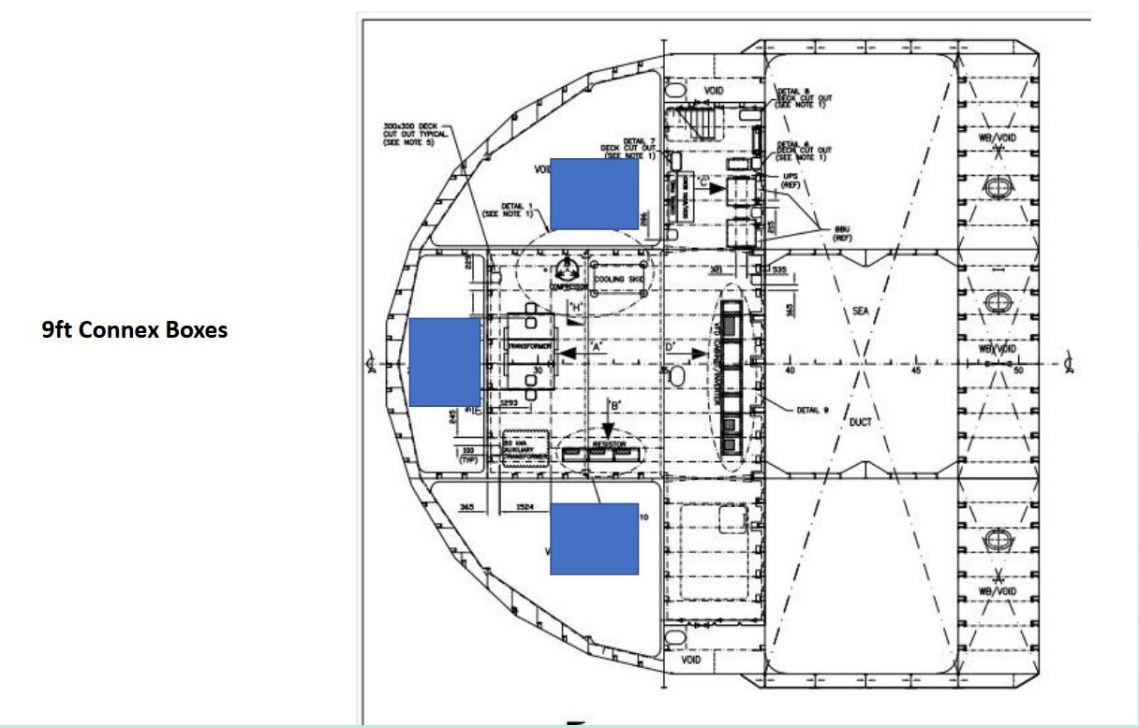
- NRL E-CEM Skid fits comfortably within the machine of OE Buoy
  - Shown by plan view of machine room and buoyancy void
- Sea water pumps used to recover sea water for treatment
- Reverse osmosis systems used to for freshwater requirements
- Small modifications required to for Buoy to meet electrical requirements
- Plenty of space available in OE Buoy for all required equipment

NRL E-CEM Module Skid



Physical Integration of E-CEM

- Physical integration of E-CEM skid is ongoing, potential for up to three 9 ft connex boxes to be fit into void spaces around machine room
- Includes ancillary equipment such as pumps, water desalination & storage
- Retrofit of E-CEM into existing OE Buoy being testing at WETS
- New build planning for future systems

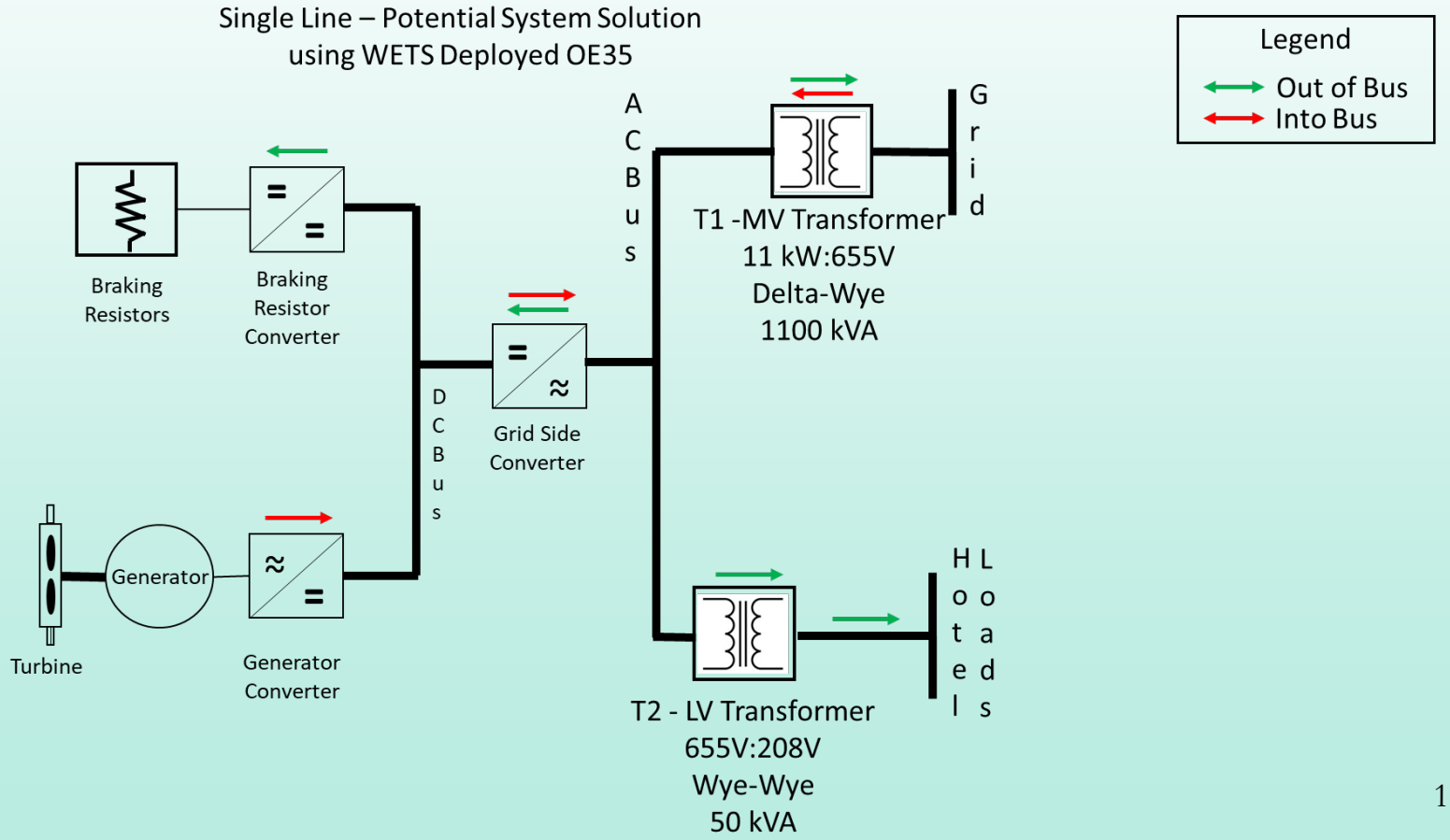


Electrical Integration of E-CEM

- The electrical integration of E-CEM skid is also ongoing
- Three different electrical solutions being investigated
  - Retrofitting existing OE35 at WETS
  - Islanded electrical system with E-CEM powered from AC Bus
  - Islanded electrical system with E-CEM powered from DC Bus
- E-CEM system required 480 VAC or 10 VDC and 30 kW to operate

Retrofitting existing OE35 Electrical System

- Current configuration does not include 480 VAC supply
- Simple solution of adding small 50 kVA transformer



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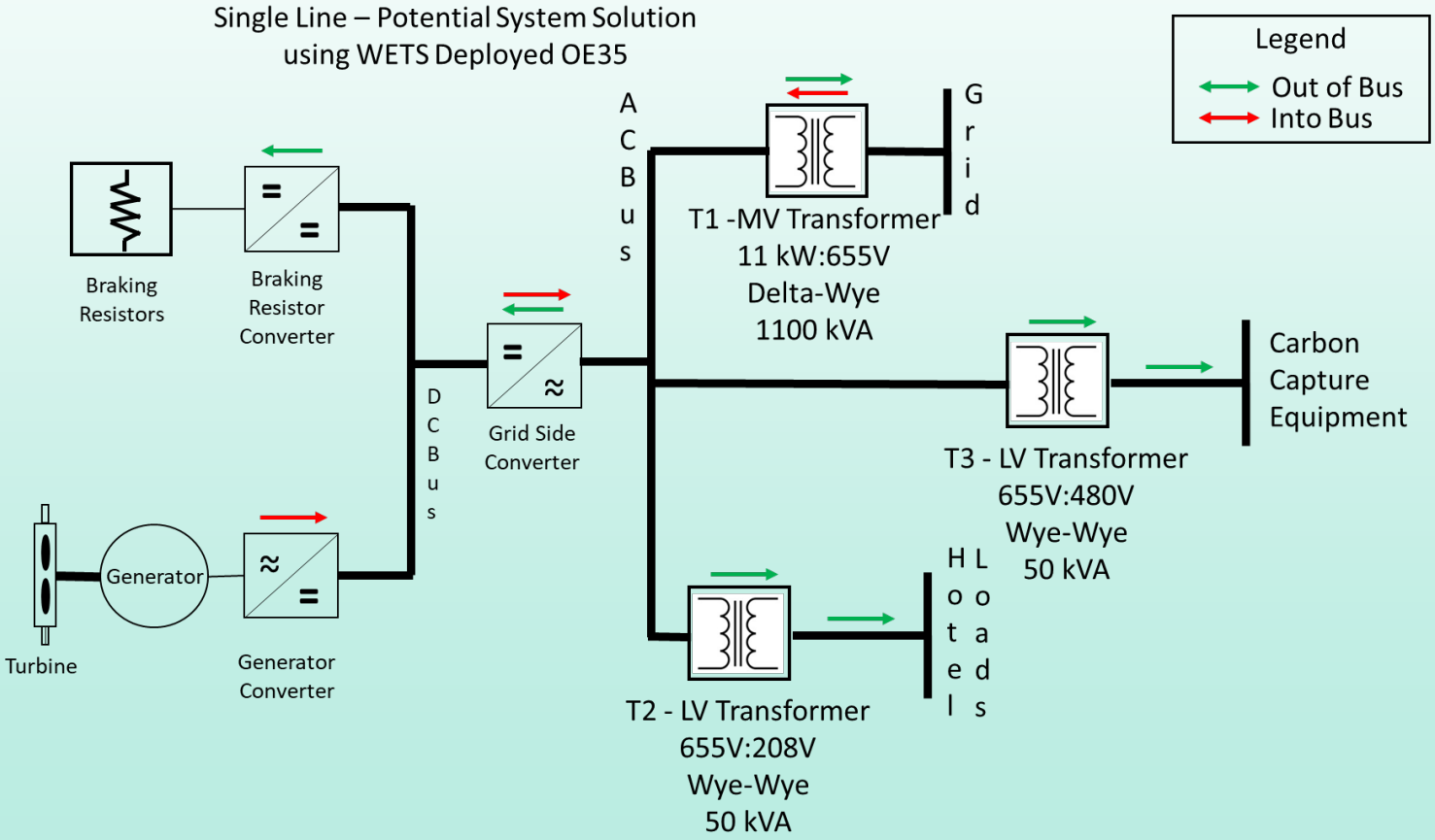
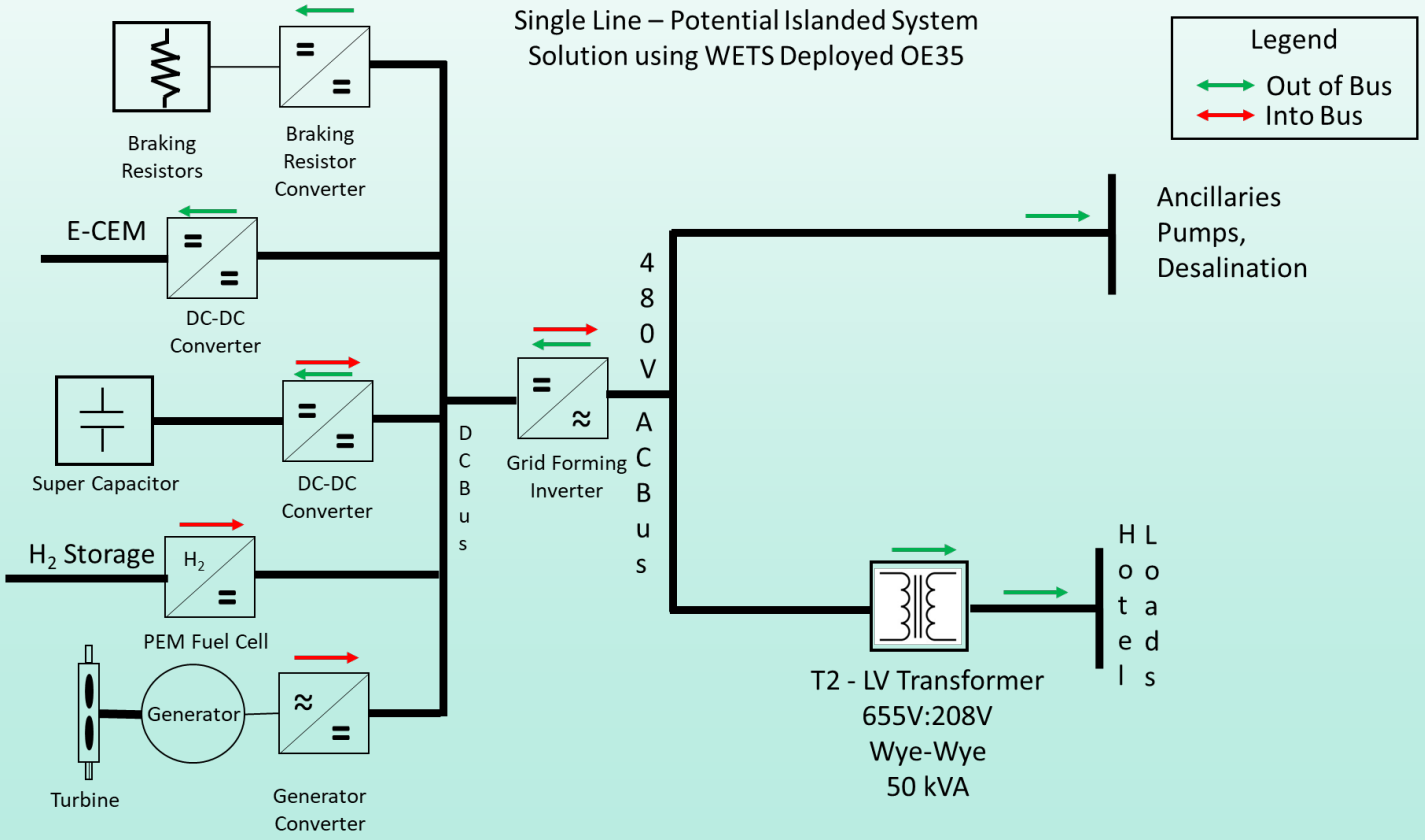


Islanded grid for OE35 Electrical System

- Critical needs include grid forming inverter & short-term energy storage
- Options include direct DC connection for E-CEM and fuel cell system
- Allows unit to operate without grid connection, increasing number of potential sites



Community Benefits Plan (CBP) Overview

- **Phase I – Oregon focus**
  - NRL & NREL DEIA Officers to Supervise CBP
  - Social Characterization Analysis – Identify Stakeholders – Coastal Communities
  - Plan Engagement Strategy with local consultant – Sol Coast Consulting LLC
  - Prepare Phase II Engagement Strategy

- **Milestones**
  - DEIA Project Manager Identified: the identification and engagement of a dedicated Project Manager to ensure the DEIA objectives are appropriate and achievable.
  - M9.1 – Quality Jobs Plan [M11]
  - M9.2 – DEIA Project Manager Identified [M11]
  - M9.3 – Measures of Implementation of DEIA Plan [M11]
  - M9.4 – Energy & Environmental Justice Assessment [M11]
  - M9.5 – Engagement Plan Development Plan (PDP) Phase I Update [M11]

Lessons Learned

- Primary Lesson learned – that potential for Carbon Dioxide Removal from the Ocean has huge potential for climate change mitigation with positive effects on the natural environment.
- Transfer of technology from Electro-chemistry to Energy Engineering can yield additive benefits.
- CDR Applications can open more opportunity for deployment of Ocean Energy conversion systems
- The mitigation strategies will be developed during the Initial Technology Environmental Health and Safety Risk Assessment – Deliverable D1.7 to be achieved by M11

Plans for future testing/development/ commercialization

a. **In this project**

Phase 1 is the feasibility study and economic assessment for the combination of Marine CDR with power from ocean waves with the design of a demonstration deployment.

Phase 2 is the modification of the existing OE35 platform to accommodate the mCDR system and to demonstrate this at the US Navy Wave Energy Test Site.

b. **The next project** will be to apply the learnings from the WETS demonstration and implement an off-grid demonstration.

c. The OE35 system is **scale-able** with maximum capacity estimated at around 2.5MW. The wide spread development of farms of OE35/mCDR systems will make significant future contributions to climate mitigation.

Current Project Summary

- NRL E-CEM compatible with OE Buoy platform
- High potential to provide multiple benefits to isolated communities
- Longer Term potential to produce Synthetic Aviation Fuel

CO2 increases in the atmosphere causes acidification of the ocean with catastrophic effects on marine life.

“The use of direct Marine Carbon Dioxide Removal, powered by the waves, results in Self Healing for the ocean environment.”

Organization Chart

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LEAD ACTIVITY
Project Management
Community Benefits Plan
Societal Considerations
Conceptual System Design & Development
Team Consolidation
Regulatory and Permitting
Phase 2 Application Preparation

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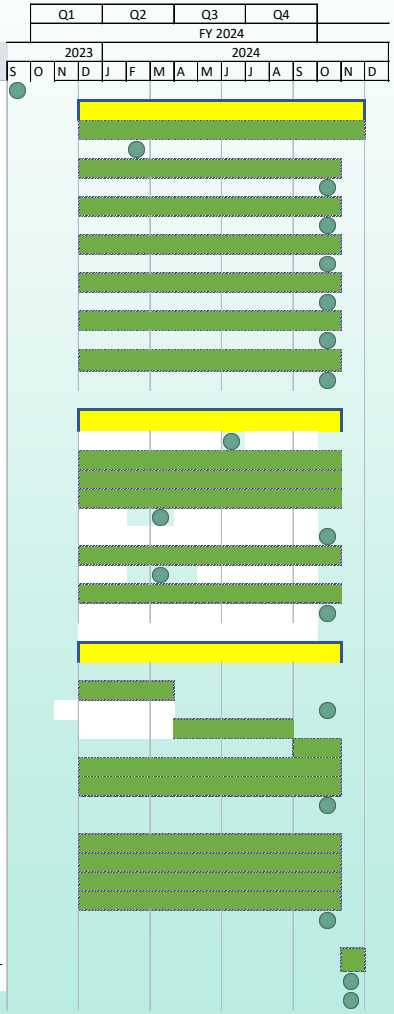
LEAD ACTIVITY
State Point Data Tables
Technology Gap Analysis
Conceptual System Design & Development

NREL
Transforming ENERGY

LEAD ACTIVITY
Technology Maturation Plan
High Level LCA
Techno-Economic Analysis
Initial Environmental H&S Risk Assessment

Gantt Chart

Task Name	Duration	Start	Finish	Lead Partner	Support Partner
Award Notification	0 days	8 Aug '23	8 Aug '23		
Task 1.0 Project Management and Planning	12 mons	20 Dec '23	19 Dec '24		
Subtask 1.1 *– Project Management Plan*	12 mons	20 Dec '23	19 Dec '24	OE	NRL
D1.1 *PMP Update*	0 days	19 Feb'24	19 Feb'24	OE	NRL
Subtask 1.2 *– Technology Maturation Plan (TMP)*	9 mons	20 Dec '23	19 Sep '24	NREL	OE /NRL
D1.2 *Final TMP Report*	0 days	19 Sep '24	19 Sep '24	NREL	
Subtask 1.3 *State Point Data Tables*	11 mons	20 Dec '23	19 Nov '24	NRL	NREL
D1.3 State Data Point Tables	0 days	19 Nov '24	19 Nov '24	NRL	NREL
Subtask 1.4 *Preliminary Techno-Economic Analysis (TEA) Assessment*	11 mons	20 Dec '23	19 Nov '24	NREL	
D1.4 Preliminary Techno-Economic Analysis (TEA)	0 days	19 Nov '24	19 Nov '24	NREL	
Subtask 1.5 *Preliminary High-Level Life Cycle Analysis (LCA)*	11 mons	20 Dec '23	19 Nov '24	NREL	
D1.5 Preliminary LCA	0 days	19 Nov '24	19 Nov '24	NREL	
Subtask 1.6 *Initial Technology Gap Analysis (TGA) Assessment*	11 mons	20 Dec '23	19 Nov '24	NRL	OE
D1.6 Technology Gap Analysis	0 days	19 Nov '24	19 Nov '24	NRL	OE
Subtask 1.7 *Initial Technology Environmental Health & Safety (EH&S) Risk Asses*	11 mons	20 Dec '23	19 Nov '24	NREL	
D1.7 Technology EH&S Risk Assessment	0 days	19 Nov '24	19 Nov '24	NREL	
Task 2.0 R&D Community Benefits Plan (CBP) and Societal Considerations and	**220 days**	20 Dec '23	19 Nov '24	OE	NRL
D2.0 Societal Considerations and Impact (SCI) Mid Project Update and Public	0 days	19 Jun '24	19 Jun '24	OE	
Subtask 2.1 *Quality Jobs Plan*	11 mons	20 Dec '23	19 Nov '24	OE	
Subtask 2.2 *Diversity, Equity, Inclusion and Accessibility Plan*	11 mons	20 Dec '23	19 Nov '24	OE	
Subtask 2.3 *Justice40 Initiative Plan*	11 mons	20 Dec '23	19 Nov '24	OE	
D2.3 Initial J40 PDP Update	0 days	19 Mar'24	19 Mar'24	OE	
D2.3 Justice40 Implementation Strategy	0 days	19 Nov '24	19 Nov '24	OE	
Subtask 2.4 *Community and Stakeholder Engagement Plan*	11 mons	20 Dec '23	19 Nov '24	OE	
D2.4 Initial Engagement PDP Update	0 days	19 Mar'24	19 Mar'24	OE	
Subtask 2.5 *Identification of SCI Consultant*	11 mons	20 Dec '23	19 Nov '24	OE	
D2.5 SCI End of Project Progress Report	0 days	19 Nov '24	19 Nov '24	OE	
Task 3.0 Development of the Ocean Based CDR System	**12 mons**	20 Dec '23	19 Dec '24		
3.1 Conceptual Design Development					
Subtask 3.1.1 *Feasibility Study*	4 mons	20 Dec '23	15 Apr'24	OE	NRL
D3.1 Concept design for the integrated system	0 days	19 Nov '24	19 Nov '24	OE	NRL
Subtask 3.1.2 *System Modelling*	11 mons	20 Dec '23	19 Nov '24	NRL	NREL
Subtask 3.1.3 *Integration Mapping*	11 mons	20 Dec '23	19 Nov '24	NRL	NREL
Subtask 3.1.4 *Data Management Plan*	11 mons	20 Dec '23	19 Nov '24	OE	NREL
Subtask 3.1.5 *– Risk Assessment and Analysis*	11 mons	20 Dec '23	19 Nov '24	NREL	OE /NRL
D3.1.5 *Risk Management Plan*	0 days	19 Nov '24	19 Nov '24	NREL	
3.2 Cross Cutting Project Team Consolidation					
Subtask 3.2.1 *Identification of Marine Science Specialist for Phase 2*	11 mons	20 Dec '23	19 Nov '24	OE	
Subtask 3.2.2 *Identification of NEPA Compliance Consultant*	11 mons	20 Dec '23	19 Nov '24	OE	
3.3 Regulatory and Permitting Analysis Activity	11 mons	20 Dec '23	19 Nov '24	OE	
Subtask 3.3.1 *Initial Field Verification Site Assessment*	11 mons	20 Dec '23	19 Nov '24	OE	
D3.3 *Regulatory and Permitting Assessment*	0 days	19 Nov '24	19 Nov '24	OE	
3.4 Phase 2 Pre-Application Preparation					
Subtask 3.4.1 *Phase 2 Application Preparation*	1mons	19 Nov '24	19 Dec '24	OE	NRL/NREL
D3.4.1 Letters of Commitment for Phase 2	0	19 Dec '24	19 Dec '24	OE	
D3.4 Phase 2 Application	0	19 Dec '24	19 Dec '24	OE	



Task
Subtask
Deliverable
Milestone
Administrative Task