U.S. DEPARTMENT OF ENERGY | OFFICE OF ELECTRICITY

OE Transmission Infrastructure Improvement Options Panel

February 14, 2024

Panelists

- **Moderator:** David Howard, Director of Grid Components, DOE Office of Electricity
- Dylan Reed, Senior Advisor of External Affairs, DOE Grid Deployment Office
- Sandy Jenkins, Director of Grid Controls, DOE Office of Electricity
- Vinod Siberry, General Engineer, DOE Office of Electricity
- Dr. Emeka Obikwelu, Director of Grid Systems, DOE Office of Electricity

Purpose of the Panel

- Transmission Capacity Expansion
- Transmission Investments
- Increasing Utilization and Reliability of Electric Infrastructure with Grid Enhancing Technologies
- Transformational Investments in Grid Scale Energy Storage
- High-Voltage Direct Current Transmission System Technologies

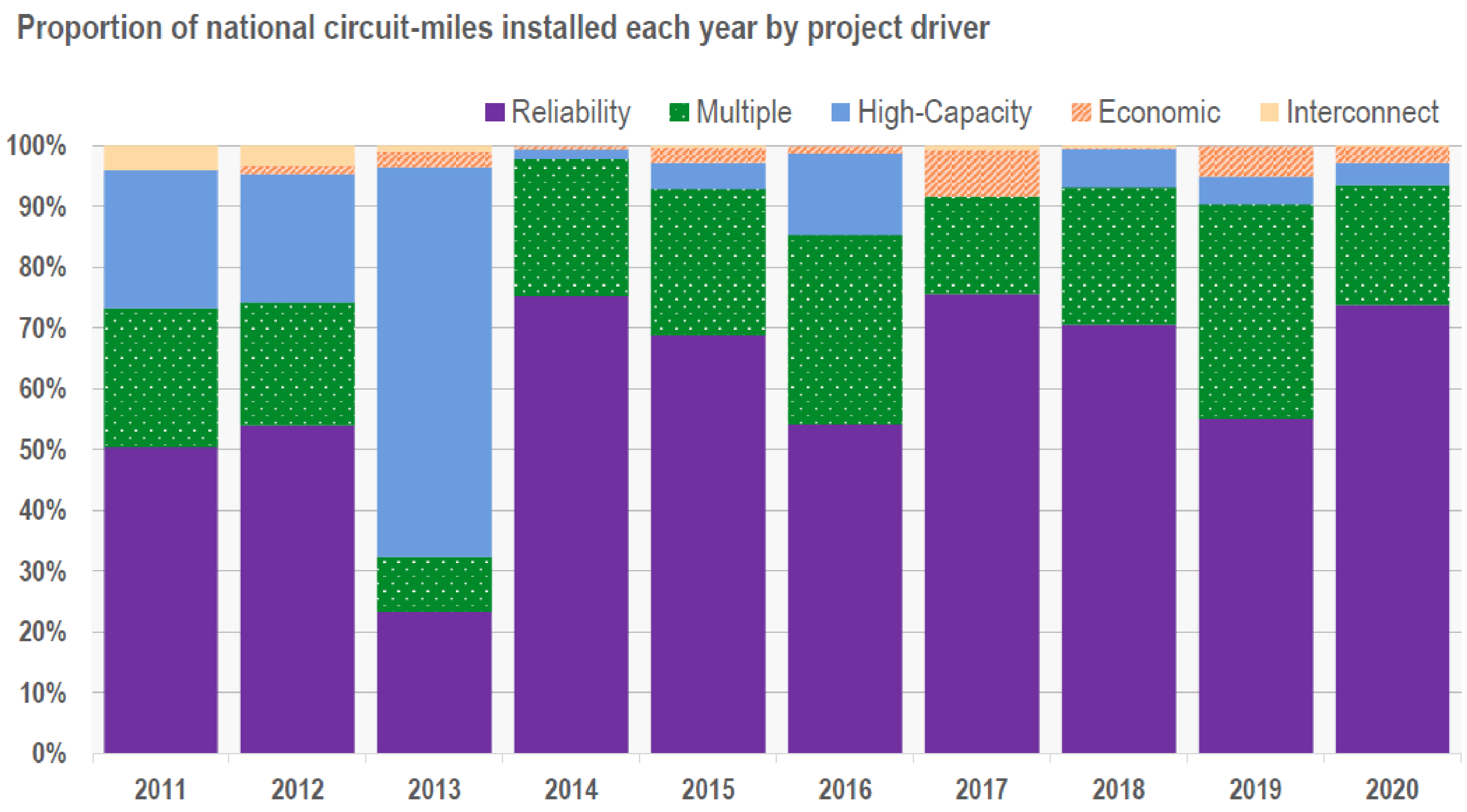
Transmission Capacity Expansion

David Howard
Director of Grid Components
DOE Office of Electricity

Transmission Capacity Expansion

- National Transmission Needs Study (Oct. 2023)
  - The main determinants for transmission expansion include:
    - Grid reliability & resilience
    - Constraint & congestion relief
    - New generation resource interconnection, and
    - Load growth accommodation
  - Transmission investment decreased during the second half of the 2010s, except for:
    - Texas, California, Midwest, and the Delta (20,000 circuit miles at >345kV)
    - Total investment for U.S. was $6.9B for total of 33,000 circuit miles (>100kV)

Transmission Capacity Expansion



Transmission Capacity Expansion

- Transmission constraints and transmission congestion are closely related but are different concepts.
  - Transmission constraints are *physical limits* on the amount of electricity flow the system is allowed to carry in order to ensure safe and reliable operation.
  - Transmission congestion refers to the *economic impacts* on the users of electricity that result from operation of the system within these limits.
- Concept of a toolbox
  - Many tools mitigating many issues.

Transmission Investments

Dylan Reed
Senior Advisor of External Affairs
DOE Grid Deployment Office

BIL provides direct funding for transmission investments

- The first round of GRIP funding totals **nearly $3.5 billion** and will support **58 projects in 44 states** across the U.S.
- This is the *largest single direct investment in critical grid infrastructure in U.S. history*.
- In total, GRIP will catalyze **$8 billion in public and private investment.**
  - The **Grid Innovation Program** invests in states, tribes, local governments, and public utility commissions to collaborate with the private sector and deploy innovative transmission, storage, and distribution infrastructure projects.

Transmission investment examples from Grid Innovation Program selections:

- **Joint Targeted Interconnection Queue Transmission Study Process and Portfolio (JTIQ)**
  - Total funding: $1.7B; Federal Share: $464M
  - Innovative partnership led by the Minnesota Department of Commerce to coordinate the planning, design, and construction of five transmission projects across seven Midwest states
- **Railbelt Innovative Resiliency Project**
  - Total funding: $413M; Federal Share: $206M
  - Unique partnership between the Alaska Energy Authority, cooperatives and municipalities, labor unions, and other stakeholders to develop transmission infrastructure in Alaska's Railbelt regions
- **Confederated Tribes of Warm Springs and Portland General Electric**
  - Total funding: $613M; Federal Share: $250M
  - 500 kV transmission project bridging renewable resources on the Confederated Tribes reservation and PGE's load centers
- **Regional Grid Improvements to Address Reliability in Georgia**
  - Total funding: $507M; Federal Share: $249M
  - Smart grid infrastructure upgrades and new transmission investments to link rural, hard-to-reach communities

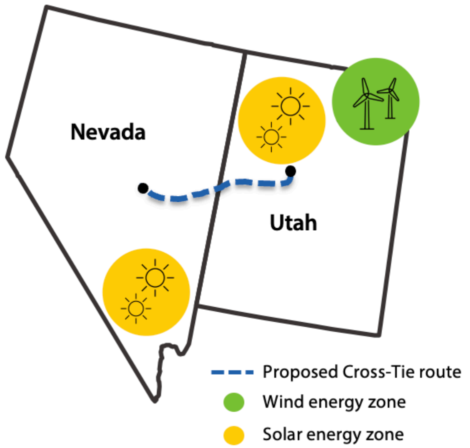
Commercial Facilitation

In October 2023, GDO announced up to **$1.3 billion in three capacity contract selections** for the first round of TFP funding. These are shovel-ready projects that will begin construction by year-end 2027 and would not otherwise be constructed or would have less capacity without federal support

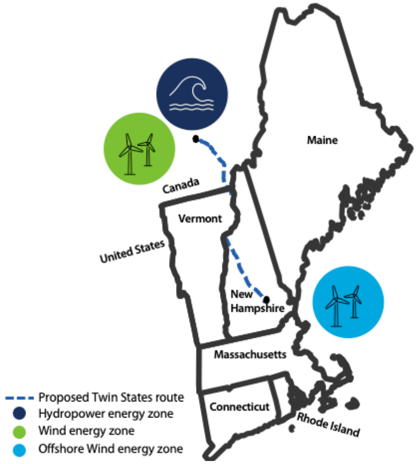
Transmission Facilitation Program

- $2.5 billion revolving fund borrowing authority
  - Provides federal support to overcome financial hurdles associated with developing large-scale new transmission lines, upgrading existing lines, and connecting microgrids in Alaska, Hawaii, and U.S. territories to the grid
- **Three tools:** (1) capacity contracts; (2) public-private partnerships; and (3) loans
- **Next deadline:** Second round of capacity contracts opened in February 2024
- **Eligibility:** Transmission developers

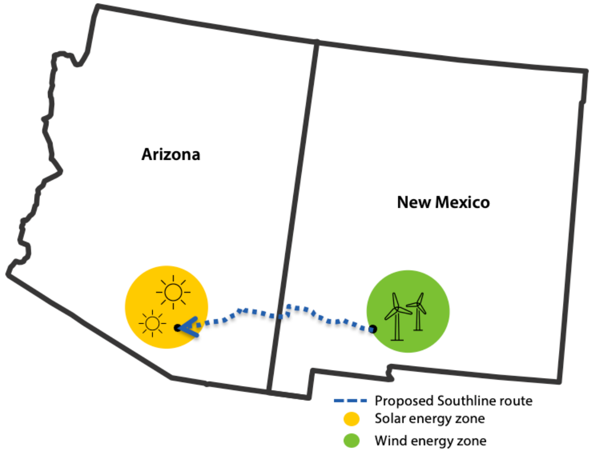
Cross-Tie: 1,500 MW, 214 miles



Twin States: 1,200 MW, 75 Miles



Southline: 748 MW, 175 miles



Siting and Permitting

Coordinated Interagency Transmission Authorizations and Permits(CITAP)

- **Federal Power Act Section 216(h)** authorizes DOE to act as the Lead Agency to coordinate Federal authorizations and related environmental reviews required to site an interstate electric transmission facility
  - Includes establishment of schedules and preparation of a single environmental document
- In May 2023, nine federal agencies executed a new Memorandum of Understanding (MOU) at the direction of the White House to implement coordinated federal permitting
- In August 2023, DOE announced a new rulemaking to implement MOU commitments and opened an RFI for comments on the rulemaking.

National Interest Electric Transmission Corridors (NIETCs)

- **Federal Power Act Section 216(a)** authorizes DOE to designate as a NIETC any geographic area that: (i) is experiencing transmission capacity constraints or congestion that adversely affects consumers; or (ii) is expected to experience such transmission capacity constraints or congestion.
  - Based on the results of the National Transmission Needs Study or other information plus additional discretionary statutory criteria
  - After DOE designates a NIETC, **FERC has the authority under Section 216(b)** to issue permits within a corridor in certain circumstances.
- Final guidance on the designation process released in December 2023

Siting and Permitting

- **Transmission Siting and Economic Development Grants (TSED)**

- $760 million in grants to support siting and permitting activities and economic development for impacted communities
  - Facilitates siting and permitting of interstate and offshore electricity transmission lines
  - Provides economic development grants to communities affected by the construction and operation of interstate and offshore transmission lines
- **Next deadline:** Full applications from those submitting concept papers in Round 1 due April 5, 2023; Round 2 expected Summer 2024 depending on availability of funding.
- **Eligibility:** State and local siting authorities and state, local, or tribal governments

Increasing Utilization and Reliability of Electric Infrastructure with Grid Enhancing Technologies

Sandy Jenkins
Director of Controls
DOE Office of Electricity

Increasing Utilization and Reliability of Electric Infrastructure with GETs FOA

The objectives of this FOA include:

- Advance the maturity of **Dynamic Line Rating (DLR)** and **Power Flow Control(PFC)** GETs technologies
- Quantify real-world benefits and usage of GETs through **at-scale field demonstrations** – focusing on exploring aspects of location-specific benefits and costs.
- Develop new tools and/or enhance existing **operational tools and procedures** to utilize GETs Technologies.
- Develop **operational planning strategies** (such as protection planning) that integrate GETs technologies.

FOA aims to address findings of the 2022 DOE Report “Grid Enhancing Technologies: A Case Study on Ratepayer Impact”.

Full FOA document can be found on FedConnect: FedConnect: Opportunity Summary

The U.S. Department of Energy (DOE) selected four organizations to receive ~$8.4M

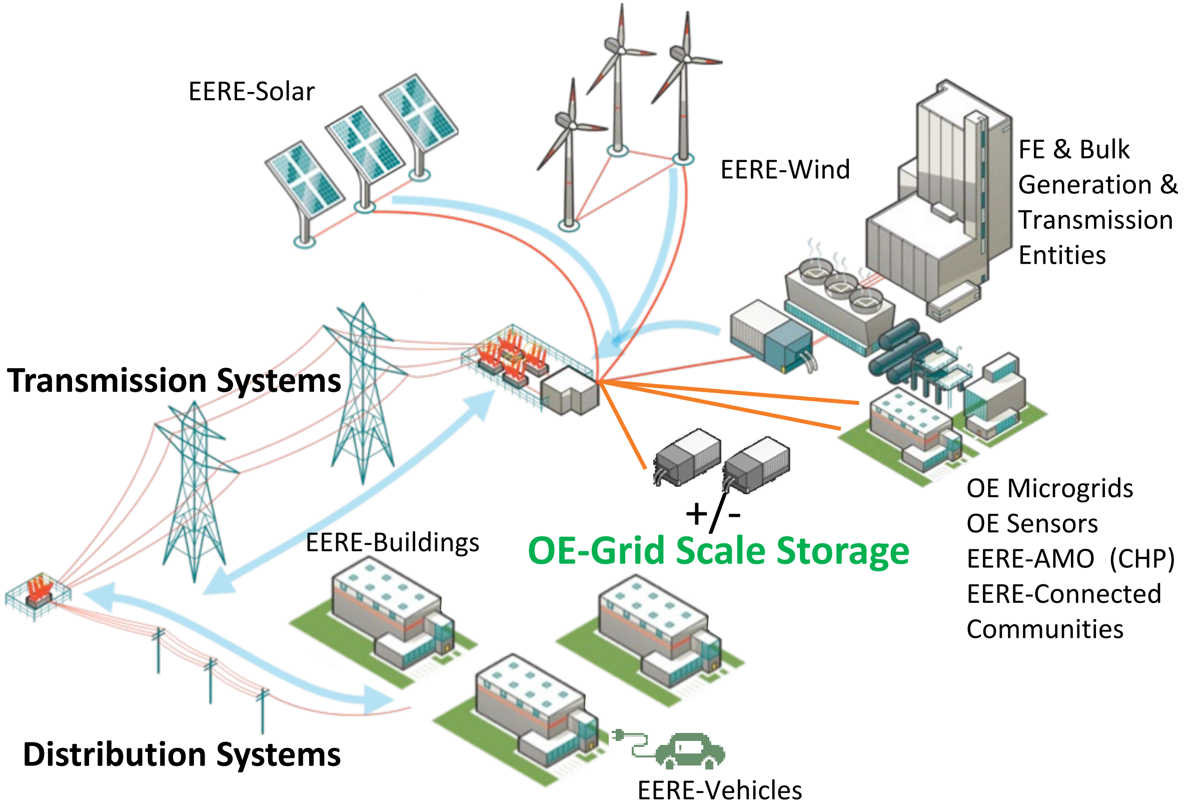
Prime RECIPIENT	PROJECT TITLE	GETs TECH
Georgia Tech Research Corporation, Atlanta, GA	Deployment and Demonstration of Advanced Power Flow Control (APFC) and Dynamic Line Rating (DLR) Solutions to Accelerate Renewable Interconnection and Load Electrification	APFC and DLR
NV Energy, Las Vegas, NV	Direct and Indirect Contact DLR Technologies; Digital Twin Technologies for Increasing Transmission Capacity and Reducing Congestion Without Reconductoring	DLR and Digital Twin
Pitch Aeronautics Inc., Boise, ID	Demonstration of Rapid Deployment of Overhead Monitoring Sensors in Combination with Weather-Based DLR System	DLR and Sensors
University of Connecticut, Storrs, CT	DLR Robust Validation, Enhancement and Field Demonstration in New England with Changing Weather and Offshore Wind Integration	DLR with PFC for offshore wind

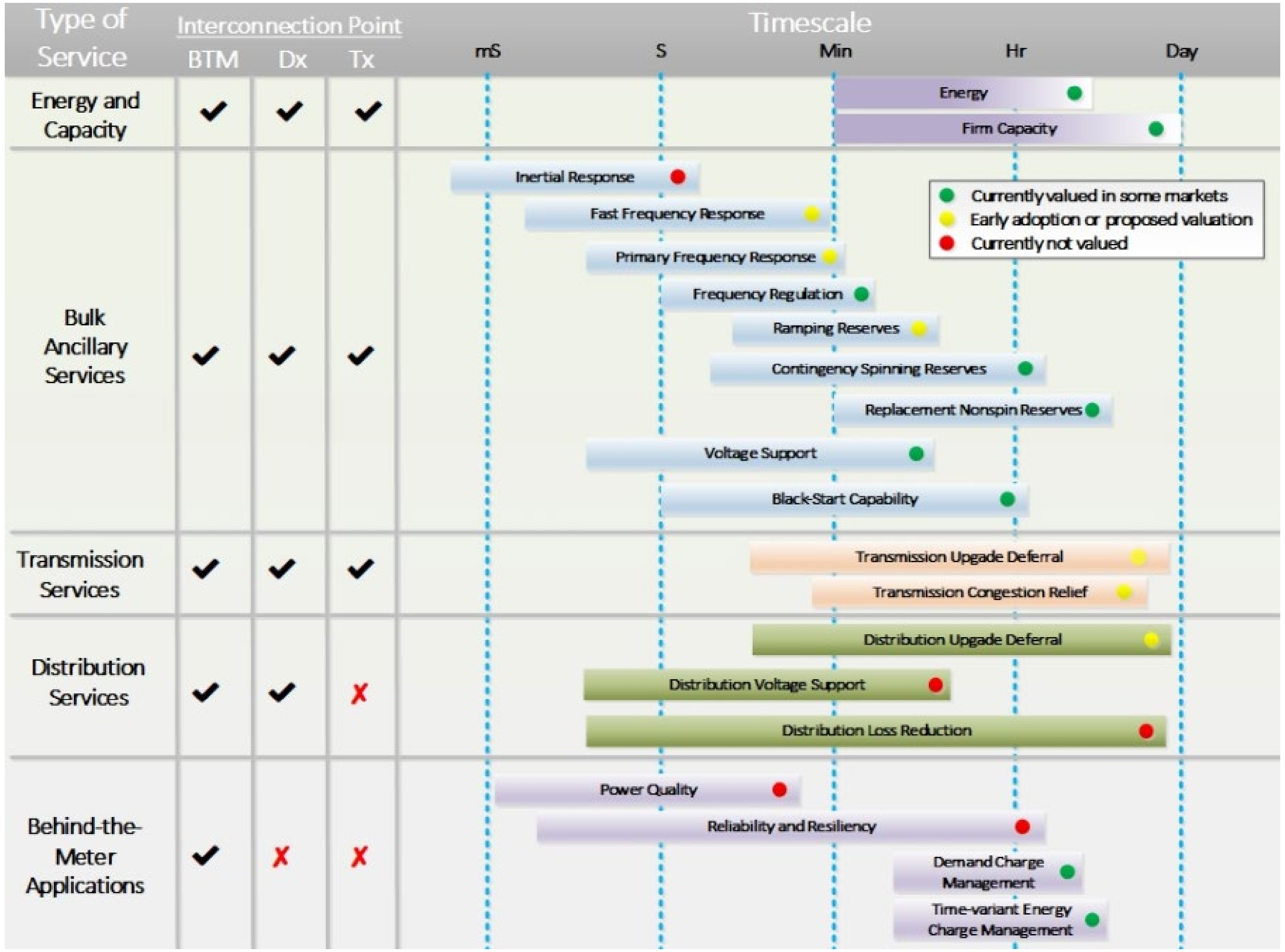
Press Release: U.S. Department of Energy Invests Nearly $8.4 Million to Advance Grid-Enhancing Technologies (GETs) | Department of Energy

Transformational Investments in Grid Scale Energy Storage

Vinod Siberry
General Engineer
DOE Office of Electricity

Grid-Scale Energy Storage Opportunities





Source: An Overview of Behind-the-Meter Solar-Plus-Storage Regulatory Design - Approaches and Case Studies to Inform International Applications (nrel.gov)

OE Storage Supported Project to Analyze ESS to Defer Transmission Investment

- Projected located in Nantucket Island, MA that considered different options that would help maintain reliability during a contingency event that took one of the two existing transmission cables connected to the mainland out of service
- Evaluated adding another submarine cable versus investing in a BESS plus expansion of existing Combustion Turbine Generators to ensure the island could supply 91 MW of energy during a peak day

Figure ES.2. Two Supply Cables connecting Massachusetts to Nantucket Island

Table ES.1. Benefits vs. Revenue Requirements and Energy Costs – Base Case

Element	Benefits	Revenue Requirements and Energy Costs
Capacity	$4,060,124	
Regulation	$18,757,805	
Spin Reserves	$1,195,419	
Volt-VAR/CVR	$80,043	
Outage Mitigation	$12,313,206	
Transmission Deferral	$109,490,163	
Energy Costs		$657,898
Revenue Requirements		$93,264,355
Totals	$145,896,759	$93,922,253

Source: PNNL - Nantucket Island Energy Storage System Assessment

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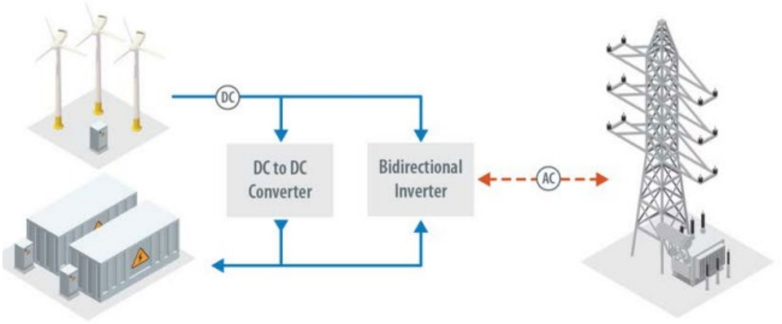
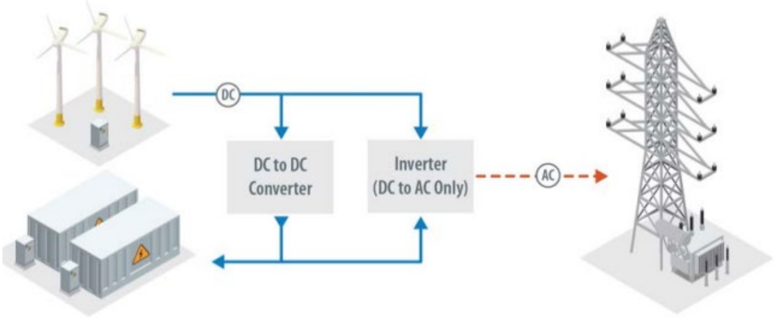
Joint WETO and OE SBIR Topic: Compact Long Duration Storage for Wind

- Motivation: Estimated that by 2035 the amount of wind penetration on the grid will increase from 10% to 30% while the unpredictable and variable nature of wind energy creates challenges to for managing its intermittency to maintain a reliable system.
- Topic: Proof of concept design for an innovative LDES technology that can be either co-located with individual wind turbines, or installed at the wind plant collector station, for either/or both onshore and offshore wind applications. Desired features include but not limited to:
  - > 10 hours of duration
  - > 20 years of lifespan
  - Round Trip Efficiency (RTE) > 70%
  - Scalable cost to meet Long Duration Storage Shot cost targets
  - Compact for co-located design with individual turbines and for offshore wind applications.
  - Lightweight (preferably non-lithium) for offshore wind applications
  - Optional DC couple systems: DC-DC integration of LDES and Wind for power quality control and applications (including overgeneration controls)

Source: FY24 SBIR Phase I Release 2 Topics (osti.gov)





Source: Hybrid Distributed Wind and Battery Energy Storage Systems (nrel.gov)

Use Cases of Interest for LDES

Emerging Opportunities for LDES to play a role in the BPS/Transmission Level

Likely deployment	Potential Market: High RES[1], GW	Potential Market: Aggressive LIB[2], GW	Use case	Application	Key stakeholders (non-exhaustive)	Competitive with LIB today[5]
2022	28 / 28[3]	30 / 30[4]	**Load management services**	Large energy consumers (e.g., distribution centers, industrials) could use LDES to manage demand changes (e.g., freight charging purposes during peak season)	• Large peaking power consumers • Energy services players	
	10 / 10[3]	1 / 1[4]	**Firming for PPAs**	Renewable PPAs can use LDES to ensure that businesses can procure 24/7 renewable electricity	• Leading ESG customers	
	24 / 24[3]	26 / 26[4]	**Microgrid resiliency**	LDES can ensure reliable power in isolated areas or where the grid has shown to be unreliable / insufficient	• Local power authorities • Microgrid developers or integrators	
	157 / 85 / 242	17 / 77 / 94	**Utility resource planning**	Utilities or CCAs can include LDES in integrated long-term energy planning to meet VRE balancing needs	• Vertically integrated & T&D utilities	
	Highly dependent on state regulatory decisions – will be most applicable for multi-day / week LDES		**Transmission and Distribution Deferral**	LDES can offset the need for new transmission and distribution capacity by installing storage in constrained areas	• Utilities • T&D developers • Equity infra investors	
2030+	117 / 101 / 217	18 / 119 / 137	**Energy market participation**	LDES can play a role in shifting electricity from times of high supply to times of high demand, meet system peaks, and provide grid stability (e.g., inertia, frequency regulation)	• RES / T&D developers • Asset owners (IPPs) • Debt investors	

1 Based on demand potential from High Renewables Net-zero 2050 scenario
2 Based on net-zero 2050 scenario with a significant drop in Li-ion CAPEX according to NREL 'optimistic' projections
3 Based on the LDES Council Report use case opportunity sizing and adjusted to meet expected ISO demand
4 Maintains ratio of demand potential relative to sum of Utility resource planning & Energy shifting, capacity provision, and power system stability used in High-RES scenario and applies to Aggressive Li-ion scenario
5 Economic (e.g., IRR for customer) and strategic (e.g., resiliency needs, ESG goals) competitiveness for LDES compared to lithium-ion batteries

Source: NREL (Storage Futures Study: Key Learnings for the Coming Decades), LDES Flagship Report (Net-zero power: Long duration energy storge for a renewable grid)

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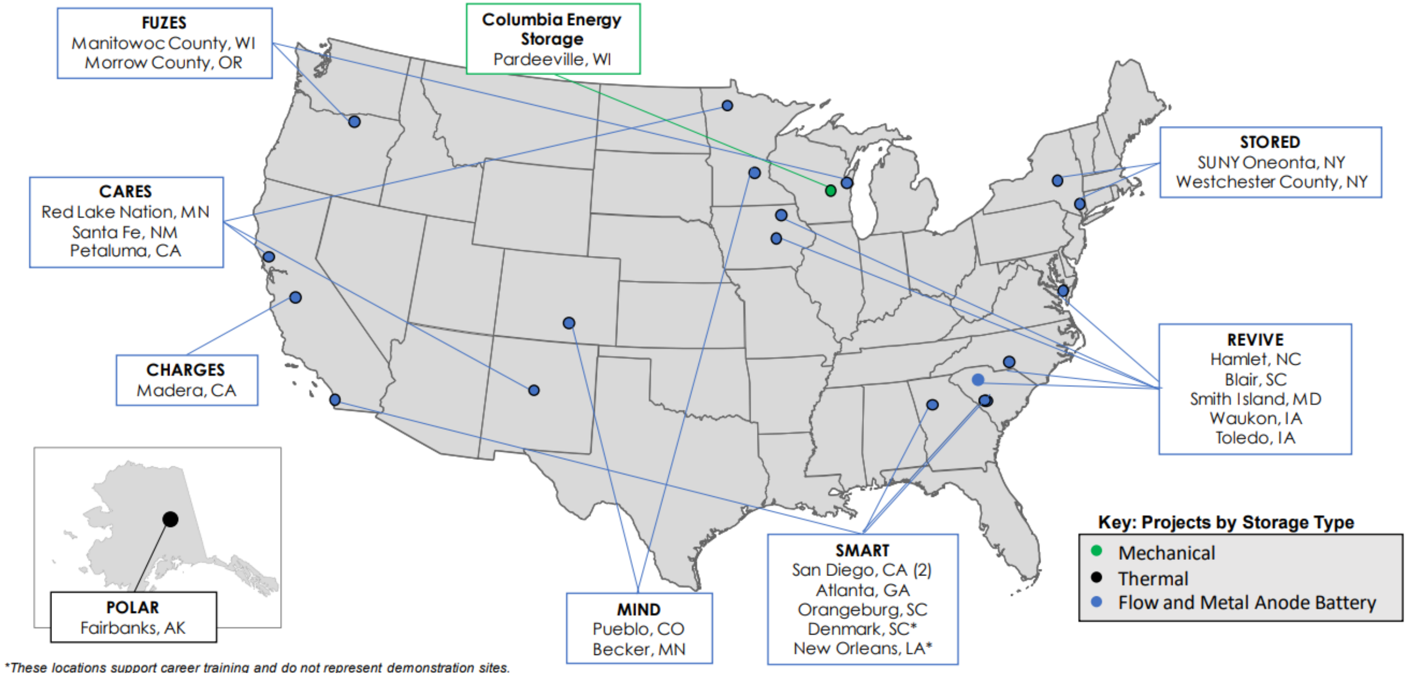
Transformational Investments in LDES Demonstrations

Selected Project Locations - OCED



Source: OCED LDES National Stakeholder Briefing Presentation.pdf (energy.gov)

Selected Project Locations – OE

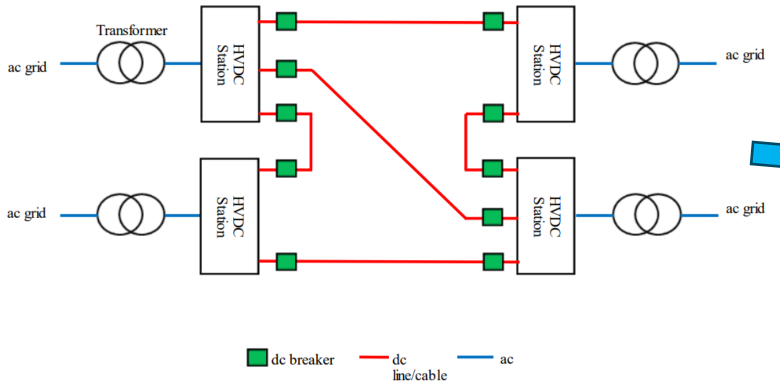
- NOMAD Transportable Power Systems (NOMAD) - Vermont
- Corvias Military Living - Kansas

Source: Energy Department Awards $19 Million for Long-Duration Energy Storage in Remote Communities and Military Housing | Department of Energy

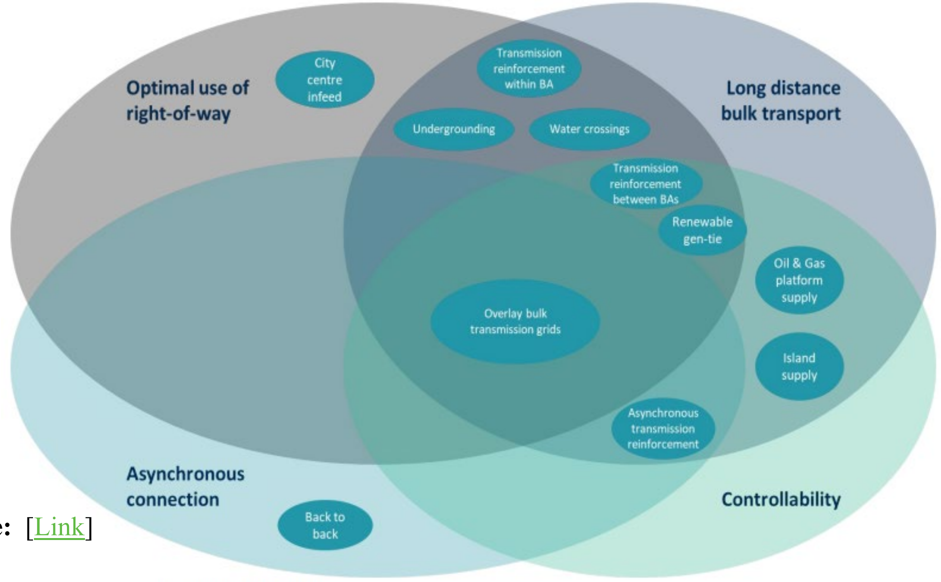
High-Voltage Direct Current Transmission System Technologies

Dr. Emeka Obikwelu
Director of Grid Systems
DOE Office of Electricity

HVDC Transmission System Technologies: Basics to Barriers



Advanced Basics: Example of a Multiterminal HVDC System, with LCC vs VSC contrast.[1]



Source: [Link]

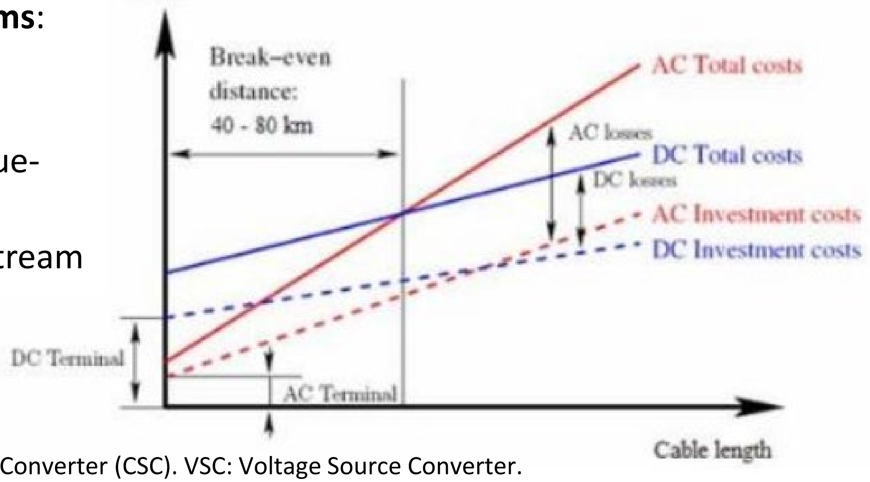
BA = Balancing Area

FOUR broad categories of HVDC Use Cases:

1. Long-distance bulk power transport.
2. Optimized utilization of ROWs.
3. Suitability for connecting asynchronous grids.
4. Controllability.

THREE key value-streams:

1. Technological value-stream.
2. Techno-economic value-stream.
3. Techno-social value-stream



Key barriers to adoption in the U.S.:

1. High upfront costs
2. Complexity
3. Absence of standards
4. Difficult regulatory structure
5. No testing, validation and certification capability.
6. Negligible manufacturing capacity.
7. Weak supply-chain.

[1] LCC: Line Commutated Converter (also, Current Source Converter (CSC). VSC: Voltage Source Converter.

HVDC Transmission System Technologies: What OE is doing.

❑ HVDC COst REduction (CORE) Initiative

- Launched officially in Q4 FY23.
- Enabled by Congressional Direction:

> *“The Department is directed to develop a high voltage direct current (HVDC) moonshot initiative to support research and development to reduce the costs of HVDC technology and long-distance transmission, including for nascent superconducting technology.” –* **House Report to the Consolidated Appropriations Act, 2023**

- **GOAL**: Establish metrics for cost reduction of HVDC technologies and work to achieve those metrics by a given timeframe.
- **PERFORMANCE TARGETS**:

  - Standardize the technology to reduce project-specific design tailoring.
  - Promote interoperability of multi-vendor systems.
  - Increase power density of converters & cables.
  - Develop modular and standard circuit breakers.
- **TARGET METRICS**:

  - Reduce the levelized cost of energy transmitted by HVDC systems by 35% by 2035.
  - Reduce the capital and O&M cost of the: (a) HVDC substation by 35% to $210 MW/kV by 2035. (b) HVDC system with overhead lines by 35% to $1000 MW/mi by 2035. (c) HVDC system with cables by 35% to $4000 MW/mi by 2035

HVDC Transmission System Technologies: What OE is doing.

- ❑ **CORE Initiative: Related Funding Opportunity Announcement (FOA)**
  - Innovative **DE**signs for high perform**A**nce **L**ow-cost VSC-based HVDC FOA (DE-FOA-0003141) - $10 Million
    - Released in Q4 FY23
    - Co-funded with the Wind Energy Technology Office (WETO)
    - Topic area focus:
      - ✓ Power capacity.
      - ✓ Voltage Limit.
      - ✓ Size & Density.
      - ✓ Lifespan & Reliability.
    - Expected Date for Selection Notification is June 2024.
- ❑ **HVDC Prize Awards** - $200K (total)
  - Launched March 2023.
  - Four winners announced in September 2023 - $50K Each
    - Virginia Tech
    - SixPoint Materials, Inc
    - University of South Florida
    - Drexel University

AMERICAN MADE CHALLENGES
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Citations

- An Overview of Behind-the-Meter Solar-Plus-Storage Regulatory Design: https://www.nrel.gov/docs/fy20osti/75283.pdf
- Nantucket Island Energy Storage System Assessment: https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-28941.pdf
- SBIR Topic C58-21:https://science.osti.gov/-/media/sbir/pdf/funding/2024/FY24-Phase-I-Release-2-TopicsV701182024.pdf
- Pathways to Commercial Liftoff: Long Duration Energy Storage: https://liftoff.energy.gov/wp-content/uploads/2023/10/Pathways-to-Commercial-Liftoff-LDES-May-5_UPDATED-v10.pdf
- OCED LDES National Stakeholder Briefing Presentation: https://www.energy.gov/sites/default/files/2023-09/OCED%20LDES%20National%20Stakeholder%20Briefing%20Presentation.pdf