Office of Clean Energy Demonstrations

OCED/2030

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Comments

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Authors

Andrew Dawson, Director, Strategy & Program Development, Office of Clean Energy Demonstrations (OCED)
Katheryn Scott, Principal Strategist, OCED
Michael O'Connor, Strategist, OCED

Acknowledgements

OCED Leadership:

Kelly Cummins,
Acting Director, OCED

Melissa Klembara,
Director, Portfolio Strategy, OCED

Brian Mahar,
Director, Engagement, OCED

Additional Contributors:

Emanuele Pecora,
Senior Manager, OCED

Sara McCoy,
Junior Consultant, InfraSage Group

Collin Stecker,
Science & Technology Policy Fellow, AAAS

Dylan Leazes,
Legislative Affairs Lead, OCED

Connor Stubbs,
Legislative Affairs Specialist, OCED

Christina Walrond,
Senior Adviser, OCED

Daniel Yawitz,
Principal Strategist, OCED

Disclaimers

This report, "OCED 2030", synthesizes insights from research and interviews performed across the Department of Energy on the current and potential future composition of clean energy and industrial technology portfolios at OCED. It also synthesizes insights from market research on clean energy supply and demand projections as well as the competitive landscape for the U.S. industrial and manufacturing base. It is intended to provide the private sector and the American public with a clearer understanding of the types of commercial-scale demonstrations that could have a catalytic impact on U.S. industrial manufacturing competitiveness and global energy markets.

The content herein reflects observations identified by OCED. It should not be interpreted as policy or procedural guidelines, recommendations, or as an investment decision framework that will apply to OCED projects or operations. The insights and perspectives shared in this document aim to enhance transparency and understanding of the long-term strategic value of OCED. They are not representations of OCED's selections, negotiation considerations, or commitments.

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OCED 2030

Executive Summary

The Office of Clean Energy Demonstrations (OCED) was authorized by Congress to fill a recognized gap in the Department of Energy (DOE) research, development, demonstration, and deployment (RDD&D) continuum. OCED partners with the private sector to fund early-of-a-kind commercial scale projects that meaningfully demonstrate operational feasibility and market adoption of emerging technology solutions. These commercial-scale demonstrations serve a range of key energy and industrial subsectors, including technologies for critical energy generation, infrastructure, and industrial manufacturing. The $25+ billion in Federal funding Congress appropriated to OCED has mobilized nearly **$90 billion in total investment** to bring demonstration projects to market. Through these long-term collaborative partnerships, OCED helps position American industry and workers **to drive efficiency, adopt innovative solutions, and capture a large share of the multi-trillion-dollar global energy market**.

This report, **OCED 2030**, seeks to **assess the initial investments** from OCED's prior funding opportunities and incorporate lessons learned to inform **future opportunities** for investment in energy and industrial sectors poised to grow.

This report also incorporates information from existing roadmaps, blueprints, national strategies, and other reports to best understand the current state of the technologic and economic outlook of the energy and industrial sectors in the U.S. economy. It identifies high-priority areas where commercial-scale demonstrations, jointly funded by the private sector, can ensure an affordable, secure domestic energy supply and improve U.S. industrial competitiveness. Based on this analysis, near-term opportunities for high-impact public-private commercial-scale demonstrations include:

- New power generation technologies, such as **advanced nuclear (Gen III+ and Gen IV)** and **next-generation geothermal power** that can enable hundreds of gigawatts of low-cost, firm generation anywhere in the country;
- **Grid reliability and resilience technologies**, such as long-duration energy storage systems, that enable the widespread adoption of a variety of energy sources and uses;
- **Innovative chemicals and alternative fuels** with new, lower-cost processes and feedstocks to continue American leadership and support competition for consumers; and
- **New business models** to let market competition drive business decisions for adopting innovative technologies while providing certainty for investors in new technologies, commodities and markets.

OCED 2030 is **not a budget request** or commitment from DOE to pursue or support any specific opportunity. Rather, this initiative is intended to offer a public and transparent snapshot of the current strategic portfolio and viable, impactful potential opportunities. This assessment may be updated as new information and input is gathered on where Federal investments can be most impactful.

Introduction

Mission & Value

OCED was established by Congress as a multi-technology, large-scale demonstration office. OCED supports technologies in the energy and industrial sectors that are ready for commercial-scale demonstration but are viewed by the private sector as too risky to take on the investment alone. OCED complements private-sector led investments in ways that are not duplicative of available private or public funding in order to buy down the risks associated with the commercialization of early-stage technologies. Through strong and trusted partnerships, OCED helps domestic private sector entities to accelerate commercial-scale energy and industrial demonstrations and drive widespread adoption such that future projects can be financed solely with private sector capital.

OCED serves three major market functions through large-scale demonstrations:

1. **Positions the U.S. to meet the growing demand for secure and reliable energy;**
2. **Supports the innovations necessary for the U.S. to continue as a global leader in manufacturing and industrial processes; and**
3. **Aids innovative technologies and their supply chains in reaching commercial scale in the U.S. to directly benefit American energy and industrial competitive advantage, rather than foreign-owned and deployed.**

OCED helps to position the United States to respond to growing demand for secure, abundant, domestic energy and energy-related infrastructure. Domestic energy demand is expected to grow by ~4% per year[i], largely driven by manufacturing, electrification of transportation and buildings, and data centers to support the growth of artificial intelligence (AI). By enabling the private sector to both scale innovative energy generation technologies, such as solutions for flexible, firm power, as well as expand the market opportunities for renewables and storage technologies, OCED helps forge viable solutions to meet this rapidly growing demand.

OCED supports innovative technologies needed to become competitive in the global market. As global demand for more novel and efficient industrial processes and products increases, there are opportunities for global leadership in those sectors. OCED's portfolio includes both energy and industrial technologies poised to capture the next generation of those markets, including low-emission hydrogen and its use in manufacturing steel and aluminum. OCED provides the capital necessary for development to occur in the United States and to help position United States companies to be dominant players in the new industrial economy and expand into new markets.

OCED supports continued American energy leadership and domestic production. OCED awards American energy companies that take innovative technologies to commercial scale in the United States, advancing U.S. leadership in the energy sector and forging new markets.

OCED's current $25+ billion of Federal funding is catalyzing nearly $65 billion in private capital. OCED directly partners with 22 Fortune 500 companies that represent over $1.4 trillion in annual revenue and employ over 2 million people. OCED's 116 projects span 42 states.[ii] OCED's solicitations overall were oversubscribe by about 400 percent given the unique opportunity to derisk new technologies. OCED also indirectly supports other companies who benefit from OCED's investments that can become central to their business and the energy sector.

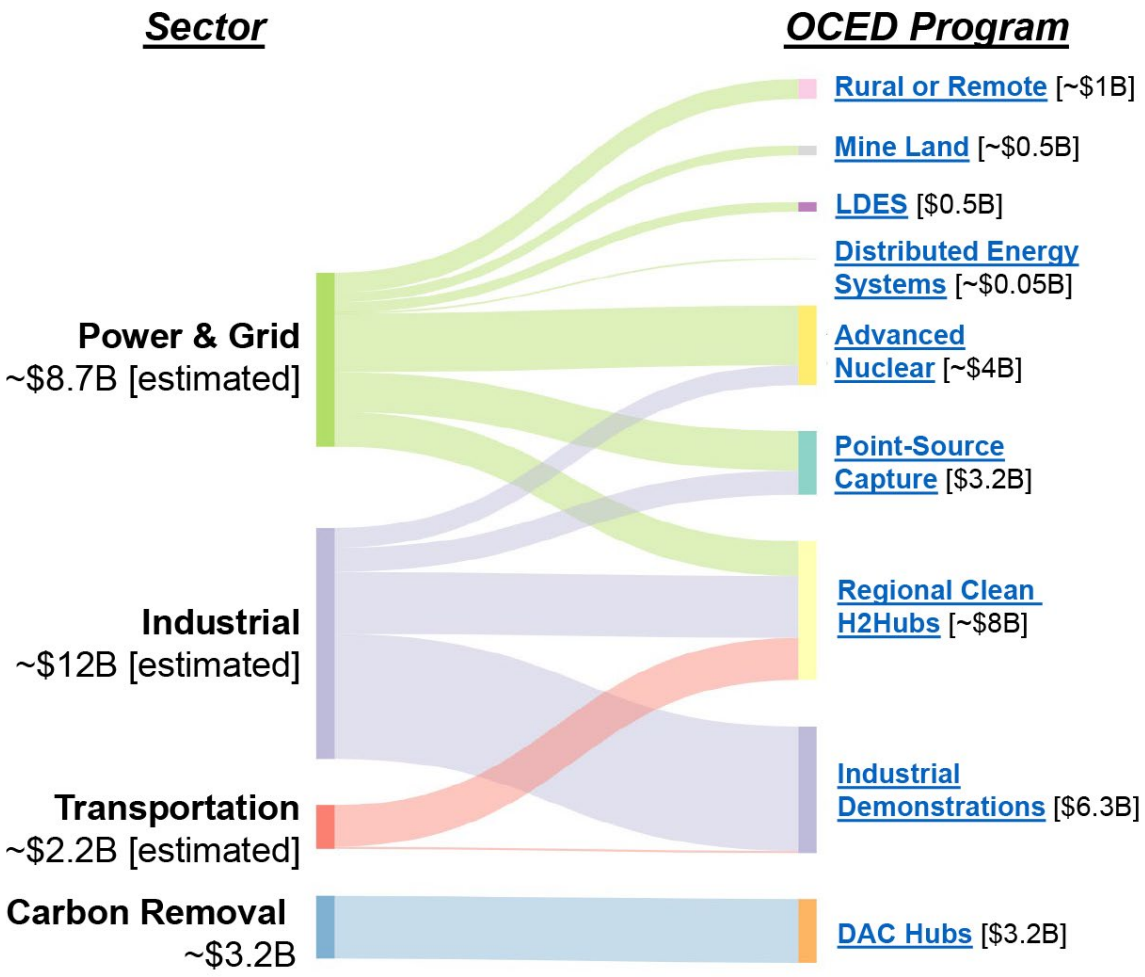
Internal OCED operations are driven by a staff with cross-sector expertise to deliver on OCED's mission. OCED staff have extensive experience across a wide range of skillsets, including engineering, project management, strategy, finance, and stakeholder engagement. Former employers include large industrial operators, utilities, private equity firms and large financial institutions, traditional and emerging technology developers, and a range of other key sectors. This concentration and breadth of expertise enables OCED to strategically award and oversee catalytic projects.

OCED's Current Portfolio

OCED's current portfolio consists of 116 projects across 11 diverse and impactful programs in 4 key sectors (Figure 1). Most of the competitive funding opportunities used to select these programs were significantly oversubscribed (see Figure 9 in **Appendix B**).

Additional investment could expand the scope of work in these areas, spurring faster commercial liftoff. The body of this report focuses on these promising additional opportunities for future consideration.

Figure 1: Approximate OCED Cost Share by Sector & Program

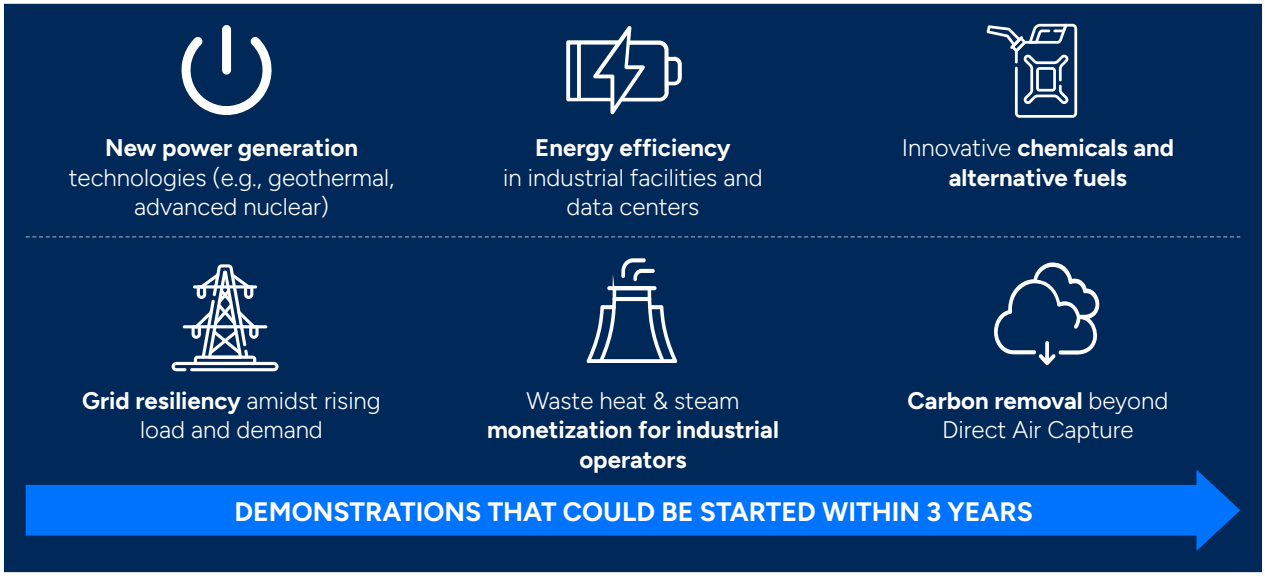


OCED 2030 Opportunity Snapshot

The OCED 2030 analysis yielded a focused list of opportunities for commercial-scale demonstrations that have an outsized opportunity to drive domestic economic growth and jumpstart U.S. leadership in these areas across the next decade. The analysis also identified the range of estimated Federal investment necessary to catalyze private sector involvement and be broadly impactful. The range is not meant to reflect total investment need, but rather to provide clarity on the level of support that could enable sufficient demonstrations to unlock follow-on private-sector investment and market adoption. The resultant opportunities presented are not meant to be exhaustive.

The methodology used to identify the opportunities for OCED 2030 align with three key principles: **1) Commercialization potential; 2) Non-duplication; and 3) Timeliness**. "Commercialization potential" refers to the size of the potential market that would adopt this technology and the amount of support being provided by the private sector. "Non-duplication" refers to the alignment between the activities the private sector needs to see completed successfully and OCED's mission. "Timeliness" refers to both the technical maturity of the technology area (through the "Technology Readiness Level," or TRL) and its current ability to integrate into the market (through the "Adoption Readiness Level," or ARL). Further detail on the methodology used in OCED 2030 can be found in **Appendix A**.

OCED 2030 identified several opportunities to grow the domestic energy and industrial base through catalytic government funding. The opportunities are summarized in the following pages based on the sector impact. Some cross-cutting opportunities appear in multiple sectors. The estimated Federal share of a portfolio of demonstrations in these areas ranges between ~$50 million to several billion dollars. These concepts span key energy sources and energy-demanding sectors, and include demonstrations of:



The full list of near-term opportunities can be found in **Appendix B**.

OCED 2030 also identified 7 opportunities where demonstrations could be catalytic in the longer term (within 4 to 6 years). These opportunites are also identified in **Appendix B**.

Power Generation & Grid

Accelerating domestic growth for the critical foundation of the energy system

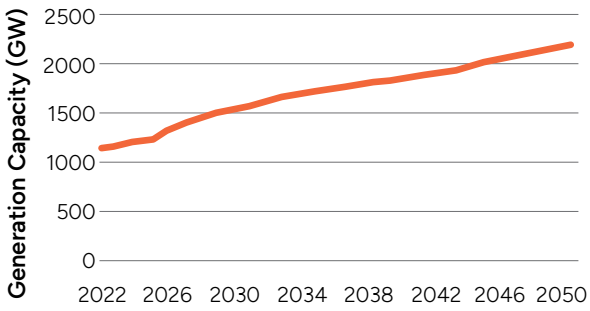


Figure 2: U.S. Electricity Demand Projection in 2023 (Source: EIA)

The United States consumes **more energy to produce electric power than any other use** and the sector currently represents a quarter of all U.S. emissions.[iii] Perhaps more importantly, **the sector is growing rapidly** (Figure 2). In 2023, the Federal Energy Regulatory Commission (FERC) estimated that electricity demand will grow by ~4% annually through 2028. However, the estimates do not include new data center buildout, which in 2023 alone led to **electricity growth forecasts jumping 81 percent**.[i] Electricity-based technologies are also being adopted in other sectors that traditionally used other fuel-based energy sources (such as industrial and transportation) leading to additional electricity need.

OCED Funded Program	Solutions in Program Portfolio	OCED Funding
Clean Energy on Mine Lands	• Solar, hydro, geothermal, battery storage	$500M
Energy Improvements for Rural or Remote Communities	• Solar, wind, small modular hydro, battery usage	$1B
Long Duration Energy Storage & Distributed Energy Systems	• 10hr and 24hr storage solutions • Enhanced grid operational flexibility	$550M
Point Source Carbon Capture	• Carbon capture retrofits on coal and natural gas generation	$2B
Advanced Reactor Demonstration Projects and FY24 GenIII+	• Advanced reactors and GenIII+ • Small Modular Reactors	$3.5B
Clean Regional Hydrogen Hubs	• Hydrogen for power generation	~$2B of 8B

OCED has several programs focused on solutions for clean, reliable electricity generation and delivery. These programs demonstrate carbon capture and storage on power plants, advanced nuclear energy, long-duration energy storage, and microgrids. OCED programs also expand new energy generation and resilience opportunities in rural or remote communities and on current and former mine lands. Near-term opportunities beyond OCED's existing portfolio include:

Opportunity Beyond Existing Portfolio	Rationale for Near-Term Consideration	OCED Funding to Catalyze Liftoff
Next-Generation Geothermal	The world's largest commercial next-generation geothermal project has seen 500% reductions in cost, making it more competitive on a commercial scale. However, limited demonstrations have inhibited the private sector from investing the necessary capital for the industry to scale.[iv] Demonstrations of successful next-generation geothermal power production in 5-10 geographies across the United States would prove the scalability and repeatability of the technology nationwide, and unlock large-scale commercial investment.	**$70M-$1.5B**
Advanced Nuclear Energy Demonstrations	Despite widespread interest in new nuclear technologies from diverse sectors, many potential customers await successful first movers. Demonstrations that absorb risk for first-of-a-kind projects will enable new applications for nuclear power, including both in front of and behind the meter electricity generation, co-generation for industrial process heat, and microreactors for off-grid applications.[v]	**$2B-$12B**
Energy-water Infrastructure for Rural Communities & Farmlands	Rural waterways can be leveraged for new electricity generation, providing reliable affordable power systems that can also reduce water loss. Demonstrations could include run-of-river and conduit hydropower designs that have proven conceptually viable but need at-scale demonstrations to improve confidence, as well as dual-use solar deployment that can limit evaporation on reserviors and aqueducts.	**$250M-$750M**
Grid Reliability, such as Long-Duration Energy Storage	As variable renewables increase due to their low cost, solutions that help ensure resource adequancy and reliable grid operations will become more critical and valuable.[vi, vii] Demostrations would enable a broad portfolio of tools that grid operators could leverage to ensure reliability & resilience. This could include energy storage, operational flexibility, grid systems, and similar technologies.	**$250M-$1B**
Offshore Wind (fixed bottom & floating)	Demonstrations could unlock new foundation technologies in different ground conditions (e.g., suction buckets) or demonstrate project constructability in areas with unique technology/logistics constraints (e.g., Great Lakes region). Demonstrations could also unlock new floating platform designs, and de-risk floating wind deployments planned for the 2030s across the United States.[viii]	**$250M-$3B**

Longer-term opportunities also include advancements in point-source carbon capture at power generation facilities, particularly with the ability to operate flexibly for grid resilience. OCED currently has multiple open funding opportunities in this area, and a more refined understanding of the out-year needs in this sector will be available upon the closing of these opportunities.

Industrial

Supporting innovation at the core of domestic manufacturing

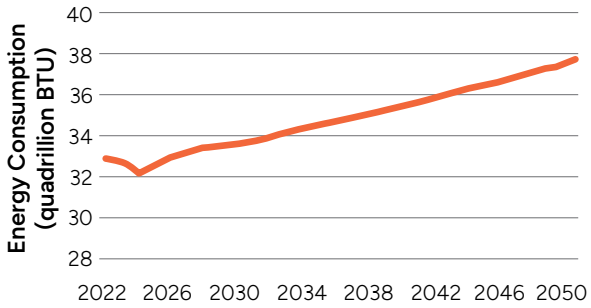


Figure 3: Projected U.S. energy demand in the industrial sector in 2023 (Source: EIA)

The U.S. industrial sector makes products and materials that Americans rely upon and many of these products are both energy-intensive to produce and essential for energy production and the economy. This sector is growing for the first time in decades, as is the energy it is expected to consume (Figure 3).

While industrial products are essential, **many facilities in the U.S. were built over 100 years ago and have not adopted best-in-class or next-generation processes** that can improve facility economics and reduce health-harming emissions like nitrogen oxides, sulfur oxides, and carbon monoxide. DOE has mapped opportunities across eight industrial sectors of focus including sectors with current and historic U.S. leadership: chemicals, refining, iron & steel, food & beverage processing, pulp & paper, cement, aluminum, and glass.

Current OCED projects demonstrate novel solutions both for industrial processes themselves (such as electrification, energy efficiency, and alternative methods) and for the energy those processes need (such as fuel substitutions). These opportunities include:

OCED Funded Program	Solutions in Program Portfolio	OCED Funding
Industrial Demonstrations	• Broad program pursuing all major technology solutions across multiple industries • Chemicals, refining, food & beverage, pulp & paper have less investment	$6B
Point Source Carbon Capture	• Cement, pulp & paper, and refining projects	$1B of $3.2B
Clean Regional Hydrogen Hubs	• Certain hubs include industrial partners: chemicals, refining and steel	~$1B of $8B
Advanced Reactor Demonstration Projects and FY24 GenIII+	• Nuclear energy for industrial offtaker	$1B of $3.5B

Opportunity Beyond Existing Portfolio	Rationale for Near-Term Consideration	OCED Funding to Catalyze Liftoff
Expanded Portfolio of Chemical and Refining Demonstrations	Chemicals and refining are a major driver of industrial activity and are underrepresented in current demonstration portfolio. There is potential to focus a follow-on effort on this subsector and align a solicitation with the relevant industry demonstration needs.[ix]	**$200M-$1B**
Alternative Liquid Fuels (*see Transportation*)	Pilot programs for new sustainable fuel production technologies, such as Power-to-Liquid or Alcohol-to-Jet technologies, are currently underway across the United States;[x] OCED's support of commercial demonstration projects would accelerate the market uptake in the United States or in export markets. Additionally, commercial demonstrations are needed for converting biomass feedstocks into drop in replacement fuels to show improved performance and reduced costs.	**$200M-$1B**
Data Center Efficiency Demonstrations	Data center buildout exceeds the growth rate of any other industrial sector, and their energy consumption is creating a surge in electricity demand that is resulting in increased costs for energy. Demonstrations can unlock efficient designs for cooling that can reduce data center energy use and cost. Demonstrations can also highlight how strategic siting of data center locations can reduce grid demand and keep costs low.	**$100M-$1B**
Sale of Commercial Heat or Steam	Heat or steam is required in all industries and novel heat sources can be monetized by being sold to industrial facilities. Third-party provider business models enable heat users (such as food and beverage, pulp and paper, or chemicals manufacturers) to purchase heat from innovative processes. Demonstrations would validate and expand this business model.[xi]	**$75M-$500M**

Longer-term industrial opportunities (4-6 years) are included in **Appendix B**. Due to the substantial over-subscription in the Industrial Demonstrations Program, a key opportunity is a second round of demonstrations as industry continues to pilot new technologies. For example, a suite of novel and potentially highly-impactful techologies for the industrials sector are currently being developed across DOE R&D programs like Applied R&D offices such as EERE's IEDO, ARPA-E, and the National Labs. Additionally, support for procurement of clean industrial products, such as cement, steel, and aluminum, can catalyze further market development. Upon private-sector partnership for these technologies and further technological development, OCED would be well positioned to support the demonstration of these approaches.

Transportation

Cost-effective, efficient, alternative liquid fuels for transport across land, water, and air

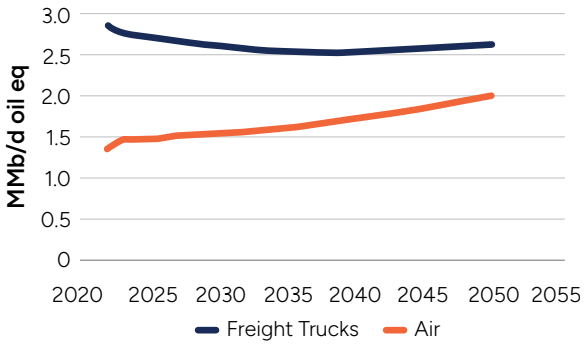


Figure 4: Projected transportation energy demand for freight and air in 2023 (source: EIA)

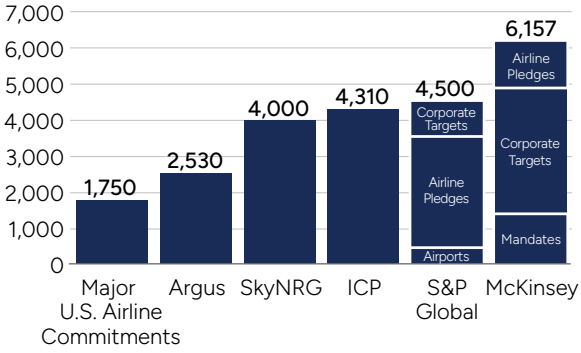


Figure 5: Projected demand for Sustainable Aviation Fuels[x]

Transportation is required for economic activity and development and covers light, medium, and heavy-duty transportation. After a reduction during COVID-19, transportation activity has returned to near pre-pandemic levels and energy demand for both air travel and heavy-duty trucks is expected to grow through 2050 (Figure 4).[xii] Currently, more than 90% of transportation energy comes from petroleum-based fuels and is responsible for more than 70% of the total U.S. petroleum consumption, making it the least energy-diverse sector and the sector most exposed to the volatility of global oil prices.[xiii] However, the demand for alternative fuels is rising (Figure 5), due to a combination of corporate commitments and mandates.[xiv]

OCED does not invest in technology areas that are already commercially viable, such as light-duty vehicles, or individual vehicle components. Rather, **OCED is focused on demonstrating the technologies and systems that can produce and deliver alternative aviation, marine, and heavy-duty trucking fuels in growing global demand.**[x]

OCED can also demonstrate fleet scale deployments of new vehicles. For example, OCED's Clean Hydrogen Hubs program includes major investments in hydrogen fueled heavy duty vehicles, helping to build out bus and truck fleets that leverage hydrogen as an alternative fuel for medium and heavy-duty vehicles, airplanes, and marine vessels.

OCED Funded Program	Solutions in Program Portfolio	OCED Funding
Clean Regional Hydrogen Hubs	• Medium- and heavy-duty transportation is a primary use case for clean hydrogen	$2B of $8B
Industrial Demonstrations	• eMethanol for shipping	$100M of $6B

Near-term opportunities to demonstrate innovative transportation technologies include:

Opportunity Beyond Existing Portfolio	Rationale for Near-Term Consideration	OCED Funding to Catalyze Liftoff
Alternative Liquid Fuels (*see Industrial*)	Pilot programs for new sustainable fuel production technologies, such as Power-to-Liquid or Alcohol-to-Jet technologies, are currently underway across the United States; OCED's support of commercial demonstration projects would accelerate the market uptake in the United States or in export markets. Additionally, commercial demonstrations are needed for converting biomass feedstocks into drop in replacement fuels to show improved performance and reduced costs.	**$200M-$1B**
Zero-carbon infrastructure for ports and shipping	Ports and waterfronts will be increasingly expected to accommodate vessels leveraging alternative fuel sources and electricity. Demonstrations of scaled production, supply chain and infrastructure of low carbon maritime fuels, and renewable generation and high speed, long-duration storage to advance electrification can ensure US ports can accommodate changing fueling landscapes.	**$150M-$500M**
Power Generation & Grid (*see all concepts in that section*)	Demonstrations of new low-cost electricity generation and delivery systems ensure that loads induced by increased electrification can be met.	**$70M-$3B**

Carbon Dioxide Removal (CDR)

A suite of technologies to remove emissions for new and existing global markets

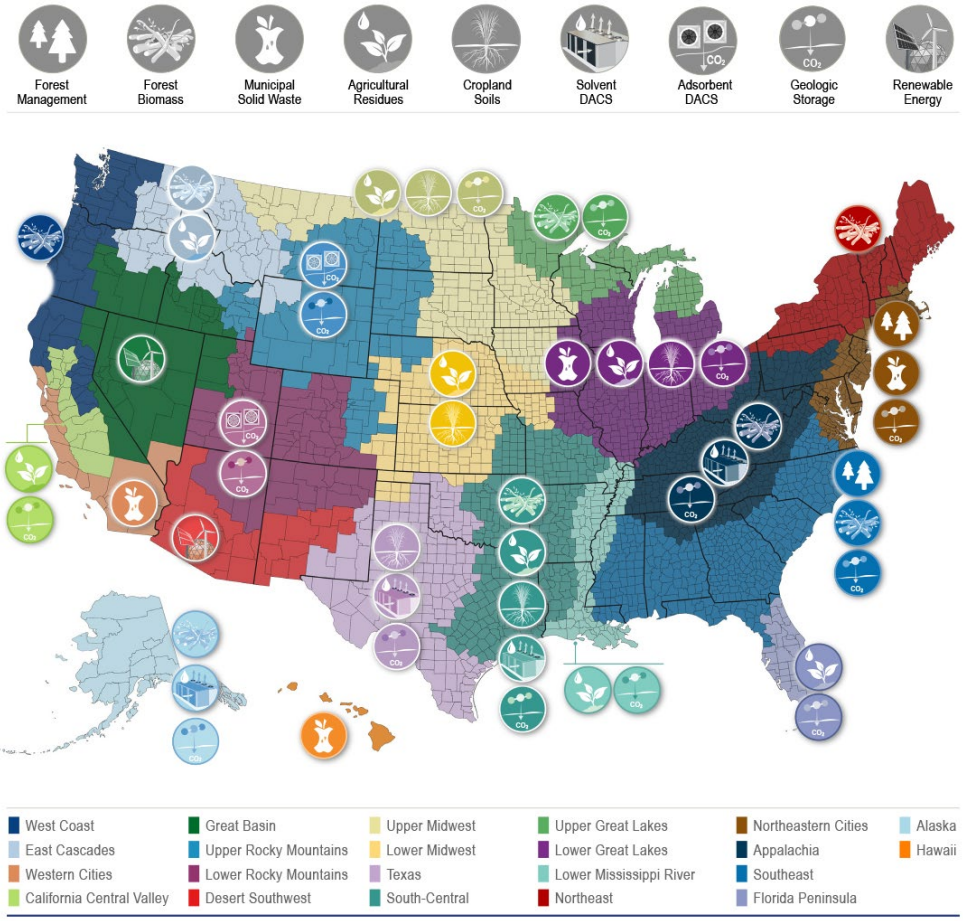


Figure 6: Options for Carbon Dioxide Removal in the U.S. (Source: Lawrence Livermore National Laboratory)

Private sector investment in CDR methods has grown significantly in recent years, and the U.S. is positioned to become a global leader in the supply of carbon removal services and technologies. Diverse energy and feedstock resources, expertise and skilled labor, favorable storage geology, and investment capital and incentives create a competitive advantage for scaling CDR. Each region has unique resources and advantages, making CDR a nationwide opportunity (Figure 6). The potential domestic economic benefit is evident by looking at the emerging direct air capture (DAC) industry in the U.S., which is home to over half of all the DAC companies in the world and which builds on unique U.S. expertise in drilling, pipelines, and sequestration.[xv]

Today, markets for CDR are driven by both the sale of carbon removal credits to global industries like large technology companies, oil and gas multinationals, and aviation and the integration of captured carbon into lower-emissions fuels and products. Some CDR methods also co-produce valuable resources like hydrogen, water, and electricity, and can leverage existing industries like oil and gas, pulp and paper, wastewater treatment, and mining. If sufficiently scaled, some CDR methods can also help balance ocean acidification over time.

OCED Funded Program	Solutions in Program Portfolio	OCED Funding
Regional DAC Hubs	• Engineered solutions to capture and store atmosphere CO_2	$3.5B

New technologies and private sector investment has grown consistently in recent years leading to the first deployments of CDR. Demonstrating these novel technologies can build out OCED's CDR portfolio to include approaches with complementary tradeoffs related to cost, energy needs, land and water use, storage medium, scalability, and measurement, among other factors. These opportunities include:

Opportunity Beyond Existing Portfolio	Rationale for Near-Term Consideration	OCED Funding to Catalyze Liftoff
Biomass Carbon Removal (BiCRS)	Several carbon removal methods based on sustainable biomass are at or nearing demonstrations readiness. Some methods use pyrolysis or gasification to co-produce electricity, hydrogen, and/or gaseous carbon dioxide suitable for storage or utilization in fuels or products.	**$50M-$500M**
Carbon Mineralization/ Enhanced Rock Weathering	Mined alkaline minerals (e.g., tailings) and subsurface formations (e.g., basalts) represent untapped resources for capture end/or storage of atmospheric CO_2. Startups and established mining companies are currently piloting a variety of technologies and business models in this area.	**$50M-$500M**
Direct Ocean Capture (DOC)	Various carbon removal methods for removing dissolved inorganic carbon from oceans or other water are at or nearing demonstration readiness. Opportunities exist to pair with desalination operations and offshore oil and gas assets. DOC options include storage in seawater as dissolved carbonates or on land as solid carbonates.	**$50M-$500M**

Over the longer term, additional CDR methods that are currently at earlier TRL stages will likely be candidates for large-scale commercial demonstrations, including new variations on DAC, ocean, biomass, and weathering/mineral pathways, and emerging techniques to manage atmospheric levels of methane.

Commercial & Residential Buildings

Technological and operational advancements that lower consumer costs while managing grid load

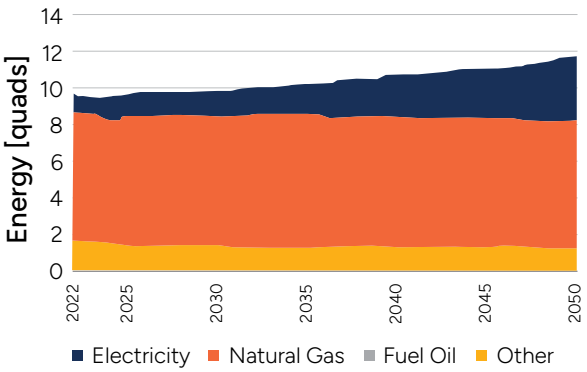


Figure 7: Projected energy demand for buildings as of 2023 (source: EIA)

Combined, commercial and residential buildings consume **27 percent of U.S. energy**. Many buildings have on-site combustion of natural gas and other fuels primarily for space & water heating. Although electricity use in buildings is currently small in comparison (~18%), **this sub-sector is growing rapidly due to rising demand for air conditioning and advanced computing resources** (Figure 7). By midcentury, electricity will account for **an estimated one-third of total energy consumption in buildings.** Innovation in building technology can lower utility costs, support more consistent and reliable systems, create safer environments, and optimize building space and infrastructure.[xvi]

OCED Funded Program	Solutions in Program Portfolio	OCED Funding
Energy Improvements in Rural or Remote Areas	• Some selections focused on the electrification of building heating and cooling	$100M of 1B
Distributed Energy Systems	• Enhanced operational flexibility for the distribution system • Buildings as a system and/or service	$50M

The small, modular, and distributed nature of many of the most impactful building solutions, such as more efficient appliances, smart meters, and heat pumps makes them relatively mismatched with the large-dollar, commercial-scale demonstration mission and expertise central to OCED, although a limited set of commercial and residential-specific opportunities exist. Notably, successful demonstrations in other key sectors, particularly electric power and industrial, could have direct and meaningful impacts on this sector as well. Key opportunities include:

Opportunity Beyond Existing Portfolio	Rationale for Near-Term Consideration	OCED Funding to Catalyze Liftoff
District Energy Systems	The networking of the HVAC infrastructure among nearby buildings can create massive operational efficiencies, particularly when coupled with shallow geothermal heat pumps, and dramatically reduce emissions and homeowner energy cost. Demonstrations are necessary to overcome high early capital investment and establish new business models to incentivize networking.	$100M-$1B
Power Generation and Grid (*see all concepts in that section*)	Electricity system advances can indirectly affect much of the commercial & residential sector as well.	$70M-$12B
Sale of Commercial Heat or Steam	Commercial & residential buildings are primary users of low temperature heat, which "Heat as a Service" business models can deliver. Demonstrations can show how industrial waste heat can be integrated into commercial & residential buildings at low cost. *See Industrial.*	$75M-$500M

Selected Issue Areas

The following Selected Issue Areas describe opportunities for multiple existing OCED programs and potential future demonstrations to address a specific challenge or opportunity. Two examples are included in this initial OCED 2030 report: Electricity Load Growth and Working Waterfronts. Load Growth was identified as a key trend affecting U.S. energy requiring a cross-cutting approach. Working Waterfronts was selected to illustrate cross-sector opportunities that may create synergies for infrastructure and energy investment at specific sites, facilities, communities and/or regions. OCED may include other issue areas in future report revisions and as similar cross-cutting demonstration opportunities emerge.

Electricity Load Growth

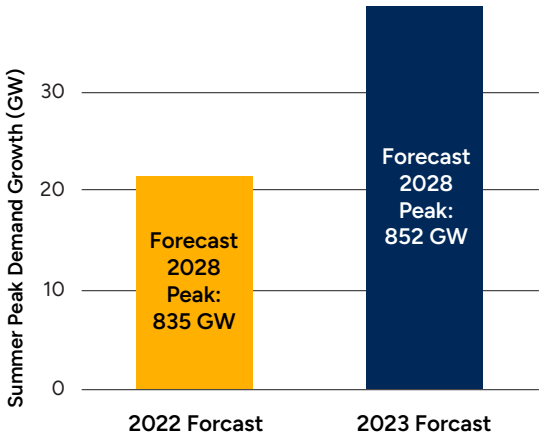


Figure 8: 5-year nationwide load growth forecast[i]

The United States is returning to a period of rapid electricity demand growth (Figure 8). Electricity demand is **expected to grow ~15-20% in the next decade and could double by 2050**.[xvii] Much of this growth is driven by the relatively rapid rise of new, large, and constant electricity loads for new manufacturing and industrial plants and AI data centers. While the American energy system has addressed similar levels of growth in the past, growing the energy system, ensuring long-term resources, and reducing electricity system emissions presents a novel challenge.

DOE estimates that 700 to 900 *new* gigawatts of firm power must be added to the grid, as well as a **terawatt or more of long-duration energy storage capacity**, to meet the load growth expected nationwide by 2035. OCED currently supports three technical areas that could support the development of these needed resources: carbon capture and storage on power plants, advanced nuclear energy, and long-duration energy storage. Additionally, its place-based program devoted to clean energy deployment on current or former mine land is demonstrating long-duration energy storage opportunities that can also support load growth. Beyond these, three opportunities outlined in OCED 2030 can also directly assist American utilities and large energy users in securing reliable, low-cost electricity being demanded in the near term.

OCED Funded Program	Solutions in Program Portfolio	OCED Funding
ARDP and FY24 GenIII+	• Advanced reactors and GenIII+ Small Modular Reactors	$3.5B
Point Source Carbon Capture	• Coal and natural gas power generation	$2B of $3.2B
Long Duration Energy Storage & Distributed Energy Systems	• 10hr and 24hr storage solutions • Enhanced grid operational flexibility	$550M

Opportunity Beyond Existing Portfolio	Rationale for Near-Term Consideration	OCED Funding to Catalyze Liftoff
Next-Generation Geothermal	The world's largest commercial next-generation geothermal project has seen 500% reductions in cost, making it more competitive on a commercial scale. However, limited demonstrations have inhibited the private sector from investing the necessary capital for the industry to scale. Demonstration portfolio would prove the scalability of this technology across an array of 5–10 geographies and the technologies value across the U.S.	$70M-$1.5B
Advanced Nuclear Energy Demonstrations	Despite widespread interest in new nuclear technologies from diverse sectors, potential customers await successful first movers Demonstrations that absorb risk for first-of-a-kind projects can enable new applications for nuclear power, including both in front of and behind the meter electricity generation, co-generation for industrial process heat, and microreactors for off-grid applications.	$2B-$12B
Grid Reliability, Such as Long Duration Energy Storage	As variable renewables increase due to their low cost, solutions that help ensure resource adequacy and reliable grid operations will become more critical and valuable. Demonstrations would enable a broad portfolio of tools that grid operators could leverage to ensure reliability & resilience. This could include energy storage, operation flexibility, grid systems, and similar.	$250M-$1B

Working Waterfronts

Nearly 40% of America's population lives in coastal counties, and America's waterfronts are a critical component of our economy.[xviii] **Global emissions from shipping are anticipated to grow 50-250% by 2050** if status quo remains, and as the shipping industry explores alternative maritime fuels, it is important for the U.S. to stay at the cutting edge to maintain competitiveness.[xix] Emerging alternative fuel candidates, including methanol and ammonia, face infrastructure and supply chain challenges that could benefit from the demonstration and scaling of new technologies.

Challenges in generating and distributing increased load to ports with already congested grids are a pressing concern. **Coastal communities have the potential to help supply additional capacity and bolster their own energy resilience by harnessing vast renewable resources via marine energy or offshore wind energy, combined with energy storage systems on shore.** For example, current pilot demonstrations of wave energy converters could be scaled at OCED to demonstrate the commercial potential of wave energy as a clean firm generation source.

Over $500M was mobilized via the Grid Deployment Office's Maintaining and Enhancing Hydroelectricity Incentives program to support America's critical hydropower resources. Still, there are further opportunities for demonstrating technical and non-technical solutions that could mobilize 85 GW of pumped hydro storage projects, realize an additional 20GW of hydropower generation and ensure that the 40GW of our hydropower fleet up for relicensing does not go offline and convert non-powered dams to generate hydropower.[xx]

Opportunities for commercial-scale demonstrations in the next five years include:

Opportunity Beyond Existing Portfolio	Rationale for Near-Term Consideration	OCED Funding to Catalyze Liftoff
Zero carbon infrastructure for ports and shipping	Ports and waterfronts will be increasingly expected to accommodate vessels leveraging alternative fuel sources and electricity. Demonstrations of scaled production, supply chain and infrastructure of low carbon maritime fuels, and renewable generation and high speed, long-duration storage to advance electrification can ensure U.S. ports can accommodate changing fueling landscapes.	**$100M-$2B**
Fixed-bottom and floating offshore wind	Demonstrations could unlock new foundation technologies in different ground conditions (e.g., suction buckets) or demonstrate project constructability in areas with unique technology/logistics constraints (e.g., Great Lakes region). Demonstrations could also unlock new floating platform designs, and de-risk floating wind deployments planned for the 2030s across the United States.	**$250M-$3B**
Wave and tidal energy demonstrations	Many promising wave and tidal energy technology approaches are being developed and tested at lab or small pilot scales. Demonstrations of those most promising technology approaches at commercial scale can allow us to tap into an enormous, continuous reservoir of wave energy.[xxi]	**$200M-$1B**
Hydropower expansion	Demonstrations of novel finance consortia are needed to realize additional pumped hydrostorage capacity, maintain hydropower projects up for relicensing, and convert non-powered dams to produce hydropower.	**$100M-500M**

Appendix A: Methodology

OCED 2030 was designed collaboratively with OCED's Portfolio Strategy Division coordinating internal and external input from industry, academia, non-profits, government entities, and other key information sources and partners. Information sources include but are not limited to reports, market assessments, strategic plans, and vision documents authored both by Government and non-Government sources. OCED also leverages insights from existing investments and information from Requests for Information (RFIs).

Opportunity Assessment

OCED 2030 considers three high-level categories to evaluate the readiness of an opportunity: commercialization potential, non-duplication, and timeliness.

Commercialization Potential

Three concepts comprise commercialization potential:

1. **Opportunity Space**: Assesses the portion of emissions or other environmental impacts that could be resolved by the commercialization of this sector, the size and trajectory of the potential market, and the strategic value to national competitiveness. Opportunity space has many metrics, including:
   a. Target sector/subsector energy use
   b. Target sector/subsector emissions
   c. Subsector market potential
   d. Share of global market
2. **Existing Coverage**: Assesses the degree to which an opportunity can be additive to, rather than duplicative of, the substantial portfolio of public-private investments OCED is already engaged in. This includes assessments of the sufficiency and intended impact of current and planned future investments, including the degree to which funding opportunities in current investment areas were oversubscribed (Figure 9) as denoted through project selections, Notices of Intent, Requests for Information, and Notices of Funding Opportunity, as well as the status of those investments. Metrics to measure existing coverage includes investment intensity, project counts, internal Program Design Documents and programmatic Theories of Change, and portfolio timelines.

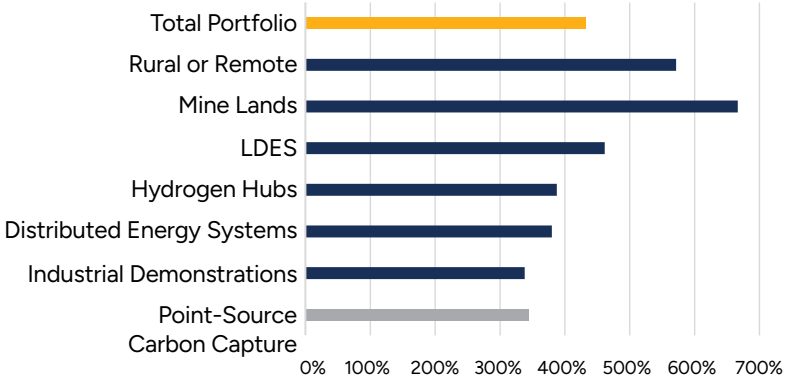


Figure 9: Degree to which current OCED portfolio areas were oversubscribed when announcements were issued.

3. **Sector Trends & Trajectory**: Assesses how the sector broadly is consuming and producing energy including if the sector is already pursuing innovative energy technology approaches as measured by interest in existing OCED funding solicitations (see Figure 9) and other public market analysis products. This criteria also assesses the impact OCED funding could have on that trajectory. Metrics include tracking sector-wide balance sheet capital invested, external capital invested, and Weighted Average Cost of Capital (WACC).

Non-Duplication

Non-duplication describes how well aligned various opportunities are with the mission and core competencies of OCED, when compared to other offices within DOE, as well as the private sector. Non-duplicative opportunities include industries that would primarily benefit from support to de-risk design, construction, or initial operation of a portfolio of large-scale demonstration projects ranging from tens of million to several billion dollars. This support can take many forms, including:

- Financial assistance wherein OCED provides capital to recipients to design, develop, construct, and operate early-of-a-kind clean energy infrastructure projects.
- Demand, revenue, and other early operations-phase support targeted to de-risk the project for commercial investors.
- Targeted support for the broader clean energy ecosystem through prizes, vouchers, consortiums, tools, or other support structures that can address industry-wide commercial adoption challenges and enable the long-term success of OCED demonstration projects.

OCED portfolio areas generally should directly benefit from the systems engineering, project management, and project finance competencies that OCED staff provide. This assessment is qualitative and determined through inter-agency discussions and analyses.

Timeliness

Timeliness assesses if a technology is ready for large-dollar demonstration funding, and the likelihood that a market could develop for the technology or the products the technology creates. Timeliness has two components: **technology** readiness and **adoption** readiness. The relationship between Technology Readiness Level and Adoption Readiness level can be seen in Figure 10 and can be further described here. Although not an explicit rule, projects best-suited for OCED capabilities tend to have moderate technology readiness and low to moderate adoption readiness.

1. **Technology Readiness**: Assesses if solutions exist at a sufficient level of maturity for large-scale demonstrations to be feasible and valuable. Technology readiness is assessed using "Technology Readiness Level" (TRL)[xxii]; TRL between 6 and 8 can generally be viable for OCED.
2. **Adoption Readiness** Assesses if we have a clear understanding of major challenges to market adoption of the technology solution, and if these challenges be addressed through large-scale demonstrations or other OCED programs. Adoption readiness is assessed using "Adoption Readiness Level" (ARL), which has four core risk areas that range from "low" to "high":
   a. Value proposition
   b. Market acceptance
   c. Resource maturity
   d. License to operate

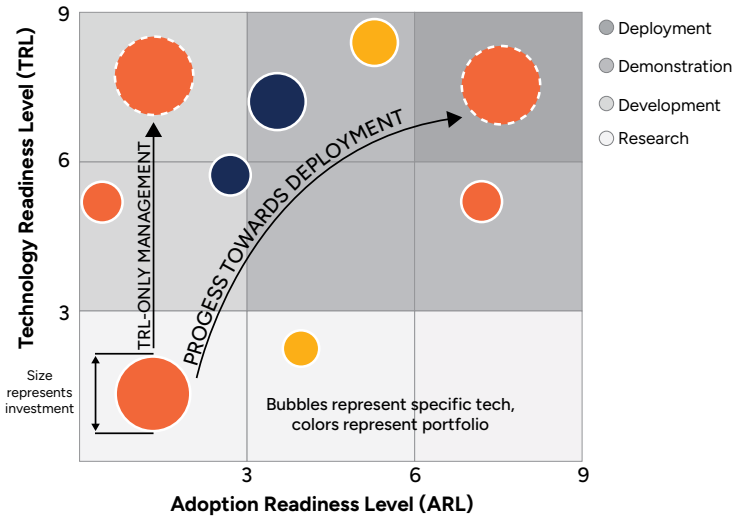


Figure 10: Relationship between ARL and TRL

Opportunities with a "low" to "moderate" ARL can be considered viable for OCED.

Appendix B: Opportunity List

Sector	Opportunity Type	Ideal Launch Timeframe	Federal Share of Viable Portfolio [$M]
Power Generation & Grid	Next-generation geothermal	0 – 3 years	$70 - 1,500
	Advanced nuclear energy demonstrations	0 – 3 years	$2,000 - 12,000
	Energy-water infrastructure for rural communities & farmlands	0 – 3 years	$250 - 750
	Grid reliability, such as long-duration energy storage	0 – 3 years	$250 - 1,000
	Offshore wind (fixed-bottom & floating)	0 – 3 years	$250 - 3,000
	Circular economy for clean energy technologies	4 – 6 years	$100 - 500
	Marine & tidal energy demonstrations	4 – 6 years	$100 - $1,000
	Flexibly-enabled carbon capture systems on power plants	4 – 6 years	$500 - 3,000
	Fusion milestone-based program	10+ years	$5,000 - 15,000
Industrial	Expanded portfolio of chemical and refining demonstrations	0 – 3 years	$200 - 1,000
	Alternative liquid fuels production *see Transportation*	0 – 3 years	$200 - 1,000
	Data Center Efficiency Demonstrations	0 – 3 years	$100-$1,000
	Sale of commercial heat or steam *see Buildings*	0 – 3 years	$75 - 500
	Second round of Industrial Demonstrations Program	4 – 6 years	$2,000 - 5,000
	Support for procurement of clean industrial products	4 – 6 years	$100 - 1,000 per sector
Transportation	Alternative liquid fuels production *see Industrial*	0 – 3 years	$200 - 1,000
	Zero-carbon infrastructure for ports and shipping	0 – 6 years	$150 - 1,000
	Power generation & delivery *see all concepts in Power Generation & Grid*	0 – 6 years	$70 - 3,000

Sector	Opportunity Type	Ideal Launch Timeframe	Federal Share of Viable Portfolio [$M]
Carbon Dioxide Removal	Biomass carbon removal (BiCRS)	0 – 3 years	$50 - 500
	Carbon mineralization/enhanced rock weathering	0 – 3 years	$50 - 500
	Direct ocean capture (DOC)	0 – 3 years	$50 - 500
Commercial & Residential Buildings	District energy systems	0 – 3 years	$100 - 1,000
	Power generation and delivery see all concepts in *Power Generation & Grid*	0 – 6 years	$70 - 12,000
	Sale of commercial heat or steam *see Industrial*	0 – 3 years	$75 - 500

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