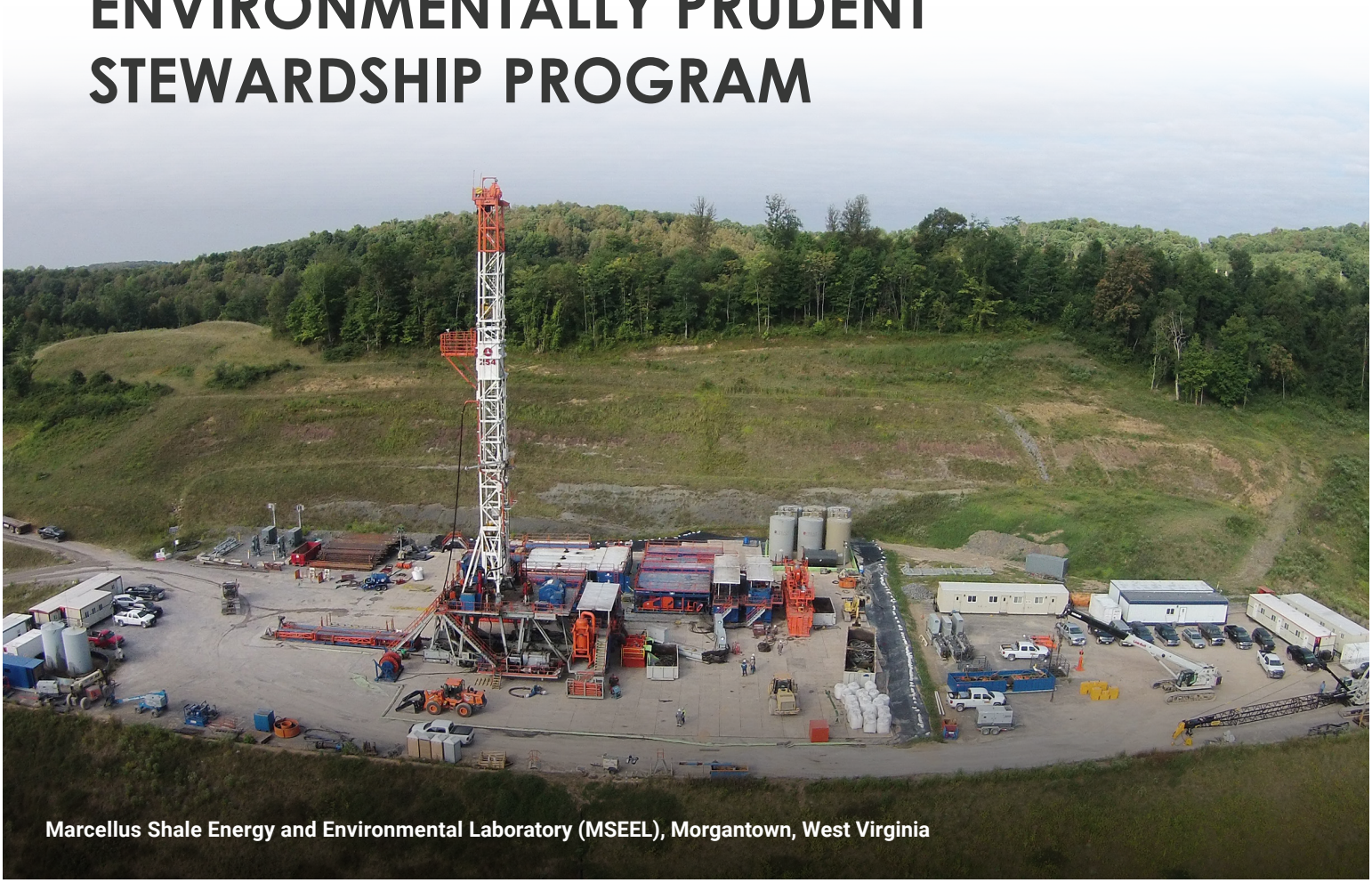
ENVIRONMENTALLY PRUDENT STEWARDSHIP PROGRAM



Marcellus Shale Energy and Environmental Laboratory (MSEEL), Morgantown, West Virginia

Program 130, December, 2024

NATIONAL ENERGY TECHNOLOGY LABORATORY

The U.S. Department of Energy's (DOE) Office of Fossil Energy and Carbon Management's (FECM) Environmentally Prudent Stewardship Program (EPS) is pursuing research focused on reducing the risks of environmental impacts to air, water and other sensitive receptors during exploration, well drilling, completion and production operations. Research efforts include field test sites where new technologies, tools and processes can be evaluated at large scale and data can be collected for scientific and engineering analysis to reduce the carbon footprint during the energy transition. Research related to advanced reservoir characterization and repurposing existing oil and natural gas assets will help accelerate future subsurface carbon and hydrogen storage opportunities and potential geothermal energy advancement in manner that is aligned with the DOE strategy, Administration policies, congressional funding appropriations and emerging regulatory developments.

The U.S. Energy Information Administration (EIA) projects that U.S. consumption and production of petroleum will grow gradually through 2050, with production slightly exceeding consumption. Production and consumption of natural gas are expected to grow as well, but with natural gas production growing approximately twice as fast as consumption. Tight oil plays will remain responsible for more than two-thirds of domestic oil production, while shale gas and associated natural gas from tight oil plays will remain the primary contributors to growth in U.S. natural gas production over the next few decades. Accordingly, as the United States works to transition to renewable energy and hydrogen, oil and natural gas will remain key portions of the nation's energy landscape and economically important elements of our exports. Ensuring that fossil energy production practices minimize environmental impacts must be a critical feature of our future energy sector.

The overarching objectives of NETL's EPS research include:

- Reducing the potential environmental impact of exploration and production operations by improving wellbore integrity; optimizing formation stimulation; utilizing advanced tools such as data analysis, machine learning and artificial intelligence to optimize well completion design; and developing improved tools for real-time monitoring of well performance. Optimizing well designs reduces the number of wells and the volume of water needed to produce a unit volume of hydrocarbon, reducing the potential for impacts.
- Increasing the effectiveness of hydrocarbon recovery while enabling accelerated safe, long-term subsurface storage of carbon dioxide (CO_2) and temporary storage of hydrogen as key parts of the nation's transition to cleaner energy sources through advanced CO_2-EOR field testing in both conventional and tight reservoirs.
- Developing an improved understanding of risk management and geohazard assessment in environmentally sensitive offshore environments.
- Enabling and accelerating development and process validation of environmentally prudent resource development technologies using field test sites that represent an array of field conditions within both mature and emerging oil and natural gas basins.

NETL'S RESEARCH WILL SUPPORT ENVIRONMENTALLY PRUDENT RESOURCE CHARACTERIZATION AND DEVELOPMENT THROUGH:

FIELD LABORATORIES

RESERVOIR CHARACTERIZATION — Provide new datasets related to reservoir characterization and accelerate the availability of those datasets to the public to support the optimization of existing natural gas resources and enable opportunities to reduce the environmental impact of resource utilization, including reducing the greenhouse gas footprint of existing exploration and production operations.

FIELD TESTING AND VALIDATION — Act as a mechanism to support the use and validation of advanced sensor systems, novel materials and optimized CO_2-EOR processes in both conventional and tight reservoirs to ensure improved recovery efficiency and environmental performance.

CROSS-CUTTING RESEARCH — Accelerate the potential for subsurface storage of carbon dioxide and hydrogen in a variety of reservoir types to further enable the future energy transition.

TECHNOLOGY DEVELOPMENT

RISK ASSESSMENT AND MANAGEMENT — Develop a suite of risk management and assessment tools to support the efficient identification and remediation of environmental hazards in both onshore and offshore environments.

NOVEL SENSORS AND EQUIPMENT — Develop technologies, tools and processes for effective, "real-time" reservoir characterization, environmental monitoring, optimized resource utilization and legacy asset transformation.

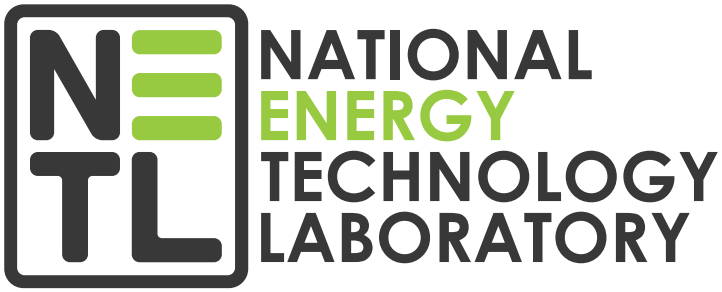
ADVANCED MODELING AND SIMULATION — Utilize advanced data analytics and artificial intelligence to better understand fundamental reservoir processes and better identify opportunities for reservoir management best practices, including support for future carbon dioxide and hydrogen storage and geothermal resource utilization operations.

ADVANCING RESEARCH THROUGH PARTNERSHIPS WITH INDUSTRY AND ACADEMIA

Historically, DOE has employed field test sites to gather basic data, test new tools and methods and demonstrate emerging technologies under field conditions so that industry will be able to assess their utility and accelerate adoption and deployment. Perhaps the most successful of DOE's field test site efforts were the tight gas and gas shales research programs of the 1980s and 90s, which played an important role in subsequent development of the nation's enormous unconventional natural gas resources. The data wells drilled for the Eastern Gas Shales and Western Gas Sands research programs provided critical early information on the character of these reservoirs, the natural gas resource held in them and how hydraulic fracturing and directional drilling might make those resources available to the market.

Other key programmatic accomplishments include DOE field research focused on finding economical ways to treat produced water for reuse in hydraulic fracturing, which led to commercial development of the AltelaRain® 4000 water desalination system for treating hydraulic fracturing flowback onsite. DOE-funded research also pursued a technology for microseismic monitoring of multi-stage hydraulic fracturing treatments, and after commercialization by Pinnacle Technology, Inc., this service is now offered by every major oilfield service company and has been applied to tens of thousands of wells worldwide. Similarly, IntelliPipe™, a revolutionary technology for communicating down-hole conditions in real time that also benefited from early field research funded by DOE, is commercially available through National Oilwell Varco's IntelliServ® system. Other examples of oilfield technology accelerated by DOE field research include wireless electromagnetic telemetry for measurement-while-drilling, downhole seismics, foam fracturing and mud pulse telemetry, to name only a few.

Eastern Gas Shales Coring Operation from the 1980s.



NETL is a U.S. Department of Energy (DOE) national laboratory dedicated to advancing the nation's energy future by creating innovative solutions that strengthen the security, affordability and reliability of energy systems and natural resources. With laboratories and computational capabilities at research facilities in Albany, Oregon; Morgantown, West Virginia; and Pittsburgh, Pennsylvania, NETL addresses energy challenges through implementing DOE programs across the nation and advancing energy technologies related to fossil fuels. By fostering collaborations and conducting world-class research, NETL strives to strengthen national energy security through energy technology development.

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