Welcome to the Webinar!

NETL RWFI Webinar:

Potential in Appalachia for the development of a new ethane storage hub

- All are on mute for the duration of the presentation
- Slides will be posted on netl.doe.gov/rwfi on the Webinar Archive Section
- Questions? Also- subscribe to NETL RWFI E-Note at (netl.rwfi@netl.doe.gov)

Disclaimer: The analysis presented and conclusions drawn herein represent solely those views of the author(s), and do not represent the views of the United States Department of Energy

I. **NETL Background – Anthony Armaly**

II. **NETL RWFI Background**

III. **Ethane Storage Presentation – Justin Adder**

NETL Overview

Solutions for Today | Options for Tomorrow

NATIONAL ENERGY TECHNOLOGY LABORATORY

Anthony Armaly

anthony.armaly@netl.doe.gov

U.S. DEPARTMENT OF ENERGY

MISSION

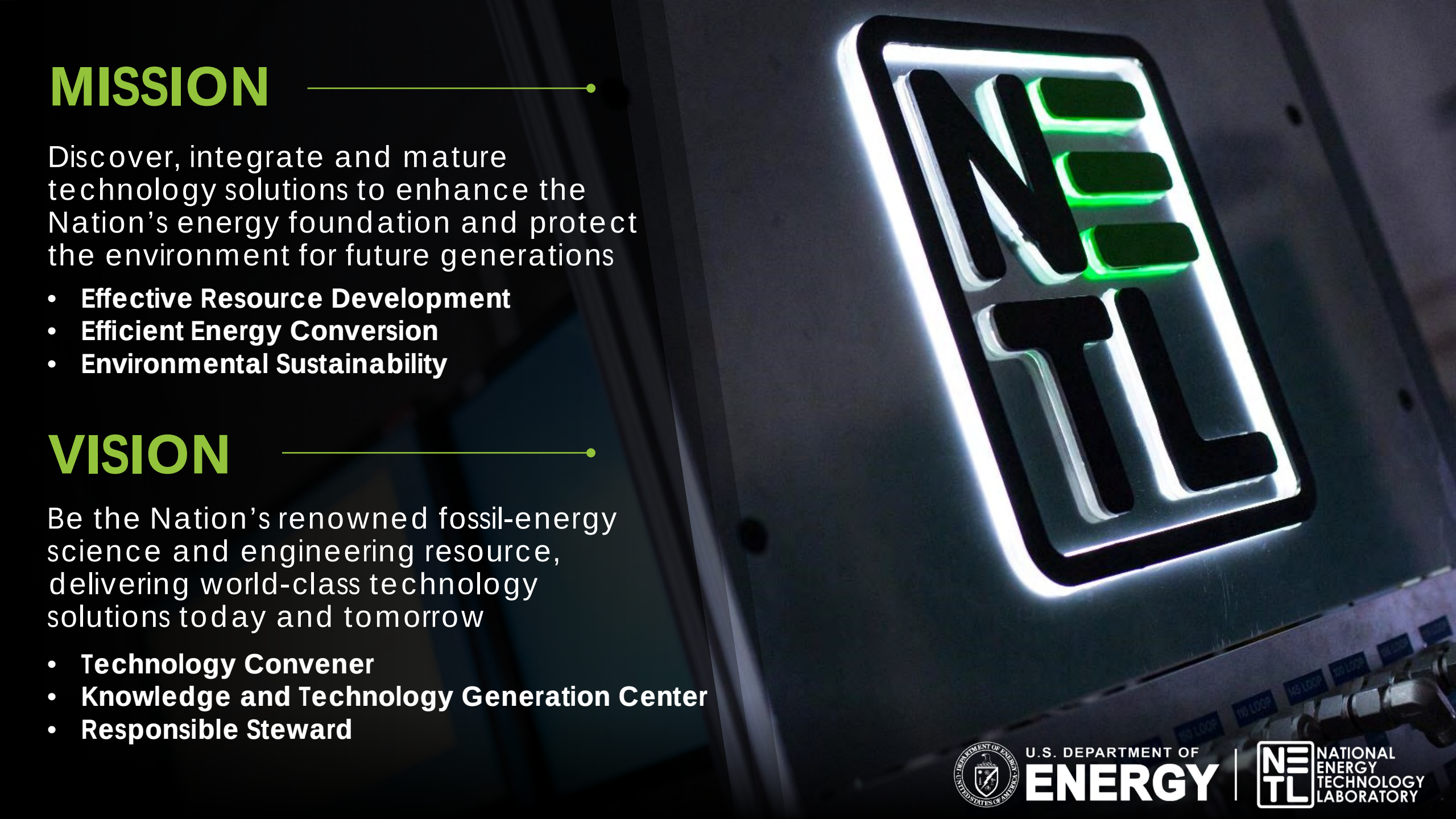
Discover, integrate and mature technology solutions to enhance the Nation's energy foundation and protect the environment for future generations

- **Effective Resource Development**
- **Efficient Energy Conversion**
- **Environmental Sustainability**

VISION

Be the Nation's renowned fossil-energy science and engineering resource, delivering world-class technology solutions today and tomorrow

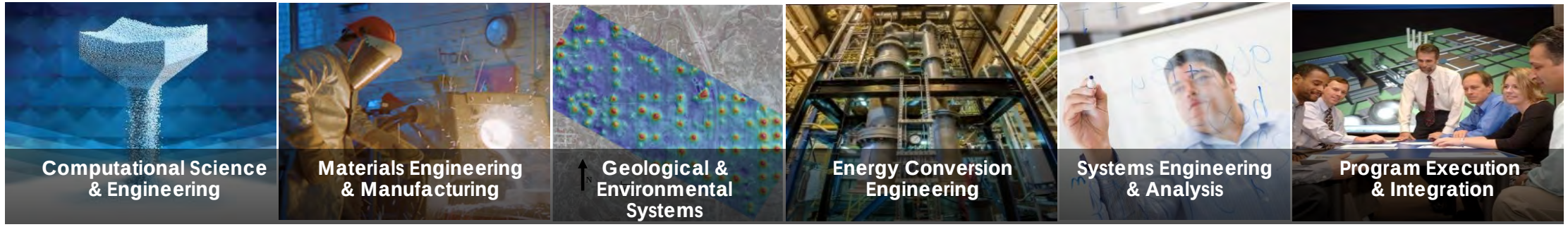
- **Technology Convener**
- **Knowledge and Technology Generation Center**
- **Responsible Steward**



U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

Core Competencies & Technology Thrusts

NATIONAL ENERGY TECHNOLOGY LABORATORY

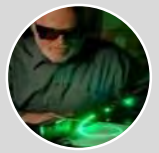


COAL

Carbon Storage

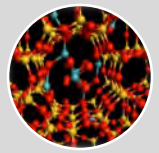
Carbon Capture

Sensors & Controls



Advanced Materials

Advanced Computing



Advanced Energy Systems

Water Management

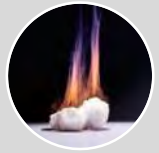
Rare Earth Elements

OIL & GAS

Enhanced Resource Production

Environmentally Prudent Development

Methane Hydrates



Offshore

Natural Gas Infrastructure

Unconventional

Support to Other DOE Offices

Energy Efficiency & Renewable Energy (EERE)

Vehicles

Solid State Lighting

Geothermal

Office of Electricity (OE)

Microgrid

Energy Storage

Cybersecurity, Energy Security, and Emergency Response (CESER)

Energy Security & Restoration

Cybersecurity

NETL Snapshot

NATIONAL ENERGY TECHNOLOGY LABORATORY

By the Numbers

3 labs across U.S.

900+ R&D projects in **50** states

$6.3B total award value

$991M FY19 budget

Workforce

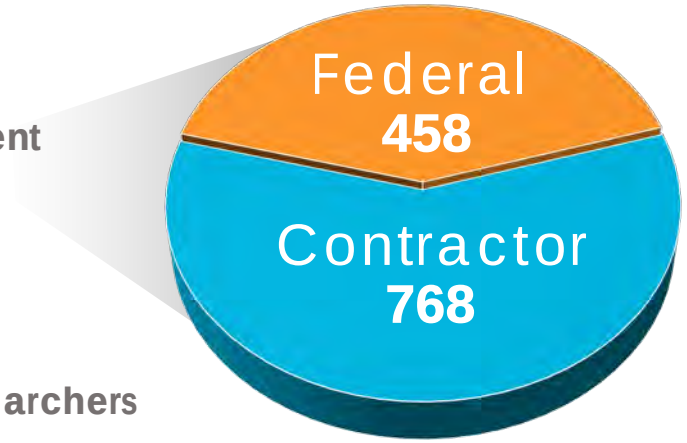
1,226 Full Time Equivalent Employees (FTEs)

70 Joint Faculty

109 Postdoctoral Researchers

54 Graduate Students

40 Undergraduate Students



NETL possesses an array of authorities to manage & implement complex R&D programs

- Program planning, development, and execution
- Legal, Financial, Procurement and Head of Contracting Authority (HCA)
- Project Management Expertise

Award Winning Laboratory

NETL's scientists have earned 51 R&D 100 Awards over the past 20 years

2016-17 Award Winners

National Risk Assessment Partnership (NRAP)

Carbon Capture Simulation Initiative (CCSI) Toolset

Computationally Optimized Heat Treatment of Metal Alloys

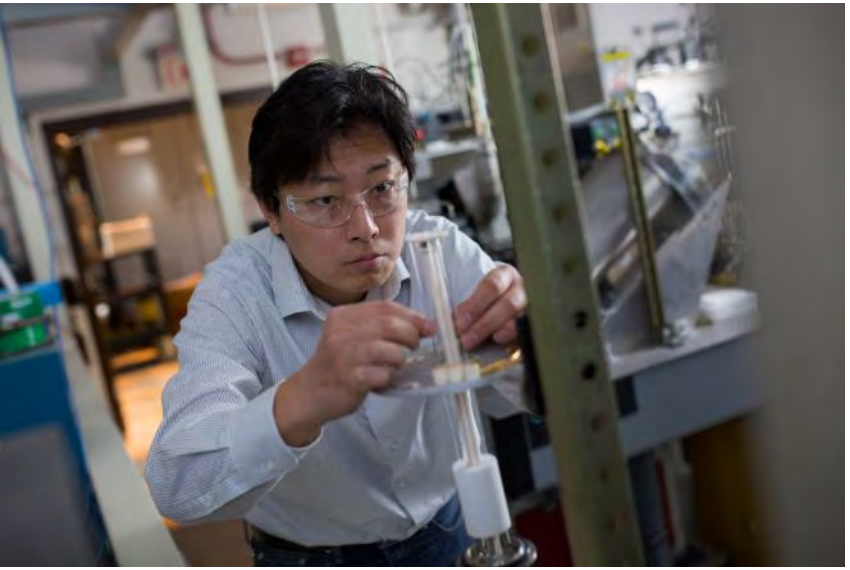
HVAC Load Reduction Technology for Commercial Buildings

Legacy of Science and Technology Excellence

Infrastructure

Snapshot

165	1.1 million ft²	237	116	$577 million
laboratories	of building space	acres of land	buildings & structures	replacement value



Technology Development Pathway

An Active Portfolio from Concept to Market Readiness

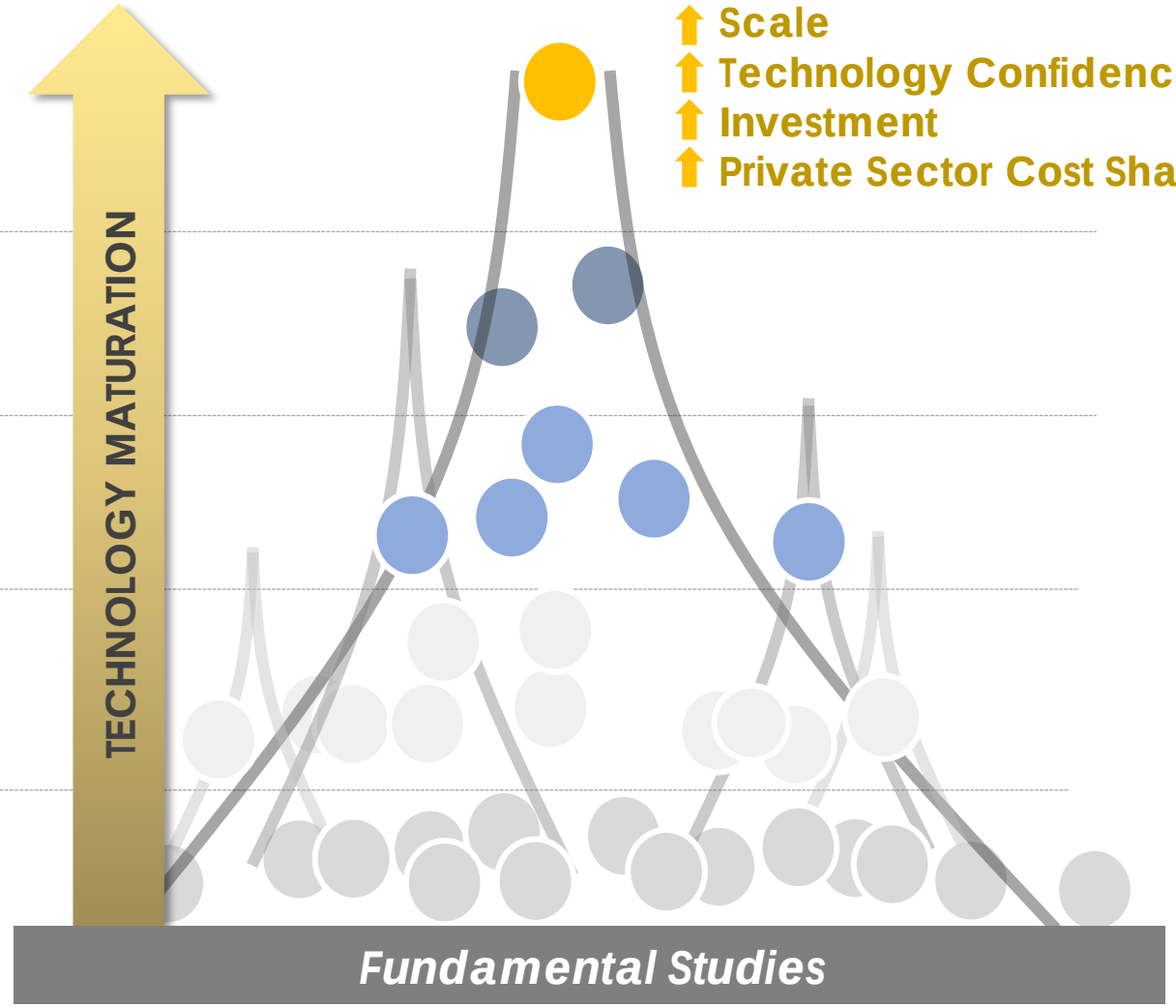
COMMERCIALIZATION
Technology available for wide-scale market use

DEMONSTRATION
System demonstrated in operational environment

SYSTEM TESTING
System performance confirmed at pilot-scale

DEVELOPMENT
Technology component validated/integrated

DISCOVERY
Concept identified/proven at laboratory-scale



KNOWLEDGE-BASED DECISION MAKING

- **Systems Engineering and Integration**
  - Engineering analysis
  - Pre-FEED/FEED studies
  - NEPA
- **Decision Science and Analysis**
  - Screening studies
  - Techno-economic analysis
  - Technology Readiness Assessments

NETL Regional Workforce Initiative (NETL RWFI)

NETL RWFI Mission Statement

NETL RWFI is a platform for engagement and collaboration with key stakeholders who are critical for the deployment of U.S. DOE and NETL Energy and Advanced Manufacturing technological research.

Supporting Regional Economic and Workforce Development opportunities.

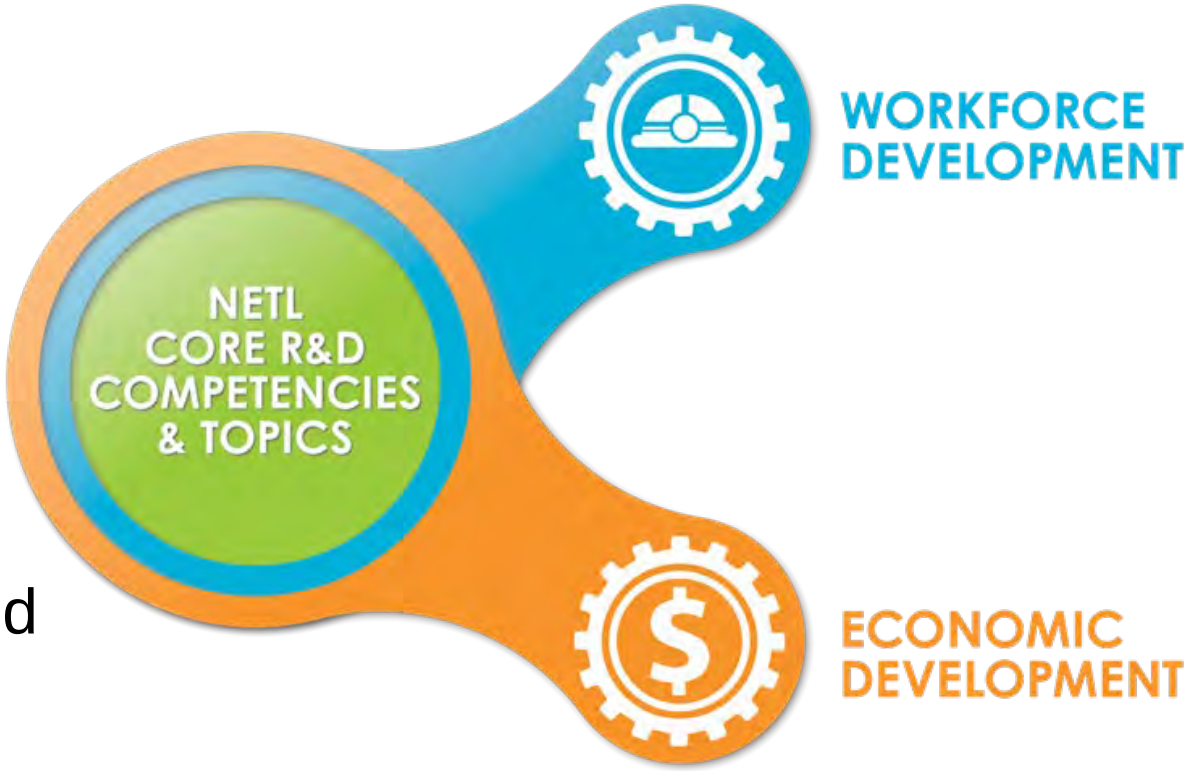
Collaboration, Coordination, and Communication

In the Energy and Advanced Manufacturing workforce

Collaboration with stakeholders and partners around workforce readiness and economic opportunities

Coordinating across economic development and workforce development initiatives

Communicating activities, research, and funding opportunities to stakeholders



Responsive to Administration Priorities

RWFI aligns with the Administration's efforts to connect R&D investment to economic growth, job growth, and development of a skilled technical workforce.

- Establishing the President's Council for the American Worker
- Establishing Apprenticeships in America
- Strengthening the Cybersecurity of Federal Networks and Critical Infrastructure

Key NETL RWFI Metrics

400+
individual regional and national stakeholders

137
institutions and organizations represented

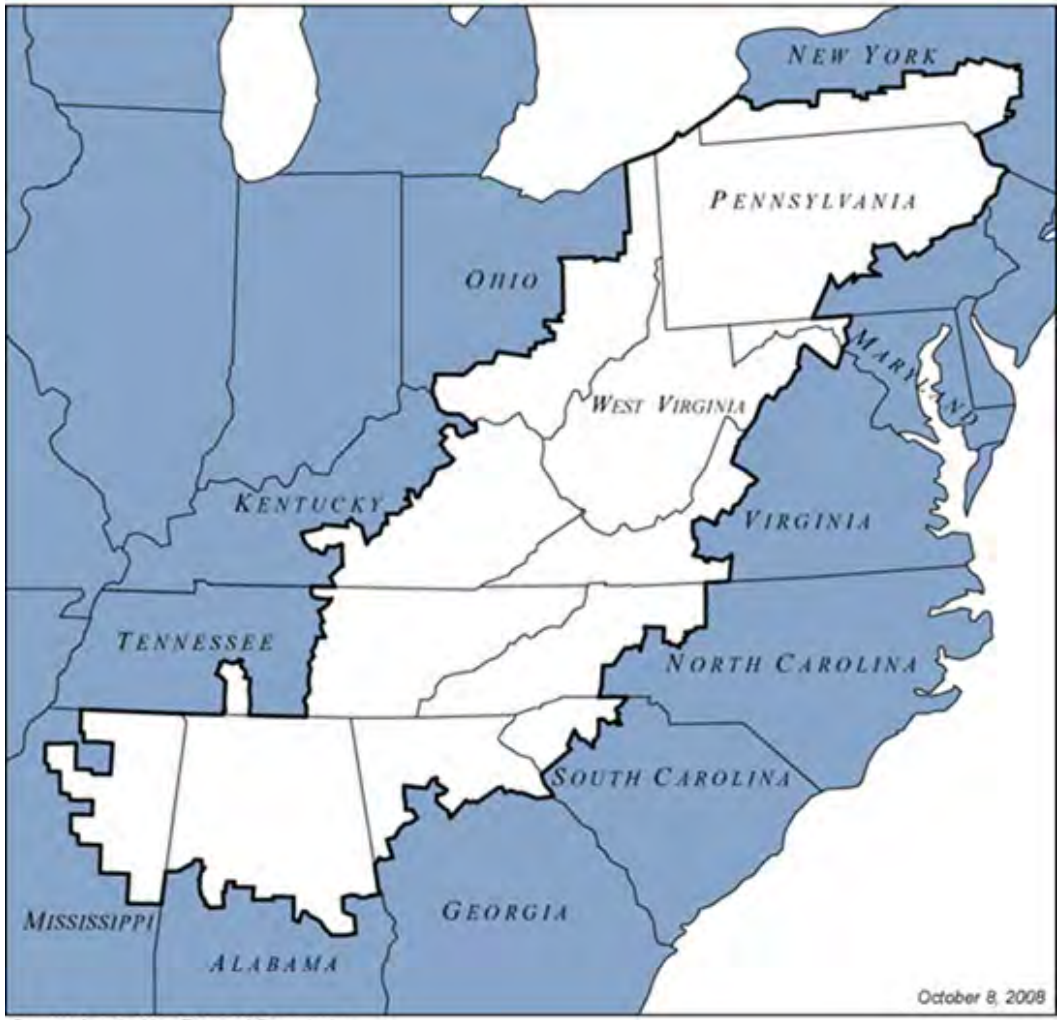
200+
subscribed to the NETL RWFI e-Note Monthly Newsletter

300+
registrants to the NETL RWFI Webinar Series

Appalachia at a Glance

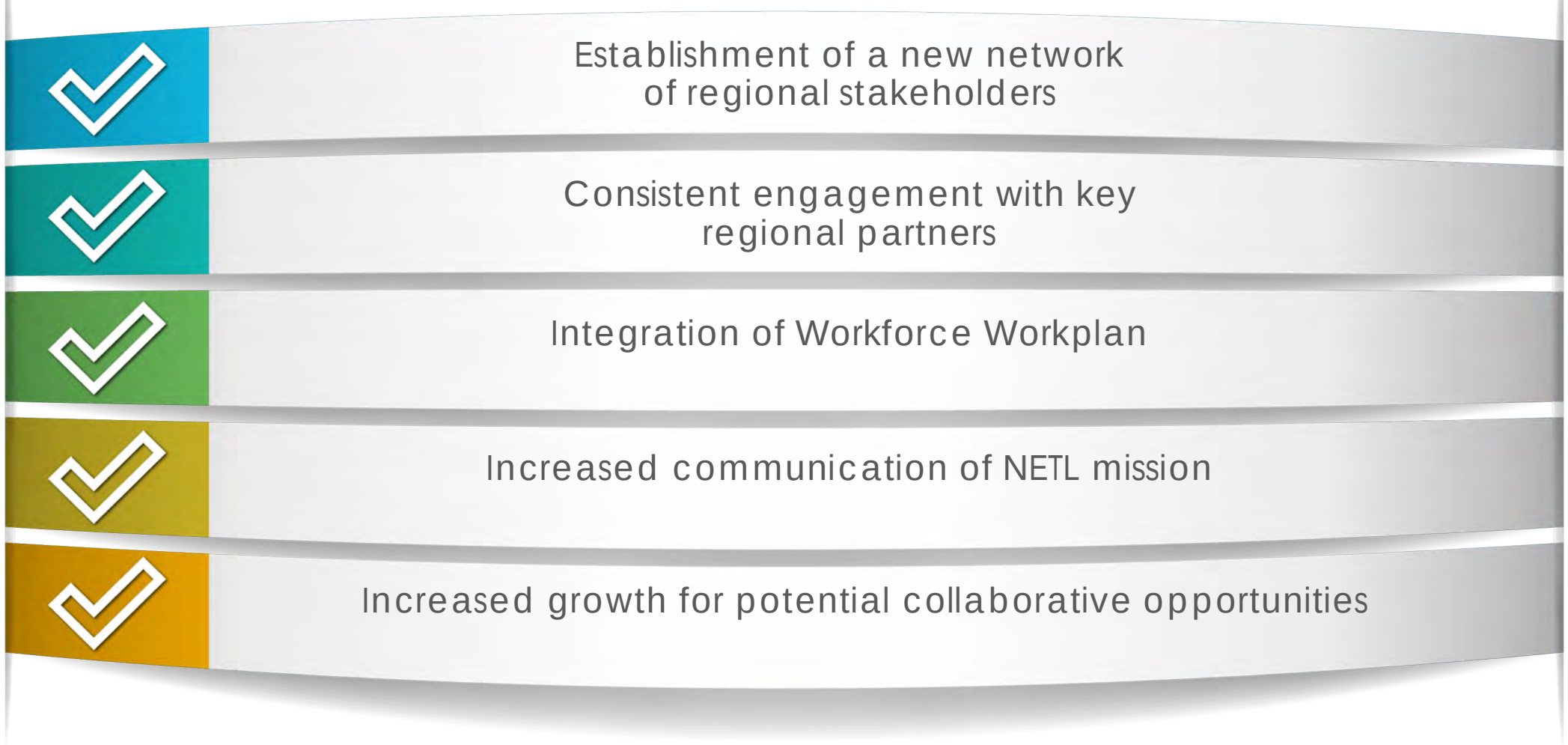
The Appalachian region is:

- a historically critical region for U.S. energy production, and will continue to be so
- a strategically important area for related technologies in advanced manufacturing and supercomputing
- expected to enjoy a manufacturing renaissance
- an area that has been adversely affected by changes in energy extraction and related manufacturing activity



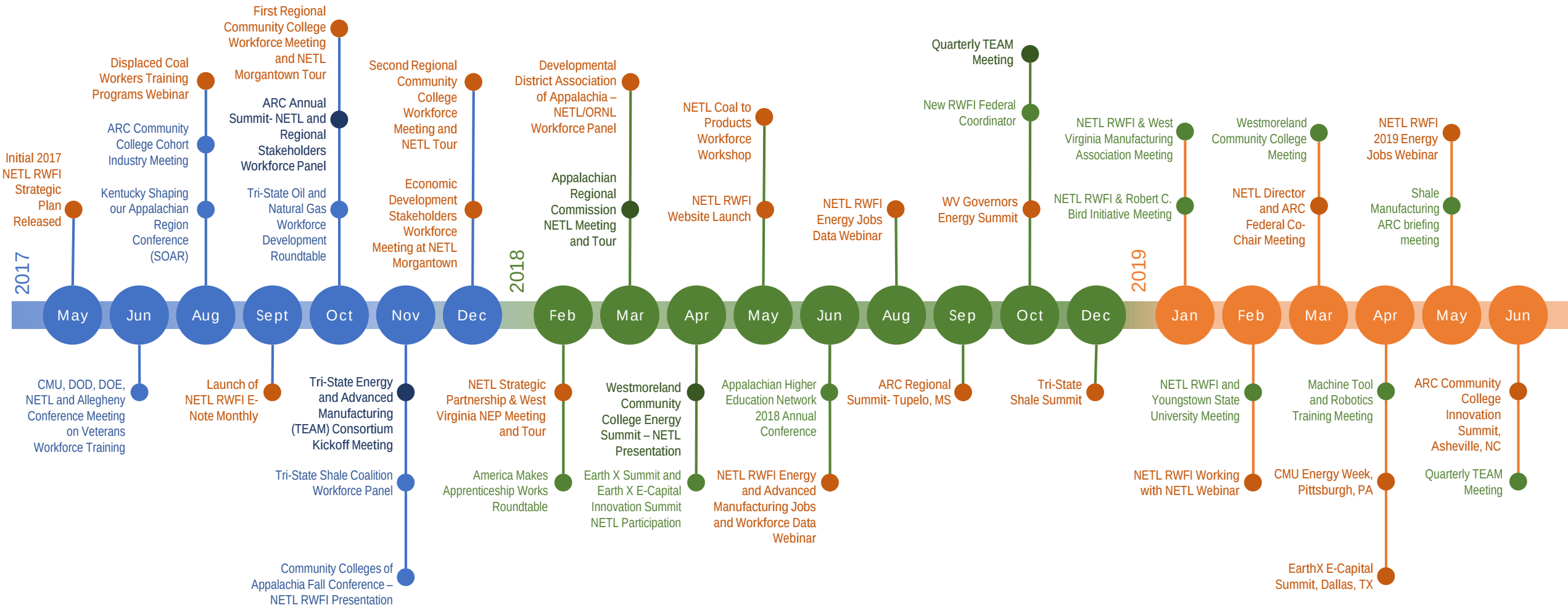
Source: Appalachian Regional Commission

Key Outcomes to Date



RWFI Outreach, Meetings, Webinars, and Workshops

Consistent, meaningful, outcome driven, engagement



Contact Information

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+1-412-386-6040

www.netl.doe.gov

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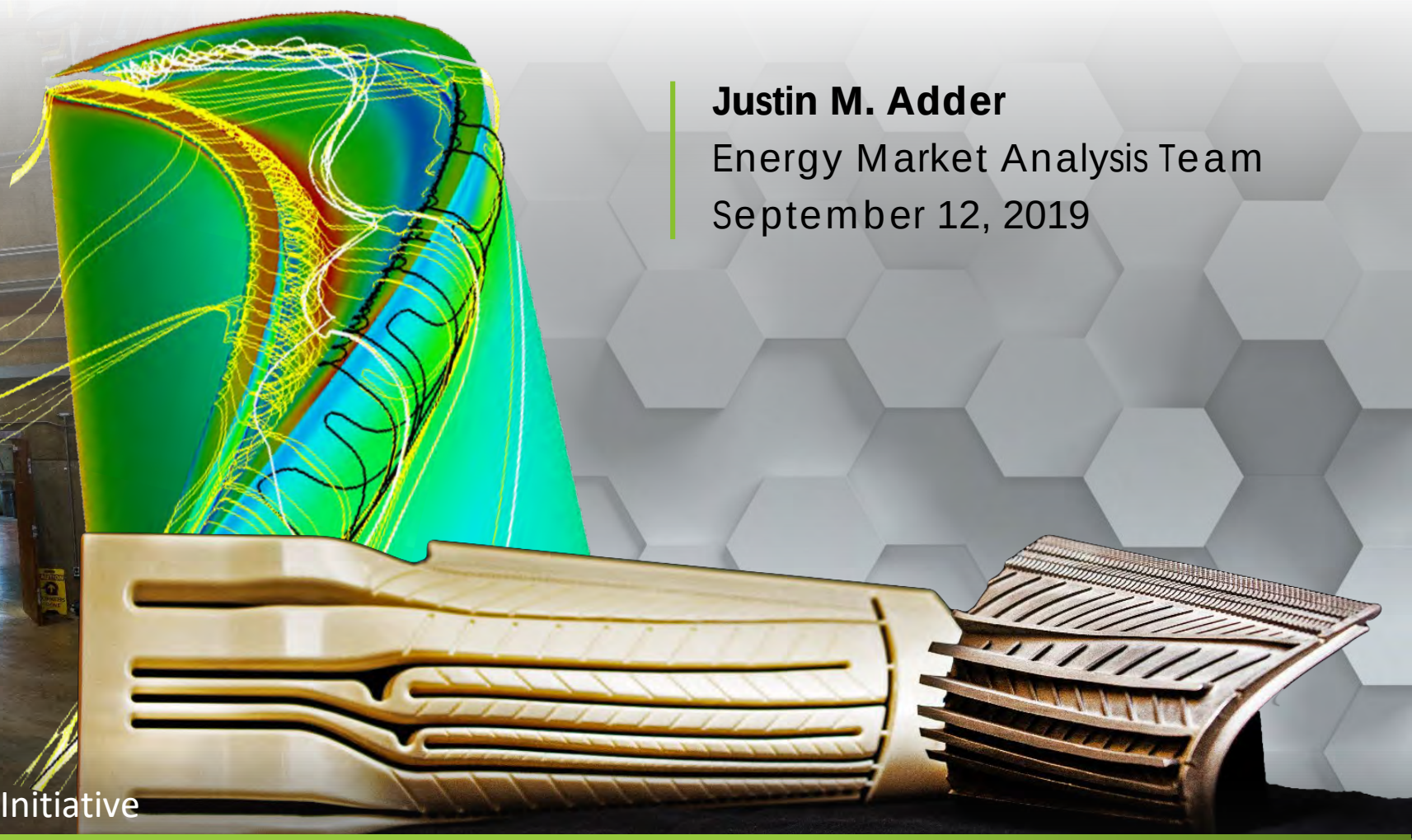
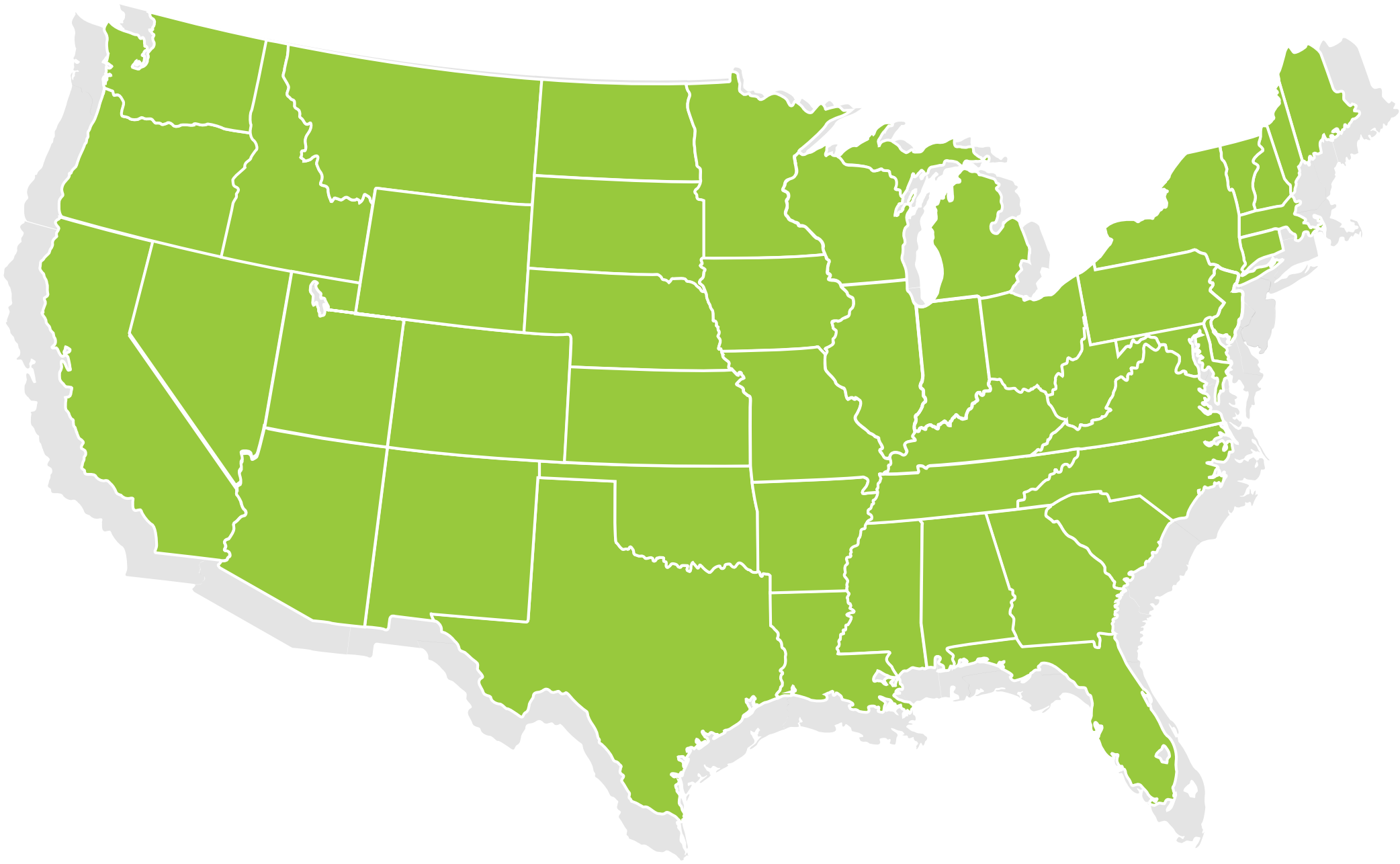
Appalachian Petrochemicals

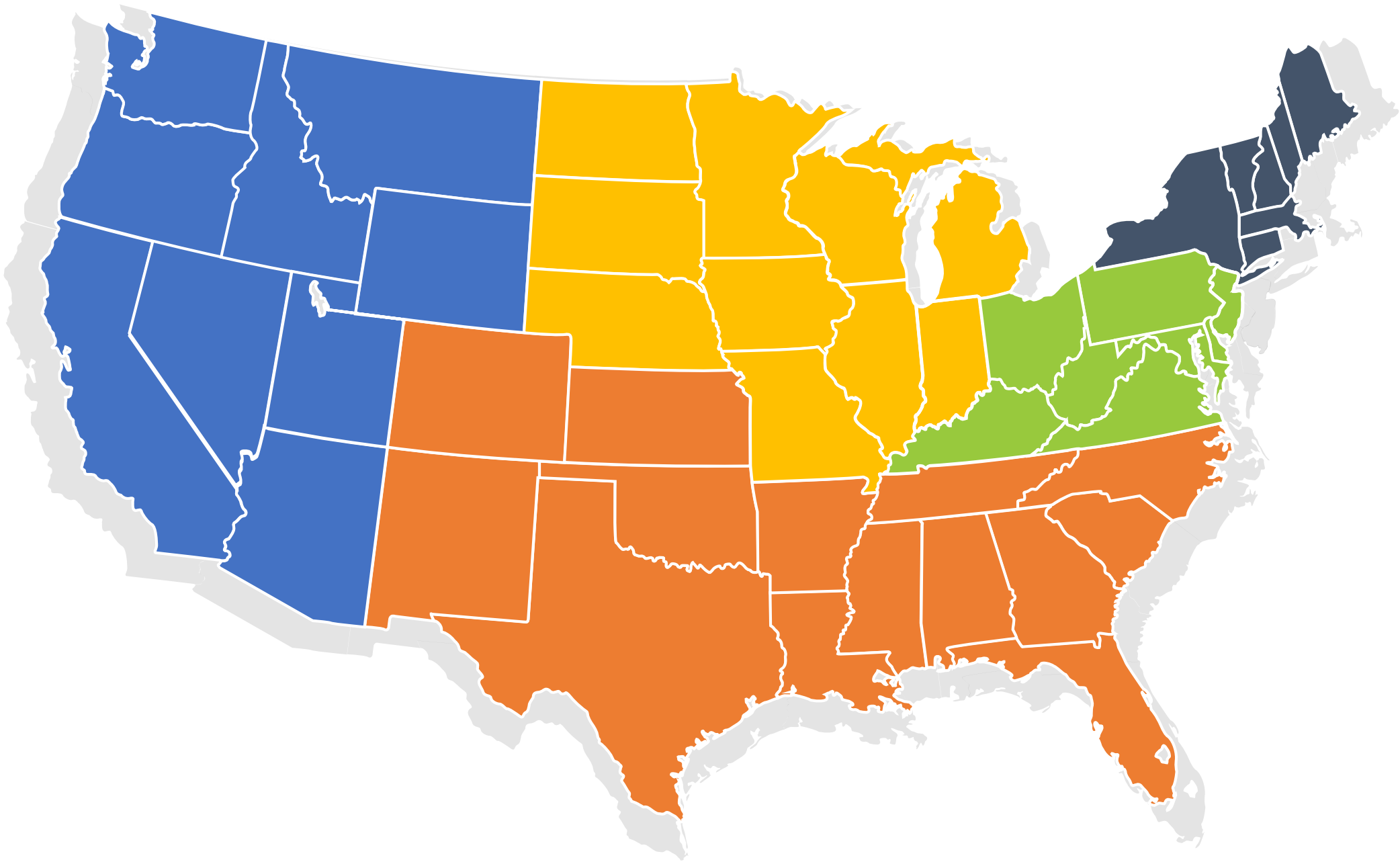
A Generational Opportunity

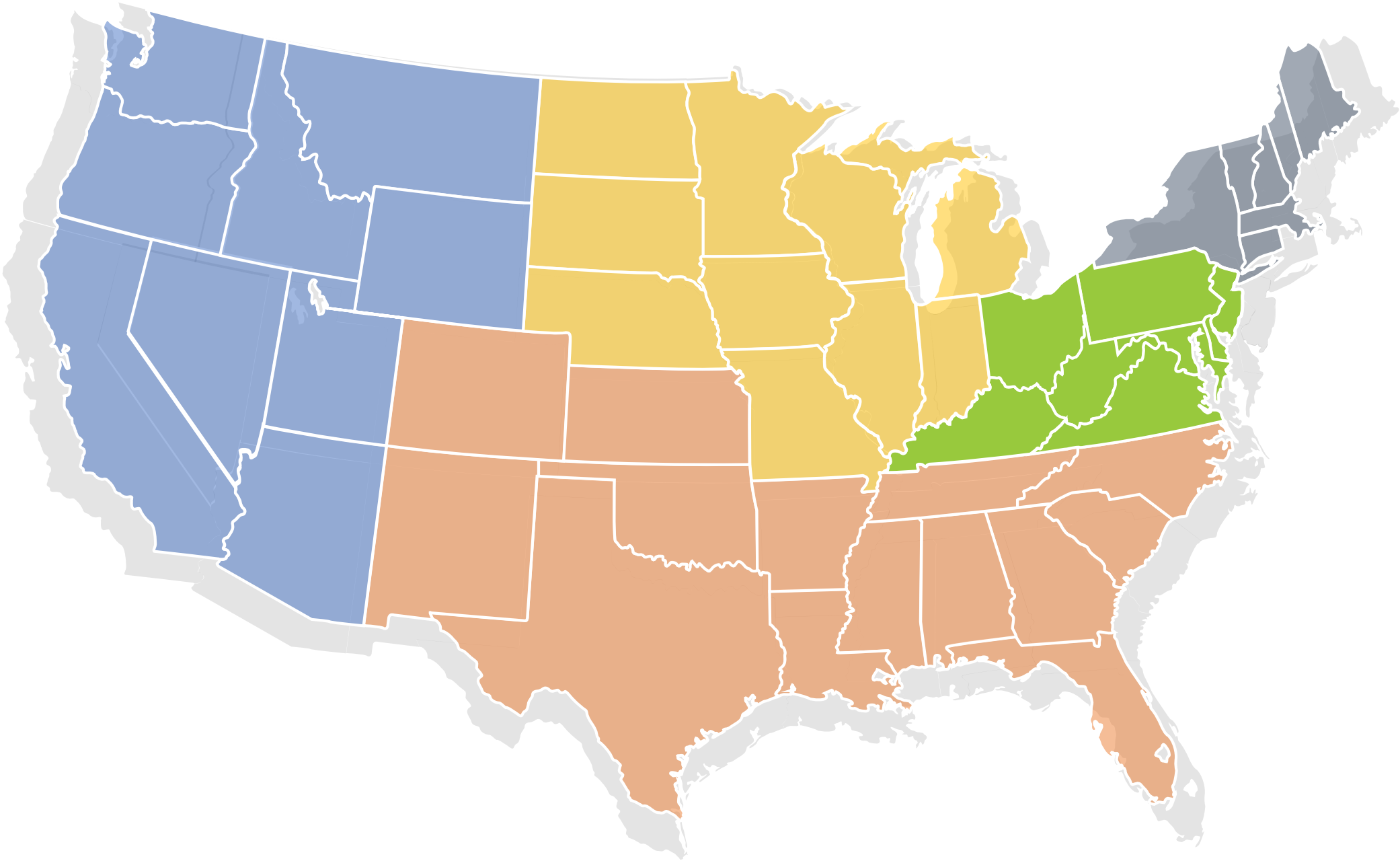


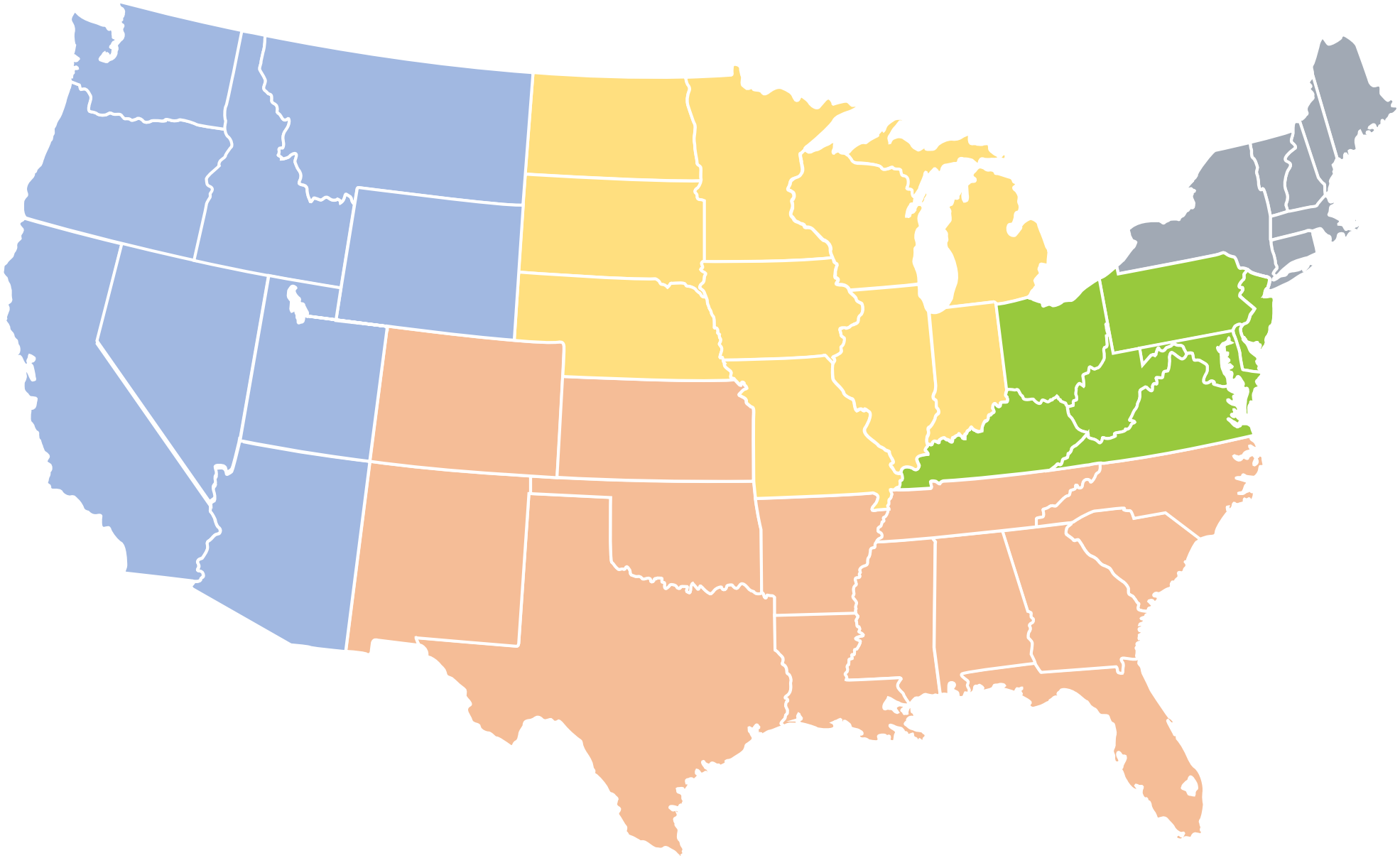
Justin M. Adder
Energy Market Analysis Team
September 12, 2019

Presentation for NETL Regional Workforce Initiative

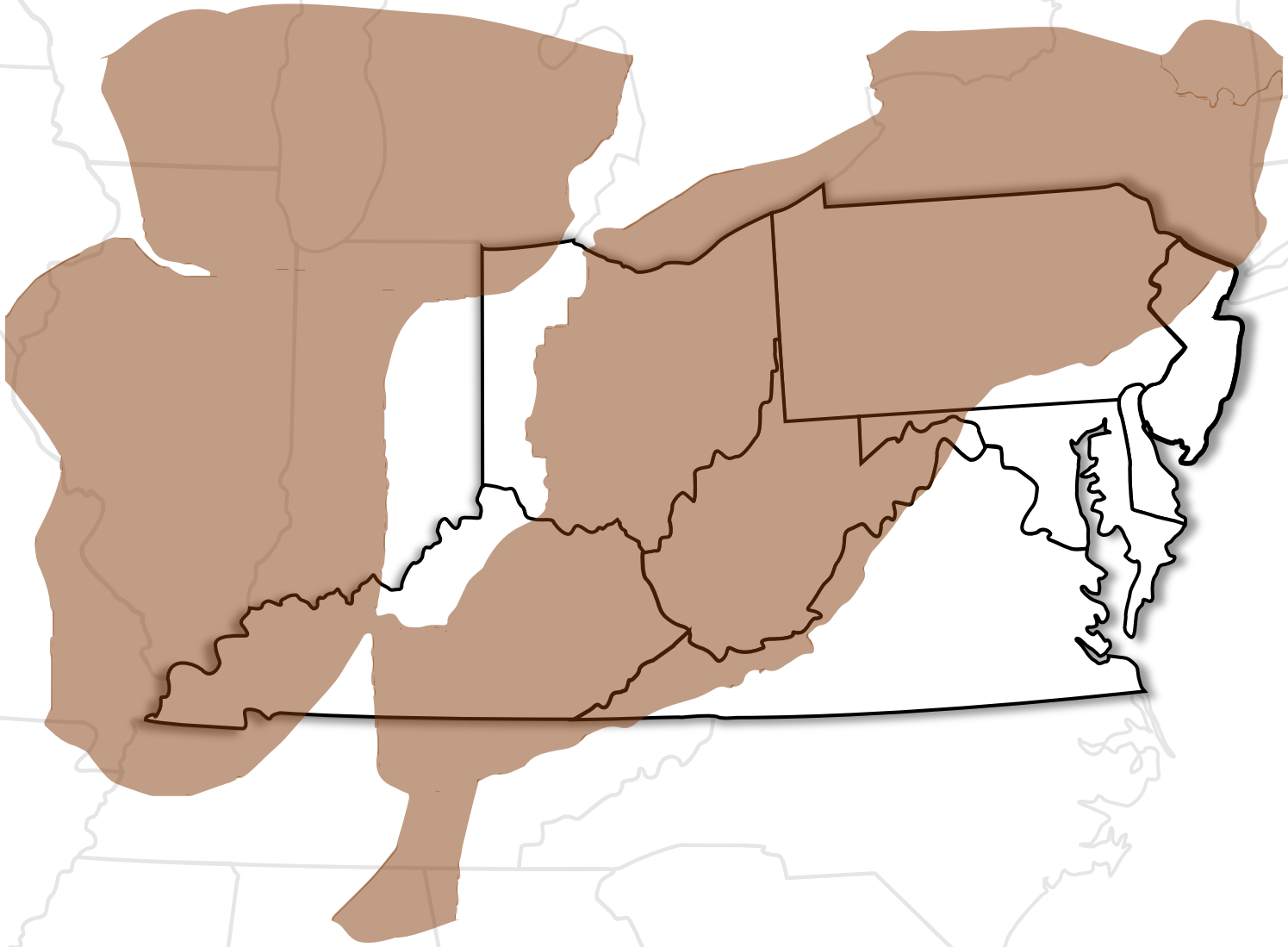






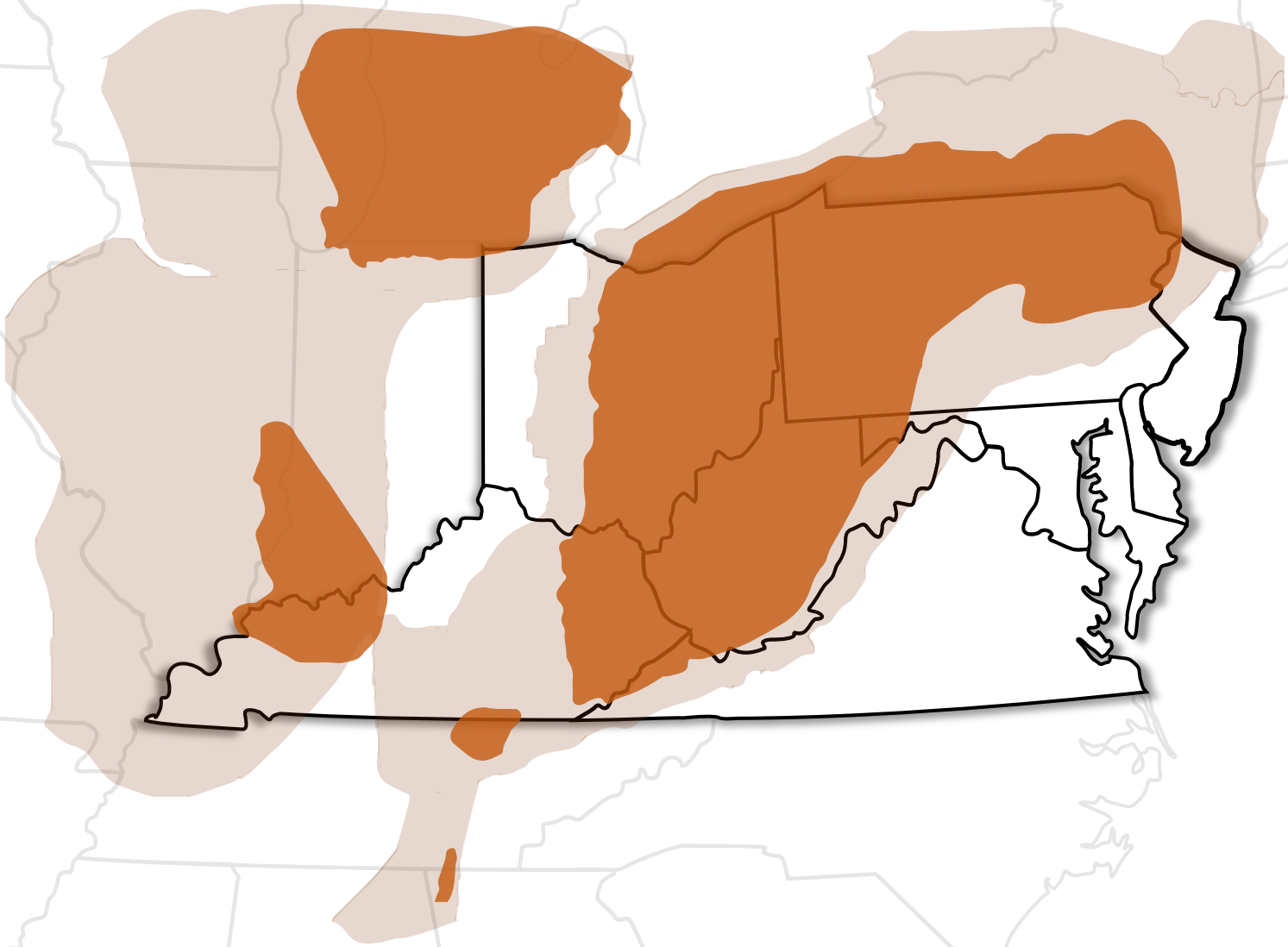


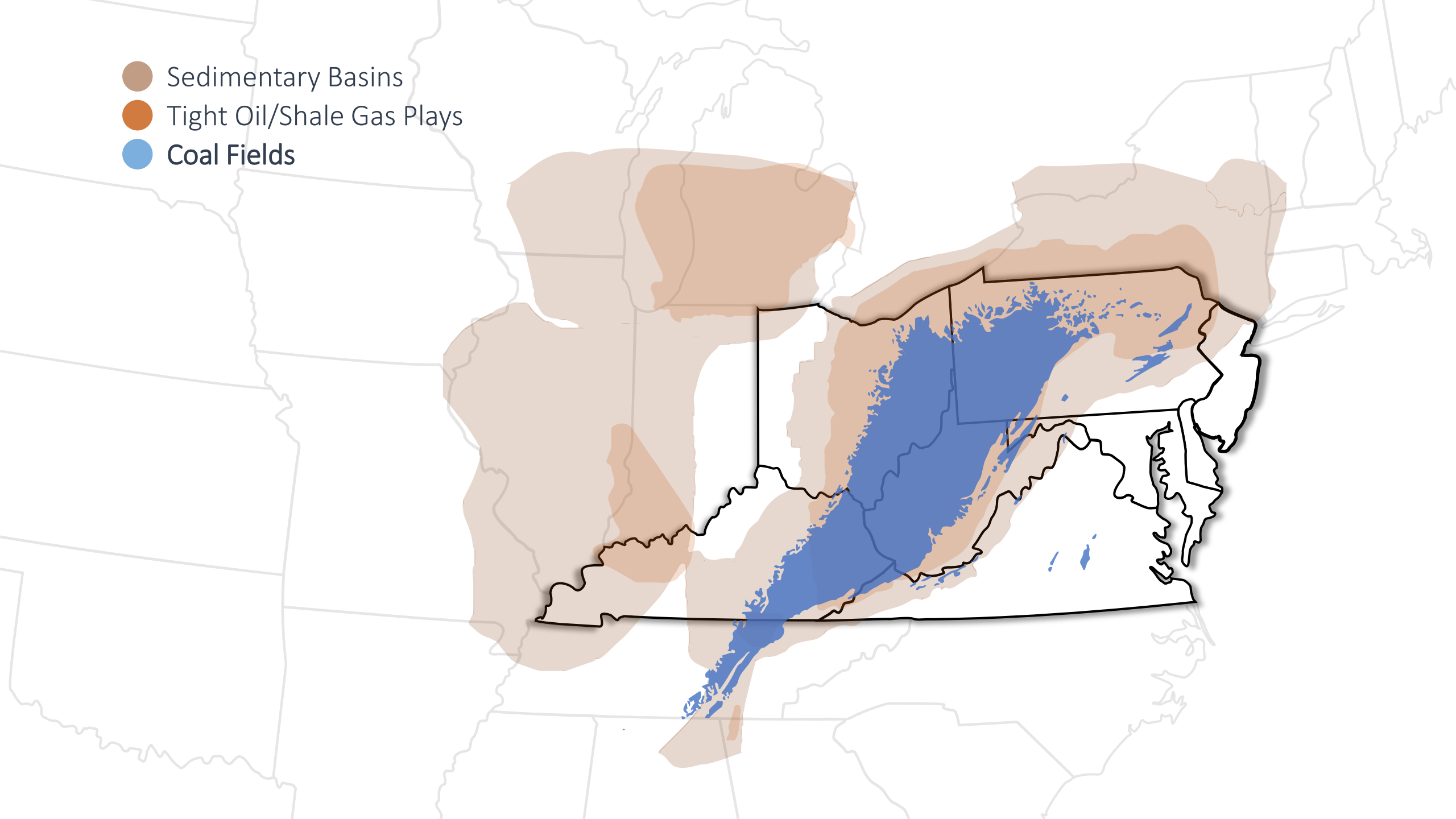
Sedimentary Basins

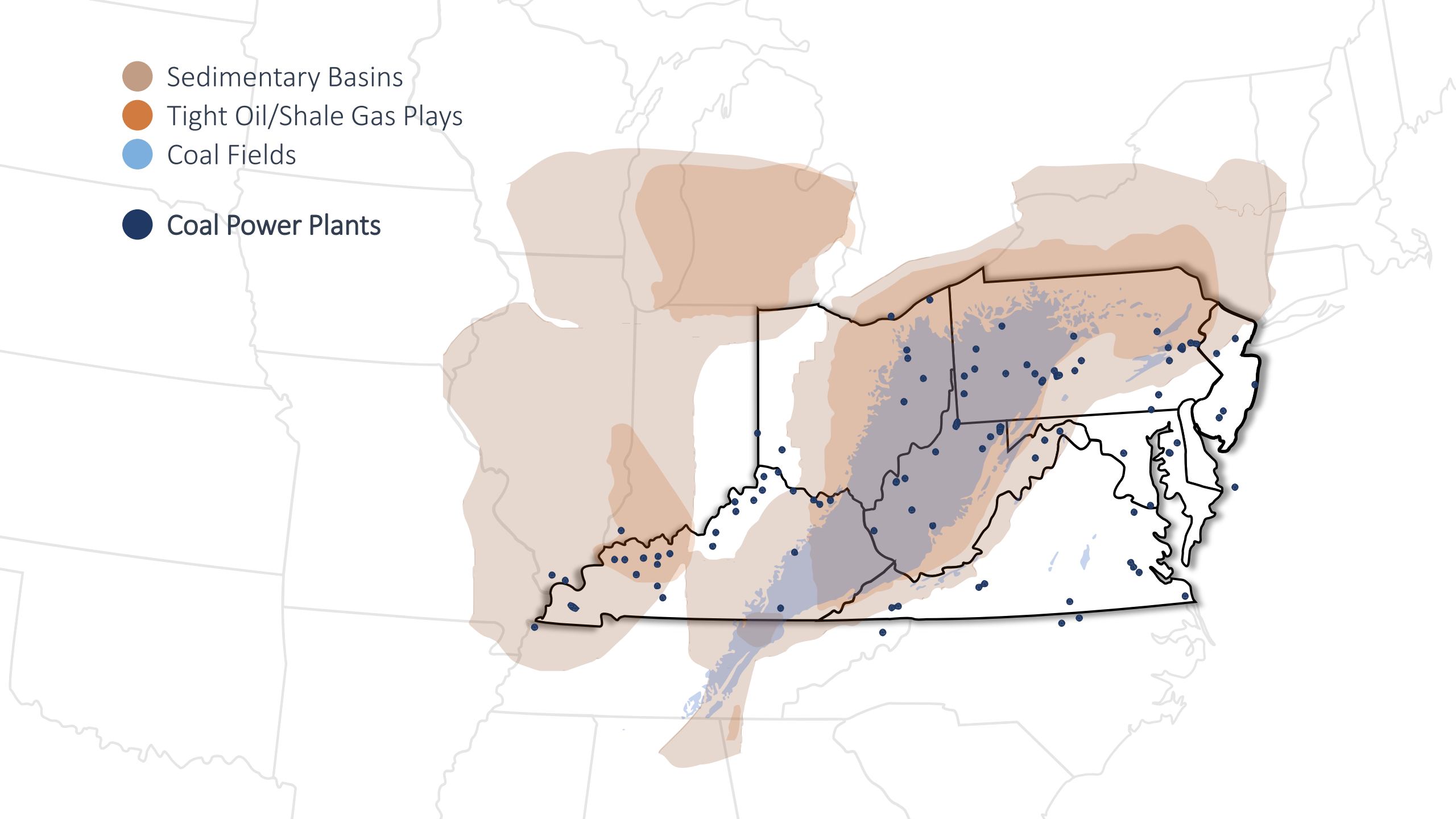


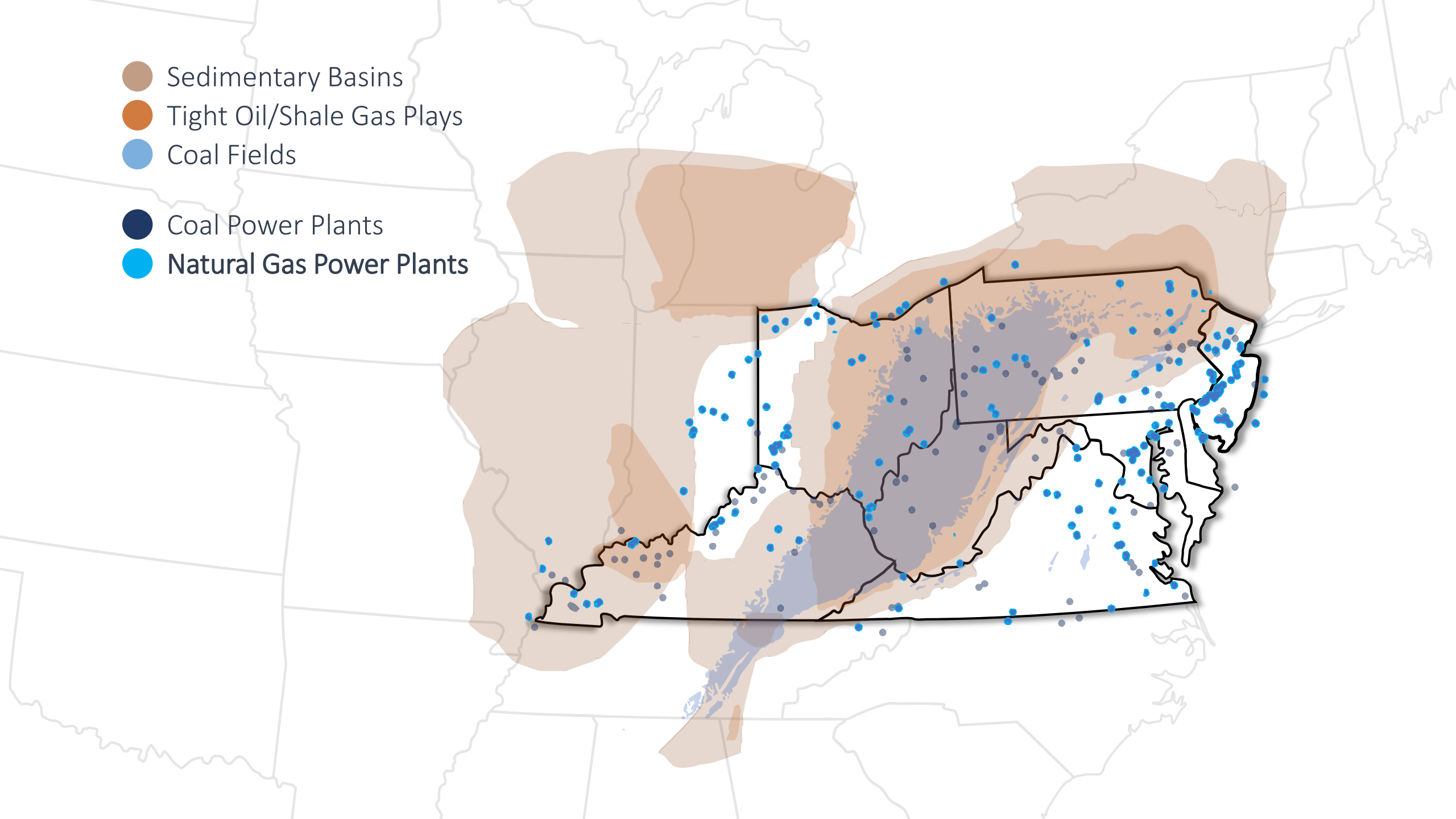
Sedimentary Basins

Tight Oil/Shale Gas Plays




Sedimentary Basins
Tight Oil/Shale Gas Plays
Coal Fields


Sedimentary Basins
Tight Oil/Shale Gas Plays
Coal Fields
Coal Power Plants


Sedimentary Basins
Tight Oil/Shale Gas Plays
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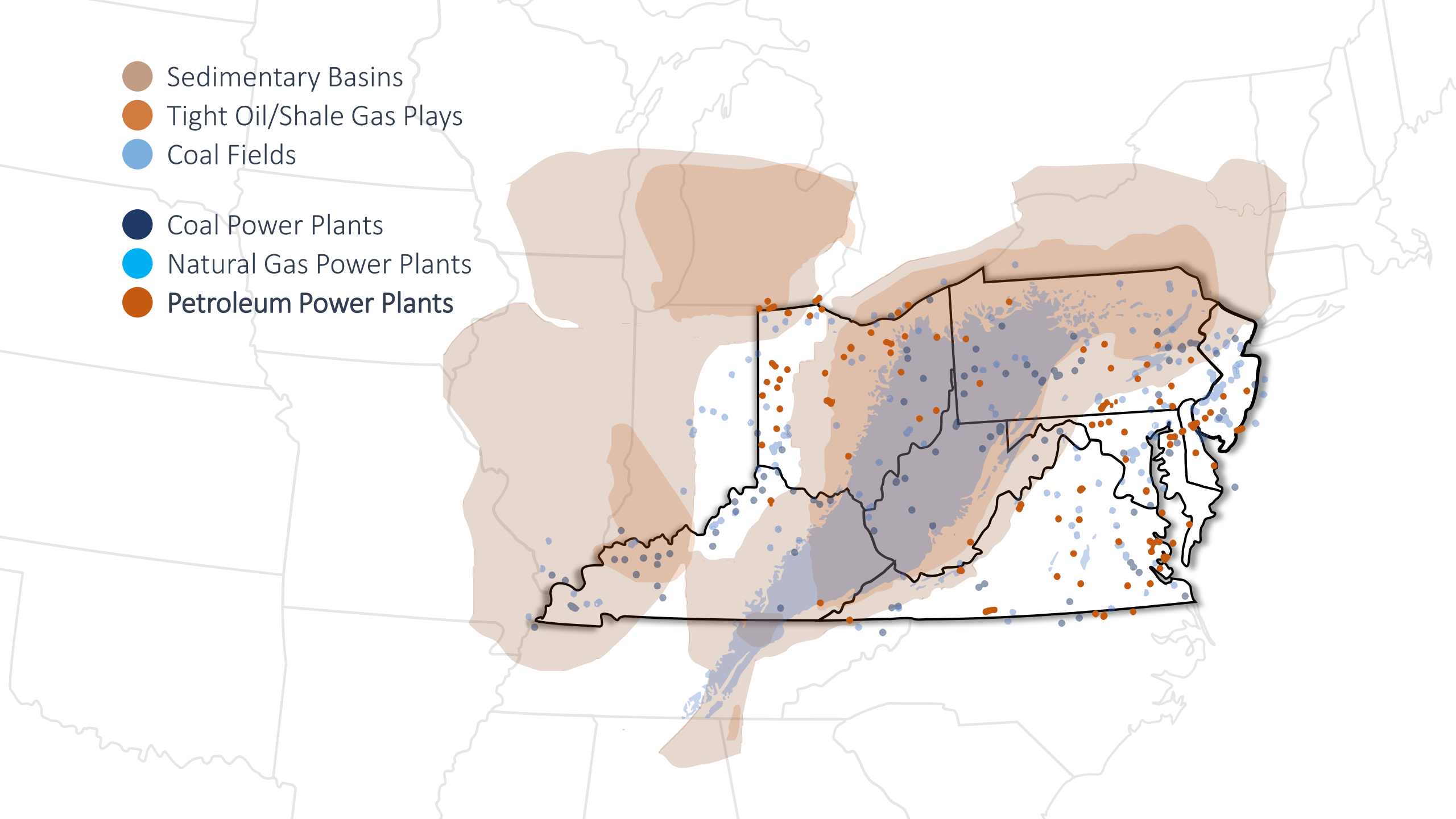
Coal Power Plants
Natural Gas Power Plants


Sedimentary Basins
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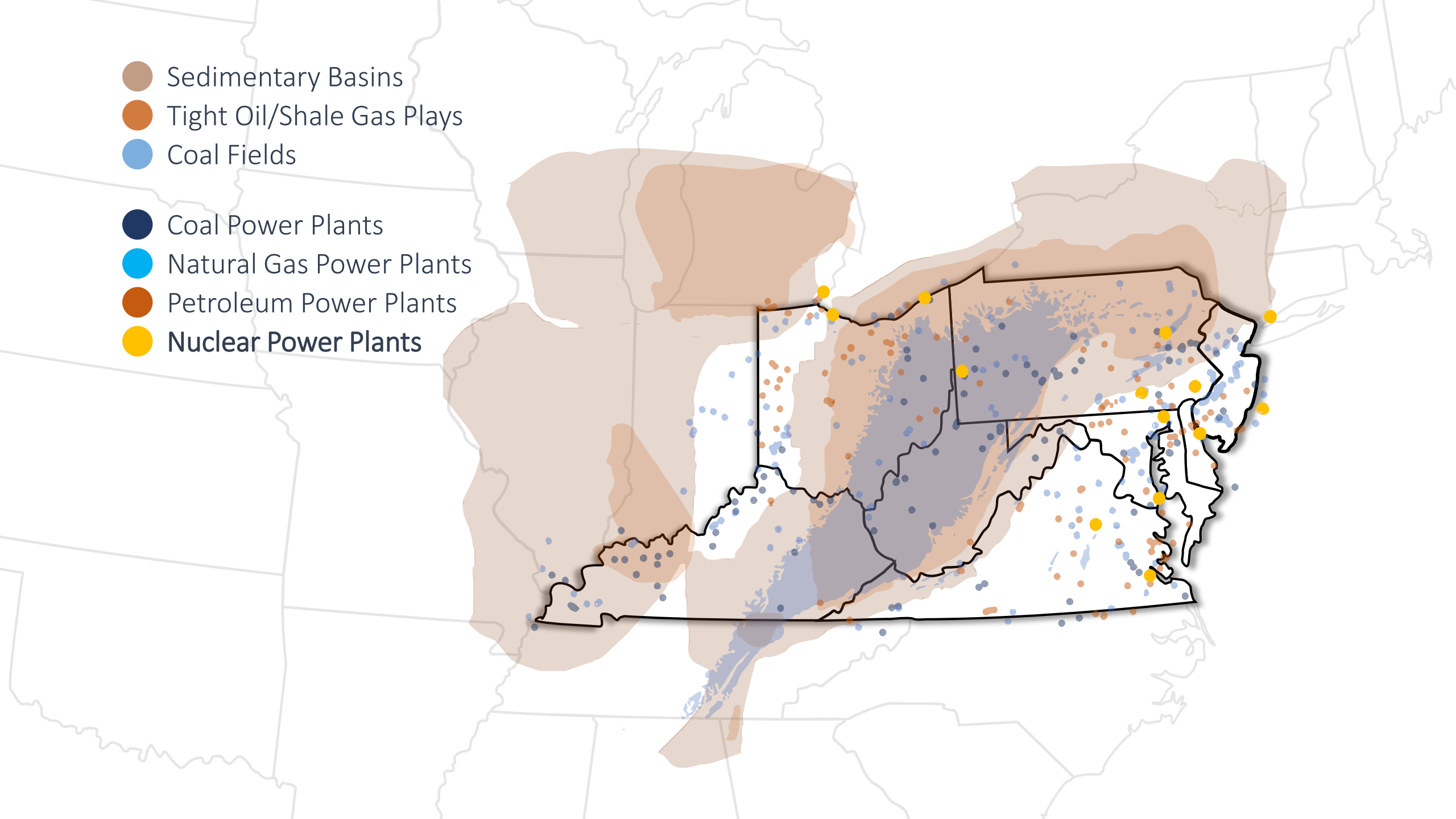
Coal Power Plants
Natural Gas Power Plants
Petroleum Power Plants


Sedimentary Basins
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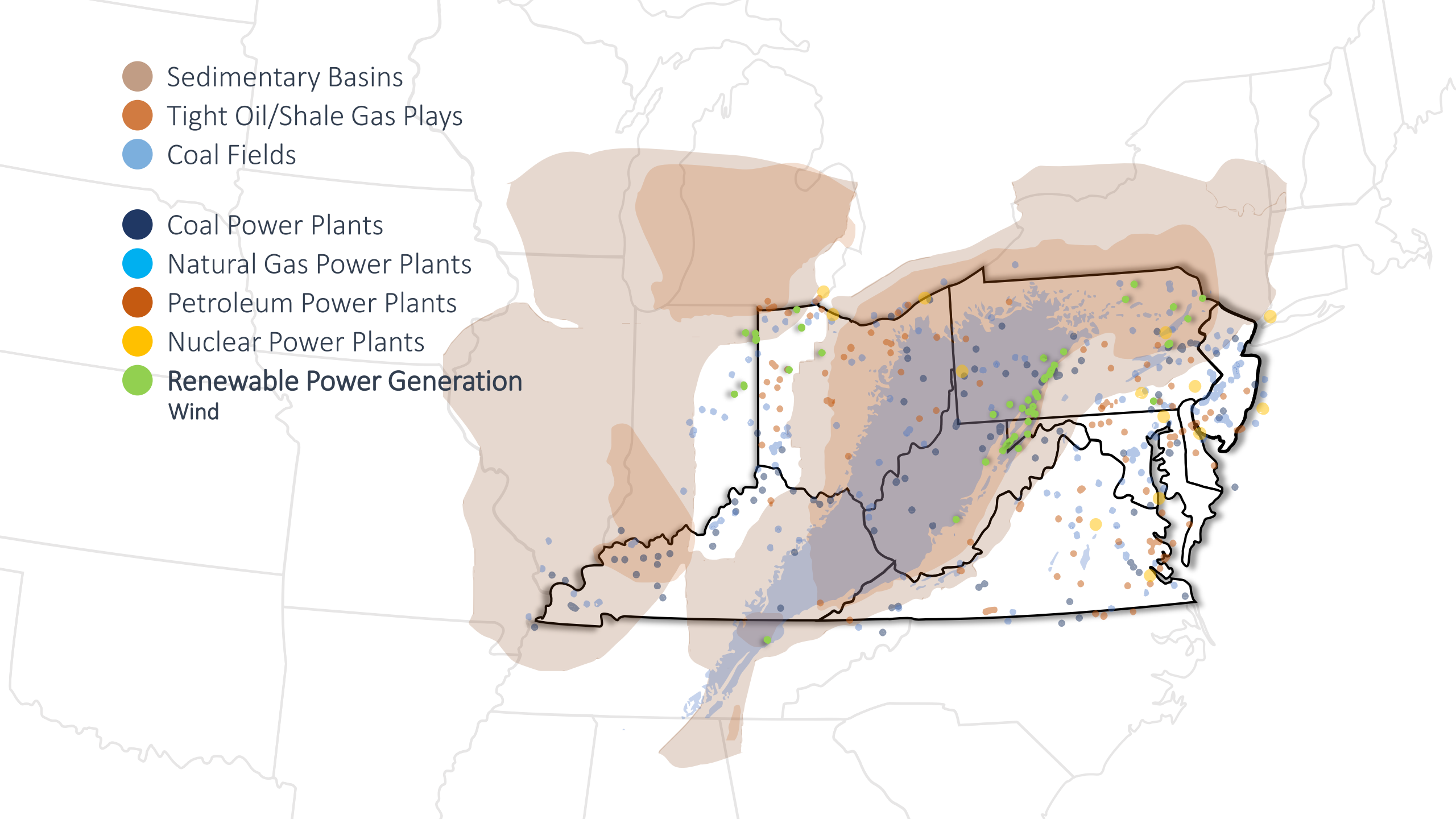
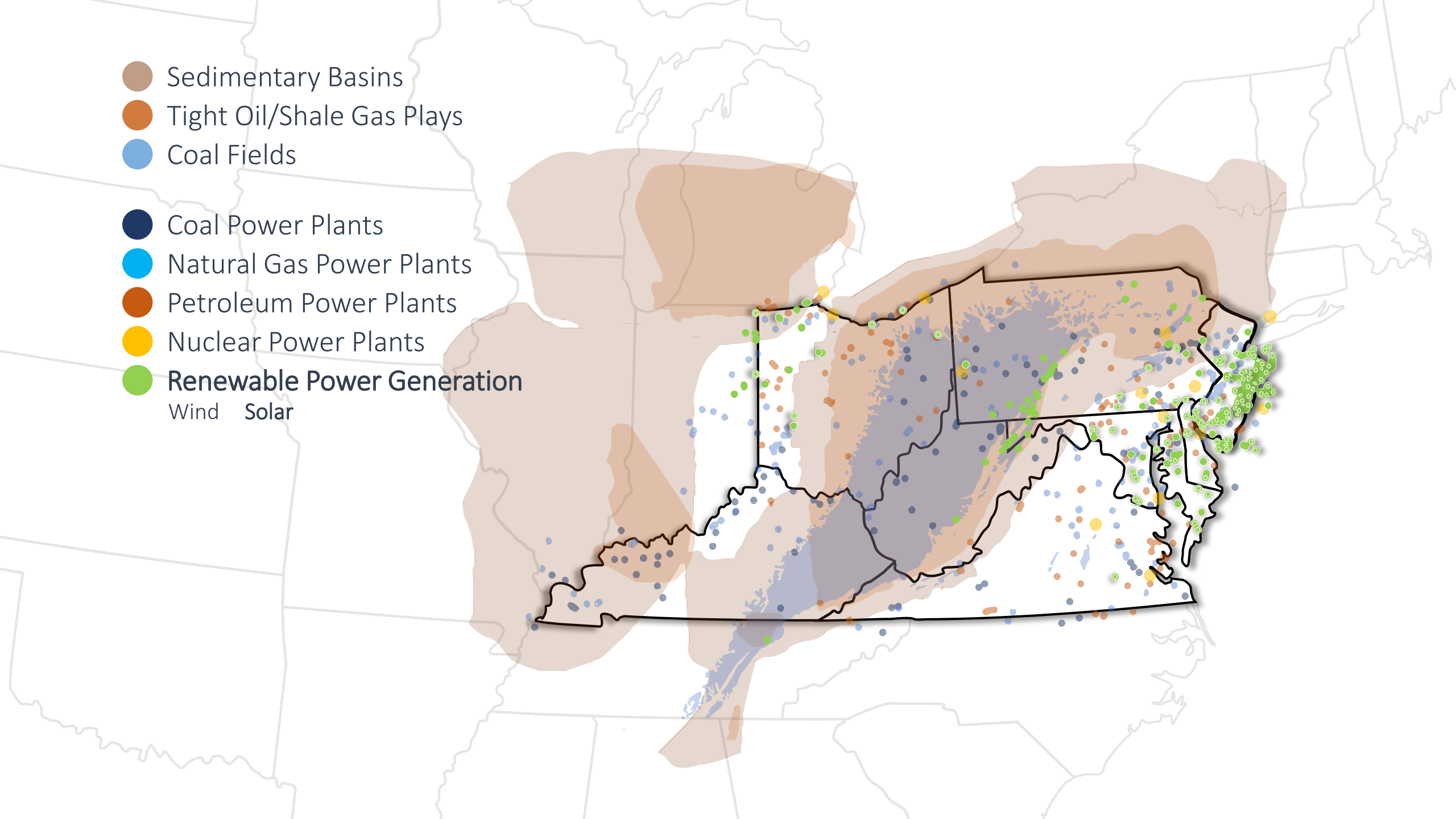
Coal Power Plants
Natural Gas Power Plants
Petroleum Power Plants
Nuclear Power Plants


Sedimentary Basins
Tight Oil/Shale Gas Plays
Coal Fields
Coal Power Plants
Natural Gas Power Plants
Petroleum Power Plants
Nuclear Power Plants
Renewable Power Generation
Wind


Sedimentary Basins
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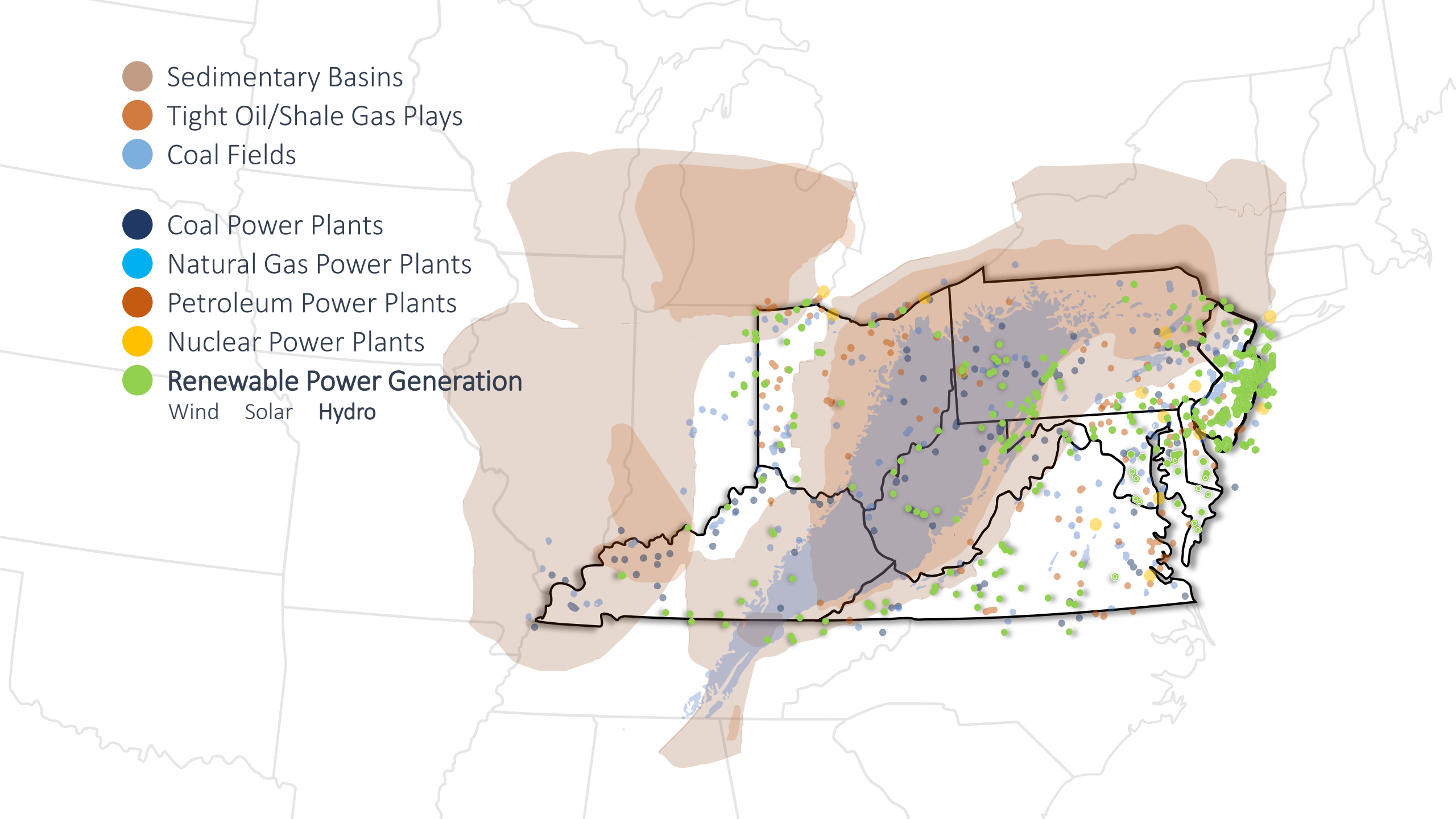
Renewable Power Generation
Wind
Solar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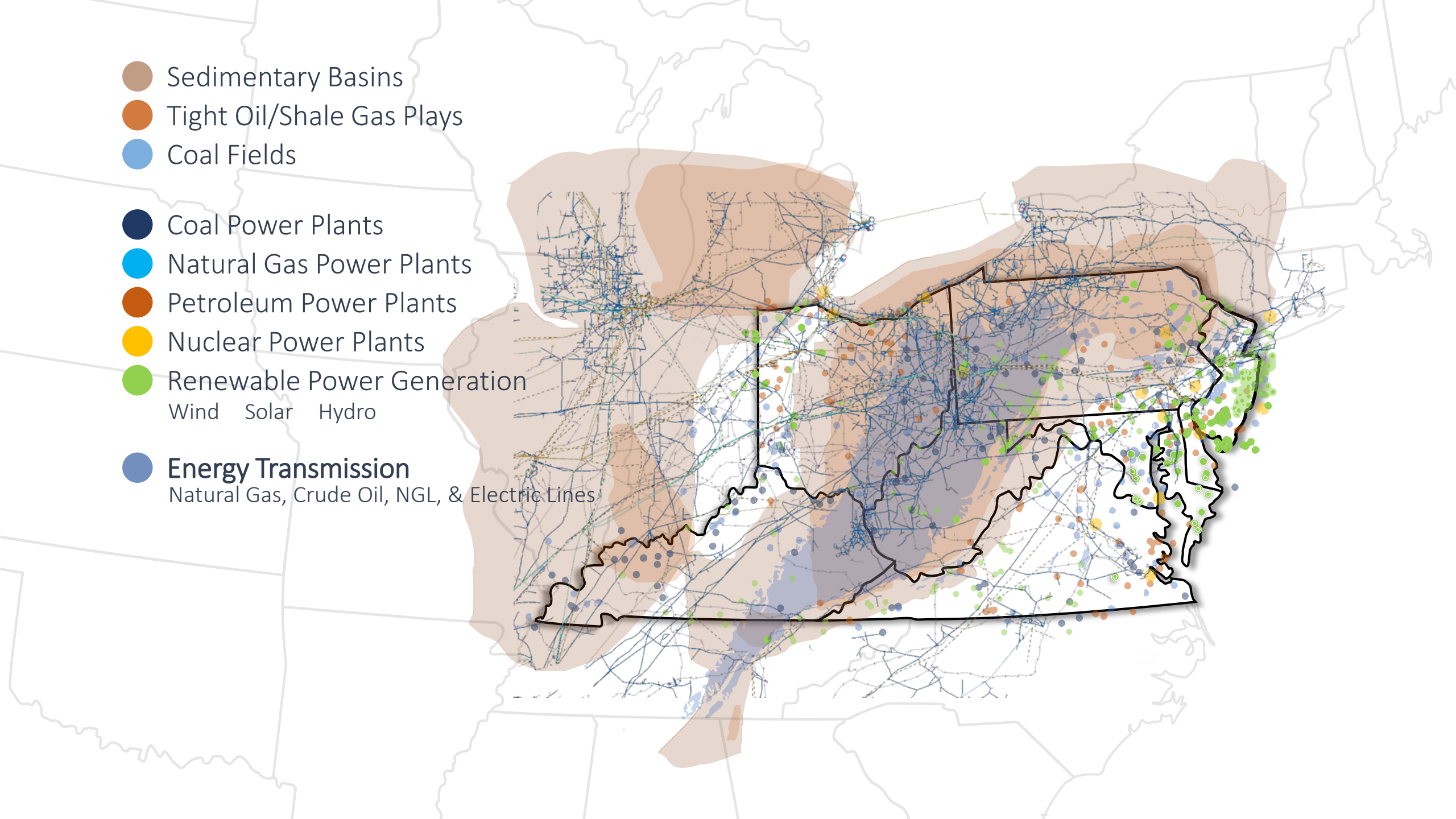
Renewable Power Generation
Wind
Solar
Hydro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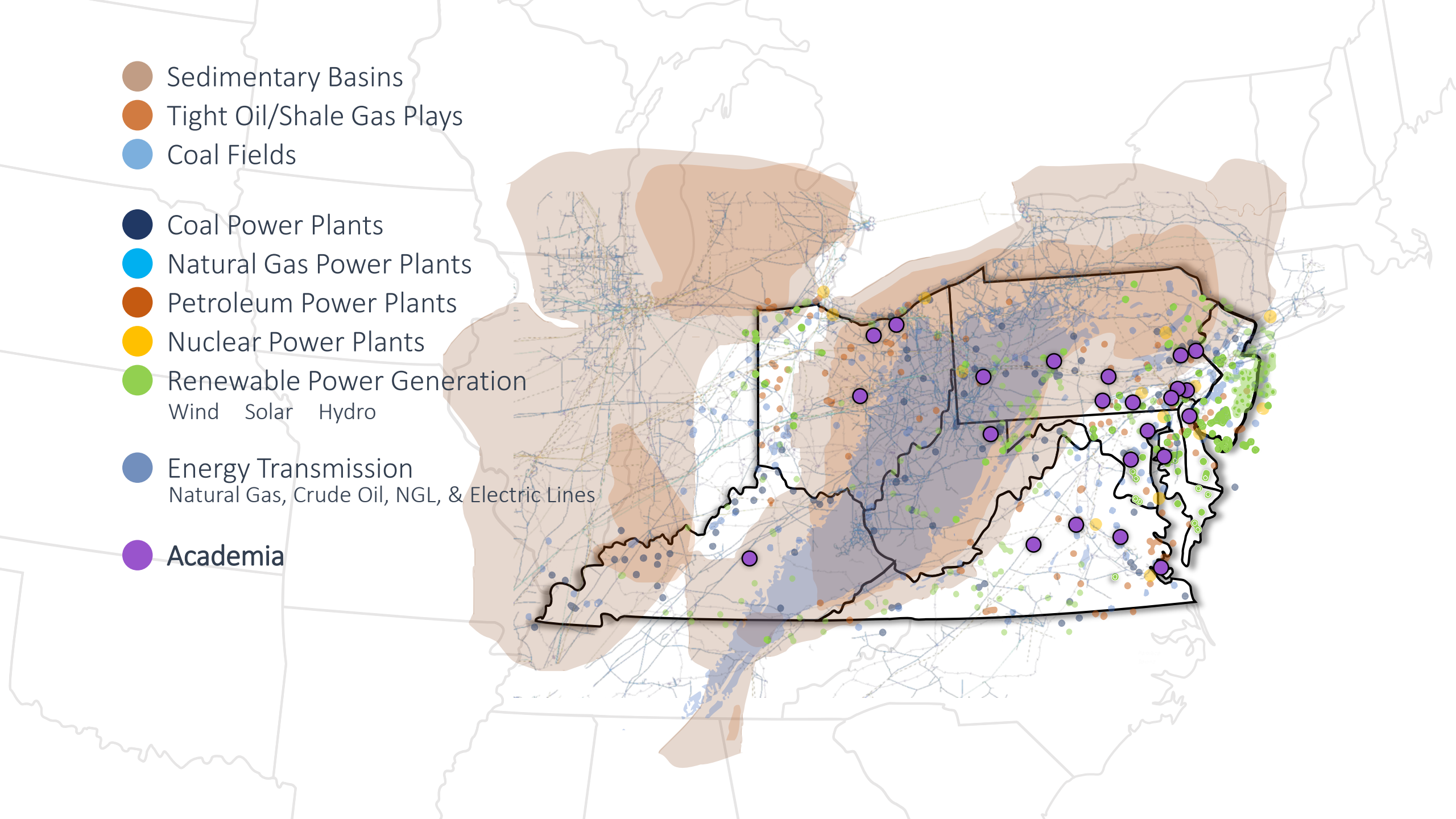
Wind Solar Hydro
Energy Transmission
Natural Gas, Crude Oil, NGL, & Electric Lines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Academia

- Sedimentary Basins
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- Coal Fields

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  - Solar
  - Hydro

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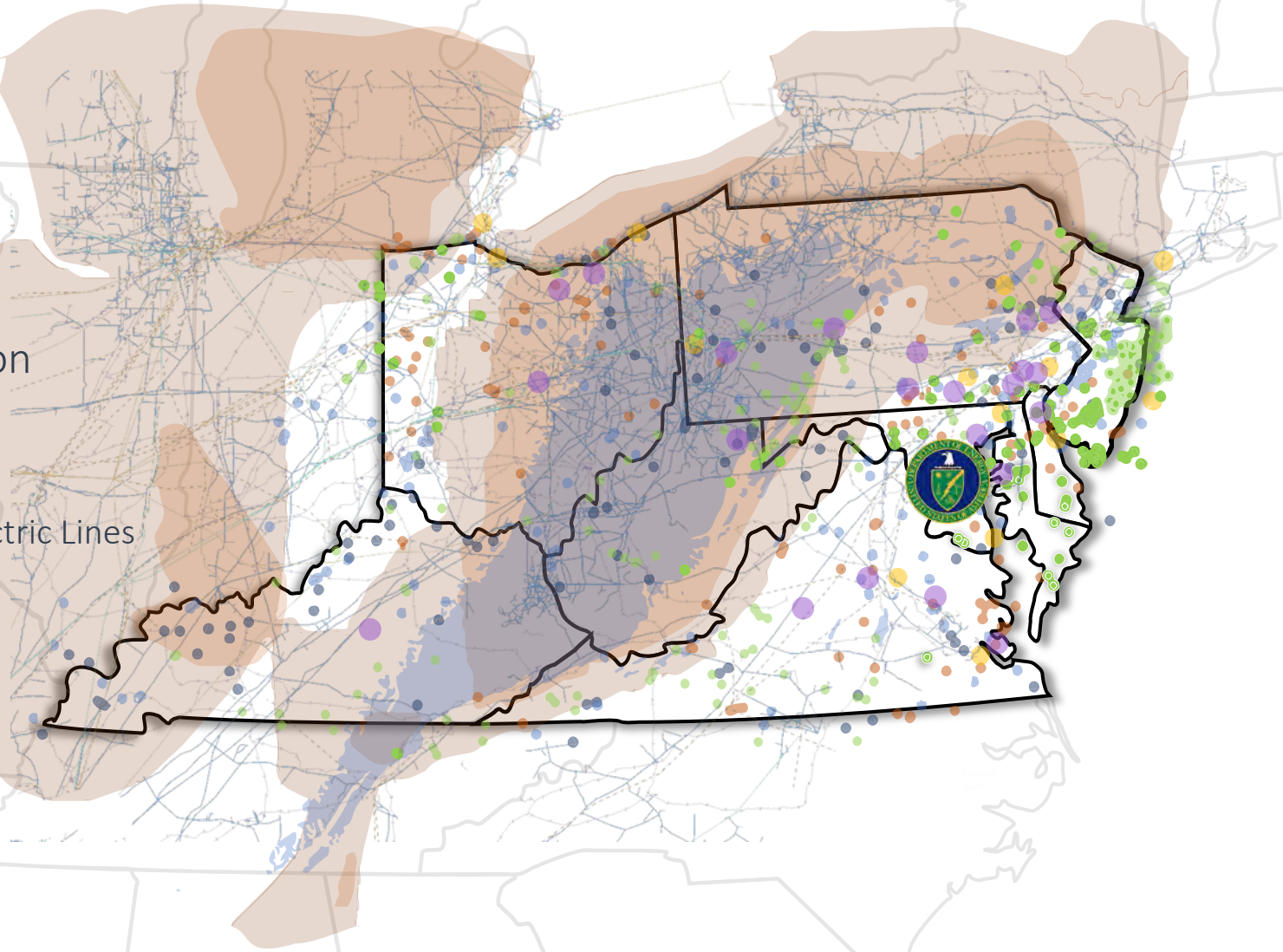
- Academia

- US DOE



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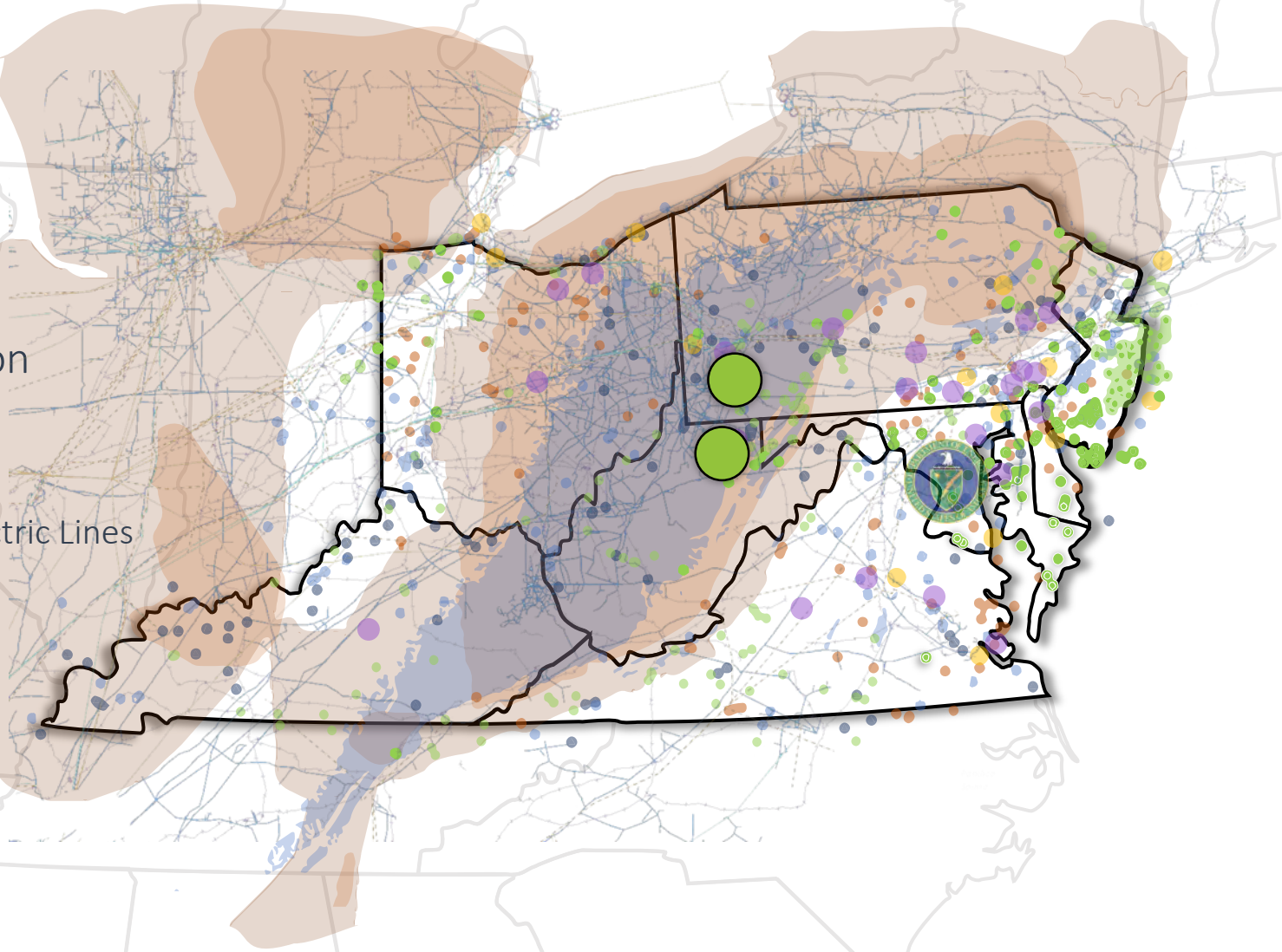


NETL
NATIONAL ENERGY TECHNOLOGY LABORATORY

NETL Core Competencies

NATIONAL ENERGY TECHNOLOGY LABORATORY

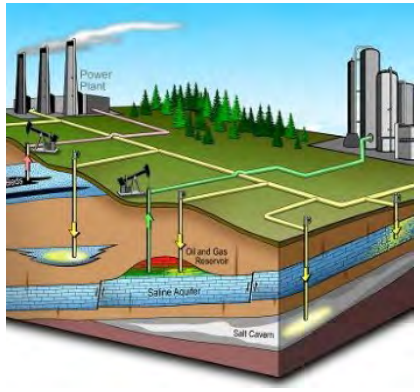
Effective Resource Development • Efficient Energy Conversion • Environmental Sustainability

Computational Science & Engineering

- High Performance Computing
- Data Analytics
- Machine Learning

Materials Engineering & Manufacturing

- Structural & Functional
- Design, Synthesis, & Performance
- Characterization



Geological & Environmental Systems

- Geo-Analysis & Monitoring
- Data Storage, Management, & Analysis
- Geochemistry

Energy Conversion Engineering

- Reaction Engineering
- Design & Validation
- Innovative Energy & Water Processes

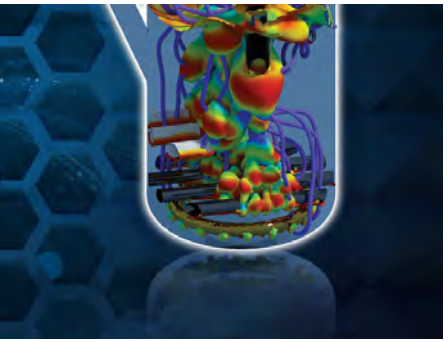
Systems Engineering & Analysis

- Process & System
- Multi-scale Modeling, Simulations & Optimization
- Energy Markets Analysis

Program Execution & Integration

- Technical Project Management
- Market & Regulatory Analysis

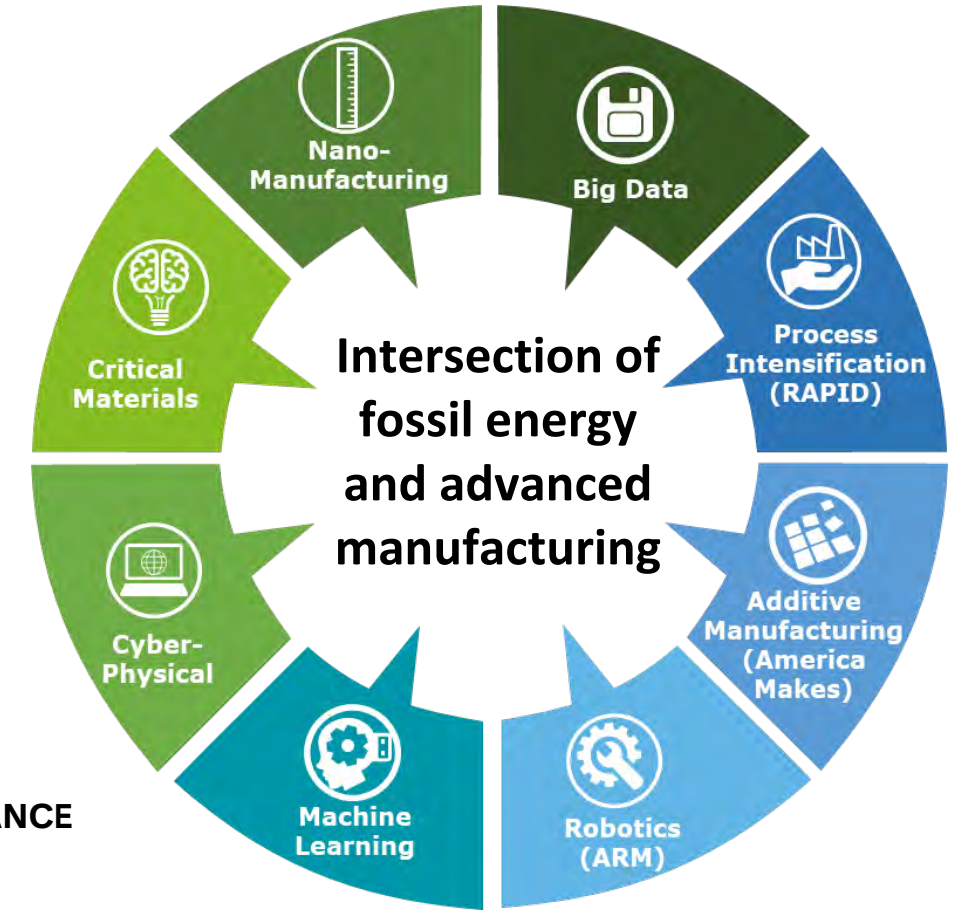
An Innovative Approach



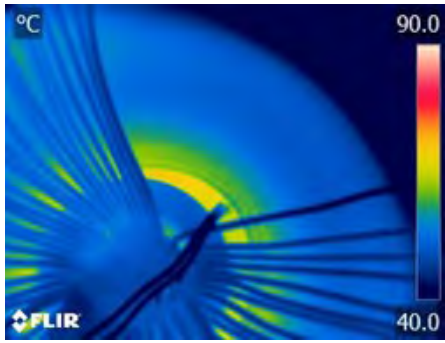
Process Intensification

Energy Conversion Technologies

High Performance Computing, Simulation, & Modeling

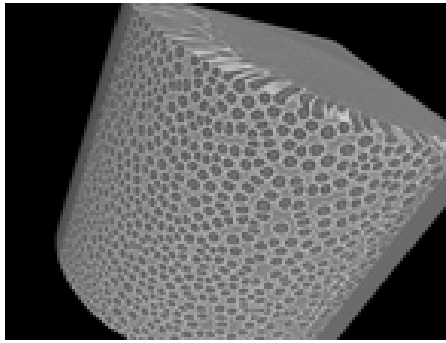


Advanced Power Electronics



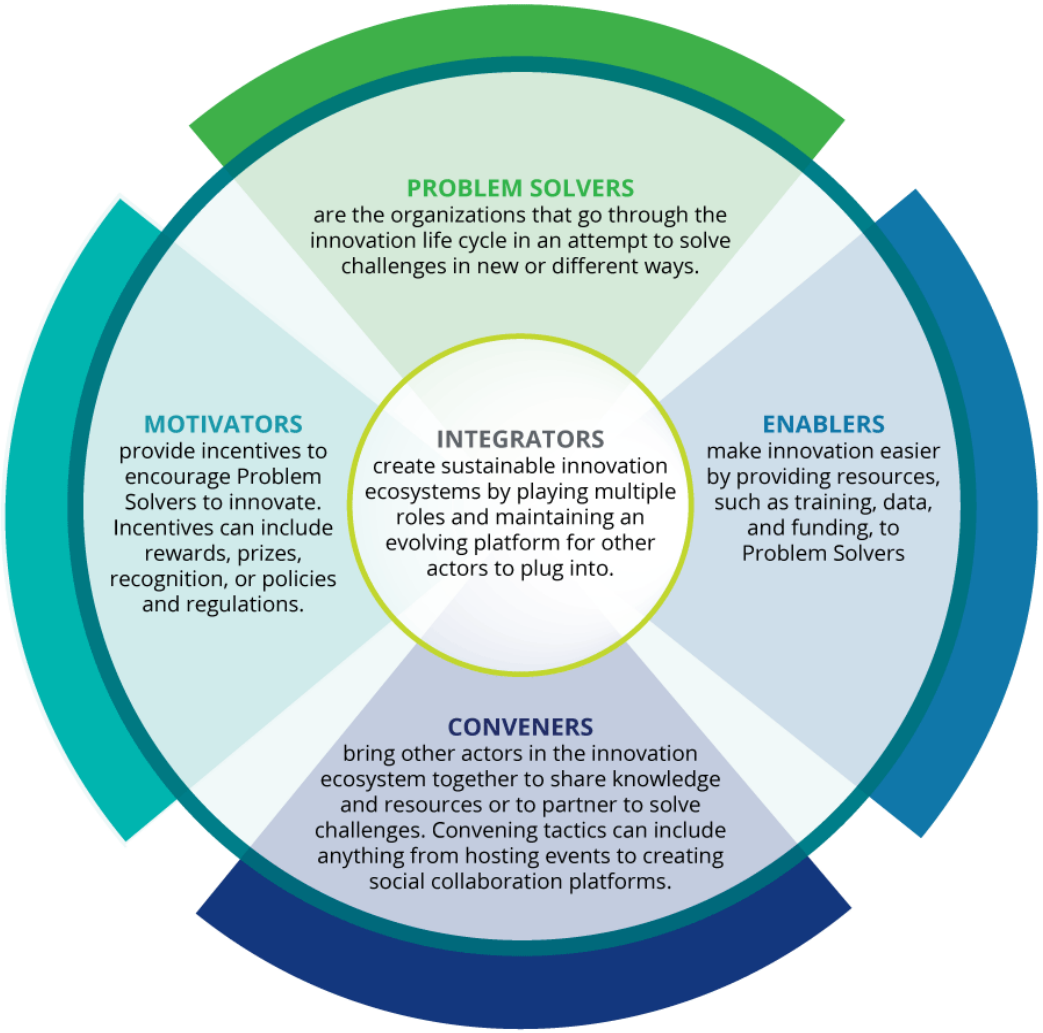
Next Generation Materials for Harsh Environments

Functional Materials



U.S. Advanced Hydrocarbon Economy

NETL's objectives span the various roles associated with collaborative endeavors



Problem Solvers

- Perform research with the aim to enhance shale gas conversion
  - Develop new materials and processes (Creation of new pathways)
  - Improve performance and economics (Enhancement of existing pathways)
- Develop roadmaps to inform S&T efforts

Enablers

- Provide data, insight, and analyses to help inform conversion strategies
- Perform system studies to evaluate optimal pathways and inform S&T efforts
- Enable access to facilities for the purpose of advancing innovative conversion solutions
- Enhance training and workforce development
- Perform and provide unbiased technical and economic analyses to support conversion strategies.

Conveners

- Facilitate meetings, conduct events, and organize conferences to engage parties across the ecosystem for the purpose of knowledge exchange
- Establish facilities that enable the demonstration of conversion technologies in relevant environments

Motivators

- Provide funding to support R&D related to shale gas conversion (catalysis, separations, reaction engineering)
- Offer grants to support small businesses with novel solutions to shale gas conversion challenges
- Conduct competitions and offer prizes to recognize innovations and problem solvers

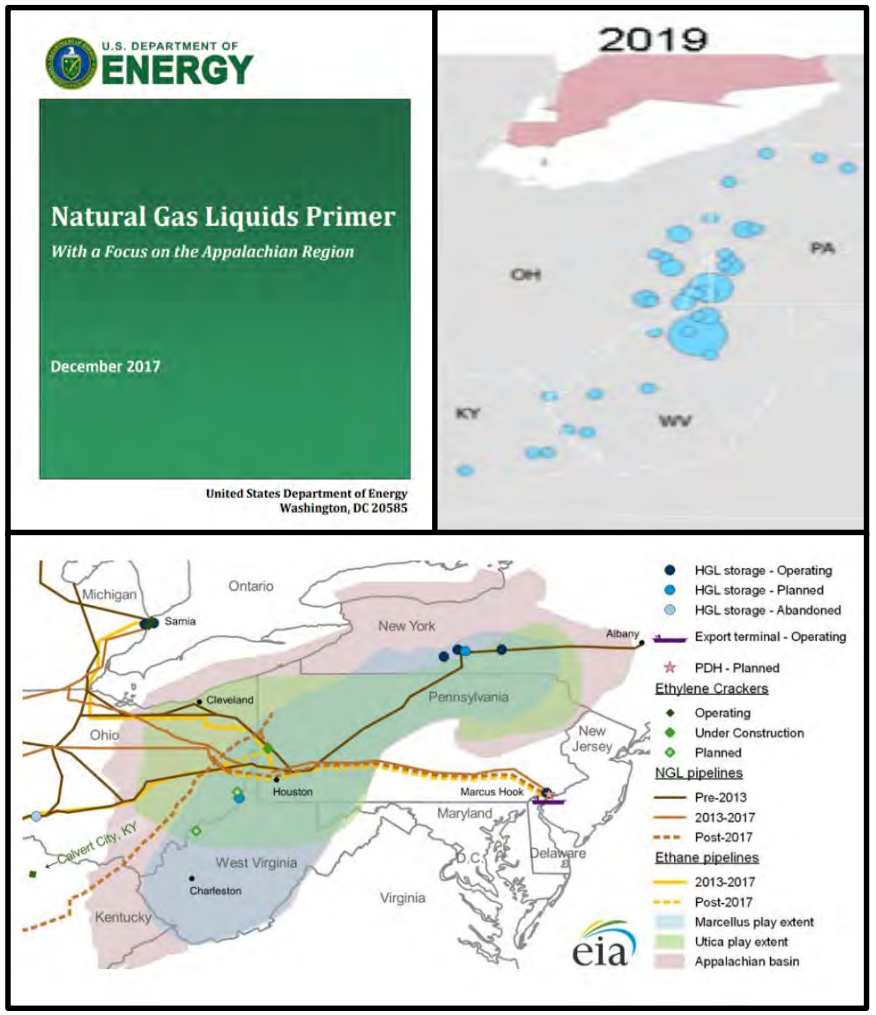
Integrators

- Align actors and enhance the effectiveness of the ecosystem as a whole
- Articulate the innovation ecosystem's goals and create processes and platforms to enable entities to work together effectively
- Identify opportunities for collaborative research among ecosystem entities
- Perform scenario analyses to help inform strategic planning exercises
- Coordinate efforts (S&T and otherwise) among disparate entities that span the public and private sectors..

DOE/NETL Report to Congress

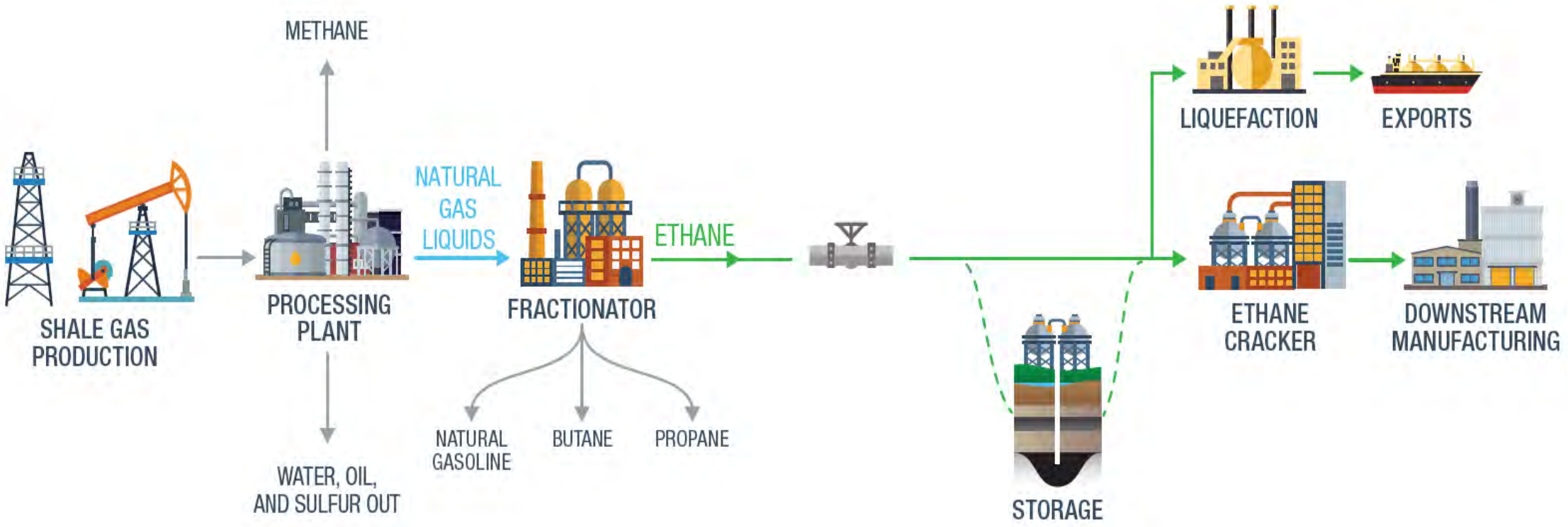
Ethane Storage and Distribution Hub in the United States

- On December 20, 2017, the U.S. Department of Energy published a Natural Gas Liquids (NGLs) primer that showcases the resource potential of NGLs, specifically in the Appalachian region.
- This primer explains what NGLs are, how they are used, recent market developments, and the supporting infrastructure in the Appalachian region.
- The Primer was updated and re-released in June 2018.
- The primer was an important step in preparing the requested Report to Congress about the benefits of Appalachian NGLs for years to come and the potential for the development of an ethane storage hub in Appalachia.
- The Report to Congress was published in November 2018.



The Ethane Supply Chain

A Generational Opportunity

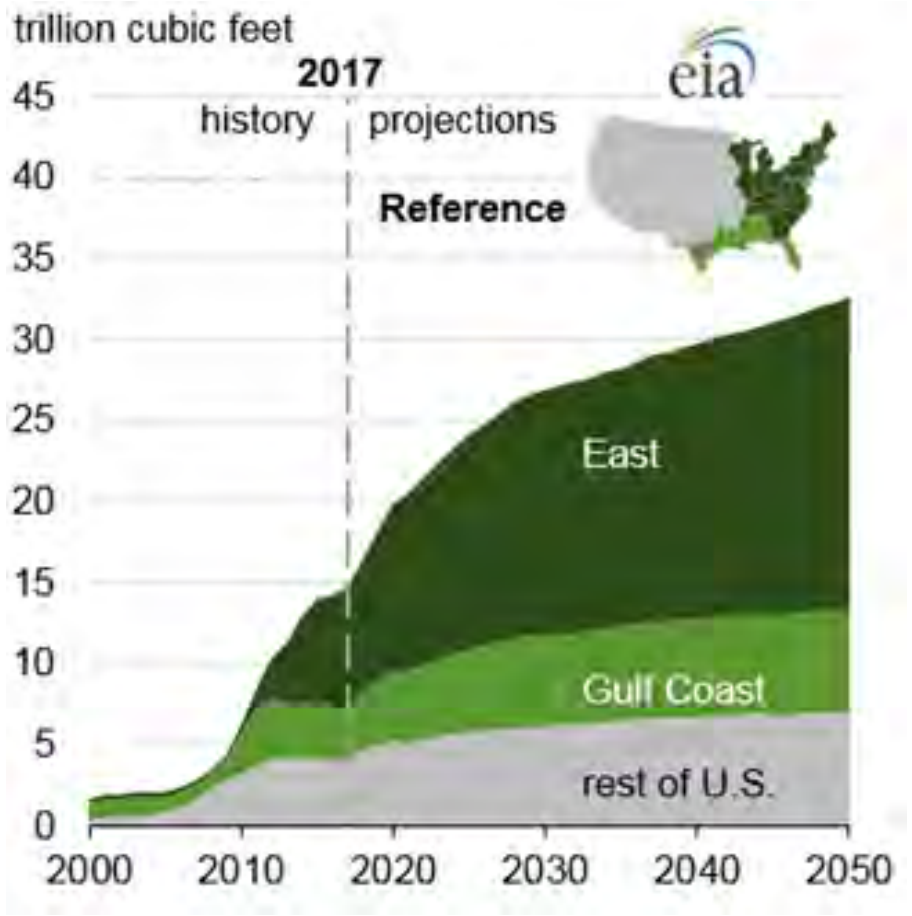


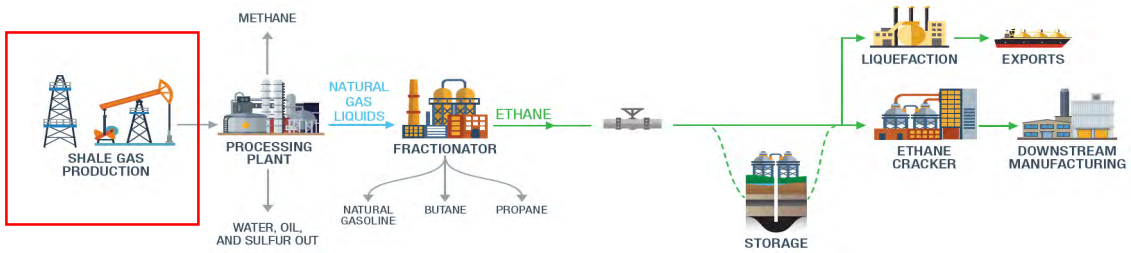
Is Appalachia Positioned to Take Advantage of the Economic Opportunity Expected to Occur in the Ethane Supply Chain?

A Rapidly Evolving Energy Landscape

Appalachian Shale Gas Projected to Transform Energy Economy

U.S. Shale Gas Production





AEO 2018 projects shale gas production to more than double by 2050

- Much of this growth driven by shale gas production in Appalachia

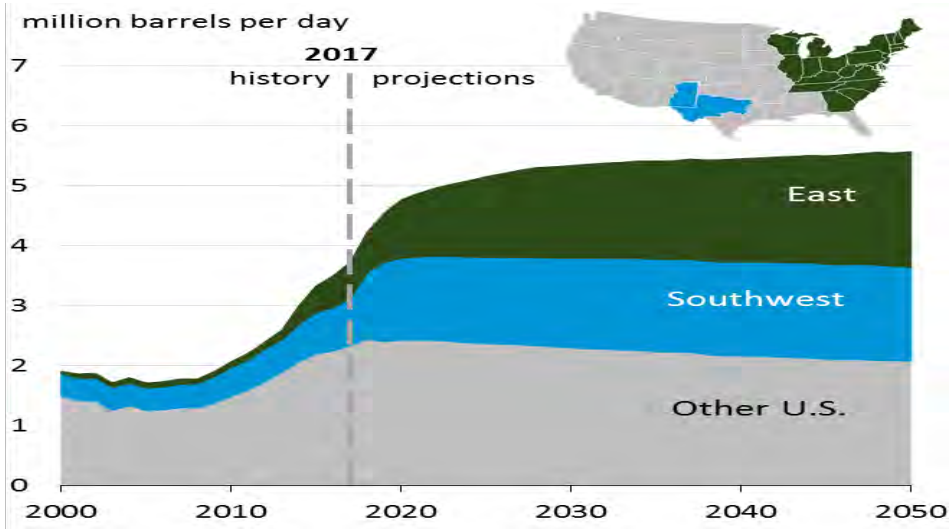
Appalachian production increased almost twenty fold from 2008 to 2017

- This trend is expected to continue

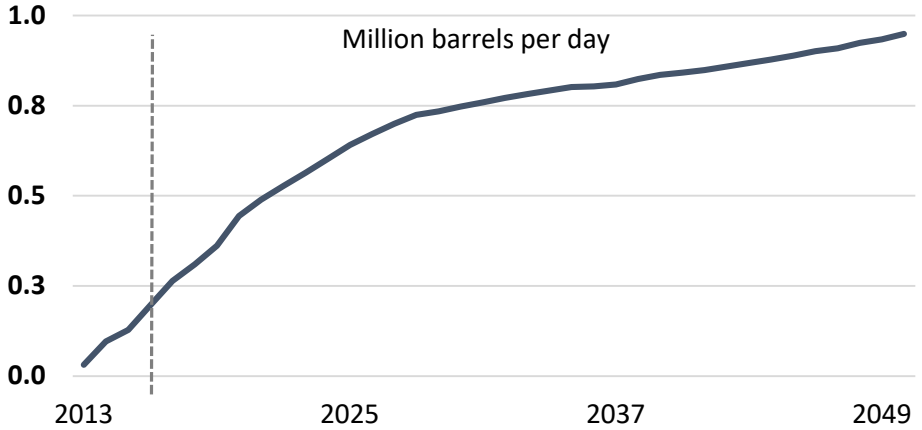
A Rapidly Evolving Energy Landscape

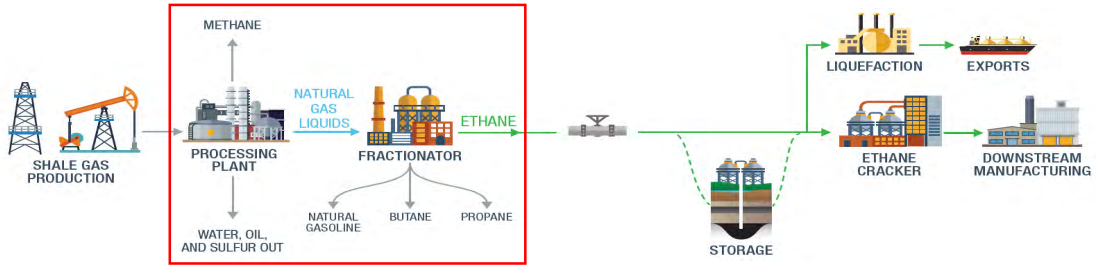
NGLs from Appalachian are Driving a Surge in Ethane Supply

U.S. NGPLs Production



Appalachian Ethane Production



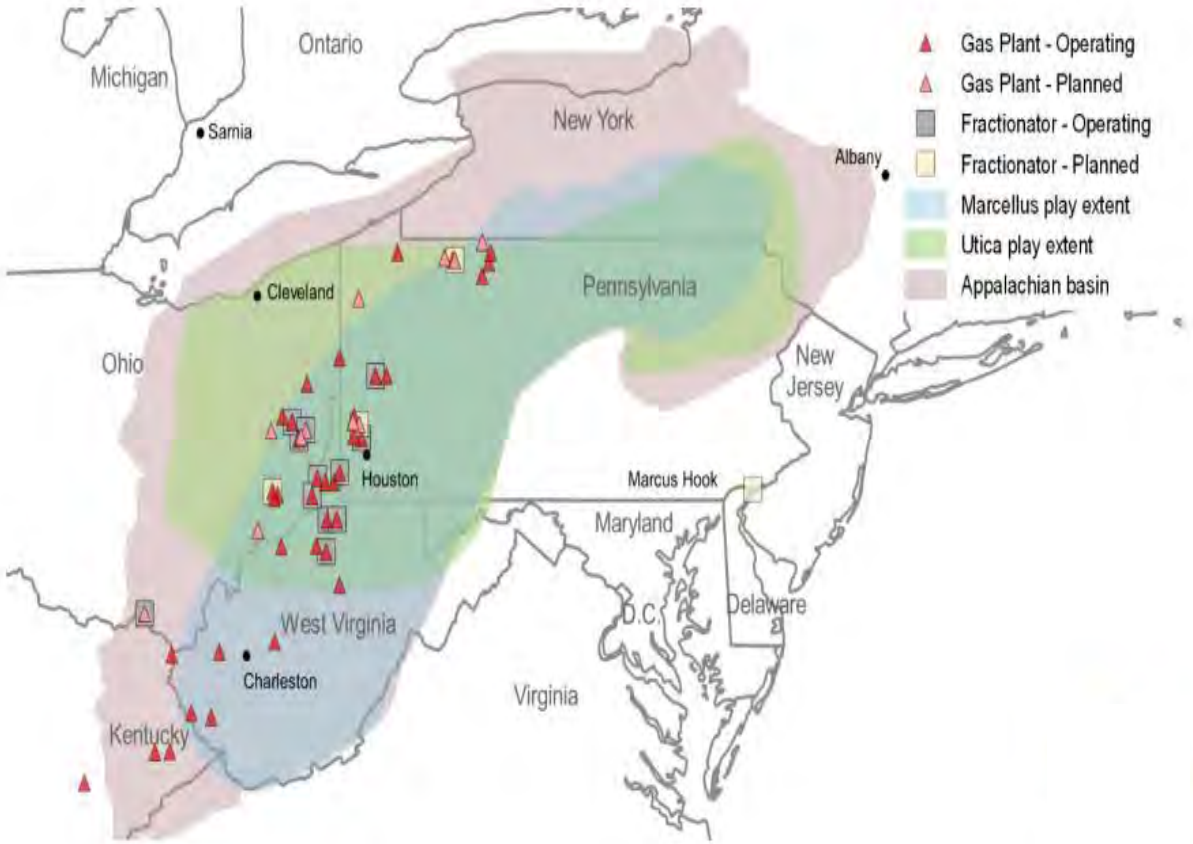


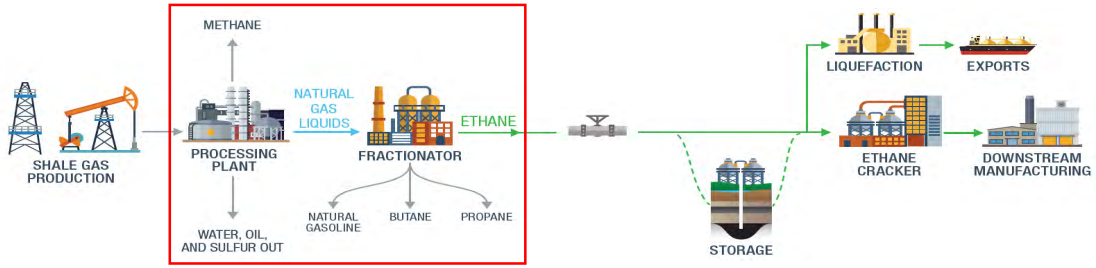
- **EIA forecasts NGPLs production to rise by more than 50% between 2017 and 2050**
- **Projected Appalachian ethane production in 2025 is more than 20 times greater than regional production in 2013**

A Rapidly Evolving Energy Landscape

Appalachian Natural Gas Processing and Fractionator Capacity

Natural Gas Processing/Fractionator Capacity



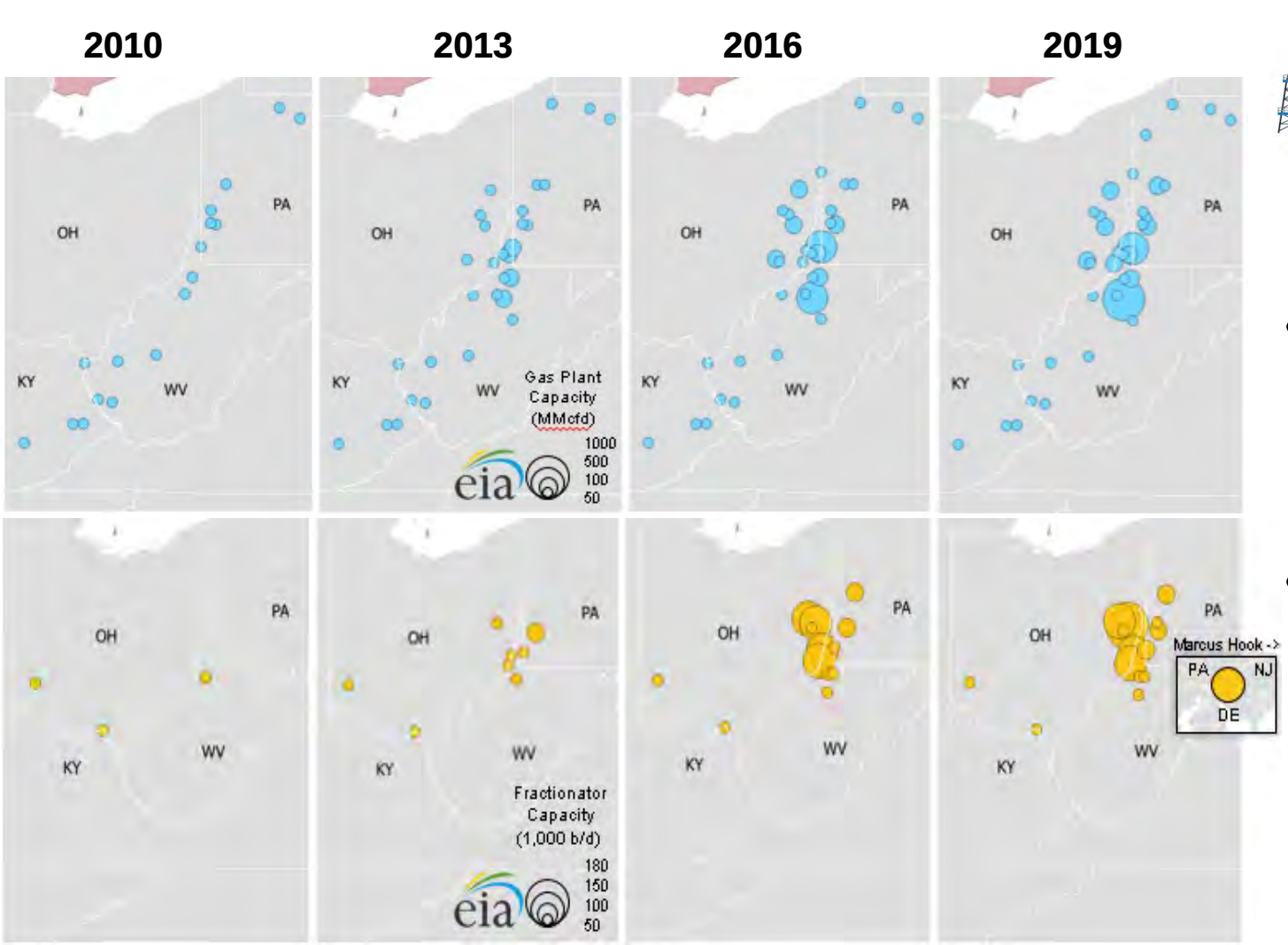


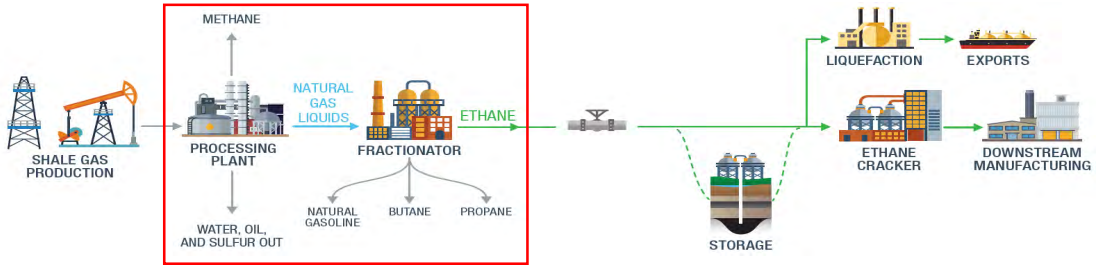
NGLs predominately produced in North-Central Appalachia in the wet-regions of the Marcellus and Utica

- NGLs are recovered from raw natural gas at gas processing plants as a mix
- The mixed stream NGL is then split into its constituent components at centralized fractionation plants

A Rapidly Evolving Energy Landscape

Appalachian Natural Gas Processing and Fractionator Capacity



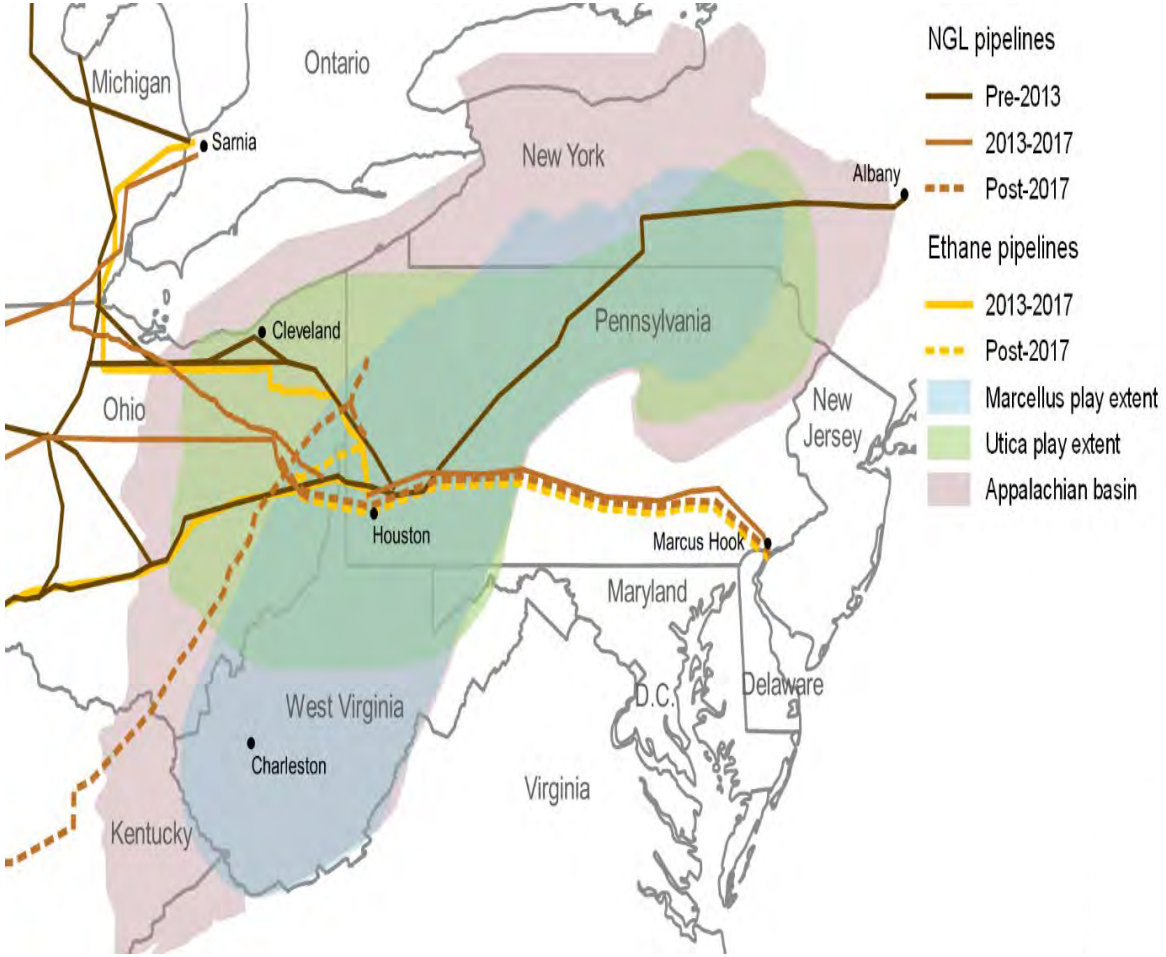


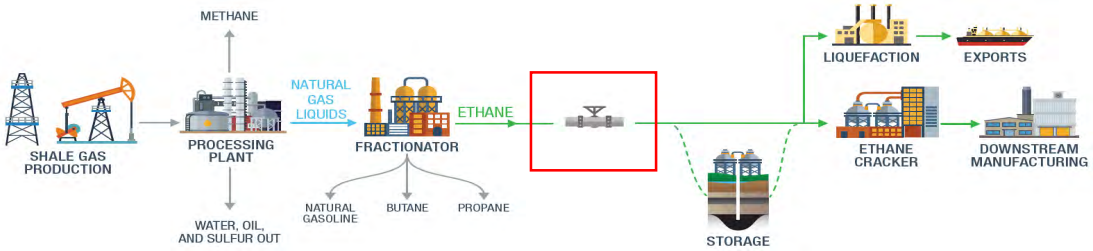
- **Between 2010 and 2016, natural gas processing capacity in Appalachia increased ten-fold**
- **Fractionation capacity has increased more than twenty-fold over the same time period**

A Rapidly Evolving Energy Landscape

Pipeline Capacity is Positioned to Transport Ethane Out of Appalachia

Appalachia NGL Pipelines





Appalachian Ethane is predominantly

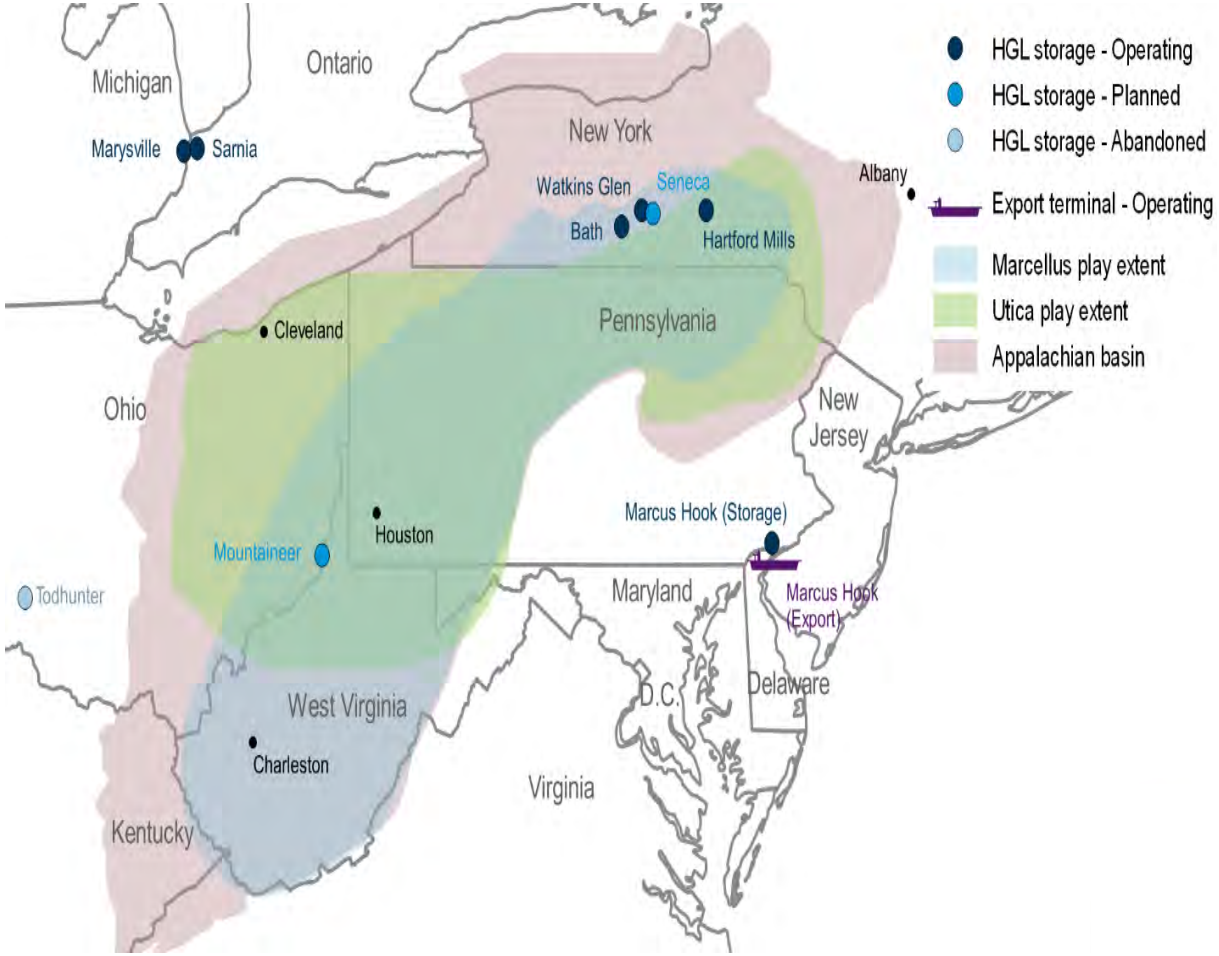
- Transported via pipeline to the Gulf Coast for processing
- Exported
- Combusted
- Avoided by producers (rejected)

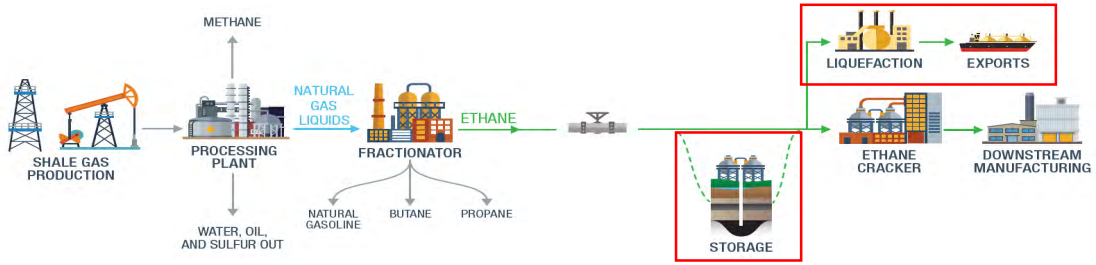
Added value of processing in-region is lost

A Rapidly Evolving Energy Landscape

Appalachia Storage Capacity Lacking

NGL Storage and Export Facilities





Storage is essential to managing

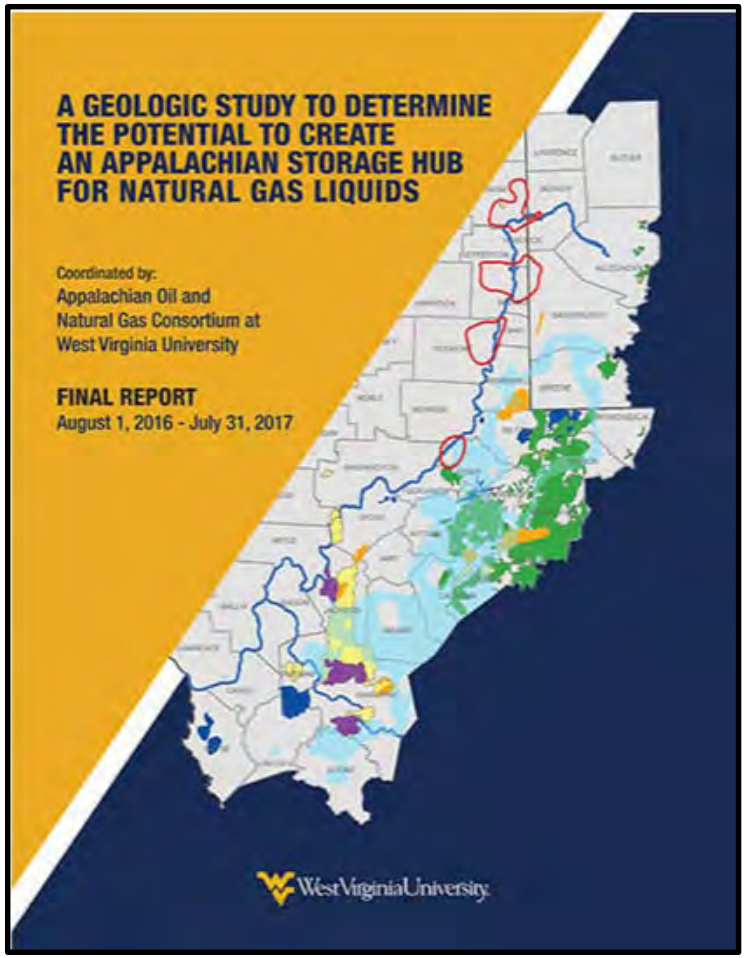
- Seasonal supply variability
- Processing facility outages
- Holding for transport or export

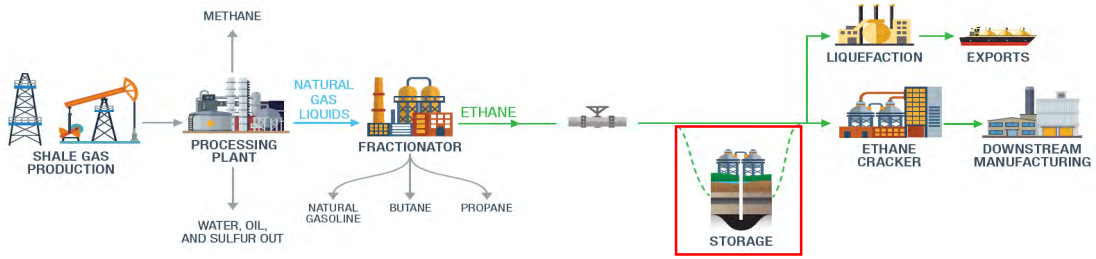
Large-scale storage does not exist in the wet gas sub-region of Appalachia

A Rapidly Evolving Energy Landscape

Area Geology Could Enable Sufficient Storage

Appalachian Basin NGL Storage Study



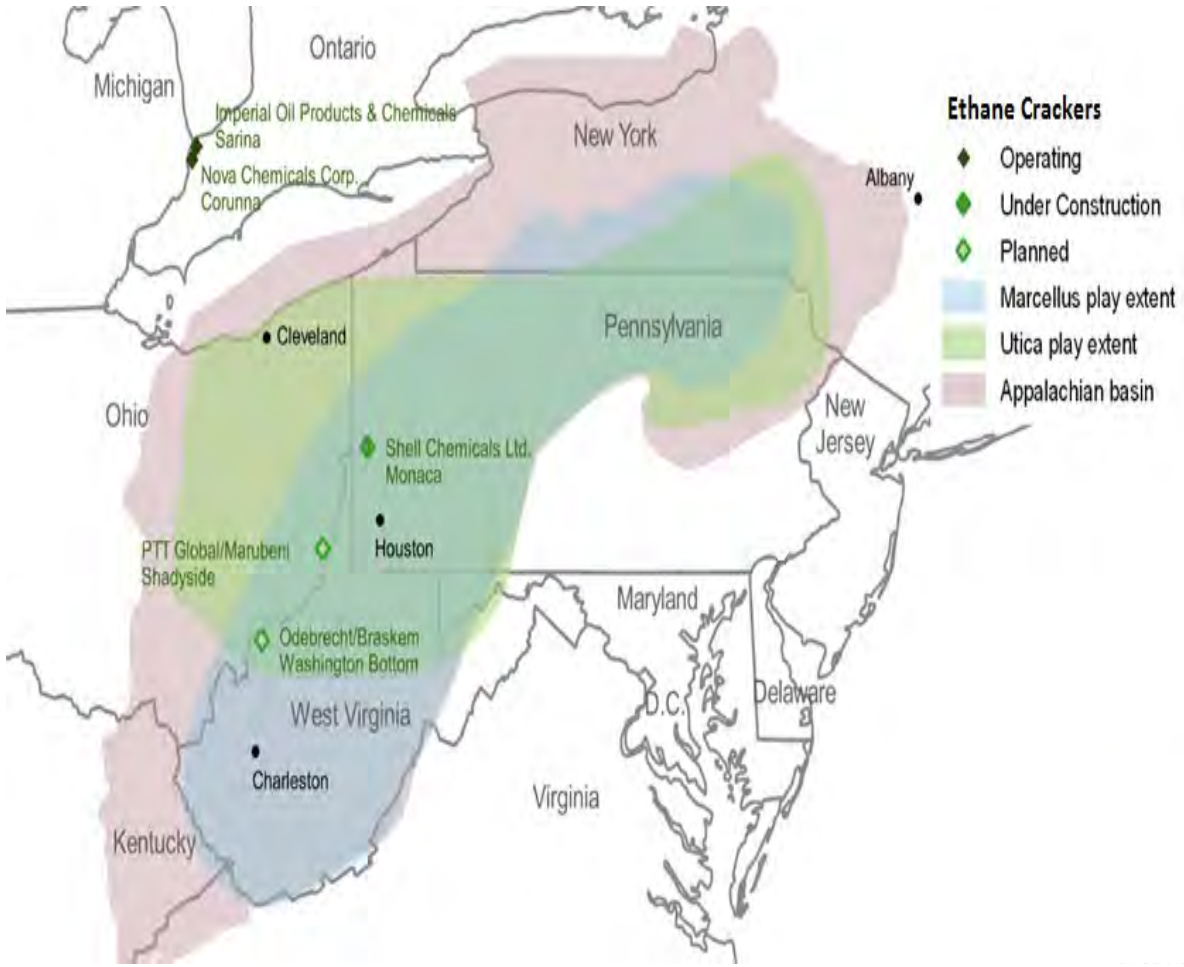


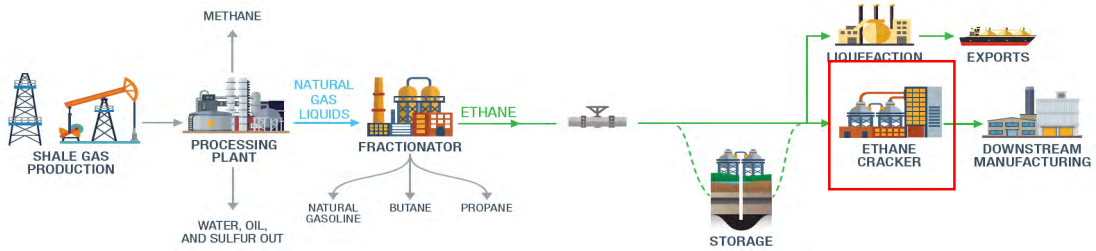
A Geological Investigation

- Candidate geology is in the wet gas region
  - Saline caverns
  - Hard rock caverns
- Underground storage is capital intensive
- Study did not consider project economics

A Rapidly Evolving Energy Landscape

Storage Increasingly Essential to Support Growth





Shell Chemicals Appalachia (under construction)

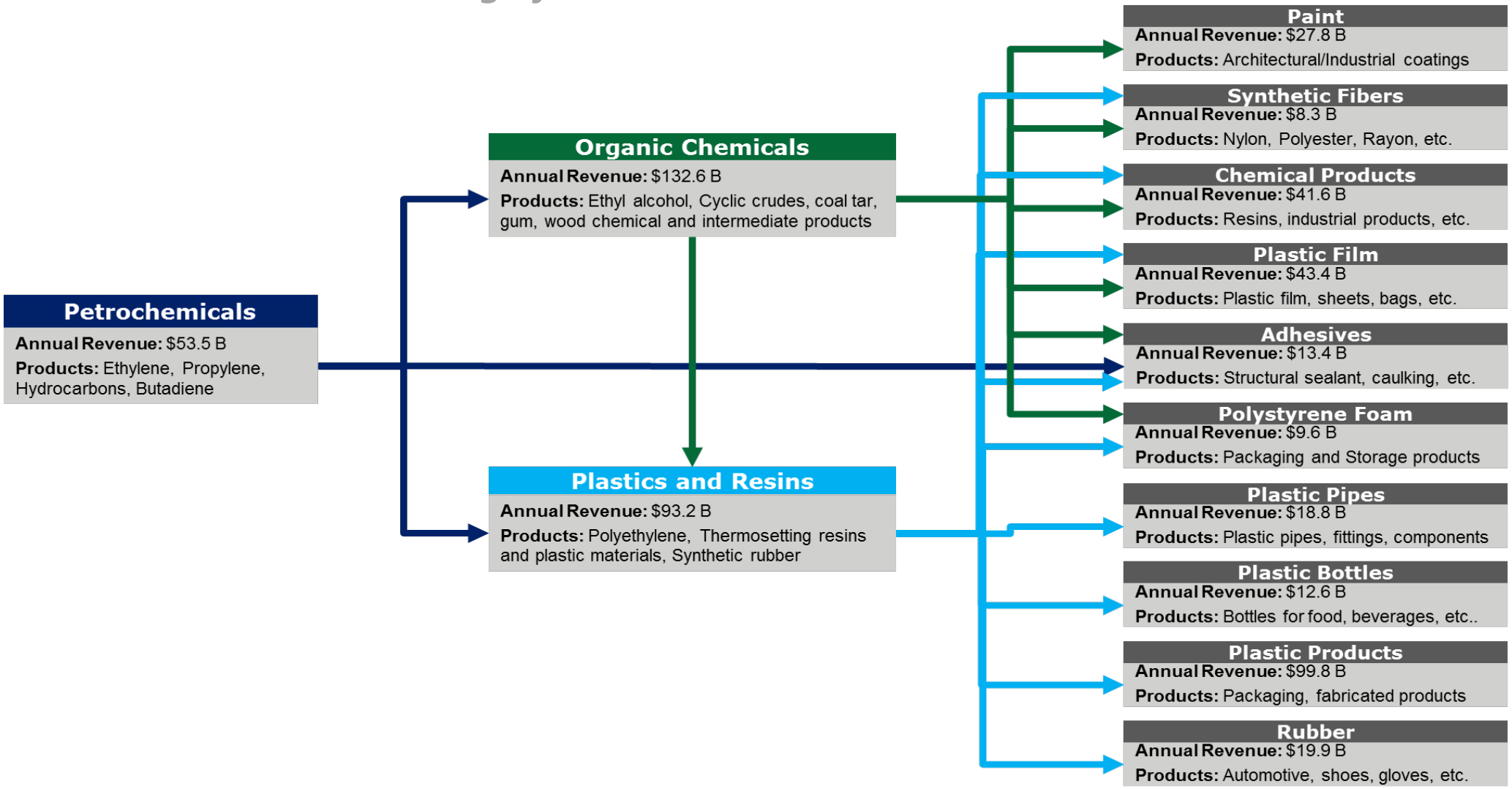
- $6B-$10B ethane cracker
- Dedicated ethane pipelines
- 6,000 person construction workforce
- 500 permanent plant operators

PTT Global Chemicals/Daelim (pending)

- $10B ethane cracker/derivatives units/other ancillary structures and equipment
- Pipeline infrastructure and some storage
- 6,000 person construction workforce
- 550 permanent plant operators

A Rapidly Evolving Energy Landscape

Ethane Related Products are a Significant Contributor to GDP

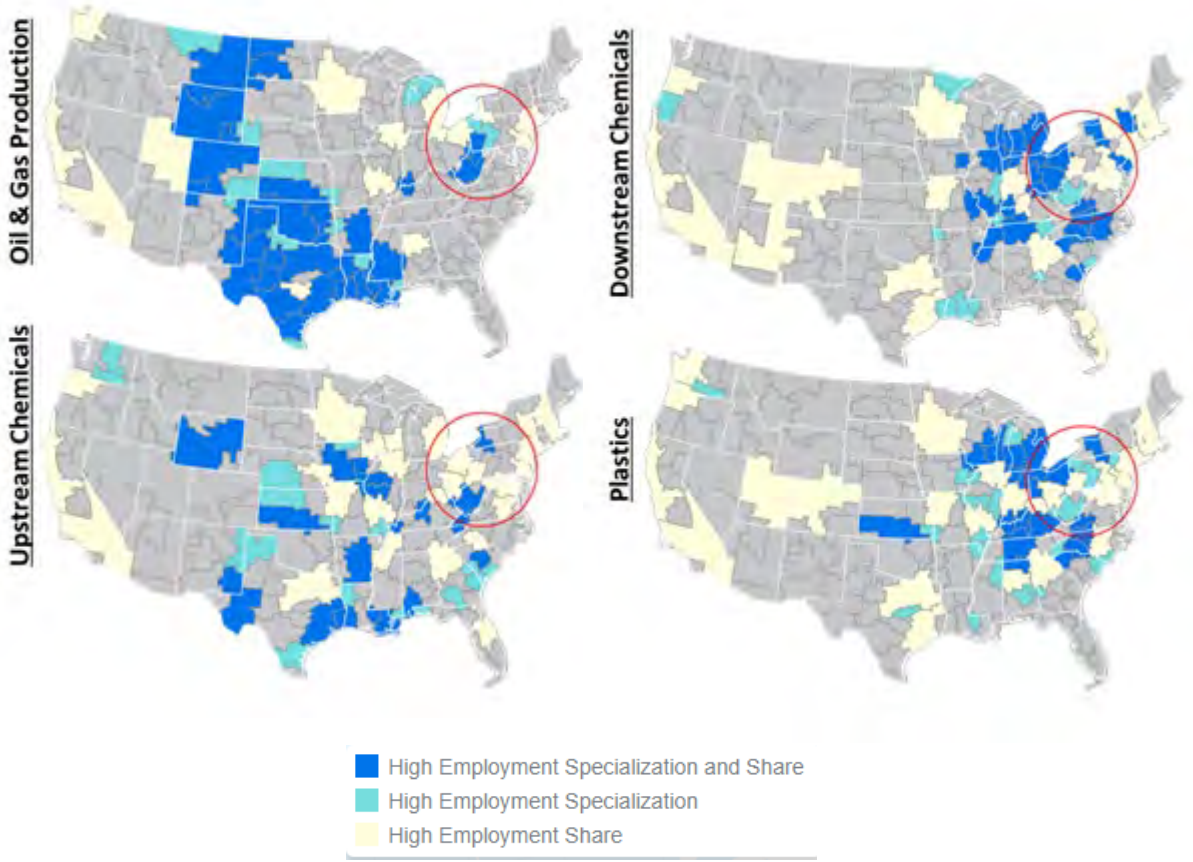


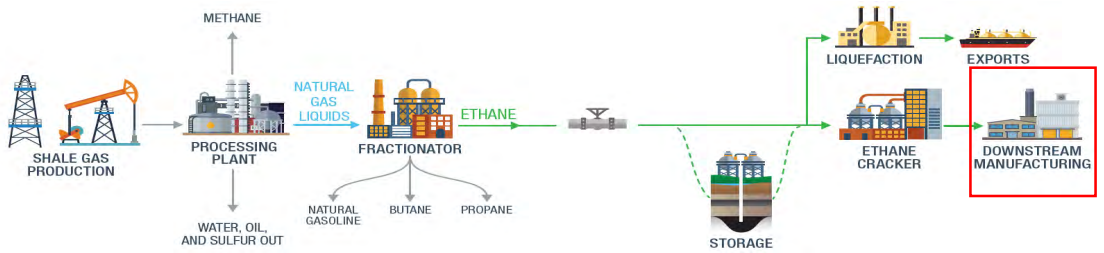
Industrial Ecosystem & Regional Activity

Is Appalachia Realizing the Full Benefit of its Ethane Resource?

NATIONAL ENERGY TECHNOLOGY LABORATORY

Petrochemical Clusters





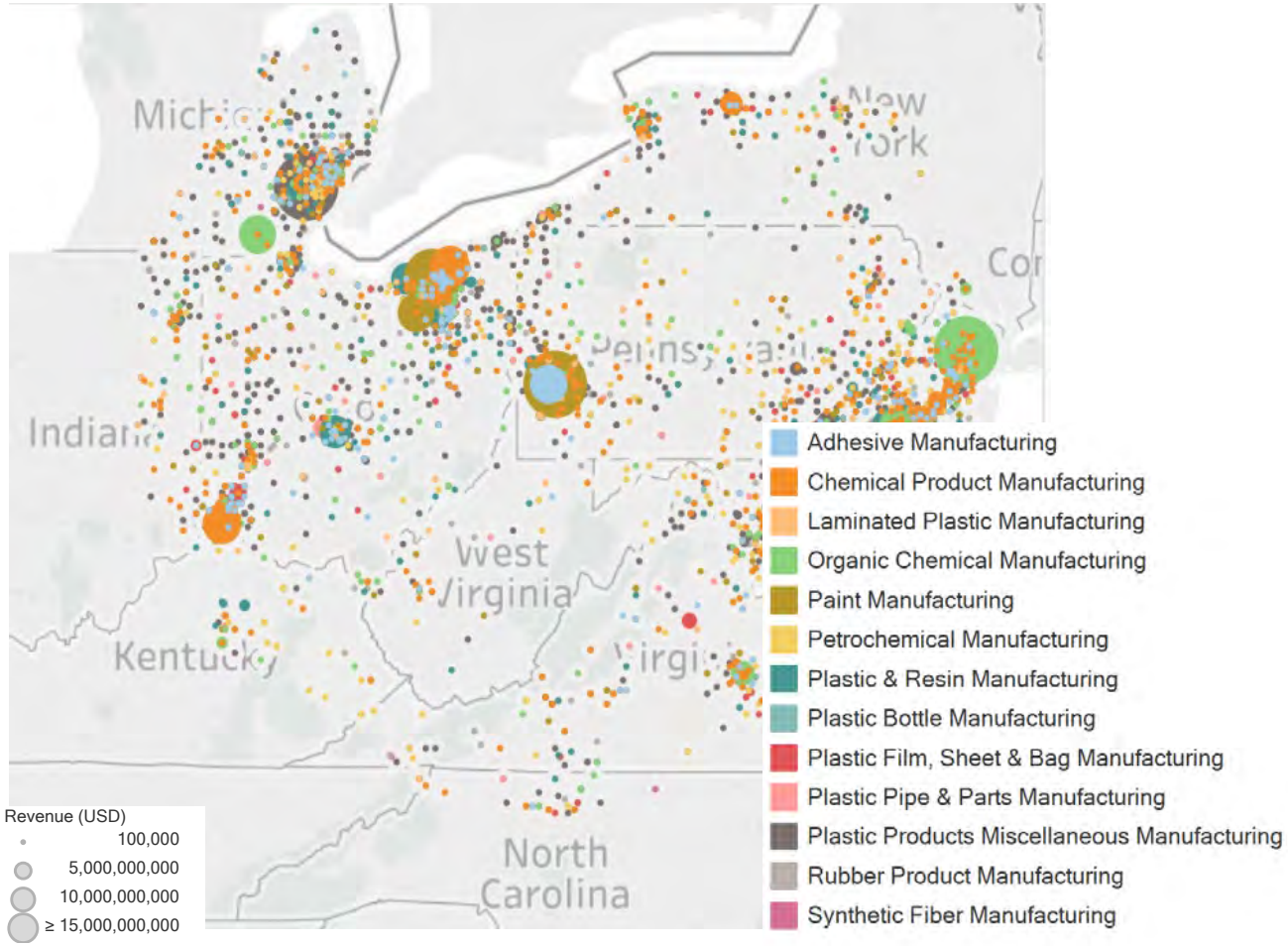
Petrochemical value chain in Appalachia has significant upstream and downstream activity with little midstream activity

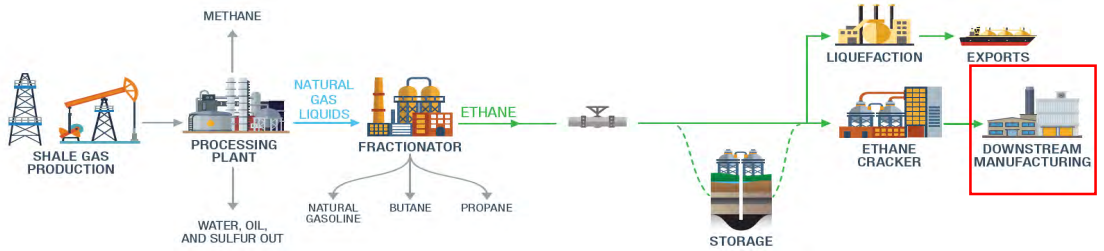
- Region is exporting its low cost ethane to Gulf Coast and internationally
- Region is importing chemical intermediates derived from ethane elsewhere

Industrial Ecosystem & Regional Activity

Appalachia and Vicinity Downstream Manufacturing is Significant

Industry revenue by NAICS





13 key petrochemical industries within 300 miles of Pittsburgh, PA

Appalachia accounts for nearly a third of U.S. activity in these 13 petrochemical industries

- $300 billion of net revenue
- 900,000 workers
- 7,500 establishments

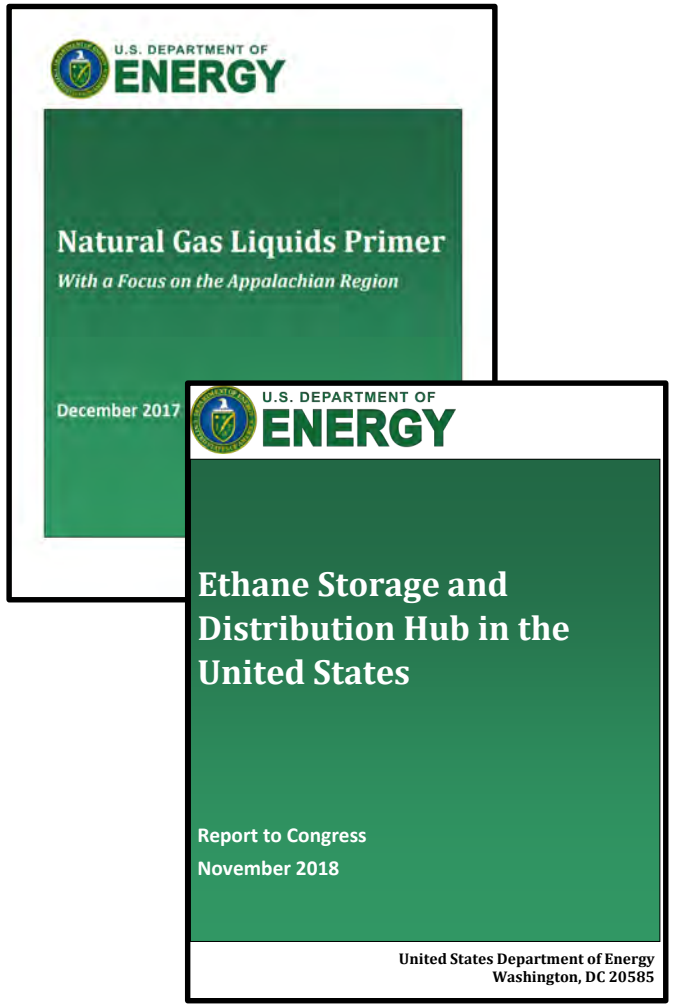
Market Analysis

Three Alternative Future Scenarios for Appalachia

Scenario A, *development of a petrochemical cluster in Appalachia is assumed to increase such that much of the incremental Appalachian supply is processed and consumed "locally"*

Scenario B, *the focus on continued development in the existing cluster of the Gulf Coast is assumed*

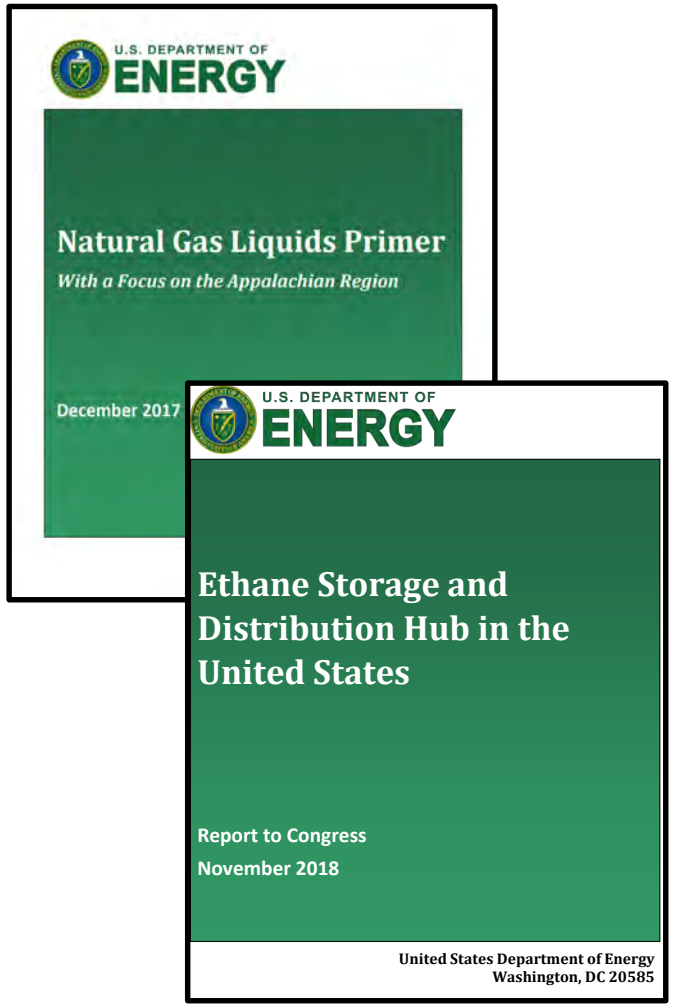
Scenario C, *incremental processing is assumed to occur elsewhere, facilitated by exports of the feedstock*



Market Analysis Findings

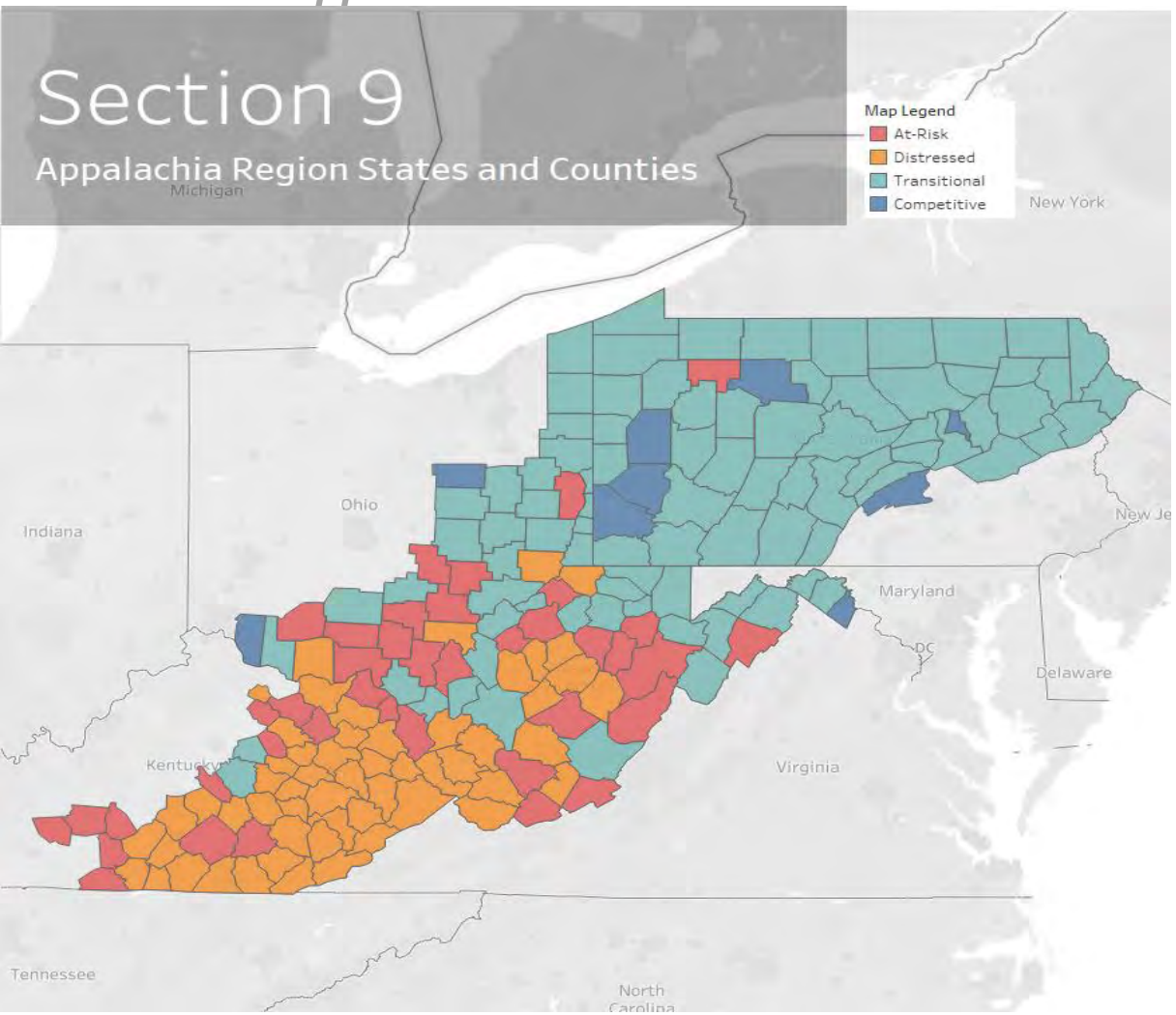
Ethane Storage and Distribution Hub in the United States: Report to Congress

- The present day geographic concentration along the Gulf Coast of petrochemical infrastructure and supply may pose a strategic risk, where severe weather events limit the availability of key feedstocks.
- Petrochemical expansion in the Appalachian region would increase geographic diversity and support resilience, reliability and security.
- This geographic diversity could provide manufacturers with flexibility and redundancy with regard to where they purchase their feedstock and how it is transported to them.
- Moreover, this flexibility and redundancy, as well as the overall increase in U.S. feedstock production, could mitigate the potential for any price spikes that could be caused by a severe weather or other disruptive event in any one region of the U.S.
- The development of new petrochemical capacity in Appalachia is not necessarily in conflict with Gulf Coast expansion; Appalachian capacity may serve regional demand for NGLs derivatives, freeing up Gulf Coast production for other markets, including exports overseas.



Presidential Executive Order 13868

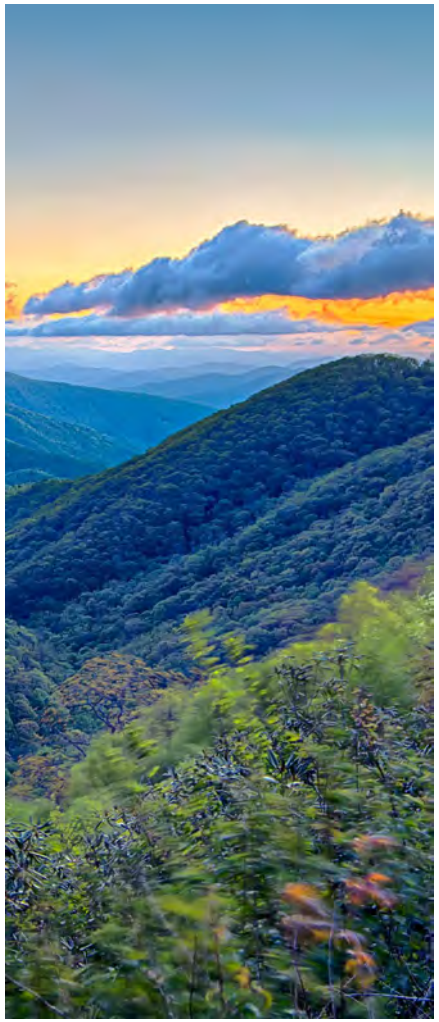
President Trump issued an EO on April 10 on Promoting Energy Infrastructure and Economic Growth in Appalachia



- **Focus on North-Central Appalachia, defined as the Appalachian counties within:**
  - Kentucky
  - Ohio
  - Pennsylvania
  - West Virginia
- **The driving theme of the report is harnessing the power of the shale natural gas revolution to develop a local petrochemical and downstream manufacturing cluster**

Presidential Executive Order 13868

A Path Forward



Facilitate the establishment of an Appalachian petrochemicals industry that:

- Enhances U.S. energy and manufacturing security
- Creates substantial economic benefit

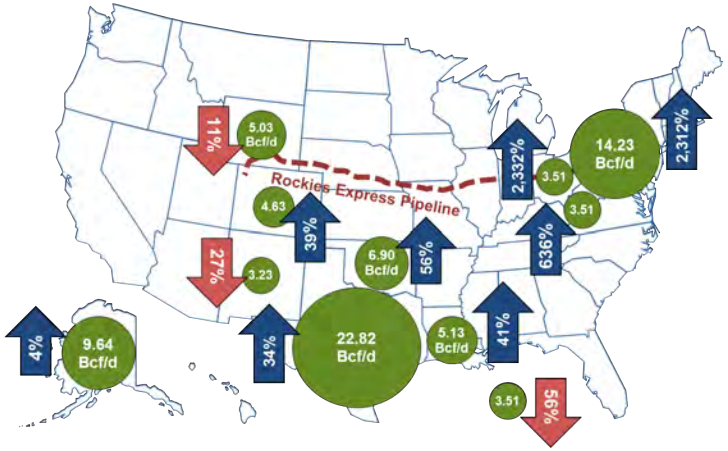
Align the economic resources of federal agencies with stakeholders to catalyze private sector investment

- Communicate the market opportunity and its benefits
- Invest in supporting public infrastructure
- Support energy infrastructure-related workforce development
- Facilitate the investment of private capital

A Generational Opportunity

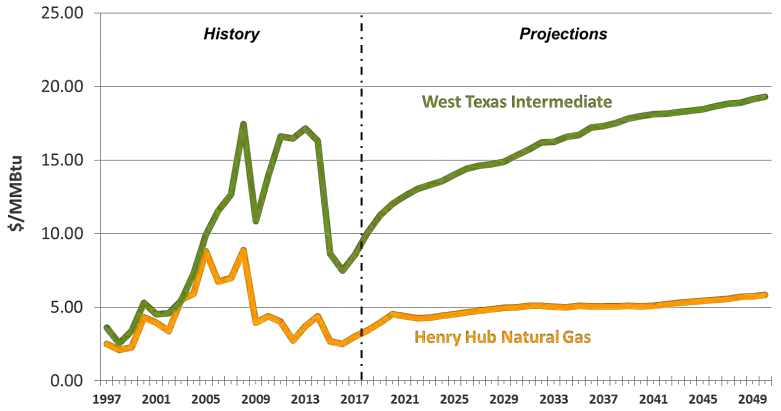
Abundant

- Rich variety of energy resources
- Natural gas feedstock
- Water availability
- Liquid Rich



Economics

- Domestic jobs
- Projected economic growth
- Location and demand of U.S. manufacturing facilities
- Proximity to markets
- Transportation cost advantage



National Alignment

- Increased National Security
- Increased domestic jobs
- Increased GDP
- Energy Independence

Innovation Ecosystem

- Advanced Manufacturing Institutes
- National Labs
- Academia
- Industry
- Start-ups
- Private Investors

Thank You

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Justin M. Adder
Economist

Thank you !

NETL RWFI Webinar:

Potential in Appalachia for the development of a new ethane storage hub

- All are on mute for the duration of the presentation
- Slides will be posted on netl.doe.gov/rwfi on the Webinar Archive Section
- Questions? Also- subscribe to NETL RWFI E-Note at (netl.rwfi@netl.doe.gov)

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