Summary: Office of Clean Coal and Carbon Management Strategic Vision

September 2020

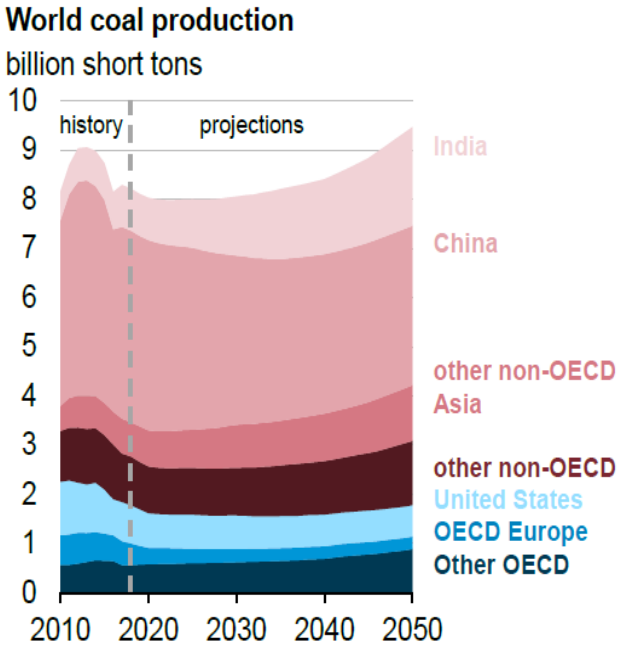
Office of Clean Coal and Carbon Management

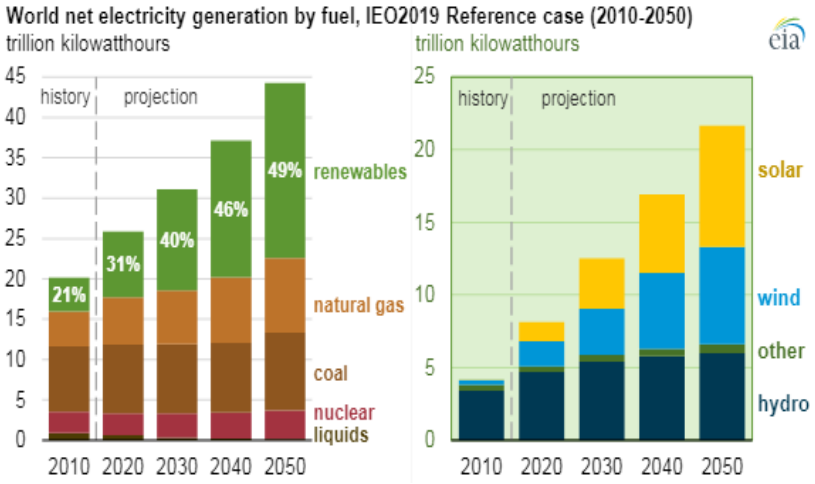
U.S. DEPARTMENT OF ENERGY

Strategic Vision

- Responds to market realities and evolving national priorities
- Builds on world-class FE-20 expertise
- Foundations:
  - DOE Fossil Energy *Vision 2018-2022*
  - Internal workshops and prior plan
  - Budget request and Congressional direction

Fossil Energy is Not Going Away





Challenges:

- Evolving grid
- Competing energy sources
- Declining demand
- Carbon reduction goals

Opportunities:

- Abundant natural resource
- World-class expertise in carbon capture
- Growing role for energy storage/blue hydrogen
- Potential to create new products from coal, empowering coal-rich regions
- Advanced tools for discovery and optimization

Powering the Future

Vision

Advanced, affordable, 21st century U.S. fossil energy systems and products stimulate a robust, global energy economy with carbon-neutral or net-negative emissions.

Mission

Drive R&D and adoption of advanced, affordable, reliable energy systems and products from coal and other fossil resources with carbon-neutral or net-negative emissions.

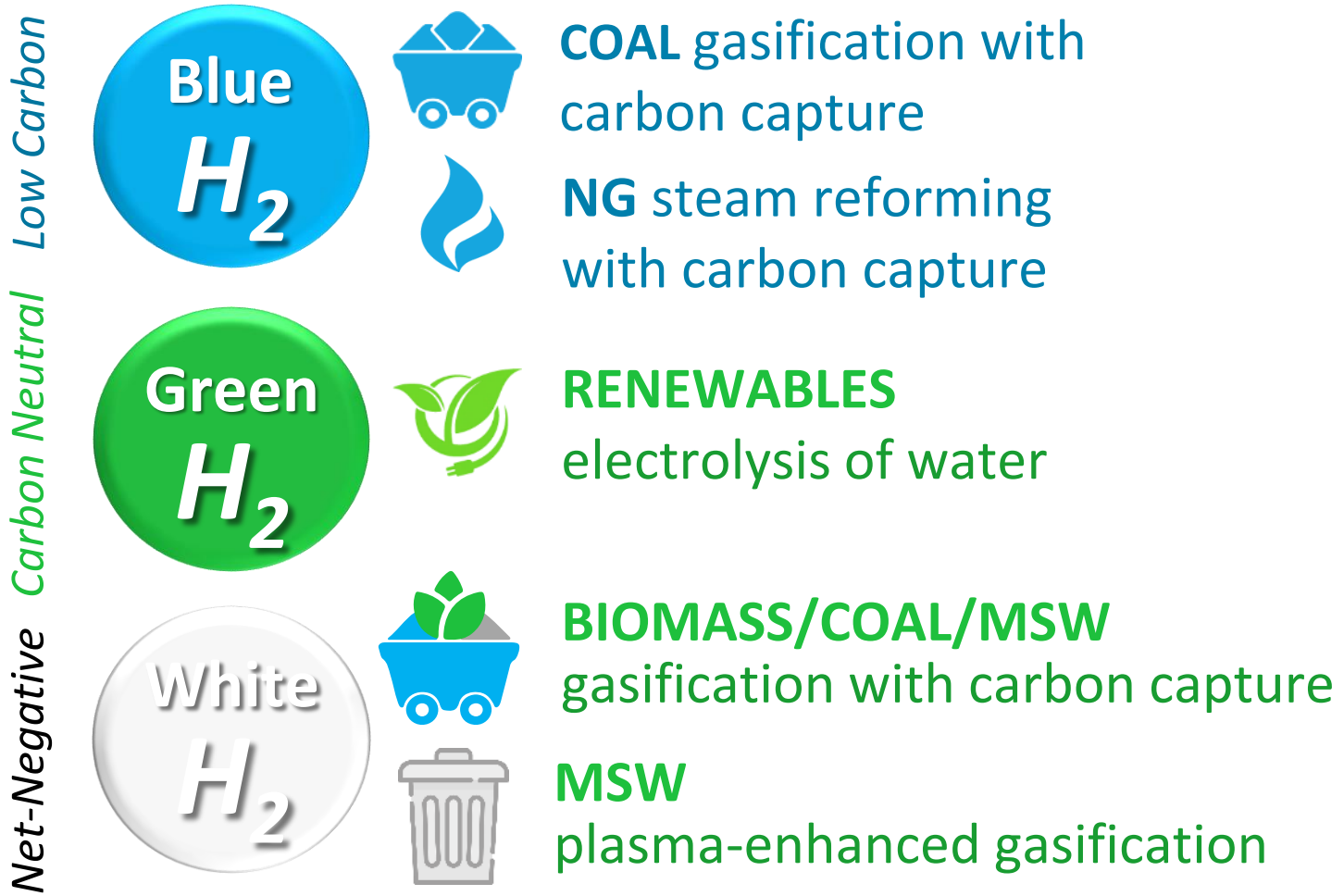
Focus Areas

- Transforming fossil energy systems for the future
- Managing carbon with confidence
- Reimagining coal
- Creating opportunities through analysis & engagement

Transforming Fossil Energy Systems for the Future

Producing Low-Carbon H_2

- Optimize use of blends to attain net-negative emissions.



Sources: World Energy Council, "New Hydrogen Economy —Hope or Hype?" 2019. Proctor, D., "Group says it will launch world's largest green hydrogen project," POWER Magazine, May 2020.

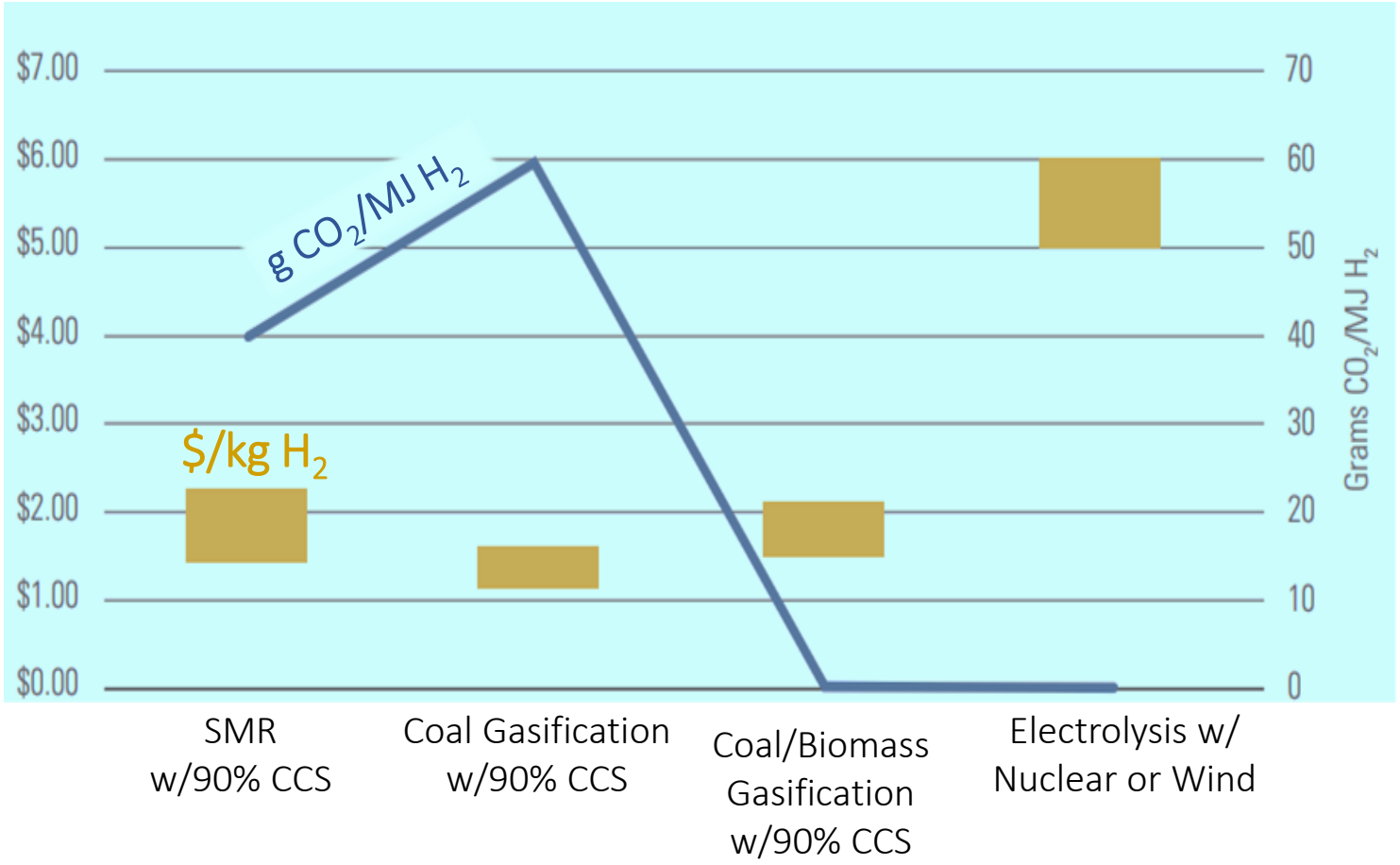
Transforming Fossil Energy Systems for the Future

Producing Hydrogen (H_2)

- Enable low-carbon economy.
- Serve transport, industry, and power generation markets.
- Improve poly-generation pathways to H_2.
- Create secure, utility-scale storage.

- **2030:** Develop turbines capable of 100% hydrogen combustion.
- **2035:** Produce H_2 from blends of coal, biomass, or MSW at commercial scale.

Current Cost of Hydrogen Production and CO_2 Intensity



Source: DOE Hydrogen Strategy, July 2020, based on IEA Roadmap for Hydrogen and Fuel Cell and DOE Baseline Studies

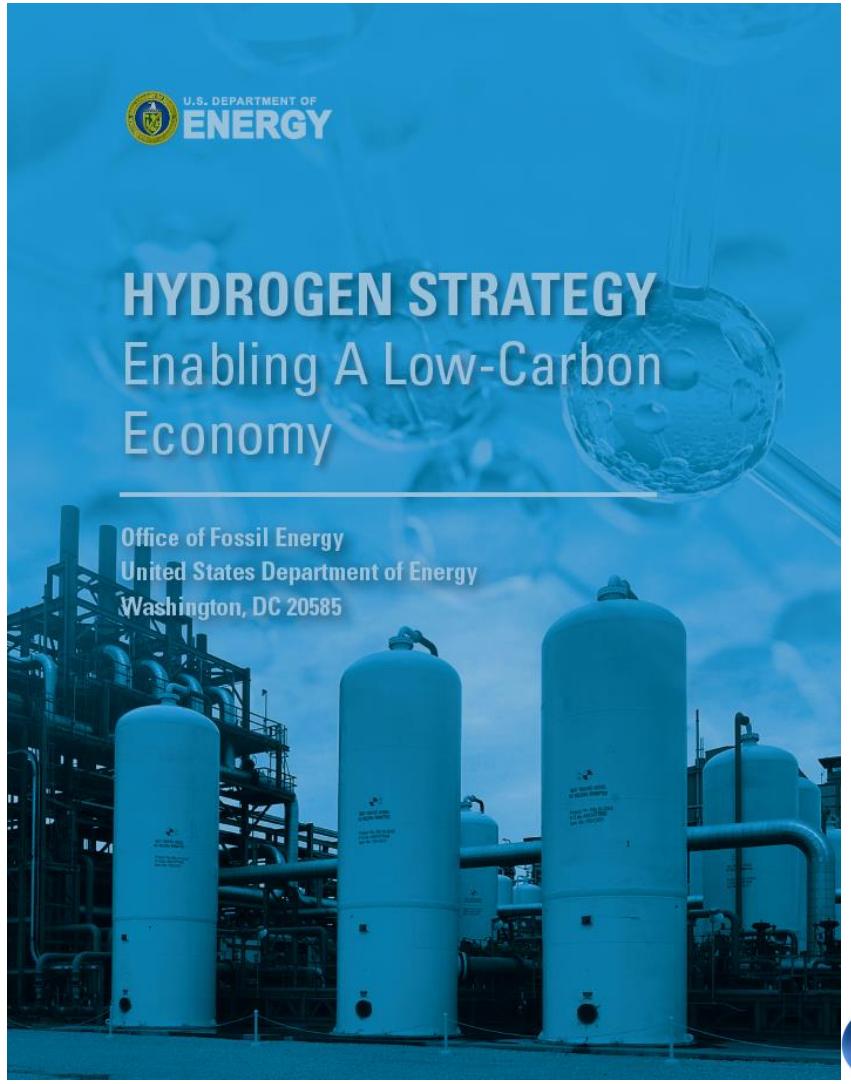
FE Investments in Hydrogen R&D

Over the past two decades FE has invested ~$1.3B in low-cost, carbon neutral hydrogen production technologies, including Turbines, Gasification, Solid Oxide Fuel Cells, and Pre Combustion R&D

- Hydrogen production with 99% CO2 capture can be achieved with small incremental costs
- Hydrogen from fossil fuels is the only carbon neutral technology

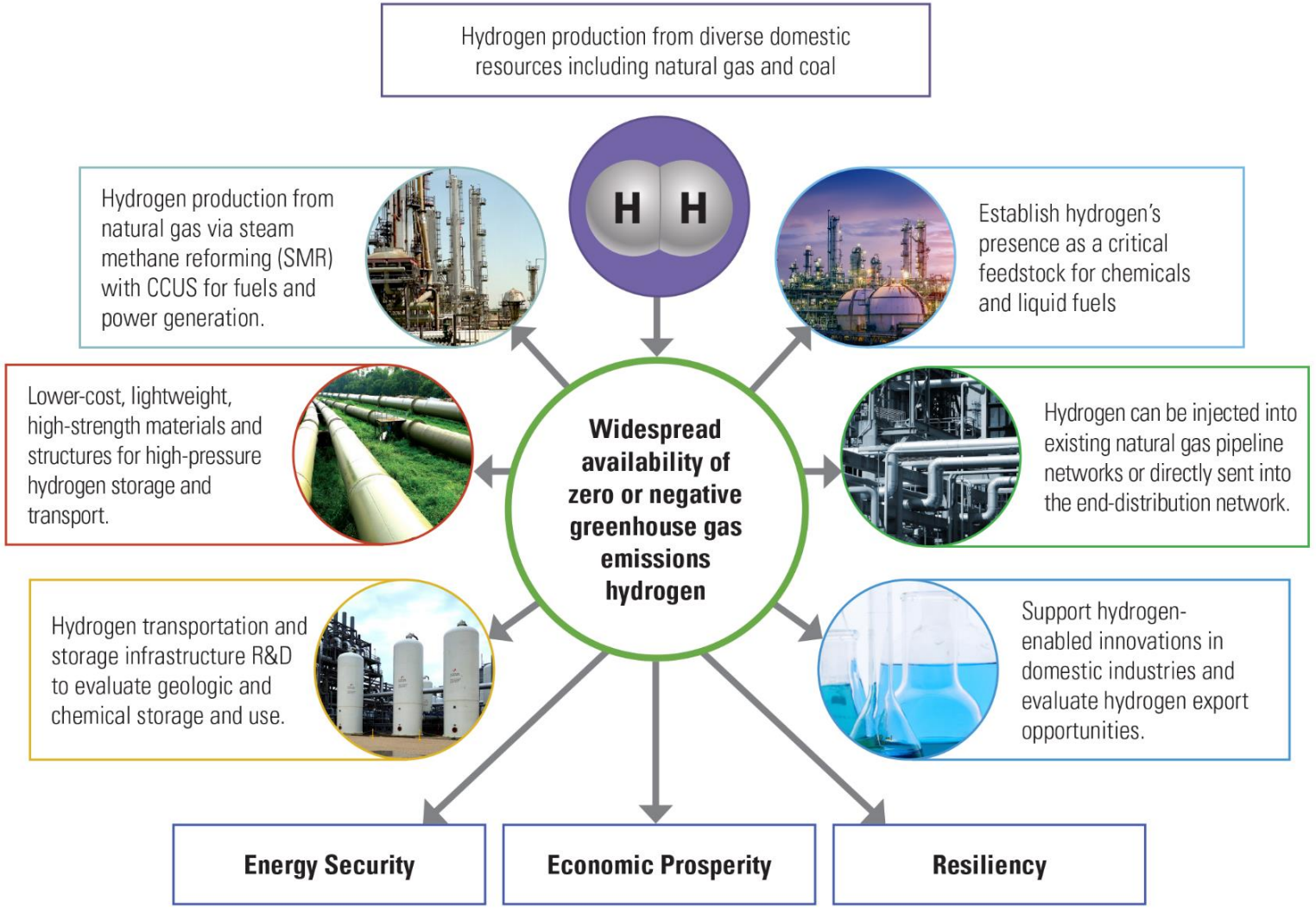
Aligning H2 R&D in Office of Fossil Energy

- Carbon-Neutral Hydrogen Production Using Gasification and Reforming Technologies
- Large Scale Hydrogen Transport Infrastructure
- Large Scale On-site and Geological Hydrogen Storage
- Hydrogen Use for Electricity Generation, Fuels, and Manufacturing.



Fossil Energy Hydrogen R&D Program Elements

Relationship of FE Program Elements to Comprehensive Hydrogen Strategy



FE Coal Hydrogen R&D

Specific R&D activities pursued by Coal Office could include the following:

- **Hydrogen Production** from the gasification of coal, biomass, and waste plastics with CCUS to produce carbon neutral, or even negative hydrogen and power.
- **Pre-combustion capture technologies** to develop novel materials and processes for > 90% capture.
- **Developing design gasification systems** for blended fuels and modular systems to reduce costs, provide distributed systems, and range of operations.
- **Advanced turbines** design, materials, and components to allow for 100% H2 combustion, flexible operation, and combustion of other carbon free fuels such as ammonia.
- **Reversible SOFC (SOFC⇔ SOEC) systems** designs and components that will for flexible polygen systems to product hydrogen or power, depending on market demand
- **Bulk Above Ground Hydrogen Storage** to meet the demands for power generation during extreme events to provide flexible operations, fuel security, and black start capabilities with zero carbon emissions.

Focus Area 1 and Research Directions

Transforming Fossil Energy Systems for the Future

Drive technology solutions for a resilient 21st century grid.

- **Future plants.** Develop technologies to enable highly flexible and reliable power systems with carbon-neutral or net-negative emissions.
- **Current fleet.** Modernize existing coal plants to achieve far greater efficiency, flexibility, and resilience.
- **Hydrogen.** Integrate hydrogen production and storage to support grid flexibility and resilience.
- **Water & Environment.** Optimize the environmental performance of energy systems, reducing impacts on water and other resources.

Transforming Fossil Energy Systems for the Future

Developing 21st Century Coal Plants

- Design compact, modular, efficient, resilient coal-powered units.
- Complement the modern grid.
- Deliver carbon neutrality.
- Advance power generation systems.
- Offer utility-scale energy storage.

CoalFIRST

Flexible
Innovative
Resilient
Small
Transformative

Achieve high overall plant efficiency (40% or more) at full load, with minimal reductions in efficiency over the required generation range.

Transforming Fossil Energy Systems for the Future

Energy Storage Grand Challenge

- Create flexible storage solutions that use secure, domestic resources.
- Build on the $158 million Advanced Energy Storage Initiative announced in the FY 2020 budget.
- Support feasibility studies, preliminary engineering design, component-level R&D, and innovative concepts.

Adobe Stock 198290164

Transforming Fossil Energy Systems for the Future

Modernizing U.S. Coal Plants

- Improve operations and efficiency of existing coal-fired plants.
- Increase cost competitiveness.
- Optimize maintenance.
- Upgrade to help integrate with modern grid.
- Increase reliability, flexibility, and resilience.

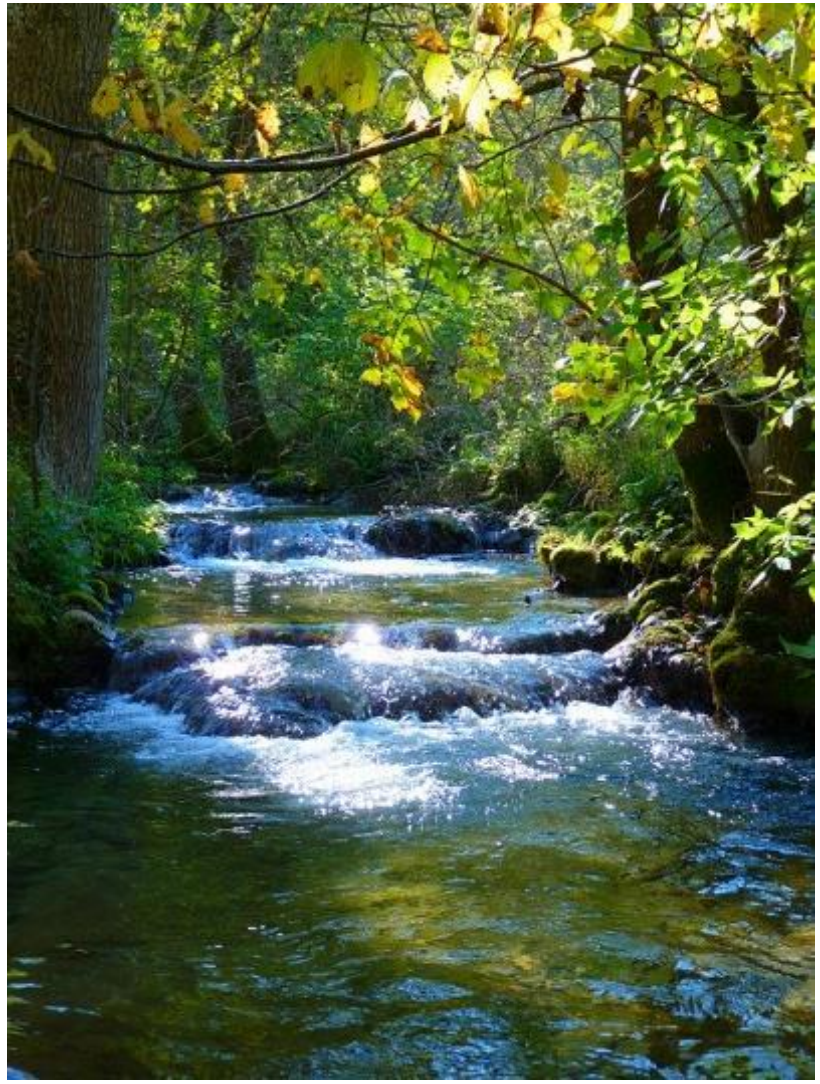
2022: Increase the efficiency of existing coal plants 5%.*

Transforming Fossil Energy Systems for the Future

Protecting the Environment

- Control and reduce emissions.
- Improve water use efficiency and security.
- Increase cooling/heat recovery efficiency.
- Monitor water quality long term.

- Accelerate development/use of efficient technologies for freshwater use and reuse.
- Reduce non-CO_2 criteria pollutants and solid and liquid emissions.
- **2025:** Achieve in-practice use of advanced emissions reduction technologies.



WATER SECURITY GRAND CHALLENGE

Abundance Through Innovation

Focus Area 2 and Research Directions

Managing Carbon with Confidence

Advance technologies to cost-effectively capture and securely store carbon across the economy.

- **Carbon capture & storage.** Accelerate the development of transformational carbon capture and storage technologies.
- **Scale up CCUS.*** Build and advance the capabilities needed to measure, scale, and optimize CCUS technologies.
- **DAC & NETs.** Advance direct air capture, storage, and negative emissions technologies to extend the reach of carbon management.
- **New CO_2 Products.** Pursue new products and uses for captured carbon dioxide (CO_2).

* CCUS: Carbon capture, utilization, and storage

Managing Carbon with Confidence

Capturing Carbon

- Lower the cost and scale up carbon capture technology.
- Reduce energy penalties and increase capture efficiency.
- Leverage advances in machine learning (ML) and advanced manufacturing.

Pursue second-generation and long-term transformational carbon capture technologies to achieve a cost of electricity at least 30% below the state of the art.

Photo: DOE NCCC

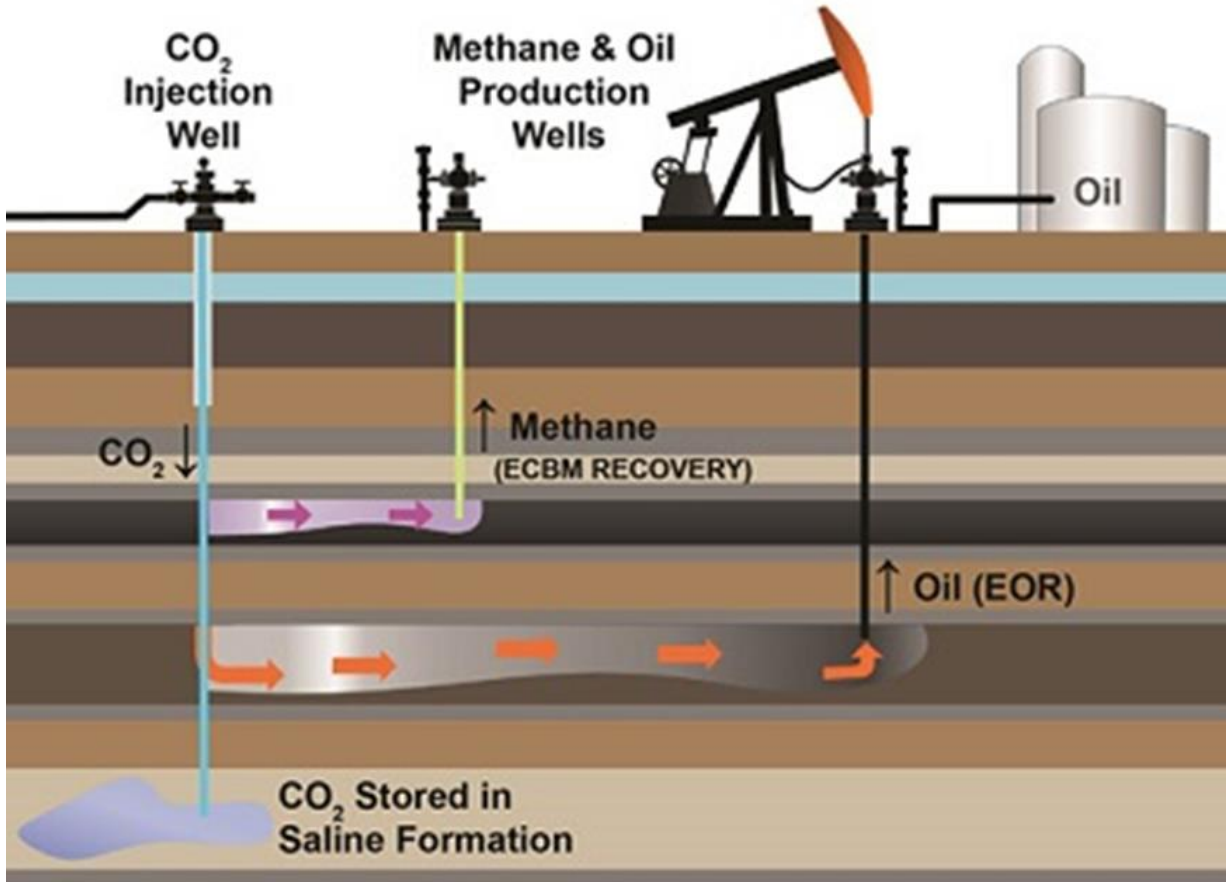
Managing Carbon with Confidence

Storing Carbon

- Optimize the safe, economic, affordable, and reliable long-term geological storage of CO_2.
- Develop transformational sensing and monitoring systems.
- Explore unconventional CO_2 storage.

Develop and prepare at least five commercial-scale saline storage sites for permitting by 2025.

2022: Complete development and prototyping for SMART-CS Initiative (Science-Informed ML to Accelerate Real-Time Decisions for Carbon Storage).



* ECBM: Enhanced Coal Bed Methane

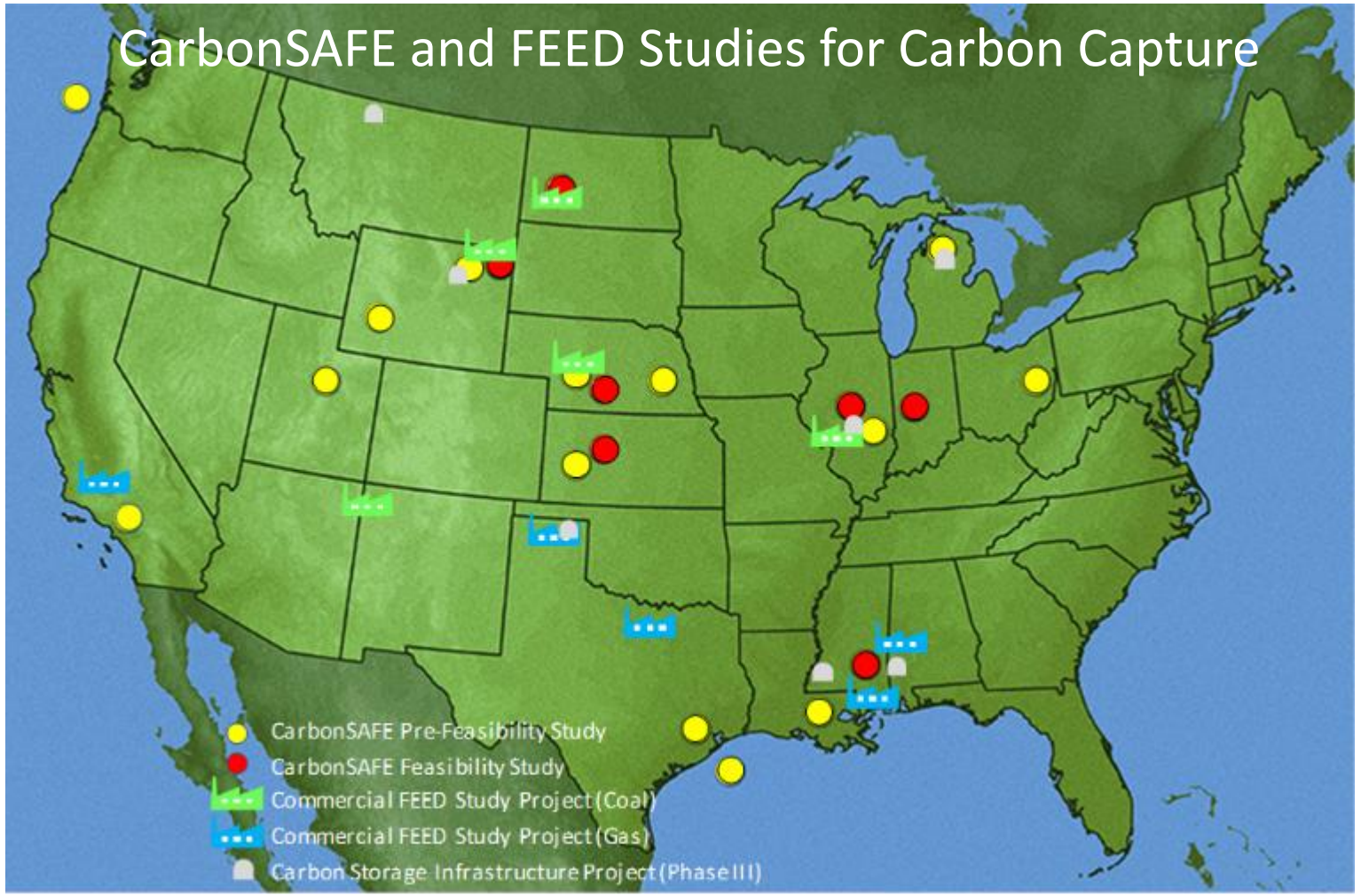
Image: NETL

Managing Carbon with Confidence

Scaling Up CCUS

- Pursue geologic site validation
  - Computational tools
  - Data development
  - Risk assessment.
- Provide foundation (data, experience, design) to stimulate private investment.

2030: Help get multiple CCUS hubs for U.S. power and industrial sectors operational—capturing and storing or utilizing 5 million metric tons of CO_2 per year (with scale-up capability).



Managing Carbon with Confidence

Enabling DAC & NETs

- Pursue negative emissions technologies (NETs).
- Build on advances in direct air capture (DAC) to cut cost and energy intensity.
- Focus on applied development and field test prototypes.

Image: Carbon Engineering (graphical representation)

- Complete bench-scale test of 2nd-generation DAC systems, novel materials, and components.
- Integrate co-firing coal with biomass and MSW to move toward net-negative CO_2 emissions.
- Build analytical capacity (models and data) to support BECCS.

Managing Carbon with Confidence

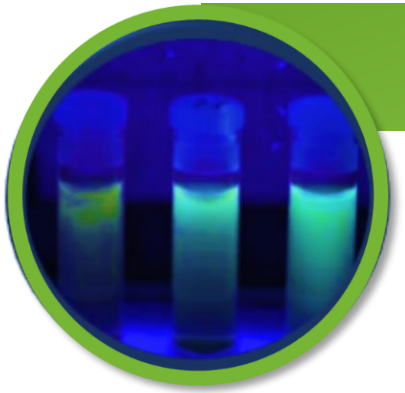
Creating New Products from Captured CO_2

- Create products that capture and store CO_2 indefinitely and provide a new revenue stream.
- Explore multiple pathways.
- Leverage partnerships.

Process	*Intermediate*	*Products*
Electrolysis		Carbon Fibers, Nanotubes
		Chemicals, Plastics, & Bioplastics
Microbial reactions	Methanol Ethanol	Resins, Pharmaceuticals
Minerali-zation	Carbonates	Cements, Tiles, Aggregates, Bicarbonates
		Materials of construction (fiberboard, nanofibers)
Electrochemical pathways		Synthetic fuels

- **2030:** Develop technologies to support markets for CO_2-derived carbon fibers.
- Advance mineralization processes for cement and similar solids using CO_2.

Focus Area 3 and Research Directions



Reimagining Coal

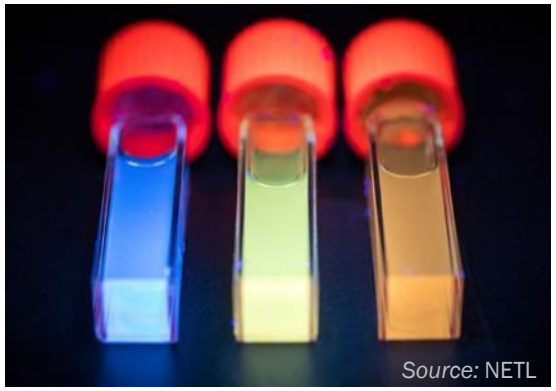
Create valuable new products from coal and its byproducts.

- **High-value products.** Explore new, high-value products and uses for coal and coal-based resources across the economy.
- **Hydrogen routes.** Accelerate pathways to valuable products via coal-produced hydrogen.

Reimagining Coal

Exploring High-Value Products

- Create novel, high-value products.
- Cost effectively extract rare earth elements (REEs) and other critical minerals.
- Incorporate valuable product streams into existing/future coal plants.



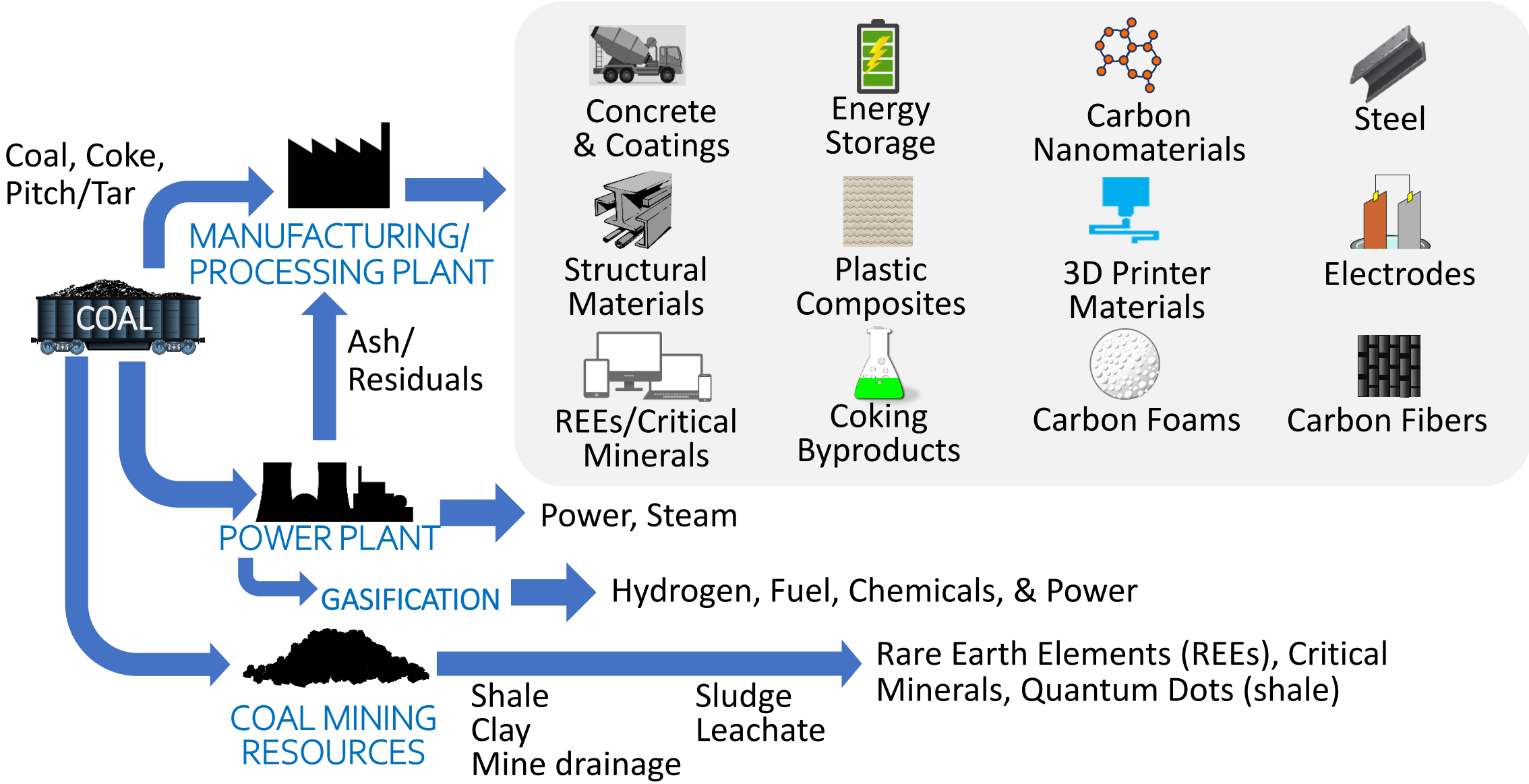
Graphene quantum dots from coal may be used in medical imaging.

Carbon fibers are lighter and stronger than traditional metals.

TenCate Geotube® technology for the recovery of REEs from AMD

- Set up commercial plants to produce 1-3 metric tons/day REE/critical minerals from coal waste.
- **2030:** Develop technologies to support markets for coal-derived solid carbon products.

Reimagining Coal: Products from Coal, Coal Resources, Ash, & Byproducts

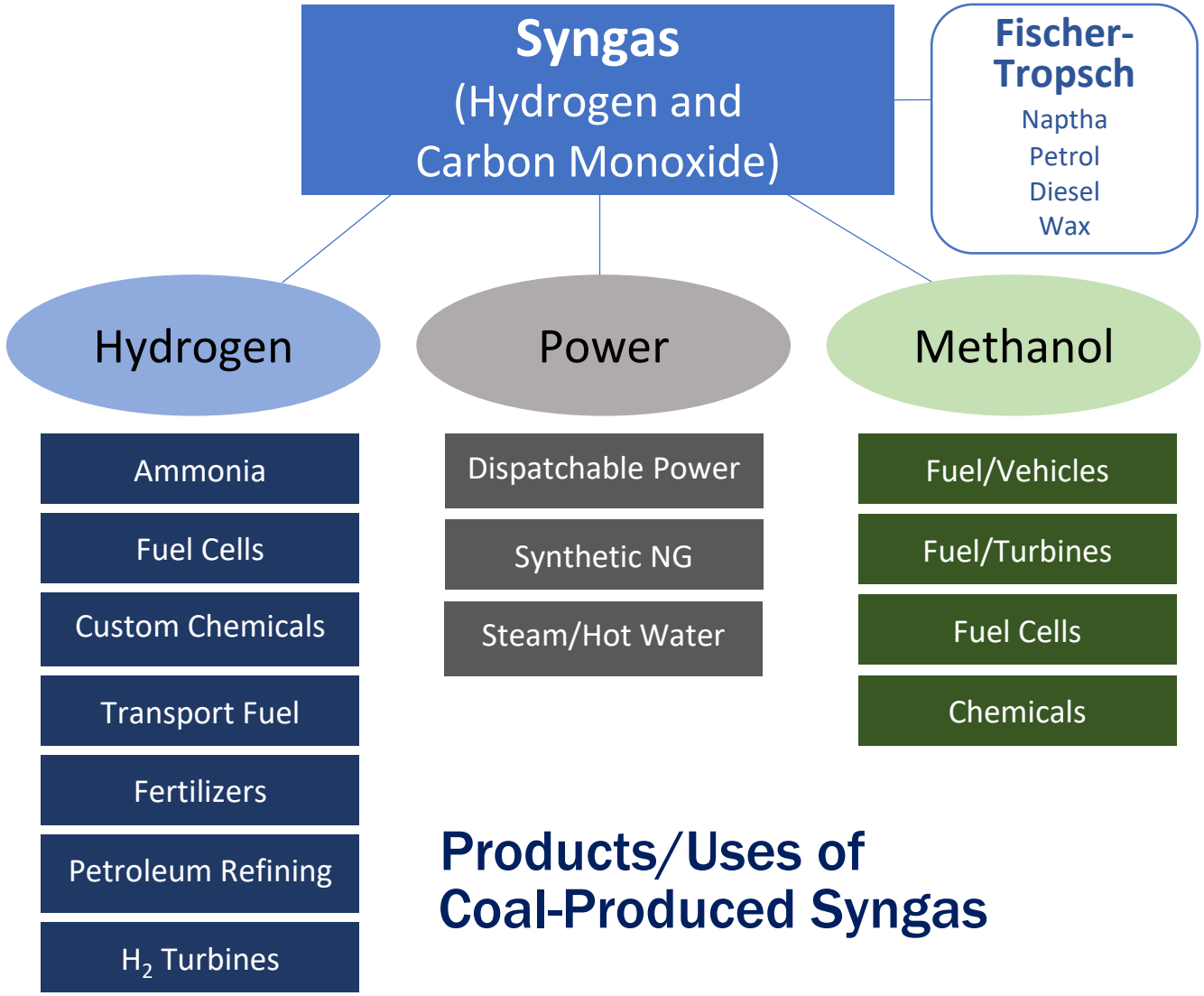


Reimagining Coal

Accelerating Product Pathways

- Convert hydrogen and other streams from coal-derived syngas into valuable products.
- Convert hydrogen to chemicals as products or for energy storage.
- Improve hydrogen purification and preparation processes.

- Establish coal-produced hydrogen as an economic feedstock stream for chemicals.
- Develop and validate flexible hydrogen energy storage concepts.



Products/Uses of Coal-Produced Syngas

Addressing 21st Century Microplastics

Near-Term

- Research coal gasifiers that co-fire biomass, plastics, and MSW.
- Safely manage byproducts and emissions.

Longer-Term:

DOE Plastics Innovation Challenge

- Deconstruct plastic wastes into useful chemicals.
- Upcycle waste streams.
- Design plastics for recyclability.

Thousands of micro-plastics are in the food we consume each year—and tens of thousands of microplastics are in the air we breathe.

Focus Area 4 and Research Directions

Creating Opportunities with Analysis & Engagement

Generate opportunities for advanced coal & carbon management technologies using expert analysis and strategic engagement.

- **Analysis.** Inform and educate stakeholders based on strategic analysis.
- **International engagement.** Engage with the international community to elevate awareness and accelerate global technology progress.
- **Partnerships.** Build strategic partnerships with government and industry.

Creating Opportunities with Analysis & Engagement

Sharing Analyses

- Assess policy instruments and priorities.
- Inform clean energy policy development.
- Guide RD&D portfolio development.
- Model emerging technology impacts.

- Analyze benefits and direction of R&D.
  - Assess impacts (economy, efficiency, CCUS)
- Perform analyses to inform dialogs and support U.S. policy and regulatory agencies.
- Highlight/share analyses to inform global partners.
- Lead process to develop and update OCCCM strategic planning documents.

Creating Opportunities with Analysis & Engagement

Engaging International Communities

- Monitor and evaluate global demand and markets for coal and carbon management technology.
- Ensure that dialogs among influential global entities consider U.S. interests.

- Proactively identify, track, and evaluate global RD&D and markets for fossil energy and carbon management technology to speed progress.
- Leverage international collaboration to advance technology development (better, faster, cheaper) via multi-lateral and bilateral activities.
- Ensure advanced, affordable coal energy systems and products are in global policy dialogs.

International Energy Agency

carbon sequestration leadership forum

Asia-Pacific Economic Cooperation

CLEAN ENERGY MINISTERIAL

Advancing Clean Energy Together

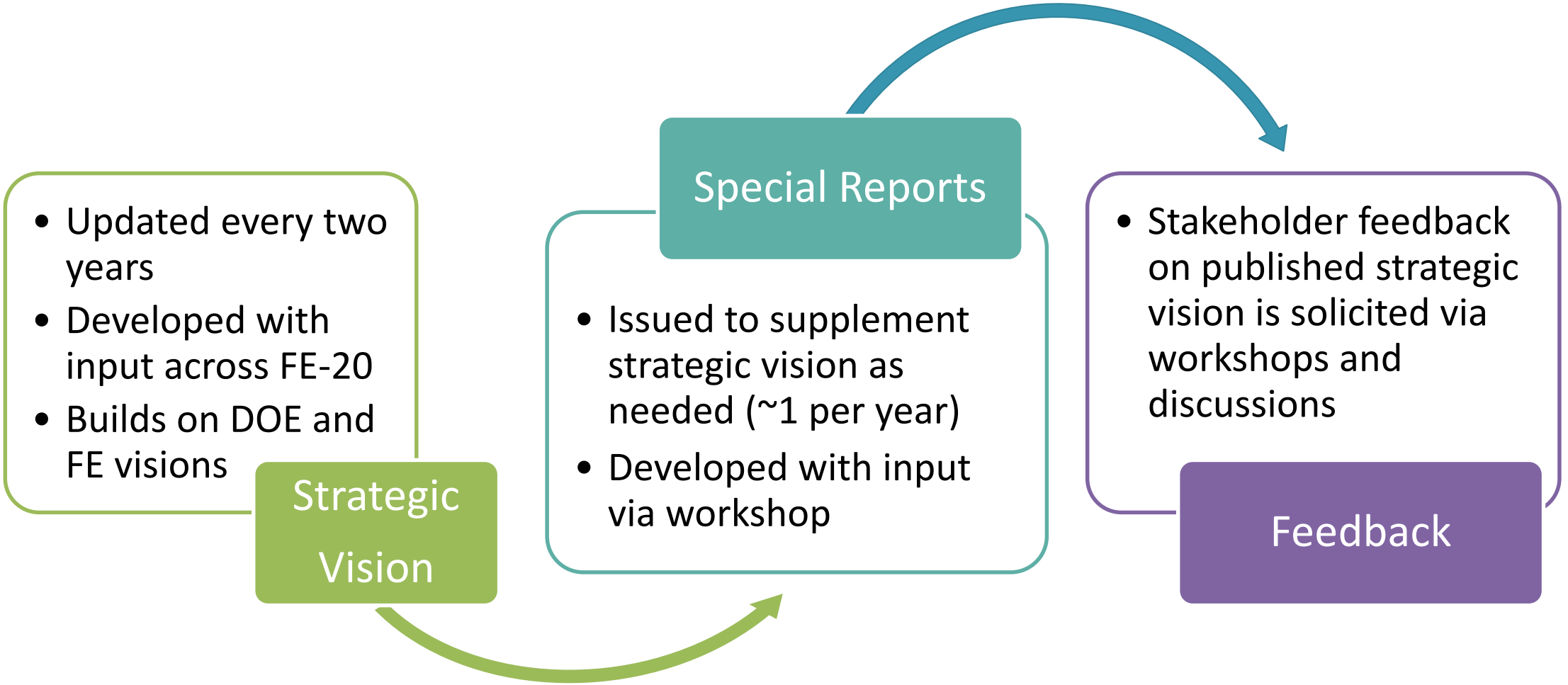
Creating Opportunities with Analysis & Engagement

Building Strategic Partnerships

- Communicate OCCCM analyses and opportunities to diverse audiences.
- Provide fact-based analyses to decision makers in all sectors.
- Continue interagency collaboration to enhance federal coordination on CCUS.

- Expand cross-agency collaboration and information exchange via stronger partnerships.
- Participate in DOE initiatives and programs, such as GMI and AITO.
- Build partnerships with industry and academia, informing efforts through technical expertise and strategic collaboration.

Next Steps


Strategic Vision
Updated every two years
Developed with input across FE-20
Builds on DOE and FE visions
Special Reports
Issued to supplement strategic vision as needed (~1 per year)
Developed with input via workshop
Feedback
Stakeholder feedback on published strategic vision is solicited via workshops and discussions

To See the full document, visit

https://www.energy.gov/fe/science-innovation/office-clean-coal-and-carbon-management/systems-analysis

Discussion

Your feedback is welcome!

The full report is available on our website.

- Specific questions
- Initial reactions?
- Major gaps (issues, emerging technologies, opportunities)?
- Concerns?
- Suggestions?