NARUC Winter Policy Summit

Electricity Committee

Subcommittee on Clean Coal and Carbon Management

May 2017: Longview Power Site Visit

- Subcommittee visited Longview Power LLC, a 700 MW coal-fired generating station outside Morgantown, WV
- Newest, cleanest, most efficient coal-fired power plant in the PJM territory with best-in-class heat rate of 8,842 Btu/kWh
- Mine-mouth design brings coal from a 4.5-mile conveyer belt
- $2 billion investment providing over 600 jobs
- Advanced supercritical boiler helps Longview attain the lowest cost of dispatch of any coal-fired power plant in PJM

May 2017: NETL Site Visit

- Subcommittee visited the National Energy Technology Lab in Morgantown, WV
- Commissioners spoke with NETL Director and research portfolio managers from multiple offices
- Topics included rare earth elements, carbon sequestration, carbon capture and reuse, advanced turbines, gasification, supercritical power cycles, economic modeling, and crosscutting R&D programs

September 2017: Petra Nova site visit

- Subcommittee members toured the Petra Nova carbon capture for enhanced oil recovery project at W.A. Parish Plant outside Houston, TX
- Commercial-scale, post-combustion carbon capture technology
- Captures 90% of CO_2 from a 240 MW slipstream of flue gas
- Compressed CO_2 is transported 80 miles via pipeline for enhanced oil recovery at an oilfield, providing financial support

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May 16 – 18, 2018: North Dakota Site Visit

- Commissioners will travel to Bismarck, ND
- Group will tour Coal Creek Station, state's largest lignite-fired power plant
- Members will also see the Great Plains Synfuels Plant, the country's only coal-to-synthetic natural gas facility
- Opportunities to connect with the Lignite Energy Council and the Univ. of North Dakota's Energy & Environmental Research Center, led by former ND commissioner Brian Kalk
- Travel assistance available to commissioners thanks to support from the U.S. Department of Energy (first-come first-serve basis)

Sept. 5 – 7, 2018: Wyoming Site Visit

- Commissioners will tour the state's Integrated Test Center, where Xprize research teams are competing to develop new uses for captured carbon dioxide
- Opportunities to visit some of the largest coal mines in the country
- Travel assistance available thanks to U.S. DOE

Other Activities

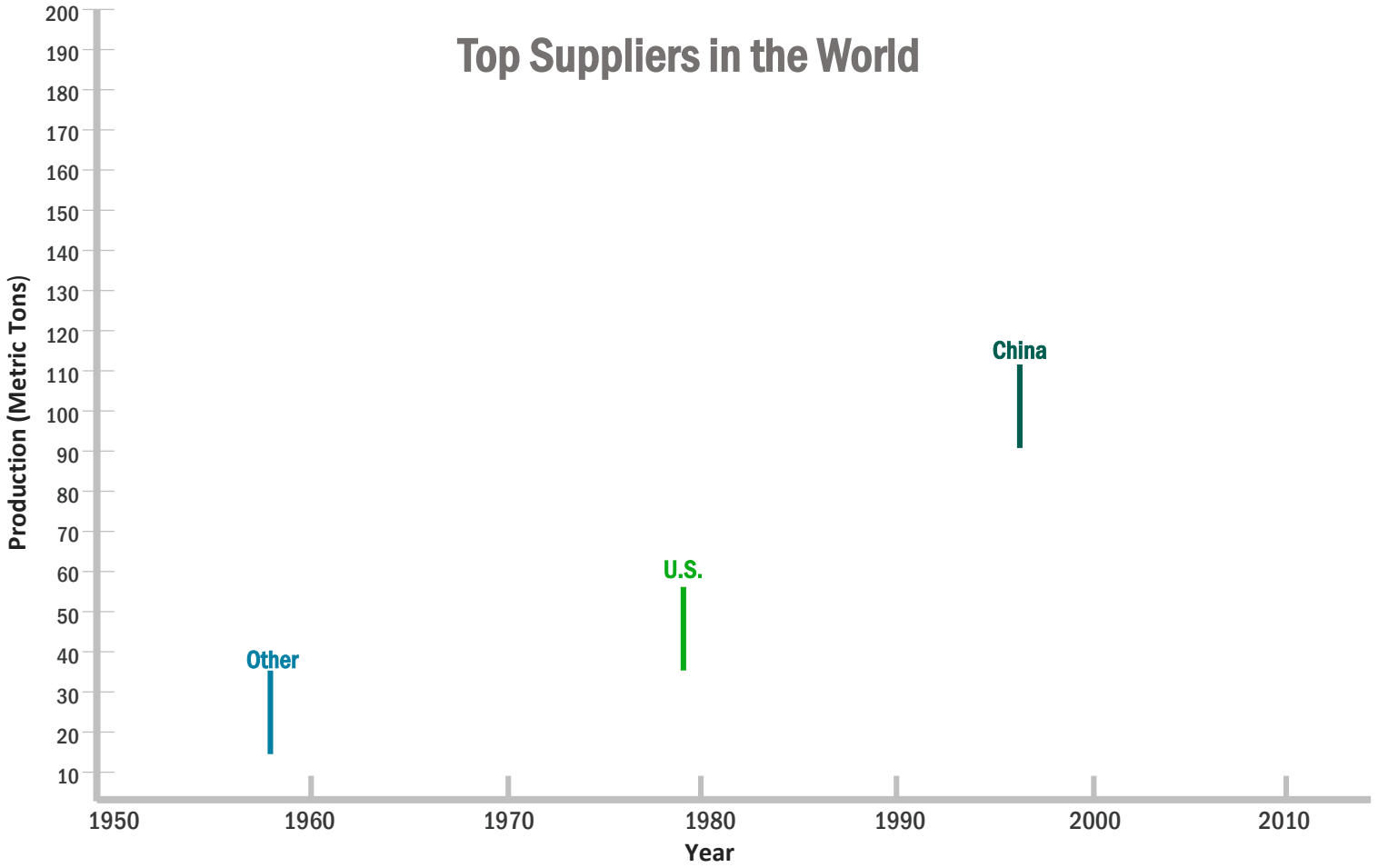
- Subcommittee calls, webcasts, and panels at NARUC meetings with experts from the public and private sectors
- Research papers to answer commissioner and commission staff questions about the latest developments in coal-fired generation and carbon capture technology
- Recruiting new members for 2018

The Rarity of Rare Earth Elements

National Association of Regulatory Utility Commissioners (NARUC) Winter Policy Summit

Washington DC| February 12, 2018

REE Suppliers



REE Market – REEs from Coal

Annual Global Rare Earth Market

- ~$5B in 2015 (~149,000 tonnes/yr)

U.S. Consumes

- 11% ($550M) or ~16,000 tonnes/yr in 2015

Approximately 750M Tons of Coal Burned in U.S. Annually

- ~75M tons of coal ash generated
  - Average concentration of ~470 ppm REE+Y, yields ~35,250 tons (~31,980 tonnes) of REE+Y annually
- If completely extracted, potential for generation of REEs from coal exceeds U.S demand

Challenges & Opportunities
Material Reserves
Environmental & Economic Impact

REE Domestic Resources

U.S. coal contains significant amounts of REEs

- Appalachian coals represent the richest REE resources in the country
- 208 coal preparation plants in WV, KY, P, VA, AL, TN with an installed capacity of 166,495 tons per hour, or more than 750 million tons annually
- Retrofitting only a portion of these plants with advanced REE separation processes would suffice the U.S. domestic need

Assessment of Rare Earth Elemental Contents in Select United States Coal Basins, Tetra Tech, January 2015

DOE-NETL REE Program

Congressional Language
– Feasibility of Recovering Rare Earth Elements (REEs) –

FY14 to perform an assessment and analysis of the feasibility of economically recovering rare earth elements from coal and coal by-product streams, such as fly ash, coal refuse, and aqueous effluents

FY15 to continue activities to economically recover rare earth elements from coal and coal by-product streams, such as refuse, and aqueous effluents

FY16-FY17 to expand its external agency activities to develop and test commercially viable advanced separation technologies at proof-of-concept or pilot scale that can be deployed near term for the extraction and recovery of rare earth elements and minerals from U.S. coal and coal by-product source showing the highest potential for success

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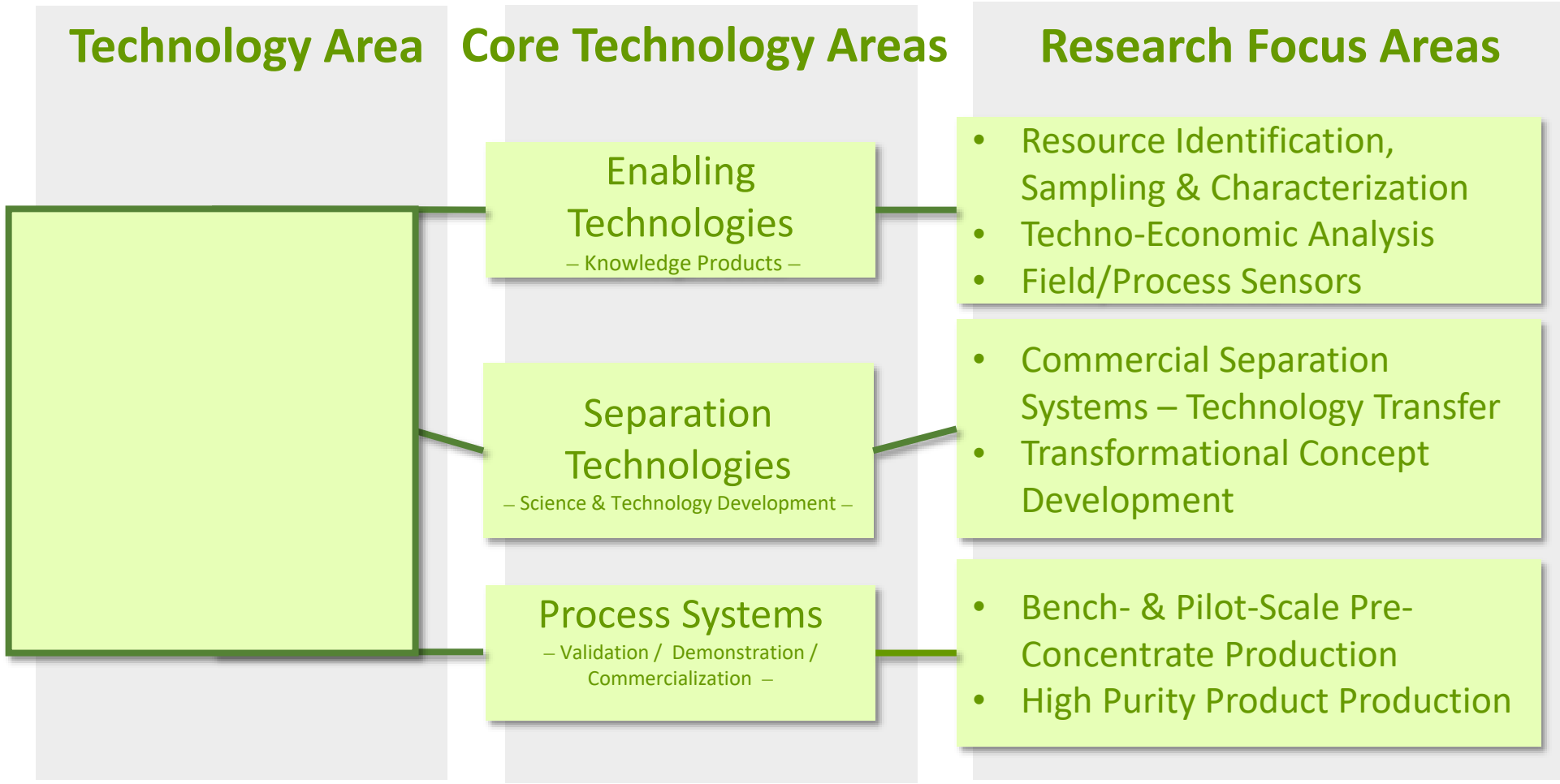
FY18 Congressional Budget Request (House Marks – May 2017) to expand its external agency activities to develop and test commercially viable advanced separation technologies at proof-of-concept or pilot-scale that can be deployed near-term for the extraction and recovery of rare earth elements and minerals from U.S. coal and coal byproduct sources having the highest potential for success. Leverage the capabilities of outside applied researchers in implementing these activities.

REE Program


Technology Area
Core Technology Areas
Research Focus Areas
Enabling Technologies
– Knowledge Products –
Separation Technologies
– Science & Technology Development –
Process Systems
– Validation / Demonstration / Commercialization –
• Resource Identification, Sampling & Characterization
• Techno-Economic Analysis
• Field/Process Sensors
• Commercial Separation Systems – Technology Transfer
• Transformational Concept Development
• Bench- & Pilot-Scale Pre-Concentrate Production
• High Purity Product Production

REE Program

Key Drivers

- National Security
- Environmental Impact
- Economic Targets
- Build U.S. Domestic Infrastructure for On-Shore Production

FY17: 15 Active Projects
FY18: >30 Active Projects

2020 GOAL

Validate Technical & Economic Feasibility of Prototype Salable High Purity REE Systems

Report to Congress; Issued 2017

Initiated NETL R&IC FWP (July 15, 2015)
~300 to >1,000 ppm ; 2wt% REEs

Feasibility Assessment

Initiate FOA-1718 (Nov 15, 2017) – Advanced Separation – Up-Stream: 2wt% REE; Mid-Stream: 2-10wt% REE; Down-Stream: 90-99wt% REO

Initiated FOA-1202 (Oct 1, 2017) – Bench & Pilot-Scale REE Separation (Phase 2– 2wt%)

Initiated RFP-10982 (Sept 15, 2017) – Field Sampling & Characterization/Round Robin

Initiated FOA-1627 (Sept 1, 2017) – Salable High Purity REE Separation (Phase 1 – 90-99wt% REO)

★ **Initiated NL FWPs** (July-Sept 2017) – Field Sensors & Technology Transfer REE Separation

Initiated RFP-9067 (Sept 1, 2016) – Field Sampling & Characterization

Initiated FOA-1202 (March 1, 2016) – Bench & Pilot-Scale REE Separation (Phase 1– 2wt%)

★ **Initiated OTT TCF Project** (Sept 2017) – LLNL EERE CMI REE Extraction

★ **Initiated OSC SBIRs** (June 2017) – Field Sensors

Separations & Extraction Criteria

Technically Feasible

Economically Viable

– Co-Production –

Environmentally Benign

– Acids/Solvents/Th –

Prospecting → Processing → Production

Feedstock: 300 ppm REEs

Pre-Concentrate: 2wt% (20,000 ppm) mixed REEs (FOA-1202)

High Purity – Salable REEs: 90-99% (900,000-990,000 ppm) REO; 10 lbs/day; 1,000 lbs total (FOA-1627)

Demonstrated >30wt% pre-concentrate production (300ppm → 300,000ppm)

Demonstrated extraction of nearly 100% REEs from acid mine drainage (AMD) sludges

REE Program – Accomplishments

Key Drivers

- National Security
- Environmental Impact
- Economic Targets
- Build U.S. Domestic Infrastructure for On-Shore Production

2020 GOAL

Validate Technical & Economic Feasibility of Prototype Salable High Purity REE Systems

NETL RIC fiber optic sensor development for detection of ppm levels of REEs in liquid samples*

NETL RIC immobilized amine and organo-clay sorbents development for REE recovery from liquid sources*

Feasibility Assessment

Physical Sciences Inc. (PSI), University of Kentucky, University of Wyoming, and others achieved **>30 wt% (300,000 ppm)** mixed REE pre-concentrates from coal-based materials*

West Virginia University achieved recovery of nearly 100 percent REEs from coal acid mine drainage (AMD) sludge*

University of North Dakota identified that approximately 80 to 95 percent of the REE content in **lignite coals** is organically associated, primarily as coordination complexes as opposed to mineral forms typically found in the older/higher-rank coals

University of Kentucky produced small quantities of **80 percent** (800,000 ppm) total REEs on a dry whole mass basis and more than 98 percent (980,000 ppm) REOs. Critical elements such as neodymium and yttrium — used in national defense technologies and the high-tech and renewable energy industries — represented more than 45 percent of the total REE concentrate*

** Patent Application(s)*

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