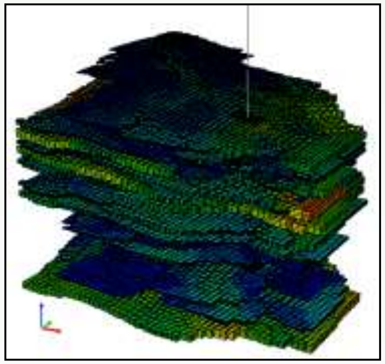

"Advanced Energy Systems, Rare Earth Elements, and Carbon Capture: DOE's Research and Development Priorities in Support of Coal Utilization Technologies"

NASEO 2019 Annual Meeting

Joseph Giove III

Director of Coal Business Operations

Office of Fossil Energy

September 17, 2019

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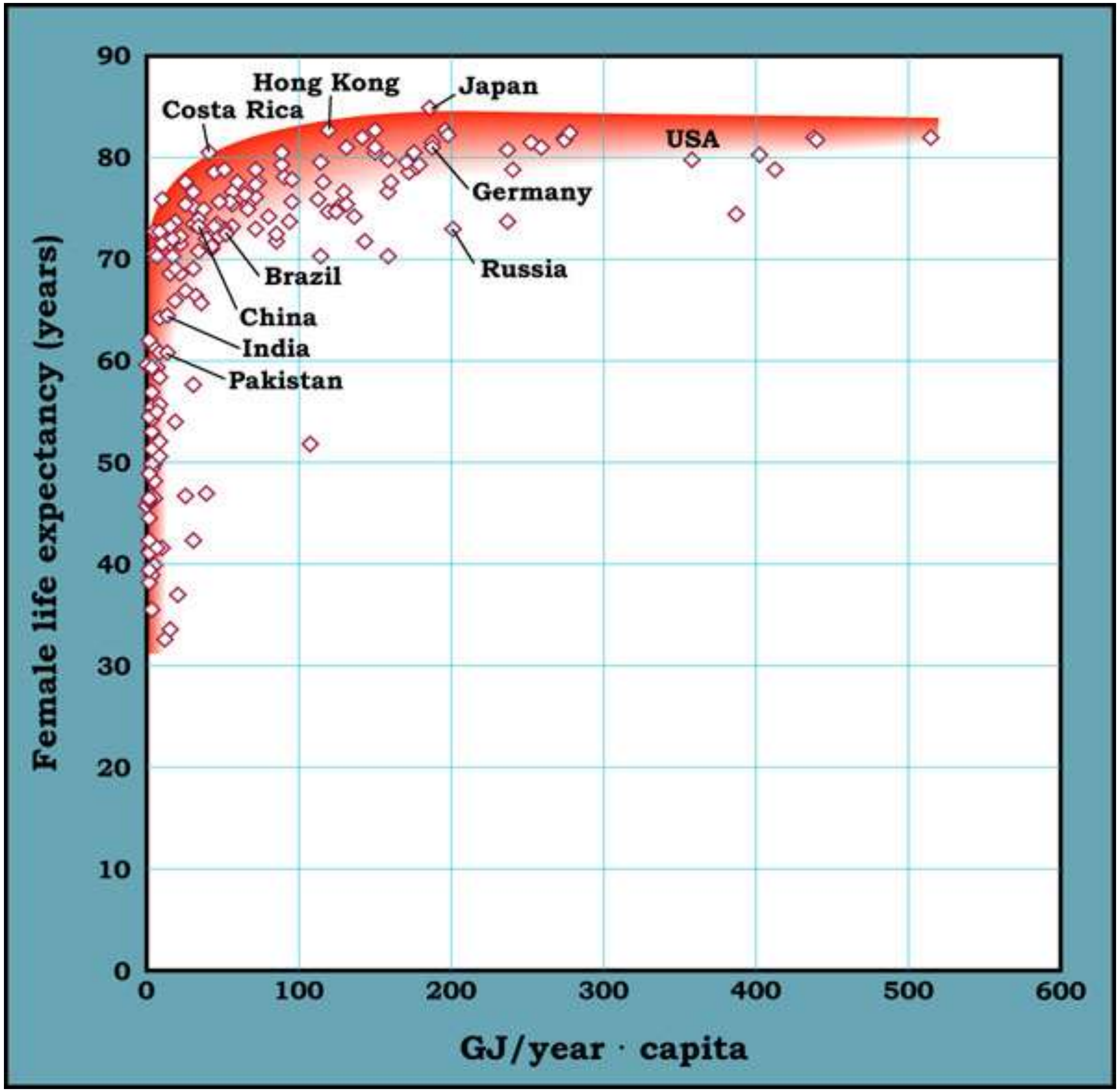
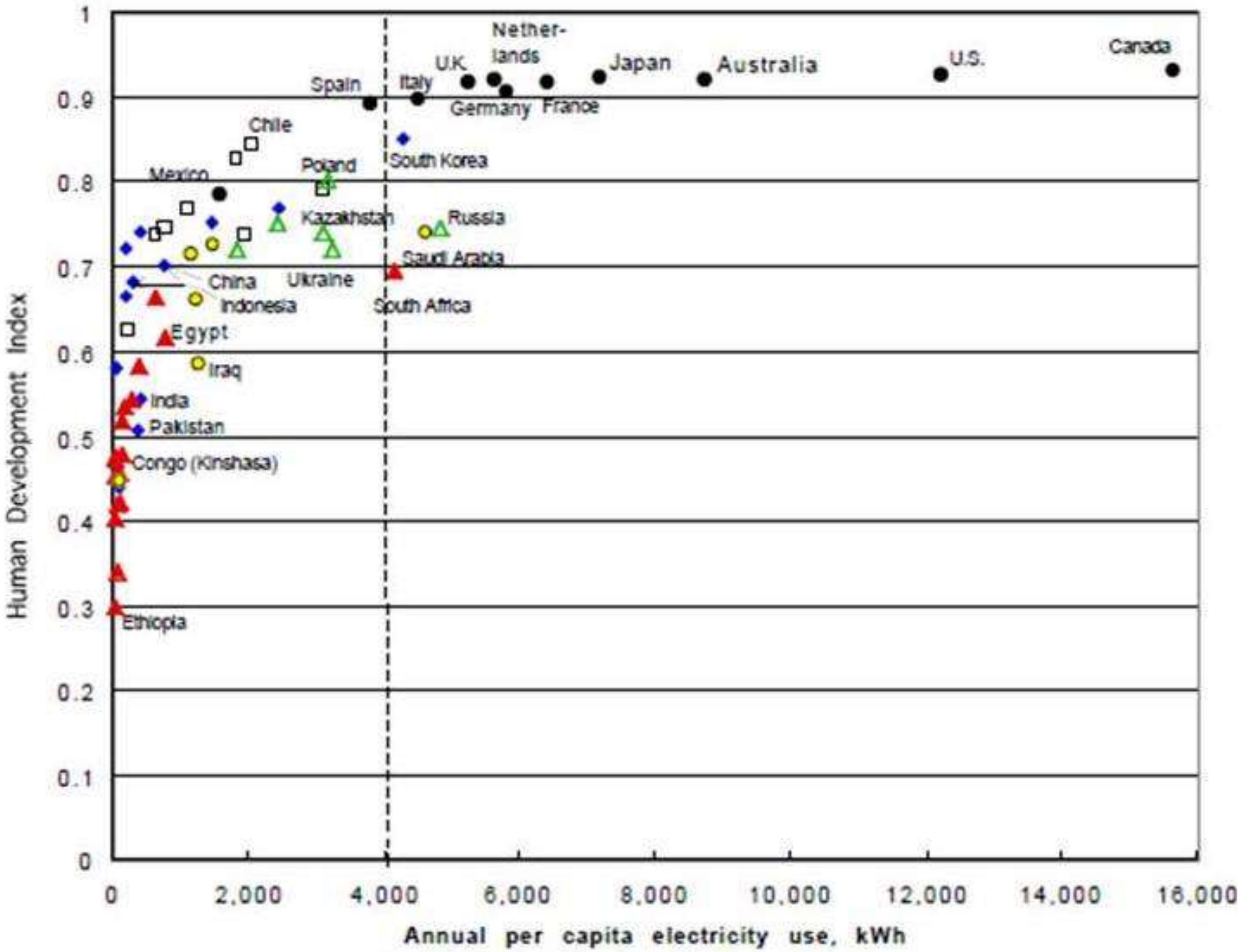
Life Expectancy and Energy

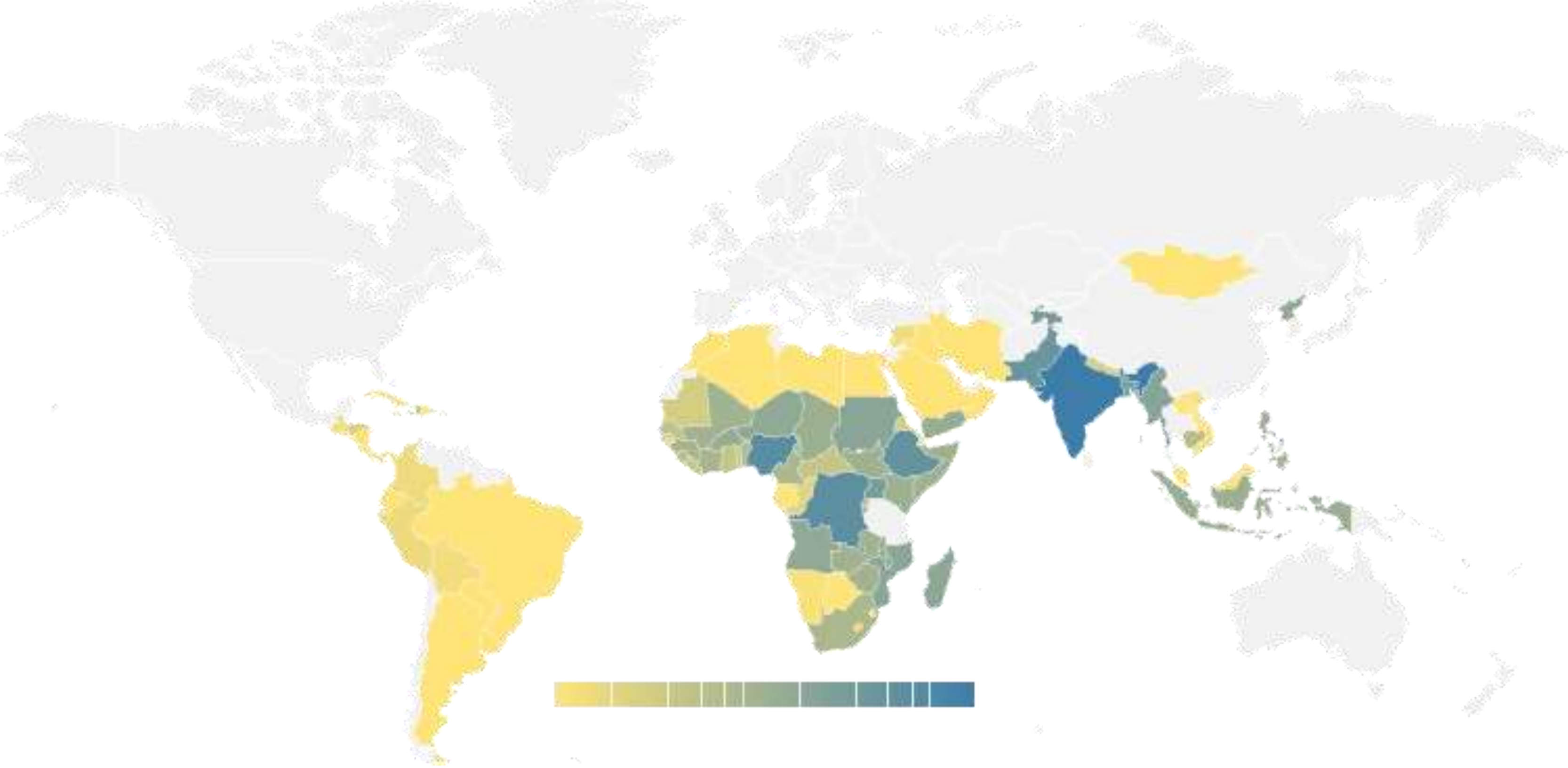


Human Development Index (HDI) and Energy



Populations without Energy

Population without access to electricity, 2017



Source: IEA - https://www.iea.org/access2017/

Is Coal Good or Evil?

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The Past

The Past

The Present

The Present

The Present

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The Present

The Present

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The Present

The Present

The Past

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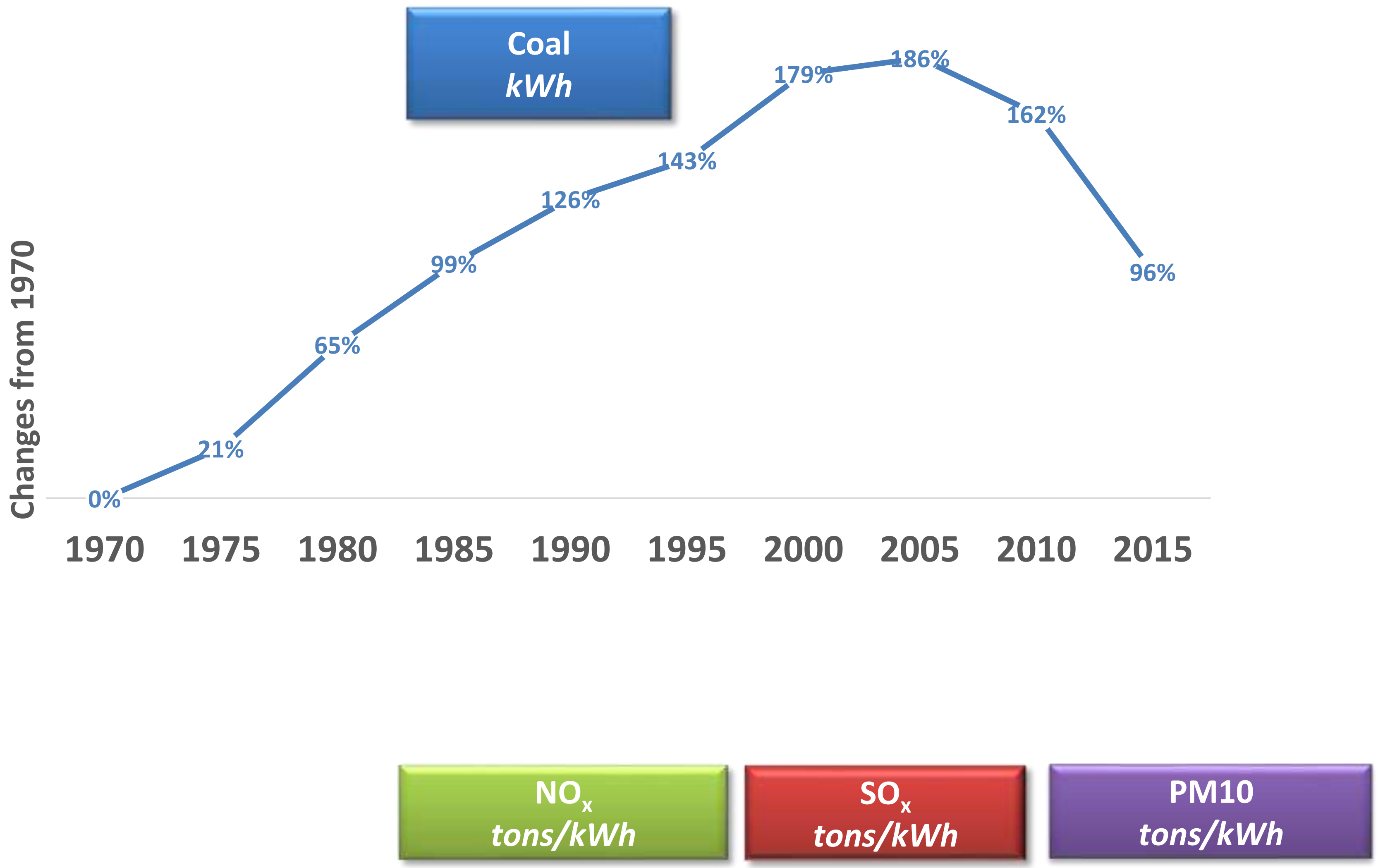
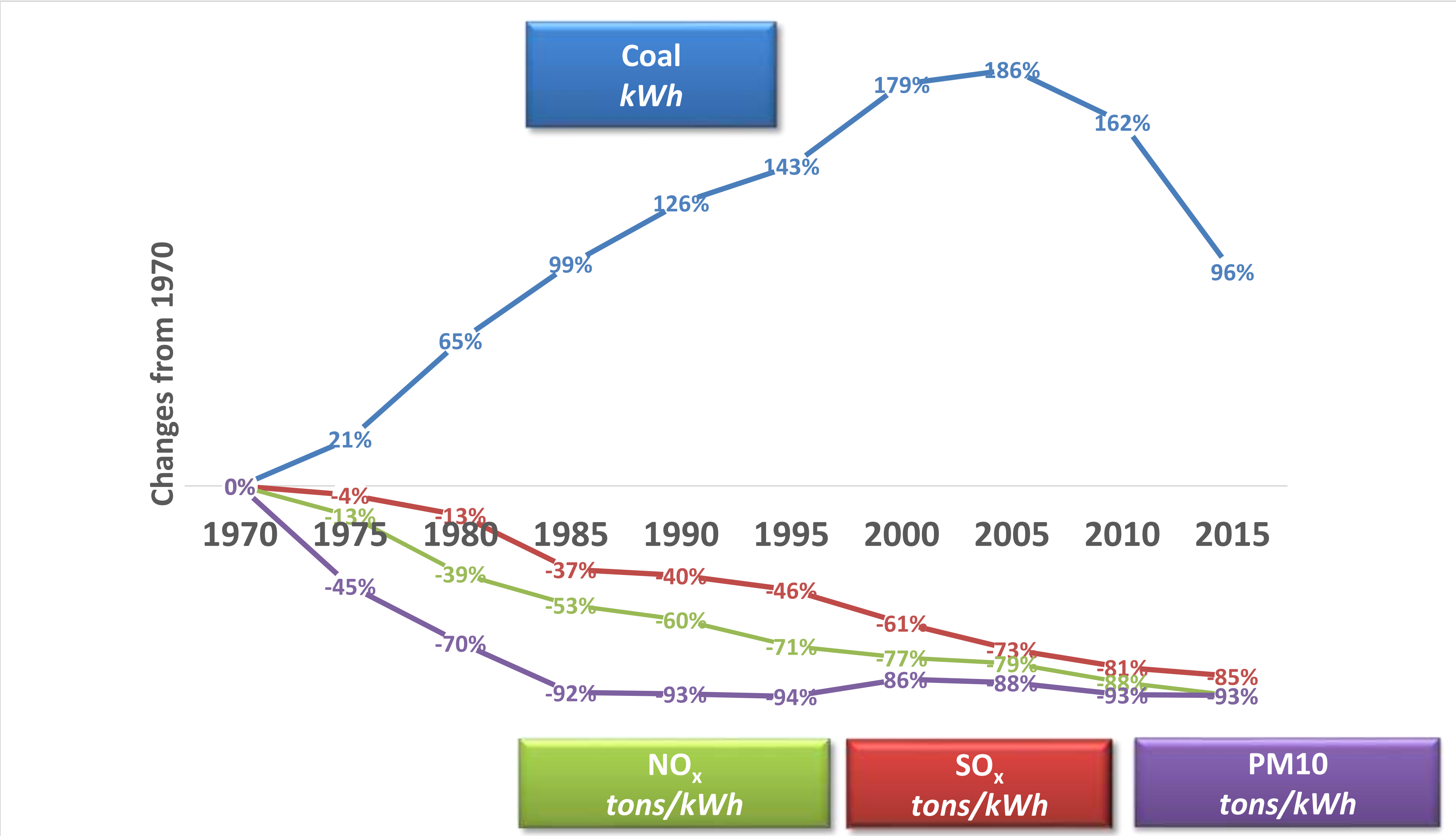
The Past

The Present

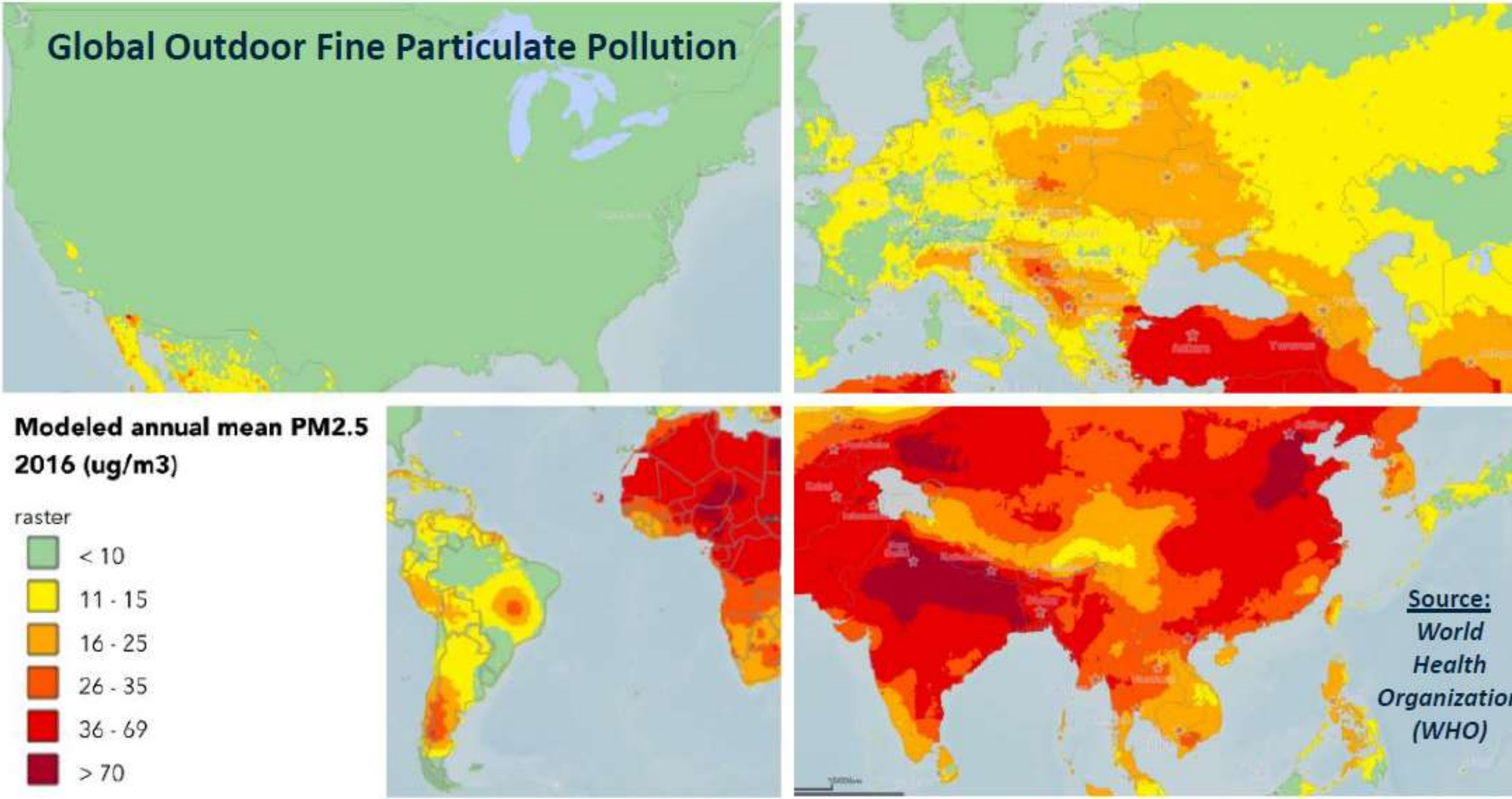
Emissions Fell While Coal Use Increased



Emissions Fell While Coal Use Increased



USA is the World Leader in Low Particulates



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GHG Emissions by Country 2005-2016

2005

Rank	Country		MtCO₂
1	United States of America	USA	6132
2	China	CHINA	5892
3	Russian Federation		1594
4	Japan		1308
5	India	INDIA	1222

2007

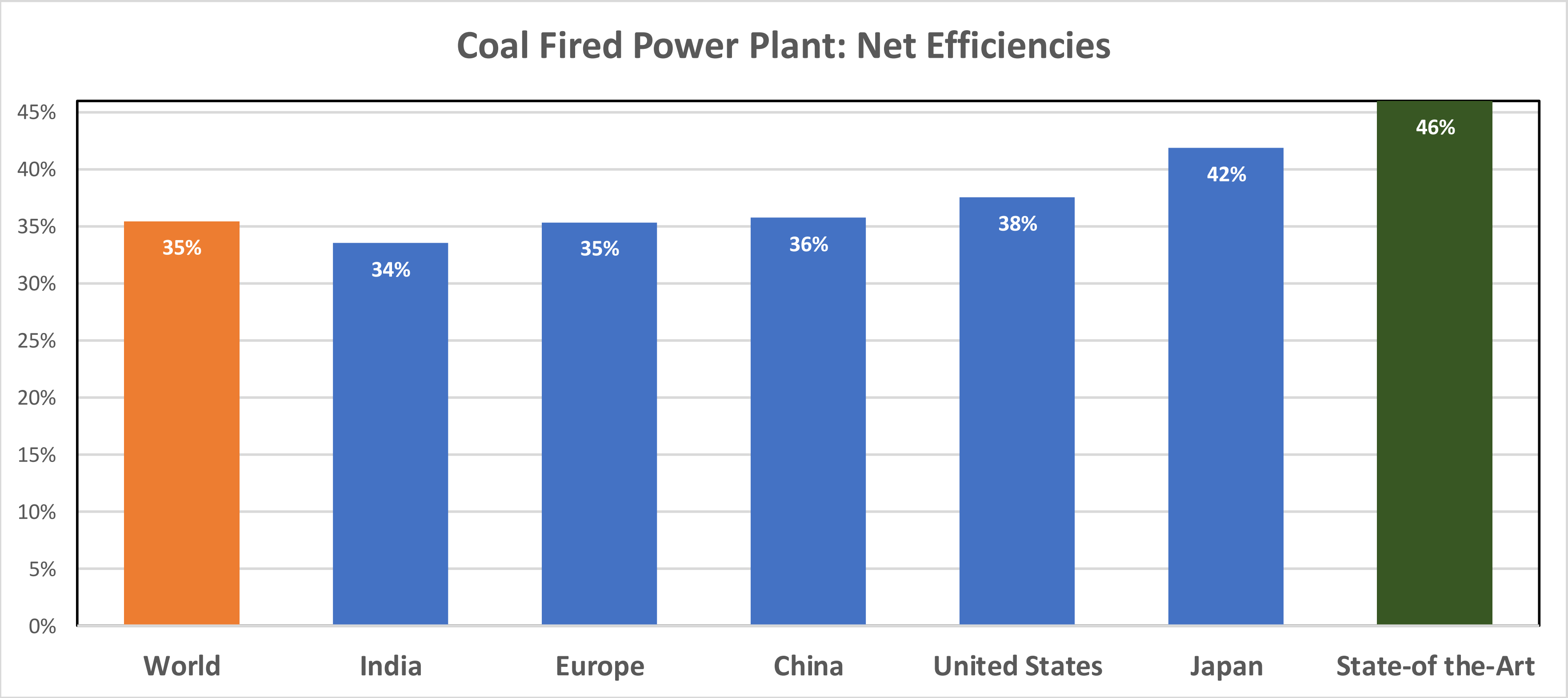
Rank	Country		MtCO₂
1	China	CHINA	7025
2	United States of America	USA	6131
3	Russian Federation		1653
4	India	INDIA	1407
5	Japan		1322

2016

Rank	Country		MtCO₂
1	China	CHINA	10151
2	United States of America	USA	5312
3	India	INDIA	2431
4	Russian Federation		1635
5	Japan		1209

Source—Global Carbon Atlas

Coal Fleet Efficiencies



Source: Energy Efficiency Indicators, World Energy Council 2014

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The United States Department of Energy

Program Offices

Advanced Research Projects Agency – Energy (ARPA-e)

Loan Programs Office

Cybersecurity, Energy Security, and Emergency Response

Electricity

Energy Efficiency & Renewable Energy

Environmental Management

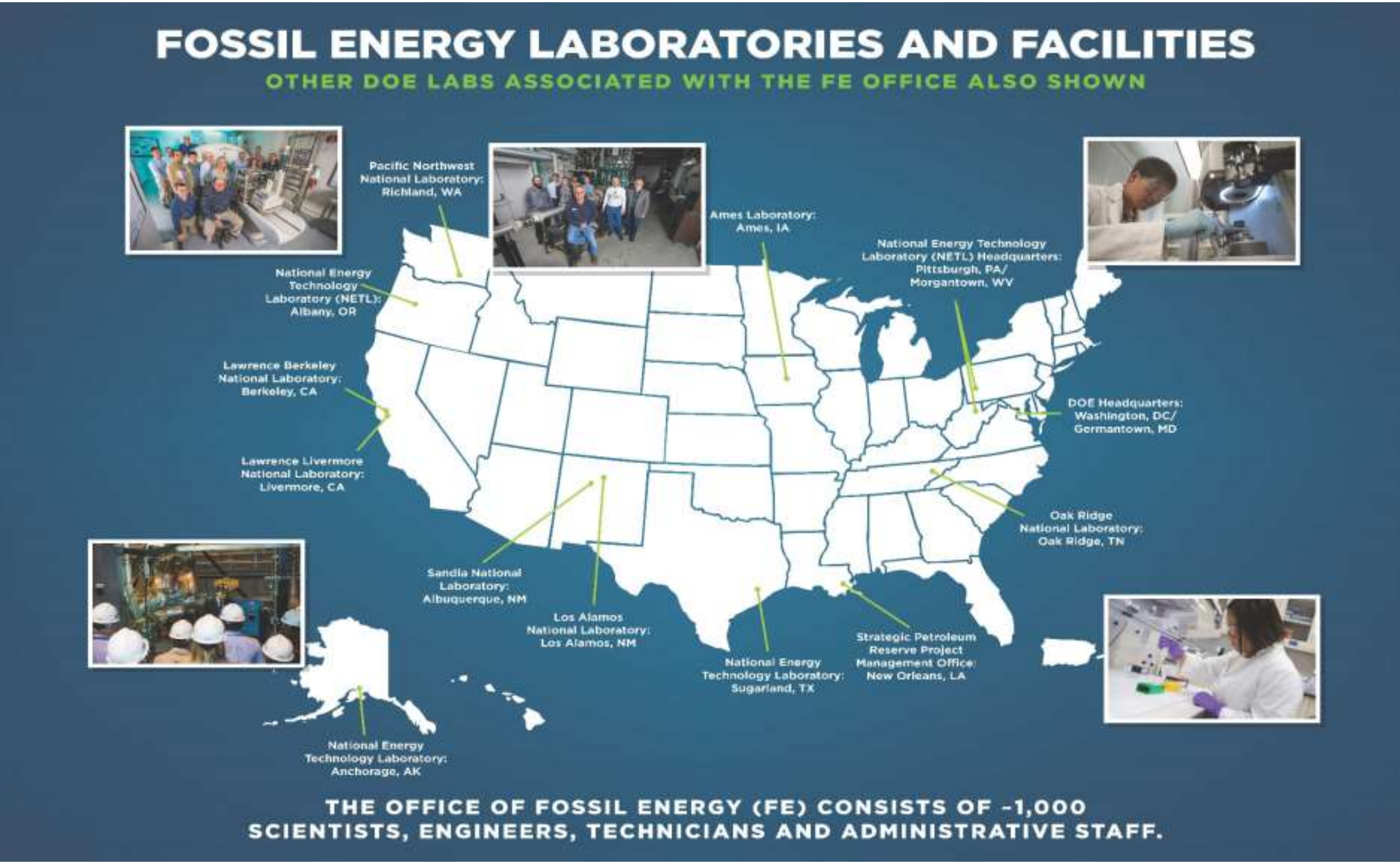
Fossil Energy

Indian Energy Policy and Programs

Legacy Management

Nuclear Energy

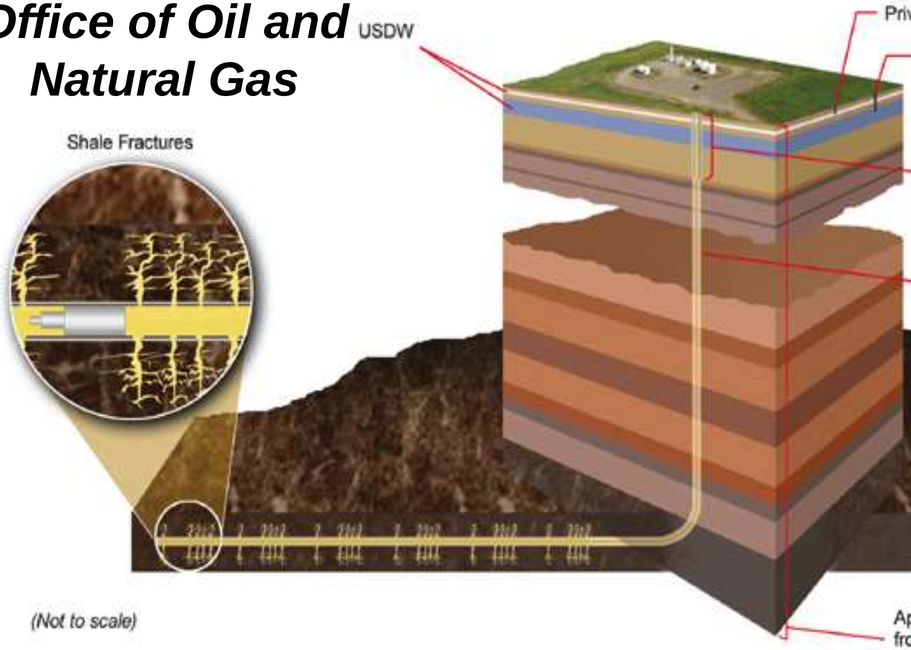
The DOE Office of Fossil Energy



DOE Office of Fossil Energy

Office of Clean Coal and Carbon Management

Office of Oil and Natural Gas



Strategic Petroleum Reserves

National Energy Technology Laboratory

Administration Energy Priorities

- Boosting Domestic Energy Production
- Grid Reliability and Resiliency
- Job Creation
- Energy Security



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"All of The Above Strategy"

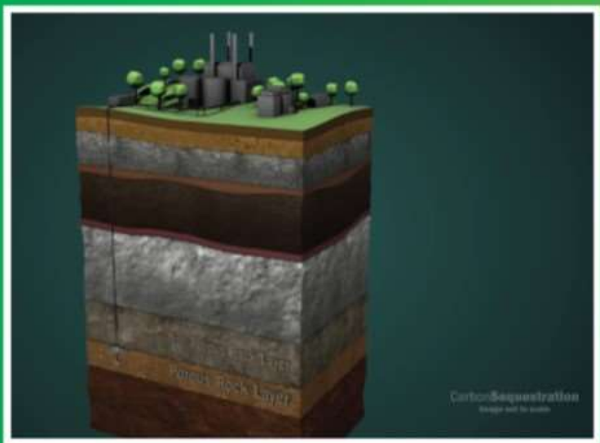
What We Work On

ADVANCED ENERGY SYSTEMS

This program is focused on improving the efficiency of coal-based power systems, enabling affordable CO2 capture, increasing plant availability, and maintaining the highest environmental standards.

CROSSCUTTING RESEARCH

This program serves as a bridge between basic and applied research by fostering the development and deployment of innovative systems for improving efficiency and environmental performance through the research and development of instrumentation, sensors, and controls targeted at enhancing the availability of advanced power systems while reducing costs.



CARBON CAPTURE, UTILIZATION AND STORAGE R&D:

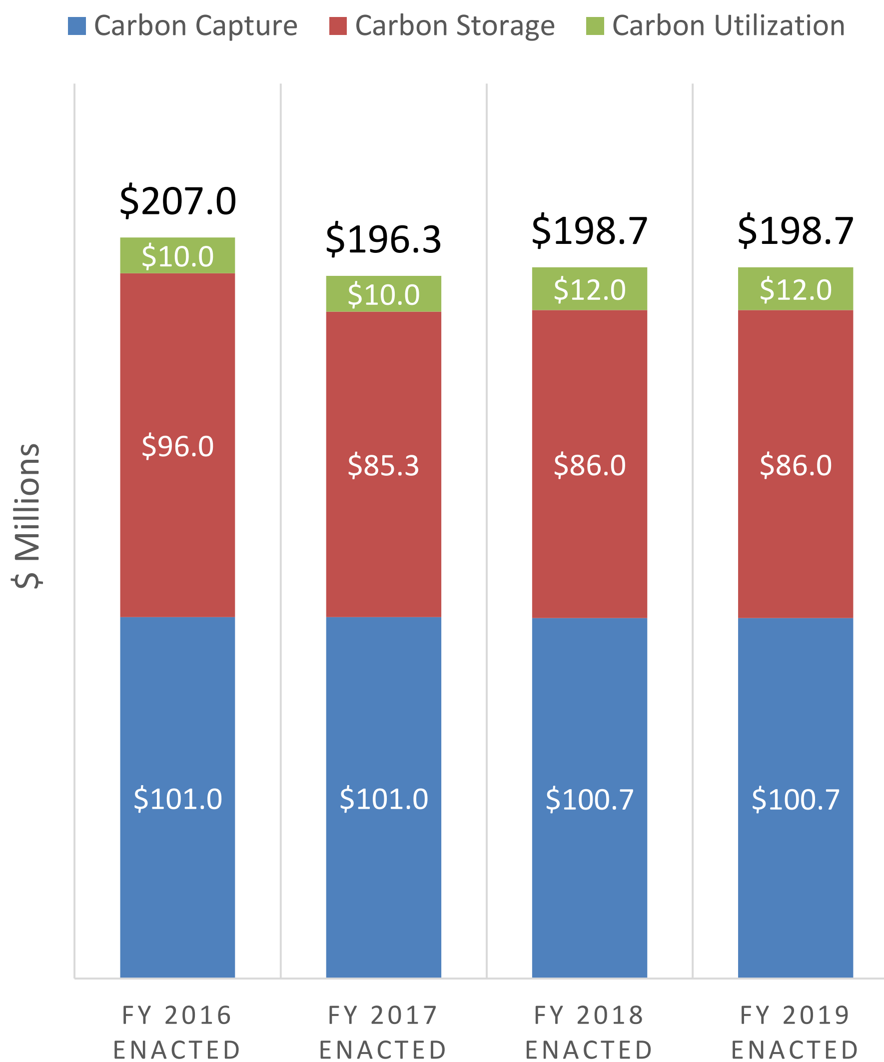
This program advances safe, cost effective, capture and permanent geologic storage and/or use of CO2.

Federal Investment in CCUS R&D

Carbon Capture
R&D and scale-up technologies for capturing CO_2 from new and existing industrial and power-producing plants

CO_2 Utilization
R&D and technologies to convert CO_2 to value-added products

Carbon Storage
Safe, cost- effective, and permanent geologic storage of CO_2



Coal FIRST Technologies

Flexible, Innovative, Resilient, Small, Transformative

Goal: *Develop the coal plant of the future needed to provide secure, stable, and reliable power*

- capable of *flexible* operations to meet the needs of the grid;
- use *innovative* and cutting-edge components that improve efficiency and reduce emissions;
- provide *resilient* power to Americans;
- are *small* compared *to* today's conventional utility-scale coal;
- and will *transform* how coal technologies are designed and manufactured.

NETL Conclusion: Bomb Cyclone

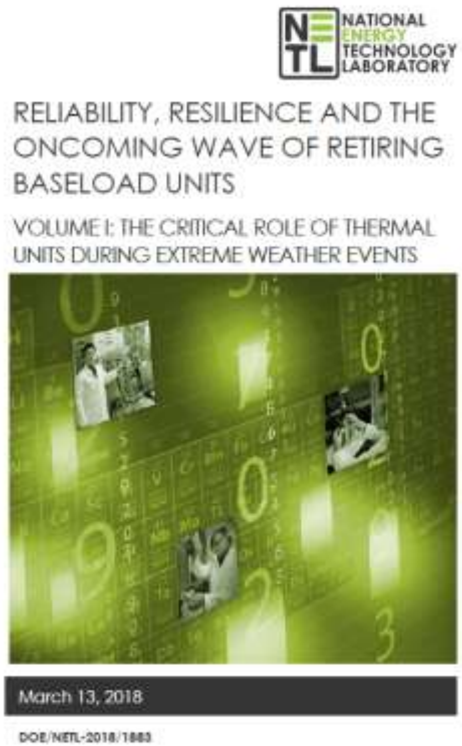
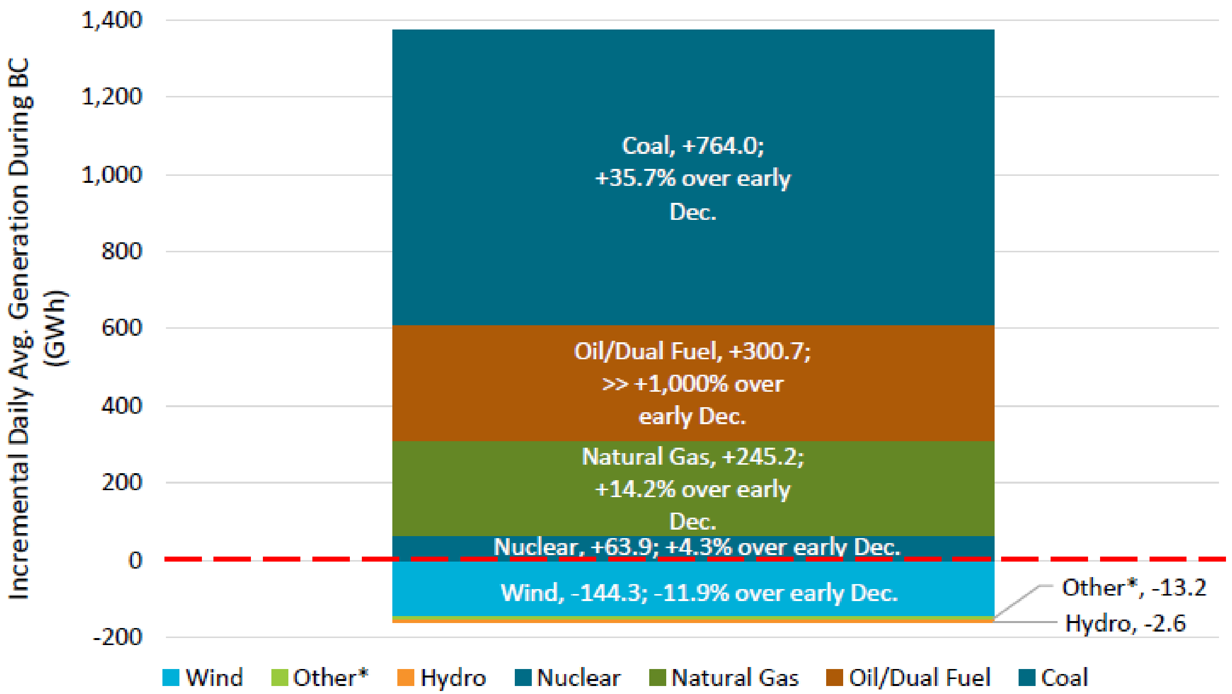


Exhibit ES-1. Fuel based generation resilience during the Bomb Cyclone, six ISOs



* 'Other' includes misc. categories, including other, refuse, solar, diesel, and multiple fuels

"During the worst of the storm from **January 5-6, 2018**, actual U.S. electricity market experience demonstrated that without the resilience of coal- and fuel oil/dual-firing plants—its ability to add 24-hour baseload capacity— ***the eastern United States would have suffered severe electricity shortages, likely leading to widespread blackouts***. "

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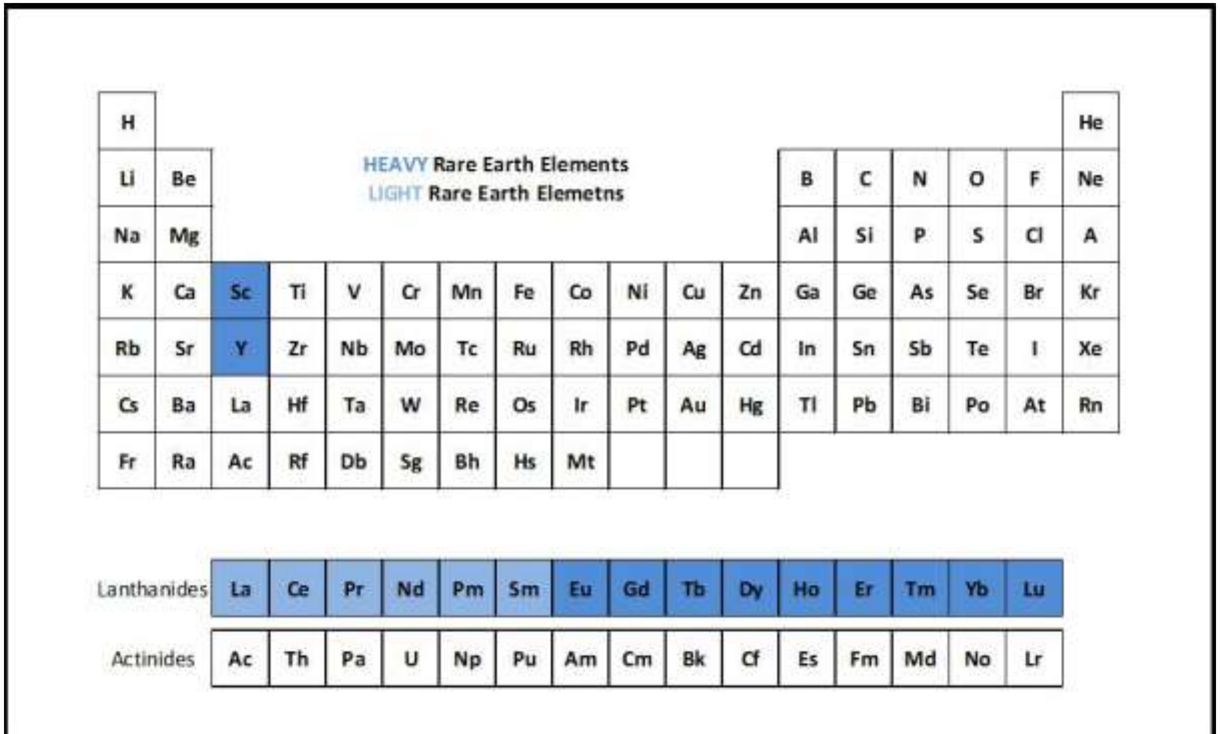
Rare Earth Elements (REEs)

- REE's are a family of 17 high-value elements including: lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb), and lutetium (Lu). The rare earths are also often considered to include the metals scandium (Sc) and yttrium (Y).



Why are REEs Important?

Light Rare Earths	Major End-Use
Scandium	TVs, fluorescent and energy-saving lamps
Lanthanum	hybrid engines, metal alloys
Cerium	catalysts, metal alloys
Praseodymium	Magnets
Neodymium	catalysts, hard drives in laptops, headphones, hybrid engines
Promethium	watches, pacemakers
Samarium	Magnets
Europium	red color for television, computer screens

Heavy Rare Earths	Major End-Use
Terbium	phosphors, permanent magnets
Dysprosium	permanent magnets, hybrid engines
Erbium	phosphors
Yttrium	red color, fluorescent lamps, ceramics, metal alloy agent
Holmium	glass coloring, lasers
Thulium	medical x-ray units
Lutetium	petroleum catalysts
Ytterbium	lasers, steel alloys
Gadolinium	magnets

Why are REEs Important?

- The market for REE has been increasing since they were first mined in the mid-1900s. Historically, the U.S. has had a large market share, being the largest producer of REEs from the 1960s to the 1980s (Mountain Pass Mine – California).
- China began production in the 1980s and by 1988 secured the position of the world's leading REE producer. China has controlled the global market throughout the majority of the last 30 years
- In 2011, global production of REEs was approximately 132,000 metric tons (MT)—95 percent of which was supplied by China.
- On September 1, 2009, China announced plans to reduce its export quota to 35,000 tons per year in 2010–2015 to conserve scarce resources and protect the environment.
- On October 19, 2010, China Daily, reported that China would "further reduce quotas for rare earth exports by 30% at most next year to protect the precious metals from over-exploitation“
- In March 2012, the US, EU, and Japan confronted China at WTO about these export and production restrictions. China responded with claims that the restrictions had environmental protection in mind.
- In August 2012, China announced a further 20% reduction in production.
- (2014-2017) – US imported 80% of its REE from China (Source: USGS)
- Estimated value of REEs imported by US in 2018: $160M (Source: USGS)

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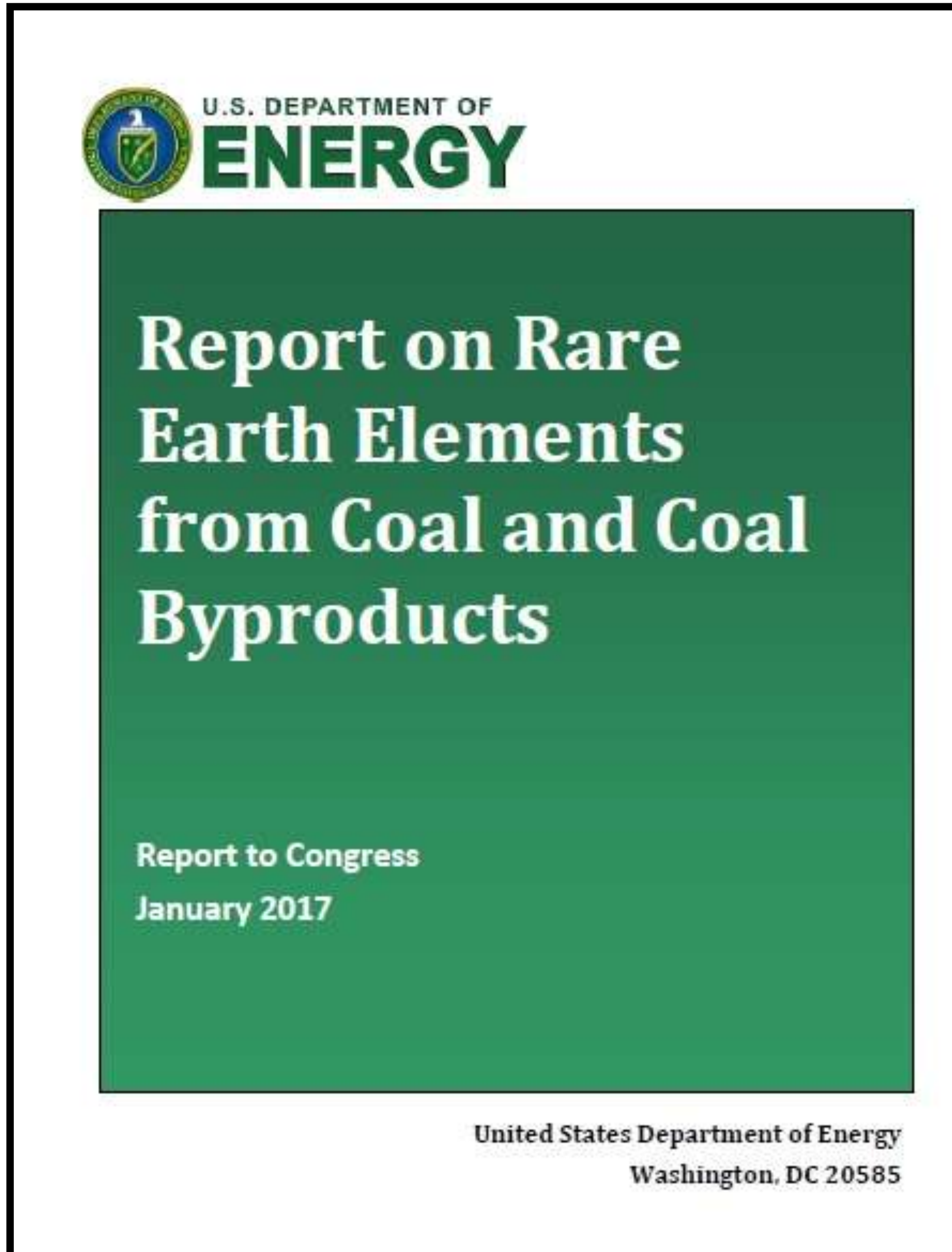
What's the Link Between REEs and Coal?

<u>REEs are found in the following locations:</u>

- Ash - Fly Ash, Bottom Ash
- Slag
- Coal
- Mining – Strata Above/Below Coal Seams
- Coal Preparation
- Acid Mine Drainage and Sludge

Key Takeaways

- The strong global interest in developing an additional REE supply creates an investment opportunity for commercial firms seeking REEs recovered from coal and coal byproducts to find competitive entry points into the REE global value chain.
- REEs present in coal-based materials currently being mined for coal production represent potential savings when compared to production of virgin ore in a mine dedicated solely to REE recovery.
- The core challenges with REE recovery from coal and coal byproducts center on the large volume of material that must be processed to recover REEs.


U.S. DEPARTMENT OF ENERGY

Report on Rare Earth Elements from Coal and Coal Byproducts

Report to Congress

January 2017

United States Department of Energy

Washington, DC 20585

For Additional Information

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