NATIONAL ENERGY TECHNOLOGY LABORATORY

FutureGen 2.0

An Oxy-Combustion Coal-Fueled Power Plant with CO_2 Storage

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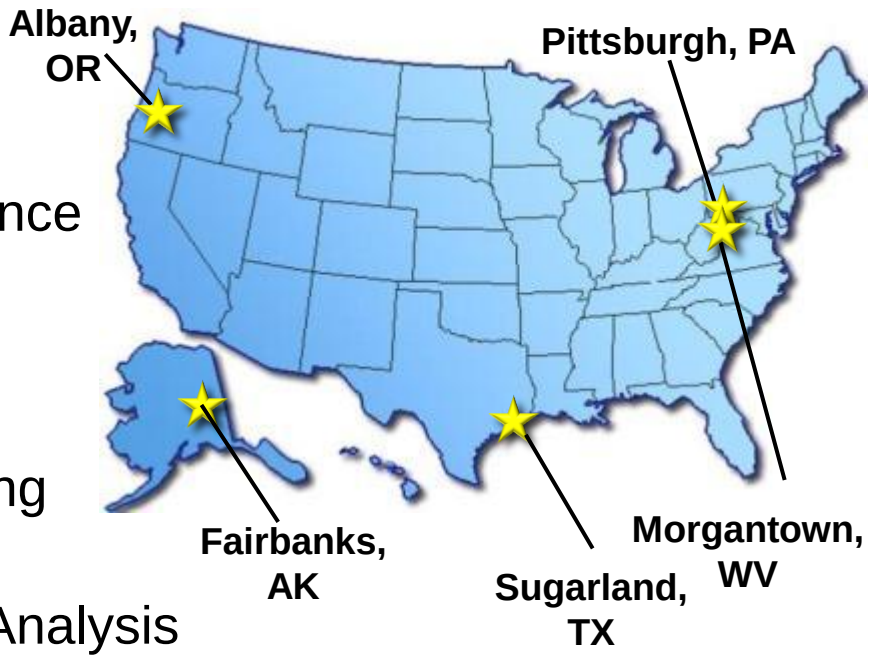
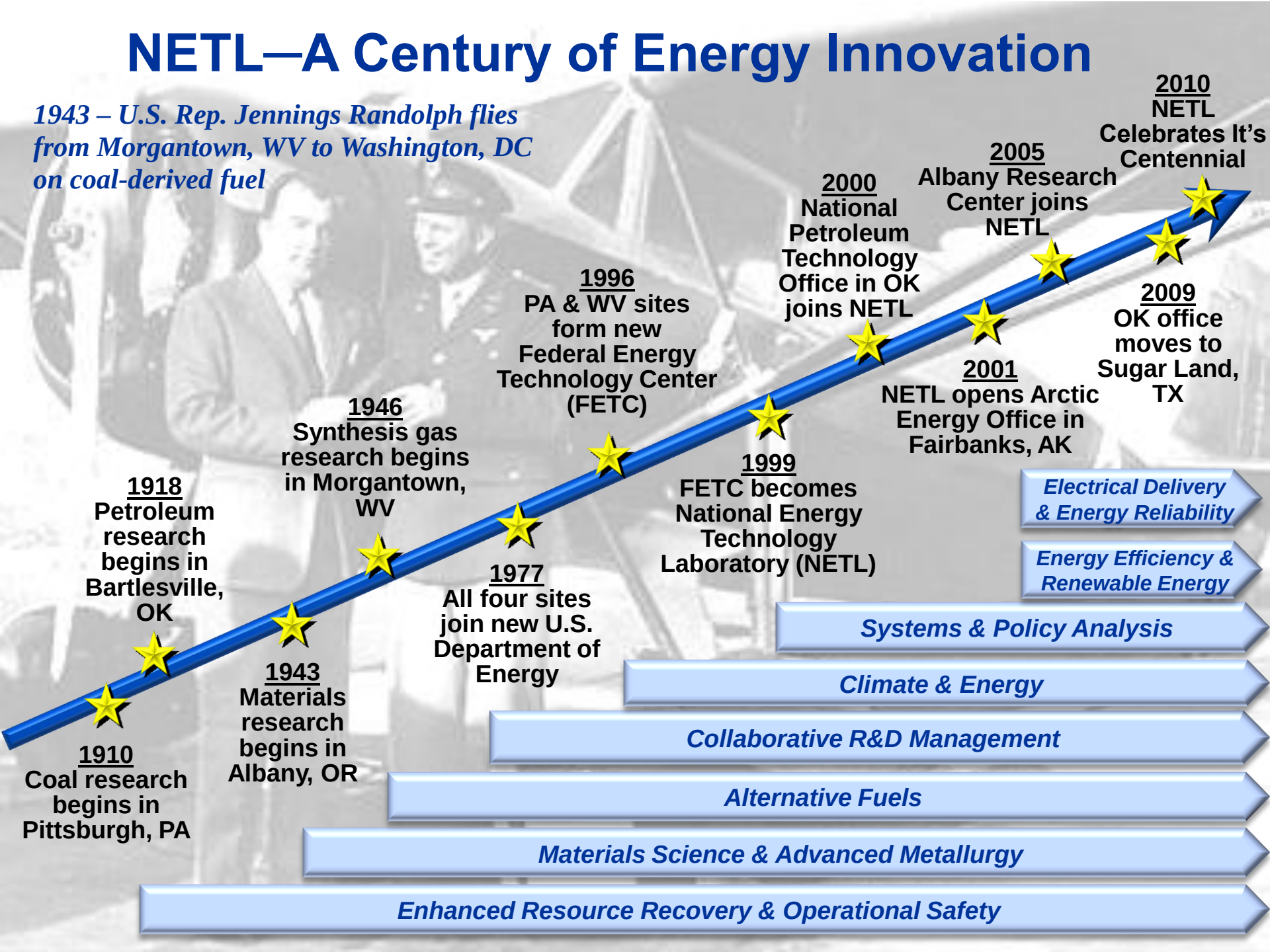
National Energy Technology Laboratory

- **Full-service DOE Federal laboratory**
  - Program Planning
  - Budget Formulation and Execution
  - Procurement
    - Contracting and Financial Assistance
  - Project Management
    - Including NEPA Compliance
  - Legal
  - Financial Management and Reporting
  - On-site Research
  - Program Performance and Benefit Analysis



- **Dedicated to energy RD&D, domestic energy resources**
  - Fossil Energy
  - Support DOE's Offices of Electricity and Energy Efficiency
- **Fundamental science through technology demonstration**
- **Unique industry–academia–government collaborations**

NETL—A Century of Energy Innovation



1943 – U.S. Rep. Jennings Randolph flies from Morgantown, WV to Washington, DC on coal-derived fuel

1910
Coal research begins in Pittsburgh, PA

1918
Petroleum research begins in Bartlesville, OK

1943
Materials research begins in Albany, OR

1946
Synthesis gas research begins in Morgantown, WV

1977
All four sites join new U.S. Department of Energy

1996
PA & WV sites form new Federal Energy Technology Center (FETC)

1999
FETC becomes National Energy Technology Laboratory (NETL)

2000
National Petroleum Technology Office in OK joins NETL

2001
NETL opens Arctic Energy Office in Fairbanks, AK

2005
Albany Research Center joins NETL

2009
OK office moves to Sugar Land, TX

2010
NETL Celebrates It's Centennial

Electrical Delivery & Energy Reliability

Energy Efficiency & Renewable Energy

Systems & Policy Analysis

Climate & Energy

Collaborative R&D Management

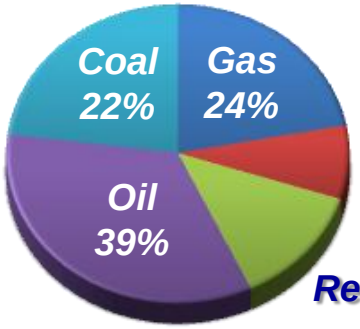
Alternative Fuels

Materials Science & Advanced Metallurgy

Enhanced Resource Recovery & Operational Safety

Energy Demand 2007

102 QBtu / Year
85% Fossil Energy



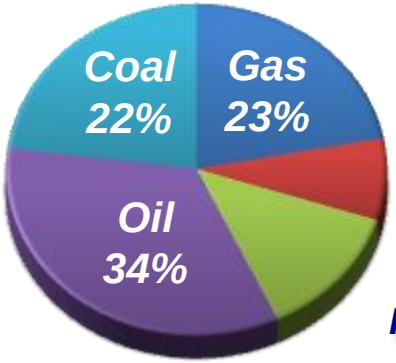
5,975 mmt CO_2

+ 9%

United States

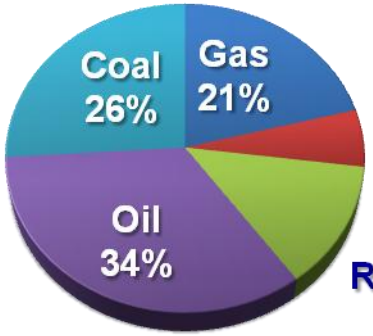
Energy Demand 2030

111 QBtu / Year
79% Fossil Energy



6,164 mmt CO_2

477 QBtu / Year
81% Fossil Energy

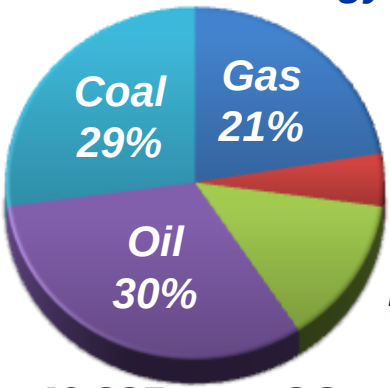


28,826 mmt CO_2

+ 40%

World

666 QBtu / Year
80% Fossil Energy

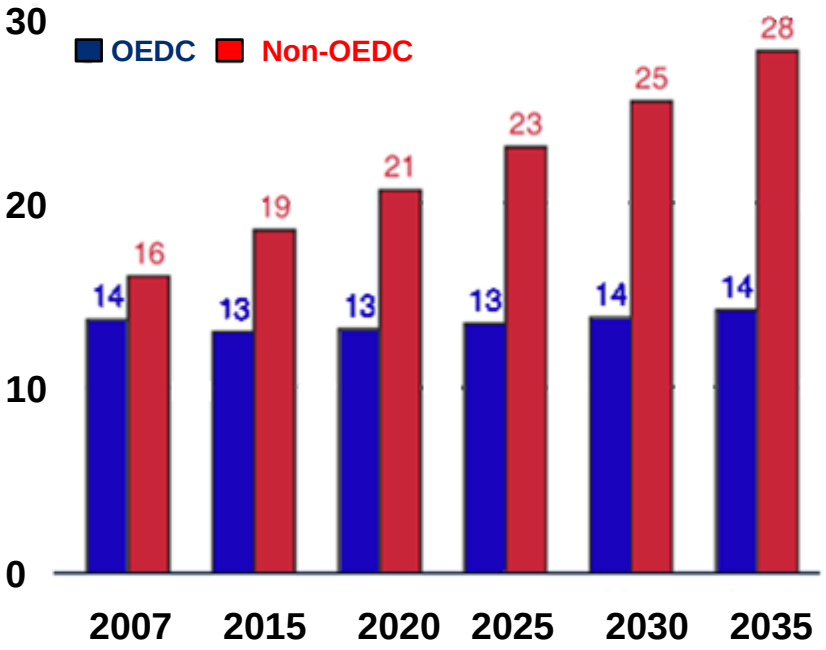


40,225 mmt CO_2

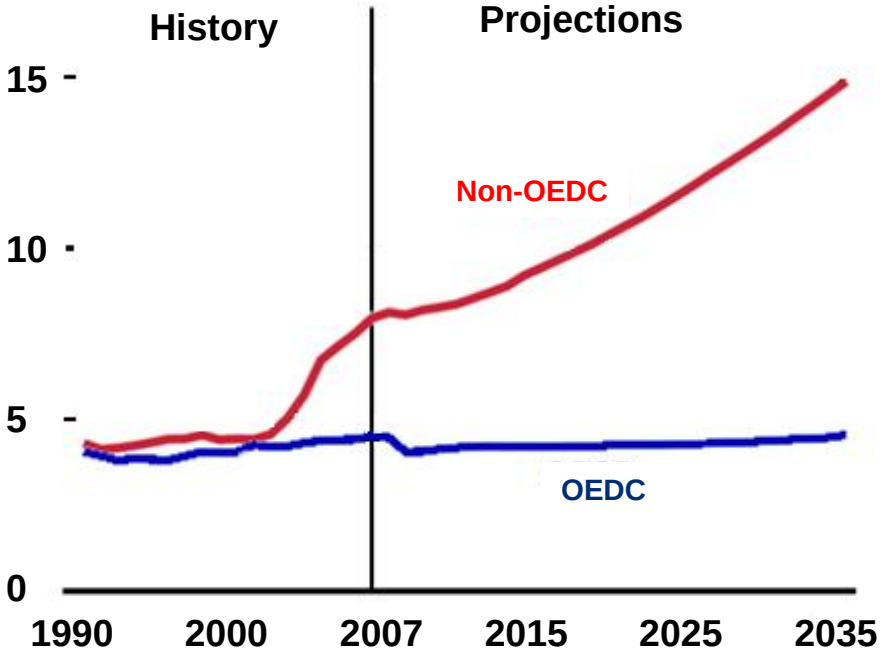
Sources: U.S. data from EIA, Annual Energy Outlook 2010; World data from IEA, World Energy Outlook 2009

Projected World Growth in CO_2 Emissions
(EIA-IEO 2010 BAU Projection)

World energy-related CO_2 emissions (gigatonnes)



World CO_2 emissions from coal combustion (gigatonnes)



EIA's International Energy Outlook 2010 *Reference case -- current laws and policies remain unchanged*

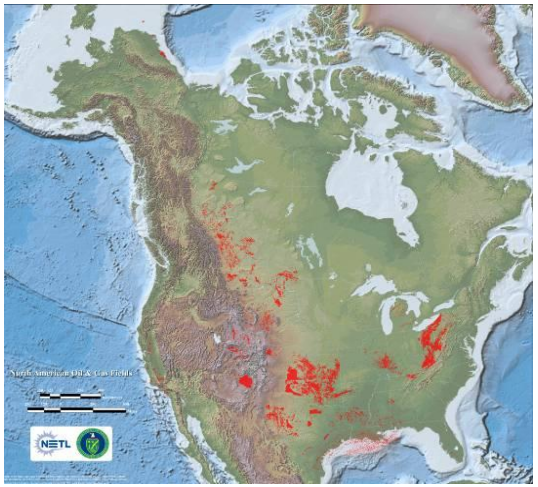
Report #:DOE/EIA-0484(2010), July 2010 http://www.eia.gov/oiaf/ieo/index.html

Adequate Geologic CO_2 Storage Projected for U.S.

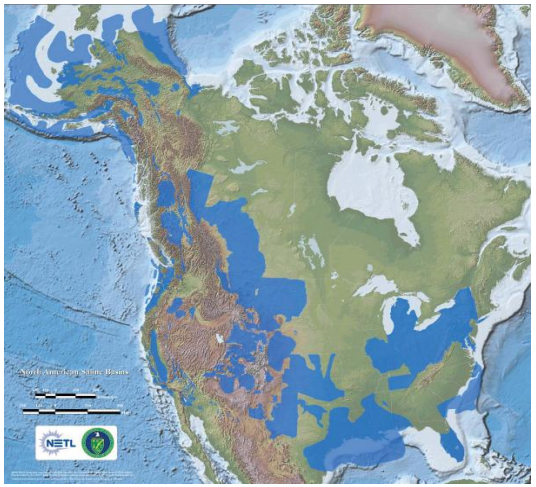
National Atlas Highlights (Atlas II)

U.S. Emissions ~6 GT CO_2 per year all sources

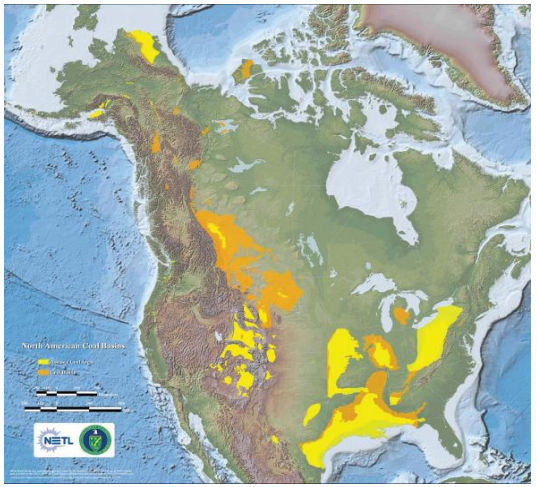
(U.S. Coal-Fueled Emissions ~2.1 GT CO_2 per year)



Oil and Gas Fields



Saline Formations



Unmineable Coal Seams

North American CO_2 Storage Potential (GT)

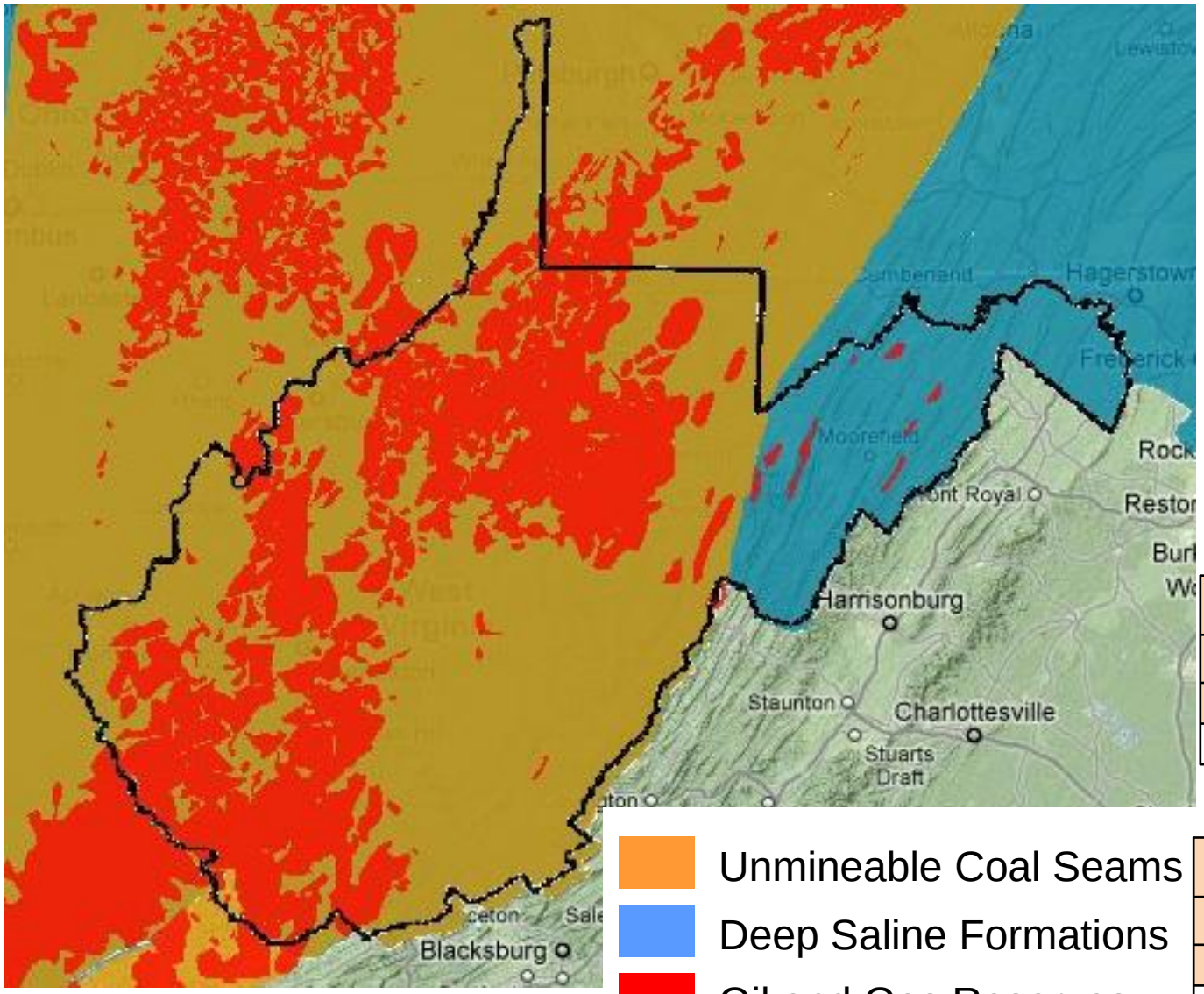
Sink Type	Low	High
Saline Formations	3300	13000
Unmineable Coal Seams	160	180
Oil and Gas Fields	140	140

Conservative Resource Assessment

Hundreds of Years of Storage Potential

Download at http://www.netl.doe.gov/technologies/carbon_seq/refshelf/atlasII/atlasII.pdf

West Virginia CO_2 Sinks



Oil and Gas Reservoir
Million Metric Tons
Low Estimate
1,353

Unmineable Coal Seams	
Million Metric Tons	
Low Estimate	High Estimate
177	177

Deep Saline Formation	
Million Metric Tons	
Low Estimate	High Estimate
3,343	13,463

Unmineable Coal Seams

Deep Saline Formations

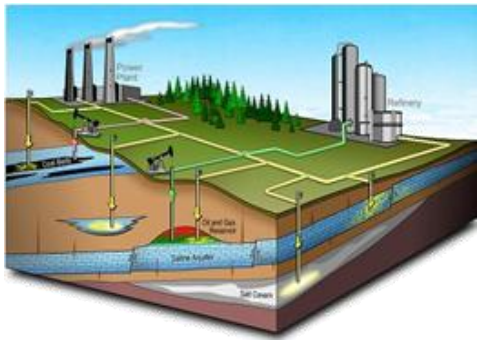
Oil and Gas Reserves

Total Storage Resource	
Million Metric Tons	
Low Estimate	High Estimate
4,873	14,994

Sources: http://www.natcarb.org/Atlas/ims_map.html and http://www.netl.doe.gov/technologies/carbon_seq/refshelf/atlasII/atlasII.pdf

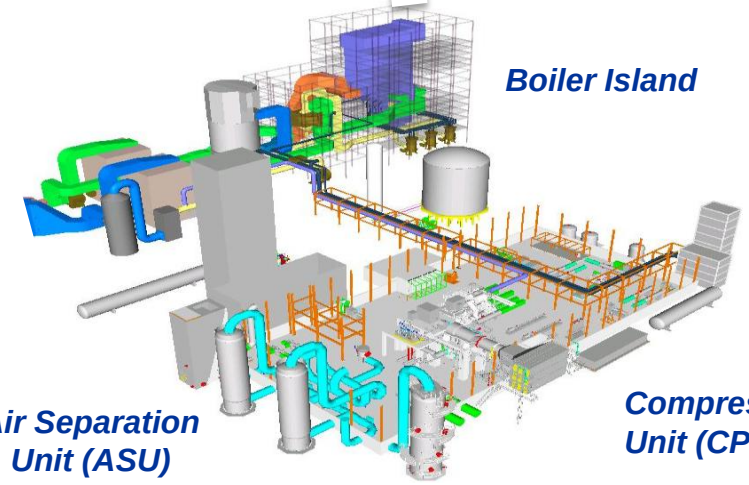
Ten Major CCS Demonstration Projects

What is FutureGen 2.0?



- **U.S. Department of Energy has awarded:**
  - **$590 million to Ameren, Babcock & Wilcox and American Air Liquide to demonstrate Oxy-Combustion technology at utility-scale**
  - **$459 million to FutureGen Alliance to transport and geologically store the CO_2**
- **The FutureGen 2.0 project will incorporate:**
  - **CO_2 Capture: Repower an existing Ameren 200 MWe power plant unit in Meredosia, Illinois with Oxy-Combustion and CO_2 compression & purification**
  - **Transport: Build a CO_2 pipeline to a CO_2 storage facility in Illinois (exact location TBD)**
  - **Storage: Develop a deep saline storage facility to sequester CO_2 from the power plant (and potentially other facilities in the region) in the Mt. Simon sandstone formation**

Meredosia Power Station Site



Boiler Island

Air Separation Unit (ASU)

Compression & Purification Unit (CPU)

Meredosia Plant

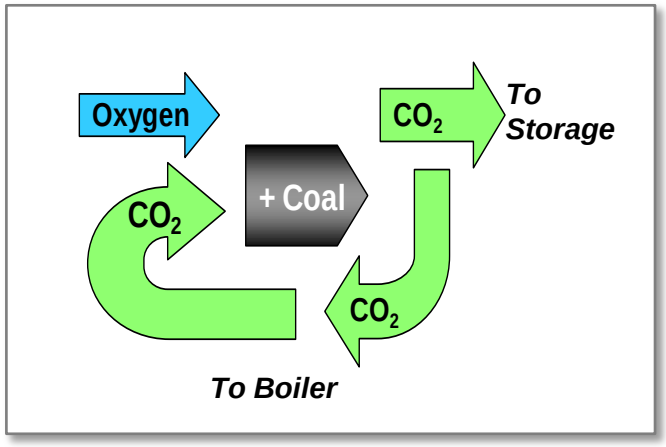
- Location - Meredosia, IL
- Operated by Ameren Energy Resources
- 4 existing units, 3-coal fired (Units 1 & 2 mothballed), Unit 4-oil-fired
- Illinois Coal, PRB or PRB Blends
- Truck & barge unloading facilities for coal
- Repower existing steam-turbine with purpose-built Oxy-Comb PC boiler
- Existing boiler, built in 1975, to be retired
- Infrastructure exists to accommodate repowering with coal
- Unit 4 turbine & generator have low operating hours

Why FutureGen 2.0 Program?

- **DOE is committed to supporting diverse portfolio of commercial-scale projects; collectively intended to advance state-of-art, and ultimate commercialization of coal-based power generation in a carbon-constrained world**
  - IGCC with pre-combustion capture
  - Post-combustion capture
  - Oxy-Combustion (FutureGen 2.0)
- **FutureGen 2.0 provides DOE and the US with opportunity to demonstrate a technology that could be retrofitted to existing coal-steam plants**
- **Pursuing these technologies, in parallel, provides DOE with the opportunity to obtain commercial-scale operating data, from major competing clean-coal technologies; yielding the results needed to help DOE evaluate its technology development portfolio, and industry to make informed investments**

What is Oxy-Combustion?

Oxy-Combustion burns coal with a mixture of oxygen and CO_2 instead of air to produce a concentrated CO_2 stream for safe, permanent, storage

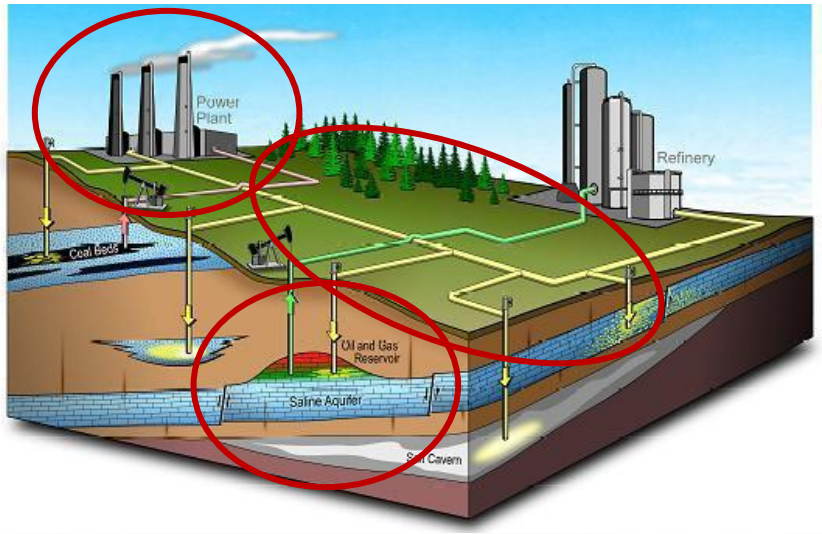


Oxy-Combustion has been tested at 0.5 MWe & 10 MWe. A large integrated commercial size test (150-200 MWe) will:

- Confirm cost basis for retrofitting/repowering existing coal-fired units – as a pathway to lower new plant costs (e.g., 500-800 MWe scale)
- Prove operability and reliability of the integrated process - Boiler Island, Air Separation Unit, Compression & Purification Unit, & CO_2 storage
- Provide performance & emissions data for future commercial guarantees
- Establish operating & maintenance experience for future commercial plants

FutureGen 2.0 Project Costs: Oxy-Combustion Repowering, CO_2 Pipeline & Storage Facility

Task	*DOE*	*Participants*
Oxy-Combustion Plant Repowering	*$ 589,744,000*	*$147,436,000*
CO_2 Pipeline & Storage Facility	*$458,604,000*	*$93,931,000*
FutureGen 2.0 Total Estimated Costs	*$ 1,048,348,000 +*	*$241,367,000*
	=	*$1,289,715,000*



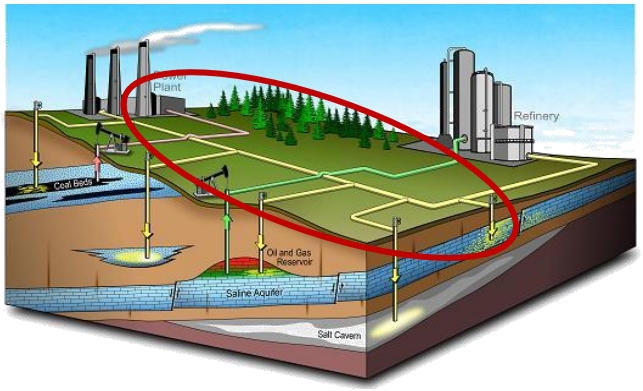
Oxy-Combustion Plant Repowering Meredosia, IL

DOE Share	*$ 589,744,000*	*80%*
Participant Contribution	*$ 147,435,996*	*20%*
Total Estimated Cost	*$ 737,179,996*	*100%*

- **A large scale integrated test to repower Ameren's existing 200 MWe Meredosia Unit 4 with Oxy-Combustion & carbon capture technology**
  - A purpose-built Oxy-Combustion system
  - Confirmation that Oxy-Combustion is a viable retrofit/new build technology for coal-fueled power plants
  - Basis for industry acceptance: lowers equipment, operational, reliability & financial risks for future commercial deployments to meet U.S. energy needs

CO_2 Transmission Pipeline

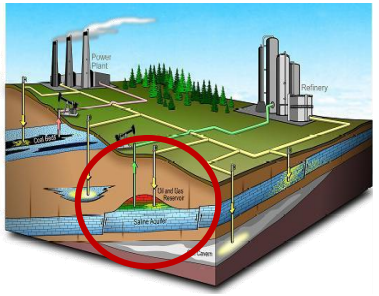
DOE Share	*$ 233,000,000*	*80%*
Participant Contribution	*$ 67,000,000*	*20%*
Total Estimated Cost	*$ 300,000,000*	*100%*



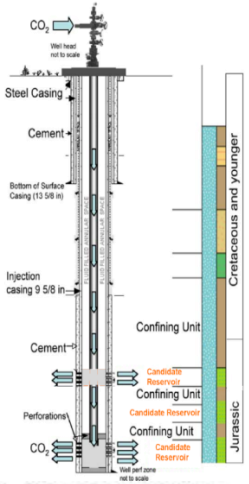
- **Collection & trunkline pipeline infrastructure to transport CO_2 from Meredosia to a deep-saline CO_2 storage site TBD**
  - CO_2 pipeline to storage facility
  - DOE & FG Alliance to establish process by which competent design/construct contractor is selected
- **Benefits**
  - Construction of both collection & trunkline pipeline infrastructure may allow for future expansion to transport CO_2 from other point sources in the area
  - Demonstration of the feasibility of pipeline CO_2 transport for long-term storage

Geological CO_2 Storage Repository

DOE Share	*$ 235,500,000*	*89%*
Participant Contribution	*$ 27,000,000[1]*	*11%*
Total Estimated Cost	*$ 252,500,000*	*100%*



- **Design, build, operate geologic storage facility capable of safely & permanently storing anthropogenic CO_2**
  - Site characterization for large volumes to be stored
    - Modeling, seismic surveys, drilling of characterization wells, injection well design
  - Visitor, education and research facilities to be co-located at the storage site
- **A potential CO_2 Storage Site**
  - The Mt. Simon formation has multiple overlying seals and large storage capacity
  - Potential cost savings for future CO_2 storage needs, and potential to generate a revenue stream
  - Strong community interest has been exhibited



1. The FGA will not cost share in the visitor, education and training facilities.

Oxy-Combustion Summary

- **An advanced coal combustion technology**
  - Capable of retrofitting or repowering an existing plant
  - As a base-load technology for new green field applications
- **Opportunity for near-zero emissions from coal**
  - Potential for nearly 100% CO_2 capture with minor economic penalty
  - Cleaner and with less CO_2 emissions than conventional NG combined-cycle
  - 40% lower water consumption than conventional amine CO_2 capture system
- **Mature commercial technology cost projected to be lower than conventional post-combustion CO_2 capture**
- **Many Opportunities for Improvement:**
  - Cryogenic ASU developments can reduce O_2 generation power consumption by 20-35%
  - Opportunity to incorporate Ion Transport Membranes, further increasing O_2 supply efficiency
  - Smaller Oxy-Combustion specific boiler designs can increase heat transfer & reduce capital cost
  - Co-sequestration of CO_2 with NOx and SO_2 possible

For Additional Information:

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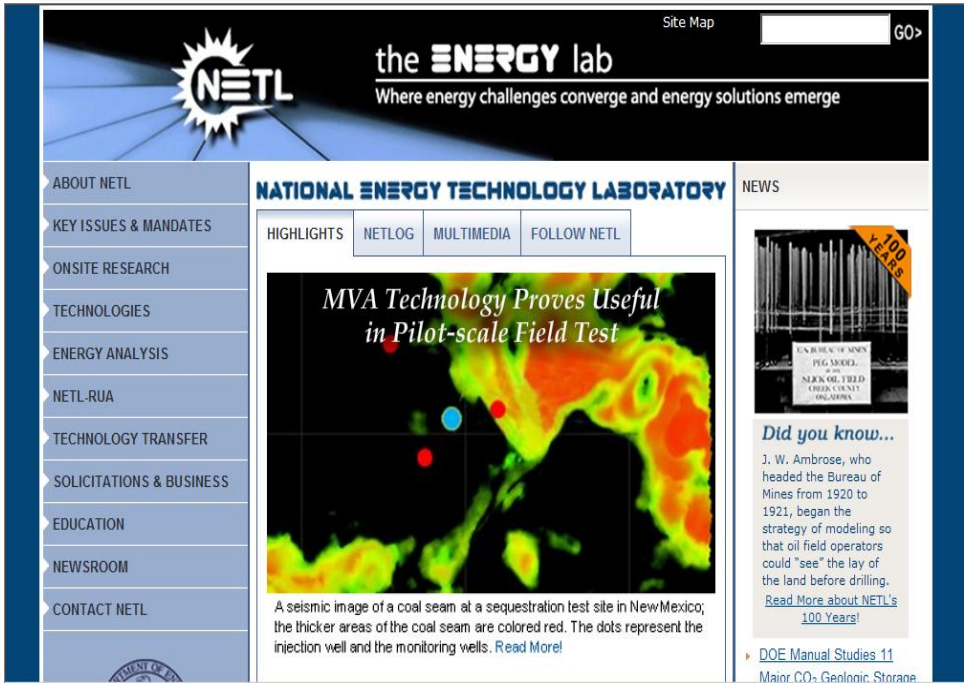
Fossil Energy website:
www.fe.doe.gov



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