EERC Technology… Putting Research into Practice

Clean Coal and Smart Grid

Presentation to the

Energy Development and Transmission Committee

September 16, 2009

Thomas A. Erickson

Associate Director for Research

Holy Grail of Energy Production

Zero CO_2, CO_2 Neutral, or Lower CO_2 Signature than Traditional Technologies

Clean

Domestically Produced

Low Water Consumption

Green

"Food Friendly" – Does Not Compete with Food Production – Directly or Indirectly

Needs to Be Low Cost!

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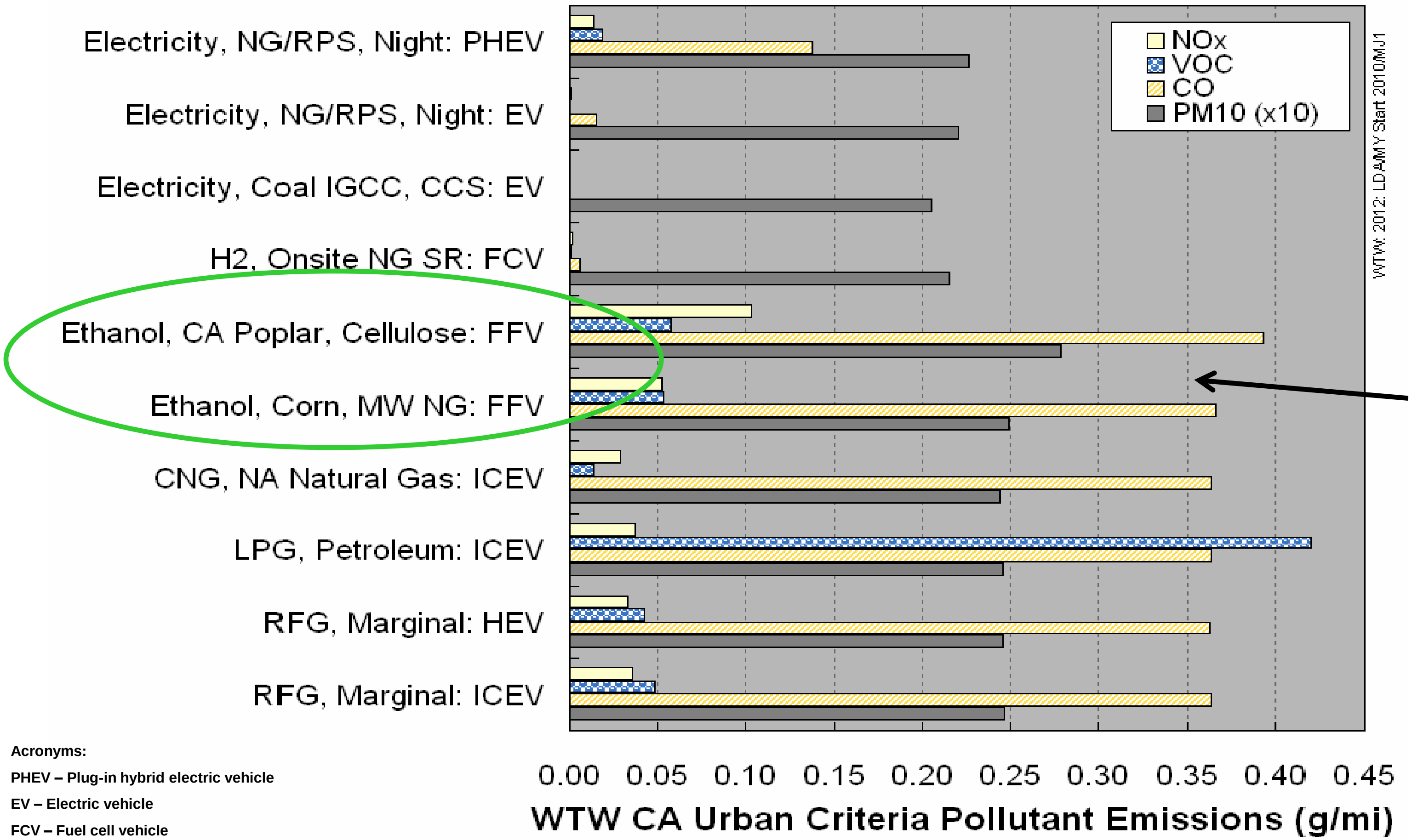
Clean vs. Green

Green does not always mean clean.

Clean does not need to mean green.

Well-to-Wheel Analysis – Criteria Pollutant Emissions



Ethanol with Higher NO_x, CO, and PM_{10}!

Acronyms:

PHEV – Plug-in hybrid electric vehicle

EV – Electric vehicle

FCV – Fuel cell vehicle

FFV – Fuel-flexible vehicle

ICEV – Internal combustion engine vehicle

HEV – High-efficiency vehicle

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Source: www.energy.ca.gov/2007publications/CEC-600-2007-004/CEC-600-2007-004-F.PDF (accessed October 2007).

We Already Have Clean Coal – We Just Need to Make It Cleaner

Early Coal Utilization – Inefficient, No Emission Control

Today – Efficiency Significantly Improved, Low Emissions at Most Facilities, Except CO_2 and Water

Future Coal Utilization – High Efficiency, Near-Zero Emissions

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Clean Coal Technologies

Conventional Combustion

Advanced Combustion

Gasification

Pyrolysis

Coal to Liquids

Emission Control

Near-Zero Emissions

Water Minimization

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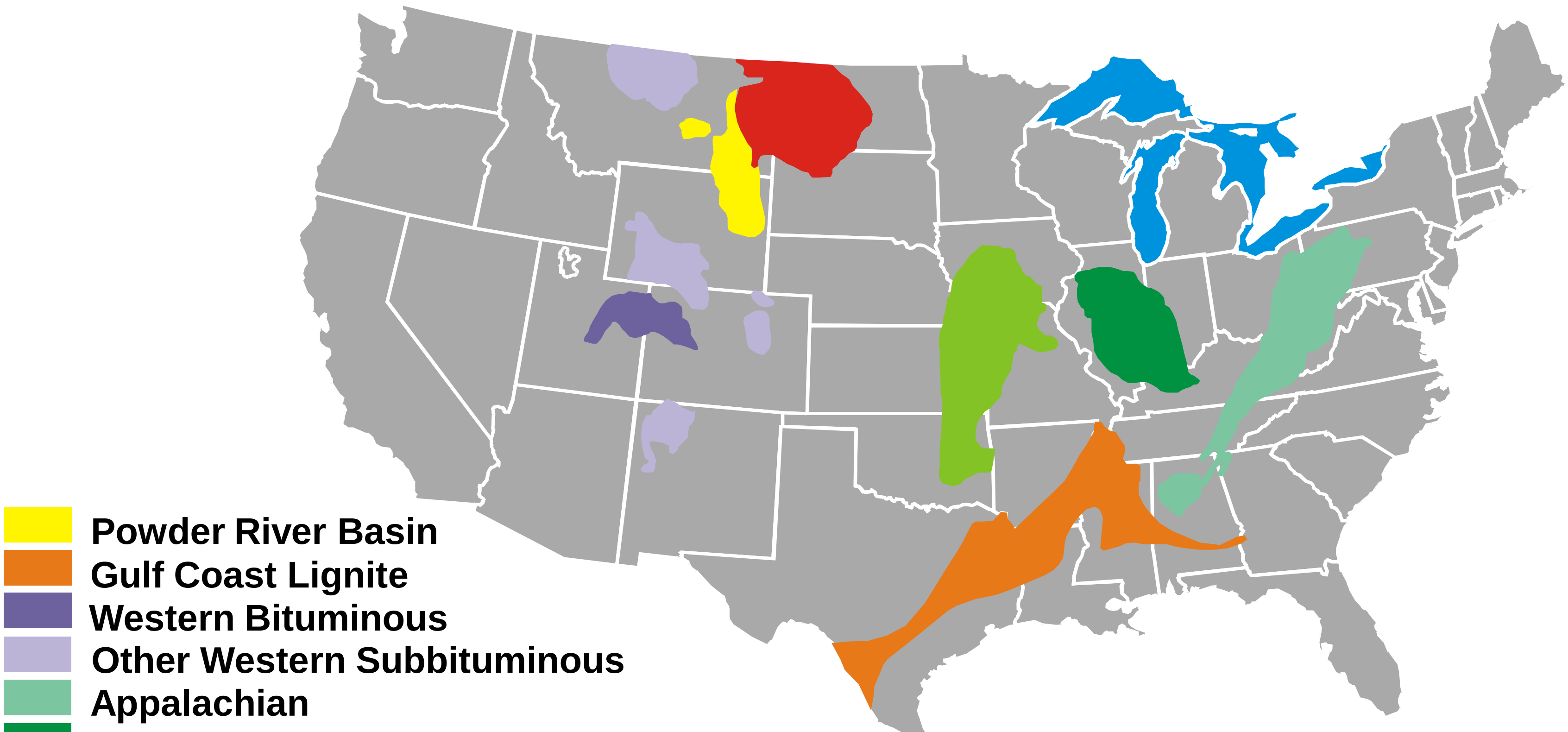
Map of Coal Basins in the United States



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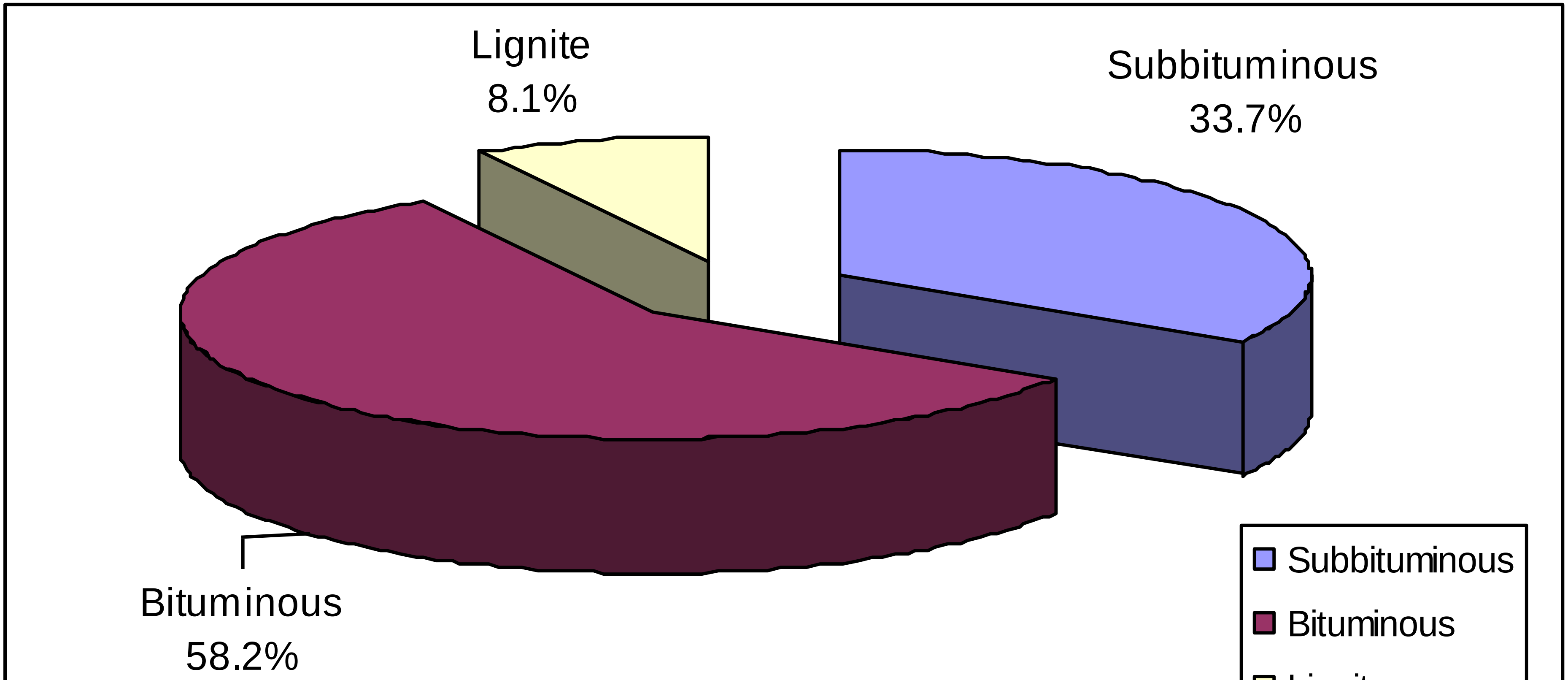
Distribution of Coal Used by Power Plants in the United States



(based on generation from ICR data)

North Dakota Coal Resources

Western North Dakota contains an estimated 351 billion tons of lignite, the single largest deposit of lignite known in the world, underlying nearly 40% of the state.

North Dakota contains an estimated 25 billion tons of economically minable coal.

- Enough to last for over 800 years at the present mining rate of 32 million tons per year
- Recovered from surface mines in beds that vary in thickness from 3 to 30 feet

Currently, there are six operations mining in western North Dakota, four of which mine lignite for use in electrical power generation.

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Lignite 101

Properties of Lignite	Commercial Value
Low energy value/lb	-
High moisture	-
High reactivity	+
Medium sulfur	-
High ash (inorganics)	-
Low mining costs	+

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Lignite Utilization 101

Lignite Utilization Issues	Commercial Value
Higher capital cost	-
Higher environ. perform. cost	-
Low fuel cost	+
High transportation cost	-
Low CO_2 Efficiency (CO_2/MW)	-
Good Collocation with CO_2 Sinks	+

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Emission Control Center

The EERC is internationally recognized for groundbreaking work in understanding the formation of air pollutants and in the development of technologies to control their emission, including:

- Air toxics
- Particulate matter
- SO_2
- SO_3
- NO_x
- CO_2
- H_2O

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Zero-Emission Power Plant Becomes a Reality

The EERC is working with numerous corporate partners to make zero-emission coal-fired power generation a reality.

Such a facility would run more efficiently and exceed current air emission regulations.

The technical hurdles are behind us; it is just a matter of time before the system economically becomes a reality.

Design consists of an entire family of technologies that, when working together, will address all major and minor environmental challenges, offer greatly enhanced efficiency and reduced emissions, and contribute to a cleaner, healthier environment.

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Traditional Emission Control

SO_x

"Acid Rain"

NO_x

Particulate

Trace Metals, in Particular Mercury

Hazardous Pollutants

The removal of moisture and CO_2 from the gas stream may dramatically change the way we control other emissions in the future.

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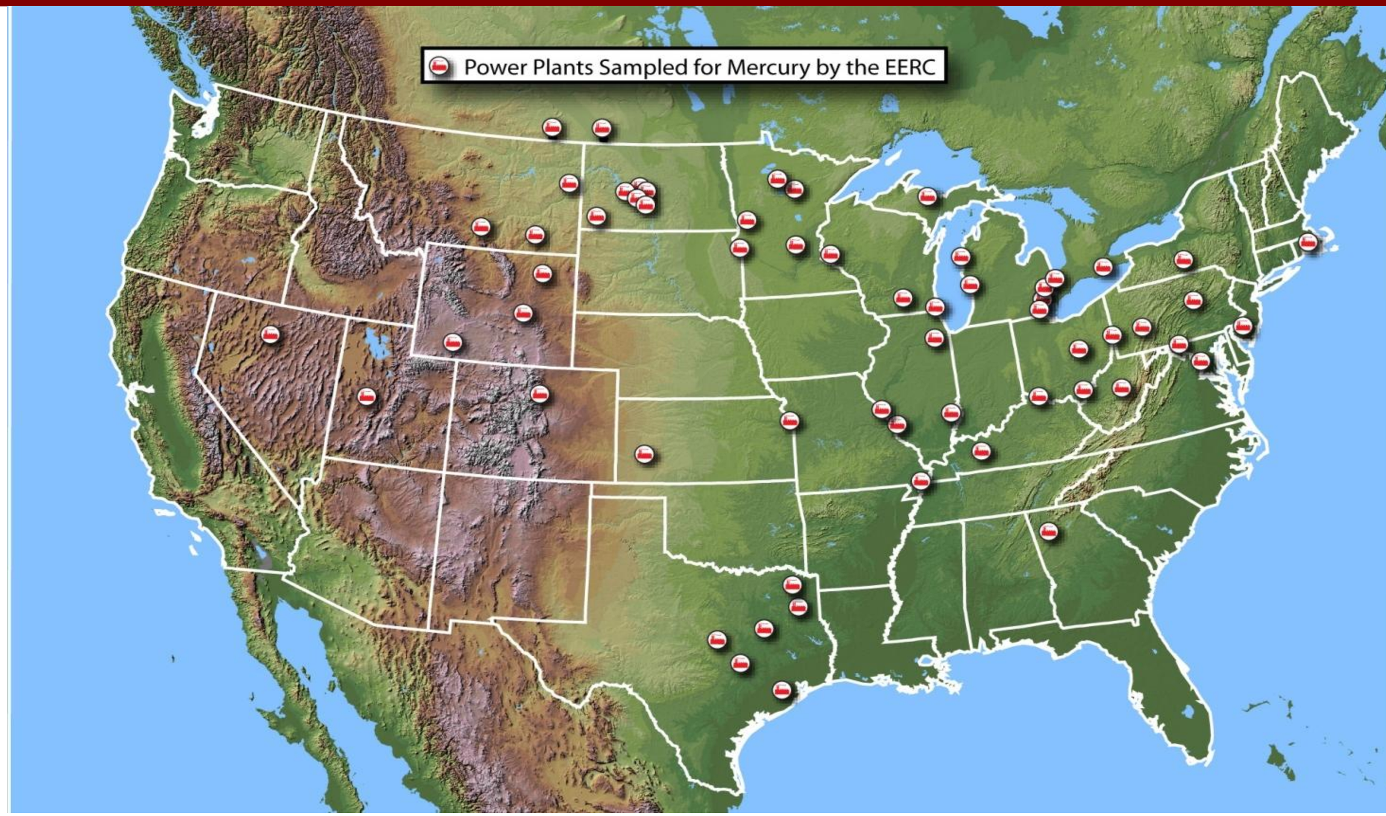
The World's Leader in Mercury Measurement and Control



In response to regulatory mandates and industry needs, the EERC has conducted over 80 mercury field tests at more than 60 power plants in North America over the past decade.

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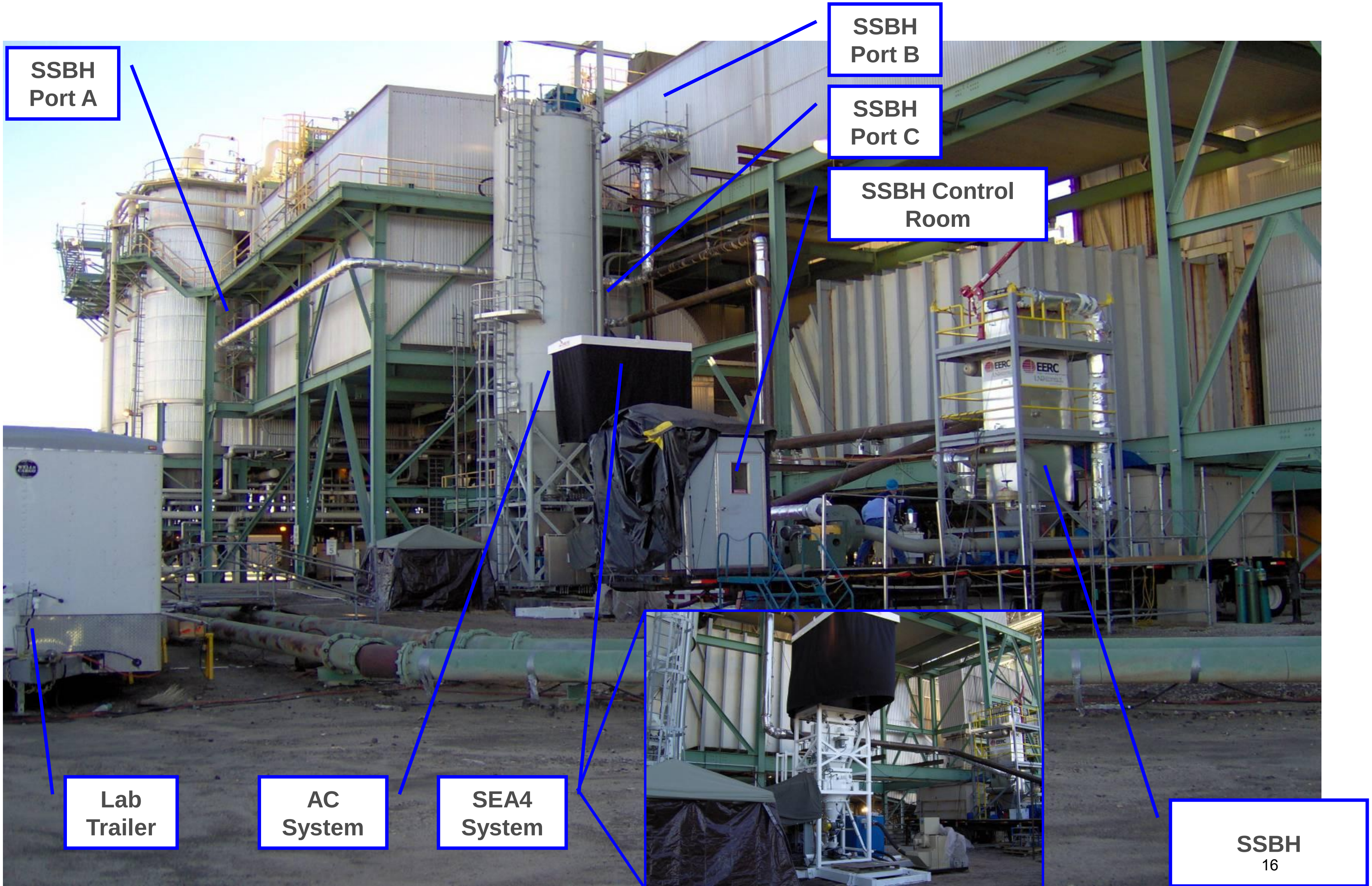
Mobile Test Equipment – Big Brown in Texas

Features: Slipstream Baghouse (SSBH), Laboratory Trailer, Activated Carbon (AC) System, and Small-Scale Sorbent Injection System



EERC Technology Spin-Off
RLP Energy – Mercury Control

RLP Energy is a privately held firm, incorporated in 2008, commercializing EERC-developed technology.

- RLP in the United States owns the mercury control business and acquired an exclusive technology license from the EERC Foundation.

Main office in the United States on-site at the EERC.

RLP Energy is currently transitioning from the commercial demonstration phase to market launch.

- It provides consulting and technology solutions to electric utilities.
- Full technology implementation is expected in 2010.

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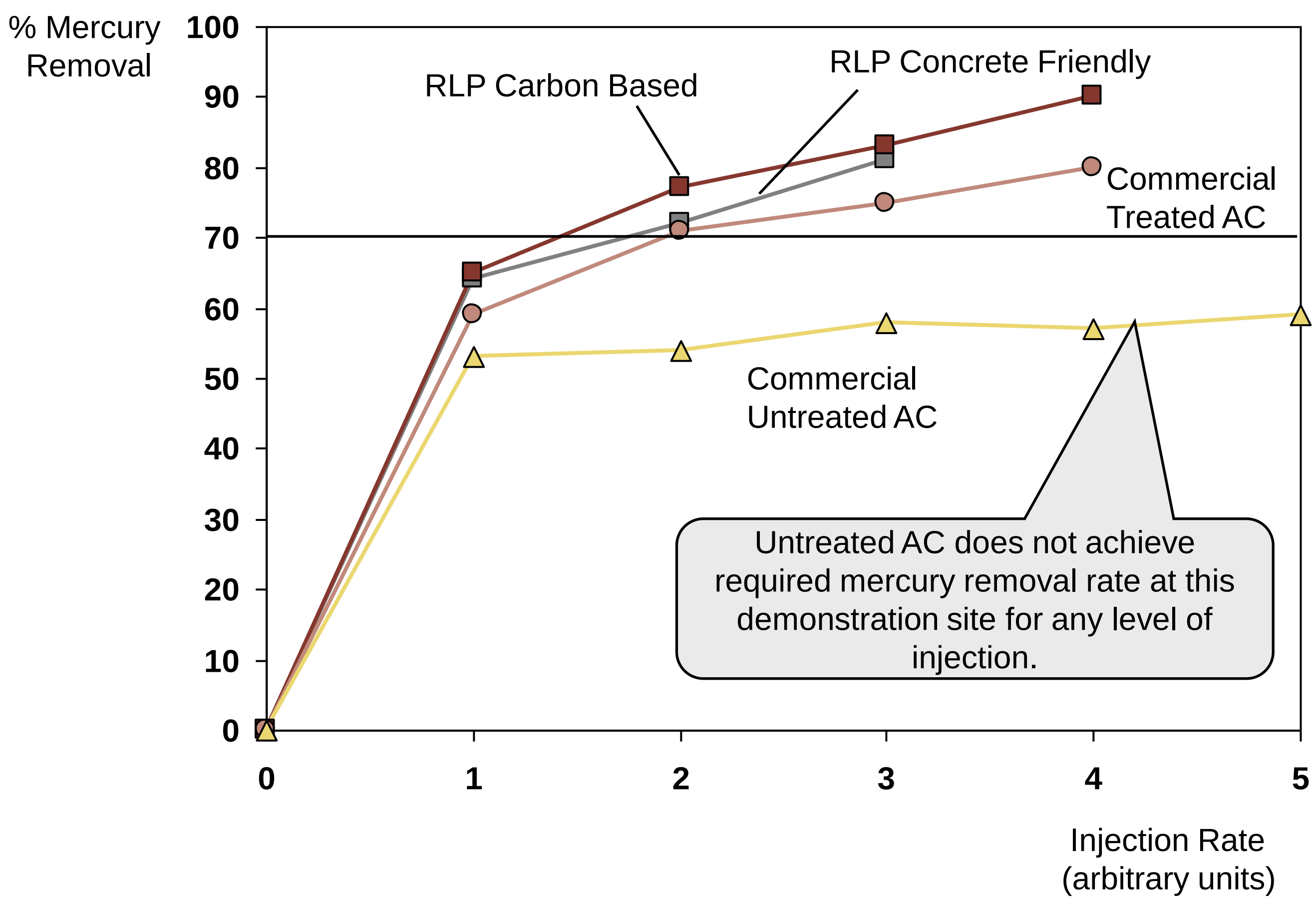
EERC Mercury Control Solutions Outperform Commercially Treated AC



In both the United States and Canada, testing has been under way at electric coal-fired power plants to find viable and economical mercury control strategies to meet pending regulations.

Note: Mercury control solutions vary based on coal, boiler, and pollution control device.
Source: Data obtained from one of the recent large-scale demonstrations with RLP Energy.

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Carbon Capture and Sequestration

Carbon capture – capturing a concentrated stream of CO_2 from a power plant

- Oxygen firing – getting rid of the nitrogen as a dilutant
- Concentrating – using chemicals to extract the CO_2

Carbon sequestration – placing the CO_2 into a “permanent” containment system

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The Partnership for CO_2 Capture

Industrial-Scale Monoethanolamine (MEA) CO_2 Scrubber

Advancing the state of CO_2 capture by evaluating and developing those technologies that are nearest to commercial viability for utility applications.

- The Partnership for CO_2 Capture includes $3,785,000 of funding from private sector sponsors (15), the North Dakota Industrial Commission, and the U.S. Department of Energy National Energy Technology Laboratory.
- Construction of oxyfiring and industrial-scale postcombustion platforms.
- Identification of technology challenges and opportunities for improvement.
- Development of strategies for cost-effective and efficient implementation at the power utility scale.

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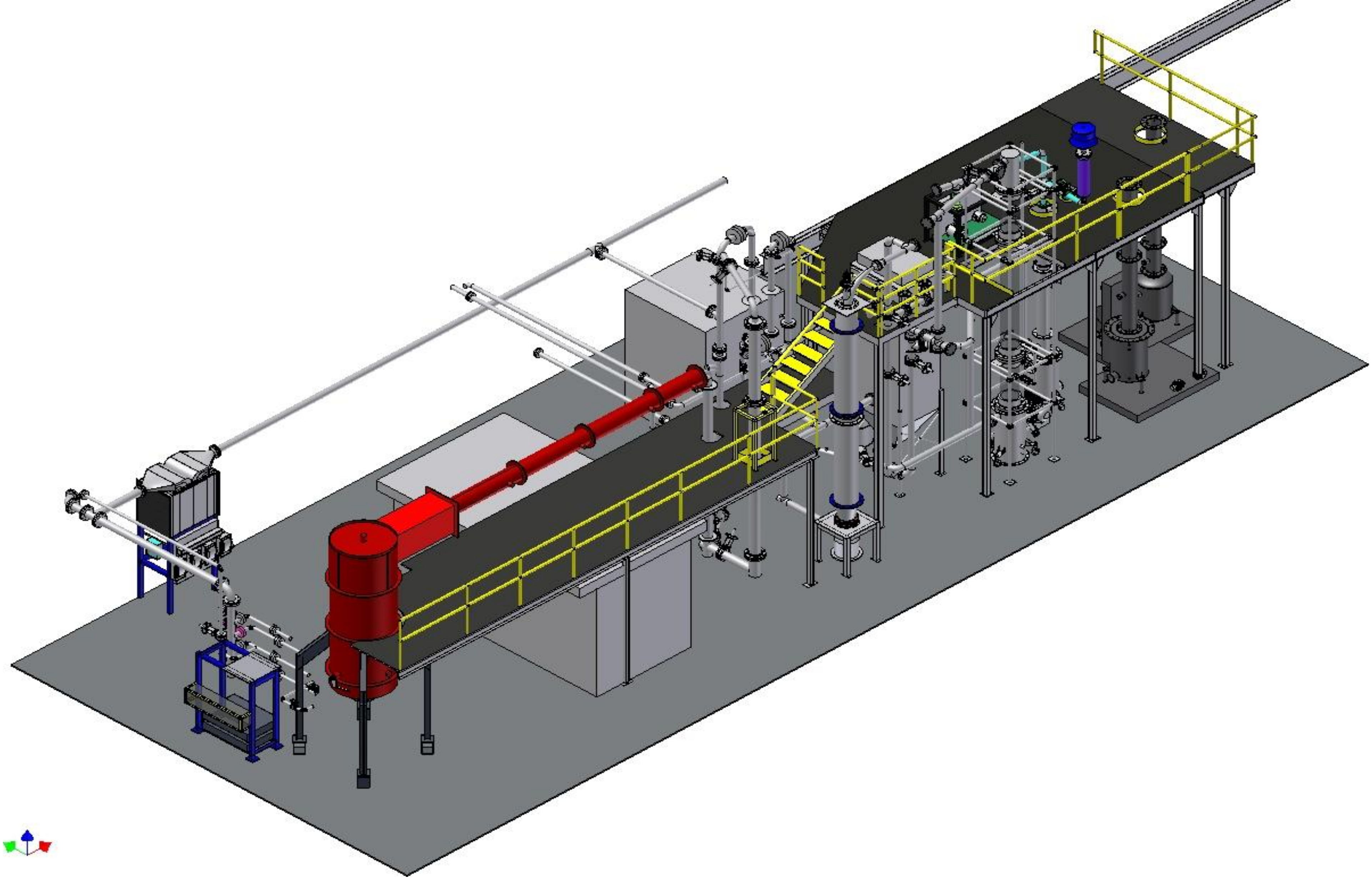
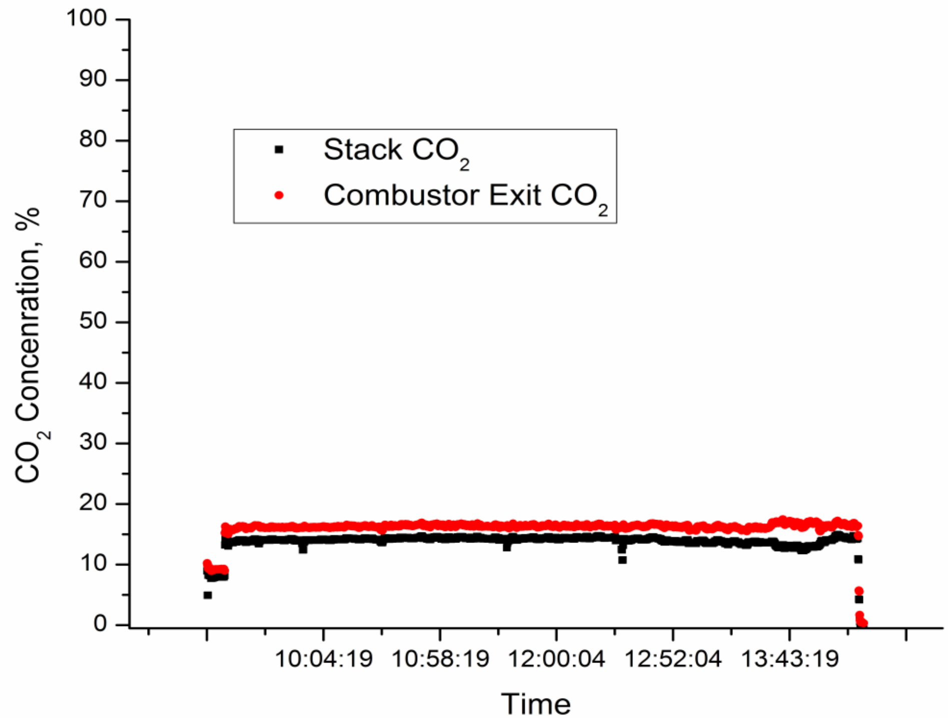
Sponsors – CO_2 Capture

Black & Veatch
C-Quest
Midwest Generation
Hitachi
Huntsman
Minnesota Power
PPL
SaskPower
TransAlta
ATCO Power
Metso Power
Constellation Energy
Basin Electric Power Cooperative
North Dakota Industrial Commission
U.S. Department of Energy
Baker Petrolite
Nebraska Public Power District

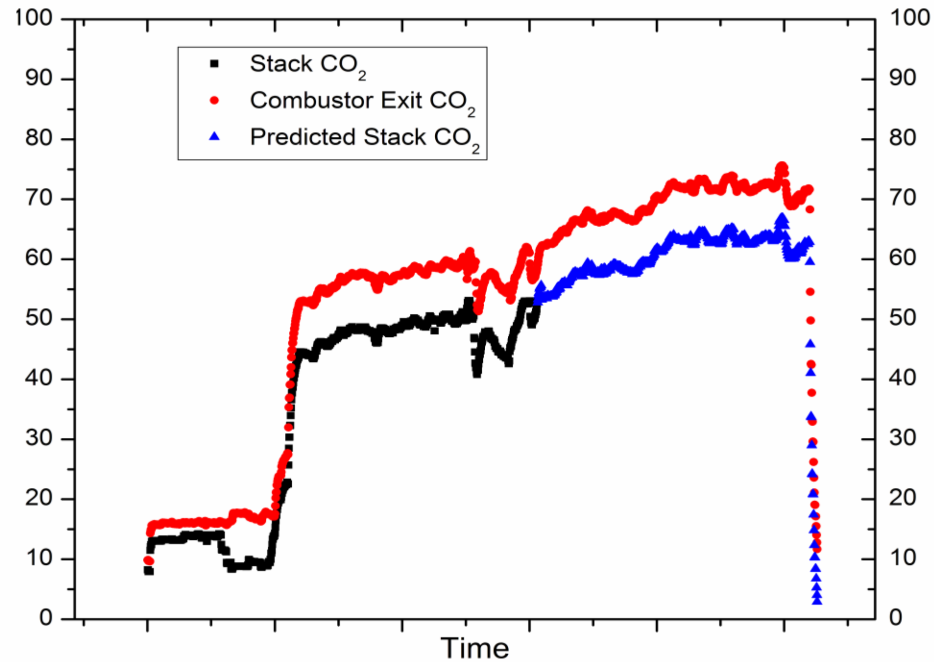
Industrial Commission of North Dakota
Lignite Research, Development and Marketing Program



Oxygen-Fired CO_2 Results



Air-Fired



Oxygen-Fired

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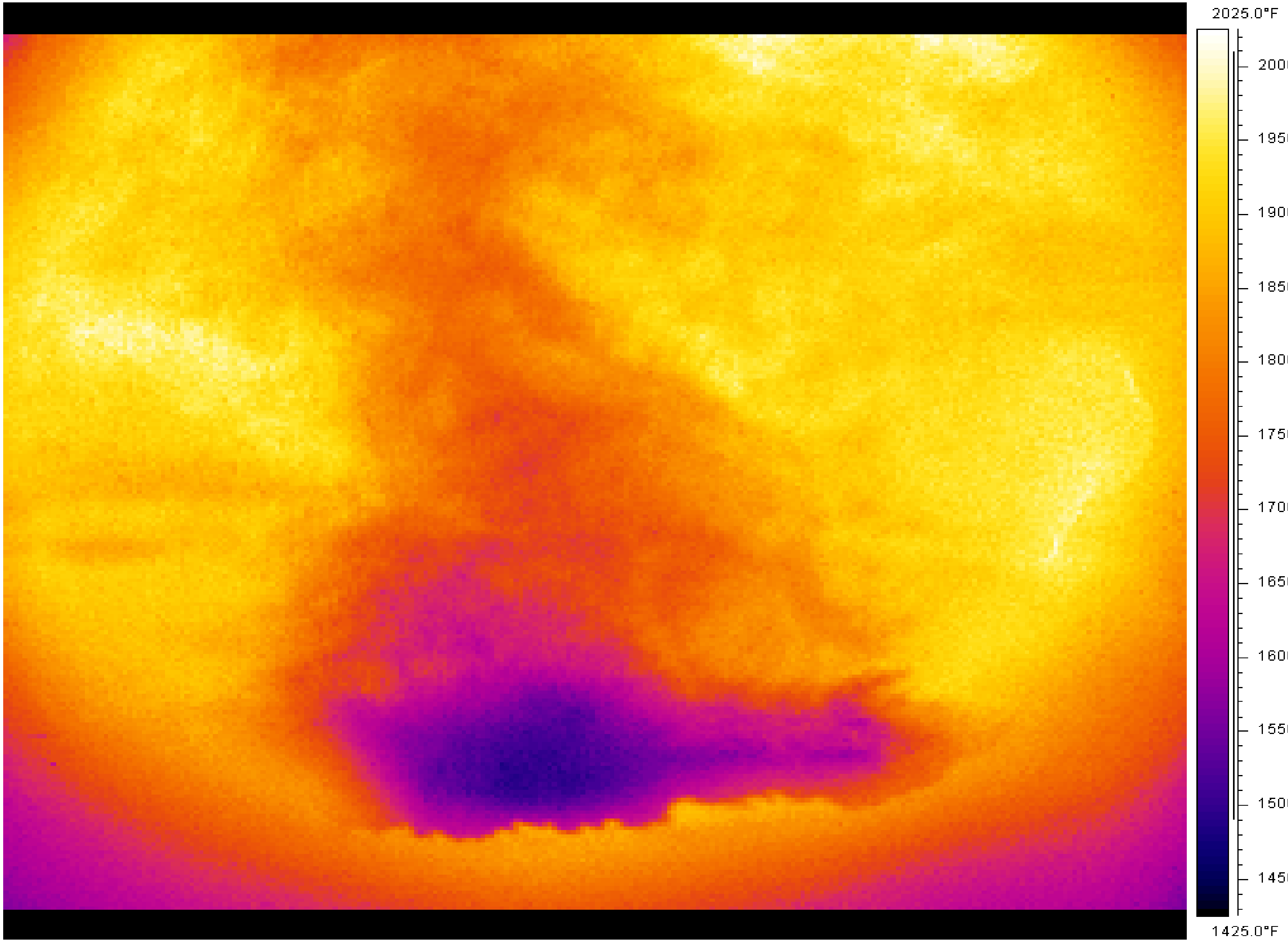
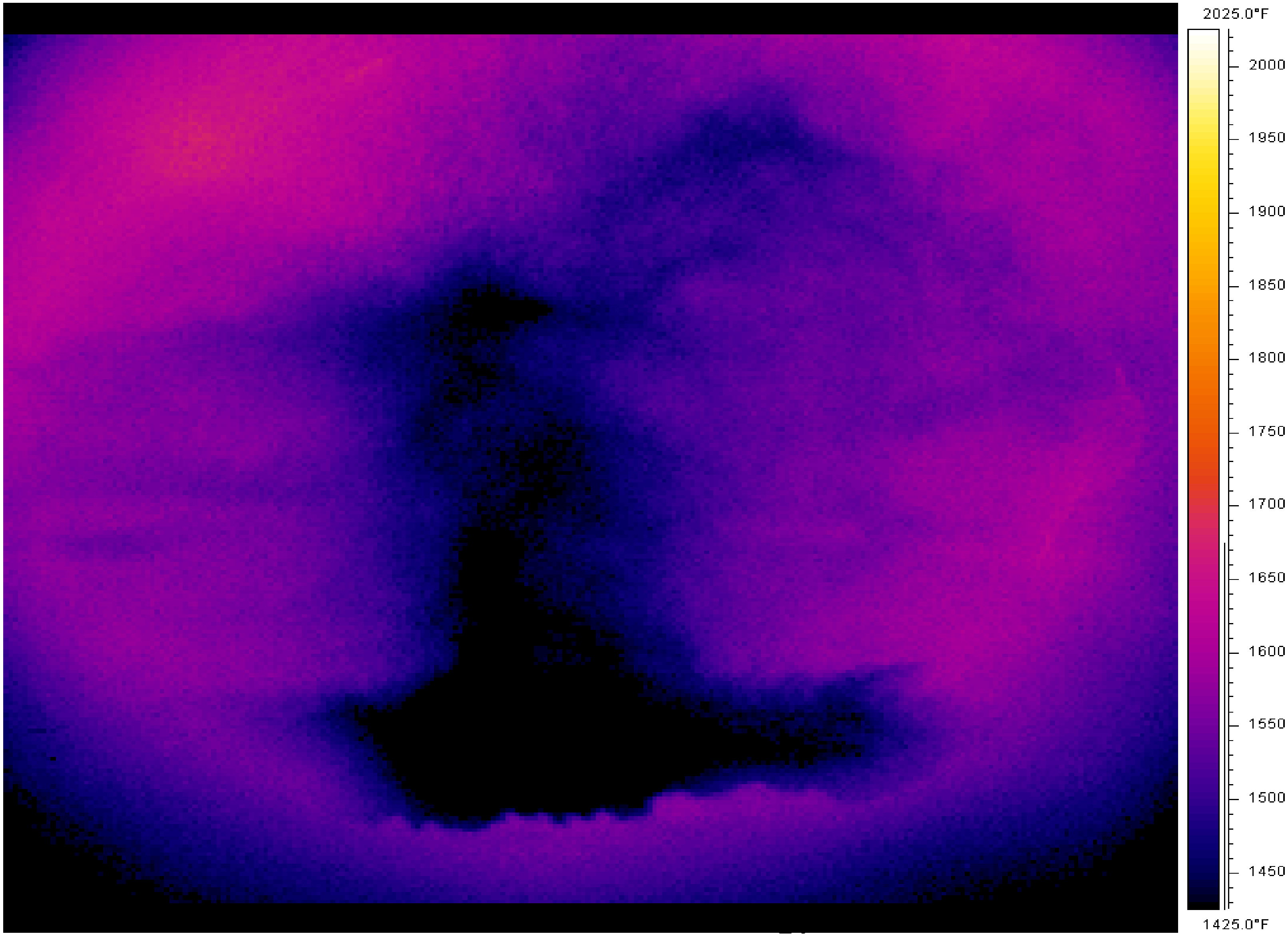
Flame Temperature – Air- to Oxygen-Fired Transition



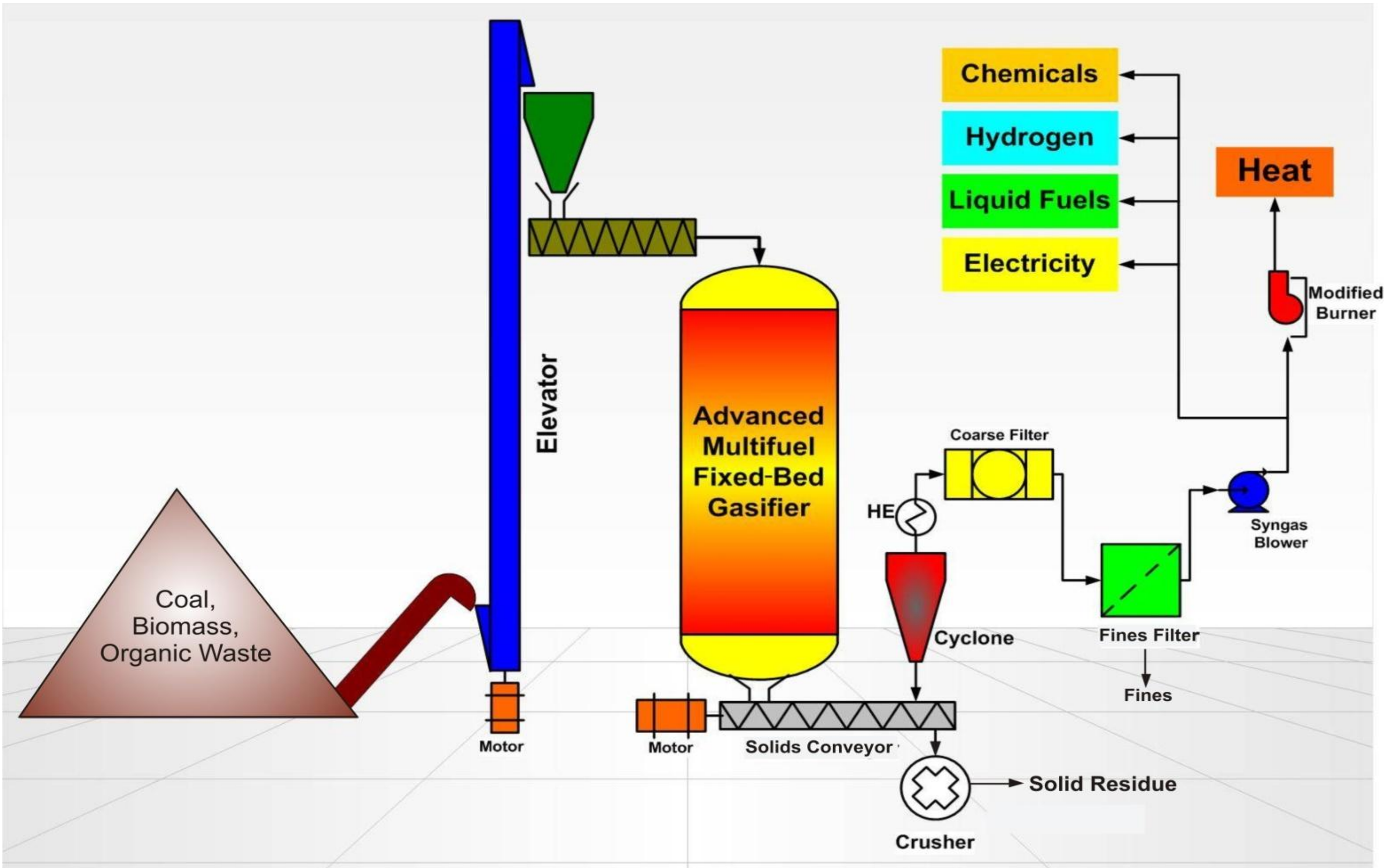
Air-fired combustion at the beginning of the switch to oxygen-fired combustion with flue gas recycle.

Flame Temperature – Air- to Oxygen-Fired Transition



Oxygen-fired combustion mode with flue gas recycle.

Coal Gasification



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EERC Gasification History and Experience

Research and Development

Support for Major Gasification Vendors, EFG, Fixed Bed, FBG, Transport

CABRE II – Computer Model for Entrained-Flow Gasifiers

CABRE III – Systems Engineering Modeling – Design of Future Systems

CABRE I – Ash Behavior Entrained-Flow Gasifiers

Coal Water Slurries

Lignite Gasification – Ash Behavior

Gasification Kinetics – Lignite High Reactivity

Refractory and Slag Flow

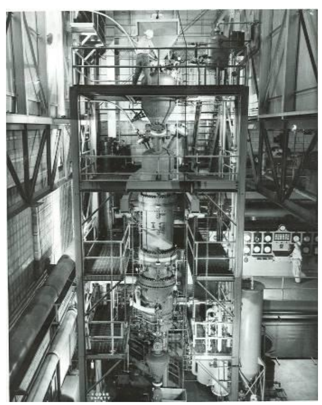
Lignite Properties – Moisture Friability

Trace Elements in Gasification

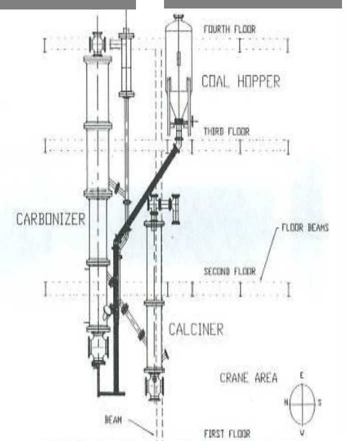
1945 | 1955 | 1965 | 1975 | 1985 | 1995 | 2005 | 2010

Technology Demonstrations

Annular Externally Heated Retort

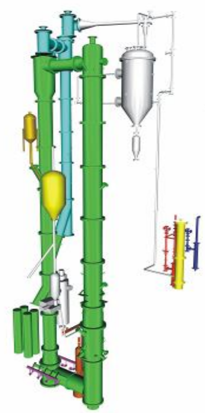


Slagging Fixed-Bed Gasifier



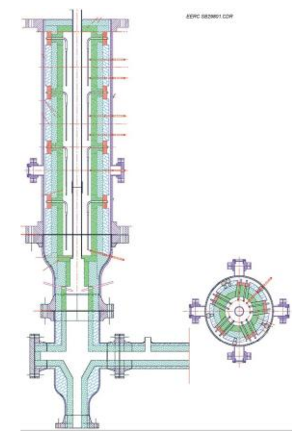
Catalytic Gasification/SOFC

Mild Gasification



Transport Reactor Development Unit

Microgasifier



Entrained-Flow Slagging Gasifier

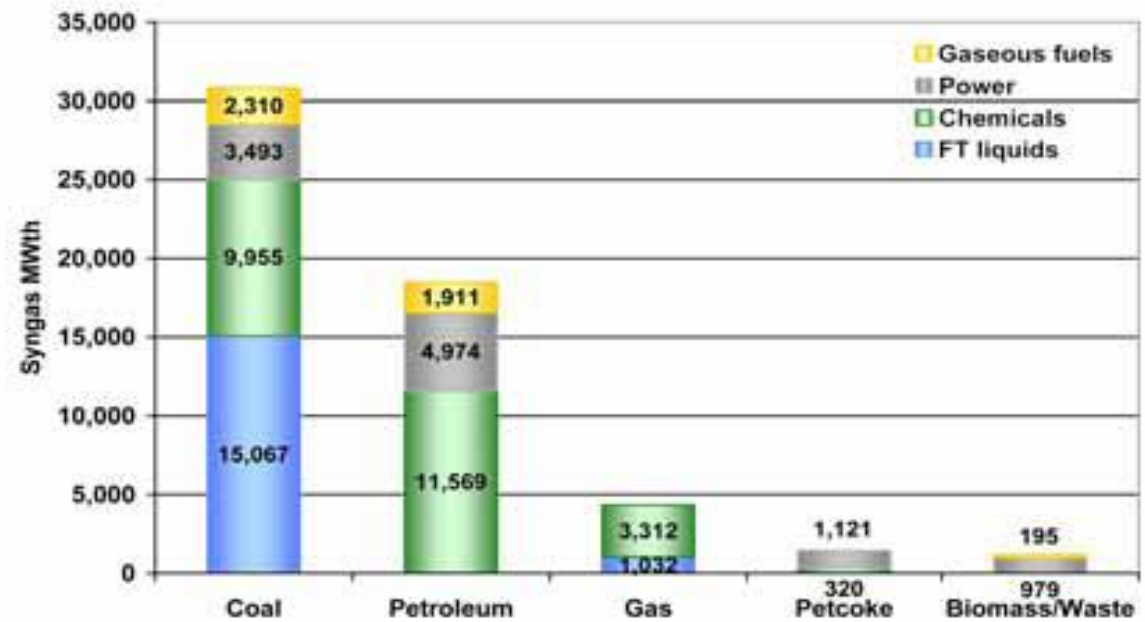
2007 Operating World Gasification Capacity – By Feedstock and Product

Coal is used to produce Fischer–Tropsch (FT) liquids (49%), chemicals (32%), power generation (11%), and gaseous fuels (8%).

Petroleum is used to produce chemicals (63%), power (27%), and gaseous fuels (10%).

Natural gas is used to produce chemicals (76%) and FT liquids (24%).

Petcoke, biomass, and waste are primarily used for power generation.



Note: Coal Combustion – Over 1,000,000 MWth in U.S. alone

U.S. Department of Energy National Energy Laboratory *Gasification World Database 2007*

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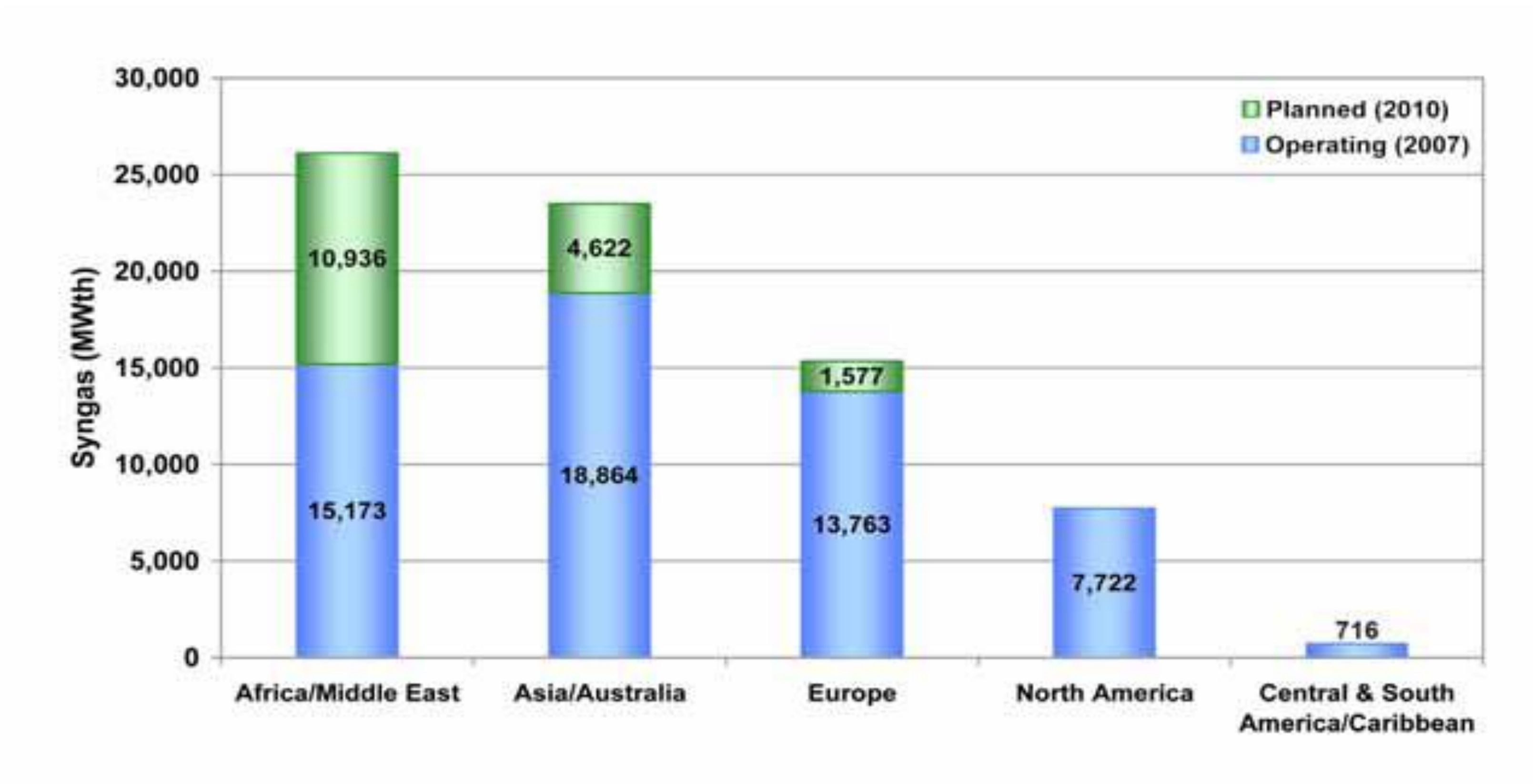
World Gasification Capacity and Planned Growth – By Region



U.S. Department of Energy National Energy Laboratory *Gasification World Database 2007*

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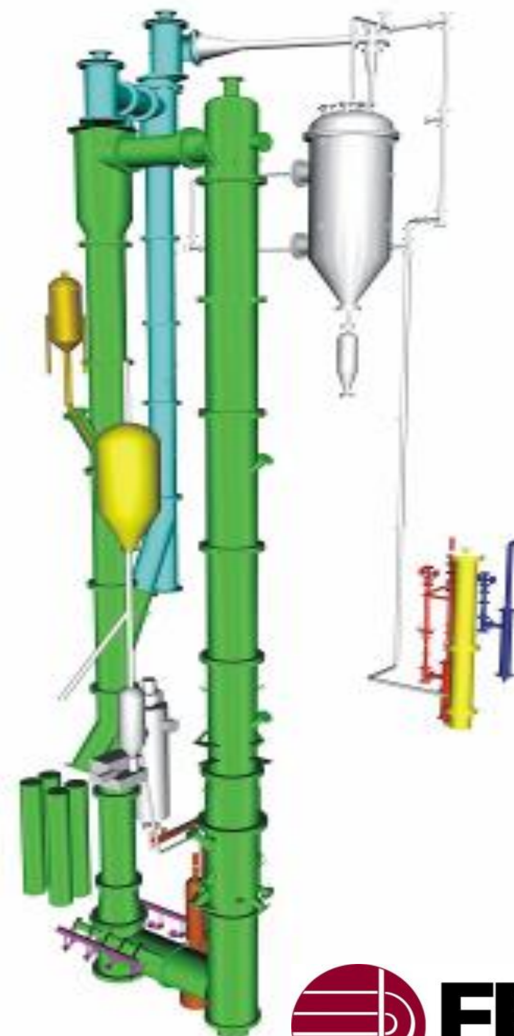
Transport Reactor Gasifier

- Lower-capital-cost system
- High throughput/unit cross sectional area
- Well suited to reactive low-rank coal
- Able to feed higher-moisture coals
- Can operate with either air or oxygen



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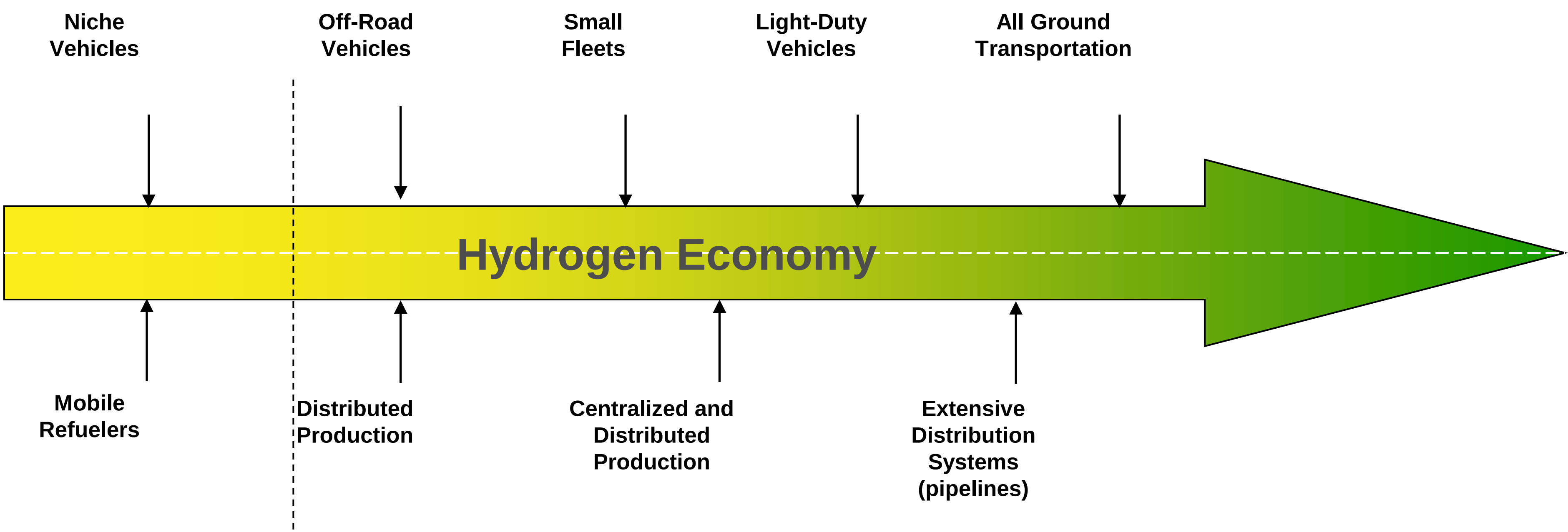
Hydrogen Economy Highway

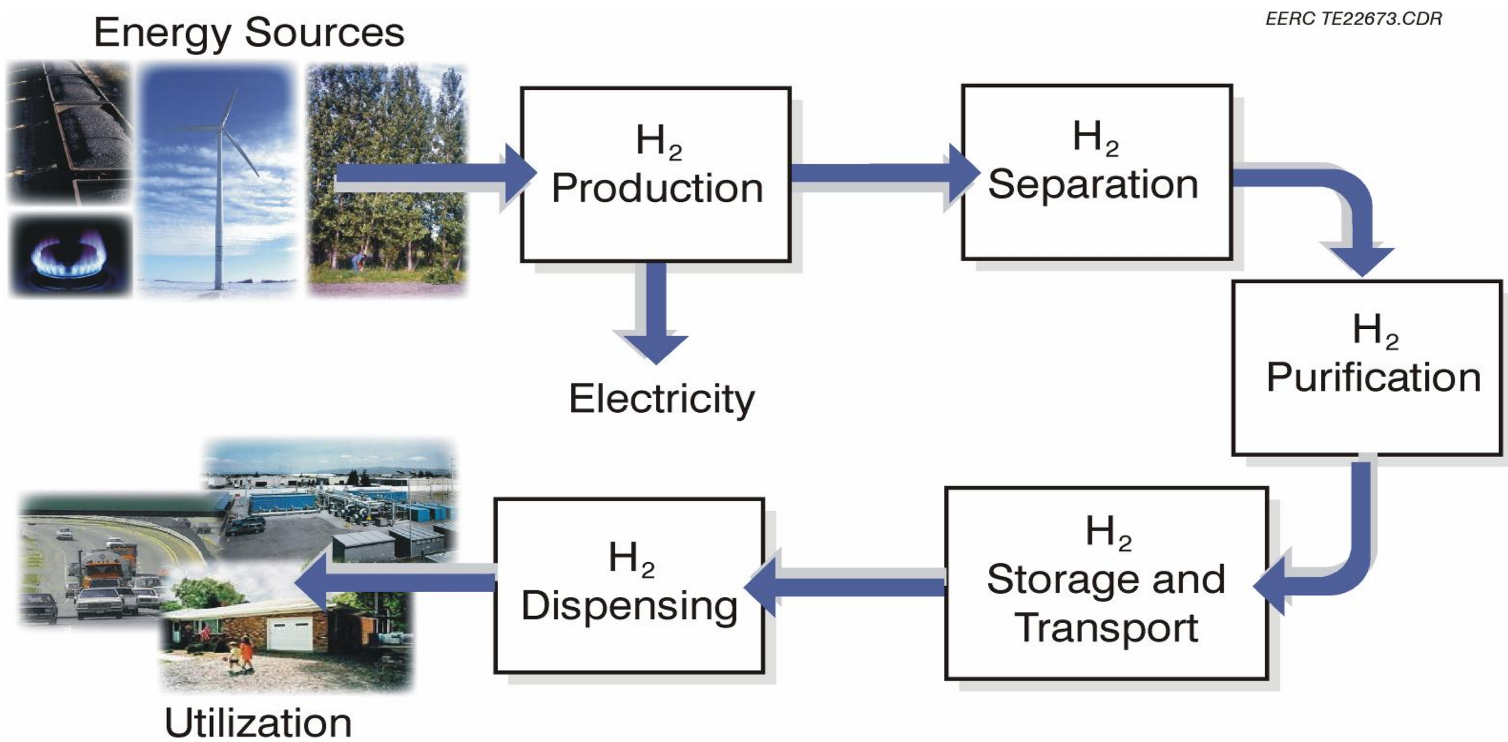
Utilization



Today

Hydrogen Is Ready for Deployment

National Center for Hydrogen Technology (NCHT)



Hydrogen Vehicles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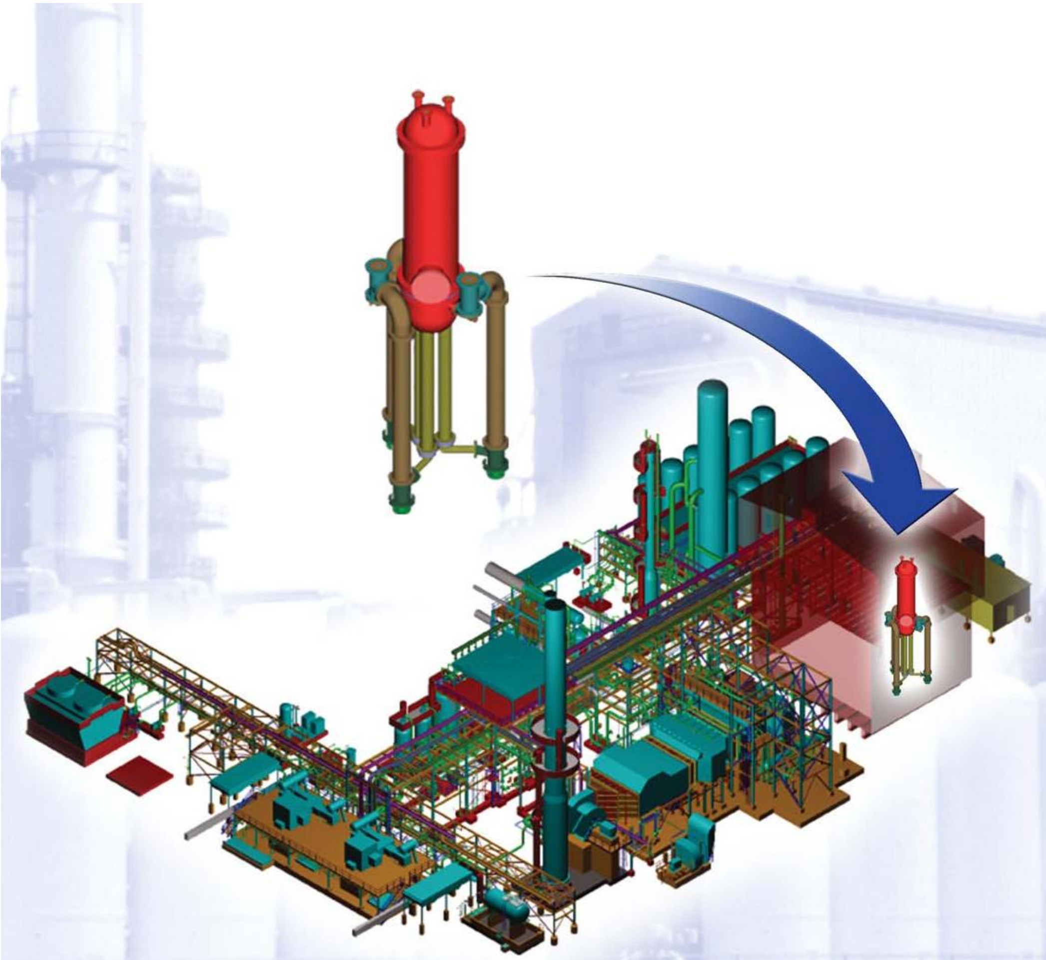
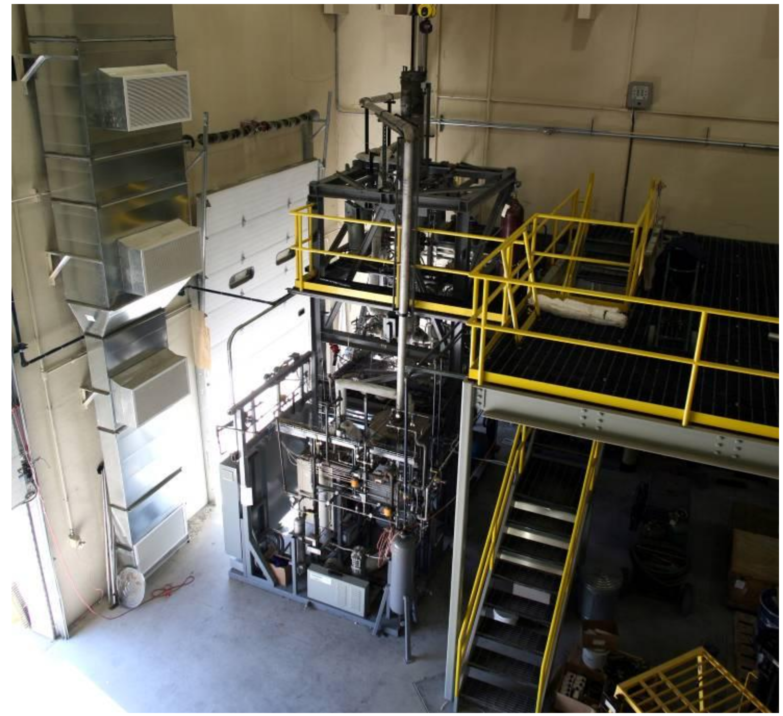
Compact Reformer for Industrial Hydrogen – PWR



* Courtesy of Pratt & Whitney Rocketdyne



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Liquid Fuels from Coal

The U.S. military has set out to rid itself of dependence on foreign oil. The Army has announced its intent to build up to seven coal-to-liquid facilities.

Coal to liquids is competitive with oil at $40–$50/barrel. However, it could take 8–10 years to build a facility.

Liquefaction of Coal and Biomass

Feedstock

Biomass

Coal

Liquefaction Process

Indirect Liquefaction

Gasification → Syngas Production → Fischer–Tropsch Synthesis

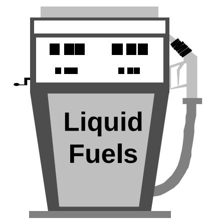
Direct Liquefaction

Direct hydrothermal processes that break down the carbon matrix

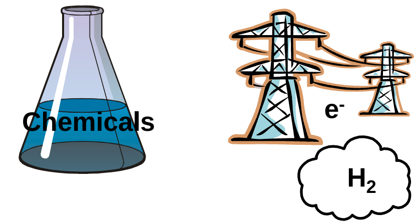
Mild Gasification or Pyrolysis

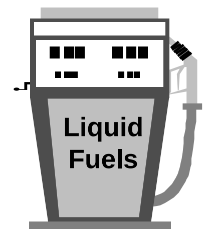
Chemical decomposition of organic materials by heating in the absence of oxygen

Production



Produces high-quality fuels and other valuable by-products





Efficient conversion process with primary products are fuels.

Liquids produced represent complex mixtures that are difficult to separate and upgrade.

Tremendous opportunity to increase North Dakota energy exports without adding transmission capacity. Includes advanced tactical fuels for the military, fuels for energy markets, and specialty chemicals.

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Smart Grid

Also know as:
Intelligent Utility Industry
Intelligrid
Modern Grid Strategy
Grid 2030

Primary Smart Grid Advantage

Higher energy efficiency and energy conservation.

Decreased spinning generation (electricity generation with no consumer for grid security).

Greater allowance for cyclical (intermittent) green power (wind and solar).

Reduced consumer costs based on personal choices.

The current grid is already “smart.” The key is:

- Making it “smarter” – in particular with respect to intermittent power.
- Giving the consumer the opportunity to take advantage by reducing cost and environmental footprint.

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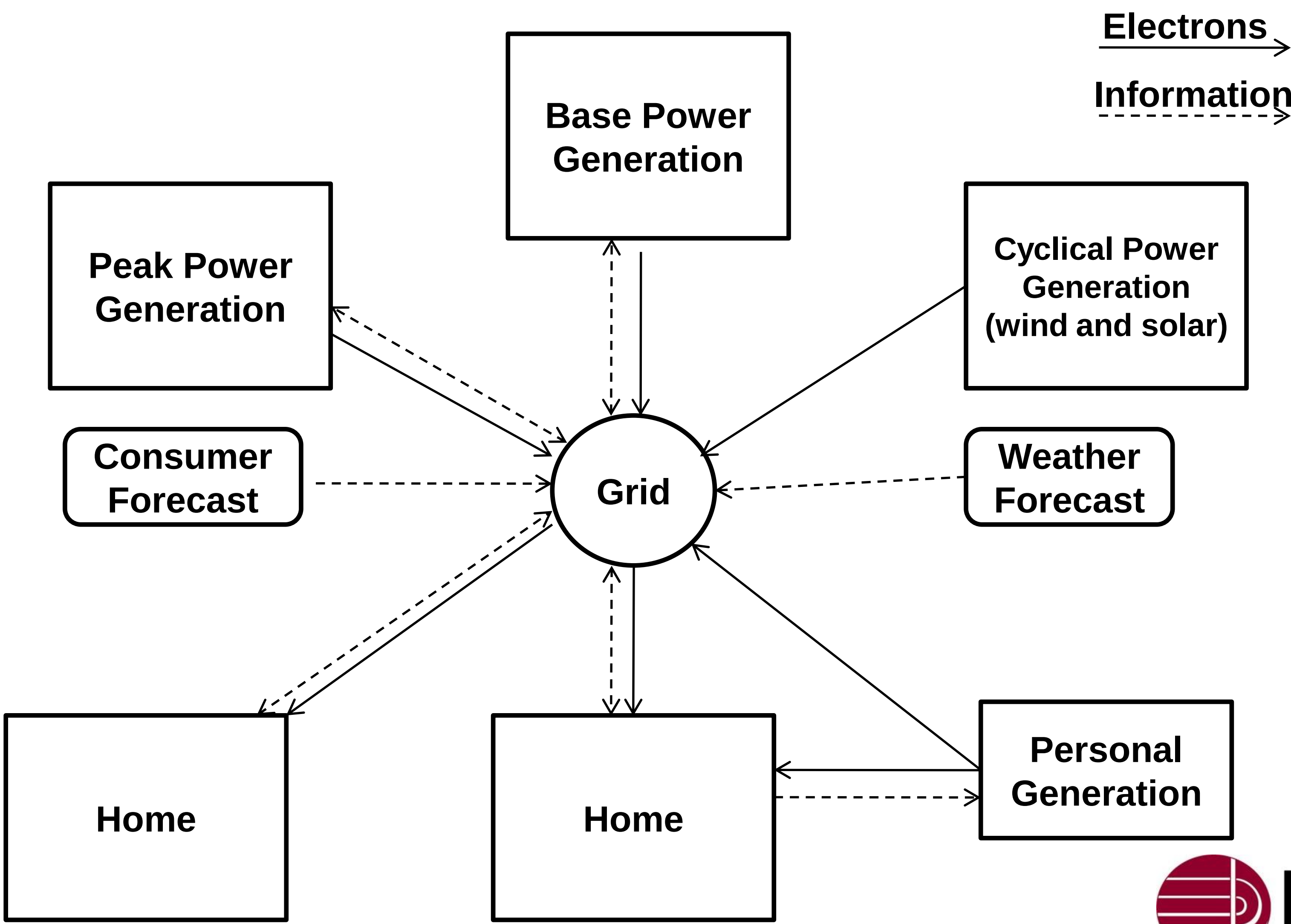
Smart Grid


Electrons
Information
Base Power Generation
Peak Power Generation
Cyclical Power Generation (wind and solar)
Consumer Forecast
Grid
Weather Forecast
Home
Home
Personal Generation

Smart Grid Characteristics

(adapted from NETL, December 2008 Presentation)

- Enables and motivates consumer participation
- Accommodates all energy generation and energy storage options
- Enables new products, services, and markets
- Optimizes asset utilization and operates efficiently (lower losses and less spinning generation)
- Provides quality power
- Operates resiliently against attack and natural disaster
- Anticipates and responds to system

What Is SmartGridCity™?

A technology pilot project in Boulder, Colorado, to:

- Improve distribution system operational efficiency and reliability.
- Facilitate expansion of energy efficiency and demand response by customers.
- Prepare for integration of higher levels of on-site renewable generation.

Transformer Overload: Detection

YEAR	UNPREDICTED FAILURES	CURRENT LOOK DETECTIONS	TOTAL
2005	7	0	7
2006	13	0	13
2007	6	0	6
2008	6	3	9
2009	0	4	4

Xcel Energy℠

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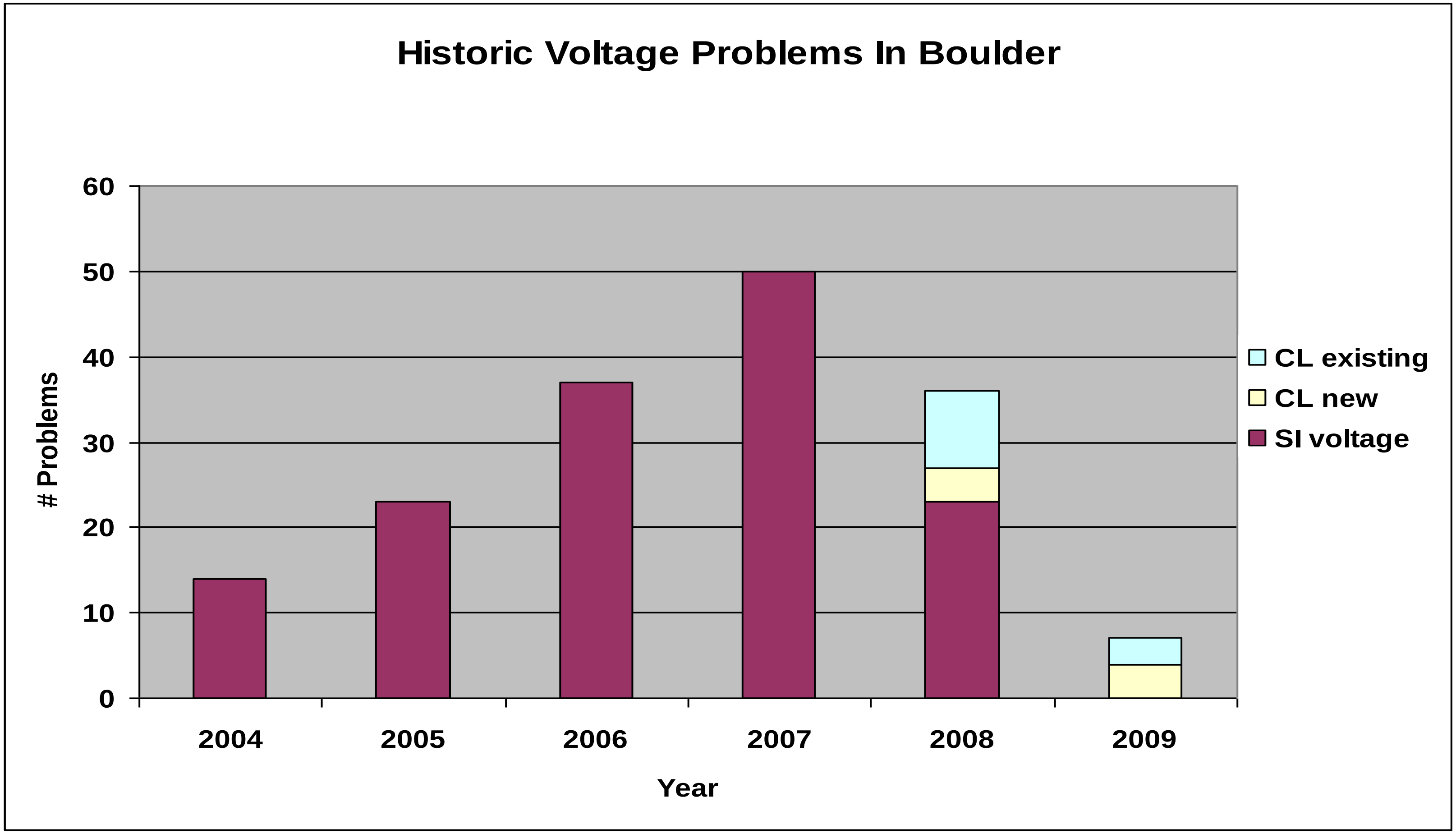
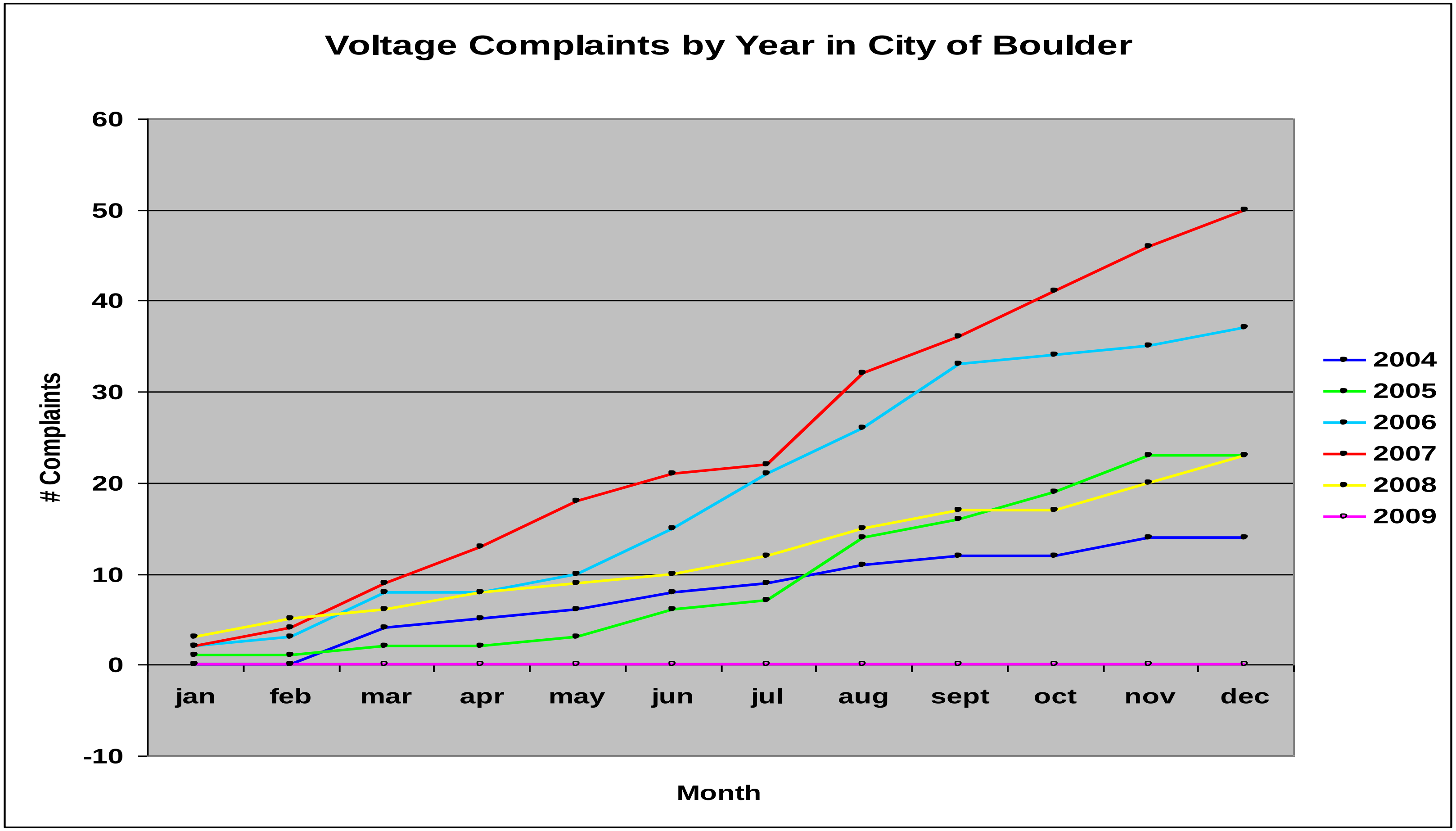
Voltage: Problem Resolution



Reduced Customer Complaints



Contact Information

Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, North Dakota 58202-9018

World Wide Web: www.undeerc.org
Telephone No. (701) 777-5153
Fax No. (701) 777-5181

Thomas A. Erickson, Associate Director for Research
terickson@undeerc.org

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