the Energy to Lead

Natural Gas Creating Value in a Carbon Constrained America

> Daniel S. LeFevers
Executive Director, Washington Operations
GTI

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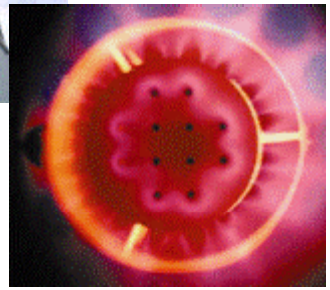
Gas Technology Institute

Addressing Key Issues for the Energy Industry

> Contract Research
> Program Management
> Technical Services
> Education and Training



> Over 1,000 patents
> Nearly 500 products commercialized

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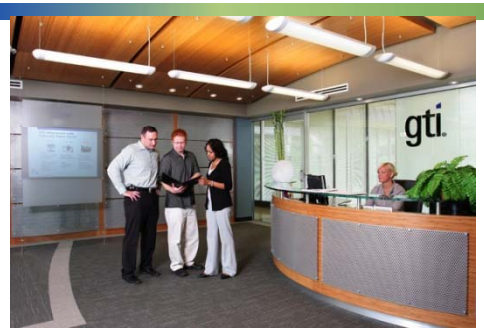
GTI Overview

- Not-for-profit research, with 65+ year history
- Facilities
  - 18 acre campus near Chicago
  - 200,000 ft^2, 28 specialized labs
  - Other sites in Oklahoma and Alabama
- Staff of 250
- Carbon Management Information Center

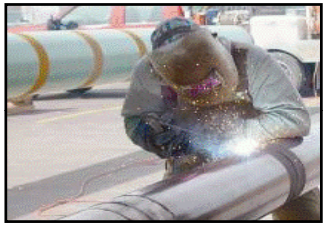


Flex-Fuel Test Facility

Offices & Labs

Energy & Environmental Technology Center

Alignment with the Energy Industry Value Chain

	SUPPLY	DELIVERY	END USE
			
Needs	Secure, stable, competitive domestic energy supply	Address strategic concerns of domestic gas T&D infrastructure	Maintain industrial competitiveness and improve affordability of end use technologies
Strategic Focus	• Unconventional Gas Resources • Gasification for Alternative Supply	• Safety • Pipeline Integrity • Cost Reduction • Efficiency	• Efficiency and environmental • Product development and commercialization

Carbon Management

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GTI R&D Units

Supply—Gasification

Vann Bush, Managing Director

- Gasification process and feedstock evaluation
- Syngas generation and processing for production of power, fuels, and chemicals
- Syngas cleanup and separation technologies
- Subquality gas upgrading

Supply—Unconventional Gas

Guy Lewis, Managing Director

- Unconventional gas resources
- Field drilling and completion
- Downhole laser energy applications
- Carbon sequestration
- Methane hydrate resources

Delivery

Eddie Johnston, Managing Director

- Third party damage prevention and leak detection
- Construction innovations
- Operations innovations
- Pipeline integrity/distribution integrity management
- Materials testing and evaluation
- Pipeline and storage solutions
- Environmental and chemical research services

End Use Solutions

William Liss, Managing Director

- Combustion
- Industrial process heating
- Power generation and combined heat and power
- Residential/commercial appliances
- Hydrogen and alternative fuel storage, fueling stations, and vehicle integration
- High-temperature and low-temperature fuel cell components and systems
- Energy conversion, fuel processors and catalysts
- LNG interchangeability
- Carbon management/energy analysis

False Energy Perceptions

(Energy end-use and power generation

- Perception regarding homes and businesses
  - > Gas has emissions - compared to electricity – which has no emissions
  - > Natural gas has no renewable option
  - > We may run out of gas within the next 20 - 40 years
- Perception for natural gas power generation
  - > A bridge fuel
  - > No means to reduce carbon emissions further
  - > Eventually nuclear and clean coal w/ccs along with renewables will be the total solution

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Lesser Known Energy Information

- CO_2 emissions per residential natural gas customer have fallen by 40% since 1970, and total CO_2 emissions have been flat in spite of an increase from 38 million customers in 1970 to 65 million customers in 2007.
- Since 1990 CO_2 emissions from residential electric use has increased by about 75% and almost every new residential device/appliance invented today and into the future will be powered by electricity.
- On average natural gas is delivered to a customer at around 91% efficiency whereas electricity is delivered to the customer at an average of about 27% efficiency
- Producing and using renewable bio-gas in natural gas applications is the most efficient use of renewable bio-mass (landfill gas, livestock manure, woody-bio-mass)
- Our nation has over a 100 year supply of natural gas
- Natural gas electricity generation has 56% less carbon emissions than coal fired electricity generation
- Natural gas power generation with CCS is less expensive to build and operate (including fuel costs) than a coal fired facility with CCS according to a recent USDOE study

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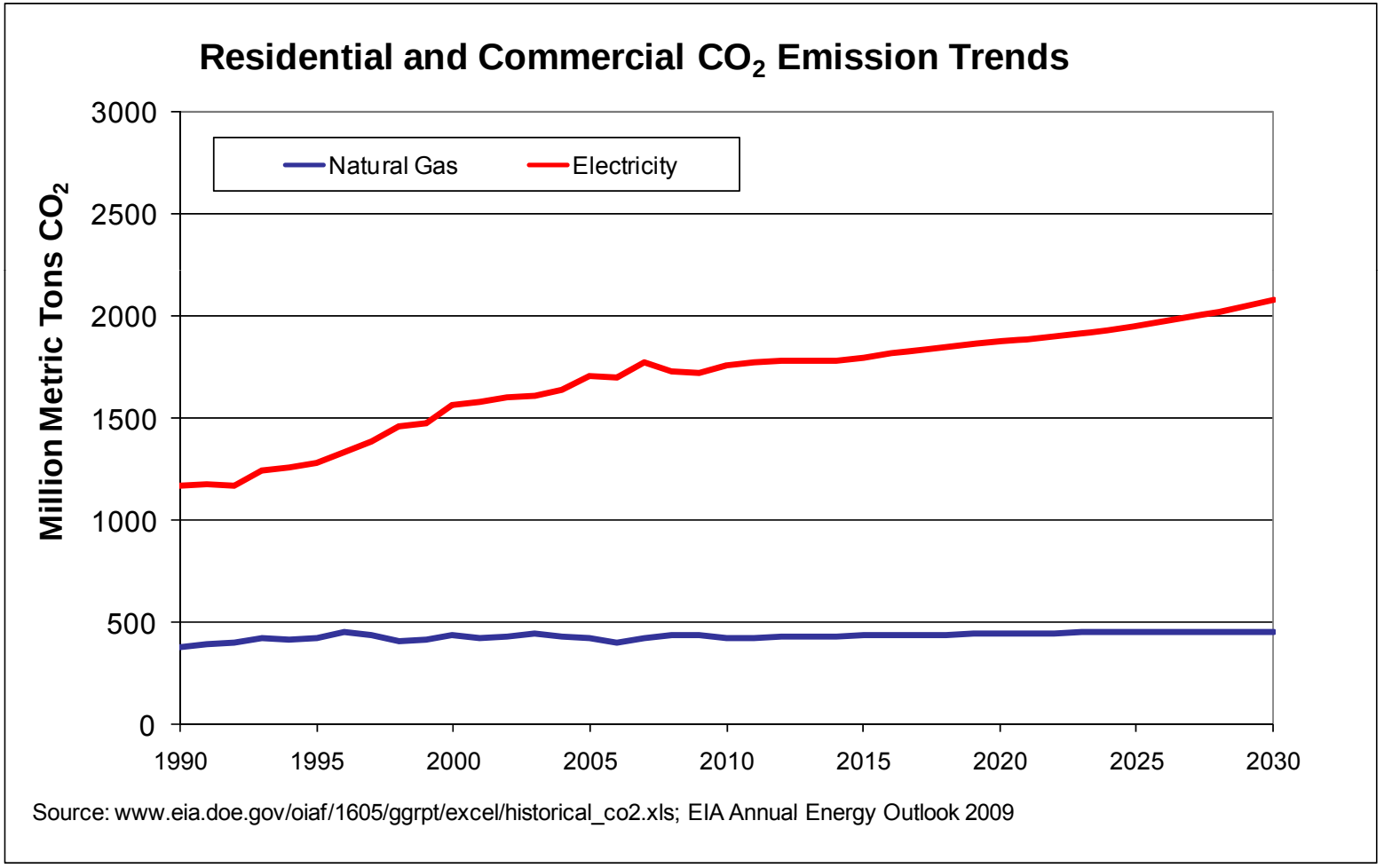
Gas and Electric CO_2 Emission Trends in Residential and Commercial Buildings



Source: www.eia.doe.gov/oiaf/1605/ggrpt/excel/historical_co2.xls; EIA Annual Energy Outlook 2009

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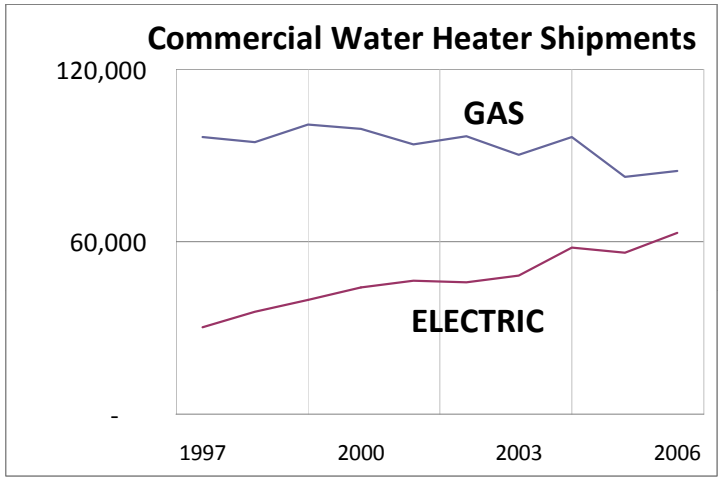
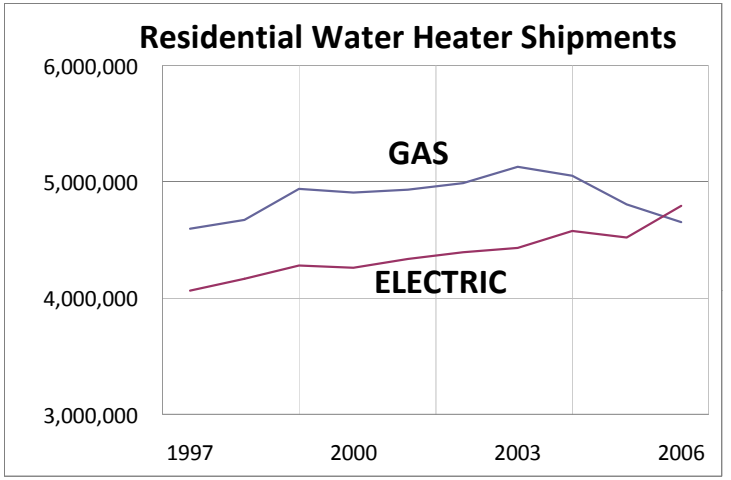
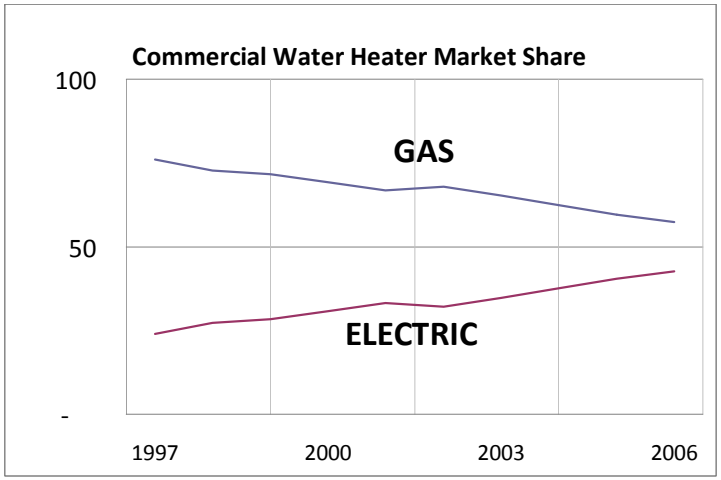
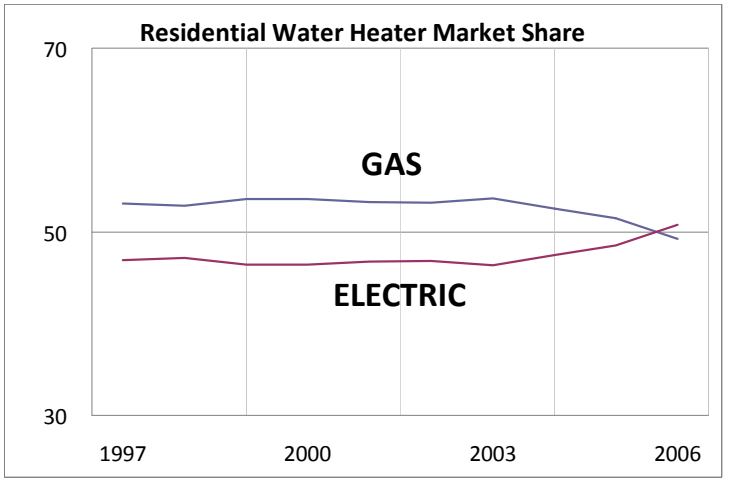
And Yet, Electric Water Heater Market Share is Growing









Source: AHRI

California Title 24 Compliance Methods

- Minimum energy efficiency standards for new buildings
  - Prescriptive and performance paths for energy budget
  - Title 24 prescribes use of natural gas hot water heating instead of electric resistance hot water heating where natural gas is available
  - All new construction includes gas water heaters where gas is available
  - Gas heating is also encouraged over electric resistance heating
  - This understanding of the efficiency and environmental benefits of natural gas in specific applications, in part, is responsible for no growth of electricity use per household in California over the past decade

Source: CEC Title 24 Building Energy Efficiency Standards , 2008

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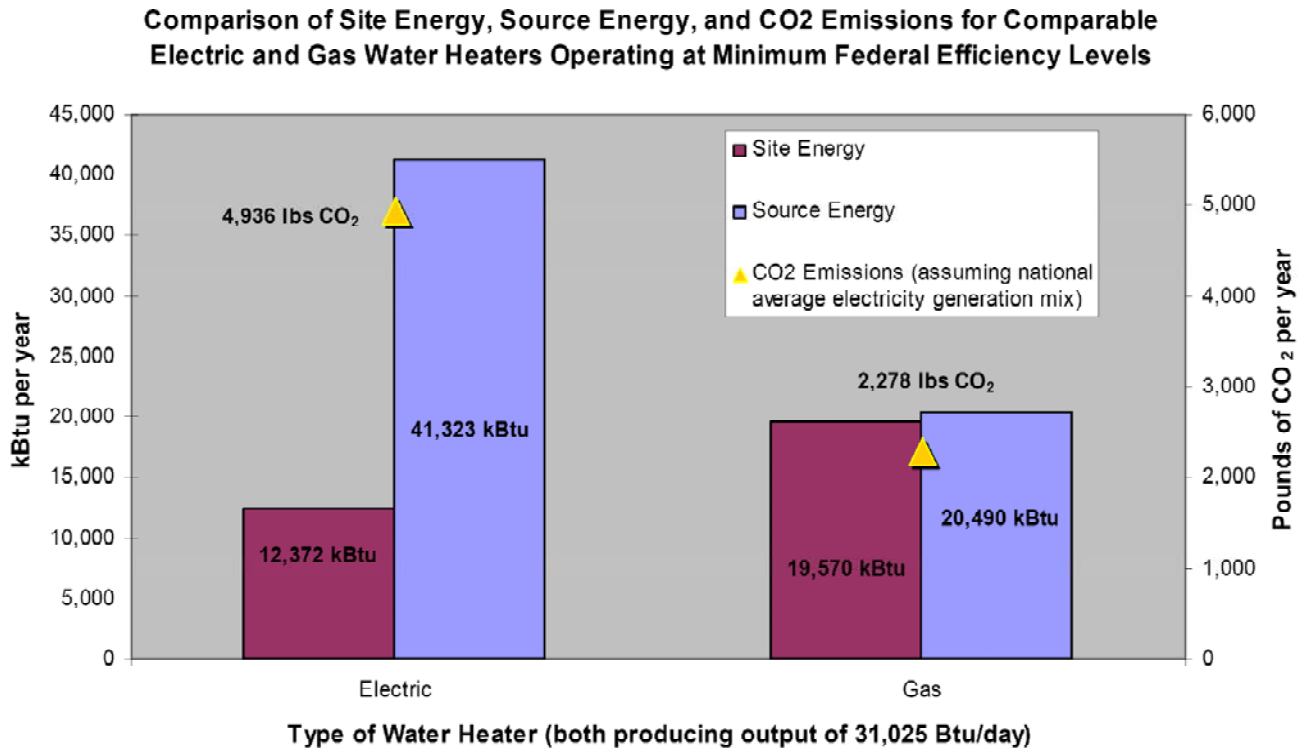
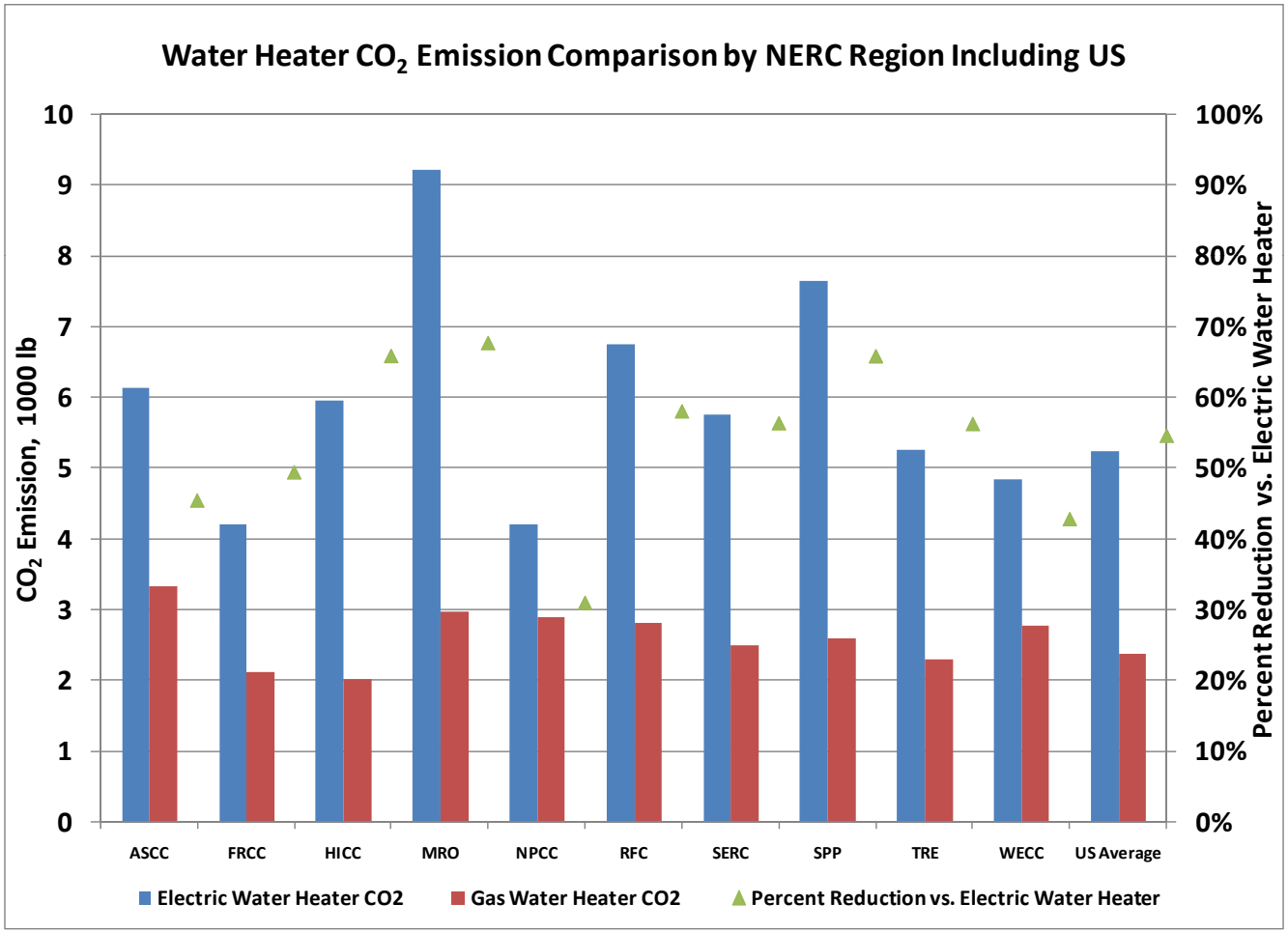
EPA Water Heater CO_2 Analysis

Example: Electric and Gas Water Heaters
Site vs. Source Energy Comparison



Source: EPA Presentation to National Academy of Sciences February 2008

Example Calculations – CO_2 Emissions by NERC Region and US



National Research Council Findings

re: full fuel cycle analysis (source vs. site energy)

- The committee's primary general recommendation is that DOE/EERE consider moving over time to the use of a full-fuel-cycle measure of energy consumption
- Using that metric would provide the public with more comprehensive information about the impacts of energy consumption on the environment and the economy
- The current use by DOE/EERE of site energy consumption is effective for setting standards for the operational efficiency of single-fueled appliances
- DOE/EERE's current use of site energy consumption does not account for the total consumption of energy when more than one fuel is used in an appliance or when more than one fuel can be used for the same application.
- For these appliances, measuring full-fuel-cycle energy consumption would provide a more complete picture of energy used as well as an improved assessment of impacts such as effects on energy security and the environment.

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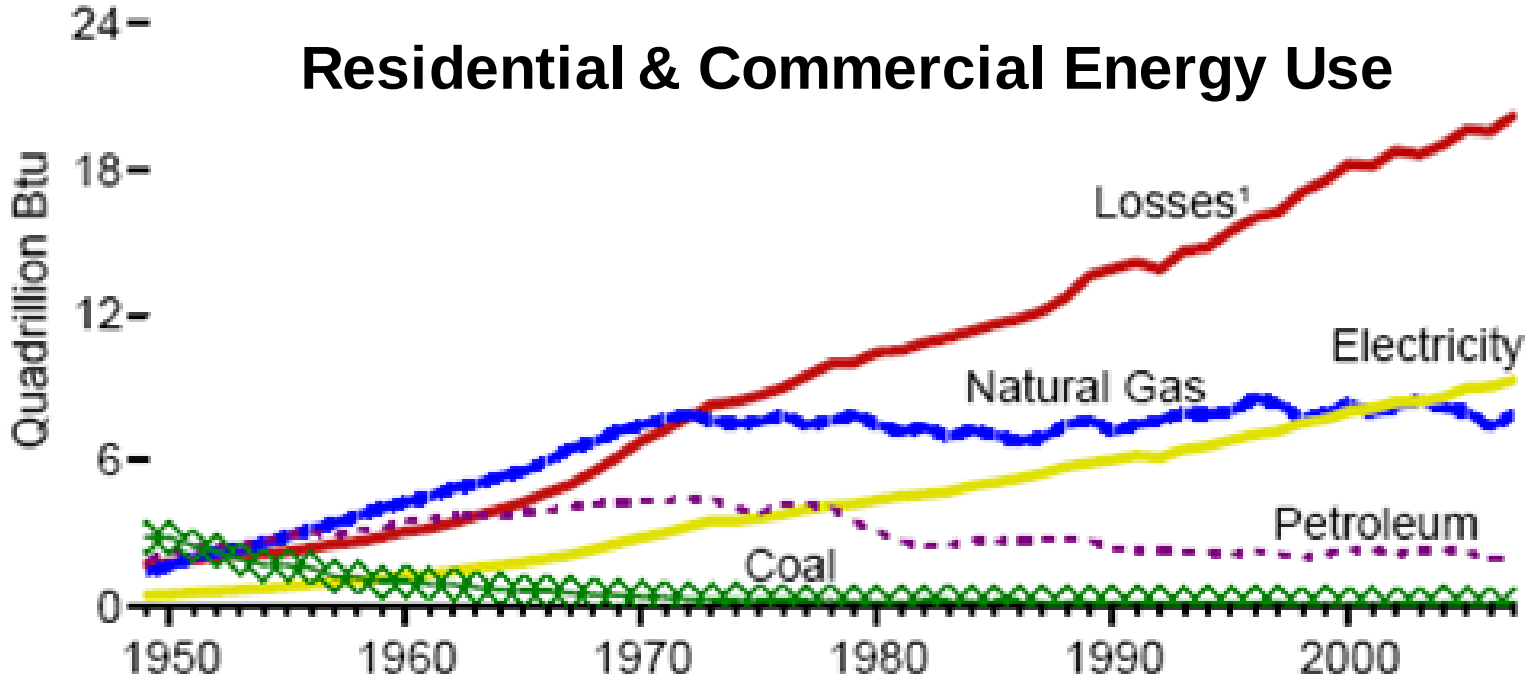
Residential and Commercial Energy Use



(1) Energy lost during generation, transmission, and distribution of electricity

Figure 2 Energy Use Trends 1950 – 2007 in Residential and Commercial Buildings
Source: DOE EIA Annual Energy Review 2007

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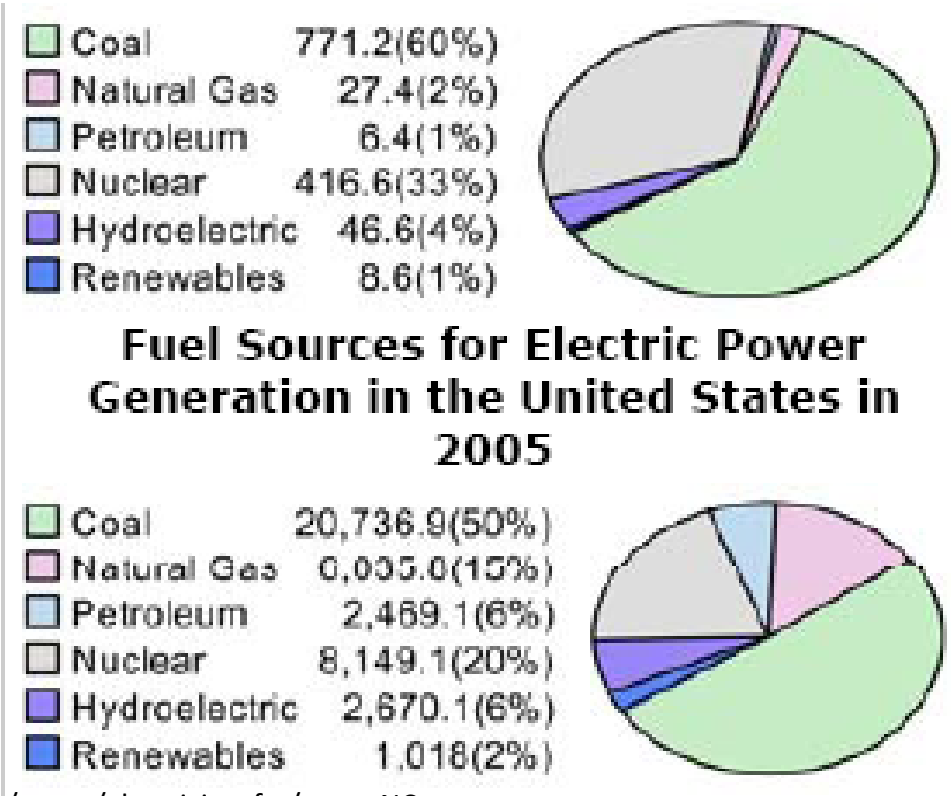
Fuel Sources for Electricity in NC

> North Carolina is more heavily dependent on coal than the U.S. average



Ref: http://apps1.eere.energy.gov/states/electricity.cfm/state=NC

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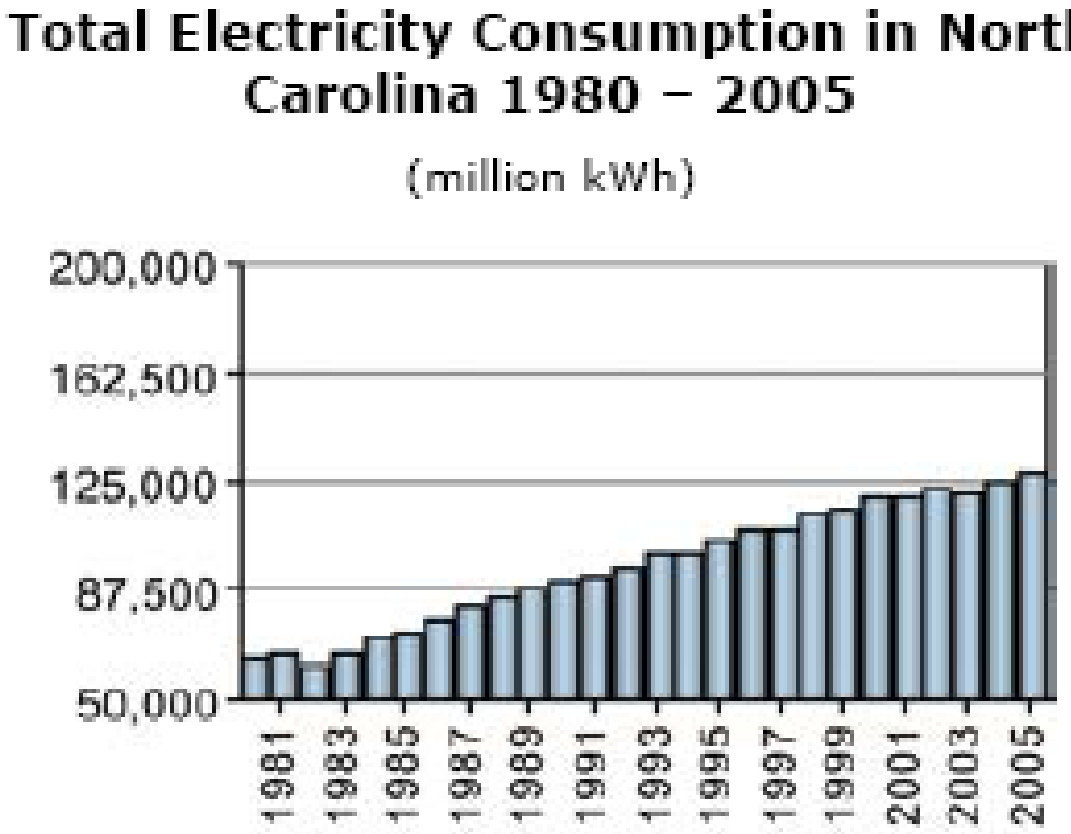
Electricity Consumption in NC has Grown Substantially



Ref: http://apps1.eere.energy.gov/states/electricity.cfm/state=NC

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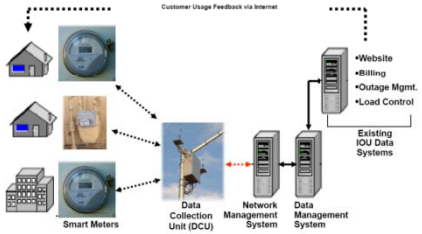
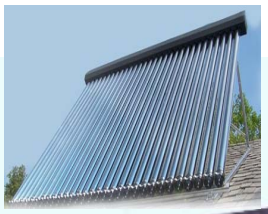
Natural Gas Technologies for Homes



Smart Energy Grid

Solar Thermal Panel



Venting Innovations

Gas Heat Pump

Real-time Energy Monitor

NGV Filling Station

Radiant Tubing

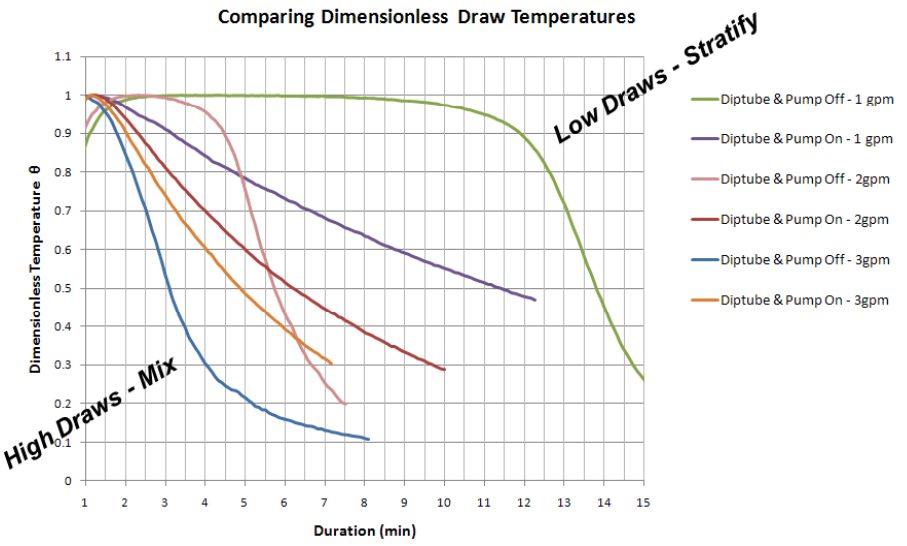
MicroCHP

Tankless/Solar Hybrid Water Heater

HOT Water Project

Technical Objective

- Hybrid Optimized Tankless Water Heater
- Develop prototype and test a hybrid water heater with best features of tankless and tank-type water heater
- Optimize performance, efficiency, and cost
- Advanced control strategies and thermal management



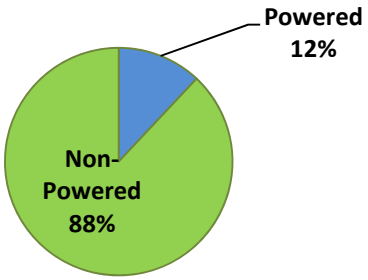
Low Power Gas Valve

New SMP Project

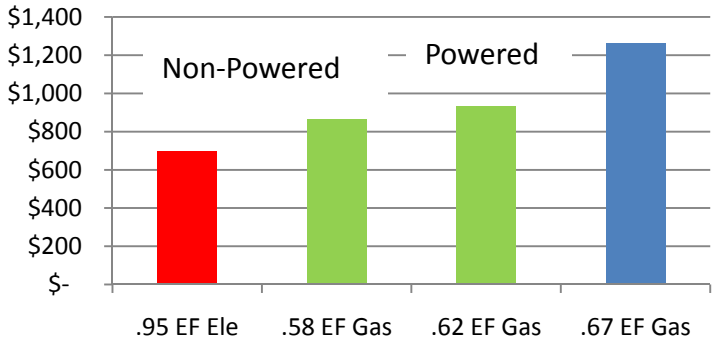
> Industry Need: Deal with the pilot light in a responsible way that does not over burden customers before it is dealt with by others

> Value to the Industry

Natural Gas Water Heaters
(63.5 Million in U.S. & Canada)



Water Heater Installed Costs



Pilot light consumes up to 17% of the total annual energy of a non-powered gas water heater, eliminating the pilot light could provide significant energy savings

> Objective: Develop a safe and reliable low power gas valve that can run battery-operated over the 10-year life of a water heater

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Solar Thermal/Natural Gas Hybrid Energy Systems

- Push natural gas equipment above 100% efficiency using hybrid solar thermal/natural gas energy solutions
- Reduced-cost domestic hot water and hydronic heating systems for residential and commercial buildings
- Higher-temperature concentrated solar thermal for steam generation, absorption cooling, process heating
  - Commercial buildings
  - Industrial plants

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Renewable gas is…

- Methane produced from digesters
  - Animal manure (dairy cows, swine)
  - Waste water treatment facilities
- Methane from Landfills
- Bio-gas produced from thermal chemical processes like gasification utilizing renewable feed-stocks including forest residues and agricultural wastes.

RENEWABLE GAS CAN BE CLEANED-UP AND PLACED IN THE NATURAL GAS PIPELINE SYSTEM

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Renewable Gas Rationale

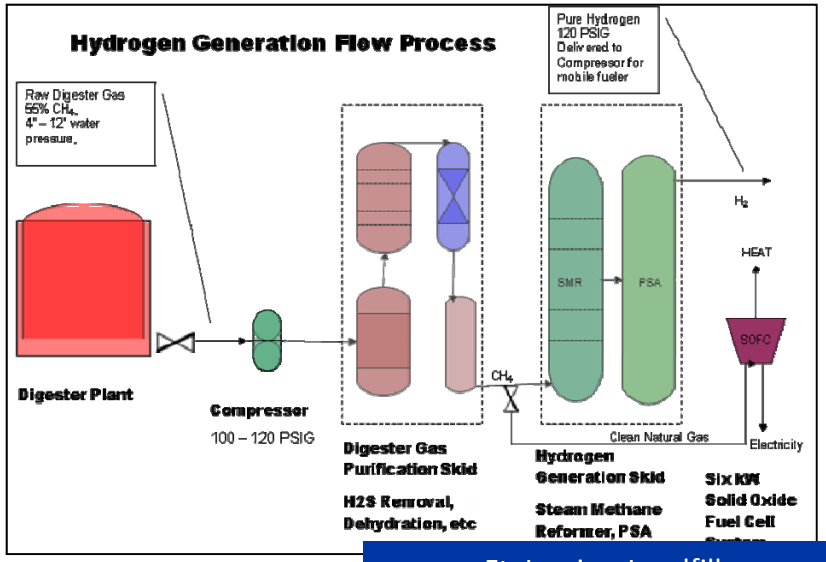
- Renewable Gas
  - Natural gas is 25% of US primary energy, has an extensive and the most efficient distribution infrastructure, and expansion of its use can reduce carbon emissions in residential and commercial sectors
- Value
  - Most efficient conversion option for renewable biomass
  - Enhances value of forest and agricultural by-products by providing additional markets
  - Renewable option for end-use combustion applications
  - Carbon neutral fuel or in some instances carbon negative
  - Can be sent to highest efficiency combined cycle natural gas facilities to produce renewable electricity

Renewable Natural Gas

End Use

- Novel end use bio-methane applications
  - Includes challenging gas quality requirements

Gills Onions – Digester to Fuel Cell Quality Methane



Ft. Lewis – Landfill Gas to Hydrogen

Linde – Waste Management Biogas to LNG for Vehicles

Skive, Denmark
Combined Heat & Power Project

Gasification – A Means to a Secure, Renewable Gas Supply

Carbon Management Opportunity

Gasification

Syngas

Excellent Environmental Performance

Liquefaction

Transportation Fuels

Pipeline Quality Gas
/ Chemical Feedstock

Pipeline / Chemical Plant

Power Plant Fuel

Power Plant

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Process Economics: Site Considerations

- Proximity to biomass resources which are managed to sustainable standards
- Existing mill site with natural gas supply and option for CHP integration
- Renewable standards in place
- Lack of other renewable options
- Supportive social/political climate
- Opportunity for Rural Economic Development

Renewable Gas
Market Growth strategy

- Generate zero carbon, pipeline-quality renewable natural gas by
  - Creating incentives for early market entrants
  - Developing projects using repeatable designs
  - Providing product to traditional natural gas users through pipeline system
    - Existing centralized power generation
    - Homes, businesses, industry
- Potential to displace 10 percent of natural gas use by 2030 - 2040
  - Depends on resource allocations

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Current Renewable Gas Legislation

- US Senator Ben Nelson (D NE) Bill – S-306
  - 11 co-sponsors
  - $4.27 per MMBtu production tax credit
  - Feedstock definition –landfills, livestock manure, renewable cellulosic
  - Supports digester and gasification technologies (includes upgrade to landfill gas also)
- Congressman Higgins (D NY) Bill – HR 1158
  - 26 co-sponsors
  - Close to being a companion bill for Senate Bill

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Current Supporters for Renewable Gas Tax Incentive Legislation

National Milk Producers Federation National Council of Farmer Cooperatives
National Pork Producers Council
American Farm Bureau Federation
Dairy Farmers of America
National Farmers Union

And 95 additional companies, NGO's and trade organizations

Resolution before NARUC for support

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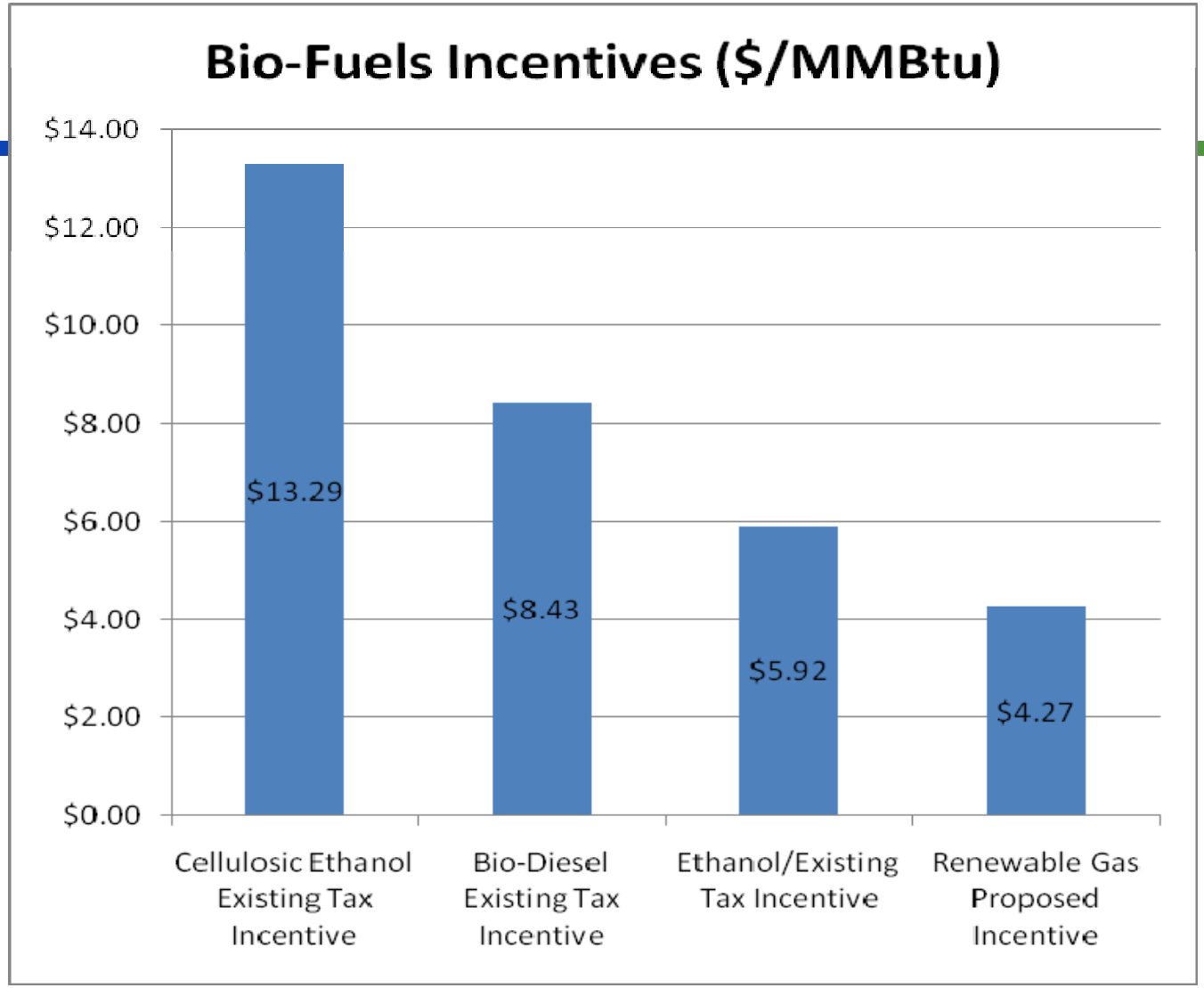
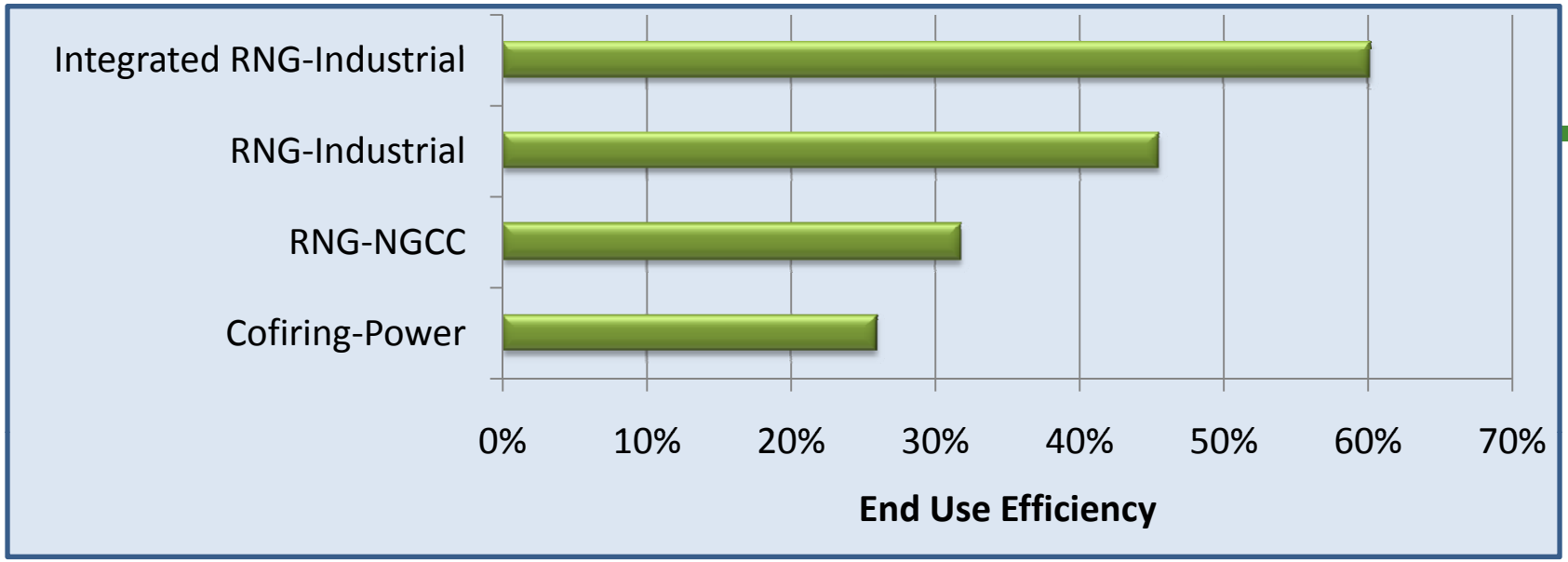
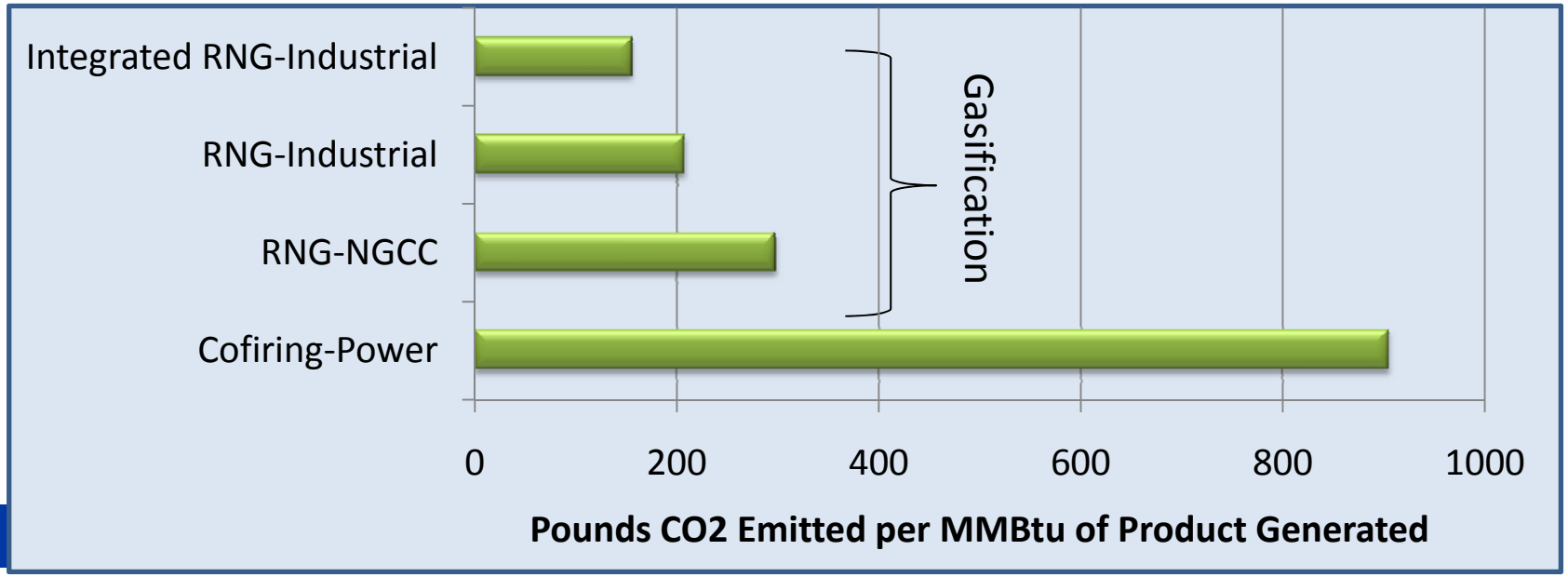
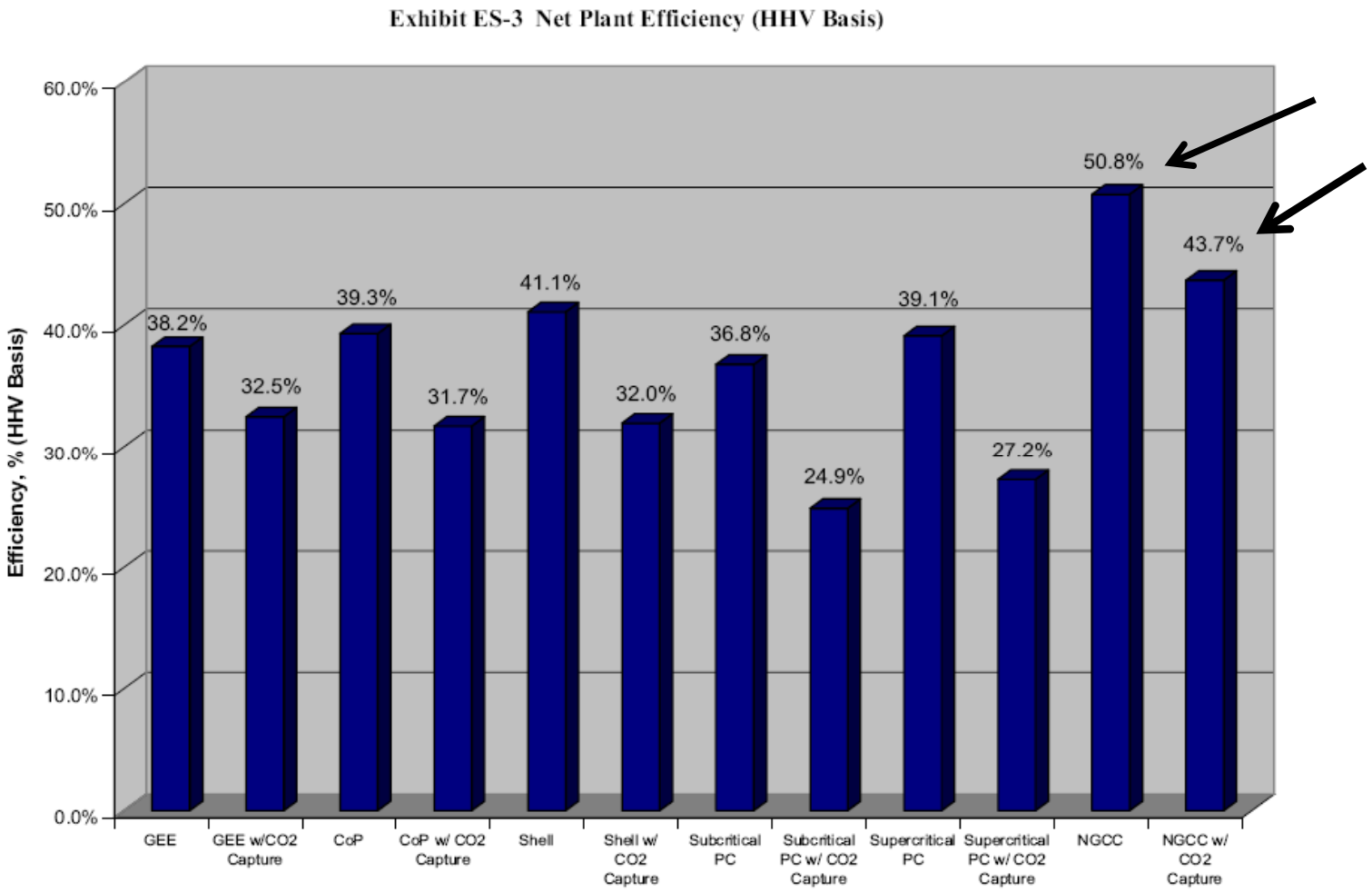

Bio-Fuels Incentives ($/MMBtu)
$14.00
$12.00
$10.00
$8.00
$6.00
$4.00
$2.00
$0.00
$13.29
$8.43
$5.92
$4.27
Cellulosic Ethanol Existing Tax Incentive
Bio-Diesel Existing Tax Incentive
Ethanol/Existing Tax Incentive
Renewable Gas Proposed Incentive

Woody Biomass Conversion Options



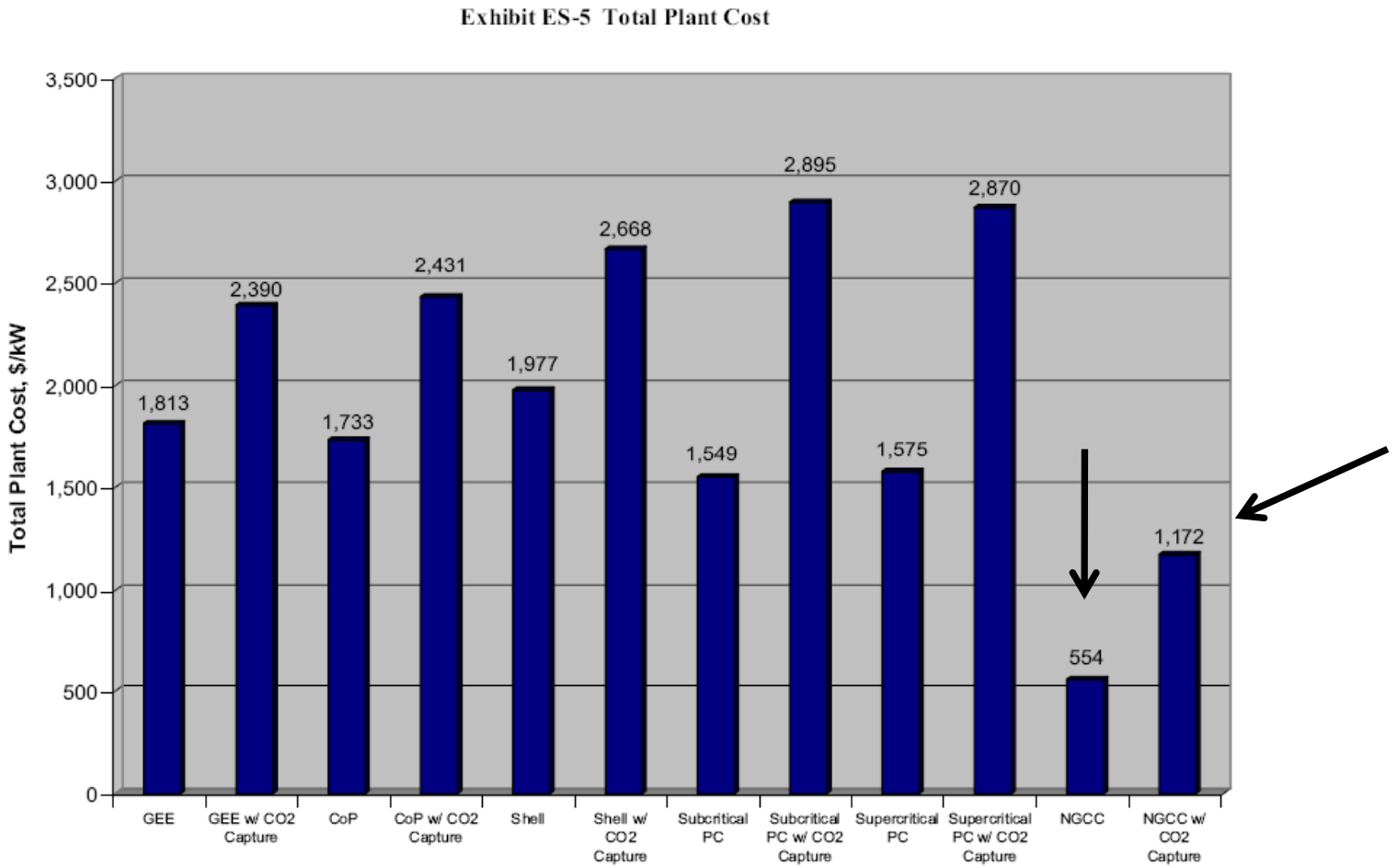


Natural Gas EG Offers the Highest Efficiency Available with and without CCS



Ref: DOE NETL, "Cost and Performance Baseline for Fossil Energy Plants'" August 2007

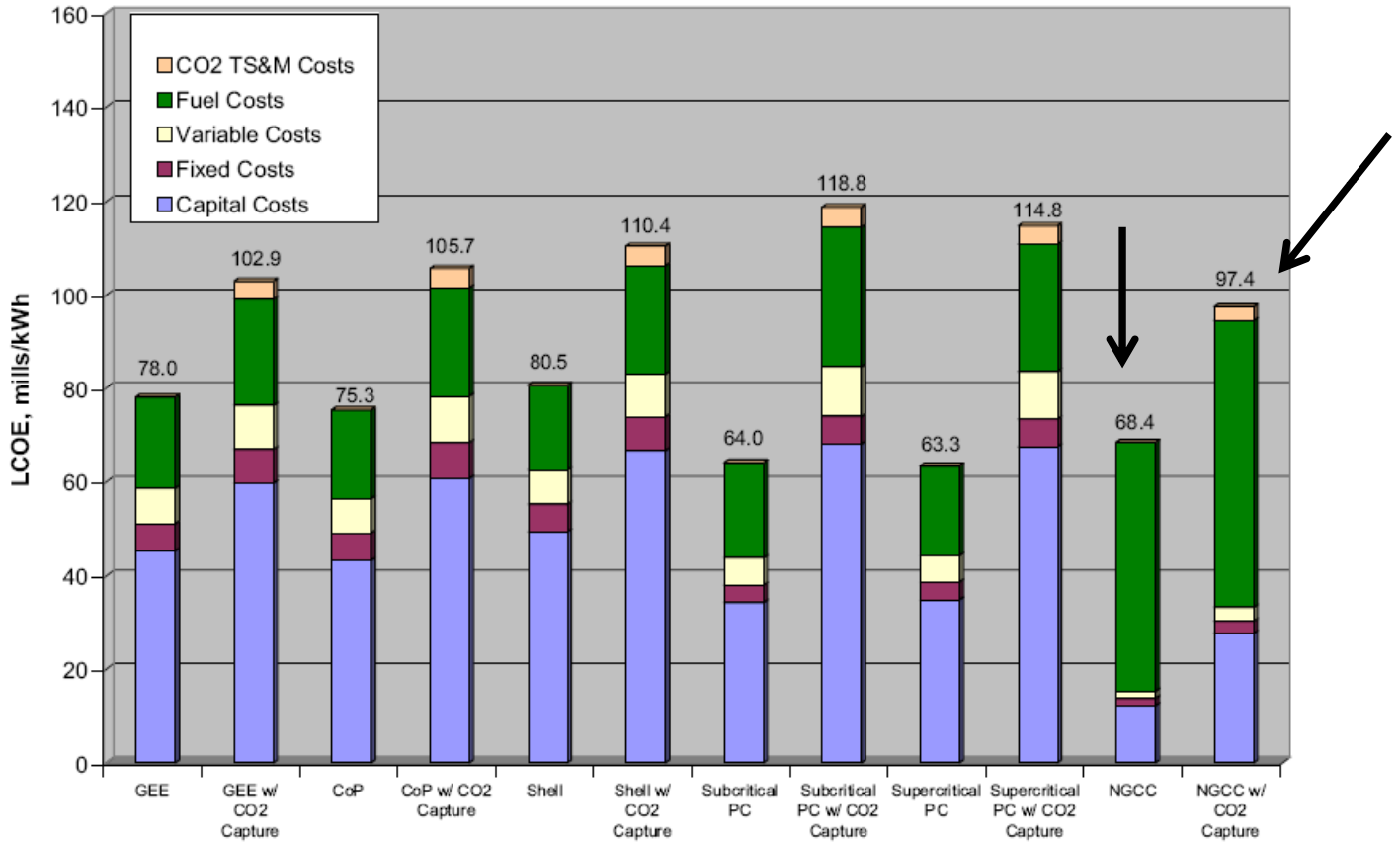
Natural Gas EG has the Lowest Capital Cost with and without CCS



Ref: DOE NETL, "Cost and Performance Baseline for Fossil Energy Plants'" August 2007

Natural Gas EG with CCS Has the Lowest Life Cycle Costs of CCS-Based Systems

Exhibit ES-7 LCOE By Cost Component



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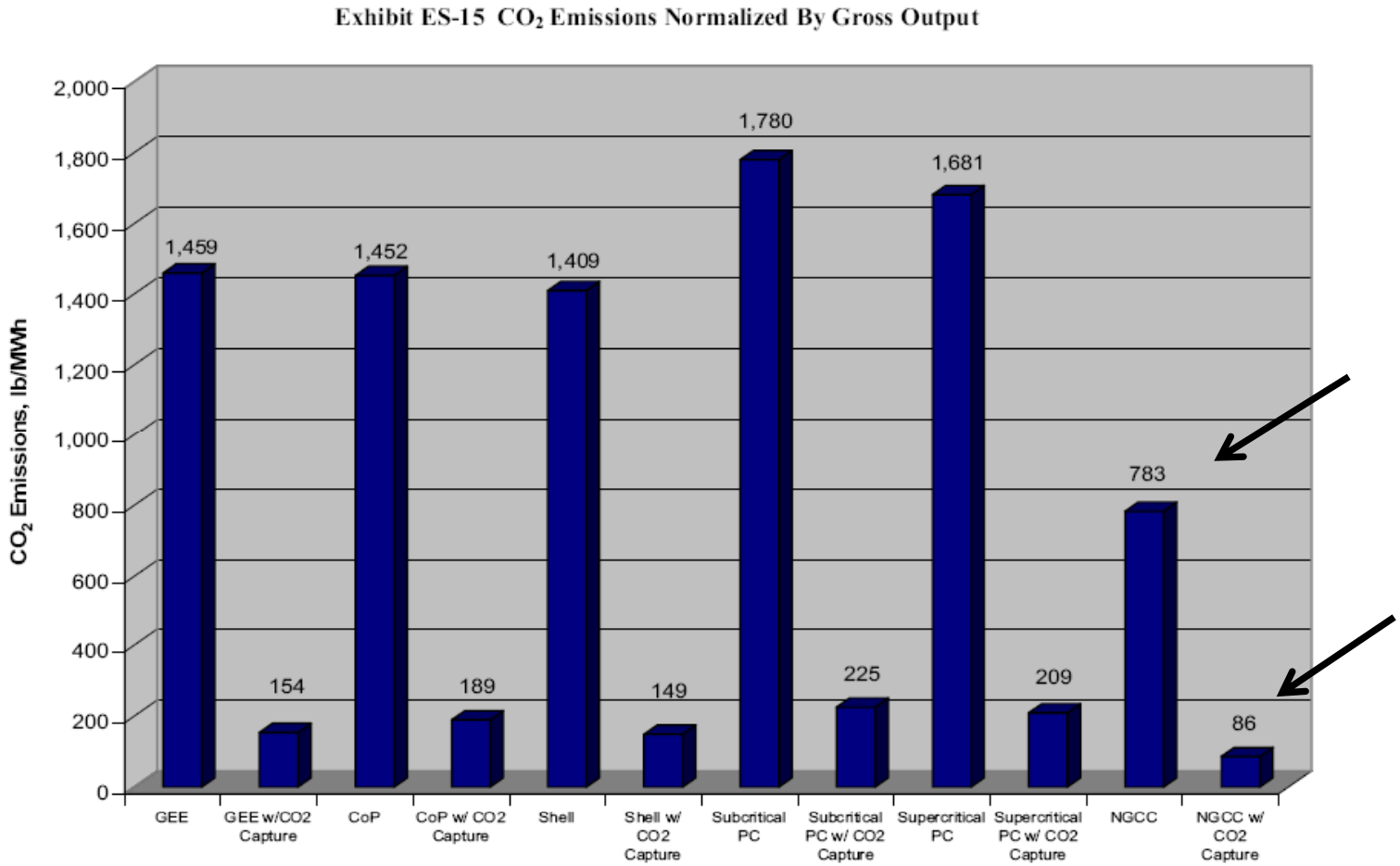
Natural gas EG with CCS Has the Lowest CO_2 Emissions



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GTI's Analysis of how to achieve 42% carbon emissions by 2030

The scenario outlined in this document is based almost entirely on the deployment of technologies which are already utilized in various applications and does not assume comprehensive development and deployment of a CO_2 capture, delivery and sequestration infrastructure or extensive deployment of new breakthrough technologies. Breakthrough technologies and new CO_2 infrastructure for coal and natural gas power generation may take several decades to deploy comprehensively, yet even without this deployment, the 2030 goal is achievable.

The scenario outlined is this document is one version of a potential future and is not suggested to be the only viable means to reaching a 42% reduction in CO_2 emissions by 2030. It is however, designed to illuminate various options and to spur policy makers to undertake additional analysis to better understand what options exist that may offer lower costs, less obstacles, more jobs and a practical path to a lower carbon future.

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GTI's Analysis of how to achieve 42% carbon emissions by 2030

- Can be done with expanded use of Energy Efficiency, Natural Gas and Renewables (some increase in Nukes)
  - **Energy Efficiency - 2004 million metric tons of CO_2 reductions**
    - Electric end-use energy efficiency improvements coupled with building envelope and insulation improvements
    - Direct use of high-efficiency natural gas appliances to displace less efficient natural gas, oil and electricity-based technologies based on full fuel cycle energy analysis
    - Improved efficiency for fossil fuel powered electricity generating facilities
  - **Renewables – 494 million metric tons of CO_2 reductions**
    - Increased renewable electricity generation 116 GW of wind, 80 GW of solar and 10 GW of hydropower
    - Increased production and use of Renewable Bio-gas (pipeline quality) for natural gas end use applications

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GTI's Analysis of how to achieve 42% carbon emissions by 2030 continued

- Can be done with expanded use of Energy Efficiency, Natural Gas and Renewables (some increase in Nukes)
  - **Nuclear - 154 million metric tons of CO_2 reductions**
    - Sixteen GW of new nuclear plants over EIA reference
  - **Transportation – 299 million metric tons of CO_2 reductions**
    - Tightened CAFE standards – 38mpg for light duty – 28mpg for trucks
    - 30 billion gallons per of bio-fuel use form starchy and cellulosic ethanol
    - Expanded use of natural gas in medium, heavy-duty and fleet vehicles

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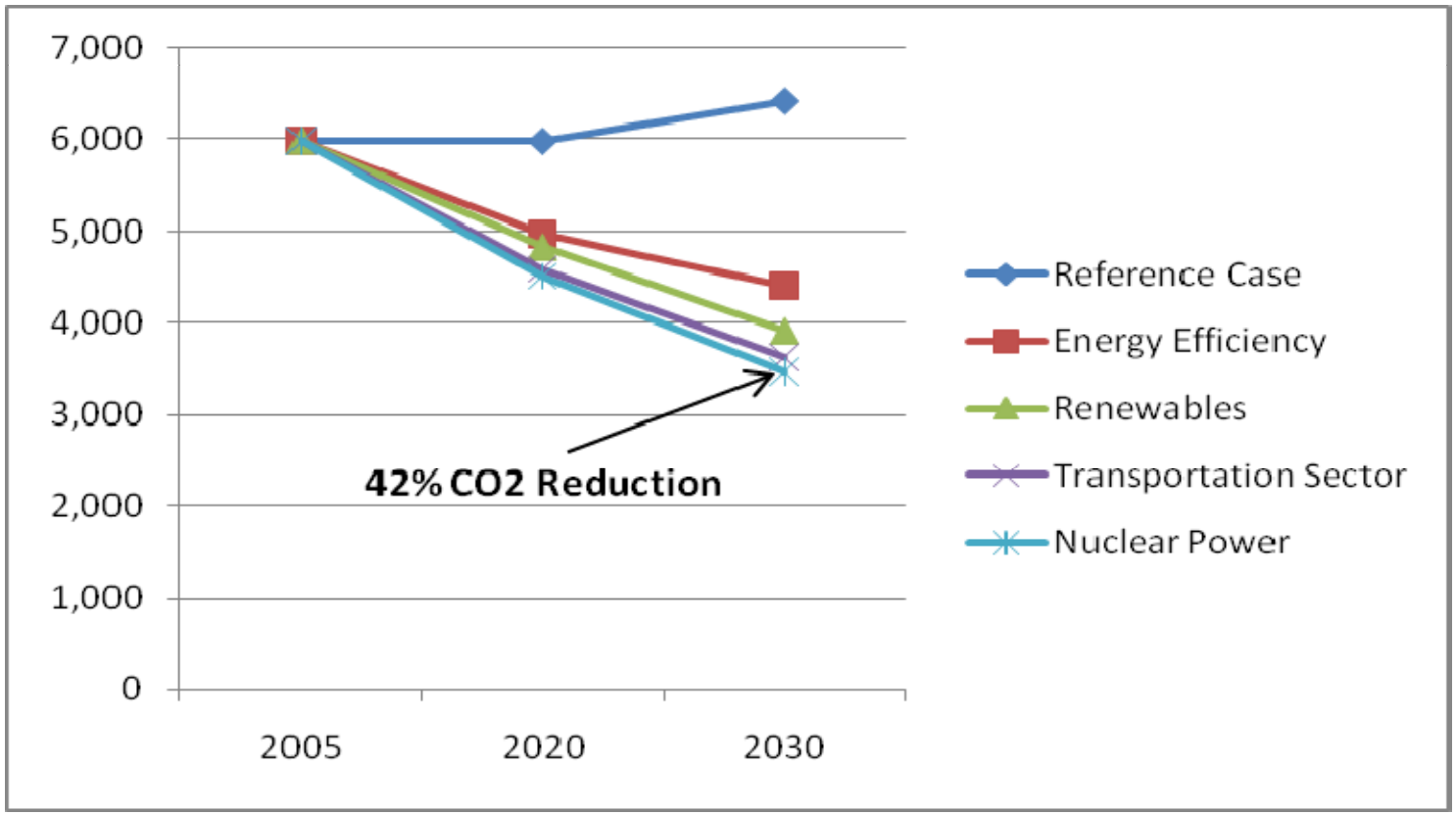
Graph of Analysis (natural gas is part of EE and Transportation Sector



Ref: GTI publication: "HOW ENERGY EFFICIENCY, NATURAL GAS AND RENEWABLES CAN SUBSTANTIALY REDUCE U.S. CARBON DIOXIDE EMISSIONS," August 2009

GHG Reduction Strategies

Utilizing Natural Gas and Existing Pipeline Infrastructure

- Expand direct use of natural gas in homes and commercial buildings
- Use existing natural gas power generation resources to fullest reasonable capacity - operate and build more natural gas combined cycle facilities
- Produce and use pipeline quality gas from renewable bio-mass (most efficient use of existing renewable bio-mass resources)