



Pearl Street

# Using E-Equity™ to Uncover Hidden Value in Power Generating Options

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Presented at:

Third Annual Carnegie Mellon Conference  
on the Electricity Industry



# Definitions

- **Equity  $n$** , A set of principles intended to enlarge, replace, enhance, or expand a narrow, rigid system of laws.
- **E-Equity  $n$** , The thermodynamics-based principle that emissions and discharges from a power station are simply a measure of inefficiencies that penalize both the economics of the facility and the ecology of the physical surroundings.
- **E-Equity Methodology**, a fresh way of thinking about power stations to drive towards a “system optimum” based in part on the principles of industrial ecology.
- **E-Equity Index**, The result of a quantitative evaluation of a power plant’s E-Equity that benchmarks it against its peers, against other power plants, etc.



# Pearl Street's E-Equity Vision

- To exert industry leadership for converting the theory and principles of industrial ecology into a practical set of corporate tools, methodologies, and models.
- To function as an implementation “bridge” between activities in academia (ISIE, e.g.) and industry.
- To continue to refine and pursue advanced energy and environmental concepts that have engaged me since the beginning of my career.



# A Recent Inflection Point?

- TXU, KKR, and ED: Alphabet soup, or a new era for coal-fired power?
  - Scrapping of planned coal projects
  - A new shade of investor “green”
- Multiple messages:
  - Investment community and the public are aligned on the global warming issue
  - Carbon management can no longer be ignored
  - Private investment will drive new goals and objectives for power generation



# Money talks...

- (The lack of) Money is the root of all evil
- Money aligned with the voting public becomes “smart” money
- Money gets people’s attention
- Carbon cap and trade converts carbon into money, monetizes global warming solutions
- Monetary value for carbon emissions radically changes the “optionality” around power generation
- Financial value for carbon is an important ingredient of E-Equity.



## Fear talks, too.

- Terror premium has been priced into a barrel of imported oil.
- Prices for oil and natural gas drive all energy prices higher.
- The U.S. is bogged down militarily in a multi-front “global war on terror.”
- America is vulnerable to attacks like 9/11.
- Energy “independence” has become a political and cultural rallying cry.



# What Drives Societal Progress?

- Money (investment, jobs)
- Care for the environment
- Electricity
- Security

*E-Equity was conceived as a means of “optimizing” our thinking about electric power generating options across these four drivers of societal progress.*



# The E-Equity Dimensions

- National energy infrastructure security (NS)
- Electricity grid management (EG)
- Economic development (ED)
- Human safety and property damage (HS)
- Environment, ecology, and human health (EH)
- Financial (F)
- Aesthetics, miscellaneous (AE)



# The Basic E-Equity Equation

$$\text{E-Equity/Societal value [V]} \sim f[a(\text{NS}), b(\text{EG}), c(\text{ED}), d(\text{HS}), e(\text{EH}), f(\text{F}), g(\text{AE})]$$

With the parameters a-g serving as weighting factors which could change on a case-by-case basis.



# Similar Methodologies

- Sustainability
- Life-Cycle Analysis
- Total Value Proposition
- System Dynamics
- Industrial Ecology
- Value Chain Analysis
- “True” Cost Studies
- Business Ecosystem Models



# How is E-Equity Different?

- Gives equal consideration to the “internalities.”
- Accepts certain realities
  - global economic growth, electricity demand growth, minimum level of emissions and discharges below which ecology or health is no longer threatened (lower may not always be better), *and the need to “price” in defense spending externalities.*
- Integrates and connects seemingly disparate industries—Power, chemicals, construction, water.



## How is E-Equity Different? (*cont.*)

- Provides a “top-down” tool and rationale for integrating energy and environmental regulations and policies.
- Focuses stakeholders on optimization, not maximization or minimization.
- Life-cycle analysis (LCA) and sustainability evaluations focus on the “externalities.”
  - NREL’s “Life-cycle assessment of Coal-fired Power production,” assesses upstream impacts



# E-Equity Overriding Objective

- Optimize among competing goals, competing “systems” and “surroundings,” instead of driving the evaluation process towards local minima or maxima (e.g. highest profit, lowest emissions, greatest employment, toughest lobbyist).
- Systems
  - Financial (debt and equity holders)
  - Economic (owner/operator, community, region)
  - Ecological (planetary surroundings)
  - Electricity Grid (Dispatch, cycling)
  - National security



# Defense-Spending Externalities

- An intellectually honest discussion about energy must at least consider expenditures for defending global supply lines.
- What happens if we make up 25% of our “fossil fuel deficit” as imported LNG from unstable regions of the world?
- Rational long-term planning scenarios must plug in values for defense costs apportioned to maintaining our energy supply lines.
- Price of oil before 9/11; \$25/bbl. Price of oil as of 9/11/06; \$68/bbl.
- Indirect cost of the Iraq War: at least \$750-billion.



# The Real World

## Applying E-Equity to a proposed mine-mouth coal-fired plant

- What is the “holistic” value of a proposed 1500-MW mine-mouth coal-fired plant in the Midwest?
  - We compared this option to 1500 MW of electricity generation from other energy sources
  - We investigated seven E-Equity Dimensions
  - We then focused the study to compare this project to one option on one dimension



# The Options Investigated

- 1500 MW coal-fired plant with rail or barge coal supply
- 1500 MW integrated gasification combined cycle
- 1500 MW wind farm (one thousand 1.5-MW turbine generators)
- 1500 MW natural-gas-fired combined cycle
- 1500 MW of gas-fired distributed generation (three thousand 500-kW DG devices)



# Comments on Specific Dimensions

- Electricity grid management
  - *all kilowatt-hours are not created equal*
- Characteristics of this project relevant to grid management
  - Flexible plant design capable of deep load cycling and quick response without undue performance sacrifice (contrast to IGCC or GCC)
  - Constant and regular output (contrast to wind)



# Comments on Specific Dimensions

- Environment, ecology, human health
  - *a power station closely coupled to its fuel source reduces emissions and saves energy*
- Characteristics of this project relevant to this dimension:
  - Project intends to achieve lowest air emissions of any coal-fired plant east of the Mississippi
  - Avoids premium fuel consumption by RR for fuel transport
  - Avoids parasitic losses in gas transmission (from 1.5-10% depending on estimate)
  - Potential for sequestration of CO<sub>2</sub> in this location



# Comments on Specific Dimensions

- National energy security
  - *a power station closely coupled to its fuel source should be a healthy “internality,” one with greater value today than before 9/11*
- Characteristics of this project relevant to national energy security:
  - No fuel supply lines
  - Stable, underground fuel source (compare to natural gas transportation)
  - Low-population location (less likely target)
  - Non-critical grid location (less likely target)



# Results as a Screening Tool

	<b>NS</b>	<b>EG</b>	<b>ED</b>	<b>HS</b>	<b>EH</b>	<b>F</b>	<b>AE</b>
<b>A</b>	High	High	High	High	Low	High	High
<b>B</b>	High	High	High	Avg.	Low	High	High
<b>C</b>	High	Avg.	High	High	Avg.	Avg.	High
<b>D</b>	Avg.	High	Avg.	Avg.	High	Avg.	High
<b>E</b>	High	Avg.	Low	High	High	High	Low
<b>F</b>	Avg.	Avg.	Low	Avg.	Avg.	High	High

A-mine-mouth coal  
B-coal by rail  
C-IGCC  
D-GCC (LNG)  
E-wind

F-DG  
NS-security  
EG-grid  
ED-econ development  
HS-safety

EH-environment;  
F-financial  
AE-aesthetics



# What the Results Told Us

- The E-Equity (societal value) this project brings to the region was very roughly estimated at \$100-million annually — this in addition to the regional economic development value of \$500 million estimated through a separate study!
- The largest component, and least understood, appeared to be the dimension of national security
- The study illuminated aspects of the project's design that could significantly improve its E-Equity Profile, especially in the environmental dimension —
  - Energy consumed in producing and supplying limestone, and its environmental impact, for SO<sub>2</sub> scrubbing is significant in life-cycle analysis of coal plants.
  - Treatment of the discharge from the wet electrostatic precipitator instead of combining with the overall water discharge from the facility



# The Next Phase: Focus, Focus!





- Mine-mouth coal project compared to an LNG-fired combined cycle at similar site
- Given emerging predictions by EIA and petroleum industry about massive imports of LNG, client wished to focus E-Equity on the dimensions of national security and environment

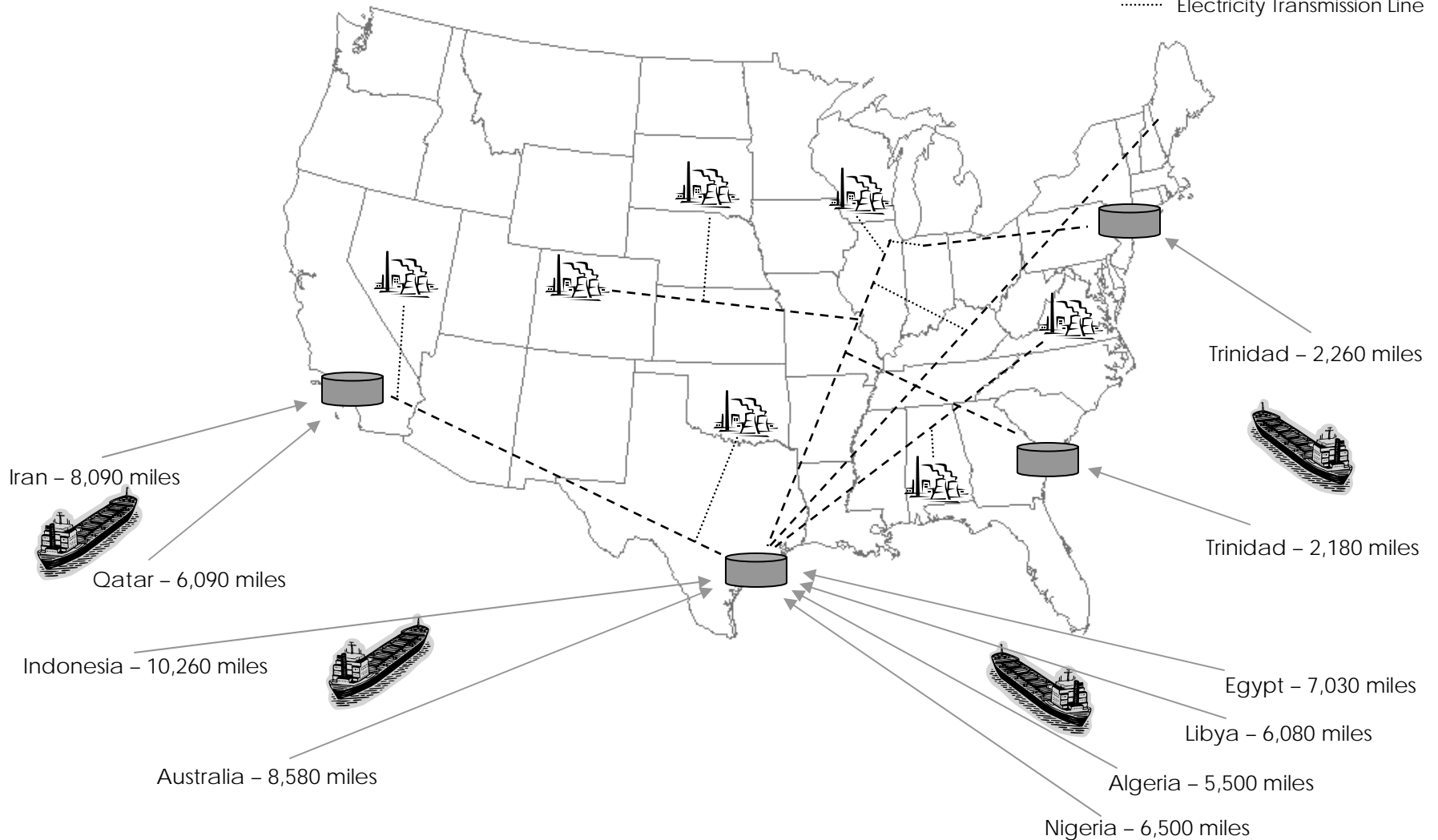
*We believe this to be one of the first evaluations of a coal-fired plant specifically for national security.*



# The "Qualitative" Message!

### Key

-  LNG Regasification Facility
-  Power Station
-  LNG Pipeline
-  Electricity Transmission Line





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# The “Qualitative” Message!

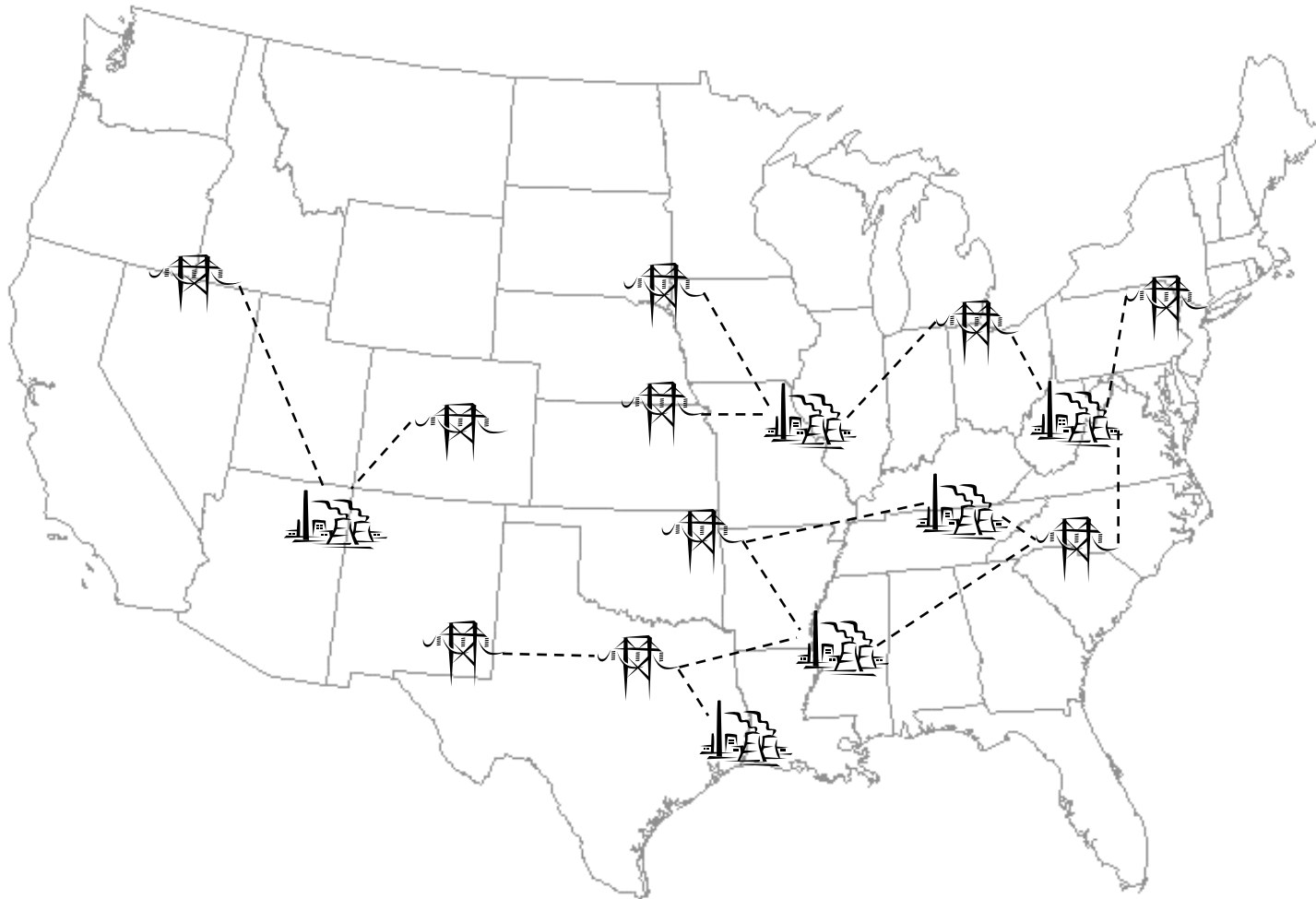
Key



Mine Mouth Coal Plant



--- Transmission Line



# The “Qualitative” Message!







# The Quantitative Results

- National security- this mine-mouth coal-fired project represents at least an estimated \$30-million in value annually with respect to national and regional security.
- Environmental- two-thirds of the global warming potential advantage normally ascribed to a gas-fired combined cycle is liquidated when LNG is compared to mine-mouth coal.



# Imported LNG “Externalities”

- Covering our energy “deficit” with imported LNG vastly extends our supply lines (distance between fuel molecules and electrons consumed)
  - Military activities for protecting LNG facilities (i.e. analogous to petroleum today) and transport
  - Costs of ensuring safety of LNG-related activities on the coasts (e.g. Coast Guard)
  - Potential for oil to no longer be priced in dollars
  - New pipeline infrastructure
  - Safety-related incidents with natural gas transport and distribution



## Value Factors: Security

- Avoidance of deaths, injuries, and property damage associated with pipeline explosions- approximately \$8-million/yr.
- Avoiding costs related to securing energy supply lines- approximately \$18-million/yr.
- Avoiding maritime costs for LNG shipments- approximately \$2-million/yr.

We believe we were very conservative in our calculations.



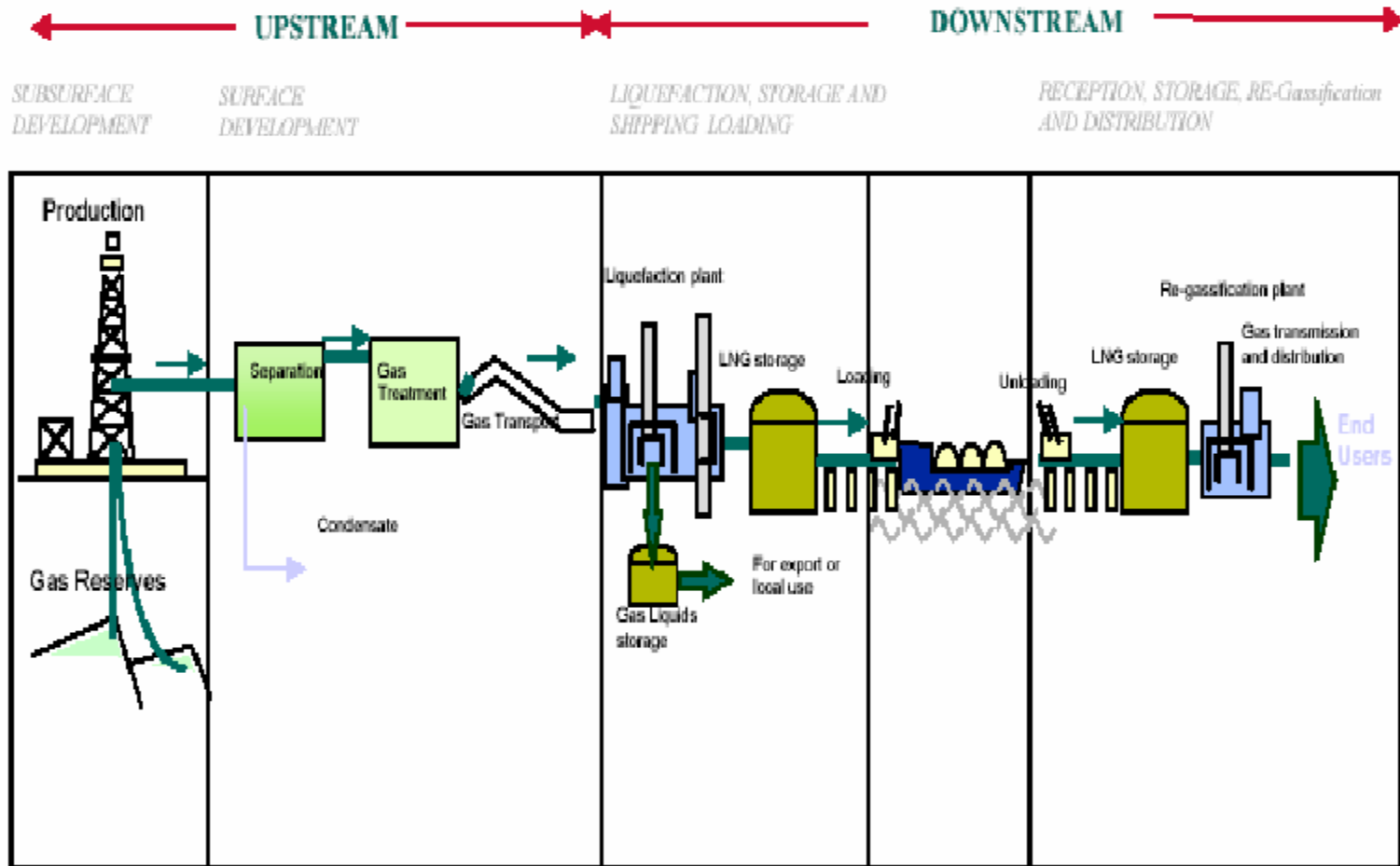
# Value Factors: Global Warming Potential (GWP)

- Parasitic energy losses involved in LNG processing.
- Additional methane losses resulting from the vastly longer supply lines, keeping in mind that methane exhibits 21 times the warming potential of carbon dioxide.



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## LNG supply chain



**Figure 7:** Additional processing steps for LNG include storage, liquefaction, tanker transport, and regasification in the destination country. 12% of the gas is consumed as parasitic energy and an additional 1-3% methane is lost to the atmosphere.

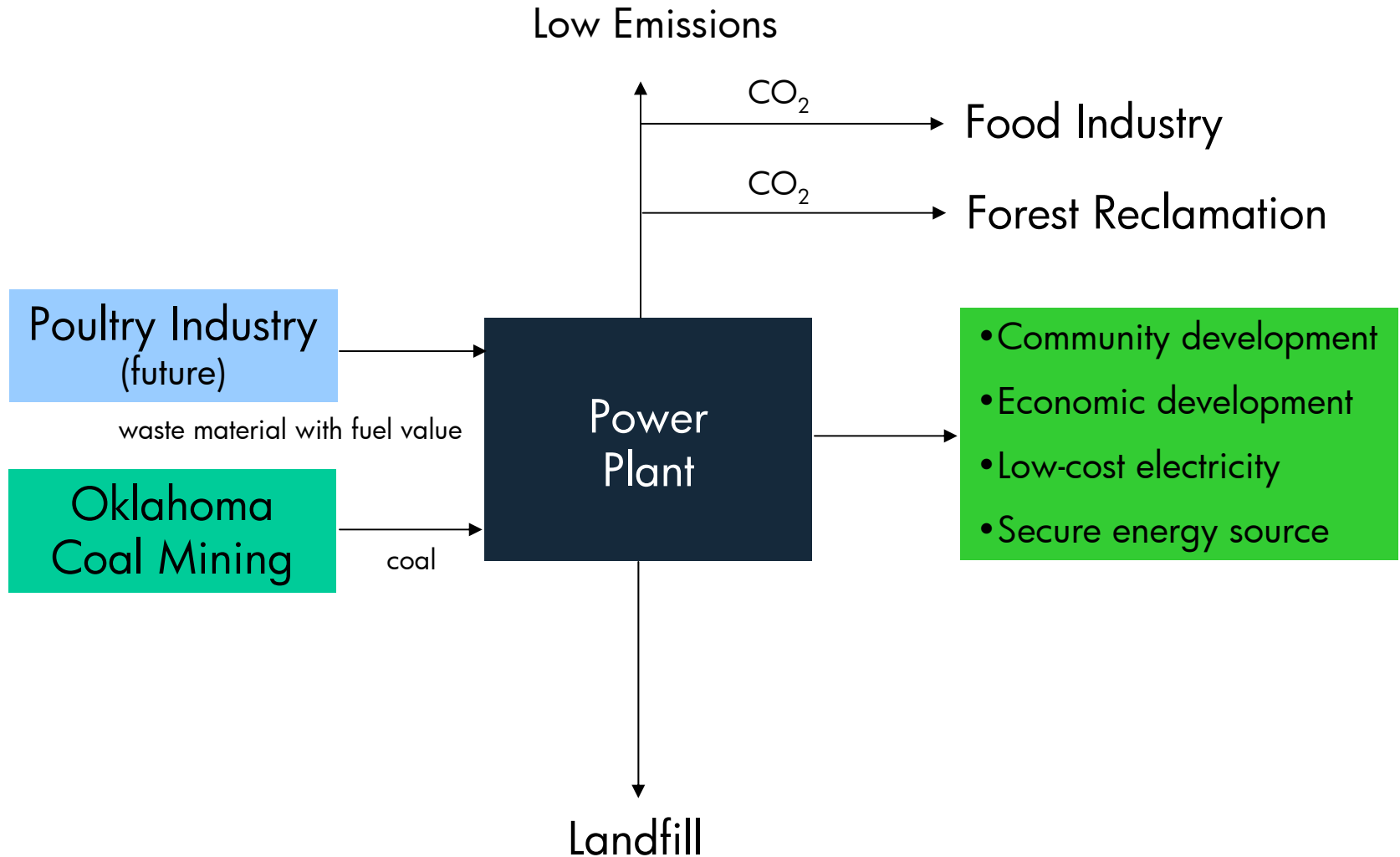


## **The Real World II: Closely-Coupled Industrial Facilities + Power Plant**

- Local coal-fired facility in an impoverished rural area
- Petroleum-coke fired facility in an active industrial zone
- Imported coal-fired CFB on an island in an active industrial zone



# E-Equity Applied: Industrial Example 1



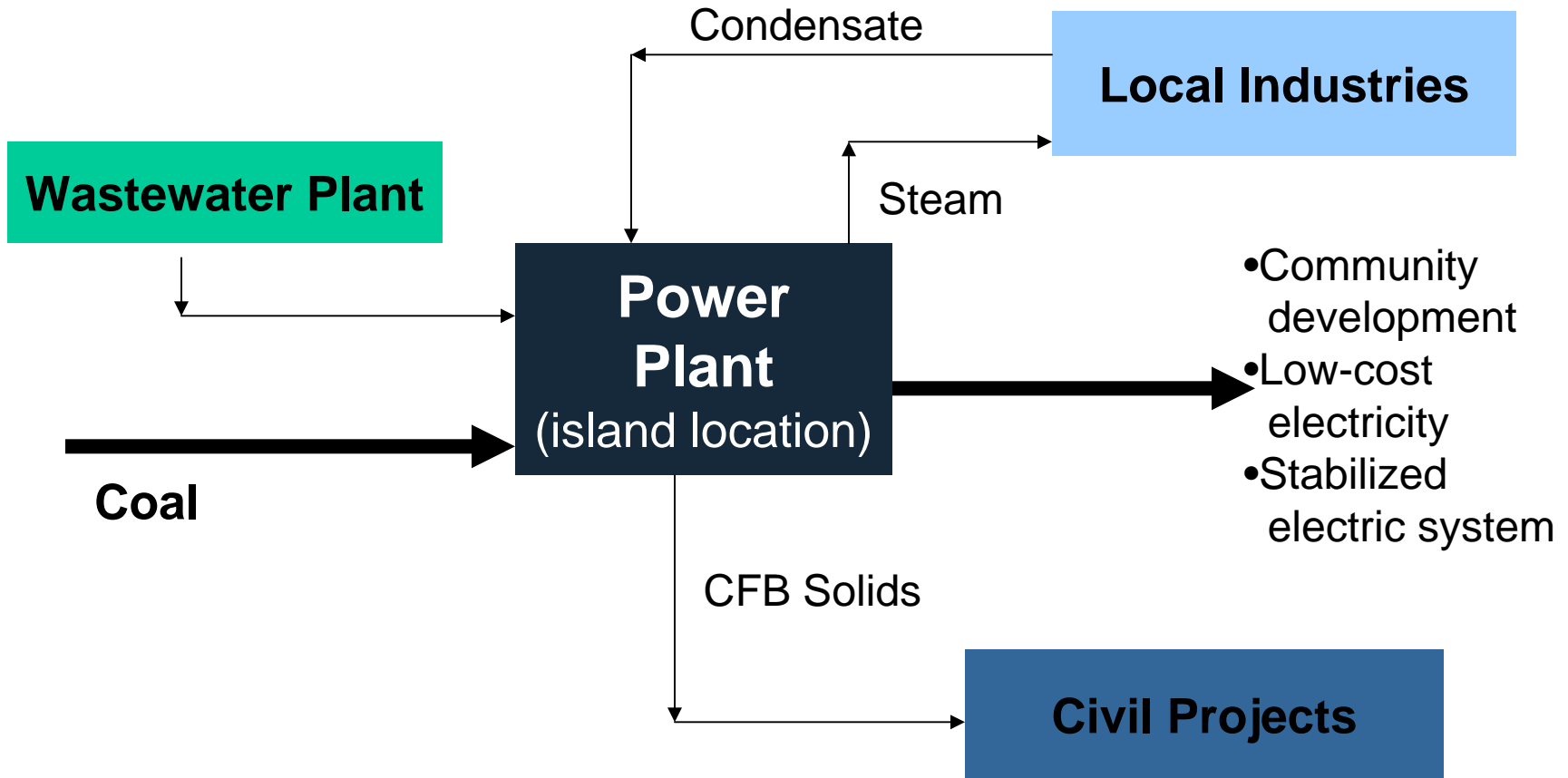


# E-Equity Characteristics

- Huge economic development of impoverished rural area
- 10% CO<sub>2</sub> recovery and recycle.
- CO<sub>2</sub> mitigation well before Kyoto a household word
- Potential combustion of poultry litter solves agricultural runoff problem.
- Close-coupling of fuel source to power plant enhances national energy infrastructure security.
- CFB solids recycle assists in mine reclamation
- Flexible power station (dispatch and load following) adds value to electricity grid.
- Numerous community and economic development funded activities.



# E-Equity Applied: Industrial Example 2





## E-Equity at Island CFB

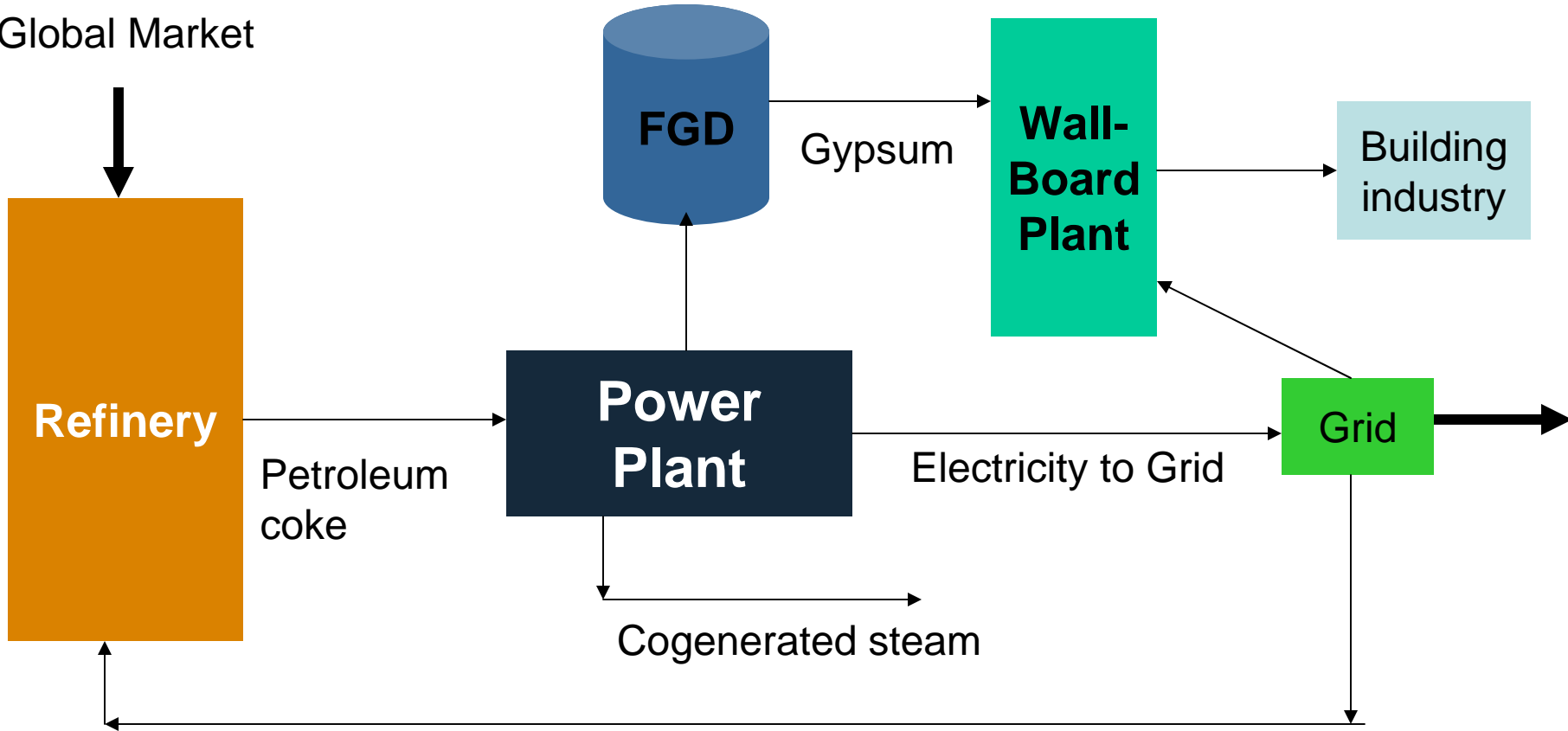
- Zero-discharge water facility
- Uses water discharged from municipal treatment plant, displaces raw sources
- Cogeneration steam for industry (raises efficiency, reduces emissions per unit output)
- Steam sales displaces heavy-oil-fired boilers, retires emission sources



## E-Equity at Island CFB (*cont.*)

- Recycle combustion products for beneficial use in civil and infrastructure projects.
  - *Power plant essentially the source for aggregate!*
- Final air emissions among the lowest in the world for coal-fired power plant
- Reliable, stable source of power for Island electricity grid (remained operating during recent hurricane!)
- Numerous community development activities

Petroleum from  
Global Market



PETROLEUM  
SUPPLY  
ECO-SYSTEM

POWER  
PLANT  
ECO-SYSTEM

CONSTRUCTION  
INDUSTRY  
ECO-SYSTEM

ELECTRICITY  
DELIVERY  
ECO-SYSTEM



# E-Equity Characteristics

- Source of low-cost power (solid fuel) in a region where gas-fired power is more than 50% of the generation base
- Consumes a waste material, recycles SO<sub>2</sub> into a useful product
- Makes more thorough use of energy value of petroleum
  - Petroleum coke often unwanted byproduct
- Avoids mining, transport of coal
  - Diesel fuel for rail transport significant energy, environmental penalty
- Avoids mining and transport of gypsum
- Avoids transport of gypsum board
  - 10% of total energy use is in final delivery of product



# The Real World III: Identifying Carbon Offsets

- Extracting energy from biomass breaking down into methane (landfills, cattle manure, etc)
- Reducing verifiable losses in an LNG extraction and delivery chain
  - Methane is 20x the global warming agent that CO<sub>2</sub> is
- Recycling coal flyash
  - For every one ton recycled, close to one ton of CO<sub>2</sub> is avoided (replacing Portland cement)



# The Real World IV: Regulatory policies

- Avoiding the consequences of seeking a “local minimum”: Gas turbine NOx emissions
  - What is the lost value of a 3-9 ppm NOx level?
    - Combustion efficiency losses
    - Forced outages
    - Hot gas path repair and replacement costs



# The Real World V: R&D priorities

- Renewables and electricity grid management-the acute need for better energy storage options
- Fertilizer for agriculture: Making ammonium nitrate and sulfate from advanced FGD processes, not natural gas.
  - *A better pathway for ethanol?*
- The value of all domestic fuels compared to imports when defense expenditure “externalities” are factored in.



# Things to Ponder

- E-Equity illuminates a more complete framework-financial, regulatory, economic-for extracting the full value of plentiful domestic fuels like coal.
- Industrial ecology facilities should be rewarded for internalities-why not production tax credits like renewables?
- Defense-related externalities need to be included in evaluations just like environmental externalities. All “domestic” energy sources (wind, solar, coal) need a more sustainable long-term financial platform on which to stand.
- Emerging practices, such as LNG imports, should be viewed critically through an E-Equity lens.

**Ensuring the “physical and human resources for the next thirty years” demands a more sophisticated methodology.**