McIlvaine Hot Topics

Greenhouse Gas Strategies

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Outline

- What is driving Greenhouse Gas Reductions?
- What solutions are we seeing?
- What are the challenges to reductions?

What is driving Greenhouse Gas Reductions?

Climate Change Drivers

- Legislation:
  - New source carbon capture requirement
  - Cap and trade
  - Nationwide RPS/energy efficiency
- Regulation: EPA endangerment finding/tailoring rule
- Legal: Court cases
- Regional/state/city: Climate initiatives
- Financial: Carbon principles, SEC, insurance
- Reputation: Corporate Sustainability Reports

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Climate Change Policies

- Cap and Trade
- Cap and Dividend
- Carbon tax
- Command & Control – BACT
  - Fuel Switch/low carbon sources
  - Efficiency improvements
  - Carbon capture/sequestration
  - Offsets

What solutions/challenges are we seeing?

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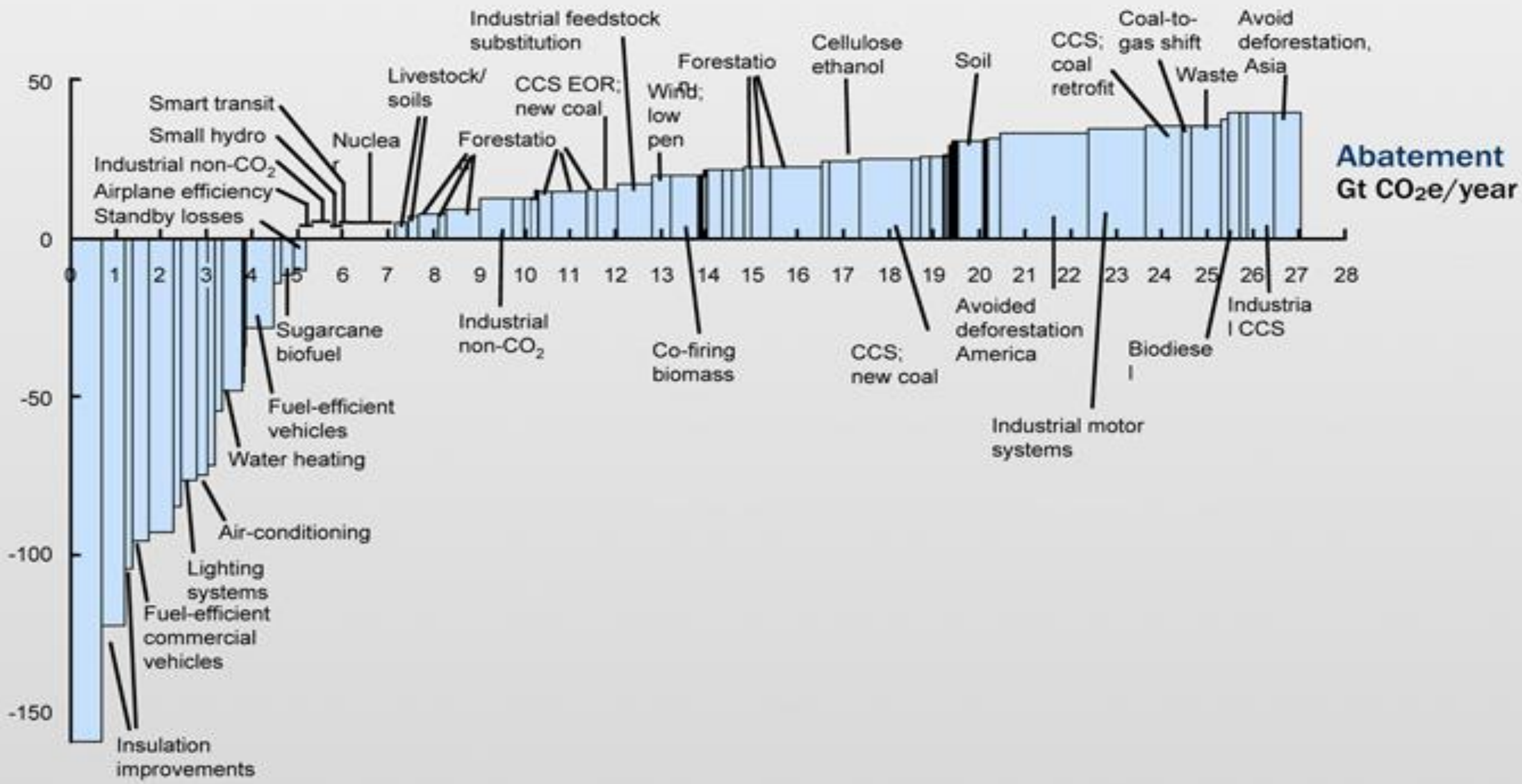
Cost Abatement

THE COST CURVE PROVIDES A "MAP" OF ABATEMENT OPPORTUNITIES

Cost of abatement, 2030, €/tCO_2e*



* Cubic feet of carbon equivalents.
Source: McKinsey and Vattenfall analysis

Reducing GHG footprint

- System level
  - Nuclear
  - Renewables
  - Gas
  - Demand Side Management
  - Smart Grid
  - Offsets
- Plant level
  - Repowering with Natural Gas/Biomass
  - Co-firing Biomass
  - Energy efficiency
  - Carbon Capture/Sequestration
  - By-products used by others
  - Algae

Plant level GHG applications

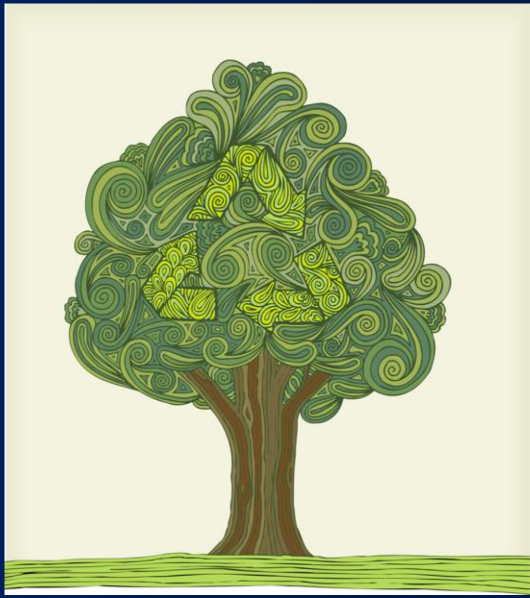
What major GHG reductions are we seeing at the Plant level?

Biomass

- Dispatchable source
  - Meets RPS
  - Carbon neutral
- Site specific
  - Fuel availability
- Cost
  - Likely strategy for meeting RPS/GHG legislation
  - No grid instability issues

Biomass

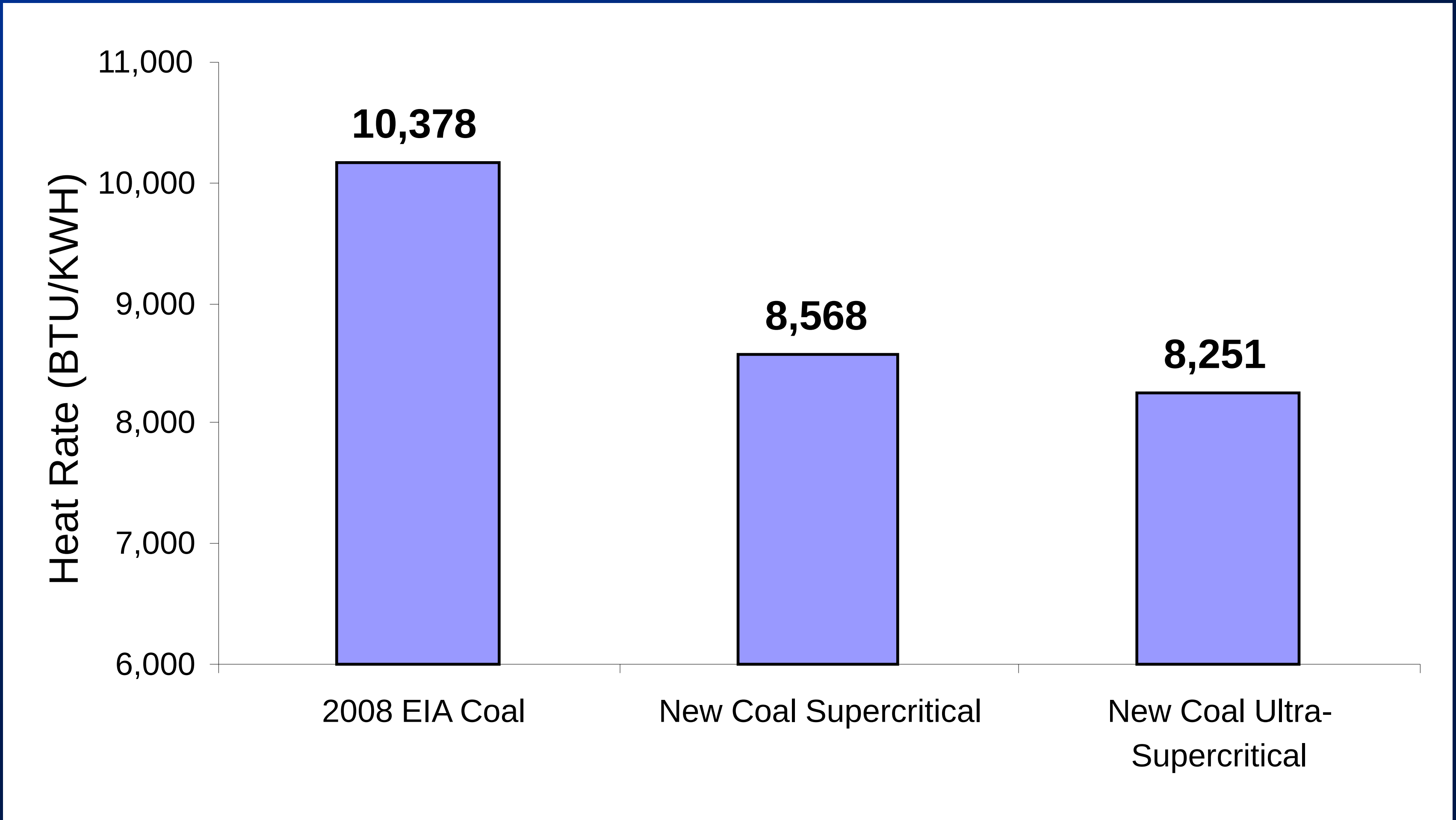
- Fuel feed systems
- Additional truck traffic
- Retrofit technology uncertainty
- Regulatory uncertainty
- Fuel supply longevity
- Fuel impacts on boiler/AQCS
- On-site fuel storage



Supply Side Efficiency

- Replace Outdated Generation Technology
  - Combined Cycle Gas Turbine (CCGT)
  - IGCC
  - Supercritical Coal
- Retrofit Existing Generation Fleet
  - Turbine Upgrades
  - VFDs – ID fans, etc.
  - Motor Efficiency
- Combined Heat & Power
  - Integrated facilities

New Coal Efficiency Opportunity



Coal Capture Technologies

Carbon Capture Technology Groups

Absorption
Amines
Ammonia
Carbonates
Hydroxide
Limestone

Oxy-Coal
Oxy-firing
Coal Chemical Looping

Biological
Algae
Micro-algae
Cyanobacteria

Adsorption
Metal Organics
Zeolites

Membranes
Fibers
Microporous

Other
Mineralization
Cold Separation

Some Algae Facts

- Economically feasible if diesel > $4/gal
- 500 acres needed for up to 2% CO_2-capture for 400 MW plant
- 21 CO_2-enhanced algae strains available
- In theory, 10 million acres to supply all U.S. transportation fuels (if all ICE's ran on biodiesel)

Median Sized States

Illinois

Or

Georgia

(Total land area needed to displace petroleum transport fuel shown in black)

Algae Farming Methods
Outdoor Ponds and Raceways

Seambiotic Open Algae Pond - Israel

BioPetroleum's Pilot Facility on the Big Island of Hawaii

Solix – CO State University Test Site

Midwest Research Inst.– FLD Raceway

Emerging Capture Technologies

Post-Combustion

- Doosan/HTC PureEnergy Amine
- Alstom Chilled Ammonia
- Powerspan ECO_2
- MHI KS-1 Amine
- Fluor FG+SM
- Shell/CanSolv Amine
- Alstom/Dow Amine
- Aker Amine
- Siemens Amino Acid

Oxy-Combustion

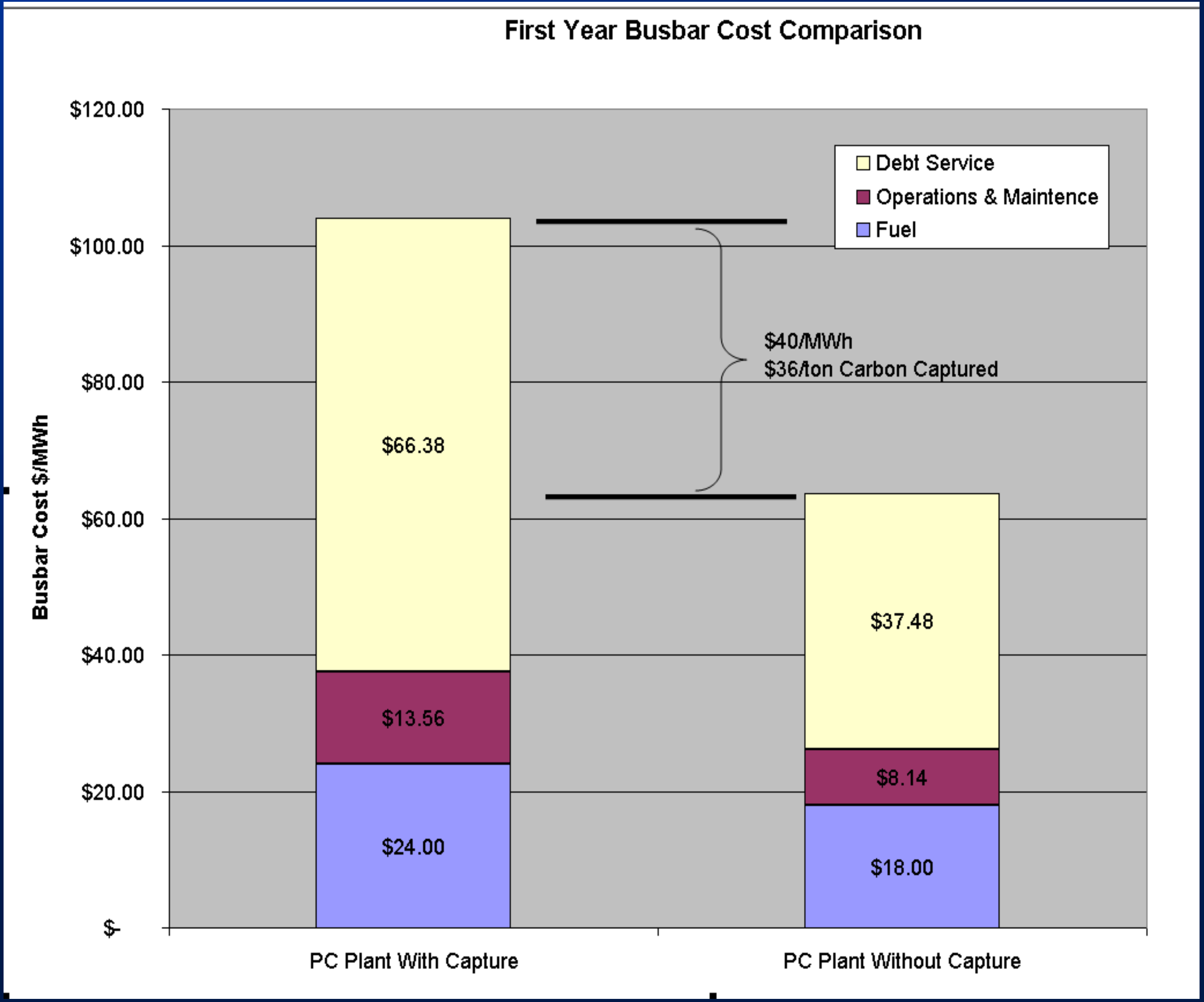
- IHI (Air Liquide)
- Doosan-Babcock (Air Products)
- Foster Wheeler (Praxair)
- Alstom (Linde)
- B&W (Air Liquide)

Carbon Capture Plant Impact

Case Study of 800 MW PC Post Combustion Capture

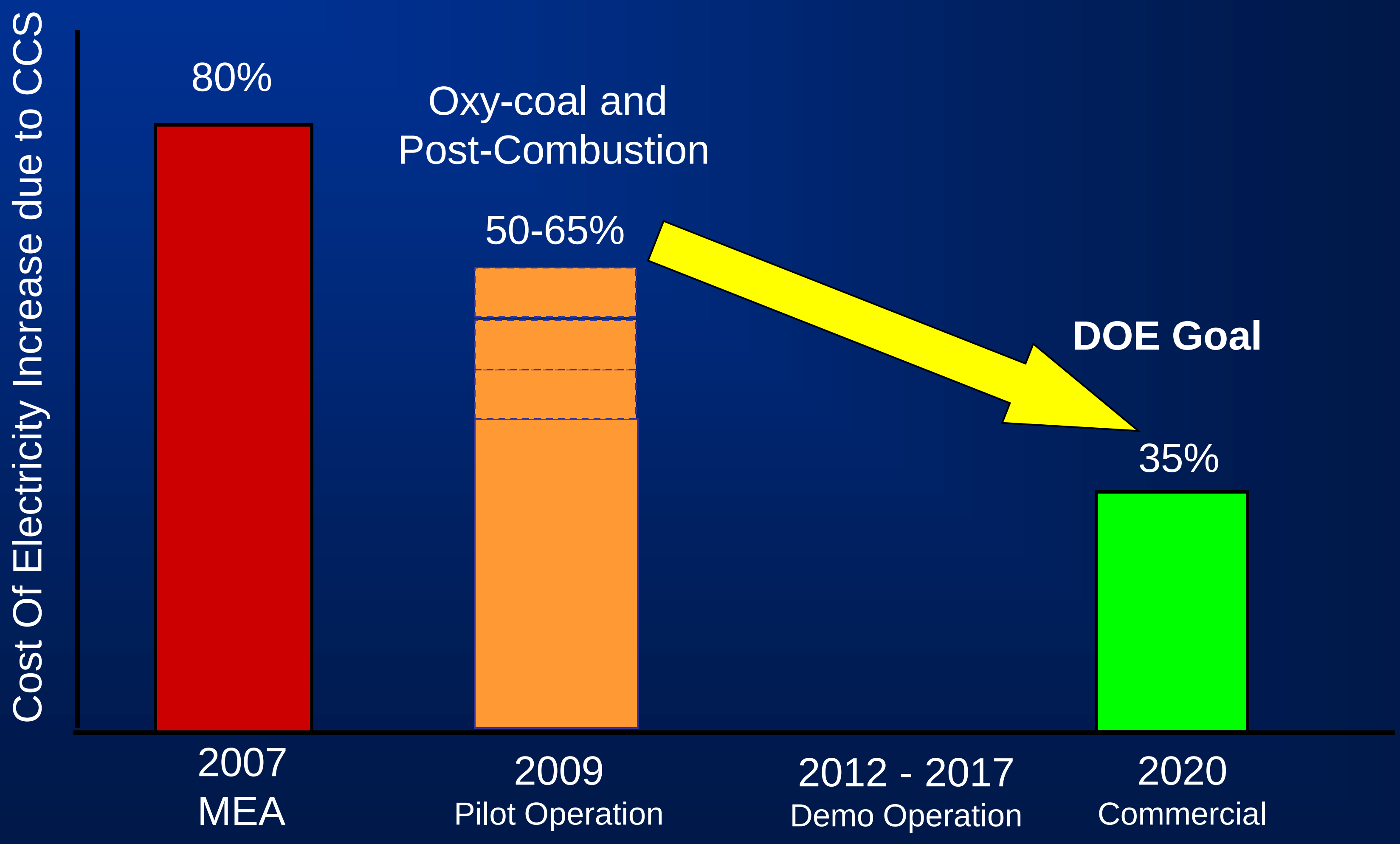
Heat Input:	No Change
Steam Extraction:	(13% of NPO)
CO_2 Capture Auxiliary Power:	(4% of NPO)
Compression Auxiliary Power:	(9% of NPO)
Total NPO:	(26% of NPO)
Cooling Water Needs:	3 gpm/MW
Fixed O&M:	+45% of Total $ (incl maintenance)
Variable O&M:	+10% of Total $

Impact to Busbar Costs – 800 MW Case Study



Based on
90% Carbon Capture
Compression to fenceline

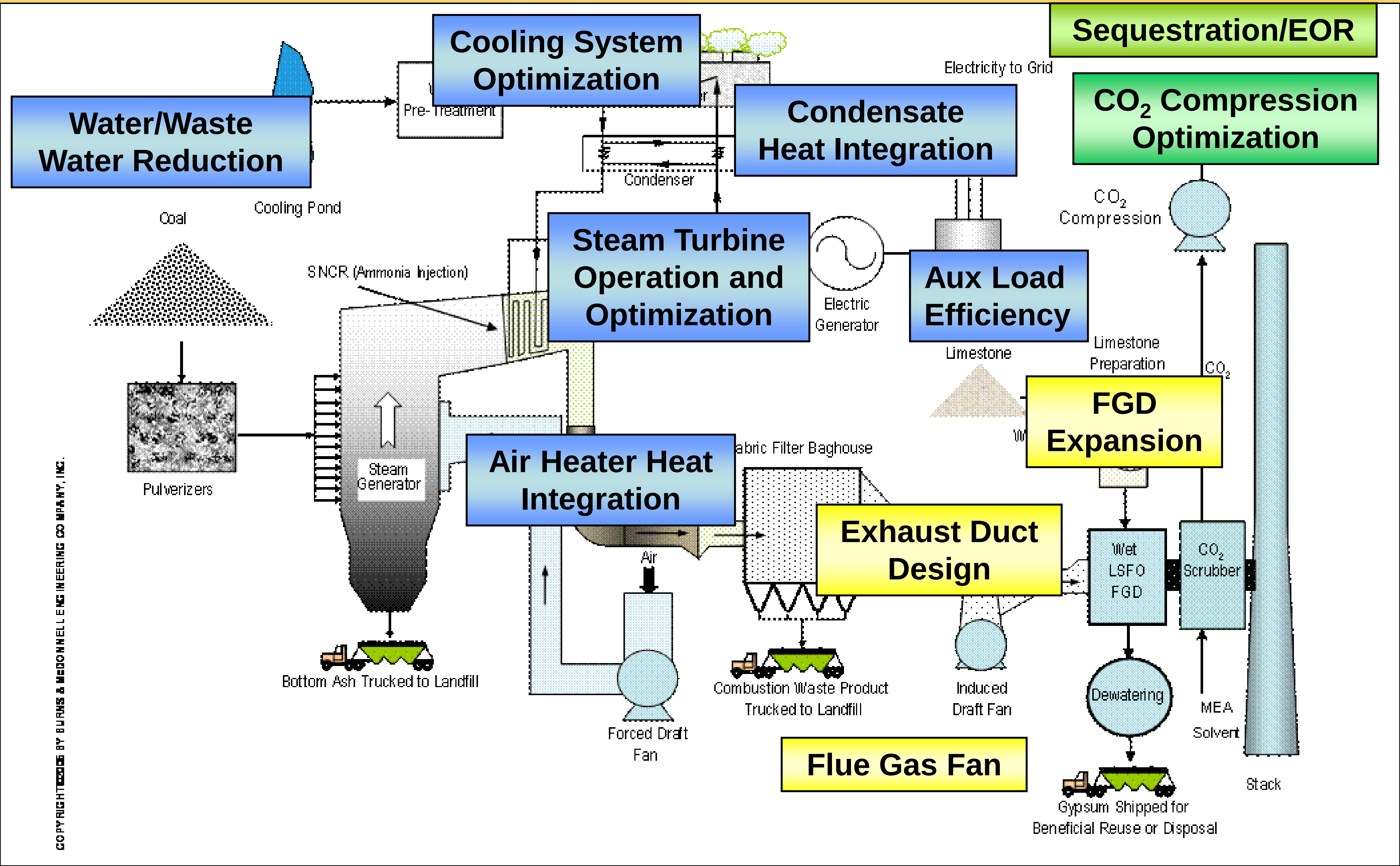
Current Projections



Capture Economics

- Costs are application dependent, each project should be evaluated on its own merits
  - Plant size (economies of scale)
  - Fuel Cost
  - Cost of Capital
  - Site water availability/cost
  - Labor Costs
  - Integration Capability

Integration is Key



CCS Determination – Economic Sensitivities

- Carbon Legislation
- EOR potential – value and longevity
- Sequestration Costs
- State Renewable Standards
- Permitting schedule
- Nat gas pricing
- Coal/transportation costs
- Load Growth
- Equipment/labor costs – market impact
- Financing costs

Significantly Impact the technology selection

Conclusions

- No clear answers for best GHG reduction strategy
- Form of GHG rules still uncertain
- Many solutions are site specific
- CO_2 capture/sequestration not yet “commercial” and may have other impediments
- Need to continually follow R&D

Legislation/Regulation is ahead of implementable technologies. Additional time is needed to fully integrate GHG solutions into the industry.