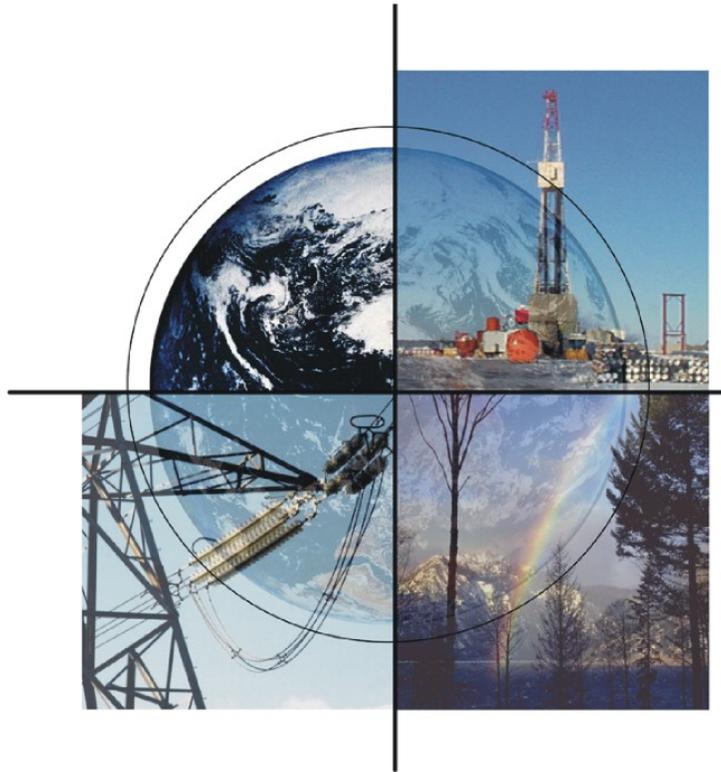


Systems Analysis Supporting the Carbon Sequestration Technology Roadmap



*Second National Conference on
Carbon Sequestration*

May 6, 2003

Scott M. Klara, NETL

Jared Ciferno, SAIC

Phil DiPietro, Energetics, Inc.



Sequestration Program Goals

Develop Technology Options for GHG Management That...

- Are safe and environmentally acceptable
- Result in
 - < 10% increase in cost of energy services (< \$10/tonne CO₂ avoided) for capture, transport, & storage
 - With Measurement, Monitoring & Verification protocols for assurance of permanent storage
- **Global Climate Change Initiative**
 - Contribute to reducing carbon intensity by 18% by 2012
 - Provide portfolio of commercially ready technologies for 2012 assessment

Cost Performance Goals

Year	COE Penalty IGCC Plants (% Increase)	COE Penalty PC Plants (% Increase)
2002	30	80
2007	20	45
2012	10	20
2015	<10	10
2018*	0	0

*Cost/Energy offset from sequestering CO₂ with criteria pollutants NO_x, SO_x, H₂S (gasification)



Why the 10% Increase in COE Goal?

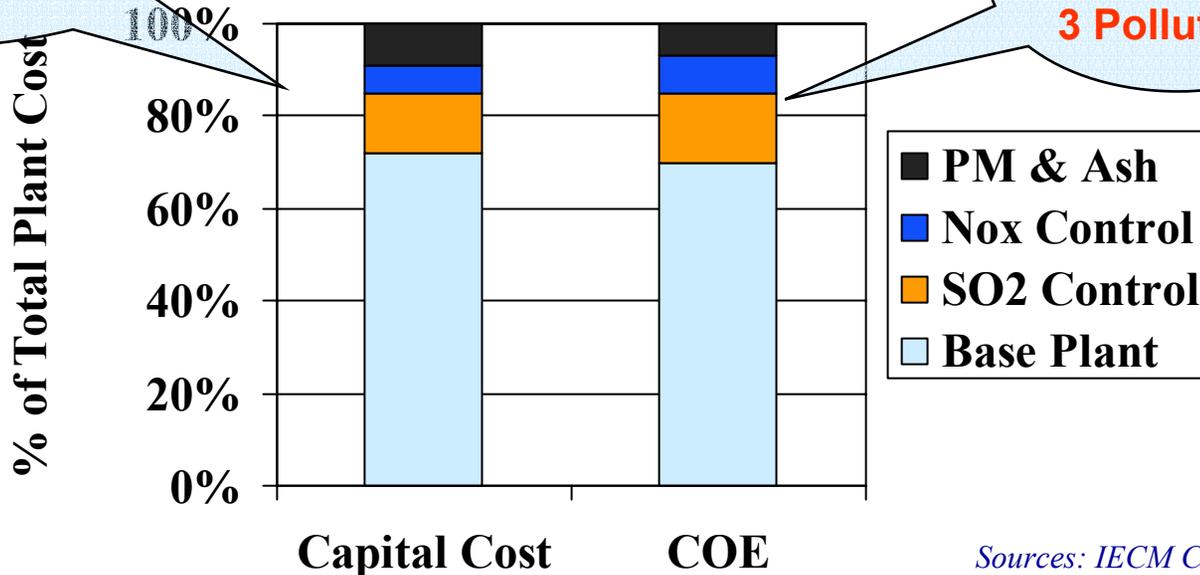
Relate to Compliance Costs Absorbed for Mandated Pollutants

**Coal Plants Absorbed ~ 10% Cost Increase
in COE & Capital for each Mandated Pollutant**

**Cost of Environmental Compliance
(Nominal 500MW PC Plant)**

**~ 30% Capital Cost
Impact for
3 Pollutants**

**~ 30% COE
Impact for
3 Pollutants**

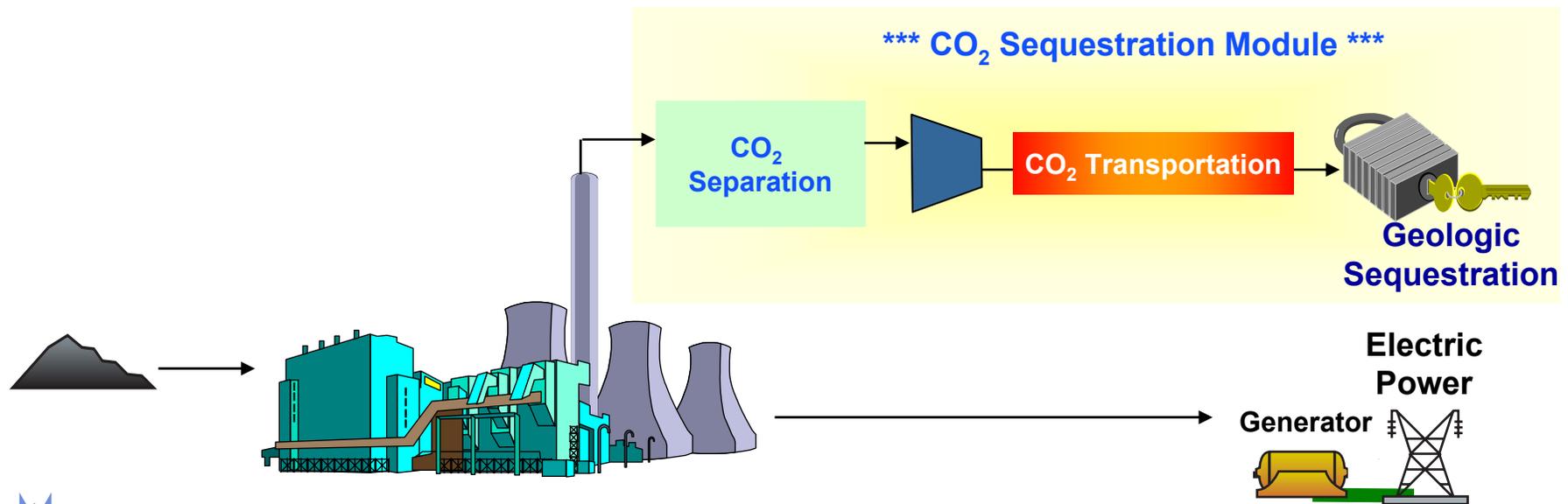


Sources: IECM Calculations

Objectives

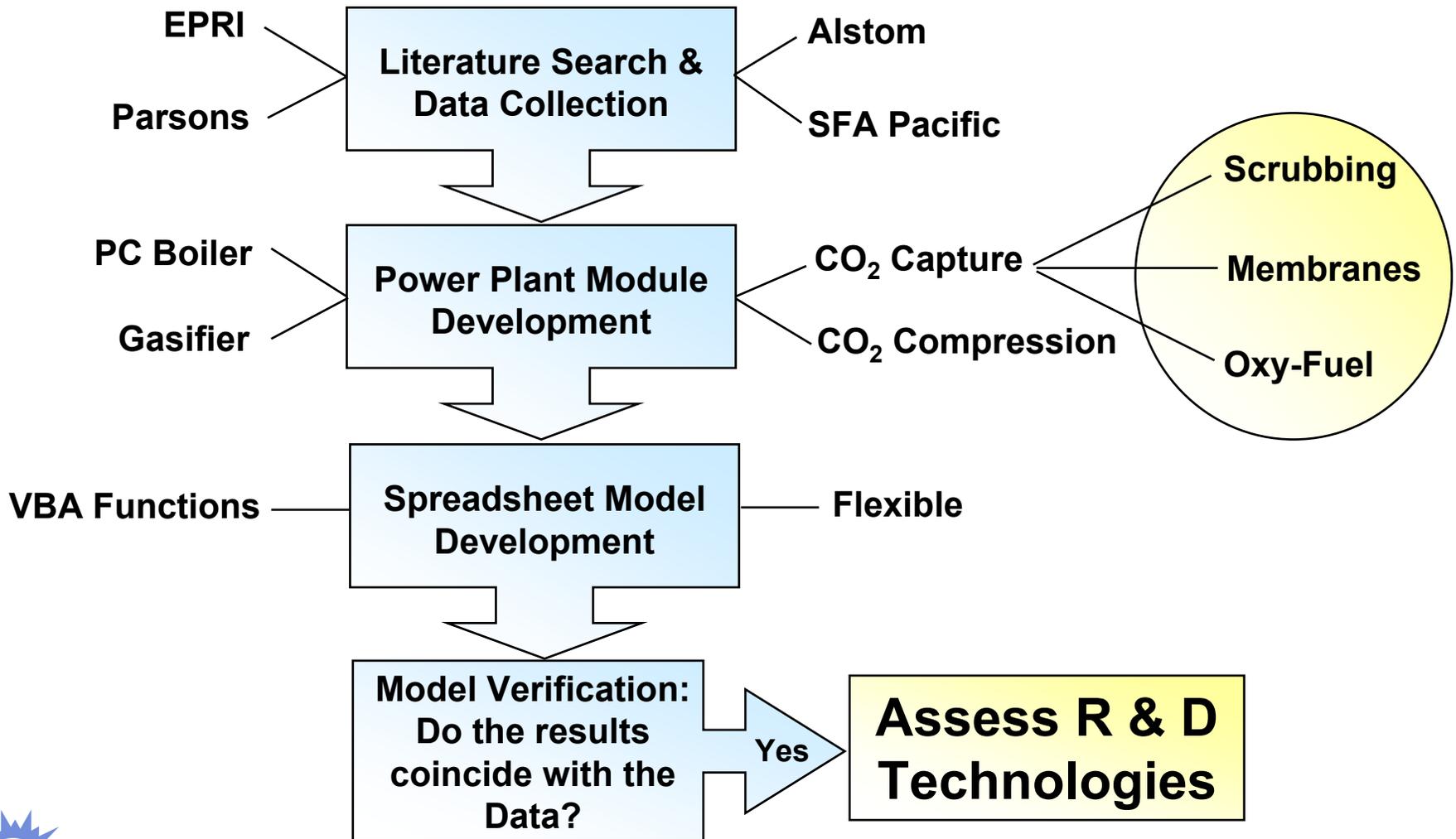
Analyze Detailed Component Costs for Capture & Storage to:

- Determine where the R&D should be focused
- Determine “best case” potential for R&D portfolio



Methodology

Don't Reinvent the Wheel for Current Technologies



Scenarios

Many Advanced Integrated Schemes Emerging

Coal Gasification

- ✓ CO₂ Hydrates
 - ✓ Membranes
 - ✓ Advanced Scrubbers
 - ✓ Inexpensive Oxygen
- Chemical Looping



Pulverized Coal

- ✓ Oxygen Combustion
 - ✓ Membranes
 - ✓ Advanced Scrubbers
 - ✓ New Sorbents
- Mineral Carbonation
- Chemical Looping

Pathways to Zero Emissions

Producing a concentrated stream of CO₂ at high pressure:

- Improves sequestration economics
- Reduces energy penalty



✓ Technology Currently Being Evaluated

Key Assumptions

Economic Parameters

Capital Charge Factor (%)	14.5
Dollars (Constant)	2001
Plant Life (Years)	20
Coal (\$/ton)	28

System parameters

Capacity Factor (%)	65
% CO ₂ Capture*	90
Pipeline Distance (miles)	50
Saline Injection Pressure (psia)	1,500

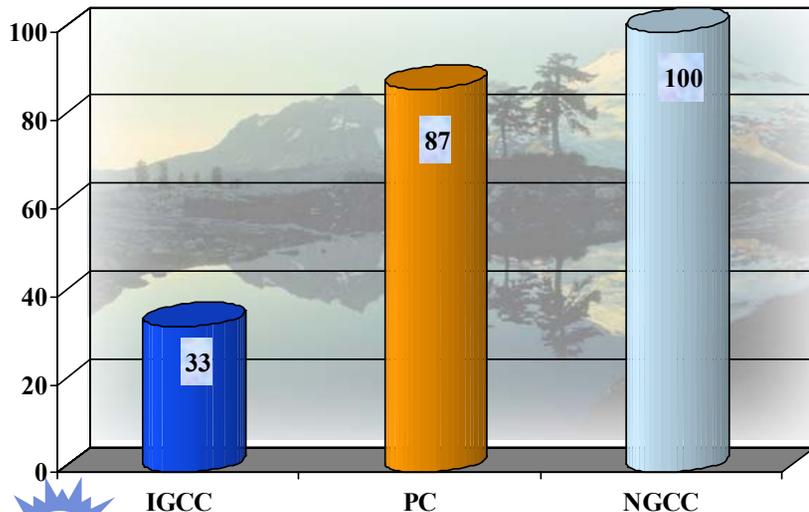


*Most Cases

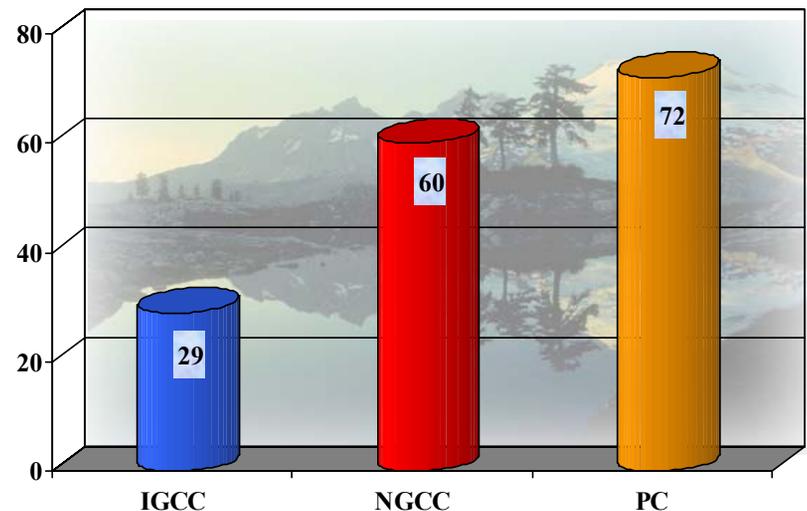
Status of Current “Best Case” Technologies *Using State-of-the-Art Scrubbing Technologies*

- 5 to 30% Parasitic energy loss
- 30 to 100% Increase in capital cost
- 25 to 100% Increase in cost of electricity

Effect of CO₂ Capture on Capital Cost
(% Increase Resulting From CO₂ Capture)

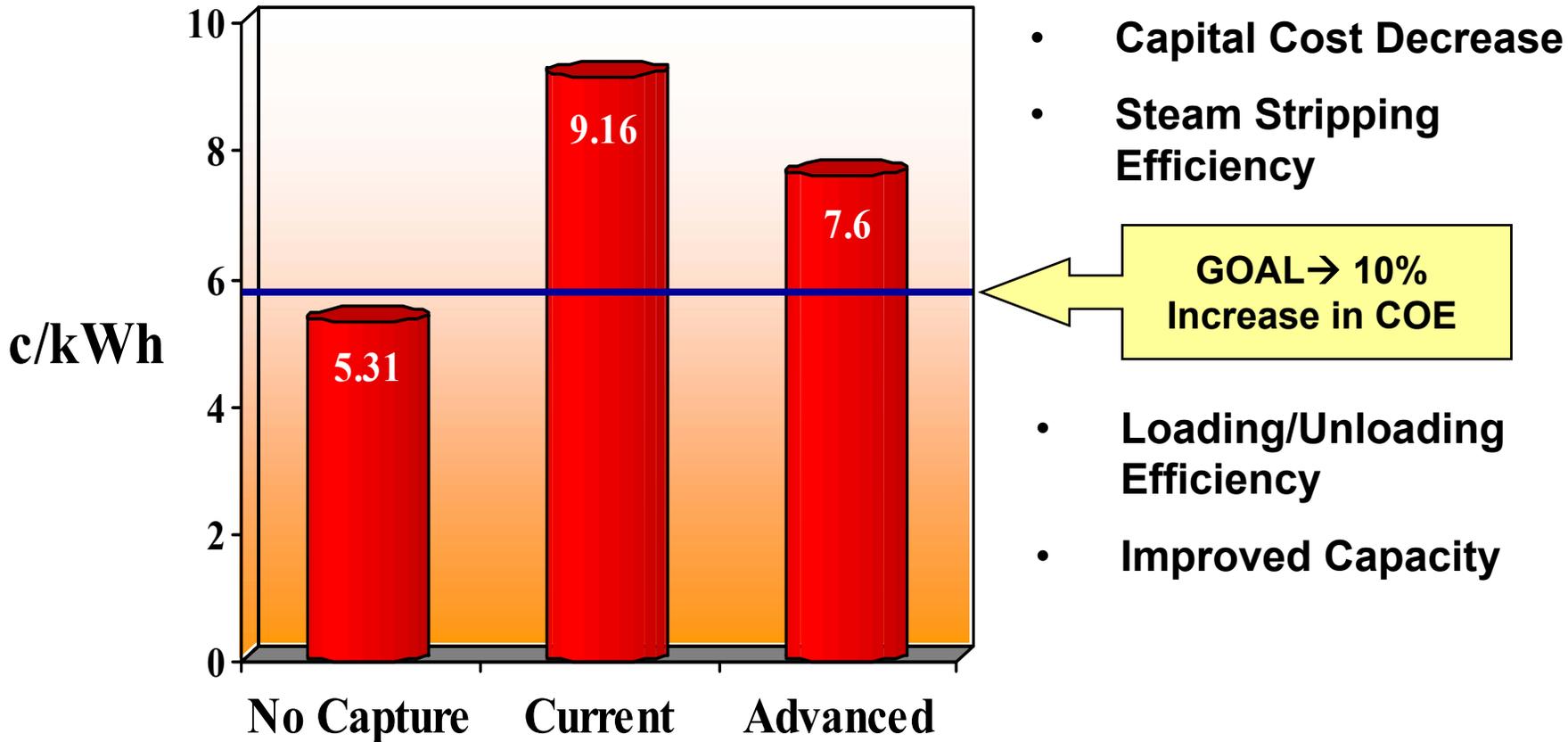


Effect of CO₂ Capture on Cost of Electricity
(% Increase Resulting From CO₂ Capture)



Analyses Allows Us To Dissect Economics

Where Should R&D Best Focus?

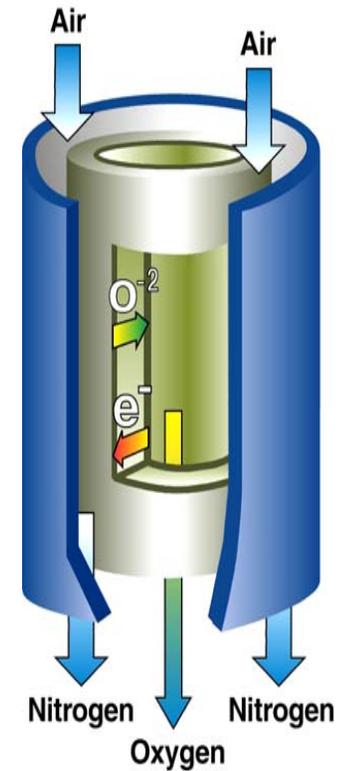


PC with Amine Scrubbing

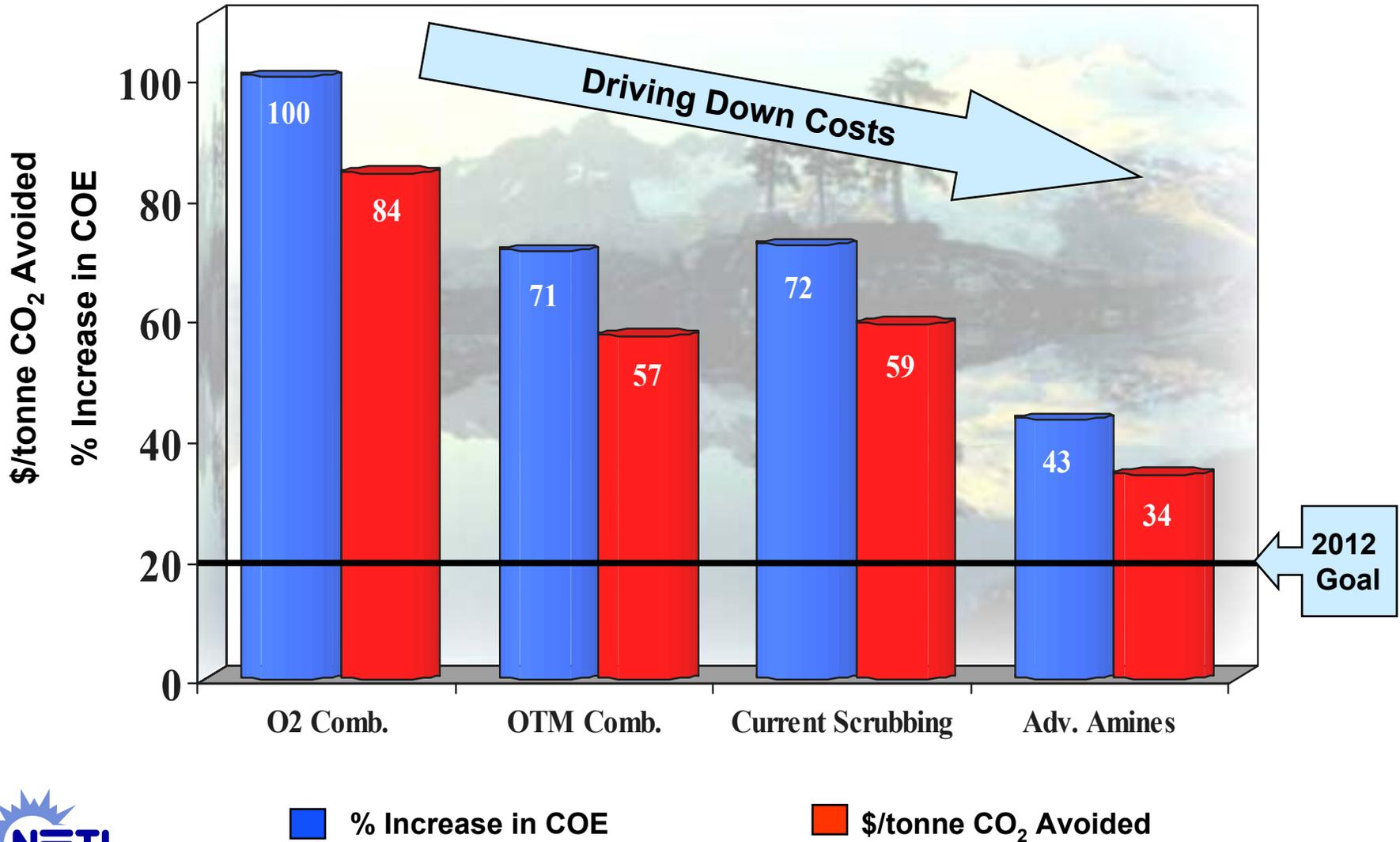


Pulverized Coal Scenarios

- Current Scrubbing - Chemical Absorbents (MEA)
- Advanced Scrubbing
- Oxy-Fuel Combustion
- Oxygen Transport Membrane



Marching Toward The Goals - PC Power Plant



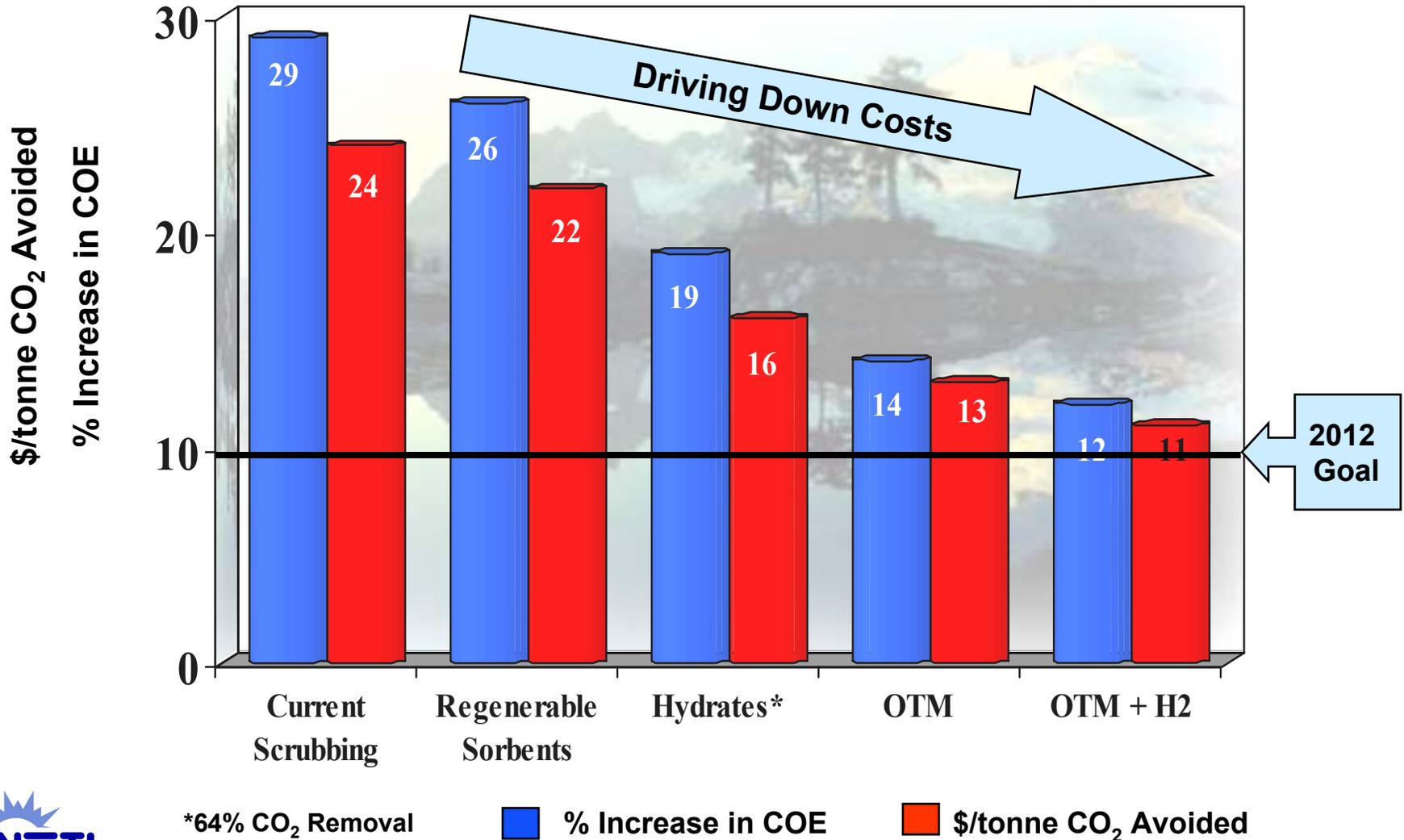
IGCC Scenarios

- **Current Scrubbing - Physical Absorbents (Selexol)**
- **Oxygen Transport Membranes**
- **CO₂ Hydrates**
- **Dry Regenerable Sorbents**



*Tampa Electric Co.
IGCC Polk Power Station*

Marching Toward The Goals - IGCC Power Plant



Future Work

- **Continuous feedback loop with emerging R&D**
- **Add new technologies as appropriate (e.g. chemical looping, mineralization)**
- **Mesh R&D technology pathways directly to program goals**
- **Develop “dynamic” documentation on results and methodology**