2014 Transformational Carbon Capture Technology Workshop:

Interpreting "Transformational"

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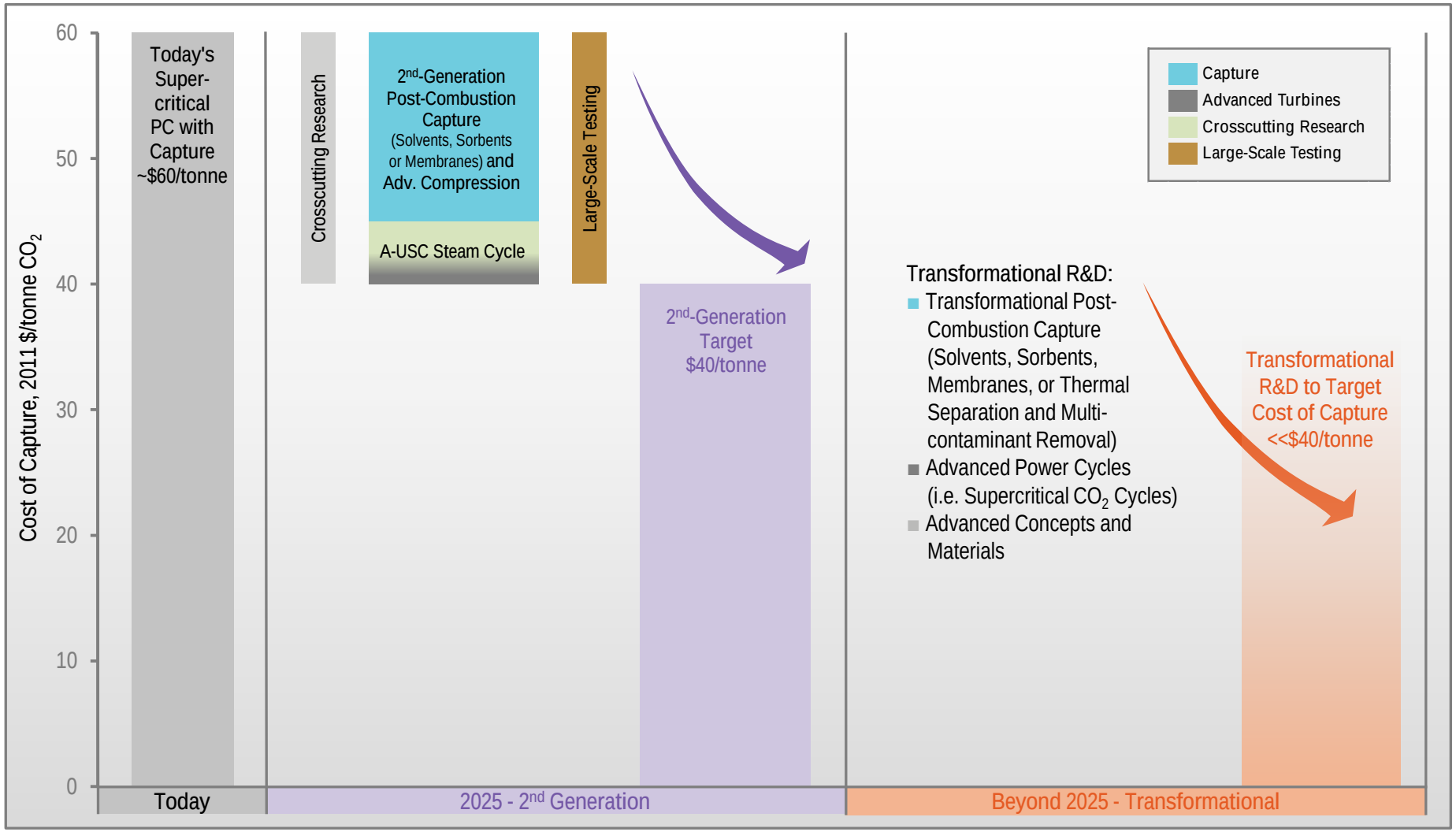
What Exactly Does Transformational Carbon Capture Technology Look Like?

We Don't Know…

But We Know What it Should Do for Us

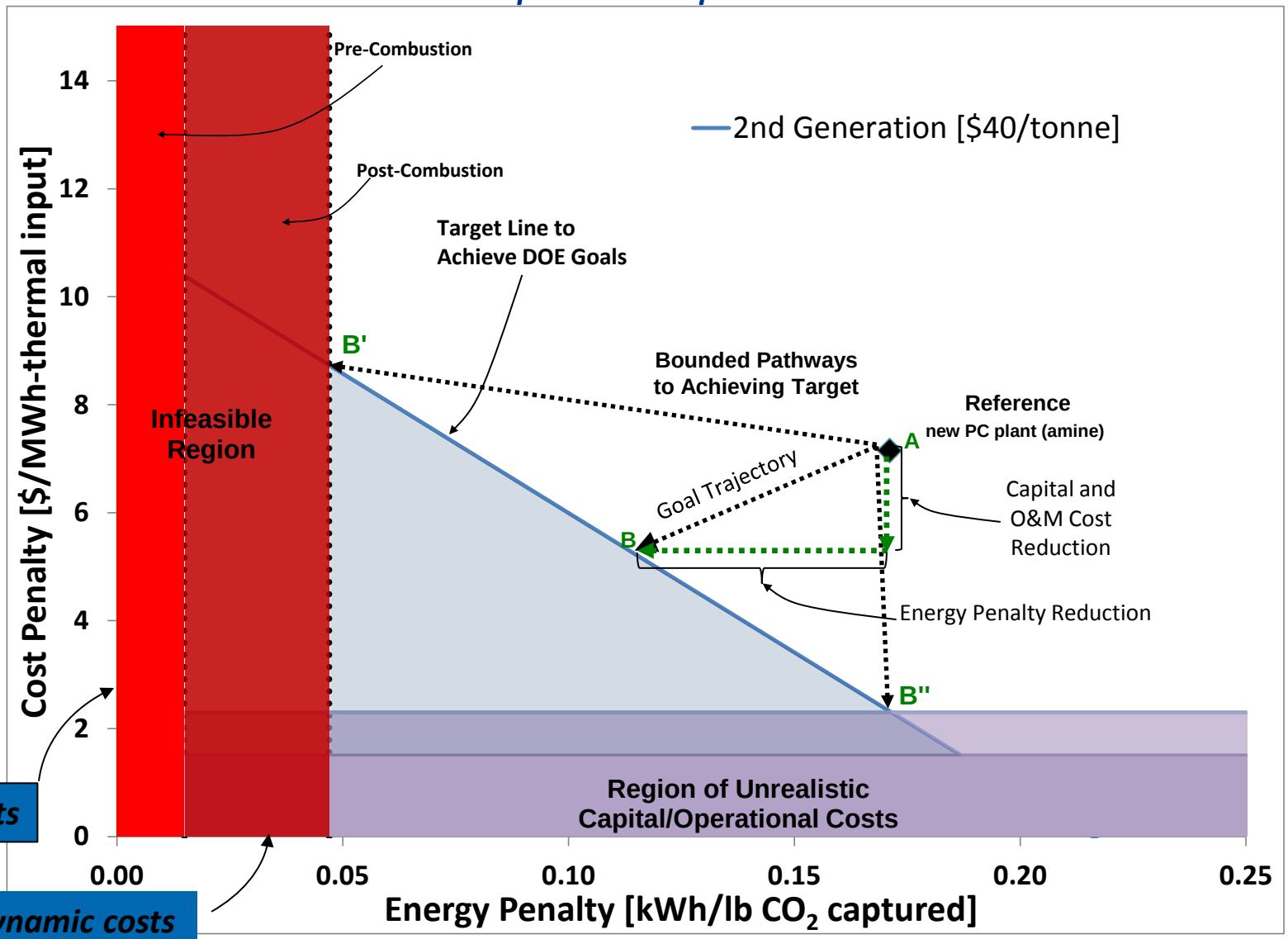
R&D Driving Down the Cost of CO_2 Capture

Greenfield Post-Combustion Capture Plants



R&D Trajectories for Achieving CCRP Goals

Via Carbon Capture Improvements



Financial costs

Thermodynamic costs

**Based on improving the cost and performance of only Capture technology to capture CO2 from today's $60/tonne with no balance of plant improvements*

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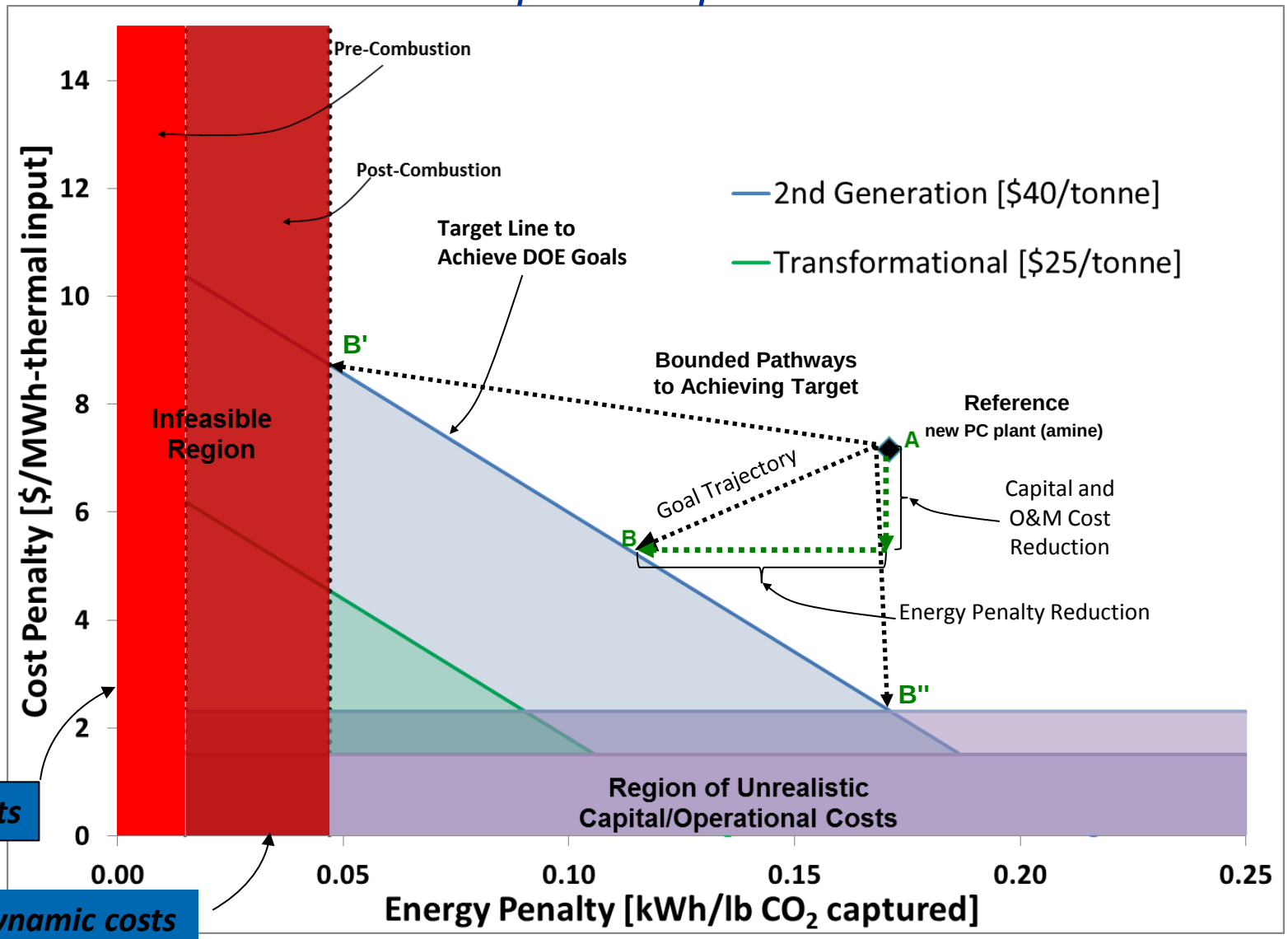

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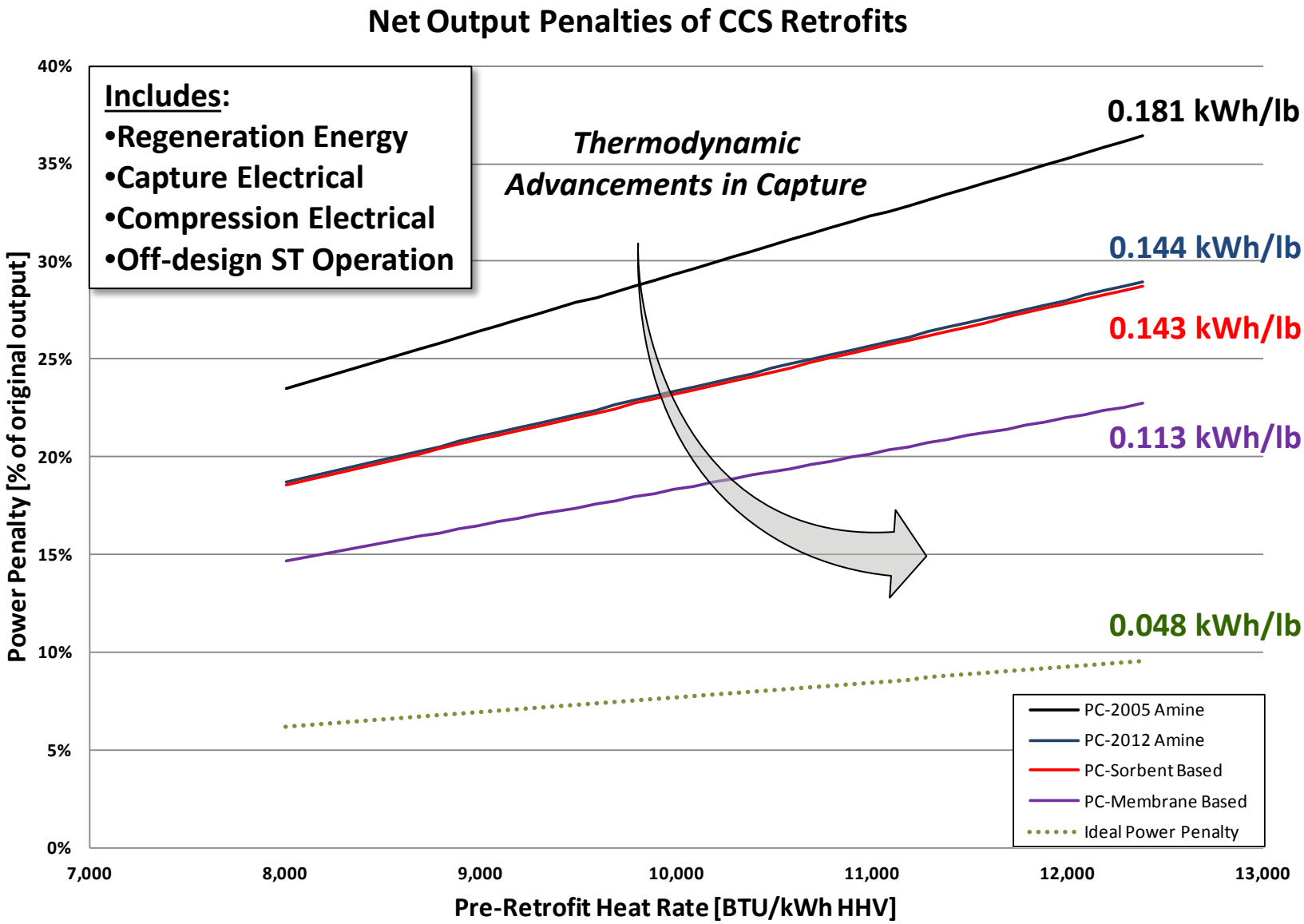
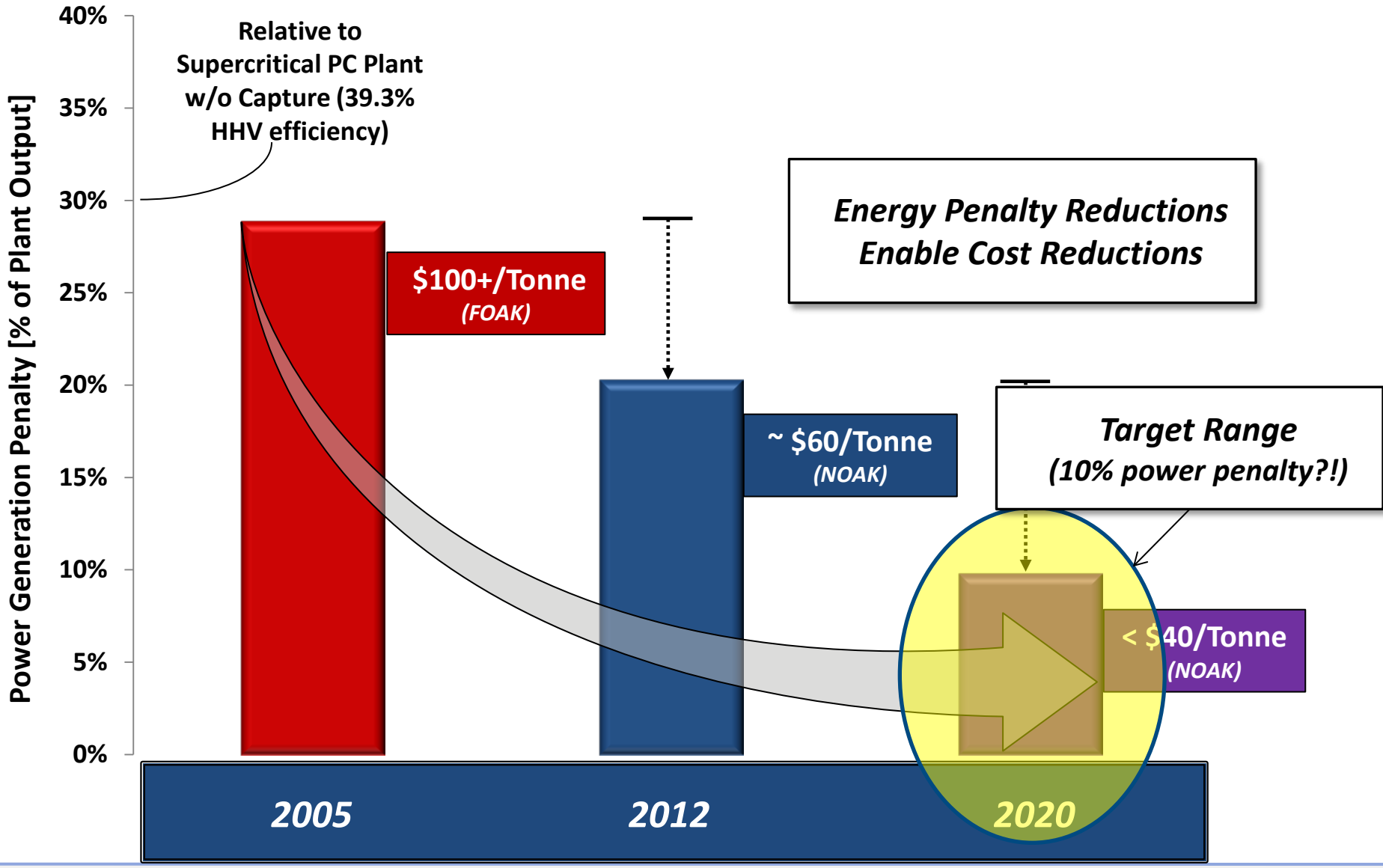
Improvements in Net Derate Projections*



As evaluated on baseline existing plant. Does not include balance of plant improvements

Great Strides Made in Clean Coal R&D

Thermodynamic Improvements Drive Cost Reductions



But How Do We Get There?

We Require Balance of Plant Improvements

How Much Better Can Carbon Capture Get?

Room for Carbon Capture Penalties to Improve

Power Platform	Ideal CCS Requirement [kWh/lb CO_2]*	Obs. CCS Requirement [kWh/lb CO_2]	Capture + Compression Efficiency [%]	Approach to Ideal CCS [kWh/lbCO_2]
PC	0.04780	0.144-0.177	27-33%	0.096-0.129
IGCC	0.01497	0.105-0.177	8-14%	0.090-0.162
Oxy	0.04759	0.133-0.162	29-36%	0.085-0.114

Reversible System Requirements*

Various Power System Study Results

W_{ideal}/W_{actual}

$W_{actual} - W_{ideal}$

- **CO_2 separation from flue gas and O_2 separation from air very similar**
- **High Pressure/High Concentration CO_2 in syngas more favorable for CCS**
- **Pre-combustion may have most room for improvement**

**IGCC assumes WGS, CO_2 separation, & compression to be the only additional processes required for CCS. PC – CO_2 sep & comp. Oxy – O_2 sep & comp.*

How Should Carbon Mitigation be Improved?

- **In context of *<u>potential for overall thermodynamic improvement</u>*, Exergy Analysis suggests ordered priority in low-carbon power research:**
  1. Fuel energy conversion/transfer (*Adv. Combustion, Adv. Research, Gasification, Fuel Cells*)
  2. Prime mover improvements (*Turbines*)
  3. CO_2 Capture Improvements (*Carbon Capture*)
- **However, <u>in context of CO_2 mitigation & climate change</u>, 90% CO_2 capture has 300% more effect than the best anticipated coal conversion improvements***
  - Projected coal-fired IGFC performance w/o CCS ~6,000BTU/kWh or ~1,350 $lbCO_2$ generated/MWh_{net} (~29% CO_2 reduction/MWh_{net})

**BB Case 9 vs. Case 10 CO_2 emissions reduction compared to CO_2 emissions reductions in going from Case 9 to IGFC in IGCC Pathway Study*

Where Can We Improve Most?

Example – PC w/CCS

1. **For combustion-based example, *nearly 60% of the lost potential for power generation* is in the transfer of high temperature combustion heat to low(er) temperature steam**
   - ΔT = ~2,000°F. *Large driving force = Large entropic losses*
   - Advanced steam cycles narrow this gap, reducing entropic loss
2. **Turbine and condenser operation next**
   - Together ~25% of steam generation losses
3. **SOA capture and compression next highest loss**
   - ~20% of steam generation losses. Nearly 3/4^{ths} of this in capture
   - SOA capture ~20% efficient. Compression ~75%.*

➢ **Advanced combustion and capture must work together to intensify the system and offset CO_2 capture and compression losses**

- Other transformational fossil fuel conversion platforms may be more successful than conventional combustion. e.g. OTM drives O_2 separation via partial combustion and expansion.

**On a 2nd Law basis*

For More Information About the NETL Carbon Capture Program

- **NETL Website:**
  - **www.netl.doe.gov**

- **Capture Program Website:**
  - **www.netl.doe.gov/technologies/coalpower/ewr/co2/index.html**

Reference Shelf

- **Annual CO_2 Capture Meeting**

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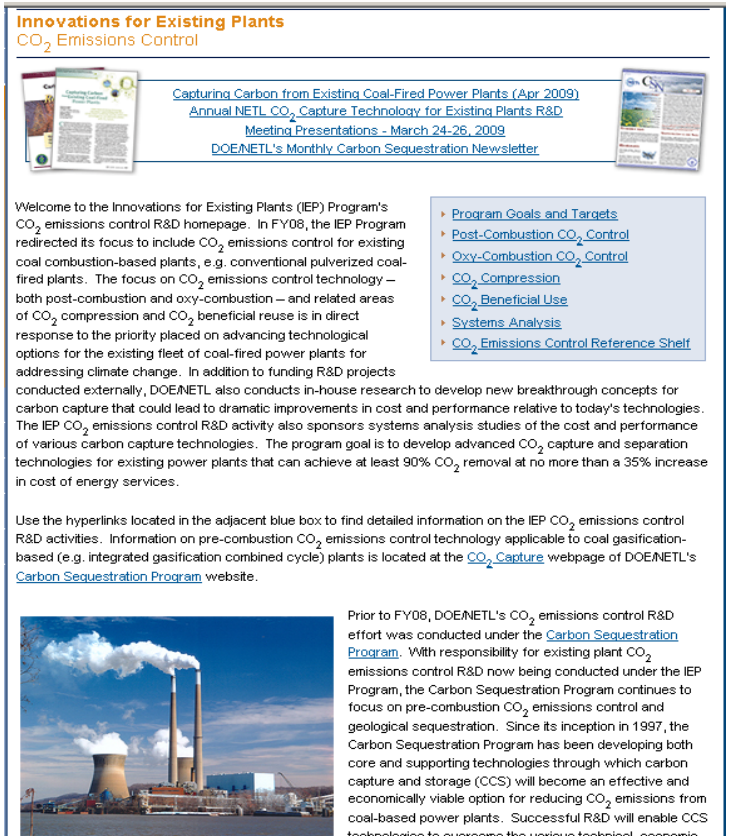
- **Office of Fossil Energy website:**
  - **www.fe.doe.gov**



Innovations for Existing Plants
CO_2 Emissions Control

Capturing Carbon from Existing Coal-Fired Power Plants (Apr 2009)
Annual NETL CO_2 Capture Technology for Existing Plants R&D Meeting Presentations - March 24-26, 2009
DOE/NETL's Monthly Carbon Sequestration Newsletter

- Program Goals and Targets
- Post-Combustion CO_2 Control
- Oxy-Combustion CO_2 Control
- CO_2 Compression
- CO_2 Beneficial Use
- Systems Analysis
- CO_2 Emissions Control Reference Shelf

Welcome to the Innovations for Existing Plants (IEP) Program's CO_2 emissions control R&D homepage. In FY08, the IEP Program redirected its focus to include CO_2 emissions control for existing coal combustion-based plants, e.g. conventional pulverized coal-fired plants. The focus on CO_2 emissions control technology – both post-combustion and oxy-combustion – and related areas of CO_2 compression and CO_2 beneficial reuse is in direct response to the priority placed on advancing technological options for the existing fleet of coal-fired power plants for addressing climate change. In addition to funding R&D projects conducted externally, DOE/NETL also conducts in-house research to develop new breakthrough concepts for carbon capture that could lead to dramatic improvements in cost and performance relative to today's technologies. The IEP CO_2 emissions control R&D activity also sponsors systems analysis studies of the cost and performance of various carbon capture technologies. The program goal is to develop advanced CO_2 capture and separation technologies for existing power plants that can achieve at least 90% CO_2 removal at no more than a 35% increase in cost of energy services.

Use the hyperlinks located in the adjacent blue box to find detailed information on the IEP CO_2 emissions control R&D activities. Information on pre-combustion CO_2 emissions control technology applicable to coal gasification-based (e.g. integrated gasification combined cycle) plants is located at the CO_2 Capture webpage of DOE/NETL's Carbon Sequestration Program website.

Prior to FY08, DOE/NETL's CO_2 emissions control R&D effort was conducted under the Carbon Sequestration Program. With responsibility for existing plant CO_2 emissions control R&D now being conducted under the IEP Program, the Carbon Sequestration Program continues to focus on pre-combustion CO_2 emissions control and geological sequestration. Since its inception in 1997, the Carbon Sequestration Program has been developing both core and supporting technologies through which carbon capture and storage (CCS) will become an effective and economically viable option for reducing CO_2 emissions from coal-based power plants. Successful R&D will enable CCS

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