Future of CCS Technology Adoption at Existing PC Plants

CO_2 Capture Technology Meeting—Pittsburgh, PA
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Project Overview

- FY2012 Funding: $275K
- Project funds remaining: $110K

- Staff
  - Donald Hanson, Ph.D., energy economist
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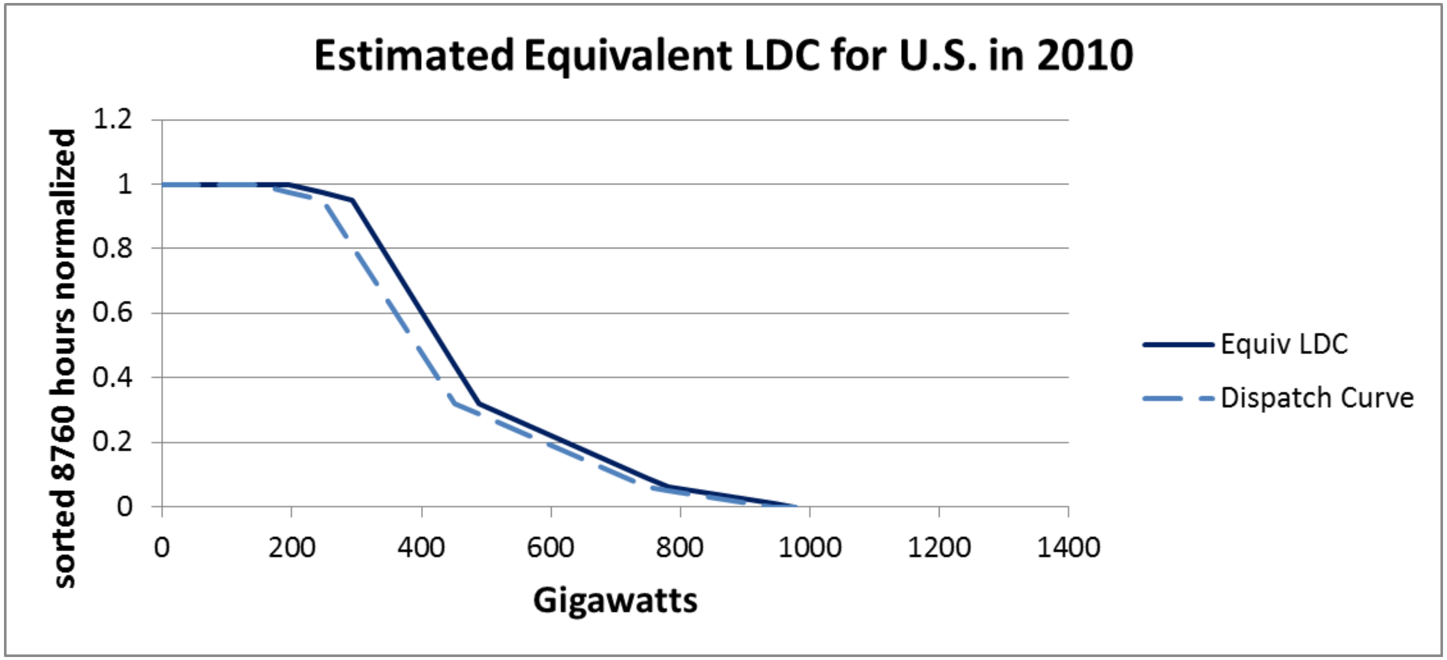
- Broad Objectives
  - Learn lessons about the economic adoption of CCUS technology under a range of different scenarios
  - Prepare a report highlighting key findings from the modeling and analysis
  - Simulate oxycombustion and amine-based processes using ASPEN
  - My focus for the presentation is on the former. We examine CCUS adoption implications within a power systems context

The shape of the equivalent Load Duration Curve (eq. LDC) is elongated at peak load to account for probabilities of unit forced outages. We fit the eq LDC to 2010 data (solid line).

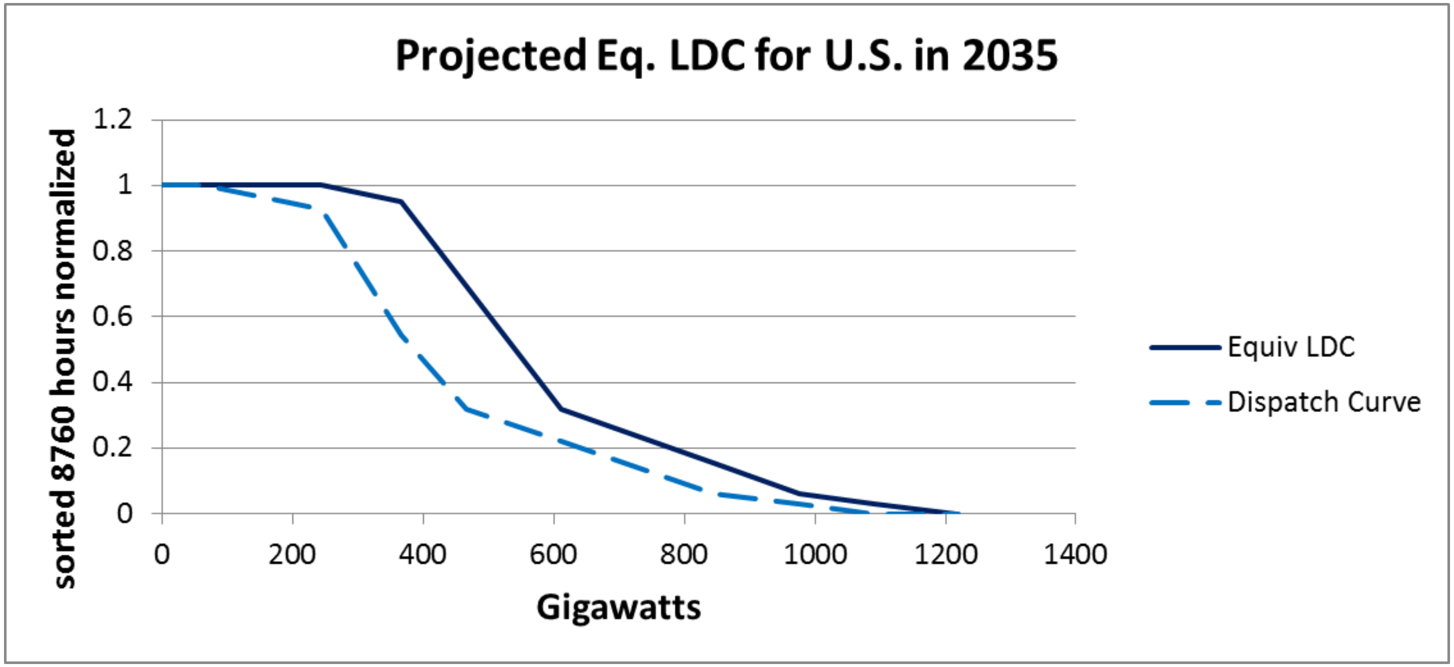


Construction of the Dispatch Curve from the LDC

- Non-dispatchable intermittent generation (e.g., wind and solar) must be subtracted from the eq LDC.
- Wind and solar generate a greater portion of power off-peak, leading to only a small capacity credit
- Hydropower is partially dispatchable, shifting its generation toward peak load
- Available dispatchable units are then stacked on the remaining load curve, shown in the previous Figure as a dashed line

By 2035, the size and shape of the eq LDC and dispatch curve have changed:

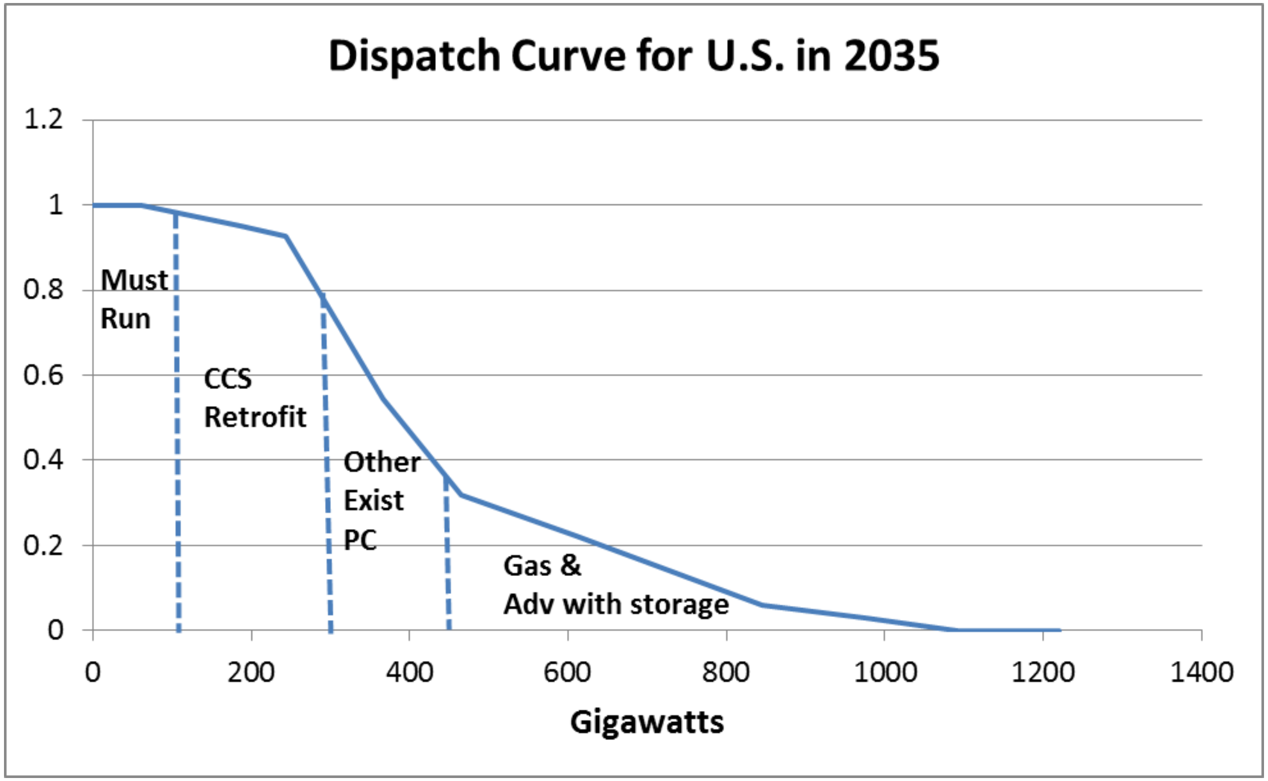
- more generation (greater area)
- greater peak load, but with some shift toward base
- more subtraction of intermittent renewables.
- high renewable penetration imposes a high systems cost



Units are loaded in order of least to highest variable costs, including any emission charges

- Must Run Units
  - Nuclear power
  - Opportunity fuels (wastes and biomass) co-fired with coal (CFBC)
  - CHP units
- Existing units retrofitted with CCS
- Not retrofitted coal units that choose to pay emission charges
- Advanced generation technologies with electricity storage (sells electricity at times of high-value)
  - E.G., IGCC co-production plants with pre-combustion CCS (may be of interest to refinery sector)
- Gas (e.g., NGCC, peaking turbines)

After PC units are retrofitted with CCS, their utilization increases.



Units Retrofitted with CCS will obtain a partial Generation Offset due to movement up the LDC

- For 162 existing PC units that were retrofitted by 2035 in a typical model simulation, on average, their generation after the retrofit was 8.2 percentage points higher than the year before retrofit.
- This increased utilization of retrofitted units offsets about 1/3 of the derated capacity (parasitic plant electric load due to CO_2 capture and compression). For example, if a unit were capacity derated by 28.2%, its net generation on average would be reduced by 20%, the difference being the increased utilization of the retrofitted unit.
- The 8.2 percentage point increase in utilization significantly increases the economics and attractiveness of CCS.

There is a lot of important specific unit variation

- The gain in generation after retrofit varies from 5 to over 15 percentage points. Units which had been operating with relatively lower capacity factors are likely to get a better than average increase from refurbishment and CO_2 capture.
- Some plants my choose not to retrofit, avoiding the retrofit costs and capacity derate. But the reverse effect will apply to these units. Their variable costs will likely rise in the future, if there is a CO_2 emissions charge. These units will slip down the loading order reducing their utilization and income streams. Eventually they may not be profitable and retire.
- With the diversity of unit characteristics, “command and control” regulations would substantially deviate from a least cost approach to a future CO_2 emissions target

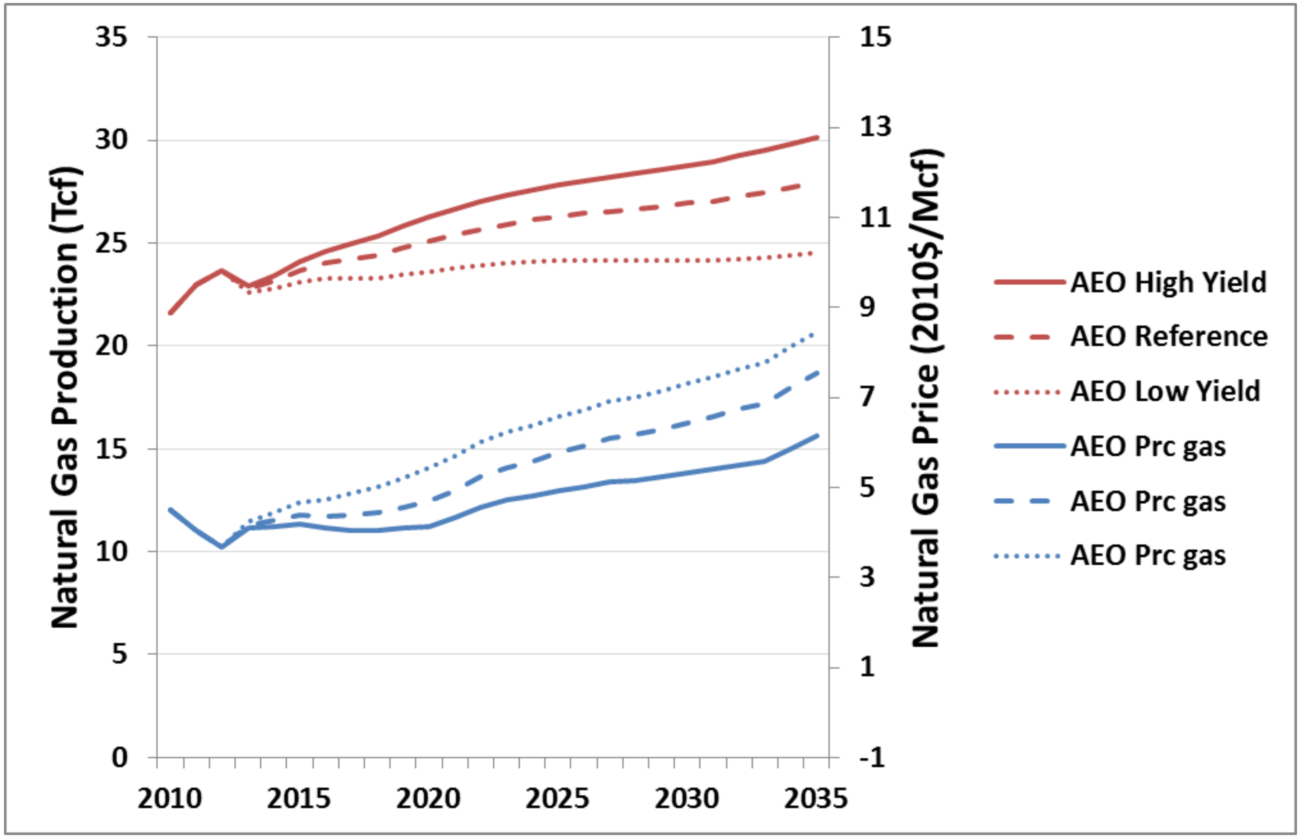
We have focused on three critical scenario drivers

- Higher and Lower Shale Gas production
  - Assumptions are based on EIA’s AEO 2012
- Higher and Lower electricity demand
  - More or Less vehicle electrification
  - Other electrification opportunities
  - Accounting for potential impact of smart grid
- Higher rates of technical progress in CO_2 capture technology
  - Many innovations are being pursued to lower the energy requirements for CO_2 capture

Features of our Natural Gas Module

- Three scenario options ("shifts in supply function")
  - AEO 2012 Reference case assumptions
  - Higher shale gas well production assumptions
  - Lower shale gas well production assumptions
- Gas supply types included: shale, conventional, Alaskan
- Using data from the sensitivity cases in the AEO 2012, we employ Identification Theory in economics to estimate the price responsiveness of these gas supply functions over time (price movements "along the supply curve")
- Under a CO_2 reduction regime, demand for gas rises, increasing both gas production and gas prices (typically by about $2/Mcf)

Our updated Gas Supply Module is calibrated to the recent Final AEO 2012, with High, Reference, and Low scenario supply function options



Lessons Learned from the Scenario Analysis

- Need for CCS is robust across scenario variability under a CO_2 reduction regime
  - More gas penetration would displace both higher and lower sources of CO_2 emissions, leaving the need about the same for CCS as part of a CO_2 reduction effort
  - Higher electrification will support more of most all generation technologies including CCS
- We find that price/cost impacts are just as important scenario adjustments as supply and demand quantity changes.
  - Higher rates of technical progress in CO_2 capture energy reductions will lower costs, which can be passed on to consumers
  - Alternative shale gas scenarios will imply different energy prices as well as the amount of gas used

Lessons Learned (continued)

- Any CO_2 emissions charge would need to be capped in the $30-35 range.
  - Higher CO_2 charges would induce instability in gas and electricity markets.
  - Gas units would be dispatched before coal units, driving up gas demand and price, making the coal units economic to run again
  - Instability in gas and electricity markets would discourage new investments
- CCS adoption can play an important role in limiting price of electricity increases
  - Wellhead gas prices would be higher under a CO_2 reduction case due to increased gas demand, increasing electric rates
  - Diversifying generation sources can take the edge off of high gas prices, as captured by our gas supply scenario model.
  - There would be a benefit of cost sharing CCS adoption using revenue collected by a CO_2 charge.

Understanding Market Investment Issues

- PJM, a leader in electric power market design, summarizes its markets in the following review paper: *A Review of Generation Compensation and Cost Elements in the PJM Markets*, PJM, 2009.
- http://www.pjm.com/documents/~/media/documents/reports/a-review-of-generator-costs-and-compensation.ashx
- PJM has also begun to think about the integration of CO_2 reduction incentives within the PJM system: *Potential Effects of Proposed Climate Change Policies on PJM's Energy Market*, PJM, 2009.
- http://www.pjm.com/documents/~/media/documents/reports/20090127-carbon-emissions-whitepaper.ashx

FY2012 work being completed and next steps

- Deliverables for FY2012
  - Summary report describing key findings for the shale gas, electricity demand, and technology driver scenarios
  - Disseminate the model run results and analysis via journal articles and presentations
  - End of year interim Technical Report
- Planned focuses in FY2013
  - Examine CCUS implementation approaches, e.g., through capacity markets such as the PJM market; regulated regions; etc.
  - Demonstrate how CCUS adoption can lower electricity price increases
  - Expand the scenario analysis to include oil security associated with more transportation electrification
  - Complete major technical report
  - Update model documentation for our electric power sector model, gas module, and vehicle and transportation energy model

Technical Appendices

- To be added to the posted presentation version

All Modular Integrated Growth Assessment (AMIGA) System *simplified*