JISEA Joint Institute for Strategic Energy Analysis

Natural Gas Dynamics and U.S. Electric Power Futures

Preliminary Results

National Association of Clean Air Agencies
2012 Fall Membership Meeting

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Today's Talk

- Electric Power Market Snapshot
- Background on JISEA Study
- Electric Power Futures
  - Baseline
  - Coal Retirements
  - Clean Energy Standard
  - NG Supply: Social License to Operate Costs

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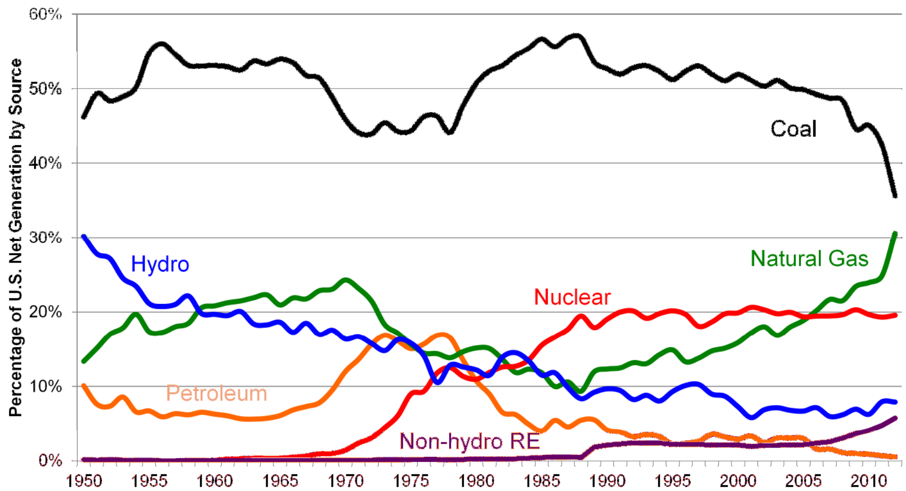
U.S. Power Sector Dynamics



Source: EIA, "Annual Energy Review," October 2011; EIA, "Electric Power Monthly," August 26, 2012. Data for 2012 includes generation through June.

Coal Percentage Down from 48% in 2008 to 35% in June 2012;
300 Million Tons of annual CO_2 mitigation (13% of total power sector)

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Background on Study

- Multi-client sponsor group composed on natural gas producers, utilities, transmission companies, investors, researchers, and environmental NGO
- Scoping workshop in Spring 2011 prioritized research questions
- Work began in Summer 2011 with 3 research thrusts:
  - Lifecycle GHG attributes of shale gas (NREL)
  - Regulatory and best management practice trends in different regions (CU School of Law; CSU Engineering; CSM; Stanford)
  - Modeling of various power sector futures using ReEDS (NREL)
- Study to be released next month

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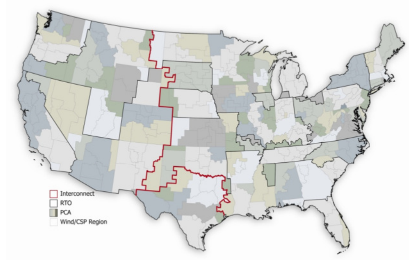
Regional Energy Deployment Systems (ReEDS)

- **Capacity expansion & dispatch** for the contiguous US electricity sector including transmission & all major generator types
- **Minimize total system cost** (20 year net present value)
  - All constraints (e.g. balance load, planning & operating reserves, etc.) must be satisfied
  - Linear program (w/ non-linear statistical calculations for variability)
  - Sequential optimization (2-year investment period 2010-2050)
- **Multi-regional** (356 wind/solar resource regions, 134 BAs)
  - regional resource characterization
  - variability of wind/solar
  - transmission capacity expansion
- **Temporal Resolution**
  - 17 timeslices in each year
  - each season = 1 typical day = 4 timeslices
  - 1 summer peak timeslice



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Scenario Framework

Coal Scenarios

- **Coal Retire** (80 GW by 2020)
- **No New Coal** (NSPS)

Clean Electricity Standard Scenarios

- **CES – Low-EUR**
- **CES – High-EUR**
- **CES – High-EUR, No-CCS**

Reference Scenarios

- **Baseline**
  - No New Policy
  - Conservative Technology Costs (B&V 2012)
  - AEO 2010 electricity demand, reference case non-electric sector gas demand
  - Mid-EUR
  - Standard Retirements
- **Baseline – Low-EUR**
- **Baseline – Low-Demand**

Technology Improvement Scenarios

- **Advanced RE**
- **Advanced Nuclear – Low-EUR**

Natural Gas Supply-Demand Scenarios

- **Dash To Gas – High-EUR**
- **Price Ramp +$0.5 +$1 +$1.5 +$2**

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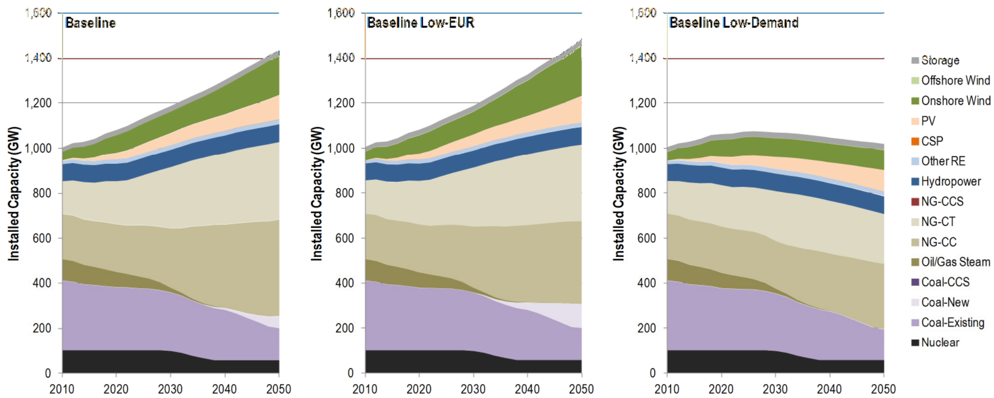
Baseline Scenarios – Capacity Expansion



- Results reflect no new policies (e.g. no clean electricity standard, no national RPS, no extension of renewable tax credits)
- Doubling of natural gas capacity by 2050
- Low EUR reduces NG capacity growth and increases coal and RE growth
- Approximately 30 GW of coal retirements by 2025; age-based retirements and load growth require significant new capacity additions in latter years
- Are we currently on the low-demand trajectory?

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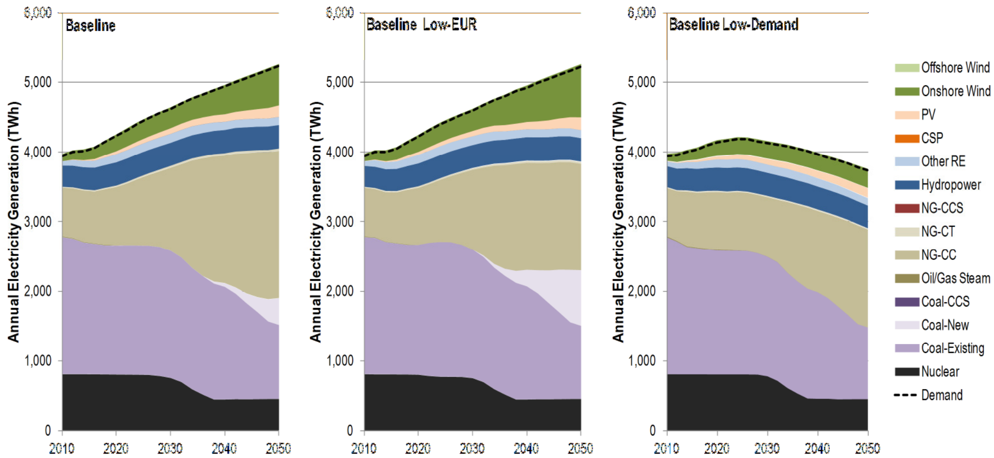
Baseline Scenarios – Generation Expansion



- In vanilla baseline, NGCC generation nearly triples by 2050; wind quadruples
- Low-EUR sees additional coal, wind after 2030; NGCC gen only doubles

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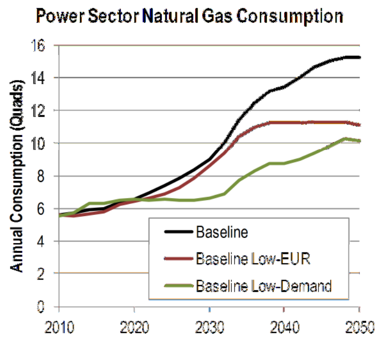
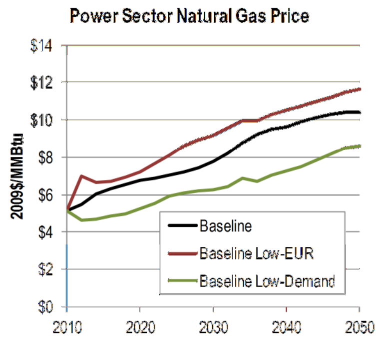
Power Sector NG Consumption and Price





- In the Baseline scenario, power sector NG consumption nearly triples over the 40-year period, while NG prices double
- In low-EUR scenario, power sector NG consumption doubles by 2050, while NG prices are $1-$1.50/MMBtu higher than the Mid-EUR Baseline
- With low demand, power sector NG consumption grows slowly until 2030, then accelerates given age-based coal and nuclear retirements
- Under Low-Demand growth, NG prices remain <$6/MMBtu for the next decade, and <$8/MMBtu for most years

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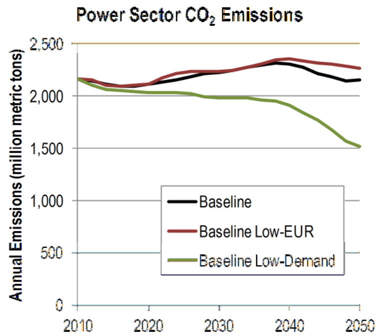
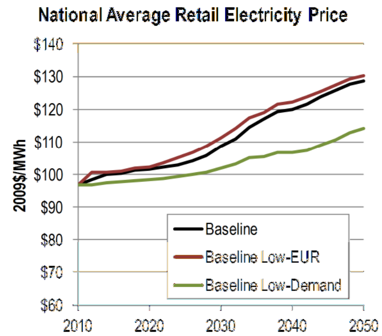
Emissions and Electricity Prices





- Even with standard load growth (~1%/year), power sector CO_2 (combustion-only) emissions are nearly flat over time due to fuel switching from coal to NG (+RE)
- Low-Demand reduces power sector CO_2 emissions by 250 MMTons/year in 2030 and 630 MMTons/year in 2050. Cumulative (2011-2050) reductions exceed 10 Gtons CO_2.
- Electricity prices (in real dollars) increase over time for all baseline scenarios, primarily as a result of load growth, coal and nuclear capacity retirements, and corresponding reliance on natural gas.
- Demand growth has a bigger influence on electricity price trajectories than EUR

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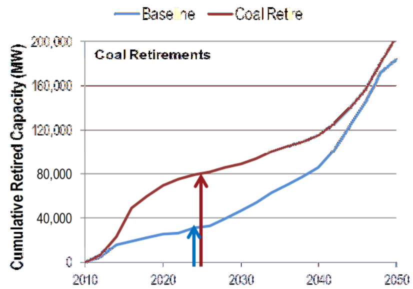
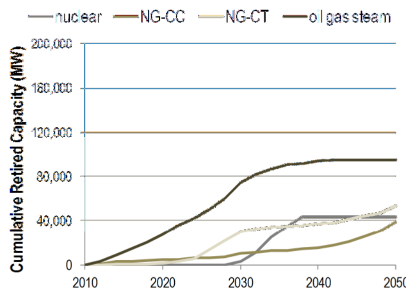
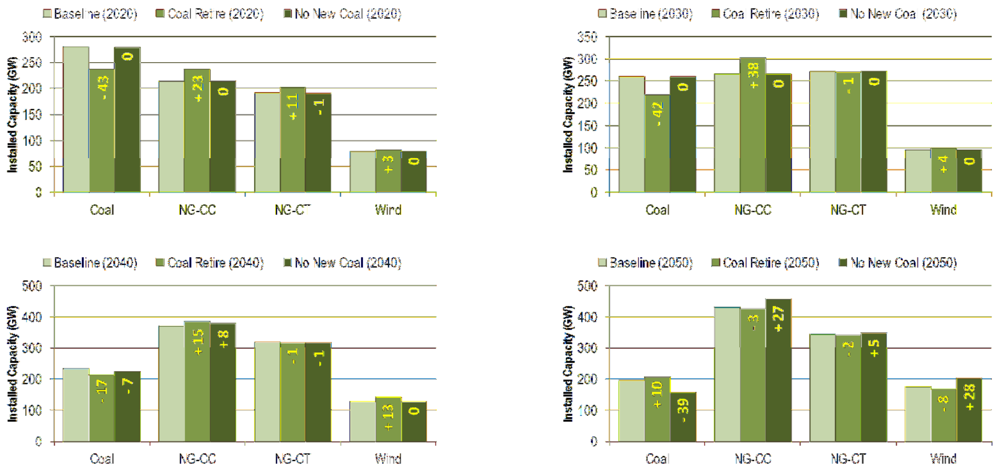
Coal Scenarios

- *Motivation*: EPA regulations (CSAPR, MATS, 316(b), CCR) accelerate motivation to retire oldest, most inefficient plants (coal + OGS); NSPS discourages installations of new pulverized (non-CCS) coal plants
- Two scenarios evaluated
  - "Coal Retire" assumes ~80 GW retired by 2025 (Baseline assumes ~30 GW retired by 2025)
  - "No New Coal" assumes no new (non-CCS) coal capacity
- ReEDS' standard treatment of retirements is based on plant lifetimes for all plant types; usage-based retirement is also considered for coal





Tradeoff Between Coal and NG (+Wind)



- Extra retired coal capacity in first two decades are largely replaced with NG capacity in the near term with little difference in the long term
- Without new coal capacity, additional NG and wind technologies are deployed in the last two decades (no effect in first two decades)

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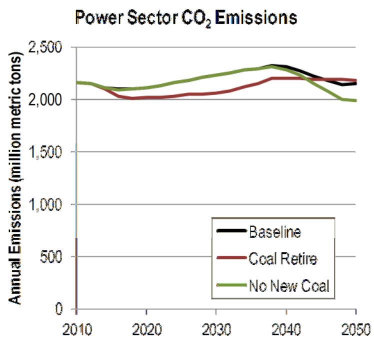
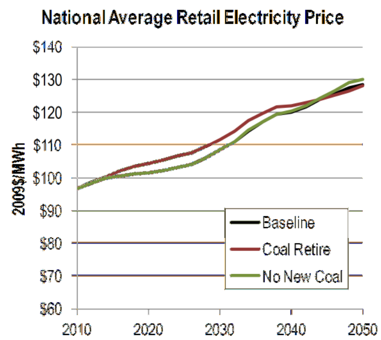
Coal Scenarios





- Near-term coal retirements can have an effect on near-term electricity prices and CO2 emissions, but little long-term effect
- Cumulative (2011-2050) avoided emissions from EPA regulation-driven retirements are ~3300 MMTons CO2
- Without new (non-CCS) coal, annual avoided emissions in 2050 are ~160 MMTons CO2 and cumulative (2011-2050) avoided emissions are ~1100 MMTons CO2. These emission savings require little incremental electricity price increases (<$3/MWh in 2050)

Clean Electricity Standard Scenarios

- Clean Electricity Standard
  - 80% clean electricity by 2035, 95% by 2050
  - Crediting: 100% for nuclear/RE, 50% for NG-CC, 95% for NG-CCS, 90% for Coal-CCS, 0% all others

- Three CES scenarios:
  - High EUR
  - High EUR, No CCS
  - Low EUR

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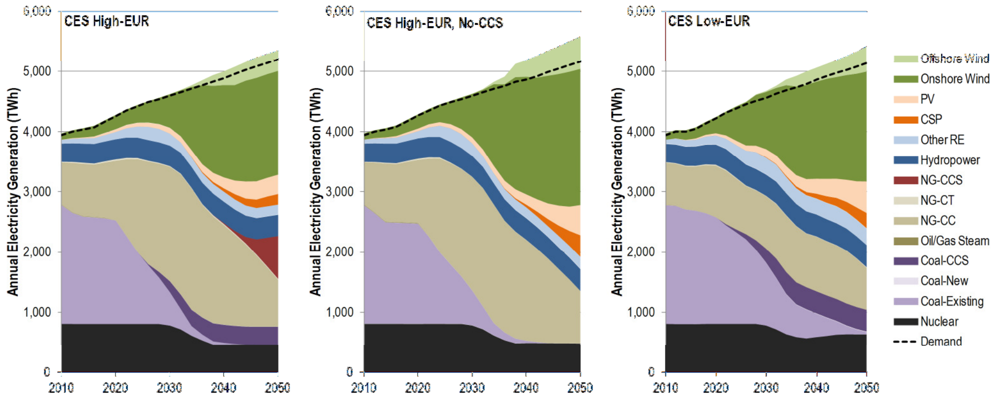
Clean Electricity Standard Scenarios



- A CES generally leads to greater NG power generation in the near-term followed by reliance on RE (and to a lesser degree, CCS and nuclear) in the long-term
- Under a CES, 2050 RE power generation is significant even with high EUR and CCS deployment: 38% wind, 9% solar, 7% hydro, 3% other RE
- New nuclear capacity expansion is more limited under cost assumptions used

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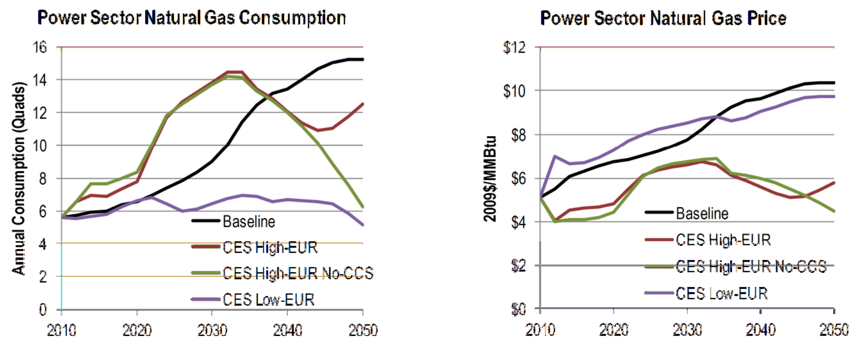
Clean Electricity Standard Scenarios



- Under a CES, sustained power sector NG consumption growth depends on the viability of CCS
- With Low-EUR, NG consumption grows slowly (compared to Baseline); RE, coal-CCS, and nuclear are much bigger contributors
- With High-EUR, NG prices remain relatively low even with significant growth in consumption

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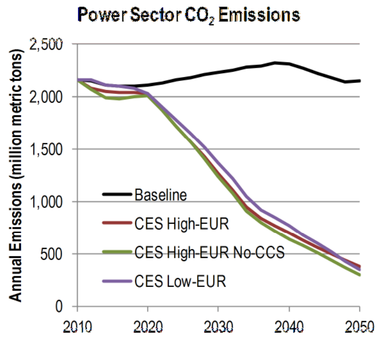
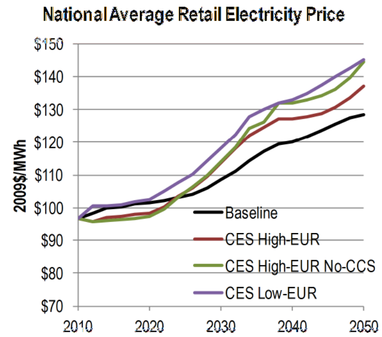
Clean Electricity Standard Scenarios





- CES can lead to deep cuts in carbon emissions (upstream and downstream emissions should also be considered)
- Abundant low cost NG (High-EUR) can help lower the cost of meeting a CES
- Availability of a greater number of clean technology options (e.g. CCS and RE) can lower the cost of meeting a CES

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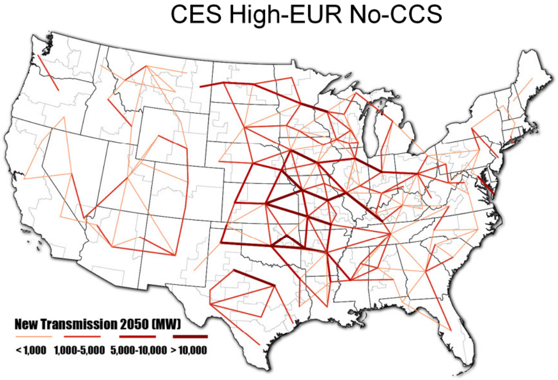
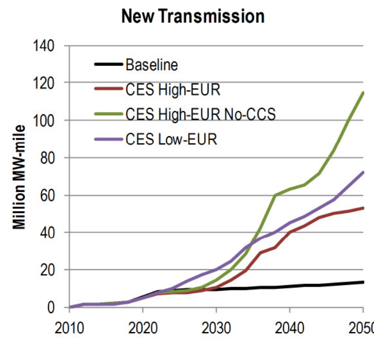
Clean Electricity Standard Scenarios

CES High-EUR No-CCS





- RE technologies can contribute significantly to meeting a CES
- Among the CES scenarios, non-hydro RE annual electricity reaches 35%-43% in 2036 and 51%-69% in 2050
- With increased RE deployment, transmission needs are increased and operational challenges (e.g. curtailment) are increased

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NG Supply Variation Scenario

- NG supply-demand sensitivity scenarios
  - Raise *supply curve* by $0.5/MMBtu increment up to +$2/MMBtu for each year starting in 2012
  - *Motivation*: Explore how additional supplier costs would effect power sector evolution (e.g. costs of best practices, regulations, social license to operate: well set-backs, greener frack-fluids, water recycling, green completions, well completions/monitoring, etc.)

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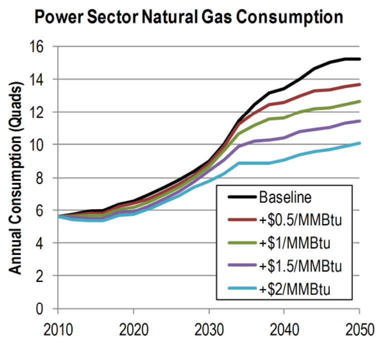
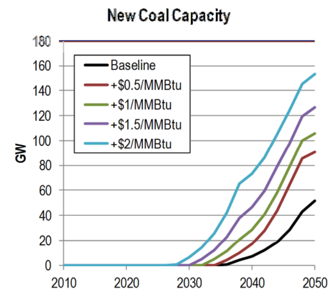
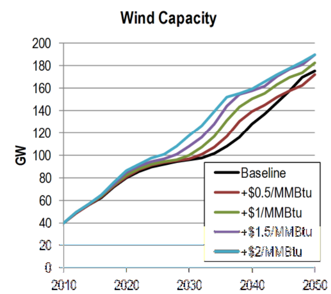
NG Price Variations







- Increased NG prices led to slower growth in power sector NG demand
- Long-term NG demand still significantly higher than today even with prices exceeding $10/MMBtu
- NG deployment replaced primarily by new coal and wind

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Preliminary Conclusions

- Recent coal-to-gas fuel switching has cut U.S. power sector CO2 emissions by approximately 13%
- Future power sector evolution is sensitive to assumptions of EUR, price, technology and policy.
- Coal retirements are largely replaced with natural gas and, to a lesser extent, wind
- CES: without CCS, NG demand peaks around 2030
- Power sector NG demand in the SLOC case doubles by 2050 when prices are +$1/MMBtu above baseline (compared to 2.5x increase in baseline)

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Discussion

Questions?

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