Retrofitting or Replacing: The Decision of Installing Equipment to reduce emissions from a coal-fired power plant

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Motivation

The average U.S. coal-fired fleet is old and inefficient and many plants are dirty and face the problem of

How to choose the best investment strategy given uncertainties on:

-Prices of emissions allowances for 3 P

-Future CO2 constraints

-Future Capital and OM for clean-coal technologies

-Fuel prices

The Problem for the regulator

- **How do current regulations affect industry decisions?**

- **How do different factors affect capital investments decisions?**
- Interest rates?
- Capital costs of new technologies?
- Expectation of CO2 constraints? Timing and cost?

- **Which policies can at the same time reduce emissions and minimize cost of compliance in the future?**
- Early announcement of mild carbon tax?
- Loan guarantees for the first n-of a kind IGCC?
- Subsidies for IGCC?

How should a “dirty” large-coal fired power plant comply with current air emissions regulations?

Assuming **Cap and Trade** and **Coal**

- **Reduce Emissions**
  - Install Add-on controls
    - WFGD to reduce SO2
    - SCR to reduce NOx
    - CI to reduce Hg
    - CCS to reduce CO2 emissions
  - Replace the plant
    - Super Critical Pulverized Coal (SC) (with or without CCS)
    - Integrated Coal Gasification Combined Cycle (IGCC)
      - With or without CCS
      - CCS ready
- **Trade Emissions Allowances**

The Payoff of each strategy is uncertain

	Capital Costs	OM Costs	Risk of shortages and high prices for allowances	Fuel Savings	Potential affordable CO2 capture
Trading Allowances			↓		
Add-on Emissions Controls	↓	↓	↑		↑
Plant replacement		↓	↑	↑	↑

A method to select the best investment strategy (and understand effects of regulation)

Use Options and Forward Contracts Analogies

- Installing ECDs that can be turned on and off to reduce emissions are equivalent to buying call options for allowances

- Inflexible ECDs provide the equivalent to forward contracts for emissions allowances

Options Analogy

1. Once installed the ECD can be operated or not

2. Operating the ECD has the same effect as buying allowances at the OMcost/ton.

→ Installing the ECD = getting a bundle of call options on emissions allowances

$$\text{Install ECD if capital cost ECD} < \int_{\tau}^{T} N_t Call_0(t, A_0, \omega, X_t, r)dt$$

N_t = Number of emissions reduced in year t

$Call_0$ = Value at time 0 of a call option on an asset with :

current price A_0

future price following a stochastic process ω

exercise price X_t

risk - free rate r

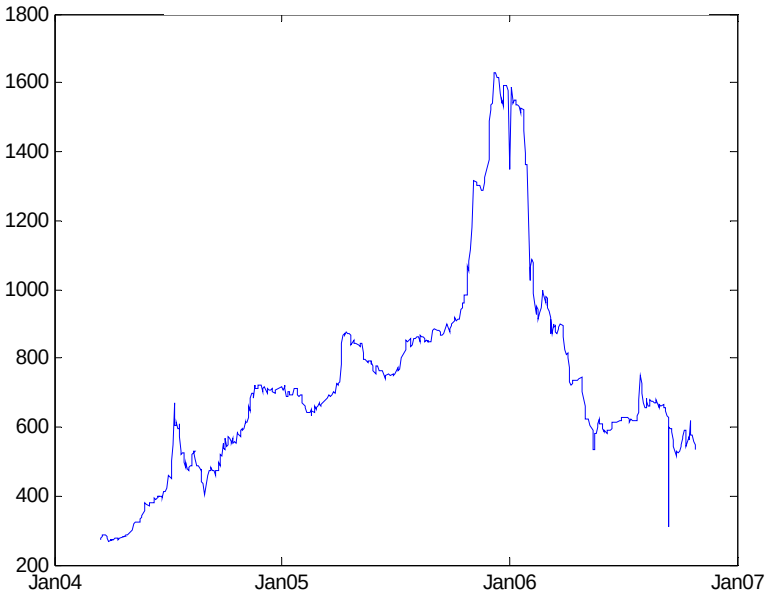
Options and Forward Contracts Analogies to quantify the benefits of the investment

- Flexible ECDs: call options for allowances (WFGD, SCR)
- Inflexible ECDs: forward contracts for emissions allowances (e.g. New plants have less emissions because are more efficient.. But these emissions reductions are not optional)
- Multi-pollutant ECDs: basket options (e.g. WFGD reduces both SO_2 and Hg emissions)
- ECDs with requirements: Disjunctive Options (e.g. A CCS cannot be operated without using the WFGD)
- Investments that make possible other investments: Embedded Options (e.g. The option to install CCS on a IGCC)

Uncertainty on Allowances Prices

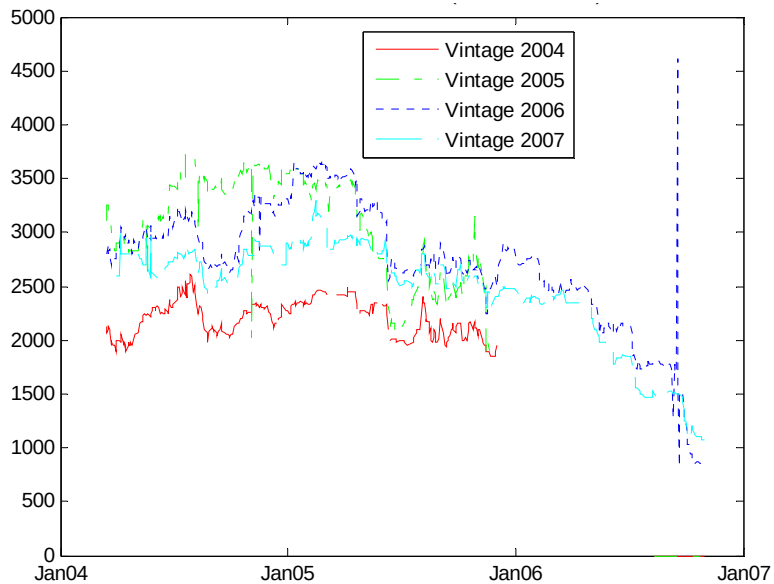
SO2 Allowances

$/ton



NOx Allowances

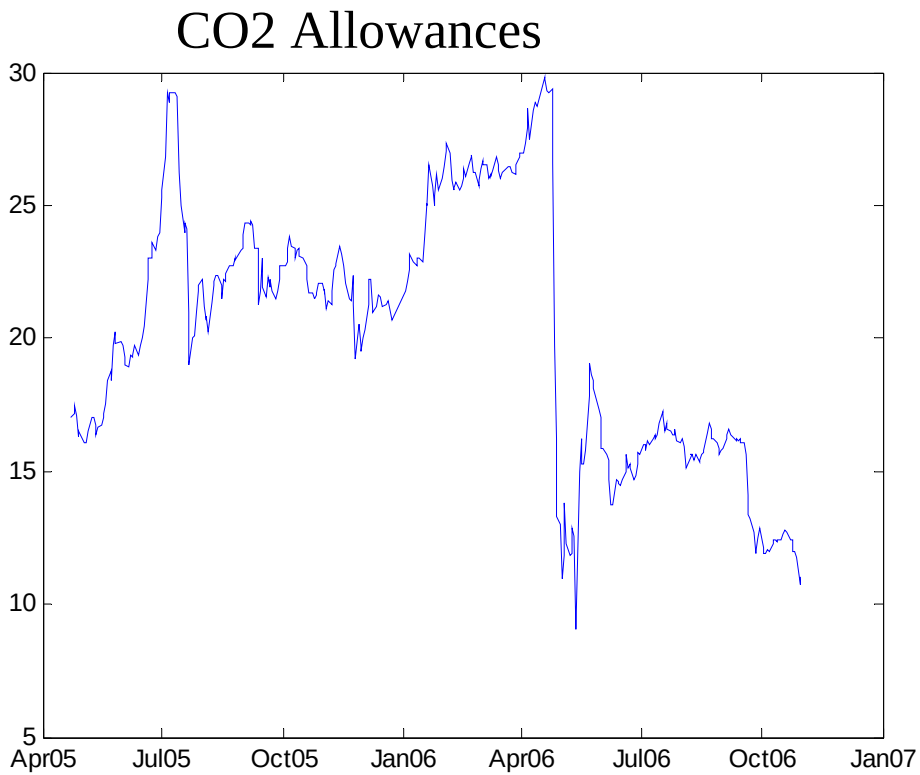
$/ton



*Nominal Dollars

Uncertainty on Allowances Prices

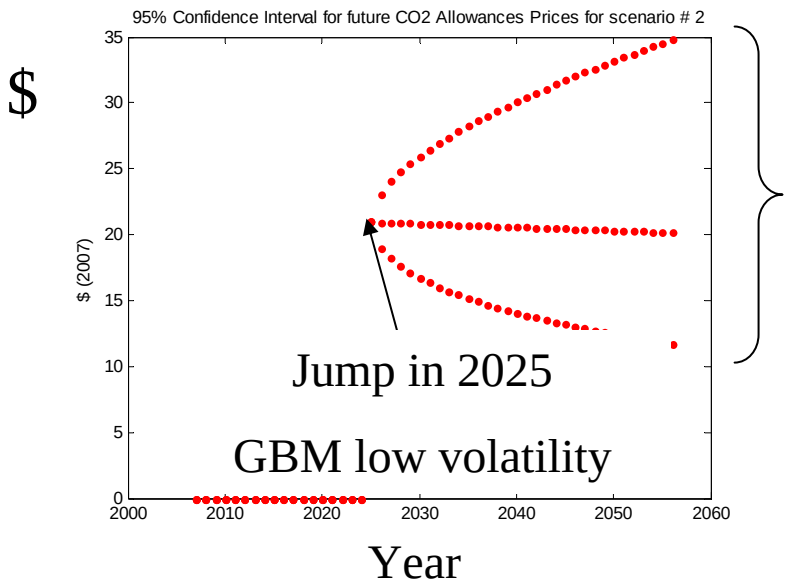
£ /tonne



Characterizing the Uncertainty on Allowances prices

Different Scenarios that specify the process followed by allowances prices for SO_2, NO_x, Hg and CO_2

- All price processes are assumed to be Geometric Brownian Motion (drift, volatility) with jumps
- Jumps account for changes in regulation that affect the new starting price of allowances and the parameters of the GBM



Baseline analysis

- Plant:
  - 1728 MW net output
  - Appalachian-Medium Sulfur Coal
  - Capacity Factor 65%. OM costs given by IECM
  - 10,019Btu/kWh (30% of US plants are more efficient)

- Capital and OM Costs for new plants as given by IECM / 30% higher for SC and IGCC
  - Retrofit factors:
    - WFGD and SCR on old plant →1.2
    - CCS → 1.2 for old plant and SCPC
    - CCS on IGCC →1.4 and 0 for IGCC cap ready
  - OM Costs grow at inflation rate
  - Capacity factor of 83% for SCPC and IGCC
  - Coal 1.269$/MBtu
  - Electricity $55/MWh

- Allowances Prices of 3P
  - Volatilities from historical Data
  - Jump time from timetable of new regulations
  - Jump size from AEO 2006 report

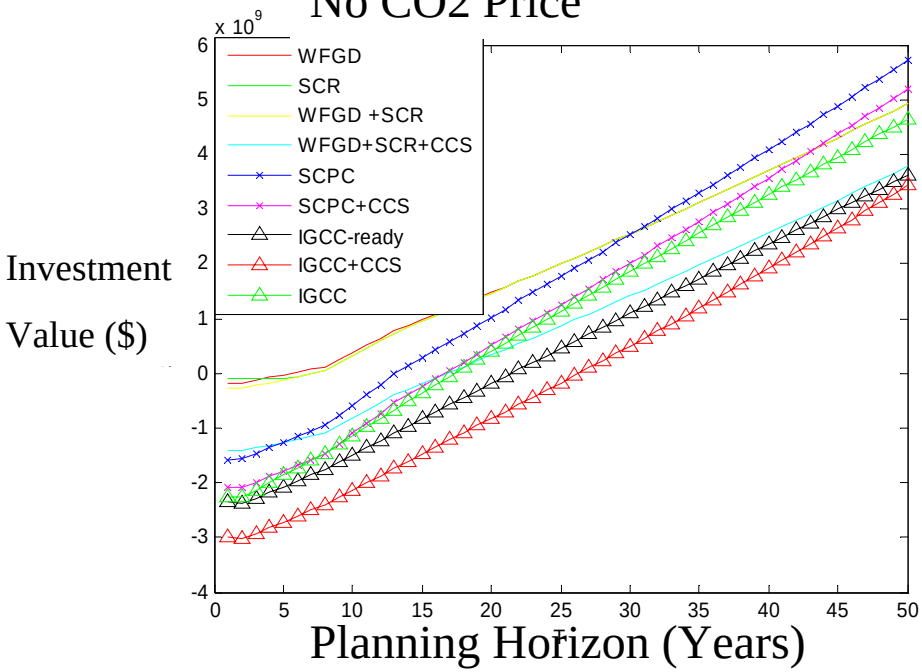
- Scenarios for Prices for CO2
  - No price / Different jump times, jump sizes and volatility

- Discount Rate
  - RFR + 3%

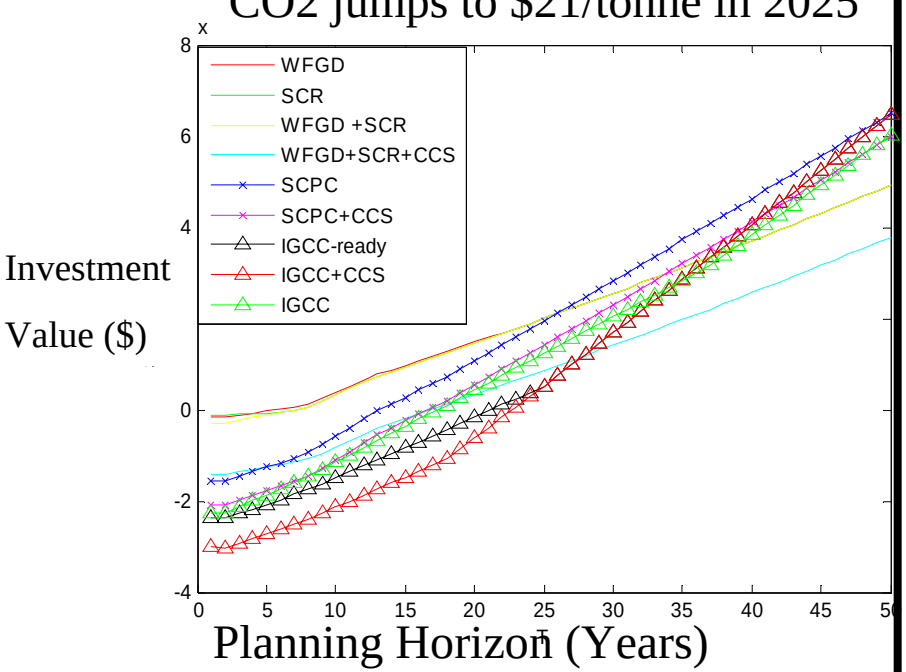
Baseline Scenario Results

Investment Value (Net Benefits – Capital Cost)

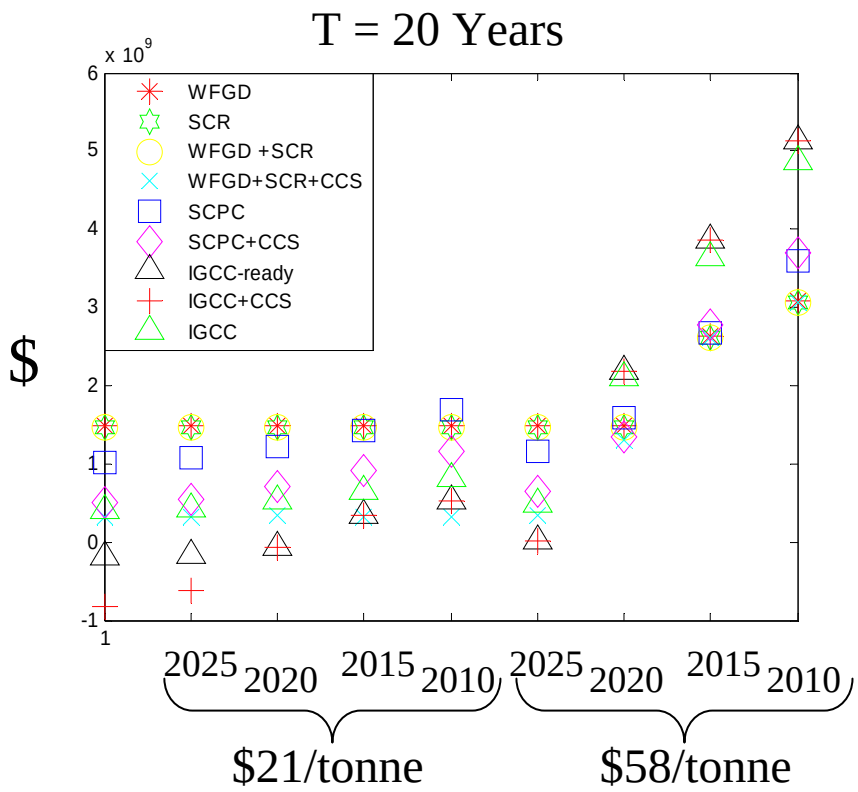
No CO2 Price



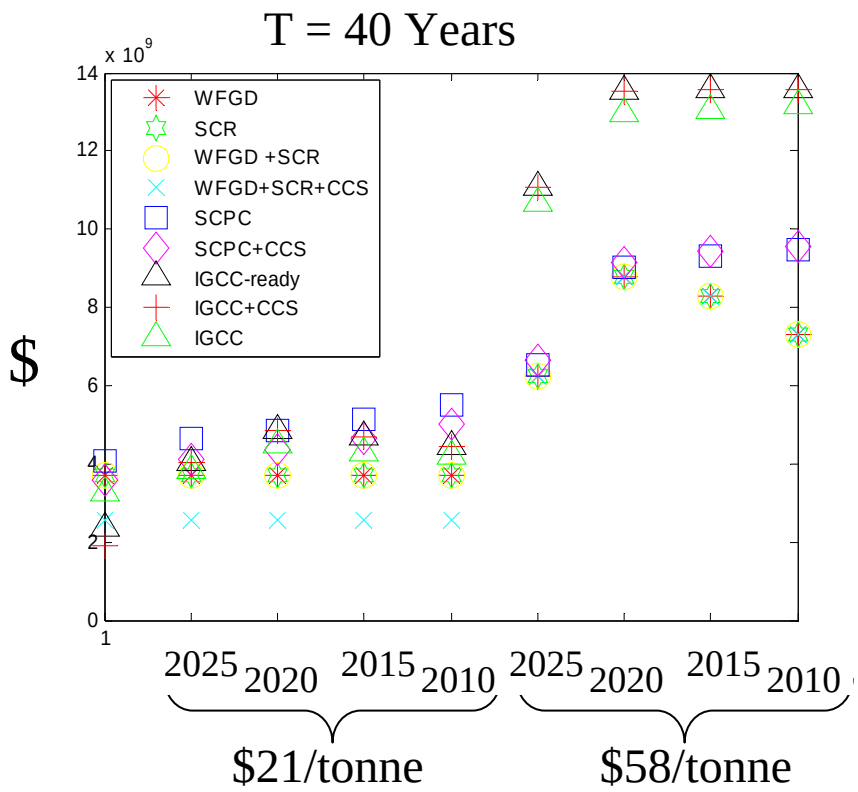
CO2 jumps to $21/tonne in 2025



Different scenarios for CO2
Volatility = 0.05



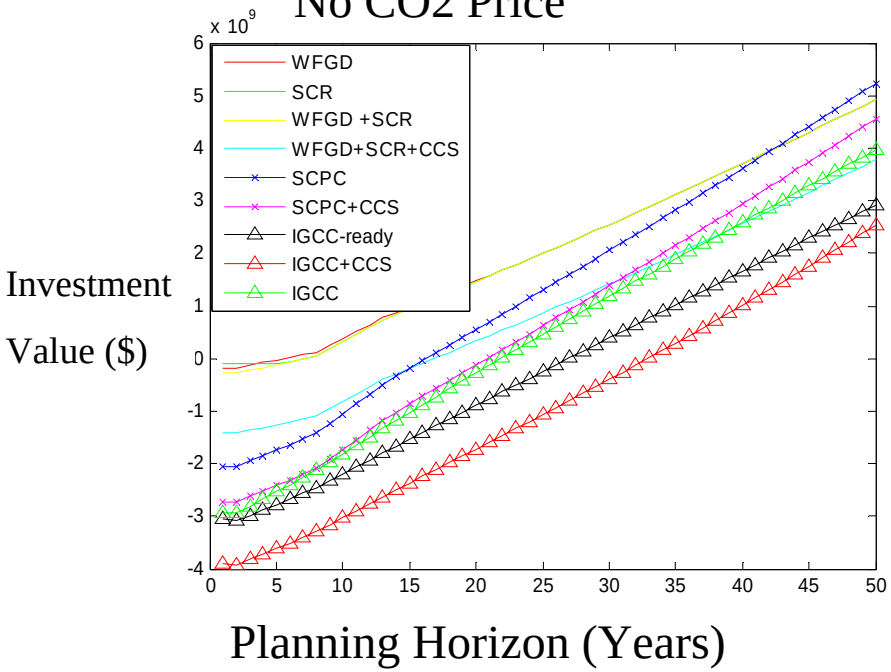
Scenarios for CO2



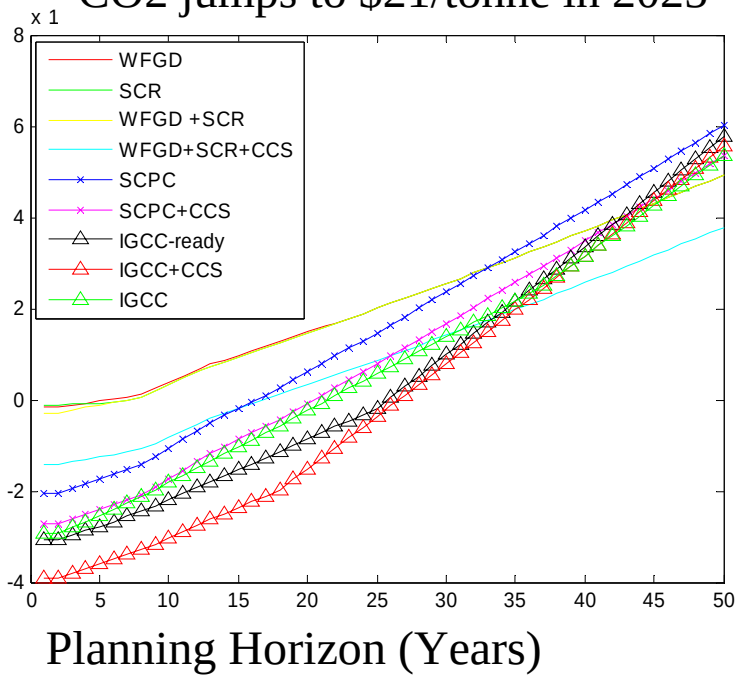
Scenarios for CO2

Capital Cost of New Plants are 30% Higher

No CO2 Price



CO2 jumps to $21/tonne in 2025



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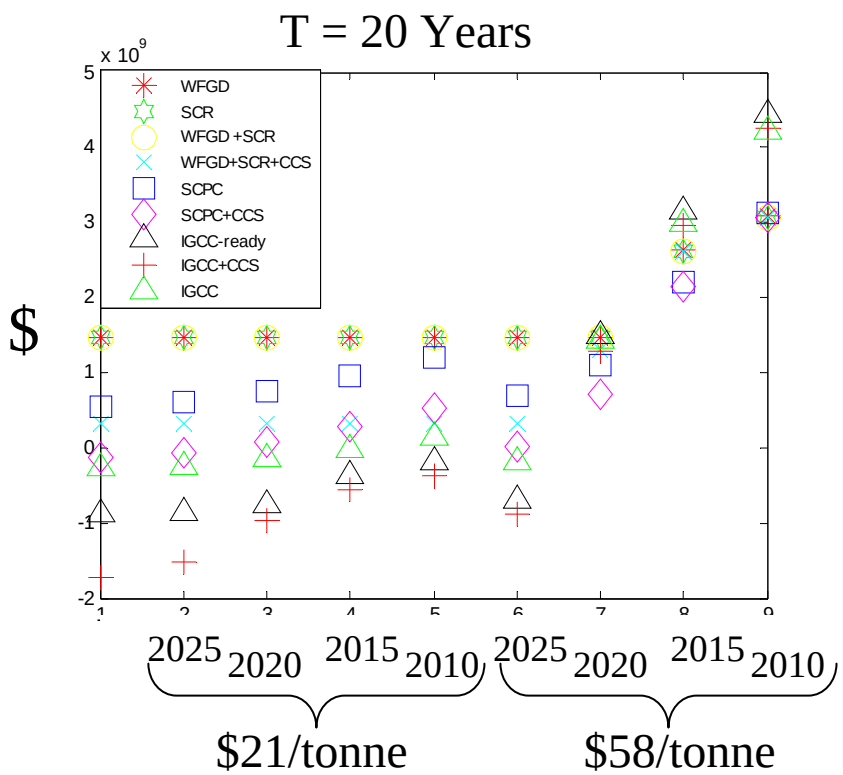
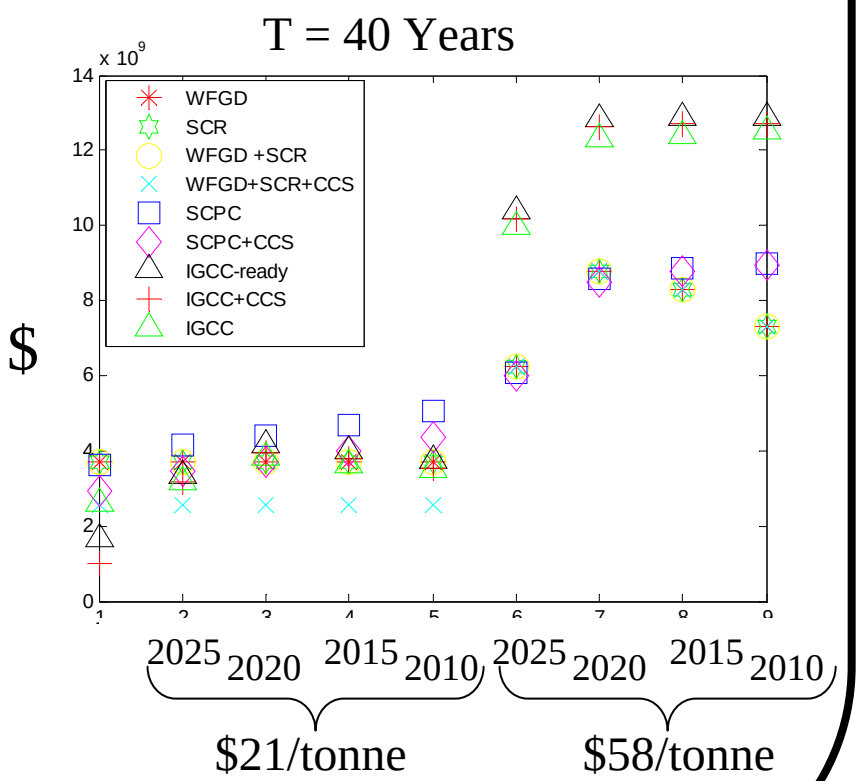


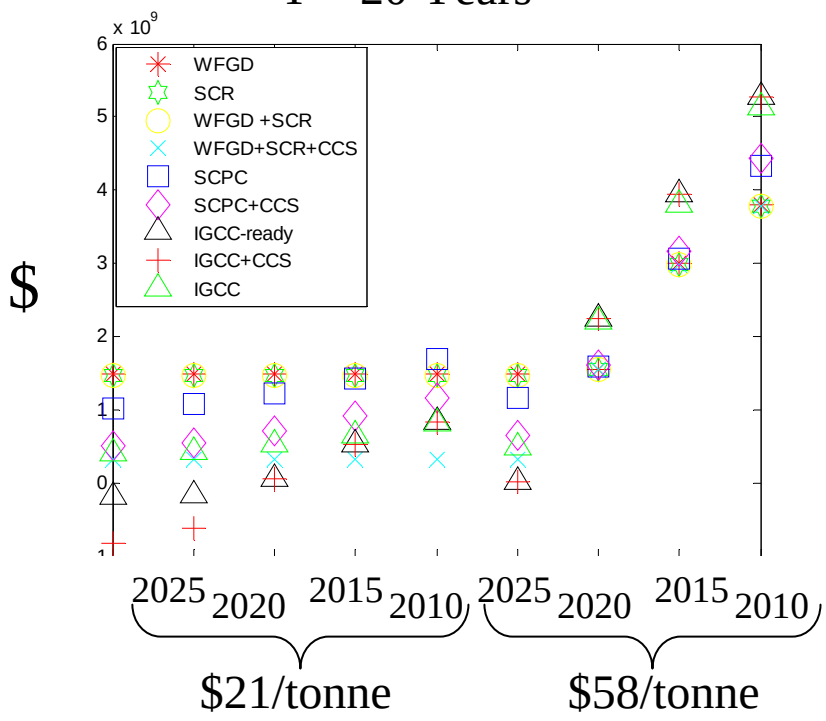
Scenarios for CO2



Scenarios for CO2

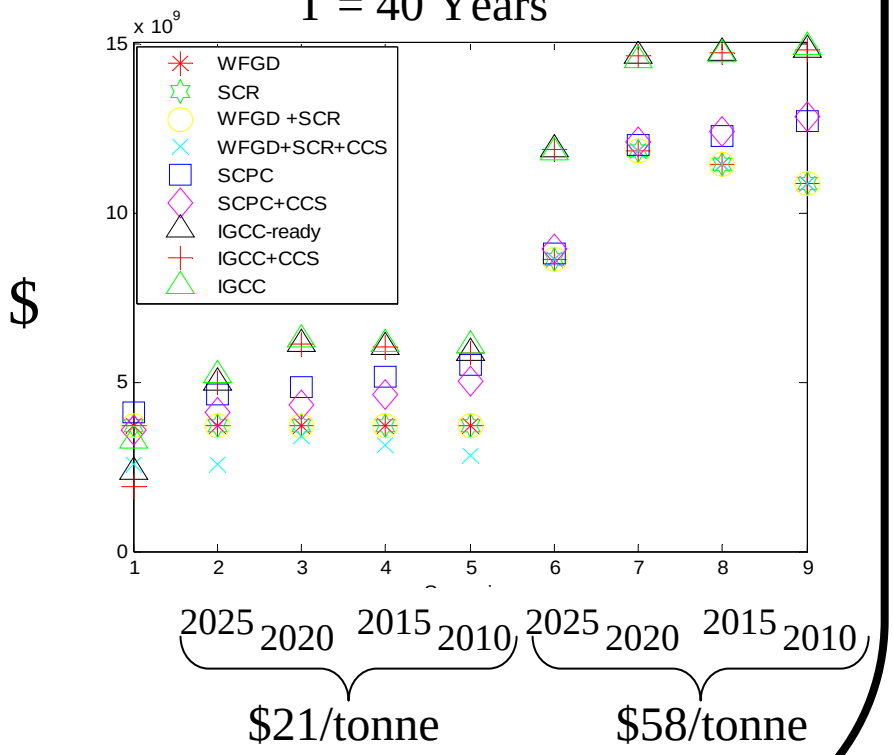
CO2 volatility = 0.75

T = 20 Years



Scenarios for CO2

T = 40 Years



Scenarios for CO2

Conclusions

- For planning horizons longer than ~35 years, efficiency improvements justify the replacement of old-plants (with efficiencies < than 70th percentile) even in the absence of CO_2 constraints
  - Less efficient plants require shorter planning horizons
- For short planning horizons, strong and early CO_2 constraints are required to justify plant replacement
- Short planning horizons and other factors (risk-premium for cost of new technologies, high interest rates) favor retrofits
- Once old and inefficient plants are retrofitted with equipment to abate SO_2 and NO_x it might be more difficult to make the case for the reduction of CO_2 emissions

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