Role of Biomass-to-Hydrogen in Deep CO2 Emission Reduction Scenarios

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"Given the high cost of emissions mitigation, the lack of readily available fuel substitutes and the fact that millions of small emission sources are involved, transport can be considered the most challenging sector for deep emission reductions."

Energy Technology Perspectives 2008
International Energy Agency

Introduction

- The goal of this analysis is to explore the role that hydrogen technologies could play in meeting deep carbon emission reduction goals.
- For this analysis we are examining:
  - The role of hydrogen fuel cell vehicles in reducing direct emissions of light duty vehicles (LDVs).
  - The impact of using biomass to produce hydrogen with carbon capture and sequestration (CCS) in generating "negative" CO2 emissions.
  - Finally, we will examine the competition for biomass feedstocks between hydrogen, other biofuels and electric generation.

Methodology

- Focused on CO2 caps from Waxman-Markey bill.
  - For this analysis, we only modeled provisions directly related to the CO2 cap and trade provisions. Renewable portfolio and appliance standards were not modeled.
- Used BNL's 10-region US MARKAL model
  - Covers all sectors of the economy
- Reference case is calibrated to AEO 2009.
  - AEO09 technology performance and cost data
  - AEO09 economic growth and demand projections
  - AEO09 energy prices
- Hydrogen production, distribution, storage and dispensing and fuel cell vehicle assumptions are based on FCTP GPRA11 assumptions.
- Other LDV cost and efficiency assumptions include the impact of the Vehicles Program R&D in batteries, light weighting and hybridization.

Cap-and-trade program

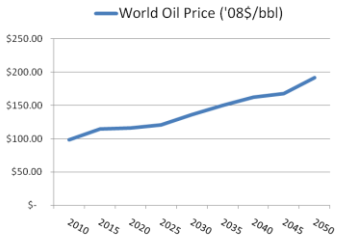
A market-based program for reducing GHG emissions

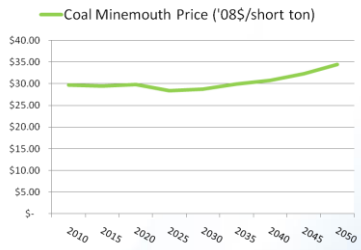
- Covered entities must obtain tradable permits (allowances) for each ton of GHGs emitted. Allowances are auctioned by the federal government.
- The program reduces the number of available allowances issued each year so that emissions are 3% below 2005 levels in 2012, 20% below in 2020, 42% below in 2030, and 83% below in 2050.
- Entities that emit less than 25,000 tons per year of CO2 equivalent are not covered by this program.
- Covered entities may increase their emissions above their allowances if they can obtain "offsetting" reductions from domestic and international sources. A total of 2 GT of offsets can be used.
- Since we wanted to explore the impacts of hydrogen technologies under more stringent carbon caps, we decided to look at what might happen if the domestic or international offsets were excluded from the legislation.

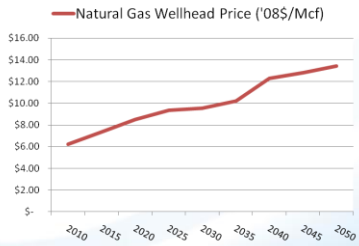
Scenario Definitions

- For this analysis we modeled the following scenarios:
  - *Reference Case:* **Ref. Case**
  - *Reference with Carbon Cap:* **Ref. w/CC**
  - *Reference with Carbon Cap Without International Offsets:* **Ref. w/CC w/o IO**
  - *Reference with Carbon Cap Without Any Offsets:* **Ref. w/CC w/o AO**
  - *Fuel Cell Technology (FCT) Program:* **FCTP Case**
  - *FCT Program with Carbon Cap:* **FCTP w/CC**
  - *FCT Program with Carbon Cap Without International Offsets:* **FCTP w/CC w/o IO**
  - *FCT Program with Carbon Cap Without Any Offsets :* **FCTP w/CC w/o AO**

Reference Case Commodity Prices







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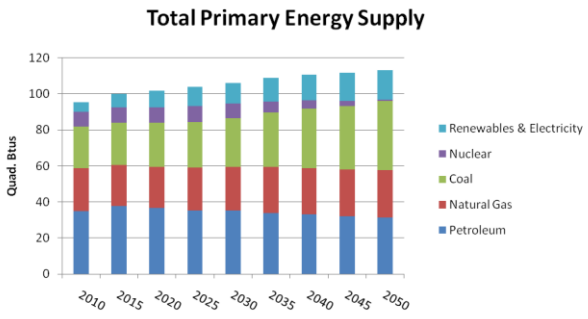
Reference Case Primary Energy Consumption



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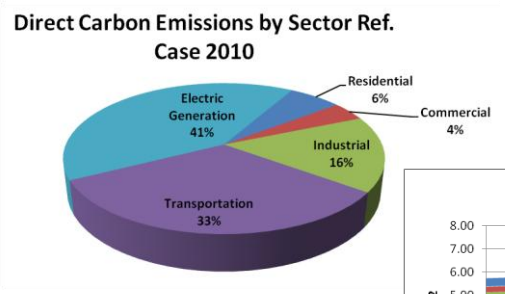
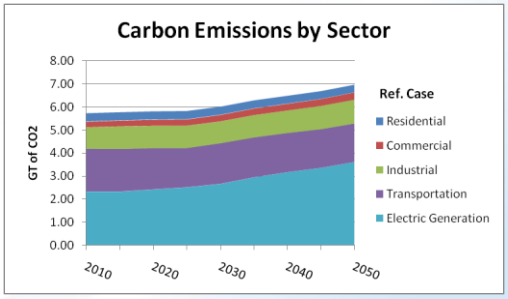
Ref. Case Carbon Emissions by Sector





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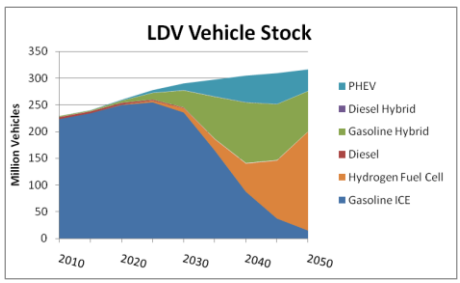
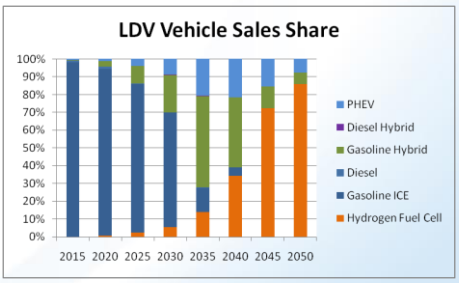
The Fuel Cell Technology Program
FCTP Case





- **With the FCTP goal assumptions, fuel cell vehicles begin to penetrate and rapidly capture market share.**

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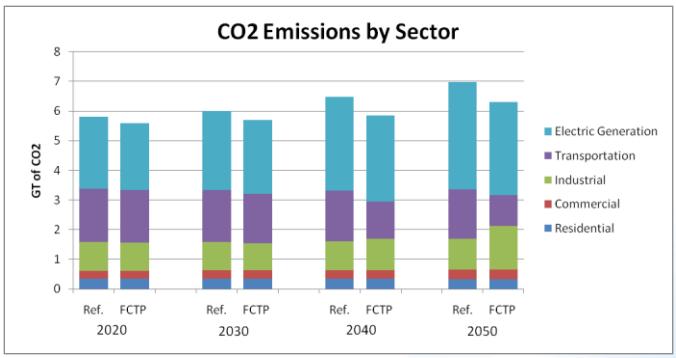
Impact of FCTP on Carbon Emissions



- The FCT Program results in a 37% reduction in direct CO2 emissions in the transportation sector.
- However, this is partially offset by a increase in industrial sector CO2 emissions and the total emission reduction is about 10%.

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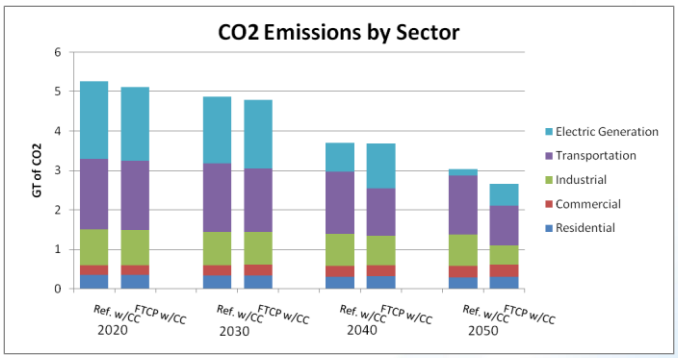
Impact of FCTP on Carbon Emissions Under the Waxman-Markey Cap



- With the FCT Program technology assumptions, we see a shift in carbon mitigation and show significant reductions in industrial and transportation sector emission relative to the reference case due to fuel cell vehicles and biomass to hydrogen with CCS.

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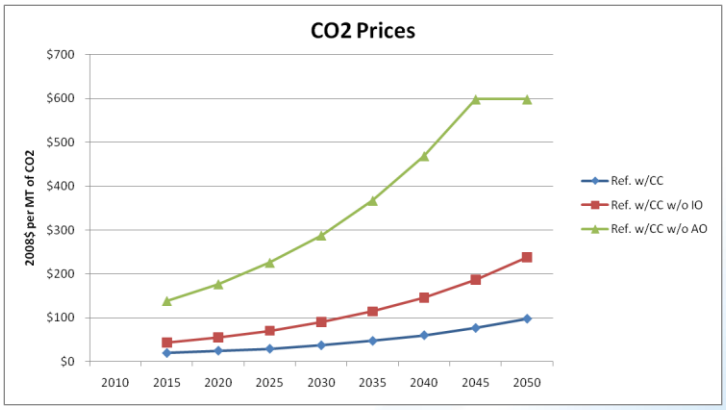
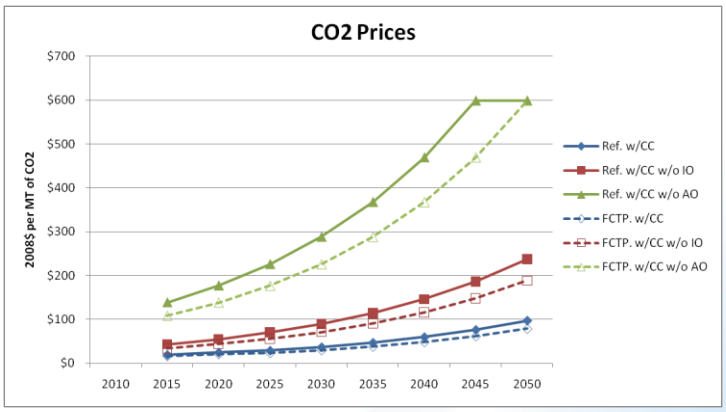
Impact of Tightening the Cap with the Reference Case Technology Set



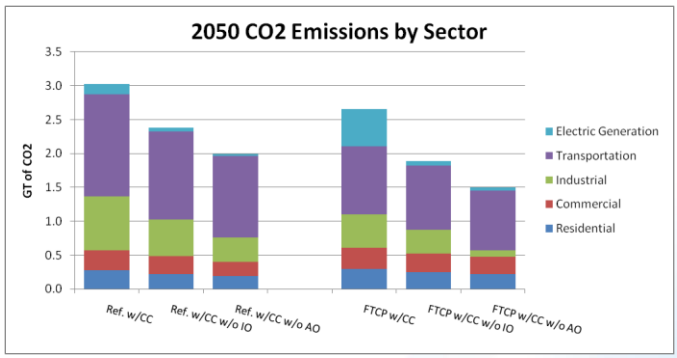
- As we tighten the cap, we see CO2 prices increase. Please note, that we included a "relief valve" for when prices hit $600/tonne.

Impact of Hydrogen Technologies on CO2 Price



- In all Cap scenarios, FCTP technologies help reduce the CO2 prices.

Carbon Emissions by Sector Under Stricter CO2 Caps



- In all FCTP Cases, we see significantly lower industrial and transportation emissions, as well as significantly lower total CO2 emissions in 2050.

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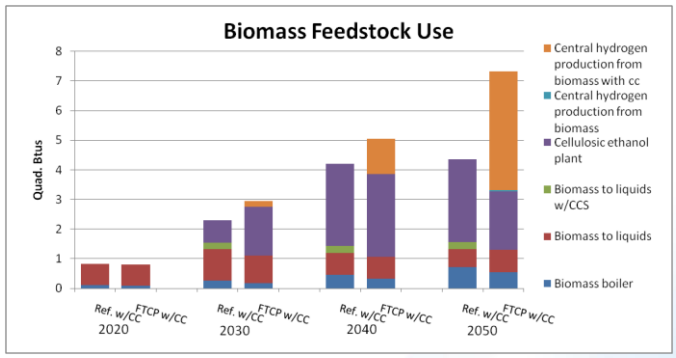
Biomass Consumption Under the Waxman-Markey Cap



- With the introduction of the Waxman-Markey cap, we see significant increases in use of biomass in both cases.
- With the FCTP assumptions, we observe significant increases in the consumption of biomass, particularly of biomass to hydrogen with CCS.

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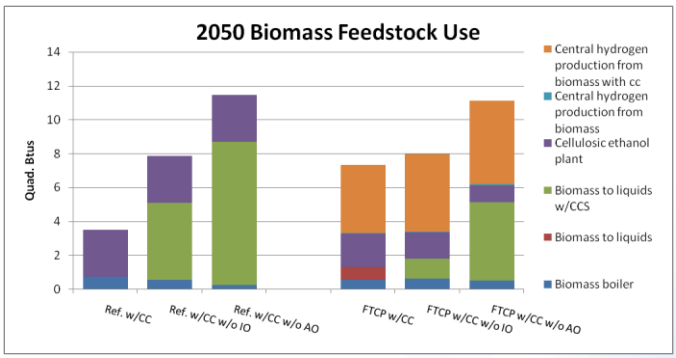
Carbon Emissions by Sector Under Stricter CO2 Caps



- Under stricter CO2 caps, the reference case technology set case catches up with the FCTP case consumption.

Conclusion

- The use of biomass-to-hydrogen with CCS can greatly reduce the cost of meeting deep carbon emission reduction goals.
- BTL with CCS also generates "negative" CO2 emissions; the hydrogen pathway generates deeper reductions.
- However, under the strictest CO2 cap, both BTL with CCS and hydrogen with CCS are needed.
- While the transport sector may be a more difficult sector to achieve deep CO2 emission reductions, with a successful R&D program, deep CO2 emission reductions can be achieved with a significant reduction in costs of meeting the CO2 cap.