CO2 Reduction Benefits Analysis for Fuel Cell Applications

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Office of Science
U.S. DEPARTMENT OF ENERGY

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Overview

Timeline

- 10/1/2007
- Ongoing

Budget

- $600,000 to date
  - DOE share: 100%
  - No cost share
- FY09: $100,000
- FY10: $100,000

Barriers

- **Barriers addressed**
  - Future Market Behavior
  - Unplanned Studies and Analysis
  - Inconsistent Data and Assumptions

Partners

- Interact with DOE staff and other analysts from national laboratories
- Project lead: Paul Friley

Approach

- Perform analysis of topics of interest to the Fuel Cell technologies program related to projected CO_2 benefits of fuel cell applications.
- Analysis performed under the direction of Fred Joseck.
- Primary tool is the 10 Region U.S. MARKAL model developed by BNL.
  - Calibrated annually to the EIA Annual Energy Outlook.
  - Covers all energy consuming sectors of the U.S. from resource extraction to end-use.
- Analysis for FY2009 and FY2010 include:
  - Sensitivity analysis of fuel cell vehicle market penetration to changes in production, distribution and vehicle costs and CO_2 prices.
  - Impact of biomass-to-hydrogen in deep CO_2 emission reduction scenarios.
  - Additional analytical support was provided to the Program to respond to departmental data requests and Program analysis needs.

Sensitivity Analysis

- This analysis used the 10 Region U.S. MARKAL model to quantify the impact of changes in production, distribution and vehicle costs and carbon prices on fuel cell vehicle penetration and overall CO_2 emissions.
- The sensitivities performed were"
  - Hydrogen distribution cost ($1.0,$1.5 and $2.0 per kg of H_2)
  - Fuel cell cost ($40,$50 and $60 per kW)
  - On board storage ($4 and $6 per kWh)
  - CO_2 price (10 prices ranging from $0 to $100 per tonne of CO_2).
  - A 10 year delay in commercialization of fuel cell vehicles.
- This analysis was performed in FY09.

Impact of CO2 Price on Hydrogen Production

Hydrogen case + $0 per tonne CO2

PJ of H2	2010	2015	2020	2025	2030	2035	2040	2045	2050
Biomass	0.000	0.000	0.000	0.005	0.016	0.039	0.098	0.197	0.396
Biomass w/CCS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Central coal	0.000	0.000	0.000	0.042	0.182	0.481	0.985	1.598	2.494
Central coal w/ CCS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Natural gas	0.000	0.001	0.020	0.059	0.180	0.425	0.907	1.944	2.389
Total	**0.000**	**0.001**	**0.020**	**0.106**	**0.378**	**0.945**	**1.990**	**3.738**	**5.280**

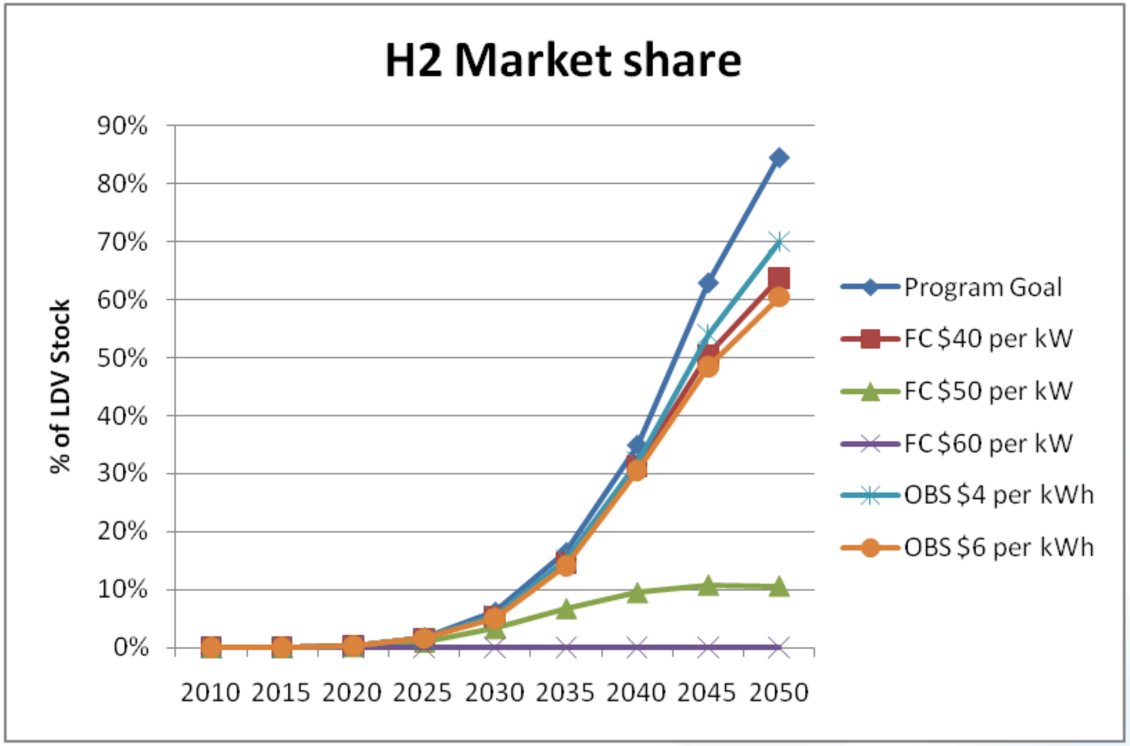
Hydrogen case + $20 per tonne CO2

PJ of H2	2010	2015	2020	2025	2030	2035	2040	2045	2050
Biomass	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biomass w/CCS	0.000	0.000	0.000	0.063	0.191	0.503	1.042	1.248	1.691
Central coal	0.000	0.000	0.000	0.013	0.068	0.192	0.483	0.799	1.283
Central coal w/ CCS	0.000	0.000	0.000	0.000	0.047	0.094	0.094	0.130	0.213
Natural gas	0.000	0.001	0.021	0.033	0.074	0.151	0.376	1.569	2.104
Total	**0.000**	**0.001**	**0.021**	**0.109**	**0.380**	**0.942**	**1.995**	**3.747**	**5.292**

Hydrogen case + $100 per tonne CO2

PJ of H2	2010	2015	2020	2025	2030	2035	2040	2045	2050
Biomass	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biomass w/CCS	0.000	0.000	0.000	0.073	0.288	0.766	1.749	2.808	3.238
Central coal	0.000	0.000	0.000	0.006	0.015	0.015	0.015	0.015	0.039
Central coal w/ CCS	0.000	0.000	0.000	0.000	0.060	0.260	0.497	0.966	1.616
Natural gas	0.000	0.001	0.021	0.031	0.026	0.058	0.073	0.346	0.665
Total	**0.000**	**0.001**	**0.021**	**0.109**	**0.389**	**1.098**	**2.334**	**4.134**	**5.559**

Sensitivity of Fuel Cell Vehicle Market Share to Fuel Cell and On Board Storage Costs



- **Fuel cell cost has a dramatic impact on fuel cell vehicle market penetration.**

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

- 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 are examining the competition for biomass feedstocks between hydrogen, other biofuels and electric generation.
- This analysis began in late FY09 still in progress. The modeling has been completed and we are currently writing the paper.

Methodology

- Focused on CO_2 caps from Waxman-Markey bill.
  - For this analysis, we only modeled provisions directly related to the CO_2 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

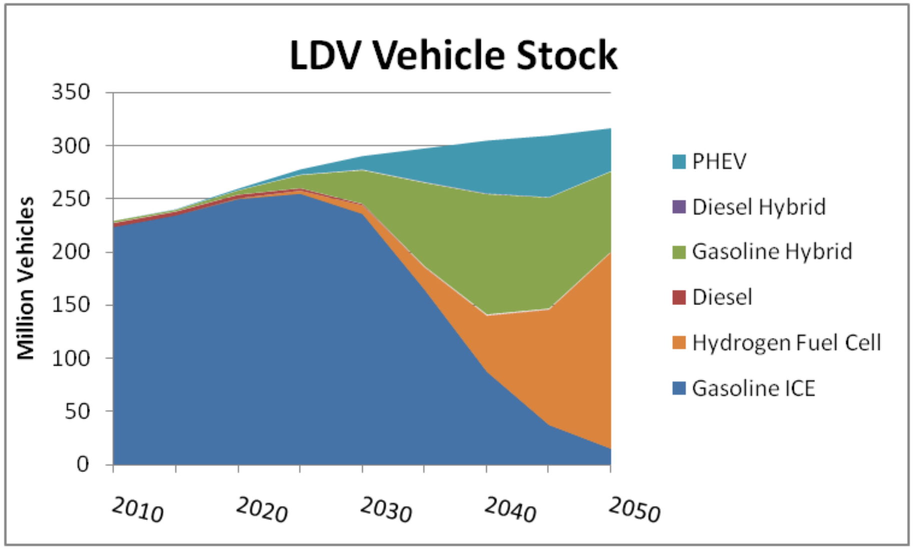
A market-based program for reducing GHG emissions

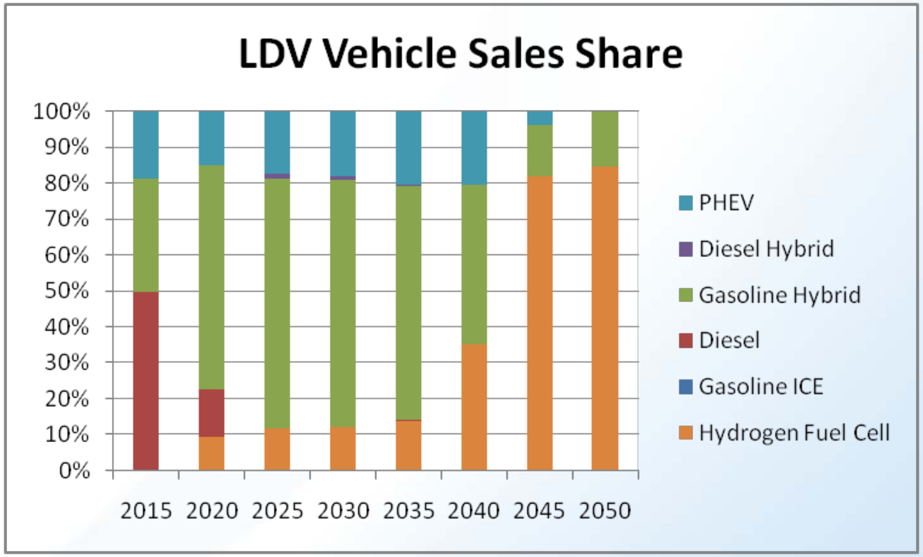
- Covered entities must obtain tradable permits (allowances) for each ton of GHGs emitted. Allowances are auctioned by the federal government.
- The program reduces the number of available allowances issued each year so that emissions are 3% below 2005 levels in 2012, 20% below in 2020, 42% below in 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 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**

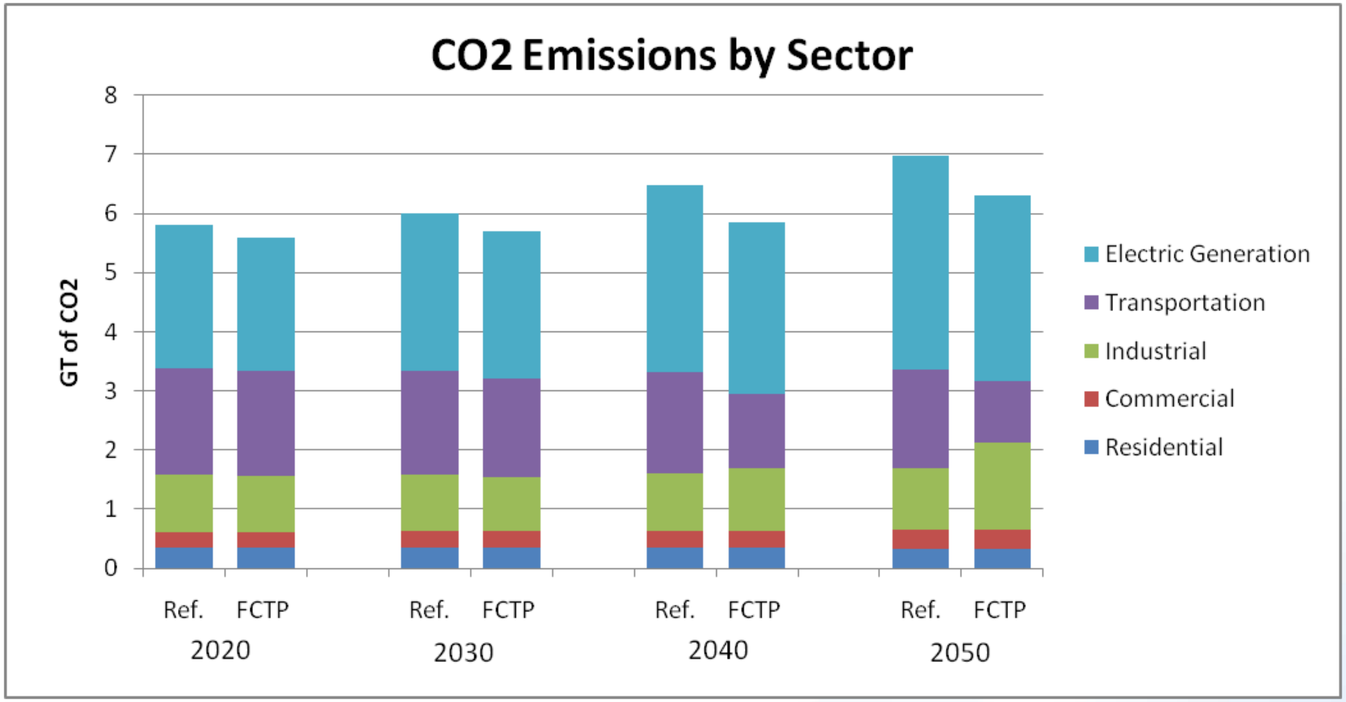
The Fuel Cell Technology Program
FCTP Case





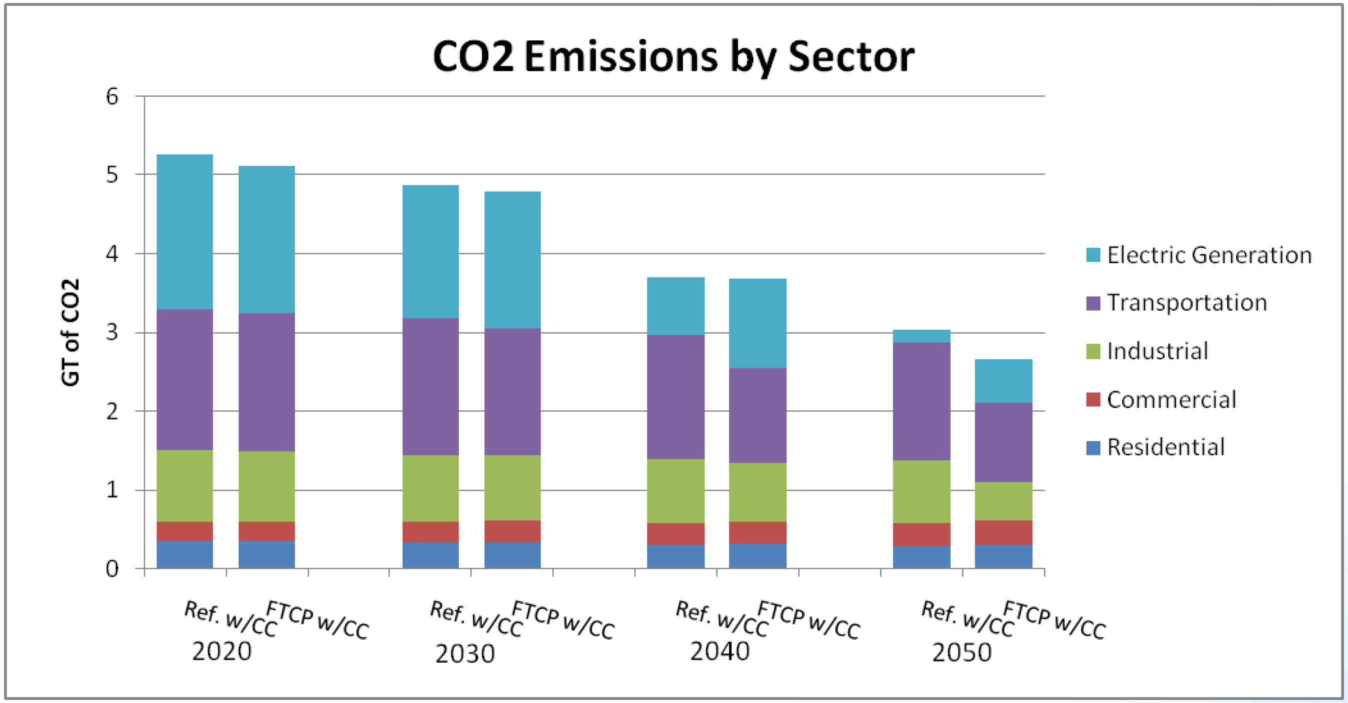
- **With the FCTP goal assumptions, fuel cell vehicles begin to penetrate and rapidly capture market share.**

Impact of FCTP on Carbon Emissions



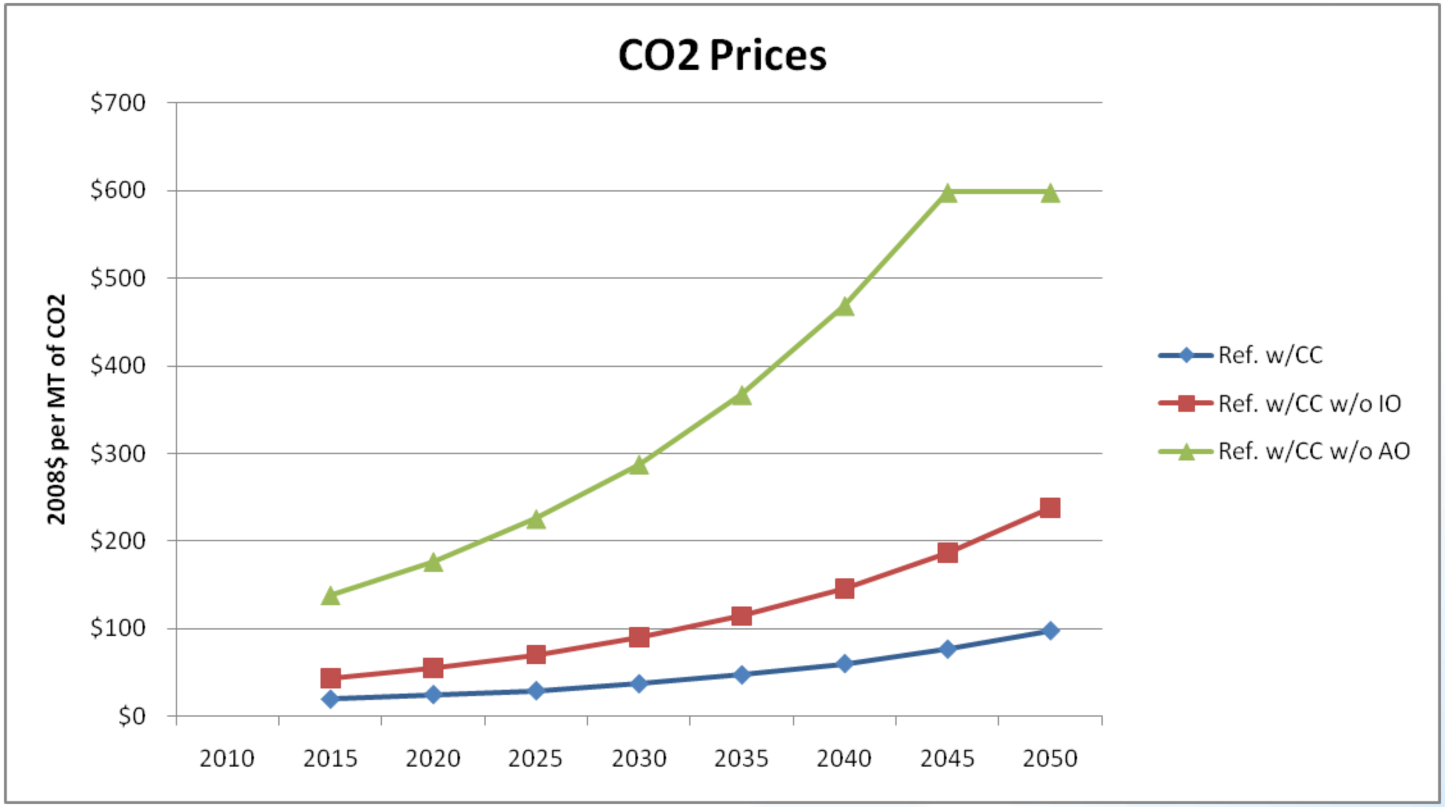
- The FCT Program results in a 37% reduction in direct CO2 emissions in the transportation sector.
- However, this is partially offset by a increase in industrial sector CO2 emissions and the total emission reduction is about 10%.

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



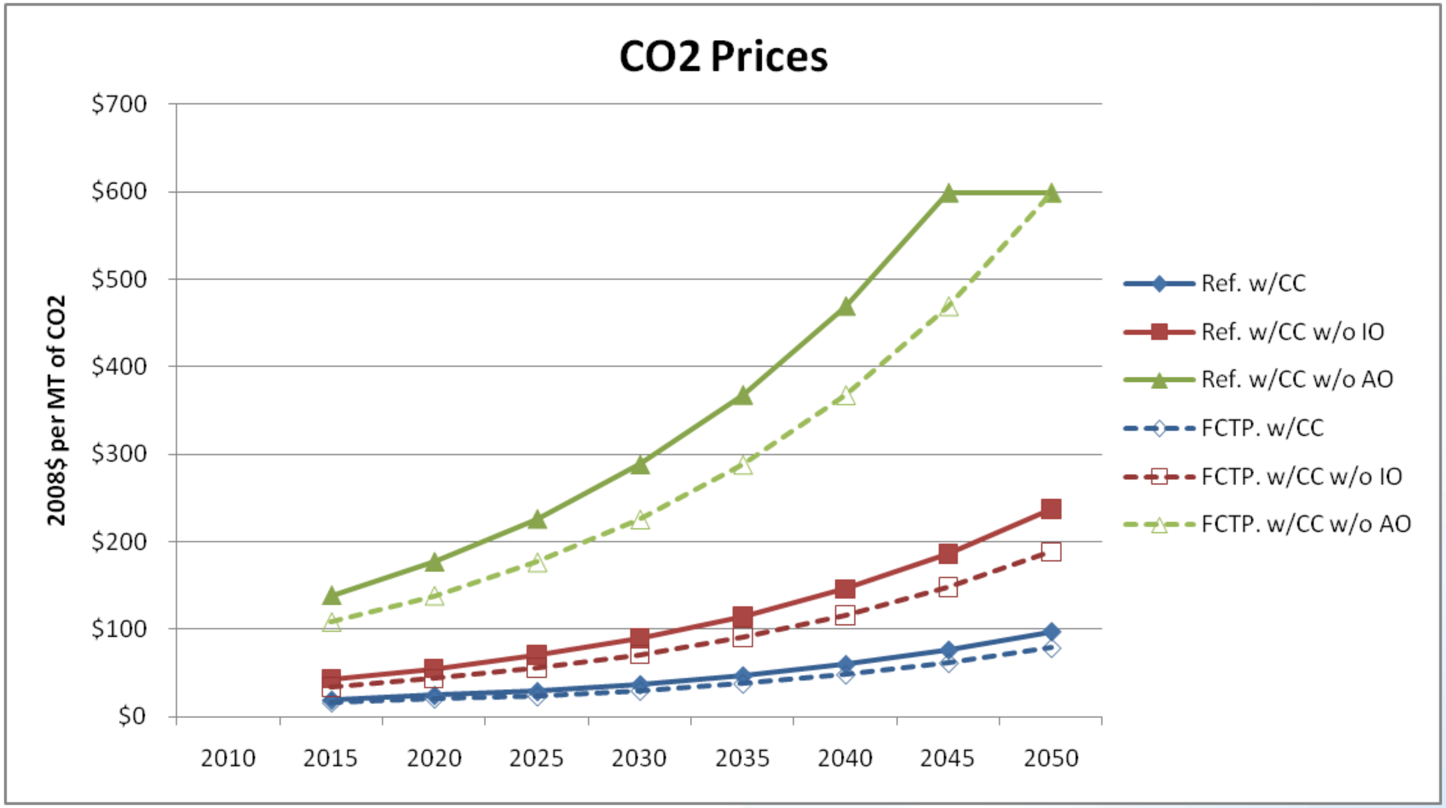
- With the FCT Program technology assumptions, we see a shift in carbon mitigation and show significant reductions in industrial and transportation sector emission relative to the reference case due to fuel cell vehicles and biomass to hydrogen with CCS.

Impact of Tightening the Cap with the Reference Case Technology Set



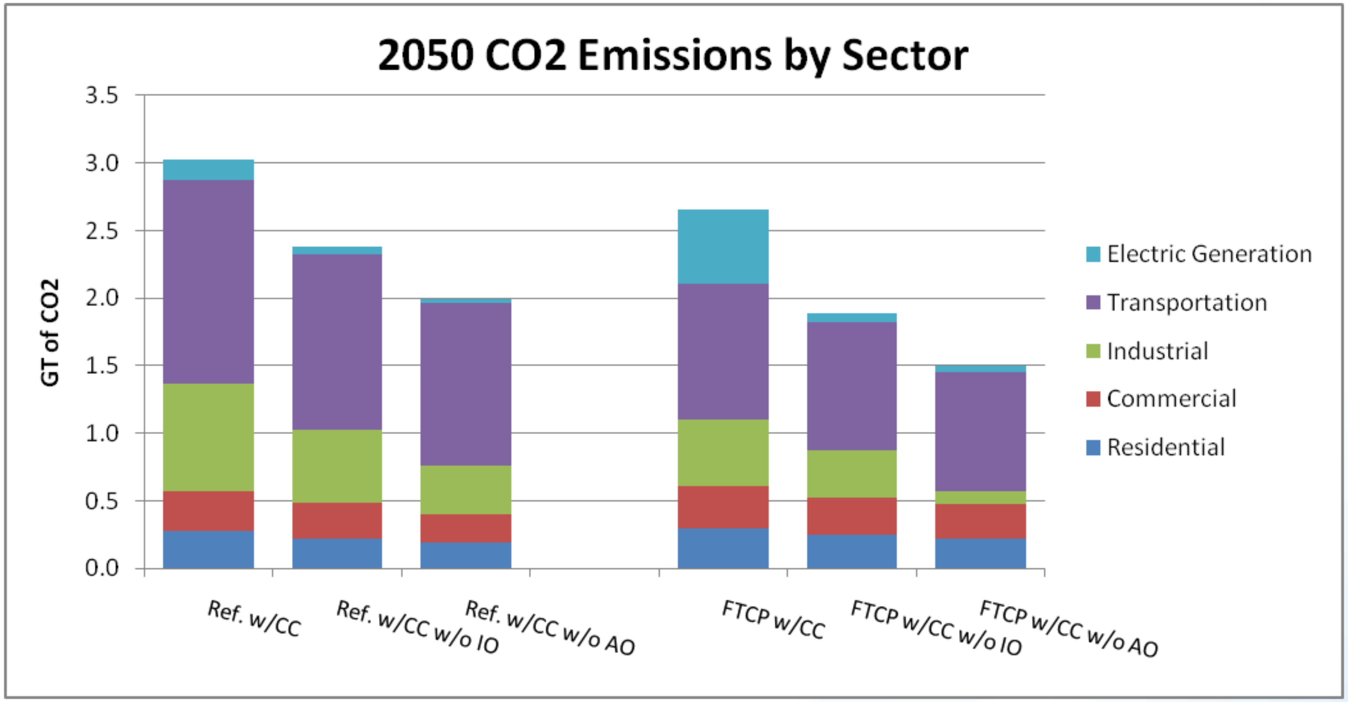
- As we tighten the cap we see CO2 prices increase. Please note, that we had a “relief valve” when prices hit $600/tonne.

Impact of Hydrogen Technologies on CO2 Price



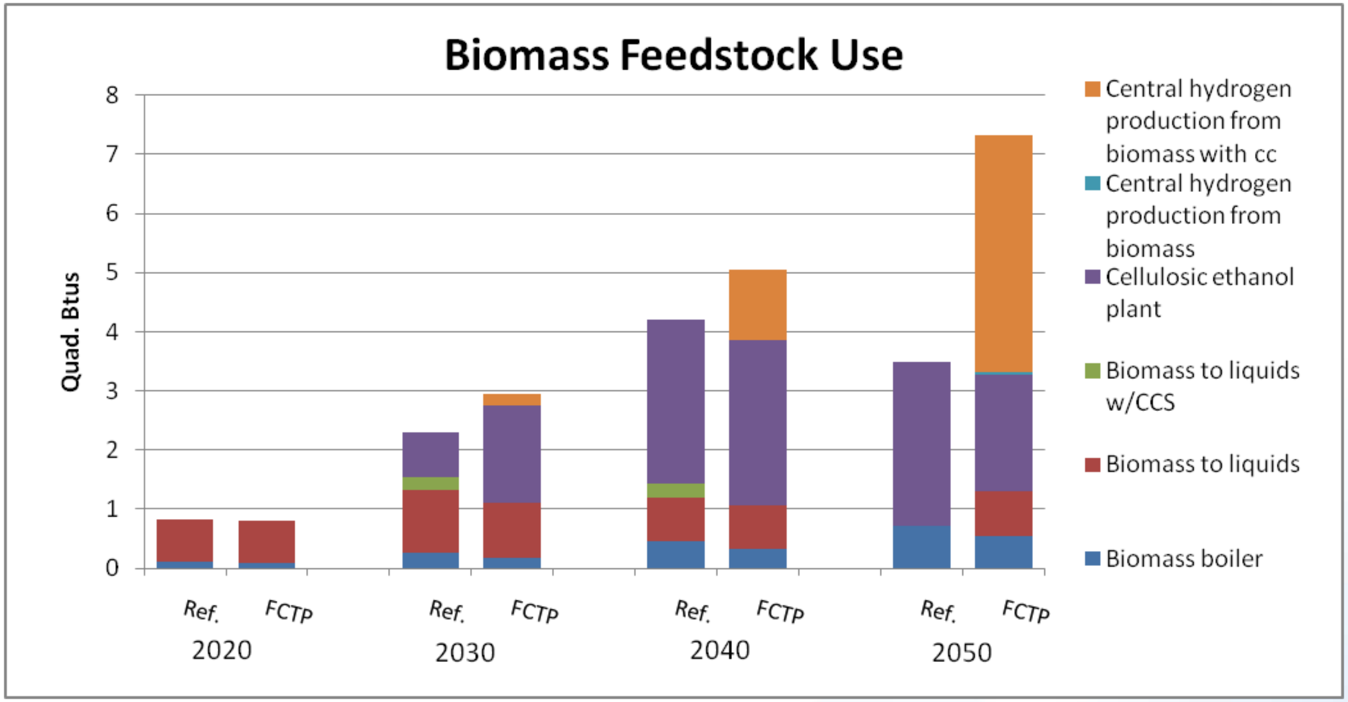
- **In all Cap scenarios, FCTP technologies help reduce the CO2 prices.**

Carbon Emissions by Sector Under Stricter CO2 Caps



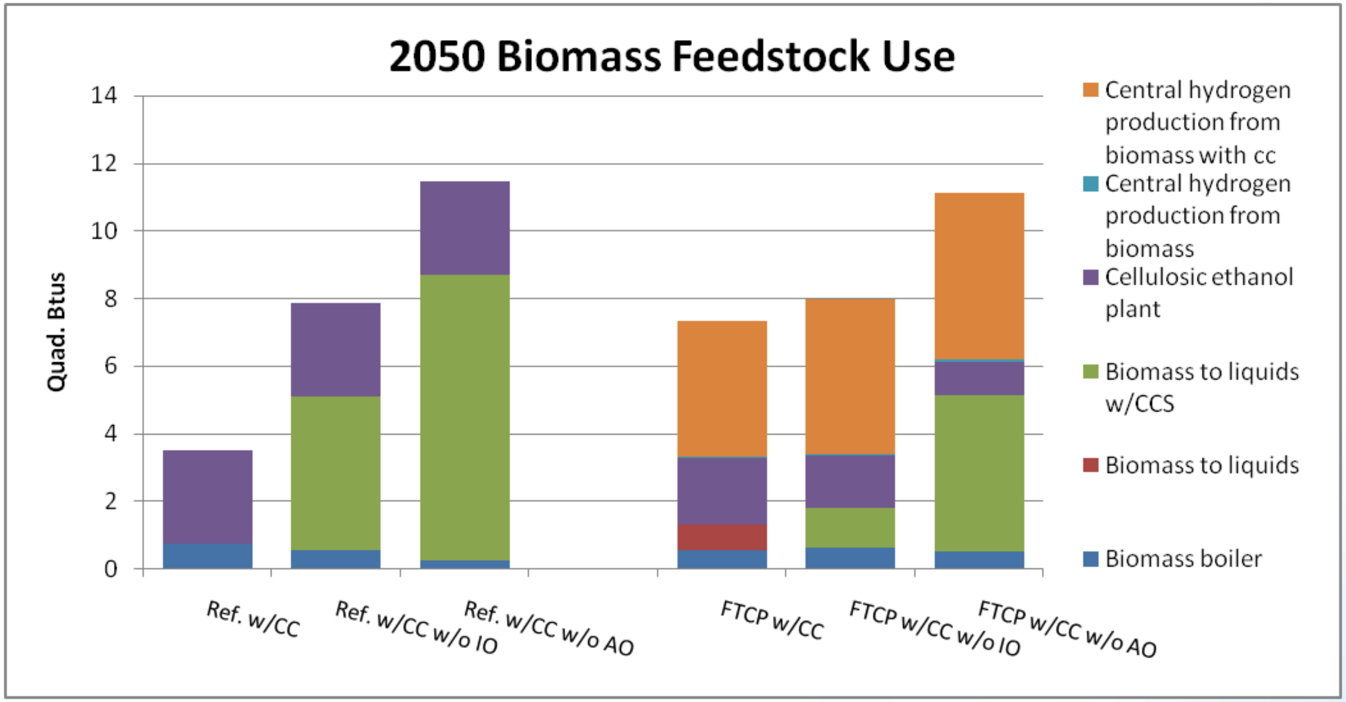
- **In all FCTP Cases, we see significantly lower industrial and transportation emissions, as well as significantly lower total CO2 emissions in 2050.**

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 get significant increase in the consumption of biomass, particularly of biomass to hydrogen with CCS.

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 cost of meeting the CO2 cap.