Innovation and Investment to Lower the Carbon Intensity of Fuels

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Goals of California's climate change strategy

1. **Cut emissions by ~25% by 2020**

2. **Stimulate innovation and investment in new technologies**

3. **Contribute to related objectives as much as possible, including economic growth, air quality, affordable energy prices, and diverse energy sources**

A Low-Carbon Fuel Standard for California

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NOTE: These are recommendations are our own views based on currently available data. The California Air Resources Board will determine all policy choices and quantitative values in accordance with California law.

We will discuss the two study questions

Part 1: Is the 10% target technically feasible and cost effective?

Alex Farrell

Part 2: What are the key policy choices?

Dan Sperling

Carbon intensity

- Global Warming Intensity
  - Total effect on climate change
  - Greenhouse gas emissions (CO_2, N_2O, black carbon, etc.)
  - Other effects due to land use change
  - Some effects are uncertain and variable (more research is needed!)
  - Unit is grams of carbon dioxide equivalent per mega-joule of energy in the fuel **(gCO_2e/MJ)**

- Adjusted for inherent drivetrain differences
  - Gasoline = 1.0 by definition
  - Diesel = 0.7 (approximate, not included in May 7 draft)
  - Electricity = 0.19
  - Hydrogen = 0.46

Baseline calculation

- Average Fuel Carbon Intensity (AFCI)
  - Weighted average of global warming intensity of all transportation fuels
- For this analysis – statewide average
- Baseline value: 92.1 gCO_2e/MJ
- 2020 target
  - 5% reduction: 87.5 gCO_2e/MJ
  - 10% reduction: 82.9 gCO_2e/MJ
  - 15% reduction: 78.3 gCO_2e/MJ

These values, and all the values in this presentation are our best estimates at this time, and need to be updated by the ARB with stakeholder input.

Scenarios examine different combinations of innovation and investment

- Fuels
  - Current ethanol – average of current technologies
  - Mid-GHG biofuels – best current technologies
  - Low-GHG biofuels – in development and pilots
  - (Advanced fuels discussed later today are *not* include)
- Vehicles
  - Conventional
  - Flex-fuel
  - Diesel
  - Hybrid
  - Plug-in hybrid
  - Battery electric
  - Hydrogen

Our study uses representative fuels

Fuel type	**Description**	**GWI** gCO2e/MJ
Gasoline	California average	92
Diesel	California average	59*
Average Midwest corn ethanol	Approximate national average	76
Mid-GHG ethanol	Corn feedstock, modern dry mills Natural gas, natural gas (wet DGs), stover	58
Low-GHG ethanol	Poplar, switchgrass, prairie grasses Cellulosic production	4
Mid-GHG biodiesel	Typical soy fatty acid methyl ester	20*
Low-GHG renewable diesel	Waste oils, California poplar Hydrogenation, Fischer-Tropsch	-4
Natural gas	California average (compressed)	68
Electricity	California average	27*
Hydrogen	Steam methane reforming	48*

* Adjusted to account for inherent drivetrain differences

These values are taken from the version of GREET used in the AB1007 study, but are uncertain. They need to be updated by the ARB with stakeholder input.

Scenarios are combinations of light duty vehicles and fuels to achieve AFCI reductions

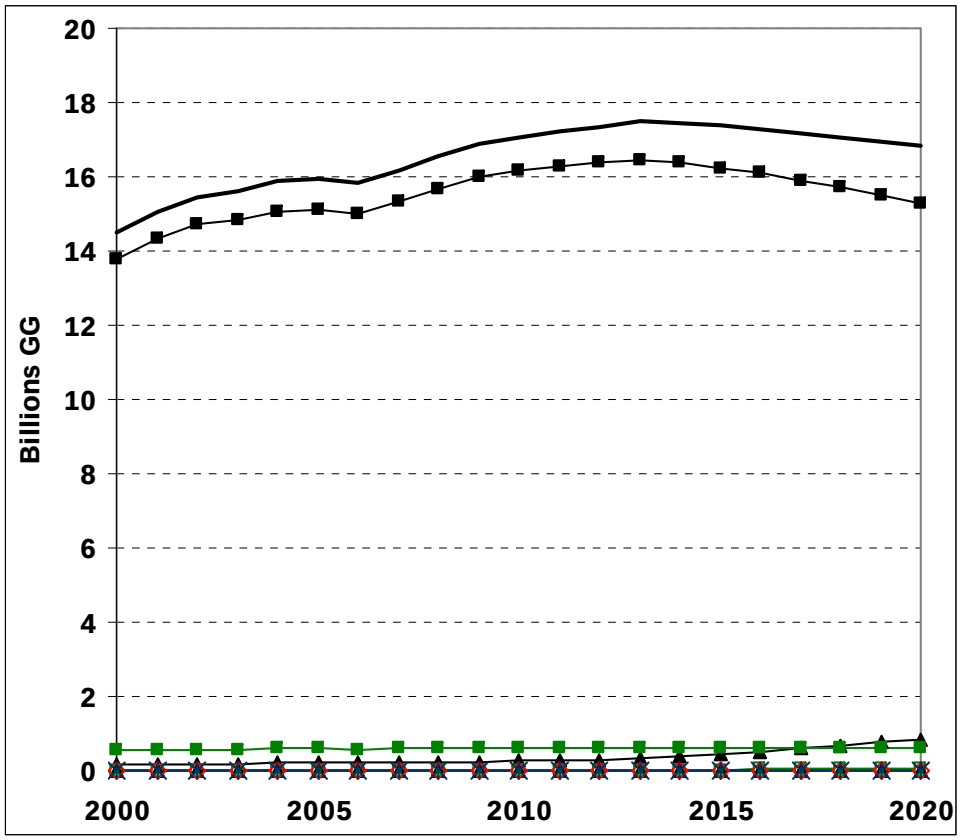
Name	**Description (beyond Business As Usual)**	**AFCI**
Business As Usual		
Electric Drive	Battery, plug-in hybrid, and hydrogen vehicles California average electricity	-5%
Existing Vehicles and Improved Biofuels	Diesel vehicles Low-GHG ethanol, low-GHG diesel	-5%, -10%
Evolving Biofuels and Improved Batteries	Battery, plug-in hybrid vehicles and FFVs Mid-GHG ethanol, mid-GHG diesel, Electricity	-5%, -10%
Biofuel Intensive	Diesel, flex-fuel, flex-fuel hybrid vehicles Mid- and low-GHG ethanol, mid- and low-GHG diesel	-5%, -10%, -15%
Multiple Vehicles and Fuels	CNG, plug-in hybrid, battery, fuel cell, flex-fuel, diesel Low-GHG ethanol & diesel, CNG, electricity, hydrogen	-5%, -10%, -15%

We used the VISION-CA model

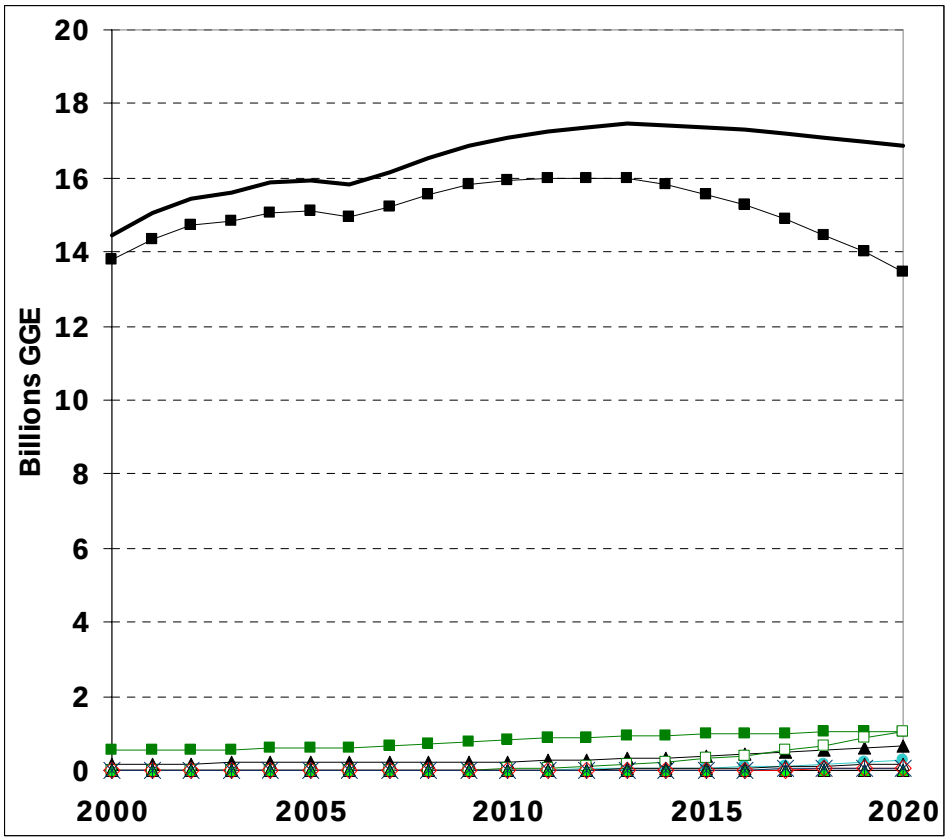
- Available next week on our websites
- Based on a Argonne National Laboratory model
  - Calibrated to California data
  - Population and economic growth
  - Vehicle stock turnover
  - Existing technological change: AB1493 (Pavley), diesels, etc.
- Smooth transitions in light duty vehicles and fuels
  - Example: Transition from current ethanol to low-GHG ethanol
  - Example: Introduction of plug-in hybrid electric vehicles
- Scenarios are created with combinations of fuel and vehicle introduction rates
- Results
  - Estimates vehicle and fuel market size, and AFCI
  - Unit: billions of gallons of gasoline equivalent (BGGE)

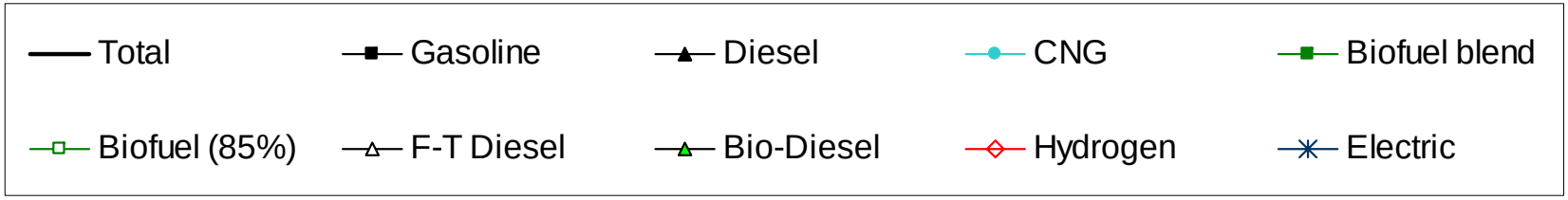
Fuel consumption changes in the scenarios

Business As Usual



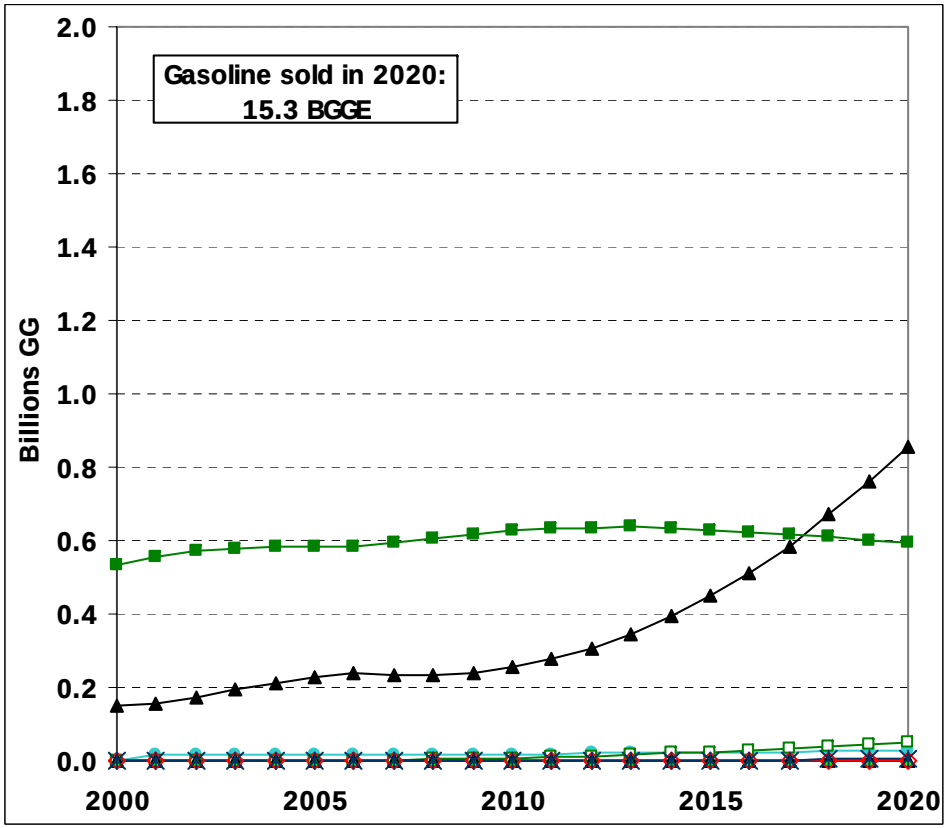
Multiple Vehicles and Fuels



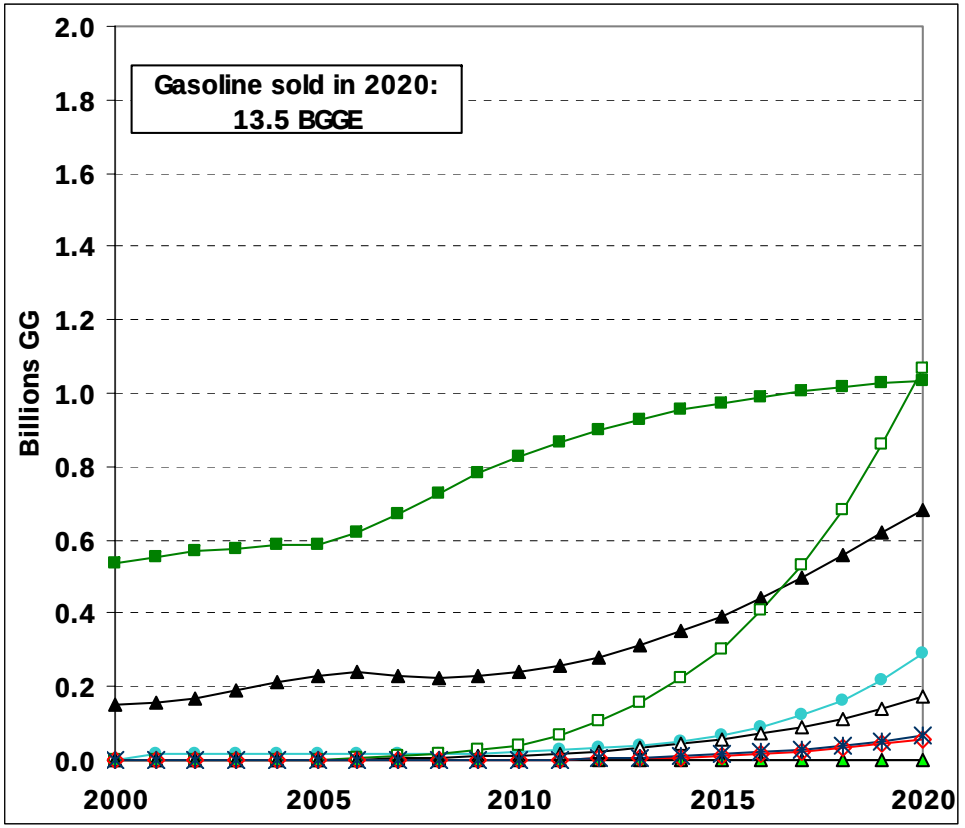


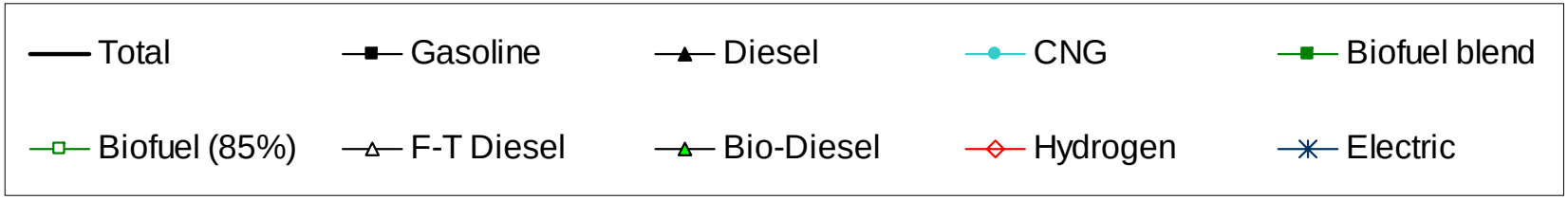
Alternative fuel consumption increases

Business As Usual



Multiple Vehicles and Fuels*





* Biofuels are getting *better* as well as increasing in volume.

Biofuel market size (-10% AFCI)

Scenario name	Million GGE/yr
Business as Usual	Gasoline: 15,300 Diesel: 850 Average ethanol: 650
Existing Vehicles and Improved Biofuels	Low-GHG ethanol: 957 Low-GHG diesel: 709
Biofuel Intensive	Mid-GHG ethanol: 3,293 Mid-GHG diesel: 423
Multiple Vehicles and Fuels	Low-GHG ethanol: 1,262 Low-GHG diesel: 171 CNG: 289 Electricity: 69 Hydrogen: 59

Biofuel consumption (Millions GGE/yr)

BAU: 650

Meet 2020 target with Mid-GHG: 3,700

Meet 2020 target with Low-GHG: 1,400-1,700

Note: Scenarios with improved electric vehicle technologies require less biofuels

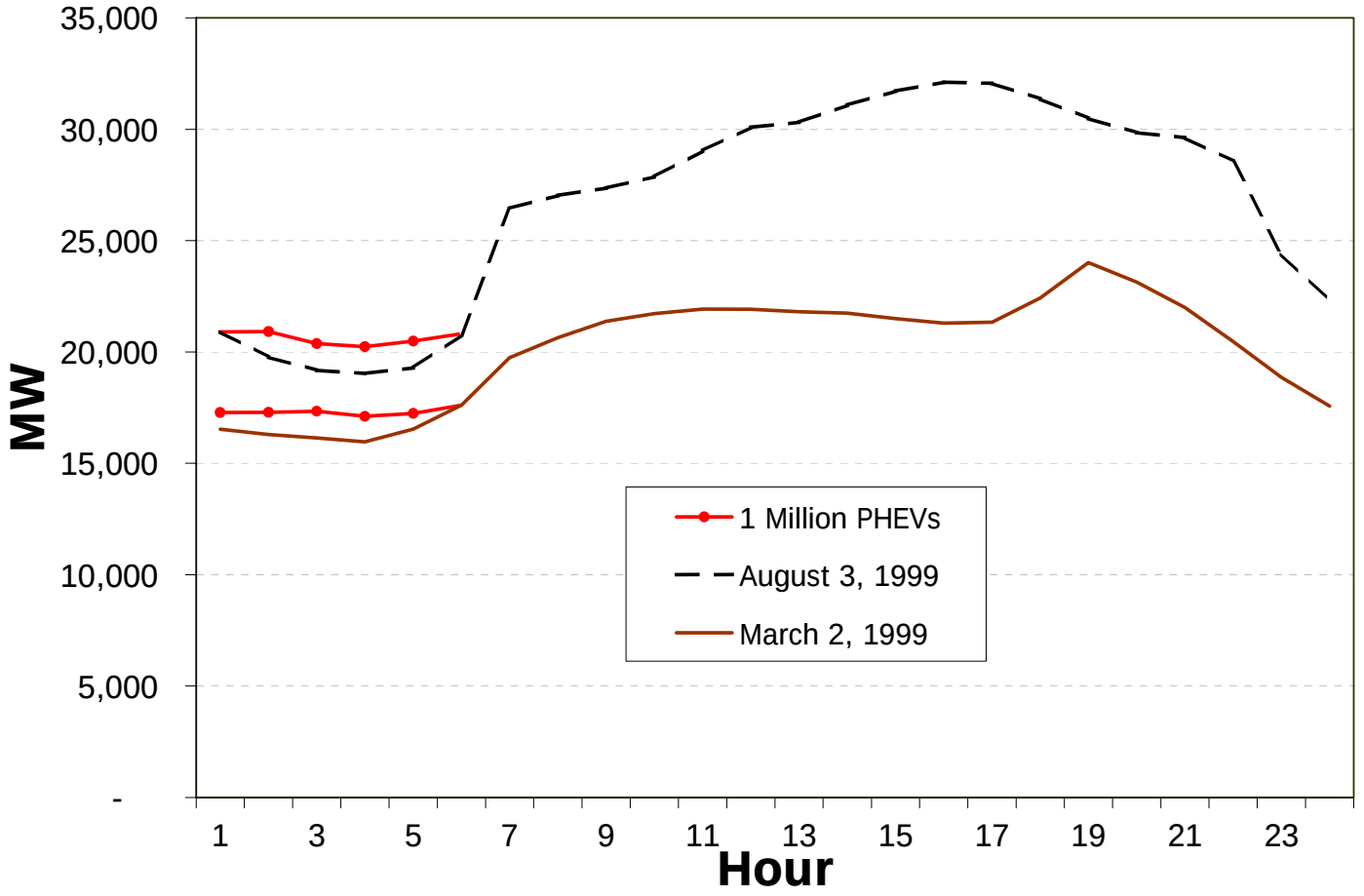
Existing and planned biofuel production in the U.S. can supply California's needs in 2012

Forecasted 2012 nationwide production capacity of existing and planned facilities	**Potential (Million GGE / yr)**
National mid-GHG ethanol	776 to 969
National mid-GHG diesel	1,400
National low-GHG ethanol	288
National low-GHG diesel	175

1. Little new innovation or investment may be needed to meet the LCFS through 2012
   - Existing and planned low-GHG biofuels are shipped to California
2. Little need for additional biofuel volume up through 2012
3. Little or no need to expand land use for biofuels up through 2012

California has more than enough electrical capacity to help meet the LCFS goals

Hourly demand curves for the California Independent System Operator (1999)



1. Vehicle buyers are incentivized to buy electric vehicles.
2. Charging is incentivized or controlled so it occurs at night.

Innovation is key to the 2020 outcome

In-state feedstocks for mid-GHG biofuels	**Potential (million GGE / yr)**
California starch and sugar crops	360 to 1,250
Imported corn for animal feed	130 to 300
In-state feedstocks for low-GHG biofuels	**Potential (million GGE / yr)**
California cellulosic agricultural residues	188
California forest thinnings	660
California waste otherwise sent to landfills	360
Cellulosic energy crops on 1.5 million acres in California	2,400 to 3,200

1. With current technologies, California will have to rely on imports to meet the 2020 target, and must increase biofuel consumption.
2. With innovation and investment in fuel technologies, California may be able to meet the 2020 target without significant imports or land use expansion.

Several options exist for heavy duty vehicles.

- Low-GHG diesel
- Electrification
  - Truckstops
  - Ports
  - Freight (cranes, forklifts, etc.)
- Natural gas

Cost-effectiveness

- The LCFS will reduce carbon intensity
  - Direct measurement of the intended effect
- The LCFS will stimulate technological innovation and investment
  - Current technologies were not developed with low carbon intensity in mind
- Numerous technologies will compete to lower costs
  - I haven't even mentioned: biocrude, direct methanol fuel cells, biobutanol, compressed air, algae, etc.
  - Fuel providers choose solutions that work for them and for their customers
- Credit trading within the fuels sector minimizes costs.
  - Experience shows that well-designed market based regulations achieve results at lower costs

Conclusions

The 10% target is technically feasible

- **Current technologies can meet the standard, but are not optimal for the job**
- **Resources for low-carbon fuels (e.g. electricity and biofuels) are adequate**
- **The LCFS will focus innovation to improve technology**
- **With modest amounts of innovation, California can reach the 2020 goal without significant expansion of land use for biofuel production**

The Low Carbon Fuel Standard is cost–effective

- **Technologies compete, government does not pick winners**
- **Incentive for innovation will increase the number of options and lower costs**
- **Market-based approach minimizes costs of compliance**

Thank You

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