

Getting the Carbon Out: The Low Carbon Fuel Standard

Energy & Environmental Study Institute
Washington, DC
June 5, 2007

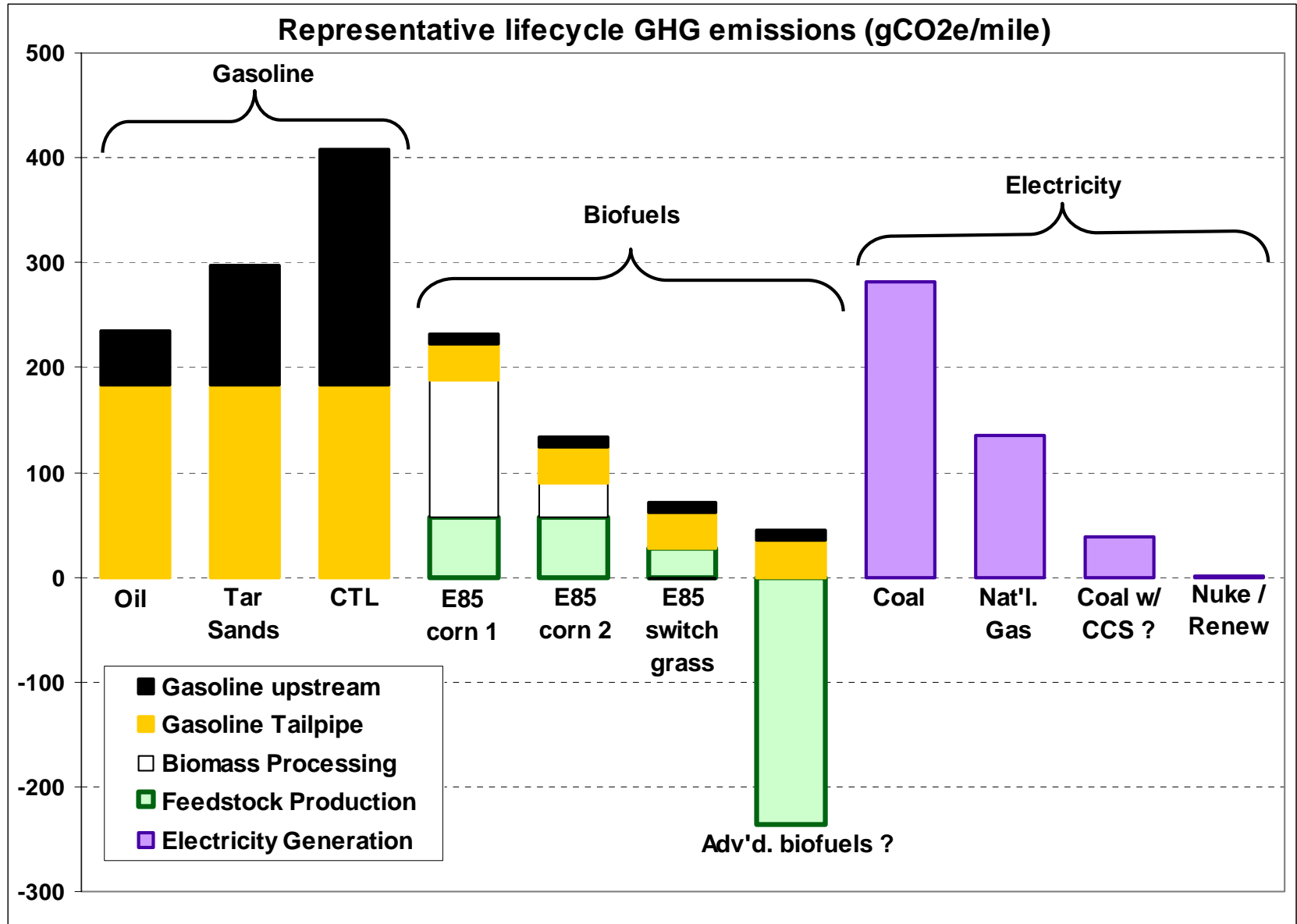
Alex Farrell

Energy and Resources Group, UC Berkeley

aef@berkeley.edu



GHG emissions from fuels depend on how they are made



Controlling GHG emissions is a prerequisite to good energy policy

- Energy policies that do not control GHG emissions may not be feasible, and certainly are not stable
- Controlling GHG emissions will stimulate innovation and investment in new technologies
- In transportation, carbon is a good proxy for petroleum
- Carbon is also a good proxy for other environmental problems
 - Land use change and biodiversity
 - Eutrophication

California has developed a comprehensive, sectoral strategy to cut GHG emissions

- **Overall goals**
 - Executive Order (S-3-05)
 - Global Warming Solutions Act (AB32)
- **Energy research portfolio**
- **Buildings and appliances**
 - Energy efficiency standards (CEC)
- **Electricity other large sources**
 - Carbon Adder (CPUC)
 - Renewable portfolio standard for electricity (SB 107)
 - GHG performance standard and cap (CPUC and SB1368)
- **Transportation**
 - Vehicle GHG performance standard (AB 1493 Pavley)
 - Low Carbon Fuel Standard (Executive Order S-1-07)
 - Vehicle use and transportation options
- **Other policies**



Why a sectoral policy is needed

- **Technological innovation is needed in every sector**
- **Multiple market imperfections**
 - Inadequate R&D for environmental technologies
 - Network effects require cross-industry coordination
 - Infrastructure is often required so prices are not sufficient
 - High discount rates of private companies and of consumers
 - Market power
- **Poor fuel-on-fuel competition in transport** (\$25/tonne CO₂)
 - Nuclear + renewable electricity \$00.01/MWh
 - Integrated gasification combined cycle with carbon capture and storage (IGCC+CCS) \$02.5/MWh
 - Natural gas combined cycle (NGCC) \$12.5/MWh
 - Pulverized coal (PC) \$20/MWh

 - Gasoline \$0.22/gallon
 - Corn ethanol \$0.11 to \$0.23/gallon

Low Carbon Fuel Standard (LCFS)

- **Compliance by blenders, refiners, and importers**
- **Government sets performance standard and does not pick technological winners**
- **Global warming intensity must decline**
 - All climate forcing effects (not just GHGs)
 - Measured in terms of carbon intensity, gCO₂e/MJ
 - At least 10% reduction by 2020
 - Default and opt-in approach
- **Scope: all gasoline and diesel (no jet or marine)**
- **Additional to vehicle performance standards**
- **Overcompliance creates credits can be traded or banked**
- **Similar to emerging European approach**

Regulatory Approach

- **Firms report average carbon intensity of fuels**
 - Carbon intensity of inputs are recorded
 - Compared to standard that declines over time
- **Default: all fuel inputs are assigned a carbon intensity**
 - Fuel inputs must be categorized
 - Highest value in common use is the default value
 - Encourages opt-in
- **Opt-in: suppliers with lower carbon intensity can get certified at a lower value**
 - Requires protocol development and data collection
- **Compliance options**
 - Improve energy efficiency or lower upstream CO₂ emissions
 - Blend in fuels with lower carbon intensity
 - Sell fuels with low carbon intensity (e.g. electricity)
 - Buy credits from within the fuels sector

A Low-Carbon Fuel Standard for California

Project Directors

Alexander E. Farrell, UC Berkeley
www.its.berkeley.edu/sustainabilitycenter

Daniel Sperling, UC Davis
www.its.ucdavis.edu

Contributors

S.M. Arons, A.R. Brandt, M.A. Delucchi, A. Eggert, A.E. Farrell,
B.K. Haya, J. Hughes, B.M. Jenkins, A.D. Jones, D.M. Kammen,
S.R. Kaffka, C.R. Knittel, D.M. Lemoine, E.W. Martin, M.W. Melaina,
J.M. Ogden, R.J. Plevin, D. Sperling, B.T. Turner, R.B. Williams, C. Yang

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.

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 are *not* included)

- **Vehicles**

- Conventional
- Flex-fuel
- Diesel
- Hybrid
- Plug-in hybrid
- Battery electric
- Hydrogen

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

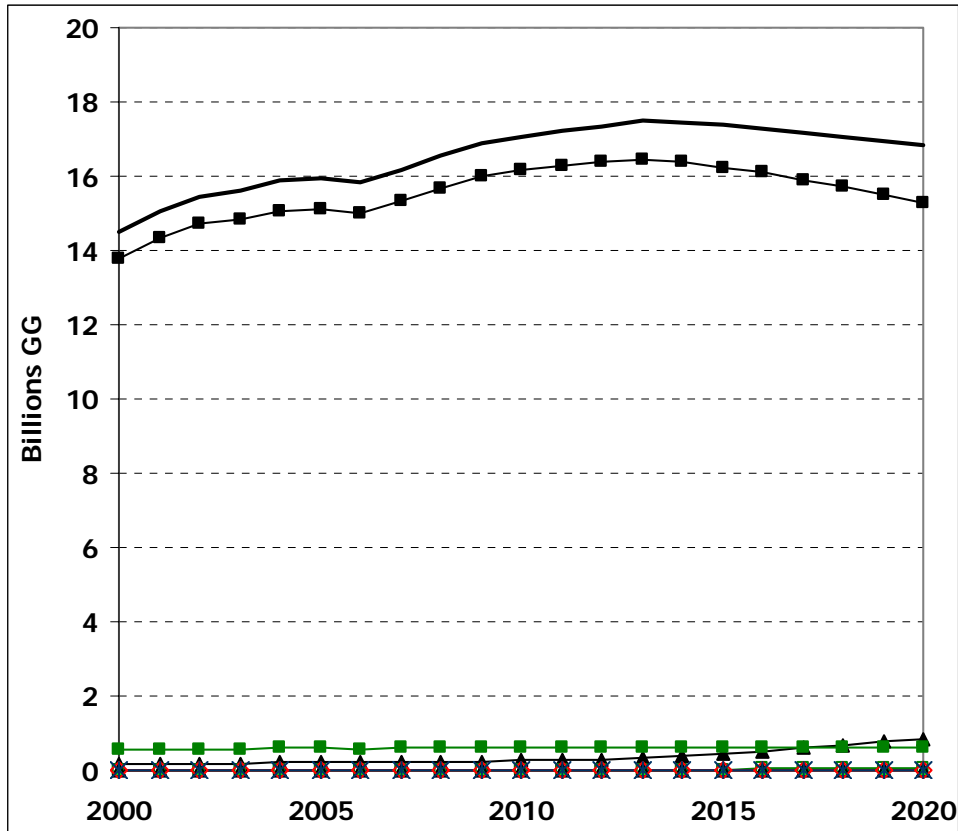
Name	Description (beyond Business As Usual)	AFCEI
Business As Usual		
Electric Drive	Battery, plug-in hybrid, and hydrogen vehicles California average electricity	-5%
Existing Vehicles and Improved Biofuels	Diesel vehicles Low-GHG ethanol, low-GHG diesel	-5%, -10%
Evolving Biofuels and Improved Batteries	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

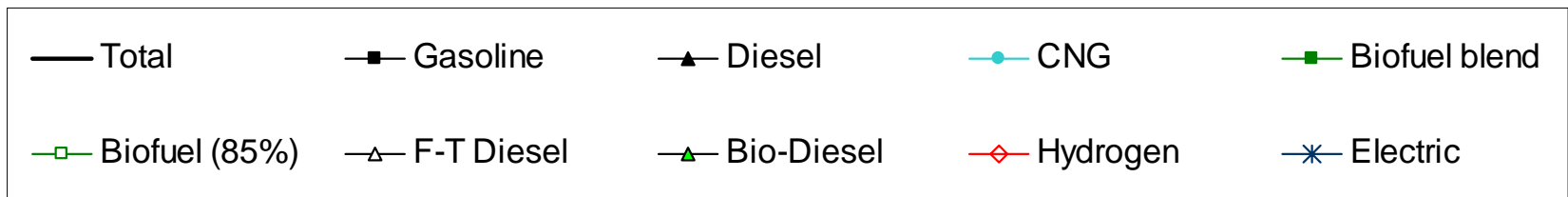
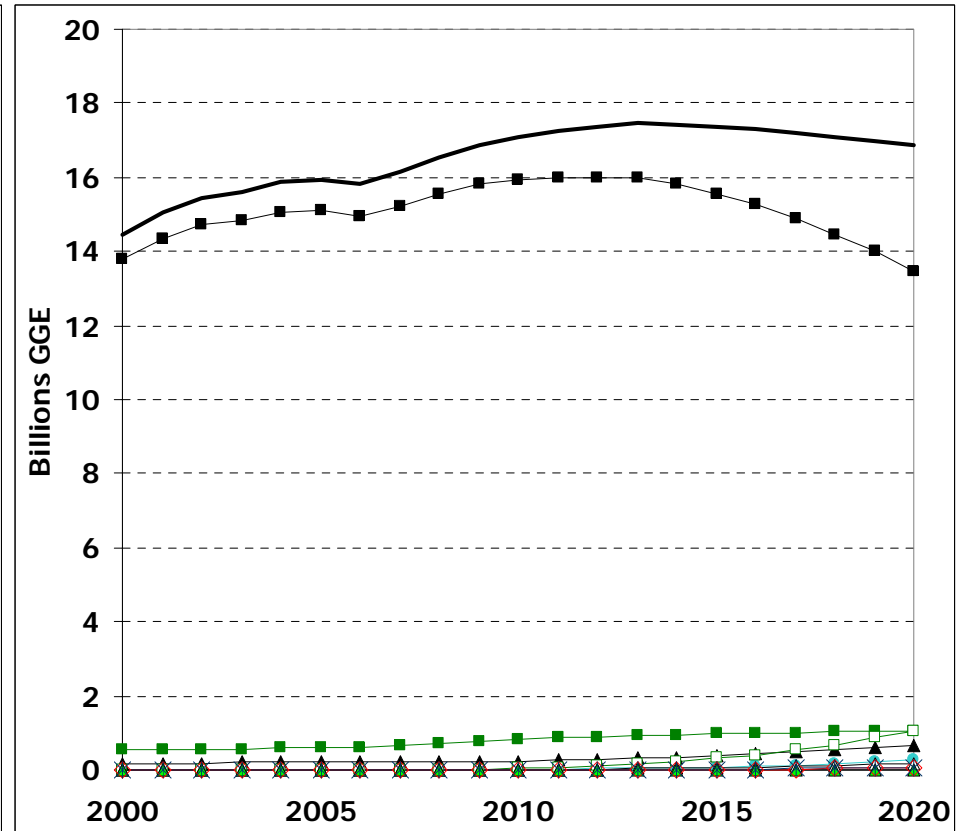
- Available next week on our websites
- Based on a Argonne National Laboratory model
 - Calibrated to California data
 - Population and economic growth
 - Vehicle stock turnover
 - Existing technological change: AB1493 (Pavley), diesels, etc.
- Smooth transitions in light duty vehicles and fuels
 - Example: 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



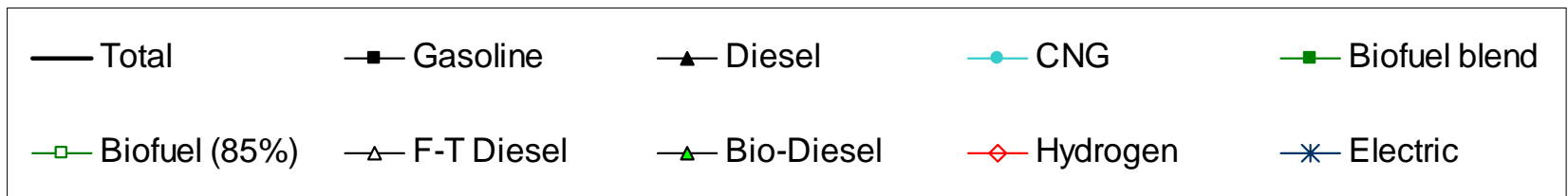
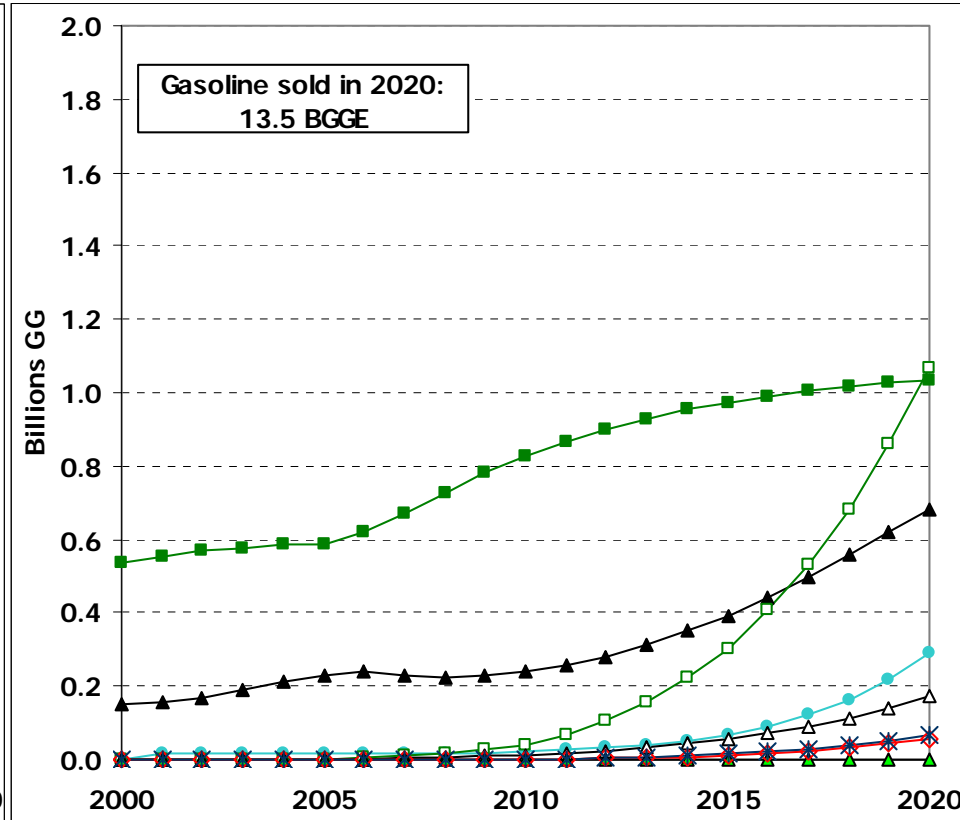
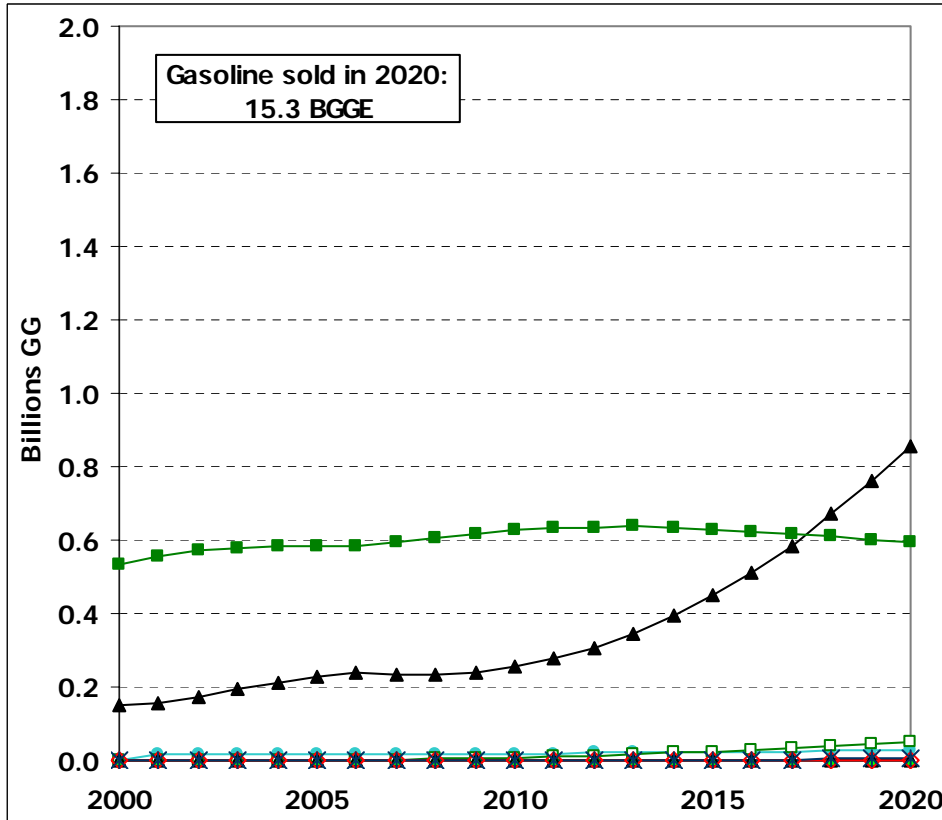
Multiple Vehicles and Fuels



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

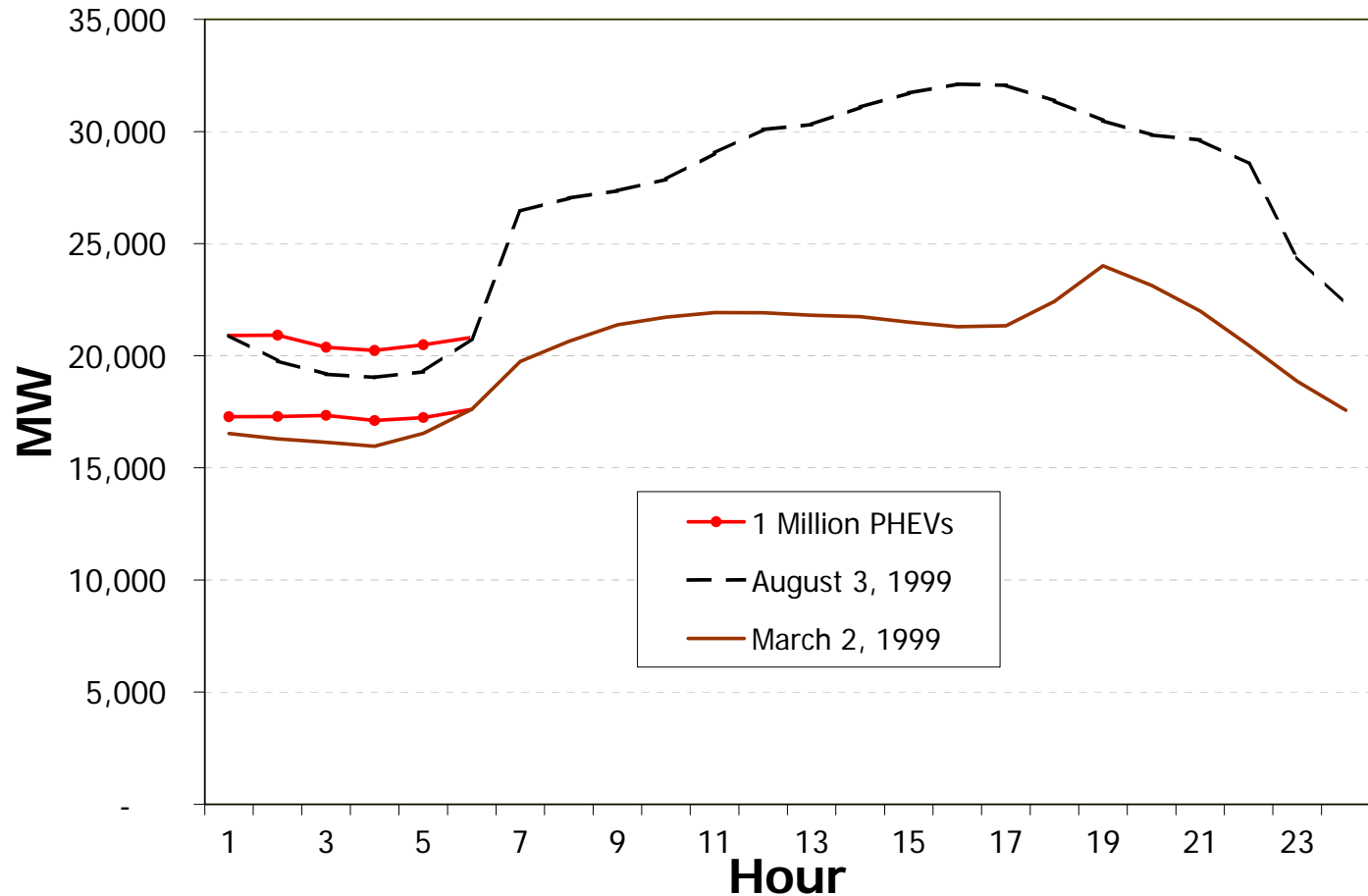
Innovation is key to the 2020 outcome

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	
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.

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.

Several options exist for heavy duty vehicles.

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

Report Findings

The Low Carbon Fuel Standard 10% target is feasible

- Several different combinations technological innovation and investment can meet this standard
- Resources for low-carbon fuels are adequate
- The LCFS will focus innovation to improve technology
- With modest innovation, California can reach the 2020 goal without significant expansion of land use for biofuel production

The Low Carbon Fuel Standard is cost-effective

- Direct measurement of the intended effect
- 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

Complementary policies may be needed

- Environmental justice and sustainability
- Research and development
- Other aspects of transportation (vehicles and travel options)

Thank You



Co-authors

Stakeholders

CARB and CEC staff

This research was supported by grants from the National Science Foundation and the Energy Foundation.