California's Low Carbon Fuel Standard

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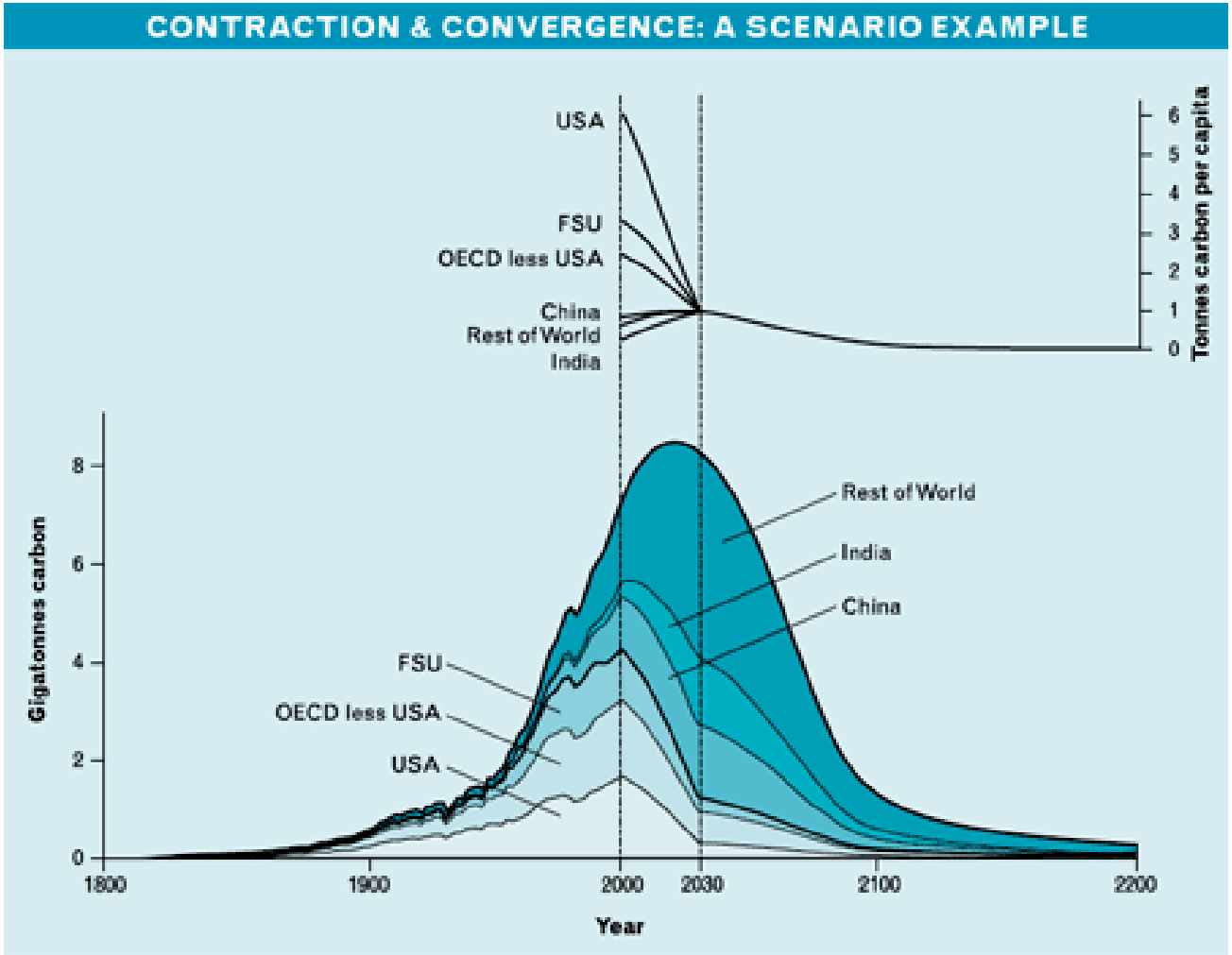
Presentation Overview

- California's GHG Reduction Goals
- What is the Low Carbon Fuel Standard and how does it work?
- Carbon Intensity as a policy metric

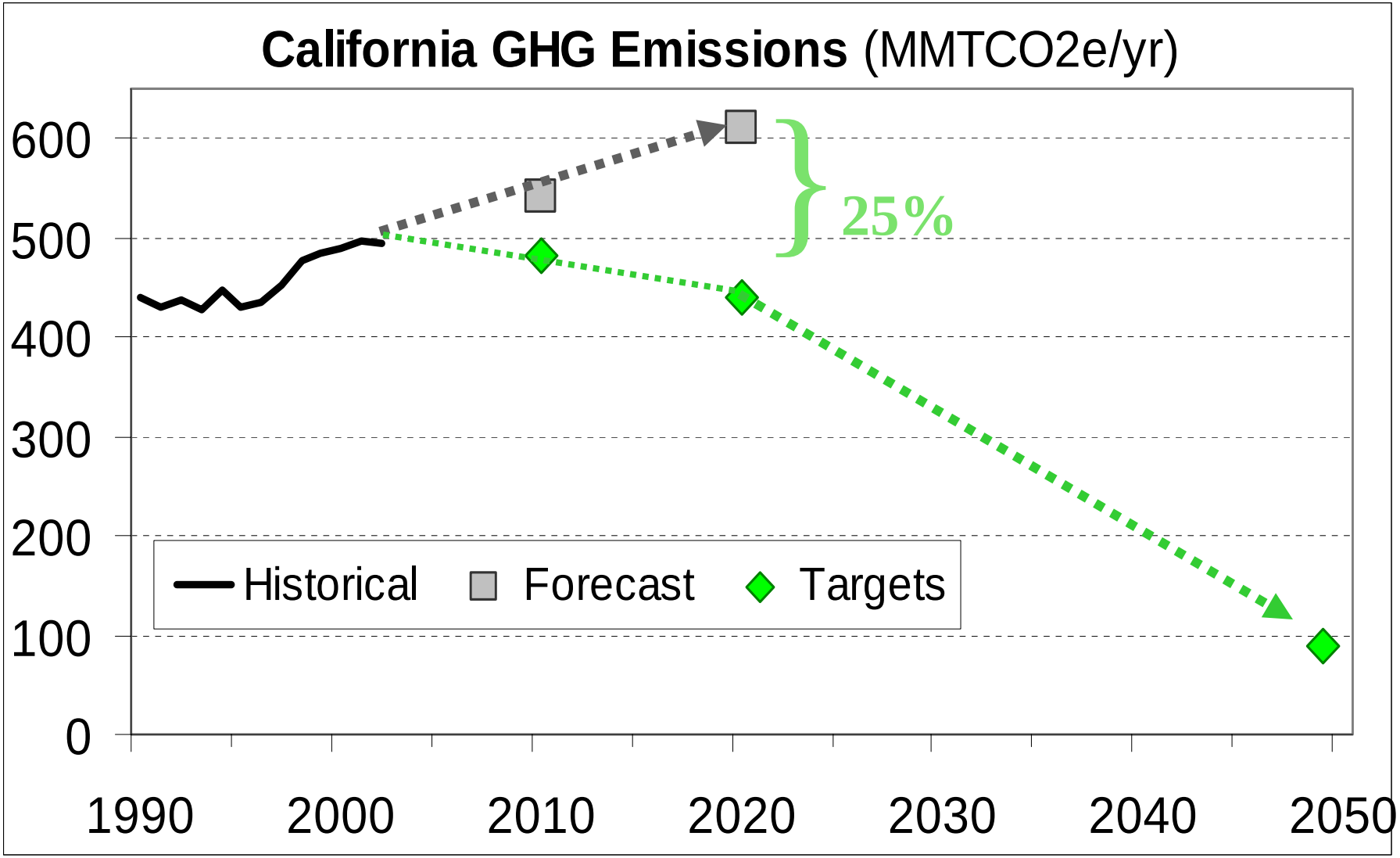
Long-term Carbon Reduction Requirements



450 ppm example of "contraction and convergence" per the Global Commons Initiative

Source: www.cru.uea.ac.uk/tiempo/newswatch/comment060704.htm

California (and others) set ambitious targets



The CA Low Carbon Fuel Standard

- Executive Order S-1-07 was signed on January 18th, 2007
- The EO calls for at least a 10% reduction in the carbon intensity of transportation fuels by 2020
- Over the next 6 months, a team of Davis and Berkeley researchers prepared a two-part recommendation report on implementing the LCFS
- The LCFS has been approved by ARB as an early action item

Signing the LCFS, Jan 18th, 2007

http://gov.ca.gov

LCFS Status: Going Global

- **California:** LCFS regulations to be in effect 2010
- **Consideration by other states and provinces:** AZ, BC, CT, DE, MD, MA, MN, NH, NJ, NY, ON, OR, NM, RI, VT, WA…
- **Federal regulations:** Proposed EPA rule in December 2007
- **Federal bills:** Boxer, Feinstein, Obama, Inslee, Dingell-Boucher, etc.
- **United Kingdom:** Renewable Transportation Fuel Obligation (like a RFS) requires GHG monitoring in 2007
- **Germany:** Sustainability requirements for biofuels in 2009
- **European Union:** monitoring in 2009, reductions in 2011 (proposed)

From Sperling, WGA 2007

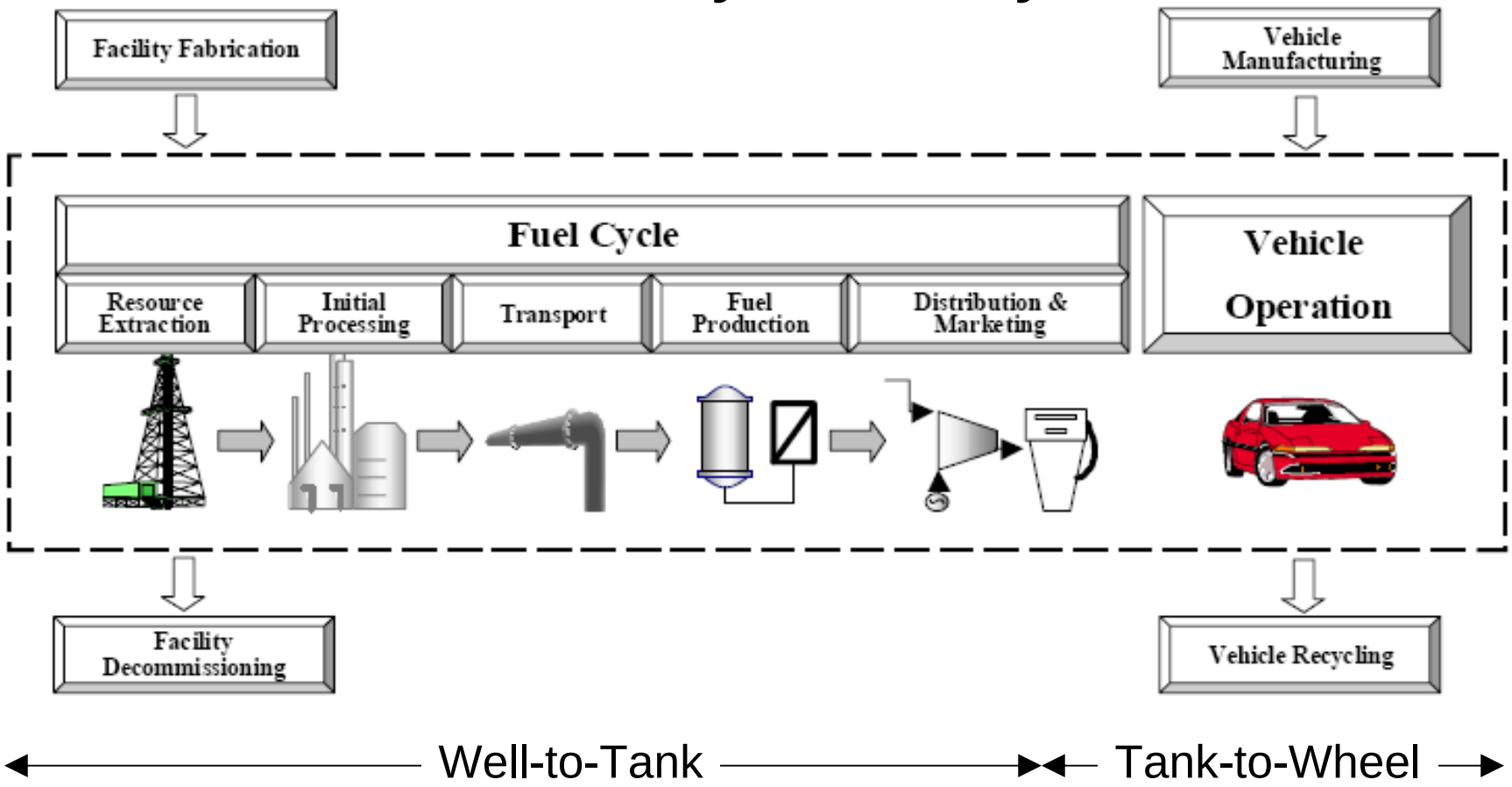
Key Features of California LCFS

- Requires a 10% reduction in the Carbon Intensity of transportation fuels by 2020 (with further reductions to follow)
- **"**Carbon" intensity measured on lifecycle basis
  - Global warming intensity, measured in gCO2e/MJ
  - Includes CO_2 and other GHGs
  - Adjusted for drivetrain efficiency: Gasoline = 1.0 by definition, Diesel = 0.78, Electricity = 0.20, H_2 = 0.47 (proposed)
- Point of regulation is oil refineries (and oil importers)
- Performance standard (no 'picking winners')
- Allows trading and banking of LCFS credits
- Could be implemented in addition to tax or cap

UC Study recommendations are based on extensive consultation with industry representatives.

Adapted from Sperling, WGA 2007

Full Fuel Cycle Analysis



Facility and vehicle life cycles are not included. They typically comprise only a fraction (< 15%) of total GHG emissions.

Well-to-Tank energy can be proportional to fuel quality, with higher quality fuels being used more efficiently in vehicles (i.e., EVs, FCVs)

Principles Underlying LCFS

- Create durable framework for orchestrating near and long term transition to low-carbon alternative fuels
  - Send consistent signals to industry and consumers to reduce GHGs
- Stimulate technological innovation
- Performance standard will tighten over time
- Use lifecycle approach
- Consistency/compatibility between states, US, EU, Japan, China, others

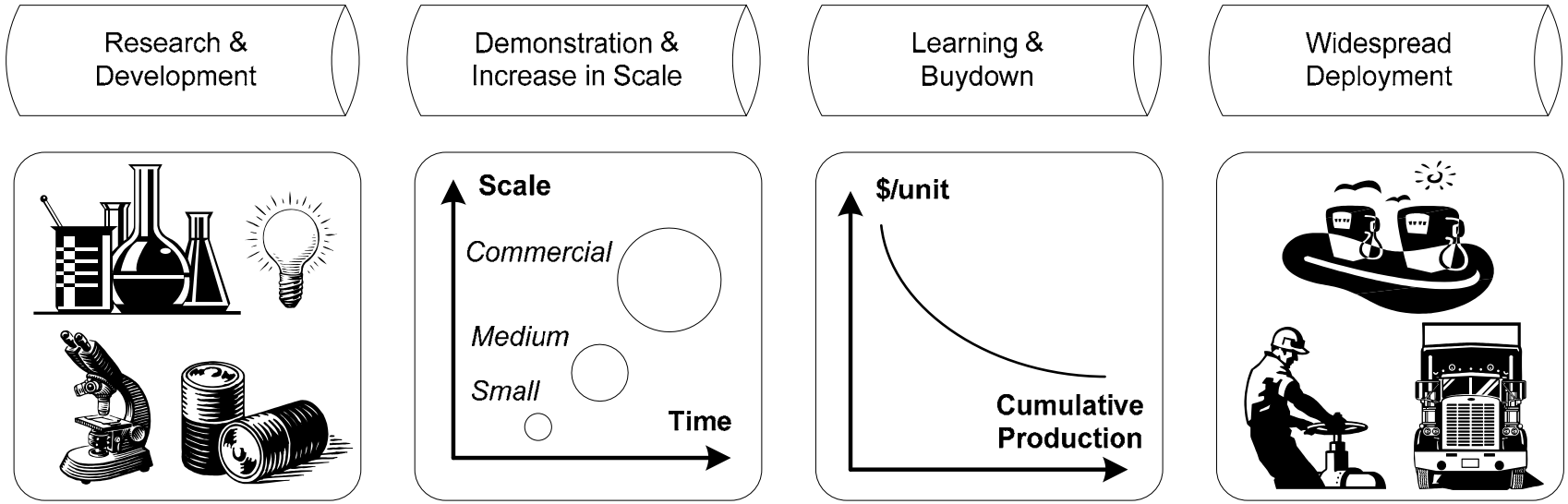
Adapted from Sperling, WGA 2007

The LCFS is a Flexible Standard

- Scope includes all transportation fuels
  - Aviation fuels excluded, diesel irrigation pumps included
- Industry has a broad range of options for making these reductions
  - Focus on alternative fuels
  - Least cost options can be identified
- Total fuel use may increase or decrease, but the carbon intensity must be reduced regardless
- The LCFS combines a technology standard with a flexible compliance mechanism
  - Attributes of previously successful policies (e.g., efficiency standards for appliances and credit trading system for SO_2)

The Technology RD^3 Innovation Pipeline

Research, Development, Demonstration and Deployment



The LCFS will have a direct influence on innovations near commercialization. Other supportive and complementary policies will be needed for others.

How to Comply?

1. Improve energy efficiency or lower upstream CO_2 emissions (e.g., eliminate flaring)
2. Blend in fuels with lower carbon intensity (e.g., biofuels)
3. Sell fuels with low carbon intensity (e.g. electricity)
4. Buy credits from other fuel providers

From Sperling, WGA 2007

Defining Carbon Intensity: What is being Reduced?

- We have defined carbon intensity (CI) as including:
  - All GHG emissions upstream from the vehicle (C_{WTT} in gCO_2/MJ)
  - The carbon content of the fuel (C_{TTW} in gCO_2/MJ)
  - A vehicle drivetrain efficiency adjustment factor (η)

$$CI = (C_{WTT} + C_{TTW}) \cdot \eta$$

- Higher quality fuels are more energy-intensive, requiring more energy inputs, but they can be used more efficiently
  - Efficiency adjustment factor is ratio of drivetrain efficiencies, using current gasoline ICE vehicles as the basis
  - *Drivetrain efficiency* (η) is inherent to fuels (excludes vehicle mass, aerodynamic drag, tire rolling resistance, accessories)
  - Electricity: ~0.20 Hydrogen: ~0.47 Diesel: ~0.78

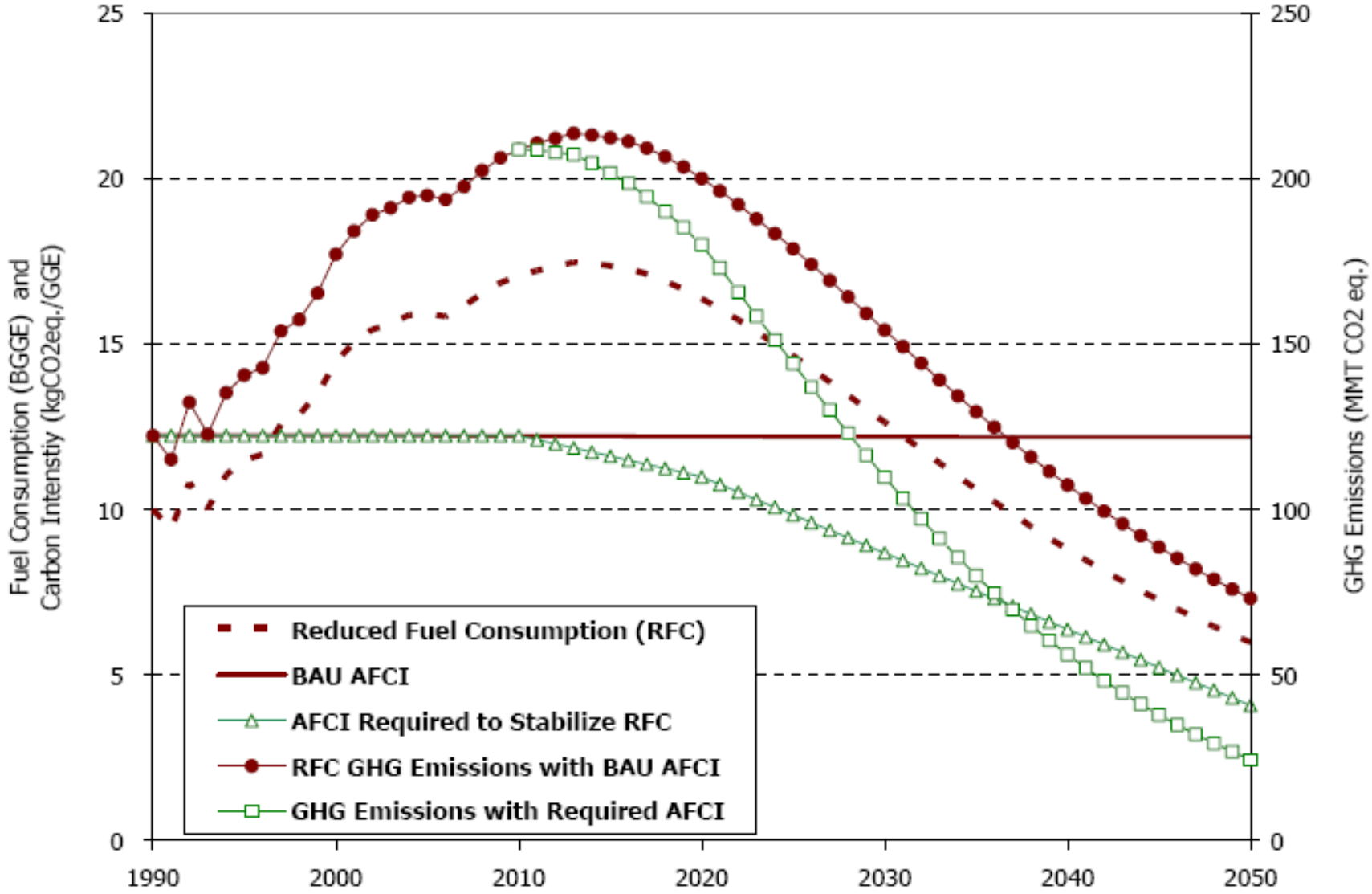


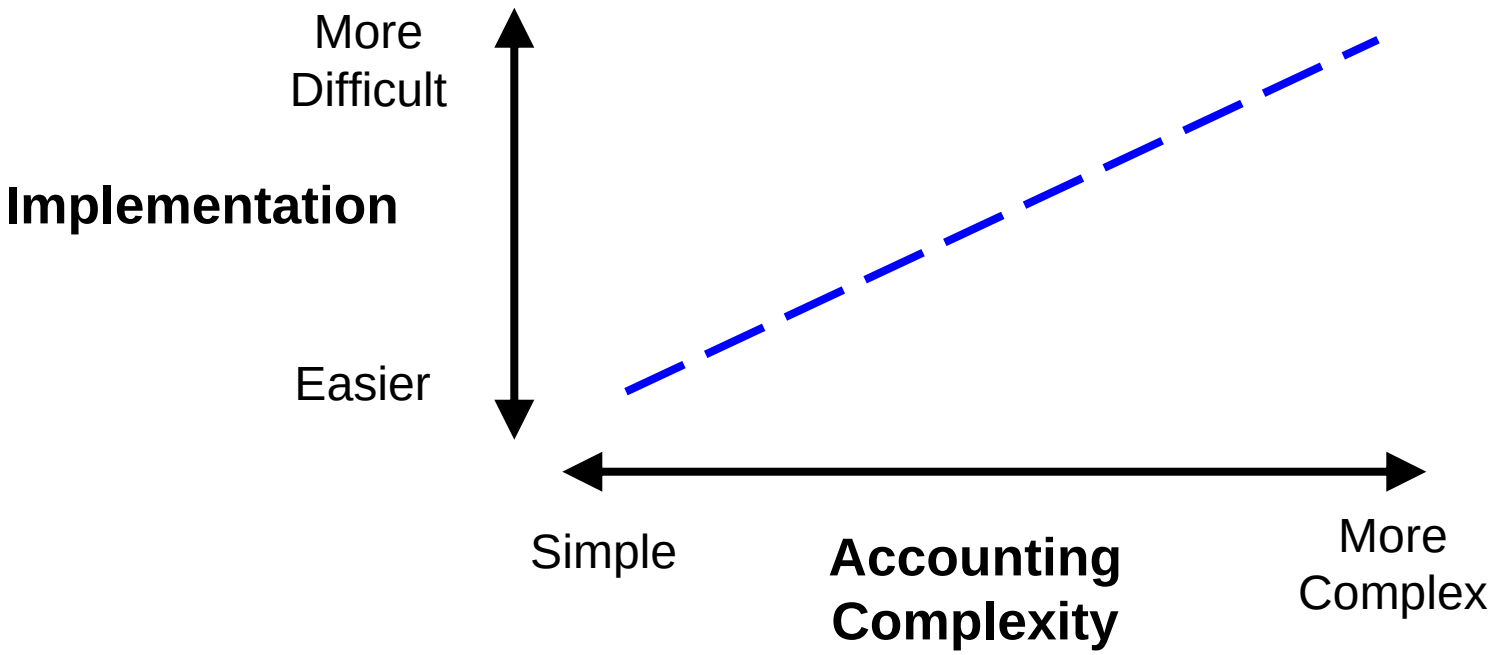
Figure 1-3: Trajectories for light duty vehicle GHG emissions to 2050

BGGE=billion gallons of gasoline equivalent; GGE=gallons of gasoline equivalent; MMT=million metric tons

Baseline, Default and Opt-in

- **Baseline: weighted average of the carbon intensity of all fuels**
- **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
  - Requires arbitrary decisions
- **Opt-in: suppliers with lower carbon intensity can get certified at a lower value**
  - CARB-approved protocols and 3rd-party certification
  - Different levels of detail are possible:
    1. Corn ethanol made in a dry mill
    2. Corn ethanol made in a dry mill that uses natural gas
    3. Ethanol made in a *particular* plant
- **Very similar to emerging UK/EU system (RTFO)**

Implementation and Complexity



Possible approaches:

- **Self certification with third party review**
- **Increase number of variables and/or certified fuels over time**

12 Scenarios were Developed

Scenario name	Fuel Innovations	Vehicle Innovations	AFCI Reduction		
			-5%	-10%	-15%
Baseline	Current technologies	Gasoline ICE dominates Increased diesel, HEVs	A*		
Electric Drive	Electric charging & H2 refueling	Significant innovation in PHEV, EV and FCV technologies	C5	**	**
Existing Vehicles with Advanced Biofuels	Significant biofuel innovation. Low-GHG biofuels (5.7% vol.) Low-GHG FT diesel blends	None required	D5	D10	**
Evolving Biofuels and Advanced Batteries	No fuel innovation. Mid-GHG biofuels (10% vol.) Mid-GHG biodiesel blends	Advances in PHEV, EV and FCV technologies	F5	F10	**
Biofuel Intensive	No fuel innovation. Mid-GHG biofuels (10%, 85%) Mid-GHG biodiesel blends Low-GHG fuels for G15	None required	G5	G10	G15
Multiple Fuels & Vehicles	Low-GHG biofuels (10%, /85%) Low-GHG FT diesel blends Electric charging & H2 refueling	Advances in PHEV, EV and FCV technologies	H5	H10	H15

5 Scenarios fall short of 10% goal, 4 meet it, 2 exceed it

Thank You!

Email: marc_melaina@nrel.gov
UCD LCFS Website: http://www.lcfs.ucdavis.edu
CARB LCFS Website: http://www.arb.ca.gov/fuels/lcfs/lcfs.htm

Study Findings

The Low Carbon Fuel Standard 10% target is feasible

- Current technologies can meet the standard, but are not optimal
- Resources for low-carbon fuels are adequate
- The LCFS will stimulate 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

- Technologies compete, government does not pick winners
- Incentive for innovation increases options and lower costs
- Market-based approach minimizes costs of compliance

Complementary policies may be needed

- Environmental justice and broad sustainability issues
- R&D, direct support for specific fuel and vehicle technologies

Fuel use under Business as Usual

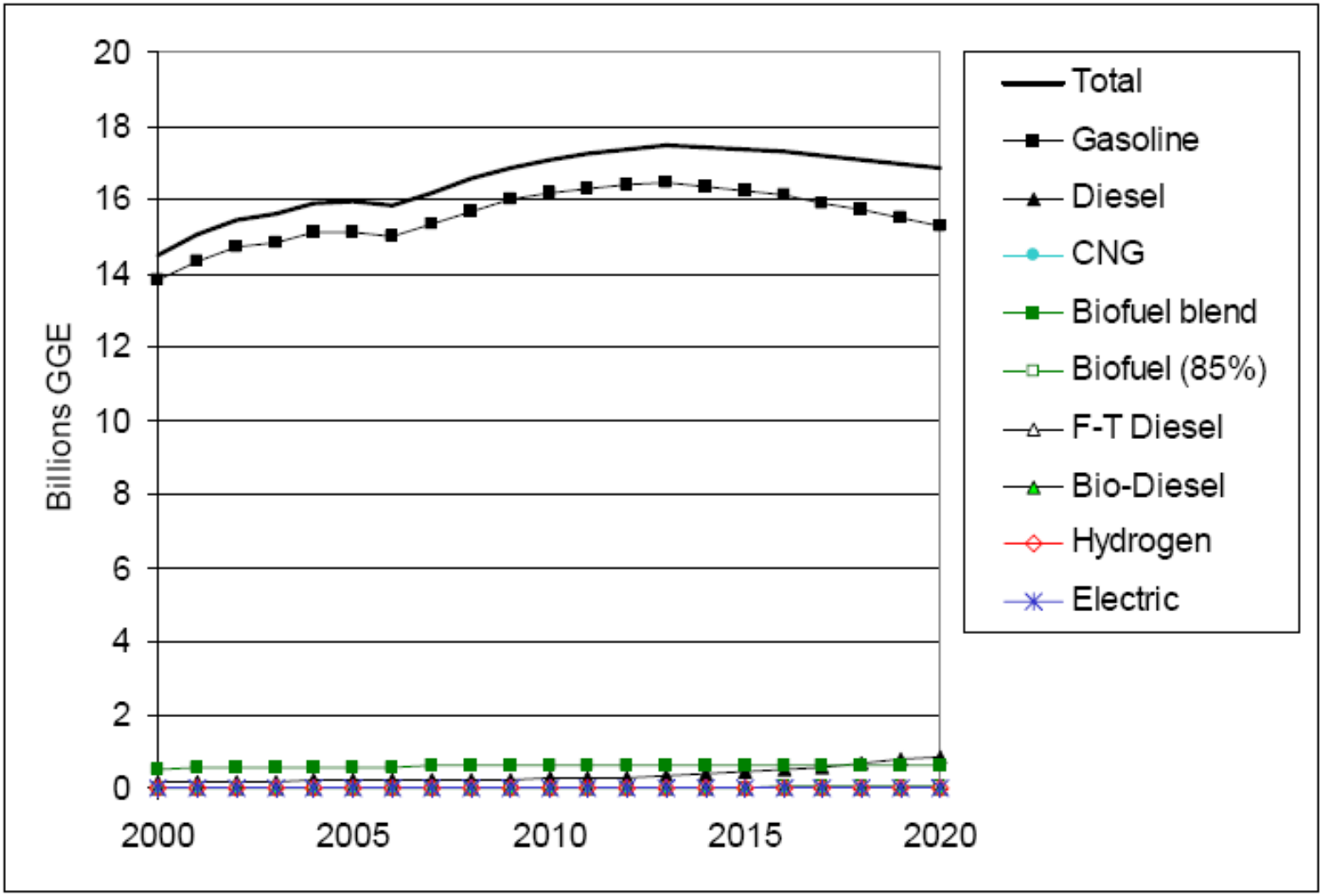


Figure 5-6: Fuel energy consumption in the BAU Scenario

Fuels in the Mixed Scenario (15%)

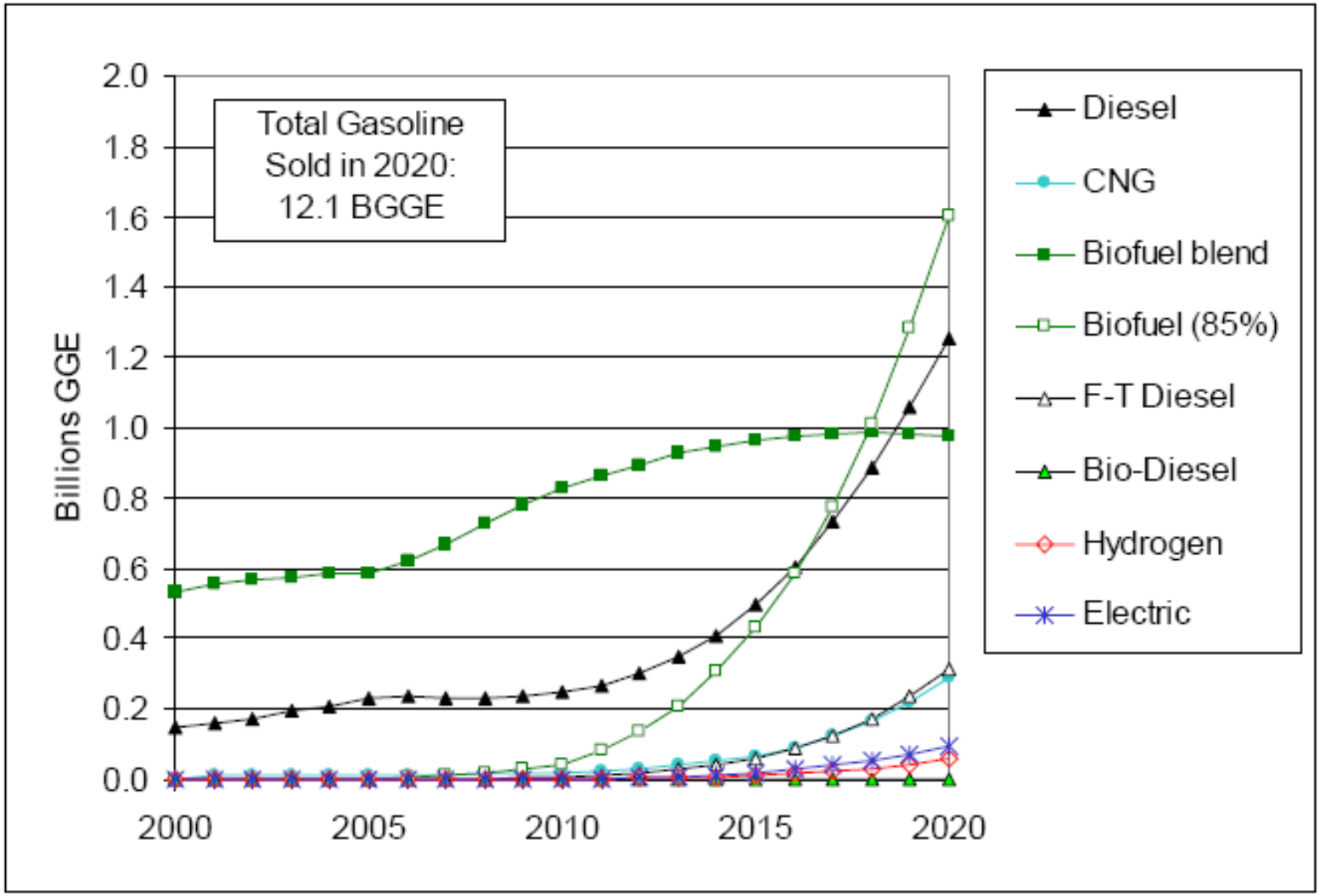


Figure 5-35: Fuel energy consumption in Scenario H15

Scenario: Multiple Fuels & Vehicles

Scenario	Major Low-Carbon Fuels and Vehicles	Carbon Intensity Reductions (AFCI)					
		-5%		-10%		-15%	
Business as Usual (A)	*For year 2020:* Gasoline: 15.3 BGGE Diesel: 0.86 BGGE LDVs sold: 2.32 million	*		*		*	
Multiple Fuels & Vehicles (H5, H10, H15)	Low-GHG Biofuel	0.216	1.3%	0.410	2.4%	0.516	3.1%
	CNG	0.289	1.7%	0.289	1.7%	0.289	1.7%
	Electricity	*BAU*	*BAU*	*BAU*	*BAU*	0.097	0.6%
	Hydrogen	*BAU*	*BAU*	*BAU*	*BAU*	0.059	0.4%
	Low-GHG FT Diesel	-	-	0.314	1.9%	0.314	1.9%
	Sub-zero GHG Biofuel	-	-	-	-	0.645	3.9%
	CNG vehicles	107	4.6%	107	4.6%	107	4.6%
	Plug-in hybrid vehicles	171	7.4%	171	7.4%	171	7.4%
	Flex-fuel vehicles	*BAU*	*BAU*	806	34.7%	806	34.7%
	Diesel vehicles	*BAU*	*BAU*	593	25.5%	593	25.5%
	Battery electric vehicles	*BAU*	*BAU*	*BAU*	*BAU*	12	0.5%
	Fuel cell vehicles	*BAU*	*BAU*	*BAU*	*BAU*	45	1.9%

Fuel Units: BGGE = billions of gallons of gasoline equivalent
Vehicle Units: 1000s of new vehicles sold per year

Vehicles in the Mixed Scenario (15%)

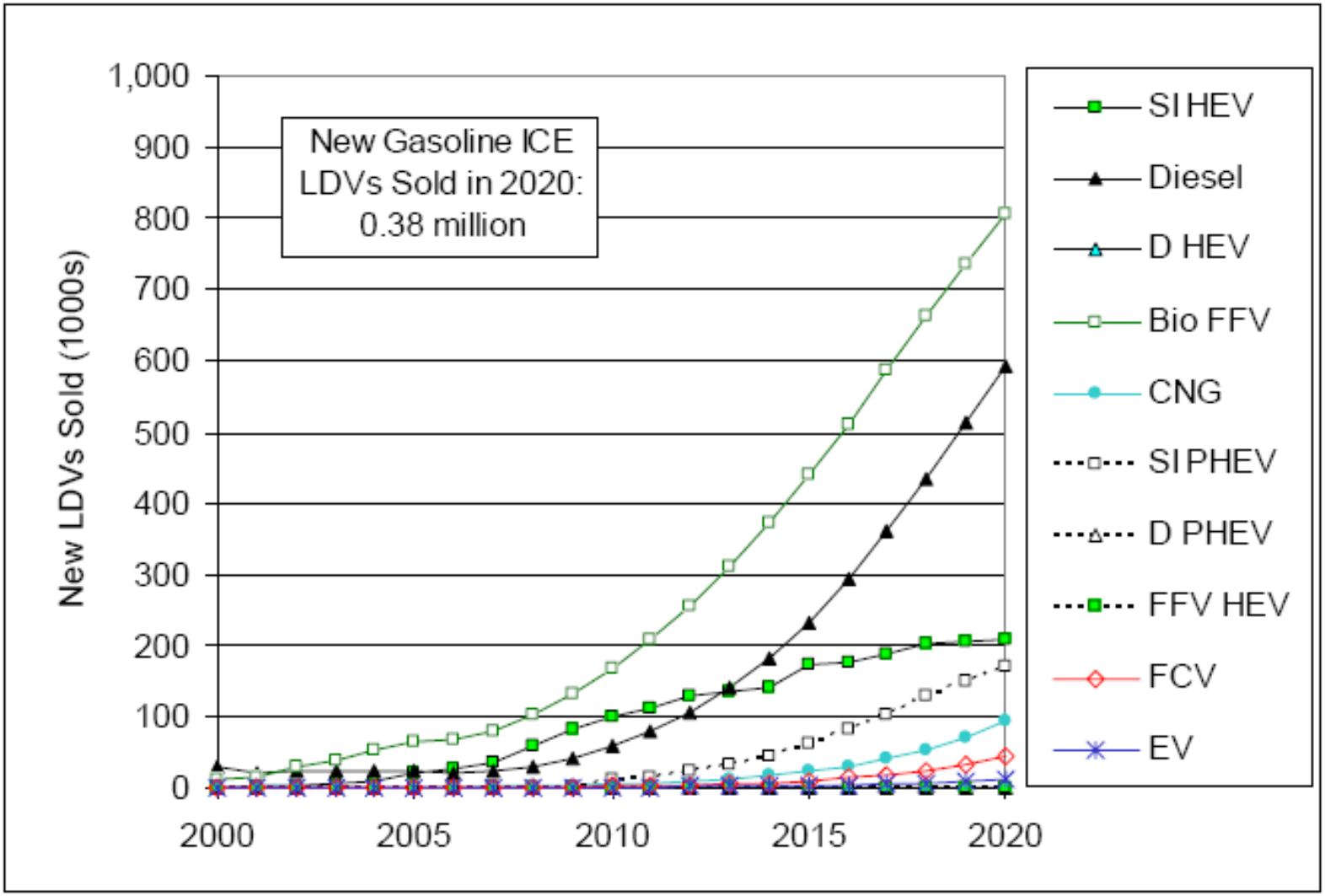


Figure 5-36: New LDVs sold per year in Scenario H15

Near and Long-Term Incentives

- Some vehicles and fuel technologies are closer to commercialization than others
- The 2020 goal will likely be met by fuels that do not require significant *vehicle* technology innovations
  - Thus a focus on biofuels, CNG
- Meeting the long-term GHG reductions (2050) for California will require significant technology innovations in both fuels and vehicles

Why a sectoral approach is needed

- An economy-wide approach would be efficient (static)
  - Possibly lowest cost approach to cutting near-term GHGs (goal #1)
- An economy-wide approach fails to meet other goals
  - At a "low" price (<$25/tonne), little would happen
  - At $25-$50 per tonne, electricity would start to decarbonize significantly while little would happen in buildings and transport
    - Innovation would be narrowly focused (goal #2), maybe not dynamically efficient
    - The "side benefits" of cutting petroleum use are lost (goals #3, #4)
  - Prices high enough to cause transportation to decarbonize might force disruptive change in the electricity sector or be politically infeasible
- Compare costs and fuel-on-fuel competition ($1/tonne CO_2)

– Nuclear + Renewables	$0.0/MWh
– Integrated gasification combined cycle with carbon capture and storage (IGCC+CCS)	$0.1/MWh
– Natural gas combined cycle (NGCC)	$0.5/MWh
– Pulverized coal (PC)	$0.8/MWh
– Gasoline	$0.01/gallon

Scenarios: BAU and Electric Drive

Scenario	Major Low-Carbon Fuels and Vehicles	Carbon Intensity Reductions (AFCI)			
		-5%		-10%	-15%
Business as Usual (A)	*For year 2020:* Gasoline: 15.3 BGGE Diesel: 0.86 BGGE LDVs sold: 2.32 million	*		*	*
Electric Drive (C5)	Hydrogen	0.183	1.1%	**	**
	Electricity	0.131	0.8%		
	Plug-in hybrid vehicles	269	11.6%		
	Fuel cell vehicles	182	7.8%		
	Battery electric vehicles	40	1.7%		

Conclusion: Relying upon electric drive vehicles alone cannot reduce the AFCI by 10% by 2020

Fuel Units: BGGE = billions of gallons of gasoline equivalent
Vehicle Units: 1000s of new vehicles sold per year

Scenario: Existing Vehicles and Advanced Biofuels

Scenario	Major Low-Carbon Fuels and Vehicles	Carbon Intensity Reductions (AFCI)				
		-5%		-10%		-15%
Business as Usual (A)	*For year 2020:* Gasoline: 15.3 BGGE Diesel: 0.86 BGGE LDVs sold: 2.32 million	*		*		*
Existing Vehicles and Advanced Biofuels (D5, D10)	Low-GHG Biofuel	0.608	3.6%	0.946	5.7%	**
	Low-GHG FT Diesel	-	-	0.471	2.8%	
	Diesel vehicles	*BAU*	*BAU*	593	25.5%	

Conclusion: A 10% AFCI reduction can be achieved with ~1.4 BGGE of low-carbon biofuels, and some increase in diesel vehicles beyond BAU

Fuel Units: BGGE = billions of gallons of gasoline equivalent
Vehicle Units: 1000s of new vehicles sold per year

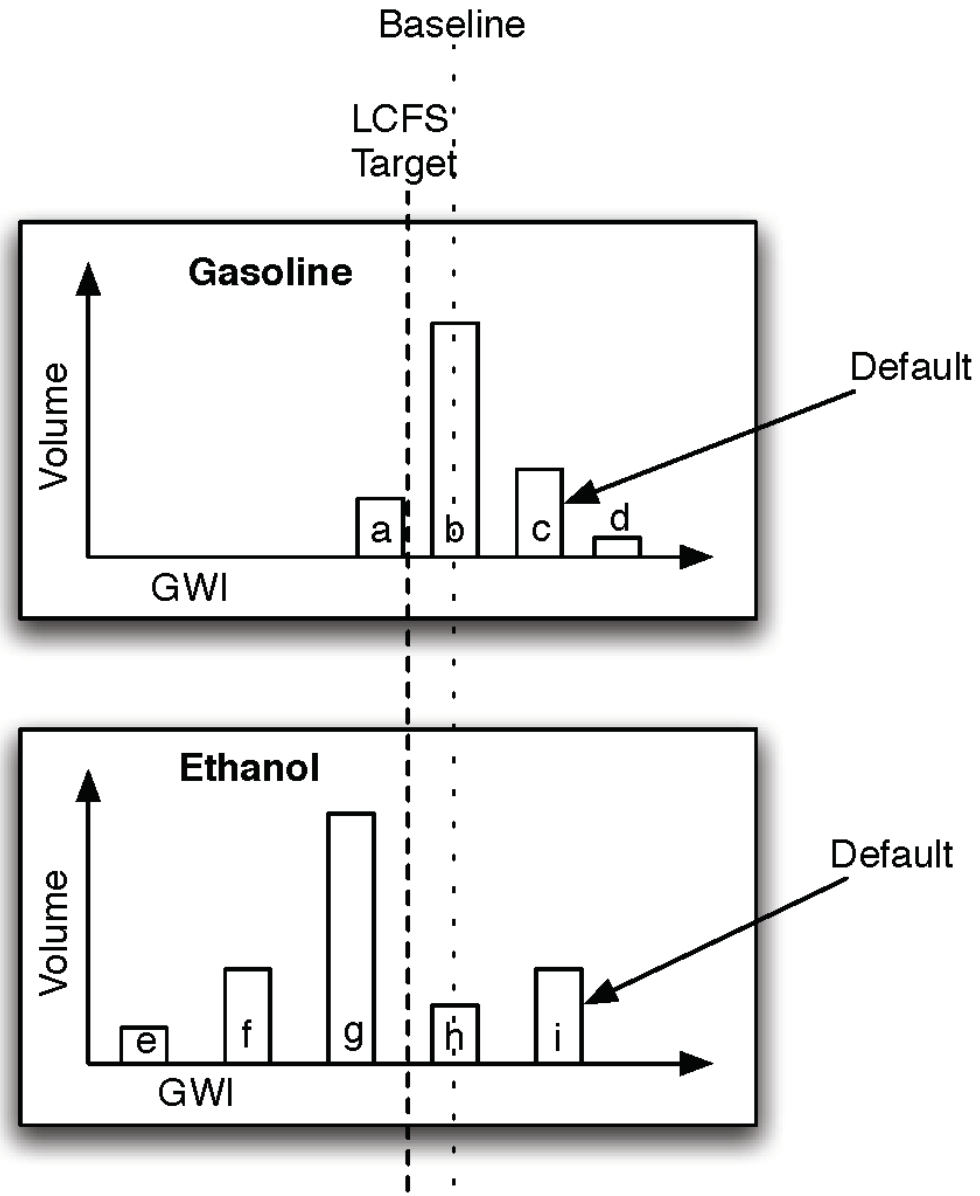



Illustration of default and opt-in