UC DAVIS
POLICY INSTITUTE FOR ENERGY, ENVIRONMENT, AND THE ECONOMY

International Transport Forum

Decarbonising Transport Initiative

EXPERT WORKSHOP

Mapping standards for low- and zero-emission electric heavy duty vehicles

17-18 February 2020 – Paris, France

Medium and Heavy Duty Vehicles Under California's LCFS

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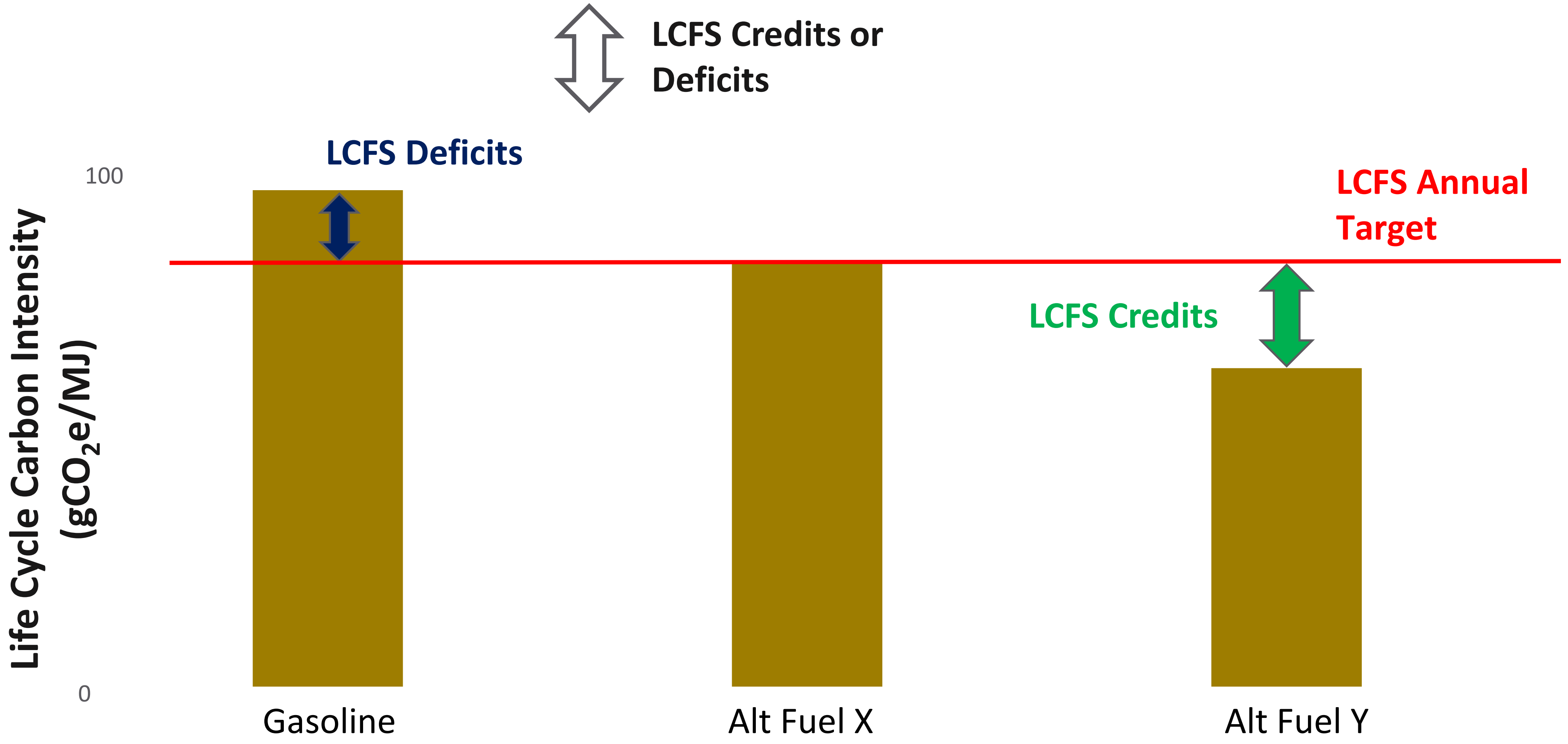
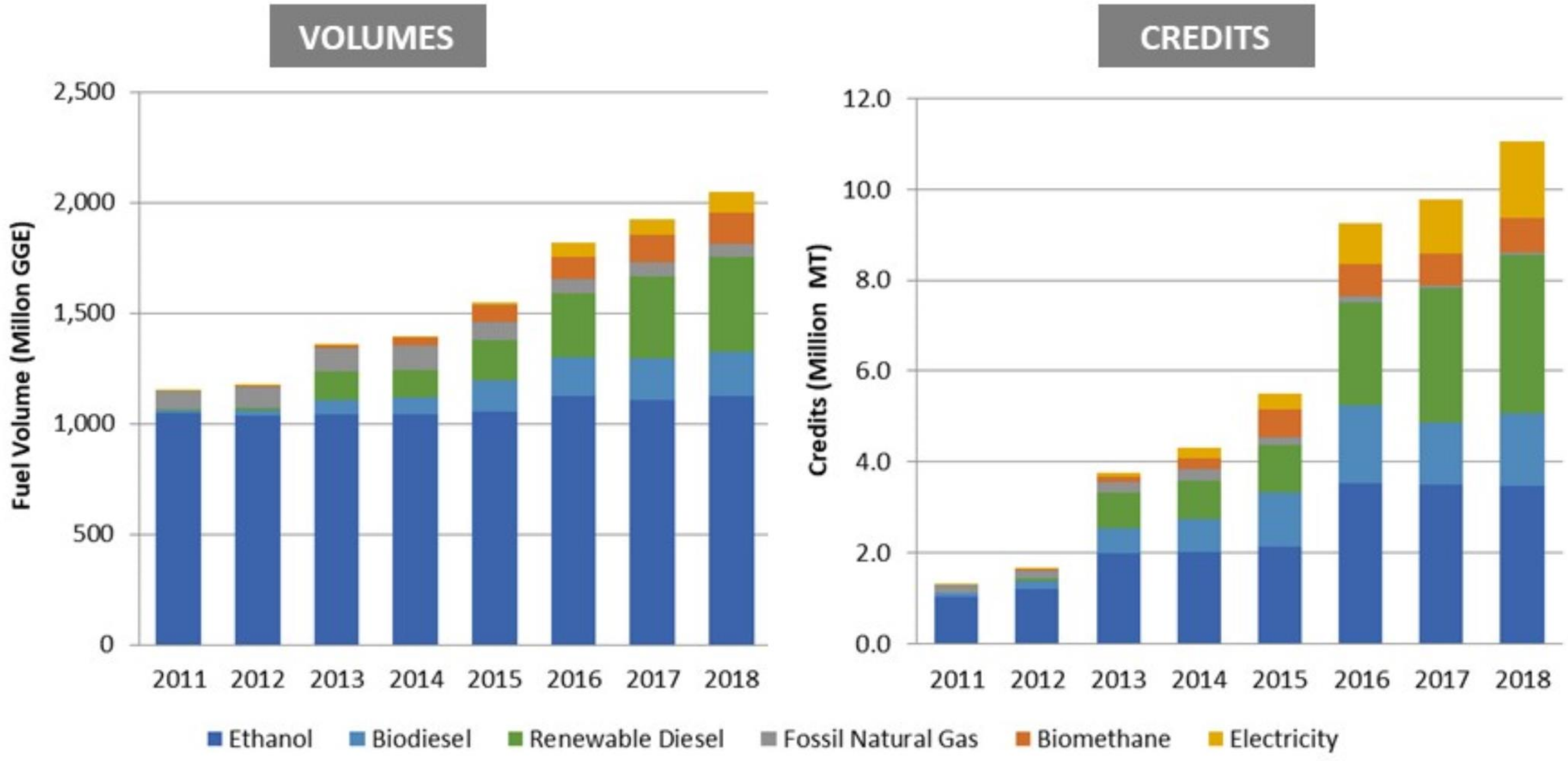
LCFS Sets a Declining Carbon Intensity Target

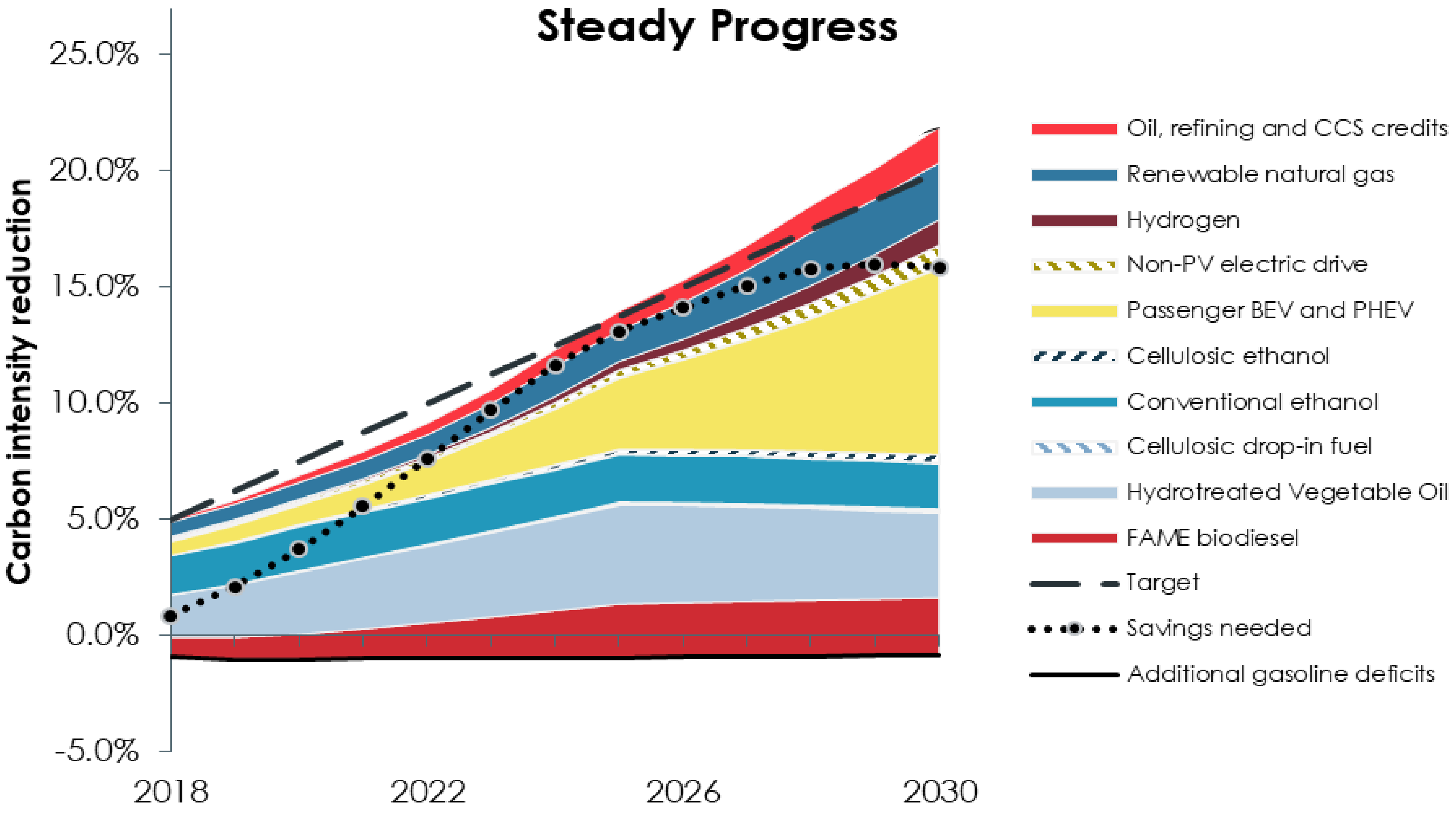


LCFS Has Diversified the Fuel Mix

Alternative Fuel Volumes and Credit Generation



LCFS – Projecting the Next Decade



Source: California's Clean Fuel Future

Medium and Heavy Duty Electrification

Electricity Under the LCFS

- Revenue from Electricity Credits must be spent supporting the expansion of the EV market, including:
  - Paying for chargers or EVs
  - Reducing the cost of charging to the consumer
  - Advertising benefits of electricity and EVs
- Credits from residential charging goes to the utility serving the home
- Credits from non-residential charging, or hydrogen fueling, generally goes to the owner of the charger or fueling station
  - Can be assigned elsewhere, by contract, e.g. to a charging service provider or aggregator

Hydrogen Under the LCFS

- Hydrogen CI determined through more conventional LCA using GREET model

- Hydrogen produced from electrolysis using renewable electricity, or from steam methane reforming of renewable natural gas, can be very low CI.

- California has a requirement that 33% of hydrogen fuel must come from renewable sources
    - Very little electrolysis at this point
    - Many competitors for limited RNG resource, ultra-low NO_x natural gas engines viewed as key strategy for near-term NO_x reduction for legally mandated targets

Infrastructure Capacity Credits

- 2018 amendments added infrastructure capacity credits for public DC Fast charging or hydrogen fueling infrastructure
  - Hydrogen and electricity credits capped at 2.5% of previous year’s deficits each.
  - Subject to public access and uptime requirements

- Electricity Capacity Credit Provisions
  - Public DC Fast chargers receive LCFS credits as if utilized at specified capacity, regardless of actual use.
  - Generally should have at least 2 types of connector
  - Eligible to receive infrastructure credits for 5 years, up to capital cost of equipment

- Hydrogen Capacity Credit Provisions
  - Receive LCFS credits as if full rated capacity was dispensed every day
  - Each station eligible for 15 years, including existing stations
  - Likely to provide value well above infrastructure cost

Electricity & Hydrogen Under the LCFS

- Alternative Fuel CI is adjusted by an **Energy Efficiency Ratio (EER)** which reflects the different engineering and system efficiency for different vehicles and powertrains.
  - Passenger vehicle EER for electricity is 3.4. Heavy Duty Trucks and Buses are 5.0
  - Passenger vehicle EER for hydrogen is 2.5. Heavy Duty vehicles are 1.9

- The full life cycle carbon intensity of electricity is assessed on a statewide average basis, updated yearly, but charger owners can use alternatives
  - Apply for a fuel pathway in which a specific piece of infrastructure charges a specific set of vehicles. The CI is then based on that combination of equipment.
  - Opt in to “Renewable Energy” charging program. Procure renewable electricity above state requirements to charge the vehicle at 0 g/MJ CI (done by retiring Renewable Energy Certificates)
  - Opt in to “Smart Charging” program, CI is determined according to hourly grid average carbon intensity, seasonally adjusted.

Calculating Credits

$$Credits(tonne\ CO_{2e}) = (CI_{Target} - \frac{CI_{Fuel}}{EER}) \times (Energy \times EER) \times 10^{-6}\frac{tonnes}{g}$$

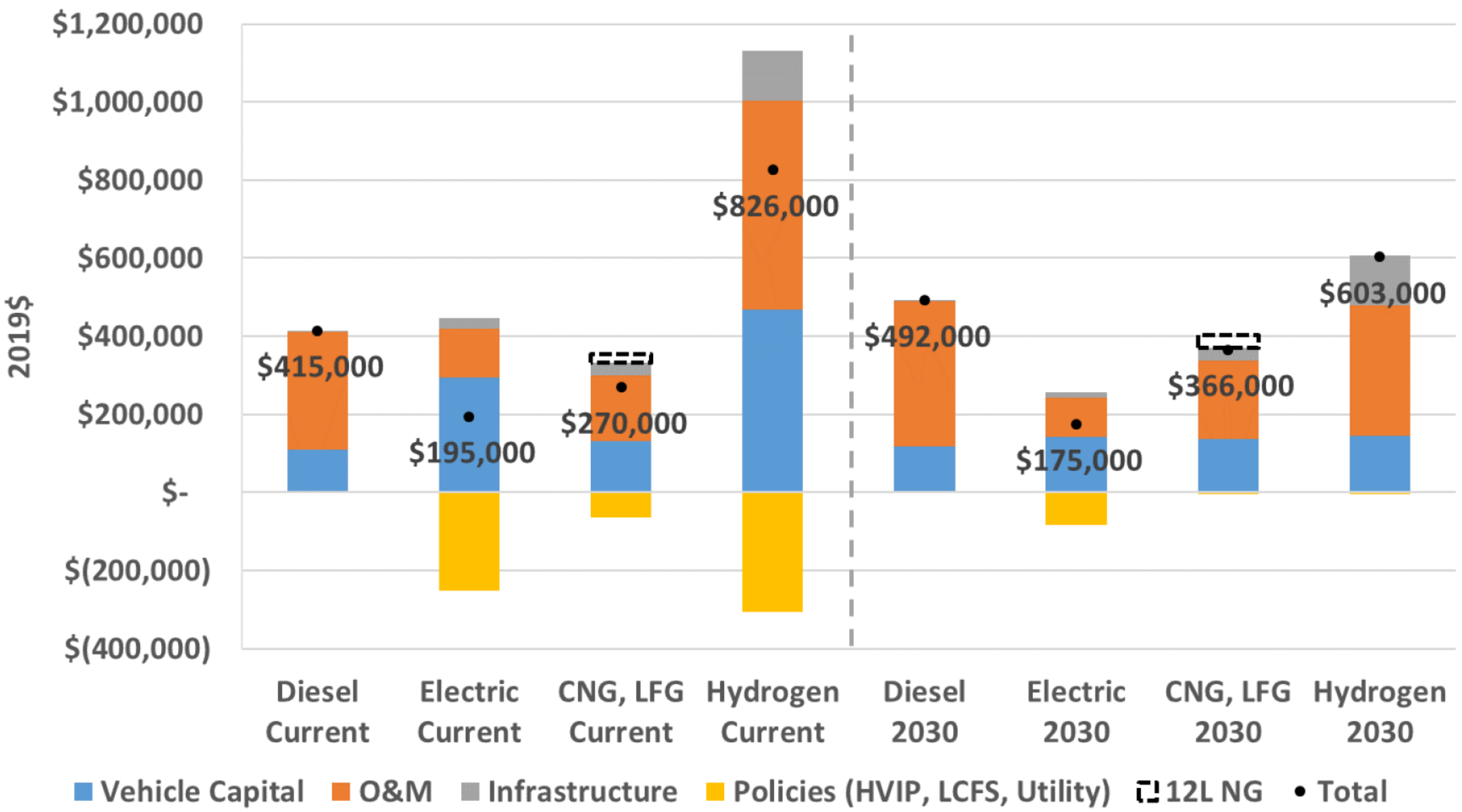
CI: Carbon Intensity (g CO_{2e}/MJ) **EER:** Energy Efficiency Ratio **Energy:** Total energy consumed (MJ)

Or, more simply: Credits and deficits represent tonnes emissions reductions above or below that year's target.

At current LCFS credit prices and targets, the effective subsidy for light duty vehicles is about $0.17/kWh and for trucks and buses it is about $0.27/kWh.

Recent analysis by ICF estimated that this would sum to about $60,000-70,000 over the first five years of life for a heavy duty freight truck in drayage service.

Figure III-1. Class 8 Tractor TCO Analysis Results



Total Cost of Ownership for a Class 8 Drayage Truck in 2020 (left) and 2030 (right)

Source: CalETC/ICF *Comparison of Medium and Heavy Duty Technologies in California*

Challenges for MD/HD Electrification

- Industry is still immature, not enough manufacturers, models, technicians
    - Longer range applications don't have a clear "winner" technology yet
- Current logistics models don't always fit need for extended charge times
    - Locating chargers at loading/unloading/queueing areas may be important
- Near-term competition from low-cost 1st generation biofuels
- Electricity rate design in critical
    - Demand charges can be massive, but rapid cycling of high-power loads can be tough on grids and lead to high demand charges (possibly a U.S. issue)

Resources

CARB LCFS Website: https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard

CA-GREET Model: https://ww2.arb.ca.gov/resources/documents/lcfs-life-cycle-analysis-models-and-documentation

California Electric Transportation Coalition / ICF International: Options for Decarbonizing MD/HD Transportation in California (2019): https://caletc.com/comparison-of-medium-and-heavy-duty-technologies-in-california/

California's Clean Fuel Future: https://nextgenamerica.org/wp-content/uploads/2018/04/Cerulogy_Californias-clean-fuel-future_Update_April2018.pdf

Thank You!

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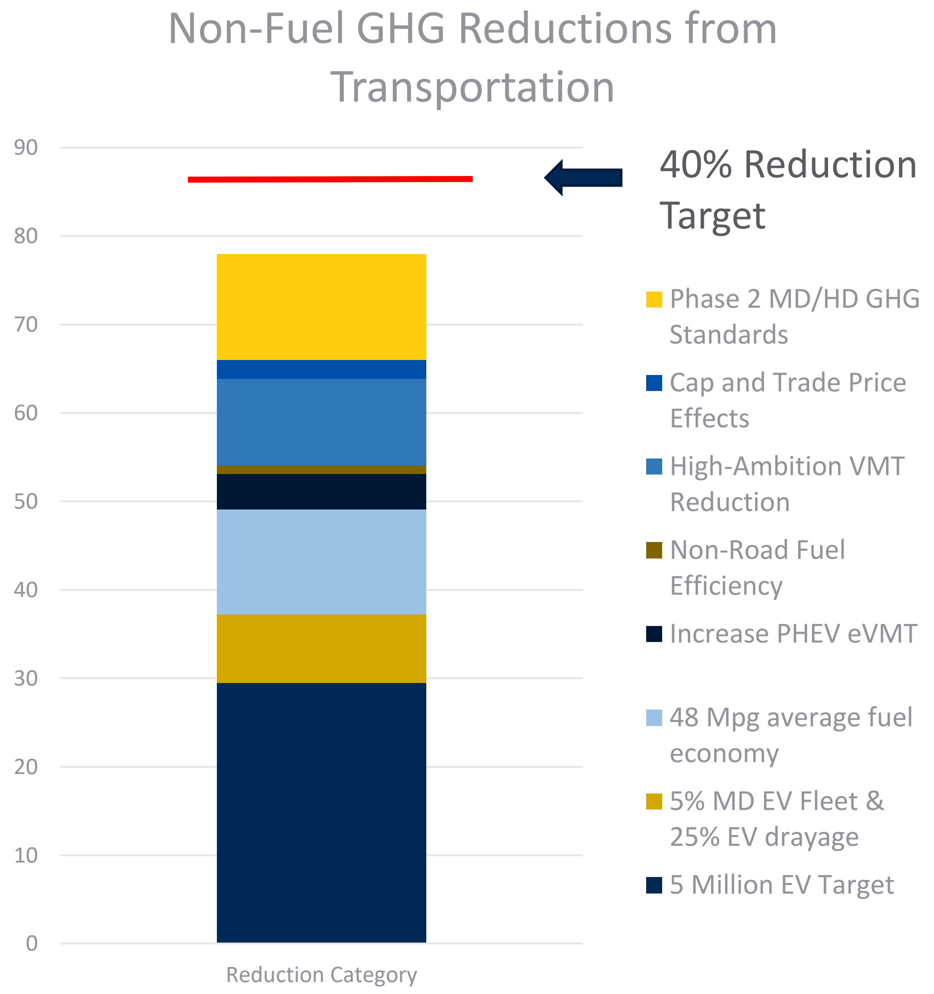
h_2EAVY-DUTY PROGRESS POWERED BY TOYOTA HYDROGEN FUEL CELL TECHNOLOGY
KENWORTH
TOYOTA
TTSI
LA
H_2Only

Non-Fuel Policies Can't Do Enough

- Transportation + Refinery Emissions: ~215 Million Tonnes CO_2e in 2017
  - 40% Reduction = 86 million tonnes/year

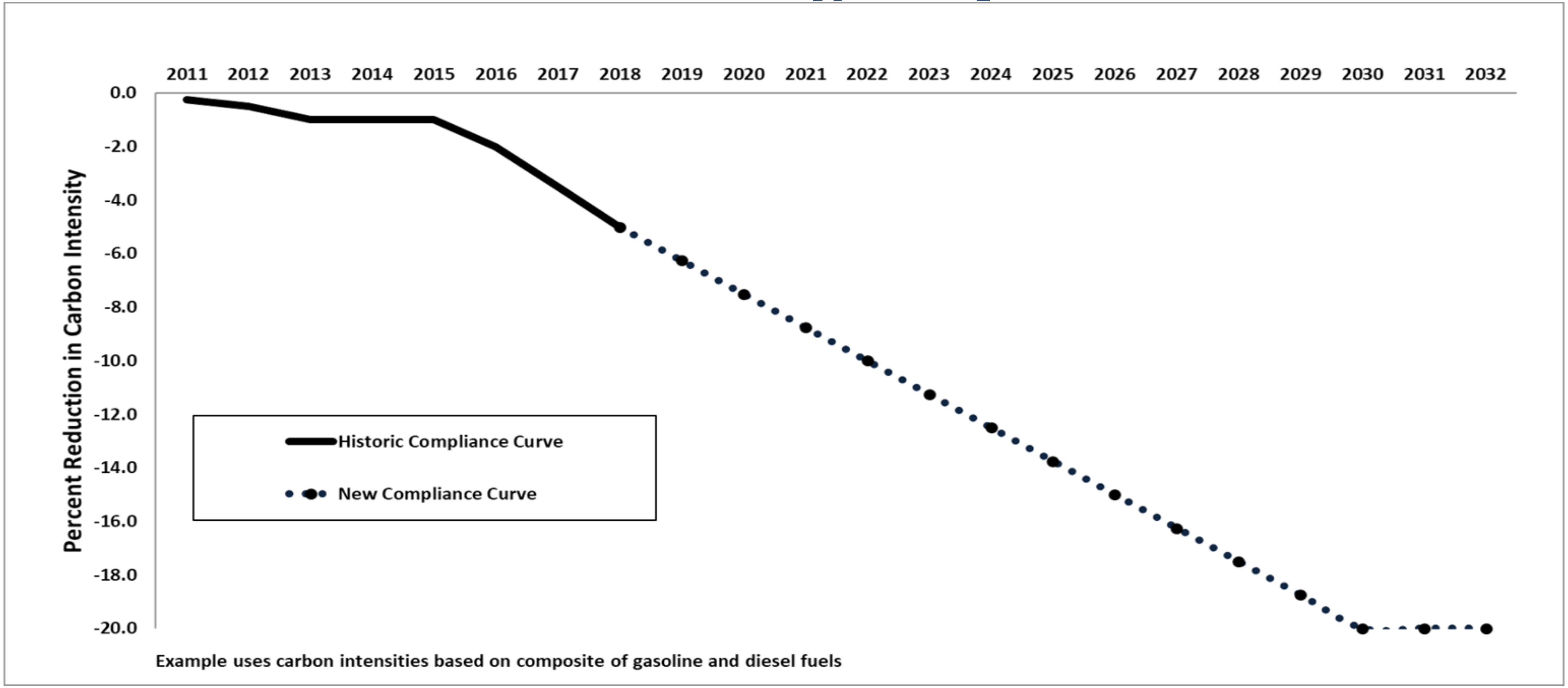
- Even if all major non-fuel GHG policies yield reductions at the high end of their plausible range, transportation doesn't reduce emissions 40% by 2030.



Emissions from 2017 GHG Data. All values approximate. Emissions reduction estimates adapted from *Half the Oil: Pathways for Petroleum Reduction on the West Coast,* or author's estimates (EVs, cap and trade)

https://www.ucsusa.org/sites/default/files/attach/2016/01/ICF-Half-the-Oil-CA-WA-OR.pdf

20% CI Reduction Target by 2030



New Credit Pathways

- Refinery Investment Credits
  - Generate reduction credits from investments at petroleum refinery
- Carbon Capture and Sequestration
  - Geological storage, requires long-term monitoring
- ZEV Fueling Infrastructure Capacity
  - Capped at 5% of total program size, will support hydrogen and DC Fast charging
- Sustainable Aviation Fuel
  - Producers can opt in to the program
- Smart Charging and Renewable Electricity Credits

Other Significant Changes

- Third Party Verification of Fuel Pathways
  - Includes conflict-of-interest, rotation provisions.
- Clean Fuel Vehicle Reward
  - Utilities would contribute a fraction of residential EV charging revenue to fund point-of-sale rebates on EVs.
  - Still under development.

2019 Developments

- New cost containment mechanism – borrowing from future residential EV charging credits.
- Biodiesel anti-NOx additives may not be as effective as thought.

Steady Progress Scenario

In 2030:

5 Million Light Duty ZEVs provide over 1/3 of the total credit generation.

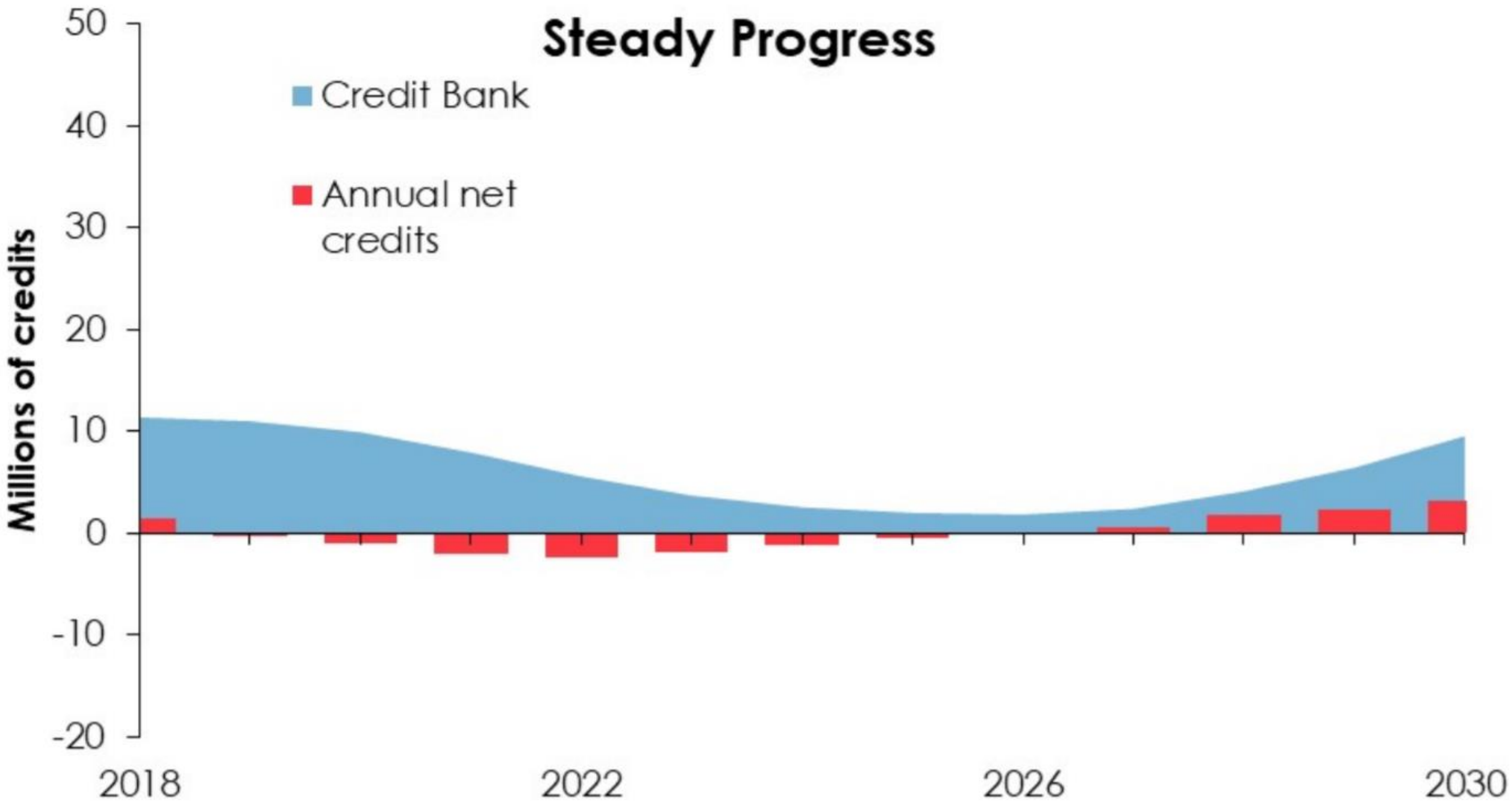
Biodiesel, renewable diesel and RNG provide another 1/3

	2020	2025	2030
Credit generation by light duty ZEVs (million tCO_2e)	1.9	5.9	13.5
Credit generation by cellulosic biofuels (million tCO_2e)	0.2	0.6	0.8
Credit generation by HVO and biodiesel (million tCO_2e)	8.6	11.1	8.6
Credit generation by renewable natural gas (million tCO_2e)	1.3	2.3	4.2
Credit generation by oil extraction and refining, CCS and other electrification (million tCO_2e)	1.1	2.7	4.8
Cumulative credit generation since 2018 (million tCO_2e)	44.6	157.0	318.1
Annual credit generation (million tCO_2e)	16.8	26.5	36.1
Banked credits at year end (million tCO_2e)	9.9	2.0	9.5
% CI reduction	7.1%	13.6%	21.7%

Credit Market Could Tighten by Mid 2020's

Both CCFF and CARB modeling expect tightening credit market through mid-2020's, though less so w/ capacity credits.

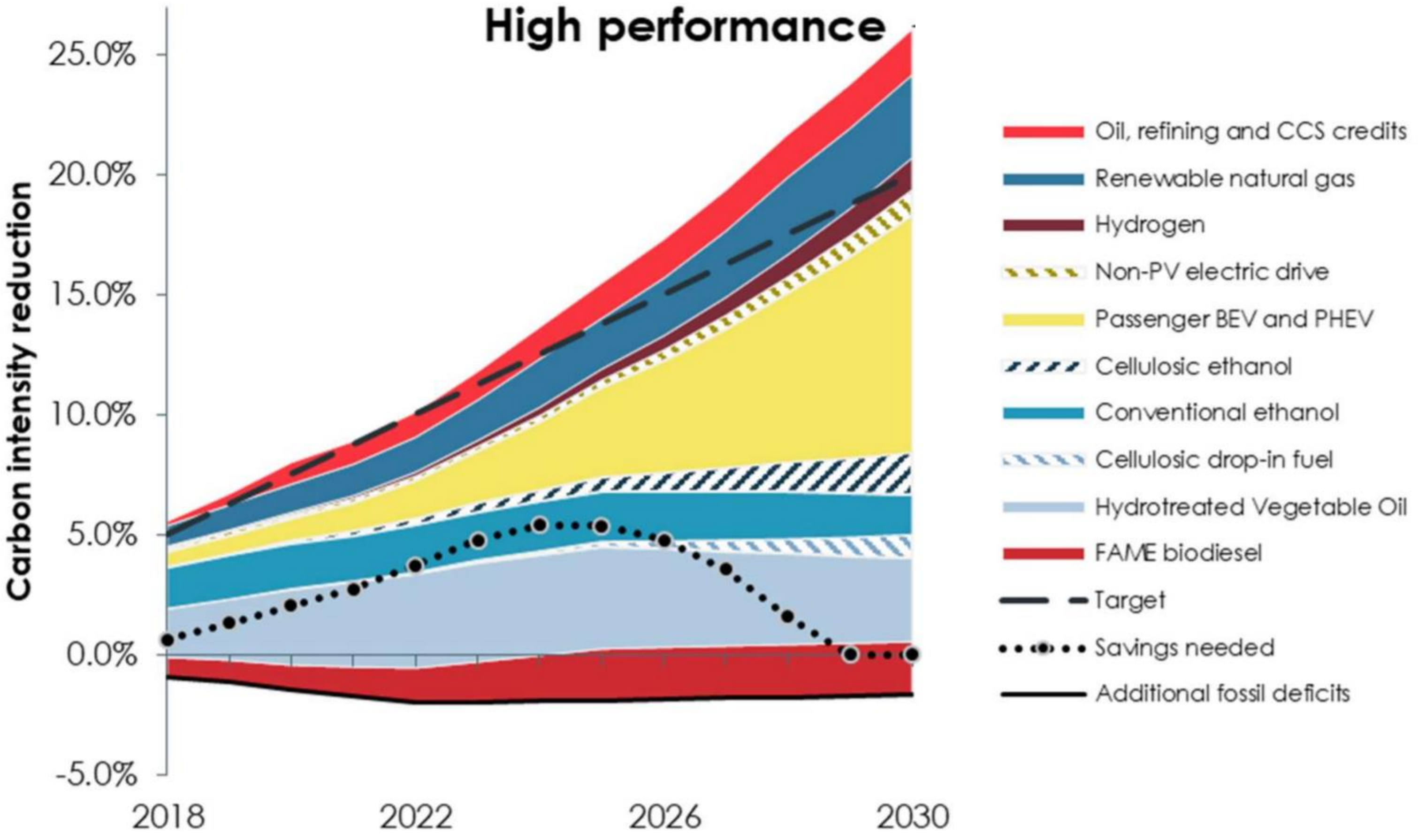
By late 2020's, EV deployment drives credit bank recovery.



CA Clean Fuel Future: Optimistic Scenario

If several key technologies deploy at the high end of their potential range, CA could greatly exceed reduction targets.

- 5.8 million EVs
- 1-2 billion gallons cellulosic biofuel.
- Lower-carbon conventional biofuels.



Sensitivity Scenarios

Scenario	Change in Credits 2025		Change in Credits 2030	
	From Scenario	Net	From Scenario	Net
Baseline "Steady Progress" Scenario		**26.5**		**36.1**
High Light-Duty ZEV (5.8 million by 2030)	1.6	1.6	4.7	4.7
High MD/HD ZEV Penetration	1.0	0.9	6.6	6.0
Cellulosic Breakthrough (800 million gal/year 2030)	1.2	0.9	4.0	3.3
Clean Refineries (CCS on ethanol and SMRs)	3.1	3.9	4.5	6.0
Slow EV and Advanced Biofuel Deployment	-1.6	-1.6	-2.5	-2.5
Higher VMT (3.5% VMT reduction in 2030)	-1.2	-0.5	-1.6	-1.1
High-ILUC Biodiesel/Renewable Diesel	-3.4	-3.4	-2.4	-2.4

Values are million LCFS credits, relative to the Steady Progress scenario. Each credit is one tonne CO_2 equivalent reduction compared to that year's target. Net emissions changes include reductions in other credit generating pathways. All data from California's Clean Fuel Future (2018)

Other Jurisdictions Following CA

Oregon, British Columbia – LCFS operational

Brazil – RenovaBio program, liquid-fuel focused, just starting

Puget Sound Air Quality Mangement District – proposal out for public comment

Washington State – 2019 Legislative attemps failed, will try again in 2020

Canada (Federal) – Draft Regulatory Approach comments received, revised proposal expected, may finalize in 2021.

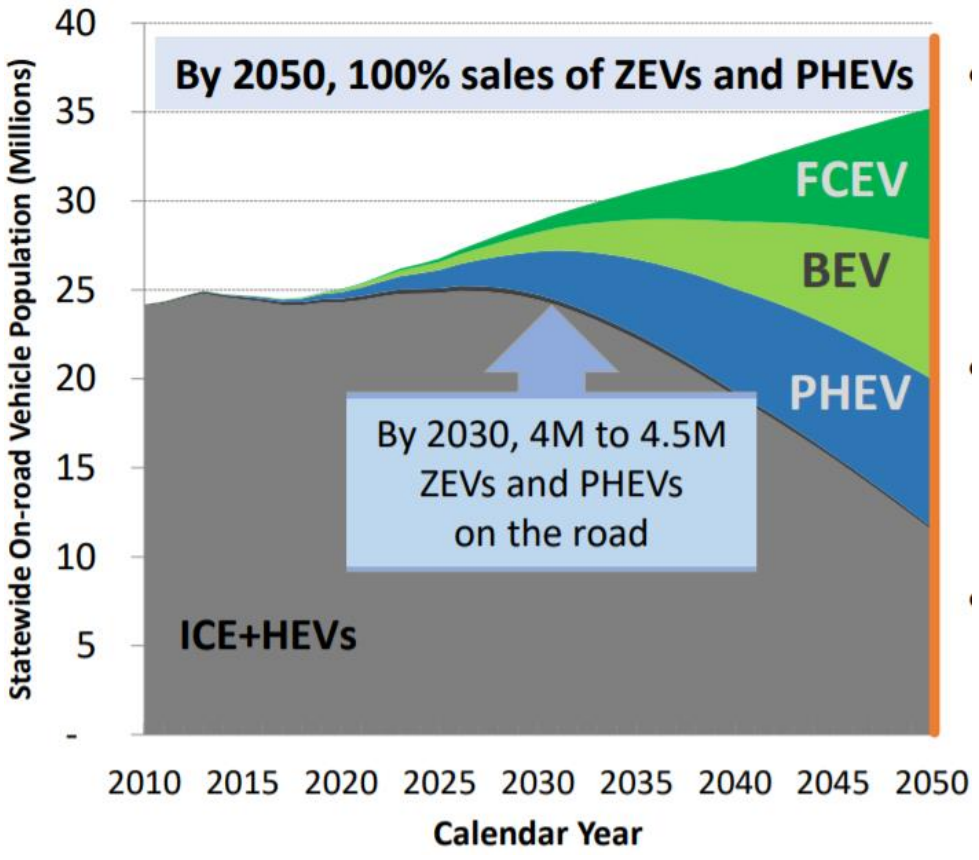
Colorado – Feasibility study under way

New York – Bill introduced, coalition working on administrative approach

Midwestern states – Early discussions

First-Generation Fuels Will Have a Role

- Even with rapid ZEV transition, there will still be a significant residual fleet.
    - Likely billions of gallons of liquid fuel demand through 2040
- Optimistic scenarios get to 1 billion gallons of advanced fuels in CA by 2030
- First-gen fuels can reduce GHGs and air pollutants compared to petroleum.
    - Biofuels have potential to incrementally reduce emissions over time.



Source: CARB (2018)

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LCFS Can Support a Broad Coalition

17 In-state biofuel production facilities

14 Businesses receive at least $6.5 million annually in LCFS credits.

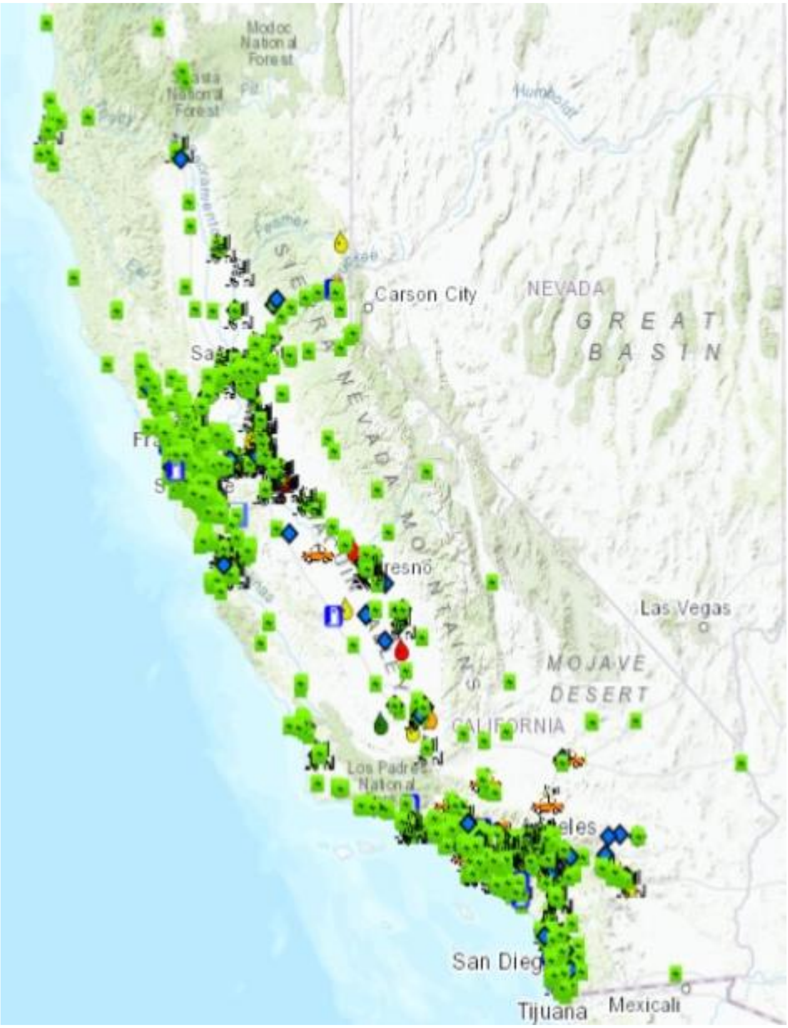
20 Utilities receive LCFS credits for household charging.

76 On-road electric fleets, 1600+ electric forklifts

12,000+ EV Charging Stations, 500 CNG Stations

Over $3 Billion in total credit value

43 million metric tons of GHG reduction to date



Source: CARB – LCFS Data Dashboard

Refining Sector at a Crossroads

- To meet statutory, administrative and global climate goals, California must massively cut consumption of petroleum by mid-century.
  - Rest of world needs to follow in a decade or two.
  - In-state petroleum consumption likely to decline significantly by 2030

- LCFS creates competition for conventional refiners, but also opportunity
  - Support for reducing emissions (refinery investment credits, coprocessing, CCS)
  - Strong incentive to deploy advanced, low-carbon fuels
  - Modest incentive to deploy high-volume, incrementally better fuels

- Refiners have infrastructure, market position and capital access to be really competitive in a carbon-conscious market

We Still Haven't Figured Out ILUC

- Estimates of corn ethanol ILUC are pointing to the 15-30 g/MJ range
- Much greater uncertainty about palm/soy ILUC
  - There is clear evidence of cross-oil substitution
- No good way to account for local policies to reduce land conversion
- European approach largely intended to screen out palm oil
- Accurate estimation of ILUC may require much more accurate models of international agricultural commodities.
  - Possible next-best solution: Consumption-based limits?

How Far Can Biomass-Based Diesel Take Us?

- CA consumed 700 Million gal of Biodiesel + Renewable Diesel in year through Q2 2019.
  - Approx: 33% used cooking oil, 30% corn oil, 28% tallow
  - Supply of "waste" oils is limited and not immune from indirect land use change (ILUC)
- Soy and palm are the marginal oils in most of the world, and cheap enough to compete against petroleum, especially w/ GHG policy.
- Tension between estimates of supply and demand
  - ICCT (2016): ~ 1.7 billion gallons total U.S. biomass based diesel capacity from oils through early/mid 2020's.
  - *California's Clean Fuel Future* estimates ~ 1.5 billion gallons/year total renewable distillates (biodiesel + renewable diesel + bio-jet)
  - CARB's Illustrative Compliance Scenario calculator estimates ~1.7 billion gallons/year

How to Support Sustainable Aviation Fuels

- CORSIA process created targets for airlines to cap total GHG emissions, but compliance is likely to be mostly through offsets.
- Global capacity very small, but rapidly growing and attracting attention.
- LCFS allows sustainable aviation fuel (SAF) providers to opt-in and generate credits. Conventional fuel does not generate deficits.
- Most near-term production pathways compete for feedstock against biomass-based diesel

LCFS Credit Market Model

Multiple complementary policies exist to support various fuel pathways

Changes in fuel price/supply/CI affect LCFS credit price, LCFS credit price affects supply

Need modeling tools to assess impacts of changing fuel or market conditions.

Price Responsive	Non-Price Responsive
Diesel Substitutes	Electricity
Low-CI ethanol (e.g. sugarcane)	Natural Gas & RNG
Bio-jet	Hydrogen
Refinery Credits / CCS	Cellulosics

Research Plan

UC Davis Policy Institute currently finalizing contract with Adam Christensen to build on his previous LCFS Credit / RIN price interaction model, using fuel supply assessments from *California's Clean Fuel Future*.

Article submission expected in approx. 1 year.

Untangling ILUC

- Recent research into corn ILUC indicates 15-30 gCO_2e/MJ ILUC assessment is probably reasonable, though uncertainty is still high.

- Oil pathways yield cheap, readily available fuels with very low carbon (apart from indirect effects).
- Uncertainty around ILUC of oils is much higher than corn.
- Evidence of significant cross-oil substitution
- Biofuel expansion almost certainly playing a role in palm expansion, though human consumption almost certainly greater.
  - Role for fatty acid distillates or other byproducts?

Alternatives to ILUC

Consequential Limit Framework

- Accurate assessment of biofuels requires understanding the change that using the biofuel imparts on the rest of the world.
- Understanding indirect effects requires modeling all involved systems

- Jurisdictions may be able to design biofuel use policies which minimize impact on rest-of-world
- E.g. assessing total generation of wastes and residues from a jurisdiction and limiting consumption to the quantity of fuels supported by those wastes

Biofuel Supply Assessment

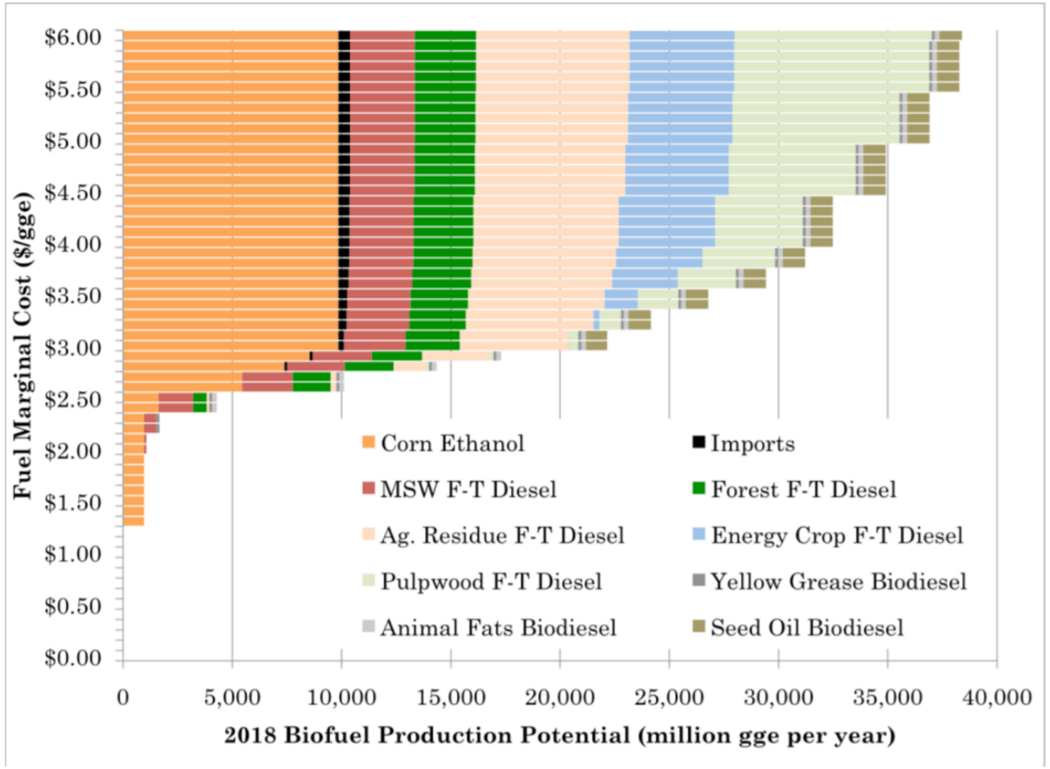
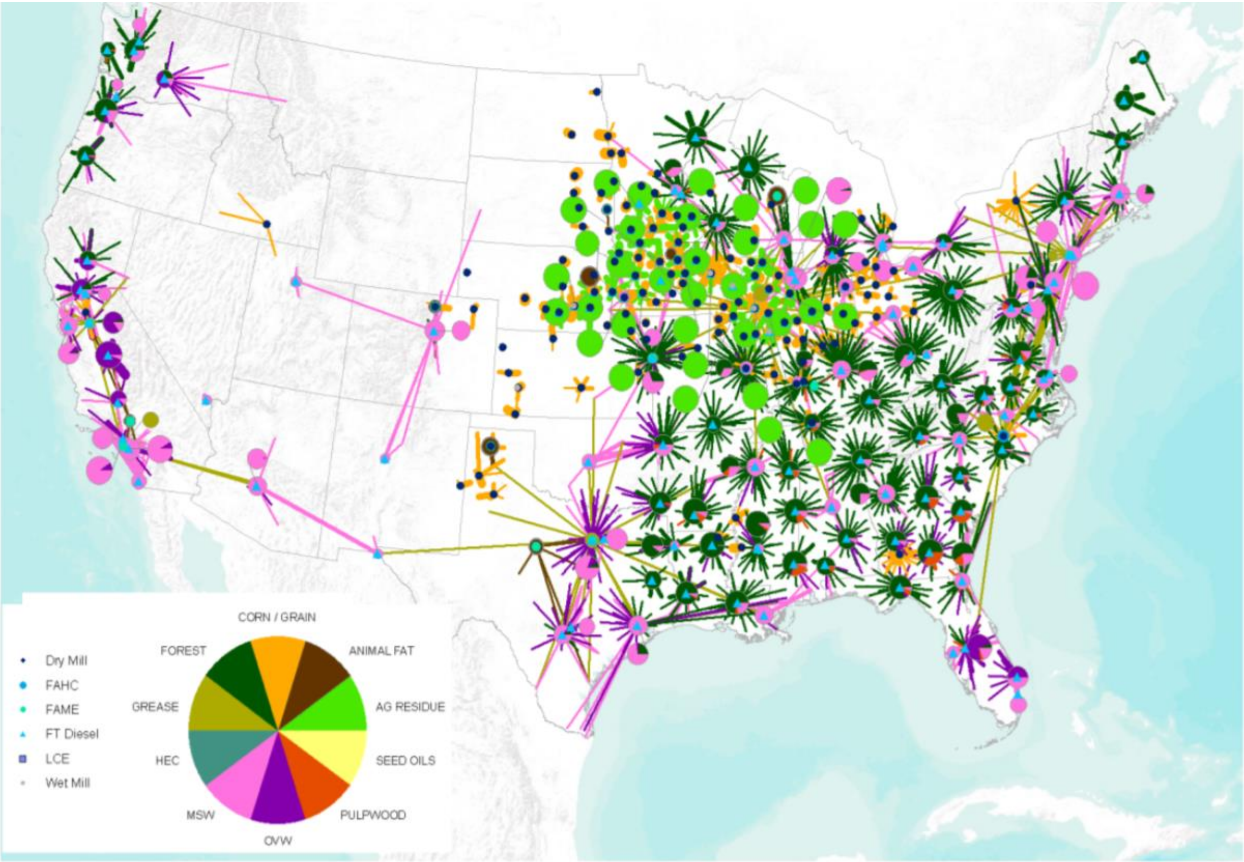


Figure 2: Baseline supply curve by fuel pathway for the 2018 production analysis (gge = gallons of gasoline equivalent).



Expansion of Sustainable Aviation Fuel

- Significant interest in sustainable aviation fuel (SAF).
- Likely short-term tradeoff between sustainable aviation fuel & renewable diesel.
- Long-term prospects dependent on technology and market development.

Research Plan

UC Davis Policy Institute & Dept. of Civil & Environmental Engineering (Mike Kleeman) will compare air quality impacts from sustainable aviation fuel and renewable diesel, in California context. If SAF expansion does trade off against renewable diesel, does this create an air quality problem?

Linkages

- Oregon and British Columbia have similar policies.
- The Puget Sound Region, Colorado, New York and the Canadian Federal Government are considering similar ones.

- Linkage reduces the risk of emissions leakage, and reduces compliance cost, but is challenging given different levels of target and cross-jurisdictional legal issues.

- In theory, LCFS markets should tend to pull prices towards convergence, so formal linkage may not add much value.

CA Clean Fuel Future: Pessimistic Scenario

Significant uncertainty about VMT trends complicates modeling. If VMT is higher than anticipated, deficit generation increases and could result in persistent deficits.