Renewable Natural Gas in California

Overview of STEPS research

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SUSTAINABLE TRANSPORTATION ENERGY PATHWAYS

An Institute of Transportation Studies Program

Alternative fuels reached 8.1 percent in 2015.

Table 1. Total transportation energy use reported in California's LCFS program (million gge).

	2011	2012	2013	2014	2015
Gasoline (CARBOB)	12,948	13,089	12,788	13,093	13,323
Diesel (ULSD)	3,905	4,026	3,831	3,875	3,884
Ethanol	1,015	1,005	1,008	1,012	1,038
Biodiesel	13	21	63	71	133
Renewable diesel	2	10	127	122	179
NG	82	94	100	109	76
Biogas	1.8	1.8	12	30	77
Electricity	0.4	1.3	3.6	8.5	13.0
Hydrogen					0.003
Total	17,968	18,249	17,933	18,322	18,722
Total alt fuel	1,115	1,134	1,314	1,354	1,515
Total alt fuel (percent of total energy)	6.2%	6.2%	7.3%	7.4%	8.1%
Non-biofuel portion of alt fuel	7.6%	8.6%	8.8%	10.9%	10.9%

Increases in alternative fuel use came primarily from **biodiesel, renewable diesel, biogas and electricity.**

Use of **ethanol**, the largest renewable fuel by volume, remained close to a **"blendwall"** of 10 percent blended with gasoline, the maximum allowed without alternative infrastructure.

Ethanol dominates in terms of volume but not in terms of credits or in terms of growth

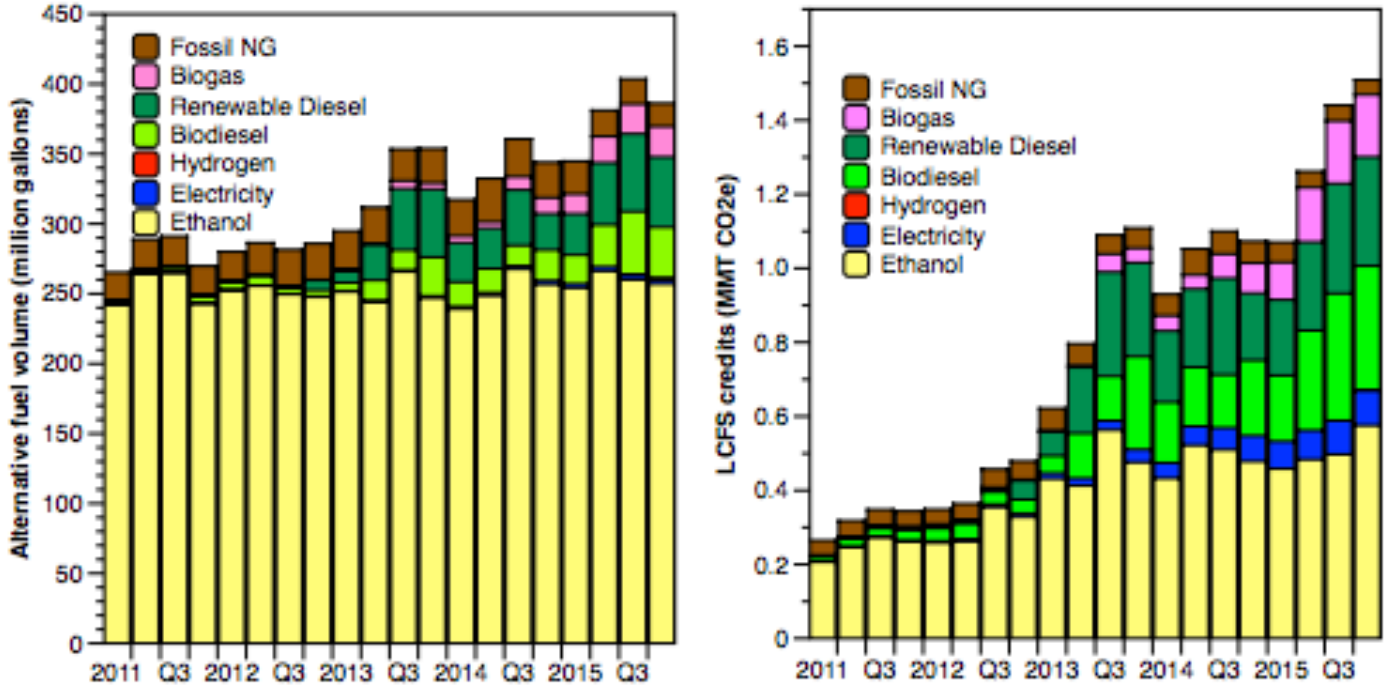
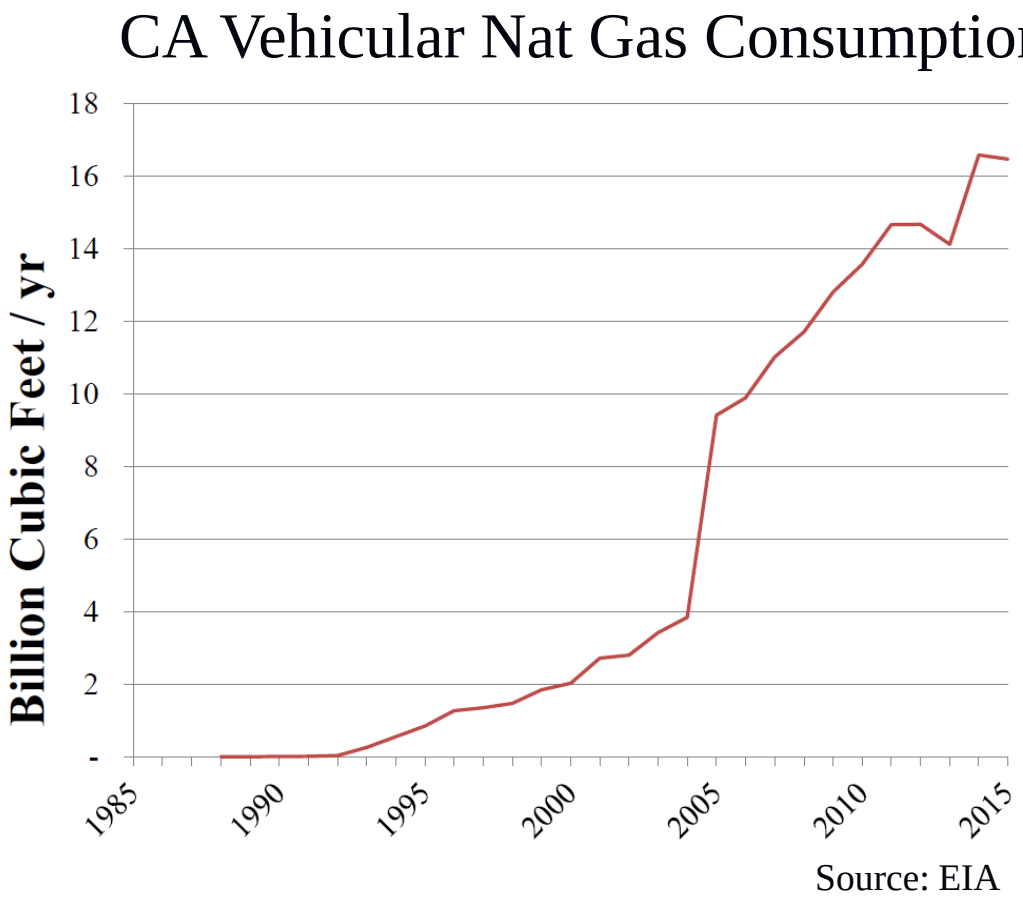


Figure 2. Volumes of alternative fuels and total net LCFS credits by fuel type by quarter. Data source: ARB (3).

LCFS credit prices have shown considerable variation. The average credit price was **$20** early in the program (and while the standard was frozen at 1%). Prices have remained above **$100/credit thus far in 2016.**

The overall nominal value of all credit transfers was calculated at **$430** million (December 2012–April 2016)

Nat Gas small but growing fuel source

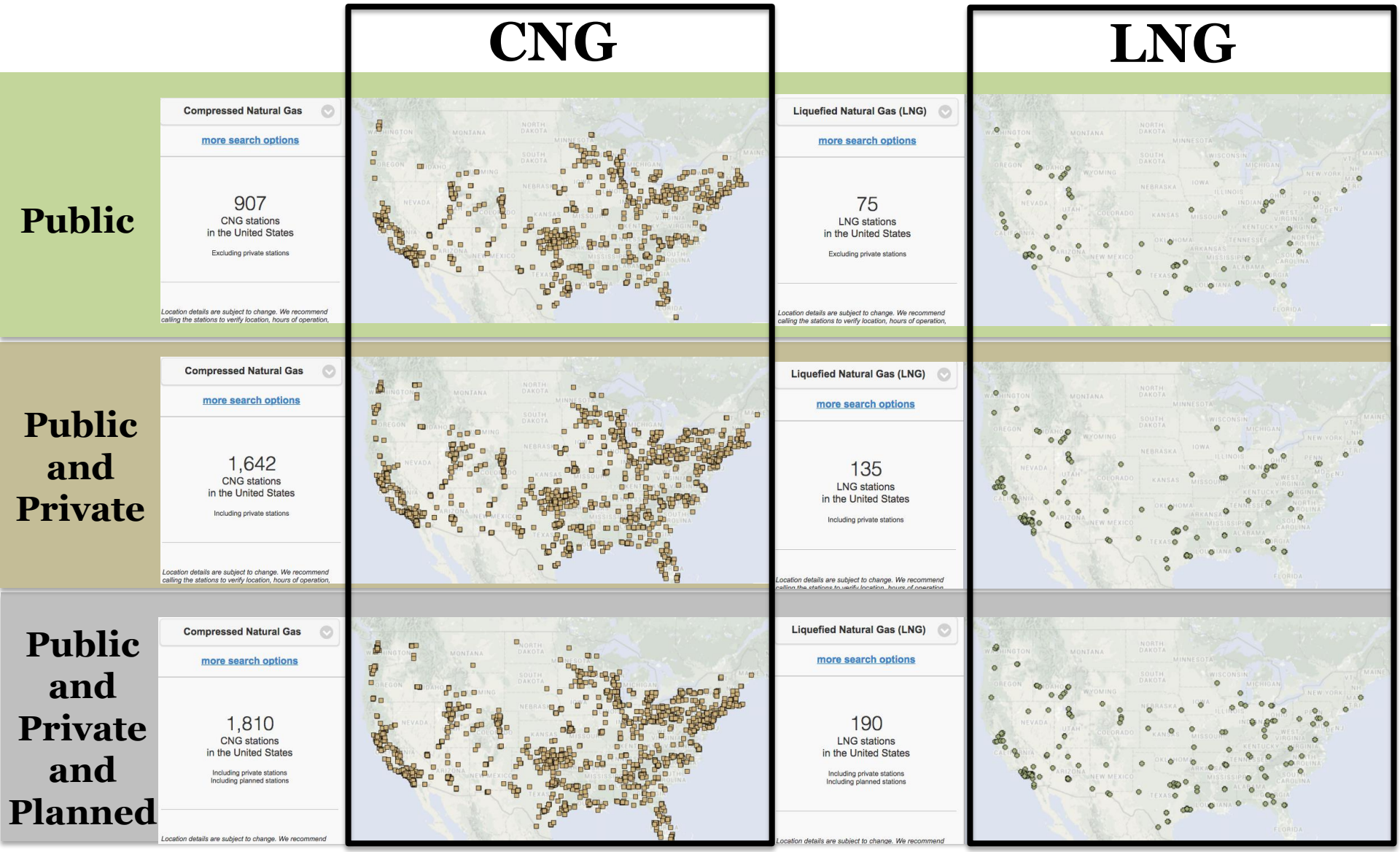


25,000 registered natural gas vehicles in California

California: 16,467 million cubic feet —> 126 Million DGE (**4.6**% of California Diesel transportation market)

US: 34,459 million cubic feet —> 263 Million DGE (**0.6**% of US Diesel market)

About half the NG stations are private fleet



DOE Alternative Fuel Data Center Natural Gas Station locations

Animal manures

Waste water biogas

Food & green waste

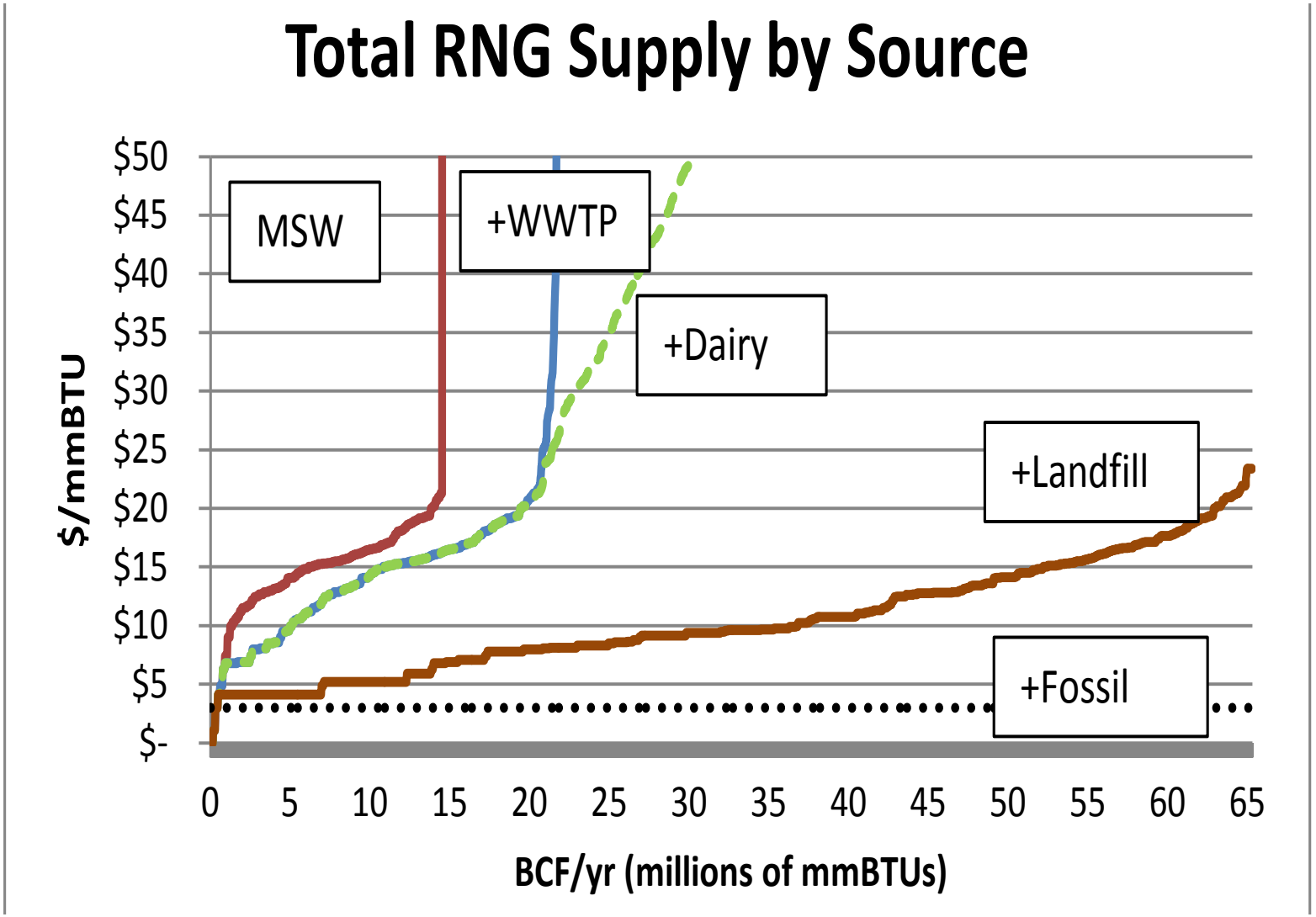
Landfill gas

RNG Technical potential in California

Table ES-1. Biofuel potential in California. No dedicated biomass crops were considered for this analysis.

Feedstock	Technically Available Supply (million bone dry tons or billion cubic feet)	Biomethane Potential (billion cubic feet)	Biofuel Potential (million gallons of gasoline equivalent)
Agricultural residues	5.4 MM BDT	31.5	272
Animal manure	3.4 MM BDT	19.7	170
Forest residues	14.2 MM BDT	82.3	710
Landfill gas	106 bcf	53	457
Municipal solid waste	1.2 MM BDT	12.3	106
Municipal solid waste (lignocellulosic)	7.0 MM BDT	40.6	350
Waste water treatment plants	11.8 bcf	7.7	66
Total		247	2,131

Almost 20 times the present NG usage in transportation in CA!

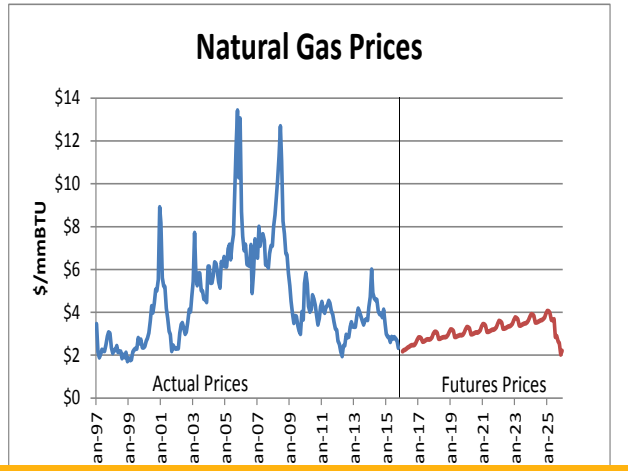


In California, 25% of the gross resource were estimated to be available below $10/mmBtu.

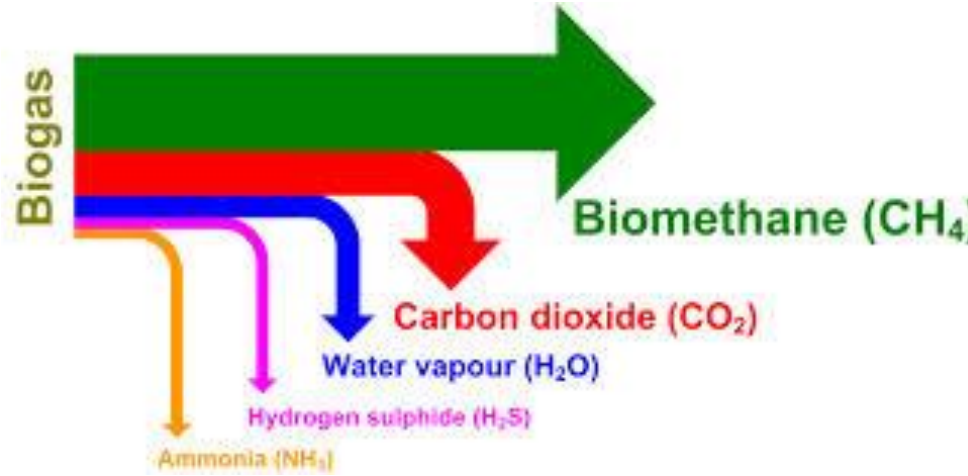
Barriers to RNG

Competitive market pressures

Fossil gas prices are low and projected to remain low into the future



Biogas vs. Biomethane vs RNG



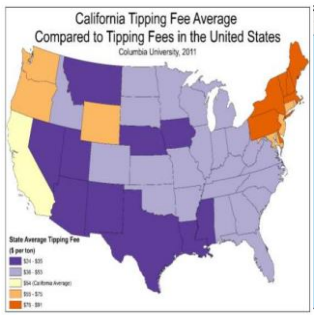
Are you going to inject in pipeline? Injection standards vary by company

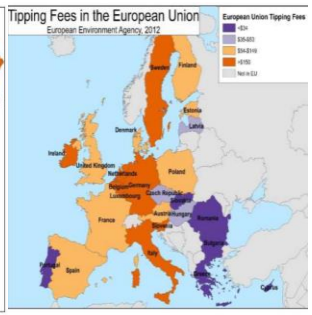
Table 7-3 Basic Pipeline Quality Standards for Major California Distributors

Gas Component or Characteristic	Pacific Gas and Electric Company	Southern California Gas Company
Carbon dioxide (CO_2)	≤1%	≤3%
Oxygen (O_2)	≤0.1%	≤0.2%
Hydrogen sulfide (H_2S)	≤0.25 grains/100 scf	≤0.25 grains/100 scf
Mercaptan sulfur	≤0.5 grains/100 scf	≤0.3 grains/100 scf
Total sulfur	≤1 grain/100 scf	≤0.75 grains/100 scf
Water (H_2O)	≤7 lb/million scf	≤7 lb/million scf
Total inerts	No requirement	≤4%
Heating value	Specific to receipt point	970 – 1,150 Btu/scf
Landfill gas	Not allowed	No requirement
Temperature	60 – 100° F	50 – 105° F
Gas Interchangeability [a]		
Wobbe number	Specific to receipt point	Specific to receipt point
Lifting index	Specific to receipt point	Specific to receipt point
Flashback index	Specific to receipt point	Specific to receipt point
Yellow tip index	Specific to receipt point	Specific to receipt point

scf = Standard cubic feet
Btu = British thermal units
[a] The various indices— Wobbe number, Lifting index, Flashback index, and Yellow tip index—are all means of determining the gas interchangeability (AGA, 1946)

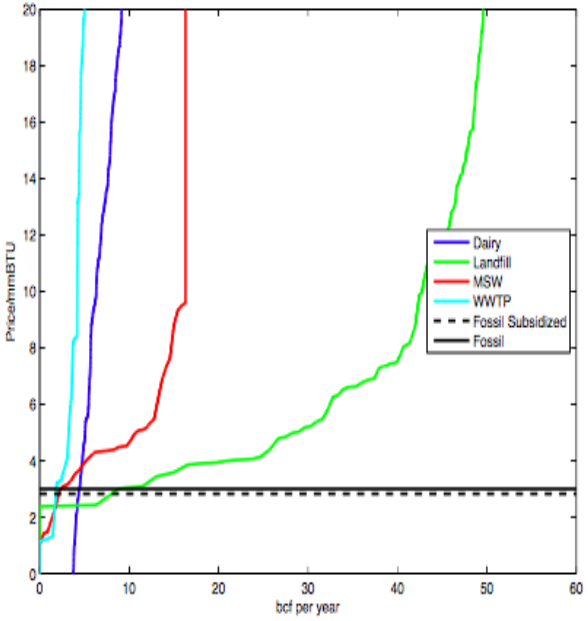
Tipping fees are very low



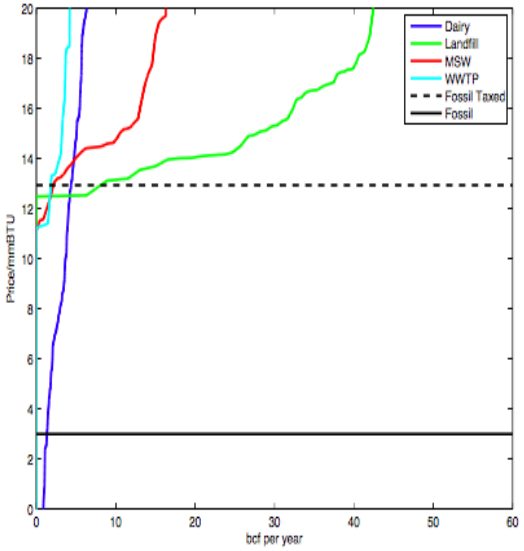


Carbon credits to the rescue *Almost 20 BCF/year*

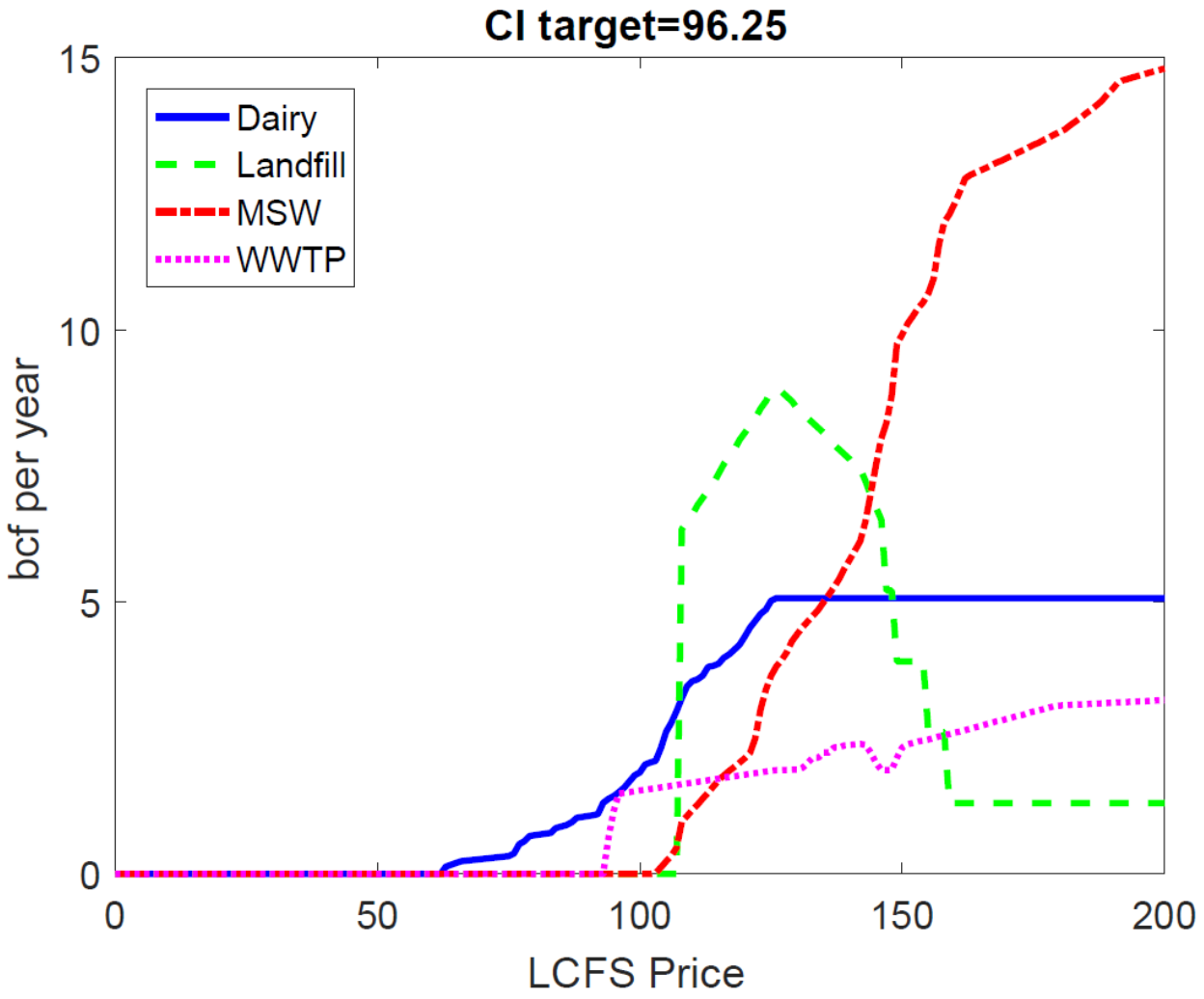
Supplies of RNG by source under a $120 LCFS Price



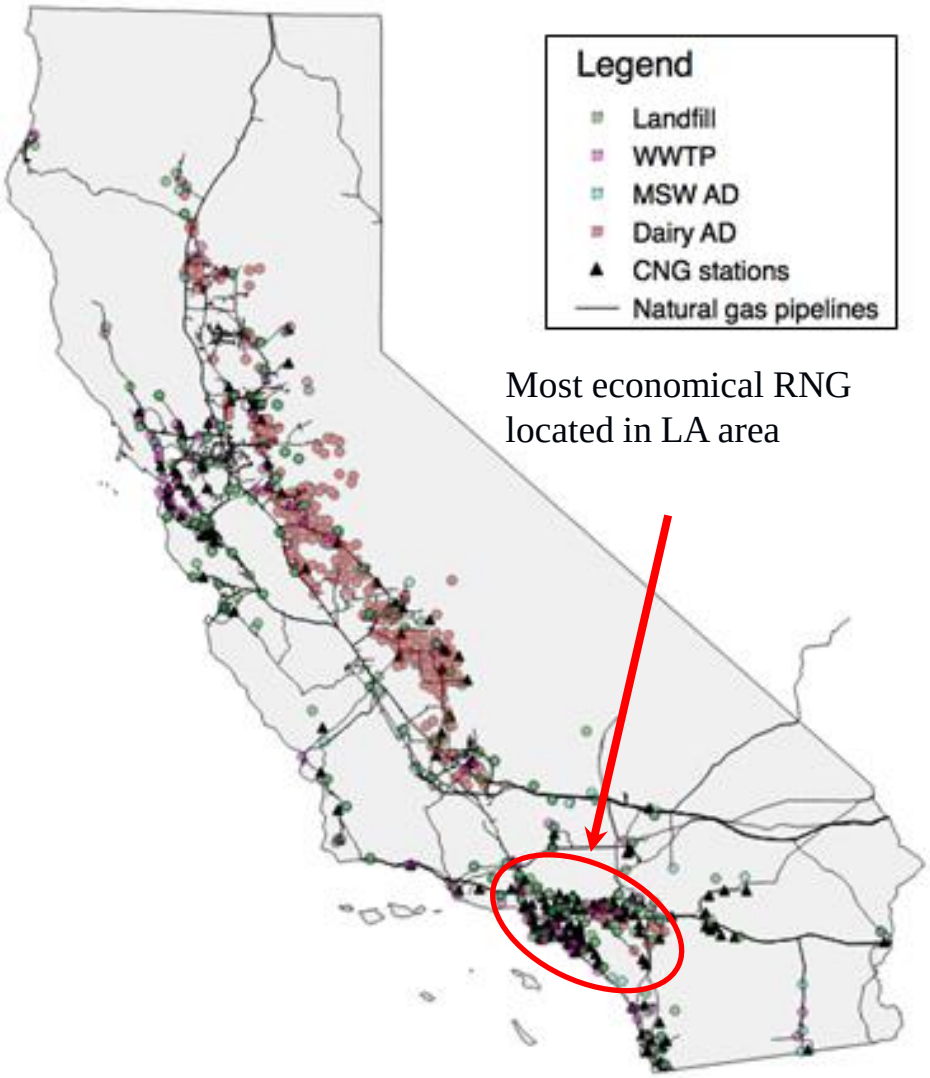
Supplies of RNG by source under a $120 Carbon Price (Tax)



RNG supplied as a function of LCFS price



RNG Estimation Data



Geolocated Data:

- **Dairies: 1,369 sites**, Central Valley and Santa Ana Regional Water Quality Control Boards
- **Landfills: 147 sites**, Landfill Methane Outreach Program
- **WWTP: 86 sites**, California Association of Sanitation Agencies
- **MSW: 38 sites**, California Biomass Collaborative, Solid Waste Information Systems, CalRecycle

Blending RNG with NG

Table 5. Carbon intensity reduction (%) achievable by blending levels (%) of each type of RNG

	% Reduction from fossil CNG			
% RNG ble	Landfill	WWTP	MSW	Dairy
5%	-2%	-4%	-6%	-23%
15%	-6%	-11%	-19%	-68%
20%	-8%	-15%	-26%	-90%
25%	-10%	-19%	-32%	-113%
35%	-14%	-26%	-45%	-158%
45%	-18%	-34%	-58%	-204%
50%	-20%	-38%	-65%	-226%
55%	-22%	-41%	-71%	-249%
65%	-26%	-49%	-84%	-294%
75%	-31%	-56%	-97%	-339%
80%	-33%	-60%	-103%	-362%
85%	-35%	-64%	-110%	-385%
100%	-41%	-75%	-129%	-452%

Summary

- Cost is sensitive to location (near humans is best)
- Cost is sensitive to productivity (dairies are less productive, and are scattered)
- RNG potential needs subsidy to compete with low NG prices
- Subsidy is sensitive to carbon intensity
- Carbon intensity sensitive to counterfactual or avoided emissions (the fact that it is a waste)
- Regulations against waste should promote the production of RNG