Natural Gas in Transportation

Rosa Dominguez-Faus

Post-doctoral Scholar

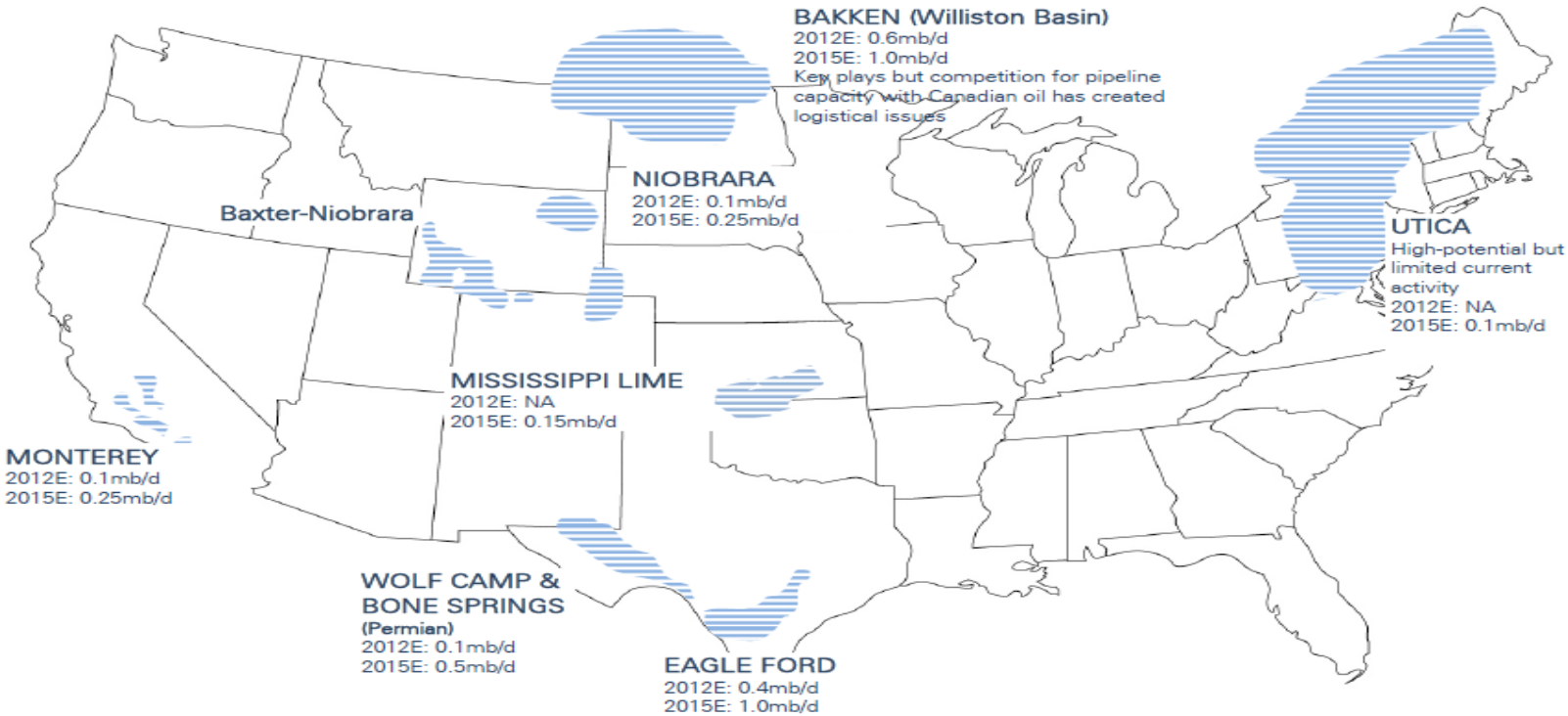
UC DAVIS GRADUATE SCHOOL OF MANAGEMENT

ITS UC DAVIS INSTITUTE OF TRANSPORTATION STUDIES

Key Points to be Covered

- **How sustainable is the shale gas revolution in the United States?**
- **What is the potential for natural gas as a direct or indirect transportation fuel in California in light of the shale revolution?**
- **What does initial ITS scenarios analysis, as well as other sources, show about the potential for natural gas to displace petroleum and reduce greenhouse gas emissions and improve air quality in CA and the U.S.?**

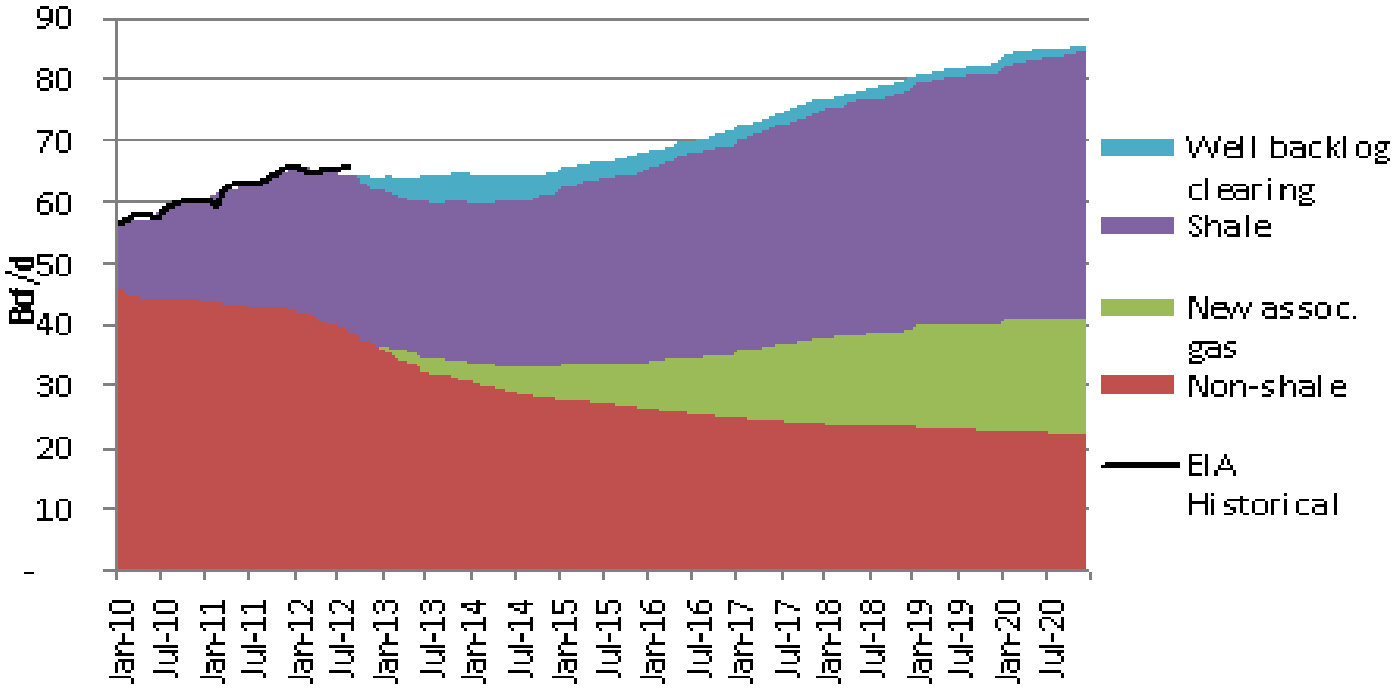
Over ten U.S. shale plays have high liquids potential



Source: Deutsche Bank, Integrated Oils: Oil & Gas for Beginners

- U.S. shale oil and shale gas potential is widely distributed geographically
- Increasingly, natural gas is being produced as associated gas by product of shale oil production
- U.S. natural gas surpluses expected to be extended and large

U.S. Natural Gas Production Profile Remains Robust through 2020 and beyond



Source: Citi

- Large resources available at breakeven costs between $2 per mcf to $3.50 per mcf in 2013-2014 time frame given a backlog of drilled wells and rising Marcellus output
- Longer term, modeling simulations indicate U.S. domestic supplies can keep up with rising demand and limited US LNG exports without pulling prices out of the $4 to $6 range, drawing on higher cost dry gas reserves

Natural Gas for Transportation: Lessons from Oklahoma

- State of Oklahoma initiative – multi-state RFP for the purchase of CNG vehicles resulted in major cost savings for direct purchases from OEMs, combined with simultaneous station provider commitments. Incentives 75% cost of filling stations, 50% home refueling costs, funded via 0.25 GGE surcharge
- Natural gas producers increasingly focused on creating new demand markets for natural gas including transportation
- Currently natural gas has a $1.00 to $1.50/gge cost advantage compared with diesel which for an LNG heavy duty vehicle that goes 90,000 miles a year means a payback of less than 3 years
- Transportation demand in US could top 1 Bcf/d to 3Bcf/d if oil-gas price ratio holds
- Oklahoma model an example for future initiatives in NGVs where natural gas production is high

Government vehicles

Oklahoma Initiative Negotiated Lower Costs from OEMs through Bulk Government Purchasing

Vehicle Awarded	Previous Contract Option & Post-RFP Option	Savings
Dodge Ram 2500, Crew Cab (b)	Before: $36,302	$6,309
	After: $29,993	
Honda Civic GX (d)	Before: $27,095	$2,191
	After: $24,904	
Ford Transit Connect (b)	Before: $31,000	$1,261
	After: $29,739	
Ford E-250 (b)	Before: $33,678	$4,689
	After: $28,989	
Ford E-350 (b)	Before: $35,827	$5,459
	After: $30,368	

¾ Ton CNG Dodge Ram		
	Gasoline	CNG
Vehicle Cost	$24,352	$29,993
Fuel Economy	14	14
Fuel Cost/GGE	$3.91	$1.19
Useful Life	175,000	175,000
Lifecycle Cost	$73,227	$44,868
OK's purchase of 242 units = $6.9 million in lifecycle cost savings!		

Source:
Jay Albert
Deputy Secretary of Energy
State of Oklahoma

Trucks- Payback Period
What works and what does not:

- Limited Range Trips – Given restrictions on fuel carrying capacity and fuel mileage, **the ideal CNG/LNG haul is roughly 400 miles**

- High Annual Mileage – Trucks need to be utilized well in order for the economics to work, and despite the shorter length of haul, tractors need to average **more than 100k miles a year**

- **Access to Terminal Fueling Infrastructure** – Refueling natural gas tanks takes longer than diesel, requires more safety procedures and precautions, and fueling stations are ideally placed near pipelines or other natural gas feeder facilities

- **Density of current stations** is limited, though GE in a Box modular technologies are enabling faster growth

Class 8 Trucks
Vehicle costs and Fuel Breakeven price

Comparison of Alternative Fuel Vehicles

Vehicle Incremental Cost	Conv. Diesel	Conv. LNG-SI	Conv. LNG-CI	Diesel Hybrid	LNG-SI Hybrid	LNG-CI Hybrid	Battery EV	Fuel Cell
OEM Additional Cost	0	$35,000	$45,200	$16,500	$51,500	$61,700	$214,000	$65,000
Retail Additional Cost [f]	0	$52,500	$67,800	$24,750	$77,250	$92,550	$321,000	$97,500

Breakeven Prices of LNG ($/DGE)

Function of:
- type of engine
- Driving cycle
- Annual driving intensity

Powertrain / Fuel	Day Drive		Short Haul		Long Haul Drive		
VMT(mile/year)	30k	60k	30k	60k	30k	60k	150k
year payback	5	3	5	3	5	3	3
Today's vehicle incremental costs							
Diesel Hybrid	4.94	3.96	9.74	7.81	26.4	21.17	8.47
LNG-SI Conventional	1.41	1.7	1.57	1.86	1.41	1.75	2.58
LNG-SI Hybrid	0.96	1.53	1.02	1.51	0.64	1.16	2.45
LNG-CI Conventional	1.41	1.94	1.49	1.97	1.12	1.67	2.98
LNG-CI Hybrid	0.5	1.36	0.65	1.35	0.13	0.9	2.76

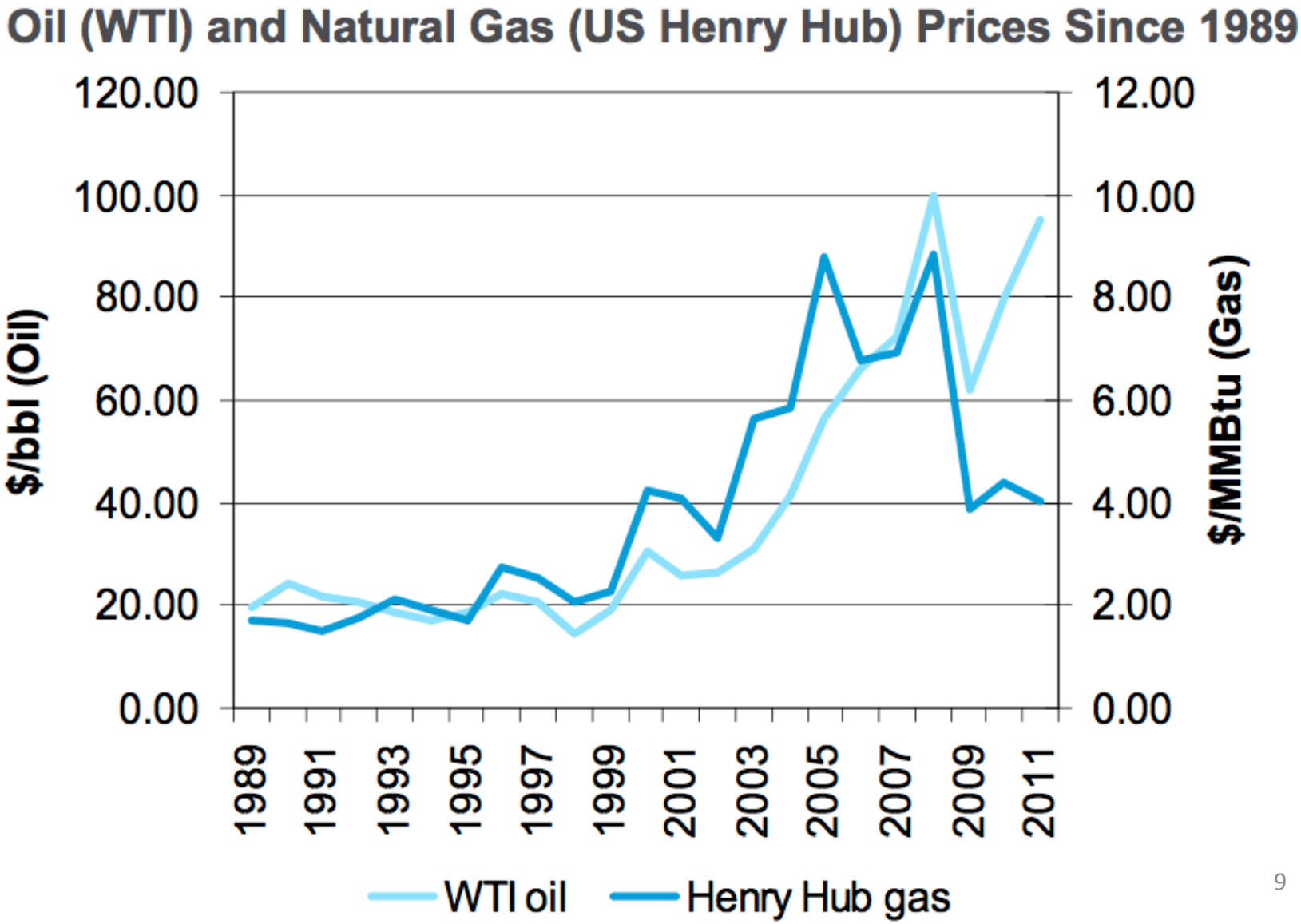
*Savings in diesel hybrids are realized from reduced fuel use, the more expensive the fuel the better your savings, while saving in NGVs are realized from using a cheaper fuel. The cheaper the LNG the higher the savings.

Assumptions:
Diesel $4/gal

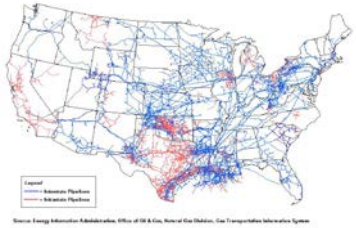
DOE Prices

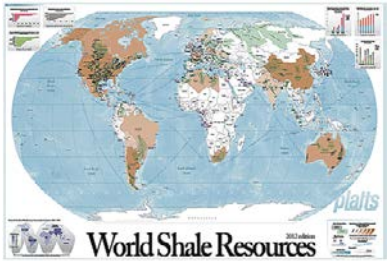
Fuel	Unit of sale	Price ($)
Diesel	gallon	3.5 - 4.0
LNG	gallon	2.9 - 3.0/DGE 1.5 - 2
Hydrogen	kg	4.0 - 5.0
Electricity	kWh	0.1 - 0.15

Uncertainty in Price Differential with Oil



Natural Gas Price Dynamics





Price Forecasts

Figure 5. Average annual Brent spot crude oil prices in three cases, 1980-2040

2011 dollars per barrel

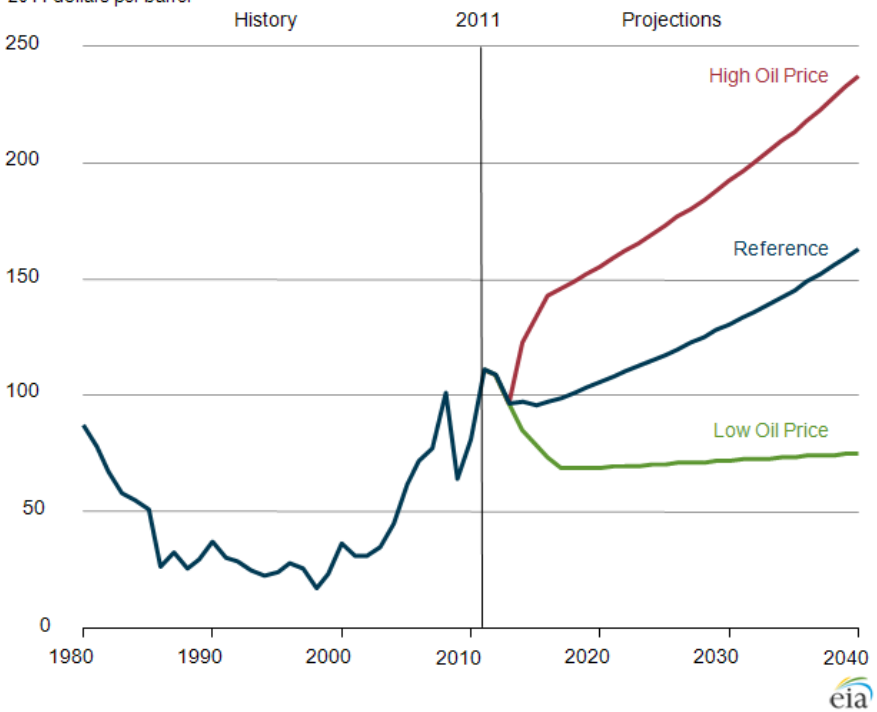
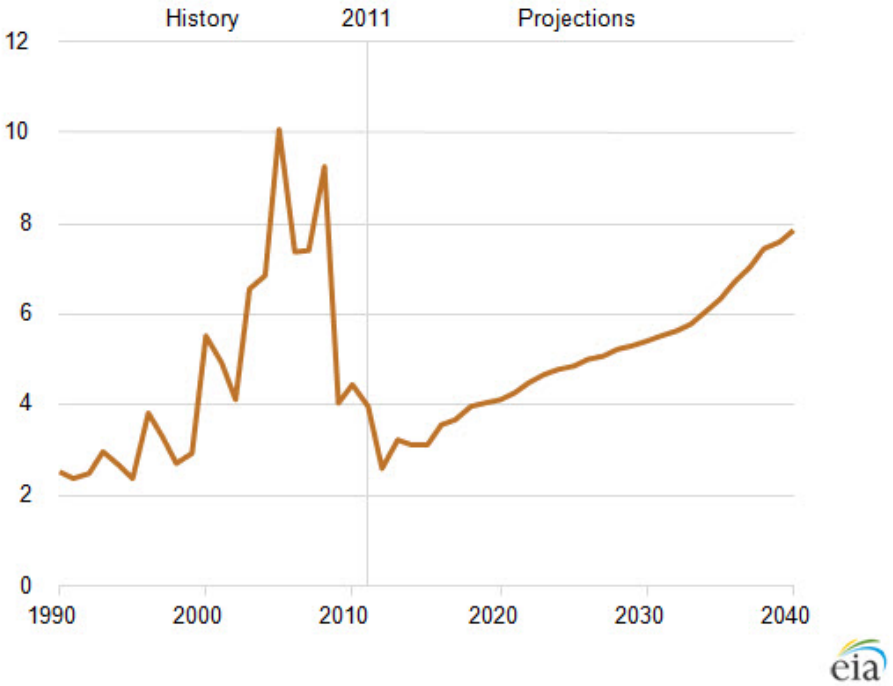
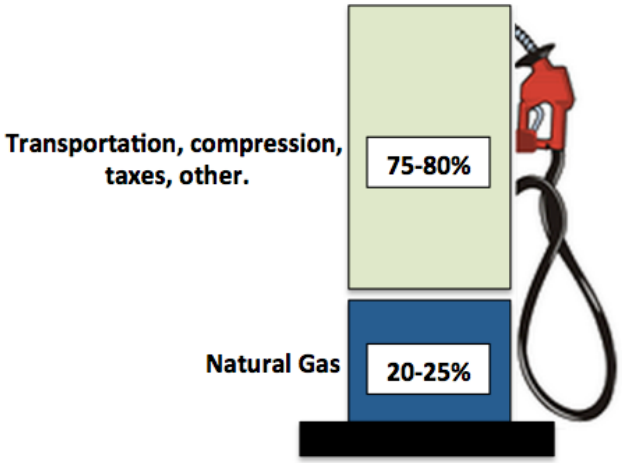
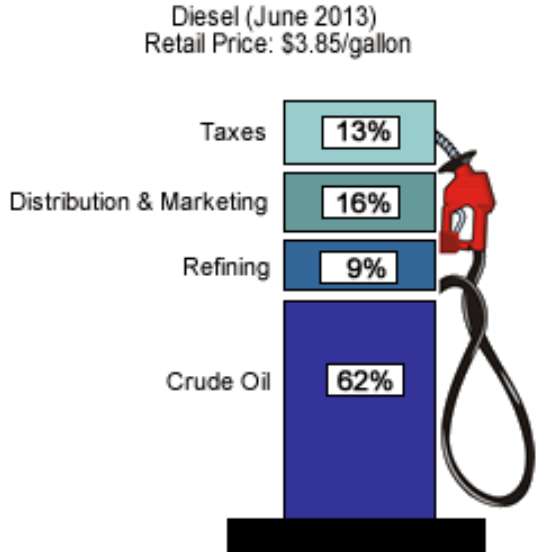


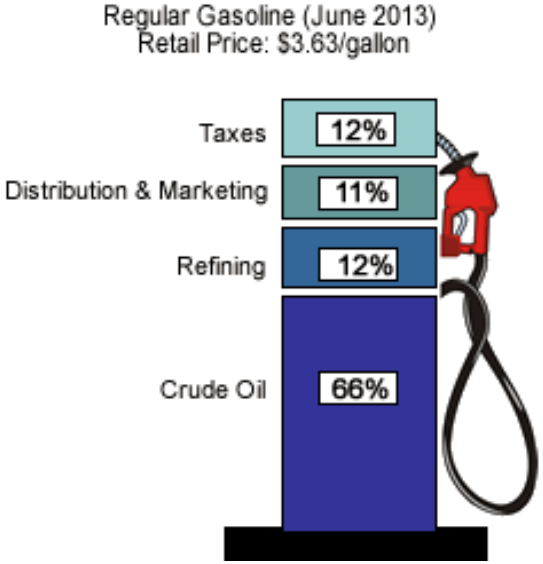
Figure 86. Annual average Henry Hub spot natural gas prices, 1990-2040 (2011 dollars per million Btu)



NG commodity price is a small part of retail price of CNG/LNG.







A $1.00 increase in the price of natural gas increases prices at the pump $0.14-$0.15

Natural Gas @ $4.00 per MCF

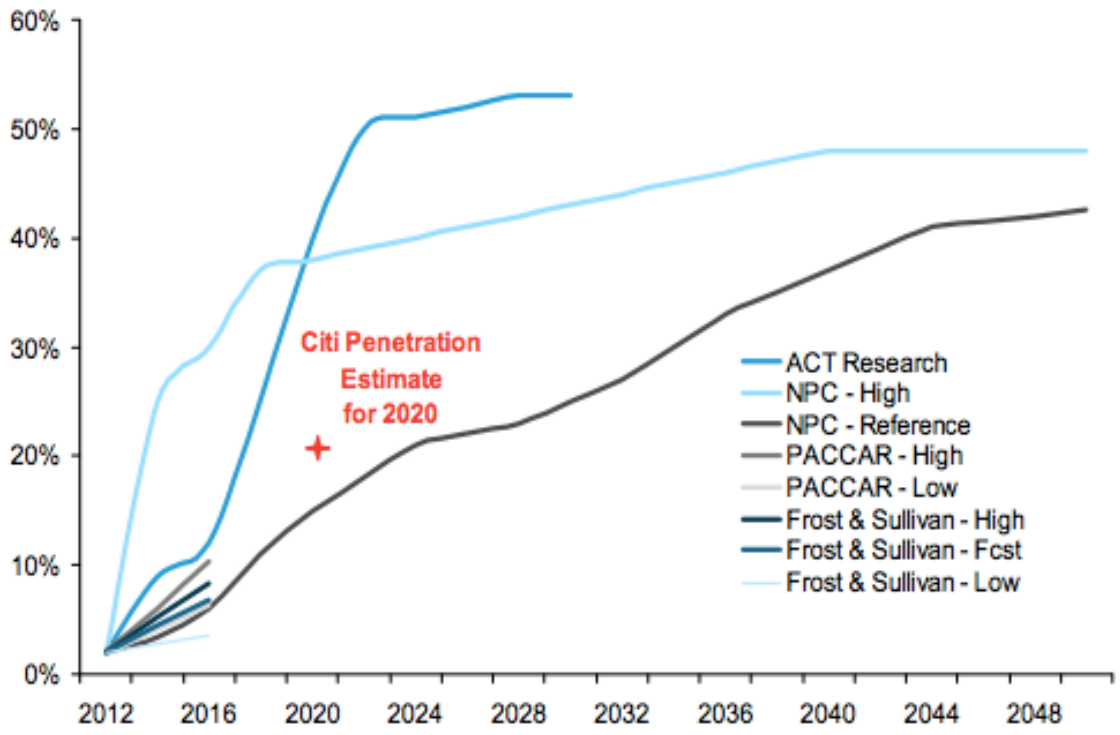
INPUT	COST
Natural Gas (divide by 8)	$0.50
Transport Costs & Fees	$0.20
Electricity Costs per GGE	$0.10
Maintenance per GGE	$0.20
Federal and State Taxes	$0.25
Fuel Card Fees per GGE	$0.05
Retailer Profit Margin	$0.40
CNG at the Pump	**$1.70**

Natural Gas @ $8.00 per MCF

INPUT	COST
Natural Gas (divide 8)	$1.00
Transport Costs & Fees	$0.20
Electricity Costs per GGE	$0.10
Maintenance per GGE	$0.20
Federal and State Taxes	$0.25
Fuel Card Fees per GGE	$0.05
Retailer Profit Margin	$0.40
CNG at the Pump	**$2.20**

Projections NGV Class 8 Truck Adoption: Penetration Likely limited Over Next 5 Years, but Could Scale by 2020

Figure 34. Long-Term Class 8 Natural Gas Penetration Forecasts



Source: Citi Research

relegated to large fleets that can leverage existing natural gas infrastructure

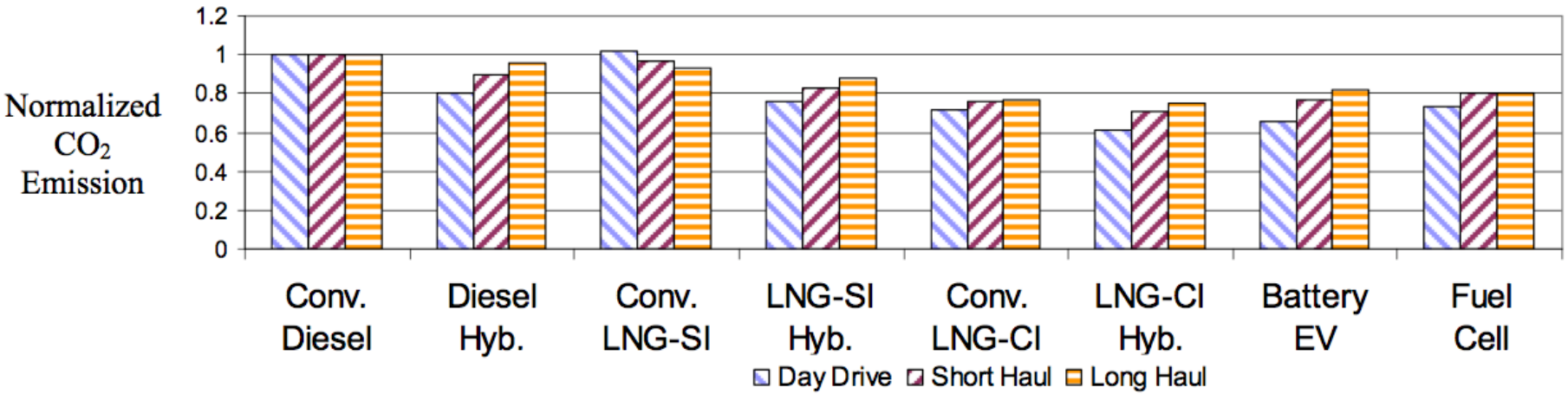
CA is heavy traffic zone

Figure 30. Heavy Traffic Truck Corridors

Source: US Department of Transportation

2. Greenhouse gas emissions reductions: Key factors, circumstances and assumptions.

Class 8 truck CO2 emissions ADVISOR Model (**engine** technology side-by-side comparison)



Stoichiometric estimates

Heavy Duty **scenario comparison**
Future emissions (TOP Model)

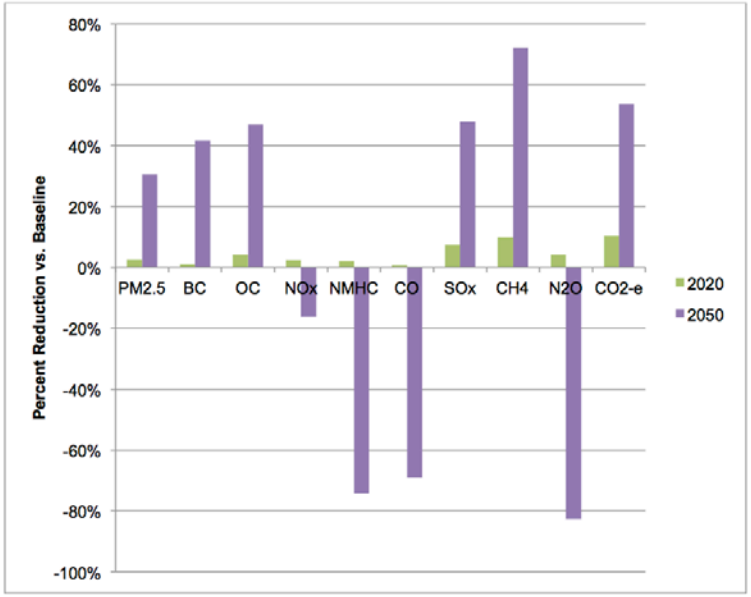


Figure 5-67: Percent reduction in annual emissions in 2020 and 2050 for the Alternative Fuels scenario as compared to the Baseline

Table 5-19: CO_2e emissions of the Baseline, High Efficiency, and Alternative Fuels scenario by lifecycle phase

Lifecycle Phase	Emissions Totals in 2050 (metric tons)			Difference vs. Alt Fuels	
	Baseline	High Efficiency	Alternative Fuels	Baseline	High Efficiency
Tailpipe	24,676,883	12,396,792	12,320,950	+50.1%	+0.6%
Upstream fuels	3,343,562	1,806,682	571,468	+82.9%	+68.4%
Vehicle manufacturing	3,248,381	3,169,167	3,602,894	-9.8%	-12.0%
Scrappage	296,316	296,316	296,316	0%	0%
Total	31,565,591	17,668,957	16,791,628	+46.8%	+5.0%

TOP Model Assumptions

On-road Heavy-duty Fuel Use

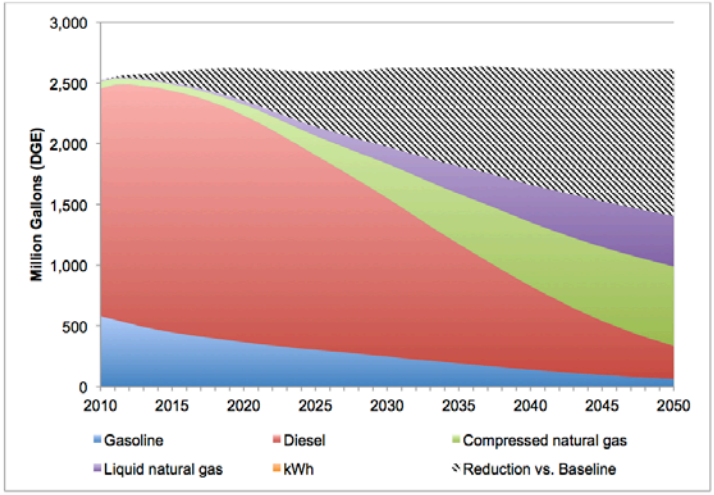


Figure 5-69: Fuel use trends of the Alternative Fuels scenario (million diesel gallon equivalents)

Table 5-17: Percentage breakdowns for diesel and NG feedstocks in the Alternative Fuels scenario

	2010-2020	2021-2030	2031-2040	2041-2050
Diesel Feedstocks				
Crude oil	98.75%	93%	80%	65%
Municipal solid waste (FT diesel)	1%	5%	15%	25%
Forest biomass (FT diesel)	0.2%	1.5%	3.5%	7%
Tallow (renewable diesel)	0.05%	0.5%	1.5%	3%
TOTAL	100%	100%	100%	100%
Natural Gas Feedstocks				
Fossil NG	99%	90%	70%	45%
Landfill gas	0.75%	9%	25%	45%
Dairy farm biogas	0.25%	1%	5%	10%
TOTAL	100%	100%	100%	100%

Biogas could supply approximately 10% of the total NG consumed in 2050 in this scenario

New Vehicle Adoption Rates

Table 5-18: Market share controls for the Alternative Fuels scenario

	HD Pickup	Urban Bus	Other Bus	MD Urban	MD Vocation	HD Vocation	LH Tractor	SH Tractor
Adoption Controls								
Initial yr. of AV adoption	2020	2011	2020	2015	2015	2011	2020	2015
Pivot year 1	2030	2020	2030	2025	2025	2025	2030	2030
Pivot year 2	2040	2030	2040	2025	2025	2035	2040	2040
Conv. Vehicle Change in Market Share								
Period 1 annual change in MS (percentage)	-3%	-5%	-3%	-3%	-3%	-3%	-3%	-3%
Period 2 annual change in MS (percentage)	-7.5%	-7.5%	-7.5%	-7.5%	-7.5%	-7.5%	-7.5%	-7.5%
Period 3 annual change in MS (percentage)	-15%	-15%	-15%	-15%	-15%	-15%	-15%	-15%
Natural Gas Controls								
Initial % of AV market	50%	75%	50%	75%	50%	75%	50%	50%
Period 1 annual change in MS (percentage points)	1%	1%	1%	1%	1%	1%	1%	1%
Period 2 annual change in MS (percentage points)	1%	1%	1%	1%	1%	1%	1%	1%
Period 3 annual change in MS (percentage points)	1%	1%	1%	1%	1%	1%	1%	1%
Hybrid Controls								
Initial % of AV market	50%	25%	50%	25%	50%	25%	50%	50%
Period 1 annual change in MS (percentage points)	-1%	-1%	-1%	-1%	-1%	-1%	-1%	-1%

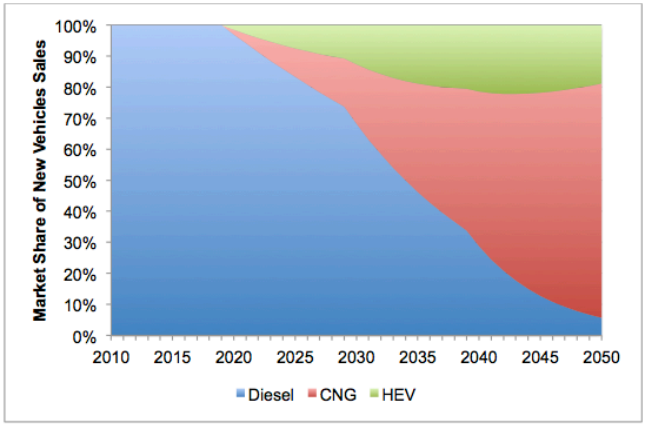


Figure 5-65: HD Pickup, Other Bus, and LH Tractor new vehicle market share in the Alternative Fuels scenario

Social Costs
TOP model

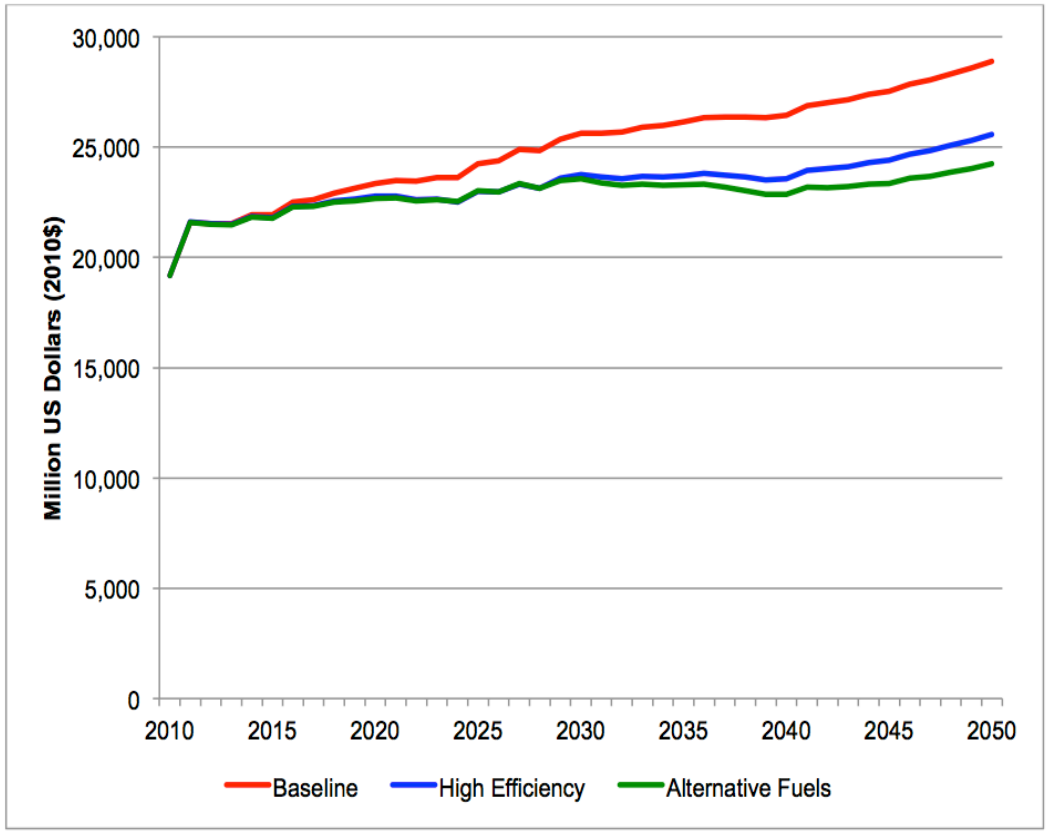


Figure 5-70: Total lifecycle costs of the Alternative Fuels, High Efficiency, and Baseline scenarios

Include both the direct costs incurred by HD vehicle users as well as the monetized externality costs imposed by HD vehicles, including air pollution, climate change, noise, and the military expenditures required to secure energy resources abroad.

Ongoing research issues

- Consequential LCA
- Rebound effect
- Time horizon to calculate GWP (20 or 100 years)
- Only difference between shale gas and conventional natural gas is production phase. Distribution infrastructure is the same as conventional gas.
- Part of the problem is that price of natural gas is low:
  - Lots of venting (LOTS)
  - New Federal EPA regs in 2015 will require green completions that greatly reduce methane leakage at wellhead

Sources

- *Amy M. Jaffe and Rosa Dominguez-Faus.* **Exploring Options for Natural Gas in Transportation**. The February 2013 NextSTEPS Natural Gas Scenarios Workshop Report (May 20, 2013)

- *Benjamin Rodriguez Sharpe.* **Examining the Costs and Benefits of Technology Pathways for Reducing Fuel Use and Emissions from On-road Heavy-duty Vehicles in California.** *PhD. Thesis (2013)*

- *Hengbing Zhao, Andrew Burke, Marshall Miller.* **Analysis of Class 8 Truck Technologies for their Fuel Savings and Economics.** Transportation Research Part D Volume 23 (August 2013)

- *Delucchi, M.A.,* ***The Social-Cost Calculator (SCC): Documentation of Methods and Data, and Case Study of Sacramento* 2006,** Institute of Transportation Studies, University of California, Davis: Davis, CA. (2013 update)

Server:
www.sharefiles.its-davis.com

Contact:
rdominguezfaus@ucdavis.edu