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**U.S. Class 8 Truck Transportation & Natural  
Gas: Evolution, Revolution or Bust?**

**Federal Reserve Bank of Chicago, New Access to Energy Conference  
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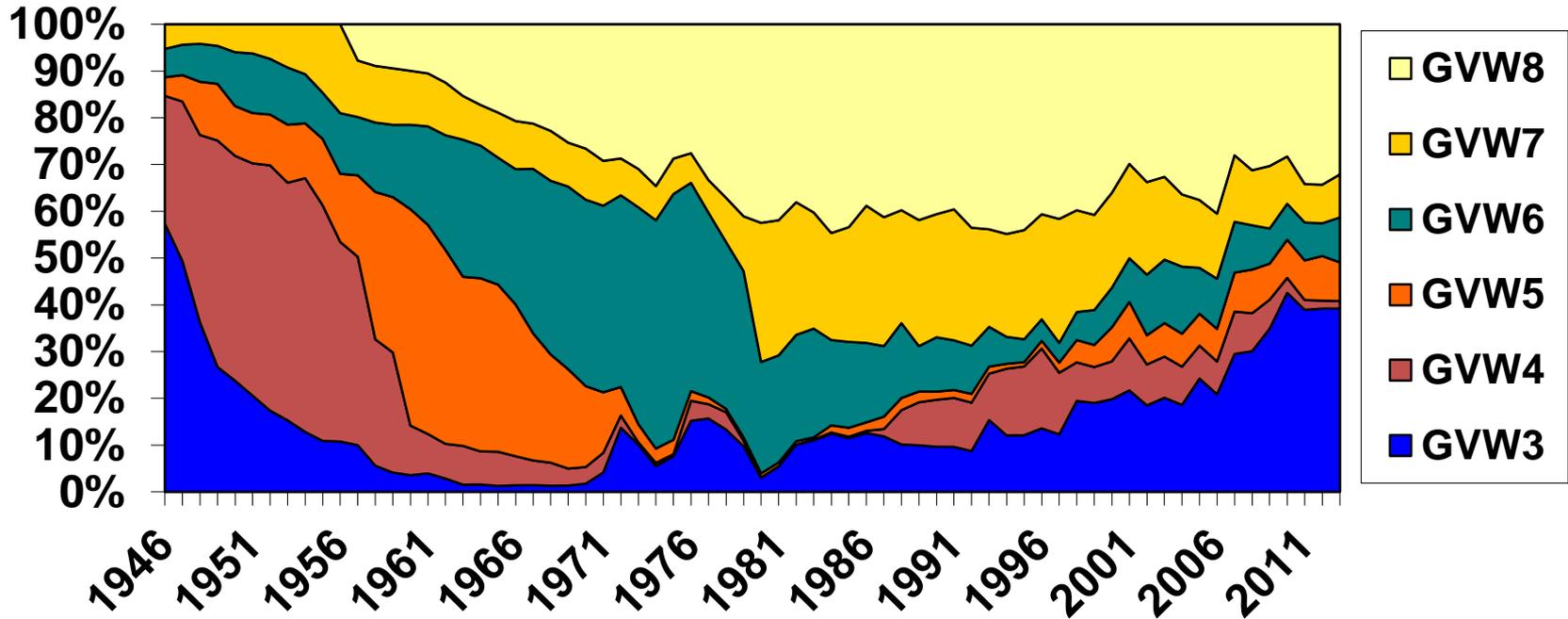
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# U.S. Classes 3-8 Trucks

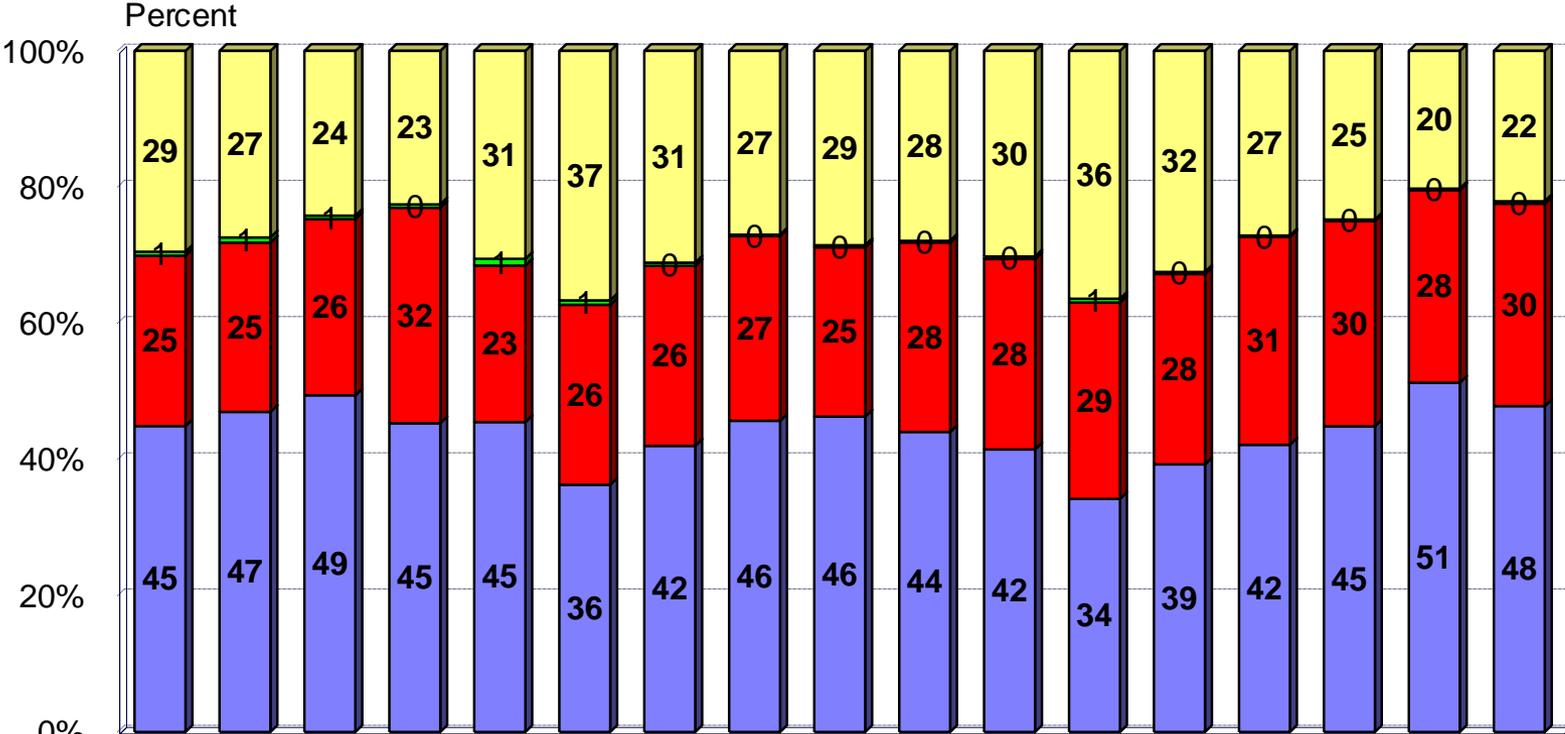
## History at a Glance

### Percent Mix 1946 – 2013 YTD



# U.S. Class 8 Retail Sales

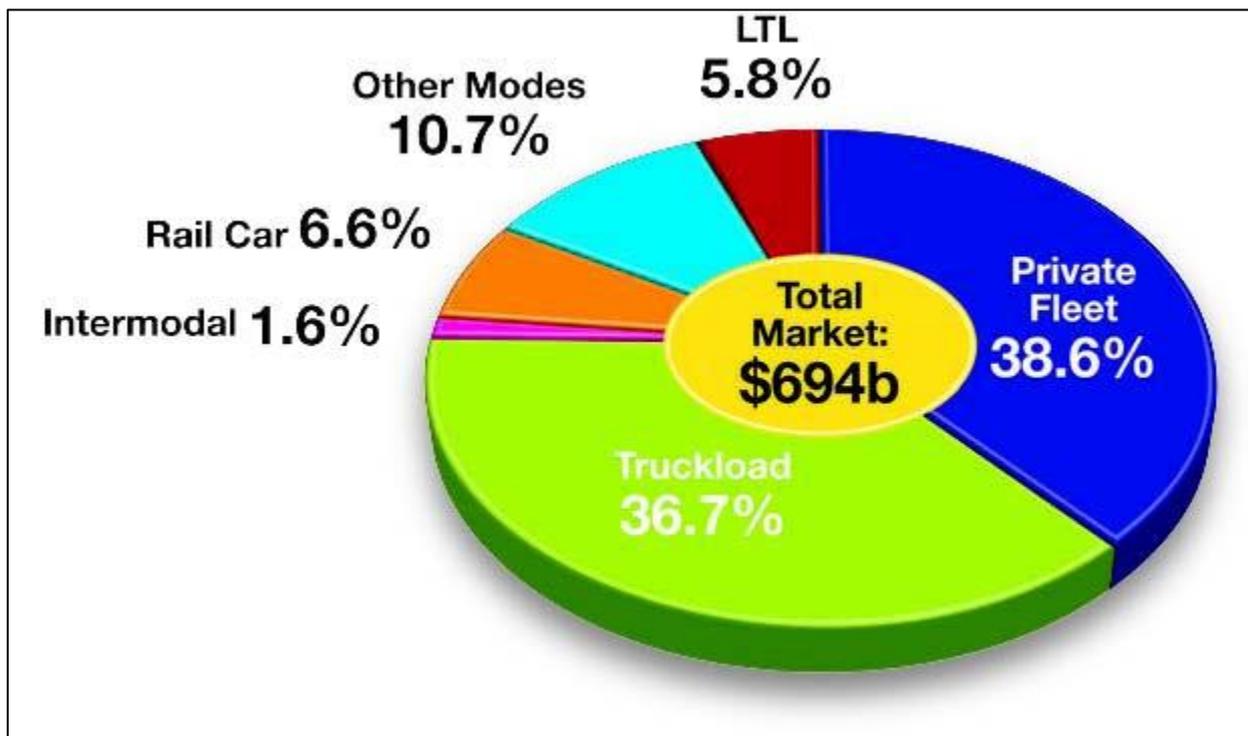
1996-2012



	'96	'97	'98	'99	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10	'11	'12
Truck Daycab	29	27	24	23	31	37	31	27	29	28	30	36	32	27	25	20	22
Truck Sleeper	1	1	1	0	1	1	0	0	0	0	0	1	0	0	0	0	0
Tractor Daycab	25	25	26	32	23	26	26	27	25	28	28	29	28	31	30	28	30
Tractor Sleeper	45	47	49	45	45	36	42	46	46	44	42	34	39	42	45	51	48

	2012	2013	2014
<b>US CI 8 Truck Build</b>	201,300	198,500 (F)	229,600 (F)
<b>Does Not Include Transit Buses</b>			
<b>NG %</b>	~3%	~6%	~8%
<b>CI 8 + T. Bus Units</b>	7,500	12,000	18-20,000

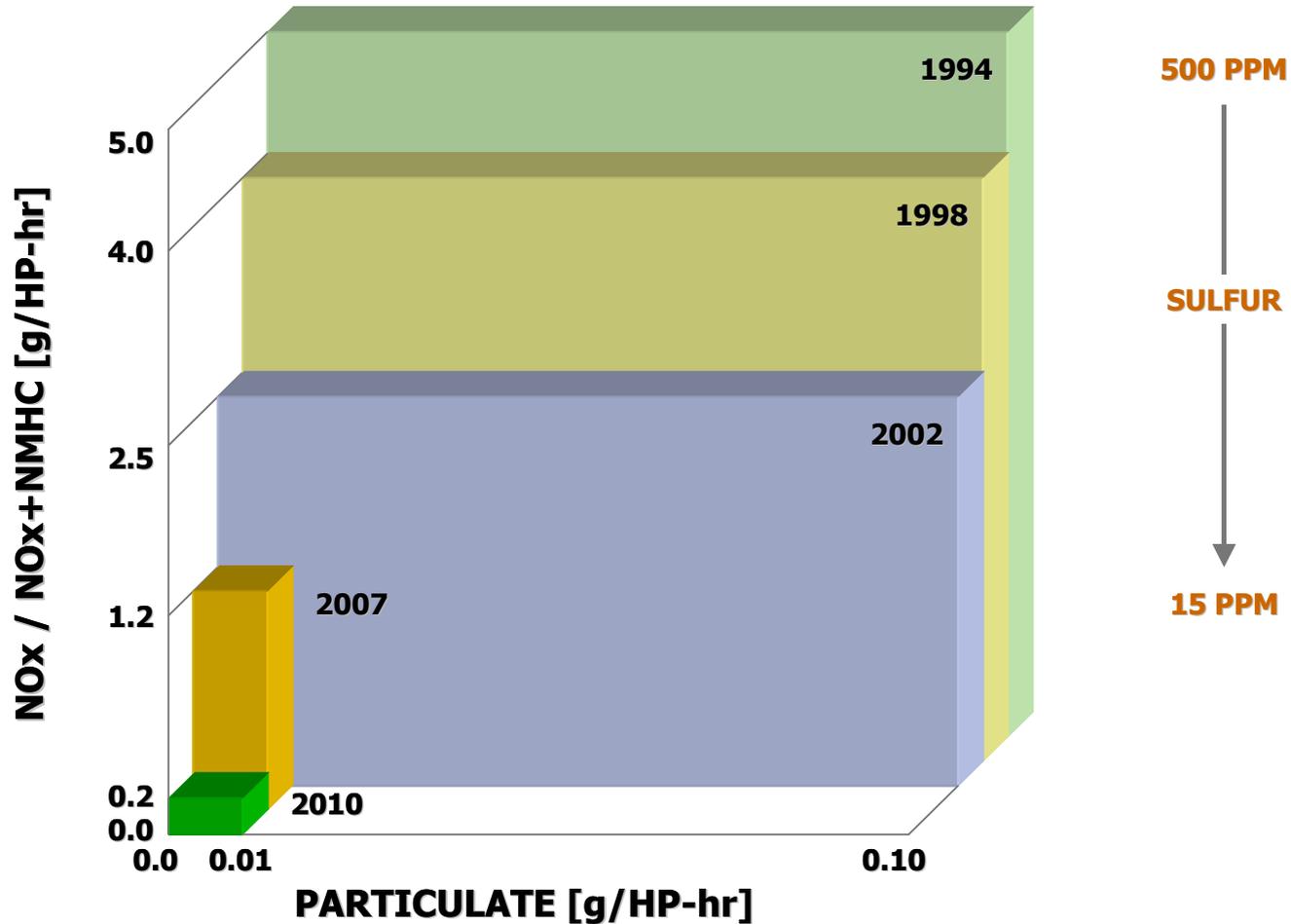
# U.S. Freight Market Modal Share (2010 as a % of Revenues)



	2022
Trucking	81.4%
Rail Car	5.8%
I-Modal	2.7%
Other	10.1%

Source: American Trucking Association, ACT Research Co., LLC

# EPA Emission Standards



# Regulatory Considerations

- CSA ('11)
  - Productivity, liability, drivers
- EOBRs
  - 2015 seems likely
  - Productivity hit (eliminates log cheating)
- Hours of Service (July 1, '12)
  - Keep 11 and 14 hours (for now)
  - NEW: 34 hour reset must include 2 overnights
- Advanced OBD ('13)
  - Last piece of the NOx, PM EPA puzzle
- CAFE/GHG Standards ('14, '18)
  - Meaningful MPG improvement means short payback
- Electronic Stability Control
  - In proposed rulemaking phase

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# The Hypothesis

**The North American commercial vehicle truck market will see a measured shift to the use of natural gas as a fuel for heavy duty class 8 vehicles, displacing currently used diesel fuel. In the next 1 to 2 decades, natural gas will become the fuel of choice for 50% of on-highway class 8 vehicles.**



Source: Clean Energy Fuels

# Annual Fuel Cost Comparisons

	<b>Diesel Fuel</b>	<b>Natural Gas @ 90% Efficiency (spark)</b>	<b>Natural Gas @ 85% Efficiency (spark)</b>	<b>Natural Gas @ 80% Efficiency (spark)</b>
<b>MPG</b>	6.0	5.4	5.1	4.8
<b>Gallons of fuel required for 100,000 miles</b>	16,667	18,519	19,608	20,833
<b>Cost of fuel at \$4.00 per gallon</b>	\$66,668	--	--	--
<b>Cost of natural gas fuel at \$2.50 per gallon DGE</b>		\$46,298	\$49,020	\$52,083
<b>DEF consumption in gallons</b>	333.34	Not Required	Not Required	Not Required
<b>DEF cost at \$2.00 per gallon</b>	\$666.68	--	--	--
<b>Diesel particulate filter cleaning</b>	\$275.00	Not Required	Not Required	Not Required
<b>Total fuel cost</b>	\$67,610	\$46,298	\$49,020	\$52,083
<b>Fuel cost savings</b>		\$21,312	\$18,590	\$15,527
<b>Five year savings</b>		<b>\$106,560</b>	<b>\$92,950</b>	<b>\$77,635</b>

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INPUTS		Enter data in Yellow Cells	
<b>Two of Three Inputs are Needed for Correct Calculation</b>			
Gallons of Diesel Consumed Per Year	<input type="text" value="16,667"/>	<b>NG or Dual Fuel Vehicle Information</b>	
Average Miles Driven Per Year	<input type="text" value="100,000"/>	NG ENGINE Efficiency	<input type="text" value="Over the Road"/> <input type="text" value="90%"/>
MPG Average Per Year	<input type="text" value="6.00"/>	Percent of Fuel that is NG	<input type="text" value="Spark Ignited"/> <input type="text" value="100%"/>
DEF as % of Diesel	<input type="text" value="2.5%"/>	Equipment Upcharge	<input type="text" value="\$ 50,000"/>
		DPF Annual Maintenance Cost	<input type="text" value="\$ 275"/>
		<b>Cost of Fuel and DEF</b>	
		Diesel Per Gallon	<input type="text" value="\$ 4.00"/>
		DEF Per Gallon	<input type="text" value="\$ 2.40"/>
		NG DGE	<input type="text" value="\$ 2.00"/>
		Other Annual Savings (-) / Costs (+); maintenance, subsidies, etc.	<input type="text" value="\$ 0"/>

	Percent of Fuel	Fuel or Additive	Gallons or DGE	Cost Per Gallon or DGE	ANNUAL COST
<b>Diesel Engine</b>	100%	Diesel	16,667	\$4.00	\$66,668
		DEF	417	\$2.40	\$1,000
		Diesel & DEF			\$67,668
		DPF Annual Maintenance Cost			\$275
		<b>Diesel Subtotal</b>			<b>\$67,943</b>
<b>Natural Gas Spark Ignited Engine</b>	100%	Natural Gas	18,519	\$2.00	\$37,038
		<b>Natural Gas Subtotal</b>			<b>\$37,038</b>



RESULTS	
Equipment Upcharge	\$50,000
Other Savings (-) / Costs (+)	\$0
Net Equipment Upcharge	\$50,000
Annual Savings for Natural Gas Spark vs Diesel	\$30,905
<b>Payback</b>	<b>1.6 Years or 19 Months</b>

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Calc

INPUTS		Enter data in Yellow Cells	
<b>Two of Three Inputs are Needed for Correct Calculation</b>			
Gallons of Diesel Consumed Per Year	<input type="text" value="16,667"/>	<b>NG or Dual Fuel Vehicle Information</b>	
Average Miles Driven Per Year	<input type="text" value="100,000"/>	NG ENGINE Efficiency	<input type="text" value="Other (Enter %)"/> <input type="text" value="100%"/>
MPG Average Per Year	<input type="text" value="6.00"/>	Percent of Fuel that is NG	<input type="text" value="Dual-HPDI"/> <input type="text" value="95%"/>
DEF as % of Diesel	<input type="text" value="2.5%"/>	Equipment Upcharge	<input type="text" value="\$ 70,000"/>
		DPF Annual Maintenance Cost	<input type="text" value="\$ 275"/>
		<b>Cost of Fuel and DEF</b>	
		Diesel Per Gallon	<input type="text" value="\$ 4.00"/>
		DEF Per Gallon	<input type="text" value="\$ 2.40"/>
		NG DGE	<input type="text" value="\$ 2.50"/>
		Other Annual Savings (-) / Costs (+); maintenance, subsidies, etc.	<input type="text" value="\$ 0"/>

	Percent of Fuel	Fuel or Additive	Gallons or DGE	Cost Per Gallon or DGE	ANNUAL COST
<b>Diesel Engine</b>	100%	Diesel	16,667	\$4.00	\$66,668
		DEF	417	\$2.40	\$1,000
		Diesel & DEF			\$67,668
		DPF Annual Maintenance Cost			\$275
		<b>Diesel Subtotal</b>			<b>\$67,943</b>
<b>Dual Fuel Engine HPDI</b>	5%	Diesel	833	\$4.00	\$3,332
		DEF	21	\$2.40	\$50
	95%	Natural Gas	15,834	\$2.50	\$39,584
		Natural Gas, Diesel & DEF			\$42,966
		DPF Annual Maintenance Cost			\$275
	<b>Dual Fuel Subtotal</b>			<b>\$43,243</b>	



RESULTS	
Equipment Upcharge	\$70,000
Other Savings (-) / Costs (+)	\$0
Net Equipment Upcharge	\$70,000
Annual Savings for Dual Fuel vs Diesel	\$24,700
<b>Payback</b>	<b>2.8 Years or 34 Months</b>



**Truck Fuel Payback Calculators**  
DIESEL, NATURAL GAS, DUAL FUEL (HPDI/DNG)

Diesel, Natural Gas, Dual Fuel

Natural Gas Pump Price

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INPUTS		Enter data in Yellow Cells	
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Gallons of Diesel Consumed Per Year	<input type="text" value="16,667"/>		
Average Miles Driven Per Year	<input type="text" value="100,000"/>		
MPG Average Per Year	<input type="text" value="6.00"/>		
<b>NG or Dual Fuel Vehicle Information</b>			
NG ENGINE Efficiency	<input type="text" value="Other (Enter %)"/>	<input type="text" value="100%"/>	
Percent of Fuel that is NG	<input type="text" value="Other (Enter % NG)"/>	<input type="text" value="50%"/>	
Equipment Upcharge	<input type="text" value="\$ 30,000"/>		
DEF as % of Diesel	<input type="text" value="2.5%"/>	DPF Annual Maintenance Cost	<input type="text" value="\$ 275"/>
		Cost of Fuel and DEF	
		Diesel Per Gallon	<input type="text" value="\$ 4.00"/>
		DEF Per Gallon	<input type="text" value="\$ 2.40"/>
		NG DGE	<input type="text" value="\$ 2.50"/>
		Other Annual Savings (-) / Costs (+); maintenance, subsidies, etc.	<input type="text" value="\$ 0"/>

	Percent of Fuel	Fuel or Additive	Gallons or DGE	Cost Per Gallon or DGE	ANNUAL COST
<b>Diesel Engine</b>	100%	Diesel	16,667	\$4.00	\$66,668
		DEF	417	\$2.40	\$1,000
		Diesel & DEF			\$67,668
		DPF Annual Maintenance Cost			\$275
		<b>Diesel Subtotal</b>			<b>\$67,943</b>
<b>Dual Fuel Engine DNG</b>	50%	Diesel	8,334	\$4.00	\$33,334
		DEF	208	\$2.40	\$500
	50%	Natural Gas	8,334	\$2.50	\$20,834
		Natural Gas, Diesel & DEF			\$54,668
		DPF Annual Maintenance Cost			\$275
	<b>Dual Fuel Subtotal</b>			<b>\$54,943</b>	



RESULTS	
Equipment Upcharge	\$30,000
Other Savings (-) / Costs (+)	\$0
Net Equipment Upcharge	\$30,000
Annual Savings for Dual Fuel vs Diesel	\$13,000
<b>Payback</b>	<b>2.3 Years or 28 Months</b>

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Calc



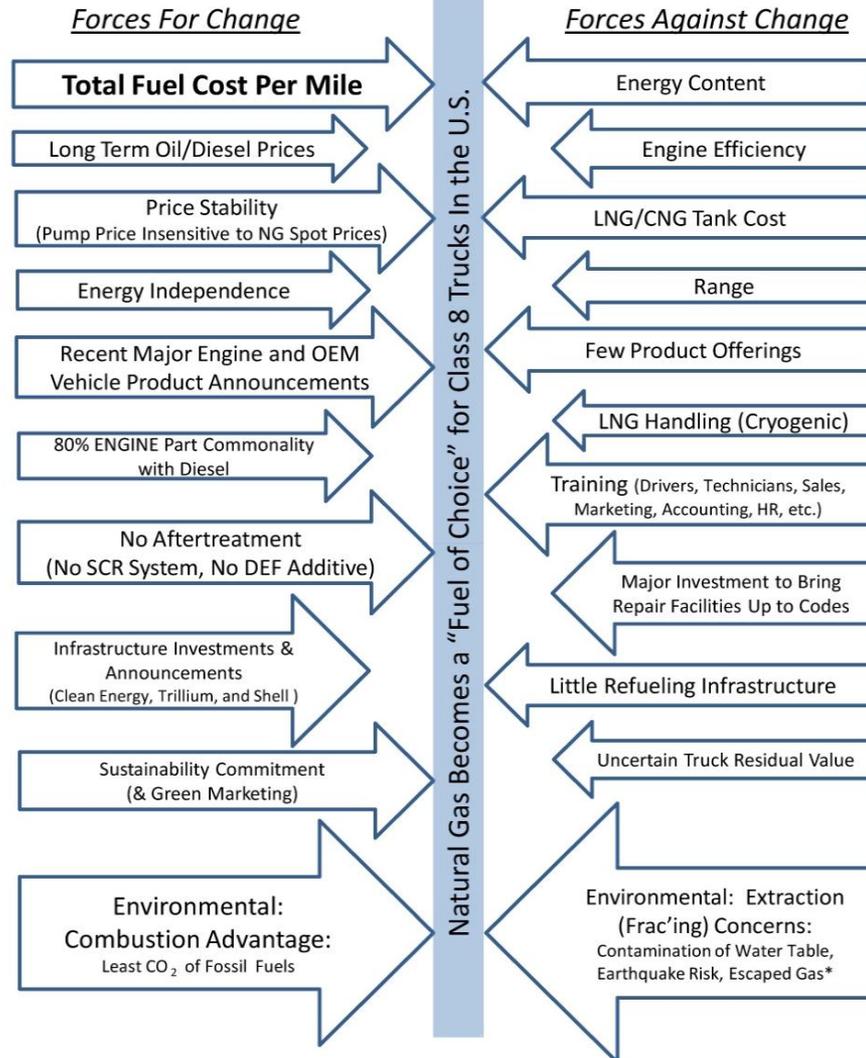
# DIESEL GALLON EQUIVALENT (DGE) PRICE AT PUMP CALCULATOR

	<u>Henry Hub*</u>	<u>Another Price for Comparison</u>	<u>Comparator % Increase (+) / Decrease (-) vs. Henry Hub</u>
Price per Million BTU (MMBtu)	<b>\$ 3.220</b>	<b>\$ 6.440</b>	<b>100%</b>
Divide MMBTU by this factor for DGE	7.213	7.213	
Subtotal, Spot (Cash) Price per DGE	\$ 0.446	\$ 0.893	
Processing--Henry Hub to the Pump	\$ 1.50	\$ 1.50	
Subtotal	\$ 1.946	\$ 2.393	
Additional Markup			
Pre Tax Price per DGE	\$ 1.946	\$ 2.393	
Federal, State, and Local Taxes	\$ 0.538	\$ 0.538	
Other	\$ -	\$ -	
Price at Pump (inc tax) per DGE	<b>\$ 2.484</b>	<b>\$ 2.931</b>	<b>18%</b>

# Lowest Total Cost

Factors For Consideration

## Natural Gas Adoption as a Class 8 Fuel of Choice



\* The radiative forcing (heat trapping ability) of methane is many times that of CO<sub>2</sub>. However, CO<sub>2</sub> lasts many times longer in the atmosphere.

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# From Force Field Analysis to

**“Yeah, BUT”**

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# Yeah, But NG....

- 1. Tractors are too heavy...**
- 2. Engines don't have a long enough operating range...**
- 3. NG Powered trucks are limited in availability...**
- 4. NG Engines are less fuel efficient and don't save money...**

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# Yeah, But NG....

- 5. Vehicles can't provide enough ROI without subsidies**
- 6. Engine maintenance costs are too high**
- 7. Engines won't be liked by drivers**
- 8. Shop modification is too costly**

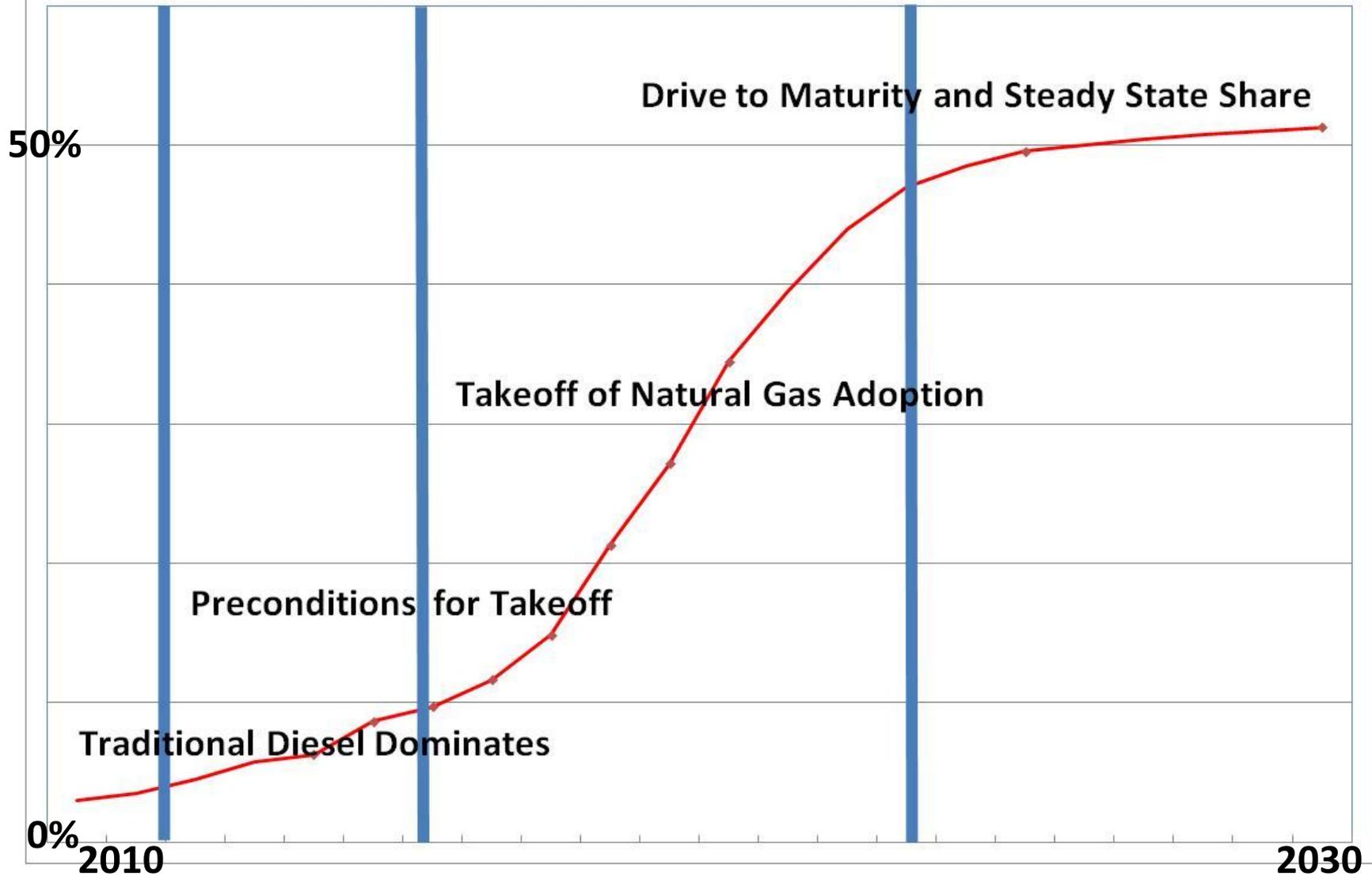
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# Yeah, But NG....

- 9. Cost-effective supply will not be available when pro-environmental (anti-frac'ing) groups successfully shutdown drilling operations**
  
- 10. It's not a safe fuel**
  
- 11. Permitting and Construction are too slow**
  
- 12. And sustainability aren't a concern of my customers**

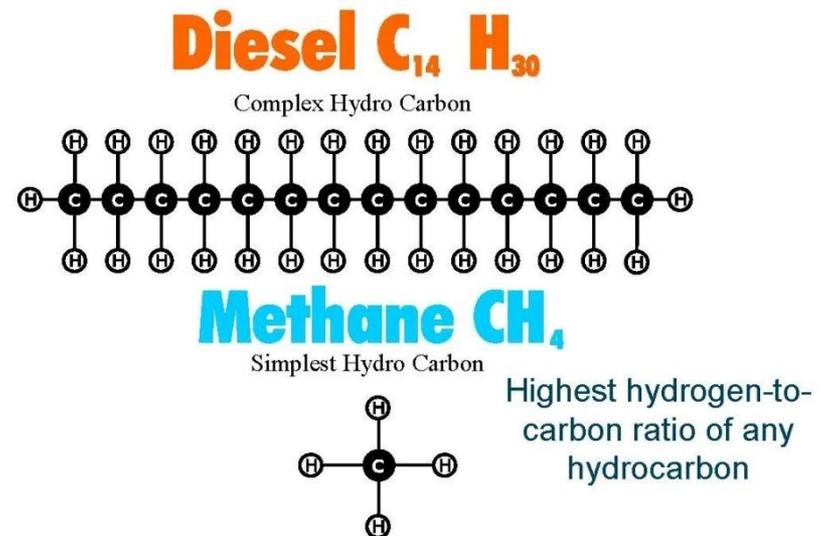
# Stages of U.S. Class 8 Natural Gas Adoption--Baseline Scenario

(Class 8 Truck Retail Sales Plus Transit Buses)



# Natural Gas

- Current penetration: Approximately 3% of annual sales in 2012
- Estimated penetration:
  - 2025 – 2030: 50%



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# **The Conclusion**

**History teaches us that profound changes in the powering of motor vehicles:**

- **Happen, but are hard to predict**
- **Do not occur overnight**
- **Are cost driven**
- **Only deviate within legal constraints**

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# **The Conclusion**

**By 2025-2030, natural gas will  
become**

**the fuel of choice**

**for 50% of Class 8**

**On-Highway Vehicles.**

# Acronyms

- GVW – Gross Vehicle Weight
- LTL – Less-than-truckload
- CSA – Compliance, Safety, Accountability
- EOBR – Electronic on-board recorder
- OBD – On-board diagnostics
- CAFE – Corporate Average Fuel Economy
- GHG – Greenhouse Gas
- MY – Model Year
- CO<sub>2</sub> - Carbon
- EPA – Environmental Protection Agency
- NHTSA – National Highway Traffic Safety Administration
- FMVSS – Federal Motor Vehicle Safety Standards
- BTL – Biomass to liquid
- DME – Dimethyl Ether
- CNG – Compressed Natural Gas
- LNG – Liquid Natural Gas
- DNG – Diesel Natural Gas
- DEF – Diesel Emissions Fluid
- DPF – Diesel Particulate Filter



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