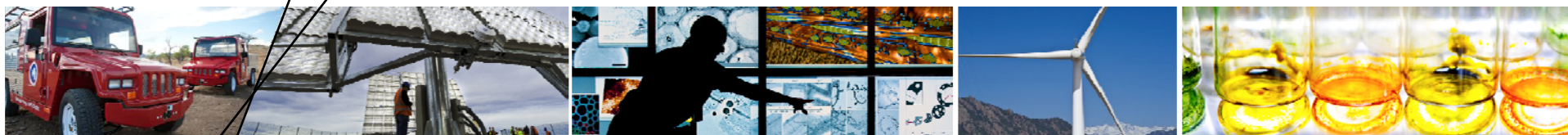


# 2014 Benefits Report for the Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP)



**Energy Commission IEPR Workshop  
Sacramento, California**

**Dr. Marc Melaina  
Senior Engineer, NREL**

**June 12, 2014**

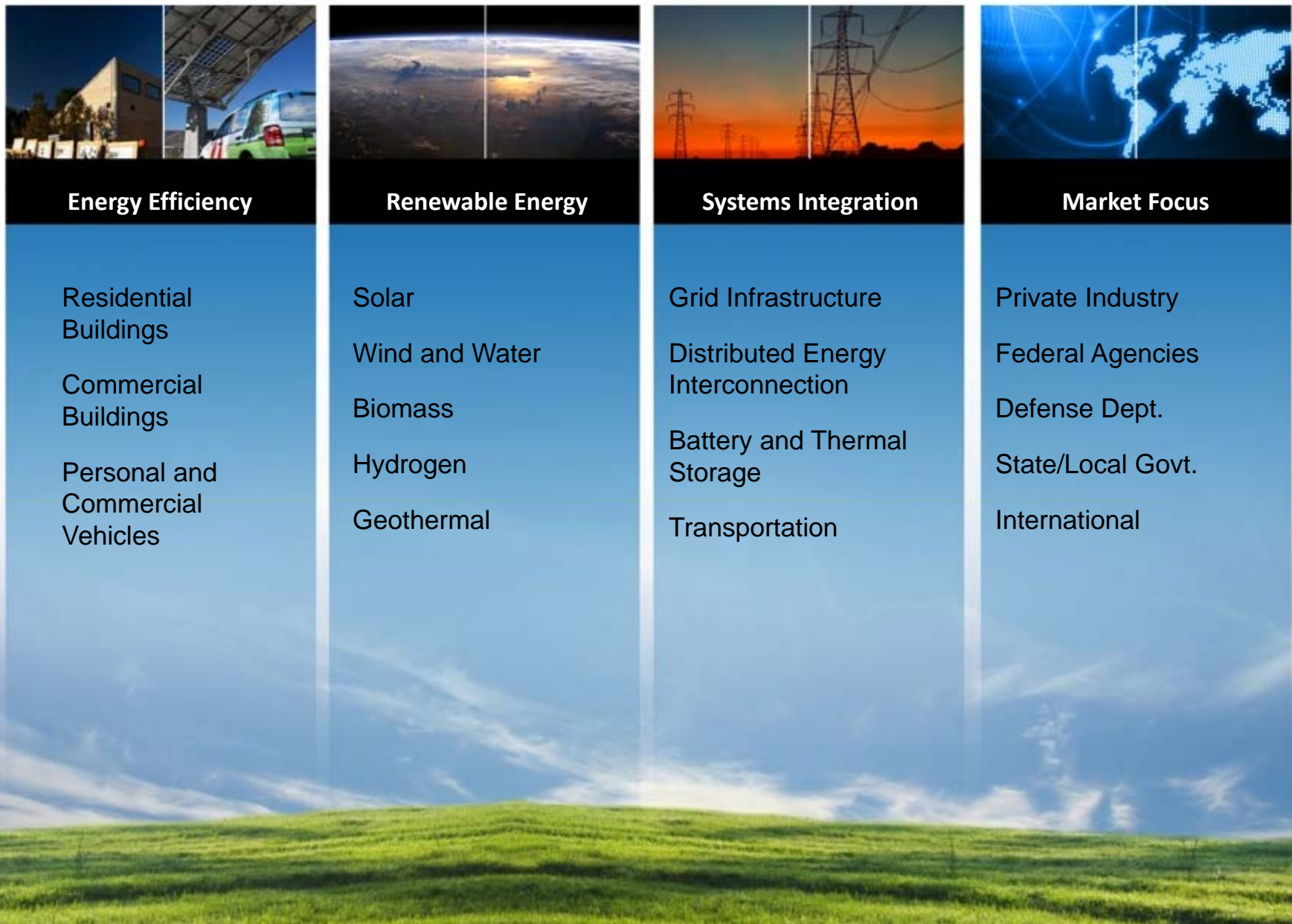
# National Renewable Energy Laboratory

## Only National Laboratory Dedicated Solely to Energy Efficiency and Renewable Energy

- Leading clean-energy innovation for 34 years
- 1,740 employees with world-class facilities
- Campus is a living model of sustainable energy
- Owned by the Department of Energy
- Operated by the Alliance for Sustainable Energy



# Scope of NREL's Mission



# Presentation Overview

- Introduction
- Summary of Benefits Results
  - Expected Benefits
  - Market Transformation Benefits
  - Required Carbon Market Growth Benefits
- Recommendations for Next Steps

# Introduction

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- **This draft report builds on previous Benefit analyses conducted by the Energy Commission (see the Dec 2011 report\*)**
- **Three quantities are estimates:**
  - Greenhouse gas emission reductions (metric tonnes CO<sub>2</sub>e per year)
  - Petroleum fuel use reductions (millions of gallons per year)
  - Criteria emissions
- **These are estimated for 207 projects (awards) representing a total investment of \$426.1 million since 2009**
  - This is a subset of the 274 total projects funded at \$487.8 million as of March 31, 2014



\* McKinney, J., C. Smith, A. Freeman, P. Magana, D. Chapman (2011). Benefits Report for the Alternative and Renewable Fuel and Vehicle Technology Program, Report No. CEC-600-2011-SD, December

# An important conceptual distinction is made between four different types of benefits

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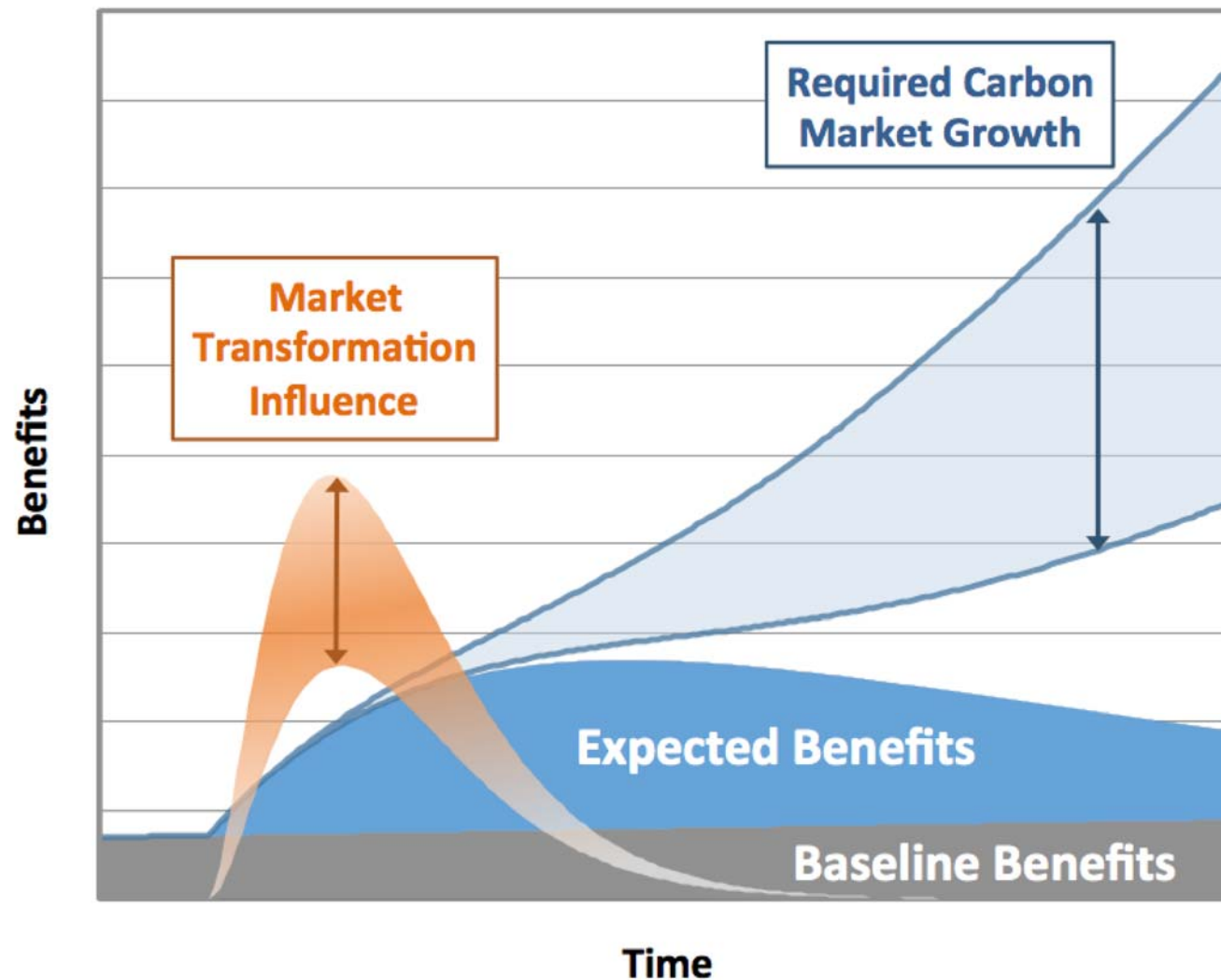
- **Baseline Benefits:** expected to accrue without support from ARFVTP.
- **Expected Benefits:** directly associated with vehicles and fuels deployed through projects receiving ARFVTP funds. Project categories include vehicles, refueling infrastructure, and fuel production.
- **Market Transformation Benefits:** accrue due to the influence of ARFVTP projects on future market conditions to accelerate the adoption of new technologies.
- **Required Carbon Market Growth Benefits:** associated with projections of future market growth trends comparable to those needed to achieve deep reductions in GHGs by 2050.

**Analysis Focuses on Expected and Market Transformation Benefits**



# Each of the four benefit types has a different contribution to understanding ARFVTP benefits

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# **Expected Benefits Methods and Results**



# Expected Benefits Assume Successful Project Completion

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- **Expected benefit calculations use inputs based upon successful completion of each project funded by ARFVTP**
  - Full utilization of vehicles or fuel production facilities funded
  - One-to-one replacement of incumbent technologies
  - *If it is funded, it is deployed and achieves all benefits expected based upon original proposal and any additional information on progress or updates*
- **GHG and Petroleum Fuel Reduction calculations are relatively straightforward. Example metrics include:**
  - Vehicle miles traveled per year (VMT)
  - Average fuel economy (miles per gallon gasoline/diesel equivalent)
  - Fuel production capacity and average utilization rate (gallons per year)
  - Fuel carbon intensity (gCO<sub>2</sub>e per MJ fuel – based on LCFS lookup tables)

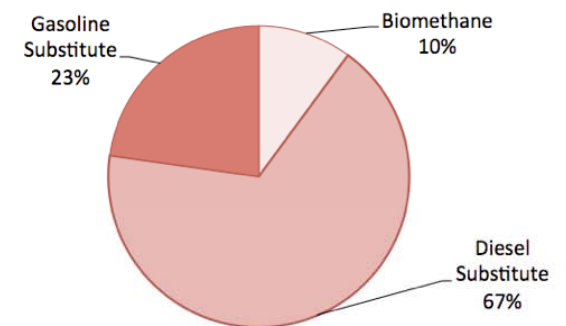
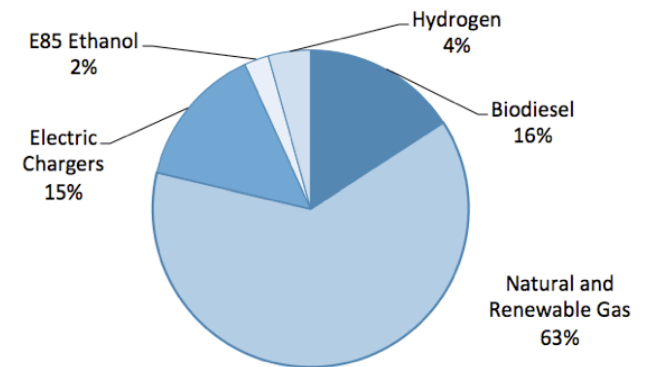
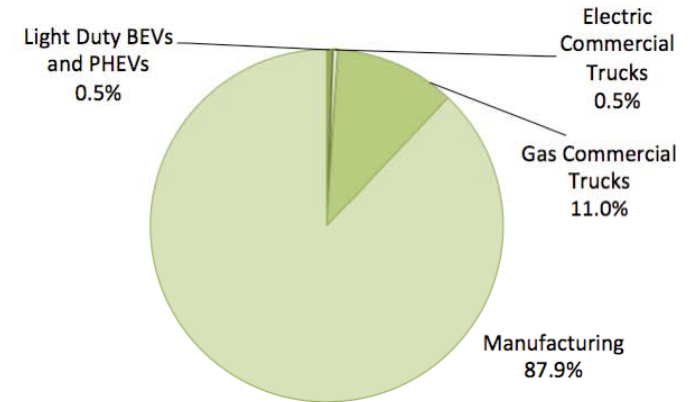
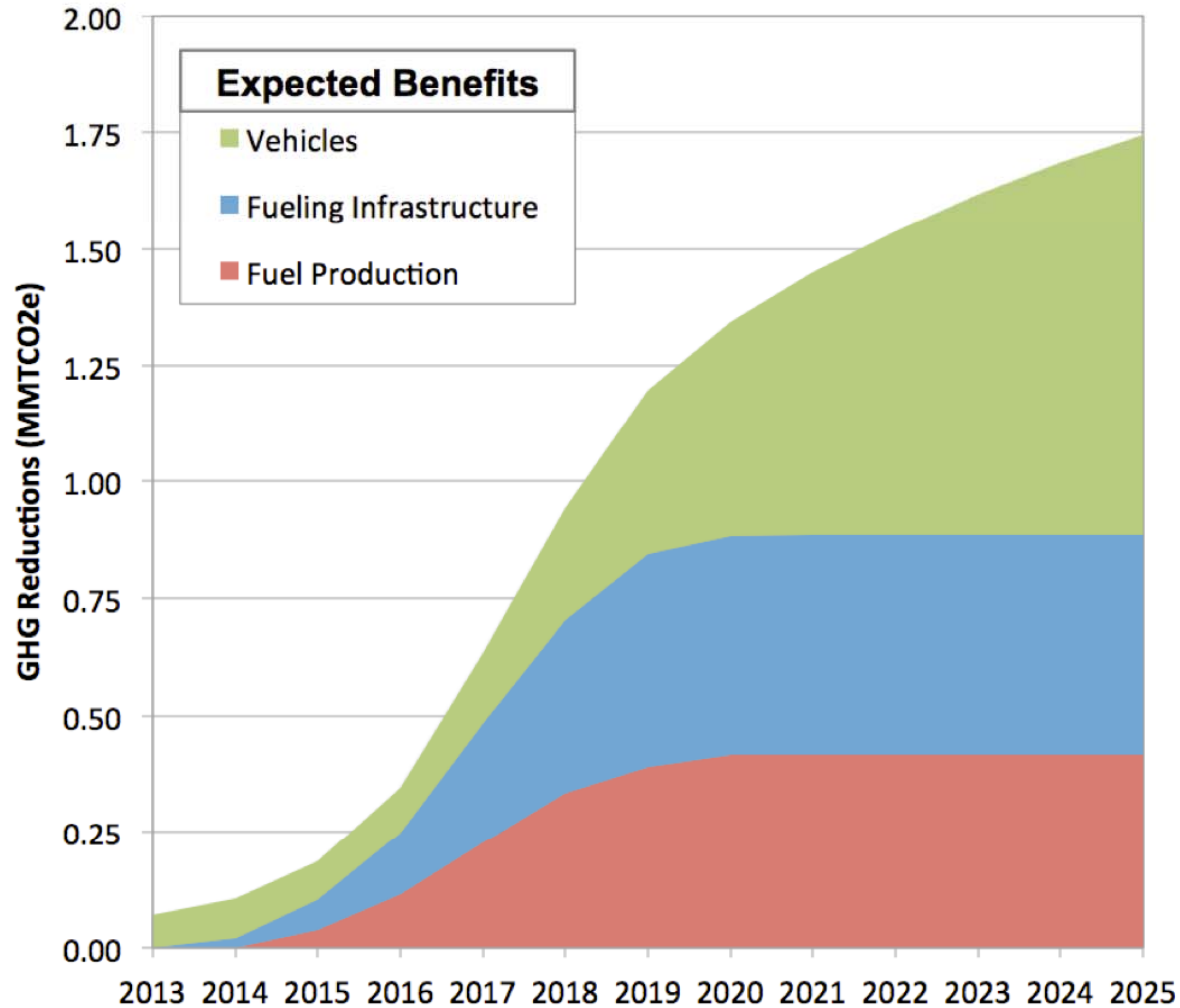
# Project Categories and Benefit Types Estimated (1 of 2)

Project Categories	Fuel Class or Sub Class	Awards to 3/14		Projects Evaluated in Benefits Analysis			Benefit Type Estimated	
		(\$M)	No. Awards	(\$M)	No. Awards	Number Units	Expected	Market Transformation
Fuel Delivery Infrastructure								
						20 Level 1 119 DCFC		
Hydrogen Fueling Infrastructure	Hydrogen	\$82.8	15	\$81.8	14	48 Stations	✓	✓
Natural Gas Fueling Infrastructure	Natural Gas	\$17.2	47	\$17.2	47	51 Stations	✓	-
E85 Fueling Stations	Gasoline Substitute	\$16.5	4	\$16.5	4	100 Stations	✓	-
Upstream Infrastructure	Diesel Substitute	\$4.0	4	\$4.0	4	Expansions	✓	-
Hydrogen Fuel Standards Development	Hydrogen	\$4.0	1	-	-	-	-	-
Fuel Delivery Infrastructure Subtotal		\$163.0	134	\$158.0	132			
Vehicles								
Light-Duty Incentives, CVRP	Electric Drive					Rebates	✓	✓
Medium- Heavy-Duty Incentives, HVIP	Electric Drive	\$4.0	1	\$4.0	1	160 vehicles	✓	-
Natural Gas Vehicle Deployment Incentives	Natural Gas	\$33.4	4	\$33.4	4	1038 vehicles	✓	-
LPG Vehicle Deployment Incentives	Propane	\$7.3	2	\$2.3	2	515 vehicles	✓	-
Light-Duty Demonstration	Electric Drive	\$0.6	1	\$0.6	1	50 LDVs	✓	-
Medium- and Heavy-Duty Vehicle Demonstration	Electric Drive	\$33.9	10	\$33.9	10	Various <sup>1</sup>	-	✓
Fuel Cell Bus Demonstration	Hydrogen	\$2.4	1	\$2.4	1	1 bus	-	✓
Medium- and Heavy-Duty Vehicle Demonstration	Natural Gas	\$6.3	2	\$6.3	2	2 natural gas engine demos	-	✓
Medium- and Heavy-Duty Vehicle Demonstration	Gasoline Substitute	\$2.7	1	\$2.7	1	1 hybrid E85 powertrain	-	✓
Component Demonstration	Hydrogen	\$1.6	2	\$1.6	2	6 vans, 1 bus	-	✓
Component Demonstration	Electric Drive	\$27.8	13	\$27.8	13	Various <sup>2</sup>	-	✓
Vehicle Manufacturing	Electric Drive	\$28.1	6	\$28.1	6	Various <sup>3</sup>	✓	✓
Vehicles Subtotal		\$192.1	46	\$187.1	46			

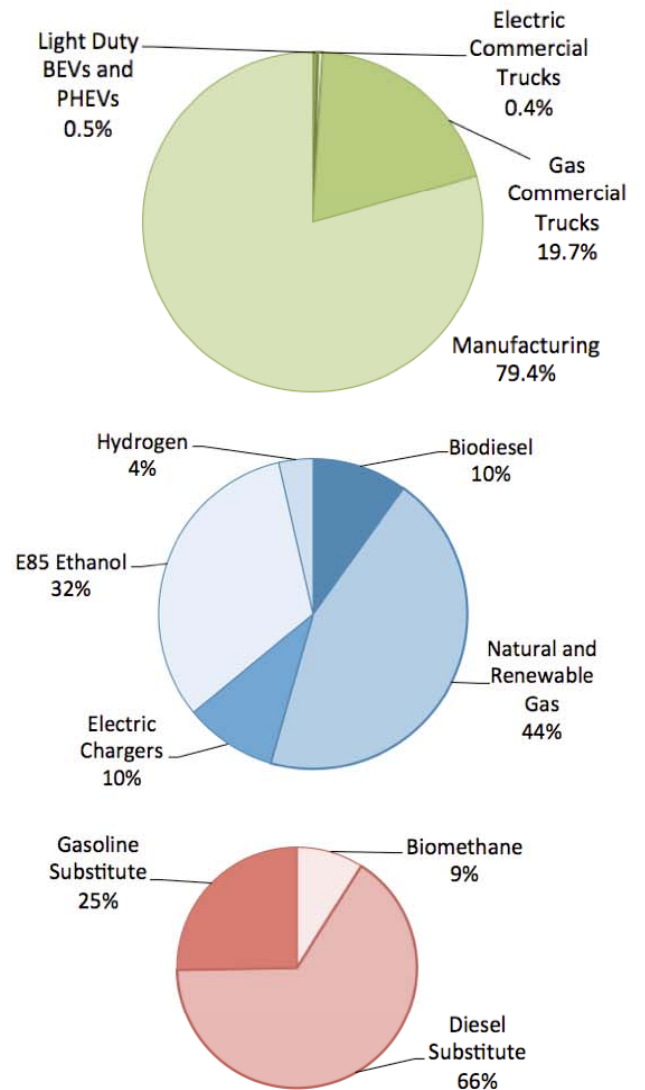
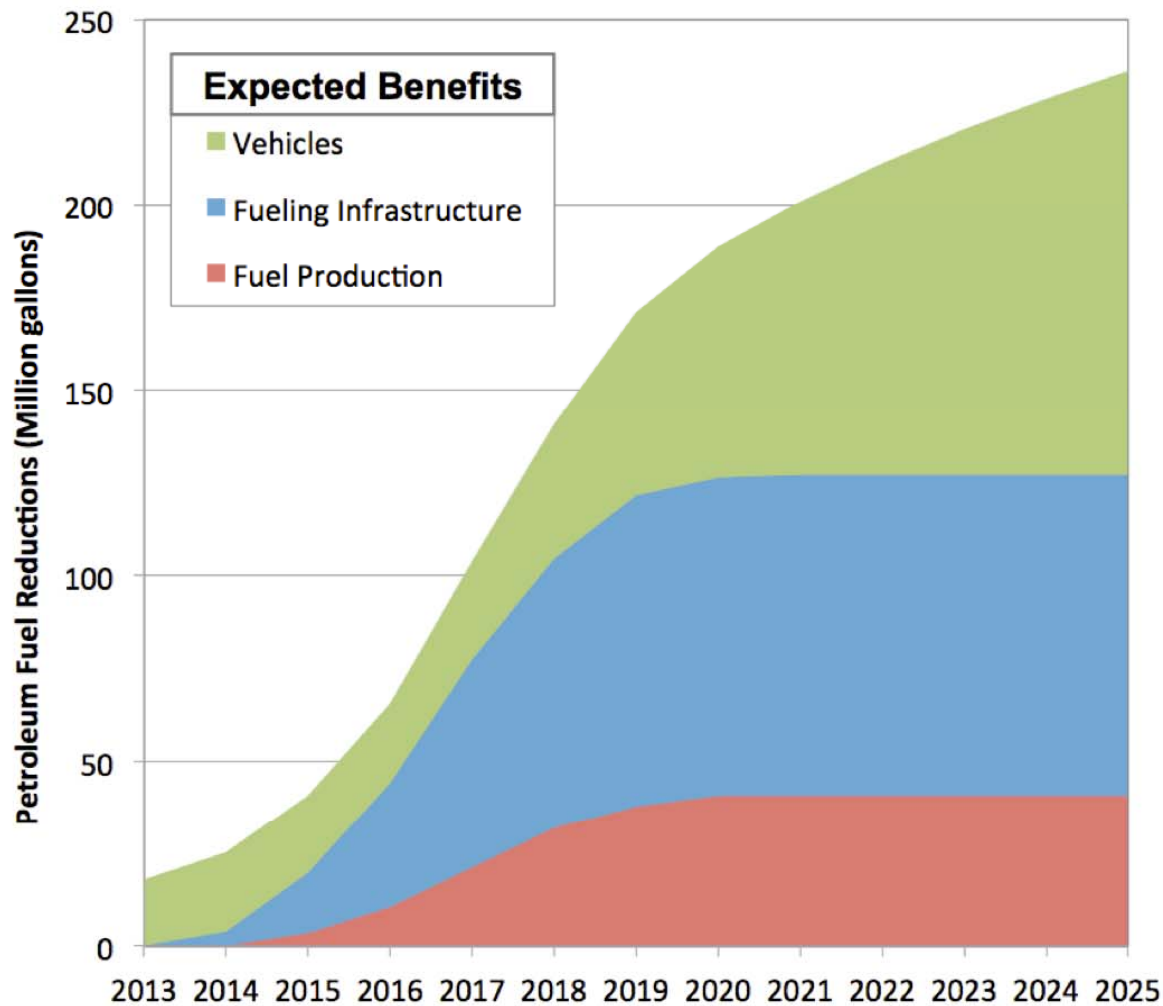
# Project Categories and Benefit Types Estimated (2 of 2)

Project Categories	Fuel Class or Sub Class	Awards to 3/14		Projects Evaluated in Benefits Analysis			Benefit Type Estimated	
		(\$M)	No. Awards	(\$M)	No. Awards	Number Units	Expected	Market Transformation
Fuel Production								
Bench Scale & Feasibility	Biodiesel	\$5.0	1	-	-	-	-	-
Commercial Production	Biomethane	\$34.5	9	\$34.5	9	-	✓	✓
Bench Scale & Feasibility	Biomethane	\$4.4	3	\$4.4	3	-	✓	✓
Commercial Production	Diesel Substitutes		9	\$26.4	9	-	✓	✓
Bench Scale & Feasibility	Diesel Substitutes	\$2.7	3	\$2.7	3	-	✓	✓
Commercial Production	Gasoline Substitute	\$10.9	3	\$10.9	3	-	✓	✓
Bench Scale & Feasibility	Gasoline Substitute	\$2.1	2	\$2.1	2	-	✓	✓
Fuel Production Subtotal		\$86.0	30	\$81.0	29			
Other								
PEV Regional Readiness	Electric Drive	\$3.7	16	-	-	-	-	-
Regional Readiness	Hydrogen	\$0.3	1	-	-	-	-	-
Sustainability Research	Biofuels	\$2.1	2				-	-
Workforce Training and Development	Workforce Training/Dev.	\$23.3	30	-	-	-	-	-
Technical Assistance and Analysis	Program Support	\$17.3	15	-	-	-	-	-
Other Subtotal		\$46.7	64	-	-			
TOTAL		\$487.8	274	\$426.1	207			

# Expected Benefits: GHG Reductions



# Expected Benefits: Petroleum Fuel Reductions



# Summary of GHG and Petroleum Fuel Use Reduction Results

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Benefit Category	GHG Reductions (Thousand Metric Tonnes CO <sub>2</sub> e)			Petroleum Fuel Reductions (million gallons)		
	2015	2020	2025	2015	2020	2025
<b>Expected Benefits</b>						
Fueling Infrastructure	63.6	464.9	469.6	16.4	85.4	86.0
Vehicles	84.1	461.6	859.4	20.7	62.4	109.1
Fuel Production	39.1	416.7	416.7	3.5	41.0	41.0
TOTAL	186.8	1,343.1	1,745.7	40.7	188.8	236.1
<b>Market Transformation Benefits</b>						
High	467.6	1,864	2,502.0	68.0	247.4	330.1
Low	338.8	628.9	1,063.4	22.3	55.1	102.5
<b>Required Carbon Market Growth</b>						
High	-	6,397	15,189	-	665.4	1,959
Low	-	2,333	6,375	-	237.2	957.3

Source: NREL

# **Market Transformation Methods and Results**



# Market Transformation Benefits are based upon three general influences

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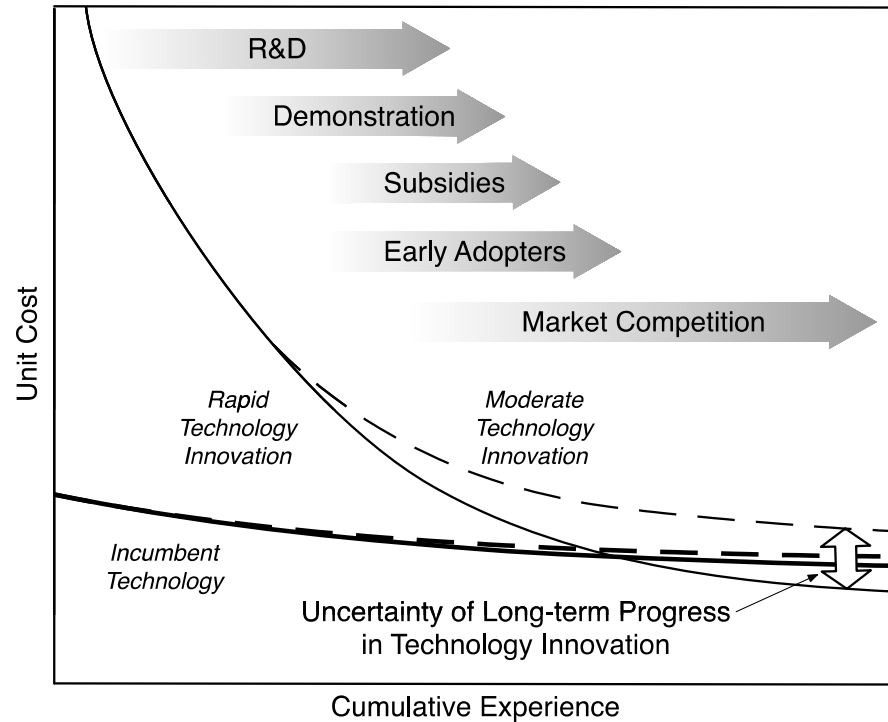
- **Vehicle price reductions.**
  - Reduction in the perceived price of PEVs due to increased availability of public EVSE stations.
  - Reduction in the perceived price of FCEVs due to increased availability of hydrogen stations.
  - Reduction in the price of PEVs due to Clean Vehicle Rebate Program (CVRP) rebates.
- **Vehicle cost reductions.**
  - Reductions due to direct investments in production.
  - Reductions due to increased experience or learning-by-doing associated with deploying additional units.
- **Next-generation technologies.**
  - Additional biofuel production facilities or advanced trucks deployed as a result of ARFVTP support for the current generation of the same (or similar) technology.

**Consumer  
Response to  
“Perceived”  
Value of Vehicle**

**Vehicle  
Production  
Improves with  
Volume**

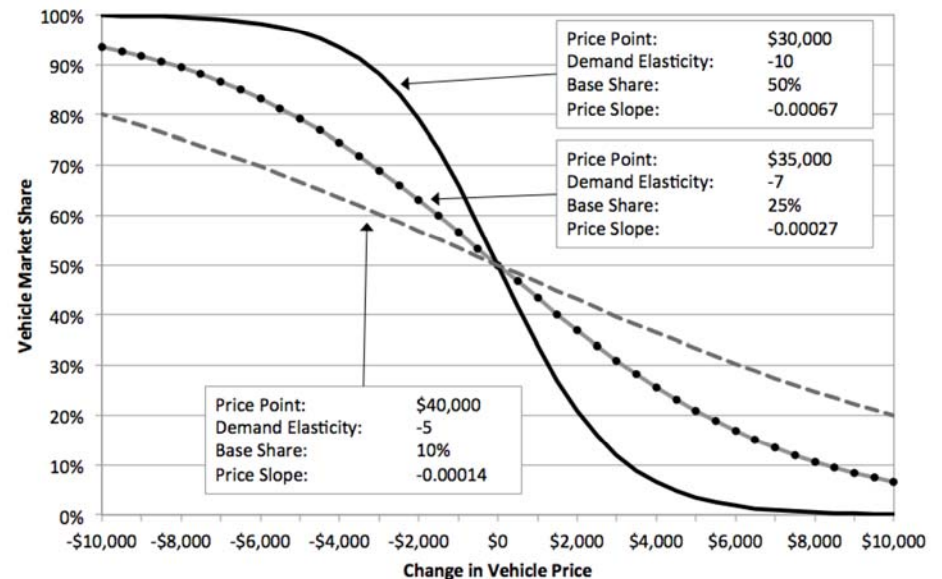
**Technology is  
Replicated**

# Increased deployment estimates based upon learning functions and consumer price elasticity function



Production costs decline with increase experience (or cumulative production)

Influence of a vehicle price change on market share depends upon consumer sensitivity to price, price point, and size of price difference



# Market Transformation Categories

Fuel or Technology Category	Market Transformation Benefits Estimation Methodology		
	Vehicle Price Reduction	Vehicle Cost Reduction	Next Generation
<b>Fueling Infrastructure</b>			
Electric Chargers	X	-	-
Hydrogen Stations	X	-	-
<b>Vehicle</b>			
Light-Duty PEVs (CVRP)	X	-	-
MD-HD ZEV Truck Demonstrations	-	X	-
Electric-Drive components	-	X	-
EV Manufacturing	-	X	-
Electric Commercial Trucks	-	-	X
<b>Fuel Production</b>			
Demonstration Biogas	-	-	X
Demonstration Biodiesel and Renewable Diesel	-	-	X
Demonstration Ethanol	-	-	X

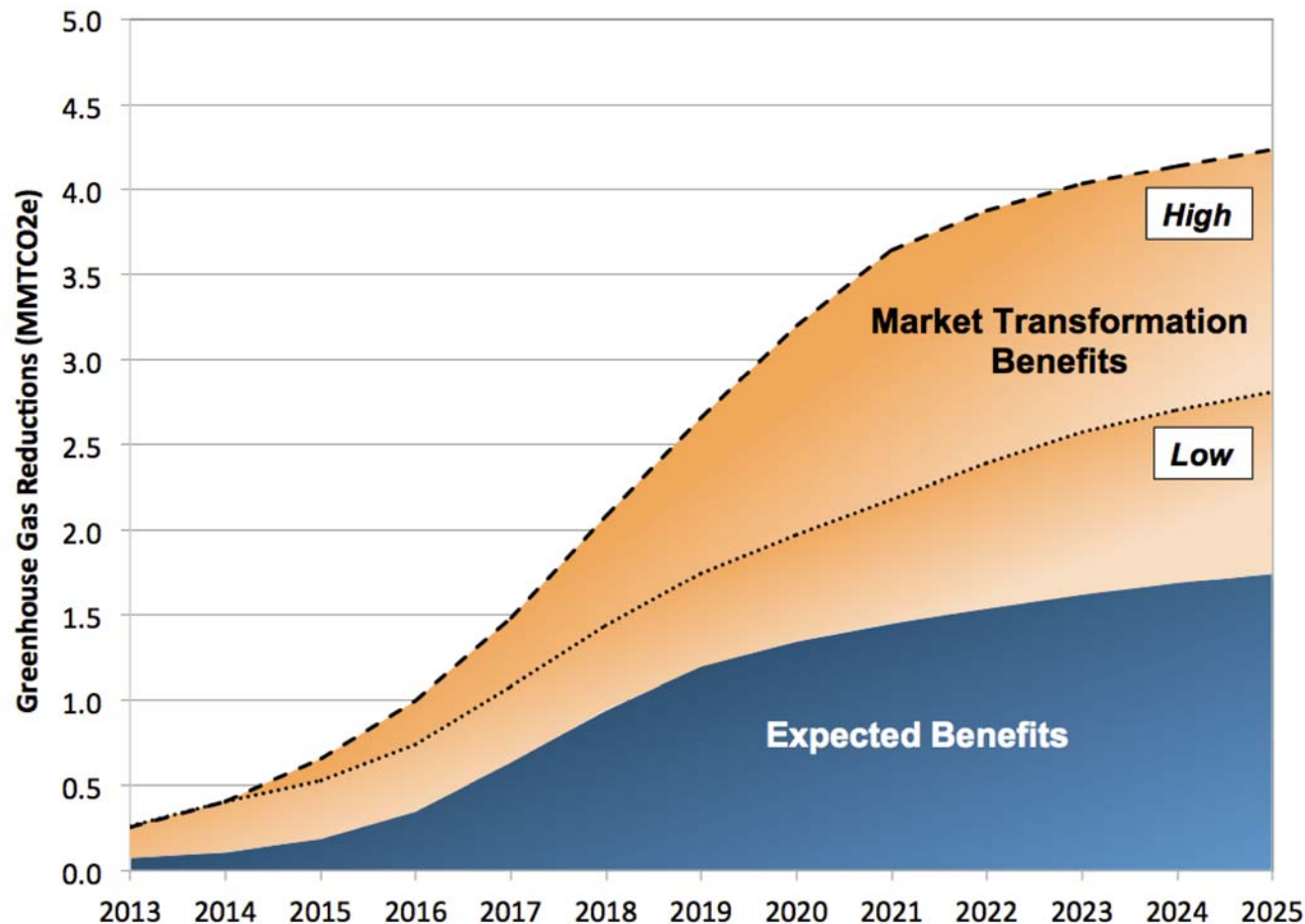
# Summary of Market Transformation Benefits

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Market Transformation Influence	Case	GHG Reductions (thousand tonnes CO <sub>2</sub> e)			Petroleum Reductions (million GGE/DGE)		
		2015	2020	2025	2015	2020	2025
Vehicle Price Reductions	High	309.8	563.8	720.4	36.9	70.1	104.6
	Low	304.4	457.5	574.2	18.5	31.2	45.9
ZEV Industry Experience	High	34.2	145.7	245.5	4.5	19.3	36.9
	Low	28.6	122.0	205.6	3.8	16.2	30.9
Next Generation Trucks	High	123.6	494.5	494.5	26.6	106.6	106.6
	Low	5.79	23.1	23.1	-	5.2	5.2
Next Generation Fuels	High	-	659.7	1,041.6	-	51.4	81.9
	Low	-	26.3	260.4	-	2.6	20.5
<b>Total</b>	<b>High</b>	<b>467.6</b>	<b>1,863.6</b>	<b>2,502.0</b>	<b>68.0</b>	<b>247.4</b>	<b>330.1</b>
	<b>Low</b>	<b>338.8</b>	<b>628.9</b>	<b>1,063.4</b>	<b>22.3</b>	<b>55.1</b>	<b>102.5</b>

Source: NREL

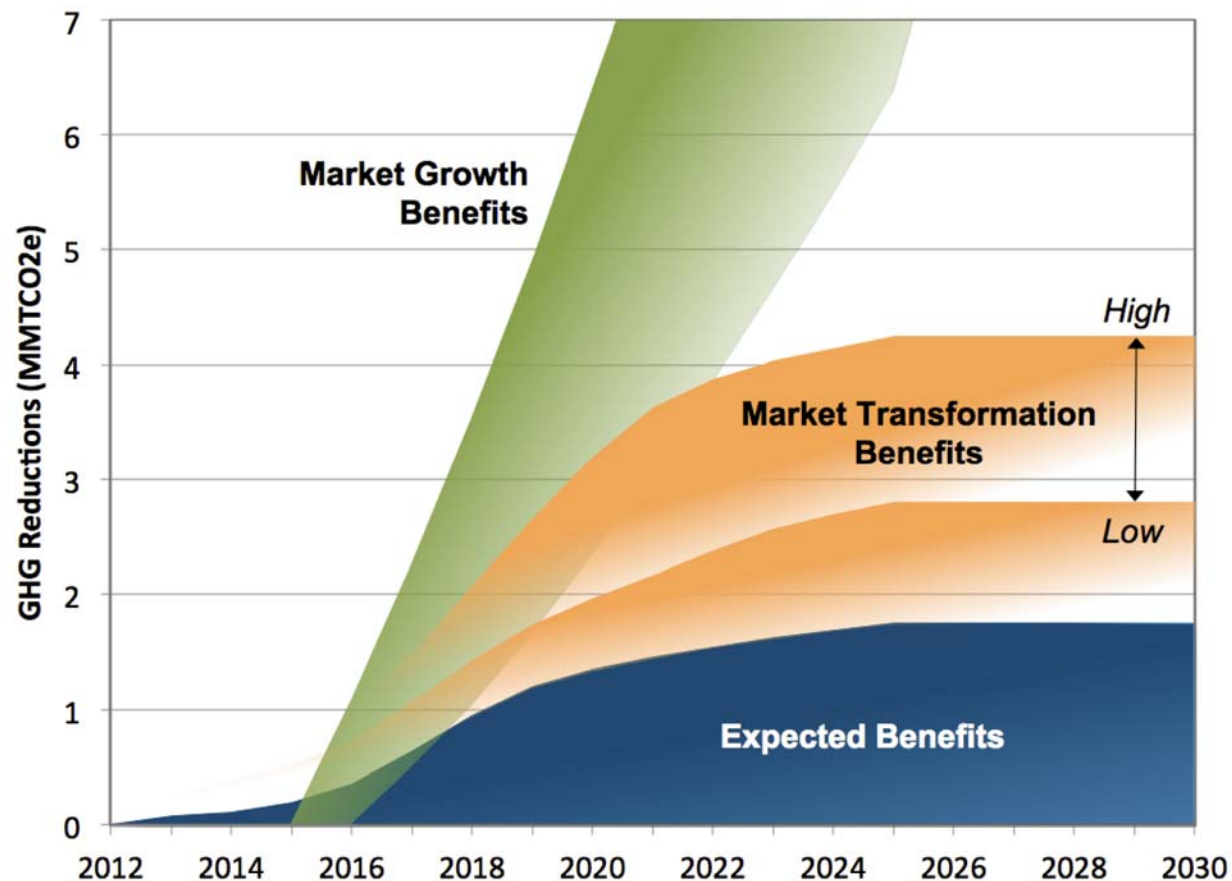
# Comparison of Market Transformation Benefits to Expected Benefits (GHGs)



**If summed with Expected Benefit results, Market Transformation GHG Reductions would roughly double total ARFVTP reductions**

# Summary of GHG Reduction Results

ARFVTP projects have the potential to make significant contributions toward meeting California's GHG reduction goals



*These comparisons reinforce the importance of continued progress to ensure that the influence of ARFVTP projects translate into favorable market conditions for low-carbon transportation technologies.*

# Required Market Growth Carbon Benefits place other results into an important temporal context

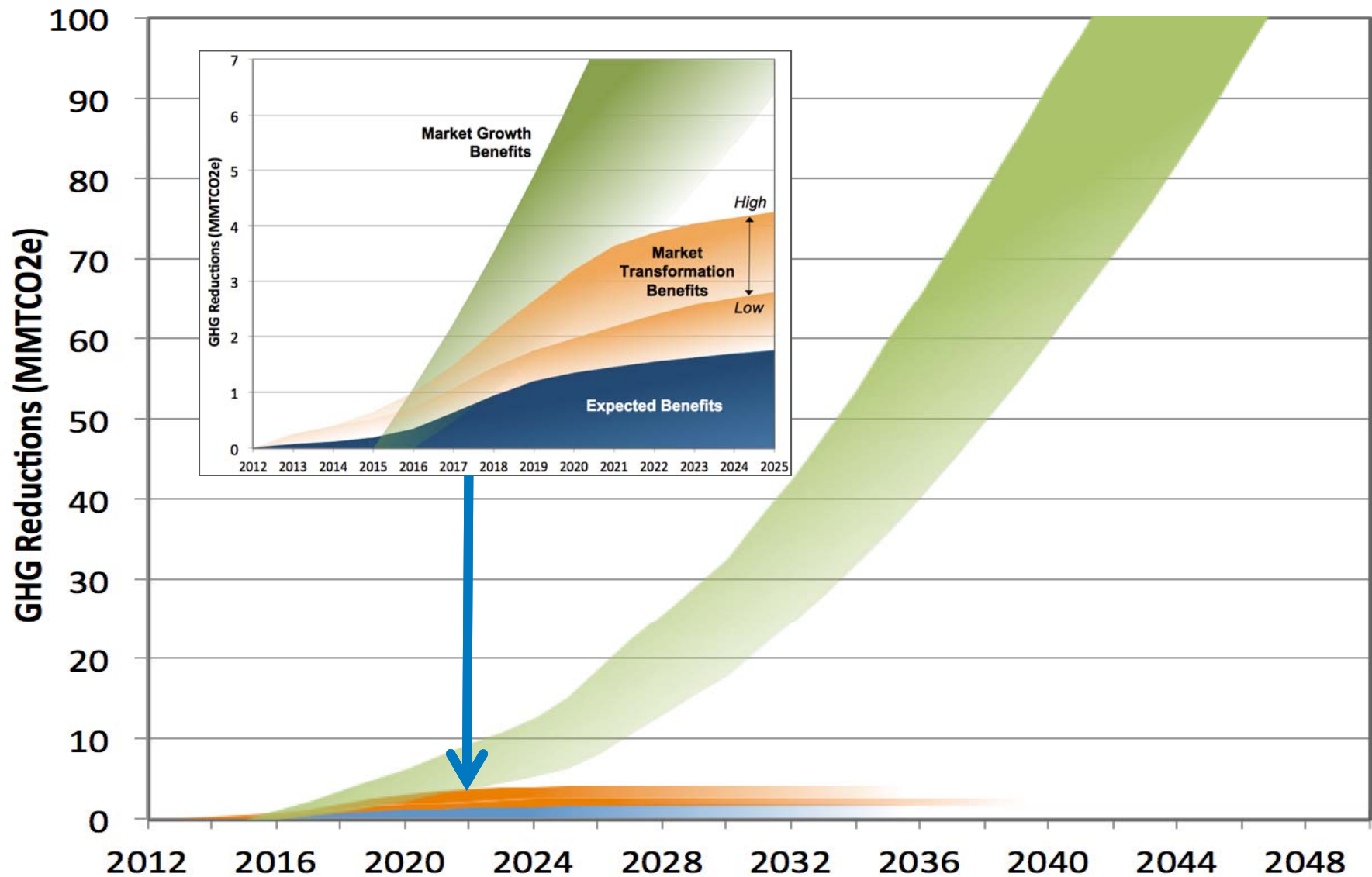
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- **Market Growth Benefits:** These suggest the benefits that would need to be achieved over time to be on track to meet the 2050 GHG reduction goal for California
  - The rate at which these benefits must be accrued is uncertain, so the benefits are indicated as a high and low range
  - Overall, the total carbon emissions that must be reduced to meet the 2050 goal swamps that reductions achieved through ARFVTP to date
  - Moreover, it is not anticipated that government programs alone would be capable of funding the entire transition to this 2050 goal
    - At some point market forces must take on the majority of the heavy lifting

**Market Growth GHG Benefits Indicate the Trajectory of Emission Reductions that California must Approach to meet the 2050 Goal**



# ARFVTP Benefits to date represent significant progress, but much more work remains for GHG goals



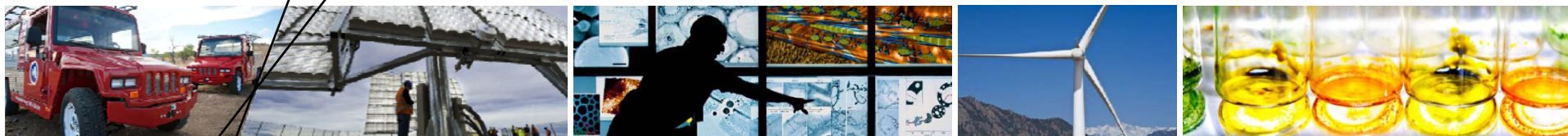
# Recommendations to improve benefits estimation methods

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- **Collect and integrate data on technology-specific deployment effectiveness metrics.**
- **Project evaluation metrics as they might be realized under market success conditions.**
- **Explicitly model competitive dynamics between advanced and incumbent technologies.**
- **Integrate value of station availability into vehicle choice modeling.**

# Questions?

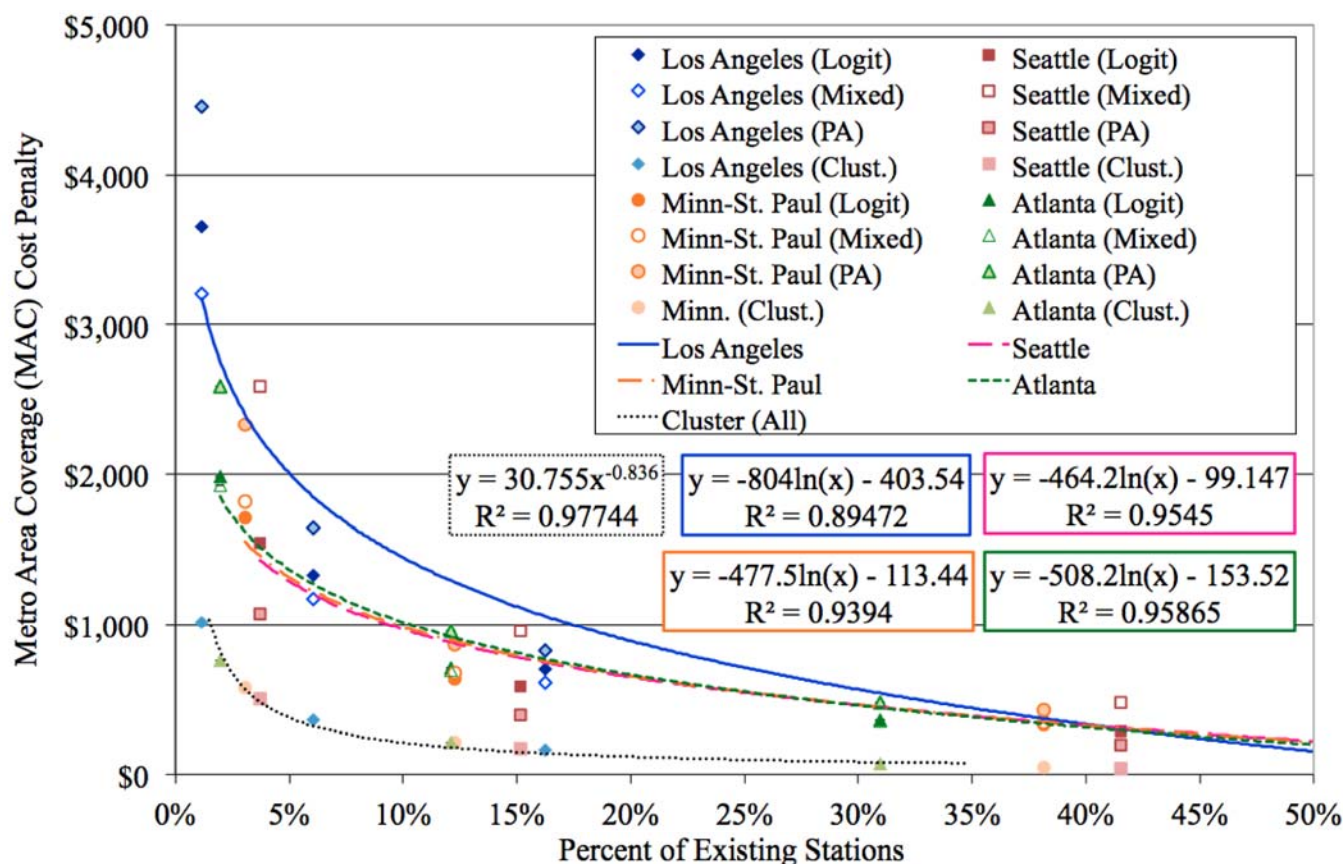




## Backup Slides

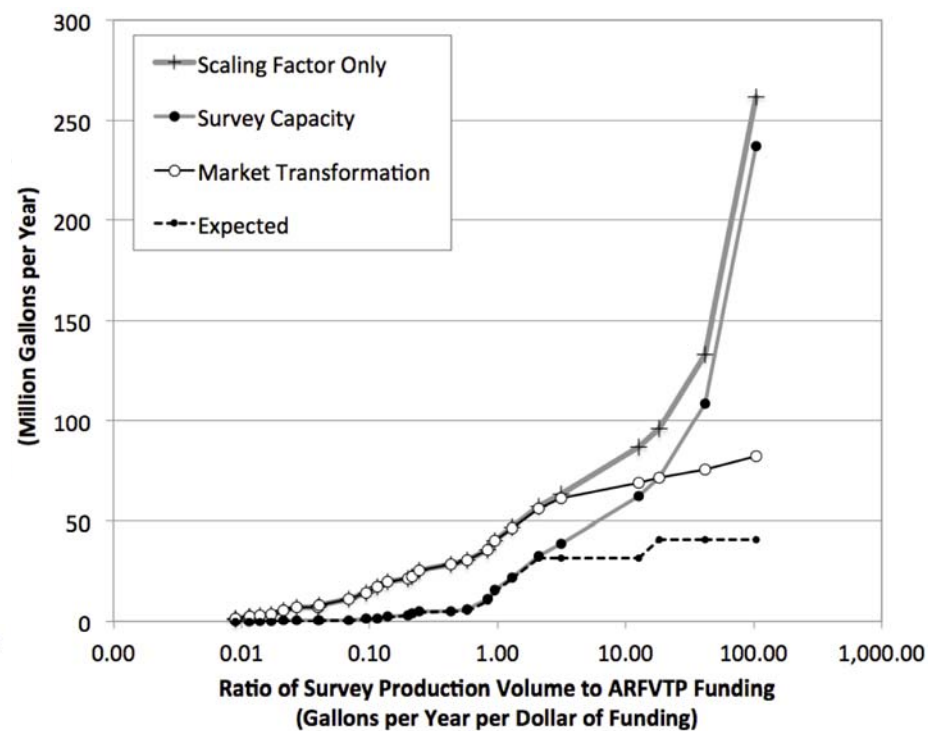
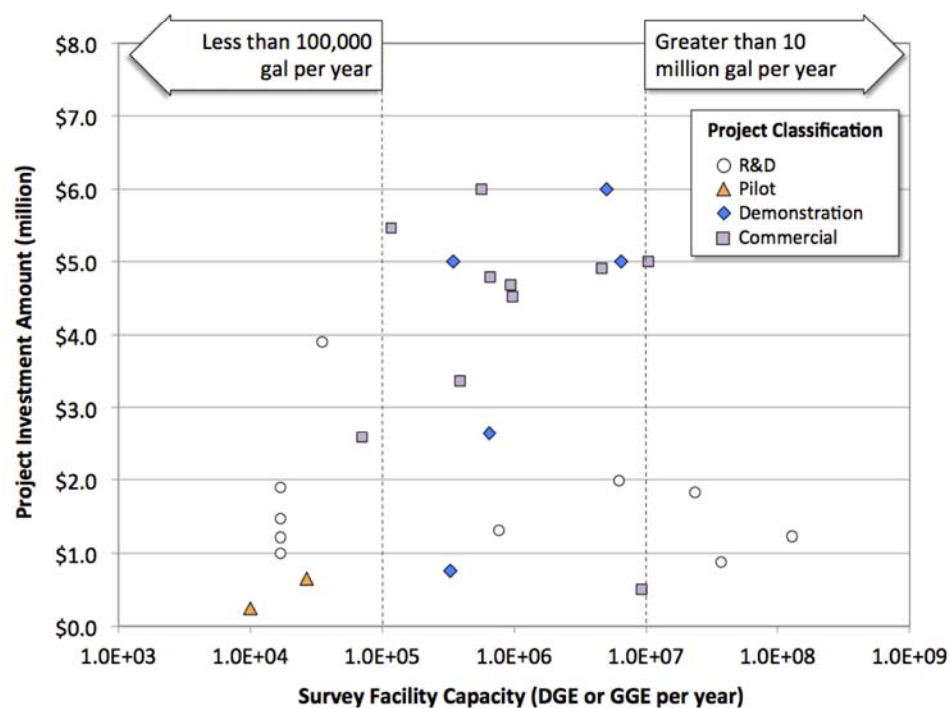
# HRS Availability Penalties

Cost Penalty Estimates Against the Purchase Price of a New Dedicated AFV for Limited Urban Area Station Availability for Both Survey Results and Cluster Simulations





# Fuel Production Original Values and Adjusted Values



# Fuel Production Adjustments by Project

Awardee	Fuel Product	Normalized Output (DGE or GGE)	Expected (1=yes)	Expected Output (DGE or GGE)	Scaling Adj.	VtF Adj.	Combined Adj.	Market Transformation Output (DGE/GGE)
New Leaf Biofuels	Biodiesel	9,307,123	1	9,307,123	1.00	24.9%	0.25	2,316,869
Eslinger Biodiesel, Inc.	Biodiesel	5,000,000	1	5,000,000	1.00	99.8%	1.00	4,990,302
Crimson Renewable Energy LP	Biodiesel	6,514,986	1	6,514,986	1.00	98.2%	0.98	6,394,959
American Biodiesel, Inc.	Biodiesel	4,653,562	1	4,653,562	1.00	99.6%	1.00	4,634,253
Springboard Biodiesel	Biodiesel	325,613	1	325,613	9.35	100.0%	9.35	3,042,857
Biodico	Biodiesel	37,228,494	0	0	1.00	11.7%	0.12	4,340,681
East Bay Municipal Utility District	Biodiesel	16,959	0	0	31.32	100.0%	31.32	531,192
City of San Jose	Gas	16,959	0	0	31.32	100.0%	31.32	531,192
Clean World Partners, LLC	Gas	767,225	0	0	2.97	100.0%	2.97	2,278,907
Environ Strategy Consultants, Inc.	Gas	16,959	0	0	31.32	100.0%	31.32	531,192
G4 Insights, Inc.	Gas	128,454,652	0	0	1.00	4.9%	0.05	6,244,304
Harvest Power California LLC	Gas	660,000	1	660,000	4.09	100.0%	4.09	2,699,624
Blue Line Transfer, Inc.	Gas	69,996	1	69,996	20.78	100.0%	20.78	1,454,400
CR&R Incorporated	Gas	973,141	1	973,141	1.20	100.0%	1.20	1,170,192
Pixley Biogas LLC	Gas	934,216	1	934,216	1.51	100.0%	1.51	1,407,020
Northstate Rendering Co Inc.	Gas	116,777	1	116,777	16.97	100.0%	16.97	1,981,899
Sacramento Municipal Utility District	Gas	23,355,391	0	0	1.00	33.5%	0.33	7,821,662
Clean World Partners	Gas	566,027	1	566,027	5.23	100.0%	5.23	2,961,851
Biostar Systems, LLC	NG	390,969	1	390,969	7.98	100.0%	7.98	3,121,742
Mendota Bioenergy, LLC (MBLLC)	Ethanol	<b>10,430,257</b>	<b>1</b>	<b>10,430,257</b>	<b>1.00</b>	<b>91.7%</b>	<b>0.92</b>	<b>9,568,968</b>
EdeniQ	Ethanol	<b>34,768</b>	<b>0</b>	<b>0</b>	<b>25.98</b>	<b>100.0%</b>	<b>25.98</b>	<b>903,352</b>
Great Valley Energy, LLC	Ethanol	<b>6,258,154</b>	<b>0</b>	<b>0</b>	<b>1.00</b>	<b>80.9%</b>	<b>0.81</b>	<b>5,061,175</b>
Mendota Advanced Bioenergy Beent	Ethanol	<b>16,959</b>	<b>0</b>	<b>0</b>	<b>31.32</b>	<b>100.0%</b>	<b>31.32</b>	<b>531,192</b>
SacPort Biofuels Corporation	FT Diesel	344,165	1	344,165	8.93	100.0%	8.93	3,074,407
Buster Biofuels LLC	Biodiesel	651,499	1	651,499	4.19	100.0%	4.19	2,727,669
Solazyme, Inc.	RD	16,959	0	0	31.32	100.0%	31.32	531,192
Cal Poly State Univ., San Luis Obispo	RD	10,000	1	10,000	35.25	100.0%	35.25	352,503
Agricultural Waste Solutions, Inc.	RD	26,611	1	26,611	27.97	100.0%	27.97	744,329
<b>SUM</b>		<b>237,158,420</b>		<b>40,974,942</b>				<b>81,949,884</b>



# Market Growth Transportation Reduction Trends

- Based upon ARB Visions Study Scenario Trends

