



# Climate Change and Energy: A Workshop for Massachusetts DOT

June 14, 2011



**massDOT**  
Massachusetts Department of Transportation

# Workshop Purpose

- To provide overview information on climate change and energy
- To provide foundation for state DOTs and partner agencies to respond to climate change and energy challenges
- To foster collaborative discussions on possible next steps



# Workshop Overview

- I. Climate Change/Energy - Science, Sources, Trends
- II. Importance of Climate Change/Energy for State DOTs
- III. Strategies to Reduce Transportation GHG Emissions
- IV. Federal Direction – Legislation, Planning, and NEPA Issues
- V. Climate Adaptation for Transportation
- VI. Massachusetts Clean Energy Plan & MassDOT's Climate/Energy Plans and Activities
- VII. Break-out Groups to Brainstorm Future Actions

# I. Climate Change/Energy: Science, Sources, Trends



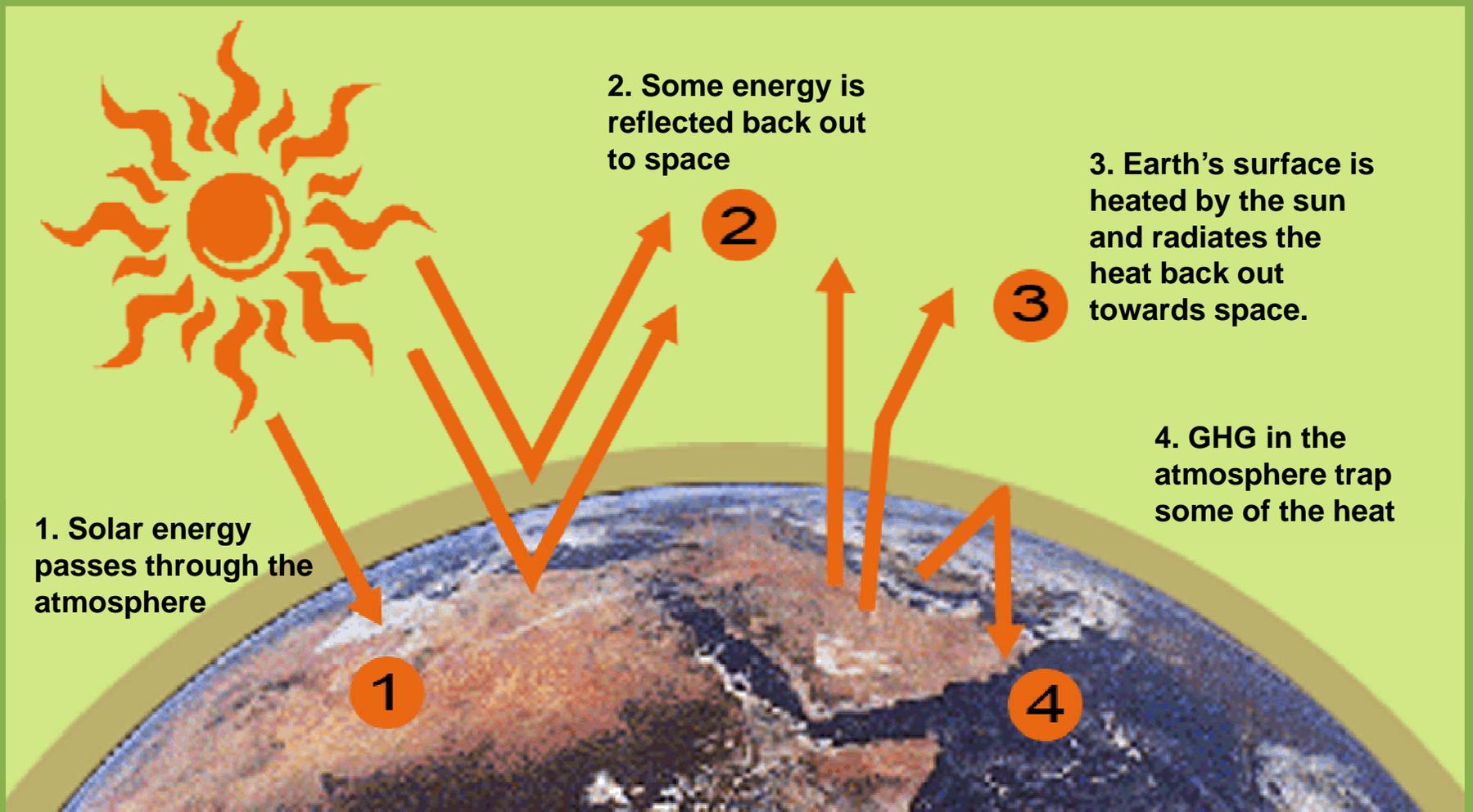
# What is climate change?

The United Nations Framework Convention on Climate Change (UNFCCC) defines Climate Change as:

*“A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.”*



# What is the Greenhouse Effect?



# What is the evidence of climate change?

- 14% increase in human GHG since 1990 – USA
- 26% increase in human GHG since 1990 – world
- GHG levels are at highest in 1000s of years
- 2000-2009 was the warmest decade on record worldwide
- Heat stored in oceans has increased substantially
- Sea surface temperatures have been higher during the past three decades than at any other time since large-scale measurement began in the late 1800s.
- In recent years, a higher percentage of precipitation in the United States has come in the form of intense single-day events.
- 8 of top 10 years for extreme one-day precipitation events occurred since 1990.
- The occurrence of abnormally high annual precipitation totals has increased.
- Intensity of tropical storms in the Atlantic, Caribbean, and Gulf has risen noticeably over the past 20 years.
- 6 of the 10 most active hurricane seasons have occurred since the mid-1990s.

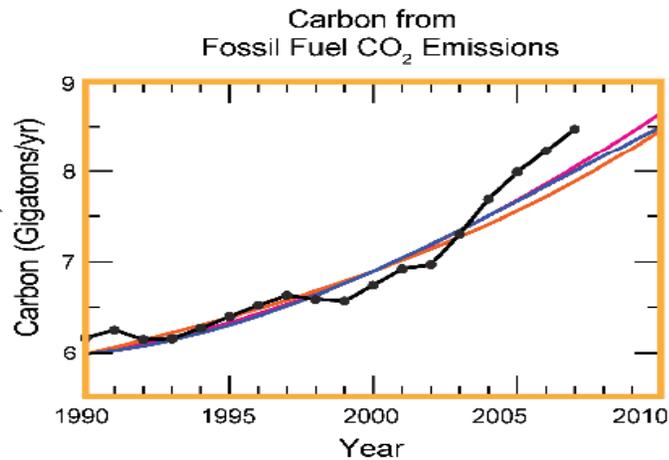
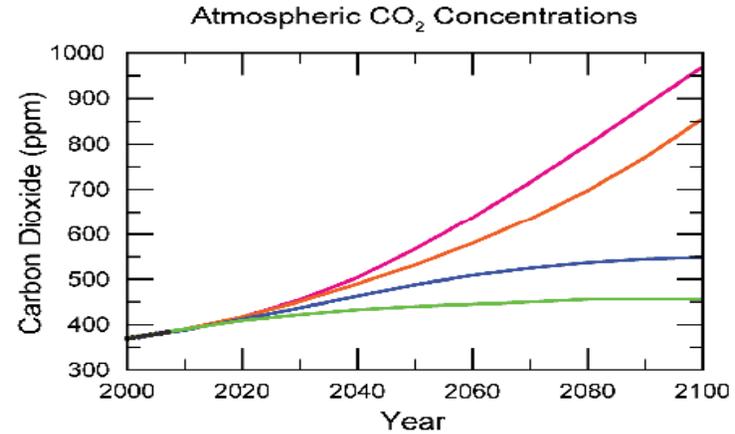
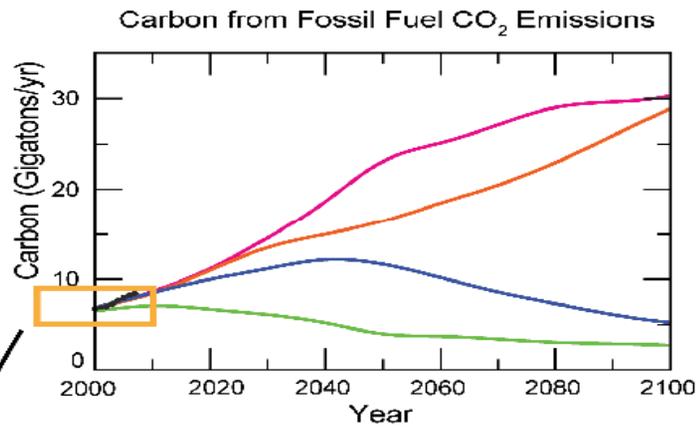
*Source: EPA, Climate Change Indicators in the U.S., May 2010*

# What is the evidence of Climate Change? (continued)

- Sea level worldwide has increased at a rate of roughly 0.6" per decade since 1870.
- Sea level increase has accelerated to more than 1"/decade in recent years.
- Oceans have become more acidic over the past 20 years, and studies suggest that the ocean is substantially more acidic now than it was a few centuries ago. Rising acidity is associated with increased levels of carbon dioxide dissolved in the water, and affects sensitive organisms such as corals.
- **Sept 2007 had least Arctic sea ice of any year on record, followed by 2008 and 2009.**
- **Arctic sea ice in 2009 was 24 percent below the 1979-2000 historical average.**
- Glaciers in U.S. and around the world have generally shrunk since the 1960s and the rate at which glaciers are melting appears to have accelerated over the last decade.
- **Glaciers worldwide have lost more than 2,000 cubic miles of water since 1960.**
- Average length of the growing season in the lower 48 states has increased by about two weeks since beginning of the 20th century.
- **North American bird species have shifted their wintering grounds northward by an average of 35 miles since 1966, with a few species shifting by several hundred miles.**

Source: EPA, *Climate Change Indicators in the U.S.*, May 2010

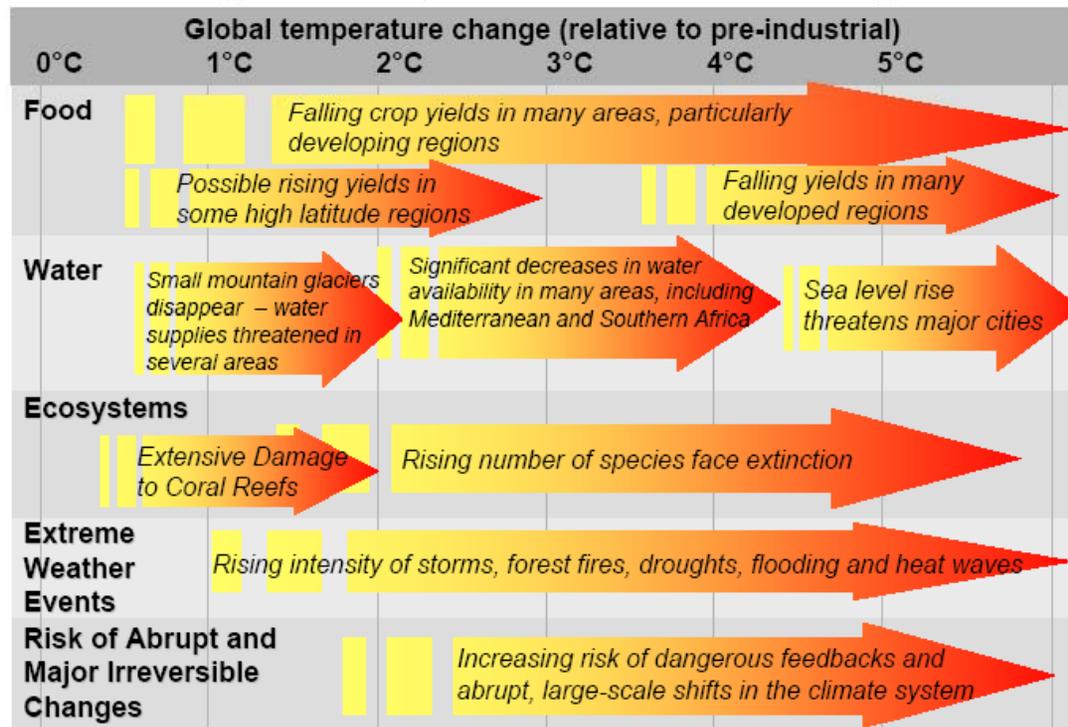
# GHG Scenarios



- Even higher emissions scenario (A1FI)<sup>91</sup>
- Higher emissions scenario (A2)<sup>91</sup>
- Lower emissions scenario (B1)<sup>91</sup>
- Stabilization 450 ppm
- Observations

# What are the impacts of climate change?

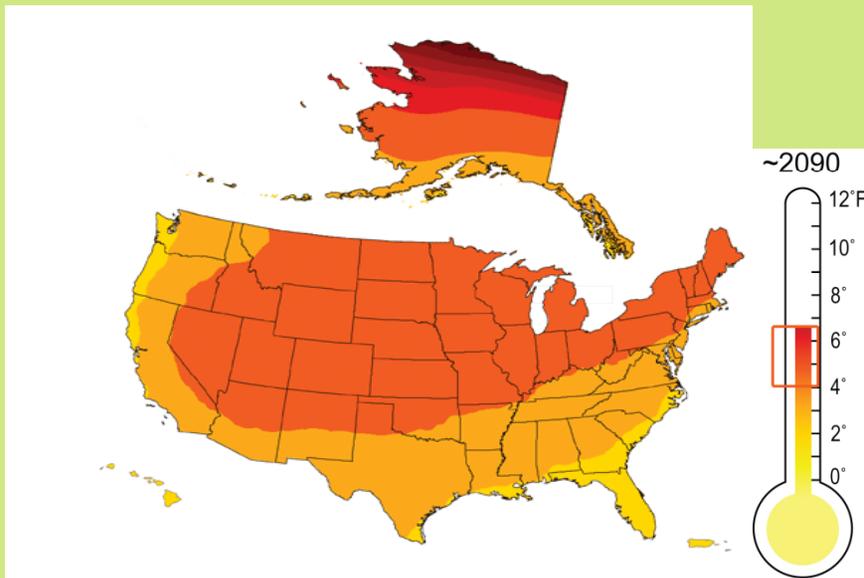
## Projected impacts of climate change



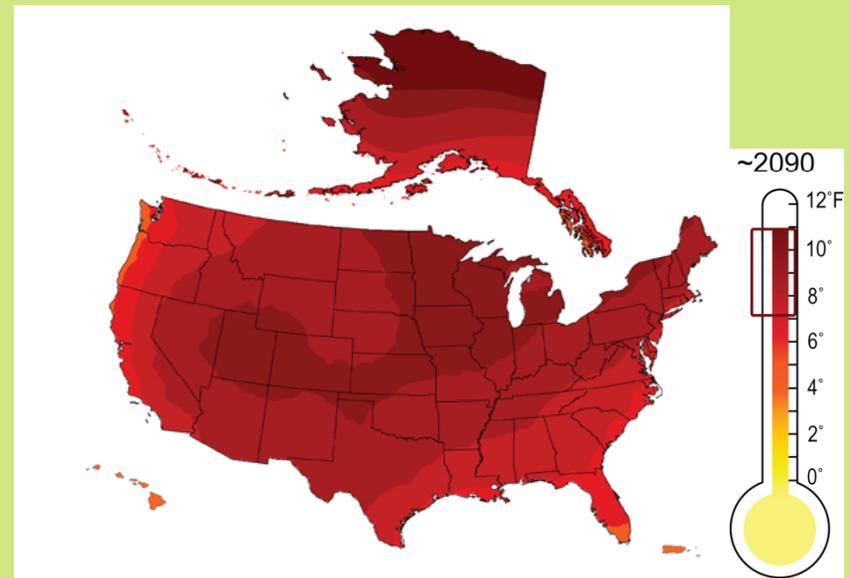
# Temperature Changes (°F)

(compared to 1961-1979 Baseline)

Low Scenario End-of-Century  
(2080-2099 average)



High Scenario End-of-Century  
(2080-2099 average)



Source: Virginia Burkett, USGS (USGCRP 2009)

# Precipitation Changes

(Change in Spring Precipitation – by 2090, showing areas of highest confidence in model prediction)

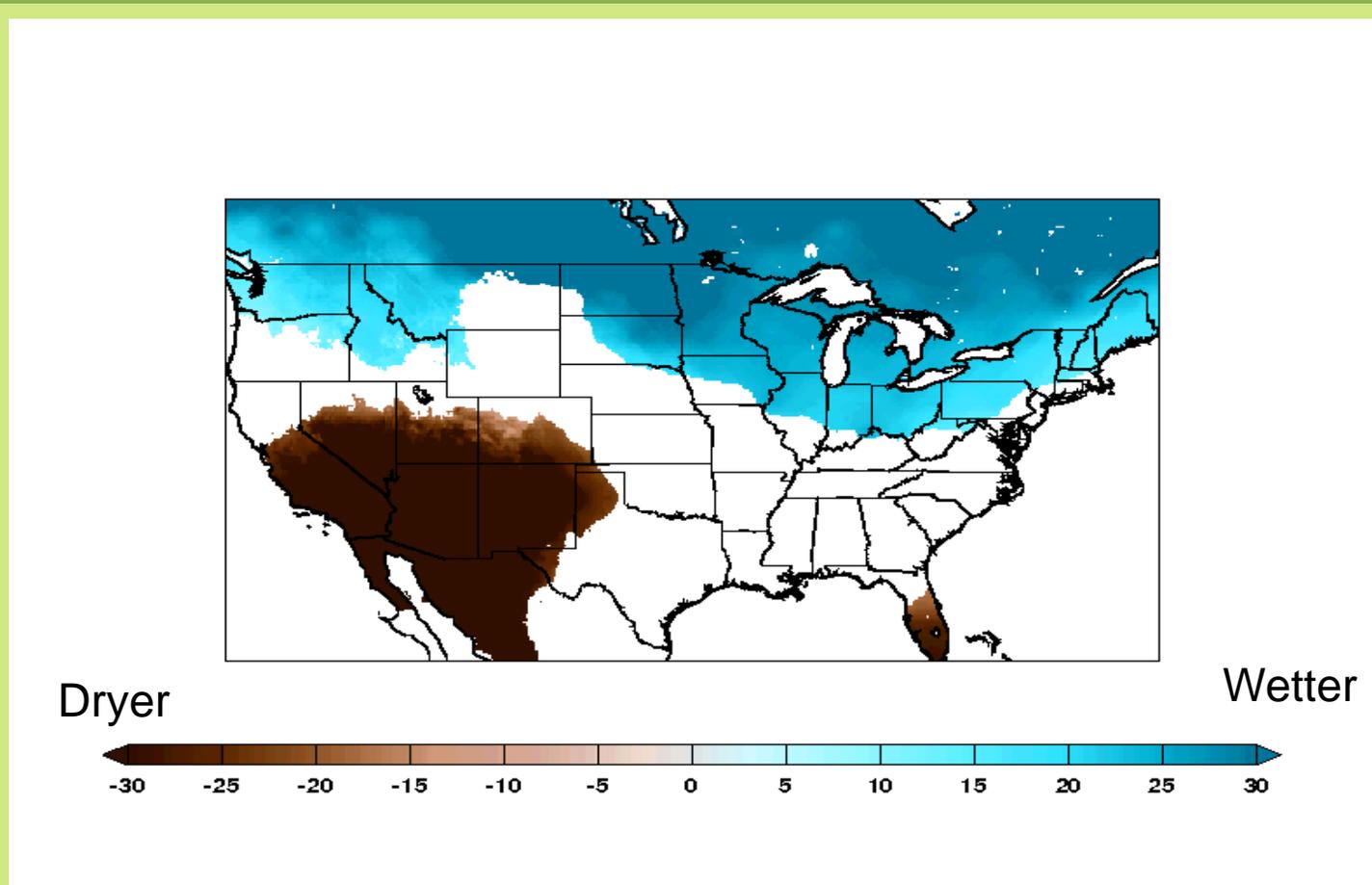


Figure courtesy of Mike Wehner, DoE and Katharine Hayhoe, Texas Tech for USGCRP, 2009

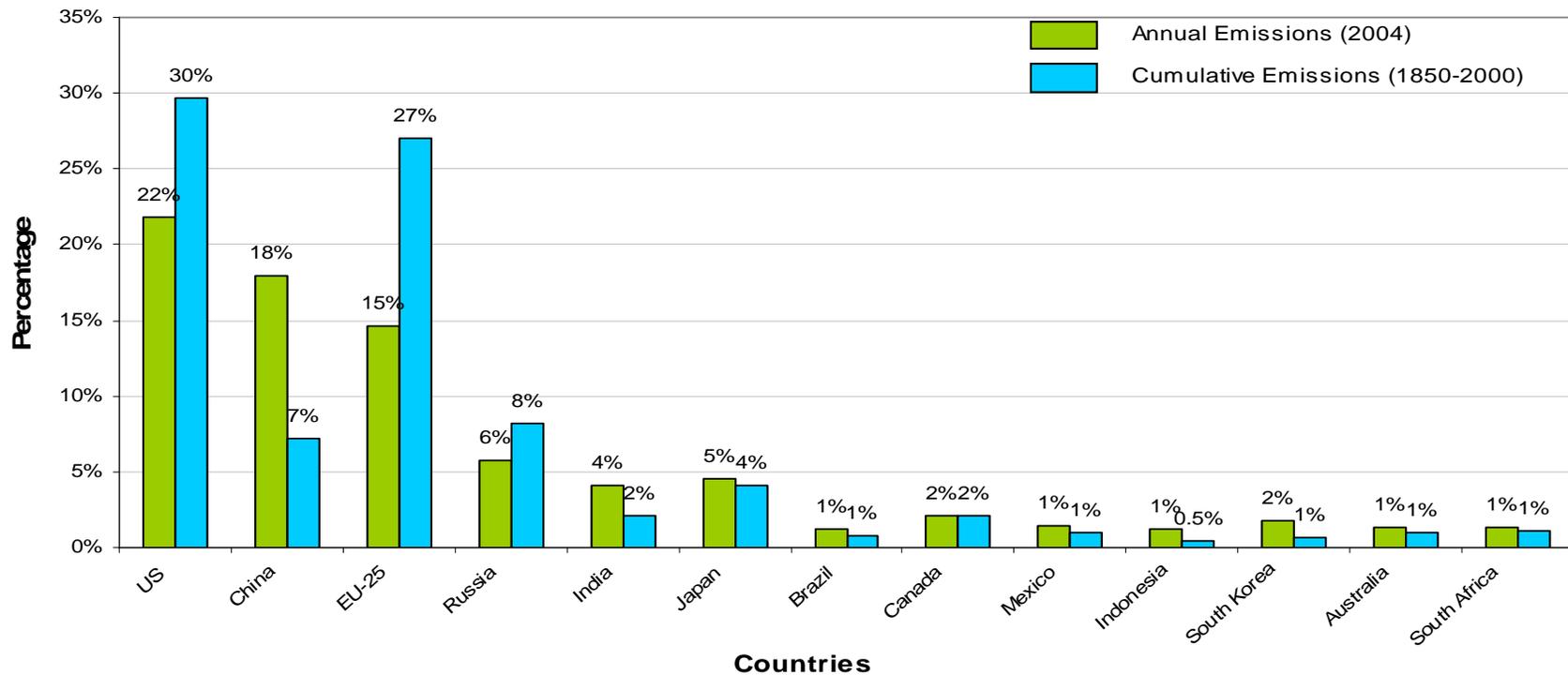
# How widespread are climate change concerns?

- Over 2000 leading scientists worldwide contributed to IPCC report
- 33 U.S. states have developed climate change action plans
- U.S. military is actively preparing for climate change
- U.S. Climate Action Partnership includes 23 major corporations and 5 nongovernmental groups which have called for U.S. Congress to enact strong GHG targets to achieve significant reductions in GHG:

[AES](#), [Alcoa](#), [Alstom](#), [Boston Scientific Corporation](#), [Chrysler](#), [The Dow Chemical Company](#), [Duke Energy](#), [DuPont](#), [Environmental Defense Fund](#), [Exelon Corporation](#), [Ford Motor Company](#), [FPL Group](#), [General Electric](#), [General Motors](#), [Honeywell](#), [Johnson & Johnson](#), [Natural Resources Defense Council](#), [The Nature Conservancy](#), [NRG Energy](#), [PepsiCo](#), [Pew Center on Global Climate Change](#), [PG&E Corporation](#), [PNM Resources](#), [Rio Tinto](#), [Shell](#), [Siemens Corporation](#), [Weyerhaeuser](#), [World Resources Institute](#).

# Where do all those GHG come from?

**Comparison: Annual\* & Cumulative\*\* CO<sub>2</sub> Emissions**



Source: \* Annual Emissions for the year 2004 from IEA (2006) CO<sub>2</sub> Emissions from Fossil Fuel Combustion

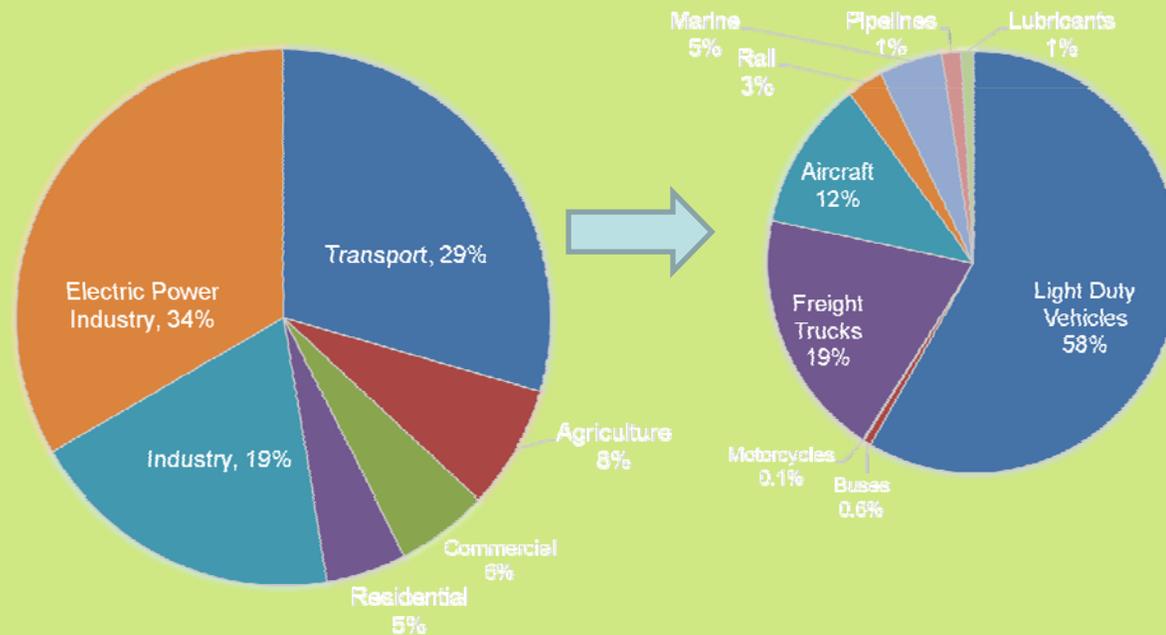
\*\* Cumulative Emissions from 1850-2000, CAIT WRI

# What GHG targets have been set?

- Scientists recommend **60-80% GHG reduction below 1990 level by 2050 to avoid worst impacts**
- Many states and countries have adopted similar targets
- President Obama's budget: **80%** GHG reduction below 2005 by 2050
- Waxman-Markey bill: **17%** below 2005 by 2020 and **83%** below 2005 by 2050
- Kerry-Lieberman bill: **17%** below 2005 by 2020 and **83%** below 2005 by 2050
- **Massachusetts: 25% below 1990 by 2020, 80% below 1990 by 2050**

# What is transportation's share of U.S. GHG?

Source: U.S. DOT Report to Congress, 2010



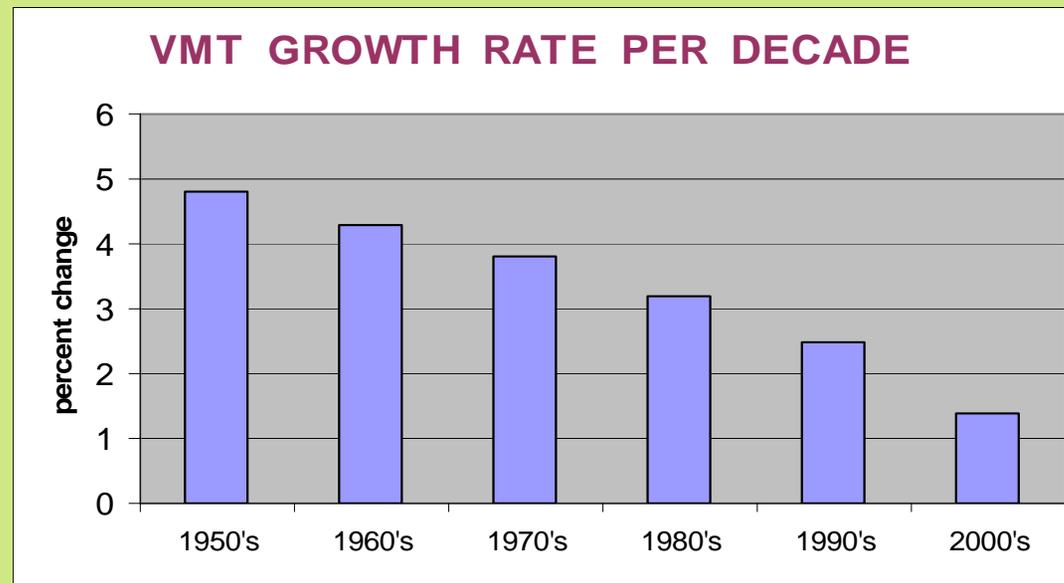
# What are U.S. transportation GHG trends?

Source: U.S.DOT Report to Congress, 2010

	Change, 1990-2006
All U.S. GHG Sources	15%
U.S. Transportation	27%
Light Duty Vehicles	24%
Freight Trucks	77%
Commercial Aircraft	4%

# U.S. VMT growth rates are declining

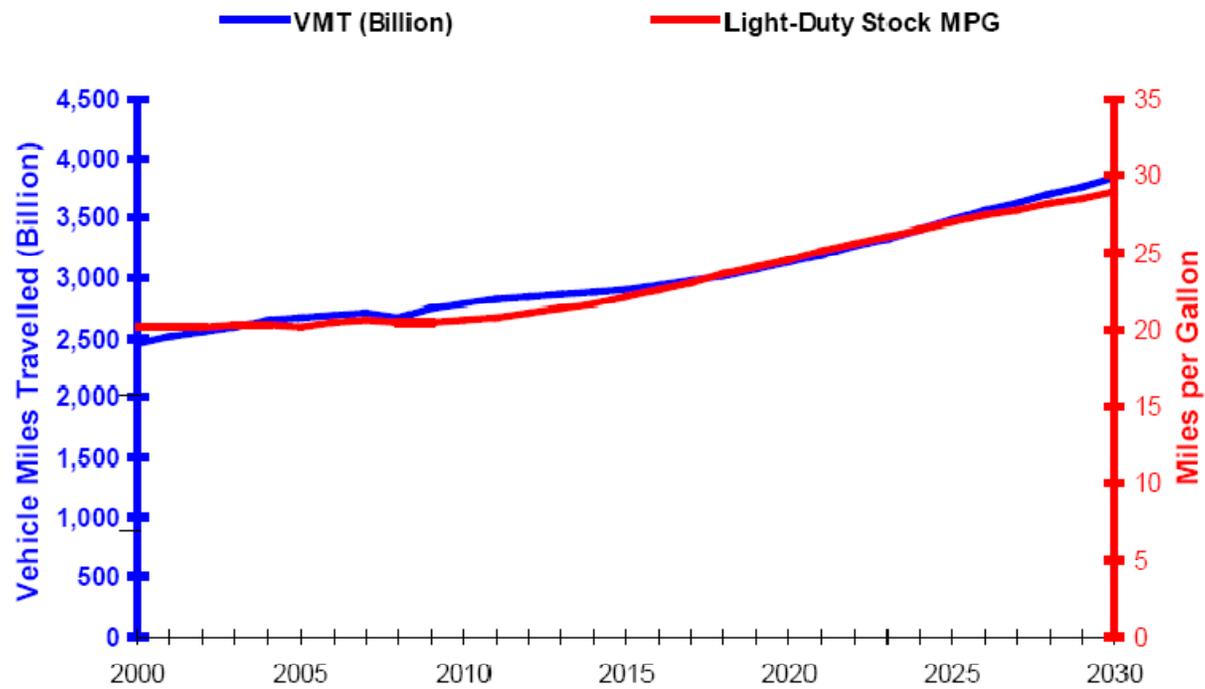
- VMT growth has been steadily declining since the 1950s
- VMT growth slowed to about 1.5% in early 2000s
- VMT growth was actually negative in 2008, pattern of upward growth in 2009
- VMT is affected by population, economy, transportation prices, demographics, land use
- AASHTO supports reducing VMT growth rate to 1% per year



Source: Alan Pisarski and Cambridge Systematics

# DOE expects VMT and MPG both to rise

## Light Duty Vehicle Miles Travelled (2 of 3)

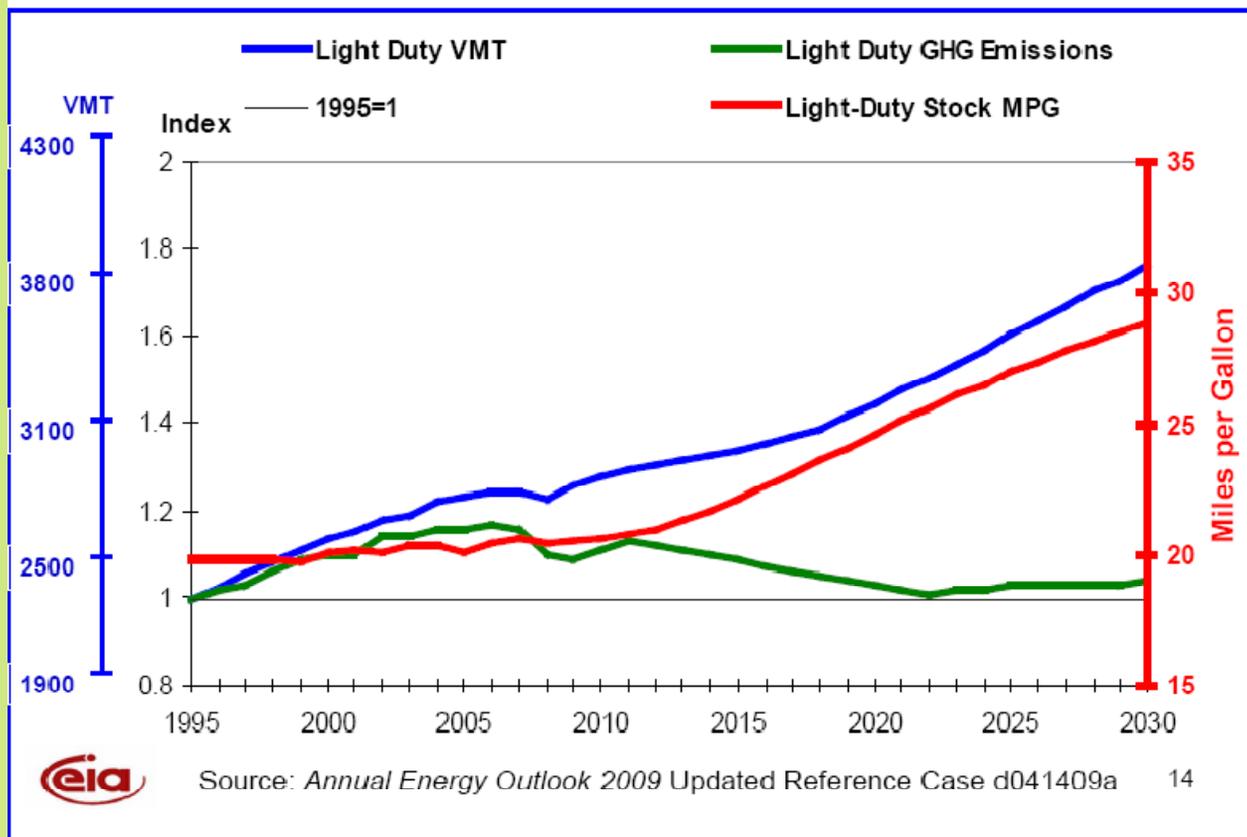


Source: Annual Energy Outlook 2009 Reference Case d041409a

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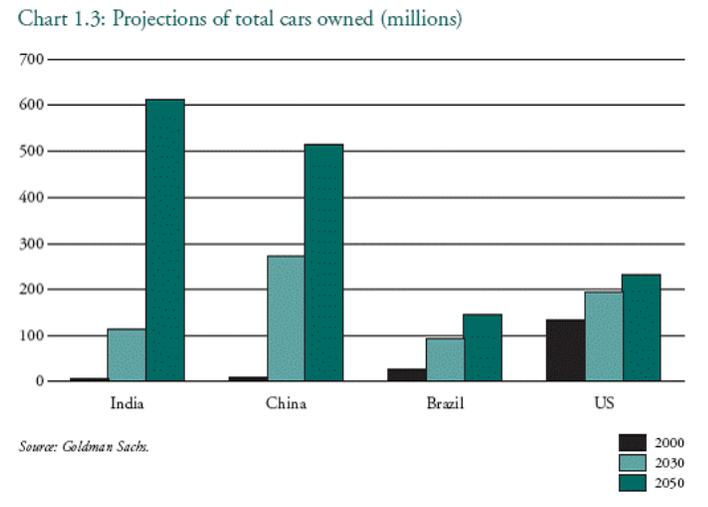
As VMT and MPG rise, GHG is nearly flat

### Light Duty VMT, MPG, and GHG Emissions (3 of 3)



# What are the global trends in vehicle ownership and use?

- Today, car ownership in the U.S. is greater than in India, China, and Brazil combined.
- By 2050, car ownership in those countries will be 5x greater than in the U.S.



Source: The King Review, Table 1.1 and Goldman Sachs, “The BRICs and Global Markets: Crude, Cars and Capital: Goldman Sachs Global Economics Paper No 118, 2004.

# Now Consider Energy Security

- Even if climate change went away, energy security is a growing concern
- ~\$1 billion/day = U.S. payments to other countries for imported oil
- Consider what \$365 billion/year could do if invested in U.S. economy (or deficit reduction) .....
- Largest transfer of wealth in human history?
- 70% of U.S. oil consumption is from transportation
- Reducing transportation energy consumption = reduced GHG, lower transportation costs, greater wealth retained in U.S., reduced vulnerability to hostile nations

# Energy Security and Climate Change

- Most of the strategies to reduce transportation energy consumption also reduce GHG emissions:
  - High MPG vehicles
  - Low-carbon fuels
  - Reduced VMT growth
  - Reduced congestion
  - Eco-driving
  - Energy efficient construction and maintenance practices and materials
  - And more.....
- And they save money for cash-strapped DOTs and households

# Wal-Mart Perspective

***“We know we need to get ready for a world in which energy will only be more expensive.”***

Wal-Mart will cut 20 MMT of GHG from its supply chain by the end of 2015 — equivalent to removing >3.8 million cars from the road for a year.

Wal-Mart is already requiring suppliers to cut packaging, selling “Walmart-label” CFL bulbs in Mexico, and labeling clothes as cold-water wash.

\*\*\*\*\*

Should state DOTs take a page from Wal-Mart’s book?

## II. Importance of Climate Change/Energy to State DOTs and their Partners

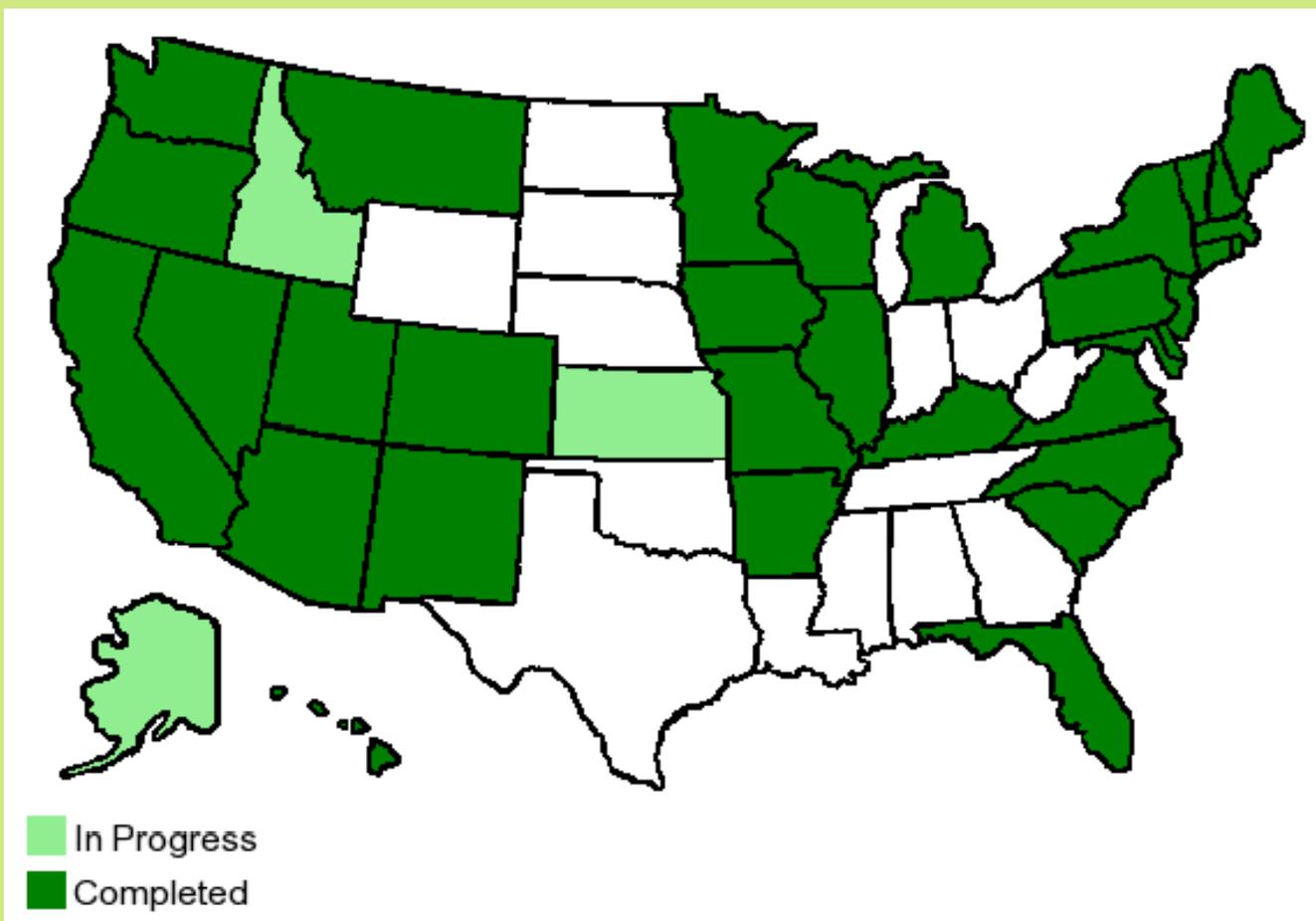


# Four Climate/Energy Issues for Transportation

1. Climate adaptation: Physical impacts of climate change on transportation facilities, systems and operations
2. GHG mitigation: State and federal policies calling for GHG reductions
3. Energy: Higher costs and energy volatility for agencies, households, and all levels of government
4. Transportation revenue: Declining revenue as U.S. shifts to alternative energy and high MPG vehicles

# State Climate Action Plans

Source: Pew Center on Climate Change



# State Climate Plan Goals

State	Year	% Reduction in Transportation GHG	% of all GHG Reductions from Transportation
Massachusetts*	2020	?	30%
New York	2020	18%	7%
Connecticut	2020	N/A	7%
Pennsylvania	2025	30%	8%
Maine	2020	23%	27%
Minnesota	2025	27%	5%
Oregon	2025	25%	8%
New Mexico	2020	30%	8%
Arizona	2020	25%	9%
North Carolina	2020	31%	11%

\*Data from Massachusetts Clean Energy and Climate Plan, 2010. Insufficient information to estimate % reduction in transport GHG.

# State Climate Plans – Transportation Elements Vary All Across the Map

State	Year	Vehicle	Low Carbon Fuels	Smart Growth and Transit	Other
<b>MA *</b>	<b>2020</b>	<b>35-42%</b>	<b>19-22%</b>	<b>7-?%</b>	<b>5-22%</b>
NC	2020	35%	12%	38%	15%
SC	2020	14%	55%	29%	1%
CT	2020	51%	38%	8%	2%
ME	2020	53%	25%	21%	1%
MD	2025	24%	12%	45%	20%
NY	2020	59%	11%	27%	4%
PA	2025	53%	15%	<1%	28%
MN	2025	15%	35%	25%	25%
VT	2028	21%	14%	49%	17%

\*Data from Massachusetts Clean Energy and Climate Plan, 2010.

# State Climate Action Plans

- Highly “aspirational”
- Managed by state environmental agencies
- Steering Committees included multiple environmental advocates and rarely had transportation agency reps
- State DOT involvement was at a technical advisory level
- Example: VT strategies would reduce 2030 VMT from 10.5 B (base case) to 3.9 B

# What are Other State DOTs Doing on Climate Change?

- California: <http://www.dot.ca.gov/docs/ClimateReport.pdf>
- Maryland: [http://www.mde.state.md.us/assets/document/Air/ClimateChange/Appendix\\_C\\_%20MDOT\\_CLimate\\_Action\\_Process.pdf](http://www.mde.state.md.us/assets/document/Air/ClimateChange/Appendix_C_%20MDOT_CLimate_Action_Process.pdf)
- Oregon: <http://www.oregon.gov/ODOT/SUS/docs/EffortsOnClimateChange2008.pdf>
- Vermont: <http://www.aot.state.vt.us/planning/Documents/Planning/VTransClimateActionPlanfinal1.pdf>
- Washington: <http://www.wsdot.wa.gov/environment/climatechange/>
- New York: [http://www.nysdot.gov/nasto/repository/WS4d\\_Zamurs%20AASHTO\\_0.ppt](http://www.nysdot.gov/nasto/repository/WS4d_Zamurs%20AASHTO_0.ppt)
- Florida: [http://www.dep.state.fl.us/climatechange/files/action\\_plan/chap5\\_trans.pdf](http://www.dep.state.fl.us/climatechange/files/action_plan/chap5_trans.pdf).

# Summary

- Moving away from our dependence on oil and reducing GHG emissions will be the greatest challenge to decision-making for transportation policies, programs, and investments in the coming decades.
- Other sectors are moving on climate change policies faster than transportation
- States are adopting sweeping policies with little or no input from transportation agencies or experts

Source: Transportation's Role in Climate Change:  
TRB Executive Committee, June 2008

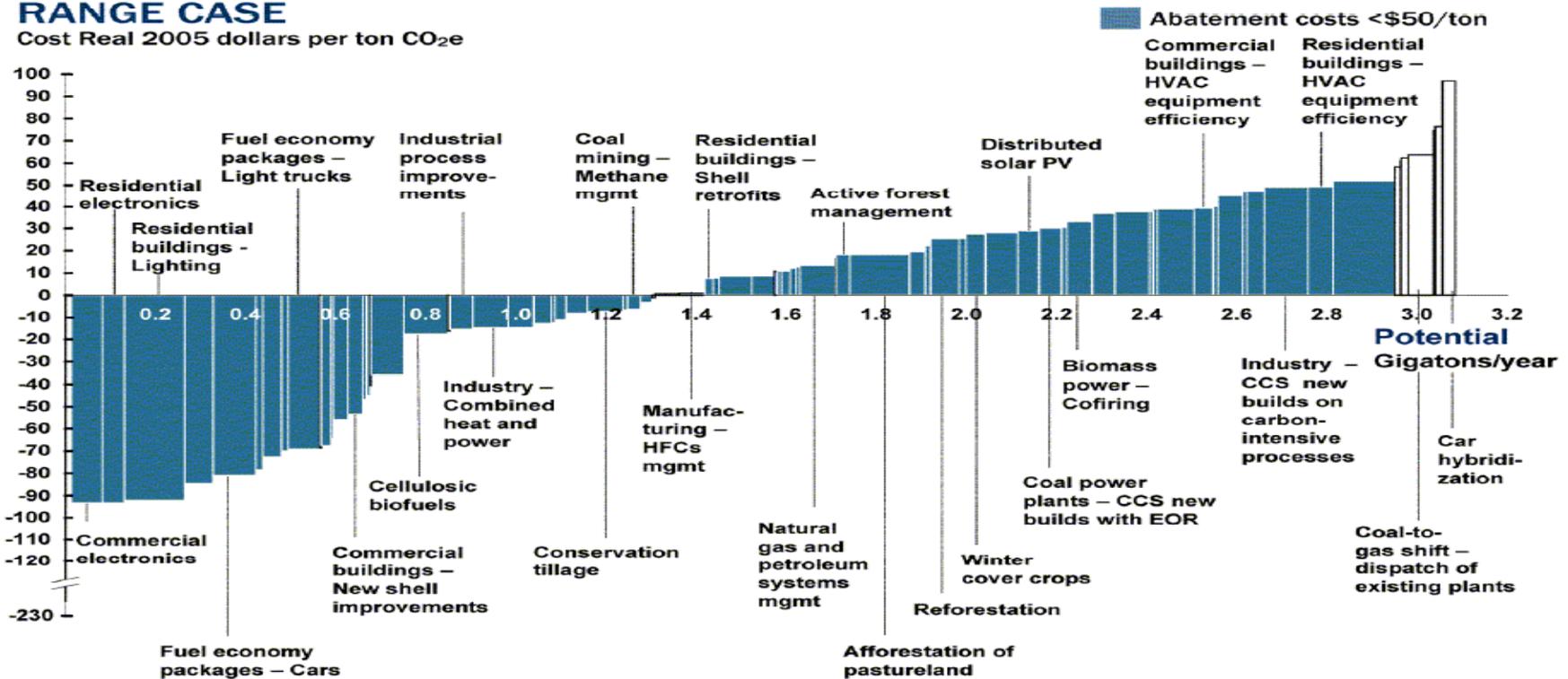
### III. Transportation Strategies to Reduce GHG/Energy Use



# CONTEXT/ALL SECTORS: McKinsey Finds Available Technologies can Reduce 3 Billion Tons GHG/Year at < \$50/ton (this is 31% of GHG economy-wide in 2030)

## GHG REDUCTION OPPORTUNITIES WIDELY DISTRIBUTED - 2030 MID-RANGE CASE

Cost Real 2005 dollars per ton CO<sub>2</sub>e



The analysis found that abatement options are highly fragmented and widely spread across the economy. Almost 40 percent of abatement could be achieved at “negative” marginal costs, i.e., the savings over the lifecycle of these options would more than pay for the incremental investment, operating, and maintenance costs. Realizing the potential of many negative-cost options would require overcoming persistent barriers to market efficiency.

# What is the full array of transportation strategies to reduce GHG?

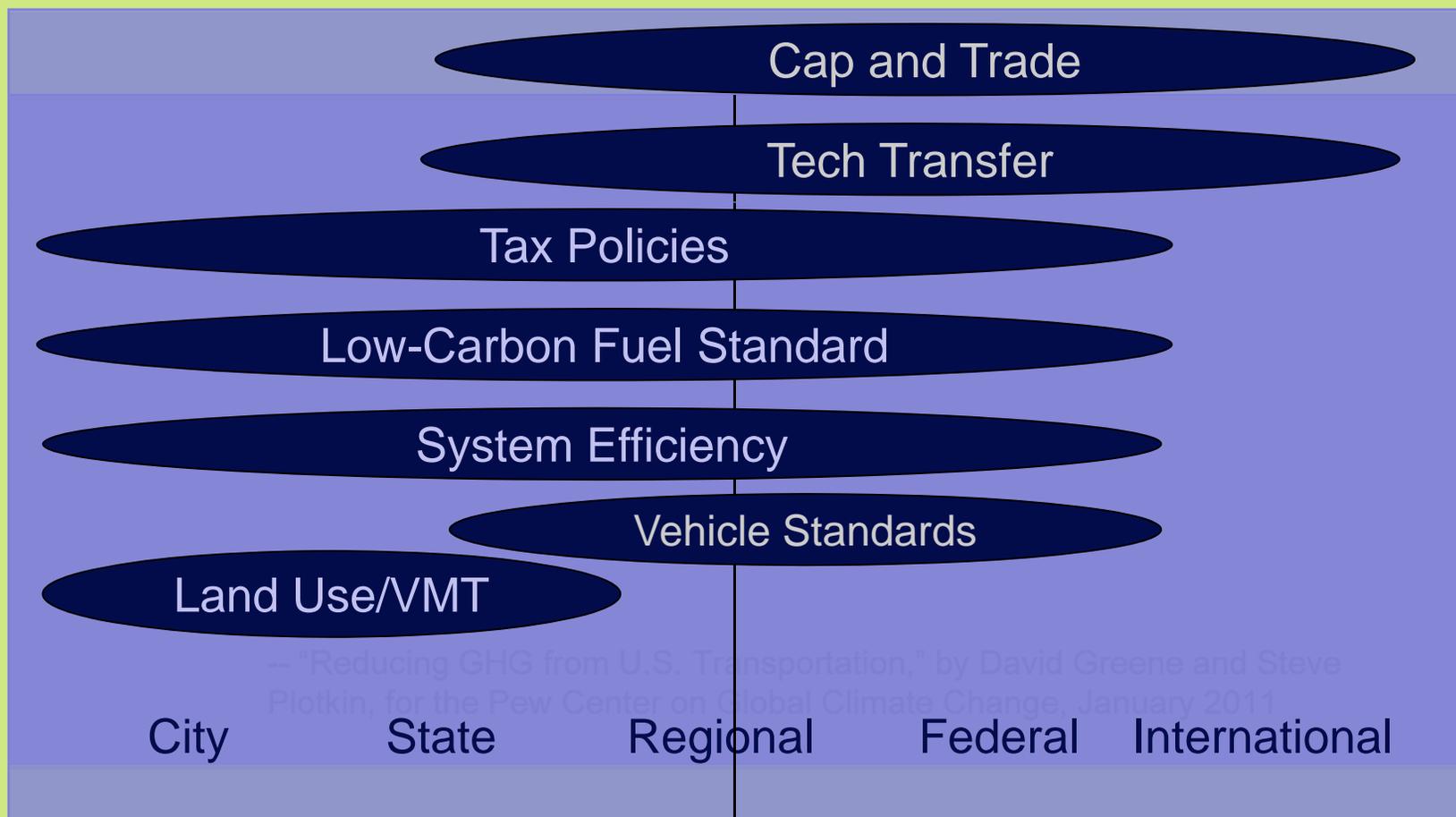
## Five GHG “legs”

1. Vehicle efficiency
2. Low-carbon fuels
3. VMT Reductions (including land use)
4. Vehicle/System Operations
5. Construction, Maintenance, and Agency Operations

## Examples

- Higher CAFE standards 380 gm/mile to 250 gm/mile 2016
- CA’s low carbon fuel standard
- Less travel, could be in part due to land use changes
- Signalization, ITS, Eco-driving
- Materials, maintenance practices

# What kinds of transportation strategies are needed? 2011 Pew Center Report



# How much can transportation strategies reduce GHG? 2011 Pew Center Report

- Presents base case + 3 scenarios for transportation GHG reductions
  - Base case: +28% in transportation GHG, 2010-2050
  - Low scenario: -17% in transportation GHG, 2010-2050
  - Mid scenario: -35% in transportation GHG, 2010-2050
  - High scenario: -65% in transportation GHG, 2010-2050
- High scenario: rapid tech progress, aggressive emission standards, 80 mpg for cars, transition to electric and hydrogen vehicles well underway by 2050, auto feebates, carbon pricing, eco-driving, land use policies, congestion pricing, PATP auto insurance, automated highways in 2050 on major routes, etc.
- GHG reductions are roughly equal from (a) vehicle efficiency; (b) low-carbon fuel; and (c) all other strategies combined.

-- "Reducing GHG from U.S. Transportation," by David Greene and Steve Plotkin, for the Pew Center on Global Climate Change, January 2011

# How much can transportation strategies reduce GHG? Five Case Examples

- Washington State DOT
- Atlanta Regional Commission
- Washington D.C. Council of Governments
- Metropolitan Transportation Commission, San Francisco Bay Area, CA
- California SB375 land use-VMT-GHG law

# Washington State DOT Case Study

“WSDOT’s analysis suggests that implementing combinations of **aggressive** transportation emission reduction strategies can achieve **roughly a ten percent reduction in total statewide GHG emissions compared to the 2050 baseline**. Implementing many of these strategies **would require changes in policy, funding, and authority**, and also **assumes ambitious improvements in vehicles and fuels**. WSDOT did not assess the political or financial feasibility of implementing the strategies.” (highlighting added)

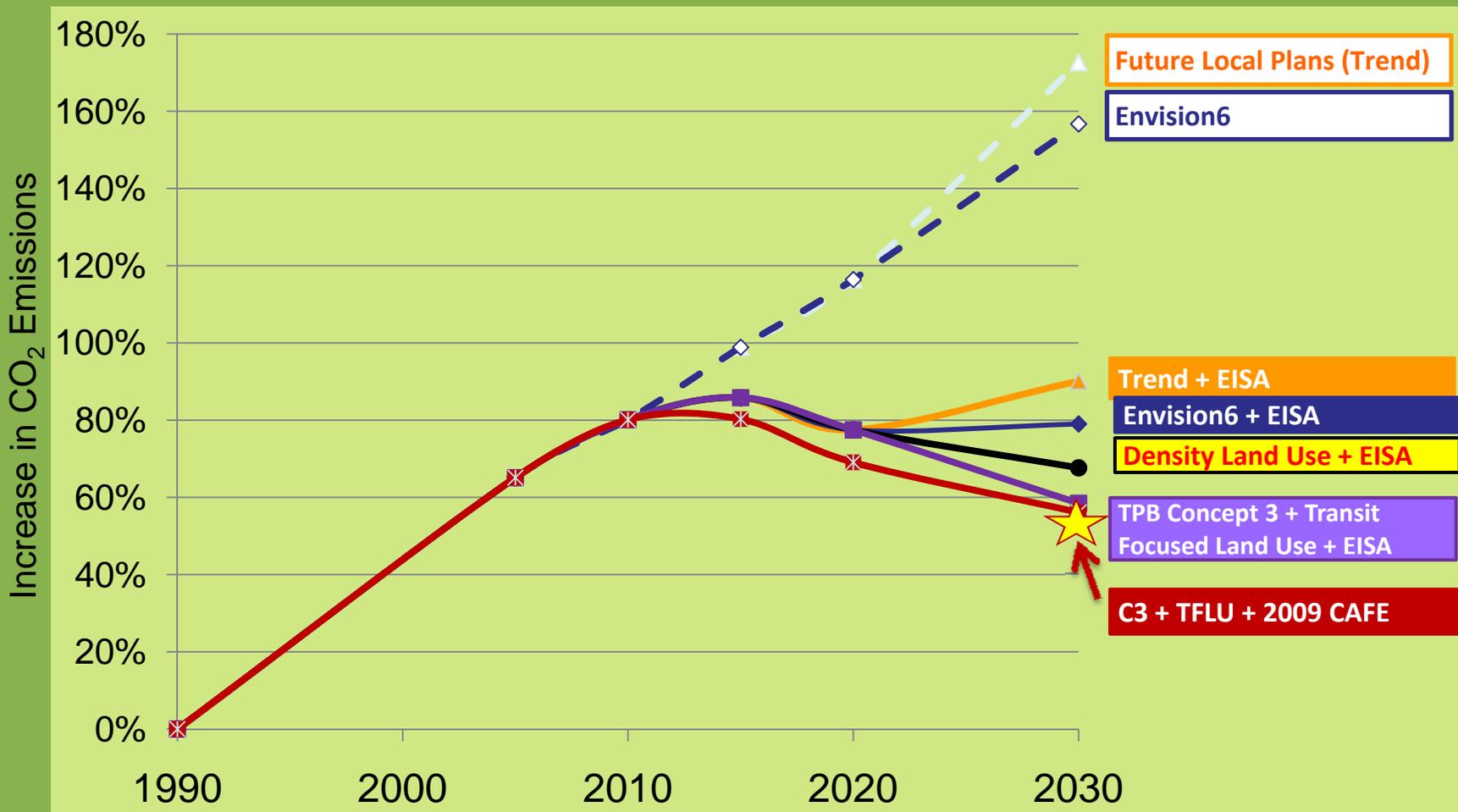
Source: 2011 WSDOT Sustainability report

Note: 10% reduction in 2050 is for GHG from all sectors, but it is not a 10% reduction below current levels. For the on-road sector, it corresponds to about 7-31% reduction in 2050 compared to 2010 on-road GHG, using “aggressive strategies.”

# MPO Scenarios Tested

- MPOs tested impacts of:
  - Land use changes
  - CAFE standards
  - Extensive transit investments
  - Operational strategies
  - Pricing measures (Wash, DC and SF)
  - Federal Policies (Wash, DC)
- Combinations of the above

# Atlanta GHG Scenario Testing



Source: Atlanta Regional Commission

# Washington, D.C. Analysis Methodology

- **MOBILE6** - develop CO2 emissions inventories and rates
- **Offline spreadsheet tool** - estimate reductions from CAFE standards using local fleet information
- **Travel demand forecasting/sketch planning** – estimate VMT reductions
- **CO2 emissions changes by speed** (UCRiverside) – estimate CO2 impacts of traffic flow improvements

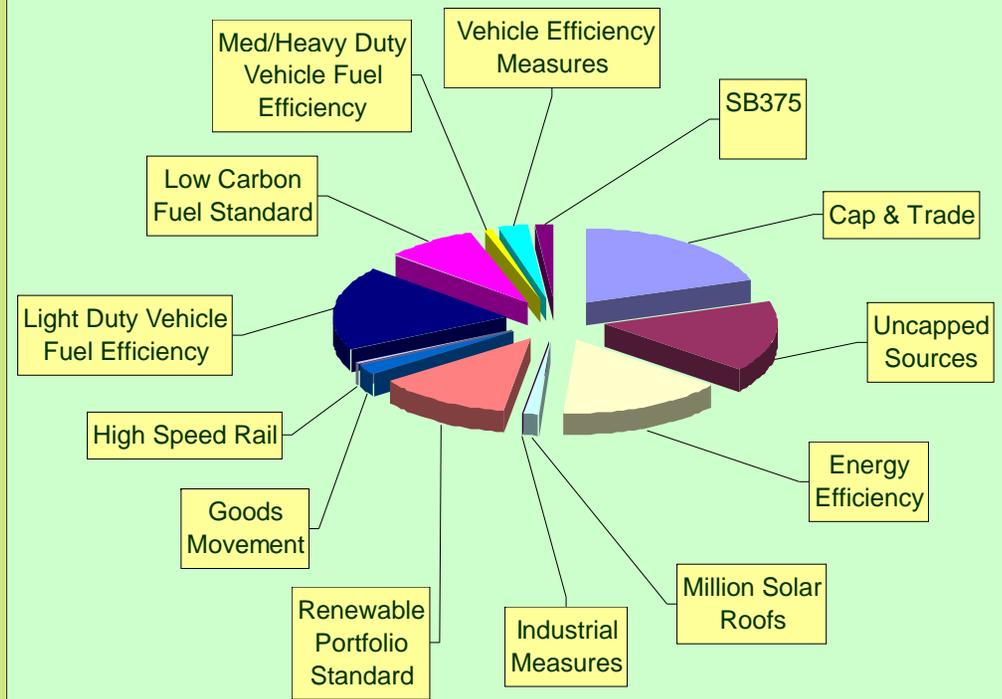
# Washington, D.C.- 2010 - 2030

- **Reduction Goal 33.5%**
  - CAFE 17.3%
  - Alt.Fuel 2.1%
  - TERMS\* .6%
  - Short term 3.9%
  - Long-term .85%
- **Shortfall 8.75%**
- \*TERMS : Access and service improvements to transit, bike/ped projects, rideshare assistance programs, telecommute programs, traffic improvements, engine technology programs
- **Short term reductions (3.9%)**
  - Increase transit .3%
  - Pricing 1.5%
  - Operational Efficiencies 1.8%
  - Reduced travel 3%
- **Long-term reductions (.85%)**
  - Increase transit .15%
  - Increase bike/ped .3%
  - Pricing .25%
  - Reduced travel .15%

Source: Washington, D.C. COG

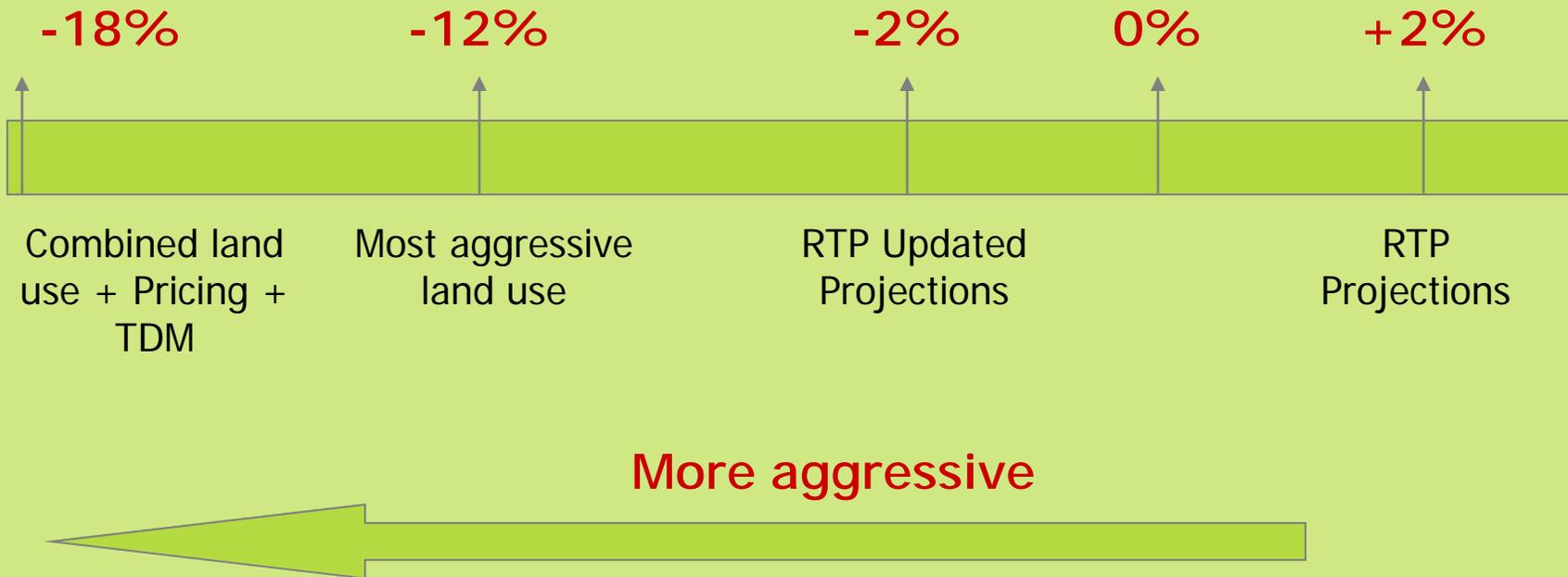
# California Climate Change Act – AB32

California GHG Emissions Reduction Measures 2020



# San Francisco MTC - Scenario Assessment (% GHG per capita - 2005 vs 2035)

- With expected pop growth from 7M to 9M, CO2 emissions from LDV actually increase 24% over this period from 74,641 tons/day to 92,223 tons/day

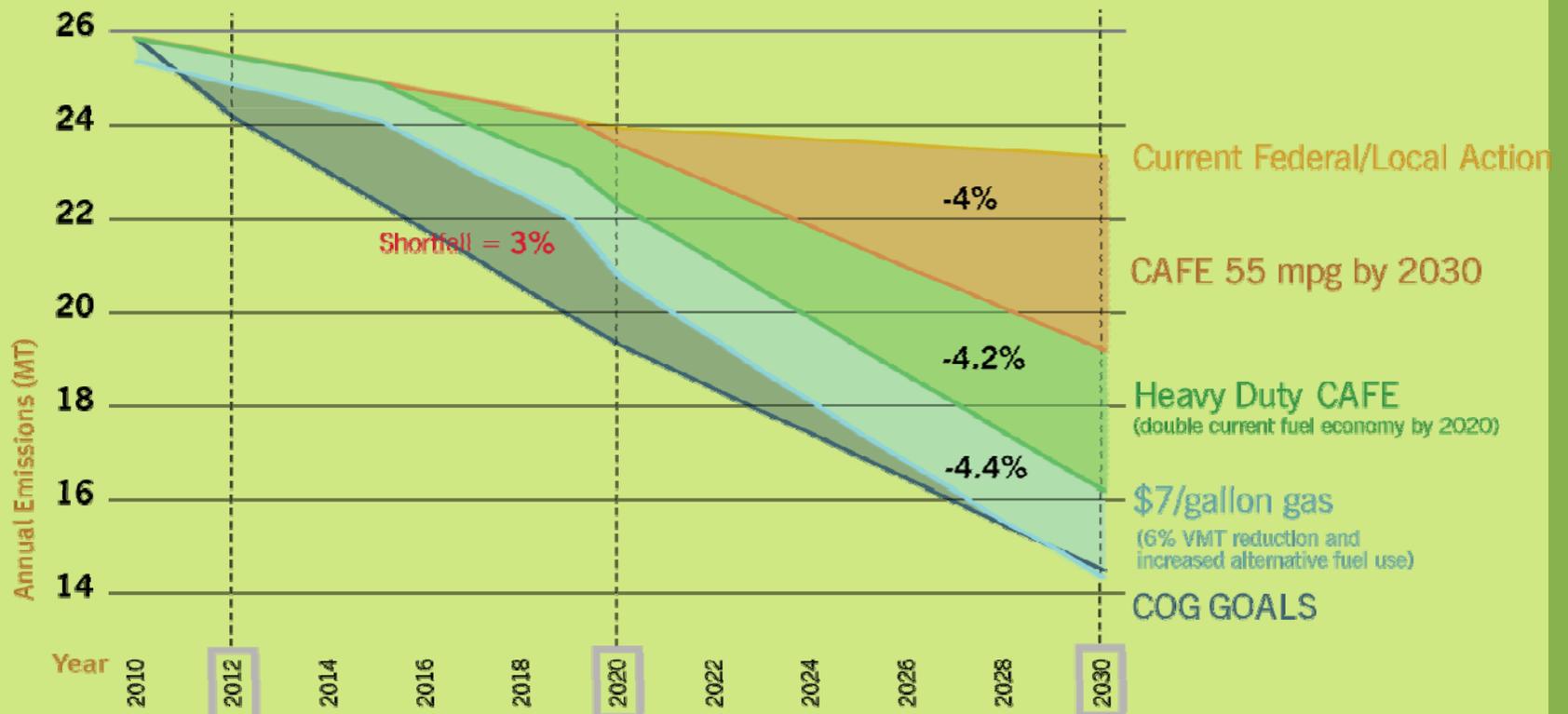


Source: Metropolitan Transportation Commission/SB375 Report to CARB

# Higher Federal Role is Needed

(WASHCOG Analysis)

## Aggressive federal measures would *almost* get us there.



Source: Washington, D.C. COG

# MPO Case Study Findings

- MPOs have small influence over reductions: combinations of land use, transit, TDM can help but fall short of goals in all cases
- Per capita reductions of GHG of 15% or more will likely require road pricing
- Net increases in GHG from transportation are likely without technology and fuel measures
- Higher Federal role in GHG reductions could result in substantial reductions
  - 55 mpg by 2030 LDV CAFE
  - HDV CAFE (double heavy duty fuel economy)
  - \$7/gallon gas

# Vehicle/Fuel Improvements Will be the Dominant Source of GHG Reductions for LDVs

- 50% cut in GHG/mile is feasible from conventional technologies and biofuels by 2020-2030
- Compare these GHG rates in U.S. and Europe:

380 grams/mile	2009 in the U.S.
250 grams/mile	2016 under new Obama standard
256 grams/mile	2007 actual in the E.U.
209 grams/mile	2012 under E.U. regulation
153 grams/mile	2020 under E.U. regulation
- LDV purchase cost will rise, but fuel savings will be greater than vehicle cost increase
- Win-win-win: reduces energy use, reduces GHG, saves money

# Vehicle “decarbonization” is critical

***“In the long term, carbon free road transport fuel is the only way to achieve an 80-90% reduction in emissions, essentially “decarbonization.”***

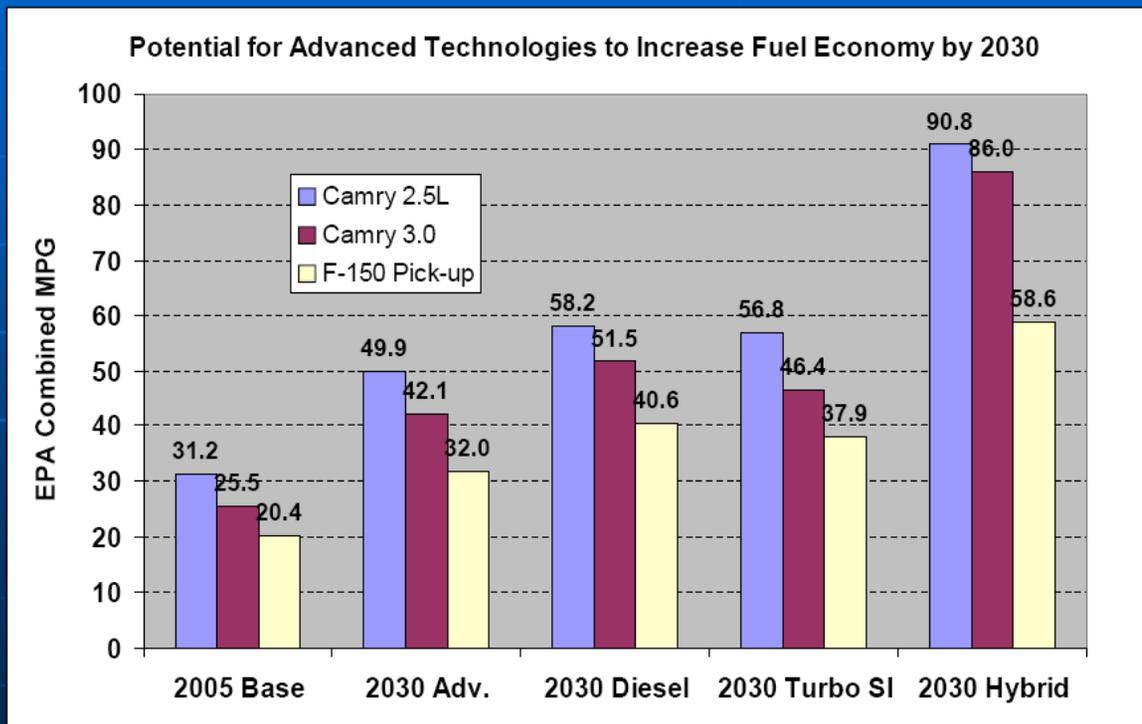
--The King Review for the U.K. Government, by Professor Julia King, Vice-Chancellor of Aston University and former Director of Advanced Engineering at Rolls-Royce plc, March 2008

***“[I]n the period beyond 2100, total GHG emissions will have to be just 20% of current levels. It is impossible to imagine this without decarbonization of the transport sector.”***

-- Sir Nicholas Stern, Stern Review to the U.K. Government, 2007

# Vehicles: Potential Fuel Economy Increase by 2030

A 2007 MIT study predicts MPG gains of 80-85% for model year 2030 vehicles via continuous improvement of conventional technology at a rate of 2-2.5%/year.



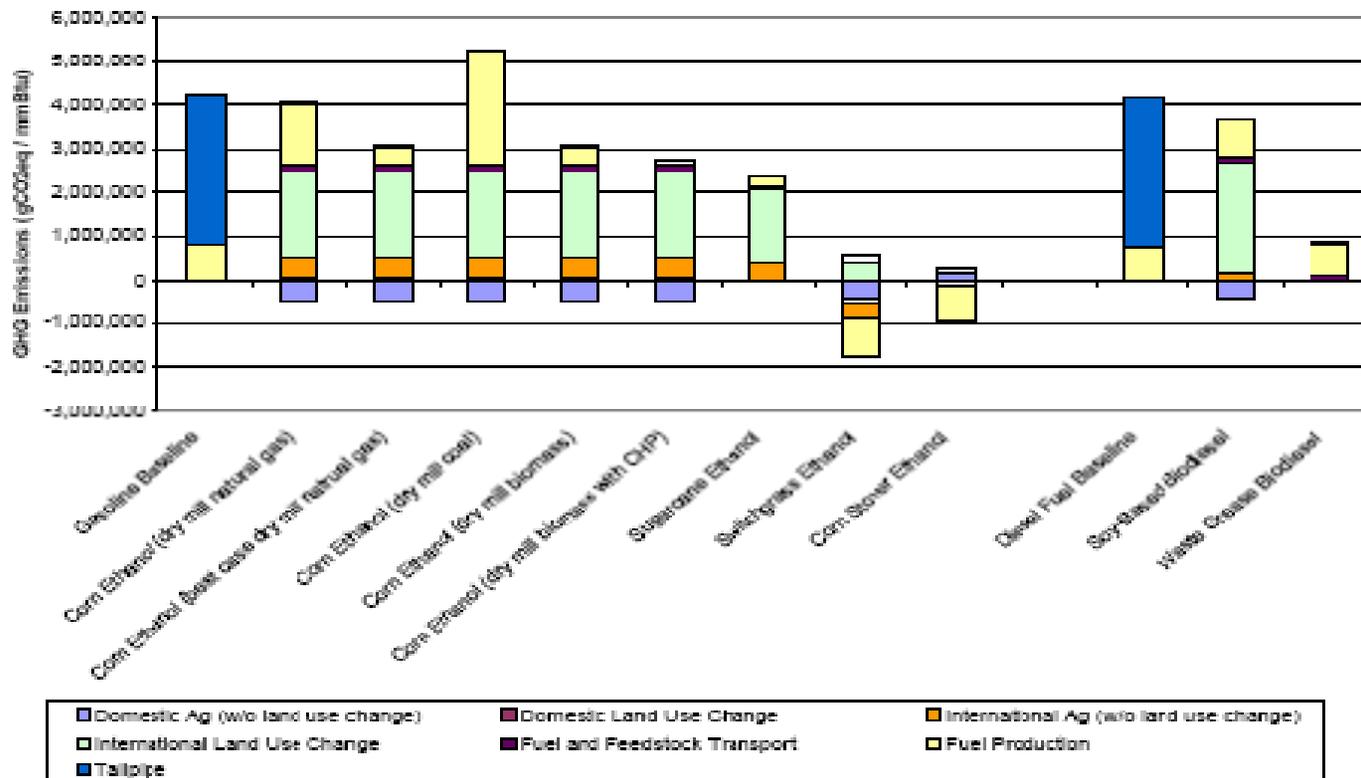
Source: Kasseris & Heywood, SAE Technical Paper 2007-01-1605, April, 2007.

# Fuels: Low-Carbon Fuels

- Many different low-carbon fuel possibilities:
  - Corn ethanol                      - Sugar cane ethanol                      - Biodiesel
  - Cellulosic biofuel                - Algae biofuels                                      - Hydrogen
  - Electricity from renewable energy or nuclear power
  - Electricity from utilities with carbon capture & storage
- Carbon intensity measured as GHG/unit of energy – must account for “life-cycle” emissions
- California LCFS:
  - Adopted in 2008
  - Aims to reduce carbon intensity of passenger vehicle fuels by 10% by 2020
  - Measures carbon-intensity on a life-cycle basis – “from field to wheel.”

# Fuels: Lifecycle GHG

**Figure 1. Net Lifecycle Greenhouse Gas Emissions By Lifecycle Component With 100 Year Time Horizon And 2% Discount Rate.**



# Lifecycle Emissions

## Components of lifecycle emissions:

Assumptions are made about the amount of emissions from these elements of the lifecycle.

- Domestic agriculture
- International land use change
- Tailpipe
- Domestic land use change
- Fuel and feedstock transport
- International agriculture
- Fuel production

# National Renewable Fuel Standard (RFS)

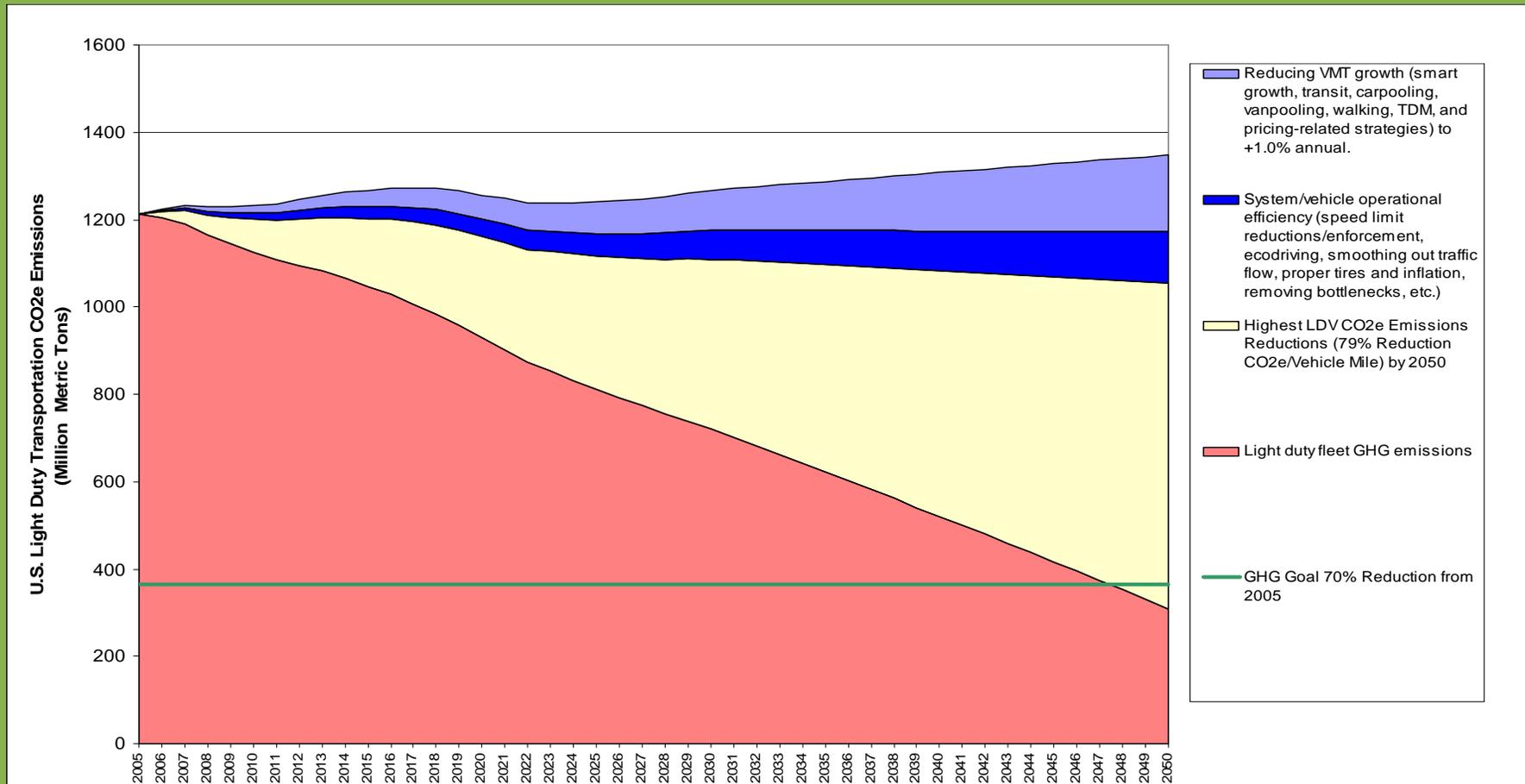
- EISA 2007 establishes fuel categories and eligibility requirements
- Determine if renewable fuels meet GHG thresholds set for **four types of** renewable fuels (E.g., corn ethanol, soy-based biodiesel, switchgrass ethanol, waste grease biodiesel)
- Emissions compared to 2005 for gasoline and diesel (depending on which is being replaced)
- Lifecycle Emissions analysis-
  - Aggregate quantity of GHGs related to full fuel cycle including all stages of production and distribution

# Vehicles & Fuels: Possible State DOT Roles in Decarbonization

1. **Influence state policies** on low-carbon fuels/vehicles
2. **Use planning scenarios** to emphasize need for decarbonization
3. **Plan/provide plug-in infrastructure** for electric and PHEV vehicles (coordinate with utilities)
4. **Support federal transportation funding** for technology/fuel R&D
5. **Educate** the public and elected officials
6. **Provide incentives** for consumers to use lower carbon fuels/vehicles (lower fees for low-carbon vehicles/fuels)
7. **Support** low -carbon fleet conversion for state vehicle fleets
8. **Adjust** facilities and operations to accommodate decarbonized vehicles and fuels

# More than Vehicles and Fuels:

Achieving 74% LDV GHG Reduction by 2050 requires 100 mpgge LDV Fleet + 10% Operational Efficiency + Lower VMT Growth (1%/year)



# VMT: Cautionary Note

VMT is not a good metric for GHG reductions, as VMT does not take into account:

- Type of fuel
- Fuel efficiency of vehicle
- Passenger vs freight trip
- Number of passengers per vehicle
- As passenger fuel economy increases, effectiveness of VMT reductions diminishes
- TCM lessons from 1990s – marginal emission reductions, increasing costs as technology improves

Reducing VMT is part of the strategy set – but just one element, not the end goal

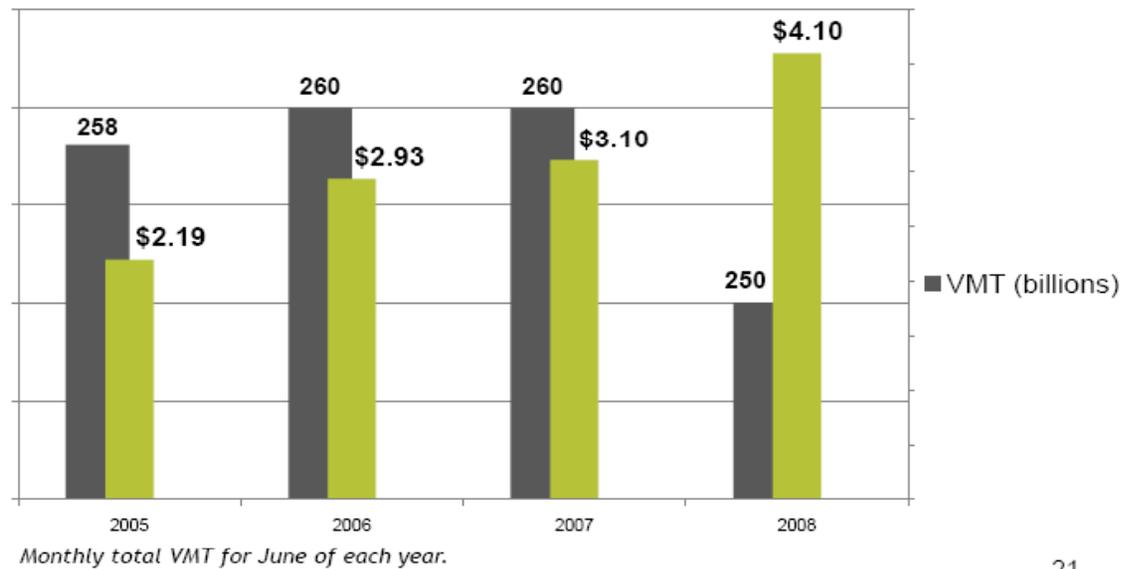
# VMT: Many Strategies to Reduce VMT Growth

- Pricing - economy-wide (carbon tax or carbon cap and trade, which would raise fuel prices)
- Pricing – transportation (PAYD insurance, parking pricing, tolls, higher user fees, cordon pricing, congestion pricing, etc.)
- Carpooling and vanpooling
- Bike/ped and transit
- Trip chaining
- Tele-working, tele-shopping, tele-education, tele-medicine
- Compact land use

# VMT: Consumers respond to pricing

Gasoline Prices Surged in Summer '08,  
and Consumers Responded, revealing fuel price elasticity

National Vehicle Miles Traveled vs. Gasoline Prices



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# VMT: Carpooling and Vanpooling Potential

- Receives limited support and has been declining
- Yet is more important than is recognized (provides 300-400% of the PMT for work trips nationally as transit)
- Low cost for government, wide availability, saves users money
- Effective in all kinds of areas – rural, small urban areas, suburban, urban
- Nearer-term payoff than most transportation strategies
- Atlanta MPO and WASHCOG pay for commuters to carpool (\$3/day Atlanta, \$2/day WASHCOG)

# VMT: Transit's Potential

- It is hard to generalize about transit
- Transit VMT/GHG benefits are realized with highly patronized, high-occupancy services -- a market limited to high volume, generally densely developed corridors
- Commuter rail is 38% less carbon intensive than average auto – but bus transit is more carbon intensive than average auto use (national averages; some corridors better, some worse)
- Two APTA studies: (a) Transit reduced GHG by 6.9 MMT\* in 2005; or (b) by 37 MMT in 2005 (this is 0.3% to 1.7% of U.S. transportation GHG)

\* MMT = million metric tons

# VMT: Carbon Intensity of Different Modes

	Occupancy	Lbs of GHG/PMT*
Auto, SOV	1.00	0.99
SUV, average	1.72	0.71
Transit Bus, average	8.80	0.71
Auto, Average	1.57	0.58
Carpools, average	2.10	0.47
Amtrak	20.50	0.39
Rail Transit, average	22.50	0.39
Motorcycles, average	1.20	0.37
Commuter Rail, average	31.30	0.36
Vanpools, average	6.10	0.21
Walking and Biking	1.00	0.00

\* PMT = Passenger Mile Travelled – national averages, DOE data

# VMT: Land Use Effect on GHG is Helpful but Modest

<1 to 11% \*      GHG reduction in 2050 on-road household GHG, for range of 3 scenarios (2009 TRB report, “Driving and the Built Environment”)

<1 to 4.4%      GHG reduction in 2050 on-road GHG, for up to 90% of new development compact with high quality transit (2009 “Moving Cooler” report)

3.5 to 5%      GHG reduction for 2007-2050, cumulative, as % of transportation GHG, for compact land use with very aggressive assumptions (2007 “Growing Cooler” report)

\* TRB Panel was not in agreement on 11%. Highest reduction supported by the full TRB panel was 1.3-1.7%, in 2050

## Compact Land Use + Transit + Bike + Ped + Intercity Passenger Rail + High Speed Rail + Car-Sharing + Urban Nonmotorized Zones + Urban Parking Restraints

Bundling these 9 strategies at the “Aggressive” level leads to these changes in on-road GHG:

~**2.7%** GHG reduction cumulatively, 2005-2050

And at the “Maximum” level:

~**4.4%** GHG reduction cumulatively, 2005-2050

What are the assumptions behind these reductions?

“Maximum” level = \$1.2 trillion transit expansion + \$220 billion in HSR and conventional intercity rail expansion + 50% cut in all transit fares + 90% of all new development is compact starting in 2005 + “complete streets” policies + bike lanes at ¼ mile intervals + 6% of CBD areas are nonmotorized by 2015 + urban parking freeze in 2015

Source: Estimates based on data in Moving Cooler, 2009

# Operations: Many Strategies, with 10-20% GHG Reduction Potential

Potential for 10-20% LDV GHG reduction by improving traffic flow and individual driving behavior:

- Managing speed (35-55 MPH is optimal)
- Speed limits/enforcement (could reduce fuel use 2-4%)
- Eco-driving
- “Active” traffic management to smooth traffic flow
- Improving signal timing (could reduce 1.315 MMT CO<sub>2</sub>/yr)
- Roundabouts (multiple benefits)
- Reducing car and truck idling
- Work zone management to smooth flow
- Incident management
- Eliminating bottlenecks

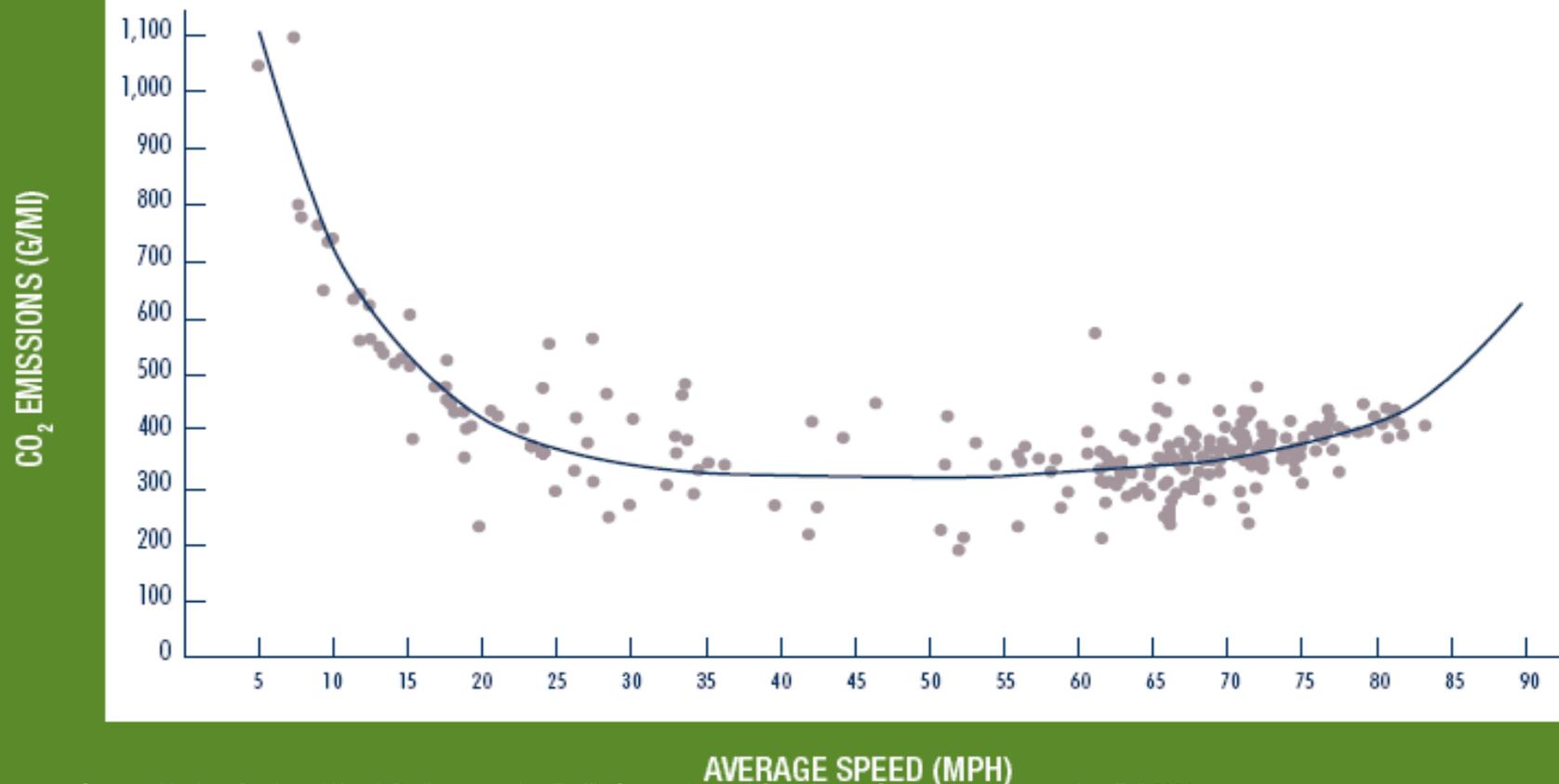
# Operations: EcoDriving

- EcoDrivers can reduce fuel and CO2 by 10-15% through smart driving and vehicle maintenance.
- 10 years of Dutch experience found 10% GHG reduction and extremely cost effective (\$6-9.50/ton reduced)
- Pilot in Denver with 300 drivers achieved 10% fuel reduction and similar GHG reduction
- Useful for HDV, MDV, and LDV drivers
- Major push in Europe as GHG strategy
- Aided by dashboard displays of real-time MPG

# Operations: EcoDriving

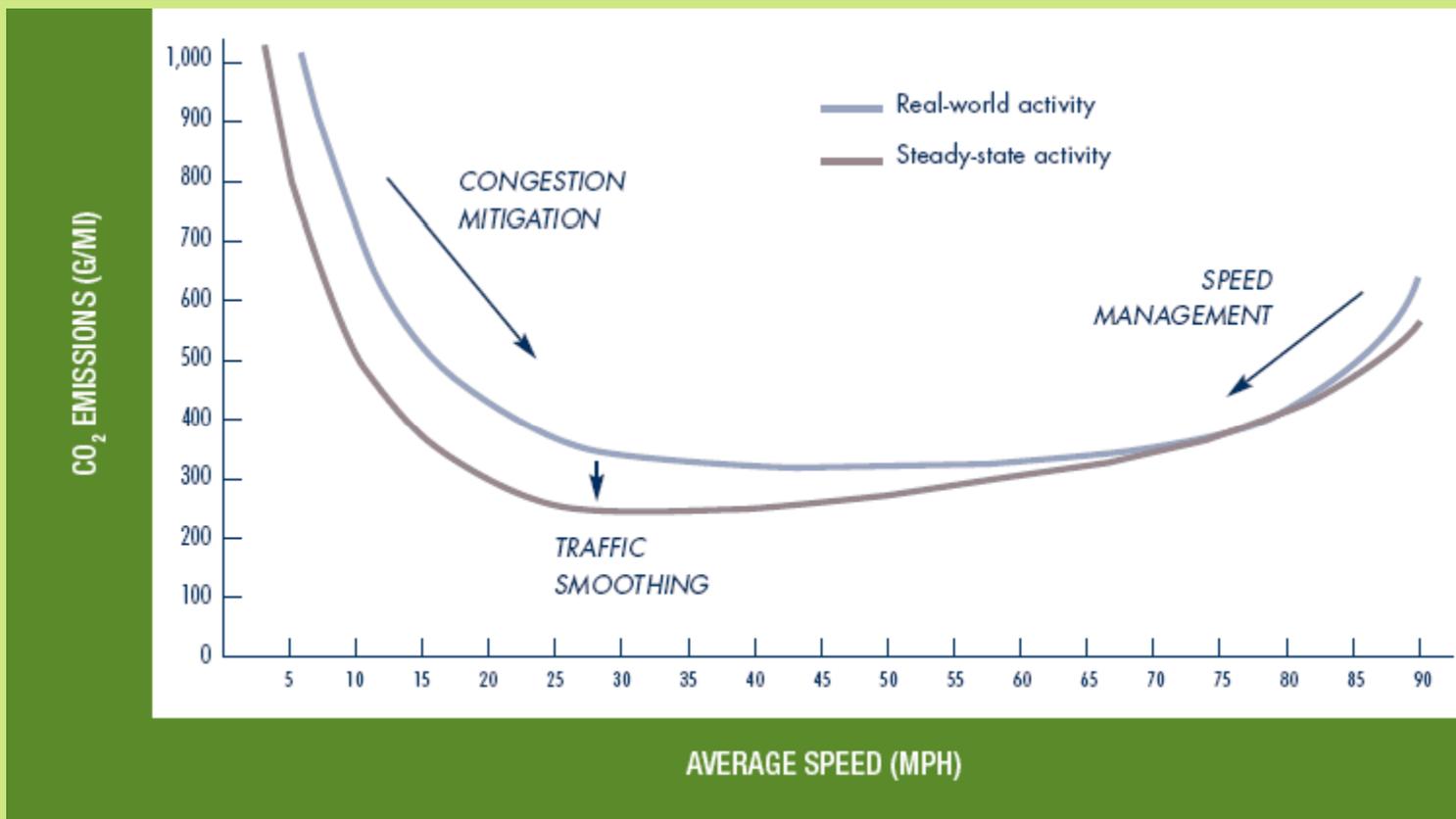
- EcoDrivingUSA™ -- nationwide effort to increase overall vehicle fuel economy and preserve the environment
- Partnership of Governors, auto industry, environmental groups
- Website:
  - [Be an EcoDriver](#)
  - [EcoCalculator](#)
  - [EcoDriving Quiz](#)
  - [Virtual Road Test](#)
  - [Is Your Community EcoDriving?](#)
  - [Educational Tools](#)
  - [News and Events](#)
  - [Join the EcoDriving Movement](#)
  - [Link this website on your blog or site](#)
- For more information contact: Seena Faqiri at 202.326.5518 or [sfaqiri@autoalliance.org](mailto:sfaqiri@autoalliance.org).

# Operations: Effect of Speed on GHG



Source: Matthew Barth and Kanok Boriboonsomsin, "Traffic Congestion and Greenhouse Gases," *Access* magazine, Fall 2009.

# Operations: Traffic Operation Strategies To Reduce CO<sub>2</sub>



Source: Matthew Barth and Kanok Boriboonsomsin, "Traffic Congestion and Greenhouse Gases," *Access* magazine, Fall 2009.

# Operations: Portland, OR Signal Timing

- Began 2002, 10-year project
- Climate Trust funded project and pays for CO2 offsets from project
- Improve signal timing on 17 major arterials
  - Optimize traffic flow
  - Reduce idling, acceleration, CO2 emissions and emissions from criteria pollutants
- Model for traffic signal offset projects

[http://www.climatetrust.org/traffic\\_signals.html](http://www.climatetrust.org/traffic_signals.html).

# Construction/Maintenance/Agency Operations: Strategies to Reduce GHG, Energy Use, and Costs

LED traffic lights

LED roadside lighting

Low carbon pavement

More durable pavements

LEED buildings

Reduced roadside mowing

Vegetation management on ROW

Solar panels/wind on ROW

Alt fuels and hybrid vehicles in DOT fleets

Alt fuel buses

# Solar Panels for Highway Lighting – Oregon DOT

- 594 solar panels produce 122,000 KWH/year to light interchange
- Avoids nearly 43 metric tons of GHG/year from normal electricity
- \$1.28 M project in operation for over a year
- PPP of OR DOT, PGE, and US Bank, using state and federal tax credits
- Could be a model for other DOTs
- ORDOT planning 2 additional projects
- [www.oregonsolarhighway.com](http://www.oregonsolarhighway.com)

## Washington State: West Coast Green (Electric) Highway

- WSDOT is using a PPP to provide “Quick Charge” stations for electric vehicles along I-5 corridor
- \$1.32 million seed funding from US DOT grant
- Target completion of EV stations: 10/31/11
- 9 stations along I-5 and SR-2, from OR border to Canadian border
- Coordination with Oregon DOT and, eventually, California
- Pooled fund study opportunity: Strategies and Best Practices to Support Commercialization of EV and Infrastructure

[www.westcoastgreenhighway.com](http://www.westcoastgreenhighway.com)

# FHWA- Carbon Sequestration Pilot Program

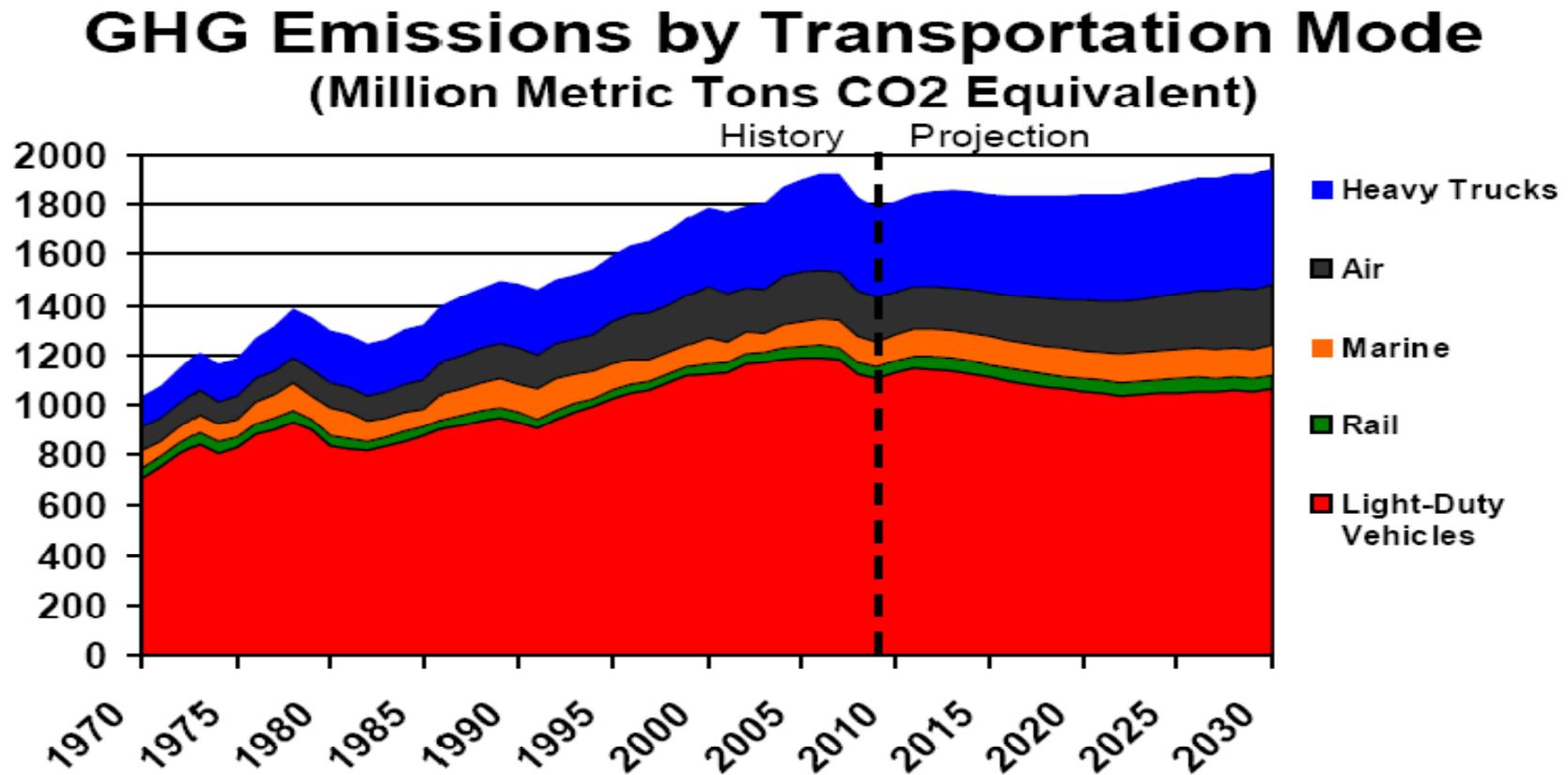
- Pilot established in 2008
- Assess how much carbon can be sequestered by native vegetation in the NHS right-of-way
- Determine feasibility of carbon credit sales by state DOTs and estimates of amount of revenue potential for state DOTs
- Final report available
  - Estimate of NHS ROW in each state
  - Highway carbon sequestration estimator
- [http://www.fhwa.dot.gov/hep/climate/carbon\\_sequestration/index.htm](http://www.fhwa.dot.gov/hep/climate/carbon_sequestration/index.htm)

# Alternative Energy Resources for State DOTs

- Missouri DOT report, January 2011
- Surveyed other state DOTs
- Evaluated cost-effectiveness of various strategies
- MoDOT recommended pursuing alt energy sources:
  - Wastewater treatment (“baffled bio-reactors”)
  - LED roadway lighting (in addition to LED traffic signals)
  - Renewable solar/wind installations
  - HVAC efficiency measures
  - Interior building lighting (including fluorescents, reflectors, and LED lamps)
  - High performance window systems
  - Energy management system
  - Re-commissioning and continuous commissioning of buildings

Source: Alternative Energy Resources for the Missouri Department of Transportation, 2011

# Freight: Truck GHG is Growing Faster than Other Transportation GHG

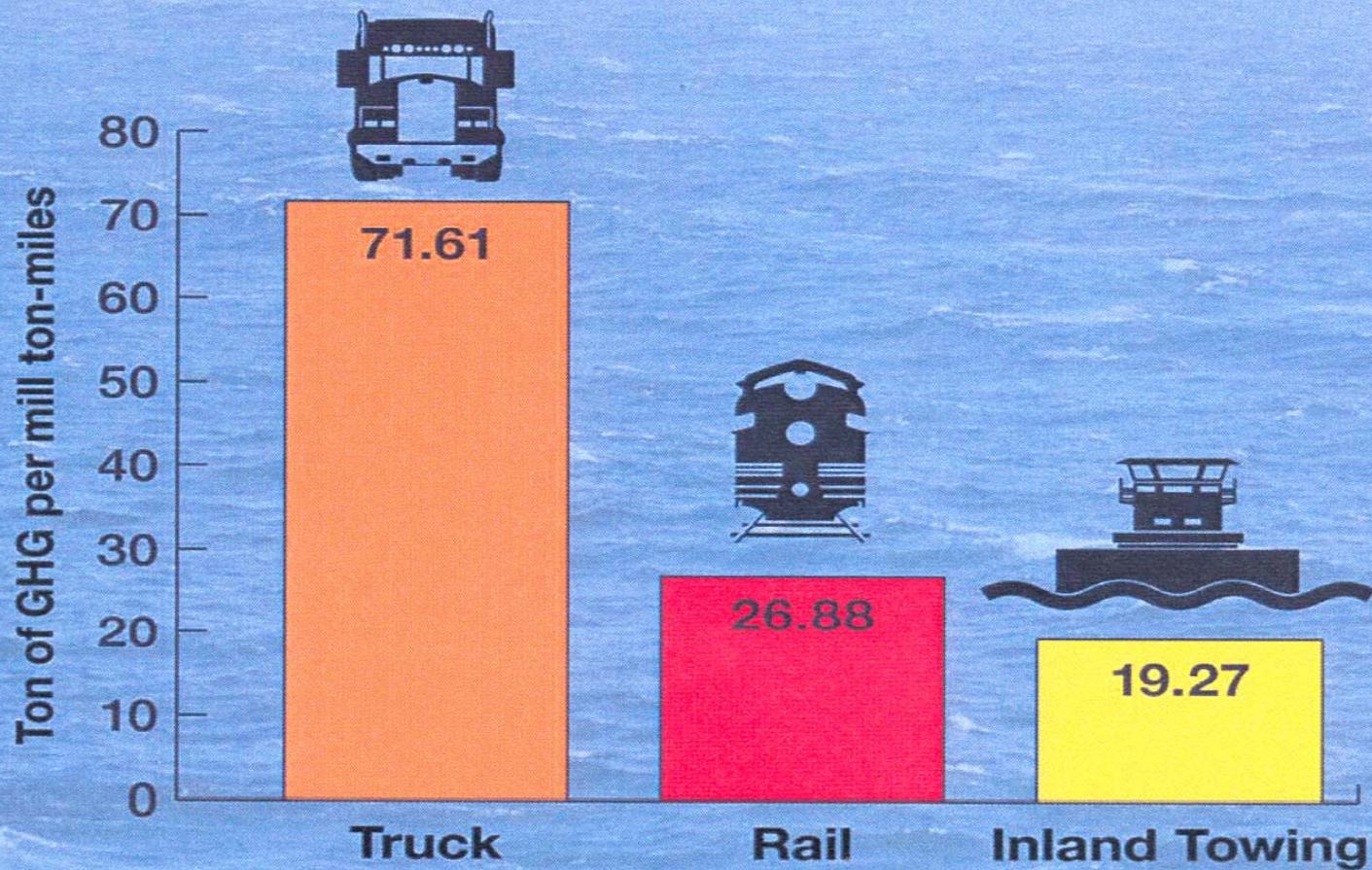


Source: History: *Transportation Energy Databook 28th Edition*  
Projection: *Annual Energy Outlook 2009 Updated Reference Case d041409a*

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# Freight: Modal GHG Comparisons

Source: Texas Transportation Institute and Center for Ports and Waterways



# Freight GHG Strategies in State Climate Action Plans

- Anti-idling programs
- Truck stop electrification
- Speed limit enforcement
- Freight villages/consolidation centers
- Feeder barge container service
- Bottleneck reduction
- Traffic flow improvements
- Pre-clearances at scale houses
- Truck driver training
- EPA SmartWay up-grade kits & loans & diesel retrofits
- Improvements to highway grade crossings
- Efficient Intermodal Facilities
- ECOdriving
- Incentives to retire older trucks
- Freight logistics improvements
- Shifting freight from truck to rail – CT shift 5% of truck traffic to rail/barge by 2020
- Hybrid power trucks
- Low-viscosity lubricants
- Single wide-base tires
- Automatic tire inflation systems
- Retrofits - PM and “Black carbon” reduction technologies 85% reduction in PM

Detailed info available in NCHRP 20-24(59), Appendix C

# “Best Practices Guidebook for GHG Reductions in Freight Transportation”

- NC State University report to US DOT, 2007
- Covers trucks, freight rail, marine, air freight, pipeline
- Identifies 33 “best practices” for reducing truck GHG (plus 26 for other freight modes)
- All 33 could reduce truck GHG in 2025 by 12% below 2003 (compared to 67% increase in truck GHG if best practices are not implemented)

# Freight: GHG, Diesel and Black Carbon

- Black carbon is a major contributor to climate change, diesel engines a primary source of BC
- Black carbon particles absorb sunlight, generate heat in the atmosphere, warms the air
- Every gallon of diesel emits 22 pounds of CO<sub>2</sub>
- CO<sub>2</sub> has long atmospheric lifetime; black carbon remains in atmosphere only a few weeks
  - Reducing black carbon provides immediate reduction in the rate of warming along with public health benefits

## Freight: Diesel Retrofits Reduce PM and Black Carbon

- Diesel truck retrofits reduce PM 99% (= 2007 EPA standards) and also reduce black carbon
- Locomotive retrofits reduce PM and black carbon; achieve over 76% PM and 25% fuel efficiency
- Cost-effective way to reduce emissions and save energy immediately
- Good CMAQ candidates
- Retrofits of construction equipment, state fleets and locomotives could be promising as state DOTs work to reduce emissions to meet air quality requirements

# Pricing: A Necessary and Powerful Tool

- Without price signals, reducing driving extremely difficult
- Pricing incentivizes 3 legs of the GHG stool
  - Purchase of lower-carbon vehicles and fuels; and
  - Lower VMT
  - Eco-driving behavior
- Many different pricing tools available: auto “feebates,” carbon/fuel prices, PAYD insurance, mileage fees, parking pricing, congestion pricing, etc.
- Pricing produces revenue to invest in alternatives

***“We know we need to get ready for a world in which energy will only be more expensive.” -- Wal-Mart***

# Strategy Comparisons

## Potential GHG reductions, cumulatively 2010-2050, compared to on-road baseline GHG

- 15,186 mmt – carbon pricing equiv to \$2.71/gallon
- 3,361 mmt – VMT fees equiv to \$2.53/gallon
- 2,428 mmt – speed limit reductions
- 2,233 mmt – PAYD auto insurance (100% coverage)
- 1,815 mmt – eco-driving by 20% of drivers
- 1,445 mmt – at least 90% of new urban development is compact, with high quality transit
- 1,241 mmt – congestion pricing fully implemented in 120 metro areas at 65 cents/mile
- 575 mmt – \$1.2 trillion transit expansion

MMT = million metric tons

Source: "Moving Cooler," 2009

# Strategy Bundling

**“Maximum” strategy bundle can reduce cumulative on-road GHG by 16% over 40 years, compared to on-road baseline:**

- Tolls imposed in 2010 at 5 cents/mile on national Interstate system
- Congestion pricing at 65 cents/mile in 120 metro areas
- \$400 permit fee to park on neighborhood streets
- \$1.2 trillion transit expansion
- Bike lanes every 1/4 mile
- New and increased parking fees
- 90% of new urban development is compact, in dense Census tracts, with high quality transit
- Heavier and longer trucks allowed (up to 139,000 lbs)
- Eight more freight strategies
- Eco-driving by 20% of drivers
- Speed limit reductions
- Top 200 bottlenecks improved to LOS

Source: “Moving Cooler,” 2009

# European View of Transport GHG Strategies (European Council of Ministers of Transport, 2006)

- “The most effective measures available include fuel taxes, vehicle and component standards, differentiated vehicle taxation, support for eco-driving and incentives for more efficient logistic organization, including point of use pricing for roads.”
- “More integrated transport and spatial planning policies might contain demand for motorized transport.”
- Mode shifts ... cannot ... form the corner-stone of effective CO2 abatement policy and the prominence given to modal shift policies is at odds with indications that most modal shift policies achieve much lower abatement levels than measures focusing on fuel efficiency.”
- “Ultimately higher cost energy sources .... will be required if there are to be further cuts in transport sector CO2 emissions.”

# Summary

Many strategies are needed to reduce transport GHG. No silver bullet. Will need full mix of strategies including:

- Maximize energy efficiency of current vehicle technology
- Decarbonize vehicles and fuels world-wide
- Adopt pricing measures to reward conservation and tech innovation
- Push “eco driving” and system/speed management
- Adopt more efficient land use
- Support carpools & vanpools, biking, walking, transit use, trip chaining, telecommuting
- Adopt low carbon, energy-conserving strategies in construction, maintenance, and agency operations
- Retrofit legacy fleets to reduce PM and black carbon
- Implement wide-ranging freight technology and logistics improvements

## IV. Federal Direction -- Legislation, Planning, NEPA



# Federal Climate/Energy Legislation

- Federal cap-and-trade legislation: unlikely for foreseeable future (but state/regional cap-and-trade programs are proceeding – Northeast and California)
- EPA authority on GHG: Congress may limit it or roll it back
- Federal energy legislation: could take many different forms (incentives for efficient vehicles, R&D, “clean energy” support, etc.)
- Political climate: volatile – uncertain outcomes
- GHG planning requirements: could be put in transportation authorization legislation – or energy bills

# Cap-and-Trade – How it Works

- Set a “cap” on total GHG emissions, and reduce it over time
  - 17 to 20% reduction by 2020
  - 83% reduction by 2050
- Issue "allowances" to emit GHGs within the cap
  - Some allowances are auctioned; others distributed free
- “Allowances” are an economic asset that can be traded
  - Receiving a free allowance is like receiving dollars
- “Offsets” can be purchased in lieu of allowances
  - An offset is obtained by paying for a reduction made by sources outside the cap, including sources in other countries
  - Example: pay to avoid deforestation in a developing country

Source: Bill Malley, Perkins Coie

# Federal Legislation: Proposed Transportation Planning Provisions

**Several bills contain these provisions – which could be added to authorization legislation or energy bills:**

- **TARGETS AND STRATEGIES:** States and TMA MPOs must develop GHG reduction targets and strategies, as part of transportation plans
- **PROGRESS:** States and TMA MPOs must “demonstrate progress in stabilizing and reducing” GHG emissions
- **METHODOLOGIES:** EPA must issue regulations on transportation GHG goals, standardized models, methodologies, and data collection
- **CERTIFICATION:** US DOT shall not certify state or MPO plans that fail to “develop, submit or publish emission reduction targets and strategies”
- **PERFORMANCE REQUIREMENTS:** US DOT must establish requirements, including performance measures, “to ensure that transportation plans... sufficiently meet the requirements.., including achieving progress towards national transportation-related GHG emissions reduction goals.”

# How should climate change be considered in NEPA ?

- Under NEPA's broad scope, some EISs/EAs are already considering climate change
- Litigation history is building
- CEQ issued draft guidance on February 18, 2010
- Comments were due: May 24, 2010
- Proposal:
  1. Evaluate proposed actions that are reasonably expected to cause direct emissions of 25,000 metric tons or more of CO<sub>2</sub>-equivalent on an annual basis, and,
  2. Consider impact of climate change on the project (e.g., effect of rising sea level on coastal bridges)
- AASHTO and FHWA provided extensive comments

# AASHTO Comments on CEQ Draft

- Planning process is the appropriate venue for developing and implementing GHG reduction strategies -- not project level
- Project-level analysis not meaningful
  - Inadequate tools
  - Disconnect between global emissions vs project-level analysis
  - Basis for 25,000 metric ton threshold?
- Major emphasis on adaptation needed in transportation policy

# GHG and NEPA: Bottom Line

It all depends...

- What emissions sources are included in total?
- How are direct and indirect emissions defined?
- Life cycle emissions?
- What analysis year (or years) are used?
- Speed assumptions?
- Fleet MPG assumptions?
- New VMT vs. VMT shifted from elsewhere?
- Many questions...

## Recent History – Court Rulings on NEPA/GHG

3 cases overturned FONSI/EA/EIS for lack of climate analysis:

- Center for Biological Diversity et al. v. NHTSA
- Mid States Coalition for Progress v. Surface Transportation Board
- Border Power Plan Working Group v. DOE

4 cases upheld lack of climate analysis or sufficiency of analysis:

- Audubon v. DOT, 2007
- Friends of the Earth v. Mosbacher, 2007
- Association of Public Agency Customers, Inc. v. Bonneville Power Admin, 1997
- Mayo Foundation v. Surface Transportation Board, 2006

# AASHTO Position on Climate Change/Energy

- Accelerate energy technology innovation to increase energy efficiency and decrease the carbon intensity of the energy supply
- Increase vehicle fuel economy and advance biofuels by:
  - Support federal R&D to de-carbonize vehicles/fuels
  - Continue to strengthen fuel economy standards
  - Promoting and providing funding for clean vehicle and fuel programs
- Reduce VMT growth to 1% per year
- Double transit ridership by 2030
- Increase intercity passenger rail

See AASHTO “Real Transportation Solutions” at <http://www.climatechange.transportation.org/>

# FHWA Climate Change Activities

## Current activities:

- **Research (Gulf Coast study, VMT, GHG mitigation strategies, GHG estimation tools, adaptation pilots)**
- **Education (webinars, workshops, Clearinghouse, Q&As, peer-to-peer exchanges)**
- **Outreach/collaboration (NOAA, USGS, USACE, CEQ, EPA, DOE, FTA, HUD, Pew Center on Climate Change, AASHTO, AMPO, etc.)**
- **Technical assistance (GHG modeling, adaptation, NEPA documentation)**
- **Preparing for final CEQ guidance on climate change in NEPA**
- **Linkages with sustainability, CSS, planning**

## Future activities:

- **Working with EPA and others on data/modeling issues**
- **Collaboration with USACE, FEMA, and Bureau of Reclamation on nonstationarity and flood risk**

# Interagency Transportation, Land Use, and Climate Change Pilot Project

- Initiative of the Federal Interagency Working Group on Transportation, Land Use, and Climate Change
- Goals
  - Climate change planning at local level
    - GHG mitigation
    - Adaptation to SLR
  - Scenario planning
  - Interagency coordination
  - Replicability
- Study Area: Cape Cod
- Workshop November 2010; Final Report/Guidebook Spring 2011

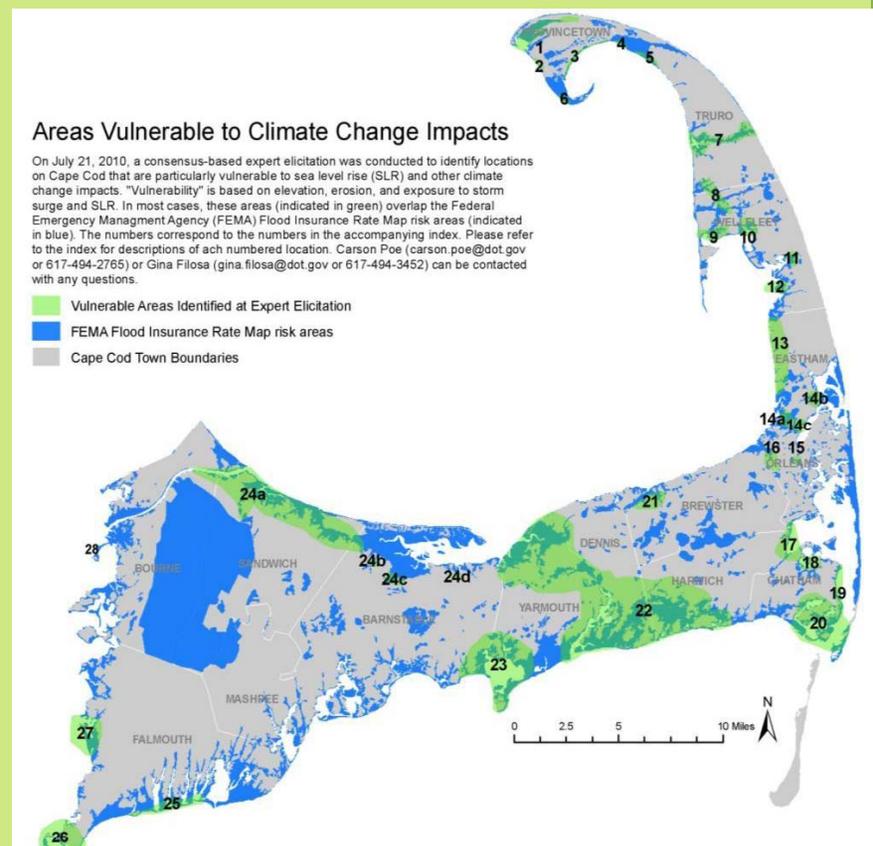
John A. Volpe National Transportation Systems Center



# Cape Cod Pilot: Climate Change in Scenario Planning

## Adaptation

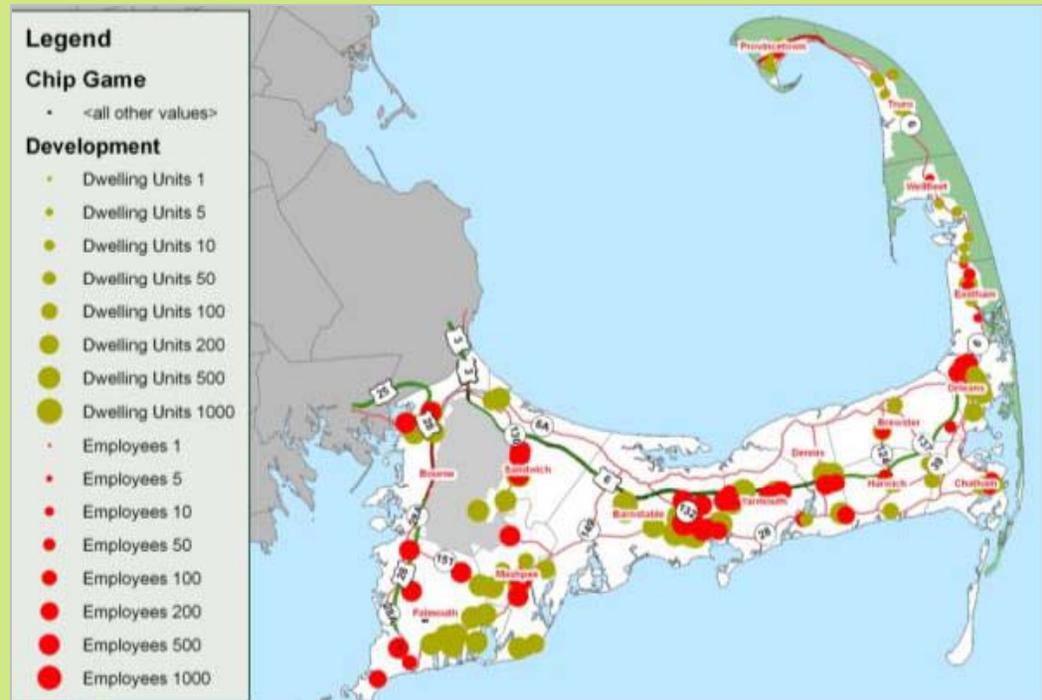
- Expert elicitation identified “Areas of Concern”
- Areas of concern incorporated into scenario development



# Cape Cod Pilot: Climate Change in Scenario Planning

## GHG Emissions Mitigation

- Scenario evaluation: change in density and transit access
- Policy strategies
  - Pricing
  - Land use
  - Ped/Bike
  - Ride- and car-sharing
  - ITS
  - Alt fuel

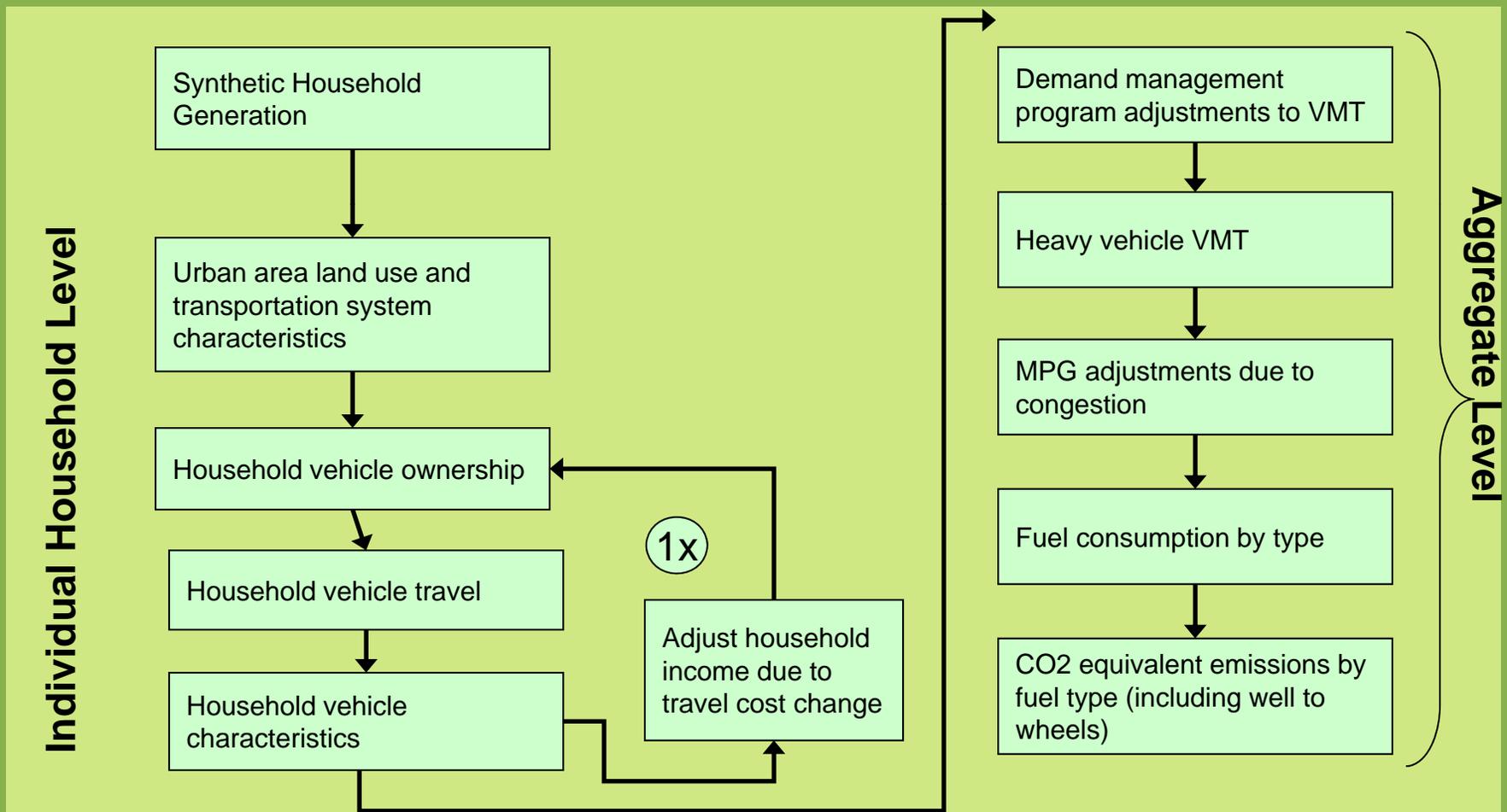


# FHWA Developing Tools for GHG Estimation

- Forecasting tools needed to estimate GHG impacts of strategies
- Most statewide and regional travel models not sensitive to GHG/TSM/TDM strategies
- Travel models need to link with GHG emission models
- FHWA is sponsoring carbon calculator and mitigation strategies guidebook
  - Enhancing GreenSTEP model for this project
  - Developing users manual

# GreenSTEP Model

(developed by Oregon DOT, enhanced by FHWA)



# GreenSTEP

Inputs

Outputs

- Demographic changes
- Urban/rural development share
- Metropolitan/other densities
- Urban form
- Transit service
- Highway capacity
- Vehicle fuel efficiency and ages
- Electric vehicles
- Pricing (fuel, carbon, VMT)
- Demand management
- Congestion effects on MPG
- Carbon content of fuels
- CO2 production from electrical power use for transportation



- VMT
- Fuel use
- Electricity use
- CO2 equivalent emissions

# Example: Using GreenSTEP to Analyze GHG Policy Options

Used GreenSTEP to analyze:

- Travel Demand Management
- Vehicle Technology: increased vehicle MPG and more EVs
- TDM and Vehicle Technology

Results:



# Guidebook: Mitigation Strategies

## System Efficiency

- Resurfacing Highways
- Speed Reductions
- Improved Construction Materials
- Signal Optimization
- Roundabouts
- Incident Management
- Road Capacity Expansion
- Bottleneck relief/routing
- Roundabouts

## Vehicle Efficiency

- Anti-idling Through Regulation
- Truck Stop Electrification
- Anti-idling Education And Campaigns
- Eco-driving, Including Maintenance And Dynamic Eco-driving
- Emission Standards
- Emissions Capping And Trading
- Encouragement Of Uptake Of Small, Low-speed Vehicles
- Feebates, Gas Guzzler Taxes And Annual Registration Fees
- Fuel Efficiency Standards
- Inspection And Maintenance (I/M) Programs, Including Roadside Emissions Monitoring
- Scrappage Programs
- Tax Credit For Cleaner Vehicles
- Transit Emission Reduction Programs Via Cleaner Fuels
- Truck Vehicle Retrofits
- Passenger Vehicle Retrofit
- Low-carbon Fuel Standard

## Travel Demand Management

- Car Sharing
- Fuel Tax Increases
- HOV Priority
- Land Use Management, Including Car-free Planning And Non-motorized Transport
- Parking Management And Parking Pricing
- Pay-as-you-drive Vehicle Insurance
- Ridesharing
- Road Pricing, Including Distance-based, Distance-based Emissions Fees, Cordonning
- TDM Education And Outreach
- Telework
- Transit Improvements
- Transit Incentives

# Summary

- Federal legislation is highly uncertain
- Energy legislation is more likely than cap-and-trade
- GHG planning requirements may be legislated
- In absence of federal requirements, states may require GHG targets and strategies
- CEQ guidance on NEPA may be issued -- meanwhile, don't ignore climate change in NEPA documents
- FHWA is focusing on research, tech assistance, outreach, tools, interagency collaboration

# VI. Climate Adaptation for Transportation



# Why Does Adaptation Matter?



# Why Does Adaptation Matter?



Source: abc.net.au

# Why Transportation Agencies Should Plan for Adaptation

- Sea level rise & storm surges
  - Destruction of bridges
  - Erosion & permanent inundation of roads
  - Disruption of evacuation routes & road network
  - Bridge clearance limitations
- Other types of impacts
  - Increased flooding
  - Pavement rutting and rail buckling
  - Landslides
  - Increased maintenance



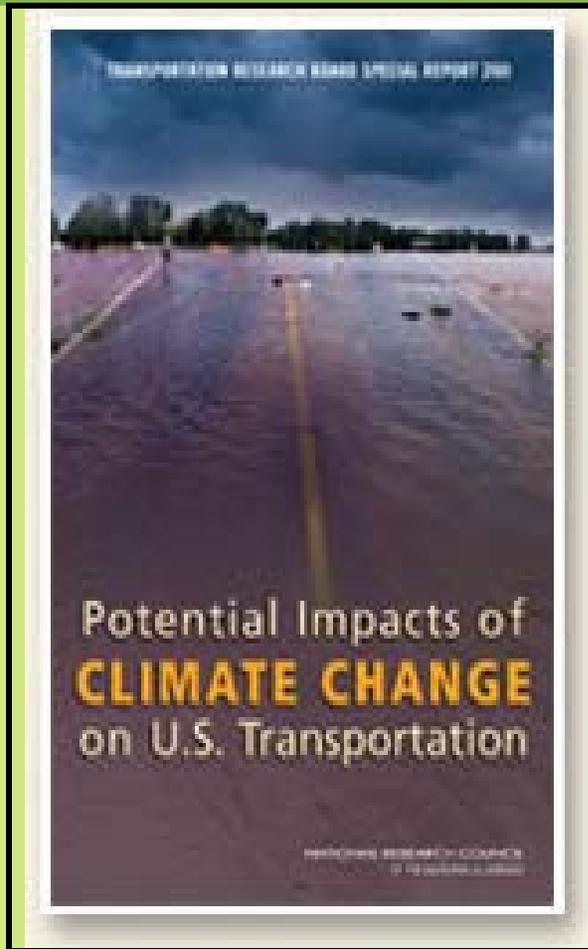
Source: <http://mceer.buffalo.edu/research/Reconnaissance/Katrina8-28-05/05BiloxiBay1/09lg.jpg>

# Definition of Climate Adaptation

*“Actions by individuals or systems to **avoid, withstand, or take advantage of** current and projected climate changes and impacts. Adaptation **decreases a system’s vulnerability, or increases its resilience to impacts.**”*

*--Pew Center on Climate Change*

# U.S. -- TRB Special Report 290



## Potential Impact of Climate Change on U.S. Transportation (TRB Special Report 290)

**Transportation Research Board  
Division on Earth & Life Studies  
National Research Council**

# U.S. -- TRB Special Report 290

- Climate change will affect every mode of transportation and every region in the United States, and the challenges to infrastructure providers will be new and often unfamiliar.
- State and local governments and private infrastructure providers will need to incorporate adjustments for climate change into long-term capital improvement plans, facility designs, maintenance practices, operations, and emergency response plans.

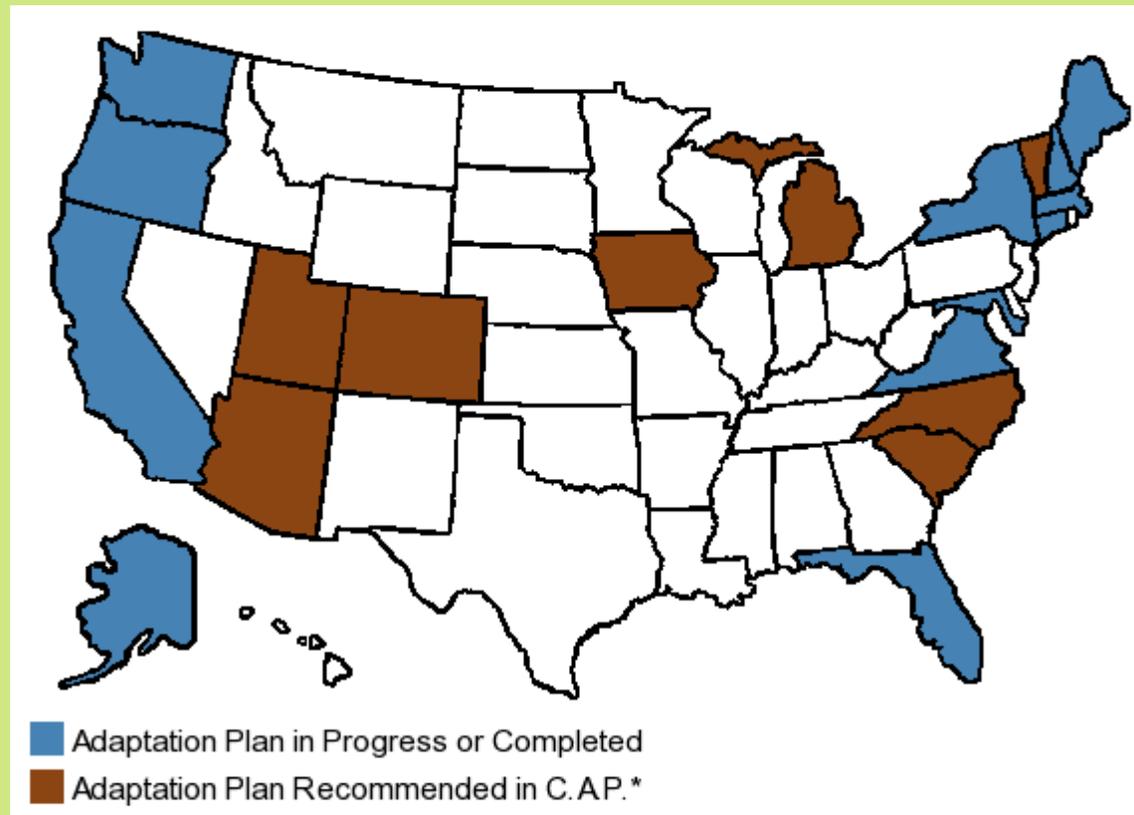
# U.S. -- TRB Special Report 290

- Design standards will need to be re-evaluated and new standards developed as progress is made in understanding future climate conditions and the options for addressing them.
- Transportation planners will need to consider climate change and its effects on infrastructure investments. Planning timeframes may need to extend beyond the next 20 or 30 years.
- Institutional arrangements for transportation planning and operations will need to be changed to incorporate cross jurisdictional and regional cooperation.

# U.S. -- States Focusing on Climate Adaptation

- Coastal states most concerned
  - Concern growing in noncoastal states
  - Multi-sector reviews of vulnerability
  - Often led by resource agencies
  - State DOT role -- significant to minor
  - Still early on the learning curve
- Connecticut
  - Massachusetts
  - New York
  - Pennsylvania
  - Maryland
  - Virginia
  - North Carolina
  - Florida
  - Michigan
  - Colorado
  - Washington
  - Oregon
  - California
  - Alaska
  - Hawaii
  - ... and more....

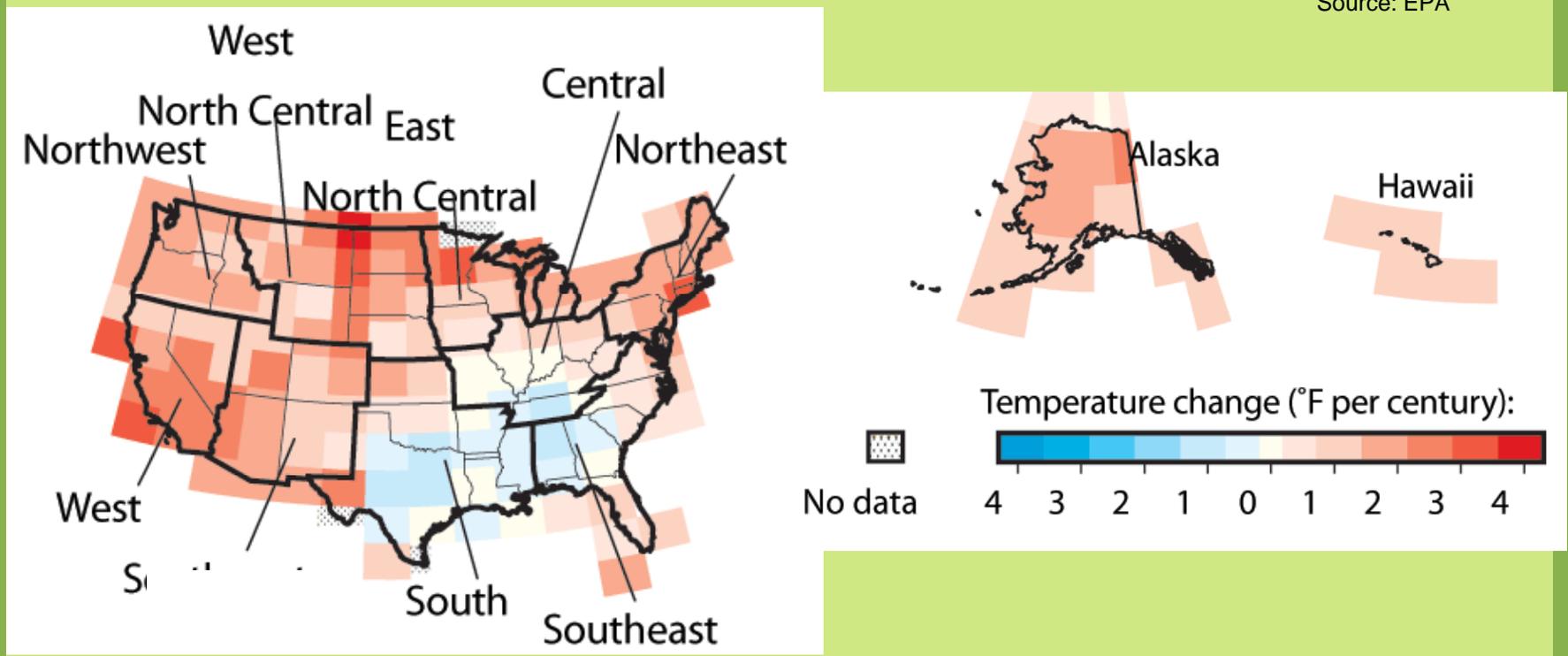
# U.S. -- State Climate Adaptation Plans



# U.S. -- Recent Temperature Changes

## Annual Mean Temperature Anomalies, 1901-2005

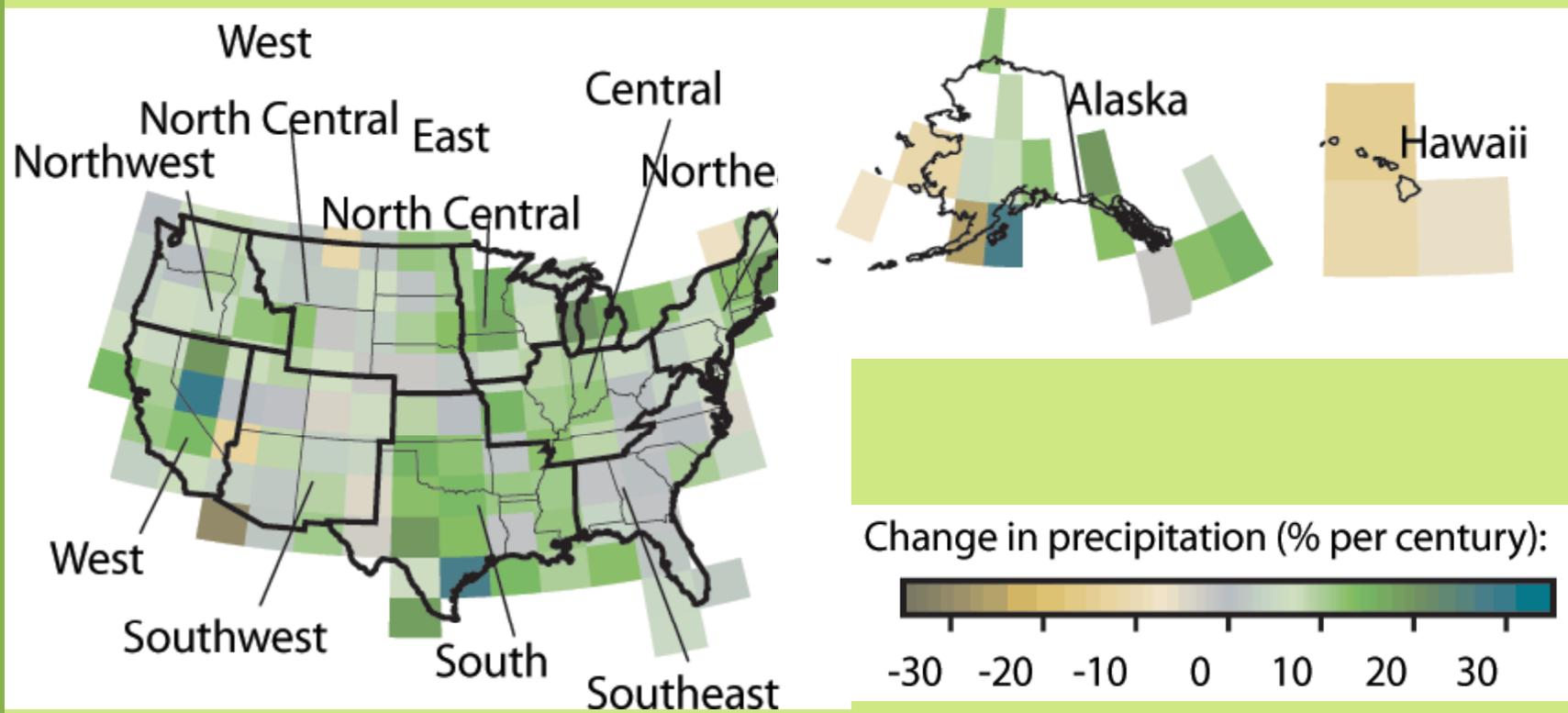
Source: EPA



# U.S. -- Recent Precipitation Changes

## Annual Precipitation Trends, 1901-2005

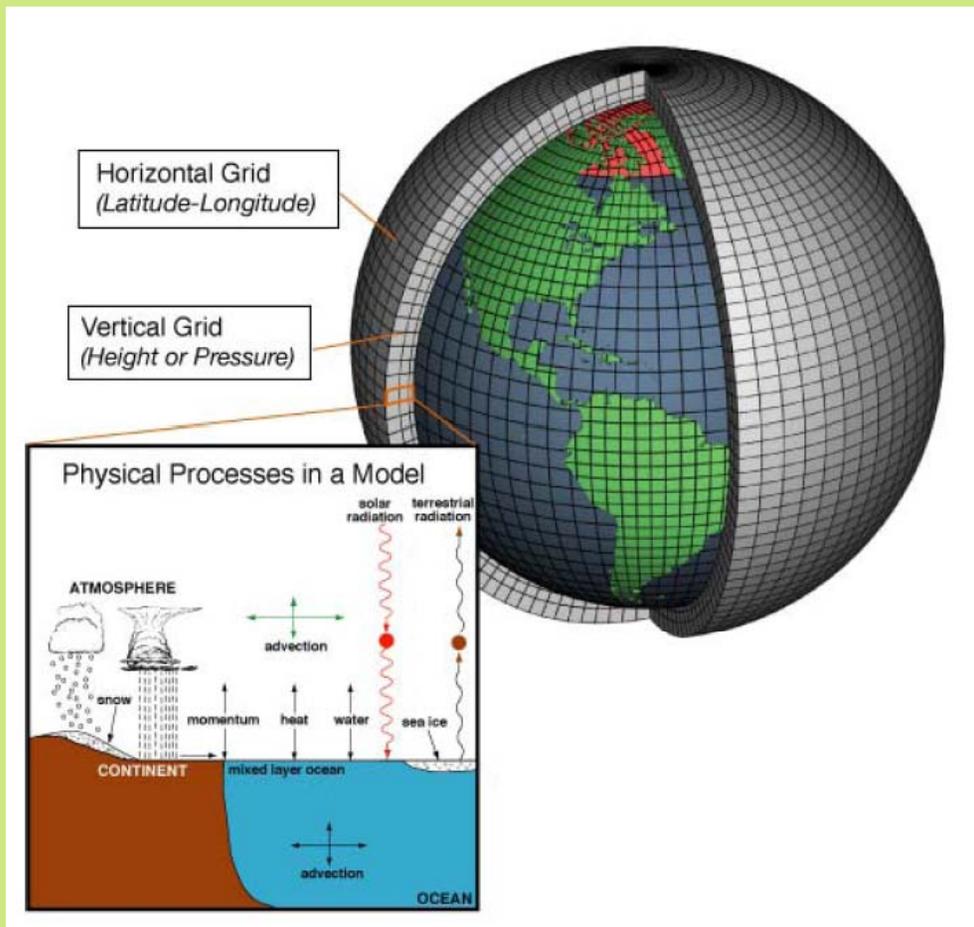
Source: EPA



# Global Climate Model Basics

- Global Climate Model (GCM): a set of computer codes that solve mathematical equations which emulate the Earth's climate system
- GCMs operate in time steps
  - Projections made for each hour
  - Hourly values compiled to form climate projections
- Calculations performed at grid cell scale

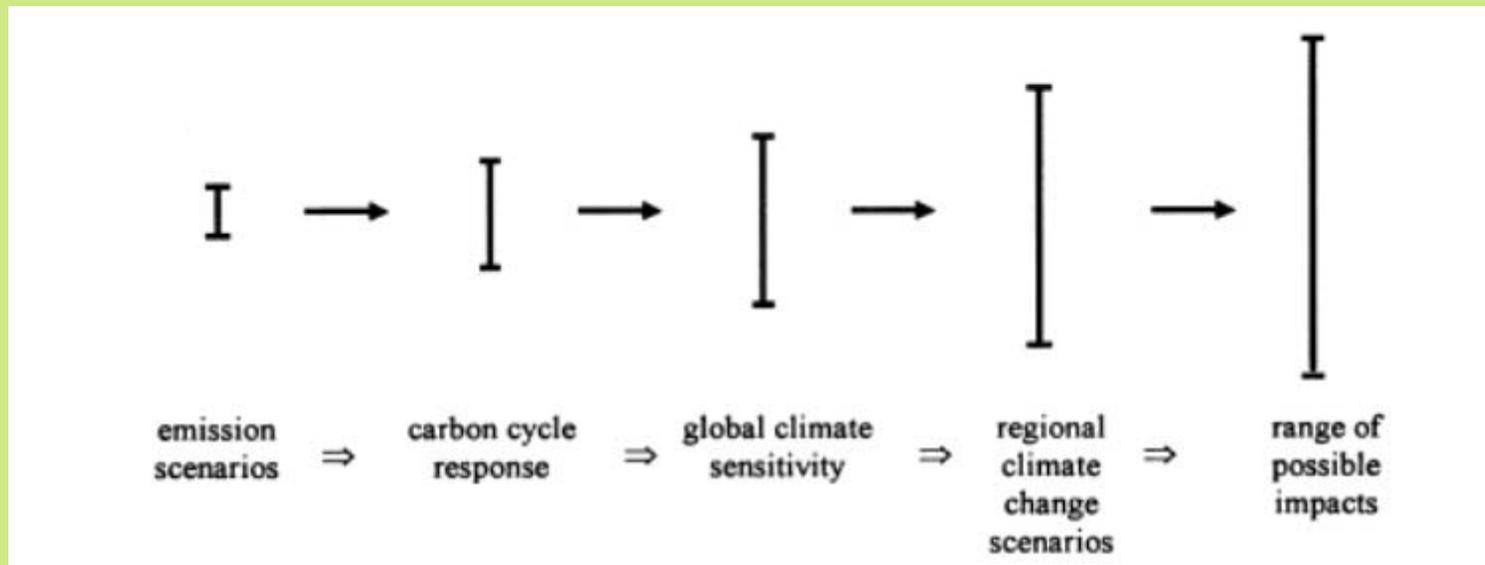
# Global Climate Model Basics



Source: NOAA

# Global Climate Model Uncertainty

- Uncertainty is substantial in climate modeling and builds each step of the way



Source: *Climate Change Policy*, edited by Stephen H. Schneider, Armin Rosencranz, and John O. Niles.

# Global Climate Model Uncertainty

(continued)

- Uncertainty in precisely how all aspects of the climate system work together
  - Result: Different models use different assumptions and produce somewhat different outputs even if given the same input data
- Some major global climate patterns have not yet been accurately modeled (e.g. El Nino)
- Uncertain climate system feedback loops
  - Methane releases from melting permafrost and arctic lake & sea bottoms?
  - Increased precipitation and snowpack in Siberia causing colder winters in the Eastern U.S. and Europe?

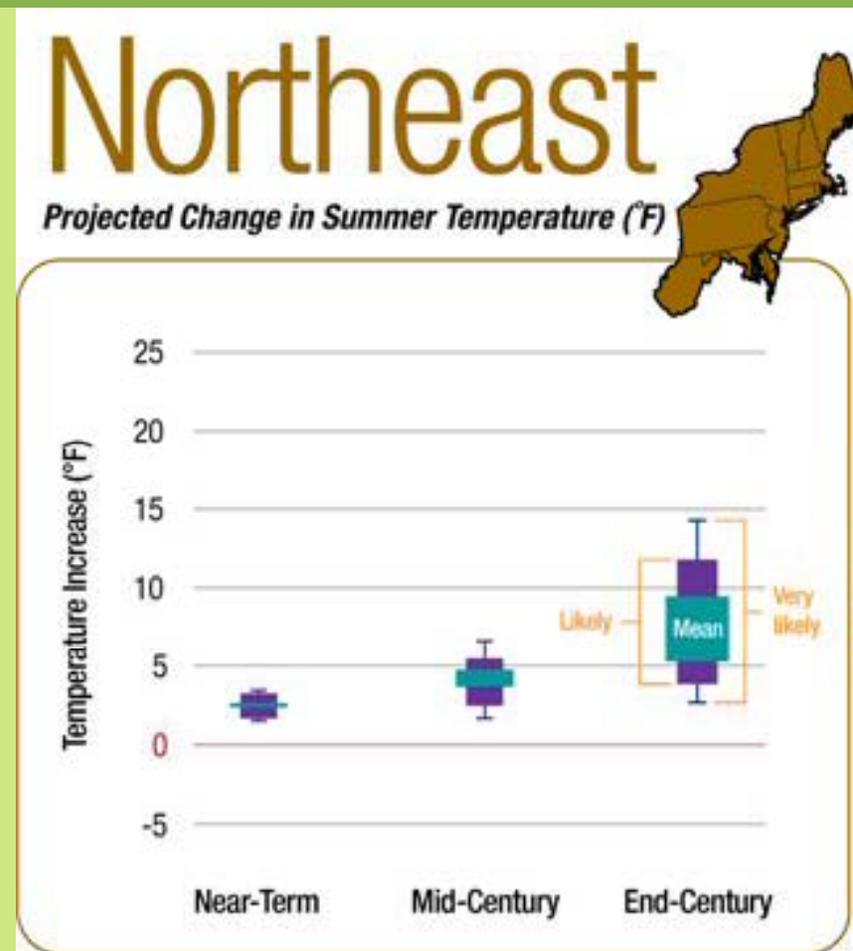
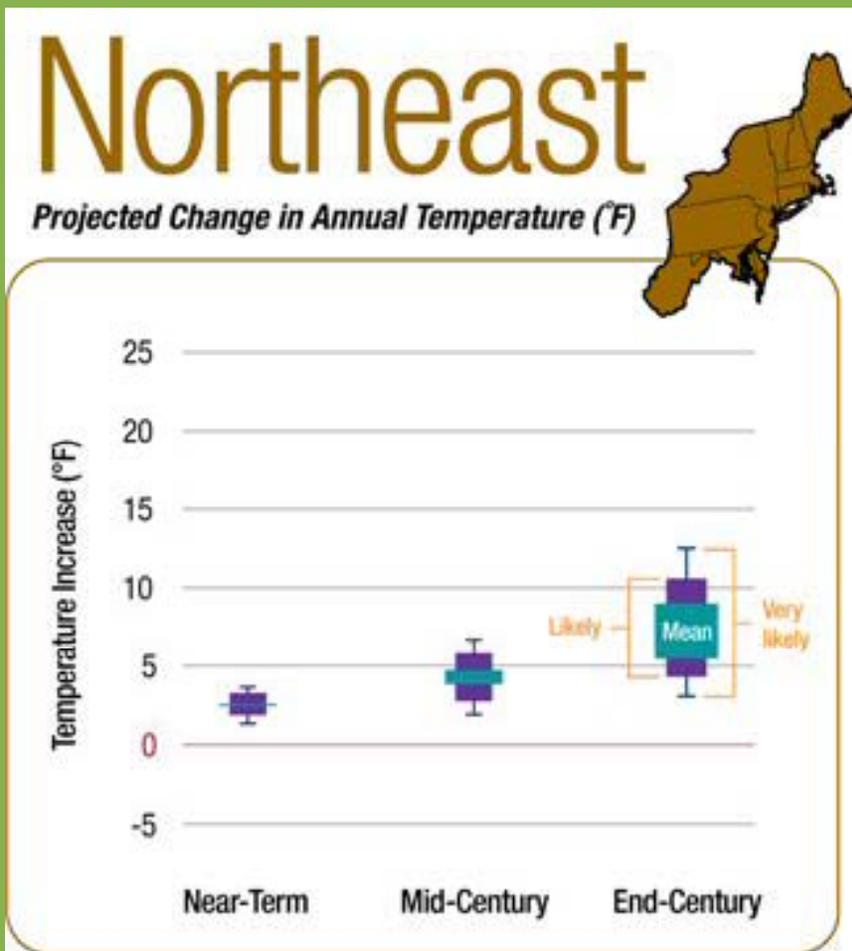
# FHWA Climate Change Effects Report

- 9 regions (6 continental US, Alaska, Hawaii, Caribbean)
- Projected *changes* by region:
  - Annual, Seasonal Temperature (change in °F)
  - Seasonal Precipitation (% change)
  - Where information exists:
    - Sea level rise
    - Storm activity
- Regional focus, also includes information at the international, national and State and local levels (as available)
- Available on FHWA climate change website

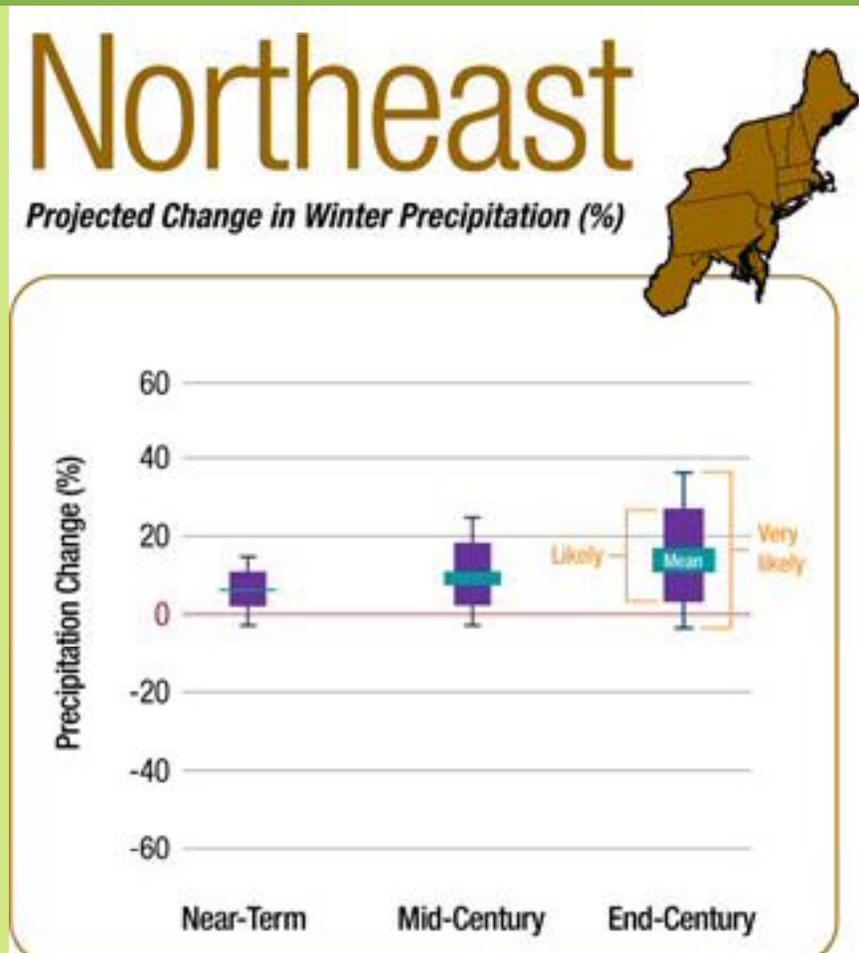
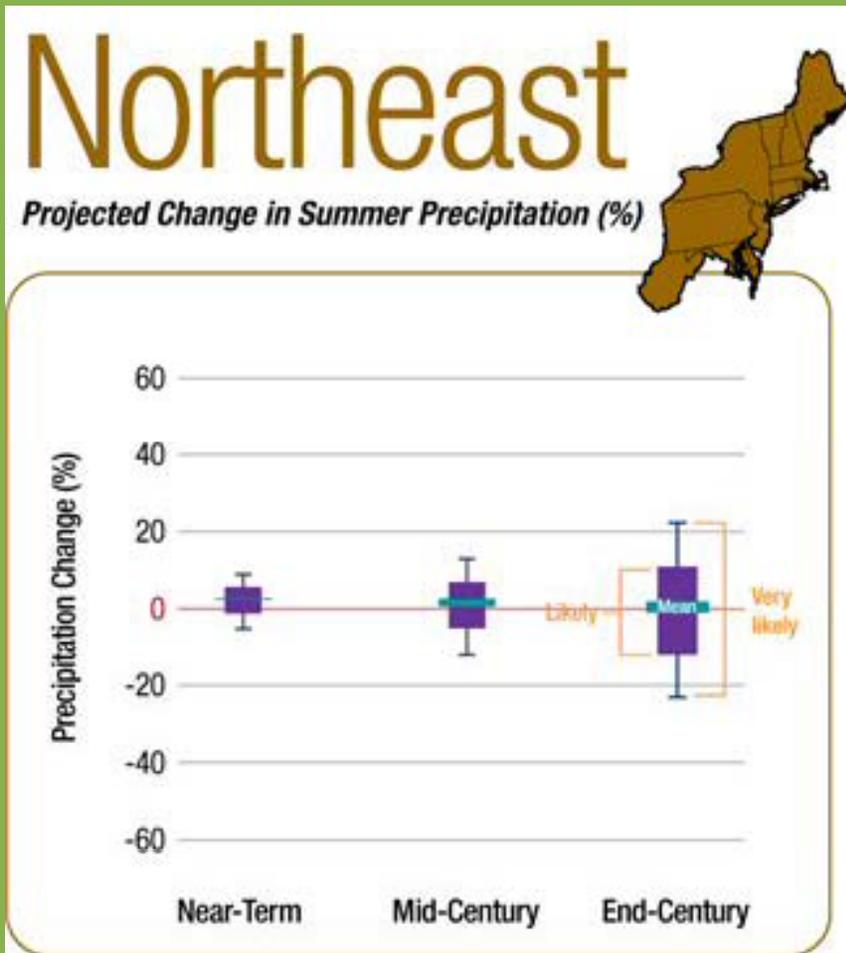
# FHWA Climate Change Effects Report

- Provides information on climate change projections for transportation decision makers
- Summarizes current science
  - Science is progressing, expect information to improve over next 3-5 years
- Short, medium and long term
- Based on low and high GHG emission scenarios
- Assistance from Climate experts -- NOAA, USGS, DOE

# FHWA Climate Change Effects Report



# FHWA Climate Change Effects Report

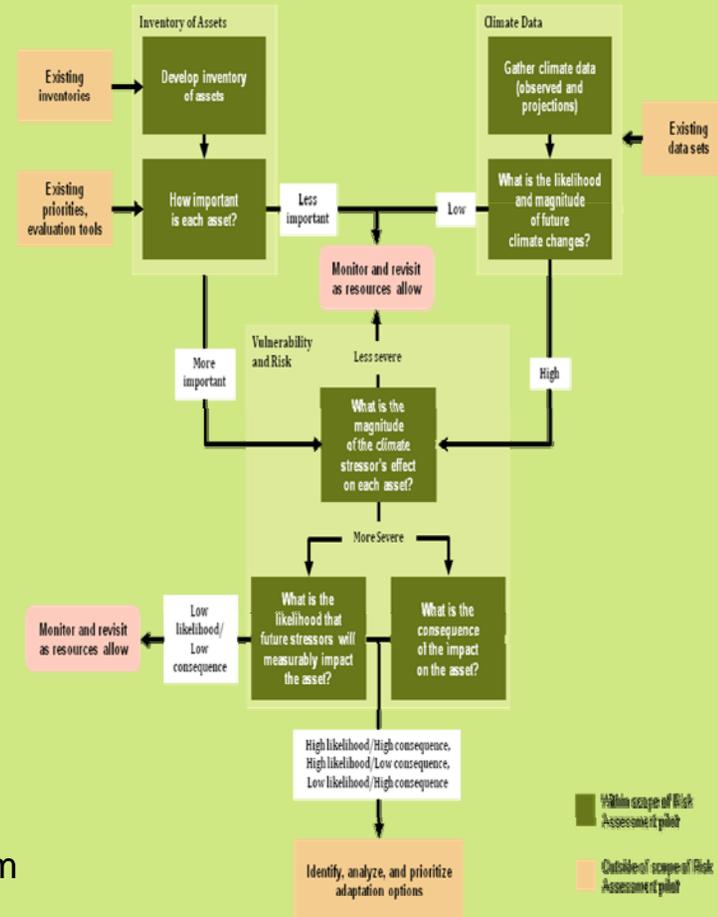


# FHWA Climate Vulnerability/Risk Assessment Model

- Goal: Help transportation decision makers identify assets:
  - most exposed to the threats from climate change;  
and/or
  - could result in the most serious consequences as a result of those threats
- Draft model completed in 2010
- 5 pilots now underway to test model: WS, NJ, HI, VA, CA
- Finalize model for wider use

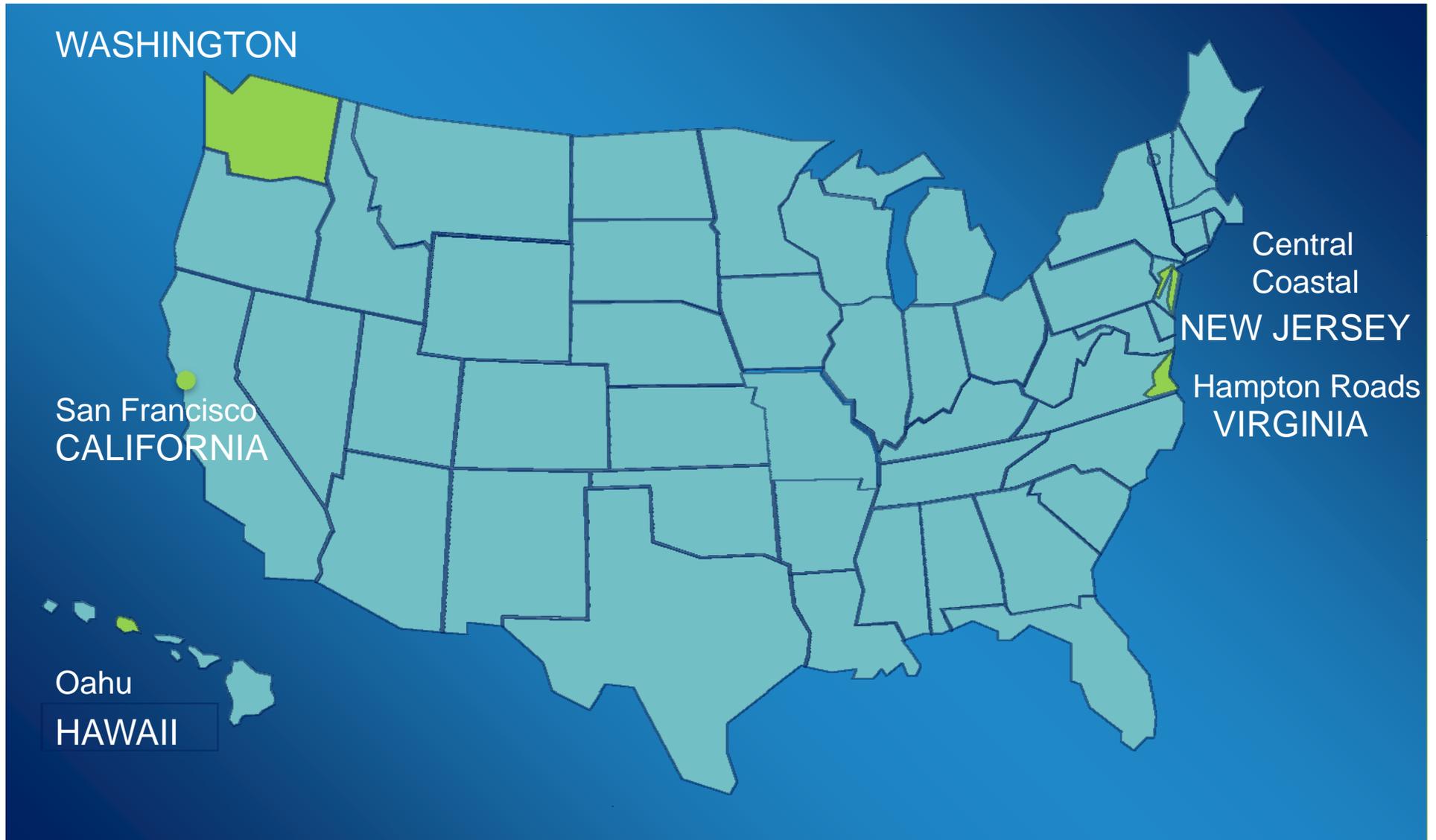
# FHWA Climate Vulnerability/Risk Assessment Model

1. Develop inventory of infrastructure assets
2. Gather climate data
3. Assess risk and vulnerability of assets to projected climate change
4. Analyze, prioritize adaptation options
5. Monitor and revisit



[www.fhwa.dot.gov/hep/climate/conceptual\\_model62410.htm](http://www.fhwa.dot.gov/hep/climate/conceptual_model62410.htm)

# Climate Change Vulnerability and Risk Assessment Pilot Locations

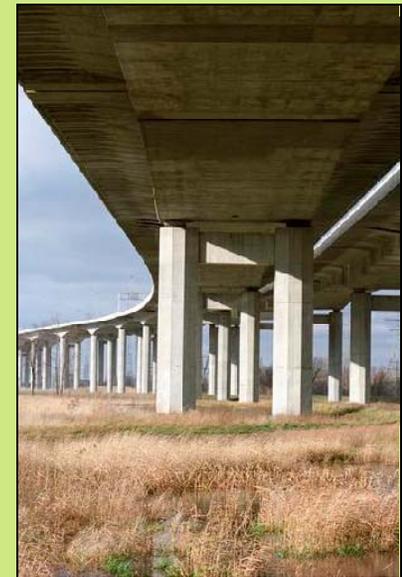


# Implications for Environmental Reviews

- In NEPA process, sponsor must consider project vulnerability to future climate change
- USACE may raise new issues in wetland permitting due to climate impacts
- USCG may raise climate impacts in bridge permitting
- DOI may raise issues & require more analysis for ESA, due to uncertainty of climate impacts on species

# More Intense Storms: Implications for Facilities Design

- Changes in bridge height, foundation and superstructure
- Larger hydraulic openings for bridges over waterways
- Changes in suspended and cable-stay bridges to withstand more severe wind and turbulence
- Changes in materials specifications
- Changes in culvert design, capacity, and location
- Changes in slope design
- Changes in pavement drainage systems
- Heavier and lengthier armoring of river and stream banks and ditches to prevent erosion
- Greater pavement crowns to move runoff off pavement quicker



# More Intense Storms: Implications for Facilities Design (cont.)

- Design additional in-system detention to meter runoff outflow
- Eliminate bridge design elements that could make a bridge scour critical
  - i.e. piers in the river, spread footings, use more sheet piling left in place
- Design terraced vegetated slopes using a variety of plant species
- Design more robust pavement markings that can be seen during wet/night conditions
- Provide larger capacity pumps/pump stations for below grade freeways to prevent flooding

# More Intense Storms: Implications for Construction

Overall Strategy: protect motorists, workers, and the environment from hazards created in work zone by strong weather events

- Stronger specifications for protection of work under construction
- Stronger specifications that require contractor response plans for work zone impacted by high intensity storms



# Hotter Drier Summers: Implications for Design

- Overall strategy: Design tougher, more resilient, lower maintenance roadways, bridges, facilities and roadsides
- Design lower maintenance bridge expansion
- Design seed/vegetation mixtures that create a denser, deep-rooted vegetation mat that is more erosion resistant
- Eliminate monoculture roadside vegetation designs that may not survive extended drought periods or invasive species attack
- Ensure all roadside building designs are LEED certified or modified to be energy efficient

# Hotter, Drier Summers: Implications for Construction

Strategy: Protect work in progress from effects of higher temperatures for both short term and long term durability

- Encourage night/cooler weather work to prevent damage such as slab curling, premature cracking, loss of air entrainment in concrete pavements, rutting and flushing in asphalt pavements
- Stronger specifications for Dust Control/Wind Erosion
- Worker Safety during extreme heat periods must be addressed
- More closely monitor moisture in aggregate piles
- Incorporate materials whose performance are less variable in weather extremes
- Modify vegetation planting periods to ensure optimal growth and survival

# Implications for Maintenance/Operations

- Pavement rutting and rail buckling
- Longer construction season
- Closures and detours due to rock slides, soil erosion, flooding
- Speed reductions
- Flooding of culverts
- Change in weight restrictions
- More grass cutting/less snow plowing
- Work crew limitations during severe heat periods



# More Intense Storms: Implications for System Operations and Maintenance

- Create detailed economic model that incorporates societal costs of delayed or inappropriate response to winter storms
- Emphasize routine maintenance such as ditch cleanout, drainage structure cleanout to avoid failure during an intense rainfall event
- Monitor and clean, as needed, bike lanes, shoulders, and non motorized trails in vertical curve sag areas.
- Remove silt, gravel, and other debris that present hazards to bicyclists and may accumulate after plowing and heavy rainfall events



# More Intense Storms: Implications for System Operations and Maintenance

More Intense Storms - Strategy: Use best practices to keep transportation infrastructure operating as safely and efficiently as possible during increased frequency and more intense winter storms

- Increased deployment and use of Roadway Weather Information Stations to plan and respond to winter storms
- Keep motorists informed of hazardous conditions/roadway closures
- Develop strong contingency response plans for extraordinary winter storms

Source: Michigan DOT

# Hotter, Drier Summers: Implications for System Operation and Maintenance

Overall Strategy: Use best practices to keep roadways and roadsides in a safe and aesthetically acceptable condition during the heat of summer

- Manage vegetation appropriately during drought periods near roadsides susceptible to wildfires
- Monitor and be ready to respond quickly to pavement “tenting” due to excessive heat periods
- Monitor health of vegetation in right of way that may be stressed due to extreme weather or invasive/new northerly migrating insect species and remove and replace as necessary

Source: Michigan DOT

# Final Words – Monitor and Reassess

- Maintain strong asset management system
- Investigate performance of adapted vs. non-adapted infrastructure during extreme weather events
  - Track any estimated cost savings (or lack thereof) from the adaptation actions
- Keep appraised of the latest climate projections for your region and reassess risks if they change

# Summary

- **All modes** of transportation threatened
- **Affects all transportation functions** – planning, programming, environment, location, design, engineering, construction, operations, emergency planning – and budgeting
- **Low lying coastal areas especially vulnerable**
- **Risk assessment and prioritization** is key
- Transportation planners need to **be aware of and adapt to climate change impacts** on our transportation infrastructure
- Looming in future: where **not to build or re-invest?**

# VI. Massachusetts Clean Energy Plan & MassDOT's Climate/Energy Plans and Activities





June 14, 2011

Massachusetts Department of Transportation



# Climate Change Adaptation Presentation by Kevin Walsh of MassDOT



The image shows the Massachusetts State House, a grand neoclassical building with a prominent golden dome. The building is constructed of red brick with white columns and arches. An American flag flies on a tall pole to the left. The sky is clear and blue. The text "July 2008 Global Warming Solutions Act Signed" is overlaid in green on the center of the image.

**July 2008 Global Warming  
Solutions Act Signed**

# Topic Areas

- Local Economy
- Natural Resources and Habitat
- Human Health and Welfare
- **Key Infrastructure**
- Coastal Zone and Oceans

# Roadway Sector Group

- Highway Design
- Environmental
- Hydraulics

Consulted with the

- Chief Engineer's Office
- Bridge
- Administrator



# Potential Adaptation Concerns

- Sea Level Rise
- Increased Temperature
- Changing Precipitation
- Extreme Weather Events

# Key Infrastructure-Roadway Sector Ongoing Adaptation Strategies

- Monitor bridges through the Bridge Inspection program and Scour program
- Projects addressed on a case-by-case basis where flooding issues have been identified.
- Bridge projects with low-chord below 10-year flood are subject to more intense review.

# Adaptation Strategies

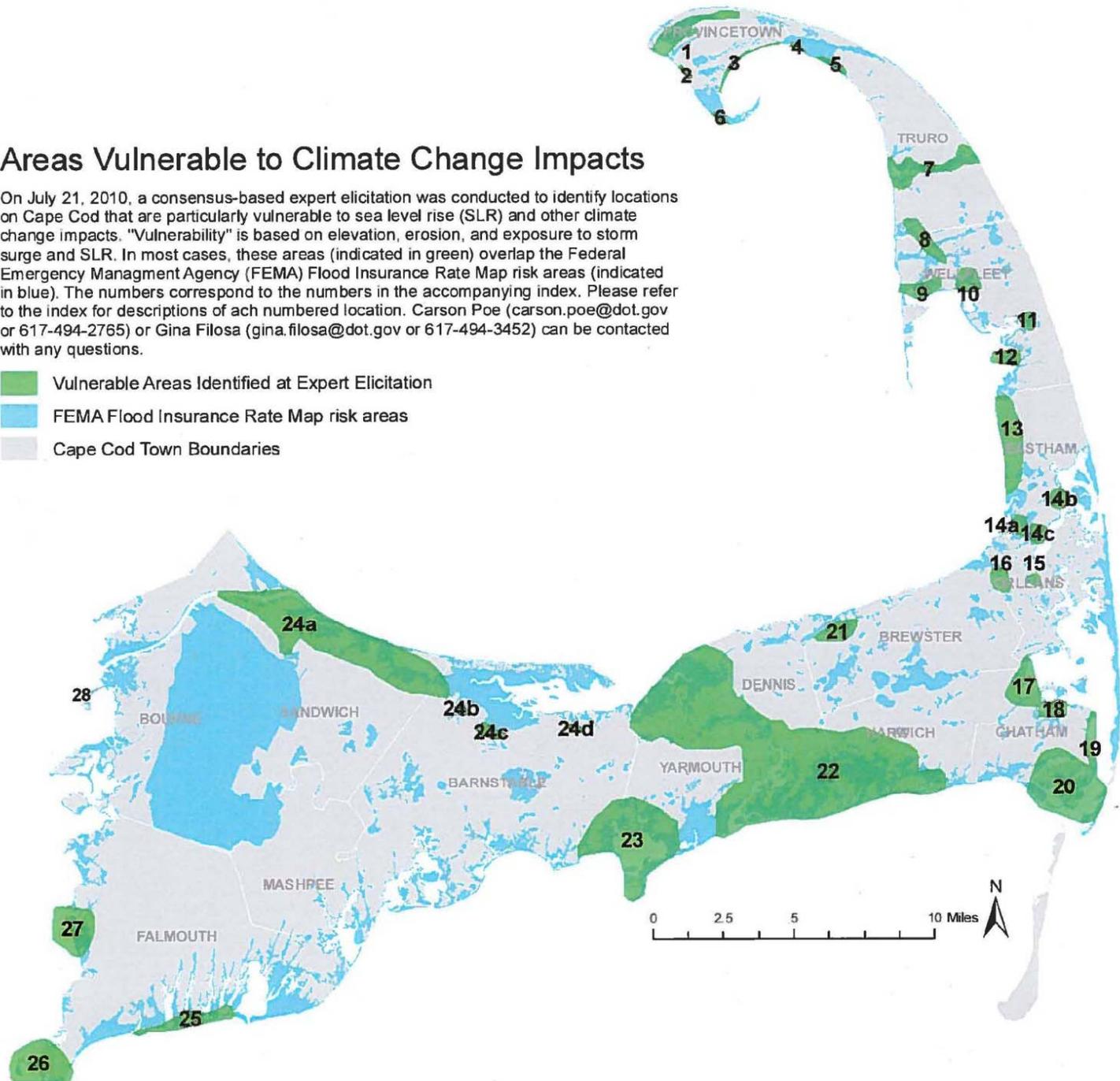
## Mid-Term (2-5 Years) – Coastal

- Mapping – Using Light Detection and Ranging (LIDAR) survey to map coastal assets
- Develop GIS based asset inventory
- Perform Sea Level Rise Vulnerability Assessment
- Identify & Prioritize Critical Transportation Assets
- Develop design requirements on a project-by-project and priority basis

## Areas Vulnerable to Climate Change Impacts

On July 21, 2010, a consensus-based expert elicitation was conducted to identify locations on Cape Cod that are particularly vulnerable to sea level rise (SLR) and other climate change impacts. "Vulnerability" is based on elevation, erosion, and exposure to storm surge and SLR. In most cases, these areas (indicated in green) overlap the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map risk areas (indicated in blue). The numbers correspond to the numbers in the accompanying index. Please refer to the index for descriptions of each numbered location. Carson Poe ([carson.poe@dot.gov](mailto:carson.poe@dot.gov) or 617-494-2765) or Gina Filosa ([gina.filosa@dot.gov](mailto:gina.filosa@dot.gov) or 617-494-3452) can be contacted with any questions.

- Vulnerable Areas Identified at Expert Elicitation
- FEMA Flood Insurance Rate Map risk areas
- Cape Cod Town Boundaries





# Adaptation Strategies

## Mid-Term (2-5 Years) – Inland Areas

- Update Peak Flood Flow Frequency Regional Regression Equations to produce more accurate flood level predictions
  - 40-year old data
- Identify and Prioritize inland vulnerable assets
- Develop design requirements on a project by project basis
  - Increased Clearances
  - Rip-Rap, Scour Protection
  - Relocation – Most Extreme





## Design of Bridges and Culverts for Wildlife Passage at Freshwater Streams

December 2010



# Key Infrastructure-Roadway Sector Adaptation Strategies

## Mid Term (5-20 years) Strategies

- Development and Implementation of New Design Standards
- Progressively adapt standards as:
  - more data becomes available
  - climate change impacts are realized
  - Climate change events are predicted with greater accuracy
  - universal models are developed

# Key Infrastructure-Roadway Sector Adaptation Strategies

## **Long Term (20+ years) Strategies**

- Continue to progressively adapt engineering standards with FHWA and AASHTO

# Next Steps

- Educate Stakeholders so they understand the consequences of no action.
- Work closely with Stakeholders to develop streamlined strategies to facilitate adaptation



# New Commuter Boat?



**MassDOT:**

**Advancing Sustainability and  
Livability Through  
Collaborative Leadership and  
Innovation**

**Massachusetts Department of Transportation**

**Catherine Cagle, RLA, LEED AP**

**June 14, 2011**

# Massachusetts Department of Transportation (MassDOT)

1. Leadership, Mission & Organization
2. Sustainability & Livability Policy Framework
  - Global Warming Solutions Act 2008
  - GreenDOT
  - Healthy Transportation Compact
3. Short Term Wins & Innovations
4. Key Take Aways

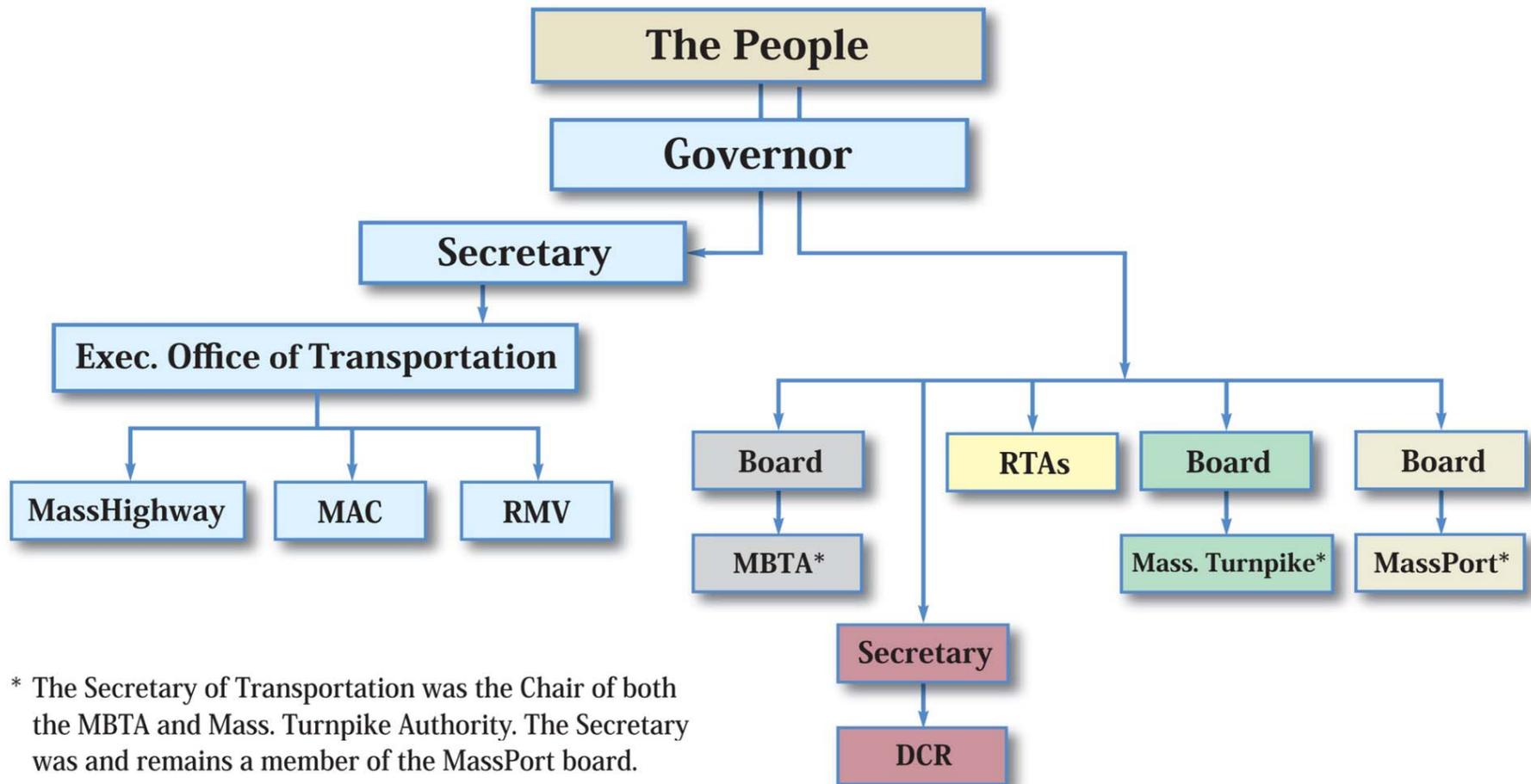
# Leadership

- In 2009, the legislature abolished our traditional agencies in favor of one transportation organization focused on customer service and safety.
- MassDOT was created on November 1, 2009
- We aspire to lead the nation in transportation excellence and be the 'greenest' DOT.

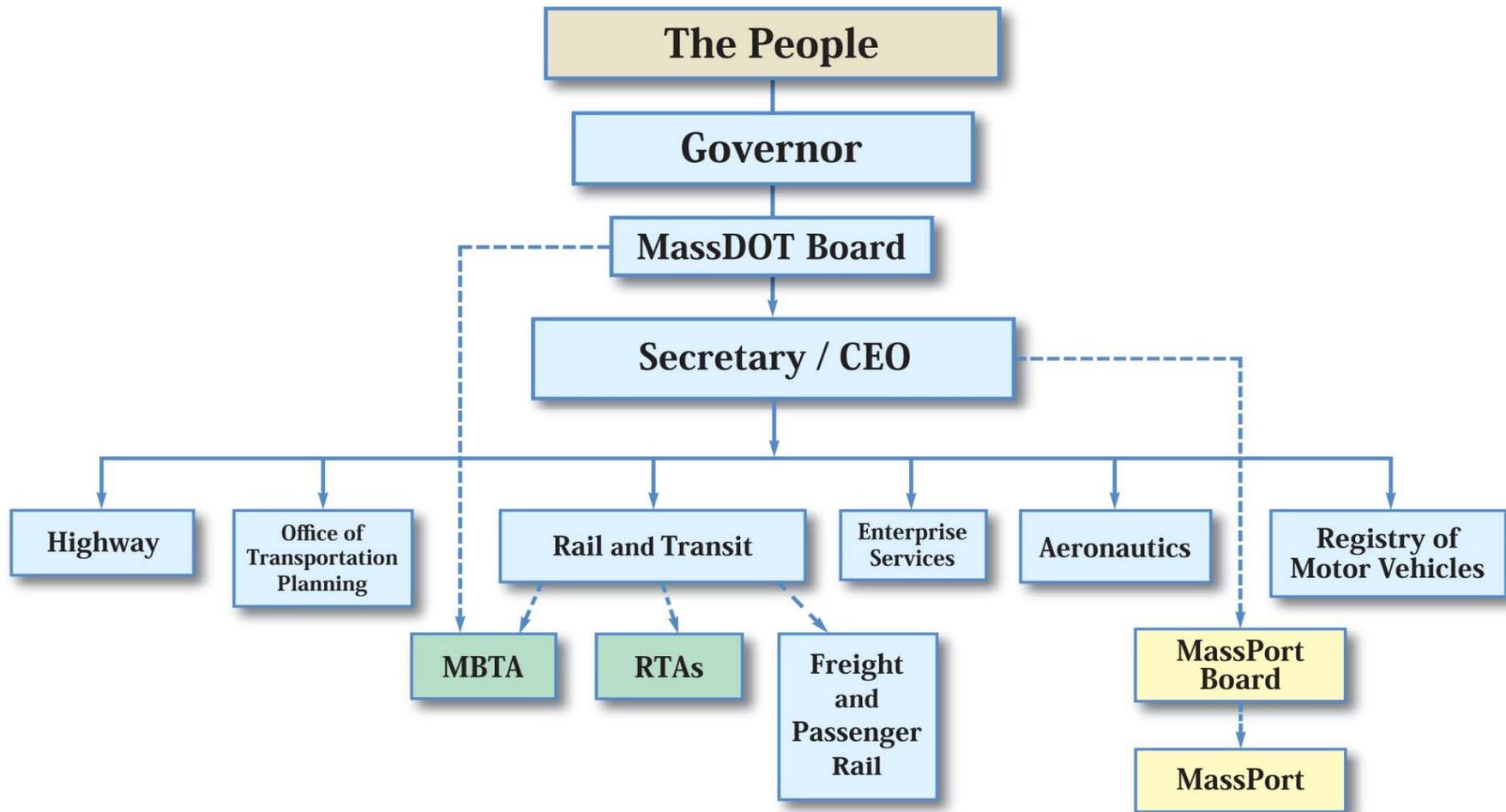
# Mission

Our mission is to deliver excellent ***customer service*** to the people who travel in the Commonwealth and to provide our nation's ***safest*** and most reliable transportation system in a way that strengthens our economy and quality of life.

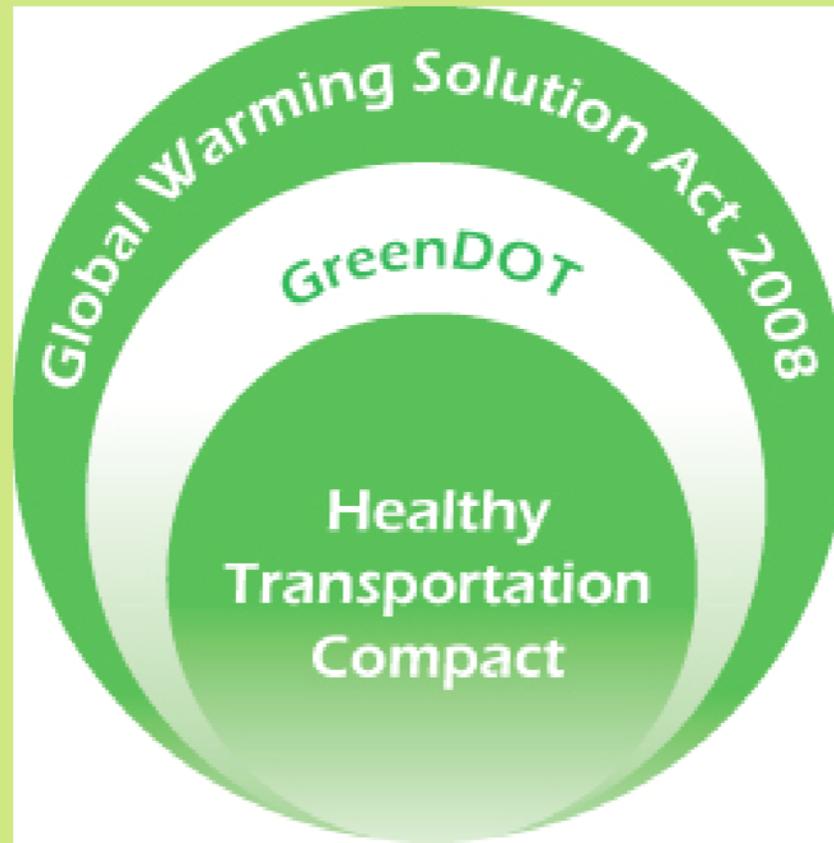
# Previous Organizations (1970-2009)



# MassDOT's Organization



# MassDOT Sustainability & Livability Policy Framework



# Healthy Transportation Compact

- Created as part of the 2009 transportation reform legislation signed by Governor Patrick
- To balance all transportation modes, expand mobility, improve health, support a cleaner, environment & create stronger communities
- Multi-state agency collaboration
  - Co-Chair Secretary and CEO MassDOT
  - CoChair Secretary of Health and Human Services
  - Secretary of Energy and Environmental Affairs
  - MassDOT Highway Administrator
  - MassDOT Transit Administrator
  - Commissioner of Public Health



# GreenDOT Policy Directive

- Coordinated approach to sustainability
- Integrate sustainability into the responsibilities & decision making of all MassDOT employees
- Use resources in a manner that serves existing customers while preserving resources for future generations



Natalia McKittrick | Pedal Power Photography | 2010

# GreenDOT Vision

Through the full range of our activities, from strategic planning to construction and system operations MassDOT will promote ***sustainable economic development***, protect the ***natural environment*** and enhance the ***quality of the life*** for all of the Commonwealth's residents and visitors.

# GreenDOT State Policy Context

- Comprehensive response to a range of state and MassDOT laws, policies and initiatives:

- Global Warming Solutions Act
- Green Communities Act
- Healthy Transportation Compact
- Leading by Example
- youMoveMassachusetts
- Complete Streets



# GreenDOT Goals

- Reduce greenhouse gas (GHG) emissions
- Promote the healthy transportation modes of walking, bicycling & transit
- Support smart growth development



# Global Warming Solutions Act 2008

- In August 2008, Governor Patrick signed the Climate Protection & Green Economy Act
- Requires Massachusetts to reduce economy-wide GHG emissions:
  - 10% -25% reduction <1990 level by 2020
  - 80% reduction <1990 level by 2050
- Clean Energy & Climate Plan for 2020 issued December 29, 2010



# Innovations and Short Term Wins

- Partnered with MassBike on 1<sup>st</sup> statewide Bike Week
- Launched statewide “green commuter” rewards NuRides
- Innovated “Open Source Data” & Smart Cards
- Changed standard paving specification to allow more RAP
- Established MassDOT ‘bike pool’
- Integrating GreenDOT goals into project prioritization/selection
- Reinforce MassDOT Complete Street policy with robust new internal/external training in 2010/11
- Evolving MassDOT Fleet to Renewable Energy Strategies

# Key Take-Aways

- GreenDOT's Three Goals:
  1. Reduce greenhouse gas (GHG) emissions
  2. Promote the healthy transportation modes of walking, bicycling & transit
  3. Support smart growth development
- GreenDOT integrates sustainability into the responsibilities & decision making of all MassDOT employees
- MassDOT Sustainability and Livability Policy Framework is our Guide to become the 'greenest' DOT in the nation
- Success will be when we no longer need to say "sustainability" as it will be embedded in our core business

# Thank You!



**MassDOT on the Web:** [www.mass.gov/massdot](http://www.mass.gov/massdot)  
(click on the GreenDOT on the lower right)

**BLOG:** <http://transportation.blog.state.ma.us/blog/greendot>

**TWITTER:** [www.twitter.com/massdot](http://www.twitter.com/massdot)

**Catherine Cagle, RLA, MBA, LEED AP**  
**Manager of Sustainable Transportation**  
**Massachusetts Department of Transportation**  
[catherine.cagle@state.ma.us](mailto:catherine.cagle@state.ma.us)  
**(617) 973-7181**

# *Massachusetts Clean Energy and Climate Plan for 2020*



**Presentation by David Cash of Massachusetts  
Executive Office of Energy and Environmental Affairs**

# MA has High Electricity Prices ...

2009 Average Retail Electric Price  
(Cents per kWh)





IF YOU THINK THESE GAS PRICES ARE STEEP ...

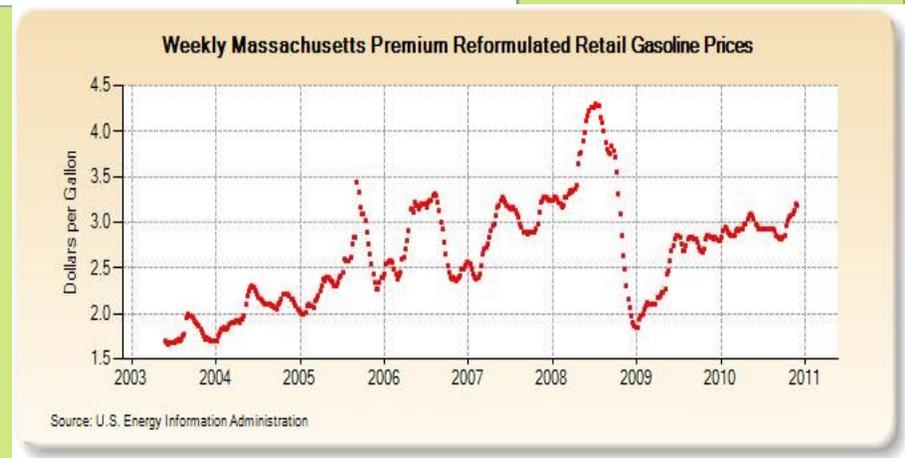
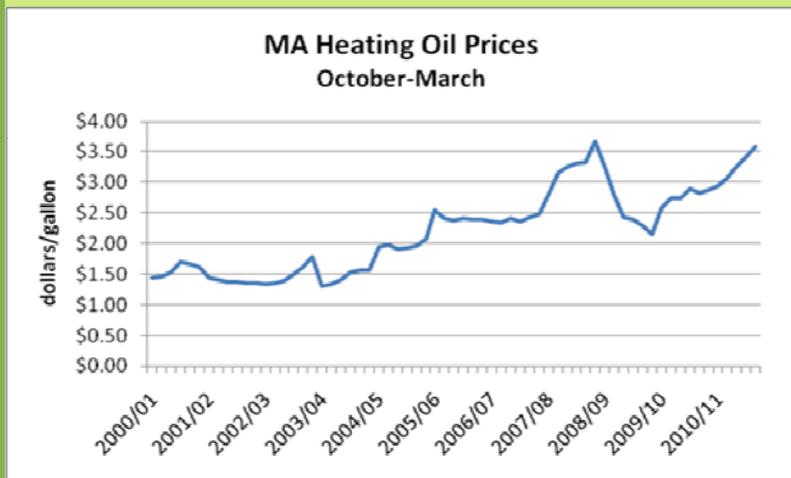
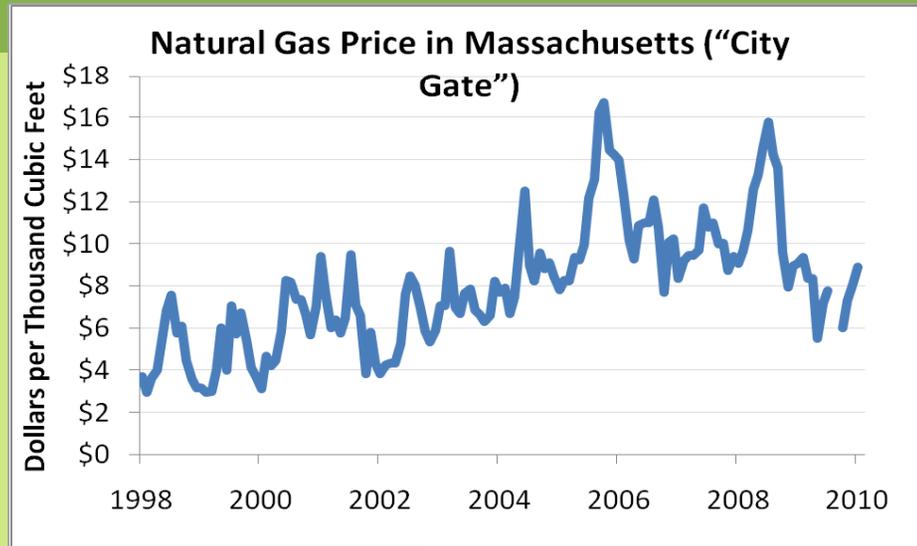


**TRY \$5!**

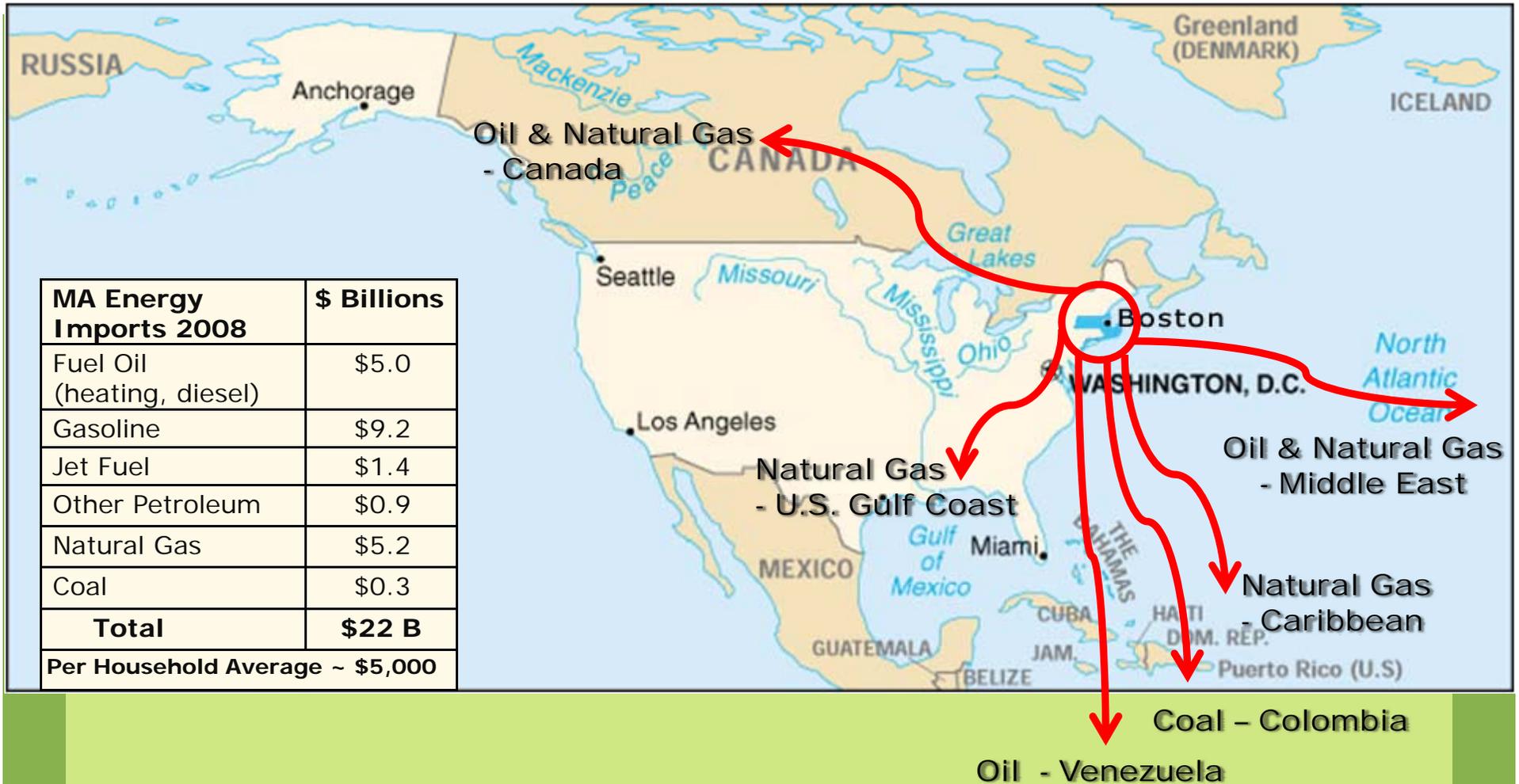
ENERGY EXPERTS: HUGE SPIKE AT PUMP POSSIBLE

WITHIN WEEKS: PAGE 5

# Energy Costs & Volatility



# Energy Dollars Flowing Out of MA



MA Energy Imports 2008	\$ Billions
Fuel Oil (heating, diesel)	\$5.0
Gasoline	\$9.2
Jet Fuel	\$1.4
Other Petroleum	\$0.9
Natural Gas	\$5.2
Coal	\$0.3
<b>Total</b>	<b>\$22 B</b>
Per Household Average ~ \$5,000	

# Energy Efficiency

- Most ambitious EE program in the country;
  - 3 X California/capita;
- Doubling of employment in EE services since 2007
- \$2 Billion Investment = \$6 Billion Savings
  - Cheapest “new” source of energy;
- By 2020 – 20% electricity through EE;
- 5%-6% GHG reductions

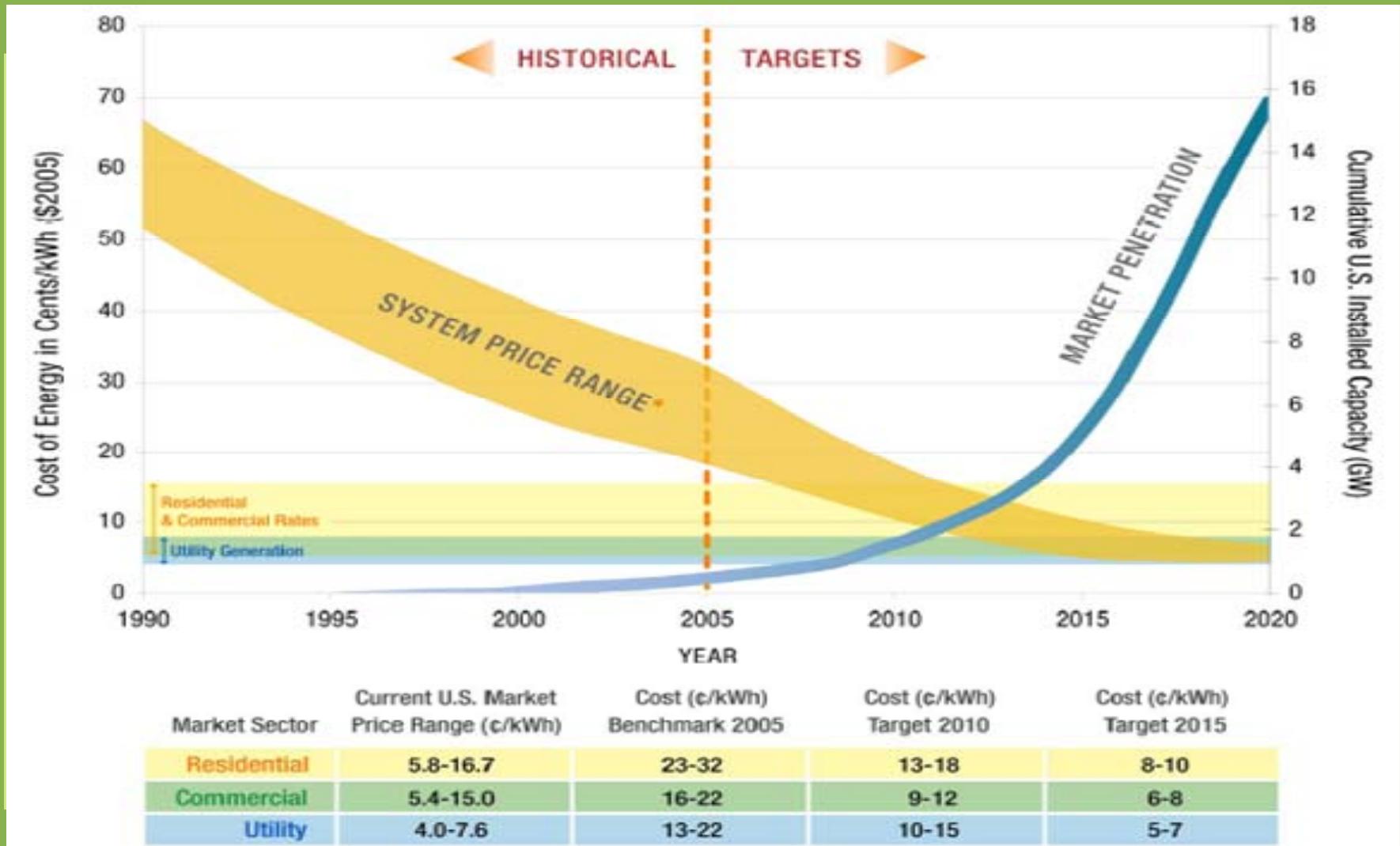


# Solar

- 20-fold increase in solar PV – from 3.5 MW to more than 70 MW by end of 2010;
- 4-fold increase in number of firms involved in solar energy installation (50 >> 200);
- Doubling of employment in solar manufacturing and installation between 2007 to 2009.



# Solar



# Wind

- 10-fold increase in wind – from 3.1 MW to more than 30 MW by end of 2010;
- Building the wind cluster:
  - Wind Blade Test Facility;
  - Cape Wind
  - Vestas R&D
  - Siemens Offshore
  - MassTank/EEW
  - New Bedford Port;
  - FloDesign
  - American Superconductor
  - First Wind

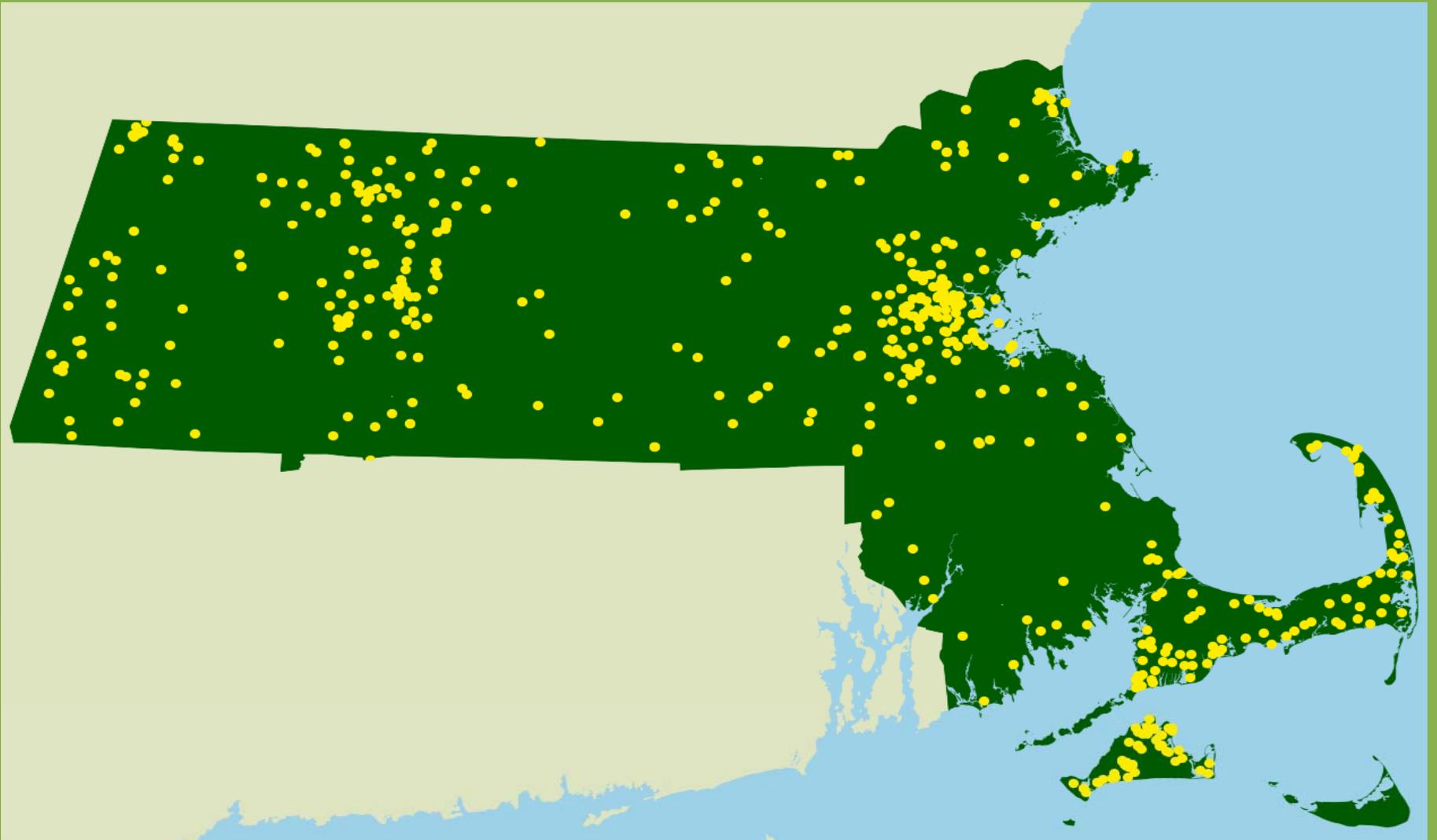


# Economic Opportunity: Energy Cost Savings and Projected Job Growth in 2020

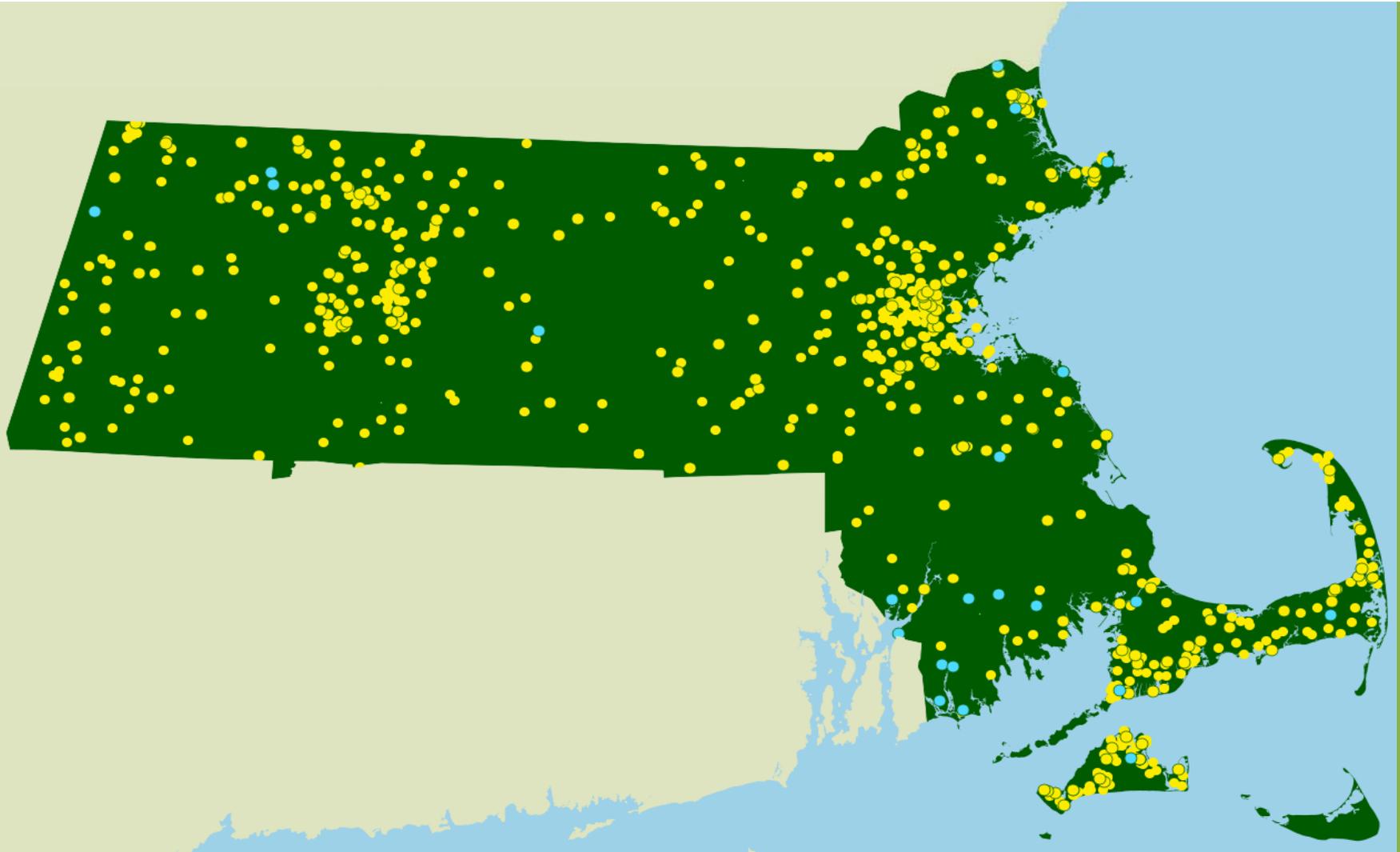
<b>Annual Energy Cost Savings for Residential, Business, Municipal Costumers</b>	
<b>Total</b>	<b>\$5.2B</b>

<b>Job growth potential</b>	
Induced or indirect job growth	39, 000
Clean energy sector job growth	3,000-9,000
<b>Total</b>	<b>42,000-48,000</b>

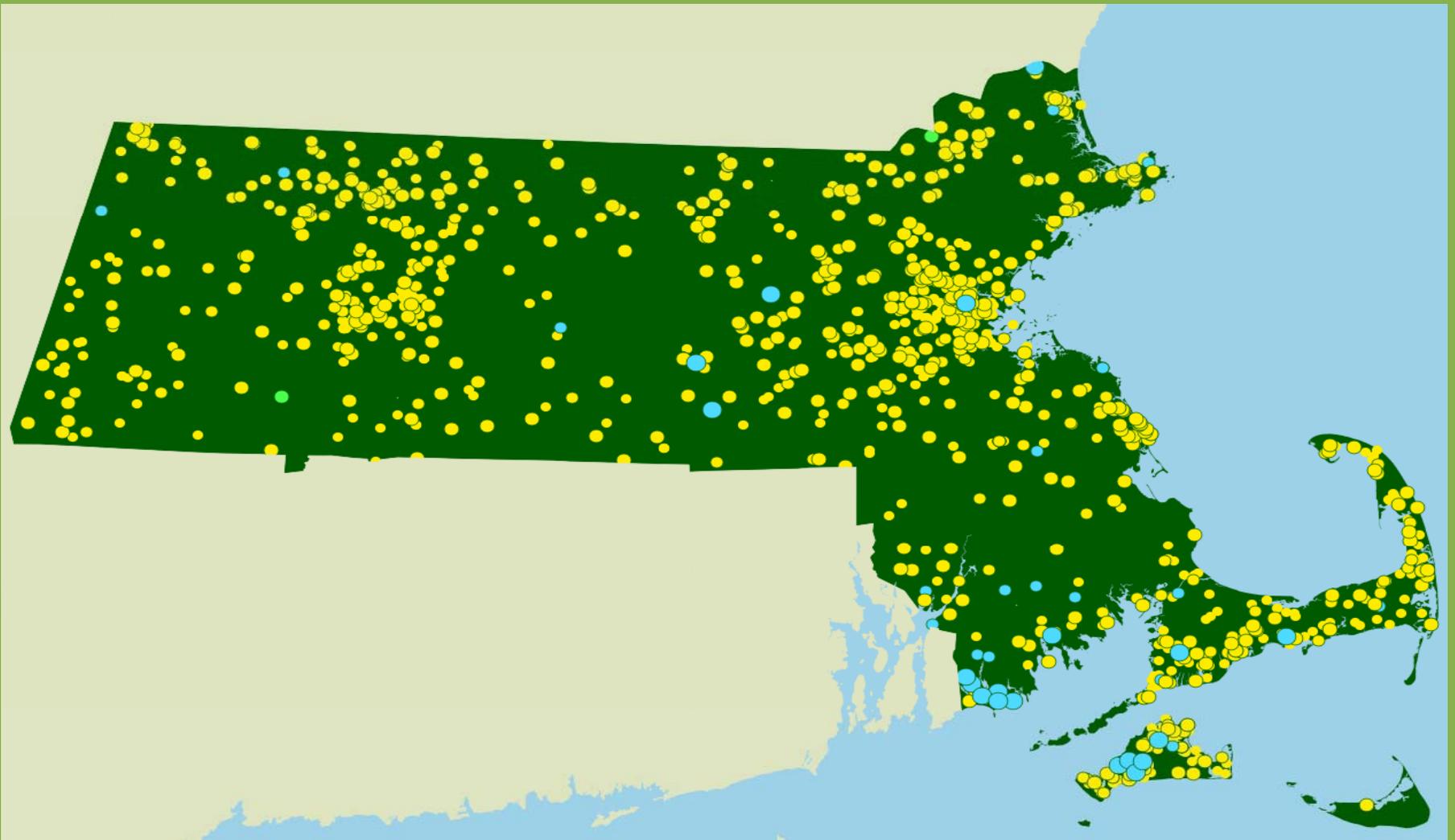
# The Massachusetts Clean Energy Revolution 2006



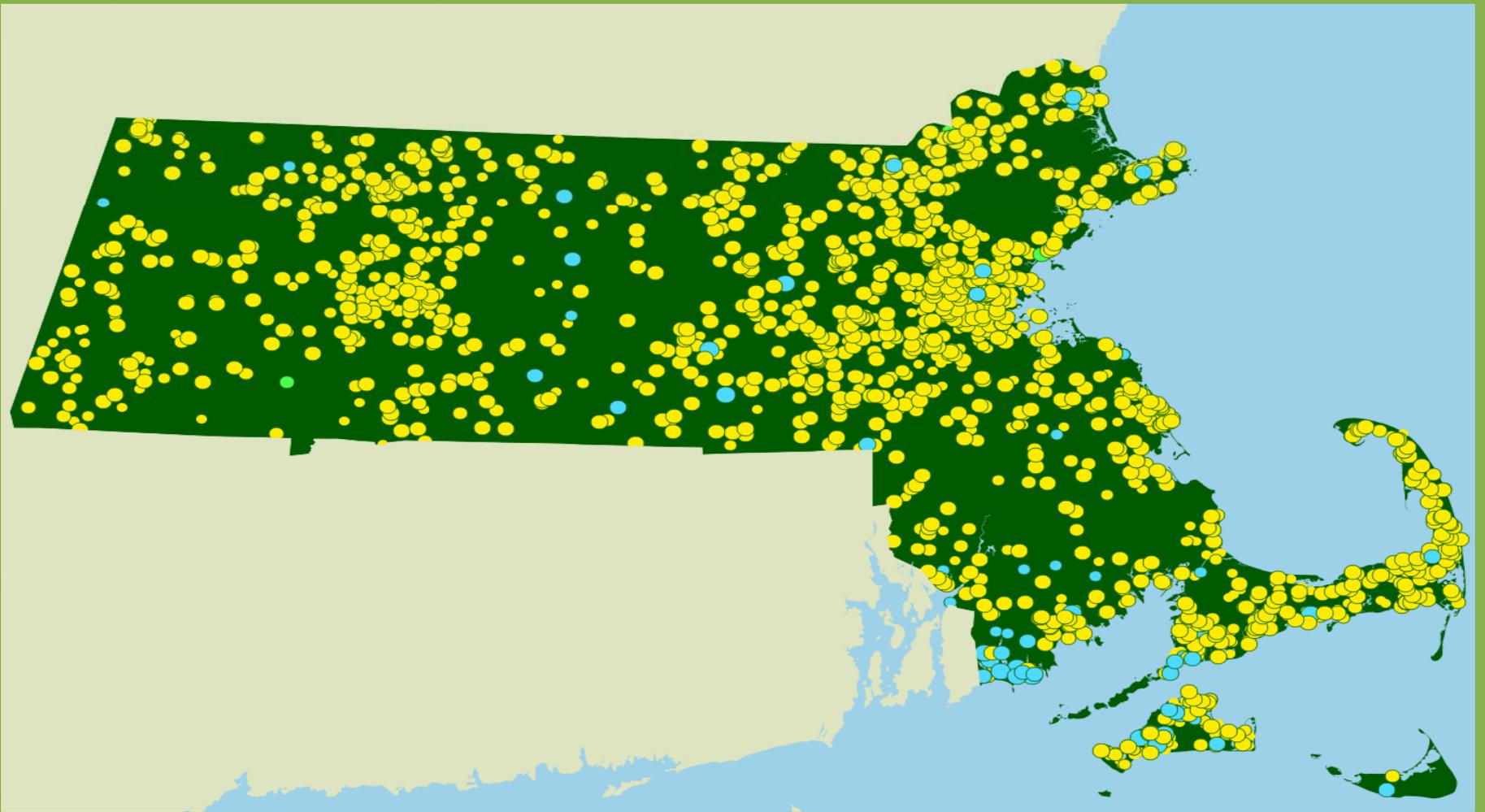
# The Massachusetts Clean Energy Revolution 2007



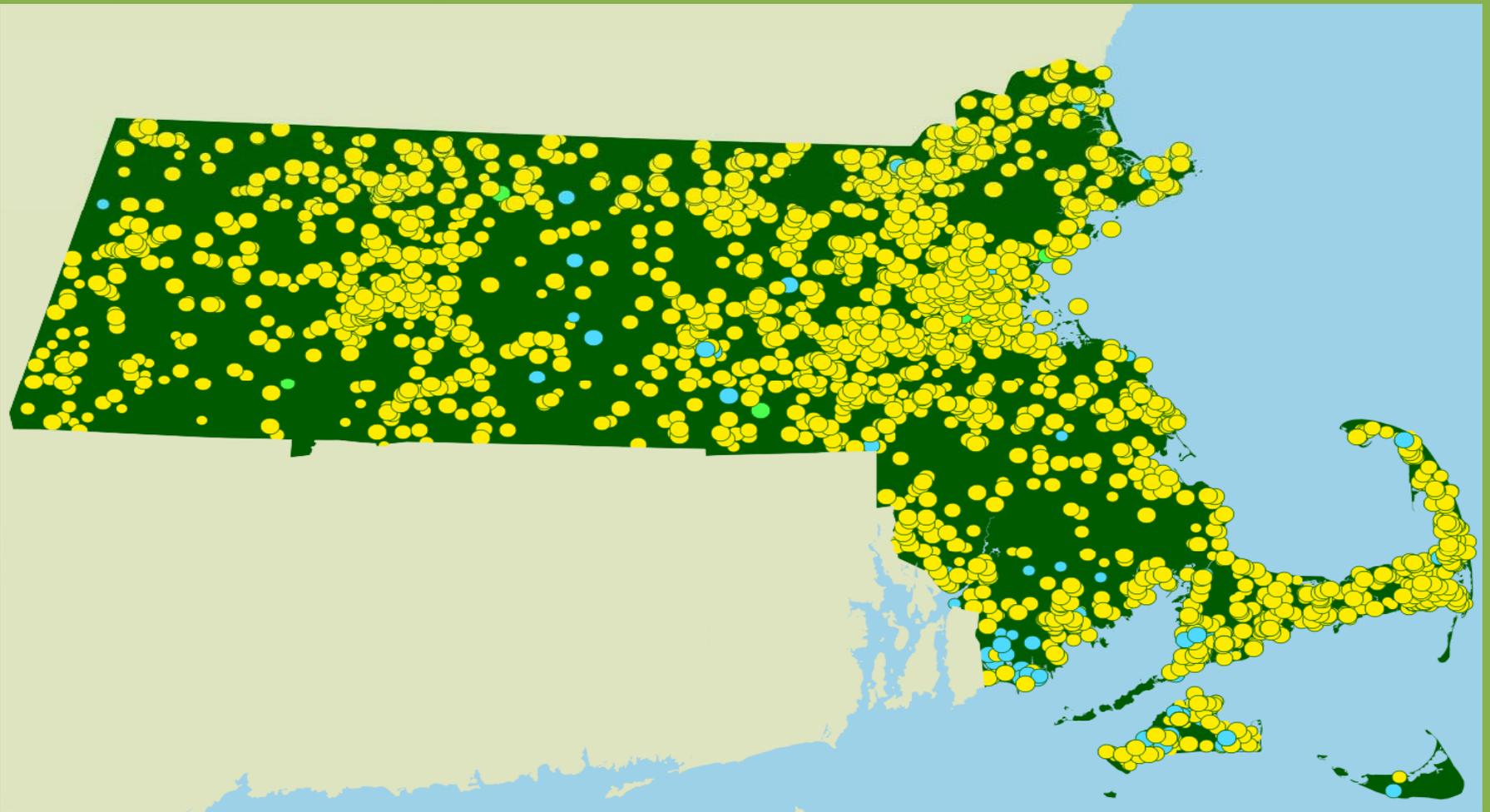
# The Massachusetts Clean Energy Revolution 2008



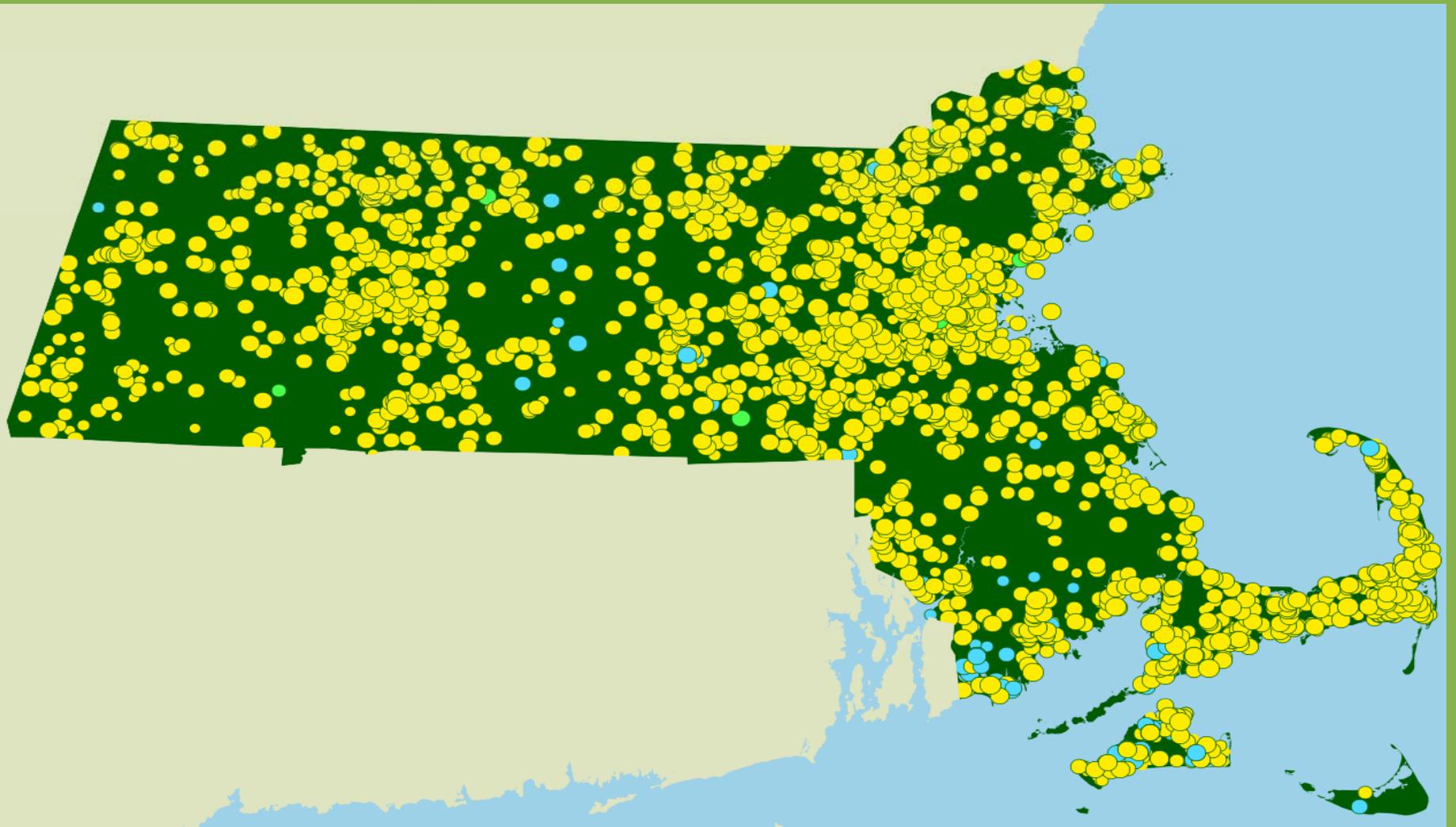
# The Massachusetts Clean Energy Revolution 2009



# The Massachusetts Clean Energy Revolution 2010



# The Massachusetts Clean Energy Revolution 2011



# An Integrated Portfolio of Policies

Buildings (9.8%)

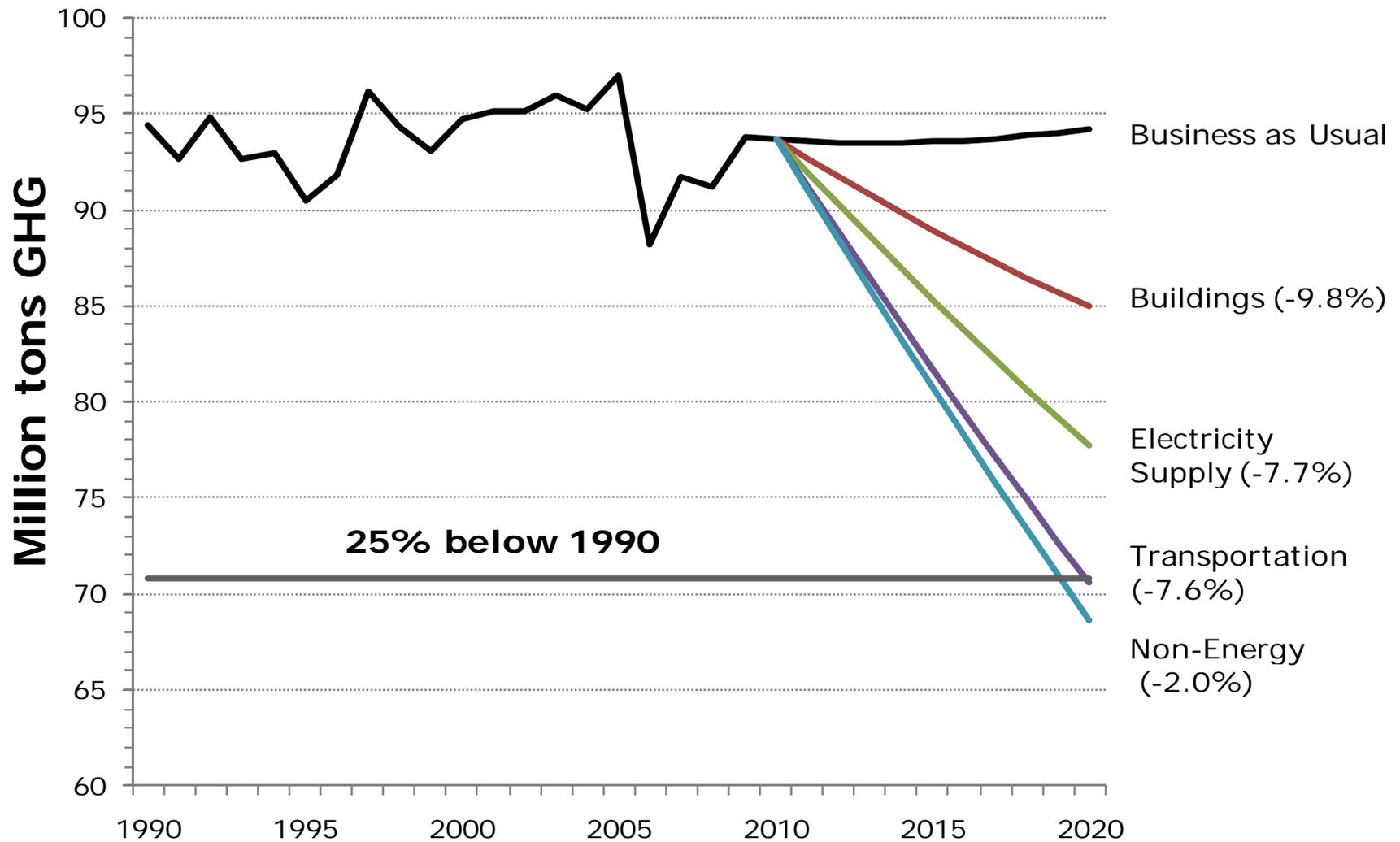
Energy Supply (7.6%)

Transportation (7.8%)

Non-energy Emissions (2.0%)

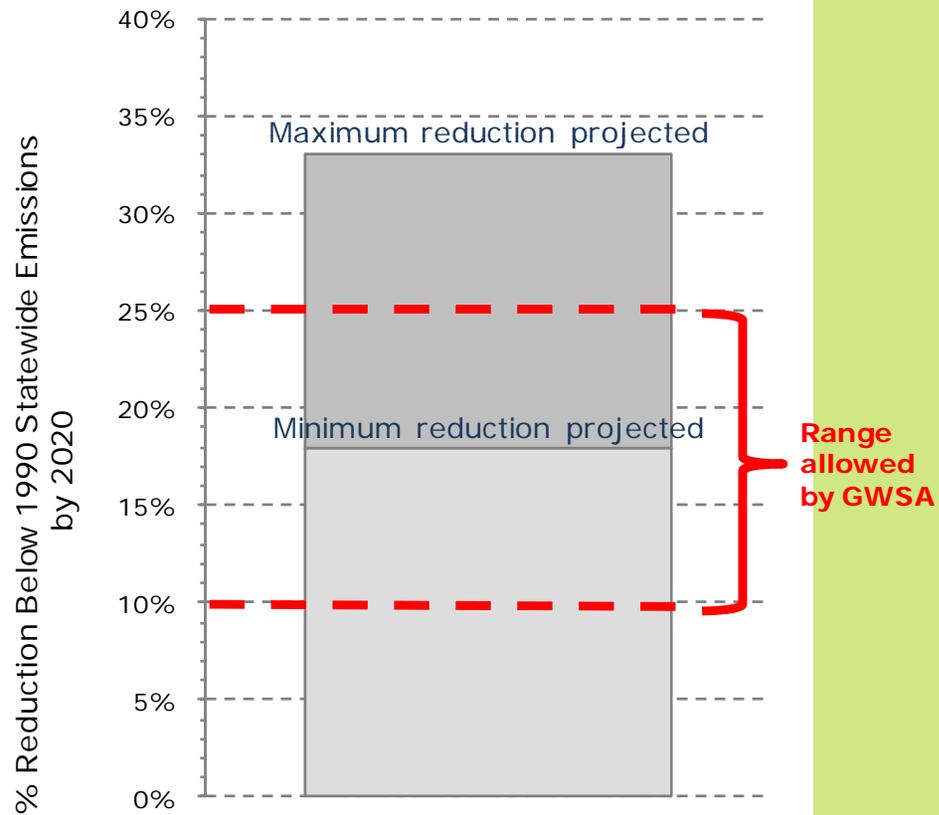
Cross-Cutting Policies

## Clean Energy and Climate Portfolio Impacts vs. Business as Usual



# Setting the Limit

## Projected Emission Reduction Range



# Putting the Plan into Action

Launch Clean Energy and Climate Advisory Committee

In 2011, state agencies responsible for each new measure will complete program development and consultative processes with stakeholders

Next four years – annual status reports to the Clean Energy and Climate Advisory Committee

Increased public, City/Town, regional groups, NGO, business community, engagement

5-year reviews

# Buildings (9.8%)

All cost-effective energy efficiency/RGGI (7.1%)

Advanced building energy codes (1.6%)

Building energy rating and labeling

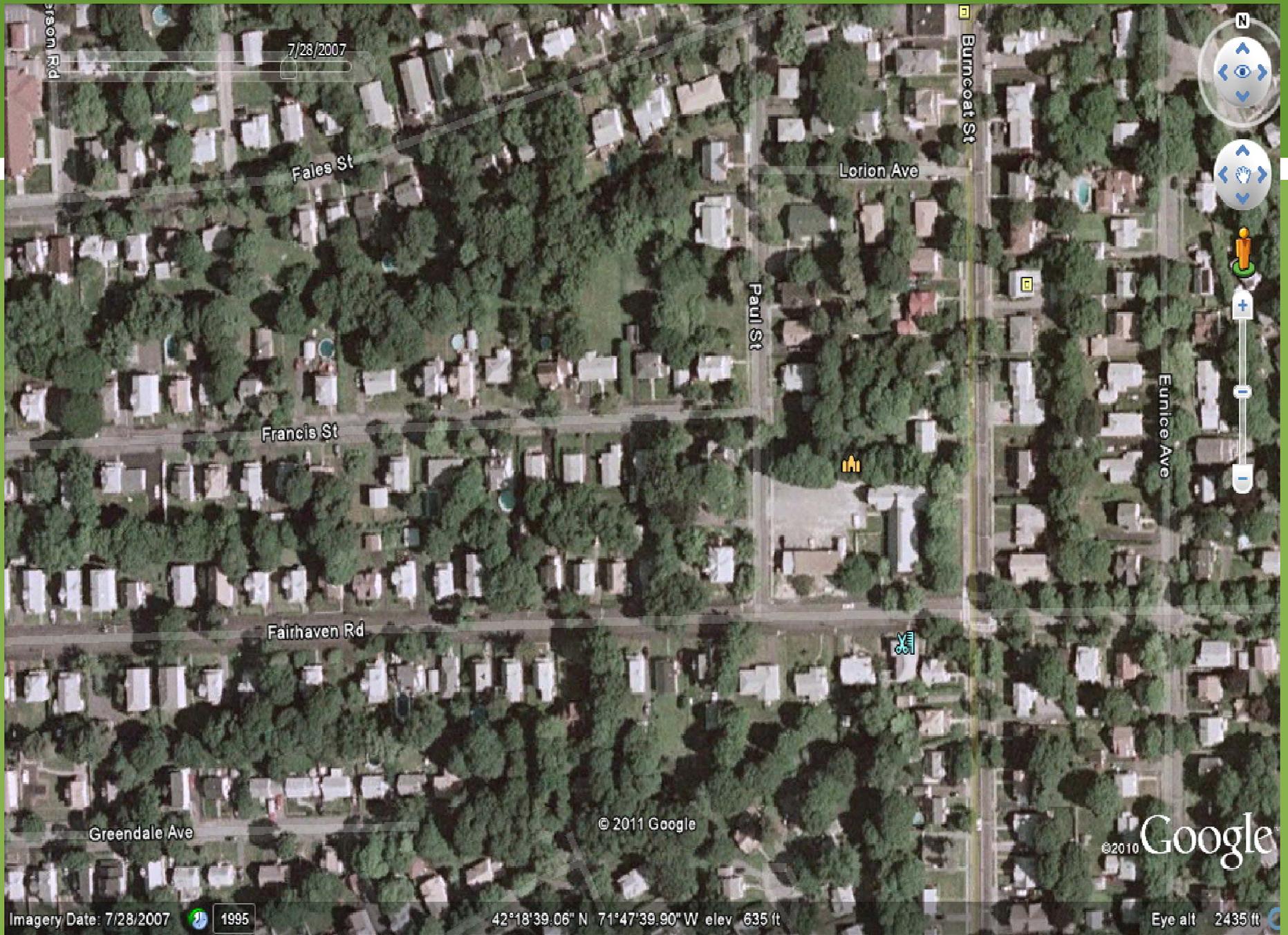
“Deep” energy efficiency improvements for buildings (0.2%)

Expanding energy efficiency programs to C/I heating oil  
(0.1%)

Developing a mature market for solar thermal water/space  
heating (0.1%)

Tree retention and planting to reduce heating and cooling  
loads (0.1%)

Federal appliance and product standards (0.6%)



7/28/2007

ason Rd

Fales St

Lorion Ave

Burncoat St

Paul St

Francis St

Eunice Ave

Fairhaven Rd

Greendale Ave

© 2011 Google

©2010 Google

Imagery Date: 7/28/2007 1995

42°18'39.06" N 71°47'39.90" W elev 635 ft

Eye alt 2435 ft



4/24/2009

ison Rd

Fales St

Lorion Ave

Burncoat St

Paul St

Francis St

Eunice Ave

Fairhaven Rd

Greendale Ave

© 2011 Google  
Image MassGIS, Commonwealth of Massachusetts EOE

©2010 Google

Imagery Date: 3/30/2009 1995

42°18'35.26" N 71°47'27.46" W elev 697 ft

Eye alt 2435 ft

# Electricity (7.7%)

Renewable Portfolio Standard (1.2%)

More stringent EPA power plant rules (1.2%)

Clean energy imports (5.4%)

Clean energy performance standard (CPS)

# Transportation (7.6%)

Federal and California vehicle efficiency and GHG standards (2.6%)

Federal emissions and fuel efficiency standards for medium and heavy duty vehicles (0.3%)

Federal renewable fuel standard and regional low carbon fuel standard (1.6%)

Clean car consumer incentives (0.5%)

Pay As You Drive (PAYD) auto insurance (pilot program, possible expansion later) (1.1%)

Sustainable Development Principles (0.1%)

GreenDOT (1.2%)

Smart growth policy package (0.4%)

# Non-Energy Emissions (2.0%)

Reducing GHG emissions from motor vehicle air conditioning (0.3%)

Stationary equipment refrigerant management (1.3%)

Reducing SF6 emissions from gas-insulated switchgear (0.2%)

Reducing GHG emissions from plastics (0.3%)

# Cross-cutting Policies

MEPA GHG policy and protocol

Leading by Example

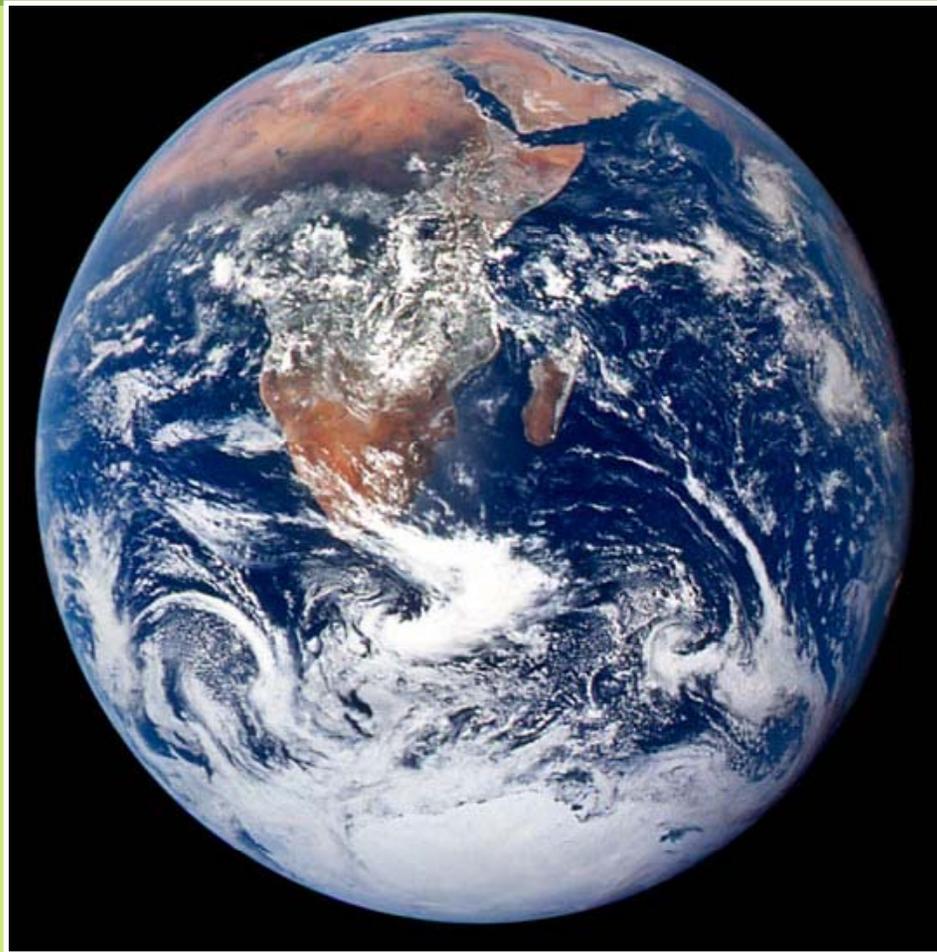
Green Communities Division

Consideration of GHG emissions in State permitting,  
licensing and administrative approvals

## VII. Break-Out Groups to Brainstorm Future Actions



# INFORMATION RESOURCES



# Resources

- AASHTO: <http://climatechange.transportation.org/>
- Intergovernmental Panel on Climate Change (IPCC):  
<http://www.ipcc.ch/>
- US DOT Transportation and Climate Change Clearinghouse:  
<http://climate.dot.gov/index.html>
- FHWA Climate Change Program  
<http://www.fhwa.dot.gov/hep/climate/index.htm>
- The Pew Center on Global Climate Change:  
<http://www.pewclimate.org/>
- EPA Climate Change Program  
<http://www.epa.gov/climatechange/>
- TRB Climate Change Activities  
<http://www.trb.org/main/SpecialtyPageClimateChange.aspx>

## Resources – Key Documents

- AASHTO, “Primer on Transportation and Climate Change,” 2008
- NCHRP 20-24 (59), “Strategies for Reducing the Impacts of Surface Transportation on Global Climate Change,” 2009
- European Council of Ministers of Transport, “Review of CO2 Abatement Policies for the Transport Sector,” 2006
- U.S. DOE, “Annual Energy Outlook,” 2009 (primary source of official U.S. data on energy and GHG)
- TRB Special Report 290: “Potential Impacts of Climate Change on U.S. Transportation,” 2008
- Pew Center on Climate Change, “Climate Change 101” and “Reducing GHG Emissions from U.S. Transportation

## Resources – AASHTO

- **AASHTO Climate Change Steering Committee:** CCSC acts as a focal point and coordinating body for AASHTO's activities related to climate change. CCSC members act as the focal point for AASHTO on climate change policy issues and provide oversight and guidance to AASHTO's Climate Change Technical Assistance Program.
- **AASHTO Technical Assistance Program on Climate Change:** This is a new, voluntary program that provides timely information, tools and technical assistance to assist AASHTO members in meeting the difficult challenges that arise related to climate change.

For more information on AASHTO's Climate Change Steering Committee and Climate Change Technical Assistance Program, please contact:

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