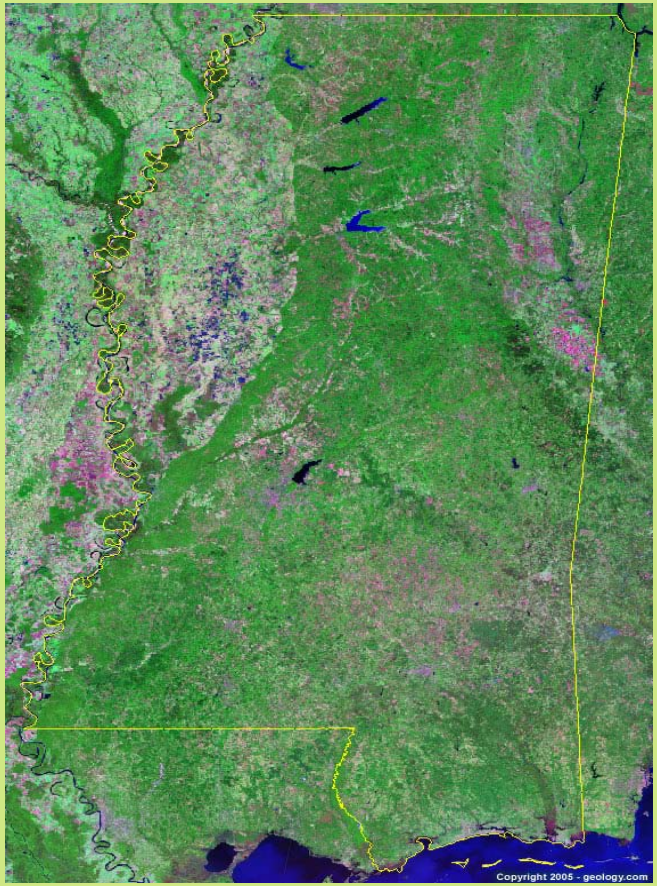
CLIMATE CHANGE: INFORMATION, CHALLENGES, AND STRATEGIES



A Workshop for
Mississippi DOT

June 17, 2010

Workshop Purpose

- What is climate change?
- How will it affect state DOTs?
- Status of federal legislation?
- What is the Gulf Coast Study?
- What are adaptation issues for MissDOT?
- What are proposed CEQ-NEPA requirements?
- How can state DOTs reduce transportation GHG?

Workshop Overview

I. Climate Change Science, Sources, and Trends
II. The Importance of Climate Change to State DOTs
III. Gulf Coast Study Presentation and Climate Adaptation
IV. Planning and NEPA Issues
V. Strategies to Reduce GHG Emissions from Transportation Sources
VI. Participant Workshop
VII. Wrap-up and Next Steps Discussion

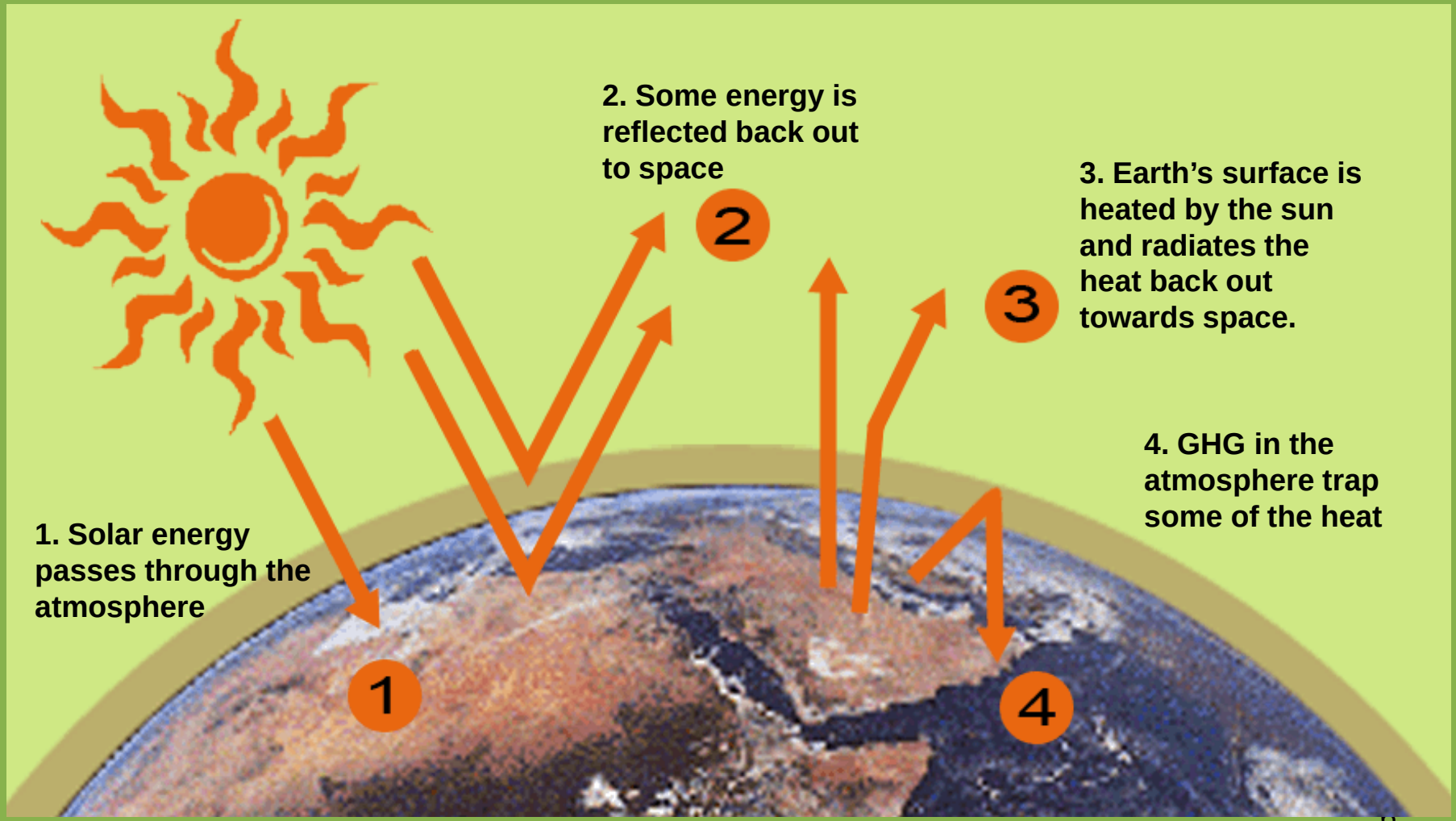
I. Climate Change Science, Sources and Trends

What is climate change?

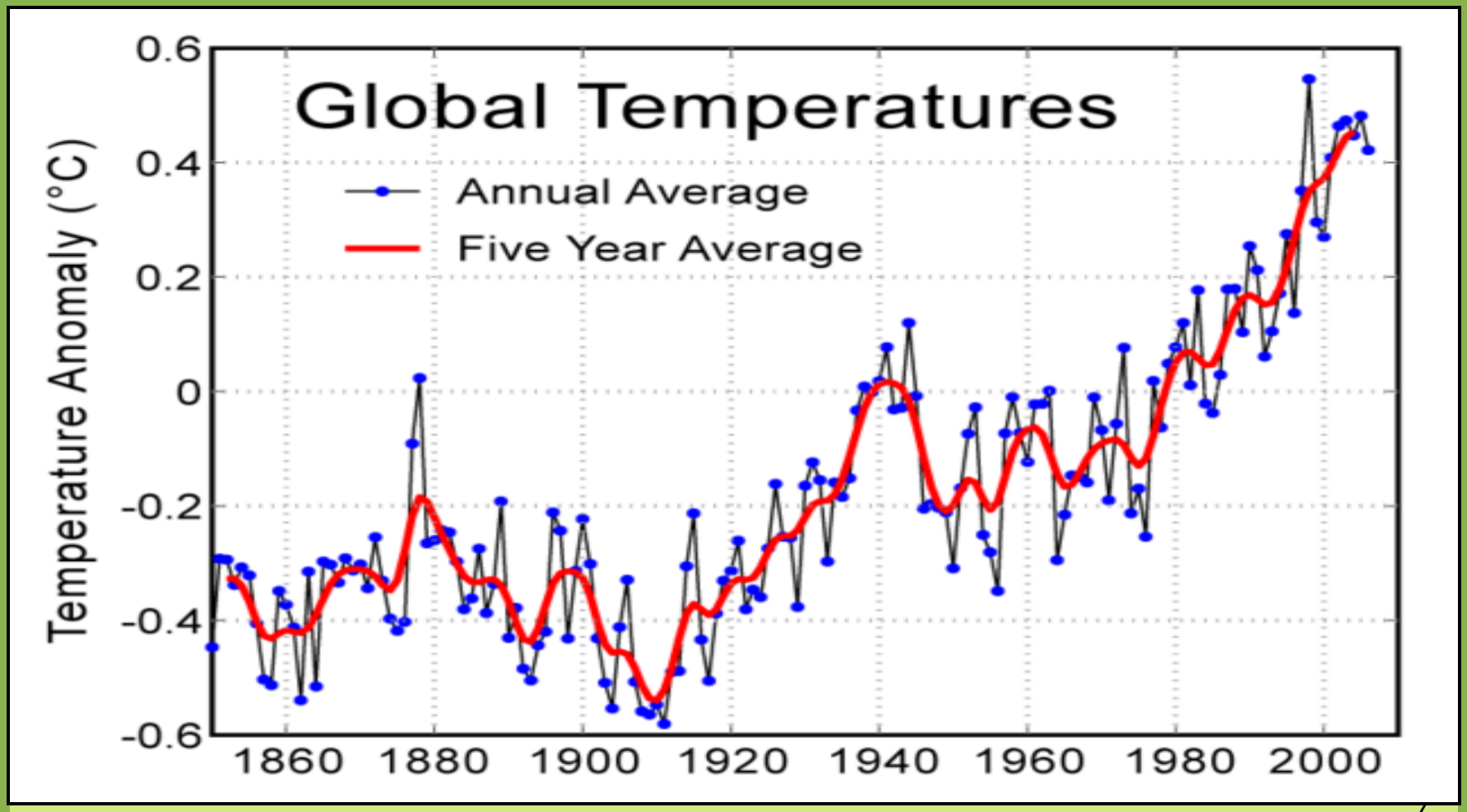
The United Nations Framework Convention on Climate Change (UNFCCC) defines Climate Change as:

"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."

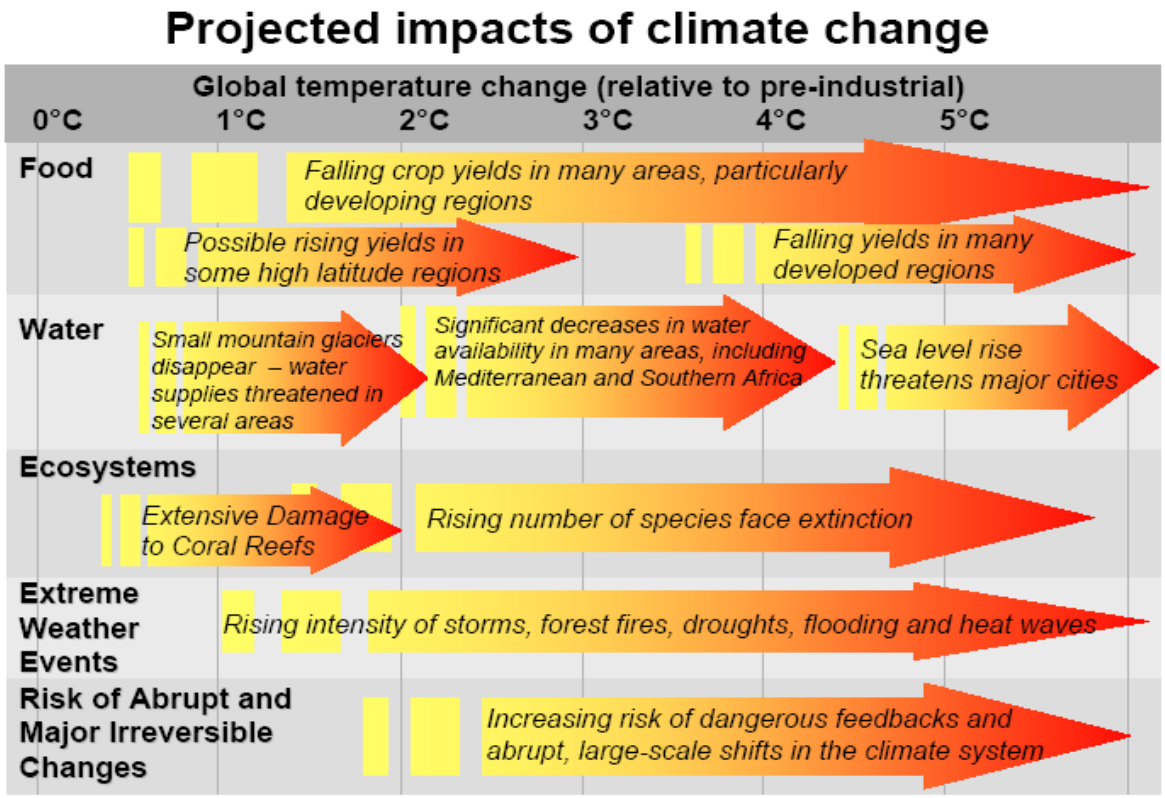
What is the “Greenhouse Effect”?



What is the evidence on temperatures?



What are the impacts at different temperature increases?



Source:
Stern Review, 2008

What are the scientific findings?

Climate Change 2007: The Physical Science Basis

- Developed by the Intergovernmental Panel on Climate Change (IPCC)
- Contributions from 2,000 scientists assessing the Earth's environment and the effects of global warming

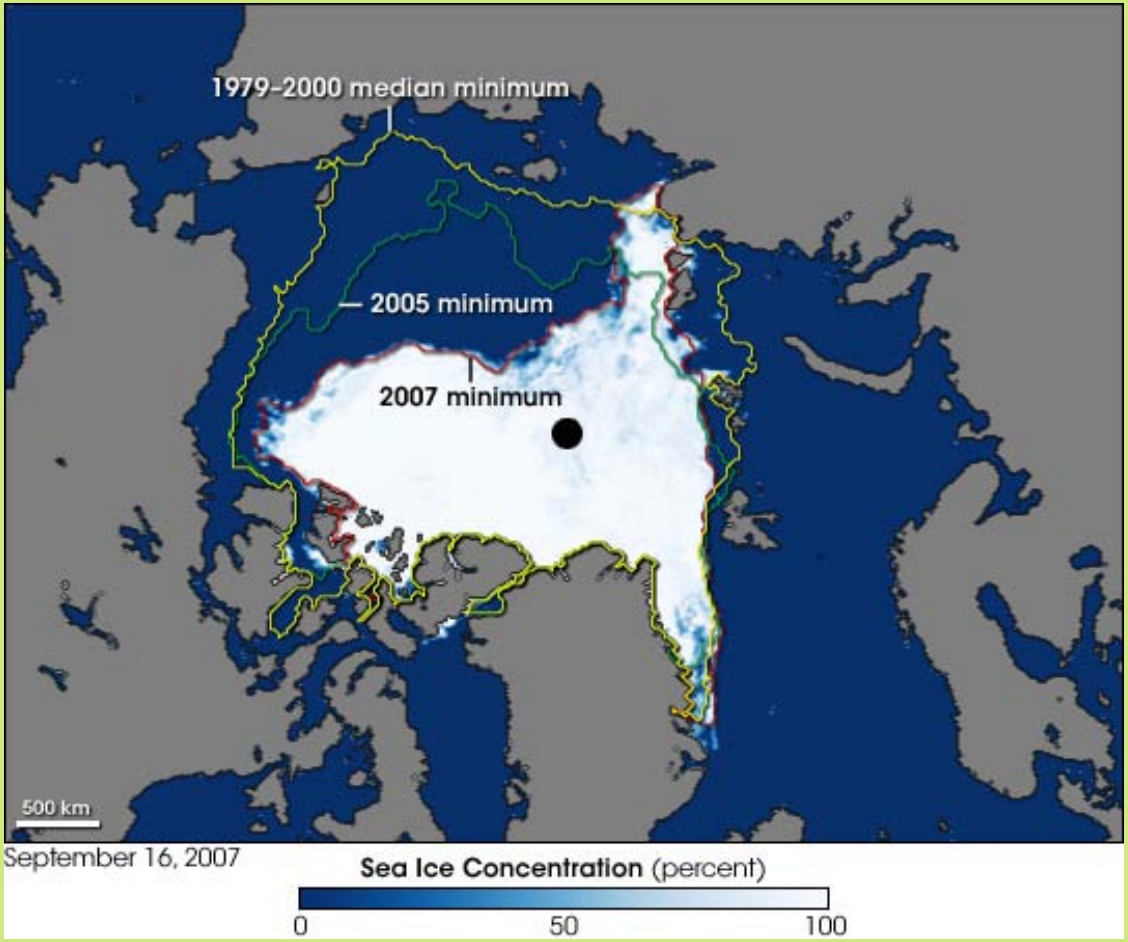
…a summary for policy makers…

There is 90% certainty that humans are the cause of global warming.

Notable findings in the report:

- Atmospheric CO_2 levels are at their highest levels in 650,000 years.
- Avg global temperatures have risen ~1.3°F since the industrial age began.
- Sea level rose ~4.8 – 8.8" worldwide during the 20th century, at a rate more than double that of the past decade

What is the physical evidence?



Arctic sea ice is retreating –

a measurable change in climate that can be seen

Source: NASA

How certain are the scientists?

- “Warming of the climate system is unequivocal…”

  -- Intergovernmental Panel on Climate Change

- “An overwhelming body of scientific evidence paints a clear picture: climate change is happening, it is caused in large part by human activity, and it will have many serious and potentially damaging effects in the decades ahead.”

  -- Pew Center on Climate Change

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 late1800s.
- 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"/year 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 the 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

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. 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.

How is climate change affecting the Gulf Coast and Mississippi?

Gulf Coast Study, Phase I Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: 3/2008.

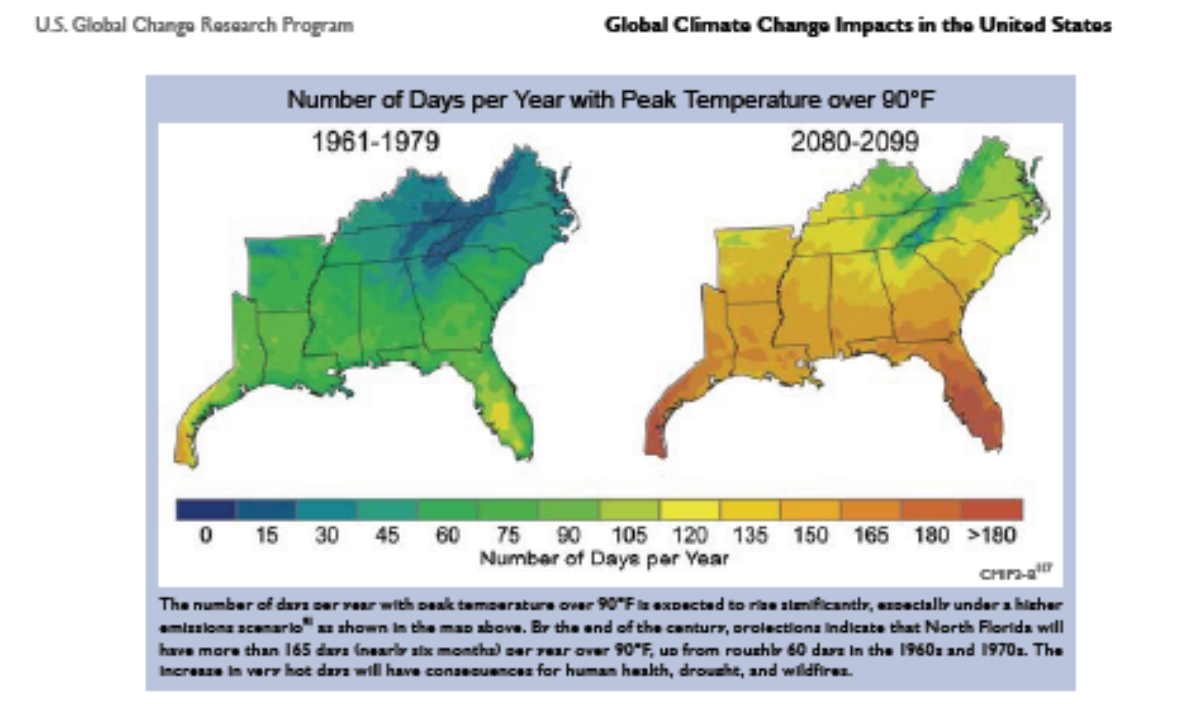
- Temperatures rising
- Sea levels in Gulf of Mexico likely to rise 2-4 feet over next 50-100 years
- Impact on transportation:

"The expected impacts of these climate effects on transportation are striking. An untenable portion of the region's road, rail, and port network is at risk of permanent flooding if sea levels rise by four feet. This includes more than 2,400 miles (27%) of the major roads, 9% of the rail lines, and 72 % of the ports."

"More than half (64% of interstates; 57% of arterials) of the area's major highways, almost half of the rail miles, 29 airports, and virtually all of the ports are subject to temporary flooding and damage due to increased storm intensity."

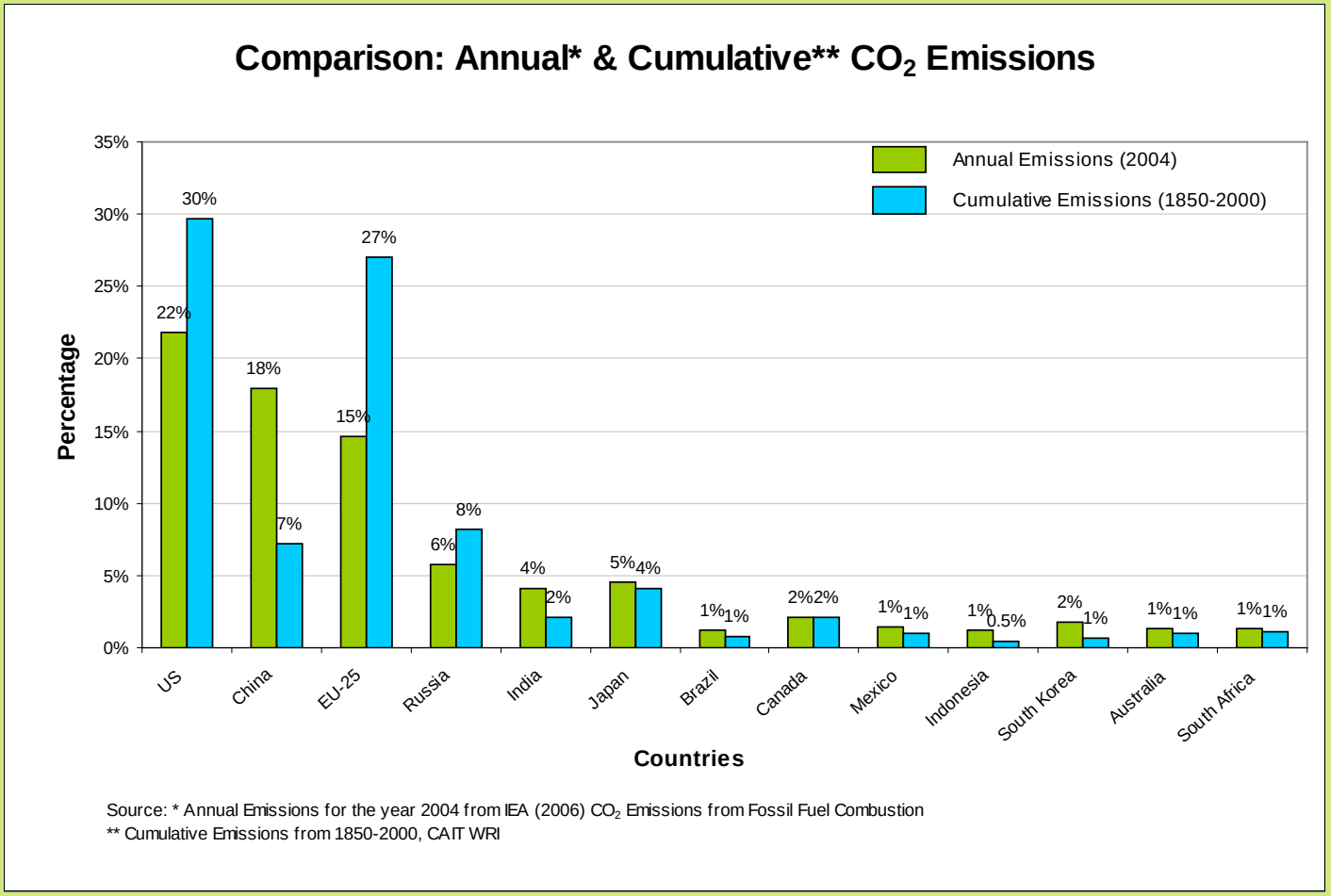
Southeast temperatures expected to rise significantly

(number of days with peak temperatures over 90F)



http://www.globalchange.gov/images/cir/pdf/southeast.pdf

Where do all those GHG come from?

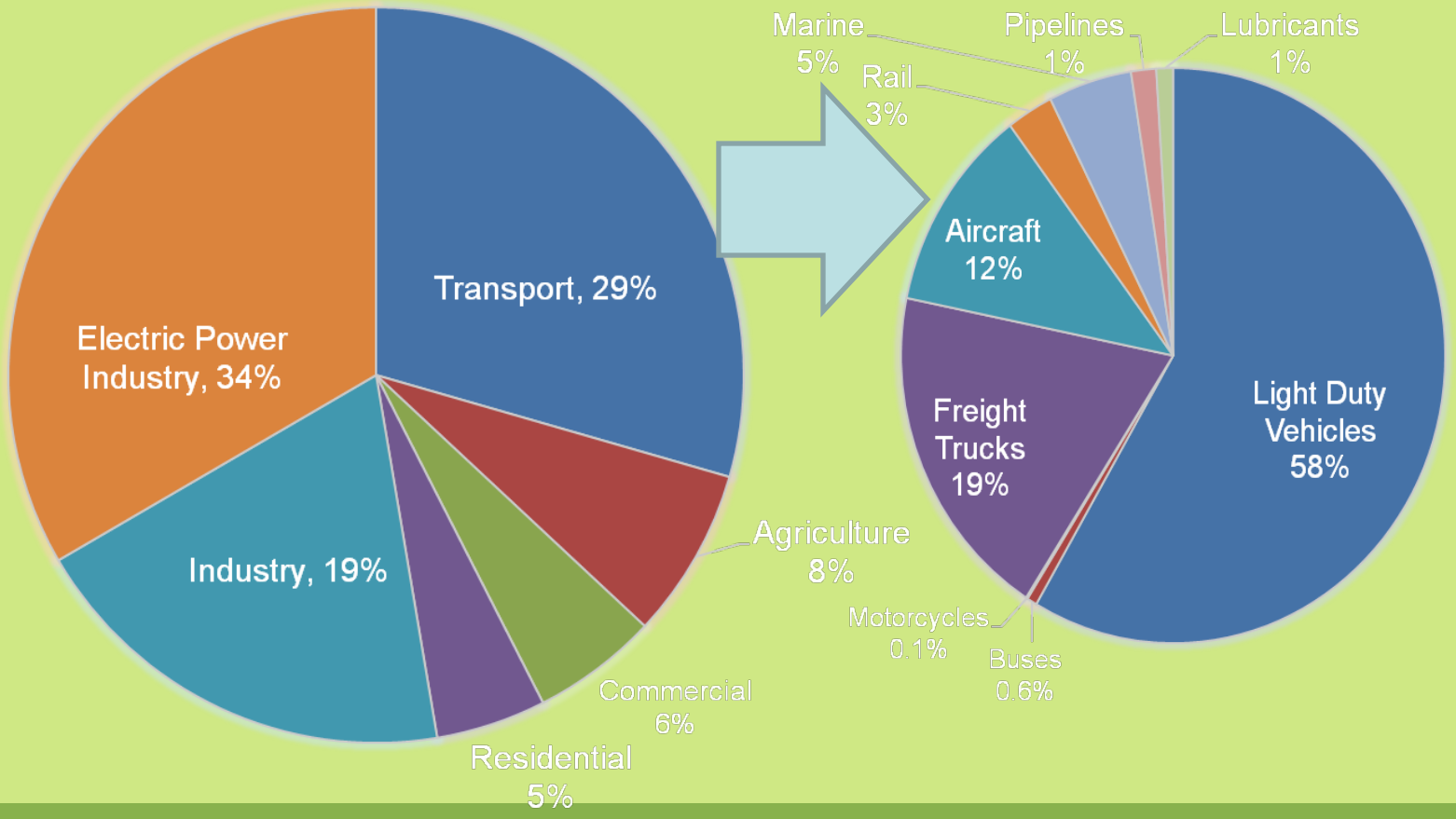


What GHG targets have been set?

- Scientists recommend **60-80% GHG reduction below 1990 level by 2050**
- Many states and countries have adopted targets in this range
- 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

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

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



What are U.S. transportation GHG trends?

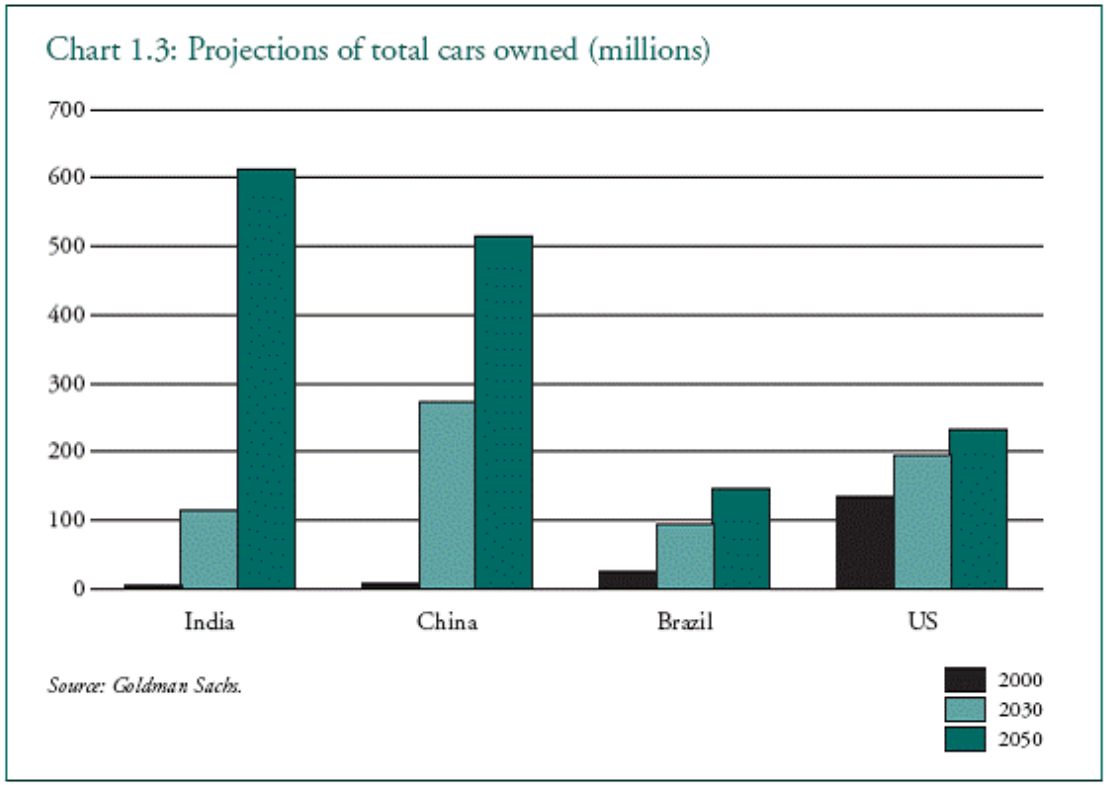
- U.S.DOT Report to Congress, 2010

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

How much will transportation GHG increase?

- **U.S.**: GHG from all transportation modes are projected to remain almost constant through 2030 – but light duty vehicle GHGs will actually decline slightly and freight GHG will increase significantly.
- **World**: GHG emissions from transportation are expected to rise sharply; soon GHG emissions from transportation in the developing world will greatly exceed those of the U.S.

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 by 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.

Why is vehicle “decarbonization” necessary?

“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

Summary

- Climate change is real
- 60-80% GHG reduction is needed
- It is a global and cumulative problem
- In developing countries, GHG emissions will increase substantially
- Delay will magnify the difficulty of reducing GHG
- Mississippi is especially vulnerable to climate change

II. The Importance of Climate Change to State DOTs

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

- 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

Wal-Mart Perspective

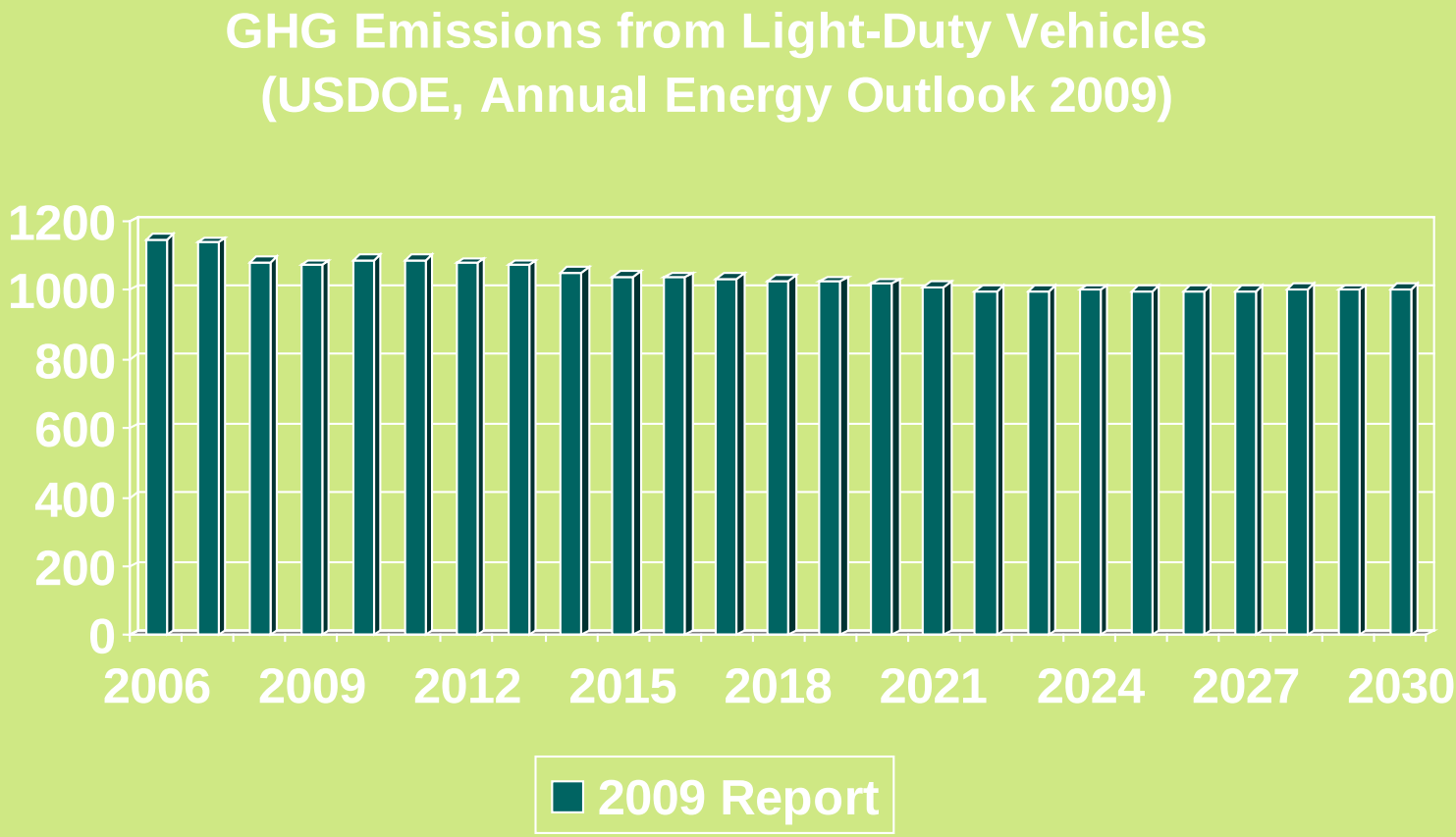
"We know we need to get ready for a world in which energy will only be more expensive."

- 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 labelling clothes as cold-water wash.

****

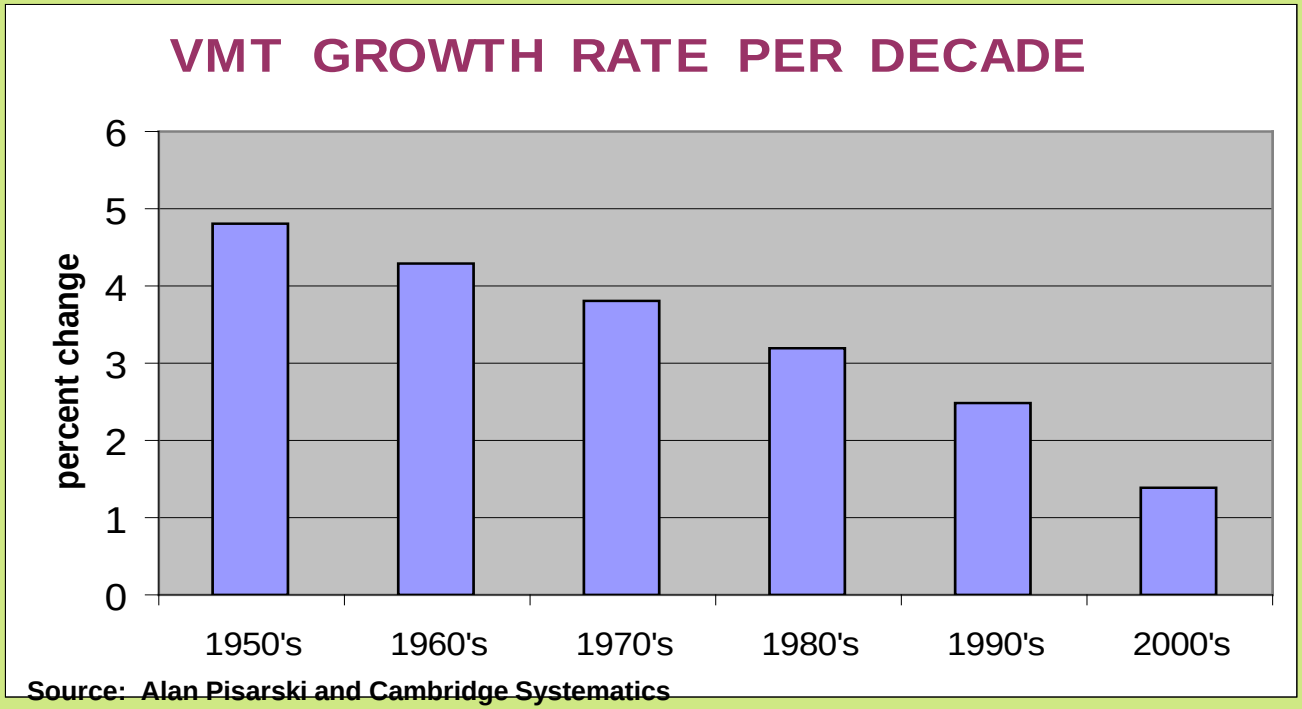
Should state DOTs take a page from Wal-Mart's book?

DOE expects slight decline in LDV GHG emissions nationally



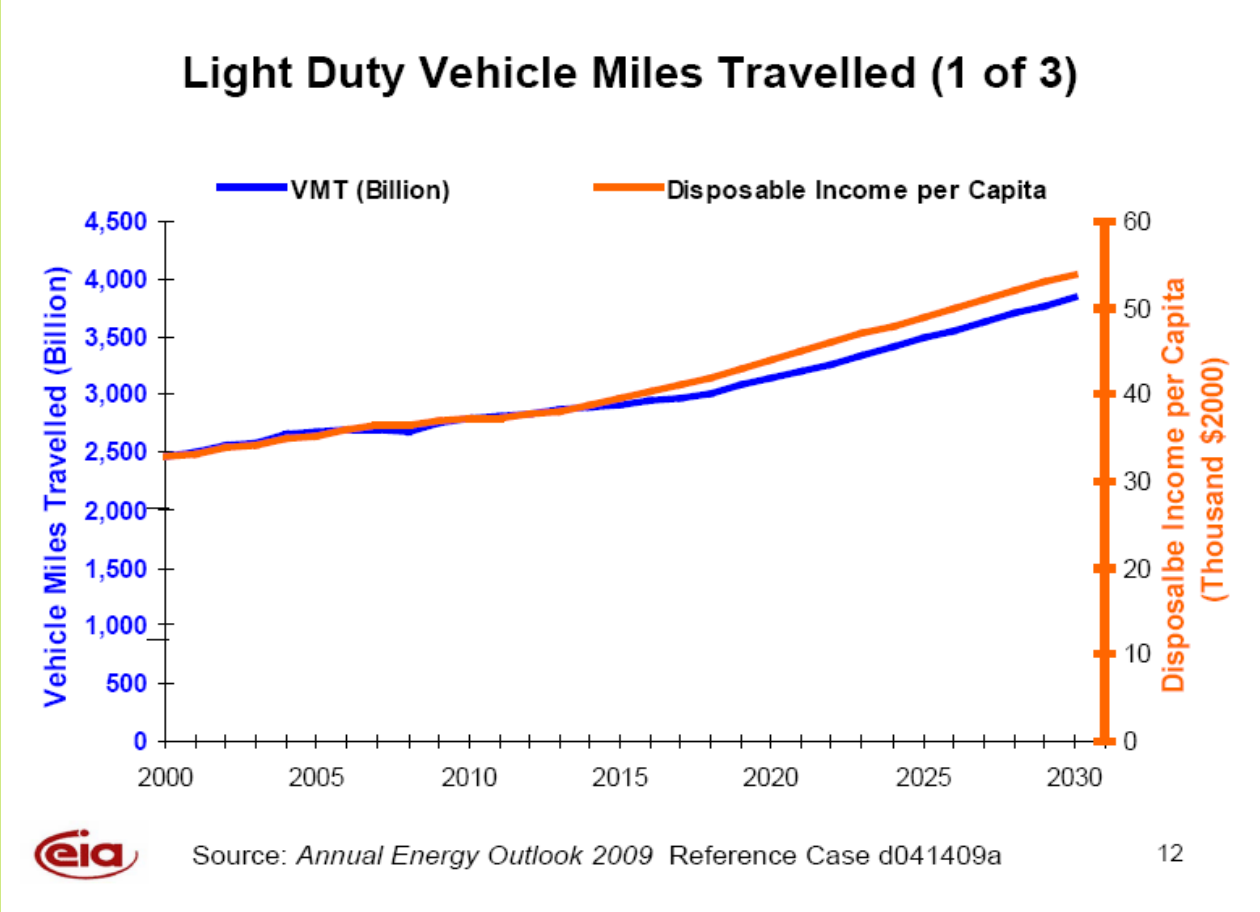
U.S. VMT growth rates are declining

- **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**

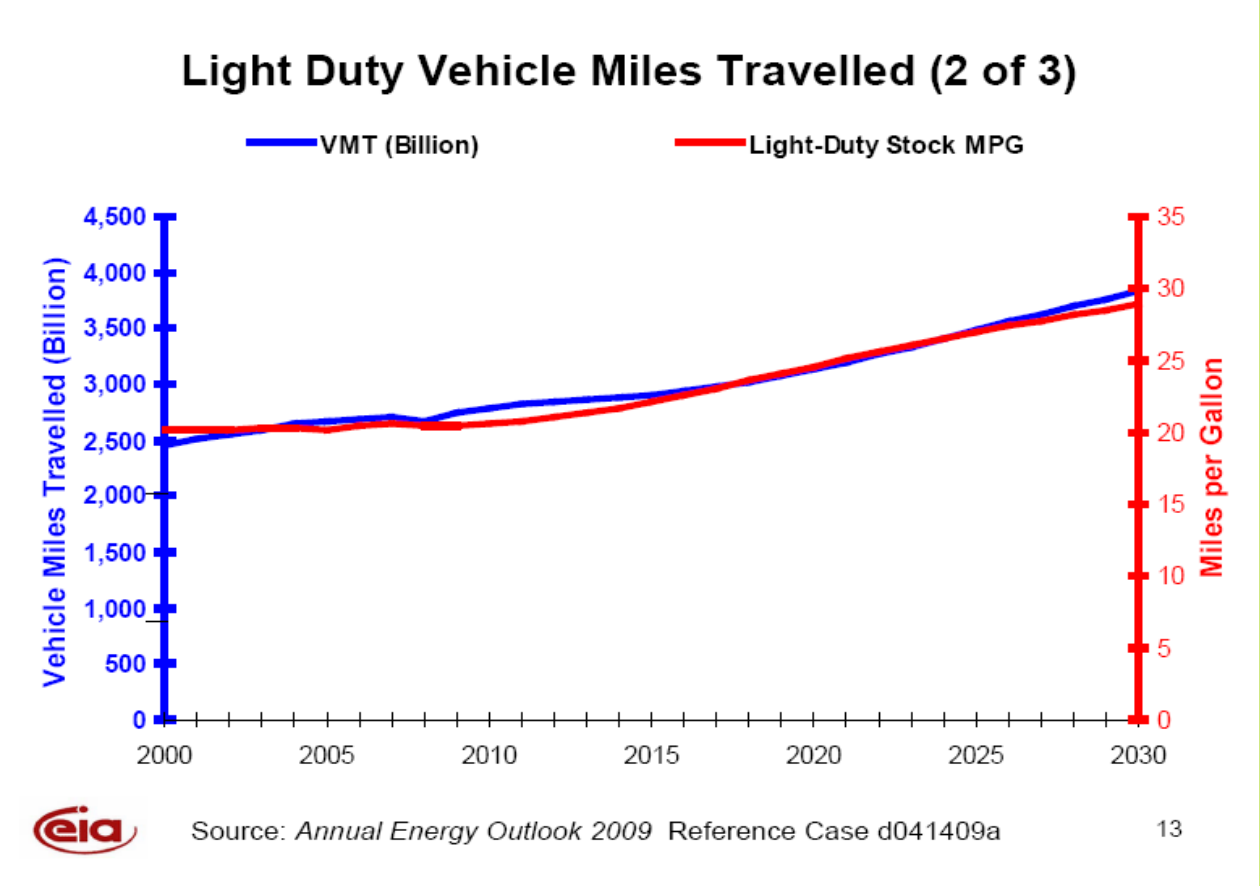


Source: Alan Pisarski and Cambridge Systematics

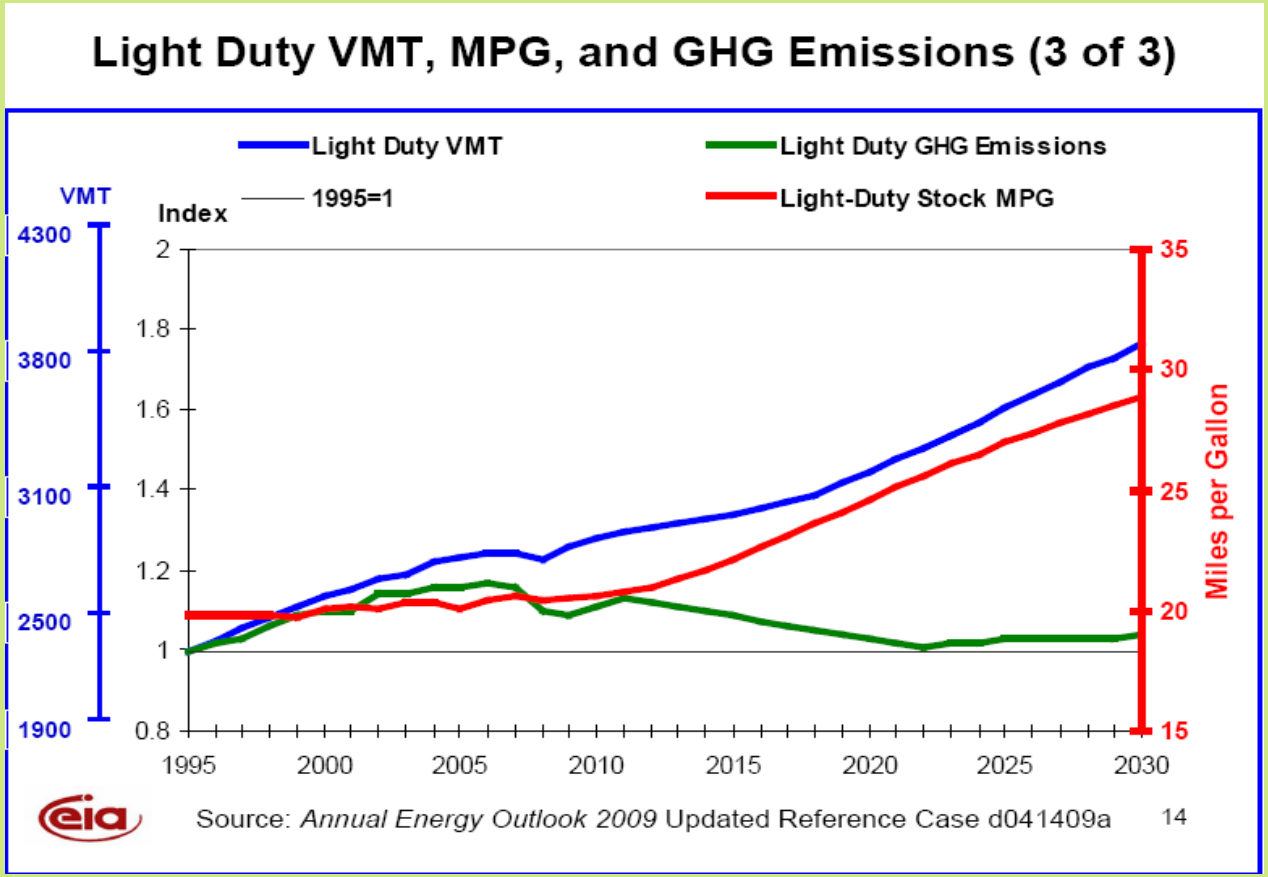
VMT closely linked to disposable income



DOE expects VMT and MPG both to rise



As VMT and MPG rise, GHG is nearly flat



What should the GHG reduction target be for the transportation sector?

- Economists:
  - Reduce GHG emissions as cost-effectively as possible, even if that means much larger reductions in some sectors than others
  - Evidence is accumulating that reducing transportation GHG 80% would be more costly than same % reduction in other sectors
  - Ergo: Transportation GHG reduction targets probably should be lower

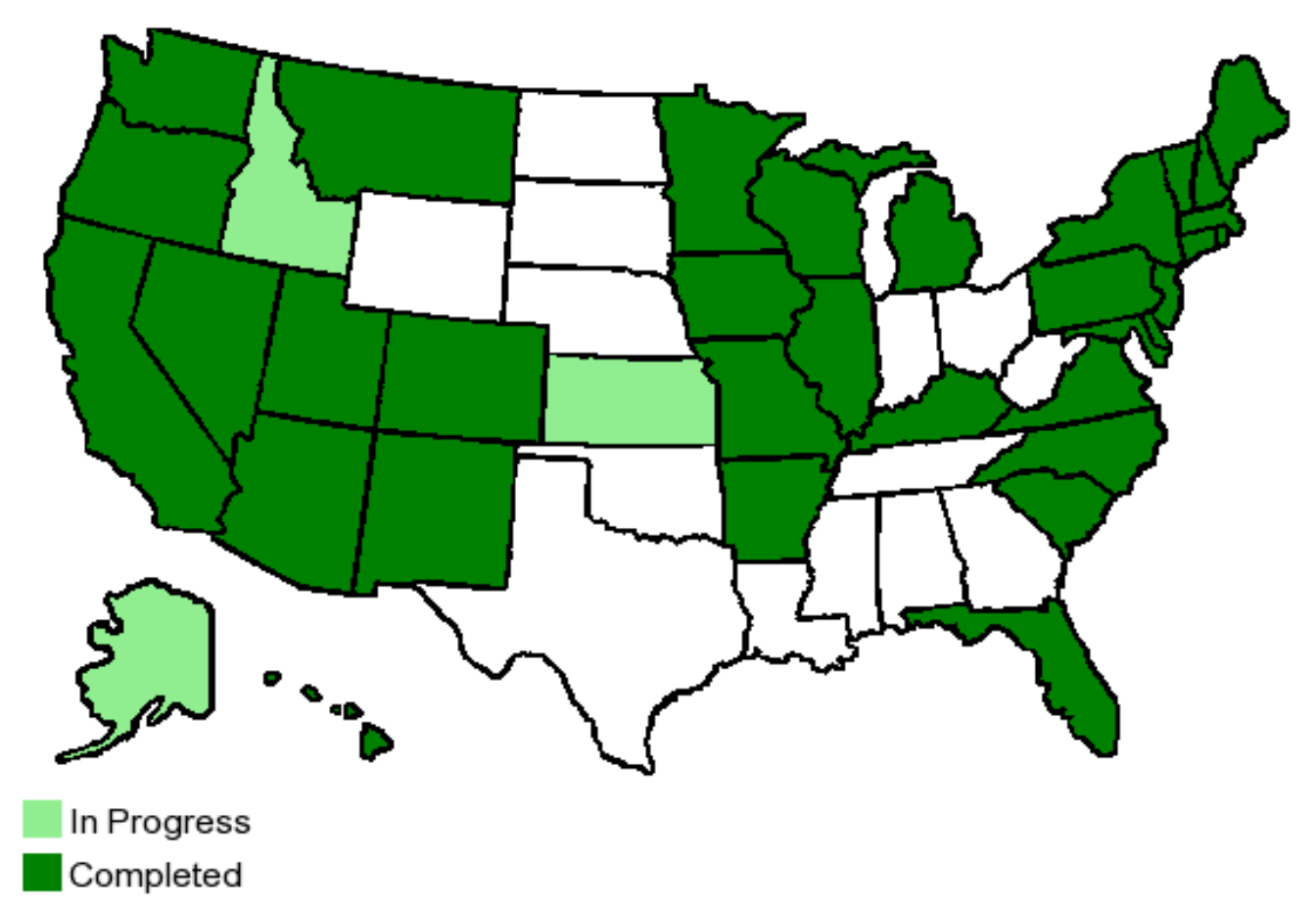
- Political reality:
  - Transportation will be expected to contribute its "fair share“
  - Room for debate about what "fair share" means.
  - Often-cited goal is **60 to 80%** from current levels.

Policy debate can be intense

- Climate skeptics: Climate change isn't happening, or isn't human-induced
- Environmental view: Transform land use, increase transit, and reduce VMT
- Techno-optimist view: Transform vehicle/fuel technology and improve highway/driver operations
- Pragmatic view: Combination -- mostly vehicles/fuels, some operational efficiency, plus modest role for land use, transit, and VMT moderation

State Climate Action Plans

Source: Pew Center on Climate Change



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, whose input was often rebuffed
- Example: VT strategies would reduce 2030 VMT from 10.5 B (base case) to 3.9 B

State Climate Plans – Transportation Share Of GHG Reductions Varies Widely

State	Year	% Reduction in Transportation GHG	% of all GHG Reductions from Transportation
Rhode Island	2020	N/A	20%
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%
Colorado	2020	22%	6%
North Carolina	2020	31%	11%

State Climate Plans – Transportation Elements Vary All Across the Map

State	Year	Vehicle	Low Carbon Fuels	Smart Growth and Transit	Other
RI	2020	46%	10%	31%	14%
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	45%	36%	18%	0%
MN	2025	15%	35%	25%	25%
VT	2028	21%	14%	49%	17%

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
- 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%20_AASHTO_0.ppt
- Florida: http://www.dep.state.fl.us/climatechange/files/action_plan/chap5_trans.pdf.

GHG reduction debates overshadow 2 more challenges bearing down on state DOTs

- New revenue sources: New revenue sources are needed that are appropriate in a climate change-dominated world, with electric vehicles and new fuels

- Climate adaptation: Huge funding increases, risk-based planning and programming, and tough policy decisions will be needed to adapt to a changing climate

III. Federal Climate Change Legislation

Federal Climate Legislation and Policy are Taking Shape

- AASHTO position
- EPA proposed “endangerment” finding
- (section 202(a) of CAA
- “Cap and Trade” bills
- 2010 Senate Bill - Kerry-Lieberman

AASHTO Position on Climate Change

- Major R&D to decarbonize vehicles/fuels (comparable to "man on the moon")
- Reduce VMT growth to 1%/year
- Double transit ridership
- Increase intercity passenger rail
- $100 M/year Federal funding for coordinated land use/transportation planning
- Oppose GHG conformity requirement
- See AASHTO "Real Transportation Solutions" at http://www.climatechange.transportation.org/

Clean Air Act – EPA Endangerment Finding

- EPA can regulate GHG under existing Clean Air Act (CAA)
- December 2009 EPA finding:
  - Atmospheric concentrations of GHG "***endanger"*** public health and welfare (per CAA section 202(a))
  - Emissions of GHG from new motor vehicles "***contribute to"*** air pollution which is endangering public health and welfare
- Based on this finding EPA is obligated to regulate GHG (e.g., GHG standards for autos)
- GHG conformity possible, but not likely
- Endangerment finding challenged by several states

Federal Climate Legislation - Status

- House: Passed Waxman-Markey bill on the floor in 2009
- Senate: Boxer-Kerry bill reached floor in 2009, then stalled
- Senate: Kerry-Lieberman “discussion draft” bill released May 12, 2010
- President Obama: Strongly supports cap-and-trade legislation

Federal Legislation – Major Elements of Climate Bills

- **Cap-and-Trade**
  - Sets "cap" on GHG emissions; cap declines over time
- **Energy Production**
  - Provides incentives and other support for production of renewable energy (and maybe nuclear, oil & gas)
- **Energy Efficiency**
  - Provides incentives and tighter regulations to promote greater efficiency – buildings, appliances, vehicles, etc.
- **Transition Assistance**
  - Provides assistance to ease impact of higher energy prices on consumers and U.S. industries

Source: Bill Malley, Perkins Coie

Federal Climate Legislation – Basics of Cap and Trade

How a cap-and-trade program 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

2010 Senate Bill: Kerry-Lieberman – American Power Act

- "Discussion draft" released May 12, 2010
- Calls for reductions from 2005 baseline
  - 17% by 2020
  - 42% by 2030
  - 83% by 2050
- Sets national GHG emissions cap
  - Transportation fuels under the cap
  - Tptn fuel producers and importers would purchase emissions allowances at a fixed price ($12 - $25/ton carbon)
  - Tptn carbon price would increase at 3% over inflation/year)
- Imposes transportation planning requirements on states & large MPOs
- Many, many other provisions, affecting all sectors

How much revenue would K-L provide for transportation?

- K-L doesn't allocate dollars to transportation – but does allocate "percentages of allowances" which can be sold and converted into dollars
- Value of allowances will fluctuate but can be estimated
- K-L caps the value of allowances for transportation at **$6.2 billion per year** (without the cap, the value could be higher)
- AASHTO/APTA estimate that 70-90% of revenues from transportation fuels are diverted to other purposes (deficit reduction, transition assistance to households, R&D, etc.)

How could the K-L allowances revenue be used for transportation?

$6.25 billion annually -- maximum

- One-third to Highway Trust Fund up to $2.5 b/yr
- One-third to TIGER grant program $1.875 b/yr
- One third for transportation planning and implementation $1.875 b/yr

What are the K-L requirements for transportation planning?

States and large MPOs (over 200,000 population) must:

- Develop GHG targets and strategies
- Integrate GHG targets and strategies into plans
- Demonstrate progress in stabilizing and reducing GHG emissions to contribute to achievement of national targets

USEPA is to:

- Issue regulations for standardized emissions models and methods

USDOT is to:

- Determine whether state and MPO plans are “likely to achieve” GHG reduction targets
- Provide performance awards ($) for states with approved plans
- Issue regulations for GHG planning (overlaps with EPA regs)

Federal Climate Legislation – Impact on Transportation Fuel Prices

- **How would the House and Senate bills affect the price of transportation fuels?**
  - EPA analysis of House Bill (6/23/09) estimated House bill would raise gas prices by 14 cents/gallon by 2015
  - EPA makes two key assumptions:
    - Relatively *low cost to adopt new technologies* that reduce GHG emissions, such as carbon capture and sequestration (CCS)
    - Relatively *widespread use of "offsets"*
  - Without these assumptions, prices could be much higher.
  - EPA has not yet released an estimate of the gasoline price impacts of the 2010 Senate bill

Source: Bill Malley, Perkins-Coie

Federal Climate Legislation – Impact on Transportation Fuel Prices

	2015	2030	2050
EPA Projection	$0.14	$0.24	$0.69
CRA: Base Case	$0.19	$0.38	$0.95
CRA: "Low-Cost"	$0.17	$0.34	$0.84
CRA: "High-Cost"	$0.36	$0.71	$1.82
CRA: "No International Offsets"	$0.52	$1.08	$2.79

Source for CRA Estimates: CRA International, "Impact on the Economy of the American Clean Energy and Security Act of 2009 (H.R.2454), pp. 4 and 64-66.

House and Senate Bills Have Small Impact on Transportation GHG

EPA projects that the price signal from cap-and-trade would have little effect on transportation emissions

"The increase in gasoline prices that results from the increase in the carbon price … is not sufficient to substantially change consumer behavior in their vehicle miles traveled or vehicle purchases …."

"The relatively modest indirect price signal on vehicle manufacturers from this particular cap-and-trade policy creates little incentive for the introduction of low-GHG automotive technology."

Source: http://www.epa.gov/climatechange/economics/economicanalyses.html

Summary

- Prepare for federal legislation and requirements
- DOTs may be expected to reduce transportation GHG by 60-80% by 2050
- Many state climate action plans include “aspirational” transportation elements that have not been thoroughly analyzed or vetted
- VMT reductions may be expected or required
- Lower VMT and more fuel efficient cars will exacerbate the transportation revenue dilemma – new revenue sources will be needed

IV. Gulf Coast Study and Climate Adaptation for Transportation

FHWA Adaptation Reports and Activities

- Impacts of Climate Change and Variability on Transportation Systems and Infrastructure – The Gulf Coast Study, Phase I (SAP 4.7)
- Phase 2 of the Gulf Coast Study
- Regional Climate Change Effects report
- FHWA Adaptation Strategy
- Vulnerability/risk assessment conceptual model (& pilots)
- Peer Exchange workshops
- Climate Change and Highway Infrastructure: Impacts and Adaptation Approaches (NCHRP)

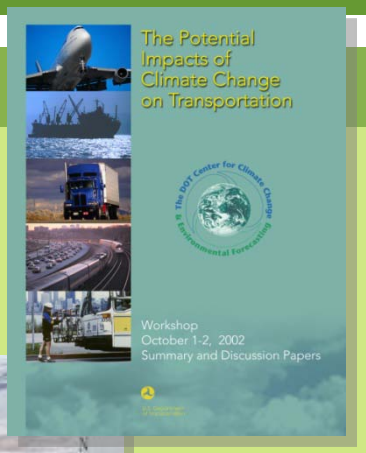
57

U.S. DOT / USGS Gulf Coast Study
Potential Impacts of Climate Change and Variability on Transportation Systems and Infrastructure

58

Why Study Impacts and Adaptation?

- As climate changes, transportation infrastructure may need to evolve to handle new conditions
- Each region has unique transportation assets and vulnerabilities
- Research on transportation impacts is limited



Bonner Bridge

Alaska Highway

59

Why the Gulf Coast?

- Nationally significant
  - 60% nation's petroleum imports
  - Largest concentration of marine freight facilities in the U.S.
  - Major urban centers
- Extensive intermodal network
  - 17,000 miles of highway; 83.5B VMT per year
  - 4 out of 5 top tonnage ports; 1,000 freight handling terminals
  - 6 of 7 Class I railroads
  - 3,800 aircraft at 61 airports
  - 56M passengers at 3 largest airports (2005)
- Engaged decision-makers

Overall Climate Change Effects - Key Drivers for Analysis

- Accelerated relative sea level rise
- Increased storm surge and storm intensity
- Changes in temperature
- Changes in precipitation

SAP 4.7

Trends in Climate and the Natural Environment
Sea Level Rise and Storm Surge

- Relative sea level will likely rise 1 to 6 feet; a 2 - to 4-foot increase is probable
  - Massive inundation due to relative sea level rise
  - Relative sea level includes:
    - Climate-induced impacts of thermal expansion and ice melt; and
    - Sinking land masses (subsidence) in the central Gulf Coast
- Hurricane vulnerability is bad today and may worsen
  - Potential for 5 – 20% increase in storm intensity due to climate change

62

Trends in Climate and the Natural Environment Temperature and Precipitation

- Average temperature is likely to increase by 2°- 4° F by 2050
  - More hot days: # of days > 90° F may increase by 50%
  - Extreme daily high temps will also increase
- Models show mixed results for changes in average precipitation
  - Intensity of rainfall events, however, will likely increase

Houston, TX

The impacts worsen as GHG concentrations increase across the range of IPCC scenarios

Trends in Climate and the Natural Environment

- The central Gulf Coast is particularly vulnerable to climate change over the next 50-100 years
- Climate change impacts need to be integrated with other coastal / environmental effects
- The timing of impacts is not clear; abrupt change cannot be ruled out

64

Implications for…

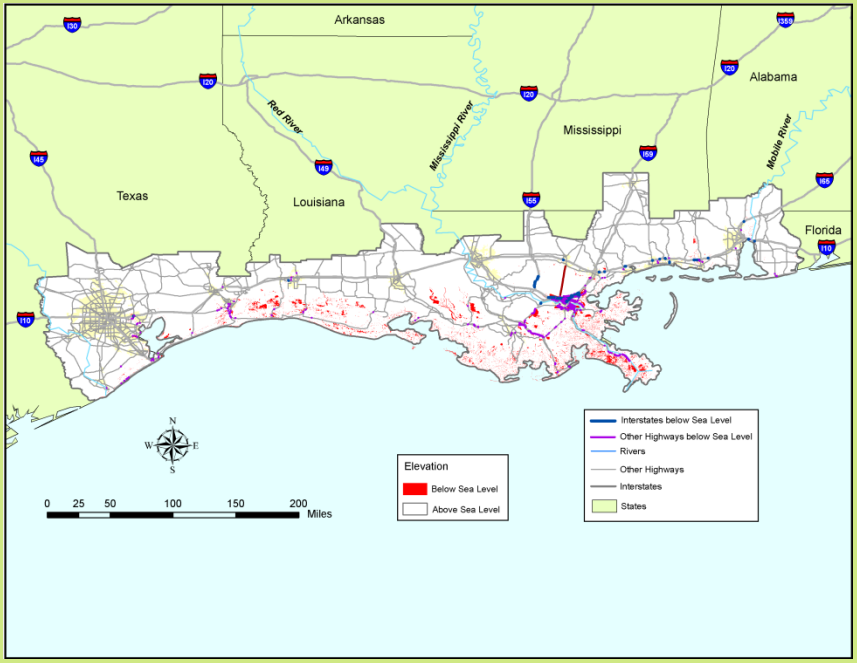
- Highways and transit
- Rail
- Ports and waterways
- Airports
- Emergency management
- Long-range planning and investment

Vulnerability Due to… Relative Sea Level Rise

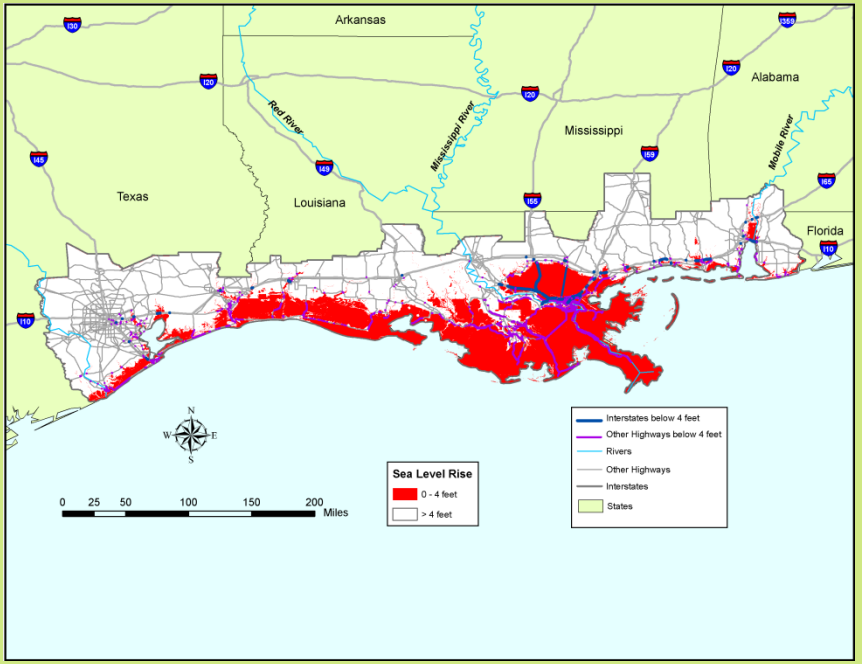
- Relative sea level rise (due to climate change and subsidence) of 4 feet could permanently flood:
  - 24% of interstate miles, 28% of arterial miles, New Orleans Transit
  - 72% of freight, 73% of non-freight facilities at ports
  - 9% of the rail miles operated, 20% of the freight facilities, no passenger stations
  - 3 airports
  - Temporary flooding in low-lying areas due to increased heavy downpours will broaden affected areas

Highways Vulnerable to Relative Sea Level Rise

Baseline (Present Day)



4 Feet of Sea Level Rise



Source: Cambridge Systematics analysis of U.S. DOT Data.

67

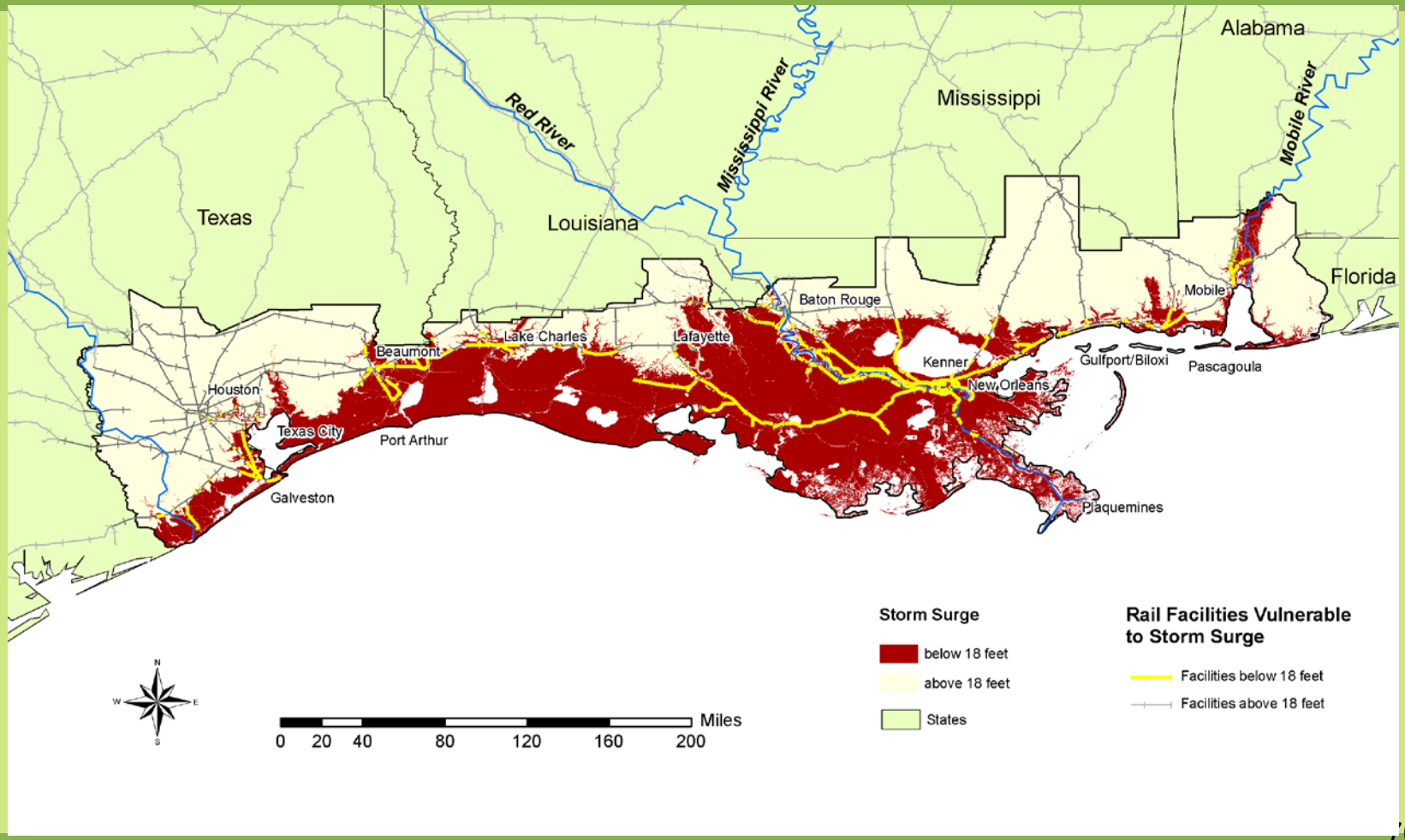
Vulnerability Due to… Storm Surge

- As witnessed by the 2005 hurricane season, transportation in the central Gulf Coast is already vulnerable to large hurricanes
- That vulnerability will be exacerbated if hurricane intensity increases, absent adaptation strategies
- Examined effect of 18 and 23 ft storm surge

Vulnerability Due to… Storm Surge

- Transportation infrastructure that is vulnerable to 18 feet of storm surge includes:
  - 51% of interstate miles, 56% of arterial miles, and most transit authorities
  - 98% of port facilities vulnerable to surge and 100% to wind
  - 33% of rail miles operated, 43% of freight facilities
  - 22 airports in the study area at or below 18 feet MSL
  - Potentially significant damage to offshore oil & gas facilities

Freight Rail Lines Vulnerable to Storm Surge of 18 feet



70

Caveats – Relative SLR and Storm Surge

- Analysis of impacts is based on land elevation rather than the height of facilities
- Analysis does not consider the presence of possible protective structures (levees, sea walls, etc.)
- A small flooded segment may render a larger portion of the infrastructure inoperable, due to the connectivity of the intermodal system
  - Many transportation facilities depend on local roads (not elevated)

71

Hurricane Katrina Damage to Highway 90 at Bay St. Louis, MS

Source: NASA Remote Sensing Tutorial.

72

Vulnerability Due to… Temperature Increases

- As temperatures increase, operations will be affected:
  - Potential rise in maintenance and construction costs
  - Increased use of energy for refrigerated storage
  - Potential rise in rail buckling
  - May result in impacts to aircraft performance and runway utilization

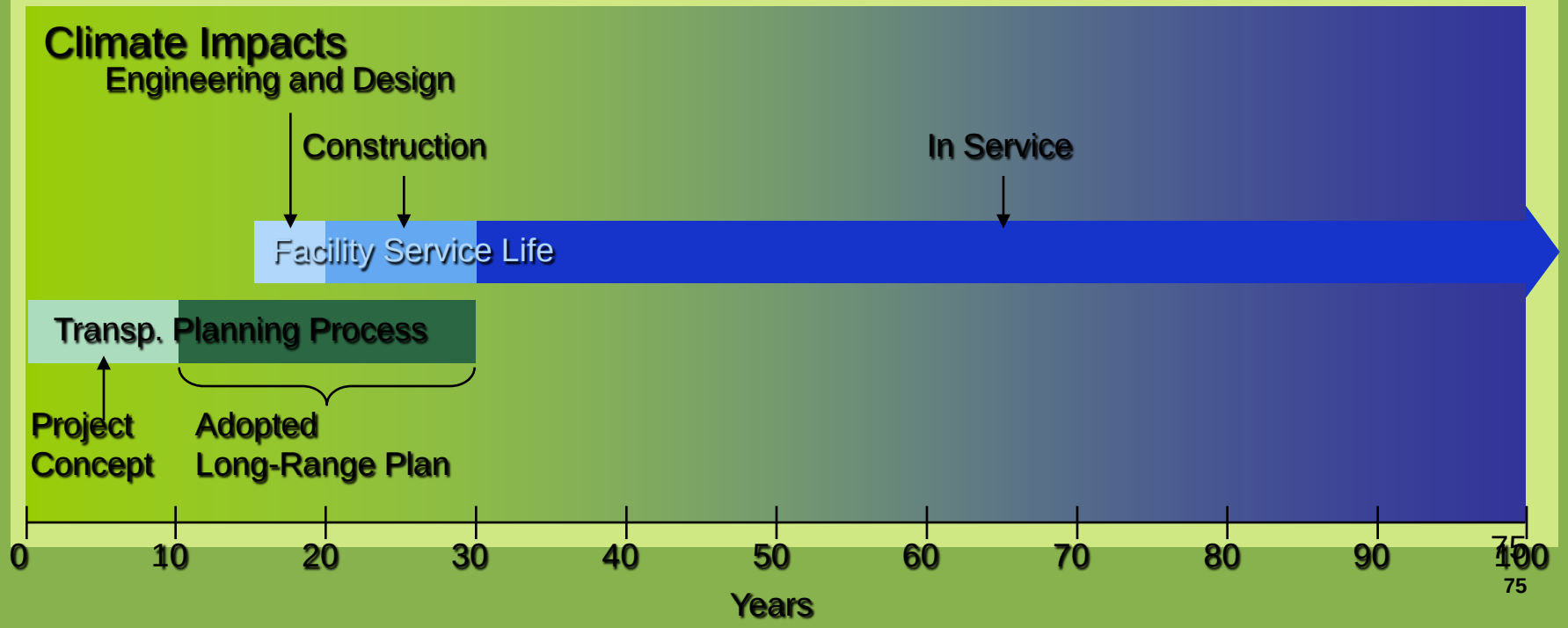
What Are Possible Adaptation Responses?

- Accommodate: Maintain and manage
  - Absorb increased maintenance / repair costs
  - Improve real-time response to severe events
- Strengthen structures / protect facilities
  - Design changes when rebuilding / new investment
  - Promote buffers, sea walls, etc.
- Relocate / avoid
  - Move key facilities
  - Site new facilities in less vulnerable locations
- Abandon and Disinvest
- Enhance redundancy
  - Identify system alternatives

74

Implications for Transportation Planning

- Climate change is rarely considered today, but the longevity of infrastructure argues for its integration
- Current practice focusing on a 20-year time frame is not well-suited to the assessment of climate impacts

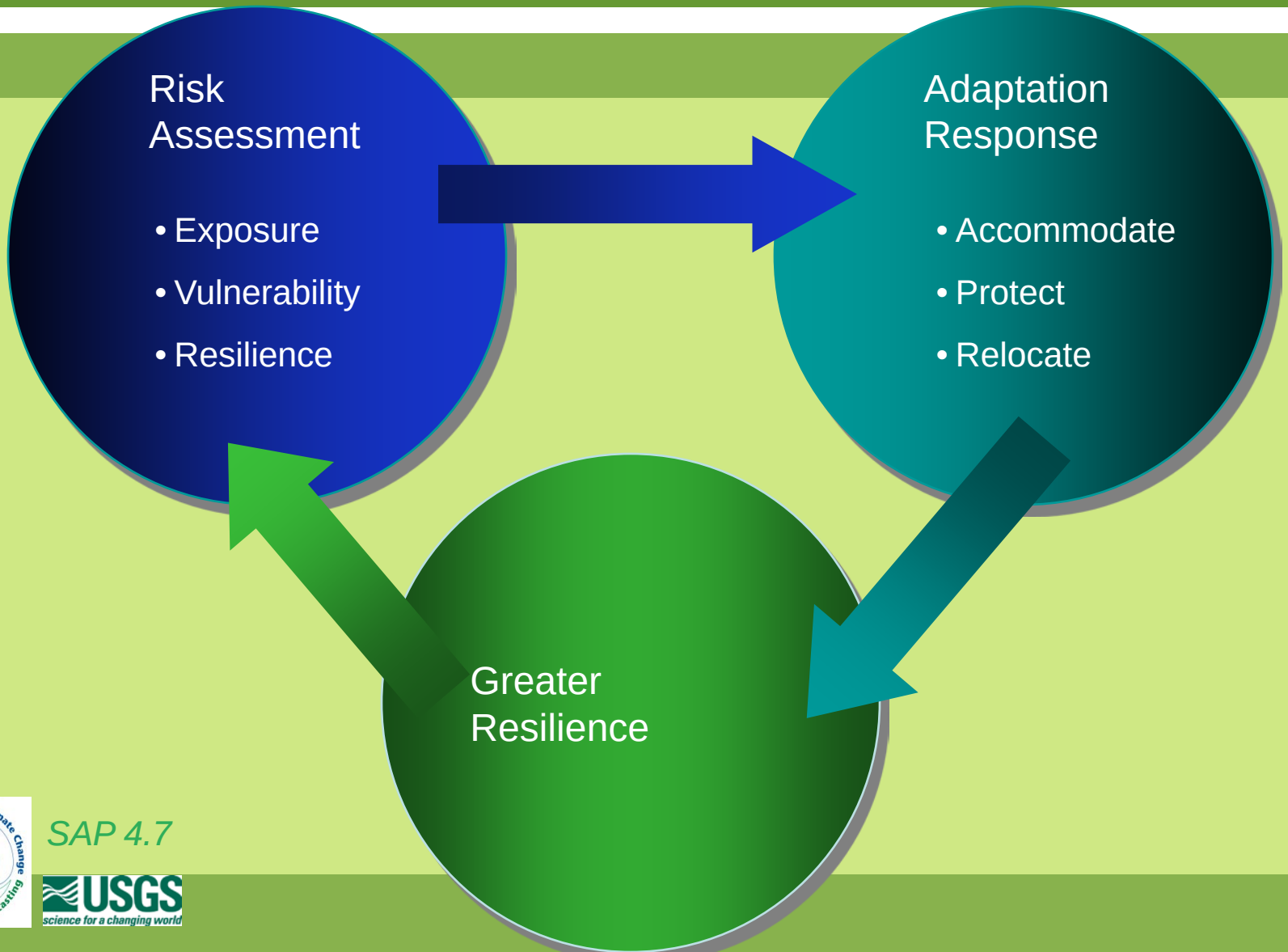


Transportation Planning: Preparing for change…

- A robust transportation systems requires reliability under a range of conditions
- It is useful to examine the vulnerability of the intermodal system in addition to specific facilities
- Use of new approaches to decision-making
  - Scenario planning
  - Integration of climate change with other regional dynamics
  - Risk assessment approach
  - Probabilistic rather than deterministic approach
  - Consider both incremental and abrupt change

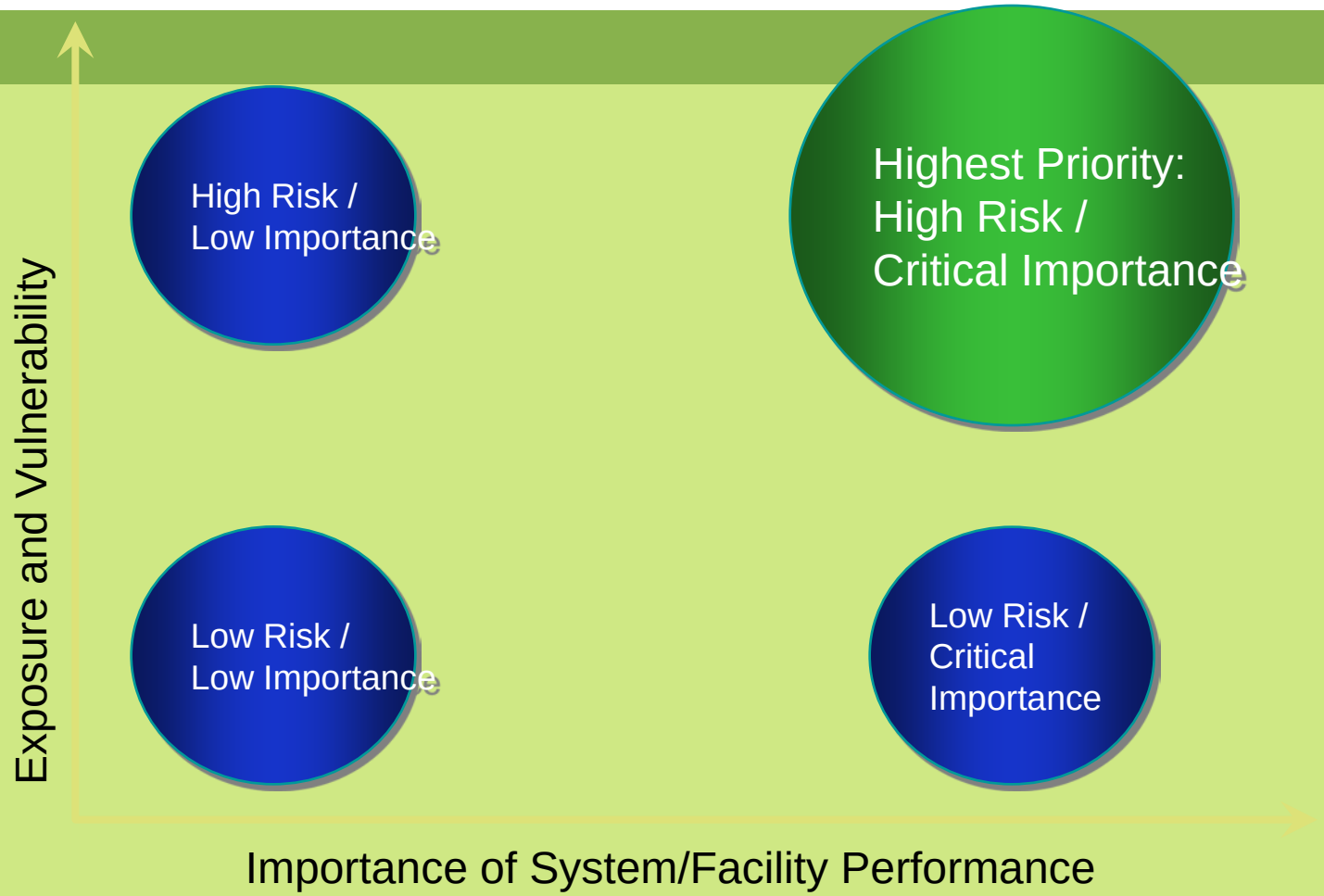
76

A Risk Assessment Approach to Transportation Decisions



SAP 4.7

But Need More Than Just Degree of Risk to Prioritize Investments…



78

Potential for Costly Impacts

79

Gulf Coast Study, Phase 2

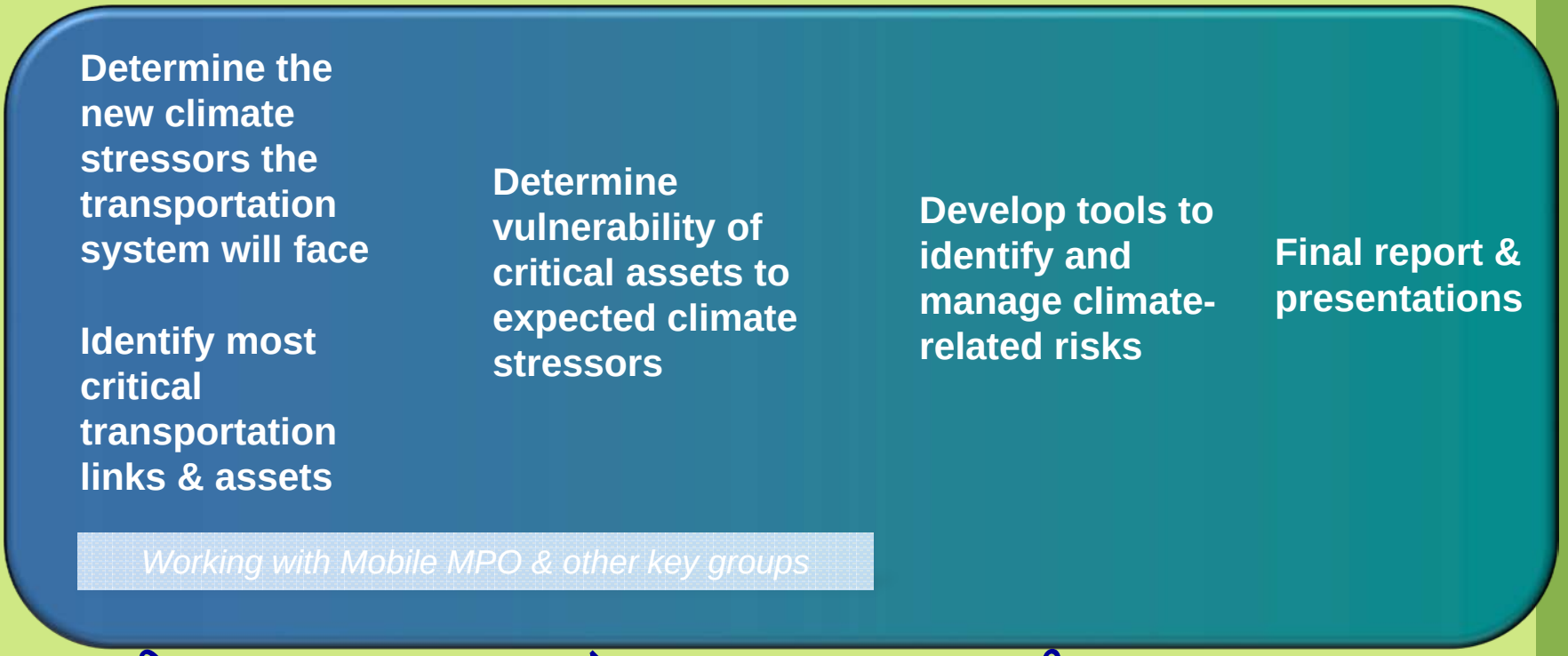
- Process for assessing critical transportation infrastructure, projecting climate change effects, evaluating vulnerability, and conducting detailed engineering assessments for vulnerable assets in Mobile

  - Lessons learned and replicable processes that could inform similar analyses in other MPOs
  - Transferrable tools and resources to assist MPOs nationwide
  - Timeframe: 2010-2012

GC2: Overview

- Focus on a single Metropolitan area in the Gulf Coast Region: Mobile, AL MPO
  - Identify "critical assets" in Mobile region
  - Evaluate projected climate change effects & stressors
  - Determine vulnerability of specific assets, given projected climate effects; conduct vulnerability assessment & detailed engineering analyses of adaptation approaches for selected assets
  - Develop risk assessment tools & approaches
  - Work with stakeholders in Mobile throughout project; take lessons learned & identify tools to make process, lessons learned, & methods accessible to other MPOs.
  - Include major findings in a final report

GC2: General Timeline

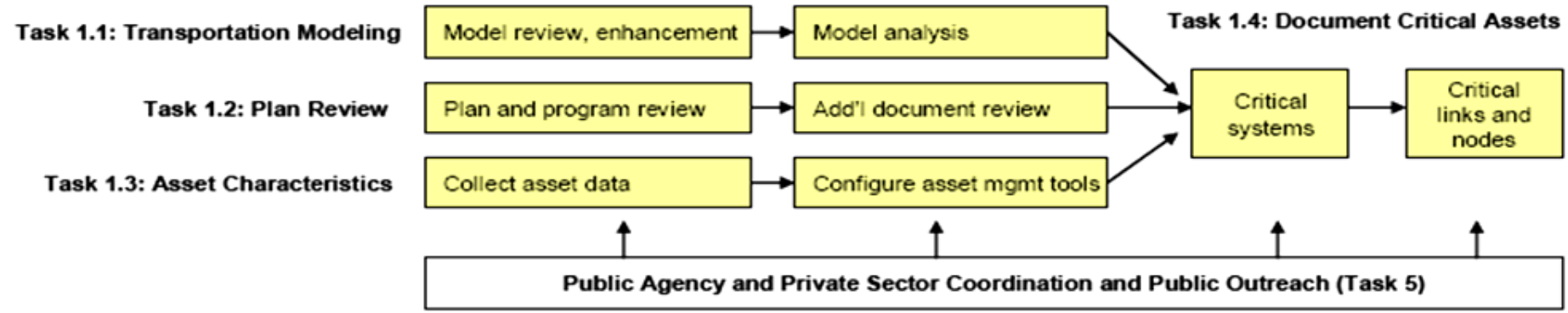


Task 1:
Identify Critical Transportation Systems

- ICF and PB will develop a preliminary list of critical assets
  - Review MPO Model & other available modal or special purpose models
    - Enhance models as needed to identify critical infrastructure & assess vulnerability
    - Re-run model as needed to test critical links (stress on rest of system if one link down)
  - Review plans & programs, interview staff
  - Collect & review asset data & asset management tools in use

Task 1:
Identify Critical Transportation Systems

- Score and rank critical assets
- Send draft critical asset list to climate workgroup to request feedback



Task 2: Identify Climate Impacts

- Obtain climate/weather data: past conditions and future scenarios
- Quantify relationships between climate and local transportation infrastructure and services
- Technical memo summarizing findings by asset category and climate effect, for review by asset managers

Table 7.3. Effects of emerging or enhanced stressors on estuaries arising from climate change.

Stressor	Water Quality	Fisheries & Wildlife	Habitat	Human Value & Welfare	Water Quantity
Sea Level Rise (shoreline armoring prevents transgression of habitats)	positive then negative	positive then negative	positive then negative	negative	negative
Increased Intensive Storms (shoreline erosion; pulsed floods and runoff)	negative	negative	negative	negative	
Temperature Increases (new species mix; disease and parasitism increase, phenology mismatch)	positive then negative	positive then negative	positive then negative	positive then negative	

Task 2: Identify Climate Impacts

- How has the transportation system been affected during recent extreme weather events?
- How have the different transportation modes been affected by:
  - Hurricanes?
  - Extreme heat episodes?
  - Unusual cold temperature events?
  - Unusual precipitation patterns (excessive rain or drought)?

86

Tasks 3 & 4: Vulnerability & Risk Management

- Task 3: Determine Vulnerability for Key Links & Assets in Each Mode
  - Apply Task 2 results to critical structures identified in Task 1 to determine link- and asset-specific vulnerability
  - Assess role of each asset in system vulnerability
  - Multiply criticality & vulnerability scores to create a prioritized list of structures
  - Conduct engineering analysis and assessment
- Task 4: Develop Risk Management Tools
  - Could be GIS maps of infrastructure overlaid with vulnerable infrastructure; Excel-based or web-based decision-support tool; or a guidance document detailing best practices for MPOs to assess climate-related risks & identify transportation options
  - Consistent with tools & approaches in use within region; developed in consultation with MPO, region, and state

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

- 9 regions (6 continental US, Alaska, Hawaii, Caribbean)
- Projected *changes* by region:
  - Annual, Seasonal Temperature (change in ^{o}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)

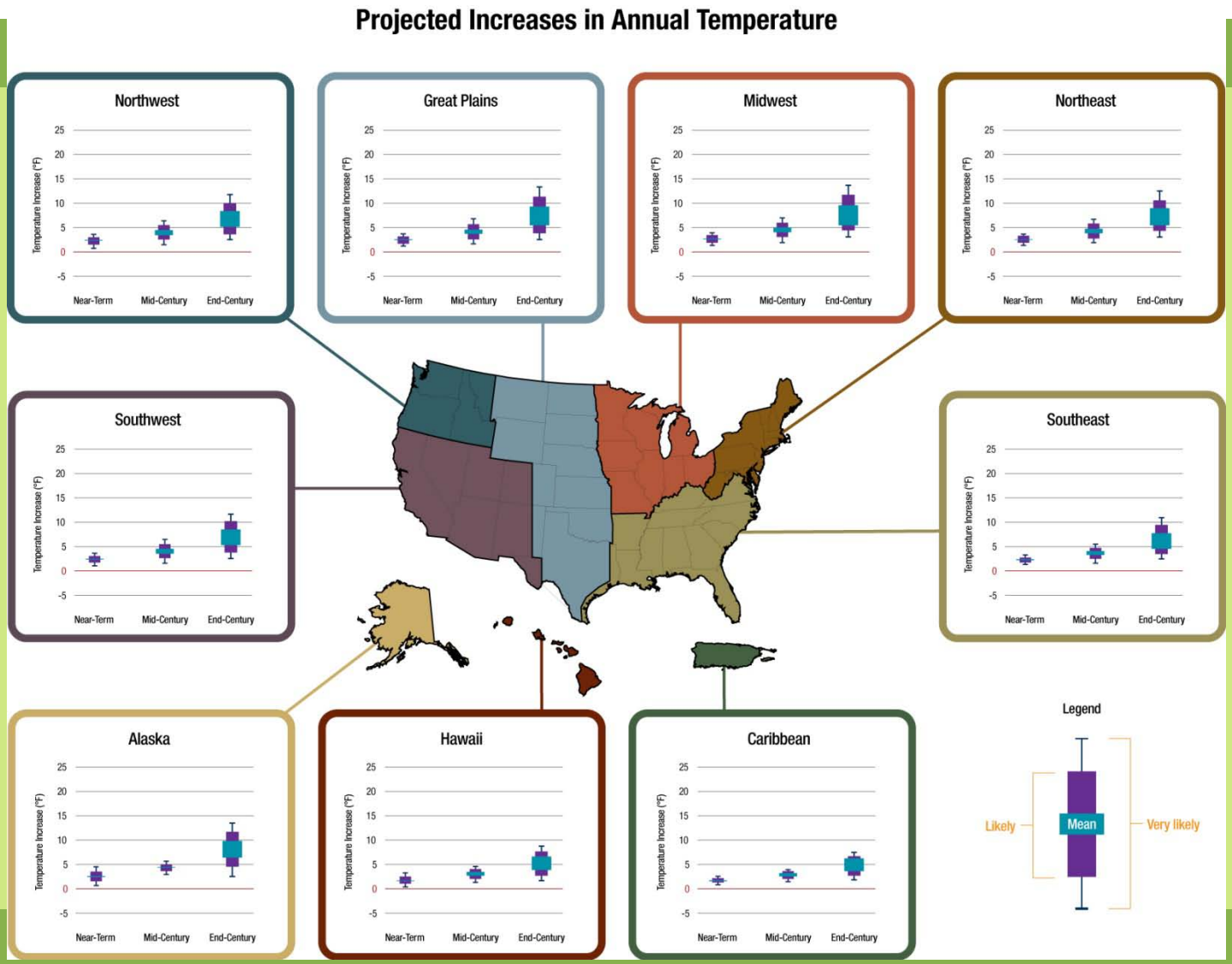
FHWA Climate Change Effects Report

Three sections

- Report
- Regional maps (Appendix B)
- Climate Effects Typology (Appendix C)

90

Annual Temperature Change (ºF)

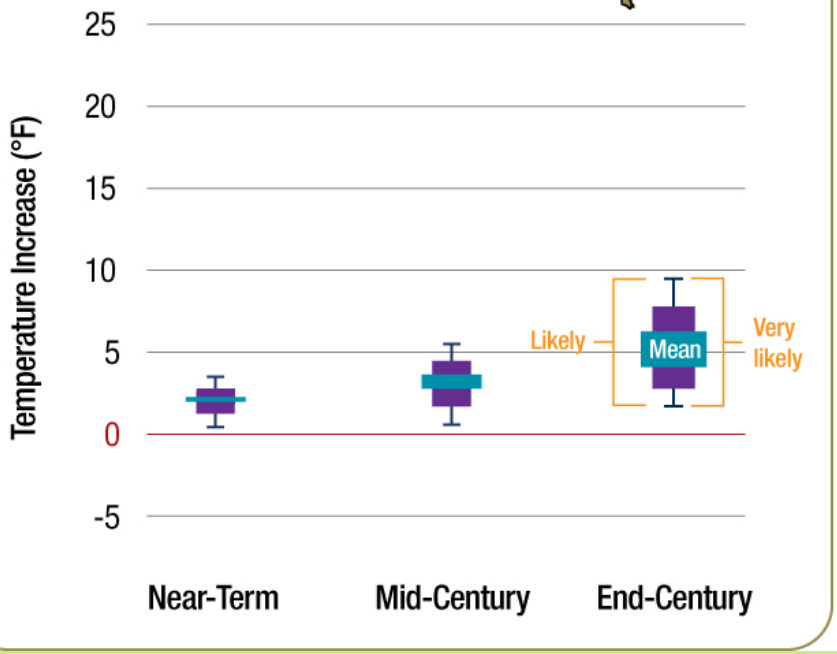


91

Regional Climate Change Effects: Temperature

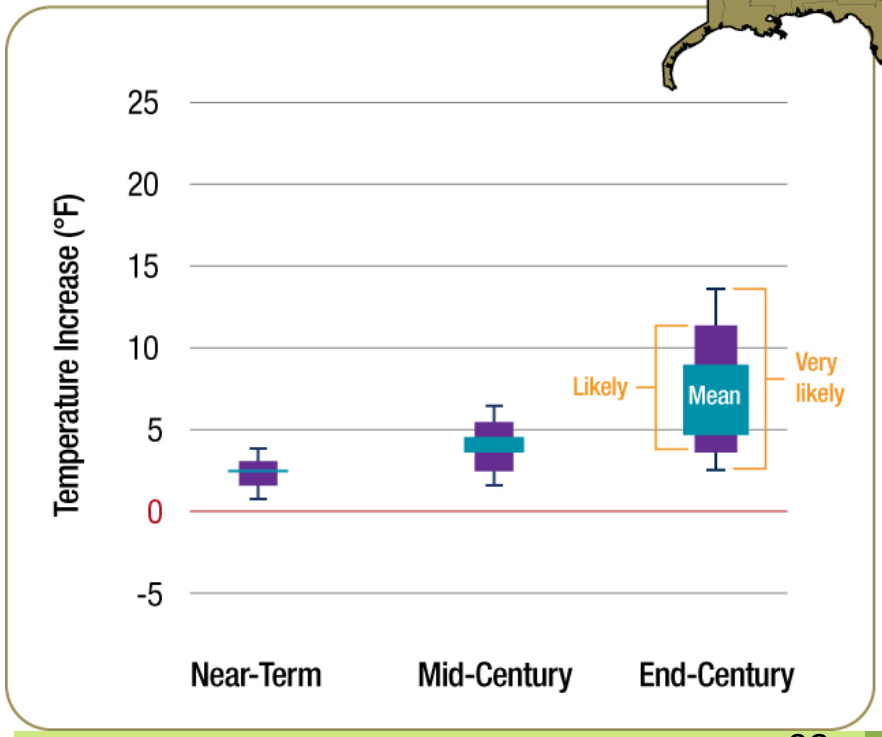
Southeast

Projected Change in Winter Temperature (°F)

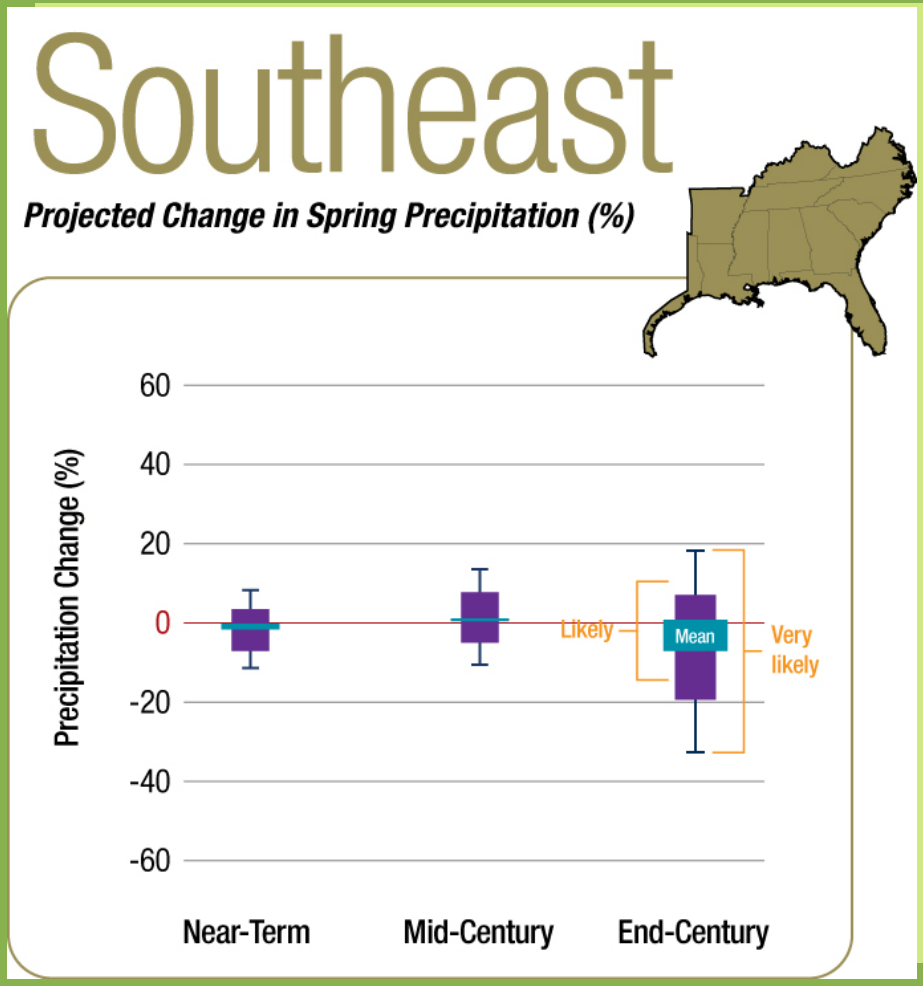


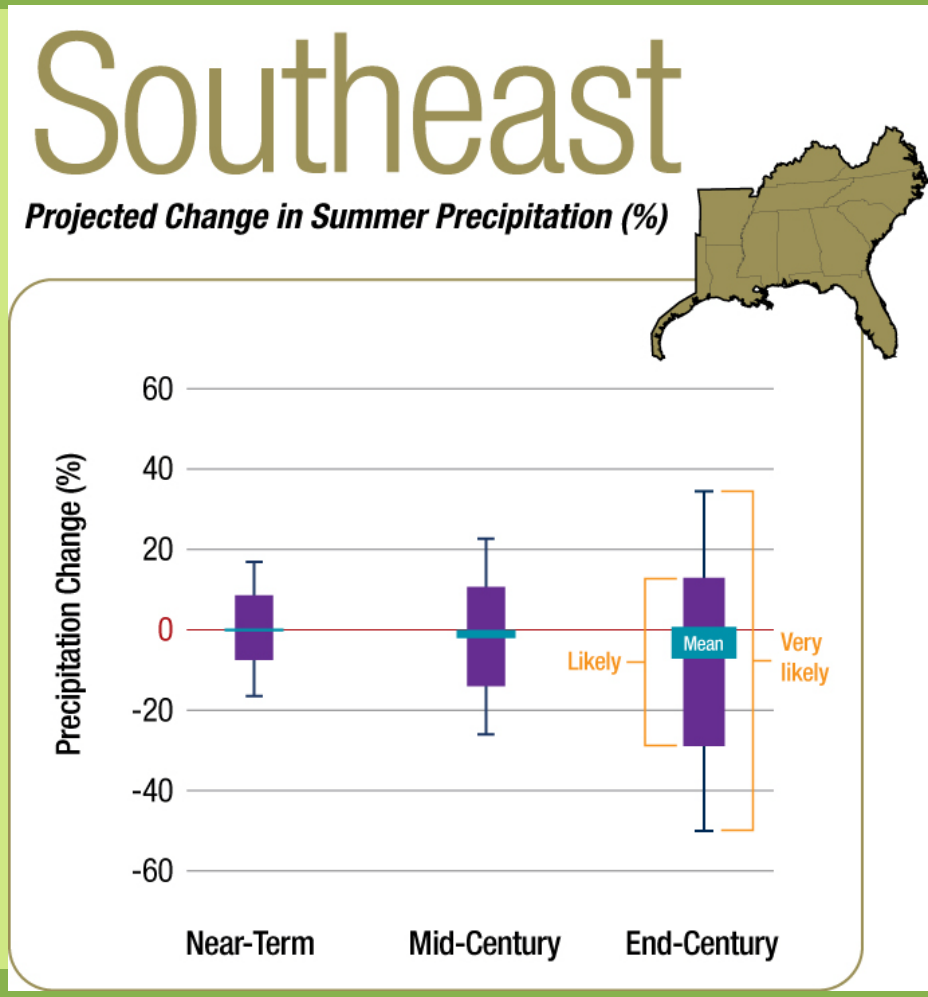
Southeast

Projected Change in Summer Temperature (°F)



Regional Climate Change Effects: Precipitation





Questions?

"Impacts of Climate Change and Variability on Transportation Systems and Infrastructure –The Gulf Coast Study, Phase I"
Synthesis and Assessment Product 4.7
http://www.climatescience.gov/Library/sap/sap4-7/final-report/

Federal Highway Administration Climate Change Website:
http://www.fhwa.dot.gov/hep/climate/index.htm

Robert.Kafalenos@dot.gov
FHWA, Sustainable Transport & Climate Change Team

94

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 and rail buckling
  - Increased flooding
  - More severe inland storms
  - Increased maintenance

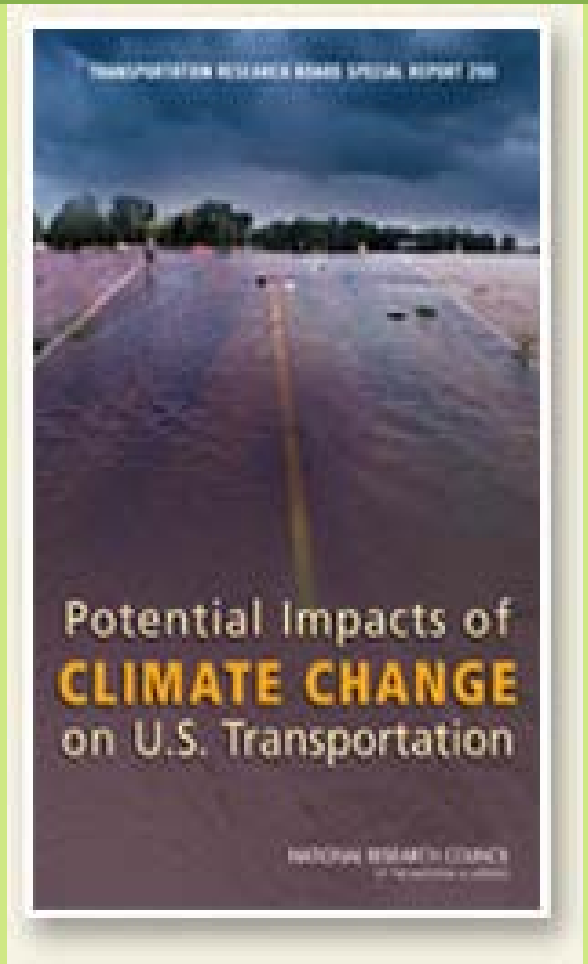
Source: http://mceer.buffalo.edu/research/Reconnaissance/Katrina8-28-05/05BiloxiBay1/09lg.jpg

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

Transportation Research Board 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

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.

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.

States Focusing on Climate Adaptation

- Coastal states are most concerned
- Multi-sector reviews of vulnerability
- Often led by resource agencies
- State DOT role -- significant to minor
- Still early on the learning curve

- California
- Pennsylvania
- Maryland
- Washington
- Hawaii
- Alaska
- Florida
- Massachusetts
- North Carolina

Implications for Design

- Changes in bridge height
- Changes in bridge foundation and superstructure
- Changes in materials specifications
- Changes in suspended and cable-stay bridges to withstand more severe wind and turbulence
- Changes in culvert design, capacity, and location
- Changes in slope design
- Changes in pavement drainage systems

Implications for Maintenance/Operations

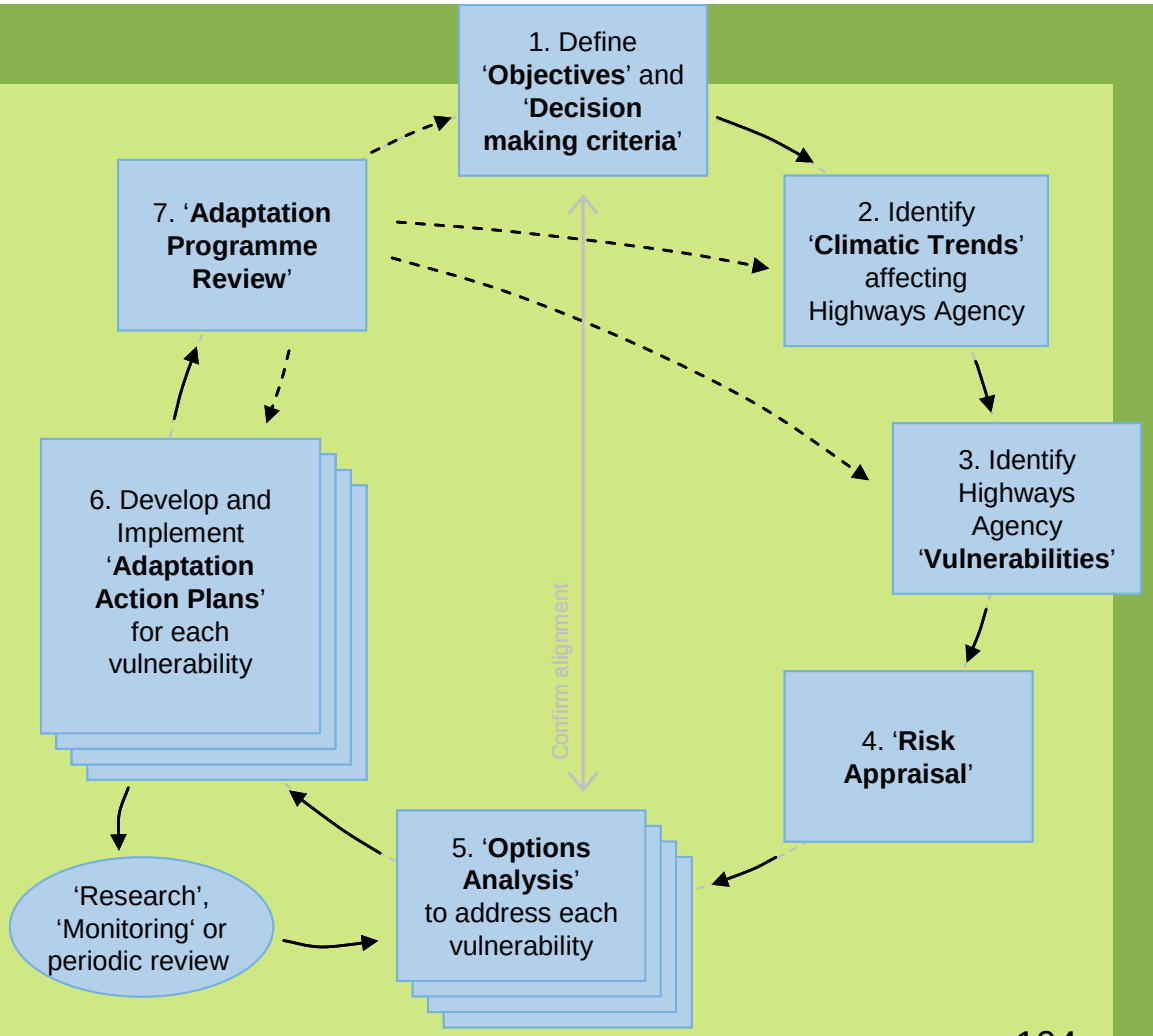
- Pavement rutting and rail buckling
- Longer construction season
- Closures and detours due to rock slides, soil erosion, flooding
- Speed reductions
- Flooding of culverts
- Change in weight restrictions
- More grass cutting/less snow plowing
- Work crew limitations during severe heat periods

Implications for Environmental Reviews

- In NEPA process, sponsor must consider project vulnerability to future climate change
- US ACE 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

U.K. Highways Agency Adaptation Strategy Model

- Model identified potential impacts of climate change of the UK road network
- Resulted in a climate change adaptation strategy
- Strategy addresses design, construction, and maintenance
- Includes a risk appraisal for all operations



Summary

- **All modes** of transportation threatened
- **Affects all transportation functions** – planning, programming, environment, location, design, 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**?

V. Planning and NEPA Issues

Federal Legislation – Transportation Planning Provisions (proposed)

- **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."

Transportation Planning – Many GHG Issues and Implications

- **GHG planning will be impacted by both state and federal policies**
- **Both state DOTs and MPOs will be affected**
- **Inventories of transportation GHG will probably be required**
- **GHG reduction targets will probably be required**
- **Methodologies to predict GHG for different plans and strategies will be needed**
- **Many Clean Air Act planning issues will carry over into GHG planning – modeling limitations, induced demand, VMT reduction expectations, uncertainties about travel behavior, land use expectations, etc.**
- **A major new issue – high degree of uncertainly about future potential new technology and fuels to reduce GHG**
- **Another key issue -- whether/how to include "upstream" and "life cycle" GHG of transportation**

NEPA: Draft CEQ Guidance

- Draft issued by CEQ on February 18, 2010
- Comments were due: May 24, 2010
- Proposal:
  - Evaluate proposed actions that are reasonably expected to cause ***direct*** emissions of 25,000 metric tons or more of CO2-equivalent ***on an annual basis, and,***
  - Consider ***impact of climate change on the project***
- AASHTO provided extensive comments

CEQ Proposal: GHG Emissions to be Considered on a Project Level

- Cumulative emissions over the life of the project
- Emissions from vehicles using the highway
- Construction-related emissions
- Up-stream emissions from fueling cycle (drilling, refining, shipping, etc.) and vehicle cycle
- Others?
- Life-cycle emissions?
- Emissions effects of land use changes, roadway maintenance and lighting, etc.

CEQ Proposal: Roadway GHG Emissions

25,000 metric tons = 43,000,000 VMT/year or about 120,000 VMT/day

- Action that would increase VMT by ***120,000/day (NEW VMT) would trigger analysis***, with all else being equal (e.g. speeds, congestion, fleet mix, etc.)

NEPA: Projects Potentially Triggering GHG Analysis under CEQ Proposal

- New 6-lane bridge,
  - 1.2 miles long, 100,000 ADT, 70 mph (in 2020, 114,400 ADT)
- New 4-lane highway,
  - 3.5 miles long, 40,000 ADT, 70 mph (2020, 45,800 ADT)
- New 2-lane highway,
  - 6 miles long, 25,000 ADT, 60 mph (2020 ADT 28,600)
- Widening existing highway –
  - 6 to 10 lanes, 13 miles, speeds increase from 60 to 70 mph (2020 volumes could increase by 14%)
- Transit Projects - Light-Rail, Heavy-rail, Inter-city Rail?

NEPA: Future Roadway GHG Emissions

- 25,000 tons is based on *annual emissions over life of the project*
- *Future fuel economy* projected by US DOE
  - 2020 fleet - ~14% more fuel efficient than 2010 fleet; raises VMT threshold to 137,000 VMT/day
- *Upstream and downstream emissions?*
  - Fuel supply (well to pump) and vehicle manufacture and disposal included in EPA national inventories
  - Proposed approach would add 40% to emissions generated to account for upstream and downstream emissions
    - 120,000 VMT becomes 86,000 VMT **IF** 40% and upstream/downstream emissions included

NEPA: Construction GHG Emissions

- Methodologies to quantify construction emissions are old
- But, based upon NY procedures
  - 25,000 metric tons could result from 30-50 lane-miles of new road work
  - Emissions vary widely
- *Construction emissions would be annualized over life of project*

NEPA: Construction GHG Emissions

Source: NYSDOT

Construction Energy Factors -- Lane-Mile Approach		
Type of Improvement	**Construction Energy Consumed per Rural[a]-Lane-Mile (10^9 Btu/mi)**	**CO2, tonnes**
New construction	12.70	637
Relocation	10.50	526
Reconstruction	5.20	261
Restoration and rehabilitation	2.30	115
Resurfacing	0.75	38
Major widening	5.00	251
Minor widening	1.90	95
New Bridges	192	9624
Bridge Replacement	222	11128
Major rehabilitation	134.4	6737
Minor rehabilitation	11.91	597
[a] Increase rural energy consumption by 20% for urban construction		

NEPA: Also Consider Climate Impacts on Project

- Climate Adaptation Planning
  - Discuss **climate change effects that should be considered in project development** such as flooding in low lying areas, development of coastal infrastructure
  - Also discuss **reasonably foreseeable future conditions** with no action

AASHTO Comments

- Planning process is the appropriate venue for developing and implementing GHG reduction strategies not project level
- Project-level analysis not meaningful
  - Inadaquate tools
  - Global emissions vs project-level analysis disconnect
  - Basis for 25,000 mmte threshold?
- Major emphasis on adaptation needed in transportation policy

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 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

DEIS for Columbia River Crossing

- Won national award for GHG analysis from National Association of Environmental Professionals
- DEIS issued May 2008
- Project is for congested river crossing between Portland OR and Vancouver WA
- Estimated cost of $3.1 - $4.2 billion
- 4 build alternatives – all are a combination of transit (BRT or LRT) and improved highway capacity

DEIS for Columbia River Crossing

The Interstate Bridge
I-5 over the Columbia River

- 2 side-by-side bridges
- Northbound built in 1917, southbound built in 1958
- 3 lanes each direction
- The only red light on I-5 from Canada to Mexico

DEIS for Columbia River Crossing - GHG Results

- Build alternatives have lower GHG than no-build
- Relatively small differences among build alternatives
- Transit GHG emissions varied substantially
- Highest GHG: The alternative with more transit, higher toll, and less highway improvement

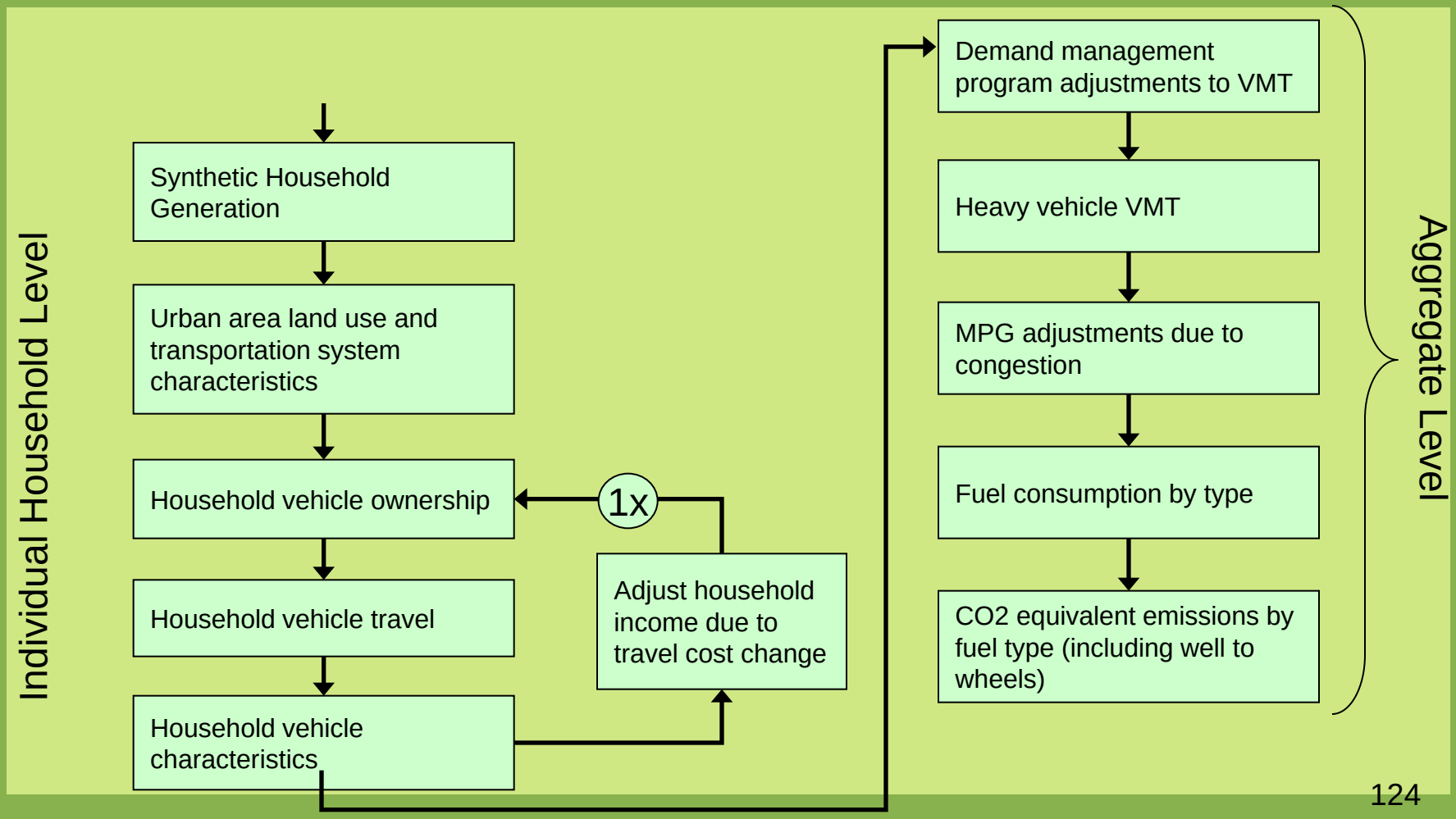
Source: Colin McConnaha, Parametrix, Inc.

One Emerging Tool: GreenSTEP

GreenSTEP = Greenhouse gas State Transportation Emissions Planning model

- A statewide planning model to help Oregon develop a statewide transportation strategy on greenhouse gas (GHG) emissions
- Complements metropolitan travel demand models and ODOT's integrated statewide model
- Peer Review by Oregon travel modelers and experts in other disciplines
- Many elements have been estimated using 2001 NHTS data
- Open source model developed and implemented in open source software (R programming language)
- Partially developed with FHWA SPR program funds

GreenSTEP Overview



GreenSTEP Inputs

- Demographic changes
- Relative amounts of development occurring in urban and rural areas
- Metropolitan and other urban area densities
- Urban form
- Amounts of metropolitan area public transit service
- Highway capacity
- Vehicle fuel efficiency
- Vehicle ages
- Electric vehicles
- Fuel & carbon pricing
- VMT pricing
- Demand management
- Effects of congestion on fuel economy
- Carbon content of fuels – including well to wheels impacts
- CO2 production from electrical power use for transportation

GreenSTEP can Analyze Many Different Strategies

Fuel Economy & Costs

Urban Planning

Vehicle Tech & Fuel

Summary

- Transportation planning process will need to consider GHG emissions and climate change impacts
- CEQ Draft Guidance will impact required NEPA Analysis
- Consider both
    * impact of project on GHG; and
    * impact of climate change on project
- Tools will be needed to evaluate GHG emissions
- Documentation will be important
- Mitigation actions can be helpful

VI. Strategies to Reduce Transportation GHGs

Five GHG Reduction "Legs"

Transportation GHG reduction has 5 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

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

By 2020-2030:

- 50% cut in GHG/mile is feasible from conventional technologies and biofuels
- 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

2010 NHTSA/EPA Rule Significantly Reduces Highway GHG Below Baseline

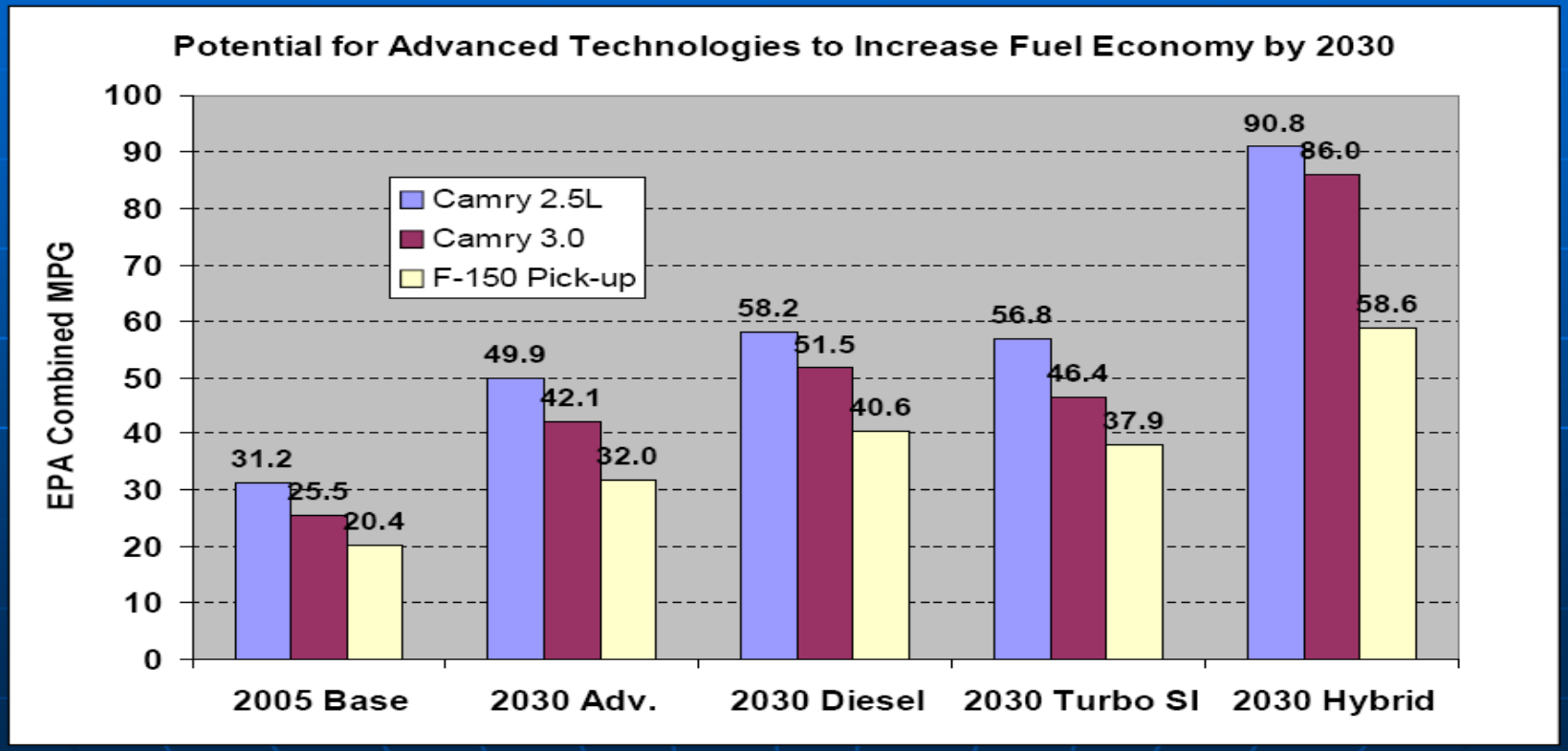
EPA MY2012-2016 GHG Standards Projections Based on Public Target

	Fuel Economy	Greenhouse Gas Emissions
2011 CAFE standard	27.3 mpg	325 gpm
2016 target GHG standard	(34-35.5 mpg)	250 gpm
% GHG reduction	--	23%

11

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.



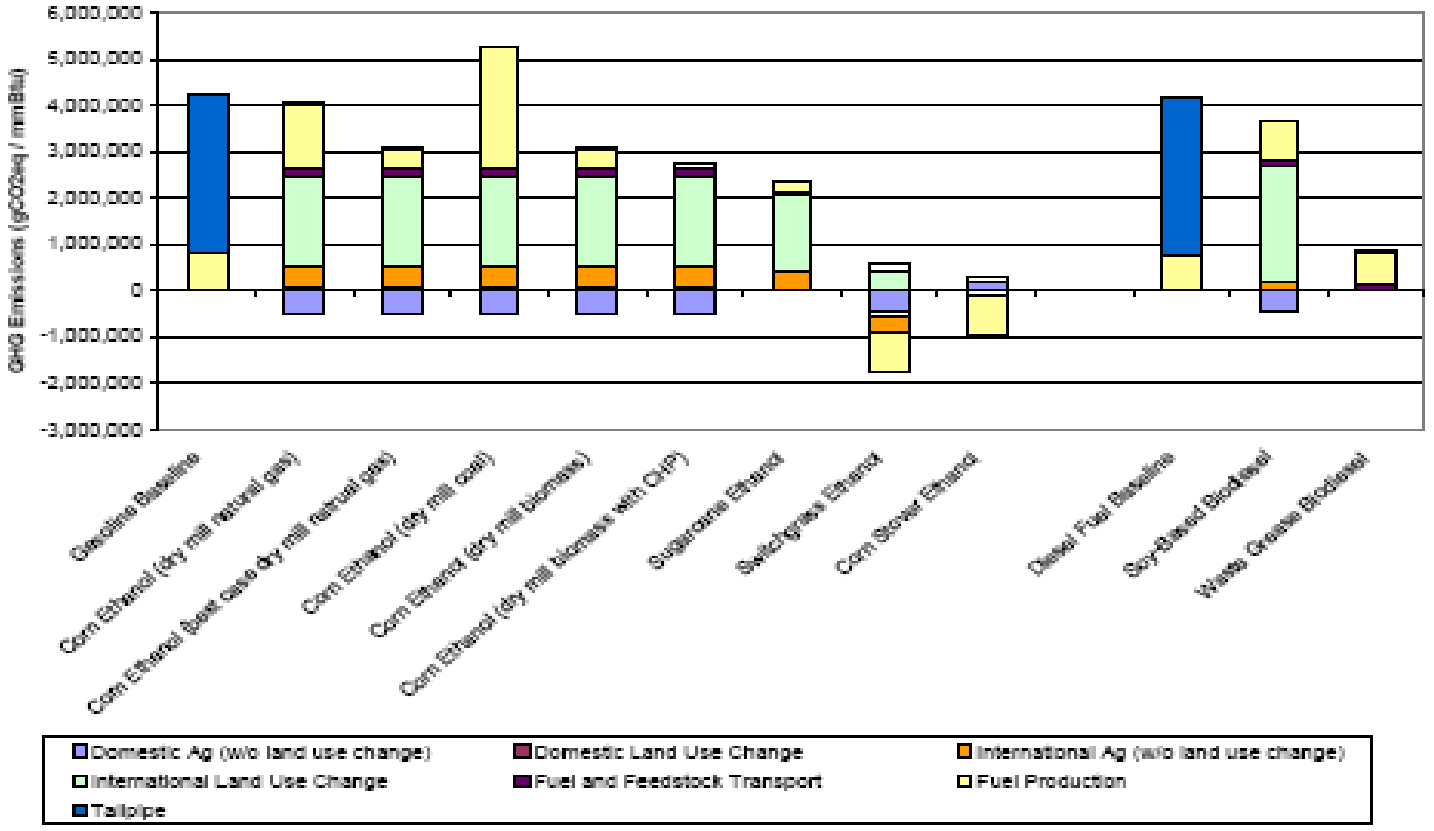
Source: Kasseris & Heywood, SAE Technical Paper 2007-01-1605, April, 2007.

Low-Carbon Fuels

- Many different low-carbon fuel possibilities:
  - Corn ethanol - Sugar cane ethanol - Diesel
  - 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."

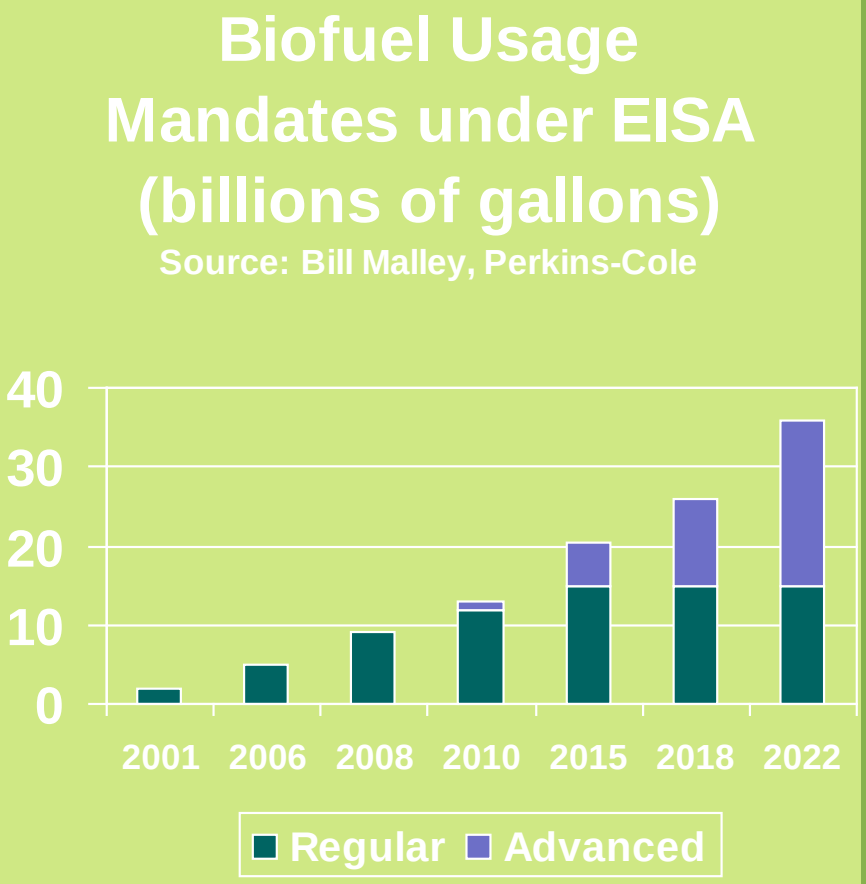
GHG Intensity of Different Fuels

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



Renewable Fuel Standard

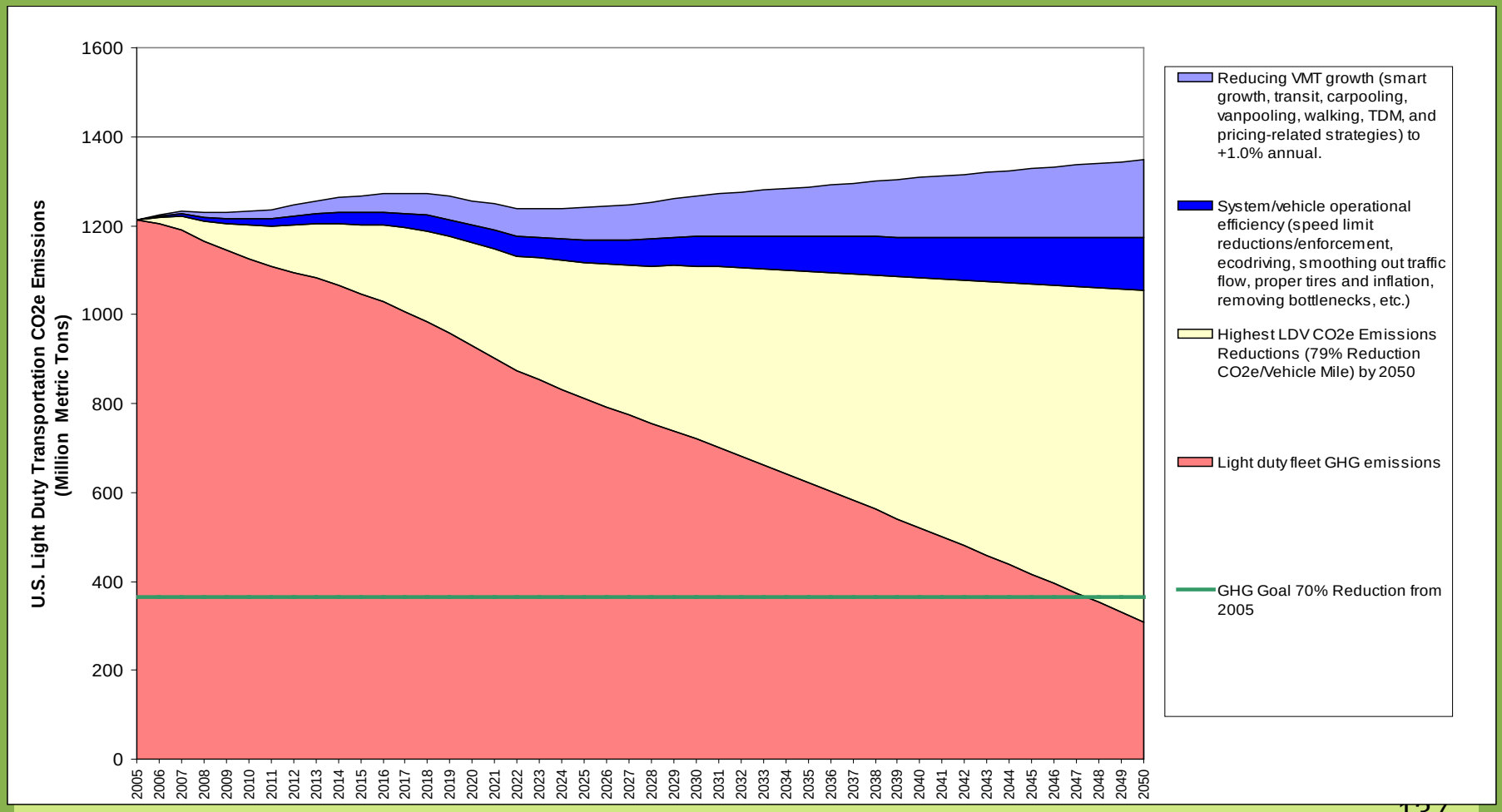
- EISA of 2007 requires use of 36 billion gallons of biofuels by 2022.
  - Includes 21 billion gallons of advanced biofuels
  - Up from 5 billion in 2006.
- To achieve that goal, EPA mandates % of biofuels to be blended into all gasoline.



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 f**uels/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

What Would it Take to Achieve 74% LDV GHG Reduction by 2050? 1% Annual VMT Growth + 100 mpgge LDV Fleet + 10% Operational Efficiency



Many Strategies to Reduce LDV VMT

- Economy-wide carbon cap and trade (raises fuel prices)
- Transportation pricing (PAYD insurance, parking pricing, tolls, higher user fees, cordon pricing, congestion pricing, etc.)
- Carpooling and vanpooling (currently carry 7 times as much work trip PMT as transit)
- Bike/ped and transit (but some transit is higher GHG than LDV)
- Trip chaining
- Tele-working, tele-shopping, tele-education, tele-medicine
- Compact land use

In 2008, when fuel prices spiked and VMT dropped, where did it go? We know <2% of the lost VMT went to transit, but don't know where the rest of the drop went.

Cautionary Note on VMT as Metric

- Does not take into account:
  - Type of fuel
  - Fuel efficiency of vehicle
  - Passenger vs freight trip
  - Number of passengers per vehicle
- As light duty passenger fuel economy increases, cost effectiveness diminishes
  - TCM lessons from 1990s – marginal emission reductions, increasing costs as technology improves

Pricing – A Necessary and Powerful Tool

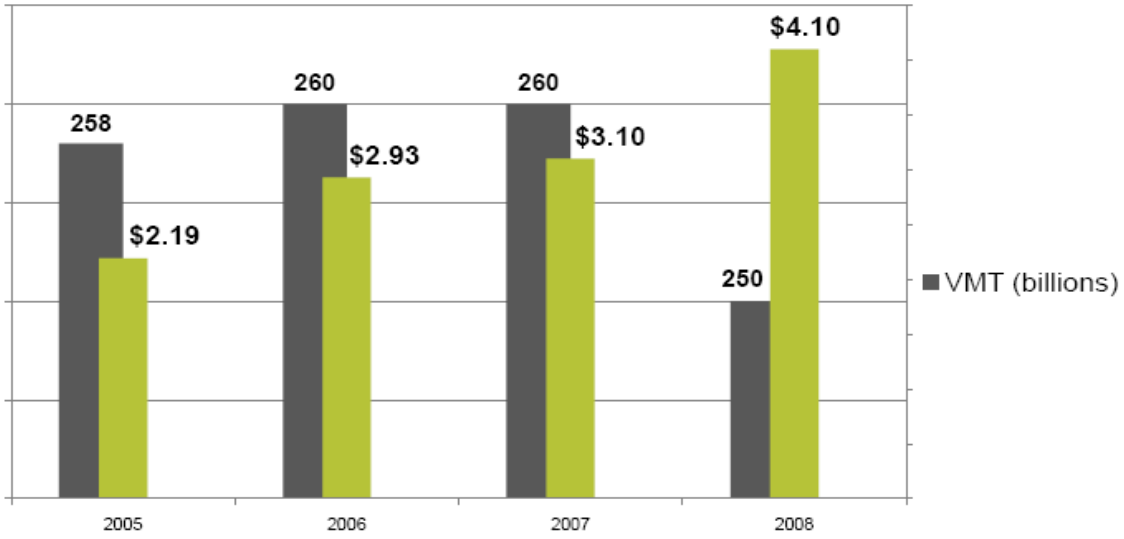
- Without price signals, reducing driving extremely difficult
- Pricing incentivizes 3 legs of the GHG stool
  - Purchase of lower-carbon vehicles and fuels; and
  - Lower VMT
  - Eco-driving behavior
- Many different pricing tools available: auto "feebates," carbon/fuel prices, PAYD insurance, mileage 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

Consumers Respond to Prices

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

National Vehicle Miles Traveled vs. Gasoline Prices



Monthly total VMT for June of each year.

21

Carpooling and Vanpooling

- Important but underappreciated (7 times as many PMT for work trips nationally are in carpools and vanpools as on 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)

Transit Helps Reduce GHG – but has Small Impact Nationally

- Transit serves many goals and has broad support, but transit serves just 1% of PMT and 0% of freight
- DOE: *Bus transit has higher GHG/passenger mile traveled than average auto use in the U.S.*
- *APTA studies: (a) Transit reduced GHG by 6.9 MMT in 2005; or (b) by 35 MMT* in 2005. This is 0.3% to 1.7% of U.S. transportation GHG
- Transit GHG benefits are realized with highly patronized services in high volume corridors -- a market limited to high volume, generally densely developed corridors.

CO_2e Emissions Per Passenger Mile for Various Modes

NATIONAL AVERAGE	Energy Intensities		Load Factor	Co2e
	(Btu or kWhrper vehicle mile)	(Btu or kWhrper per passenger mile)	Persons Per Vehicle	(Estimated Pounds Co2e Per Passenger Mile)
Single Occupancy Vehicle (SOV) LDV's	5,987	5,987	1.00	0.99
Personal Trucks at Average Occupancy	6,785	4,329	1.72	0.71
Transit Bus	37,310	4,318	8.80	0.71
Cars at Average Occupancy	5,514	3,496	1.57	0.58
Electric Trolley Bus	5.2	0.39	13.36	0.52
High Occupancy Vehicle (HOV) LDVs at 2+ Occupancy	5,987	2,851	2.10	0.47
Intercity Rail (Amtrak)	54,167	2,760	20.50	0.39
Light and Heavy Rail Transit	62,797	2,750	22.50	0.39
Motorcycles	2,226	2,272	1.20	0.37
Commuter Rail	92,739	2,569	31.30	0.36
Vanpool	8,048	1,294	6.10	0.21
Walking or Biking	-	-	1.00	0.00

Land Use Effect on GHG is Modest – and Depends on Assumptions

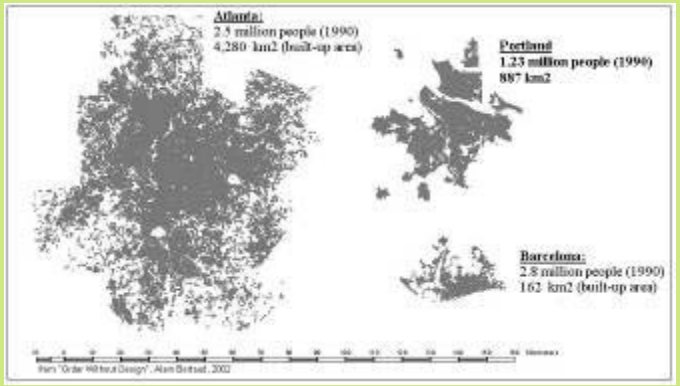
- "Growing Cooler" finds compact development can achieve 3.5-5% reduction in transportation GHG, 2007-2050
- GC's assumptions of land use change are very aggressive:
  - 67% of all development in place in 2050 will be constructed or rehabbed after 2005
  - 60-90% of that development is compact (comparable to 13.3 housing-units per acre)
  - Compact development has 30% less VMT than very sprawling development
- "Moving Cooler" finds smaller GHG effect, even with 90% compact land use for future urban development

TRB Study: “Driving and the Built Environment”

- 2009 TRB Study finds <1% to 11% household GHG reduction by 2050, depending on aggressiveness of assumptions
  - Study looks at effects of compact development on travel, energy use, and CO2 emissions
  - Disagreement among committee members about feasibility of changes in development patterns and public policies necessary to achieve high-end of estimated reductions
- Recommendations
  - Policies that support compact, mixed use development should be encouraged
  - More carefully designed studies of the effects of land use patterns on VMT, energy use, CO2 emissions are needed to implement compact development more effectively
- Source: National Academies, Transportation Research Board, *Driving and the Built Environment*, August 2009

Less VMT via Land Use: The 8 "D"s

1. Diversity (mix) of land uses
2. Density of urban form – e.g. UGB
3. Design - quality of the (ped/bike) environment
4. Destination accessibility – O/D links
5. Distance to transit
6. Development scale (site, sector, municipality, region)
7. Demographics
8. Demand Management



“Moving Cooler” (MC)

- Evaluated non-technology transportation strategies for (a) GHG reductions and (b) cost-effectiveness in reducing GHG
- Analyzed 46 individual transportation strategies and 6 “bundles” of strategies
- The 46 individual strategies: pricing strategies, transit strategies, land use strategy, operational strategies, freight strategies, nonmotorized strategies, regulatory strategies, bottleneck/capacity strategies, etc.

MC Findings – Individual Strategies

Individual strategies achieve GHG reductions ranging from <0.5% to 4.0% 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%)
- 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
- 352 mmt – combination of 10 freight strategies

MC Findings – Maximum Bundle

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

- Intercity tolls imposed in 2010 at 5 cents/mile
- 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 D

Vehicle/System Operations to Reduce GHG

Potential for 10-20% LDV GHG reduction by:

- Managing speed (35-55 MPH is optimal)
- Speed limits/enforcement (could reduce fuel use 2-4%)
- Eliminating bottlenecks
- “Active” traffic management to smooth traffic flow
- Improving signal timing (could reduce 1.315 MMT CO_2/yr)
- Roundabouts (multiple benefits)
- Reducing car and truck idling
- Work zone management to smooth flow
- Encouraging eco-driving

Eco-Driving – 15% GHG Reduction Potential

- EcoDrivers can reduce fuel and CO2 by an average of 15% through smart driving and vehicle maintenance.
- If 50% of drivers practiced EcoDriving, CO2 would drop by 100 million tons annually (the equivalent of heating and powering 8.5 million households)
- Pilot by City of 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

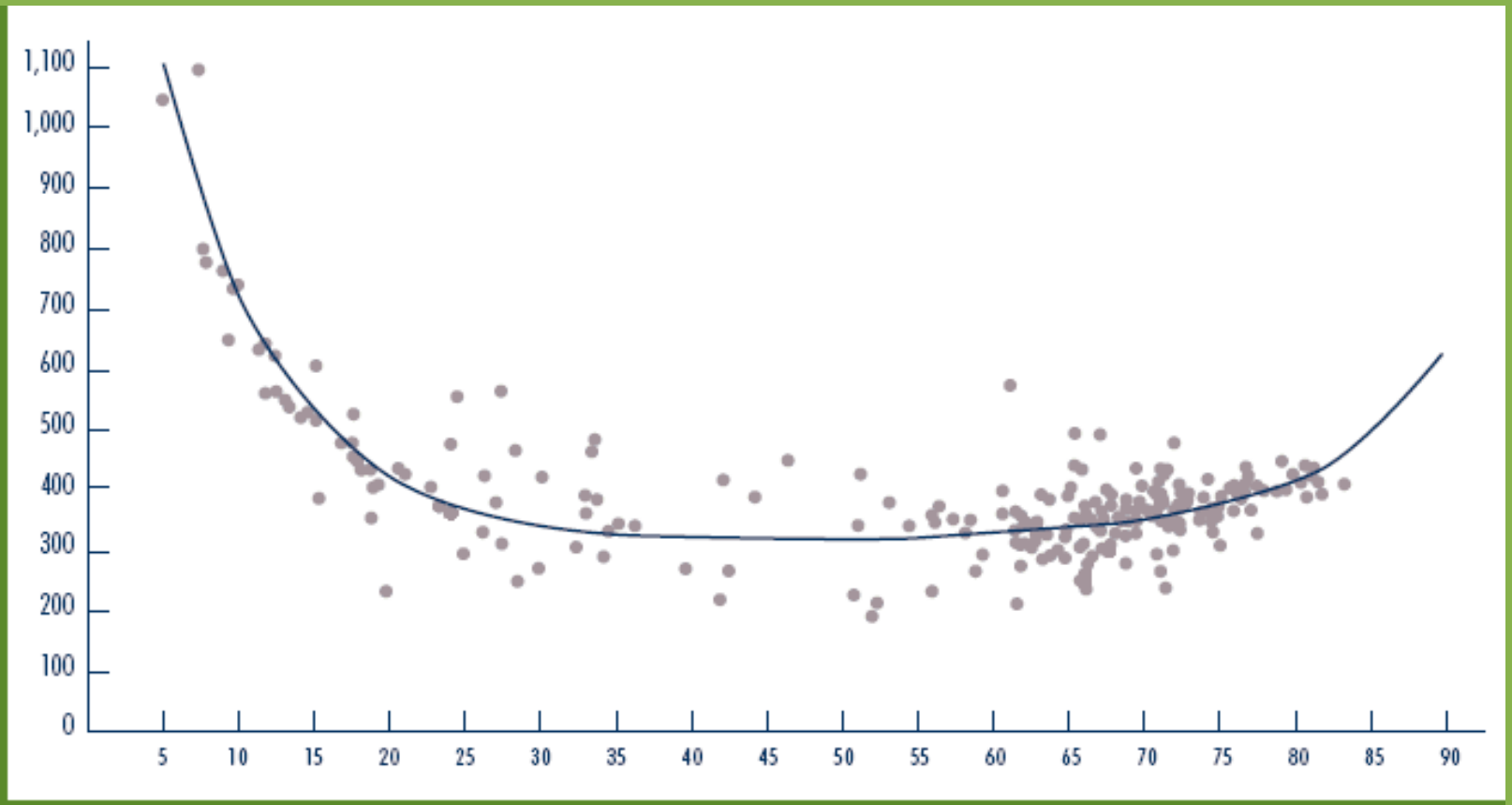
www.EcoDrivingUSA.com

- 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 and to join the EcoDriving movement contact: Seena Faqiri at 202.326.5518 or sfaqiri@autoalliance.org.

U.C. Riverside - Traffic Congestion and Its Impact of GHG Emissions: Can ITS Help?

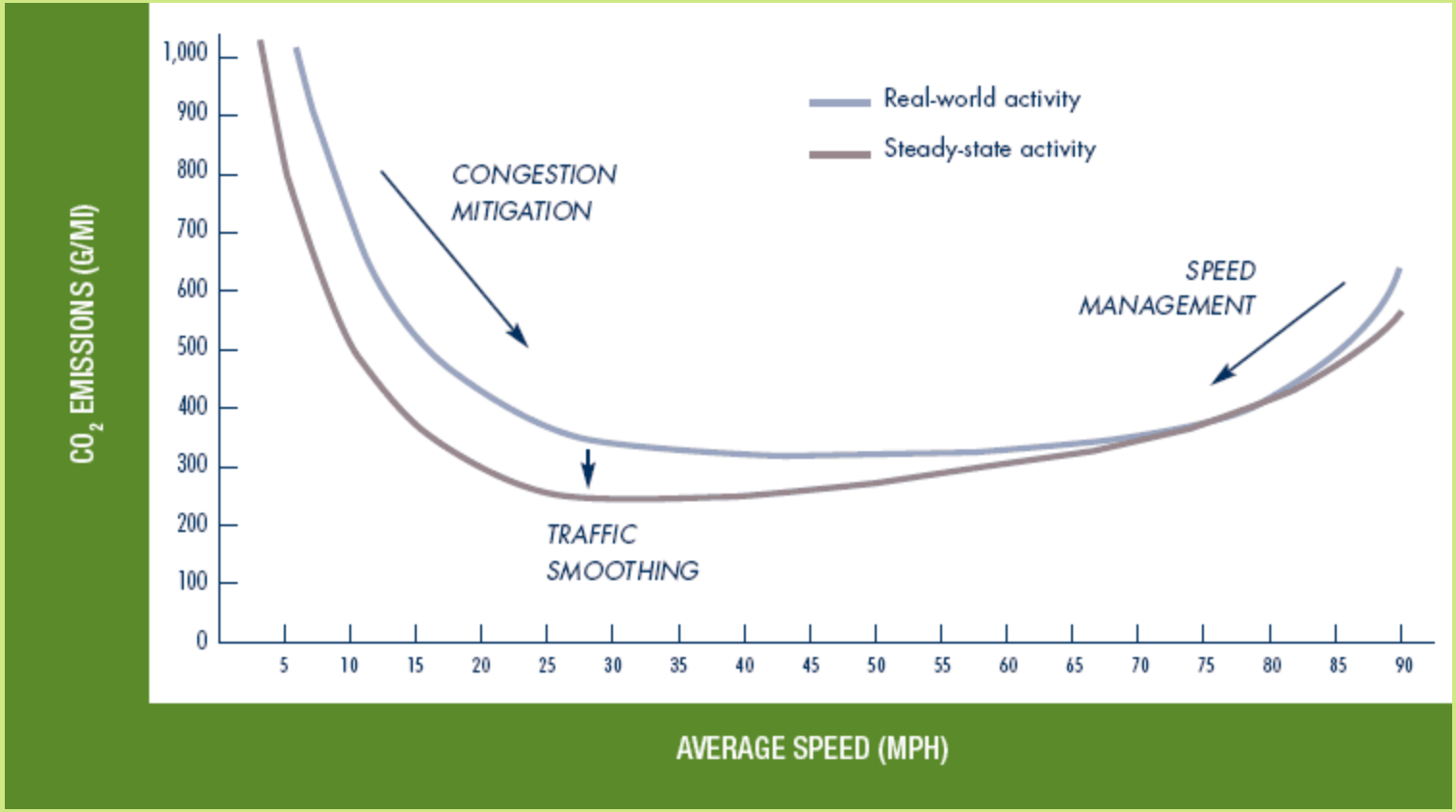
- Studied congestion and impact on CO2, used detailed energy and emissions models linked to real-world conditions
- CO2 emissions can be reduced with three strategies
  - Reduce severe congestion, allow traffic to flow at higher speeds
  - Reduce excessively high free-flow speeds to more moderate conditions
  - Eliminate accel/decel events associated with stop and go traffic in highly congested conditions
- Author: Dr. Matthew Barth, et al., May 2008
- http://www.its.uci.edu/its/whatsnew/barth2.pdf.

Effect of Speed on GHG



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

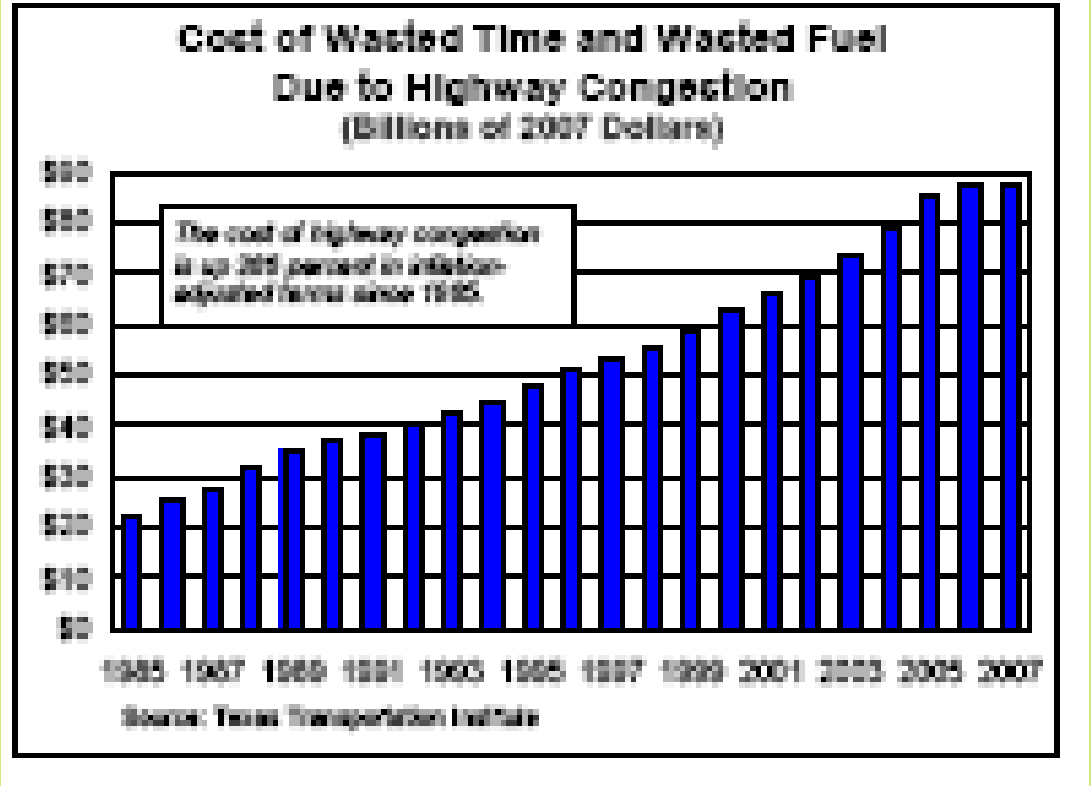
Traffic Operation Strategies To Reduce CO_2



Parsons Brinckerhoff / Sarah J. Siwek & Associates, Inc. | Climate Change

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

Cost of Congestion



Construction, Maintenance, & Agency Operations Strategies

- Significant sources of GHG and energy use
- Many opportunities to reduce GHG and energy cost from current system:
  - LED traffic lights
  - Low carbon pavement
  - Energy-efficient buildings
  - Reduced roadside mowing
  - Solar panels on ROW
  - Alt fuels and hybrid vehicles in DOT fleets
  - Alt fuel buses

Portland, OR Traffic Signal Timing Project

- 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, C02 emissions and emissions from criteria pollutants
- Model for traffic signal offset projects

http://www.climatetrust.org/traffic_signals.html.

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

FHWA- Carbon Sequestration Pilot Program

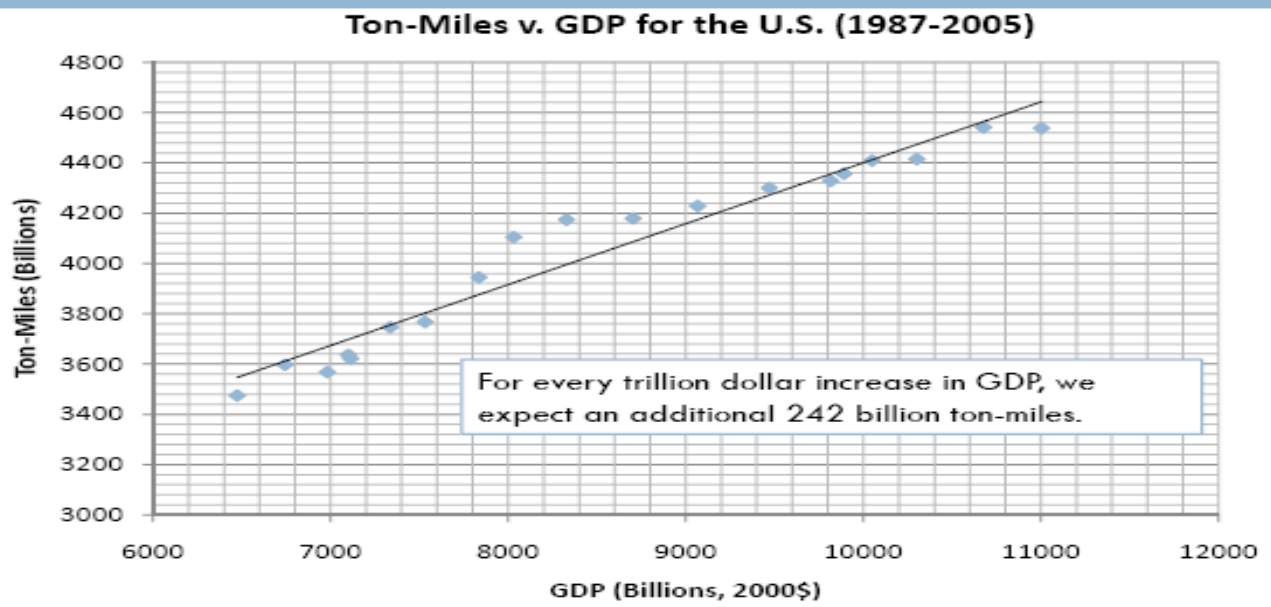
- Pilot established in 2008
- Assess how much carbon can be sequestered by native vegetation in the NHS right-of-way
- Determine feasibility of carbon credit sales by state DOTs and estimates of amount of revenue potential for state DOTs
- Final report available
  - Estimate of NHS ROW in each state
  - Highway carbon sequestration estimator
- Webinar Wednesday, July 14 to discuss findings

- http://www.fhwa.dot.gov/hep/climate/carbon_sequestration/index.htm

.

Freight – Ton-Mile/GDP Trends

Goods Movement and GDP



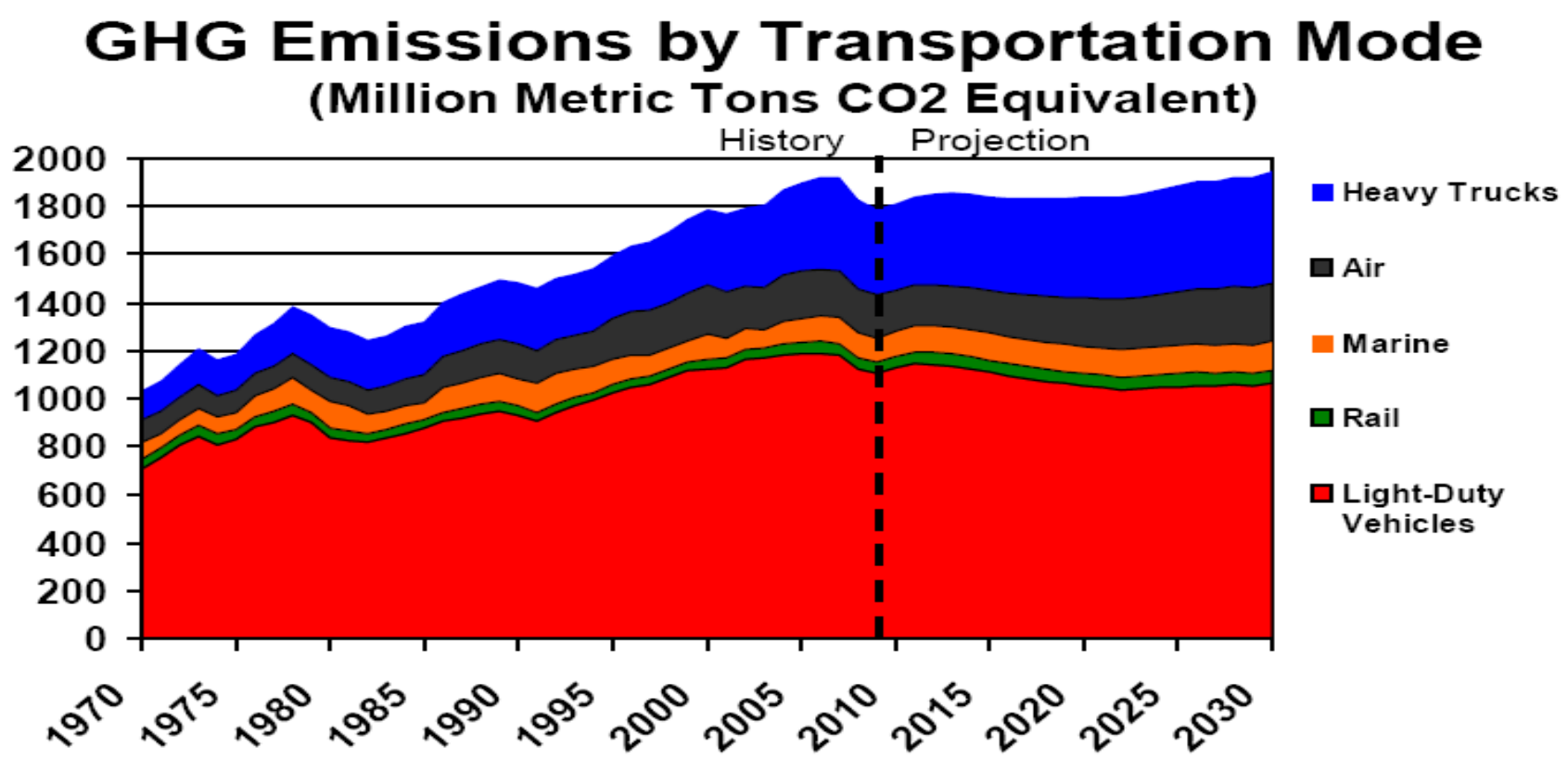
Source: Corbett and Winebrake, 2009.

J. Winebrake, Asilomar, 2009.

GHG, Diesel and Black Carbon

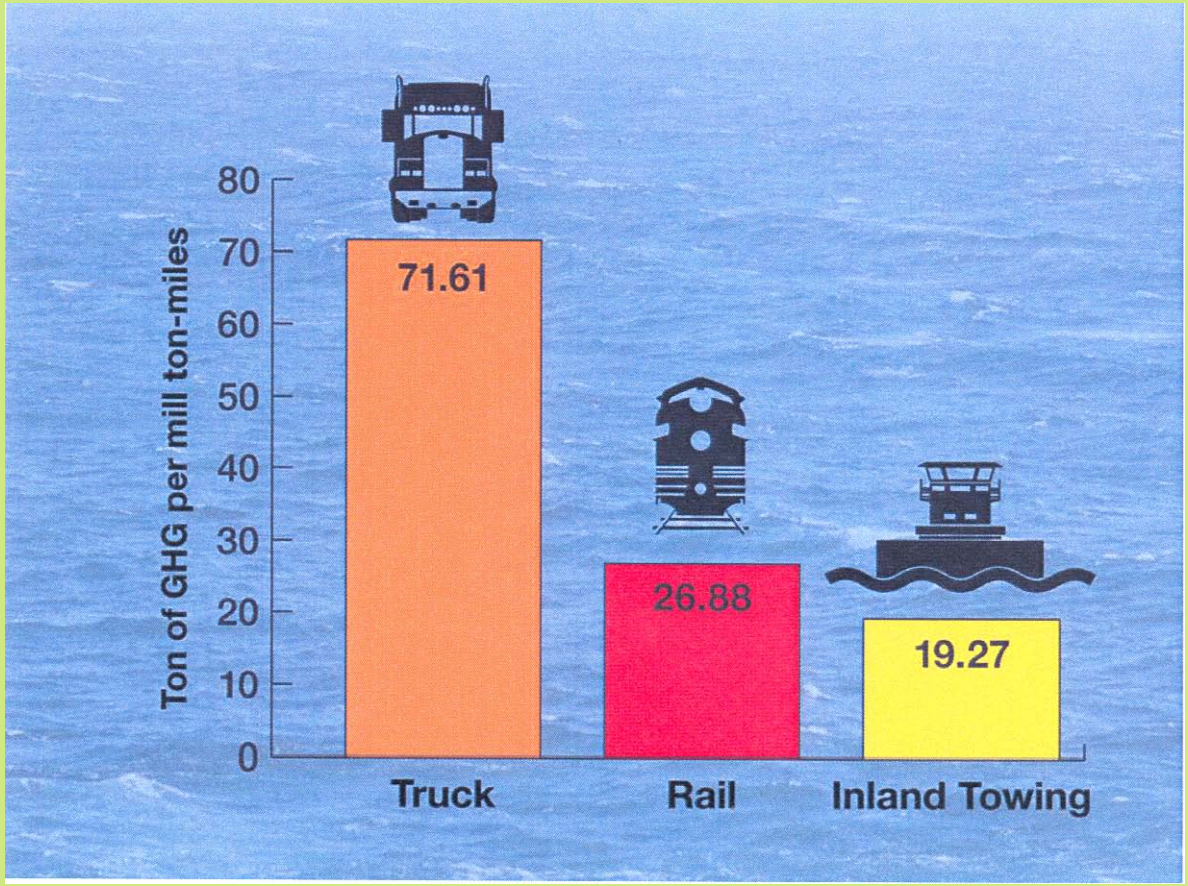
- Black carbon is a major contributor to climate change, diesel engines a primary source of BC
- Black carbon particles absorb sunlight, generate heat in the atmosphere, warms the air
- CO2 has long atmospheric lifetime; black carbon remains in atmosphere only a few weeks
  - Reducing black carbon provides immediate reduction in the rate of warming along with public health benefits.
- Freight strategies that impact diesel engines reduce black carbon and PM and provide immediate benefits.

Truck GHG is Growing Faster than Other Transportation GHG

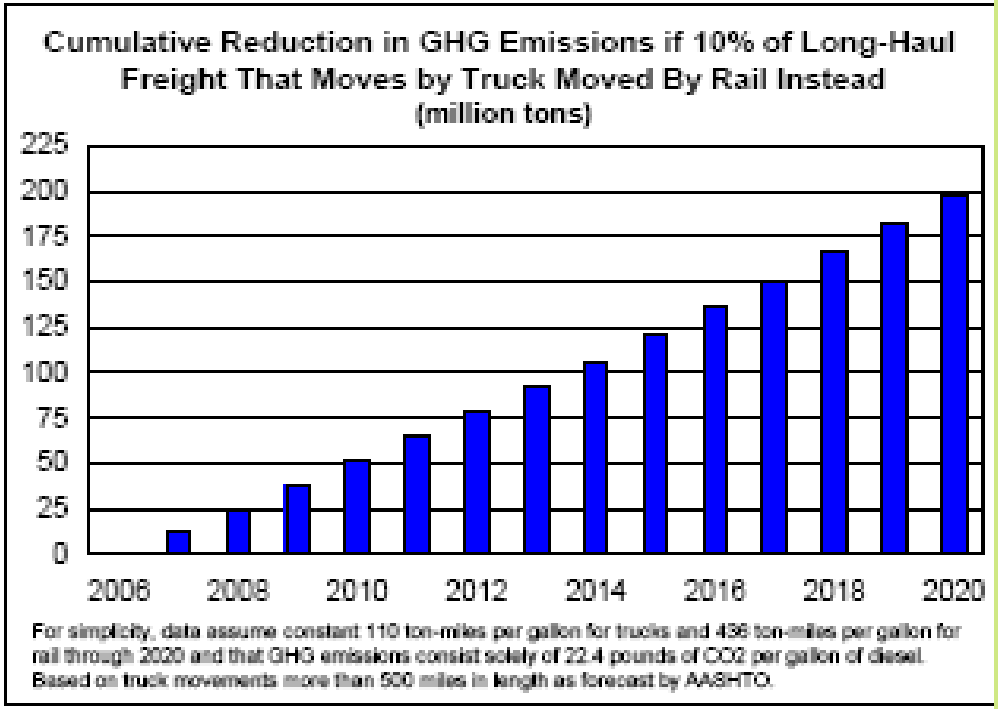


Freight GHG – Barges and Rail

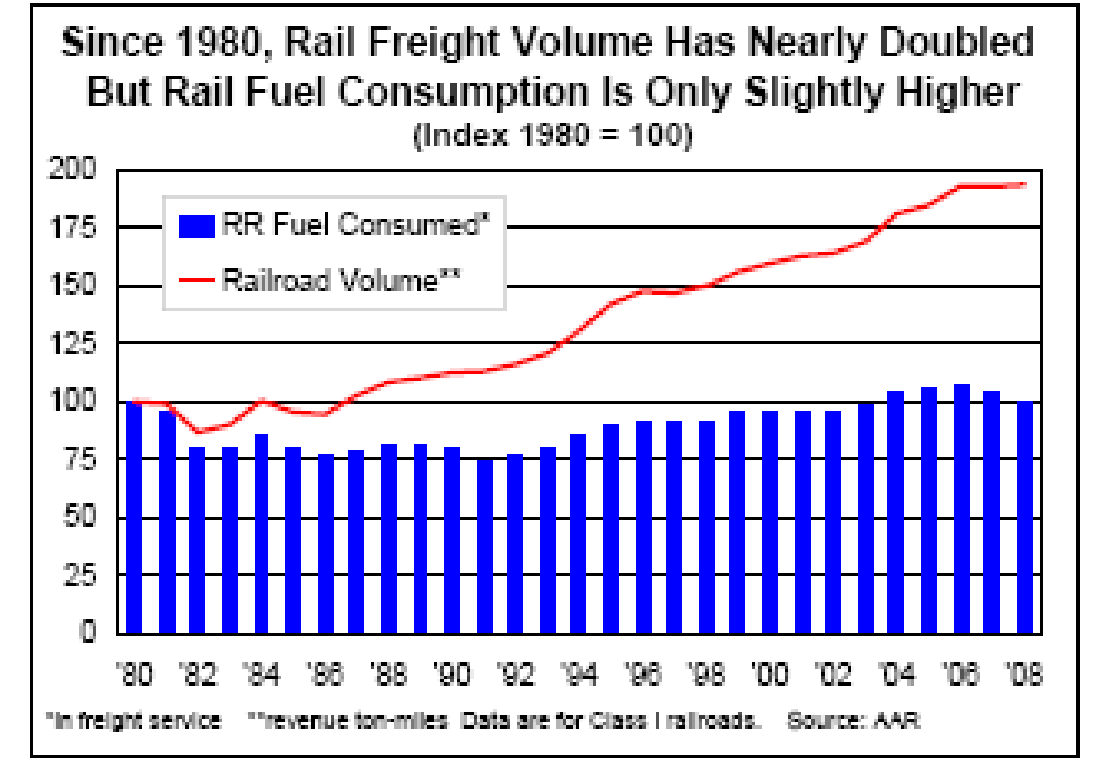
Source: Texas Transportation Institute and Center for Ports and Waterways



Freight Rail Can Relieve Congestion



Rail Fuel Efficiency has Improved



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
- 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)

Diesel Retrofits Reduce PM and Black Carbon

- On-road 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.
- Retrofits of construction equipment, state fleets and locomotives could be promising as state DOTs work to reduce emissions to meet potential planning requirements

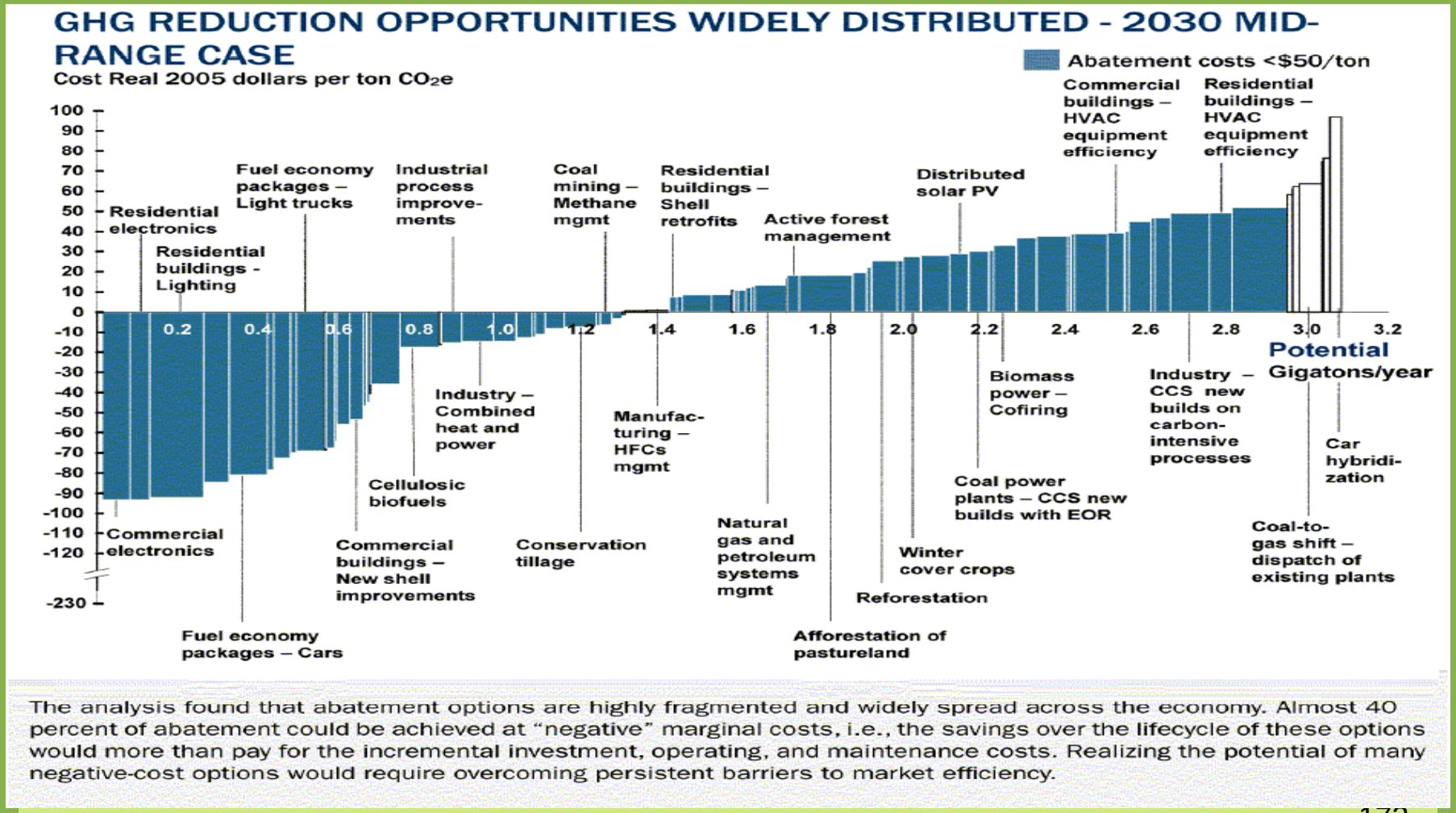
The Diesel Locomotive Retrofit Process

- Each existing locomotive is stripped from the deck up, removing the large, single diesel engine
- Three smaller, ultra-clean diesel generators are fitted onto the platform, along with control and operating equipment
- An immediate emissions reduction of 86% ozone precursors, 76% Particulate Matter, and a 25% fuel savings, with a corresponding 25% reduction in greenhouse gas CO_2 emissions, is realized following this diesel retrofit
- Very cost-effective CMAQ project

Cleaner Locomotive

McKinsey: Available Technologies can Reduce 3 Billion Tons GHG/Year at < $50/ton

(compare to projected 9.7 billion tons economy-wide in 2030)



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.

-- McKinsey & Company

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

VII. Participant Workshop

Participant Workshop

A working session in break-out groups to identify an initial set of activities for Mississippi DOT to pursue:

(a) GHG reduction strategies and framework;

(b) Climate adaptation planning;

(c) Public communication strategies;

(d) Outreach/collaboration with other agencies and organizations.

INFORMATION RESOURCES

Resources -- Websites

- 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”

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:

  Caroline Paulsen at AASHTO (202) 624- cpaulsen@aashto.org

Contact Info for Workshop Instructors

Cynthia J. Burbank
Parsons Brinckerhoff
burbank@pbworld.com
202-661-9262

Sarah J. Siwek
Sarah J. Siwek & Associates
ssiwek@aol.com
310-417-6660 x224

Rob Kafalenos
FHWA Sustainable Transport and Climate Change Team
robert.kafalenos@dot.gov