TRANSPORTATION AND CLIMATE CHANGE: POTENTIAL IMPLICATIONS FOR CALIFORNIA'S TRANSPORTATION SYSTEM

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INTRODUCTION

In a rare joint appearance before the U.S. Congress in March 2007, the top executives from four of the world's largest automakers indicated they would cooperate with ambitious legislative plan to address global warming and support devising a mandatory carbon emission "cap-and-trade" program. The automakers' pledge marked a significant shift in debate over drafting the first national global warming legislation. The prospect and nature of that plan, however, may require more hurdles to overcome. The States' climate initiatives are playing significant role in shaping industries' view and federal legislative process. Likewise, a comprehensive federal legislation would bring synergy and consistency between state's individual approach to global warming and provide long-term stability and resources for climate programs and more certainty for climate related business activity.

While the national debate is taking a new dimension, states are moving forward with setting targets for reducing greenhouse gas emissions, adopting policies to promote renewable energy and energy efficiency, developing statewide climate action plans, and initiating emissions trading programs. States are taking action, because they are concerned with potential long-term impact of changing climate on the socioeconomic viability and natural resources of the state. They also recognize that policies that protect the climate could have multiple benefits with potential economic gains and opportunity for creating new markets such as clean technologies and alternative fuels, high-tech industries, and emission trading while improving environment and diversifying state's energy infrastructure. As a result, many states have been able to build broad support for climate policies among public and decision makers, and provide a basis for linking state and national policy agenda.

- Climate Action Plan
- State GHG Emission Targets
- Renewable Portfolio Standards
- Public Benefits Funds
    - Net Metering
    - Mandates and Incentives Promoting Ethanol
    - Regional Initiative
    - Low Carbon Fuel Standards for transportation fuel sold in California
    - International Agreement with UK and Canada

Figure 1 – California Climate Initiatives

California is setting the pace for climate policy and greenhouse gas emission reduction measures in the U.S., going as far as making the practice of sustainability part of the fabric of the government itself with a new level of commitment to environmental stewardship.

This paper examines a set of climate-related implications for California's transportation infrastructure and provides a review of some current and potential state greenhouse gas mitigation activities within the transportation sector – looking toward less carbon intensive economy in the future.

CLIMATE CHANGE AND TRANSPORTATION

The transportation system is the fabric of socioeconomic activities, but it does come with a cost. California's economy, including foreign and domestic trade, and socio-cultural activities rely heavily upon its transportation infrastructure. In 2006, shipments by land, sea, and air through California ports totaled $491 billion - an increase of nearly $200 billion since 1996. Californian's generated 330 billion miles of multi-purpose trips on the state's roadway network. Transportation accounts for over 40% of the total greenhouse gases (GHG) in the State, because fossil fuels provide much of the power for transportation. While efforts to improve transportation system efficiency and reduce emissions have been positive, transportation-generated greenhouse gas emissions continue to grow, primarily due to increased population, economic growth and vehicle ownership.

Are the goals of mobility and accessibility in conflict with environmental quality? Is the impact of transportation on climate as large as it seems to be? The answer, in part, depends on what are the sources of greenhouse gases. From planning, programming and regulatory perspective, it would be helpful to differentiate between to distinct, but interrelated systems. Essentially, transportation emissions are the outcome of two interactive systems at work - the transportation system (a network of roads and modes) and its energy infrastructure or fuel and vehicle technology. The interaction between these two hardware and software, so to speak, make movement of people, goods and services possible. While improving efficiency of the transportation system is important to reducing fuel consumption (the quantity), it is the energy infrastructure and technology system that determine the nature of the fuel being used (quality and quantity). It takes efficiency in both systems to drastically reduce greenhouse gases from transportation where energy infrastructure and technology taking a more direct and substantial role in that effort.

Our air quality conformity experiences show that significant gain in emission reductions can be made while transportation system is essentially expanding but operating more efficiently. Addressing the transportation energy issues is more in line with regulatory and legislative branches of the government. The transportation system efficiency is the strategic role of the transportation agencies. Therefore, Improving performance of transportation systems and operations along with strong technology and market policy to encourage innovations are important steps toward lowering fossil fuel consumption and GHG emissions.

The casual relation between transportation and climate change in terms of greenhouse gas emissions is fairly well established, however, our knowledge of the ways by which our transportation infrastructure may be impaired and ability to adapt to the consequences of global warming is still developing. Figure 2 presents a conceptual framework that climate initiatives can be further organized in terms of causal relationships and in order to develop more effective sets of prioritized mitigation measures relative to adoptive capacity of economic sectors.

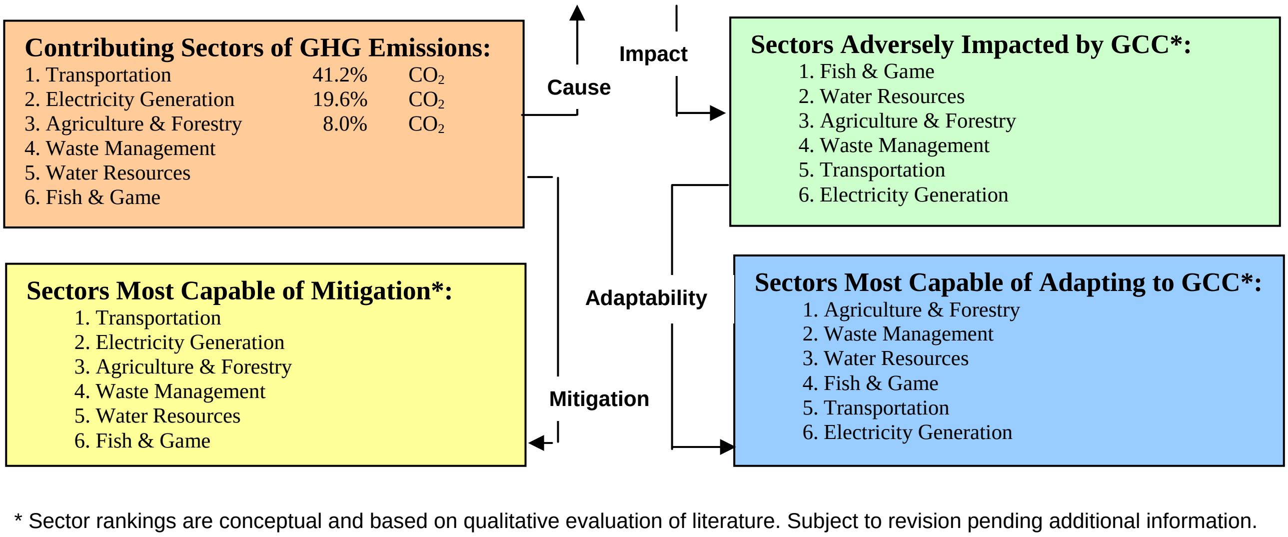

Figure 2 - Climate Change: Causal Framework

1. Carbon Dioxide (CO_2)	83.3%
2. Methane (CH_4)	6.4%
3. Nitrous Oxides (N_2O)	6.8%
4. High GWP Gases	3.5%

A. Impact of Climate Change on Transportation

An enhanced greenhouse effect will generate new patterns of microclimate and will have significant impacts on the economy, environment, and transportation infrastructure and operations due to increased temperatures, intensity of storms, sea level rise, and changes in precipitation. Impacts may include flooding of tunnels, coastal highways, runways, and railways; buckling of highways and railroad tracks, submersion of dock facilities, and shift in agriculture to areas are now cooler. Such prospects will have strategic security as well as transportation implications and require new generations of transportation facilities and material that satisfy concerns of climate change and demonstrate that reducing GHG must be a priority.

Transportation planners realize that the transportation sector is an important cause of increasing concentrations of atmospheric greenhouse gasses. However, less attention has been given to the effects of climate change on transportation and even lot less to adoptive measures to minimize consequences of global warming on transportation infrastructure. There are at least two issues that complicate the matter. While temperatures are projected to shift significantly, resulting in permanent alteration of ecosystems, scenarios of regional or local weather patterns and variations or microclimate are not as well understood. There is also a question of magnitude - how might these effects demonstrate themselves in a region? Will these changes be moderate or severe? To what extent current assumptions and practices leave our transportation infrastructure vulnerable to climate change? The effects on transportation and corresponding mitigating measures depend to a great extent on answers to these questions. There is no single or simple answer to these questions. Nevertheless, there are good qualitative summaries describing the vulnerabilities of transportation-related activities to climate variability and change.

The weather and climate factors (based on typical regional temperature and precipitation regimes) have always been considered in the planning, design, construction and maintenance of transportation infrastructure as well as analysis of demand for transportation services. Nevertheless, the prospect of climate change would mean that certain assumptions about future climate conditions, geology, and other environmental features may not hold true, possibly resulting in premature deterioration or failure of infrastructure. It could also mean certain assumptions on projected demand for transportation services, patterns of development and agricultural production, and movement of goods could be wrong, effecting long range transportation plans as well as the type and location of new facilities.

Transportation Infrastructure

California is one of the most diverse regions – ecologically, geographically, and culturally – of any in the world. It has foggy coastal forests, hot low deserts, cold high deserts, forested mountains, alpine glaciers, vast dry valleys, rich agricultural lands, rocky shores, sandy beaches, protected harbors, inland seas, freshwater lakes, and wild rivers. Climate change and variability could gradually change the characteristics of these regions and will have important implications for California's vast transportation network.

In order to identify and evaluate the potential interaction between transportation and climate change, we need a reliable, comprehensive assessment of the anthropogenic microclimate changes or projections at the regional level, the scope and magnitude of transportation infrastructure sensitivity to climate variability, and how such climatic changes could influence those interactions. Then the future vulnerability of transportation activities or facilities and appropriate adaptation and mitigation measures can be considered based on this sensitivity assessment.

The present tendency to average climate change impact globally is likely to obscure consequences for local and regional areas and focus on regional solutions. There is no comprehensive, quantitative assessment of the various transportation sector costs and opportunities associated with climate change. While information is only starting to emerge about how climate change might lead to changes in weather extremes, a range of possible transportation related vulnerabilities seem possible, including some that are location dependent and some that are event specific.

California has experienced weather-related impacts to transportation systems including flooded airports, interstate highways and roads washed out, land-slides disrupting major rail lines, and heat waves causing freeways to buckle. Future impacts due to extreme events and other impacts of climate change could pose important challenges with significant socioeconomic and environmental impacts, particularly considering that California's transportation infrastructure has been developed based on certain temperature and precipitation regimes.

Extreme heat and cold - Climate change will increase the frequency and severity of hot days while the number of extremely cold days will be reduced. As a result, pavement softening and traffic-related rutting, buckling of pavement, and flushing or bleeding of asphalt from older pavements might become more common, leading to increased maintenance costs and safety concerns. Railway track is also subject to buckling from extreme heat, although cold temperatures and winter conditions are responsible for significant portion of track, switch, and rail car damage. Increasing temperatures could lower engine efficiency of motorized transportation in the summer months, leading to increased fuel consumption and air pollution, and the offsetting impact of reduced use of snow tires and defrosting systems.

Some research suggests that increasing temperatures could exacerbate near-surface ozone concentrations, making it more difficult for metropolitan areas to maintain air quality standards. Benefits may be realized where warmer temperatures reduce the loadings of road salt, glycols and other de-icing chemicals into environment. Conversely, major sources of air pollutions i.e., NOx, VOC, CO, and other particulate matter may become more frequent and of longer duration under certain climate change scenarios. However, the magnitude and direction of this impact may be highly variable and require further analysis.

Run off, precipitation Sensitivities – Changes in the location and timing of storms will alter the timing and amount of precipitation and runoff and warmer conditions will change snow to rain, creating the potential for enhanced flooding in watersheds that experience frequent rainfall. Increased runoff during the winter and spring months will increase the risk of flooding and land slides, both in the mountains and throughout most watersheds. Many rural roadways are especially at risk due to the increased chances of flooding in the winter and spring months. Accessibility via the rural road system is a key concern to California rural economy. Increase water flows as a result of winter rainstorm will lead to both a greater number and severity of erosion events and consequent damage to roadways. These events in turn lead to additional restrictions in transportation system capacity. Although, fewer extremely cold days, warmer minimum temperature, and less snow on the road may offset some of the increased summer maintenance costs and improve winter season accessibility.

Increased flooding may also result in an inability to access the state’s forests for prolonged periods of time. This has the potential to increase risks of large damaging fires by preventing vegetation management and resulting in increased fuel loads. One of the most significant short-term impacts will be reduced capacity to respond to emergency situations. An increase in intensity of storms will result in additional backlog of maintenance on these roads that are a key part of the transportation system for many rural counties and further reductions in access to these areas [1].

In low-elevation coastal watersheds, flooding is most common when a wet winter results in frequent storm events. Numerous coastal mountain watersheds in northern California have rivers that flow over their banks once or twice every ten years. In 1995 and 1997, Russian River floods created large economic losses that were amplified by the presence of many housing developments within the 10-year flood plain. Similar flood events occur in southern California coastal watersheds during severe precipitation events.

Coastal erosion is another important climate-related impact in California caused by sea level rise and increased storm activity. Cliff under-cutting is a serious issue for coastal road, pipeline, and railroad systems. Further erosion due to climate change and rising sea level will worsen already narrow or stressed coastal shorelines. Coastal roads and railroads are likely to be more vulnerable as a result of increased climate variability. Highway 1 already experiences frequent mudslides and high waves during mild winter storms, as well as wash outs every year.

Increased precipitation and greater temperature fluctuations are likely to trigger more rock and snow slides and slope failures that could result in considerable number of disruption and delays, damage road and rail infrastructure, and force greater levels of maintenance.

Figure 3 - Photo of Land Slide, February 2007 - Humboldt County, CA, State Highway 96.

Adaptation strategies have been suggested but likely at significant cost to society. Some roads near the coast may have to be removed or protected from additional exposure to the ocean. The Coastal Land Use group participating in the California Regional Assessment Workshop provided a tiered response strategy: the existing built environment, the natural environment, and future coastal development. They suggested establishing priorities in addressing impacts to the built environment: a) protect structures with high strategic value such as airports, ports, and delta levees, b) relocate vital structures to higher ground or find alternative solutions, c) retreat and let nature take over less strategic aspects of the built environment. These contingency strategies clearly recognize the need to consider potential risks associated with new coastal developments from future climate change and variability.

Precipitation and moisture are also important factors that contribute to the weathering of transportation infrastructure. Premature deterioration of bridges, parking garages and other concrete structures may be magnified where climate change induces more frequent precipitation events.

Sea-level rise and storm surge - Climate change may result in gradual change in sea level or waterways, damaging or making low lying coastal infrastructure including road and railway beds, port and airport facilities, tunnels and underground rail/subway/transit corridors. Rising sea level could also erode beaches and wetlands, increase flooding from storm surges and rainstorms, and enable saltwater to advance upstream. California has several airports very close to sea level where maintenance of levees or embankment fortifications may become more difficult and costly with future climate changes. Rising sea level and higher winter water flows in the Sacramento River-Delta Region are likely to cause a variety of significant problems including: disruptions to sections of railroads, pipelines, and roadways within the costal regions, effects on the transport of water from north to south, and problems with shipping into and out of the ports of Stockton and Sacramento (e.g., more difficult to maintain channels depth). Climate changes may bring a lowering of water density in the Bay (due to warmer waters and greater volume of fresh water in some seasons), which would lead to ships riding lower in the water, and potentially affect navigation in the shallower channels or requiring more trips to transport the same amount of cargo with higher shipping costs [1].

The California Regional Assessment states: The California Regional Assessment states: Many coastal airports built on wetland are vulnerable to flooding such as the San Francisco, Oakland, and Santa Barbara airports. “Extreme high tides, coupled with flood conditions, can reach close to the existing levels. A recent tidal flux in the San Francisco Bay area closed Highway 101 north of the city due to eight-foot tides, two feet above what had been expected. With an additional meter of sea level, a number of critical facilities would be highly vulnerable. In the future, sea level rise, storm surges, and high tides could conspire to inundate runways. Harbors may suffer wave damage, additional siltation from storm runoff, and other navigation and safety problems. Jetties and seawalls may have to be raised and strengthened to protect harbors, which support commercial shipping, recreation, tourism, and many other economic sectors." [2].

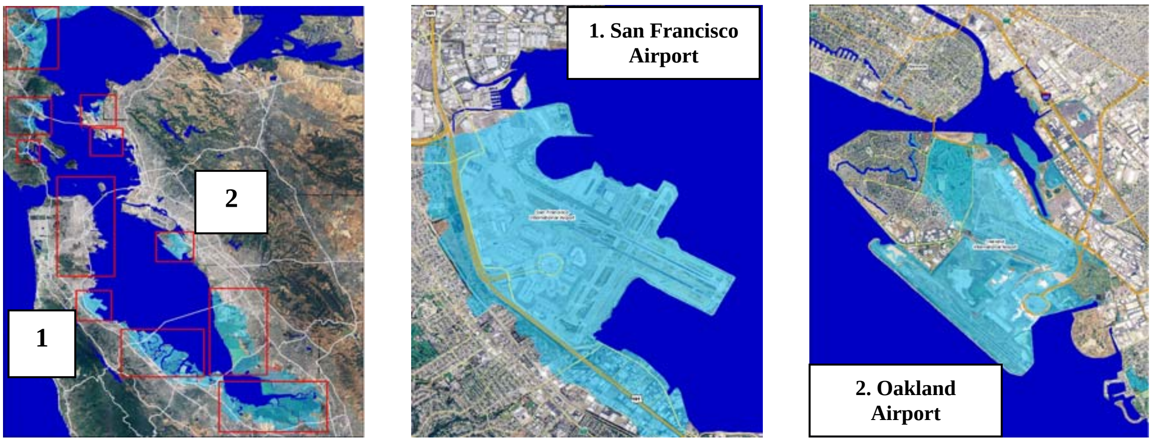

Figure 4 - San Francisco -Oakland Bay Area – One meter sea level rise scenario.

A sketch mapping of one meter sea level rise show about 120 square miles of low areas and a number of critical facilities in Bay Area could be vulnerable, conspiring to inundate San Francisco and Oakland airports. Most of the Bay Area is on relatively high ground, however, erosion can threaten relatively high ground as well.

Transportation Systems and Operations

Changes in rain and snowfall and in seasonal flooding patterns could affect safety and maintenance operations of the transportation infrastructure. Weather is identified as a contributing factors in many train derailment, aircraft accidents, shipping accidents, and road collisions in California.   It is likely that milder winter conditions would improve the safety record for surface and air transportation. This benefit could come, however, at a significant cost to winter related recreational activities and water reserves.

Precipitation generally compromise driving conditions and increases collision risk significantly. A shift from snowfall to rainfall could increase risk where precipitation events become more frequent and more severe. All modes of transportation experience weather related service disruptions, particularly during winter.   Highway capacity and through put is notably reduced during storm or rain, lowering speed and impacting mobility.   Flooding, land slides, and forest fires are other examples of weather related impacts on mobility. Any reduction or increase in intensity of storm or weather extremes could hamper or improve mobility and transportation operations.

Transportation is demand responsive. The potential impact of climate change on demand for transportation services need further research. Shifts in climate that affects ecosystems and the viability of natural resources are projected to impact agriculture, fisheries, and forestry production, as well as pattern of development in certain extreme scenarios. Its seems plausible that the global warming could effect, directly or indirectly, the sources of specific demands for fright and passenger services and the implications for various modes of transportation. For example, there is potential for changes in spatial pattern, type, and productivity of the agriculture and certain industrial and business activities may slow down or relocate in response to shift in microclimate. Consequently, it seems reasonable to expect new demands for transportation to arise and others to decline. This could mean shifts in demand for new roads and rail lines and require significant investments in transportation and other infrastructure.

The impact of climate change on urban infrastructure is rather difficult to assess. The urban transportation infrastructure will be at risk of more frequent flooding and higher flood levels, the effects, however, depend on location. Socioeconomic, demographic and technological factors influence future transportation needs and types, where transportation networks are located, and the level of investment needed in sustaining the California's transportation infrastructure and productivity. Colorado river provides limited by vital supply of water to Southern California. The rainfall and snowfall supporting the river is projected to decline. If the flow is reduced or disrupted that could have significant impact on the cost of living and farm product that depend upon water resources, lowering demand for housing and businesses in Southern California, and potentially relocation to areas with lower cost and greater stability of resources, such as Pacific Northwest or Canada. We need to have better information on what could happen at specific regional and local areas, however, complexity of projecting the potential microclimate changes present a challenge for climate models and transportation decision makers.

Climate change may induce investments in development of alternative fuels and vehicles and renewable energy sources to reduce greenhouse gases. A widespread adoption of renewable energy and clean technologies could dramatically transform the transportation sector – creating new opportunities and challenges.

B. Impact of Transportation on Climate

The correlation between mobile sources, greenhouse gas emissions, and climate change is well established and this paper presents no further discussion. As indicated before, It takes efficiency in both transportation system and its energy infrastructure or technology system to drastically reduce greenhouse gases from transportation operations where energy infrastructure and technology taking a more direct and substantial role in that effort.

Reducing the rate of change of atmospheric composition to slow climate change will require significant and long-lasting reduction in emissions, i.e., reducing per capita CO_2. In the U.S. per capita emission is about 5-6 tons of carbon per year and Europeans' produce about 3 tons respectively. MacCracken relates that a 50% cutback in emission needed to move toward stabilization at 550 ppmv (double the pre-industrial level)[3]. This would require a multi-faceted approach, particularly significant reduction in carbon intensive energy and introduction of non-fossil energy technologies. Considering that transportation almost entirely dependent upon petroleum, consuming about 50% of total petroleum consumption, reducing carbon intensity of transportation operations could significantly contribute to over all and per capita CO_2 reduction.

The effects on climate of greenhouse gas emissions are not fully evident until many years later, therefore, it is generally understood that we have to reduce emissions now to mitigate the future problem. The consolation prize is that reducing greenhouse gas emissions can deliver multiple benefits such as economic opportunity, reducing traffic congestion, improving air quality and diversifying energy supplies. In the process of working to address climate concerns, the state can adopt policies and investment strategies to promote new markets for transportation and communication technology along with potential improvements in the safety and security of transportation facilities, vehicles and the supporting infrastructure.

The remaining of this paper will focus on the California Department of Transportation's (Department) contributions to reducing greenhouse gases.

California's Transportation Sector

On June 1, 2005, Governor Schwarzenegger signed Executive Order (EO) S-3-05, establishing climate change emission reduction targets for the State. The Climate Action Team (CAT) was created to coordinate the statewide effort. Assembly Bill (AB) 32: California Global Warming Act of 2006 gave new weight to the State's renewable energy goal by requiring the reduction of GHG emissions to 1990 levels by 2020. The California Department of Transportation is a member of the CAT and committed to implementing transportation strategies that will help reduce fossil fueled energy and GHG emissions.

The Department's strategy to reduce GHG emission from transportation is twofold: a) making transportation system(s) more efficient through operational improvements, application of Intelligent Transportation Systems (ITS), and smart land use thus reducing congestion and lowering the rate of growth in fuel consumption and CO_2 from motor vehicles. In this case, GHG emission reductions are being realized through the Department's strategic growth plan and congestion relief program with collateral benefit for climate change, and b) cleaner, more energy efficient transportation systems and operations which focuses on integrating consideration of energy and GHG emission reduction measures into planning, project development, operations, and maintenance of transportation facilities, fleets, buildings, and equipments. In this case, reducing energy consumption and GHG emissions is the primary reason for implementing this strategy. If fully funded and implemented, these strategies could result in lowering CO_2 growth by 2.72 MMT in 2010 and 18.67 MMT by 2020.

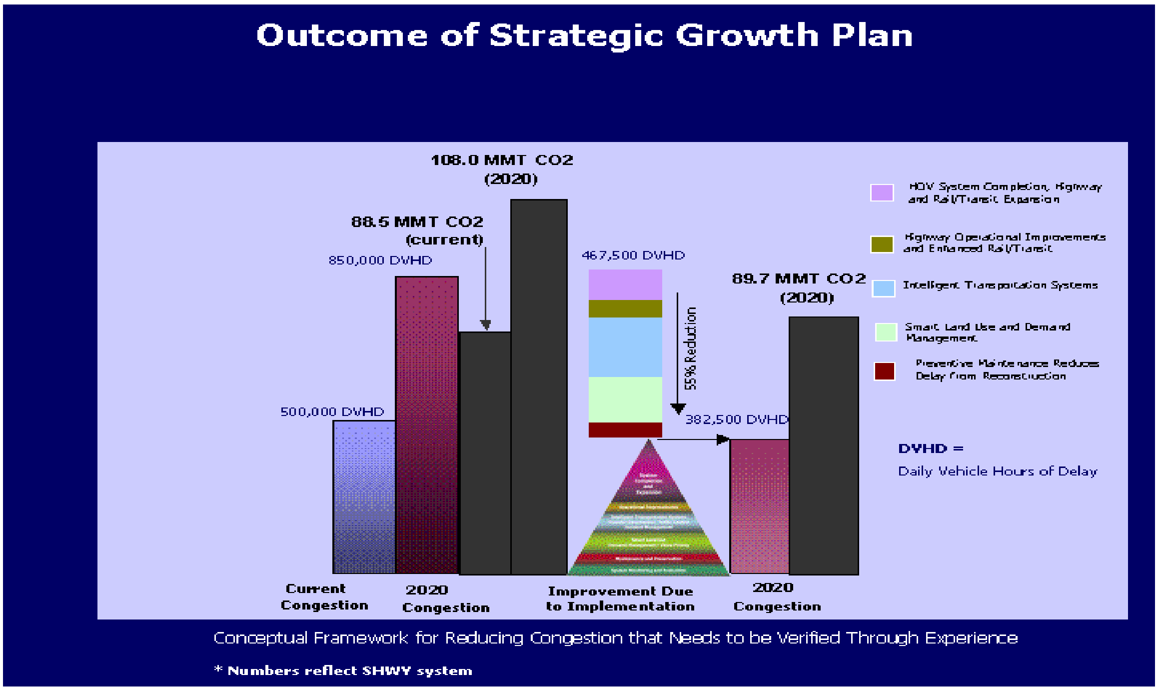

Figure 5 – Outcome of the California Strategic Growth Plan in terms of CO_2 reduction

Figure 5 shows the strategic growth investment strategies and projected outcome to reduce congestion in California and its secondary impact on the level of CO_2 produced.

a. Improving Transportation System Efficiency

The intent of this strategy is to reduce, manage, and eliminate trips, that are primary means of congestion, GHGs, and air pollution through smart land use, ITS, demand management, value pricing, and market based strategies.

1. *Mainstream Energy Efficiency and Conservation Measures* - Currently the statewide and regional transportation planning and project development programs require no energy and conservation element and analysis. The extent of transportation energy related activities at the state, local and regional levels is limited and disjointed with at times offsetting activities. This effort provides a strategic shift to focus on transportation energy and ensure that energy efficiency and climate change measures and analysis are systematically integrated into transportation plans, programs, projects, and investment decisions.

2. *Smart Growth/Land Use Strategy* - Smart growth refers to development practices that result in more compact, accessible, multi-modal communities. Smart growth policies could reduce per capita vehicle travel 10-30 percent. Although these land use changes provide diverse and durable benefits, they take many years to be achieved and require coordination of land use and transportation investment policies toward measurable outcomes. Increasing transit share, use of alternative modes and intermodal connectivity is one of the most effective non-regulatory strategies to improve air quality and reduce energy consumption and greenhouse gas emissions.

3. *The California Regional Blueprint Program* - This is a strategic planning process and one of the tools the Department is using to link land use, transportation, housing, environment, economic development, and equity by developing consensus on a preferred growth scenario for each region. This comprehensive, collaborative, and integrated process provides a framework for the state, local and regional agencies and the community to agree on long-term, land use patterns and transportation systems that improve mobility through smart land use measures.

4. *Intelligent Transportation Systems* - Today, nearly half of the State's urban freeways are classified as "congested" – meaning they carry more traffic than they were designed to handle. This also means wasted time and fuel. The highest levels of CO_2 from mobile sources are associated with congested, stop-and-go speeds (0-to-25 miles) and speeds over 55 mph**.** These measures along with demand management strategies could significantly contribute to reducing fuel consumption and CO_2 from transportation.

Two major elements of the Department's ITS program are the State Architecture and the Transportation Management System (TMS) Master Plan. The State Architecture is designed to provide a developmental framework and consistency between regional architectures and facilitate system integration and deployment of ITS technologies. The TMS elements, within the framework of the State Architecture, focuses on traveler information, traffic control, incident management, and system monitoring and evaluation to maximize the productivity of the transportation system and minimize a need for system expansion. Analysis shows these measures could reduce the VMT and delay by 20 percent in congested corridors *b. Cleaner, More Energy Efficient Transportation Systems and Operations*

The most direct approach to improving energy efficiency of the transportation sector is to increase vehicle fuel economy in new cars, light and heavy-duty trucks with rapid development and availability of alternative fuels and infrastructure. The State needs to pursue a diverse portfolio based on technology and fuel options that are achievable and cost-beneficial. Table III shows metrics associated with this strategy.

1. *Vehicle and Fleet Efficiency* - The on-going turnover of California's fleet of vehicles offers the opportunity to move toward cleaner and more efficient vehicles for the private sector and especially the public sector. The State can accomplish this by committing to replace vehicles at their planned retirement date. The Department currently uses over 13 million gallons of fuel annually. By 2020, it is feasible that the Department could be using B100 biodiesel (75 percent reduction of GHG) for nearly all of its diesel fuel and E85 ethanol could replace gasoline.

2. *Non-Vehicular Conservation M*easures - The Department's energy conservation program focuses on non-vehicular energy consumption by the Department. Based upon the forecasted potential savings from projects currently not implemented and added to the existing energy infrastructure upgrades, the estimated annual electrical savings will approach 258,000,000 KWH. The avoided GHG impact of that total effort should approach 58,864 metric tons of CO_2 per year.

3. *Portland Cement* - Cement production in California was about 12 MMT in 2004, 12 percent of which was used in Department projects (1.44 MMT). Assuming the production of one ton of cement generates about one ton of CO_2, this level of production corresponds to 12 MMT of CO_2. The Department goal is to reduce the amount of cement used in pavements and bridges by up to 50 percent, and yet have stronger, longer-lasting concrete. Supplementary cementitious materials, such as fly ash, slag, silica fume, etc., are potential substitutes. Consequently, CO_2 levels will be lowered and waste products used instead of newly produced materials.

The typical Department concrete mix is about 25 percent fly ash, generally with no other cement substitutions. This has produced 25 percent less GHG from cement production statewide. Further reduction can be achieved by including interground limestone up to 2.5 percent without loss in concrete performance.

The Department is also researching 100-year pavement designed to last 100 years to significantly reduce maintenance and congestion caused by the current rate of rehabilitation/ maintenance and significant savings in construction material and GHG by increasing the pavement life cycle.

4. *Improve Data Collection and Analysis* - This program will enhance technical knowledge and capabilities of transportation planners and engineers and generate transportation related climate change and greenhouse gas emission statistics for transportation communities and policy makers.

5. *Enhanced Education and Performance Standards* - This program would provide information and support to the legislature and to policy makers to advance global warming related issues and funding sources. The intent is to explain greenhouse gas emissions in language that the public can readily understand, and explain immediate benefits and costs in terms of economic and strategic security and cost of transportation. Research proposed

in the state includes developing an aggregate agent-based model of the California economy that includes representations of large-scale climate change impacts.

6. *Increase Freight Transport Efficiencies* - Freight is responsible for a notable portion of energy use and carbon emission in transportation. Since cost reduction is a dominant factor in freight shipping, and energy use in the freight industry is driven by cutting costs and increasing speed, a mix of improvements in engine and vehicle design and in management and operations would be desirable.

7. *Interagency Coordination and Cooperation* - This framework for a clean and energy efficient transportation initiative can only be advanced through joint efforts and close coordination among state, federal and regional agencies, nonprofit organizations and the private sector. Many of the proposed programs already exist in basic form at varying levels of implementation. Many of the strategies listed have been successfully demonstrated in California and elsewhere; however, their level of success is often constrained by lack of sufficient resources and effective coordination or comprehensive planning. Many of the initiatives pursued for decreasing emissions may also change how California adapts to climate change.

CONCLUSION

There is a general consensus that the transportation is an important cause of increasing concentrations of greenhouse gases, however, our knowledge of the ways by which our transportation infrastructure may be impaired and ability to adapt to the consequences of climate change is still developing. Figure 2 presented a conceptual framework that climate initiatives can be further organized in order to develop more effective sets of prioritized mitigation measures relative to adoptive capacity of economic sectors. Therefore, Achieving climate objectives require an aggressive approach to implementing early mitigating measures such as those initiated in California to drastically reduce greenhouse gases. In the short-to-medium term, rapid development and availability of alternative fuels and vehicles, increased efficiency in new cars and trucks (light and heavy duty), and super clean fuels are the most direct approach to reducing GHG emissions from motor vehicles (emission performance standards and fuel or carbon performance standards).

Second, it is not too early to begin evaluating the vulnerabilities of transportation infrastructures and incorporating the effects of climate change projections into transportation planning and project development, because some of our transportation infrastructure have long enough lifetimes to justify a consideration of long-term environmental change such as ones discussed above. The climate impact scenarios should, however, stay within the range where the future remains the most probable and consensus can be reasonably established, rather than focusing on the most extreme events such as dramatic sea level changes or expansions of desert. This would minimize the debate from different perspectives about how to factor in the need for scientific certainty. For example, develop scenarios and mitigating measures around regional climate changes that can result from periodic sever weather patterns regardless of their fundamental cause, but may also be recognized as symptomatic of major changes to come in weather patterns in the future. The intent is to begin developing technical requirements and procedures necessary to mainstream climate change into the transportation and land use agencies business decisions.

There is a clear role for transportation and land use agencies in keeping up to date with climate change developments and improving understanding about likely impacts on transportation infrastructure. Transportation agencies need to establish climate action program and an ongoing focal point to coordinate climate activities.

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