Driving Change

Reducing Vehicle Miles Traveled in California

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Senate Bill (SB) 375, adopted in 2008, calls on regional transportation planning agencies and local governments to develop strategies for reducing greenhouse gas emissions from passenger vehicles by reducing per capita vehicle miles traveled (VMT). Three specific strategies, traditionally used to reduce traffic congestion and improve air quality, are to be employed to help reduce emissions.

Higher-density development, particularly in areas well served by transit;

Investments in alternatives to solo driving, such as transit, biking, walking, and carpooling; and

Pricing policies that raise the cost of driving and parking.

Although SB 375 is expected to reduce emissions only modestly relative to vehicle efficiency standards and low-carbon fuels, it is also expected to improve public health and reduce energy and water use by encouraging denser development and more "livable" communities. The integration of these three approaches is consistent with an emerging research consensus that policies integrating all three strategies have a much greater chance of reducing VMT than any one approach on its own. This report reviews the opportunities and challenges of each of these strategies and assesses California's recent experience and future prospects for successfully integrating them.

On balance, California has started with the right approach by attempting to integrate its emission-reduction policies. However, recent experiences within the state and elsewhere have revealed numerous challenges—some quite formidable. On the plus side, more local governments are undertaking climate change activities, and many local planners see significant potential for reducing VMT, especially in localities that have experience in implementing these strategies and in more populous areas of the state. Also, planners are beginning to recognize the importance of using multiple approaches. And transit ridership in California is increasing, with recent transit investments appropriately directed toward higher-density areas.

But red flags abound, potentially limiting California's ability to reduce VMT. Employment density (the number of jobs per square mile) is low and declining, and employment density matters more than residential density for encouraging transit use as an alternative to driving. Furthermore, major transit investments since the early 1990s have not produced an overall reduction in VMT, and densities around new stations have not increased. The vast majority of commuters still drive to work, even if they live or work near a transit station. And planners are skeptical about pricing policies—a key component of integrated strategies—especially in localities with higher-income households, which tend to be less sensitive to changes in the cost of driving and parking. Finally, funding transit investments and operations remains a perennial challenge.

If California is to make the most of SB 375, several priorities require attention. Regions and localities should encourage greater commercial (that is, nonresidential) development around transit stations. Pricing policies need to accompany land use and transportation strategies, despite public resistance. State or federal leaders need to raise general road use fees (either the traditional gas tax or a new VMT-based fee), both to provide incentives to reduce driving and to help fill the widening gap in transportation funding. And, finally, regional strategies must recognize the wide variation in attitudes and conditions among localities and address the lack of coordination (even among transit systems within the same region) that exists today.

This report is based on reviews of the research literature, our survey of local governments and planning agencies, and our analysis of population, employment, and transportation data. The report draws heavily on two companion papers: "Views from the Street" (Bedsworth, Hanak, and Stryjewski 2011) and "Making the Most of Transit" (Kolko 2011). To find these and other related resources, please visit the report's publication page: http://www.ppic.org/main/publication.asp?i=948

Introduction

> In the communities of the future, homes and jobs, recreation and education, shopping and health care, will be more accessible with less dependency on the single-occupant vehicle.
> —California Air Resources Board (2010)

With the adoption of Senate Bill (SB) 375 in late 2008, California became one of the first states in the nation to establish an explicit policy aimed at reducing the amount of driving by passenger vehicles—or vehicle miles traveled (VMT)—in an attempt to reduce the greenhouse gas (GHG) emissions that contribute to global warming.[1] Achieving this goal will entail a major behavioral shift for Californians, often known for their love affair with the automobile. Per capita VMT and associated GHG emissions in California have been increasing for decades, but the new targets in the state's largest metropolitan areas envision per capita GHG emission reductions from passenger vehicles on the order of 7 to 8 percent by 2020 and 13 to 16 percent by 2035 (California Air Resources Board 2010). Although some of these reductions can be achieved by improving traffic flow (which reduces emissions by increasing fuel efficiency), most will need to come from reductions in the length and frequency of automobile trips.[2]

Three broad policy strategies, traditionally used to reduce traffic congestion and improve air quality, will now also aim to reduce GHG emissions:

Integrating land use and transportation decisions to bolster the effectiveness of transportation policy and investments (e.g., development or redevelopment around transit stations);

Investing in alternatives to solo driving, such as public transit, biking, walking, and carpooling; and

Using pricing incentives to manage traffic and parking.

Because meeting SB 375 targets will require using these strategies more aggressively than in the past, the new law could bring major shifts in the way state, regional, and local governments make transportation and land use decisions.

In particular, SB 375 envisions collaboration between regional transportation authorities and local governments. California's regional transportation authorities—the Metropolitan Planning Organizations (MPOs)—are responsible for demonstrating compliance with SB 375, whereas local governments—cities and counties—oversee most transportation spending and have authority over land use. Rather than sanctions for noncompliance, SB 375 includes regulatory incentives to encourage local governments to collaborate with MPOs by easing requirements for the environmental review of suitable development projects under the California Environmental Quality Act (CEQA).

In calling for collaboration between the agencies responsible for transportation planning and governments responsible for land use planning, SB 375 reflects the emerging research consensus that integrating transportation, land use, and related policies has greater potential to reduce VMT than any one of the approaches taken alone. The success of SB 375 hinges on how well California's regional and local governments can integrate these policies to promote a behavioral shift from solo driving by California residents.

In terms of climate policy, SB 375 is expected to achieve only modest benefits, accounting for 8 percent of all GHG emission reductions in the transportation sector by 2020 and approximately 3 percent of all emission reductions economy-wide (California Air Resources Board 2008). Yet by reducing the distances between residences and other destinations, reducing the amount of time people spend in their cars, and enhancing "walkability," SB 375 is likely to meet the broader social goal of building more livable, healthy communities.[3] In addition, by facilitating the development of denser communities, SB 375 may help meet other sustainability goals, including reduced energy and water use.

This report reviews the role of transportation in California's climate policy; synthesizes current knowledge

about the effectiveness of land use, transit, and pricing policies; and tries to gauge how well California is positioned to implement an integrated strategy for VMT reduction. The first section reviews the role of transportation in California's climate change policy, describing efforts to reduce GHG emissions through various transportation strategies. The second section explores land use, transit, and pricing policies aimed at reducing VMT. The third section discusses the integration of these strategies. We look at local readiness to use integrated strategies, drawing on our survey of California city and county planners, and analyze California's recent experiences with transit-oriented development (TOD)—a prime example of integrated land use and transportation planning. The final section summarizes our key findings and explores policy implications.

Transportation and California's Climate Change Policy

California's efforts to reduce air pollution have focused on transportation issues for decades. The state led the nation with the first emission regulations for vehicles in the early 1960s, and this leadership continues today in California's quest to reduce GHG emissions.

GHG Emission Trends

Greenhouse gas emissions in California have been increasing steadily over the past several decades, with the fastest growth occurring in the transportation sector. Statewide, GHG emissions increased almost 10 percent between 1990 and 2008, and emissions from transportation increased by over 16 percent. Without regulations to reduce emissions, this growth is expected to accelerate over the next several decades (California Air Resources Board 2008). The transportation sector is the largest single contributor to GHG emissions in the state, accounting for 37 percent of all emissions. Passenger cars and trucks account for almost three-quarters of this total.

Policy Context

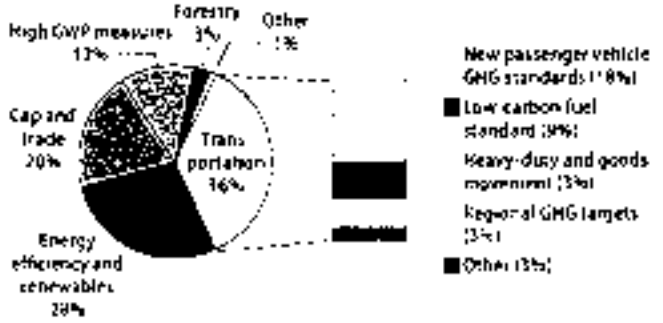
Recognizing the high risks associated with climate change, California has taken a leadership role in global efforts to reduce GHG emissions. Assembly Bill (AB) 32, the Global Warming Solutions Act of 2006, set a target for California to reduce statewide emissions to 1990 levels by 2020 (a roughly 30 percent reduction relative to business as usual), and the state is aiming to reduce emissions an additional 80 percent by 2050—the level considered globally necessary to stabilize the planet's climate.[3]

The California Air Resources Board (CARB) is responsible for implementing AB 32, and it has outlined a comprehensive "scoping plan" that includes all of the programs needed to achieve the state's 2020 emission reduction target (California Air Resources Board 2008). The largest share of these reductions (36%) is expected to come from programs that involve the transportation sector, including establishing GHG emission standards for new passenger vehicles, decreasing the carbon content of fuels, and lowering the number of miles driven. VMT reductions are included in the "regional GHG targets" established under SB 375 and depicted in Figure 1.

VMT reductions play a relatively modest role in the overall emission reduction plan—6 percent of all transportation sector reductions and only 3 percent of AB 32's overall target for 2020—anticipating the length of time needed to register cumulative effects from such measures as land use changes and new transit investments, which also require behavioral changes by the public.[4]

These estimates do not include other potential emission benefits of SB 375 associated with changes in land use. For example, higher-density housing units are smaller and therefore use less energy.[5] And, as noted above, SB 375 may

Figure 1. Transportation is a primary concern in near-term efforts to reduce emissions



also lead to broader public health benefits, since reductions in driving improve air quality and tend to increase physical activity, such as walking and biking.

Reducing Vehicle Miles Traveled: The Challenge of Coordination

SB 375 directs the California Air Resources Board to establish GHG emission reduction targets for passenger vehicles in each of the state's 18 MPOs—regional agencies that cover roughly 98 percent of the state's population. MPOs are responsible for developing long term (20 year or longer) regional transportation plans (RTPs). Although MPOs are responsible for compliance with SB 375 through the development of a Sustainable Communities Strategy (SCS) in the RTP, their success will require close coordination with two other key groups: local transportation and land use authorities. Most of the spending identified in a regional transportation plan is carried out by local entities—county transportation agencies, city public works departments, transit agencies and districts, and others—that control their own budgets.[7] Statewide, local governments and transit agencies are responsible for 77 percent of transportation expenditures (see Bedsworth, Hanak, and Strylewski 2011 for details on expenditures). Cities and counties are also essential collaborators with the MPOs because of their authority over land use decisions.[8]

Successful implementation of SB 375 will require more interplay between the regional and local entities than there has been in the past. The new law provides some regulatory incentives to local governments to increase collaboration, and MPOs can create financial incentives by directing their resources toward projects that meet SB 375 goals.[9] But local willingness to participate will be a key ingredient to success.

Early Responses to Transportation and Land Use Goals

Even before the passage of SB 375, the state's largest regions had been collaborating with cities and counties to reduce driving and manage traffic congestion. Indeed, part of the impetus for SB 375 came from the "Regional Blueprint" planning process, which has encouraged MPOs and local governments to coordinate transportation and land use planning to meet a range of sustainability goals.[10]

Accordingly, several MPO planning directors we interviewed reported that SB 375 codifies what they were already doing and provides "wind at their backs." But the new law has also pushed regions to look for further improvements, as reflected in a comparison of carbon dioxide emission trends under current RTPs and the SB 375 targets set for 2035 (Table 1).[11]

And despite the recession and considerable local fiscal stress, an increasing number of cities and counties are undertaking two important climate change activities: GHG emission inventories and climate action plans (Table 2). Emission inventories develop a baseline of GHG emissions from different sources, enabling localities to identify areas for emission reductions and to monitor progress in meeting their goals. Climate action plans are general planning documents that define strategies for emission reductions and other sustainability measures. Roughly 70 percent of all local governments are actively engaged in these programs, covering over 85 percent of the state's population, and the vast majority report that their activities include goals, policies, or programs to reduce the number and shorten the length of car trips.[12]

Table 1. MPOs are stepping up GHG emission reductions since the passage of SB 375

		Per capita GHG emission reductions, 2005–2035 (%)	
	Current RTP adoption date	Current RTP projection	New target
Southern California (SCAG)	2008	–4	–13
San Francisco Bay Area (MTC)	2009	–3	–15
San Diego (SANDAG)	2007	–10	–13
Sacramento Area (SACOG)	2008	–13	–16

SOURCES: [illegible] 2011; California Air Resources Board 2010.

NOTES: For the SCAG region, the target set by the California Air Resources Board (CARB) is higher than the level initially set by the region, but it was increased 2% prior to CARB's approval for [illegible] The SCAG board voted in September 2012 to set the new target with the 2012 RTP proposal. SACOG's CARB-approved target includes the emissions reduction from land use changes [illegible] Southern California Association of Governments 2012.

Table 2. Despite the recession, local climate action programs have increased

	Share of local governments with programs (%)	
	2008	2010
Emission inventory, municipal operations	55	70
Emission inventory, community at large	42	69
Climate action plan	52	69

SOURCES: For 2008, [illegible] 2008. For 2010, [illegible] Research Partners 2010.

Thus, it appears that California's new climate policy goal to reduce driving is encouraging regions and localities to continue in the direction that many have already taken.

Policies and Programs to Reduce Driving

Three primary approaches can reduce VMT: changing land use patterns to reduce the need to drive; investing in mass transit and other alternatives to driving; and increasing the cost of driving and parking to encourage the use of alternatives. Although each of these strategies has received some attention in past planning efforts, SB 375 focuses specifically on ways to increase the effectiveness of these approaches. In this section, we discuss where California stands and what the research says about the usefulness of each approach on its own. We also describe some of the activities local governments are undertaking in each area.

Land Use Policies

Land use patterns—density, the proximity of jobs and housing, and design elements, such as shorter blocks and more street intersections—have a modest but often statistically significant effect on transportation behaviors, such as trip length, trip frequency, and the decision to drive or travel by other means (Ewing and Cervero 2010). Evidence also suggests that people who live in denser neighborhoods drive less (Ewing and Cervero 2001). But VMT reductions of more than a couple of percentage points would require increases in residential density that many researchers consider infeasible (Transportation Research Board 2009).[3]

High *employment* densities appear to boost transit ridership (and therefore reduce VMT) more than high residential densities, in part because it is relatively easy for workers to drive or bike from home (where their cars or bikes are) to a transit stop or station but not as easy to drive or bike from a transit station or stop to their workplace (Barnes 2005; Arrington and Cervero 2008; Transportation Research Board 2009). As we discuss below, greater focus on encouraging employment densities may create opportunities for California to boost the effectiveness of its VMT reduction efforts.

Land Use Trends

Despite the conventional wisdom that California (particularly Southern California) is the epitome of sprawl, residential density in California is well above the national average. Residential density in California in 2000 was 49 percent higher than the national average (Kolko 2011; see the text

box). Residential density increased from 1990 to 2008 in California but did not change at the national level.

Employment density is another story. Employment density in California is lower than in the nation overall (in 2005, 15% below the U.S. average) and, like the long-term national trend, is declining. In the six largest California metropolitan areas, employment densities within three miles of downtown fell nearly 25 percent between 1992 and 2005, whereas employment densities ten miles or more from downtown rose slightly over the same period. The movement of jobs away from dense downtowns is a decades-long trend with economic, political, and technological causes (Kolko 2011).

California's large metro areas display considerable variation in density. The Los Angeles metropolitan area ranks second nationally in residential density, and San Francisco–Oakland ranks third. In contrast, Los Angeles ranks only 22nd nationally in employment density. Of California's twelve largest metros, all but two—San Francisco–Oakland and Sacramento—have lower employment density than residential density.

[redacted]

Current land use patterns in most California metropolitan areas (high residential density, low employment density) do not offer much promise for reducing VMT. Furthermore, density patterns tend to have long life spans: They represent the cumulative result of decisions made over many years by governments, businesses, and households. Moreover, communities often resist higher-density development—local officials surveyed by PPIC ranked public opposition to density as the biggest barrier to reducing driving in their communities.[4]

Land Use Strategies in Action

Given the challenges of unfavorable long-term trends and public opposition, what land use strategies are cities and counties currently pursuing? Our survey inquired about a range of land use policies that constitute a "smart growth" approach to raising densities and increasing proximity to transit:[5]

Urban growth boundary or greenbelt: Restricts development outside designated areas; seeks to increase density within the core urbanized area and prevent leap-frog development;

Transit-oriented development: Designates priority sites or site-specific zoning and building standards around transit nodes and hubs; seeks to increase density in close proximity to transit.

Measuring density

Conventional density is measured as the number of people (or housing units or workers) per square mile (or other measure of area). But metropolitan areas and states often include undeveloped or sparsely developed land.

Weighted density takes this unevenness into account by measuring the number of people (or housing units or workers) in the areas where people actually live or work. It weights the average of conventional density measured at the Census tract or other small geographic level by the number of people or workers in that tract. Weighted density better reflects the land use patterns experienced by a typical person or worker.

Consider two hypothetical cities, Sparseville and Densetown. Each has a population of 1,000 residents and consists of two square-mile Census tracts. In Sparseville, 500 people live in each tract, whereas in Densetown, all 1,000 residents live in one tract and the other is undeveloped. Both Sparseville and Densetown have a conventional density of 500 people per square mile (1,000 residents divided by two square miles). But the weighted density measure is 500 people per square mile in Sparseville, since the average person lives in a tract with 500 people per square mile, whereas the weighted density measure in Densetown is 1,000 people per square mile, since the average person (in fact, all people) lives in a tract with 1,000 people per square mile.

Throughout this report, we report weighted density measures for metropolitan areas and states.

Mixed use, higher-density, or infill development: Designates priority sites or site-specific standards to encourage these types of development; seeks to facilitate fewer and shorter car trips by providing more diverse land uses within close proximity;

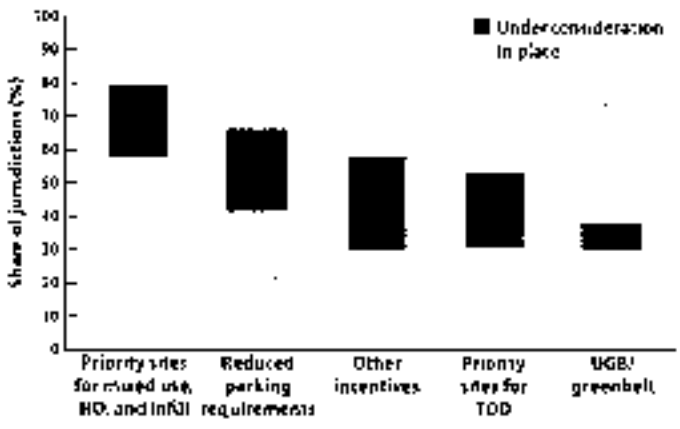
Reduced parking requirements: Reduces the number of spaces developers must provide per unit of residential or commercial space; seeks to facilitate infill and higher-density development by reducing costs to developers;[9]

Other incentives: Encourage density by reducing developer costs (e.g., preferential fees or permit streamlining for qualifying development).

Many localities are already employing a number of these strategies, and many others are considering them. Statewide, the designation of priority sites and site-specific standards to encourage mixed use, higher-density, or infill development is the most prevalent undertaking (used in 58% of all localities and under consideration in 22%), but other approaches except urban growth boundaries are also already in use or under consideration in more than half of all localities (Figure 2).

In general, localities with larger populations have higher adoption rates for most individual policies and are most likely to rely on multiple approaches. Another important factor is experience with smart growth strategies. Communities that have already adopted one land use policy are significantly more likely to have adopted or be considering others. Transit-oriented development is much more likely in communities that already have some form of rail transit (commuter rail, subway, light rail, and streetcar) or expect to have rail in the future.[10]

Figure 2. Local governments are using various land use tools to increase density and improve access to transit



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Investments in Transit and Other Alternatives

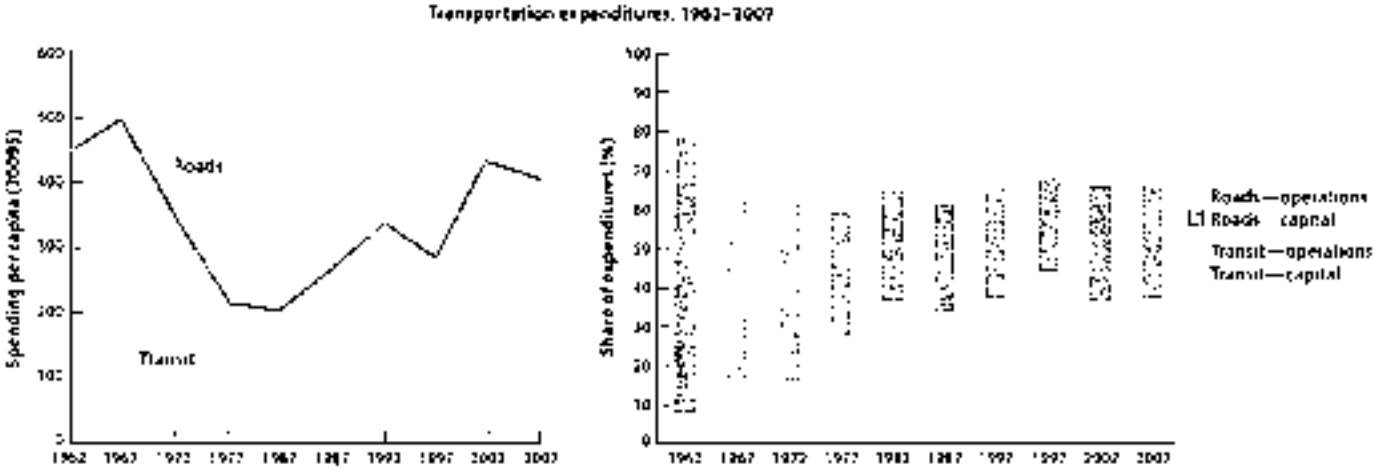
Transit serves multiple goals, including providing mobility for low-income, disabled, and elderly residents without cars. But one of transit's key goals, especially since the 1970s, has been to help reduce congestion (and air pollution) on roadways during peak periods (Fielding 1995; Hanak and Barbour 2005).[11] This goal relates most closely to SB 375's call to reduce GHG emissions from passenger vehicles.

Transit has been an important component of transportation spending in California since the end of the federal freeway expansion program in the 1960s (Figure 3). Since the early 1980s, transit has accounted for well over a third of all transportation spending in California and from 20 to 30 percent of capital investments, with even higher shares in the major metropolitan areas.[12]

Most transit capital spending is associated with rail projects (subways, commuter rail, light rail, and streetcars). Between 1992 and 2006, 217 new rail stations (including several bus-rapid-transit stations) opened in the state, and dozens more are planned. These expansions appear consistent with the public's spending priorities: In surveys of California residents in 2004 and 2006, rail transit ranked as high or higher than highways (and nearly three times higher than buses) as a top priority for transportation spending.[13] Yet, bus service—generally a far less costly option—is much more widely available.[14]

To date, ridership trends for California's transit systems have been disappointing, relative to investments in this sector. For the state as a whole, the share of commuters taking transit increased from 5 percent to 5.5 percent between 1990 and 2008 (Table 3)—76.4 percent of all commuters still drive alone to work. Transit is most important

Figure 3. Transit has become an important component of California's transportation spending



for commutes in the San Francisco–Oakland metropolitan area (15.3%)—second only to the New York City metro area nationally—and accounts for a much higher share of commutes along congested corridors, such as trips across the bay into downtown San Francisco. Transit ridership in Los Angeles (6.6%) is slightly higher than the state average, but it is much lower in other major metropolitan areas, such as Sacramento (3%) and Riverside–San Bernardino (1.9%).

Although rail represents only a small share of transit commutes (1.4% versus 4.1% for buses), it accounted for much of the increase in transit ridership between 1990 and 2009. In the San Francisco–Oakland and San Diego areas, increasing rail use actually displaced some bus use, which declined as a share of all commutes.[17] During this period, per capita VMT increased in California by 3.5 percent, suggesting that growing transit ridership did not displace road travel—or at least not enough to reduce overall driving.[18] This may be due to an increase in car use for noncommute trips. Work commutes account for just over a quarter of all car use, and noncommute trips are much less likely to involve transit.[19] Nonetheless, per capita VMT increased less in California than in the nation overall, where per capita VMT rose by 13.7 percent over the same period.

Cost is a major challenge for transit. Transit systems the world over rely heavily on operating subsidies. Statewide, transit fares cover only about a quarter of operating costs.[20] And a recent analysis of transit systems in the Bay Area found that operating costs have been increasing much more rapidly than inflation.[21] Many survey respondents expressed concerns about the ability to maintain adequate transit

Light rail and buses in Long Beach, just 6.6 percent of Los Angeles area commuters ride transit to work.

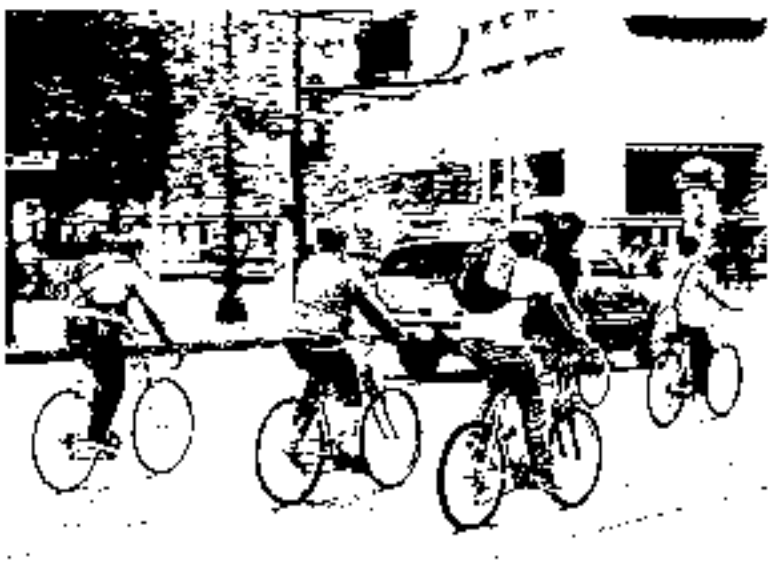
Table 3. Transit has increased slightly as a share of commutes since 1990

Metropolitan area/region	Transit share of commutes (%) 1990	2000	2008	Change in share 1990–2008 (%) Rail	Bus
Los Angeles–Long Beach–Santa Ana	5.7	5.8	6.6	0.5	0.4
San Francisco–Oakland	14.5	14.4	15.3	1.8	−0.8
San Diego	3.4	3.5	3.6	0.4	−0.2
Riverside–San Bernardino	0.8	1.7	1.9	0.7	0.3
Sacramento	2.4	2.9	3.0	0.2	0.3
San Jose	3.0	3.5	3.8	0.8	0.0
California	5.0	5.2	5.5	0.6	−0.1
United States	5.3	4.2	5.2	0.2	−0.3

SOURCES: U.S. Census American Community Survey.
NOTES: [illegible]

service in the face of recent state cuts to transit budgets, and in three of the largest regions, insufficient transit availability was ranked as one of the top three barriers to meeting goals for reducing driving.[27] Rail systems—which users often prefer to buses—are especially expensive to build and operate, saving them open to criticism of cost-ineffectiveness and waste (O'Toole 2010; Poole and Moore 2010).

If transit is to contribute to achieving the SB 375 goals of reducing VMT, strategies will be needed to increase ridership and improve cost-effectiveness. Research has found that the likelihood of transit use increases with easy access (Ewing and Cervero 2010). Ridership falls significantly when workers live more than a quarter to a half mile from a transit station. In California, only 6 percent of residents live within a half-mile of a transit station, and only 12 percent of workers have jobs within a half-mile of a transit station.[28]



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ore than 90 percent of Californians live in places with bicycle master plans completed or under way

Transit use is more likely when there is greater street connectivity (e.g., grid-like plans) and a diversity of land uses, both of which can smooth transit operation and make using transit more appealing by reducing travel times and increasing convenience for riders (Ewing and Cervero 2010). Transit ridership by commuters is higher in metropolitan areas that have higher employment densities, especially in downtown areas, as well as higher residential densities in many neighborhoods throughout the metropolitan area.

In metropolitan areas with multiple transit systems, better connectivity of the overall system is also important. This is a particular challenge in the San Francisco Bay Area, which has more than two dozen distinct transit systems, many of which operate within the same service areas.[29] Maximizing transit ridership will require integrating services, timetables, and ticketing policies among systems in a region, so that transit becomes a more appealing option for long-distance commuters.

Walking and biking alternatives

Encouraged by state and federal financial support, many California localities are focusing on improving bicycle and pedestrian networks. Over 90 percent of California's residents live in a city or county that has completed or plans to complete a bicycle master plan (40% of all jurisdictions have already established a continuous network of bicycle routes). Just over half of the state's residents live in localities with similar planning under way for a pedestrian master plan or a "complete streets" plan that aims to improve safe access for all users, including pedestrians, bicyclists, drivers, and transit users (National Complete Streets Coalition 2013). Planners tend to be quite optimistic about the potential for bicycle networks to reduce VMT, although from a relatively low baseline. Bicycles accounted for only 1 percent of all commutes in 2008 (American Community Survey 2008). Walking (3% of commutes in 2008) accounts for a greater share of (typically shorter) nonwork trips (Hu and Reuscher 2004). Reducing car use for shorter trips can have disproportionately high benefits for GHG emission reductions, because gas mileage tends to be lower on such trips. Walking and biking also offer the benefit of improving public health (Ewing et al. 2003; Doyle et al. 2006).

Pricing Policies

Policies that increase the cost of solo driving have the most immediate and highest potential to reduce VMT (Rodier 2009). This strategy includes explicit pricing mechanisms, such as fuel and road-use charges and parking fees, as well as a strategy that practitioners often refer to as "demand management"—incentives such as carpool lanes, employee shuttles, and other employer inducements to use transit. Both strategies create financial or time-saving incentives to shift trip-taking away from peak periods, making alternatives, such as transit, carpooling, and telecommuting, relatively more attractive (Deakin et al. 1996; Parry 2009).[2]

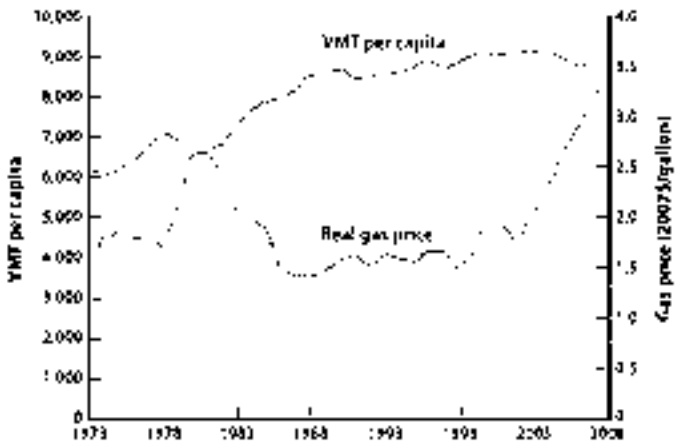
In addition, more explicit pricing strategies can generate revenues to support the transportation system, which is a growing concern.[3] Transportation analysts consider pricing policies to be a preferred way to fund transportation investments and maintenance, because they simultaneously raise revenues and send a signal to users to use the system more efficiently. The alternative—funding transportation through general tax revenues—pays for infrastructure but does not help to manage demand. Local sales tax revenues, which have become an important transportation funding source in recent years, are also highly regressive. However, public opposition can be a formidable challenge to implementing fee increases, as discussed below.

Federal, State, and Regional Pricing Policies

Federal and state gas taxes, introduced in the early 20th century, are the primary pricing incentive today. These taxes are a simple form of user fee, generally resulting in higher charges for those who drive more (i.e., consume more fuel). Recent experience shows that such price signals can have a discernible effect on VMT: Between 2004 and 2008, when average real gas prices jumped by 54 percent, per capita VMT in California declined by 5.8 percent (Figure 4). Although the onset of the recession likely played a role in declining road travel toward the end of this period, the reductions in VMT per capita began in 2005, when the economy was still booming.

Over time, however, rising fuel economy and public opposition to increasing the gas tax have reduced its usefulness as a source of revenue and as a price signal to drivers

Figure 4. VMT per capita in California declined when gas prices began rising in the mid-2000s



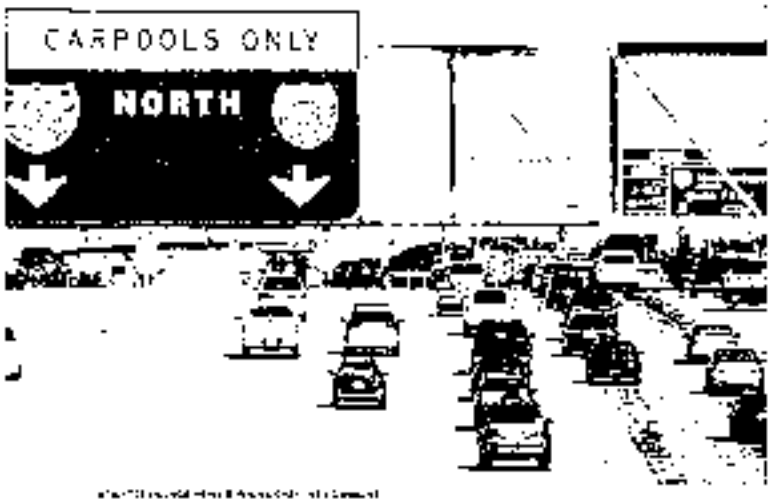
(Wachs 2010).[12] The federal gas tax has held steady at $0.184 per gallon since 1993, and California's gas tax has remained at $0.18 since 1994,[13] somewhat below the national average and far lower than fuel taxes in Europe and Japan.[14] Although raising these taxes and indexing them to inflation could help

restore transportation revenues while sending a stronger price signal to drivers, transportation experts see far greater potential over the longer term in an alternative form of user fee: per mile, or VMT, charges.

VMT-based fees, which rely on new electronic toll collecting and geographic positioning system technologies, have the potential to be more flexible than the gas tax: They can be varied according to time of day, type of road, and type of vehicle. Road metering has been gaining ground outside the United States, and a pilot program was recently completed in Oregon that functioned smoothly and reduced VMT (Sorenson and Taylor 2005a, 2005b; Spears, Boarnet, and Handy 2010; Rufolo and Kimpel 2009). These experiences led a national panel to recommend that the federal government actively promote pilot programs with VMT charges as part of the next federal transportation funding authorization, with a goal to fully convert from gas taxes to VMT charges by 2020 (National Surface Transportation Infrastructure Financing Commission 2009).

In the absence of comprehensive federal and state legislation, California's largest MPOs have been adopting more targeted road pricing initiatives. Bridge tolling has long been a feature of transportation policy in the San Francisco Bay Area, and the MTC recently introduced variable pricing on the highly traveled San Francisco–Oakland Bay Bridge to help manage congestion during peak periods. Most expansions of highway lane miles since the early 1990s have focused on providing carpool or high occupancy vehicle (HOV) lanes in metropolitan areas (Hanak and Barbour 2005). Following the principle that "time is money," these lanes provide an incentive to reduce solo driving, and modeling has shown that they are more effective in areas where there are longer traffic delays on regular lanes (Dahlgren 1998).

Since the mid-1990s, some Southern California metro areas have also experimented with road tolling.[15] Most of these high-occupancy-toll (HOT) or express lanes combine free access for carpoolers with a toll option for solo drivers, sometimes with variable prices. Just as with general VMT based pricing, HOT lanes rely on electronic toll-collection technology. Conversions and expansions of HOT lanes are a major component of planned roadway spending within the Bay Area, Southern California, and San Diego regions, and the Sacramento region plans to expand HOV lanes (Heminger et al. 2010).[16] Once these plans are realized, roughly 40 percent of the localities in our survey (constituting over 60% of the population) will be within 5 miles or less of at least one HOT lane. As with HOV lanes, the efficacy of HOT lanes depends on existing traffic conditions and delays (Dahlgren 2002).



HOV lanes, carpool lanes, and other "demand management" and pricing policies have the greatest potential to reduce VMT.

Local Parking Policies

Placing a charge on public parking spaces within a given area can reduce the congestion resulting from drivers looking for free parking spaces, encourage the use of alternative means of transportation, and generate revenues (Giuliano and Agarwal 2010; Shoup 2005). In addition, limiting requirements on developers to provide parking can increase density and make car use relatively more costly (Shirap 1999). The effects on driving are particularly strong when workers must pay to park (Legislative Analyst's Office 2002; Taylor and Fink 2003).[17]

Yet parking pricing and management is still a seldom-used strategy in California.[18] Statewide, only 16 percent of the cities and counties in our survey (including the most populous localities) have initiated any type of charges for public parking in commercial areas.[19] And nearly nine-tenths of all localities (including the larger ones) continue to require that new commercial developments provide employee parking, with free parking for employees remaining the norm. However, as discussed above, a large and growing number of jurisdictions are relaxing minimum requirements for parking in some new developments to encourage density (Figure 2).

The Challenge of Public Acceptance

Although our survey of local officials indicated that public opposition posed an obstacle for all three types of VMT-reduction policies (increasing population density, transit use, and pricing), this problem may be especially important for pricing. Our survey showed that public opposition to higher charges for driving ranks a close second to public opposition to higher density. And as evidenced by the inability of both Congress and the state legislature to raise the gas tax since the early 1990s, the need to gain significant legislative or voter approval increases the difficulties of raising fees. Proposition 26, a new state constitutional amendment passed in November 2010, is likely to compound these difficulties for some types of fees.[20]

Experience may help overcome opposition to pricing options that involve some choice. For example, early concerns that toll lanes were inequitable have been allayed somewhat by use patterns: A broad cross-section of the population uses the toll facilities on the I-15 and Route 91 (Sullivan 1998; University of California Transportation Center 2003). According to the Southern California transportation officials we interviewed, government use of toll revenues to support parallel infrastructure and services can help garner public support for tolling.

Board members of SANDAG, the San Diego region MPO, recently rejected the introduction of a regional VMT fee because, in contrast to HOT lanes, it would have been applied uniformly across the board, without providing alternative travel options to drivers (San Diego Association of Governments 2010). Any large increases in federal or state road charges through a gas tax or VMT fee would

> Our survey showed that public opposition to higher charges for driving ranks a close second to public opposition to higher density.

surely raise public ire. In the short run, a large increase in gas prices or VMT fees could also raise equity concerns, because lower- and middle-income households would have less flexibility to respond by moving closer to transit or by purchasing more fuel-efficient vehicles.

Parking policies face the challenge of meeting the needs of commercial areas to attract customers while also managing congestion. They can also lead to objections in mixed use areas, where efforts to reduce parking near commercial enterprises can result in spillover to nearby residential streets.[21] One strategy that has helped to overcome opposition to parking restrictions and fees has been the reinvestment of parking revenues back into the downtown area in which they have been collected, a model used in Redwood City (Zack 2005) and Pasadena (Salzman 2010). Resistance to higher parking charges may also be offset once residents find that it is easier to find a parking space (since one of the goals of such fees is to hold vacancy rates to a low but acceptable level).

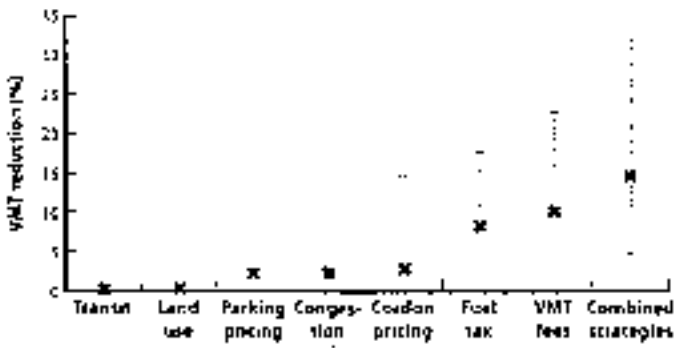
Building an Integrated Strategy

Research suggests that integrated strategies will be far more effective in reducing VMT than individual land use, transportation, or pricing strategies pursued on their own, making it possible for California to meet the goals of SB 375 (Figure 5). The Transportation Research Board (2009) predicts twice as large a reduction in VMT when higher-density strategies are paired with complementary policies, such as increased transit availability.[42] The extensive literature on transit-oriented development also stresses the need for complementary policies, demonstrating that transit investments in isolation are unlikely to lead to new development and increased densities (Giuliano and Agarwal 2010).

It is encouraging to note that, to some extent, California's largest MPOs are already pursuing combined strategies. Their most recent RTPs include increases in housing density, HOV/HOT lanes, and transit use.[43] In developing scenarios for SB 375 targets, the MPOs envisage increased efforts in several of these areas (Deminger et al. 2010).[44] At the same time, interviews with local officials revealed challenges in coordinating land use and transportation policies: For instance, transit may spur development, but without existing dense development it is more difficult to justify (and secure federal funding for) transit projects.

To shed light on the potential for success, we discuss the observations of local governments, the key players in this process. We then examine California's experience since the early 1990s with one of the primary integrated strategies—transit-oriented development.

Figure 5. Integrated policies have the highest potential to reduce VMT



SOURCE: Authors' 2009 review of studies that model the effects of policies on VMT reduction.

NOTES: The figure shows the median (red line) and 95 percent confidence intervals (blue bars) from a range of studies over a range of time frames. The results of the combined strategies (green) are from approaches that combine land use changes (density, diversity, VMT fees (22 studies), parking pricing (20 studies), and cost (3% to 60% increase in VMT reduction) and fuel-economy (10% to 40% increase in VMT reduction) standards. Land use strategies (11 studies) and congestion pricing (including HOT/HOV lanes) (7 studies) are excluded from the figure because they are not applicable to all areas. Land use strategies (density, diversity, and design) can reduce VMT by 5% to 12% (Ewing and Cervero 2010). Congestion pricing (including HOT/HOV lanes) can reduce VMT by 1% to 4% (Transportation Research Board 2009). Parking pricing can reduce VMT by 2% to 5% (Shoup 2005). Fuel taxes can reduce VMT by 1% to 3% (Transportation Research Board 2009). VMT fees can reduce VMT by 10% to 23% (Transportation Research Board 2009). Combined strategies can reduce VMT by 5% to 30% (Transportation Research Board 2009; Ewing and Cervero 2010; Cambridge Systematics 2009).

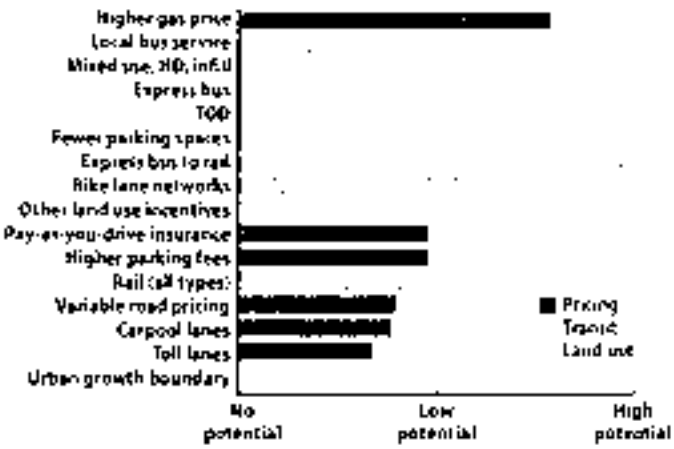
Local Perspectives on the Potential to Reduce Driving

Our statewide survey of local planning officials sheds light on the potential of local governments to meet the goals of SB 375 (Bedsworth, Hanak, and Stryjewski 2011). Respondents were asked to gauge their localities' potential to reduce driving relative to other localities within their region and to offer their opinions on the potential effectiveness of a range of land use, transit, and pricing strategies in their jurisdictions. The results reveal local planners' views of the feasibility of these strategies within their communities, taking into account both political acceptability and various community characteristics.[45]

In general, local officials appear cautiously optimistic about their overall ability to reduce driving in their localities. More than a third of all those surveyed reported that their community had below-average potential relative to others within their region. But after accounting for community size, we find that 45 percent of the population lives in localities that perceive above-average potential, compared to 27 percent in localities with below-average potential.

Local governments see the potential to reduce VMT through a range of approaches. Respondents were asked to gauge the potential effectiveness of a variety of land use, transit, and pricing strategies based on a three-point scale (high/low/no potential). Figure 6 presents the rankings of these strategies across the statewide sample, with each policy option color-coded by the type of strategy involved. The top five options—higher gas prices; local bus service; priority sites for mixed use, higher-density, and infill land uses; express bus service; and priority sites for transit-oriented development—come from all three strategies. And many respondents expressed the need for integrated approaches, in particular linking smart-growth land

Figure 6. Planners believe that a range of policies offers high potential for reducing VMT



SOURCE: Sacramento Transportation Authority.

NOTES: The policy-specific rankings used in the sample average of the potential-driving-reduction policy options. A score of 3 was given for "high potential," 2 for "low potential," and 1 for "no potential" for each individual policy. The scores were then summed and averaged to create an overall "high potential" score.

uses with improved transit options and more accessible streetscapes.

Pricing policies stand out for their widely varied rankings. Higher gas prices rank first among all 16 policies examined, but all other pricing strategies rank in the bottom third.[40] Planners' views of the effectiveness of gas price increases are consistent with the research literature, but their low expectations regarding the potential of other pricing strategies are in conflict with the research.[41] This may reflect both recent gas price history and political realities. The state's recent experience with high gas prices demonstrated the potential of higher driving costs to reduce VMT (Figure 4). But this experience happened through market forces, not an explicit policy change. Most other pricing options would be implemented through local or regional policies, and planners are aware of the political difficulties of imposing higher costs on drivers.

[redacted]

Several local characteristics appear important to planners' optimism about the potential of various strategies to reduce driving:[42]

Experience matters. A given strategy is nearly always ranked significantly higher in a locality that is already using it or planning to use it. Of course, localities are most likely to adopt policies that they expect will work, and officials might be inclined to favorably evaluate policies they have worked to implement. But optimism is as high or higher for policies already in use, rather than those under consideration, suggesting that experience has been at least somewhat encouraging, even in places where public opposition is cited as a serious concern.

Rail transit is a plus. Officials in jurisdictions served by rail tend to feel more optimistic about the overall potential to reduce driving, as well as about almost all of the individual policy options. This strong showing is consistent with the research finding that integrated strategies can have a greater effect on VMT. Rail is a relatively attractive alternative to driving, and it provides a focal point for denser land development—which makes other alternatives to driving, such as walking and bicycling, more feasible, especially for noncommute trips. As one official noted: "We have substantial vacant land . . . [and] existing light rail. This combination gives us the opportunity to 'get it right.'"

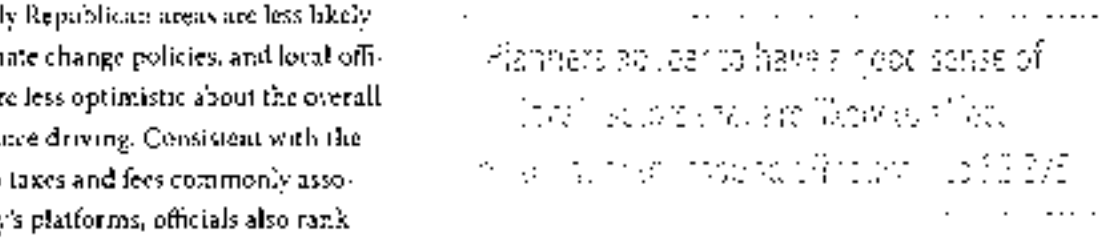
Local conditions shape expectations. Planners in more populous locales are more optimistic about their overall ability to reduce driving, the full range of pricing policies, and the potential for transit-oriented development. Consistent with the research literature, which finds that lower-income residents are more sensitive to changes in gas prices and more likely to use transit, officials in lower-income localities believe that higher gas prices and most transit options will prove more effective than in higher-income localities.[43] Perhaps as a result, these officials also perceive their localities' overall potential to reduce driving to

be higher than elsewhere. Consistent with the idea that proximity of jobs makes it easier to employ integrated strategies, officials in localities with a higher jobs-housing ratio are more optimistic about the potential of most pricing tools, access to rail, and the promotion of transit-oriented development.[35]

Party leanings are influential . . . The partisan split on climate policy in California, which has widened over the past two years, is also reflected in planners' perceived potential to respond to SB 375.[36] Local governments in more heavily Republican areas are less likely to adopt general climate change policies, and local officials in these areas are less optimistic about the overall local potential to reduce driving. Consistent with the stronger objection to taxes and fees commonly associated with this party's platforms, officials also rank the potential of most pricing strategies lower in these localities. They are also more skeptical of the potential for transit-oriented development and less likely to use this strategy, even when they have access to rail transit. Because many of the state's fastest growing counties are located in the more heavily Republican inland regions of the state, this partisan split may limit the effectiveness of SB 375 in places where there is the greatest potential to "build smart" from the ground up.

. . . but not determinative. Adoption of most smart-growth land use policies is not affected by residents' party affiliation, nor is the perceived potential of many of the individual options that can support SB 375 goals. And experience in the Republican-leaning San Diego region demonstrates that party affiliation is not a deal-breaker when it comes to developing aggressive regional strategies. Using a combination of increased housing densities, increased transit, and more HOV and HOT lanes, the SANDAG region's existing RTP is already one of the most ambitious in the state (Table 1).[37]

In sum, planners appear to have a good sense of local factors that are likely to affect the potential to respond effectively to SB 375. Much of the emerging message suggests grounds for optimism. Planners recognize the importance of using multiple strategies in combination, and they are optimistic about the policies they are already using or planning to use, highlighting the positive role of experience. They are also more hopeful about the potential of most other options when they have the availability of rail—the most popular (if most costly) form of transit. Planners in more populous communities generally perceive greater potential to reduce driving and are already more likely to be adopting the needed strategies.



But our findings also highlight some important constraints. Planners recognize the difficulties associated with higher-income households (which tend to support climate change policies but are less likely to respond to SB 375–related strategies), as well as those associated with political opposition—a potential barrier to implementing some of the supportive policy options in the fast-growing inland counties. They are also pessimistic about the prospects for most pricing strategies—an important component of effectively integrated strategies—underscoring the political challenges of making headway on this front. Finally, the optimism associated with the availability of rail appears largely unrealized in light of current transit ridership levels, suggesting that much progress is needed to capitalize on this potential. Improving the performance of transit-oriented development may play an important role in realizing this potential, as described below.

Transit-Oriented Development in California

Transit-oriented development is a prime example of the type of integrated land use and transportation planning that has the potential to reduce VMT. TOD's aim is to create higher densities around transit stations, making

transit ridership feasible for more residents and workers. Our survey revealed that planners are optimistic about the potential of TOD to help reduce VMT (figure 6), particularly when they have or expect to have rail.

As we discussed above, density and proximity to transit influence ridership for employees even more than for residents. However, California has been experiencing a decline in employment density, making it harder for transit systems to achieve high ridership and making commercial development around new transit stations especially important (by "commercial" we mean any nonresidential development, such as office, retail, or industrial). Here, we evaluate how well TOD has worked over the past two decades of extensive rail transit expansion. We look at the location of new transit stations and analyze employment growth in the areas surrounding these stations.[51]

TOD is most suitable around fixed-line transit stations—rail or "bus rapid transit," which has fixed stations and dedicated bus lanes. In these areas—and in contrast to areas around ordinary bus lines—developers have some certainty that the transit service will not move; fixed-line transit also offers higher speeds and greater regional accessibility than the typical bus system.[52] Our analysis focused on the four largest MPO regions, where 217 new rail, subway, streetcar, and bus rapid transit stations opened between 1992 and 2006.[53]

We found that these new transit stations were located in areas with higher residential density and much higher employment density than other areas in the same counties.[54] Thus, California has successfully located transit stations in areas most able to deliver higher transit ridership. However, these new stations also reflect challenges faced by system expansions. Density around newer transit stations was lower than density around transit stations that opened before 1992. Many older transit stations, such as the San Francisco and Oakland portions of BART and the LA Metro Rail, are located in big-city downtowns: areas with the highest employment density. New transit stations in existing systems often extend lines into lower-density suburbs. And many new transit stations, such as portions of the LA Metro Rail green line and many BART stations in the East Bay, are located in freeway medians. Although freeway medians offer a cost advantage (since they are an existing right-of-way), stations in medians may pose a challenge for land use development, given that the area immediately adjacent to the station is a freeway.[55]

The Fruitvale BART station. Transit ridership depends on jobs and housing being close to transit stations.

Did localities take advantage of these new stations through new development efforts? This is the essential question for transit oriented development, which should *increase* the concentration of residents, workers, or both near stations, thus raising overall transit ridership and lowering VMT. We examined both employment and residential growth.[56] Our analysis considered density changes within a quarter mile of new transit stations, comparing growth before and after the station opened with areas that lacked transit stations but were similar economically and geographically.

Averaging across all new transit stations, we found no increase in employment growth around new transit stations after they opened, either immediately or several years thereafter, relative to comparison areas. This suggests that localities were not effectively taking advantage of these new stations to encourage job-based TOD.[57] Nor were station openings associated with consistent employment growth

patterns in specific industries. Moreover, it does not appear that employment growth suffered from competition with residential growth: Residential densities *fell* over the period when new transit stations opened.

Despite the lack of employment growth on average, we did find considerable variation across stations. Employment growth was much higher around some new stations and much lower around others, even within the same locality, within the same transit system, and on the same route.

Although employment growth occurred around very different types of stations (see the text box), it followed regular patterns, tending to be higher around stations in areas that already had higher residential and employment densities and those located farther from an older transit station.[60] It may be that areas with higher density already had zoning in place that supported further development or lacked local opposition. At the same time, this finding implies that employment growth around transit stations does not hinge on having abundant vacant land.

The lack of additional job growth around many new transit stations represents a missed opportunity for raising employment densities, raising transit ridership, and lowering VMT. It is also consistent with the results of our survey of local officials about the focus of their TOD efforts: Among localities with existing or planned projects to increase density around transit stations, projects were much more likely to emphasize residential than commercial uses.[61] Regional transportation agencies appear to have been assuming that localities need more encouragement to build housing in the right places. In contrast, jobs—in the words of one transportation planner we interviewed—"take care of themselves."

These assumptions have probably taken root because land use policies in California have traditionally favored commercial over residential development, both because these uses generate more local sales tax revenues and because it is generally believed that businesses require less expensive local public services than residents (Bourassa and Crane 2001). Zoning practices reflect these assumptions.[62]

However, our evidence shows that employment growth around transit stations does not take care of itself, even if zoning around transit stations favors nonresidential uses.

Different paths to employment growth: Hollywood/Highland and Sylmar/San Fernando

Stations associated with large, statistically significant increases in employment growth include the Hollywood/Highland and Hollywood/Vine stations on the LA Metro Red Line in Hollywood and the Sylmar/San Fernando station on the Metrolink Antelope Valley Line in Los Angeles County's northern San Fernando Valley. These stations are located in very different neighborhoods with very different TOD strategies.

The Hollywood/Highland underground subway station opened in 2000 and was a high-profile transit-oriented development project focused on retail and entertainment along Hollywood Boulevard. The Los Angeles Community Redevelopment Agency was integral in assembling land for development, negotiating financing with the city, and securing approvals for the $600 million project that resulted in the Hollywood & Highland Retail Center, the Renaissance Hollywood Hotel, and the Kodak Theater (Cervero et al. 2004; California Department of Transportation 2007). Both the Hollywood/Highland and the neighboring Hollywood/Vine stations were dense, developed, mixed-use areas even before their station openings.

The Sylmar Metrolink station in Santa Clarita opened in 1994. The nearby "Montage at Village Green" housing development opened in 2000. Whereas most TODs focusing on housing are "mixed-use developments" incorporating some commercial space, the Montage was exclusively a housing development (Moses, Lewis, and Lastrape 2009). Kolko (2011) finds that employment growth that accompanied the station development included small businesses across numerous industries, including grocery wholesaling, light manufacturing, construction, and real estate brokerage. Many of these businesses were located between the station and the housing development. The Sylmar example shows that employment can grow around new stations even when the station TOD strategy emphasizes residential development.

Existing zoning that allows retail, office, or industrial development may not be sufficient to spur employment growth. A set of case studies of San Diego stations concluded that TODs were most successful when they coincided with local authorities' development plans for the area (Boarnet and Crane 2001). A study of the Washington DC Metro rail system found that dense development around new suburban stations hinged on the "determination and foresight" of local officials (Schrag 2006). The major Hollywood/Highland TOD (see the text box) illustrates the importance of regional transportation and local development authorities working together, well beyond a favorable zoning plan.

Numerous specific policies could encourage development around transit stations. Parking policies are one strategy: To encourage denser residential development, relax requirements that mandate the minimum number of parking spaces a developer must provide in residential TODs (Arrington and Cervero 2008); and to encourage transit ridership, restrict the availability or raise the cost of parking (Giuliano and Agarwal 2010; Shoup 2004). In addition, building a mix of TOD businesses, including retail and personal services that employees use during the day, encourages transit use by making it easier to run errands near the workplace (Center for Transit-Oriented Development 2008). And bolstering connectivity—including local bus feeder service to transit stations and surrounding streets that are friendly to walking and biking—helps increase transit ridership around TODs and, in making the location more accessible, is likely to raise demand for the location (Center for Transit-Oriented Development 2008).

A Hollywood & Highland Retail Center is not—and should not be—the model for employment growth at all transit stations. Appropriate levels of growth and industries differ across transit stations, depending on existing land uses, densities, and location in the transit network. Yet it is surprising that, on average, employment growth around new transit stations was no faster than in comparison areas. A shift in focus toward more job-based TOD may be in order for future development efforts around existing and planned transit stations. Expanding job growth around the increasing number of stations located outside downtown areas would improve employment exchanges with the broader metro area job market and increase the two-way use of costly rail systems. Employment growth near stations, even in residential areas, should be encouraged to exceed employment growth in similar nearby neighborhoods lacking transit access.

Policy Recommendations

With the adoption of SB 375, the state is once again taking a "leadership role in national environmental policy."[3] The success of SB 375 will depend on how well all levels of government, working together, integrate land use planning, transit investments, and pricing policies and make them attractive to California's residents. For residents, the law implies a major behavioral shift, reversing a decades-long trend in which per capita VMT has been rising.

The success of SB 375 will depend on how well all levels of government, working together, integrate land use planning, transit investments, and pricing policies and make them attractive to California's residents.

The anticipated emission benefits of SB 375 are relatively modest—rather than a silver bullet, the new policy is one of many discrete actions that make up California's overall strategy for addressing climate change. But the same policies that can contribute to a reduction in GHG emissions from driving can generate other benefits. Higher-density development—essential for a viable transit system—consumes less energy and water per resident or worker, providing additional environmental and economic benefits. By making housing more affordable in milder coastal areas, policies encouraging higher density could also shift population and economic activity to places with

lower energy requirements and overall emissions, reducing statewide or national emissions per capita.[64] Reducing the need to drive and providing "walkable" streets would also provide public health benefits to California's residents.

Our analysis offers hope, as well as warning signs. The clearest grounds for optimism come from our survey of city and county officials—the local authorities who control land use decisions and oversee a majority of transportation dollars. Despite the recession, they have increased their climate-change–related activities and are adopting numerous land use strategies that can support the goals of SB 375. Furthermore, local officials tend to rate the policies and strategies they have already begun to implement as having strong potential to reduce VMT, despite various barriers to implementation, including public opposition to denser development.

Another reason for optimism is the extent to which both regional transportation authorities and local governments recognize the importance of integrated strategies that combine land use, transit, and pricing policies. Regional authorities in the state's major metropolitan areas are gaining support from local officials as they develop strategies to increase the use of toll lanes, focus more spending on transit, and move away from the typical model of suburban sprawl development. This pattern is evident even in regions where many residents do not support the state's climate policy goals.

Recent trends in residential and employment growth present a mixed picture. On the one hand, California's residential density is higher than the national average and rising—a plus for integrated strategies that encourage transit use. On the other hand, the state's employment density is lower than the national average—dramatically so in many metro areas—and falling. Low employment densities limit the potential for VMT reduction because employment density is even more strongly related to transit ridership than residential density.

The failure of rail transit to realize its potential—despite receiving a large share of transportation investments for several decades—is another warning sign. Rail ridership as a share of commutes has increased slightly in California—rising to 1.4 percent of all commutes in 2008 from 0.9 percent in 1990, before major investments in rail took place. But this growth is much slower than the pace of transit cost increases and service expansion.

However, voters and commuters think favorably of rail, often supporting local sales tax increases to fund rail investments, and they tend to switch from bus to rail when rail becomes available. Our local government survey respondents were also more hopeful about the success of VMT-reduction policies—land use and pricing as well as transit—if their localities already had rail service in place, suggesting that they perceive rail as an important platform for building an integrated strategy.

One contributing factor in the limited success of rail investments is the failure of transit-oriented development to live up to its potential. Jobs near fixed-line transit stations (including rail and bus rapid transit) are especially important for increasing transit ridership, because once workers arrive at a station, they do not have many options for commuting to more distant locations. Unfortunately, new transit stations, on average, have not been greeted by faster job growth in the surrounding area, even though local fiscal incentives and zoning have traditionally favored commercial development near transit stations. Paradoxically, SB 375 could make employment growth around transit stations even more difficult, because the law explicitly favors residential development in TODs: To receive the benefit of exemption from CEQA requirements, development projects near transit stations (called Transit Priority Projects) must be at least 50 percent residential, as measured by building square footage.

If California is to reap the benefits that greater employment density around transit brings, the state must consider encouraging commercial development over residential development near stations—the opposite of the current incentives in SB 375. In addition, local and regional authorities could adopt numerous specific policies to encourage commercial development around transit stations, including relaxing minimum parking requirements, providing development incentives, and ensuring good

connectivity between the transit station and surrounding areas through development of local bus feeder service and neighboring streets favorable to walking and biking. Failing to take advantage of rail through more intense land development around stations represents a significant missed opportunity to increase ridership and to make the most of costly transit investments.

Pricing represents another area of missed opportunity. Although regional authorities in the major coastal metro areas are moving forward with toll roads, few local authorities are raising the cost or limiting the availability of parking to encourage the use of alternatives to solo driving. Indeed, nearly 90 percent of all localities still require that new commercial developments provide employee parking. But the greatest shortcoming lies in state and federal policies: For nearly two decades, both the federal and state governments have failed to raise charges for road use through a higher gas tax or new VMT-based fees. These price increases are urgently needed to bolster the transportation finance system, and they are the most effective way to send the signal to businesses and residents to change their transportation behaviors and location decisions. Such fees are not politically popular, but in this case, responsible fiscal policy aligns with the efficient use of the transportation network.

> [illegible] is to reap the benefits [illegible] commercial development over residential development near stations.

To make the most of all of the available policies—land use, transportation, pricing, and their integration—a regional perspective is essential, and a regional perspective must acknowledge the diversity of localities without losing sight of their interconnectedness. SB 375 encourages coordination, but it will be up to regional and local leaders to put the vision to work, recognizing local differences while overriding the temptation to yield to fragmented local interests. ◆

Notes

[1] Washington state has adopted ambitious per capita VMT reduction targets as part of its climate change legislation, and several East Coast states have also adopted explicit VMT reduction goals as part of their climate change policies.

[2] Technically, SB 375 calls for a reduction in emissions from passenger vehicles beyond the reductions expected from improvements in vehicle fuel efficiency and the use of low-carbon fuels, as required by other regulations (described below). In the "most ambitious scenarios" for meeting the regional 2035 targets under SB 375, transportation system improvements (which include measures to improve traffic flow as well as some demand management measures we consider under "pricing," such as carpool programs) are expected to achieve 8–17 percent of regional GHG emission reductions in the Bay Area, Southern California, and Sacramento regions. San Diego examined one scenario in which these measures could achieve over half of the total GHG emissions goal (Heminger et al. 2010).

[3] The state's Strategic Growth Council, created in a companion bill to SB 375, is funding planning grants for SB 375, in recognition of the potential benefit to public health, conservation, and livability (Planning Grants and Incentives Management Team 2010).

[4] This goal was established under Executive Order S-3-05, signed in 2005.

[5] Some have argued that greater reductions in VMT than those in CARB's scoping plan are possible (Ewing and Nelson 2008; Winkelman, Bishins, and Kooshian 2010), whereas others argue that VMT reductions constitute a costly, inefficient, uncertain GHG emission reduction strategy (Moore, Staley, and Poole 2010). Boarnet (2010) provides a critical overview of this debate.

[6] High-density housing units also use less water for landscaping, providing additional energy savings and helping California to cope with increasing water scarcity (Hanak and Davis 2006; Hanak et al. 2011). In addition, land use policies that encourage growth in mild climate areas, such as coastal California, could reduce emissions generated by heating and cooling (Kahn 2010; Glaeser and Kahn 2010).

[7] In one extreme case—the vast region encompassing the Southern California Association of Governments (Imperial, Los Angeles, Orange, Riverside, San Bernardino, and Ventura Counties)—the MPO is responsible only for planning; all investments and maintenance are carried out by subregional and local authorities.

[8] Counties have authority over land use in unincorporated areas. City and county government representatives also constitute the majority of MPO boards.

[9] SB 375 offers three paths to ease requirements for environmental review of projects under CEQA: (1) programmatic streamlining for certain residential projects that are consistent with a region's SCS or Alternative Planning Strategy (APS), (2) streamlining or exemption for transit priority projects that are consistent with a region's SCS or APS and are at least 50 percent residential (as opposed to commercial), and (3) adoption of a uniform set of traffic mitigation measures for higher-density residential developments, which exempts these projects from further traffic mitigation requirements.

[10] For information on the program, see http://calblueprint.dot.ca.gov/

[11] Although the analyses are at an earlier stage, efforts are also under way in the smaller regions, including the San Joaquin Valley councils of governments (Bedsworth, Hanak, and Stryjewski 2011).

[12] These local programs also include activities addressing many areas outside transportation and land use, including energy and water use efficiency, green buildings, renewable energy, and waste reduction (Hanak et al. 2008).

[13] Changes in residential densities result from new construction or redevelopment. Because housing has a long life and new developments are a small share of the housing stock in all but recently built cities, even large increases in the density of new developments have only a modest effect on the overall average residential density of a city or metropolitan area.

[14] See Bedsworth, Hanak, and Stryjewski (2011), Appendix Table B.24(j). Out of nine barriers, public opposition to density ranked among the top three in every region but the San Joaquin Valley. But achieving higher commercial densities is often more politically feasible than achieving higher residential densities (Barnes 2005).

[15] Other smart-growth approaches available to local governments include improving the interconnectivity of roads and other elements of street design, which influence the attractiveness of driving versus alternative modes of travel (Ewing and Cervero 2010).

[16] Another parking strategy is "unbundling," in which developers sell the parking spaces separately from the residential or commercial units. This allows those who value parking most to buy it and facilitates providing less parking overall.

[17] In localities without rail, transit-oriented development tends to focus on higher-density and mixed use development along major bus corridors or on ensuring good bus connections for retail establishments. Several Central Valley cities also mentioned the possibility of capitalizing on high-speed rail as a focal point for TOD in the future.

[18] As a recent example, over half of the $4.9 billion dollars committed to projects designed to reduce congestion under the state's Traffic Congestion and Relief Act of 2000 was allocated to rail and other transit (Legislative Analyst's Office 2007).

[19] In the most recent RTPs of the four largest MPOs, the projected shares expenditures for transit over the next few decades range from 40 percent of the total in the San Diego region to 65 percent in the Bay Area (Bedsworth, Hanak, and Stryjewski 2011).

[20] Residents were asked, "What type of surface transportation project do you think should have the top priority for public funding as California gets ready for the growth that is expected by 2025?" In 2004, the ranking was freeways and highways (32%), light rail (31%), public bus systems (13%), local streets and roads (10%), and carpool lanes (7%). In 2006, the ranking was light rail (36%), freeways and highways (25%), public bus systems (14%), local streets and roads (9%), and carpool lanes (6%) (Baldassare 2004, 2006).

[21] Survey respondents reported the availability of local bus service in all but the least populous jurisdictions, and nearly half of all localities also have express bus services. Just over a quarter reported the availability of some forms of rail transit, and rail is planned in another 11 percent. Rail tends to be concentrated in more populous jurisdictions.

[22] In a national study, Baum-Snow and Kahn (2005) find that rail investments often fail to increase overall transit ridership, because many new rail transit commuters are former bus commuters, not former drivers.

[23] Data on VMT are from Federal Highway Administration, *Annual Highway Statistics*, Table VM-2.

[24] In a 2001 national survey of travel behavior, commutes accounted for 27 percent of VMT, though a much higher share of VMT at peak times and on the most congested routes. Transit was used for 3.7 percent of commute trips, 1.1 percent of trips was for family or personal business, and 1.0 percent of trips was for social or recreational purposes (Hu and Reuscher 2004, Tables 6 and 9). In California, 39 percent of trips originating from home are to work (California Department of Transportation 2003). Transit investments may also fail to reduce VMT because the reduction in road congestion encourages additional driving—for example, trucks moving goods (Duranton and Turner 2009).

[25] This finding is based on the authors' calculations using data from the Census of Governments, 1992–2007. Recovery rates vary across systems. For instance, at 64.5 percent, the Bay Area's BART system rate of operating cost recovery is far higher than the statewide average for transit in California. It is also one of the highest rates of recovery of any rail transit system in the country (O'Toole 2010).

[26] For the seven largest transit systems in the San Francisco Bay Area, operating costs increased 83 percent between 1997 and 2008, whereas the consumer price index increased by 39 percent. Over this same period, transit service (measured as hours in service) increased only 15 percent and ridership increased only 7 percent (Metropolitan Transportation Commission Transit Sustainability Project, 2010, available at www.mtc.ca.gov /planning/tsp/ABAG_Focus_presentation.pdf).

[27] See Bedsworth, Hanak, and Stryjewski (2011), Appendix Table B.24(j). For the Bay Area, insufficient transit availability ranked highest among nine barriers; this constraint ranked second highest (after public opposition to raising charges for driving) in the Southern California region, and third (after public opposition to density and the jobs-housing balance) in the San Diego region.

[28] See Kolko (2011). In California, fewer than 10 percent of people who live or work within a half mile of a transit station commute using rail transit; including bus riders, transit share rises to only 20 percent. Farther than a half-mile from transit stations, transit ridership drops off sharply. Here and elsewhere in the report, "transit stations" refer to stops on fixed-line transit systems—primarily rail (commuter rail, subways, light-rail, and streetcars). We do not include stops along a regular bus route as "transit stations" because, unlike stations in fixed-line systems, these stops do not require capital investment and tend not to be focal points for new residential or commercial development.

[29] The Bay Area's traffic and transit information portal, www.511 .org, lists 22 bus operators in the region as well as several rail and ferry operators. With the adoption of Resolution 3866 in early

2010, MTC will consider an operator's compliance with the region's Transit Connectivity Plan when allocating funding. The Transit Connectivity Plan requirements include consistent signage, dissemination of real-time transit information, provision of information on schedules and connections from other transit agencies, and guidelines for the use of a single, cross-system fare payment card (www.mtc.ca.gov/planning/tcip/RES-3866_approved.pdf).

[30] To the extent that these strategies improve gas mileage—a benefit of reduced congestion—they can also reduce GHG emissions for a given level of VMT.

[31] Numerous studies indicate a large and growing gap between revenues and funding needs (National Surface Transportation Infrastructure Financing Commission 2009).

[32] Americans' sensitivity to gas prices also appears to have declined over the past several decades—a phenomenon analysts have attributed to the fact that more sprawling land use patterns have made people more reliant on cars (Hughes, Knittel, and Sperling 2008) and to a declining share of transportation in household budgets (Small and Van Dender 2007).

In early 2010, California's gas tax was increased, with a corresponding decrease in the sales tax on gasoline. This revenue-neutral "fuel tax swap"—adopted to provide more budget flexibility—will be invalidated under Proposition 26 (described below) unless the legislature approves it again with a two-thirds majority by November 2011 (Legislative Analyst's Office 2011).

[34] Gas taxes within the European Union range from about $1.90/gallon in Bulgaria to $3.70/gallon in the Netherlands and are usually augmented by general value-added taxes. Japan's gas tax is roughly $2.25/gallon (October 2010 exchange rates).

[35] Hanak and Rueben (2006) describe the early projects in Southern California.

[36] Conversion without expansion of lane capacity is likely to be more effective at reducing VMT, but it is also more politically difficult, particularly if it reduces open-access lanes. One challenge with conversion of HOV to HOT lanes is the desirability of having more than one HOT lane, so that traffic can flow smoothly in the event of an accident. Since most HOV lanes are single lanes, this means either building an additional lane or converting an existing open-access lane to HOT status. In the Bay Area, planners are working to create single-lane HOT lanes from existing HOV lanes in ways that avoid these problems. The new HOT lane on I-680 has double lanes at entry and exit points, but a single lane elsewhere.

[37] One study found that 77 percent of San Francisco Bay Area commuters provided with free parking drove alone, compared to only 39 percent of those required to pay for parking. The corresponding figures for how much these same people use transit were 4.8 percent and 42 percent, respectively (RIDES for Bay Area Commuters 2000).

[38] California adopted a parking cash-out law in 1992 requiring that employers with more than 50 employees in areas out of attainment with any state air quality standard, and who offer employees subsidized parking, give employees the option of "cashing out" that parking option. Employees can then use this money to pay for alternative means of commuting to work, such as transit or carpools. The federal tax code and the complexity of employer parking situations have made the program difficult to implement, though emission reduction benefits have been observed when it has been implemented. See www.arb.ca.gov/planning/tsaq/cashout/cashout.htm.

[39] San Francisco is conducting a pilot program that will vary on-street and garage parking rates to manage demand (http://sfpark.org/).

[40] This amendment, passed by 53 percent of voters, raises the vote threshold for new state regulatory fees from one-half to two-thirds of each house of the legislature, and it requires a two-thirds supermajority of the voting public to approve local regulatory fees that formerly could be approved by a simple majority of governing boards. Although this change does not affect strict user fees—i.e., charges that cover the costs of providing a service to the person being charged—it does affect fees that are used to benefit others. Litigation will likely be required to sort out the boundaries of the new rules. Thus, although parking fees, toll lane charges, the gas tax, and VMT charges could easily be considered user fees (i.e., used to help cover the cost of providing transportation services), some may interpret the new rules as a restriction on the types of programs that the fees can fund.

[41] In Bakersfield, for example, efforts to limit parking availability met with resistance from retailers who felt that they needed additional parking to accommodate peak shopping days such as "Black Friday." Residents in the cities of Los Angeles and Cypress objected to the spillover problems often experienced in mixed use areas.

[42] The Transportation Research Board (2009) summarized the research literature with the conclusion that doubling residential density would be associated with a 5–12 percent reduction in VMT, and possibly up to a 25 percent reduction with complementary changes in transit availability, the jobs-housing bal-

ance, and other factors. However, as mentioned above, doubling the density for even a large share of new housing would have only a modest effect on average residential density across a city or metropolitan area.

[43] Notably, none of the RTPs includes metrics of employment density, though some discuss the concept of a jobs-housing balance.

[44] Modeling scenarios done by SANDAG, which examined the potential gains from individual policy strategies relative to an integrated approach, highlight the benefits of combined strategies (Heminger et al. 2010). The San Joaquin Valley Blueprint (2009) also envisages an integrated approach. To some extent, planning for VMT reductions will be a learning-by-doing process, given the challenges of developing a comprehensive picture of how various policies might interact to affect driving behaviors in particular regions (Rose 2010).

[45] We did not explicitly refer to SB 375, so that we could avoid concerns that the responses might be used to gauge compliance with the law. Also, the survey was completed before CARB released draft regional emission targets in June 2010, so respondents did not know the level of the regional targets.

Note, moreover, that our survey asked about gas prices, not gas taxes. We chose this wording to avoid conflating concerns over the perceived political feasibility of raising the gas tax with the perceived effectiveness of a resulting rise in gas prices.

[47] It is worth noting that the high marks for local bus service also conflict with the research, which finds that the potential for traditional local bus service to reduce VMT is fairly low. It is possible that planners were thinking about enhanced service lines, although they generally ranked express bus service lower than local bus service, except in localities with rail access, where express bus to rail service ranked highest among transit options.

[48] Results reported here are from multiple regression analyses, which control for the effects of population, household income, population growth rate, political party affiliation of voters, and other community characteristics.

[49] On gas price sensitivity, see Hughes, Knittel, and Sperling (2008). On transit use and income, see Barbour (2006).

[50] The jobs-housing ratio is calculated as the number of jobs relative to the number of households within a jurisdiction in 2006. Interestingly, a jobs-housing imbalance ranked as one of the top two perceived barriers to implementing policies to reduce driving in several regions: San Diego, the San Joaquin Valley, the "Other MPO" group (including Central Coast counties and several northern Sacramento Valley counties), and the "non-MPO" group (including rural counties not currently required to comply with SB 375) (Bedsworth, Hanak, and Stryjewski 2011, Table B.24).

[51] Statewide surveys find that Republican voters are less supportive of AB 32 goals than are Democrats or independent voters, and this gap has widened since 2008 (Baldassare et al. 2008, 2010).

[52] See Heminger et al. (2010).

[53] This section summarizes the "Transit and Development in California" section of Kolko's (2011) paper, "Making the Most of Transit."

[54] Bus rapid transit does not necessarily involve construction of a fixed or dedicated lane but typically, at a minimum, includes investments in advanced technologies and infrastructure that can speed the movement of buses and improve service. This larger investment makes it more of a "fixed" investment than typical bus service.

[55] These stations include extensions to BART in the San Francisco Bay Area, the Sacramento light rail system, the San Jose light rail system, San Francisco MUNI, LA Metro Rail (including the LA Metro bus-rapid-transit Orange Line through the San Fernando Valley), and new or mostly new systems such as the Altamont Commuter Express, Coaster San Diego, Harbor Transitway, and Metrolink Southern California.

[56] Employment density is the most important factor. Residential density does not positively affect the location of new transit stations holding other factors, including employment density, constant.

[57] In fact, CARB recommends against development immediately adjacent to freeways for public health reasons (California Air Resources Board 2005). Still, proximity to a freeway could boost ridership by facilitating park-and-ride use.

[58] Data limitations restricted our analysis of residential growth to a shorter time period and different method. For employment growth, we have detailed data for all years from 1992 to 2006 from the National Establishment Time-Series (NETS) database, whereas for residential growth, we have detailed data for only 1990 and 2000 from the U.S. Census.

[59] This result is somewhat surprising, given that the new transit stations were generally located in areas where employment growth was *already* faster than in comparison areas. One might therefore expect a boost in employment growth after the station

opened, if builders were to respond to the increased demand for land that typically occurs around new stations.

[60] The residential density measure is for 1990, and the employment density measure is for 1992.

[61] Over half (56%) of the communities with these projects reported that they were all or mostly residential, versus only about a third (31%) evenly split between residential and commercial and 13 percent mostly commercial (Bedsworth, Hanak, and Stryjewski 2011).

[62] Land surrounding transit stations in Southern California in the mid-1990s was much more likely to be zoned for commercial (including industrial) use than for residential use, relative to other portions of the cities containing those transit stations (Boarnet and Crane 2001). More recently, a 2007 review of San Francisco Bay Area TOD policies reports that development goals for TODs include minimum density requirements for residential development but not for employment, in part because "cities already have considerable incentives to zone for nonresidential uses, such as sales tax revenue and reduced fiscal impacts" (Nelson\Nygaard 2007, pp. 5–7).

[63] Recent federal climate change legislative proposals contain provisions that would extend requirements nearly identical to SB 375 to all MPOs in the nation.

[64] Recognizing this potential, Bay Area leaders have called for a reassessment of the region's growth barriers (King 2008).

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House GOP Readies Ban on EPA Greenhouse Gas Regulations

Published February 02, 2011 | Associated Press

In a sharp challenge to the Obama administration, House Republicans intend to unveil legislation Wednesday to bar the Environmental Protection Agency from regulating greenhouse gases under the Clean Air Act and hoped to advance the bill quickly, officials disclosed Tuesday night.

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The officials said the bill would nullify all of the steps the EPA has taken to date on the issue, including a threshold finding that greenhouse gases constitute a danger to the public health and welfare.

In addition, it seeks to strip the agency of its authority to use the law in any future attempts to crack down on the emissions from factories, refineries and other stationary sources.

Many scientists say that carbon dioxide and other heat-trapping pollutants contribute to global warming and attempts at regulating them is a major priority for President Barack Obama as well as environmentalists. Critics argue the evidence is unclear and that new rules will drive up the cost of business and cause the loss of jobs.

The officials who described the GOP plans did so on condition of anonymity, saying they were not authorized to preempt the release of a draft measure prepared by the Energy and Commerce Committee chaired by Rep. Fred Upton of Michigan.

The legislation marks yet another arena in which newly empowered House Republicans are moving quickly to challenge the administration.

Sworn into office less than a month ago, the House has already voted to repeal last year's health care law and is advancing toward a series of expected confrontations with Obama over Republican demands for deep spending cuts. In addition, Speaker John Boehner, R-Ohio, recently announced support for legislation to restrict abortions.

A vote on the greenhouse gases bill would occur first in the Energy and Commerce Committee and is expected later this week. The measure would then go to the House floor, where Republicans express confidence they have a strong enough majority to overcome objections by Democrats, many of whom are expected to oppose it on environmental grounds.

Republicans are attempting similar restrictions in the Senate, where the Democrats are in a majority and the political situation is more complicated. Sen. John Barrasso of Wyoming has introduced a more sweeping measure than the one House Republicans are drafting. At the same time, Sen. Jay Rockefeller, D-W.Va., has proposed a two-year moratorium on EPA attempts to regulate greenhouse gases under the Clean Air Act, a plan that already has attracted a handful of Democratic supporters.

The Supreme Court ruled in 2007 that the EPA has authority to regulate greenhouse gases under the Clean Air Act, but it wasn't until the Obama administration took office that the effort began.

Initially, the administration's principal focus in the area was on passage of legislation to impose restrictions, but that attempt failed when the Senate balked at a bill Democrats pushed through the House in 2009.

Since the Republican election gains of last fall, Obama has made several moves to accommodate the concerns of business, including an executive order to weed out proposed new regulations that would hurt job growth. Despite the order, there has been no indication to date

that the White House intends to stop plans to regulate greenhouse gases through the Clean Air Act.

In a statement posted on its website late last year, the EPA announced it is moving unilaterally to clamp down on power plant and oil refinery greenhouse emissions, announcing plans for developing new standards over the next year.

EPA administrator Lisa Jackson said the aim was to better cope with pollution contributing to climate change.

"We are following through on our commitment to proceed in a measured and careful way to reduce GHG pollution that threatens the health and welfare of Americans," Jackson said in a statement. She said emissions from power plants and oil refineries constitute about 40 percent of the greenhouse gas pollution in this country.

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Scientists Dig 2-Mile Long Ice Core From Antarctica's Ice

Published January 27, 2011 | FoxNews.com

An astounding long tube raised from the Antarctica's icy belly may hold the answers to Earth's past.

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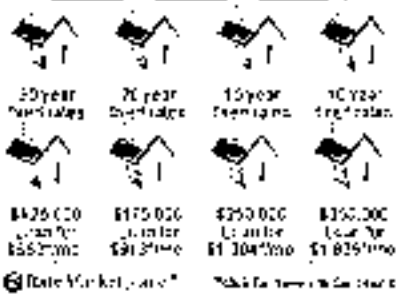

The West Antarctic Ice Sheet Divide Ice Core Project recently finished extracting the longest ice core ever drilled by U.S. scientists in Antarctica. The ice core – a cylindrical sample of ice removed from a sheet in the southernmost continent – measures 10,998 feet in length – that's just over 2 miles – and took five years to finally unearth.

Essentially layers upon layers of ancient frozen air, the core could potentially provide a detailed look at the planet's climate up to 100,000 years ago.

"We'd like to get the most detailed record possible of how the Earth's climate changes from an ice age into a warm period like the one we're experiencing now, which started about 11,000 plus years ago," Professor Ed Brooks, a lead investigator on the project, told FoxNews.com. "There's a lot of ice per year, and it's detailed enough that we can look at things changing from decade to decade. No one's been able to do that in Antarctica yet."

Brook was a member of a team of scientists from across the country who have traveled to and from Antarctica in order to finally dig out the core. He said the process was very difficult, but well worth the hardship.

"This was really a heroic effort over a number of years," Brook said. "You can only drill for two or three months during the Antarctic summer, which is stormy, but terribly cold and you can get a lot of drifting snow. The cores come up one piece at a time and it's just slow, difficult work."

Now that new labs have proved fruitful, the researchers will ship the ice core back to the United States where the sampling process will begin. The 6-inch diameter ice core is cut into 3 foot-long pieces and sent by ship and refrigerated truck to the National Science Foundation's National Ice Core Laboratory in Denver. The ice will then be cut into smaller samples and sent to 27 investigators around the U.S., who can then make measurements. From it

After much processing, photographing, and chemical measurements, those involved in the project may soon be able to uncover an extremely detailed record of Earth's climate history.

By analyzing gases trapped in ancient bubbles in the ice formed tens of thousands of years ago, the timeline of Earth's atmosphere will start to unfold. That timeline may include information on the Earth's future.

"What we'd like to do now is to see how sensitive the Earth's system is to changes in greenhouse gasses," Brook told FoxNews.com. "How has the planet responded when carbon levels in the atmosphere change?"

"We have mathematical models to predict that response, but we'd really like to be able to test these. And with this core, we can actually watch the carbon dioxide levels evolve," he said.

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USA TODAY

Groups ramp up lobbying as new regulations loom

Updated 3h 48m ago

By Fredreka Schouten, USA TODAY

WASHINGTON — Industries ranging from for-profit colleges and electric utilities to some high-tech companies are spending record sums on lobbying to combat federal efforts to tighten regulations of their consumer practices.

Kimihiro Hoshino, AFP/Getty Images Chris Yerga, engineering director of Google, demonstrates some applications of the mobile operating system Android 3.0 known as Honeycomb Thursday in Mountain View, Calif.

Enlarge

By Kimihiro Hoshino, AFP/Getty Images

Chris Yerga, engineering director of Google, demonstrates some applications of the mobile operating system Android 3.0 known as Honeycomb Thursday in Mountain View, Calif.

The Association of Private Sector Colleges and Universities, for instance, spent $440,000 on lobbying during the last three months of 2010, more than twice the amount it spent during all of 2009. It is fighting proposed regulations that would stop sending federal aid to these colleges if too many of their students default on their loans or don't earn enough money to repay them, new lobbying reports show.

At the same time, the association dramatically increased its campaign giving, putting thousands into the coffers of lawmakers who have oversight of their industry.

"This is a fundamental, existential threat to schools, programs and opportunities for students," Harris Miller, the association's president, said of the Obama administration's proposed rules, which would also attempt to end misleading recruitment and other practices. Most of the rules go into effect July 1; those linking college's federal aid to their graduates' income and loan-default rates are scheduled to take effect in 2012.

The surge comes as total federal lobbying

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dipped to roughly $3.5 billion last year, according to an initial tally by CQ MoneyLine, which analyzes lobbying. The drop, from more than $3.6 million in 2009 amid the intense debate on the health care law, marks the first time in nearly a decade that spending on lobbying has not increased.

Even so, some industries significantly stepped up their efforts to influence Washington policy as the Obama administration and Congress have proposed new rules that affect them:

•Electric utilities, for instance, spent nearly $134.8 million on lobbying last year, a nearly 50% jump over 2009 levels, according to CQ MoneyLine's totals. The surge came as Congress weighed climate-change legislation and the Environmental Protection Agency launched plans to regulate the emission of greenhouse gases from power plants.

"It was a very busy year," said James Owen, a spokesman for the Edison Electric Institute, a trade association for utilities. The institute's own lobbying hit $13.1 million last year — a nearly 25% increase over 2009. "Everything from climate change to financial reform to federal tax policy and beyond was on the table," he said.

• Search-engine giant Google, meanwhile, spent nearly $5.2 million on lobbying last year, an increase of nearly 30% over 2009 levels as the government considers forbidding companies from tracking consumers' activities across the Internet.

Google spokesman Dan Martin said the company's lobbying activity has increased as the Internet has "become a bigger part of our lives" and a "bigger part of the debate here in Washington."

Internet icon Facebook also spent more than $350,000 in lobbying last year, a nearly 70% leap over 2009, when the social-networking site began lobbying.

For-profit colleges have waged an all-out battle against the package of rules to rein in the industry, which has seen enrollment soar to more than 2.2 million students in 2009 from nearly 673,000 in 2000.

The colleges, which range from universities offering four-year bachelor's degrees online to schools offering certificates in auto repair, account for nearly 11% of higher-education enrollment, but 43% of student-loan defaults, according to the U.S. Department of Education.

"Too many students are graduating from these programs with unsustainable debt and d egrees or certificates they cannot use," said Justin Hamilton, a department spokesman.

Miller said it is unfair to compare for-profits to other colleges with fewer low-income and

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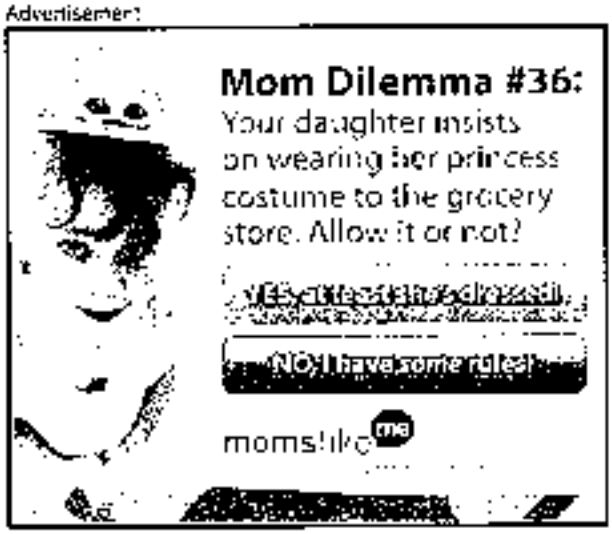

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non-traditional students

The association's political action committee pumped more than $350,000 during last year's election into the coffers of national parties and congressional candidates. That's more than three times what the association's PAC donated to candidates and parties during the last midterm election for Congress in 2006.

"It is a way of helping show members who support our students that we support them," Miller said.

Among the recipients: Rep. John Kline, R-Minn., chairman of House education panel and an opponent of the Obama administration's proposed rules. The PAC gave $15,000 to Kline's fundraising committees in the 2010 election. Democratic lawmakers, including some members of the Congressional Black Caucus, also have opposed the rules.

Kline and nine other House members last year wrote to Education Secretary Arne Duncan objecting to many of the new rules.

Kline spokesman Brian Newell said campaign contributions have no bearing on the congressman's actions. "My boss has been a long-time proponent of student choice," he said. The proposed regulations will drive for-profit colleges out of business, Newell said, when "there's a need in our country to have young adults more equipped and able to compete in our workforce."

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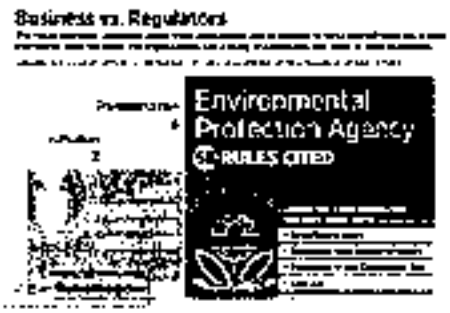
BUSINESS

Business Groups' Target: EPA

By LOUISE RADNOFSKY

The Environmental Protection Agency, which enforces rules that affect the U.S. economy from factories to farms, is the No. 1 target of complaints from business groups collected by House Republican leaders.

EPA rules were cited more than those from any other agency in more than 100 letters sent by trade associations, businesses and some conservative groups to House oversight committee chairman Darrell Issa (R., Calif.) in response to his call for businesses to identify regulations they deemed burdensome, according to documents reviewed by the Wall Street Journal. The letters are scheduled for release today.



The letters will become fuel for a running debate between Republican lawmakers and the Obama Administration over what role, if any, increased federal regulation is playing in the sluggish pace of job creation. The Labor Department reported Friday that non-farm employers added just 36,000 jobs in January, far fewer than most economists had expected.

The EPA's rules to curb emissions of carbon dioxide and other greenhouse gases were cited as an impediment to growth by at least 30 organizations writing to Mr. Issa, including representatives of the agriculture, business, chemicals, energy, paper, manufacturing and steel and iron sectors.

Groups complained about dozens of other proposed and existing EPA regulations in letters viewed by the Journal, including the agency's plans to tighten limits on emissions of some pollutants from industrial boilers, ground-level ozone, mountain-top mining, cooling water intake structures, the level of nutrients in Florida waters, and pollutants in the Chesapeake Bay.

The problem is not simply that EPA is issuing a lot of regulations. Rather, it is that it has significantly increased the number of major rules," wrote William Kovacs, vice president of regulatory affairs for the U.S. Chamber of Commerce.

The Financial Services Roundtable warned against aggressive implementation of the so-called Volcker rule, intended to restrict financial firms from trading with their own money.

The Department of Labor and Occupational Safety and Health Administration drew heat from construction and manufacturing industries, which criticized a 2009 executive order requiring contractors on large federal construction projects to allow union representation for workers and a planned policy which would encourage agencies to take into account the record of firms getting government contracts.

Plans to tighten the management of combustible dust were attacked by paper, iron and steel, wire, wood and oilseed producers.

Some industry groups took the opportunity to highlight issues of specific concern. The National Marine Manufacturers Association said it's worried about the Army Corps of Engineers making more adult boaters wear life-jackets. Plumbing Manufacturers International said that the Energy Department's proposed changes to the definition of "showerhead" would eliminate many commonly-used showering systems.

Occasionally, the trade associations were at odds with each other, including over Mexican truckers' access to U.S. highways, which was supported by grocers and opposed by at least one drivers' association.

President Barack Obama launched last month a review of all regulations to eliminate those which are outdated or place "unreasonable burdens on businesses." Since then, the Labor Department has shelved rules that could have forced manufacturers to install noise-reducing equipment and gather more data on workplace injuries—both targets in the letters to Mr. Issa. The EPA has said it is reworking a proposal to limit emissions from industrial boilers to address industry concerns about costs.

But the Obama administration has so far defended the EPA's efforts to regulate emissions of carbon dioxide and other greenhouse gases which business groups fear could ultimately require costly new technology for power plants, factories, refineries and drive up energy costs for all businesses.

The White House has said its review will focus on older regulations which could be obsolete because of changes in behavior or technology, not its own greenhouse gas proposals.

"While all significant regulations are subject to this process, it would stand to reason that any regulations promulgated by this administration are current and already reflect the principles outlined by the president," said Meg Reilly, a spokeswoman for the Office of Management and Budget.

House Republicans have questioned whether the administration's review will go far enough, and will likely use the business letters to bolster their case.

Congressional Democrats say Mr. Issa's initiative reflects Republicans' unwillingness to hold businesses to account. The top Democrat on the oversight committee, Elijah Cummings of Maryland, has protested that Mr. Issa has not sent him copies of all the letters, and said he will demand tougher scrutiny of the industry groups' gripes.

Mr. Issa has said that he has simply tried to listen to businesses.

"These aren't judgments or recommendations from a congressional committee, but rather information from job creators about regulations they see as flawed and harmful to job creation and economic recovery," he said.

Write to Louise Radnofsky at louise.radnofsky@wsj.com

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How Ocean Currents Once Warmed the Arctic

New research could explain why the Arctic was much warmer during a period millions of years ago that scientists say most closely resembles Earth's climate today

By Lauren Morello and ClimateWire | Monday, February 7, 2011 | 5

New research could explain why the Arctic was much warmer during a period millions of years ago that scientists say most closely resembles Earth's climate today.

The climate during the mid-Pliocene Epoch, roughly 3 million years ago, is a good overall match for conditions today with regard to average temperature and the level of carbon dioxide in the atmosphere. But there are some differences that scientists have had trouble explaining.

Analyses of fossils, pollen and chemicals contained in core samples of seafloor sediments suggest the North Atlantic Ocean and the Arctic were much warmer during the mid-Pliocene than they are today. But climate models haven't been able to accurately reproduce that past Arctic warming.

Now, researchers in the United States and United Kingdom say the difference between the Arctic of the Pliocene and that of the present may boil down to shifts in the topography of the ocean floor -- in particular, of a group of underwater ridges and channels that extend from Greenland to Scotland.

Known as the Greenland-Scotland Ridge, the undersea mountain range divides the basin of the North Atlantic Ocean from those of the Nordic Seas. Researchers believe it was about 300 meters (roughly 984 feet) deeper during the mid-Pliocene.

"Geophysicists have studied this ridge in the past. It's a hot spot, with mantle coming up from underneath" the ocean floor, said lead author Mary Robinson, a micropaleontologist with the U.S. Geological Survey. "The Earth's crust will swell when it's hot and condense when it's cold, and that changes the height of the ridge."

When Robinson and her colleagues tweaked their climate model to account for the ridge's depth during the mid-Pliocene, "almost like magic, the data and the model results matched up really well," she said.

A help to 'hindcasting'

Today, the ridge traps North Atlantic Ocean water as it sinks to lower depths, redirecting it back toward the equator. But the new study suggests that during the mid-Pliocene, when the ridge was lower, it allowed deep ocean currents to flow freely. That ultimately increased the flow of warm surface water, leading to the unusual warming in the North Atlantic and Arctic.

Robinson said the study results could help improve the accuracy of climate models, leading to better predictions of the future climate.

That's because scientists who work with the models test them by seeing how well they can replicate the climate of the past, a process called "hindcasting." If a model can accurately reproduce past conditions, the thinking goes, researchers can be more confident about the model's ability to project the future climate.

But Robinson said there is still work to be done to test the new theory about the influence of the Greenland-Scotland Ridge on the Pliocene-era Arctic and North Atlantic Ocean.

She and her colleagues used a simplified model of the ocean ridge for their initial research, for example.

"The (paleoclimate) data say the ridges only dropped by about 300 meters," Robinson said. "In this study, we just removed them. It's the equivalent of dropping by about 600 meters, more than what's realistic. But this was a pilot study."

The research team plans to conduct new analyses that incorporate a more realistic picture of the drops and ridges, she said.

The study was published online last month in the journal *Palaeogeography, Palaeoclimatology, Palaeoecology*. Its authors include researchers from the U.S. Geological Survey, the British Geological Survey and several universities in the United Kingdom.

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As GreenWorks begins, how much should it cost?

Poll: Americans back EPA and clean energy

Feb 07, 2011

Is climate change causing millions to migrate?

10:14 AM

By Yvette Cabrera, USA TODAY

[illegible] Comments

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Two new studies paint contrasting views of whether climate change-induced weather will force millions of people to migrate to safer areas. One says yes, the other no.

In an upcoming report, the Asian Development Bank (ADB) warns that more extreme weather [illegible] of climate change -- floods, droughts and storms -- will prompt mass migration that no international organization is set up to handle.

"In the past year alone, extreme weather in Malaysia, Pakistan, the People's Republic of China, the Philippines and Sri Lanka has caused temporary or longer term displacement of millions," the Manila-based organization said Monday. "This process is set to accelerate in coming decades as climate change leads to more extreme weather."

The report, to be released next month, is part of ADB's broader effort to focus attention on the issue and urge preparedness. If managed well, it says climate-induced migration could help people settle in less vulnerable places. But it also says that poor people are the ones most likely to be affected and least equipped to make changes.

Yet other research, published last week, has looked at case studies from Bolivia, Senegal and Tanzania and finds no evidence that environmental degradation linked to climate change caused massive migration. Rather, it finds social and economic factors play a bigger role in who moves, where they move and for how long.

"People affected by environmental degradation rarely moved across borders," says study author Cecilia Tacoli of the London-based International Institute for Environment and Development. "Instead they moved to other rural areas or to [illegible] towns, often temporarily."

Like the ADB report, however, this research agrees that migration can ultimately help people reduce their vulnerability, and it urges governments to better understand the issue.

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Feb 07 2011

Obama fast-tracks Mid-Atlantic offshore wind energy

06:19 PM

By USA TODAY
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The Obama administration announced plans Monday to spend $3 million to speed the development of offshore wind farms, including to lease wind farms off four Mid-Atlantic states by the end of this year.

The Interior Department said it will expedite environmental reviews for four wind projects off the coasts of Virginia, Maryland, Delaware and New Jersey. That spring, it expects to identify other wind energy areas off Massachusetts, Rhode Island and the South Atlantic region, mostly North Carolina.

"This initiative will spur the type of innovation that will help us create new jobs, build a clean energy future and compete and win in the technologies of the 21st century," Interior Secretary Ken Salazar said in the announcement, which notes President Obama's goal of generating 80% of U.S. electricity from clean energy sources by 2035.

Wind advocates called for a streamlined process after it took eight years for the Cape Wind project off Cape Cod, Mass., to obtain a lease as the nation's first offshore wind farm. That project faced opposition from Indian tribes, some environmentalists and residents, who argued it threatened marine life and ruined ocean views.

Salazar said the wind farms identified Monday — all off major tourist destinations, including Atlantic City, N.J.; Ocean City, Md.; and Virginia Beach, Va. — would be up to 20 miles offshore so they shouldn't mar vacationers' views, according to the Associated Press.

The Department of Energy said it would spend up to $93 million over five years to support the development of innovative wind technology, up to $48 million over three years to study how to optimize the wind market and up to $5 million over three years to find more cost-effective turbine drive trains.

"Offshore wind power holds incredible potential to drive our energy and economic engine forward while reducing pollution," Sean Garren, clean energy advocate for Environment America, said in a statement welcoming the news. "Nations around the world have already proven the effectiveness of this resource. If we do not move quickly, we risk falling behind."

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Tree Rings Reveal History of History-Changing Mexican Droughts

"Super droughts" may have helped bring down the Toltec and Aztec civilizations

By Tiffany Stecker and ClimateWire | Tuesday, February 8, 2011 | 6

The water-stressed Central American region of today experienced super-droughts centuries ago that helped bring down two civilizations, says a study.

Using dendrochronology -- the study of tree rings -- a team from the University of Arkansas created a model using thousand-year-old Montezuma baldcypress (*Taxodium mucronatum*) from Barranca de Amealco in Querétaro state.

The drought observed through tree rings was "more severe and prolonged than anything we've seen in the modern era," said David Stahle, lead researcher of the study, to be published in the American Geophysical Union's *Geophysical Research Letters*.

The study's home base in Mexico is critical, as the climate models used by the U.N. Intergovernmental Panel on Climate Change (IPCC) to measure climatic change have predicted a "drying out" of the country leading up to 2050, said Richard Seager, a research professor at the Lamont-Doherty Earth Observatory at Columbia University, another lab that works with tree rings to decode past climate patterns.

"The fact that they occurred in the past means they could occur again," said Seager, but the events would be "much greater and more extreme."

Connie Woodhouse, a professor at the University of Arizona specializing in the climatology of western North America, said the records indicate that a similar event could happen in the future, with the added exacerbation of human-induced global warming.

"It's not a forecast or a predictive tool," she said. "It's sort of a heads-up."

Climatic conquests

Through studying bald cypress rings, the team was able to reconstruct the soil moisture balance during the rise and fall of the Toltecs and Aztecs, two of Mexico's great indigenous civilizations. The Toltecs flourished from 800 to 1000. Prime time for the Aztecs ran from 1500 to 1700.

The data identified droughts as long as 19 years, and are linked with destabilizing events that eventually brought down the Toltec state. Droughts during Aztec rule coincided with devastating famines.

The shift to a severe climate had secondary effects, as well. "Prolonged drought over Mesoamerica during the early Colonial era may have interacted with epidemic disease to contribute to the catastrophic depopulation of Aztec Mexico in the aftermath of the [Spanish] conquest," states the study.

So will modern civilizations finish off like the Toltecs? Stahle is careful not to draw a direct parallel.

"We don't know for sure if it caused a decline," he said. "We don't know for sure if it caused the collapse of the ancient city of Tula [the Toltec capital]." But the drought's role is apparent.

Dendrochronology is an effective method for constructing climate models back to 2,000 years because it directly calibrates with ancient weather patterns, said Stahle. The bald cypress is a rare variety in the region to survive more than 1,000 years. One tree in southern Mexico is ranked one of the oldest in the world.

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EPA Chief Faces Grilling Over Global Warming Curbs

Published February 08, 2011 | Associated Press

WASHINGTON – The head of the Environmental Protection Agency is in for some grilling by Congress this year, so much so that a top House Republican joked that she should line up a permanent parking spot at the Capitol.

Topic A is the agency's attempt to curb the release of gases blamed for global warming. Having failed last year to enact new legislation to reduce greenhouse gases, the administration is left to use existing law to achieve its goals.

That, Republicans contend, will penalize industries that otherwise could be creating new jobs, and they've made the agency a central target of their anti-regulatory agenda.

On Wednesday, EPA chief Lisa Jackson goes before a House committee determined to block her agency's steps to address climate change. Jackson contends the law and compelling scientific evidence on global warming give her no choice but to act.

The agency has been caught before in shifting political winds. But in the 40 years since Republican President Richard Nixon created the federal agency charged with protecting the public from pollution, and Congress nearly unanimously passed laws that have cleaned up the air and water, long-time observers say the atmosphere for the agency has never been more toxic than it is now.

"It's really been quite extreme," said William Ruckelshaus, who was the first EPA administrator under Nixon and later ran the agency under President Ronald Reagan, of the rhetoric being aimed at the agency this time around. "What are they supposed to do? Sit there and do nothing?"

The ugliest and perhaps most draconian attack came from former House speaker and possible 2012 GOP presidential candidate Newt Gingrich, who called for abolishing the EPA and replacing it with an organization more friendly to business.

That followed Democrat Sen. Joe Manchin's use of a rifle to blast a hole through legislation limiting the gases blamed for global warming in a campaign commercial. The stunt helped him win West Virginia's open Senate seat.

Mike McKenna, a Republican strategist, says Gingrich and Manchin are outliers in a more reasoned debate over how big the global warming problem is and the different approaches for dealing with it.

"I don't think the political peak is ready to throw EPA out the window," McKenna said. "There are plenty of people across the country who want EPA reached down and thinks has gone too far, too fast."

Lawmakers of both parties have already introduced a slew of bills aimed at weakening, delaying or blocking pollution regulations. Business groups invited by congressional Republicans to describe their biggest regulatory burdens singled out EPA rules more than any others.

The main target is the agency's use of the Clean Air Act to control emissions of greenhouse gases, a law that the Supreme Court said in 2007 could be used to fight global warming.

In 2009, the EPA under President Barack Obama put the law in motion when it concluded

climate changes being caused by pollution from industries, automobiles and other sources burning fossil fuels are a threat to public health and welfare. Some Republicans -- and some Democrats from industrial states -- aren't convinced that's the case.

There's also growing resistance to a host of other regulations expected from the agency. Some were initiated by Obama, but others are the result of courts throwing out Bush-era regulations. Still others stem from reviews required by law to update standards to reflect the latest science. They cover everything from ground-level ozone, the main ingredient in smog, to coal ash disposal, to a rule aimed at reducing pollution blowing into downwind states.

"There has been an onslaught of job crushing regulations emerging from the EPA over the last few years," said Sen. John Barrasso, R-Wyo., at a recent hearing of the Senate Environment Committee. It was Jackson's first trip to Capitol Hill since Republicans took over the House and gained more seats in the Senate.

The EPA's defenders say the agency is simply following statutes aimed at protecting people's health -- something they say has strong support and is necessary for a healthy economy.

"Simply put, you can't work if you can't breathe," Sen. Barbara Boxer, D-Calif., has said.

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USA TODAY

Expect higher food prices as corn reserves lowest in 15 years

Posted 2h 55m ago |

ST. LOUIS (AP) — U.S. reserves of corn have hit their lowest level in more than 15 years, reflecting tighter supplies that will lead to higher food prices in 2011. Increasing demand for corn from the ethanol industry is a major reason for the decline.

By Seth Perlman, AP In this Sept. 17, 2010 file photo, central Illinois farmers harvest their corn crops near Monticello. The U.S. reserves of corn have hit their lowest level in more than 15 years.

Enlarge

By Seth Perlman, AP

In this Sept. 17, 2010 file photo, central Illinois farmers harvest their corn crops near Monticello. The U.S. reserves of corn have hit their lowest level in more than 15 years.

The U.S. Department of Agriculture reported Wednesday that the ethanol industry's projected orders this year rose 8.4%, to 13.01 billion bushels, after record-high production in December and January.

China drought China prepares for 'severe, long-lasting drought'

That means the United States will have about 675 million bushels of corn left over at the end of year. That's roughly 5% of all corn that will be consumed, the lowest surplus level since 1996.

One bushel of corn equals 25 kilograms, or 55 pounds.

INFLATION AHEAD? Bernanke's not worried

The USDA report, which measures global supply and demand for grains, oilseeds and other crops, said its projections for wheat and soybean stocks remained unchanged at

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historical low levels for reserves.

Corn prices have already doubled in the last six months, rising from $3.50 a bushel to more than $7 a bushel.

Consumers won't see the broader impact right away. It takes months for higher grain costs to work their way through the food system and show up at the grocery store. The cost of corn and soybeans represents just 10% of the total cost of food, and big processors such as General Mills are hesitant to pass along those costs quickly to consumers.

Still, companies such as Hormel Foods, have already announced price hikes for 2011 to cover the increases. Hormel said prices will rise by about 3% on a variety of products, from Spam to canned soups.

Rising grain costs hit meat producers first. Tyson Foods, the biggest U.S. meat company, says it is aiming to cut $200 million in operational costs to offset higher corn and soybean costs. CEO Donnie Smith calls that the "new normal" price range. Tyson said chicken, beef and pork prices are expect to rise, if only slightly, this year as producers seek to cover costs.

Shares of meat producers like Tyson, Smithfield Foods and Pilgrim's Pride opened lower Wednesday, falling less than 1% in early trading.

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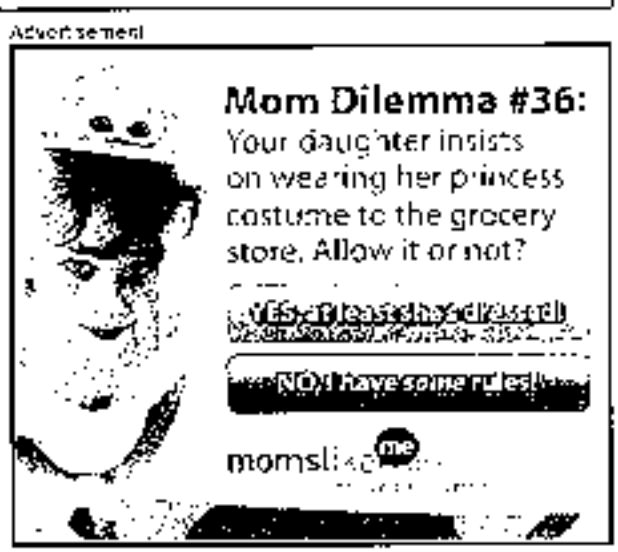

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USA TODAY

High pressure pushed wacky weather over USA

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By Doyle Rice, USA TODAY

Record, or near-record, snowfalls in Chicago, New York City and Tulsa.

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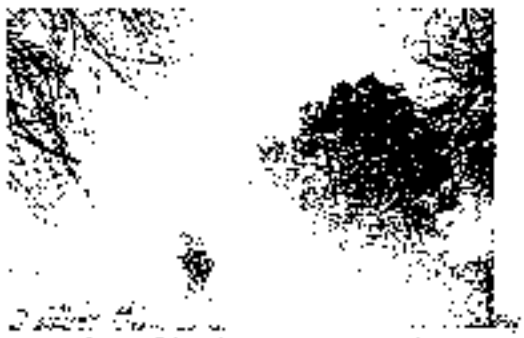

Kiichiro Sato, AP A pedestrian walks along the shoreline of Lake Michigan on Feb. 2 in

Chicago Enlarge

By Kiichiro Sato, AP

A pedestrian walks along the shoreline of Lake Michigan on Feb. 2 in Chicago

Brutal, relentless cold from the Midwest to the South.

ARTIC BLAST: 40 states brrr-ace for big chill

CURRENT TEMPERATURES: Check your areaFor much of the USA, the winter has been a seemingly endless series of intense cold snaps and colossal snowstorms during months of record-shattering weather.

Q: So what's causing our wacky winter?

A: It may not sound too dramatic, but when we've had extreme winter weather in North America and Europe, the common denominator has been unusually high pressure at upper levels of the atmosphere over the Arctic and Greenland, says Weather Channel senior meteorologist Stu Ostro.

Such high atmospheric pressure has made temperatures warmer than average over Canada, Greenland and Alaska, but has opened the door to lower pressure, cold outbreaks and ferocious storms over the USA and Europe.

Q: So what causes those shifts in pressure?

A. Ostro says the high pressure over

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Greenland this winter was characteristic of the "negative phase" of the North Atlantic Oscillation (NAO) and its close cousin the Arctic Oscillation. Both oscillations refer to seesaw patterns in atmospheric pressure between the polar regions and the middle latitudes, where lots of people live.

In the oscillations' "negative phase," higher-than-normal pressure areas form over the polar regions and lower-than-normal pressure troughs form over the middle latitudes. These persistent "troughs" helped stir up storms down here.

"I wish the NAO was as much of a household term as El Niño and La Niña have become," Ostro says.

Q: Speaking of La Niña — was it a factor?

A: La Niña — cooler-than-average water in the central Pacific Ocean — played a role this winter, Ostro says, but other climate patterns, such as the NAO and the persistently strong ridges and troughs overwhelmed the effects of La Niña in some areas. In a typical La Niña winter, much of the southern and central USA see a warmer- and drier-than-average winter while the West Coast and Northwest are colder than average.

A strong El Niño can mean a stormy winter along the West Coast, a wet winter across the South and a warmer-than-average winter for parts of the North. "They (La Niña and El Niño) are not the be-all and end-all of everything," Ostro says.

Q: How about global warming? Does this cold winter disprove it?

A: Not really. As global temperatures rise, higher pressure is more likely at upper levels of the atmosphere, Ostro says, which is what happened this winter. Strong ridges aloft in recent months and years have been conducive to potent troughs of low pressure that help form intense storms.

"It's important to look at the context and the big picture," he says. "While major population centers such as London, Paris, Chicago and Atlanta were shivering, which got a lot of media attention, large expanses in and near the Arctic, including northeast Canada and Greenland, have been experiencing unusually warm conditions this winter."

Q: Anything else to worry about?

The loss of Arctic sea ice, which was at its lowest December and January levels on record, according to the National Snow and Ice Data Center.

"It could be changing atmospheric patterns," Ostro says.

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USA TODAY

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OPINION ESSAY | FEBRUARY 12, 2011

The Weather Isn't Getting Weirder

The latest research belies the idea that storms are getting more extreme.

By ANNE JOLIS

Last week a severe storm froze Dallas under a sheet of ice, just in time to disrupt the plans of the tens of thousands of (American) football fans descending on the city for the Super Bowl. On the other side of the globe, Cyclone Yasi slammed northeastern Australia, destroying homes and crops and displacing hundreds of thousands of people.

Some climate alarmists would have us believe that these storms are yet another baleful consequence of man-made CO2 emissions. In addition to the latest weather events, they also point to recent cyclones in Burma, last winter's fatal chills in Nepal and Bangladesh, December's blizzards in Britain, and every other drought, typhoon and unseasonable heat wave around the world.

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But is it true? To answer that question, you need to understand whether recent weather trends are extreme by historical standards. The Twentieth Century Reanalysis Project is the latest attempt to find out, using super computers to generate a dataset of global atmospheric circulation from 1871 to the present.

Anne Jolis, editorial writer for WSJ Europe, has been following data on extreme weather events.

As it happens, the project's initial findings, published last month, show no evidence of an intensifying weather trend. "In the climate models, the extremes get more extreme as we move into a doubled CO2 world in 100 years," atmospheric scientist Gilbert Compo, one of the researchers on the project, tells me from his office at the University of Colorado, Boulder. "So we were surprised that none of the three major indices of climate variability that we used show a trend of increased circulation going back to 1871."

In other words, researchers have yet to find evidence of more-extreme weather patterns over the period, contrary to what the models predict. "There's no data-driven answer yet to the question of how human activity has affected extreme weather," adds Roger Pielke Jr., another University of Colorado climate researcher.

We do know that carbon dioxide and other gases trap and re-radiate heat. We also know that humans have emitted ever-more of these gases since the Industrial Revolution. What we don't know is exactly how sensitive the climate is to increases in these gases versus other possible factors—solar variability, oceanic currents, Pacific heating and cooling cycles, planets' gravitational and magnetic oscillations, and so on.

Given the unknowns, it's possible that even if we spend trillions of dollars, and forgo trillions more in future economic growth, to cut carbon emissions to pre-industrial levels, the climate will continue to change—as it always has.

That's not to say we're helpless. There is at least one climate lesson that we can draw from the recent weather: Whatever happens, prosperity and preparedness help. North Texas's ice storm wreaked havoc and left hundreds of football fans stranded, cold, and angry. But thanks to modern infrastructure, 21st century health care, and stockpiles of magnesium chloride and snow plows, the storm caused no reported deaths and Dallas managed to host the big game on Sunday.

Compare that outcome to the 55 people who reportedly died of pneumonia, respiratory problems and other cold-related illnesses in Bangladesh and Nepal when temperatures dropped to just above freezing last winter. Even rich countries can be caught off guard: Witness the thousands stranded when Heathrow skimped on de-icing supplies and let five inches of snow ground flights for two days before Christmas. Britain's GDP shrank by 0.5% in the fourth quarter of 2010, for which the Office of National Statistics mostly blames "the bad weather."

Getty Images

Some climate alarmists claim that cyclones, such as Cyclone Yasi, are a result of man-made CO2 emissions.

Arguably, global warming *was* a factor in that case. Or at least the idea of global warming was. The London-based Global Warming Policy Foundation charges that British authorities are so committed to the notion that Britain's future will be warmer that they have failed to plan for winter storms that have hit the country three years running.

A sliver of the billions that British taxpayers spend on trying to control their climes could have bought them more of the supplies that helped Dallas recover more quickly. And, with a fraction of *that* sliver of prosperity, more Bangladeshis and Nepalis could have acquired the antibiotics and respirators to survive their cold spell.

A comparison of cyclones Yasi and Nargis tells a similar story: As devastating as Yasi has been, Australia's infrastructure, medicine, and emergency protocols meant the Category 5 storm has killed only one person so far. Australians are now mulling all the ways they could have better protected their property and economy.

But if they feel like counting their blessings, they need only look to the similar cyclone that hit the Irrawaddy Delta in 2008. Burma's military regime hadn't allowed for much of an economy before the cyclone, but Nargis destroyed nearly all the Delta had. Afterwards, the junta blocked foreign aid workers from delivering needed water purification and medical supplies. In the end, the government let Nargis kill more than 130,000 people.

Global-warming alarmists insist that economic activity is the problem, when the available evidence show it to be part of the solution. We may not be able to do anything about the weather, extreme or otherwise. But we can make sure we have the resources to deal with it when it comes.

Miss Jolis is an editorial page writer for The Wall Street Journal Europe.

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TIME
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Monday, Feb. 14, 2011

Why Biofuels Help Push Up World Food Prices

By Bryan Walsh

It's easy to miss amid the drama of Egypt — though the two stories are connected — but the world is in the grip of a full-blown food crisis. According to the U.N., world food prices hit a record high in January, meaning food is now more expensive than it has ever been in real terms since the U.N. first began tracking the numbers in 1990. Grains, in particular, are more expensive than ever, with corn prices up 53% in 2010, wheat up 47% and rice now at its highest level in more than two years. At a time when much of the global economy is still struggling to bounce back from the crisis of the past few years, high food prices could push millions back into poverty and cause millions more to go hungry. "The impact is really being felt, especially in outside the U.S.," says Marie Brill, the senior policy analyst at the antipoverty NGO ActionAid USA.

Less clear is what's actually behind the spike in food prices. Bad weather plays a major role — a devastating heat wave in Russia last summer ruined grain harvests and prompted that country to suspend exports, jolting global markets. Excessive heat in the Midwest stunted the corn crop, leading to a 5% drop in production last year. Rising demand for food — especially meat, whose production requires lots of grain and water — in the richer parts of the developing world is straining supplies. And then there's ethanol, the production of which sucks up grain and cropland that could be used for food. In America, 40% of the corn crop is currently diverted to make fuel for cars. "Ethanol uses 4.9 billion bushels of corn in the U.S.," says Lester Brown, president of the Earth Policy Institute, a environmental think tank. "That's enough grain to feed 350 million people." (Read "Food Prices: Up, Up and Away.")

Princeton researcher Tim Searchinger, in a column last week in the Washington *Post*, argued that biofuels are contributing to the food crisis. He noted that biofuels -- both corn-based ethanol in the U.S. and biodiesel, which depends on palm oil, elsewhere — now consume more than 6.5% of the world's grain and 8% of its vegetable oil. That's up from 2% and virtually nothing in 2004. In a tight world food market, tightened by bad weather, that diversion of grain and oil makes a difference for food prices, especially in developing countries where a rise in the price of staples is passed directly to consumers. (In developed countries, marketing and packaging often make up the lion's share of food value, cushioning consumers from a rise in staple grains.) "Today, the market is out of

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equilibrium," Searchinger wrote.

While this year's food-price spike hasn't been thoroughly analyzed, the world went through a similar crisis just around three years ago. In 2007 and 2008, grain prices hit what had been record highs, prompting food riots in a number of developing countries, just as they do today — the high price of bread may have helped spark protests in Tunisia and Egypt. A major review of the 2007-08 food crisis by the International Food Policy Research Institute found that the surge in U.S. corn production for biofuels played a key role in the increase of prices. A 2008 report by the World Bank agreed, pegging the rise of biofuels in Europe and the U.S. as the most important factor in the run-up of prices. "It's pretty simple — corn that could go for food or fuel is diverted to fuel," says Brill. "That influences prices." (See TIME's special report "The Middle East in Revolt.")

The ethanol industry in the U.S., though, is hitting back against the suggestion that it is pushing up food prices. In a press call on Friday, Growth Energy CEO Tom Buis complained that a "highly well-funded and highly orchestrated campaign of misinformation" was overstating the impact of biofuels on food prices. While 4.9 billion bushels of corn may be used for ethanol in the U.S., Buis said that the industry uses "No. 2 yellow corn" — a strain fed to animals, not humans. Also, some of the corn remains after its distillation for food. The industry claims that up to 2 billion bushels of that original 4.9 billion can be recovered and used for animal feed, blunting the impact on food prices. "Ethanol today is 10% of our nation's fuel consumption," said Buis. "If it went away, you would have to find more petroleum to replace that, and you'd see fuel prices go up." (Comment on this story.)

No one is arguing that biofuels are solely responsible for driving up food prices. Rising demand and bad weather play significant roles — droughts, heat waves and floods could become more common in the future as the climate warms. Speculators who buy up food futures as investments contribute to price volatility, too, though it can be tough to trace their exact role. But it's clear that in a tighter market, diverting corn and other crops to biofuels will only act to raise prices. That might be worth it if biofuels provided substantial environmental and economic benefits, but there's significant research showing that corn ethanol's carbon footprint isn't much better than that of oil. Nor has ethanol done much to wean the U.S. off foreign oil — replacing 90% of our oil consumption with ethanol would require four times more corn than American farmers produce in total. The world will have 219,000 more mouths to feed tomorrow, and another 219,000 the next day. We'd be wise to use our food for food, not for fuel.

See the top 20 green tech ideas.

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EPA 430-R-11-005

DRAFT INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS AND SINKS:

1990 – 2009

FEBRUARY 15, 2011

U.S. Environmental Protection Agency
1200 Pennsylvania Ave., N.W.
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Executive Summary

An emissions inventory that identifies and quantifies a country's primary anthropogenic[1] sources and sinks of greenhouse gases is essential for addressing climate change. This inventory adheres to both 1) a comprehensive and detailed set of methodologies for estimating sources and sinks of anthropogenic greenhouse gases, and 2) a common and consistent mechanism that enables Parties to the United Nations Framework Convention on Climate Change (UNFCCC) to compare the relative contribution of different emission sources and greenhouse gases to climate change.

In 1992, the United States signed and ratified the UNFCCC. As stated in Article 2 of the UNFCCC, "The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."[2]

Parties to the Convention, by ratifying, "shall develop, periodically update, publish and make available…national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, using comparable methodologies…"[3] The United States views this report as an opportunity to fulfill these commitments.

This chapter summarizes the latest information on U.S. anthropogenic greenhouse gas emission trends from 1990 through 2009. To ensure that the U.S. emissions inventory is comparable to those of other UNFCCC Parties, the estimates presented here were calculated using methodologies consistent with those recommended in the Revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (IPCC/UNEP/OECD/IEA 1997), the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC 2000), and the IPCC Good Practice Guidance for Land Use, Land-Use Change, and Forestry (IPCC 2003). Additionally, the U.S. emission inventory has continued to incorporate new methodologies and data from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006). The structure of this report is consistent with the UNFCCC guidelines for inventory reporting.[4] For most source categories, the IPCC methodologies were expanded, resulting in a more comprehensive and detailed estimate of emissions.

[BEGIN BOX]

Box ES 1: Methodological approach for estimating and reporting U.S. emissions and sinks

In following the UNFCCC requirement under Article 4.1 to develop and submit national greenhouse gas emissions inventories, the emissions and sinks presented in this report are organized by source and sink categories and calculated using internationally accepted methods provided by the IPCC.[5] Additionally, the calculated emissions and sinks in a given year for the U.S. are presented in a common manner in line with the UNFCCC reporting guidelines for the reporting of inventories under this international agreement.[6] The use of consistent methods to calculate emissions and sinks by all nations providing their inventories to the UNFCCC ensures that these reports

[1] The term "anthropogenic", in this context, refers to greenhouse gas emissions and removals that are a direct result of human activities or are the result of natural processes that have been affected by human activities (IPCC/UNEP/OECD/IEA 1997).

[2] Article 2 of the Framework Convention on Climate Change published by the UNEP/WMO Information Unit on Climate Change. See <http://unfccc.int>.

[3] Article 4(1)(a) of the United Nations Framework Convention on Climate Change (also identified in Article 12). Subsequent decisions by the Conference of the Parties elaborated the role of Annex I Parties in preparing national inventories. See <http://unfccc.int>.

[4] See <http://unfccc.int/resource/docs/cop8/08.pdf>.

[5] See < http://www.ipcc-nggip.iges.or.jp/public/index.html>.

[6] See < http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/3270.php>.

are comparable. In this regard, U.S. emissions and sinks reported in this inventory report are comparable to emissions and sinks reported by other countries. Emissions and sinks provided in this inventory do not preclude alternative examinations, but rather this inventory report presents emissions and sinks in a common format consistent with how countries are to report inventories under the UNFCCC. The report itself follows this standardized format, and provides an explanation of the IPCC methods used to calculate emissions and sinks, and the manner in which those calculations are conducted.

[END BOX]

Background Information

Naturally occurring greenhouse gases include water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3). Several classes of halogenated substances that contain fluorine, chlorine, or bromine are also greenhouse gases, but they are, for the most part, solely a product of industrial activities. Chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) are halocarbons that contain chlorine, while halocarbons that contain bromine are referred to as bromofluorocarbons (i.e., halons). As stratospheric ozone depleting substances, CFCs, HCFCs, and halons are covered under the Montreal Protocol on Substances that Deplete the Ozone Layer. The UNFCCC defers to this earlier international treaty. Consequently, Parties to the UNFCCC are not required to include these gases in their national greenhouse gas emission inventories.[7] Some other fluorine-containing halogenated substances—hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6)—do not deplete stratospheric ozone but are potent greenhouse gases. These latter substances are addressed by the UNFCCC and accounted for in national greenhouse gas emission inventories.

There are also several gases that do not have a direct global warming effect but indirectly affect terrestrial and/or solar radiation absorption by influencing the formation or destruction of greenhouse gases, including tropospheric and stratospheric ozone. These gases include carbon monoxide (CO), oxides of nitrogen (NO_x), and non-CH_4 volatile organic compounds (NMVOCs). Aerosols, which are extremely small particles or liquid droplets, such as those produced by sulfur dioxide (SO_2) or elemental carbon emissions, can also affect the absorptive characteristics of the atmosphere.

Although the direct greenhouse gases CO_2, CH_4, and N_2O occur naturally in the atmosphere, human activities have changed their atmospheric concentrations. From the pre-industrial era (i.e., ending about 1750) to 2005, concentrations of these greenhouse gases have increased globally by 36, 148, and 18 percent, respectively (IPCC 2007).

Beginning in the 1950s, the use of CFCs and other stratospheric ozone depleting substances (ODS) increased by nearly 10 percent per year until the mid-1980s, when international concern about ozone depletion led to the entry into force of the Montreal Protocol. Since then, the production of ODS is being phased out. In recent years, use of ODS substitutes such as HFCs and PFCs has grown as they begin to be phased in as replacements for CFCs and HCFCs. Accordingly, atmospheric concentrations of these substitutes have been growing (IPCC 2007).

Global Warming Potentials

Gases in the atmosphere can contribute to the greenhouse effect both directly and indirectly. Direct effects occur when the gas itself absorbs radiation. Indirect radiative forcing occurs when chemical transformations of the substance produce other greenhouse gases, when a gas influences the atmospheric lifetimes of other gases, and/or when a gas affects atmospheric processes that alter the radiative balance of the earth (e.g., affect cloud formation or albedo).[8] The IPCC developed the Global Warming Potential (GWP) concept to compare the ability of each greenhouse gas to trap heat in the atmosphere relative to another gas.

[7] Emissions estimates of CFCs, HCFCs, halons and other ozone-depleting substances are included in the Annexes of the inventory report for informational purposes.

[8] Albedo is a measure of the Earth's reflectivity, and is defined as the fraction of the total solar radiation incident on a body that is reflected by it.

The GWP of a greenhouse gas is defined as the ratio of the time-integrated radiative forcing from the instantaneous release of 1 kilogram (kg) of a trace substance relative to that of 1 kg of a reference gas (IPCC 2001). Direct radiative effects occur when the gas itself is a greenhouse gas. The reference gas used is CO_2, and therefore GWP-weighted emissions are measured in teragrams (or million metric tons) of CO_2 equivalent (Tg CO_2 Eq.).[9,10] All gases in this Executive Summary are presented in units of Tg CO_2 Eq.

The UNFCCC reporting guidelines for national inventories were updated in 2006,[11] but continue to require the use of GWPs from the IPCC Second Assessment Report (SAR) (IPCC 1996). This requirement ensures that current estimates of aggregate greenhouse gas emissions for 1990 to 2009 are consistent with estimates developed prior to the publication of the IPCC Third Assessment Report (TAR) (IPCC 2001) and the IPCC Fourth Assessment Report (AR4) (IPCC 2007). Therefore, to comply with international reporting standards under the UNFCCC, official emission estimates are reported by the United States using SAR GWP values. All estimates are provided throughout the report in both CO_2 equivalents and unweighted units. A comparison of emission values using the SAR GWPs versus the TAR and AR4 GWPs can be found in Chapter 1 and, in more detail, in Annex 6.1 of this report. The GWP values used in this report are listed below in Table ES-1.

Table ES-1: Global Warming Potentials (100-Year Time Horizon) Used in this Report

Gas	GWP
CO_2	1
CH_4*	21
N_2O	310
HFC-23	11,700
HFC-32	650
HFC-125	2,800
HFC-134a	1,300
HFC-143a	3,800
HFC-152a	140
HFC-227ea	2,900
HFC-236fa	6,300
HFC-4310mee	1,300
CF_4	6,500
C_2F_6	9,200
C_4F_{10}	7,000
C_6F_{14}	7,400
SF_6	23,900

Source: IPCC (1996)

* The CH_4 GWP includes the direct effects and it does not include indirect effects due to the production of tropospheric ozone and stratospheric water vapor. The indirect effect due to the production of CO_2 is not included.

Global warming potentials are not provided for CO, NO_x, NMVOCs, SO_2, and aerosols because there is no agreed-upon method to estimate the contribution of gases that are short-lived in the atmosphere, spatially variable, or have only indirect effects on radiative forcing (IPCC 1996).

Recent Trends in U.S. Greenhouse Gas Emissions and Sinks

In 2009, total U.S. greenhouse gas emissions were 6,659.7 Tg CO_2 Eq. While total U.S. emissions have increased by 7.4 percent from 1990 to 2009, emissions decreased from 2008 to 2009 by 6.0 percent (422.2 Tg CO_2 Eq.). This decrease was primarily due to (1) a decrease in economic output resulting in a decrease in energy consumption across all sectors; and (2) a decrease in the carbon intensity of fuels used to generate electricity due to fuel switching as the price of coal increased, and the price of natural gas decreased significantly. Since 1990, U.S. emissions have increased at an average annual rate of 0.4%.

[9] Carbon comprises 12/44[ths] of carbon dioxide by weight.

[10] One teragram is equal to 10^{12} grams or one million metric tons.

[11] See <http://unfccc.int/resource/docs/2006/sbsta/eng/09.pdf>.

Figure ES-1 through Figure ES-3 illustrate the overall trends in total U.S. emissions by gas, annual changes, and absolute change since 1990. Table ES-2 provides a detailed summary of U.S. greenhouse gas emissions and sinks for 1990 through 2009.

Figure ES-1: U.S. Greenhouse Gas Emissions by Gas

Figure ES-2: Annual Percent Change in U.S. Greenhouse Gas Emissions

Figure ES-3: Cumulative Change in Annual U.S. Greenhouse Gas Emissions Relative to 1990

Table ES-2: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks (Tg CO_2 Eq. or million metric tons CO_2 Eq.)

Gas/Source	1990	2000	2005	2006	2007	2008	2009
CO_2	5,100.2	5,976.2	6,114.7	6,022.6	6,121.5	5,922.5	5,508.1
Fossil Fuel Combustion	4,741.2	5,597.7	5,755.6	5,657.0	5,760.6	5,568.7	5,212.0
Electricity Generation	1,820.8	2,296.9	2,402.1	2,346.4	2,412.8	2,360.9	2,154.0
Transportation	1,485.9	1,809.5	1,896.6	1,878.1	1,894.0	1,789.9	1,718.6
Industrial	949.3	853.9	825.5	852.1	845.9	805.6	738.4
Residential	338.3	370.7	357.9	321.5	342.4	348.2	340.2
Commercial	219.0	230.8	223.5	208.0	219.4	224.2	218.8
U.S. Territories	27.9	35.9	50.0	50.3	46.1	39.8	41.7
Non-Energy Use of Fuels	116.2	142.5	141.5	142.4	134.1	138.7	122.1
Iron and Steel Production & Metallurgical Coke Production	99.5	85.9	65.9	66.8	71.0	66.0	42.6
Natural Gas Systems	37.6	29.9	29.5	30.8	31.1	32.8	32.2
Cement Production	33.3	41.2	45.9	46.6	45.2	41.1	29.4
Incineration of Waste	8.0	11.1	12.5	12.5	12.7	12.2	12.3
Ammonia Production and Urea Consumption	15.8	16.4	12.8	12.7	14.0	11.9	11.5
Lime Production	11.5	14.2	14.4	15.1	14.6	14.3	11.2
Cropland Remaining Cropland	7.1	7.5	7.9	7.9	8.2	8.7	7.8
Limestone and Dolomite Use	5.1	5.1	6.8	8.0	7.9	6.3	7.6
Soda Ash Production and Consumption	4.1	4.2	4.2	4.2	4.1	4.1	4.3
Aluminum Production	6.8	6.1	4.1	3.8	4.3	4.5	3.0
Petrochemical Production	3.3	4.5	4.2	3.8	3.9	3.4	2.7
Carbon Dioxide Consumption	1.4	1.4	1.3	1.7	1.9	1.8	1.8
Ferroalloy Production	2.2	1.9	1.4	1.5	1.6	1.6	1.6
Titanium Dioxide Production	1.2	1.8	1.8	1.8	1.9	1.8	1.5
Wetlands Remaining Wetlands	1.0	1.2	1.1	0.9	1.0	1.0	1.1
Phosphoric Acid Production	1.5	1.4	1.4	1.2	1.2	1.2	1.0
Zinc Production	0.7	1.0	1.1	1.1	1.1	1.2	1.0
Lead Production	0.5	0.6	0.6	0.6	0.6	0.6	0.5
Petroleum Systems	0.6	0.5	0.5	0.5	0.5	0.5	0.5
Silicon Carbide Production and Consumption	0.4	0.2	0.2	0.2	0.2	0.2	0.1
Land Use, Land-Use Change, and Forestry (Sink)[a]	*(861.5)*	*(576.5)*	*(1,556.5)*	*(1,064.3)*	*(1,060.9)*	*(1,040.5)*	*(1,015.1)*
Biomass - Wood[b]	*215.2*	*218.1*	*206.9*	*255.8*	*263.3*	*198.4*	*181.8*
International Bunker Fuels[c]	*111.8*	*98.5*	*110.5*	*129.1*	*127.1*	*135.2*	*151.2*
Biomass - Ethanol[b]	*4.1*	*9.0*	*22.1*	*29.5*	*37.5*	*52.8*	*59.0*
CH_4	674.9	659.9	631.4	672.1	664.6	676.7	686.5

Natural Gas Systems	189.8	209.3	193.4	217.7	205.2	211.3	221.2
Enteric Fermentation	132.1	136.5	136.5	138.8	141.0	140.6	139.8
Landfills	147.4	111.7	102.5	101.7	101.3	115.9	117.5
Coal Mining	84.1	60.4	56.9	58.2	57.9	67.1	71.0
Manure Management	31.7	42.4	46.6	46.7	50.7	49.4	49.5
Petroleum Systems	35.4	31.5	29.4	29.4	30.0	30.2	30.9
Wastewater Treatment	25.5	25.2	24.3	24.5	24.4	24.5	24.5
Forest Land Remaining Forest Land	2.2	14.3	5.8	21.6	20.0	11.9	7.8
Rice Cultivation	7.1	7.5	6.8	5.9	6.2	7.2	7.3
Stationary Combustion	7.4	6.6	6.6	6.2	6.5	6.5	6.2
Abandoned Underground Coal Mines	6.0	7.4	5.5	5.5	5.6	5.9	5.5
Mobile Combustion	4.7	3.4	2.5	2.3	2.2	2.0	2.2
Composting	0.3	1.3	1.6	1.6	1.7	1.7	1.7
Petrochemical Production	0.9	1.2	1.1	1.0	1.0	0.9	0.8
Iron and Steel Production & Metallurgical Coke Production	1.3	0.9	0.7	0.7	0.7	0.6	0.4
Field Burning of Agricultural Residues	0.3	0.3	0.2	0.2	0.2	0.3	0.2
Ferroalloy Production	+	+	+	+	+	+	+
Silicon Carbide Production and Consumption	+	+	+	+	+	+	+
Incineration of Waste	+	+	+	+	+	+	+
International Bunker Fuels[3]	*0.2*	*0.1*	*0.1*	*0.2*	*0.2*	*0.2*	*0.2*
N_2O	**315.2**	**348.0**	**322.9**	**326.4**	**325.1**	**310.8**	**299.5**
Agricultural Soil Management	197.8	206.8	211.3	208.9	209.4	210.7	214.6
Mobile Combustion	43.9	53.2	36.9	33.6	30.3	26.1	27.8
Manure Management	14.5	17.1	17.3	18.0	18.1	17.9	17.9
Nitric Acid Production	17.7	19.6	16.5	16.2	19.2	16.4	14.6
Stationary Combustion	12.8	14.6	14.7	14.4	14.6	14.2	12.8
Forest Land Remaining Forest Land	2.7	12.1	8.4	18.0	16.7	10.1	6.7
Wastewater Treatment	3.7	4.5	4.8	4.8	4.9	5.0	5.0
N_2O from Product Uses	4.4	4.4	4.4	4.4	4.4	4.4	4.4
Adipic Acid Production	15.8	5.5	5.0	4.3	3.7	2.0	1.5
Composting	0.4	1.4	1.7	1.8	1.8	1.5	1.8
Settlements Remaining Settlements	1.0	1.1	1.5	1.5	1.6	1.5	1.5
Incineration of Waste	0.5	0.4	0.4	0.4	0.4	0.4	0.4
Field Burning of Agricultural Residues	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Wetlands Remaining Wetlands	+	+	+	+	+	+	+
International Bunker Fuels[3]	*1.1*	*0.9*	*1.0*	*1.2*	*1.2*	*1.2*	*1.2*
HFCs	**36.9**	**103.2**	**120.2**	**123.4**	**129.5**	**129.1**	**125.0**
Substitution of Ozone Depleting Substances[4]	0.3	74.2	104.2	109.3	112.2	115.2	118.3
HCFC-22 Production	36.4	28.6	15.8	13.8	17.0	13.6	5.4
Semiconductor Manufacture	0.2	0.3	0.2	0.3	0.3	0.3	0.3
PFCs	**20.8**	**13.5**	**6.2**	**6.0**	**7.8**	**6.6**	**5.6**
Semiconductor Manufacture	2.2	4.9	3.2	3.5	3.7	4.0	4.0
Aluminum Production	18.5	8.6	3.0	2.5	3.8	2.7	1.6
SF_6	**34.4**	**20.1**	**19.0**	**17.9**	**16.7**	**16.1**	**14.8**
Electrical Transmission and Distribution	28.4	16.0	15.1	14.1	13.2	13.3	12.8
Magnesium Production and Processing	5.4	3.0	2.9	2.9	2.6	1.9	1.1

Semiconductor Manufacture	0.5	1.1	1.0	1.0	0.8	0.9	1.0
Total	6,182.2	7,113.9	7,214.5	7,168.4	7,264.8	7,061.9	6,639.7
Net Emissions (Sources and Sinks)	5,320.7	6,537.3	6,158.1	6,104.1	6,203.9	6,021.5	5,624.6

+ Does not exceed 0.05 Tg CO_2 Eq.

[1] Parentheses indicate negative values or sequestration. The net CO_2 flux total includes both emissions and sequestration, and constitutes a net sink in the United States. Sinks are only included in net emissions total.

[2] Emissions from Wood Biomass and Ethanol Consumption are not included specifically in summing energy sector totals. Net carbon fluxes from changes in biogenic carbon reservoirs are accounted for in the estimates for Land Use, Land-Use Change, and Forestry.

[3] Emissions from International Bunker Fuels are not included in totals.

[4] Small amounts of PFC emissions also result from this source.

Note: Totals may not sum due to independent rounding.

Figure ES-6 illustrates the relative contribution of the direct greenhouse gases to total U.S. emissions in 2009. The primary greenhouse gas emitted by human activities in the United States was CO_2, representing approximately 83.3 percent of total greenhouse gas emissions. The largest source of CO_2, and of overall greenhouse gas emissions, was fossil fuel combustion. CH_4 emissions, which have increased by 1.7 percent since 1990, resulted primarily from natural gas systems, enteric fermentation associated with domestic livestock, and decomposition of wastes in landfills. Agricultural soil management and mobile source fuel combustion were the major sources of N_2O emissions. Ozone depleting substance substitute emissions and emissions of HFC-23 during the production of HCFC-22 were the primary contributors to aggregate HFC emissions. PFC emissions resulted as a by-product of primary aluminum production and from semiconductor manufacturing, while electrical transmission and distribution systems accounted for most SF_6 emissions.

Figure ES–4 2009 Greenhouse Gas Emissions by Gas (percents based on Tg CO_2 Eq.)

Overall, from 1990 to 2009 total emissions of CO_2 and CH_4 increased by 408.0 Tg CO_2 Eq. (8.0 percent) and 11.7 Tg CO_2 Eq. (1.7 percent), respectively. Conversely, N_2O emissions decreased by 15.7 Tg CO_2 Eq. (5.0 percent). During the same period, aggregate weighted emissions of HFCs, PFCs, and SF_6 rose by 52.4 Tg CO_2 Eq. (58.1 percent). From 1990 to 2009, HFCs increased by 88.1 Tg CO_2 Eq. (238.6 percent), PFCs decreased by 15.1 Tg CO_2 Eq. (73.0 percent), and SF_6 decreased by 19.5 Tg CO_2 Eq. (56.8 percent). Despite being emitted in smaller quantities relative to the other principal greenhouse gases, emissions of HFCs, PFCs, and SF_6 are significant because many of these gases have extremely high global warming potentials and, in the cases of PFCs and SF_6, long atmospheric lifetimes. Conversely, U.S. greenhouse gas emissions were partly offset by carbon sequestration in forests, trees in urban areas, agricultural soils, and landfilled yard trimmings and food scraps, which, in aggregate, offset 15.3 percent of total emissions in 2009. The following sections describe each gas' contribution to total U.S. greenhouse gas emissions in more detail.

Carbon Dioxide Emissions

The global carbon cycle is made up of large carbon flows and reservoirs. Billions of tons of carbon in the form of CO_2 are absorbed by oceans and living biomass (i.e., sinks) and are emitted to the atmosphere annually through natural processes (i.e., sources). When in equilibrium, carbon fluxes among these various reservoirs are roughly balanced. Since the Industrial Revolution (i.e., about 1750), global atmospheric concentrations of CO_2 have risen about 36 percent (IPCC 2007), principally due to the combustion of fossil fuels. Within the United States, fossil fuel combustion accounted for 94.6 percent of CO_2 emissions in 2009. Globally, approximately 30,398 Tg of CO_2 were added to the atmosphere through the combustion of fossil fuels in 2009, of which the United States accounted for about 17 percent.[12] Changes in land use and forestry practices can also emit CO_2 (e.g., through conversion of forest land to agricultural or urban use) or can act as a sink for CO_2 (e.g., through net additions to forest biomass). In addition to fossil-fuel combustion, several other sources emit significant quantities of CO_2. These sources include,

[12] Global CO_2 emissions from fossil fuel combustion were taken from Energy Information Administration *International Energy Statistics 2010* <http://tonto.eia.doe.gov/ftproot/pub/project/IEDIndex3.cfm> EIA (2010a).

but are not limited to non-energy use of fuels, iron and steel production and cement production (Figure ES-5)

Figure ES-5: 2009 Sources of CO_2 Emissions

As the largest source of U.S. greenhouse gas emissions, CO_2 from fossil fuel combustion has accounted for approximately 78 percent of GWP-weighted emissions since 1990, growing slowly from 77 percent of total GWP-weighted emissions in 1990 to 78 percent in 2009. Emissions of CO_2 from fossil fuel combustion increased at an average annual rate of 0.5 percent from 1990 to 2009. The fundamental factors influencing this trend include (1) a generally growing domestic economy over the last 20 years, and (2) overall growth in emissions from electricity generation and transportation activities. Between 1990 and 2009, CO_2 emissions from fossil fuel combustion increased from 4,741.2 Tg CO_2 Eq. to 5,212.0 Tg CO_2 Eq.—a 9.9 percent total increase over the twenty-year period. From 2008 to 2009, these emissions decreased by 356.7 Tg CO_2 Eq. (6.4 percent), the largest decrease in any year over the twenty year period.

Historically, changes in emissions from fossil fuel combustion have been the dominant factor affecting U.S. emission trends. Changes in CO_2 emissions from fossil fuel combustion are influenced by many long-term and short-term factors, including population and economic growth, energy price fluctuations, technological changes, and seasonal temperatures. In the short term, the overall consumption of fossil fuels in the United States fluctuates primarily in response to changes in general economic conditions, energy prices, weather, and the availability of non-fossil alternatives. For example, in a year with increased consumption of goods and services, low fuel prices, severe summer and winter weather conditions, nuclear plant closures, and lower precipitation reducing hydroelectric dams, there would likely be proportionally greater fossil fuel consumption than a year with poor economic performance, high fuel prices, mild temperatures, and increased output from nuclear and hydroelectric plants. In the long term, energy consumption patterns respond to changes that affect the scale of consumption (e.g., population, number of cars, and size of houses), the efficiency with which energy is used in equipment (e.g., cars, power plants, steel mills, and light bulbs) and consumer behavior (e.g., walking, bicycling, or telecommuting to work instead of driving).

Figure ES-6: 2009 CO_2 Emissions from Fossil Fuel Combustion by Sector and Fuel Type

Figure ES-7: 2009 End-Use Sector Emissions of CO_2, CH_4, and N_2O from Fossil Fuel Combustion

The five major fuel consuming sectors contributing to CO_2 emissions from fossil fuel combustion are electricity generation, transportation, industrial, residential, and commercial. CO_2 emissions are produced by the electricity generation sector as they consume fossil fuel to provide electricity to one of the other four sectors, or "end-use" sectors. For the discussion below, electricity generation emissions have been distributed to each end-use sector on the basis of each sector's share of aggregate electricity consumption. This method of distributing emissions assumes that each end-use sector consumes electricity that is generated from the national average mix of fuels according to their carbon intensity. Emissions from electricity generation are also addressed separately after the end-use sectors have been discussed.

Note that emissions from U.S. territories are calculated separately due to a lack of specific consumption data for the individual end-use sectors.

Figure ES-8, Figure ES-9, and Table ES-3 summarize CO_2 emissions from fossil fuel combustion by end-use sector.

Table ES-3: CO_2 Emissions from Fossil Fuel Combustion by Fuel Consuming End-Use Sector (Tg CO_2 Eq.)

End-Use Sector	1990	2000	2005	2006	2007	2008	2009
Transportation	1,489.0	1,813.0	1,901.3	1,882.6	1,899.0	1,794.6	1,723.3
Combustion	1,485.9	1,809.5	1,896.6	1,878.1	1,894.0	1,789.9	1,718.9
Electricity	3.0	3.4	4.7	4.5	5.0	4.7	4.4
Industrial	1,536.0	1,643.7	1,562.4	1,564.1	1,575.9	1,520.4	1,341.7
Combustion	849.3	853.9	825.5	852.1	845.9	805.6	738.4

Electricity	686.7	739.3	737.0	712.0	733.0	714.8	503.9
Residential	931.4	1,133.1	1,214.7	1,152.4	1,198.5	1,182.2	1,124.6
Combustion	338.3	370.7	357.9	321.5	342.4	348.2	340.2
Electricity	593.0	762.4	856.7	830.8	855.1	834.0	784.5
Commercial	757.0	972.8	1,027.2	1,007.6	1,041.1	1,031.6	980.5
Combustion	219.0	230.8	223.5	208.6	219.4	224.2	218.8
Electricity	538.0	741.3	803.7	799.2	821.7	807.4	761.7
U.S. Territories[a]	27.9	35.9	50.0	50.3	46.1	39.8	41.7
Total	4,741.2	5,597.7	5,765.6	5,657.0	5,760.6	5,568.7	5,212.0
Electricity Generation	1,820.8	2,296.9	2,402.1	2,346.4	2,412.8	2,360.9	2,154.0

Note: Totals may not sum due to independent rounding. Combustion-related emissions from electricity generation are allocated based on aggregate national electricity consumption by each end-use sector.

[a] Fuel consumption by U.S. territories (i.e., American Samoa, Guam, Puerto Rico, U.S. Virgin Islands, Wake Island, and other U.S. Pacific Islands) is included in this report.

Transportation End Use Sector. Transportation activities (excluding international bunker fuels) accounted for 33 percent of CO_2 emissions from fossil fuel combustion in 2009.[13] Virtually all of the energy consumed in this end-use sector came from petroleum products. Nearly 54 percent of the emissions resulted from gasoline consumption for personal vehicle use. The remaining emissions came from other transportation activities, including the combustion of diesel fuel in heavy-duty vehicles and jet fuel in aircraft. From 1990 to 2009, transportation emissions rose by 16 percent due, in large part, to increased demand for travel and the stagnation of fuel efficiency across the U.S. vehicle fleet. The number of vehicle miles traveled by light-duty motor vehicles (passenger cars and light-duty trucks) increased 38 percent from 1990 to 2009, as a result of a confluence of factors including population growth, economic growth, urban sprawl, and low fuel prices over much of this period.

Industrial End-Use Sector. Industrial CO_2 emissions, resulting both directly from the combustion of fossil fuels and indirectly from the generation of electricity that is consumed by industry, accounted for 26 percent of CO_2 from fossil fuel combustion in 2009. Approximately 55 percent of these emissions resulted from direct fossil fuel combustion to produce steam and/or heat for industrial processes. The remaining emissions resulted from consuming electricity for motors, electric furnaces, ovens, lighting, and other applications. In contrast to the other end-use sectors, emissions from industry have steadily declined since 1990. This decline is due to structural changes in the U.S. economy (i.e., shifts from a manufacturing-based to a service-based economy), fuel switching, and efficiency improvements.

Residential and Commercial End Use Sectors. The residential and commercial end-use sectors accounted for 22 and 19 percent, respectively, of CO_2 emissions from fossil fuel combustion in 2009. Both sectors relied heavily on electricity for meeting energy demands, with 70 and 78 percent, respectively, of their emissions attributable to electricity consumption for lighting, heating, cooling, and operating appliances. The remaining emissions were due to the consumption of natural gas and petroleum for heating and cooking. Emissions from these end-use sectors have increased 25% since 1990, due to increasing electricity consumption for lighting, heating, air conditioning, and operating appliances.

Electricity Generation. The United States relies on electricity to meet a significant portion of its energy demands. Electricity generators consumed 36 percent of U.S. energy from fossil fuels and emitted 41 percent of the CO_2 from fossil fuel combustion in 2009. The type of fuel combusted by electricity generators has a significant effect on their emissions. For example, some electricity is generated with low CO_2 emitting energy technologies, particularly non-fossil options such as nuclear, hydroelectric, or geothermal energy. However, electricity generators rely on coal for over half of their total energy requirements and accounted for 95 percent of all coal consumed for energy in the United States in 2009. Consequently, changes in electricity demand have a significant impact on coal consumption and associated CO_2 emissions.

Other significant CO_2 trends included the following:

- CO_2 emissions from non-energy use of fossil fuels have increased 5.8 Tg CO_2 Eq. (5.0 percent) from 1990

[13] If emissions from international bunker fuels are included, the transportation end-use sector accounted for 35 percent of U.S. emissions from fossil fuel combustion in 2009.

through 2009. Emissions from non-energy uses of fossil fuels were 122.1 Tg CO_2 Eq. in 2009, which constituted 2.7 percent of total national CO_2 emissions, approximately the same proportion as in 1990.

- CO_2 emissions from iron and steel production and metallurgical coke production decreased by 25.4 Tg CO_2 Eq. (35.5 percent) from 2008 to 2009, continuing a trend of decreasing emissions from 1990 through 2009 of 57.2 percent (57.0 Tg CO_2 Eq.). This decline is due to the restructuring of the industry, technological improvements, and increased scrap utilization.
- In 2009, CO_2 emissions from cement production decreased by 12.7 Tg CO_2 Eq. (28.5 percent) from 2008. After decreasing in 1991 by two percent from 1990 levels, cement production emissions grew every year through 2006; emissions decreased in the last three years. Overall, from 1990 to 2009, emissions from cement production decreased by 11.6 percent, a decrease of 5.9 Tg CO_2 Eq.
- Net CO_2 uptake from Land Use, Land-Use Change, and Forestry increased by 153.5 Tg CO_2 Eq. (17.8 percent) from 1990 through 2009. This increase was primarily due to an increase in the rate of net carbon accumulation in forest carbon stocks, particularly in aboveground and belowground tree biomass, and harvested wood pools. Annual carbon accumulation in landfilled yard trimmings and food scraps slowed over this period, while the rate of carbon accumulation in urban trees increased.

Methane Emissions

Methane (CH_4) is more than 20 times as effective as CO_2 at trapping heat in the atmosphere (IPCC 1996). Over the last two hundred and fifty years, the concentration of CH_4 in the atmosphere increased by 148 percent (IPCC 2007). Anthropogenic sources of CH_4 include natural gas and petroleum systems, , , agricultural activities, landfills, coal mining, wastewater treatment, stationary and mobile combustion, and certain industrial processes (see Figure ES-8).

Figure ES-8: 2009 Sources of CH_4 Emissions

Some significant trends in U.S. emissions of CH_4 include the following:

- Natural gas systems were the largest anthropogenic source category of CH_4 emissions in the United States in 2009 with 221.2 Tg CO_2 Eq. of CH_4 emitted into the atmosphere. Those emissions have increased by 31.4 Tg CO_2 Eq. (16.6 percent) since 1990. Methane emissions from this source increased 4 percent from 2008 to 2009 due to an increase in production and production wells.
- Enteric Fermentation is the second largest anthropogenic source of CH_4 emissions in the United States. In 2009, enteric fermentation CH_4 emissions were 139.8 Tg CO_2 Eq. (20 percent of total CH_4 emissions), which represents an increase of 7.7 Tg CO_2 Eq. (5.8 percent) since 1990.
- Landfills are the third largest anthropogenic source of CH_4 emissions in the United States, accounting for 17 percent of total CH_4 emissions (117.5 Tg CO_2 Eq.) in 2009. From 1990 to 2009, CH_4 emissions from landfills decreased by 29.9 Tg CO_2 Eq. (20 percent), with small increases occurring in some interim years. This downward trend in overall emissions is the result of increases in the amount of landfill gas collected and combusted, [4] which has more than offset the additional CH_4 emissions resulting from an increase in the amount of municipal solid waste landfilled.
- In 2009, CH_4 emissions from coal mining were 71.0 Tg CO_2 Eq., a 3.9 Tg CO_2 Eq. (5.8 percent) increase over 2008 emission levels. The overall decline of 13.0 Tg CO_2 Eq. (15.5 percent) from 1990 results from the mining of less gassy coal from underground mines and the increased use of CH_4 collected from degasification systems.
- Methane emissions from manure management increased by 55.9 percent since 1990, from 31.7 Tg CO_2 Eq. in 1990 to 49.5 Tg CO_2 Eq. in 2009. The majority of this increase was from swine and dairy cow manure,

[4] The CO_2 produced from combusted landfill CH_4 at landfills is not counted in national inventories as it is considered part of the natural C cycle of decomposition.

since the general trend in manure management is one of increasing use of liquid systems, which tends to produce greater CH_4 emissions. The increase in liquid systems is the combined result of a shift to larger facilities, and to facilities in the West and Southwest, all of which tend to use liquid systems. Also, new regulations limiting the application of manure nutrients have shifted manure management practices at smaller dairies from daily spread to manure managed and stored on site.

Nitrous Oxide Emissions

N_2O is produced by biological processes that occur in soil and water and by a variety of anthropogenic activities in the agricultural, energy-related, industrial, and waste management fields. While total N_2O emissions are much lower than CO_2 emissions, N_2O is approximately 300 times more powerful than CO_2 at trapping heat in the atmosphere (IPCC 1996). Since 1750, the global atmospheric concentration of N_2O has risen by approximately 18 percent (IPCC 2007). The main anthropogenic activities producing N_2O in the United States are agricultural soil management, fuel combustion in motor vehicles, manure management, nitric acid production and stationary fuel combustion, (see Figure ES-9).

Figure ES-9: 2009 Sources of N_2O Emissions

Some significant trends in U.S. emissions of N_2O include the following:

- Agricultural soils accounted for approximately 68.3 percent of N_2O emissions in the United States in 2009. Estimated emissions from this source in 2009 were 204.6 Tg CO_2 Eq. Annual N_2O emissions from agricultural soils fluctuated between 1990 and 2009, although overall emissions were 3.4 percent higher in 2009 than in 1990. N_2O emissions from this source have not shown any significant long-term trend, as they are highly sensitive to the amount of N applied to soils (which has not changed significantly over the time-period), and to weather patterns and crop type.
- In 2009, N_2O emissions from mobile combustion were 27.8 Tg CO_2 Eq. (approximately 5.5 percent of U.S. N_2O emissions). From 1990 to 2009, N_2O emissions from mobile combustion decreased by 36.8 percent. However, from 1990 to 1998 emissions increased by 25.6 percent, due to control technologies that reduced NO_x emissions while increasing N_2O emissions. Since 1998, newer control technologies have led to an overall decline in N_2O from this source.
- N_2O emissions from adipic acid production were 5.9 Tg CO_2 Eq. in 2009, and have decreased significantly since 1996 from the widespread installation of pollution control measures. Emissions from adipic acid production have decreased by 57.7 percent since 1990, and emissions from adipic acid production have remained consistently lower than pre-1996 levels since 1998.

HFC, PFC and SF_6 Emissions

HFCs and PFCs are families of synthetic chemicals that are used as alternatives to ODS, which are being phased out under the Montreal Protocol and Clean Air Act Amendments of 1990. HFCs and PFCs do not deplete the stratospheric ozone layer, and are therefore acceptable alternatives under the Montreal Protocol.

These compounds, however, along with SF_6, are potent greenhouse gases. In addition to having high global warming potentials, SF_6 and PFCs have extremely long atmospheric lifetimes, resulting in their essentially irreversible accumulation in the atmosphere once emitted. Sulfur hexafluoride is the most potent greenhouse gas the IPCC has evaluated (IPCC 1996).

Other emissive sources of these gases include electrical transmission and distribution systems, HCFC-22 production, semiconductor manufacturing, aluminum production, and magnesium production and processing (see Figure ES-10).

Figure ES-10: 2009 Sources of HFCs, PFCs, and SF_6 Emissions

Some significant trends in U.S. HFC, PFC, and SF_6 emissions include the following:

- Emissions resulting from the substitution of ODS (e.g., CFCs) have been consistently increasing, from small amounts in 1990 to 119.3 Tg CO_2 Eq. in 2009. Emissions from ODS substitutes are both the largest and the fastest growing source of HFC, PFC, and SF_6 emissions. These emissions have been increasing as phase-outs required under the Montreal Protocol come into effect, especially after 1994, when full market penetration was made for the first generation of new technologies featuring ODS substitutes.
- HFC emissions from the production of HCFC-22 decreased by 85.2 percent (31.0 Tg CO_2 Eq.) from 1990 through 2009, due to a steady decline in the emission rate of HFC-23 (i.e., the amount of HFC-23 emitted per kilogram of HCFC-22 manufactured) and the use of thermal oxidation at some plants to reduce HFC-23 emissions.
- SF_6 emissions from electric power transmission and distribution systems decreased by 54.8 percent (15.6 Tg CO_2 Eq.) from 1990 to 2009, primarily because of higher purchase prices for SF_6 and efforts by industry to reduce emissions.
- PFC emissions from aluminum production decreased by 91.5 percent (17.0 Tg CO_2 Eq.) from 1990 to 2009, due to both industry emission reduction efforts and lower domestic aluminum production.

Overview of Sector Emissions and Trends

In accordance with the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC/UNEP/OECD/IEA 1997), and the 2003 UNFCCC Guidelines on Reporting and Review (UNFCCC 2003), Figure ES-11 and Table ES-4 aggregate emissions and sinks by these chapters. Emissions of all gases can be summed from each source category from IPCC guidance. Over the twenty-year period of 1990 to 2009, total emissions in the Energy and Agriculture sectors grew by 468.7 Tg CO_2 Eq. (9 percent), and 35.9 Tg CO_2 Eq. (9 percent), respectively. Emissions decreased in the Industrial Processes, Waste, and Solvent and Other Product Use sectors by 52.3 Tg CO_2 Eq. (10 percent), 24.7 Tg CO_2 Eq. (14 percent), and less than 0.1 Tg CO_2 Eq. (0.4 percent), respectively. Over the same period, estimates of net C sequestration in the Land Use, Land-Use Change, and Forestry sector (magnitude of emissions plus CO_2 flux from all LULUCF source categories) increased by 143.5 Tg CO_2 Eq. (17 percent).

Figure ES-11. U.S. Greenhouse Gas Emissions and Sinks by Chapter/IPCC Sector

Table ES-4: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks by Chapter/IPCC Sector (Tg CO_2 Eq.)

Chapter/IPCC Sector	1990	2000	2005	2006	2007	2008	2009
Energy	5,288.7	6,158.4	6,283.1	6,210.9	6,291.5	6,117.1	5,757.0
Industrial Processes	315.8	349.6	324.8	340.2	351.6	332.0	285.5
Solvent and Other Product Use	4.4	4.9	4.4	4.4	4.4	4.4	4.4
Agriculture	383.6	410.6	418.8	418.8	425.8	426.3	419.3
Land Use, Land-Use Change, and Forestry (Emissions)	15.0	56.5	29.6	49.8	47.5	33.2	25.0
Waste	175.2	149.9	144.9	144.4	144.1	149.0	150.5
Total Emissions	6,182.2	7,113.9	7,214.5	7,168.4	7,264.8	7,061.9	6,639.7
Net CO_2 Flux from Land Use, Land-Use Change, and Forestry (Sinks)*	(861.5)	(576.6)	(1,056.5)	(1,064.5)	(1,060.9)	(1,040.5)	(1,015.1)
Net Emissions (Sources and Sinks)	5,320.7	6,537.3	6,158.1	6,104.1	6,203.9	6,021.5	5,624.6

* The net CO_2 Flux total includes both emissions and sequestration, and constitutes a sink in the United States. Sinks are only included in net emissions total.

Note: Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

Energy

The Energy chapter contains emissions of all greenhouse gases resulting from stationary and mobile energy

activities including fuel combustion and fugitive fuel emissions. Energy-related activities, primarily fossil fuel combustion, accounted for the vast majority of U.S. CO_2 emissions for the period of 1990 through 2009. In 2009, approximately 83 percent of the energy consumed in the United States (on a Btu basis) was produced through the combustion of fossil fuels. The remaining 17 percent came from other energy sources such as hydropower, biomass, nuclear, wind, and solar energy (see Figure ES-12). Energy-related activities are also responsible for CH_4 and N_2O emissions (49 percent and 14 percent of total U.S. emissions of each gas, respectively). Overall, emission sources in the Energy chapter account for a combined 87 percent of total U.S. greenhouse gas emissions in 2009.

Figure ES-12: 2009 U.S. Energy Consumption by Energy Source

Industrial Processes

The Industrial Processes chapter contains by-product or fugitive emissions of greenhouse gases from industrial processes not directly related to energy activities such as fossil fuel combustion. For example, industrial processes can chemically transform raw materials, which often release waste gases such as CO_2, CH_4, and N_2O. These processes include iron and steel production and metallurgical coke production, cement production, ammonia production and urea consumption, lime production, limestone and dolomite use (e.g., flux stone, flue gas desulfurization, and glass manufacturing), soda ash production and consumption, titanium dioxide production, phosphoric acid production, ferroalloy production, CO_2 consumption, silicon carbide production and consumption, aluminum production, petrochemical production, nitric acid production, adipic acid production, lead production, and zinc production. Additionally, emissions from industrial processes release HFCs, PFCs, and SF_6. Overall, emission sources in the Industrial Process chapter account for 4 percent of U.S. greenhouse gas emissions in 2009.

Solvent and Other Product Use

The Solvent and Other Product Use chapter contains greenhouse gas emissions that are produced as a by-product of various solvent and other product uses. In the United States, emissions from N_2O from product uses, the only source of greenhouse gas emissions from this sector, accounted for about 0.1 percent of total U.S. anthropogenic greenhouse gas emissions on a carbon equivalent basis in 2009.

Agriculture

The Agriculture chapter contains anthropogenic emissions from agricultural activities (except fuel combustion, which is addressed in the Energy chapter, and agricultural CO_2 fluxes, which are addressed in the Land Use, Land-Use Change, and Forestry Chapter). Agricultural activities contribute directly to emissions of greenhouse gases through a variety of processes, including the following source categories: enteric fermentation in domestic livestock, livestock manure management, rice cultivation, agricultural soil management, and field burning of agricultural residues. CH_4 and N_2O were the primary greenhouse gases emitted by agricultural activities. CH_4 emissions from enteric fermentation and manure management represented 20 percent and 7 percent of total CH_4 emissions from anthropogenic activities, respectively, in 2009. Agricultural soil management activities such as fertilizer application and other cropping practices were the largest source of U.S. N_2O emissions in 2009, accounting for 68 percent. In 2009, emission sources accounted for in the Agriculture chapter were responsible for 6.3 percent of total U.S. greenhouse gas emissions.

Land Use, Land-Use Change, and Forestry

The Land Use, Land-Use Change, and Forestry chapter contains emissions of CH_4 and N_2O, and emissions and removals of CO_2 from forest management, other land-use activities, and land use change. Forest management practices, tree planting in urban areas, the management of agricultural soils, and the landfilling of yard trimmings and food scraps resulted in a net uptake (sequestration) of C in the United States. Forests (including vegetation, soils, and harvested wood) accounted for 65 percent of total 2009 net CO_2 flux, urban trees accounted for 9 percent, mineral and organic soil carbon stock changes accounted for 4 percent, and landfilled yard trimmings and food scraps accounted for 1 percent of the total net flux in 2009. The net forest sequestration is a result of net forest growth and increasing forest area, as well as a net accumulation of carbon stocks in harvested wood pools. The net sequestration in urban forests is a result of net tree growth in these areas. In agricultural soils, mineral and organic soils sequester approximately 5.5 times as much C as is emitted from these soils through liming and urea fertilization. The mineral soil C sequestration is largely due to the conversion of cropland to permanent pastures and

hay production, a reduction in summer fallow areas in semi-arid areas, an increase in the adoption of conservation tillage practices, and an increase in the amounts of organic fertilizers (i.e., manure and sewage sludge) applied to agriculture lands. The landfilled yard trimmings and food scraps net sequestration is due to the long-term accumulation of yard trimming carbon and food scraps in landfills.

Land use, land-use change, and forestry activities in 2009 resulted in a net C sequestration of 1,015.1 Tg CO_2 Eq. (Table ES- 5). This represents an offset of 18 percent of total U.S. CO_2 emissions, or 15 percent of total greenhouse gas emissions in 2009. Between 1990 and 2009, total land use, land-use change, and forestry net C flux resulted in a 17.8 percent increase in CO_2 sequestration, primarily due to an increase in the rate of net C accumulation in forest C stocks, particularly in aboveground and belowground tree biomass, and harvested wood pools. Annual C accumulation in landfilled yard trimmings and food scraps slowed over this period, while the rate of annual C accumulation increased in urban trees.

Table ES- 5: Net CO_2 Flux from Land Use, Land-Use Change, and Forestry (Tg CO_2 Eq.)

Sink Category	1990	2000	2005	2006	2007	2008	2009
Forest Land Remaining Forest Land[a]	(681.1)	(578.5)	(911.5)	(917.5)	(911.9)	(891.0)	(865.1)
Cropland Remaining Cropland	(29.4)	(30.2)	(18.3)	(19.1)	(19.7)	(18.1)	(17.4)
Land Converted to Cropland	2.2	2.4	5.9	5.9	5.9	5.9	5.9
Grassland Remaining Grassland	(52.2)	(52.6)	(8.9)	(8.8)	(8.6)	(8.5)	(8.3)
Land Converted to Grassland	(19.8)	(27.2)	(24.4)	(24.2)	(24.0)	(23.8)	(23.6)
Settlements Remaining Settlements[a]	(57.1)	(77.5)	(87.8)	(89.8)	(91.9)	(93.9)	(95.9)
Other (Landfilled Yard Trimmings and Food Scraps)	(24.2)	(13.2)	(11.5)	(11.0)	(10.9)	(11.2)	(12.6)
Total	(861.5)	(576.6)	(1,056.5)	(1,064.3)	(1,060.9)	(1,040.5)	(1,015.1)

Note: Totals may not sum due to independent rounding. Parentheses indicate net sequestration.

Emissions from Land Use, Land-Use Change, and Forestry are shown in Table ES-6. The application of crushed limestone and dolomite to managed land (i.e., liming of agricultural soils) and urea fertilization resulted in CO_2 emissions of 7.8 Tg CO_2 Eq. in 2009, an increase of 11 percent relative to 1990. The application of synthetic fertilizers to forest and settlement soils in 2009 resulted in direct N_2O emissions of 1.9 Tg CO_2 Eq. Direct N_2O emissions from fertilizer application to forest soils have increased by 455 percent since 1990, but still account for a relatively small portion of overall emissions. Additionally, direct N_2O emissions from fertilizer application to settlement soils increased by 55 percent since 1990. Forest fires resulted in CH_4 emissions of 7.8 Tg CO_2 Eq., and in N_2O emissions of 5.4 Tg CO_2 Eq. in 2009. CO_2 and N_2O emissions from peatlands totaled 1.1 Tg CO_2 Eq. and less than 0.01 Tg CO_2 Eq. in 2009, respectively.

Table ES 6: Emissions from Land Use, Land-Use Change, and Forestry (Tg CO_2 Eq.)

Source Category	1990	2000	2005	2006	2007	2008	2009
CO_2	8.1	8.8	8.9	8.8	9.2	9.6	8.9
Cropland Remaining Cropland: Liming of Agricultural Soils	4.7	4.3	4.3	4.2	4.5	5.0	4.3
Cropland Remaining Cropland: Urea Fertilization	2.4	3.2	3.5	3.7	3.7	3.6	3.6
Wetlands Remaining Wetlands: Peatlands Remaining Peatlands	1.0	1.2	1.1	0.9	1.0	1.0	1.1
CH_4	3.2	14.3	9.8	21.6	20.0	11.9	7.8
Forest Land Remaining Forest Land: Forest Fires	3.2	14.2	9.8	21.6	20.0	11.9	7.8
N_2O	3.7	13.2	9.8	19.5	18.3	11.6	8.3
Forest Land Remaining Forest Land: Forest Fires	2.6	12.7	8.0	17.5	16.3	9.8	6.4
Forest Land Remaining Forest Land: Forest Soils	0.1	0.4	0.4	0.4	0.4	0.4	0.4
Settlements Remaining Settlements: Settlement Soils	1.0	1.1	1.5	1.5	1.6	1.5	1.5
Wetlands Remaining Wetlands: Peatlands Remaining Peatlands	–	–	–	–	–	–	–
Total	15.0	36.3	28.6	49.8	47.5	33.2	25.0

– Less than 0.05 Tg CO_2 Eq.

Note: Totals may not sum due to independent rounding.

Waste

The Waste chapter contains emissions from waste management activities (except incineration of waste, which is addressed in the Energy chapter). Landfills were the largest source of anthropogenic greenhouse gas emissions in the Waste chapter, accounting for just over 78 percent of this chapter's emissions, and 17 percent of total U.S. CH_4 emissions.[15] Additionally, wastewater treatment accounts for 20 percent of Waste emissions, 4 percent of U.S. CH_4 emissions, and 2 percent of U.S. N_2O emissions. Emissions of CH_4 and N_2O from composting are also accounted for in this chapter, generating emissions of 1.7 Tg CO_2 Eq. and 1.8 Tg CO_2 Eq., respectively. Overall, emission sources accounted for in the Waste chapter generated 2.3 percent of total U.S. greenhouse gas emissions in 2009.

Other Information

Emissions by Economic Sector

Throughout the Inventory of U.S. Greenhouse Gas Emissions and Sinks report, emission estimates are grouped into six sectors (i.e., chapters) defined by the IPCC: Energy; Industrial Processes; Solvent Use; Agriculture; Land Use, Land-Use Change, and Forestry; and Waste. While it is important to use this characterization for consistency with UNFCCC reporting guidelines, it is also useful to allocate emissions into more commonly used sectoral categories. This section reports emissions by the following economic sectors: Residential, Commercial, Industry, Transportation, Electricity Generation, Agriculture, and U.S. Territories.

Table ES-7 summarizes emissions from each of these sectors, and Figure ES-13 shows the trend in emissions by sector from 1990 to 2009.

Figure ES-13: Emissions Allocated to Economic Sectors

Table ES-7: U.S. Greenhouse Gas Emissions Allocated to Economic Sectors (Tg CO_2 Eq.)

Implied Sectors	1990	2000	2005	2006	2007	2008	2009
Electric Power Industry	1,868.9	2,337.6	2,444.6	2,388.2	2,454.0	2,400.7	2,193.0
Transportation	1,545.2	1,952.5	2,013.4	1,994.4	2,003.7	1,890.7	1,815.8
Industry	1,564.9	1,545.2	1,442.9	1,458.8	1,484.5	1,448.9	1,320.5
Agriculture	429.0	485.1	493.2	516.7	520.7	503.9	499.0
Commercial	395.5	381.4	387.2	375.2	389.6	403.5	404.3
Residential	345.1	386.2	371.0	339.8	358.8	360.8	360.5
U.S. Territories	33.7	46.3	58.2	59.3	53.5	68.4	65.5
Total Emissions	6,182.2	7,113.9	7,214.5	7,168.4	7,264.8	7,061.9	6,039.7
Land Use, Land-Use Change, and Forestry (Sinks)	(861.5)	(576.6)	(1,056.5)	(1,064.3)	(1,060.9)	(1,040.5)	(1,015.1)
Net Emissions (Sources and Sinks)	5,320.7	6,537.3	6,158.1	6,104.1	6,203.9	6,021.5	5,024.6

Note: Totals may not sum due to independent rounding. Sectors include CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6.
See Table 2-12 for more detailed data.

Using this categorization, emissions from electricity generation accounted for the largest portion (33 percent) of U.S. greenhouse gas emissions in 2009. Transportation activities, in aggregate, accounted for the second largest portion (27 percent), while emissions from industry accounted for the third largest portion (20 percent) of U.S. greenhouse gas emissions in 2009. In contrast to electricity generation and transportation, emissions from industry have in general declined over the past decade. The long-term decline in these emissions has been due to structural changes in the U.S. economy (i.e., shifts from a manufacturing-based to a service-based economy), fuel switching, and energy efficiency improvements. The remaining 20 percent of U.S. greenhouse gas emissions were contributed by, in order of importance, the agriculture, commercial, and residential sectors, plus emissions from U.S. territories.

[15] Landfills also store carbon due to incomplete degradation of organic materials such as wood products and yard trimmings, as described in the Land-Use, Land-Use Change, and Forestry chapter of the Inventory report.

Activities related to agriculture accounted for 7 percent of U.S. emissions. Unlike other economic sectors, agricultural sector emissions were dominated by N_2O emissions from agricultural soil management and CH_4 emissions from enteric fermentation. The commercial sector accounted for 6 percent of emissions while the residential sector accounted for 5 percent of emissions and U.S. territories accounted for 1 percent of emissions; emissions from these sectors primarily consisted of CO_2 emissions from fossil fuel combustion.

CO_2 was also emitted and sequestered by a variety of activities related to forest management practices, tree planting in urban areas, the management of agricultural soils, and landfilling of yard trimmings.

Electricity is ultimately consumed in the economic sectors described above. Table ES-8 presents greenhouse gas emissions from economic sectors with emissions related to electricity generation distributed into end-use categories (i.e., emissions from electricity generation are allocated to the economic sectors in which the electricity is consumed). To distribute electricity emissions among end-use sectors, emissions from the source categories assigned to electricity generation were allocated to the residential, commercial, industry, transportation, and agriculture economic sectors according to retail sales of electricity.[16] These source categories include CO_2 from fossil fuel combustion and the use of limestone and dolomite for flue gas desulfurization, CO_2 and N_2O from incineration of waste, CH_4 and N_2O from stationary sources, and SF_6 from electrical transmission and distribution systems.

When emissions from electricity are distributed among these sectors, industrial activities account for the largest share of U.S. greenhouse gas emissions (29 percent) in 2009. Transportation is the second largest contributor to total U.S. emissions (27 percent). The commercial and residential sectors contributed the next largest shares of total U.S. greenhouse gas emissions in 2009. Emissions from these sectors increase substantially when emissions from electricity are included, due to their relatively large share of electricity consumption (e.g., lighting, appliances, etc.). In all sectors except agriculture, CO_2 accounts for more than 80 percent of greenhouse gas emissions, primarily from the combustion of fossil fuels. Figure ES-14 shows the trend in these emissions by sector from 1990 to 2009.

Table ES-8: U.S Greenhouse Gas Emissions by Economic Sector with Electricity-Related Emissions Distributed (Tg CO_2 Eq.)

Implied Sectors	1990	2000	2005	2006	2007	2008	2009
Industry	2,238.7	2,315.6	2,169.5	2,196.1	2,194.4	2,147.6	1,918.9
Transportation	1,548.3	1,936.8	2,022.2	1,999.0	2,008.9	1,995.4	1,820.3
Commercial	947.7	1,135.8	1,205.1	1,188.5	1,225.3	1,224.5	1,179.7
Residential	953.8	1,162.2	1,242.8	1,181.4	1,229.5	1,214.8	1,159.3
Agriculture	460.0	518.4	522.7	544.1	553.2	531.1	516.0
U.S. Territories	33.7	46.0	58.2	59.3	53.5	48.4	45.5
Total Emissions	6,182.2	7,113.9	7,214.5	7,168.4	7,264.8	7,061.9	6,639.7
Land Use, Land-Use Change, and Forestry (Sinks)	(861.5)	(576.6)	(1,056.5)	(1,064.3)	(1,060.9)	(1,040.5)	(1,015.1)
Net Emissions (Sources and Sinks)	5,320.7	6,537.3	6,158.1	6,104.1	6,203.9	6,021.5	5,624.6

See Table 2-14 for more detailed data.

Figure ES-14: Emissions with Electricity Distributed to Economic Sectors

[BEGIN BOX]

Box ES-2: Recent Trends in Various U.S. Greenhouse Gas Emissions-Related Data

[16] Emissions were not distributed to U.S. territories, since the electricity generation sector only includes emissions related to the generation of electricity in the 50 states and the District of Columbia.

Total emissions can be compared to other economic and social indices to highlight changes over time. These comparisons include: (1) emissions per unit of aggregate energy consumption, because energy-related activities are the largest sources of emissions; (2) emissions per unit of fossil fuel consumption, because almost all energy-related emissions involve the combustion of fossil fuels; (3) emissions per unit of electricity consumption, because the electric power industry—utilities and nonutilities combined—was the largest source of U.S. greenhouse gas emissions in 2009; (4) emissions per unit of total gross domestic product as a measure of national economic activity; and (5) emissions per capita.

Table ES-9 provides data on various statistics related to U.S. greenhouse gas emissions normalized to 1990 as a baseline year. Greenhouse gas emissions in the United States have grown at an average annual rate of 0.4 percent since 1990. This rate is slightly slower than that for total energy and for fossil fuel consumption, and much slower than that for electricity consumption, overall gross domestic product and national population (see Figure ES-15).

Table ES-9 Recent Trends in Various U.S. Data (Index 1990 = 100)

Variable	1990	2000	2005	2006	2007	2008	2009	Growth Rate[a]
GDP[b]	100	140	157	162	165	165	160	2.5%
Electricity Consumption[c]	100	127	134	135	138	138	132	1.5%
Fossil Fuel Consumption[c]	100	117	119	117	119	116	108	0.5%
Energy Consumption[c]	100	116	118	118	120	118	112	0.5%
Population[d]	100	113	118	120	121	122	123	1.1%
Greenhouse Gas Emissions[e]	100	115	117	116	118	114	107	0.4%

[a] Average annual growth rate
[b] Gross Domestic Product in chained 2005 dollars (BEA 2010)
[c] Energy content-weighted values (EIA 2010b)
[d] U.S. Census Bureau (2010)
[e] GWP-weighted values

Figure ES-15 U.S. Greenhouse Gas Emissions Per Capita and Per Dollar of Gross Domestic Product
Source: BEA (2010), U.S. Census Bureau (2010), and emission estimates in this report

[END BOX]

Indirect Greenhouse Gases (CO, NO_x, NMVOCs, and SO_2) – TO BE UPDATED

The reporting requirements of the UNFCCC[7] request that information be provided on indirect greenhouse gases, which include CO, NO_x, NMVOCs, and SO_2. These gases do not have a direct global warming effect, but indirectly affect terrestrial radiation absorption by influencing the formation and destruction of tropospheric and stratospheric ozone, or, in the case of SO_2, by affecting the absorptive characteristics of the atmosphere. Additionally, some of these gases may react with other chemical compounds in the atmosphere to form compounds that are greenhouse gases.

Since 1970, the United States has published estimates of annual emissions of CO, NO_x, NMVOCs, and SO_2 (EPA 2009),[8] which are regulated under the Clean Air Act. Table ES- 10 shows that fuel combustion accounts for the majority of emissions of these indirect greenhouse gases. Industrial processes—such as the manufacture of chemical and allied products, metals processing, and industrial uses of solvents—are also significant sources of CO, NO_x, and NMVOCs.

Table ES- 10: Emissions of NO_x, CO, NMVOCs, and SO_2 (Gg)

[7] See <http://unfccc.int/resource/docs/cop8/08.pdf>.

[8] NO_x and CO emission estimates from field burning of agricultural residues were estimated separately, and therefore not taken from EPA (2009).

Gas/Activity	1990	2000	2005	2006	2007	2008	2009
NO_x	21,728	19,145	15,933	15,072	14,410	13,578	
Mobile Fossil Fuel Combustion	10,862	10,159	9,032	8,486	7,965	7,441	
Stationary Fossil Fuel Combustion	10,023	8,052	5,858	5,545	5,432	5,148	
Industrial Processes	592	626	569	553	537	520	
Oil and Gas Activities	139	313	321	319	318	318	
Incineration of Waste	82	114	129	121	114	106	
Agricultural Burning	30	37	40	46	38	40	
Solvent Use	1	3	3	4	4	4	
Waste	0	2	2	2	2	2	
CO	130,536	92,872	71,555	67,909	64,348	60,739	
Mobile Fossil Fuel Combustion	119,360	83,559	62,593	58,972	55,253	51,533	
Stationary Fossil Fuel Combustion	5,000	4,140	4,649	4,695	4,744	4,792	
Industrial Processes	4,125	2,219	1,595	1,597	1,640	1,682	
Incineration of Waste	938	1,650	1,403	1,412	1,421	1,430	
Agricultural Burning	769	883	930	905	960	970	
Oil and Gas Activities	302	146	318	319	328	322	
Waste	1	5	7	7	7	7	
Solvent Use	5	45	2	2	2	2	
NMVOCs	20,930	15,227	13,761	13,594	13,423	13,254	
Mobile Fossil Fuel Combustion	10,932	7,229	6,330	6,037	5,742	5,447	
Solvent Use	5,216	4,384	3,851	3,846	3,839	3,834	
Industrial Processes	2,422	1,773	1,997	1,933	1,869	1,804	
Stationary Fossil Fuel Combustion	912	1,077	716	918	1,120	1,321	
Oil and Gas Activities	554	388	510	510	509	509	
Incineration of Waste	222	257	241	238	234	230	
Waste	673	119	114	113	111	109	
Agricultural Burning	NA	NA	NA	NA	NA	NA	
SO_2	20,935	14,830	13,466	12,388	11,799	10,368	
Stationary Fossil Fuel Combustion	18,407	12,849	11,541	10,612	10,172	8,891	
Industrial Processes	1,307	1,031	831	818	807	795	
Mobile Fossil Fuel Combustion	793	652	839	759	611	472	
Oil and Gas Activities	390	281	181	182	184	187	
Incineration of Waste	38	29	24	24	24	23	
Waste	0	1	1	1	1	1	
Solvent Use	0	1	0	0	0	0	
Agricultural Burning	NA	NA	NA	NA	NA	NA	

Source: (EPA 2009, disaggregated based on EPA 2003) except for estimates from field burning of agricultural residues.
NA (Not Available)
Note: Totals may not sum due to independent rounding.

Key Categories

The 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006) defines a key category as a "'source or sink category' that is prioritized within the national inventory system because its estimate has a significant influence on a country's total inventory of direct greenhouse gases in terms of the absolute level of emissions, the trend in emissions, or both."[19] By definition, key categories are sources or sinks that have the greatest contribution to the absolute overall level of national emissions in any of the years covered by the time series. In addition, when an entire time series of emission estimates is prepared, a thorough investigation of key categories must also account for the influence of trends of individual source and sink categories. Finally, a qualitative evaluation of key categories should be performed, in order to capture any key categories that were not

[19] See Chapter 7 "Methodological Choice and Recalculation" in IPCC (2006) <http://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch7.pdf>

identified in either of the quantitative analyses

Figure ES-16 presents 2009 emission estimates for the key categories as defined by a level analysis (i.e., the contribution of each source or sink category to the total inventory level). The UNFCCC reporting guidelines request that key category analyses be reported at an appropriate level of disaggregation, which may lead to source and sink category names which differ from those used elsewhere in the inventory report. For more information regarding key categories, see section 1.5 and Annex 1 of the inventory report.

Figure ES-16: 2009 Key Categories

Quality Assurance and Quality Control (QA/QC)

The United States seeks to continually improve the quality, transparency, and credibility of the Inventory of U.S. Greenhouse Gas Emissions and Sinks. To assist in these efforts, the United States implemented a systematic approach to QA/QC. While QA/QC has always been an integral part of the U.S. national system for inventory development, the procedures followed for the current inventory have been formalized in accordance with the QA/QC plan and the UNFCCC reporting guidelines.

Uncertainty Analysis of Emission Estimates

While the current U.S. emissions inventory provides a solid foundation for the development of a more detailed and comprehensive national inventory, there are uncertainties associated with the emission estimates. Some of the current estimates, such as those for CO_2 emissions from energy-related activities and cement processing, are considered to have low uncertainties. For some other categories of emissions, however, a lack of data or an incomplete understanding of how emissions are generated increases the uncertainty associated with the estimates presented. Acquiring a better understanding of the uncertainty associated with inventory estimates is an important step in helping to prioritize future work and improve the overall quality of the inventory. Recognizing the benefit of conducting an uncertainty analysis, the UNFCCC reporting guidelines follow the recommendations of the IPCC Good Practice Guidance (IPCC 2000) and require that countries provide single estimates of uncertainty for source and sink categories.

Currently, a qualitative discussion of uncertainty is presented for all source and sink categories. Within the discussion of each emission source, specific factors affecting the uncertainty surrounding the estimates are discussed. Most sources also contain a quantitative uncertainty assessment, in accordance with UNFCCC reporting guidelines.

[BEGIN BOX]

Box ES-3. Recalculations of Inventory Estimates

Each year, emission and sink estimates are recalculated and revised for all years in the Inventory of U.S. Greenhouse Gas Emissions and Sinks, as attempts are made to improve both the analyses themselves, through the use of better methods or data, and the overall usefulness of the report. In this effort, the United States follows the IPCC Good Practice Guidance (IPCC 2000), which states, regarding recalculations of the time series, "It is good practice to recalculate historic emissions when methods are changed or refined, when new source categories are included in the national inventory, or when errors in the estimates are identified and corrected." In general, recalculations are made to the U.S. greenhouse gas emission estimates either to incorporate new methodologies or, most commonly, to update recent historical data.

In each Inventory report, the results of all methodology changes and historical data updates are presented in the "Recalculations and Improvements" chapter; detailed descriptions of each recalculation are contained within each source's description contained in the report, if applicable. In general, when methodological changes have been implemented, the entire time series (in the case of the most recent inventory report, 1990 through 2009) has been recalculated to reflect the change, per IPCC Good Practice Guidance (IPCC 2000). Changes in historical data are generally the result of changes in statistical data supplied by other agencies. References for the data are provided for additional information.

[END BOX]

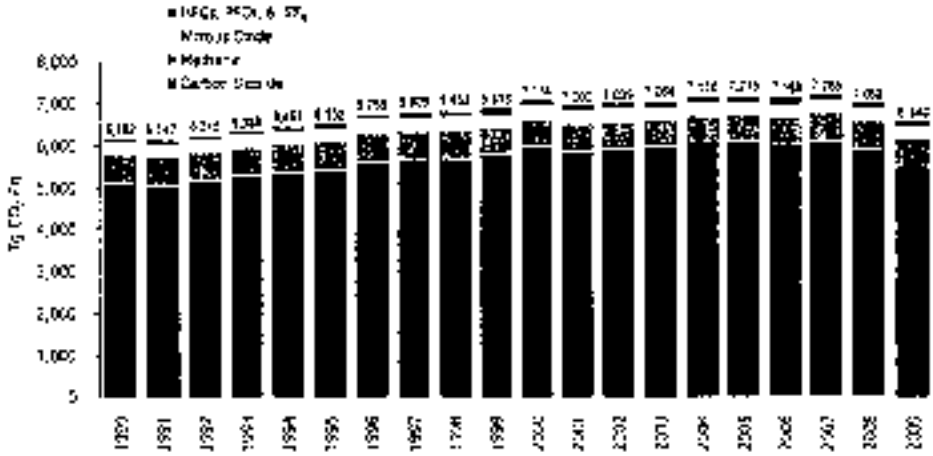


Figure ES-1 U.S. Greenhouse Gas Emissions by Gas

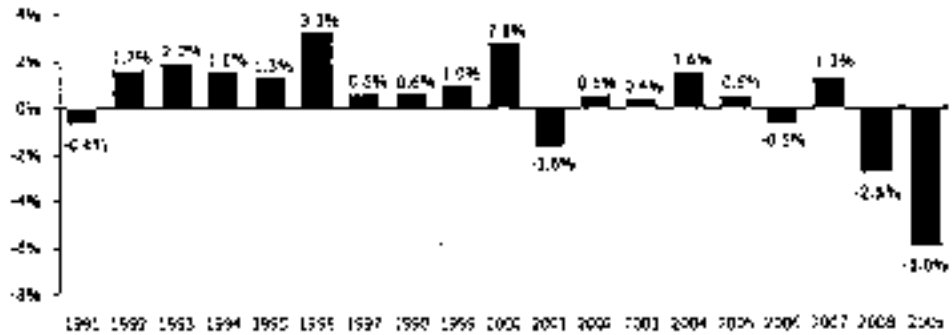


Figure ES-2 Annual Percent Change in U.S. Greenhouse Gas Emissions

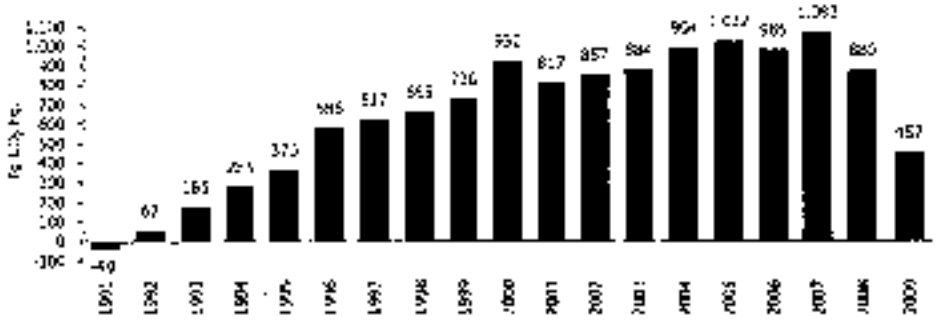


Figure ES-3: Cumulative Change in Annual U.S. Greenhouse Gas Emissions Relative to 1990

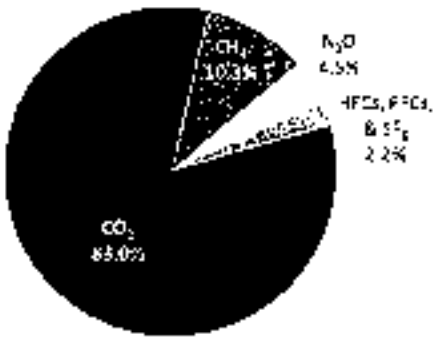


Figure ES-4: 2009 Greenhouse Gas Emissions by Gas (percents based on Tg CO_2 Eq.)

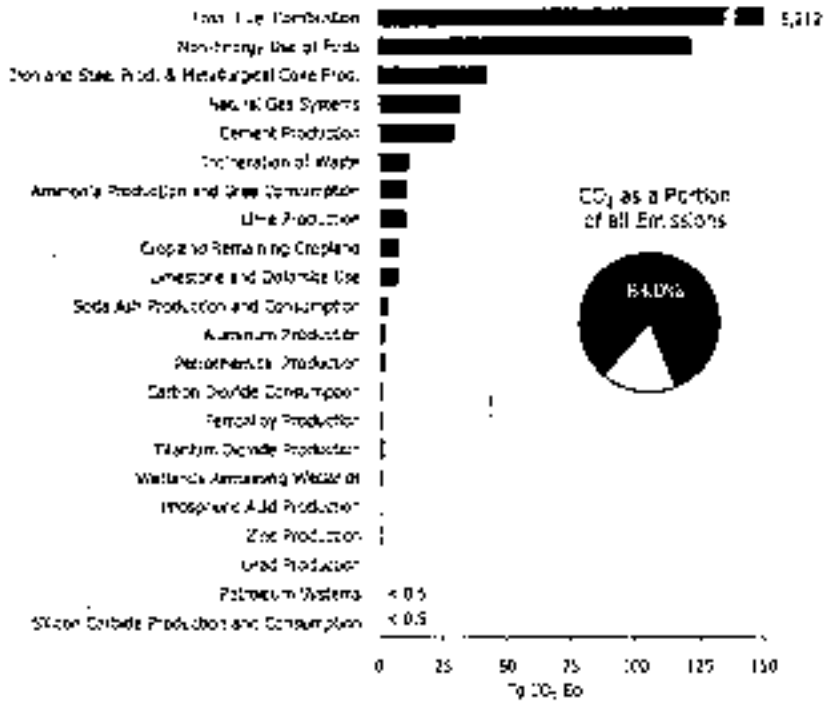


Figure ES-5: 2009 Sources of CO_2 Emissions

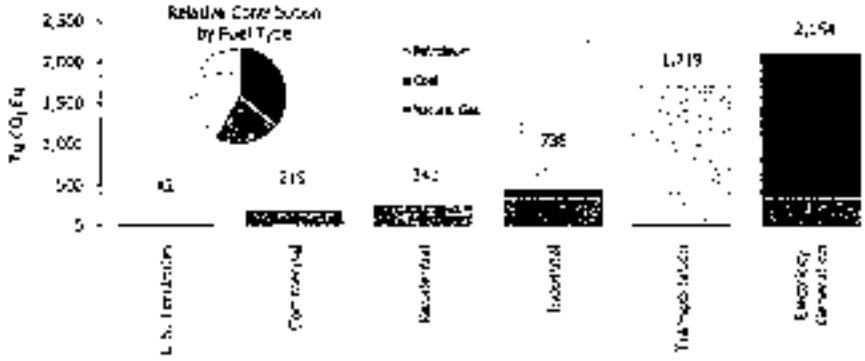


Figure ES-6: 2009 CO_2 Emissions from Fossil Fuel Combustion by Sector and Fuel Type

Note: Electricity generation also includes emissions of less than 0.5 Tg CO_2 Eq from geothermal-based electricity generation.

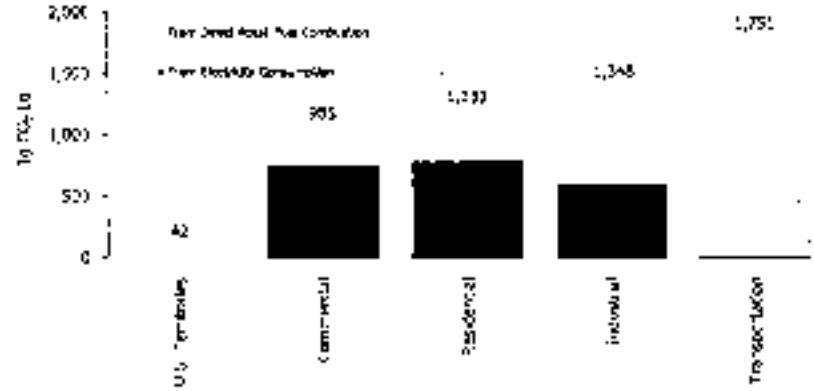


Figure ES-7: 2009 End-Use Sector Emissions of CO_2, CH_4, and N_2O from Fossil Fuel Combustion

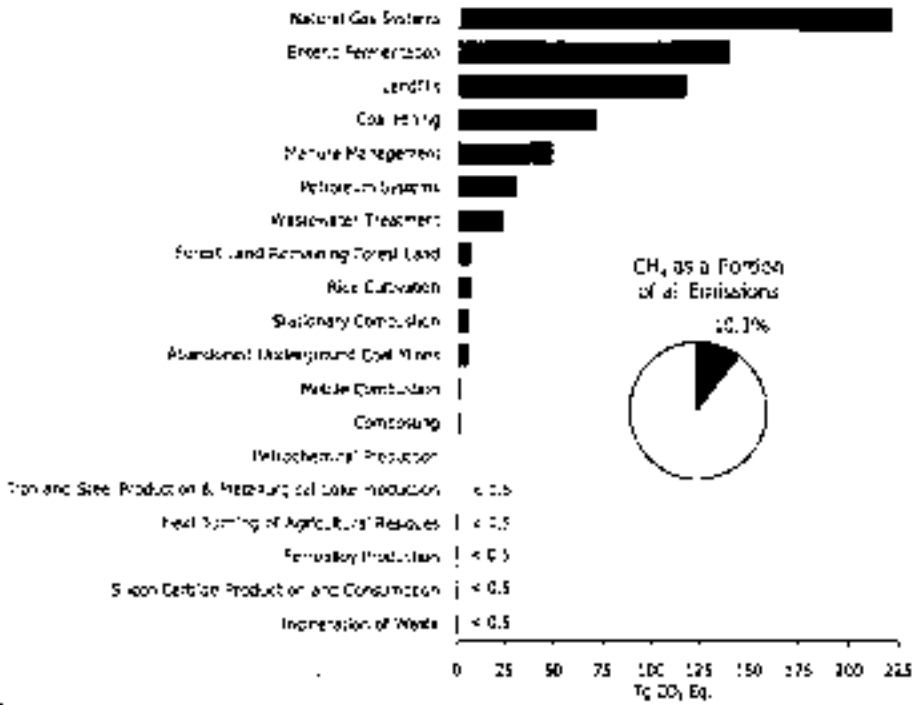


Figure ES-8: 2009 Sources of CH_4 Emissions

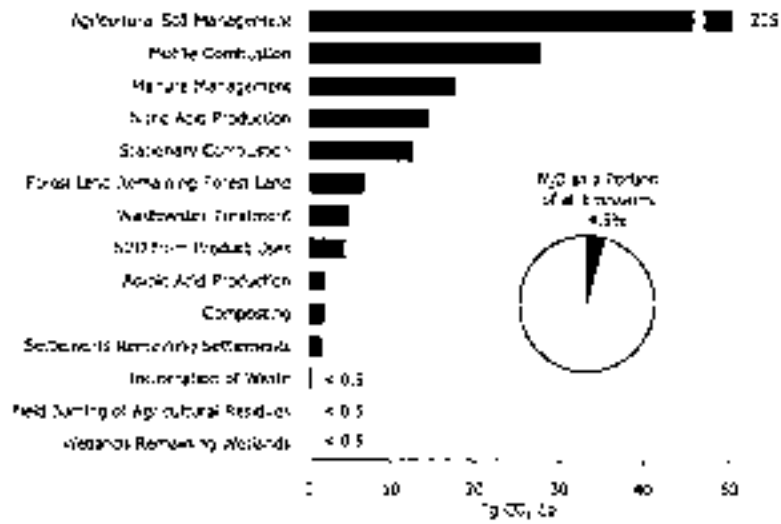


Figure ES-9: 2009 Sources of N_2O Emissions

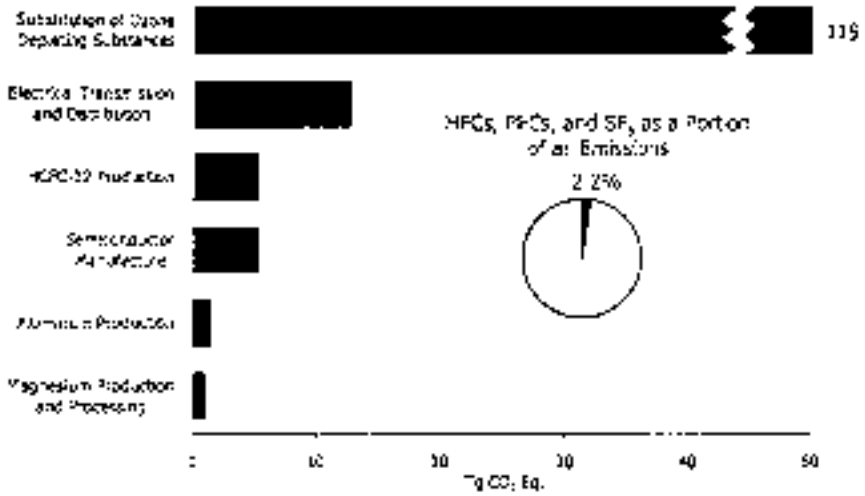
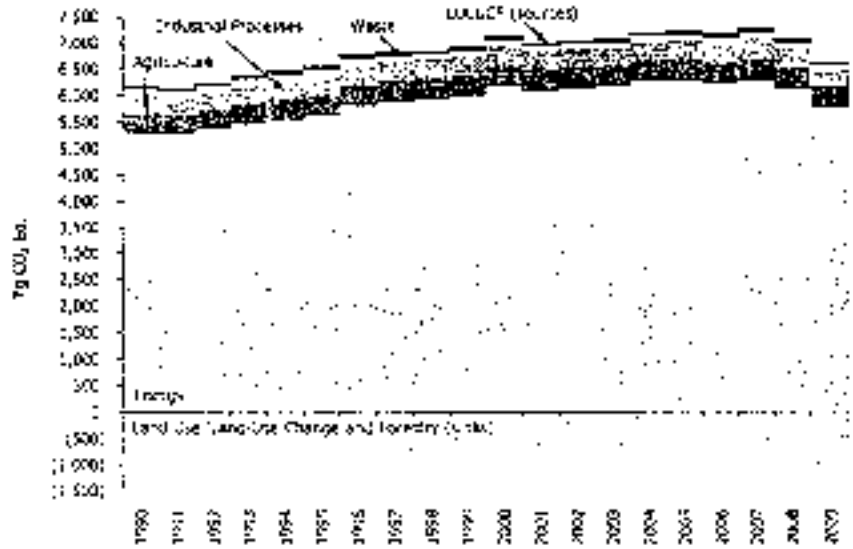


Figure ES-10: 2009 Sources of HFCs, PFCs, and SF_6 Emissions



Note: Recovery and other amounts of CH4 recognized emissions are also omitted from the Solvent and Other Product Use sectors.

Figure ES-11: U.S. Greenhouse Gas Emissions and Sinks by Chapter/IPCC Sector

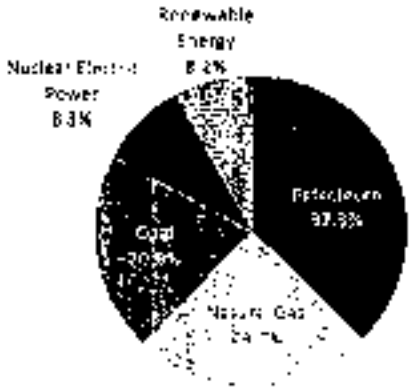


Figure ES-12: 2009 U.S. Energy Consumption by Energy Source

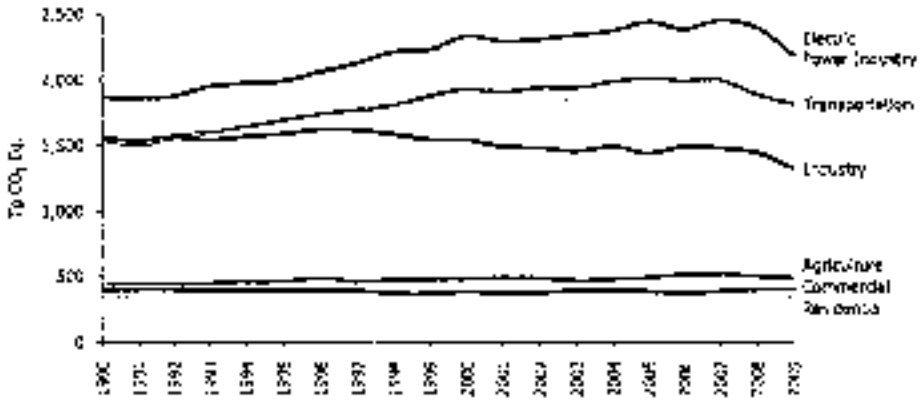


Figure ES-13: Emissions Allocated to Economic Sectors
Note: Does not include U.S. Territories.

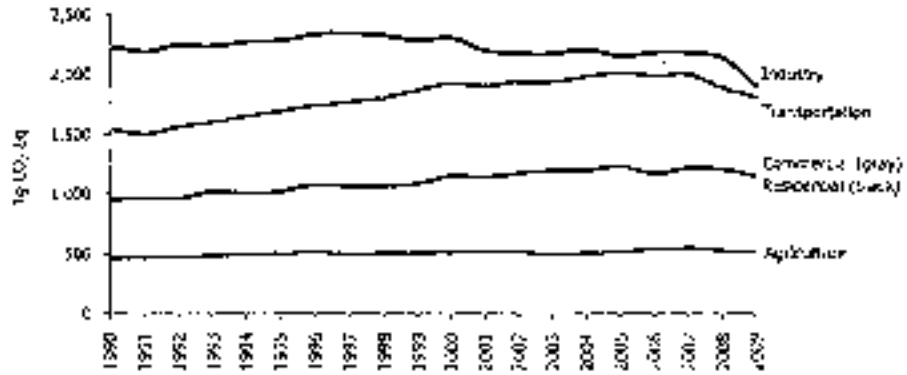


Figure ES-14: Emissions with Electricity Distributed to Economic Sectors
Note: Does not include U.S. Territories

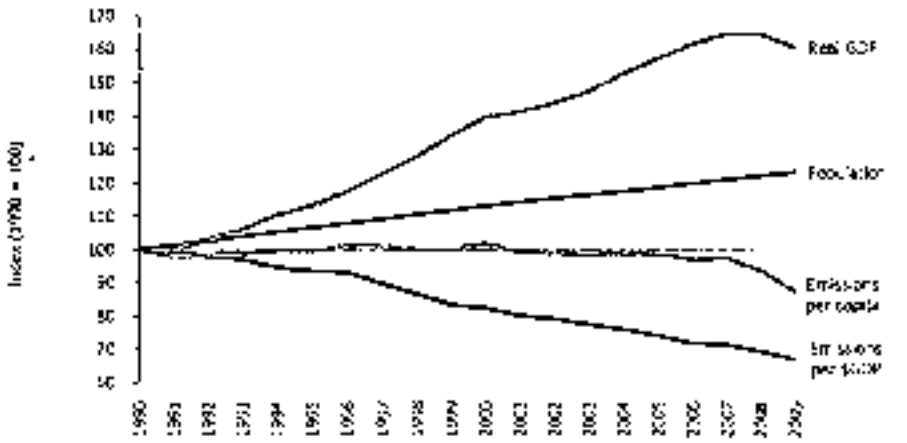


Figure ES-15: U.S. Greenhouse Gas Emissions Per Capita and Per Dollar of Gross Domestic Product

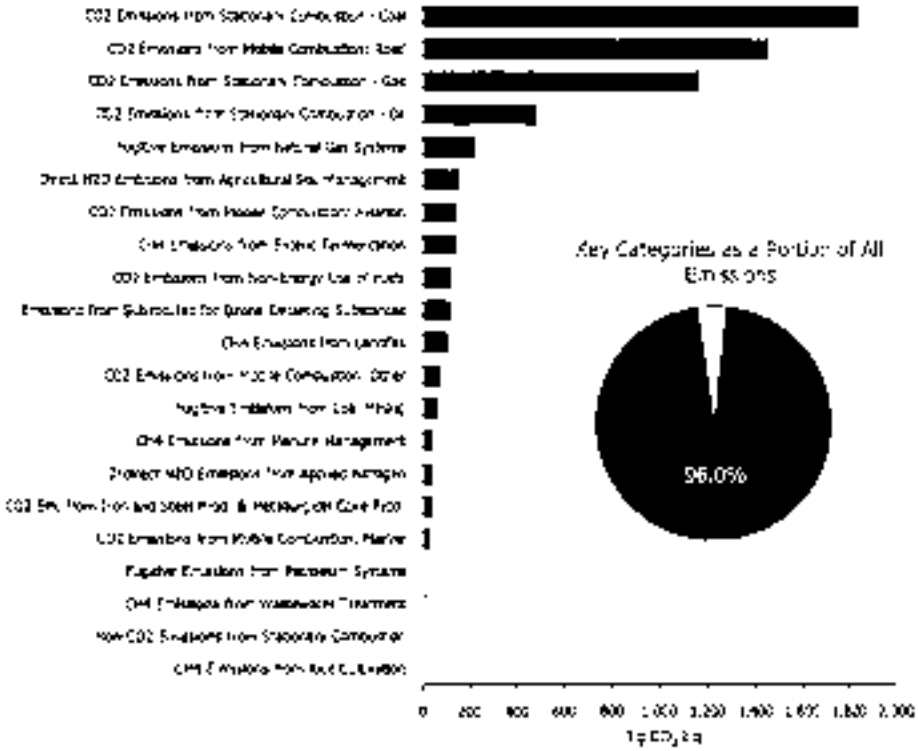


Figure ES-16: 2003 Key Categories

Notes: For a complete discussion of the key category analysis, see Annex 1
Black bars indicate a Tier 1 level assessment key category
Gray bars indicate a Tier 2 level assessment key category.

Print Close

Federal Government Charges Up Electric Car Market

By Judson Berger

Published February 15, 2011 | FoxNews.com

The federal government is hitting the gas on incentive programs meant to propel the electric car market, raising questions about whether it's appropriate for Washington to continue subsidizing an industry it's already invested in heavily.

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As part of that interplay, nine cities across the country are set to receive thousands of free charging stations this year as part of a special program. In Austin, one of the lucky cities, the City Council could vote as early as this week to set the rates for those stations.

If the local utility company has its way, drivers will get a deal — a $25 flat fee for six months of unlimited charging. The deal is to serve electric car owners, while making prospective buyers comfortable with the technology, potentially inspiring them to buy an electric vehicle of their own.

But the experiment is coming at a cost to taxpayers, who whether they realize it or not are subsidizing several initiatives designed to boost the electric vehicle market — raising concerns among free enterprisers.

If electric cars are the wave of the future, they say, the industry should be able to attract private investment. If it's not, then the government is throwing away money. And if it's a viable idea but not quite ready for prime time, they worry the government is pushing it out too early, falling the sector to live off a perpetual federal lifeline the way ethanol, sugar and other commodities have done.

"I have never seen an industry that receives subsidies for any period of time like this that didn't fail and then cost taxpayers even more," said David Lindman, senior economist at the Michigan-based Mackinac Center for Public Policy.

The auto industry, government officials and environmentalists are hopeful that electric car technology can take off. The benefits are apparent — a nationwide electric or hybrid-car craze would reduce pollution and help wean the United States off foreign oil.

But several barriers remain. A report released last fall from J.D. Power and Associates found that consumers are worried about the relatively short driving range of the vehicles, the amount of time it takes to charge them and the higher retail cost. The first two concerns are more applicable to all-electric cars than hybrid ones. The Nissan LEAF, for instance, takes six to eight hours to charge and has a range of about 100 miles.

"I certainly would not be a car you would be very comfortable driving through West Virginia," the Cato Institute's Patrick Michaels said of the all-battery vehicles. He said the industry is understandably jittery about the new investment.

"If they could easily make money from it without a federal subsidy, they would be there. Obviously, they don't think there's a big demand," he said.

But that's exactly why the government is getting involved — to incentivize the industry, and consumers, on the front end with the hope of building the groundwork for a bona fide market that would be good for America's economic and energy security.

The Alliance of Automobile Manufacturers has described the Obama administration's support as foolicant. The administration has set a goal of getting 1 million electric vehicles on the road by

2015. To advance that goal, the administration also reportedly has included a $7,500 rebate in its 2012 budget proposal for drivers who buy electric vehicles.

"It's a slow process for a few years, but eventually people are predicting that this will really take off," said Carlos Cordova, spokesman with Austin Energy, the local utility company that will operate charging stations in Austin.

Karl Rabago, Austin Energy's vice president for distributed energy services, said the federal aid is critical for getting the market off the ground. He said the subsidies won't be indefinite and expressed confidence that the industry can eventually survive on its own. He said the private sector is eager to step in with investment as soon as it has the confidence it will pay off.

"Customers are just not going to buy these cars until they can look around and say, I'm comfortable. I won't feel stranded." This is the chicken that has to come before the egg," Rabago told FoxNews.com. "This is just government doing what government does best."

The plug-in station program is a $37 million subsidized initiative run by Coulomb Technologies. Fifteen million dollars came from the 2008 federal stimulus, another few million came from the California Energy Commission and the rest came from Coulomb and other sources. Coulomb already sells charging units on its own, outside the program. But through what's known as the ChargePoint America initiative, it plans to deliver nearly 5,000 of them to Austin, Detroit, Los Angeles, Orlando and other cities.

In Austin, the city is getting more than 100 stations -- worth about $700 apiece -- free of charge from Coulomb. Austin Energy and other private companies will front the cost, estimated at about $3,000 apiece, for installing the stations.

Rabago said that if the program were not subsidized, his company could probably afford to get on board, considering the cost of the units. But he said, "it just makes it a lot easier."

"Utilities are, I think the word is, conservative," Rabago said.

But some worry the government is taking a risk on behalf of taxpayers, better reserved for venture capitalists, banks and the companies themselves. Lithmann said that if and when the technology is at a marketable level, "there's plenty of capital here, and worldwide, and plenty of entrepreneurs to take care of that for expanding demand."

Nick Loris, a research associate at the Heritage Foundation, said he assumes America's vehicle fleet will look a lot different 50 years from now, but that it's not the government's role to promote electric vehicles before they're "economically viable."

Michael Quinn Sullivan, president of Texans for Fiscal Responsibility, said his organization takes a "dim view" of the charging station program in his state.

"Electric cars -- by definition -- shouldn't require a jump start, and neither should their market," he said in an e-mail. "If the people benefiting from the sale of the cars won't invest in the infrastructure to make core consumers confident about the product, it's troubling taxpayers would be asked to do so. Taxpayer subsidies become a narcotic, and once begun, it's hard to wean off."

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The President's 2012 Budget, Local Governments, and Sustainability

climate policy · funding opportunities · energy efficiency

Feb 15, 2011

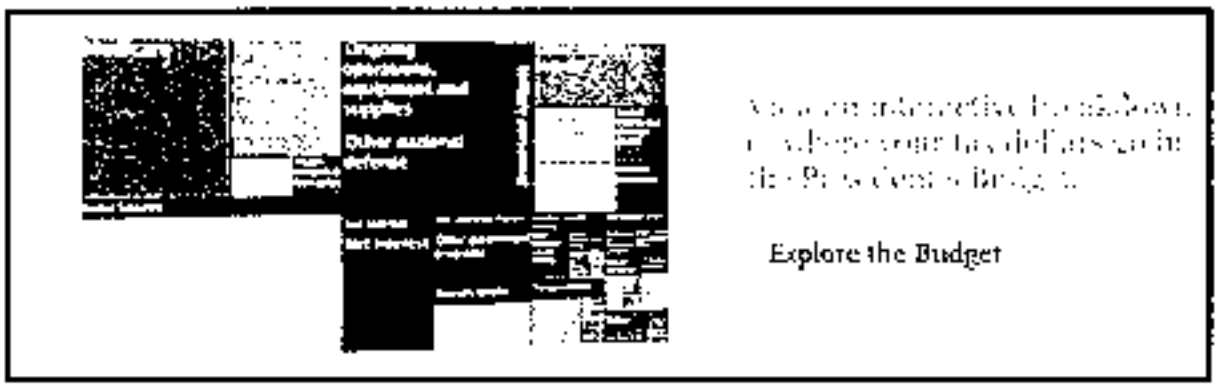

Photo credit: Whitehouse.gov

The President released his budget proposal to Congress today for FY2012. While today's proposal will undoubtedly go through many changes given the recent shifts in power in Washington, the announcement provided insight into his priorities for energy, the environment, land use, transportation and infrastructure.

Of interest to local governments advancing sustainability:

Block Grant Programs

- Community Development Block Grants reduced
  - A reduction of the overall program by 7.5%

- Energy Efficiency and Conservation Block Grants unfunded
  - The budget does not call for any funding of this program

Land Use, Transportation and Infrastructure

- Sustainable Communities Partnership maintained
  - The budget calls to sustain the current level of support for the HUD, DOT, EPA Sustainable Communities Partnership - $150 Million

- Surface Transportation Reauthorization proposal
  - The overall $556 Billion, six-year proposal includes $32 billion competitive grant programs designed to create incentives for state and local partners to adopt critical reforms in variety of areas, including safety, livability, lowering greenhouse gas emissions and addressing demand management

- High-speed rail proposed
  - $53 billion for high speed rail funding over six years proposed

- One million electric vehicles by 2015 proposed
  - $200 million in a competitive grant program to encourage communities to invest in electric vehicle infrastructure

- State Revolving Fund cuts
  - A proposed reduction of funding totaling $947 million from 2010 levels for the Clean Water and Drinking Water State Revolving Funds (SRFs) budget

- Green infrastructure capacity building
  - The budget calls for a sustainable water infrastructure policy that focuses on working with states and communities to enhance technical, managerial, and financial capacity including enhancing alternatives analysis to expand "green infrastructure" options and their multiple benefits.

Environment

- EPA authority over greenhouse gasses
  - Of most interest to localities that own power producing utilities, the budget calls for $46 million for the EPA to regulate GHGs through a permitting program to address the causes of climate change.

- State air programs
  - The budget proposes $306 million in state grant funding from the EPA for air programs

Energy

- 80% "clean energy" by 2035 proposed
  - The President proposed a national "Clean Energy Standard" that includes renewables,

natural gas, nuclear and "clean coal."
    - Part of this standard will include a new initiative to upgrade commercial buildings, municipal buildings, universities and hospitals.

- A call for the repeal of $4B in fossil fuel subsidies

- Commercial buildings – 20% more energy efficient in 10 years proposed
    - Leveraging private sector investment through incentives to upgrade buildings.
    - "Race to the Green" incentives to promote voluntary and experimental regulatory reform and other investments at the local level

- Residential buildings
    - $6B for the President's proposed "Homestar" program to provide incentives to homeowners for residential upfits

- Power Saver Loan Guarantee Program
    - Designed to supplement currently hampered local level Property Assessed Clean Energy (PACE) financing programs. The Power Saver pilot program would deploy up to $25 million to participating lenders to support energy efficient mortgages for homeowners up to $25,000.

- Energy Star increases
    - Provides an increase of $3M to the Energy Star program, some of which will go to strengthening residential and commercial building programs

For More Information

- White House's Budget page
- List of budget terminations, reductions and savings (pdf)
- List of priories for state and local governments (pdf)

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NASA scientists' work and news from around the solar system

Posted by Dr. Tony Phillips | Science at NASA

Feb. 16, 2011

Study: Climate change linked to extreme rain

3:27 PM

By Doug Mohr, USA TODAY
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John Tegarty once mocked "What's up with the rain?" But humans apparently are now responsible for at least some of it, a new research study concludes. Climate change has significantly increased the chances of extreme rain and snowfall around the world, including the deadly floods that hit Queensland, Australia, in January.

This is according to two new studies published Wednesday in the British journal Nature.

While other studies have suggested that global warming may be partly responsible for an increase in heavy precipitation, "what's new in this study is the finding that human influence has likely made intense precipitation more widespread, over the second half of the 20th century," says study co-author Francis Zwiers of the University of Victoria in Victoria, British Columbia.

"The observed changes cannot be explained by natural fluctuations of the climate system alone," he says.

One of the studies reported that the most significant rain and snow events were 7 percent wetter in the 1990s than they had been in the 1950s.

Scientists based their findings on 1951-2000 data from 1,951 to 1999 in Northern Hemisphere land areas, including North America, Europe and India.

The scientists looked at the information that showed an increase in extreme rain and snow events from the 1950s through the 1990s, and ran dozens of computer models numerous times. They put in the effects of greenhouse gases — which come from the burning of fossil fuels — and then ran numerous models without those factors.

Only when the greenhouse gases are factored in did the models show a similar increase to what actually happened. Essentially, the computer runs show climate change is the only way to explain what is happening.

The other study dealt with the floods that swamped the U.K. in fall 2000 and determined that climate change made them over twice as likely to occur.

Why would global warming lead to more precipitation? According to study co-author Myles Allen of the University of Oxford in England, warmer air holds more water.

Senior scientist Kevin Trenberth of the National Center for Atmospheric Research in Boulder, who was not part of either study, expands on this: "The water holding capacity of the atmosphere goes up with [a] global temperature rise. [A] warmer surface temperature [and] ocean is simply more moisture coming into [a] storm, so it is a straightforward physical effect."

The effects of greenhouse gases on precipitation appear to be global. "Extreme precipitation is expected to increase almost everywhere in a warmer world, even if [a] region experiences reductions in mean precipitation, as in some tropical areas and subtropical deserts," reports Zwiers.

Overall, according to Zwiers, computer models suggest that the northern high latitudes will see the largest percentage increases in mean annual precipitation, and that the tropics will see the largest percentage increases in extreme precipitation.

"Damaging weather events have always happened and will before humans had any substantial influence on climate," says Allen. "This research allows us to ask [if] how rising greenhouse gas levels may be loading the dice for [certain] events, such as the U.K. floods of 2000, and against other events."

However, climate scientist Jerry North of Texas A&M University, while praising the work, said he worried that the studies were missing ice from a connection based on weather data that could be gone in some locations.

Contributing: Associated Press

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Toyota Unleashes the Super Prius

By Gary Gastelu

Published February 17, 2011 | FoxNews.com

When General Motors set out to build the Chevrolet Volt, it had one goal in mind above all else: give Toyota nightmares.

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Fed up with watching the Prius cruising along as the vehicular carting of the environmental set, GM launched the automotive equivalent of a mechanical program, hoping to steal the spotlight with a next gen hybrid that could be plugged-in to the electrical grid, increasing fuel efficiency to unheard of levels via the ability to run as an electric car part of the time. To complete this mission, its engineers developed a complex, all-new powertrain that is truly like nothing else on the road today.

But if they wanted to make a semi-electric car, why go to all the trouble? Wouldn't it have been easier just to put a larger battery on an existing hybrid and call it a day? Well, aside from hoping to impress everyone with its new creation, GM didn't really have one of those at the time. At least not one with an electric motor that was both small enough and robust enough to be used as the primary propulsion system for a compact car, like the one in the Prius.

Clearly this logic wasn't lost on the folks at Toyota, because they plan to introduce the Prius Plug-In Hybrid later this year, which — surprise, surprise — is little more than a Prius with a bigger battery pack. Now who's waking up screaming at night?

Still in the final stages of development, Toyota has unleashed a small fleet of demonstration vehicles into the wild to collect real world data as it puts the finishing touches on its new creation. We snagged the keys to one for a few days.

Aside from the garish exterior graphics on the test car to advertise what it is, the only obvious difference between the Prius Plug-In and the standard model is the addition of a door covering the charge port on the left front fender. Exactly the same as the one found on every plug-in car coming to market, it can be connected to either a 110- or 220-volt outlet to replenish the car's 5.2 kilowatt-hour (kWh) stream-ion battery pack in 1.5 to 4 hours.

That's triple the capacity of the one in a standard Prius, but only a third of the Volt's 16 kWh pack. The idea is to provide a small electric boost without adding too big of a boost in the price of the car. When it hits showrooms, the Prius Plug-In is expected to sucker at $28,100 — about $5,000 more than the base model, or about what an optional navigation system and upgraded stereo costs. The Volt goes for $41,000.

The trade-off is that the Prius Plug-In can't look like it into electricity mode the way that the Volt can for 35 miles on a full charge, as rated by the EPA. Technically, under the right circumstances — which surely include a flat road and a driver with a light-light foot — Toyota says that it can reach a top speed of 62 mph and travel up to 13 miles on battery power alone. In reality, it operates very much like a standard Prius, blending gas and electric operation as demands require, but relying on the battery more often than usual.

The idea behind it is that while gasoline is expensive, electricity is relatively cheap, so if you can bring a few electrons with you from home every morning you'll lower your overall cost of operation, at least on short trips. If your commute is five or six miles through the suburbs you can easily get to work without using the internal combustion engine at all. Driving normally on a mix of low and high-speed roads, I saw a 75 mpg average over the course of 15 miles before the plug-in charge depleted, a 50 percent increase over the 50 mpg rating for the standard Prius.

Like the Hulk turning back into Dr. Bruce Banner after he runs out of steam, that's what the Prius Plug-In becomes at this point: a standard Prius. The bookish five-door will churn out that kind of

fuel economy for as long as you need it to, or until you plug it in again to get juiced up. (If you must know, when the Volt is running in its extended-range mode it gets 37 mpg.)

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Drawbacks are few. That is, if you're already a fan of the Prius. Located under the cargo bay floor as it is, the battery chips away at cargo capacity a little and takes up the space normally reserved for a spare tire. A fix-a-flat kit is provided in its absence. This could change some as the production model will use a different battery but with similar specifications. As it stands, the weight gain of the conversion – about 300 pounds – won't be an issue for most of the people who are attracted to this type of car, but would be noticeable at a drag strip.

(Sorry, I got caught up in a moment of JDL there. I'm fine now. No, wait a minute... and we're good.)

Easy, but bad jokes aside, the latest Prius is actually a competent handler and not at all sloppy on wonderful, twisty roads. The position of that extra battery in the rear even seems to give the Plug In model better balance through turns. I can live without the meaning that comes from the carry-over 1.8-liter four-cylinder engine under hard acceleration, but the roomy interior is fine by me. Eco-hipster aspirations aside, it is its practicality that makes the Prius a 5-0-20 selling car.

Toyota is reportedly planning to move 25,000 Prius Plug-ins in its first year – about 20 percent of overall Prius volume. Ambitious? Chevrolet has set the same target for the Volt's debut season. It will be interesting to see what happens when they go head to head in the sales race. I'll let on a racetrack.

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Economic Slump and Energy Efficiency Drive U.S. Greenhouse Gas Emissions Drop

The period between 2008 and 2009 saw the biggest decrease in U.S. greenhouse gas emissions in decades thanks to the Great Recession and better technology

By Tiffany Stecker and ClimateWire | Thursday, February 17, 2011 | 5

The period between 2008 and 2009 saw the largest decrease in U.S. greenhouse gas emissions in 20 years, according to U.S. EPA's Greenhouse Gas Inventory Report.

While the 6 percent decrease correlates with the construction of the global economy that followed the financial crisis in 2008, it was not the only reason for the drop, the report says. Advances in technology, efficiency and reuse of scrap industrial material also decreased energy use in key sectors. In addition, an increase in coal prices and a decrease in natural gas prices led to a switch from one source to the other.

However, over the past 20 years, greenhouse gas emissions in the United States have increased steadily by about 0.4 percent annually.

"In a year with increased consumption of goods and services, low fuel prices, severe summer and winter weather conditions, nuclear plant closures, and lower precipitation, feeding hydroelectric dams, there would likely be proportionally greater fossil fuel consumption than a year with poor economic performance, high fuel prices, mild temperatures and increased output from nuclear and hydroelectric plants," states the report.

Industries that lowered their emissions include iron and steel manufacturing and metallurgical coke, whose emissions decreased by 35.5 percent from 2008 to 2009 and by more than half over 20 years, thanks to increased efficiency in scrap use, technological improvements and industrial restructuring.

Emissions from cement making also went down, by 28 percent from 2008. The decrease has been a trend over the previous three years, after a steady increase throughout the 1990s and early 2000s.

Output of carbon dioxide, the most abundant greenhouse gas, dropped 7 percent from 2008 to 2009 and rose almost 8 percent over 20 years. Transportation accounts for 33 percent of CO_2 emissions. Over 20 years, emissions rose by 16 percent in this sector, due to an increase in demand for flying and vehicle usage -- 38 percent for cars and light trucks.

Residential and commercial emissions have increased 23 percent in the past 20 years.

The report also calculated carbon sequestration through "sinks," carbon-trapping bodies in the form of forests, cropland, grassland and even landfilled yard trimmings and food scraps. Land-use changes to sinks resulted in an 18 percent offset in carbon emissions and a 15 percent offset in total greenhouse gas emissions in 2009.

Slight increase of methane, drop in nitrous oxide

Methane emissions between 2008 and 2009 increased minimally by 1 percent, and rose 1.7 percent since 1990, sourced primarily from the digestive mechanics of livestock, natural gas systems and decaying organic matter in landfills.

A gas 20 times more effective in trapping heat than carbon, methane is a by-product of natural gas combustion. These systems have

increased their methane output by 16 percent over 20 years. A flurry of natural gas well construction in 2008 and 2009 pushed methane emissions up 4 percent.

However, methane has the advantage of being captured, stored and combusted as a fuel -- a method that has been put to use in many landfills. As a result, methane emissions from landfills have decreased a whopping 29 percent over 20 years.

"[This] has more than offset the additional CH_4 emissions resulting from an increase in the amount of municipal solid waste landfilled," states the report.

Even coal, the scapegoat of carbon heavy industry, has lowered its emissions of methane by 15.5 percent. Mining companies are extracting less gassy coal from underground mines.

Nitrous oxide, with a warming effect more than 300 times that of carbon dioxide, dropped by 3.6 percent in 2009. The 1990-2009 period saw fluctuations in nitrous emissions from soils, but overall, emissions in 2009 were 3.4 percent higher than in 1990. Emissions are caused by a reaction between soil and water and vary according to the amount of nitrogen fertilizer that is applied on crop beds.

The EPA has established a 30-day period for the public to comment on the report.

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BUSINESS

Push to Further Limit Carbon Emissions

By ALESSANDRO TORELLO

The European carbon market will not live up to its promise of encouraging investment in green technologies unless an additional hundreds of millions of permits to emit CO2 are withdrawn from the market in 2013, the European Commission said in a draft document seen by Dow Jones Newswires Thursday.

The multimillion-euro Emissions Trading System, or ETS—the market through which the European Union puts a price on CO2 by capping the quantity of allowances that give the owner the right to emit one metric ton of CO2—will undergo a major overhaul in 2013.

In that year, allowances on the market will start decreasing by 1.74 percentage point per year until 2020, with the aim of slowly driving down greenhouse gas emissions.

By doing so, the price of the allowance should rise and make expensive green investments more profitable than buying permits.

However, unused allowances—whose estimates range between 500 million and 800 million—from the five years before will be carried over, potentially dampening the price and undermining the incentive mechanism of the market.

To avoid this, the commission proposes to withdraw from the market an equivalent number of allowances, for the period 2013-2020. "This would restore the reward for low carbon investments, preparing the sector for the innovations needed in a 2030 perspective," the draft said.

The commission declined to comment on a leaked document, but said the ETS continues to be "the most cost-effective" tool to cut CO2.

The ETS is the EU's flagship program for cutting CO2 emissions and fighting global warming, but it has suffered from repeated setbacks since its creation in 2005. Some parts of the spot activities are still shut, after the commission was forced to close down the whole market last January, when hackers stole tens of millions worth of allowances in three different countries.

In the document is the draft of a strategic paper aimed at setting the path toward a EU 80% to 95% carbon-dioxide-emission reduction by 2050, expected to be finalized by Mar. 8.

In it, the commission also said the power sector will likely have to do more in cutting emissions within the ETS, because the current path will not lead it to the level of cuts necessary in 2030 to then meet the 2050 goals.

Write to Alessandro Torello at alessandro.torello@dowjones.com

USA TODAY

Montana bill would 'embrace' global warming

Posted 4d ago |

HELENA, Montana (AP) — A Montana legislator is proposing the state embrace global warming as good for the economy.

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Republican Rep. Joe Read of Ronan aims to pass a law that says global warming is a natural occurrence that "is beneficial to the welfare and business climate of Montana."

Reaction by scientists and environmentalists to House Bill 549 has been harsh. University of Montana climate change professor Steve Running calls it an indefensible attempt to repeal the laws of physics

The bill was to be heard in the House Natural Resources Committee Friday.

Another climate change bill by Read was also being heard Friday. House Bill 550 would claim the state has authority over the federal Environmental Protection Agency when it comes to regulating greenhouse gases.

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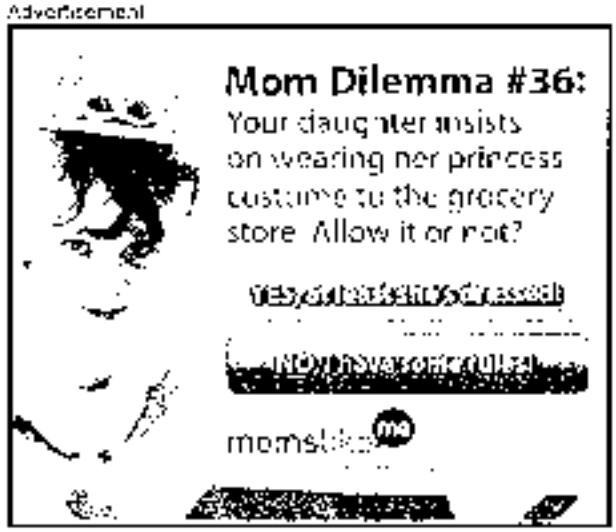
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Feb 18, 2011

Study: Sea level rise to swamp coastal cities by 2100

Oct 24 PM

By [illegible], USA TODAY
Comment

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2100. That's 63 years from now — the end of the next century. I think I'm fairly certain I'm not going to be around to see it, but my children and grandchildren will be. And I'm willing to bet that many of you reading this post now will be, too.

My son, born in 2000, would be 100 years old if he lives that long.

I bring this up because a study this year that many of climate change experts see as a marker on what will happen with various aspects of climate change. For example, the Intergovernmental Panel on Climate Change predicts that by 2100, the world's average temperature will have risen anywhere from 1.1 to 6.4 degrees warmer than it was in 1990.

2100. That's a drawing it's president, Governor, and Big Super Bowl — from now.

In this day and age of the instant and endless news cycle, thinking that far ahead is actually difficult to do. I doubt there are many stories or blog posts on Climate that reference the year 2100.

It's relevant at the moment because yet another Climate change report — this one about sea-level rise in the USA — proved my assertion to be true. In fact, the report states that rising sea levels could threaten the U.S. coastal cities by 2100, according to [illegible].

The coastal cities the research identified had 49 million people living in them, according to the 2000 U.S. Census. By 2100, that number will certainly be exponentially higher.

The report states that the Gulf and southern Atlantic coasts will be particularly hard hit. Miami, New Orleans, Tampa, Fla., and Virginia Beach, Va., could lose more than 10 percent of their land area by 2100 due to sea-level rise.

The paper appears in the journal, Climate Change Letters.

"With the current rate of greenhouse gas emissions, the projections are that the global average temperature will be 4 degrees warmer than present by 2100," researcher Jeremy L. Weiss, a senior research specialist in the University of Arizona's Department of geosciences

"That amount of warming will likely lock in at least a 40 meters (131 feet) sea-level rise in subsequent centuries, because parts of the Greenland and Antarctic ice sheets will slowly melt away like a block of ice on Grandma's walk in the countryside," Weiss says.

So, is Obama right, or just more hot air? Skeptics will say it's more hot air, used to drum up more funding for more research. But if the rise is [illegible]

Whatever happens with climate change by the year 2100 — from more severe heat waves and massive wildfires to devastating floods and sea-level rise — only our Children, grandchildren and great-grandchildren will see it for sure. 2100 will be in their hands, not ours.

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Cutting Black Carbon and Methane Promises Immediate Climate Change Impacts

Reducing emissions of black carbon and methane can be done today with existing technologies and could significantly slow climate change

By Lauren Morello and ClimateWire | Tuesday, February 22, 2011 | 29

Placing strict limits on a handful of common air pollutants could pay big dividends for efforts to limit climate change, improve public health and increase agricultural productivity, according to a new U.N. report.

Curbing emissions of black carbon, a component of soot, along with methane and tropospheric ozone, could cut projected climate warming by 0.5 degree Celsius, or about 0.9 degrees Fahrenheit, by 2050.

Such cuts could be made with existing technology, the report says, and would "have immediate and multiple benefits for human well-being."

Possible strategies for reducing black carbon, methane and ozone include capturing methane produced by landfills and fossil fuel extraction, introducing cleaner-burning cookstoves, installing particulate filters on diesel engines and banning the practice of burning fields of agricultural waste.

The research shows that cutting black carbon and methane emissions would slow the rate of warming up until about 2040, while starting soon to cut emissions of carbon dioxide would only have an appreciable effect after 2040.

Drew Shindell, the scientist who coordinated the international team that wrote the new report, said that suggests that both approaches are needed.

"When you put them together, this is the only scenario where you have a reasonable fighting chance of staying below the 2 degree [Celsius] target," said Shindell, a climate researcher at NASA's Goddard Institute of Space Studies. "One targets the near term, one targets the long term."

Meanwhile, limiting emissions of black carbon and chemicals that react with sunlight to form tropospheric ozone could prevent 2.4 million premature deaths and the loss of 1 to 4 percent of the global output of maize, rice, soybean and wheat each year, the analysis found.

Looking for impetus from governments

Shindell and other researchers who worked on the new report presented their findings over the weekend at the annual meeting of the American Association for the Advancement of Science.

The study was supported by the U.N. Environment Programme, the World Meteorological Organization and the Stockholm Environment Institute. The analysis will be delivered tomorrow to the U.N. environment body's governing council at a meeting in Nairobi, Kenya.

"Hopefully, there will be some impetus there to move forward," said Ashbindu Singh, chief of UNEP's Division of Early Warning and Assessment. "UNEP on its own cannot do much unless the governments tell us what to do."

UNEP commissioned the study, originally asking researchers to examine the effect of cutting emissions of black carbon, a particle produced by burning fossil fuels and biofuels like wood and dung.

Shindell said researchers expanded the analysis to look at chemicals like methane and precursors to ozone because they are emitted by the same processes -- like biomass burning -- that produce black carbon.

Like black carbon, methane and ozone are potent -- albeit short-lived -- greenhouse warmers. Black carbon, for example, lingers in the atmosphere for weeks, compared to CO_2, which can last for centuries to millennia.

All three can damage human health, while ozone can lower crop yields.

Meanwhile, black carbon acts in several ways to accelerate climate change. It absorbs heat from sunlight, warming the surrounding air. When particles of black carbon fall from the atmosphere on ice or snow, they hasten melting. Shindell's earlier work suggests that black carbon emissions caused half the total warming in the Arctic between 1890 and 2000.

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7 Ways to Transform California Climate Policy and Empower Local Action

climate policy climate mitigation clean power

Feb 23, 2011

Capitol Building in Sacramento.

The Golden State offers great promise for the country when it comes to forward-thinking climate policy. Even Big Oil didn't have the juice to stop California's growing clean energy economy when Prop. 23 went down decisively in November. But if we want to turn this promise into reality we'll have to navigate the challenge of the state budget crisis and identify the policy levers that will keep the ball rolling. With the eyes of the nation on California, we've got to get this right.

Here's the key: We need to refine state climate and energy policies to empower California's cities and counties, and improve local-state coordination. ICLEI has been collecting feedback from local governments across the state—on ways to simplify existing regulations, streamline permitting, provide more accurate data for climate action planning, save money, and unleash local innovation to scale energy efficiency and renewables development.

A vision is taking shape. Big cities, small towns, and counties from all corners of the state can come together to present sound policy solutions in Sacramento. Below are some of the specific ideas ICLEI has collected so far. But what's missing? What ideas can be improved? How can we take this vision to the next level, driving local action in the real world?

Please leave a comment below with your policy suggestions. Or, if you prefer, submit your thoughts to us directly.

Idea #1: Help local governments make climate action planning more efficient and effective.

The issue: Gaps remain in the data collection process for local climate planning. High-quality, efficient data collection is essential to doing climate action planning right. Getting the relevant data from the right sources allows a jurisdiction to develop the best possible inventory of its emissions and to plan with precision its reduction strategies. But this is often more difficult than it sounds and some simple fixes may require changes at the state or agency level.

The solution: Increase local government's access to relevant data.

How to do it:

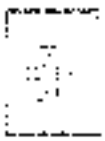
- California's Department of Motor Vehicles could provide VMT data annually on the make and mileage of vehicles registered within that municipality. Such data would better reflect the driving habits of businesses and residents within that community and enable cities to directly evaluate the public response to local climate action plan strategies (carpooling, EV infrastructure, etc.).
- Regional water districts and agencies could improve facilitation of data requests regarding local governments' electricity consumption, including eliminating cases of charging customers for access to their own data.
- Local governments could receive data on Direct Access Emissions within their jurisdictions for the purposes of inventories and climate action plans if independent energy service providers were directed to provide it by regulators.

Idea #2: Support the financing of local climate action planning.

The issue: Climate action plans are now a required component of general plan updates and are a central part of sustainability work; yet there is no consistent source of funding for these mandatory planning processes.

The solution: Dedicate revenue from established sources to ensure compliance with state requirements. For example:

- Dedicate a percentage of cap-and-trade revenue to financing local climate action planning.
- Dedicate a portion of proceeds from clean air actions taken by the state Attorney General to pay for local climate action planning.



Idea #3: Improve state-local coordination.

The issue: State programs are not always well informed by, or integrated with, local climate action planning.

The solution: Provide mechanisms for cities and counties with climate action plans to help guide state program implementation to ensure state-local integration where possible.

How to do it:

- Climate action plans that have been passed and/or implemented should be channeled upstream to inform state policymaking, not simply providing proof of local compliance.
- The California Air Resources Board (CARB), California Public Utilities Commission (PUC) and the California Energy Commission (CEC) could create a clearinghouse for any local climate action plan that is passed and implemented as a way to maintain real-time understanding of the practices on the ground. Relevant state agencies should be required to stay informed of these policies—ensuring two-way learning.
- The Attorney General's office could set up a portal for completed local climate action plans as part of providing more clarity in its guidance regarding compliance with CEQA. This could provide more peace of mind for local governments when they fully develop climate action plans—providing a safe harbor for the good actors trying to do the right thing.

Idea #4: Help bring energy efficiency and renewable energy development to scale at the local level.

The issue: The federal shutdown of PACE financing programs has stymied local financing.

The solution: Create other sources of revenue for local financing districts. In February 2010, ICLEI co-founder and California Assemblymember Nancy Skinner introduced one such approach, the "Clean Energy Reserve Program," which would provide a backstop to existing PACE programs.

The issue: Local governments have limited authority to raise new revenue to finance energy efficiency and renewable goals.

The solution:

- Push for state legislation enabling local authority with requisite local accountability to raise revenue and promote energy efficiency and local renewable projects—with narrow scope and clear focus.
- Ensure additional this local authority demonstrates a clear nexus. For example, authorize local gasoline taxes to fund local renewable (alternative) transportation projects (electric plug-in, rail, bike paths). Local control over the use of these funds could lead to innovative projects and give local voters more say on how we reduce our carbon footprint.

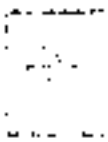
Idea #5: Streamline and make consistent the permitting for local renewable projects.

The issue: Local permitting processes for renewable projects are not uniform or consistent, making this "soft cost" a significant impediment to getting online.

The solution: Streamline permits for renewable projects by having uniform model code language promulgated statewide that can be used as a template by local jurisdictions and bring permitting processes online.

How to do it:

- Work through the Governor's office of Planning and Research or the State's Strategic Growth Council, which promote policies that assist state and local entities in the planning of sustainable communities and meeting AB 32 goals.
- Regional planning organizations charged with creating sustainable community strategies under SB 375 also could play the role of promoting regional permitting approaches to allow larger, regional-scale development—which is often hindered by inconsistent local permitting.



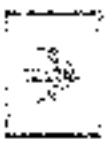
Idea #6: Close gaps in market development programs.

The issue: Gaps exist in the programs designed to develop the renewables market.

The solution: Ensure all market segments are covered and market development programs are harmonized to ensure that a full range of sizes and approaches are supported.

How to do it:

- Work with energy providers to implement current feed-in tariff legislation (under the PUC) to fully credit renewable energy generated at a city-owned site for overall municipal energy use (at fair time-of-use electricity billing rates).
- Develop "CLEAN" or "FIT" programs for mid-sized projects. This could involve paying residents and businesses a fixed contract rate for power they generate and feed into the grid.



Idea #7: Ensure cities and counties can benefit from Cap and Trade under AB 32

The issue: Current regulations for California's cap-and-trade program are largely silent on the role of local governments—creating uncertainty about the ability to benefit from the program as well as the potential for regulation.

The solution: Formalize the role of local governments under AB 32 to ensure clarity in the regulations (through the CARB and CPUC) regarding any potential opportunities to benefit from cap-and-trade for local governments, as well as clarifying any potential compliance issues.

How to do it:

- Draft legislation that provides a mechanism for cities and counties to realize the benefits of the sale of allocations. The mechanism could be similar to last session's AB 1405 (DeLeon) with community benefits, set at 10% of proceeds, going to the most impacted communities.
- CARB could adopt regulations creating opportunity for local governments to receive emission reduction credits for "reach" energy code/standards.

Working Paper Number 3

Case Studies for Transit Oriented Development

Prepared for:

LISC Phoenix
Local Initiatives Support Corporation

Prepared by:

RECONNECTING AMERICA

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ENCOURAGING TRANSIT ORIENTED DEVELOPMENT
CASE STUDIES OF TOOLS THAT WORK

INTRODUCTION

This document is a short summary of the TOD tools that are used by communities all across the country. Ten tools have been selected by the Center for Transit Oriented Development and Reconnecting America to represent the best and most relevant ideas for the Phoenix metropolitan areas in promoting TOD and ensuring that the investments made over last decade will spur additional development and support for this growing transit system.

The tools are:

- Livable Communities
- Station Area Planning
- Community Effort
- Right-Sizing Parking
- Shared Parking
- Aesthetic Zoning
- Collaboration (Public Private Partnerships)
- Joint Development
- Land Assembly
- Housing Trust Funds

These tools are a subset of those featured in other products for this project.

Each tool is featured in a 2-page case study. The tool is described with an attention to revealing the benefits of livable communities and how this can be attained through each strategy or policy. The cases draw upon location-based application of the tool. This illustrates how the tools are used and what the expected results were. In some instances, the direct investment to support the tool and the expected results are highlighted.

In the end, these write-ups give the reader a baseline perspective of what other communities are doing to support TOD. This information can then be used by staff and decision makers to better understand how these tools can be used locally.

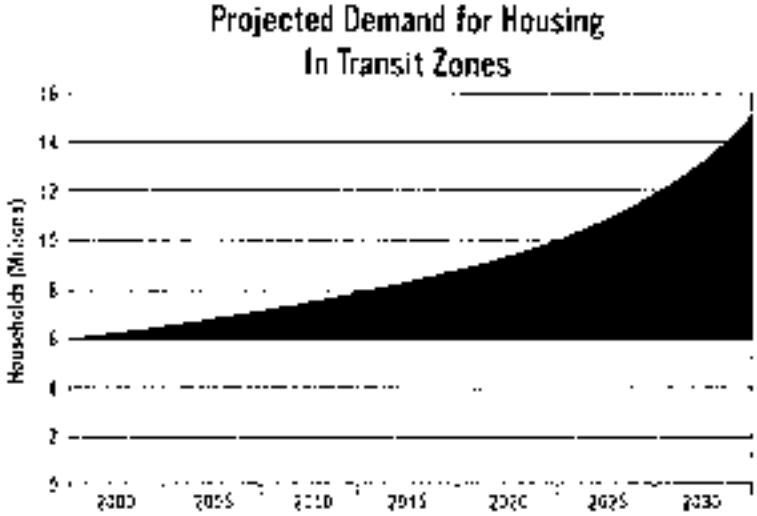
LIVABLE COMMUNITIES

Keeping affordable housing in the transit-oriented mix

Good transit-oriented development can provide all the benefits associated with livable communities: a mix of uses that makes it possible to get around without a car, a greater mix of housing types and transportation choices, an increased sense of community among residents, a heightened sense of place. This kind of development produces lower greenhouse gas emissions (a recent study by the Center for Transit-Oriented Development shows that TOD produces 43 percent less emissions than conventional suburban development, www.reconnectingamerica.org), it promotes walking and biking and more active lifestyles, and it creates value for property owners, businesses, local governments, transit agencies and residents. This is development that responds to the concerns of the 21st century because it's more environmentally and economically sustainable. And it provides a convenient, affordable and active lifestyle for people of all ages, including those who don't drive.

Local jurisdictions control multiple pools of funding that can be used to support affordable and mixed-income housing in transit zones

Increasingly Americans are showing a preference for more compact, walkable, mixed-use communities over typical suburban development, in part because traffic is so bad that no one wants to spend time commuting. But the changing housing market has as much to do with demographics: While the vast majority of US households used to be families with both a mom and dad and more than one child, this demographic group now comprises just 25 percent of households and it is shrinking. More and more households are childless or headed by single parents, and single adults comprise 41 percent of households. The demographic groups that are increasing in size – households that are smaller, older and more ethnically diverse – are the same demographic groups that have historically shown a preference for higher density housing near transit.



Today many people want a "room with a view" within walking distance of coffee, restaurants, yoga, a dog park, art, film and culture. Lifestyles are changing, and convenience and affordability are paramount considerations. Research by the Center for Transit-Oriented Development shows that by 2030 nearly a quarter of all US households looking to rent or to buy are likely to want higher-density housing near transit. The Urban Land Institute has also noted the changing real estate market: ULI's annual "Emerging Trends in Real Estate"

The Rosslyn Ballston Corridor in Arlington, VA, illustrates how TOD can accommodate tremendous development in a livable community that provides benefits to both new and existing residents. This was a declining low-density commercial corridor 30 years ago when the local government decided to focus development around five closely spaced rail stations. Despite the enormous amount of development that has occurred, single-family neighborhoods have been preserved just a short walk away.

report has ranked locations near transit as a best bet for investors five years in a row.

Moreover, transit is proven to generate value that can be captured and reinvested in communities because it concentrates development and business activity and the tax base in a way that allows for focused value capture strategies. Tried and true value capture strategies include: property and sales taxes, real estate lease and sales revenues, farebox revenues, fees on everything from parking to business licenses, joint development, special assessment districts and public-private partnerships.

The Rosslyn Ballston Corridor in Arlington, VA, illustrates how TOD can accommodate tremendous development in a livable community that provides benefits to both new and existing residents. This was a declining low-density commercial corridor 30 years ago when the local government decided to focus development around five closely spaced rail stations, working with residents and the private sector. Despite the enormous amount of development that has occurred, single-family neighborhoods have been preserved just a short walk away, and there has been only a modest increase in traffic. The overall results have been extraordinary:

- The assessed value of land around stations increased 81 percent in 10 years;
- 8 percent of county land generates
- 33 percent of county revenues – allowing Arlington to have the lowest property tax in Northern Virginia;
- 50 percent of residents take transit to work; 73 percent walk to stations.

Shifting demographics and the changing real estate market have opened up an unprecedented window of opportunity to channel growth into livable communities near transit. This opportunity should be exploited since it is increasingly clear that one of the most sustainable, low-cost, long-term solutions to a host of pending problems – including climate change and dependence on foreign oil -- is public-private investment in neighborhoods where people don't have to drive.

STATION AREA PLANNING

Getting the most out of transit-oriented development

Station area plans are conceptual or specific plans for the areas around transit stations or along transit corridors. There is some variation in what these plans contain, but they all lay out the basics, including zoning, design standards, parking requirements and information about transit access and bike and pedestrian circulation. The most effective plans have a clear time frame and strategy for implementation, such as an investment or infrastructure improvement plan that has clearly identified funding sources. Station area plans work best for encouraging TOD when there are significant development opportunities such as a large surface parking lot or other underutilized land; they are far less useful for development of a limited scope. Detailed station area planning efforts are especially important for high-priority sites.

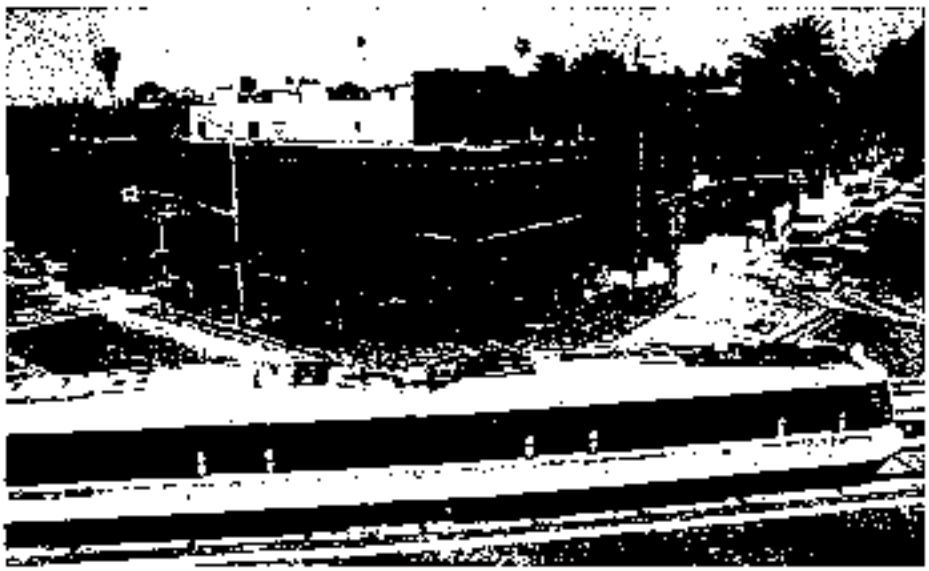
Detailed station area plans help leverage the potential of transit-oriented development

The neighborhood surrounding Highlands Garden Village, a mixed-income, mixed-use urban infill project near downtown Denver, provided significant input on the project design, greatly enhancing its success.

VISIONING NEW STATIONS

Station area plans that are based on a visioning process with community input can help set standards and expectations before projects are proposed, smoothing the way for the approval of appropriate development. This certainty and predictability can help ensure that projects will be approved without delay or community opposition—both of which increase risk and result in increased development costs. The community should be involved in determining what public infrastructure is needed, the desired mix of uses, whether there should be public space and what kind, as well as other design considerations. In some cases plans may be advanced enough to allow for "by-right" zoning that can greatly expedite the time it takes to move from project conception to construction.

The developer of Mission Meridian Village in South Pasadena, just north of downtown Los Angeles, solicited the input of residents before building what was a relatively high-density mixed-use TOD project in a historic single-family neighborhood that had long resisted development. By cultivating their interest, input and enthusiasm he succeeded in getting their support for what became a catalytic and immensely popular development that activated and improved the entire neighborhood. Similarly, the neighborhood surrounding Highlands Garden Village, a mixed-income, mixed-use urban infill project near downtown Denver, provided significant input on the project design,



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greatly enhancing its success. In both instances community input resulted in a design that located new single-family homes on the sides of the development that faced existing single-family homes, with more density and commercial space facing the commercial streets. The result was a truly sensitive design that integrated significant density a into single-family neighborhood.

Some elements of station area plans may be proscriptive, such as prohibitions on auto-oriented retail, or prescriptive, such as a provision that 50 percent of groundfloor space should be devoted to retail. Other elements can be "permissive." For example, the developer may have the option of providing a certain feature, but it is not required. The challenge lies in finding the right balance between what is optional and what is required with the goal of ensuring that the plan will result in a successful project, but not scare developers away. Planners and policymakers should be careful not to let perfection get in the way of the good.

While some plans are custom-designed for specific stations, a "transit district" or "transit village" overlay zone can be applied more generally to ensure that plans or projects near stations meet certain criteria including a mix of uses, a pedestrian orientation, or a standard of affordability. A "floating" TOD overlay zone offers more flexibility; it can be applied when the opportunity arises instead of pre-zoning the site before the market is ready – which can cause land speculation and higher costs, as well as difficulties for existing property owners. Transit agencies and cities should consider the corridor as well as the station area, and balance overall considerations about system performance with each station area plan. Considering the corridor as well as the station allows local governments to identify those stations that should serve as parking lots for commuters, and those that should be developed as high-activity nodes. Parking ratios can be reduced as neighborhoods near stations develop. At BART's Fruitvale station in Oakland, for example, parking was reduced to allow for a higher density, mixed-use, mixed-income transit village that was developed by a local community organization. The lower parking requirements reduced development costs, which reduced the cost of housing and commercial space, resulting in a vibrant mixed-use pedestrian corridor with high-quality public space and plazas leading from the BART station to Fruitvale's nearby commercial center.

COMMUNITY EFFORT

Following the lead of community-based organizations

Community development corporations (CDC) can use transit-oriented development to bring about comprehensive and lasting revitalization in neighborhoods and increase affordability because families that use transit spend less money on transportation. Community development corporations can play an especially important role in neighborhoods that have been bypassed by the market and that aren't a high priority for local governments or transit agencies by initiating projects that will benefit the community.

Community Development Corporations play an important role in neighborhoods bypassed by the market

The Dudley Village project developed by the Dorchester Bay Economic Development Corporation in Boston will bring 50 affordable housing units to Roxbury.

Community support for a CDC's efforts can go a long way toward convincing lenders to invest in and retailers to move into a community. It may be possible, for example, to attract an otherwise reluctant vendor, such as a grocery store, if community members say they will support the store.

TOD success stories

There are many TOD success stories involving CDCs: San Diego's transit-oriented Barrio Logan neighborhood was developed by a community services organization, as was the Lake-Pulaski neighborhood in Chicago, where a CDC named Bethel New Life made an El station the anchor for its revitalization efforts. Beginning with $10,000 raised from a church congregation, Bethel New Life has since assembled and brokered land around the station, building or rehabilitating 1,000 housing units and a new "green" station building that houses a child care center and retail, creating a comprehensive mixed-use development. The cities of Chicago and San Diego were both supportive of these developments but had prioritized development in neighborhoods where it was easier to attract developers. Bethel New Life had to buy land, develop the housing and negotiate with the city, developers and the transit agency in order to realize their vision. Financing came together through a combination of loans, grants, tax credits to make the deal work.

Similarly, four CDCs have come together in Boston to build mixed-income transit-oriented projects along the Fairmount commuter rail line to help ensure that gentrification doesn't displace current residents. The combination of a strong housing market and improvements to the commuter rail line -- including

better service and new infill stations -- had prompted developers to build market-rate housing in what had been high-poverty transit-dependent neighborhoods. The four CDCs mobilized support for the transit improvements, raised funds for planning and development capacity, and are developing projects near the new stations that provide affordable units and economic development opportunities for lower-income residents.

Perhaps the most famous example of a CDC-led TOD effort is the Fruitvale BART (Bay Area Rapid Transit) station near Oakland, California. This large mixed-use mixed-income TOD project grew out of community resistance to BART's plan to build a parking garage between the BART station and the Latino neighborhood's commercial center, which the community worried would hasten the decline of the already distressed neighborhood. BART withdrew the plan and agreed to work with the neighborhood on an alternative. The Spanish-speaking Unity Council, which had led the opposition, became the developer, working with a variety of federal and local partners to build the project. Fifteen years later, the Fruitvale "transit village" links the commercial center and BART station with a pedestrian corridor and plazas lined with shops, offices, apartments and community services – the village includes a clinic, child development center, senior center and library.

The Fruitvale BART station in Oakland, a large mixed-income TOD project, grew out of community resistance to BART's plan to build a parking garage between the BART station and the Latino neighborhood's commercial center, which the community worried would hasten the decline of the already distressed neighborhood. The Spanish-speaking Unity Council became the developer, working with a variety of federal and local partners to build the project.

All of these examples illustrate how TOD can be used to catalyze neighborhood revitalization, ensure affordability, leverage public and private investment, provide more choices for residents, increase transit ridership, reduce traffic and pollution, and enhance the economic and environmental sustainability of a neighborhood. There are also some lessons learned: In each of the examples discussed above there were effective public-private-nonprofit partnerships, effective leadership, public involvement, creative financing, quality design and construction and -- perhaps most importantly -- perseverance.

RIGHT-SIZING PARKING

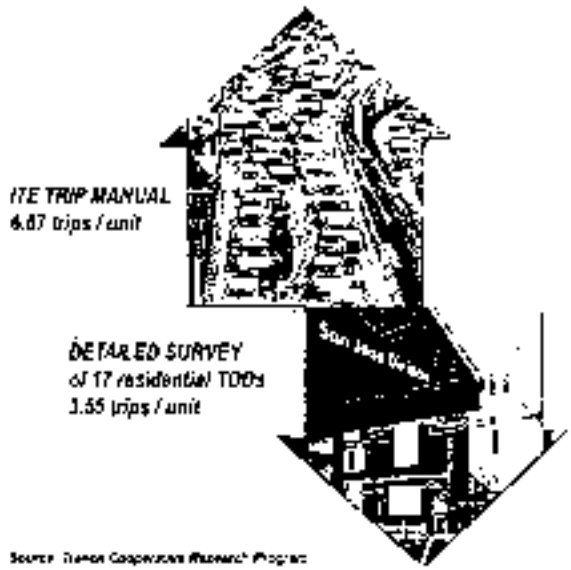
Taking advantage of transit-oriented development

Parking mandates crafted for single land uses overestimate the parking needs of development near transit and undermine opportunities for higher-value uses. Providing parking is expensive – estimated to cost from $20,000 to $40,000 per space in a parking structure and as much as $60,000 or more per space in high-value real estate markets like San Francisco. Because parking requirements can drive the budget for TOD projects, parking becomes a key factor in determining real estate prices.

Housing in transit-oriented developments produces as much as 50 percent less traffic than conventional developments

Local parking standards are usually set in accordance with the Institute of Transportation Engineers trip generation and parking forecasts. The ITE model, however, is based on suburban examples where parking is typically inexpensive and plentiful, and because surrounding low-density uses make travel by car necessary. The Center for Transit Oriented Development's database of transit systems and TOD shows that, in contrast, homeowners in walkable communities with a mix of uses and good transit access own 43 percent fewer cars than those who live in suburban communities.

There's increasing proof that TOD projects generate less traffic. The Transit Cooperative Research Program (TCRP) released new research in 2008 by PB PlaceMaking, Robert Cervero of UC-Berkeley, the Urban Land Institute and the Center for TOD that shows that transit-oriented housing produces just half as many car trips as conventional suburban development. The study counted the number of cars driving

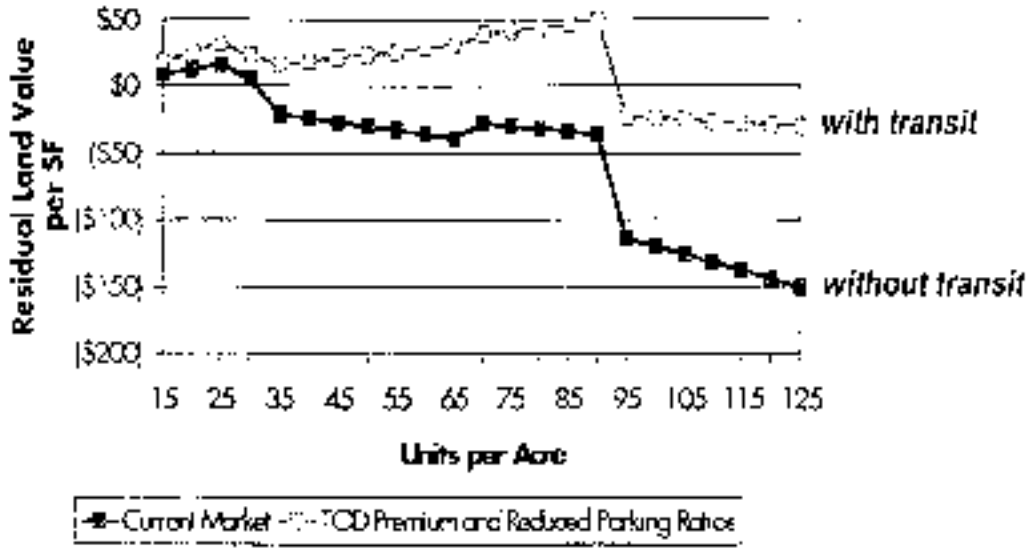


Source: Transit Cooperative Research Program

across pneumatic tubes stretched across the driveways of 17 transit-oriented housing projects in Philadelphia, Washington D.C., the San Francisco Bay Area, and in Portland, OR. The research was intended to provide guidance for an update of the ITE trip generation and parking generation rates.

ECONOMICS OF PARKING

Reducing parking requirements can increase the feasibility of mixed-income and mixed-use development, and from a design perspective largely determines if there is space for retail, childcare or other nonresidential uses. Consider, for example, a one-acre parcel zoned for up to 100 units of residential development. A parking requirement of two spaces for each residential unit would consume 320-350 square feet per space at a cost of $20,000 to $40,000 per space. Reducing the requirement to 1:1 would allow the project to save as much as $2 million. By reducing the parking requirement to 0.75:1, enough ground floor space would be available to allow



Source: Strategic Economics

Higher-densities in transit-oriented developments are often not enough to make them pencil out. The lower line shows that a developer would require subsidies in order reach densities of more than 35 units per acre and 25 units per acre would be the optimal density. But if the higher rents a project near transit can demand and the lower development costs from reduced parking are added to the equation, the site's profitable maximum moves to the 90 units per acre range.

for a childcare center and 10,000 square feet of retail.

Similarly, the TCRP study showed that under the right conditions lowering residential parking ratios by 50 percent for TOD projects near high-quality transit service could provide for increases in residential density of between 20 to 33 percent and a savings to the developer ranging from 5 to 36 percent. The TCRP research suggests that reducing residential parking ratios for TOD makes sense and would help these projects realize the expected community benefits by limiting traffic, encouraging walking and biking and transit use, making TOD housing prices more affordable by limiting project costs, and providing room for higher-value uses.

COUNTING TOD TRIPS

In addition, neighborhoods may be more likely to support density near transit if they understand that TOD produces fewer trips than conventional development. The savings to developers can be passed on to consumers in the form of more affordable housing. Lower parking ratios will help promote transit ridership. And less parking will mean that TOD projects are more compact and sustainable.

In Evanston, IL, for example, recent multifamily residential developments included a minimum of 1.25 spaces for housing units that are one bedroom or smaller and 2 spaces per unit for three or more bedrooms. But an onsite survey to determine whether all these parking spaces were actually used found an actual parking demand of 0.8 spaces to 1.18 spaces per unit. As a result, Evanston planners proposed reducing parking requirements and shifting from a per-bedroom rule to a per-square-foot rule that will range from one parking space for an 800 square-foot-unit to 1.5 spaces for 1,500 square feet or more.

For more information see: Parking Spaces/Community Places: Finding the Balance through Smart Growth Solutions. http://epa.gov/smartgrowth/parking.htm

SHARED PARKING

Making parking work 24/7 in mixed-use districts

Parking policy is every bit as important to creating vibrant, pedestrian-friendly mixed-use districts as streetscapes, parks and high-quality public space, because it largely determines whether a neighborhood is compact and walkable. Shared parking is a valuable tool because it provides for a more cost-efficient use of parking resources, and frees up land for higher-value uses, creative site planning and landscaping – all of which will enhance the vibrancy, appeal and value of the development.

Shared parking is most effective when land uses have significantly different peak parking characteristics

Shared parking is a parking management policy that allows for parking spaces to be shared by more than one user, since most parking spaces are only used some of the time and many parking facilities include many unused spaces with patterns of usage that follow predictable daily, weekly and annual cycles. For example, an office complex can efficiently share parking facilities with restaurants or theaters, since offices require maximum parking during weekdays, while restaurants and theaters require maximum parking in the evenings and weekends. As a result, it is estimated that the total amount of parking can be reduced 40-60 percent.

One of the best ways to provide shared parking is to build shared parking facilities rather than having each building provide private off-street parking, thereby allowing each public space to serve many users and destinations. It is estimated that 100 public parking spaces can be the equivalent of 150 to 250 private parking spaces, and developers or building owners can be asked to pay in-lieu fees to fund construction of these public parking facilities. On-street parking is also easy to share since it's so visible and convenient, but in order to make this work the on-street parking must be managed for maximum use, particularly in busy commercial centers, by limiting the time to two hours or less, or applying short-term pricing. Parking can also be shared among a group of employees or residents: For example, 100 employees or residents can usually share 60-80 spaces since not all employees will drive to work at one time.

WEEKDAY **EVENING** **WEEKEND**

Shared parking works best with multiple destinations with different peak parking demand periods.

AGREEING TO SHARE PARKING

Shared parking is typically implemented by municipal governments, with sharing arrangements made between individual facility developers

The seven-story Gaia complex in downtown Berkeley, less than a block from the Berkeley BART station and the University of California-Berkeley campus, was allowed a height bonus in exchange for providing a performance and arts space. In addition to the cultural space, there is a cafe on the ground floor, a rooftop garden and a solarium as common areas. The 91-unit project has 42 spaces in parking lifts along with space for car sharing and bike storage facilities.

and managers. Some local jurisdictions incorporate language in local ordinances to permit and even encourage shared parking. These jurisdictions allow shared parking to meet minimum parking requirements for uses located in the same building and also permit off-site shared parking arrangements to meet on-site requirements for complementary uses within a defined area. These location requirements are typically based on acceptable walking distances. San Diego's municipal code, for example, states that shared parking facilities must be located within 600 feet of the uses served, while Eugene, Oregon, and Los Angeles both allow for 1,320 and 1,500 feet, respectively.

IN-LIEU PARKING FEES

The city of Long Beach recognizes that parking is expensive and consumes valuable land, and allows for shared parking and in-lieu parking fees. For example, the city's minimum parking requirements would have required a proposed 162-room downtown hotel to provide 302 spaces, costing an estimated $4.83 million, making the project financially infeasible. In the interest of encouraging urban revitalization the city agreed to lower the parking requirements to 218 and allow the developer to pay in-lieu fees of $3,000 per space for a quarter of these spaces plus an additional $50 per space per month to cover parking operating and maintenance expenditures. The revised parking requirements provided a savings of more than $2 million to the developer and has facilitated the revitalization of the surrounding area, increased pedestrian traffic, generated approximately $300,000 in property tax revenues and helps to support Long Beach's downtown.

AESTHETIC ZONING

Emphasizing form over use to create human-scale places

Most U.S. cities regulate development through conventional or Euclidean zoning, the primary purpose of which is to segregate incompatible land uses and accommodate the movement and storage of vehicles. But these codes date back to concerns about the industrialization of American cities at the turn of the last century and aren't as relevant to the economic realities of cities today. Demographics in America are changing. Whereas the family was the major demographic group in the 1950s, making the suburban single family home popular, singles and "non-family" households (single-parents, empty nesters, friends living together) have become the new majority. These households are much more interested in multi-family housing types -- including the loft and live-work space and condo – in lively mixed-use neighborhoods that are walkable.

Physical form and beauty of a city are defined by the sum of its public spaces

Mixed-use zoning has become popular as a result, and mixed-use districts are often overlaid on the conventional zoning grid through creation of special zones or districts. But this is a makeshift strategy and doesn't change the underlying requirements of auto-dependent planning, and many cities are instead turning to form-based codes to achieve more vibrant and human-scaled neighborhoods.

Form-based codes, in contrast to conventional codes, focus on the architectural and urban "form" of the built environment, and regulate key aspects such as building heights and setbacks, windows and doors, the street and sidewalks. The intent is to get all of these elements to work together to create a desirable public realm and allow for the complexity, diversity and flexibility that can create dynamic and vibrant neighborhoods.

One of the earliest codes was created for the new town of Seaside, Florida, in the 1990s. It was subsequently recognized as one of the most important planning efforts of the post-World War II era.

FLEXIBILITY IN CODES

Form-based codes are much more user-friendly than the typically complex and oft-amended conventional codes, which are composed of lengthy text and numerical descriptions. Form-based codes, in contrast, use charts and illustrations with the intent of simplifying the code; they depict desired outcomes through the use of two- and three-dimensional drawings and diagrams. Most importantly, form-based codes allow for much greater flexibility

The former Safeway site on Columbia Pike will include an 188-unit rental apartment building. Approximately 34,340 square feet of retail and 14,650 square feet of office space will be included on the ground floor and mezzanine. There will be 408 parking spaces on three below-ground levels; at least 107 of which are non-reserved and shared for visitors and shoppers. The project also includes 79 bicycle parking racks. The project is in compliance with the Form Based Code and consistant with the goals of the Columbia Pike Initiative.

with regard to the uses located in the buildings so that property owners can adapt to changing market conditions, and to allow the mix of uses to change over time. They also simplify and streamline the planning process, thereby appealing to both cities and developers.

Form-based codes focus on the relationships between building facades and the public realm, the form and mass of buildings in relation to one another, and the scale and types of streets and blocks. The primary concern is the impact on the public realm or right of way, in acknowledgement of the fact that architectural design, how buildings relate to the street, and walkability are important elements in creating places that people want to visit -- which is why form-based codes focus on enforcing these elements instead of on restricting uses.

BUILT-IN INCENTIVES

One of the earliest codes was created for the new town of Seaside, Florida, in the 1990s and was subsequently recognized as one of the most appealing and important planning efforts of the post-World War II era. Arlington, VA, adopted an optional form-based code for Columbia Pike in 1998 that incentivized its use by expediting projects that met code requirements – thereby prompted a wave of development. It has been lauded as providing for up-front citizen consultation, less regulation, quicker approvals, and for making development less expensive (less parking, expedited approvals), which has allowed for the construction of more workforce housing. Denver is also adopting a form-based code to help implement the city's recent comprehensive plan, which directs higher-density development along public transit corridors in the hopes of promoting ridership.

COLLABORATION

Leveraging public-private partnerships for better results

A public-private partnership is a contractual agreement between a public agency (federal, state or local) and a private sector entity that leverages the skills and assets of both with the goal of delivering a service or development for public benefit. Public-private partnerships are especially useful for leveraging private investment in transit-oriented development, they are more flexible than joint development arrangements, and they don't require publicly owned land – though, as with joint development, each partner brings something to the deal. Local governments, for example, can help assemble land, rezone it, and fund environmental remediation with a grant from the federal government. Private investment can also be leveraged if a local government provides an in-kind match, in-lieu-of fees, or gap financing.

Melding of public and private goods is a progressive, pragmatic solution to the practical difficulty of getting things done.

Local governments can be particularly effective in incentivizing the kind of development they want by working with developers to mitigate the four risks associated with in the development process: They can help with entitlement risk by bringing communities to consensus on a station area plan that creates predictability for both the community and the developer, and by expediting the review process. They can help with construction risk by prioritizing inspection services for TOD, and by vetting contractors. They can help with financing risk by working with local banks to provide lower-cost mezzanine loans, a type of debt used for commercial and multifamily construction that is typically very expensive.

Government can also help with the marketing of the finished development, advertising its proximity to transit, for example. Lenders typically want to be "taken out," or paid off, as quickly as possible by a mortgage. If marketing helps sell the units more quickly, transit access can help developers secure financing more quickly, lowering the costs at the end of the project. This cost savings can help subsidize below-market-rate units, or pay for pedestrian amenities like parks and plazas and streetscapes. DART in Dallas has done a particularly good job of using transit to market TOD. The agency's real estate department reaches out to developers, providing them with a basic market analysis for sites near stations, including information about demographics, land ownership, characteristics of the surrounding communities. Some cities, like Portland, have made infrastructure investments -- including parks, sidewalk improvements, and transit stop enhancements – to increase the curb appeal and marketability of larger developments.

Portland's Pearl District streetcar

Local governments can also help with predevelopment costs, which are typically hard to finance, especially if the land to be developed has to be held for several years until it is developable because of zoning or design issues. Local governments can help by provid-

One of the best examples of a successful public-private partnership that used transit to leverage large-scale redevelopment is Portland's Pearl District, a neighborhood built along a streetcar line. The streetcar was built to connect two large parcels of vacant industrial land north and south of downtown.

ing patient capital from funding sources such as redevelopment funds. They can also provide funding for public parking and therefore become an equity partner in the development. Value capture strategies and zoning incentives including density bonuses can be used to fund affordable housing and infrastructure.

One of the best examples of a highly successful public-private partnership that used transit to leverage large-scale redevelopment is Portland's Pearl District, a new neighborhood built along a streetcar line. The streetcar was built to connect two large parcels of vacant industrial land north and south of downtown. The city struck a deal with the owner of 40 acres: The city would build the streetcar past his property and make other improvements if he would up-zone his property from 15 dwelling units per acre to 125. This was in the early '90s, when there was no market for this kind of development, but today it is the city's densest and most popular neighborhood, and at build-out it will be home to 10,000 residents and 21,000 jobs. The streetcar was subsequently extended to the second vacant parcel, the South Waterfront, where an even more ambitious redevelopment effort is underway.

This private investment – an estimated $3.5 billion in 2008 – helped the city meet several public goals and objectives, including accommodating a significant number of new housing units within the city's urban growth boundary. The result:

- 10,000 units of housing, one quarter of which is affordable;
- 4.6 million square feet of commercial space within two blocks of the streetcar;
- Portland's 20-year housing goal was met in just 7 years on one-tenth the projected land;
- A record number of building permits were issued 7 years in a row;

Properties closest to the streetcar were developed at 90 percent of permitted density, compared to 43 percent of allowable density at 3 blocks and further away.

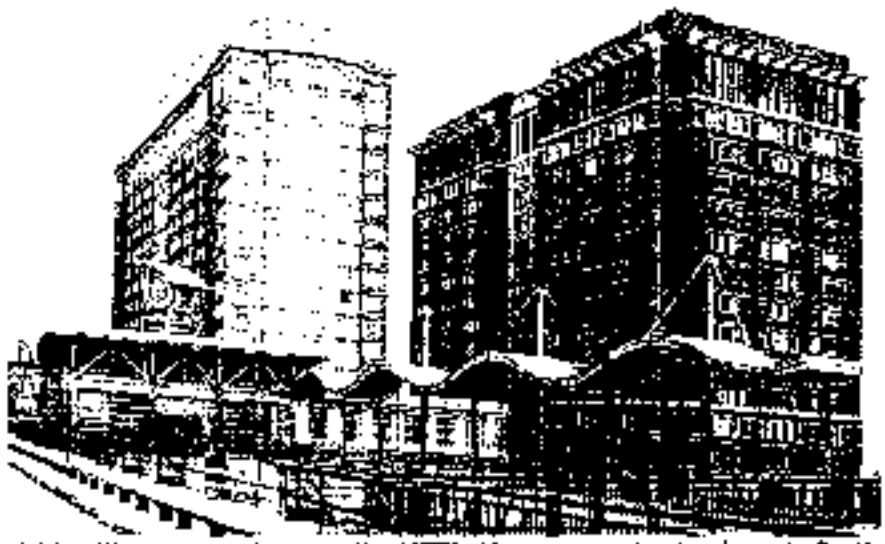
The Portland streetcar proved to be a public investment that attracted private investment that helped the city meet many public goals including affordable housing, very high-quality streetscapes and parks and plazas, and which generated a high volume of business activity for downtown. The streetcar has been so successful in stimulating development that there are now at least 60 US cities trying to follow Portland's example by building streetcars.

JOINT DEVELOPMENT

Leveraging agency land to improve TOD prospects

Generally speaking, transit agencies or cities cannot create transit-oriented neighborhoods that generate high ridership and achieve other public goals on their own. They aren't likely to own enough land at stations to create truly catalytic projects, and their real estate departments may lack the necessary staff, resources and/or sophistication. However, many transit agencies and cities do enter into joint development with private development partners on publicly owned land to ensure that it is built with uses that will support transit ridership, or development that supports other public goals including affordability and the revitalization of neighborhoods. Private developers bring their own resources, including additional property, and expertise to joint development projects, which can result in more successful development.

The most common joint development arrangements are ground leases and operation-cost sharing

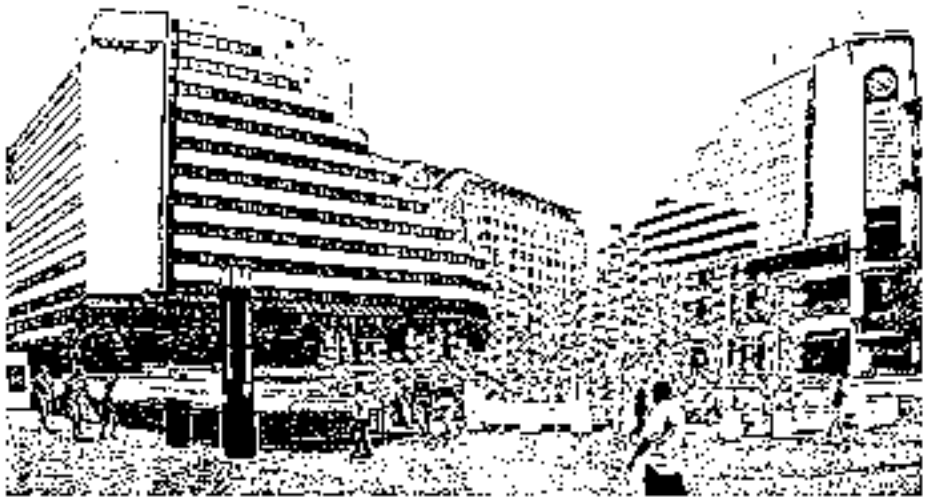


A tripartite agreement among the MBTA, Massport, and a developer in South Boston led to construction of a new underground Silver Line BRT station.

Research shows that transit can add significant value to land near stations. Developing the land maximizes that value and can yield significant revenues from long-term ground leases, rents or sales, as well as increased property and sales taxes and farebox revenues, and provide increased revenues from fees on everything from parking to business licenses. All these revenues can be used to fund additional improvements for the neighborhood in which the station is located, or to support additional transit investments. Moreover, transit agencies have found that joint development is a cost-effective way to help ensure higher ridership -- much more so than building costly parking structures or providing feeder bus service.

There are challenges, however. One key issue is the disposition of land. Many transit agencies prefer to lease their land rather than sell it outright, which can have a critical impact on the cost of financing. Lenders and equity providers perceive more risk with deals in which the land is not permanently secured to the real estate improvements they make. The cost of joint development is high to begin with – because of the added time and complexity of these projects – and the added cost of financing makes it hard to make these projects pencil out.

There may also be the thorny question of providing replacement parking for transit users – which has killed the financial feasibility of many joint



The Washington (D.C.) Metropolitan Area is, by far, the nation's leader in transit joint development. The region presently has some 30 joint development projects, including such notable air-rights developments (and revenue generators) as this Bethesda station project.

development projects. With the cost of structured parking estimated at between $20,000 and $40,000 a space, the requirement to replace a large surface parking lot with structured parking in order to make room for development can price most projects out of the box. In the recognition that joint development projects may be the highest and best use for transit agency properties, many transit agencies that engage in joint development are abandoning their one-for-one replacement parking policies for more flexible guidelines that allow replacement parking to be moved to other stations along a corridor.

JOINT-DEVELOPMENT EXAMPLES

The Washington Metropolitan Area Transit Authority (WMATA), the Massachusetts Bay Transportation Authority, and BART in the San Francisco Bay Area are among the transit agencies that have aggressively pursued joint development opportunities. In one of the more interesting and complicated joint development deals, BART's $70 million West Dublin station is being built in part with $15 million generated by the pre-payment of lease revenues on development planned for 18 acres around the station. Other project partners included the state DOT, the council of governments, congestion management agency, and the cities of Dublin and Pleasanton, which surround the station and owned some of the land.

The Massachusetts Bay Transportation Authority has also been selling and leasing land near stations to private developers, and taking an equity interest in the development. At the Ashmont Square Station, for example, the MBTA entered into an agreement with a developer to build 150 units of housing on agency land. Proceeds were used to help fund construction of a new parking structure with 5,000 spaces near the station. MBTA also entered into an agreement with Massport and a private developer to construct a new underground Silver Line BRT station at the World Trade Center complex in South Boston, with each each development partner contributing something to the deal.

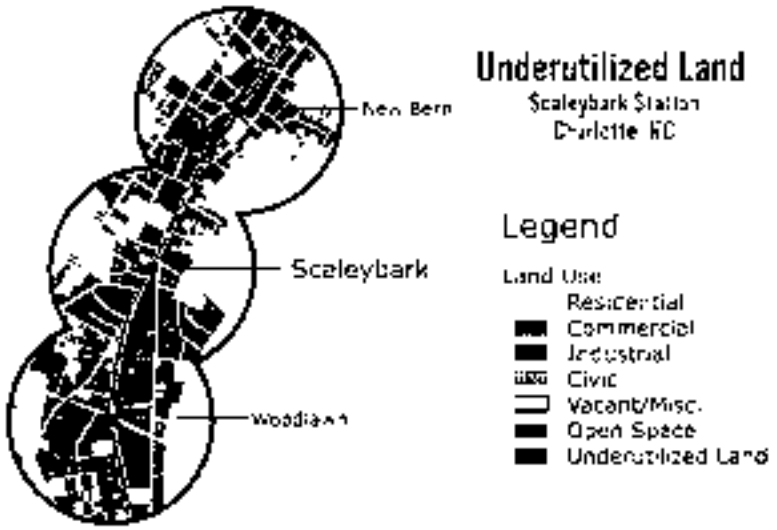
LAND ASSEMBLY

Packaging a project to leverage development opportunity

Land assembly can be a challenge when developing pedestrian-friendly transit-oriented neighborhoods. Neighborhoods around stations are often built-out, sometimes with transit-unfriendly uses, there may be few vacant or underutilized lots, and sites that are developable may be small, disconnected and not under the control of any one owner. Exceptional TOD projects require large sites, and large sites reduce construction costs, provide for a more even quality of building design, and ensure a phased build-out that will maximize profits. For all of these reasons some local governments use their land assembly powers to acquire sites and then sell or donate the land to the development team. The power to assemble land provides leverage for public agencies, giving them greater say in decisions about the kind of development that should be built.

Local governments can help package and assemble land for development purposes

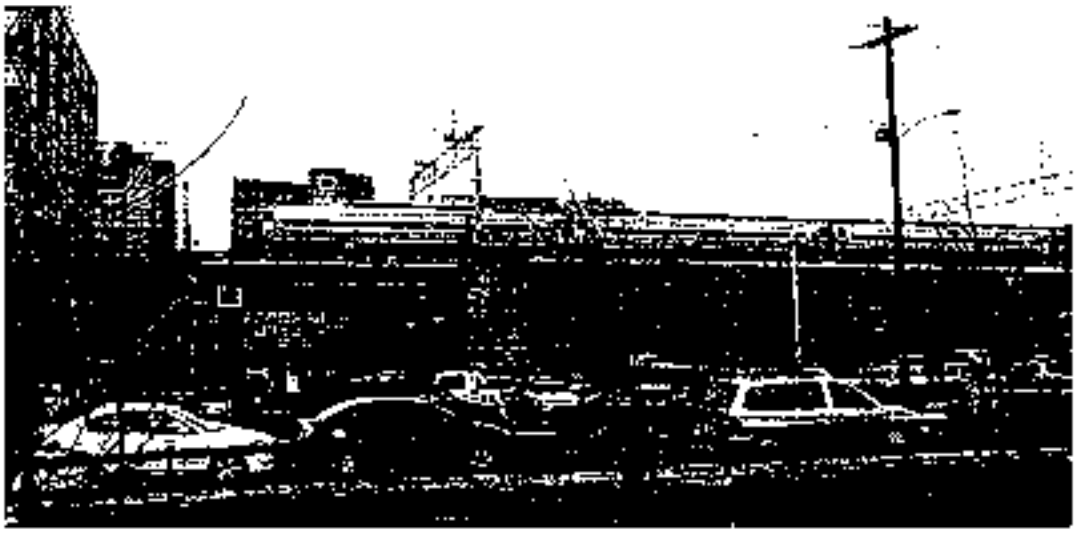
There are a number of innovative land assembly and financing techniques that are being employed, including making the planning of infrastructure investments and land assembly concurrent. Land acquisition or land-banking funds are being considered in many cities to enable the early purchase of land around stations or along transit corridors while the land is still affordable. Development fees, flexible state transportation and housing funds, and grants from corporate and family foundations can be a source of capital for land acquisition.



Charlotte's Scaleybark station is surrounded by large industrial and commercial sites that are ready to be redeveloped, making it well suited for catalytic TOD projects

There are barriers to land assembly, of course, including the fact that property owners may be unwilling to sell or have unrealistic expectations about what their properties are worth, given the speculative rush that can accompany the construction of a new transit line. Moreover, it takes a long time to assemble sites and then get them entitled, zoned, platted and approved for development, and there are legal issues surrounding the use of eminent domain. Many developers are not able to handle the holding costs of long-term or even medium-term site assembly and entitlement, which is why the help of public agencies is often necessary.

Because of these difficulties, brownfield sites, underutilized commercial and industrial sites, and redevelopment project areas offer



Philadelphia has the third largest rail system in the United States but stations are dominated by auto-oriented uses. In addition, the Temple Regional Rail station and elevated rail line separate Temple University in North Philadelphia from the Asociacion de Puertorriqueos en Marcha (APM) community, which has long struggled to revitalize after population loss.

some of the best opportunities for TOD because they make large-scale development possible. For example, the City of Baltimore was able to offer 30 acres for redevelopment as TOD around the Metro station at Center Square. These sites link the Metro station to a light rail station surrounded by city and county offices and cultural attractions. Land assembly is also a major element of the Atlanta Beltline effort to turn more than 20 miles of mostly unused railroad tracks and adjacent land into an "emerald necklace" of parks, workforce housing and mixed-use development on either side of a transit line looping around the city.

REDEVELOPMENT AND TRANSIT

In Philadelphia, land assembly has been deemed so important to the stabilization and rebuilding of neighborhoods that the city has implemented a new approach driven by redevelopment considerations. The city has nearly 60,000 vacant parcels, but few are large enough to support significant and catalytic development that can spur other projects. So the city has begun acquiring large quantities of vacant land, and by holding title will be able to market the land in accordance with neighborhood plans and dispose of the properties without the delays associated with a more piecemeal approach.

Land swaps are another option that can help clear the way for development of critical sites near stations. At the Fruitvale BART (Bay Area Rapid Transit) station, for example, the developer needed to assemble all the parcels of land at the site under single ownership. BART owned the land, but couldn't part with the property because of a long-standing policy requiring the agency to retain ownership of the land for long-term planning. The problem was addressed through a land swap in which the developer was awarded a 96-year lease on the land in return for a parcel the developer owned behind the transit station as well as several nearby vacant parcels owned by the City of Oakland. This swap gave the developer proprietary rights to the entire development site without reducing the value of BART's land assets near the transit station.

For more information, see: Tools for Mixed-Income TOD, Douglas Shoemaker with the Center for Transit Oriented Development

HOUSING TRUST FUNDS

Preserving affordable housing near transit

Housing trust funds establish a stable and steady source of funding for affordable housing outside of the unreliable political budgetary process, enabling jurisdictions to provide developers with a dependable funding source. These funds are typically established by the city, county or state via legislation or ordinance. While there are different constitutional or procedural issues that determine how this can be done in each jurisdiction, nearly 600 funds have been established in 43 states in the country, generating more than $1.6 billion a year to support housing needs. State housing trust funds are the most significant source of money, and are usually funded with proceeds from the real estate transfer tax or documentary stamp tax. Cities typically use developer fees. Counties have a more difficult time finding a funding source, but they are well-positioned to provide broad support for affordable housing outside municipal boundaries.

Socio-economic diversity enhances community stability and sustainability

The City of Charlotte purchased property at Scaleybark station, which is surrounded by large industrial and commercial sites, to ensure that development remains affordable.

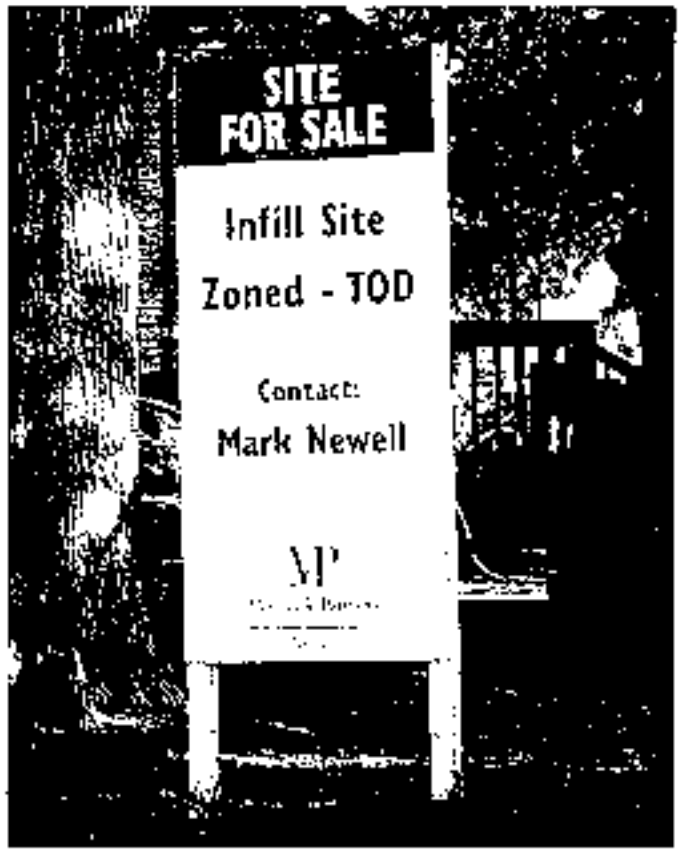
PURCHASING AFFORDABILITY

Housing trust funds are used for a variety of purposes, including the construction and maintenance of affordable housing, homebuyer assistance, homeless shelters, gap financing (for projects where other funding sources leave a gap requiring additional resources), loans for developers, and/or matching funds used to leverage private investment. One of the appeals of a city-controlled fund is that it can be tailored to the particular needs and opportunities of a community.

Targeting these resources to sites near transit is especially important because transit-oriented development provides increased affordability. The American Public Transportation Association estimates that households that live near transit and use it can save $9,499 a year on transportation compared to households that drive (www.apta.com). Research by the Center for Transit-Oriented Development shows that households living in walkable, mixed-use neighborhoods near transit spend about 16 percent less on transportation than households that live in conventional suburban development (www.reconnectingamerica.org). For these reasons, trust funds and well as other affordable housing resources should be used around stations and along transit corridors to preserve existing affordable

housing, to purchase rental properties for permanent use as affordable housing, and/or to build new affordable housing.

Charlotte, North Carolina, established an Affordable Housing Trust Fund to provide public funding to private developers in exchange for affordable units using a competitive bid process. The City Council set aside $10 million for the fund in 2001, and voters then approved another $35 million. The city has the flexibility to make the funds available as either a loan or grant for land acquisition or construction. By 2007 the fund had enabled the construction or rehabilitation of more than 2,800 units, more than half of which were for households earning below 30 percent of area median income. This number included 223 units of new affordable ownership housing, more than 900 new multifamily rental units, nearly 600 rehabilitated multifamily rental units, and more than 1,100 units for households with special needs. The average subsidy per unit was less than $14,000 and sometimes included other affordable housing funds.



Land acquisition funds or land banking funds can also be used to secure sites near transit for affordable housing or transit-oriented projects while the land is still affordable. This is especially important now because changing demographics in the U.S. are boosting the demand for housing in these locations, driving up the price of real estate near stations.

AFFORDABLE HOUSING

Land acquisition funds or land banking funds can also be used to secure sites near transit for affordable housing or transit-oriented projects while the land is still affordable. This is especially important now because changing demographics in the U.S. – households are older, smaller and more diverse – are boosting the demand for housing in these locations, driving up the price of real estate near stations. Land acquisition or land banking funds can also be used to acquire existing housing in order to preserve affordability in neighborhoods where gentrification is a threat.

Development fees, flexible state transportation and housing funds, and grants from philanthropic organizations are often used to create land acquisition funds.

The city of Charlotte has also established a land acquisition fund to purchase land near the stations planned along its South Corridor light rail line to ensure the development of mixed-income, mixed-use TOD. The City Council capitalized the fund with an initial grant of $5 million. It is jointly managed by Coldwell Banker Commercial, the Charlotte Area Transit System, and several city departments. The first site, the Scaleybark station area, was purchased with the help of the city's Housing Trust Fund, and development is required to meet a minimum affordable housing threshold.

Produced by Reconnecting America on behalf of the Local Initiatives Support Corporation

TRANSIT ORIENTED DEVELOPMENT AND PROPOSITION 207 IN METROPOLITAN PHOENIX

In 2007, the city of Phoenix and its partners, Valley Metro Rail and the city of Mesa sought policy analysis assistance to address how to promote transit oriented development (TOD) along its newly opened light rail and future extensions given the impact of the passage of Proposition 207 (Private Property Rights Protection Act). Over the course of the past 18 months, the U. S. Environmental Protection Agency (US EPA) lead a group of national experts to help the local team and its supporters including the Local Initiative Support Corporation and the Sonoran Institute develop options for encouraging transit oriented development while addressing Proposition 207.

The project evolved into a discussion of the most appropriate tools and incentives that localities can use to promote TOD. Four documents were developed as the team's analysis for this project, each covering some specific aspect and nuance of these tools and how they will be utilized.

These documents include:

Transit Oriented Development in Phoenix and Mesa: Developing a Policy Toolbox for the Post-Proposition 207 Environment

Strategic Package of Tools to Transit Oriented Development in Metropolitan Phoenix

Encouraging Transit Oriented Development in Metropolitan Phoenix: Case Studies that Work

Impact of TOD and Smart Growth Incentives on Development in Phoenix

These documents are meant to be used as a whole to create a complete picture of addressing TOD in Phoenix, but because of the distinct nature of the individual analysis presented, each are also intended to stand alone as a resource.

Furthermore, these documents are still draft, as they will be presented to stakeholders and a group of developers and property owners during a two-day work session April 16-17, 2009. Input from this discussion will be assessed and incorporated to these documents. Finally, a brief next steps memo (5 to 7 pages) will be delivered to the cities and partners in May 2009 along with the final documents. This action will complete the project.

For more information and project update please call:

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UNEP

Integrated Assessment of Black Carbon and Tropospheric Ozone

Summary for Decision Makers

A complete explanation of the topics covered in this summary can be found in the Integrated Assessment of Black Carbon and Tropospheric Ozone report and in the fully referenced underlying research, analyses and reports.

For details of UNEP's regional and subregional areas referred to throughout this document see
http://geodata.grid.unep.ch/mapgallery.php

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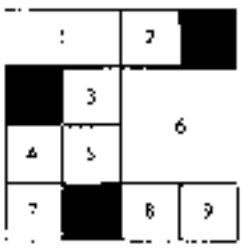

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Integrated Assessment of Black Carbon and Tropospheric Ozone

Summary for Decision Makers

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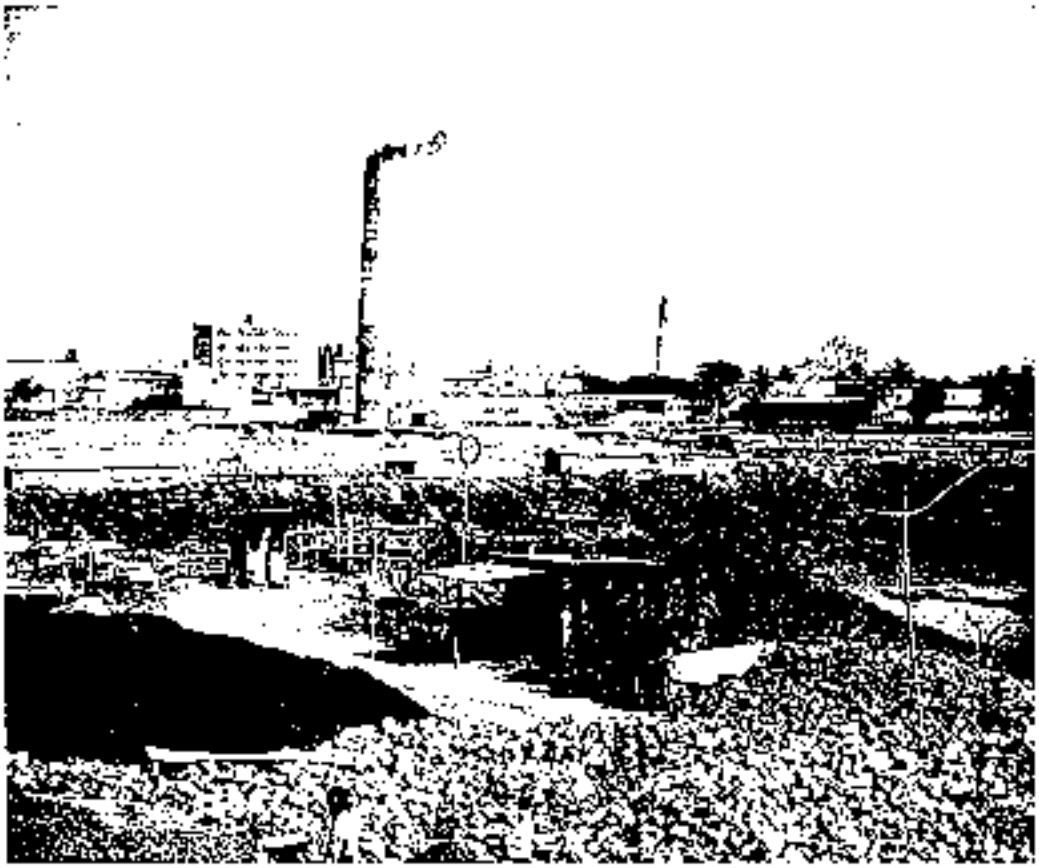
Main Messages

Scientific evidence and new analyses demonstrate that control of black carbon particles and tropospheric ozone through rapid implementation of proven emission reduction measures would have immediate and multiple benefits for human well-being.

Black carbon exists as particles in the atmosphere and is a major component of soot. It has significant human health and climate impacts. At ground level, ozone is an air pollutant harmful to human health and ecosystems, and throughout the troposphere, or lower atmosphere, is also a significant greenhouse gas. Ozone is not directly emitted, but is produced from emissions of precursors of which methane and carbon monoxide are of particular interest here.

THE CHALLENGE

1. **The climate is changing now, warming at the highest rate in polar and high-altitude regions.** Climate change, even in the near term, has the potential to trigger abrupt transitions such as the release of carbon from thawing permafrost and biodiversity loss. The world has warmed by about 0.8°C from pre-industrial levels, as reported by the



Traditional brick kilns in South Asia are a major source of black carbon. Improved kiln designs in that region is significantly reducing emissions.

Intergovernmental Panel on Climate Change (IPCC). The Parties to the United Nations Framework Convention on Climate Change (UNFCCC) have agreed that warming should not exceed 2°C above pre-industrial levels.

2. **Black carbon and ozone in the lower atmosphere are harmful air pollutants that have substantial regional and global climate impacts.** They disturb tropical rainfall and regional circulation patterns such as the Asian monsoon, affecting the livelihoods of millions of people.

3. **Black carbon's darkening of snow and ice surfaces increases their absorption of sunlight, which, along with atmospheric heating, exacerbates melting of snow and ice around the world, including in the Arctic, the Himalayas and other glaciated and snow-covered regions.** This affects the water cycle and increases risks of flooding.

4. **Black carbon, a component of particulate matter, and ozone both lead to adverse impacts on human health leading to premature deaths worldwide. Ozone is also the most important air pollutant responsible for reducing crop yields, and thus affects food security.**

REDUCING EMISSIONS

5. **Reducing black carbon and tropospheric ozone now will slow the rate of climate change within the first half of this century. Climate benefits from reduced ozone are achieved by reducing emissions of some of its precursors, especially methane which is also a powerful greenhouse gas.** These short-lived climate forcers – methane, black carbon and ozone – are fundamentally different from long-lived greenhouse gases, remaining in the atmosphere for only a relatively short time. Deep and immediate carbon dioxide reductions are required to protect long-term climate, as this cannot be achieved by addressing short-lived climate forcers.

6. **A small number of emission reduction measures targeting black carbon and ozone precursors could immediately begin to protect climate, public health, water and food security, and ecosystems.** Measures include the recovery of methane from coal, oil and gas extraction and transport, methane capture in waste management, use of clean burning stoves for residential cooking, diesel particulate filters for vehicles and the banning of field burning of agricultural waste. Widespread implementation is achievable with existing technology but would require significant strategic investment and institutional arrangements.

7. **The identified measures complement but do not replace anticipated carbon dioxide reduction measures.** Major carbon dioxide reduction strategies mainly target the energy and large industrial sectors and therefore would not necessarily result in significant reductions in emissions of black carbon or the ozone precursors methane and carbon monoxide. Significant reduction of the short-lived climate forcers requires a specific strategy, as many are emitted from a large number of small sources.

BENEFITS OF EMISSION REDUCTIONS

8. **Full implementation of the identified measures would reduce future global warming by 0.5°C (within a range of 0.2–0.7°C, Figure 1).** If the measures were to be implemented by 2030, they could halve the potential increase in global temperature projected for 2050 compared to the Assessment's reference scenario based on current policies and energy and fuel projections. The rate of regional temperature increase would also be reduced.

9. **Both near-term and long-term strategies are essential to protect climate.** Reductions in near-term warming can be achieved by control of the short-lived climate forcers whereas carbon dioxide emission reductions, beginning now, are required to limit long-term climate change. Implementing both reduction strategies is needed to improve the chances of keeping the Earth's global mean temperature increase to within the UNFCCC 2°C target.

10. **Full implementation of the identified measures would have substantial benefits in the Arctic, the Himalayas and other glaciated and snow-covered regions.** This could reduce warming in the Arctic in the next 30 years by about two-thirds compared to the projections of the Assessment's reference scenario. This substantially decreases the risk of changes in weather patterns and amplification of global warming resulting from changes in the Arctic. Regional benefits of the black carbon measures, such as their effects on snow- and ice-covered regions or regional rainfall patterns, are largely independent of their impact on global mean warming.

11. **Full implementation of the identified measures could avoid 2.4 million premature deaths (within a range of 0.7–4.6 million) and the loss of 52 million tonnes (within a range of 30–140 million tonnes), 1–4 per cent, of the global production of maize, rice, soybean and wheat each year (Figure 1).** The most substantial benefits will be felt immediately in or close to the regions where action is taken to reduce emissions, with the greatest health and crop benefits expected in Asia.

RESPONSES

12. The identified measures are all currently in use in different regions around the world to achieve a variety of environment and development objectives. **Much wider and more rapid implementation is required to achieve the full benefits identified in this Assessment.**

13. **Achieving widespread implementation of the identified measures would be most effective if it were country- and region-specific, and could be supported by the considerable existing body of knowledge and experience.** Accounting for near-term climate co-benefits could leverage additional action and funding on a wider international scale which would facilitate more rapid implementation of the measures. Many measures achieve cost savings over time. However, initial capital investment could be problematic in some countries, necessitating additional support and investment.

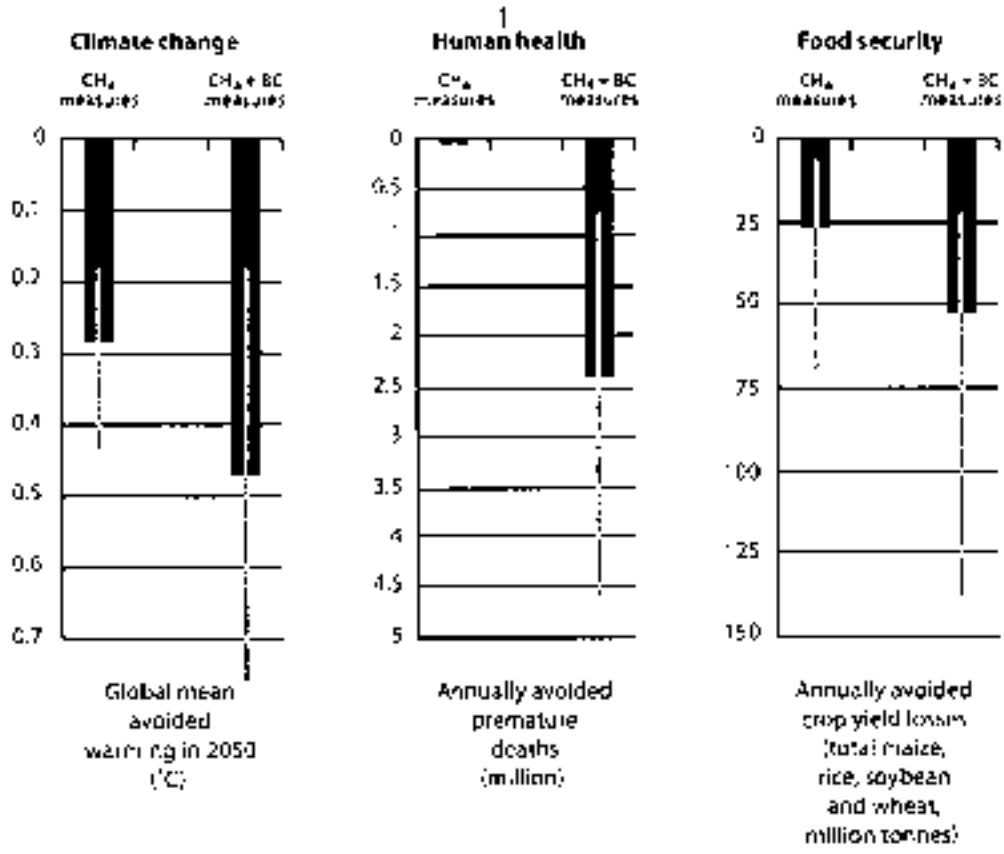


Figure 1. Global benefits from full implementation of the identified measures in 2050 compared to the reference scenario. The climate change benefits estimated for a given year (2050) and human health and crop benefits are for 2030 and beyond

14. **At national and sub-national scales many of the identified measures could be implemented under existing policies designed to address air quality and development concerns. Improved cooperation within and between regions would enhance widespread implementation and address transboundary climate and air quality issues.** International policy and financing instruments to address the co-benefits of reducing emissions of short-lived climate forcers need development and strengthening. Supporting and extending existing relevant regional arrangements may provide an opportunity for more effective cooperation, implementation and assessment as well as additional monitoring and research.

15. **The Assessment concludes that there is confidence that immediate and multiple benefits will be realized upon implementation of the identified measures.** The degree of confidence varies according to pollutant, impact and region. For example, there is higher confidence in the effect of methane measures on global temperatures than in the effect of black carbon measures, especially where these relate to the burning of biomass. There is also high confidence that benefits will be realized for human health from reducing particles, including black carbon, and to crop yields from reducing tropospheric ozone concentrations. Given the scientific complexity of the issues, further research is required to optimize near-term strategies in different regions and to evaluate the cost-benefit ratio for individual measures.

Introduction

Black carbon (BC; Box 1) and tropospheric ozone (O_3; Box 2) are harmful air pollutants that also contribute to climate change. In recent years, scientific understanding of how BC and O_3 affect climate and public health has significantly improved. This has catalysed a demand for information and action from governments, civil society and other stakeholders. The United Nations (UN) has been requested to urgently provide science-based advice on action to reduce the impacts of these pollutants.[1]

The United Nations Environment Programme (UNEP), in consultation with partners, initiated an assessment designed to provide an interface between knowledge and action, science and policy, and to provide a scientifically credible basis for informed decision-making. The result is a comprehensive analysis of drivers of emissions, trends in concentrations, and impacts on climate, human health and ecosystems of BC, tropospheric O_3 and its precursors. BC, tropospheric O_3 and methane (CH_4) are often referred to as short-lived climate forcers (SLCFs) as they have a short lifetime in the atmosphere (days to about a decade) relative to carbon dioxide (CO_2).

The Assessment is an integrated analysis of multiple co-emitted pollutants reflecting the fact that these pollutants are not emitted in isolation (Boxes 1 and 2). The Assessment determined that under current policies, emissions of BC and O_3 precursors are expected globally either to increase or to remain roughly constant unless further mitigation action is taken.

The Integrated Assessment of Black Carbon and Tropospheric Ozone convened more than 60 authors to assess the state of science and existing policy options for addressing these pollutants. The Assessment team examined policy responses, developed an outlook to 2070 illustrating the benefits of political decisions made today and the risks to climate, human health and crop yields over the next decades if action is delayed. Placing a premium on robust science and analysis, the Assessment was driven by four main policy-relevant questions:

- Which measures are likely to provide significant combined climate and air quality benefits?
- How much can implementation of the identified measures reduce the rate of global mean temperature increase by mid-century?
- What are the multiple climate, health and crop-yield benefits that would be achieved by implementing the measures?
- By what mechanisms could the measures be rapidly implemented?

In order to answer these questions, the Assessment team determined that new analyses were needed. The Assessment therefore relies on published literature as much as possible and on new simulations by two independent climate chemistry aerosol models – one developed and run by the NASA-Goddard Institute for Space Studies (GISS), and the other developed by the Max Planck Institute in Hamburg, Germany (ECHAM), and run at the Joint Research Centre of the European Commission in Ispra, Italy. The specific measures and emission estimates for use in developing this Assessment were selected using the International Institute for Applied Systems Analysis Greenhouse Gas and Air Pollution Interactions and Synergies (IIASA GAINS) model. For a more detailed description of the modelling see Chapter 3.

[1] The Antananarivo Declaration of 24 April 2009 adopted by the 1st Intergovernmental Panel on Climate Change Conference on Black Carbon and Tropospheric Ozone; the Bali Ministerial Meeting of the Arctic Council and the Bali Session of the Permanent Forum on Indigenous Issues; the Joint Arctic Experts Meeting; and Special Council, Jan. 2009, called on UNEP to conduct a full scientific assessment of black carbon and tropospheric ozone as climate forcers, and to develop options for reducing regional and global emissions to protect the Arctic. A need to take rapid action to address significant climate forcers, specifically tropospheric O_3, HCFCs and BC, was affirmed in the 2008 declaration of the Antarctic Treaty Consultative Parties, Antarctic Treaty Consultative Meeting XXXI, Kyiv, 4–13 June 2008.

Box 1: What is black carbon?

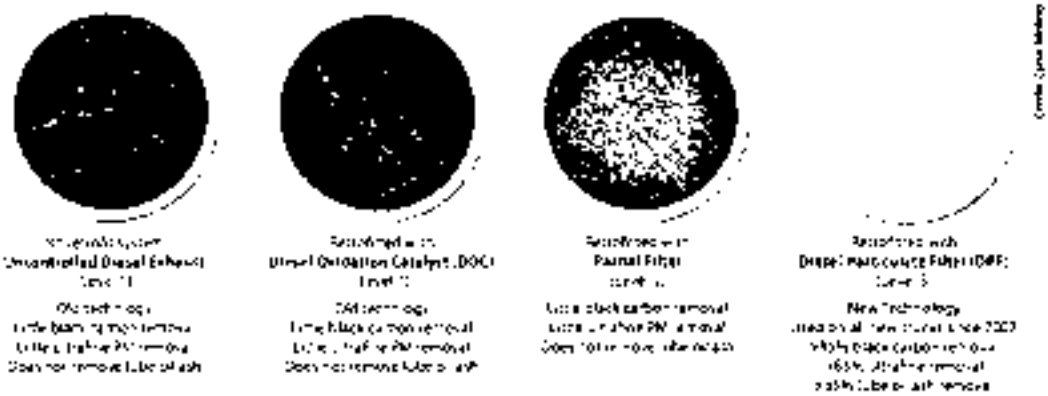
Black carbon (BC) exists as particles in the atmosphere and is a major component of soot. BC is not a greenhouse gas. Instead it warms the atmosphere by intercepting sunlight and absorbing it. BC and other particles are emitted from many common sources such as cars and trucks, residential stoves, forest fires and some industrial facilities. BC particles have a strong warming effect in the atmosphere, darken snow where it is deposited, and influence cloud formation. Other particles may have a cooling effect in the atmosphere and all particles influence clouds. In addition to having an impact on climate, anthropogenic particles are also known to have a negative impact on human health.

Black carbon results from the incomplete combustion of fossil fuels, wood and other biomass. Complete combustion would turn all carbon in the fuel into carbon dioxide (CO_2). In practice, combustion is never complete and CO_2, carbon monoxide (CO), volatile organic compounds (VOCs), organic carbon (OC) particles and BC particles are all formed. There is a close relationship between emissions of BC (a warming agent) and OC (a cooling agent). They are always co-emitted, but in different proportions for different sources. Similarly, mitigation measures will have varying effects on the BC/OC mix.

The black in BC refers to the fact that these particles absorb visible light. This absorption leads to a disturbance of the planetary radiation balance and eventually to warming. The contribution to warming of 1 gramme of BC seen over a period of 100 years has been estimated to be anything from 100 to 2 000 times higher than that of 1 gramme of CO_2. An important aspect of BC particles is that their lifetime in the atmosphere is short, days to weeks, and so emission reductions have an immediate benefit for climate and health.

Hazy with high particulate matter concentrations containing BC and OC, such as this over the Bay of Bengal, is widespread in many regions

High-emitting vehicles are a significant source of black carbon and other pollutants in many countries



Some of the largest emission reductions are obtained using diesel particulate filters on high-emitting vehicles. The circles show an actual particulate matter (PM) collection samples from an engine testing laboratory (International Council of Clean Transportation (ICCT))

Box 2: What is tropospheric ozone?

Ozone (O_3) is a reactive gas that exists in two layers of the atmosphere: the stratosphere (the upper layer) and the troposphere (ground level to ~10–15 km). In the stratosphere, O_3 is considered to be beneficial as it protects life on Earth from the sun's harmful ultraviolet (UV) radiation. In contrast, at ground level, it is an air pollutant harmful to human health and ecosystems, and it is a major component of urban smog. In the troposphere, O_3 is also a significant greenhouse gas. The threefold increase of the O_3 concentration in the northern hemisphere during the past 100 years has made it the third most important contributor to the human enhancement of the global greenhouse effect, after CO_2 and CH_4.

In the troposphere O_3 is formed by the action of sunlight on O_3 precursors that have natural and anthropogenic sources. These precursors are CH_4, nitrogen oxides (NO_x), VOCs and CO. It is important to understand that reductions in both CH_4 and CO emissions have the potential to substantially reduce O_3 concentrations and reduce global warming. In contrast, reducing VOCs would clearly be beneficial but has a small impact on the global scale while reducing NO_x has multiple additional effects that result in its net impact on climate being minima.

Tropospheric ozone is a major constituent of urban smog; left Tokyo, Japan; right Denver, Colorado, USA

Limiting Near-Term Climate Changes and Improving Air Quality

Identifying effective response measures

The Assessment identified those measures most likely to provide combined benefits, taking into account the fact that BC and O_3 precursors are co-emitted with different gases and particles, some of which cause warming and some of which, such as organic carbon (OC) and sulphur dioxide (SO_2) lead to cooling. The selection criterion was that the measure had to be likely to reduce global climate change and also provide air quality benefits, so-called win-win measures. Those measures that provided a benefit for air quality but increased warming were not included in the selected measures. For example, measures that primarily reduce emissions of SO_2 were not included.

The identified measures (Table 1) were chosen from a subset of about 2 000 separate measures that can be applied to sources in IIASA's GAINS model. The selection was based on the net influence on warming, estimated using the metric Global Warming Potential (GWP), of all of the gases and particles that are affected by the measure. The selection gives a useful indication of the potential for realizing a win for climate. All emission reduction measures were assumed to benefit air quality by reducing particulate matter and/or O_3 concentrations.

This selection process identified a relatively small set of measures which nevertheless provide about 90 per cent of the climate benefit compared to the implementation of all 2 000 measures in GAINS. The final analysis of the benefits for temperature, human health and crop yields considered the emissions of all substances resulting from the full implementation of the identified measures through the two global composition-climate models GISS and ECHAM (see Chapter 4). One hundred per cent implementation of the measures globally was used to illustrate the existing potential to reduce climate and air quality impacts, but this does not make any assumptions regarding the feasibility of full implementation everywhere. A discussion of the challenges involved in widespread implementation of the measures follows after the potential benefit has been demonstrated.

Achieving large emission reductions

The packages of policy measures in Table 1 were compared to a reference scenario (Table 2). Figure 2 shows the effect of the packages of policy measures and the reference scenario relative to 2005 emissions.

There is tremendous regional variability in how emissions are projected to change by the year 2030 under the reference scenario. Emissions of CH_4 – a major O_3 precursor and a potent greenhouse gas – are expected to increase in the future (Figure 2). This increase will occur despite current and planned regulations, in large part due to anticipated economic growth and the increase in fossil fuel production projected to accompany it. In contrast, global emissions of BC and accompanying co-emitted pollutants are expected to remain relatively constant through to 2030. Regionally, reductions in BC emissions are expected due to tighter standards on road transport and more efficient combustion replacing use of biofuels in the residential and commercial sectors,

Table 1. Measures that improve climate change mitigation and air quality and have a large emission reduction potential

Measure[1]	Sector
CH_4 measures	
Extended pre-mine degasification and recovery and oxidation of CH_4 from ventilation air from coal mines	Extraction and transport of fossil fuel
Extended recovery and utilization, rather than venting, of associated gas and improved control of unintended fugitive emissions from the production of oil and natural gas	
Reduced gas leakage from long-distance transmission pipelines	
Separation and treatment of biodegradable municipal waste through recycling, composting and anaerobic digestion as well as landfill gas collection with combustion/utilization	Waste management
Upgrading primary wastewater treatment to secondary/tertiary treatment with gas recovery and overflow control	
Control of CH_4 emissions from livestock, mainly through farm-scale anaerobic digestion of manure from cattle and pigs	Agriculture
Intermittent aeration of continuously flooded rice paddies	
BC measures (affecting BC and other co-emitted compounds)	
Diesel particle filters for road and off-road vehicles	Transport
Elimination of high-emitting vehicles in road and off-road transport	
Replacing coal by coal briquettes in cooking and heating stoves	Residential
Pellet stoves and boilers using fuel made from recycled wood waste or sawdust, to replace current wood-burning technologies in the residential sector in industrialized countries	
Introduction of clean-burning biomass stoves for cooking and heating in developing countries[2,3]	
Substitution of clean-burning cookstoves using modern fuels for traditional biomass cookstoves in developing countries[2,3]	
Replacing traditional brick kilns with vertical shaft kilns and Hoffman kilns	Industry
Replacing traditional coke ovens with modern recovery ovens, including the improvement of end-of-pipe abatement measures in developing countries	
Ban of open field burning of agricultural waste[4]	Agriculture

[1] There are measures other than those identified in the table that could be implemented. For example, electric cars would have a similar impact to diesel particulate filters but these have not yet been widely introduced. Forest fire controls could also be important but are not included due to the difficulty in establishing the proportion of fires that are anthropogenic.
[2] Motivated in part by its effect on health and regional climate, including areas of ice and snow.
[3] For cookstoves, given their importance for BC emissions, two alternative measures are included.

although these are offset to some extent by increased activity and economic growth. The regional BC emission trends, therefore, vary significantly, with emissions expected to decrease in North America and Europe, Latin America and the Caribbean, and in Northeast Asia, Southeast Asia and the Pacific, and to increase in Africa and South, West and Central Asia.

The full implementation of the selected measures by 2030 leads to significant reductions of SLCF emissions relative to current emissions or to the 2030 emissions in the reference scenario (Figure 2). It also reduces a high proportion of the emissions relative to the maximum reduction from the implementation of all 2 000 or so measures in the GAINS model. The measures designed to

reduce BC also have a considerable impact on OC, total fine particulate matter ($PM_{2.5}$) and CO emissions, removing more than half the total anthropogenic emissions. The largest BC emission reductions are obtained through measures controlling incomplete combustion of biomass and diesel particle filters.

The major sources of CO_2 are different from those emitting most BC, OC, CH_4 and CO. Even in the few cases where there is overlap, such as diesel vehicles, the particle filters that reduce BC, OC and CO have minimal effect on CO_2. The measures to reduce CO_2 over the next 20 years (Table 2) therefore hardly affect the emissions of BC, OC or CO. The influence of the CH_4 and BC measures is thus the same regardless of whether the CO_2 measures are imposed or not.

Reducing near-term global warming

The Earth is projected to continue the rapid warming of the past several decades and, without additional mitigation efforts, under the reference scenario global mean temperatures are projected to rise about a further 1.3°C (with a range of 0.8–2.0°C) by the middle of this century, bringing the total warming from pre-industrial levels to about 2.2°C (Figure 3). The Assessment shows that the measures targeted to reduce emissions of BC and CH_4 could greatly reduce global mean warming rates over the next few decades (Figure 3). Figure 3 shows that over half of the reduced global mean warming is achieved by the CH_4 measures and the remainder by BC measures. The greater confidence in the effect of CH_4 measures on warming is reflected in the narrower range of estimates.

When all measures are fully implemented, warming during the 2030s relative to the present day is only half as much as if no measures had been implemented. In contrast, even a fairly aggressive strategy to reduce CO_2 emissions under the CO_2 measures scenario does little to mitigate warming over the next 20–30 years. In fact, sulphate particles, reflecting particles that offset some of the committed warming for the short time they are in the atmosphere, are derived from SO_2 that is co-emitted with CO_2 in some of the highest-emitting activities, including coal burning in large-scale combustion such as in power plants. Hence, CO_2 measures alone may temporarily enhance near-term warming as sulphates are reduced (Figure 3).

Table 2. Policy packages used in the Assessment

Scenario	Description[1]
Reference	Based on energy and fuel projections of the International Energy Agency (IEA; *World Energy Outlook 2009* and incorporating all presently agreed policies affecting emissions
CH_4 measures	Reference scenario plus the CH_4 measures
BC measures	Reference scenario plus the BC measures (the BC measures affect many pollutants, especially BC, OC, and CO)
CH_4 + BC measures	Reference scenario plus the CH_4 and BC measures
CO_2 measures	Emissions modelled using the assumptions of the IEA *World Energy Outlook 2009* 450 Scenario[2] and the IIASA GAINS database. Includes CO_2 measures only. The CO_2 measures affect other emissions, especially SO_2[3]
CO_2 – CH_4 + BC measures	CO_2 measures plus CH_4 and BC measures

[1] All scenarios (national pollutant emissions are assumed through 2030, after which only trends in CO_2 are included)

[2] The 450 Scenario aims to keep total forcing due to long-lived greenhouse gases, including CH_4, in this case at a level equivalent to 450 ppm CO_2 by the end of the century

[3] Emissions of SO_2 are reduced by 35–40 per cent by implementing CO_2 measures. A further reduction in sulphur emissions would be beneficial to health but would increase global warming. This is because sulphate particles cool the Earth by reflecting sunlight back to space

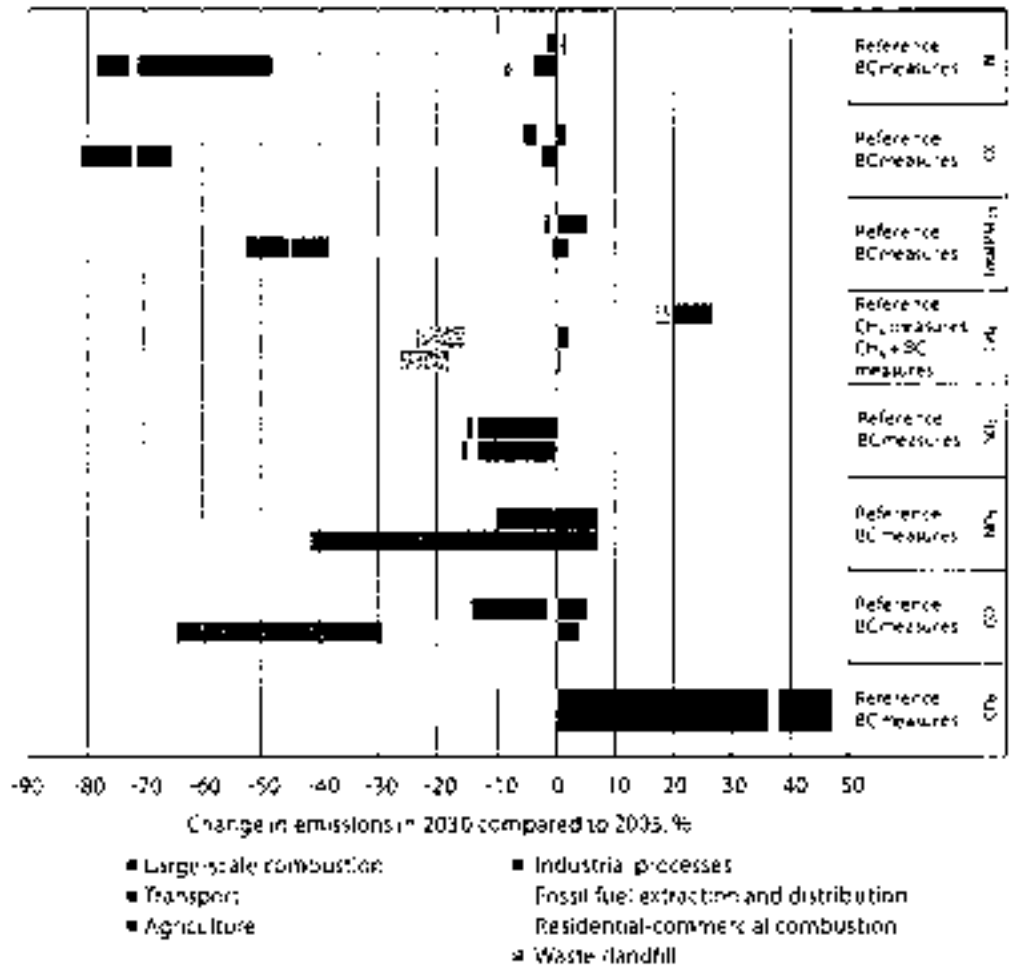


Figure 2. Percentage change in anthropogenic emissions of the indicated pollutants in 2030 relative to 2005 for the reference, CH_4, BC and CH_4 + BC measures scenarios. The CH_4 measures have minimal effect on emissions of anything other than CH_4. The identified BC measures reduce a large proportion of total BC, OC and CO emissions. SO_2 and CO_2 emissions are hardly affected by the identified CH_4 and BC measures, while NO$_x$ and other $PM_{2.5}$ emissions are affected by both BC measures.

temperatures in the CO_2 measures scenario are slightly higher than those in the reference scenario during the period 2030–2040).

The CO_2 measures clearly lead to long-term benefits, with a dramatically lower warming rate in 2070 than under the scenario with only near-term CH_4 + BC measures. Owing to the long residence time of CO_2 in the atmosphere, these long-term benefits will only be achieved if CO_2 emission reductions are brought on quickly. In essence, the near-term CH_4 and BC measures examined in this Assessment are effectively decoupled from the CO_2 measures both in that they target different source sectors and in that their impacts on climate change take place over different timescales.

Near-term warming may occur in sensitive regions and could cause essentially irreversible changes such as loss of Arctic land-ice, release of CH_4 or CO_2 from Arctic permafrost and species loss. Indeed, the projected warming in the reference scenario is greater in the Arctic than globally. Reducing the near-term rate of warming hence decreases the risk of irreversible transitions that could influence the global climate system for centuries.

Staying within critical temperature thresholds

Adoption of the near-term emission control measures described in this Assessment, together with measures to reduce CO_2 emissions, would greatly improve the chances of keeping Earth's temperature increase to less than 2°C relative to pre-industrial levels (Figure 3). With the CO_2 measures alone, warming exceeds 2°C before 2050. Even with both the CO_2 measures and CH_4 measures envisioned under the same IEA 450 Scenario, warming exceeds 2°C in the 2040s (see Chapter 5). However, the combination of CO_2, CH_4, and BC measures holds the temperature increase below 2°C until around 2070. While CO_2 emission reductions even larger than those in the CO_2 measures scenario would of course mitigate more warming, actual CO_2 emissions over the past decade have consistently exceeded the most pessimistic emission scenarios of the IPCC. Thus, it seems unlikely that reductions more stringent than those in the CO_2 measures scenario will take place during the next 20 years.

Examining the more stringent UNFCCC 1.5°C threshold, the CO_2 measures scenario exceeds this by 2030, whereas the near-term measures proposed in the Assessment delay that exceedance until after 2040. Again, while substantially deeper early reductions in CO_2 emissions than those in the CO_2 measures scenario could also delay the crossing of the 1.5°C temperature threshold, such reductions would undoubtedly be even more difficult to achieve. However, adoption of the Assessment's near-term measures (CH_4 + BC), along with the CO_2 reductions would provide

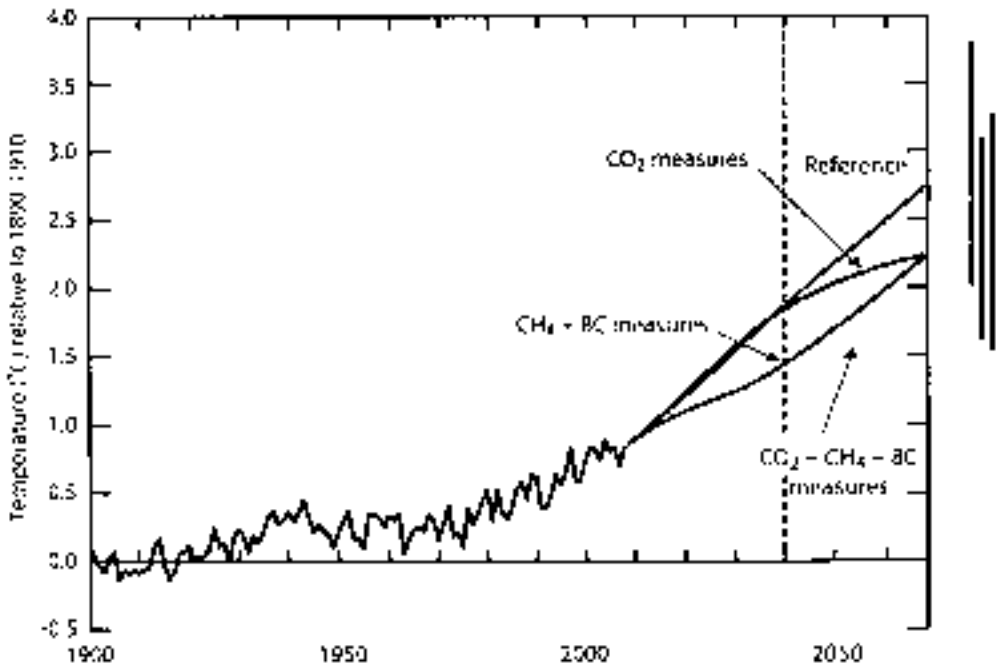


Figure 3. Observed deviation of temperature to 2009 and projections under various scenarios. Immediate implementation of the identified BC and CH_4 measures, together with measures to reduce CO_2 emissions, would greatly improve the chances of keeping Earth's temperature increase to less than 2°C relative to pre-industrial levels. The bulk of the benefits of CH_4 and BC measures are realized by 2040 (dashed line).
Explanatory notes: Actual mean temperature observations through 2009, and projected under various scenarios thereafter, are shown relative to the 1890–1910 mean temperature. Estimated ranges for 2030 are shown in the bars on the right. A portion of the uncertainty is common to all scenarios, so that overlapping ranges do not mean there is no difference. For example, if climate sensitivity is large (3.0 temperature regardless of the scenario, so temperatures in all scenarios would be toward the high end of their ranges.

a substantial chance of keeping the Earth's temperature increase below 1.5°C for the next 30 years.

Benefits of early implementation

There would clearly be much less warming during 2020–2060 were the measures implemented earlier rather than later (Figure 4). Hence there is a substantial near-term climate benefit in accelerating implementation of the identified measures even if some of these might eventually be adopted owing to general air-quality and development concerns. Clearly the earlier implementation will also have significant additional human health and crop-yield benefits.

Accelerated adoption of the identified measures has only a modest effect on long-term climate change in comparison with waiting 20 years, however (Figure 4). This reinforces the conclusion that reducing emissions of O_3 precursors and BC can have substantial benefits in the near term, but that mitigating long-term climate change depends on reducing emissions of long-lived greenhouse gases such as CO_2.

Regional climate benefits

While global mean temperatures provide some indication of climate impacts, temperature changes can vary dramatically from place to place even in response to relatively uniform forcing from long-lived greenhouse gases. Figure 5 shows that warming is projected to increase for all regions with some variation under the reference scenario, while the Assessment's measures provide the benefit of reduced warming in all regions.

Climate change also encompasses more than just temperature changes. Precipitation, melting rates of snow and ice, wind patterns, and clouds are all affected, and these in turn have an impact on human well-being by influencing factors such as water availability, agriculture and land use.

Both O_3 and BC, as well as other particles, can influence many of the processes that lead to the formation of clouds and precipitation. They alter surface temperatures, affecting evaporation. By absorbing sunlight in the atmosphere, O_3 and especially BC can affect cloud formation, rainfall and weather patterns. They can change wind patterns by affecting the regional temperature contrasts that drive the winds, influencing where rain and snow fall. While some aspects of these effects are local, they can also affect temperature, cloudiness, and precipitation far away from the emission sources. The regional changes in all these aspects of climate will be significant, but are currently not well quantified.

Tropical rainfall patterns and the Asian monsoon

Several detailed studies of the Asian monsoon suggest that regional forcing by absorbing particles substantially alters precipitation patterns (as explained in the previous section). The fact that both O_3 and particle changes are predominantly in the northern hemisphere means that they cause temperature gradients between the two hemispheres that influence rainfall patterns throughout the tropics. Implementation of the measures analysed in this Assessment would substantially decrease the regional atmospheric heating by particles (Figure 6), and are hence very likely to reduce regional shifts in precipitation. As the reductions of atmospheric forcing are greatest over the Indian sub-continent and other parts of Asia, the emission reductions may have a substantial effect on the Asian monsoon, mitigating disruption of traditional rainfall patterns. However, results from global climate models are not yet robust for the magnitude or timing of monsoon shifts resulting from either greenhouse gas increases or changes in absorbing particles. Nonetheless, results from climate models provide examples of the type of change that might be expected. Shifts in the timing and strength of precipitation can have significant impacts on human well-being because of changes in water

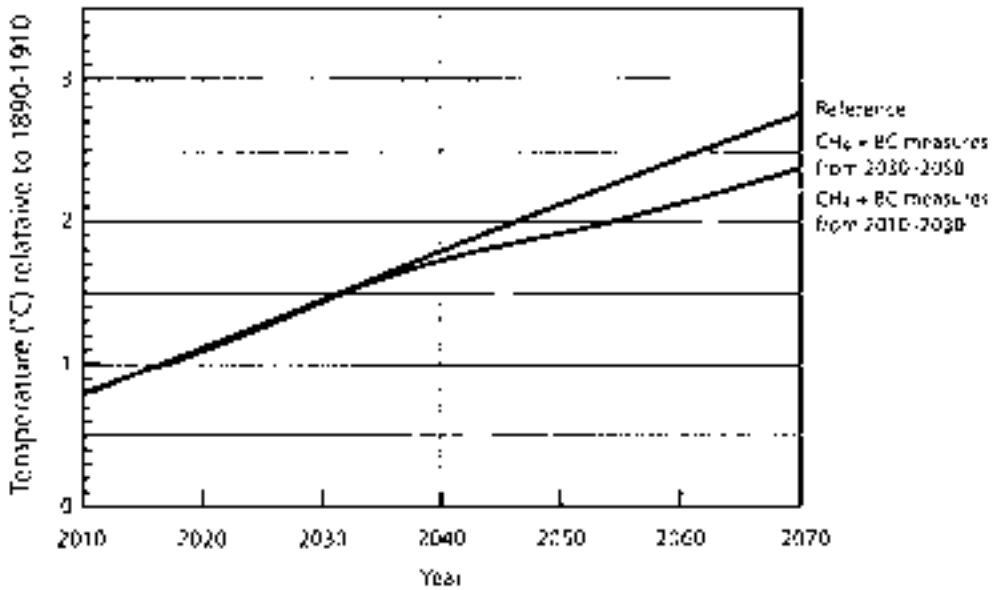


Figure 4. Projected global mean temperature changes for the reference scenario and for the CH_4 and BC measures scenario with emission reductions starting immediately or delayed by 20 years.

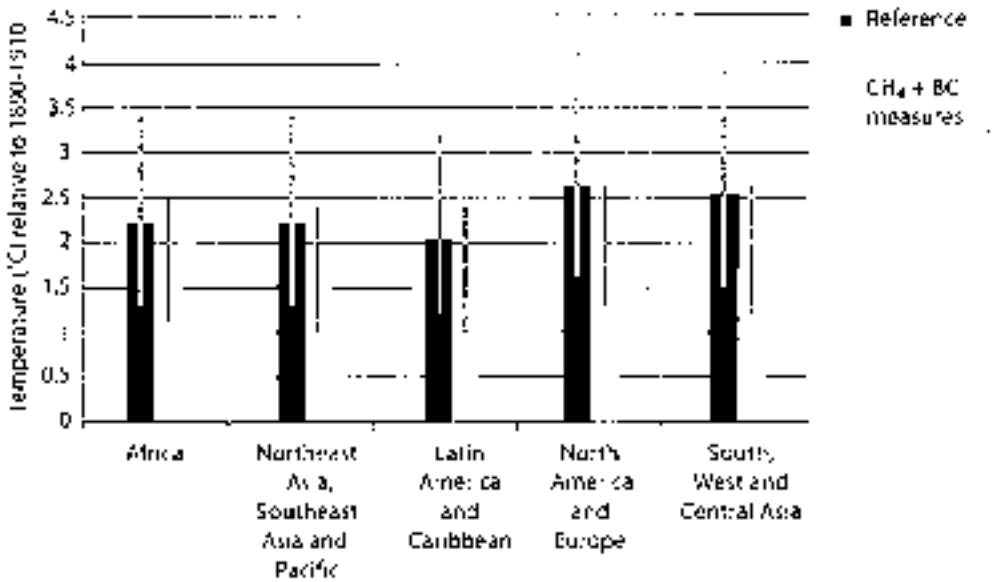


Figure 5. Comparison of regional mean warming over land (°C) showing the change in 2070 compared with 2005 for the reference scenario (Table 2) and the CH_4 + BC measures scenario. The lines on each bar show the range of estimates.

supply and agricultural productivity, drought and flooding. The results shown in Figure 6 suggest that implementation of the BC measures could also lead to a considerable reduction in the disruption of traditional rainfall patterns in Africa.

Decreased warming in polar and other glaciated regions

Implementation of the measures would substantially slow, but not halt, the current rapid pace of temperature rise and other changes already occurring at the poles and high-altitude glaciated regions, and the reduced warming in these regions would likely be greater than that seen globally. The large benefits occur in part because the snow/ice darkening effect of BC is substantially greater than the cooling effect of reflective particles co-emitted with BC, leading to greater warming impacts in these areas than in areas without snow and ice cover.

Studies in the Arctic indicate that it is highly sensitive both to local pollutant emissions and those transported from sources close to the Arctic, as well as to the climate impact of pollutants in the mid-latitudes of the northern hemisphere. Much of the need for implementation lies within Europe and North America. The identified measures could reduce warming in the Arctic by about 0.7°C with a range of 0.2–1.3°C in 2040. This is nearly two-thirds of the estimated 1.1°C (with a range of 0.7 – 1.7°C) warming projected for the Arctic under the reference scenario, and should substantially decrease the risk of global impacts from changes in this sensitive region, such as sea ice loss, which affects global albedo, and permafrost melt. Although not identified as a measure for use in this Assessment, the control of boreal forest fires may also be important in reducing impacts in the Arctic.

The Antarctic is a far less studied region in terms of SLCF impacts. However, there are studies demonstrating BC deposition even in central portions of the continent, and reductions in O_3 and CH_4 should slow warming in places like the Antarctic Peninsula, currently the spot on the globe showing the most rapid temperature rise of all.

The Himalayas and the Tibetan Plateau are regions where BC is likely to have serious impacts. In the high valleys of the Himalayas, for example, BC levels can be as high as in

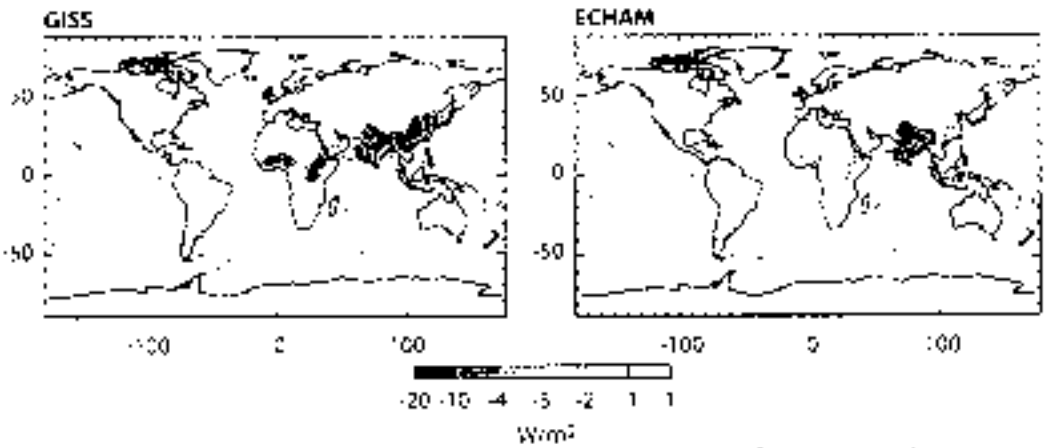


Figure 6. Change in atmospheric energy absorption (Watts per square metre, W/m²) as annual mean, an important factor driving tropical rainfall, and the monsoons resulting from implementation of BC measures. The changes in absorption of energy by the atmosphere are linked with changes in regional circulation and precipitation patterns, leading to increased precipitation in some regions and decreases in others. BC solar absorption increases the energy input to the atmosphere by as much as 5–15 per cent, with the BC measures removing the bulk of that heating. Results are shown for two independent models to highlight the similarity in the projections of where large regional decreases would occur.

a mid-sized city. Reducing emissions from local sources and those carried by long-range transport should lower glacial melt in these regions, decreasing the risk of impacts such as catastrophic glacial lake outbursts.

Benefits of the measures for human health

Fine particulate matter (measured as $PM_{2.5}$, which includes BC) and ground-level O_3 damage human health. $PM_{2.5}$ causes premature deaths primarily from heart disease and lung cancer, and O_3 exposure causes deaths primarily from respiratory illness. The health benefit estimates in the Assessment are limited to changes in these specific causes of death and include uncertainty in the estimation methods. However, these pollutants also contribute significantly to other health impacts including acute and chronic bronchitis and other respiratory illness, non-fatal heart attacks, low birth weight and results in increased emergency room visits and hospital admissions, as well as loss of work and school days.

Under the reference scenario, that is, without implementation of the identified measures, changes in concentrations of $PM_{2.5}$ and O_3 in 2030, relative to 2005, would have substantial effects globally on premature deaths related to air pollution. By region, premature deaths from outdoor pollution are projected to change in line with emissions. The latter are expected to decrease significantly over North America and Europe due to implementation of the existing and expected legislation. Over Africa and Latin America and the Caribbean, the number of premature deaths from these pollutants is expected to show modest changes under the reference scenario (Figure 7). Over Northeast Asia, Southeast Asia and Pacific, premature deaths are projected to decrease substantially due to reductions in $PM_{2.5}$ in some areas. However, in South, West and Central Asia, premature deaths are projected to rise significantly due to growth in emissions.

In contrast to the reference scenario, full implementation of the measures identified in the Assessment would substantially improve air quality and reduce premature deaths globally due to significant reductions in indoor and outdoor air pollution. The reductions in $PM_{2.5}$ concentrations resulting from the BC measures would, by 2030, avoid an estimated 0.7–4.6 million annual premature deaths due to outdoor air pollution (Figure 1).

Regionally, implementation of the identified measures would lead to greatly improved air quality and fewer premature deaths, especially in Asia (Figure 7). In fact, more than 80 per cent of the health benefits of implementing all measures occur in Asia. The benefits are large enough for all the worsening trends in human health due to outdoor air pollution to be reversed and turned into improvements, relative to 2005. In Africa, the benefit is substantial, although not as great as in Asia.

Benefits of the measures for crop yields

Ozone is toxic to plants. A vast body of literature describes experiments and observations showing the substantial effects of O_3 on visible leaf health, growth and productivity for a large number of crops, trees and other plants. Ozone also affects vegetation composition and diversity. Globally, the full implementation of CH_4 measures results in significant reductions in O_3 concentrations leading to avoided yield losses of about 25 million tonnes of four staple crops each year. The implementation of the BC measures would account for about a further 25 million tonnes of avoided yield losses in comparison with the reference scenario (Figure 1). This is due to significant reductions in emissions of the precursors CO, VOCs and NO_X that reduce O_3 concentrations.

The regional picture shows considerable differences. Under the reference scenario, O_3 concentrations over Northeast, Southeast

Asia and Pacific are projected to increase, resulting in additional crop yield losses (Figures 7 and 8). In South, West and Central Asia, both health and agricultural damage are projected to rise (Figure 8). Damage to agriculture is projected to decrease strongly over North America and Europe while changing minimally over Africa and Latin America and the Caribbean. For the whole Asian region maize yields show a decrease of 1–15 per cent, while yields decrease by less than 5 per cent for wheat and rice. These yield losses translate into nearly 40 million tonnes for all crops for the whole Asian region, reflecting the substantial cultivated area exposed to elevated O_3 concentrations in India – in particular the Indo-Gangetic Plain region. Rice production is also affected, particularly in Asia where elevated O_3 concentrations are likely to continue to increase to 2030. Yield loss values for rice are uncertain, however, due to a lack of experimental evidence on concentration-response functions. In contrast, the European and North American regional analyses suggest that all crops will see an improvement in yields under the reference scenario between 2005 and 2030. Even greater improvements would be seen upon implementation of the measures.

The identified measures lead to greatly reduced O_3 concentrations, with substantial benefits to crop yields, especially in Asia (Figure 8). The benefits of the measures are large enough to reverse all the worsening trends seen in agricultural yields and turn them into improvements, relative to 2030, with the exception of crop yields in Northeast and Southeast Asia and Pacific. Even in that case, the benefits of full implementation are quite large, with the measures reducing by 60 per cent the crop losses envisaged in the reference scenario.

It should be stressed that the Assessment's analyses include only the direct effect of changes in atmospheric composition on health and agriculture through changes in exposure to pollutants. As such, they do not include the benefits that avoided climate change would have on human health and agriculture due to factors such as reduced disruption of precipitation patterns, dimming, and reduced frequency of heat waves. Furthermore, even the direct influence on yields are based on estimates for only four staple crops, and impacts on leafy crops, productive grasslands and food quality were not included, so that the calculated values are likely to be an

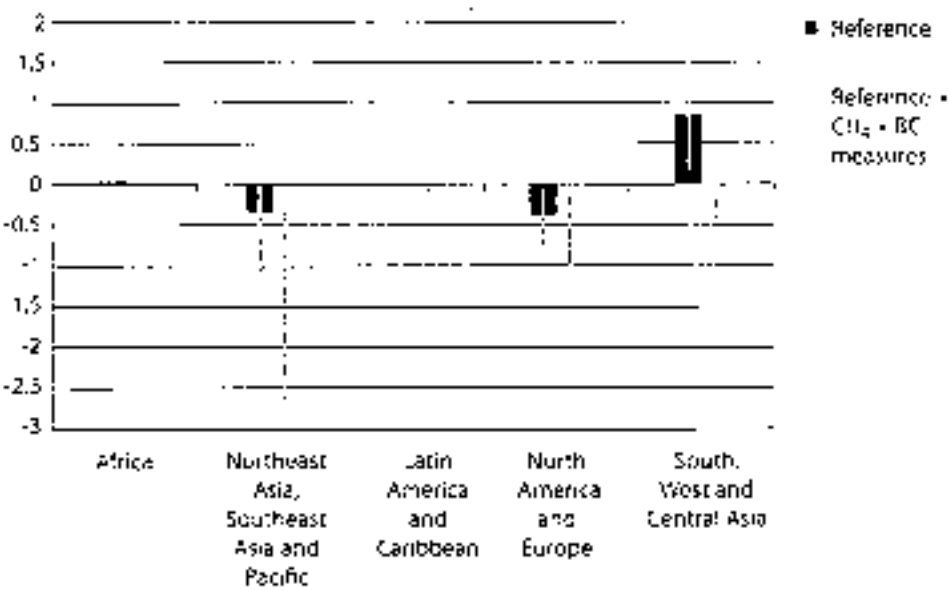


Figure 7. Comparison of premature mortality (millions of premature deaths annually) by region, showing the change in 2030 in comparison with 2005 for the reference scenario emission trends and the reference plus CH_4 + BC measures. The lines on each bar show the range of estimates.

The measures identified in the Assessment include replacement of traditional cookstoves, such as that shown here, with clean burning stoves which would substantially improve air quality and reduce premature deaths due to indoor and outdoor air pollution.

underestimate of the total impact. In addition, extrapolation of results from a number of experimental studies to assess O_3 impacts on ecosystems strongly suggests that reductions in O_3 could lead to substantial increases in the net primary productivity. This could have a substantial impact on carbon sequestration, providing additional climate benefits.

Relative importance and scientific confidence in the measures

Methane measures have a large impact on global and regional warming, which is achieved by reducing the greenhouse gases CH_4 and O_3. The climate mitigation impacts of the CH_4 measures are also the most certain because there is a high degree of confidence in the warming effects of this greenhouse gas. The reduced methane and hence O_3 concentrations also lead to significant benefits for crop yields.

The BC measures identified here reduce concentrations of BC, OC and O_3 largely through reductions in emissions of CO_2. The warming effect of BC and O_3 and the compensating cooling effect of OC_4 introduces large uncertainty in the net effect of some BC measures on global warming (Figure 1). Uncertainty in the impact of BC measures is also larger than that for CH_4 because BC and OC can influence clouds that have multiple effects on climate that are not fully understood. This uncertainty in global impacts is presumably large for the

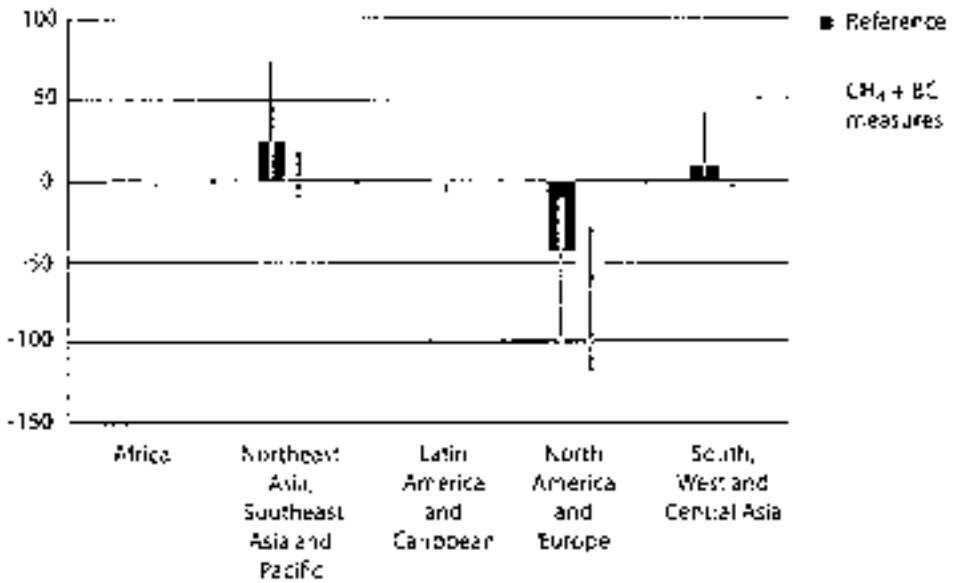


Figure 8. Comparison of crop yield losses (in millions of tonnes annually of four key crops – wheat, rice, maize and soy combined) by region, showing the change in 2030 compared with 2005 for the reference emission trends and the reference with CH_4 + BC measures. The lines on each bar show the range of estimates.

Widespread haze over the Himalayas where BC concentrations can be as high as in industrialized cities.

Reducing emissions should lower glacier melt and decrease the risk of outburst from glacier lakes.

measures concerning biomass cookstoves and open burning of biomass. Hence with respect to global warming, there is much higher confidence for measures that mitigate diesel emissions than biomass burning because the proportion of co-emitted cooling OC particles is much lower for diesel.

On the other hand, there is higher confidence that BC measures have large impacts on human health through reducing concentrations of inhalable particles, on crop yields through reduced O_3, and on climate phenomena such as tropical rainfall, monsoons and snow-ice melt. These regional impacts are largely independent of the measures' impact on global warming. In fact, regionally, biomass cookstoves and open biomass burning can have much larger effects than fossil fuels. This is because BC directly increases atmospheric heating by absorbing sunlight, which, according to numerous published studies, affects the monsoon and tropical rainfall, and this is largely separate from the effect of co-emitted OC. The same conclusion applies with respect to the impact of BC measures on snow and ice. BC, because it is dark, significantly increases absorption of sunlight by snow and ice when it is deposited on these bright surfaces. OC that is deposited along with BC has very little effect on sunlight reflected by snow and ice since these surfaces are already very white. Hence knowledge of these regional impacts is, in some cases, more robust than the global impacts, and with respect to reducing regional impacts, all of the BC measures are likely to be significant. Confidence is also high that a large proportion of the health and crop benefits would be realized in Asia.

Mechanisms for rapid implementation

In December 2010 the Parties to the UNFCCC agreed that warming should not exceed 2°C above pre-industrial levels during this century. This Assessment shows that measures to reduce SLCFs, implemented in combination with CO_2 control measures, would increase the chances of staying below the 2°C target. The measures would also slow the rate of near term temperature rise and also lead to significant improvements in health, decreased disruption of regional precipitation patterns and water supply, and in improved food security. The impacts of the measures on temperature change are felt over large geographical areas, while the air quality impacts are more localized near the regions where changes in emissions take place. Therefore, areas that control their emissions will receive the greatest human health and food supply benefits; additionally many of the climate benefits will be felt close to the region taking action.

The benefits would be realized in the near term, thereby providing additional incentives to overcome financial and institutional hurdles to the adoption of these measures. Countries in all regions have successfully implemented the identified measures to some degree for multiple environment and development objectives. These experiences

Field burning of agricultural waste is a common way to dispose of crop residue in many regions

provide a considerable body of knowledge and potential models for others that wish to take action.

In most countries, mechanisms are already in place, albeit at different levels of maturity, to address public concerns regarding air pollution problems. Mechanisms to tackle anthropogenic greenhouse gases are less well deployed, and systems to maximize the co-benefits from reducing air pollution and measures to address climate change are virtually non-existent. Coordination across institutions to address climate, air pollution, energy, and development policy is particularly important to ensure achievement of all these goals simultaneously.

Many BC control measures require implementation by multiple actors on diffuse emission sources including diesel vehicles, field burning, cookstoves and residential heating. Although air quality and emission standards exist for particulate matter in some regions, they may or may not reduce BC, and implementation remains a challenge. Relevance, benefits and costs of different measures vary from region to region. Many of the measures entail cost savings but require substantial upfront investments. Accounting for air quality, climate and development co-benefits will be key to scaling up implementation.

Methane is one of the six greenhouse gases governed by the Kyoto Protocol, but there are no explicit targets for it. Many CH_4 measures are cost-effective and its recovery is, in many cases, economically profitable. There have been many Clean Development Mechanism (CDM) projects in key CH_4 emitting sectors in the past, though few such projects have been launched in recent years because of lack of financing.

Case studies from both developed and developing countries (Box 3) show that there are technical solutions available to deliver all of the measures (see Chapter 5). Given appropriate policy mechanisms the measures can be implemented, but to achieve the benefits at the scale described much wider implementation is required.

To the naked eye, no emissions from an underground coal mine are visible (left), but with the aid of an infrared camera, escaping CH_4 is evident (right)

Box 3: Case studies of implementation of measures

CH_4 measures

Landfill biogas energy

Landfill CH_4 emissions contribute 10 per cent of the total greenhouse gas emissions in Mexico. Bioenergía de Nuevo León S. A. de C. V. (BENLESA) is using landfill biogas as fuel. Currently, the plant has an installed capacity of 12.7 megawatts. Since its opening in September 2003, it has avoided the release of more than 81 000 tonnes of CH_4, equivalent to the reduction in emissions of 1.7 million tonnes of CO_2, generating 409 megawatt hours of electricity. A partnership between government and a private company turned a liability into an asset by converting landfill gas (LFG) into electricity to help drive the public transit system by day and light city streets by night. LFG projects can also be found in Armenia, Brazil, China, India, South Africa, and other countries.

Recovery and flaring from oil and natural gas production

Oil drilling often brings natural gas, mostly CH_4, to the surface along with the oil, which is often vented to the atmosphere to maintain safe pressure in the well. To reduce these emissions, associated gas may be flared and converted to CO_2, or recovered, thus eliminating most of its warming potential and removing its ability to form ozone (O_3). In India, Oil India Limited (OIL), a national oil company, is undertaking a project to recover the gas, which is presently flared, from the Kumchai oil field, and send it to a gas processing plant for eventual transport and use in the natural gas grid. Initiatives in Angola, Indonesia and other countries are flaring and recovering associated gas yielding large reductions in CH_4 emissions and new sources of fuel for local markets.

Livestock manure management

In Brazil, a large CDM project in the state of Minas Gerais seeks to improve waste management systems to reduce the amount of CH_4 and other greenhouse gas emissions associated with animal effluent. The core of the project is to replace open-air lagoons with ambient temperature anaerobic digesters to capture and combust the resulting biogas. Over the course of a 10-year period (2004–2014) the project plans to reduce CH_4 and other greenhouse gas emissions by a total of 50 580 tonnes of CO_2 equivalent. A CDM project in Hyderabad, India, will use the poultry litter (CH_4) to generate electricity which will power the plant and supply surplus electricity to the Andhra Pradesh state grid.

Farm-scale anaerobic digestion of manure from cattle is one of the key CH_4 reductions

Box 3: Case studies of implementation of measures (cont.)

BC measures

Diesel particle filters

In Santiago, municipal authorities, responding to public concern on air pollution, adopted a new emissions standard for urban buses, requiring installation of diesel particle filters (DPFs). Currently about one-third of the fleet is equipped with filters; it is expected that the entire fleet will be retrofitted by 2018. New York City adopted regulations in 2000 and 2003 requiring use of DPFs in city buses and off-road construction equipment working on city projects. London fitted DPFs to the city's bus fleet over several years beginning in 2003. Low emission zones in London and other cities create incentives for diesel vehicle owners to retrofit with particle filters, allowing them to drive within the city limits. Implementation in developing regions will require greater availability of low sulphur diesel, which is an essential prerequisite for using DPFs.

Improved brick kilns

Small scale traditional brick kilns are a significant source of air pollution in many developing countries; there are an estimated 20 000 in Mexico alone, emitting large quantities of particulates. An improved kiln design piloted in Ciudad Juárez, near the border with the United States of America, improved efficiency by 50 per cent and decreased particulate pollution by 80 per cent. In the Bac Ninh province of Viet Nam, a project initiated with the aim of reducing ambient air pollution levels and deposition on surrounding rice fields piloted the use of a simple limestone scrubbing emissions control device and demonstrated how a combination of regulation, economic tools, monitoring and technology transfer can significantly improve air quality.

A traditional brick kiln (left) and an improved kiln operating in Mexico.

Potential international regulatory responses

International responses would facilitate rapid and widespread implementation of the measures. Since a large portion of the impacts of SLCFs on climate, health, food security and ecosystems is regional or local in nature, regional approaches incorporating national actions could prove promising for their cost-effective reduction. This approach is still in its very early stage in most regions of the world. For example, the Convention on Long-Range Transboundary Air Pollution (CLRTAP) recently agreed to address BC in the revision of the Gothenburg Protocol in 2011 and to consider the impacts of CH_4 as an O_3 precursor in the longer term.

Other regional agreements (Box 4) are fairly new, and predominantly concentrate on scientific cooperation and capacity building. These arrangements might serve as a platform from which to address the emerging challenges related to air pollutants from BC and tropospheric O_3 and provide potential vehicles for finance, technology transfer and capacity development. Sharing good practices

Box 4: Examples of regional atmospheric pollution agreements

The Convention on Long-Range Transboundary Air Pollution (CLRTAP) is a mature policy framework covering Europe, Central Asia and North America. Similar regional agreements have emerged in the last decades in other parts of the world. The Malé Declaration on Control and Prevention of Air Pollution and its Likely Transboundary Effects for South Asia was agreed in 1998 and addresses air quality including tropospheric O_3 and particulate matter. The Association of Southeast Asian Nations (ASEAN) Haze Protocol is a legally binding agreement addresses particulate pollution from forest fires in Southeast Asia. In Africa there are a number of framework agreements between countries in southern Africa (Lusaka Agreement), in East Africa (Nairobi Agreement); and West and Central Africa (Abidjan Agreement). In Latin America and the Caribbean a ministerial level intergovernmental network on air pollution has been formed and there is a draft framework agreement and ongoing collaboration on atmospheric issues under UNEP's leadership.

on an international scale, as is occurring within the Arctic Council, in a coordinated way could provide a helpful way forward.

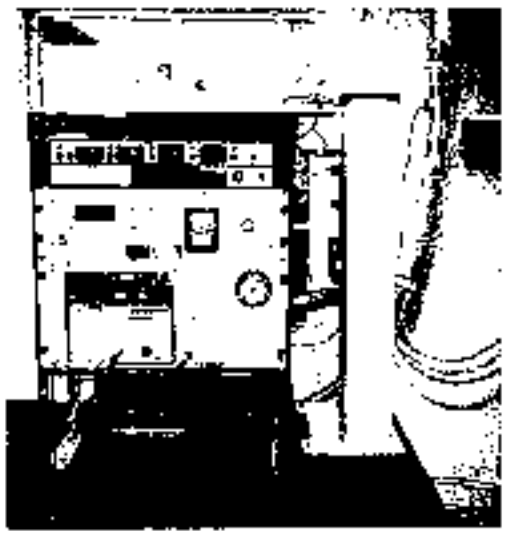
This Assessment did not assess the cost-effectiveness of different identified measures or policy options under different national circumstances. Doing so would help to inform national air quality and climate policy makers, and support implementation on a wider scale. Further study and analyses of the local application of BC and tropospheric O_3 reduction technologies, costs and regulatory approaches could contribute to advancing adoption of effective action at multiple levels. This work would be best done based on local knowledge. Likewise further evaluation of the regional and global benefits of implementing specific measures by region would help to better target policy efforts. In support of these efforts, additional modelling and monitoring and measurement activities are needed to fill remaining knowledge gaps.

Opportunities for international financing and cooperation

The largest benefits would be delivered in regions where it is unlikely that significant national funds would be allocated to these issues due to other pressing development needs. International financing and technology support would catalyse and accelerate the adoption of the identified measures at sub-national, national and regional levels, especially in developing countries. Financing would be most effective if specifically targeted towards pollution abatement actions that maximize air quality and climate benefits.

Funds and activities to address CH_4 (such as the Global Methane Initiative; and the Global Methane Fund or Prototype Methane Financing Facility) and cookstoves (the Global Alliance for Clean Cookstoves) exist or are under consideration and may serve as models for other sectors. Expanded action will depend on donor recognition of the opportunity represented by SLCF reductions as a highly effective means to address near-term climate change both globally and especially in sensitive regions of the world.

Black carbon and tropospheric O_3 may also be considered as part of other environment, development and energy initiatives such as bilateral assistance, the UN Development Assistance Framework, the World Bank Energy Strategy, the Poverty and Environment Initiative of UNEP and the United Nations Development Programme (UNDP), interagency cooperation initiatives in the UN system such as the Environment Management Group and UN Energy, the UN Foundation, and the consideration by the UN Conference on Sustainable Development (Rio+20) of the institutional framework for sustainable development. These, and others, could take advantage of the opportunities identified in the Assessment to achieve their objectives.



Aerosol measurement instruments

Concluding Remarks

The Assessment establishes the climate co-benefits of air-quality measures that address black carbon and tropospheric ozone and its precursors, especially CH$_4$ and CO. The measures identified to address these short-lived climate forcers have been successfully tried around the world and have been shown to deliver significant and immediate development and environmental benefits in the local areas and regions where they are implemented.

Costs and benefits of the identified measures are region specific, and implementation often faces financial, regulatory and institutional barriers. However, widespread implementation of the identified measures can be effectively leveraged by recognizing that near-term strategies can slow the rate of global and regional warming, improving our chances of keeping global temperature increase below bounds that significantly lower the probability of major disruptive climate events. Such leverage should spur multilateral initiatives that focus on local priorities and contribute to the global common good.

It is nevertheless stressed that this Assessment does not in any way suggest postponing immediate and aggressive global action on anthropogenic greenhouse gases in fact it requires such action on CO_2. This Assessment concludes that the chance of success with such longer-term measures can be greatly enhanced by simultaneously addressing short-lived climate forcers.

The benefits identified in this Assessment can be realised with a concerted effort globally to reduce the concentrations of black carbon and tropospheric ozone. A strategy to achieve this, when developed and implemented, will lead to considerable benefits for human well-being.

Glossary

Aerosol	A collection of airborne solid or liquid particles (excluding pure water), with a typical size between 0.01 and 10 micrometers (μm) and residing in the atmosphere for at least several hours. Aerosols may be of either natural or anthropogenic origin. Aerosols may influence climate in two ways: directly through scattering or absorbing radiation, and indirectly through acting as condensation nuclei for cloud formation or modifying the optical properties and lifetime of clouds.
Biofuels	Biofuels are non-fossil fuels. They are energy carriers that store the energy derived from organic materials (biomass), including plant materials and animal waste.
Biomass	In the context of energy, the term biomass is often used to refer to organic materials, such as wood and agricultural wastes, which can be burned to produce energy or converted into a gas and used for fuel.
Black carbon	Operationally defined aerosol species based on measurement of light absorption and chemical reactivity and/or thermal stability. Black carbon is formed through the incomplete combustion of fossil fuels, biofuel, and biomass, and is emitted in both anthropogenic and naturally occurring soot. It consists of pure carbon in several linked forms. Black carbon warms the Earth by absorbing heat in the atmosphere and by reducing albedo, the ability to reflect sunlight, when deposited on snow and ice.
Carbon sequestration	The uptake and storage of carbon. Trees and plants, for example, absorb carbon dioxide, release the oxygen and store the carbon.
Fugitive emissions	Substances (gas, liquid, solid) that escape to the air from a process or a product without going through a smokestack; for example, emissions of methane escaping from coal, oil, and gas extraction not caught by a capture system.
Global warming potential (GWP)	The global warming potential of a gas or particle refers to an estimate of the total contribution to global warming over a particular time that results from the emission of one unit of that gas or particle relative to one unit of the reference gas, carbon dioxide, which is assigned a value of one.
High-emitting vehicles	Poorly tuned or defective vehicles (including malfunctioning emission control system), with emissions of air pollutants (including particulate matter) many times greater than the average.
Hoffman kiln	Hoffmann kilns are the most common kiln used in production of bricks. A Hoffmann kiln consists of a main fire passage surrounded on each side by several small rooms which contain pallets of bricks. Each room is connected to the next room by a passageway carrying hot gases from the fire. This design makes for a very efficient use of heat and fuel.
Incomplete combustion	A reaction or process which entails only partial burning of a fuel. Combustion is almost always incomplete and this may be due to a lack of oxygen or low temperature, preventing the complete chemical reaction.
Oxidation	The chemical reaction of a substance with oxygen or a reaction in which the atoms in an element lose electrons and its valence is correspondingly increased.

Ozone	Ozone, the triatomic form of oxygen (O_3), is a gaseous atmospheric constituent. In the troposphere, it is created both naturally and by photochemical reactions involving gases resulting from human activities (it is a primary component of photochemical smog). In high concentrations, tropospheric ozone can be harmful to a wide range of living organisms. Tropospheric ozone acts as a greenhouse gas. In the stratosphere, ozone is created by the interaction between solar ultraviolet radiation and molecular oxygen. Stratospheric ozone provides a shield from ultraviolet B (UVB) radiation.
Ozone precursor	Chemical compounds, such as carbon monoxide (CO), methane (CH_4), non-methane volatile organic compounds (NMVOC), and nitrogen oxides (NO_x), which in the presence of solar radiation react with other chemical compounds to form ozone in the troposphere.
Particulate matter	Very small pieces of solid or liquid matter such as particles of soot, dust, or other aerosols.
Pre-industrial	Prior to widespread industrialisation and the resultant changes in the environment. Typically taken as the period before 1750.
Radiation	Energy transfer in the form of electromagnetic waves or particles that release energy when absorbed by an object.
Radiative forcing	Radiative forcing is a measure of the change in the energy balance of the Earth-atmosphere system with space. It is defined as the change in the net, downward minus upward, irradiance (expressed in Watts per square metre) at the tropopause due to a change in an external driver of climate change, such as, for example, a change in the concentration of carbon dioxide or the output of the Sun.
Smog	Classically a combination of smoke and fog in which products of combustion, such as hydrocarbons, particulate matter and oxides of sulphur and nitrogen, occur in concentrations that are harmful to human beings and other organisms. More commonly, it occurs as photochemical smog, produced when sunlight acts on nitrogen oxides and hydrocarbons to produce tropospheric ozone.
Stratosphere	Region of the atmosphere between the troposphere and mesosphere, having a lower boundary of approximately 8 km at the poles to 15 km at the equator and an upper boundary of approximately 50 km. Depending upon latitude and season, the temperature in the lower stratosphere can increase, be isothermal, or even decrease with altitude, but the temperature in the upper stratosphere generally increases with height due to absorption of solar radiation by ozone.
Trans-boundary movement	Movement from an area under the national jurisdiction of one State to or through an area under the national jurisdiction of another State or to or through an area not under the national jurisdiction of any State.
Transport (atmospheric)	The movement of chemical species through the atmosphere as a result of large-scale atmospheric motions.
Troposphere	The lowest part of the atmosphere from the surface to about 10 km in altitude in mid-latitudes (ranging from 9 km in high latitudes to 16 km in the tropics on average) where clouds and "weather" phenomena occur. In the troposphere temperatures generally decrease with height.

Acronyms and Abbreviations

ASEAN	Association of Southeast Asian Nations
BC	black carbon
BENLESA	Latin America Bioenergia de Nuevo León S.A. de C.V.
CDM	Clean Development Mechanism
CH_4	methane
CLRTAP	Convention on Long Range Transboundary Air Pollution
CO	carbon monoxide
CO_2	carbon dioxide
DPF	diesel particle filter
ECHAM	Climate-chemistry-aerosol model developed by the Max Planck Institute in Hamburg, Germany
G8	Group of Eight: Canada, France, Germany, Italy, Japan, Russian Federation, United Kingdom, United States
GAINS	Greenhouse Gas and Air Pollution Interactions and Synergies
GISS	Goddard Institute for Space Studies
GWP	global warming potential
IEA	International Energy Agency
IIASA	International Institute for Applied System Analysis
IPCC	Intergovernmental Panel on Climate Change
LFG	landfill gas
NASA	National Aeronautics and Space Administration
NO_x	nitrogen oxides
O_3	ozone
OC	organic carbon
OIL	Oil India Limited
PM	particulate matter ($PM_{2.5}$ has a diameter of 2.5µm or less)
ppm	parts per million
SLCF	short-lived climate forcer
SO_2	sulphur dioxide
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UV	ultraviolet
VOC	volatile organic compound
WMO	World Meteorological Organization

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About the Assessment:

Growing scientific evidence of significant impacts of black carbon and tropospheric ozone on human well-being and the climatic system has catalysed a demand for information and action from governments, civil society and other main stakeholders. The United Nations, in consultation with partner expert institutions and stakeholder representatives, organized an integrated assessment of black carbon and tropospheric ozone, and its precursors, to provide decision makers with a comprehensive assessment of the problem and policy options needed to address it.

An assessment team of more than 50 experts was established, supported by the United Nations Environment Programme, World Meteorological Organization and Stockholm Environment Institute. The Assessment was governed by the Chair and four Vice-Chairs, representing Asia and the Pacific, Europe, Latin America and the Caribbean and North America regions. A High-level Consultative Group, comprising high-profile government advisors, respected scientists, representatives of international organizations and civil society, provided strategic advice on the assessment process and preparation of the *Summary for Decision Makers*.

The draft of the underlying Assessment and its *Summary for Decision Makers* were extensively reviewed and revised based on comments from internal and external review experts. Reputable experts served as review editors to ensure that all substantive expert review comments were afforded appropriate consideration by the authors. The text of the *Summary for Decision Makers* was accepted by the Assessment Chair, Vice-Chairs and the High-level Consultative Group members.