ISSN:1047-3289 *J. Air & Waste Manage. Assoc.* **58**:1386–1400
DOI:10.3155/1047-3289.58.11.1386

Prospects for Future Climate Change and the Reasons for Early Action

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INTRODUCTION

The 2008 *A&WMA Critical Review*, which was entitled "Prospects for Future Climate Change and the Reasons for Early Action,"[1] focused on the vital issue of global climate change. During the presentation of the review on June 25, 2008, in Portland, OR, Dr. Michael C. MacCracken, chief scientist for climate change programs at the Climate Institute in Washington, DC, gave an overview of the basic science and history of the science behind climate change, and presented a strong case for why urgent and early action is needed to reduce ongoing changes in global climate. He summarized the adverse impacts on human systems and the environment that are occurring and are projected for the future, and described the extent of emissions reductions needed to prevent catastrophic impacts.

After MacCracken's presentation, a panel of four invited discussants was asked to contribute additional material relevant to the review. The discussants were told that this material could either dispute or reinforce and augment the original review. The discussion presented here by each panelist is self-contained, and joint authorship of this article does not imply that a discussant subscribes to the opinions expressed by others. In addition, a discussant's commentary does not necessarily reflect the position of his or her respective organization.

The topic of the 2008 A&WMA Critical Review is very different from any other critical review undertaken by the *Journal of Air & Waste Management* in several ways. The primary way this topic differs is in the extent to which it has received broad and comprehensive scientific attention. The science, impacts, economics, mitigation of, and adaptation to climate change have been extensively studied over the last 30 yr. The Intergovernmental Panel on Climate Change (IPCC), established by world governments in 1988, has completed four comprehensive assessments and many additional reports on climate change.[2–15] The assessments were all written and peer-reviewed by thousands of scientists worldwide with expertise in the fields that contribute to climate change science. Where there is not yet full agreement, the IPCC findings were expressed as a range, and where possible, the degrees of likelihood and confidence in the results were expressed. For example, because we cannot know precisely what future technologies and emissions will be, the IPCC considered the potential consequences for a family of emissions scenarios representing very different global futures.

The IPCC assessments, and particularly their supporting chapters, are the most authoritative and complete reviews of the scientific literature on climate change. MacCracken notes in the critical review[1] that "these assessments represent the international scientific consensus on climate change, its impacts, and the possibilities for responding. Taken as a whole, the IPCC's work provides a comprehensive baseline of information for consideration by governments and the public."

Because many multidisciplinary scientific fields contributing to the subject of climate change (e.g., atmospheric science, oceanography, geology, ecology, hydrology, social science, economics), and the overwhelming amount of relevant material in each field, it would have been impossible for MacCracken to cover all of these areas in the critical review. Instead, his review, organized around six overarching findings related to the nature and impacts of climate change, provided a bridge of understanding from the basic physics and chemistry of the climate system to the important scientific results of the IPCC assessments, especially those relevant to decision-makers. In addition, MacCracken eloquently articulated the underlying reasoning needed to build an intuitive understanding of the IPCC conclusions and their implications for humanity.

This paper presents a discussion of the 2008 *A&WMA Critical Review* by invited panelists and others who chose to comment. It includes written submissions and presentation of transcripts that were, in a few instances, edited for conciseness, to minimize redundancy, and to provide supporting and instructional citations. Substantial deviations from the intent of a discussant are unintentional and can be addressed in a follow-up letter to the journal.

The invited discussants are listed below.

- Dr. Mark Jacobson is the director of the Atmosphere and Energy Program and professor of civil and environmental engineering at Stanford University. He holds a B.S. in civil engineering (Stanford, 1988), an A.B. in economics (Stanford, 1988), an M.S. in environmental engineering (Stanford, 1988), an M.S. in atmospheric sciences (UCLA, 1991), and a Ph.D. in atmospheric sciences (UCLA, 1991). His work relates primarily to the development and application of numerical models to understand better the effects of air pollutants on climate and air quality and to the analysis and impacts of energy systems.
- Dr. Alberto Ayala is chief of the Climate Change Mitigation and Emissions Branch in the Research Division of the California Air Resources Board (CARB). He has been with CARB since 2000. He is also an adjunct professor of mechanical and aerospace engineering at West Virginia University and a visiting professor of civil engineering at the University of the Pacific.
- Dr. Carol Whitman is senior legislative principal in environmental policy at the National Rural Electric Cooperative Association (NRECA). She manages climate change issues and agricultural energy policy, including work on environmental and energy legislation, climate change proposals, renewable energy, and clean coal technology. Before joining NRECA, she was the U.S. Department of Agriculture (USDA)'s special assistant for climate change, representing USDA on the U.S. delegation negotiating the Kyoto Protocol. She holds her M.S. and Ph.D. from the University of California–Davis.
- Dr. Mark Trexlor is managing director of global consulting services at EcoSecurities. His 20 yr of climate change experience include time at the World Resources Institute in Washington, DC, and as a lead author for the IPCC. As a climate change consultant since 1991 he has advised companies around the world on climate change policy, strategy, and markets.

INVITED COMMENTS FROM DR. MARK JACOBSON

Two issues mentioned in the critical review that are worth expanding on further include the effects of global warming on air pollution, and an analysis of proposed solutions to global warming.

Effects of Global Warming on Air Pollution

The critical review correctly pointed out that warmer temperatures due to climate change may increase ozone (O_3), as suggested by many computer modeling studies.[16–25]

However, this is only part of the story. Recent work suggests that higher temperatures and higher water vapor due to increased carbon dioxide (CO_2) independently increases O_3 preferentially where O_3 is already high and most people live.[26] Such increases are illustrated in Figure 1, right side, with a chemistry-only calculation and were demonstrated with a three-dimensional (3D) computer model that considered emissions, meteorology, radiation, clouds, and other factors.

The study also showed that warming due to CO_2 increases particulate matter (PM) for three reasons. First, CO_2 increases air temperatures more than ground temperatures over land. This stabilizes the air, reducing vertical dispersion and the vertical flux of horizontal momentum, slowing down surface winds, and reducing horizontal pollution dispersion. Reduced vertical and horizontal dispersion increases gas and particle concentrations near emission sources. Second, warmer temperatures due to CO_2 increase emissions of biogenic organic gases, such as isoprene and monoterpenes. These oxidize to enhance O_3 and secondary PM. Third, higher water vapor due to CO_2 increases the relative humidity (RH) in some locations, although such RH increases are offset in other locations by higher temperatures due to CO_2. On average, the net effect over the United States was a RH increase. Higher

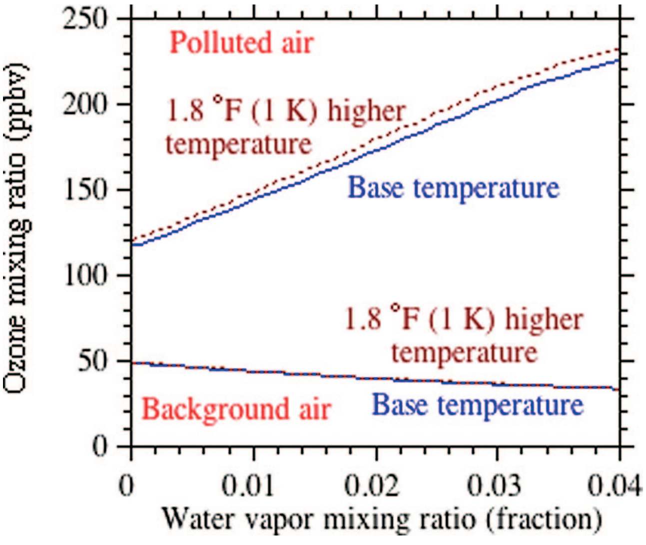

Figure 1. Mixing ratio of O_3 as a function of water vapor mixing ratio after 12 hr of a box-model chemistry-only simulation initialized at 4:30 a.m. under two nitrogen oxides and non-methane organic gas mixing ratio combinations (ppbv [parts per billion by volume]) at 298.15 K (solid lines) and 299.15 K (dashed lines). The simulations assumed sinusoidally varying photolysis between 6:00 a.m. and 6:00 p.m. This figure is based on data from Jacobson.[26]

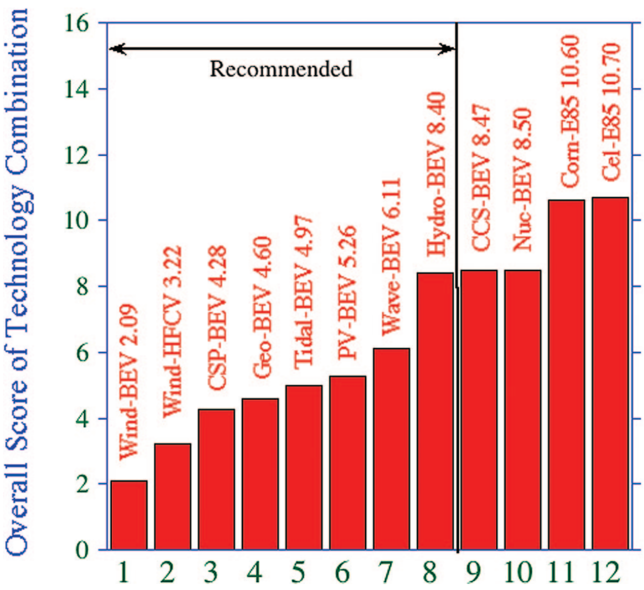

Figure 2. Relative ranking of technology options for mitigating climate change and reducing impacts. This ranking was based on 11 factors as described in the text. The relative ranking of each electricity-BEV option also applies to the electricity source when used to provide electricity for general purposes. The results here suggest that policies to expand biofuels, coal with CCS, and nuclear power at the expense of wind, solar, geothermal, wave, tidal, and hydroelectric power will delay the solution to global warming and will cause human health, water supply, land use, and other environmental damage relative to the other proposed solutions. Because opportunity costs are significant, targeting specific beneficial solutions to global warming will have a greater and faster impact on the problem than trying all of the proposed solutions simultaneously without consideration of their impacts. From a study by Jacobson.[28]

humidity increases water uptake by particles, increasing the size and absorption of soluble gases in such particles. Whereas these three factors tend to increase PM, enhanced rainfall over land in some locations due to CO_2-induced warming reduces PM in such locations. Averaged over the United States, the increases in PM were found to outweigh the decreases, resulting in a net increase in PM due to CO_2-induced warming.

However, the relative PM increase was dominated slightly by the O_3 increase, because enhanced precipitation had less of an effect on O_3 than on PM. The changes in O_3, particles, and carcinogens from the 3D calculations in Jacobson[26] were combined with population and health-effects data to estimate that CO_2 increased the annual U.S. air pollution death rate by about +1000 (+350 to +1800) per 1.8 °F (1 °C), with approximately 40% due to O_3. These annual additional deaths are occurring today, as historic temperatures are approximately 1.5 °F (0.85 °C) higher than in preindustrial times.

The fact that global warming increases air pollution the most where the pollution is already high has significant policy implications. On March 6, 2008, the U.S. Environmental Protection Agency (EPA) Administrator denied California's request for a waiver of Clean Air Act preemption.[27] The major basis for the denial was the claim that there is no difference in the impact of globally emitted CO_2 on California versus U.S. health. However, because CO_2 increases pollution the most where it is already high, and California has 6 of the 10 most O_3-polluted cities in the United States—Los Angeles, Visalia-Porterville, Bakersfield, Fresno, Merced, and Sacramento (http://www.citymayors.com/environment/polluted_uscities.html), it is expected that a warmer planet will increase O_3 in California more per capita than in the United States as a whole. Indeed, it was found from further analysis of the results in Jacobson[26] that, of the 1000 additional deaths per 1 °C temperature increase, more than 30% (>300) occurred in California, which has only 12% of the U.S. population. As such, the death rate per capita in California was over 2.5 times that of the nation because of CO_2-induced air pollution.

Evaluation of Solutions to Global Warming

The critical review identified several proposed solutions to global warming. However, being focused mainly on the global scale aspects of the issue, it could have benefited from a discussion of whether the solutions were useful or what the impacts of the solutions might be in the United States on air pollution, land use, water supply, energy security, energy reliability, or water contamination. A recent analysis was performed to analyze proposed solutions to global warming.[28]

Jacobson[28] evaluated and ranked 12 combinations of electric power and fuel sources from among nine electric power sources, two liquid fuel sources, and three vehicle technologies with respect to their ability to simultaneously address climate, air pollution, and energy problems. The results are shown in Figure 2. This analysis also evaluated the impacts of each on water supply, land use, wildlife, resource availability, thermal pollution, water chemical pollution, nuclear proliferation, and undernutrition.

The electric power sources considered included solar photovoltaics (PV), concentrated solar power (CSP), wind turbines, geothermal power plants, hydroelectric power plants, wave devices, tidal turbines, nuclear power plants, and coal power plants fitted with carbon capture and storage (CCS) technology. The two liquid fuel options considered were corn-E85 (85% ethanol, 15% gasoline) and cellulosic-E85. To place the electric and liquid fuel sources on an equal footing, their comparative abilities to address the problems mentioned by powering new-technology vehicles, including battery-electric vehicles (BEVs), hydrogen fuel cell vehicles (HFCVs), and E85-powered flex-fuel vehicles, were examined. Specifically, the combinations of PV-BEVs, CSP-BEVs, wind-BEVs, wind-HFCVs, geothermal-BEVs, hydroelectric-BEVs, wave-BEVs, tidal-BEVs, nuclear-BEVs, CCS-BEVs, corn-E85 vehicles, and cellulosic-E85 vehicles were analyzed.

Among energy-vehicle options, the highest-ranked (Tier 1 technologies) were wind-BEVs and wind-HFCVs. Tier 2 technologies were CSP-BEVs, Geo-BEVs, PV-BEVs, tidal-BEVs, and wave-BEVs. Tier 3 technologies were hydroelectric-BEVs, nuclear-BEVs, and CCS-BEVs. Tier 4 (lowest ranked) technologies were corn- and cellulosic-E85.

Wind-BEVs performed best in 6 of 11 categories, including mortality, climate-relevant emissions, footprint, water consumption, effects on wildlife, thermal pollution, and water chemical pollution. The footprint area on the ground of wind-BEVs is 5.5–6 orders of magnitude less than that for E85 regardless of the ethanol source, 4 orders of magnitude less than those of CSP-BEVs or solar-BEVs, 3 orders of magnitude less than those of nuclear- or coal-BEVs, and 2–2.5 orders of magnitude less than those of geothermal-, tidal-, or wave BEVs.

Although wind did not rank high in terms of intermittency, the intermittency or its effects of wind, solar, and wave power can be reduced in several ways: (1) interconnecting geographically dispersed intermittent sources through the transmission system; (2) combining different intermittent sources (wind, solar, hydro, geothermal, tidal, and wave) to smooth out loads, using hydro to provide peaking and load balancing; (3) using smart meters to provide electric power to electric vehicles at optimal times, (4) storing wind energy in hydrogen batteries, pumped hydroelectric power, compressed air, or a thermal storage medium; and (5) forecasting weather to improve grid planning.

Although HFCVs are less efficient than are BEVs, the combination of wind-HFCVs still provided a greater benefit than any other vehicle technology aside from wind-BEVs. Wind-HFCVs were also deemed to be the most reliable combination because of the low downtime of wind turbines, the distributed nature of turbines, and the ability to accumulate hydrogen over time.

The Tier 2 combinations (CSP-BEVs, Geo-BEVs, PV-BEVs, tidal-BEVs, and wave-BEVs) all provided outstanding benefits with respect to climate and mortality. Among Tier 2 combinations, CSP-BEVs resulted in the lowest CO_2-equivalent emissions and mortality. (The phrase "equivalent CO_2 emission" refers to the "amount of CO_2 that would cause the same integrated [warming influence] over a given time horizon as an emitted amount of a well-mixed greenhouse gas or a mixture of well-mixed greenhouse gases). Geothermal-BEVs required the lowest array spacing among all options. Although PV-BEV resulted in slightly less climate benefit than CSP-BEVs, the resource for PVs is the largest among all technologies considered. Furthermore, much of it can be implemented unobtrusively on rooftops. Underwater tidal-BEVs were suggested to be the least likely to be disrupted by terrorism or severe weather.

The Tier 3 technologies (hydro-BEVs, nuclear-BEVs, CCS-BEVs) are less beneficial overall than the others. However, hydroelectricity is a much better load balancer and cleaner than coal-CCS or nuclear with respect to carbon-equivalent emissions and air pollution. As such, hydroelectricity is recommended ahead of these other Tier-3 power sources.

The Tier-4 technologies (cellulosic- and corn-E85) are not only the lowest in terms of ranking, but may enhance climate and air pollution problems. They also require significant land relative to other technologies. Cellulosic-E85 may have a larger land footprint and higher upstream air-pollution-relevant emissions than corn-E85. The smallest consumers were wind-BEVs, tidal-BEVs, and wave-BEVs.

In summary, this study concluded that the use of wind, CSP, geothermal, tidal, solar, wave, and hydroelectric to power electricity for BEVs and HFCVs will result the most benefit and least impact among the options considered. Coal with CCS and nuclear provide less benefit with greater negative impacts. The biofuel options provide no quantifiable benefit and result in significant negative impacts. Thus, there is an opportunity cost to selecting these options relative to the cleaner ones.

INVITED COMMENTS FROM DR. ALBERTO AYALA

The critical review is an excellent overview of climate change science and an effective argument for early greenhouse gas (GHG) reduction action. The California experience is complementary and supportive of MacCracken's six overarching findings. These comments expand his review by highlighting how climate change affects California specifically at a regional level. They also support his call for early action by highlighting concrete examples of the "1000 blooming flowers" that discussant Dr. Mark C. Trexler argued are necessary to solve a problem such as climate change. Some of those "blooming flowers" are the early actions[29] that California is taking to meet the aggressive targets called for in the California Global Warming Solutions Act of 2006, also known as Assembly Bill 32 (AB 32).

There is a growing body of evidence indicating that climate change is already occurring in California and that many sectors will experience effects. Over the past century, rising average temperatures have led to sea level rise, changes to snowmelt cycles, a decrease in water runoff, advancement in spring blooms, and longer and more active wildfire seasons.[30,31] In mid-2005, Governor Schwarzenegger commissioned a comprehensive analysis of climate change impacts. Approximately 80 state agency, university, and national laboratory scientists studied the effects on public health, water resources, agriculture, forests and landscapes, and sea level (http://www.climatechange.ca.gov).[32] They found significant effects even at a lower warming range of 3–5.5 °F, and severe effects including a loss of most of the Sierra snowpack, California's main water reservoir, and increases in extreme heat events for a higher warming scenario. As temperatures rise, Californians will face greater health risks. Increasing temperatures will also exacerbate air pollution and lead to O_3 and $PM_{2.5}$ (particulate matter with aerodynamic diameters <2.5 μm) increases in some of our major population centers,[33] making some air quality standards more difficult to attain and maintain and the costs of control rise.

Although the CARB has made progress in improving air quality in the state over the past 40 yr,[34] there remains much more to be accomplished, because most Californians still breathe unhealthy air at times. Figure 3 illustrates that historically reduction of some important ambient air pollutants has been achieved over the same period as significant growth of population, vehicle number, and vehicle miles traveled (VMT) has been observed. M. Williams[35] observed, "Significant synergies and co-benefits are possible through a concerted consideration of air quality and climate change policies." We agree and recognize that the AB 32 climate protection plan is an opportunity to provide a wide range of public health and environmental benefits from reducing GHG emissions.

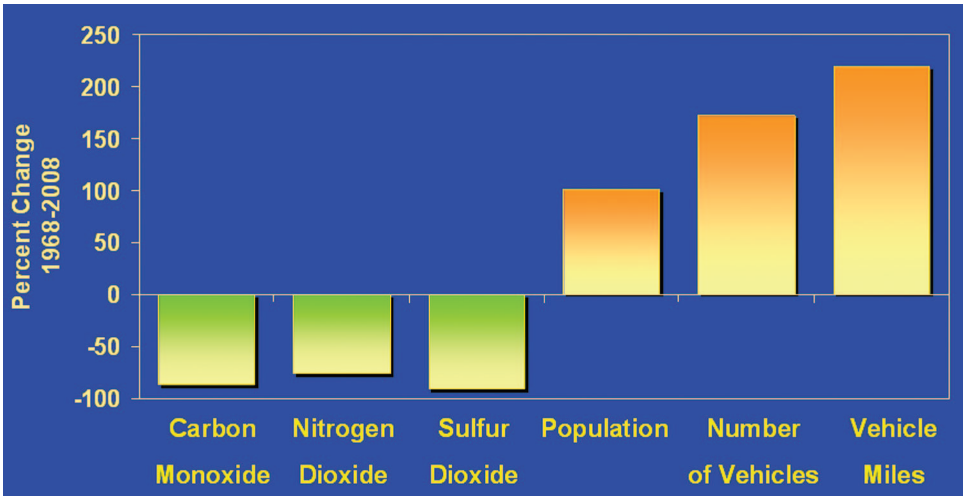

Figure 3. Ambient air pollutant reduction despite significant growth in California. Since 1968, carbon monoxide, nitrogen dioxide, and SO_2 peak levels have decreased by 80% or better. In the same time period, California's population almost doubled, the number of vehicles on the road increased by 170%, and the number of VMT almost tripled.

The science summarized by MacCracken tells us that the time to act is now. Governor Schwarzenegger acknowledged that fact by setting the state's efforts in motion and calling for returning to 1990 GHG emission levels by 2020 and an 80% reduction in GHG emissions below 1990 levels by 2050. These are ambitious targets and worldwide adoption is needed if we are to constrain global warming to a 2 °C rise, or what is needed to avoid the catastrophic consequences of a warming world.

In September of 2007, the legislature and the governor put meeting the 2020 target into law and gave CARB the primary responsibility for the design of GHG reduction measures in a manner that minimizes costs and maximizes the benefits for California's economy. CARB, its state government partners, and the Climate Action Team (CAT) established by the governor as coordinator of overall climate policy, have laid out a plan that will culminate in the adoption of limits and measures no later than 2012. Several milestones have already been met, including developing a list of early actions, assembling a GHG emissions inventory, establishing the 2020 emissions limit of 427 $MMTCO_2E$ (millions of metric tons of CO_2 equivalent), and setting a reduction target of approximately 169 $MMTCO_2E$. These reductions are 30% below the state's projected business-as-usual GHG emissions for the year 2020. The most recent accomplishment is the release of the Climate Change Draft Scoping Plan: "a comprehensive set of actions designed to reduce overall carbon emissions in California, improve our environment, reduce our dependence on oil, diversify our energy sources, save energy, and enhance public health while creating new jobs and enhancing the growth in California's economy" (http://www.arb.ca.gov/cc/scopingplan/document/draftscopingplan.pdf).

Meeting the targets will require achieving GHG emission reductions in all sectors of the economy. The transportation sector accounts for the majority of the GHG emissions in California; hence it is a major focus for control. The state's efforts began in 2004 with the adoption of new light-duty vehicle standards that lowered GHG emissions beginning with the 2009 model year (Pavley standards under Assembly Bill 1493 [AB 1493]). California cannot implement these regulations unless EPA grants an administrative waiver, which was denied in late 2007. California is now challenging that denial in court. AB 32 specifically states that if these regulations cannot be enforced, CARB must devise an alternative regulation to achieve or exceed the Pavley GHG reductions.

Several vehicle-related measures have already been included in the AB 32 Early Action Plan. By 2009, we expect a new low-carbon fuel standard and implementation of regulations for high global warming potential (GWP) refrigerants used in motor vehicle air conditioning systems, truck efficiency, and new tire inflation requirements. Following these discrete early actions, additional measures are expected on areas such as cool automobile paints, hybridization of medium- and heavy-duty vehicles, and the next generation "Pavley" II regulation. In total, CARB identified 44 distinct early actions and other agency members of the CAT similarly identified many more.

The vision for a low-carbon future for California described in the Scoping Plan encompasses all sectors of the economy: electricity and natural gas, transportation (vehicles and fuels), business and industry, high-GWP GHGs, land use, agriculture, and forests. Possible measures will include direct regulations, alternative compliance mechanisms, market-based approaches, or incentives. In developing these measures, we must be equitable, minimize costs and maximize total benefits, encourage early action, avoid disproportionate impacts, ensure that voluntary reductions get appropriate credit, consider cost-effectiveness, overall societal benefits, minimize administrative burden, minimize leakage, and consider the overall significance of sources.

The AB 32 GHG reduction goals are in addition to the air pollution targets set by Governor Schwarzenegger since he came into office in 2003. We expect to reduce diesel PM by 85% from 2000 levels by 2020, with similar goals for goods movement. Because of the tripling in freight traffic expected to occur over this time period, this equates to 95% control which we are accomplishing through a combination of new engine standards, cleaner fuels, retrofits, and hundreds of millions of dollars each year for incentive programs. These programs will have a climate co-benefit because O_3 and fossil-fuel soot are climate forcers.

O_3-depleting substances (ODSs) are covered by the Montreal Protocol. But because they have significant warming potential, they are included in California's GHG reduction program. Current global banks of ODSs and hydrofluorocarbons are significant. As illustrated in Figure 4, those found in California are comparable in magnitude to the entire state GHG inventory. When comparing the emissions of non-Kyoto climate forcers to the Kyoto Protocol bundle of six GHGs, it must be noted that there are uncertainties in the GWPs, especially for the short-lived air pollutants. But collectively, they may add up to nearly one-fourth of the Kyoto GHG emissions and, in some cases, may represent low-hanging fruit opportunity for control.

In summary, we have already seen the impacts of climate change on California. Continued warming is inevitable, but the world needs to greatly reduce its GHG emissions to avoid catastrophic effects on many sectors of the California economy. These effects include increases in the number of extreme heat days by up to a factor of 10 by the end of the century. Climate change will also make meeting our goals to improve air quality much more difficult to achieve. CARB and our partners are already moving aggressively to respond to this challenge, with progress on multiple fronts, and a comprehensive program should include all climate forcers, not just those that are part of the Kyoto Protocol.

Questions from the audience varied greatly. The panel acknowledged population control as a factor in the climate protection debate, but California is proof that feasible mitigation options exist and are sufficient for meeting GHG reduction targets under business-as-usual population growth. One question specifically addressed nuclear electric power and the California success in energy efficiency. Strategies have been identified for California in energy efficiency such as green buildings and a 33% renewable portfolio standard by 2020 for both investor-owned and publicly owned utilities. A specific idea for a potential pricing strategy for vehicle use and use of funds for incentives for car sharing was discussed, but no example of such an approach in current practice was found. One audience member pointed out the lack of suitable GHG inventories and meteorological data for Latin America to support actions. Finally, a light-hearted personal question was posed for the panel: "How do you stay positive when facing the enormity of the challenge?" Responses varied, but California draws encouragement from the success stories of cities like Portland and many others that have implemented sustainability programs that are already yielding real GHG emission reductions.

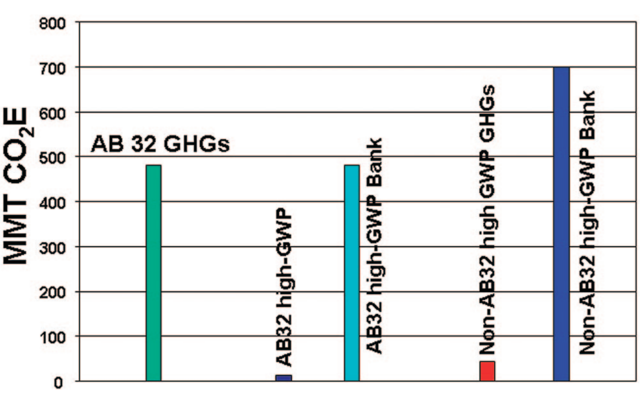

Figure 4. California's current GHG inventory and comparison to emissions and banks of other substances, most prominently ODSs, not included in the Kyoto basket of GHGs.

INVITED COMMENTS FROM DR. CAROL WHITMAN

The critical review proposes a reduction in global GHG emissions of 80% by 2050 to manage the risks of climate change. Although there is high-level recognition of the magnitude of this challenge, there is no discussion of the technical, economic, regulatory, and policy challenges we face in making these deep emission reductions in such a short time. A look at the U.S. electricity sector will provide a better understanding of the complexity of this endeavor.

In the United States, more than 80% of GHG emissions are energy-related, with 40% of these emissions from electricity generation. Under carbon restrictions such as those proposed in the Lieberman-Warner Climate Security Act of 2007—70% below 2005 levels by 2050—the electric sector is projected to dominate U.S. energy-related CO_2 emission reductions, accounting for 80–90% of all reductions by 2030 or approximately 2.5 $GtCO_2$/yr.[36,37] The challenge for the electric sector is even more daunting given that U.S. electricity demand is forecasted to increase 30% by 2030 and will require 264 GW of new capacity.[36] To meet the growing demand and simultaneously decarbonize power generation on this timetable would require a complete transformation of the power sector, with an estimated investment of $1.5 trillion.[38]

The Electric Power Research Institute (EPRI) has assessed available technologies, including end-use efficiency, renewable energy, coal with carbon capture and storage, and nuclear, to determine the technical capability of the U.S. electric sector to reduce CO_2 emissions assuming no economic or policy constraints.[39,40] With aggressive research, development, demonstration, and deployment, EPRI concluded that advanced technologies could reduce electricity sector emissions nearly 50% by 2030 relative to the Energy Information Administration's reference case projections. But technical, economic, regulatory, and policy challenges must be overcome.

End-use energy efficiency improvements in lighting, electronic equipment, and appliances are the least costly options to reduce emissions from power generation by decreasing electricity demand. EPRI[40] estimates that the achievable potential—the likely impact of energy efficiency programs—is a 7–11% reduction in electricity demand by 2030 with a similar decrease in carbon emissions, approximately 0.3 $GtCO_2E$/yr. The McKinsey report argues that these technologies—and therefore the emission reductions—are available at negative cost (i.e., the value of the energy savings exceeds the cost of installing the technologies).[41] But consumers fail to purchase the most energy-efficient products for a variety of reasons, including the higher up-front cost of the most energy-efficient technology, low expected rates of return, the associated risks, capital constraints, and consumer preferences.[42] The cost of changing consumer investment decisions through financial incentives can be substantial. Rebate programs that offer $50 to $100 per appliance are often necessary to offset the additional cost of energy efficiency and encourage consumers to buy them (http://www.dsireusa.org/).

Renewable generation holds considerable promise for lowering emissions, but policy, cost, and technical challenges remain. The U.S. Department of Energy projects that by 2030 0.8 $GtCO_2E$/yr would be avoided by generating 20% of electricity from wind.[43] It would require more than 293 GW of additional wind capacity in 23 yr; that is, three times the capacity that EPRI projects is feasible.[40] In addition, this scenario includes more than 50 GW of offshore wind turbines that undoubtedly would face local opposition because of visual pollution and threats to marine and bird life, just as the Cape Wind Project has in Massachusetts. The integration of intermittent wind resources to the grid will improve with storage and smart grid technologies currently under development, but wind will continue to require backup generation, adding to its cost. Transmission capacity, already in short supply, would also need to be expanded to deliver wind from remote sources to urban load centers. Estimated transmission infrastructure costs range from $60 billion[43] to over $200 billion.[38] Pubic opposition to transmission lines makes the siting and permitting process prone to lengthy and expensive delays. And the question of who pays for major new interstate lines for remote renewables, whether costs are socialized or those who benefit pay, remains unresolved.

CCS of emissions from coal-based generation can make large contributions to CO_2 reductions—0.6 $GtCO_2E$/yr by 2030—and provide a bridge to the future. When the technology is commercially available around 2020, 90% of CO_2 produced will be stored safely underground. But at this time, no one is capturing CO_2 at scale from coal plants. Currently available CCS technology is very expensive, increasing the cost of electricity 50–80%. In addition, the energy required to capture the CO_2 would reduce the net power output by 30%, further increasing costs and fuel use. Technology development is expected to increase efficiency and hold electricity cost increases to approximately 10%. There are large geologic formations in the United States suitable for underground storage of CO_2, and EPA is developing the regulatory framework for siting, construction, operation, monitoring, testing, and closure for the injection wells. For widespread adoption of CCS, CO_2 will have to be transported via pipelines to suitable injection sites. This will require additional transportation infrastructure with its siting, permitting, and public acceptance issues. Federal policy will have to address long-term liability if there is a loss of CO_2 from geologic formations and harm results to human health, the environment, or property, just as the Price-Anderson Act does for nuclear power. And finally, public acceptance may be an issue depending on how people perceive associated risks.[44]

Nuclear power is a readily available technology without emissions and could potentially avoid 0.4 $GtCO_2E$/y by 2030.[39] But this requires finding permanent storage for nuclear waste, overcoming public acceptance issues, addressing nuclear proliferation and security concerns. There are also engineering, procurement, and construction capability challenges facing the industry such as a component that has a single manufacturer supplying nuclear power projects worldwide. High upfront capital costs and long timelines before electricity is produced (9–10 yr with streamlined regulation) can undermine the economic competitiveness of nuclear power.

Additional reductions in emissions could be achieved by increasing the efficiency of existing coal-based generation, and these modifications could be very cost-effective. However, many utilities will be unlikely to make them because they can trigger new source review requirements and lead to additional expensive investments. Switching from coal to natural gas generation can cut CO_2 emissions in half. But the price of natural gas is high and the U.S. supply and demand balance is tight. Meeting the increase in demand for natural gas for power generation would require imports from the same countries from which we import oil and would result in the same supply security concerns.

The technical, economic, and policy challenges associated with each of the technology options discussed above demonstrate the difficulty of realizing change in the power sector with its capital-intensive infrastructure. Achieving an 80% reduction in carbon emissions by 2030 as projected in analyses of the Lieberman-Warner Climate Security Act may not be possible. Achieving a 50% reduction will require aggressive technology development, substantial investments, and public commitment.

Reducing greenhouse gas emissions 80% by 2050 will require a transformation from fossil fuels to non-fossil energy sources on an extraordinary scale. Consequently, the timetable may be slower and costs higher than commonly assumed. As the critical review also concludes, technology development is critical to reducing the sector's emissions and controlling costs.

INVITED COMMENTS FROM DR. MARK TREXLER

We Can All Agree We Need to Act on Climate Change, but Will We?

If it was not already clear, it is certainly clear from the critical review presented above that the scientific case for addressing climate change is growing more and more compelling. And at least superficially, it may look like we are gearing up for the challenge. At all levels in the United States, from individual cities to the federal government, climate change mitigation is being more actively discussed than ever before. Even the last 18 months has witnessed a revolution in the magnitude of voluntary and regulatory policy development around the climate change issue, from consumers purchasing carbon offsets for their cars to California's passage of AB 32 with its aggressive emissions reduction targets.

However, as we get closer and closer to actual mandates it will become more and more obvious why climate change is not only one of the most compelling environmental problems we have ever faced, but why it is clearly the most challenging in terms of successfully addressing it.

A close look at the characteristics of climate change and its mitigation reveals the unique complexity of designing and implementing public policy that would seriously address the problem. Frank discussion of this complexity is more often than not considered defeatist and unhelpful and thus tends to be downplayed. However, from any serious policy perspective it is abundantly clear that understanding the challenges of climate change mitigation efforts will prove key to any future success.

Put into the context of other environmental problems that we have successfully tackled to one extent or another, relevant characteristics of the climate change problem include the following:

- You cannot see or smell it. Most environmental problems that we have tackled previously are characterized by a tangible manifestation that we can characterize and attack. In contrast to relatively successful efforts to manage oil spills and address the O_3 hole, the equivalent of a "climate hole" will come too late and will be largely irreversible once it has unequivocally arrived.
- The world's climate is an incredibly complex system, and modeling it is correspondingly difficult. There will always be uncertainty in climate modeling, allowing skeptics and critics to delay and even derail complicated policy-making processes that result in big-time winners and losers.
- The primary technical measure of climate change—changes in the world's average global temperature—is unsuited to easy explanation to the public. It is hard for most people to get excited about few degrees of change in average global temperature when local temperatures change much more than that from hour to hour, much less season to season. Yet on a worldwide scale, talking about seemingly small changes in global average temperatures hides the dramatic localized environmental effects that scientists are predicting.
- The primary GHG, CO_2, is not an unwanted byproduct of combusting fossil fuels, as are criteria pollutants. It is the very production of CO_2 that produces the energy we get from fossil fuels. This makes it a totally different kind of pollutant, and a much harder one to tackle.
- Almost all human activities contribute to the GHG emissions that are linked to global climate change. Unlike most other environmental problems we have successfully tackled—from oil spills to the O_3 hole—there are no silver bullet technological solutions to the need to reduce GHG emissions.
- Climate change has all of the characteristics of a "tragedy of the commons." Whereas the benefits of stabilizing GHG concentrations in the atmosphere are widespread (spatially and temporally), the impacts of aggressive emissions reduction policies will fall heavily on specific sectors and regions.
- The countries perhaps most obviously susceptible to climate change (e.g., small island states threatened with complete destruction by sea level rise) have no political power. Conversely, the United States, with approximately 25% of global GHG emissions, may conclude that it will be able to adapt to many if not most of the manifestations of climate change.
- The magnitude of the changes in our energy economy (and beyond) that scientists are calling for is immense. Simply stabilizing the concentration of CO_2 in the atmosphere would require a 70% reduction in global CO_2 emissions. Even the Kyoto Protocol, much maligned in the United States for its potential economic impacts, was merely intended as a modest first step towards an international climate regime.
- The absence of silver bullet solutions means that climate change mitigation could be very expensive, particularly if undertaken suddenly. Large quantities of capital stock could be stranded if not enough time is provided for technologies and systems to evolve to cushion costs. Yet without the appropriate policy and market incentives, how will new technologies evolve?
- Under the popular rubric of "think globally, act locally" the message is being delivered that "every little bit helps" with respect to GHG emissions reductions. However, it is not at all clear that the mantra even applies in this case. If we do not succeed in preventing "dangerous anthropogenic interference" with the climate system, it will not really matter how much well-meaning individuals and companies tried to reduce their emissions.

To my knowledge none of these points can be factually debated; however, on the basis of these characteristics one can convincingly argue that there is nothing in the history of international environmental cooperation to suggest that we have the capacity to successfully address the climate change problem.

That said, many of us have spent many years on just such an effort. Laying out the problem as I have above is not meant to suggest we do not have to try to address the climate change problem; after all, the scientific case for mitigation is increasingly compelling. But the implementation barriers to successfully avoiding "dangerous anthropogenic interference" with the climate system, or even materially reducing the magnitude of such interference, are mammoth. It is easy to understand why we do not normally discuss the barriers in quite this way, because they can quickly seem insurmountable. But to ignore the reality of these barriers, or to downplay their importance, actively undercuts the likelihood of successfully addressing the climate change problem. It is a scientific, technological, educational, social, economic, political, and ethical problem unlike any that we have previously tried to tackle.

It is therefore high time we got started! All of the policy and technical tools are at our disposal. But let us not spend too much time debating what the "right" approach to climate change mitigation is. In a situation where it is so difficult to figure out how to get from where we are to where we need to be, we would be well served to let 1000 flowers bloom when it comes to mitigation policies and measures. In other words, let us deploy all of the policy and technical tools at our disposal. If we are lucky, some of these measures will interact in synergistic ways that we could not have predicted and get us much farther down the path to a solution than we might be able to predict today.

COMMENTS BY HERBERT MCKEE AND RESPONSE BY DR. MACCRACKEN

Excerpted Comments

The critical reviews at annual conferences have always been interesting and informative, but the recent one in Portland on climate change[1] was better than most. Likely this was due to the intense public and political interest in the subject, as well as the high quality of the presentation and discussion.

No mention was made of a different body of knowledge that has developed over the past 10–20 yr, part of which has been published in various scientific publications. Several people that I talked with at the conference mentioned some of these ideas, along with the idea that the "party line" being followed to solve global warming problems does not appear to agree with some of the background evidence.

Throughout its history, A&WMA (previously the Air Pollution Control Association) has followed the principle of providing a forum for all points of view. Perhaps it is time to look at some of the ideas and questions outlined below.

- Why did the worldwide temperature curve decrease or remain below the long-term curve in 1940–1980, but increase the rest of the past century?
- The complexity of the problem exceeds our ability to insure dependable results; no methods exist to verify models with actual data.
- Temperature increases so far are well within the range of previous historical changes, but model results vary widely depending on which models are used and how input data are chosen.
- Minor changes in the Earth's axis or the Earth's orbit have been associated with temperature variations, but results do not agree and there is little agreement on which results are realistic.
- Several investigators have demonstrated a relationship between worldwide temperature and the length of solar cycles related to sunspots. These two variables have maintained consistent relationships with each other for approximately 250 yr, a long enough time to suggest a significant cause-and-effect relationship.

Response to Herbert McKee from Dr. MacCracken

Although statements by some scientists and some media coverage have created an impression that, as McKee suggests, there is a different body of knowledge leading to quite different perspectives, in reality the assessments of the IPCC consider all of the relevant literature, including the literature said to be supporting an alternative outcome. Indeed, forthrightly seeking to resolve discrepancies between various well-argued perspectives promotes the most rapid advances in scientific understanding.

What creates the difference in view is thus not different bodies of literature, but different interpretations of what the literature means, and what allows the differences to arise are quite different approaches to the review process used to test, hone, and refine the findings. What has gained IPCC's findings the endorsement of all of the major national academies of science and many professional societies is the breadth of their author selection process and the rigor, openness, and breadth of their multistage review process, especially as compared with the very narrow and exclusive process followed by those critiquing the IPCC viewpoint. It was for this reason that in the critical review I drew extensively from the IPCC findings and tried to indicate clearly and with considerable justification where I thought newer evidence led me to conclude that IPCC was being too cautious in its views.

This is not to say that there are not uncertainties with respect to the findings, and McKee's letter raises several of the issues that have been said to place limits on the validity of the IPCC's results. In my review, I tried to cover the uncertainties relating to several of these issues, but chose to do so as they arose in the framework for the overall summary rather than by separating them out into a specific list. In responding to the issues raised in McKee's letter, I will give the pages of the review where I addressed the points that I did try to cover. The responses below offer an overview of findings that are also covered in the various IPCC assessment reports in much more detail.

Taking McKee's questions in turn (page numbers refer to MacCracken[1]):

- Detection and attribution studies reported on by the IPCC indicate that the cooling from approximately 1940 to the mid-1970s (which occurred mainly in the northern hemisphere) was mainly a result of the cooling effect of sulfate aerosols, the atmospheric loading of which builds up quickly as compared with the longer time it takes for the concentrations of CO_2 and other long-lived species to build up and exert their warming influence (see pages 757–762). The increasing fraction of the precursor sulfur dioxide (SO_2) emissions coming from tall stacks during this period also likely led to a greater fraction of the emissions being converted to sulfate and its atmospheric lifetime increasing. Figure 8 of the paper shows the contributions of the various terms to the forcing, although, being for the globe, this figure underemphasizes the cooling effect of sulfate aerosols on the northern hemisphere. Basically, it took until the 1970s, when SO_2 emissions started being controlled whereas CO_2 emissions accelerated, for the warming effect to become dominant. In addition, there remain uncertainties about this period. Not much mentioned by IPCC (yet) is that there still may be warm biases in the temperature record during and just after World War II because of changes in how and where measurements were made (see page 753). A recent paper by Thompson et al.[45] incorporates additional observations from just after World War II that actually tend to diminish the cooling indicated in the current results.

- It is mainly the uniqueness of what is occurring that makes it difficult to verify model performance (see box on pp 758–760). One cannot really confirm models are right for all situations, only that they do not fail in explaining various test cases. So, model simulations are tested against diurnal, seasonal, annual, and interannual cycling, and against volcanic eruptions to evaluate the performance of their short- to intermediate-term processes, and then against the past few centuries and paleoclimatic variations to test longer-term processes (in this latter case often with somewhat simplified models). Over the short term, agreement is reasonably good except that there remain a lot of uncertainties relating to some of the natural oscillations, especially El Niño/La Niña variations. For paleoclimatic timescales and variations, the models tend to not be as responsive to forcings as observations indicate, and so efforts are being made to add some of the longer-term feedback processes (ice sheet development and movement, isostatic lifting and subsidence of the land, changes in vegetation cover, the natural carbon cycle feedback, etc.). So, although significant testing and validation of models is done (e.g., see http://www-pcmdi.llnl.gov/), there are no climatic periods where the CO_2 concentration increased several hundred parts per million over a couple of centuries as we are experiencing; as a result, we only have a somewhat limited crystal ball. The modeling approach, however, has not significantly failed any of the important and most relevant tests and is, therefore, very likely to be much more reliable than arm waving and speculation.
- It is true that over the planet's history, temperatures have been quite different, including perhaps 5–6 °C warmer during the Cretaceous that ended 65,000,000 yr ago, and 5–6 °C colder during the peak of the Last Glacial Maximum approximately 20,000 yr ago. However, reconstructions of the last 1000–2000 yr suggest that the late 20th century/early 21st century is the warmest period over the globe as a whole, although data coverage is pretty limited earlier than approximately 500 yr ago. Indeed, there have been variations in the climate of the lands adjoining the North Atlantic that suggest warmer conditions than at present roughly 1000 yr ago and colder conditions several centuries ago, but it is not at all clear that these variations were globally synchronous as is the present warming. Indeed, although there were few observing stations, it is clear from Inuit wisdom and language and from proxy information that the present warming is much more extensive and intense than was the North Atlantic regional warming of the early 20th century, which did not extend across the Arctic Ocean and into northwestern North America and Siberia. Given the glacial melting going on and other such changes, it is thus very clear that the present global warming is taking conditions well outside the bounds of experience for the periods when society developed, and very likely since at least the last interglacial 125,000 yr ago.
- As to variations among model results, substantial efforts have been made to ensure agreement on model inputs (and for climate change studies these inputs are mainly past and projected changes in atmospheric trace gas concentrations and aerosol loadings). The models do vary in their response to a specified set of forcings, due mainly to how some feedbacks (including the indirect effects of sulfate aerosols) are handled, but the differences mainly relate to how large the ultimate warming will be (IPCC's best estimate for equilibrium warming in response to CO_2 doubling is ~3 °C, with a likely range of 2–4.5 °C) rather than to the rate of warming over coming decades (~0.2 °C per decade). In addition, the models do give different results when the forcings are changed, as for example, when there are different projections of what future emissions of CO_2 and other trace gases will be; although this contribution to expanding the range of model results, which depends on how society evolves and not on the climate models, is often mistakenly laid on the climate modeling community.
- Although the cycling of the Earth's orbital elements may seem small, these variations can cause significant latitudinal and seasonal redistributions of the energy striking the top of the atmosphere (e.g., increasing the amount of solar radiation striking northern hemisphere mid-latitudes by roughly 7% back ~6000–9000 yr ago, whereas diminishing incoming radiation by like amounts elsewhere). These "small" variations have a very strong correlation with the cycling of the climate into and out of ice ages, suggesting that the climate is apparently quite responsive to changes in forcings. The model-calculated responses to these changes in forcings are much smaller than geological records indicate occurred, and so over recent decades climate modelers have come to recognize the roles of additional long-term, natural feedbacks, including the CO_2 and methane (CH_4) feedbacks that are recorded in the ice cores, changes in surface albedo caused by shifts in vegetation cover and the extent of ice sheets, changes in surface altitude caused by the weight

of the ice, and more. Not everything is yet pinned down (after all, our observation network only really goes back ~150 yr, so data mainly come from proxy records that can be somewhat imprecise), but we have a pretty good handle on much of what went on, with the exception of what could possibly have caused high latitudes during the Cretaceous to be as warm as they were.

- The relationship between changes in solar radiation and climate that has been shown is based almost completely on correlations, and, in science, correlations can be interesting, but are not definitive. Attempts to quantify the relationship have had serious problems, especially because satellite measurements over the past few decades have found that the actual variations in solar radiation are smaller than had been estimated from variations in sunspot number, and because solar radiation is actually declining at the same time that the world is warming. In addition, if indeed such small variations in solar energy deposited at the surface and in the atmosphere are responsible for the observed changes in climate, then it is, to put it mildly, hard to explain how the GHG-induced changes in the energy balance, which are about 10 times as large as the solar influences, are having an effect on temperature that is only perhaps one-tenth of the effect of the changes in solar radiation. The consistency required by Occam's law forces the conclusion that the changes in climate must be predominantly caused by the changes in atmospheric composition.

Given the shortcomings of these alternative, unconventional views that have come up in the detailed discussions, it did not seem appropriate, therefore, to present them for the A&WMA audience—outdated views just do not merit a full and equal presentation, although it is certainly reasonable for those who have heard them to ask about their strengths and weaknesses.

SAMPLING OF QUESTIONS RAISED DURING THE PANEL MEETING AND THE RESPONSES OF DR. MACCRACKEN

Question

Steve Mrazik (BP Cherry Point Refinery). To what extent do you think the Earth's population contributes to the problem of climate change, and to what extent do you think population control is going to be part of the solution?

Response

Although population plays a role, stopping population growth would not come close to solving the problem. It turns out that if the developed world stays on its current energy path, even if the developing world went to zero emissions tomorrow (so, essentially imagining there were no people in the developing world), "dangerous" temperature thresholds would be crossed only a decade or two later than is presently projected. Conversely, if the developed world went to zero emissions tomorrow, projected emissions from the developing world would also delay passing dangerous temperature thresholds by only a decade or two. Although having a stable population would be likely to make the transition easier, we are basically past the point where population is the dominant factor—what matters now are the energy choices that we are making and will make. The whole world is playing a role, and the whole world must participate to seriously address this problem.

Question

Humberto Bravo (Universidad Nacional Autonoma de Mexico [National University of Mexico]). Given challenges such as the limited datasets available for Latin America, what needs to be done to improve estimates of the role that Latin America is playing in contributing to climate change?

Response

One cause of uncertainty results from uncertainties regarding the emissions of GHGs. With respect to the sources of CO_2 emissions, there are two components: combustion of coal, oil and natural gas; and land-cover change. The fossil-fuel component is pretty well defined, because almost all of the fuels go through major oil companies or are drawn off for electricity generation; considerable effort has also been devoted to reconstructing past emissions. The land management component, although generally smaller, is much less well defined. Global carbon-cycle models can be used to back-calculate this term from the seasonal cycle and latitudinal gradient in the CO_2 concentration. These models show very high emissions in the United States and Europe.

You also commented that the emissions are generally small in Latin America. That is true for CO_2 emissions from combustion of fossil fuels, but many nations in this region have high emissions of CO_2 from deforestation and high emissions of CH_4 from landfills, polluted rivers, decay of vegetation, and other factors. That CH_4 is an important GHG is evident from the factor used to calculate its CO_2-equivalent concentration. Most conversions use the 100-yr GWP, which indicates that, on a per unit mass basis, CH_4 is approximately 22 times more effective than CO_2. On a 20-yr basis, which is the time scale over which dangerous warming seems likely to be reached, the GWP is approximately 75, making even clearer the importance of an accurate emissions inventory for CH_4. In addition, emissions of soot and other precursors of air pollution that come out of biomass burning will be very important to document.

Question

Suresh Ultano (Syracuse Center of Excellence, Syracuse University). Although leaders in developing nations often cite the high levels of per capita emissions in developed countries to justify their calls for emissions reduction, the leaders of some developed nations focus on the amount of GHG emissions per unit of gross domestic product (GDP), and urge developing nations to become more efficient. With developing nations making many of the products used in developed nations (e.g., the pens that were distributed at the conference), how do you expect these different metrics will play into policy considerations?

Response

Pretty clearly, we need global leadership and a global agreement. This is difficult for the developed nations because very sharp cutbacks are needed, but it is essential because the developed nations have yet to show that a modern economy can prosper without depending on unlimited release of CO_2 from combustion of fossil fuels. To really address the problem over the long term will require the developing nations to participate, but their highest priority at present is ensuring that their people survive from this year to next year, and relatively inexpensive and abundant fossil fuels, particularly coal, are the least expensive way to ensure this, even though this can lead to significant air pollution. That the developing nations are not yet participating in limiting GHG emissions has then been invoked by some leaders as an excuse for developed nations not to act (which is a bit like not trying to pull out of an impending head-on collision because the other vehicle has not yet done so).

Despite the seeming intractability of the situation, I think there is at least some reason for hope. An international panel on which I (MacCracken) served prepared a report for the U.N. Commission on Sustainable Development (http://www.unfoundation.org/seg/index.asp) that developing nations can play an important role in limiting climate change by doing exactly what they know they need to do to improve the current lives and health of their people; that is, efforts to reduce air and water pollution, improve efficiency, and end land degradation, which are all essential to meeting the millennium development goals that have been set to alleviate poverty, and will contribute to reducing emissions of CH_4, soot, air pollutants, and CO_2 from deforestation. Although an absolute cap on fossil fuel emissions is considered unfair, efficiency goals and standards are already being enacted in some developing nations, seeking to reduce their carbon-per-GDP ratio to a value more like the developed countries. The U.N. Framework Convention on Climate Change calls for differentiated responsibilities, and the developed nations have to be willing to act first, given that emissions from developed nations are so large and have been going on for so long. As explained in the critical review, I believe that a deal should be possible—with all nations contributing, each in their way.

Question

Howard Ellis (President, Enviroplan Consulting). Our company has been the consultant to the American National Standards Institute for the past year to develop a national accreditation program for verification/validation bodies that will provide the third-party verification of GHG assertions in all of the voluntary and mandatory reporting programs that are underway and being developed in the United States. My question is: Do you really think that the United States will be able to stabilize total carbon emissions and then have them go down further without having a high price of carbon built into all of the economic decisions that are made throughout the country in the future? Basically, is having a high price of carbon an absolute condition or not for really stabilizing and reducing GHG emissions?

Response

One of the things that Dr. Whitman said early on about efficiency is very important. The question is “Why isn’t efficiency being adopted more?” A National Academy of Sciences study in 1992 and the McKinsey report in 2007 both indicated that the United States could reduce its emissions by approximately 30% at low cost if we moved to optimum technologies. So the question is “Why isn’t that happening?”

As a homeowner, one of the things that you find if you try to reduce emissions is that you have to do an awful lot of research to make it happen (e.g., what type of solar panels, what contractor, how large of an area, will the utility bank electricity). I believe the state of Delaware is embarking, or is about to embark, on an effort where they are going to use state funding to fund teams that will come to you as a homeowner and say, “We will green your home. This will reduce your emissions and your electric bill. Our costs will be a loan to you that can be repaid with part of the savings you will have on your utility bill over the coming 5 yr, and then, after that, you will reap the full savings.” Once the public understands how this will work and experienced installation teams are available, those planning this effort expect it be taken over by private-sector companies, and that a 7-yr payback will be achievable—so a good deal for everyone. This greening could happen now, but it is not, partly because it sounds too good to be true, and if someone came to your door with this deal, there would be many doubters that this could be true, and those who accepted would likely do so after significant research and inquiry. Basically, the transaction costs are just too high for widespread acceptance. A solar utility company, Citizenrē (http://www.citizenre.com/web/index.php), is one company trying to get past public resistance. Right now, buying solar for your home can be costly and time-consuming. With the new approach, the installing company will do everything for you—get permits, install, maintain, update, etc. All the homeowner does is to pay them a lease rate, the cost of which, at least for my home in Maryland, would be equivalent to the cost of the present mix we get of coal-fired and nuclear energy, and less expensive than energy from wind or biomass.

Another barrier to moving ahead with several of these energy saving steps is, as Carol mentioned, regulatory. To overcome these barriers and to give utilities incentives to help with reducing the demand for energy, California has redone its regulatory law. Such changes are needed around the country. In Maryland, if I put solar PVs on my roof, the local utility will provide a daily and seasonal banking service for only the amount of my use—any extra power would be a donation from me to the utility. Basically, there is no provision yet (the law is being changed) for the utility to purchase excess power from the homeowner and there is no indication of how time-of-day pricing will affect the arrangement. So, regulations need updating.

The second part of the question asked about the likelihood of changes occurring across the United States. California has shown that change is possible. Their leaders have pushed to improve energy efficiency, appliances, building design, awnings, glazings, motion-detecting light switches, and much more—and those from California hardly notice any more, but these steps have reduced their per capita electric use to half that of the rest of the nation.

Just one other example. As I understand it, the average electric utility in the United States is approximately 35% efficient. In Denmark, the comparable figure is over 60%. This difference is a result of the recycling of energy, sometimes referred to as cogeneration. In some states it remains illegal for companies to do this—to use the waste heat to generate energy, but it can be done very cost effectively (e.g., see http://www.recycled-energy.com/main/what_it_does.html). Whether big company or personal home, in many states it is not legal to make extra power and transfer it to others over the grid—and the utility is not allowed to, or has no incentive to, purchase any excess power from individuals and non-utility companies. The regulations were likely put in place for good reason in the past, but it is time to update them. We need a smart transmission grid that can deal with distributed and time-varying sources, large and small.

So there is a lot that can be done without a price on carbon, but, indeed, adding a cost for emitting carbon will certainly make the transition happen more rapidly.

Question

Fred Blood (Austin Energy). We are a municipally owned power company, and the price signals are out there for efficiency. Over the past 9 yr we have saved our customers over 700 MW of electricity at the meter, and we did this at approximately 15% of the cost of what it would take to do at the power plant. We have a climate action plan in place, and we are trying to save what we call another "conservation power plant," another 800 MW, essentially at the meter through conservation efforts that the power company is underwriting in the form of loans and low-price efforts. So the price signal is there. We can meet projected energy needs out to 2030 without building another power plant, just through energy conservation. And this is something that gets down to who is paying, who is gaining, and who is making the savings. If you talk about sustainability, so selling services instead of selling electrons, the power companies would earn the benefits, because they would have more efficient lights and better air-conditioning and they would have combined heating-power units out there. But the utilities are not selling the service; they are selling the power. And I do not know, from an administrative perspective, how they can be expected to do that because we have sliced and diced some of the vertically integrated power companies such that the people building the power companies understand the cost of building the kilowatt of construction, not the cost of saving the kilowatt in use. But all of the other people who are in between, they are not part of it. So there is your policy apple to grab and to deal with. We can meet our energy needs by 2030 without building another power plant at less than 10% of the cost of building a power plant. So how can you make this happen with your policy approach?

We have four Priuses that are getting approximately 110 mi/gal; we can talk about how that is done. We plug them in during the evening; that is when most of the wind generation in west Texas comes up. Until you have a more distributed grid you are going to have a storage issue. But all of those things are doable, and the fact that we can go the next several, maybe two, decades—a decade and a half—without building one more power plant if everyone would go after energy conservation is a good place to start. That provides time to put in the wind and the solar. If the price of carbon power goes up, you will see that wind power will be cheaper than natural gas (it is competitive now). One more or two more advances in solar and solar may be competing with natural gas. When you get up to \$50/t (of CO_2 emitted) you will see solar competing with coal.

I think all of this is an economic issue to get off of depending on "fossil sunshine" and get on to using real sunshine. But an underlying part of all of this, so you can live off of energy that falls on your roof, is you have to be very intense on your energy conservation. You are going to have to have an energy computer in your house that will turn off the defrosting and the ice-making of your refrigerator/freezer and turn off all of your vampire power, such as your cell-phone chargers at 5:00 in the afternoon when there is going be a peak, so that utilities do not have to turn on gas turbines to do the peaking. These are all things we can do with a lot less technology than we used to put a rover on Mars that is now running 2 yr after it was supposed to run out of power. This is a matter of some willpower, because it is not a new technology. It is a matter of who is paying and who is gaining, and how you turn that around from a policy standpoint to make it work. Because it is cheaper!

Response

Well, if everybody were as progressive as Austin, TX, that would be the solution. We need leaders such as your mayor Will Wynn—the one with the perfect political name. As I understand what is going on, Austin is testing plug-in hybrids that are recharged at night with Texas wind power, and the cost is the equivalent of gasoline costing under \$1/gal.

Question

Brad Dawson (Praxair R&D). Today we heard, several times, the quote that, "There's always going to be uncertainty, but that the risk is certain," sort of indicating that the problem, or the challenge, right now, is global climate change, and I agree with that. Yesterday, Thomas Dunn, of EPA and involved with Homeland Security, came and said basically the same thing, but with respect to Homeland Security; he said "it's not if it's going to happen, but when it's going to happen," and I think that there are a lot of people that probably agree with him. My question to the panel is, do we have the resources to solve both of these issues at the same time? Or are there ways that we can solve them both with the same pathways; so, solutions for both problems that are common.

Response

That was partly what I was getting at when talking about climate change as being a stalking horse for sustainability. Basically, the footprint of the developed nations over the world means we are extracting a lot of resources from a lot of different places, taking up resources that those nations want, and creating ill will. The issue of importing so much oil from volatile places and transferring money there is part of the terrorism problem. So if we can get to dispersed domestic energy systems, we will have started to address that problem.

We have to look at the problems together and there is a lot that can be done. Aside from California being a leading state, New York has been moving as well. Under former Governor Pataki, a compilation was done of the amount of money that New Yorkers exporting were paying for their energy. When oil was $60 a barrel, the total came to about $55 billion, or about $2000 per resident per year. Obviously then, the importing of energy to the state is a huge economic issue. It is therefore also a jobs issue. And approximately 90% of their transportation energy is imported, making it an energy-security issue and an economic-security issue. And, oh, yes, their energy mix is contributing to the climate problem. So, in justifying their efforts, they considered all of those reasons together. Upstate New York has been losing residents and it is an agricultural area known for cool-season crops. With summers becoming warmer, they are not going to be able to grow cool-season crops, such as apples, sugar maples, and asparagus, and they do not have the soil to compete for warm summer crops. So what are they going to do? Well, maybe they can grow cellulosic biomass on some of those existing farmlands, and find ways to not spend so much money for energy out-of-state; doing this would also create jobs, reduce their dependence on foreign oil, and help with climate change. Plus they want to develop products to sell elsewhere, which has been another issue that Governor Schwarzenegger and others have used to justify their actions. Indeed, we can solve a lot of the problems together, if we just put our minds to it.

Question

Frank Princiotta (EPA). Tomorrow I'll have a talk on the issue of technology as it relates to this issue. I have really enjoyed the panel's deliberations quite a bit, but it seemed to me you were a little bit light on the issue of the availability of technology. Based on all of the references I've looked at, technology is not available, currently, to get the kinds of reductions we need, nor is it being developed at the rate needed if we're serious about mitigation and preventing temperature rise of approximately 2.5 °, plus or minus the uncertainty. I'd welcome the response of the panel to that conclusion.

Response

My sense of the Senate debate was that, although there were lots of issues, there was a disagreement about this very issue. There are those who think that if you increase the price (i.e., impose a carbon tax or require carbon permits) the technologies will come, and there are those who want to see that all of the technologies are available before they take the first step of imposing costs. I think the question is "how are we going to get past that divide?" Clearly, we need to have a much larger energy R&D program, because there are going to have to be different technologies. We need a whole portfolio of technologies, as well as a whole portfolio of policies. So we have to have a better-funded research program.

But how do we get over that hump, getting people willing to take the jump and say, "We are going to commit to the energy transition and figure out how to do this." It is very reminiscent, rather than of the Apollo or Manhattan projects, of actually going to war in World War II. We just decided we were going to do it, and nobody had the foggiest idea of how we were going to make all of those airplanes, and ships, and everything else. But we did it! So, are we going to make such a commitment again, and when are the impacts going to become large enough to convince people to say: "We are willing and we have got to do that."

Some states are doing it, and that is great. And I agree with Dr. Ayala that the only thing that keeps me positive is seeing some examples and working to help some examples come to fruition; otherwise, the future with unchecked climate change is just too depressing to contemplate.

CONCLUSIONS

It is certainly not surprising that an issue as complex as global climate change would raise so many significant and important responses from the AW&MA community. Because of the seriousness of the projected impacts and the extremely difficult choices that the world nations will have to make to reduce them, AW&MA scientists and members should continue to debate and analyze the options for addressing the problem of climate change. Most important is the need to keep the dialogue open and to the extent possible to continue to engage the broader community in finding joint solutions that are fair and effective.

DISCLAIMER

The questions and answers were taken from an audio transcript of the panel meeting, and we apologize if any words were misunderstood or any names are misspelled.

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