Climate Change: The Public Health Response

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There is scientific consensus that the global climate is changing, with rising surface temperatures, melting ice and snow, rising sea levels, and increasing climate variability. These changes are expected to have substantial impacts on human health. There are known, effective public health responses for many of these impacts, but the scope, timeline, and complexity of climate change are unprecedented. We propose a public health approach to climate change, based on the essential public health services, that extends to both clinical and population health services and emphasizes the coordination of government agencies (federal, state, and local), academia, the private sector, and nongovernmental organizations. (*Am J Public Health.* 2008;98:435–445. doi:10.2105/AJPH.2007.119362)

Weather and climate have been known to affect human health since the time of Hippocrates.[1] Heat causes hyperthermia,[2,3] cold causes hypothermia,[4] and droughts cause famine.[5] Injuries, displacement, and death result from floods,[6,7] hurricanes,[8] tornadoes,[9] and forest fires.[10] An entire category of diseases—the tropical diseases—is named for a particular climate; climate and weather affect the distribution and risk of many vector-borne diseases, such as malaria,[11] Rift Valley fever,[12] plague,[13] and dengue fever.[14] Weather also affects the risk of foodborne[15] and waterborne[16,17] diseases and of emerging infectious diseases such as hantavirus,[18] Ebola hemorrhagic fever,[19] and West Nile virus.[20] There is a well-established if less intuitive association between weather and mortality from cardiovascular and respiratory disease.[21,22]

The world's climate has been relatively stable for thousands of years, with a strong temperate central tendency and a nearly constant atmospheric level of carbon dioxide (CO_2).[23] For more than a century, however, levels of CO_2, methane, and other greenhouse gases have been rising, a trend associated with changes in climate and other earth systems. For example, global mean temperature has increased approximately 0.6°C since 1860,[23] rainfall patterns have changed in many regions,[23] and sea levels have risen.[24] There is evidence that severe storms have become more common,[25,26] although the science on this point is not settled.[27,28] Global emissions of CO_2 continue to increase, and CO_2 persists in the atmosphere for approximately 100 years, so the climate will continue to change into the foreseeable future.[29] Models predict that by the year 2100, the world's mean temperature will rise an additional 1.8 to 4.0°C, sea levels will rise 0.18 to 0.59 m, and weather variability will increase significantly.[23]

The potential health effects of climate change have been extensively reviewed.[30–35] Principal concerns include injuries and fatalities related to severe weather events and heat waves; infectious diseases related to changes in vector biology, water, and food contamination; allergic symptoms related to increased allergen production; respiratory and cardiovascular disease related to worsening air pollution; and nutritional shortages related to changes in food production. Indirect concerns, for which data to support projections are less available and uncertainties are greater, include mental health consequences, population dislocation, and civil conflict. In addition, changes in the patterns of pests, parasites, and pathogens affecting wildlife, livestock, agriculture, forests, and coastal marine organisms can alter ecosystem composition and functions, and changes in these life-support systems carry implications for human health.[36] These health effects, summarized in Table 1, are not discussed in detail here. In the United States, the burden of these conditions is expected to increase as climate change advances.

There is evidence that climate change has already affected human health. The World Health Organization (WHO) estimates that by 2000, the global burden of disease from climate change had exceeded 150 000 excess deaths per year.[31,39] Although individual weather events cannot be attributed to climate change, the rising burden of storms such as Hurricane Katrina suggests that climate change has already affected public health in the United States. Public health planners and professionals at the state and local level, policymakers, and members of the public all need to consider health a central dimension of climate change and to plan and act accordingly. We propose a public health approach to climate change.

PUBLIC HEALTH PERSPECTIVES ON CLIMATE CHANGE

Scientists, clinicians, and public health professionals have called for attention to climate change on both practical and ethical grounds.[34,40–45] Several well-established principles point to a vigorous, proactive public health approach to climate change.

One such principle is *prevention.* Primary prevention aims to prevent the onset of injury or illness; clinical examples include immunization, smoking cessation efforts, and the use of bicycle helmets. Secondary prevention aims to diagnose disease early to control its advance and reduce the resulting health burden; clinical examples include screening for hypertension, hyperlipidemia, and breast cancer. Tertiary prevention occurs once disease is diagnosed; it aims to reduce morbidity, avoid complications, and restore function.

There are clear analogies in the approach to climate change. Primary prevention corresponds to *mitigation*—efforts to slow, stabilize, or reverse climate change by reducing greenhouse gas emissions. Secondary and tertiary prevention corresponds to *adaptation*—efforts to anticipate and prepare for the effects of climate change, and thereby to reduce the associated health burden.[46,47] Mitigation efforts will occur mainly in sectors other than health, such as energy, transportation, and architecture (although the health sciences can contribute useful information regarding the choice of safe, healthful technologies). Adaptation efforts, on the other hand, correspond closely to conventional medical and public health practices.

TABLE 1—Anticipated Health Effects of Climate Change in the United States

Weather Event	Health Effects	Populations Most Affected	Additional US Health Burden	Nonclimate Determinants	Adaptation Measures	Health Data Sources for Surveillance	Meteorological and Other Data for Surveillance
Heat waves	Heat stress	The very old; athletes; the socially isolated; the poor; those with respiratory disease	Low to moderate	Acclimation; built environment	Architecture; air conditioning; warning systems; distributed, resilient, "smart power grid"; community response	ED and ambulatory visits; hospital admissions; mortality	Daily minimum and maximum temperatures; humidity; soil moisture
Extreme weather events	Injuries; drowning	Coastal, low-lying land dwellers; the poor	Uncertain: likely moderate	Engineering; zoning and land-use policies	Architecture; engineering; planning; early warning systems	Attributed risk; ED visits; hospital admissions; FEMA records; mortality	Meteorological event data: extent, timing, severity, return time for rare events
Winter weather anomalies (e.g., rain, ice)	Slips and falls; motor vehicle crashes	Dwellers in northern climates; elderly people; drivers			Public education; mass transit	ED visits	Meteorological event data
Sea-level rise	Injuries; drowning; water and soil salinization; ecosystem and economic disruption	Coastal dwellers; those with low SES	Low	Water pollution; storms; coastal development; land-use policies	Sea walls and levees; abandonment	Attributed risk; ED and ambulatory visits; mental health measures (indirect effects)	Satellite mapping of coastal areas; sea level and tidal surge records
Increased ozone and pollen formation	Respiratory disease exacerbation (e.g., COPD, asthma, allergic rhinitis, bronchitis)	The elderly; children; those with respiratory disease	Low to moderate	Smoking; air quality; respiratory infections; industrial activity; electric demand and production mode; access to health care	Pollution controls; air conditioning; education; medical therapy	ED and ambulatory visits; hospital admissions	Daily and weekly temperature; rainfall; pollen counts; ozone levels; particulate measures
Drought, ecosystem migration	Food and water shortages; malnutrition	Those with low SES; elderly; children	Low	Population growth; food distribution systems; economic and trade issues; biotechnology; petroleum cost	Technological advances; enhanced delivery systems; trade negotiations	Growth monitoring; food insecurity data	Crop yields; rainfall patterns; data on food sources and marketing
Droughts, floods, increased mean temperature	Food- and waterborne diseases	Swimmers; multiple populations at risk depending on outcome of interest	Low to moderate	Travel; land use; water treatment and quality; housing quality; food-handling practices	Public education; water treatment; medical treatment; watershed management	Disease surveillance; ED and ambulatory visits; seasonal patterns in incidence; focused observations at geographic margins	Temperature and rainfall data; vector population and habitat/range monitoring
Droughts, floods, increased mean temperature	Vector-borne disease	Outdoor workers; people pursuing outdoor recreation; the poor (without air conditioning/window screens)	Low to moderate	Travel; vector and animal host distribution; habitat change; land use	Public education; vector control; medical prophylaxis and treatment; vaccination	Disease surveillance; ED and ambulatory visits; focused observations at geographic margins	Temperature and rainfall data; vector population and habitat/range monitoring
Extreme weather events; drought	Mass population movement; international conflict	General population	Uncertain: potentially moderate to high	Sociopolitical factors; resource use and conflicts; economic development	Negotiation and conflict mediation; postdisaster response	Event and population movement monitoring; mental health outcomes surveillance	Meteorological event data; regional economic and resource use data

Continued

TABLE 1—*Continued*

Climate change generally; extreme events	Mental health	The young; the displaced; those with depression or anxiety	Uncertain: potentially moderate	Baseline mental health disease burden	Health communication; postdisaster mental health outreach; various therapeutic and medical management options	Mental health outcomes surveillance	Correlation of mental health outcomes with regional variable responses to extreme events; climate change as a whole

Source. Adapted from Patz et al.[37] and Balbus and Wilson.[38]
Note. ED = emergency department; FEMA = Federal Emergency Management Agency; SES = socioeconomic status; COPD = chronic obstructive pulmonary disease.

This set of practices is collectively known as *public health preparedness.* Preparedness efforts have assumed a central role in public health in recent years. The threat of terrorist attacks, especially since September 11, 2001; the emergence of new infectious diseases and the reemergence of old ones (including the possibility of pandemics such as avian influenza); and the occurrence of natural disasters such as earthquakes and hurricanes have all compelled health professionals to study, anticipate, and prepare for such eventualities. Public health preparedness for the predicted effects of climate change is consistent with this approach.

Preparedness often occurs in the face of scientific uncertainty. Events such as an influenza pandemic, a terrorist attack, or a hurricane cannot be predicted with precision, but protecting public health remains essential. The precautionary principle, as articulated at the 1998 Wingspread Conference, holds that "When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically."[48] Specific climate change outcomes are uncertain, especially indirect and derivative outcomes such as population displacement. However, the notion that steps to protect the public from the threats of climate change cannot await full scientific certainty, and the use of "margins of safety" to ensure safer conditions, are consistent with prevailing public health practice.[49,50]

Risk management—systematic ongoing efforts to identify and reduce risks to health—is another relevant framework Industries that manufacture, use, or store dangerous chemicals are required by the US Environmental Protection Agency to analyze their processes (including assessing worst-case scenarios), identify vulnerable steps, develop strategies to reduce the risk of chemical releases or other mishaps, and implement those strategies.[51] Similarly, the hazard analysis and critical control point paradigm for food safety assesses the entire "life cycle" of food, from production to consumption, analyzes potential hazards, identifies critical control points, corrects, and verifies.[52] By analogy, health scientists can analyze relevant activities such as energy production and transportation. Using techniques such as health impact assessment,[53,54] they can provide data to support decisionmaking and in some cases recommend specific actions to protect public health.

Cobenefits provide another important framework for public health action on climate change. Steps that address climate change frequently yield other health benefits, both direct and indirect. For example, reducing emissions of greenhouse gases from power plants can also improve regional air quality, with direct benefits for respiratory and cardiovascular health.[55–57] Reducing vehicle miles traveled by encouraging walking, bicycling, and transit use not only lowers motor vehicle contributions to climate change, it also promotes physical activity, an important solution to the obesity epidemic.[58,59] Steps that reduce social isolation not only improve overall health[60] but also reduce vulnerability to heat waves.[61,62] A broad public health approach that fully accounts for health benefits may provide important evidence-based support for climate change strategies.

Economic considerations are critical in public health planning. The mandate to maximize health protection at the lowest short-term and long-term cost is highly relevant to climate change. In 2006, the United Kingdom Government Economic Service released *The Stern Review* on the economics of climate change,[63] which predicted that climate change would bring enormous costs, including health care costs, and that mitigation and adaptation efforts would be far less costly if undertaken soon. Indeed, the costs of procrastinating may far exceed the costs of timely action, in both economic terms and health terms.[43] Timely action to address the health impacts of climate change makes good economic sense.

Finally, ethical considerations guide public health attention to climate change.[64] Medical ethics are usually based on 4 principles: autonomy, beneficence, nonmaleficence, and justice.[65,66] Addressing climate change embodies beneficence, because it protects people now and in the future, and nonmaleficence, because it avoids harms (including distant "downstream" harms) that flow from climate change. Justice considerations arise in the inequities that characterize the impacts of climate change and the ability to cope with them.[67,68]

Public health ethics reflect 3 traditions—utilitarianism, liberalism, and communitarianism[69]—that also offer a rationale for addressing climate change. Utilitarians would note that the net sum of human well-being—especially when future generations are taken into account—will likely increase if the health impacts of climate change are controlled. Liberal analysts, following Kant, would posit a right to a healthy environment and would therefore support policies and practices that prevent environmental degradation. Communitarians would argue that climate change undermines the requisite conditions for an intact social order. The principles of the ethical practice of public health, as presented by Thomas et al., begin with a statement that prima facie directs attention to climate change: "Public health should address principally the fundamental causes of disease and

requirements for health, aiming to prevent adverse health outcomes."[70(p1058)] Thus, attention to climate change is dictated by the traditions of both medical and public health ethics.

PUBLIC HEALTH ACTIONS TO ADDRESS CLIMATE CHANGE

As climate change has become a certainty, so has the need for public health action to anticipate, manage, and ameliorate the health burdens it will impose. The standard framework for public health action is the 10 Essential Services of Public Health, developed in 1994 by the American Public Health Association and a group of federal, state, and local agencies and partners.[71] These services, with examples pertinent to climate change, appear in Table 2 and are discussed in detail in this section.

In developing and implementing services to address climate change, public health professionals will need to confront several practical realities. First, the effects of climate change will vary considerably by region. Second, they will vary by population group; not all people are equally susceptible. Third, these effects are highly complex, and planning and action will need to be multidimensional.

Regional variation will play a critical role in public health responses to climate change.[72] Although CO_2 and other greenhouse gases are relatively uniformly distributed in the atmosphere, the human health effects of climate change will vary by region, topography, and capacity for response.[31] For example, far northern locations will see relatively dramatic changes in temperature, hydrology, and ecosystem conditions, with effects ranging from infectious disease risk to inadequate health services.[73,74] Low-lying coastal regions may face flooding, salt infiltration of fresh water tables, harmful algal blooms, and in some cases severe storms.[75–77] The western United States may experience significant strains on water supplies as regional precipitation declines and mountain snowpacks are depleted,[78] in turn raising the risk of forest fires.[10] As a result, planning for and managing the health impacts of climate change will need to draw on local data and will involve local and regional authorities and health care providers.

Health disparities are well recognized in public health and clinical practice, and a central tenet of public health is that such disparities need to be eliminated. One contributor to health disparities is environmental risks that disproportionately threaten certain populations, especially poor people and members of ethnic and racial minority groups—the basis of environmental justice advocacy.[79,80] Climate change is expected to perpetuate health disparities in this way.[81] Events such as Hurricane Katrina highlighted the vulnerability of the poor in New Orleans, La,[82–84] and on a global scale, people in poor countries will face greater health risks, with fewer resources and less resiliency than will those in wealthy nations.[67,68,85–88] Public health action on climate change must include vulnerability assessments, identification of the most vulnerable populations, and a focus on eliminating health disparities.

Complexity is a cardinal feature of climate change. Vast numbers of factors influence meteorological systems, many feedback loops operate, and sufficient data needed for a full evaluation are rarely available. The same is true of the health impacts of climate change. These effects will unfold over coming decades against a backdrop of other changes: demographic shifts including population growth and an aging population, increasing scarcity of fossil fuels, continuing migration to Southern and Southwestern states, and urbanization. To grapple successfully with this complexity, public health scientists will need to engage in systems thinking[89] and learn and apply techniques such as system dynamics modeling.[90]

The recognition of these 3 realities—geographic variability, population variability, and complexity—set the stage for considering public health actions to address climate change based on the following 10 essential services of public health.

TABLE 2—The 10 Essential Services of Public Health, With Climate Change Examples

Service	Climate Change Example
1. Monitor health status to identify and solve community health problems.	Tracking of diseases and trends related to climate change
2. Diagnose and investigate health problems and health hazards in the community.	Investigation of infectious water-, food-, and vector-borne disease outbreaks
3. Inform, educate, and empower people about health issues.	Informing the public and policymakers about health impacts of climate change
4. Mobilize community partnerships and action to identify and solve health problems.	Public health partnerships with industry, other professional groups, faith community, and others, to craft and implement solutions
5. Develop policies and plans that support individual and community health efforts.	Municipal heat-wave preparedness plans
6. Enforce laws and regulations that protect health and ensure safety.	(Little role for public health)
7. Link people to needed personal health services and ensure the provision of health care when otherwise unavailable.	Health care service provision following disasters
8. Ensure competent public and personal health care workforce.	Training of health care providers on health aspects of climate change
9. Evaluate effectiveness, accessibility, and quality of personal and population-based health services.	Program assessment of preparedness efforts such as heat-wave plans
10. Research for new insights and innovative solutions to health problems.	Research on health effects of climate change, including innovative techniques such as modeling, and research on optimal adaptation strategies

Source. Public Health Functions Steering Committee.[71]

Monitor Health Status to Identify and Solve Community Health Problems

Information is key to a responsive and functioning public health system. Data from public health surveillance or tracking systems are used to determine disease burdens and trends, identify vulnerable or affected people

and places, recognize disease clusters, and plan, implement, and evaluate public health interventions.[91] When these data are systematically collected, analyzed, interpreted, and disseminated, they guide the design of effective public health interventions and the judicious use of public health resources.

To respond to climate change, several categories of data—on environmental risks, vulnerability, and disease—are needed. Examples of risk data include meteorological data (such as temperature trends) and ecological data (such as mosquito density). Indicators of vulnerability include not only physical factors such as elevation, urban infrastructure, loss of forest cover, and prevalence of household air conditioning,[92–95] but also social factors such as isolation and poverty.[96] One example, the Climate Vulnerability Index, focuses on susceptibility to floods using a combination of factors measured at the local level.[94] Disease surveillance is a traditional public health function; data systems for infectious diseases known to be linked to climate variability, including foodborne[15] and waterborne[97,98] diseases, need to be strengthened.

These data—on risk, vulnerability, and disease—are often collected at different spatial scales and through different methods. It is essential that they be harmonized and integrated. Epidemic early warning systems combine clinical data such as emergency department and outpatient clinic syndromic surveillance with climate data, vector biology data, clinical laboratory data, veterinary data, telephone hotline call tracking, pharmaceutical use data, and other data.[99–103] Such systems exist in many parts of the world for vector-borne,[104–107] foodborne,[108,109] waterborne,[110] and respiratory[111] diseases and for acts of terrorism.[112] Such early warning systems need to be evaluated and strengthened.[113–115] In the United States, the National Environmental Public Health Tracking Program is a comprehensive approach to collecting and integrating data on environmental exposures, human body burdens, and diseases.[116,117] This program needs to expand in terms of the number of participating jurisdictions, data elements collected, integration of diverse data sources, and greater spatial resolution of the data. This will enable health authorities to understand more clearly the associations among long-term climate changes, weather events, ecological changes, and direct and indirect health outcomes.

Diagnose and Investigate Health Problems and Hazards in the Community

Identifying, investigating, and explaining health problems at the population level remain classic public health responsibilities—the community equivalent of a physician's diagnostic workups of patients. These functions, which flow directly from the previous task (monitoring health status), are well established in public health. However, climate change will require enhanced diagnostic and investigative capacity throughout the health system. For example, ecological changes may alter traditional vector-borne disease dynamics, possibly redefining animal hosts, vectors, and disease outcomes at the local and regional scales. Techniques that help assess health vulnerability to climate change have been proposed and offer a proactive approach to diagnosis.[47] The capacity of public health laboratories must be enhanced to allow rapid diagnosis and reporting of diseases that are reintroduced or alter their distribution.

An example of such investigation comes from British Columbia, where an outbreak of *Cryptococcus gattii*, formerly considered a tropical organism, was observed in 2001.[118,119] Investigation of the outbreak, a collaborative effort of a university and a provincial center for disease control, included such innovative sampling techniques as testing of air, soil, trees, garden waste, vehicle wheel wells, and the shoes of personnel participating in sampling, and it required laboratory capacity to culture the organism and identify it using the methods of restriction fragment length polymorphism.[120]

A component of diagnosis and investigation is attribution—determining the extent to which health problems can be attributed to climate change. Understanding attribution will help in developing the most effective and cost-effective strategies for health system response. Methods for estimating the health burden of climate change use techniques analogous to risk assessment.[39,121] These methods need further development and application.

Inform, Educate, and Empower People About Health Issues

Most Americans believe that climate change is already having effects, and a large and increasing plurality report that they worry about it "a great deal." However, only 1 in 5 reports understanding climate change very well. Moreover, Americans are equally divided among those who believe that media coverage of climate change is exaggerated, correct, and underestimated.[122] There is a high and growing level of concern, but clearly public understanding of climate change is incomplete, and a majority lacks confidence in information presented in the media.

This situation, which is familiar to health professionals, in many ways reflects public views of health and illness. The need to inform, educate, and empower people about health is critical, and experience with smoking cessation, HIV prevention, physical activity promotion, and other health issues has yielded rich insights into effective health communication.[123,124] However, little of this insight has been applied to climate change.[125–128]

Effective health communication on climate change will inform the public and policymakers about potential health effects and about steps that can be taken to reduce risk. The communication needs to be targeted to specific groups, accounting for varying levels of understanding, cultural and ethnic differences, vulnerability to the health effects of climate change, and other factors. Messages should empower people to access and use necessary health resources. Since frightening scenarios may elicit despair and helplessness, it is important to design messages that minimize these responses and that lead instead to constructive behaviors. For example, the Environmental Protection Agency offers a "What You Can Do" Web page[129] that provides tips for use at home, at the office, on the road, and at school, together with user-friendly tools such as a personal greenhouse gas emissions calculator. Other nations may provide useful models. For example, Health Canada offers the Canadian public a regular publication called *Your Health and a Changing Climate*, a user-friendly Web site,[130] and other information

channels. Research on the most effective means of communication is needed, and once implemented, communication strategies should be evaluated for efficacy.

Mobilize Community Partnerships to Identify and Solve Health Problems

Responding to the health challenges posed by climate change requires a multilevel, interdisciplinary, and integrated response, so efforts should focus on developing partnerships among federal, state, and local government agencies, academia, nongovernmental organizations, and the private sector. Many of these partnerships must evolve at the local and state levels, because identifying health threats and vulnerable populations, designing and implementing adaptive measures, and responding to emergencies occur largely at those scales.

Although existing relationships with traditional public health partners should be strengthened, new collaborations must be developed. Leading examples include collaborations with architects and city planners (whose design work can reduce energy demand and limit vulnerability to heat, flooding, and other risks), transportation planners (who can design transportation systems that reduce greenhouse gas emissions and promote safe, healthy travel), and the faith community (which shares an emphasis on long-term stewardship and can help disseminate public health information). For example, the National Religious Partnership for the Environment[131] identifies human health as a central issue in climate change, offering a firm basis for collaboration with public health agencies.

Develop Policies and Plans That Support Individual and Community Health Efforts

National policy on the mitigation of climate change will likely evolve in coming years. Although responsibility for reducing greenhouse gas emissions lies outside the health arena, health input is appropriate in at least 2 ways. First, health professionals can explain the health rationale for climate change mitigation in terms of reduced morbidity and mortality. Second, health scientists can provide evidence on the health impacts of various approaches to climate change mitigation (including cobenefits and disbenefits),[132] using such techniques as health impact assessment.[53,54] Such input will help produce decisions that best protect public health.

The health sector should play a major role in developing plans that address health threats related to climate change. For example, cities at risk of heat waves need preparedness plans[133,134] that provide early warnings, educate the public and health care providers, identify vulnerable people and places,[135] implement health surveillance,[136] create buddy systems and other rescue plans, identify shelter facilities, ensure that backup generators are available and supplied with fuel, prepare transport and evacuation plans, and prepare clinical facilities to deliver appropriate care, including surge capacity.[137] Similar plans are needed for severe weather events,[138] infectious disease outbreaks, and other health threats. A good example is the Hospital Safety Index proposed by the Pan-American Health Organization, to help plan and achieve "hospitals safe from disasters."[139] Health data can inform the design of "climate-proof" housing, enhanced infectious disease control programs, early warning systems, and other plans. Public health authorities need to collaborate with other agencies, such as those responsible for law enforcement and emergency response, in planning and exercising. Initiatives in Portland, Ore,[140] and Seattle, Wash,[141] exemplify local health department engagement in such planning.

Other policies and plans are internal to the health system, relating to the operation of health facilities. The health sector, like many other industries, can examine its own contributions to climate change and work to reduce them. Hospitals and clinics can be designed, built, and operated in ways that lower energy demand, reduce their waste streams, and link with local transit systems to cut driving by staff, patients, and visitors. "Green purchasing" refers to preferential purchasing of environmentally friendly supplies and equipment, another set of strategies to reduce health sector contribution to climate change. The British National Health Service has adopted these approaches as policy,[142] and technical advice is available to US health organizations in the peer-reviewed literature[143] in sources such as the *Green Guide for Health Care*,[144] from organizations such as Hospitals for a Healthy Environment[145] and from private architects and consultants.

Enforce Laws and Regulations That Protect Health and Ensure Safety

Few public health laws and regulations have a direct bearing on climate change. However, public health can provide science-based input regarding laws and regulations in the environmental, transportation, and energy arenas. As policies are codified, there may be roles for state and local public health agencies in enforcing such policies as building codes, water quality regulations, and air quality laws.

Link People to Needed Health Services and Ensure Provision of Care

A strong infrastructure for delivering health care services must be part of the health response to climate change. To prepare for disasters such as hurricanes, floods, and heat waves, support is needed for developing local, regional, and national emergency medical systems and enhancing their disaster response capacity, including specialized services and surge capacity. These requirements are included as part of the National Response Plan under Emergency Support Function No. 8, called Public Health and Medical Services.[146] Although disaster medical planning often focuses on trauma care, disasters may interrupt ongoing care for diseases such as HIV infection and renal failure, routine laboratory testing such as newborn screening, and other services, all of which must be restored. System failures during and after Hurricane Katrina made clear the need for effective, coordinated approaches for delivering clinical services.[147–150]

In the context of climate change, mental health services may be an important component of health service delivery. The mental health burden following acute disasters is considerable,[151–155] especially for high-risk groups such as children.[156,157] In addition, the long-term stresses of climate change—living with uncertainty, environmental threats, and alterations in familiar habitats and habits—may impose a chronic mental health burden.[158–163] The health system needs the capacity for rapid needs assessment, mental health service delivery, and long-term follow-up.[164]

Ensure a Competent Public and Personal Health Care Workforce

A trained and competent workforce is central to the success of the health system.[165] Preparing the health workforce for the potential impacts of climate change and for a host of other challenges over the coming decades will require a concerted effort at the local, state, and federal levels. It will involve ensuring a basic set of competencies throughout the system and developing a cadre of scientists with multidisciplinary, specialized skills in nontraditional fields.

Medical care providers should be trained to recognize and manage emerging health threats that may be associated with climate change. For public health professionals, training networks need to provide a systematic approach to training, linked directly to essential services and needs as identified by local and state health officials. Partnerships should be developed between health science schools and other academic institutions to provide cutting-edge education for health professionals in nontraditional subjects such as economics, health impact assessments, ecology, urban health, and vulnerability modeling. It is critical that the health system develop a wider range of expertise at every level to respond adequately to the challenges of climate change. Health professional training in climate change can be found at several universities; examples include Harvard's course on human health and global environmental change[166] and the University of Wisconsin's graduate certificate on humans and the global environment.[167]

TABLE 3—Research Topics on Global Environmental Change and Human Health

Research Domain	Examples
Understanding the health effects of global environmental change	Identification of key health indicators to monitor
	Empirical studies of current health effects, taking advantage of circumstances (extreme weather events) and localities (environmental hotspots) where these effects already manifest themselves
	Scenario analyses of future health effects, combining theoretical insights, empirical data, and quantitative and qualitative modeling exercises[169]
	Integrated assessment analyses of current and future health effects, comparing different environmental changes to facilitate priority setting
Adaptation to reduce the health effects of global environmental change	Development of more-effective methods for the health management of heat waves, floods, and other extreme weather events
	Development of more-effective methods to control emerging infectious diseases, such as vector control, vaccination, and pharmacological treatment
	Development of diets that are nutritious, palatable, and affordable and do not require unsustainable food production and transportation methods
	Economic analyses of various adaptation strategies, including health costs and benefits
Understanding the contribution of the health sector to global environmental change	Assessment of the environmental effect ("footprinting") of health sector resource use and waste generation
	Development of health sector practices that are sustainable in terms of resource use and waste generation
Communication research	Assessment of public and policymaker knowledge, attitudes, and behaviors with respect to climate change and identifying audience segments
	Testing of various communication strategies regarding climate change

Source. Adapted from Mackenbach.[170]

Evaluate Effectiveness, Accessibility, and Quality of Health Services

As they work to reduce the health impacts of climate change, health professionals must demonstrate accountability for the effectiveness, accessibility, and quality of programs and interventions. The evaluation of preparedness plans, health communication strategies, and other initiatives not only helps improve public health efforts, but it can also facilitate communication with key community stakeholders.

Evaluation requires robust surveillance capacity, a well-trained public health workforce, and established, efficient, reliable systems for sharing information among different levels of government and parts of the health sector. It also requires a periodic inventory of available services and assessment of the degree to which those services are accessible to the most vulnerable populations they are designed to serve. As with many other essential public health services, evaluation activities related to climate change and health will have cobenefits with other important public health activities and will likely exhibit synergistic effects in strengthening the nation's public health system.

Search for New Insights and Innovative Solutions to Health Problems

Several lines of health research are needed to provide data-based support for public health action on climate change.[168,169] These include empirical research on the association between climate change and health, scenario development to forecast health impacts and vulnerabilities, and development and testing of strategies to reduce risk. For each intervention, research is needed on the level of public health protection produced and on attendant costs. Examples are shown in Table 3.

CONCLUSIONS

There is widespread scientific consensus that the world's climate is changing. Mounting evidence suggests current and future effects on human health, including injuries and illnesses

from severe weather events, floods, and heat exposure; increases in allergic, respiratory, vector-borne, and waterborne diseases; and threats to food and water supplies. Indirect effects may include anxiety and depression and the consequences of mass migration and regional conflicts.

Addressing these occurrences is a pressing challenge for public health. Although the scope and complexity of the challenge are unprecedented, the conceptual framework for responding draws on long-standing public health thinking. An effective public health response to climate change is essential to preventing injuries and illnesses, enhancing public health preparedness, and reducing risk. Science-based decisionmaking, informed by public health ethics, will help manage uncertainty and optimize health, environmental, and economic outcomes. The Essential Services of Public Health serve as a useful framework for planning and implementing a public health response. ■

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This article was accepted September 7, 2007.

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All authors helped conceptualize the article, collect and interpret relevant information, write the article, and review drafts.

Acknowledgments

We thank the following participants of the January 2007 expert workshop at the Centers for Disease Control and Prevention for their invaluable input: Gail Bingham, Diarmid Campell-Lendrum, Kristie Ebi, Sally Edwards, Paul English, Ken Gage, Janet Gamble, Paul Glover, Julia Gohlke, John Haynes, Sandra Howard, Patrick Kinney, Nancy Lewis, Joshua Lipsman, Edward Maibach, Dennis McBride, Frank Nutter, Alan Parkinson, Jonathan Patz, Barbara Rogers, Marc Safran, Jacinthe Seguin, Jan Semenza, Gina Solomon, Dan Sosin, Darren Springer, and Michael St. Louis. We also thank the following staff of the Office of Policy and Program Evaluation at the National Center for Environmental Health/Agency for Toxic Substances and Disease Registry who have worked on climate change issues: Ken Rose, Sascha Chaney, Steven Vindigni, and Maggie Kelly.

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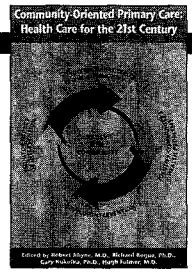

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