Developing Climate Change Environmental Public Health Indicators: Guidance for Local Health Departments

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INTRODUCTION

Climate change contributes to the global burden of disease through environmental hazards such as heat waves, drought, extreme weather events, and sea-level rise (Confalonieri et al. 2007), with one estimate attributing over 150,000 global mortalities and 5,500,000 Disability Adjusted Life Years (DALYs)[1] to climate change just in the year 2000 (Campbell-Lendrum et al. 2003). The direct health effects associated with these hazards include injury or death after exposure to an extreme weather event such as a flood or a heat wave (Portier et al. 2010). Indirect health effects include increased incidence of diseases that are sensitive to climatic changes, such as: vector-borne disease, waterborne disease, respiratory diseases such as asthma, and allergies caused by exposure to environmental triggers such as pollen and poor air quality (Portier et al. 2010).

Local public health departments (LHDs) take the lead in activities that are directly impacted by the changing climate, such as hazard mitigation planning and response (Maibach et al. 2008). They also actively participate in collecting data and conducting surveillance on community health concerns that are directly or indirectly effected by climate change, such as the possibility of permanent evacuation from the sites of major climate disasters (Frumkin et al. 2008) like Hurricanes Katrina, Ike, and Sandy. Through the course of this work, many LHDs have experienced the burden climate change is placing on the public health infrastructure. For example, a 2008 membership survey by the National Association of County and City Health Officials (NACCHO) found that close to 70% of respondents believed that their jurisdiction had already experienced climate change over the past 20 years. And, over 50% believed that their jurisdiction would experience serious public health problems over the next 20 years as a result of climate change (Maibach et al. 2008).

Public health interventions addressing the direct, short-term effects of climate change-related events seek to prevent or mitigate exposure, for example: opening cooling centers during heat waves, announcing ozone action days on days with high levels of air pollution, and closing roads during flooding events. LHDs also participate in first responder efforts to protect the public after events occur (Frumkin et al. 2008).

The long-term health effects of climate change can be more difficult to link directly with the day-to-day work of a local health department. For example, a public health tracking program might record the gradual migration of disease-carrying vectors to new habitats or the probability of a higher incidence of foodborne disease due to increasing strains on the U.S. food system. LHD infrastructure will become increasingly strained as the climate continues to change, triggering the need for more frequent public health interventions.

Environmental Public Health Indicators (EPHIs) are measures of population health status in relation to certain environmental factors, such as climate change. They are used by local, state, and federal health agencies to track the status of: environmental hazards; exposure to those hazards; health effects of exposure; and, public health interventions designed to reduce or prevent the hazard, exposure, or resulting health effect (U.S. Centers for Disease Control and

[1] The World Health Organization defines Disability Adjusted Life Years as follows: "One DALY can be thought of as one lost year of 'healthy' life. The sum of these DALYs across the population, or the burden of disease, can be thought of as a measurement of the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free of disease and disability." (World Health Organization)

Prevention National Center for Environmental Health 2006). LHDs will need to develop quantitative measures (or indicators) to track trends in environmental risk, human health outcomes, and population vulnerability to specific climatic events (Frumkin et al. 2008). The role of climate change EPHIs within the context of LHDs is to incorporate these climate-related trends into the larger health department planning process. These metrics can be used to perform vulnerability assessments highlighting health disparities that may be impacted by climate change (Hess et al. 2012). When incorporated into the adaptation planning process, vulnerability assessments can be leveraged to ensure that interventions designed to address climate change do not further exacerbate existing disparities.

Climate change EPHIs form the backbone of a local climate and health program, because they provide metrics that can be used both to track community vulnerability to climate change and to evaluate the effectiveness of interventions designed to enhance community resilience (English et al. 2009). In this way, the health effects of climate change can be considered alongside other core public health outcome indicators. For example, a set of environmental, vulnerability, and health outcome indicators in the Multnomah County Health Department adaptation plan establish a baseline for tracking population vulnerability to three climate change-related hazards — heat, air quality, and vector-borne disease — over time (Lyons-Eubanks et al. 2013).

Purpose of this Document

Climate change EPHI frameworks have been developed at the state level by the Council of State and Territorial Epidemiologists' (CSTE) State Environmental Health Indicators Collaborative (SEHIC) (available at: http://www.cste.org/?page=EHIndicatorsClimate) and at the federal level by the U.S. Centers for Disease Control and Prevention's (CDC) National Environmental Health Tracking Network (NEHTN) (available at: http://ephtracking.cdc.gov). The purpose of this guidance document is to help LHDs leverage existing resources such as the SEHIC and NEHTN climate change indicators for use at the local level.

Many of the data sets used in these resources aggregate data to a scale that is too large to identify local vulnerabilities or inform local policies. While it is preferable to develop local indicators using national, peer-reviewed datasets, it may be necessary to replace the data suggested by a SEHIC and/or NEHTN indicator with a local source — such as data collected through the epidemiology department, a partner agency, or a local university. In some cases, it may even be necessary to collect new data sets. Local data sets can be costly to access and convert into EPHIs. They also may not have undergone as thorough a review process as their national counterparts. However, in many situations, they may be the only option at a small enough scale to inform local planning conversations. Where possible, local data sets should be designed to display the same information as the SEHIC and NEHTN indicators, only at a smaller scale.

This guidance document outlines a three-tiered approach to establishing a local climate change environmental public health tracking (EPHT) program — placing emphasis on opportunities to partner with external resources at the local, state, and federal levels. It also explains how climate and health tracking programs can support LHDs' efforts to provide the 10 Essential Services of Public Health and to achieve accreditation.

This document is not designed to establish the links between climate change and human health or to provide guidance about how to launch a climate and health program. Furthermore, it does not

offer specific technical information about how to conduct geospatial analysis or downscaled climate modeling. Instead, it is designed to assist LHDs in making use of existing climate change EPHI frameworks using current capacity. For readers who are interested in delving into greater detail, links to more specific information are included throughout the document.

Key Points

- *Leverage existing frameworks*: Several EPHI frameworks already exist that can be tailored to local needs. It is therefore not necessary to increase capacity or expertise within the LHD to develop basic climate change EPHIs.
- *Take advantage of technical assistance*: For communities interested in developing more advanced EPHIs, technical assistance is available through state tracking programs, the CDC, local universities, and others.
- *Data is becoming increasingly available*: All of the data sets listed in this guidance document are publicly available through national data sources. While local data sets can be more difficult to find, it is often possible to gain access to them in at least some format.

DEVELOPING LOCAL CLIMATE CHANGE EPHIs

Climate and health tracking programs should be tailored to the needs of the jurisdictions they serve. A jurisdiction with an active climate change policy, expertise to perform geospatial analysis, and access to downscaled climate models may have the political support and internal capacity to develop a full blown climate change tracking program at the local level. However, these factors are not prerequisites for developing local climate change EPHIs. Any LHD can use the existing climate change EPHI frameworks developed by the CDC and SEHIC to establish their population's baseline vulnerability to climate change-related hazards.

Every LHD is characterized by a unique mix of internal capacity, technical expertise, and political mandate, which will determine the level of engagement around climate and health issues that is appropriate for their community. As a result, the following guidance offers a tiered approach to developing climate change EPHIs that respond to the local context. Some LHDs may have access to the expertise and capacity required to complete all three tiers. However, many communities may find that Tier 1 EPHIs are sufficient to meet their climate and health planning needs.

Tier 1: Getting Started

1. *Identify the highest priority climate change-related hazards in the LHD's region.*

   Review the National Climate Assessment for an overview of regional climate change-related hazards both according to historical data and future climate projections.

   Another useful resource for this step is the online tool published by the Natural Resources Defense Council Climate Change Threatens Health, which uses historical data to calculate rates of exposure to climate-related hazards at the state and county levels.

   See case studies from the Climate Ready States and Cities programs sponsored by the CDC for examples of the environmental hazards targeted by other states and cities in the U.S.

   Maximize the relevancy of the local set of EPHIs by prioritizing the hazards identified in a local climate assessment, if applicable. For example, LHDs in the Washington, D.C. metropolitan area might consider developing EPHIs tracking the health effects of the one or more of the following natural hazards, which were identified by the Metropolitan Washington, D.C., Council of Governments as the most significant climate-related threats facing their region: extreme heat, heavy precipitation, severe storms, and sea level rise (Davis and Campbell 2013).

2. *Compile relevant* NEHTN *and* *SEHIC* *indicators.*

   Note: The state tracking, epidemiology, and/or climate change program may have already performed this step. It may be possible to ask for technical assistance or to collaborate with them to compile indicators that are relevant at the local level.

   Compile data for the NEHTN and SEHIC indicators relevant to the short list of climate change hazards developed in Step 1.

- For NEHTN: download the data relevant to the LHD's county over the period of time available on the NEHTN web portal.
- For SEHIC: follow the instructions in the "How To" guides on the SEHIC web portal to compile the relevant indicators.

3. *Where possible, replace national data sets with more granulated data from local sources.*

   Identify data gaps. For example, the aggregation level for some data sets may be too broad to inform local policy. If a data set from a local source is available at a smaller spatial scale (such as the neighborhood scale), replace the national data source with the local source in the final set of local EPHIs.

   Additionally, many of the vulnerability and health outcome indicators outlined in the NEHTN and SEHIC frameworks are relevant to other LHD public health surveillance activities, such as asthma reduction programs, chronic disease programs, and flood safety programs. If these programs are already tracking an indicator, replace the national data source with the local source in the final set of local EPHIs. This approach will reduce the likelihood of duplication of efforts across the LHD. And, it will also help integrate climate readiness considerations into core public health services.

4. *Create and disseminate a baseline set of local indicators.*

   Share the baseline set of local climate change EPHIs with agency leadership and the general public. Consider developing accompanying educational material to assist community engagement efforts in reducing vulnerability, particularly among high-risk populations such as the young, the elderly, and populations with low socioeconomic status.

5. *Identify data gaps that can be filled in using qualitative data, such as oral histories.*

   Given the challenges associated with data collection at the local level, it is unlikely that quantitative data sets will paint a comprehensive picture either of population vulnerability or of direct links between public health interventions and community resilience. It is therefore important to identify opportunities for incorporating qualitative data into the overall tracking program to capture the determinants of health that might otherwise be overlooked.

6. *Integrate the climate change EPHIs into the overall LHD surveillance program.*

   This step will increase the sustainability of the climate change EPHI program by leveraging existing capacity and data sources. It will also raise awareness throughout the LHD and the community about the many ways that climate change impacts population vulnerability and health outcomes.

Tier 2: Vulnerability Assessment

After performing Tier 1, an LHD may decide that it would be helpful to have a clearer understanding of where the most vulnerable populations are located within its jurisdiction. For example, if policy makers are developing a plan for reducing the urban heat island effect, it is important to know whether vulnerable populations are clustered in neighborhoods with a high

concentration of impervious surface. In such a case, it may be necessary to use geospatial analysis to perform a vulnerability assessment.

Such an undertaking can be a daunting challenge, particularly for local health departments with limited staff and budgets. However, much of the data required for the analysis is likely available through sister departments and external partners such as research institutions and non-profits. Also, the state health department may be available to provide technical assistance in the form of geospatial analysis. For example, the state of Florida is developing an online tool to assist LHDs develop public health hazard and vulnerability analyses.

To perform a climate change vulnerability assessment, perform the following steps:

1. *Develop a definition of exposure based on the list of climate change-related hazards developed under Tier 1.*

   For example, the definition of exposure to an extreme heat event varies across the country. Therefore, a local heat exposure EPHI should align with regional best practices (such as the definition set by the local Weather Forecast Office) and be tailored to the research question answered by the vulnerability assessment. For additional suggestions and examples, see Section V: Example Data Sources.

2. *Research historical trends in climate change-related morbidity and mortality in your city, county, and/or region.*

   A number of methodologies are available, including:

Example Methodologies	Source
Mortality directly attributed to exposure to specific climatic events.	Borden, K. A., & Cutter, S. L. (2008). Spatial patterns of natural hazards mortality in the United States. *International Journal of Health Geographics*, 7(64), 13. Available at: http://www.ij-healthgeographics.com/content/7/1/64
Review of multiple epidemiologic studies of mortality associated with a specific climatic event: high ambient temperature.	Basu, R. (2009). High ambient temperature and mortality: a review of epidemiologic studies from 2001 to 2008. *Environmental Health*, 8(40), 1–13. Available at: http://www.ehjournal.net/content/pdf/1476-069X-8-40.pdf
Mortality and health costs associated with climatic events.	Knowlton, K., Rotkin-Ellman, M., Geballe, L., Max, W., & Solomon, G. M. (2011). Six climate change-related events in the United States accounted for about $14 billion in lost lives and health costs. *Health Affairs*, 30(11), 2167–76. Available at: http://www.ncbi.nlm.nih.gov/pubmed/22068410

3. *Identify populations that are particularly vulnerable to the climatic hazards under study.*

   The following articles present summaries of the populations that are more likely to exhibit adverse health outcomes during and after climatic events. Studies specific to the LHD's region may also be available through the local or state health department or a local university. For additional suggestions and examples, see the Example Data Sources section of this document.

   - Frumkin H, Hess J, Luber G, Malilay J, McGeehin M. Climate Change: The public health response. *American Journal of Public Health*. 2008;98(3):435–445. Available at: http://ajph.aphapublications.org/cgi/content/abstract/98/3/435.
   - Balbus JM, Malina C. Identifying vulnerable subpopulations for climate change health effects in the United States. *Journal of occupational and environmental medicine / American College of Occupational and Environmental Medicine*. 2009;51(1):33–7. Available at: http://www.ncbi.nlm.nih.gov/pubmed/19136871.

4. *Identify elements of the natural and built environment that contribute to community vulnerability associated with the climatic hazards under study.*

   Perform a literature review to establish the state of the evidence regarding factors that contribute to vulnerability to the climatic hazards under study. For additional suggestions and examples, see the Example Data Sources section of this document.

5. *Create a vulnerability index by combining the socioeconomic and demographic data with the environmental data.*

   The following articles and report outline methodologies for developing a vulnerability index for heat vulnerability, flooding vulnerability, and cumulative vulnerability to multiple climatic events. Studies specific to the LHD's region may also be available through the local or state health department or a nearby university.

   - English P, Richardson M, Morello-Frosh R, Pastor M, Sadd J, King G, Jesdale W, Jerrett M. Racial and Income Disparities in Relation to a Proposed Climate Change Vulnerability Screening Method for California. 2013. *International Journal of Climate Change.* 2013:4(2):1-18. Available at: http://ijc.cgpublisher.com/product/pub.185/prod.185]
   - Houghton A, Prudent N, Scott J E, Wade R, Luber G. Climate change-related vulnerabilities and local environmental public health tracking through GEMSS: a web-based visualization tool. *Applied Geography*. 2012;33:36-44. Abstract available at: http://www.sciencedirect.com/science/journal/01436228
   - Jerrett M, Su J G, Reid C E, Jesdale B, Ortega Hinojosa A M, Shonkoff S B, Seto E, Morello-Frosch R (University of California, Berkeley). 2012. *Mapping Climate Change Exposures, Vulnerabilities, and Adaptation to Public Health Risks in the San Francisco Bay and Fresno Regions*. California Energy Commission. Publication number: CEC-500-2012-041. Available at: http://www.energy.ca.gov/2012publications/CEC-500-2012-041/CEC-500-2012-041.pdf

- Reid C E, O'Neill M S, Gronlund, C J, Brines S J, Brown D G, Diez-Roux A V, Schwartz J. Mapping community determinants of heat vulnerability. *Environmental Health Perspectives*. 2009;117:1730–1736. Available at: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2801183/

Tier 3: Predict Future Impacts

The final step in developing local climate change EPHIs is to move beyond historical data to predict future effects. This step is crucial for long-term planning purposes. However, it requires a downscaled climate model and access to the technical expertise necessary to develop credible scenarios that are relevant to the needs of the community.

1. *Identify IPCC (Intergovernmental Panel on Climate Change) climate change projections that have been downscaled to the LHD's state, region, and/or city.*

   A national source for this data is the National Climate Assessment. However, local research institutions may have developed models that offer even more granular information. In particular, look for projections that include geospatially referenced data.

2. *Compare the projected climatic changes (i.e., increased extreme heat events, precipitation events, etc.) with the current spatial distribution and projected changes in the built environment and socio-demographic data that has been shown by the literature to increase or reduce vulnerability to priority climatic events.*

   If data sharing and / or internal capacity at the LHD are of concern, consider contracting this step out to the institution that developed the downscaled model.

3. *Estimate future climate-related mortality for the prioritized environmental hazards.*

   A few possible methodologies to consider include:

Example Methodologies	Source
Heat wave mortality	Hayhoe, K., Sheridan, S., Kalkstein, L., & Greene, S. (2010). Climate change, heat waves, and mortality projections for Chicago. *Journal of Great Lakes Research*, 36, 65–73. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0380133009002275 Li, T., Horton, R. M., & Kinney, P. L. (2013). Projections of seasonal patterns in temperature- related deaths for Manhattan, New York. *Nature Climate Change*, 3(8), 717–721. Available at: http://www.nature.com/doifinder/10.1038/nclimate1902 Peng, R. D., Bobb, J. F., Tebaldi, C., McDaniel, L., Bell, M. L., & Dominici, F. (2010). Towards a Quantitative Estimate of Future Heat Wave Mortality under Global Climate Change. *Environmental Health Perspectives*, 1002430(December). Available at: http://www.ncbi.nlm.nih.gov/pubmed/21193384

Excess all-cause mortality attributable to climate change	Deschênes, O., & Greenstone, M. (2011). Climate Change, Mortality, and Adaptation: Evidence from Annual Fluctuations in Weather in the US. *American Economic Journal: Applied Economics 3*, 3(4), 152–185. Available at: http://dspace.mit.edu/openaccess-disseminate/1721.1/73124 Nicholls, N. (2009). Estimating changes in mortality due to climate change. *Climatic Change*, 97(1-2), 313–320. Available at: http://www.springerlink.com/index/10.1007/s10584-009-9694-z

4. *Compare the projected climatic changes (i.e., increased extreme heat events, precipitation events, etc.) with historical trends in morbidity, mortality, and cost (if applicable).*

USING CLIMATE CHANGE EPHIs TO SUPPORT CORE PUBLIC HEALTH SERVICES

The sections below demonstrate how local climate change EPHIs can support delivery of several of the 10 Essential Services of Public Health and implementation of the CDC's Building Resilience Against Climate Effects (BRACE) framework for integrating climate readiness into existing surveillance programs.

10 Essential Public Health Services (EPHS) (source: http://www.cdc.gov/nphpsp/essentialservices.html)

Organized around the three core functions of public health(Institute of Medicine Committee for the Study of the Future of Public Health 1988) — assessment, policy development, and assurance — the 10 Essential Public Health Services (EPHS) provide a framework for LHD services. They offer a clear, standardized way to assess the relative success of both programs within a LHD and of the department as a whole. For this reason, they act as the organizational framework for both the National Public Health Performance Standards Program (NPHPSP)(U.S. Centers for Disease Control and Prevention 2012) and the National Voluntary Public Health Accreditation(Public Health Accreditation Board 2011) process.

The following list outlines a few ways that climate change EPHIs can be leveraged within the EPHS framework.

EPHS 1. Monitor health status to identify and solve community health problems.
Climate change EPHIs allow LHDs to identify trends in exposure to climate change-related events, particularly among populations that are most vulnerable to experiencing negative health outcomes. In many cases, these trends overlap with existing health priorities, such as cardiovascular disease, respiratory disease, disparities among populations of differing socioeconomic status, and policies to protect children and the elderly from harmful exposures.

EPHS 2. Diagnose and investigate health problems and health hazards in the community.
Climate change EPHIs track vulnerabilities and health outcomes associated with the most significant climate change-related hazards facing a specific community, such as tracking asthma rates associated with increases in ozone formation.

EPHS 3. Inform, educate, and empower people about health issues.
The trends identified through a local set of climate change EPHIs can be used to inform vulnerable populations about the links between climate and health, the dangers associated with exposure, and best practices for reducing their own and their neighborhood's vulnerability to climatic events.

EPHS 4. Mobilize community partnerships and action to identify and solve health problems.
Visualizations (i.e., maps, charts, etc.) of the trends identified through a local set of climate change EPHIs can be used to mobilize community support for climate and health policies and interventions. Furthermore, incorporating them into tabletop exercises with agency partners enables climate and health considerations to inform the cross-departmental planning process.

For example, a heat vulnerability map combined with an urban forestry or tree canopy map used at a community engagement meeting would help identify geographic areas that are vulnerable, and suggest where to prioritize greenspace and tree planting activities.

EPHS 5. Develop policies and plans that support individual and community health efforts.
The trends identified through a local set of climate change EPHIs can be used to inform policies that could reduce vulnerability – such as planting trees in neighborhoods with high surface temperature and residents highly vulnerable to heat.

EPHS 6. Enforce laws and regulations that protect health and ensure safety.
The trends identified through a local set of climate change EPHIs can be used to inform assessments of regulations that require climate adaptation measures designed to protect public health—such as access to air conditioning in residential units.

EPHS 8. Assure competent public and personal health care workforce.
The trends identified through a local set of climate change EPHIs can be used to inform assessments of workforce competency, capacity, access to training, and certifications relevant to climate change.

EPHS 9. Evaluate effectiveness, accessibility, and quality of personal and population-based health services.
The trends identified through a local set of climate change EPHIs can be used to inform assessments of climate adaptation policies designed to protect public health—such as use of cooling centers during heat waves.

EPHS 10. Research for new insights and innovative solutions to health problems.
The process of developing a set of locally relevant EPHIs will uncover data and research gaps. This is particularly true of climate change EPHIs, because climate change is a multi-disciplinary topic. Furthermore, the data supporting a climate and health tracking program will likely be drawn from multiple departments within the LHD, as well as from external sources.

Building Resilience Against Climate Effects (BRACE) framework
(source: http://www.cdc.gov/climateandhealth/BRACE.htm)

In approaching the health implications of climate change, it is of paramount importance to find ways to understand and incorporate complex atmospheric data and both short and long-range climate projections into public health planning and response activities. Coupling atmospheric data and projections with epidemiologic analysis enables a jurisdiction to more effectively anticipate, prepare for and respond to a range of climate sensitive health impacts.

CDC has developed a framework that supports health departments to incorporate advanced models such as these into otherwise routine planning and response activities. The Building Resilience Against Climate Effects (BRACE) framework is a five step process that enables a health department to incorporate the best available atmospheric science into a process designed to improve the quality of inputs and assumptions made during the traditional planning process, and supports the development and implementation of a unified climate and health adaptation strategy for a jurisdiction.

As outlined the table below, climate change EPHIs can be used to support implementation of key steps of the BRACE Framework.

Five sequential steps in the BRACE Framework *(**Credit:** CDC Climate and Health Program)*	**Role of Climate Change EPHIs**
Step 1: Forecasting Climate Impacts and Assessing Vulnerabilities — where a health department identifies the scope of the most likely climate impacts, the potential health outcomes associated with those climatic changes, & the populations and locations vulnerable to these health impacts within a jurisdiction.	Local-level environmental exposure and population vulnerability indicators are developed under this step. In some cases, LHDs may need to identify local data sources rather than rely on the national databases referenced by the SEHIC and EPHTN indicators. For example, the SEHIC indicator for environmental exposure to wildland fires points the user to a database that is organized by state. While this information is helpful to LHDs as a comparison with other states, more granular data will be required to develop an indicator that can be used to inform local land use planning and hazard mitigation policies. In this case, the local emergency management agency, an area forestry agency, or a nearby university might have developed a more granular map of wildfire risk. Localized vulnerability assessments should be geospatially referenced to identify neighborhoods with particularly high vulnerability to specific climatic events.
Step 2: Projecting the Disease Burden — where a health department, as best as possible estimates or quantifies the additional burden of health outcomes due to Climate Change – to support prioritization and decision making.	Human health outcome indicators are identified under this step. Historical trends should be developed, if data is accessible. And, future expected trends should be modeled by combining historical trends with the projections from downscaled climate models. The SEHIC health outcome indicators that may be useful during this stage are: heat deaths, hospitalizations, and emergency room visits during summer months; injuries and deaths due to extreme weather events; human cases of Lyme disease; human cases of West Nile Virus; and, allergic disease.
Step 3: Assessing Public Health Interventions — where a health department seeks to identify the most suitable health interventions for the health impacts of greatest concern. The health impacts will have been quantified or better defined in the previous health risk assessment step.	This step focuses on assessing interventions for the climate-related health impacts of greatest concern. The SEHIC mitigation and adaptation indicators that may be useful during this stage are: total energy consumption per capita; renewable energy consumption per capita; vehicle miles traveled; development of a state adaptation plan; access to cooling centers; heat island mitigation plan; health surveillance systems

	related to climate change; and, public health workforce trained in climate change research, surveillance, and adaptation. In many cases, LHDs will support other departments (such as public works, parks and recreation, or a climate change task force) both in policy implementation and in data gathering. It is therefore important to actively engage key stakeholders outside of the health department in the entire BRACE process. Identifying existing data sets and relevant policies and programs early on will minimize the likelihood of duplicative and/or contradictory efforts.
Step 4: Developing and Implementing a Climate and Health Adaptation Plan —where a health department develops and implements a health adaptation plan for climate change that addresses health impacts, gaps in critical public health functions/services, and a plan for enhancing adaptive capacity in the jurisdiction.	EPHIs should align with the overarching goals and priorities of an existing local climate and health adaptation plan (if applicable), so that the health impacts of climate change are tracked alongside other performance measures. The SEHIC policy indicators that may be useful during this stage are: development of a state climate change advisory board; development of a state climate change action plan; completion of a greenhouse gas inventory; local governments participating in ICLEI; and, percent of population living in cities participating in the U.S. Conference of Mayors Climate Protection Agreement.
Step 5: Evaluating Impact and Improving Quality of Activities — whereby a health department can evaluate the processes it has used, determine the value of utilizing the framework and the value of climate and health activities undertaken. This step is also important for quality improvement and to incorporate refined inputs such as updated data or new information.	EPHIs will form the quantitative evidence-base for tracking reductions in population vulnerability to the health effects of climate change.

POLICY FRAMEWORK

In order to become useful decision-support tools, climate change EPHIs at the local level must reflect their political, economic, and social context. It is therefore important to balance a review of the scientific evidence of climate-related hazards with existing and planned policies that could influence implementation of interventions tailored to enhance community resilience. For example, a review of the scientific literature and downscaled climate projections might indicate that heat waves and air quality are the most significant environmental hazards in a city. However, if it is located just inland from a highly populated region in a hurricane-prone zone, the political climate might encourage an increased focus on preparing for expected large-scale population displacement in the wake of severe storms.

At a minimum, use existing **local, regional, and/or state climate change policies** to inform the development of climate change EPHIs at the local level. Also research whether or not your community's hazard mitigation plan addresses the health effects of climate change. Many climate change policies in the U.S. only address mitigation activities (i.e., activities that reduce greenhouse gas emissions, such as increasing building energy efficiency or transitioning the city's fleet of vehicles to hybrids). However, even if they do not directly address public health programs, they still indicate policymakers' priorities and objectives. It is therefore important to prioritize policy and intervention indicators in the climate change EPHI system with co-benefits for both climate change mitigation and community health.

Resources for finding local, regional, and state-level climate change policies include:

The Center for Climate Strategies: Nonpartisan nonprofit that compiles a database of state and local climate initiatives, among other resources.

U.S. Conference of Mayors Climate Protection Agreement: list of cities that have committed to reducing community greenhouse gas emissions.

U.S. EPA State and Local Climate and Energy Program: map of states and communities that have instituted climate change action plans.

Resources for incorporating climate and health into hazard mitigation plans:

Baltimore Disaster Preparedness and Planning Project: Combines hazard mitigation planning, floodplain mapping, and climate adaptation planning into a single project.

Bridging the Gap Between Hazard Mitigation and Adaptation: Webinar hosted by the Center for Clean Air Policy and the Natural Hazard Mitigation Association that includes local case studies.

City of Lewes Hazard Mitigation and Climate Adaptation Action Plan: Report integrates climate change adaptation (including the health effects of climate change) into local hazard mitigation planning.

City of Santa Cruz Climate Adaptation Plan (2012-2017): Update to the 2007 Local Hazard Mitigation Plan. Includes a chapter on the results of a vulnerability assessment that addresses both social equity and health outcomes.

Examples of local climate change EPHIs being used to inform the policymaking process include:

Climate Change and Public Health: Impact Assessment for the NYC Metropolitan Region: See section IV. "Climate-Related Public Health Stressors" for an example of how to use existing published information to establish the localized health effects of climatic events.

Public Health Impacts of Climate Change in California: Community Vulnerability Assessments and Adaptation Strategies: Includes an overview of climate-related hazards and vulnerable populations.

Davis, Matthew; Lyons-Eubanks, Kari. Understanding the local health impacts of climate change in Multnomah County.

CONCLUSION

Integrating climate readiness considerations into an already overburdened LHD can be a daunting challenge, particularly in an era of shrinking budgets. However, given the strain that climate-related events are already placing on the public health infrastructure, investing in a climate readiness tracking program may actually lead to cost savings in the long term through avoided emergency response and reconstruction activities.

As this guidance document demonstrates, resources are also increasingly becoming available that reduce the need to invest in technology or increased capacity at the local level in order to develop climate change EPHIs. Freely available data sets, in particular, are proliferating, as evidenced by the Metadata Access Tool for Climate and Health that was recently launched by the U.S. Global Change Research Program. Furthermore, state health departments are increasingly building internal capacity to provide technical assistance to LHDs that do not have local tracking programs.

It is important to note that data gaps remain in national and state datasets, particularly at smaller geographic scales, such as the neighborhood level. While this data may be available through a local partner, accessing it may require signing a data sharing agreement. Although potentially lengthy to establish, the resulting partnership can ultimately lead to increased efficiency across programs, shared capacity, and a more effective strategy to both protect population health and advance community resilience.

EXAMPLE DATA SOURCES

When developing the baseline set of EPHIs, prioritize existing data sources over collecting new data. It may be necessary to conduct a survey of potential internal and external partners to identify what type of data is already being collected and its geographic scale. The more granular the spatial resolution, the more likely the EPHIs will be able to inform targeted public health interventions and the land use planning process.

Examples of existing national data sources that may be useful to incorporate into a local EPHI tracking program are listed below.

Extreme Heat

Environmental Exposure Indicators

- *Exposure to heat waves* (U.S. Environmental Protection Agency 2010; World Health Organization Europe 2010, 2011)*:* National Climatic Data Center
- *Exposure to Urban Heat Islands (UHIs)* (Mazur and Milanes 2009; Mazur et al. 2010)*:* no national database
- *Exposure to Salmonella* (World Health Organization Europe 2010, 2011)*:* no national database

Human Health Outcome Indicators

- *Excess morbidity and mortality due to heat wave* (English et al. 2009; World Health Organization Europe 2010, 2011)*:* U.S. CDC WONDER database; U.S. CDC, NCHS Mortality Data, Multiple Cause-of-Death Public-Use Data Files; U.S. CDC, BioSense; U.S. Centers for Medicare and Medicaid Services, Research, Statistics, Data, and Systems
- *Heat-related mortality* (ICD-9: E900, E900.0; ICD-10: X30, T67) (Mazur and Milanes 2009; Mazur et al. 2010; U.S. Centers for Disease Control and Prevention; U.S. Environmental Protection Agency 2010): U.S. CDC WONDER database
- *Incidence of Salmonellosis* (World Health Organization Europe 2010, 2011)*:* U.S. CDC BioSense

Population Vulnerability Indicators

- *General vulnerability*[2]*:* U.S. CDC, Behavioral Risk Factor Surveillance System; U.S. Census
- *Access to cooling centers* (English et al. 2009; National Research Council 2010)*:* no national database
- *Air conditioning ownership & cost* (Mazur and Milanes 2009; Mazur et al. 2010)*:* U.S. Census American Housing Survey

[2] General Vulnerability: Elderly living alone; poverty status; children; infants; individuals with disabilities (English et al. 2009; National Research Council 2010).

- *Outdoor workers* (Mazur and Milanes 2009; Mazur et al. 2010)*:* no national database
- *Heat Vulnerability Index combining socioeconomic and environmental vulnerability measures* (U.S. Centers for Disease Control and Prevention) (diabetes, heart disease, poverty, race, advanced age, social isolation, disabilities, population density, forest canopy, developed land use, and cultivated crop land use): U.S. CDC National Environmental Public Health Tracking Network

Policy/Intervention Indicators

- *Heat wave early warning systems* (English et al. 2009; National Research Council 2010)*:* U.S. National Weather Service (NWS); NOAA Storm Events

Air Quality

Environmental Exposure Indicators

- *Exposure to ozone* (English et al. 2009; National Research Council 2010; World Health Organization Europe 2010, 2011)*:* U.S. EPA Trends in Ozone Levels
- *Exposure to air pollution* (National Research Council 2010)*:* U.S. EPA; local air quality authority
- *Temperature Inversions/Stagnation Air Mass Events* (English et al. 2009; National Research Council 2010)*:* NOAA National Climate Impact Indicators
- *Deforestation* (National Research Council 2010)*:* Woods Hole Research Center National Biomass and Carbon Dataset

Human Health Outcome Indicators

- *Respiratory morbidity and mortality* (English et al. 2009; National Research Council 2010; World Health Organization Europe 2010, 2011)*:* U.S. CDC Asthma Data and Statistics
- *Cancer rates* (National Research Council 2010)*:* U.S. CDC Cancer Data and Statistics

Population Vulnerability Indicators

- *General vulnerability*[2]*:* U.S. CDC Behavioral Risk Factor Surveillance System; U.S. Census
- *Levels of exercise and physical fitness in urban environments* (National Research Council 2010)*:* U.S. CDC Physical Activity Statistics

Policy/Intervention Indicators

- No national indicators

Allergens

Environmental Exposure Indicators

- *Exposure to tree, grass, and flower pollen* (National Research Council 2010; World Health Organization Europe 2010, 2011)*:* American Academy of Allergy Asthma & Immunology: National Allergy Bureau

Human Health Outcome Indicators

- *Incidence of respiratory/allergic disease morbidity and mortality* (English et al. 2009; National Research Council 2010; World Health Organization Europe 2010, 2011)*:* U.S. CDC Health Data Interactive website: Allergic Conditions Tables

Population Vulnerability Indicators

- *General vulnerability*[2]*:* US CDC Behavioral Risk Factor Surveillance System; U.S. Census
- *Population Migration* (National Research Council 2010)*:* U.S. Census Geographical Mobility/Migration

Policy/Intervention Indicators

- *Anti-allergy medication sales* (World Health Organization Europe 2010, 2011)*:* No national database
- *Remove allergenic plants:* No national database

Drought

Environmental Exposure Indicators

- *Drought index* (English et al. 2009; National Research Council 2010)*:* US Drought Monitor
- *Surface water levels* (National Research Council 2010)*:* USDA Surface Water Supply Index
- *Precipitation & evaporation rates* (National Research Council 2010)*:* NOAA Standardized Precipitation Index
- *Soil moisture* (National Research Council 2010)*:* US Drought Monitor

Human Health Outcome Indicators

- No national indicators

Population Vulnerability Indicators

- *General vulnerability*[2]*:* US CDC Behavioral Risk Factor Surveillance System; U.S. Census
- *Population migration* (National Research Council 2010)*:* US Census Geographical Mobility/Migration

Policy/Intervention Indicators

- No national indicators

Hurricanes & Tropical Storms

Environmental Exposure Indicators

- *Exposure to Hurricane or Tropical Storm* (English et al. 2009; National Research Council 2010)*:* U.S. National Climatic Data Center, Storm Data Publications

Human Health Outcome Indicators

- *Number of injuries/ mortality from extreme weather event* (English et al. 2009)*:* U.S. CDC, NCHS Mortality Data, Multiple Cause-of-Death Public-Use Data Files; Centre for Research in the Epidemiology of Disasters, Emergency Events Database; U.S. National Climatic Data Center, Storm Data Publications
- *Mental health* (Abramson and Garfield 2006; Coker et al. 2006; Curtis et al. 2007; Lein et al. 2006): No national database

Population Vulnerability Indicators

- *General vulnerability*[2]*:* US CDC Behavioral Risk Factor Surveillance System; U.S. Census
- *Population migration* (National Research Council 2010)*:* U.S. Census Geographical Mobility/Migration
- *Population density* (National Research Council 2010)*:* U.S. Census Geographical Mobility/Migration
- *Population living in 100- and 500- year flood zones* (English et al. 2009; National Research Council 2010): Federal Emergency Management Agency Map Service Center

Policy/Intervention Indicators

- *Medical and Public Health Infrastructure* (National Research Council 2010)*:* No national database

Flood

Environmental Exposure Indicators

- *Heavy Precipitation Events* (National Research Council 2010; World Health Organization Europe 2010, 2011)*:* U.S. National Climatic Data Center Storm Data Publications

Human Health Outcome Indicators

- No national indicators

Population Vulnerability Indicators

- *General vulnerability*[2]*:* US CDC Behavioral Risk Factor Surveillance System; U.S. Census
- *Population Migration* (National Research Council 2010)*:* U.S. Census, Geographical Mobility/Migration
- *Population Living in 100- and 500- Year Flood Zones* (National Research Council 2010)*:* Federal Emergency Management Agency, Map Service Center

Policy/Intervention Indicators

Water-use practices following disasters (National Research Council 2010)*:* No national database**Wildfires**

Environmental Exposure Indicators

- *Frequency, severity, distribution, and duration of wild fires* (English et al. 2009; National Research Council 2010)*:* National Interagency Fire Center Homepage

Human Health Outcome Indicators

- No national indicators

Population Vulnerability Indicators

- *General vulnerability*[2]*:* US CDC Behavioral Risk Factor Surveillance System; U.S. Census
- *Rural Poor Living in Wildland-Urban Interface* (Mazur and Milanes 2009; Mazur et al. 2010)*:* No national database

Policy/Intervention Indicators

- No national indicators

Water Quality

Environmental Exposure Indicators

- *Harmful Algal Blooms* (English et al. 2009; National Research Council 2010; World Health Organization Europe 2010, 2011)*:* NOAA Harmful Algae Bloom Forecasting System
- *Exposure to contaminated water* (World Health Organization Europe 2010, 2011)*:* U.S. EPA Water Quality Assessment and Total Maximum Daily Loads Information

Human Health Outcome Indicators

- *Human shellfish poisonings* (National Research Council 2010)*:* U.S. CDC WONDER database
- *Cryptosporidiosis incidence and seasonality* (World Health Organization Europe 2010, 2011)*:* U.S. CDC BioSense

Population Vulnerability Indicators

- *General vulnerability*[2]*:* US CDC Behavioral Risk Factor Surveillance System; U.S. Census

Policy/Intervention Indicators

- *HAB Monitoring* (National Research Council 2010)*:* No national database
- *Municipal Water Treatment Practices* (National Research Council 2010)*:* No national database

Disease-Carrying Vectors

Environmental Exposure Indicators

- *Exposure to ticks carrying Lyme disease* (World Health Organization Europe 2010, 2011)*:* U.S. CDC Lyme Disease Data
- *Exposure to disease transmission* (National Research Council 2010)*:* U.S.G.S. Arbonet
- *Exposure to domestic and feral animals; animal husbandry practices; consumption of bush meat* (National Research Council 2010)*:* No national database

Human Health Outcome Indicators

- *Lyme borreliosis incidence* (World Health Organization Europe 2010, 2011)*:* U.S. CDC Lyme Disease Data
- *Incidence of environmental infectious disease; morbidity and mortality; disability-adjusted life years* (English et al. 2009; National Research Council 2010)*:* U.S. CDC Division of Vector Borne Infectious Diseases
- *Incidence of mosquito-borne diseases* (Mazur and Milanes 2009; Mazur et al. 2010)*:* U.S.G.S. Arbonet
- *Incidence of zoonotic diseases* (Jones et al. 2008; Patz et al. 2004): no national database, but local surveillance programs may exist (for example: Cuyahoga County voluntary zoonotic disease reporting program)

Population Vulnerability Indicators

- *General vulnerability*[2]*:* US CDC Behavioral Risk Factor Surveillance System; U.S. Census

Policy/Intervention Indicators

- No national indicators

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