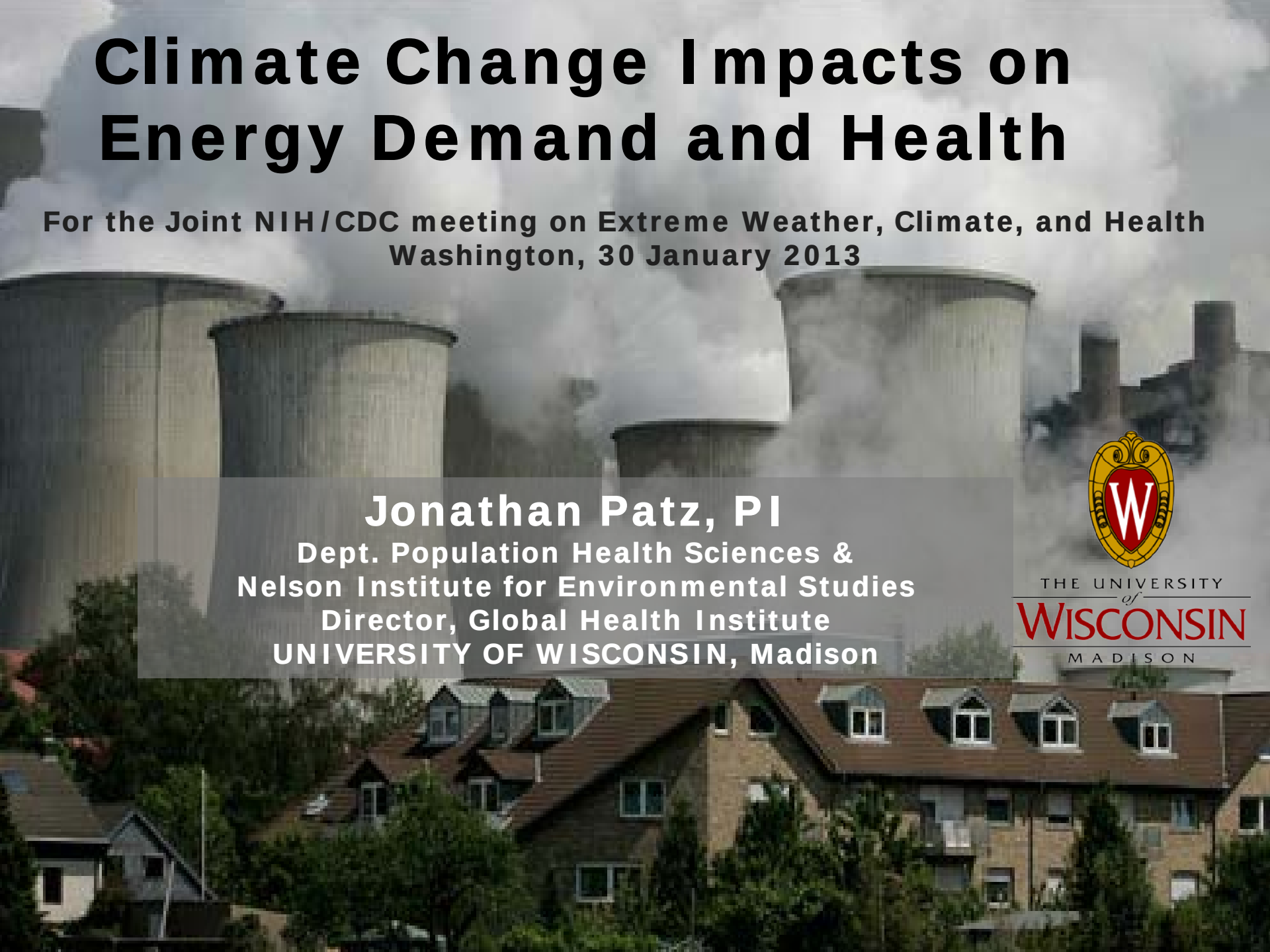
Climate Change Impacts on Energy Demand and Health

For the Joint NIH/CDC meeting on Extreme Weather, Climate, and Health
Washington, 30 January 2013



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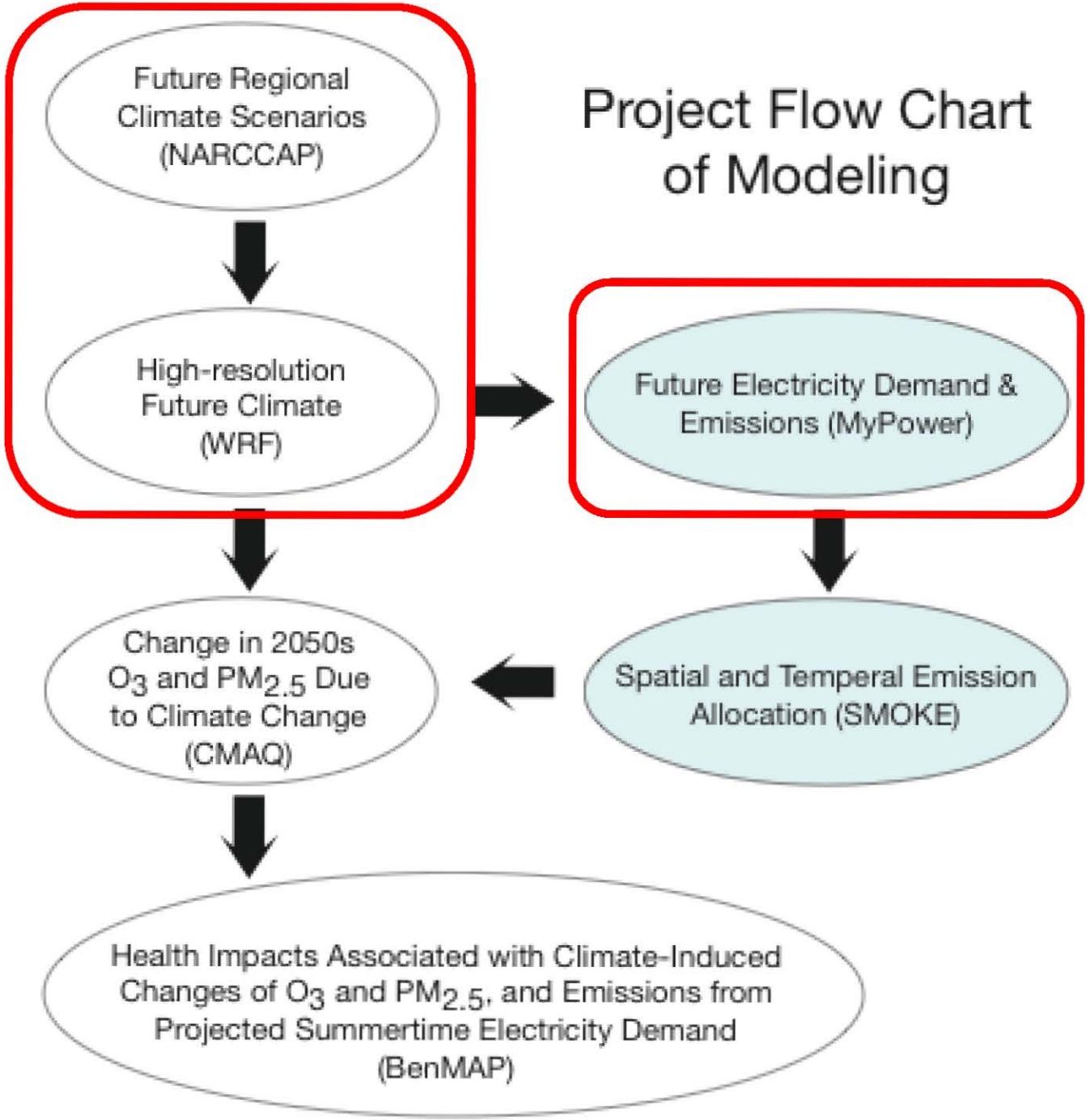
Specific Aims

1. Model the effects of climate change on **air quality**

2. Model the effects of climate change on summer **electricity demand**

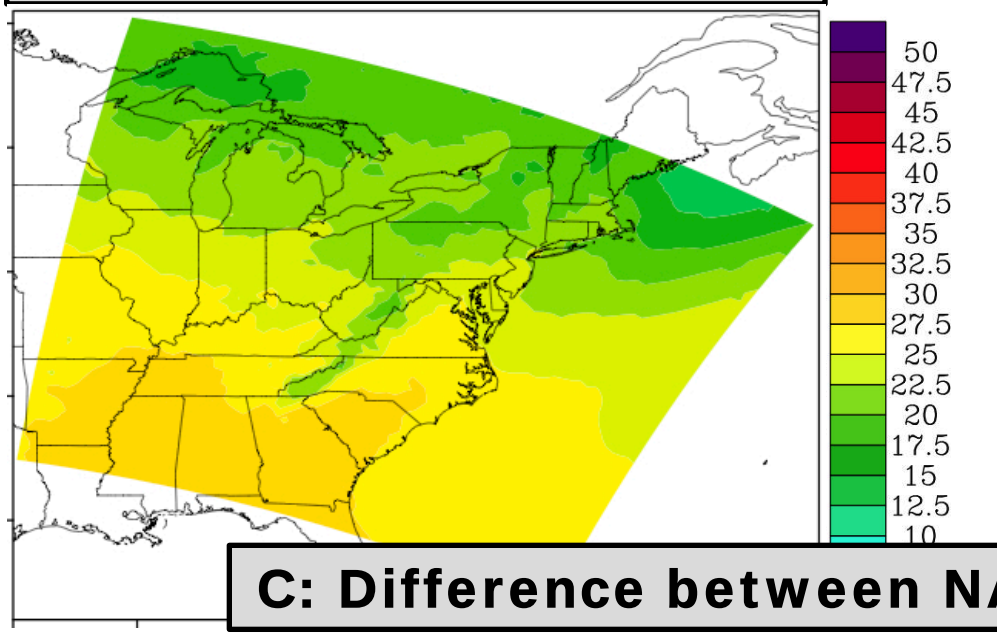
3. Quantify and map **health risks** for populations vulnerable to climate change-driven air pollution

Project Flow Chart of Modeling

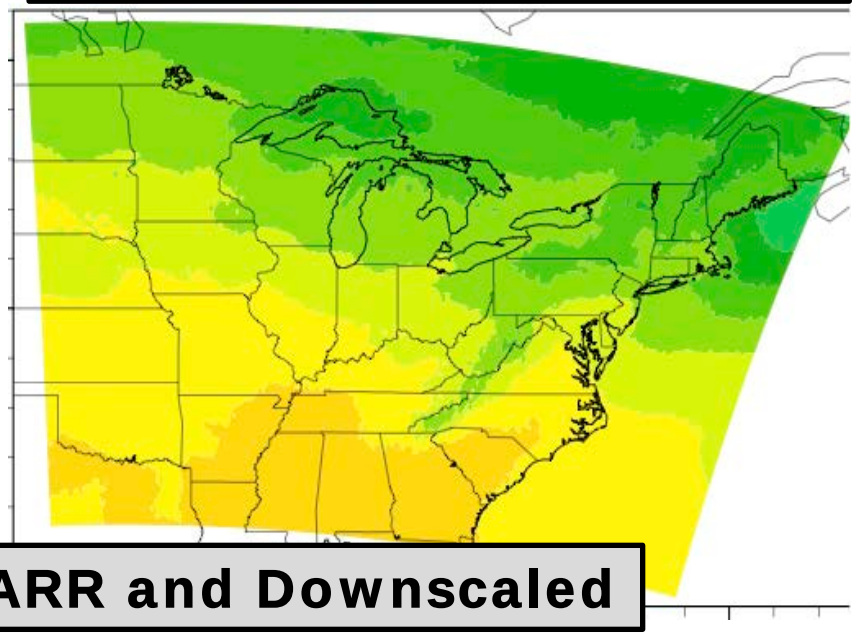


Downscaling Results

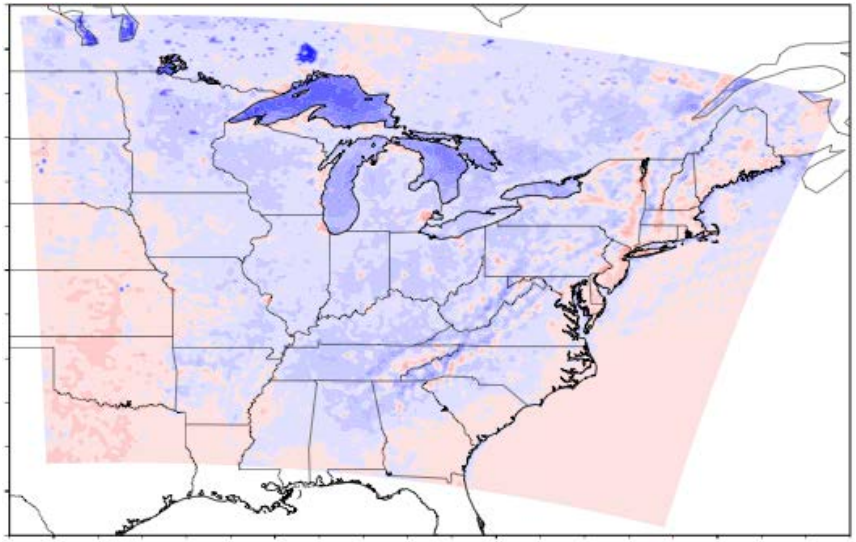
A: Regional Reanalysis

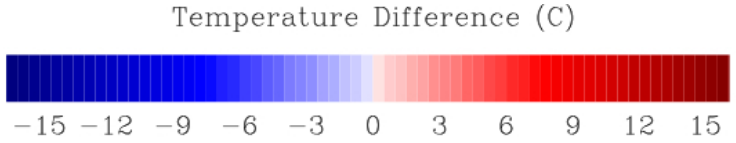


B: Downscaled to 12km



C: Difference between NARR and Downscaled





Source: Harkey and Holloway, in press.

How does climate affect air quality?

Direct processes:

- Ozone
  - Warmer weather favors the chemical formation of ground-level ozone (smog)
- Fine Particulate Matter ($PM_{2.5}$)
  - Associated with stagnant air, less frequent precipitation

How does climate affect air quality?

Indirect processes:

Warmer summers…

- Increased demand for electricity

- Dirtiest generators come online when demand is heaviest [Gilmore et al. 2010]

Is A/C really an important strain on the electrical grid?

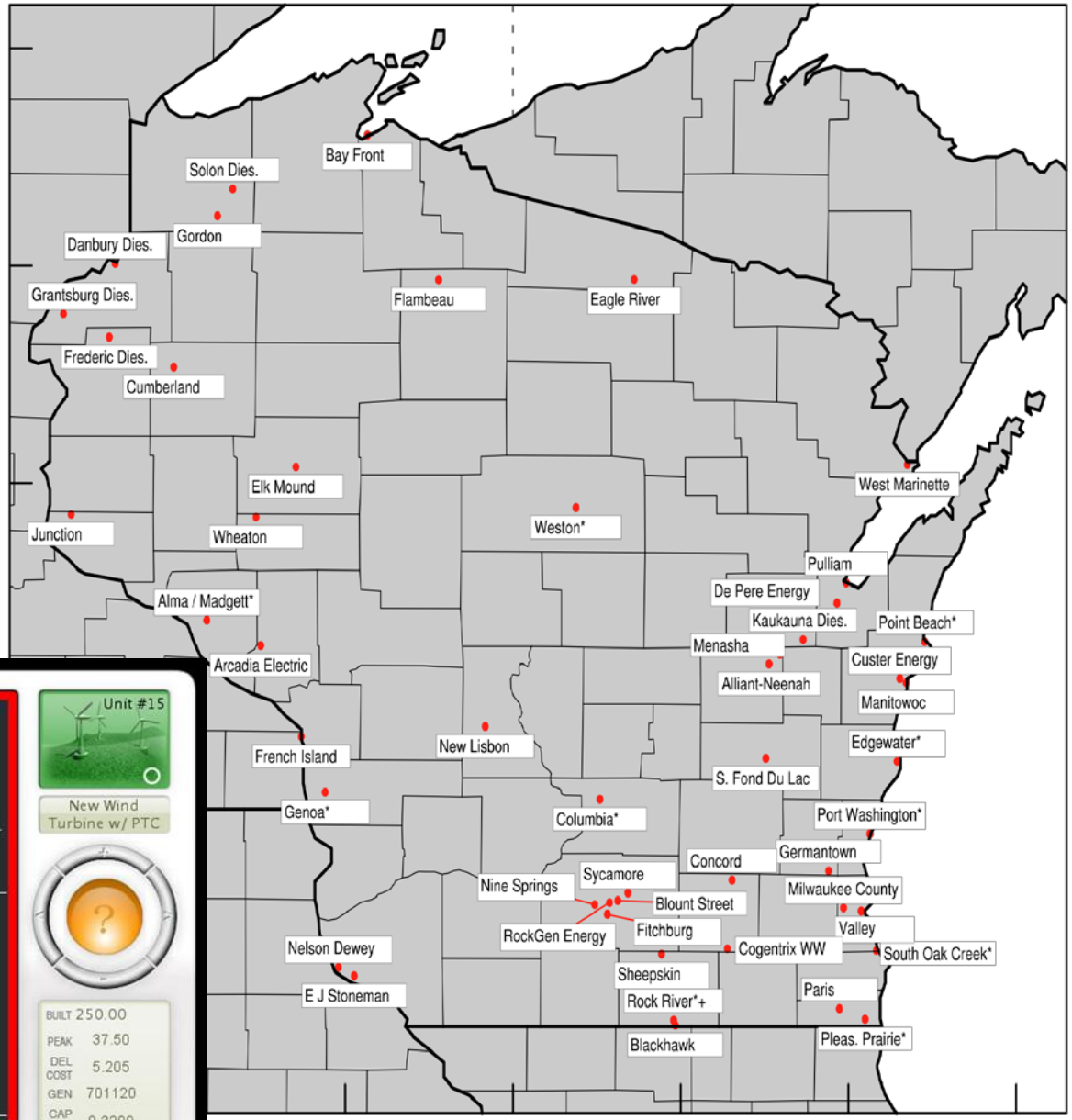
- Relationship between temperature and electricity demand

- 22% of all end-use energy is used for heating and cooling
(Amato et al., 2005)

- Primary concerns: residential and commercial energy demand

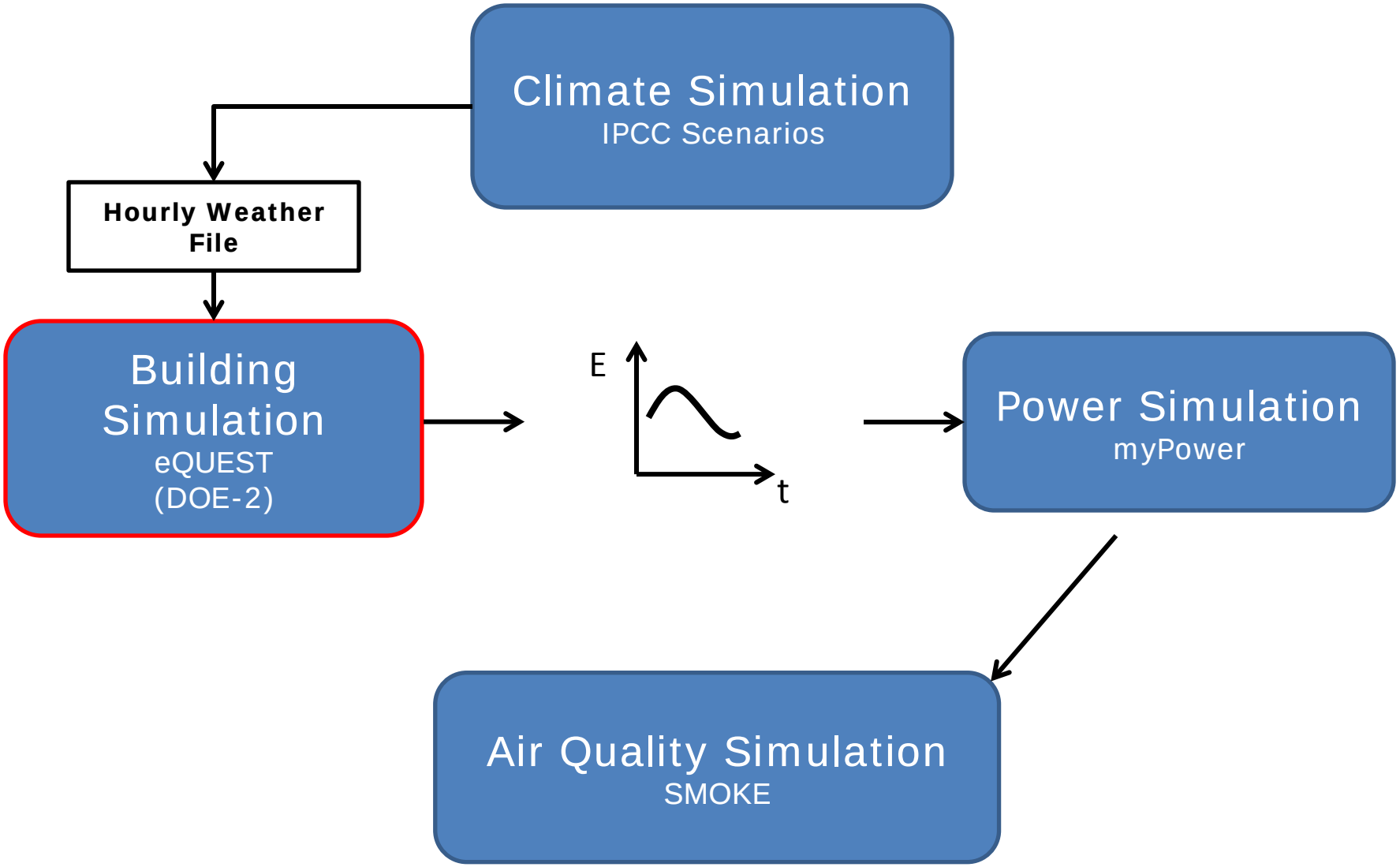
Modeling the power grid:

MyPower model



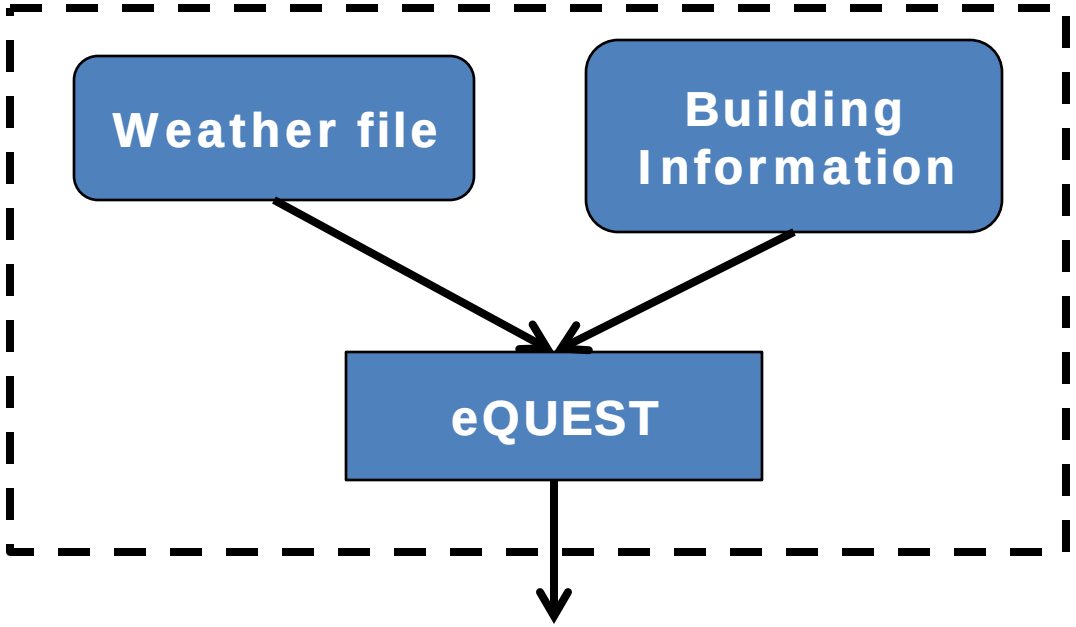
Source: Paul Meier

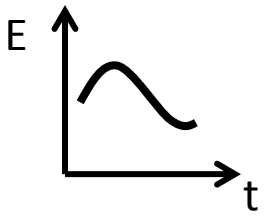
Simulation Framework



Source: Lu et al., 2010 via Energy Center of Wisconsin

Simulation Process



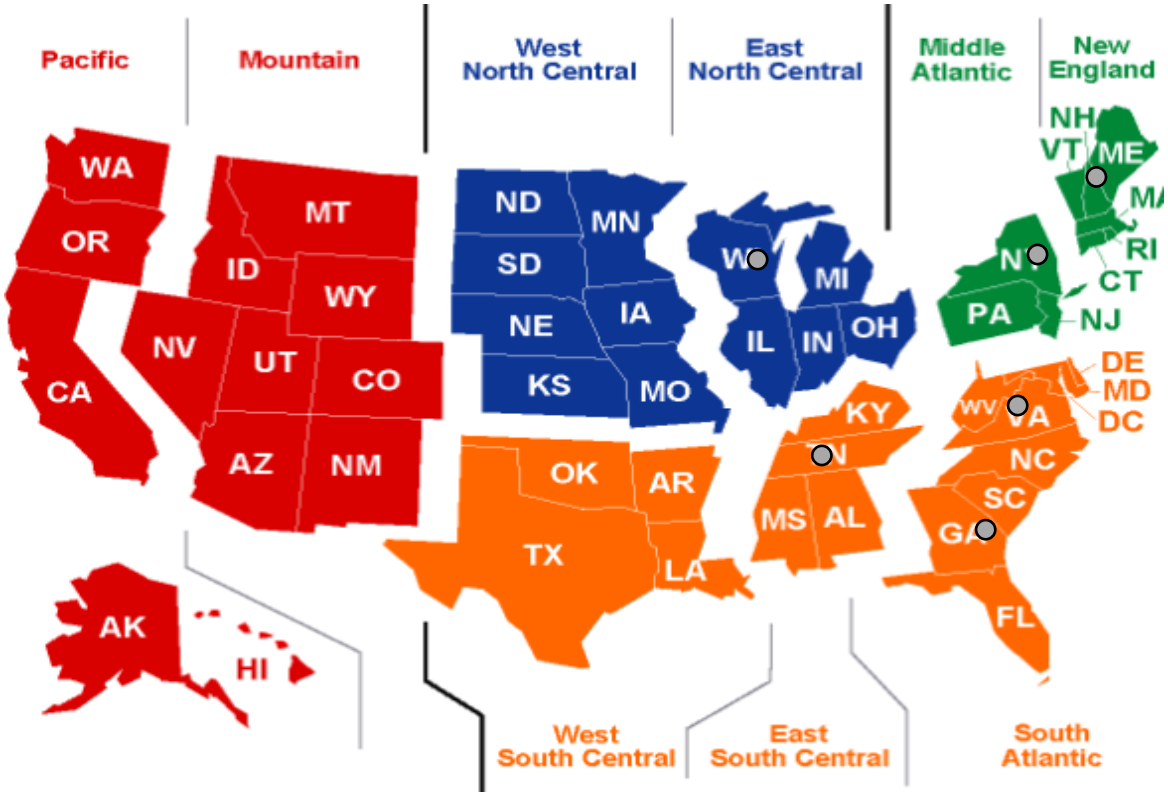


14 building types
5 regions
6 weather stations

Regional E(t) =

$$\sum_{j\ \text{b-types}} \text{Building } E_j * w_j$$

Regional Analysis

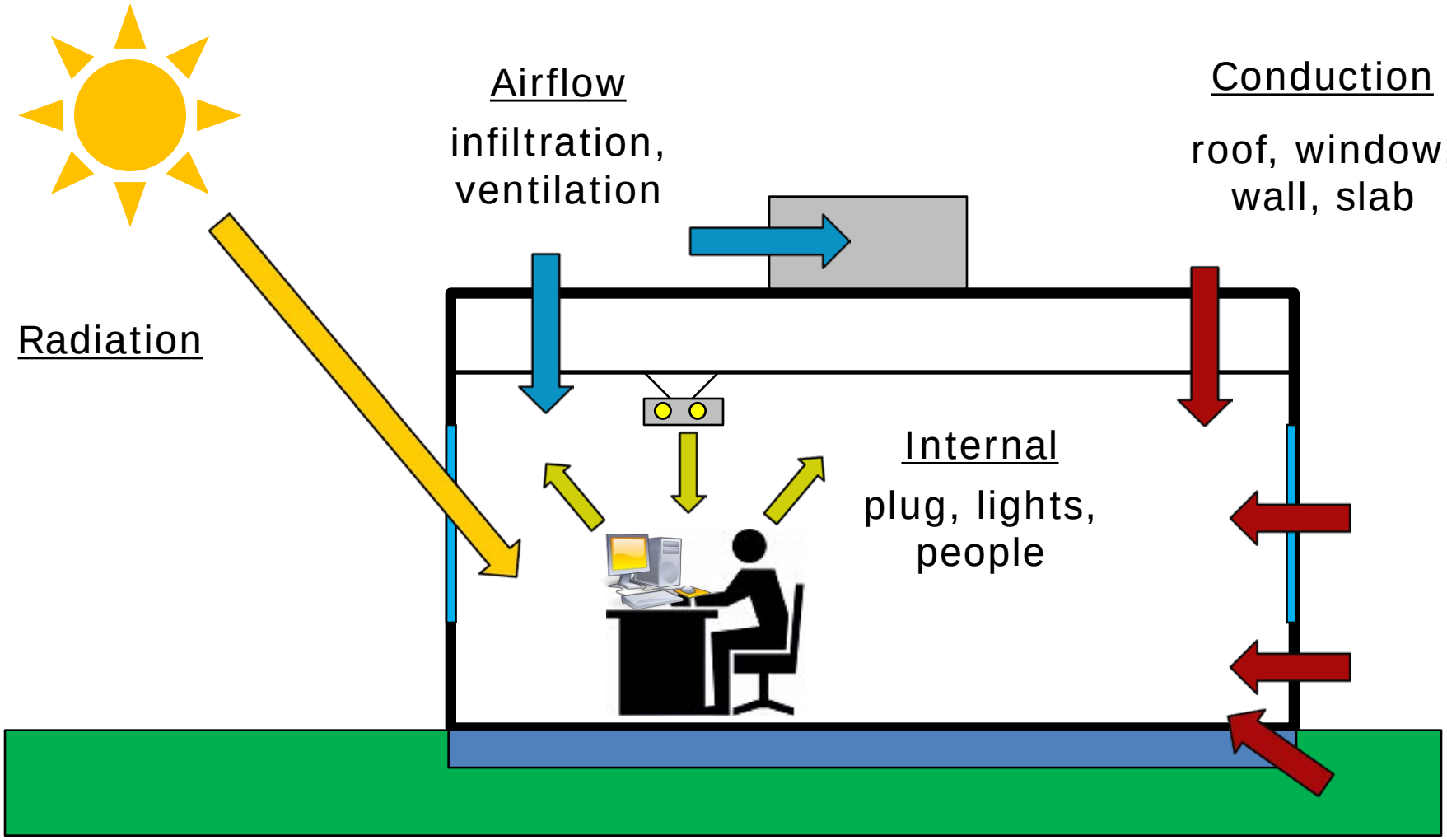


Region	Weather Location
New England	Boston, MA
Middle Atlantic	New York, NY
East North Central	Chicago, IL
South Atlantic	Jacksonville, FL
	Raleigh, NC
East South Central	Birmingham, AL

Five regions were identified to characterize the eastern U.S., each with a given weather location or locations.

Source: Energy Center of Wisconsin

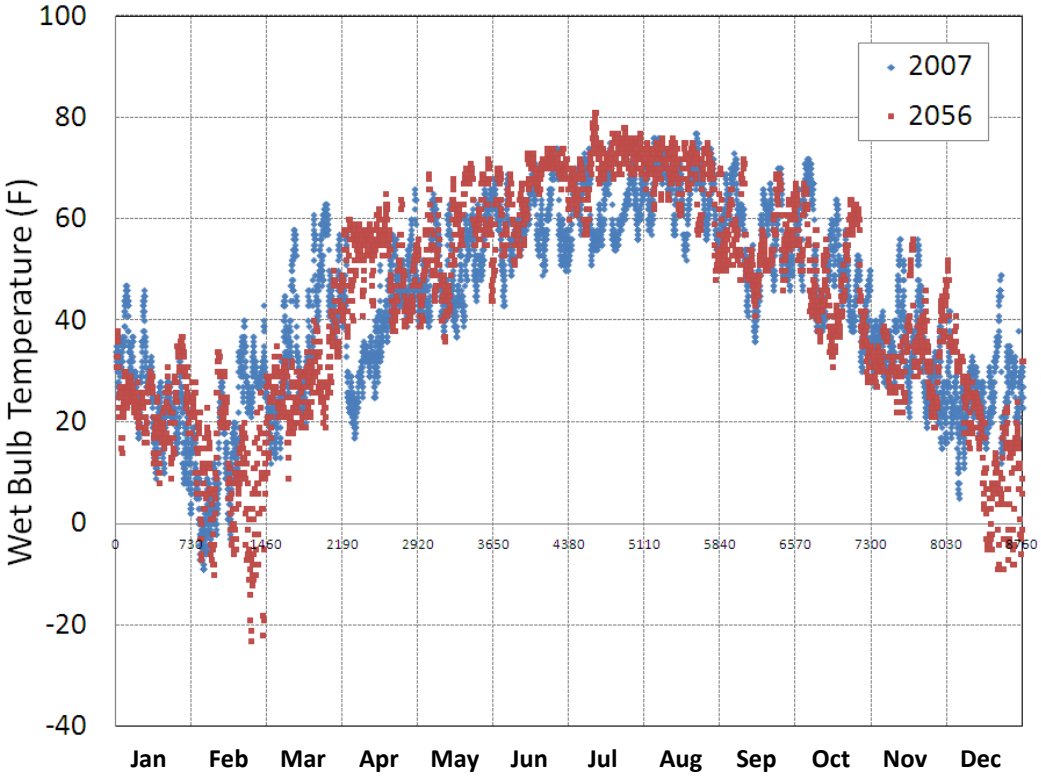
Building Modeling - Loads



Source: Energy Center of Wisconsin

Wet Bulb Temperature

Chicago, IL

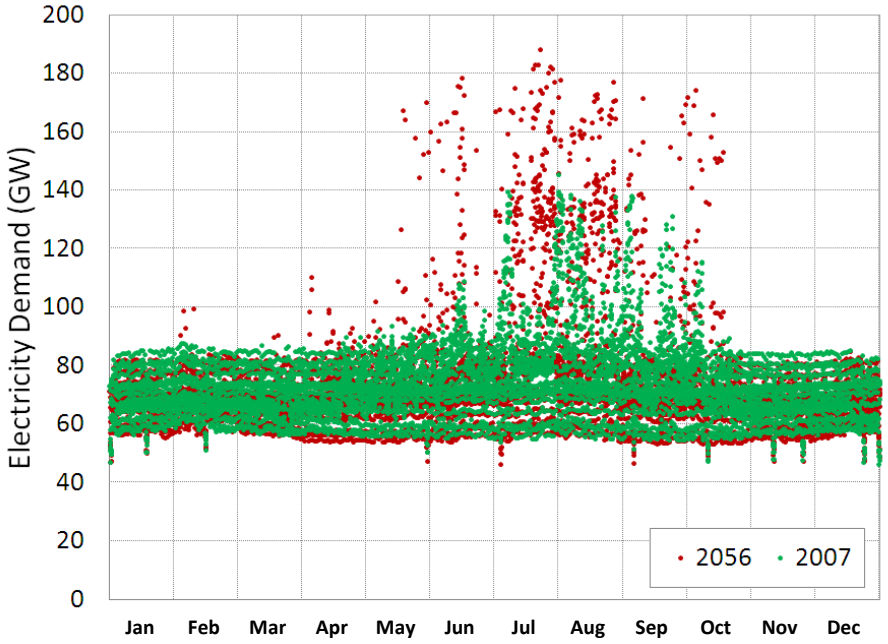


- Maximum wet bulb temperature increases by 5% from 77 to 81 °F.

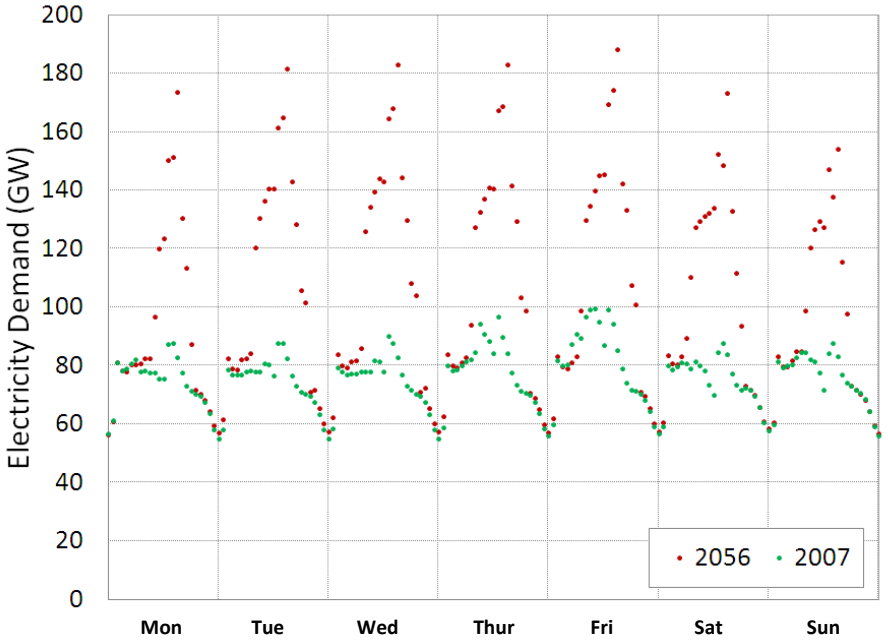
Load Shape: 2007 vs 2056

East North Central Region

Annual

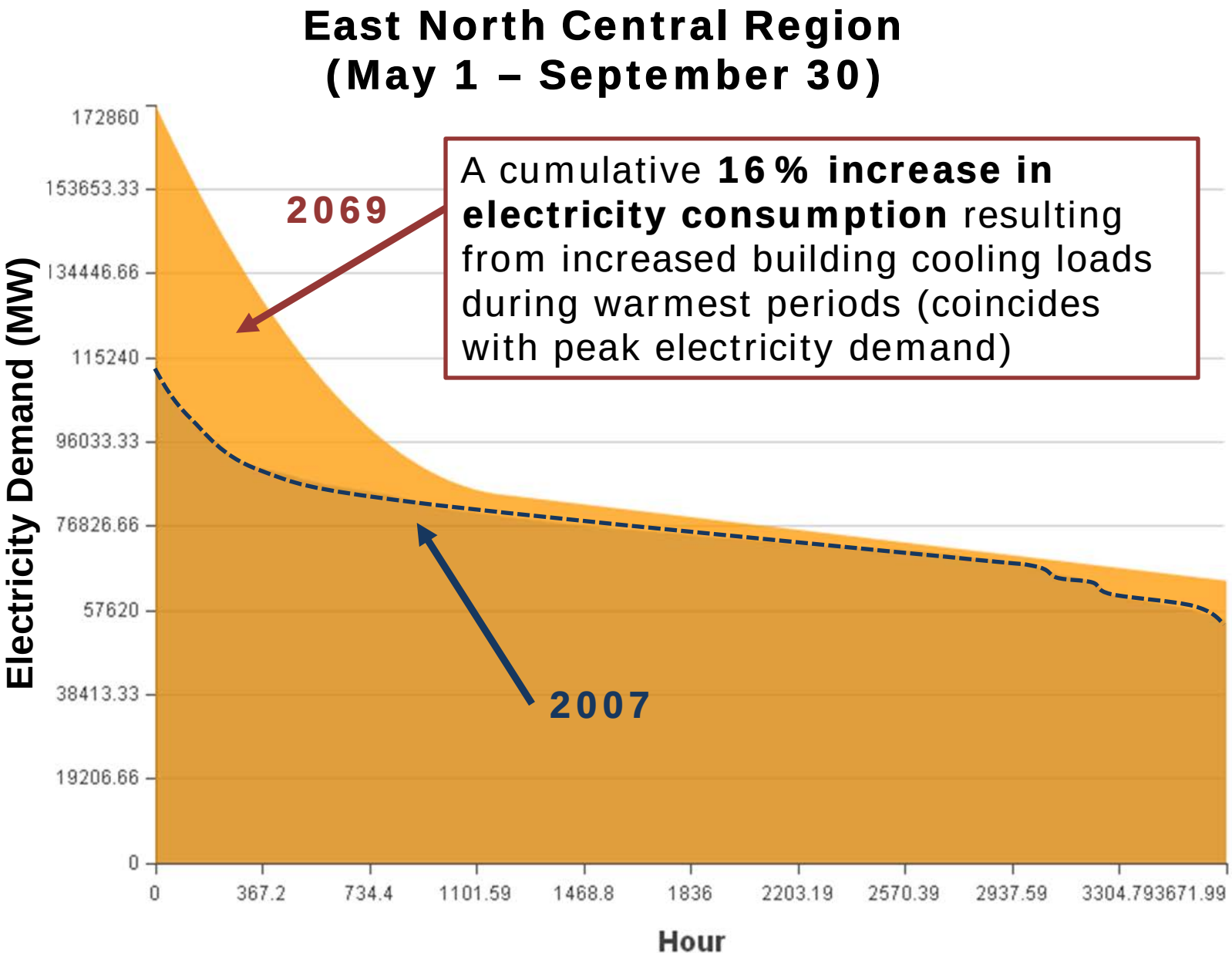


Worst Week

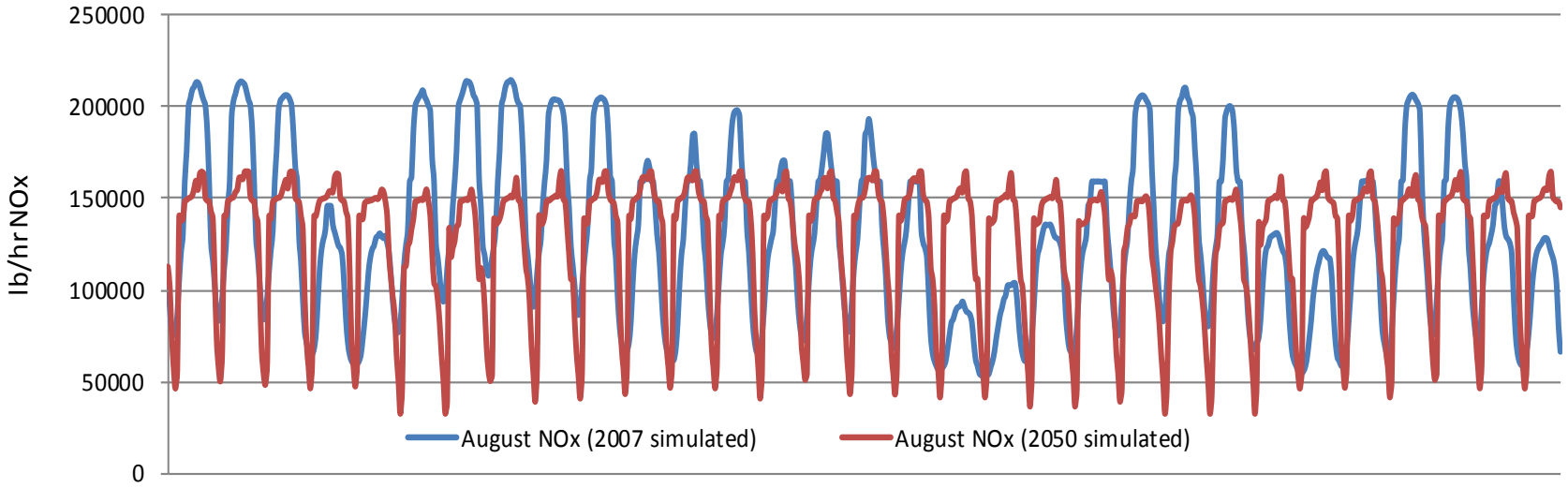


- Hourly peak demand increases by 29% from 146 to 188 GW.

Comparing Load Curves

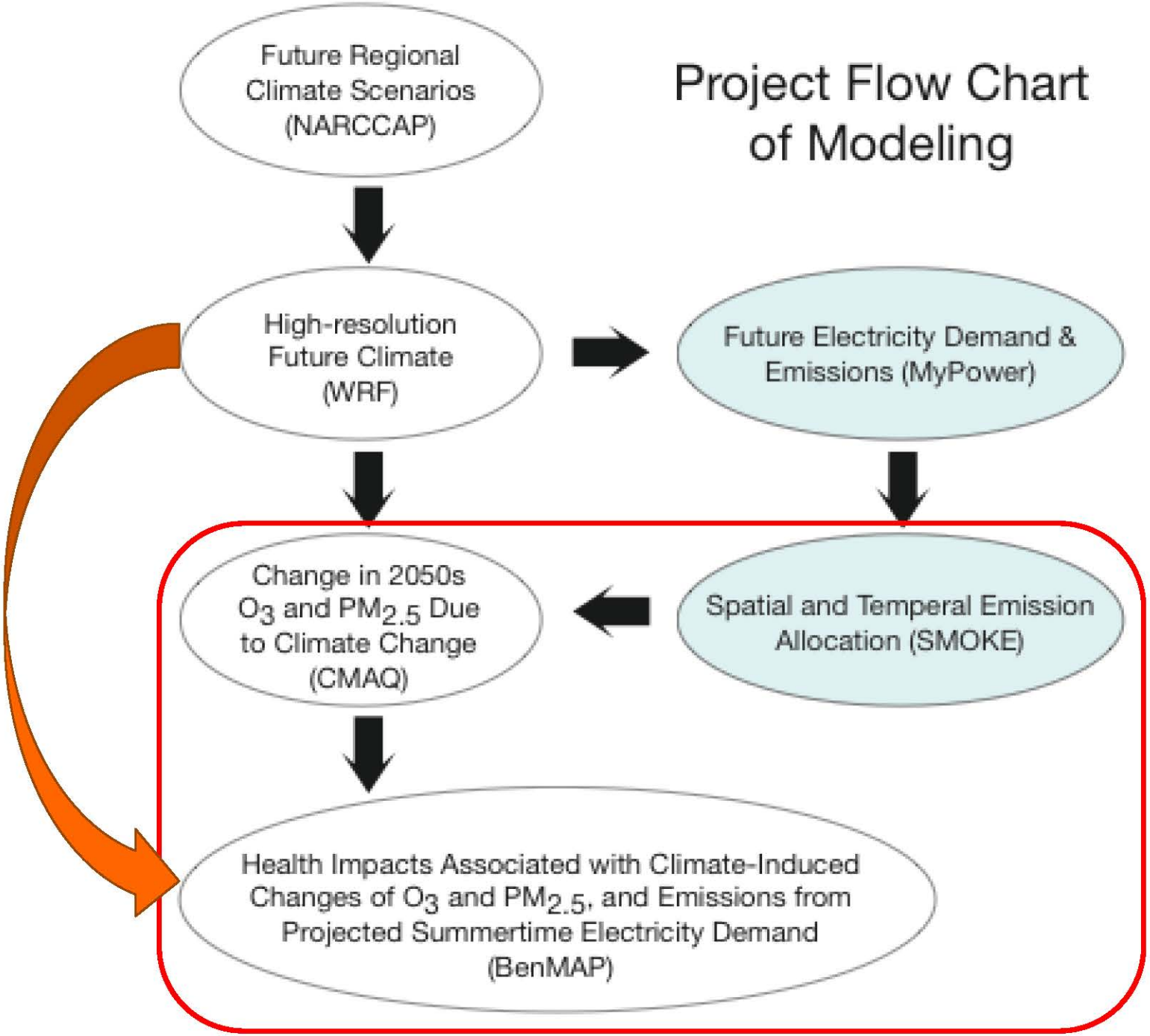


Hourly Emissions Changes
Resulting from Increased Building Loads (Preliminary)

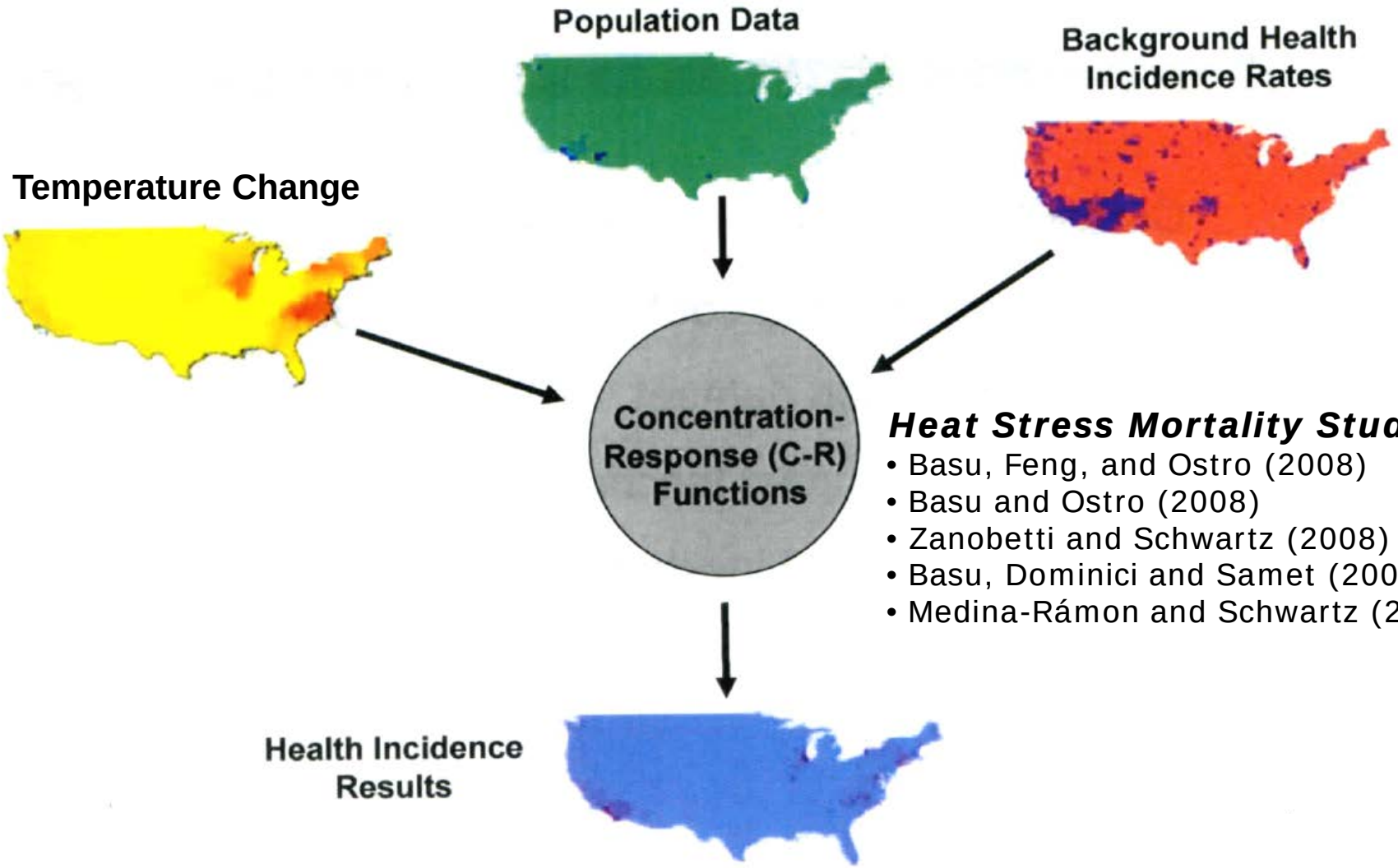


	2007 demand / weather	2050 demand / weather	change
Annual Electricity (GWh)	646,677	693,064	7%
Annual NOx Emission (tons)	417,777	463,862	11%
August Electricity (GWh)	61,818	73,622	19%
August NOx Emission (tons)	47,999	47,345	-1%
% Renewable	1.1%	13%	1202%

Note that other changes will influence emissions as well, such as increased renewables and newer/cleaner generation displacing older power plants.


Project Flow Chart of Modeling
Future Regional Climate Scenarios (NARCCAP)
High-resolution Future Climate (WRF)
Future Electricity Demand & Emissions (MyPower)
Change in 2050s O_3 and $PM_{2.5}$ Due to Climate Change (CMAQ)
Spatial and Temperal Emission Allocation (SMOKE)
Health Impacts Associated with Climate-Induced Changes of O_3 and $PM_{2.5}$, and Emissions from Projected Summertime Electricity Demand (BenMAP)

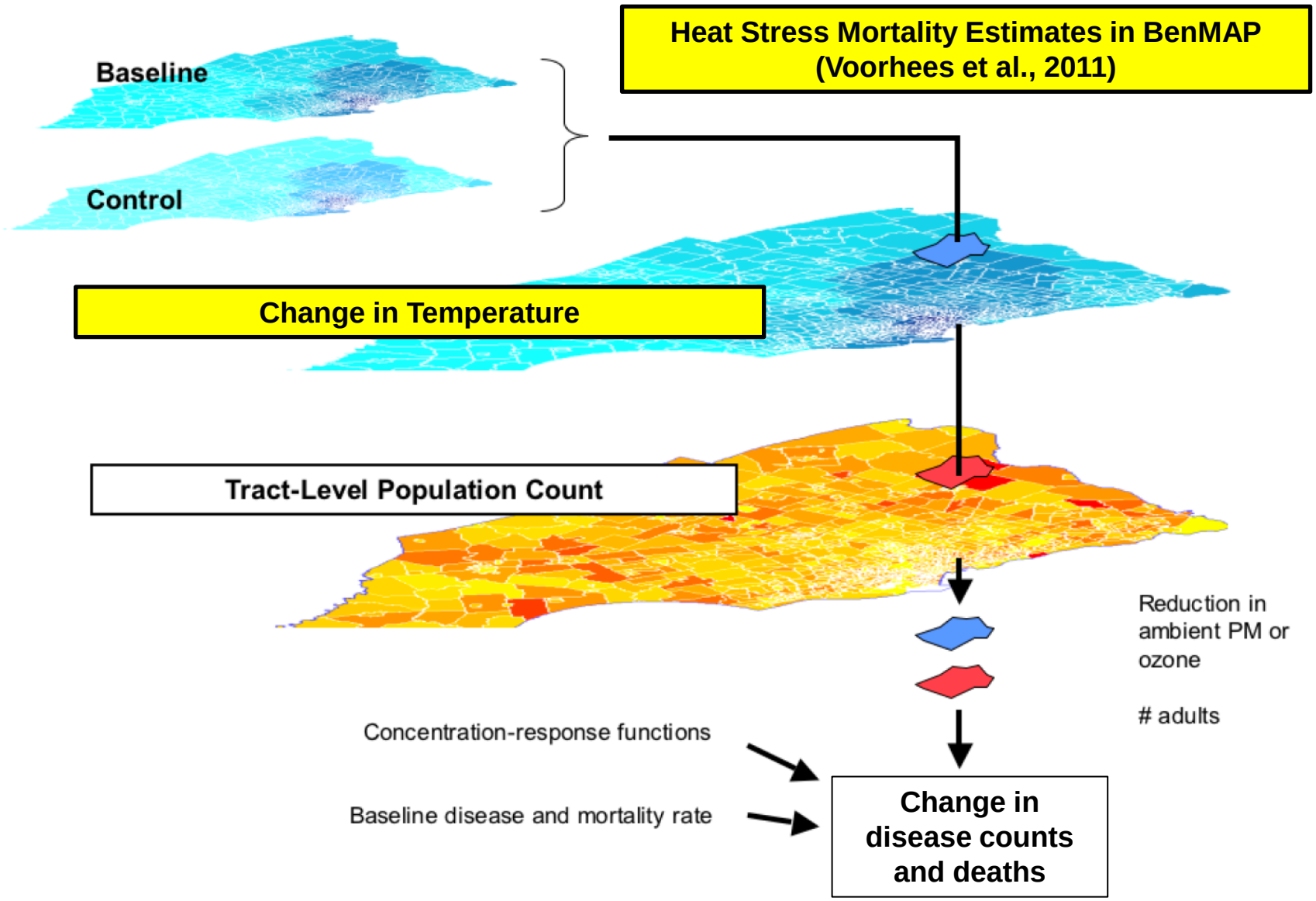
Benefits Mapping and Analysis Program (BenMAP)



Heat Stress Mortality Studies:

- Basu, Feng, and Ostro (2008)
- Basu and Ostro (2008)
- Zanobetti and Schwartz (2008)
- Basu, Dominici and Samet (2005)
- Medina-Rámon and Schwartz (2009)

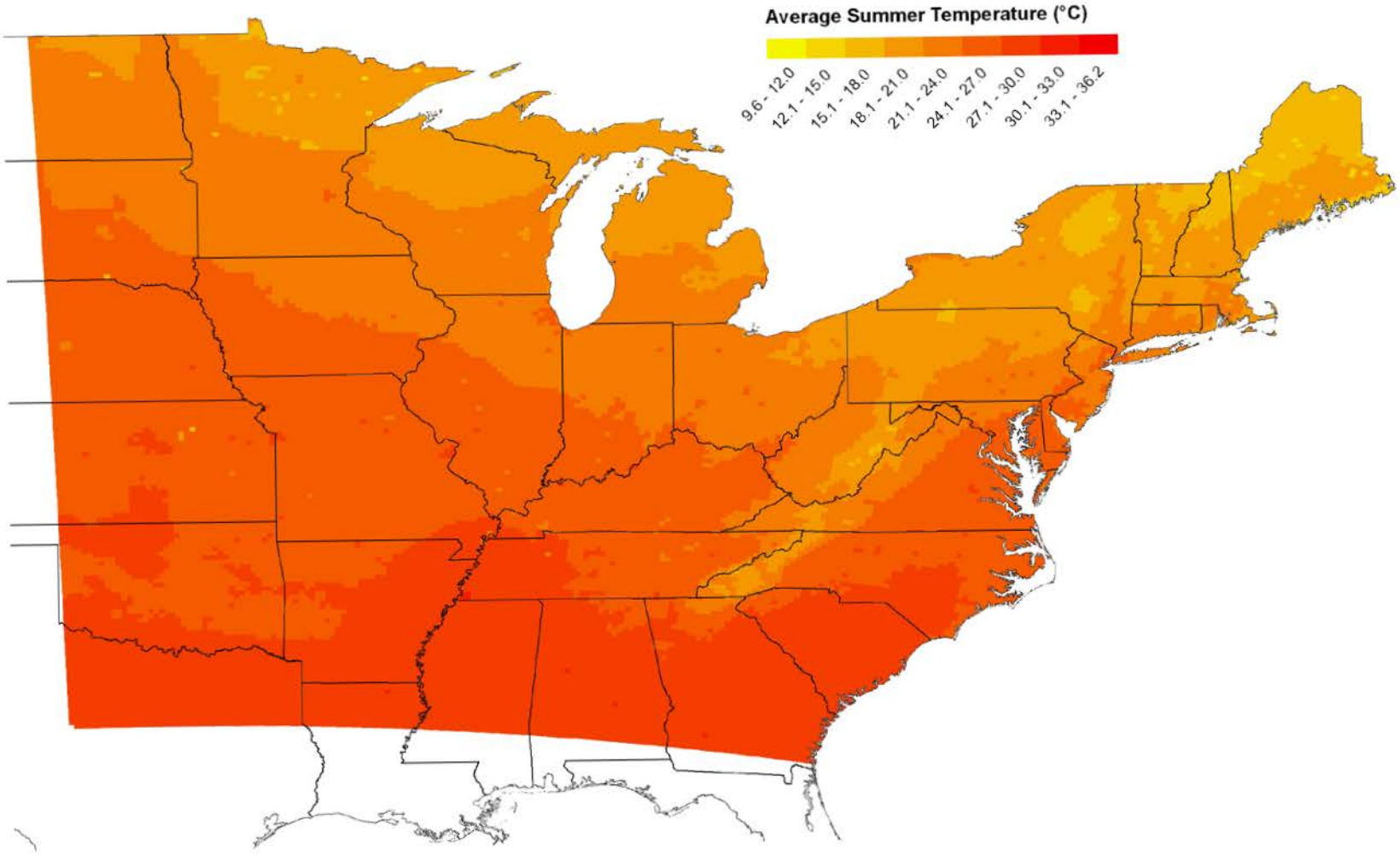
Source: EPA



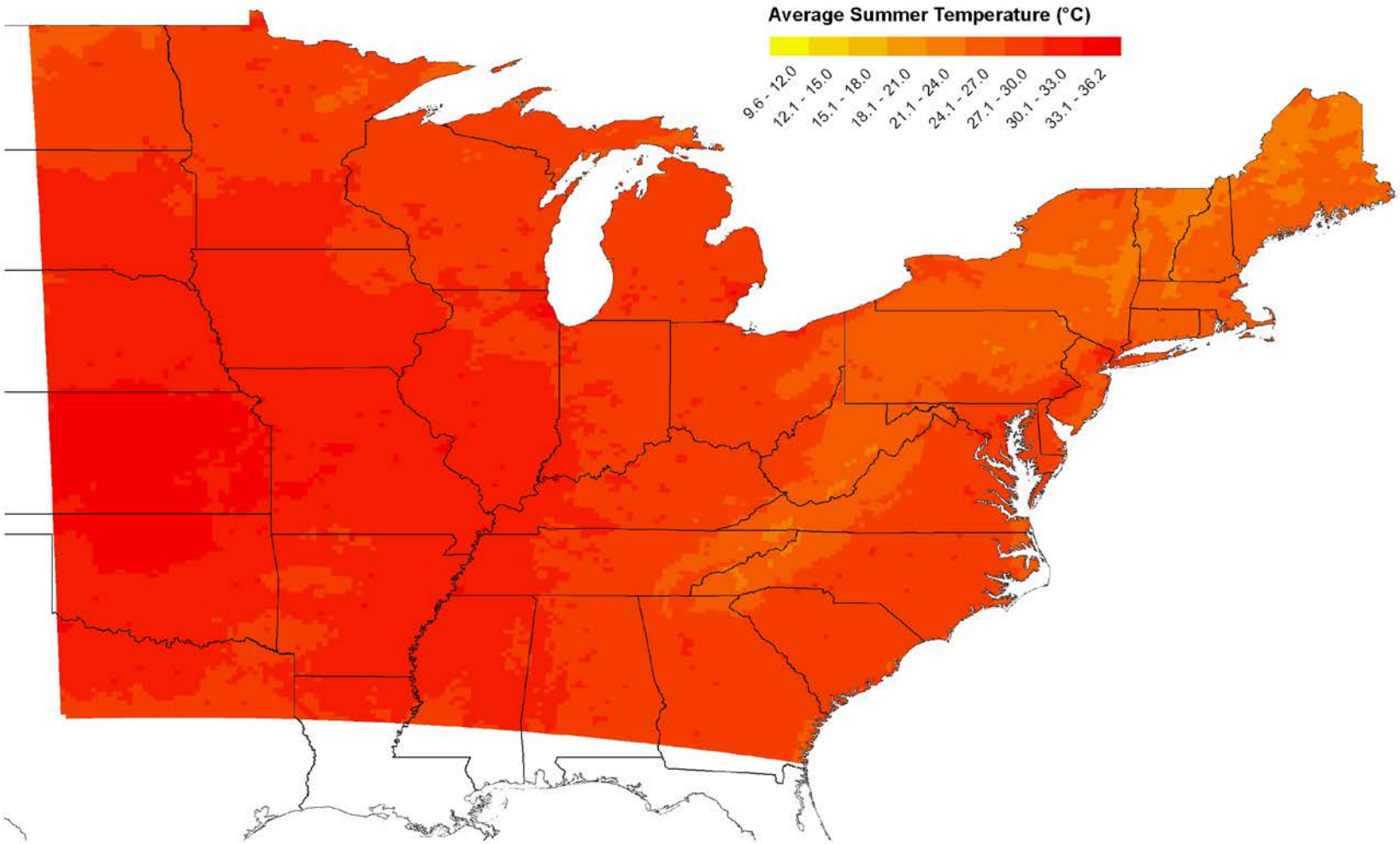
Schematic description of BenMAP model. “Baseline” air pollutant concentrations are compared with a “control” scenario (reflecting a change in climate and/or electricity emissions). Patterns in pollutant concentrations and population health are combined in a Geographic Information System (GIS) to calculate health risk. Source: EPA (http://www.epa.gov/air/benmap/docs.html)

Source: EPA

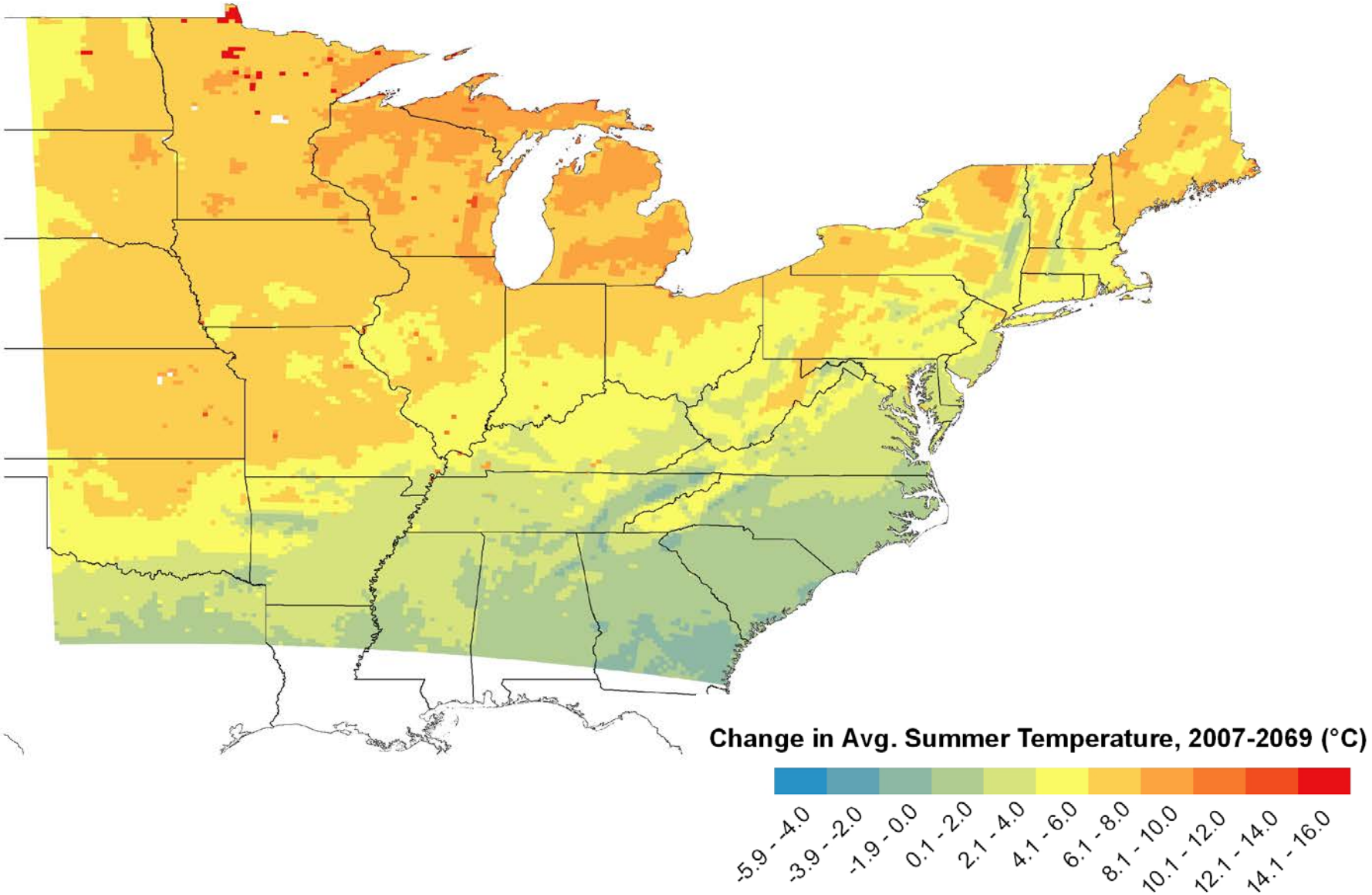
Summer Average Temperatures (2007)



Summer Average Temperatures (2069)

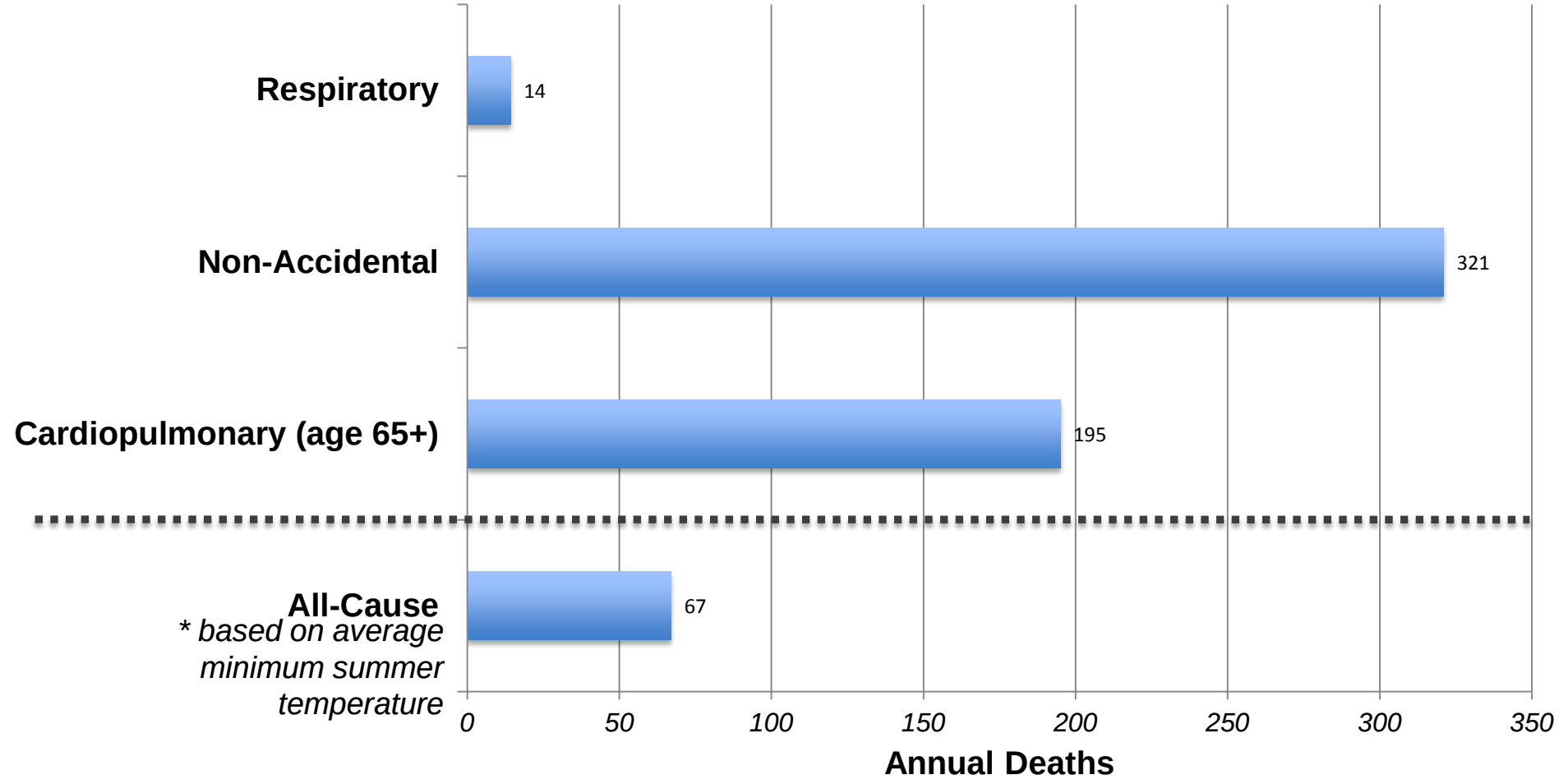


Change in Summer Average Temperatures (2007-2069)



Heat Stress Mortality

BenMAP mortality projections comparing average* summer temperatures in 2007 and 2069:



Climate-Energy-Health Nexus

Climate / Air Quality

Electricity Demand

Health Risks

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