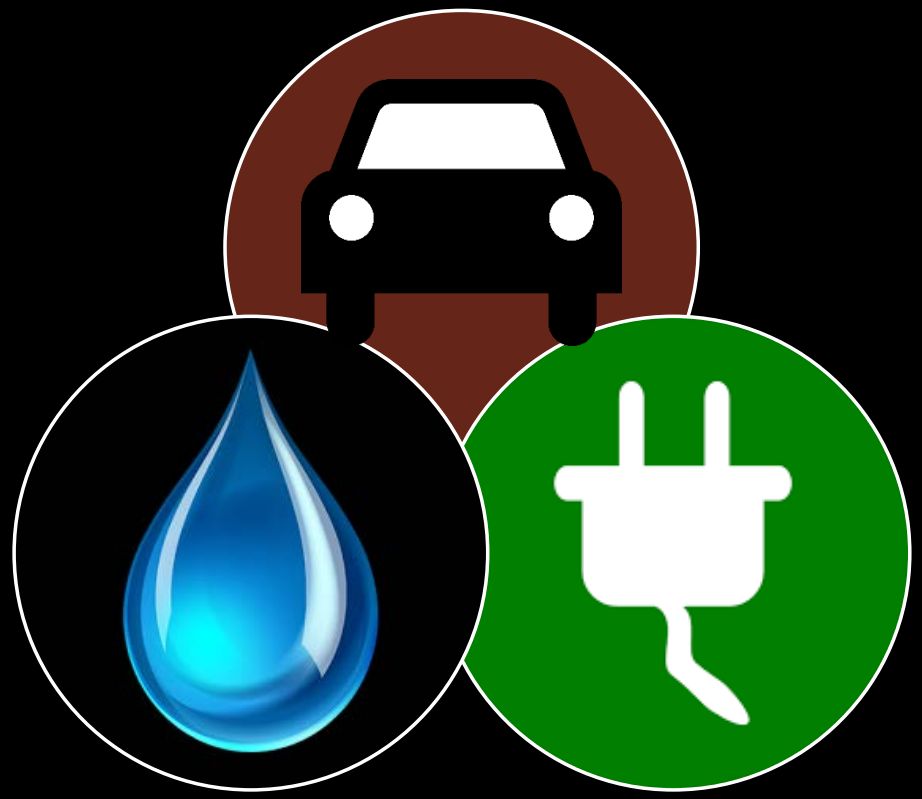
The Vulnerability of Interdependent Urban Infrastructure Systems to Climate Change: Could Phoenix Experience a Katrina of Extreme Heat?

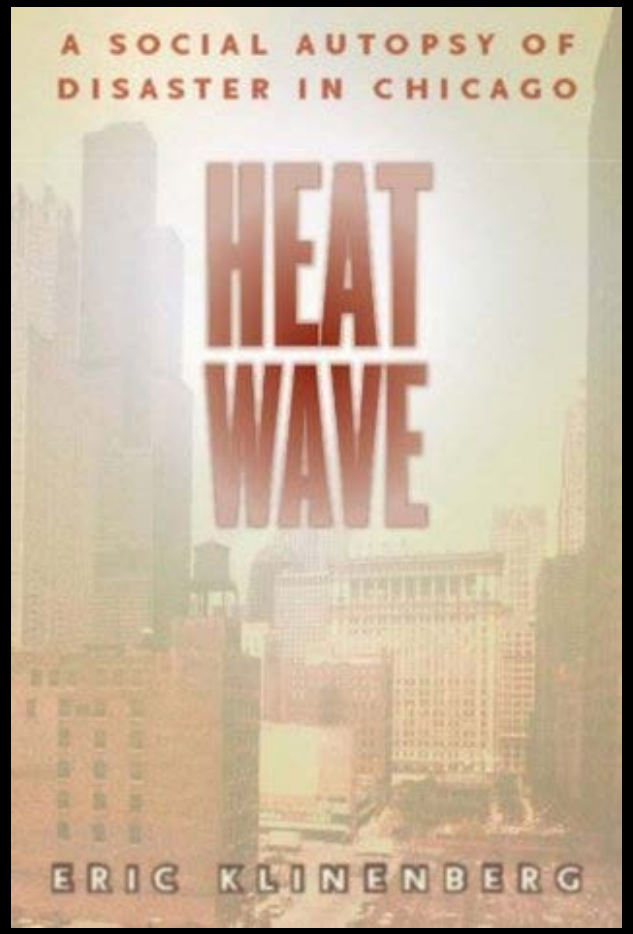


SUSAN SPIERRE CLARK, MIKHAIL V. CHESTER, THOMAS P. SEAGER
School of Sustainable Engineering and the Built Environment
Arizona State University

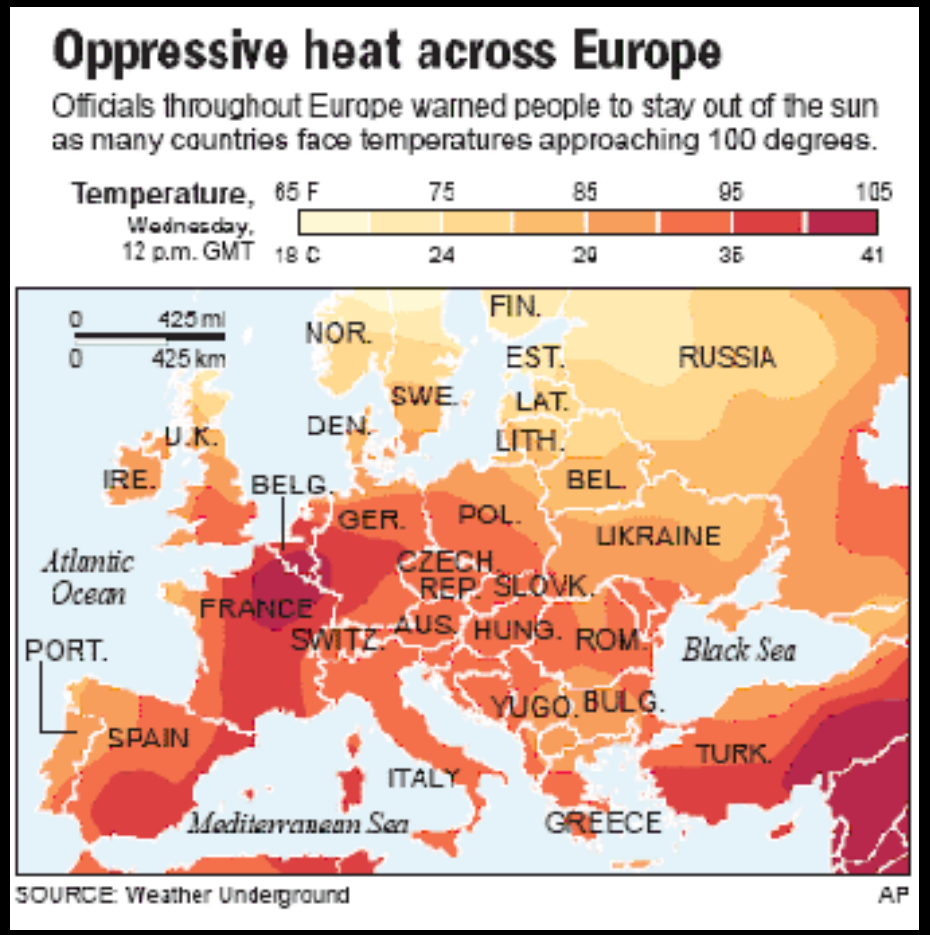
Resilience Week, August 18, 2016 in Chicago, IL

2011 San Diego Blackout

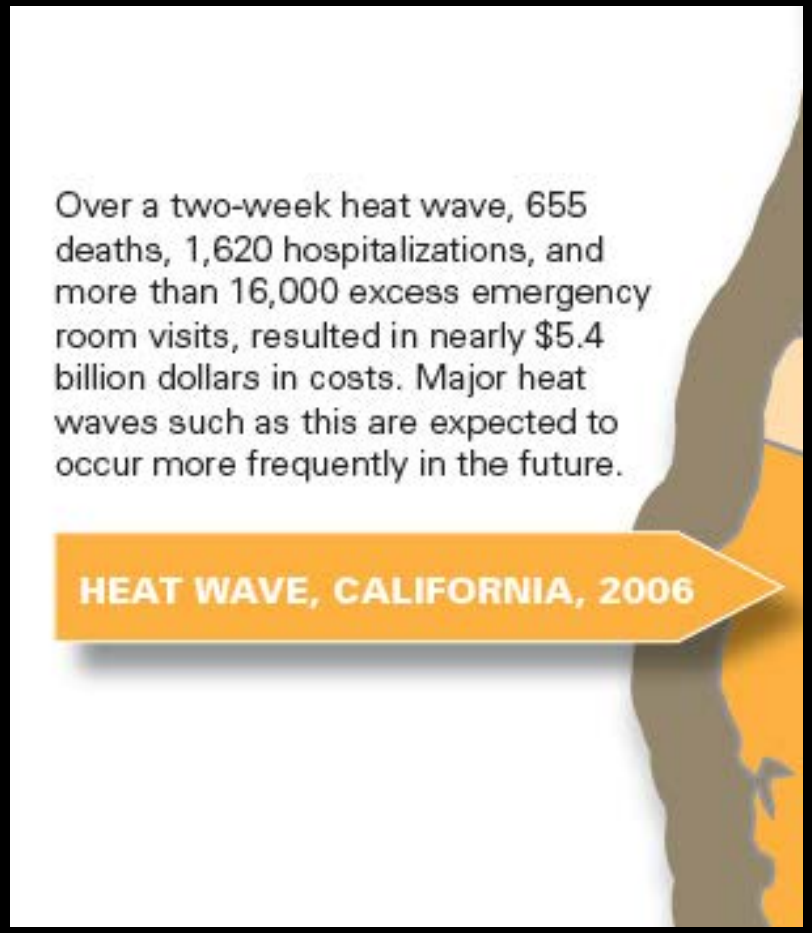
Extreme Heat



1995 Chicago Heat Wave
739 deaths

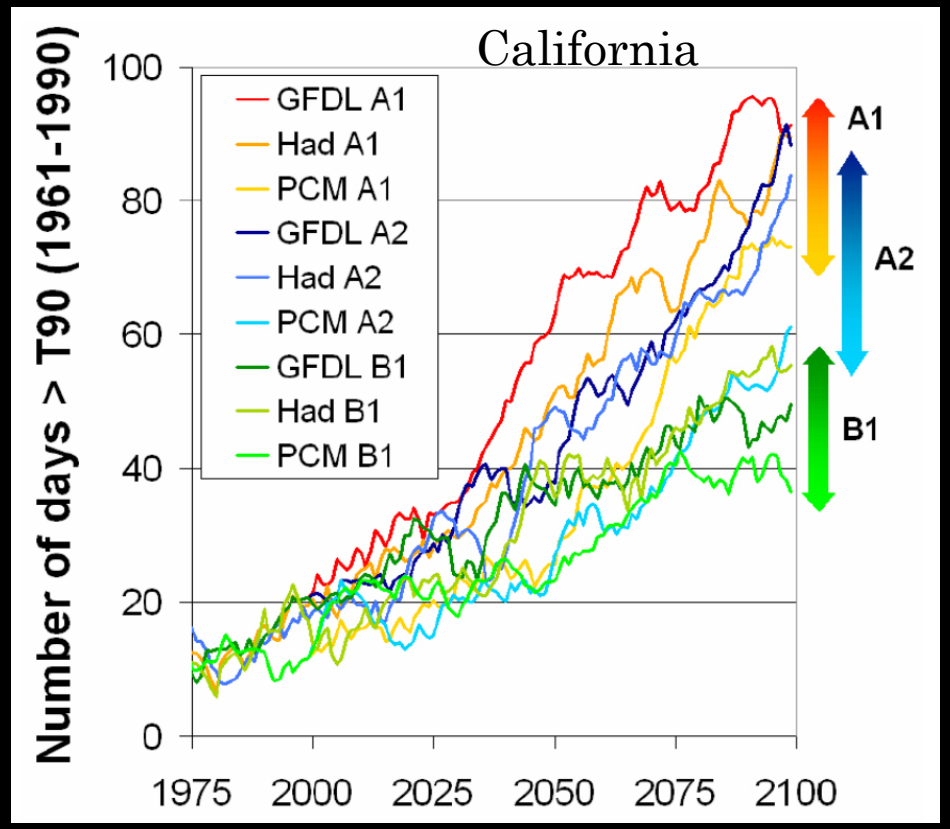


2003 European Heat Wave
35,000 deaths

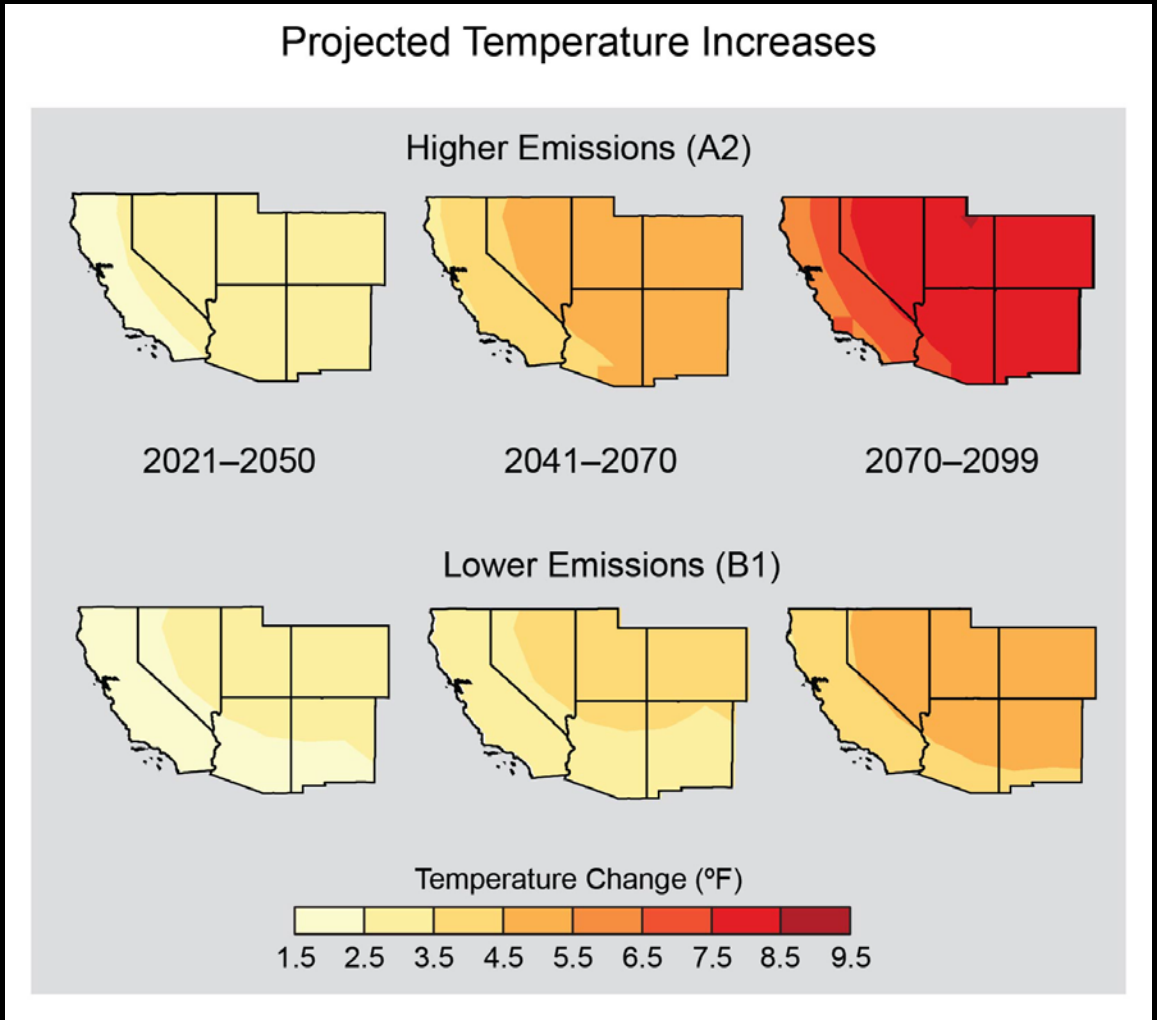


2006 California Heat Wave
655 deaths

More Extreme Heat



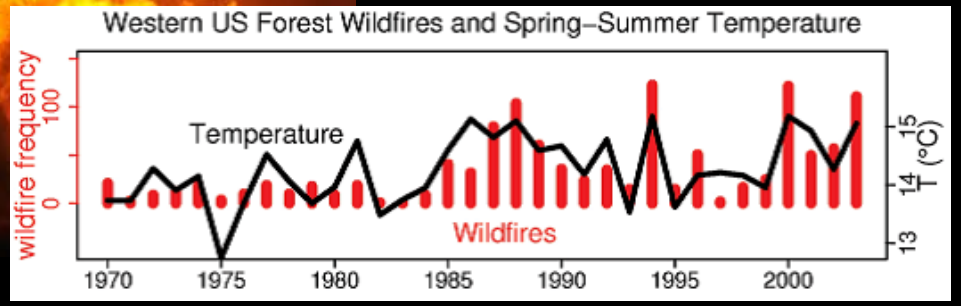
Projected average number of summer days that exceed the 90% probability of the daily maximum temperatures for a location per year from 1975 to 2100 for California. Source: Miller et al. (2008).



Projected changes in average, as compared to 1971-1999. Top row shows projections assuming heat-trapping gas emissions continue to rise (A2). Bottom row shows projections assuming substantial reductions in emissions (B1). (Figure source: adapted from Kunkel et al. 2013).

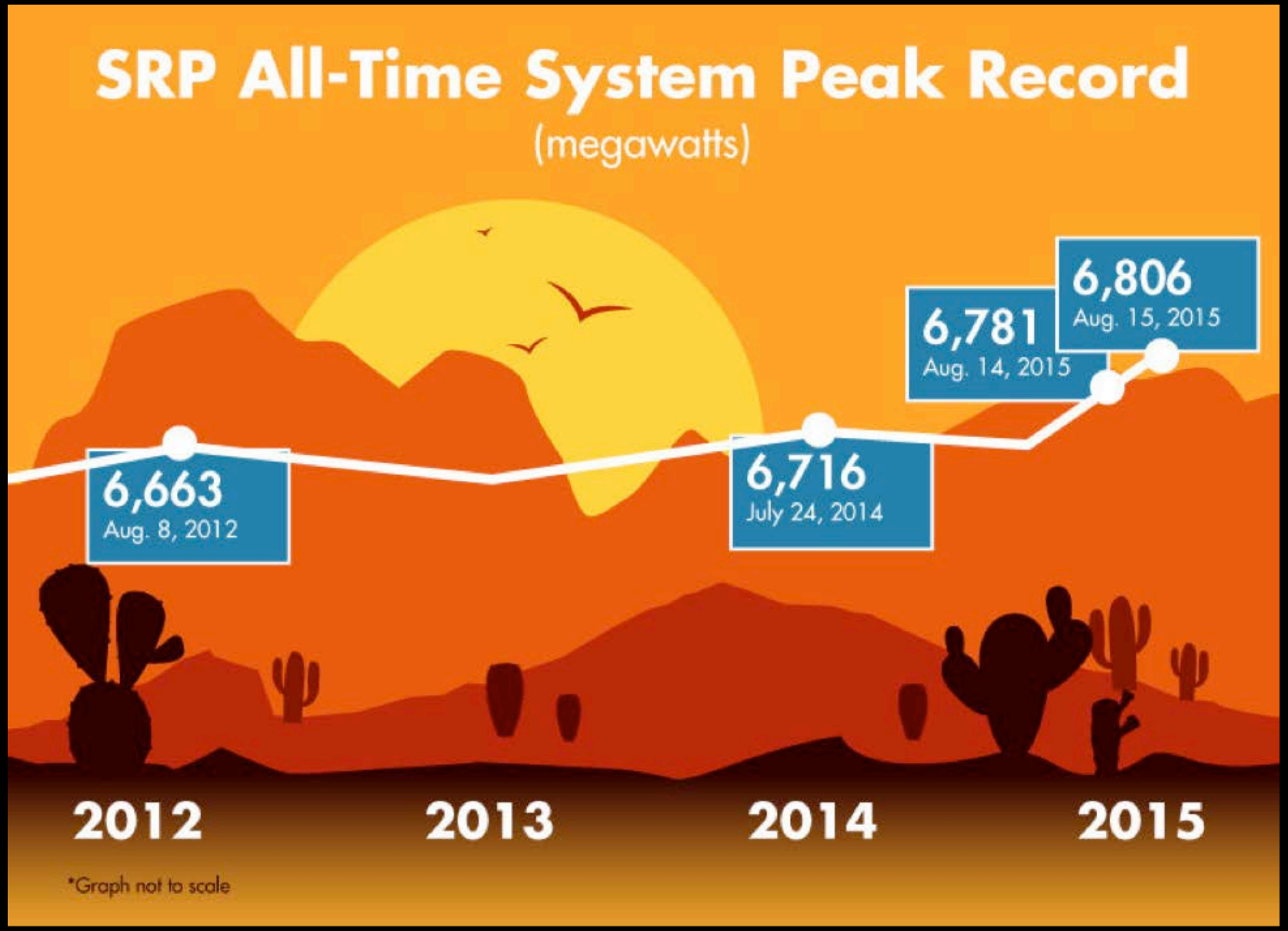
More Frequent and Larger Wildfires

October 2007 Wildfire near San Diego

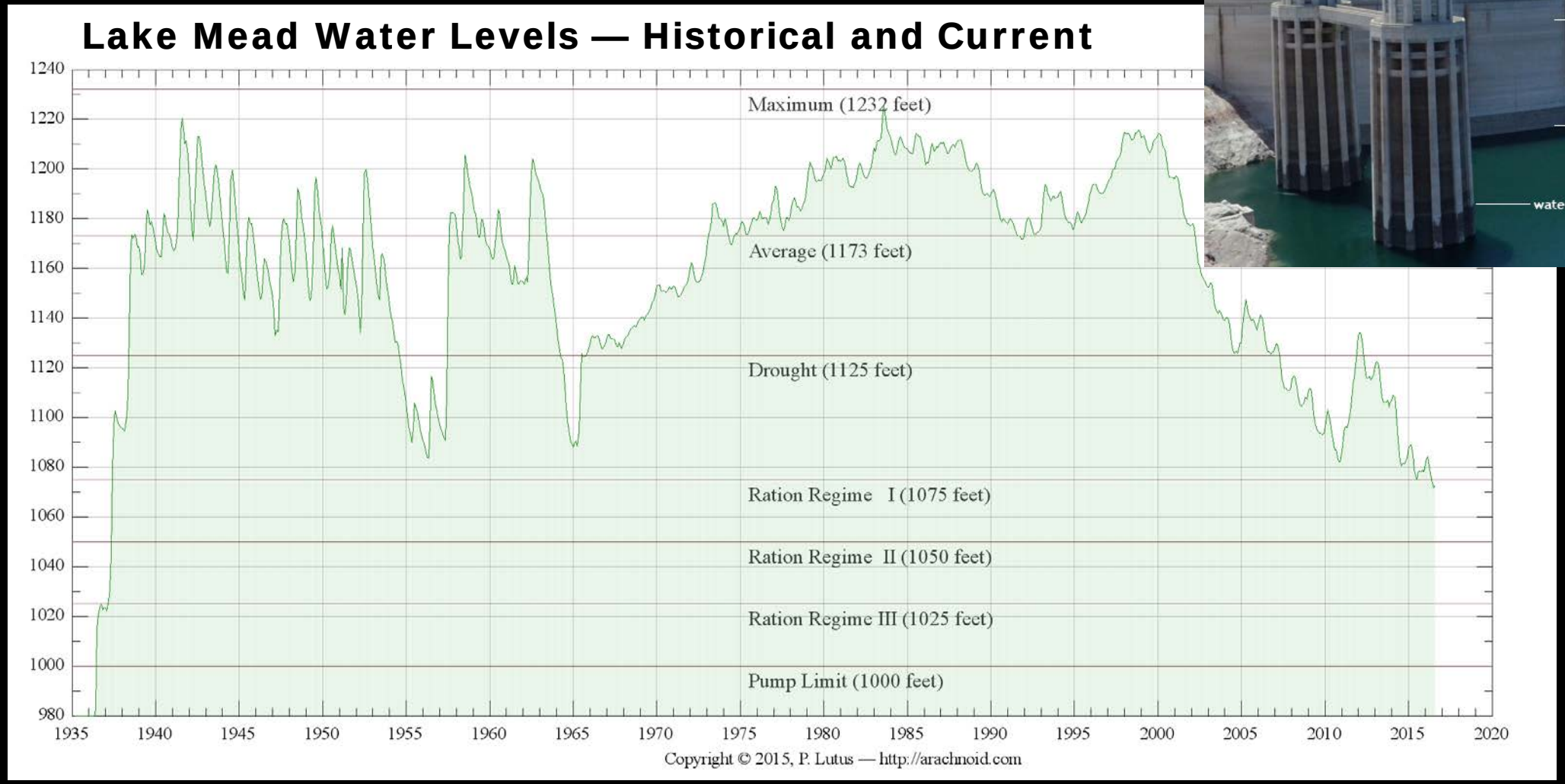


Source: Westerling et al., (2006)

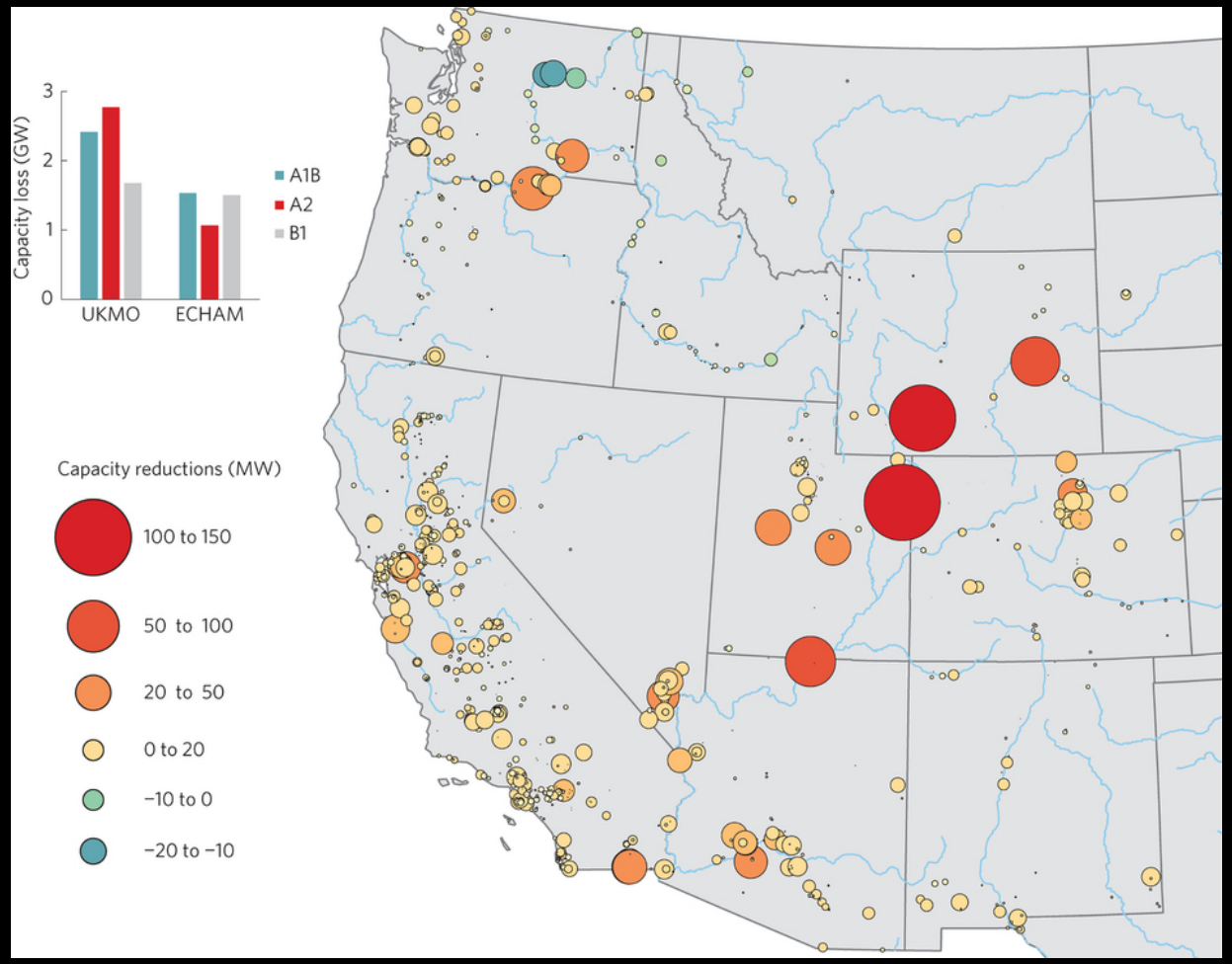
Increased Energy Demand



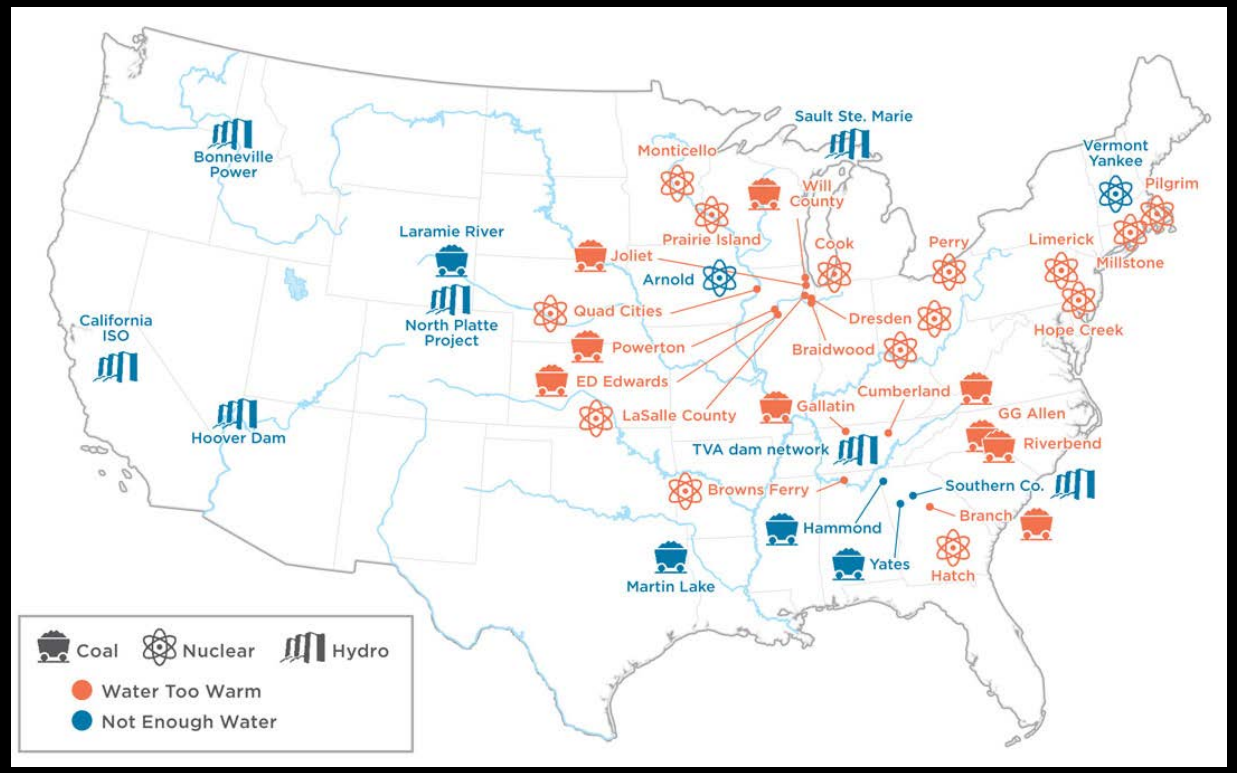
Reduced Water Supplies



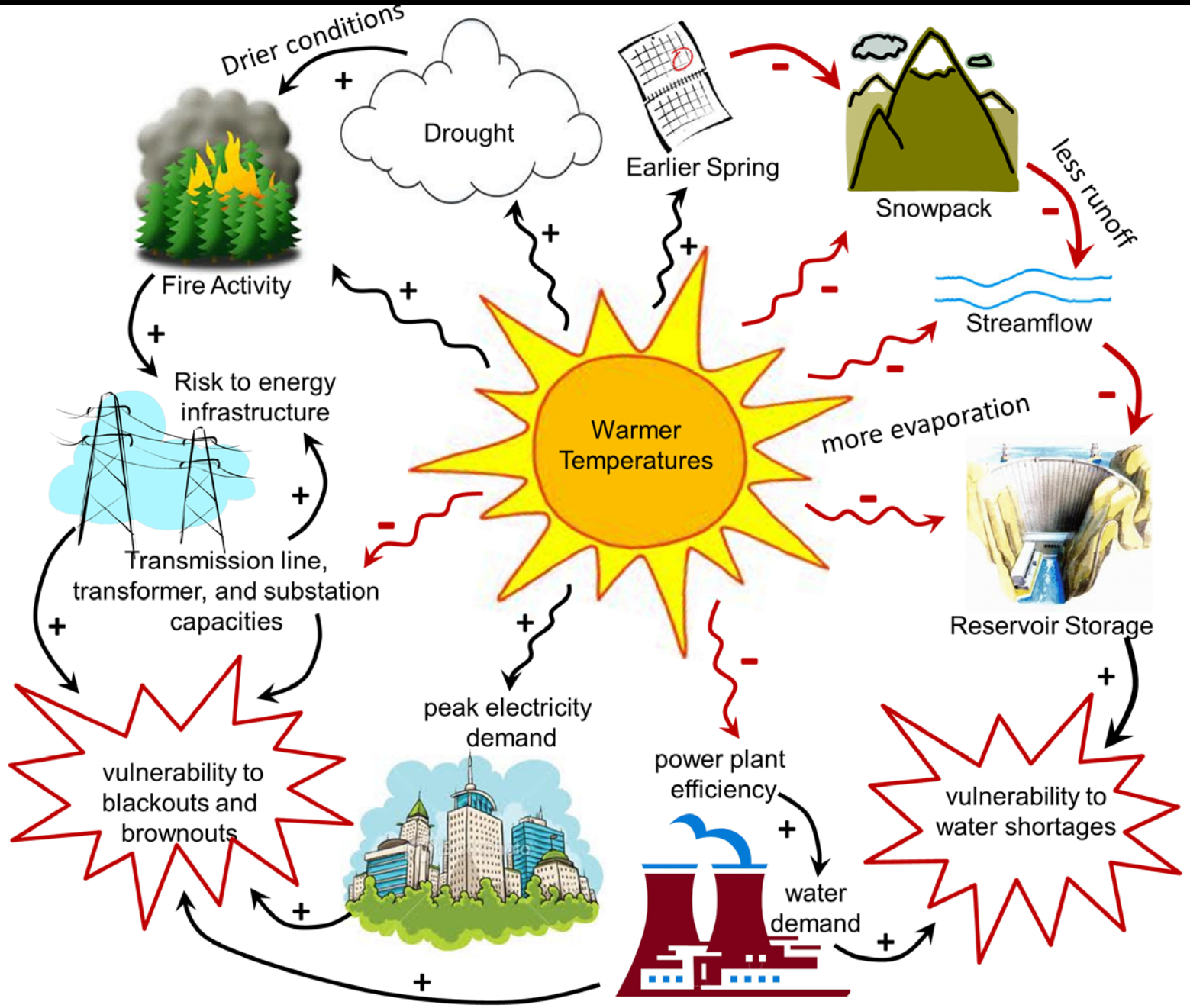
Reduced Electricity Generation

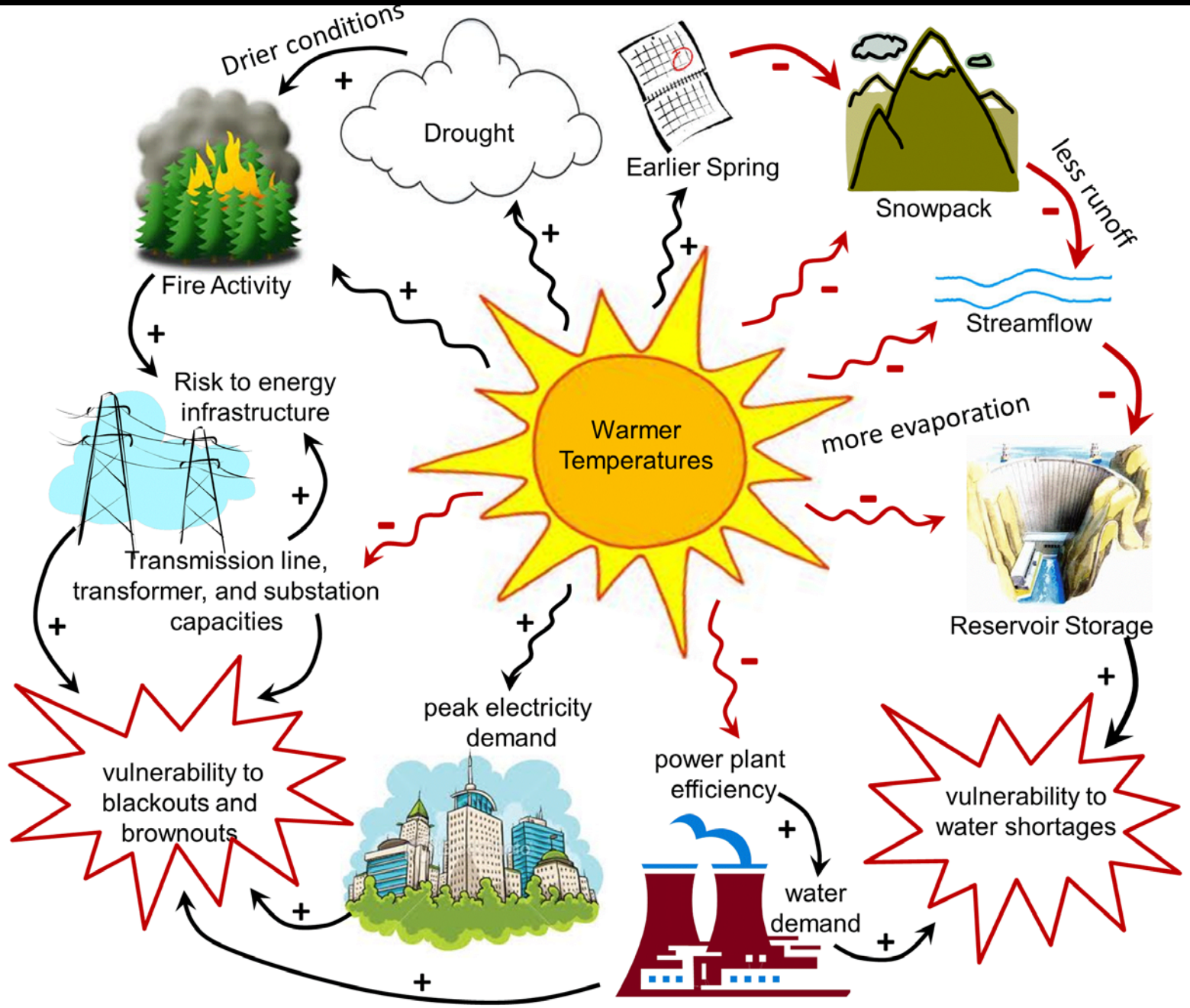


Average reductions in summertime capacity by mid-century (2040–2060) for vulnerable facilities in the WECC region. Source: Chester & Bartos 2015



Power Plants that have shut down or reduced output because of climate related water problems from 2006-2013. Source: Union of Concerned Scientists, 2015.


Drier conditions
Drought
Earlier Spring
Snowpack
less runoff
Fire Activity
Streamflow
Risk to energy infrastructure
Warmer Temperatures
more evaporation
Transmission line, transformer, and substation capacities
Reservoir Storage
peak electricity demand
power plant efficiency
vulnerability to blackouts and brownouts
vulnerability to water shortages
water demand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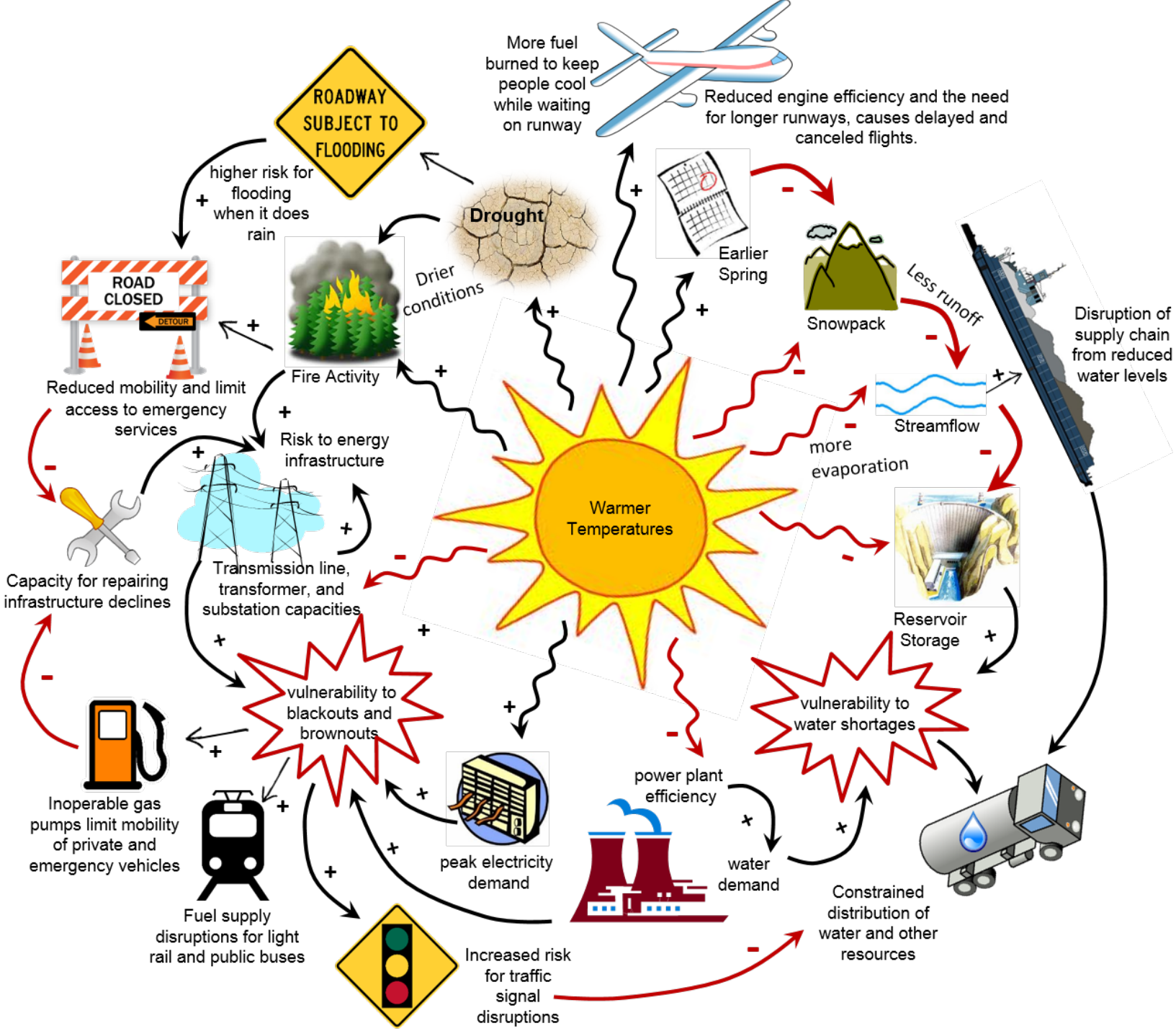

More fuel burned to keep people cool while waiting on runway
Reduced engine efficiency and the need for longer runways, causes delayed and canceled flights.
ROADWAY SUBJECT TO FLOODING
higher risk for flooding when it does rain
Drought
Earlier Spring
Snowpack
Less runoff
Disruption of supply chain from reduced water levels
ROAD CLOSED
DETOUR
Drier conditions
Fire Activity
Reduced mobility and limit access to emergency services
Risk to energy infrastructure
Streamflow
more evaporation
Warmer Temperatures
Capacity for repairing infrastructure declines
Transmission line, transformer, and substation capacities
Reservoir Storage
vulnerability to blackouts and brownouts
vulnerability to water shortages
Inoperable gas pumps limit mobility of private and emergency vehicles
power plant efficiency
peak electricity demand
water demand
Fuel supply disruptions for light rail and public buses
Increased risk for traffic signal disruptions
Constrained distribution of water and other resources

A Catastrophic Extreme Heat Scenario for Phoenix:

- Over **4 million people** could lose direct access to cooling resources, potable water, and/or transportation resources
- In case of **wildfire**: reduced air quality, road closures, increased demand for resources to fight fire
- **Evacuation** or relocations expected within a day or two
  - ~280,000 people without private transportation options
  - Access to fuel limited due to no electricity at gas stations
- **Economic damages** would likely be in the hundreds of millions of dollars
- **Death toll** expected to be high and health facilities would be overwhelmed
  - 1 death -> ~ 100 hospital admissions
- Damages would be worse in **shoulder months** due to students and snowbirds

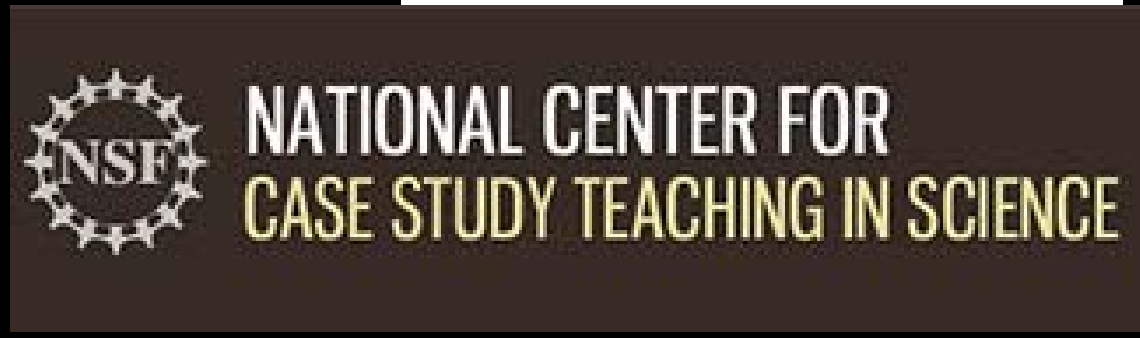
Mitigating Vulnerability and Impacts from Extreme Heat:

- Need to consider **impacts across infrastructure systems**
- Infrastructure managers and planners must **map and define how their systems interact**
- **Emergency response and recovery plans** must be developed around interdependencies
- **Improve infrastructure** to withstand increasing temperature conditions and mitigate heat exposure (Fraser & Chester, in review)
- All of this requires **increased communication, coordination, and awareness** beyond single utilities and departments

Future Work:

Develop methods to **transfer experiences** from one geographic area or political jurisdiction to others.

Future Work:

The Center for Army Lessons Learned

National Center of Infrastructure Case Studies!