

Grid vulnerability due to high heat events

Alex Ricklefs June, 2016

California Center for Sustainable Communities at UCLA

Background

Climate change has increased the amount of extreme weather events

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- Energy sector is especially vulnerable to increases in temperature and decreases in available water sources^{*+}
 - Higher energy consumption levels to maintain thermal comfort
 - High air and water temperatures reduce efficiency of cooling for power plants
 - Oil and natural gas production requires significant amounts of water
 - Reduced efficiency for electricity transmission and distribution systems
 - Flooding and storm surges can damage energy infrastructure



Extreme weather events have become much more common as well as costly over the past three decades.

SOURCES: NOAA 2013A; WEISS AND WEIDMAN 2013A.



Figure 3. Rate of warming in the United States by region, 1901–2011 Source: EPA 2012a

*D.O.E., U.S. Energy Sector Vulnerabilities to Climate Change and Extreme Weather, July 2013 +Union of Concerned Scientists, How Climate Change Puts Our Electricity at Risk – and What We Can Do, April 2014

Renewable energy's effect on the grid

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- Solar energy generates electricity during day time, but causes large spike in grid energy demand at night
- Wind sources produce energy at variable times and levels
- Energy storage is needed to balance out renewable energy generation
- Demand spike puts strain on grid
 - Traditional power plants produce constant energy rates and cannot be switched on/off quickly
 - 'Peaker' plants are needed to meet demand spikes
 - Natural gas plants that can be turned on and off quickly
 - Expensive and produce GHG



SOLAR ROOFTOP POTENTIAL IN LOS ANGELES COUNTY



Background

 Global climate models can predict temperature increases based on representative concentration pathway (RCP) scenarios^{*,+}

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- Five global climate models and two RCPs for mid and end century projections were used
- RCP 2.6: GHG emission reductions over century
- RCP 8.5: Continued 21st century GHG emissions increases
- Monthly mean temperature increases for 2 km by 2 km grids were determined for LA county^{*,+}
- Heating and cooling needs are expected to be the biggest factor to increase energy consumption



(c) End-Cen (RCP2.6)





FIG. 2. Ensemble mean of downscaled annual-mean surface warming (°C) for (a) midcentury (2041–60) under RCP2.6, (b) midcentury under RCP8.5, (c) end of century (2081–2100) under RCP2.6, and (d) end of century under RCP8.5. White contours are plotted at 1000-m elevation.

*D. Walton, F. Sun, A. Hall, S. Capps, *A Hybrid Dynamical-Statistical Downscaling Technique. Part I: Development and Validation of the Technique,* Journal of Climate, 2015

⁺F. Sun, D. Walton, A. Hall, *A Hybrid Dynamical-Statistical Downscaling Technique. Part II: End-of-Century Warming Projections Predict a New Climate State in the Los Angeles Region*, Journal of Climate, 2015c

4



Task 3: Electricity Demand Increases Under Climate Change

- Estimate how electricity demand will change with temperature change, at census tract scale across Los Angeles to 2060
- Develop calibrated prototypical models of current and future building electricity use
- Assess how building stock changes or greater densities will impact demand
- Analyze the effects of various global climate model 2 km results on electricity demand across climate zones

Grant Tasks

- Task 4: Vulnerability of the Electricity System and Adaptation Planning
 - Use existing models that characterize how climatological and hydrological changes will impact electricity supply across the Western Electricity Coordination Council region to characterize how Los Angeles utilities might be impacted by climate change.
 - Assess how electricity mix changes including local renewables (i.e., photovoltaics) will reduce the demand for centralized power systems.
 - Estimate how transmission and distribution networks to Los Angeles County as well as substations will be impacted by hotter temperatures by evaluating the thermal ratings of the infrastructure
 - Make recommendations for reducing vulnerabilities by suggesting local and regional energy mix changes and where utility providers can expect that more transmission and distribution capacity will be needed
 - Prepare a *Future Grid Vulnerability Report* that describes the existing vulnerabilities of the grid throughout LA County at a substation level
 - Prepare visualizations (using ArcGIS) of existing grid vulnerabilities to enable the IOU, local governments, and regional agencies to better understand the location and scale of projected heat events



- What opportunities for energy storage exist on the supply side?
 - How will the existing grid react to storage, what upgrades are needed
 - How can storage be used to remove the need of peaker plants
- How will commercial building energy consumption change due to more high heat events?
- How will heat high predictions impact UHI?

- How can cool roofs and pavements be utilized?
- How is the urban infrastructure changing and how can energy efficient changes be made?
- How significant are standby power draws and how can they be reduced?
- What is the embodied energy in new technologies for energy efficiency and how do they effect the life cycle analysis?

- Electricity demand for SCE territories can be obtained for CAISO
- Hourly temperature data for SCE territories
 - Hourly temperature data was pulled for 4 areas within SCE territory:
 - Camarillo (Ventura County)
 - Edwards Air Force Base (Los Angeles County)
 - Long Beach (Los Angeles County)
 - Riverside (Riverside County)
 - Temperatures were averaged across 4 locations to approximate SCE area temperature



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Electricity Demand



Electricity demand for average temperature days (T_{max} , T_{min}) June 4th: (70,61) Nov 3rd: (70,53) March 4th: (70,57) April 10th: (70,58)

Electricity demand for cold temperature days (T_{max}, T_{min}) Nov 16th: (63,50) Dec 14th: (59,47) Jan 7th: (59,45) Feb 1st: (58,43)



Electricity demand for hot temperature days (T_{max}, T_{min}) Aug 15th: (96,71) Aug 28th: (97,73) Sept 9th: (101,76) Oct 11th: (100,74)

- Hot temperature days result in a significant increase in total electricity demand
- Cold temperature days have a larger electricity demand than days with an average climate (high of 70, low around 55-60)
- Temperature, along with the hour of the day, play an important role in the shape of the electricity demand profile

- 2-D curve fit (hourly temperature vs. electricity demand)
 - 2nd order Exponential fit
 - R squared of 0.5838
 - 2nd order Power fit

- R squared of 0.5851
- 3rd order Fourier series fit
 - R squared of 0.5796





Hourly Temperature



Hourly Temperature

3-D plot fitting

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- Hour, hourly temperature, electricity demand (MW)
- 3-D Polynomial fit had a much better agreement (R squared of 0.9895)
- Edges (high temperatures at early and late hours) are not comparable due to data
- Comparison to electricity forecast data
 - Using temperature predictions, how does electricity demand fit compare with CEC forecasts



12

Energy Storage

 Renewable energy sources produce time variant electricity

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- Peak generation times may not coincide with peak demand times
- Excess levels of energy can be produced at peak generation times
- Storage technologies can help renewable sources mirror demand profiles
- Different types of storage for different applications
 - Storage needs are very different at the local community level than the macro grid level



Illustrative example of peak demand vs. peak solar $\!\!\!^*$

Electricity Storage Technologies





- Where does energy storage make sense and what type of storage technology?
 - Electricity generation level? Community level? Individual homes?
 - Thermal energy storage? Chemical batteries? Kinetic storage?
- Grid analysis for storage capabilities
 - SCE grid capacity data injunction with energy consumption and solar potential data can illustrate vulnerable areas
 - Analysis can be used to generate a map of areas for community or home level storage for solar additions
 - SCE grid capacity data and eGRID data can highlight measures to replace peaker plants and areas that might be in need of storage

Commercial Building Energy Use

- Similar to Janet Reyna's work* on residential building energy consumption, the impact of heat on commercial building energy use is of importance
 - Analysis of commercial building stock, vintage, and consumption patterns
 - Modeling energy consumption using Energy Plus and calibrating with Energy Atlas data
- Can commercial buildings be grouped based on size, age, and use?
 - Energy Atlas data can provide building characteristics to determine the effectiveness and feasibility of grouping
- Modeling tools
 - Energy Plus is a DOE and NREL developed tool that is widely used in building energy analysis
 - NREL has reached out to validate their Open Studio API (URBANopt) using Energy Atlas data



other

13%

- Commercial building survey for Los Angeles
 - Commercial building characteristics (i.e. equipment types, operating hours, envelope) are not widely available
 - Can reach out to building owners to see if they are interested in performing whole building energy modeling

office equipment



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3% computing 6% water heating 7% lighting 10% cooking 7% total energy use 6.963 trillion Btu cooling 9% refrigeration eia ventilation 10% 10%

space heating 25%

Source: U.S. Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey.

Average building end use energy break down

Energy use intensity for different commercial building types

Urban Heat Island

- Reductions to urban heat island (UHI) may provide noteworthy energy savings as temperatures increase
 - Savings can come from cool roof or cool pavement measures
- Information needed to UHI analysis:
 - Hourly temperature, solar irradiance, wind, and cloud coverage data (NREL Solar Radiation Database*)
 - Roof albedo data (Berkeley Lab⁺)
 - Pavement albedo data (?)
- LBL has additional UHI technical resources available⁻



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- heatisland.lbl.gov/resources/technical-resources

^{*} nsrdb.nrel.gov

⁺ albedomap.lbl.gov/

Plug Loads and Standby Power Draw

- Plug loads represent 10% and 8% of electricity consumption for residential and commercial buildings, respectively, in 2010*
- Plug loads increase the electricity demand (in kW) that a building draws and the reactive power that the grid will need to supply
 - DVARs (dynamic volt-amp reactive power) contribute additional complexity in grid infrastructure upgrades and require oversizing
- Standby power draw can contribute to plug load energy consumption⁺
- Older devices have higher standby power loads
 - In 2007, CA passed an appliance standard reducing new device standby power to 0.5 W
- Energy conservation can take place through technology or behavioral changes⁻

Embodied Energy and Life Cycle Assessment

- Embodied energy is "the sum of all the energy required to produce any goods or services"
- High tech solutions have been a key focus for addressing issues involving energy efficiency and sustainability

- However, technology heavy approaches typically large embodied energy costs
- Behavioral changes on the other hand, have no embodied energy costs but are typically disregarded as being low tech or 'dumb'
- What does the embodied energy of energy efficiency technologies look like, and how does it affect the benefit that these technologies provide?