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Climate Change in Los Angeles County: Grid Vulnerability to Extreme Heat

University of California Los Angeles

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CLIMATE CHANGE IN LOS ANGELES COUNTY: GRID VULNERABILITY TO EXTREME HEAT

A Report for:

California's Fourth Climate Change Assessment

Prepared By:
Daniel Burillo[1], Mikhail Chester[1], Stephanie Pincetl[2], Eric Fournier[2], Daniel Walton, Fengpeng Sun, Marla Schwartz, Katharine Reich[2], Alex Hall[2]

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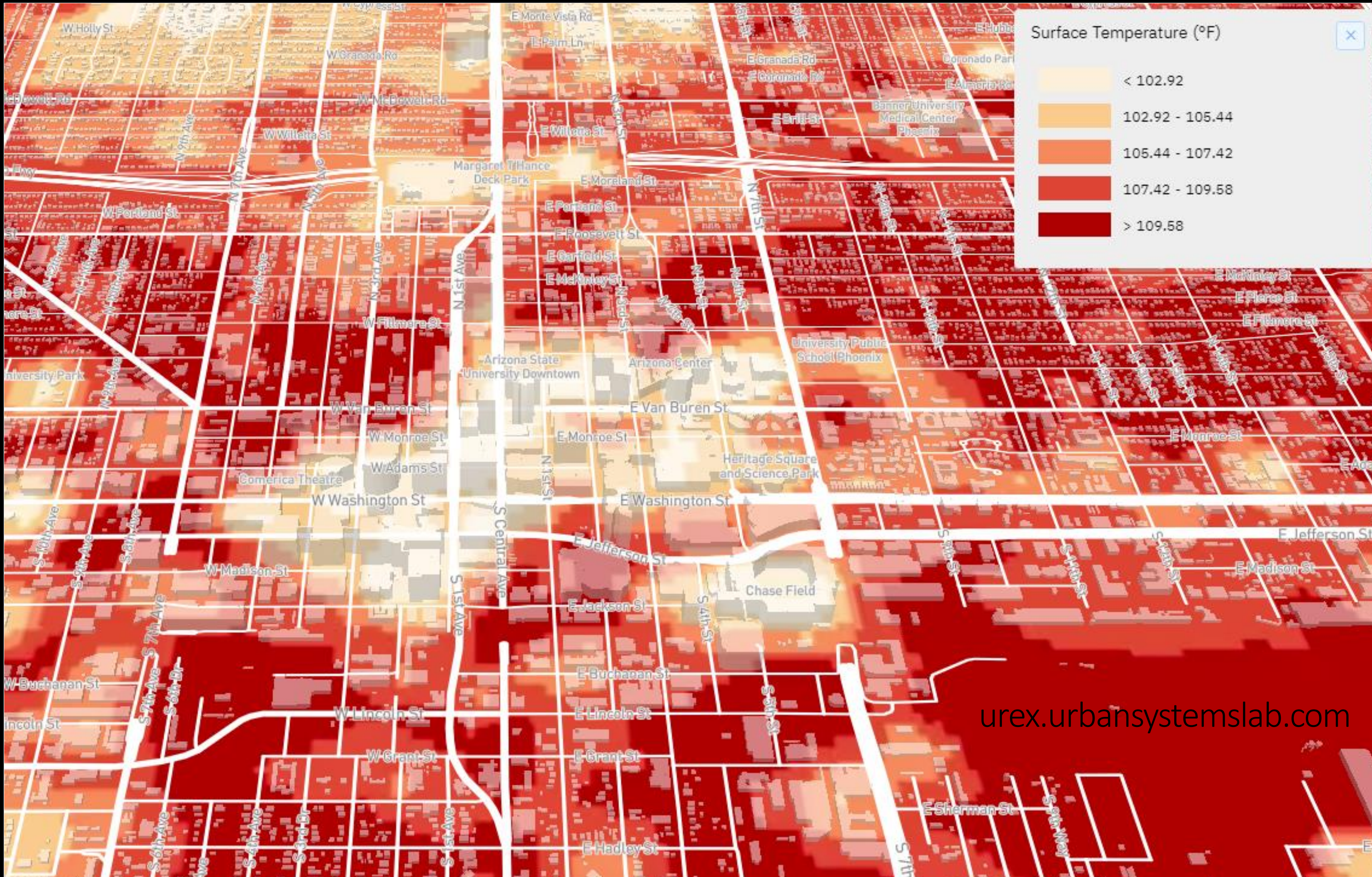
Edmund G. Brown, Jr., *Governor*

August 2018
CCCA4-CEC-2018-013



Infrastructure vulnerability analysis so far has been largely synonymous with spatial coincidence of hazards (i.e., exposure analysis).

LBNL-Report

ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

ESTIMATING RISK TO CALIFORNIA ENERGY INFRASTRUCTURE FROM PROJECTED CLIMATE CHANGE

Jayant Sathaye, Larry Dale, Peter Larsen, Gary Fitts,
Lawrence Berkeley National Laboratory (LBNL)

Kevin Koy and Sarah Lewis,
Geospatial Innovation Facility, University of California at Berkeley

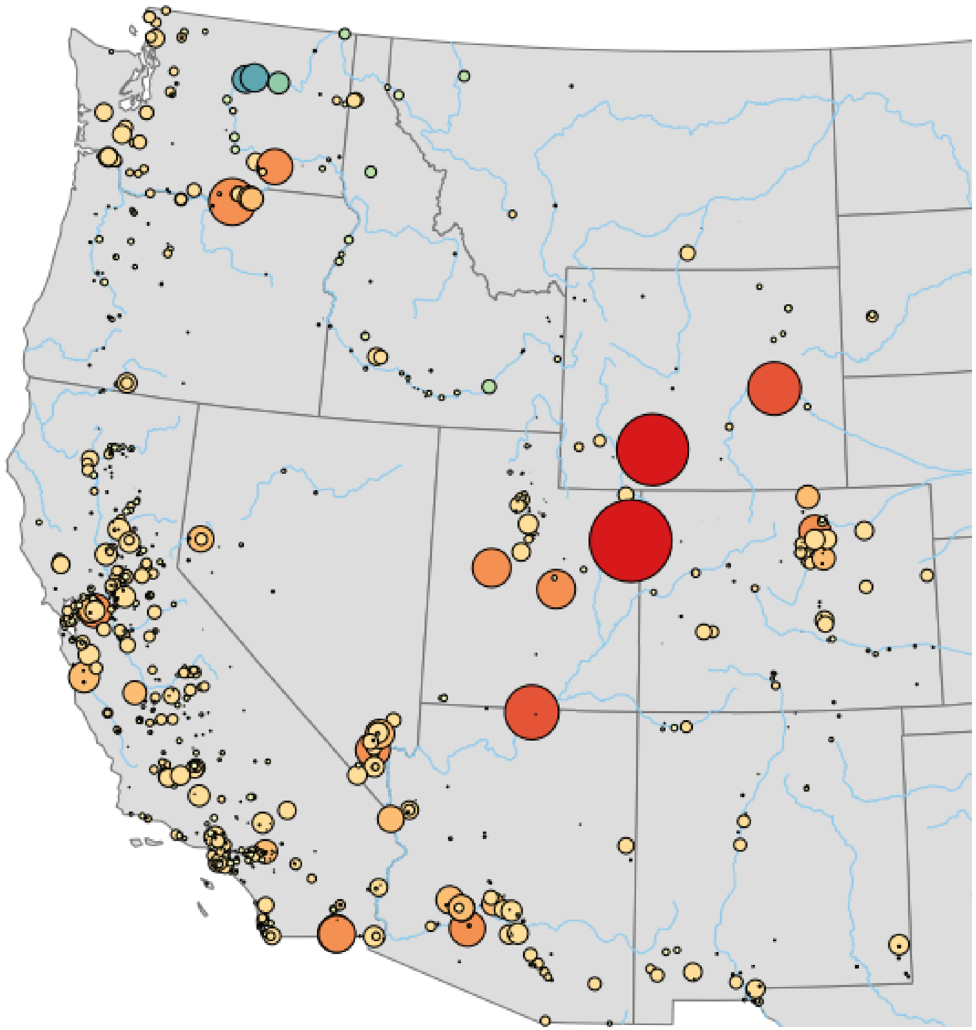
Andre Lucena, Federal University of Rio de Janeiro

Environmental Energy Technologies Division

June 2011

This work was supported by the the California Energy Commission through the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

Impacts of Climate Change on Electric Power Supply in the Western United States, M Bartos and M Chester, Nature Climate Change, 2015, 4(8), pp. 748-752, doi: 10.1038/nclimate2648.

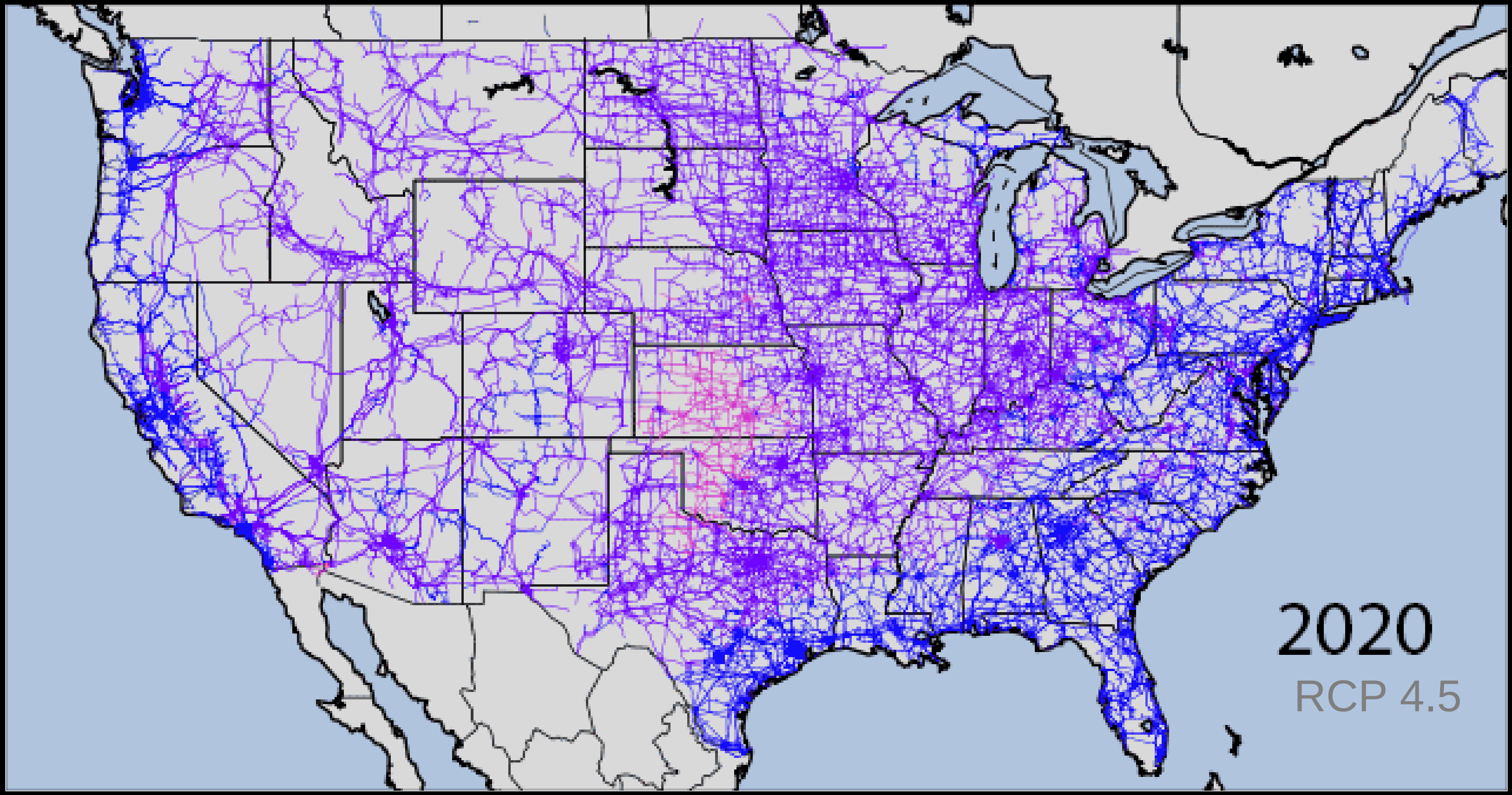


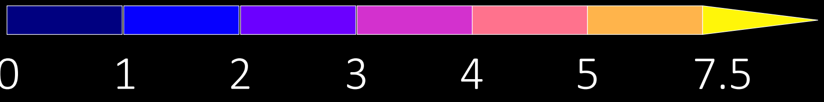
Capacity Reductions (MW)

- 100 to 150
- 50 to 100
- 20 to 50
- 0 to 20
- -10 to 0
- -20 to -10

- 46% of generating capacity is vulnerable.
- Generating capacity reductions:
  - Up to 3% under average summertime conditions.
  - Up to 8.8% under 10-year drought
- 25% reduction in planning reserve margin under a 10 year drought.

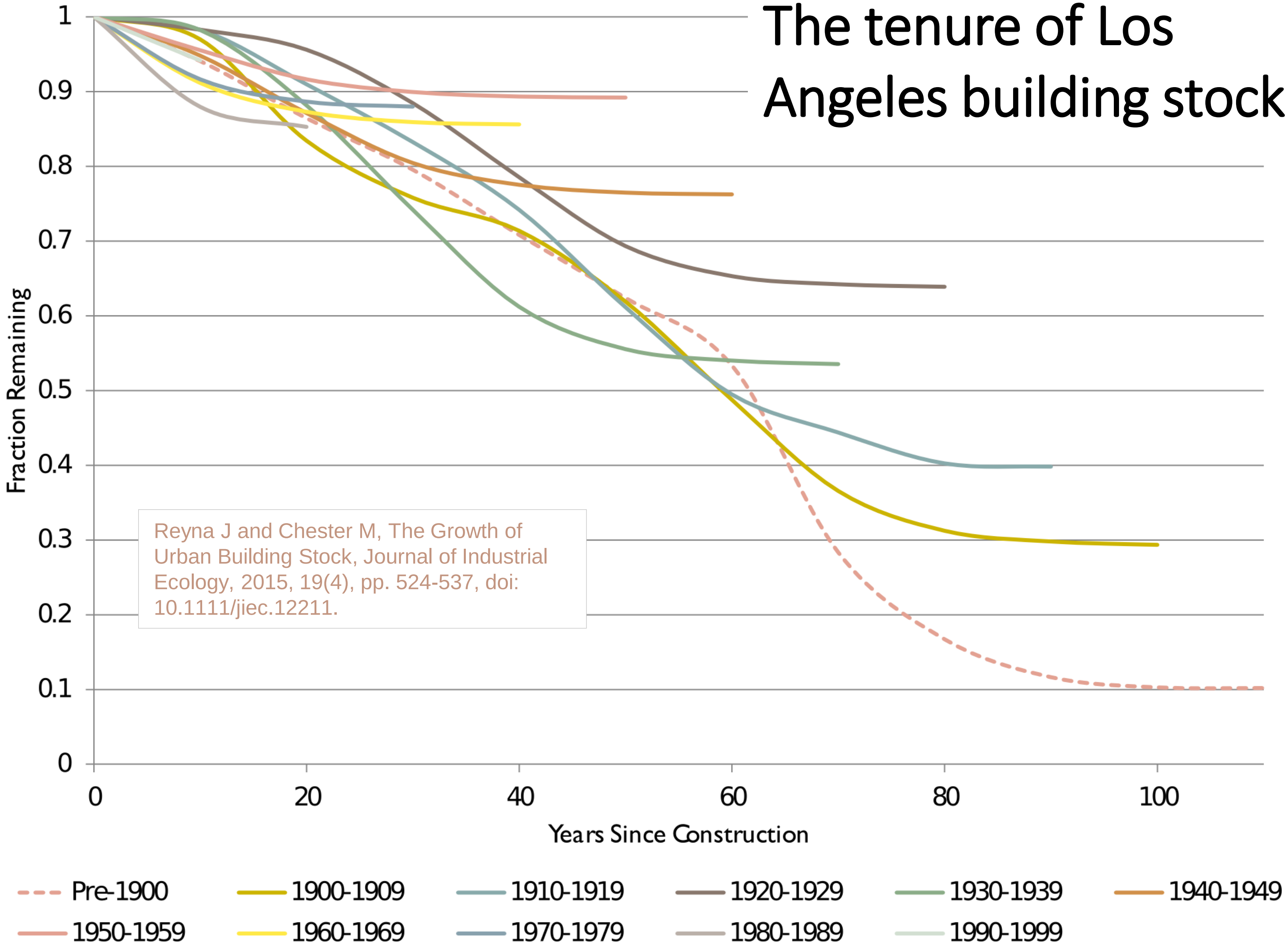
By mid-century, summertime transmission capacity may by reduced by 1.9%–5.8%





Impacts of Rising Air Temperatures on Electric Transmission Ampacity and Peak Electricity Load in the U.S., M Bartos, M Chester, N Johnson, B Gorman, D Eisenberg, I Linkov, & M Bates, Environmental Research Letters, 2016, 11(11), doi: 10.1088/1748-9326/11/11/114008.

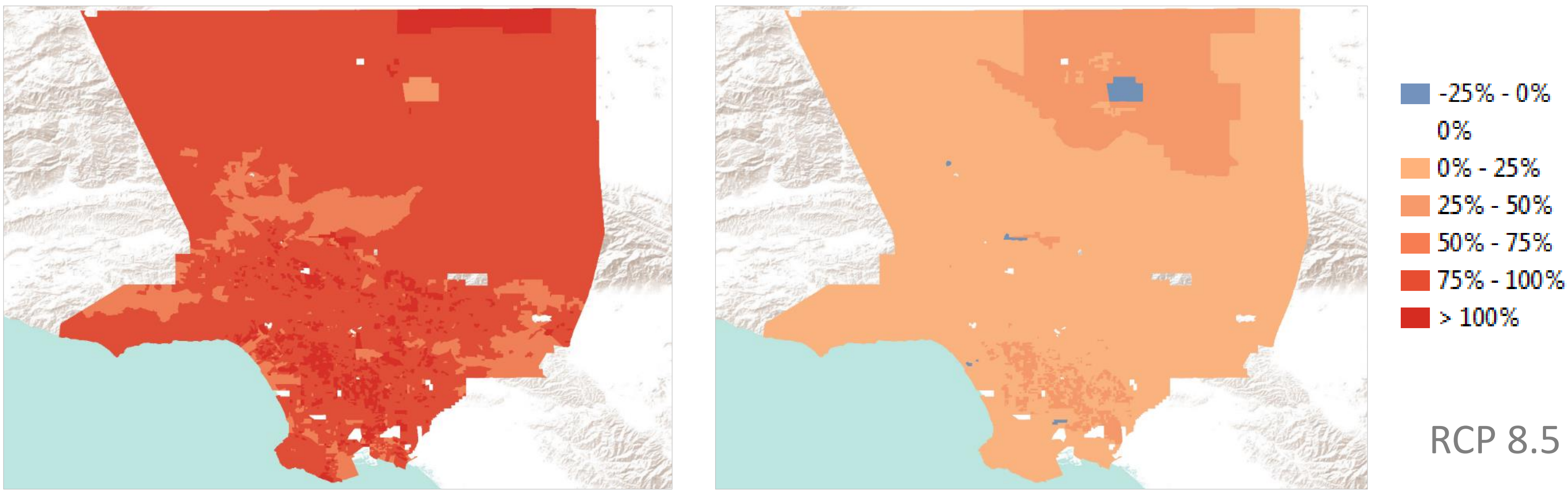
The tenure of Los Angeles building stock



Electricity consumption in Los Angeles County can double with climate change

Heavy AC Adoption with Few Gains in Efficiency

Heavy AC Adoption with Strong Gains in AC & Appliance Efficiency



Energy Efficiency to Reduce Residential Electricity and Natural Gas Use Under Climate Change
Janet Reyna and Mikhail Chester, Nature Communications, 2017, 8, 14916, doi: 10.1038/ncomms14916

Temperature Change

Generation

+

Transmission & Distribution

+

Supply Infrastructure

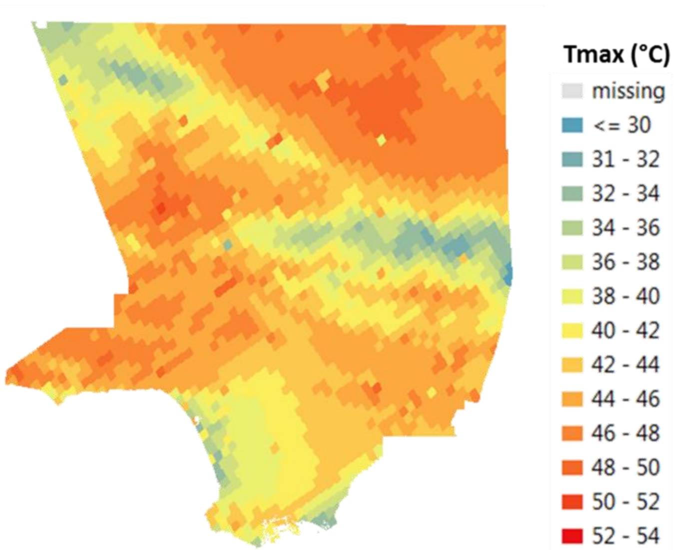
+

Demand Changes

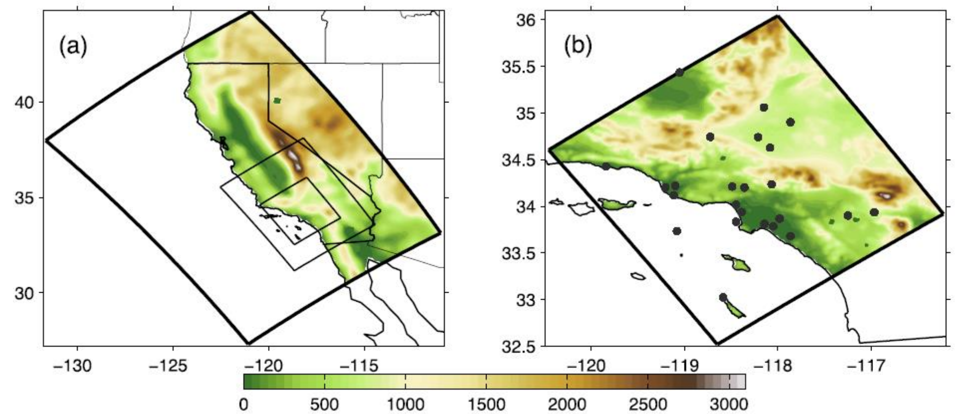
How and where might rising temperatures create bottlenecks in the Los Angeles grid?

Temperature Change

Historical temperatures (1981-2000)

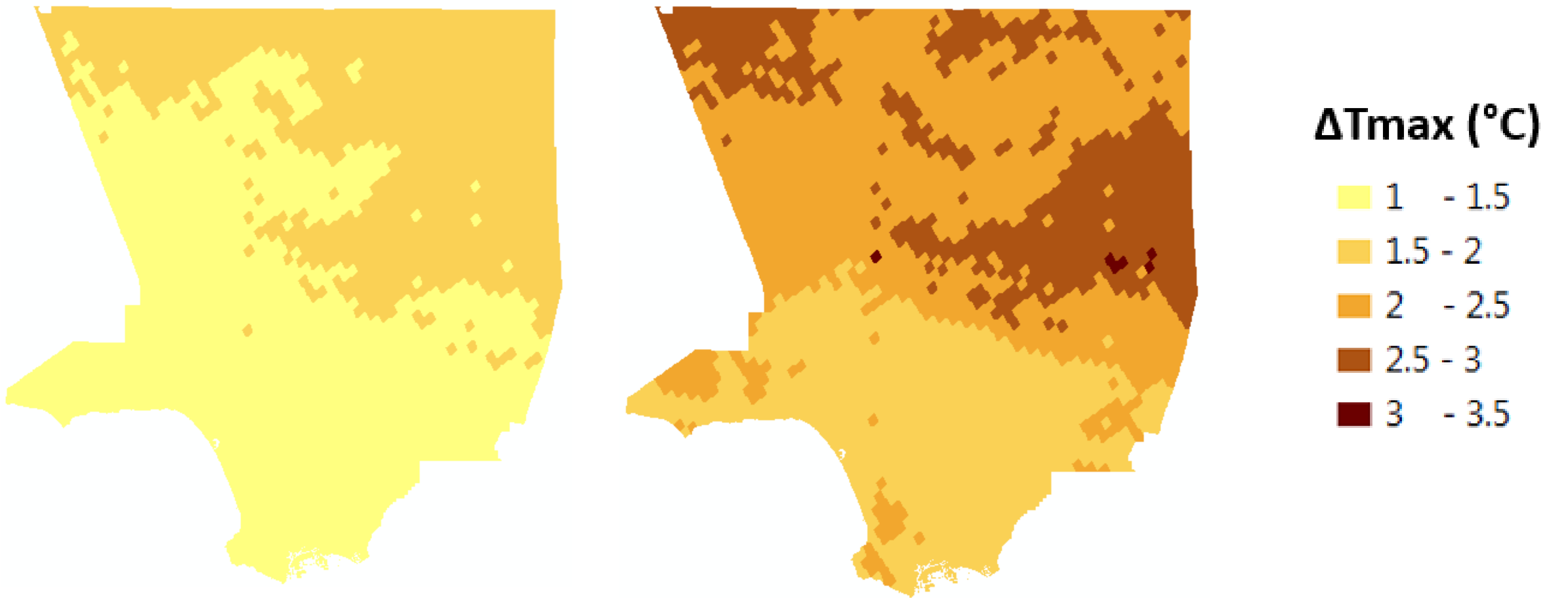


Hall Lab (UCLA) WRF Dynamical and Statistical Downscaling (2 km^2)



Future Scenarios

2040-2060 (RCP 4.5) | **2040-2060 (RCP 4.5)**



Composite: Highest project T_{max} in each grid cell
Hottest Day: T_{max} in each grid cell of hottest day in county

Demand Change

Building Energy Modeling

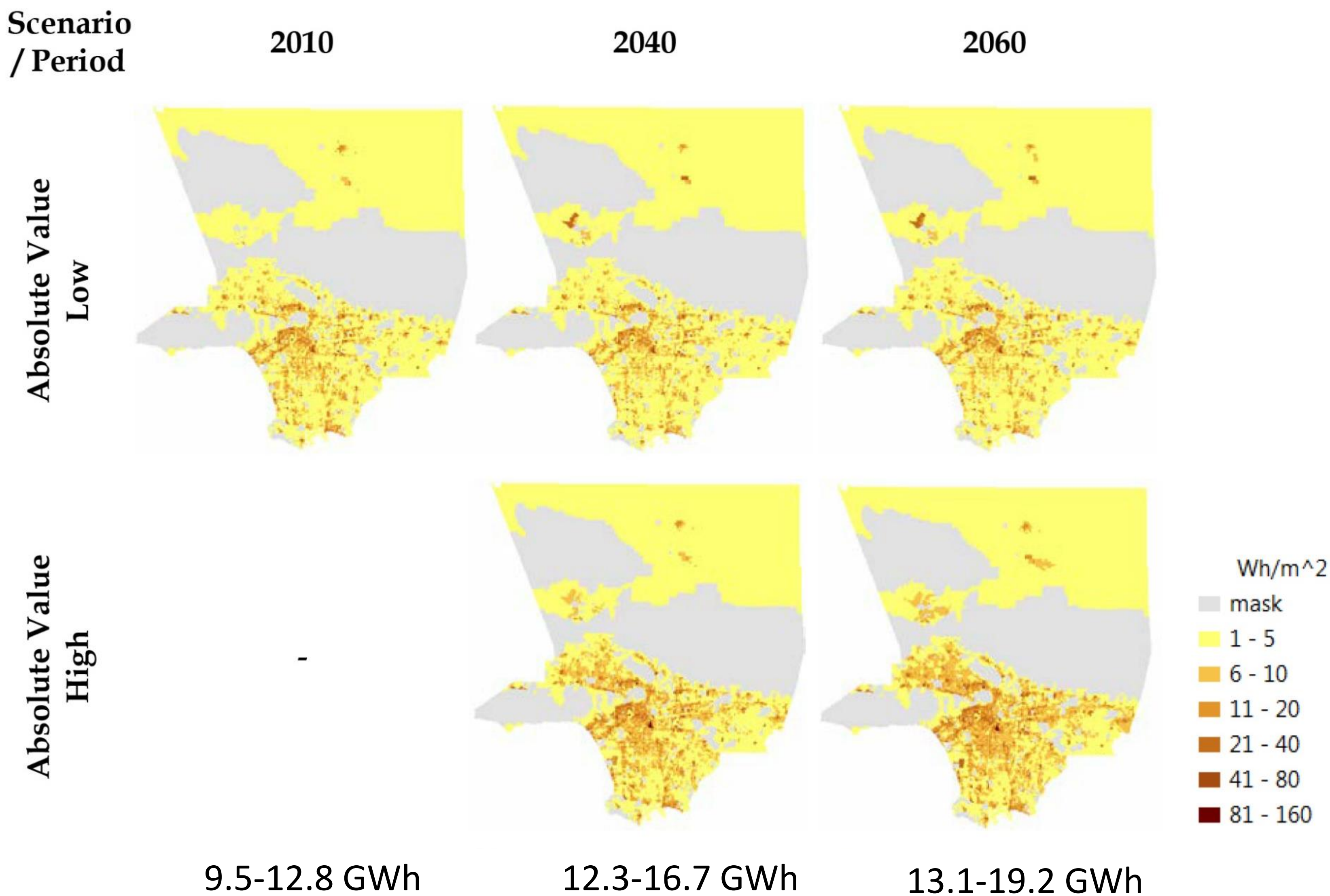
Building Turnover

Population Change

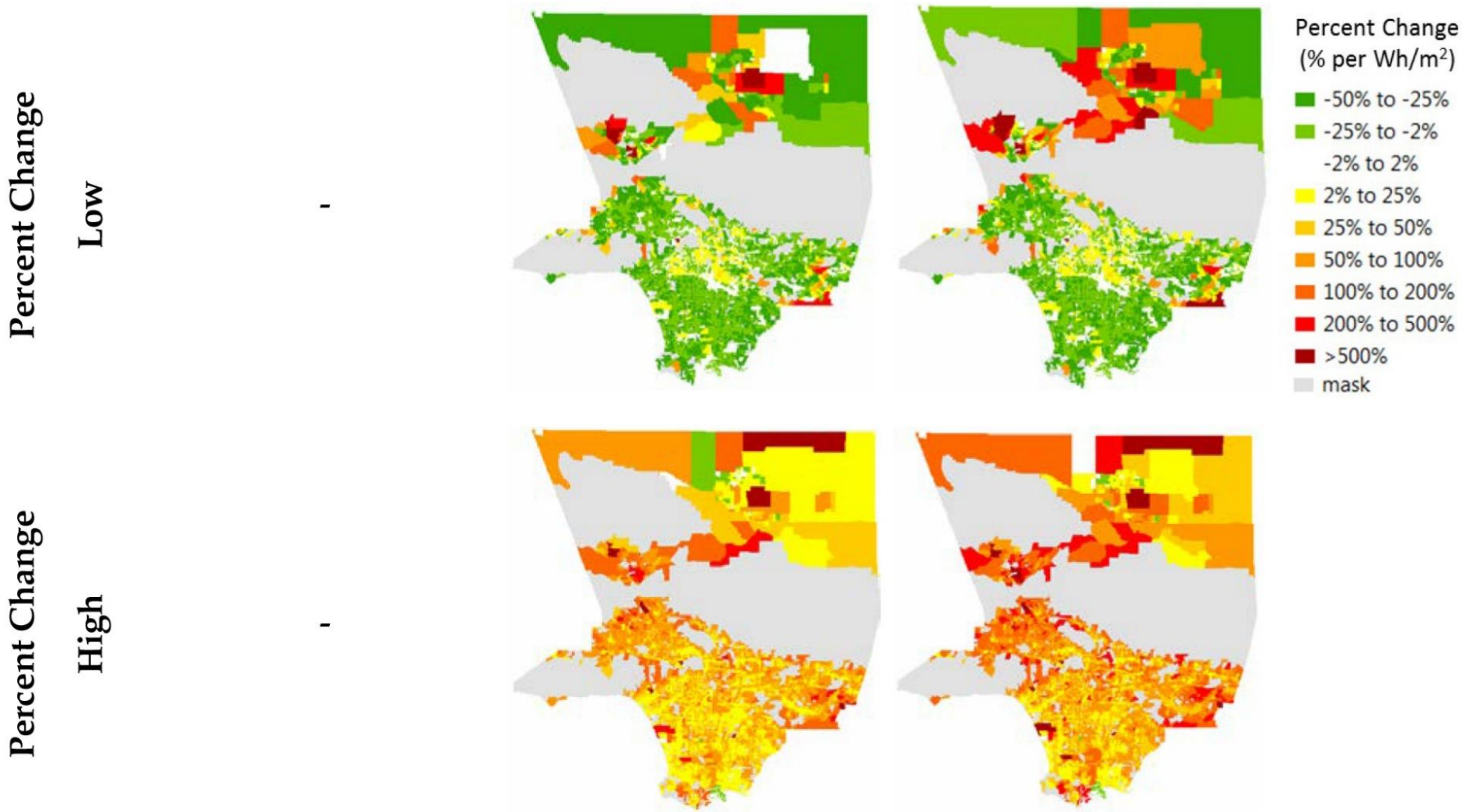
9.7m currently
SCAG: 10.3m (2040), 10.9m (2060)
DOF: 11.4m (2040), 12.8m (2060)

AC Saturation & Turnover

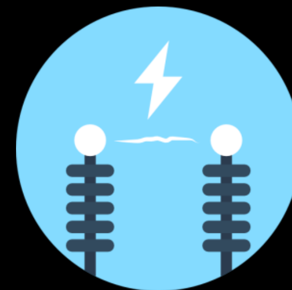
Appliance Efficiency



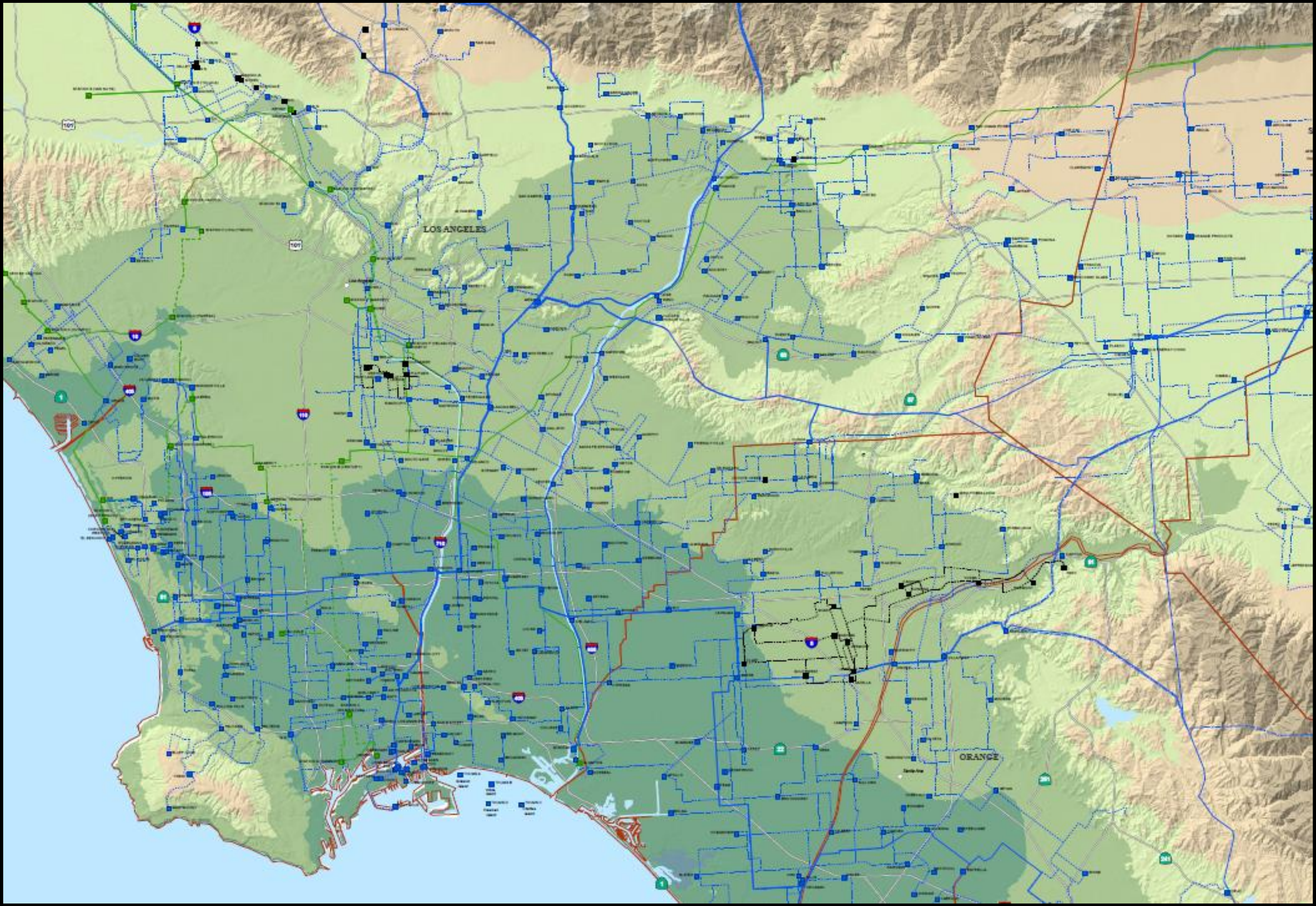
Final report Figure 12. Composite peak demand projections for base and future period high and low scenarios.



Final report Figure 12. Composite percent change projections for base and future period high and low scenarios.

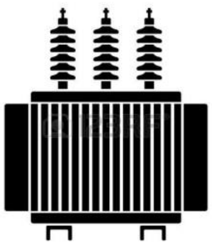


Infrastructure & Supply

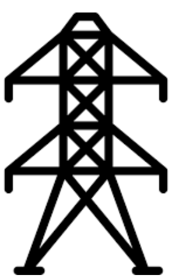


LOS ANGELES
ORANGE

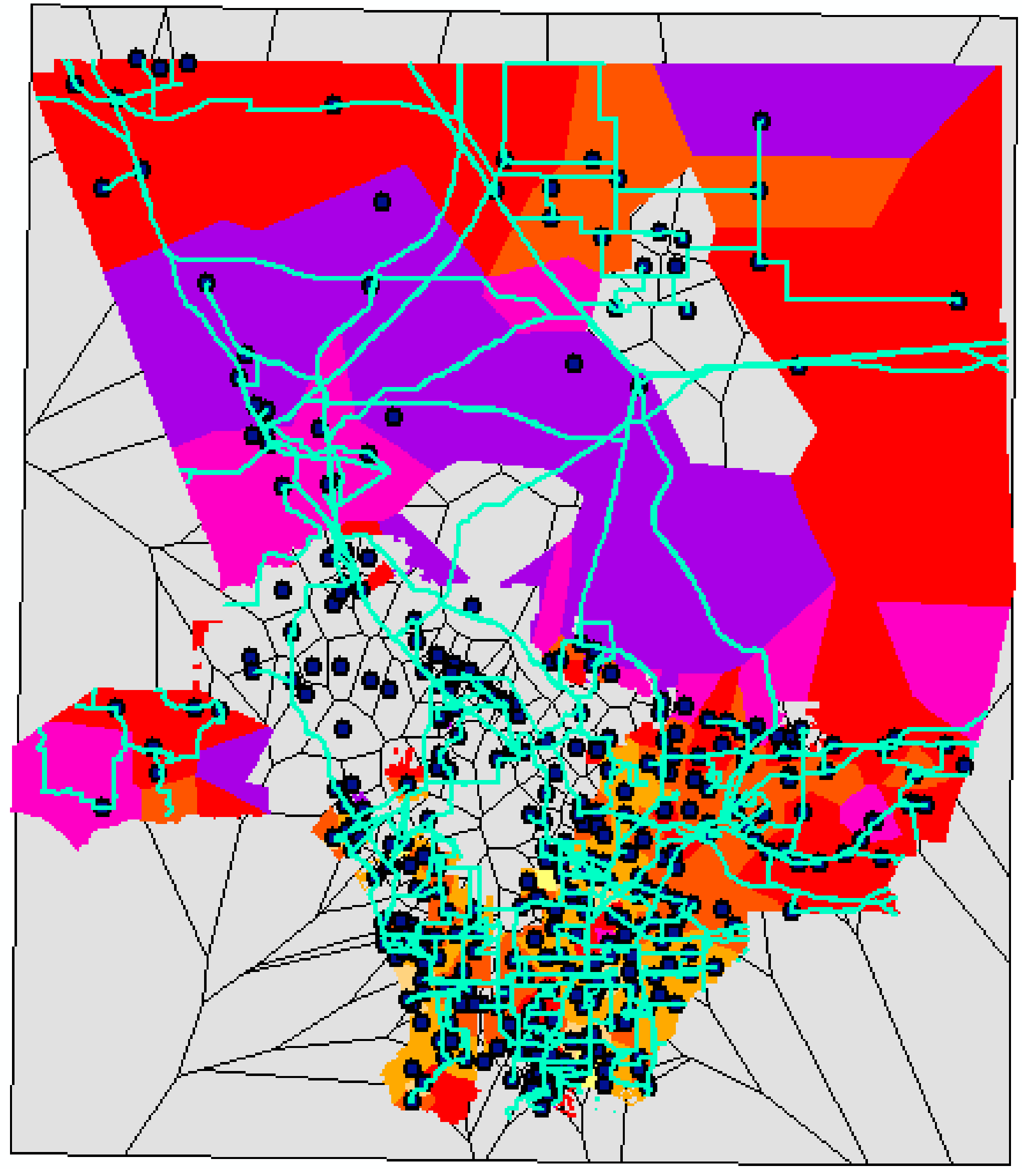
Delivery Infrastructure



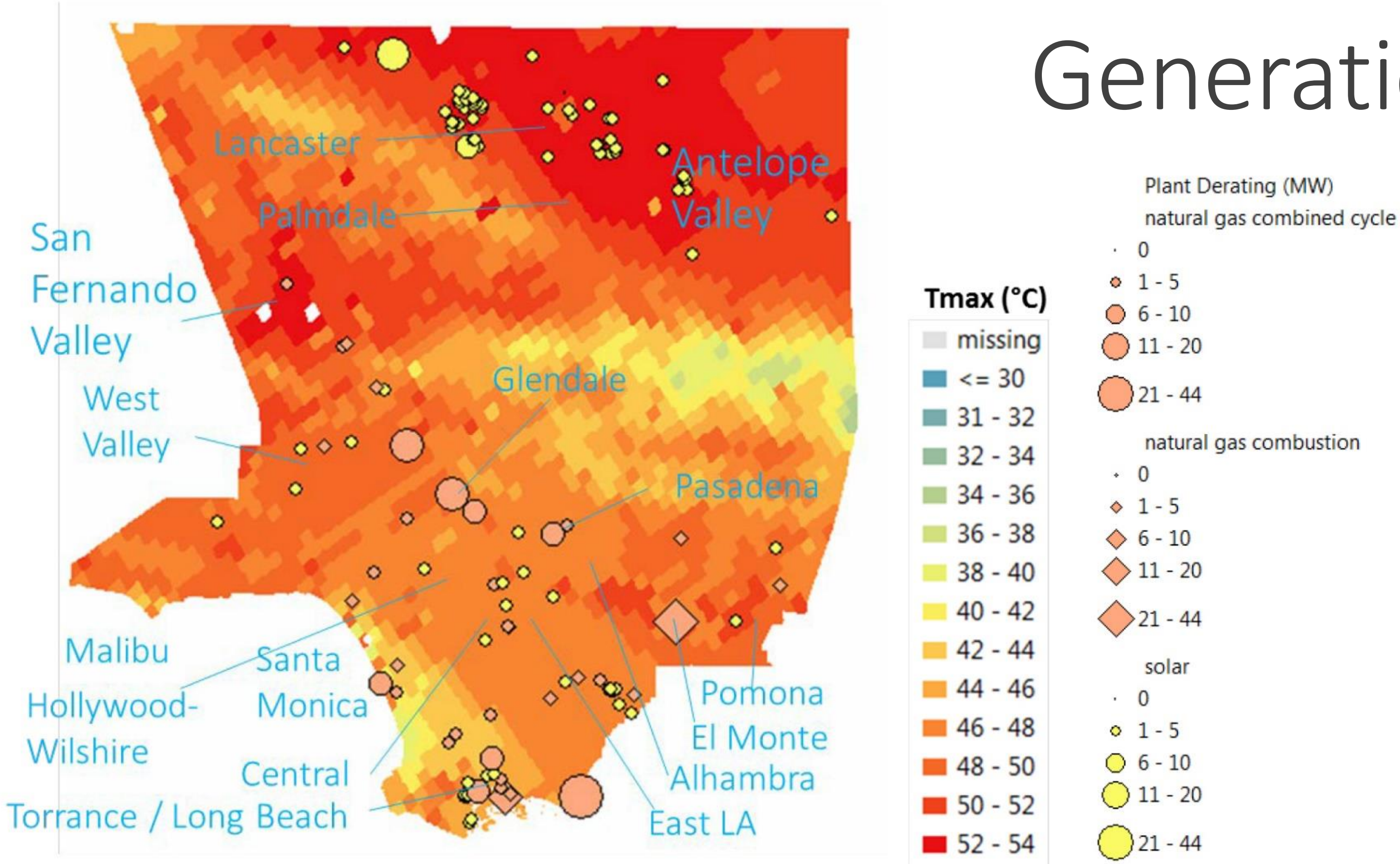
Substations



Transmission Lines



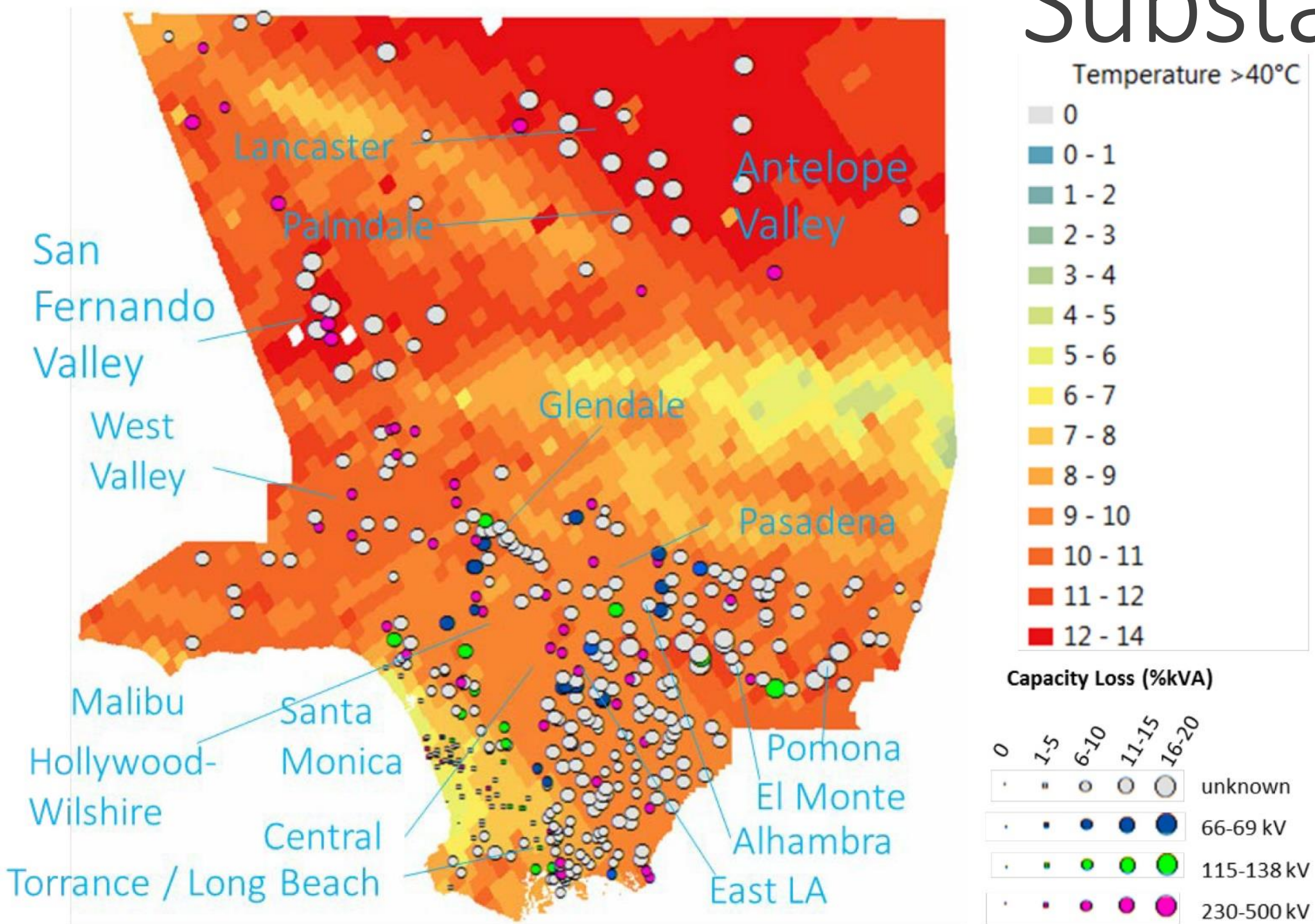
Generation



Of LAC's 13.5 GW of local power generation, up to 240 MW (1.8%) is vulnerable to rises in air temperature. For worst-case 2060 temperature projections under RCP 8.5, the majority of the vulnerable generation capacity is the 23 combined cycle and 15 combustion natural gas plants located in the San Fernando Valley and on the outer basin areas away from the ocean.

Final report Figure 23. Map of worst-case losses in plant capacity for composite temperatures in 2060 RCP 8.5.

Substations



Of LAC's 410 substations, 99% are vulnerable to air temperatures over 40 °C (104 °F), including reductions in loadability of up to 20% of their kVA ratings.

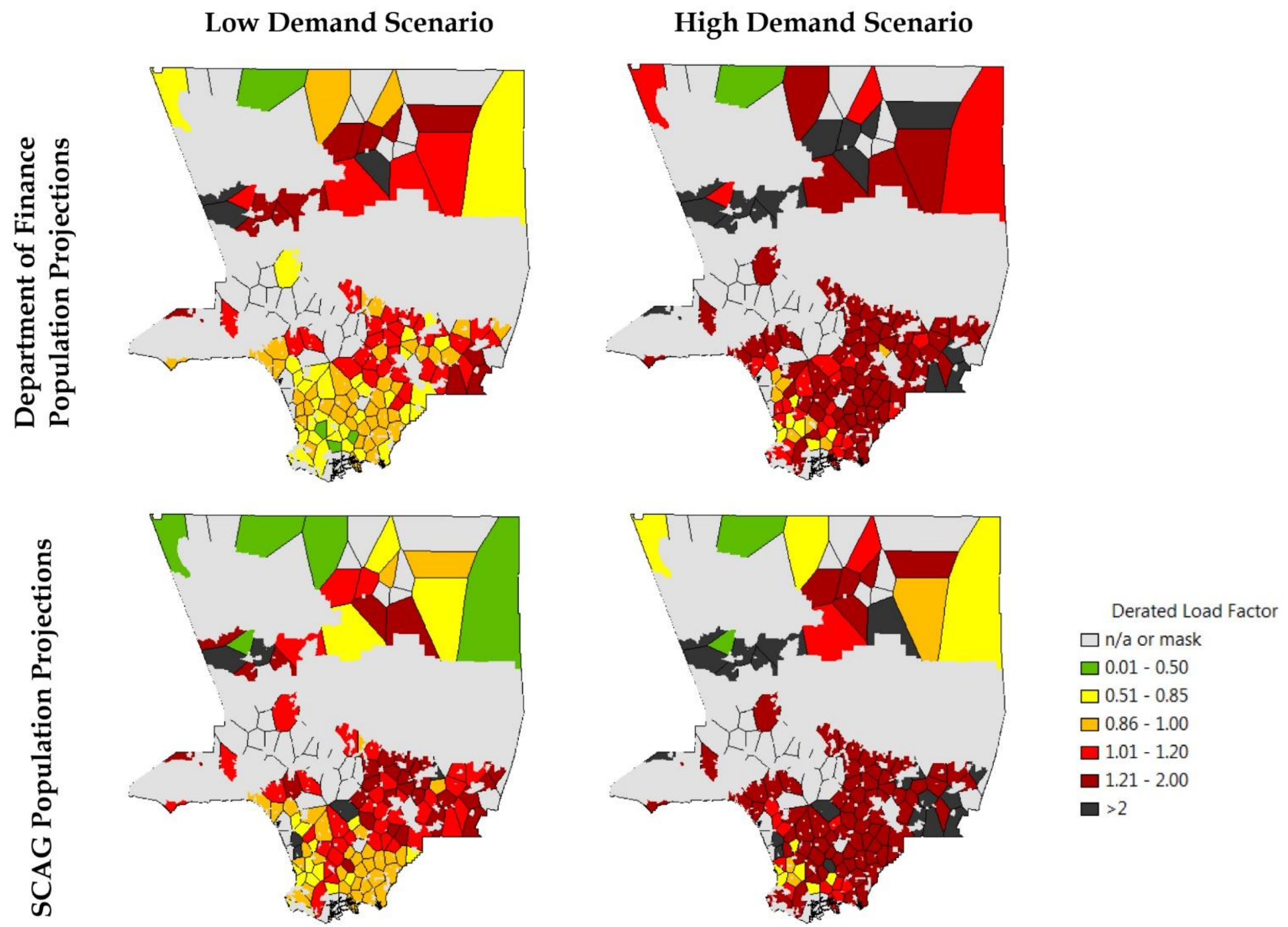
Final report Figure 25. Map of worst-case losses of substation capacity for composite temperatures in 2060 RCP 8.5.

Substation Risk

Load Factor	Risk Level	Reference	Description
n/a	Unknown	n/a	Substation(s) exists in this space according to DHS database [76], but not SCE DERiM [77], so loading data were unavailable.
0.01-0.5	Very Safe	Assumption	Negligible thermal wear, probably n-2 reliable if in parallel/redundant configuration.
0.51-0.85	Safe	15% rule	Very low thermal wear, probably only n-1 reliable if in parallel/redundant configuration.
0.86-1.00	Caution	15% rule	Non-negligible thermal wear, probably not n-1 reliable.
1.01-1.20	Warning	[70], [8]	Thermal wear, component overloaded, automatic switching may occur in 24 hours to 30 days if loading continues at this level, or sooner with sub-hourly spike, depending upon switch gear settings.
1.21-2.00	Emergency	[70], [8]	Significant thermal wear, component very overloaded, automatic switching will occur in 30 min, or sooner with sub-hourly spike, depending upon switch gear settings.
> 2	Outage	[8]	Extreme thermal wear, switchgear will automatically trip to prevent hardware damage and failure.

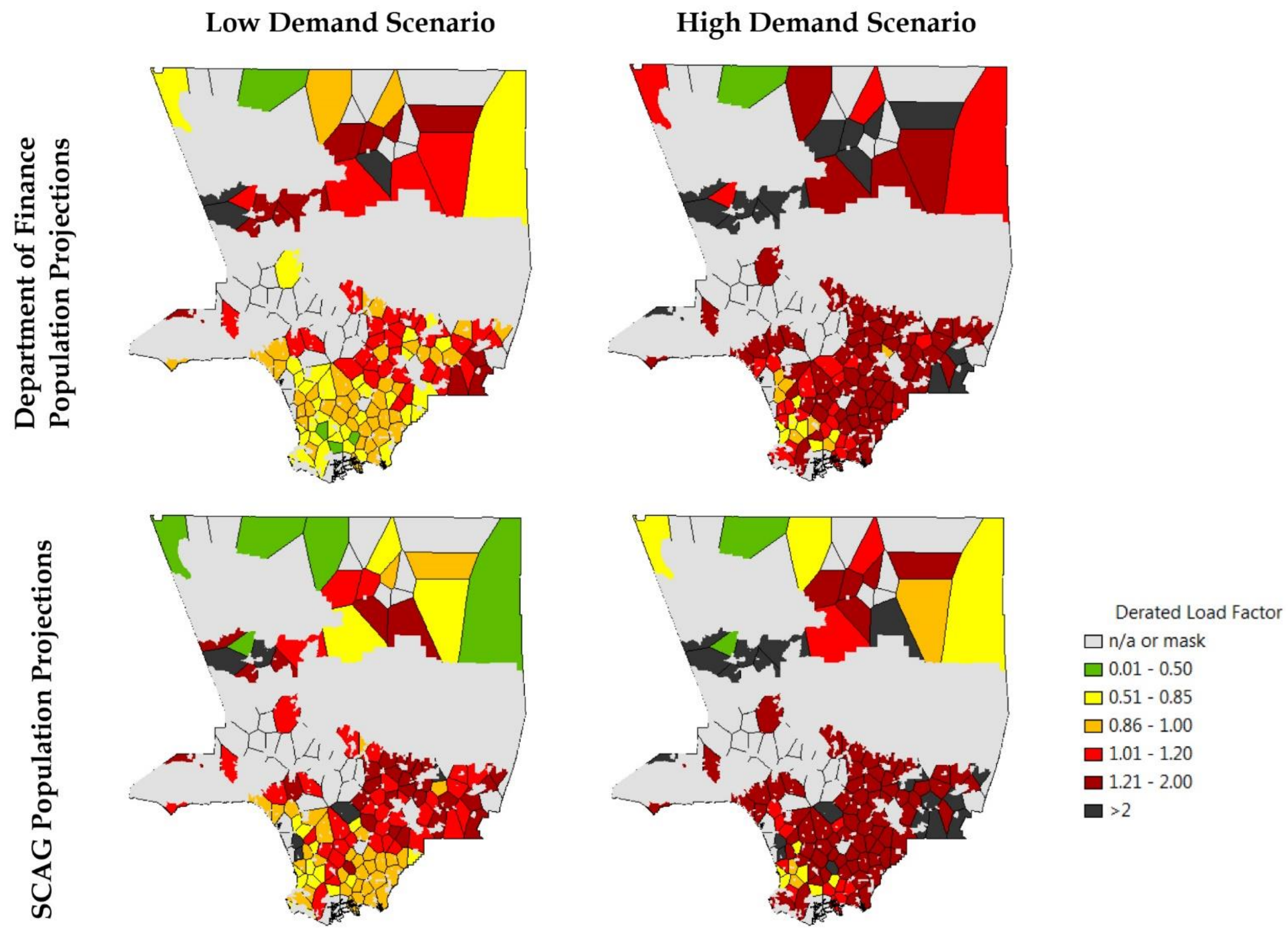
Final report Table 13. Substation Derated Load Factor Risk Metrics.

Substation Risk



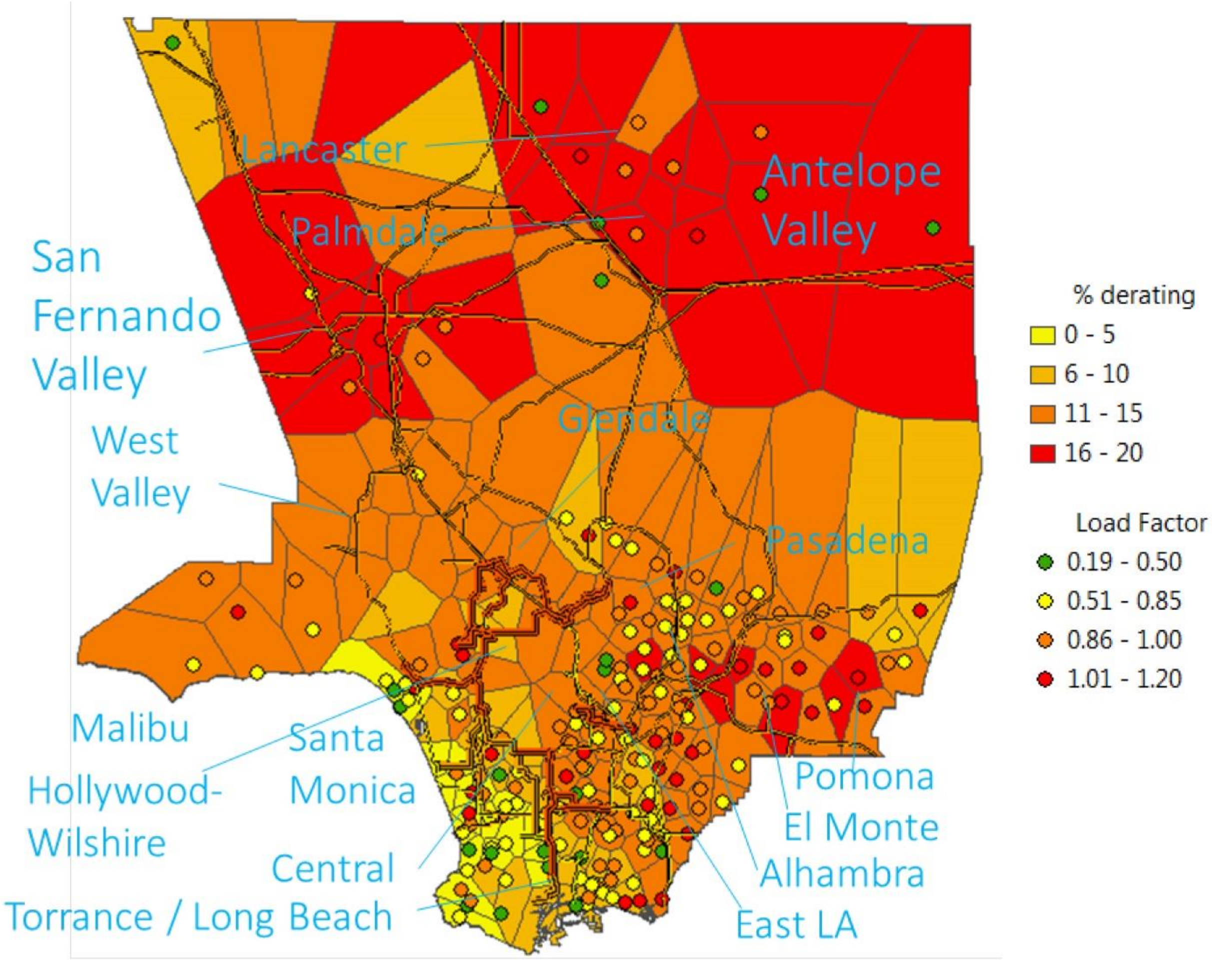
Final report Figure 32. Maps of substation risks in 2060. Future substation load factors derated for composite worst-case 2060 heat waves.

Substation Risk



Final report Figure 32. Maps of substation risks in 2060. Future substation load factors derated for composite worst-case 2060 heat waves.

Vulnerability



Final report Figure 36. Map of worst-case percent derating in lines and substations from historical heat waves overlaid with present substation load factors.

Options / Effects		Peak load, normal	Peak load, heatwave	Load variance	Delivery congestion	Power quality		Total energy consumption	Water use	Air emission	Land use
		Reliability factors						Other factors			
Electrical systems											
Resources	Distributed - solar PV without VAR control or storage	↓	↓	↓	↓	⇩		-	-	-	-
Resources	Distributed - solar PV with smart-inverter & storage	↓	↓	↓	↓	↑		-	-	-	-
Resources	Central - CCNG, nuclear, or other	-	-	-	⇧	↑		-	⇧	⇧	⇧
Resources	Imports, long distance transmission	-	-	-	⇧	↑		-	-	-	⇧
Loads	Appliances: higher energy efficiency	↓	↓	↓	↓	-		↓	-	↓	-
Loads	ACs: peak performance metric	-	↓	↓	↓	-		-	-	-	-
Loads	ACs: dual-systems with ice thermal storage	-	↓	↓	↓	-		-	⇧	-	-
Loads	ACs: water-based evaporative systems	-	↓	↓	↓	↑		↓	⇧	↓	-
Urban systems											
	Growth on fringe (single-family or multi-family)	⇧	⇧	⇧	⇧	-		⇧	⇧	-	⇧
	Growth in-basin (densification with multi-family units)	⇧	⇧	⇧	⇧	-		⇧	⇧	-	-
	Improved building albedo and shading	↓	↓	↓	↓	-		↓	-	↓	-
	Improved building thermal insulation	↓	↓	↓	↓	-		↓	-	↓	-

Final report Figure 38. Climate change risk mitigation options and effects.

Key Takeaways

- The vulnerability of Los Angeles's electricity infrastructure to rising air temperatures was estimated as a 2-20% loss of rated component capacity by 2060 based on RCPs 4.5 and 8.5 with average temperature rises of 0.9 to 3.2 °C (1.6 to 5.8 °F), and worst-case maximum temperatures of 54.3 °C (129.7 °F).
- The effects of population growth, building densification, AC penetration, AC efficiency, and rising air temperatures were modeled, and peak hour electricity demand was projected to increase in residential and commercial sectors by 0.2-6.5 GWh (2-51%) by 2060.
- Air temperature was estimated to have a non-linear effect ranging 2-5% per 1°C, which could increase to 3-7% by 2060 depending upon change in the other factors modeled.
- By 2060 the western-facing coast of Santa Monica Bay is projected to be the least impacted region of LAC, with inland areas experiencing the greatest vulnerability.
- Inland regions, specifically the San Gabriel Valley and the Antelope Valley, were projected to experience the highest temperatures at up to 54 °C (129 °F).
- Santa Clarita is the community at the greatest risk of service interruptions due to substation overloading (load factor ≥2) by 2060.
- Depending upon the choice of population growth scenario, California Department of Finance or SCAG, an additional 0.9--1.1 GW (8-11% increase from today) of substation capacity, DER, or peak load shifting, will be needed throughout Los Angeles county to keep substation load factors at or below one during the worst-case heat waves by 2060.
- The SCAG population growth projections can be satisfied within the in-basin area of the county without significantly increasing peak demand by pursuing the development of high-efficiency, high density housing. However, the portion of SCE service territory in California Building Climate Zone 9, spanning from West Valley to Pomona, would require 700 MW additional capacity, DER, or load shifting to avoid overloading local substation capacities.
- Multi-family (shared wall) housing units were estimated to reduce peak demand by up to 50% per capita relative to single-family detached housing.
- While further improvements in air conditioner ratings beyond SEER 16 can be effective in reducing total energy consumption, a new "peak performance rating" at or above 45°C would be useful to adapt air conditioners' performance for extreme heat.
- Use of projected climate change impacts should continue to be used in the demand forecast and related analysis for California to ensure changing conditions are taken into account in energy planning.

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