



Greenbuild

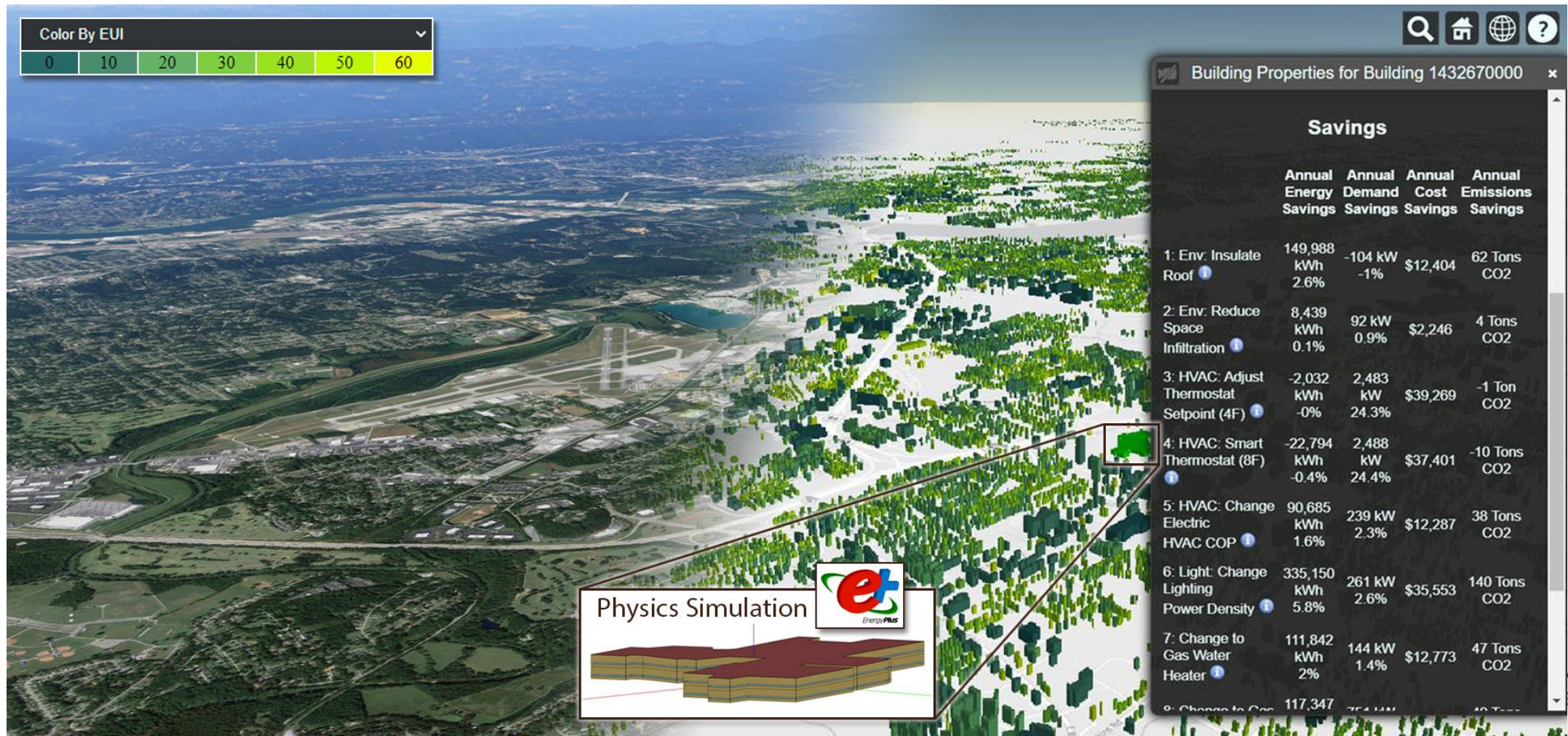
Resilience In Design: Integrating Future Climate Data Into Practice

future Typical Meteorological Year
(fTMY) weather files

ModelAmerica

bit.ly/ModelAmerica1

- Digital twin of every U.S. building (125.7M data, 122.1M models; MAv2 -141.5M bldgs)
- Estimates energy (kBtu), demand (kW), emissions (CO2-eq) and cost (\$) savings



ModelAmerica – MAv1 vs. MAv2

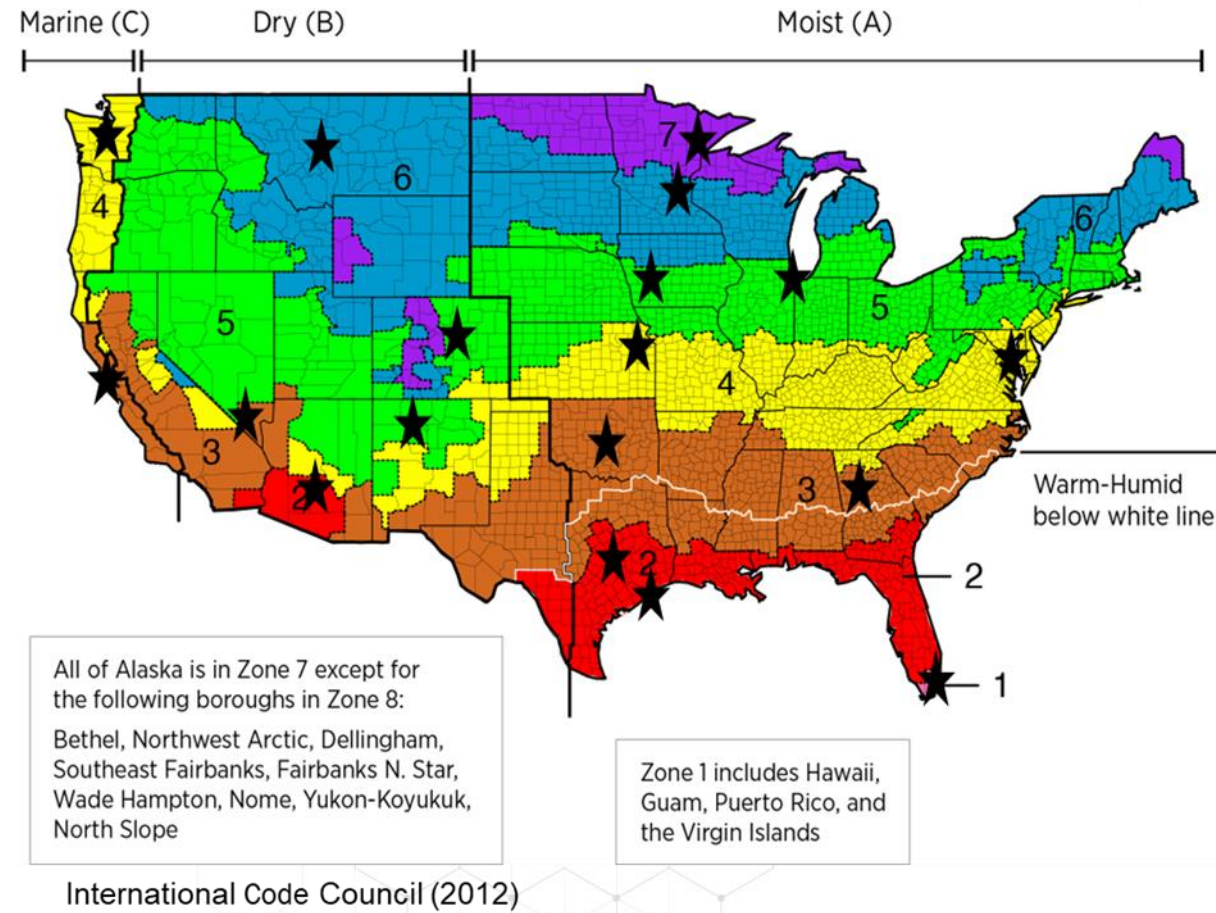
- MAv1 - 122,146,671 models **MAv2 (US+PR) - 138,990,701 models**
 - Open-source OpenStudio (v3.1) & EnergyPlus (v9.4)
- Data for 125.7M buildings (year 2015: 125,715,609) **MAv2 (US+PR): 141.5M (year 2021: 141,494,048)**
 1. ID - unique building ID
 2. Centroid - building center location in latitude/longitude (from Footprint2D)
 3. Footprint2D - building polygon of 2D footprint (lat1/lon1_lat2/lon2_...)
 4. State_abbr - state name
 5. Area - estimate of total conditioned floor area (ft²)
 6. Area2D - footprint area (ft²)
 7. Height - building height (ft)
 8. NumFloors - number of floors (above-grade)
 9. WWR_surfaces - percent of each facade (pair of points from Footprint2D) covered by fenestration/windows (average 14.5% for residential, 40% for commercial buildings)
 10. CZ - ASHRAE Climate Zone designation
 11. BuildingType - DOE prototype building designation (IECC=residential) as implemented by OpenStudio-standards **MAv2: support buildings with mixed types (by floor area)**
 12. Standard - building vintage

Data Descriptors:

- 1- Unique Bldg ID (UBID)
 - Allows easier merging with other data sources
- 3 – Precision/Recall – 82%
 - **MAv2: 98.5%/92.4%**
- 7 – Problematic for tall buildings, cluttered environments
 - **MAv2: sub-1 meter vertical resolution avg.; resolve all bldgs**
- 11 – Problematic, heuristics and AI for prediction
 - **MAv2: 150+ subverticals from Google mapped to DOE types**
- 12 – Pixel categorization from non-urban to urban
 - **MAv2: Construction and time of major renovations from LightBox**

What is likely future weather in your area?

- future Typical Meteorological Year (fTMY, bit.ly/fTMY)
 - County-specific for CONUS
 - Hourly data, 20-year periods, years 1980-2100
 - Climate change scenarios (across 6 models)
 - 6 Climate Models (data available as well)
 - 9 Weather Variables

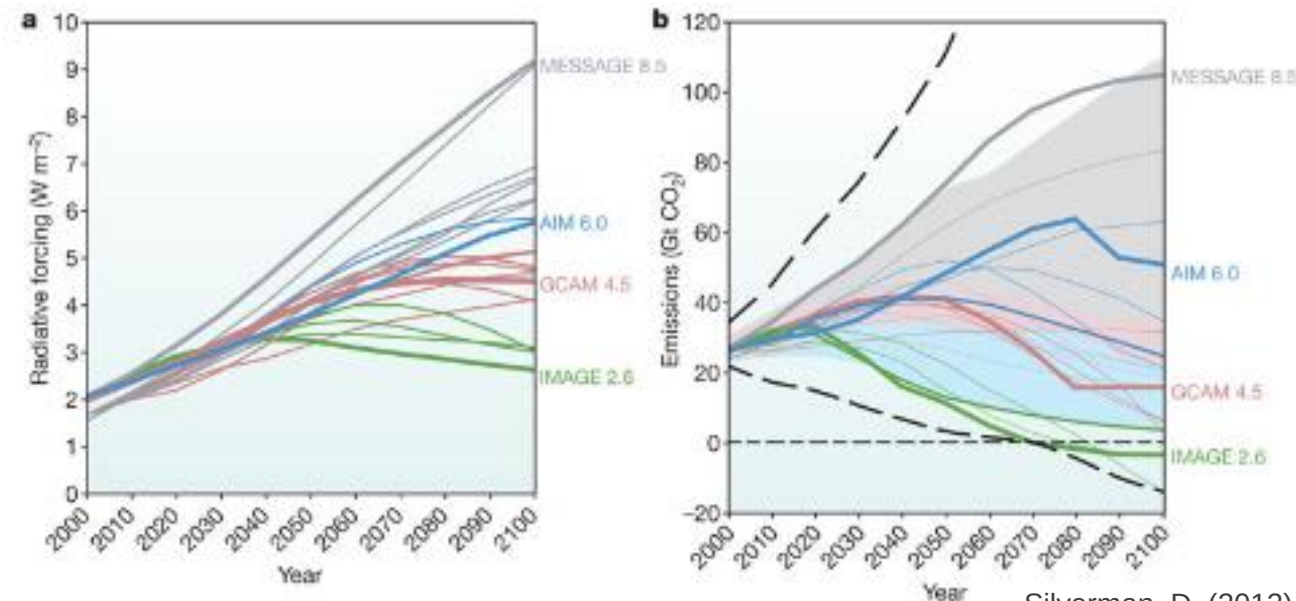
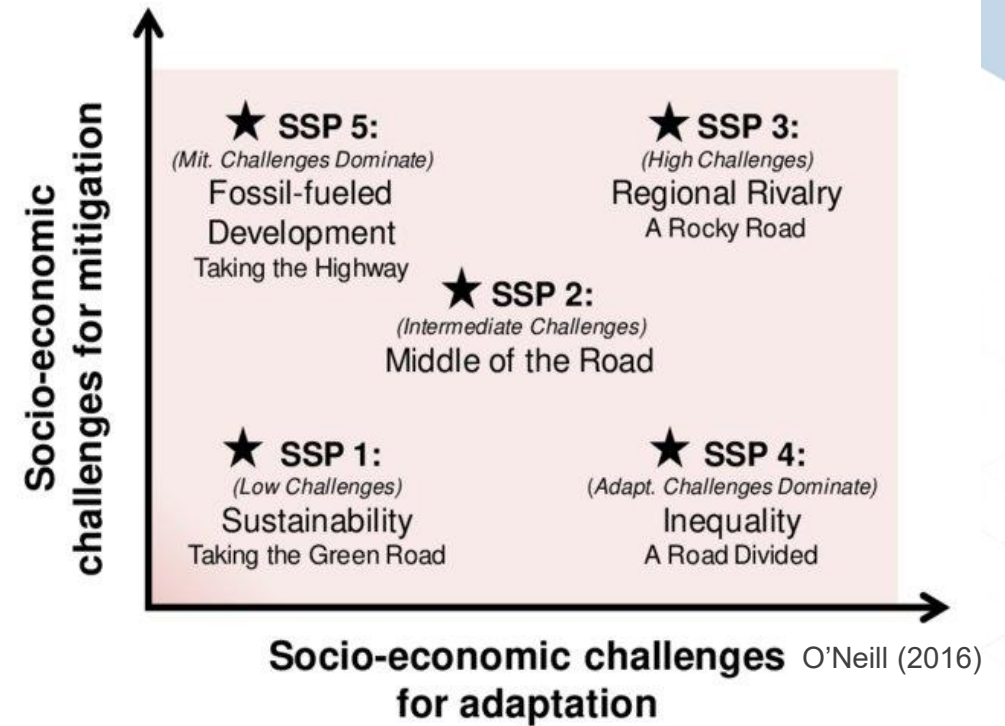


Clarification on weather data

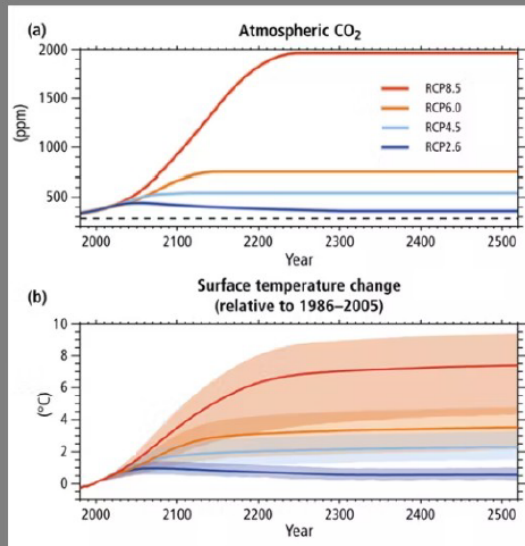
- (Actual) Meteorological Year (AMY, MY) – measured weather data period at a location for a period of time (usu. Jan 1-Dec 31)
 - Use: estimating actual energy use of a building (compared to utility bills)
- Typical Meteorological Year (TMY) – typical weather at a location over a 15+ year period
 - Use: estimating expected energy use of a building/city/state/nation
- future Typical Meteorological Year (fTMY) – typical weather at a location in the future over a ~20-year period
 - Use: estimating expected energy use of a building/city/state/nation in the future
- eXtreme Meteorological Year (xMY) – extreme weather peaks at a location (now or in the future)
 - Use: HVAC sizing (minimize unmet hours); electric grid stress (peak loads)

Visual summary of IPCC

- Intergovernmental Panel on Climate Change (IPCC) created Shared Socioeconomic Pathways (SSPs) to define different future worlds
 - Varying factors such as population, technological, and economic growth
- IPCC created Representative Concentration Pathways (RCPs) to set pathways for greenhouse gas concentrations
 - Named for amount of radiative forcing by the year 2100
 - Based on future climate policies



Stakeholders – what scenario?



RCP: Representative Concentration Pathway
SSP: Shared Socio-economic Pathway

https://ar5-syr.ipcc.ch/topic_futurechanges.php

What RCP+SSP scenario is most important to you? (Multiple Choice)

Mentimeter

1st

SSP2-RCP 4.5: Intermediate GHG Emissions (~3.5°C by 2081-2100)

2nd

SSP5-RCP 8.5: Very High GHG Emissions (~5.7°C by 2081-2100)

3rd

SSP3-RCP 7.0: High GHG Emissions (~4.6°C by 2081-2100)

4th

SSP1-RCP 2.6: Low GHG Emissions (~2.4°C by 2081-2100)

5th

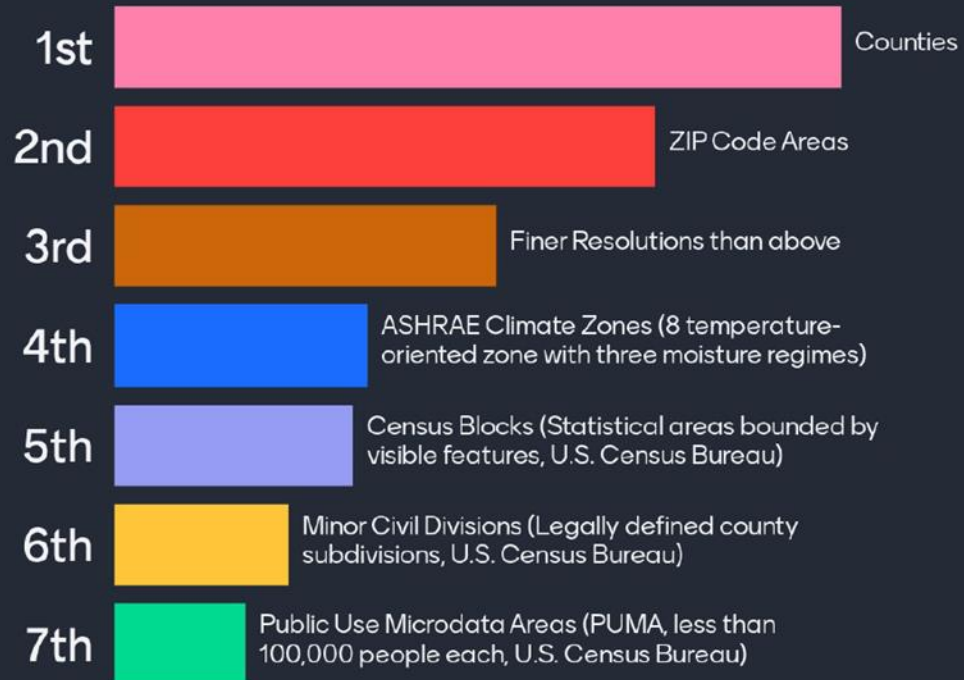
SSP1-RCP 1.9: Very Low GHG Emissions (~1.8°C by 2081-2100)

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Stakeholders – spatial resolution?

What's the need for geographical resolution? (Multiple Choice)

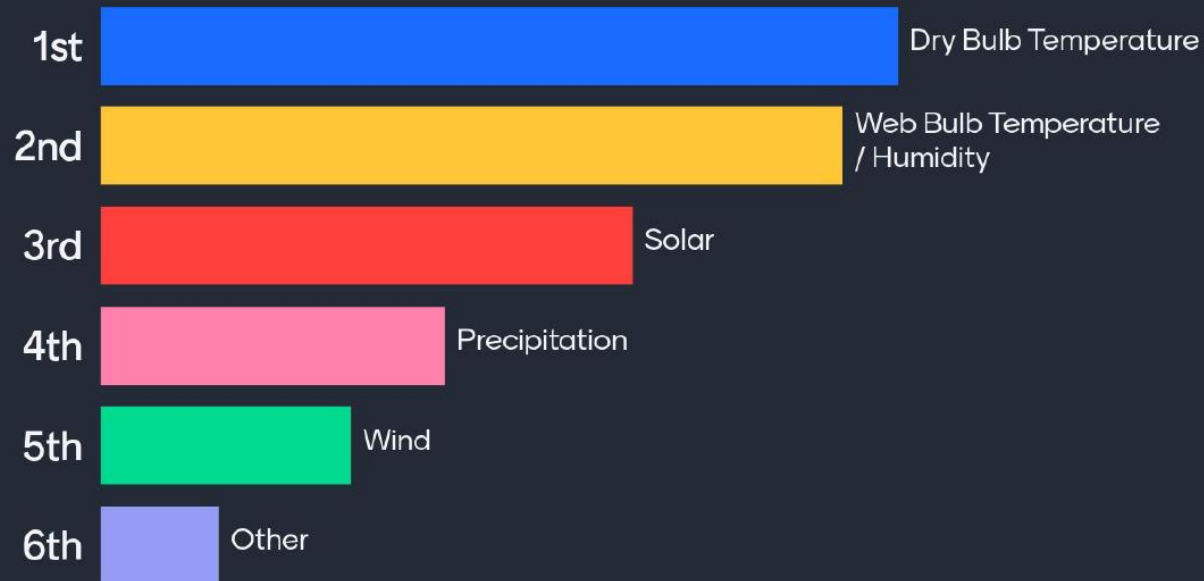
Mentimeter



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Stakeholders – Weather variables?

What meteorological variables are most important? (Multiple Choice)



Mentimeter

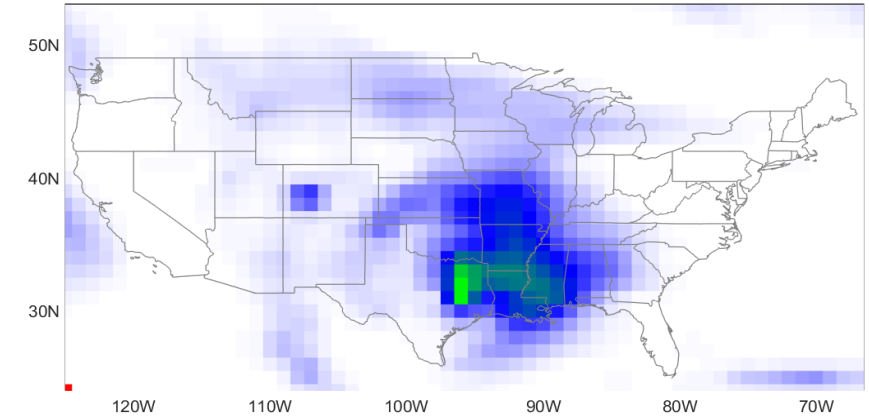


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How do you make planetary models local?

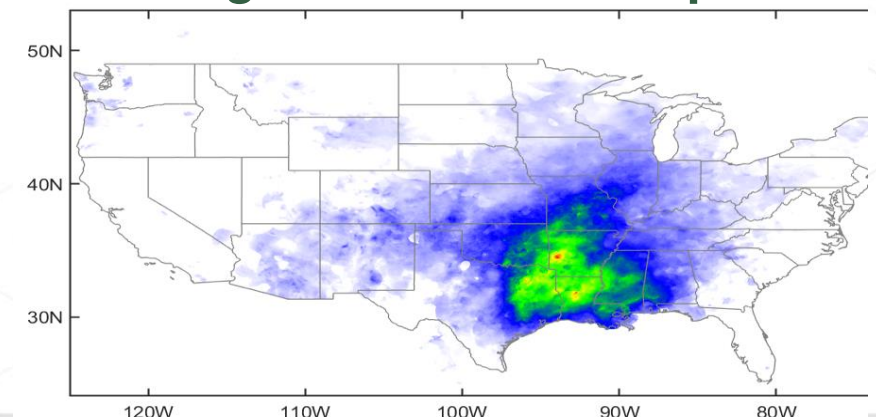
- Majority of General Circulation Models (GCMs) in the latest CMIP6 is around 1 degree (~110 km) with a few models at 0.5 degrees (~55km).
 - This low resolution restricts their ability to accurately represent fine-scale features such as topography that govern local-scale climatic variations.
 - High-resolution data is needed for reliable climate impact evaluation

Original Global Climate Model (GCM)

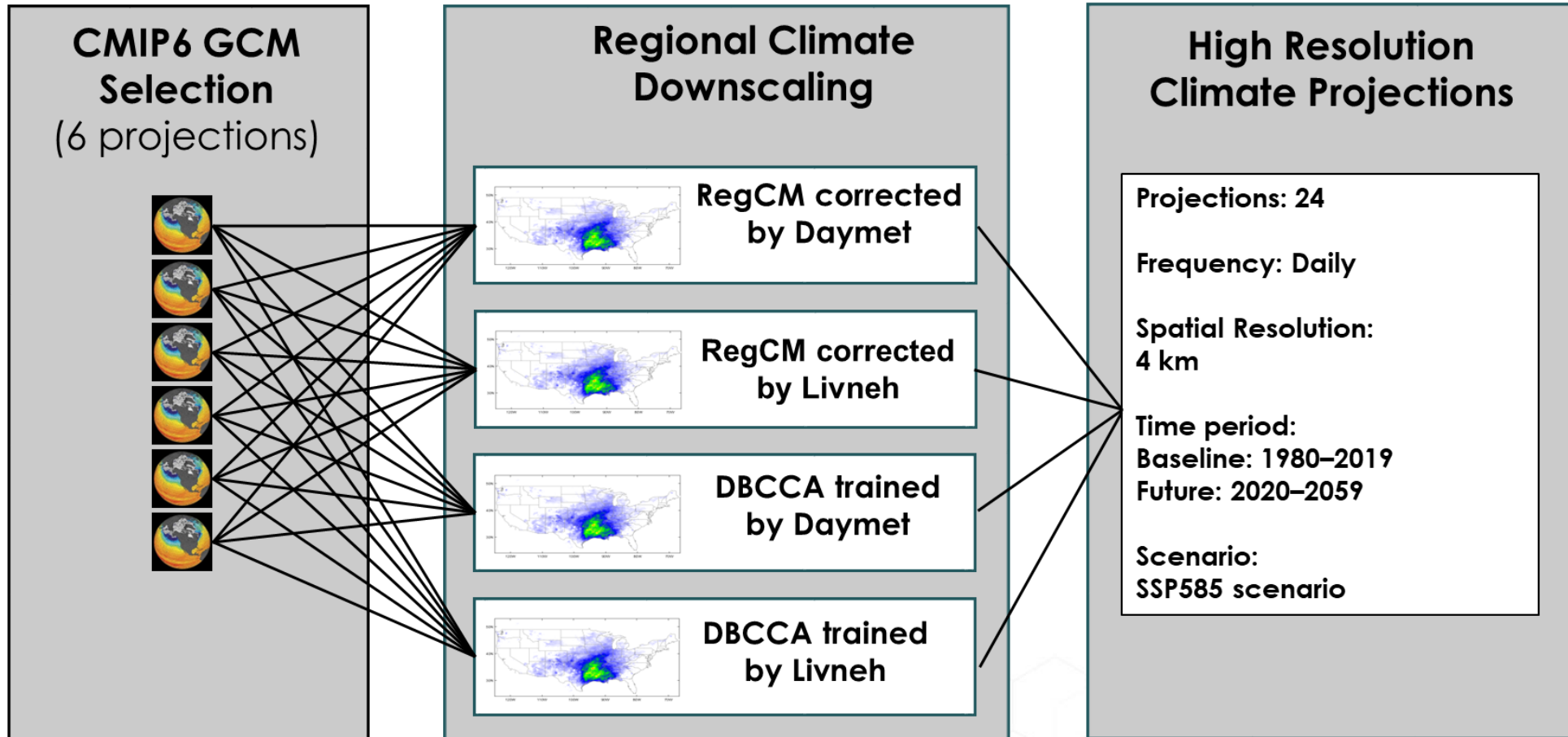


↓ **Downscaling**

High Resolution Output

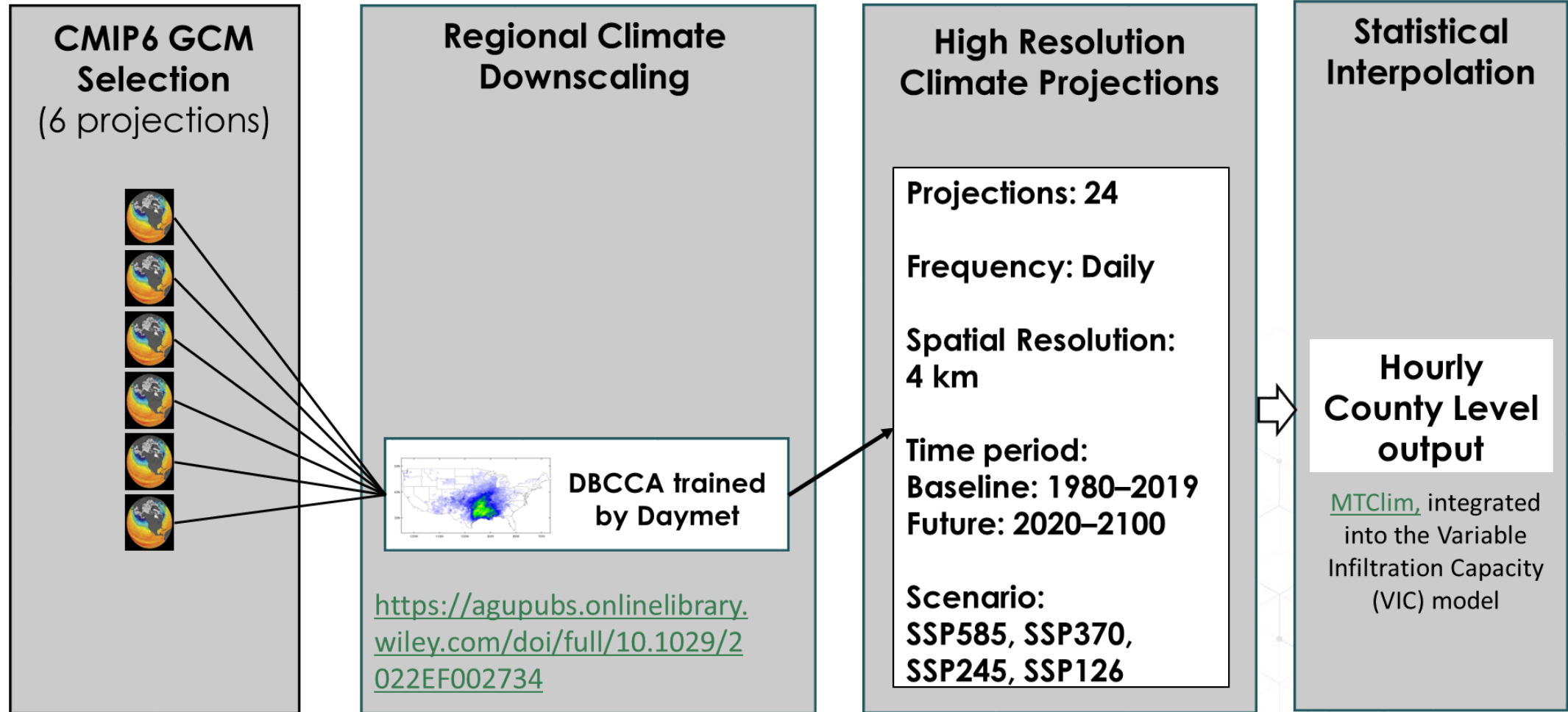


Downscaling method



Effects of Climate Change on Federal Hydropower – The Third 9505 Assessment.
Sponsor: Water Power Technologies Office, U.S. Department of Energy (PI: Shih-Chieh Kao)

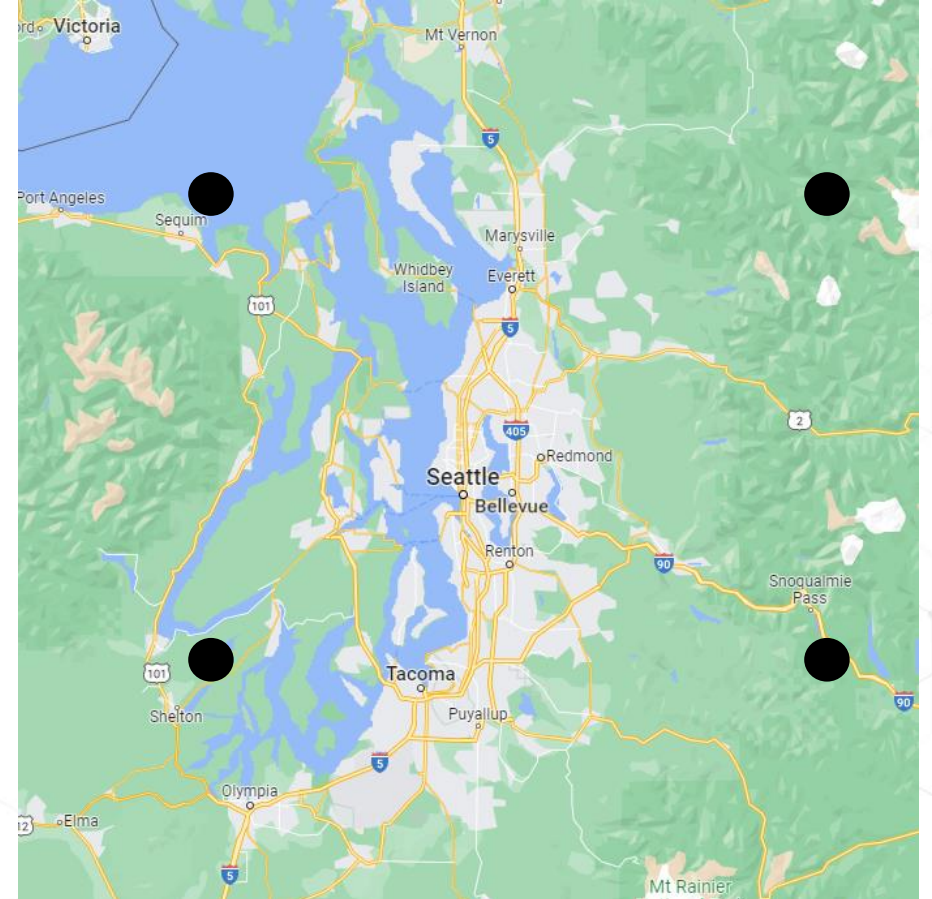
Downscaling method – level 2



(Deeksha Rastogi, Shih-Chieh Kao)

Why Downscaling? Variability?

- ORNL's Model America version 2 (MAv2) data contains location, footprint, building type, vintage of 141.5 million buildings
- Largest spatial cluster of buildings in each US county was selected and median centroid used as the county's representative lat/lon



● Global Climate Model Grid Points



Accounting for variability

- Convert IPCC model data to meteorological variables
- Three levels of sophistication
 - Individual future years (as with historical years) may be outliers; how to account for multi-year/temporal variability?
 - There are many different climate models from institutions studying climate around the world; how to account for model variability?
 - There are many grid points that may not be within a region of interest or have multiple points within the area of interest; how to account for spatial variability?
- ORNL proposes an existing technique to rule them all.

Typical Meteorological Year

- Typify weather conditions at a location over a period of time
- Representative month selection
 - Sandia Method
 - Considers statistical representation of several weather variables
 - Dry bulb, dew point, wind velocity, solar radiation
 - Cumulative Distribution Functions (CDFs) are calculated based on each weather variable/statistic combination
 - Each month's variable/statistic combination CDF is compared to the long-term CDF using Wasserstein Distance
 - A weighted sum of the distances is used
 - The months with the lowest weighted sum distances are selected and concatenated

Typical Meteorological Year (TMY)

2010	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2011	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2012	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2015	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2016	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2017	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2018	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2019	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

TMY	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Year	2011	2018	2014	2016	2016	2012	2017	2018	2015	2013	2019	2019

future Typical Meteorological Year (fTMY)

2090	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2091	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2092	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2093	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2094	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2095	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2096	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2097	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2098	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2099	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

fTMY	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Year	2090	2094	2094	2096	2092	2090	2099	2093	2096	2098	2091	2092

Variability – climate models

2090a	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2090b	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2091a	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2091b	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2092a	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2092b	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2093a	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2093b	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2094a	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2094b	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2095a	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2095b	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2096a	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2096b	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2097a	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2097b	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2098a	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2098b	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2099a	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2099b	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2100a	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2100b	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

fTMY	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Year	2091a	2096b	2093a	2098b	2091a	2100b	2090a	2095b	2093b	2098a	2091a	2099b



fTMY Weather Files

- Future Typical Meteorological Year (fTMY) – bit.ly/fTMY
- County-specific for CONUS (3,281 counties, 18 cities)
- Hourly data, 20-year periods, years 1980-2100
- Climate change scenarios (across 6 models)
 - SSP5, RCP8.5; SSP3, RCP7.0; SSP2, RCP 4.5; SSP1, RCP2.6
- 6 Climate Models (data available as well)
 - ACCESS-CM2; BCC-CSM2-MR; CNRM-ESM2-1; MPI-ESM1-2-HR; MRI-ESM2-0; NorESM2-MM
- 9 Weather Variables
 - Air Temp; Longwave; Shortwave; Vapor Pressure; Vapor Pressure Deficit; Relative Humidity; Precipitation; Wind; Pressure

Maricopa County, Arizona

- Phoenix, AZ – potential 5°F increase in 2100, 16% more electricity use, and 23% more demand



Scenario	Average Dry Bulb Temperature (°F)
TMY	23.8
fTMY 2020-2040	24.1
fTMY 2040-2060	25.8
fTMY 2060-2080	26.6
fTMY 2080-2100	29.1

Scenario	Total Energy	Electricity	Natural Gas
TMY	0.24 Quads	0.20 Quads	0.04 Quads
fTMY 2020-2040	-1.0%	-1.0%	-1.1%
fTMY 2040-2060	3.4%	4.6%	-3.2%
fTMY 2060-2080	4.6%	6.9%	-8.1%
fTMY 2080-2100	11.6%	15.9%	-12.3%

Scenario	Total Costs	Total Emissions
TMY	\$ 8.5 Billion	26 Million Tons CO2
fTMY 2020-2040	-1.0%	-1.0%
fTMY 2040-2060	4.0%	3.4%
fTMY 2060-2080	5.85%	4.6%
fTMY 2080-2100	14.0%	11.6%

Scenario	July Total Energy
TMY	0.02 Quads
fTMY 2020-2040	1.9%
fTMY 2040-2060	11.1%
fTMY 2060-2080	14.3%
fTMY 2080-2100	23.0%

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