Estimating Future Changes of Energy Demand for Heating and Cooling Buildings at NASA Centers - GC23J-1198

Bradley M. Hegyi, Paul Stackhouse[2], Jr., Falguni Patadia[2], Patrick C. Taylor[2], Faezeh Mosellat[3], and Nathalie Meloche[3]

[1]Analytical Mechanics Associates, [2]NASA , [3]RETScreen® International – Natural Resources Canada

1. Introduction

The NASA Prediction of Worldwide Energy Resources (POWER) project provides data products and services to renewable energy, sustainable infrastructure, and agroclimatology user groups. Our data products originate from NASA satellite observations and reanalysis products, and cover the years 1981 through near present (within days of current date).

In support of the NASA Climate Adaptation Science Investigators (CASI2) working group, whose purpose is to provide key climate information relevant to planning and management of NASA infrastructure, POWER is developing new data services using climate model projections. In partnership with RETScreen®, we provide heating and cooling energy needs for several building archetypes.

Challenges with using climate model data:
- Model data is coarse and prone to local biases
- Over 100 models exist
- Uncertainty in future emissions

NASA POWER is meeting these challenges by:
- Using high resolution downscaled climate model data and applying a bias correction to downscaled data using NASA Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA2) reanalysis
- Calculating ensemble averages of a group of models and selecting a set of individual models that span range of future change and variability
- Considering three different emission scenarios

2. Data and Key Methods

Heating (HDD) and cooling (CDD) degree days are calculated from daily mean surface air temperature using a 10-degree Celsius threshold for cooling degree days and an 18.3-degree Celsius threshold for heating degree days.

Downscaled data from NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP-CMIP6)
- Daily data for 9 meteorological variables – 2015-2100
- 0.25°X0.25° grid spacing (compare to 1.5° -2° for raw model data)

Bias correction: Linear regression of 1985-2022 MERRA2 data vs. model projection data is calculated. Bias calculated based on difference between 2022 value calculated from regression for both data sets.

Two ways to summarize spread of models:
- Ensemble average: Averaging 22 models selected by CASI2 working group
- RETScreen® analysis: Choose 6 models that cover range of trend and variability

References: Hegyi, BM, PW Stackhouse, PC Taylor, F Patadia, Estimating Future Changes in Total Annual Heating and Cooling Degree Days at NASA Center Locations in Downscaled CMIP6 Climate Model Data, *Energy,* under review.

3. Results

The monthly distribution (figure below) and annual total (tables at bottom) of heating and cooling degree days (in degrees C) significantly changes in the future climate.

Monthly Distribution of HDD/CDD - Glenn
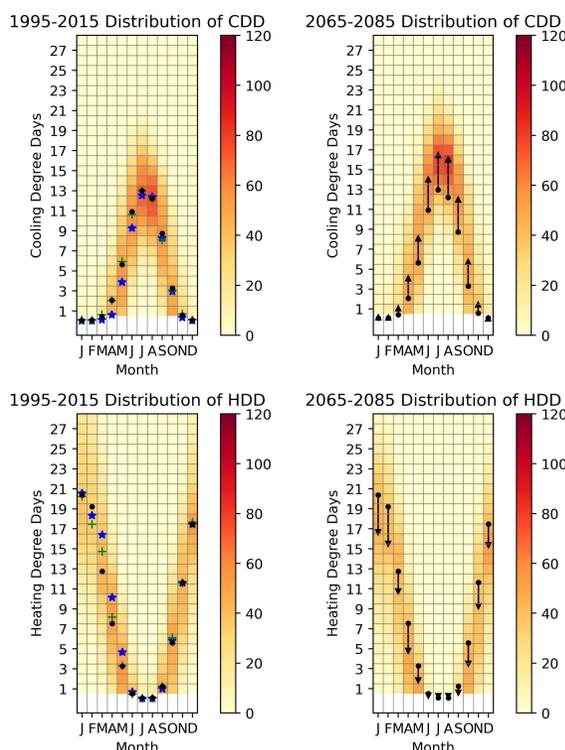
Right column: Dots: 1995-2015 historical model data
Blue Stars: MERRA2 1995-2015
Green Plus: Observations 1995-2015

Left column: Dots show 2015-2035 values. Arrows show change from current period to 2065-2085 average (high emissions scenario).

Center Name	Annual HDD 50-Year Difference (2065-2085 average minus 2015-2035 average) (°C) [percent change]		
	High Emissions	Medium Emissions	Low Emissions
Ames – California	-312.9 [-35%]	-269.7 [-30%]	-122.0 [-14%]
Langley – Virginia	-327.4 [-23%]	-244.5 [-17%]	-139.0 [-10%]
Glenn – Ohio	-559.3 [-19%]	-389.2 [-13%]	-239.3 [-8%]
Marshall – AL	-313.7 [-22%]	-219.2 [-15%]	-146.9 [-10%]
Johnson – Texas	-146.8 [-33%]	-111.4 [-25%]	-74.7 [-17%]

Center Name	Annual CDD 50-Year Difference (2065-2085 average minus 2015-2035 average) (°C) [percent change]		
	High Emissions	Medium Emissions	Low Emissions
Ames – California	606.6 [+25%]	422.4 [+17%]	211.2 [+9%]
Langley – Virginia	601.8 [+19%]	396.1 [+13%]	200.7 [+6%]
Glenn – Ohio	540.6 [+28%]	357.4 [+19%]	188.7 [+10%]
Marshall – AL	629.0 [+20%]	400.7 [+13%]	210.0 [+7%]
Johnson – Texas	652.8 [+14%]	426.5 [+9%]	239.6 [+5%]

A higher proportion of energy will be needed to cool in future climate conditions. Cooling demands increase more in locations with a cooler present-day climate. However, total energy needed to heat and cool may decrease, especially for sites with a cooler climate.

Annual Heating and Cooling Load Changes
Medium Office Building, High Slope
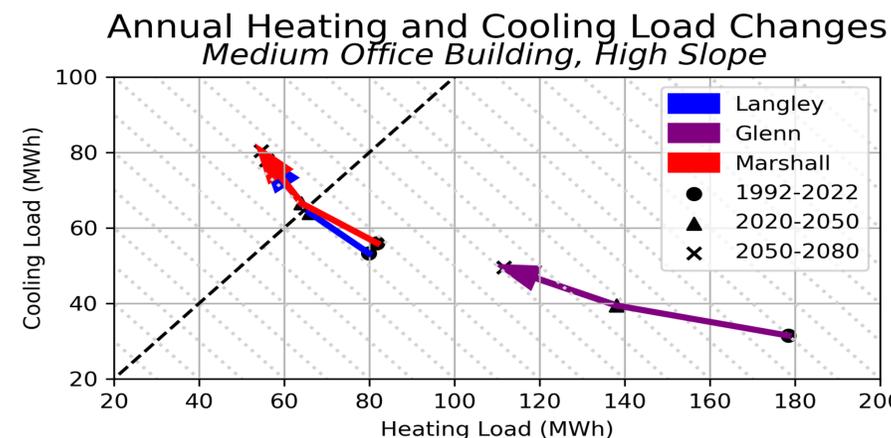
Data calculated from RETScreen® using model data as inputs. Black dashed line is line of equal heating/cooling load. Diagonal lines are lines of equal energy use.

Heating and Cooling Loads

Langley - Virginia

1992-2021	Heating (kWh)	Cooling (kWh)
MERRA2	79,898	53,274

2050-2080	Heating (kWh) [percent change]	Cooling (kWh) [percent change]
Low Var	64,362 [-19%]	69,571 [+33%]
Med Var	59,806 [-25%]	71,569 [+37%]
High Var	66,258 [-17%]	67,609 [+29%]
Low Slope	71,537 [-10%]	61,503 [+18%]
Med Slope	65,471 [-18%]	68,064 [+30%]
High Slope	55,891 [-30%]	77,925 [+49%]

Glenn - Ohio

1992-2021	Heating (kWh)	Cooling (kWh)
MERRA2	178,398	31,468

2050-2080	Heating (kWh) [percent change]	Cooling (kWh) [percent change]
Low Var	128,690 [-28%]	43,208 [+37%]
Med Var	125,837 [-29%]	45,111 [+43%]
High Var	137,074 [-23%]	41,622 [+32%]
Low Slope	138,594 [-22%]	36,009 [+14%]
Med Slope	126,740 [-29%]	42,108 [+34%]
High Slope	111,583 [-37%]	49,585 [+58%]

CO_2 Emissions

Current Grid (tCO2)

Site	1992-2022	2050-2080
Langley- Virginia 39.53 gCO2/kWh	23.7	20.9
Glenn – Ohio 114.29 gCO2/kWh	56.3	48.6

Projected Future Grid (tCO2)

Site	1992-2022	2050-2080
Langley- Virginia 20.01 gCO2/kWh	23.7	20.9
Glenn – Ohio 35.93 gCO2/kWh	56.3	48.6

4. Future Work:

- Provide data products for all locations globally (north of 60°S latitude)
- Explore what is driving changes in energy use in different regions across the United States (changes in mean or extremes)
- Quantify the seasonality of the changing energy demand: Is the increased future cooling demand occurring on extreme temperature days?
- Expand RETScreen® calculations to other locations across the United States and the world

We want to hear from you! What quantities you would like to see calculated from future climate data?