2020 Building Performance Analysis Conference and SimBuild
co-organized by ASHRAE and IBPSA-USA

Seminar 24 – Systems, Components and Loads Analysis

Brett Bass,
University of Tennessee
Oak Ridge National Laboratory
bbass11@vols.utk.edu

Future Meteorological Year weather data from IPCC Scenarios

Learning Objectives

- Understand how climate models can be used to modify *.epw files for building simulation.
- Describe the impacts of changing weather conditions on building energy use in Chattanooga, TN.

ASHRAE is a Registered Provider with The American Institute of Architects Continuing Education Systems. Credit earned on completion of this program will be reported to ASHRAE Records for AIA members. Certificates of Completion for non-AIA members are available on request.

This program is registered with the AIA/ASHRAE for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product. Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

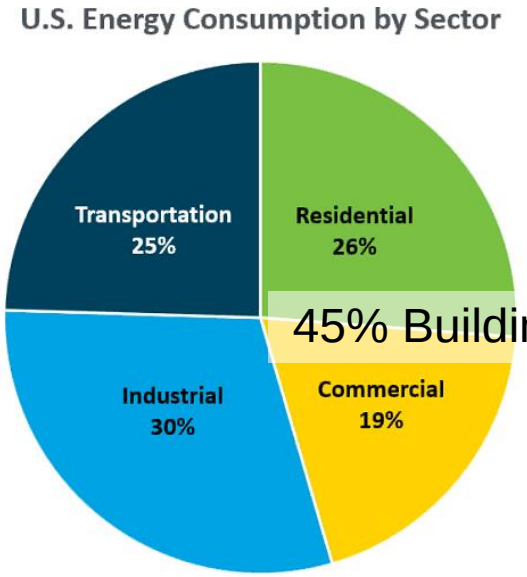
Acknowledgements

- Funding
  - U.S. Department of Energy
  - National Nuclear Security Administration
  - Building Technologies Office
  - Office of Electricity
  - Oak Ridge National Laboratory
  - Oak Ridge Leadership Computing Facility – HPC1
  - Argonne Leadership Computing Facility – HPC2
- Team Members
  - ORNL – Joshua New
  - Counties of Hamilton, Rhea, and Marion
- Software
  - EnergyPlus – Software 1
  - OpenStudio – Software 2
  - Automatic Building Energy Modeling (AutoBEM) – Software 3
    - AutoGen – Software 4
    - AutoSim – Software 5

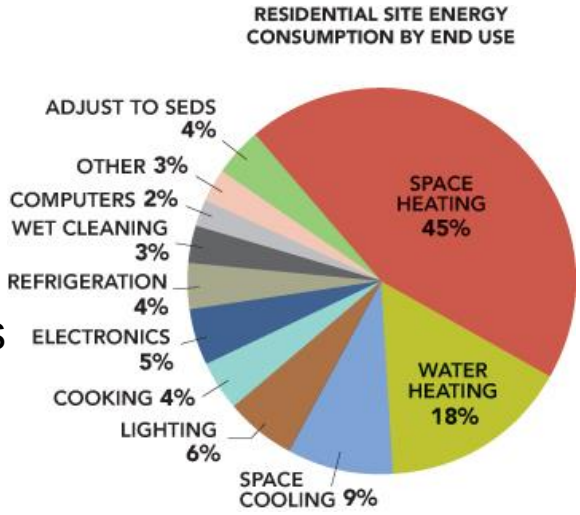
Outline/Agenda

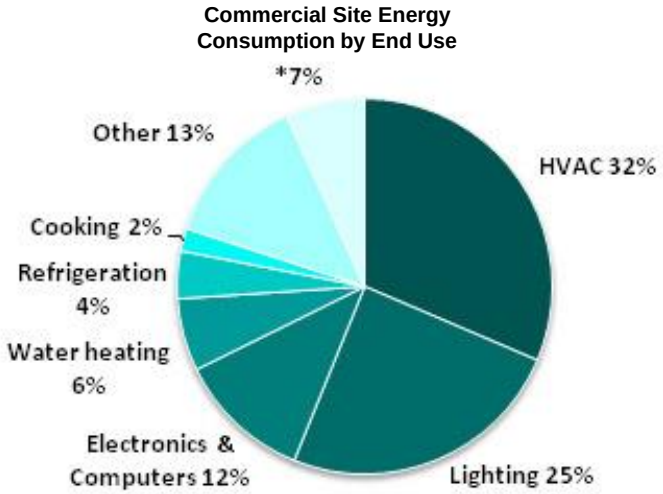
- Building Energy/Building Energy Modeling
- Virtual EPB Project (Electric Power Board of Chattanooga, TN)
- Climate Modeling

Building Energy



45% Buildings





Buildings consume 73% of the nation's electricity

Source: U.S. Energy Information Administration, January 2016 to January 2017, *Monthly Energy Review* – Table 2.1.

125 million U.S. buildings
$412 billion/yr energy bills (2019)

Goal of the DOE
Building Technologies Office:
30% energy reduction per sq. ft.
by 2030 compared to 2010 baseline

Building Energy Modeling – building descriptions + weather = estimated building energy consumption

Outline/Agenda

- Building Energy/Building Energy Modeling
- Virtual EPB Project (Electric Power Board of Chattanooga, TN)
- Climate Modeling

Building Energy Modeling - Process

Digital Twin of every U.S. building

Methodology: Scalable compute, data, simulation, and empirical validation

1. Quantitatively rank most important building inputs

	Small Office	Outpatien t	Large Office	Medium Office	Hospital	Warehous e	Small Hotel	Large hotel
Inputs	458	3483	1072	760	1955	333	1823	887

Class	Object	Field	Default	Minimum	Maximum	Distribution Type	Group	Constraint
Sizing Parameters		Heating Sizing Factor	1.33	0.931	1.729	uniform	float	
Sizing Parameters		Cooling Sizing Factor	1.33	0.931	1.729	uniform	float	
Lights	Core_bottom_Lights	Watts per Zone Floor Area	10.76	7.532	13.988	uniform	float	G0001
Lights	Core_mid_Lights	Watts per Zone Floor Area	10.76	7.532	13.988	uniform	float	G0001
Lights	Core_top_Lights	Watts per Zone Floor Area	10.76	7.532	13.988	uniform	float	G0001
Lights	Perimeter_top_ZN_4_Lights	Watts per Zone Floor Area	10.76	7.532	13.988	uniform	float	G0001
ElectricEquipment	Core_bottom_PlugElec_Equip	Watts per Zone Floor Area	10.76	7.532	13.988	uniform	float	G0002
ElectricEquipment	Core_bottom_Elevators_Equip	Watts per Zone Floor Area	10.76	7.532	13.988	uniform	float	G0002
Exterior Lights	Exterior Facade Lighting	Design Level	32109.89011	22476.92	41742.86	uniform	float	
		Design Level	14804	10362.8	19245.2	uniform	float	
		Flow per Exterior Surface Area	0.0003020	0.000211	0.000393	uniform	float	G0003
		Flow per Exterior Surface Area	0.0003020	0.000211	0.000393	uniform	float	G0003
ZoneInfiltration DesignFlowRate	FirstFloor_Plenum_Infiltration	Flow per Exterior Surface Area	0.0003020	0.000211	0.000393	uniform	float	G0003

Sensitivity Analysis

2. Time on world's #1 fastest high-performance machines

Supercomputers

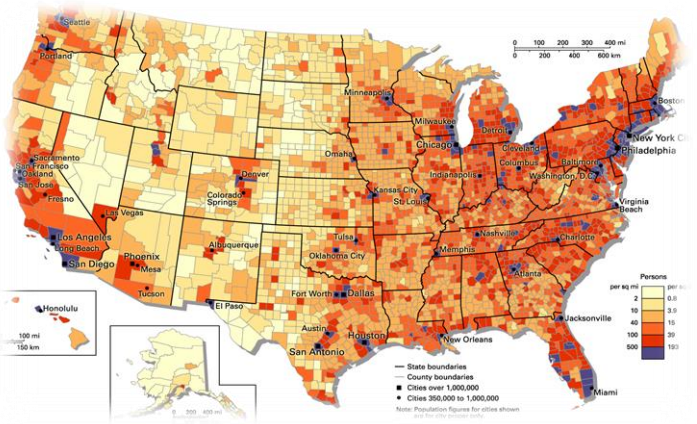
3. Identify and compare data sources for important inputs

	Short Title
Summary	Satellite imagery, including panchromatic and multispectral images
Data type	Image
Company	
Website	
Temporal resolution	Cities - 3-11 times per week
Spatial resolution	0.3 m
Measure accuracy	
Cost	$11 per sq. km
Format	GeoTiff
Mapping to building input variables	Building footprints
Mapping to area properties	Vegetated areas, road surface, buildings, parking lots
Mapping to material properties	Road pavement materials (e.g., concrete, asphalt), parking lots (e.g., gravel, soil)
Coverage of US	Over 10 million km² of coverage of the contiguous US
Orientation	Aerial
Existing internal software	N/A
Existing expertise	Remote sensing data analysis tool
Restrictions	N/A
Comments	

Comparison Matrix

4. Establish partnerships and APIs for scalable data retrieval

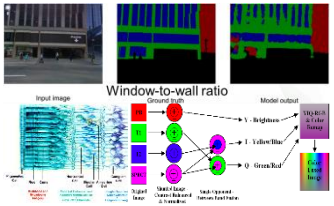
Databases



Demonstrate and stimulate GEB opportunities toward a sustainable built environment

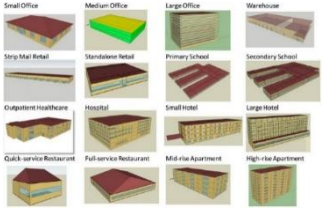
HPC2, Software 4-5, Software 1-2

5. Algorithms to extract building properties



Computer Vision

6. Create BEM data and models



DOE Prototype Buildings

7. Make BEM info freely available online

Download BEM via street address

Use cases:

- Simulation-informed analysis
- Sales/market leads
- Utility program formulation
- Rate structures
- Resilience
- Automated financing
- Business model evaluation
- **Climate model simulation**

Outline/Agenda

- Building Energy/Building Energy Modeling
- Virtual EPB Project (Electric Power Board of Chattanooga, TN)
- Climate Modeling

Climate Modeling – Climate Zones

- Climate zones based on 18+ years of quality data from 8,000+ met stations
- Most state building codes based on weather data from 1961-1990
- Redefining climate zones, include trends

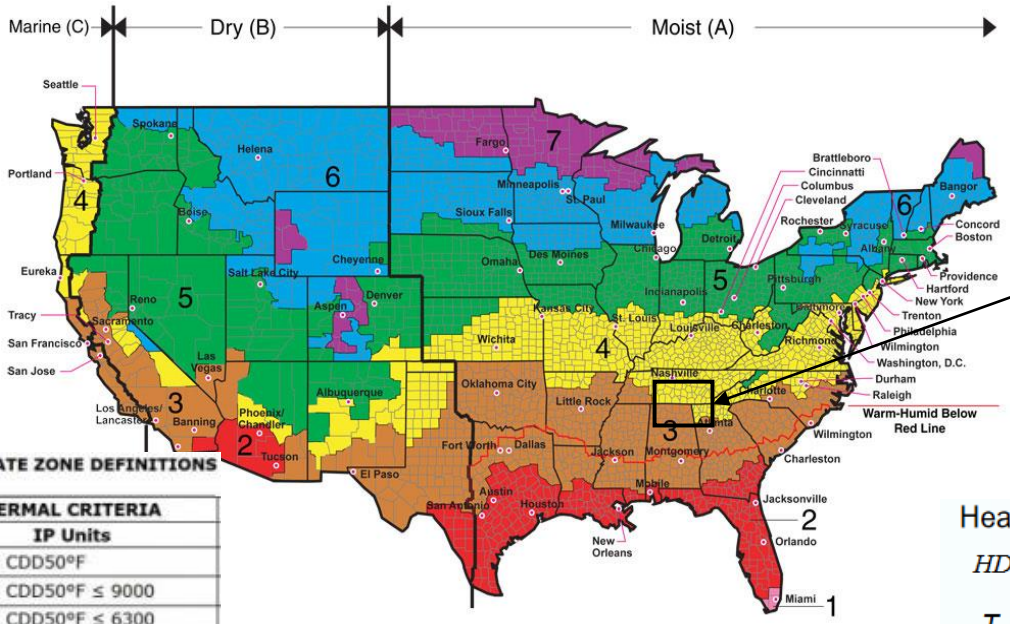


TABLE 301.3(2) INTERNATIONAL CLIMATE ZONE DEFINITIONS

ZONE NUMBER	THERMAL CRITERIA IP Units
1	9000 < CDD50°F
2	6300 < CDD50°F ≤ 9000
3A and 3B	4500 < CDD50°F ≤ 6300 AND HDD65°F ≤ 5400
4A and 4B	CDD50°F ≤ 4500 AND HDD65°F ≤ 5400
3C	HDD65°F ≤ 3600
4C	3600 < HDD65°F ≤ 5400
5	5400 < HDD65°F ≤ 7200
6	7200 < HDD65°F ≤ 9000
7	9000 < HDD65°F ≤ 12600
8	12600 < HDD65°F

Updated every 4 years (2021)

2017 - Climate Zone 0 (extremely hot):
10,800 < CDD 50°F
Int'l Energy Conservation Code (IECC) adopts for 2018 code

Heating Degree Days:

$$HDD = \sum (T_{base} - < T_i >)^+$$

T_{base} = 18°C (65°F)

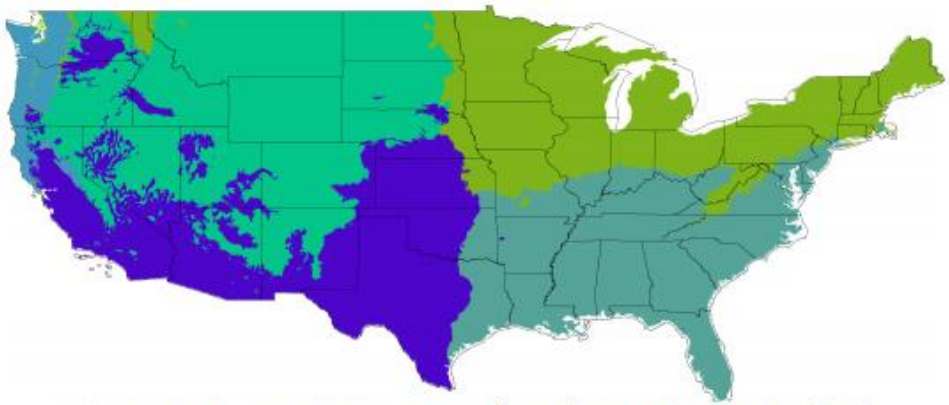
Cooling Degree Days:

$$CDD = \sum (< T_i > - T_{base})^+$$

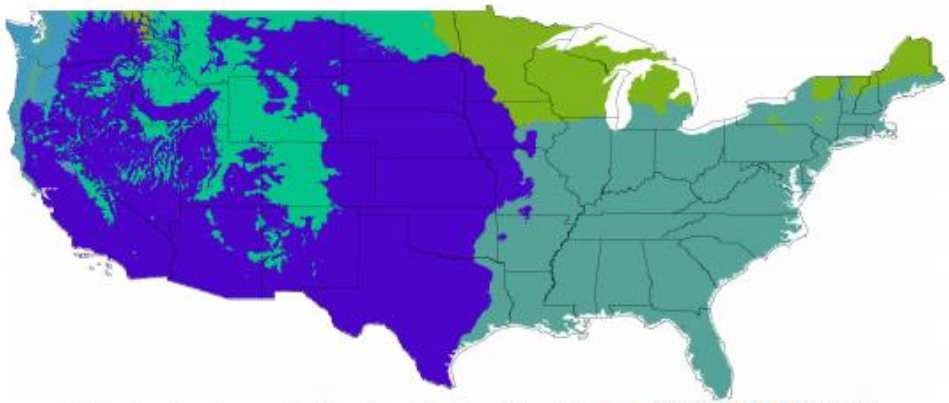
T_{base} = 10°C (50°F)

Climate Modeling – Climate Zones

Contemporary Period

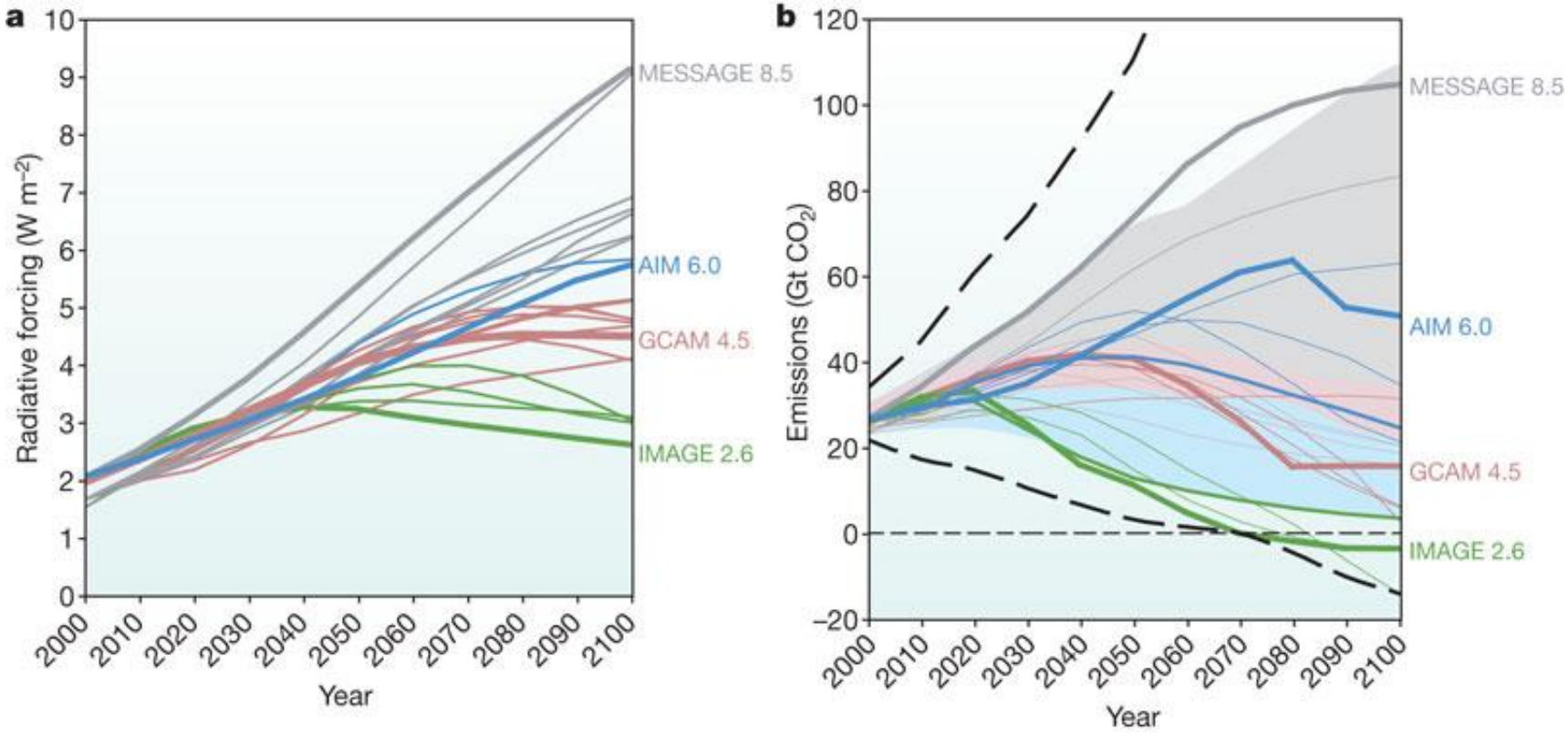


Clustering-based Climate Zones (K=5): HadGCM A1FI 2050

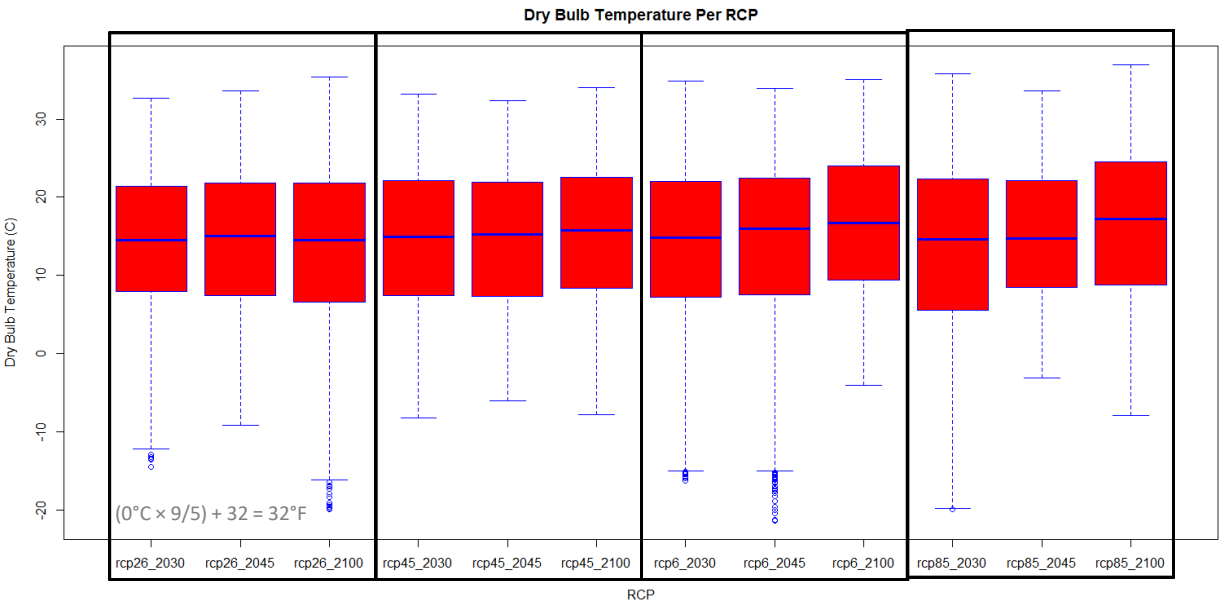


Clustering-based Climate Zones (K=5): HadGCM A1FI 2100

Climate Modeling – RCP Scenarios



Climate Modeling – Model Outputs



Project	CMIP5
Model	MRI-CGCM3
Modeler	Meteorological Research Institute
Experiment	2.6, 4.5, 6, 8.5
Time Frequency	3hr
Modeling Realm	atmos
Ensemble	r1i1p1
Version	20120119

Variable Long Name	Variable Short Name	Unit
Near-Surface Air Temperature	tas	K
Surface Downwelling Shortwave Radiation	rsds	W m-2
Surface Diffuse Downwelling Shortwave Radiation	rsdsdiff	W m-2
Surface Air Pressure	ps	Pa
Near-Surface Specific Humidity	huss	1

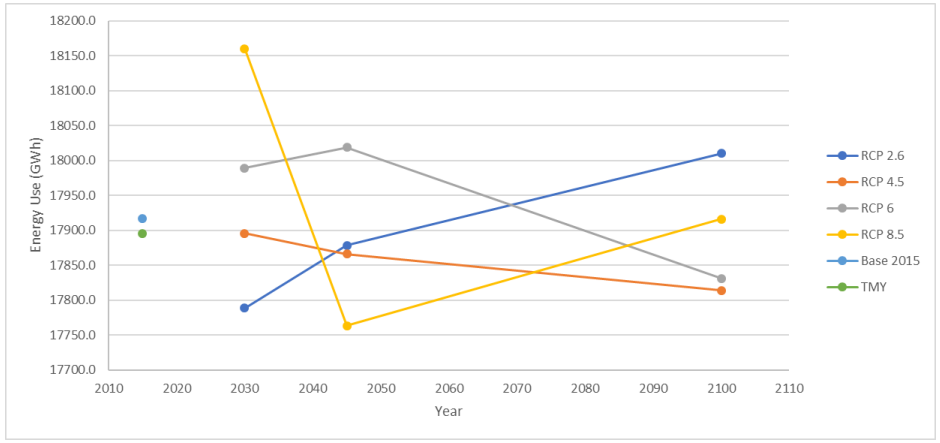
(0K − 273.15) × 9/5 + 32 = -459.7°F

3.1549 W/m^2 = 1 BTU/Hour*Ft^2

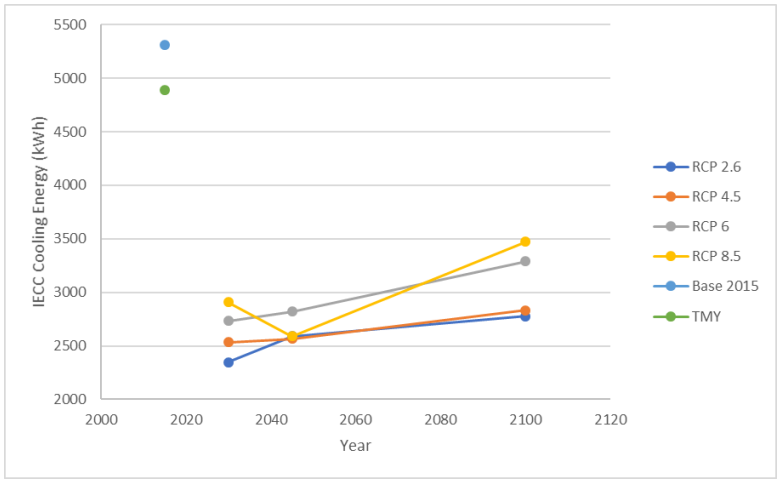
1 Pa = 0.00014503773 Psi

Climate Modeling – Energy Use/Demand

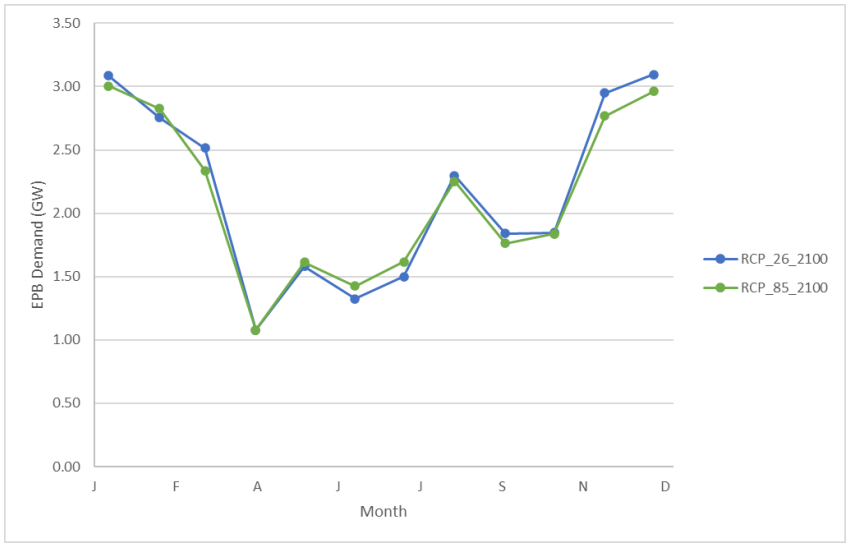
Total Energy Use



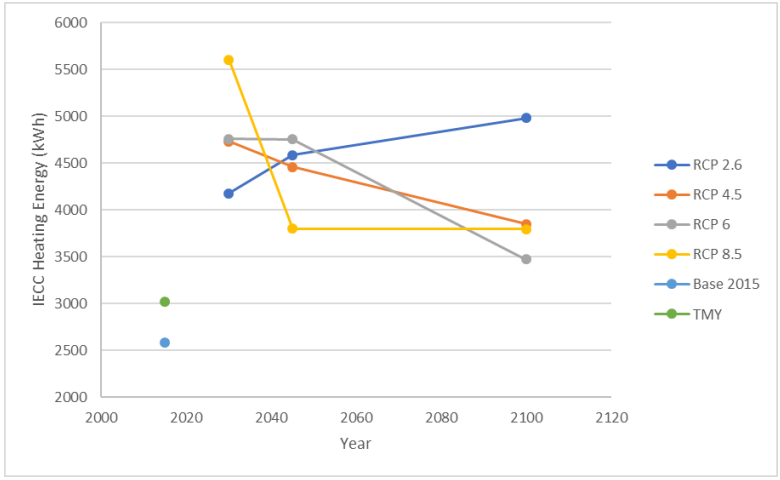
Residential Cooling Energy Use



Aggregated Monthly Demand



Residential Heating Energy Use



Next Steps

- *Commercial* Buildings simulation using FMY files for Entire US
- All US Climate Zones

QUESTIONS?

Brett Bass

bbass11@vols.utk.edu