Impacts of Climate Change and Urbanization on Future Building Performance

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Bentley Systems, Inc.

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ASHRAE Cleveland Chapter
AIA Cleveland
Cleveland BEC Building Enclosure Council

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Impacts of Climate Change and Urbanization on Future Building Performance
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Impacts of Climate Change and Urbanization on Future Building Performance

By Drury B. Crawley

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1

General CE hours

1

LEED-specific hours

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LEED AP BD+C

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Learning Objectives

- Explain difference between weather and climate
- Recognize climate change scenarios
- Explain impacts of urban heat islands on diurnal temperature
- Explain impact of climate change on energy performance in different climate zones

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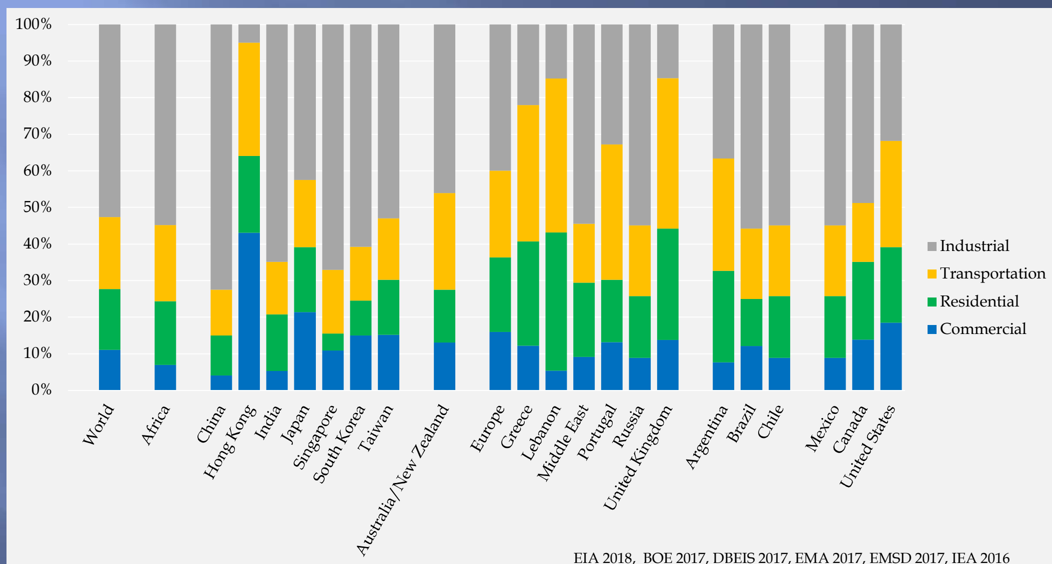
Buildings energy use worldwide



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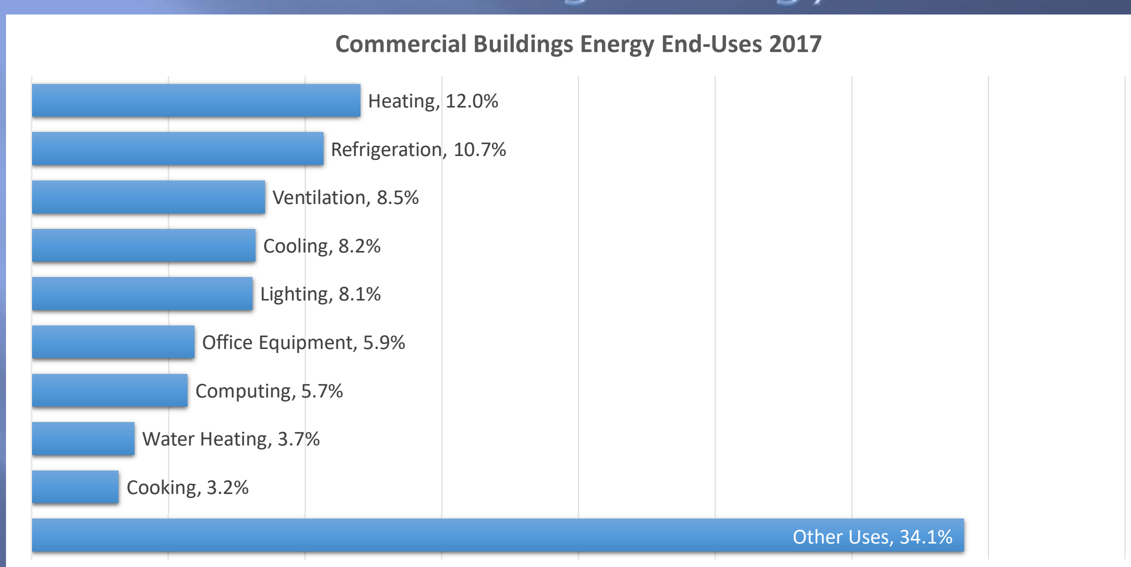
U.S. Buildings Energy Use



US Energy Information Administration. 2018. *Annual Energy Outlook 2018* EIA-0383 (2018) (2017 data)

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Weather ≠ Climate

Weather:

the state of the atmosphere with respect to wind, temperature, cloudiness, moisture, pressure, etc.

Climate:

the composite or generally prevailing weather conditions of a region, as temperature, air pressure, humidity, precipitation, sunshine, cloudiness, and winds, throughout the year, averaged over a series of years.

www.dictionary.com

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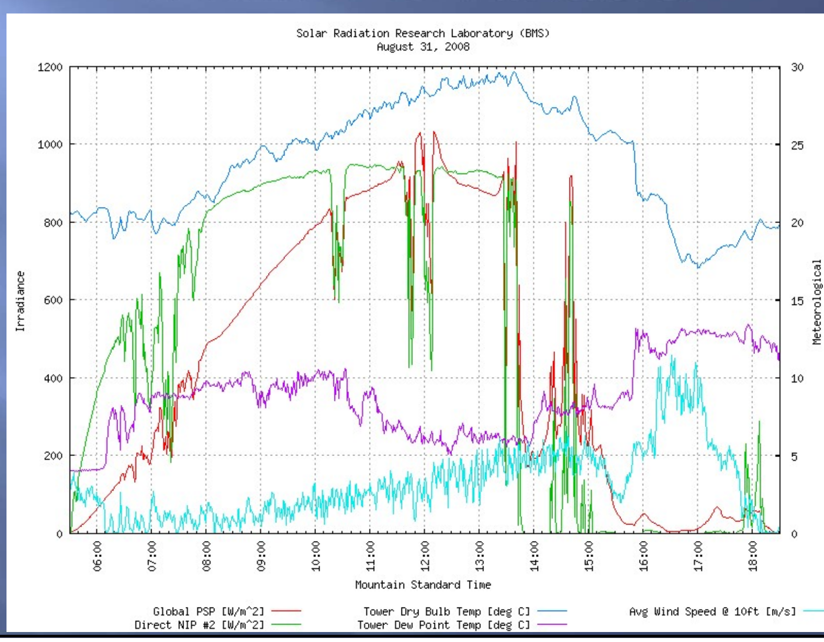
Weather is Variable!



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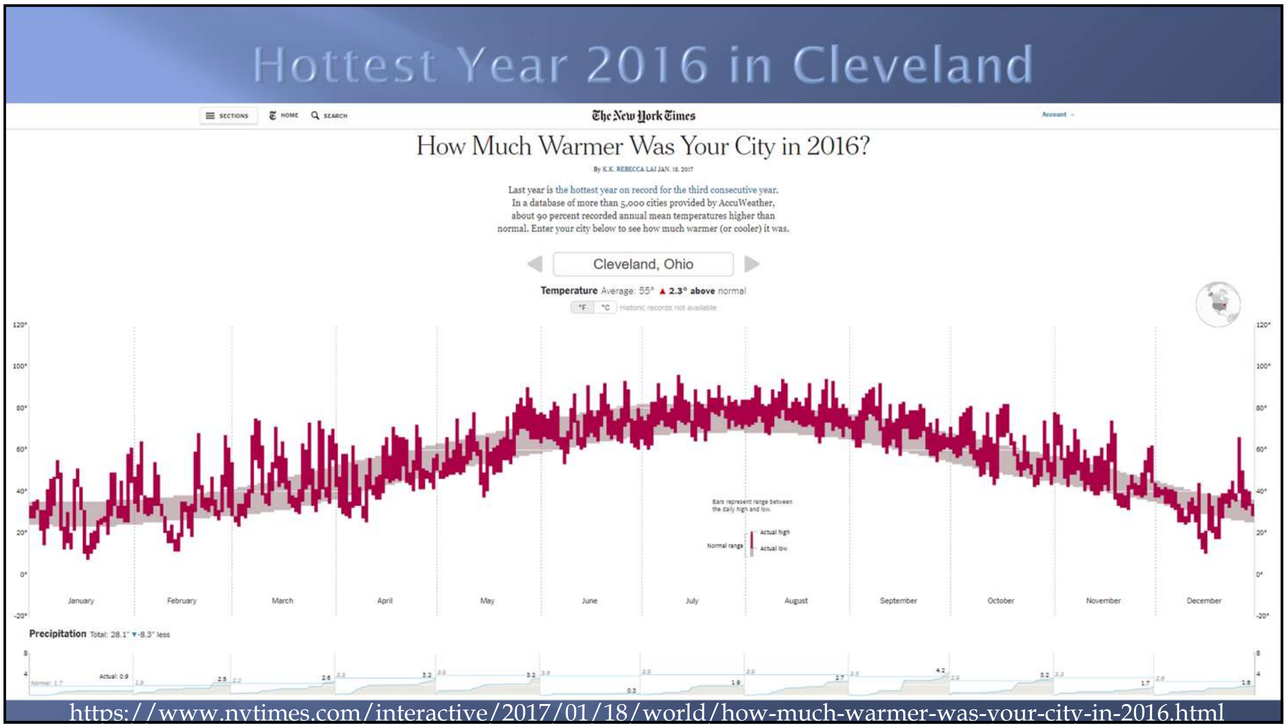
Hottest Year 2016 in Cleveland
The New York Times
How Much Warmer Was Your City in 2016?
Last year is the hottest year on record for the third consecutive year.
In a database of more than 5,000 cities provided by AccuWeather,
about 90 percent recorded annual mean temperatures higher than
normal. Enter your city below to see how much warmer (or cooler) it was.
Cleveland, Ohio
January
February
March
April
May
June
July
August
September
October
November
December
Precipitation
https://www.nytimes.com/interactive/2017/01/18/world/how-much-warmer-was-your-city-in-2016.html

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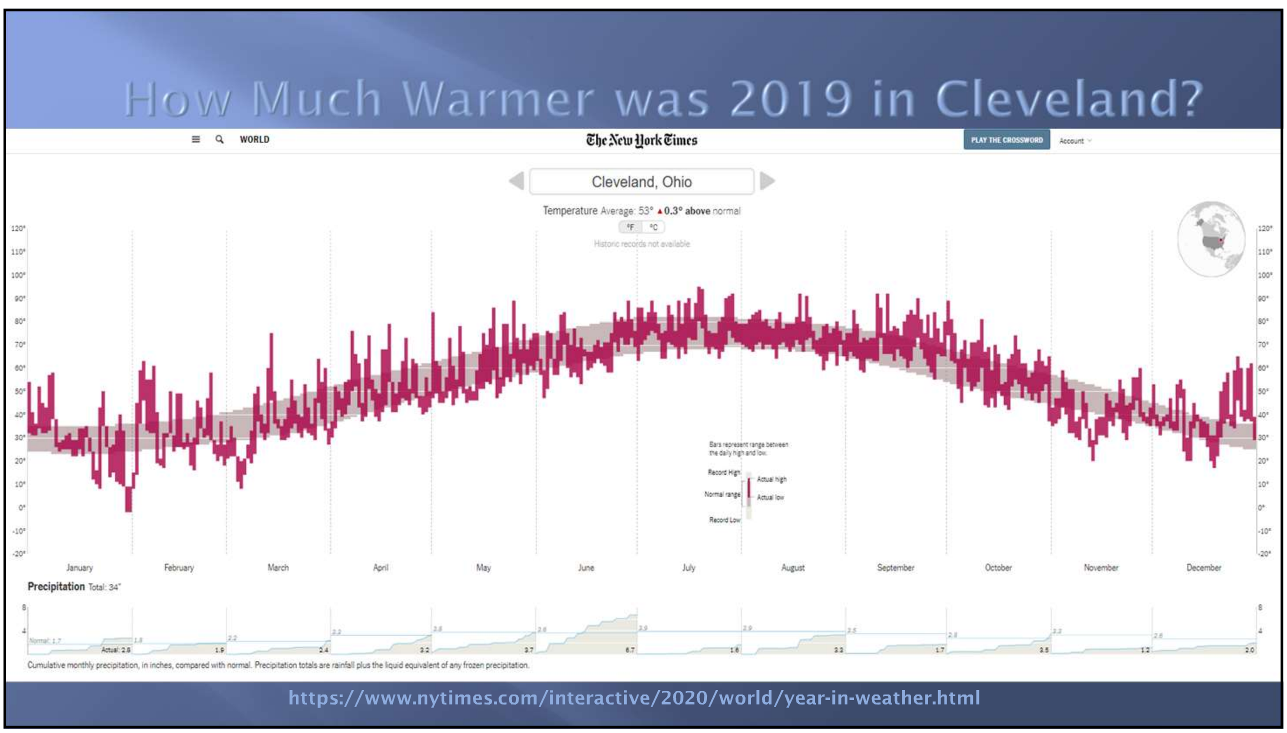
How Much Warmer was 2019 in Cleveland?
WORLD
The New York Times
PLAY THE CROSSWORD
Cleveland, Ohio
Temperature Average: 53° ▲0.3° above normal
January
February
March
April
May
June
July
August
September
October
November
December
Precipitation Total: 34"
https://www.nytimes.com/interactive/2020/world/year-in-weather.html

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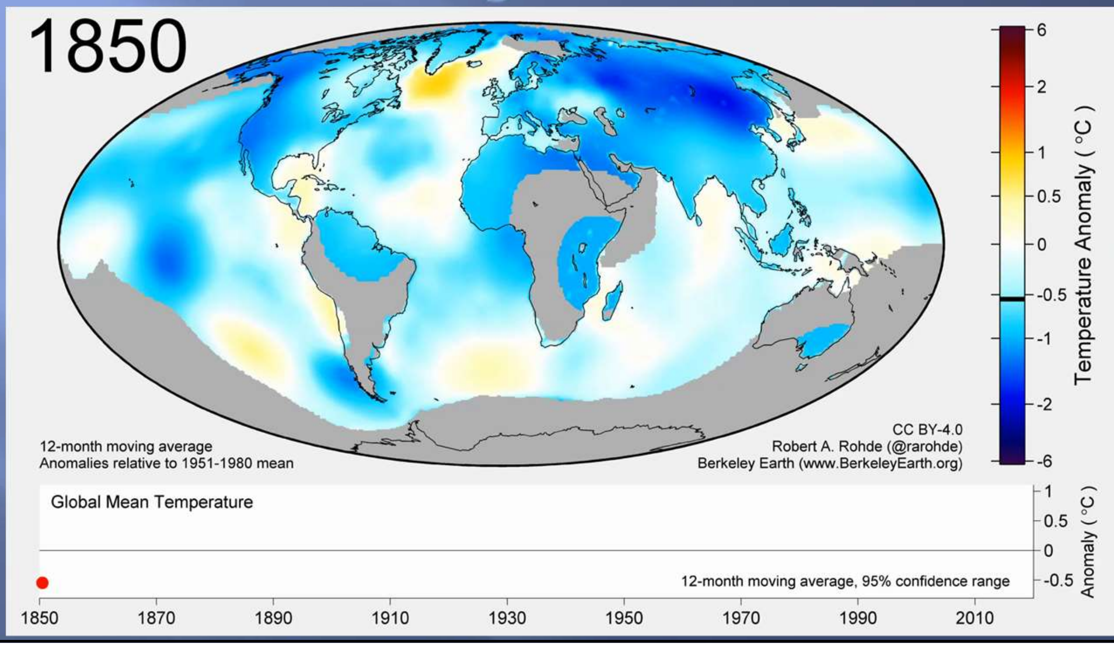
Climate Change 1850-2018



http://berkeleyearth.org/2018-temperatures/

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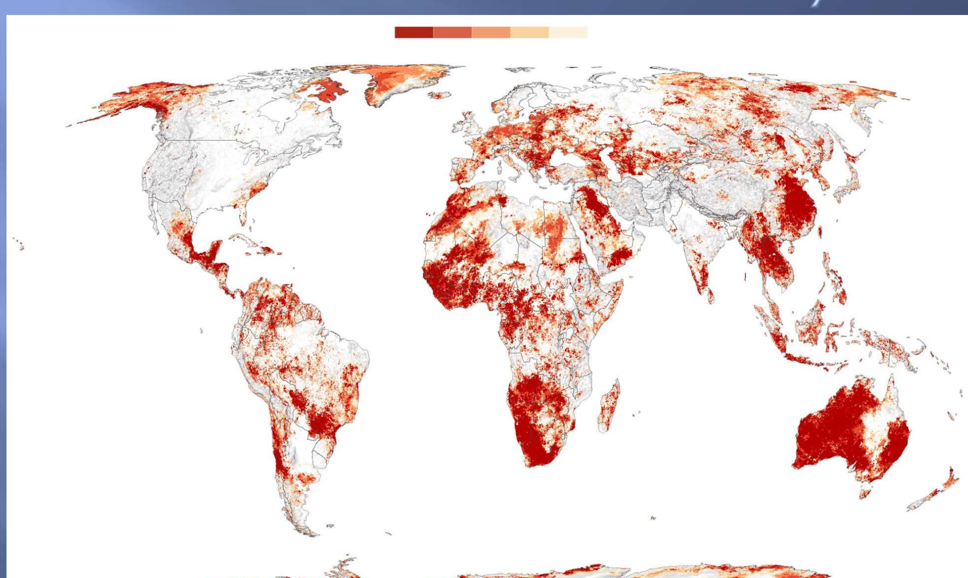
Where was 2019 the hottest year?



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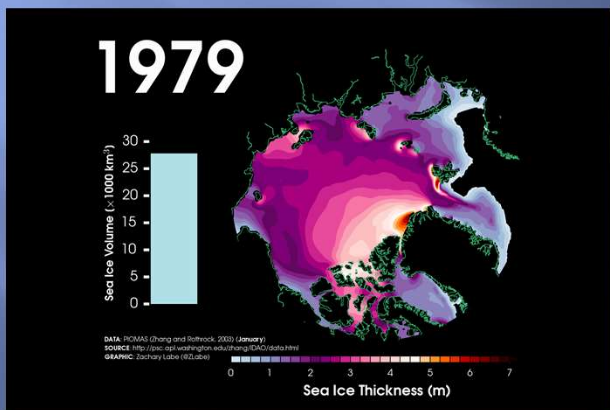
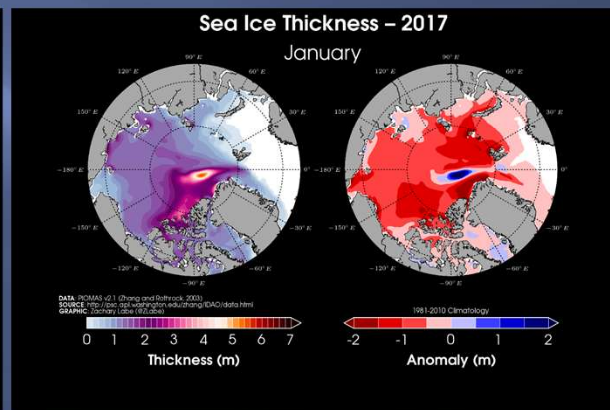
North Pole Sea Ice





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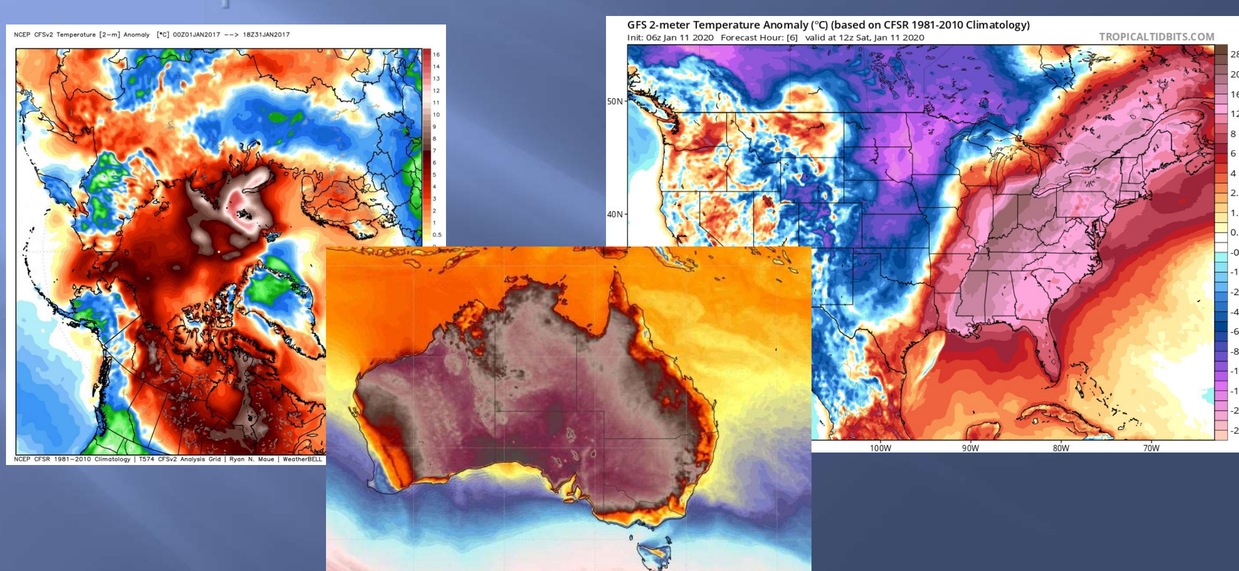
Temperature Anomalies Recent Years



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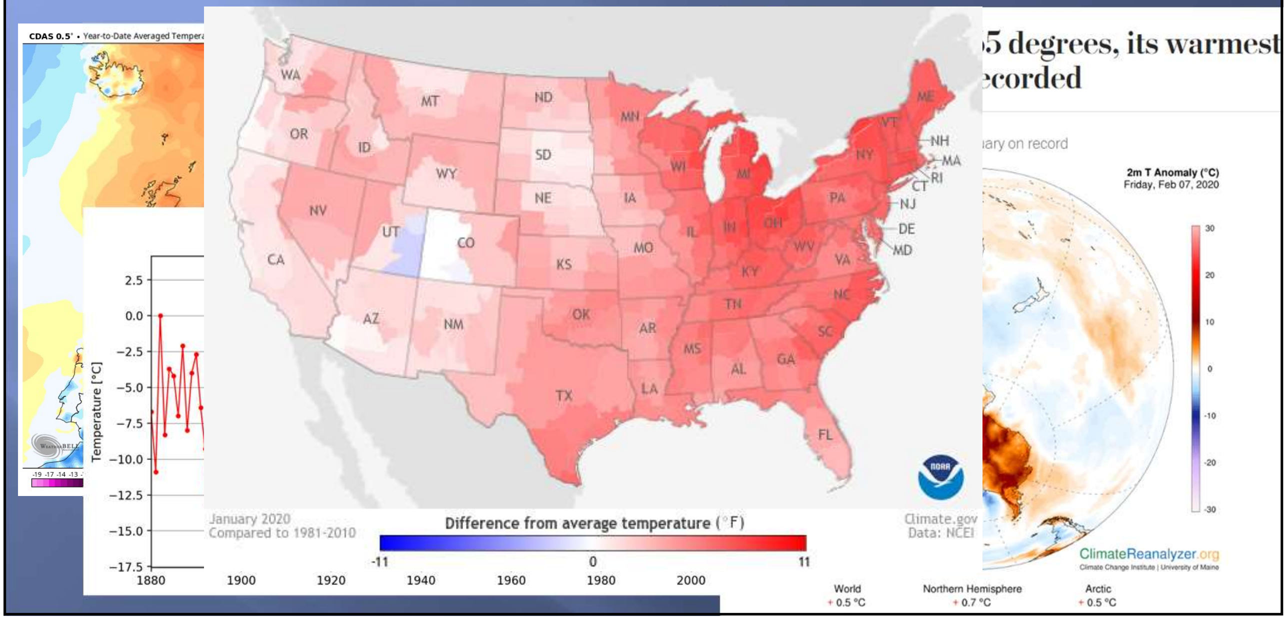
2020 so far



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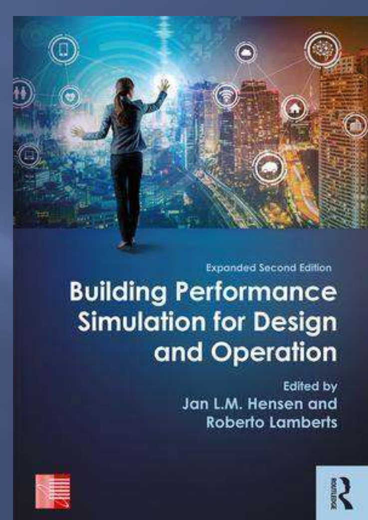
Building Performance Simulation for Design and Operation

- Released January 2011, 2nd Edition April 2019
- Endorsed by IBPSA
- Contents:



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Simulation Applications and Climatic Data Requirements

Simulation Application	Type of weather data required
Energy design and compliance analysis of fully-conditioned buildings	Typical (full year) hourly data
Performance of un- or semi- conditioned buildings	Typical data not adequate –require application specific data (e.g., warm summer, multi-year data)
Equipment sizing	Design-day or short period calculations using near-extreme conditions
Model calibration, building trouble shooting, control optimization, and actual savings estimation	Weather data observed during the study period at or near the building site
Engineering studies (e.g., hours when economizer is feasible)	Simple weather information (e.g., bin temperature data)
Natural ventilation design	Local wind conditions highly variable – airport data often unreliable for other sites. Locally measured wind data.
Daylighting studies	Hourly illuminance data usually sufficient for sensor-control lighting systems but sub-hourly data often required for visual comfort or control dynamics.
Renewable energy systems	Solar-electric systems require short-term data and spectral variation of incident solar radiation. Wind turbine systems require sub-hourly wind velocity data. (Standard hourly data may produce unreliable results for systems with non-linear characteristics.)

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Climatic Data Availability

- In the past, usually only available from ground observing stations
  - Rarely includes solar data
  - Temperature/humidity data generally robust.
  - Wind data is problematic – extremely variable due to terrain and site obstructions.
  - Other data can be limited or incomplete.
- Now, more sources incorporate remote sensing (satellite) data. Accuracy is quite good. Advantage – comprehensive global data, relatively decent grid. Not dependant on ground stations.
- In general master data sets such as those from NOAA/NCEI are near-real-time. Data is posted within a few days to weeks.
- But design conditions and data for simulation often require summary and further calculations before it can be used
  - Design conditions based on historical period of record
  - Ground observing stations (near real-time data) do not record solar radiation.

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Design Conditions

- Used for design sizing of heating, ventilating, air-conditioning, and dehumidification equipment, as well as or other energy-related processes in residential, agricultural, commercial, and industrial applications.
- Includes as a minimum dry-bulb, wet-bulb, and dew-point temperature, and wind speed with direction at various frequencies of occurrence.
- Typical annual percentiles* used:
  99.6% heating dry-bulb temperature and
  1% cooling dry-bulb temperature with coincident wet-bulb.
- Depending on the application, use other percentiles (99, 0.4, 2, 5) or variables (wind speed, dewpoint, wetbulb, etc.). Monthly cooling percentiles also available (0.4, 2, 5, 10).

*Percentiles represent number of hours that the design condition can be expected to be exceeded in a typical year, based on15-30 years of data. 99.6% ≈ 35 annual hours (8760 – (99.6% * 8760)). 1% ≈ 88 annual hours (8760 – (1% * 8760)).

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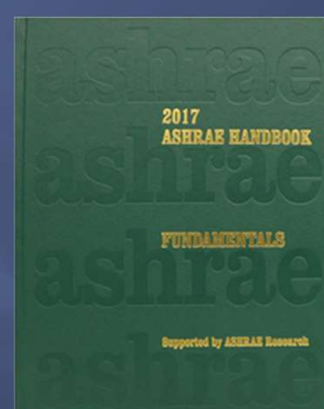
Design Conditions (cont'd)

- Best source for design conditions:
  Chapter 14 Climatic Design Information,
  ASHRAE Handbook-Fundamentals:
  - 8,118 locations through the world
  - Integrated Surface Dataset (ISD) data for stations from around the world provided by NCDC for the period 1990 to 2014
  - Updated every four years
- Climate changing!
  Comparing design conditions for 1274 locations between 1977-1986 and 1997-2006:
  - 99.6% annual dry-bulb temperature increased 1.52°C
  - 0.4% annual dry-bulb increased 0.79°C
  - annual dew point increased by 0.55°C
  - HDD base 18.3°C) decreased 237°C-days,
  - CDD base 10°C increased 136°C-days.



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Average Decadal Changes Last '30 Years'

99.6% heating dry bulb temperature	+ 0.76 °C	+ 1.37 °F
0.4% cooling dry bulb temperature	+ 0.38 °C	+ 0.68 °F
0.4% dehum. dew point temperature	+ 0.28 °C	+ 0.50 °F
Dry bulb temperature range	~ 0 °C	~ 0 °F
Average temperature	+ 0.41 °C	+ 0.73 °F
Heating degree-days base 18.3°C / 65°F	- 118 °C-day	- 212 °F-day
Cooling degree-days base 10°C / 50°F	+ 68 °C-day	+ 122 °F-day

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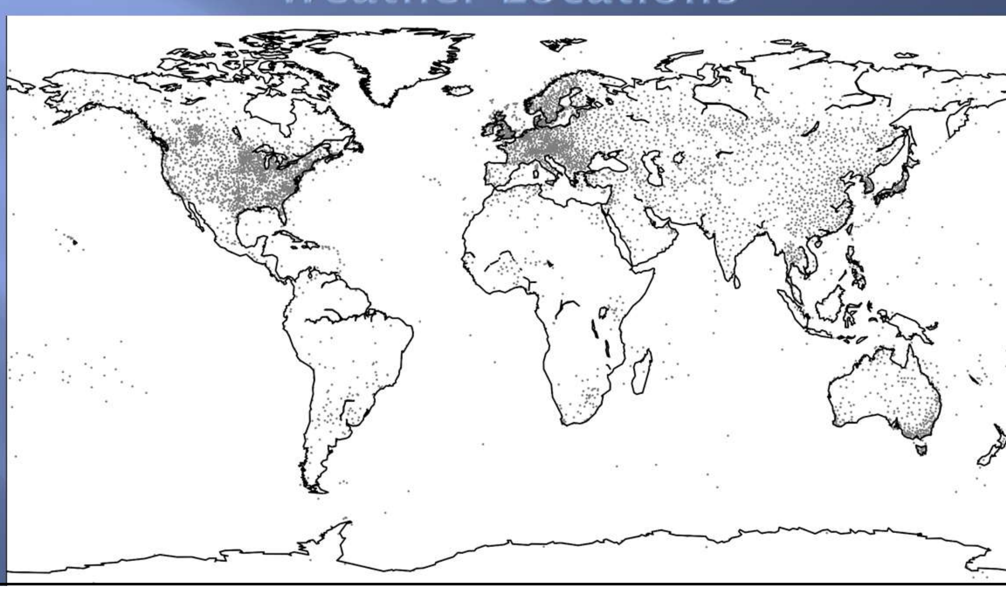
ASHRAE 2017 Handbook Fundamentals Weather Locations



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2017 ASHRAE Station Finder
Map
Satellite
WDView 6.0 (2017)
Search places...

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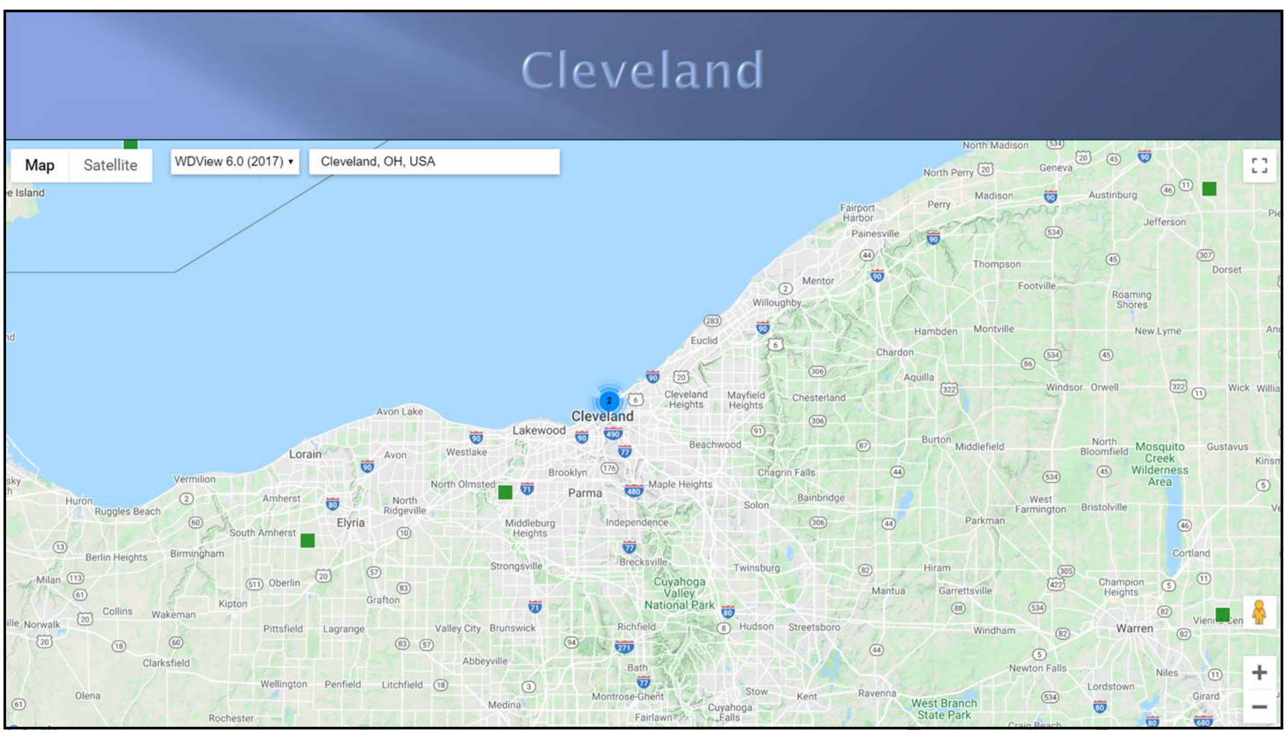
Cleveland
Map
Satellite
WDView 6.0 (2017)
Cleveland, OH, USA

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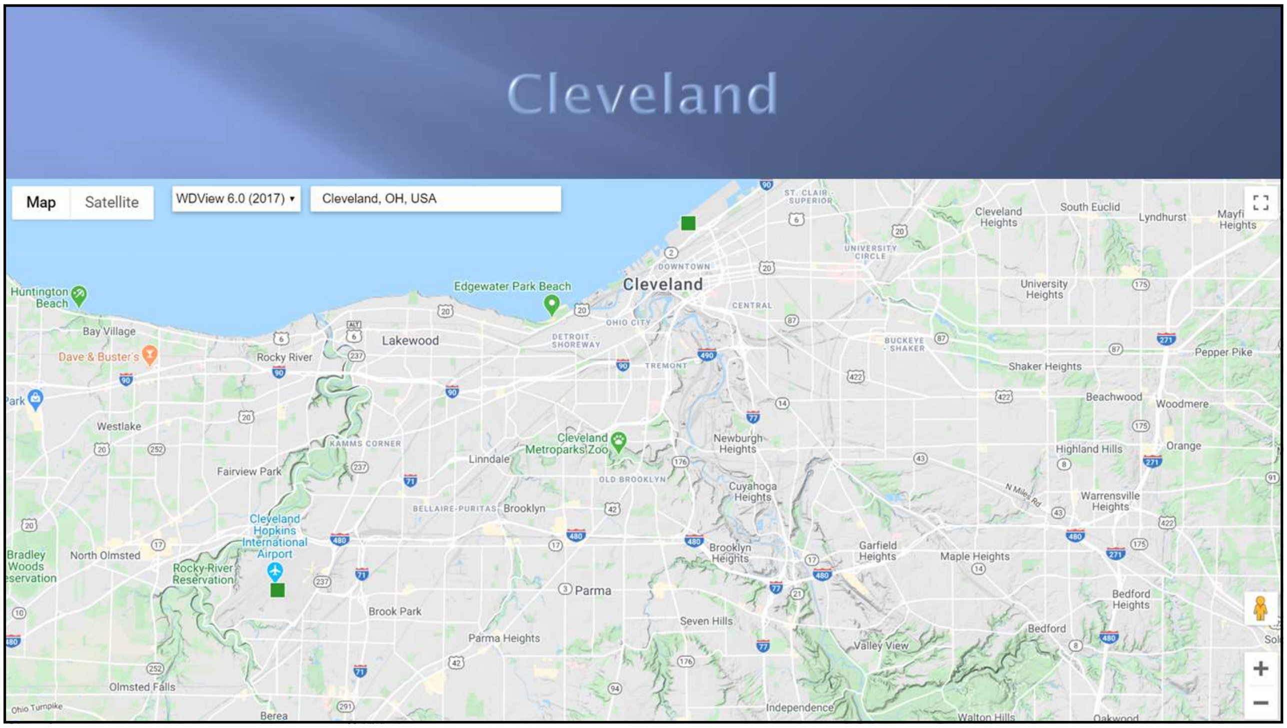
Cleveland
Map
Satellite
WDView 6.0 (2017)
Cleveland, OH, USA
Cleveland
Lakewood
Edgewater Park Beach
Huntington Beach
Bay Village
Rocky River
Westlake
Fairview Park
Cleveland Hopkins International Airport
North Olmsted
Brook Park
Parma
Parma Heights
Brooklyn
Linndale
Cleveland Metroparks Zoo
Newburgh Heights
Cuyahoga Heights
Garfield Heights
Maple Heights
Shaker Heights
Cleveland Heights
University Heights
South Euclid
Lyndhurst
Beachwood
Woodmere
Pepper Pike
Orange
Highland Hills
Warrensville Heights
Bedford
Bedford Heights
Seven Hills
Valley View
Independence
Olmsted Falls
Berea

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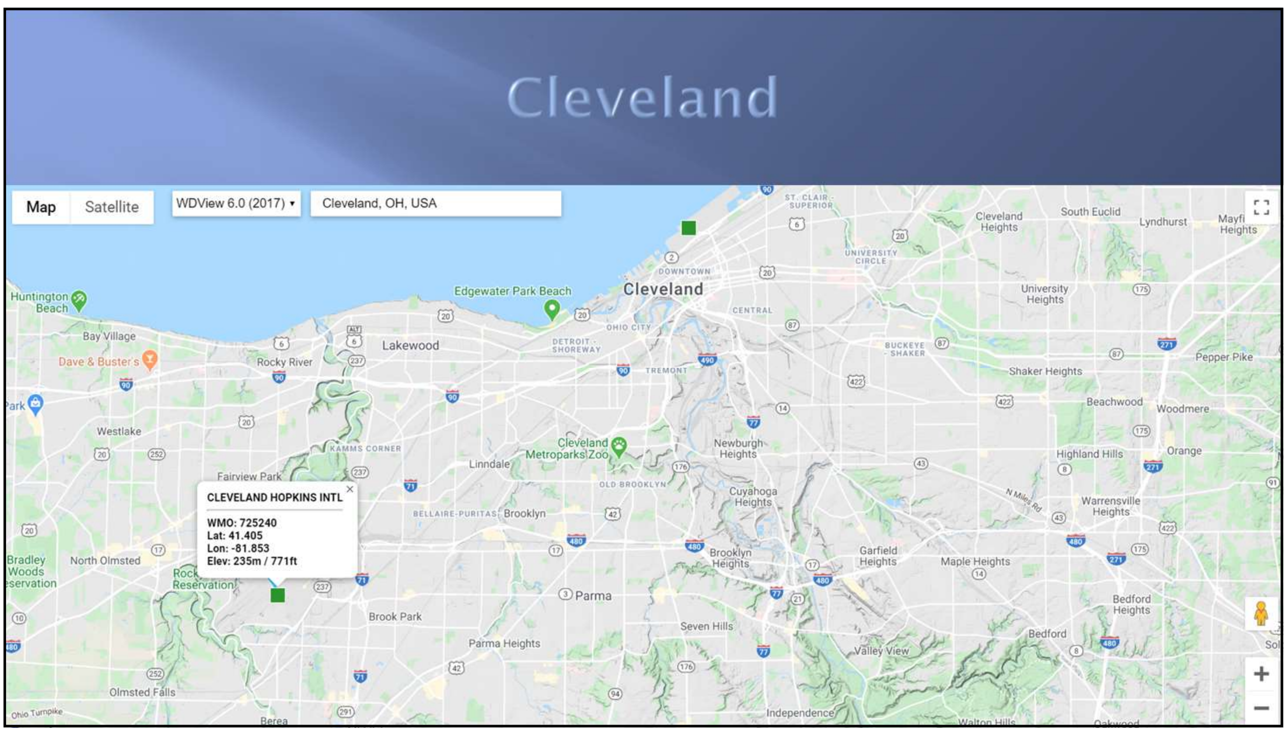
Cleveland
Map
Satellite
WDView 6.0 (2017)
Cleveland, OH, USA
CLEVELAND HOPKINS INTL
WMO: 725240
Lat: 41.405
Lon: -81.853
Elev: 235m / 771ft
Cleveland
Lakewood
Parma
Brook Park
Parma Heights
Brooklyn
Garfield Heights
Maple Heights
Shaker Heights
Bedford
Independence

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2017 Fundamentals Design Conditions

2017 ASHRAE Handbook - Fundamentals (IP)

CLEVELAND HOPKINS INTL, OH, USA WMO#: **725240**

Lat: **41.405N** Long: **81.853W** Elev: **770** StdP: **14.29** Time Zone: **-5.00 (NAE)** Period: **90-14** WBAN: **14820**

Annual Heating and Humidification Design Conditions

	Coldest Month	Heating DB		Humidification DP/MCDB and HR						Coldest month WS/MCDB				MCWS/PCWD to 99.6% DB		
		99.6%	99%	99.6%			99%			0.4%		1%				
				DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD	
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	
(1)	1	4.6	10.0	-3.4	4.7	6.6	1.4	6.1	11.8	28.5	31.2	26.1	29.0	10.6	220	(1)

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

	Hottest Month	Hottest Month DB Range	Cooling DB/MCWB						Evaporation WB/MCDB						MCWS/PCWD to 0.4% DB		
			0.4%		1%		2%		0.4%		1%		2%				
			DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD	
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	
(2)	7	16.9	89.4	73.6	86.8	72.2	84.2	70.9	76.1	85.3	74.6	83.1	73.1	81.1	11.1	230	(2)

	Dehumidification DP/MCDB and HR									Enthalpy/MCDB						Extreme Max WB	
	0.4%			1%			2%			0.4%		1%		2%			
	DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB		
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	
(3)	73.1	126.7	81.2	71.8	120.7	79.5	70.3	114.9	78.1	39.9	85.5	38.4	83.1	37.1	81.3	84.0	(3)

Extreme Annual Design Conditions

	Extreme Annual WS				Extreme Annual Temperature				n-Year Return Period Values of Extreme Temperature								
					Mean		Standard Deviation		n=5 years		n=10 years		n=20 years		n=50 years		
	1%	2.5%	5%		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	
	(n)	(o)	(p)		(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	
(4)	24.6	21.0	18.9	DB	-1.1	93.4	6.9	2.9	-6.0	95.5	-10.1	97.2	-14.0	98.8	-19.0	100.9	(4)
(5)				WB	-1.8	79.0	6.7	2.0	-6.6	80.4	-10.6	81.6	-14.4	82.7	-19.3	84.1	(5)

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2017 Fundamentals Design Conditions

Monthly Climatic Design Conditions

				Annual (d)	Jan (e)	Feb (f)	Mar (g)	Apr (h)	May (i)	Jun (j)	Jul (k)	Aug (l)	Sep (m)	Oct (n)	Nov (o)	Dec (p)	
(6)	Temperatures, Degree-Days and Degree-Hours		DBAvg	51.3	28.2	30.1	38.0	49.6	59.8	69.2	73.0	71.6	64.5	53.7	43.0	33.0	(6)
(7)			DBStd	18.17	11.41	10.29	11.21	9.85	8.63	7.08	5.50	5.24	7.09	8.18	9.26	9.69	(7)
(8)			HDD50	2626	681	561	406	127	12	0	0	0	1	53	251	534	(8)
(9)			HDD65	5801	1141	977	840	473	211	40	4	7	92	362	661	993	(9)
(10)			CDD50	3085	4	4	34	115	317	577	714	670	437	167	40	6	(10)
(11)			CDD65	786	0	0	3	10	51	167	253	212	78	12	0	0	(11)
(12)			CDH74	6183	0	0	13	103	462	1354	2093	1544	545	68	1	0	(12)
(13)			CDH80	1779	0	0	1	16	114	414	668	429	132	5	0	0	(13)
(14)	Wind		WSAvg	9.5	11.3	10.7	10.6	10.3	9.1	8.3	8.0	7.4	8.2	9.3	10.5	10.8	(14)
(15)	Precipitation		PrecAvg	36.90	2.20	2.20	2.90	3.20	3.60	3.50	3.50	3.40	3.50	2.60	3.20	3.00	(15)
(16)			PrecMax	53.80	4.40	4.70	5.20	6.60	9.10	9.10	9.10	9.00	7.30	5.60	8.80	8.60	(16)
(17)			PrecMin	18.80	0.40	0.50	0.90	1.20	1.00	0.60	0.70	0.50	0.70	0.70	0.80	1.10	(17)
(18)			PrecStd	6.40	1.00	1.00	1.00	1.20	1.70	1.80	1.50	1.80	1.50	1.10	1.70	1.20	(18)
(19)	Monthly Design Dry Bulb and Mean Coincident Wet Bulb Temperatures	0.4%	DB		61.7	62.9	75.2	82.5	86.9	90.9	93.3	91.3	89.0	80.2	70.0	62.0	(19)
(20)			MCWB		56.1	54.1	61.4	64.4	70.4	73.1	76.8	75.4	71.9	66.6	60.1	56.9	(20)
(21)		2%	DB		55.8	55.2	68.0	77.0	83.4	87.9	89.7	87.8	83.7	75.3	65.1	56.5	(21)
(22)			MCWB		52.2	49.3	57.0	61.9	68.4	72.6	74.4	73.3	70.0	63.3	57.1	52.2	(22)
(23)		5%	DB		50.1	49.4	62.5	72.0	79.6	85.0	86.6	84.7	80.0	71.2	61.4	51.3	(23)
(24)			MCWB		45.8	43.6	54.1	59.0	66.6	71.0	72.6	71.9	68.4	61.7	54.9	47.6	(24)
(25)		10%	DB		43.6	44.4	56.3	66.9	75.2	81.7	83.7	81.9	76.5	67.2	57.6	46.5	(25)
(26)			MCWB		39.8	39.9	49.7	56.5	64.2	69.6	71.3	70.7	66.7	59.1	51.5	42.7	(26)
(27)	Monthly Design Wet Bulb and Mean Coincident	0.4%	WB		56.6	55.8	62.6	67.9	73.8	76.4	78.8	78.0	75.0	69.4	62.6	57.5	(27)
(28)			MCDB		60.5	61.2	73.0	77.2	82.9	86.4	89.5	87.6	83.5	77.5	67.4	60.8	(28)
(29)		2%	WB		52.7	50.3	58.7	64.0	70.9	74.5	76.7	75.4	72.4	65.8	58.7	53.3	(29)
(30)			MCDB		55.9	54.7	66.2	74.1	80.0	84.3	86.8	83.4	79.6	72.6	63.7	56.1	(30)
(31)			WB		46.3	44.7	54.9	60.6	68.5	72.8	74.7	74.0	70.5	63.1	55.5	47.9	(31)

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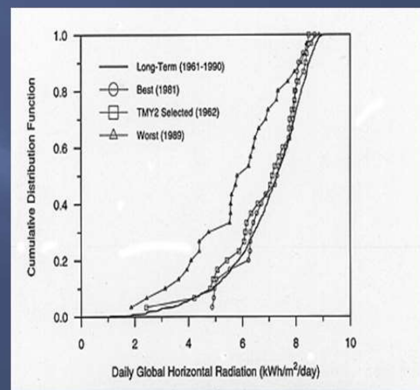
Climatic Data in Building Performance Simulation

- Climatic data needed for simulating representative performance from a single year analysis.
- TMY (Typical Meteorological Year) approach is most widely used– a composite of months (not all from same year), each representative for the period of record. ISO Standard 15927-4 uses this method.
- Months selected using statistical of indices (daily min, mean, max) dry-bulb temperature, dew-point temperature, wind speed, and total global and direct solar radiation. Each method varies the weightings of the indices based on their importance.



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Typical Meteorological Year Hourly Data Sets

- Best for:
  - Comparison of alternatives during design
  - Compliance with building standards/codes and green building rating system points
- Limitations:
  - No explicit effort to represent extreme conditions
  - Files not intended to represent design conditions (can be mild)

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Typical Meteorological Year Weather Data Sets Available

Weather Data Sets		Number of Locations	Geographic Coverage
Acronym	Name		
CTZ2	California Climate Zones 2	16	California
CWEC	Canadian Weather for Energy Calculations	80	Canada
CIBSE	Chartered Institute of Building Services Engineers Test Reference Years and Design Summer Years	14	United Kingdom
CSWD	Chinese Standard Weather Data	270	China
CTYW	Chinese Typical Year Weather	57	China
IGDG	Italian Climate data collection 'Gianni de Giorgio'	66	Italy
IMGW	Instytutu Meteorologii i Gospodarki Wodnej Weather Data Set	61	Poland
IMS	Israel Meteorological Service Weather Data for Israel	4	Israel
ISHRAE	Indian Society of Heating, Refrigerating and Air-Conditioning Engineers	58	India
ITMY	Iranian Typical Meteorological Year	6	Iran
IWEC2	International Weather for Energy Calculations v2	3012	Worldwide (except USA and Canada)
NIWA	National Institute of Water & Atmospheric Research	16	New Zealand
RMY	Representative Meteorological Year	80	Australia
SWEC	Spanish Weather for Energy Calculations	52	Spain
SWERA	Solar and Wind Energy Resource Assessment	156	Belize, Brazil, China, Cuba, El Salvador, Ethiopia, Ghana, Guatemala, Honduras, Kenya, Maldives, Nicaragua, and Sri Lanka
TMY3	Typical Meteorological Year 3	1020	USA, Guam, Puerto Rico, US Virgin Islands
TMYx	Typical Meteorological Year	13,000+	Worldwide (data up through 2018)

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Actual Weather Data

- Actual hourly weather data required to calibrate to utility bills in existing buildings and subsequent evaluation of retrofit alternatives.
- Many sources – some providing near-real time data and/or prediction:
  - NOAA/NCEI/WMO Data Center
  - Weather Bank
  - Weather Source
  - Weather Underground
- Biggest issue – how complete are the data – does it include temperature, humidity, wind, solar radiation?

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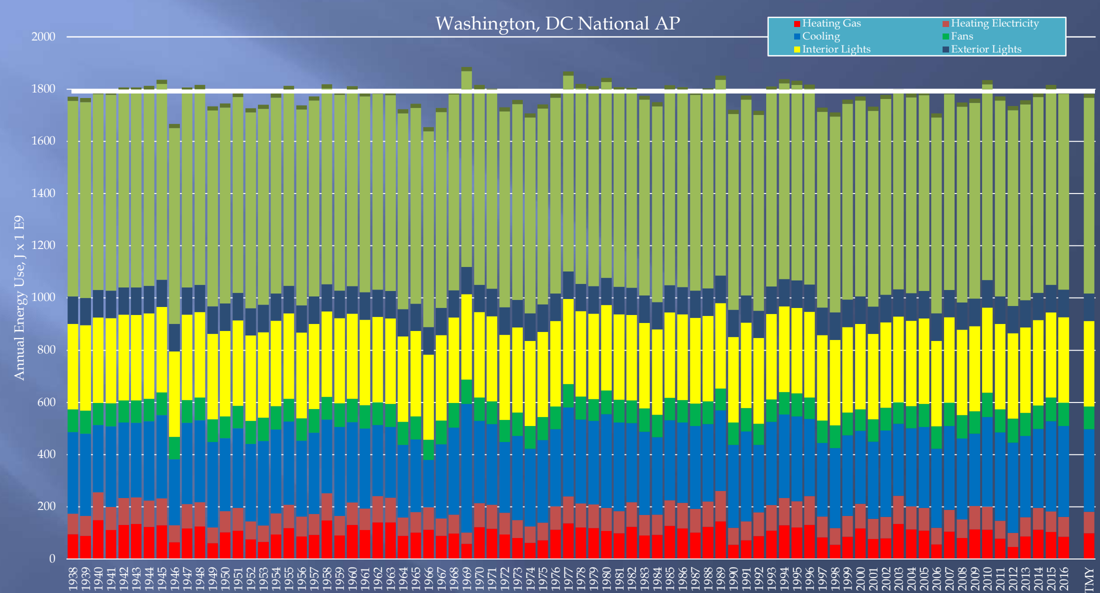
Typical vs. Actual



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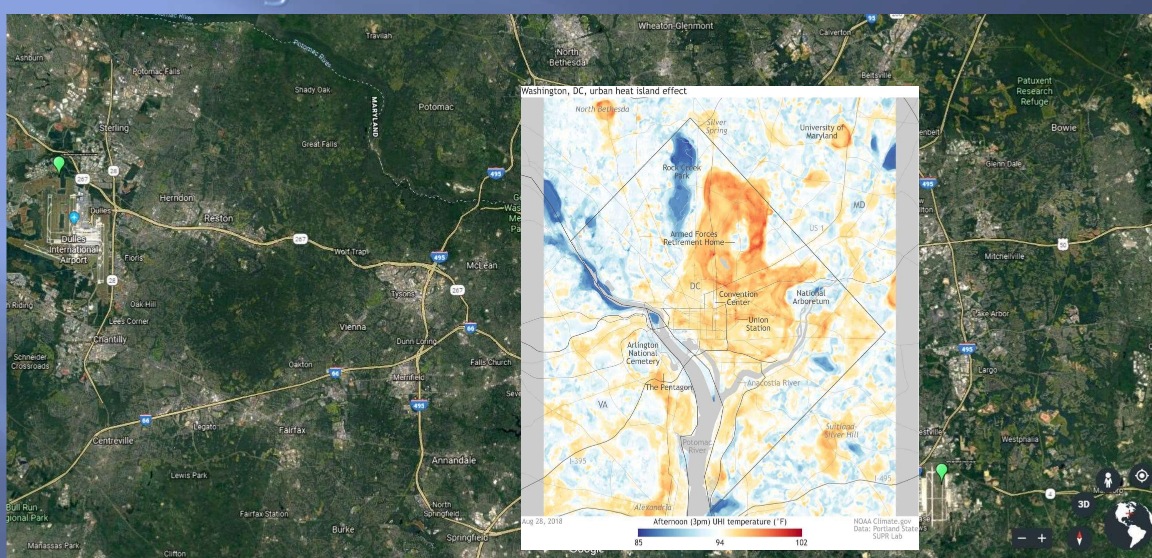
Washington DC Measured Heat Island



https://www.washingtonpost.com/weather/2018/10/15/sizzling-summer-days-northeast-dc-heats-up-most-noaa-analysis-shows/

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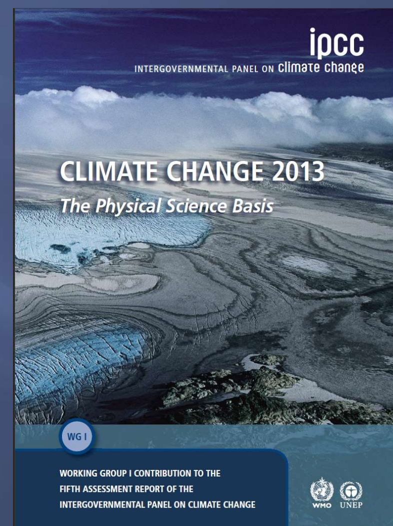
IPCC Climate Change Scenarios

- Four major storylines developed to represent different demographic, social, economic, technological, and environmental developments.
- Updated for each Assessment Report, latest AR5 was released in 2013
- Four emissions scenarios, called Representative Concentration Pathways (RCPs) derived from the storylines – RCP2.6, RCP4.5, RCP 6.0 RCP8.5– represent the range of potential climate impact



https://www.ipcc.ch/ https://www.ipcc.ch/report/ar5/index.shtml

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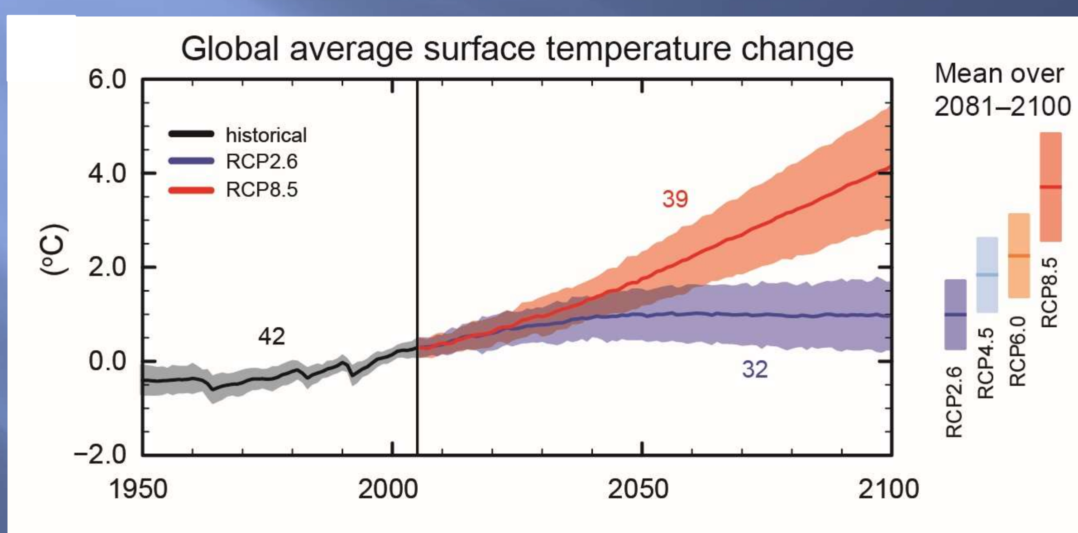
Range of Annual Average Temperature Change Predicted



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Creating Future Climatic Data

- Methods
  - Dynamic downscaling
    - Physics-based model used to downscale global climate model results
  - Analogue scenarios
    - Find existing locations with comparable data to the predicted climate change scenario results
  - Time series adjustment (morphing)
    - Shift and stretch the existing data to match the predicted monthly change
  - Statistical models
    - Stochastic model trained on observed data adjusts data based on altered frequency distributions of weather variables

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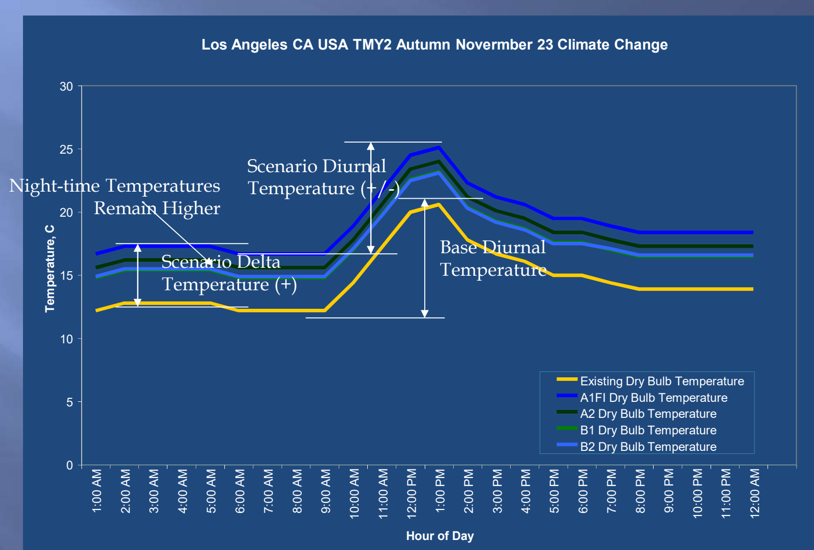
TMY2 Data Morphed with Climate Change Scenarios



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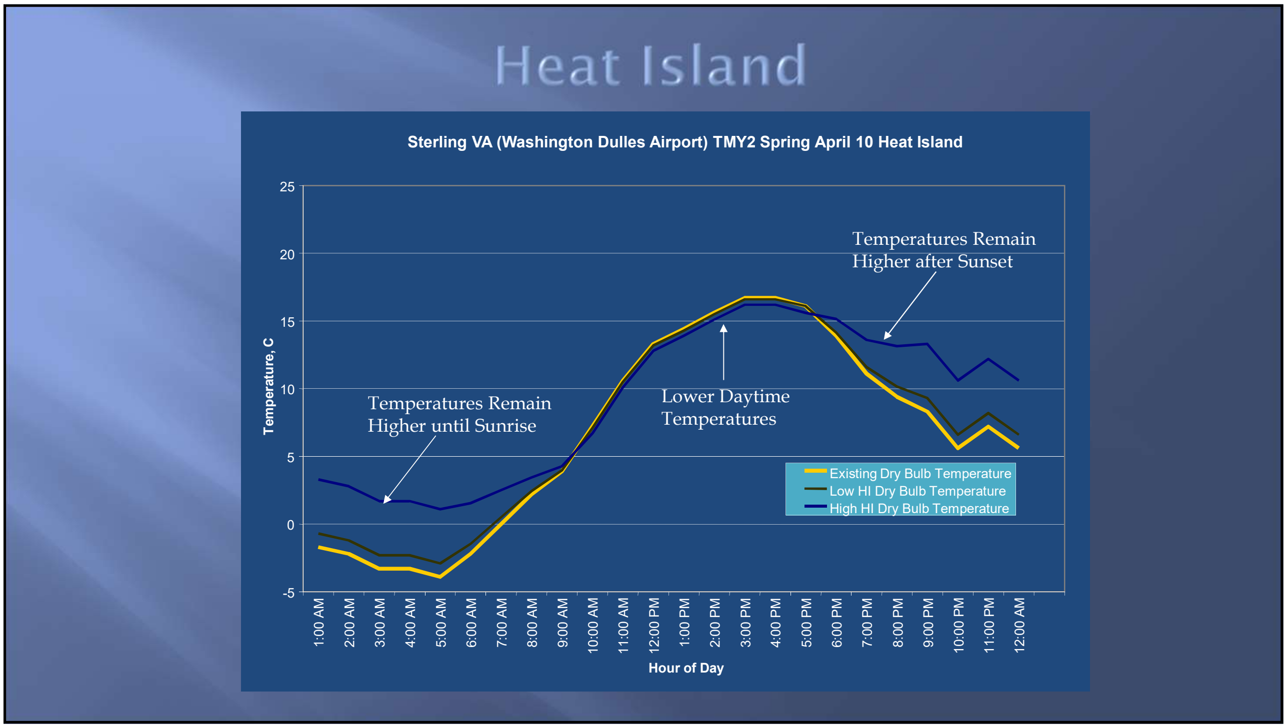

Heat Island
Sterling VA (Washington Dulles Airport) TMY2 Spring April 10 Heat Island
Temperature, C
25
20
15
10
5
0
-5
Temperatures Remain Higher after Sunset
Temperatures Remain Higher until Sunrise
Lower Daytime Temperatures
Existing Dry Bulb Temperature
Low HI Dry Bulb Temperature
High HI Dry Bulb Temperature
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM
Hour of Day

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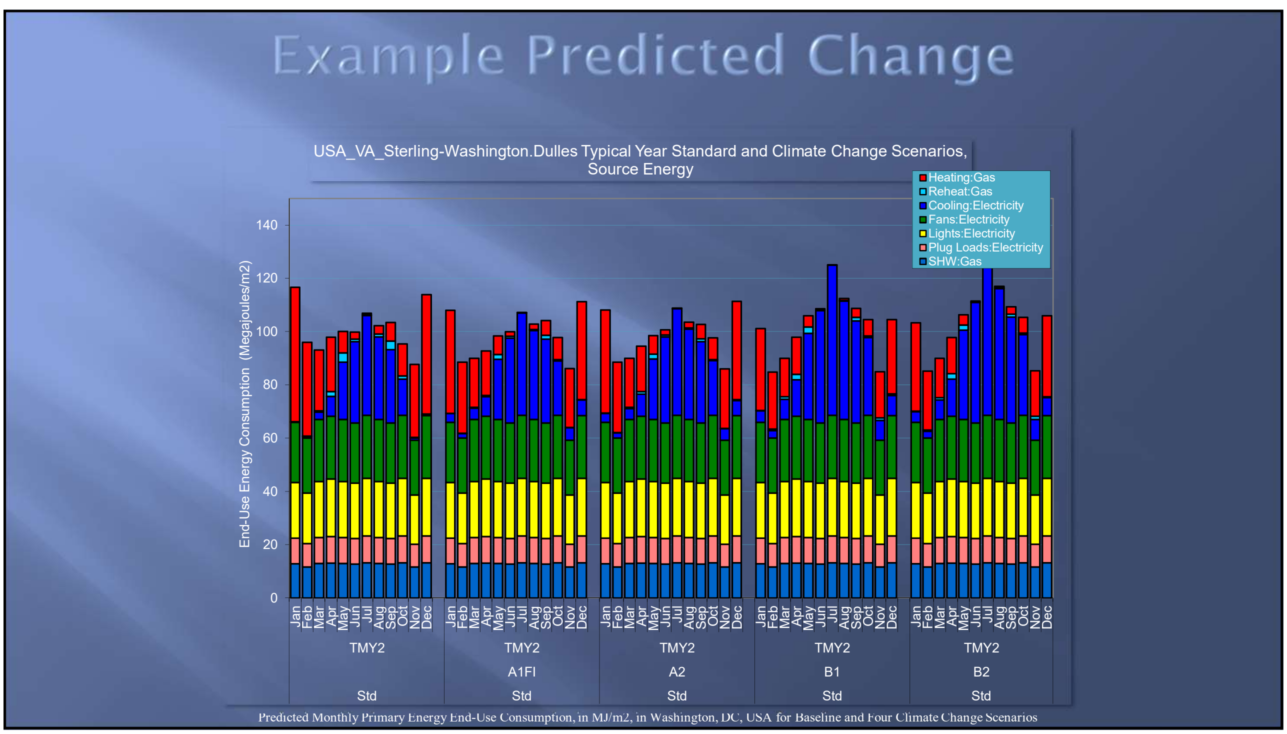

Example Predicted Change
USA_VA_Sterling-Washington.Dulles Typical Year Standard and Climate Change Scenarios, Source Energy
Heating:Gas
Reheat:Gas
Cooling:Electricity
Fans:Electricity
Lights:Electricity
Plug Loads:Electricity
SHW:Gas
End-Use Energy Consumption (Megajoules/m2)
140
120
100
80
60
40
20
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
TMY2
A1FI
A2
B1
B2
Std
Predicted Monthly Primary Energy End-Use Consumption, in MJ/m2, in Washington, DC, USA for Baseline and Four Climate Change Scenarios

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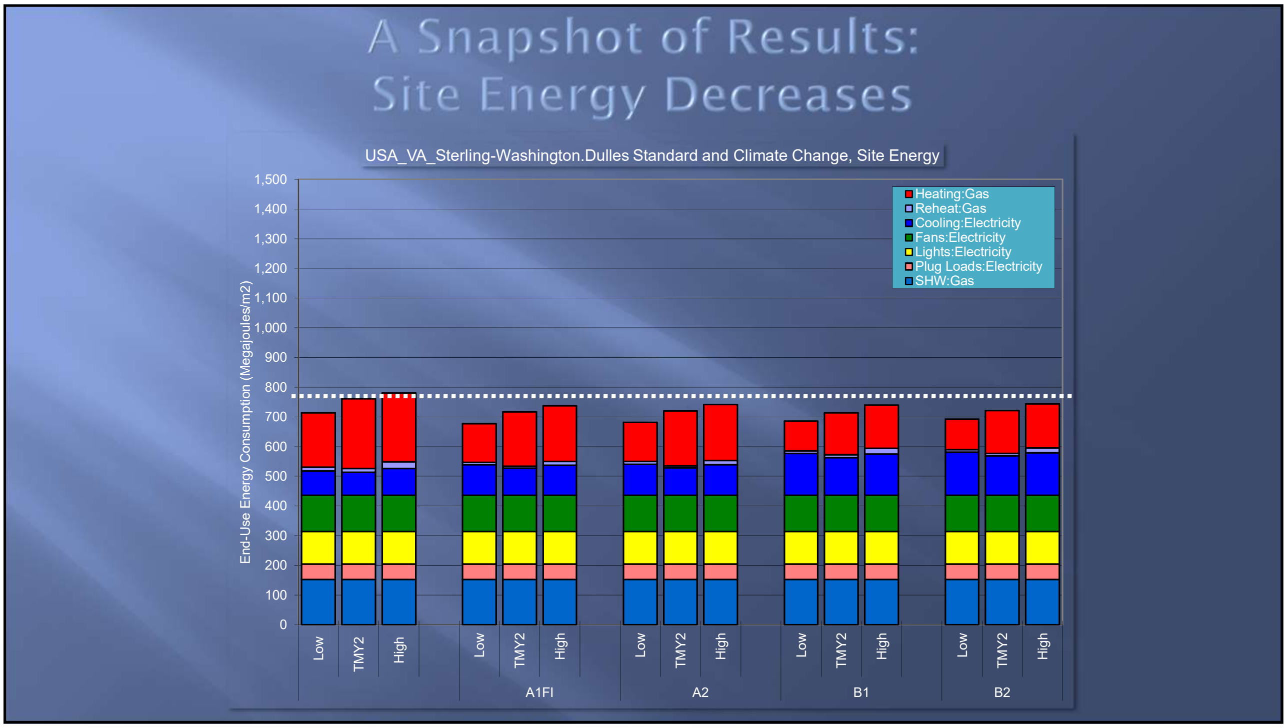
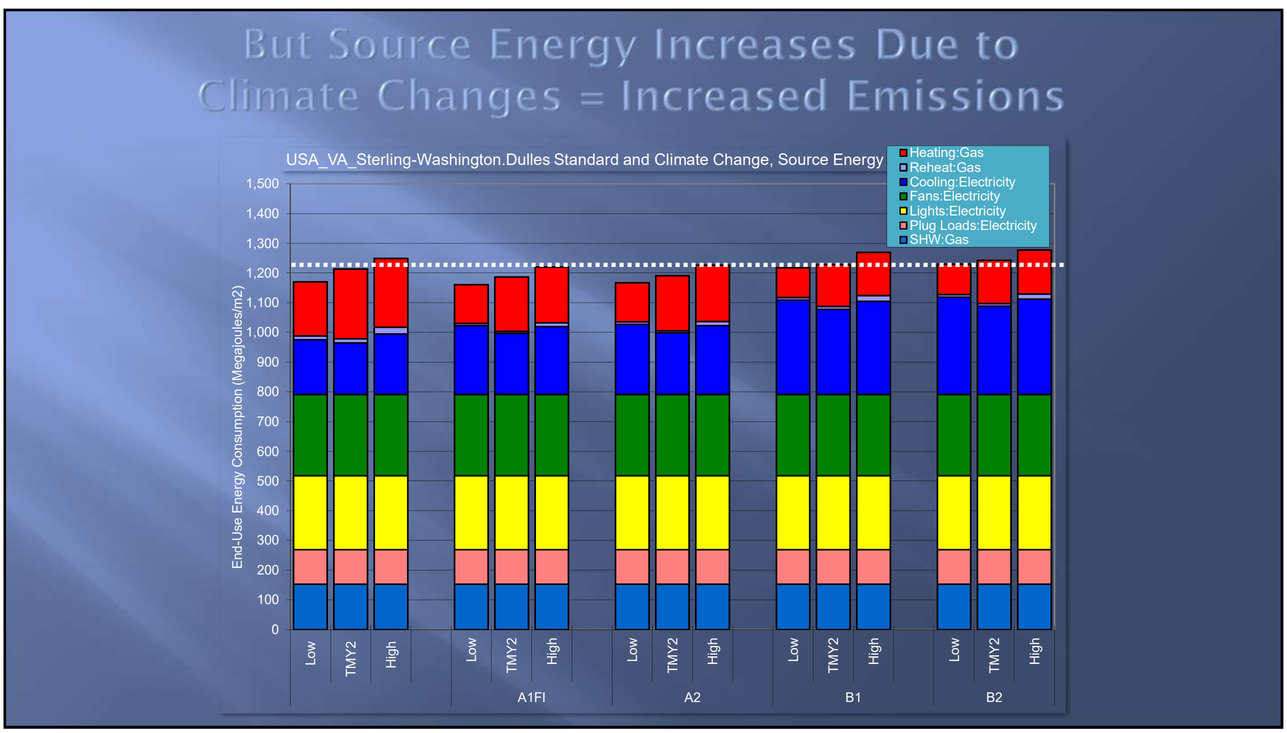
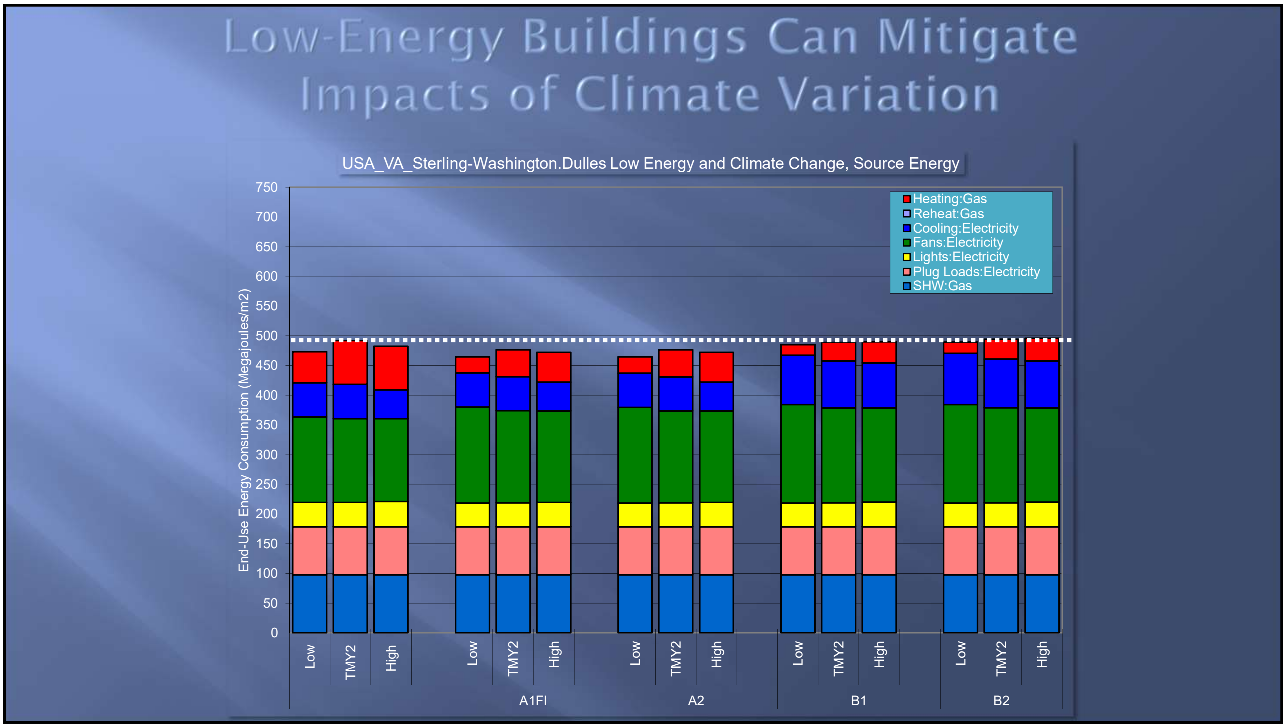

A Snapshot of Results:
Site Energy Decreases
USA_VA_Sterling-Washington.Dulles Standard and Climate Change, Site Energy
End-Use Energy Consumption (Megajoules/m2)
Heating:Gas
Reheat:Gas
Cooling:Electricity
Fans:Electricity
Lights:Electricity
Plug Loads:Electricity
SHW:Gas
Low
TMY2
High
A1FI
A2
B1
B2

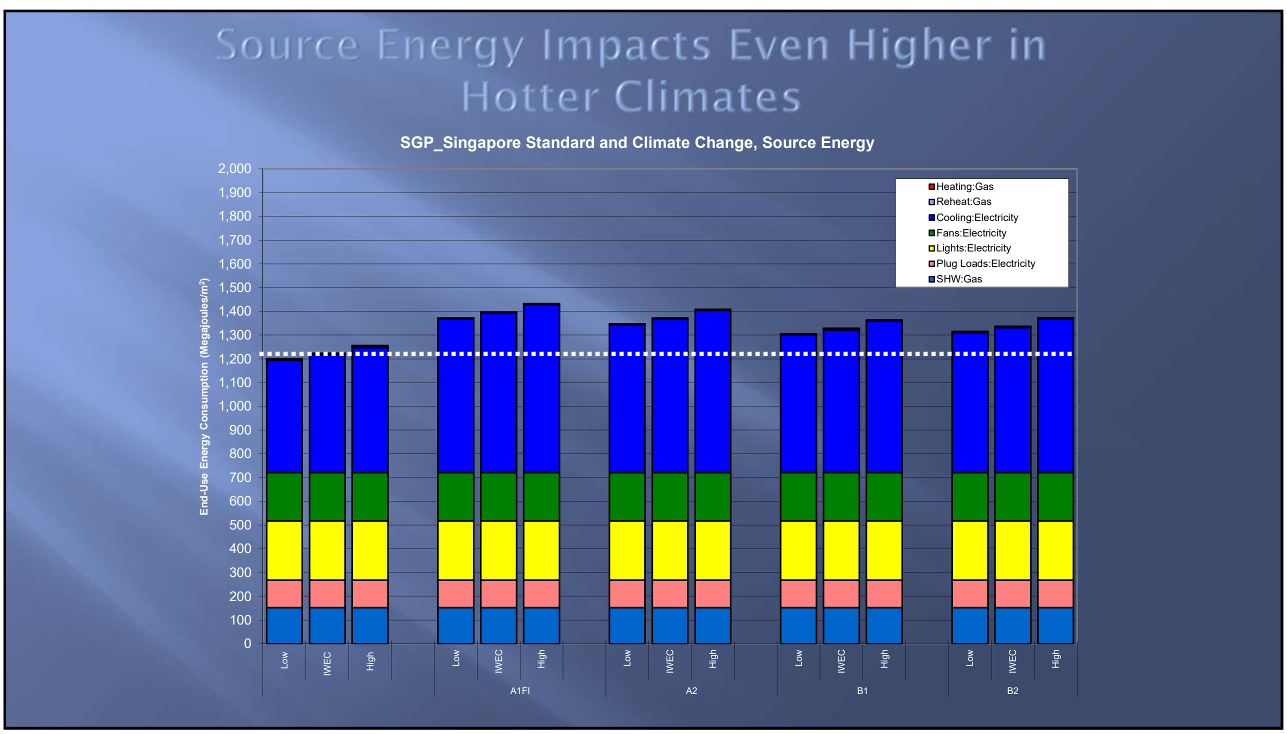
50


But Source Energy Increases Due to
Climate Changes = Increased Emissions
USA_VA_Sterling-Washington.Dulles Standard and Climate Change, Source Energy
End-Use Energy Consumption (Megajoules/m2)
Heating:Gas
Reheat:Gas
Cooling:Electricity
Fans:Electricity
Lights:Electricity
Plug Loads:Electricity
SHW:Gas
Low
TMY2
High
A1FI
A2
B1
B2

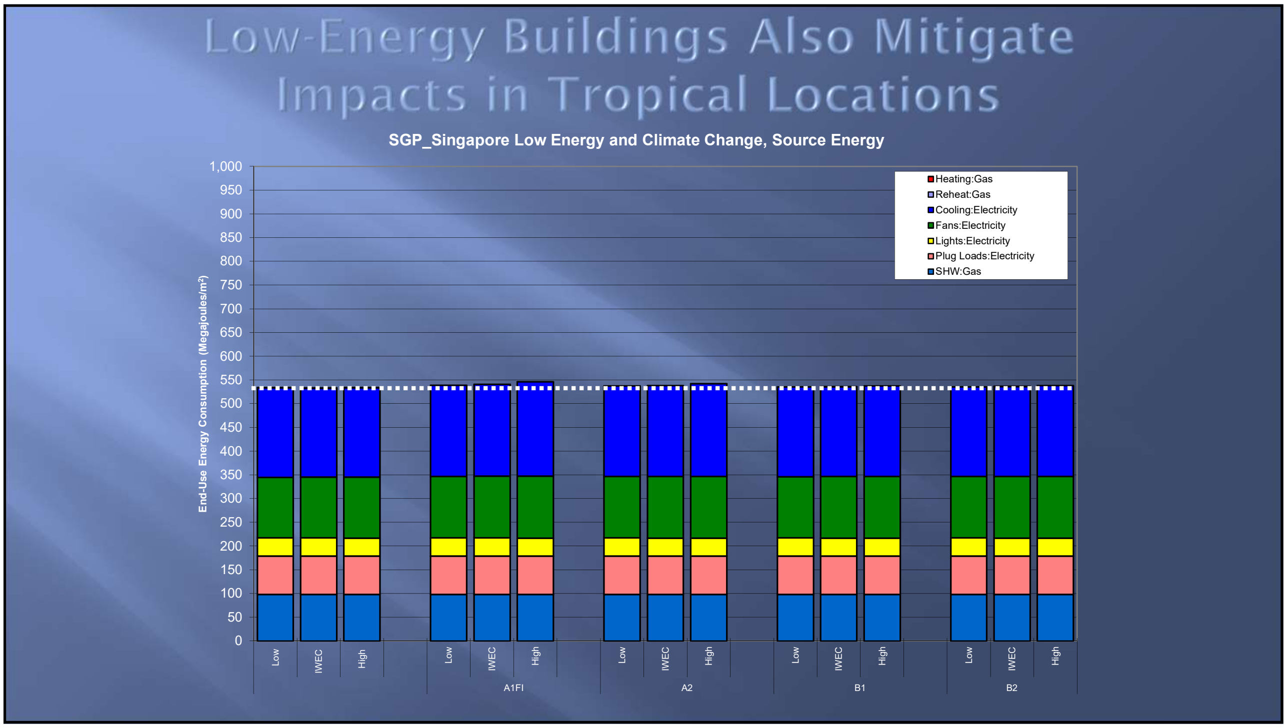
51


Low-Energy Buildings Can Mitigate Impacts of Climate Variation
USA_VA_Sterling-Washington.Dulles Low Energy and Climate Change, Source Energy
End-Use Energy Consumption (Megajoules/m2)
Heating:Gas
Reheat:Gas
Cooling:Electricity
Fans:Electricity
Lights:Electricity
Plug Loads:Electricity
SHW:Gas
Low
TMY2
High
A1FI
A2
B1
B2

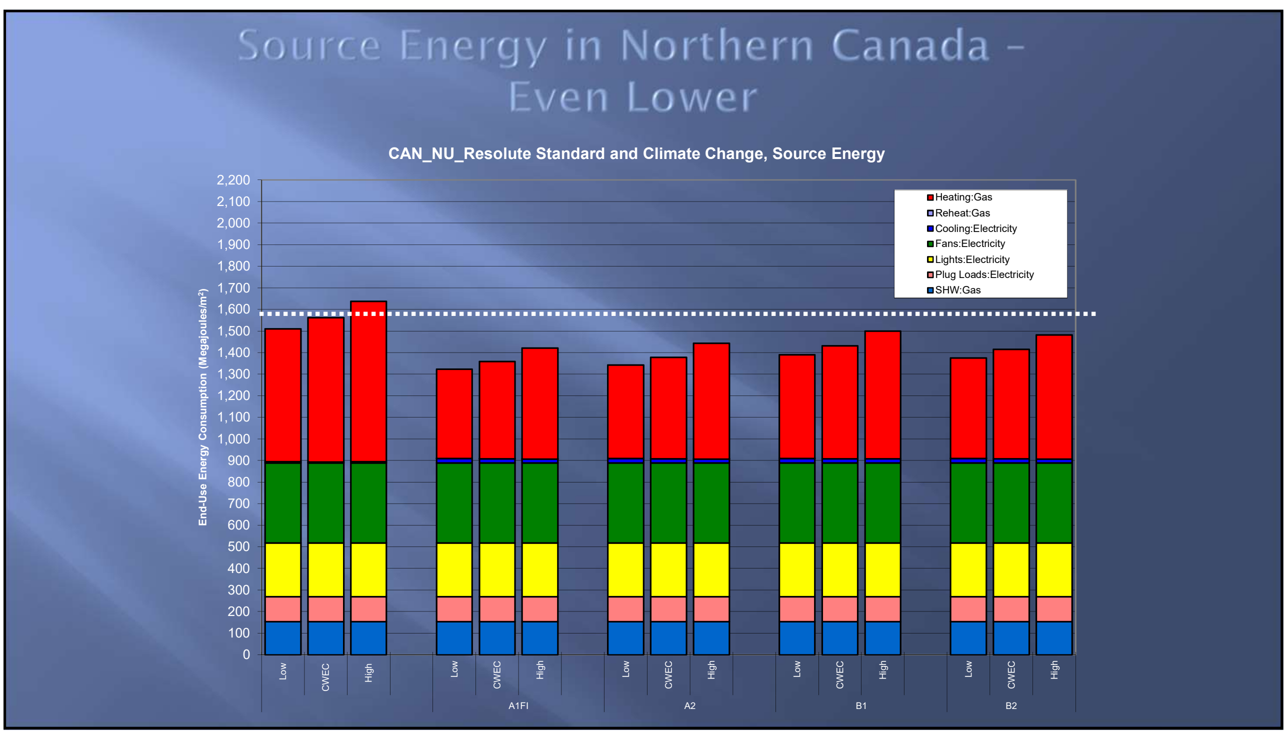
52


Source Energy Impacts Even Higher in Hotter Climates
SGP_Singapore Standard and Climate Change, Source Energy
End-Use Energy Consumption (Megajoules/m²)
Heating:Gas
Reheat:Gas
Cooling:Electricity
Fans:Electricity
Lights:Electricity
Plug Loads:Electricity
SHW:Gas
Low
IWEC
High
A1FI
A2
B1
B2

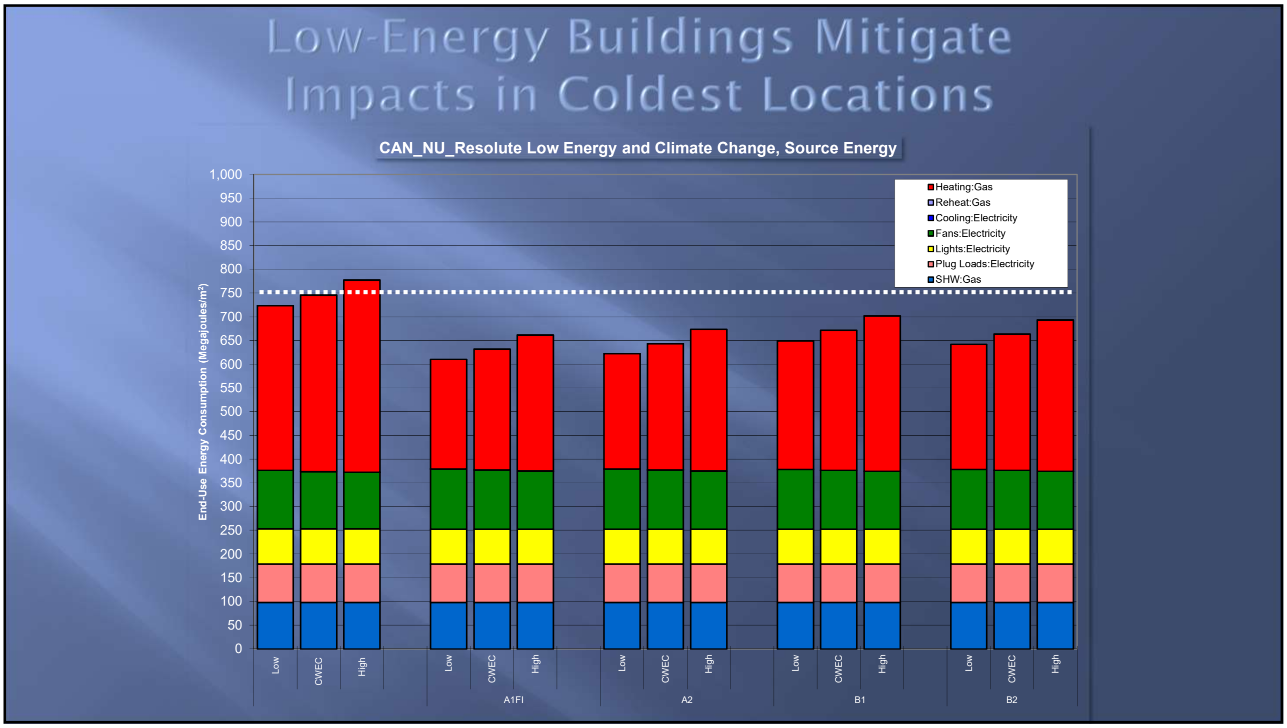
54


Low-Energy Buildings Also Mitigate Impacts in Tropical Locations
SGP_Singapore Low Energy and Climate Change, Source Energy
End-Use Energy Consumption (Megajoules/m²)
1,000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
Heating:Gas
Reheat:Gas
Cooling:Electricity
Fans:Electricity
Lights:Electricity
Plug Loads:Electricity
SHW:Gas
Low
IWEC
High
A1FI
A2
B1
B2

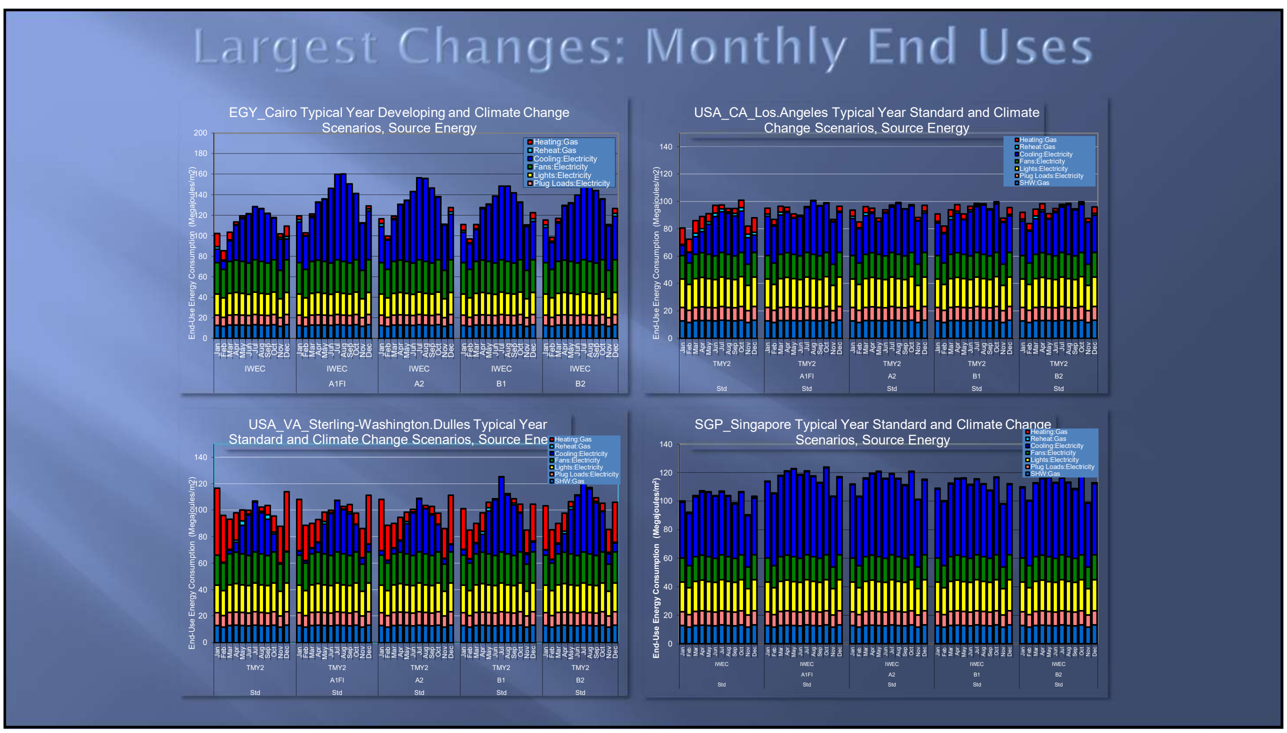
55


Source Energy in Northern Canada – Even Lower
CAN_NU_Resolute Standard and Climate Change, Source Energy
End-Use Energy Consumption (Megajoules/m²)
2,200
2,100
2,000
1,900
1,800
1,700
1,600
1,500
1,400
1,300
1,200
1,100
1,000
900
800
700
600
500
400
300
200
100
0
Heating:Gas
Reheat:Gas
Cooling:Electricity
Fans:Electricity
Lights:Electricity
Plug Loads:Electricity
SHW:Gas
Low
CWEC
High
A1FI
A2
B1
B2

65


Low-Energy Buildings Mitigate Impacts in Coldest Locations
CAN_NU_Resolute Low Energy and Climate Change, Source Energy
End-Use Energy Consumption (Megajoules/m²)
1,000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
Heating:Gas
Reheat:Gas
Cooling:Electricity
Fans:Electricity
Lights:Electricity
Plug Loads:Electricity
SHW:Gas
Low
CWEC
High
A1FI
A2
B1
B2

66


Largest Changes: Monthly End Uses
EGY_Cairo Typical Year Developing and Climate Change Scenarios, Source Energy
USA_CA_Los.Angeles Typical Year Standard and Climate Change Scenarios, Source Energy
USA_VA_Sterling-Washington.Dulles Typical Year Standard and Climate Change Scenarios, Source Ene
SGP_Singapore Typical Year Standard and Climate Change Scenarios, Source Energy
Heating:Gas
Reheat:Gas
Cooling:Electricity
Fans:Electricity
Lights:Electricity
Plug Loads:Electricity
SHW:Gas
IWEC
TMY2
A1FI
A2
B1
B2
Std

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Summary

- Climatic data is critical for building design (equipment and systems sizing)
- For building performance simulation, typical (TMY), actual, and future weather support building evaluation
  - Some question of whether single TMY is enough (research on XMYs underway)
  - Rich resources of data now available – both ground observing stations and satellite data.
- Climate change scenarios can be represented today by modifying existing hourly weather files
  - Buildings in higher latitude climates (north and south) will likely see decreases (heating decreases more than cooling increases)
  - Buildings in tropical and semi-tropical locations will see increases – but lower than changes in higher latitudes – primarily due to increased cooling
  - Energy-efficient buildings mitigate most impacts of both climate change and heat islands.
  - Result – significantly more hours of cooling equipment operation.

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Ok, So What Can/Should I Do?

- Design the best building you can – beyond code towards zero-energy, WELL, 2030, etc
  - Remember that most building components/equipment have a 10-30 year life
  - Plan for future upgrading
- Concerned about potential impacts?
  - Look at next warmest climate (Cleveland→ Louisville, Boise→ Salt Lake City, Boston → NYC, San Francisco→ LA)
  - How different are the design conditions?
  - Will my safety factors/oversizing be able to cover (in real life, oversizing means we rarely see full loading)
- If doing building simulation, use a future climate file or substitute a climate file from next warmer climate

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No Single Metric Tells the Building Performance Story

- Energy
- Demand
- Cost
- Water
- IEQ
- Carbon
- Business
  (student, occupied room, sales, beer barrels)

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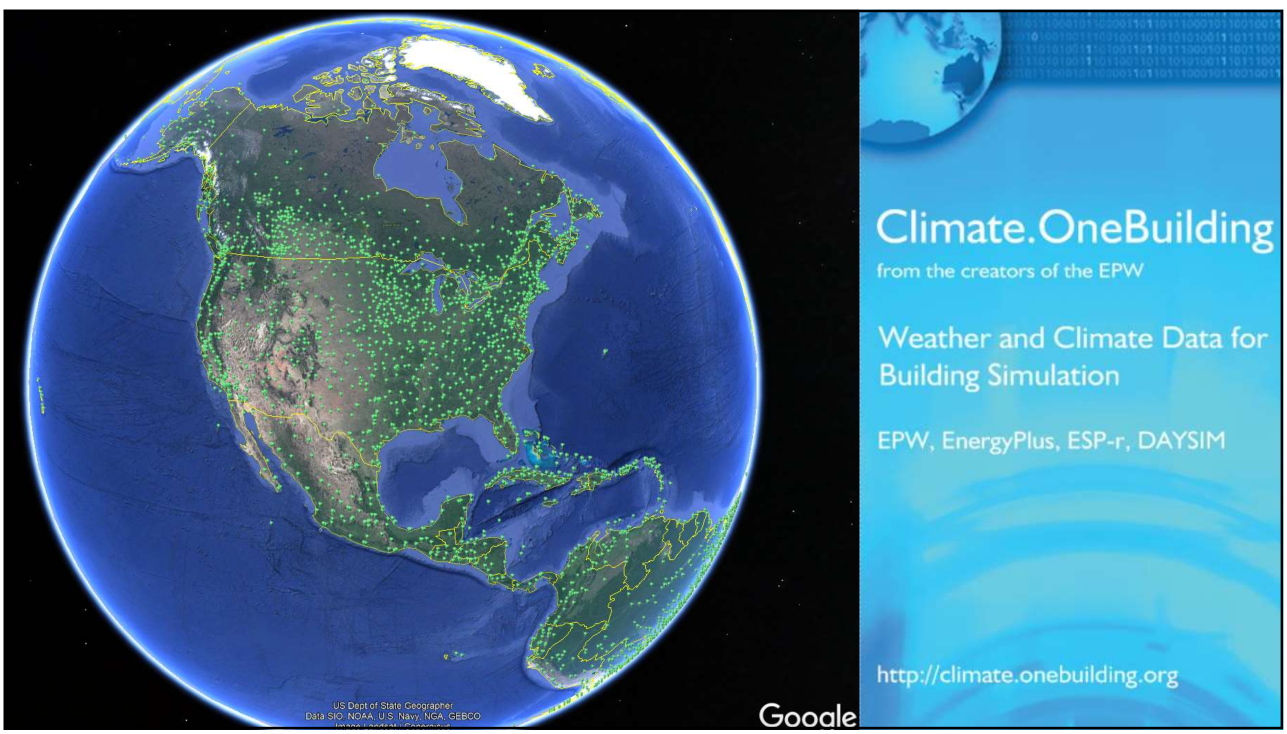

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Thank you!

Questions?

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ASHRAE Cleveland Chapter

AIA Cleveland

Cleveland BEC Building Enclosure Council

GBCI Approved | 1 CE Hour | 920020234
AIA Approved | 1 LU/HSW | CRAWLEY05

DrDru.Crawley DruCrawley @DruCrawley Drury_Crawley

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Resources/URLs

- Building Performance Simulation for Design and Operation www.routledge.com/books/details/9780415474146/
- ASHRAE Handbook—Fundamentals 2017 www.ashrae.org
- NOAA/NCEI Integrated Surface Data
  Documentation: www1.ncdc.noaa.gov/pub/data/noaa/isd-format-document.pdf
- Data: www.ncei.noaa.gov/data/global-hourly/access/
- Typical Meteorological Year Data Sets (Climate.OneBuilding free weather data for more than 13,000 locations worldwide in EPW, ESP-r and DAYSIM formats) climate.onebuilding.org/
- Drury B. Crawley. 1998. "Which Weather Data Should You Use for Energy Simulations of Commercial Buildings?" in *ASHRAE Transactions*, pp. 498-515, Vol. 104, Pt. 2. Atlanta: ASHRAE.
  climate.onebuilding.org/papers/1998_06_Crawley_Which_Weather_Data_Should_You_Use_for_Energy_Simulations_of_Commercial_Buildings.pdf
- Crawley, Drury B. 2008. "Estimating the Impacts of Climate Change and Urbanization on Building Performance," Building Performance Simulation, pp. 91-115, Vol. 1, No. 2 (June).
  climate.onebuilding.org/papers/2008_06_Crawley_Estimating_the_impacts_of_climate_change_and_urbanization_on_building_performance.pdf
- Meteonorm www.meteonorm.com
- Weather Underground www.weatherunderground.com
- National Centers for Environmental Information lwf.ncdc.noaa.gov/oa/climate/climatedata.html
- CIBSE Technical Manual 48 (TM48), Use of climate change scenarios for building simulation: the CIBSE future weather years www.cibse.org/index.cfm?go=publications.view&item=449
- Climate Change World Weather Generator (CCWorldWeatherGen) www.energy.soton.ac.uk/ccworldweathergen/
- Dview (tool for displaying and comparing weather data (and CSV data) beopt.nrel.gov/downloadDView

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