EXPLORING ALTERNATIVES TO THE "TYPICAL METEOROLOGICAL YEAR" FOR INCORPORATING CLIMATE CHANGE INTO BUILDING DESIGN

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Learning objectives for this session

- Understand the difference between a Complex Fenestration System and a standard Fenestration System.
- Recognize that a Complex Fenestration System can contribute to the success of a design to meet the user’s needs without sacrificing energy efficiency.
- **Explore alternate data methods to determine climatic conditions for building design.**
- **Describe the need to use climate data that is different than has been traditionally used in the past for building design.**
- Define the attic radiant barriers and interior radiation control coatings.
- Understand the appropriate application of radiant barriers and their potential energy savings.

Acknowledgements

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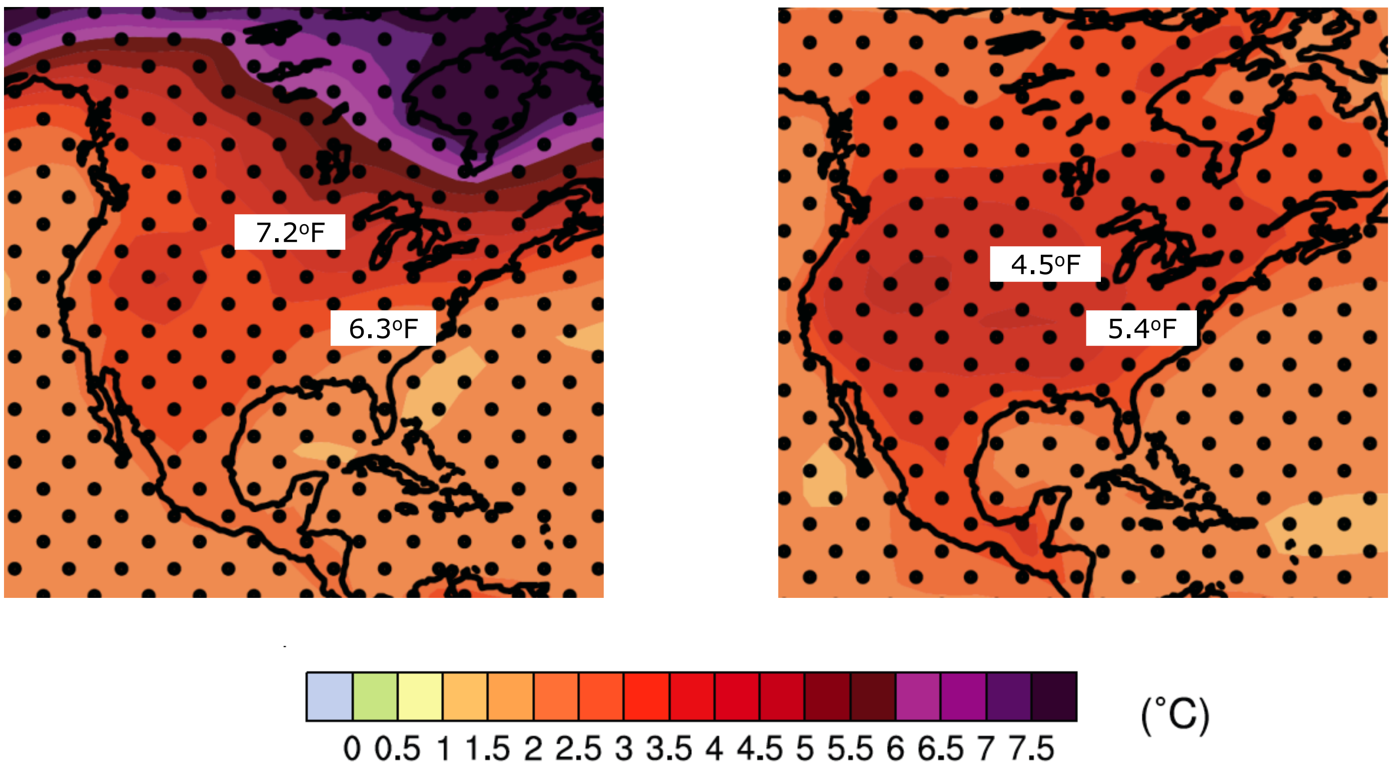
Climate change prediction

- Typical climate conditions for the 20th century may not provide adequate design parameters for the built environment of the 21st century.

Projected temperature change

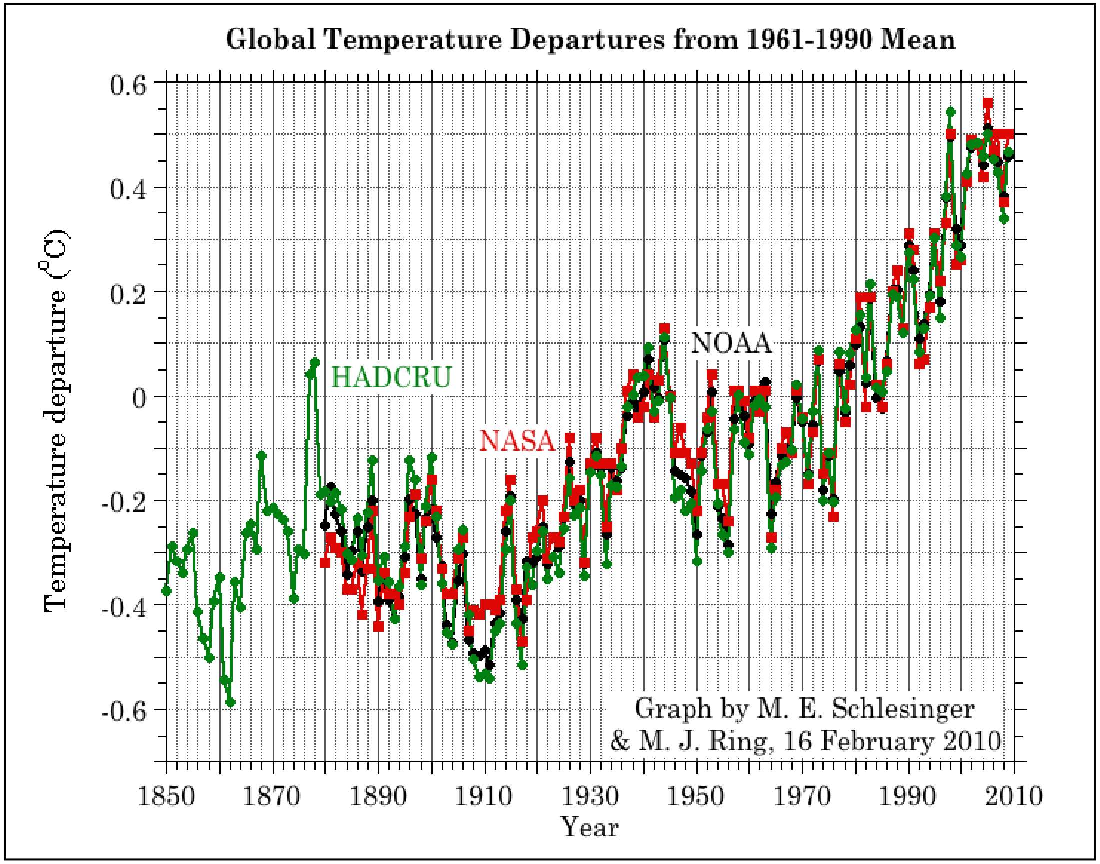
December- January-February Temperature Change

June-July-August Temperature Change



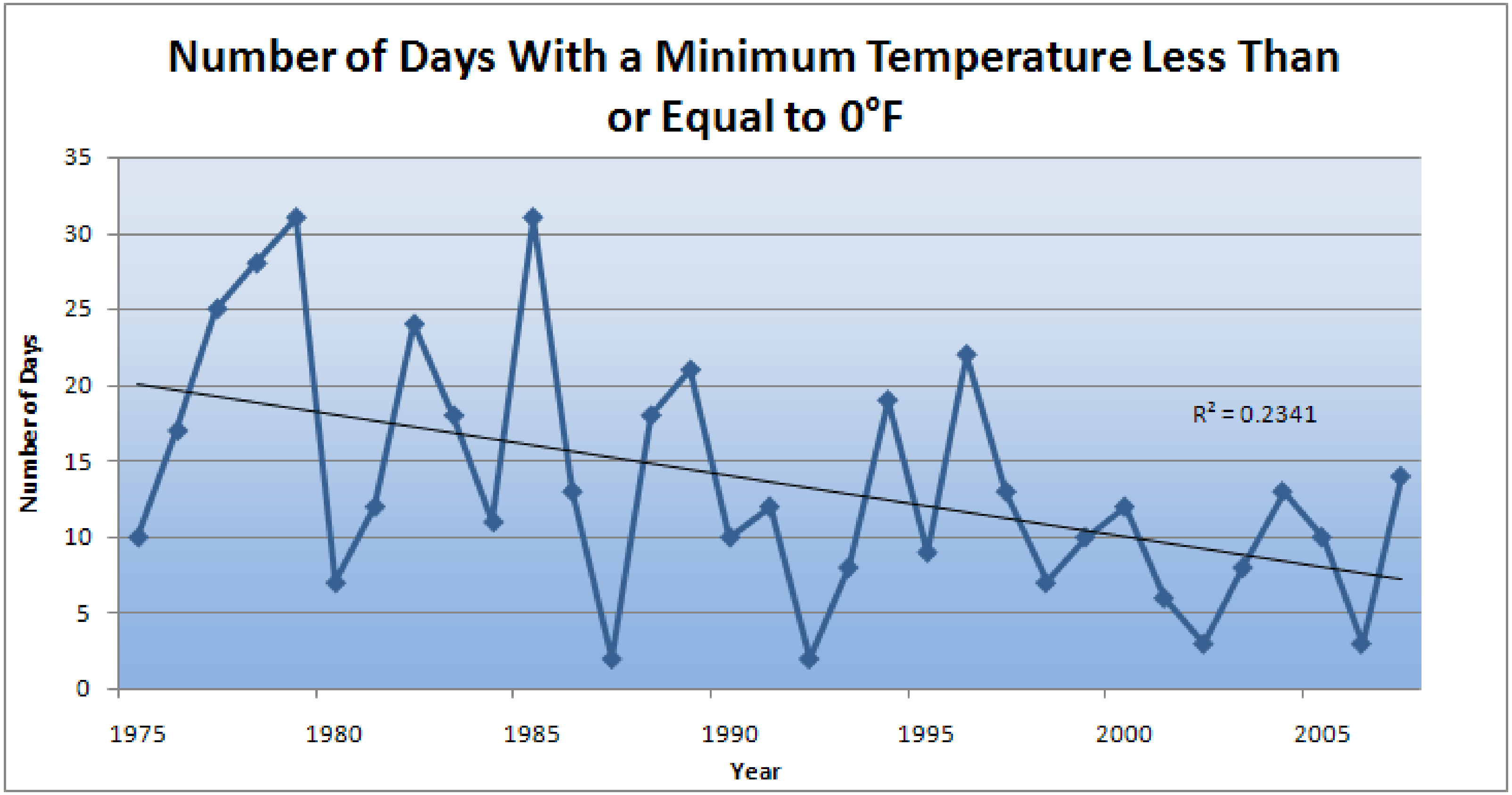
A1B Emission Scenario: 2080-2099 minus 1980-1999 (IPCC Fourth Assessment Report, Climate Change 2007: Working Group I: The Physical Science Basis)

Observed climate change



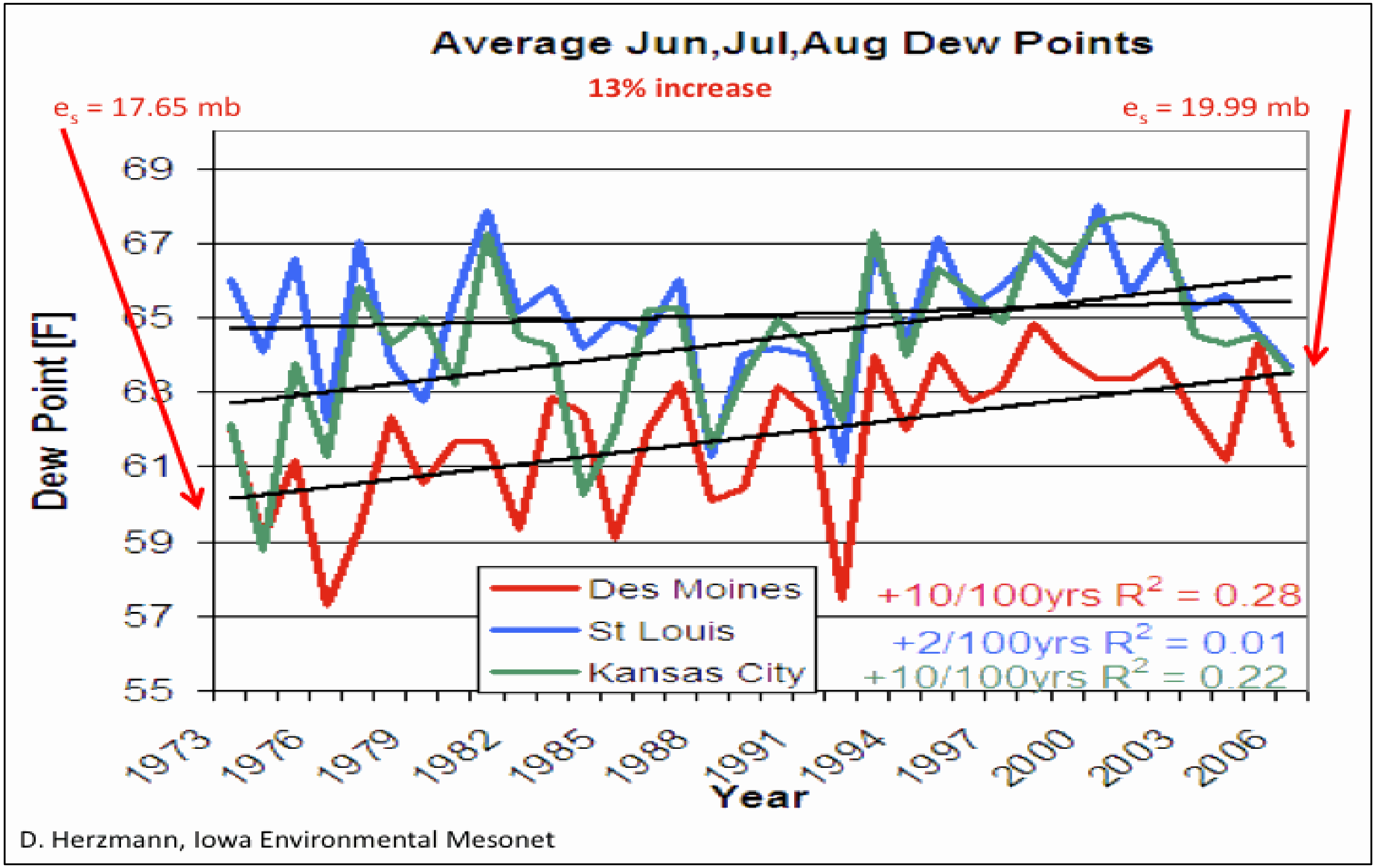
Three separate analyses of the temperature record –
Trends are in close agreement (Don Wuebbles)

Observed climate change: Iowa



Des Moines Airport Data

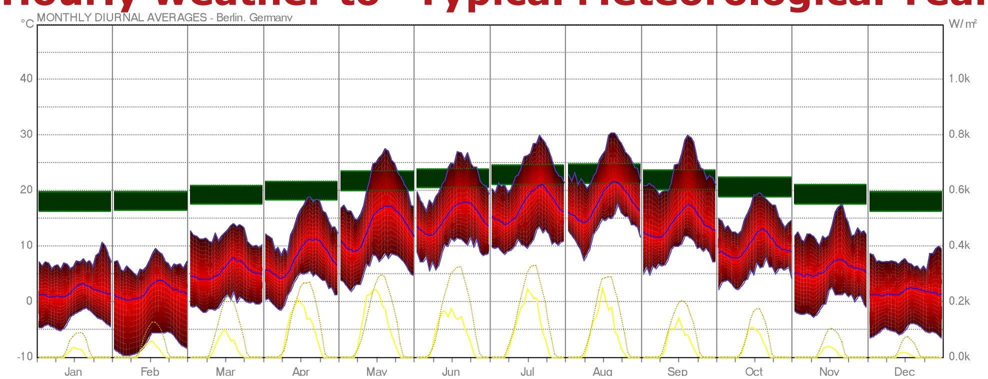
Observed climate change: Iowa



Climate data in energy modeling

- Energy Plus and other modeling software pairs a building design with one weather file to predict energy performance

Hourly weather to "Typical Meteorological Year"



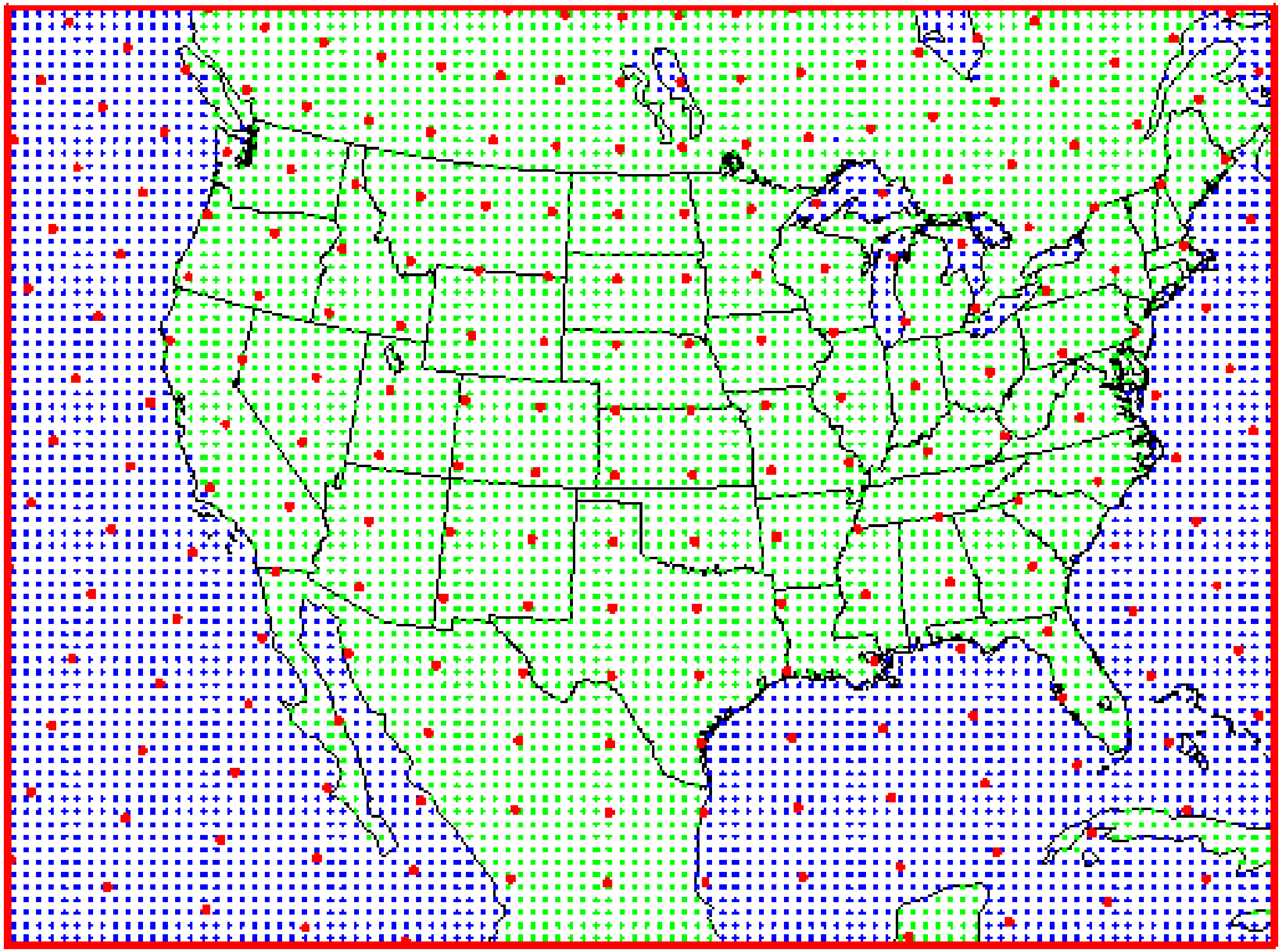
kWh

$$$$$$$$

Previous work: Literature review

- Huang (2006)
  - Used global climate models (GCMs) for four future climate scenarios
  - Finding: Net energy use will increase by 25 - 28% by 2100 in L.A.
- Crawley (2008)
  - Used GCMs with statistical downscaling for four climate change scenarios
  - Finding: Change in energy use by climate:
    - Cold: -10%
    - Tropical: +20%
    - Mid-latitude: change from heating to cooling

Grid resolution



- global
- regional (land)
- regional (water)

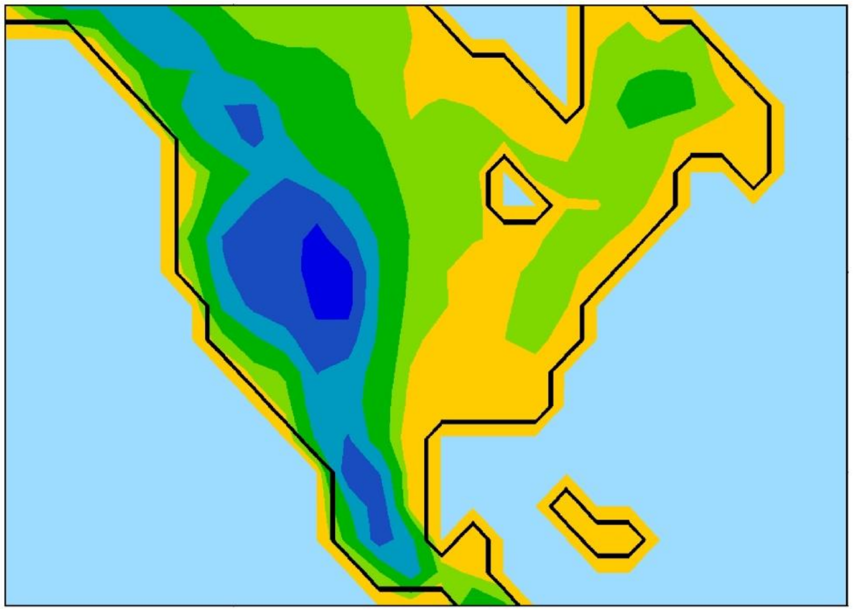
Only every second RCM grid point is shown in each direction

RCMs: Dynamical downscaling

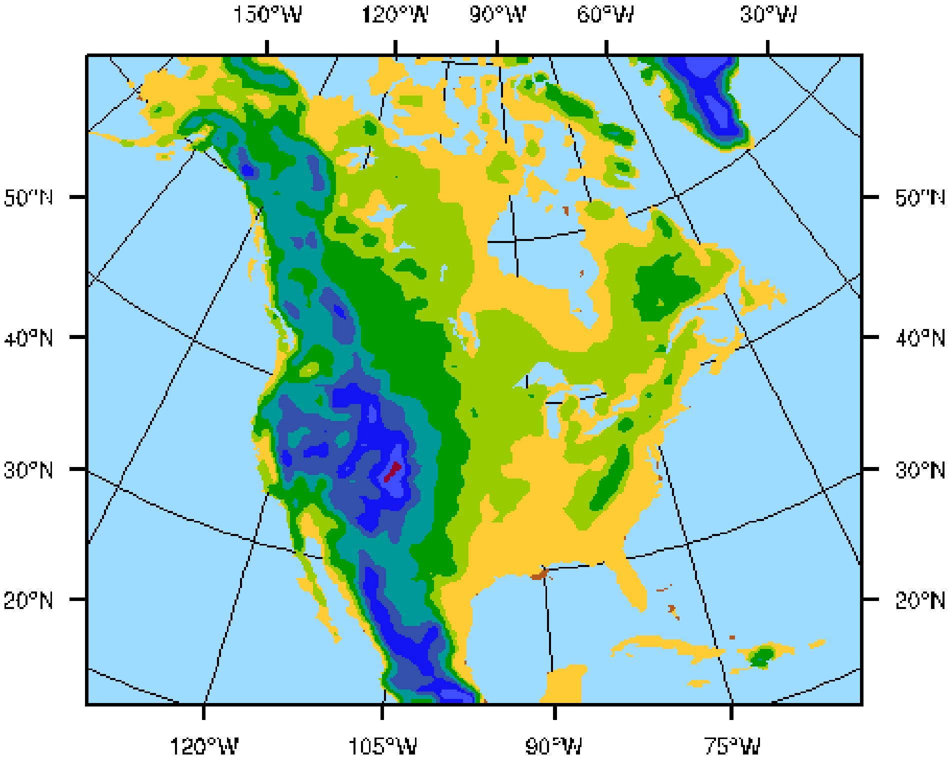
- Impacts of climate change are currently assessed by “statistically downscaling” information produced by GCMs for specific locations.

- “Dynamical” downscaling
  - An alternative method to that used by Karl et al. (2009), Xu et al. (2009), Crawley (2008), and Guan (2009)
  - GCMs provide boundary conditions for RCMs
  - North American Regional Climate Change Assessment Program (NARCCAP, 2010)

Example: Modeled terrain



GCM



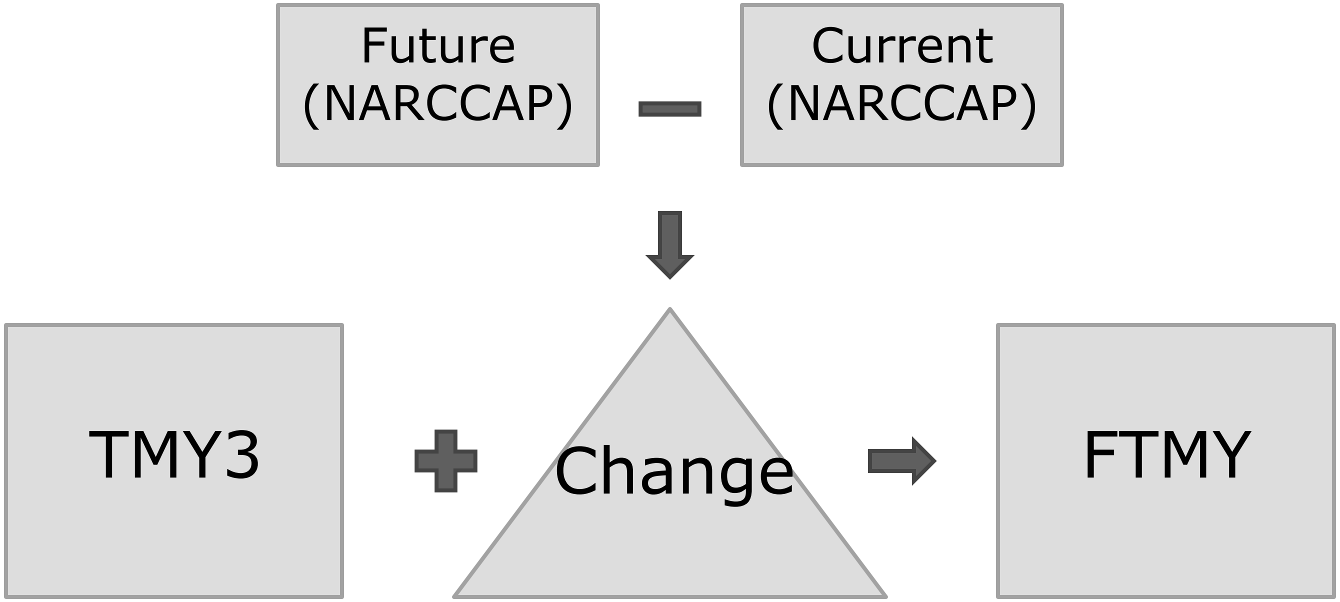
RCM

Our study methodology

- Dynamical downscaling
- One location first: **Mason City Iowa**
- Results applicable to all U.S. locations available in the TMY3 database
- Use of multiple GCMs and RCMs to quantify the range of uncertainty in future climate projections

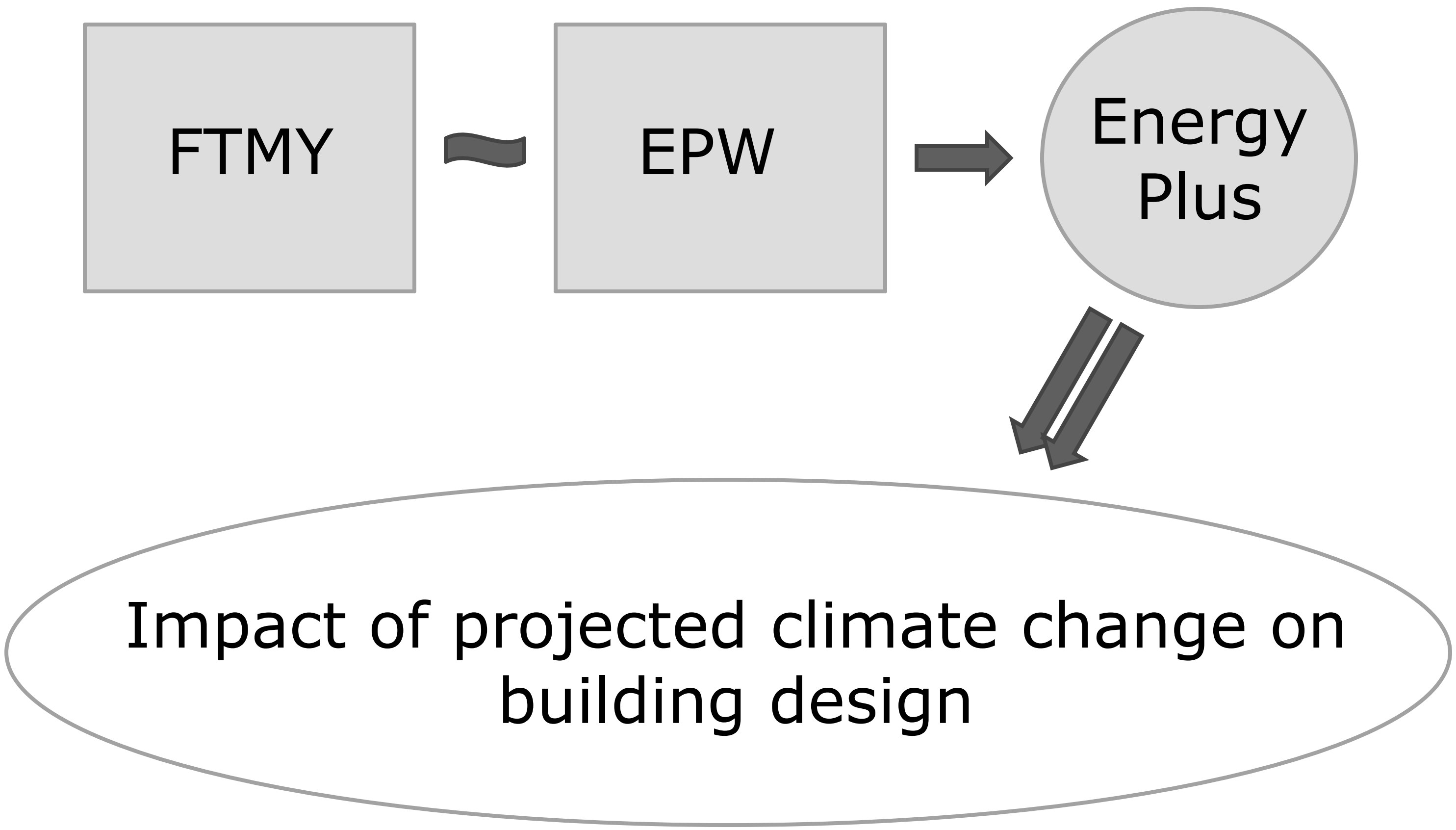
Our study methodology

- Creation of future typical meteorological year (FTMY) dataset



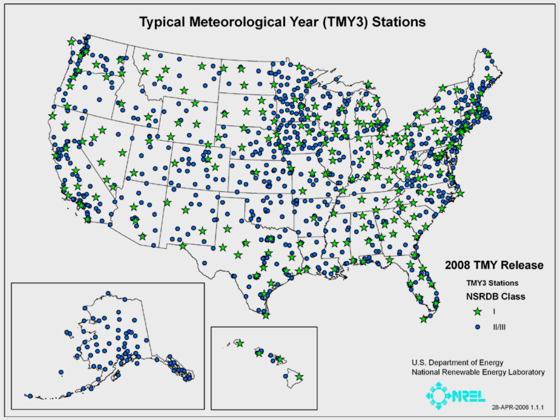
Our study methodology

- Simulations of buildings using FTMY



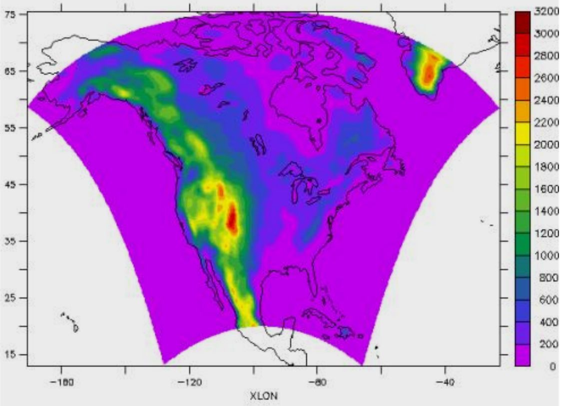
Three different datasets used

TMY 3

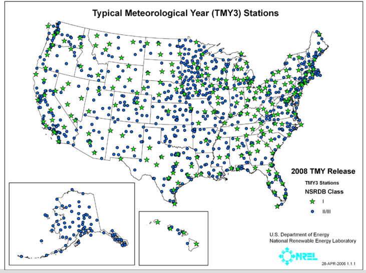


OBSERVATION

NARCCAP



TMY 3 and Observations



- TMY3 dataset (Wilcox and Marion 2008)
  - 1976 - 2005
  - Derived from observations
  - Annual dataset consisting of hourly values
  - Includes natural diurnal and seasonal variations

- Observed dataset (NCDC ISD)
  - 1976 - 2005
  - 30-year dataset consisting of hourly values
  - Months influenced by volcanoes removed

‘Typicalness’ of TMY

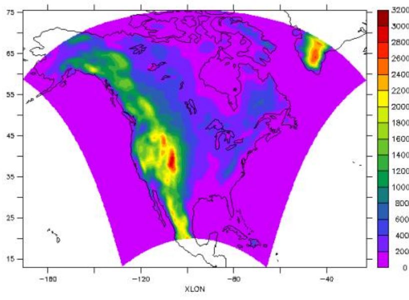
- The “typicalness” of the TMY3 was evaluated for nine variables.
  - Monthly TMY3 averages were compared to monthly averages for the 1976-2005 base period of observations.
  - Differences were generally quite small, less than the monthly standard deviation in all months and all variables except relative humidity, pressure, and precipitation.

→ **TMY3 data does represent typical climate conditions for Mason City, IA.**

North American Regional Climate Change Assessment Program

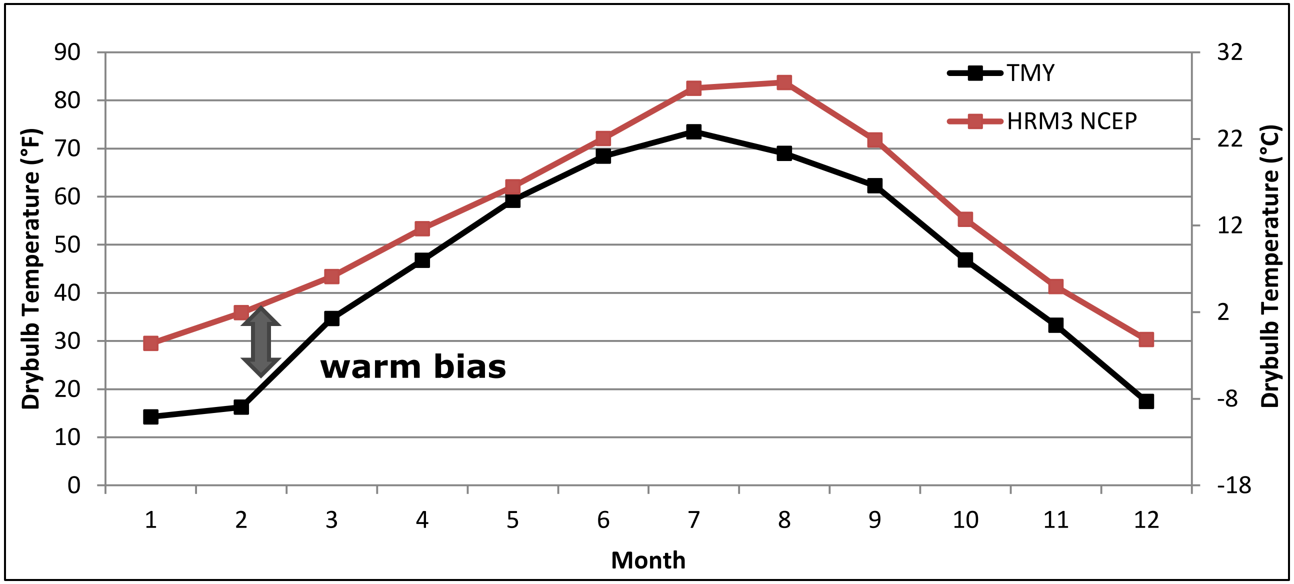
- International program to produce high resolution climate change simulations

- Configuration
  - Domain covers U.S. and most of Canada
  - 50 km spatial resolution
  - Forcing is high-emissions scenario (SRES A2)
  - NCEP Reanalysis (obs-driven; 1979-2004), current period (GCM-driven; 1971-2000), and future period (GCM-driven; 2041-2070)
  - 3-hourly values



Reproduction of TMY with RCM's

- The second step was to evaluate the skill of individual RCMs to reproduce TMY3 data.



All models have bias; can correct / avoid bias by using only projected *changes*

Evaluation of projected change

Variable	Mean projected change	SD of models' change	SD of 20th C obs
Totcld (tenths)	-0.06*	0.17	0.83
Drybulb (°F / K)	4.52 / 2.51	0.85 / 0.47	1.66 / 0.92
Dewpoint (°F / K)	4.36 / 2.42	0.76 / 0.42	2.11 / 1.17
Rhum (%)	-0.10	1.80	3.21
Ahum (g cm^{-3})	1.09	0.19	0.42
Pressure (in Hg / mbar)	0.007 / 0.25	0.013 / 0.44	0.016 / 0.54
Wspd (mph / m s^{-1})	-0.07 / -0.03	0.10 / 0.05	0.54 / 0.24
Wdir (degrees)	-1.01	7.33	14.80
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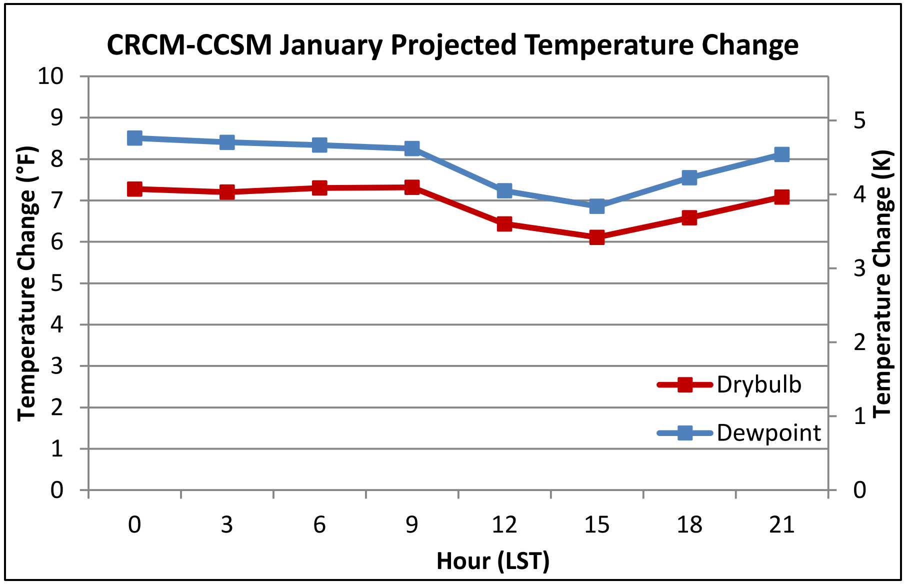
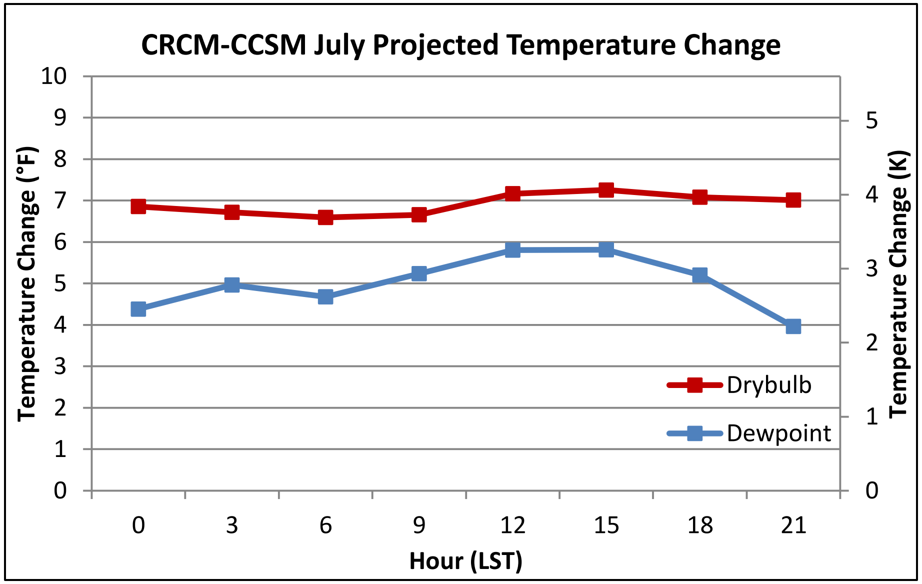
Overall results (increases)

Month	Drybulb (°F / K)	Dewpoint (°F / K)	Ahum (g cm^{-3})
1	5.83 / 3.24	6.05 / 3.36	0.55
2	4.52 / 2.51	4.26 / 2.37	0.41
3	3.49 / 1.94	3.31 / 1.84	0.49
4	3.57 / 1.98	3.90 / 2.16	0.83
5	3.05 / 1.69	3.85 / 2.14	1.20
6	4.50 / 2.50	4.35 / 2.42	1.97
7	5.05 / 2.81	4.17 / 2.32	2.06
8	5.58 / 3.10	3.90 / 2.17	1.83
9	5.16 / 2.86	4.55 / 2.86	1.45
10	4.26 / 2.37	4.71 / 2.62	1.06
11	4.20 / 2.34	3.92 / 2.18	0.65
12	5.07 / 2.82	5.33 / 2.96	0.56

Seasonal changes

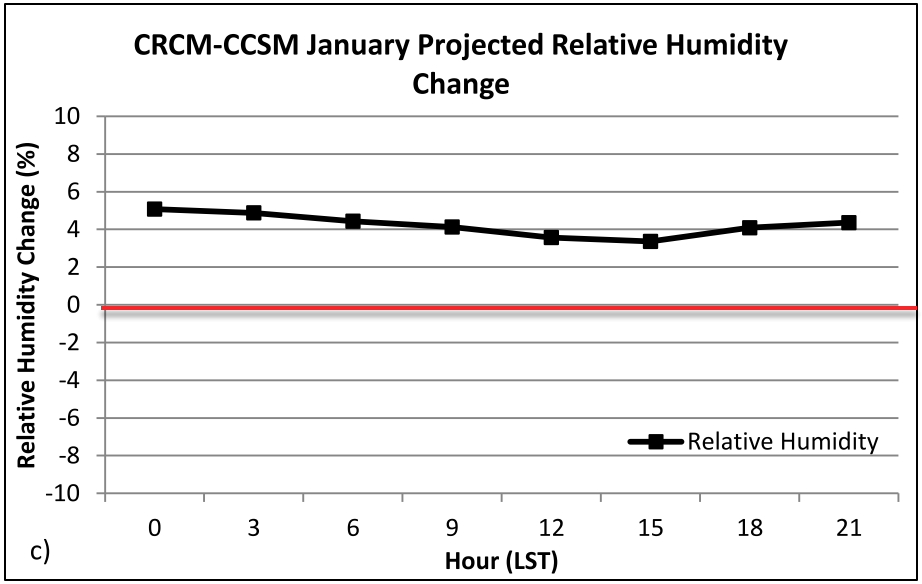
Projected change in dry bulb temperature and dew-point temperature with season due to climate change

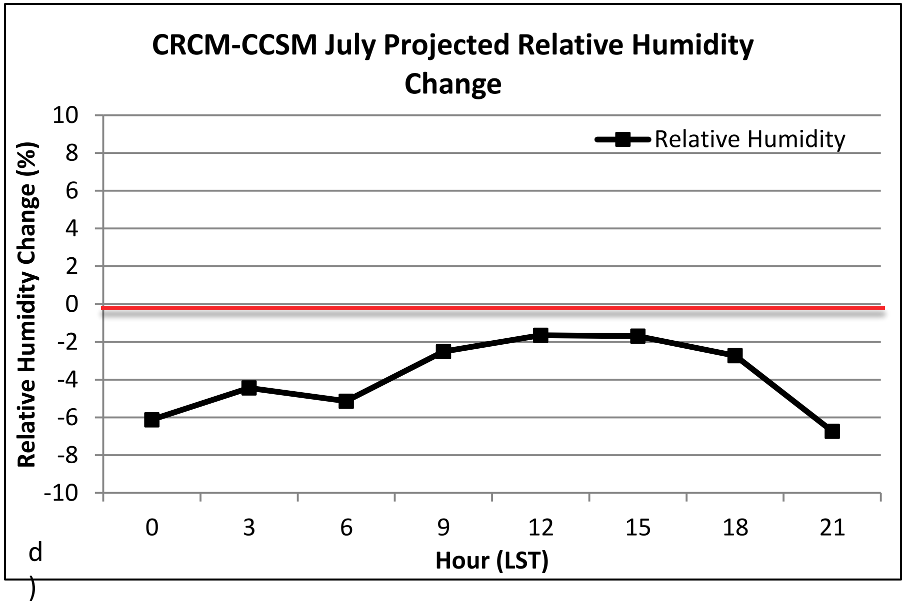




Temperature increases more than dew-point temperature in winter but less in summer

Diurnal changes





Relative humidity increases in winter but decreases in summer

FTMY construction

- Building energy consumption is influenced by many design and operational factors, but weather data play a major role.

- A “future typical meteorological year” (FTMY) was constructed to evaluate the impact of climate change on buildings
  - Projected changes (future - current) added to original TMY
  - Linear interpolations between 3-hourly data

Building simulation

- 16 Reference Buildings provided by the United States Department of Energy
- 16 climate zones (TMY 3 files)
- Using the software EnergyPlus, energy simulations were conducted with the Reference Buildings (from the climate of Chicago, Illinois) and the weather data of Mason City, Iowa (TMY 3).
- TMY 3 data compared with "moderate" FTMY (both transformed into EPW files)

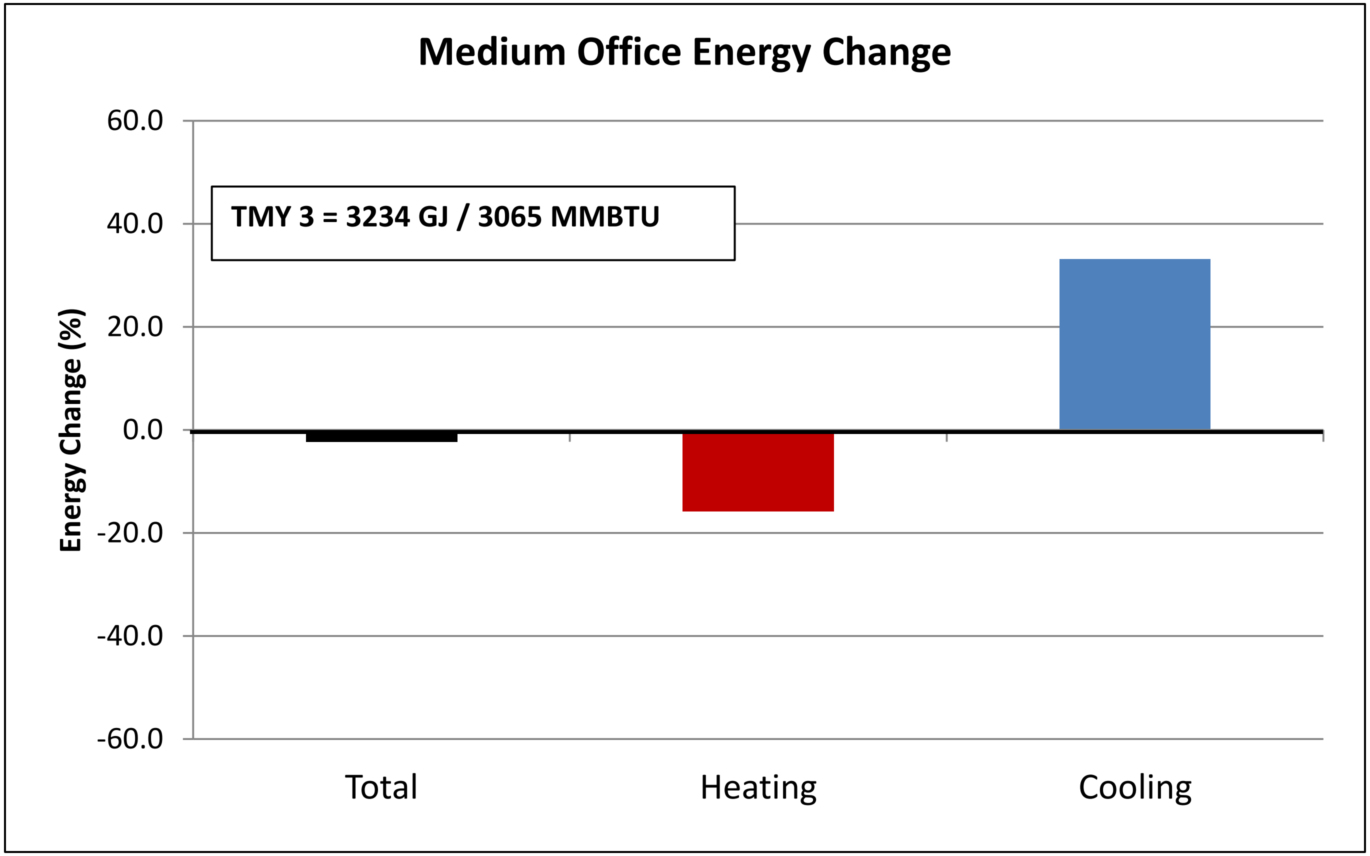
Medium Office: 511m2/5502 ft2 - 3,304 GJ/3,132 MMBTU

Secondary School: 19,592 m2/210,886 ft2 – 21,976 GJ/20,829 MMBTU

Stand Alone Retail: 2,293 m2/24,692 ft2 – 2,467 GJ/2,338 MMBTU

- http://www1.eere.energy.gov/buildings/commercial_initiative/reference_buildings.html
- http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=3.2.2

Projected impact on buildings



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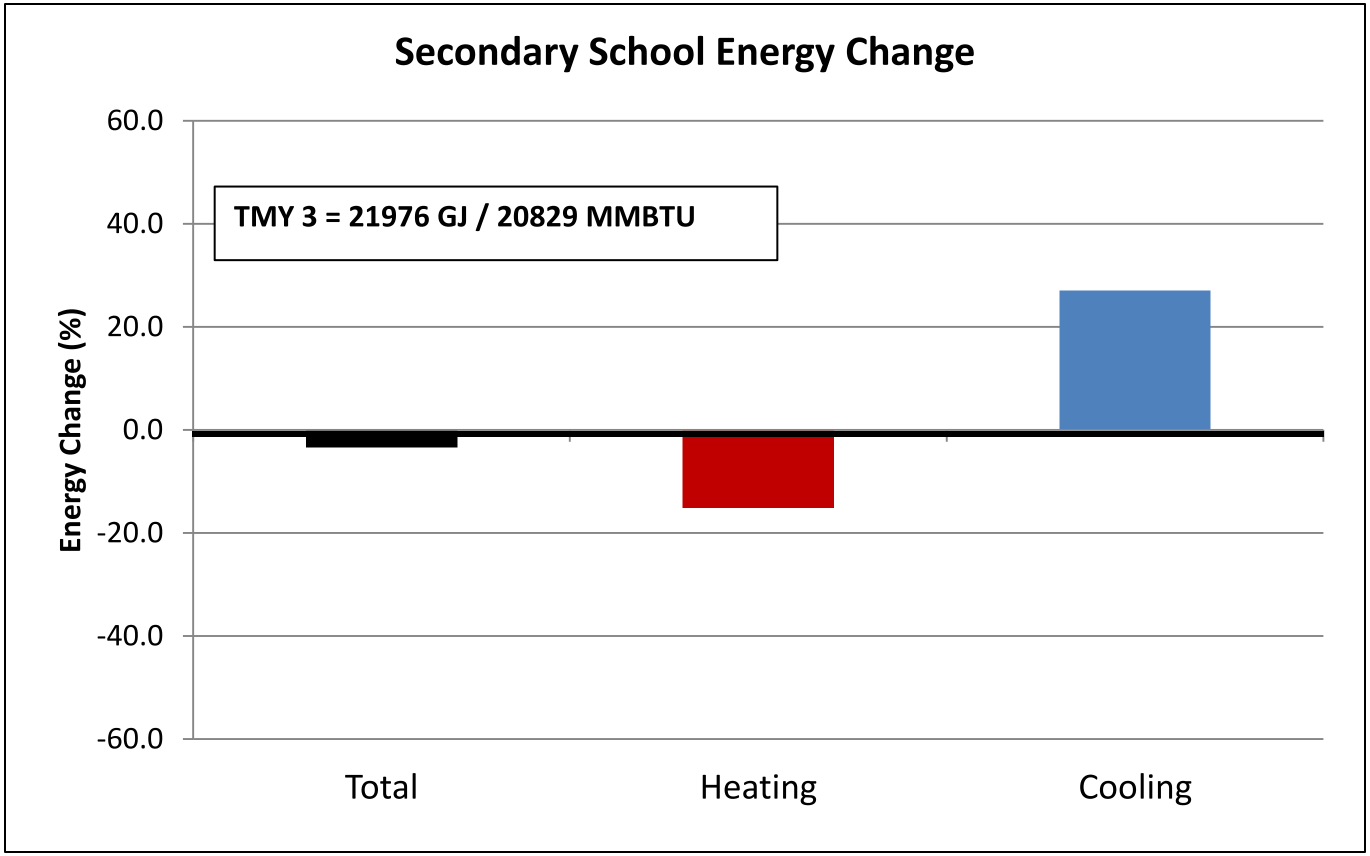

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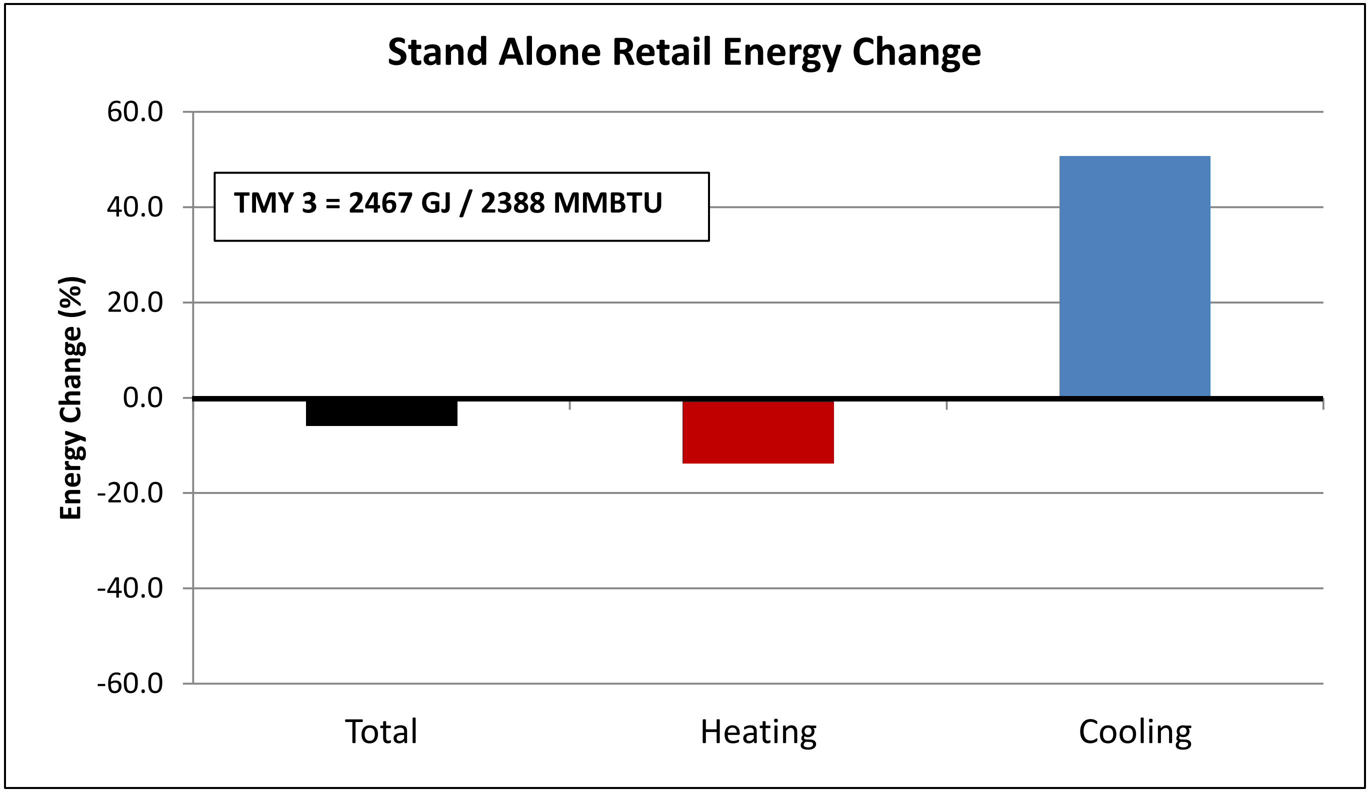

Reductions in heating are greater than increases in cooling, creating an overall decrease in energy demand

Conclusions and Future work

- ✓ Overall annual energy consumptions predicted to decrease with future meteorological year data (FTMY).
- ✓ Heating energy consumption predicted to decrease.

BUT:

- ✓ Cooling energy consumption predicted to increase significantly.

FUTURE WORK:

- ➢ Expand study to include more locations:
  - ➢ 16 different climate zones used in the creation of the U.S. Department of Energy (DOE) reference buildings, that represent about 60% of the U.S. commercial.
- ➢ Future typical meteorological year data can be prepared for risk analysis of a changing climate.

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