Estimating the Impacts of Climate Change and Urbanization on Building Performance.

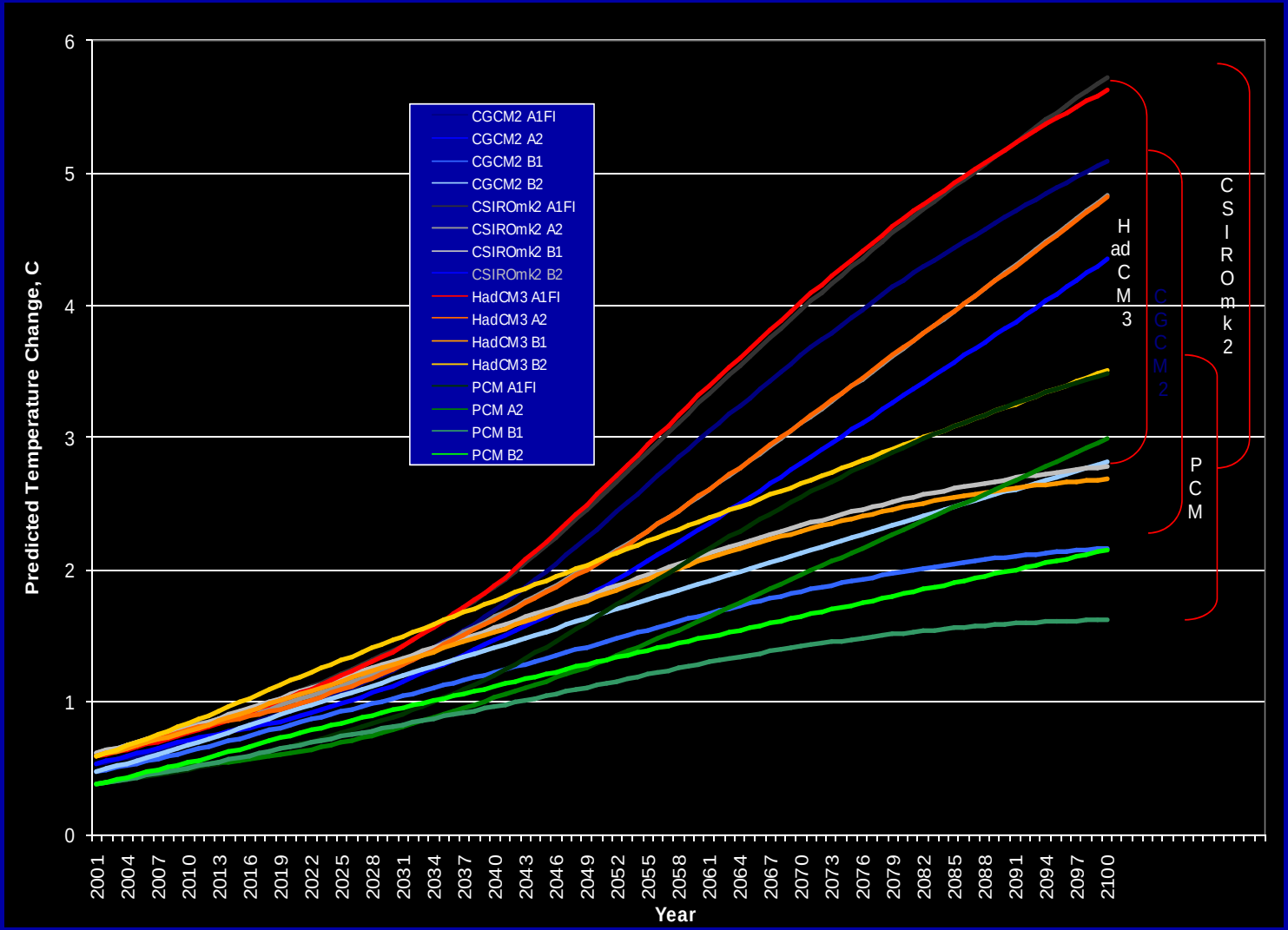
Drury B. Crawley
U.S. Department of Energy:
Washington, DC

IPCC Climate Change Scenarios:

- Four major storylines developed to represent different demographic, social, economic, technological, and environmental developments.
- Four emissions scenarios from the storylines – A1FI, A2, B1, B2 – represent the range of potential climate impact.
- Four major Global Climate Models (GCMs): HadCM3, CSIRO2, CGCM2, PCM.

Result: 16 scenario and climate prediction combinations.

Range of Annual Average Temperature Change Predicted:

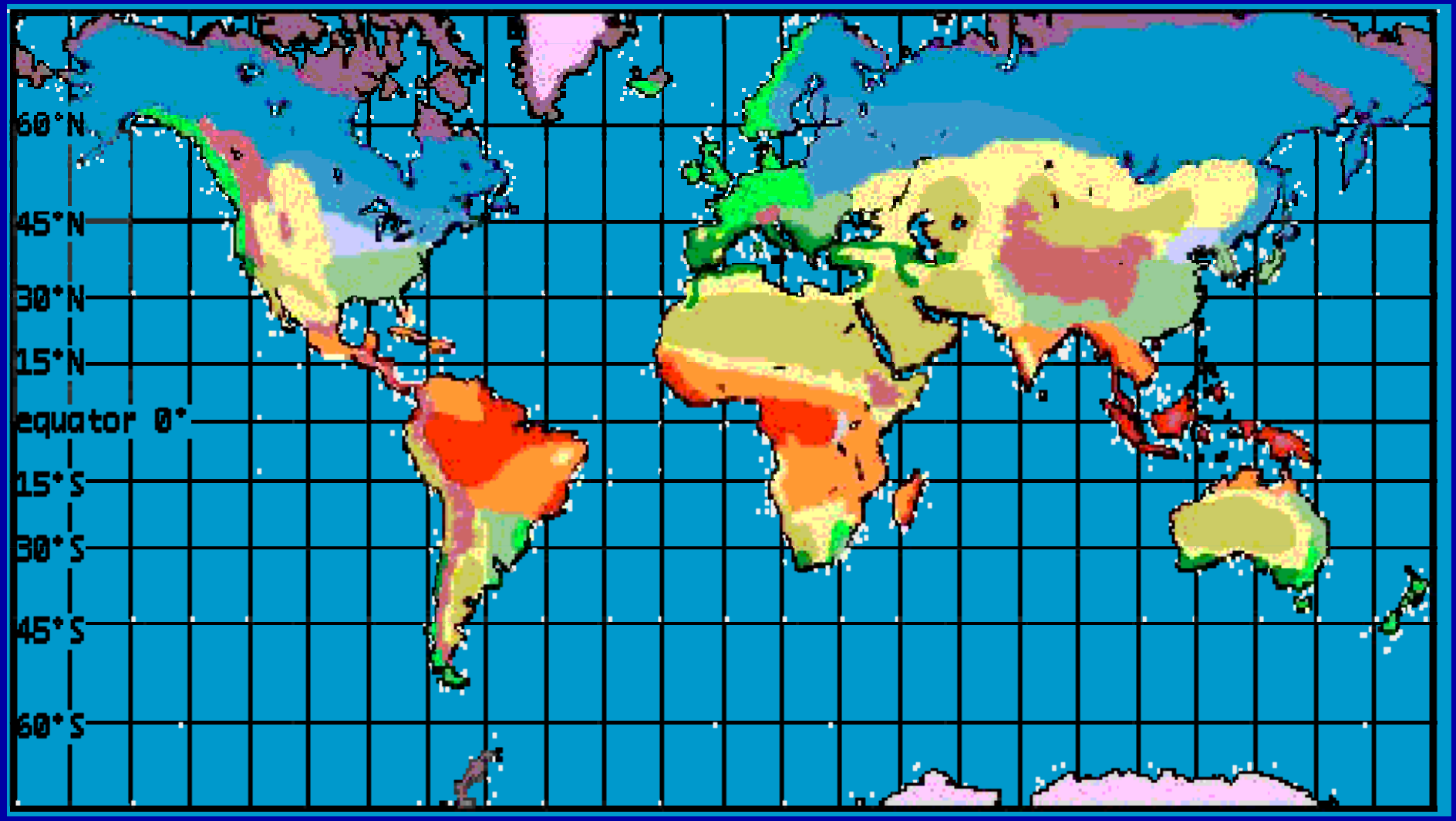


Köppen Climate Regions:

- A – tropical humid climates.
- B – hot dry climates.
- C – mild mid-latitude climates.
- D – cold mid-latitude climates.
- E – polar climates.
- H – highland climates.

Total of 20 subcategories including hot/cold, and dry/wet.

Köppen Climate Regions:



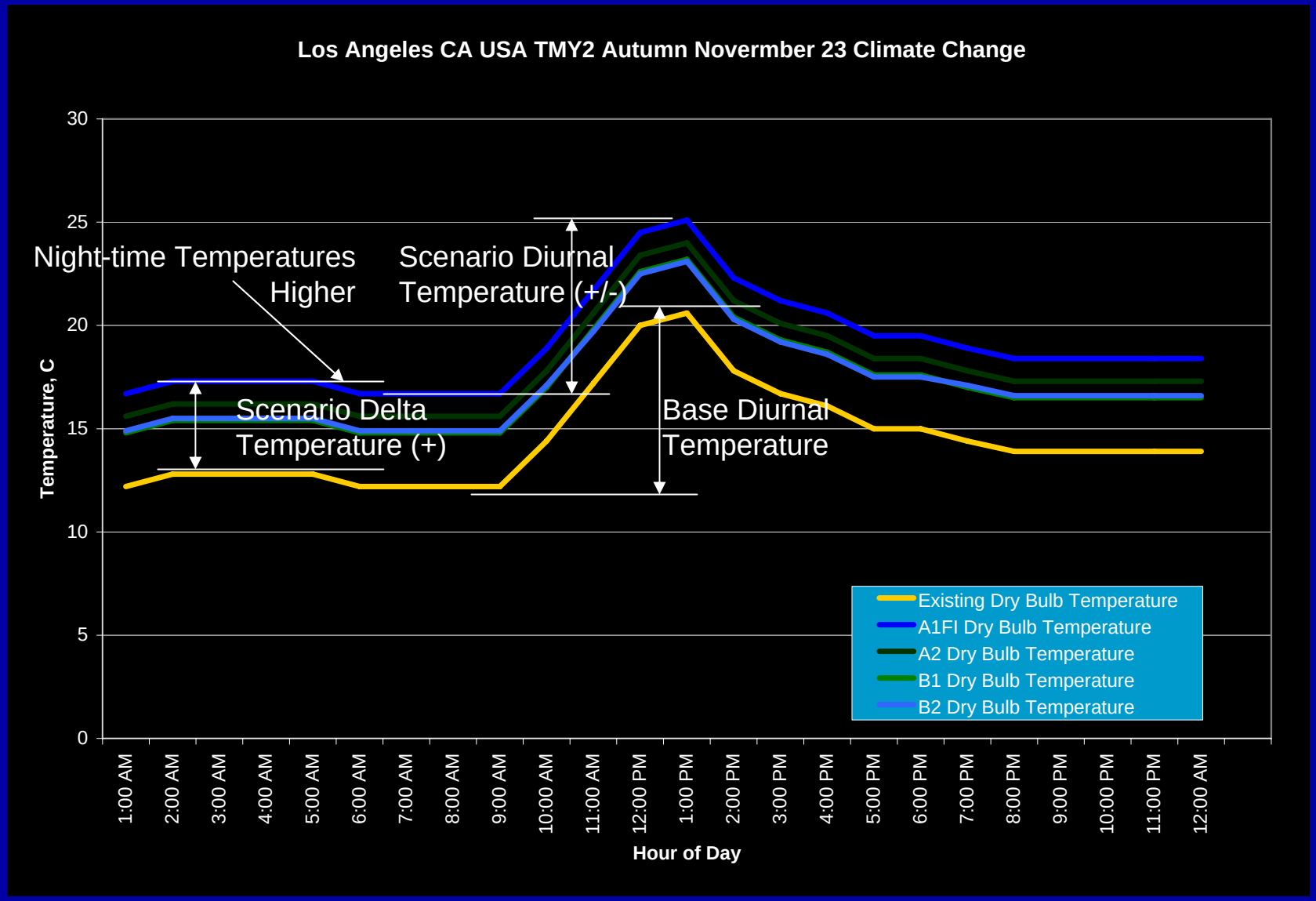
Representing Climate Scenarios:

- IPCC baseline period: 1961-1990, same as existing TMY2 typical weather files.
- Based on scenarios, GCMs calculate changes in temperature, precipitation, and cloud cover.
- 1.0 degree grid for Hadley average monthly temperature changes, diurnal temperature change, and cloud cover change from scenarios used to modify existing files.
- Typical, high and low energy cases.
- New files representing scenarios to test energy impacts.

What do the Climate Change Scenarios look like?

- Average monthly temperature change (+)
- Diurnal temperature change (+ and -)
- Cloud cover decrease (more solar radiation)
- Precipitation changes (+ and -)

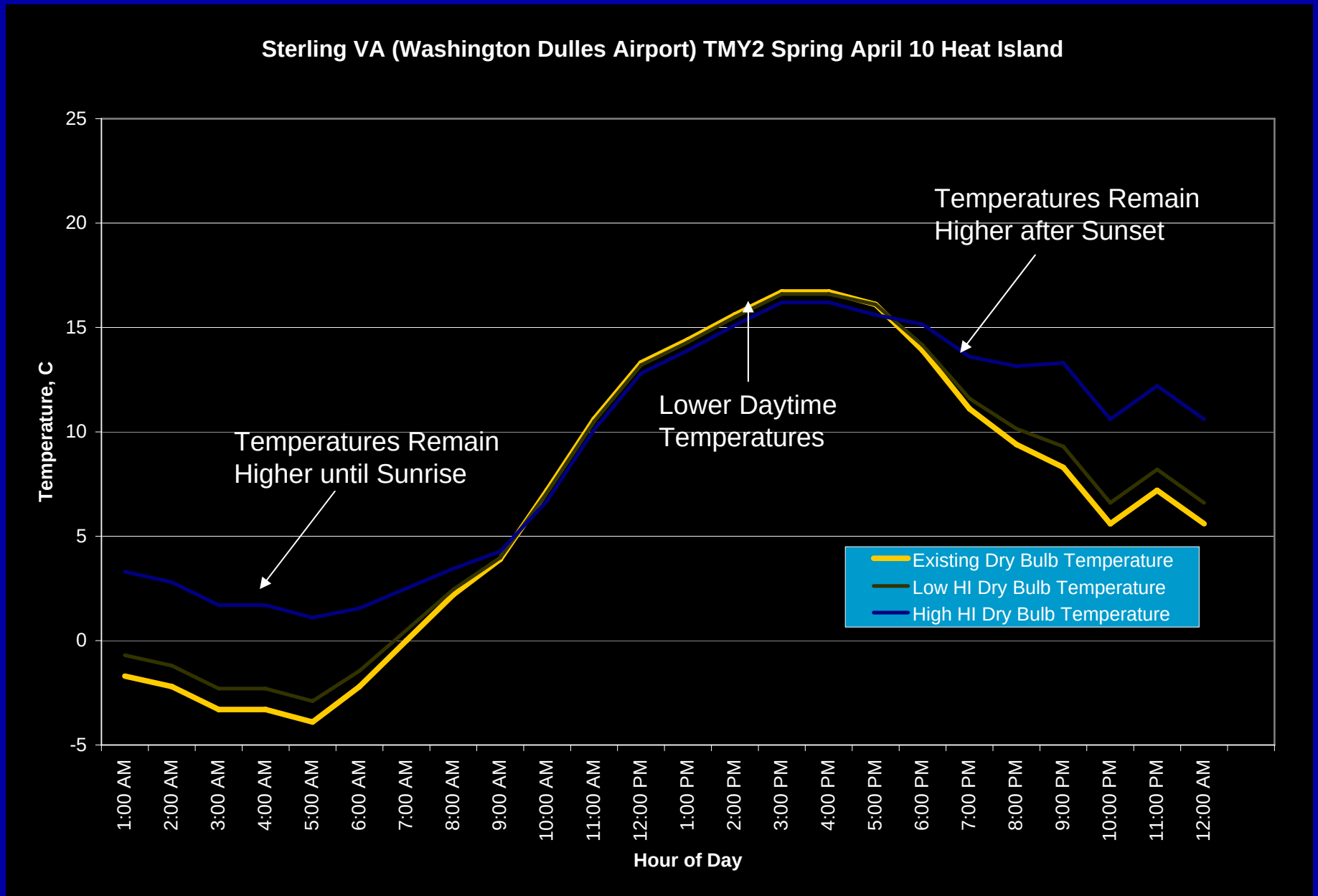
What do the Climate Change Scenarios look like?



Heat Island:

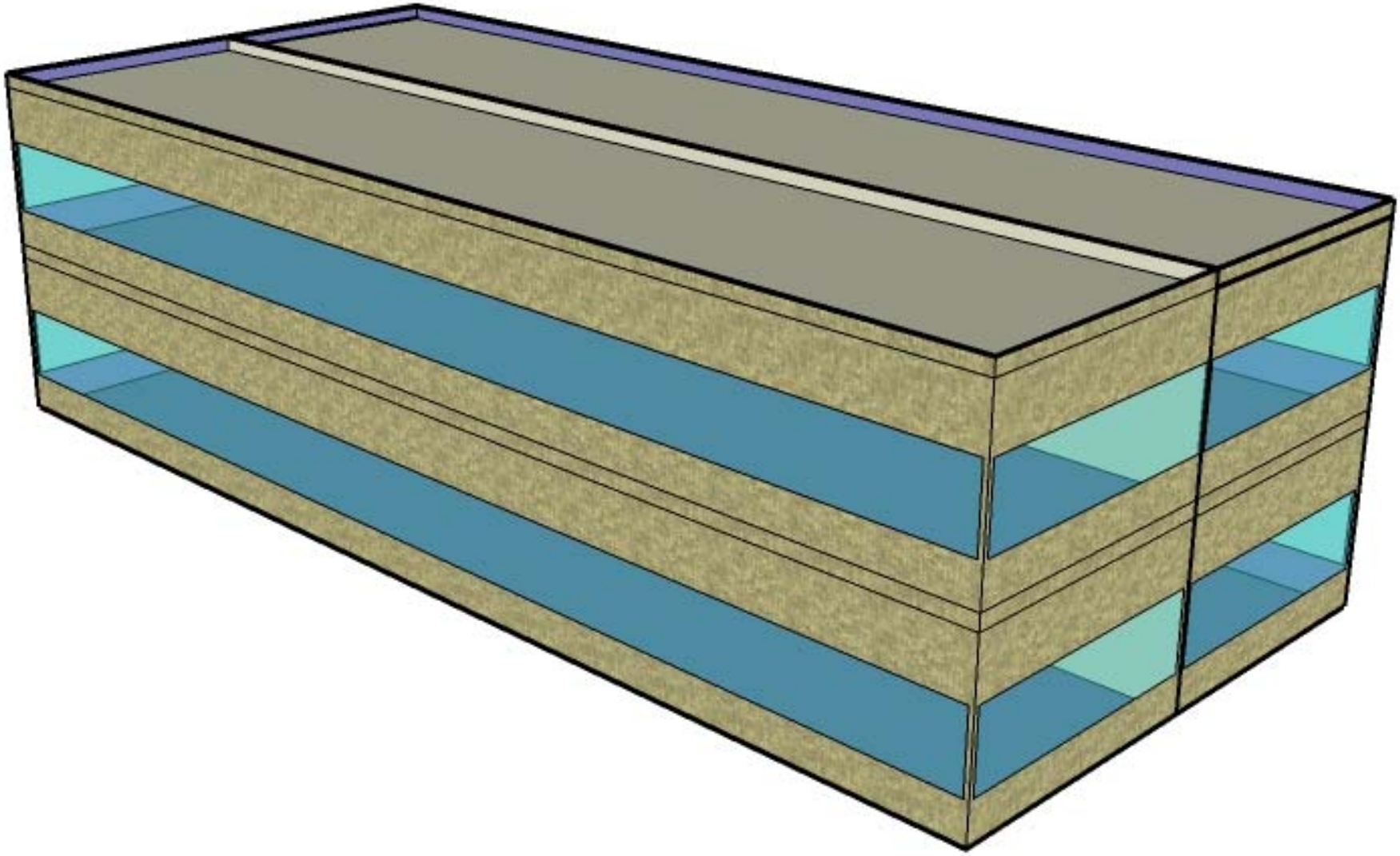
- Heat Island size and temperature are function of city population.
- Range is roughly 1-5 degrees C.
- Beyond 5 million people, roughly 5 degrees C.
- Depresses daytime temperature.
- Raises nighttime temperature.

Heat Island:

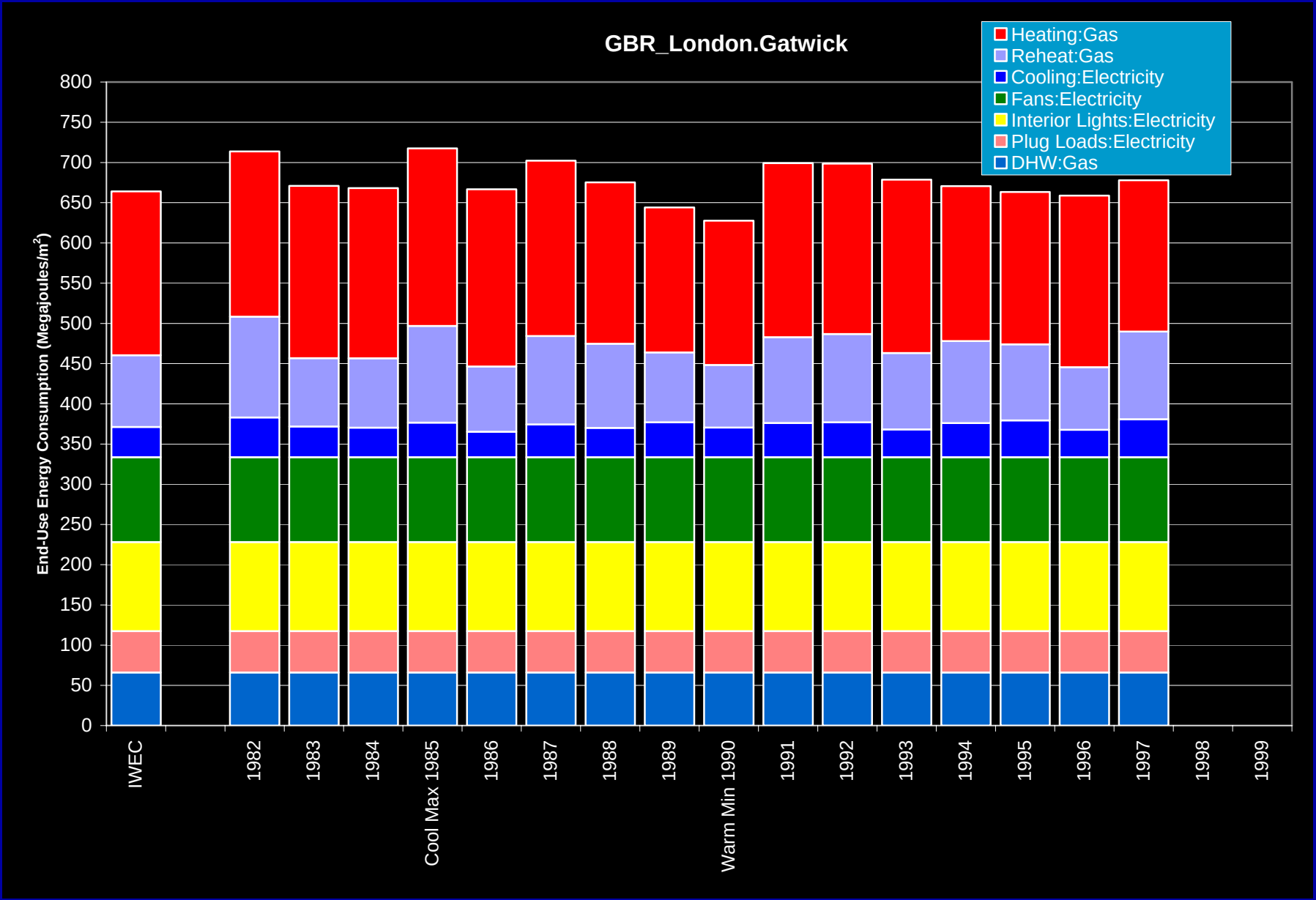

Sterling VA (Washington Dulles Airport) TMY2 Spring April 10 Heat Island
Temperature, C
25
20
15
10
5
0
-5
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00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

Test Case: Building Prototype.

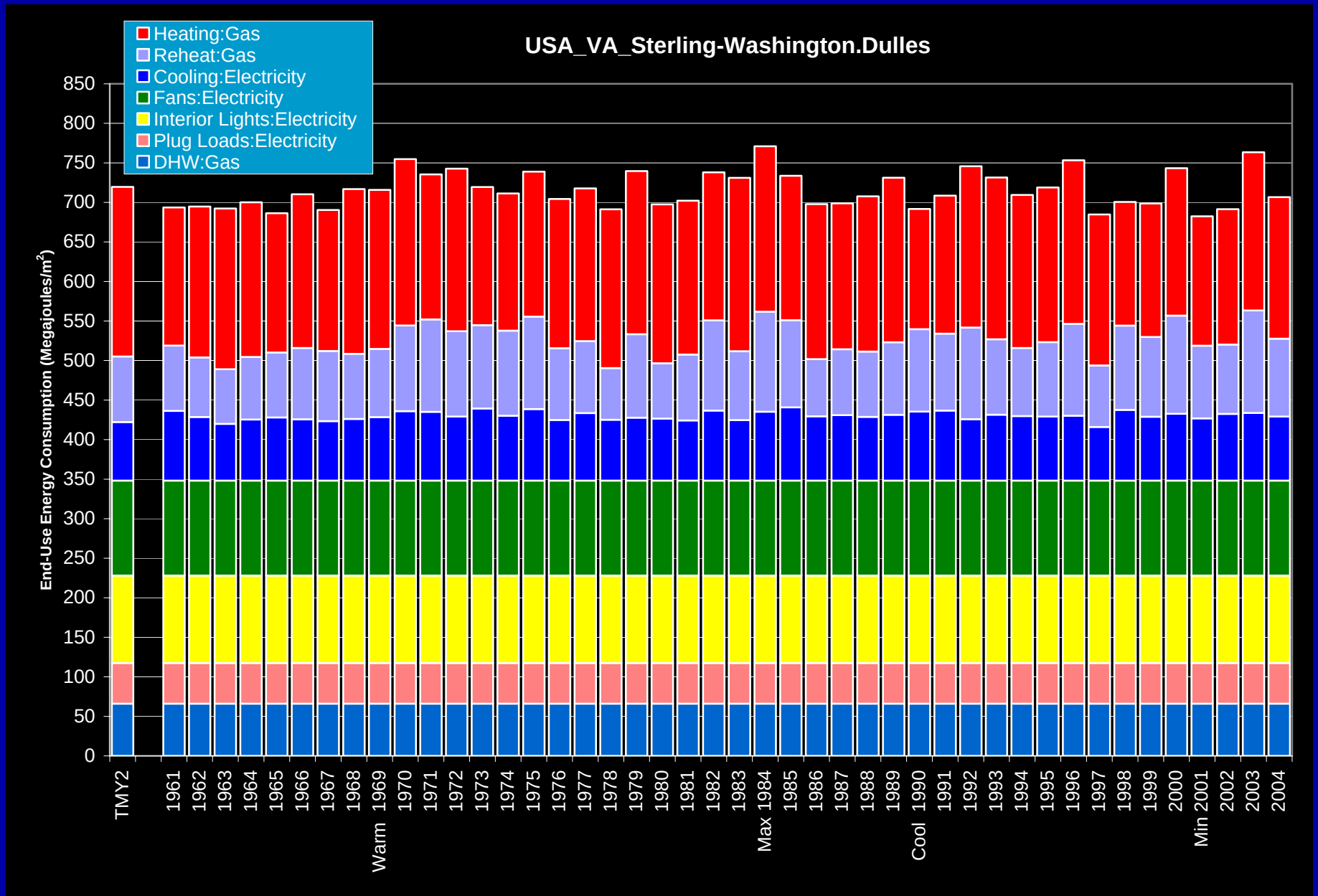
- Small, 360 meters squared, two story office building.
- 14 meters squared/person.
- Lighting at 13 Watts/meter squared.
- Office Equipment at 8.5 Watts/meter squared.
- Natural gas heating and hot water.
- Electric packaged cooling units.
- Building fabric (opaque and windows) and equipment efficiencies roughly equivalent to current minimum regulations (ASHRAE Standard 90.1.)
- US national average pollution emission factors.
- Simulated using EnergyPlus.



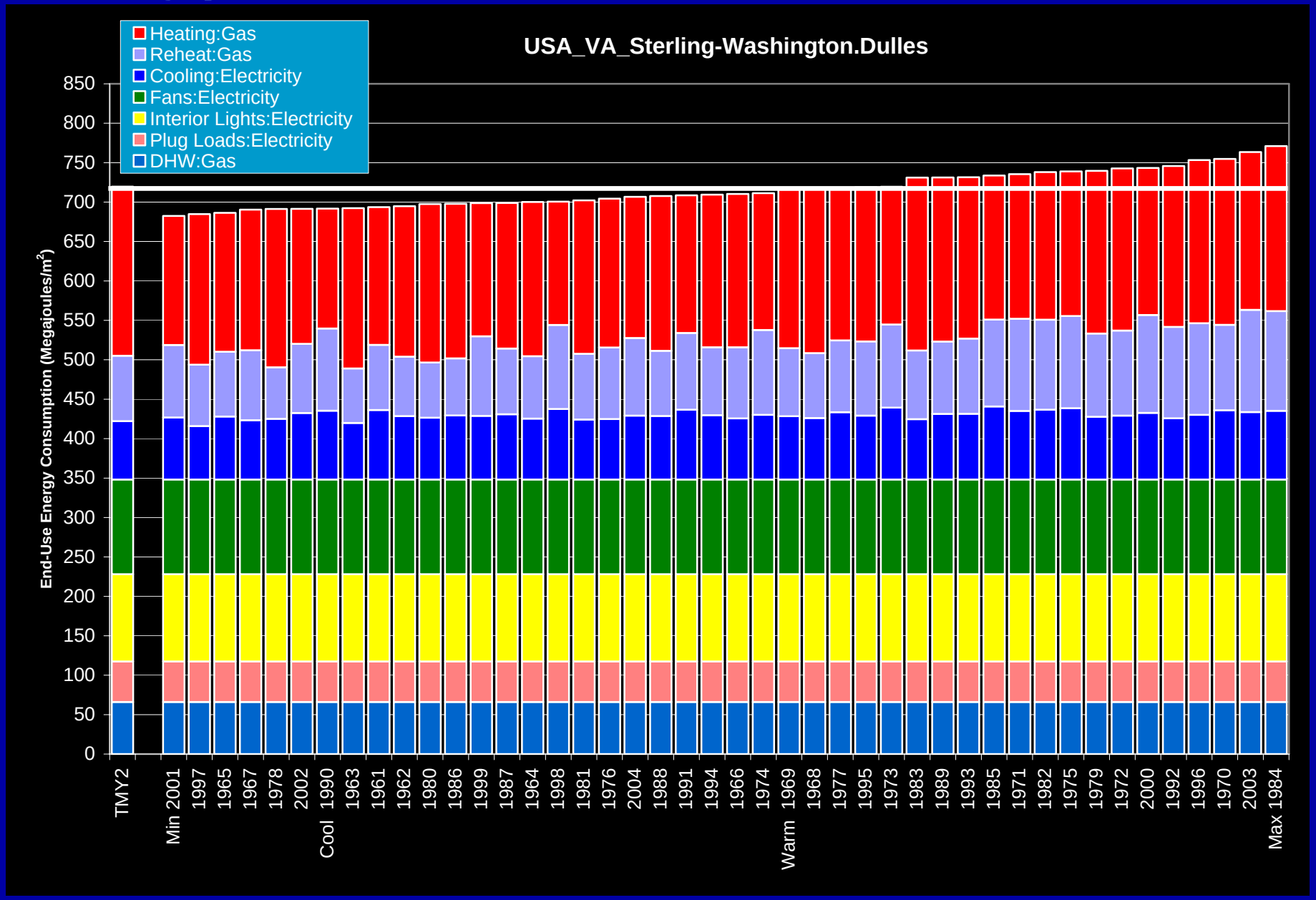
Typical vs. Actual Years:



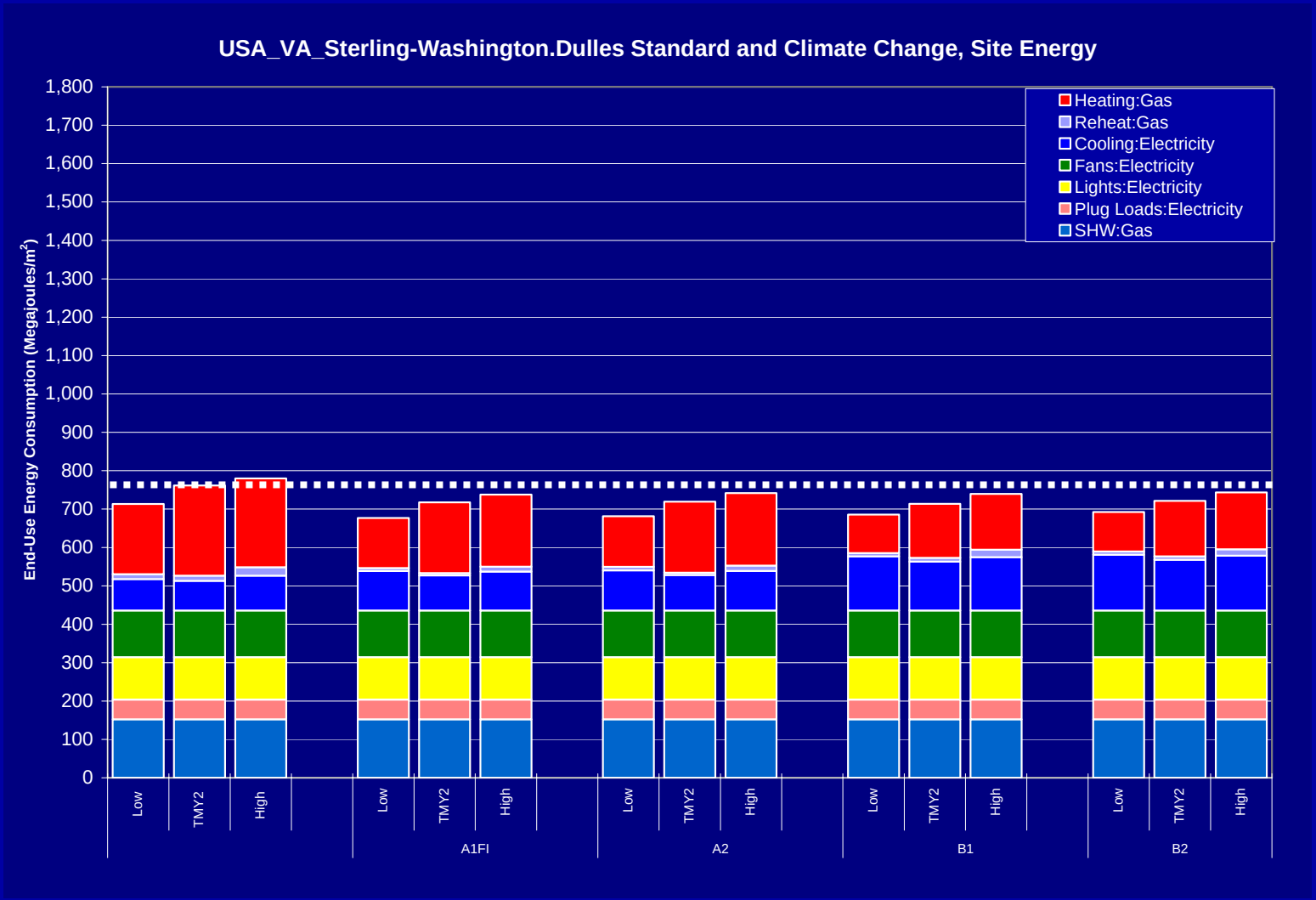
Typical vs. Actual:



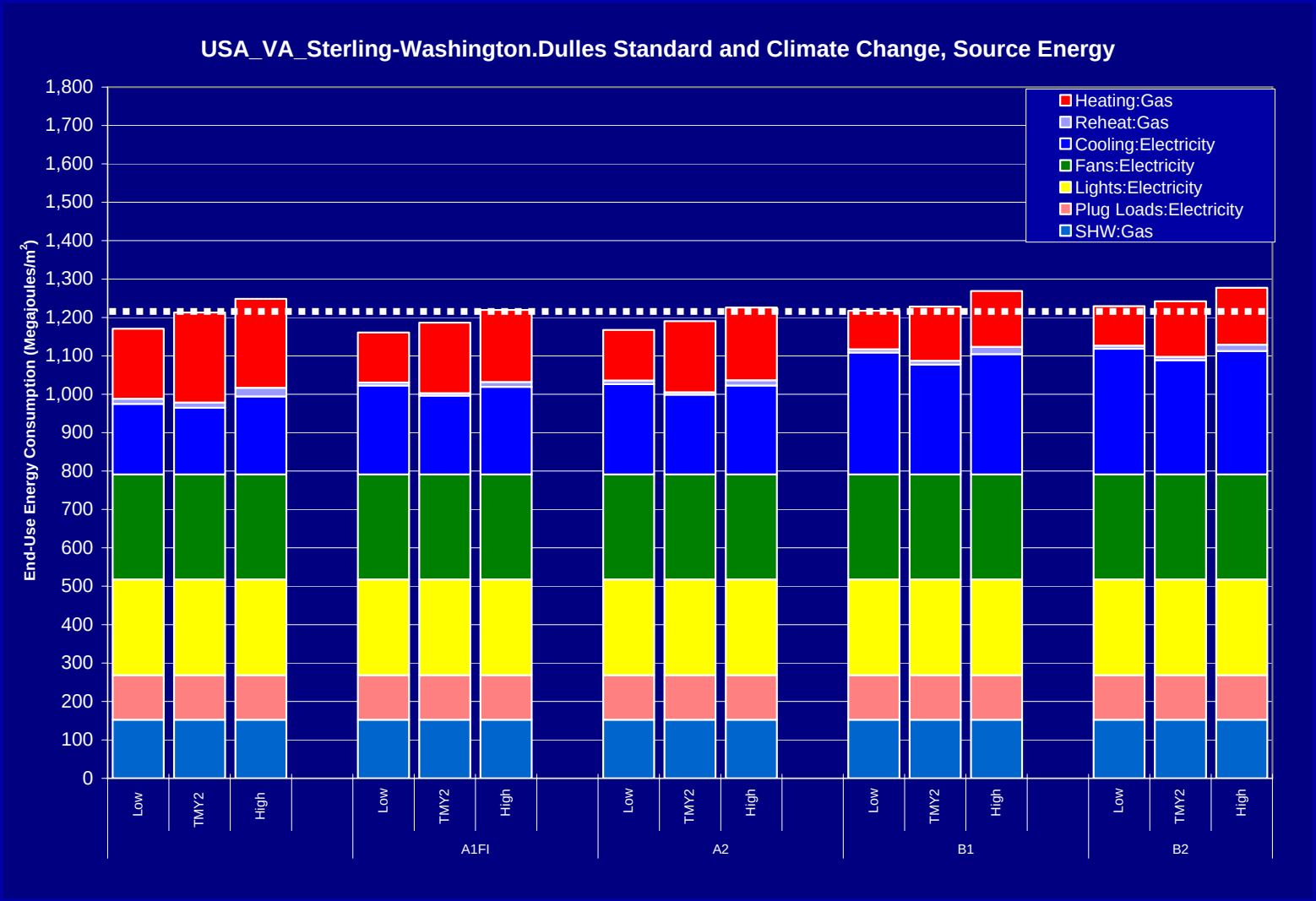
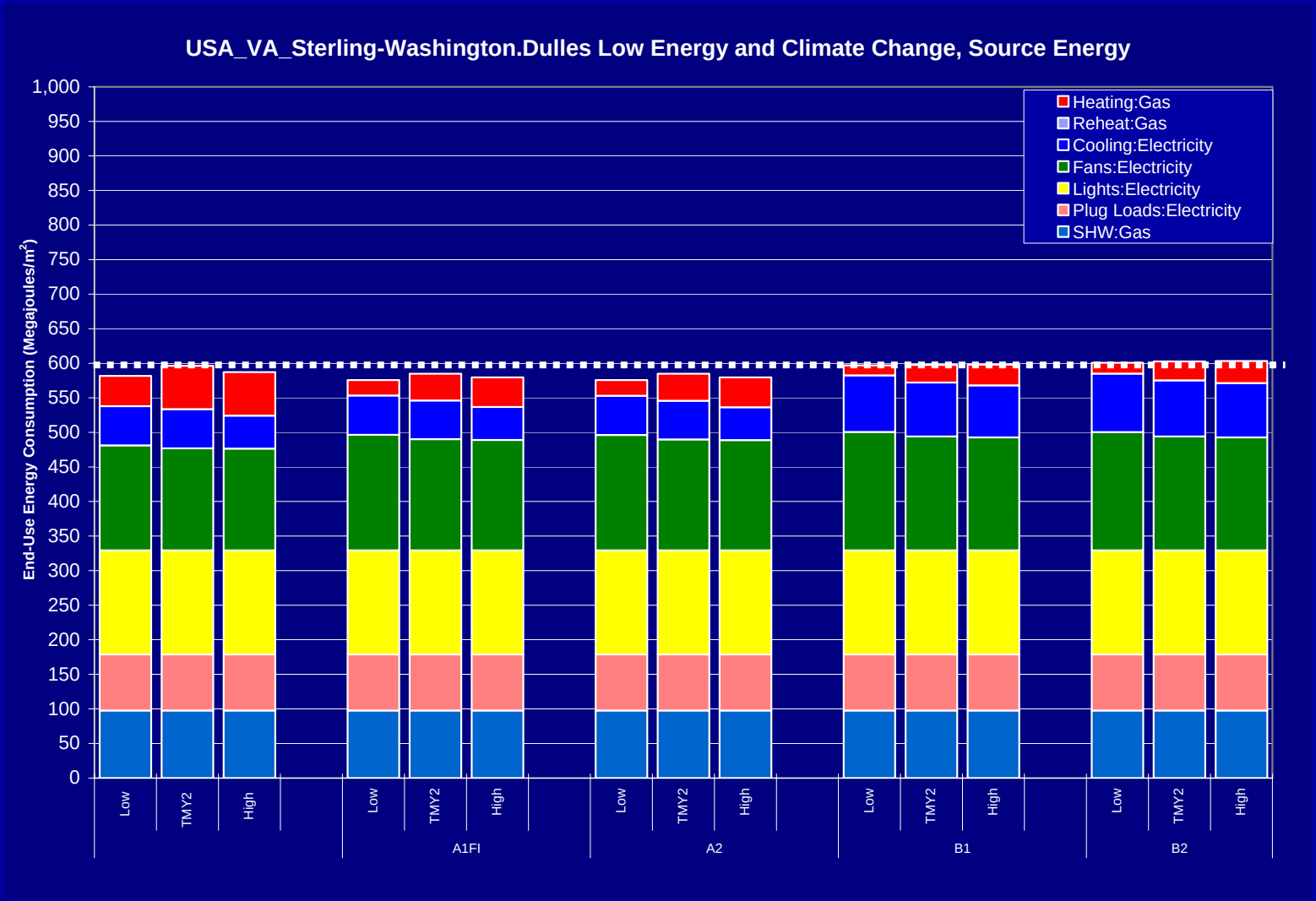
Typical vs. Sorted Actual Years:



A Snapshot of Results: Site Energy Decreases.



But Source Energy Increases Due to Climate Changes equaling Increased Emissions



And Low-Energy Buildings Can Mitigate Impacts of Climate Variation.