PROPOSED RETROFIT OF DUKE UNIVERSITY DORMITORY

Duke UNIVERSITY | BASS CONNECTIONS

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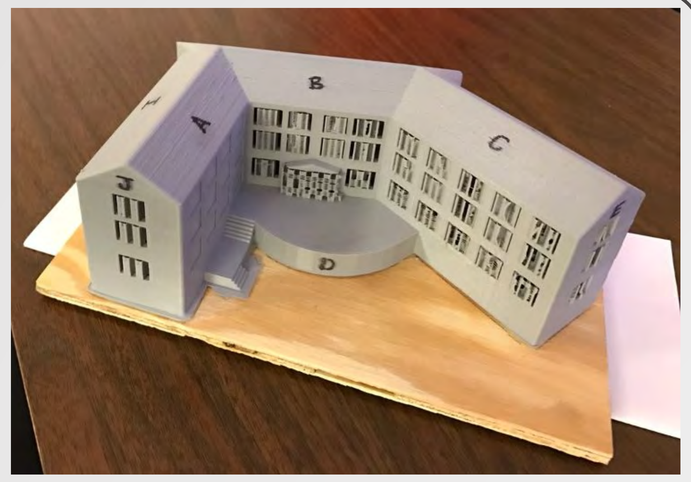
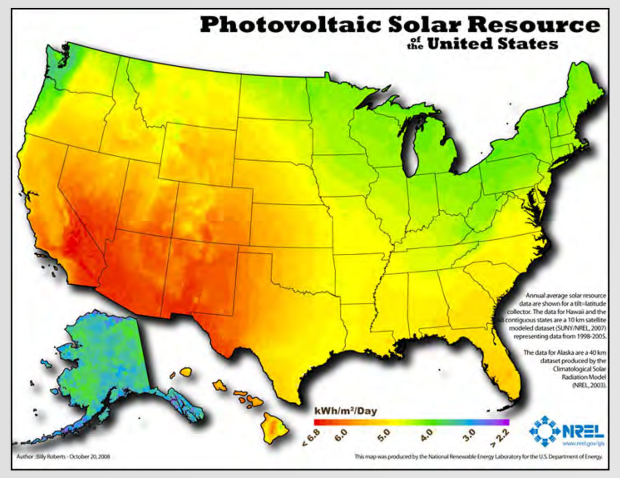
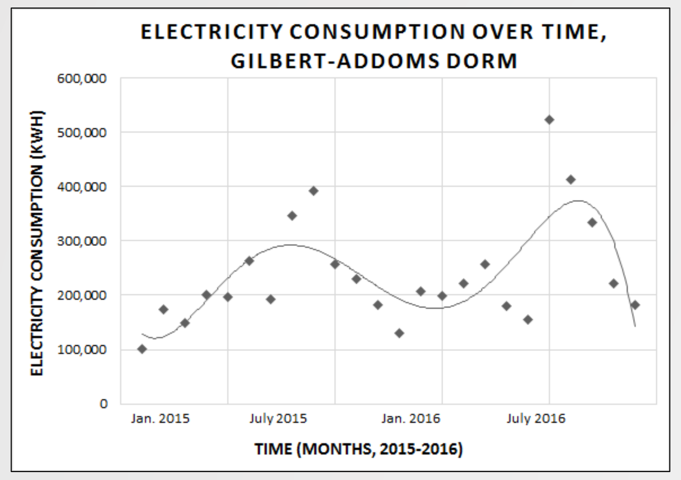
Physics, Mechanical Engineering, Chemistry, Environmental Engineering, Environmental Engineering, Chemistry

Introduction

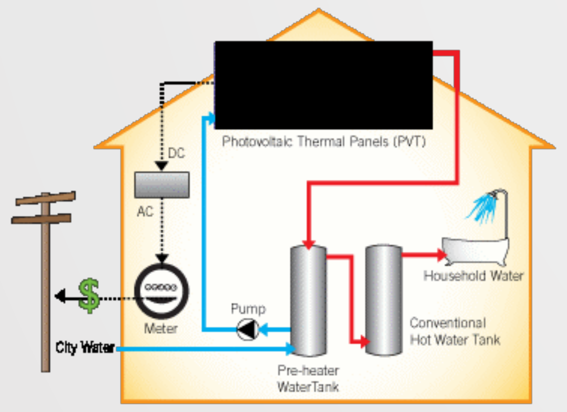






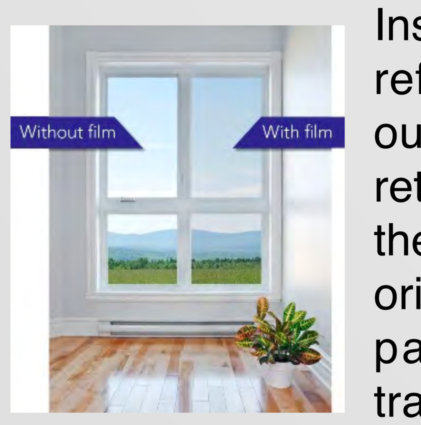
We are investigating the potential of incorporating green building concepts into college dormitories by examining the current state of energy consumption. Gilbert-Addoms (GA), a dormitory on Duke's East Campus, was large enough and used a sufficient amount of energy to be a good candidate for optimization. Based on the insolation of Durham, NC and the noticeable cracks in the dorm's envelope, we focused on the dorm's fenestration design as well as the implementation of photovoltaics, optimizing for summer.

Solar Panel Retrofit



The PV/T system makes use of water to cool the solar panels to make the cell more efficient while also heating water for domestic use. The panels are optimized to face south and tilt to a summer specific angle of 46°.

Fenestration Retrofit

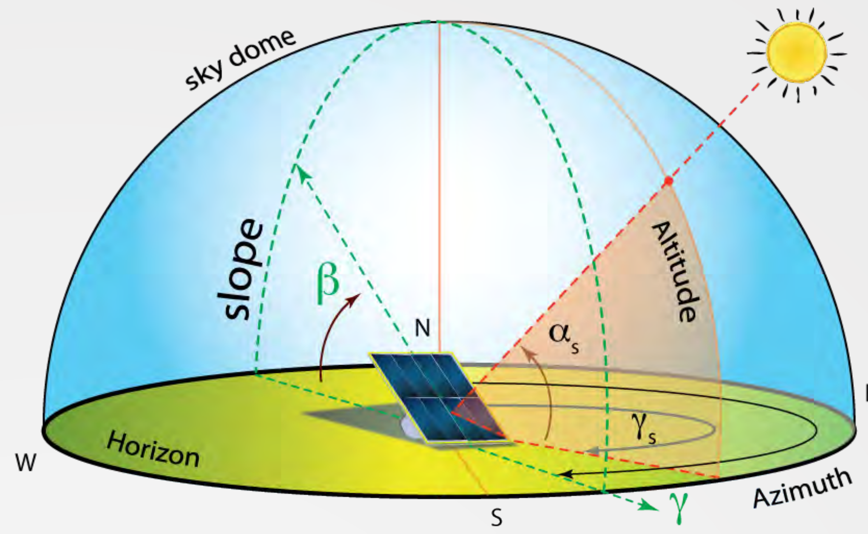


Insulating window films work by reflecting radiation from the outside in the summer and retaining heat on the inside in the winter. Weather tapes fill orifices between windows and panels and stop air from traveling between the inside and outside reducing heat loss.

Solar

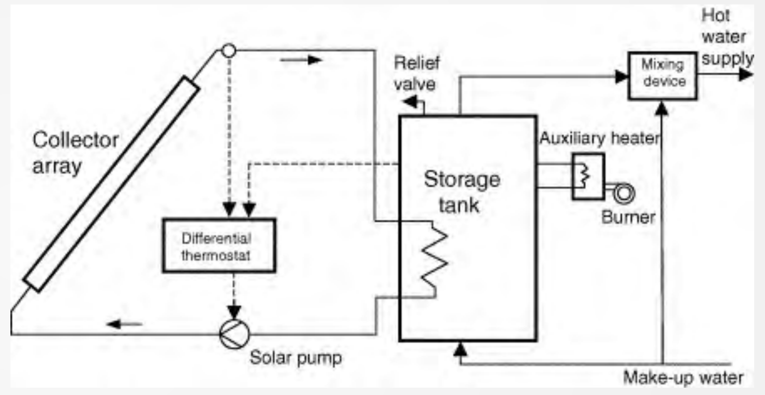
Insolation Governing Equations

- Parameters of interest
  - Solar azimuth angle
  - Solar zenith angle
  - Solar declination angle
  - Hour angle, in local solar time
  - Local latitude



Thermal and Solar Energy Equations

- Photovoltaic Parameters
  - Efficiency of PV: ~15%
  - Optimize panel tilt angle
  - For summer: latitude+10
- Solar Thermal Parameters
  - Efficiency of T: ~38%
  - Compare to 120°F
    - Typical shower
- Determine electricity generated
- Calculate Energy/Cost savings
  - Payback in years



Solar Viability Testing

- Solar model's goal: predict energy savings from solar PV/T efforts
- Solar Advisory Model (SAM) from NREL calculated energy generated per month
- Solar Thermal energy savings were calculated using water's heat capacity and amount of heat released by panels

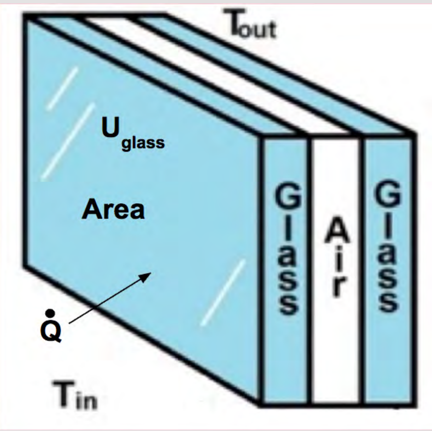
Fenestration

Fenestration Governing Equations

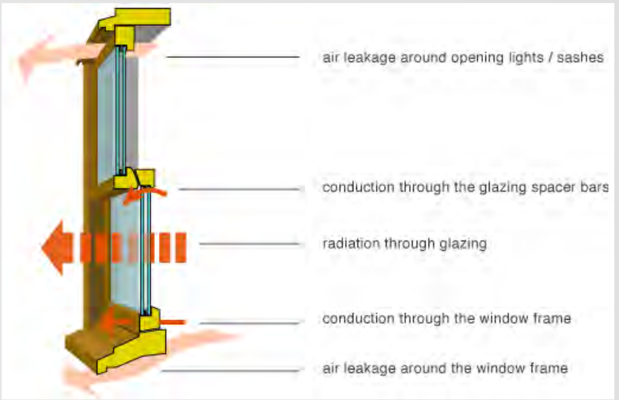
Net Rate of Heat Transfer through Window:

$$\dot{Q}_{net}=UA\Delta T+c_p\dot{m}\Delta T-IA\tau$$

Heat Conduction — Air Leakage — Heat Gain due to Insolation



Assumptions:
- Double-paned, regular-emissivity windows with air between panes
- U_{glass} (provided by manufacturer) accounts for both conductance and radiation
- Steady, incompressible flow of air
- Frictional losses are negligible



Proposed Fenestration Retrofit

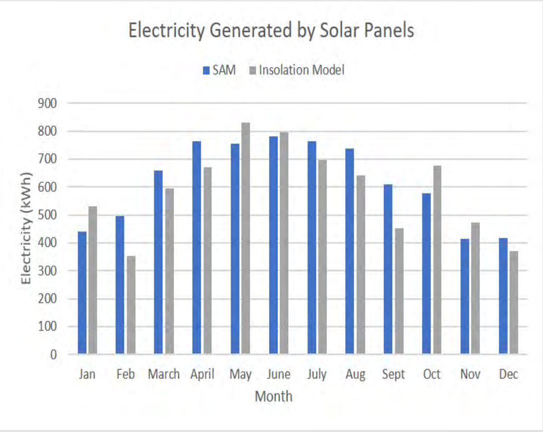
- Add film to windows during the summer months
- Use a sealant to minimize air leakage through orifices

Fenestration Viability Testing

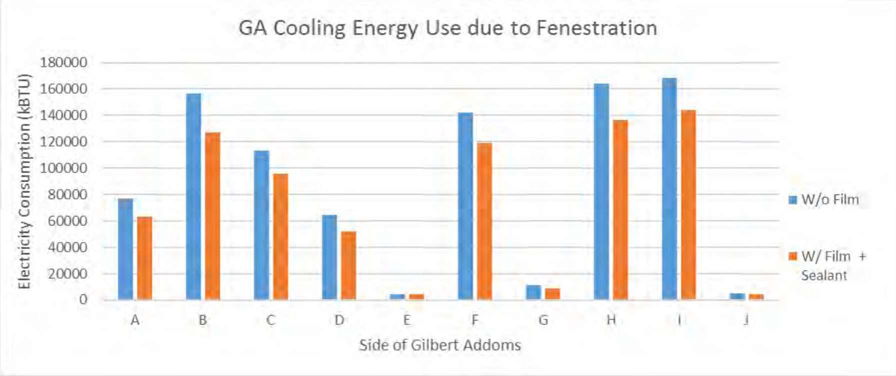
Comparing model results to actual energy consumption in cooling months (Mar-Aug) of 2016:
- Previous energy consumption for GA in August 2016: **266,000 kWh**
- Estimated energy consumption for GA due to fenestration: **490,000 kWh**
- Estimated % of energy consumption due to fenestration losses: **54.4%**

Results

During the March-Aug period in the Duke East Campus Gilbert-Addoms Dormitory,
- By implementing the Nitto PX-7060S weather insulating film and weather-stripping, **45,000 kWh** of energy is estimated to be saved annually
- Annual electricity saved by implementing PV panels on the rooftop is **7,100 kWh**
- Annual thermal energy generated can be up to **10,500 kWh**
- By summing up the energy conserved from installing both films and solar panels, the EUI of the building decreases from 81 kBtu/ sf to about 78 kBtu/ sf
- Estimated annual energy reduction: **62,600 kWh**
- Total energy savings per year: 62,600 kWh/ yr*$0.0745/ kWh= **$4664/ yr**



Electricity generated by solar panels



Energy consumption results for Gilbert-Addoms with and without retrofit (see model for reference)

Acknowledgments

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