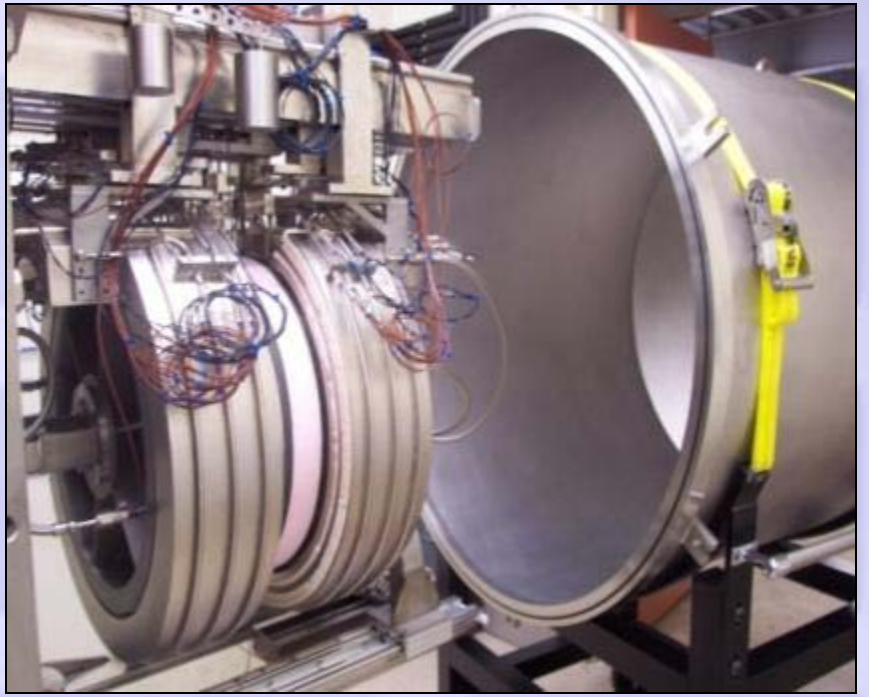
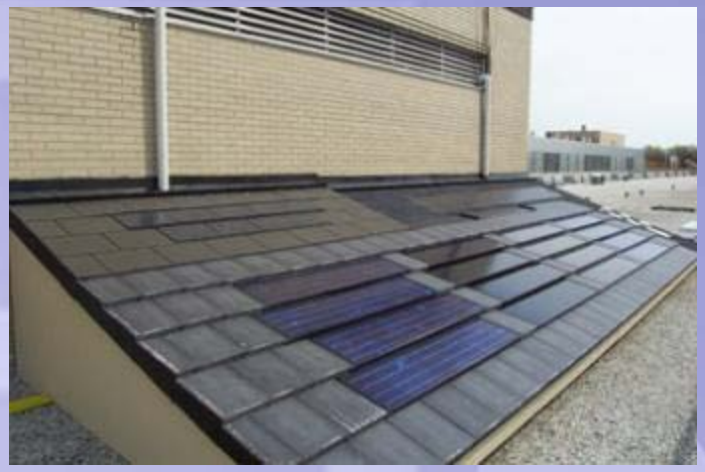
Buildings and Energy R&D



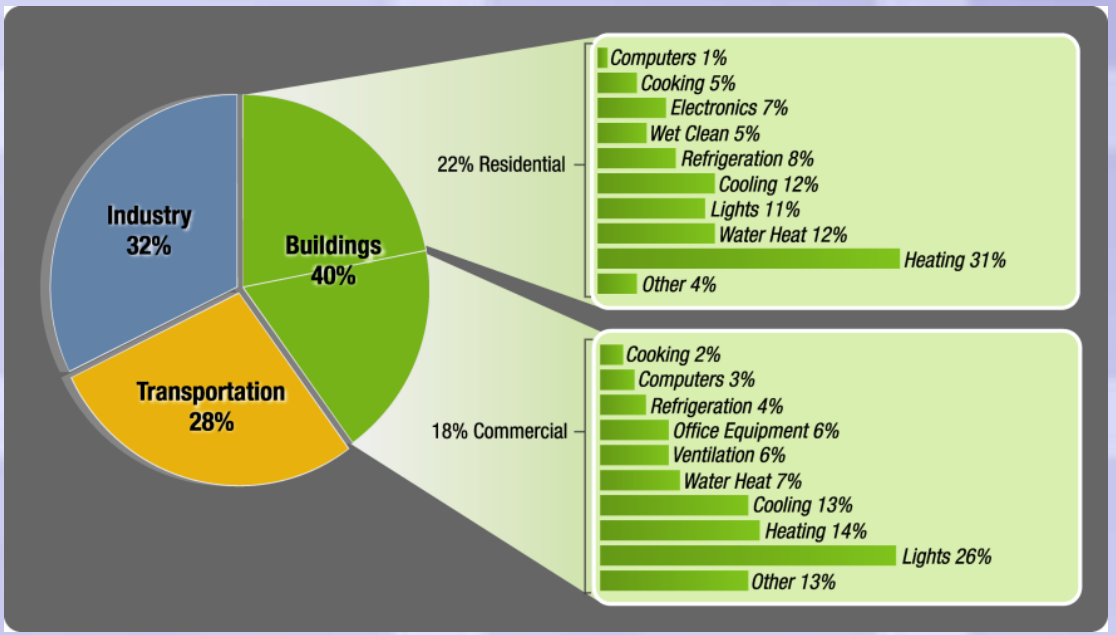


A. Hunter Fanney
Chief, Building Environment Division
Engineering Laboratory
National Institute of Standards and Technology

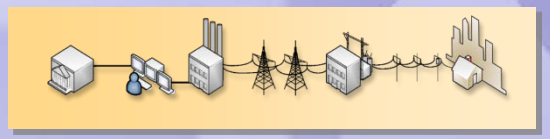
Why Buildings' Energy Use Is Important

The combined residential and commercial buildings sector is the largest energy consumer in the U.S.

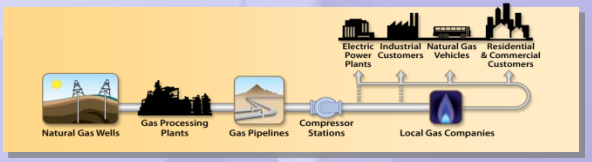
40% of U.S. Primary Energy Consumption



72% of U.S. Electricity



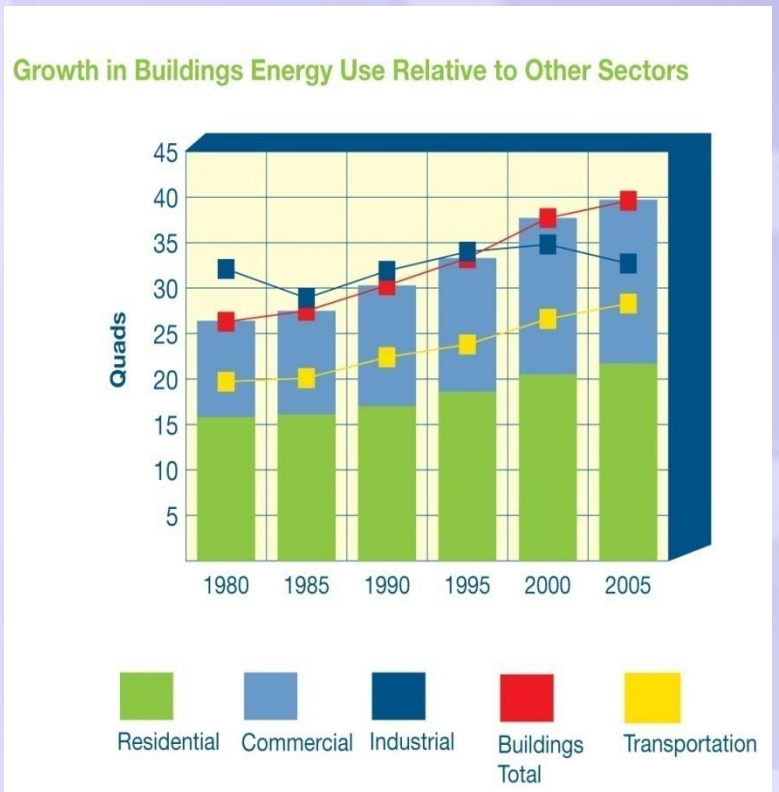
55% of U.S. Natural Gas



U.S. spends $515B/year in energy costs for operation and use of constructed facilities

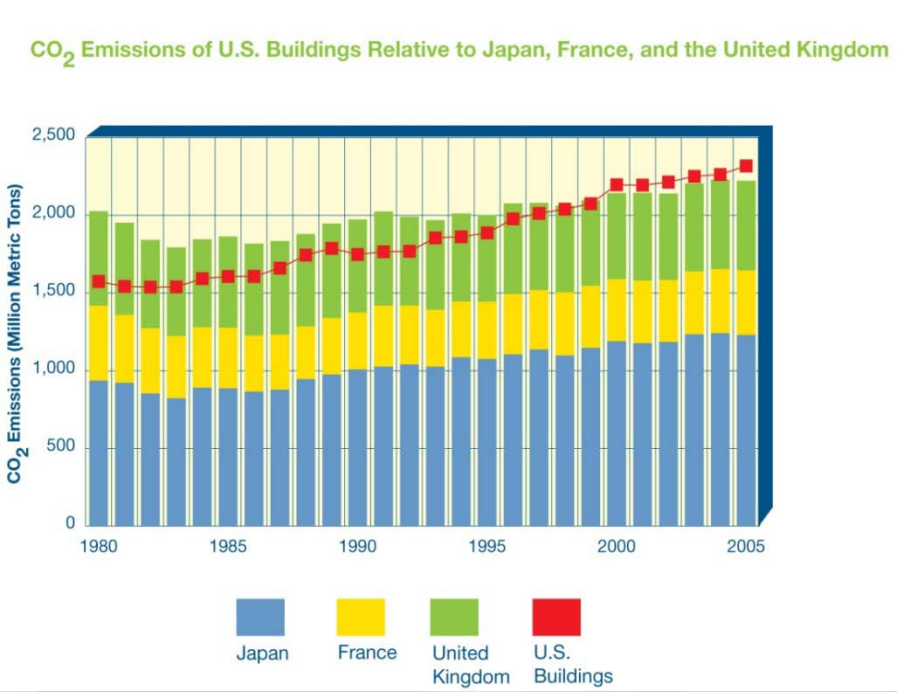
Fastest-Growing Energy Sector

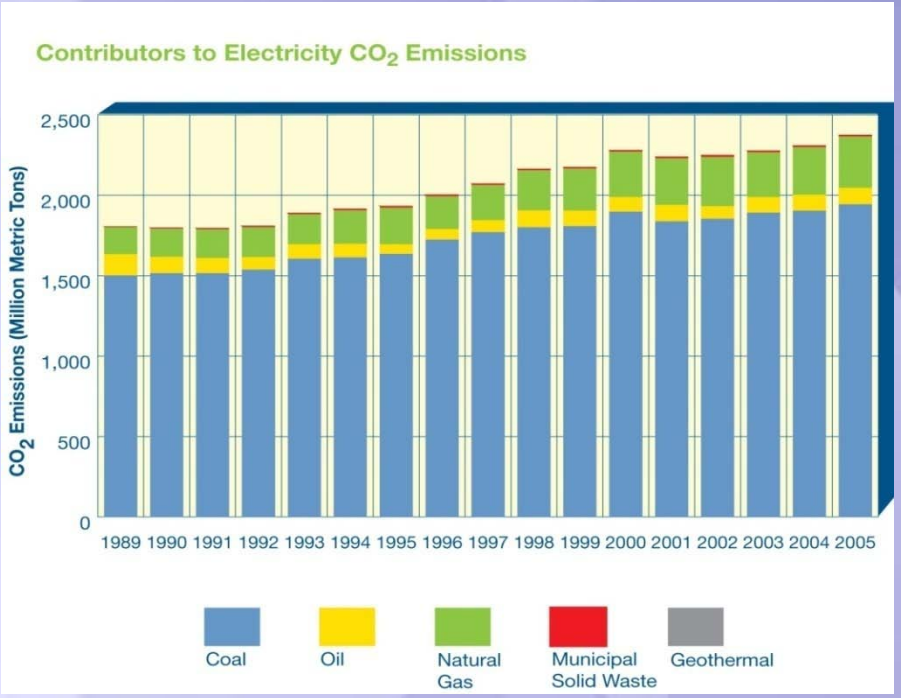
Energy consumption by commercial buildings sector rose 70% between 1980 and 2005



Buildings' Environmental Footprint Is Large

U.S. buildings contribute 9% of world's carbon dioxide emissions (double the emissions of India)

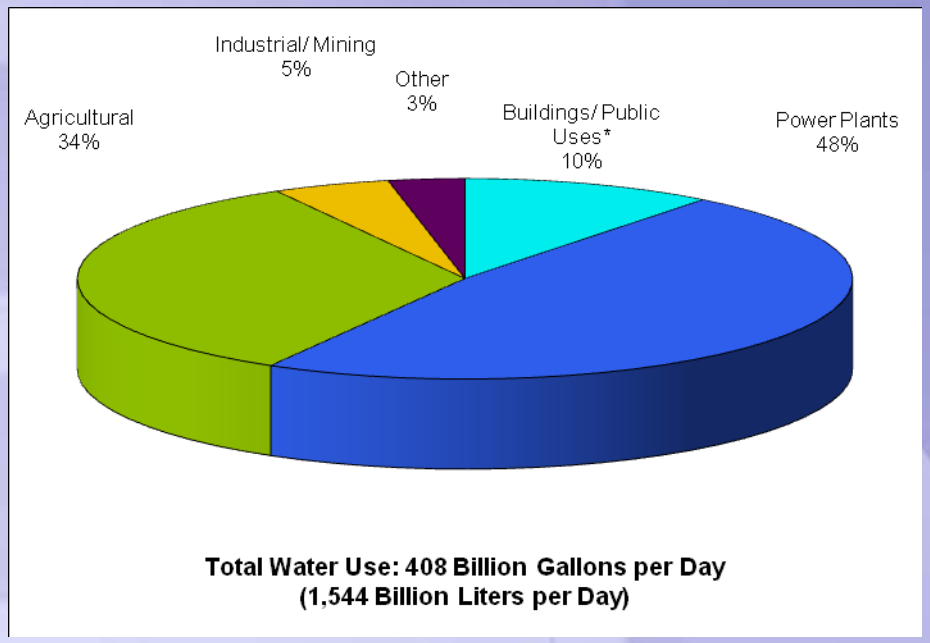




Buildings' Water Use Is Significant

Including electric generation, buildings account for 45 percent of U.S. water use:

- Not including electricity, U.S. per capita domestic water use is 100 gal/day (378 liters/day)
- Approximately 140 billion gal/day (530 billion liters/day)), is used to produce electricity for buildings or an estimated 470 gal/person/day (1,779 liters/person/day)

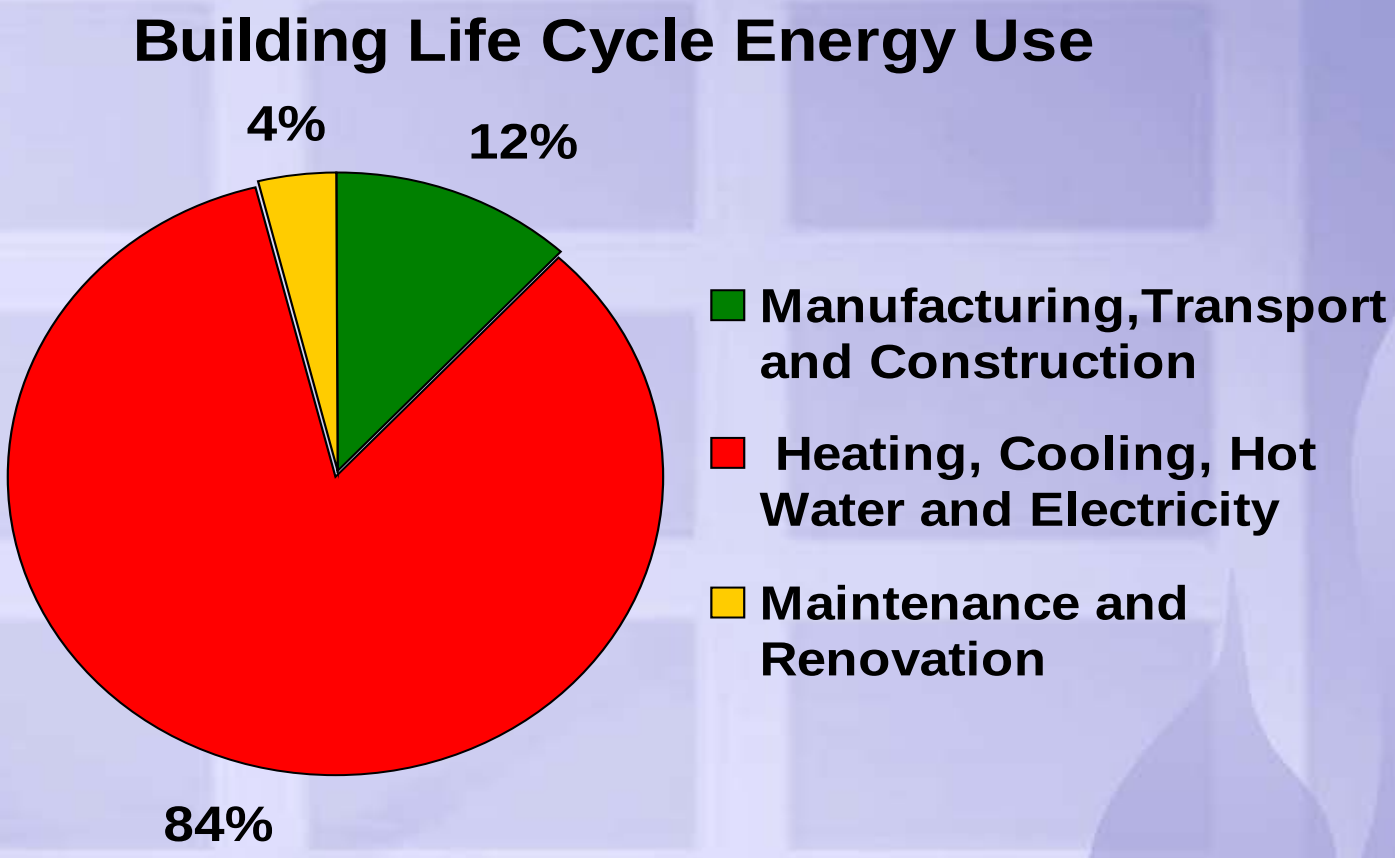


*Does not include self-supplied water of approximately 15 billion liters/day.

Source: Hutson, S.S., Barber, N.L., Kenny, J.F., Linsey, K.S., Lumia, D.S., and Maupin, M.A., 2004, Estimated use of water in the United States in 2000: Reston, Va., U.S. Geological Survey Circular 1268; http://www.epa.gov/WaterSense/water/save/use.htm

A recent U.S. study shows 36 states will have local, regional or statewide water shortages by 2013.

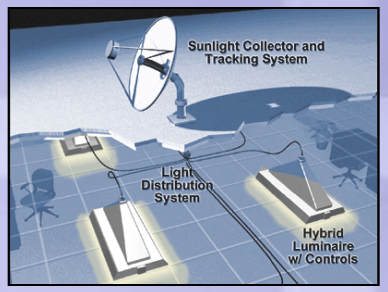
Operational Vs. Embodied Energy



Future High-Performance Technologies

Lighting Systems

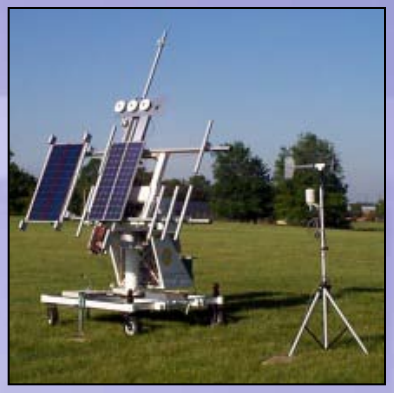
- Solid State Lighting
- Intelligent natural daylighting distribution systems



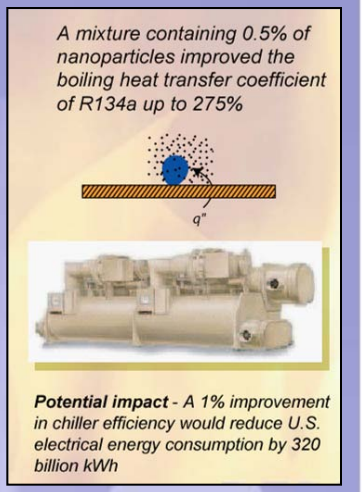
Hybrid Solar Lighting

Building Envelope Systems

- Dynamic response (shades and electrochromic windows)
- Highly insulating façade systems
- Natural lighting technologies/designs (Green)

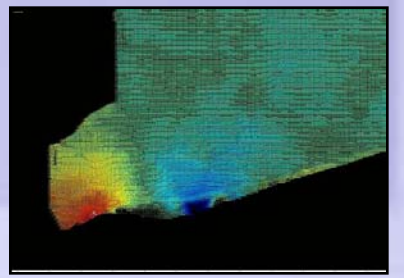


Solar Tracking Facility to Characterize Performance of Photovoltaic Cell Technologies

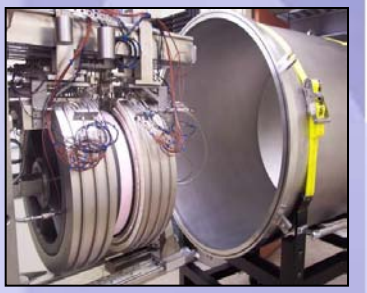


Intelligent Systems and Controls

- Diagnostic and real-time monitoring tools
- Sensors for improved building monitoring
- Grid/consumer supply/demand integration



Particle Image Velocimetry Image of Air Flow Distribution through Heat Exchanger



NIST's 0.5 meter Guarded Hot Plate Capable of Providing Measurements of Thermal Insulation from 90 to 900 K

Heating, Cooling, and Refrigeration

Boric Acid Nano Lubricant

- Nano-fluids and lubricants
- Thermally-activated heat pumps
- Distributed refrigeration/water-source heat pump
- Thermoelectric cooling
- Frostless heat pump
- Improved residential HVAC air distribution systems

NIST Efforts on Renewable Energy

- 2000 – CFMO Embraced BFRL's Efforts to Install Photovoltaics
-
- 2001 – 35 kW PV System Installed on Building 101
- 2009 – BFRL Requested $5M ARRA Funds for PV
- 2009 – BFRL Completed Solar Site Analysis
- 2009/2010 – Joint CFMO/BFRL Design Efforts
- Fall 2010 – PV System Installations Commence
- Proposed System Sizes/Locations
  - East of Building 216 – 252 kW
  - 227 Parking Lot Canopy – 181 kW
  - Building 101 Vehicle Charging Station – 7.5 kW
- Potential Additional Sites
  - Increase Size of Existing 101 System (35 to 105 kW)
  - Increase Size of Canopy Parking Lot System

Proposed Photovoltaic System – Location 216

Proposed Photovoltaic System – Building 227

BFRL Contributors	*CFMO Contributors*
Hunter Fanney	Susan Cantilli
Brian Dougherty	Silvio Baruzzi
Lindsay Murdock	Dan Gilmore
Luis Luyo	Warren Livengood

NIST Energy Retrofit for Existing Lab Bldgs

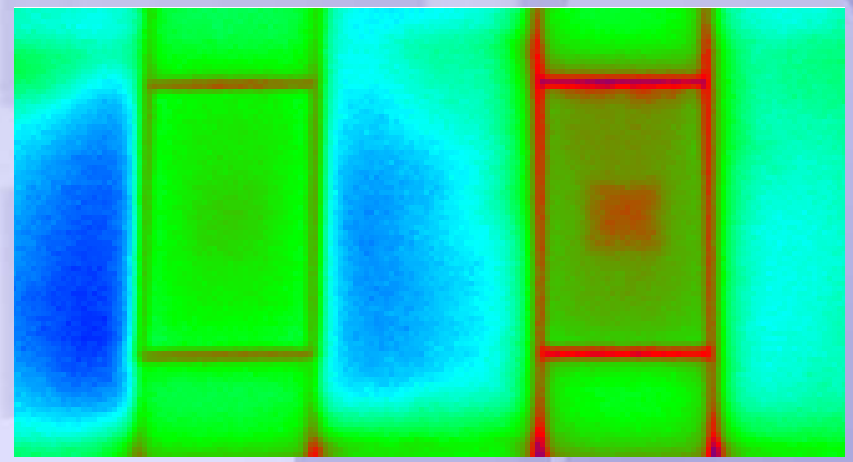
- BFRL Responsibilities
  - Develop Various Strategies to Reduce GPL Energy Needs
  - Oversee Installation of Various Retrofit Packages
  - Instrument/Collect Data/Predict Annual Results
- CFMO Responsibilities
  - Provide Existing Building/Equipment Specifications
  - Oversee with BFRL Installation of various Retrofit Packages
  - Develop Final Retrofit Package
  - Install Retrofit Package throughout NIST GPLs
- Results
  - Air Leakage Reduced by 50%
  - Exterior Wall Heat Loss reduced by 59%
  - Annual Savings per Exterior Module $190
  - Comfort Level Improved (Eliminate Drafts/Cold Windows)
  - Retrofit Package Being Applied to Entire Building (226)
  - Retrofit Package to be applied to all GPL's

Retrofit Exterior Wall
R-32 Insulation – Double Pane
Low-E Argon Filled Window

Exterior Wall After Retrofit

Existing Exterior Wall
No Insulation- Single Pane Glass

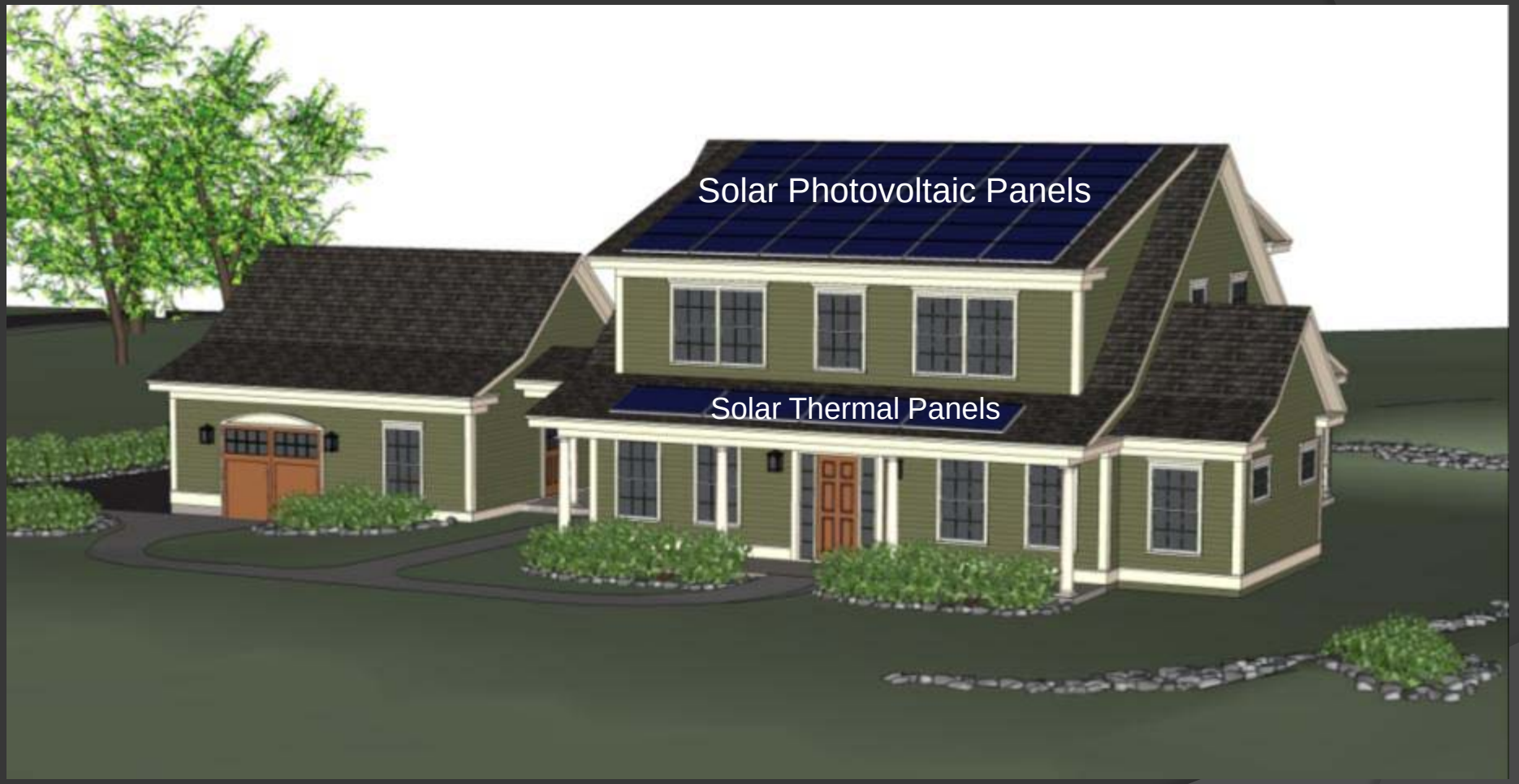
Exterior Wall Before Retrofit



Blue/Light Green Denotes Reduced Heat Loss Compared to Red/Dark Green with Greater Heat Loss 227

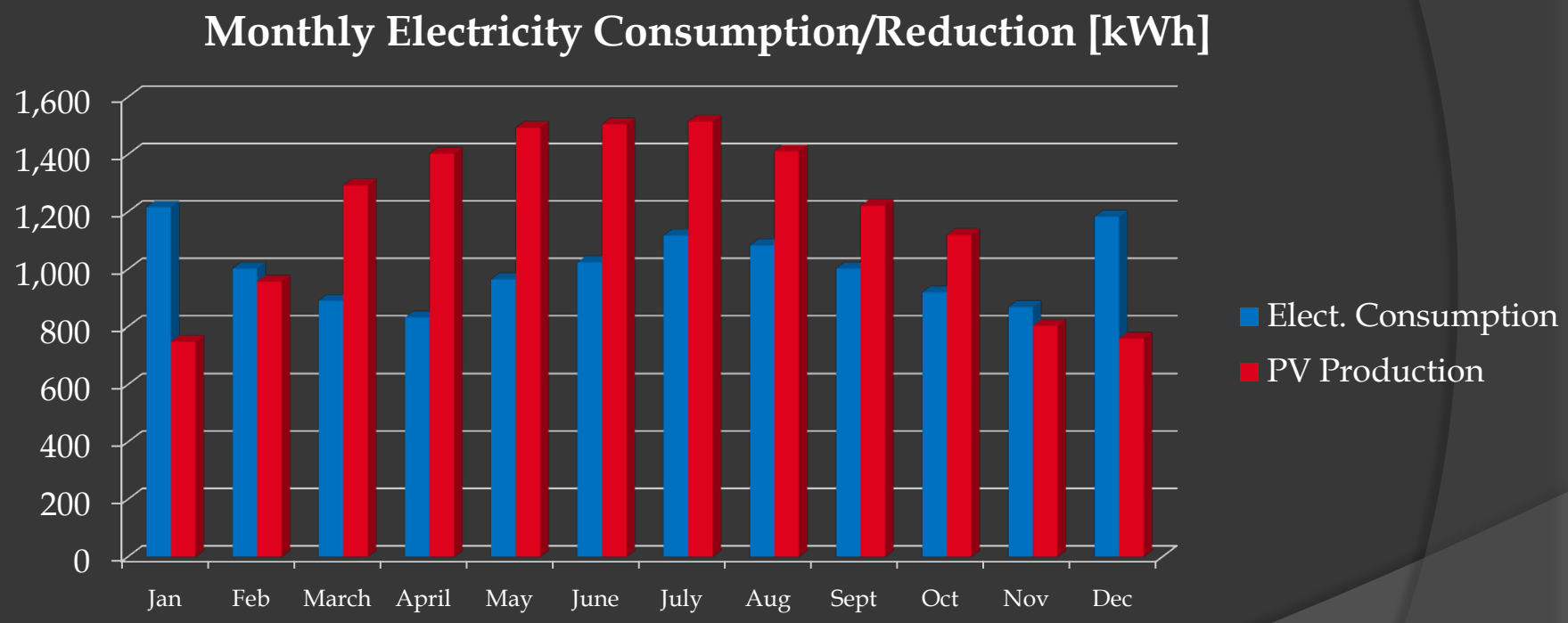
BFRL Contributors	*CFMO Contributors*
Hunter Fanney	John R. Bollinger
Mark Davis	Jatin Patel
Bob Chapman	Daniel Mann
Luis Luyo	Dan Gilmore

Net-Zero Energy Residential Test Facility



What is a Net-Zero Energy Building?

A building that produces as much energy as it uses on an annual basis, using renewable energy sources such as solar photovoltaics, solar thermal, or small wind turbines.



Annual Energy Produced 14,234 kWh
Annual Energy Consumed 12,060 kWh

NZERTF

Gaithersburg, MD

Objectives

- **Demonstrate Net-Zero Energy for a typical home**
- **Provide “real world” field data to validate/improve models**
- **Provide a test bed for in-situ measurements of various components and systems**
- **Improve laboratory test procedures of systems/components to give results that are representative of field performance**

Design Approach

- **Design and Build Shell of House (Thermal Envelope) to Minimize Heat Loss During Winter and Heat Gain During Summer**
- **Provide Adequate Controlled Ventilation vs Unintended Air Leakage**
- **Place All Heating/Cooling Equipment within Conditioned Space**
- **Select Energy Efficient Appliances and Space-Conditioning Equipment**
- **Design House as a System, not Collection of Components**
- **Provide Energy Requirements with Renewables**

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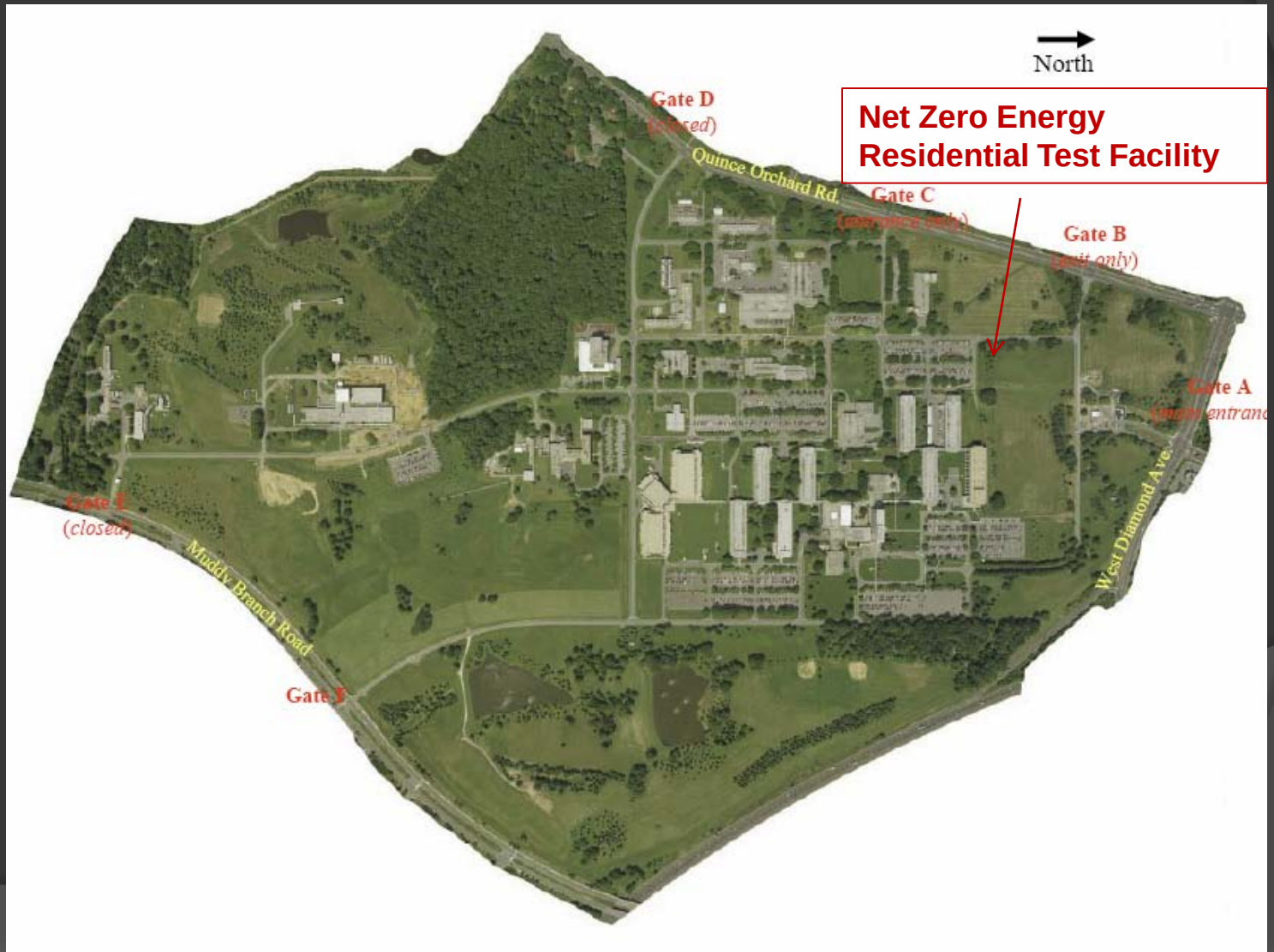
Location



NZERTF

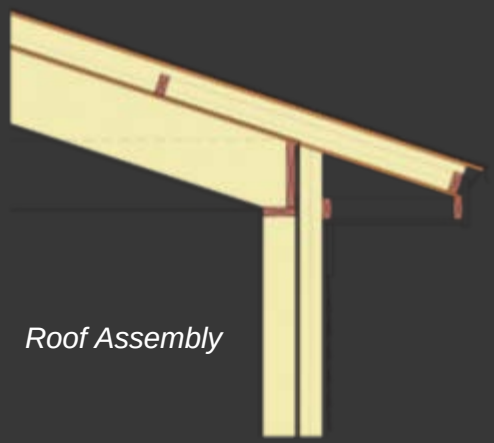
Gaithersburg, MD

- Project Overview
  - Type: Single-Family
  - Stories: 2
  - Bedrooms: 4
  - Baths: 3
  - Floor Area: 2,709 sq. ft.
  - Basement Area: 1,518 sq. ft.
  - Smart Grid Ready
  - Electric Vehicle Ready
  - A family of four occupancy will be simulated
    - Showers
    - Appliances
    - Heat Load Associated with People (Sensible and Latent)

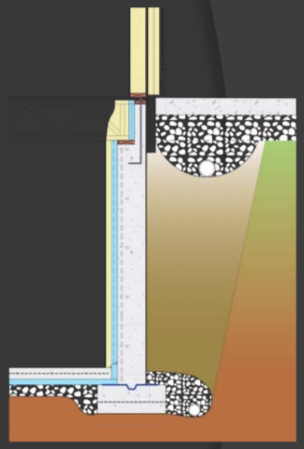
NZERTF

Gaithersburg, MD

- Enclosure Design
  - Roof Insulation R-72 (Typical R-38)
  - Walls R- 45 (Typical R-13)
  - Windows R-5.3 (Typical R-2.9)
  - Rim Joist Area R-35 (Typical R-13)
  - Basement Walls R-23 (Typical R13)
  - Basement Slab R-10 (Typical R10 Two Foot In from Perimeter)



Roof Assembly



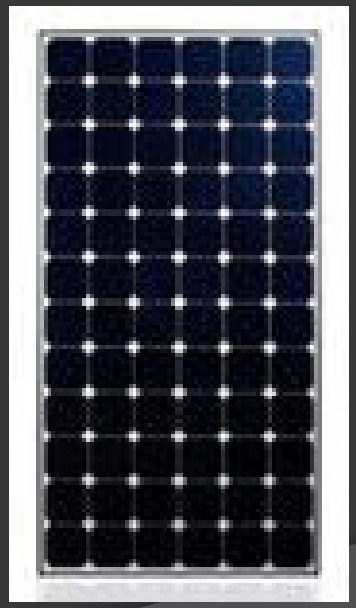
Basement Wall Cross Section

Typical values taken from 2009 International Energy Conservation Code Climate Zone 4

NZERTF

Gaithersburg, MD

- Solar Photovoltaic Array
  - Roof Mounted
    - South half of main roof
    - PV modules in same plane as roof
    - 4:12 pitch (18 degrees compared to 39 degree optimum)
  - High efficiency PV modules
    - 9.6 kW on roof
  - Balance of System
    - 3 DC-to-AC inverters
    - Grid Interconnected (No Batteries)



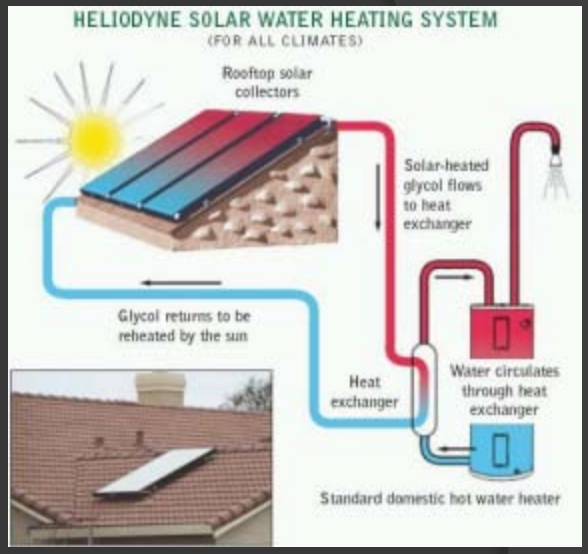
Module 18.5% efficient module using mono-Si Back-contact cells

Inverter Features: 93+% efficiency over most of loading range; Robust: 10-year warranty

Water Heating System

Solar thermal preheat

- 80-gal tank, electric auxiliary heating
- Active, indirect forced-circulation system for cool climates
- Four solar thermal flat-plate collectors (dimensions 6’ x 4’) installed on porch roof
- Capability to vary number of collectors included in circulation loop
- OG-300 certified and ENEGY STAR® qualified
- Control unit with Wi-Fi hub and stored energy data



Source: Solar Force Corporation

GE GeoSpring™ hybrid water heater w/ digital control panel

Heat pump water heater downstream

- 50-gal tank, electric auxiliary heating
- Multiple operating modes: heat pump, hybrid and standard electric
- ENEGY STAR® qualified
- Energy Factor (EF) of 2.35 and consumes 62% less energy than standard electric WH

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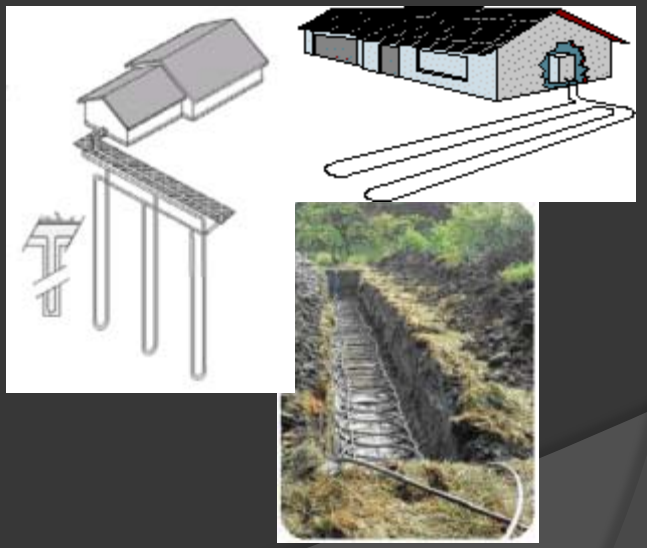
Gaithersburg, MD

- Heating, Cooling and Ventilation Systems
  - Facility is Configured to Accommodate Various Technologies
  - Advanced Air-to-Air Heat Pump Systems Suitable for Low Energy Homes
  - Geothermal Heat Pump Systems with Three Distinct Earth Coupled Fields
  - Combined Solar/Geothermal Heat Pump Systems
  - Multisplit heat pump with minimal duct system
  - Fully ducted Heat Recovery System
  - Multiple Zoning Capabilities
    - Floor
    - Perimeter
    - Individual Register



Three types of ground heat exchangers

Two indoor unit multi-split heat pump

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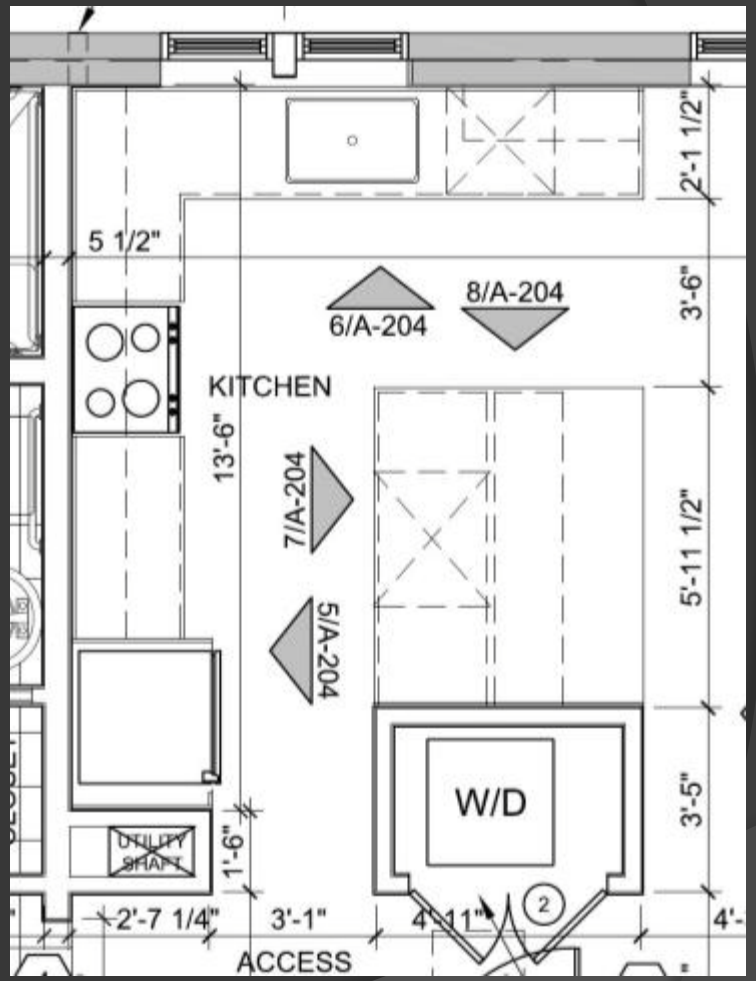
Gaithersburg, MD

- Appliances
  - Range/Oven
  - Clothes Washer/Dryer
  - Microwave Oven
  - Range Hood
  - Refrigerator
  - Dishwasher
- Selection Criteria
  - Energy efficiency
    - Energy Star, CEE Tier rating
    - Low standby power consumption
  - Smart-Grid compatibility



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- Ventilation and Indoor Air Quality
  - Ventilation specifications
    - Heat recovery ventilator compliant with ASHRAE Standard 62.2
    - High-efficiency, low sone whole house exhaust fan
    - Envelope airtightness, 1 h^{-1} at 50 Pa per ASTM E779
    - Maximum Allowable Emissions of Materials Specified

Heat Recovery Ventilator

Air tightness testing w/ blower door

Chamber testing of material emissions

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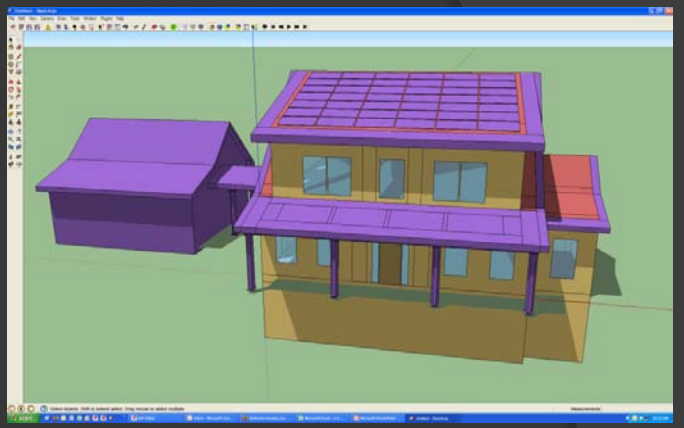
Gaithersburg, MD

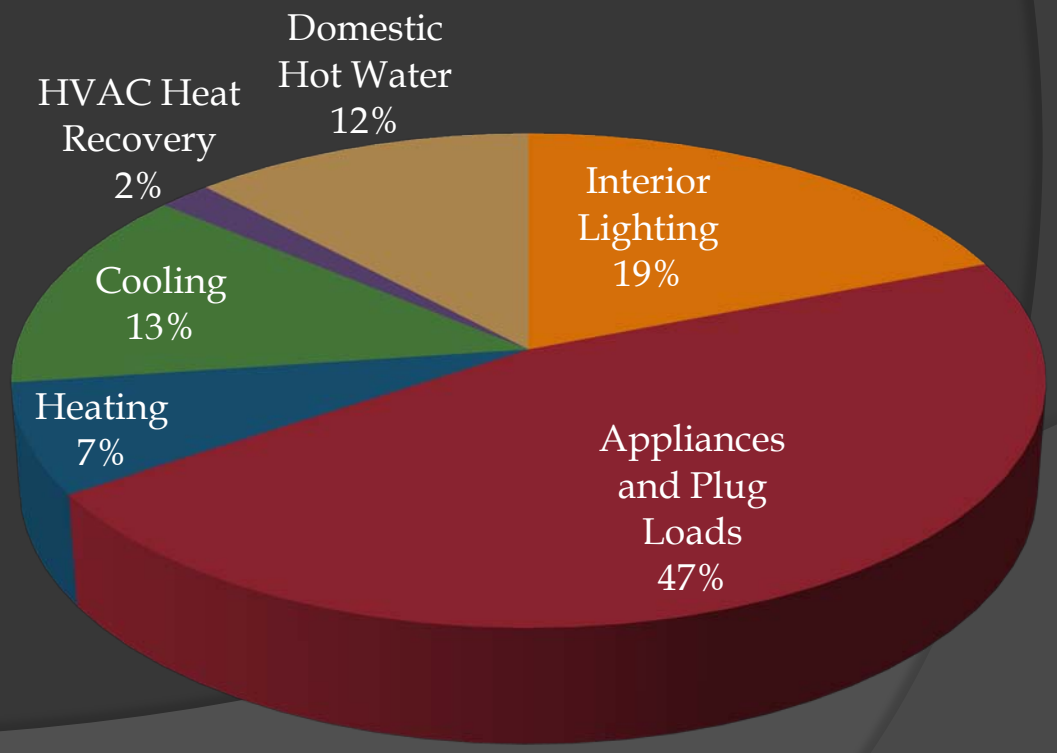
- Energy Simulation
  - Software
    - EnergyPlus 5.0
    - Google SketchUp with Open Studio Plug-In
  - Design
    - Exterior Envelope
      - Building Science Corporation's Architectural Documents
    - Equipment
      - Product Specifications
    - Load Profiles
      - "Building America Research Benchmark Definition" – Dec. 2009
    - Ventilation
      - Meets ASHRAE Standard 62.2 Requirements
  - Annual Simulation
    - Typical Meteorological Year (TMY3) weather file



NZERTF

Gaithersburg, MD

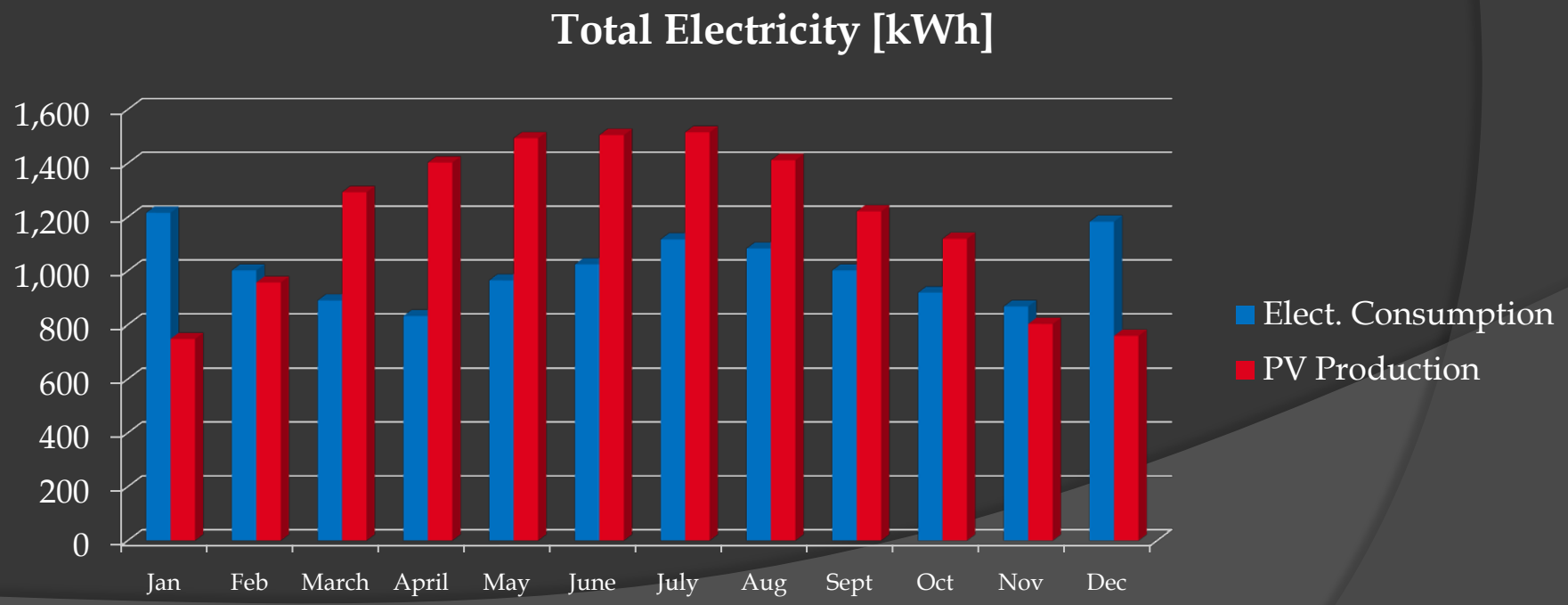
- Simulation Results – Electricity Consumption
  - As of October 29, 2010
  - Total – 12,106 kWh
  - HVAC and DHW – 34%
  - Lighting – 19%
  - Appliances/Plug Loads– 47%



NZERTF

Gaithersburg, MD

- Computer Simulation Results (October 29, 2010)
  - Solar PV Electricity Production
    - 14,234 kWh
    - **118%** of Total Electricity Consumption of Home



Thank You!

My Dad and I after installing solar hot water system at my parents home. Provided hot water for the next 26 years!

June 1978 – Suffolk, Va.

Questions?