Energy Simulation and Optimized Retrofit Practices Applied to a Real Dwelling

Giulia MARINELLO[1]*, Stephen L. CASKEY[1],

Eric J. BOWLER[2], Eckhard A. GROLL[1]

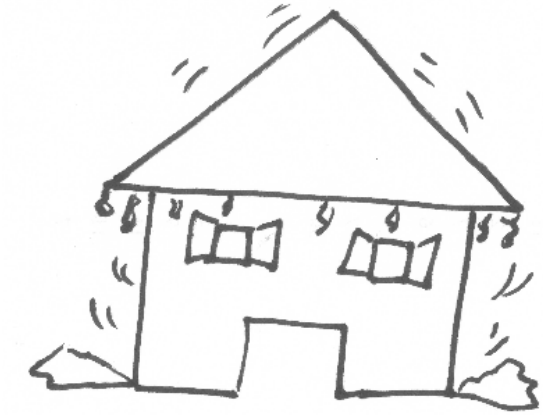
[1]Purdue University, School of Mechanical Engineering, Ray W. Herrick Laboratories

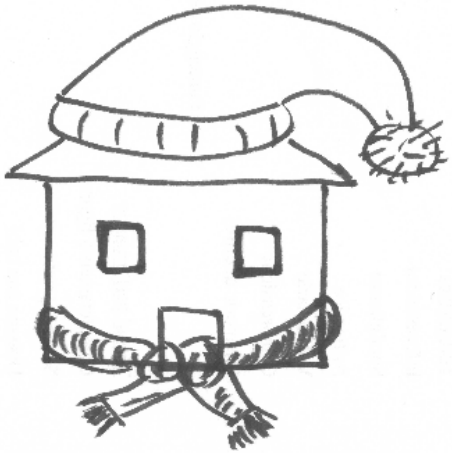
[2]Whirlpool Corporation, Saint Joseph, MI, USA

Importance of Retrofit Practices

- Residential Housing account for 22% of the total primary energy usage in US
- The average age of a single family home in the US is 34 years
- Around 130 million existing homes in US, new construction accounts for about 1 million per year.

Importance of Retrofit Practices

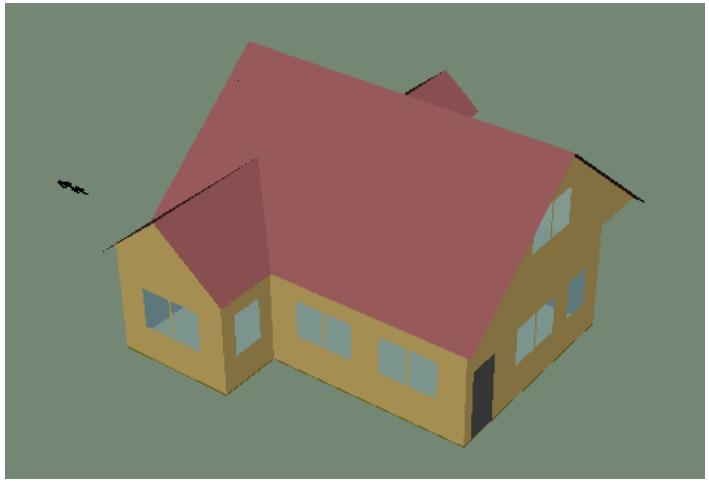




Test House

Test House

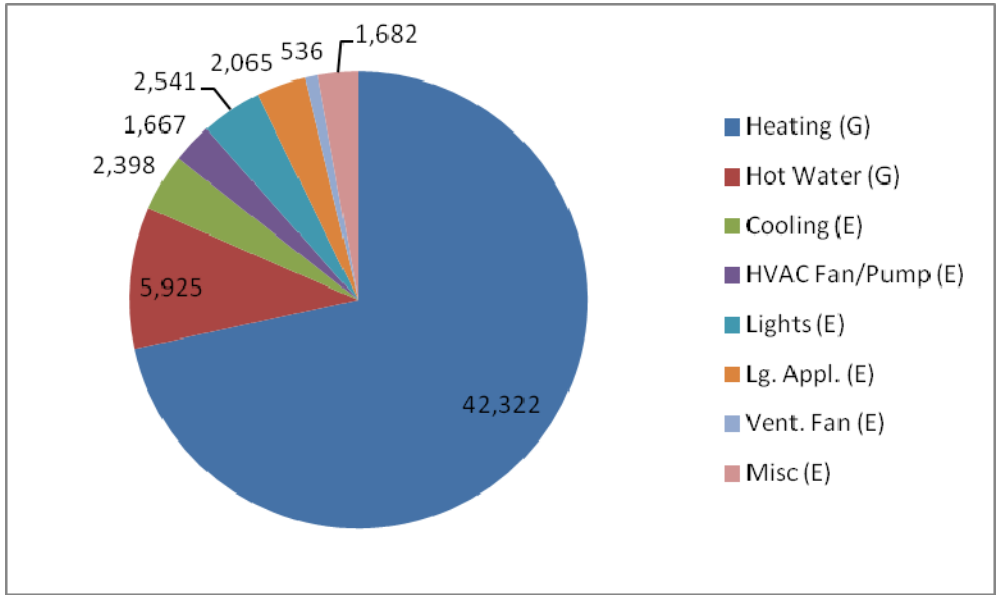
3D Model



Main Characteristics

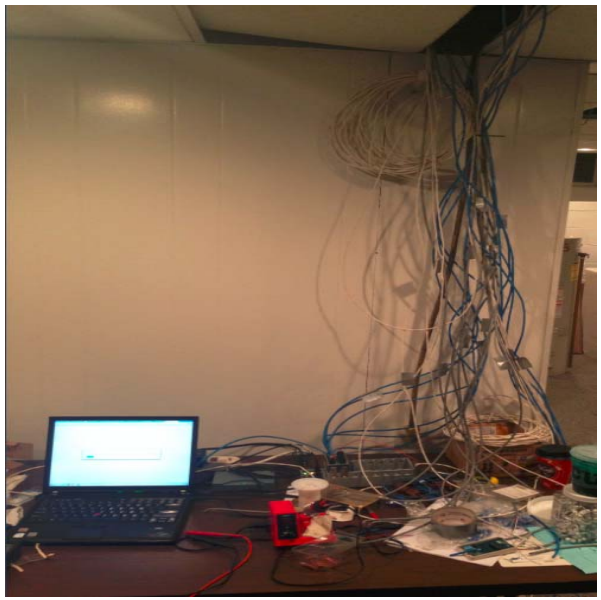
- Location: West Lafayette, Indiana, USA
- Square footage: 266 m^2
- Age: 86 years
- Envelope: Uninsulated
- Air Leakage: 10 ACH50
- Heating System: natural gas furnace

Baseline Energy Consumption



Instrumentation System

- Electricity consumption of each circuit
- Gas consumption (furnace and water boiler)
- Sub-metered Water Consumption
- Temperature and Relative Humidity in each room



Baseline Simulation and Real Data

- The DOE Building America Simulation Protocol is used in the software to reflect the average American family behavior
- The same schedule was replicated in the test house for a week and the data were recorded.

Load	Simulated (kWh)	Measured Data (kWh)	% difference
Heating	42,322	45,455	7.1%
HVAC fan	1667	1538	8.0%
Lights + miscellaneous	4223	4076	3.5%
Appliances	2065	1862	10.3%

Optimization Parameters

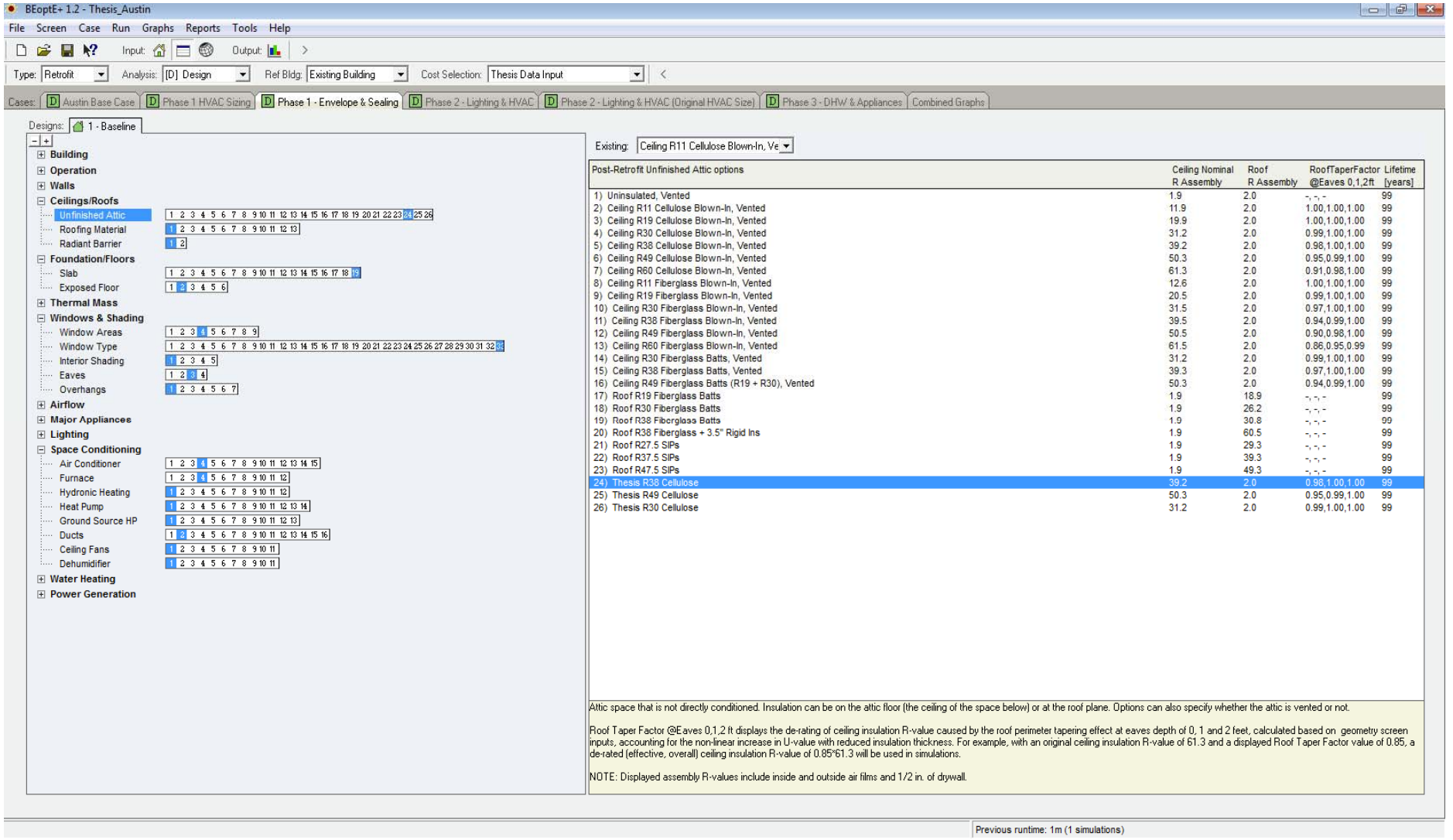
Building Shell

Appliances

Lighting

Costs from National Residential Efficiency Measures Database

Simulation Program Parameter Input



Optimization Results

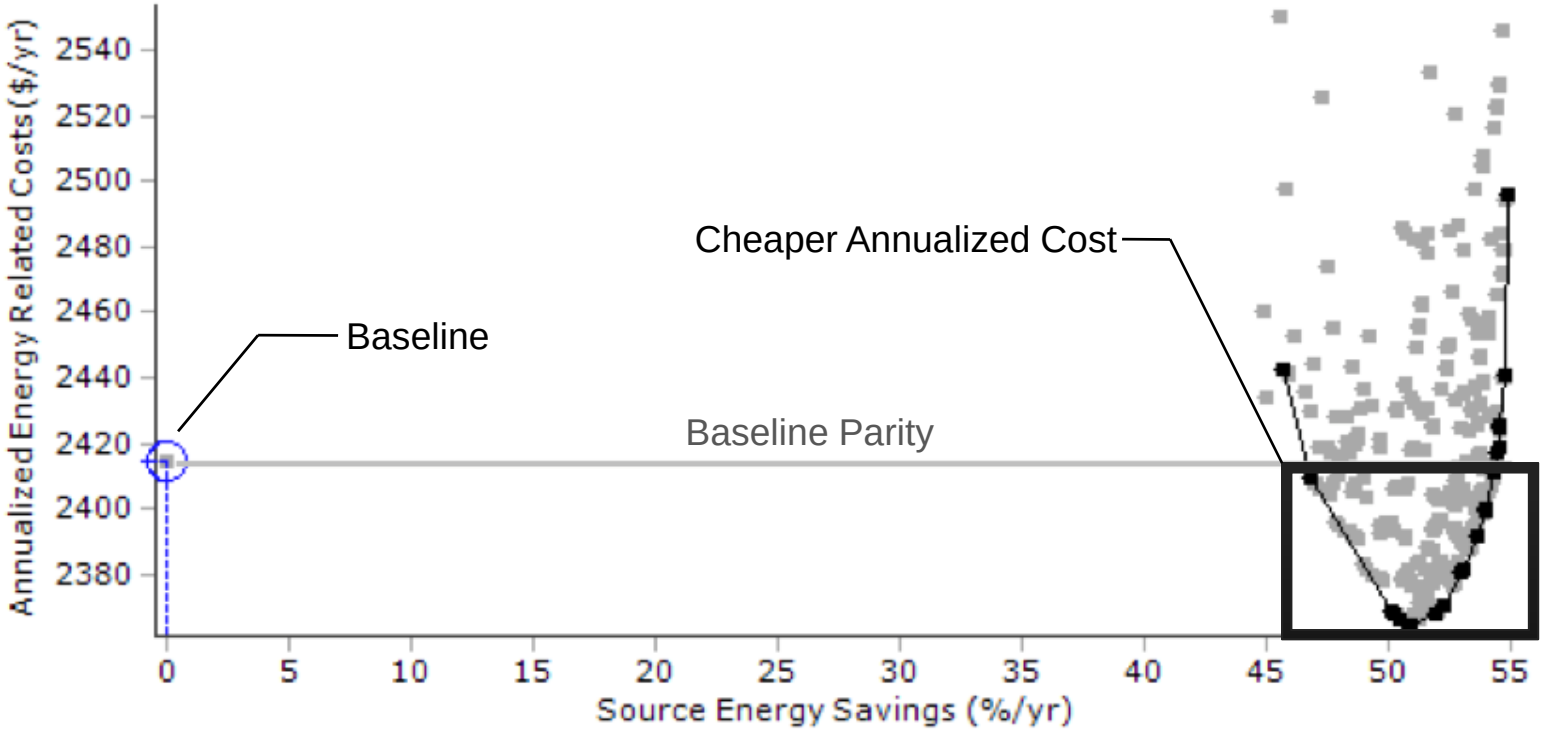


Figure 5: Cost/Energy Savings Optimization Curve

Equivalent annualized energy costs can be achieved using ~46 to 54% less source energy

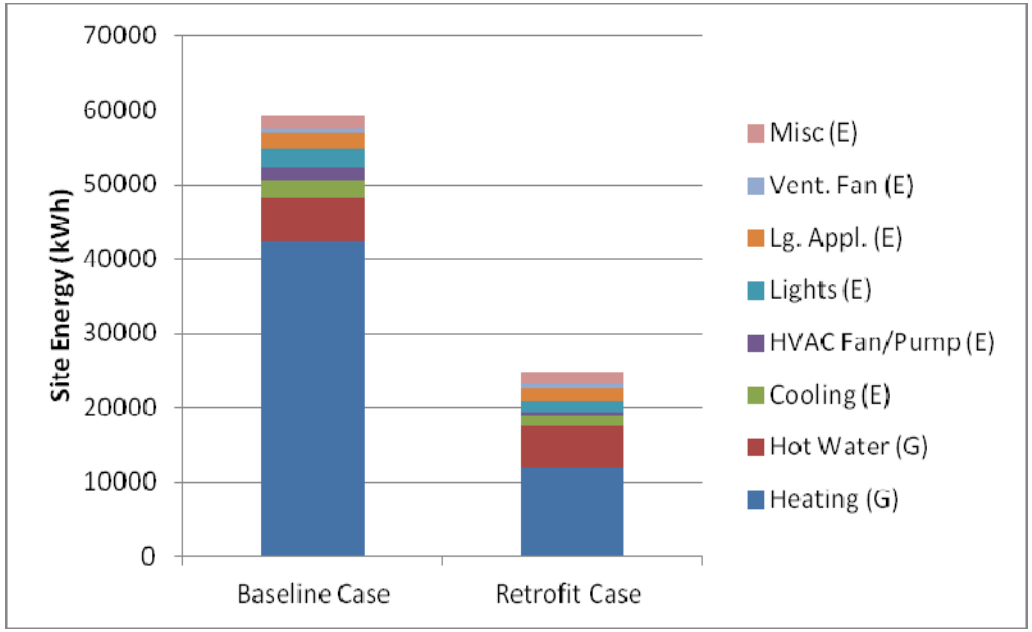
Optimum Solution

- Total Energy Consumption:

  59,136 kWh/year ⟹ 24,855 kWh/year

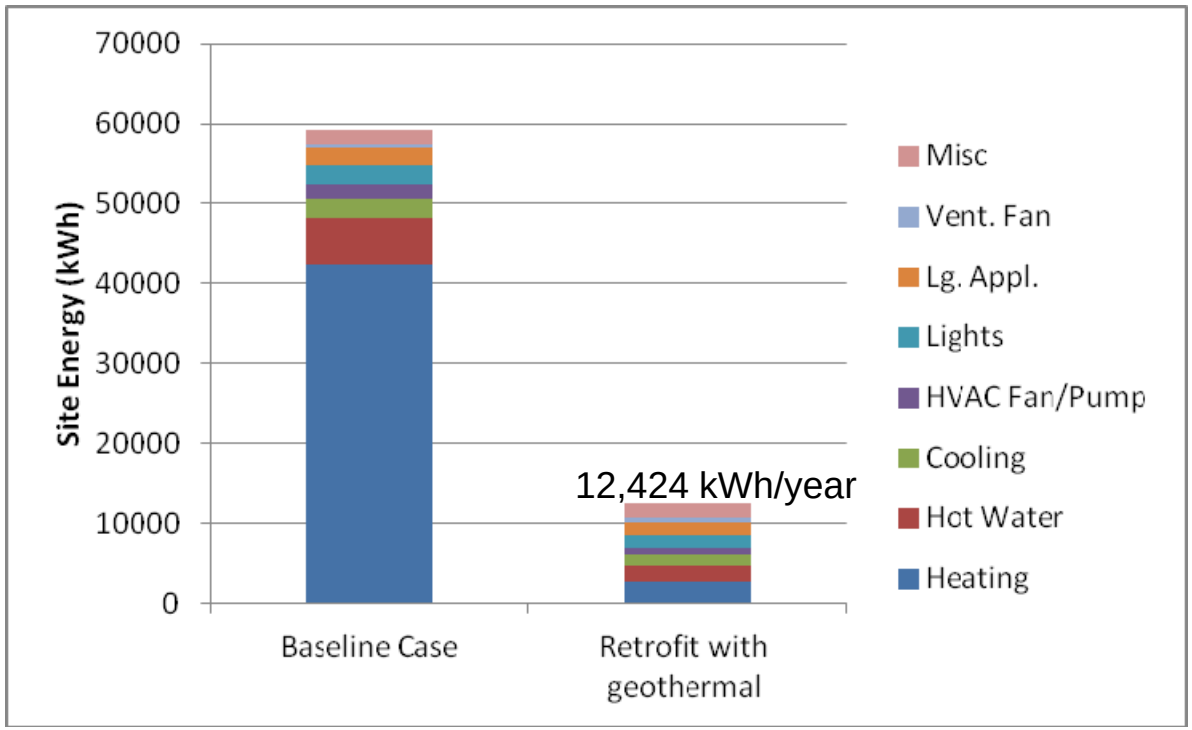
- Heating Demand:

  42,322 kWh/year ⟹ 11,966 kWh/year



Path to Net-Zero Energy

- HVAC system: geothermal heat pump;
- Water Heater: heat pump water heater;
- Electricity generation: Solar Photovoltaic



11.3 kWp photovoltaic system will produce 12,313 kWh/year

Work In Progress

Thank you!

Back-up Slide

Objective is to minimize Annualized Energy Related Costs while maximizing energy efficiency

Energy Related Costs are comprised of 4 separate cash flows

Utility Bills: Equivalent Yearly Electric & Natural Gas Costs (Home Operating Costs)

Loan Costs: Equivalent Yearly Principle & Interest Payments for Retrofit Work

Replacement Costs: Equivalent Yearly Cost to Replace Equipment at End of Life

Residual Value: Equivalent Yearly Receipt for the Salvage Value of all Equipment

Annualizing the energy related costs is a process of translating these four yearly costs to a single cost at the start of the analysis period, which is 30 years long.