Retrofitting Existing Residential Buildings with PV Systems to Achieve Net-Zero Energy in Humid, Sub-Tropical Climates

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Abstract

The conversion of existing residential buildings into Net-Zero Energy Buildings (NZEBs) promises to offset a substantial portion of total U.S. greenhouse gas emissions. Therefore, the purpose of this paper is to determine a retrofitting solution for existing residential buildings in subtropical, humid climates so they can achieve net-zero energy, which would contribute to the larger issue of retrofitting buildings in similar climates around the world. However, there are significant challenges to address regarding the amount of energy produced by green energy sources and the amount of energy consumed by existing residential buildings. After reviewing the current literature on NZEBs, the methodology involves analyzing empirical data related to residential buildings then utilizing Building Energy Optimization Tool (BEopt) software to simulate existing residential buildings' energy production, consumption, and efficiency with the goal of optimizing them to achieve a net-zero energy production/consumption balance. Once simulations are complete, a cost-effective retrofitted NZEB solution can be proposed, specifically for humid, sub-tropical climates.

PURPOSE

- Develop a cost-effective solution for retrofitting existing residential buildings with individual PV systems to achieve net-zero energy in humid, subtropical climates

INTRODUCTION

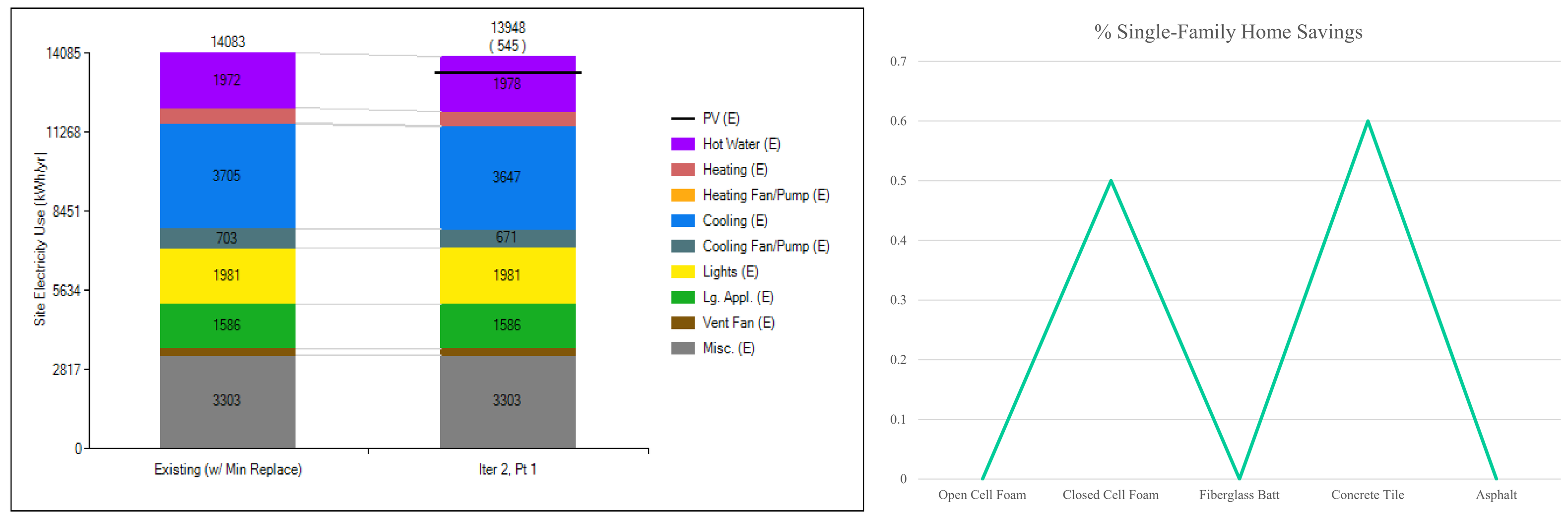
- **THE PROBLEM**
  - Residential buildings comprise about 21% of total U.S. energy consumption [1].
  - There are significant challenges to address before this can be reduced
    - Different building energy requirements
    - Energy "schedules"
    - Unique regional climates
    - Energy efficiency
    - And numerous other variables
- **THE NZEB DESIGN**
  - Maximizes energy efficiency and decentralize energy production [2].
  - The building envelope (i.e. insulation) is the most crucial aspect of NZEB design [2].
  - NZEBs offer two key benefits [3]:
    - reduction in net energy consumption and carbon emission
    - relying mainly on renewable energy sources (RES) [3]
    - A major advantage of the NZEB is that it can utilize any RES
- **PV SYSTEMS**
  - a PV system by itself can provide more than enough energy to meet an NZEB's energy requirements [4].
  - Most popular and commonly utilized RES for residential NZEBs
    - ready availability
    - low prices
    - unit cost being relatively independent of installation size

METHODS

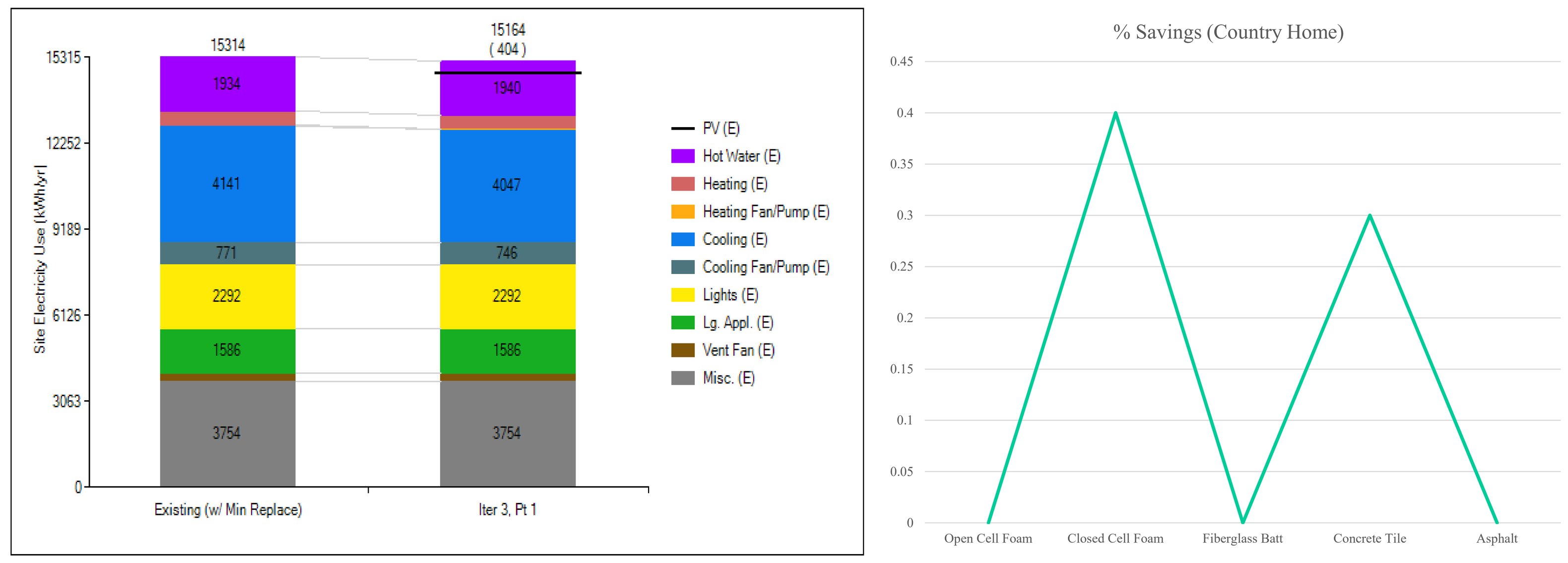
- **STUDY DESIGN**
  - Quantitative Experimental Design
- **Collected empirical data**
  - The energy efficiency and components of the pre-retrofit house are based on Texas standards:
    - 2014 Building America House Simulation Protocols
    - IECC Zone 2 (Southern)
- Two layouts used (a single-family home and country residence) are based on standard designs used in the U.S.
- **BEopt is used to "recreate" existing residential buildings**
  - Widely used and highly regarded in the industry
- PV panels are the RES system for the NZEB design in this study
- **INDEPENDENT VARIABLES**
  - **BUILDING ENVELOPE**
    - Wall Insulation
      - Given building frame, 2x4
      - Fiberglass (R13/R15) vs Cell Spray Foam (Closed vs Open)
    - Roof type
      - Asphalt (medium shade) vs Tile (medium shade)
  - **PV SYSTEM**
    - PV system vs no PV system
    - The goal is for energy consumption/production to fluctuate as little as possible
- **DEPENDENT VARIABLE**
  - Annual net energy consumption of the building (pre- and post-retrofit)

RESULTS

To access the full results, please scan the QR code.



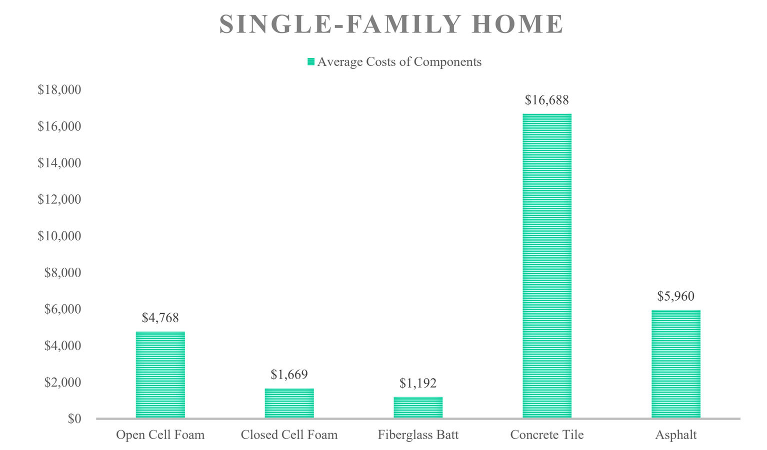
Single Family Home results

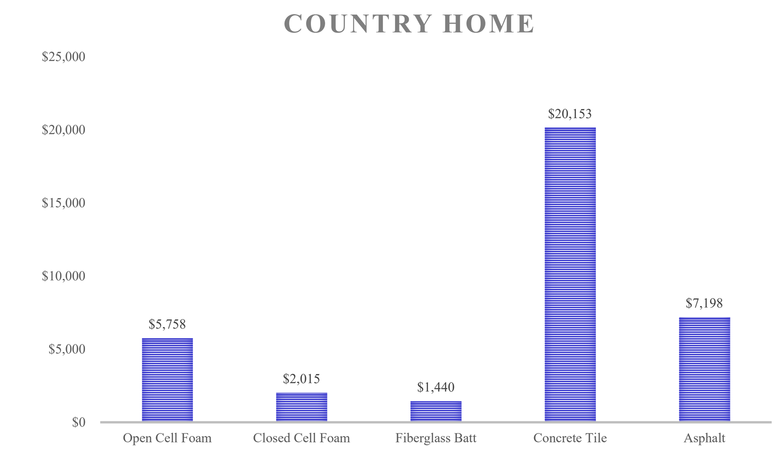


Country Home results

DISCUSSION

- **COSTS of Parts (Austin, Texas)**
  - Wall insulation
    - $2.00/sqft Open Cell Spray Foam Insulation
    - $0.70/sqft Closed Cell Spray Foam Insulation
    - $0.50/sqft Fiberglass Batt
  - Roof
    - $0.70/sqft Concrete Tile
    - $2.50/sqft Asphalt Shingle
  - PV system
    - $2.69 per watt (-30% federal tax credit)
- **RETROFIT STRATEGY**
  - Reference house annually:
    - ~14,083 kWh needed for the single-family home
    - ~15,314 kWh needed for the country home.
  - Optimal house annually:
    - 530 kWh for the single-family home using 10 kW PV system (3.8% of 13,948 kWh)
    - 409 kWh for the country home using 10.5 kW PV system (2.7% of 15,164 kWh)





CONCLUSIONS

- It is preferable for the NZEB retrofit to produce slightly less energy than what is needed for the residential building, within 1% or as close to 0% as possible
- Net-Zero is crucial to maintain to avoid a power grid failure through the constant fluctuation of power between the city power grid and NZEBs.
- Compared various wall insulation types and roof coverings and then conducted a cost-benefit analysis
- Results indicate the more costly components are the most energy efficient.
  - Closed Cell Spray foam and Tile roofing are ideal for energy savings
- The NZEB was able to stay near a near-net zero energy balance, without its PV system producing more energy as is consumed by the building.

REFERENCES

To access the full references, please scan the QR code.

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