Interdependence between Structural Engineering and Construction Management
Edited by Ozevin, D., Ataei, H., Modares, M., Gurgun, A., Yazdani, S., and Singh, A.

ISBN: 978-0-9960437-6-2

STUDY AND ANALYSIS OF INCENTIVES FOR STATE-OF-THE-ART NET-ZERO ENERGY HOUSES

DAVOUD SHABAN RAFSANJANI[1], DEEPAK SHARMA[2], TUNG TRAN[1], AND PHOUNG NGUYEN[1]

[1]*Dept of Civil and Environmental Engineering California State University Fullerton, Fullerton, USA*

Over the past several years, the US Energy Information Administration (EIA) has reported that buildings consume about 40% of the total energy produced. As a consequence, buildings emit high volumes of carbon dioxide (CO_2). The ever-increasing population demand implies that buildings will continue their consumption and emit gasses in high proportions if appropriate steps are not taken. Federal and state agencies offer various financial incentives to motivate homeowners to adopt energy efficient alternatives. In this research, major cash inflows and outflows are identified for Net Zero Energy Houses (NZEH) and breakeven analysis is conducted by considering that the houses are constructed in two US states having significantly different climatic conditions. The cash inflows considered in this research are from Federal and State incentive programs and savings generated by adopting NZEH. Sensitivity analysis is also conducted to determine the impact of variation in in government incentives, market interest rate, electricity rates and rate of construction. Results show that when some of the incentives are utilized the breakeven for a NZEH construction could be less than 4 years. Sensitivity analysis shows that the breakeven is most sensitive to changes in government incentives and market interest rate.

Keywords: Energy conservation, Cash-flow analysis, Sensitivity analysis.

1 INTRODUCTION

Building energy efficiency has substantial impact on environment and emissions. Statistics show that buildings consume about 40% of the total energy production in the US and the EU (EIA 2018, Cao *et al*. 2016). So, any improvement in home energy efficiency will have significant impact on the overall environment. Improvements can be made by using energy efficient alternatives easily available in the market. Through this paper an attempt is made to present some of the latest state of the art systems used to achieve net-zero consumption and incentives that can help reduce energy intake in buildings. In addition, cash flows for houses in two US states are estimated to determine breakeven year for NZEH. The initial cost of NZEH being higher than traditional construction demoralizes homeowner to adopt green alternatives but a reasonable breakeven period can reverse this and motivate homeowners to adopt green alternatives. This is important because lack of proper adoption of energy efficient technologies will make it difficult to achieve any environmental benefits.

International Energy Agency (IEA) reported a historic increase in carbon emissions due to slowing of energy efficiency improvements and increase in energy demand (Chestney 2018). The EIA reported an increase of 1.7% carbon dioxide emissions (EIA 2017). Carbon emissions can be reduced in several ways. For example, some researchers focused on controlling emissions by focusing on embodied carbon (Pomponi and Moncaster 2018) while some others suggested adopting green contracting methods (Cui *et al.* 2011). The authors here suggest changing the way building energy is consumed. However, change is not easy, and a barrier exists when it comes to switching to energy efficient alternatives in buildings. A report by National Institute of Standards and Technology (NIST) stressed the importance of end users' acceptance of green technologies. It discusses financial, behavioral, policy level, and several other barriers faced when pursuing green alternatives. For example, the report mentions "*Investment costs are too high to encourage a transformation in consumer decisions*" (McNabb 2013). Similarly, social and cultural aspects were identified as barriers towards environment friendly options (Pomponi and Moncaster 2016). Clearly, when end-users 'see' such constraints ahead, the chances of large-scale adoption to green policies will be low. Agencies put tremendous amount of resources to implement green policies, but the existing barriers hinder their adoption and success.

The overall aim of this research is to lower some of the barriers towards green initiatives. To achieve this, Federal and State financial incentives supporting homeowners to adopt NZEH systems are documented. Government incentives such as tax credits and property tax are included in this paper. The paper also includes details of some of the state-of-the-art energy efficient systems that have been used and proven at 2017 Solar Decathlon competition. The details from incentives and the energy efficient systems are then collectively used to develop cash-flow for houses built in the states of California (CA) and New York (NY). The analysis is further extended by including sensitivity analysis which enabled identifying the most impactful parameters on breakeven. This research will help end users to understand that the NZEHs are not as expensive as they are perceived. As a result, agencies will be able to achieve higher end-user acceptance leading to achieving the desired green goals.

2 PREVIOUS STUDIES AND RESEARCH MOTIVATION

Energy efficient housing has several benefits. However, multiple barriers exist in making energy efficient housing a norm. Researchers have pointed out that one of the main barriers felt by home owners is cost. Li *et al.* (2018) surveyed 69 energy efficient housing stakeholders in Canada and found that half of the respondents were not ready to spend more than 5% additional money for NZEH. Similarly, Hast *et al.* (2015) found that cost was one of the main barriers that prevented end-users in China to adopt NZEH. However, Risholt *et al.* (2013), and Seto *et al.* 2016 found that the adoption barriers can be reduced by education and creating awareness.

Agencies are taking definite steps by promoting energy efficient houses and are gradually advancing towards making them a norm (Seto *et al.* 2016). For example, California Energy Commission conducts webinar to educate people about the various energy efficient options (Timothy 2017). Synchronously, researchers have advocated educating and bringing awareness about energy efficiency to overcome barriers for largescale adoption to green alternatives (Risholt *et al.* 2013). To support such a cause, the US DOE conducts Solar Decathlon competition every two years to promote and investigate affordable NZEH. In conjunction with all such awareness initiatives this research builds upon all the earlier works and attempts to bridge the gap between the technological advancements, incentives and financial analysis that can be used for promoting NZEH.

3 METHODOLOGY

In this research, the first task was to identify and study the designs of winning teams from Solar Decathlon 2017 competition. The designs used latest technologies and the teams made them work in a single-family home. Some of the innovative technologies are discussed in this paper. As a second task, the team identified information about incentives available from government agencies. Assuming that the energy efficient houses are constructed in CA and NY, applicable government incentives were identified for solar systems. Average utility bills for traditional houses were determined and potential energy savings were calculated. Cash flow statements were developed for all cash flow which became the basis of comparison between NZEH and traditional houses. The cash flow statement enabled conducting breakeven analysis. This was followed by sensitivity analysis that enabled determining influential parameters.

3.1 Studying NZEH Houses

Solar Decathlon 2017's competition documents of top three teams were studied. These teams were Swiss Team, Maryland and the UC Berkeley/ University of Denver team (UCB/UD). All these teams scored more than 800/1000. The teams were evaluated for excellence in architecture, market potential, engineering, communications, innovation, water usage, health & comfort, appliances, home life and energy. While all these teams presented great ideas, some of the main ones from UCB/UD are briefly described here.

The team used specialized glass having R value of 10 and paired them with frames of R value of 16. These items enabled having good lighting and insulation. The team chose to use water recycling system that treated grey water for reusing in toilet. Self-cleaning filters in the recycling system saved significant quantities of water. The team used an efficient, sustainable, and non-toxic wool that had a minimum R-value of 3.6 per inch. For lighting, the team used scrap optical fibers to let light enter from walls and thus increase the overall brightness in the house. The team chose to use moss matt panels to cover the entire north façade. This helped in generating a natural living surface contributing to the overall vegetation of the house. The team also used solar panels to transform sunlight to usable electrical energy. For a house that uses the above innovative methods can qualify for several government incentives, but for this research only solar panel incentives are included.

3.2 Identifying Federal and State Incentives

At the Federal level, a homeowner qualifies for a Federal subsidy in the form of tax credits. The tax credit for solar energy system covers 30% of the cost (including installation costs). Similarly, in the state of CA, property-tax incentive for solar photovoltaics and solar thermal covers 100% of proportionate system value. In NY, property tax credit for qualified solar energy system enables a credit of 25%. These incentives could help offset some of the expenses incurred from energy consumption in the states of CA and NY. For this research, single family houses with an area of 1048 sqft were assumed to be constructed in Westminster (CA) and New York City (NY).

Table 1. Federal and state incentives (source dsireusa.org).

Description of Incentive	**Westminster (CA)**	**New York City (NY)**
Federal Tax Credit	$5,357	$5,357
100% Proportionate Solar System for Property Taxes	$145	-
25% Proportionate Solar System for Property Taxes	-	$70
Total	**$5,502.28**	**$5,427.54**

3.3 Cost Comparison for Constructing and Consuming Energy

As per Zillow.com, for a single-family house in Westminster and NYC, the average cost of constructing a traditional house is $406/sqft and $630/sqft which translates to a total cost of $425,488 (i.e. 1048×406) and $659,999 (i.e. 1048×630) respectively. As expected, for NZEH the average cost/sqft is higher. With reference to UCB/UD team's construction the NZEH costs are estimated as $434/sqft and $646/sqft which totals to $455,230 (i.e. 1048×434) and $677,018 (i.e. 1048×646) respective. The differences in cost for pursuing NZEH in Westminster and NYC are $29,742 (i.e. $455,230-$425,488) and $17,020 (i.e. $677,018-$659,999) respectively. These differences are the financial barriers that can deter a decision maker to pursue NZEH but these must be supplemented with government's incentives to determine the actual financial burden.

3.4 Developing Cash Flow

Cash flow statements were developed to differentiate between the NZEH and traditional alternatives. Cash flow statements are developed by considering cash outflow and inflows. Annual electricity bills can have significant impact on the cash flow and so average annual electricity bills were determined. For Westminster, the average annual utility bills were $2,763 and for NYC it was $2,521 with an average increase of 20% every three years. A 3% interest rate was assumed for discount throughout the analysis. Putting together all the cash outflows and inflows following Table 2 was obtained.

Table 2. Cash outflow and inflow for breakeven analysis.

	Westminster, CA				**New York City, NY**			
Yr	**Utility Saving**	**Gov. Incentives**	**Total Savings**	**Total Difference**	**Utility Savings**	**Gov. Incentives**	**Total Savings**	**Total Difference**
0	2763	5502	8265	-29742	2521	5428	7948	-17020
1	2682	5342	8024	-21718	2447	5269	7717	-9303
2	2604	5186	7791	-13927	2376	5116	7492	-1811
3	3034	5035	8069	-5858	2768	4967	7735	5924
4	2946	4889	7834	1977	2688	4822	7510	13434
Note: All values are discounted to present time at 3%								

In Table 2, column "Utility Savings" represents discounted yearly electricity bill savings; "Gov. Incentives" represent all the solar incentives; and "Total Savings" is obtained by summing electricity bill saving and government incentives. The column "Total Difference" represents the cumulative difference between traditional and NZEH construction. The difference is seen reducing every in the table and the signs changes from negative to positive indicating breakeven. Sensitivity analysis was also conducted to determine the effectiveness of government benefits, interest rate, change in electricity rates and rate of construction in cost/sqft.

4 RESULTS

Results indicate that a CA homeowner can offset the cost of NZEH in three years and for the same construction in NY the offset occurs in four years as shown in Figure 1. Thus, after three years in CA and four years in NY the NZEH is equivalent to a traditional home in terms of cost.

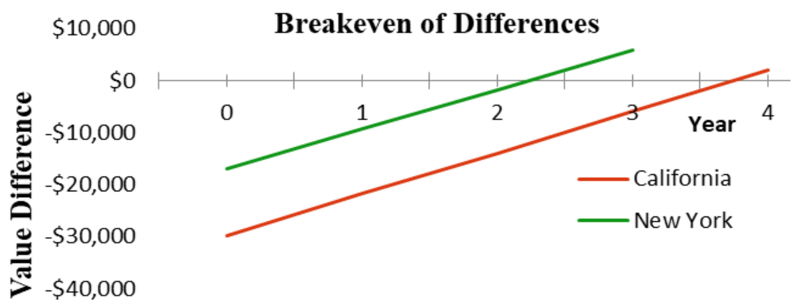

Figure 1. Breakeven analysis

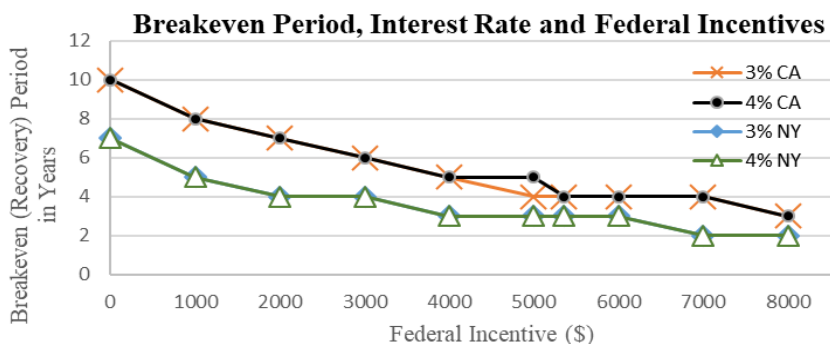

Figure 2. Sensitivity analysis results.

Sensitivity analysis showed that the breakeven period is sensitive to change in interest rate and the Federal incentives (Figure 2). It can be concluded that if Federal incentive is $5,000 the breakeven occurs within three years in NY even if the market interest rate increases from 3% to 4%. However, in CA the breakeven occurs in years when the market interest rate is 3% but it increases to five years if interest rate increases to 4%. Lastly, the breakeven period was found to be relatively insensitivity to changes in electricity rates and rate of construction in $/sqft.

5 CONCLUSION

This research was aimed at determining the impact of government incentives on adoption of NZEH. State-of-the-art systems used by top three teams at Solar Decathlon 2017 were studied and some of them were briefly described in this paper. Federal and State level solar system incentives were identified and used in this study. All the cash inflows and outflows were calculated and used to conduct breakeven analysis. The analysis showed that the difference between NZEH and traditional houses can be offset in three years in NY and four years in CA.

This study establishes relation between the additional cost incurred for NZEH housing and the time it takes to get even with traditional housing. The results indicate that while the NZEH construction appears expensive, the government incentives and utility bill savings enable to get even in less than four years in states like CA and NY that are the most expensive states in the US. Sensitivity analysis shows that breakeven periods are the most responsive to government incentives and market interest rate. This research can be further expanded to include other US states and other available incentives for sustainability.

References

Cao, X., Dai, X., and Liu, J., Building Energy-Consumption Status Worldwide and the State-of-the-Art Technologies for Zero-Energy Buildings During the Past Decade, *Journal of Energy and Buildings*, 128, 198–213, 2016.

Chestney, N., Global Carbon Emissions Hit Record High in 2017, Environment, Reuters, Published on 3/22/2018, 2018.

Cui, Q., Zhu, X., Whitten, L., and Deane, R., *Innovative Contracting Strategies for Combating Climate Change*, Report Number MD-11-SP009B4G, University of Maryland, 2011.

EIA, U.S. Energy-Related Carbon Dioxide Emissions, 2016, Report by U.S. Department of Energy, Washington DC, 2017.

EIA, How Much Energy is Consumed in US Residential and Commercial Building?, US Energy Information Administration. Retrieved from https://www.eia.gov/tools/faqs/faq.php?id=86&t=1 on Jan 08, 2018.

Hast, A., Alimohammadisagvand, B., Syri, S., Consumer Attitudes Towards Renewable Energy in China—The Case of Shanghai, *Sustainable Cities and Society*, 17, 69–79, 2015.

Li, H. X., Patel, D., Al-Hussein, M., Yu, H., and Gül, M., Stakeholder Studies and the Social Networks of NetZero Energy Homes (NZEHs), *Sustainable Cities and Society*, 38, 9–17, 2018.

McNabb, N., *Strategies to Achieve Net-Zero Energy Homes: A Framework for Future Guidelines*, Workshop Summary Report, NIST Special Publication 1140, 2013.

Pomponi, F., and Moncaster, A., Embodied Carbon Mitigation and Reduction in the Built Environment – What Does the Evidence Say? *Journal of Environmental. Management*, 181, 687–700, 2016.

Pomponi, F., and Moncaster, A., Scrutinising Embodied Carbon in Buildings: The Next Performance Gap Made Manifest, *Renewable and Sustainable Energy Reviews*, 81, 2431–2442, 2018.

Risholt, B., Time, B., and Hestnes, A. G., Sustainability Assessment of Nearly Zero Energy Renovation of Dwellings Based on Energy, Economy and Home Quality Indicators, *Journal of Energy and Buildings*, 60, 217–224, 2013.

Seto, B., Leahy, J., Herrschaft, B., Butterworth B., and Punjabi S., *Zero Net Energy Communities: Three Cities Leading the Way*, ACEEE Summer Study on Energy Efficiency in Buildings, 2016.

Timothy, N., *Upcoming Title 20 Lighting Standards Coming into Effect*, Appliances and Outreach and Education Office, California Energy Commission, 2017.