ANALYZING TAX CREDITS FOR RESIDENTIAL ENERGY EFFICIENCY USING ENERGY MODELING

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ABSTRACT

From roughly 2013 to 2016, ten building product categories related to residential energy efficiency were eligible for United States ENERGY STAR Federal Tax Credits. In general, the objective of residential energy-efficiency tax credits is to encourage individuals to increase residential energy-efficiency investments and invest in properties that generate renewable energy. This research analyses eight of the available tax credit categories for four climatic zones and recommends packages based on low Life Cycle Cost and low First Cost for the eligible ENERGY STAR products. An experiment was conducted using energy modeling software for different tax credits and costs combinations, to explore potential variability in economic impact of the federal program. Analysis used Building America B10 Benchmark as a reference, and the energy computations were completed using Building Energy Optimization (BEopt) software. Results suggest that ENERGY STAR product packages that include PV systems generally have the lowest (best) Life Cycle Costs and packages that include Geothermal Heat Pumps generally have the highest (worst) Life Cycle Costs. However, there are tradeoffs between cost savings and energy source savings, and the particular economics of tax incentives for ENERGY STAR products depend on project specifics as well as owner priorities.

KEYWORDS

ENERGY STAR products, energy performance, lifecycle costs

INTRODUCTION

ENERGY STAR denotes a standard for energy efficient consumer products in the United States. The goal of the ENERGY STAR program is to provide financial incentives to support technologies that pay back through lower energy bills within a reasonable amount of time. Research suggests that tax credits are essential to encourage people to invest in energy efficient technologies (Crandall-Hollick and Sherlock, 2014). In addition to personal federal tax credits, other types of incentives include corporate or state tax credits, exemptions and deductions, cash incentives such as grants and rebates from utilities or other organizations, sales or property tax incentives, and financing incentives such as favorable loan terms (Young and Sarzynski, 2009).

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In 2013, taxpayers were eligible to claim two separate tax credits for residential energy efficiency on their federal income tax. The first non-business energy property tax credit (Internal Revenue Code [IRC] §25C) could be claimed by the homeowners for the energy efficiency improvements like Heating Ventilation and Air Conditioning (HVAC), Insulation, Roofs, Water Heaters, and Windows. To qualify for this non-business energy property tax credit, improvements must be installed in the primary residence. The second residential energy efficient property credit (IRC §25D) provided a 30% tax credit for investments in properties that generate renewable energy, such as solar energy systems, geothermal heat pumps, small wind turbines, and fuel cells. Renewable investments on both principal and second homes qualify, with the exception that fuel cells qualify only if installed on principal residences. It is important to note that IRC §25C and parts of IRC §25D expired at the end of 2016, with the exception that IRC §25D for solar energy properties is scheduled to expire at the end of 2021. The temporary nature of such credits make their study even more important. Table 1 summarizes product eligibility requirements for the residential energy-efficiency tax credits available from 2013 to 2016 with some extending. It should be noted that fuel cells and wind turbines were outside the scope of this research work due to energy modeling limitations.

A difference between many eligible products and ENERGY STAR windows in particular is the potential for design, namely orientation, self-shading of the building, and placement, to impact performance (Jalili et al., 2015). Whereas many products (e.g., biomass stoves, insulation, roofing, etc.) provide relatively consistent performance irrespective of the building orientation, research has shown that windows' impact on building performance can vary significantly depending on placement. Gasparella et al. (2011) utilized TRNSYS to investigate the impacts of double and triple glazed systems, window sizes, and orientation of the main windowed façade on energy usage and peak demand for well-insulated residential buildings across four climate types in south and central Europe in both winter and summer. The study suggests that placing the windows on south orientation improves the energy performance of the building, especially during winter, and recommended the use of shading systems to improve the summer performance without sacrificing winter performance (Gasparella et al., 2011). Other research estimates that Life Cycle Cost performance of ENERGY STAR windows could vary by as much as 15 percent depending on orientation of the windows installed (Jalili et al., 2015).

For this research, the U.S. Department of Energy's BEopt™ (Building Energy Optimization) software is used for analysis. BEopt is an optimization tool for determining cost effectiveness and energy efficient building designs for new construction. In particular, for residential construction, BEopt evaluates the incremental energy and cost effects of designs relative to a geometrically similar reference building (e.g., a building that complies with Building America and International Energy Conservation Code (IECC)). Analysis provides a "least-cost" curve that allows users to determine minimum-cost building designs at various levels of energy savings and under various sets of economic assumptions (Polly et al., 2011).

BEopt is an energy modeling tool developed and currently supported by the National Renewable Energy Laboratory (NREL) (Christensen, 2006). It is widely used for residential whole building analysis. A few studies have revealed certain limitations, including the fact that BEopt estimates for annual energy usage can vary from actual by roughly 30% for individual homes. Furthermore, models using typical versus actual annual meteorological data, as well as residences with relatively low energy usage have more variation between predicted and actual (Rhodes et al., 2015). Nevertheless, significant precedent exists for using BEopt to estimate residential energy performance. Additional, previous research has indicated that individuals are willing to pay more for ENERGY STAR products, and that the willingness-to-pay is motivated by both private (energy cost savings) and public (environmental) benefits (Ward et al, 2011). Additional studies have confirmed that ENERGY STAR labeled products successfully contribute to reducing carbon emissions through its voluntary labeling efforts (Sanchez et al, 2008). Limited research, however, exists regarding the specific economic impact of various ENERGY STAR products and associated tax incentives.

Research Objective

The objective of this research is to explore, quantify and provide data and recommendations on investments in ENERGY STAR products with the goal to maximize long-term energy savings. To address budget constraints, the performance of ENERGY STAR product packages with lowest Initial Costs were analyzed. In addition, researchers ranked individual tax credit options based on initial and lifecycle costs of ENERGY STAR products.

METHODOLOGY

The reference building for this research is a two story single-family model home of total floor size 225.75 m2 (2430 SF) with four bedrooms, three baths and an attached garage. Geometric characteristics align with the characteristics of new single-family housing completed in United States in 2014 (U.S. Department of Commerce, 2014). Baseline building characteristics follow the 2009 International Energy Conservation Code. The model has 2-ft eaves and a slab foundation. The window area is 15% of wall area and is equally distributed on the four facades. Occupancy and operational assumptions are based on the Building America Research Benchmark, and the building is orientated with the front door façade facing north (Hendron 2005). BEopt 2.3.0.2 building energy optimization software was used to model performance using an analysis period of 30 years. The model was simulated using weather files from four cities, representative of the four ENERGY STAR climate zones: Denver, CO (Northern Zone); Albuquerque, NM (North-Central Zone); Atlanta, GA (South-Central Zone) and Miami, FL (Southern Zone) (Gary, G., & Dubay, K. n.d.). To perform an economic analysis of implementing ENERGY STAR products in the aforementioned four climate zones, the authors performed the following steps. Table 1 summarizes the economic inputs assumed. The authors developed this innovative method to support the research and do not claim prior validation.

TABLE 1. Economic Assumptions

Characteristic	Assumption
Project Analysis Period	30 years
Inflation rate	2.4%
Real Discount rate	3%
Material cost multiplier	1.00
Labor cost multiplier	1.00

The steps for performing the analysis of implementing ENERGY STAR products in the aforementioned four climate zones are summarized below. The authors developed this innovative method to support the research and do not claim prior validation:

Step 1: The goal of this step is to analyze initial costs and life cycle costs of eight ENERGY STAR products relative to baseline in four representative climate zones. The outcome is two lists ranking the products according to lowest initial cost and life-cycle cost in the four representative climate zones. Table 1 summarizes individual energy model inputs used for eight ENERGY STAR compliant products in four representative climate zones. The baseline inputs represent the characteristics assumed for the reference building across all regions prior to any upgrades using ENERGY STAR products. Table 2 summarizes model economic inputs. Finally, utility costs were assumed to escalate at the rate of inflation (2.4%).

Step 2: This step is performed to use initial cost and life-cycle cost rankings for each of the eight ENERGY STAR products to create lists of the seven lowest net initial cost packages and the seven lowest aggregate net life-cycle cost packages when using various combinations of ENERGY STAR products in four representative climate zones (see Table 3). The reason for generating these two lists of ranked packages is to address consumer goals of 1) minimum cost and/or 2) maximum performance. Net Initial Cost is the Initial Cost minus the Tax Incentive provided by ENERGY STAR. BEopt was used to calculate Initial Costs where costs are based on national average cost data from sources such as R.S. Means or California's Database for Energy Efficient Resources or quotes from manufacturers' distributors. Life Cycle Cost is calculated using BEopt analysis and refers to the total cost of ownership over the life of a technology including Initial Cost, Service Cost, Preventive Maintenance Cost, Operating Cost, and Disposal Cost. Net Life Cycle Cost is the Life Cycle Cost calculated by BEopt including the Tax Incentive provided by ENERGY STAR Aggregate net life-cycle cost for packages were assessed through summations of the lowest life cycle costs for individual products. Table 4 summarizes the economic incentives provided by ENERGY STAR according to tax codes IRC 25C and IRC 25D as associated with individual upgrades

Step 3: This step is used to analyze the Net Life Cycle Cost of the seven lowest net initial cost packages and the seven lowest net life cycle cost packages by representative climate regions. The seven lowest net initial cost packages were identical across representative climate regions. However, each representative climate region ranked packages differently according to lowest net life cycle cost packages. Therefore, the lowest net life cycle cost packages in aggregate were different in each representative climate region, and were, therefore analyzed separately during this step.

TABLE 2. Model Inputs for ENERGY STAR products

	Baseline	Representative Climate Region			
		North-Central Zone	South-Central Zone	Northern Zone	Southern Zone
HVAC	Central Air Conditioner—SEER13 Furnace-Gas, 78% AFUE	Central Air Conditioner—SEER 21 Furnace—Gas, 98% AFUE			
Insulation	Walls—R-13 Fiberglass, 2x4, 16 in o.c. Unfinished Attic—Ceiling R-38 Fiberglass, Vented	Walls—R-23 Closed Cell Spray Foam, 2x4, 16 in o.c Unfinished Attic—Ceiling R-60 Cellulose, Vented			
Roofs	Asphalt Shingles, Medium	Metal Medium			
Water Heaters	Gas Benchmark, Energy factor = 0.58	Gas Tankless, Condensing Energy factor = 0.96			
Windows	U-Value – 0.37 SHGC – 0.3	U-Value – 0.29 SHGC – 0.38	U-Value – 0.29 SHGC – 0.26	U-Value – 0.32 SHGC – 0.56	NA (same window type as benchmark)
Geothermal Heat Pumps	NA	EER 20.2, COP 4.2, Low-k soil, Std grout			
PV Systems	NA	5 KW			
Solar Water Heaters	NA	64 sqft Closed Loop—Southeast			

TABLE 3. Tax Incentive assumed for ENERGY STAR Upgrades

ENERGY STAR Product	Financial Tax Incentive
HVAC	$450
Insulation	$500
Roofs	10% or Up to $500
Water Heaters	$300
Windows	$200
Geothermal Heat Pumps	$4,277
Photovoltaic Systems	$8,024
Solar Water Heaters	$2,266

RESULTS

Step 1, Table 4 shows the results of Net Initial Costs for upgrades to the reference building using individual ENERGY STAR products. The eight individual ENERGY STAR products had identical rankings in terms of Net Initial Costs, with the exception of windows in the Southern Zone where the reference building requires windows with performance characteristics that qualify for ENERGY STAR. Table 5 shows the results of Net Life Cycle Costs for upgrades to the reference building using individual ENERGY STAR products.

The eight analyzed ENERGY STAR products had independent rankings in terms of Net Life Cycle Costs across climate regions. Note in each representative climate region there were products that, individually, did not result in lower Net Life Cycle Cost, meaning the performance improvement resulting from the upgrade of the individual product was not sufficient to pay back the initial cost. Nevertheless, these products were included in the alternative packages generated using aggregate net life cycle cost estimates since interactive effects accounted for in whole building analysis could still result in beneficial overall change in Net Life Cycle Cost.

Step 2, Table 6 shows the generated ENERGY STAR product packages ranked according to net initial cost. While the ordinal rank does not vary across climate regions, the estimations for net initial cost change due to differing ENERGY STAR requirements as well as regional pricing. Table 7 shows the generated ENERGY STAR product packages ranked according to estimated net life cycle cost packages. These rankings are merely intended to identify which combinations of ENERGY STAR products will be analyzed as packages in the next step of research, and subsequently can be seen not necessarily as, nor intended to be predictive of whole building life cycle cost performance.

TABLE 4. Net Initial Costs and Ranking of ENERGY STAR Products by Climate

	North-Central Zone		South-Central Zone		Northern Zone		Southern Zone	
ENERGY STAR Product Upgrade	Net Initial Cost	Initial Cost Ranking (Lowest)	Net Initial Cost	Initial Cost Ranking (Lowest)	Net Initial Cost	Initial Cost Ranking (Lowest)	Net Initial Cost	Initial Cost Ranking (Lowest)
HVAC	$1,876	3	$1,876	3	$1,375	3	$1,855	3
Insulation	$4,958	5	$5,144	5	$4,799	5	$5,185	5
Roofs	$2,568	4	$2,341	4	$2,568	4	$2,568	4
Water Heaters	$501	1	$501	1	$501	1	$501	1
Windows	$1,537	2	$1,371	2	$775	2	N/A	1
Geothermal Heat Pumps	$9,981	7	$9,981	7	$9,981	7	$9,981	7
PV Systems	$18,721	8	$18,721	8	$18,721	8	$18,721	8
Solar Water Heaters	$5,288	6	$5,288	6	$5,288	6	$5,288	6

TABLE 5. Net Life Cycle Costs and Ranking of ENERGY STAR Products by Climate

	North-Central Zone		South-Central Zone		Northern Zone		Southern Zone	
ENERGY STAR Product Upgrade	Net Life Cycle Cost Savings	Net Life Cycle Cost Ranking (Lowest)	Net Life Cycle Cost Savings	Net Life Cycle Cost Ranking (Lowest)	Net Life Cycle Cost Savings	Net Life Cycle Cost Ranking (Lowest)	Net Life Cycle Cost Savings	Net Life Cycle Cost Ranking (Lowest)
HVAC	–$2,059	2	–$2,107	3	–$1525	2	–$1,977	1
Insulation	–$2,020	3	–$2,864	1	–$1,414	3	–$15	4
Roofs	$2,910	7	$1,807	8	$2,233	7	$2,665	7
Water Heaters	–$1,013	4	–$1,727	5	–$902	5	–$1,497	2
Windows	$1,918	6	–$1,421	6	–$1,300	4	0	5
Geothermal Heat Pumps	$3,710	8	–$2,300	2	$4,927	8	$3,397	8
PV Systems	–$12,668	1	–$1,937	4	–$9,155	1	–$1.388	3
Solar Water Heaters	$1,582	5	$602	7	$1,889	6	$684	6

TABLE 6. Ranking of alternative ENERGY STAR Package based on aggregated Net Initial Costs by Climate

		Aggregated Individual Net Initial Costs			
Rank	Generated Packages	North-Central Zone	South-Central Zone	North Zone	South Zone
1	Water Heater, Window	$2,038	$1,872	$1,276	$501
2	Water Heater, Windows, HVAC	$4,364	$4,198	$3,101	$2,156
	Water Heater, Windows, HVAC, Roofs	$7,217	$6,799	$5,702	$4,724
3	Water Heater, Windows, HVAC, Roofs, Insulation	$12,675	$12,443	$11,001	$9,909
4	Water Heater, Windows, HVAC, Roofs, Insulation, Solar Water Heaters	$17,963	$17,731	$16,289	$15,197
5	Water Heater, Windows, HVAC, Roofs, Insulation, Solar Water Heaters, Geothermal Heat Pumps	$27,944	$27,712	$26,270	$25,178
6	Water Heater, Windows, HVAC, Roofs, Insulation, Solar Water Heaters, Geothermal Heat Pumps, Photovoltaic System	$46,665	$46,433	$44,991	$43,899

TABLE 7. Estimated Rank of Package based on aggregated Individual Net Life Cycle Costs by Climate used to Generate Packages to be Analyzed

	Generated Packages			
Estimated Rank	North-Central Zone	South-Central Zone	Northern Zone	Southern Zone
1	Photovoltaic Systems, HVAC	Insulation, Geothermal Heat Pump	Photovoltaic Systems, HVAC	HVAC, Water Heater
2	Photovoltaic Systems, HVAC, Insulation	Insulation, Geothermal Heat Pump, HVAC	Photovoltaic Systems, HVAC, Insulation	HVAC, Water Heater, Photovoltaic System
3	Photovoltaic Systems, HVAC, Insulation, Water Heaters	Insulation, Geothermal Heat Pump, HVAC, Photovoltaic System	Photovoltaic Systems, HVAC, Insulation, Windows	HVAC, Water Heater, Photovoltaic System, Insulation
4	Photovoltaic Systems, HVAC, Insulation, Water Heaters, Solar Water Heaters	Insulation, Geothermal Heat Pump, HVAC, Photovoltaic System, Water Heater	Photovoltaic Systems, HVAC, Insulation, Windows	HVAC, Water Heater, Photovoltaic System, Insulation, Windows
5	Photovoltaic Systems, HVAC, Insulation, Water Heaters, Solar Water Heaters, Windows	Insulation, Geothermal Heat Pump, HVAC, Photovoltaic System, Water Heater, Windows	Photovoltaic Systems, HVAC, Insulation, Water Heaters, Solar Water Heaters, Windows	HVAC, Water Heater, Photovoltaic System, Insulation, Windows, Solar Water Heater
6	Photovoltaic Systems, HVAC, Insulation, Water Heaters, Solar Water Heaters, Windows, Roofs	Insulation, Geothermal Heat Pump, HVAC, Photovoltaic System, Water Heater, Windows, Solar Water Heater	Photovoltaic Systems, HVAC, Insulation, Windows, Water Heaters, Solar Water Heaters, Roofs	HVAC, Water Heater, Photovoltaic System, Insulation, Windows, Solar Water Heater, Roofs
7	Photovoltaic Systems, HVAC, Insulation, Water Heaters, Solar Water Heaters, Windows, Roofs, Geothermal Heat Pumps	Insulation, Geothermal Heat Pump, HVAC, Photovoltaic System, Water Heater, Windows, Solar Water Heater, Roofs	Photovoltaic Systems, HVAC, Insulation, Windows, Water Heaters, Solar Water Heaters, Roofs, Geothermal Heat Pumps	HVAC, Water Heater, Photovoltaic System, Insulation, Windows, Solar Water Heater, Roofs, Geothermal Heat Pumps

Step 3: The following tables (Tables 8–12) show the final results for the packages generated using ENERGY STAR products. A negative number indicates that the performance of the package has improved (uses less energy) with respect to the benchmark. A positive number indicates that the performance of the package has declined (uses more energy) with respect to the benchmark. Table 8 shows the Net Life Cycle Costs for the ENERGY STAR product packages generated based on lowest Net Initial Cost. Tables 9–11 show the Net Life Cycle Costs for

TABLE 8. Net Life Cycle Cost performance and rank of ENERGY STAR Packages generated using lowest Net Initial Cost by Climate

	Net Life Cycle Cost and Rank							
Package	North-Central Zone		South-Central Zone		Northern Zone		Southern Zone	
Water Heater, Window	–$373	3	–$1,670	2	–$1,052	2	–$1,662	2
Water Heater, Windows, HVAC	–$1,553	2	–$2,996	1	–$1,606	1	–$3,116	1
Water Heater, Windows, HVAC, Roofs	–$179	4	–$1,609	3	–$223	4	–$1,787	3
Water Heater, Windows, HVAC, Roofs, Insulation	$149	5	–$1594	4	–$750	3	–$975	4
Water Heater, Windows, HVAC, Roofs, Insulation, Solar Water Heaters	$2,348	6	–$305	6	$1,539	6	$792	5
Water Heater, Windows, HVAC, Roofs, Insulation, Solar Water Heaters, Geothermal Heat Pumps	$4,923	7	$283	7	$4,397	7	$5,748	7
Water Heater, Windows, HVAC, Roofs, Insulation, Solar Water Heaters, Geothermal Heat Pumps, Photovoltaic System	–$8,676	1	–$1,243	5	$494	5	$4,993	6

TABLE 9. North-Central Zone Net Life Cycle Cost performance and rank of ENERGY STAR Packages generated using lowest aggregated Individual Net Life Cycle Costs

Package	Net LCC	Rank
PV Systems, HVAC	-$14,088	2
PV Systems, HVAC, Insulation	-$13,750	3
PV Systems, HVAC, Insulation, Water Heaters	-$14,383	1
PV Systems, HVAC, Insulation, Water Heaters, Solar Water Heaters	-$12,242	4
PV Systems, HVAC, Insulation, Water Heaters, Solar Water Heaters, Windows	-$11,476	5
PV Systems, HVAC, Insulation, Water Heaters, Solar Water Heaters, Windows, Roofs	-$10,100	6
PV Systems, HVAC, Insulation, Water Heaters, Solar Water Heaters, Windows, Roofs, Geothermal Heat Pumps	-$8,591	7

TABLE 10. South-Central Zone Net Life Cycle Cost performance and rank of ENERGY STAR Packages generated using lowest aggregated Individual Net Life Cycle Costs

Package	Net LCC	Rank
Insulation, Geothermal Heat Pump	-$1,800	5
Insulation, Geothermal Heat Pump, HVAC	-$1,800	5
Insulation, Geothermal Heat Pump, HVAC, PV System	-$7,725	3
Insulation, Geothermal Heat Pump, HVAC, PV System, Water Heater	-$4,824	4
Insulation, Geothermal Heat Pump, HVAC, PV System, Water Heater, Windows	-$10,423	1
Insulation, Geothermal Heat Pump, HVAC, PV System, Water Heater, Windows, Solar Water Heater	-$8,960	2
Insulation, Geothermal Heat Pump, HVAC, PV System, Water Heater, Windows, Solar Water Heater, Roofs	-$1,099	6

TABLE 11. Northern Zone Net Life Cycle Cost performance and rank of ENERGY STAR Packages generated using lowest aggregated Individual Net Life Cycle Costs

Package	Net LCC	Rank
PV Systems, HVAC	-$6,270	1
PV Systems, HVAC, Insulation	-$5,727	2
PV Systems, HVAC, Insulation, Windows	-$4,986	4
PV Systems, HVAC, Insulation, Windows	-$5,540	3
PV Systems, HVAC, Insulation, Water Heaters, Solar Water Heaters, Windows	-$3,367	5
PV Systems, HVAC, Insulation, Windows, Water Heaters, Solar Water Heaters, Roofs	-$1,984	6
PV Systems, HVAC, Insulation, Windows, Water Heaters, Solar Water Heaters, Roofs, Geothermal Heat Pumps	$494	7

TABLE 12. Southern Zone Net Life Cycle Cost performance and rank of ENERGY STAR Packages generated using lowest aggregated Individual Net Life Cycle Costs

Package	Net LCC	Rank
HVAC, Water Heater	-$3,115	2
HVAC, Water Heater, PV System	-$3,896	1
HVAC, Water Heater, PV System, Insulation	-$3,008	3
HVAC, Water Heater, PV System, Insulation, Windows	-$3,008	3
HVAC, Water Heater, PV System, Insulation, Windows, Solar Water Heater	-$1,507	4
HVAC, Water Heater, PV System, Insulation, Windows, Solar Water Heater, Roofs	-$151	5
HVAC, Water Heater, PV System, Insulation, Windows, Solar Water Heater, Roofs, Geothermal Heat Pumps	$4,993	6

the ENERGY STAR product packages generated based on lowest aggregates of Net Life Cycle Cost in the North-Central Climate Region, South-Central Climate Region, Northern Climate Region, Southern Climate Region, respectively.

Results indicate that significant variation exists across climate zones with regard to the cost effectiveness of ENERGY STAR packages. Furthermore, it is evident that economics surrounding decisions regarding ENERGY STAR products are complex, and not, necessarily, transferable between projects or climate zones. Specifically, there are tradeoffs between cost savings and energy source savings. As a result, the economics of the tax incentives surrounding ENERGY STAR products are heavily dependent on project specifics as well as owner personal priorities. Furthermore, numerous variables can quickly confound results.

DISCUSSION

The goal of residential energy-efficiency tax credits is to encourage individuals to increase residential energy-efficiency investments and to invest in properties that generate renewable energy. The objective of this study is to inform choices based on the return on the investment for various tax credits or combination of tax credits. Specifically, results from Tables 4 through 12 were analyzed, and the following findings and recommendations were derived:

- The ENERGY STAR product that ranked highest according to lowest (best) Net Initial Costs across all climates was a Water Heater.
- ENERGY STAR products package with lowest (best) aggregated Individual Net Life Cycle Costs across all climate zones included PV systems and HVAC upgrades.
- ENERGY STAR products package with highest (worst) aggregated Individual Net Life Cycle Costs across all climate zones included geothermal heat pumps.

In general, such results provide tax payers with information to invest efficiently using the tax credits based on available finance and in order to gain a better return from their investment.

CONCLUSIONS

Numerous factors contribute to the performance impact of selected ENERGY STAR products or packages that include program eligibility requirements, availability of tax incentives, homeowner budget and time-horizon, building design, building science, and climate. Furthermore, the number of possible combinations of ENERGY STAR products is great and many products have complex, interactive effects on whole building performance that are difficult to intuit. For these reasons, assessment of the impact of ENERGY STAR products presents a significant challenge for homeowners and researchers alike. The contribution of this research is to explore the potential variability in the economic impact of federal programs across various energy efficiency packages and climate zones. Findings indicate that for budgets <$5,000 the ENERGY STAR products package with maximum Life Cycle Cost performance consists of the following: Water Heater, Windows, and HVAC. However, performance results for this package can differ by up to 87% based on climate region. For budgets >$5,000, the performance of all ENERGY STAR packages vary significantly by climate region. Findings indicate that the following ENERGY packages products provide the lowest Life Cycle Cost. For the North-Central Zone: Photovoltaic Systems, HVAC, Insulation, Water Heaters (Initial Cost: $26,806); South-Central Zone: Insulation, Geothermal Heat Pump, HVAC, Photovoltaic System, Water

Heater, Windows (Initial Cost: $38,544); Northern Zone: Photovoltaic Systems, HVAC (Initial Cost: $20,096); and Southern Zone: HVAC, Water Heater, Photovoltaic System (Initial Cost: $21,327). However, performance results for packages can differ by up to 370% according to Life Cycle Cost estimates across climate regions. The goal of residential energy-efficiency tax credits is to encourage individuals to increase residential energy-efficiency investments. However, this and previous research demonstrates that the impact of ENERGY STAR TAX credits is effected by a variety of factors, and the economics can be complex and difficult to assess. More research is recommended to illuminate patterns in performance of ENERGY STAR products relative to Life Cycle Costs. In addition, in the future, an Internal Rate of Return (IRR) analysis may be performed. Without project-specific energy modeling, however, it will remain difficult for homeowners to make cost effective decisions regarding the benefits of various ENERGY STAR products.

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