Triple Bottom Line Analysis of Water and Energy Conservation in A LEED Platinum Project

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This paper applies Triple Bottom Line (TBL) analysis to evaluate the benefits of water and energy conservation in a LEED (Leadership in Energy and Environmental Design) Platinum building project. This TBL analysis considers Economic (Profit), Environmental (Planet), and Social (People) perspectives. The results show obvious economic benefit from water conservation with a payback period within 3.5 years. The environmental and social benefits of water conservation also include enhanced agricultural production and improved life quality. However, due to a high initial cost of insulation and energy-saving equipment, the net present value of energy conservation enhancement remains significantly negative after a building's lifespan. To support energy conservation measures in a green building project, there must be sufficient incentives to help solicit the associated environmental and social benefits. Efforts and initiatives from public policies are necessary to sustain the continuous advancement of energy-conservation technologies developed and applied to future green building projects.

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I. INTRODUCTION

This paper analyzes the value of water and energy conservations in a LEED Platinum building project, which conforms to the highest standards proposed by U.S. Green Building Council (USGBC) and its Leadership in Energy and Environmental Design (LEED) green building rating requirement. LEED is based on a points system that focuses on new commercial-building projects. The more points earned, the higher the rating. It is administered by the United States Green Building Council (USGBC). There are 4 levels of LEED certification: Platinum (80 points or more, out of 110 possible points), Gold (60-79 points), Silver (50-59 points), and Certified (40-49 points). The rating system's objective is to encourage and reward sustainable design across several metrics – sustainable site choice, energy savings, water efficiency, reduction of CO2 emissions, and indoor environmental quality, among others – all while improving company profitability and employee well-being. This analysis consists of an integrated procedure and its implications Economic (Profit), Environmental (Planet), and Social (People) perspectives - the three major dimensions of Triple Bottom Line (TBL) or 3Ps analysis.

Sustainable living is no longer a mere choice, but a necessity. Elkinton (1996) first proposed measurement sustainability by encompassing a new framework to assess performance in corporate America. This accounting framework, called the triple bottom line (TBL) analysis, went beyond the traditional measures of profits, return on investment, and shareholder value to include environmental and social dimensions. Following this evaluation approach, instead of focusing solely on the direct financial impacts of a LEED Platinum construction project (USGBC, 2019), applying a TBL analysis adds considerations for environmental and social equity factors to the overall decision-making and evaluation process (Elkington, 1997). Quantifying the environmental and social benefits of a project can be a complex process in water and energy conservation cases. However, applying a TBL approach can result in more holistic, and presumably, better management decisions (Onyali, 2014). This is attributed to the growing demands from stakeholders for more extensive information on the operations and financial standing of businesses, thus necessitating that managers include information on sustainability-related issues (Jackson, Boswell and Davis, 2011). Fig.1 shows the overlapping aspects of the broad categories of environmental, economic, and social benefits that converge on sustainability.

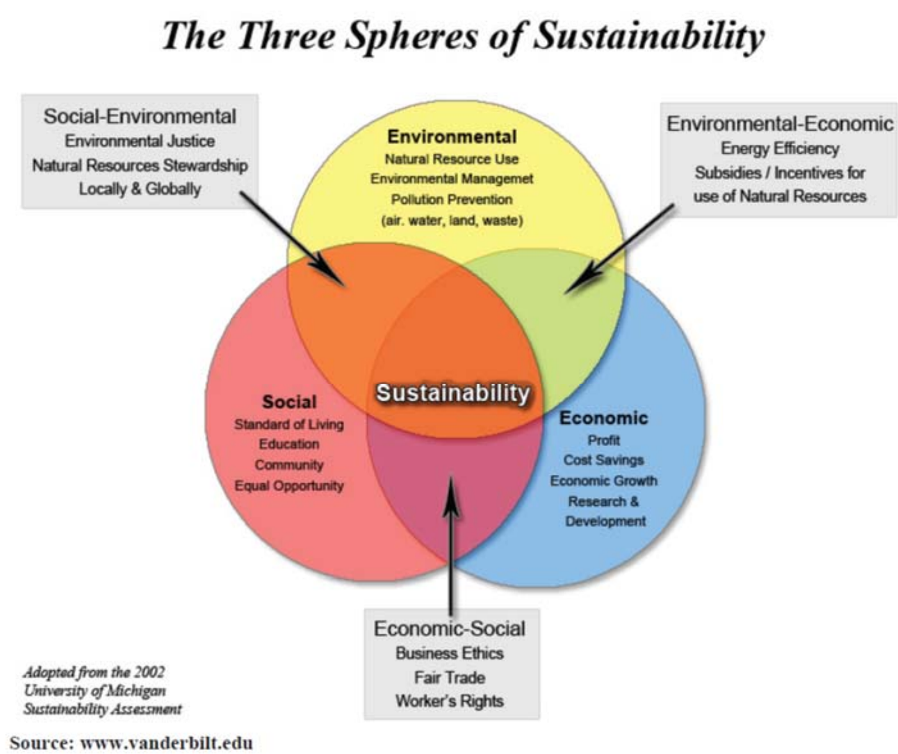


FIGURE 1. ELEMENTS IN TBL ASSESSMENT

TBL focuses on profit, people and planet. The companies applying these interrelated elements will support the firm's sustainability. Sustainability in practice can be seen as the art of doing business in an interdependent world. They need to identify a wide range of stakeholders to whom they may be accountable, develop open relationships with them, and find ways to work with them for mutual benefit. TBL is operating business in a way that causes minimal harm to living creatures and that does not deplete, but rather restores and enriches the environment. A sustainable corporation is one that creates profit for its stakeholders while protecting the environment and improving the lives of those with whom it interacts.

Alternatives to TBL analysis are as follows:

- Life Cycle Assessment (LCA): This is a method used to evaluate the environmental impact of a product through its life cycle encompassing extraction and processing of the raw materials, manufacturing, distribution, use, recycling, and final disposal (Ilgin and Gupta, 2010). Life Cycle Assessment considers various dimensions of sustainability impacts of civil infrastructures are limited and the research is important to attempt to analyze the sustainability impacts in general (Toniolo, Mazzi, Mazzarotto, et al., 2019).
- Corporate Sustainability Report: A sustainability report is a report published by a company or organization about the economic, environmental and social impacts caused by its everyday activities (Adams, Muir, Hoque, 2014). Sustainability reporting can help organizations to measure, understand and communicate their economic, environmental, social and governance performance, and then set goals, and manage change more effectively (Wilson, 2003).

What makes TBL stand out from alternatives is that the TBL concept represents a more broad and balanced approach for measuring project or business success not only by the traditional bottom line of financial performance, most often expressed in terms of profits or shareholder value, but also by their impact on the broader economy, the environment, and on the society in which they operate (Deng, 2015). Companies not only use financial resources but also environmental resources and social resources. TBL captures the essence of sustainability by measuring the impact of an organization's activities on the world.

To achieve the TBL of sustainability, total management efforts must analyze alternatives to address the potentially conflicting goals of economic, environmental, and social issues (Slaper, 2011). Traditionally, financial performance heavily influences construction-related decisions (Kucukvar and Tatari, 2013). Castro-Lacouturea, Sefairb, Flórezb, and Medaglia (2009), for example, proposed a mixed-integer optimization model that incorporates design and budget constraints while maximizing the number of credits reached under the LEED rating system (Shan and Hwang, 2018). While maximizing decision makers' value continues to be an overriding concern, it is not sustainable long-term if they do not meet notable environmental or social interests (Ballou, Heitger, and Landes, 2006). The alternative with the best cost-benefit ratio to include environmental and social goals was generally considered superior. As the need to make sustainable decisions becomes increasingly important, a similar need surfaces for a methodology balancing sustainability objectives in a realistic manner (Liner and deMonsabert, 2011).

This paper adopts case study research methodology. Case study designs have been used across a number of disciplines, particularly the social sciences, business, law, health, and environmental issues, to address a wide range of research questions. They are capable of providing a comprehensive, in-depth understanding of a diverse range of issues across a number of disciplines. A typical case study is based on an in-depth investigation of a single residential construction project. The scopes in this case study include both descriptive and explanatory perspectives (Creswell, 2014).

In this paper, we incorporate the LEED rating process in a residential building project. Water usage and building materials data are collected and analyzed for the three aspects of TBL: Economic, Environmental and Social objectives (Kucukvar and Tatari, 2013). This study is conducted on the sustainability of the building's construction to match the top LEED Platinum rating based on the LEED v4 for Homes Design and Construction standards (Uğura and Leblebici, 2018). It is then cross-verified with LEED at every step to determine the effectiveness of the Triple Bottom Line dimensions analyzed. The resulting values are compared with the standard building cost analysis (Geng, Ji, Lin, Hong, and Zhu, 2018), and their differences and efficiency are discussed.

II. SCOPE OF LEED PLATINUM PROJECT

The definition of a green building is constantly evolving. While a green building is also known as a sustainable or high-performance building, the Environmental Protection Agency (EPA) defines green building as "the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation and deconstruction". The green building we are investigating conforms to LEED requirement in Platinum (the highest) level - a building rating system developed by the U.S. Green Building Council (USGBC). LEED is the most widely used green building rating system in the world. Available for all building, community and home project types, LEED provides a framework to create healthy, highly efficient, and cost-saving green buildings. A globally recognized symbol of sustainability achievement, LEED certified green buildings offer a number of financial benefits that include cost savings on utility bills for residents through energy and water efficiency, and lower construction costs and higher property value for building owners. Building owners report that new green buildings obtain an increase in asset value over traditional buildings.

LEED is a point-based system; different green features of a building earn various points. LEED projects earn points by adhering to prerequisites and credits across measurements for building excellence from integrative processes to indoor environmental quality. The number of points the project earns determines its level of LEED certification. Based on the number of credits achieved, a project earns one of four LEED rating levels: Certified, Silver, Gold, and Platinum. A basic LEED certification is awarded if a building amasses between 40 and 49 points, Silver if between 50-59 points, Gold if between 60-79 points, and Platinum with points 80 and above. Within each of the LEED credit categories, projects must satisfy prerequisites and earn points. The basic credit categories of LEED certification include the following areas shown in Fig. 2.

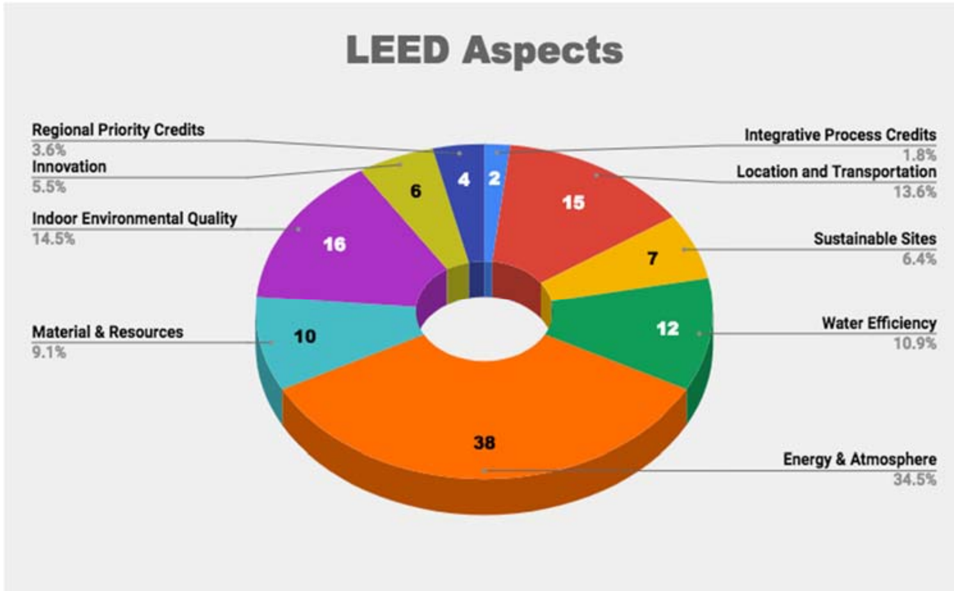


FIGURE 2. LEED ASPECTS BASED ON LEED V4 HOME 2017

The house selected in this project is located in Dublin, California. This is a single-family house with 11800 ft^2 of lot size, in which the building area is of approximately 2200 ft^2. The proposed building area is approximately 3320 ft^2 with about 9600 ft^2 of vegetation scope and paved ground surrounding the building. The climactic conditions must be considered while designing green building solutions, whether it is a new or a retrofit project. Dublin is mostly sunny throughout the year with an average of 262 sunny days and 18 inches of rain each year. This requires a rainwater harvesting mechanism to add onto the sustainability project. The data considered in the project includes home energy usage summary, water usage summary, house orientation, the glazing percentage and the building materials used to decide on the appropriate sustainable development undertaken. After selecting the right preventive and efficient sustainable measures to build the building, it is cross-verified with LEED at every step to determine its effectiveness. The resulting values are then compared with the standard building cost analysis.

III. TRIPLE BOTTOM LINE ANALYSIS OF WATER CONSERVATION

Water is a necessity for all life on the planet, therefore easy access to sufficient quantities of clean water is a high priority. To that end, productive use of available water resources, effective ways to conserve water, and water supply system expansions can guarantee long-term water availability on the planet. Water savings can have significant impact on society, from sustaining life to agriculture food production. Water-savings and reducing fresh water usage lessens diversion from our natural reservoirs like rivers, lakes, wells and bays, which leaves more water in the natural ecosystem. In addition, there are financial savings, as this reduces water and wastewater treatment costs, as well as the amount of energy used to make the water usable for humans. Energy creation, supply, and usage activities all contribute directly to atmospheric pollution and are responsible for the emission of greenhouse gases and other pollutants. This results in decreased human health and productivity. When designing a sustainable building, it is important to enhance the efficiency of water consumption from the design and construction stage, through to the final operation. Less water usage will increase the sustainability and in turn support the overall well-being of the residents. The following are the components considered for the Water Efficiency credit project: 1). Indoor Water Reduction, and 2). Outdoor Water Reduction. Both indoor and outdoor water reduction is essential for LEED credit.

For indoor water reduction, the data released by the California Legislative Analyst's Office (LAO) on March 8, 2017 implies that the average Californian used 85 gallons of water per day in 2016. The water usage was highest in the summer months of June through September, where it averaged 109 gallons per person per day. In contrast, in the cooler and wetter months from January to March, the average water used was only 64 gallons per person per day. The statistics and estimations depict that 115,200 gallons of indoor water is consumed in a year.

An effective way to reduce indoor water usage is to install appliances and fixtures certified as "WaterSense" or "Energy Star" (Energy Star, 2019). Table 1 below interprets the water usage reduction as compared to older appliances. It demonstrates that water usage can be reduced from 320 gallons per day to 100 gallons (a 68% reduction) by simply switching to Energy Star or Water Saver faucets, aerators, showerheads, and other appliances.

TABLE 1. TRADITIONAL VS WATERSENSE OR ENERGYSTAR APPLIANCES.

Components considered	**Approximate water usage with traditional appliances (gallons/day)**	**Approximate water usage with WaterSense or EnergyStar appliances**
Shower	160 gallons	48 gallons
Teeth brushing	8 gallons	4 gallons
Hands/face washing	16 gallons	8 gallons
Dishwasher	16 gallons	4 gallons
Dishwashing by hand	40 gallons	10 gallons
Clothes washer	40 gallons	14 gallons
Toilet flush	32 gallons	12.8 gallons
Total Water Usage/ day	**320 gallons**	**100.8 gallons**

This LEED project has approximately 6,000 square feet of open space for outdoor water usage in gardening and landscaping. Considering this complete area, the average water usage per month would be 18,823 gallons, a significant amount of water used outdoors. In order to reduce the water consumption required for landscaping, the Water Budget Tool published by The Environmental Protection Agency (EPA) is shown in Table 2.

TABLE 2. EPA CALCULATOR FOR OUTDOOR WATER USAGE.

WaterSense New Home Specification: Water Budget Tool (V 1.03)
This water budget tool shall be used to determine if the designed landscape meets Criteria 4.1.1 of the specification.
Please refer to the WaterSense Water Budget Approach for additional information.

Your Name: Peng House
Builder Name:
Lot Number/Street Address: Castilian Ct
City, State, Zip Code: Dublin, California,94568

Peak Watering Month: July
Obtain from Water Budget Data Finder at https://www.epa.gov/watersense/water-budget-data-finder

Is an irrigation system being installed on this site? No

This worksheet determines the baseline and the landscape water allowance (LWA) for a site based on its peak watering month.

The baseline is the amount of water required by the site during the peak watering month if watered at 100 percent of reference evapotranspiration (ET_o). The following formula is used to calculate the baseline:

$$Baseline = ET_o \times A \times C_u$$

Where:
ET_o = Local reference evapotranspiration (inches/month)
A = Landscaped area (square feet)
C_u = Conversion factor (0.6233 for results in gallons/month)

The LWA is the water allotment for the site. The following formula is used to calculate the LWA:

$$LWA = 0.70 \times Baseline$$

Where:
LWA = Landscape water allowance (gallons/month)
Baseline = ET_o x landscaped area x 0.6233

To calculate the Baseline and LWA for a site, enter the designed landscaped area and average monthly reference evapotranspiration for the site's peak watering month. (Enter data in white cells only.)

STEP 1A - ENTER THE LANDSCAPED AREA (A)
6,000 **Area of the designed landscape (square feet)**

STEP 1B - ENTER THE AVERAGE MONTHLY REFERENCE EVAPOTRANSPIRATION (ET_o)
7.19 **Average monthly reference ET (inches/month) for the site's peak watering month**
Obtain from Water Budget Data Finder at https://www.epa.gov/watersense/water-budget-data-finder

OUTPUT - BASELINE FOR THE SITE
26,891 **Monthly baseline (gallons/month) based on the site's peak watering month**

OUTPUT - WATER ALLOWANCE FOR THE SITE
18,823 **Monthly landscape water allowance (gallons/month) based on the site's peak watering month**

It is estimated that with the appropriate types of plants, the monthly outdoor water usage can be reduced from 18,223 gallons (Landscape Water Allowance, LWA) to 7,288 gallons (Landscape Water Requirement, LWR). The detailed breakdown is shown in Table 3.

TABLE 3. OUTDOOR WATER USAGE DETAILS.

Components considered	Values
Total open space/gardening area	6,000 sq. feet
Output Baseline Water usage/monthly	26,891 gallons
Water Allowance/monthly	18,823 gallons
After designing the layout using the tool, the water usage monthly	7,288 gallons
The water requirement reduction after designed landscape	**61%**

To further help water conservation, a filtering system is installed to recycle daily shower water (approximately 40 gallons per day) for watering non-vegetation plants in landscaping. As shown in Table 4, it consequently saves 1,200 gallons of water per month.

TABLE 4. WATER SAVING FROM RECYCLEING.

Water Components	Values
Recycled Water/day	40 gallons
Recycled Water/month	1,200 gallons
Exact total monthly water usage	6,088 gallons
The water requirement reduction after designed landscape	**68%**

3.1. Economic Impact of Water Conservation

The financial costs for water usage include 1). Operating and Maintenance Cost, 2). Capital Cost, and 3). Replacement Cost. For the financial impact, the net present value of the combined financial costs is calculated over a period of 30 years with a discounted rate of 7%. The rainwater harvesting system cost is also considered. Table 5 depicts the cost savings on Indoor Water Usage, using latest water rate/unit taken from the Dublin San Ramon Services District (DSRSD) website.

TABLE 5. WATER COST SAVING CALCULATION BASED ON DSRSD PRICING.

Dublin, CA- Water rate/unit	$2.99
1 Unit	748 gallons
Water Bill – Bi Monthly	60 days

Components	Indoor Usage			Outdoor Usage		
	Before	After	Savings	Before	After	Savings
Bi-Monthly Water Bill	$74.83	$24.18	$50.65	$150.48	$48.67	$101.81
Yearly Water Bill	$448.98	$145.05	$303.92	$902.90	$292.03	$610.87
Total Annual Savings	**$914.80**					

Table 6 shows the Net Present Value (NPV) calculations. The initial investment for this house, which includes all the Water Sense or Energy Star appliances, will be around $2,235. Considering the house lifespan is 30 years, and all these appliances have 15 years of average life, the appliances are to be replaced once every 15 years. Therefore, the total expenditure on indoor appliances for a lifetime would be $4,470. For outdoor water usage, the expense will be $1,100 for two filters. These filters also have an average life of 15 years and will be replaced once in the house's lifetime. Considering the discount rate as 7%, the following table shows the NPV calculations.

TABLE 6. THE 30-YEAR NPV CALCULATIONS OF WATER CONSERVATION.

Cost Incurred by Efficient solutions 30 years (Indoor & Outdoor)		
Capital Cost	$	3,335.00
Operations & Management cost	$	33.35
Replacement Cost	$	6,670.00
Total Cost	$	10,038.35
Net Present Value (NPV) for 50 years with 7% discount rate	$	7,844.61

Years	**Inflows and Outflows**	**Comments**
1st	$(3,335.00)	Water efficient appliances and water recycle filter installation (Outflow)
2nd -14th	$ 11,458.80	Annual savings worth $914.80 minus O&M cost $ 33.35 from 2nd year to 14th year (Inflow)
15th	$(2,453.55)	Total Annual Savings MINUS Water efficient appliances and water recycle filters installation cost (Inflow - Outflow)
16th -30th	$ 13,221.69	Annual savings worth $914.80 minus O&M cost $ 33.35from 16nd year to 30th year (Inflow)
NPV	**$7,844.61**	For 30 years life of house, the NPV is **$7,844.61**

3.2. Environmental Impact of Water Conservation

Over the past 50 years, the US population has doubled and the need for water has increased by nearly 200%. The need for conserving water has become serious. About 71% of the Earth's surface is covered by water. Only 2.5% of that is fresh water, with only 31% of that being usable, accessible fresh water. The remaining 69% of available fresh water resides in glaciers and perpetual ice. Freshwater is needed by plants, animal and humans. Freshwater is in the ground water, lakes, rivers, streams, ponds, glaciers, ice sheets, icebergs bogs and underground water called ground water. One of the greatest threats on the planet is the over-consumption of water. The irresponsible use of water to produce goods and services will endanger availability of water resources. If we conserve water, we don't need to treat and pump as much water. Hence, we don't need to spend as much on chemicals, energy, and additional reservoirs of boreholes. Water conservation in homes or businesses will reduce the amount of water that has to be treated or that uses energy unnecessarily. In addition, when considering the reduction of energy used in the pumping and filtering of water, it will further decrease our carbon emissions by additional 28%. The environmental impact of water conservation is also a factor in avoiding displacement or extinction of wildlife. Another impact of water conservation is to avoid resource depletion in forests, foods, and more. Saving water will lead to saving energy and reduce our carbon footprint.

Applying water-saving techniques helps divert less water from our reservoirs, rivers, lakes, bays, and estuaries, keeping the environment healthy. It also reduces energy demand, helping prevent pollution.

Furthermore, reducing the amount of energy used in pumping water lowers carbon emissions, combating climate change. Based on a 2015 survey published by USGS, total irrigation withdrawals were 118,000 Mgal/d from all-natural resources, altering groundwater levels and impacting the life and development of surrounding habitats and wetlands. Reducing fresh water usage at homes (27,833 gallons/month in this project) will ensure less withdrawals from natural resources, thus reducing soil erosion and protecting soil quality, wildlife habitats, and marine life (USGS, 2019)

3.3. Social Impact of Water Conservation

The social value of water savings is derived from the environmental value of water savings. The project/house is located in Dublin, CA, where these social and environmental values greatly overlap. In addition, water is necessary for life, therefore access to sufficient quantities of low-cost water is a fundamental necessity. Some land developments decrease the water available for both human use and for the environment, a social concern for humanity. Therefore, the preventive measures taken for this project will have a significant social impact on the community. Furthermore, the total water usage for irrigation is increasing regularly, affecting the yield of crops. This project results in one home saving 18,795 gallons/month. If every other house becomes LEED certified, the amount of more fresh water available for agriculture would be monumental. This will have social impacts in not only decreasing the prices of vegetables and fruits, but also making them more available for every class of society.

There are four areas, health, hunger, education, and poverty, which will be affected directly if water is used inefficiently. Specifically, failing to conserve water can eventually lead to a lack of adequate water supply, which can have drastic consequences. It will affect people's livelihoods in terms of rising costs, reduced food supplies, health hazards, and political conflicts. In addition, misuse of water will result to less water and will mean sewage will not flow and mosquitoes are other insects breed on still dirty water and could lead to various human diseases.

The objective of sustainable building is to reduce water consumption and protect water quality. To conserve water, people are now using water conserving fixtures. They install ultra-low flushing toilets, low-flow show heads, bidets which help eliminate the use of toilet paper and reduce sewer traffic and likelihood of re-using water onsite. In addition, people are increasingly using energy efficient appliances such as dishwashers and washing machines, and installing solar water heating systems.

Overall, water conservation objectives can be summarized as the following:

- Ensuring availability of water for future generations where the withdrawal of freshwater from an ecosystem does not exceed its natural replacement rate.
- Energy conservation where water pumping, delivery and wastewater treatment facilities consume significant amounts of energy. In some regions of the world over 15% of total electricity consumption is devoted to water management.
- Habitat conservation where minimizing human water use helps to preserve freshwater habitats for local wildlife and migrating waterfowl, as well as water quality.

IV. TRIPLE BOTTOM LINE ANALYSIS OF ENERGY CONSERVATION

In this section, energy conservation methods are studied and a TBL Analysis is performed in the LEED Platinum building project. Energy supply and usage activities all contribute directly to the atmospheric pollution and are responsible for the emission of greenhouse gases and other pollutants. This worsens human health and productivity. From start to finish, while designing a sustainable building, it is important to consider energy preservation overall efficiency. Less energy usage will increase the internal air quality of the house, in turn supporting the overall well-being of the residents. In addition, we also assess the level of CO_2 emissions added (or reduced/sequestered) from each option. The net savings in emissions are valued using a "social cost of carbon" estimate derived from the Intergovernmental Panel on Climate Change (Wachter and Wong, 2008). Less energy usage will reduce the carbon footprint of the house to support the overall well-being of the surrounding environment. The financial costs for energy usage are calculated similarly to that of water usage. It includes 1). Operating and Maintenance Cost, 2). Capital Cost, and 3). Replacement Cost. For the financial impacts, the net present value of the combined financial costs is calculated over a period of 30 and 50 years, with a discounted rate of 7%.

The energy saving approaches aim to achieve LEED Energy & Atmosphere Credits via performance path, a 50% improvement of annual energy usage when compared with California Title 24 benchmark. In other words, to reduce environmental and social burdens associated with excessive use of energy, a LEED Platinum project must achieve increasing levels of energy efficiency beyond the standard Title 24 prerequisites. The analysis covers two of the major residential energy consumptions: HVAC (heating, ventilation, and air conditioning) and Lighting. As shown in Fig. 3, the HVAC counts for approximately 73% of the total household energy usage.

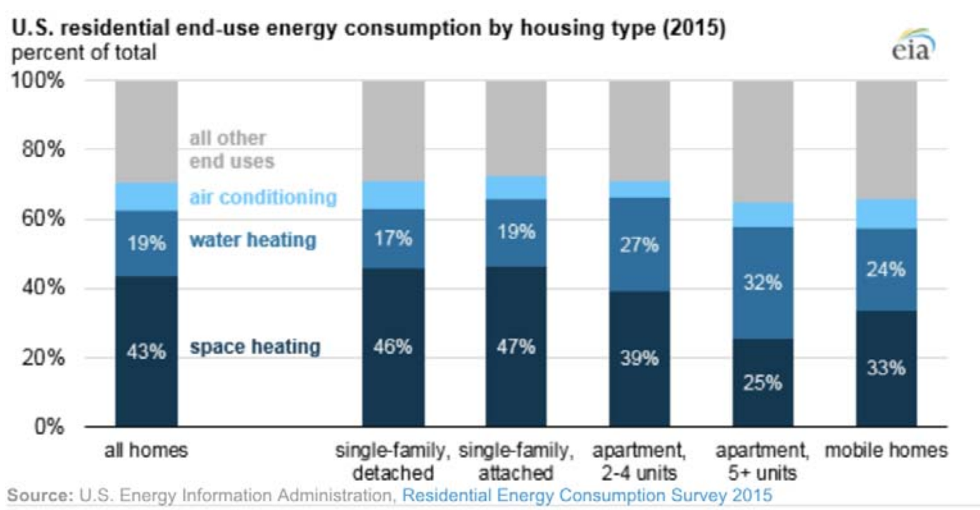


FIGURE 3. U.S. RESIDENTIAL END-USE ENERGY CONSUMPTION IN 2015.

The second energy usage analyzed is the energy consumed for Lighting purposes. In this analysis, the energy performance of the previous type of light bulbs is compared with that of the new LED bulbs installed. Figure 4 Shows the Energy Usage Summary in Title 24 report, indicating a 51.1% improvement in this LEED Platinum project.

The HVAC energy conservation is significantly improved by incorporating special features such as quality building envelope, good ceiling and wall insulation, cool roof, great ventilation system, and HERS verified heating and cooling systems. The Title 24 analysis certificate below briefly compares the standard design and the proposed building design. To determine the energy consumption efficiency, we followed the current version of LEED (version 4.0) in the Energy and Atmosphere (EA) category, and discussed the financial and social impact of the implemented LEED credits.

CERTIFICATE OF COMPLIANCE - RESIDENTIAL PERFORMANCE COMPLIANCE METHOD — **CF1R-PRF-01**

Project Name: Peng Residence — **Calculation Date/Time:** 15:17, Sat, May 26, 2018 — **Page 1 of 9**

Calculation Description: Title 24 Analysis — **Input File Name:** Peng.05.26.18.2013 Code.ribdx

GENERAL INFORMATION					
01	Project Name	Peng Residence			
02	Calculation Description	Title 24 Analysis			
03	Project Location	11624 Castilian Court			
04	City	Dublin	05	Standards Version	Compliance 2015
06	Zip Code	94568	07	Compliance Manager Version	BEMCmpMgr 2013-4b (433)
08	Climate Zone	CZ12	09	Software Version	EnergyPro 6.8
10	Building Type	Single Family	11	Front Orientation (deg/Cardinal)	180
12	Project Scope	Newly Constructed	13	Number of Dwelling Units	1
14	Total Cond. Floor Area (ft^2)	2813	15	Number of Zones	3
16	Slab Area (ft^2)	0	17	Number of Stories	2
18	Addition Cond. Floor Area	N/A	19	Natural Gas Available	Yes
20	Addition Slab Area (ft^2)	N/A	21	Glazing Percentage (%)	12.9%

COMPLIANCE RESULTS	
01	Building Complies with Computer Performance
02	This building incorporates features that require field testing and/or verification by a certified HERS rater under the supervision of a CEC-approved HERS provider.
03	This building incorporates one or more Special Features shown below
	This compliance analysis is valid only for permit applications through December 31, 2016

ENERGY USE SUMMARY				
04	05	06	07	08
Energy Use (kTDV/ft^2-yr)	Standard Design	Proposed Design	Compliance Margin	Percent Improvement
Space Heating	20.46	10.20	10.26	50.1%
Space Cooling	23.19	9.20	13.99	60.3%
IAQ Ventilation	1.33	1.33	0.00	0.0%
Water Heating	10.64	6.47	4.17	39.2%
Photovoltaic Offset	----	0.00	0.00	----
Compliance Energy Total	55.62	27.20	28.42	51.1%

Registration Number: — Registration Date/Time: — HERS Provider:

CA Building Energy Efficiency Standards - 2013 Residential Compliance — Report Version - CF1R-01212016-433 — Report Generated at: 2018-05-26 15:18:27

FIGURE 4. TITLE 24 REPORT OF THIS LEED PLATINUM PROJECT.

The average American home has approximately 50 light sockets. In regard to energy conservation achieved by using energy star LED bulbs over CFL and Incandescent bulbs, as shown in Fig. 5, about 60% of homes use inefficient light bulbs. Two-dollar, high-quality LED bulbs can fill those sockets and save Americans more than $6 billion a year. With around 250 million sockets in California that still contain inefficient bulbs, there are significant potential savings. If all of these lights are changed to a more efficient alternative, California consumers and businesses will save an estimated $1 billion every year on their electric bills.

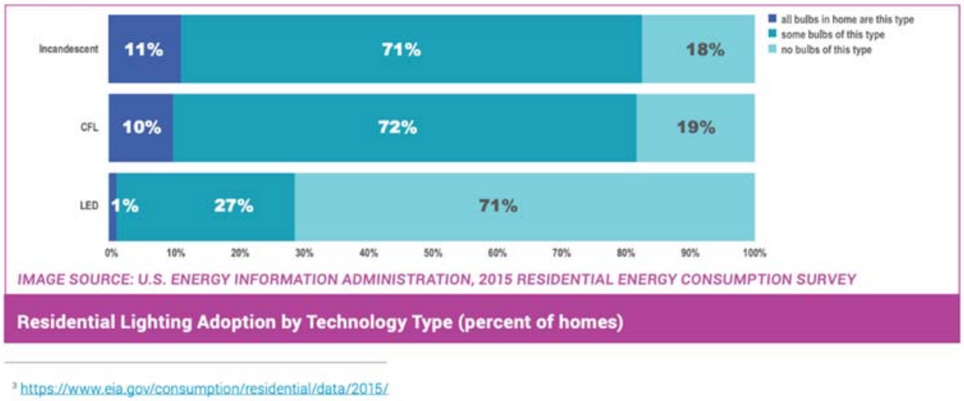


FIGURE 5. 2015 RESIDENTIAL ENERGY SURVEY OF LIGHTING TYPE.

4.1. Economic Impact of Energy Conservation

The HVAC energy usage of a standard building is derived from the average annual PG&E bill of California residential buildings. The approximate construction and equipment cost of $40,000 for the LEED Platinum compliant building is also considered. Both the costs are analyzed by calculating the Net Present Value for a 30-year period.

TABLE 7. STANDARD CALIFORNIA HVAC ENERGY USAGE VS. LEED PLATINUM PROJECT WITH 50% TITLE 24 ENERGY IMPROVEMENT.

	Energy Consumption by residential house of approximately 2819 sq.ft. area in Dublin City, CA				
LEED solution	Route 1: Total Annual Energy Savings	LEED Credits Earned - 25 + 2			
		Standard Californian House Energy Usage Data		Proposed House re-modeled with Title24 construction modifications to enhance energy usage efficiency and savings	
			Average annual energy consumption in kWh (considering $260 per month for 3320 sq.ft. 6 bedroom house)		
			20782		
		Percentage of the total energy used for each of the below Title24 energy activities:	Total Annual Energy Consumption for each activity below (kWh)	Total energy percentage saved in each of the below activity in the new house	Total Annual Energy Savings due to the Title24 modification (kWh)
	Space Heating	46%	9559.72	50.10%	4789.42
	Space Cooling	10%	2078.2	60.30%	1253.15
	Water Heating	17%	3532.94	39.20%	1384.91
	Total	73%	15170.86	49.87%	7565.20
Price and Cost Incurred	Residential Electricity in California is 15.59¢/kWh i.e., $0.1559	Average Annual Energy Usage Cost	Average Annual Energy Usage Cost for Heating & Cooling purpose		Average Annual Energy Usage Cost Savings on the new house
		$ 3,239.91	$ 2,365.14		$ 1,179.42

Standard American homes use approximately 73% of the total energy for HVAC purposes. As shown in Table 7, LEED Platinum construction method reduces about 51% of the HVAC energy consumption (7565.20 kWh) or $1,179.42 saving annually. When considering $200 maintenance cost, the annual savings becomes $1,179.42 – $200 = $979.42.

TABLE 8. THE 30 AND 50-YEAR NPV CALCULATIONS OF HVAC ENERGY CONSERVATION.

Years	Cost incurred
1st year	$ (40,000.00)
2nd year to 30th/50th year	$ 979.42
NPV using 7% discount ratio for 30 years	$ (26,144.92)
NPV using 7% discount ratio for 50 years	$ (24,781.86)

As shown in Table 8, however, it is noticeable that the NPV values of the building for both a life span of 30 and 50 years is significantly negative. This is expected due to the high initial cost of construction and equipment. The incorporation of advanced insulation materials within the building's architectural design make major contributions to the energy-efficient building. This is advantageous considering that standard buildings do not contribute to energy savings or efficiency.

Next, we analyze the energy savings in the area of lighting by comparing the Benefit-Cost Analysis of using LED bulbs vs CFL or Incandescent bulbs. The average price of each LED is eight times higher than an Incandescent bulb and four times higher than a CFL bulb. In contrast, LED bulbs consume a quarter of the energy consumed by Incandescent bulbs, and half the energy consumed by CFL bulbs. Table 9 compares the number of light bulbs with the required lumens using different bulbs. The 30 and 50-Year NPV analysis is summarized in Table 10.

TABLE 9. NUMBER OF BULBS VS LUMENS REQUIRMENT FOR LEED PLATINUM PROJECT.

	No. of bulbs	lumens	watt (Incandescent)	LED equivalent	Capital Cost (LED)
6 Bedroom	6	24000	1600.00	400.00	$ 108.00
4.5 Bathroom	5	18900	1260.00	315.00	$ 60.00
Garage - 443 Sq.ft.	1	31010	2067.33	516.83	$ 30.00
Porch - 65 Sq.ft.	1	650	43.33	10.83	$ 10.00
Kitchen	1	16150	1076.67	269.17	$ 100.00
Living room	2	9000	600.00	150.00	$ 30.00
Dining	1	540	36.00	9.00	$ 20.00
Family Room	2	3000	200.00	50.00	$ 40.00
Exterior	4	3000	200.00	50.00	$ 40.00
TOTAL	**23**	**106250**	**7083.33**	**1770.83**	**$ 438.00**

LEED	**Sq.Ft.**	
Total Building Area	3320.3	
W/sq.ft requirement	**Equivalent LEED Points**	**Total Watts possible**
0.72	0.5	2390.616
0.6	**1**	**1992.18**
0.48	1.5	1593.744

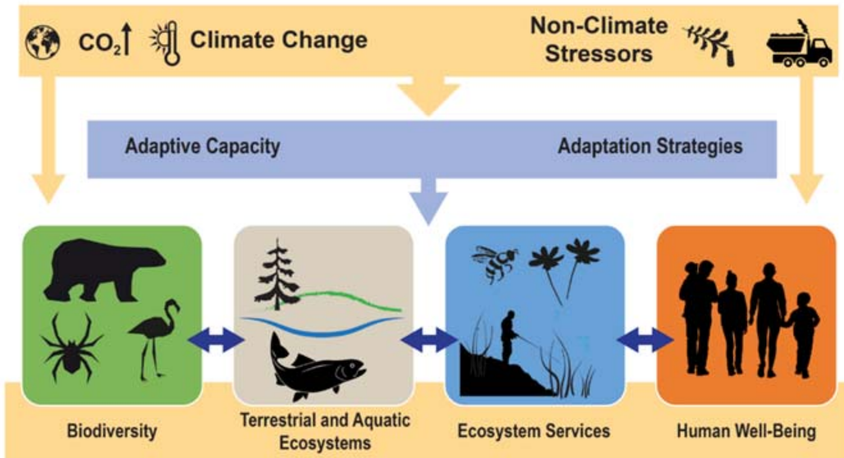
TABLE 10. THE 30 AND 50-YEAR NPV CALCULATIONS OF LED ENERGY CONSERVATION

Costs Comparison between Incandescent vs CFL vs LED bulbs			
	Incandescent	CFL	LED
Approximate Cost of 23 bulbs of each type	$ 54.75	$ 109.50	$ 438.00
Average Life Span in hrs. of each type bulb	1200	8000	50,000
Number of bulbs needed for 50,000 hrs of lighting from each type	41.67	6.25	1
Number of years individual bulb of each type would last	0.36	2.4	15
Number of times we need to change the bulb over the span of 30 years	83.33	12.5	2
Number of times we need to change the bulb over the span of 50 years	138.88	20.83	3.33
Total purchase price for 30 years	$ 4,562.50	$ 1,368.75	$ 876.00
Total purchase price for 50 years	$ 7,603.68	$ 2,280.89	$ 1,458.54
Cost incurred for Lighting over the span of 30 & 50 yrs.			
	Incandescent	**CFL**	**LED**
Capital Cost	$ 54.75	$ 109.50	$ 438.00
Operation Cost (Over the period of 30 years)	$ 40,825.65	$ 9,725.22	$ 6,825.72
Replacement Cost (Over the period of 30 years)	$ 4,507.57	$ 1,259.25	$ 438.00
Total Cost for 30 years	**$ 45,387.97**	**$ 11,093.97**	**$ 7,701.72**
Operation Cost (Over the period of 50 years)	$ 68,040.93	$ 16,205.04	$ 11,361.60
Replacement Cost (Over the period of 50 years)	$ 7,548.93	$ 2,171.39	$ 1,020.54
Total Cost for 50 years	**$ 75,644.61**	**$ 18,485.93**	**$ 12,820.14**
NPV for 30 years duration	**$ 42,418.66**	**$ 10,368.19**	**$ 7,197.87**
NPV for 50 years duration	**$ 70,695.89**	**$ 17,276.57**	**$ 11,981.44**

With positive Net Present Value, using LED bulbs saves approximately $3000 for 30 years' duration as opposed to CFL bulbs, and yields almost $6500 net present worth profit when calculated for 50 years' duration.

4.2. Environmental Impact of Energy Conservation

Studies have shown that the major contributors to global warming and climatic change are the increasing levels of greenhouse gases and carbon dioxide in the atmosphere. Al-Ghamdi and Bilec, (2015) studied a building's life cycle and the related environmental and human health impacts from the buildings' energy consumption. The results revealed considerable environmental impact from various sites in the U.S. and international locations with significant greenhouse gas emissions ranging from 394 to 911 tons CO_2 equivalent. The energy sector, which includes energy production, conversion, and use, accounts for 84% of greenhouse gas emissions, as well as 80% of emissions of NO_x and 96% of sulfur dioxide. Strict policies to alleviate greenhouse gas and CO_2 emissions will not only slow climate change, but also improve air quality. Fig. 9 shows an example of how CO_2 level may affect an ecosystem. As a result, it is imperative to save on energy and make a positive contribution by being as energy efficient as possible. Saving approximately 50% of the overall energy usage of one home gives us a glimpse of the overall potential energy savings if all buildings incorporated green measures.



(Picture Source: Fourth National Climate Assessment 2018)

FIGURE 6. EFFECT OF CO2 ON CLIMATE CHANGE.

4.3. Social Impact of Energy Conservation

The social impact of the sustainable building evaluation is determined by calculating the reduced greenhouse gas emission and its expected social cost taken from LEED v4. Kılıç and Altun (2018) reported a case of energy-efficiency refurbishment that helped reduce energy consumption of the building, eventually decreasing operational costs and carbon dioxide emissions in a very short payback period. Reduction in energy consumption of the building led to energy-cost savings of $169,725 per year. Carbon dioxide emissions decreased by 87%. Fig. 7 shows the results to hazardous gas emissions according to the EPA's eGrid numbers. The results indicate the pollution intensities of each electrical sub-grid in the US.

Considering the above result of pollutant reduction, we get the following social benefit of reduced health cost (or less negative health impact) due to the reduced energy consumption and hazardous-materials emission in this LEED Platinum project.

As summarized in Table 11, with a positive NPV value, we can conclude that the said green building saves about $2565.45 for 30 years and $2853.17 for 50 years in carbon and greenhouse gas emissions. This building contributes positively to global health benefits by reducing the toxic gas emission into the environment. The increase in internal air quality is profitable to the residents' health and wellbeing, in turn benefitting the society from their productive work.

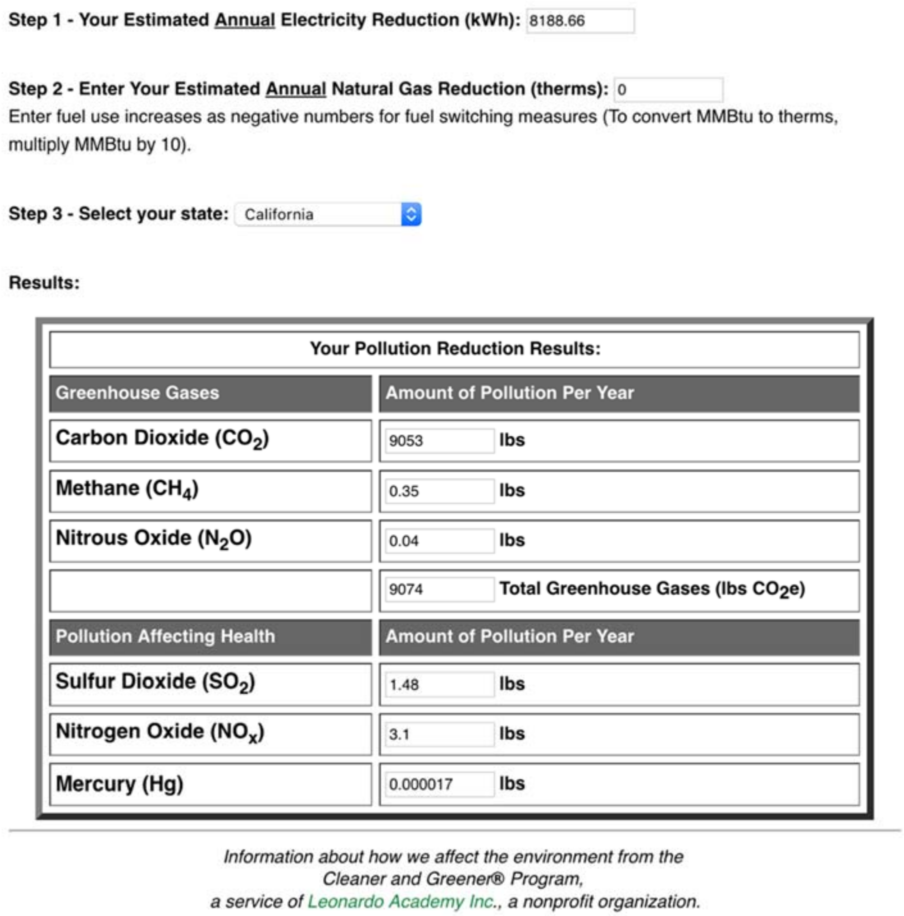


FIGURE 7. ONLINE GREEN HOUSE GAS EMISSION CALCULATOR.

TABLE 11. THE 30 AND 50-YEAR NPV OF HEALTH COST SAVING

GHG ==> $50/ ton = 4.12 ton * $50	=	$206
SOx ==> $977/ton = 0.00067 ton * $977	=	$0.655
NOx ==> $59/ton = 0.00141 ton * $59.	=	$0.0832
Total Annual Health Cost Saving	=	$206.74
30-Year NPV with 7% discounted ratio	=	$2565.45
50-Year NPV with 7% discounted ratio	=	$2853.17

V. CONCLUSIONS

This paper analyzes the value of water conservation and energy conservation in a LEED Platinum green building project. This analysis consists of an integrated TBL (Triple Bottom Line) procedure to consider Economic (Profit), Environmental (Planet), and Social (People) perspectives. The results show obvious economic benefit from water conservation with a simple payback period of less than 3.5 years. The environmental and social benefits of water conservation also include enhanced agricultural production and improved life quality. In contrast, as shown in Table 12, due to a high initial investment cost of insulation and energy-saving equipment, the net present value of energy conservation enhancement remains significantly negative after a building lifespan of 50 years. To gain support of energy conservation measures in a green building project, there must be sufficient incentives due to the environmental and social benefits of energy conservation. Efforts and initiatives from public policies and incentives are necessary to support the continuous advancement of energy-conservation technologies developed and applied to future green building projects.

TABLE 12. SUMMARY OF TBL ANALYSIS ON WATER AND ENERGY CONSERVATIONS.

	Water Conservation in the LEED Platinum Project	*Energy Conservation in the LEED Platinum Project*
Economic Impact	**30-yr NPV: $7845** **50-yr NPV: $6418** - Payback in 3 years - It is clear that investing in appliances designed to reduce water usage result in substantial savings	**30-yr NPV: -$26,144** **50-yr NPV: -$24,781** - The high cost of construction yields a negative value with no payback time possible. Need to consider the overall impact of energy reduction.
Environmental Impact	- Lowers carbon emissions - Reduces soil erosion - Lessens irrigation withdrawals - Protects wildlife	- Lowers greenhouse gas and carbon dioxide emissions - Improves air quality
Social Impact	- Greater access to low-cost water - Provide more water for agricultural crop yield	- Less pollution - Enhance in global health - Improves residential wellbeing

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