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# Economic feasibility of campus-wide photovoltaic systems in New England

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ABSTRACT

Compared to the national average residential retail electricity price, Connecticut (CT) had the 4th highest electricity price in the country with 19.23 cents/kWh in September 2015, nearly 50% higher than the national average for price of electricity. This study aims to assess the economic feasibility of the solar PV systems at the campus under realistic constraints, by analyzing actual data from the solar array on campus. The project focused on the economic feasibility of solar PV systems on campus with physical, spatial, and practical constraints that result in a project to deviate from theoretical (estimated) values. To achieve that, the prediction of the PV power generation from the building was developed and compared with the actual (measured) data.

The average payback period of a campus-wide PV system was calculated as primarily 11 years, within a range of 8–12 years, and was estimated to reduce overall building operating expenses by $250,000, or 8%. The economic parameters such as NPV and IRR also validated the investment worthiness. The results of the study could be used to analyze or further develop feasibility studies of PV systems at other universities in Connecticut and neighboring states that share similar climatic characteristics and economic factors.



## 1. Introduction

In 2014, the U.S. generated about 4093 billion kWh of electricity, of which approximately 67% were derived from fossil fuels, namely coal, natural gas, and petroleum. The share of renewable energy sources in the electricity grid were minimal, with electricity from wind contributing 4.4%, and solar 0.4% [1]. The problems are exacerbated not only due to consumption of non-renewable fuel sources for electricity generation, but when these facts are evaluated in light of the 2015 United Nations Climate Change Conference, also known as the 2015 Paris Agreement to Combat Climate Change, in which participating countries have agreed to work towards keeping global temperature rise below 2 °C compared to pre-industrial levels [2].

The Paris Agreement acknowledges that meeting this goal will require all countries to take steps to curb their greenhouse gas emissions as soon as possible. Even before signing of the international Agreement, the U.S. had committed to reduce its greenhouse gas emissions by 26–28% from the 2005 levels by the year 2025 [3,4]. Considering that the electricity sector was the largest source of U.S. greenhouse gas emissions in 2013 and was responsible for 31% of the total amount of 6673 million metric tons of $CO_2$, it is evident that policies and agreements that aim to curb greenhouse gas emissions would not succeed by disregarding the electricity sector [5].

Switching to renewable forms of energy has important economic and social benefits in addition to direct environmental benefits in the form of less pollution derived from energy generation. Creation of new green jobs, developing a more resilient energy infrastructure, and enabling a more competitive energy market would benefit the society overall while opening new markets and sectors for growth [6].

A necessity for solar PV technology to gain a foothold and provide a noticeable portion of grid electricity in the U.S. is that cost of electricity from solar PV must be economically competitive with other, more conventional forms of electricity generation [7]. This

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requirement by itself may not be too difficult as historical trends indicate a rapidly declining cost for solar PV technologies and an exponentially increasing installed capacity, as presented in Fig. 1.

Solar PV applications in the U.S. were not distributed uniformly. In 2015, almost 40% of distributed PV capacity was located in California, and the next 9 top states had a share of 44%. The remaining 40 states and the District of Columbia shared the remaining 16% installed capacity. As of September 2015, Connecticut was the 10th state with the largest installed solar PV capacity with 129 MW [11].

Through research efforts via the Sunshot Initiative under the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy, the cost of solar PV has been reduced drastically in recent years. A significant drop in utility-scale cost of electricity from PV projects has been reported in a few years since program initiation, with installed costs dropping from 21.4 cents/kWh in 2010 to 11.2 cents/kWh in 2013, with a further goal to reduce costs to 6 cents/kWh by 2020 [12]. Even with the 2013 unit price, solar PV is already cost-competitive with traditional energy sources for electricity generation in certain states and regions. The electricity price in Connecticut is one of the highest in the nation. Compared to the national average residential retail electricity price of 13.06 cents/kWh, Connecticut had the 4th highest electricity price with 19.23 cents/kWh in September 2015, nearly 50% higher than the national average for price of electricity [13].

Ma et al. [14]. investigated the quantified impacts of climate change on the future performance of PV roof system with a general electricity load and legal maximum size of solar array. The morphing method in the study was employed and simulated the long-term implementation of the systems in Australian states. Results show that for the PV system in the majority of cities, a 10–20% increase of economic costs between the 2030 and 2050 climate scenario would be required.

A study conducted by Baurzhan et al. [15]. shows that with an estimated annual rate of decrease in PV system costs of 4% and 7.67% in Sub-Saharan Africa, solar home systems are expected to become very competitive with conventional diesel electricity generators within 9–17 years. This study also insists of necessity of government incentives for the initial development in PV market. A similar cost-effective policy study [16] was conducted in India.

The Desert Research Institute [17] installed eight solar PV systems in Nevada with total nameplate capacity of 2.4 MW. The PV systems supply approximately 40% of total electricity used at DRI's two campuses. For the six systems larger than 50 kW, the simple payback period of 14.4–26.7 years were estimated, and 25 year return on investment showed double for some systems. Another solar PV feasibility study [18] details the multi-level estimation methodology used to estimate rooftop PV potential in the commercial and residential sectors in three states including California, Arizona, and New Jersey. Those three states account for two-thirds of the cumulative installed PV capacity in the U.S. The estimation methodology in the study shows that rooftop PV could provide 35%, 43%, and 61% of state electricity demand in New Jersey, Arizona, and California, respectively. The paper concluded that these states could increase current installed distributed PV capacity by 20, 30, and 40 times, respectively.

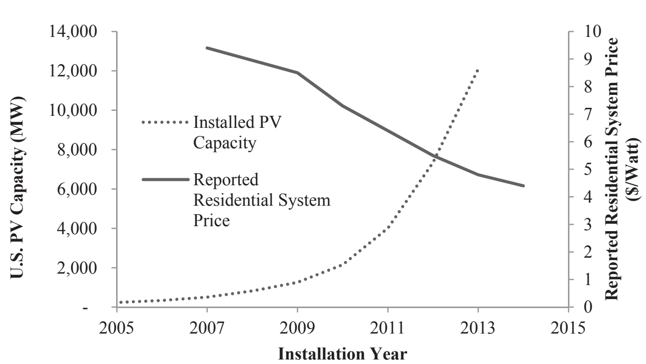


**Fig. 1.** U.S. Solar PV installed capacity and reported residential system price [8–10].

Perhaps an equally significant barrier to further advancing the system-wide integration of solar PV would be the lack of public awareness of the potential benefits of the technology. The social and economic barriers of actual and perceived cost differential between electricity price of solar and conventional sources of energy, together with a lack of awareness of the potential applications of PV technology into the built environment remains to be solved for solar PV to achieve desired market penetration.

University campuses are prime targets to implement solar PV technology for multiple reasons. They act as incubators for new ideas and places where research takes place. They also educate future generations not solely in their respective discipline, but also by the physical environment that they are exposed to. Hence, exposure to solar PV through campuses combined with effective communication on generation rates and the feasibility of the system would contribute towards overcoming the social and economic barriers related to solar PV technologies. A more pragmatic reason for campuses to implement solar PV would be the American College and University Presidents' Climate Commitment (ACUPCC) agreement, where commitments are made to reduce campus-wide greenhouse gas emissions and environmental impacts. There were 679 signatory institutions as of 2014, which cumulatively represent 41.6% of U.S. students in higher education [19,20]. As was discussed previously, an effective policy aiming to curb greenhouse gas emissions must take energy generation into account.

A 42 kW PV system and a 50 kW wind turbine system were installed to reduce energy use from the electrical grid consumption at West Texas A&M University (WTAMU). Alternative Energy Institute (AEI) [21] at WTAMU performed the installation of the PV and wind turbine systems and conducted feasibility study. The AEI also developed the solar and wind maps that show potential renewable energy places in Texas.

The goal of the study was to assess the economic feasibility of expanding solar PV systems at the University of New Haven (UNH) campus under realistic constraints, by analyzing data from a recently implemented solar array on campus. To achieve that, the prediction of the PV power generation from the building was developed and compared with the actual (measured) data. The results of the study could be used to assess the feasibility of PV systems at other universities in the state of Connecticut (CT) that share similar climatic characteristics and economic factors. Solar energy generation was estimated by using actual weather data and by determining favorable roof pitches and cardinal directions of UNH buildings. The payback periods were estimated individually for each building and optimal buildings have been identified. Other universities especially in CT and the New England region could directly benefit from the economic analysis presented here as they would have similar, if not exactly the same, electricity costs as well as offered incentives.

## 2. Background

### 2.1. University of New Haven (UNH) campus

UNH is located in West Haven, Connecticut, and thereby lies in the Northeast region of the U.S. A solar insolation map (see Fig. 2) developed by NREL in 2012 indicates that the state of CT overall has 4.5–5.0 kWh/$m^2$/day of PV solar resource [22], which places the region in an average rating for solar resource. As for other climatic