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Proposal Title: Integration of Solar Thermal Energy at Rutgers University

Total Number of Pages (not counting cover pages): 9

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200 word (maximum) summary of the proposal or video:

Installation of solar water heaters on the flat top roofs of residence halls on College Avenue and Cook-Douglass campuses represents an efficient means of lower the university's energy consumption from the grid and its effective carbon footprint. With an estimated total cost of $1,102,104 for hardware, permitting, inspection, and installation of these systems on nine dormitories and three laboratories at Rutgers, the systems could potential save $742,894 per year on hot water when displacing electrical water heaters or $62,160 per year when displacing natural gas. The total energy savings of the installed systems is estimated at 208,620 Therms or 6,108,000 kWh annually. This is equivalent to a reduction of approximately 1,106 metric tons of CO_2 according to figures from the EPA [12]. Furthermore, implementation of solar water heaters at Rutgers University could raise public awareness of solar thermal systems as efficient renewable energy sources both domestically and commercially.

Integration of Solar Thermal Energy at Rutgers University

By Ian Stewart

I. Introduction

As the largest institution for higher education in the state of New Jersey, Rutgers University is tasked with supporting the energy needs of a combined student body of 67,000 undergraduate and graduate students, as well as some 22,000 faculty and staff members [1]. This includes the operation of facilities across multiple campuses in Piscataway, New Brunswick, Newark, and Camden. Dormitories, academic buildings, stadiums, administrative buildings, computer labs, and bus systems among others, all contribute to the energy bill of the University and ultimately, to its carbon footprint. Given Rutgers-New Brunswick's position as a national research university and its research-intensive classification by the Carnegie foundation (Rutgers-New Brunswick is classified as RU/VH) [2], it is no surprise that the university has a comparably high energy requirement. In fact, between 2013 and 2014 Rutgers required a total of 546,703,576 kWh of electricity and 40,213,110 Therms of gas to support its campuses [3] (This figure includes consumption by Rutgers Biomedical and Health Sciences). In comparison Penn State University campuses consume an estimated 300 million kWh of electricity annually [4] and the University of Maryland-College Park used approximately 270 million kWh of electricity in 2011 [5].

To meet these high energy demands, Rutgers produces roughly 134 million kWh per year from two cogeneration plants on Busch campus and Rutgers Biological and Health Sciences in Newark [3]. The university also produced 10,990,726kWh between 2013-2014 from the Livingston campus photovoltaic solar installation [3]. While cogeneration plants represent an efficient means of gaining additional useful heat energy from conventional electricity generation,

they still must consume fossil fuels (natural gas in the case of the Busch cogeneration plant) and emit green house gases into the atmosphere. In addition, the Livingston solar panels only produce roughly 6% of the combined Busch-Livingston energy needs. The disparity between consumption and production can be seen in Figures 1 and 2 below [3].

Figure 1

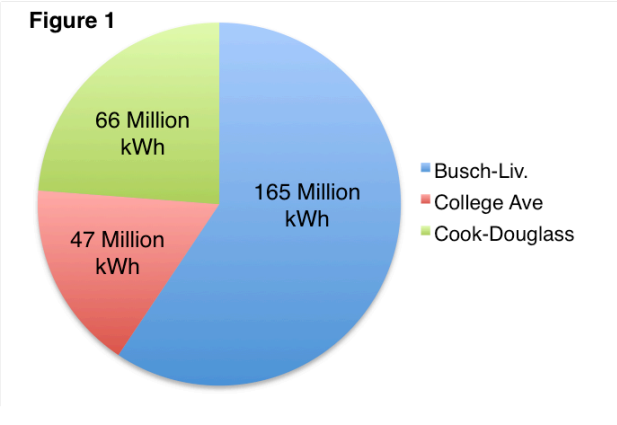
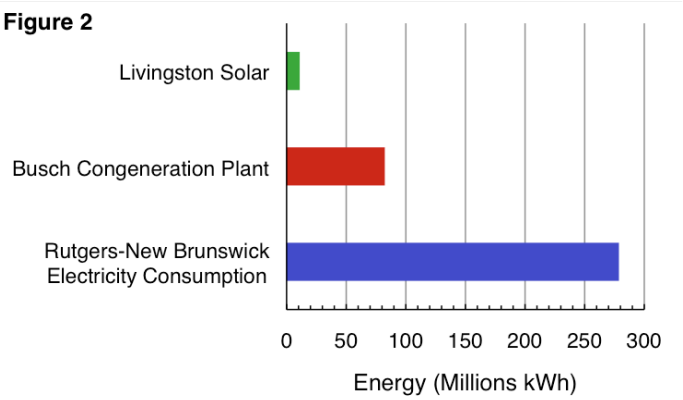


Figure 2



Given that renewable energy at Rutgers, namely photovoltaic solar power, still accounts for so little of the energy budget, it is crucial for the university to continue investing in renewables in order to reduce its carbon footprint and the amount of energy it purchases from the grid.

Implementation of solar thermal energy with the installation of solar water heaters at Rutgers University would effectively reduce the amount of energy Rutgers purchases from the grid as well as the university's CO_2 emissions. Solar water heaters have been widely deployed in China, Europe, Japan, and Israel in order to supply hot water to homes and businesses throughout the year, while simultaneously lowering the energy needs of the building from conventional energy sources (i.e. oil and natural gas). Solar water heaters represent an attractive renewable energy source, with efficiencies of up to 74%, that is largely overlooked in the United States in favor of the more popular photovoltaics. However, since heating water accounts for about 20% of household energy use in the United States [5] and since dormitories and other campus facilities (dining halls and laboratories) likewise require comparable amounts of energy for hot

water, installation of solar water heaters on campus is an efficient solution to lowering Rutgers external energy consumption. In fact, a recent study at The City University of New York indicates that deployment of solar water heaters in New York City dormitories could result an energy savings of 449,220MMBtu annually and reduction in green house gas emissions by 1,331 tons per year [6].

II. The Plan

Since hot water is currently supplied to Busch and Livingston campus via cogeneration plant and with the current high temperature water line replacement for this system costing a projected $8 million dollars [7], this proposal recommends the installation of solar water heaters on College Avenue and Cook-Douglass Campuses. College Avenue has several residence halls including Tinsley, Demarest, Brett, and Clothier, with the addition of the newly completed Residential Honors College and the soon to be completed 14-story university apartments: "The Yard." The honors college and the new university apartment building (slated to house approximately 440 students) will no doubt increase the total energy consumption of the campus, which stood at roughly 47 million kWh of electricity and 2.5 million Therms of gas two years ago [3]. The need for hot water in these buildings also makes them an attractive option for solar water heater installation.

Cook-Douglass also features several residence halls including: Jameson, Nicholas, and Lippincott as well as university laboratories including: the Institute of Marine and Coastal Sciences, the Food Sciences Building, and the McLean Research Laboratory that no doubt contribute to the energy bill of 66 million kWh and 3.8 million Therms of gas [3]. These facilities, along with the newly finished Institute for Food, Nutrition and Health, are also prime targets for solar water heater utilization.

The Department of Energy has concluded that solar water heaters can provide 50-60% of a building's hot water needs [6]. In fact, solar water heaters installed on a dormitory at American University saved a quoted 17,385 Therms of natural gas annually, equivalent to 509,000 kWh of electricity [8]. At $0.298 per Therm of natural gas provided by New Jersey Natural Gas [9], the total financial savings for the dorm stand at $5,180 per year for gas heating units if it was located in New Jersey. At $0.1216 per kWh of electricity supplied by PSE&G [9], the financial savings would be $61,894 per year for electrical units. Commercial deployment of the system for large facilities can cost between $40 and $70 dollars per square foot in New Jersey [10]. Using costs estimated by Meister Consultants Group [6], a commercial unit would cost about $135,000 in New York City including installation, permitting and inspection, etc. However, solar water heater costs in NYC are admittedly much higher than elsewhere with a $204 per square foot cost. The Meister Consultant Group estimates systems in other states such as Massachusetts cost roughly half as much as those in New York City. In order to reconcile this difference for a reliable cost estimate for commercial installation in New Brunswick, one can effectively halve the hardware cost given by [10] since the cost per square foot is less than half in New Jersey. Keeping installation and permitting and inspecting costs equivalent, one arrives at a reasonable estimate for deployment at Rutgers of $91,845 (See Table 1 below).

Table 1

	Hardware	Installation	Permitting & Inspection	Customer Acquisition	Total Cost
NYC Commercial Installation [10]	$85,592	$29,632	$8,000	$11,417	$134,641
NJ Estimated	$42,796	$29,632	$8,000	$11,417	$91,845

This figure puts the payback period (total cost divided by energy savings per year for a system) at 1.48 years when displacing electrical heating and 17.7 years when displacing natural

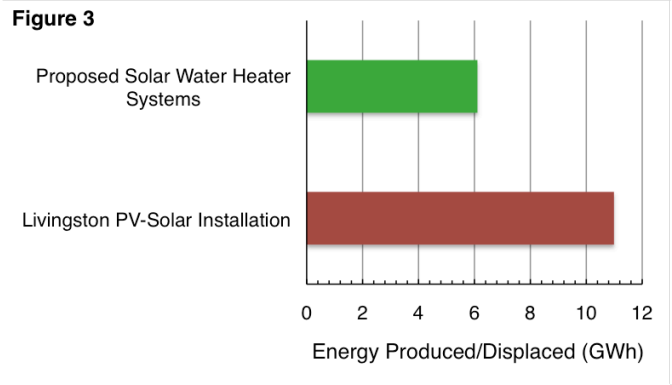
gas. The large difference between the two payback estimates can be largely attributed to low cost of natural gas in New Jersey however, the statistics are in line with estimates by the Meister Consultants Group. Integration of this plan would entail installing the system in a single building in order to gauge the effectiveness of solar water heaters over the course of a year. With the rooftop space soon to be available at the new university apartments at The Yard, it is a prime candidate to be a prototype for the system. If successful, the project would continue with installations of solar water heaters on Brett, Tinsley, Stonier and Clothier residence halls. The project could then be expanded to Cook-Douglass residence halls such as Lippincott and eventually on to the Cook-Douglass laboratories. A timeline of the implementation scheme for the project is shown below in Table 2.

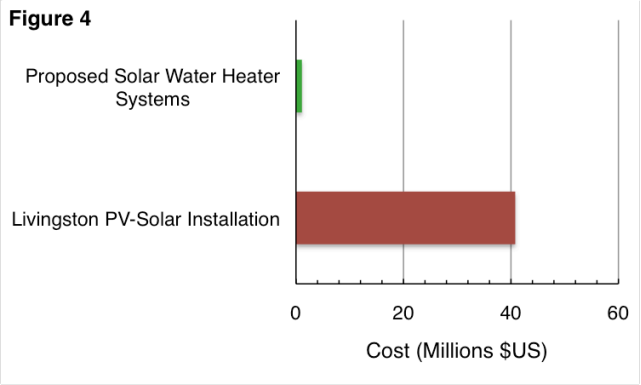
Table 2

Phase I: Test Phase	• Receive quotes for installation costs and price ranges for a solar water heater system for The Yard apartments • Begin installation of the system and monitor hot water bill for the building over the course of one fiscal year • Determine if energy savings are in line with this proposal
Phase II: Expansion on College Ave	• Install solar water heater systems on Mettler, Tinsley, Brett, Clothier, and Stonier Halls (These are all of similar design and have flat top roofing) • Monitor these five residence halls over the next fiscal year to determine if the energy and financial savings are proportional on the smaller residence halls as on Clothier and The Yard
Phase III: Expansion to Cook-Douglass Dormitories	• Install solar water heaters on Jameson, Nicholas, and Lippincott residence halls • Receive quotes for installation in Cook-Douglass Laboratories
Phase IV: Expansion to Cook-Douglass Laboratories	• Install solar water heaters on the Institute of Marine and Coastal Sciences, the Food Sciences Building, and the McLean Research Laboratory
Phase V: Future Plans	• If the program is successful in these facilities, solar water heaters could be installed on dinning halls or other potential buildings (including Gibbons Residence Halls and the Henderson Apartments) on these campuses • Solar thermal collectors could also be used to power dehumidification systems to lower air-conditioning bills on all four campuses especially during summer months

These residence halls and laboratories have been specified based on their flat roof designs and their potential demand for hot water. The flexibility and incremental nature of the proposal allows for small increases to the effective number of buildings with solar water heaters, allowing one to test the effectiveness of the system on each residence hall configuration before expanding the project to more facilities. Given the projected cost of a solar water heater at $91,845 from before, one can estimate the total cost from dormitory installation by multiplying this cost by the number of residence halls planned in the proposal (nine in total). The total cost for the purchase and installation of the systems is then slated at $826,605 for all nine residence halls. Estimating that the purchase and installation of solar water heaters on the three Cook-Douglass laboratories should be comparable to that of residence halls, one can arrive at a total $1,102,104 cost for all facilities. The energy savings for one year with these full installations would then stand at $62,160 (energy savings for one year $5,180 multiplied by the number of solar water heaters) when displacing natural gas and $742,894 when displacing electrical heating. These two cost estimates then have the same payback periods of 1.48 year and 17.7 years for electric and gas respectively.

In terms of energy savings, using the quoted energy savings from American University Dormitories [8] of 17,385 Therms or 509,000 kWh and multiplying by the number of facilities in the proposal, one arrives at an estimated 208,620 Therms or 6,108,000 kWh of energy. This is roughly half the amount of power generated by the Livingston solar panels annually (10,990,726 kWh [3]), however the 32-acre solar canopy project cost a quoted 40.8 million dollars with the aid of federal tax incentives [11]. Figure 3 and Figure 4 show a summary of the energy and cost comparison between the Livingston solar installation and the proposed solar thermal project.





In summary, the solar water heaters would generate a comparatively large amount of heat energy for the 12 proposed facilities and cost much less than previous solar installments on Livingston Campus.

Using EPA calculations [12], where the emission factor is given as 0.005302 metric tons of CO_2 per Therm of natural gas, and the total energy displacement of the project 208,620 Therms, the estimated reduction in CO_2 emissions is 1,106 metric tons. This is roughly the amount emitted by 230 average passenger vehicles over an entire year [12].

III. Conclusion

By implementing solar water heaters on College Avenue and Cook-Douglass Campus, the university will be producing an estimated 6 million kWh of energy every year and reducing the amount of energy it must pull from the grid to maintain its facilities. The reduction of roughly 1,106 metric tons of CO_2 will also help to mitigate green house gas emissions by the university in an era when energy efficiency and green technology have become vital to stymieing global warming and climate change.

More importantly, the installation of solar water heaters at Rutgers could help give more public exposure to solar thermal technology, which would raise public awareness of its availability as a potential alternative energy source. Residential use of solar water heaters is comparatively low in the United States and in New Jersey. With the cheap cost of installation

and generous federal tax incentives (30% tax credit) for residential use, solar water heaters are an efficient way of lowering household energy bills and lowering the domestic carbon footprint. The program could also give incentives for other universities to implement the use of solar water heaters on residence halls, especially in states such as California, Arizona, and Nevada, where sunlight is plentiful. As it stands, New Jersey consumes 713 Trillion Btu of natural gas, 446.1 Trillion Btu of gasoline, and 25.9 Trillion Btu of coal every year (2013 figures) [13]. Meanwhile it produces 348 Trillion Btu from nuclear plants and a meager 55.2 Trillion Btu from renewable energy [13]. As the flagship university of New Jersey, Rutgers can play a leading role in our sustainable energy future by continuing to invest in renewable technology, such as solar thermal energy, in order to pave the way towards more widespread use of green technologies in the state and elsewhere in the United States.

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