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The Decision to Install a Rooftop Photovoltaic System by a Small Business: A Case Study*

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Abstract: The potential of rooftop solar power has been identified as a main driver of clean energy adoption in an urban environment. While residential solar projects have lower capacity than commercial systems, residential solar represents most of the installation base for rooftop solar projects. Rooftop solar adoption in the commercial market lags behind residential solar installation. To better understand why this is the case, we conduct a case study of a small manufacturing firm. Based on the firm's energy demand and the physical attributes of its location, we study a 25-kilowatt solar array using the National Renewable Energy Laboratory's (NREL) System Advisor Model (SAM). Our empirical study evaluates the economic prospects of a rooftop solar installation project for the firm under study. This analysis sheds light on the financial ramifications of the adoption of solar panels by small, commercial firms in New York state.

Keywords: decision-making, incentive, photovoltaic system, solar energy, small business
JEL Codes: Q42, M21, D81

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1. INTRODUCTION

1.1. Setting the scene

Researchers now agree that when it comes to fossil fuel consumption, "business as usual" will exacerbate the environmental challenges such as climate change—also known as global

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warming—facing planet Earth. One important way to address these environmental challenges is to ensure that energy use in the future is sustainable (Chu and Majumdar, 2012). Related to this, we need to analyze how sustainable practices can be brought to bear on all aspects of human activity. Only then will future generations benefit from what Dasgupta (1996) calls the planet's "environmental resource base" in the way that the present generation does.

In this era of globalization, the expansion of world trade and industry has led to increased consumption of fossil fuels (Kibria et al., 2019). We use fuel to travel from one place to another and use fossil fuels in our homes, businesses, and public spaces. The influence of fossil fuels is everywhere. Because the energy supplied to individuals and households typically comes from local utilities, these individuals and households often do not have a choice about where their energy comes from (Braun, 2020). Despite the adoption of green technologies in recent years, the global fuel mix is still dominated by fossil fuels (Apeaning, 2021). This situation leads to two questions. First, if we are to address the scourge of climate change meaningfully, then how might we prioritize the transition from fossil fuels to renewable energy? Second, how might we safeguard our ability to conduct research designed to discover ways in which we might protect our planet's future? (Abbas et al., 2022).

The actual move away from fossil fuel consumption promises increases in global welfare. That said, the transition thus far towards renewables has been a gradual process, leading to a distinct lag in the projected efforts necessary to avoid the catastrophic impacts of ongoing climate change. The success of a nation's efforts designed to offset the effects of fossil fuel consumption depends on its technological capabilities and investment in green infrastructure (Nawaz et al., 2021). Therefore, to the extent possible, it makes sense for a nation to use recent technological advances to fight the deleterious effects of climate change. In the United States, some of the most promising technological advances have occurred in *renewable energy infrastructure* (Hoicka et al., 2021). Therefore, it makes sense for policymakers to take steps to encourage the widespread adoption of renewable energy infrastructure. Specifically, this involves focusing on and encouraging the broad utilization of renewable energy systems by home and business owners.

Using the rich research context of solar energy policy and the adoption of solar energy in the United States, we focus specifically on New York state. Residents of New York are contending with the transition towards renewables on multiple fronts. In the case of a non-residential solar system, projects can range in capacity from 25 to 200 kilowatts (KW) of nameplate capacity. Considering that residential rooftop installations are advertised at a maximum of 25 KW of total capacity, there is a greater degree of system complexity and scale in the case of commercial rooftop photovoltaic systems. In addition, the commercial market for renewable energy systems is adaptive, offering a wide variety of system configurations and products suited for different environmental and production conditions (VR, 2024). One way to see the iterative and adaptive nature of technological progress in renewables is to consider the case of microinverters, which are a component of new photovoltaic systems. These microinverters, tied to individual solar modules, are commercially unavailable at the scale of high-capacity solar panels meant for utility and industrial generation (400-500KW).

For any household or business, adopting renewables involves augmenting an existing energy infrastructure. As such, this decision calls for an evaluation of potential *benefits* and *costs* in each case (Shimada and Honda, 2022). To address the knowledge gap between the commercialized photovoltaic market and consumers, New York state policymakers have packaged and streamlined the process of "going green" for individual firms.[1] The New York Sun (NY-SUN) program—which is described in greater detail in Section 3 below—connects certified solar contractors in the state with local homeowners and businesses. This structure promotes cooperation between local utilities and contractors. At the same time, it provides access to economic incentives and resources of New York State Energy Research and Development Authority (NYSERDA).

Incentives for photovoltaic (PV) installation provide a path toward developing the user base for solar energy generation within a grid. These incentives[2] include offsetting the cost of purchasing and installing a solar panel system in a business, tax credits under the Inflation Reduction Act,[3] and New York state tax credits and rebates for installing one or more solar panels. In addition, there are several options for loans. These are the small business/not-for-profit On-Bill Recovery loans, small commercial participation loans, and large commercial/industrial loans offered through the so-called Energy Improvement Corporation.

The package of incentives for solar energy generation in New York state and a competitive installer market within the state have been effective in encouraging growth within the solar industry. Despite having a lower amount of peak sun hours than other states in the country, residential rooftop PV systems in New York have been adopted on a wide scale, supported by a rich incentive base (Parag and Sovacool, 2016). In comparison, the system of incentives available to non-residential properties has not, until recently, been as generous.[4]

1.2. Objectives

The primary objective of our paper is to shed light on how small businesses (firms)[5] in New York State go about the task of adopting clean energy infrastructure by focusing on the case of a particular small business, namely, DGM Leather, based in Brooklyn, New York. As we explain in more detail in section 2 below, our objective is significant because there are *very few* case studies of the solar PV system adoption decision faced by small businesses. Moreover, even the existing studies do *not* focus on the impact of higher intensity demands for energy that fall in the 25-200 kilowatts range.

In our case study, we use the motivation of a small business to install a rooftop solar PV

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[1] Go to https://www.nyseia.org/ for more details on this point. Accessed on 1 March 2024.

[2] Go to https://www.nyserda.ny.gov/All-Programs/NY-Sun/Solar-for-Your-Business/Financial-Support/Incentives-and-Financing for more details. Accessed on 1 March 2024.

[3] Go to https://www.nyserda.ny.gov/All-Programs/Inflation-Reduction-Act/Businesses for more details. Accessed on 1 March 2024.

[4] To see this, consider the following example. New York offers a 25 percent state tax credit for home solar systems, which can be combined with a 30 percent federal tax credit. However, unlike the NY-SUN rebate, available for homes and businesses, the state tax credit is exclusively for homeowners who install solar panels in their main residence. Go to https://www.marketwatch.com/guides/solar/new-york-solar-incentives/#:~:text=New\%20York\%20offers\%20a\%2025,panels\%20for\%20their\%20primary\%20residence for additional details. Accessed on 1 March 2024.

[5] In the remainder of this paper, we shall use the terms "business" and "firm" interchangeably.

system to get a better idea about the energy needs of a manufacturing firm and the financial profile of rooftop PV adoption in New York State.[6] DGM Leather occupies a 4,000-square-foot industrial loft space, and it employs 60 persons. For this business, energy needs fluctuate over time; they typically spike due to the seasonal nature of the demand they confront, and this feature is compounded by both the weather and production factors.

More generally, as noted by Bradford and Fraser (2007) and Grannell et al. (2014), the energy needs of small businesses such as DGM Leather fluctuate over time for various reasons. Seasonal variations, such as changes in temperature and daylight hours, impact the demand for heating, cooling, and lighting. Additionally, when this type of business operates during peak hours, it is likely to experience higher energy demand than businesses with more flexible schedules. In addition, technological advancements and the adoption of energy-intensive equipment also contribute to fluctuations, as newer technologies are likely to be more energy-efficient. Furthermore, economic factors and market dynamics can influence production levels and energy consumption for manufacturing small businesses. In sum, a combination of environmental, operational, technological, and economic factors leads to the dynamic nature of energy needs for small businesses like DGM Leather.

That said, the reader should note that weather impacts the production of solar panels, and the efficiency of these panels degrades over time, resulting in an overall decrease in energy production. To cope with rising electricity prices, DGM Leather is considering a move towards a solution that promotes sustainable energy use.

In this business's specific circumstance, the solar PV market in New York is attractive because of the favorable tax credits available for non-residential solar installation and existing capacity-base rebates. As such, this business has expressed an interest in adopting solar PV infrastructure primarily for economic reasons but also because it would like to promote what is sometimes referred to as "corporate social responsibility" (Lindgreen and Swaen, 2010). To this end, we contend that our research provides insight into how a niche-manufacturing firm incorporates clean energy considerations into its intertemporal economic decision-making. Now, before we proceed to the details of our analysis, let us first review the literature and related issues on the subject of our paper.

2. LITERATURE REVIEW

Rooftop PV installation for a profit-maximizing small business requires careful thought before initiating the project due to the nature and the magnitude of this capital investment. Our literature review is motivated by an understanding of the solar energy project from the point of view of a profit-maximizing firm. This firm pays specific attention to the structure of the installation process, as well as to logistical considerations. Consistent with the observations of Sun and Sankar (2022), in each stage of the installation process, direct and indirect costs incurred by DGM Leather are largely determined by the maturity of the local energy market, which can be measured by the number of ongoing installations at a given point in time.

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[6] See Bristow and Kennedy (2010) for a comparison of PV systems with other technologies for homeowners, small businesses, and large commercial and institutional entities.

In a market where independent contractors are competing against each other, the number of quotes distributed by an individual firm becomes a noteworthy attribute of the wider economic system. While costs, in general, in this system can be compared across a market and other states, in the case of commercial firms, in addition to the quoted prices, the business processing costs associated with a PV project are an important consideration.

For DGM Leather and, more generally, other small businesses, interruptions in energy supply and the impact of this interruption on production can have an adverse impact on the goal of profit maximization and, therefore, lead to this business abandoning its decision to invest in clean energy infrastructure (O'Shaughnessy and Margolis 2018). That said, if we were to make the decision to install a PV project in terms of benefits and costs, then it is important to recognize that the opportunity cost of undertaking this PV project is the next best alternative, which, for this firm, is the *status quo*. In other words, the default option if the PV project is not undertaken would be to continue to rely on the local utility company to provide electricity.

The literature demonstrates concern—see Dong and Wiser (2013)—for the stalled development of PV installations due to onerous permit processing. In this regard, a solar contractor is well suited to navigate the permitting process to varying degrees, where the value of its collaboration with customers is related to its ability to expedite the permitting process (O'Shaughnessy et al. 2020, O'Shaughnessy et al. 2022). While the time frames for the permitting process vary from state to state in the United States, it is generally understood that while permitting applications may be submitted remotely, an experienced firm is more likely to engage with permitting officials directly. This direct engagement can lead to faster turnaround times for permitting. We highlight these points in the installation process of PV systems to demonstrate the *complexities* associated with the choice of an installer.

Related to this notion of complexity is the concept of *trust* in the interactions between the consumers and the producers of PV systems. Fuller and Richmond (2013) contend that because solar PV installations do *not* fit into the traditional power delivery system, if the number of such installations is to increase, then the present legal and regulatory structure will have to address the needs of what they call the "consumer-producer hybrid." This will help create trust and attract potential investors to the installations market.

Even though trust is important, economic considerations of two kinds are important in determining the viability of new PV installations. First, consider the matter of *cost*. The question is: Are new solar PV installations competitive in terms of how much it costs to generate electricity from this power source? Reichelstein and Yorston (2013) analyze data from 2011 and point out that although commercial-scale PV installations are cost-competitive with fossil fuel power plants because of federal tax subsidies, new PV installations are not. Second, consider the matter of *subsidies*. The empirical analysis conducted by these authors demonstrates that commercial-scale PV installations are likely to reach what the authors call "grid parity" in about ten years, even if the federal subsidies are removed.

Given the importance of incentives—in the form of subsidies in the work of Reichelstein and Yorston (2013)—in determining PV installation decisions, Hsu (2014) continues this focus on incentives. However, her study focuses on the factors responsible for the adoption of PV systems by both *families* and *businesses*. This analysis shows that whereas businesses prioritize carbon emission reductions and their contribution to corporate social responsibility when making PV adoption decisions, families are a lot more concerned about *economic metrics* such as the cost of the PV system to be installed and whether subsidies are available to attenuate this installation cost.

Since DGM Leather is considering the rooftop installation of a PV system, it is interesting to ask what the literature says about the relevant factors when considering the rooftop installation of a PV system. Mauritzen (2017) analyzes over 100,000 solar PV installations in California between 2007 and 2014 and concludes that cost considerations are very significant but so are indirect factors such as the *number* of PV installations in a particular zip code and the *size* of the installations (also see Hsu 2018).

Economic decisions about PV system installation are affected by and also cause *uncertainty* in power generation owing to the variability of solar resources and changes in consumer behavior. How do these matters play out in Hawaii where electricity rates are already very high? Assane et al. (2019) shed light on this question. These researchers show that contrary to the concerns of some observers, the “old grids” in Hawaii can withstand a much higher level of PV penetration than what was previously understood about them.

Uncertainty is also a concern in the recent work of Alqahtani and Patino-Echeverri (2019). These researchers study how uncertainty about whether “business-as-usual” conditions will prevail and the extent to which buildings will comply with energy codes greatly affects the extent to which there will be cost savings and carbon dioxide emission reductions from the large increase in residential rooftop PV system installations in the Carolinas. What is salient for DGM Leather is this paper’s finding that there are plausible circumstances in which PV installation and the subsequent generation of electricity not only increases the *share* of total electricity generated by PV systems but that this kind of PV installation can have a non-trivial impact on the *reduction* in carbon dioxide emissions.

Finally, what impact do political factors such as one’s political party affiliation have on the decision to install rooftop PV systems in the United States? Lemay et al. (2023) focus on a large dataset to shed light on this and related questions. Their analysis shows that the fraction of people voting Democrat in a region has a positive effect on PV system installations. In addition, if the anticipated electricity *cost savings* from PV system installations are believed to be high, then this has a positive impact on installations in majority Republican regions. This dichotomy notwithstanding, the study shows that insufficient *knowledge* about PV systems and installation *costs* remain barriers to the greater adoption of PV systems. This implies that firms like DGM Leather should do all they can to familiarize themselves with how commercial PV systems work and how much it will cost to install a PV system.

Our review of the literature yields two key conclusions. First, we learn that there are *very few* case studies that have explicitly analyzed the solar PV system adoption decision faced by small businesses. Second, even when studies have focused on small businesses adopting PV systems, they have *not* addressed the impact of higher intensity demands for energy that fall in the range of 25-200 kilowatts.

Consistent with our observation in section 1.2 and the work of Hsu (2014), this lacuna in the existing literature needs to be addressed to *increase* our knowledge of the *factors* that determine the decision to adopt PV systems by small businesses. In this regard, it is worth acknowledging that metrics that look at the average price of electricity per watt based on installation cost rarely differentiate between residential and non-residential solar PV systems. Therefore, in the context of the lacuna identified above, it is important to understand where *small businesses* stand in terms of the economic incentives available to them. This will allow us to ascertain the extent to which the existing market for solar PV systems has caught up to the needs of independent small businesses.

To undertake our analysis of decision-making by DGM Leather about whether to install a rooftop PV system, we shall make use of a publicly accessible software model made available by the National Renewable Energy Laboratory (NREL), based in Golden, Colorado, in the United States.[7] This free software model is known as the System Advisor Model (SAM)[8]. This software model is useful in the planning stage of the solar PV system adoption decision, especially in designing efficient rooftop PV arrays (also see Udell and Toole (2019)). Using a combination of user-provided input values and a current internal library of PV system components and technical attributes, as well as weather data, we use the SAM to design a realistic system and then analyze this designed system from a technical and economic perspective. Several efficiency measures come out of the SAM model. Because this model is consistently updated, it gives stakeholders a thought-provoking, quantitative perspective on various aspects of their PV system installation decision.

We now proceed to analyze the installation decision problem faced by DGM Leather. Before we do so, it is worth reiterating the following two points. First, DGM Leather *is* a profit-maximizing firm, and therefore, the overarching goal of this firm is to ensure that all decisions made are consistent with this general goal. Second, selecting whether or not to install a PV system is a decision about *optimal input use* when the input choice involves selecting either an installed PV system as the source of electricity or relying on the local utility Con Edison (https://www.coned.com) to provide electricity.

3. ANALYSIS

On the assumption that DGM Leather faces a 15-year project lifespan, we economically evaluate two funding scenarios for this small business. In the first scenario, the PV installation project is self-financed. In the second scenario, the PV installation is financed with a loan of $49,215.97 for ten years at 5 percent interest per annum. These scenarios are based on discussions with the firm's management about its understanding of the total cost of the PV installation project at a scale of 25 kW, reinforced by information from the New York SUN program.[9] We also note that when evaluating these two scenarios, we have paid attention to

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[7] Go to https://www.nrel.gov/ for details on this laboratory. Accessed on 1 March 2024.

[8] Go to https://sam.nrel.gov/ for more details on this model. Accessed on 1 March 2024.

[9] The New York SUN program is a dynamic private-public partnership that is intended to drive growth in the solar industry and make solar technology more affordable for all New Yorkers. This program brings together and expands existing programs administered by the York State Energy Research and Development Authority (NYSERDA), the Long Island Power Authority (LIPA), Public Sector Enterprise Group (PSEG) Long Island, and the New York Power Authority (NYPA). In general, the goal of the program is to ensure a coordinated and properly supported solar energy expansion plan and a transition to a sustainable solar industry. Go to https://www.nyserda.ny.gov/All-Programs/NY-Sun\#:~:text=NY\%2DSun\%20has\%20multiple\%20resources,make\%20informed\%20decisions\%20about\%20solar for additional details on this program. Accessed on 1 March 2024.

three key metrics alluded to by the owner of DGM Leather. These metrics are the discounted payback period for the project, the net savings in year 1, and the net present value (NPV) of the project. We now break down the costs of the project and study the results from the SAM simulations for the self-financing and the loan scenarios.

3.1. Installation cost breakdown

The direct capital costs of the PV system are broken down into the unit costs of the modules and inverters, as well as the balance of the system equipment, installation labor, installer margin, and overhead. Additionally, the firm reserves a contingency fund at 4 percent of the subtotal. At a unit price of \$594.00, 54 units of the solar modules cost \$32,076 at the wholesale price. The unit price of the inverter is \$3,389.02, resulting in a total cost, for two inverters, of \$6,778.04. Material costs are hence equal to \$38,854.04. The balance of system equipment, installation labor, installer margin, and overhead costs are calculated in dollars per installed wDC or watts direct current.[10] The balance of the system equipment accounts for all technical equipment besides the module and inverter components. SAM NREL quotes the cost of system equipment at \$0.36 per each wDC installed, costing a total of \$9,516.19. The labor cost is calculated at \$0.16 per installed wDC, resulting in a cost of \$4,229.42. And finally, the installer margin is \$8,194.50 at \$0.31 per wDC. Putting these amounts together, the subtotal is \$38,854.04+\$9,516.19+\$4,229.42+\$8,194.50=\$60,794.15. Working with a contingency fund of 4 percent (\$2,431.77) brings the total direct cost to \$63,225.91.

Concerning the breakdown of direct capital costs, 61 percent of direct capital costs are owed to the module and the inverters. Of these material costs, 83 percent go to the modules, with the remaining 17 percent owed to the cost of the inverters. With regard to the other elements of the direct capital cost, system equipment accounts for 15 percent of the total, labor installation costs 6 percent, and installer overhead accounts for 13 percent of the direct capital cost. This cost breakdown captures the *numerous* costs associated with working with a contractor to complete the installation, and leverages NREL data on average price per watt associated with these contracting costs, allowing for use of the SAM across all solar markets.

To arrive at the total installed cost, several indirect capital costs need to be considered. The total of these costs represents a 16 percent share of the total installed cost. Permitting and environmental studies, Engineering and Developer overhead, and grid interconnections are valued based on their price per wDC. Engineer and Developer overhead costs represent 80 percent of the indirect costs, exceeding both the installer margin and the balance of system equipment. Permitting and environmental studies account for 13 percent, and grid interconnection accounts for 7 percent of the indirect costs. This cost breakdown is intended to evaluate direct quotes for the project.

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[10] The installed nominal nameplate capacity of a PV system is measured by counting direct current (DC) power in watt-peak and is denoted by wDC. Go to https://www.nrel.gov/docs/fy22osti/80694.pdf for additional details on this and related matters. Accessed on 1 March 2024.

Metric	Value
Annual AC energy in Year 1	38,336 kWh
DC Capacity factor in Year 1	16.6%
Energy Yield in Year 1	1,450 kWh/kW
Performance Ratio in Year 1	0.83
LCOE Levelized cost of energy nominal	7.12 ¢/kWh
LCOE Levelized cost of energy real	6.05 ¢/kWh
Electricity bill without system (year 1)	$16,571
Electricity bill with system (year 1)	$7,899
Net savings with system (year 1)	$8,671
Net Present Value	$37,276
Simple payback period	2.9 years
Discounted payback period	3.9 years
Net capital cost	$49,216
Equity	$49,216
Debt	$0

Table 1: SELF-FINANCING

Metric	Value
Annual AC energy in Year 1	38,336 kWh
DC Capacity factor in Year 1	16.6%
Energy Yield in Year 1	1,450 kWh/kW
Performance Ratio in Year 1	0.83
LCOE Levelized cost of energy nominal	3.24 ¢/kWh
LCOE Levelized cost of energy real	2.75 ¢/kWh
Electricity bill without system (year 1)	$16,571
Electricity bill with system (year 1)	$7,899
Net savings with system (year 1)	$8,671
Net Present Value	$48,943
Simple payback period	2.9 years
Discounted payback period	3.9 years
Net capital cost	$49,216
Equity	$0
Debt	$49,216

Table 2: LOAN

3.1.1. Base case analysis of NPV

Moving to a comparison of the two funding scenarios, the NPV of both the cash and the loan strategies were simulated using the same project parameters, which yielded our base case results. In the base case, the NPV of the self-financing scenario was $37,276 (Table 1), compared to the loan scenario, with a NPV of $48,943 (Table 2). So, relative to the self-financing scenario, the loan scenario results in a 31 percent higher valuation of the project. Even so, the project provides economic benefit to the firm *regardless* of the financing method, but the loan strategy is preferable based on a higher NPV. These results correspond to the logic that paying the total balance of the installation over a period of time will provide *greater* financial benefit relative to making a single lump sum payment.

To contrast the base case scenarios, cash flow over the 15-year project lifespan is considered. Overlaying the discounted payback period with the yearly cash flow gives us an idea of how the cash flow profile influences the length of the payback period. One hopes that the scenario with the higher net present value will also coincide with a shorter payback period.

In the base case, as shown in Tables 1 and 2, the self-financing and the loan strategies both reach their payback point in year 2.9. Looking more closely at the cash flow profile, the self-financing strategy has a negative cash flow equal to the net capital cost (Table 1). In addition to the monetary benefit of energy savings, state and federal tax incentives contribute to a positive cash flow in year 1 of $29,031 (Figure 1). In each year thereafter, the cash flow remains positive, beginning at $11,572 in year 2, and then slightly diminishes with each year until year 7, where after-tax cash flow reaches a minimum of $6921.50. After year 7, where the modified accelerator cost recovery system (MACRS) property tax depreciation effects cease, the cash flow increases slightly, reaching $8342 in year 15 (Figure 1).

Considering the loan scenario, the after-tax cash flow follows a negative trend from year 1 to year 10 of the project (Figure 2). In year 1, the cash flow peaks at $23,435, then drops to $600 in year 2, diminishing year after year until reaching a low of $847.61 in year 7. From year 7 to 10, the cash flow gradually increases. Year 10 coincides with the loan term ending, and the net capital cost at this time has been paid in full. As such, cash flow abruptly increases, reaching $6,468.56 in year 11, and then increases very slowly year

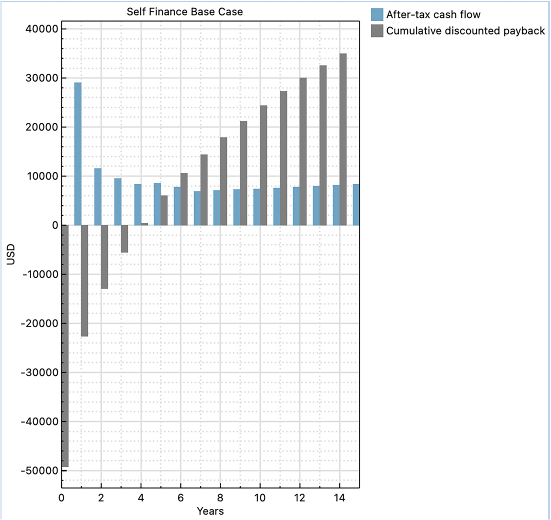

Figure 1

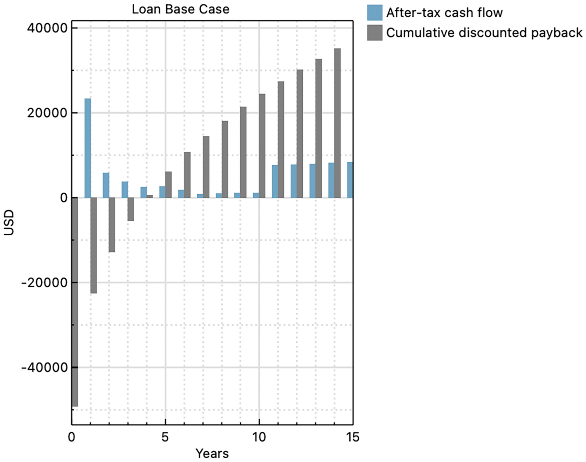

Figure 2

over year through project year 15 (Figure 2). The cash flow in the loan base case sets the expectations for the return on investment for the PV system and the *status quo* for the payback period for the investment in discussions with the firm. The payback period ends in year 2.9 of the loan scenario (Table 2).

The discounted payback period is an important metric to DGM Leather, and it is also of interest to us because of its usefulness in modeling the financial project under different economic conditions. The discounted payback period for the self-finance scenario is 3.92 years and it is 3.86 years for the loan scenario—both rounded to 3.9 years in Tables 1 and 2. Based on these metrics, not only is the project advisable in the base case, but the loan scenario is dominant using more than one criterion (NPV and discounted payback period). In both cases, the project breaks even in the first third of the project's lifespan. Therefore, the firm under study should take out a loan to finance the PV system, especially when compared to the standing interest rate on New York green bank loans, an alternative to the firm's loan strategy.

For context, NYSERDA offers a program for small business owners, the so-called on-bill recovery loan. This loan has a maximum amount of $50,000, in collaboration with a commercial lender at a competitive price, for a maximum period of 10 years. The annual percentage rate (APR) offered is the *Wall Street Journal* prime interest rate plus 2 percent, secured at closing. When writing our paper, this loan rate would be 8.5 percent, meaning that a loan for 50,000 at 10.5 APR for ten years has been tested for practical usage. In comparison, the loan terms that DGM Leather has identified are *more* favorable, with a lower APR during the same period.

To better characterize the economic benefit of the project in the base case, we also look at the after-tax savings in year 1. Inspecting Tables 1 and 2, the after-tax savings in year 1, in both scenarios, is $8,671, as a result of installing the PV system. These savings applied to the $16,571 yearly energy bill without the PV system account for *more* than one-half of the expected energy expenditure in the default scenario where solar is *not* pursued. Over time, the nominal value of these savings rises, but the proportion of energy generated by the grid-tied system remains the same. Additionally, in the base case scenarios, the installed cost per watt is less than the average $3.34 in New York State reported for 2023 by EnergySage (https://www.energysage.com/data/), at the cost of $2.86/wDC.

3.2. Modeling parameters

The SAM NREL software has 13 categorical inputs, of which some were left unaltered in our computation of the base case results reported in section 3.1.1. This means that the results reported in the analysis are a composite of chosen values and assumed system values. In some cases, specifically about the grid limit, the location, and resource tabs, the pertinent inputs were dictated by the weather file used. In the location section of the software, a single input was used to inform the location and the resource tab by accessing the National Solar Radiation Database (NSRDB)[11]. This allows us to use location data to inform expectations about energy output and albedo[12]. In order to alter grid limits, data has to be formatted using the time-step of the weather file, which itself has been taken from the above-mentioned database. Therefore, the grid limit category has not been altered.

With regard to "shading" and "layout," the SAM defaults to a model that assumes no losses due to shading. Based on the total physical footprint of the array, equaling less than half of the 4000 square foot roof space available to DGM Leather, it is expected that shading losses will be negligible. The lifetime and degradation category applies a default value of 0.5 percent to the annual alternating current (AC) degradation rate. All other inputs available in this category are available to enhance outputs for daily and hourly time steps and are outside the scope of our analysis. That said, it should be noted that the lifetime of the project under consideration in the base case is shorter than the projected lifetime of the technologies used. The project timeline reflects the current lease agreement between the building and the tenants.

In addition to these default values, inputs into the NREL SAM model require us to choose values. Our chosen values form the basis for calculating incentives based on the total cost of the installation. The project's financial profile is linked to the system's technical components as much as the funding method. To construct the system, we sought out wholesale modules and inverters for commercial use.

The modules used in our modeling exercise were taken from the OPEN EI database available through SAM NREL. In this case, a SIL 490HN module was used, which is a high-efficiency solar panel that has been optimized for commercial projects and where maximum power density and superior performance are essential. We chose this specific module because of the availability of a wholesale price quote and because DGM Leather has expressed interest in acquiring panels manufactured in the USA. For the 25KW range, these panels provided

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[11] The National Solar Radiation Database (NSRDB) is a serially complete collection of hourly and half-hourly values of meteorological data and the three most common measurements of solar radiation, i.e., of global horizontal, direct normal, and diffuse horizontal irradiance. Go to https://nsrdb.nrel.gov/ for additional details on these matters. Accessed on 1 March 2024.

[12] Albedo is the fraction of light that a surface reflects. If it is all reflected, the albedo is equal to 1. If 30% is reflected, the albedo is 0.3. Go to https://mynasadata.larc.nasa.gov/mini-lessonactivity/what-albedo for more details about this concept. Accessed on 1 March 2024.

an energy-efficient panel that worked within the project's physical bounds. To convert the cumulative AC electricity to direct current (DC), we chose the *Fronius Symo 10.0* inverter for the modeled system. This choice accommodates the desired size of the system without incurring losses stemming from AC to DC bottlenecking. AC to DC bottlenecking is a condition where the output in AC from the solar panels is limited in its conversion to DC for use from outlets and by the capacity of the inverters responsible for the conversion.

We specified a desired system capacity of 25 KW based on average monthly energy usage and the firm's energy usage and billing records from 2022 to 2023. Although we explain this point in detail below, we note that the estimated system size accommodates energy usage in low-intensity months, mitigating over half of the energy demand from the grid for the firm. Otherwise, the savings the system generates reduce the energy bill by more than one-half, responding to the high rate applied to energy demand. To achieve the designated array capacity of 25 KW, 54 SIL 490HN units are used in the system, offering 26.433 KW of nameplate DC capacity. Accounting for the total inverter capacity of 20.683 KWdc, the system achieves a capacity of 19.990 KWac, with a 1.32 capacity factor. Seeing that without achieving a capacity factor of at least 1.2, system reliability comes into question, the higher capacity factor is preferable to one that falls below the threshold of 1.2.

Installation costs were determined using the NREL format, and wholesale prices were used as the input price per unit. In the baseline model, each module costs $594.00 and each inverter costs $3,389.00. In addition to the cost of material, installation labor, installer margin, and overhead are also included in the direct capital cost. Inputs to both these variables were default values from SAM. The indirect cost and tax result in a $75,649.83 valuation of the total installed price, providing energy at the cost of $2.86/wDC. To calculate operating costs, the fixed operation and maintenance (O&M) cost was set at $9 a year. In the financial parameters tab, the loan scenario is modeled with a period of 10 years at a 5 percent interest rate, covering 100 percent of the total installation cost. To configure the cash strategy in the SAM, the loan conditions are voided by setting the terms of the loan to 0 percent of the total cost within the SAM.

To account for incentives, the maximum NY-SUN incentive was input into the model as a single value of $5,000. The federal investment tax credit was set to equal 30 percent of the total installed cost. Finally, the NY-Megablock incentives for the con Edison non-commercial region account for $1 per every watt of solar installed. To calculate the load and cost profile of the firm's energy use, billing records from 2022-2023 were used. In addition, the electricity rate was determined using geographic information from SAM, which accessed the SC-2 rate schedule from the utility, which charged $24.95/kW in demand rates. Also, these incentives include an exemption from the state and federal sales taxes for the development of the rooftop solar project.

3.3. Sensitivity analysis

To better understand the confidence we should have in the base case scenarios, we carried out sensitivity analyses for three of the model's key inputs. These three inputs are the discount rate, the project term, and the rebate conditions. In principle, each of these inputs can be expected to affect one or more of the three metrics that were emphasized by the owner of

DGM Leather and hence our focus on these three inputs. In addition, this kind of sensitivity analysis tells us how robust our base case NPV findings are about the two different funding methods– self-financing and loan.

3.3.1. The discount rate

We begin by varying the discount rate. *Ceteris paribus*, higher discount rates tend to emphasize costs that are borne in the "here and now" and deemphasize benefits that accrue in the future. The base case discount rate used in the simulations is 6.4 percent. Table 1 shows that in the cash base case, the project is valued at a net present value of $37,276. Similarly, Table 2 shows that the loan strategy has a net present value of $48,943 in the base case. We ran several simulations that yielded outputs for the NPV, the discounted payback period, and the cumulative discounted payback year after year. The discount rate input ranged in value from a low of 4.4 percent to a high of 8.4 percent, centered on the base case value of 6.4 percent. By studying the situation symmetrically, on both sides of the base case value of 6.4 percent, we learn more about the functional relationship between the outputs of interest and the altered values of the discount rate. We used the SAM software to simulate the outputs when the discount rate changed from 4.4 percent to 8.4 percent in increments of 0.2 percent.

Metric	**Value**
Annual AC energy in Year 1	38,336 kWh
DC Capacity factor in Year 1	16.6%
Energy Yield in Year 1	1,450 kWh/kW
Performance Ratio in Year 1	0.83
LCOE Levelized cost of energy nominal	3.80 ¢/kWh
LCOE Levelized cost of energy real	3.21 ¢/kWh
Electricity bill without system (year 1)	$16,571
Electricity bill with system (year 1)	$7,899
Net savings with system (year 1)	$8,671
Net Present Value	$54,086
Simple payback period	2.9 years
Discounted payback period	3.6 years
Net capital cost	$49,216
Equity	$0
Debt	$49,216

Table 3: LOAN; 4.4 PERCENT

Metric	**Value**
Annual AC energy in Year 1	38,336 kWh
DC Capacity factor in Year 1	16.6%
Energy Yield in Year 1	1,450 kWh/kW
Performance Ratio in Year 1	0.83
LCOE Levelized cost of energy nominal	2.63 ¢/kWh
LCOE Levelized cost of energy real	2.25 ¢/kWh
Electricity bill without system (year 1)	$16,571
Electricity bill with system (year 1)	$7,899
Net savings with system (year 1)	$8,671
Net Present Value	$44,773
Simple payback period	2.9 years
Discounted payback period	4.2 years
Net capital cost	$49,216
Equity	$0
Debt	$49,216

Table 4: LOAN; 8.4 PERCENT

Metric	**Value**
Annual AC energy in Year 1	38,336 kWh
DC Capacity factor in Year 1	16.6%
Energy Yield in Year 1	1,450 kWh/kW
Performance Ratio in Year 1	0.83
LCOE Levelized cost of energy nominal	6.10 ¢/kWh
LCOE Levelized cost of energy real	5.15 ¢/kWh
Electricity bill without system (year 1)	$16,571
Electricity bill with system (year 1)	$7,899
Net savings with system (year 1)	$8,671
Net Present Value	$46,258
Simple payback period	2.9 years
Discounted payback period	3.6 years
Net capital cost	$49,216
Equity	$49,216
Debt	$0

Table 5: LOAN; 4.4 PERCENT

Metric	**Value**
Annual AC energy in Year 1	38,336 kWh
DC Capacity factor in Year 1	16.6%
Energy Yield in Year 1	1,450 kWh/kW
Performance Ratio in Year 1	0.83
LCOE Levelized cost of energy nominal	8.15 ¢/kWh
LCOE Levelized cost of energy real	6.99 ¢/kWh
Electricity bill without system (year 1)	$16,571
Electricity bill with system (year 1)	$7,899
Net savings with system (year 1)	$8,671
Net Present Value	$29,979
Simple payback period	2.9 years
Discounted payback period	4.2 years
Net capital cost	$49,216
Equity	$49,216
Debt	$0

Table 6: LOAN; 8.4 PERCENT

In the increased (8.4 percent) discount rate scenario, Table 4 shows that the NPV of the *loan* financing strategy *fell* from $48,943 to $44,773. In the decreased (4.4 percent) discount rate scenario, Table 3 points out that the NPV of the loan financing strategy *rose* from $48,943 to 54,086. Regarding the *cash* financing strategy, Tables 5 and 6 are of interest.

In the increased discount rate scenario, Table 6 tells us that the NPV of the project, once again, *fell* from $37,276 to $29,979. Finally, in the reduced discount rate scenario, Table 5 demonstrates that the NPV *rose* from $37,276 to $46,258. In other words, reductions and increases in the discount rate have the *same qualitative impact* on the desirability of the PV project in both the cash and the loan financing scenarios.

We now focus on the discounted payback period in the differing discount rate scenarios under study. For instance, in the extreme case where the discount rate is 8.4 percent in the loan financing scenario, Table 4 shows that the discounted payback period *rises* to 4.2 years from 3.9 years. Looking at Figures 2 and 4, we obtain the same qualitative result. For the cash financing scenario, we also observe this rise in the payback period. Specifically, looking at Table 6, we see that the discounted payback period rises to 4.2 years from 3.9 years. Inspection of Figures 1 and 6 yields the same result, albeit in a less stark manner.

3.3.2. The analysis period

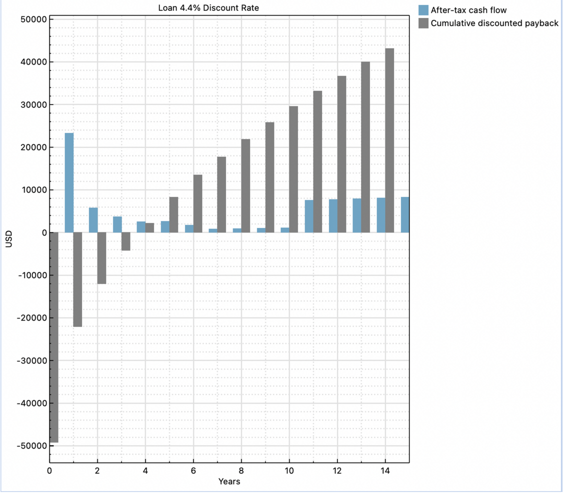
The second variable we altered is the analysis time period input, which is simulated in a range between 12 to 18 years, with tests varying in one-year increments. In this analysis, the lower endpoint, 12 years, represents a scenario where the business owner breaks his lease term but has begun to benefit from installing the PV system. Of the metrics considered, only this variable affects NPV; therefore, our results are discussed in terms of NPV. Table 7 shows that *increasing* the project lifespan for the cash financing scenario *increases* the NPV to $43,397 from $37,276, while the discounted payback period remains 3.9 years. Table 8 tells us that *decreasing* the project lifespan brings the NPV down to $30,115 from $37,276 (also see Figures 7 and 8). In the 18-year or *increased* project lifespan loan financing scenario, Table 9 shows that the NPV is $54,567, a clear *jump upwards* from the original figure of $48,943. In contrast, the *decreased* time period NPV is $41,286, which is obviously *lower* than the baseline figure of $48,943 (also see Figures 9 and 10). We see that when changing the lifespan of the PV project, the absolute value of the change in NPV is *larger* ($41,286-$48,943) when the project lifespan is *reduced* than when it is increased ($54,567-$48,943).

Metric	**Value**
Annual AC energy in Year 1	38,336 kWh
DC Capacity factor in Year 1	16.6%
Energy Yield in Year 1	1,450 kWh/kW
Performance Ratio in Year 1	0.83
LCOE Levelized cost of energy nominal	6.67 ¢/kWh
LCOE Levelized cost of energy real	5.55 ¢/kWh
Electricity bill without system (year 1)	$16,571
Electricity bill with system (year 1)	$7,899
Net savings with system (year 1)	$8,671
Net Present Value	$43,397
Simple payback period	2.9 years
Discounted payback period	3.9 years
Net capital cost	$49,216
Equity	$49,216
Debt	$0

Table 7: CASH; LIFE UP

Metric	**Value**
Annual AC energy in Year 1	38,336 kWh
DC Capacity factor in Year 1	16.6%
Energy Yield in Year 1	1,450 kWh/kW
Performance Ratio in Year 1	0.83
LCOE Levelized cost of energy nominal	7.76 ¢/kWh
LCOE Levelized cost of energy real	6.76 ¢/kWh
Electricity bill without system (year 1)	$16,571
Electricity bill with system (year 1)	$7,899
Net savings with system (year 1)	$8,671
Net Present Value	$30,115
Simple payback period	2.9 years
Discounted payback period	3.9 years
Net capital cost	$49,216
Equity	$49,216
Debt	$0

Table 8: CASH; LIFE DOWN



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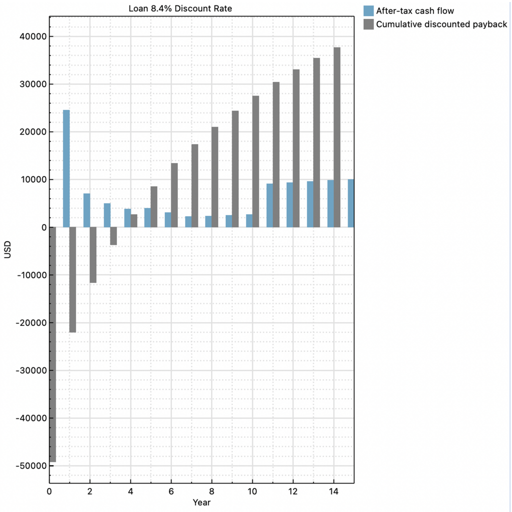

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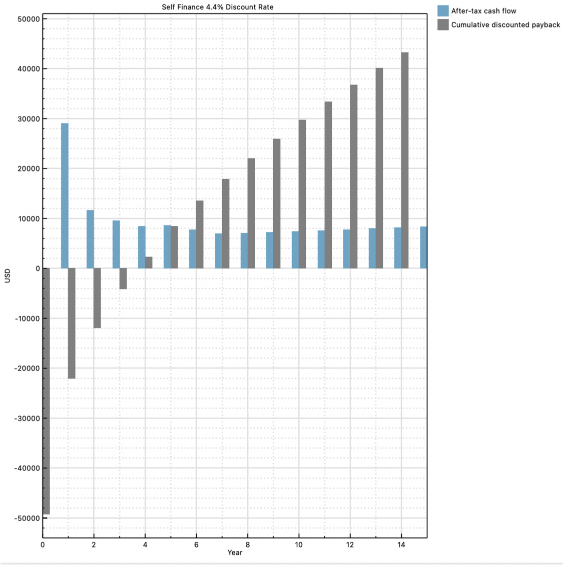

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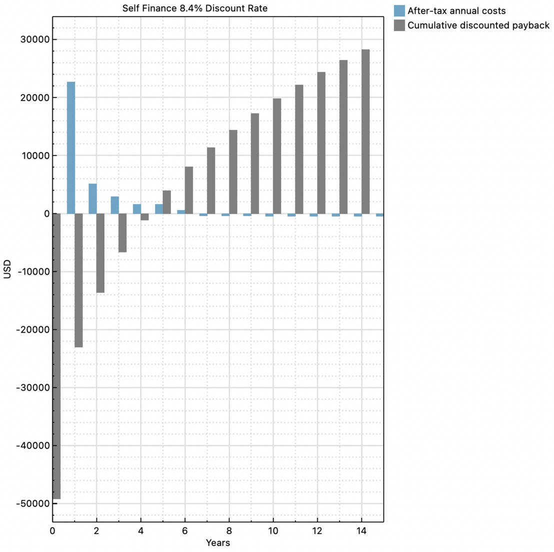

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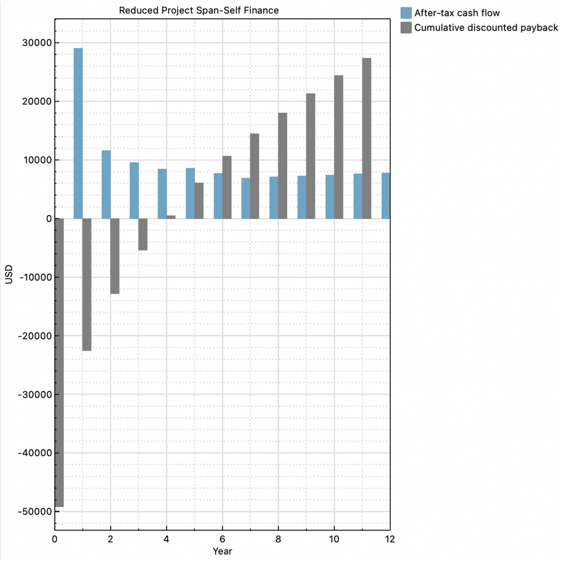

Figure 7

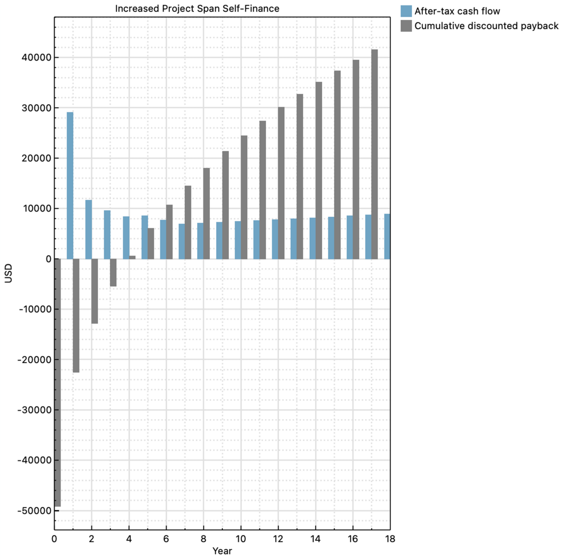

Figure 8

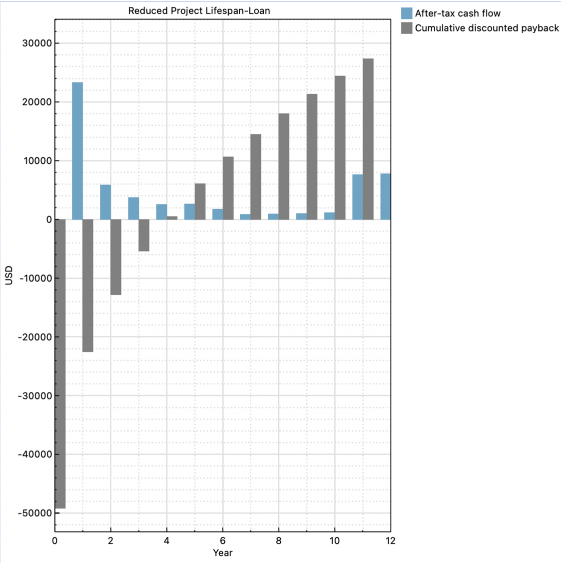

Figure 9

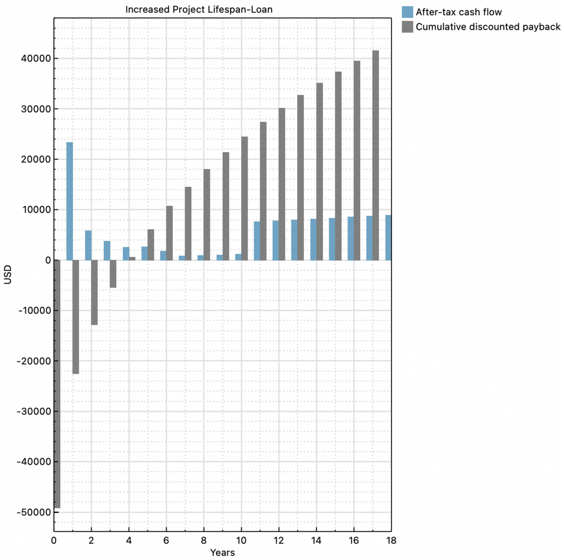

Figure 10

Metric	Value
Annual AC energy in Year 1	38,336 kWh
DC Capacity factor in Year 1	16.6%
Energy Yield in Year 1	1,450 kWh/kW
Performance Ratio in Year 1	0.83
LCOE Levelized cost of energy nominal	3.23 ¢/kWh
LCOE Levelized cost of energy real	2.69 ¢/kWh
Electricity bill without system (year 1)	$16,571
Electricity bill with system (year 1)	$7,899
Net savings with system (year 1)	$8,671
Net Present Value	$54,567
Simple payback period	2.9 years
Discounted payback period	3.9 years
Net capital cost	$49,216
Equity	$0
Debt	$49,216

Table 9: LOAN; LIFE UP

Metric	Value
Annual AC energy in Year 1	38,336 kWh
DC Capacity factor in Year 1	16.6%
Energy Yield in Year 1	1,450 kWh/kW
Performance Ratio in Year 1	0.83
LCOE Levelized cost of energy nominal	3.59 ¢/kWh
LCOE Levelized cost of energy real	3.13 ¢/kWh
Electricity bill without system (year 1)	$16,571
Electricity bill with system (year 1)	$7,899
Net savings with system (year 1)	$8,671
Net Present Value	$41,286
Simple payback period	2.9 years
Discounted payback period	3.9 years
Net capital cost	$49,216
Equity	$0
Debt	$49,216

Table 10: LOAN; LIFE DOWN

3.3.3. The incentive base

The third variable we tested was the evaluation of the project with changes in the incentive base. This analysis was informed by the concept of socket parity as a technical milestone in the adoption of PV energy. In addition, the sensitivity analysis we conduct reflects a range of scenarios that are practical in the sense that, by altering the federal investment tax credit (FITC) and capacity-based incentives as if the system were installed without claiming the incentives, the viability of an installation that is subsidized to a lesser degree can be evaluated for a business.

Metric	Value
Annual AC energy in Year 1	38,336 kWh
DC Capacity factor in Year 1	16.6%
Energy Yield in Year 1	1,450 kWh/kW
Performance Ratio in Year 1	0.83
LCOE Levelized cost of energy nominal	15.36 ¢/kWh
LCOE Levelized cost of energy real	13.06 ¢/kWh
Electricity bill without system (year 1)	$16,571
Electricity bill with system (year 1)	$7,899
Net savings with system (year 1)	$8,671
Net Present Value	$12,502
Simple payback period	8.5 years
Discounted payback period	NaN
Net capital cost	$75,650
Equity	$0
Debt	$75,650

Table 11: LOAN

Metric	Value
Annual AC energy in Year 1	38,336 kWh
DC Capacity factor in Year 1	16.6%
Energy Yield in Year 1	1,450 kWh/kW
Performance Ratio in Year 1	0.83
LCOE Levelized cost of energy nominal	21.07 ¢/kWh
LCOE Levelized cost of energy real	17.92 ¢/kWh
Electricity bill without system (year 1)	$16,571
Electricity bill with system (year 1)	$7,899
Net savings with system (year 1)	$8,671
Net Present Value	$-4,669
Simple payback period	8.5 years
Discounted payback period	NAN
Net capital cost	$75,650
Equity	$75,650
Debt	$0

Table 12: CASH

The NPV of the project *decreases* significantly for both the loan and cash financing strategies. Looking at Table 11 for the loan financing scenario, we see that the NPV of the project *declines substantially* from the baseline figure of $48,943 to $12,502. Similarly, inspecting Table 12, we see that in the self-financing or cash scenario, the NPV of the project *drops dramatically* from the baseline figure of $37,275 to a *negative* value of $-4,669, thereby making the project economically unviable. Put differently, with a negative NPV, self-financing the PV installation without accessing federal incentives would be to the *detriment* of DGM Leather, despite the energy savings. In both financing scenarios, the discounted payback period does not exist. If we consider the criterion of the simple payback period,

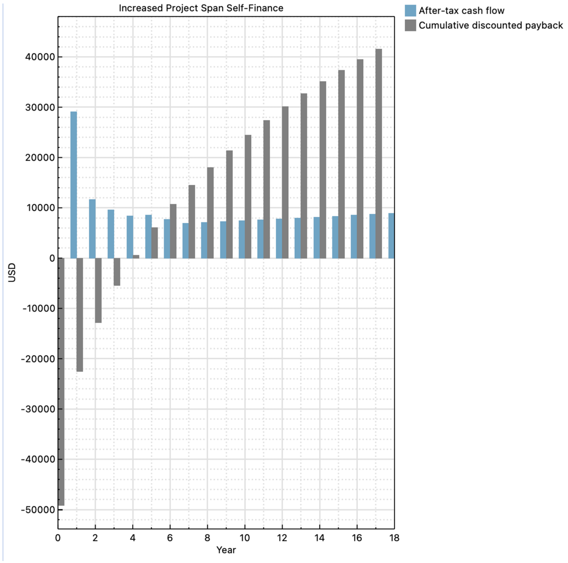

Figure 11

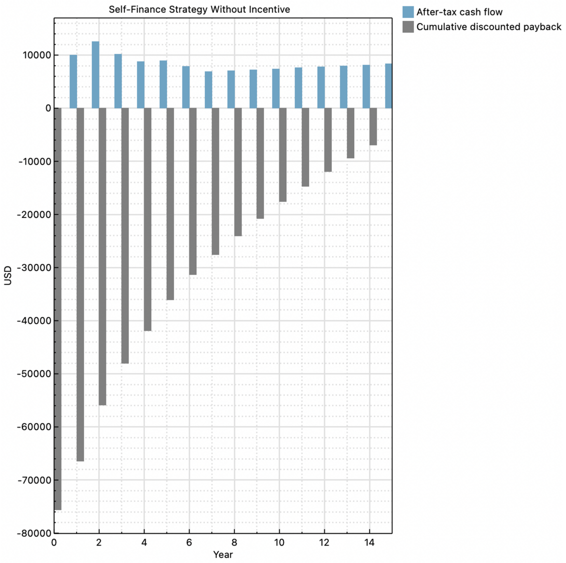

Figure 12

then Tables 11 and 12 tell us that this payback period *increases greatly* from 2.9 years in the baseline case to 8.5 years for both the loan and the cash financing scenarios. Figures 11 and 12 tell the same story but in graphical terms. In sum, the PV project's economic viability depends greatly on the available incentives. If these incentives are removed, then the project becomes unviable in the cash financing scenario and a lot less attractive but viable in the loan financing scenario.

3.4. Discussion

In most sensitivity analyses we conducted, financing the PV installation with a loan is preferable to self-financing. In general, it seems that market conditions for a solar PV installation are more favorable than expected by the firm under consideration. We note that throughout the sensitivity analyses, the NPV of the project remained positive in every scenario except one. In addition, we also evaluated the module price to determine the impact of price uncertainty. We find that between a range of $400-$800 per module, the project's payback period for either funding method will not exceed the fifth year of the project. These findings reinforce the point that the initial investment for the project will be paid in full in the first third of the term of the project.

The recommendations for the firm are primarily based on our understanding that the available incentives for commercial rooftop solar on the relevant scale (25KW) provide the basis upon which responses to rising energy prices and utility demand charges are built. Specifically, three different incentives factor into the decision to install a PV system. The capacity-based incentives decrease the net capital cost of the installation, which is being subsidized by the local utility. In year 1, the state and federal tax credits contribute to the year 1 cash flow. These three incentives work together to alleviate the initial capital investment cost and funds paid toward taxes in later years. In addition to these incentives, the potential PV project benefits from a state sales tax exemption and a depreciation scheme for the property tax.

The economic value of the project is rooted in its technical specifications, in particular, the system capacity. At a scale of 25 KW, the rooftop solar array meets monthly energy demands in the least energy-intensive months. Operation of the system will effectively eliminate the costs of energy consumption in these months. However, during the hot and cold seasons when energy needs are most intensive, the energy supplied by the rooftop solar system is *insufficient*. In these months, energy production stands to make surge costs and machinery load management more flexible, but it does not eliminate the costs associated with energy usage. In this case, the system directly addresses utility demand charges. That said, while this does not diminish the usefulness of a PV project as a hedge against future energy prices, the original goal of our case study, which is to inform the firm about the possibilities it confronts for sustainable energy use, has been met. In addition, the firm under study should now better understand the commercial solar market in the New York City area.

4. CONCLUSIONS

Based on the results of our case study, we can recommend to DGM Leather—and other similarly placed small businesses—that it ought to pursue the PV installation project and that it ought to use loan financing to fund the project. Using the NPV criterion, the loan financing option is preferred to the self-financing option. In pursuing the loan financing option, DGM Leather increases its economic flexibility during the term of the project by conserving capital, opting to fund the PV project over time with periodically scheduled payments. It should be noted that both funding options result in a positive NPV, and, the benefits of tax credits are a significant component of the positive NPV of the project. For example, the capacity-based incentive from the New York Megawatts program, at this current time, still offers a capacity-based incentive of \$1/w, which exceeds the \$0.30/w residential capacity incentive.

Without subsidies, rooftop solar in New York City does *not* achieve socket parity (Hagerman et al., 2015). At present, socket parity is only achievable in the states with the highest amounts of irradiance, such as Hawaii. In contrast, the lower 48 states (excluding Alaska and Hawaii) have yet to achieve parity. Under the Inflation Reduction Act, socket parity with subsidies has become more achievable with the capacity-based incentives available in the commercial solar market. However, despite the favorable economic environment these incentives provide, if commercial adoption of solar power continues to lag behind residential installed capacity, policies that support the incentive base described in this case study stand to lose coherence as far as climate mitigation efforts are concerned. While projects planned in the current period stand to generate a positive NPV with the scheduled diminishment of the subsidies, we believe that installed capacity is a factor that ought to be thought about carefully when pondering the boundary between the residential and commercial markets.

Based on the encouraging financial results, the firm under study intends to scale the project to meet its total energy demand with the cooperation of other independent firms to incorporate panels with higher capacity (Graziano and Gillingham, 2015). Considering the rooftop area available, it is possible to scale the project to accommodate this firm's entire energy demand. An analysis of a larger system design is a potential subject for further research, specifically in terms of how the system's design can influence the installation price (also see Gillingham and Bollinger, 2020).

Focusing on the effectiveness of the incentives, it is possible to measure the returns to increasing system capacity with current capacity-based incentives and then optimize the system size within the scope of the property that the relevant manufacturers share. It should be noted that while the project can be scaled up in terms of capacity within the current physical constraints, the use of different array modules or inverters may be necessary to accommodate increased capacity needs.

When capacity needs exceed the physical attributes of the property where the firm operates, participation in off-site solar projects can be considered a potential solution to the property's energy needs. In this regard, research that involves the growth of the solar project will benefit from data on the performance of the PV system after its installation, where the energy cost can be determined using real values for the installation cost.

Addressing the favorable evaluation of this commercial solar project in a landscape dominated by residential PV, there is a question as to why commercial adoption of rooftop solar is progressing at a slower rate than residential installation. We observe that this can be based on the influence of business-to-business marketing models that tend to discourage firms from participating in high-net capital projects involving solar sales. We note that in the past, DGM Leather has viewed unsolicited quotes as fraudulent. The benefits from the installation of PV systems are apparent in the rooftop PV installation project that we have modeled.

Even in unfavorable economic conditions that we explored in the sensitivity analysis in section 3.3, the PV project under study is economically *viable*. The business under consideration here considers the transition to clean energy as both necessary and unavoidable in the future. As such, the value of the current capacity-based incentive has prompted DGM Leather to inquire about participation in the NY-SUN program, and about potential collaboration with adjacent properties to expand the capacity of the rooftop solar array.

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