# Effect of Incentives on Profitability of Solar Technology in Texas, California, and District of Columbia

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Spring 2020

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## EXECUTIVE SUMMARY

This project's purpose is to determine and advocate for the best method to drive solar investment while increasing its profitability. The main statewide and national incentives for solar technology are described. These incentives include several benefits related to taxes, net metering, and solar renewable energy certificates (SRECs).

The MATLAB model used to compare these incentives is described. This model calculates the power production of a solar system for a given set of parameters. It then determines which of the incentives are used in each of several circumstances by varying type of solar technology and location. It calculates the costs of taxes and energy for the given parameters. Finally, it calculates the Present-Day Simplified Wealth (PDSW) for each of ten years under the given parameters.

The model graphs the PDSW over time for each location and type of solar technology used. It condenses these values into a Ten-Year Condensed Wealth, or TYCW. The TYCW is graphed while varying the cost of the solar system to illustrate the profitability of solar under the given circumstances. The TYCW is compared for each location to show the comparative importance of SRECs.

The strengths and weaknesses of SRECs are outlined. While they are a powerful incentive when properly and strictly codified, the inherent variability and lack of transparency in SREC markets can cause consumer indifference. Additionally, when utility companies and large-scale solar providers are not regulated, they can produce and sell enough SRECs to saturate the market.

SRECs are identified as the best incentive compared within the scope of this project. Extensive and strict solar set-asides are recommended, along with transparency measures and regulations on large-scale SREC generation.

# 1 INTRODUCTION

The United States is a global leader in solar technology. This has several benefits, like reducing the national carbon footprint and decreasing reliance on dwindling natural resources. Although solar technology is not always the best option, its use should be incentivized on national and statewide levels.

The purpose of this project is to determine and advocate for the most effective incentive for individuals and businesses to adopt solar technology while increasing its profitability. To do this, the comparative values of various incentives are analyzed using a MATLAB model.

## 1.1 Descriptions of Incentives

The major nationwide financial incentives to adopt solar technology are listed below. The model generated for this project quantifies these incentives and uses their expected yields in given situations to evaluate the profitability of solar technology.

### 1.1.1 Tax-Related Incentives

The incentives outlined in this section are either tax credits, tax exemptions, tax or deductions. Both deductions and exemptions are incentives that reduce taxable income. Credits directly reduce taxes paid.

#### 1.1.1.1 Business Energy Investment Tax Credit

The Business Energy Investment Tax Credit (BEITC) is an often-amended tax credit based on the amount spent by a business on renewable energy equipment each year. The incentive credits 26% of costs in 2020, 22% in 2021, and 10% in all following years.

#### 1.1.1.2 Renewable Energy Systems Property Tax Exemption

The Renewable Energy Systems Property Tax Exemption (RESPTE) is a tax exemption for the amount spent installing renewable technology. As an exemption, it reduces taxable property value by this amount, rather than directly crediting the installer of the technology. As such, its benefits are directly tied to the property.

#### 1.1.1.3 Franchise Tax Exemptions and Deductions

Franchise taxes are Texas' equivalent to corporate taxes. The total cost of a system may be deducted from the company's taxable capital, or 10% of the system's cost may be deducted from the company's income. Due to the complexity of corporate taxes and their variability by location, franchise tax exemptions and deductions have not been included in this model.

#### 1.1.1.4 Modified Accelerated Cost-Recovery System

The Modified Accelerated Cost-Recovery System (MACRS) allows businesses to recover investments in many types of properties through depreciation deductions. Many renewable energy technologies are classified as five-year depreciation properties, meaning that they are fully depreciated after six years.

For a given year, the property's depreciated value is subtracted from that year's taxable income. For five-year depreciation properties, MACRS designates a different percentage of the property's cost to be depreciated each year for six years. These depreciated values sum to the value of the property.

### 1.1.2 Net Metering

Net metering allows a resident or business generating excess solar energy to sell that energy back to the grid at a prorated cost. Different utility companies have different policies regarding whether and how they implement net metering. These policies may also differ by the amount of energy being generated.

### 1.1.3 Solar Renewable Energy Certificates

Solar Renewable Energy Certificates (or Credits), or SRECs, are only available and worthwhile in a handful of states. 38 states and Washington, D.C. require electric companies to generate a portion of power renewably, according to these states' Renewable Portfolio Standards (RPS). Some states have solar energy carve-outs within their RPS, meaning electric companies are required to generate a portion of their power via solar energy. This is verified using SRECs.

When electric companies cannot meet the required standards on their own, they may present SRECs purchased from residential solar producers. Homeowners earn one SREC for every 1000 kWh of solar energy generated. In states with solar carve-outs, there is often an active market for SRECs. However, the inherent variability of these markets sometimes prevents them from being taken advantage of.

## 2 MODEL

This model intends to cover various possibilities for the programmed locations. Accordingly, it requires user input for the following variables:

- Sector type: commercial, industrial, and/or residential
- Area available for solar panels
- Property value without solar panels
- Total energy usage (kW)

- Year purchasing solar, between 2020 and 2029, for analysis within the same 10-year period
- Yearly income
- Solar panel tilt angle from horizon
- Solar panel direction

Using these variables, the model seeks to compare the costs of buying different types of solar cells in different areas. The model repeats all calculations for different panel types to account for different costs and efficiencies. It repeats all calculations for three different locations, to display effects of altitudes, coordinates, and local policies. The model functions as follows.

### 2.1 Power Production

To understand the relative costs of adopting solar energy, the power produced by the user's solar panels is calculated. The yearly power [kWh] is a function of location properties (i.e., altitude, latitude, longitude, and standard time zone longitude) and panel properties (i.e., degrees from horizon, degrees toward west, total area, panel efficiency). For a given time of day, the power [W] is calculated using equations outlined in *Energy Systems Engineering* (Vanek et al., 2016). This power is integrated over each day to give a total daily power [Wh]. This is calculated for each day of the year, then summed to give the yearly power [kWh].

The ideal system size [kW] is defined as the yearly power generation divided by the number of hours in a year. By comparing this to the total energy needs defined by the user, the excess energy generation is defined. This will be used when calculating earnings through net metering.

## 2.2 Government and Utility Incentives

Before calculating the values of tangible incentives, the increase in property value from installing solar panels is estimated as a linear increase in value up to an additional 30% of the installation's cost. The percent of the total possible increase applied is the same as the percent of power needs that are generated by the installation.

Since some government and utility incentives change value in different years, they are all reevaluated each year from 2020 to 2029. The model uses the user-inputted sector (i.e., residential, industrial, and/or commercial) and location to determine which of the following incentives are activated.

### 2.2.1 Tax-Related Incentives

#### 2.2.1.1 Business Energy Investment Tax Credit

If the system is bought in 2020, the BEITC credits 26% of its cost. In 2021, this changes to 22%. For all following years, it changes to 10%.

#### 2.2.1.2 Renewable Energy Systems Property Tax Exemption

If this incentive is not marked as active by the program, the taxable property value is considered the same as the property value. Otherwise, the taxable property value is the property value minus the increase in property value brought about by installing a solar system.

#### 2.2.1.3 Modified Accelerated Cost-Recovery System

Starting in the year solar technology is bought, a percentage of its cost is deducted from taxable revenue. This percentage, or the depreciated value of the system, is directly calculated from the official MACRS five-year recovery plan.

### 2.2.2 Net Metering

The credit gained from net metering depends on the location and size of the system. Austin Energy has no specific net metering plan in place. In Washington, D.C., Pepco's net metering plan depends on both the customer's sector and whether they are generating less than 400 kWh/month. In Sacramento, CA, SMUD's net metering plan depends primarily on the customer's sector.

### 2.2.3 Austin Energy Incentives

Instead of net metering, Austin Energy uses rebate programs for solar customers. Commercial customers earn rebates depending on their system's size, whereas residential customers earn a $2500 rebate for installing a system of at least 3 kW.

### 2.2.4 SRECs

Of the three locations, only Washington, D.C. has an active SREC market. Based on an average of recent SREC prices, the model assumes a homeowner can earn $450 for each SREC they generate. It should be noted that this is on the high end for states with active SREC markets.

## 2.3 Financial Calculations

### 2.3.1 Taxes

After applying incentives to taxable income and calculating taxable property value, taxes are calculated. Income taxes are calculated according to US tax law, which taxes each portion of income within a different income bracket separately. Property is taxed at a flat rate of 18.03%.

### 2.3.2 Energy Costs

Depending on the location of the installation, energy costs can be calculated in one of three different ways. The three utility companies considered (Austin Energy, Pepco, and SMUD) employ a mixture of policies including net metering, various rebates, and cost variability by bracket and plan.

Austin Energy calculates energy costs differently for residents and other sectors. Residents are taxed in brackets of 0-500, 500-1000, 1000-1500, 1500-2500, and >2500 kWh/month. For other sectors, the model uses AE's standard Primary and Secondary Voltage plans. Brackets for these sectors are 0-10, 10-300, 300-3000, 3000-20000, and >20000 kW.

Pepco calculates energy costs for Schedule-R residents based on whether they are using more than 400 kWh/month. Other sectors have various plans, but the model uses the popular Schedule GS-3A prices, which are essentially bracketless.

SMUD has a bracketless plan for residents, byt charges other sectors differently depending on whether they need more than 20 kW. The model approximates some peak rates, given that SMUD has different rates during peak hours and seasons.

### 2.3.3 PDSW and TYCW

The PDSW, or Present-Day Simplified Wealth, is a variable invented for this model in order to examine the user's effective wealth at any point in time. The PDSW in a given year is defined in Equation (1) as

$$PDSW = I + \left(\frac{P}{10}\right) + \sum i - (T + \left(\frac{C}{y}\right) + E) \quad (1)$$

where $I$ is the projected income for that year, $P$ is the user's property value, $i$ is an incentive's yield for that year, $T$ is all taxes for that year, $C$ is the total cost of a solar system, *y* is the number of years within the 2020-2029 period that any solar tech bought is owned, and *E* is the amount spent each year on energy.

The TYCW, or Ten-Year Condensed Wealth, is the present-day value of all 10 years of PDSW. It is calculated using time-value-of-money equations with an interest rate of 2%. The TYCW is a useful variable to directly compare the feasibility of purchasing solar when the location or type of technology differs.

# 3 RESULTS AND ANALYSIS

The model is analyzed here for a hypothetical residential case with the following parameters: a max system area of 40 $m^2$, a base property value of \$100,000, energy needs of 10,000 kWh/year, 2020 as the year of purchase, and a yearly income of \$100,000/year. The plots in section 3.1 are for solar systems costing \$10,000.

## 3.1 PDSW over Time

The three plots in this section show the PDSW over ten years (from 2020-2029) in each of three locations—Sacramento, CA, Austin, TX, and Washington, D.C. The four lines on each graph show PDSW for different types of solar technology, including polycrystalline, monocrystalline, CdTe, and a line for PDSW without purchasing solar.

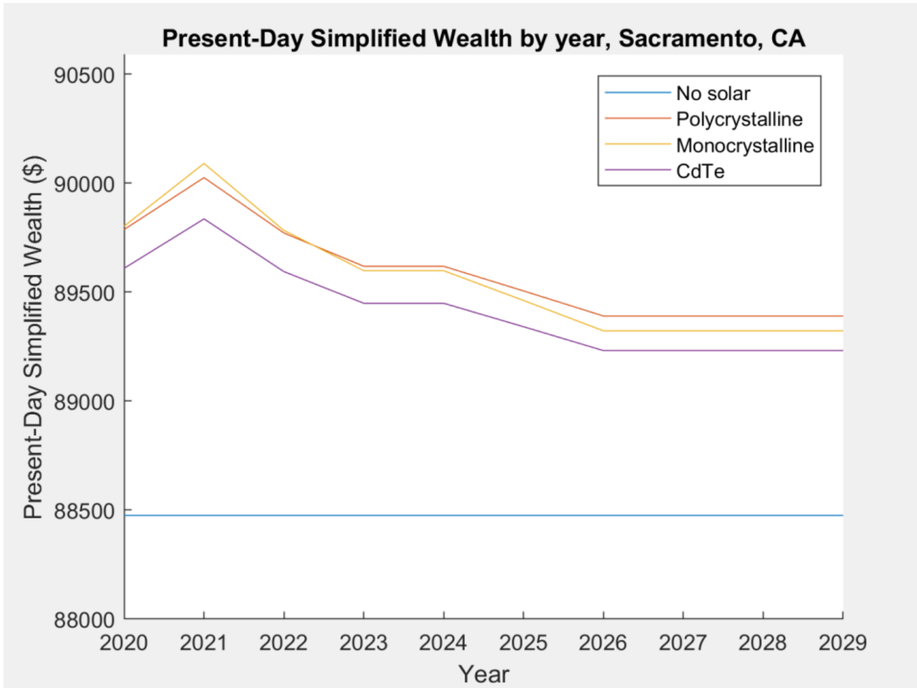


Figure 1. Present-Day Simplified Wealth by year, Sacramento, CA

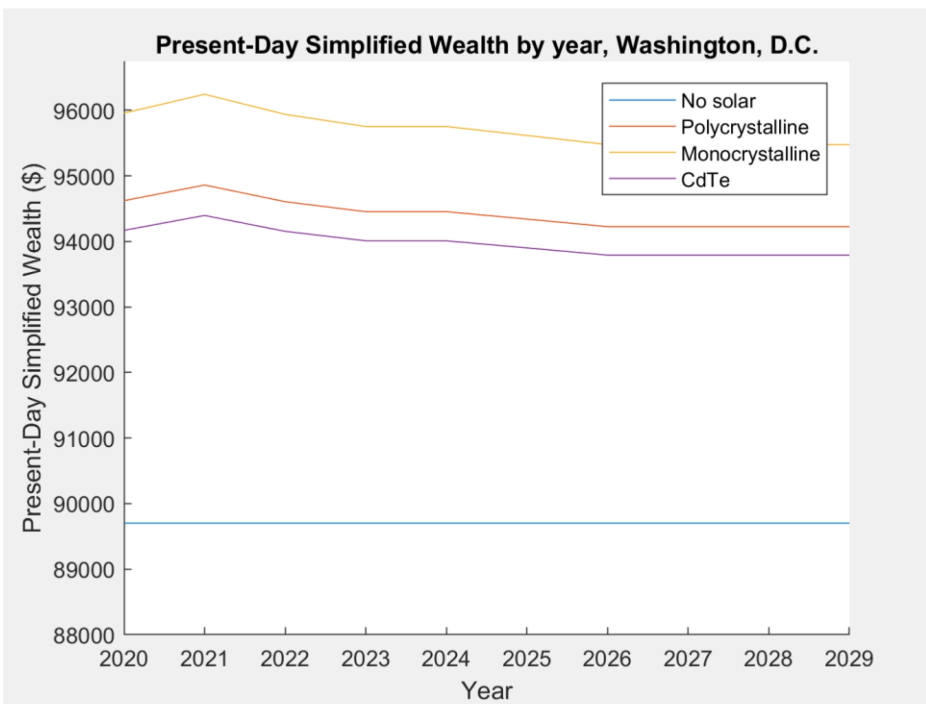


Figure 2. Present-Day Simplified Wealth by year, Washington, D.C.

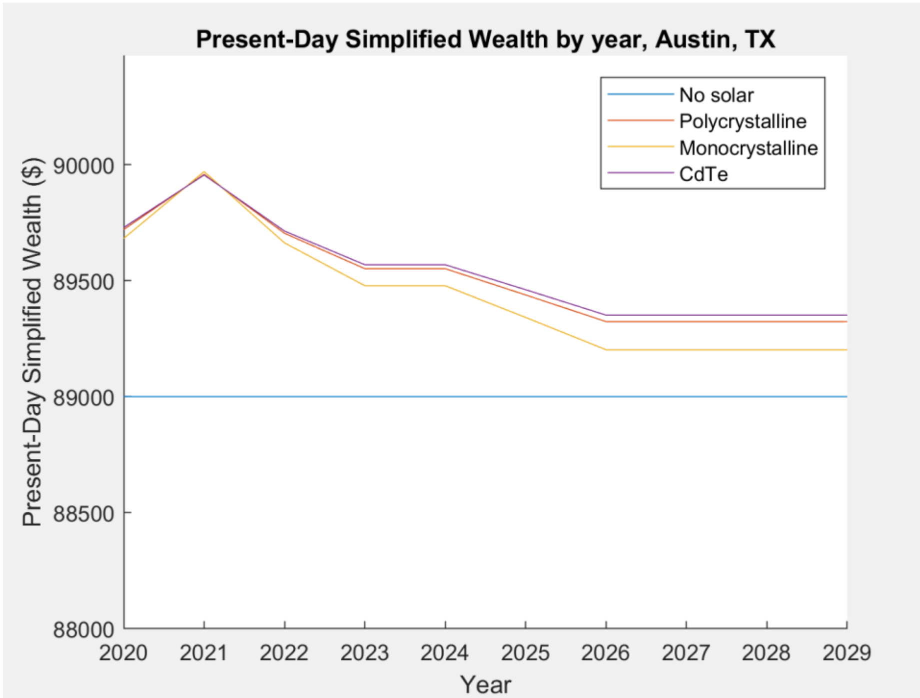


Figure 3. Present-Day Simplified Wealth by year, Austin, TX

As shown in these figures, in none of the three solar-purchasing cases does the PDSW dip below that of the "No solar" case. This indicates that in any of the locations examined, under these conditions, it would be profitable to install solar technology, regardless of type. The most profitable type of solar technology usually depends on whether incentives or costs of saved energy make up more of the savings in each location.

### 3.2 TYCW and Max Solar Spending

The following three plots show how the TYCW changes in different solar cases (under the conditions specified at the start of section 3) given how much is spent on the solar system. Of course, spending less on a solar system leads to a higher TYCW—but these plots assume a solar system of each type can be found for any amount of money, so the TYCWs at the left end of each graph are effectively impossible to reach.

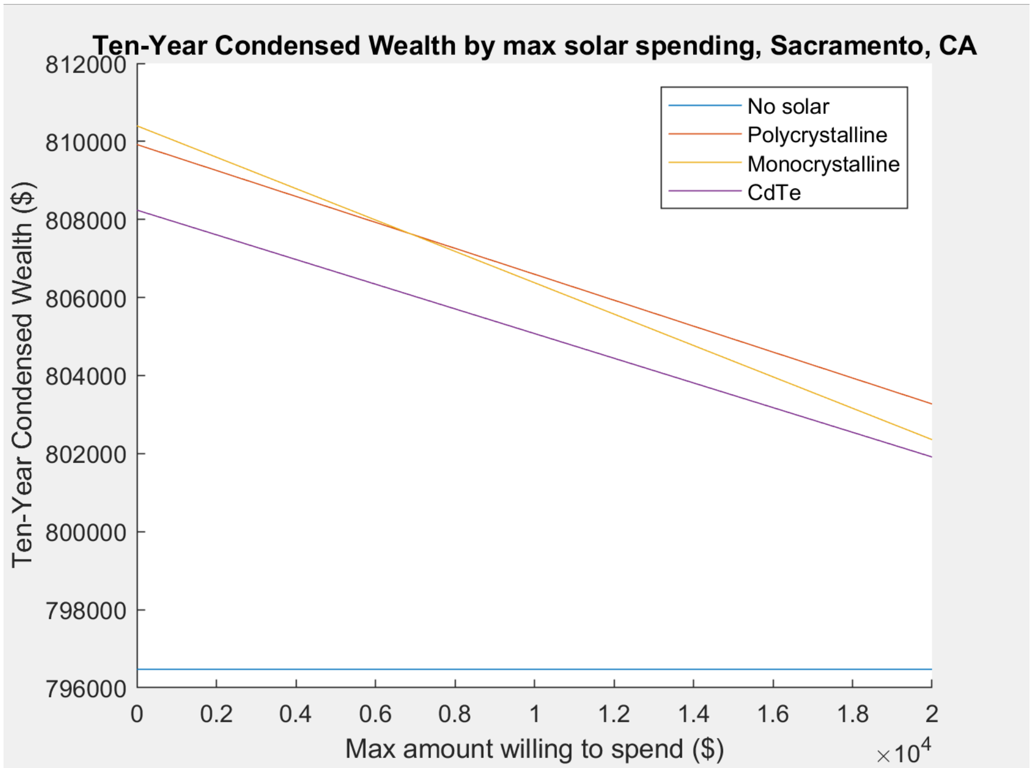


Figure 4. Ten-Year Condensed Wealth by max solar spending, Sacramento, CA

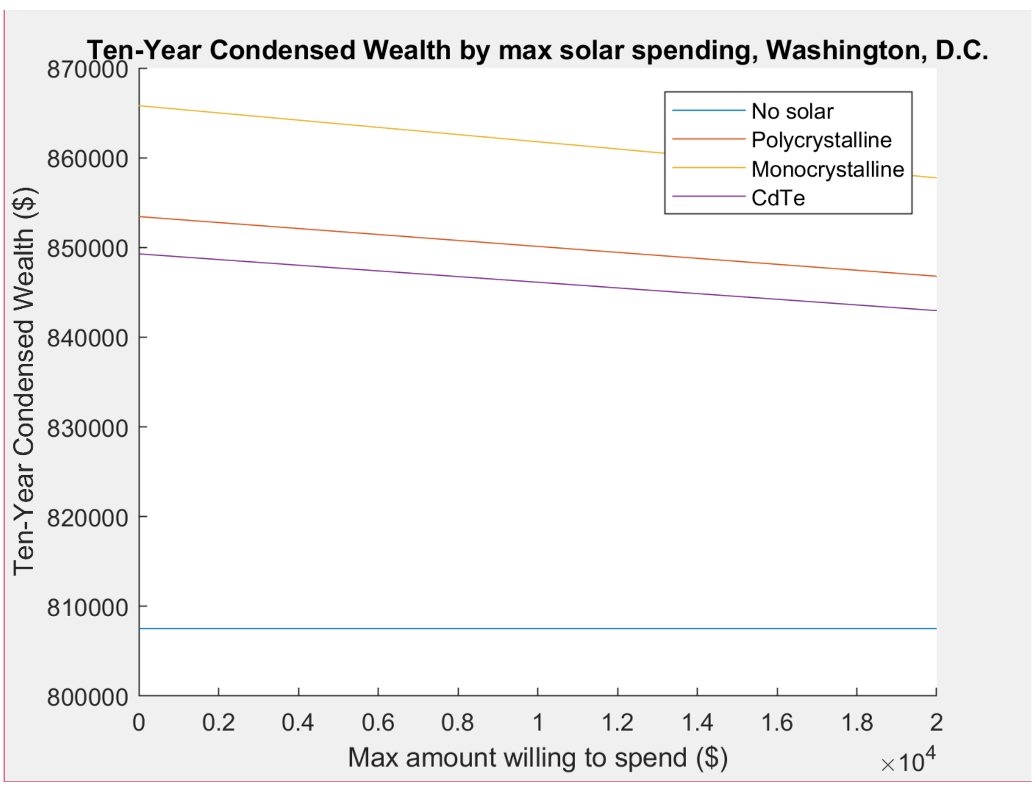


Figure 5. Ten-Year Condensed Wealth by max solar spending, Washington, D.C.

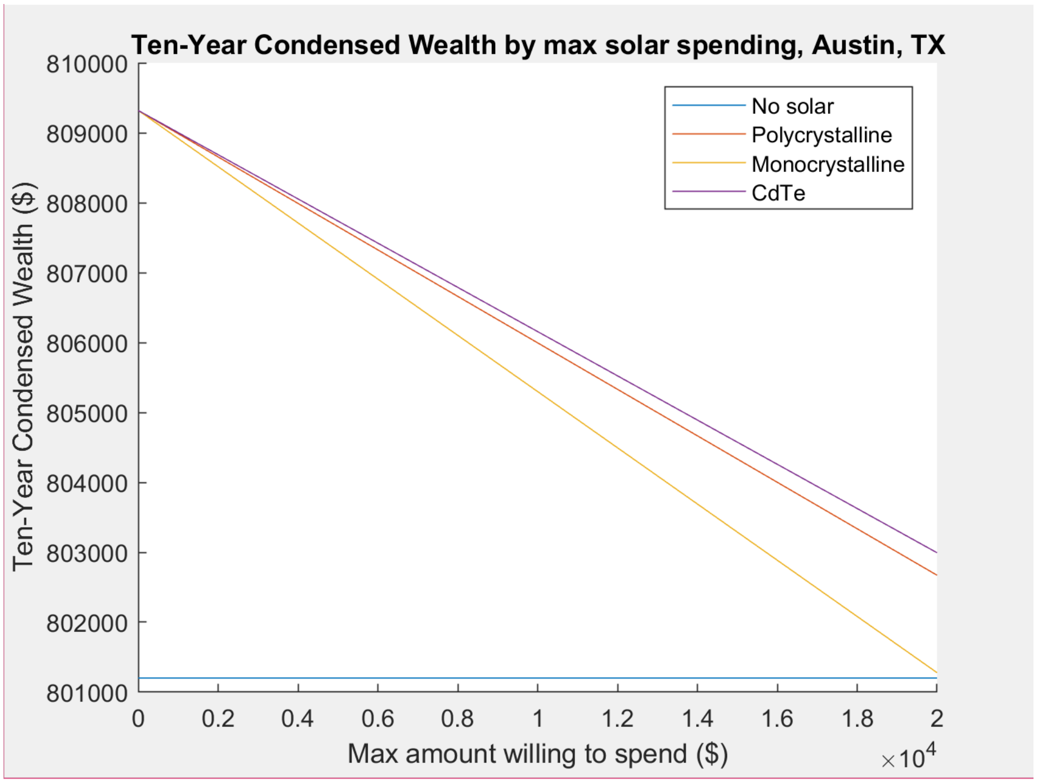


Figure 6. Ten-Year Condensed Wealth by max solar spending, Austin, TX

The most important inference to draw from these graphs is that even when spending as much as $20,000 on a solar system (for the assumptions given at the beginning of Section 3), it is still more profitable than not doing so. Monocrystalline solar technology is much more profitable in Washington, D.C. due to its potential to produce an additional SREC under the given conditions.

Though all six of the figures above display the profitability of solar technology in Washington, D.C., the comparative profitability is best showcased in the following figure.

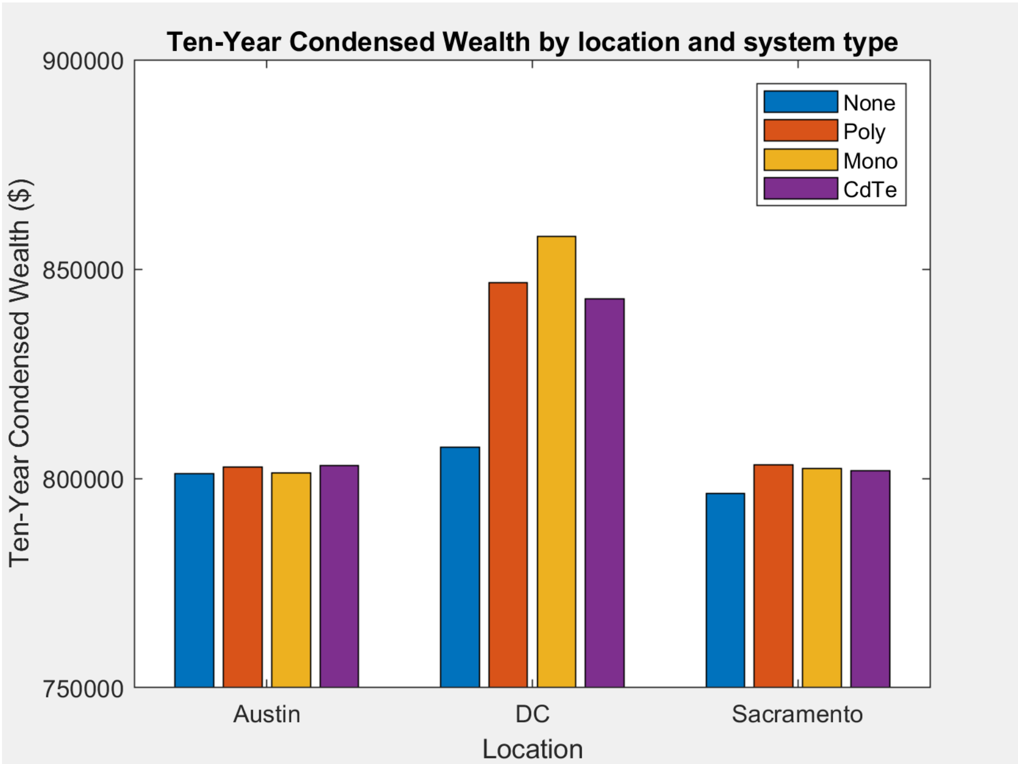


Figure 7. Ten-Year Condensed Wealth by location and system type

In the above figure, note that the TYCW (the y-axis) does not start at zero. Still, in both Austin and Sacramento, increases in wealth are on a different order than in Washington, D.C. This is because of SRECs, the importance of which is outlined in the following section.

# 4 Importance of SRECs

The different policies pursued in different US states allow for a great deal of experimentation. Solar energy is usually regulated on the state level, meaning that state- and utility-level incentives can make a substantial difference in the financial feasibility of adopting solar technology. Indeed, the decentralization of such incentives was intended to promote the use of solar technology (Burns & Kang, 2012). Though this has led to successful SREC programs in several states, currently, only Washington, D.C., Massachusetts, and New Jersey have SREC markets with values on the order of those explored in this report. Less than half of US states even have solar set-asides in their renewable portfolio standards.

The highest indicator of SRECs' strength as incentives in an area is local energy prices. Northeastern states in which energy prices are high have more active SREC markets than states in which energy is already cheap, where even SRECs cannot convince people of the value of purchasing solar. In such states, stricter policies for solar carve-outs may have to be imposed if they are to be effective.

The potential for SRECs to increase solar profitability is great, but predicting their future values is difficult and dangerous. SRECs have inherently variable prices. Not only does this mean that they may suddenly become unprofitable, but it may also dissuade consumers from using them as justification for purchasing solar technology. Additionally, some states lack transparency on statewide supply of and demand for SRECs. As a result, even a robust solar set-aside may have only a mild influence on possible customers.

In many locations, especially those where small customers lack confidence in solar technology, utility companies reap the benefits of SREC programs. Rather than residents and small businesses taking advantage of SREC markets, a small number of solar power producers generate and sell the majority of SRECs needed by utility companies to fulfill SREC quotas (Gaul & Carley, 2012).

One possible solution to the inherent uncertainty of SREC markets is government mandated minimum SREC prices, or floor prices. Studies on floor price policies in

Belgium and similar policies in Massachusetts showed that floor prices can reduce the uncertainty of SREC markets (Burns & Kang, 2012).

Additionally, increasing the transparency of these markets would drive investment in solar technology. This could be accomplished by publicly disclosing current SREC prices, disseminating information about the viability of SREC trading for small-scale solar system owners, and increasing utility companies' demand for small consumers via stricter solar set-asides.

# 5 CONCLUSIONS AND RECOMMENDATIONS

The model created for this project suggested that SRECs are the most useful and viable incentive to drive solar investment on the state level. This agrees with data about states with active SREC markets with competitive pricing. However, the few states that have solar carve-outs are plagued by a lack of public confidence in SRECs.

The best way to drive solar investment while increasing the profitability of solar for consumers is through SRECs. States should implement solar set-asides in their RPS, and use public information campaigns to increase awareness of the profitability of small-scale solar systems when taking advantage of SRECs. To ensure that SRECs are profitable, market transparency should be promoted and utility companies/large-scale solar providers should be limited in the amount of SRECs they can generate.

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# APPENDIX A: **LIST OF ASSUMPTIONS**

All assumptions included in the model are mentioned in the table below. Consider these assumptions when evaluating the conclusions presented.

Table A-1. List of Assumptions

| **Assumption** | **Reason for assumption** |
|---|---|
| Panel efficiencies do not vary with temperature | Simplicity of model |
| 23km haze model (Vanek et al., 2016) | Simplicity of model |
| Ideal system size [kW] is true system size | Simplicity of model |
| Property value can only increase by up to 30% of a system's cost | Reasonable precedent |
| For Austin Energy's Commercial Solar PV Rebate Program, the user has an approved contractor and solar panels | Required for incentive |
| The BEITC does not apply to residential solar purchases | Though the BEITC will apply to residential purchases until the end of 2021, these contributions are negligible. |
| Franchise taxes and corporate taxes are simplified as personal taxes. | Simplicity of model |
| Customers in each city use energy from either Austin Energy, Pepco, or SMUD. | Simplicity of model |
| The hypothetical customer in Section 3 has 40 square meters of space for a solar installation. | While this is unlikely, it is the best way to illustrate the comparative value of SRECs. |

# APPENDIX B: **MAIN MATLAB CODE**

The main code for the model described in Section 2 follows.

```
clear

for location = 1:3

%% new loop

cost_interval = 200;
cost_interval_max = 20000; %^must be divisible
time_interval_for_loop = 30/60; %hours. Previously five minutes - this
should help with speed
wealth_plot_x = zeros(1,(cost_interval_max/cost_interval)+1);
wealth_plot_y = zeros(4,(cost_interval_max/cost_interval)+1);
cost_loop_ctr = 0;
for max_system_cost = 0:cost_interval:cost_interval_max
cost_loop_ctr = cost_loop_ctr + 1;

%% user inputs

%facility
sector_commercial = 0;
sector_industrial = 0;
sector_residential = 1;

max_system_area = 40; %m^2
max_system_cost_initial = 10000; %$ %for graph
base_property_value = 100000; %no panels
total_energy_needs = 10000/8760; %kW %energy usage of facility %typical
house: 10000 kWh/yr
year_of_purchase = 2020; %2020 to 2029
yearly_income = 100000; %$

panel_beta = 22; %deg from horizon
panel_gamma = 46; %deg west

%location = 1; %1 for austin, 2 for W,D.C., 3 for Sacramento

%% initialize

credit_AE_CSPVRP = zeros(4,10);
credit_BEITC = zeros(4,10);
credit_AE_RSPVRP = zeros(4,10); %$
credit_NM = zeros(1,4);
depreciated_value = zeros(4,10);
system_gen = zeros(1,4);
system_size = zeros(1,4);
system_cost = zeros(1,4);
system_energy_ratios = zeros(1,4);
SRECs = zeros(1,4);
srec_gen = zeros(1,4);
credit_SREC = zeros(4,10);
property_value_increase = zeros(1,4);
```

```matlab
property_value = zeros(1,4);
property_value_matrix = zeros(4,10);
MACRS_percent = zeros(4,10);
taxable_property_value = zeros(1,4);
credit = zeros(4,10);
taxable_income = zeros(4,10);
property_tax = zeros(4,10);
income_tax = zeros(4,10);
tax = zeros(4,10);
energy_costs_matrix = zeros(4,10);
profit = zeros(4,10);
wealth = zeros(1,4);

%78705
%Loan programs not included

active_AE_CSPVRP = 0; %Austin Energy - Commercial Solar PV Rebate
Program
active_AE_RSPVRP = 0; %Austin Energy - Residential Solar PV Rebate
Program
active_BEITC = 0; %Business Energy Investment Tax Credit (ITC)
active_MACRS = 0; %MACRS
active_RESPTE = 0; %Renewable Energy Systems Property Tax Exemption
active_SaWEBFTE = 0; %Solar and Wind Energy Business Franchise Tax
Exemption
active_SaWEDFTD = 0; %Solar and Wind Energy Device Franchise Tax
Deduction
active_NM = 0; %Net Metering

%% Main system type loop; Variables to define for facility

if location == 1 %Austin, Texas - 78705
    city_altitude = 0.149 ; %km
    latitude_north = 30.260596; % deg N
    longitude_west = 97.752747; % deg W
    timezone_longitude = 90; % deg - standard timezone longitude
elseif location == 2 %Washington, D.C. - 20007 for Georgetown
    city_altitude = 0.01;
    latitude_north = 38.904722;
    longitude_west = 77.016389;
    timezone_longitude = 75;
elseif location == 3 %Sacramento 95816
    city_altitude = 0.01;
    latitude_north = 38.581667;
    longitude_west = 121.494444;
    timezone_longitude = 120;
end

system_eff_ratios = [0 .8 1 .7];
system_efficiencies = [0 0.16 0.2 0.14];
% Efficiency assumptions (by area) - Poly: 0.16; Mono: 0.2; CdTe: 0.14
% First Solar
system_cost_ratios = [0 0.8267 1 0.7867];
% Price comparisons (MINIMUMS) Using price ratios since it fluctuates -
% these are ~ 2013 prices and efficiencies. Let's assume it's the same
for $/m2, so the ratios make your "max willing to spend" into "what
you'll be spending for the same area".
```

```
    % Mono: 0.75 $/Wdc
    % Poly: 0.62 $/Wdc
    % Thin: 0.59 $/Wdc  ??
%(Lowest actual price around $3)
% There is more below on property value increases

for system_type = 1:4 %1 for no solar; 2 for poly; 3 for mono; 4 for
cdte

system_gen(system_type) = power_prod_over_year(city_altitude,
latitude_north, longitude_west, timezone_longitude, panel_beta,
panel_gamma, system_efficiencies(system_type), max_system_area,
time_interval_for_loop); %kWh
% kWh
system_size(system_type) = system_gen(system_type)/8760; %kW
system_cost(system_type) =
max_system_cost*system_cost_ratios(system_type);

if total_energy_needs > system_size(system_type)
    excess_energy_needs = total_energy_needs -
system_size(system_type); %kW
    excess_energy_generated = 0; %kW
else
    excess_energy_needs = 0;
    excess_energy_generated = system_size(system_type) -
total_energy_needs;
end
energy_CC_1 = excess_energy_needs*730; %kWh/month %energy for Cost
Computation
energy_CC_2 = energy_CC_1*12; %kWh/yr
energy_CC_3 = excess_energy_generated*730; %kWh/month
energy_CC_4 = energy_CC_3*12; %kWh/yr

%This part increases property value by an amount relating to how much
of your energy needs you recoup AND how much the system costs, up to
30% of its cost and 100% of energy coverage.
system_energy_ratios(system_type) =
system_size(system_type)/total_energy_needs;
if system_energy_ratios(system_type) > 1
    system_energy_ratios(system_type) = 1;
end
property_value_increase(system_type) =
(system_cost(system_type)*0.3)*system_energy_ratios(system_type);
property_value(system_type) = base_property_value +
property_value_increase(system_type);

projected_income = [yearly_income yearly_income yearly_income
yearly_income yearly_income yearly_income yearly_income yearly_income
yearly_income yearly_income]; %10-year matrix of yearly incomes
stdized_yr_of_purchase = year_of_purchase - 2019;
cost_matrix_1 = [0 0 0 0 0 0 0 0 0 0]; %matrix of zeroes except the
year you buy the equipment
cost_matrix_1(stdized_yr_of_purchase) = system_cost(system_type);
cost_matrix_2 = [system_cost(system_type) system_cost(system_type)
system_cost(system_type) system_cost(system_type)
system_cost(system_type) system_cost(system_type)
```

```
system_cost(system_type) system_cost(system_type)
system_cost(system_type) system_cost(system_type)];
cost_per_year = system_cost(system_type)/(11-stdized_yr_of_purchase);
cost_matrix_3 = [cost_per_year cost_per_year cost_per_year
cost_per_year cost_per_year cost_per_year cost_per_year cost_per_year
cost_per_year cost_per_year];
if stdized_yr_of_purchase ~= 1
    cost_matrix_3(1:(stdized_yr_of_purchase-1)) = 0;
end
years_matrix = [2020 2021 2022 2023 2024 2025 2026 2027 2028 2029];
property_value_matrix(system_type,:) = [property_value(system_type)/10
property_value(system_type)/10 property_value(system_type)/10
property_value(system_type)/10 property_value(system_type)/10
property_value(system_type)/10 property_value(system_type)/10
property_value(system_type)/10 property_value(system_type)/10
property_value(system_type)/10];

%% check active incentive variables

if system_type == 1
    active_AE_CSPVRP = 0; %Austin Energy - Commercial Solar PV Rebate
Program
    active_AE_RSPVRP = 0; %Austin Energy - Residential Solar PV Rebate
Program
    active_BEITC = 0; %Business Energy Investment Tax Credit (ITC)
    active_MACRS = 0; %MACRS
    active_RESPTE = 0; %Renewable Energy Systems Property Tax Exemption
    active_SaWEBFTE = 0; %Solar and Wind Energy Business Franchise Tax
Exemption
    active_SaWEDFTD = 0; %Solar and Wind Energy Device Franchise Tax
Deduction
    active_NM = 0; %Net Metering
else
    if sector_commercial == 1
        active_MACRS = 1;
        active_BEITC = 1;
        active_SaWEDFTD = 1;
        active_SaWEBFTE = 1;
        active_RESPTE = 1;
        active_AE_CSPVRP = 1;
        active_NM = 1;
    end
    if sector_industrial == 1
        active_MACRS = 1;
        active_BEITC = 1;
        active_SaWEDFTD = 1;
        active_SaWEBFTE = 1;
        active_RESPTE = 1;
        active_AE_CSPVRP = 1;
        active_NM = 1;
    end
    if sector_residential == 1
        active_MACRS = 1;
        active_RESPTE = 1;
        active_AE_RSPVRP = 1;
        active_NM = 1;
    end
```

```
end

%% Main year 1-10 loop

year_ctr = 0;
for year_ctr = 1:10
    year = 2019+year_ctr;

%% Business Energy Investment Tax Credit (ITC)
%Here I assume that residential gets 0% for ITC all 10 years (though it
is actually just 8 of them).

if active_BEITC == 1
    if year == 2020
        credit_BEITC(system_type,year_ctr) =
0.26*cost_matrix_1(year_ctr);
    elseif year == 2021
        credit_BEITC(system_type,year_ctr) =
0.22*cost_matrix_1(year_ctr);
    else
        credit_BEITC(system_type,year_ctr) =
0.1*cost_matrix_1(year_ctr);
    end
end

%% MACRS
% Assumes solar gear is depreciated thru 5-year MACRS each year,
revenue is taxed for six years, a percent of the system cost is
deducted from revenue (means less taxes)

if active_MACRS == 1
if cost_matrix_1(year_ctr) > 0
    MACRS_percent(system_type,1:10) = [0 0 0 0 0 0 0 0 0 0];
    MACRS_percent(system_type,year_ctr) = 0.2;
    MACRS_percent(system_type,year_ctr+1) = 0.32;
    MACRS_percent(system_type,year_ctr+2) = 0.192;
    MACRS_percent(system_type,year_ctr+3) = 0.115;
    MACRS_percent(system_type,year_ctr+4) = 0.115;
    MACRS_percent(system_type,year_ctr+5) = 0.058;
    MACRS_percent(system_type,:) = MACRS_percent(system_type,1:10);
    depreciated_value(system_type,1:10) = [0 0 0 0 0 0 0 0 0 0];
    depreciated_value(system_type,:) =
MACRS_percent(system_type,:)*system_cost(system_type);
end
end

%% Solar Renewable Energy Credits (SRECs)

if location == 2
    srec_gen(system_type) = floor(system_gen(system_type)/1000)*1000;
    SRECs(system_type) = srec_gen(system_type)/1000;
    credit_SREC(system_type,year_ctr) = 450*SRECs(system_type);
end

%% Renewable Energy Systems Property Tax Exemption (78705) / ... /
Solar Energy System and Cogeneration System Personal Property Tax
Credit (20007)
```

```
if location == 1 || location == 2 || location == 3
if active_RESPTE == 1
    taxable_property_value(system_type) = property_value(system_type) -
property_value_increase(system_type);
else
    taxable_property_value(system_type) = property_value(system_type);
end
end

%% Austin Energy - Commercial Solar PV Rebate Program
%lasts 10 years, must have approved contractor and solar panels

if active_AE_CSPVRP == 1 && location == 1

    %Calculate the estimated rebate
    if system_size(system_type) < 75 %kW
        energy_rebate = 0.055 + 0.025*((75-
system_size(system_type))/75); % $/kWh
    elseif system_size(system_type) < 400 %kW
        energy_rebate = 0.035 + 0.02*((400-
system_size(system_type))/(400-75)); % $/kWh
    elseif system_size(system_type) < 1000 %kW
        energy_rebate = 0.02 + 0.015*((1000-
system_size(system_type))/(1000-400)); % $/kWh
    else
        energy_rebate = 0;
    end

    credit_AE_CSPVRP(system_type,year_ctr) =
energy_rebate*(system_size(system_type)*8760); %conversion factor from
kW to kWh/yr

end

%% Austin Energy - Residential Solar PV Rebate Program
%PV system must be AT LEAST 3kW (AC); only for installing a system

if active_AE_RSPVRP == 1 && system_size(system_type) >= 3 && year_ctr
== 1 && location == 1
    credit_AE_RSPVRP(system_type,year_ctr) = 2500; %$
else
    credit_AE_RSPVRP(system_type,year_ctr) = 0;
end

end

%% Net Metering
% it also works for larger systems at generation rate

if active_NM == 1
    if location == 2 && system_size(system_type) <= 100 %kW
        if sector_residential == 1 %Schedule R
(https://www.pepco.com/MyAccount/MyBillUsage/Documents/Pepco%20DC%20FC%
201130%20and1155%20-TOU%20Rate%20Make-Ready%202.7.20-
%20filed%202.7.20%20-%20Copy.pdf)
            if energy_CC_3 <400 %kWh
```

```
                credit_NM(system_type) = (energy_CC_3*0.008*12);
            else
                credit_NM(system_type) = (400*0.008*12) +
((energy_CC_3-400)*0.0194*12);
            end
        elseif sector_commercial == 1 || sector_industrial == 1
%Schedule GS-3A
                credit_NM(system_type) =
(10.82*excess_energy_generated) + (.0176*energy_CC_2);
        end
    elseif location == 3
        if sector_residential == 1 %(https://www.smud.org/-
/media/Documents/Electric-Rates/Residential-and-Business-Rate-
information/PDFs/1-R.ashx)
                credit_NM(system_type) =
(energy_CC_3*0.1071*5)+(energy_CC_3*0.1711*4)+(energy_CC_3*0.1103*3);
        elseif sector_commercial == 1 || sector_industrial == 1
%(https://www.smud.org/-/media/Documents/Electric-Rates/Residential-
and-Business-Rate-information/PDFs/1-GS.ashx)
            if excess_energy_needs <= 20
                credit_NM(system_type) =
(0.1365*energy_CC_3*5)+(0.21*energy_CC_3*4)+(0.1406*energy_CC_3*3);
%approximated peak rate to $.21/kWh
            else
                credit_NM(system_type) =
(0.1071*energy_CC_3*5)+(0.135*energy_CC_3*4)+(0.1103*energy_CC_3*3);
%approximated peak rate to $.135/kWh
            end
        end
    end
end

%% Finance calculations

%% Tax costs
taxable_income(system_type,:) = projected_income -
depreciated_value(system_type,:);
property_tax(system_type,1:10) =
taxable_property_value(system_type)*0.01803;
for year_ctr = 1:10
    if taxable_income(system_type,year_ctr) > 510300
        income_tax(system_type,year_ctr) = 153798.5 +
(0.37*(taxable_income(system_type,year_ctr)-510300));
    elseif taxable_income(system_type,year_ctr) > 204100
        income_tax(system_type,year_ctr) = 46628.5 +
(0.35*(taxable_income(system_type,year_ctr)-204100));
    elseif taxable_income(system_type,year_ctr) > 160725
        income_tax(system_type,year_ctr) = 32748.5 +
(0.32*(taxable_income(system_type,year_ctr)-160725));
    elseif taxable_income(system_type,year_ctr) > 84200
        income_tax(system_type,year_ctr) = 14382.5 +
(0.24*(taxable_income(system_type,year_ctr)-84200));
    elseif taxable_income(system_type,year_ctr) > 39475
        income_tax(system_type,year_ctr) = 4543 +
(0.22*(taxable_income(system_type,year_ctr)-39475));
    elseif taxable_income(system_type,year_ctr) > 9700
```

```
        income_tax(system_type,year_ctr) = 970 +
(0.12*(taxable_income(system_type,year_ctr)-9700));
    else
        income_tax(system_type,year_ctr) =
0.1*taxable_income(system_type,year_ctr);
    end
end
tax(system_type,:) = property_tax(system_type,:) +
income_tax(system_type,:) ;

%% Energy costs
if location == 1
    if sector_residential == 1
%(https://austinenergy.com/ae/residential/rates/residential-electric-
rates-and-line-items)
        if energy_CC_1 > 2500
            energy_costs = 120 + 12*(energy_CC_1*(.00613+.01252+.03139)
+ (500*.02801 + 500*.05832 + 500*.07814 + 1000*.09314 + (energy_CC_1-
2500)*.10814)); %($/kWh * kWh(/month))
        elseif energy_CC_1 > 1500
            energy_costs = 120 + 12*(energy_CC_1*(.00613+.01252+.03139)
+ (500*.02801 + 500*.05832 + 500*.07814 + (energy_CC_1-1500)*.09314));
        elseif energy_CC_1 > 1000
            energy_costs = 120 + 12*(energy_CC_1*(.00613+.01252+.03139)
+ (500*.02801 + 500*.05832 + (energy_CC_1-1000)*.07814));
        elseif energy_CC_1 > 500
            energy_costs = 120 + 12*(energy_CC_1*(.00613+.01252+.03139)
+ (500*.02801 + (energy_CC_1-500)*.05832));
        else
            energy_costs = 120 +
12*(energy_CC_1*(.00613+.01252+.03139+.02801));
        end
    elseif sector_residential == 0 %Only using AE's standard Primary &
Secondary Voltage categories
(https://austinenergy.com/ae/commercial/rates)
        if excess_energy_needs > 20000 %Primary 3
            energy_costs = (2750*12) +
((4.5+10.37+3.41)*excess_energy_needs) +
((0.00152+0.03068)*energy_CC_2);
        elseif excess_energy_needs > 3000 %Primary 2
            energy_costs = (2200*12) +
((4.5+9.17+3.41)*excess_energy_needs) +
((0.00052+0.03068)*energy_CC_2);
        elseif excess_energy_needs > 300 && sector_industrial == 1
%Primary 1
            energy_costs = (275*12) +
((4.5+7+3.41)*excess_energy_needs) + ((0.00053+0.03068)*energy_CC_2);
        elseif excess_energy_needs > 300 && sector_industrial == 0
%Secondary 3
            energy_costs = (71.5*12) +
((4.5+6.4+3.49)*excess_energy_needs) + ((0.01955+0.03139)*energy_CC_2);
        elseif excess_energy_needs > 10 %Secondary 2
            energy_costs = (27.5*12) +
((4.5+4.19+3.49)*excess_energy_needs) +
((0.02421+0.03139)*energy_CC_2);
        else %Secondary 1
```

```
            energy_costs = (18*12) +
((0.04802+0.03139+0.01252)*energy_CC_2);
        end
    end
elseif location == 2
    if sector_residential == 1 %Schedule R
(https://www.pepco.com/MyAccount/MyBillUsage/Documents/Pepco%20DC%20FC%
201130%20and1155%20-TOU%20Rate%20Make-Ready%202.7.20-
%20filed%202.7.20%20-%20Copy.pdf)
        if energy_CC_1 <400 %kWh
            energy_costs = (15.09*12) + (energy_CC_1*0.008*12);
        else
            energy_costs = (15.09*12) + (400*0.008*12) + ((energy_CC_1-
400)*0.0194*12);
        end
    elseif sector_commercial == 1 || sector_industrial == 1 %Schedule
GS-3A
            energy_costs = (89.41*12) + (10.82*excess_energy_needs) +
(.0176*energy_CC_2);
    end
elseif location == 3
    if sector_residential == 1 %(https://www.smud.org/-
/media/Documents/Electric-Rates/Residential-and-Business-Rate-
information/PDFs/1-R.ashx)
            energy_costs = (21.05*9)+(21.7*3) +
(energy_CC_1*0.1071*5)+(energy_CC_1*0.1711*4)+(energy_CC_1*0.1103*3);
    elseif sector_commercial == 1 || sector_industrial == 1
%(https://www.smud.org/-/media/Documents/Electric-Rates/Residential-
and-Business-Rate-information/PDFs/1-GS.ashx)
        if excess_energy_needs <= 20
            energy_costs = (21.15*5)+(21.15*4)+(21.8*3) +
(0.1365*energy_CC_1*5)+(0.21*energy_CC_1*4)+(0.1406*energy_CC_1*3);
%approximated peak rate to $.21/kWh
        else
            energy_costs = (25.75*5)+(25.75*4)+(26.5*3) +
(7.94*9)+(8.18*3) +
(0.1071*energy_CC_1*5)+(0.135*energy_CC_1*4)+(0.1103*energy_CC_1*3);
%approximated peak rate to $.135/kWh
        end
    end
end
if energy_costs < credit_NM(system_type)
    energy_costs = 0;
else
    energy_costs = energy_costs - credit_NM(system_type);
end

energy_costs_matrix(system_type,:) = [energy_costs energy_costs
energy_costs energy_costs energy_costs energy_costs energy_costs
energy_costs energy_costs energy_costs];

%% The rest

credit(system_type,:) = credit_AE_CSPVRP(system_type,:) +
credit_AE_RSPVRP(system_type,:) + credit_BEITC(system_type,:) +
credit_SREC(system_type,:);
```

```
profit(system_type,:) = credit(system_type,:) +
property_value_matrix(system_type,:) + projected_income(1:10) -
cost_matrix_3(1:10) - tax(system_type,:) -
energy_costs_matrix(system_type,:); %all else equal
%Single-year value of home purchase and panel costs are normalized for
10-year period.

%P = F(1/(1+i)^n)
interest = 1.02;
bar_type_ctr = 0;
for bar_type_ctr = 1:4
    wealth(bar_type_ctr) = profit(bar_type_ctr,1) +
profit(bar_type_ctr,2)/(interest^2) +
profit(bar_type_ctr,3)/(interest^3) +
profit(bar_type_ctr,4)/(interest^4) +
profit(bar_type_ctr,5)/(interest^5) +
profit(bar_type_ctr,6)/(interest^6) +
profit(bar_type_ctr,7)/(interest^7) +
profit(bar_type_ctr,8)/(interest^8) +
profit(bar_type_ctr,9)/(interest^9) +
profit(bar_type_ctr,10)/(interest^10);
end
categories = categorical({'None','Poly','Mono','CdTe'});
categories = reordercats(categories,{'None','Poly','Mono','CdTe'});
bar_range = max(wealth) - min(wealth);
bar_min = min(wealth) - bar_range;
bar_max = max(wealth) + bar_range; %lol

end

if max_system_cost == max_system_cost_initial

    %% Profit plot

    profit_none = profit(1,:);
    profit_poly = profit(2,:);
    profit_mono = profit(3,:);
    profit_cdte = profit(4,:);

    figure
    hold on
    plot(years_matrix, profit_none)
    plot(years_matrix, profit_poly)
    plot(years_matrix, profit_mono)
    plot(years_matrix, profit_cdte)
    if location == 1
        title('Present-Day Simplified Wealth by year, Austin, TX')
    elseif location == 2
        title('Present-Day Simplified Wealth by year, Washington,
D.C.')
    elseif location == 3
        title('Present-Day Simplified Wealth by year, Sacramento, CA')
    end
    legend('No solar','Polycrystalline','Monocrystalline','CdTe')
    xlabel('Year')
    ylabel('Present-Day Simplified Wealth ($)')
```

```
    maxes =
[max(profit_none)+500,max(profit_poly)+500,max(profit_mono)+500,max(pro
fit_cdte)+500];
    ylim([88000 max(maxes)])
    %xlim([2020 2022])
    ax = gca;
    ax.YRuler.Exponent = 0;

    %% Wealth plot for one location

%     figure
%     bar(categories,wealth);
%https://www.mathworks.com/help/matlab/ref/bar.html
%     ylim([bar_min bar_max])
%     xlabel('Type of installation')
%     ylabel('10-year condensed wealth ($)')

end

%% Wealth line plot

wealth_plot_x(cost_loop_ctr) = max_system_cost; %for x:max willing to
spend,  y: wealth for each type
for wealth_var = 1:4
wealth_plot_y(wealth_var,cost_loop_ctr) = wealth(wealth_var);
end

end

figure
hold on
plot(wealth_plot_x,wealth_plot_y(1,:))
plot(wealth_plot_x,wealth_plot_y(2,:))
plot(wealth_plot_x,wealth_plot_y(3,:))
plot(wealth_plot_x,wealth_plot_y(4,:))
if location == 1
    title('Ten-Year Condensed Wealth by max solar spending, Austin,
TX')
elseif location == 2
    title('Ten-Year Condensed Wealth by max solar spending, Washington,
D.C.')
elseif location == 3
    title('Ten-Year Condensed Wealth by max solar spending, Sacramento,
CA')
end
legend('No solar','Polycrystalline','Monocrystalline','CdTe')
    xlabel('Max amount willing to spend ($)')
    ylabel('Ten-Year Condensed Wealth ($)')
    %ylim([0 inf])
    %xlim([2020 2022])
    ax = gca;
    ax.YRuler.Exponent = 0;

%%final plot
wealth_comparison(location,:) = wealth;
end
locs = categorical({'Austin','DC','Sacramento'});
```

```
locs = reordercats(locs,{'Austin','DC','Sacramento'});
figure
bar(locs,wealth_comparison);
%https://www.mathworks.com/help/matlab/ref/bar.html
%ylim([bar_min bar_max])
xlabel('Location')
ylabel('Ten-Year Condensed Wealth ($)')
title('Ten-Year Condensed Wealth by location and system type')
legend(['None';'Poly';'Mono';'CdTe'])
ylim([750000 900000])
    ax = gca;
    ax.YRuler.Exponent = 0;
```

## APPENDIX C: MATLAB FUNCTION – YEARLY POWER PRODUCTION

The following function was used to calculate the power production over a given year in kWh.

```
function yearly_power = power_prod_over_year(city_altitude,
latitude_north, longitude_west, timezone_longitude, panel_beta,
panel_gamma, panel_eff, panel_area, time_interval_for_loop)
%Spits out yearly power in kWh.
%**DEGREES for angles, DECIMAL for time**

%% inputs

%location properties
altitude = city_altitude; %km
L = latitude_north; %latitude, north ^
Long = longitude_west; %west
Long_stand = timezone_longitude; %standard timezone longitude

%panel properties
beta = panel_beta; %angle from horizontal
gamma = panel_gamma; %azimuthal angle ->west
n_panel = panel_eff; % 0.157 previously
A_panel = panel_area; % 1.64 * 0.99 previously    %m^2

%also
tinterval = time_interval_for_loop; %(30/60) ; %hours

%% year loop

total_daily_power_graph = zeros(1,365);
ET_comps = zeros(1,4);
Nctr = 0 ;
for N = 1:365
Nctr = Nctr + 1 ;

%% day loop

tctr = 0 ;
total_power_temp = zeros(1,((24/tinterval)+1));
for t_clock = 0:tinterval:24
tctr = tctr + 1 ;

%% calculations

ET_a = [-7.34,-9.38,-0.32,-0.17] ;
ET_b = [0.49,-3.26,-0.08,-0.13] ;
ET_tau = N*360/365 ;
for ET_i = 1:4
    ET_comps(ET_i) = ((ET_a(ET_i))*sind(ET_tau*ET_i)) +
((ET_b(ET_i))*cosd(ET_tau*ET_i)) ;
end
ET_mins = sum(ET_comps) ;
```

```
ET = ET_mins/60 ;
t_s = t_clock + (4/60)*(Long_stand - Long) + ET ; %solar time, decimal
omega = -180 + 15*(t_s) ;
delta = 23.45*sind(360*((284+N)/365)) ;
%
alpha = asind( sind(delta)*sind(L) + cosd(delta)*cosd(L)*cosd(omega) )
;
if alpha < 0
    alpha = 0 ;
end
gamma_s = asind( cosd(delta)*sind(omega)/cosd(alpha) ) ;
theta_i = acosd( sind(alpha)*cosd(beta) +
cosd(alpha)*sind(beta)*cosd(gamma-gamma_s) ) ;
theta_z = 90 - alpha ;
%seasons
    if N < 80 || N >= 355
        season = 4 ;
    elseif N >= 80 && N < 172
        season = 1 ;
    elseif N >= 172 && N < 264
        season = 2 ;
    elseif N >= 264 && N < 355
        season = 3 ;
    end
    if season == 1 || season == 3
        r0 = 1      ;
        r1 = 1      ;
        rk = 1.01   ;
    elseif season == 2 %summer
        r0 = 0.97   ;
        r1 = 0.99   ;
        rk = 1.02   ;
    elseif season == 4 %winter
        r0 = 1.03   ;
        r1 = 1.01   ;
        rk = 1      ;
    end
a0_s = 0.4237 - (0.008216 * ((6 - altitude)^2)) ; %assuming 23km haze
model
a1_s = 0.5055 - (0.00595 * ((6.5 - altitude)^2)) ; %assuming 23km haze
model
k_s = 0.2711 - (0.01858 * ((2.5 - altitude)^2)) ; %assuming 23km haze
model
%
a_0 = r0 * a0_s ;
a_1 = r1 * a1_s ;
k = rk * k_s ;
%all above was for these variables, so finally:
tau_b = a_0 + a_1 * exp(-k / cosd(theta_z)) ;
tau_d = 0.271 - (0.294 * tau_b) ;

I_0 = 1368*(1 + 0.034*cosd(360*(N-3)/365)) ;
I_cnb = I_0 * tau_b ;
I_cd = I_0 * tau_d * (cosd(theta_z)) * (1 + (cosd(beta)/2)) ;

I_c = (I_cnb * cosd(theta_i)) + I_cd ;
if alpha == 0
```

```
    I_c = 0 ;
end

Wdot_elec = I_c * n_panel * A_panel ; %watts

if tctr == 1
    total_power_temp(tctr) = Wdot_elec * tinterval;
else
    total_power_temp(tctr) = total_power_temp(tctr-1) +
(Wdot_elec*tinterval) ;
end

end

total_daily_power_graph(Nctr) = total_power_temp(tctr) * (10^-6) ; %W*h
to MW*h

end

yearly_power = sum(total_daily_power_graph)*1000; %kWh

end
```