Solar Photovoltaic

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Executive Summary

Total Potential

Energy Source	Electricity (GWh)	Percent of Total 2008 Electricity Demand
Solar Energy Potential		**315%**
Residential	125.1	
Non-residential	233.9	
PV Farms	2,093.4	
Total	**2,452.4**	
2008 Community Demand	779.3	

Major Assumptions

	Residential PV Systems	Non-Residential PV	PV Farms
Solar Panel Type	Yingli Energy YL255P-29b, 255W, efficiency of 14.5 W/ft^2 [1]	Yingli Energy YL255P-29b, 255W, efficiency of 14.5 W/ft^2 [1]	Yingli Energy YL255P-29b, 255W, efficiency of 14.5 W/ft^2 [1]
Annual Electricity Output Calcs	Binghamton, NY solar radiation, DC/AC derate factor of 0.77, array tilt/azimuth of 42.2/180	Binghamton, NY solar radiation, DC/AC derate factor of 0.77, array tilt/azimuth of 42.2/180	Binghamton, NY solar radiation, DC/AC derate factor of 0.77, array tilt/azimuth of 42.2/180
Mounting	Urban – roof-mount only, Rural – both roof- and ground-mounts. Assumed 1 PV system per tax parcel in rural areas	Roof-mount only	Ground-mount only
Land/Buildings Included	Single family house, duplex, multi-family up to 5-units, Roof areas >1,000sf, Urban – land within City and Villages, Rural – land outside of those areas	Commercial (including apartment buildings with 5-units or more), Community and Public Service and Industrial buildings with roof areas >1,000sf	Undeveloped parcels .10 acres, within 1 mile of a utility substation
Land/Buildings Excluded	Apartment buildings, manufactured homes	Buildings owned by Cornell, IC, and TC3	Unique Natural Areas, Slopes >20%, Important Bird Areas, Publicly owned open space, Critical Environmental Areas, Designated Distinctive scenic viewsheds, Airport approach and clear zones

[1] http://www.yinglisolar.com/assets/uploads/products/downloads/YGE_60_Cell_Series_EN.pdf

Constraints	Roofs with moderate to severe shading were excluded, as were roofs with predominantly facing north, northeast, and northwest surfaces	Only used percent of roof areas suitable for PV based on analysis of building types (54.6%-71.2% range of suitability), Small apartment buildings were analyzed per residential urban PV systems	n/a
System Sizes	Urban – 4kW, Rural – 7kW	Tied to roof area per structure	Minimum 2 MW systems

The overall objectives of this section are 1) to quantify the technical potential of solar photo-voltaics (PV) systems with practical constraints in Tompkins County including roof-mounted and ground-mounted solar systems, and 2) to identify challenges and opportunities for future solar PV penetration in the County. Solar PV systems convert sunlight into electricity, and can be roof- or ground-mounted. We categorize the solar PV systems, loosely according to the convention by the New York State Energy Research and Development Authority (NYSERDA), as Residential Systems, Nonresidential Systems, and PV Farms.

- *Residential Systems*: roof-mounted systems in urban areas and roof- or ground-mounted systems in rural areas, typically smaller than 25 kW.
- *Nonresidential Systems*: roof-mounted systems in the commercial, industrial and educational sectors, typically smaller than 2 MW
- *PV Farms*: Ground-mounted, large arrays of PVs, typically 2 MW or larger and corresponding to the very high end of NYSERDA-defined large nonresidential systems (2 MW) and large renewable projects (>2 MW)

Table 1 summarizes the potential for the three categories of solar PV systems to generate electricity in Tompkins County. The overall annual electricity generation (~2452.4 GWh) is more than three times the annual electricity demand in Tompkins County at the 2008 level (~779.3 GWh) according to the Tompkins County Greenhouse Gas Emissions Report, 1998-2008. Among the three types of PV systems, PV Farms alone could generate electricity that amounts to almost three times the annual electricity demand in terms of kWh. The data, methodologies and assumptions to derive those estimates are detailed in Section 2.

Table 1: Potential of Solar PV in Tompkins County

Category		Installation Capacity (MW)	Annual Electricity Output (GWh)
Residential	Urban*	14.6	16.2
	Rural	98.2	108.9
Nonresidential[#]	Commercial	119.2	132.2
	Industrial	19.0	21.0
	Community and public services	72.7	80.7

PV Farms	1,887.7	2,093.4
Total	2,192.4	2,452.4

*Urban areas are defined in this chapter as the City of Ithaca and the 6 Villages

#: Not including buildings at Cornell University, Ithaca College and Tompkins Cortland Community College

While we have learned that there is significant solar PV potential in Tompkins County, there are challenges to achieving that potential. Obstacles to deployment include high capital investment, shading, limited solar resources and integration of intermittent solar energy into power systems. In particular, there is a need to upgrade the power system infrastructure at both the distribution level and the transmission level.

These challenges are significant, but there are reasons for confidence in an expanded solar energy future. Government policies and incentives at both the State and Federal level are encouraging more solar projects to be installed. Technological development in solar cells, energy storage, power electronics, and energy management paves the way for high levels of solar penetration. Tompkins County is already a leader in solar PV installation in New York State. The example of Solar Tompkins, the nonprofit county-wide community solar program, has shed light on how to facilitate the widespread adoption of residential solar in a small region like Tompkins County.

1. Introduction

Photovoltaic (PV) panels convert sunlight to electricity directly. As solar insolation varies diurnally, seasonally and with meteorological conditions, the electricity generation from PVs is inherently intermittent. Currently, the majority of PV systems are grid tied, meaning they are interconnected with the electricity grid. In most of the Residential and Nonresidential Systems, the grid can act as a de facto battery, accepting any extra electricity the PV system produces that is higher than the demand, and supplying electricity if the PV system does not meet the demand. It should be noted that under future scenarios with high PV penetration the grid may not be able to absorb an influx of a large amount of solar power without compromising the grid stability, as suggested by countries with high renewable installation (Del Franco, 2014). Upgraded Infrastructure, energy storage and demand-side management can play important roles in managing solar intermittency.

(a)  (b) 

(c) 

Figure 1: (a) Roof-mounted solar system; (b) Ground-mounted solar system; (c) PV farm

PV systems that are installed on rooftops are called roof-mounted systems, see Figure 1(a), and those on the ground are referred to as ground-mounted systems, see Figure 1(b). A large-scale ground-mounted PV system designed for the supply of utility-scale power into the electric grid is known as a PV Farm, see Figure 1(c).

Over the past few decades, the United States has seen rapid growth in solar energy. In 2013, there were 4,751 MW of new photovoltaic capacity installed; a 41 percent increase from 2012 and nearly 15 times the amount installed in 2008[2]. According to the United States renewable energy attractiveness indices, which provide scores for state renewable energy markets, New York is tied with Maine, Pennsylvania, and Nevada for 8th most attractive state in the country for developing renewable energy[3].

Table 2. Solar PV installed or under construction in Tompkins County as of Feb2015

Sectors		Installation Capacity (MW)	Average size (kW)
Residential		5.2	6.7
Nonresidential	Commercial/industrial	1.2	22.3
	Public and community services	0.4	27.2
PV Farms		4.0	2,000
Total		10.8 MW	

Table 2 lists the existing and ongoing solar installations in the County as of February 2015. The County had 874 residential and non-residential solar PV systems (not including PV Farms) with total installation capacity of 6.8 MW, including 806 residential, 52 commercial/industrial, and 16 government/non-profit. According to NYSERDA PowerClerk, Tompkins County is a photovoltaic leader in central New York, as may be seen in Table 3.

[2] Solar Market Insight Report 2013 Year in Review. SEIA/GTM Research, 2013. http://www.seia.org/research-resources/solar-market-insight-report-2013-year-review
[3] United States renewable energy attractiveness indices, Ernst & Young, 2013, http://www.ey.com/Publication/vwLUAssets/United_States_renewable_energy_attractiveness_indices/$FILE/United_States_renewable_energy_attractiveness_indices.pdf

Table 3. Solar PV systems (not including PV Farms) installed or approved in neighboring counties as of Feb 2015

County	Installation Capacity (MW)	Average size (kW)
Cayuga	1.6	12.5
Cortland	0.76	8.2
Tioga	0.93	8.9
Chemung	0.86	12.3
Schuyler	0.32	8.1
Seneca	0.86	16.2
Tompkins	6.8	7.8

A more recent development is the construction of two solar farm projects and the planning for several others. In September 2014, Cornell University began generating electricity from a 2 MW PV Farm constructed on 11 acres of land in the Town of Lansing. It is expected to reduce the university's annual GHG emissions by 625 metric tons per year. In 2015, Tompkins Cortland Community College (TC3) completed a 2.6 MW solar system on the main college campus in Dryden. The system, installed on approximately 10 acres, is expected to meet 90 percent of the college's electricity needs. Cornell University is currently planning an additional 8 MW of PV Farms. Tompkins County and the City of Ithaca are working with the Municipal Electric and Gas Alliance and contractor Solar City to develop a NYSERDA-supported 2 MW PV project that will be built on 10 acres of County land adjacent to the Ithaca Tompkins Regional Airport. The project will supply energy to the City of Ithaca per an agreement between the City and Solar City. The County will lease the land on which the PV project will be built to the City and Solar City will build and own the PV Farm.

The report is organized as follows. First, we explain the methodologies and results in estimating the solar PV potential in Tompkins County (Section 2), and then we discuss the opportunities and challenges in future solar PV development in the County (Section 3). It should be noted that this report does not discuss solar thermal systems, which can be coupled with geothermal or air-source heat pumps to provide heating or hot water. The related discussion will be presented in the report on energy efficiency.

2. Solar PV Potential of the Tompkins County

The overall PV potential for the county was broken down into Residential Systems, Nonresidential Systems and PV Farms. Nonresidential Systems are divided by sectors, namely, commercial, industrial and community and public services. The PV potential is represented by both installation capacity (MW) and annual electricity output (GWh).

The installed capacity is the nameplate DC power rating of the PV system (typically consisting of multiple panels) determined under Standard Testing Conditions (STC, e.g., 1000 W/m^2 direct insolation, 25 ^oC temperature and 1.5 air mass). PV systems do not necessarily reach installed capacity due to factors such as lower insolation values (i.e., <1000 W/m^2), unfavorable weather conditions, shading, soiling and DC to AC conversion losses.

We chose a mainstream polycrystalline solar panel manufactured by Yingli Energy (YL255P - 29b) with DC rating as 255 W for our analysis. Dividing the STC rating by the panel surface area gives 156 W/m^2 (or 14.5 W/ft^2) [4]. Later on, we used this number to convert roof area to installed capacity of solar panels for the Nonresidential Systems.

We used an online PV calculator, PVWatt, developed by the National Renewable Energy Laboratory (NREL), to estimate the annual electricity output[5]. PVWatt calculates the electricity production of a grid-connected photovoltaic system based on a few user inputs including location, DC rating, array tilt, etc. For our analysis, we selected the location as Binghamton, NY, the closest city to Ithaca that has historical solar radiation measurements; the DC to AC derate factor as 0.77 (accounting for conversion loss from DC current to AC current); and the array tilt and array azimuth as 42.2^o and 180^o respectively. Based on those assumptions, the expected AC electricity that could be generated from the installed capacity is approximately 1,109 kWh annually per installed kW. The installation capacity is then converted to annual electricity output by multiplying the installation capacity by the 1,109 kWh per installed kW.

2.1 Residential Systems

Residential units considered in this section included all single-family houses, duplexes, and multi-family units up to 5-units per building. Not included were apartment buildings, which were treated as commercial properties described in Section 2.2, and manufactured homes, which were assumed to be not suitable for PV installation due to their temporary nature. Different methodologies were employed to analyze PV potential for residences in urban areas and potential in rural areas.

Urban Residential Systems – For this section, we defined “urban areas” in Tompkins County as the City of Ithaca, and the Villages of Cayuga Heights, Dryden, Freeville, Groton, Lansing and Trumansburg, which are all primarily characterized by closely spaced houses and limited roof areas. The rest of the County was defined as “rural areas”.

The overall methodology for analyzing the potential of urban residential PV systems is described as follows.

- First, we acquired a list of all 6,456 residential buildings in the urban areas with roof areas greater than 1000 ft^2,
- Second, we randomly selected 287 buildings out of the updated list and conducted individual analysis of suitability for installing PVs. The sample size led to a margin of error of 5% at 90% confidence level[6]. Two main criteria were used to determine if a roof was suitable for solar PV:1) low-to-moderate shading from surrounding structures and vegetation (and assumed that home owners would be willing to trim/remove vegetation to mitigate shading); and 2) availability of south-, west- and east-facing roofs (in other words, north-, northeast- and northwest-facing roofs are not suitable). We conduct the

[4] http://www.yinglisolar.com/assets/uploads/products/downloads/YGE_60_Cell_Series_EN.pdf
[5] http://pvwatts.nrel.gov/
[6] http://www.raosoft.com/samplesize.html

analysis using two online imaging tools, Pictometry[7] and Google Earth. It should be noted that we are unable to estimate roof strength from aerial images. According to the Solar Tompkins program, less than 2% of the homes evaluated as part of that program needed structural support or major upgrade to hold a PV system. Out of the 287 randomly selected buildings, 162 were estimated to be suitable for PV installation. In other words, we estimate that 56.4% +/- 5% of the residential buildings with roof areas larger than 1000 ft^2 (or 3,641 buildings) are suitable for PV systems.

- According to the Solar Tompkins Program, the current average size of a PV system in the urban areas is ~ 4 kW. We multiplied 4 kW by 3,641 buildings to arrive at 14.6 MW +/- 1.3 MW. The underlying assumption is that only roof-mounted PV systems are suitable in urban areas. Applying the conversion factor of 1,109 kWh per installed kW, the annual electricity output is estimated to be 16.2 GWh +/- 1.4 GWh.

Rural Residential Systems – The general methodology for rural systems analysis is similar to that for urban systems analysis with some major differences:

- In contrast to urban areas, rural homes tend to have much more roof area and/or land area to install a PV system. Thus, both roof-mounted and ground-mounted PV systems can be viable options. According to the Solar Tompkins Program, the current average size of a PV system in rural areas is ~7 kW, and most of them are ground-mounted. Therefore, 7 kW was selected as average PV size for rural areas.
- Instead of conducting analysis based on a list of buildings, we obtained a list of residential tax parcels for rural areas. The underlying assumption is that a rural resident may own multiple buildings, but chooses to install a single PV system on the property. Then we randomly selected 266 parcels out of a total of 14,695 for individual analysis. 249 of the 266 parcels were identified as having either sufficient suitable roof areas or land areas, i.e., 93.7% +/- 5% of the rural residential parcels (or 14,030 parcels) are estimated to be suitable for 7 kW PV systems.
- We multiplied 7 kW by 14,030 parcels to arrive at 98.2 MW +/- 5.2 MW. Applying the conversion factor of 1,109 kWh per installed kW, the annual electricity output is estimated to be 108.9 GWh +/- 5.8 GWh.

Table 4 summarizes the results from the residential PV systems analysis.

Table 4: PV potential of urban and rural residential systems

	Urban	Rural
Number of units	6,456[a]	14,965[b]
Average PV size (kW)	4	7
Fraction of suitable units	56.4% +/- 5%	93.7% +/- 5%
Installation capacity (MW)	14.6 +/- 1.3	98.2 +/- 5.2
Annual electricity output (GWh)	16.2 +/- 1.4	108.9 +/- 5.8
Total installation capacity (MW)	112.8	
Total Annual electricity output (GWh)	125.1	

[7] https://pol.pictometry.com/en-us/app/login.php

Fraction of annual electricity consumption in the County at 2008 level	16%

[a]: Number of buildings on residential lots with roof areas > 1000 ft^2, not including apartments and mobile homes.
[b]: Number of residential parcels on rural areas

2.2 Nonresidential Systems by Sectors

The analyses for Nonresidential systems are conducted in three sectors, commercial, industrial and community and public services.

2.2.1 Commercial

We acquired a list of commercial buildings from the Tompkins County Planning Department. Then we selected those with roof areas larger than 1000 ft^2, and further grouped them into three categories, i.e., non-apartment buildings, large apartment buildings (with roof areas larger than 3,500 ft^2) and small apartment buildings (with roof areas smaller than 3,500 ft^2).

- We randomly selected 240 out of 1,671 non-apartment commercial buildings (>1000 roof areas), and conducted imaging analysis. Because they usually have flat roofs, we estimated the fraction of the total roof area for each building that can host PVs. The area selection tools in Pictometry facilitated our analysis, which showed that 54.6% +/- 5% (at 90% confidence level) of the roof areas are suitable for PVs. Applying this fraction to the total areas of 1,671 buildings and the conversion factor of 14.5 W/ft^2, we estimated the potential to be 85.7 MW +/- 7.8MW, and 95.0 GWh +/- 8.7GWh.
- We applied the same methodology described above to large apartment buildings. We estimated the potential to be 21.3 MW +/- 1.9 MW, and 23.6 GWh +/- 2.0 GWh, respectively.
- We applied the methodology described for urban residential buildings to the small apartment buildings, because they mostly either are converted residential buildings or resemble residential buildings. We estimated the potential to be 2.2 MW +/- 0.2 MW, and 2.4 GWh +/- 0.2 GWh, respectively.

Table 5 summarizes the results from the commercial PV systems analysis.

Table 5. PV potential of commercial buildings

Type	Non-apartment	Large apartment Buildings	Small apartment Buildings
Number of buildings[a]	1,671	407	934
Total roof area (ft^2)	10,818,950	2,591,233	1,964,396
Fraction of suitable units	N/A	N/A	60.0% +/- 5%
Fraction of suitable roof areas	54.6% +/- 5%	56.7% +/- 5%	N/A
Installation Capacity (MW)	85.7 +/- 7.8	21.3 +/- 1.9	2.2 +/- 0.2
Annual Electricity Output (GWh)	95.0 +/- 8.7	23.6 +/- 2.0	2.4 +/- 0.2
Total Installation Capacity	119.2		

(MW)	
Total Annual Electricity Output (GWh)	132.2
Fraction of annual electricity consumption in the County at 2008 level	17%

[a]: Not including those with roof areas smaller than 1000 ft^2

2.2.2 Industrial

We obtained a list of 112 industrial buildings with roof areas larger than 1000 ft^2 from the Tompkins County Planning Department. We applied the same methodology for non-apartment commercial buildings to each of the industrial buildings on the list (i.e., random sampling is not applicable). Table 6 summarizes the results.

Table 6. PV potential of industrial buildings

Number of buildings[a]	112
Total roof area (ft^2)	1,836,722
Fraction of suitable roof areas	71.2%
Installation Capacity (MW)	19.0
Annual Electricity Output (GWh)	21.0
Fraction of annual electricity consumption in the County at 2008 level	2.7%

[a]: Not including those with roof areas smaller than 1000 ft^2

2.2.3 Community and Public Services

The community and public services sector includes banks, hospitals, schools, governments, etc. The Tompkins County Planning Department provided a list of buildings with roof areas larger than 1000 ft^2. We deselect the buildings owned by Cornell University, Ithaca College and TC3 from the list because the three higher educational institutions all have plans to achieve carbon neutrality and it is assumed each will maximize the contribution from their buildings to achieve this goal. For the remaining list of 769 buildings, we randomly selected 221 for individual analysis with margin of error at 5% at 90% confidence level. The same methodology for non-apartment commercial buildings was applied here. Table 7 summarizes the results.

Table 7. PV potential of community and public services buildings

Number of buildings[a]	769
Total roof area (ft^2)	7,057,200
Fraction of suitable roof areas	64.1% +/- 5%
Installation Capacity (MW)	72.7 +/- 5.7
Annual Electricity Output (GWh)	80.7 +/- 6.3
Fraction of annual electricity consumption in the County at 2008 level	10.3%

[a]: Not including those with roof areas smaller than 1000 ft^2

2.3 PV Farms

A multi-criteria GIS model was developed to identify areas suitable for developing PV Farms. Those criteria include:

- Land acreage: We selected lands of sufficient size to host a PV array installation. We choose 10 acres (for a 2 MW system) as the minimum size. Smaller size is typically not economically attractive.
- Land availability: We selected undeveloped lands in the County that were not forests, water or wetlands. If multiple properties had contiguous suitable lands, we treated them as a single parcel. In other words, even if a vacant property was smaller than 10 acres, it could be part of a site that is larger than 10 acres. Our underlying assumption was that developers will work with multiple owners of connected vacant parcels for PV Farm projects. We omitted lands identified by the Audubon Society of New York as Important Bird Areas, and lands identified by the Tompkins County Environmental Management Council as Unique Natural Areas, local parks, State Forests, State Wildlife Management Areas, State Parks, Critical Environmental Areas, Conservation Easements, Nature Preserves, and Cornell University Natural Areas. This is because it is unlikely that a large solar farm would be located in these areas, nor would it be desirable to locate such a facility there.
- Lands with slopes greater than 20% were also omitted, as they would make installation of solar farms impractical.
- Transmission: Proximity to medium voltage power lines and substations should be considered for controlling interconnection costs. Considering there are only 19 substations in the County, proximity to substations (i.e., rather than proximity to medium voltage power lines) likely becomes a limiting factor. In this analysis, we set the maximum distance between a viable site for a PV Farm and the nearest substation to be 1 mile. In addition, we do not have information on the available capacity of the substations and power lines to accommodate PV Farm interconnections, which we assumed is not a limiting factor.

Figure 2 shows the suitable lands for potential PV Farm development based on this analysis. 171 contiguous sites are identified with a total area of 10,487 acres. Next, we applied a conversion factor of 0.18 MW (AC) per acre (based on the Cornell Snyder Road Solar Farm) to estimate the potential. Table 8 summarizes the results. Overall, PV Farms have the largest potential among the three types of PV systems we analyzed. PV Farms alone can provide close to three times the annual electricity demand in the County at the 2008 level.

Table 8. Potential of PV Farms in Tompkins County

Number of contiguous sites	171
Total area (acres)	10,487
Installation capacity (MW)	1,887.7
Annual electricity output (GWh)	2,093.4
Fraction of annual electricity consumption in the County at 2008 level	270%

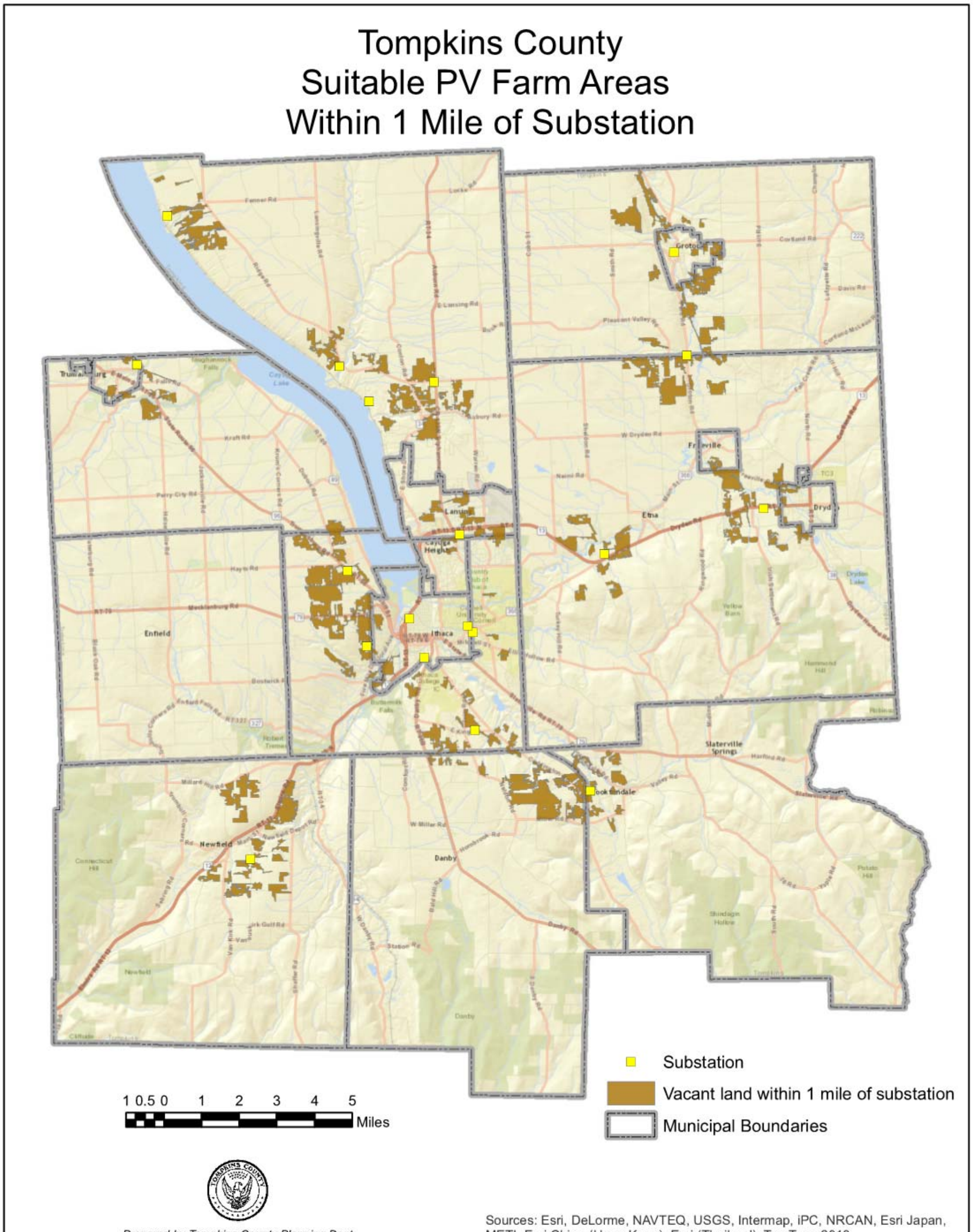

Figure 2: Lands suitable for PV Farms within 1 miles of substations

3. Opportunities and Challenges

3.1 Shading, landscape service and solar-friendly landscaping designs

One of the major challenges for siting a PV system in Tompkins County (and most of the Eastern U.S.) is shading. Even small amounts of shading, such as leafless tree branches or small rooftop obstructions, can have dramatic impacts on the solar electricity generation. The vast majority of the urban residential buildings identified as unsuitable for PV systems in our analysis are due to shading from surrounding vegetation. According to a survey from Solar Tompkins, many homeowners with moderate shading are willing to trim or remove trees that interfere with solar collection. However, homeowners are responsible for the landscape services, adding to the costs of installing PVs. Solar Tompkins has considered working with homeowners as a group to negotiate the prices for landscaping services. An alternative approach is to transfer the responsibility of shading mitigation to PV installers, who can potentially negotiate the prices for landscaping services much more effectively than individual homeowners.

Since removing shading from vegetation will potentially increase the cooling demand for electricity in summer, a study on the net benefit of shading mitigation is needed. Furthermore, solar-friendly landscaping designs for new construction will avoid the need to cut down trees in order to install PVs in the future.

3.2 Less competitive solar incentives in Tompkins County

The New York Independent System Operator (NYISO) divides New York State into eight zones based on differential energy pricing. Tompkins County, located in the Central Zone, has lower electricity prices than other New York State regions such as the Capital Zone and the Hudson Zone. For solar developers, lower prices in Tompkins County generate less competitive revenue than other regions where electricity prices are higher.

Beyond electricity prices, solar insolation in central New York is not as abundant as in the Hudson Zone. As a result, larger amounts of solar energy can be utilized by the same solar system installed in Middletown, NY than in Ithaca. This makes it more difficult for solar companies to finance projects in Tompkins County.

3.3 Solar parking lots

Commercial buildings usually have spacious parking lots with little shading, and can be potentially converted to covered parking with solar PV. One example of a solar parking lot can be found on Long Island. The Eastern Long Island Solar Array has added 8.25 MW of solar capacity while at the same time providing shading for commuter parking for the Long Island Railroad. (LIPA 2014)

Frequently, large chain stores do not give local managers the authority to decide to install solar panels on the rooftops or in parking lots, and it can be cumbersome to get such a decision from a regional or corporate headquarters. While this challenge persists, there seems to be more corporate interest in solar, and chain stores have begun to adopt solar power more widely.

There is great potential for growth if head offices give their blessing for solar installations, or grant local managers more autonomy in making such decisions (Cardwell 2014).

3.4 A model for community marketing: Solar Tompkins

Solar Tompkins is a local non-profit solar initiative in Tompkins County. Its public launch was in the spring of 2014, and it has been focused on facilitating solar power adoption by homeowners and small businesses in the County. The program seeks to eliminate the few remaining barriers to solar adoption by providing: attractive 20% lower-than -market pricing, a simple process with vetted technology and installation partners, grassroots-led educational outreach events to build enthusiasm, and deadlines to generate the impetus for adoption. The program has been very successful. As of the summer of 2014, Tompkins County had around 2.2 MW of residential solar installed. By end of 2014, this number, including contracts signed for installation in 2015, was 5.2 MW. In other words, Solar Tompkins was able to more than double the amount of residential solar with over 3 MW of new installations in Tompkins County in less than a year.

3.5 Availability of land for PV Farms

In the near term, the biggest challenge for deploying PV farms is likely to be the availability of land. Most of the substations, shown in Figure 2, are located in areas that are likely to have relatively high land values. The lease rates for land for PV farms may be too low to be competitive with the value of land for other purposes, except where land use is constrained, such as in the airport runway clear zone, or is owned by an entity such as the County or Cornell where the use of the land in this way supports organizational objectives.

3.6 Power System Integration

New York State has adopted very effective net metering policies, which make the installation of renewables more attractive to homeowners and businesses. Net metering allows residential and commercial customers who generate their own electricity from solar power to feed electricity they do not use back into the electric grid, and credits solar energy system owners for the electricity they add to the grid.

While net metering is an important step to encourage deployment of renewables, it does affect overall grid function and stability in various ways, depending on the level of penetration on a distribution circuit and the size (capacity and voltage) of said distribution circuit (APPA, 2013). Medium and high levels of distributed solar penetration can create safety and grid stability concerns (APPA, 2013). These concerns include:

- Excess Load at Substations – Occurs when distributed generation systems produce more power than the circuit is consuming. This causes “power to flow from the substation to the transmission grid, creating a reverse power flow that grids are not designed to handle. This could lead to high voltage swings and other stress being placed on electrical equipment.” (APPA, 2013)
- Grid Stability Problems – Occurs if there is a high level of distributed generation penetration and grid frequency fluctuates past the distributed generation system’s trip

point. Once that occurs, all distributed generation systems could simultaneously trip causing huge grid fluctuations or, even worse, blackouts (Coddington et al., 2012).

- Load and System Planning Uncertainty – Grid operators generally have no way to evaluate or monitor distributed generation systems. This makes grid forecasting and planning especially difficult since operators cannot decipher between load changes and solar output changes (APPA, 2013).
- Other potential hazards and negative effects of medium and high levels of distributed solar penetration may include higher voltage at point of distributed generation (Coddington et al., 2012) and unintentional islanding of the distributed generation system from the grid (APPA, 2013).

Because of these potential strains on the grid, the Federal Energy Regulatory Commission (FERC) requires that distributed generation within a line section (i.e., distribution circuit) must not exceed 15% of the annual peak load of the line section (Coddington et al., 2012). Generally speaking, the 15% threshold is meant to prevent distributed generation capacity from exceeding the maximum load in a distribution circuit.

However, with rapid growth in PV systems, foreseeably the grid will need to integrate more electricity generated from distributed solar sources in the future. The 15% rule may become a significant constraint in the County. To embrace distributed energy generation, the FERC will need to update their regulations, which in turn will make it necessary for utilities to make further capital investment in system upgrades (e.g., a distribution system with bidirectional power flows) to proactively address the safety and grid stability concerns.

We foresee that technology development in the next decades will overcome many of the challenges associated with power systems integration of solar energy.

- Power electronics – Smart grid-ready microinverters typically have a digital architecture, bidirectional communications capability and robust software infrastructure. They are capable of providing a suite of advanced grid functions such as ramp rate control, power curtailment, fault ride-through and voltage support through reactive power control. Those advanced grid functionalities will allow remote system upgrades and engage utilities in PV deployment and smoothing out the electricity system when lots of solar gets installed in concentrated areas (SEPA, 2014).
- Demand-side management – A PV system coupled with energy storage (e.g., battery or thermal energy storage) and smart appliances can allow home owners to utilize more of the energy its solar panels produce, thereby reducing the reliance on net metering. The ongoing development of home automation software, energy management systems, and sensor technologies will greatly enhance the capability of demand-side management, providing great synergy with solar PV penetrations.
- Bulk transmission systems – The New York Independent System Operator (NYISO) has begun assessing strategies to offset the reliability issues with increasing renewable penetration into the power system. Technologies being investigated include: flexible hydro and gas turbines that can quickly be ramped up, new energy storage technologies, and introducing policies to improve demand-side management (NYISO,

2012). It is expected that the electricity grid of the future will able to handle high levels of intermittency from renewable generation.

3.7 Policy and Incentives

New York State and the federal government have several programs under consideration and in place to support the adoption of solar power. The Shared Clean Energy Bill will make it easier for homeowners with properties in non-optimal locations to adopt solar power. Remote Net Metering allows solar technologies to be built in one location and gain benefits in another. Federal and state tax credits allow for an effective reduction in the capital cost of solar systems.

Shared Renewables Initiative - Also referred to as community distributed generation, was passed in 2015 and is being rolled out in phases. The first phase of Shared Renewables will focus on promoting low-income customer participation and installations in areas of the power grid that can benefit most from local power production. New York State residents will now be able to buy local solar energy without having solar panels installed on their individual properties, or needing to remove shade trees to allow for such installations. By subscribing to local off-site solar energy projects and receiving a utility bill credit for their portion of the energy produced, all residents will be able to participate in building more sustainable and clean communities whether they own or lease their houses or apartments. With respect to the initiative's economic implications, a shared renewable energy program has the potential to unlock a new market and establish significant new private investment in New York State solar energy systems.

Reforming the Energy Vision (REV) - New York State Department of Public Service (DPS) has proposed a plan, known as "Reforming the Energy Vision" (REV), to transform New York's electric industry[8]. The centerpiece of REV is to integrate Distributed Energy Resources (DERs) into the New York electricity market, via a Distributed System Platform (DSP) framework. In this context, DERs include Energy Efficiency (EE), Demand Response (DR), and Distributed Generation (DG) including solar PV[8]. The promise of integrating DER is to offer customers the opportunity to manage their usage and reduce their bills while at the same time creating important system and societal benefits, moving towards an energy landscape that is increasingly decentralized with consumers playing a more active role in energy decisions. Although REV is still in the proposal stage, it has the potential to greatly facilitate the penetration of solar PV through improving regulations and creating new market products.

Remote Net Metering - In the process of securing approvals to construct its solar farm project on Snyder Road, Cornell University filed a petition with the NYS Public Service Commission (PSC) seeking clarification on how "remote net metering" rules had to be applied by electric distribution companies (Cornell, 2014). Remote net metering allows an entity to build a renewable energy project (e.g., solar, wind, etc.) where it has space that is well-suited for this purpose, and to credit the energy value generated by the project towards consumption of energy at another location. In a ground-breaking ruling the PSC determined that: utilities must credit electricity at the same rate they charge for electricity at a particular location; the customer

[8] NYSDPS *Developing the REV Market in New York: DPS Staff Straw Proposal on Track One Issues*; New York State Department of Public Service: 2014.

does not have to have an account at the particular location of generation prior to the installation of the renewable energy project; and there is no minimum electrical load required (NYPSC, 2013). The PSC ruling was extended to apply to all utilities and types of renewable generation projects throughout New York State. This ruling means that there are now many more options for siting renewable projects at locations with electricity rates that make such projects economically feasible (Cornell, 2014).

NYSERDA incentives - Governor Andrew Cuomo launched the NY-Sun Initiative on August 21, 2014, to consolidate New York State's existing solar incentive programs into a single support scheme, aimed at adding 3GW of solar generation capacity by 2023 (GPO, 2014). A key part of the NY-Sun Initiative is the "the MW block system". The intention is to ultimately transform New York's solar market into a self-sustaining industry. The state is divided into three regions – Con Edison territory, Long Island and Upstate. Each region is assigned separate MW blocks and incentive levels for residential solar projects up to 25 kilowatts (kW) and small non-residential solar projects up to 200 kW. When the MW target for the first block in each sector (residential or small non-residential) within a region is reached, that block is closed and a new block for the sector is started with a new MW target and a lower incentive level. Once all of the blocks for a particular region and sector are filled, an incentive for that region and sector will no longer be offered. The program for non-residential systems larger than 200 KW is yet to be announced.

New York State Tax Credits and Property Tax Exemption - In addition to direct incentives, there are also tax credits and incentives that can be applied to residential solar systems. Since tax issues can become very complicated, only a basic overview of the tax opportunities available will be presented here. New York State offers a tax credit of 25% of the system expenditures (after incentives have been applied) capped at $5000. The system must be grid-tied and net metered, and any excess credits can be carried forward five years (DSIRE, Residential Solar Tax Credit). New York State also recognizes that a PV system may increase the value of a property. If the municipal assessor's office determines that it does, this would increase the homeowner's property tax burden. As such, the state provides 15 year property tax exemptions for systems purchased and installed before January 1, 2025[9]. The total amount of the exemption is equal to the increase in assessed value attributable to the solar system.

Federal Tax Credits - Finally, the federal government also offers a tax credit of 30% for residential PV systems. Due to recently passed legislation, there is now no cap on the amount that may be claimed. The tax credit is calculated from the net cost of the system after any direct incentives, such as the NYSERDA incentive, which are not federally taxable. There is a degree of subtlety to the federal tax credit, though, because it is only a credit against federal taxes owed. It is not a line item deduction to lower a homeowner's tax liability nor an automatic refund from the government. The homeowner must owe federal taxes, and the tax credit is simply carved out of that. If the tax credit is larger than the homeowner's federal tax burden for the year, the remaining balance may be rolled over one more year, but no more. So if, for example, a homeowner owes $5,000 in federal taxes in the two years following the installation of a PV system, and the federal tax credit comes to $6,000, then the homeowner will have lost that extra

[9] http://programs.dsireusa.org/system/program/detail/192

$1,000 credit. This is why it is imperative for homeowners to speak with tax professionals before committing to a PV system to ensure they are receiving the full benefit.

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References

APPA (2013) *Distributed Generation: Overview of Recent Policy and Market Development.* American Public Power Association (APPA), Nov. 2013. Web. Mar. 2014.

California Energy Commission, Incentive Eligible Photovoltaic Modules Compliance with SB1 Guidelines (September 2014). Retrieved from http://www.gosolarcalifornia.ca.gov/equipment/pv_modules.php

Cardwell, Diane (2012) Chain Stores Said to Lead Firms in Use of Sun Power. Retrieved from: http://www.nytimes.com/2012/09/12/business/energy-environment/chain-stores-lead-firms-in-solar-power-use-study-finds.html?_r=1&

Cornell (2014) Sustainable Campus: Solar Power, http://www.sustainablecampus.cornell.edu/initiatives/solar-power

Coddington, Michael, Barry Mather, Benjamin Kroposki, Kevin Lynn, Alvin Razon, Abraham Ellis, Roger Hill, Tom Key, Kristen Nicole, and Jeff Smith (2012). Updating Interconnection Screens for PV System Integration. Tech. US Department of Energy, Feb. 2012. Web.
Ekwaro-Osire, Henry, Manuel Hernandez, Peter Ingato, and Tim Reiher (2014, May). *Effects of Increasing Distributed Solar Generation in Tompkins County*. Cornell University.

Del Franco, M (2014) North American Solar Seeks To Learn From Germany's Grid Integration Trials, Solar Industry Magazine, March 11 2014

http://solarindustrymag.com/e107_plugins/content/content.php?content.13895

Department of Energy. (n.d.) Demand Response. Retrieved from: http://energy.gov/oe/technology-development/smart-grid/demand-response.

Energy Conservation Improvements Property Tax Exemption . Retrieved from http://www.tax.ny.gov/research/property/assess/manuals/vol4/pt1/sec4_01/sec487_a.htm

Ekwaro-Osire, H.; Hernandez, M.; Ingato, P.; Reiher, T. (May 2014). Effects of Increasing Distributed Solar Generation in Tompkins County.

GPO (2014), Governor Cuomo Launches Program to Transform New York's Solar Market Into Self-Sustaining Industry, Governor's Press Office (GPO), August 21, 2014

Grace Communications Foundation. (n.d.) Net Metering. Retrieved from: http://www.gracelinks.org/201/net-metering

Incentives/Policies for Renewables & Efficiency. Retrieved from http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US37F

Jordan, D.; Kurtz, S. (June 2012), Photovoltaic Degradation Rates - An Analytical Review. Retrieved from http://www.nrel.gov/docs/fy12osti/51664.pdf

Kousksoua, T., P. Bruelb, A. Jamilc, T. El Rhafikid, and Y. Zeraoulia. Energy Storage: Applications and Challenges. Solar Energy Materials and Solar Cells 120 (2014) 59-80. Retrieved from: http://www.sciencedirect.com/science/article/pii/S0927024813004145

LIPA (2014) Eastern Solar Long Island Project. Retrieved from: http://www.lipower.org/xx_powering/solar-enxco.html

Muenster, R. (February 2012), Shade Happens. Retrieved from: http://www.renewableenergyworld.com/rea/news/article/2009/02/shade-happens-54551

New York Consolidated Laws Tax Law. Retrieved from http://www.dsireusa.org/documents/Incentives/NY03F.htm

NYSERDA PowerClerk (2014). Retrieved from http://nyserda.powerclerkreports.com

NYISO Zone Maps (September 2014). Retrieved from http://www.nyiso.com/public/markets_operations/market_data/maps/index.jsp

NYISO. Envisioning a Smarter Grid for New York Consumers. Albany: NYISO, 2012.

NYPSC (2013) CASE 13-E-0150 Cornell University - Petition for a Declaratory

Ruling Concerning New York State Electric & Gas Corporation's Remote Net Metering Tariff. Declaratory Ruling on Minimum Load Requirements for Remote Net Metering. State of New York Public Service Commission (NYPSC), March 16, 2013

New York State Senate (2014) A9931-2013 - NY Senate Open Legislation - Relates to Shared Renewable Facilities - New York State Senate. Web. 05 Sept. 2014.

PVWatts Calculator (2014). Retrieved from http://rredc.nrel.gov/solar/calculators/pvwatts/version1/

Residential Energy Credits Federal Tax form 5695. Retrieved from http://www.irs.gov/pub/irs-pdf/f5695.pdf

Solar Electric Power Association (SEPA, 2014). Unlocking Advanced Inverter Technology: Roadmap to a Future of Utility Engagement and Ownership. Retrieved from http://www.solarelectricpower.org/explore-resources/publications-and-media.aspx

SUNY Cortland, Sustainable Energy Systems. Retrieved from http://www2.cortland.edu/departments/physics/ses/index.dot

State of New York (2014). Bill 9931-2013. Retrieved from http://open.nysenate.gov/legislation/bill/A9931-2013

Raosoft (August 2014). Retrieved from http://www.raosoft.com/samplesize.html

Tompkins Cortland Community College, Major Solar Project Coming to TC3 (2013). Retrieved from http://www.tc3.edu/news/news_release.asp?guid=749

TCPD, Tompkins County Planning Department (2010). Tompkins County Community Greenhouse Gas Emissions Report, 1998-2008. Retrieved from http://www.tompkins-co.org/planning/energyclimate/documents/DraftCommunity10-yearGHGEmissionsReport.pdf

Tompkins County Tax Parcels (Shapefile: 2013). Retrieved from http://cugir.mannlib.cornell.edu/bucketinfo.jsp?id=8159

Yingli Energy, YGE-Z60 Cell Series US Datasheet (March 2014). Retrieved from http://d9no22y7yqre8.cloudfront.net/assets/uploads/products/downloads/YGEZ60CellSeries_US_201403_V01_LR.pdf

Figure Sources

Figure 1(a): http://netzerorenewableresources.com

Figure 1(b): http://www.circularenergy.com/circular-energy-ebulletin/the-anatomy-of-a-solar-energy-system-part-ii-mount-systems/

Figure 1(c):http://www.seia.org/research-resources/solar-industry-data

Figure 2 Data layer resources:

Tompkins County Tax Parcel (2013)	Albert R. Mann Library
Tompkins County Buildings	Tompkins County Planning Department
Land Use	Tompkins County Planning Department
Transmission Lines	Tompkins County Planning Department